

April 2, 1968

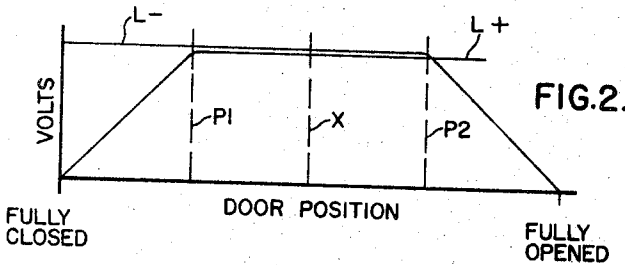
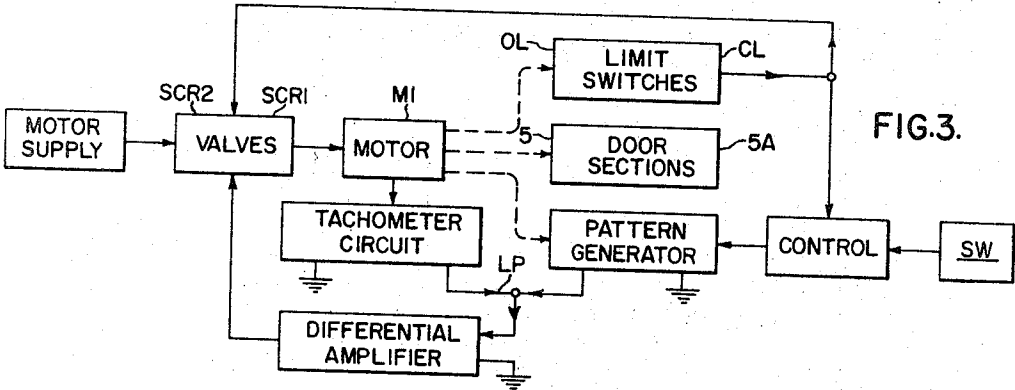
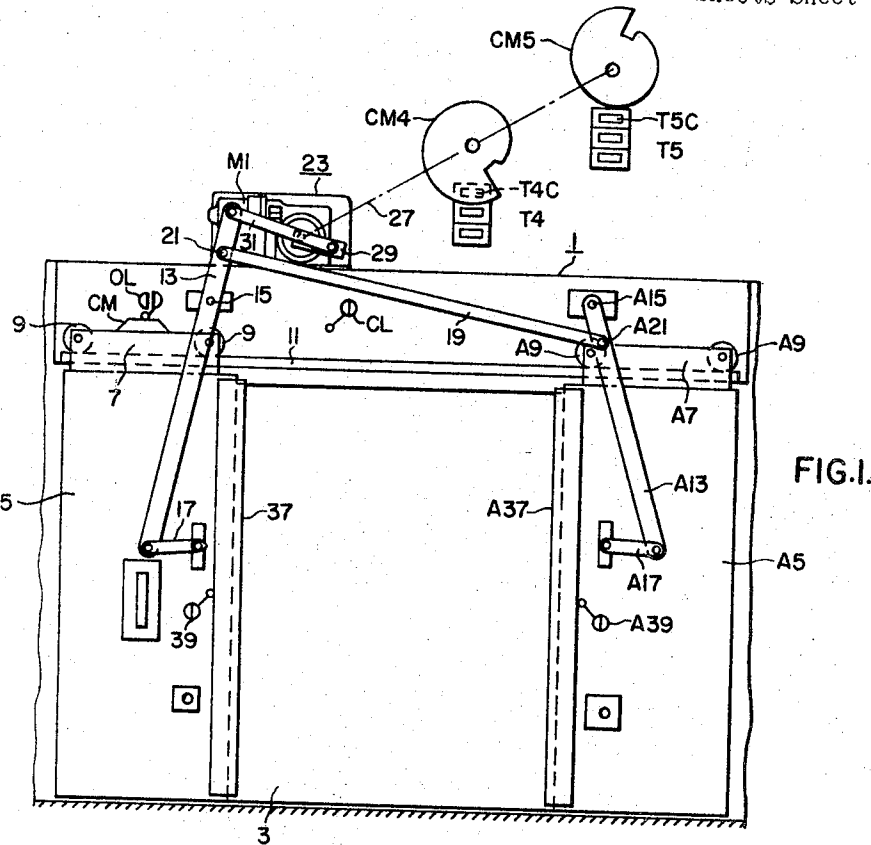
W. R. CAPUTO

3,376,486

SPEED-CONTROLLED SERVO-POSITIONER

Filed July 22, 1964

3 Sheets-Sheet 1



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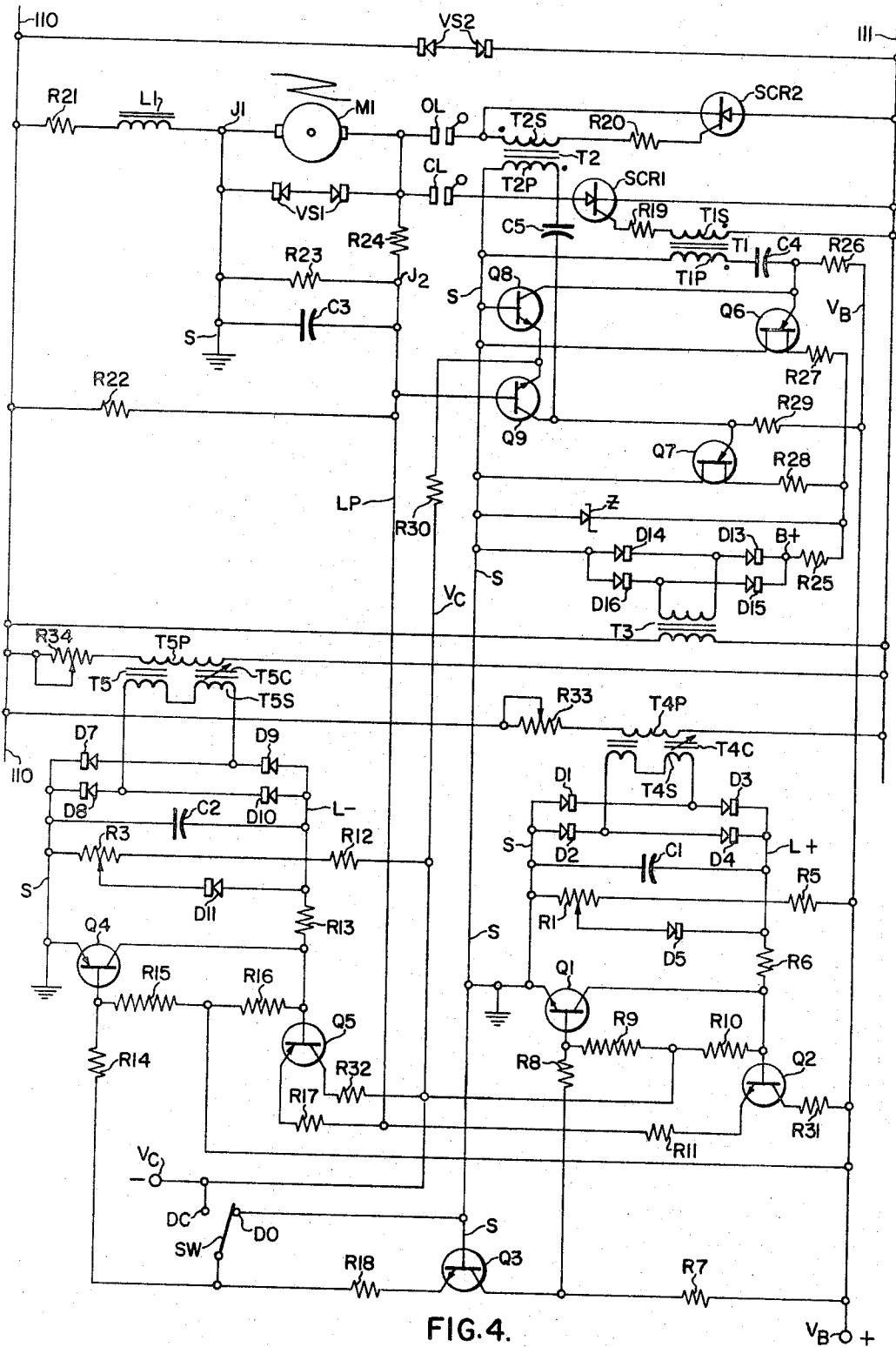
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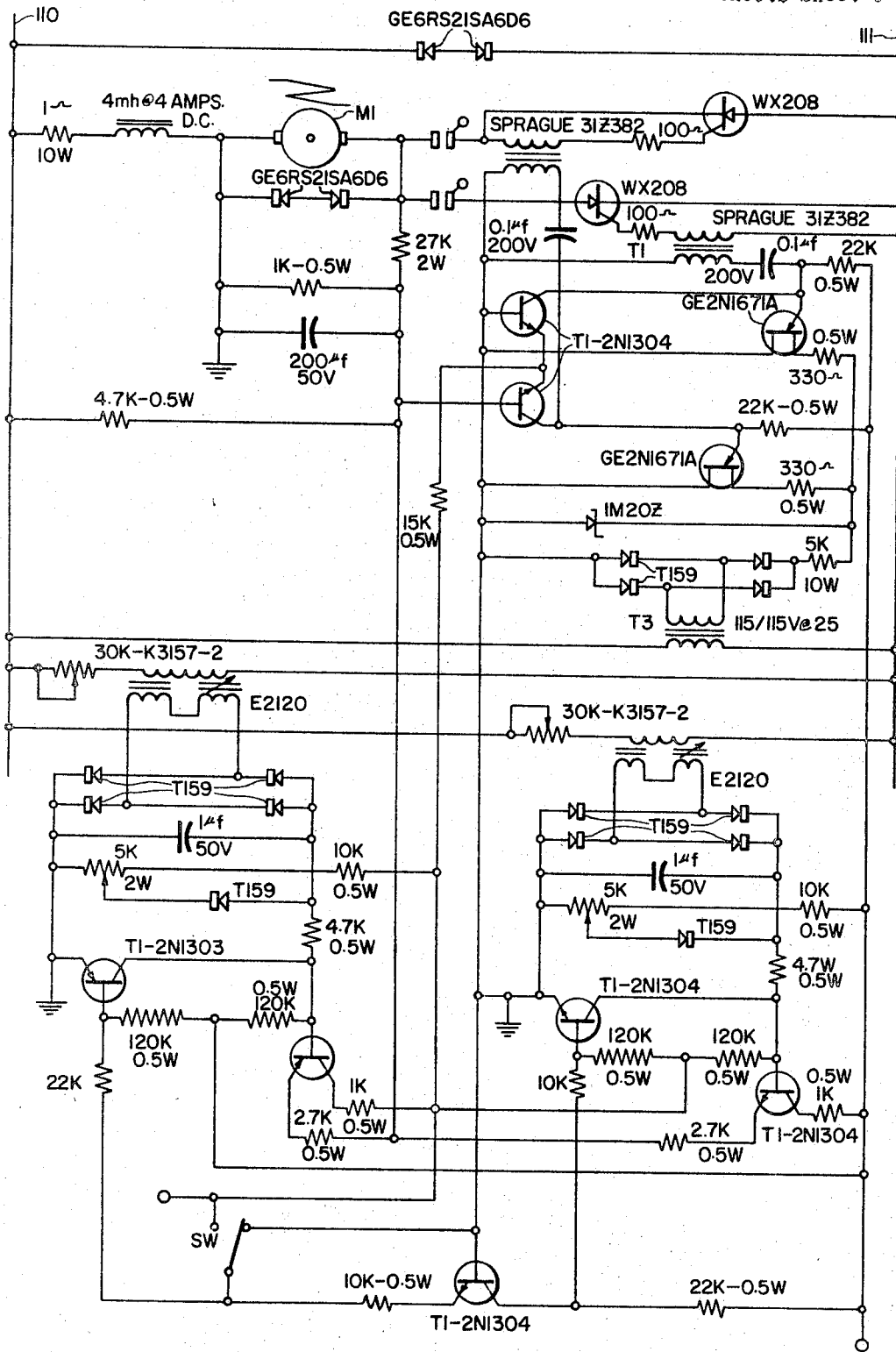


FIG. 5.

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SPEED-CONTROLLED SERVO-POSITIONER

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10 Claims. (Cl. 318-257)

ABSTRACT OF THE DISCLOSURE

A speed-controlled door positioner wherein the door is positioned by a direct-current motor energized from an alternating-current source through two silicon controlled rectifiers so connected in the armature circuit of the motor as to supply pulses of current of opposite polarity when fired. A variable reluctance pattern generator connected to the door produces a control voltage proportional to the desired speed of the door as a function of door position and direction of travel. The difference between the control voltage and the back electromotive force of the motor controls the firing of the silicon controlled rectifiers through a differential amplifier and pulse generators connected between the outputs of the amplifier and the control electrode of the associated silicon controlled rectifiers.

This invention relates to the electric drives and has particular relationship to drives for automatically opening or closing doors. In its specific aspects this invention concerns itself with the automatic opening and closing of the door of an elevator entranceway.

In the opening and closing of an elevator door it is essential that the door close in a short time interval but without the application of substantial impacts or other damaging forces to the closure sections, to their suspensions or to the bearings on which they move. It is desirable then that the closure sections be brought up to the maximum speed in as short a time as feasible at the start of the opening or closing and that their speed be reduced from this speed to substantially zero or a low speed when the closure sections approach the closed position. It is also essential that if a passenger is interposed in the path of the closure sections that the closure sections either be stopped or reversed without injury to the passenger. These requirements impose demands for precise control of the door speed and it is a principal object of this invention to achieve such precise control of the speed in the automatic operation of a door.

In accordance with the teachings of the prior art automatic operation of doors is effected by a motor in the control circuit of which a bank of resistors is connected. The speed of the motor is varied by a plurality of relays which connect these resistors in the motor circuit in a predetermined sequence or disconnect them from the motor circuit in reverse sequence. This prior art practice has been adopted in a large number of elevator installations and has proved reasonably successful. But in installations where high precision in the control of the door is demanded, this practice has not been entirely satisfactory. It is accordingly an object of this invention to improve materially the precision of the control of the velocity of opening-or-closing movement of an automatically operable door, and particularly the door of an

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elevator entranceway, over that achievable in accordance with the teachings of the prior art.

This invention arises from the realization that the prior art door control has the important deficiencies that the changes in the resistance of the supply circuit of the door motor are introduced abruptly in steps and independently of the instantaneous speed of the door. It is then an object of this invention to provide apparatus for automatically controlling the operation of a door, and particularly of an elevator door, in which the command pattern governing the operation of the door shall be continuous and, in its effect on the supply circuit for the door motor, shall be modified in accordance with the instantaneous actual speed of the door sections as they are moving. It is another object of this invention to provide static apparatus devoid of mechanical contacts for controlling the operation of the door.

In accordance with this invention the operation of the door is controlled by a continuous command-potential pattern which has a form to achieve the demanded conditions of the operation. Specifically, the pattern potential may have a form such as to cause the motor which drives the door to apply the maximum torque at the start of a closing or opening operation and during a substantial part of the movement of the door sections, and to apply gradually decreasing torque as the closed or opened position is approached. This command potential is compared at each instant to a potential dependent on the speed of the motor, which is in effect the speed of the door, and the motor is controlled in dependence upon the difference between the instantaneous potential of the command-potential pattern and the motor-speed-dependent potential.

The supply circuit for the motor is of the type permitting the motor to operate regeneratively; that is, to be braked by regenerative supply of power by the motor to the energizing source. This regenerative operation permits the motor speed to follow the command-potential pattern closely. If the pattern potential exceeds the motor-speed-dependent potential, the motor is supplied with power; if the motor-speed dependent potential exceeds the potential of the pattern, the motor supplies power to the energizing source and is braked regeneratively, thus immediately returning to the speed corresponding to the command potential.

An ancillary feature of this invention is a novel motor-control circuit particularly suitable for elevator door operation but having other uses. This motor control circuit includes electric valve means interposed between an alternating current supply and the motor. The valve means is energized from an alternating current supply and its conductivity is controlled by potentials derivable from a control circuit. In this control circuit the potential from the command-potential pattern is compared with the motor-speed-dependent potential and pulses are derived which have a phase position, with reference to the alternations of the alternating potential supply, dependent on the difference between the instantaneous potential of the pattern and the instantaneous motor-speed-dependent potential. The pulses are impressed to render the valve means conducting at instants in the half periods of the alternating supply such as to reduce the difference between the potential of the pattern and the motor-speed-dependent potential and to compensate for these differences. If the motor speed is excessively high, the

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motor is operated regeneratively promptly reducing its speed. If the motor speed is low, the pulses render the valve means conducting early in the half periods of the supply to cause substantial current to flow through the motor.

Certain novel features considered characteristic of this invention are disclosed above. For a better understanding of this invention, both as to its organization and as to its method of operation, together with additional objects and advantages thereof, reference is made to the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a view partly diagrammatic and partly in front elevation showing an elevator door controlled in accordance with this invention together with certain control components which are used in the practice of this invention;

FIG. 2 is a graph showing the command-potential patterns for controlling the door shown in FIG. 1;

FIG. 3 is a block diagram of control apparatus in accordance with this invention;

FIG. 4 is a schematic of control apparatus in accordance with this invention; and

FIG. 5 is a schematic similar to FIG. 4 but identifying the actual electrical components used in apparatus with which this invention was successfully practiced.

FIG. 5 is included for the purpose of aiding those skilled in the art in practicing this invention, and is not intended in any way to limit the scope of this invention.

FIG. 1 illustrates an elevator car 1 having a door for opening and closing an elevator-car entranceway 3 through which load may enter and leave the car. This elevator car may serve any desired number of floors or landings.

The elevator-car door may be of any desired conventional construction, such as a center-opening or a side-opening door, or a double or a single door. For purpose of illustration, it is assumed that the door is a center-opening door mounted for horizontal sliding movement. In FIG. 1 the door is shown in its fully open position.

The center-opening car door has two sections 5 and A5. A number of similar components is employed for the door sections 5 and A5. Insofar as is practicable, a component for the door section A5 which is similar to a component for the door section 5 is identified here by the same reference numeral as is employed for the corresponding component associated with the door section 5 prefixed by the letter A.

The door section 5 is provided with a door hanger 7, on which wheels 9 are rotatably mounted. The door-hanger wheels for the door sections 5 and A5 are positioned for movement along a horizontally mounted track 11 in a conventional manner. The track 11 is secured to the elevator car by any suitable means. The door section 5 carries a cam CM at the top. This cam CM opens a normally-closed limit switch OL (FIG. 4) in the fully open position and a normally-closed limit switch CL in the fully closed position.

Movement of the door section 5 is effected by a lever 13 pivotally mounted about pin 15 on the elevator car. The lower end of the lever 13 is pivotally connected to one end of a link 17, the other end of the link being pivotally connected to the door section 5. The lever 13 is coupled to the lever A13 by a link 19, the ends of which are pivotally attached to the levers 13 and A13 by pivots 21 and A21, respectively. Pivot 21 is positioned above the pin 15, whereas the pivot A21 is located below the pin A15. Rotation of the lever 13 to open or close the door section 5 then moves the link 19 in the proper direction to open or close the door section A5.

The lever 13 preferably is operated by a suitable door operator 23 which may include a reversible rotation direct-current electric motor M1 coupled through suitable gearing to a shaft 27. The shaft 27 carries an arm 29 which is pivotally connected to one end of a link 31, the re-

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maining end of the link 31 being pivotally connected to the lever 13. The motor M1 may be energized in a conventional manner for the purpose of opening and closing the door sections 5 and A5. When the door is to be opened, the motor M1 is operated to rotate the arm 29 in a clock-wise direction as viewed in FIG. 1. To reclose the door, the electric motor M1 is reversed and returns the arm 29 to the position illustrated in FIG. 1.

Conveniently, the car-door sections 5 and A5 may have associated therewith mechanical safety edges 37 and A37, respectively. The edges 37 and A37 are movable by an obstructing object in the closing path of movement of their associated door sections to actuate limit switches 39 and A39, respectively, for controlling movement of the door sections.

Cams CM4 and CM5 are mounted on shaft 27 rotatable therewith. These cams CM4 and CM5 are composed of magnetizable material, such as iron. Each is coupled to cores T4C and T5C (FIG. 4), respectively of a transformer T4 and T5 and as each cam is rotated it varies the reluctance of its coupled core between a low magnitude and a high magnitude. The cams are rotated in synchronism with the movement of the sections 5 and A5 and vary the reluctance of cores T4C and T5C in synchronism with the movement of the doors. The reluctance of T4C is varied oppositely to that of T5C; the variation of T4C produces the command-potential pattern during closing and of T5C the potential during opening.

The speed of the sections 5 and A5 is precisely controlled in accordance with this invention by a control circuit for the motor M1 the operation of which is governed by the command-potential pattern and schematics of which are shown in FIGS. 4 and 5. This control circuit includes a Pattern Generator, a Motor Supply and a Differential Amplifier. These units are supplied with alternating current from the buses or conductors 110 and 111 usually of a commercial alternating current supply. In addition, direct current is supplied from the positive and negative poles (with reference to ground) V_B and V_C of a direct current supply (not shown) which may be energized through rectifiers (not shown) from the buses 110-111.

The relationship of the major components of the apparatus is shown in the block diagram, FIG. 3. The motor M1 is energized through Valves (SCR1 or SCR2) in the appropriate direction on the operation of a Control which is actuated by a switch or contact SW. The switch may be the contact of a relay which is operated to open the doors 5-A5 when the elevator reaches a landing and to close the doors before departure from the landing. Actuation of the switch SW causes the Control to actuate the Pattern Generator to produce the command-potential pattern.

The motor supply includes a tachometer circuit from which a motor-speed dependent potential is derivable. The Pattern Generator potential and the motor-speed dependent potential are supplied to the Differential Amplifier which controls the Valves so that the motor M1 is appropriately energized.

The Pattern Generator includes the transformers T4 and T5. Transformer T4 includes a primary T4P energized from conductors 110 and 111 through resistor R33; T5 includes primary T5 energized through resistor R34 from 110 and 111. R33 and R34 are variable and serve to set the maximum speed of sections 5 and A5 in closing and opening respectively. Transformer T4 includes secondary T4S a part or section of which is coupled to T4P through variable reluctance core T4C; transformer T5 includes secondary T5S similarly coupled to T5P through variable reluctance core T5C.

Secondary T4S impresses between a conductor L+ and ground a positive direct-current potential which varies in accordance with the setting of cam CM4 through diodes D1, D2, D3 and D4. This potential is filtered by

capacitor C1. Likewise a negative direct-current potential filtered by capacitor C2 is supplied between a conductor L— and ground through diodes D7, D8, D9, D10. The potential of L+ does not become zero at its lowest magnitude but attains a magnitude set by R1 to correspond to the desired closing creep speed of the door. R1 is connected in circuit V_B, R5, R1, ground. The adjusting arm of R1 is connected to L+ through diode D5 which is so poled that when the potential of L+ becomes more negative than the potential of this arm L+ is in effect connected to this arm. R3 and D11 likewise set L— to the desired opening creep speed.

The potential between L+ and ground is the door-closing pattern and the potential between L— and ground is the door-opening pattern. These are the command-pattern potentials and their magnitudes are shown as a function of door position in FIG. 2. In this view volts are plotted vertically and door position horizontally. Each pattern-potential is at a predetermined magnitude with the door at rest in the corresponding position. The potential remains at this magnitude until the door reaches position P1, during closing, and P2, during opening. From this point the potential decreases gradually to a low or zero magnitude. P1 and P2 are near the closed and open positions, respectively but are spaced sufficiently (from these) positions, taking into consideration the inertia of the sections 5 and A5, to assure that the door reaches zero or creep speed before closing.

The door-closing pattern is impressed between a pattern-output conductor LP and ground through a transistor, Q2, in the following circuit: V_B, R31, Q2, R11, LP, ground. The door-opening pattern is impressed between LP and ground through a transistor Q5, in the following circuit: V_C, R32, Q5, R17, LP, ground. Transistor Q2 is controlled from transistor Q1, which in turn is controlled by transistor Q3. Q1 is supplied from L+ in the following circuit: L+, R6, Q1, ground. The collector of Q1 is connected to the base of Q2. No current flows in the collector circuit of Q3 while SW is in the "door open" position. Q3 is saturated while SW is in the "door close" position as follows: V_B, R7, Q3, R18, SW, V_C, ground. SW is a two-position overcenter contact having a door-open pole DO and a door-closed pole DC. DC is connected to pole V_C of the supply and DO to ground. Typically, switch SW is an appropriate contact of a relay or output of solid-state logic circuits.

It may be assumed that the doors were opened. Switch SW is then closed to DO. The emitter of Q3 and its base are at ground and Q3 is non-conducting. The potential of the base of Q1 is then determined by a voltage divider as follows: V_B, R7, R8, R9, V_C, ground. R7 and R8 are substantially smaller than R9 so that the base of Q1 is positive. L+ is at maximum potential with the doors fully open (see FIG. 2) and Q1 is saturated during door-open stand-by. During door-open stand-by the base of Q2 is grounded through Q1 and its emitter is also grounded (through R11, LP and R23); Q2 is non-conducting. When SW is closed to DC, Q3 becomes highly conducting and its collector approaches ground potential. The base of Q1 is then connected to V_C through R9 and Q1 becomes non-conducting. The potential on the base of Q2 is then determined by the divider: L+, R6, R10, V_C, ground. The conduction of Q2 then follows the pattern on L+.

Transistor Q5 is controlled from Q4. The collector circuit of Q4 is supplied from L— and is as follows: L—, R13, Q4, ground. The base of Q4 is adapted to be connected to V_C through R14 and SW when the doors are closed or closing. With SW in the DC (door-closed) position the potential of the base of Q4 is determined by divider V_B, R15, R14, SW, V_C and is negative relative to ground because R15 is about five times R14; Q4 is then saturated, Q5 is then substantially non-conducting.

When the door is to be open SW is set in position DO. The base of Q4 is then rendered electrically positive relative to the emitter by divider V_B, R15, R14, SW, ground and Q4 becomes non-conducting. The potential of the base of Q5 is then determined by divider V_B, R16, R13, L—. R16 is high compared to R13 so that Q5 and LP follow the pattern on L—.

The Motor Supply includes the silicon-controlled rectifiers SCR1 and SCR2. The motor M1 is connected to be supplied with current of one polarity through SCR1 in the following circuit: 111, SCR1, limit switch CL, M1, the reactor L1, R21, 110. The motor is supplied with current of opposite polarity through SCR2 in the following circuit: 110, R21, L1, M1, limit switch OL, SCR2, 111. The semiconductor components are protected by surge suppressor VS1 connected directly across the motor armature and by surge suppressor VS2 connected between conductors 110 and 111.

The firing electrode for SCR1 is supplied from the secondary T1S of transformer T1 in the Differential Amplifier through resistor R19. The firing electrode of SCR2 is supplied from the secondary T2S of transformer T2 in the Differential Amplifier through resistor R20. Transformers T1 and T2 supply pulses in a phase relationship to the alternations of the supply 110-111 which is dependent on the relationship between a motor-speed dependent potential and the pattern potential.

To derive the motor-speed dependent potential the armature of motor M1 is connected in a bridge. The arms of the bridge are the armature of M1, reactor L1 and resistor R21, resistor R24 and resistor R22. The output conjugate terminals of the bridge are J1 and J2; J1 is connected to ground and J2 to LP. In this bridge the motor M1, the inductor L1 and resistor R21 are connected in balanced relationship with the resistors R22 and R24. The inductor L1 is connected to counterbalance the inductance of motor M1 and the resistors R21, R22 and R24 are connected to balance the IR drop across the motor M1. A potential proportional to the back electromotive force of the motor M1 is impressed across resistor R23. A capacitor C2 is connected across R23 to suppress ripple. During operation of the doors a current flows into the base of Q9 which is the difference between the output current of the pattern generator and the output current of the tachometer bridge circuit.

The Differential Amplifier includes transistors Q8 and Q9 and the uni-junction transistors Q6 and Q7. The Differential Amplifier also includes pulsing networks. One network includes the primary T1P of transformer T1 and a capacitor C4. The other network includes the primary T2P of transformer T2 and a capacitor C5. Q8 cooperates with Q6 to control the flow of pulses through C4 and T1P and Q9 and Q7 control the flow of pulses through C5 and T2P.

The uni-junction transistors Q6 and Q7 and the pulsing networks are supplied from the conductors 110 and 111 through transformer T3 and rectifier bridge D13, D14, D15, and D16 having positive pole B+. The base electrodes of uni-junction transistor Q6 are supplied in the following circuit: B+, R25, R27, Q6, ground. The uni-junction transistor Q7 is supplied in the following circuit: B+, R25, R28, Q7, ground. The potential derivable from the rectifier bridge D13-16 is unfiltered and its wave form essentially consists of a succession of half waves of one polarity. The potentials on the base electrodes of Q6 and Q7 are then each a succession of positive half waves.

Capacitor C4 is maintained charged in circuit: V_B, R26, C4, T1P, ground; C5 in circuit: V_B, R29, C5, T2P, ground. The charging of these capacitors C4 and C5 is at a relatively low rate so that the current conducted through T1P and T2P do not induce pulses of substantial amplitude in T1S and T2S. C4 is connected to the emitter of Q6 and C5 to the emitter of Q7. The charge on capac-

itor C4 is bled-off through transistor Q8 and that on C5 through Q9. Q8 and Q9 are controlled from LP. LP is connected to the base Q9 and the base of Q8 is grounded. The emitter collector circuits of both transistors are connected in common through the resistor R30 to V_C so that the collector current of either transistor Q8 or Q9 conducted by the resistor R30 controls the conduction of the other transistor Q9 or Q8.

With the apparatus in stand-by so that no current flows through LP the transistors Q8 and Q9 are set to conduct so that the potentials on C4 and C5 are inadequate to cause the capacitors to discharge through the emitter-base circuit of transistors Q6 and Q7. The capacitors C4 and C5 then remain charged at a predetermined potential.

Assume that the door is closed and it is desired that it be opened. For this purpose the switch SW is snapped from DC to DO. A negative potential is then impressed between LP and ground. Initially with the motor at rest J2 and J1 are substantially at ground and this potential on LP causes positive current to flow along LP from J2 to Q5 of the Pattern Generator. This current reduces the conduction of Q9 substantially. At the same time the conduction of Q8 is increased since the drop across R30 is decreased. C5 is then raised to a potential such that it discharges early during each of the half wave pulsations impressed on Q7. The potential on C4 is insufficient to render Q6 conducting. Successive pulses are then transmitted through T2P early in the half periods of the alternating supply derived from the conductors 110 and 111 and silicon controlled rectifier SCR2 is rendered conducting at instants beginning early in the alternate half periods. The motor M1 is then energized and supplies substantial torque to overcome the inertia of the door sections 5 and A5 and to start the opening of the door. The counter-electromotive-force produced by the motor also becomes substantial reducing the current in LP and increasing the conduction of Q9. The silicon controlled rectifier SCR2 is then rendered conducting later in the half periods of the supply reducing the power supplied to the motor M1 so that the doors move at the desired speed.

If during the operation the motor M1 exceeds the desired speed, the counter-electromotive-force of the current through LP becomes reversed increasing the conduction of Q9 above the stand-by magnitude. The discharge of C5 is stopped. On the increase of the conduction of Q9 the drop across R30 is increased and the conduction of Q8 is reduced so that the potential on C4 increases so as to discharge C4 through the emitter and base of Q6. The pulsing through the primary T2P is interrupted so that silicon controlled rectifier SCR2 becomes non-conducting. But pulses are now transmitted through the primary T1P so that silicon controlled rectifier SCR1 is rendered conducting. The motor M1 is now operating in a direction such as to supply power to the conductors 110 and 111 through silicon controlled rectifier SCR1. The motor is then regeneratively braked and promptly reduces its speed to a magnitude corresponding to the potential pattern.

The above-described operation continues until the door sections 5 and A5 are near or in the closed position. At this point the potential of the potential pattern is reduced decreasing the speed of the motor substantially so that the doors close without applying any undesired shocks to the door edges or to any other parts of the apparatus.

Now assume that the doors are closing (SW closed to DC) and a passenger in the entranceway is engaged by the sections 5 and A5. Assume that this event occurs with the door in position X. The elevator is provided with a mechanism which actuates SW from DC to DO and the opening command potential pattern is applied to the door. At X the opening command potential is high so that the door promptly retracts to the open position.

The following summary is made in understanding this invention:

This invention relates to the control of elevator doors by contactless switching. Continuous command potential patterns of speed versus position are generated for the open and close operations; and actual door speed is measured and used for regulation.

A functional block diagram of the system is shown in FIG. 3. The motor M1 receives power whenever the valves are open. The motor M1 drives the door sections 5 and A5, limit switches and pattern generators. Pattern potential and motor speed are compared in a Differential Amplifier which in turn controls the Valves. When the motor speed is lower than the desired speed, power flows from power supply 110-111 to motor M1; when the motor speed is higher than the desired speed, power flows from motor M1 to power supply 110-111; the motor decelerates by regeneration. The larger the error, the greater the power flow.

The Pattern Generator (FIGS. 4, 5) is controlled by a variable reluctance differential transformer. This control is simple, reliable, and can easily achieve greater than ten to one change in output voltage for maximum change in reluctance. Two patterns are generated to allow flexibility in setting the cams for doors of various opening widths. When SW is connected to DC, the closing pattern is effective and when SW is connected to DO the opening pattern is effective. Variable resistors R33 and R34 and R1 and R3 are used to adjust the open and close maximum and minimum speeds. The output appears on the conductor LP.

FIGS. 4 and 5 also show the motor and tachometer (motor speed derivative) circuits. The voltage across R23 is proportional to the actual motor speed. A capacitor C3 is connected across R23 to filter any ripple due to either bridge imbalance or ripple in counter EMF. SCR2 conducts for opening acceleration and closing deceleration; SCR1 conducts for closing acceleration and opening deceleration. Limit switches OL and CL cut power at the extreme limits of travel for motor burn-out protection in the event of any failures throughout the system.

Currents proportional to motor speed and pattern potential flow in conductor LP and act in the Differential Amplifier to control the uni-junction transistors Q7 and Q8 ultimately SCR1 and SCR2. Among the desirable features of the apparatus according to this invention are:

- (1) Ease of adjustment because of speed regulation.
- (2) Possibility of mounting on the car because of lightweight of the apparatus and the noiseless switching.

While a preferred embodiment of this invention has been disclosed herein many modifications thereof are feasible. This invention then is not too be restricted except insofar as is necessitated by the spirit of the prior art.

I claim as my invention:

1. A speed-controlled servo-positioner comprising a moveable body, a motor connected to said body for positioning said body, means connected to said motor and controllable by a voltage impressed thereon for variably energizing said motor for rotation in either direction in accordance with said impressed voltage, control-voltage producing means for producing a control voltage having predetermined pattern corresponding to the desired speed of said motor while positioning said body, means connected to said control-voltage producing means and to said motor for deriving a signal dependent on the difference between said control voltage and the counter-electromotive force across said motor; and means connected to said deriving means for impressing the derived signal on said energizing means to control said energizing means.

2. A speed-controlled servo-positioner comprising a movable body, a motor connected to said body for positioning said body, means connected to said motor and controllable by a voltage impressed thereon for variably energizing said motor for rotation in either direction in accordance with said impressed voltage, control-voltage producing means for producing a control voltage having predetermined pattern corresponding to the desired speed of said motor while positioning said body, means connected to said control-voltage producing means and to said motor for deriving a signal dependent on the difference between said control voltage and the counter-electromotive force across said motor; and means connected to said deriving means for impressing the derived signal on said energizing means to control said energizing means.

cordance with said impressed voltage, control-voltage producing means operable in synchronism with the movable body the magnitude of which is a continuous function of the position of the body corresponding to the desired speed of said motor while positioning said body, means connected to said control-voltage producing means and to said motor for deriving a signal dependent on the difference between said control voltage and the counter-electromotive force across said motor; and means connected to said deriving means for impressing the derived signal on said energizing means to control said energizing means.

3. A speed-controlled servo-positioner comprising a movable body, a motor connected to said body for positioning said body, means connected to said motor and controllable by a voltage impressed thereon for variably energizing said motor for rotation in either direction in accordance with said impressed voltage, control-voltage producing means for producing a control voltage having predetermined pattern corresponding to the desired speed of said motor while positioning said body, first deriving means connected to said motor for deriving a voltage dependent on the speed of said motor, second deriving means connected to said control-voltage producing means and to said first deriving means for deriving a signal dependent on the difference between said control voltage and said speed-dependent voltage, and means connected to said second deriving means for impressing the derived signal on said energizing means to control said energizing means.

4. Apparatus for controlling a direct current motor comprising an alternating-current supply, a first asymmetrically conductive valve having a control electrode, for controlling the conduction thereof, interposed between said supply and said motor to supply current of one polarity thereto to cause the motor to rotate in one direction, a second asymmetrically conductive valve having a control electrode, for controlling the conduction thereof, interposed between said supply and said motor to supply current of the opposite polarity thereto, to cause the motor to rotate in the opposite direction, means for producing a command control-potential pattern for each said direction of rotation, first deriving means connected to said motor for deriving a potential dependent on the speed of said motor, selective means connected to said producing means for selecting one of said patterns in dependence upon the desired direction of rotation of said motor, second deriving means connected to said producing means and to said first deriving means for deriving a plurality of pulses, each pulse having a phase position with reference to the alternating of said supply, dependent on the instantaneous difference between the potential of the selected pattern and said speed-dependent potential, and means connected to said control electrode of the valve corresponding to said selected pattern for impressing said pulses on said control electrode to render said corresponding valve conducting at instants in half periods of said supply potential that are earlier the greater the difference between said pattern potential and said speed-dependent potential.

5. Apparatus for controlling direct-current motor having opposite directions of rotation, comprising an alternating-current supply, first and second asymmetrically conductive valves, each valve having a control electrode for controlling the conduction thereof, means connecting said first valve between said supply and said motor to conduct current of one polarity between said supply and said motor, means connecting said second valve between said supply and said motor to conduct current of the opposite polarity between said supply and motor, means for producing a command control-potential supply pattern for each said direction of rotation, first deriving means connected to said motor for deriving a potential dependent on the speed of said motor, selective means connected to said producing means for selecting one of said patterns dependent on the desired direction of rotation of said

motor, second deriving means connected to said producing means and said first deriving means for deriving a plurality of pulses, each pulse having a phase position, with reference to the alternations of said supply, dependent on the instantaneous difference between the potential of the selected pattern and said speed dependent potential, and means connected to said control electrodes for impressing said pulses on said control electrodes to render one of said valves conducting to supply current from said supply to said motor to drive said motor in the desired direction, when the potential of said pattern exceeds the speed-dependent potential, and to render the other of said valves conducting to supply current from said motor to said supply when said speed-dependent potential exceeds said potential of said pattern.

6. A speed-controlled servo-positioner comprising a movable body, a motor connected to said body for positioning said body, a power supply, valve means interposed between said supply and said motor for variably controlling the conduction of current between said supply and said motor, means for producing a voltage pattern corresponding to the desired operation of said motor, means connected to said motor for deriving a potential dependent on the speed of said motor, and means responsive to said deriving means and to said producing means connected to said valve means for causing power to flow from said supply to said motor when said pattern potential exceeds said speed-dependent potential and for causing power to flow from said motor to said supply when said speed-dependent potential exceeds said pattern potential.

7. The servo-positioner of claim 6 in which the means for producing a voltage pattern is connected to and is responsive to movement of the movable body so that the voltage pattern is a function of the relative position of said body.

8. The servo-positioner of claim 7 in combination with a second substantially similar means for producing a voltage pattern, the first producing means generating a voltage pattern for a first direction of rotation of said motor, the second producing means generating a voltage pattern for the opposite direction of rotation of said motor, and selector means for selecting the proper pattern for the desired direction of rotation.

9. A speed-controlled servo-positioner comprising a movable body, a motor connected to said body for positioning said body, an alternating-current power supply, first and second asymmetrically conductive valves, each valve having a control electrode for controlling the conduction thereof, means connecting said first valve between said supply and said motor to conduct current of one polarity between said supply and said motor, means connecting said second valve between said supply and said motor to conduct current of the opposite polarity between said supply and said motor, means for producing a separate command voltage pattern for each direction of rotation of said motor, said patterns being a function of the relative position of said body, selector means for selecting one of said patterns dependent upon the desired direction of rotation of said motor, deriving means connected to said motor for deriving a potential dependent upon the speed of said motor, first and second pulse generators connected to said respective control electrodes for initiating conduction in the associated valves, and control means connected to said selector means and said deriving means for activating said first pulse generator if the command voltage exceeds the speed derived potential, activating the second pulse generator if the speed derived potential exceeds the selected command voltage, and causing the selected pulses to occur later in each half cycle of the alternating-current supply the smaller the difference between the relative magnitudes of the command voltage and the speed derived potential.

10. The speed-controlled servo-positioner of claim 9 in which each pulse generator comprises a capacitor, an

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electronic switch shunting the associated capacitor, said switch being normally an open-circuit state but presenting substantially a short circuit across the associated capacitor when the voltage on the capacitor exceeds a predetermined proportion of a bias voltage applied to said switch, a direct-current power supply for charging said capacitors, and means for applying the bias voltage to each switch at the onset of each half cycle of said alternating-current power supply, said bias voltage being maintained for substantially the entire half cycle, and in which said control means comprises an electronic valve connected to each pulse generator, said electronic valves being electrically coupled to differentially control the charges on the capacitors of the associated pulse generators.

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