

[54] **FINAL STOPPING CONTROL**

[75] Inventors: **Joseph W. Kuhl**, Toledo; **Robert J. Lauer**, Bowling Green, both of Ohio

[73] Assignee: **Reliance Electric Company**, Euclid, Ohio

[22] Filed: **May 9, 1972**

[21] Appl. No.: **251,801**

[52] U.S. Cl. **187/29 R**

[51] Int. Cl. **B66b 1/30**

[58] Field of Search 187/29

[56] **References Cited**

UNITED STATES PATENTS

3,627,080	12/1971	Yuminaka et al.	187/29
3,570,630	3/1971	Voigt et al.	187/29
3,589,474	6/1971	Wavre	187/29
3,613,835	10/1971	Vizzotto	187/29

Primary Examiner—Bernard A. Gilheany

Assistant Examiner—W. E. Duncanson, Jr.

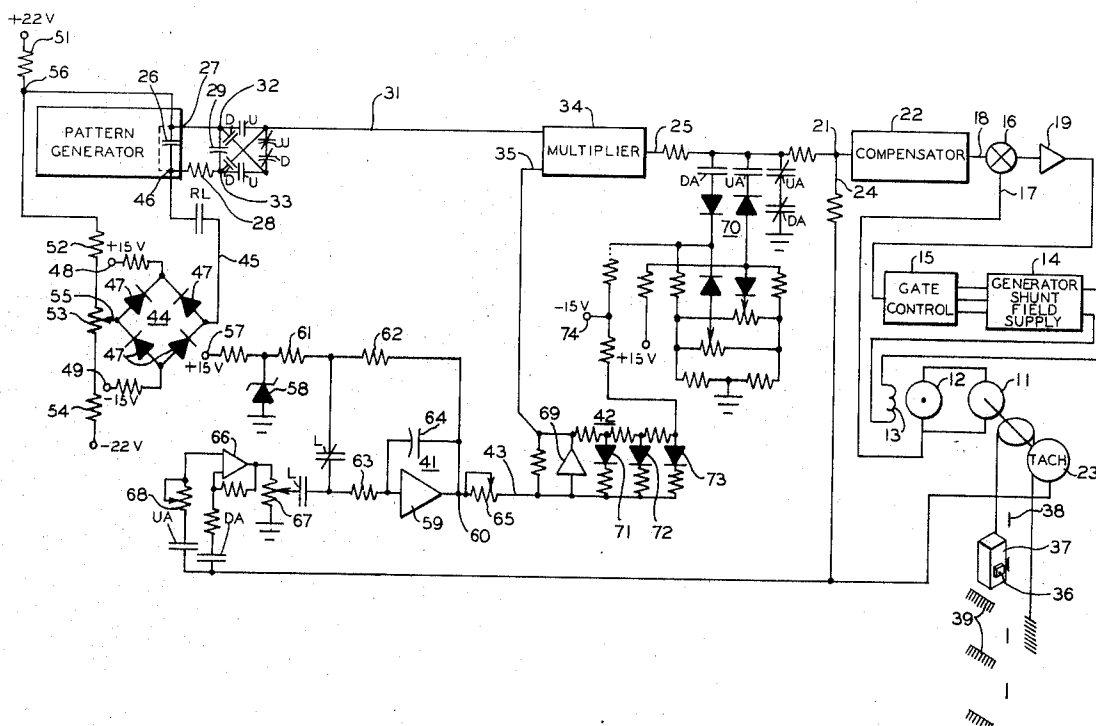
Attorney—Wilson & Fraser

[57] **ABSTRACT**

A pattern generator for controlling the terminal por-

tion of the travel of an object along a fixed path. The pattern is a velocity signal which diminishes as the object approaches its destination whereby a smooth stop is dictated. The generator is particularly adapted to the final stopping of vehicles for passengers and is illustrated as the source of control signals for driving an elevator. As an elevator pattern generator, it integrates the pattern signal velocity as represented by voltages when the car is at a point within a given distance from a landing to provide a signal representing displacement. The required displacement to the stop is proportioned to the actual velocity of the car at that point to define a leveling pattern as the product of the proportioning factor and the velocity. As a compromise between square root function, which would afford smoothness and require a long stopping interval, and a straight line function, which would provide minimum transition time to zero velocity and impose infinite jerk at the stop position, the integrated signal is modified as a function of the integrated signal value during approach to the stop. The pattern signal upon initiation of leveling is corrected if a significant disparity with the predetermined desired speed occurs.

16 Claims, 11 Drawing Figures



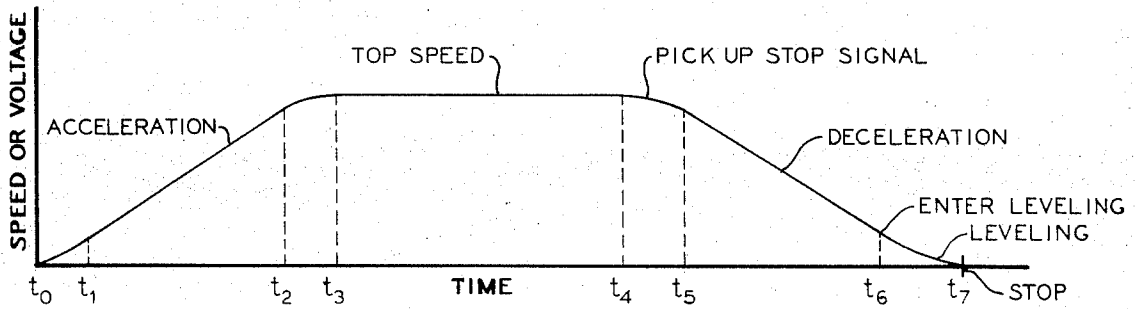


FIG. 1

- FIG. 3**
- a SIGNAL AT 31
 - b SIGNAL AT 60
 - c SIGNAL AT 35
 - d SIGNAL AT 25

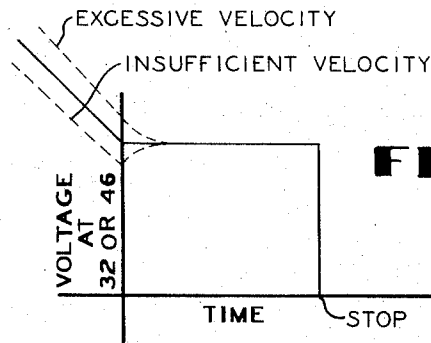


FIG. 3a

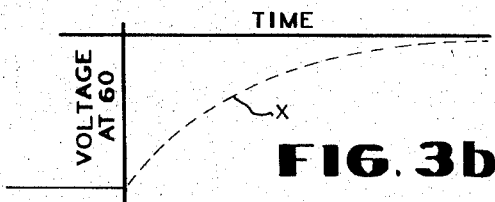


FIG. 3b

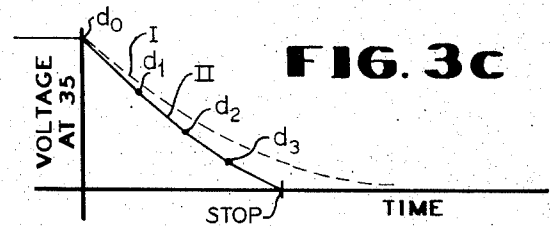


FIG. 3c

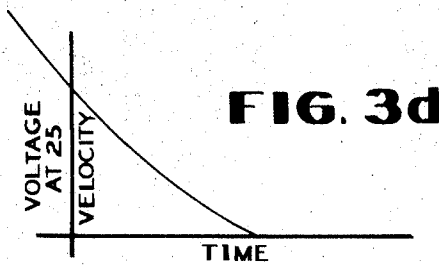
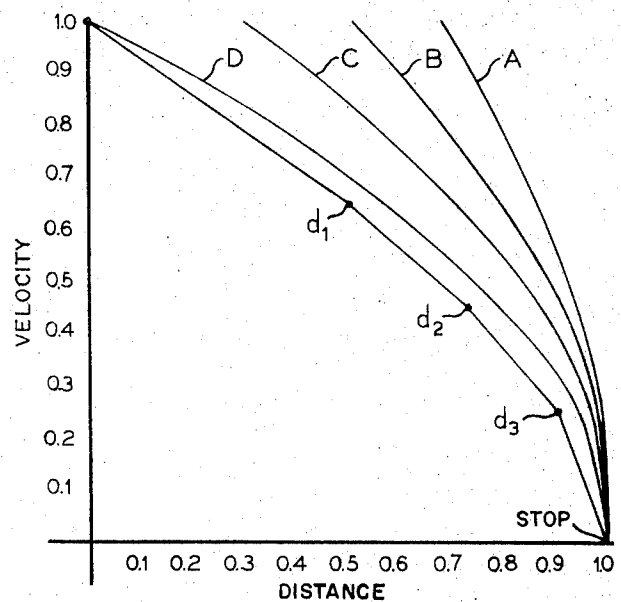


FIG. 3d

FIG. 4



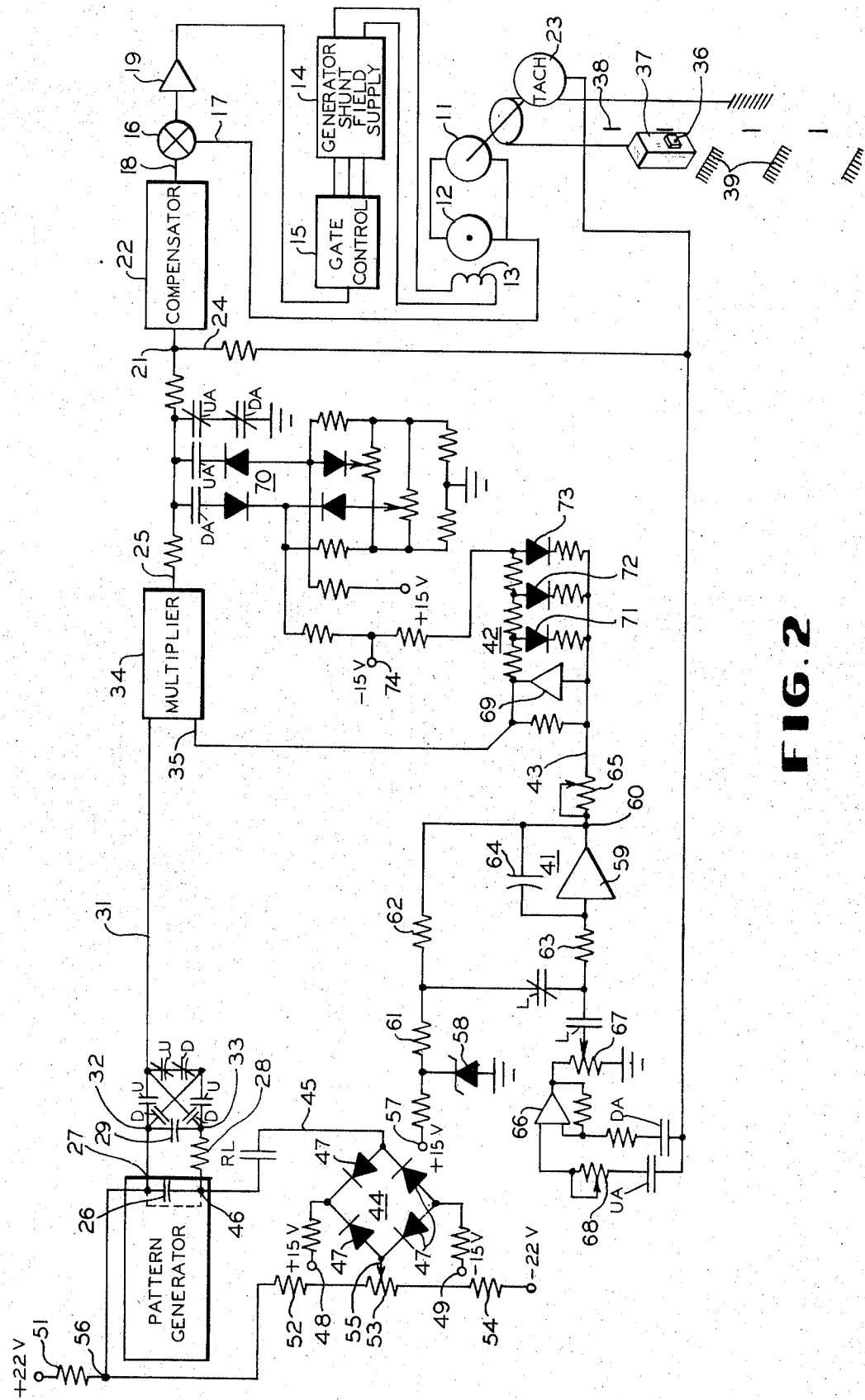


FIG. 2

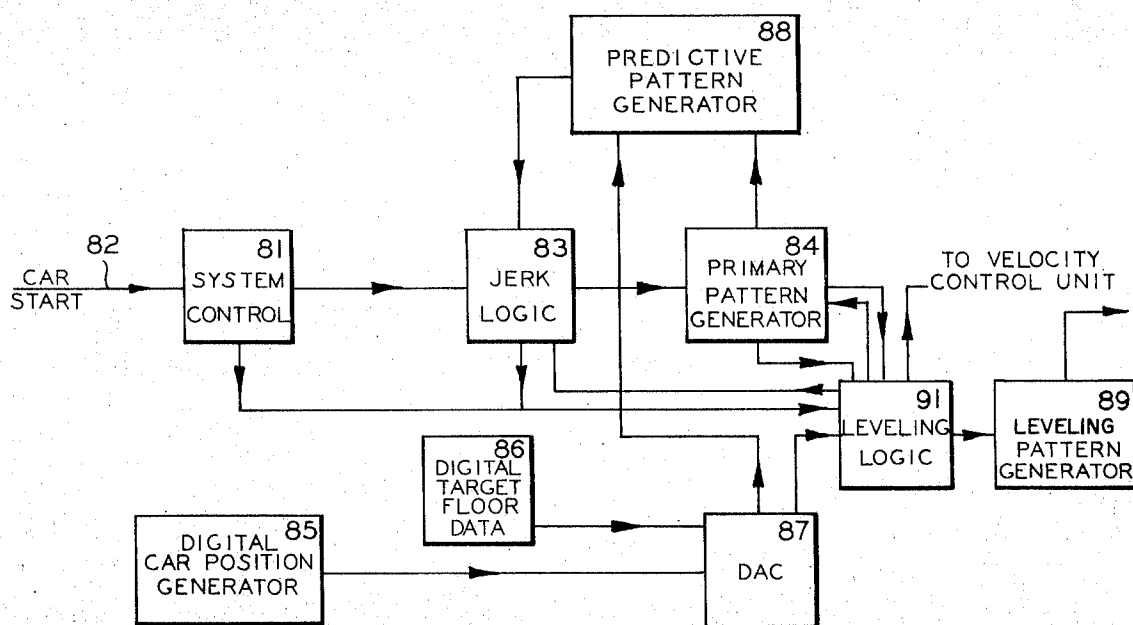


FIG. 5

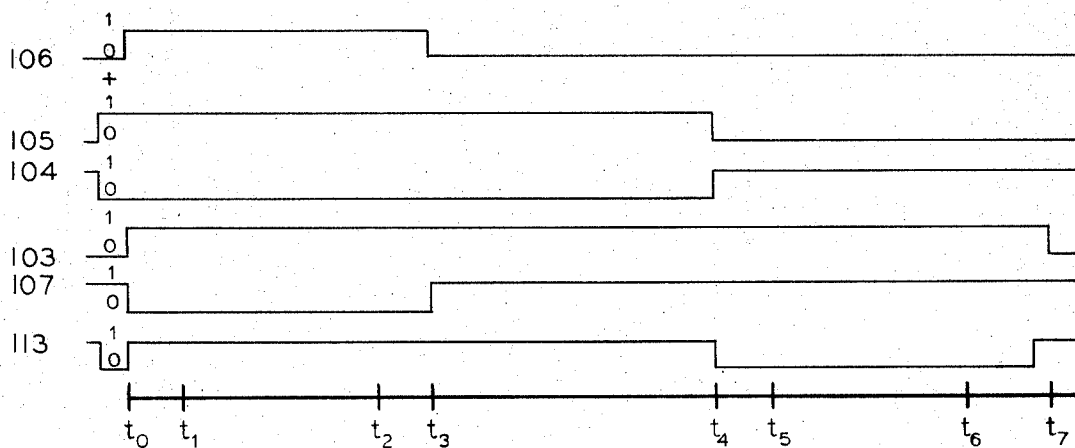


FIG. 7

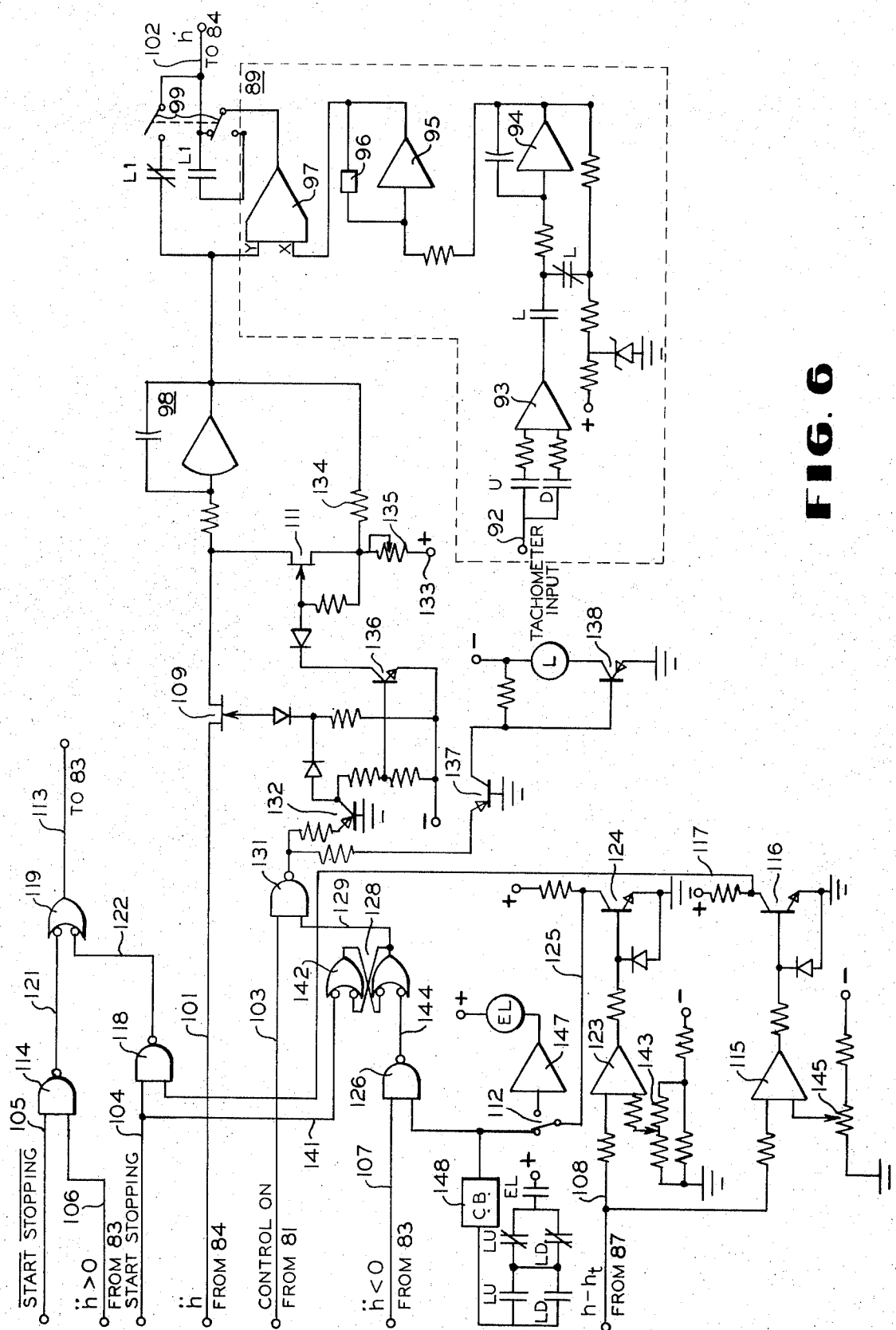


FIG. 6

FINAL STOPPING CONTROL

CROSS REFERENCES TO RELATED APPLICATIONS

This invention has been disclosed for utilization with two forms of elevator controls. One of those forms is embodied in patent applications filed herewith in the names of George S. Dixon, Edward O. Gilbert and Gerald D. Robaszekiewicz entitled "Elevator Electronic Position Device," Ser. No. 251,793, filed May 9, 1972 and in the names of Edward O. Gilbert and Elmer G. Gilbert entitled "Predictive Elevator Control," Ser. No. 251,810 filed May 9, 1972.

BACKGROUND OF THE INVENTION

It is known to generate desired voltage signals as a function of time and to scale voltage to velocity of an object for the pattern signal in a velocity based drive control system. In U.S. Pat. No. 3,584,706 which issued June 15, 1971 to D. L. Hall et al. entitled "Safties for Elevator Hoist Motor Control Having High Gain Negative Feedback Loop," an elevator hoist motor control is shown wherein a velocity pattern signal is issued by a pattern generator to a summing point at which it is compared with a speed signal derived from a tachometer coupled to the elevator to generate a voltage proportioned to elevator car speed. The resultant difference between the actual speed signal and the pattern speed signal is employed, with suitable compensation for the inherent lag of the actual speed relative to the pattern, to control the shunt field current in a generator supplying the armature of the hoist motor. The variable voltage control of the above arrangement can be refined with an inner closed loop to compensate for current drop and iron-saturation, non-linearity by effectively employing the velocity error signal as a desired motor-generator loop voltage to be compared with actual loop voltage. It can also be arranged to supply the generator shunt field through controlled rectifiers from a conventional alternating current source by applying the controlling error signal to a gate control for the rectifiers.

The above general organization can be utilized with various forms of pattern generators to produce a superior ride insofar as passenger comfort and trip time are concerned. Mechanically driven pattern generators have been employed as where a motor driven rheostat produces a signal as a function of time. Such patterns when employed in elevator controls have been employed through the initial slowdown portion of a run, however, the final portion has usually involved a shift to a position base as derived from the spatial relationship of the car to a landing at which a stop is to be made. Usually, a large number of leveling points are defined to develop the final stopping or leveling pattern.

Patterns have also been generated by charging and discharging a condenser. Such patterns when velocity based have also utilized at least position check points in the generation of a final stopping pattern.

A step pattern input representing jerk has been employed in conjunction with integrators and limiters whereby a pattern constrained to a constant jerk within comfortable limits such as 8 ft/sec.³, maximum acceleration within comfortable limits such as 4 ft/sec.² and a maximum velocity can be generated. This latter pattern generator integrates a step input of a predetermined value representing the jerk constraint to produce a

gradual transition of acceleration to maximum value. That maximum acceleration signal is sustained until the velocity signal derived from its integration achieves a value representing the velocity from which the transition to maximum velocity can be made within the negative jerk constraints, at which time negative jerk is imposed until acceleration returns to zero at the maximum velocity signal level. When a stop is to be initiated, the pattern signal generator by its double integration of the negative jerk signal produces a pattern which follows an ideal curve into slowdown subject to the limited jerk and acceleration values. Drift in component values coupled with the high degree of precision required in final leveling of the car at landings has dictated that a position base be employed for the final control into the floor.

The utilization of a number of slowdown positions in the control of a driven object such as an elevator requires a substantial amount of hardware in the form of switches or sensors and actuators mounted both on the object and along its travel path. Each of these elements must be precisely located with respect to the desired stopping position. Hence, substantial installation expense is added to their cost. The elements must be maintained and where a number of stop positions are required even such maintenance becomes significant. Further, the discrete signals during approach to a stop frequently lead to discontinuities in the desired smooth travel of the object.

SUMMARY OF THE INVENTION

This invention relates to pattern generators for control of the drive mechanisms of movable objects. While it is illustrated as applied to passenger carrying vehicles and particular elevator cars, it is to be understood that it is applicable to the drive control for other movable objects. The pattern generators of this invention are contemplated for use in the final slowdown and stopping portion of travel of the object and are illustrated for elevator application. They are utilized with velocity based patterns of various types including those developed on a position vs. velocity basis, those developed on a time vs. velocity basis, and combinations of the position and time vs. velocity basis.

In each instance of elevator utilization the pattern generator of this invention is rendered effective when the elevator car enters the range of influence of a leveling control such as when the car motion carries a magnetic switch and switch controlling vane into their range of mutual influence. The pattern generator develops a pattern velocity as a function of displacement through the leveling zone by proportioning its pattern velocity at the moment it entered the zone progressively downward to zero as the car is displaced through the zone. The proportioning factor is developed by integrating car velocity as represented by a tachometer signal to indicate displacement of the car through the leveling zone and effectively subtracting the displacement from the distance to be traveled to a stop in the leveling zone. The value of the proportioning factor is employed as a multiplier which is progressively reduced while the multiplicand is the pattern signal level upon car entry into the leveling zone. The product of this multiplication is the leveling pattern velocity signal.

Correction of the pattern signal level at car entry into the leveling zone to the desired level for good riding

characteristics is provided by means which gradually corrects to the desired level a signal which does not correspond to that level. The square law proportioning factor developed by the car velocity signal integration frequently required too much time to bring the car to the stop since it approaches its zero value as a multiplier asymptotically. Signal modification of the multiplier is undertaken to accelerate the stop pattern by increasing the slope of that multiplier value in discrete increments.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a curve of car velocity or pattern voltage as a function of time;

FIG. 2 is a composite block and schematic diagram of one form of leveling control for elevators typical of the final slowdown pattern generator of this invention;

FIGS. 3a through 3d are curves of the voltages which provide the leveling pattern as a function of time as represented at various junctions in the circuit of FIG. 2;

FIG. 4 is a curve of leveling speed pattern as a function of distance in the leveling zone;

FIG. 5 is a simplified block diagram illustrating the application of the leveling pattern generator of this invention to the predictive elevator control system of the forenoted Gilbert et al. patent application;

FIG. 6 is a logic diagram of the logic control for the control of the leveling pattern generator as utilized with the system of FIG. 5; and

FIG. 7 is a logic sequence for the control of FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

While the illustrative embodiments of the final slowdown pattern control are for application to elevator hoist motors it should be appreciated that such controls are applicable to other vehicles such as those operating on horizontal or inclined tracks and to other objects such as tool and work carriages of machines.

Ideally an elevator follows a pattern for a given run which completes that run in a minimum time interval within the limits of comfort of the passengers. Constraints are imposed on acceleration and rate of change of acceleration (jerk) for passenger comfort. The ideal pattern will employ a constant jerk on starting until maximum acceleration is achieved, maintain that acceleration until the negative value of constant jerk will bring the maximum velocity pattern value and initiate stopping with the negative constant jerk to negative maximum acceleration which is maintained until application of positive constant jerk brings the pattern to zero velocity at the desired position of the car. Compromises are made on this ideal pattern in view of equipment and economic limitations.

FIG. 1 shows a typical velocity pattern employed to control velocity of an elevator car including the positive jerk start, $t_0 - t_1$, constant acceleration, $t_1 - t_2$, negative jerk to top speed, $t_2 - t_3$, top speed, $t_3 - t_4$, negative jerk for stop initiation, $t_4 - t_5$, constant deceleration, $t_5 - t_6$, and leveling, $t_6 - t_7$. The pattern of FIG. 1 is developed in the system of FIG. 2 as an approximation of the above-noted ideal pattern by charging and discharging capacitors. The present invention is concerned with an improved pattern for the leveling interval $t_6 - t_7$.

In the system illustrated in FIG. 2 a final stopping control for an object traveling along a predetermined

path as illustrated according to this invention as applied to the control of a hoist motor for an elevator wherein hoist motor 11 is a d-c motor having a variable voltage control. Motor 11 has a field control (not shown) and an armature circuit connected to the armature of a generator 12 driven by a suitable rotating drive such as an induction motor (not shown). Generator output voltage is controlled by control of shunt field 13 from a supply 14, in the example, phase controlled rectifiers such as SCRs (not shown) wherein the SCRs are connected back to back across a suitable a-c source such as a 60 cycle 117 volt source and are controlled as to their respective firing angles by a gate control 15.

The controlling signal to the gate control 15 is derived at summing point 16 as the difference between actual emf from the generator on lead 17, and the desired emf as dictated from a velocity error signal on lead 18. Amplifier 19 provides the desired gain for this signal and includes means to force the signal to zero when the elevator is stopped (by means not shown).

The velocity error signal is developed at junction 21 and passed to compensator 22 which adjusts it for the inherent lag of the actual elevator speed represented by the signal from tachometer 23 on lead 24 relative to the requested speed represented by the signal on lead 25.

A requested speed signal on the form shown in FIG. 1 is developed across capacitor 26 within pattern generator 27 by the coupling of appropriate charging and discharging circuits (not shown) in the pattern generator 27 as the signals are developed in the elevator control to start, slowdown and stop the elevator. Further, smoothing of the signal resulting from the charging and discharging of capacitor 26 is provided by resistance 28 and capacitance 29. Directionalizing contacts, in the example contacts of the up and down generator field relays U and D, present the pattern signal on lead 31 with the appropriate polarity for the desired direction of travel of the elevator such that on an ascending operation with contacts U closed, junction 32 is coupled to lead 31 and junction 33 is grounded while for a descending operation with contacts D closed junction 33 is coupled to lead 31 and junction 32 is grounded. When the elevator is stopped back contacts U and D are closed to ground lead 31.

Multiplier 34 provides the speed pattern signal to lead 25 in response to the pattern signal on 31. Acceleration and all but final deceleration, as the deceleration in the leveling zone for elevator control, is controlled by pattern signals from pattern generator 27. During such operation the multiplier can be considered to have a constant input on lead 35 and to issue a signal on lead 25 proportioned at a constant, for example unity, to its input signal on lead 31. During final deceleration, the pattern signal at 25 is developed in multiplier 34 by variation of the input on lead 35, coupled, where necessary, with adjustment of the signal level on lead 31.

The basic pattern from generator 27 is time based. Precision in stopping the car at the landings is enhanced by establishing a reference pattern level on a positional base as the car approaches the landing. According to the present invention, the final stopping pattern is generated by establishing a velocity signal as a reference value at a predetermined distance from the landing or stop and then proportioning that velocity signal to zero on a scale which brings the car to the landing at the instant the velocity signal has reached

zero. This is accomplished by effectively establishing a velocity signal on the pattern curve at a given distance from the landing which when integrated generates a displacement equal to that given distance. For example, if the given distance is thirty inches from the landing this can be indicated by operation of a leveling relay L actuated by the entry of a magnetically actuated switch 36 on the elevator car 37 into the range of influence of a magnetic vane 38 suitably positioned with respect to the landing 39 at which the stop is to be made and mounted in the hatchway along the path of travel of the car. When the car 37 reaches the thirty inch point in its leveling to a stop, the pattern signal from the generator 27 is fixed as shown in FIG. 3a, and control is switched to a leveling pattern signal. The leveling pattern signal is produced as a product by employing the velocity signal at that point as derived from pattern generator 27 as a multiplicand at lead 31 to multiplier 34 and utilizing a varying signal as a multiplier on lead 35. The signal on lead 35 is proportioned from a base value representing actual car velocity as derived from tachometer 23 by an integrator 41.

The use of an integrated velocity signal from tachometer 23 as a multiplier accurately brings the pattern to zero without discontinuities and provides a smooth drive throughout the leveling slowdown. However, the signal from the multiplier follows a square law by virtue of the integration and becomes asymptotic to zero velocity so that in practice the pattern dictates a very slow final approach to the stop and therefore an excessive delay in the travel of the elevator over this final travel to the stop. An alternative approach in proportioning the velocity pattern signal for leveling slowdown would be to employ a straight line relationship. However, such a relationship would result in a hard stop since infinite jerk (rate of change of acceleration) would be imposed at the stop. The straight line final slowdown pattern avoids the slow approach to the stop and reduces travel time during leveling. A suitable compromise has been accomplished by modifying the integrated leveling pattern to maintain the positional relationship and by superimposing new slope values on the signal from the integrator by means of stepped changes in amplification in amplifier 42 which advances the signal from integrator 41 to multiplier signal input 35. These changes alter the integrated signal at lead 60, as shown in FIG. 3b to the form of the input signal to the multiplier 34 at lead 35 as shown is a dotted line in FIG. 3c by introducing changes in the slope as at break points d_1 , d_2 and d_3 of FIG. 3c. As a result the travel time is reduced from that of the square law curve control to a value approaching that attainable with straight line control while maintaining the car position proportioning of the integration.

Another feature of the leveling control corrects the pattern signal multiplicand at lead 31 if it differs in value from the ideal value of velocity at the reference value. When the position at which leveling is initiated is achieved by the car, the value of the pattern voltage is maintained as shown in FIG. 3a. This value can be held as the charge on the capacitance 26 by opening the discharge circuits within pattern generator 27. If the value deviates from its designed level, the resultant leveling pattern from multiplier 34 will have a slope which will result in an excessive travel time in leveling for a reference speed below design value and excessive deceleration and jerk for a reference speed above de-

sign value. Accordingly, it is advantageous to correct the reference speed signal. This correction should be accomplished as early as possible in the leveling pattern without undue acceleration or jerk.

Correction of the reference velocity signal on lead 31 is by the voltage divider-rectifier bridge circuit 44. As the car enters the leveling zone, leveling relay L (not shown) is energized to transfer contacts L from their illustrated condition. At that time, the pattern generator 27 output is fixed by inhibiting any further change on capacitor 26 from pattern generator 27. With the output of pattern generator 27 fixed and the car in leveling, relay RL (not shown) is energized to close its contacts in lead 45 to the junction 46 between pattern capacitor 26 and resistor 28. This connects rectifiers 47 of the bridge supplied from positive and negative voltage sources at 48 and 49 across pattern capacitor 26. If the potential across pattern capacitor 26 balances that developed in the voltage divider of resistors 51, 52, 53 and 54 between adjustable contact 55 on resistor 53 and junction 56, no change will occur. However, if the design value of the velocity signal at initiation of leveling deviates from that established by the setting of contact 55, the unbalance across the rectifier bridge will adjust the charge on capacitor 26 to the predetermined value set with contact 55 in a gradual transition toward that predetermined value. Thus the multiplicand is brought to its desired value for control of the leveling pattern. As viewed in FIG. 3a, the solid line represents the voltage across the pattern capacitor 26 with that to the left of the voltage coordinate representing pattern velocity immediately prior to the car's entry into its leveling zone for the stop. Dashed lines represent an excessive and insufficient leveling zone entry velocity. The horizontal voltage value to the right of the voltage coordinate is ideally at the ideal leveling zone entry velocity as shown by the solid line. Correction, as shown by the dashed lines, follows the charging characteristic of pattern capacitor 26.

The signal which is the variable multiplier during final slowdown is held to a fixed value during the other intervals of operation including both running and stopping as shown in FIG. 3b for the signal at lead 60. This fixed value is established from a positive source at terminal 57 by Zener diode 58 through back contact L. With back contact L closed at all times except during final slowdown, amplifier 59 of integrator 41 tends to maintain the output at 60 negative at a value determined by Zener diode 58, resistances 61, 62 and 63 and capacitance 64. This constitutes the constant multiplying factor for input 35 and the offset value from which tachometer velocity signals are integrated to zero during leveling as shown in FIG. 3b. In this manner, amplifier 59 provides a constant input on lead 35 to multiplier 34 with a gain adjustment according to the setting on variable resistance 65.

When the car reaches the leveling zone, the fixed multiplier signal is transferred to the integrated signal by the opening of the back contact L and closing of front contact L to connect the tachometer signal amplifier 66 to the input to integrator 41. Amplifier 66 is arranged to accommodate the tachometer signal directionally through contact UA, closed during up travel, or DA, closed during down travel. The signal from 66 is adjustable to adjust the rate of integration of integrator to match the leveling zone. That is potentiometer 67 is adjusted so that the integration of the tachometer

signal to zero occurs in the travel of the car through the leveling zone for a down traveling car. Up travel is then trimmed in a similar fashion by adjustment of up distance trim potentiometer 68. When adjusted by 67 and 68, amplifier 66 provides an output independent of direction by virtue of the application of the signals to inverting and non-inverting inputs of the amplifier.

The curve of FIG. 3c represents the leveling signal issued at input 35. FIG. 3a shows the signal level representing velocity present across pattern capacitor 26. The pattern generator controlled decline of the velocity signal terminates at the start of leveling and is maintained at the value to which it declines until it is grounded by the drop of the direction relay U or D and closure of its back contact as the car is stopped and its brake is set. In the event the pattern signal is not at the desired level for entry into leveling, as set by positioning contact 55 on resistance 53, the closure of contact RL causes pattern capacitor 26 to charge to that desired level. The curves of FIG. 3a represent the form of the signal to multiplier 34 on lead 31.

The signal at 60 follows the curve *x* of FIG. 3b with a constant level determined by Zener diode 58 prior to leveling and an integrated value determined by the signal from tachometer 28 integrated by integrator 41. This is inverted and modified to a suitable input signal on lead 35 to multiplier 34 by amplifier circuit 42 wherein the gain of amplifier 69 is altered as the input signal changes at predetermined signal levels on lead 43 as determined by the resistance in the circuits to diodes 71, 72 and 73. The dashed line of FIG. 3c represents the signal output of amplifier 69 when no diodes are present. This output is effectively an inversion of the signal form at junction 60 and FIG. 3b.

Diodes 71, 72 and 73 initially are forward biased to conduction from the negative bias at terminal 74 and cause amplifier 69 to have a relatively low gain. As the input signal declines, the diodes are successively cut off to increase the feedback resistance for amplifier 69 and thereby increase its gain, whereby it dictates a pattern velocity which causes the car to approach the stop more rapidly. Each of diodes 71, 72 and 73 have the same forward drop. Each diode break point establishes a characteristic gain in the amplifier 69 thereby modifying the slope of the curve of the true integration signal as imposed on lead 35 at the points *d*₁, *d*₂ and *d*₃.

The resulting product signal from multiplier 34 is represented by the curves of FIG. 3d as velocity vs. time plot. This curve is proportioned to a car position as the car advances through the leveling of FIG. 3b zone since integrated actual velocity represents displacement during leveling. Curve I represents the leveling pattern where no modification is imposed by diode break points of the variable gain amplifier circuit 42 and curve II illustrates the more rapid final approach to the stop achieved with variable gain amplification of circuit 42.

In the event the pattern terminates before the car reaches a position level with the landing, a creep speed is maintained until the level is achieved. This creep speed pattern is issued through circuit 70. As previously noted, the generator field direction relays U and D and their auxiliaries UA and DA remain energized for the direction of travel set until the brake is set and the car is level with the landing at which it is to stop. Accordingly, contact UA or DA couples the appropriate polarity for up or down velocity to lead 25 until lev-

eling switches indicate the car is at the stopping position. This velocity may be at a low level such as 6 feet per minute. When the final stopping position is achieved, the generator field direction relays U, D, UA, DA and the leveling relays L and RL drop out and their contacts assume the condition illustrated.

Variations in the leveling pattern can be made in accordance with the velocity vs. distance relationships illustrated generally in FIG. 4. Curves A, B, C and D represent the form of the characteristic as the rate of integration is changed through adjustment as by potentiometer 67. Curve D is modified by the successive cut off of the diodes 71, 72 and 73 at *d*₁, *d*₂ and *d*₃ represents the characteristic for the system as shown in FIGS. 3c and 3d. It will be noted that when the car has traversed half the zone, its velocity is about 66 percent of its entry velocity and it reaches 25 percent of entry velocity after traversing all but 10 percent for the leveling zone.

The leveling pattern described above can be employed in the predictive control system of the aforementioned Gilbert et al. patent application utilizing digital signals to indicate car position. In this system, a count of one pulse for each 1/100 of a foot of car displacement indicates car position from a pulse generator coupled to the car. Hence, leveling switches need not be employed as the means of defining a leveling zone. Further, the pattern generator is coupled directly to the velocity control unit typified by compensator 22, amplifier 19, gate control 15 and the associated elements of FIG. 2 rather than through the multiplier and the multiplier is introduced into the circuit only for the leveling control.

The leveling control is shown with alternative connections in FIG. 6 to illustrate mechanisms responsive to analogue signals representing car position to indicate car entry into the leveling zone and arrival at the stopping position for either enabling leveling switches of the type discussed with regard to FIG. 2, for starting and stopping operation of the leveling pattern generator or for directly starting and stopping its operation.

Predictive control according to the system disclosed in the Gilbert et al. patent application involves repetitively generating a signal of the form of that produced by the pattern generator at a high rate. That signal represented as a displacement is extended from the current pattern position velocity and acceleration to zero velocity. That predicted signal is subject to the acceleration and jerk constraints on system operation which control the pattern. In this manner, it produces a signal indicative of the displacement to a stop from the current car drive status and position. When the displacement and car position indicate the predicted stop coincides with a landing for which a call for a stop is registered, the pattern generator is switched into its stopping mode and issues a pattern tending to stop the car at the desired destination. As in the previously described system stopping accuracy is enhanced by the leveling pattern control of this invention whereby the idealized speed is established for car entering the leveling zone and a tachometer generated car velocity signal is integrated to produce a car position proportioning factor applicable to the idealized leveling zone entry speed.

FIG. 5 is a simplified block diagram of the system of the Gilbert et al. application wherein a system control 81 responds to "car start" signals from terminal 82 to

cause a positive jerk signal to be imposed by jerk logic 83 on the primary pattern generator 84. The pattern generator 84 indicates an acceleration pattern which continues until a breakover within jerk constraints will produce a maximum velocity pattern. Car position and destination location are digitally presented by digital car position generator 85 and digital target floor data source 86 to the digital to analogue converter 87. The predictive pattern generator or fast plant 88 receives its basic pattern signal data from the pattern generator 84 and its car and destination position data from digital to analog converter 87 so that it causes the jerk logic 83 to institute negative jerk and thus the slowdown pattern when its predicted stop position coincides with a destination for which a call is registered.

The leveling pattern generator 89 in FIG. 6 is shown in simplified form as a tachometer input terminal 92, an input amplifier 93 with directionalizing relay contacts U and D to direct and inverting inputs, a Zener diode as a reference signal level; an integrator 94; a square root amplifier 95 with a control 96 for predetermining breakpoints and an analog multiplier 97. These elements correspond to those of FIG. 2 and can include the adjuncts shown in FIG. 2 for adjustment and trim. Generator 89 is coupled in series with the acceleration-to-velocity integrator 98 of primary pattern generator 84 either continuously, as with switch 99 in the state illustrated, or only during leveling, as with switch 99 in its alternative position, whereby leveling relay contacts L1 are effective. The isolation of the leveling pattern generator 89 is advantageous where signal levels from integrator 98 are in excess of the rating of 89 during generation of higher speed patterns.

Leveling logic controls shown in FIG. 6 couple and decouple the output of the jerk-to-acceleration integrator (not shown) of the primary pattern generator 84 on lead 101 effectively to insert and remove the leveling pattern generator 89 and its output at the output lead 102 of the acceleration-to-velocity integrator 98 of primary pattern generator 84 as a velocity signal, $\dot{h}$. These controls respond to a "control on" signal on lead 103 indicating the interval of a pattern generation from start to stop as dictated by system control 81; to a "start stopping" signal on lead 104 and its complement on lead 105, both from system control 81; to an acceleration greater than zero, $\dot{h} > 0$, on lead 106 from the jerk logic 83; to an acceleration less than zero, $\dot{h} < 0$, on lead 107 from the jerk logic 83; and to the analog value on lead 108 of the digital distance of the car has to go to the target floor ($h-h_i$) from the digital to analog converter. These signals indicate the car's entry into the leveling zone of a landing at which it is to stop and in response thereto decouple the primary pattern from the pattern output at FET 109 while assuring ideal leveling zone, pattern signal entry velocity is imposed through FET 111. If coupled through the enable leveling relay EL, as where switch 112 is displaced to the alternate position from that shown, it enables leveling switches of the type previously discussed, such as LU and LD for leveling up and leveling down to control the car from its leveling switches on the car. The logic also correlates the leveling with the high speed pattern as by issuing a hold high speed signal to the jerk logic at lead 113.

Consider operation with switch 99 shifted to its position alternative to that shown. The leveling pattern generator 89 is coupled to the circuit through which the

primary pattern is applied to the velocity control unit in a manner which requires the presence of multiplier 97 corresponding to multiplier 34 of FIG. 2 only for the leveling pattern. The decoupling of the primary pattern generator 84 is accomplished in response to a digital count representing car displacement from the target floor or car destination, and in the specific example to an analog signal converted from that digital count.

The switching of the pattern from the primary pattern generator utilizes the characteristic of an integrating amplifier to maintain the value most recently dictated by its input as its output in order to provide the fixed multiplicand value for the leveling pattern which is representative of pattern speed at the time of leveling zone entry. Primary pattern signals are generated in 84 from a step input jerk signal of fixed value scaled to the jerk constraint and integrated to acceleration subject to limits on the signal value representing maximum acceleration constraints. Velocity pattern signals are produced in integrator 98 by integrating the acceleration signal and therefore the signal coupling between the acceleration stage output and the velocity stage input of the pattern generator is interrupted when the leveling zone is entered by the car to establish the pattern velocity value to be proportioned against integrated car speed during leveling. Idealized leveling zone entry velocity is forced on the integrator through FET 111 by issuing the velocity signal in the event the pattern velocity at the time the car enters the leveling zone deviates from the ideal.

The switching from the primary pattern generator 84 to the leveling pattern generator 89, the activation of leveling pattern generator 89, the ideal leveling zone entry velocity, and the termination of control by jerk logic 83 is controlled by the leveling logic 91 as shown in FIG. 6. Logic sequences for the leveling logic 91 are shown in FIG. 7 as related to the time intervals in a pattern generation cycle as shown in FIG. 1.

FET 109 is placed in its on or signal passing condition and a logical "1" signal is issued on lead 113 to start the pattern when the car is to be started. With the car stopped, prior to time t_0 , coincident "0"s on 105 and 106 cause NAND 114 to issue a "1." Line 108 is at zero so that amplifier 115 has not output and transistor 116 is turned off allowing its collector to be at the positive source voltage to impose a "1" on lead 117 to NAND 118. At this time lead 104 is also at "1" and NAND 118 issues a "0." NAND 119 issues a "1" to the jerk logic 83 via lead 113 with a "0" on lead 121 and a "1" on 122.

Input 108 also applies the analog distance to go signal to amplifier 123 so that at the zero level amplifier 123 turns off transistor 124 to allow lead 125 to be at a positive voltage issuing a "1" at NAND 126. Lead 107 is at "1" so that the output of NAND 126 is a "0" to NAND flip flop 128. Flip flop 128 issues a "1" on lead 129 to NAND 131. When the "start car" signal in system control 81 is imposed, it institutes the application of a jerk signal value in primary pattern generator 84 on the integrator (not shown) which produces an acceleration pattern signal on lead 101, and a "0" on lead 103. This causes NAND 131 to issue a "1" at time t_0 whereby transistor 132 is turned on and drives its collector positive to turn on FET 109. FET 109 is the coupling switch between the acceleration pattern signal section and the input 101 to the integrator 98 which integrates that signal to a velocity pattern signal. FET

109 is turned off when the car enters the leveling zone to block any signal on lead 101 to the input to the acceleration to velocity integrator 98 of the primary pattern generator 84 and thereby stabilize its output at the leveling zone entry pattern velocity.

FET 111 operates with and in an opposite sense to FET 109 to insure that the Y input to amplifier 97, the effective pattern velocity signal is at the idealized value for car entry into leveling. If that value is present, the turn on of FET 111 has no effect. If it is not at that value the positive potential at terminal 133 through resistance 134 and potentiometer 135 impose the desired signal on integrator 98 to cause it to gradually approach the ideal.

FET 111 is turned off by the turn on of transistor 136. The collector of 136 goes negative turning off FET 111 when transistor 132 is turned on and its collector current causes the base of 136 to go positive.

The "1" from NAND 131 also turns on transistor 137 causing its collector to go toward positive and turning off transistor 138. This terminates current flow in leveling relay L so that its contacts L1 transfer to the state shown. With switches 99 in the alternate position, this disconnects the leveling pattern generator 89 and couples integrator 98 to lead 102 to the velocity control unit. Contacts L of relay L are returned to their illustrated state within leveling pattern generator 89 to establish the unity multiplier value to the X input of multiplier 97 as described. The start stopping signal is removed from lead 104 by changing to a "0" prior to t_0 . This switches NAND 118 to a "1" on lead 122. Line 105, the complement of line 104 switches to "1" but since line 106 is at "0" NAND 118 continues to issue a "1" so that coincident "1"s to NAND 119 switch 113 to a "0" turning off the hold on jerk logic 83.

At time t_0 the pattern starts and line 106 goes to "1" indicating positive acceleration. This causes NAND 114 to switch 121 to "0." Line 108 goes negative, indicating a distance to go, and causes a positive output from amplifier 115. This turns on transistor 116 to place a "0" on lead 117 and NAND 118. The coincident "0"s maintain to "1" on lead 122 so that the "1" and "0" inputs to 119 switch line 113 to a "1" and institute jerk logic control of the primary pattern generator.

The output of amplifier 123 also becomes positive at time t_0 to turn on transistor 124 so that lead 125 is placed at "0." Positive acceleration imposes a "0" on lead 107 from jerk logic 83. Coincident "0" on the inputs to NAND 26 switch it to a "1." When 104 switched from "1" to "0" lead 141 switched NAND 142 to issue a "1" without effect on flip flop 128 at that time since NAND 126 was holding its output at "0." When 126 issues a "1" the flip flop 128 is transferred in state to issue a "0" on 129. At this time 103 is a "1" since the control is on and NAND 131 continues to issue a "1" leaving FET 109 on and FET 111 off while relay L remains dropped out.

When the pattern of FIG. 1 enters constant velocity at t_3 , line 107 goes to "1" without changing the output of NAND 126 although it is now conditioned to respond a "1" on lead 125 when the car enters a leveling zone. It will be noted that this condition is established also if the car is involved in less than a full speed run and its leveling pattern generator can only be activated when positive acceleration has been terminated.

Pick up of a stop signal at t_4 is indicated by a "1" on "start stopping" lead 104 and a "0" on its complement 105 without effect at this time. NAND 142 of flip flop 128 is thereby enabled to respond when the car enters its leveling zone whereby the pattern can be shifted from primary generator 84 to leveling generator 89.

When the car enters the leveling zone as indicated by the distance to go to the floor signal on lead 108 achieving a value matching that set in potentiometer 143 and coupled to leveling amplifier 123, the amplifier ceases conduction. This may occur at the initiation of the final positive jerk at time t_6 although it is independent of the primary pattern form as determined by primary pattern generator 84 and usually occurs after positive jerk has been initiated to begin the decrease of deceleration in the pattern. Termination of a signal to the base of transistor 124 turns it off causing its collector to go positive and imposing a "1" on lead 125. Coincident "1"s from lead 125 and 107 during deceleration cause NAND 126 to transfer flip flop 128 by a "0" to its input 144 causing it to issue a "1" on 129. This makes NAND 131 "0" since a "1" is also present on 103 while the pattern is being generated. The "0" to transistors 132 and 137 turn them off. Transistor 132 places a negative control voltage on FET 109 turning it off to disconnect the primary acceleration pattern from integrator 98. Transistor 136 is turned off putting a positive voltage on the control of FET 111 to turn it on and couple the idealized initial leveling pattern velocity signal to the integrator 98 and thereby assure the Y input or multiplier to 97 will stabilize at that value.

Transistor 137 is turned off by the "0" from NAND 131 to turn on transistor 138 and pull in relay L so that the leveling pattern generator is activated to begin its proportioning through relay contacts L within 89. It also transfers the signal transmission from integrator 98 to output 102, if contacts of switch 99 are in their alternative position, since back contact L1 opens to interrupt a transmission path and contact L1 closes to couple the output of multiplier 97 to lead 102.

As the car approaches the landing, and desirably when it is level, the leveling amplifier 115 has its output go to zero. This value is adjusted against the distance to go signal on lead 108, by potentiometer 145. When the distance to go is zero the amplifier signal is zero and transistor 116 is turned off to cause lead 117 to impose a "1" on NAND 118. This in coincidence with the "start stopping" 1 imposed at the initiation of the stop causes NAND 118 to issue a "0" whereby NAND 119 issues a "1" on lead 113 to the jerk logic 83 and stops the operation of the primary pattern generator.

Where safety code requirements provide for leveling control from hatch switches, the definition of the car's entry into the leveling zone can be accomplished with such switches by transfer of switch 112 to the alternative position to that in which it is illustrated. Under such conditions leveling switches LU and LD carried in spaced relationship on the car are arranged to be actuated by a vane mounted in the hatch and so oriented that entry of the car into the leveling zone on an up trip actuates LU or on a down trip actuates LD. The leveling switches are maintained actuated until the car is level with the landing, at which time the vane is centered between the switches LU and LD and is just beyond the range in which it actuates the switches. Such an arrangement is provided at each landing. Accordingly, it should be enabled only selectively since the car

must pass landings in normal operations. Even during slowdown of a car following a "start stopping" signal, it may pass several landings prior to its approach to its target landing.

An enable leveling relay EL is energized when the car is approaching its leveling zone. Relay EL is energized when the distance to go signal on 108 indicates the leveling zone is about to be entered and leveling amplifier 123 has its output go to zero to cause lead 125 to go positive and through switch 112 cause amplifier 147 to pull in relay EL. Contact EL in circuit with the leveling switch contacts LU and LD loses to enable the switches when function through contact buffer 148 to gate NAND 126 and trigger flip flop 128 to transfer to the leveling pattern generator control as described.

In summary, a system which enhances leveling control has been illustrated in which upon advance of the elevator to a predetermined point precedent to the target floor the leveling logic 91 receives a signal which causes it to stop the primary pattern generator 84 and substitute the output of leveling pattern generator 89 as the input for the velocity control unit. The velocity signal from 89 then runs the car the final travel into the floor.

The pattern generator 84 supplies the velocity signal to the velocity control unit through normally closed relay contact L1. When the leveling logic 91 receives signals to commence leveling from system control 81, jerk logic 83 and the digital-to-analog converter 87, relay "L" activates and contact L1 closes while back contact L1 opens. The velocity signal is applied to the input of signal storage device 98 whose output represents the velocity of the car at the instant of changeover to leveling control.

The output from signal storage device 98 is applied to the "Y" input of analog multiplier 97 whose output is equal to the product of the voltage at the "Y" input times the voltage at the "X" input. Leveling pattern generator 89 also receives a voltage proportional to the actual velocity of the elevator from tachometer input 92. This voltage is applied to an integrator 94 which produces an output as shown in FIG. 3b. This output is proportioned to the distance to go to the target floor and is applied to a square root amplifier 95.

Two well known equations of motion are $v = at$ (velocity equals acceleration times time) and $d = \frac{1}{2} a t^2$ (distance equals one half the acceleration times the square of the time). If we substitute the first equation into the second so as to eliminate time then we have $V = \sqrt{2ad}$ (velocity equals the square root of the quantity two times acceleration times distance). The square root amplifier 95 solves this equation using fixed values for the "a" term which in this case is a deceleration. The output is represented by the dashed curve I in FIG. 3c. However, this curve presents a problem since it approaches the stopping point asymptotically and the car theoretically will never reach the target floor. To solve this problem a diode matrix is used in combination with the square root amplifier to produce a series of values of gain of the amplifier as functions of its input which approximate straight lines of FIG. 3c curve II.

The output of the square root amplifier 95 is applied to the "x" input of the analog multiplier 97 whose output is shown in FIG. 3d. At d_0 the leveling pattern signal generator 89 replaces the pattern generator as the signal source for the velocity control unit. At d_1 the first diode break point is reached, at d_2 the second, and at

d_3 the third. In this way the velocity is decreased until the car reaches the target floor where it stops.

It is to be understood that the final stopping control can be applied to the control of objects other than elevators, that the means of defining entry into a final stopping zone where a final stopping pattern generator is activated can be other than leveling switches or the analog conversion of a positional pulse count and that the displacement across the leveling zone can be defined by other than a tachometer signal without departing from the spirit or scope of this invention. Accordingly, the above described embodiments are to be read as illustrative of the invention and not in a limiting sense.

We claim:

1. A velocity pattern generation system for controlling the movement of an object through a zone between two points along a predetermined path comprising, means to define the arrival of said object at one of said points in its approach to said zone; a primary velocity pattern generator to issue a variable primary velocity pattern signal for said object; a signal storage means for an initial pattern velocity signal value generated by said primary velocity pattern generator at the time said object arrives at said one point; means continuously to define displacement of said object within said zone; and means continuously to proportion said initial velocity pattern signal to a predetermined value as a function of said defined displacement.

2. A combination according to claim 1 wherein said signal storage means is a capacitance.

3. A combination according to claim 1 wherein said signal storage means is an integrator.

4. A combination according to claim 1 wherein said means to define displacement of said object is a velocity integrator.

5. A combination according to claim 1 wherein said means to define displacement of said object includes means to develop a signal proportional to the velocity of said object and means to integrate said signal.

6. A combination according to claim 5 wherein said proportioning means is a multiplier for multiplying the initial velocity pattern signal and the integrated signal.

7. A combination according to claim 6 including amplifier means for the integrated signal; and means to alter the gain of said amplifier means in accordance with the value of said integrated signal.

8. A combination according to claim 7 wherein said gain altering means is a plurality of parallel diode-resistor series combinations each having different diode cut off values and coupled between an input and an output of said amplifier.

9. A combination according to claim 1 including means to gradually adjust the initial velocity signal value in said signal storage means to an optimum initial velocity signal when said initial velocity signal deviates from said optimum velocity signal.

10. A combination according to claim 1 wherein said object is an elevator car, said zone is a leveling zone and one of said points is a landing associated with said leveling zone.

11. A combination according to claim 10 including first means for ascertaining the approach of said elevator car within a given distance of a landing; a leveling switch comprising said means to define arrival of said car at said one point; and means responsive to said first means for enabling said leveling switch.

15

12. A combination according to claim 1 wherein one of said points along said predetermined path is defined by a count scaled to displacement.

13. A combination according to claim 12 wherein said count is converted to an analog signal and including a detector responsive to said analog signal.

14. A combination according to claim 1 wherein said primary velocity pattern generator includes an acceleration pattern output and an acceleration signal to velocity signal integrator having an input and an output; a first switch between said acceleration pattern output and said integrator input; and means responsive to said arrival defining means to operate said switch.

15. A combination according to claim 14 including a second switch coupled to said integrator input, a signal source of a signal which is scaled to a desired pri-

16

mary pattern velocity signal for said object upon arrival of said object at said one point, and means responsive to said arrival defining means to close said second switch.

16. A combination according to claim 1 wherein said predetermined value is a value less than said initial value, and including means to maintain a minimum velocity pattern signal in excess of said predetermined value while said object is in said zone and until said object reaches the other of said two points, whereby said maintaining means supersedes said proportioning means when said proportioning means reduces said signal below said minimum velocity pattern signal while said object is in said zone.

* * * * *

20

25

30

35

40

45

50

55

60

65