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[21] Appl. No. 793,747
[22] Filed Jan. 24, 1969
[45] Patented May 4, 1971
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[56]

References Cited

UNITED STATES PATENTS

3,213,343	10/1965	Sheheen	318/345
3,351,148	11/1967	Solomon	318/341
3,411,065	11/1968	Tedd	318/345
2,924,680	2/1960	Swenson	200/61.3
3,303,403	2/1967	Bonanno	318/257

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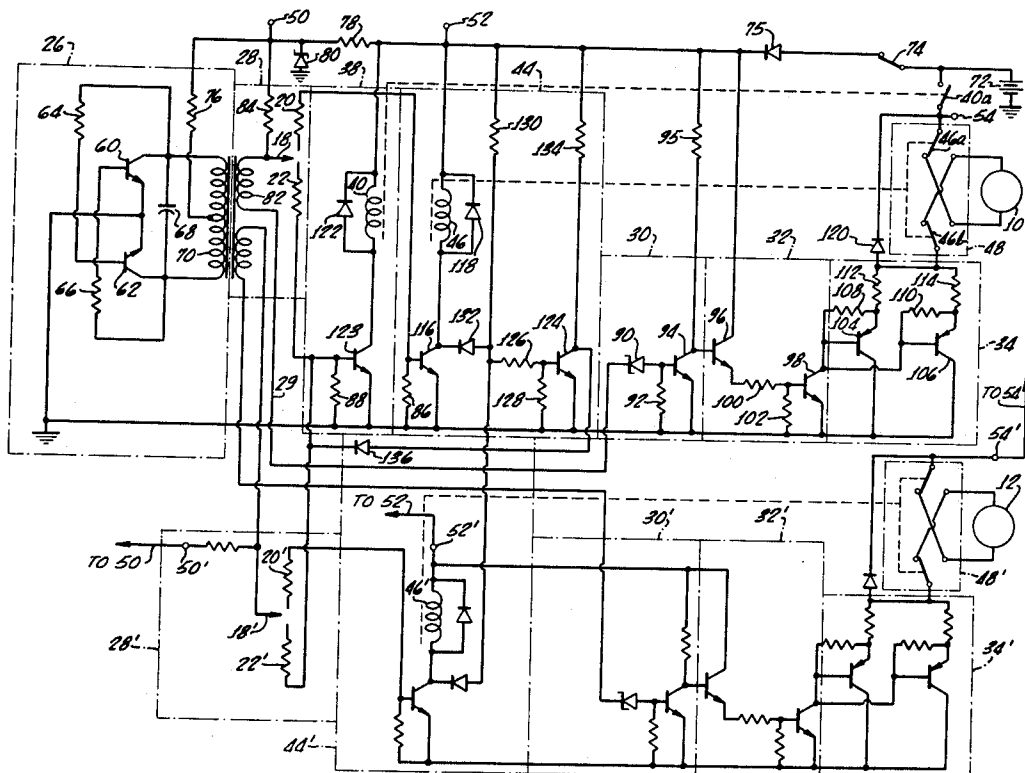
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[54] REVERSIBLE FAIL-SAFE WHEELCHAIR DRIVE CONTROL CIRCUIT

7 Claims, 4 Drawing Figs.

[52] U.S. Cl. 318/257,
317/60A, 318/295, 318/305
[51] Int. Cl. H02p 1/22
[50] Field of Search 318/17,
256, 257, 280, 290; 200/12; 318/341, 345;
318/295, 305, 308, 374; 317/60 (A)

ABSTRACT: A drive control circuit for a motorized wheelchair whereby the wheelchair occupant can select both the direction and the rate of motion of the chair by means of a joystick. In both directions the same motor control circuit is used. To prevent a runaway motor condition which might be caused by a component breakdown in the drive control circuit, means are provided to deenergize the wheelchair motor rapidly.



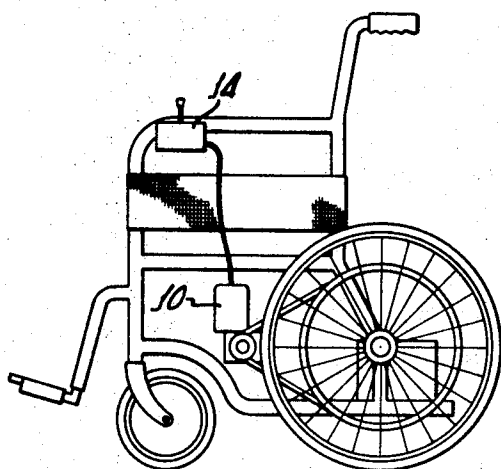


FIG. 1.

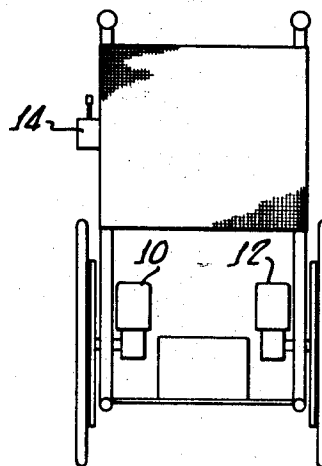


FIG. 2.

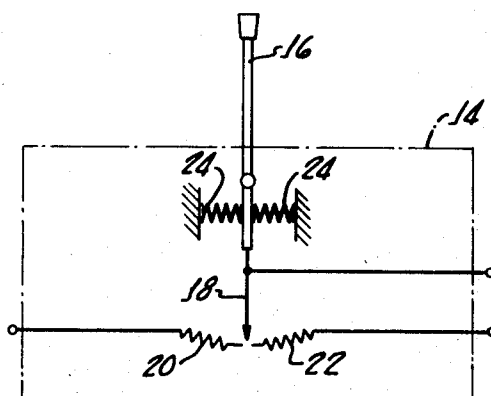


FIG. 3.

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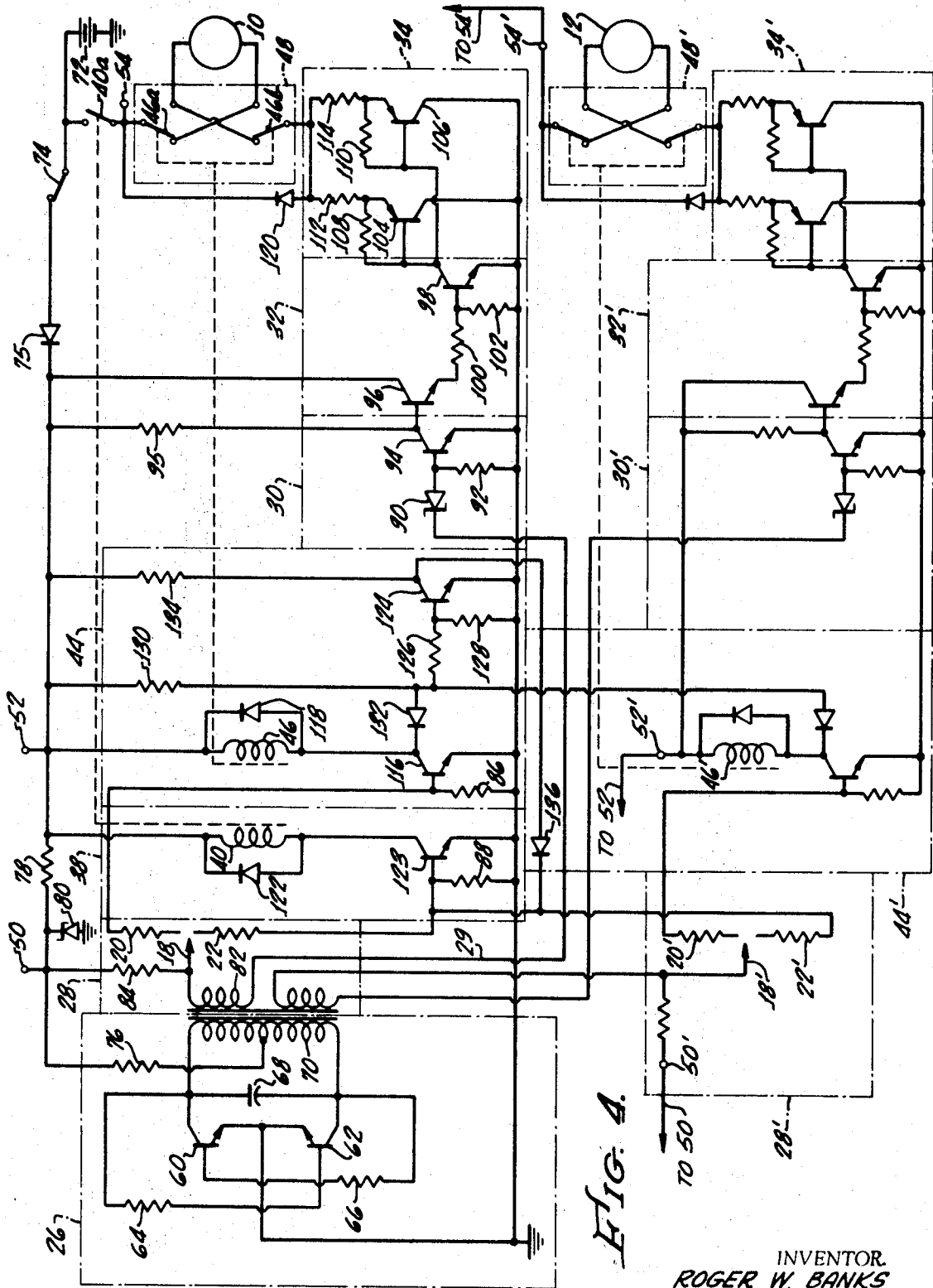


FIG. 4.

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REVERSIBLE FAIL-SAFE WHEELCHAIR DRIVE CONTROL CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates to power control circuits for motor on wheelchairs.

The advantages to a wheelchair occupant of a means of self-propulsion which requires little or no physical exertion on his part and no help from others is evident. The prior art has achieved this desired mobility by using electric motors controlled to operate at variable speeds by electronic drive control circuits. Unfortunately, such arrangements have heretofore risked injury to the wheelchair occupant. The risk of injury exists because the motor control circuit includes semiconductors which short circuit when they fail. Since the power requirements for driving a wheelchair approach the limit of semiconductor capabilities, there is a tendency for the semiconductors to overheat and fail catastrophically. When this occurs the motor control circuit becomes a direct connection between the current source and the wheelchair motor causing the wheelchair to be driven at full power regardless of the position of the operator's control.

Another disadvantage of the prior systems is their high cost. For example, these systems typically use duplicate motor control circuits for controlling the drive motor in opposite directions, thereby making the cost approximately twice that of a unidirectional system.

SUMMARY OF THE INVENTION

The present invention alleviates the risk of injury to the wheelchair occupant by arranging an operator controlled joystick to both operate the motor control circuit and disconnect the motor from the current source when the joystick is in its rest position. The circuit of the present invention allows no current to be applied to the motor when the joystick is in its rest position. In the preferred embodiment the system is made failsafe by the use of a self-centering joystick, so that the occupant need only release the joystick to stop the wheelchair.

Moreover, the present invention overcomes the circuitry duplication required in the prior art devices for driving the wheelchair in reverse. A switching circuit which reverses the current flow through the wheelchair drive motor is inserted between the motor control circuit and the motor. This switching circuit is actuated when the joystick is deflected through its rest position. The motor control circuit operates identically for forward or reverse driving of the wheelchair, but the switching circuit controlled by the joystick reverses the polarity of the connections between the motor control circuit and the motor. System cost can be reduced considerably, since the cost of this switching circuit is much lower than that of a separate motor control circuit.

The features of the present invention which are believed to be novel are set forth particularly in the appended claims. The present invention, both as to its organization and manner of operation, together with further advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are side and front elevations of a wheelchair showing placement of the joystick and motors.

FIG. 3 shows the construction of the joystick control box.

FIG. 4 is a diagrammatic illustration of one embodiment of the invention.

DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is shown a wheelchair with a motor 10 coupled to drive one wheel and a control box 14 conveniently situated, preferably on an arm rest. A rear view of the same chair appears in FIG. 2 which also shows an additional motor 12 similarly arranged to drive the other wheel. Referring to FIG. 3, the control box 14 carries an actuator, preferably a pivotally mounted joystick 16 having on its lower end a contact arm 18 attached for movement along the resistors 20 and 22. The joystick is urged to a noncontacting rest

position between the resistors 20 and 22 by a pair of springs 24.

FIG. 4 illustrates a direct current motor control circuit including an oscillator 26 which produces a periodically repeating signal having a substantial rise or decay time, or both. After being transformer-coupled to a DC biasing and summing circuit 28, the signal from the oscillator 26 is superimposed upon a variable DC level, the magnitude of which depends on the displacement of the contact arm 18 along the resistor 20 or 22 caused by movement of the joystick 16 from its rest position. The output of the biasing and summing circuit 28, a signal periodically varying about a changeable direct current bias, is coupled via lead 29 to a detector circuit 30 which produces an output signal only when this coupled voltage is less than a predetermined level. If the oscillator signal is less than this predetermined level during a segment of each periodic repetition, the detector 30 will alternately produce and not produce an output signal. Since the time varying output of the oscillator 26 is superimposed in the biasing and summing circuit 28 on a DC level, and since the oscillator output has a substantial rise and/or decay time, the time segment of each periodic repetition of the oscillator 26 during which an output signal is produced by the detecting circuit 30 changes as the DC biasing level is changed in the summing circuit 28. Therefore, the detecting circuit 30 can be made to produce an output signal through a varying portion of any one of the periodic outputs of the oscillator 26. In other words, the duty cycle of the detector 30 changes in accordance with the direct current bias superimposed on the output of oscillator 26 in the biasing and summing circuit 28.

Current flows through the power switching circuit 34 to the motor 10 to drive the wheelchair. Therefore, the average amount of current available to the motor 10 is dependent upon the duty cycle at which the power switching circuit 34 operates, which is in turn dependent upon the direct current bias applied in the biasing and summing circuit 28.

In accordance with the present invention, two significant improvements are made in the direct current motor control described above. The first improvement comprises on-off switching means 38 in series with the motor 10 and the source of electric current for deenergizing the motor 10 when the joystick is at its rest position. The on-off switching means 38 includes a fail-safe relay 40 through which current flows only when the joystick 16 urges the contact arm 18 onto either one of the resistors 20 and 22. When current flows through the armature coil of relay 40, its contacts 40a close, allowing the motor 10 to be energized. Therefore, the motor 10 can drive the chair only when the joystick 16 is displaced from its rest position to engage contact arm 18 with resistor 20 or 22.

The second improvement in the motor control circuit comprises circuit 44 for selectively applying the output of the proportional current control to the motor 10 to control its direction of rotation. This selective application of current to the motor is controlled by the joystick 16 so as to provide the wheelchair occupant with a ready control of motor rotation. Circuit 44 produces a current flow through a relay 46 only when contact arm 18 is in contact with resistor 20. The relay 46 carries a pair of contacts 46a and 46b connected as a double-pole double-throw switch 48 between the current source and the motor 10. By reversing the polarity of the motor 10 terminals, the switch 48 determines the direction of current flow through the motor 10 and therefore the direction of rotation of the motor 10. Thus the reversing circuit 44 changes the direction of rotation of the motor 10 when the contact arm 18 moves through the rest position between the resistors 20 and 22. In other words, the direction of rotation of motor 10 depends on the direction in which joystick 16 is displaced from its rest position.

The circuits shown at 28', 30', 32', 34', 44', 46' and 48' in FIG. 4 are the same as their unprimed counterparts and operate the second motor 12. This motor is independently controlled to allow the operator to steer the wheelchair but the motor control shares the same oscillator 26, fail-safe cir-

cuit 38 and fail-safe switch 40a with the control circuit for motor 10. Toward this end the points 50, 52 and 54 of the control circuit for the motor 10 are connected to their primed counterparts in the control circuit for the motor 12.

A detailed description of the circuitry shown in FIG. 4 is as follows: The oscillator 26 includes a pair of transistors 60 and 62 which are alternately conductive due to biasing at the base of each from the collector of the other through the resistors 64 and 66. The collectors of both transistors 60 and 62 are connected to a parallel combination of a capacitor 68 and transformer primary 70, a center tap of which is connected to a current source 72 through a primary power switch 74, a circuit protection diode 75, a current limiting resistor 76, and a series resistor 78, which, together with a Zener diode 80, stabilizes the voltage at the transformer center tap 70. The oscillator 26 has an output frequency of approximately 350 cycles per second, this being the optimum compromise between lower frequencies which cause the wheelchair to vibrate when driven and higher frequencies which increase the inductive impedance of the motor.

Magnetically coupled to the transformer secondary 82, the output signal from the oscillator 26 is superimposed in the summing circuit 28 upon a direct current voltage level which is produced by the voltage divider made up of either resistors 84, 20 and 86 or resistors 84, 22 and 88, depending on the direction of displacement of the contact arm 18. The displacement of the contact arm 18 along either resistor 20 or 22 will lower the voltage level applied to the transformer secondary 82 proportionately, since the voltage divider ratio is thereby changed. The output from this summing circuit on lead 29 is thus a 350 cycle oscillation superimposed upon a variable DC voltage level.

This output is detected by a Zener diode 90 of the detecting circuit 30 which allows current to flow through a biasing resistor 92 only when the summing circuit output exceeds a predetermined voltage level. A current flow through the resistor 92 raises the voltage level at the base of a transistor 94, causing it to become conductive. This transistor 94, whose conduction current is limited by a collector resistor 95, is thus conductive during a variable portion of each periodic output of the oscillator, this portion being dependent upon the displacement of the contact arm 18 along the resistor 20 or 22.

The two stage current amplifier 32 reproduces the conductive cycling of the detector circuit 30 at a higher current level by first amplifying the signal present at the collector of the transistor 94 in a transistor 96, and subsequently biasing the base of a transistor 98 at the junction of two emitter resistors 100 and 102 of the transistor 96. When the transistor 98 is conductive, its collector assumes the potential of its grounded emitter. The collector is thus alternately grounded and ungrounded in response to the duty cycle of the detector 30. This cyclic signal is coupled to a pair of parallel power transistors 104 and 106 in the power switching circuit 34, which again reproduce the conductive cycling of the detector circuit 30 but have the capability of handling sufficient current to operate the motor 10. The resistors 112 and 114 cause the transistors 104 and 106 to share the motor current equally when they are conductive.

The transistor 104 is biased to conduction by current flow through the resistor 112, the emitter to base junction of the transistor 104, and the collector emitter junction of the transistor 98 when the latter is conductive. The transistor 106 is biased to conduction similarly by current flow through the resistor 114, and the transistors 106 and 98. Resistors 108 and 110, which are connected between the base and emitter of transistors 104 and 106 respectively, prevent excessive leakage current in these transistors. The motor 10 is thus pulsed with current in a cyclic pattern in accordance with the duty cycle of the detector circuit 30, and the average current applied to the motor 10 is changed by displacement of the contact arm 18 along either resistor 20 or 22.

Selective application of the control circuit output to reverse motor direction is accomplished in the circuit 44 by the relay

46 and its associated double-pole double-throw connected contacts 48. This relay is actuated when the transistor 116 is made conductive by biasing of its base due to current flow through the resistor 86. This current flows only when the arm 18 is in contact with the resistor 20. The coil of the relay 46 is shunted by a diode 118, and the switch contacts 46a and 46b are shunted by a diode 120, each diode operating to reduce reverse currents caused by magnetic field collapse in the relay coil or motor winding. Thus, when the arm 18 is in contact with neither the resistor 20 nor the resistor 22, or is in contact with the resistor 22, the contacts 46a and 46b are in their rest position, causing current to flow through the motor 10 in one direction. When the arm 18 is in contact with the resistor 20, the contacts 46a and 46b are switched to their energized position, causing current to flow through the motor 10 in the opposite direction. Motor direction thus depends on the deflection of the arm 18 in a given direction away from its rest position, without the need for a second motor control circuit for reverse operation.

The fail-safe relay 40 of on-off switching means 38 is shunted by a diode 122. Contacts 40a of relay 40 close when current flows through the resistor 88 so as to raise the voltage at the base of transistor 123 in a manner identical to the operation of the reversing circuit 44, except that the relay 40 is actuated only when contact arm 18 is in contact with the resistor 22. However, since the fail-safe relay is to close its contacts 40a whenever the joystick is displaced from its rest position in either direction, a transistor 124 and its associated circuits are added to actuate the relay 40 whenever the reversing relay 46 is actuated.

The transistor 124 is normally conductive, due to biasing at its base between a pair of resistors 126 and 128 in the voltage divider formed by the resistors 126, 128 and 130. When the transistor 116 becomes conductive to actuate the relay 46, its collector is shorted to ground, which in turn shorts the voltage divider to ground through a diode 132 between the resistors 130 and 126. Grounding the voltage divider lowers the base potential of the transistor 124, making it nonconductive. Once the transistor 124 is nonconductive, its collector becomes isolated from its grounded emitter, and biasing current is thus allowed to flow through a collector resistor 134, a diode 136, and the resistor 88 to ground. The diode 136 allows the base of the transistor 123 to be independently biased even when the collector of the transistor 124 is grounded due to conduction to the grounded emitter.

Current through the resistor 88 raises the potential at the base of the transistor 123 to cause conduction and a resultant actuation of relay 40. The relay 40 is thus actuated when the contact arm 18 is in contact with either resistor 20 or 22. Since the motor 10 cannot function unless the contacts 40a are closed, the motor will stop whenever the arm 18 is in its rest position between the resistors 20 and 22, regardless of whether the transistors 104 and 106 are shorted. This relay 40, therefore, makes the motor circuit fail-safe during output transistor malfunction.

In effecting control over operation of the motor 12, all parts of circuits 28', 30', 32' and 44' function in the same way as their unprimed counterparts.

In order to facilitate a thorough understanding of the above-described circuits, the functioning of each major mode of operation will now be explained.

To drive the wheelchair in a forward direction, the occupant deflects the joystick 16 forward, causing the contact arm 18 to contact the resistor 22. The reversing circuit 44 is not energized, and contacts 46a and 46b remain in their rest position, allowing current to drive the motor 10 forward. The fail-safe circuit 38 is energized, and contacts 40a are closed, allowing current to flow to the motor 10. The duty cycle of the switching circuit 34 increases as the displacement of contact arm 18 along resistor 22 increases, thus increasing the average current flow through motor 10. If the transistors 104 and 106 were to become shorted in this mode, the motor 10 would drive the wheelchair at full power. The operator may still stop

the chair, however, by releasing the self-centering joystick 16 to place the circuit in its deenergized mode which will be described subsequently.

To drive the wheelchair in reverse, the occupant deflects the joystick 16 toward the rear. Circuit operation is identical to that described for forward operation, except that the contact arm 18 is now in contact with the resistor 20, and the reversing circuit 44 is energized. The contacts 46a and 46b are in their respective energized positions, and current flows through the motor 10 in a direction opposite to the forward drive current described above. Again, release of the joystick 16 brings the circuit to its deenergized mode.

When the joystick is not deflected from its rest position, it is centered by the pair of springs 24 shown in FIG. 3 so that the contact arm 18 is in contact with neither the resistor 20 nor the resistor 22. When the contact arm is thus isolated from both of the resistors 20 and 22 the duty cycle of the switching circuit 34 is reduced to zero, since the detector circuit 30 produces no output signal, and the fail-safe circuit 38 is deenergized so that the switch contacts 40a are open. Thus, the current path to the motor 10 is interrupted both in the switching circuit 34 and at the switch contacts 40a so that if the circuit 34 should become short circuited, the contacts 40a would continue to maintain the motor 10 in a deenergized condition.

While a particular embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. A control system for motorized wheelchair comprising in combination:

an electric motor operatively connected to drive said wheelchair when said motor is energized;
an actuator having a limited range of travel and a rest position;

variable resistance means including a resistance element and a contact coupled to said actuator selectively movable both (i) out of electrical engagement with said element in the rest position of said actuator and (ii) into electrical engagement with said element when said actuator is displaced from said rest position;

semiconductor current control means electrically connected between said motor and a source of current for varying the amount of current applied to said electric motor, said semiconductor current control means responsively coupled to said variable resistance means so that selective movement of said contact correspondingly varies the amount of current supplied to said electric motor when said contact is in electrical engagement with said resistance element, said semiconductor current control means having the adverse characteristic that failure thereof can result in maximum energization of said motor independent of said actuator; and

on-off switching means connected in series with said motor and said semiconductor current control means, said on-off switching means coupled to and responsive to current flowing through said resistance element of said variable resistance means when said contact and said resistance element are in electrical engagement so that the electric motor is positively deenergized when said contact is out of electrical engagement with said resistance element, said positive deenergization being provided regardless of failure of said current control means.

2. The control system of claim 1 wherein:

said on-off switching means includes a relay;
said means for operatively connecting said actuator to said switching means opens the circuit of said relay only when

said actuator is at said rest position; and
said actuator automatically returns to said rest position when not manually deflected therefrom.

3. The control system of claim 1 wherein:

said current control means is a transistor current amplifier;
said means for selectively applying the output of said current control means is a double-pole double relay connected to reverse the direction of current flow through said motor;

said means for operatively connecting said actuator to said means for selectively applying the output of said current control means includes switching means responsive to the shifting of said actuator through its rest position for applying electric current to said double-pole double-throw relay so as to reverse the position of its movable contacts; and

said actuator automatically returns to said rest position when not manually deflected therefrom.

4. The control means of claim 1 wherein:

said means for actuating said on-off switching means is a semiconductor switch;

said on-off switching means is a relay whose coil is electrically connected to said semiconductor switch; and

said semiconductor current control means is a semiconductor amplifier whose output is electrically connected between said motor and said current source.

5. A control system for a motorized wheelchair comprising in combination:

an electric motor operatively connected to drive said wheelchair when said motor is energized;

an actuator having a limited range of travel in each of two directions from a rest position;

variable resistance means including a first and second resistance element and a contact coupled to said actuator selectively movable both (i) out of electrical engagement with both of said resistance elements in the rest position of said actuator, and (ii) into electrical engagement with respective ones of said resistance elements when said actuator is displaced from said rest position in a forward or reverse position;

current control means responsively coupled to said variable resistance means and electrically connected between said motor and a source of current for varying the amount of current applied to said electric motor in proportion to the excursion of said actuator from said rest position; and

reversing means coupled between said current source and said motor having a deenergized position wherein the motor is caused to rotate in a predetermined direction and an energized position wherein the motor is caused to operate in an opposite direction, said reversing means coupled to and responsive to current flowing through one of said resistance elements of said variable resistance means when said contact and said resistance element are in electrical engagement so that said reversing means is deenergized when said contact is out of electrical engagement with said resistance element.

6. The control system of claim 5 wherein:

said second means has an energized state in which the motor operates in one direction and a deenergized state in which the motor operates in the opposite direction, and said fourth means energizes said second means only when said actuator is displaced in one of said two directions from said rest position.

7. The control system of claim 6 wherein:

said second means is a double-pole double-throw relay connected to reverse the direction of current flow through said motor; and

said fourth means includes means for energizing said double-pole double-throw relay only when said actuator is displaced in one of said two directions from said rest position.