(54) Title: ELECTRICAL CONTROL APPARATUS FOR CONTROL OF AN AUTOMATIC TRANSMISSION APPARATUS WITH REMOTE MOTOR CONTROLLER CIRCUIT

(57) Abstract

This invention is an electrical control apparatus for control of an automatic transmission in a motor vehicle. The electrical control apparatus includes an operator input device (36a) for generating a desired transmission state signal, an encoder (72) for generating a present transmission state signal from the position of a mode select shaft (30) on the transmission, and a logic control unit (36b) developing signals enabling a motor controller circuit to control operation of a motor which changes the state of the automatic transmission. The motor controller circuit is disposed remotely from the logic control unit (36b), preferably in a power module (34) which also includes the motor (38), and the encoder (72). This location of the motor controller circuit advantageously reduces the need for a high current wire harness, improves the dynamic braking efficiency, enhances serviceability, reduces the size of the part of the apparatus which must be mounted in the crowded instrument panel and reduces the effect of noise on the logic control unit.
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ELECTRICAL CONTROL APPARATUS FOR CONTROL OF AN AUTOMATIC TRANSMISSION APPARATUS WITH REMOTE MOTOR CONTROLLER CIRCUIT

This invention relates to the field of electrical shift apparatus especially suited for use with a motor vehicle having an automatic transmission.

Motor vehicles since their inception have required some manner of gear change mechanism to satisfy the varying torque and speed requirements encountered during the typical duty cycle. For many years these gear change mechanisms were manual in the sense that they required an operator input from a shift lever or the like to effect each desired gear change ratio. More recently, so called "automatic" transmissions have become popular in which much of the shifting is done without operator input in response to sensed speed and throttle opening parameters. These automatic transmissions typically include a mode select shaft positioned on the transmission housing and movable between a plurality of selectively rotated positions corresponding to a respective plurality of shift modes within the transmission. The mode select shaft is rotated between its several shift positions by a mechanism extending from the mode select shaft to a suitable gear selector lever located in the passenger compartment of the vehicle.

The prior art is exemplified by U.S. Patent No. 4,922,769 issued to Tury on May 8, 1990, entitled "ELECTRICAL CONTROL SYSTEM FOR CONTROL OF AN AUTOMATIC TRANSMISSION APPARATUS" and assigned to the assignee of
this application. This electrical control apparatus is used with a motor vehicle having an automatic transmission including a mode select shaft having a free end positioned outside of the transmission housing. An electric motor drives the mode select shaft through a speed reduction unit. A shaft encoder senses the shift position of the transmission and generates an encoder signal representative of the sensed shift position.

The electrical control apparatus of the prior art receives input signals corresponding to the desired transmission state and to the present state of the transmission. A logic control unit within the electrical control apparatus determines if the desired transmission state differs from the present transmission state. If the desired transmission state differs from the present state, the logic control unit controls the motor for movement in the appropriate direction to shift the transmission to the desired transmission state. A motor controller circuit supplies electric power to the motor in a first polarity for rotating this motor clockwise in response to the clockwise motor drive signal and in an opposite polarity for rotating this motor counter-clockwise in response to the counter-clockwise motor drive signal. The motor controller circuit electrically brakes the motor when neither the clockwise motor drive signal nor the counter-clockwise motor drive signal is generated.

In the improvement of the present invention, the motor controller circuit is disposed remotely from the logic control unit. In the preferred embodiment the motor
controller circuit is disposed in a power module which also includes the motor, the speed reduction unit and the encoder. This power module is attached to the transmission and coupled to the mode select shaft. This location of the motor controller circuit advantageously reduces the need for a high current wire harness, improves the dynamic braking efficiency, enhances serviceability, reduces the size of the part of the apparatus which must be mounted in the crowded instrument panel and reduces the effect of noise on the logic control unit.

These and other objects and aspects of the present invention will become clear from the following description of the invention, in which:

Figure 1 is a fragmentary perspective view of a front wheel drive motor vehicle embodying the invention electrical shift apparatus;

Figure 2 is a fragmentary plan view of the front wheel drive assembly of the vehicle of Figure 1;

Figure 3 is a view taken on line 3-3 of Figure 2;

Figure 4 is a fragmentary exploded perspective view of the structure within the circle 4 of Figure 3;

Figure 5 is a view taken on line 5-5 of Figure 3;

Figure 6 is a fragmentary perspective view of a control module employed in the invention electrical shift apparatus;

Figure 7 is a schematic view of the electrical control apparatus of the present invention;

Figure 8 is a schematic diagram of the motor controller circuit;
Figure 9 is a schematic diagram of the connections between the logic chip and the motor controller circuit in accordance with an alternate embodiment; and

Figure 10 is a schematic diagram of the details of the motor controller circuit illustrated in Figure 9.

The electrical shift apparatus of the present invention is seen schematically in Figure 1 in association with a motor vehicle of the type including an instrument panel assembly 10 positioned within the passenger compartment of the motor vehicle; a steering wheel 12 associated with the instrument panel; an accelerator pedal 14; a brake pedal 15; and a front wheel drive assembly 16.

Front wheel drive assembly 16 includes an internal combustion engine 18 mounted transversely in the engine compartment of the vehicle, a torque converter driven by engine 18, a gear drive assembly 22, an automatic transmission 24, and drive shafts 26 connected to the opposite ends of transmission 24 by U joints 28. Transmission 24 includes a mode select shaft 30 having a free upper end positioned above the housing 32 of the transmission 24 and operable in known manner in response to rotation of the shaft to operate internal devices within the transmission to position the transmission in a plurality of transmission modes such as park, neutral, drive, etc.

The invention electrical shift apparatus comprises a power module 34 and a control module 36. Power module 34 is bolted to transmission housing 32 in proximity to mode select shaft 30 and control module 36 is positioned
in the instrument panel assembly 10 of the vehicle for convenient operator access.

Power module 34 is in the form of a motor assembly and includes a DC electric motor 38 and a speed reduction unit 40. Motor 38 is a direct current motor having, for example, an output torque rating of 200 inch pounds, and includes a housing 42 and an output shaft 44. Speed reduction unit 40 includes a housing 46 secured to motor housing 42 and defining an internal cavity 46a, a worm gear 48 formed as a coaxial extension of motor output shaft 44 and extending into cavity 46a, a worm wheel 50 positioned in cavity 46a and driven by worm gear 48, and an output shaft 52 driven by worm wheel 50, journaled in housing walls 46b and 46c, and including a free lower end 52a positioned outside of and below housing wall 46c. Shaft lower end 52a includes a D shaped opening 52b for driving, coupling receipt of the D shaped upper end portion 30a of mode select shaft 30.

Power module 34 further includes an encoder assembly 72 operative to sense the instantaneous shift position of the transmission and generate an encoded signal representative of the sensed shift position. Encoder assembly 72 includes an encoder wheel 74 and a pickup device 76. Encoder wheel 74 may be formed for example of a suitable plastic material and is secured to a side face of worm wheel 50 within reduction unit housing chamber 46a. Encoder wheel 74 includes a central aperture 74a passing speed reduction unit output shaft 52 and further includes code indicia 80 provided on the exposed outer face of the
wheel and arranged along four arcuate tracks 80a, 80b, 80c and 80d centered on the center line of the encoder wheel.

In accordance with the improvement of this invention, power module 34 further includes motor controller circuit 222. As illustrated in Figures 1 and 2, motor controller circuit 222 is mounted on the end of motor 38 and is connected to leads 86. Alternately, motor controller circuit 222 may be mounted in the cavity 46a within the housing 46. Motor controller circuit 222 responds to signals on lead 86 to control motor 38 for clockwise rotation, counter-clockwise rotation and dynamic braking.

Lead 86 from motor controller circuit 222 and a lead 88 from pickup device 76 are combined into a pin-type plug 90.

Control module 36 is intended for ready installation in an opening 10a in instrument panel 10 by insertion of the module from the rear of the panel and fastening of the module within opening 10a by the use of several fasteners such as 96 shown in Figure 1. Module 36 includes a housing structure 98 of general box-like configuration enclosing an operator access or push button submodule 36a and a logic submodule 36b.

The invention electrical shift assembly is delivered to the vehicle manufacturer in the form of power module 34 and control module 36. During the assembly of the vehicle, the power module 34 is mounted on the transmission housing 32 in coupling relation to mode select
shaft 30 and the control module 36 is mounted in the instrument panel 10.

The mounting of power module 34 on the transmission housing is accomplished simply by positioning the lower end 52a of reduction shaft 52 over the upper end 30a of mode select shaft 30 and passing bolts 54 downwardly through bores 46d and spacers 56 for threaded engagement with tapped bores 32a in transmission housing 32.

Installation of control module 36 in instrument panel 10 is affected simply by moving the control module from the rear of the panel into the opening 10a and fastening the module in place by the use of fasteners 96 or the like. Following the plugging of plug 90 into plug 114 and the plugging of plugs 110 and 118 into connector terminals 106 and 108, the system is operational and ready for use.

Figure 7 illustrates a schematic block diagram of the electrical control apparatus of the present invention. This block diagram includes: speed analog-to-digital converter 210, RPM analog-to-digital converter 212, logic control unit 220, all of which are embodied in logic chip 141; limp home switch 147; lamp decoder/driver 214; indicator lamps 216; and motor controller circuit 222.

Logic control unit 220 receives the encoder output from encoder assembly 72, described above.

Speed analog-to-digital converter 210 receives an analog signal indicative of speed on line 125. Speed analog-to-digital converter 210 generates an output signal on one or more of the output lines MPH3, MPH7, MPH20 and
MPH30, depending upon the magnitude of the analog speed signal.

RPM analog-to-digital converter 212 receives an analog signal RPM indicative of engine revolutions per minute on line 126. RPM analog-to-digital converter 212 generates a multibit digital revolutions per minute signal DRPM corresponding to the magnitude of the analog engine revolutions per minute signal RPM.

Logic unit 220 preferably includes sufficient number of input lines to directly receive the signals from push buttons 100. These switches indicate to logic control unit 220 the desired transmission state selected by the operator.

Additional switches are connected to logic control unit 220. Door switch 130 is connected via line 120 and indicates the open/closed status of the driver's door. Seat switch 132 is connected via line 121 and indicates whether or not the driver's seat is occupied. Ignition switch 134 is connected via line 122 and indicates the status of the ignition switch. Accelerator switch 138 is connected via line 123 and indicates when accelerator pedal 14 is fully depressed. Override switch 143, which is on the front face of control module 36, is connected via line 127 and indicates operator selection of a manual override mode. Brake switch 133 is connected via line 128 and indicates the depression of brake pedal 15. Lastly, seat belt switch 135 is connected via line 129 and indicates the closure of the driver's seat belt.
Lamp decoder/driver 214 receives the present gear signals PG1 to PG4. Lamp decoder/driver 214 generates a signal to illuminate a single light of indicator lamps 216. In accordance with the preferred embodiment of the present invention each of the lamps of indicator lamps 216 is associated with one of the push-button switches 100. In particular, it is desirable that push-buttons 100 comprise lighted push-button switches with the indicator lamps enclosed therein. The individual indicator lamps are preferably connected to the illumination supply in a manner that enables the intensity of these lamps to be adjusted in accordance with the adjustment of the intensity of the interior instruments.

Logic control unit 220 receives the above described input signals and generates two output signals. These include the clockwise motor drive signal and the counter-clockwise motor drive signal which are connected to motor controller circuit 222. In the embodiment of this example, clockwise motor motion corresponds to downshifting the transmission 24 and counter-clockwise motor motion corresponds to upshifting the transmission 24. Those skilled in the art would understand that this is just an example and the opposite convention can be employed.

In use various input signals, such as described above and illustrated in Figure 7, are supplied to logic control unit 220. Logic control unit 220 is configured to receive these input signals and generate the necessary drive signals to motor 38 for providing the selection of the desired gear. Logic control unit 220 could be
constructed of a programmed microprocessor circuit or it may be constructed in hardware logic in a programmable logic array or a gate array.

The operation of logic control unit 220 will now be described. Logic control unit 220 serves to compare the inputs indicating the desired gear with the inputs indicating the present gear. If they differ, then logic control unit 220 generates an output signal to motor 38 to rotate the motor until the present gear matches the desired gear. This process includes an indication of which shifts are upshifts (counter-clockwise motor rotation) and which are down shifts (clockwise motor rotation). The other inputs to logic control unit 220 are used for safety lock out of shifts. For example, logic control unit 220 will not shift to a desired gear if the vehicle speed, as indicated by the MPH3, MPH7, MPH20 and MPH30 signals, exceeds a predetermined speed for that gear. This prevents overspeeding engine 18. Other safety conditions, such as requiring the brake to be engaged to shift out of PARK are also implemented.

The clockwise motor drive signal CW and the counter-clockwise motor drive signal CCW are generated by logic control unit 220. These signals are then conditioned via a one shot circuit before being applied to motor controller circuit 222. The length of time of the one shot circuit is set to be longer than the longest time for ordinary shifting. Thus if this time is exceeded some error condition has resulted and it is best to stop motor
38. A similar one shot circuit operates on the clockwise motor drive signal CW.

H-bridge circuit 224 is illustrated in detail in Figure 8. The counter-clockwise motor drive signal CCW is applied to inverter 301. The output of inverter 301 is applied to field effect transistor 302 and to inverter 303. The output of buffer 303 is applied to field effect transistor 304. In a similar manner the clockwise motor drive signal CW is applied to the input of inverter 305. The output of inverter 305 is applied to field effect transistor 306. The output of inverter 305 is also applied to the input of inverter 307, which supplies the input to field effect transistor 308. Field effect transistors 302, 304, 306 and 308 operate as electrically controlled switches in this circuit.

Motor 38 is connected in an H configuration between field effect transistors 302, 304, 306 and 308. Both clockwise motor drive signal CW and counter-clockwise motor drive signal CCW are normally inactive at a low voltage. Thus the output of inverter 301 is high therefore field effect transistor 302 is conductive and field effect transistor 304 is not conductive. Similarly, field effect transistor 306 is normally conductive and field effect transistor 308 is normally not conductive. Thus both terminals of motor 38 are connected to ground.

Upon receipt of an active counter-clockwise motor drive signal CCW inverter 301 switches states. Thus field effect transistor 304 is turned on and field effect transistor 302 is turned off. Because field effect
transistor 306 remains on, a current flows through motor 38 in a first direction through field effect transistors 304 and 306. When the desired shift position is reached, counter-clockwise motion drive signal CCW returns to the inactive low state. Thus field effect transistor 302 is turned on and field effect transistor 304 is turned off. Dynamic braking is achieved because both terminals of motor 38 are connected to ground (note field effect transistor 306 has remained conductive during this sequence).

When clockwise motor drive signal CW is active, field effect transistor 306 is turned off and field effect transistor 308 is turned on. This causes a current to flow through motor 38 in the opposite direction through field effect transistors 308 and 302. Likewise when the clockwise motor drive signal CW ceases motor 38 is dynamically braked by both terminals being connected to ground.

It is known in the art that N-channel field effect transistors require a gate voltage above their source voltage to turn fully on. Because the sources of field effect transistors 304 and 308 are tied to the motor vehicle 12 volt supply, these field effect transistors will not turn fully on absent a boosted gate voltage. The boosted voltage is supplied via a DC to DC power supply formed of oscillator 228 and charge pump 226. In the preferred embodiment oscillator 228 operates at about 40 KHz. Charge pump 226 operates in manner known in the art in response to the oscillatory signal from oscillator 228 to alternately charge capacitors to the vehicle 12 volt
supply. These capacitors are effectively coupled in series to provide a doubled output voltage to H-bridge circuit 224. This doubled voltage is employed in invertors 303 and 307 to supply the base bias voltage to field effect transistors 304 and 308, respectively. Note that field effect transistors 302 and 306 do not need this boosted voltage due to the voltage drop across motor 38.

Figures 9 and 10 illustrate an alternative embodiment of this invention. Figure 9 illustrates the connections between logic control unit 220 and motor controller circuit 222 in accordance with this alternative embodiment. Figure 10 illustrates the alternative motor controller circuit 222 in further detail.

Figure 9 illustrates the connection and interaction between logic control unit 220 and motor controller circuit 222 in the alternative embodiment. Logic chip 141 produces two additional signals in this embodiment, which are supplied to motor controller circuit 222. Figure 9 illustrates only logic control unit 220 within logic chip 141. Other portions of logic chip 141 are as previously illustrated in Figure 7.

The first of these new signals is a MOTOR ENABLE signal. The MOTOR ENABLE signal is employed to enable control of motor 38. The MOTOR ENABLE signal must precede supply of either the clockwise motor control signal CW or the counter-clockwise motor control signal CCW. The MOTOR ENABLE signal must also remain on during the dynamic braking interval.
The second of these signals is the WATCHDOG signal. In the event that logic control unit 220 is embodied as a microprocessor circuit, a watchdog circuit is employed. This watchdog circuit is normally inactive and does not produce an active WATCHDOG signal. However, the watchdog circuit includes a timer which changes the WATCHDOG signal to active upon expiration of a predetermined period of time. During normal operation of the microprocessor embodying logic control unit 220 the program calls for periodically resetting the watchdog timer. However, if for any reason the microprocessor ceases functioning, then eventually the timer in the watchdog circuit expires and the WATCHDOG signal becomes active. An active WATCHDOG signal serves to inhibit operation of motor controller circuit 222. It is considered prudent to inhibit shifting if the microprocessor fails in this manner.

Motor controller circuit 222 also produces a new signal coupled to logic chip 141. This new signal is the OVERCURRENT signal. This signal is produced by current sensor 310. The OVERCURRENT signal indicates that motor 38 is drawing excessive current. Logic chip 141 preferably stops production of the CW, CCW and MOTOR ENABLE signals upon detection of the OVERCURRENT signal.

Figure 10 illustrates the motor controller circuit 222 of this alternative embodiment in further detail. Motor controller circuit 222 includes H-bridge circuit 225 which is similar to H-bridge circuit 224. If the MOTOR ENABLE signal is active, then field effect
transistors 302, 304, 306 and 308 are turned on under the same conditions as previously described in conjunction with Figure 8. If neither counter-clockwise motor control signal CCW nor clockwise motor control signal CW are active, then field effect transistors 302 and 306 are turned on. This dynamically brakes motor 38. If counter-clockwise motor control signal CCW is active and clockwise motor control signal CW is inactive, then field effect transistors 304 and 306 are turned on. This causes current to flow through motor 38 in one direction causing counter-clockwise motor rotation. If counter-clockwise motor control signal CCW is inactive and clockwise motor control signal CW is active, then field effect transistors 302 and 308 are turned on. This causes current to flow through motor 38 in the opposite direction causing counter-clockwise motor rotation.

The OVERCURRENT signal is produced by current sensor 310. When operating the entire motor current flows through resistor 311, regardless of the direction of motor rotation. This voltage drop is proportional to the current drawn by motor 38. Current sensor 310 compares this voltage drop across resistor 311 with a predetermined voltage. When the current through motor 38 exceeds a certain amount, the voltage across resistor 311 exceeds the predetermined voltage. Then output of current sensor 310 is high. This OVERCURRENT signal is supplied to logic chip 141 and is employed within motor controller circuit 222.

Gate circuit 320 provides a summation of the MOTOR ENABLE, OVERCURRENT and WATCHDOG signals. An active
WATCHDOG signal causes the operational amplifier to ground the base of the transistor thereby cutting off the supply of gate voltage to field effect transistors 302 and 306. Thus neither the clockwise motor control signal nor the counter-clockwise control signal is effective to control motor 38. An active OVERCURRENT signal cuts off the supply of a gate voltage to field effect transistors 302 and 306 in the same fashion. Under normal circumstances an active MOTOR ENABLE signal supplies a low signal to the operational amplifier permitting the transistor to turn on and supply a gate voltage to field effect transistors 302 and 306. This also supplies a logic high to invertors 303 and 307, which thus turn off their respective field effect transistors 304 and 308. In this state, motor controller circuit 220 operates as previously described in conjunction with Figure 8.

The provision of the MOTOR ENABLE signal serves two safety purposes. First, field effect transistors 302 and 306 are not continuously on. Thus any momentary glitch which might turn on either field effect transistor 304 or field effect transistor 308 does not result in a short between the +12 volt supply and ground. Such a short has the capability of damaging one of the field effect transistors. Second, the requirement of two signals to preform a shift, the MOTOR ENABLE signal and either clockwise motor control signal CW or counter-clockwise motor control signal CCW, means less likelihood of an unintentional shift.
Motor controller circuit 222 illustrated in Figure 10 includes a further refinement over that of Figure 8. The circuit of Figure 10 does not require a boosted voltage supply to fully turn on the high side field effect transistors 304 and 308. Field effect transistors 304 and 308 require a gate voltage above the +12 volt supply voltage to turn fully on. This voltage is provided by capacitors 332 and 336, respectively.

This boosted gate voltage is provided by bootstrap circuits as follows. When MOTOR ENABLE is active and neither the clockwise motor control signal CW nor the counter-clockwise motor control signal CCW are active, then both field effect transistors 302 and 306 are turned on. Capacitor 333 charges through current limiting resistor 331 and diode 332 to the +12 volt supply less the voltage drop across field effect transistor 302. Capacitor 337 is likewise charged through resistor 335 and diode 336. When the clockwise motor control signal CW becomes active, field effect transistor 302 turns off. The charge across capacitor 333 is then discharged between the source and gate of field effect transistor 304. This provides a voltage to the gate of field effect transistor 304 greater than the voltage on its drain, thus turning field effect transistor 304 fully on. Capacitor 337 supplies a similar voltage to the gate of field effect transistor 308 when the counter-clockwise motor control signal CCW is active.

This boosted voltage must be maintained during the entire shift time. The maximum shift time is expected to be about 400 milliseconds. The capacitors may be
selected with sufficient capacity to store enough charge to continue to supply the boosted gate voltage for this length of time. Alternately the motor control signal may be halted for a short time to refresh the charge on the capacitors. A time of 5 milliseconds should suffice. Such a short halt should not adversely effect the shift operation and may be used to slow the final transmission state shift.

Motor controller circuit 222 is preferably disposed remotely from logic chip 141 and near motor 38. In accordance with the preferred embodiment motor controller circuit 222 is disposed as part of power module 34 as illustrated in Figures 1 and 2. There are several reasons why this location is advantageous over locating motor controller circuit 222 in control module 36. Motor controller circuit 222 supplies a high current to motor 38. Location of motor controller circuit 222 in control module 36 would require a greater length of more high current capacity wire within lead 86. High current capacity wire requires greater conductive material than low current capacity wire and is consequently more expensive. Locating motor controller circuit 222 near motor 38 permits the wires from control module 36 to motor controller circuit 222 to be of the less expensive low current capacity type. High current capacity wire is only required for the short distance between motor 38 and the adjacent motor controller circuit 222.

This location increases the efficiency of the dynamic braking. The dynamic braking efficiency depends on
the rate of motor energy dissipation, which is determined
by the impedance of the current path. This current path
includes the motor 38, field effect transistors 302 and 306
and the connecting wires. If motor controller circuit 222
were disposed in control module 36, then the relatively
long current path through leads 86 would add to the
impedance and increase the time required to brake the
motor. Thus locating motor controller circuit 222 in the
power module 34 provides better shifting performance by
providing better dynamic braking.

Locating motor controller circuit 222 in power
module 34 provides better serviceability of the automatic
transmission electrical control apparatus. Premature
failure of H-bridge circuit 224 could cause damage to motor
38 and vice versa. It is thus advantageous to insure these
units are replaced at the same time. This simultaneous
replacement is greatly facilitated by locating motor
controller circuit 222 in power module 34. Otherwise this
replacement would require access to both the power module
34 and to the control module 36 located in the instrument
panel.

The size of control module 36 is reduced about
40% by location of motor controller circuit 222 in power
module 34. This is advantageous because there is limited
room for parts in the motor vehicle instrument panel.
Locating the motor controller circuit 222 remote from the
instrument panel thus frees space for other instrument
panel circuits.
Lastly, this location of the motor controller circuit 222 can reduce noise problems in logic chip 141 if a charge pump is employed. Oscillator 228, required to produce the boosted voltage, tends to create noise in logic chip 141 and interfere with proper operation. Locating oscillator 228 remotely from logic chip 141 reduces this source of noise.

Whereas preferred embodiments of the invention have been illustrated and described in detail it will be apparent that various changes have been made in the disclosed embodiments not departing from the scope or spirit of the invention. In particular, although this invention has been described in conjunction with the transmission of a front wheel drive motor vehicle it is equally applicable to a rear wheel drive vehicle or to a four wheel drive vehicle. This application describes an automatic transmission controlled by rotation of a mode select shaft. Those skilled in the art would realize the invention can be practiced in electrical control of a "manual" transmission such as disclosed in U.S. Patent No. 4,817,468 and U.S. Patent No. 4,821,590, assigned to the assignee of this application. These patents disclose electric control of two degrees of freedom. The teachings of this application can be applied to a motor controller circuit for a motor for each degree of freedom. The motor vehicle need only include a transmission whose state can be changed employing a controlled motor.
Claims

1. An electric shift control apparatus for control of the shifting of the transmission of a motor vehicle of the type including a motor module adapted to be positioned adjacent the vehicle transmission and operative to shift the transmission, a motor controller circuit for controlling the motor module, and a control module adapted to be positioned in the vehicle passenger compartment and operative to transmit operator instigated shift signals to the motor controller circuit, the improvement characterized in that:

   the motor controller circuit is located remotely from the control module.

2. The electric shift control apparatus claimed in claim 1, the improvement further characterized in that:

   the motor controller circuit is located proximate the motor module.

3. The electric shift control apparatus claimed in claim 1, the improvement further characterized in that:

   the motor controller circuit dynamically brakes said motor module in the absence of any operator instigated shift signals.

4. The electric shift control apparatus claimed in claim 1, wherein the motor vehicle includes an electric power supply having a first DC voltage source and a common
voltage terminal, the motor having first and second terminals, the improvement further characterized in that:

said motor controller circuit includes

a DC to DC power supply connected to the electric power supply for generating from the first DC voltage source a second DC voltage higher than the first DC voltage;

a first switch device connected between the first terminal of the motor and the common voltage terminal including a first field effect transistor having a source, a drain and a gate;

a second switch device connected between the first DC voltage source and the first terminal of the motor including a second field effect transistor having a source, a drain and a gate;

a third switch device connected between the second terminal of the motor and the common voltage terminal including a third field effect transistor having a source, a drain and a gate;

a fourth switch device connected between said first DC voltage source and the second terminal of the motor including a fourth field effect transistor having a source, a drain and a gate; and

a switch control circuit connected to said first, second, third and fourth switch devices including means for controlling said first and fourth switch devices to be conductive thereby applying DC power to the motor in a first polarity upon
receipt of only said upshift signal, including means for supplying said second DC voltage to said gate of said fourth field effect transistor for controlling said fourth switch device to be conductive,

means for controlling said second and third switch devices to be conductive thereby applying DC power to the motor in a second opposite polarity upon receipt of only said downshift signal, including means for supplying said second DC voltage to said gate of said second field effect transistor for controlling said second switch device to be conductive, and means for controlling said first and third switch devices to be conductive thereby dynamically braking the motor upon receipt of neither said upshift signal nor said downshift signal.

5. The electric shift control apparatus claimed in claim 4, the improvement further characterized in that:
said DC to DC power supply of said motor controller circuit includes an oscillator and a charge pump circuit.

6. The electric shift control apparatus claimed in claim 1, wherein the motor vehicle includes an electric power supply having a first DC voltage source and a common voltage terminal, the motor having first and second terminals, the improvement further characterized in that:
said motor controller circuit includes
a first switch device connected between the first
terminal of the motor and the common voltage
terminal including a first field effect
transistor having a source, a drain and a gate;
a second switch device connected between the
first DC voltage source and the first terminal of
the motor including a second field effect
transistor having a source, a drain and a gate;
a third switch device connected between the
second terminal of the motor and the common
voltage terminal including a third field effect
transistor having a source, a drain and a gate;
a fourth switch device connected between said
first DC voltage source and the second terminal
of the motor including a fourth field effect
transistor having a source, a drain and a gate;
a first resistor having a first terminal
connected to said drain of said second field
effect transistor and a second terminal;
a first diode having an anode connected to said
second terminal of said first resistor and a
cathode;
a first capacitor having a first terminal
connected to said cathode of said first diode and
a second terminal connected to said source of
said second field effect transistor;
a first coupling between said first terminal of said first capacitor and said gate of said second field effect transistor;
a second resistor having a first terminal connected to said drain of said fourth field effect transistor and a second terminal;
a second diode having an anode connected to said second terminal of said second resistor and a cathode;
a second capacitor having a first terminal connected to said cathode of said second diode and a second terminal connected to said source of said fourth field effect transistor;
a second coupling between said first terminal of said second capacitor and said gate of said fourth field effect transistor; and
a switch control circuit connected to said first, second, third and fourth switch devices including means for controlling said first and fourth switch devices to be conductive thereby applying DC power to the motor in a first polarity upon receipt of only said upshift signal, means for controlling said second and third switch devices to be conductive thereby applying DC power to the motor in a second opposite polarity upon receipt of only said downshift signal, and
means for controlling said first and third switch devices to be conductive thereby dynamically
braking the motor upon receipt of neither said upshift signal nor said downshift signal.
AMENDED CLAIMS

[received by the International Bureau on 30 April 1992 (30.04.92);
original claims 1-6 replaced by amended claims 1-16 (13 pages)]

1. In an electric shift control apparatus for control of the shifting of the transmission of a motor vehicle of the type including a motor module adapted to be positioned adjacent the vehicle transmission and operative to shift the transmission, a motor controller circuit for controlling the motor module, and a control module adapted to be positioned in the vehicle passenger compartment and operative to transmit operator instigated shift signals to the motor controller circuit, the improvement wherein:

the motor controller circuit is located remotely from the control module.

2. The electric shift control apparatus claimed in claim 1, wherein:

the motor controller circuit is mounted on the motor module.

3. The electric shift control apparatus claimed in claim 1, wherein:

the motor controller circuit dynamically brakes said motor module in the absence of any operator instigated shift signals.

4. The electrical shift control apparatus as claimed in claim 1, wherein:

said motor controller circuit includes a plurality
of field effect transistors, an oscillatory DC to DC power
supply generating an increased voltage, said motor controller
circuit selectively supplying said increased voltage to a gate
of at least one of said field effect transistors in response
to either said first drive signal or said second drive signal.

5. The electrical shift control apparatus as claimed
in claim 1, wherein:

said motor controller circuit includes

a first field effect transistor having a
drain connected to the first terminal of the motor,
a source connected to the common voltage terminal
and a gate;

a second field effect transistor having a
drain connected to the first DC voltage source, a
source connected to the first terminal of the motor
and a gate;

a third field effect transistor having a
drain connected to the second terminal of the motor,
a source connected to the common voltage terminal
and a gate;

a fourth field effect transistor having a
drain connected to said first DC voltage source, a
source connected to the second terminal of the motor
and a gate;

a switch control circuit connected to said
first, second, third and fourth field effect
transistors including

means for supplying a voltage
to said gate of said first and fourth
field effect transistors thereby turning
on said first and fourth field effect
transistors and applying DC power to the
motor in a first polarity upon receipt of
only said first drive signal,

means for supplying a voltage
to said gate of said second and third
field effect transistors thereby turning
on said second and third field effect
transistors and applying DC power to the
motor in a second opposite polarity upon
receipt of only said second drive signal,

means for supplying a voltage
to said gate of said first and third
field effect transistors thereby turning
on said first and third field effect
transistors and dynamically braking the
motor upon receipt of neither said first
drive signal nor said second drive
signal,

a first bootstrap circuit including a
first capacitor and means for charging said first
capacitor when said first field effect transistor is
turned on and means for connecting said first
capacitor between said gate and said source of said second field effect transistor when said first field effect transistor is turned off, and a second bootstrap circuit including a second capacitor and means for charging said second capacitor when said third field effect transistor is turned on and means for connecting said second capacitor between said gate and said source of said fourth field effect transistor when said third field effect transistor is turned off.

7. The electrical shift control apparatus as claimed in claim 1, wherein:

said motor controller circuit further includes means for enabling supply of electric power to the motor in either said first polarity or said second polarity only upon receipt of said motor enable signal.

8. The electrical shift apparatus as claimed in claim 1, wherein:

said motor controller circuit further includes means for disabling supply of electric power to the motor in either said first polarity or said second polarity upon receipt of said watchdog signal.
9. The electrical control apparatus as claimed in claim 1, wherein:

said motor controller circuit includes

a first field effect transistor having a drain connected to the first terminal of the motor, a source connected to the common voltage terminal and a gate;

a second field effect transistor having a drain connected to the first DC voltage source, a source connected to the first terminal of the motor and a gate;

a third field effect transistor having a drain connected to the second terminal of the motor, a source connected to the common voltage terminal and a gate;

a fourth field effect transistor having a drain connected to said first DC voltage source, a source connected to the second terminal of the motor and a gate;

a switch control circuit connected to said first, second, third and fourth field effect transistors including means for supplying no voltage to said gate of said first, second, third and fourth field effect transistors thereby applying no power to the motor upon failure to receive said motor enable
signal,
means for supplying a voltage
to said gate of said first and fourth
field effect transistors thereby turning
on said first and fourth field effect
transistors and applying DC power to the
motor in a first polarity upon receipt of
both said first drive signal and said
motor enable signal,
means for supplying a voltage
to said gate of said second and third
field effect transistors thereby turning
on said second and third field effect
transistors and applying DC power to the
motor in a second opposite polarity upon
receipt of both said second drive signal
and said motor enable signal,
means for supplying a voltage
to said gate of said first and third
field effect transistors thereby turning
on said first and third field effect
transistors and dynamically braking the
motor upon receipt of said motor enable
signal and neither said first drive
signal nor said second drive signal,
a first bootstrap circuit including a
first capacitor and means for charging said first
capacitor when said first field effect transistor is turned on and means for connecting said first capacitor between said gate and said source of said second field effect transistor when said first field effect transistor is turned off, and

a second bootstrap circuit including a second capacitor and means for charging said second capacitor when said third field effect transistor is turned on and means for connecting said second capacitor between said gate and said source of said fourth field effect transistor when said third field effect transistor is turned off.

10. An power module for use with a motor vehicle having an automatic transmission including a housing, and a mode select shaft to selectively shift the transmission between a plurality of shift positions, said power module comprising:

a motor assembly having an output shaft adapted to be drivingly connected to the mode select shaft,
an encoder means adapted to be connected to the mode select shaft for generating a transmission state signal indicative of the shift position of the mode select shaft, and

a motor controller circuit electrically connected to said motor assembly for supplying electric power to said motor assembly in a first polarity in response to a first drive signal and for supplying electric power to said motor assembly
in a second polarity opposite to said first polarity in response to a second drive signal.

11. The power module as claimed in claim 10, wherein:

said motor controller circuit further includes means for dynamically braking the motor assembly in response to receipt of neither said first drive signal nor said second drive signal.

12. The power module as claimed in claim 10, wherein:

said motor controller circuit further includes a plurality of field effect transistors, an oscillatory DC to DC power supply generating an increased voltage, said motor controller circuit selectively supplying said increased voltage to a gate of at least one of said field effect transistors in response to either said first drive signal or said second drive signal.

13. The power module as claimed in claim 10, wherein:

said motor controller circuit includes a first field effect transistor having a drain connected to the first terminal of the motor, a source connected to the common voltage terminal
and a gate;

a second field effect transistor having a drain connected to the first DC voltage source, a source connected to the first terminal of the motor and a gate;

a third field effect transistor having a drain connected to the second terminal of the motor, a source connected to the common voltage terminal and a gate;

a fourth field effect transistor having a drain connected to said first DC voltage source, a source connected to the second terminal of the motor and a gate;

a switch control circuit connected to said first, second, third and fourth field effect transistors including

means for supplying a voltage to said gate of said first and fourth field effect transistors thereby turning on said first and fourth field effect transistors and applying DC power to the motor in a first polarity upon receipt of only said first drive signal,

means for supplying a voltage to said gate of said second and third field effect transistors thereby turning on said second and third field effect
transistors and applying DC power to the motor in a second opposite polarity upon receipt of only said second drive signal, means for supplying a voltage to said gate of said first and third field effect transistors thereby turning on said first and third field effect transistors and dynamically braking the motor upon receipt of neither said first drive signal nor said second drive signal,
a first bootstrap circuit including a first capacitor and means for charging said first capacitor when said first field effect transistor is turned on and means for connecting said first capacitor between said gate and said source of said second field effect transistor when said first field effect transistor is turned off, and
a second bootstrap circuit including a second capacitor and means for charging said second capacitor when said third field effect transistor is turned on and means for connecting said second capacitor between said gate and said source of said fourth field effect transistor when said third field effect transistor is turned off.

14. The power module as claimed in claim 10,
wherein:

said motor controller circuit further includes means for enabling supply of electric power to the motor in either said first polarity or said second polarity only upon receipt of a motor enable signal.

15. The power module as claimed in claim 10, wherein:

said motor controller circuit further includes means for disabling supply of electric power to the motor in either said first polarity or said second polarity upon receipt of a watchdog signal.

16. The power module as claimed in claim 10, wherein:

said motor controller circuit includes a first field effect transistor having a drain connected to the first terminal of the motor, a source connected to the common voltage terminal and a gate;

a second field effect transistor having a drain connected to the first DC voltage source, a source connected to the first terminal of the motor and a gate;

a third field effect transistor having a
drain connected to the second terminal of the motor, 
a source connected to the common voltage terminal 
and a gate; 

a fourth field effect transistor having a 
drain connected to said first DC voltage source, a 
source connected to the second terminal of the motor 
and a gate; 

a switch control circuit connected to said 
first, second, third and fourth field effect 
transistors including 

means for supplying no voltage 
to said gate of said first, second, third 
and fourth field effect transistors 
thereby applying no power to the motor 
upon failure to receive said motor enable 
signal,

means for supplying a voltage 
to said gate of said first and fourth 
field effect transistors thereby turning 
on said first and fourth field effect 
transistors and applying DC power to the 
motor in a first polarity upon receipt of 
both said first drive signal and said 
motor enable signal,

means for supplying a voltage 
to said gate of said second and third 
field effect transistors thereby turning
on said second and third field effect transistors and applying DC power to the motor in a second opposite polarity upon receipt of both said second drive signal and said motor enable signal,

means for supplying a voltage to said gate of said first and third field effect transistors thereby turning on said first and third field effect transistors and dynamically braking the motor upon receipt of said motor enable signal and neither said first drive signal nor said second drive signal,

a first bootstrap circuit including a first capacitor and means for charging said first capacitor when said first field effect transistor is turned on and means for connecting said first capacitor between said gate and said source of said second field effect transistor when said first field effect transistor is turned off, and

a second bootstrap circuit including a second capacitor and means for charging said second capacitor when said third field effect transistor is turned on and means for connecting said second capacitor between said gate and said source of said fourth field effect transistor when said third field effect transistor is turned off.
**INTERNATIONAL SEARCH REPORT**

**I. CLASSIFICATION OF SUBJECT MATTER**
According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): F16H 59/62, F16H 61/32, B60K 41/22
U.S. CL.: 364/424.1, 74335,866

**II. FIELDS SEARCHED**

<table>
<thead>
<tr>
<th>Classification System</th>
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<tr>
<td>U.S. CL.</td>
<td>364/424.1, 74335,866</td>
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<td>318/293,294</td>
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US, A, 4,581,565 (VAN PELT ET AL.) 08 April 1986, See figures 3-4.</td>
<td>4-6</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,649,326 (MANSMAAN ET AL.) 10 March 1987, See entire document.</td>
<td>4-6</td>
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<tr>
<td>A</td>
<td>US, A, 4,677,356 (TSUNDEA ET AL.) 30 June 1987, See figures 1 and 3.</td>
<td>4-6</td>
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<tr>
<td>A</td>
<td>US, A, 4,816,726 (NOVIS ET AL.) 28 March 1989, See entire document.</td>
<td>4-6</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,859,916 (McCABRIDGE) 22 August 1989, See entire document.</td>
<td>4-6</td>
</tr>
<tr>
<td>X</td>
<td>US, A, 4,817,471 (TURY) 04 April 1989, See columns 3 and 13; figures 19 and 15; claims</td>
<td>1-3/4-6</td>
</tr>
<tr>
<td>Y</td>
<td>US, A, 4,922,769 (TURY) 08 May 1990, See figures 19 and 15; columns 1 and 2.</td>
<td>1-3/4-6</td>
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</tbody>
</table>

* Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed
  - "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  - "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
  - "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  - "A" document member of the same patent family

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search: 12 FEBRUARY 1992
Date of Mailing of this International Search Report: 10 MAR 1992

International Searching Authority: ISA/US

Signature of Authorized Officer: COLLIN W. PARK
FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

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V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. Claim numbers because they relate to subject matter not required to be searched by this Authority, namely:

2. Claim numbers because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claim numbers because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest
- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.