



(11) (21) (C) **2,150,848**  
(22) 1995/06/02  
(43) 1995/12/09  
(45) 2000/02/01

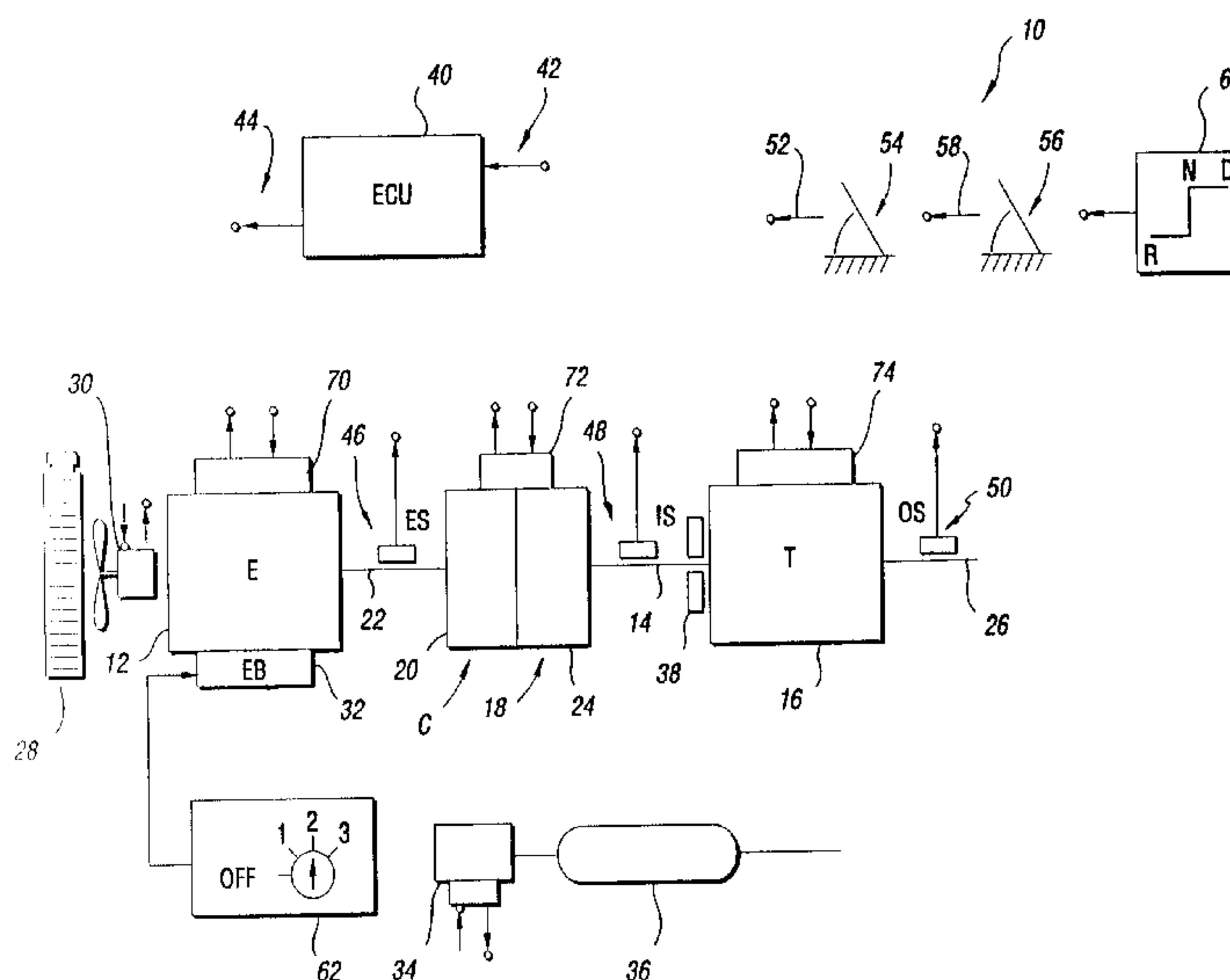
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(51) Int.Cl.<sup>6</sup> F16H 59/00

(30) 1994/06/08 (9411494.9) GB

(54) **SYSTEME ET METHODE POUR REDUIRE LE TEMPS DE  
CHANGEMENT DE RAPPORT DANS LES TRANSMISSIONS  
ELECTRONIQUES**

(54) **SYSTEM AND METHOD FOR DECREASING RATIO  
CHANGING TIME ELECTRONICALLY ENHANCED  
POWERTRAIN SYSTEMS**



(57) A system and method for decreasing the time required to complete a ratio change in an electronically enhanced powertrain system (10) is provided. The powertrain system (10) includes a number of devices for providing a retarding torque to engine rotation to increase the decay rate of the engine speed during an upshift. These devices include an engine brake (32) and an input shaft brake (38). A retarding torque is also provided by increasing engine accessory load by controlling various engine accessories such as a cooling fan (30), an air compressor, a hydraulic pump, an air conditioning compressor (34), and an alternator.



**SYSTEM AND METHOD FOR  
DECREASING RATIO CHANGING  
TIME IN ELECTRONICALLY  
ENHANCED POWERTRAIN SYSTEMS**

5

**Abstract**

A system and method for decreasing the time required to complete a ratio change in an electronically enhanced powertrain system (10) is provided. The powertrain system (10) includes a number of devices for providing a retarding torque to engine rotation to increase the decay rate of the engine speed during an upshift. These devices include an engine brake (32) and an input shaft brake (38). A retarding torque is also provided by increasing engine accessory load by controlling various engine accessories such as a cooling fan (30), an air compressor, a hydraulic pump, an air conditioning compressor (34), and an alternator.

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**SYSTEM AND METHOD FOR  
DECREASING RATIO CHANGING  
TIME IN ELECTRONICALLY  
ENHANCED POWERTRAIN SYSTEMS**

**Technical Field**

The present invention relates to a system and method for decreasing the time required to complete a ratio change in an electronically enhanced engine and transmission system.

**Background Art**

5                    Electronically enhanced transmission systems have been well developed in the prior art as may be seen by reference to United States Patents Nos. 4,361,060; 4,595,986; 4,648,290; 4,722,248; and 5,050,427..

10

Transmission systems such as these have been utilized to provide a variety of gear ratios to enhance the flexibility and torque multiplication of an engine to

service a plethora of applications. The most common applications include MVMA Class 7 and Class 8 tractor semi-trailer vehicles although other applications, such as automobile or stationary power plant powertrains, may also be serviced.

An electronic control module which includes a microprocessor is often used to control the powertrain, which includes an engine as well as a multiple gear ratio transmission. The continuous evolution of microprocessor technology has enabled increased accuracy and expanded the scope of control over engine and transmission operations. The electronic control module collects data from various sensors and issues commands appropriate for the current operating conditions to control the engine and transmission. Engine control may include modulating fuel, operating engine accessories, or managing application of an engine brake or driveline retarder. Transmission control may include selection of an appropriate gear ratio, including disengagement of the current gear ratio and engagement of a new target gear ratio, or operation of an input shaft brake.

Efficient ratio changing improves fuel economy and enhances drivability of a vehicle. Under certain demanding situations, such as when negotiating a steep grade with a heavily loaded vehicle, swift ratio changes are required to prevent the vehicle from losing momentum and missing the window of opportunity to complete the shift entirely. Under normal driving conditions, an operator may have to shift gears more than fifteen times before reaching highway speeds. In these applications, inefficiency in ratio changing may accumulate to a significant amount of wasted time.

Thus, it is desirable to reduce the time necessary to complete a ratio change or shift.

5 A typical ratio change involves a number of steps. First, the operator must interrupt the transfer of torque from the engine through the transmission to the driveline. This may be accomplished by disengaging a master clutch which provides a frictional coupling between the engine and the transmission. Alternatively, a "throttle dip" may  
10 be performed where the throttle is abruptly decreased. Once the torque transfer has been interrupted, the current gear is disengaged and the transmission is in a neutral state.

15 The next step in a typical ratio change involves selecting the target gear ratio. This may be the next available gear ratio in the sequence, or a number of available ratios may be skipped, depending on the current operating conditions. Before engaging the target gear, the transmission input shaft should  
20 rotate at a substantially synchronous speed for the current output shaft speed and target gear ratio. When the master clutch is engaged, the input shaft speed may be controlled by controlling engine speed since the engine and transmission are coupled. Engine  
25 speed may be increased (for a downshift) or decreased (for an upshift) to realize synchronous speed. On transmissions equipped with an input shaft brake, the input shaft speed may be reduced by disengaging the master clutch and applying the input shaft brake (also  
30 known as an inertia brake or clutch brake). However, input shaft brakes with sufficient capacity to decrease ratio changing time add cost and complexity to the transmission system and require accurate

sequencing of events for satisfactory operation, so many transmissions only utilize simple versions of these devices.

For transmissions without input shaft  
5 brakes, synchronous speed will not be attained with the master clutch engaged on an upshift until the engine speed naturally decays to synchronous. As engines become more and more efficient, the reduction of internal frictional losses results in a  
10 substantially lower natural engine decay rate. This results in a correspondingly longer time to complete a ratio change. Thus, it is desirable to increase engine deceleration during an upshift to achieve synchronous speed shortly after disengagement of the  
15 current gear.

A device often utilized to provide a variable retarding force to an engine, is an engine brake. The most common engine brakes may be either engine compression brakes or exhaust brakes. These  
20 devices are well known in the prior art and are commonly provided on heavy-duty vehicles. Examples of vehicular automated mechanical transmission systems utilizing engine brakes may be seen by reference to United States Patent Nos. 4,933,850 and 5,042,327.  
25

Engine compression brakes are usually manually operated and provide a variable retarding force resisting engine rotation by altering valve  
30 timing of one, two, or three banks of cylinders. This creates compressive force within the cylinders which resists rotation of the crankshaft. Exhaust brakes

operate in a similar fashion by restricting exhaust flow from the engine. Exhaust brakes do not offer the responsiveness or flexibility of engine compression brakes although they are less expensive to employ.

5                   Traditionally, engine brakes are utilized to assist the vehicle service brakes by supplying a resisting torque on the driveline when descending long grades. Manual operation of the engine brake in these situations continues to be a desirable option. More  
10 recently, engine brakes have been manually operated to decrease the time required for ratio changes. For this application, manual operation of the engine brake often results in large torque disturbances to the vehicle driveline due to inappropriate timing in  
15 applying and releasing the engine brake. This reduces drivability of the vehicle and may also adversely affect the durability of powertrain components. Furthermore, proper operation is largely dependent upon the skill and experience of the vehicle operator.

## 20                   Summary of the Invention

The present invention provides a system and method for reducing the time required to complete a ratio change, in particular, an upshift ratio change, in a manual, semi-automatic or fully automatic  
25 transmission. Additionally, the present invention provides a system which reduces the time required to achieve synchronous speed by increasing a retarding force acting on engine rotation. The present

invention also provides a system which automates control  
5 of an engine compression brake to decrease ratio  
changing time in a manual, semi-automatic or fully  
automatic transmission. Further, the present invention  
provides a system which increases engine load to supply  
a variable retarding force so as to improve ratio  
changing times in a manual, semi-automatic transmission.  
10 The present invention also provides a system which  
reduces driveline disturbances during an upshift by  
utilizing an engine brake when a transmission neutral  
condition is sensed.

15 In carrying out the above and other features of  
the present invention, a  
control system is provided for reducing the ratio  
changing time of a mechanical transmission system.  
The transmission system includes an engine selectively  
20 coupled by a master friction clutch to a mechanical  
change gear transmission. The system also includes an  
electronic control unit for receiving a plurality of  
input signals indicative of an engine speed, an output  
shaft speed, and a neutral gear state of the  
25 transmission. The electronic control unit also  
generates command signals for controlling the engine  
and the transmission. The transmission includes a  
plurality of gear ratio combinations, and a neutral  
gear state, selectively engageable between a  
30 transmission input shaft and a transmission output  
shaft. The control system utilizes a sensor for  
sensing the neutral gear state which occurs after

disengaging a current gear ratio and before effecting  
a target gear ratio in the transmission. The system  
also includes devices for applying a retarding torque  
to the engine in response to a command from the  
5 electronic control unit. The retarding torque is  
applied to the engine while the engine speed is above  
the synchronous speed at which the target gear ratio  
is effected, so as to increase engine deceleration and  
reduce ratio changing time. A method is also provided  
10 for use with the system and similar systems.

The above and other  
features, and advantages of the present invention will  
be readily appreciated by one of ordinary skill in the  
art from the following detailed description of the  
15 best mode for carrying out the invention when taken in  
connection with the accompanying drawings.

### **Brief Description of the Drawings**

FIGURE 1 is a schematic representation of  
a powertrain system including a mechanical  
20 transmission and an engine brake according to the  
present invention;

FIGURE 2a is a graphical representation of a  
typical upshift with a master friction clutch engaged,  
unassisted by an engine brake;

25 FIGURE 2b is a graphical representation of  
an attempted upshift under demanding conditions  
without utilizing an engine brake;

FIGURE 2c is a graphical representation of  
an engine brake assisted upshift with a master

friction clutch engaged according to the present invention; and

FIGURE 3 is a flow chart illustrating the method of reducing ratio changing times according to the present invention;

### Best Mode For Carrying Out The Invention

Figure 1 schematically depicts a vehicular powertrain system, indicated generally by reference numeral 10. The system includes an internal combustion engine 12 which is selectively coupled to the input shaft 14 of a multiple gear change transmission 16 via a master friction clutch 18. Engine 12 may be any of a number of types of internal combustion engines, such as a diesel engine or a gasoline engine. Master friction clutch 18 includes driving elements 20 which are attached to the crankshaft 22 of engine 12, and driven elements 24 which are attached to input shaft 14. When master friction clutch 18 is engaged, substantially all the torque delivered by engine 12 is transmitted through driving elements 20 and driven elements 24 to transmission 16.

Output shaft 26 of transmission 16 is adapted to engage an appropriate driveline component (not specifically illustrated), such as a differential, drive axle, transfer case, or the like. Powertrain system 10 may also include a heat exchanger 28, such as a conventional radiator, an electrically controllable cooling fan 30, and an engine brake 32. Other components may include a hydraulic pump for power steering or other oil operated devices, an air

conditioned compressor for cab climate control, an alternator for supplying electrical power, and an air compressor 34 and a compressed air storage tank 36 for powering pneumatically actuated devices or systems, such as the transmission input shaft brake 38, or the vehicle service brakes (not specifically illustrated).

Powertrain system 10 includes a number of sensors and actuators to effect control of the system as determined by the electronic control unit (ECU) 40. The various sensors provide information indicative of the current operating conditions to ECU 40 via input means 42. ECU 40 utilizes this information in executing a predetermined set of instructions, stored in a memory, to generate command signals. The command signals are relayed to the various actuators via output means 44.

Some representative sensors in communication with ECU 40 include a crankshaft sensor 46 for indicating engine speed (ES), an input speed sensor 48 for indicating transmission input speed (IS), and an output shaft sensor 50 for indicating transmission output speed (OS). Other sensors include a throttle position sensor 52 for indicating the position of throttle pedal 54, a brake-applied sensor 58 to indicate the state of service brake pedal 56 for applying the vehicle service brakes, and a gear selection indicator 60 for selecting a reverse (R), neutral (N), or drive (D) gear of transmission 16. In some applications, an additional gear selector is provided to indicate a request for an upshift or downshift. A manual engine brake selector 62 is provided for allowing manual control of the engine

brake under certain operating conditions, as described below.

Powertrain system 10 also includes a number of actuators in communication with ECU 40. The  
5 actuators receive commands from ECU 40 via output means 44. Preferably, a standard communications link, such as the SAE J1922 or SAE J1939, is utilized for the actuators and sensors. The actuators may also provide feedback to ECU 40 via input means 42 to  
10 effect a closed-loop control system. Typical actuators include a fuel controller 70 for regulating the amount of fuel delivered to engine 12, and a clutch operator 72 for engaging and disengaging master friction clutch 18. Commands from ECU 40 may also be  
15 directed to actuators through other controllers. For example, fuel controller 70 may be responsible for activating engine brake 32 upon request by ECU 40. Transmission operator 74 is operative to change the gear ratio of transmission 16 to achieve a selected  
20 gear. Transmission operator 74 also provides a signal indicative of the currently engaged gear or a neutral gear state of transmission 16.

Any of a number of known sensor types may be utilized to provide information related to the current  
25 operating conditions to ECU 40 without departing from the spirit or the scope of the present invention. Similarly, known electric, hydraulic, pneumatic, and combination actuators may be implemented to realize the present invention. Transmission system controls  
30 and actuators of the type described above may be appreciated in greater detail by reference to U.S. Patent Nos. 4,959,986; 4,576,065; and 4,445,393.

5 A better understanding of the operation of the present invention will be facilitated by reference to Figures 2a through 2c which are graphical representations of various component rotational speeds during three different upshifts.

10 Figure 2a is a graphical representation of an upshift performed by powertrain system 10 of Figure 1 with master friction clutch 18 engaged and without utilizing engine brake 32. The upshift begins at time  $t_1$  where the current gear is disengaged so that transmission 16 is in a neutral gear state as indicated by transmission operator 74 or by a  
 15 comparison of transmission input and output speeds. Also at time  $t_1$ , the engine is defuelled by fuel controller 70. Since master friction clutch 18 is still engaged, input shaft 14 is coupled to crankshaft 22 and engine speed (ES) is equal to input speed (IS).  
 20 As illustrated, ES (and IS) decreases until achieving synchronous with output shaft speed (OS) at time  $t_2$  (illustrations assume a target gear ratio of 1.00). Synchronous speed is achieved when  $IS = OS * GR_T$ , where  $GR_T$  is the target gear ratio.

25 Since engine brake 32 is not being used, the rate at which ES decreases is the natural decay rate of the system. The natural decay rate is a function of the rotational inertia of the rotating engine, clutch, and transmission components. Also near time  
 30  $t_2$ , when ES is within approximately 40 RPM of synchronous, transmission operator 74 engages the selected target gear. At time  $t_3$ , fuel is restored to

engine 12 by fuel controller 70 and the upshift has been completed.

In Figure 2b, a graphical representation of an attempted upshift under demanding conditions, such as when ascending a steep grade, is shown. Similar to the event illustrated in Figure 2a, at time  $t_1$ , transmission operator 74 disengages the current gear and indicates a neutral gear state to ECU 40 while engine 12 is defuelled by fuel controller 70. Without engine fueling, the vehicle slows down rapidly, causing OS to decrease. The natural decay rate of engine 12 is too gradual to attain synchronous before reaching engine idle speed at time  $t_4$ . Thus, the window of opportunity to complete the desired upshift has passed and the upshift must be aborted.

Figure 2c is a graphical representation of an upshift performed by powertrain system 10 with master friction clutch 18 engaged while also utilizing engine brake 32. At time  $t_a$ , the current gear is disengaged, engine 12 is defuelled, and ES begins to decrease at its natural decay rate. ECU 40 generates a command signal to apply engine brake 32 when a neutral gear state is indicated by transmission operator 74 at time  $t_b$ . Engine brake 32 is operative to increase the decay rate of ES such that synchronous speed may be attained at time  $t_c$ . The target gear is engaged at time  $t_c$  by transmission operator 74 in response to a command signal from ECU 40. Power to engine 12 is restored at time  $t_d$  as fuel controller 70 increases the delivered fuel in response to a command from ECU 40, thereby completing the upshift. Of course, transmission gear disengagement and engagement could remain under control of the vehicle operator,

and still be within the scope of the present invention. In the case of manual control of gear engagement, at time  $T_c$  fuel controller 70 would operate to maintain ES and IS at synchronous speed until  
5 transmission operator 74 indicated that the target gear had been manually engaged.

As illustrated in Figure 1, engine brake 32 is in communication with engine brake selector 62, which provides for manual operation of engine brake 32  
10 when descending a long grade. Typically, the engine brake is actuated when ES is above idle and throttle pedal 54 is fully released. Engine brake selector 62 could also be arranged to allow driver selection of the level of retardation to be provided during an  
15 upshift, so that zero, one, two or three banks of cylinders are activated when signaled by ECU 40. Engine brake activation could also be limited to multiple ratio upshifts only, or only when the required engine speed decay rate for an acceptable  
20 upshift exceeds a given threshold. These techniques minimize the wear and tear resulting from engine brake use.

As previously discussed, an engine brake may be either a compression brake or an exhaust brake. In  
25 addition to conventional engine brakes, the present invention controls engine accessories to effect a modified form of engine braking. By selectively energizing and de-energizing accessories such as cooling fan 30, air compressor 34, or other devices  
30 (not shown) such as hydraulic pumps, air conditioning compressors, or alternators, the load on engine 12 may be increased or decreased, respectively, so as to vary the engine speed decay rate. Furthermore, an input

shaft brake 38 under control of ECU 40 may be applied with the master clutch engaged to supply an additional retarding force operative to increase the decay rate of engine 12. Of course, any combination of the above  
5 devices, or other similar devices such as a driveline retarder, may be used together to produce a variable retarding force depending upon the particular system operating conditions.

Since various engine braking devices, such  
10 as an engine compression brake, take a significant time to respond relative to the total time required for an upshift, these devices may be actuated prior to sensing a neutral gear state. For example, in Figure 2c, the engine brake would be actuated before time  $t_a$   
15 to reduce or eliminate the time lapse between time  $t_a$  and time  $t_b$ . The exact actuation time would depend upon the response time of the particular braking device being utilized and the details of the arrangements to ensure that the current gear will be  
20 disengaged. This strategy works particularly well with engines which revert to idle fuelling when the engine brake is activated. Reverting to idle fuelling accomplishes the throttle dip function which interrupts torque transfer through the transmission to  
25 allow disengagement of the current gear.

Engine brake response time is also considered in determining when to deactivate the engine brake. The present invention deactivates the engine brake at an appropriate time to anticipate a  
30 natural engine speed decay rate when ES will be within the synchronous window, i.e. within about 40 RPM of synchronous speed.

If the target speed for IS is below a reference value such as 200 RPM above engine idle speed, alternative synchronization methods must be implemented, such as disengaging the master clutch and actuating an input shaft brake. One situation where this occurs is in completing a stationary shift since OS is near zero so synchronous speed is below the engine idle reference speed.

The present invention also provides for various contingencies to accommodate diverse operating conditions. If the engine brake engages prior to its predicted engagement (due to a varying response time), clutch operator 72 may disengage master friction clutch 18 while the current gear is being disengaged so the shift may progress acceptably. Other alternative control sequences are initiated by ECU 40 in the event that synchronization is not being accomplished, as in the case illustrated in Figure 2b. For example, engine braking may be increased by using a combination of conventional engine braking with engine accessory loading and application of input shaft brake 38.

Typically, input shaft brakes are utilized to decelerate the input shaft of a transmission when the master friction clutch is disengaged. Thus, traditional input shaft brakes are designed to decelerate a limited rotational inertia. Therefore, utilizing input shaft brake 38 according to the present invention may require a high-capacity input shaft brake. This allows input shaft brake 38 to accommodate the rotational inertia generated by engine 12, crankshaft 22, and master friction clutch 18 so

that input shaft brake 38 may be applied while master friction clutch 18 is still engaged.

Figure 3 is a flowchart illustrating the method of decreasing ratio changing times according to the present invention. At step 80, the ECU gathers information from the various sensors and actuators of the system and obtains values for ES, IS, OS, and a limiting value for engine braking. If an upshift has been requested by the operator, or is indicated by the ECU, step 82 directs processing to continue with step 84. Otherwise, the process loops back to step 80.

As also shown in Figure 3, step 84 includes disengaging the current gear and selecting an appropriate target gear. Once the current gear is disengaged, the transmission is in a neutral gear state. If ES is above an idle reference value, as determined by step 86, then a test is performed to determine if engine speed is within the synchronous window step 88. Otherwise, if ES is below idle speed, alternate control strategies are initiated by step 98 which include those contingencies discussed above. If a speed within the synchronous window has not been attained, a retarding torque is applied as indicated by step 94. This may include activating an engine compression brake, increasing engine accessory load, or a combination of these as previously discussed.

Still referring to Figure 3, the closure rate between ES and synchronous speed is examined at step 96. If the closure rate is satisfactory for current operating conditions, the process continues with step 86. Otherwise, alternate control strategies are implemented by step 98. Once the synchronous

speed window is attained as determined by step 88, the retarding torque is removed at step 90 and the target gear is engaged at step 92 so as to complete the upshift.

5                   It is understood, of course, that while the  
form of the invention herein shown and described  
constitutes a preferred embodiment of the invention,  
it is not intended to illustrate all possible forms  
thereof. It will also be understood that the words  
10 used are descriptive rather than limiting, and that  
various changes may be made without departing from the  
spirit or scope of the invention as claimed below.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for reducing a ratio changing time in a mechanical powertrain system including an engine having a device operative to retard engine rotation, the engine being coupled to a mechanical change gear transmission having a plurality of gear ratio combinations and a neutral gear state selectively engageable between a transmission input shaft and a transmission output shaft, the system also including an electronic control unit for receiving a plurality of input signals indicative of an engine speed, an output shaft speed, and a neutral gear state, the electronic control unit also being operative to generate command signals for controlling the engine retarding device, the method comprising:

sensing the neutral gear state which occurs after disengaging a current gear ratio and before effecting engagement of a target gear ratio; and

while the master friction clutch is engaged, applying a retarding torque to the engine while the engine speed is above a synchronous speed at which engagement of the target gear ratio is effected so as to increase engine deceleration and reduce ratio changing time.

2. The method of claim 1 wherein the transmission further includes an input shaft brake for retarding rotation of the input shaft and wherein applying a retarding torque comprises actuating the engine retarding device in combination with actuating the input shaft brake.

3. The method of claim 2 wherein the engine retarding device is an engine compression brake.

4. The method of claim 1 wherein the transmission system further includes a plurality of engine accessories coupled to the engine and in communication with the electronic control unit and wherein applying a retarding torque comprises energizing at least one of the plurality of engine accessories to increase engine load.

5. The method of claim 4 wherein the engine accessories include a cooling fan, an air compressor, a hydraulic pump, an air conditioning compressor, and an alternator.

6. The method of claim 1 wherein the transmission system further includes a plurality of engine accessories coupled to the engine and in communication with the electronic control unit, the transmission further includes an input shaft brake for retarding rotation of the input shaft, and wherein applying a retarding torque comprises actuating a combination of devices selected from the group consisting of the plurality of engine accessories, the engine retarding device, and the input shaft brake.

7. The method of claim 1 further comprising:  
monitoring the closure rate at which the engine speed approaches the synchronous speed; and  
controlling application of the retarding torque based on the closure rate.

8. The method of claim 7 wherein  
controlling application of the retarding torque  
includes increasing the retarding torque.

5 9. The method of claim 7 wherein monitoring  
the closure rate includes determining if the  
engine speed is above an engine idle reference speed.

10 10. A control system for reducing a ratio  
changing time of a mechanical powertrain system  
including an engine coupled to a mechanical change  
gear transmission having a plurality of gear ratio  
combinations and a neutral gear state selectively  
engageable between a transmission input shaft and  
a transmission output shaft, the powertrain  
system also including an electronic control unit  
15 for receiving a plurality of input signals indicative  
of an engine speed, an output shaft speed,  
and a neutral gear state, the electronic control unit  
also being operative to generate command signals for  
controlling the engine and the transmission, the  
20 control system comprising:

a sensor for determining the neutral  
gear state which occurs after disengaging a current  
gear ratio and before effecting engagement of a target  
gear ratio; and

25 means for applying a retarding torque  
in response to a command from the  
electronic control unit, the retarding torque  
being applied to the engine while the engine speed  
is above a synchronous speed at which the target gear  
30 ratio is effected so as to increase engine  
deceleration and reduce ratio changing time.

11. The control system of claim 10 wherein the means for applying a retarding torque comprises an input shaft brake attached to the transmission and in communication with the electronic control unit for retarding rotation of the input shaft.

12. The control system of claim 10 wherein the means for applying a retarding torque comprises an engine brake.

13. The control system of claim 12 wherein the engine brake is an engine compression brake.

14. The system of claim 10 wherein the means for applying a retarding torque comprises a plurality of engine accessories coupled to the engine for increasing a load on the engine so as to retard engine rotation.

15. The system of claim 10 wherein the means for applying a retarding torque comprises an engine cooling fan for increasing a load on the engine so as to retard engine rotation.

16. The system of claim 15 wherein the means for applying a retarding torque further comprises an air compressor, a hydraulic pump, an air conditioning compressor, and an alternator, all of which are coupled to the engine for increasing a load on the engine so as to retard engine rotation.

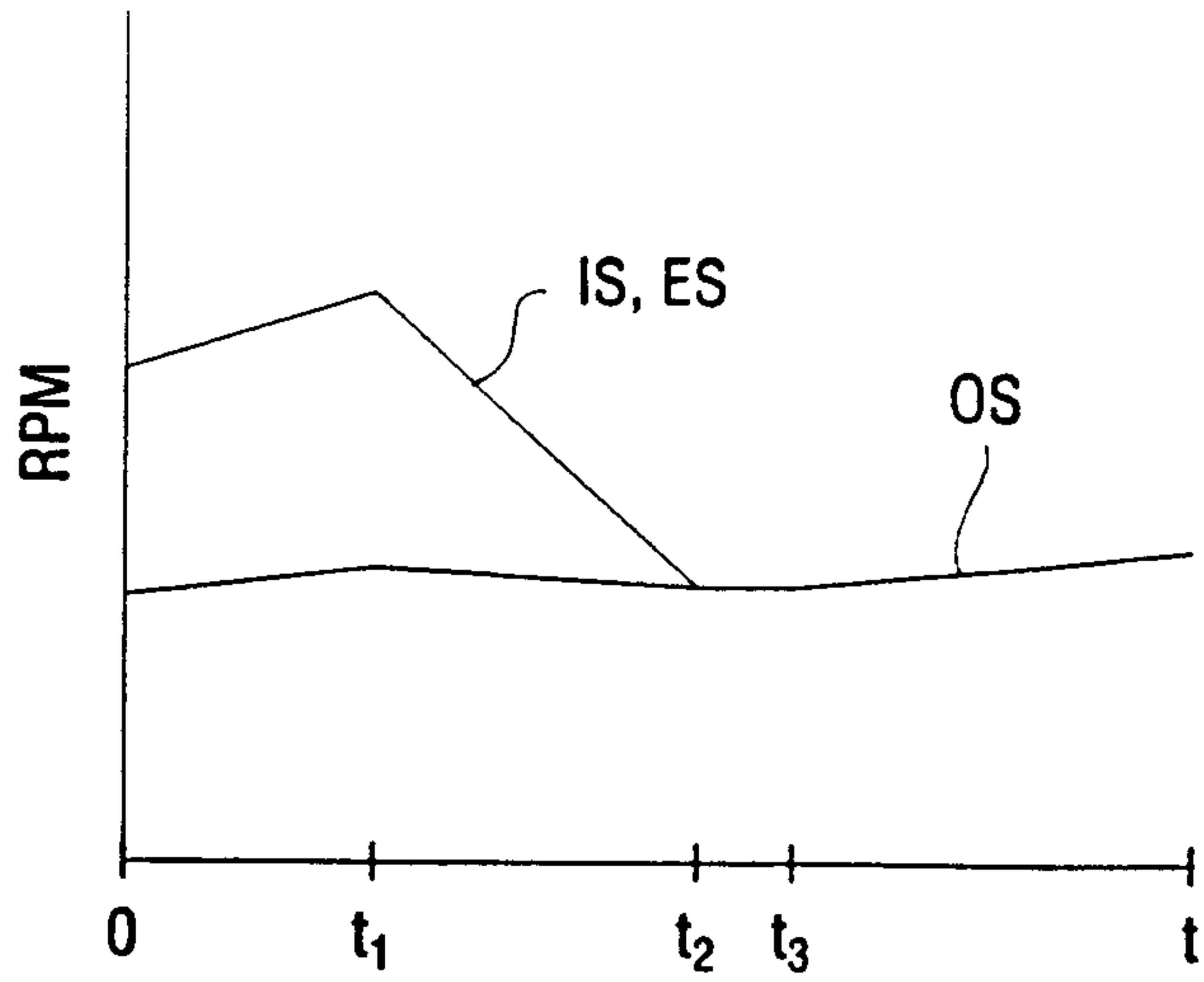
17. The system of claim 10 further comprising:

means for monitoring the closure rate  
at which the engine speed approaches the  
synchronous speed; and

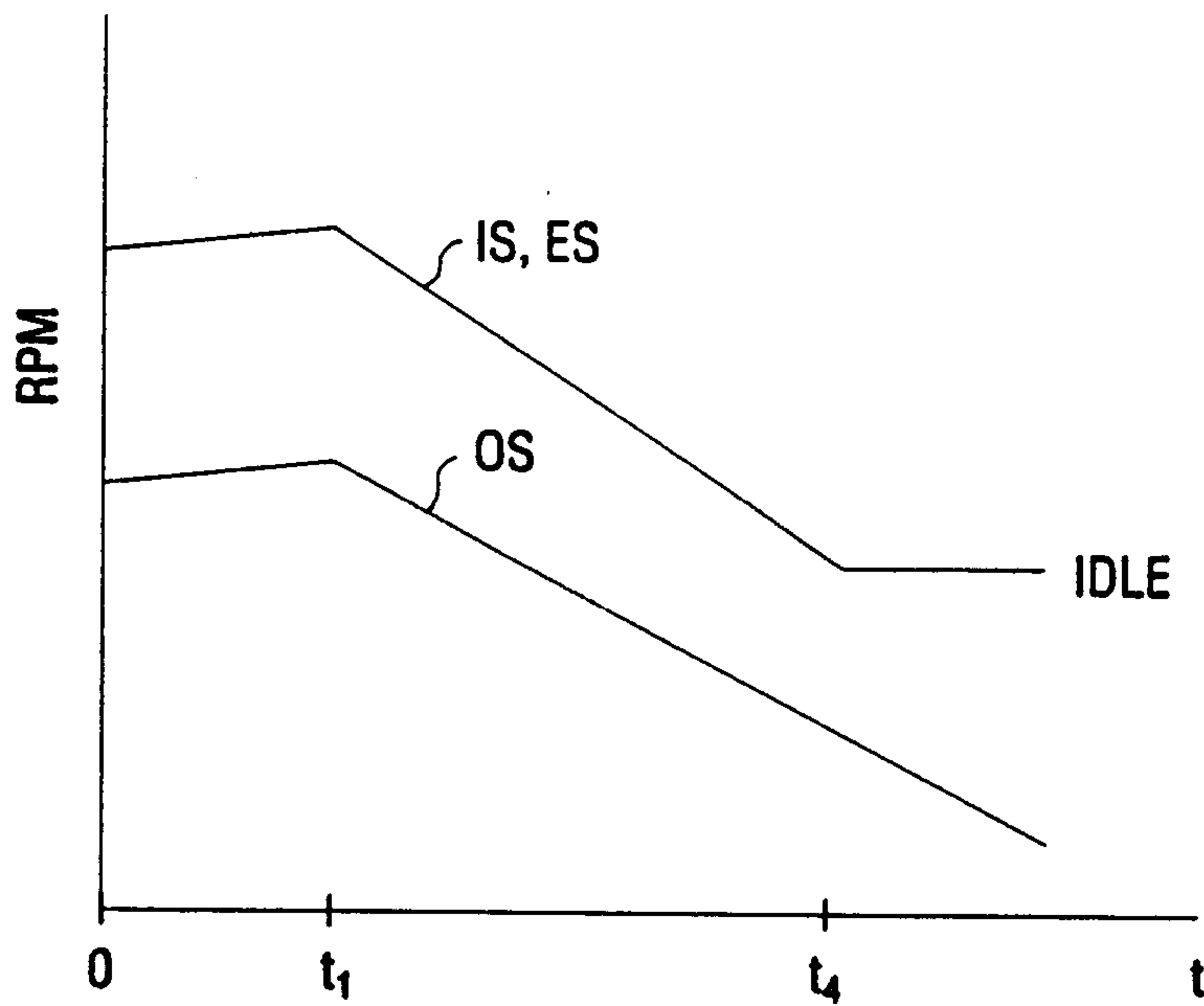
5 means for controlling application of  
the retarding torque based on the closure rate.

18. The system of claim 17 wherein the  
means for monitoring the closure rate includes means  
for determining if the engine speed is above an engine  
idle reference speed.

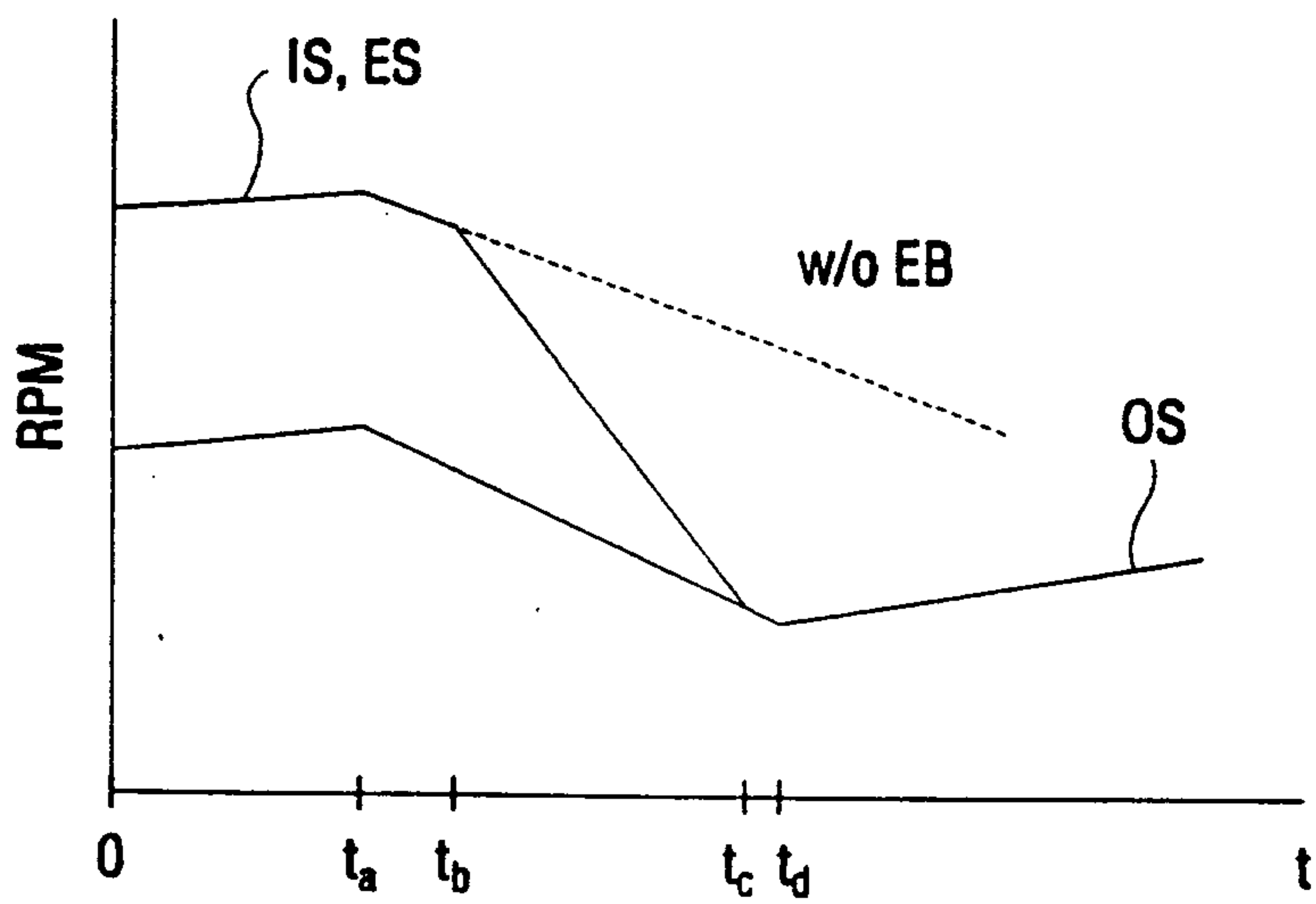




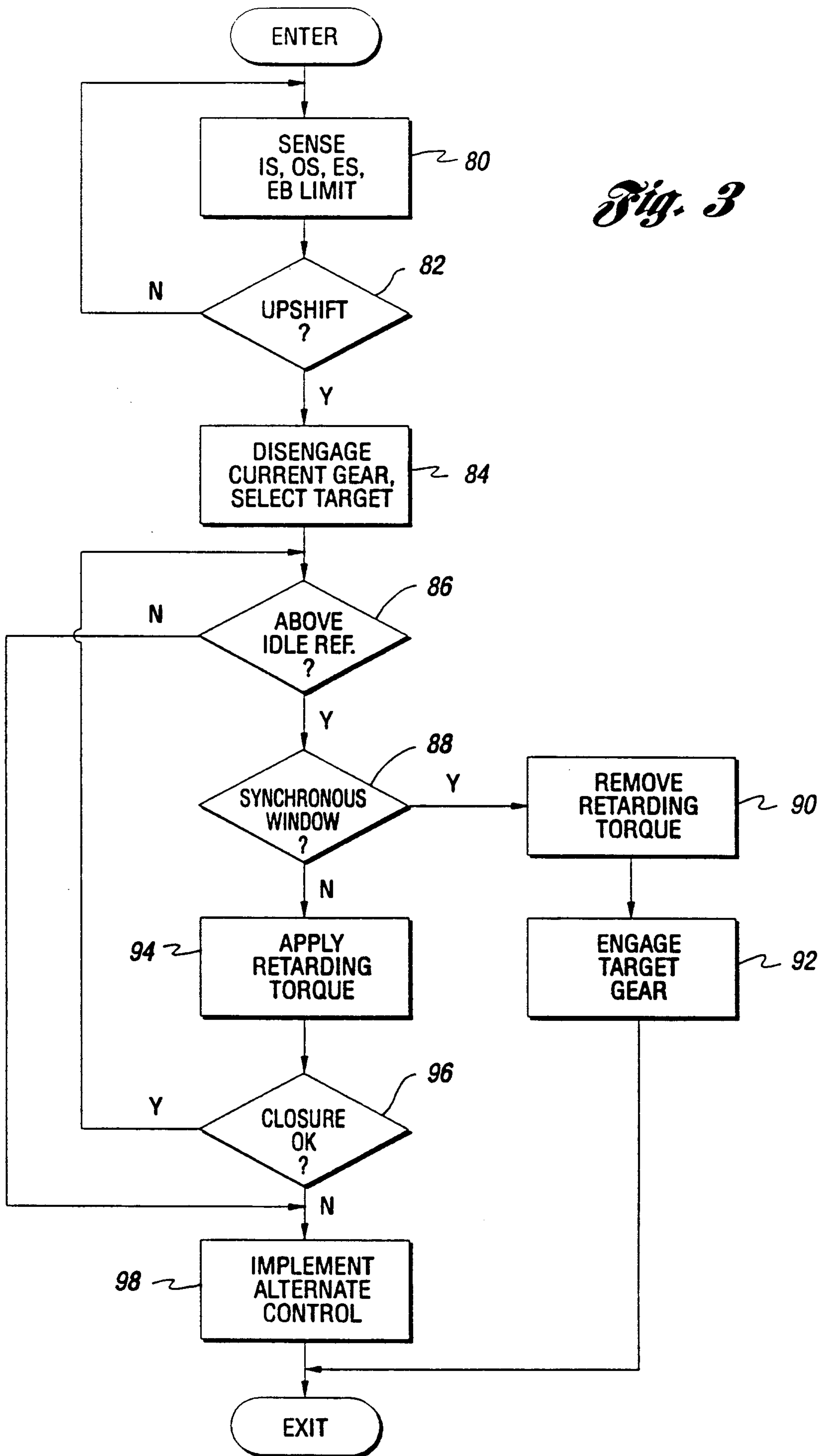
*Fig. 2a*



*Fig. 2b*



*Fig. 2c*



*Fig. 3*