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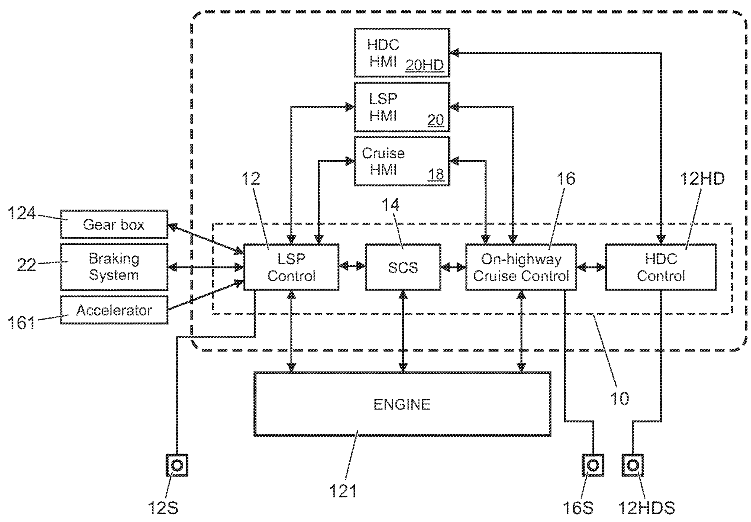
EP 1355209 A1 **WO 2007/006659 A1**
DE 102009033953 A1

(58) Field of Search:
INT CL **B60W**
Other: **WPI; EPODOC**

(54) Title of the Invention: **Vehicle speed control system and method**
Abstract Title: **A vehicle speed control system and method**

(57) A vehicle control system and method are provided. The control system is operable to cause a vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system 22 and an amount of drive torque applied by a powertrain 129 to one or more wheels 111, 112, 114, 115 of a vehicle 100. When the system is causing a vehicle to operate in accordance with the target speed value the system is operable automatically to cause vehicle speed not to exceed a limit value by means of the braking system 22 if the powertrain 129 assumes a torque suspension mode which is a mode in which the powertrain 129 is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain 129, the ratio selection portion being a portion through which a transmission of the powertrain 129 is operable to deliver drive torque to one or more wheels 111, 112, 114, 115 of the vehicle 100. The ratio selection portion is operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

FIGURE 3



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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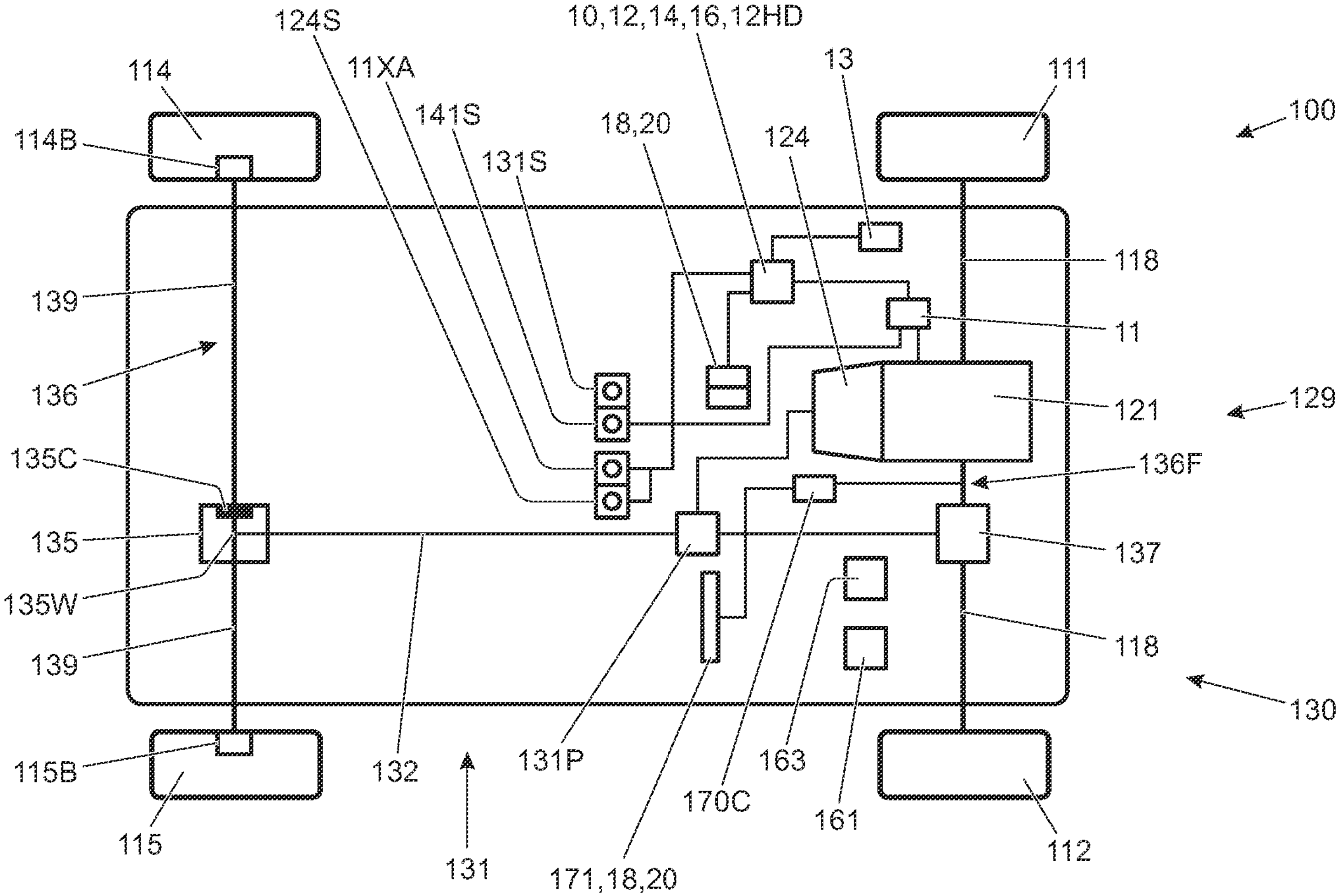

FIGURE 1

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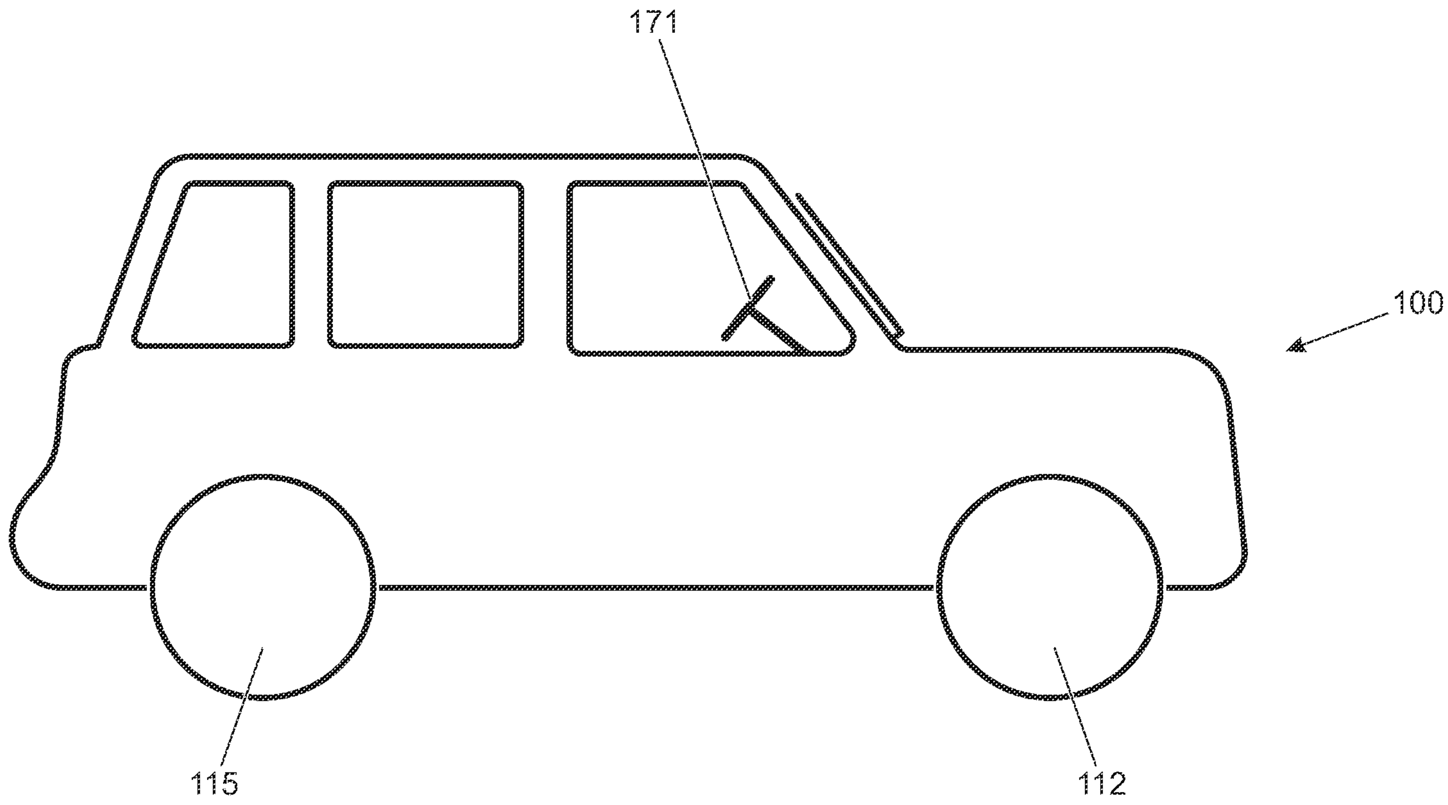

FIGURE 2

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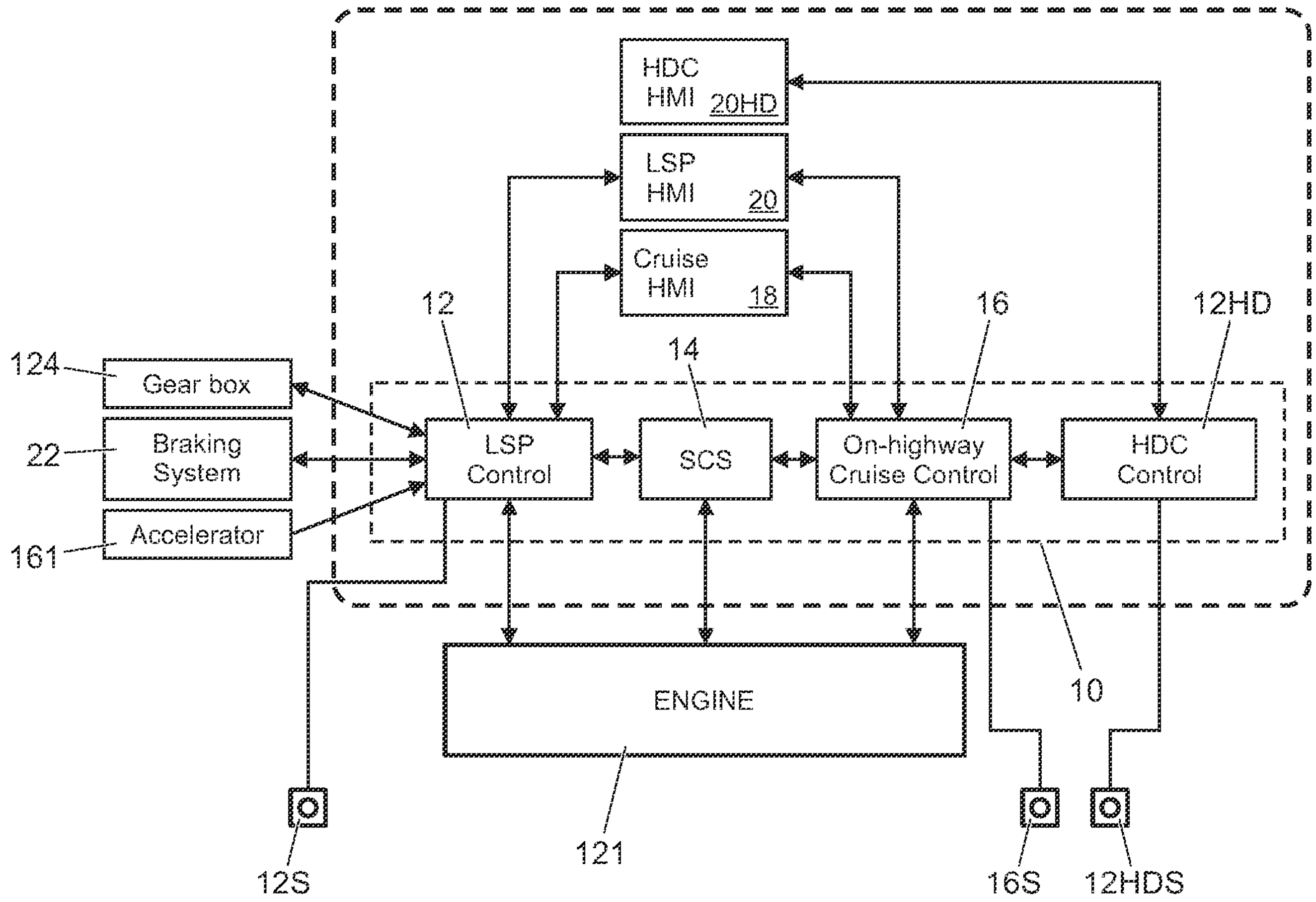
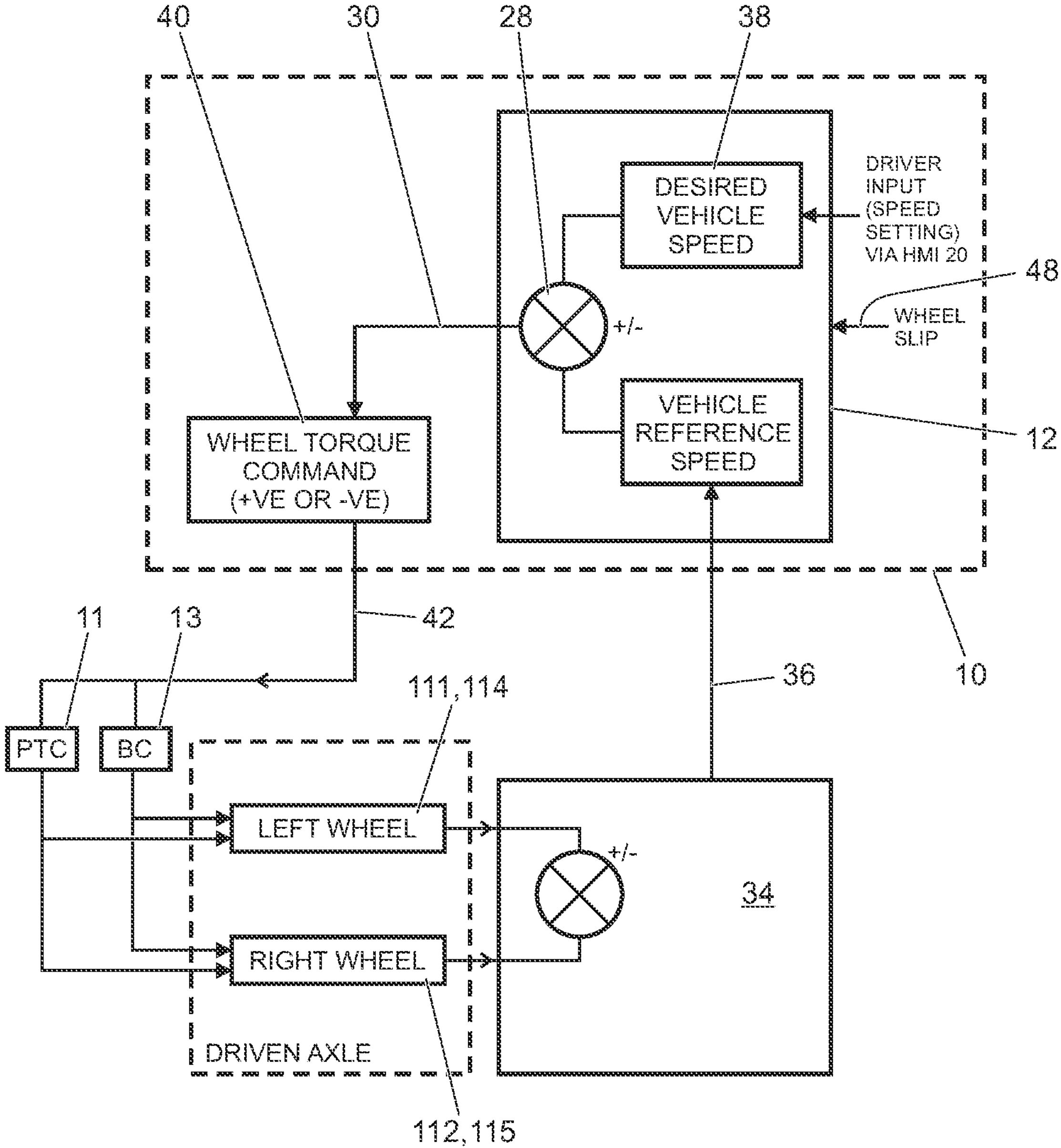


FIGURE 3



40
30
28
38
DESIRED VEHICLE SPEED
DRIVER INPUT (SPEED SETTING) VIA HMI 20
48
WHEEL SLIP
+/-
WHEEL TORQUE COMMAND (+VE OR -VE)
VEHICLE REFERENCE SPEED
12
42
11
13
36
10
111,114
PTC
BC
LEFT WHEEL
+/-
34
RIGHT WHEEL
DRIVEN AXLE
112,115

FIGURE 4

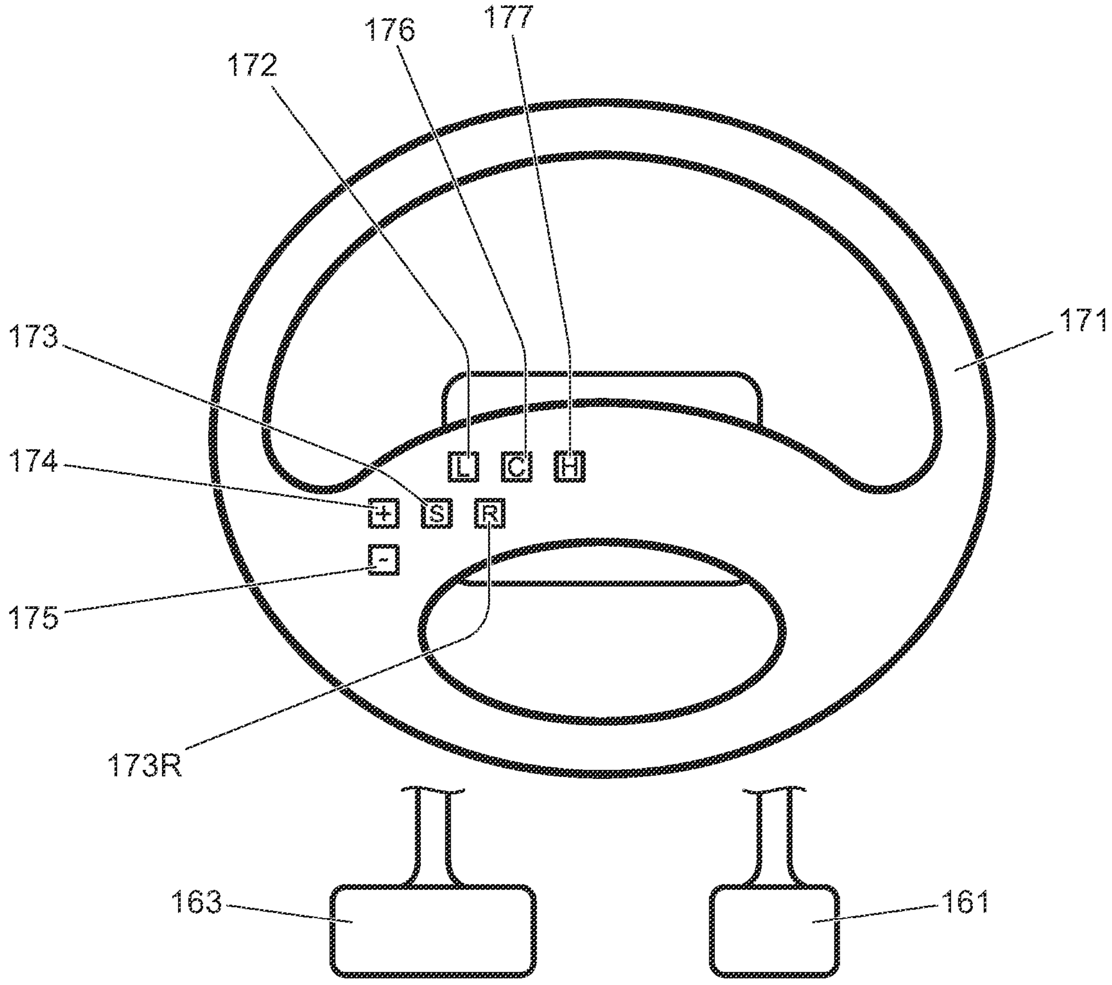


FIGURE 5

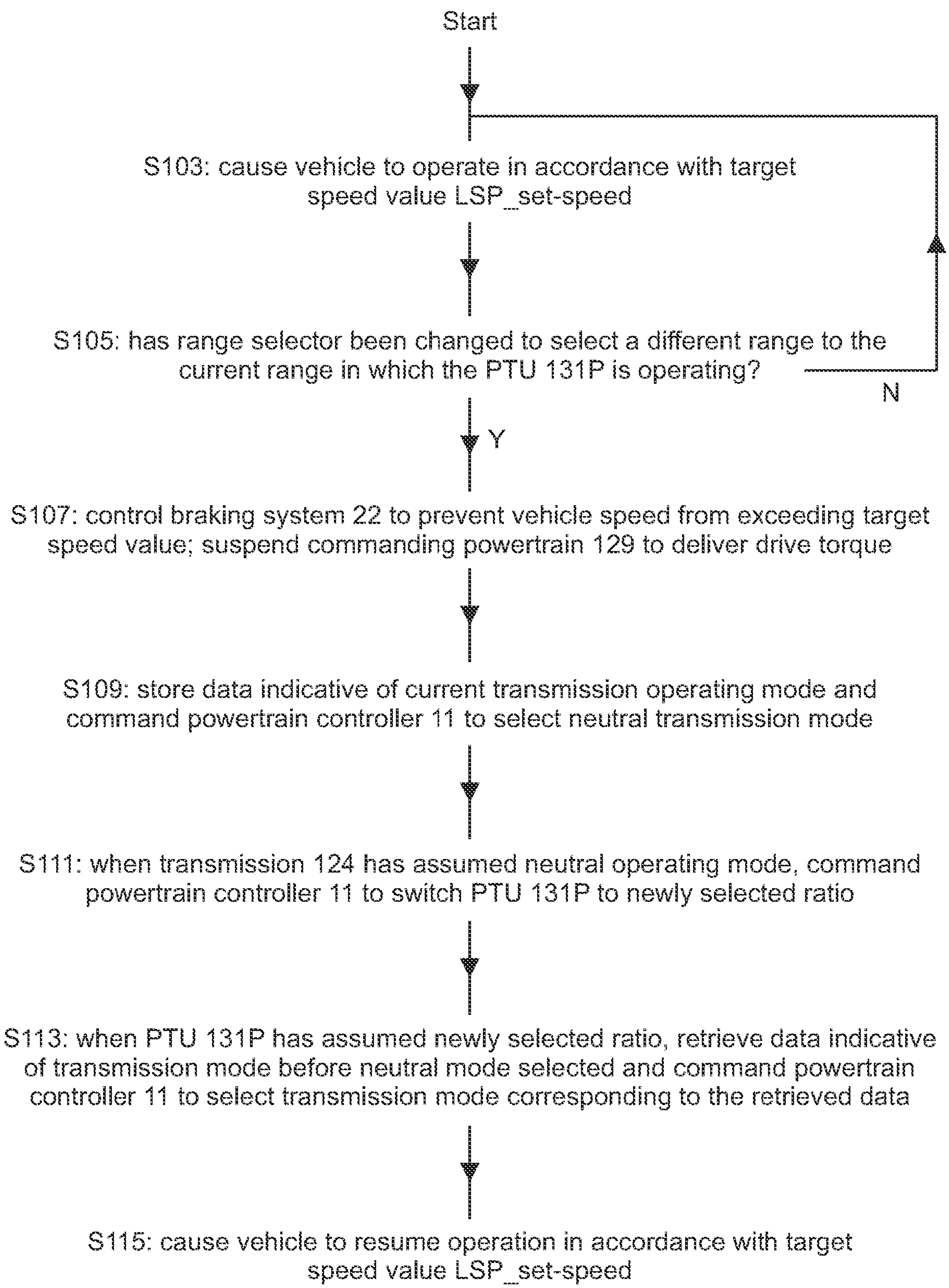


FIGURE 6

27 08 14

VEHICLE SPEED CONTROL SYSTEM AND METHOD

FIELD OF THE INVENTION

The invention relates to a system for controlling the speed of a vehicle. In particular, but not exclusively, the invention relates to a system for controlling the speed of a land-based vehicle which is capable of driving in a variety of different and extreme terrains and conditions.

The content of co-pending UK patent application no GB1214651.0 and US patent no US7349776 are hereby incorporated by reference.

BACKGROUND

In known vehicle speed control systems, typically referred to as cruise control systems, the vehicle speed is maintained on-road once set by the user without further intervention by the user so as to improve the driving experience for the user by reducing workload.

With typical cruise control systems, the user selects a speed at which the vehicle is to be maintained, and the vehicle is maintained at that speed for as long as the user does not apply a brake or, in the case of a vehicle having a manual transmission, depress a clutch pedal. The cruise control system takes its speed signal from a driveshaft speed sensor or wheel speed sensors. When the brake or the clutch is depressed, the cruise control system is disabled so that the user can override the cruise control system to change the vehicle speed without resistance from the system. If the user depresses the accelerator pedal the vehicle speed will increase, but once the user removes his foot from the accelerator pedal the vehicle reverts to the pre-set cruise speed by coasting.

Such systems are usually operable only above a certain speed, typically around 15-20kph, and are ideal in circumstances in which the vehicle is travelling in steady traffic conditions, and particularly on highways or motorways. In congested traffic conditions, however, where vehicle speed tends to vary widely, cruise control systems are ineffective, and especially where the systems are inoperable because of a minimum speed requirement. A minimum speed requirement is often imposed on cruise control systems so as to reduce the likelihood of low speed collision, for example when parking. Such systems are therefore ineffective in certain driving conditions (e.g. low speed) and are set to be automatically disabled in circumstances in which a user may not consider it to be desirable to do so.

More sophisticated cruise control systems are integrated into the engine management system and may include an adaptive functionality which takes into account the distance to the vehicle in front using a radar-based system. For example, the vehicle may be provided with a forward-looking radar detection system so that the speed and distance of the vehicle in front is detected and a safe following speed and distance is maintained automatically without the need for user input. If the lead vehicle slows down, or another object is detected by the radar detection system, the system sends a signal to the engine or the braking system to slow the vehicle down accordingly, to maintain a safe following distance.

Known cruise control systems also cancel in the event that a wheel slip event is detected requiring intervention by a traction control system (TCS) or stability control system (SCS). Accordingly, they are not well suited to maintaining vehicle progress when driving in off road conditions where such events may be relatively common.

It is also known to provide a control system for a motor vehicle for controlling one or more vehicle subsystems. US7349776 discloses a vehicle control system comprising a plurality of subsystem controllers including an engine management system, a transmission controller, a steering controller, a brakes controller and a suspension controller. The subsystem controllers are each operable in a plurality of subsystem function modes. The subsystem controllers are connected to a vehicle mode controller which controls the subsystem controllers to assume a required function mode so as to provide a number of driving modes for the vehicle. Each of the driving modes corresponds to a particular driving condition or set of driving conditions, and in each mode each of the sub-systems is set to the function mode most appropriate to those conditions. Such conditions are linked to types of terrain over which the vehicle may be driven such as grass/gravel/snow, mud and ruts, rock crawl, sand and a highway mode known as ‘special programs off’ (SPO). The vehicle mode controller may be referred to as a Terrain Response (TR) (RTM) System or controller. The driving modes may also be referred to as terrain modes, terrain response modes, or control modes.

SUMMARY OF THE INVENTION

Embodiments of the invention may be understood with reference to the appended claims.

Aspects of the present invention provide a system, a vehicle and a method.

In an aspect of the invention for which protection is sought there is provided a control system operable to cause a vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of a vehicle, wherein when the system is causing a vehicle to operate in accordance with the target speed value the system is operable automatically to cause vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

Embodiments of the present invention have the advantage that the control system may remain in control of vehicle speed by means of the braking system if the powertrain is prevented from delivering drive torque to the ratio selection portion. This has the advantage that if a change of ratio of the ratio selection portion is required and the powertrain is placed in the torque suspension mode in order to prevent torque loading being placed on the ratio selection portion, vehicle speed remains under the control of the control system and is prevented from exceeding the limit value. It is to be understood that in some embodiments the powertrain may be placed in the torque suspension mode by placing the transmission in a neutral mode of operation.

It is to be understood that in the case of a vehicle propelled by an electric machine operated as a propulsion motor, the prevention of delivery of drive torque may be accomplished in some embodiments by substantially terminating supply of electrical power to the electric machine, or by limiting the amount of electrical power to a prescribed amount.

The motor may be an internal combustion engine, an electric motor or any other suitable motor. The system may be used with vehicles having more than one motor. Optionally two or more of the motors may be operable to deliver drive torque to the input portion of the ratio selection portion of the powertrain. For such vehicles, in some embodiments the system may be configured such that in the torque suspension mode each of the two or more motors are prevented from delivering drive torque to the input portion of the ratio selection portion of the powertrain.

In some embodiments an existing vehicle controller may be employed to control the braking system such as an anti-lock braking system (ABS) controller. The controller that controls the vehicle braking system may be operable to control the braking system only and not operable to command application of positive powertrain drive torque. In such a case a separate controller may be employed to command application of positive drive torque, such as a separate powertrain controller. Other arrangements are also useful.

The controller may be or comprise a discrete physical controller such as a dedicated electronic control unit (ECU). Alternatively the controller may be implemented by means of software code run on an existing ECU. Other arrangements are also useful.

It is to be understood that the ratio selection portion is a portion of the powertrain through which a transmission of the powertrain is operable to deliver drive torque to one or more wheels of the vehicle.

The limit value may correspond to the target speed value, optionally being substantially equal to the target speed value.

Alternatively, in some embodiments the limit value may be a substantially fixed value that is independent of the target speed value. Other arrangements are also useful.

Optionally, if the system is causing a vehicle to operate in accordance with a target speed and the powertrain assumes the torque suspension mode, the system is operable automatically to cause the vehicle to resume operation in accordance with the target speed value when the powertrain ceases to be in the torque suspension mode.

The system may be operable to cause a ratio change operation to be performed in which the ratio selection portion changes from one operating mode to another.

It is to be understood that one operating mode may be a ‘low’ ratio operating mode in which a relatively low gear ratio is provided between input and output portions of the ratio selection portion, and another operating mode may be a ‘high’ ratio operating mode in which a relatively high gear ratio is provided between input and output portions of the ratio selection portion. The low ratio mode may be particularly useful when driving at relatively low speed in off road conditions. Relatively large values of wheel torque are achievable and this may be useful when attempting to ascend relatively steep gradients.

The system may be operable to cause the ratio change operation to be performed in response to user selection of a ratio change operation.

Thus in some embodiments the system may be operable to monitor a ratio change input device such a switch, soft-key or touch screen operable to trigger the ratio change operation. The switch may be a bi-stable switch that may assume a low ratio position or a high ratio position. Alternatively the switch may be a mono-stable switch operable to trigger a change from a currently selected ratio to another ratio.

The system may be operable automatically to trigger a ratio change operation when one or more predetermined conditions are met.

One predetermined condition may be that the ratio selection portion is in the high ratio operating mode and the vehicle is attempting to ascend or descend a slope having a gradient exceeding a predetermined value.

One predetermined condition may be that the ratio selection portion is in the high ratio operating mode and the vehicle is travelling for a predetermined time below a threshold speed.

Alternatively or in addition a predetermined condition may be that the ratio selection portion is in the high ratio operating mode and one of one or more prescribed driving modes have been selected. One or more said one or more prescribed driving modes may be terrain response modes. For example the system may be arranged automatically to trigger assumption of the low ratio operating mode of the ratio selection portion if a rock crawl mode is selected. Other arrangements are also useful.

The system may be operable automatically to cause the transmission to assume the torque suspension mode when a ratio change operation is in progress.

The system may be operable automatically to limit vehicle speed to a prescribed maximum value in dependence on a type of terrain over which a vehicle is moving.

Thus, if the value of target speed is greater than the prescribed maximum value for the terrain over which the vehicle is moving the system may be configured not to allow vehicle speed to exceed the prescribed value. The prescribed maximum value may correspond to a value determined to be an upper limit of speed at which the vehicle should be permitted to travel. The speed may be determined in dependence on one or more terrain indicators such as surface roughness, gradient, surface coefficient of friction with a tyre of the vehicle or any other suitable indicator.

The system may be operable to determine the type of terrain by reference to a selected driving mode of a vehicle.

The driving mode may correspond to a terrain mode or terrain response (TR) mode.

The system may be operable temporarily to prevent the powertrain from delivering drive torque to the input portion of the ratio selection portion of the powertrain by causing a clutch to open.

The clutch may be a clutch located in a torque transmission path between motor means of the powertrain and the ratio selection portion. The motor means may comprise an engine. The motor means may comprise an electric machine.

The system may be operable temporarily to prevent the powertrain from delivering drive torque to the input portion of the ratio selection portion by causing the transmission to assume a neutral operating mode.

The system may be operable to cause the vehicle to operate in accordance with the target speed value by causing the vehicle to maintain a speed substantially equal to the target speed. If the target speed is greater than the prescribed maximum speed described above, the speed may be limited to the prescribed maximum speed.

In a further aspect of the invention for which protection is sought there is provided a vehicle powertrain comprising a control system according to a preceding aspect.

The powertrain may comprise a ratio selection portion comprising a high/low range gearbox operable in a high ratio mode and a low ratio mode. The high ratio mode may present a substantially 1:1 gear ratio between input and output portions thereof (which may be in the form of input and output shafts). The low ratio mode may present a substantially 3:2 gear ratio between input and output portions thereof. That is, for every three revolutions of the input portion the output portion performs two revolutions. Other ratios are useful.

The ratio selection portion may comprise or be part of a power transfer unit operable to transfer torque to one or both of a front axle and a rear axle.

It is to be understood that the powertrain may be operable to assume either a two wheel drive mode or a four wheel drive mode. The control system may be operable automatically to cause vehicle speed not to exceed the limit value by means of the braking system when the powertrain assumes the torque suspension mode only if the powertrain is operating in the four wheel drive mode. Other arrangements are also useful.

In some embodiments the system is operable to restricted ratio change operation if the vehicle is operating in a prescribed mode of operation.

In some embodiments the system is operable to permit a ratio change operation from low to high to be performed when the vehicle is travelling below a predetermined speed only if the powertrain is requested to switch from operating in the four wheel drive mode to operating in the two wheel drive mode.

In some embodiments the system is operable to permit a ratio change operation to be performed only if the powertrain is operating in the four wheel drive mode.

The powertrain may comprise an internal combustion engine.

Alternatively or in addition the powertrain may comprise an electric machine.

In a further aspect of the invention for which protection is sought there is provided a vehicle comprising a powertrain according to a preceding aspect.

The vehicle may be a conventional vehicle having propulsion means in the form of one internal combustion engine only. Alternatively the vehicle may be an electric vehicle not having an internal combustion engine. In a further alternative the vehicle may a hybrid electric vehicle. The hybrid vehicle may be a parallel hybrid vehicle or a series hybrid vehicle.

In an aspect of the invention for which protection is sought there is provided a method of controlling a vehicle implemented by means of a control system comprising:

causing the vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of the vehicle, and

automatically causing vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode, the torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being a portion through which a transmission of the powertrain is operable to deliver drive torque to one or more wheels of the vehicle, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

The method may comprise causing the powertrain to assume the torque suspension mode.

Optionally, causing the powertrain to assume the torque suspension mode comprises causing the transmission to assume a neutral mode of operation.

Further optionally, causing the powertrain to assume the torque suspension mode comprises causing a clutch of the transmission to open thereby to isolate a source of drive torque from the ratio selection portion.

Some embodiments of the present invention have the advantage that vehicle composure may be enhanced and driver workload reduced when a change of range of a high/low range gearbox is required whilst vehicle speed is being controlled automatically by a control system such as a low speed cruise control system. This permits the user to switch between low range and high range whilst the vehicle is in motion and the vehicle speed is under the control of the low speed cruise control system, without causing suspension of said cruise control system. This is at least in part because in some embodiments the control system is operable automatically to continue control of vehicle speed if the driver disconnects a propulsion motor from a driveline of the vehicle, for example by selecting a neutral mode of operation of a transmission. Thus during the period for which the motor is disconnected from the driveline, whilst the driver commands the high/low range gearbox to change ratio, the driver does not need to control vehicle speed in addition to selecting the different gear ratio and steering the vehicle. Rather, the driver can concentrate on steering and selecting the required gear ratio. It is to be understood that the feature that the control system automatically controls vehicle speed if a propulsion motor is disconnected from a driveline may be employed in more sophisticated control systems that also cause one or more other changes to take place. The one or more other changes may include causing the high/low range gearbox to change range, and/or selection of the neutral mode of the transmission in order to allow the high/low range gearbox to change range.

Accordingly, in some embodiments, the system may automatically cause: (i) the transmission to assume the neutral mode from a current operating mode; subsequently, (ii) the high/low range gearbox to change range; and subsequently, (iii) the transmission to assume the operating mode in which the transmission operated prior to the user requesting the change of range.

For example, in some embodiments the control system may be configured such that if, whilst the vehicle is being driven with speed controlled by the control system, a driver presses a range selector button indicating a change of range is required, the control system automatically selects a neutral mode of a transmission, causes the high/low range gearbox to change to an alternate range, and changes the transmission from the neutral operating mode back to a driving operating mode such as drive or reverse. Where a plurality of transmission operating modes are available in a given direction of travel, the transmission operating mode in which the vehicle resumes operation may be arranged to be the mode in which the vehicle operated before the range change operation was triggered. In some embodiments the transmission operating mode may be a mode suited to the newly selected range of the high/low range gearbox.

In an aspect of the invention for which protection is sought there is provided a vehicle speed control system operable to cause a vehicle to operate in accordance with a target speed value, the system being operable automatically to cause vehicle speed not to exceed a limit value by means of a braking system when a propulsion motor of the vehicle is prevented from delivering drive torque to a driveline of the vehicle and the speed control system is in operation.

In an aspect of the invention for which protection is sought there is provided a method of controlling a speed of a vehicle by means of a speed control system comprising: causing a vehicle to operate in accordance with a target speed value; and causing vehicle speed not to exceed a limit value by means of a braking system if a propulsion motor of the vehicle is prevented from delivering drive torque to a driveline of the vehicle and the speed control system is in operation.

In an aspect of the invention for which protection is sought there is provided a vehicle speed control system operable to cause a vehicle to operate in accordance with a target speed value, the system being operable automatically to cause vehicle speed not to exceed a limit value by means of a braking system if the system detects that a driveline of the vehicle is no longer coupled to a motor of the vehicle.

Within the scope of this application it is envisaged that the various aspects, embodiments, examples and alternatives, and in particular the individual features thereof, set out in the preceding paragraphs, in the claims and/or in the following description and drawings, may be taken independently or in any combination. For example features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example only with reference to the following figures in which:

FIGURE 1 is a schematic illustration of a vehicle according to an embodiment of the invention in plan view;

FIGURE 2 shows the vehicle of FIG. 1 in side view;

FIGURE 3 is a high level schematic diagram of an embodiment of the vehicle speed control system of the present invention, including a cruise control system and a low-speed progress control system;

FIGURE 4 is a schematic diagram of further features of the vehicle speed control system in FIG. 3;

FIGURE 5 illustrates a steering wheel and brake and accelerator pedals of a vehicle according to an embodiment of the present invention; and

FIGURE 6 is a flowchart illustrating operation of a vehicle according to an embodiment of the present invention.

DETAILED DESCRIPTION

References herein to a block such as a function block are to be understood to include reference to software code for performing the function or action specified which may be an output that is provided responsive to one or more inputs. The code may be in the form of a software routine or function called by a main computer program, or may be code forming part of a flow of code not being a separate routine or function. Reference to function block is made for ease of explanation of the manner of operation of embodiments of the present invention.

FIG. 1 shows a vehicle 100 according to an embodiment of the present invention. The vehicle 100 has a powertrain 129 that includes an engine 121 that is connected to a driveline 130 having an automatic transmission 124. It is to be understood that embodiments of the present invention are also suitable for use in vehicles with manual transmissions, continuously variable transmissions or any other suitable transmission.

The driveline 130 is arranged to drive a pair of front vehicle wheels 111,112 by means of a front differential 137 and a pair of front drive shafts 118. The driveline 130 also comprises an auxiliary driveline portion 131 arranged to drive a pair of rear wheels 114, 115 by means of an auxiliary driveshaft or prop-shaft 132, a rear differential 135 and a pair of rear driveshafts 139.

Embodiments of the invention are suitable for use with vehicles in which the transmission is arranged to drive only a pair of front wheels or only a pair of rear wheels (i.e. front wheel drive vehicles or rear wheel drive vehicles) or selectable two wheel drive/four wheel drive vehicles. In the embodiment of FIG. 1 the transmission 124 is releasably connectable to the auxiliary driveline portion 131 by means of a power transfer unit (PTU) 131P, allowing operation in a two wheel drive mode or a four wheel drive mode. It is to be understood that embodiments of the invention may be suitable for vehicles having more than four wheels or where only two wheels are driven, for example two wheels of a three wheeled vehicle or four wheeled vehicle or a vehicle with more than four wheels.

A control system for the vehicle engine 121 includes a central controller 10, referred to as a vehicle control unit (VCU) 10, a powertrain controller 11, a brake controller 13 and a steering controller 170C. The brake controller 13 forms part of a braking system 22 (FIG. 3). The VCU 10 receives and outputs a plurality of signals to and from various sensors and subsystems (not shown) provided on the vehicle. The VCU 10 includes a low-speed progress (LSP) control system 12 shown in FIG. 3 and a stability control system (SCS) 14. The SCS 14 improves the safety of the vehicle 100 by detecting and managing loss of traction. When a reduction in traction or steering control is detected, the SCS 14 is operable automatically to command a brake controller 13 to apply one or more brakes of the vehicle to help to steer the vehicle 100 in the direction the user wishes to travel. In the embodiment shown the SCS 14 is implemented by the VCU 10. In some alternative embodiments the SCS 14 may be implemented by the brake controller 13. Further alternatively, the SCS 14 may be implemented by a separate controller.

Although not shown in detail in FIG. 3, the VCU 10 further includes a Dynamic Stability Control (DSC) function block, a Traction Control (TC) function block, an Anti-Lock Braking System (ABS) function block and a Hill Descent Control (HDC) function block. These function blocks are implemented in software code run by a computing device of the VCU 10 and provide outputs indicative of, for example, DSC activity, TC activity, ABS activity, brake interventions on individual wheels and engine torque requests from the VCU 10 to the engine 121 in the event a wheel slip event occurs. Each of the aforementioned events indicate that a wheel slip event has occurred. Other vehicle sub-systems such as a roll stability control system or the like may also be useful.

As noted above the vehicle 100 also includes a cruise control system 16 which is operable to automatically maintain vehicle speed at a selected speed when the vehicle is travelling at speeds in excess of 25 kph. The cruise control system 16 is provided with a cruise control HMI (human machine interface) 18 by which means the user can input a target vehicle speed to the cruise control system 16 in a known manner. In one embodiment of the invention, cruise control system input controls are mounted to a steering wheel 171 (FIG. 5). The cruise control system 16 may be switched on by pressing a cruise control system selector button 176. When the cruise control system 16 is switched on, depression of a 'set-speed' control 173 sets the current value of a cruise control set-speed parameter, cruise_set-speed to the current vehicle speed. Depression of a '+' button 174 allows the value of cruise_set-speed to be increased whilst depression of a '-' button 175 allows the value of cruise_set-speed to be decreased. A resume button 173R is provided that is operable to control the cruise control system 16 to resume speed control at the instant value of cruise_set-speed following driver over-ride. It is to be understood that known on-highway cruise control systems including the present system 16 are configured so that, in the event that the user depresses the brake or, in the case of vehicles with a manual transmission, a clutch pedal, the cruise control function is cancelled and the vehicle 100 reverts to a manual mode of operation which requires accelerator pedal input by a user in order to maintain vehicle speed. In addition, detection of a wheel slip event, as may be initiated by a loss of traction, also has the effect of cancelling the cruise control function. Speed control by the system 16 is resumed if the driver subsequently depresses the resume button 173R.

The cruise control system 16 monitors vehicle speed and any deviation from the target vehicle speed is adjusted automatically so that the vehicle speed is maintained at a substantially constant value, typically in excess of 25 kph. In other words, the cruise control system is ineffective at speeds lower than 25 kph. The cruise control HMI 18 may also be configured to provide an alert to the user about the status of the cruise control system 16 via a visual display of the HMI 18. In the present embodiment the cruise control system 16 is configured to allow the value of cruise_set-speed to be set to any value in the range 25-150kph.

The LSP control system 12 also provides a speed-based control system for the user which enables the user to select a very low target speed at which the vehicle can progress without any pedal inputs being required by the user. Low-speed speed control (or progress control) functionality is not provided by the on-highway cruise control system 16 which operates only at speeds above 25 kph.

The LSP control system 12 is activated by means of a LSP control system selector button 172 mounted on the steering wheel 171. The system 12 is operable to apply selective powertrain, traction control and braking actions to one or more wheels of the vehicle 100, collectively or individually, to maintain the vehicle 100 at the desired speed.

The LSP control system 12 is configured to allow a user to input a desired value of set-speed parameter, LSP_set-speed to the LSP control system 12 via a low-speed progress control HMI (LSP HMI) 20 (FIG. 1, FIG. 3) which shares certain input buttons 173-175 with the cruise control system 16 and HDC control system 12HD. Provided the vehicle speed is within the allowable range of operation of the LSP control system (which is the range from 2 to 30kph in the present embodiment although other ranges are also useful) the LSP control system 12 controls vehicle speed in accordance with the value of LSP_set-speed. Unlike the cruise control system 16, the LSP control system 12 is configured to operate independently of the occurrence of a traction event. That is, the LSP control system 12 does not cancel speed control upon detection of wheel slip. Rather, the LSP control system 12 actively manages vehicle behaviour when slip is detected.

The LSP control HMI 20 is provided in the vehicle cabin so as to be readily accessible to the user. The user of the vehicle 100 is able to input to the LSP control system 12, via the LSP HMI 20, an indication of the speed at which the user desires the vehicle to travel (referred to as “the target speed”) by means of the ‘set-speed’ button 173 and the ‘+’/ ‘-‘ buttons 174, 175 in a similar manner to the cruise control system 16. The LSP HMI 20 also includes a visual display upon which information and guidance can be provided to the user about the status of the LSP control system 12.

The LSP control system 12 receives an input from the braking system 22 of the vehicle indicative of the extent to which the user has applied braking by means of the brake pedal 163. The LSP control system 12 also receives an input from an accelerator pedal 161 indicative of the extent to which the user has depressed the accelerator pedal 161. An input is also provided to the LSP control system 12 from the transmission or gearbox 124. This input may include signals representative of, for example, the speed of an output shaft of the gearbox 124, torque converter slip and a gear ratio request. Other inputs to the LSP control system 12 include an input from the cruise control HMI 18 which is representative of the status (ON/OFF) of the cruise control system 16, and an input from the LSP control HMI 20.

The HDC function block of the VCU 10 forms part of a HDC system 12HD. When the HDC system 12HD is active, the system 12HD controls the braking system 22 (of which the ABS function block forms part) in order to limit vehicle speed to a value corresponding to that of a HDC set-speed parameter HDC_set-speed which may be set by a user. The HDC set-speed may also be referred to as an HDC target speed. Provided the user does not override the HDC system by depressing the accelerator pedal when the HDC system is active, the HDC system 12HD controls the braking system 22 (FIG. 3) to prevent vehicle speed from exceeding the HDC_set-speed. In the present embodiment the HDC system 12HD is not operable to apply positive drive torque. Rather, the HDC system 12HD is only operable to apply negative brake torque.

A HDC system HMI 20HD is provided by means of which a user may control the HDC system 12HD, including setting the value of HDC_set-speed. An HDC system selector button 177 is provided on the steering wheel 171 by means of which a user may activate the HDC system 12HD to control vehicle speed.

As noted above, the HDC system 12HD is operable to allow a user to set a value of HDC set-speed parameter HDC_set-speed and to adjust the value of HDC_set-speed using the same controls as the cruise control system 16 and LSP control system 12. Thus, in the present embodiment, when the HDC system 12HD is controlling vehicle speed, the HDC system set-speed may be increased, decreased or set to an instant speed of the vehicle in a similar manner to the set-speed of the cruise control system 16 and LSP control system, using the same control buttons 173, 173R, 174, 175. The HDC system 12HD is operable to allow the value of HDC_set-speed to be set to any value in the range from 2-30kph.

If the HDC system 12HD is selected when the vehicle 100 is travelling at a speed of 50kph or less and no other speed control system is in operation, the HDC system 12HD sets the value of HDC_set-speed to a value selected from a look-up table. The value output by the look-up table is determined in dependence on the identity of the currently selected transmission gear, the currently selected PTU gear ratio (Hi/LO) and the currently selected driving mode. The HDC system 12HD then controls the powertrain 129 and/or braking system 22 to slow the vehicle 100 to the HDC system set-speed provided the driver does not override the HDC system 12HD by depressing the accelerator pedal 161. The HDC system 12HD is configured to slow the vehicle 100 to the set-speed value at a deceleration rate not exceeding a maximum allowable rate. The rate is set as 1.25ms-2 in the present embodiment, however other values are also useful. If the user subsequently presses the 'set-speed' button 173 the HDC system 12HD sets the value of HDC_set-speed to the instant vehicle speed provided the instant speed is 30kph or less. If the HDC system 12HD is selected when the vehicle 100 is travelling at a speed exceeding 50kph, the HDC system 12HD ignores the request and provides an indication to the user that the request has been ignored.

It is to be understood that the VCU 10 is configured to implement a known Terrain Response (TR) (RTM) System of the kind described above in which the VCU 10 controls settings of one or more vehicle systems or sub-systems such as the powertrain controller 11 in dependence on a selected driving mode. The driving mode may be selected by a user by means of a driving mode selector 141S (FIG. 1). The driving modes may also be referred to as terrain modes, terrain response modes, or control modes. In the embodiment of FIG. 1 four driving modes are provided: an ‘on-highway’ driving mode suitable for driving on a relatively hard, smooth driving surface where a relatively high surface coefficient of friction exists between the driving surface and wheels of the vehicle; a ‘sand’ driving mode suitable for driving over sandy terrain; a ‘grass, gravel or snow’ driving mode suitable for driving over grass, gravel or snow, a ‘rock crawl’ driving mode suitable for driving slowly over a rocky surface; and a ‘mud and ruts’ driving mode suitable for driving in muddy, rutted terrain. Other driving modes may be provided in addition or instead.

In some embodiments, the LSP control system 12 may be in either one of an active condition, a standby condition and an ‘off’ condition. In the active condition, the LSP control system 12 actively manages vehicle speed by controlling powertrain torque and braking system torque. In the standby condition, the LSP control system 12 does not control vehicle speed until a user presses the resume button 173R or the ‘set speed’ button 173. In the off condition the LSP control system 12 is not responsive to input controls until the LSP control system selector button 172 is depressed.

In the present embodiment the LSP control system 12 is also operable to assume an intermediate condition similar to that of the active mode but in which the LSP control system 12 is prevented from commanding the application of positive drive torque to one or more wheels of the vehicle 100 by the powertrain 129. Thus, only braking torque may be applied, by means of the braking system 22 and/or powertrain 129. This intermediate condition may be an LSP control system ‘hill descent control’ mode in which the LSP control system 12 operates in a similar or substantially identical manner to the HDC control system 12HD. That is, the LSP control system 12 is operable to command application of the braking system 22 but not positive drive torque via the powertrain 129. Other arrangements are also useful.

With the LSP control system 12 in the active condition, the user may increase or decrease the vehicle set-speed by means of the ‘+’ and ‘-‘ buttons 174, 175. In addition, the user may also increase or decrease the vehicle set-speed by lightly pressing the accelerator or brake pedals 161, 163 respectively. In some embodiments, with the LSP control system 12 in the active condition the ‘+’ and ‘-’ buttons 174, 175 are disabled such that adjustment of the value of LSP_set-speed can only be made by means of the accelerator and brake pedals 161, 163. This latter feature may prevent unintentional changes in set-speed from occurring, for example due to accidental pressing of one of the ‘+’ or ‘-‘ buttons 174, 175. Accidental pressing may occur for example when negotiating difficult terrain where relatively large and frequent changes in steering angle may be required. Other arrangements are also useful.

It is to be understood that in the present embodiment the LSP control system 12 is operable to cause the vehicle to travel in accordance with a value of set-speed in the range from 2-30kph whilst the cruise control system is operable to cause the vehicle to travel in accordance with a value of set-speed in the range from 25-150kph although other values are also useful. If the LSP control system 12 is selected when the vehicle speed is above 30kph but less than or substantially equal to 50kph, the LSP control system 12 assumes the intermediate mode. In the intermediate mode, if the driver releases the accelerator pedal 161 whilst travelling above 30kph the LSP control system 12 deploys the braking system 22 to slow the vehicle 100 to a value of set-speed corresponding to the value of parameter LSP_set-speed. Once the vehicle speed falls to 30kph or below, the LSP control system 12 assumes the active condition in which it is operable to apply positive drive torque via the powertrain 129, as well as brake torque via the powertrain 129 (via engine braking) and the braking system 22 in order to control the vehicle in accordance with the LSP_set-speed value. If no LSP set-speed value has been set, the LSP control system 12 assumes the standby mode.

It is to be understood that if the LSP control system 12 is in the active mode, operation of the cruise control system 16 is inhibited. The two systems 12, 16 therefore operate independently of one another, so that only one can be operable at any one time, depending on the speed at which the vehicle is travelling.

In some embodiments, the cruise control HMI 18 and the LSP control HMI 20 may be configured within the same hardware so that, for example, the speed selection is input via the same hardware, with one or more separate switches being provided to switch between the LSP input and the cruise control input.

FIG. 4 illustrates the means by which vehicle speed is controlled in the LSP control system 12. As described above, a speed selected by a user (set-speed) is input to the LSP control system 12 via the LSP control HMI 20. A vehicle speed sensor 34 associated with the powertrain 129 (shown in FIG. 1) provides a signal 36 indicative of vehicle speed to the LSP control system 12. The LSP control system 12 includes a comparator 28 which compares the set-speed 38 (also referred to as a ‘target speed’ 38) selected by the user with the measured speed 36 and provides an output signal 30 indicative of the comparison. The output signal 30 is provided to an evaluator unit 40 of the VCU 10 which interprets the output signal 30 as either a demand for additional torque to be applied to the vehicle wheels 111-115, or for a reduction in torque applied to the vehicle wheels 111-115, depending on whether the vehicle speed needs to be increased or decreased to maintain the speed LSP_set-speed. An increase in torque is generally accomplished by increasing the amount of powertrain torque delivered to a given position of the powertrain, for example an engine output shaft, a wheel or any other suitable location. A decrease in torque at a given wheel to a value that is less positive or more negative may be accomplished by decreasing powertrain torque delivered to a wheel and/or by increasing a braking force on a wheel. It is to be understood that in some embodiments in which a powertrain 129 has one or more electric machines operable as a generator, negative torque may be applied by the powertrain 129 to one or more wheels by the electric machine. Negative torque may also be applied by means of engine braking in some circumstances, depending at least in part on the speed at which the vehicle 100 is moving. If one or more electric machines are provided that are operable as propulsion motors, positive drive torque may be applied by means of the one or more electric machines.

An output 42 from the evaluator unit 40 is provided to the powertrain controller 11 and brake controller 13 which in turn control a net torque applied to the vehicle wheels 111-115. The net torque may be increased or decreased depending on whether the evaluator unit 40 demands positive or negative torque. In order to cause application of the necessary positive or negative torque to the wheels, the evaluator unit 40 may command that positive or negative torque is applied to the vehicle wheels by the powertrain 129 and/or that a braking force is applied to the vehicle wheels by the braking system 22, either or both of which may be used to implement the change in torque that is necessary to attain and maintain a required vehicle speed. In the illustrated embodiment the torque is applied to the vehicle wheels individually so as to maintain the vehicle at the required speed, but in another embodiment torque may be applied to the wheels collectively to maintain the required speed. In some embodiments, the powertrain controller 11 may be operable to control an amount of torque applied to one or more wheels by controlling a driveline component such as a rear drive unit, front drive unit, differential or any other suitable component. For example, one or more components of the driveline 130 may include one or more clutches operable to allow an amount of torque applied to one or more wheels to be varied. Other arrangements are also useful.

Where a powertrain 129 includes one or more electric machines, for example one or more propulsion motors and/or generators, the powertrain controller 11 may be operable to modulate torque applied to one or more wheels by means of one or more electric machines.

The LSP control system 12 also receives a signal 48 indicative of a wheel slip event having occurred. This may be the same signal 48 that is supplied to the on-highway cruise control system 16 of the vehicle, and which in the case of the latter triggers an override or inhibit mode of operation in the on-highway cruise control system 16 so that automatic control of vehicle speed by the on-highway cruise control system 16 is suspended or cancelled. However, the LSP control system 12 is not arranged to cancel or suspend operation in dependence on receipt of a wheel slip signal 48 indicative of wheel slip. Rather, the system 12 is arranged to monitor and subsequently manage wheel slip so as to reduce driver workload. During a slip event, the LSP control system 12 continues to compare the measured vehicle speed with the value of LSP_set-speed, and continues to control automatically the torque applied to the vehicle wheels so as to maintain vehicle speed at the selected value. It is to be understood therefore that the LSP control system 12 is configured differently to the cruise control system 16, for which a wheel slip event has the effect of overriding the cruise control function so that manual operation of the vehicle must be resumed, or speed control by the cruise control system 12 resumed by pressing the resume button 173R or set-speed button 173.

In a further embodiment of the present invention (not shown) a wheel slip signal 48 is derived not just from a comparison of wheel speeds, but further refined using sensor data indicative of the vehicle's speed over ground. Such a speed over ground determination may be made via global positioning (GPS) data, or via a vehicle mounted radar or laser based system arranged to determine the relative movement of the vehicle 100 and the ground over which it is travelling. A camera system may be employed for determining speed over ground in some embodiments.

At any stage of the LSP control process the user can override the function by depressing the accelerator pedal 161 and/or brake pedal 163 to adjust the vehicle speed in a positive or negative sense. However, in the event that a wheel slip event is detected via signal 48, the LSP control system 12 remains active and control of vehicle speed by the LSP control system 12 is not suspended. As shown in FIG. 4, this may be implemented by providing a wheel slip event signal 48 to the LSP control system 12 which is then managed by the LSP control system 12. In the embodiment shown in FIG. 1 the SCS 14 generates the wheel slip event signal 48 and supplies it to the LSP control system 12 and cruise control system 16.

A wheel slip event is triggered when a loss of traction occurs at any one of the vehicle wheels. Wheels and tyres may be more prone to losing traction when travelling for example on snow, ice, mud or sand and/or on steep gradients or cross-slopes. A vehicle 100 may also be more prone to losing traction in environments where the terrain is more uneven or slippery compared with driving on a highway in normal on-road conditions. Embodiments of the present invention therefore find particular benefit when the vehicle 100 is being driven in an off-road environment, or in conditions in which wheel slip may commonly occur. Manual operation in such conditions can be a difficult and often stressful experience for the user and may result in an uncomfortable ride.

The vehicle 100 is also provided with additional sensors (not shown) which are representative of a variety of different parameters associated with vehicle motion and status. These may be inertial systems unique to the LSP or HDC control system 12, 12HD or part of an occupant restraint system or any other sub-system which may provide data from sensors such as gyros and/or accelerometers that may be indicative of vehicle body movement and may provide a useful input to the LSP and/or HDC control systems 12, 12HD. The signals from the sensors provide, or are used to calculate, a plurality of driving condition indicators (also referred to as terrain indicators) which are indicative of the nature of the terrain conditions over which the vehicle is travelling.

The sensors (not shown) on the vehicle 100 include, but are not limited to, sensors which provide continuous sensor outputs to the VCU 10, including wheel speed sensors, as mentioned previously and as shown in FIG. 5, an ambient temperature sensor, an atmospheric pressure sensor, tyre pressure sensors, wheel articulation sensors, gyroscopic sensors to detect vehicular yaw, roll and pitch angle and rate, a vehicle speed sensor, a longitudinal acceleration sensor, an engine torque sensor (or engine torque estimator), a steering angle sensor, a steering wheel speed sensor, a gradient sensor (or gradient estimator), a lateral acceleration sensor which may be part of the SCS 14, a brake pedal position sensor, a brake pressure sensor, an accelerator pedal position sensor, longitudinal, lateral and vertical motion sensors, and water detection sensors forming part of a vehicle wading assistance system (not shown). In other embodiments, only a selection of the aforementioned sensors may be used.

The VCU 10 also receives a signal from the steering controller 170C. The steering controller 170C is in the form of an electronic power assisted steering unit (ePAS unit). The steering controller 170C provides a signal to the VCU 10 indicative of the steering force being applied to steerable road wheels 111, 112 of the vehicle 100. This force corresponds to that applied by a user to the steering wheel 171 in combination with steering force generated by the ePAS unit 170C.

The VCU 10 evaluates the various sensor inputs to determine the probability that each of a plurality of different control modes (driving modes) for the vehicle subsystems is appropriate, with each control mode corresponding to a particular terrain type over which the vehicle is travelling (for example, mud and ruts, sand, grass/gravel/snow).

If the user has selected operation of the vehicle in an automatic driving mode selection condition, the VCU 10 then selects the most appropriate one of the control modes and is configured automatically to control the subsystems according to the selected mode. This aspect of the invention is described in further detail in our co-pending patent application nos. GB1111288.5, GB1211910.3 and GB1202427.9, the contents of each of which is incorporated herein by reference.

The nature of the terrain over which the vehicle is travelling (as determined by reference to the selected control mode) may also be utilised in the LSP control system 12 to determine an appropriate increase or decrease in drive torque that is to be applied to the vehicle wheels. For example, if the user selects a value of LSP_set-speed that is not suitable for the nature of the terrain over which the vehicle is travelling, the system 12 is operable to automatically adjust the vehicle speed downwards by reducing the speed of the vehicle wheels. In some cases, for example, the user selected speed may not be achievable or appropriate over certain terrain types, particularly in the case of uneven or rough surfaces. If the system 12 selects a set-speed that differs from the user-selected set-speed, a visual indication of the speed constraint is provided to the user via the LSP HMI 20 to indicate that an alternative speed has been adopted.

A-566 Range change

In the embodiment of FIG. 1 the transmission 124 may be set to a park mode, a reverse mode, a neutral mode, a drive mode and a sport mode by means of a transmission mode selector dial 124S. The selector dial 124S provides an output signal to the powertrain controller 11, in response to which the powertrain controller 11 causes the transmission 124 to operate in accordance with the selected transmission mode.

In the present embodiment, the PTU 131P includes a high/low range gearbox or 'transfer box' operable in a high gear ratio or a low gear ratio in dependence on a setting of a user operable selector dial 131S accessible to the user whilst driving. It is to be understood that the transmission 124 must be set to the neutral or park mode in order to 'unload' the driveline 130 before the gear ratio may be changed from high to low or low to high.

If whilst the LSP control system 12 is controlling vehicle speed the system 12 detects that the transmission 124 selector dial 124S has been set to the neutral mode, the LSP control system 12 is configured to cause the HDC system 12HD to take over control of vehicle speed from the LSP control system 12. As described above, the HDC system 12HD is operable to control vehicle speed by causing application of the braking system 22 as required, but is configured not to command application of positive powertrain drive torque.

In the present embodiment, the HDC system 12HD is arranged to set the value of target speed employed by the system 12HD, HDC_set-speed to the same value as that of the LSP control system 12 at the instant the LSP control system 12 hands speed control over to the HDC system 12HD. It is to be understood that in some alternative embodiments the HDC system 12HD may be arranged to set the value of HDC_set-speed to a slightly lower speed. Other arrangements are also useful.

Once speed control has been handed over to the HDC system 12HD, the LSP control system 12 provides a signal to the powertrain controller 11 indicating that vehicle speed control has been handed over to the HDC system 12HD. The powertrain controller 11 then causes the transmission 124 to assume the neutral mode as requested by the user via the selector 124S.

The HDC system 12HD remains in control of vehicle speed during the period for which the transmission 124 remains in the neutral mode.

Whilst the transmission 124 is in the neutral mode, the user may operate the high/low range gearbox unit comprised by the PTU 131P by means of the selector dial 131S. Thus if the PTU 131P is set to the low gear ratio the user may select the high gear ratio via the selector dial 131S, and vice-versa.

If the user subsequently sets the transmission selector dial 124S to a setting corresponding to a transmission operating mode that delivers drive torque in the direction in which the vehicle is moving or, if stationary, the direction corresponding to the mode in which the transmission operated immediately prior to selection of the neutral mode, the LSP control system 12 signals to the powertrain controller 11 that assumption of this transmission operating mode is permitted, and the powertrain controller 11 causes the transmission 124 to assume the selected operating mode.

Once the transmission 124 has assumed a mode in which the engine 121 is coupled to the driveline 130, the LSP control system 12 takes over vehicle speed control from the HDC control system 12HD. The LSP control system 12 then controls vehicle speed in accordance with the value of target speed employed prior to user selection of the neutral mode of the transmission 124. If vehicle speed has reduced below the target speed during coasting in the neutral mode of the transmission 124, the LSP control system 12 may cause the vehicle 100 to accelerate to resume the target speed at a rate that is within a prescribed range of allowable values of acceleration or that is substantially equal to a target value of acceleration employed by the LSP control system 12. This has the advantage that a driver may be reassured that the vehicle 100 is behaving in a manner consistent with normal operation, with which the driver is familiar, following the range change operation. Other arrangements are also useful.

In some embodiments, the LSP control system 12 may control vehicle speed in accordance with the target speed employed by the system 12 when the LSP control system 12 last controlled vehicle speed with the newly selected gear ratio of the high/low range gearbox. Thus the LSP control system 12 may be configured to store a value of LSP_set-speed most recently employed by the system 12 when the PTU 131P was operated in each of the high and low ratio modes.

It is to be understood that in some embodiments the LSP control system 12 may cause light braking to be applied and/or powertrain slip to be induced when the transmission 124 transitions from the neutral mode to a driving mode (in a forward or reverse direction) to reduce or eliminate noise, vibration or harshness (NVH) associated with driveline reengagement. Thus, driveline ‘shunt’ may be reduced or substantially avoided in some embodiments.

The manoeuvre described above, in which the selected ratio of the high/low ratio gearbox is changed whilst the vehicle 100 is moving, may be described as a ‘range change on the move’ manoeuvre, since the selected range of ratios of operation of transmission 124 is effectively switched from one range to another whilst the vehicle 100 is moving.

In some embodiments, the LSP control system 12 may be operable automatically to perform the ‘range change’ manoeuvre. That is, if a user selects via selector 131S a different ratio of the PTU 131P whilst the vehicle is moving under the control of the LSP control system 12, the LSP control system 12 may be operable automatically to cause the selected ratio of the PTU 131P to assume the newly requested range.

The LSP control system 12 may accomplish this by first handing over speed control to the HDC control system 12HD. The LSP control system 12 may then provide a signal to the powertrain controller 11 requesting that the transmission 124 be caused to operate in the neutral mode.

Once the transmission 124 is in the neutral mode, the LSP control system 12 may command the powertrain controller 11 to cause the PTU 131P to switch from the currently selected ratio (high or low) to the alternate ratio (low or high). Once this is complete, the LSP control system 12 may command the powertrain controller 11 to cause the transmission 124 to resume the operating mode in which it operated prior to selection of the neutral mode.

The LSP control system 12 may then resume control of vehicle speed in accordance with the value of target speed employed prior to handing over speed control to the HDC system 12HD. In some alternative embodiments, the LSP control system 12 may resume control of vehicle speed in accordance with the value of target speed employed when the system 12 was last employed to control vehicle speed with the currently selected gear ratio. Other arrangements are also useful. In some embodiments, if the value of LSP_set-speed for the newly selected ratio is lower than the instant speed, the LSP control system 12 may cause a reduction in vehicle speed towards the value of LSP_set-speed for the newly selected ratio whilst the range change manoeuvre is in progress.

In some embodiments, whilst the transmission 124 is in the neutral mode and the change of ratio of the PTU 131P is taking place, the HDC control system 12HD may be arranged to control vehicle speed. The system 12HD may in some embodiments control vehicle speed in accordance with a value of HDC_set-speed that is determined in dependence at least in part on one of an estimated time to change the gear ratio of the PTU 131P, prevailing driving surface gradient and an estimate of a rolling resistance of the vehicle 100. In some embodiments, the HDC control system 12HD may be configured to set the value of HDC_set-speed so as to simulate coasting of the vehicle 100. In some embodiments the system 12HD may control deceleration of the vehicle 100 such that the speed of the vehicle 100 gradually reduces over time even if the vehicle 100 is descending a relatively steep gradient. This may enhance vehicle composure and provide a more reproducible vehicle response to a range change operation regardless of prevailing terrain.

In some embodiments, when the change of ratio of the PTU 131P has taken place and the transmission 124 is to resume an operating mode in which the transmission 124 is connected to the driveline 130, i.e. the transmission 124 is to be re-engaged, the LSP control system 12 may be configured to cause matching of engine speed to transmission speed before the transmission 124 is re-engaged so as to improve vehicle composure. This may be accomplished by the LSP control system 12 in some embodiments by commanding the powertrain controller 11 to set a value of engine speed 121 corresponding to an input speed of the transmission 124. In this way, the control system 12 may be operable to control vehicle speed by automated control of the vehicle braking system 22 whilst simultaneously controlling engine speed to match driveline speed when the transmission 124 is re-engaged, reducing driveline shunt.

In some embodiments the LSP control system 12 is configured to monitor speed and direction of travel of the vehicle 121. If whilst the range change operation is being performed the system 12 detects that vehicle speed has fallen substantially to zero, the system 12 is operable to command the brake controller 13 to apply the braking system 22 to prevent a reversal of direction of travel. Thus the brake controller 13 may apply the braking system to hold the vehicle substantially stationary until the transmission 124 has re-engaged with the driveline 130 or a user intervenes to cancel control of vehicle speed by the LSP control system 12. Other arrangements are also useful.

FIG. 6 illustrates operation of a vehicle 100 according to an embodiment of the present invention in which a range change on the move operation is performed.

At step S103 LSP control system 12 causes the vehicle 100 to operate in accordance with target speed value LSP_set-speed.

At step S105 the LSP control system 12 checks whether PTU range selector 131S has been changed to select a different range to the current range in which the PTU 131P is operating. If the range selector 131S has been changed, the method continues at step S107 else the method continues at step S103.

At step S107 the LSP control system 12 suspends commanding the powertrain 129 to deliver drive torque. Instead, the LSP control system 12 causes the braking system 22 via brake controller 13 to prevent vehicle speed from exceeding the target speed value LSP_set-speed.

At step S109 the LSP control system 12 stores data indicative of the mode in which the transmission 124 is currently operating. The system 12 then causes the powertrain controller 11 to select the neutral operating mode.

At step S111, once the transmission 124 has assumed the neutral operating mode the powertrain controller 11 is caused to switch the PTU 131P to the newly selected ratio.

At step S113, when the PTU 131P has assumed the newly selected ratio the LSP control system 12 retrieves the stored data indicative of transmission mode before the neutral mode was selected and commands the powertrain controller 11 to cause the transmission 124 to assume the mode corresponding to the retrieved data.

At step S115 the LSP control system 12 causes the vehicle 100 to resume operation in accordance with the target speed value LSP_set-speed.

It is to be understood that in some embodiments the LSP control system 12 may cause the vehicle 100 to operate in accordance with the target speed value that was employed when the PTU 131P was last operated in the newly selected ratio range. Other arrangements are also useful.

Embodiments of the present invention have the advantage that driver workload may be reduced because the speed control system 12 performs functions, such as speed control whilst the transmission 124 is in neutral, that would otherwise have to be performed by the user. In some embodiments the LSP control system 12 is able to enhance vehicle composure by ensuring that vehicle speed is carefully controlled and the system 12 continues to operate in accordance with a target speed value once the range change manoeuvre is complete.

In one embodiment there is provided a vehicle speed control system operable to cause a vehicle to operate in accordance with a target speed value. The system is operable automatically to cause vehicle speed not to exceed a limit value by means of a braking system if a driveline of the vehicle is disconnected from a motor of the vehicle.
Embodiments of the present invention may be understood with reference to the following numbered paragraphs:

1. A control system operable to cause a vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of a vehicle,

wherein when the system is causing a vehicle to operate in accordance with the target speed value the system is operable automatically to cause vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being a portion through which a transmission of the powertrain is operable to deliver drive torque to one or more wheels of the vehicle, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

2. A system according to paragraph 1 wherein the limit value corresponds to the target speed value.

3. A system according to paragraph 1 operable wherein if the system is causing a vehicle to operate in accordance with a target speed and the powertrain assumes the torque suspension mode, the system is operable automatically to cause a vehicle to resume operation in accordance with the target speed value when the powertrain ceases to be in the torque suspension mode.

4. A system according to paragraph 1 operable to cause a ratio change operation to be performed in which the ratio selection portion changes from one operating mode to another.

5. A system according to paragraph 4 operable to cause the ratio change operation to be performed in response to user selection of a ratio change operation.

6. A system according to paragraph 4 operable automatically to trigger a ratio change operation when one or more predetermined conditions are met.

7. A system according to paragraph 4 operable automatically to cause the transmission to assume the torque suspension mode when a ratio change operation is in progress.

8. A system according to paragraph 1 operable automatically to limit vehicle speed to a prescribed maximum value in dependence on a type of terrain over which a vehicle is moving.

9. A system according to paragraph 8 operable to determine the type of terrain by reference to a selected driving mode of a vehicle.

10. A system according to paragraph 1 operable to prevent the powertrain temporarily from delivering drive torque to the input portion of the ratio selection portion of the powertrain by causing a clutch to open.

11. A system according to paragraph 1 operable temporarily to prevent the powertrain from delivering drive torque to the input portion of the ratio selection portion by causing the transmission to assume a neutral operating mode.

12. A system according to paragraph 1 operable to cause a vehicle to operate in accordance with the target speed value by causing a vehicle to maintain a speed substantially equal to the target speed.

13. A vehicle powertrain comprising a system according to paragraph 1.

14. A powertrain according to paragraph 13 comprising a ratio selection portion comprising a high/low range gearbox operable in a high ratio mode and a low ratio mode.

15. A powertrain according to paragraph 13 comprising an internal combustion engine.

16. A powertrain according to paragraph 13 comprising an electric propulsion motor.

17. A vehicle comprising a powertrain according to paragraph 13.

18. A method of controlling a vehicle comprising implemented by means of a control system comprising:

causing the vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of a vehicle, and

automatically causing vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being a portion through which a transmission of the powertrain is operable to deliver drive torque to one or more wheels of the vehicle, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

19. A method according to paragraph 18 comprising causing the powertrain to assume the torque suspension mode.

20. A method according to paragraph 19 whereby causing the powertrain to assume the torque suspension mode comprises causing the transmission to assume a neutral mode of operation.

21. A method according to paragraph 19 whereby causing the powertrain to assume the torque suspension mode comprises causing a clutch of the transmission to open thereby to isolate a source of drive torque from the ratio selection portion.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of the words, for example “comprising” and “comprises”, means “including but not limited to”, and is not intended to (and does not) exclude other moieties, additives, components, integers or steps.

Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

CLAIMS:

1. A control system operable to cause a vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of a vehicle,

wherein when the system is causing a vehicle to operate in accordance with the target speed value the system is operable automatically to cause vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

2. A system according to claim 1 wherein the limit value corresponds to the target speed value.

3. A system according to claim 1 or claim 2 operable wherein if the system is causing a vehicle to operate in accordance with a target speed and the powertrain assumes the torque suspension mode, the system is operable automatically to cause the vehicle to resume operation in accordance with the target speed value when the powertrain ceases to be in the torque suspension mode.

4. A system according to any preceding claim operable to cause a ratio change operation to be performed in which the ratio selection portion changes from one operating mode to another.

5. A system according to claim 4 operable to cause the ratio change operation to be performed in response to user selection of a ratio change operation.

6. A system according to claim 4 or claim 5 operable automatically to trigger a ratio change operation when one or more predetermined conditions are met.

7. A system according to any one of claims 4 to 6 operable automatically to cause the transmission to assume the torque suspension mode when a ratio change operation is in progress.

8. A system according to any preceding claim operable automatically to limit vehicle speed to a prescribed maximum value in dependence on a type of terrain over which the vehicle is moving.

9. A system according to claim 8 operable to determine the type of terrain by reference to a selected driving mode of the vehicle.

10. A system according to any preceding claim operable to prevent the powertrain temporarily from delivering drive torque to the input portion of the ratio selection portion of the powertrain by causing a clutch to open.

11. A system according to any preceding claim operable temporarily to prevent the powertrain from delivering drive torque to the input portion of the ratio selection portion by causing the transmission to assume a neutral operating mode.

12. A system according to any preceding claim operable to cause the vehicle to operate in accordance with the target speed value by causing the vehicle to maintain a speed substantially equal to the target speed.

13. A vehicle powertrain comprising a system according to any preceding claim.

14. A powertrain according to claim 13 comprising a ratio selection portion comprising a high/low range gearbox operable in a high ratio mode and a low ratio mode.

15. A powertrain according to any one of claims 13 or 14 comprising an internal combustion engine.

16. A powertrain according to any one of claims 13 to 15 comprising an electric propulsion motor.

17. A vehicle comprising a powertrain according to any one of claims 13 to 16.

18. A method of controlling a vehicle comprising implemented by means of a control system comprising:

causing the vehicle to operate in accordance with a target speed value by controlling an amount of brake torque applied by a braking system and an amount of drive torque applied by a powertrain to one or more wheels of a vehicle, and

automatically causing vehicle speed not to exceed a limit value by means of the braking system if the powertrain assumes a torque suspension mode being a mode in which the powertrain is prevented temporarily from delivering drive torque to an input portion of a ratio selection portion of the powertrain, the ratio selection portion being operable in a plurality of different respective operating modes in each of which a different respective gear ratio is provided between an input portion and an output portion thereof.

19. A method according to claim 18 comprising causing the powertrain to assume the torque suspension mode.

20. A method according to claim 19 whereby causing the powertrain to assume the torque suspension mode comprises causing the transmission to assume a neutral mode of operation.

21. A method according to claim 19 or claim 20 whereby causing the powertrain to assume the torque suspension mode comprises causing a clutch of the transmission to open thereby to isolate a source of drive torque from the ratio selection portion.

22. A vehicle comprising a system according to any of claims 1 to 12.

23. A system, a powertrain, a vehicle or method substantially as hereinbefore described with reference to the accompanying drawings.

Intellectual Property Office

Application No:	GB1313260.0	**Examiner:**	Mr Kevin Hewitt
Claims searched:	1 to 23	**Date of search:**	20 January 2014

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	EP 1355209 A1 (FORD GLOBAL TECHNOLOGY) See especially the Abstract; and Figures 2, 3 & 4.
A	-	DE 102009033953 A1 (GM GLOBAL TECHNOLOGY OPERATIONS) See especially the WPI Abstract Accession Number 2010-B17729; and Figures 1 & 2.
A	-	WO 2007/006659 A1 (ROBERT BOSCH) See especially the Abstract; and Figures 1 & 2.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B60W

The following online and other databases have been used in the preparation of this search report

WPI; EPODOC

International Classification:

Subclass	Subgroup	Valid From
B60W	0030/14	01/01/2006
B60W	0010/11	01/01/2012