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WO 2014/037541 A **WO 2014/026986 A**
WO 2013/186208 A **JP 2008213531 A**
US 20140257669 A

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(54) Title of the Invention: **Driveline component protection**
Abstract Title: **Vehicle engine control that limits the output torque of the engine based on the terrain type**

(57) The torque output of an engine in a vehicle, is limited, based on the terrain over which said vehicle is travelling. An overall torque ratio between the engine and driveline may be used to calculate the engine torque limit request from the driveline torque limit, the driveline torque limit being selected based on the terrain. Other factor used in the calculation of the torque limit include: the transfer box ratio, the transmission ratio, the engine speed, the transmission input shaft speed, a torque converter slip ratio, the hydrodynamic torque ratio and/or the lockup clutch torque. Torque is limited to protect driveline components over different terrains.

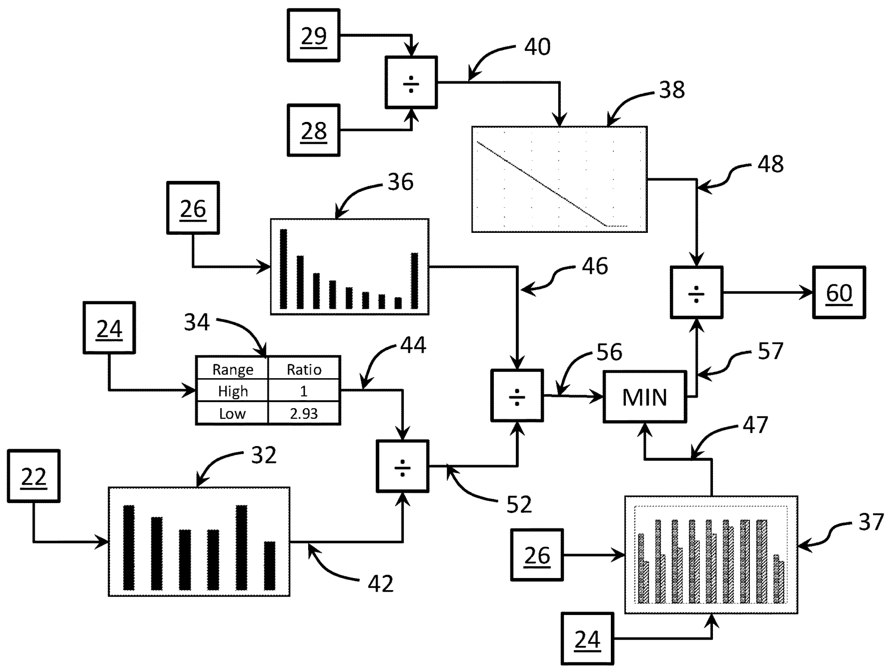


Figure 3

GB 2534368 A

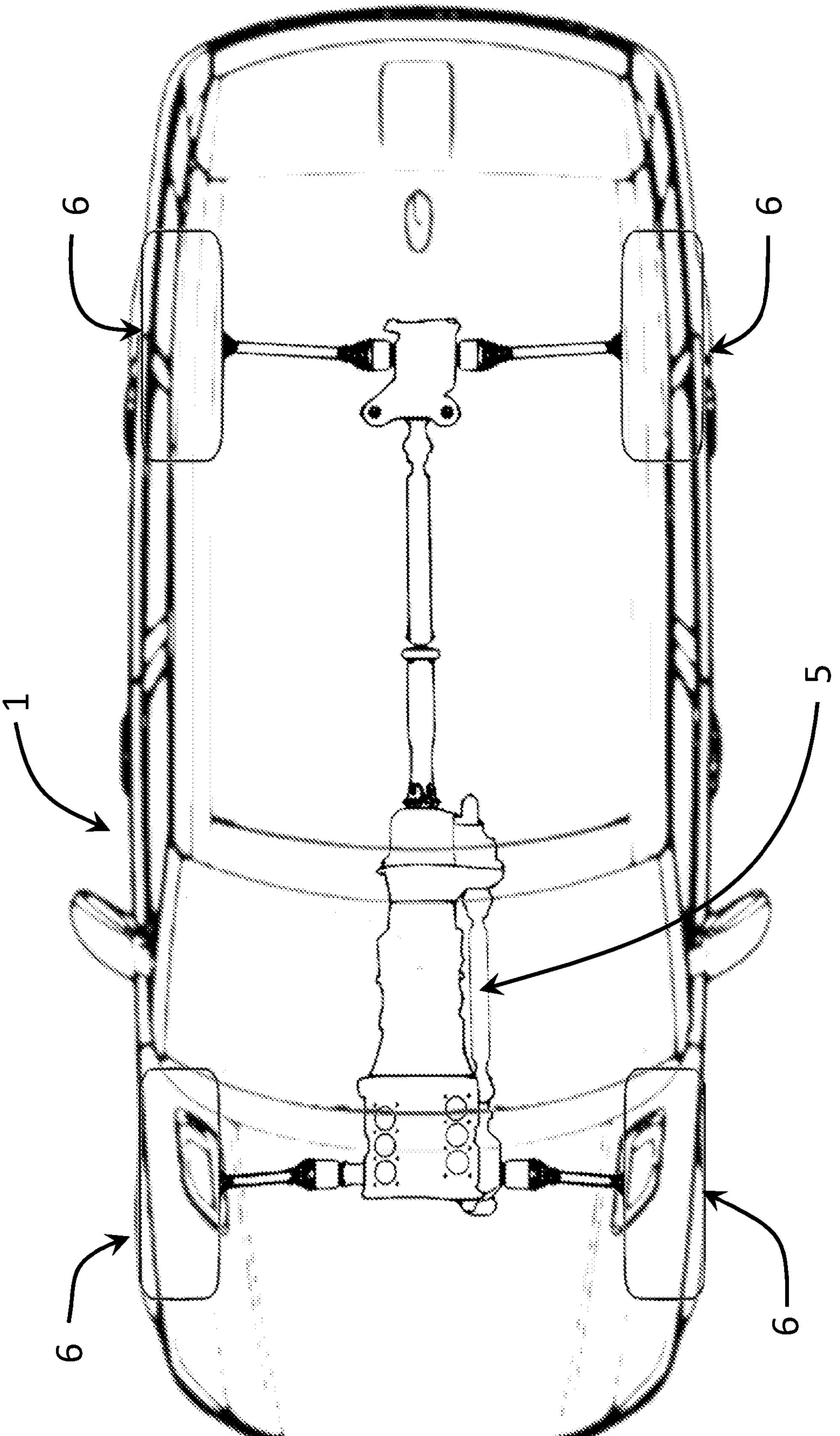


Figure 1

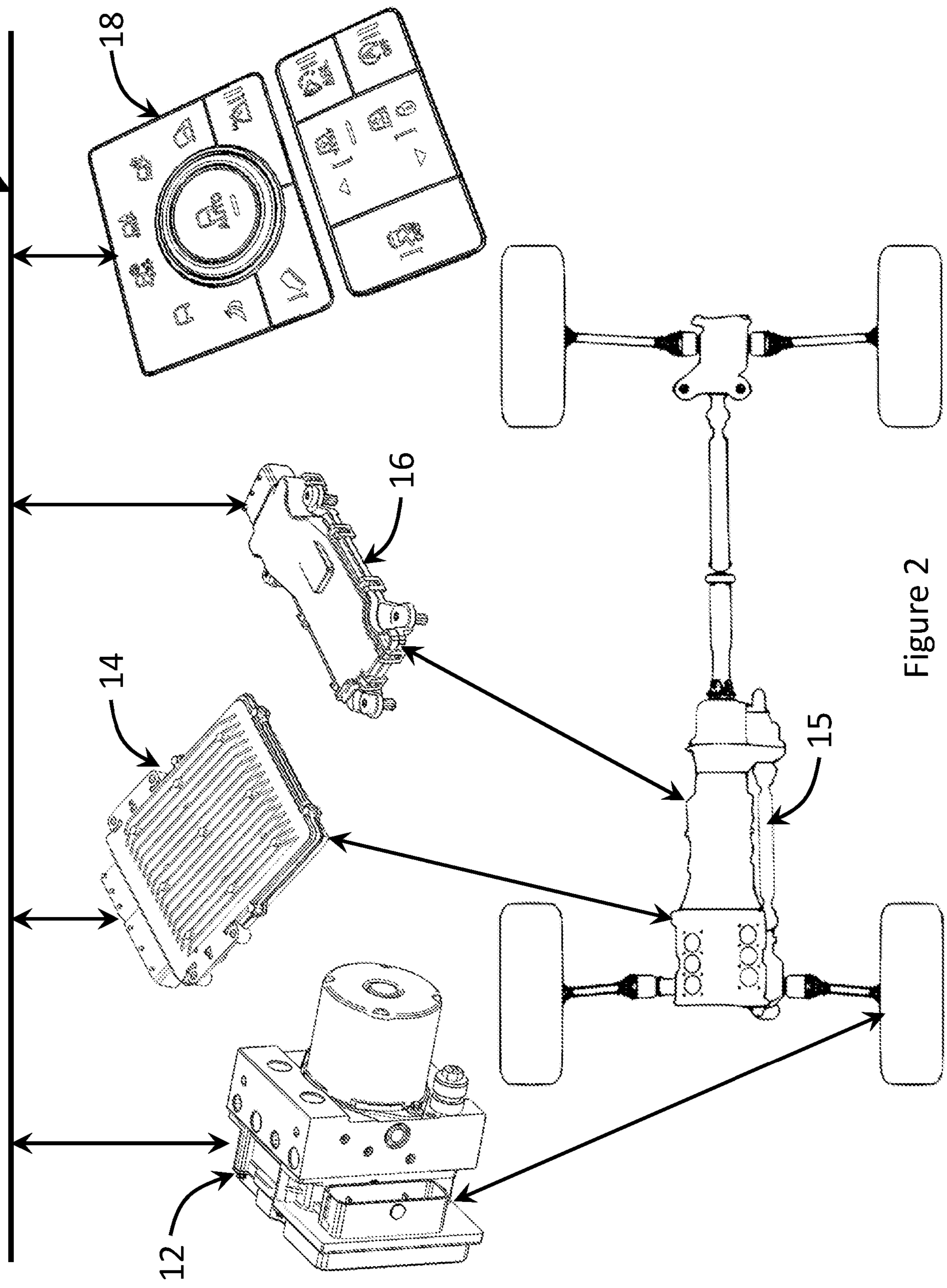
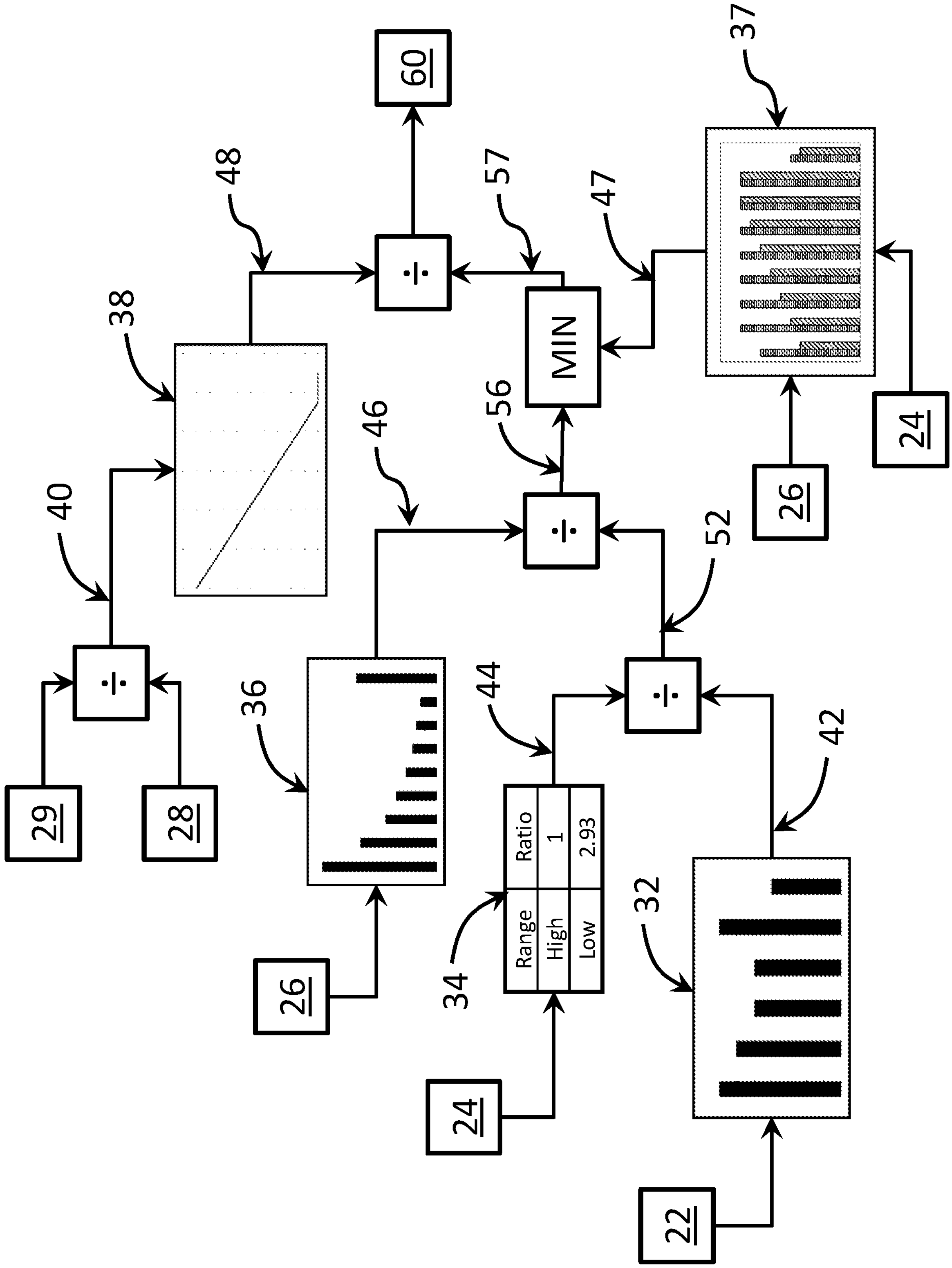


Figure 2



60
48
57
38
47
37
MIN
40
46
56
29
28
36
52
24
26
44
Range
High
Low
Ratio
1
2.93
34
42
32
22

Figure 3

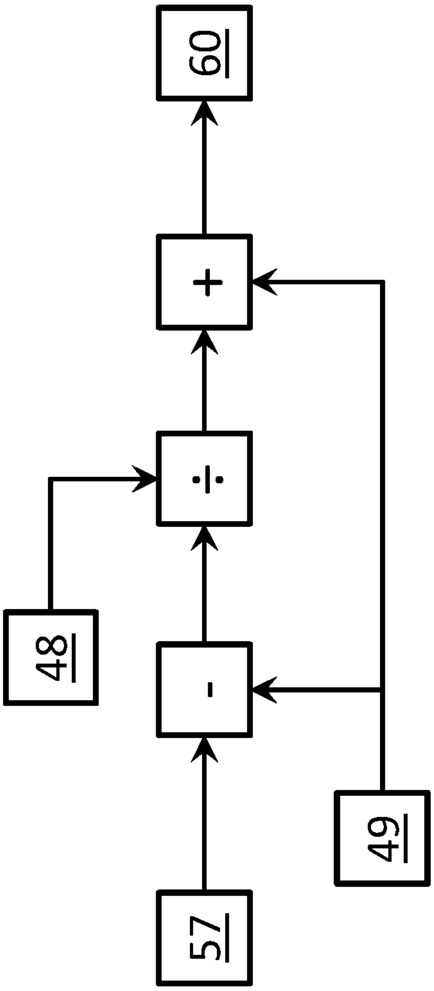


Figure 4

DRIVELINE COMPONENT PROTECTION

TECHNICAL FIELD

The present disclosure relates generally to driveline component protection and particularly, but not exclusively, to a method of controlling a powertrain to protect components of a vehicle. Aspects of the invention relate to a method, to a controller, to a powertrain, and to a vehicle.

BACKGROUND OF THE INVENTION

It is known that during the development of a vehicle it is common for a vehicle manufacturer to collect data concerning the torque experienced in transmission and driveline components while a vehicle is driving in a range of routes or environments, commonly known as road load data (RLD). The information from the various environments is then combined according to well-known fatigue damage accumulation techniques such as the Palmgren Miner linear cumulative fatigue damage theory. Individual components are then designed to meet fatigue life and failure mode requirements within the predicted usage range of the vehicle both in terms of low and high cycle fatigue.

It is also known to provide a vehicle capable of both on-road and off-road travel such as sport-utility and other multi-purpose vehicles. The rate of fatigue damage accumulation is known to vary with different terrain due to the frequency and amplitude of torque loading associated with wheel slip, driving resistance and surface friction. The proportion of use between on and off-road can vary widely and because of this components are often designed to meet arduous driving conditions with associated increases in size, weight, material choice and cost. Different vehicle manufacturers design their vehicles according to varying proportions of off-road driving based on historical customer usage information and this leads to variations in vehicle mass, fuel economy and cost.

In order to protect driveline components it is known to limit engine torque in a vehicle and in some cases this limit may vary in different gears. This allows vehicle performance to be optimised within the fatigue life of driveline components. However this method still relies on an assumed combination of different driving environments and conservatively restricts performance, particularly when driving on-road. This invention seeks to improve the compromise between performance and component protection, allowing a reduction in component size and weight with resulting improved performance and economy.

SUMMARY OF THE INVENTION

Aspects of the present invention relate to a method of controlling a powertrain to protect components of a vehicle; a controller; a powertrain; and a vehicle.

According to an aspect of the present invention there is provided a method for operating a vehicle, comprising:

determining a terrain type over which the vehicle is travelling;
determining a maximum torque limit based on the terrain type; and
controlling an output torque of the engine in dependence on said limit.

According to embodiments of the invention, a lower maximum torque limit may be imposed on a terrain where high shock loading or high rolling resistance is likely to be encountered. Conversely the maximum torque limit may be increased providing improved performance where high shock loads are unlikely based on the terrain type. By controlling the output torque of the engine such that the maximum torque limit is not exceeded, driveline component life is less sensitive to the proportion of distance travelled off-road and more demanding users are less likely to experience component failures.

According to another aspect of the present invention there is provided a system for a vehicle, the system comprising:

means for determining a terrain type over which the vehicle is travelling;
means for determining a maximum torque limit based on the terrain type; and
means for controlling an output torque of the engine based on said limit.

In an embodiment, the means for determining the terrain type comprises one or more processors, the or each processor having an input for receiving signals from one or more sensors, each signal being indicative of a value of a parameter relating to the terrain type. The one or more processors may be configured to determine the terrain type in dependence on the values detected by the one or more sensors.

The one or more processors may be configured to communicate a maximum torque limit, according to the determined terrain type, to an engine controller or the like configured to control the operation of the engine.

In an embodiment, determining a maximum torque limit based on the terrain type may comprise:

selecting a component maximum torque limit for at least one driveline component based on the terrain type; and

dividing said component maximum torque limit by an overall torque ratio between the engine and driveline to determine a torque limit.

In an embodiment, the torque limit may be communicated to the engine as a maximum torque limit request.

In an embodiment, dividing said component maximum torque limit by the overall torque ratio between the engine and driveline may comprise one or more of:

determining a transfer box ratio in dependence on a status of the transfer box;

dividing the driveline torque limit by the transfer box ratio to determine a transfer box input torque limit;

determining a transmission ratio in dependence on a status of the transmission;

dividing the transfer box input torque limit by the transmission ratio to determine the transmission input torque limit;

determining the engine speed and transmission input shaft speeds;

dividing the transmission input shaft speed by the engine speed to determine a torque converter slip ratio;

determining a torque converter torque multiplication ratio based on the torque converter slip ratio; and

dividing the transmission input torque limit by the torque converter torque multiplication ratio to determine the torque limit request.

The above method may be modified when either a multiple range transfer box or a torque converter is not present in the vehicle. In the event that a single range transfer box is present in the vehicle, or if no transfer box is present in the vehicle, then high range may be assumed. In the event a launch device without torque multiplication is present in the vehicle, a torque ratio of 1:1 may be assumed. For the purposes of embodiments of the invention ,a launch device capable of torque multiplication may be considered equivalent to a torque converter.

According to an embodiment of the present invention there is provided a method as previously described wherein the results of some calculation steps are stored in an array and the result selected according to the status of the transmission and transfer box.

Further, an input torque limit of the transfer box or transmission may be selected as a minimum of the torque limit calculated from the driveline torque limit and the torque limit of the currently selected gear or range. Also the torque converter torque multiplication ratio may be calculated by combination of the hydrodynamic torque ratio and the lockup clutch torque.

According to an aspect of the present invention there is provided a controller for controlling torque of a vehicle engine, wherein the controller is configured to limit a torque output of the engine in dependence upon a terrain type over which the vehicle is travelling or about to travel.

Different terrain types provide varying friction coefficients, surface drag and obstacles. These features combine to impart loading into driveline components such as shafts, gears, bearings, structural housings and mounting systems. The fatigue durability of these components is affected by such loadings. The maximum engine torque also affects the durability of these components so by reducing the maximum engine torque it is possible to balance the fatigue durability input from the engine and the environment.

According to an aspect of the present invention there is provided a powertrain of a vehicle comprising an engine and a controller as previously described. The powertrain of a vehicle may comprise a transmission, a driveline system and an engine with associated fuelling, ignition, cranking, induction, exhaust, cooling and ancillary drive systems. Several powertrain control modules may control the function of elements of these systems and interact through a communication bus or network.

According to an aspect of the present invention there is provided a vehicle comprising a powertrain or a controller as previously described.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic representation of a vehicle and a powertrain;

Figure 2 shows a number of controllers related to a vehicle communication bus and a powertrain;

Figure 3 shows a block diagram indicating a calculation method;

Figure 4 shows a block diagram indicating a further calculation method.

DETAILED DESCRIPTION

A method of controlling a vehicle in accordance with an embodiment of the present invention is described herein with reference to the accompanying Figures.

With reference to Figure 1, a vehicle (1) incorporates a powertrain (5) which is arranged to provide motive force to wheels (6).

With reference to Figure 2, the powertrain (5) includes a braking controller (12) which communicates with wheel speed sensors and/or accelerometers (not shown) and applies braking force to the wheels (6) through hydraulic braking means (not shown). The braking controller (12) also communicates with other controllers in the vehicle through a communication bus (10). The communication bus (10) may be a controller area network (CAN) or other networking bus and multiple networks may be linked by gateway modules within a single vehicle. An engine control module (ECM) (14) is configured to receive signals output from engine sensors (not shown) and to apply control to engine systems which may include fuel injection and ignition. The ECM (14) also communicates to other controllers through the communication bus (10). A transmission control module (TCM)(16) is configured to receive signals output from transmission sensors (not shown) and to apply control to transmission systems (15) which may include clutch and brake actuation. The TCM (16) also communicates to other controllers (not shown) through the communication bus. Other driveline controllers, for example controllers for a transfer box, driveline coupling and/or locking differential, may be configured in a similar manner transmitting and receiving information to and from the communication bus (10) while receiving sensor inputs and transmitting control outputs.

The vehicle 1 is also provided with sensors (not shown) which are configured to detect a variety of different parameters associated with vehicle motion, environment and/or driver commands. Vehicle motion sensors may include: wheel speed sensors, suspension displacement sensors, vehicle body gyroscopic and/or acceleration sensors and other sensors that may be indicative of vehicle body and wheel movement. Environmental sensors may include ambient temperature, humidity and pressure sensors, rain sensors, fog sensors, daylight sensors and wading sensors. Driver command sensors may include steering angle, steering rate and/or steering torque sensors, accelerator pedal sensors, brake pedal position and brake pressure sensors, one or more terrain mode selection switches and other switches operated by the driver such as screen wash or headlamp control. Other vehicle sensors and/or actuators may be employed to calculate any parameter values which are not directly measured such as engine torque.

Signals from sensors and/or actuators are evaluated by various controllers and communicated across one or more vehicle communications buses (10) to a terrain controller 18. The terrain controller may comprise an independent control unit or may be combined into another control unit. The terrain controller (10) evaluates the various signals to determine the probability that each of a plurality of different terrain modes for the vehicle subsystems is appropriate for the nature of the terrain conditions over which the vehicle is travelling. Each terrain mode corresponds to a particular terrain type over which the vehicle is travelling (for example, mud and ruts, sand, grass/gravel/snow). The terrain mode is communicated as a signal across one or more vehicle communications buses (10) to other controllers.

Such a terrain controller (18) is further described in GB2492655. It will be appreciated that distributed controllers allow software to reside in any controller while providing control through another controller. It will also be appreciated that not all controllers will be present in all vehicles. Thus, for example, a vehicle may not include a dual range transfer box and so may not require the associated controller. In such a case the appropriate signal will be assumed in the control software, so in the example where a single range transfer box is fitted, the software may assume the vehicle remains in high range at all times.

An electronic engine controller may be provided in a vehicle to control parameters such as fuel injection quantity, injection timing, throttle valve opening, ignition timing and boost pressure in addition to other parameters. Said engine controller takes signals from engine sensors and generates control signals so as to provide torque from the engine while also controlling emission of undesirable combustion products. The engine controller modulates the supply of torque dependent on control inputs such as the accelerator pedal position and this is often referred to as the 'driver demand'. Other vehicle systems may supply additional control inputs which are also used to modulate the engine torque. For example, a traction control system may respond to a wheel slip condition by requesting an engine torque reduction to a value less than that requested by the driver based on the accelerator pedal position. The associated reduction in torque allows wheel slip to be reduced and improve control and traction of the vehicle. It is also known for an automatic transmission to request a torque reduction during a gear shift. This allows the engine speed to reduce during an upshift while reducing the engine torque produced by combustion by an amount equivalent to the inertia torque generated by engine deceleration. This method provides a smooth output torque from the transmission during the shift. A similar process may be used for a number of controllers simultaneously requesting different maximum torque limits. An arbitration function is able to select the correct torque at any time based on relative values and signal priority. So, for example a driveline maximum torque limit request may override a higher driver demand torque.

With reference to Figure 3, a software control system is described whereby a terrain selection signal (22) from the terrain controller is compared with a torque limit map (32) to provide a driveline torque limit (42). A transfer box range signal (24) from a transfer box controller (not shown) is compared with a transfer box ratio map (34) to produce a transfer box ratio (44). The driveline torque limit is then divided by the transfer box ratio to produce a transfer box input torque limit (52). A gear signal (26) from the transmission controller (16) is compared with a gear ratio map (36) to provide a gear ratio (46). The transfer box input torque limit (52) is divided by the gear ratio (46) to provide a first gearbox input torque limit (56) based on the driveline torque limit.

The transmission (15) may also have restricted torque capacity in different gears. The transfer box may be similarly limited. A gearbox torque limit map (37) may receive signals output from the transmission (15) and transfer box to indicate the selected gear (26) and range (24) in order to provide a second gearbox input torque limit (47). The lower of the first and second gearbox input torque limit is selected to provide a preferred gearbox input torque limit (57). A transmission input speed (29) is divided by an engine speed (28) to provide a torque converter slip ratio (40). The torque converter slip ratio (40) is input into a torque multiplication map (38) to provide the torque converter torque multiplication (48). The preferred gearbox input torque limit (57) is divided by the torque converter torque multiplication (48) to provide a torque limit request (60) which is communicated to the engine controller (14). The engine controller (14) uses the torque limit request in combination with other signals to control the engine torque so as to remain at or below the torque limit request unless another torque request of higher priority overrides this request. A higher priority torque request may be made by a braking stability control system in the event that this is required to maintain stability of the vehicle.

With reference to Figure 4, further detail of a torque converter calculation is shown. In the event a torque converter lockup clutch is used, the final calculation shown in figure 3 is modified whereby a lockup clutch torque (49) is subtracted from the preferred gearbox input torque limit (57) to provide a hydrodynamic output torque limit. The hydrodynamic output torque limit is divided by the torque converter torque multiplication (48) to provide a hydrodynamic input torque limit. The lockup clutch torque (49) is then added to the hydrodynamic input torque limit to provide the torque limit request (60). This function is used when the torque converter slip ratio is substantially non-zero and the lockup clutch torque is substantially non-zero so the torque is shared between the lockup clutch and hydrodynamic torus.

Where the transmission (15) does not incorporate a torque converter, the torque limit request (60) will correspond to the preferred gearbox input torque limit as torque multiplication is not present in clutch systems. Other transmission configurations are also possible whereby the engine torque is multiplied by a launch device. In this event the control follows the same method. In the event an engine is combined with an additional torque source such as an electric machine, the combined torque is limited by the torque limit request.

As the process is mathematical, it will be appreciated that the combination of some steps or maps may be advantageous to reduce calculation overhead or memory space required. For example a single map may be produced taking range and gear information to provide a combined transmission and transfer box ratio.

It will also be appreciated that, for example, a manual transmission (15) may not include a controller (14). In this case the gear position may be sensed in the gear lever or on the transmission and the associated signal used for input into the gear ratio map. Alternatively the ratio may be detected by speed sensing at points before and after the transmission, for example the engine flywheel and a speedometer drive or a combination of wheel speeds.

It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

CLAIMS:

1. A method of controlling an engine of a vehicle, comprising:
   determining a terrain type over which the vehicle is travelling;
   selecting a torque limit based on the terrain type; and
   generating a torque limit request for limiting the output torque of the engine according to said torque limit.

2. A method as claimed in claim 1 wherein the selection of the torque limit comprises:
   selecting a driveline torque limit for one or more components of a driveline of the vehicle based on the terrain type;
   and dividing said driveline torque limit by the overall torque ratio between the engine and the driveline to determine the torque limit request.

3. A method as claimed in claim 2 wherein dividing said torque limit by the overall torque ratio between the engine and the driveline comprises one or more of:
   determining a transfer box ratio in dependence on a status of a transfer box of the vehicle;
   dividing the driveline torque limit by the transfer box ratio to determine a transfer box input torque limit;
   determining a transmission ratio in dependence on a status of a transmission of the vehicle;
   dividing the transfer box input torque limit by the transmission ratio to determine the transmission input torque limit;
   determining the engine speed and transmission input shaft speeds;
   dividing the transmission input shaft speed by the engine speed to determine a torque converter slip ratio;
   determining a torque converter torque multiplication ratio based on the torque converter slip ratio;
   and dividing the transmission input torque limit by the torque converter torque multiplication ratio to determine the torque limit request.

4. A method as claimed in claim 2 wherein dividing said torque limit by the overall torque ratio between the engine and the driveline comprises one or more of:
   determining a transmission ratio in dependence on a status of a transmission of the vehicle;

dividing the driveline input torque limit by the transmission ratio to determine the transmission input torque limit;

determining the engine speed and transmission input shaft speeds;

dividing the transmission input shaft speed by the engine speed to determine a torque converter slip ratio;

determining a torque converter torque multiplication ratio based on the torque converter slip ratio; and

dividing the transmission input torque limit by the torque converter torque multiplication ratio to determine the torque limit request.

5. A method as claimed in claim 2 wherein dividing said torque limit by the overall torque ratio between the engine and the driveline comprises one or more of:

determining a transfer box ratio in dependence on a status of a transfer box of the vehicle;

dividing the driveline torque limit by the transfer box ratio to determine a transfer box input torque limit;

determining a transmission ratio in dependence on a status of a transmission of the vehicle;

dividing the transfer box input torque limit by the transmission ratio to determine the transmission input torque limit;

6. A method as claimed in claim 2 wherein dividing said torque limit by the overall torque ratio between the engine and the driveline comprises one or more of:

determining a transmission ratio in dependence on a status of a transmission of the vehicle;

and dividing the driveline torque limit by the transmission ratio to determine the torque limit request.

7. A method as claimed in any one of claims 3 to 6 wherein the results of one or more calculations are stored in a memory or an array and the result is selected according to the status of the transmission and transfer box.

8. A method as claimed in any one of claims 3 to 7 wherein the input torque limit of the transfer box or transmission is selected as a minimum of the torque limit calculated from the driveline torque limit and the torque limit of the currently selected gear or range.

9. A method as claimed in any one of claims 3 to 8 wherein the torque converter torque multiplication ratio is calculated by combination of the hydrodynamic torque ratio and the lockup clutch torque.

10. A controller for control of a vehicle engine, wherein the controller is configured to limit a torque output of the engine dependent upon a terrain type over which the vehicle is travelling.

11. A controller as claimed in claim 10, configured to perform a method as claimed in any preceding claim.

12. A powertrain of a vehicle comprising an engine and a controller as claimed in claim 10 or claim 11.

13. A vehicle comprising a powertrain as claimed in claim 12 or a controller as claimed in claim 10 or claim 11.

Intellectual Property Office

Application No: GB1500901.2 **Examiner:** Jason Clee
Claims searched: 1-13 **Date of search:** 25 June 2015

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
X	1, 2 & 10-13	WO 2014/037541 A (JAGUAR LAND ROVER LTD) especially see the abstract, page 27 line 18 to page 28 line 21 and figures
X	1 & 10-13	JP 2008213531 A (TOYOTA JIDOSHA KK) especially see the paragraph 0034 noting the maximum torque set for snow, the figures and abstract WPI AN 2008-K80084
X	1 & 10-13	WO 2013/186208 A (JAGUAR LAND ROVER LTD) especially see the abstract, page 4 line 33 to page 5 line 11 noting the maximum allowable drive torque is calculated based on driving modes such as the grass/gravel/snow driving mode
X	1 & 10-13	WO 2014/026986 A (JAGUAR LAND ROVER LTD) especially see the abstract, paragraphs 0059 and 0062 and figures, noticing the relationship between the torque limit and the different types of terrain
X	1 & 10-13	US 2014/257669 A (WU et al.) especially see the abstract and figures, noting the torque limit using impending terrain and speed conditions

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

B60K; B60W; F02D

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

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B60W	0030/184	01/01/2012
B60W	0010/04	01/01/2006