US010385965B2

(12) **United States Patent**
Wippler

(10) **Patent No.: US 10,385,965 B2**
(45) **Date of Patent: Aug. 20, 2019**

(54) **VEHICLES, ELECTRONIC CONTROL UNITS, AND METHODS FOR GEAR SHIFTING BASED ON VEHICLE ATTITUDE**

(71) Applicant: **Toyota Motor Engineering & Manufacturing North America, Inc.**, Erlanger, KY (US)

(72) Inventor: **Erik Anthony Wippler**, Canton, MI (US)

(73) Assignee: **TOYOTA MOTOR ENGINEERING & MANUFACTURING NORTH AMERICA, INC.**, Plano, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 222 days.

(21) Appl. No.: **15/487,496**

(22) Filed: **Apr. 14, 2017**

(65) **Prior Publication Data**

US 2018/0299008 A1 Oct. 18, 2018

(51) **Int. Cl.**

F16H 61/02 (2006.01)
F16H 59/60 (2006.01)
F16H 59/66 (2006.01)
F16H 61/16 (2006.01)

(52) **U.S. Cl.**

CPC ***F16H 61/0213*** (2013.01); ***F16H 59/60*** (2013.01); ***F16H 59/66*** (2013.01); ***F16H 61/16*** (2013.01); *F16H 2059/663* (2013.01); *F16H 2059/666* (2013.01); *F16H 2061/0216* (2013.01); *F16H 2061/0234* (2013.01); *F16H 2061/0237* (2013.01)

(58) **Field of Classification Search**

CPC B60W 2550/142; F16H 2059/666
See application file for complete search history.

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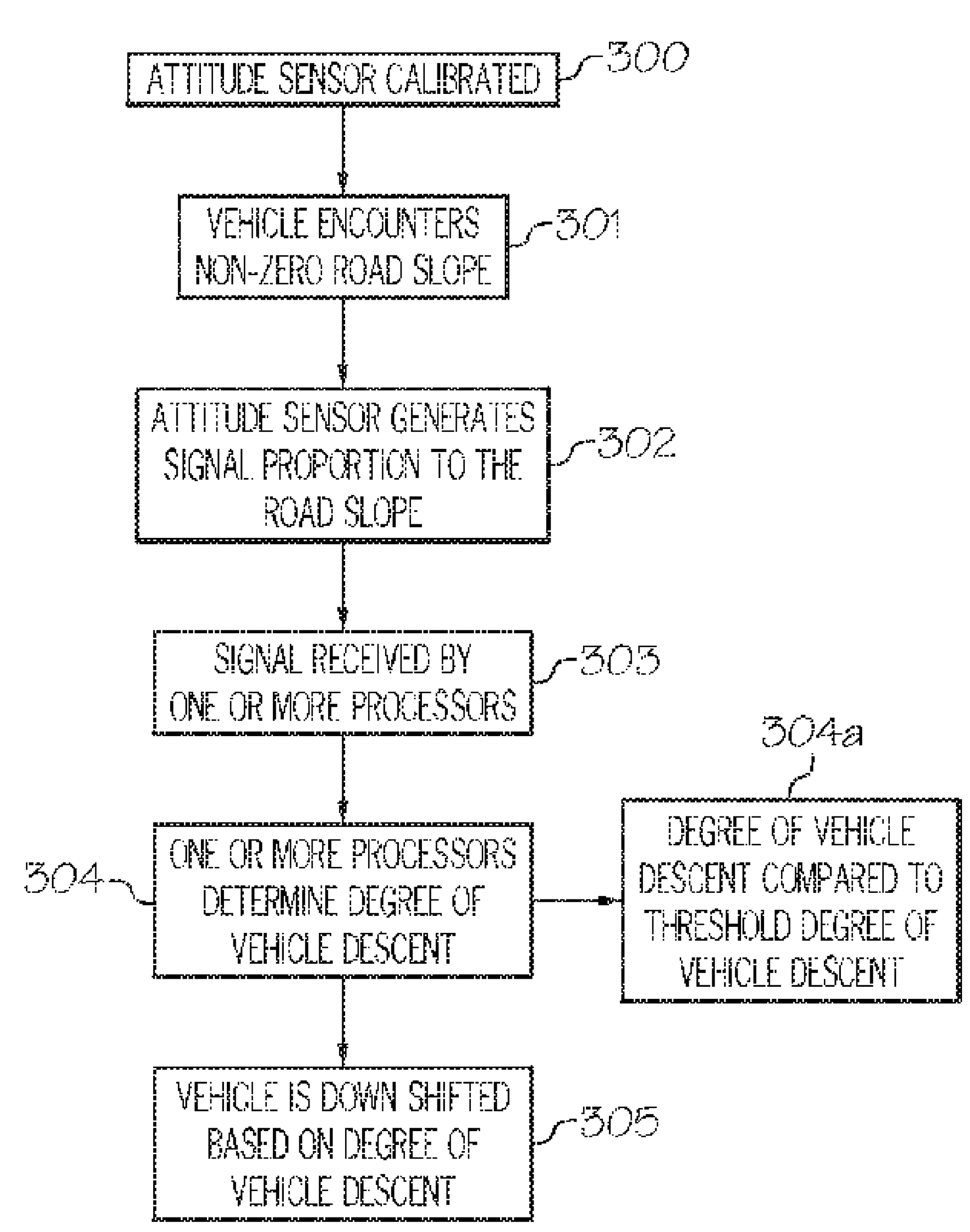
Primary Examiner — Tisha D Lewis

(74) *Attorney, Agent, or Firm* — Dinsmore & Shohl LLP

(57) **ABSTRACT**

A vehicle includes an engine, a plurality of drive wheels, a vehicle transmission configured to transmit power from the engine to the plurality of drive wheels, one or more vehicle attitude sensors, and an electronic control unit communicatively coupled to the one or more vehicle attitude sensors and the vehicle transmission. The electronic control unit is configured to receive a signal from the one or more vehicle attitude sensors, determine a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors, and downshift the vehicle transmission based on the degree of vehicle descent determined based on the signal received from the one or more vehicle attitude sensors.

14 Claims, 5 Drawing Sheets



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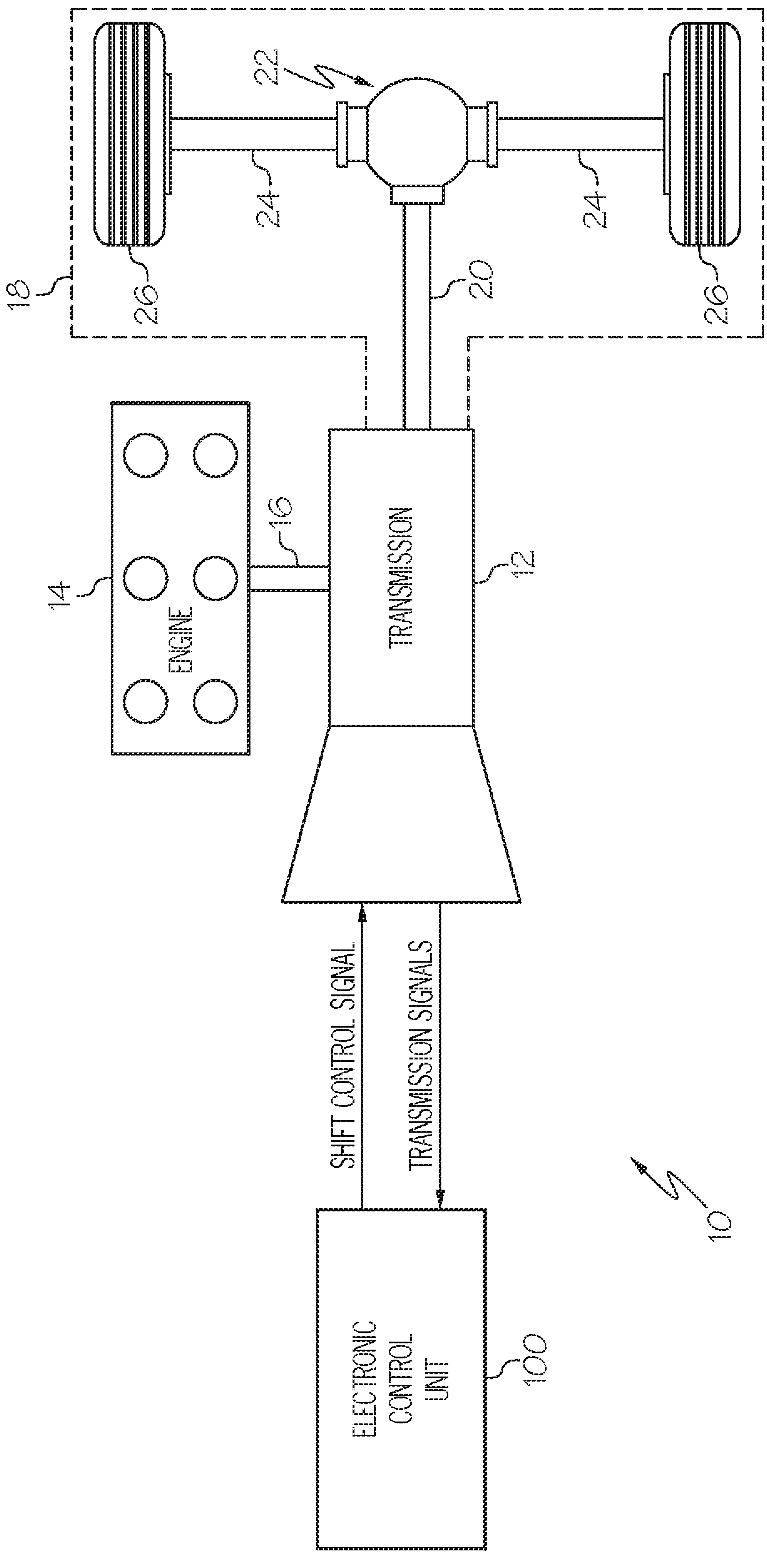

22
24
24
18
26
20
26
16
14
12
ENGINE
TRANSMISSION
SHIFT CONTROL SIGNAL
TRANSMISSION SIGNALS
10
ELECTRONIC CONTROL UNIT
100

FIG. 1

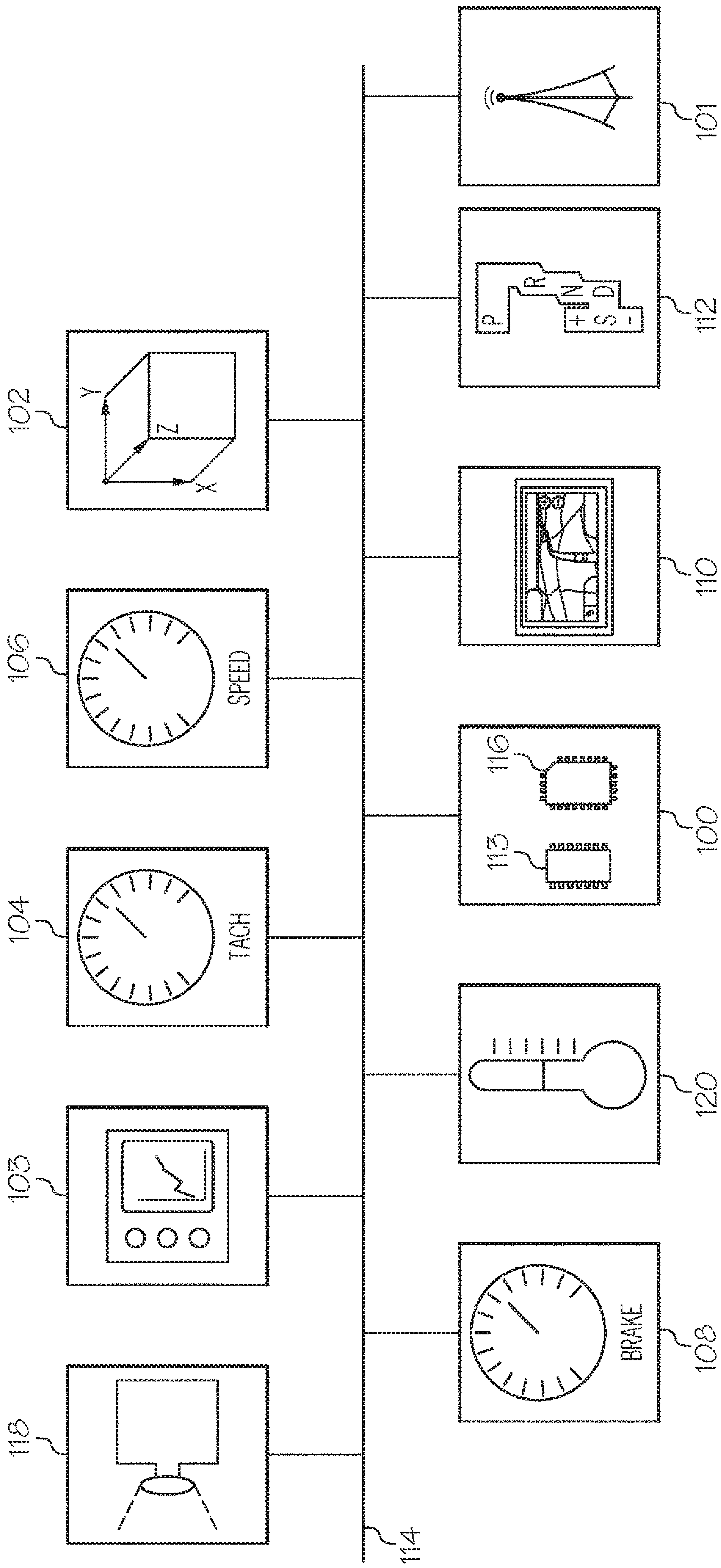
101
112
110
100
116
113
120
108
102
106
104
103
118
114
SPEED
TACH
BRAKE
X
Y
Z
P
R
N
D
S
+
-

FIG. 2

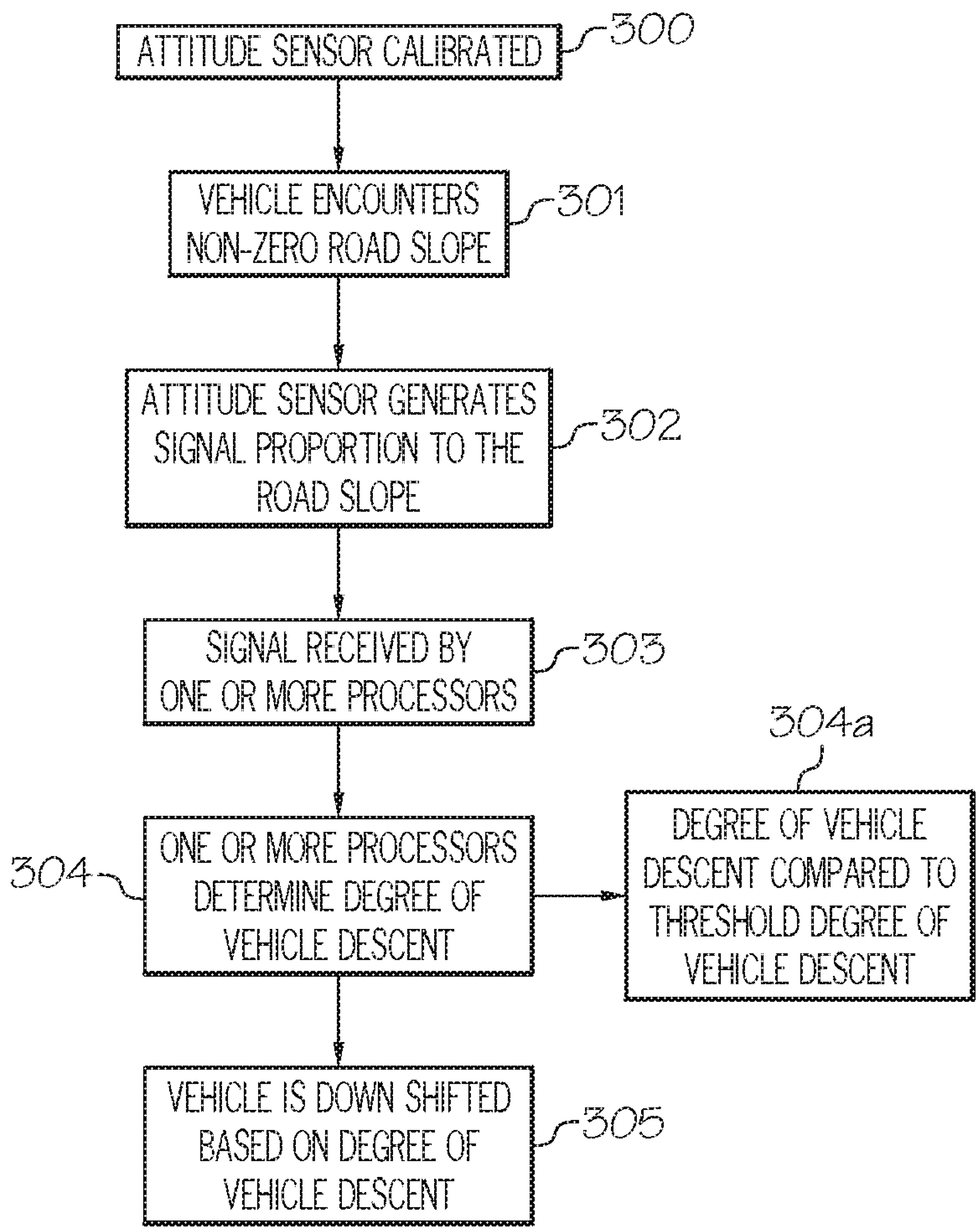
ATTITUDE SENSOR CALIBRATED
300
VEHICLE ENCOUNTERS NON-ZERO ROAD SLOPE
301
ATTITUDE SENSOR GENERATES SIGNAL PROPORTION TO THE ROAD SLOPE
302
SIGNAL RECEIVED BY ONE OR MORE PROCESSORS
303
ONE OR MORE PROCESSORS DETERMINE DEGREE OF VEHICLE DESCENT
304
DEGREE OF VEHICLE DESCENT COMPARED TO THRESHOLD DEGREE OF VEHICLE DESCENT
304a
VEHICLE IS DOWN SHIFTED BASED ON DEGREE OF VEHICLE DESCENT
305

FIG. 3

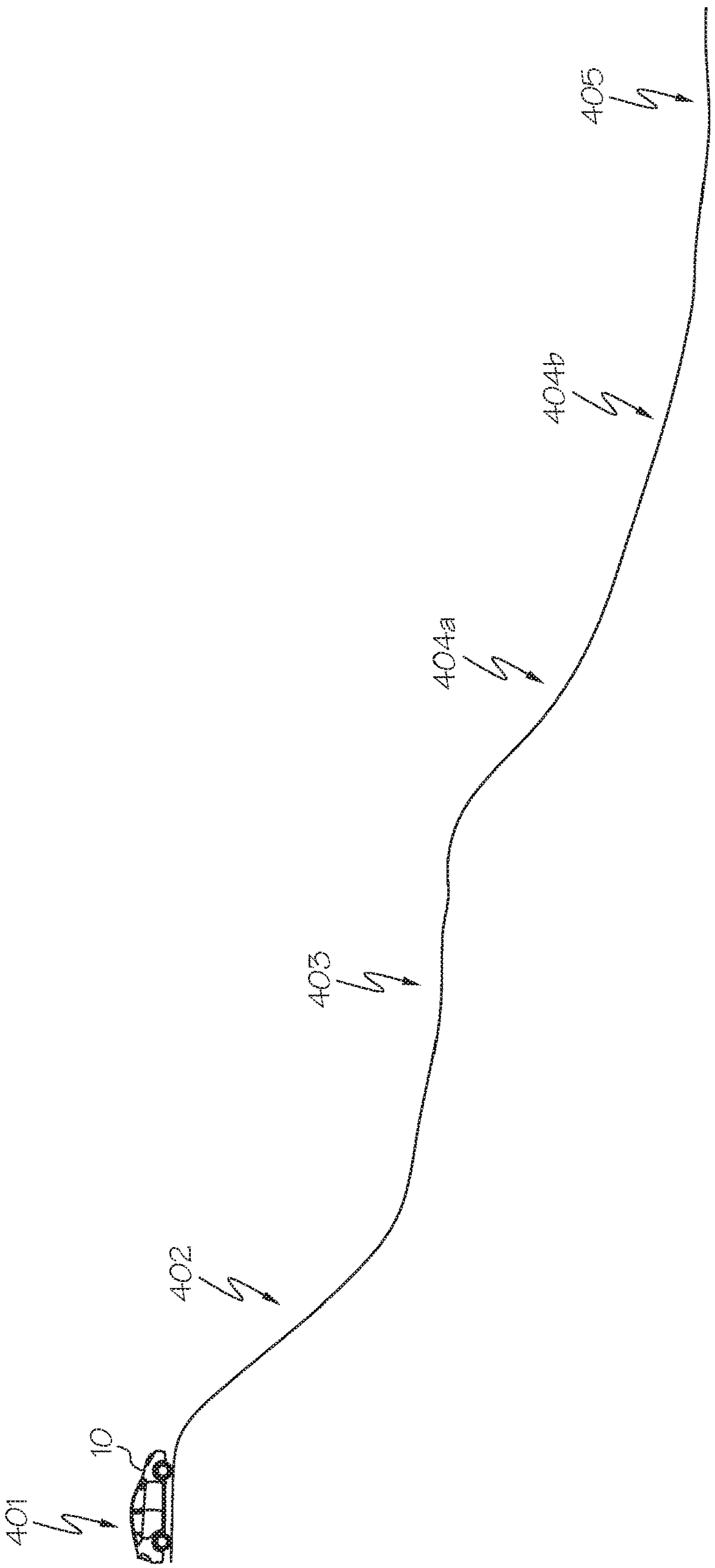

FIG. 4

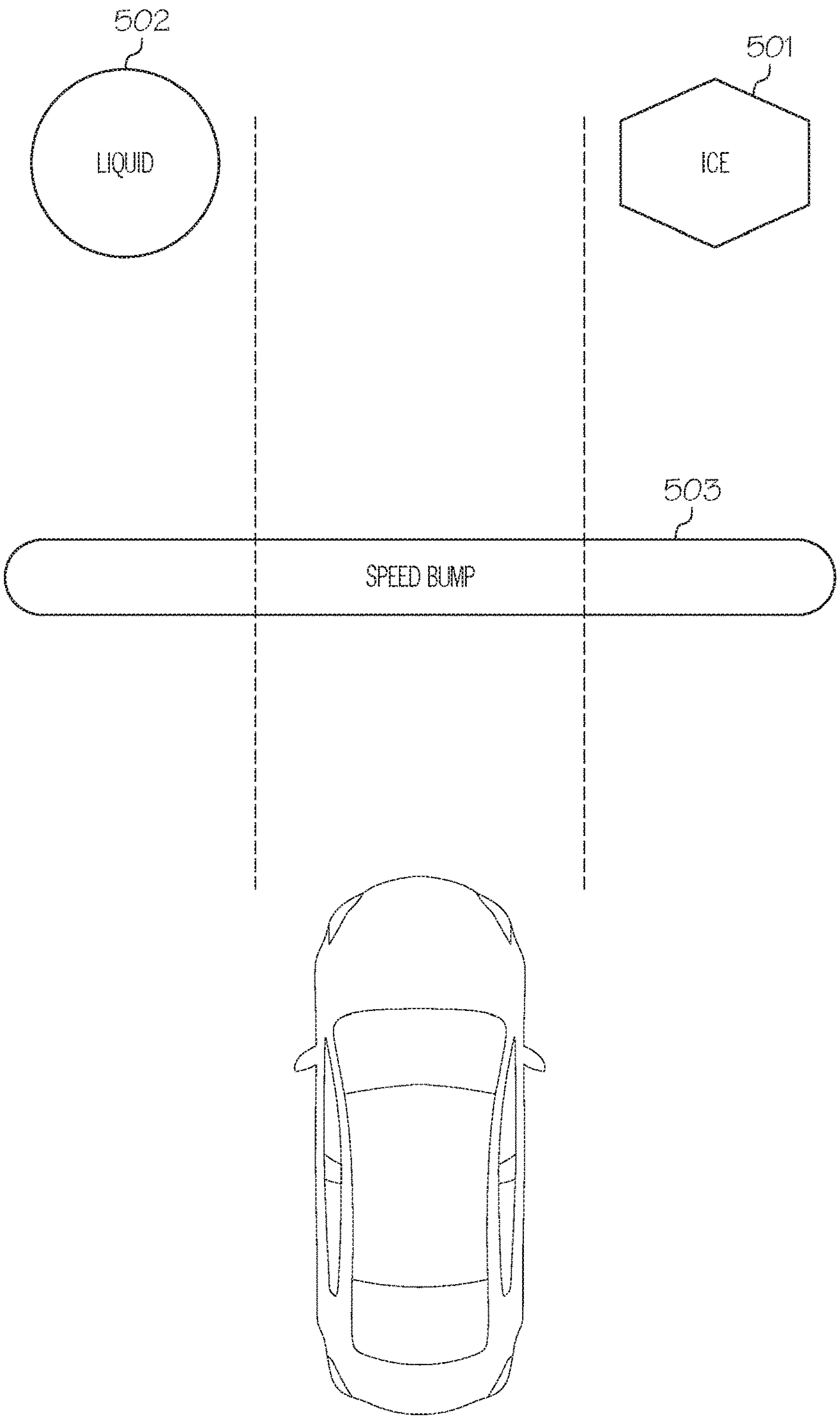

FIG. 5

VEHICLES, ELECTRONIC CONTROL UNITS, AND METHODS FOR GEAR SHIFTING BASED ON VEHICLE ATTITUDE

TECHNICAL FIELD

The present specification relates to vehicles, electronic control units, and methods for gear shifting based on vehicle attitude.

BACKGROUND

Many vehicles include an automatic transmission. Generally, an automatic transmission automatically upshifts or downshifts based upon a particular transmission schedule and vehicle load. When a vehicle enters an uphill or downhill slope, the load on the engine may increase or decrease, respectively, as the effects of gravity act on the vehicle. Accordingly, in some situations, it may be advantageous for a vehicle to shift gears depending on the grade of the terrain on which the vehicle is driving.

SUMMARY

In one embodiment, a vehicle includes an engine, a plurality of drive wheels, a vehicle transmission configured to transmit power from the engine to the plurality of drive wheels, one or more vehicle attitude sensors, and an electronic control unit communicatively coupled to the one or more vehicle attitude sensors and the vehicle transmission. The electronic control unit is configured to receive a signal from the one or more vehicle attitude sensors, determine a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors, and downshift the vehicle transmission based on the degree of vehicle descent determined based on the signal received from the one or more vehicle attitude sensors.

In another embodiment, an electronic control unit for a vehicle is configured to receive a signal from one or more vehicle attitude sensors, determine a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors, and downshift a vehicle transmission based on the degree of vehicle descent determined based on the signal received from the one or more vehicle attitude sensors.

In yet another embodiment, a method for downshifting a vehicle transmission configured to transmit power from an engine to a plurality of drive wheels includes receiving a signal from one or more vehicle attitude sensors, determining a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors, and downshifting the vehicle transmission based on the degree of vehicle descent determined based on the signal received from the one or more vehicle attitude sensors.

These and additional features provided by the embodiments described herein will be more fully understood in view of the following detailed description, in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments set forth in the drawings are illustrative and exemplary in nature and not intended to limit the subject matter defined by the claims. The following detailed description of the illustrative embodiments can be understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

FIG. **1** schematically depicts a vehicle having a transmission and an electronic control unit for automatically shifting the transmission according to one or more embodiments shown and described herein;

FIG. **2** schematically depicts a transmission shifting electronic control unit and various connected systems of the vehicle of FIG. **1**;

FIG. **3** depicts a flow chart illustrating a method of downshifting the vehicle of FIG. **1** based on a signal generated by an attitude sensor;

FIG. **4** schematically depicts the vehicle of FIG. **1** encountering various scenarios and road slopes to describe the functionality of the electronic control unit and other systems of FIG. **2**; and

FIG. **5** schematically depicts the vehicle of FIG. **1** approaching various road conditions, according to one or more embodiments shown and described herein.

DETAILED DESCRIPTION

Embodiments of the present disclosure are directed to vehicles, electronic control units, and methods for gear shifting based on vehicle attitude. On significant downhill slopes, the force of gravity may act on the vehicle to undesirably accelerate the vehicle down the slope. In this scenario, it may be advantageous to shift the engine to a lower gear (i.e., "downshift") to increase the ratio between the rotational velocity of the drive wheels and the rotational velocity of the engine so that the rotating components of the engine and drivetrain act as a load upon the drive wheels (i.e., "engine brake"). This engine braking may slow the vehicle's descent. In turn, less friction braking force may be required to slow the vehicle. In some embodiments, electronic control units may receive a signal from one or more vehicle attitude sensors, determine a degree of vehicle descent based on the signal received from one or more vehicle attitude sensors, and downshift the vehicle transmission based on the degree of vehicle descent determined based on the signal received from one or more vehicle attitude sensors, thereby resulting in less brake wear and allowing the use of smaller brake components, which reduces vehicle weight. Various embodiments of vehicles, electronic control units, and methods for gear shifting based on vehicle attitude will now be described.

FIG. **1** illustrates a portion of a vehicle **10** having a transmission **12** (for the purposes of this application, the terms "transmission" and "vehicle transmission" may be used interchangeably). Embodiments of the vehicle **10** comprise the transmission **12**, an engine **14**, an output shaft **16**, and a drive train **18** comprising one or more drive shafts **20**, one or more differentials **22**, one or more axles **24**, and one or more drive wheels **26**. The transmission **12** may be electronically coupled to and controlled by an electronic control unit (ECU) **100**.

The engine **14** may couple to various components of the drive train **18** through the output shaft **16** and the transmission **12**. The engine **14** provides rotational velocity to the transmission **12** through the output shaft **16** at a given rotational velocity (revolutions per minute ("RPM")). The engine **14** may be any type of reciprocating or rotational device, such as, for example, a gasoline-fired piston engine, a diesel engine, an electric motor, or any other device for imparting torque to rotate a shaft. As discussed below, the transmission **12** may be operable to change the ratio of the rotational velocity between the engine **14** and one or more components of the drive train **18**, such as the one or more drive wheels **26**, as the velocity of the vehicle **10** changes.

In one embodiment, the transmission **12** may be an automatic transmission commonly used in automobiles. The transmission **12** may comprise sets of discreet, selectable gears capable of being engaged to change the proportion of engine RPM to drive train RPM through the transmission **12**. In some embodiments of the transmission **12**, the gears are planetary gears, but embodiments are not so limited. Each discreet ratio between engine RPM and drive train RPM may be defined as a particular gear ratio. Some embodiments of the transmission **12** include a torque converter for shifting between consecutive gear ratios during vehicle operation. In some embodiments, the torque converter may momentarily disengage the engine **14** from the transmission **12** to permit a gear ratio change to occur. Of course, the transmission **12** may be provided with particular gear sets and gear ratios different from the embodiments described above. Furthermore, in other embodiments, other transmissions may be implemented such as a shift-assisted manual transmission, continuously variable transmissions, and the like.

As illustrated, the drive train **18** may comprise a differential **22**, a drive shaft **20** and the axles **24** for providing rotational velocity from the transmission **12** to the drive wheels **26**. In such embodiments, rotational velocity from the transmission **12** may be provided to the axles **24**, through the differential **22** and the drive shaft **20**, to the drive wheels **26**. It should be understood that such an embodiment is merely illustrative and other embodiments may be configured according to particular vehicle specifications or designs. For instance, some embodiments of the drive train **18** may comprise two differentials, two drive shafts, and four axles for providing rotational velocity from the transmission **12** to four wheels, such as on a 4-wheel-drive vehicle. Furthermore, the drive train **18** may be configured to drive any number of wheels such as six wheels (e.g., an ATV), four rear wheels (e.g., a tractor trailer), one wheel (e.g., a motorcycle) or any other number of drive wheels for driving a given vehicle. Consequently, it should also be understood that the configuration of the drive train **18** is illustrative and may be configured according to particular vehicle specifications or designs. For instance, in some vehicles, the transmission **12** may be coupled directly to the axles **24**, thereby eliminating the need for the drive shaft **20** and the differential **22**. Similarly, in some vehicles, additional transmissions may be implemented and coupled directly to the axles **24** thereby eliminating the need for the drive shafts **20** and the differentials **22**.

The engine **14** may be coupled with the transmission **12** through the output shaft **16** such that the engine **14** may rotate the output shaft **16** at a given rotational velocity to provide rotational velocity to the transmission **12**. The engine **14** may be an internal combustion engine, but other embodiments may be provided such as a steam engine, an electric motor or the like. As is common in many vehicles, a user may selectively control vehicle speed by controlling the rotational velocity of the engine **14** (e.g., varying an engine throttle). In one embodiment, the user may vary engine rotational velocity by depressing an accelerator pedal. However in other embodiments, the user may vary the rotational velocity by engaging a knob, a lever, a trigger, or any other device for enabling a user to vary engine rotational velocity. As is common in vehicles, the engine **14** may operate within a finite range of rotational velocities (e.g., 0-6,000 RPM) capable of driving a vehicle at low speeds. The transmission **12** may proportionally change the rotational velocities provided by the engine **14** by implementing the selectable gear ratios described above. In particular, the engine **14** may operate within its finite range of rotational velocities for each gear ratio such that each particular gear ratio may correspond to a particular range of vehicle speed. For instance, engine rotational velocities for a first gear ratio may provide vehicle speeds from zero to ten miles per hour (MPH), engine rotational velocities for a second gear ratio may provide vehicle speeds from ten MPH to twenty MPH, engine rotational velocities for a third gear ratio may provide vehicle speeds from twenty MPH to forty MPH, etc. It should be understood that other configurations are contemplated having any number of gear ratios, gear ratios having different ranges of speed or other gear ratio configurations suitable for corresponding engine rotational velocity to vehicle drive wheels.

In some embodiments, the transmission **12** comprises a shift controller configured to provide hydraulic pressure to the transmission **12** to select between gear ratios. As is common in transmissions, a gear ratio may be selected when a particular hydraulic pressure is achieved within the transmission **12**. The shift controller may regulate the flow of transmission media (i.e., automatic transmission fluid, transmission oil, hydraulic fluid, or the like) by controlling a shift valve to select a particular shift point. It should be understood that the example of a hydraulic shift controller is merely illustrative and other embodiments are contemplated. For instance, the shift valve may be electronically controlled. In such an embodiment, vehicle conditions may be monitored to determine whether a transmission shift is appropriate. When the logic appropriate shift point is determined (i.e., through algorithms, lookup tables stored in memory or the like), the shift valve may be controlled to regulate transmission media to shift the transmission **12**.

As a vehicle changes speeds, shift points may be selected to initiate gear ratio change(s). Shift points may be determined based upon vehicle conditions (i.e., engine rotational velocity, engine torque, vehicle speed, vehicle weight, acceleration, deceleration, environmental conditions, or road conditions and the like). Particular shift points may be assigned based upon limits associated with the conditions. When the limits of a particular condition are achieved (i.e., shift point achieved) a gear ratio change may occur. Accordingly, as used herein, a "shift" refers to a gear ratio change.

Shift points may be selected using calculation/selection methods now known or hereafter developed. In one embodiment, shift points may be calculated using predefined algorithms or programs or firmware associating shift points with particular condition limits. In another embodiment, shift points may be selected from a lookup table associating shift points with particular condition limits. In yet another embodiment, shift points may be selected from storage in one or more memory modules **113** communicatively coupled to the transmission shifting electronic control unit ("ECU") **100** (see FIG. **2**) when a particular condition limit value is achieved. Various other embodiments are contemplated wherein shift points may be based upon conditions, such as vehicle attitude, and may be calculated in manners which may comport with a particular vehicle or transmission configuration.

In one embodiment, a shift point may be determined based upon engine rotational velocity. As described above, the engine **14** may be capable of operation within a range of rotational velocities having an upper and lower limit (e.g., 0-6,000 RPM). Shift points may be assigned based upon the upper and lower engine rotational velocity limits to ensure the engine **14** operates within a given rotational velocity range during vehicle operation. For instance, a shift point may be selected for an upper rotational velocity limit where, upon reaching the particular shift point (e.g., during vehicle acceleration), a higher gear ratio may be selected and the rotational velocity of the engine **14** may be decreased (i.e., upshift) while the vehicle speed (i.e., the rotational velocity of the drive wheels) remains constant. Conversely, a shift point may be selected for a lower rotational velocity limit where, upon reaching the particular shift point (e.g., during a downhill stretch when the vehicle may accelerate without increasing the throttle position), a lower gear ratio may be selected and the rotational velocity of the engine **14** may be increased (i.e., downshift). It should be understood that upper and lower rotational velocity limits may be breached as a vehicle accelerates or decelerates. Therefore, shift points may be selected for different gear ratios to ensure proper engine operation during vehicle acceleration and deceleration.

In another embodiment, a shift point may be determined based upon vehicle speed and accelerator depression. As a vehicle operates, a user may indicate a desire to accelerate a vehicle by depressing an accelerator pedal. Since vehicle acceleration may be easier to achieve at high engine rotational velocities, a particular shift point may be assigned to allow the engine **14** to reach a high rotational velocity. For instance, substantial pedal depression may indicate a desire to quickly increase vehicle speed. A shift point may be assigned wherein gear shift is delayed and the engine **14** achieves a high rotational velocity to provide additional acceleration. Conversely, because the engine braking force may be greater when engine braking at higher engine RPM, a downshift point may be assigned wherein gear shift is hastened depending on the rate of change of vehicle attitude to provide additional engine braking force.

As used herein, the term "engine braking force" is that force which is created by retarding forces within the vehicle's engine and drive train, as opposed to other braking forces created by, for example, friction brakes, that slow the velocity of the vehicle in a direction opposite the direction of travel. This may result, for example, in gasoline engines when the accelerator is released thereby shutting one or more air intake valves, restricting airflow to the one or more pistons, and resulting in a high manifold vacuum through the intake. Other sources of engine braking force may include friction forces within the engine and drive train, such as the friction between the one or more pistons and the cylinders.

As illustrated in FIGS. **1** & **2**, the transmission shifting ECU **100** may be provided to control the transmission **12** based upon vehicle condition data (e.g., vehicle data, transmission data, environmental data, user-provided data or any other data which may support transmission control). The transmission shifting ECU **100** includes one or more memory modules **113** and one or more processors **116**.

The transmission shifting ECU **100** is communicatively coupled to the transmission **12** to provide control signals to the transmission **12**. Additionally, and as shown in FIG. **2**, the transmission shifting ECU **100** may be communicatively coupled to network interface hardware **101**, one or more attitude sensors **102**, a user preferences module **103**, a tachometer **104**, a speedometer **106**, a brake meter **108**, a GPS **110**, a transmission status relay **112**, one or more road condition sensors **118**, and one or more weather condition sensors **120** through a communication path **114**.

The transmission shifting ECU **100** may comprise one or more processors **116** to process data. Such processors may calculate shift points, control routines, optimize schemes, perform error correction, calculate protection schemes or process data in any other manner to support transmission control. Each of the one or more processors **116** of the transmission shifting ECU **100** may be any device capable of executing the logic described herein. Accordingly, each of the one or more processors **116** may be a controller, an integrated circuit, a microchip, a computer, or any other computing device. In some embodiments, each of the one or more processors **116** may be configured to execute machine-readable instructions to carry out the logic described herein. In some embodiments, at least one of the one or more processors **116** is hard coded to perform at least a portion of the logic described herein.

In one embodiment, the transmission shifting ECU **100** may calculate transmission shift points based upon vehicle condition data and may control the transmission **12** based upon such shift points. The various transmission shift points may be referred to as a "shift schedule." In another embodiment, the transmission shifting ECU **100** may provide shift inhibition routines by monitoring vehicle and environmental conditions such as braking, precipitation, temperature or wind speed to determine whether a transmission shift may cause undesirable vehicle performance, such as, for example, the engine exceeding an RPM limit. In yet another embodiment, the transmission shifting ECU **100** may control the transmission **12** by querying a user to provide information or one or more preset user preferences and controlling the transmission **12** based upon such information.

The one or more processors **116** may be communicatively coupled to the other components of the vehicle **10** through the communication path **114**. Accordingly, the communication path **114** may communicatively couple any number of processors with one another, and allow the components coupled to the communication path **114** to operate in a distributed computing environment. Specifically, each of the components may operate as a node that may send and/or receive data. As used herein, the term "communicatively coupled" means that coupled components are capable of exchanging data signals with one another such as, for example, electrical signals via conductive medium, electromagnetic signals via air, optical signals via optical waveguides, and the like.

The communication path **114** may be formed from any medium that is capable of transmitting a signal such as, for example, conductive wires, conductive traces, optical waveguides, or the like. The communication path **114** may also refer to the expanse in which electromagnetic radiation and their corresponding electromagnetic waves traverses. Moreover, the communication path **114** may be formed from a combination of mediums capable of transmitting signals. In one aspect, the communication path **114** comprises a combination of conductive traces, conductive wires, connectors, and buses that cooperate to permit the transmission of electrical data signals to components such as processors, memories, sensors, input devices, output devices, and communication devices. Accordingly, the communication path **114** may comprise a vehicle bus, such as for example a LIN bus, a CAN bus, a VAN bus, and the like. Additionally, it is noted that the term "signal" means a waveform (e.g., electrical, optical, magnetic, mechanical or electromagnetic), such as DC, AC, sinusoidal-wave, triangular-wave, square-wave, vibration, and the like, capable of traveling through a medium.

Each of the one or more memory modules **113** of the vehicle **10** is coupled to the communication path **114** and communicatively coupled to the one or more processors **116**. Each of the one or more memory modules **113** comprises non-transitory computer readable memory. The one or more memory modules **113** may comprise RAM, ROM, flash memories, hard drives, or any device capable of storing machine-readable instructions such that the machine-readable instructions can be accessed and executed by the one or more processors **116**. The machine-readable instructions may comprise logic or algorithm(s) written in any programming language of any generation (e.g., 1GL, 2GL, 3GL, 4GL, or 5GL) such as, for example, machine language that may be directly executed by the processor, or assembly language, object-oriented programming (OOP), scripting languages, microcode, etc., that may be compiled or assembled into machine-readable instructions and stored on the one or more memory modules **113**. Alternatively, the machine-readable instructions may be written in a hardware description language (HDL), such as logic implemented via either a field-programmable gate array (FPGA) configuration or an application-specific integrated circuit (ASIC), or their equivalents. Accordingly, the methods described herein may be implemented in any conventional computer programming language, as pre-programmed hardware elements, or as a combination of hardware and software components.

Embodiments of the vehicle **10** include network interface hardware **101**. The network interface hardware **101** can be communicatively coupled to the communication path **114** and can be any system or device capable of transmitting and/or receiving data. Accordingly, the network interface hardware **101** can include a communication transceiver for sending and/or receiving any wired or wireless communication. For example, the network interface hardware **101** may include an antenna, a modem, LAN port, Wi-Fi card, WiMax card, mobile communications hardware, near-field communication hardware, satellite communication hardware and/or any wired or wireless hardware for communicating with other networks and/or devices. The vehicle **10** may communicate, through the network interface hardware **101**, with a network. The network may include one or more computer networks (e.g., a personal area network, a local area network, a server network, or a wide area network), cellular networks, satellite networks and/or a global positioning system and combinations thereof. Suitable local area networks may include wired Ethernet and/or wireless technologies such as, for example, wireless fidelity (Wi-Fi). Suitable personal area networks may include wireless technologies such as, for example, IrDA, Bluetooth, Wireless USB, Z-Wave, ZigBee, and/or other near field communication protocols. Suitable personal area networks may similarly include wired computer buses such as, for example, USB and FireWire. Suitable cellular networks include, but are not limited to, technologies such as LTE, WiMAX, UMTS, CDMA, and GSM.

Embodiments of the vehicle **10** include the one or more attitude sensors **102** or other sensors for detecting a vehicle angle at least along the vehicle's direction of motion. Each of the one or more attitude sensors **102** comprises, for example, an accelerometer arrangement having three sensitive axes nominally orthogonal to each other where a signal indicative of the acceleration along each of the sensitive axes is generated by the one or more attitude sensor **102**. The accelerometer may comprise three accelerometers whose sensitive axes are not co-linear, most typically a set of three accelerometers arranged in a nominally orthogonal configuration, known as a triaxial accelerometer. In certain embodiments, the three accelerometers have a nonzero DC response such that when the sensor is at rest, the projection of the static gravitational acceleration vector onto each of the three accelerometers is measured. From these values, the pitch and roll of the attitude sensor and the magnitude of the gravitational acceleration vector can be determined. In some embodiments, only one accelerometer is used and its sensitive axis is parallel to the direction of forward or reverse motion of the vehicle **10**.

As used herein, a sensitive axis refers to the axis along which a sensor is capable of sensing and generating a signal indicative of a vector having a magnitude and direction related to acceleration along that axis. The accelerometers or other sensors of the one or more attitude sensors **102** may comprise any device capable of generating a signal in response to acceleration along a sensitive axis, such as, without limitation, a bulk micromachined capacitive accelerometer, a bulk micromachined piezoelectric resistive accelerometer, a capacitive spring mass system, a micro electro-mechanical system (MEMS), or the like. In some embodiments, the one or more attitude sensors **102** may include an inertial measurement unit, a gyroscope, a magnetometer, or the like. The one or more attitude sensors **102** are communicatively coupled via the communication path **114** to the other systems of the vehicle **10**.

In some embodiments, the one or more attitude sensors **102** comprise one or more fluid-based tilt sensors such as electrolytic tilt sensors. Electrolytic tilt sensors are mature, small, low power devices that are inherently free of bias drift. Fluid-based tilt sensors are used in a wide array of applications that demand highly repeatable tilt sensing, including seismic monitoring, avionics, construction, and solar tracking. The sensor is composed of a small container, typically made of glass, ceramic, or plastic, that houses electrically conductive fluid and a small air bubble. A number of electrodes protrude into the container, and as the sensor tilts, the air bubble moves, causing a change in impedance between the electrodes, which can be used to measure the angle of the sensor with high repeatability. Fluid-based tilt sensors may comprise one or more sensitive axes, such that the sensor measures the absolute rotational position about each sensitive axis. Fluid-based tilt sensors are available in small packages and can easily be integrated with an accelerometer onto a circuit board. Additionally, they are sensitive over limited ranges of roll and pitch.

Some embodiments of the vehicle **10** include a tachometer **104** and a speedometer **106**. The tachometer **104** and the speedometer **106** may generate one or more signals to send to the transmission shifting ECU **100** regarding the current engine RPM and the vehicle speed. Other methods of measuring engine RPM and vehicle speed may generate a similar signal, such as the GPS and/or a transmission status relay. The one or more signals generated by the tachometer **104** and the speedometer **106** may determine whether or not the transmission shifting ECU **100** shifts the transmission **12** or not, such as, if the engine RPM is above a certain level, the transmission **12** will not downshift to avoid exceeding an RPM limit.

Some embodiments of the vehicle **10** include one or more brake meters **108**. The brake meters **108** measure the force of the applied brakes and generate a signal to the transmission shifting ECU **100**. In some embodiments, the transmission shifting ECU **100** may downshift the transmission based on an applied force as measured by the brake meters **108**. Such a downshift might help slow the vehicle **10** when the brakes are being applied with a certain force. The brakes of the vehicle may be any type of vehicle brake to include rotary brakes, disc brakes, brakes by wire, electronic brakes, etc.

In some embodiments, the vehicle **10** includes a road condition sensor **118**. In some embodiments, the road condition sensor **118** includes a camera or other sensor for determining the condition of the road surrounding the vehicle. Embodiments include sensors such as SONAR, RADAR, LIDAR, and other sensors suitable for detecting a surrounding environment. The one or more road condition sensors **118** may provide information to the transmission shifting ECU **100** for determining shift points. Additionally, some embodiments of the vehicle **10** include road condition updates from the GPS **110** or some other system that is capable of updating a road conditions signal in real time as inputs to the transmission shifting ECU **100** for determining whether to adjust shift points or not.

In some embodiments of the vehicle **10**, the GPS **110** provides a location signal to the transmission shifting ECU **100**. The location signal may prevent the transmission shifting ECU **100** from downshifting the transmission **12** when the vehicle **10** is within particular geographic locations. In one non-limiting example, the user may prefer that the transmission shifting ECU **100** not downshift the vehicle **10** when the user is within X miles from the user's home. By providing the GPS with the location of the user's home and a particular radius or geographic location to prevent shifting, the user might prevent shifting of the transmission on well-known or frequently travelled routes. As another example, some geographic locations regulate the use of engine braking. Thus, these geographic locations could be provided to the GPS **110** and the GPS could generate a signal to prevent shifting the transmission when the vehicle **10** is in such a location.

Some vehicles **10** and transmission shifting ECUs **100** include weather condition sensors **120** for sensing the weather conditions surrounding the vehicle **10**. Embodiments of the vehicle **10** include barometers, thermometers, wind gauges, and other systems for determining weather conditions. In some embodiments, the transmission shifting ECU **100** may receive weather updates from the GPS **110** or some other system capable of broadcasting weather conditions. The weather condition sensors **120** may assist in determining shift points by, for example, determining whether icy road conditions exist such as to shift the transmission in order to initiate engine braking more readily.

One or more embodiments may include a transmission status relay **112**. The transmission status relay **112** may transmit information regarding the current status of the transmission **12** to the other components of the vehicle **10** such as the transmission shifting ECU **100** or the one or more processors **116**. Information regarding the current status of the transmission may include current gear ratio, current gear selected, current gear transmission status (e.g., in park (i.e., when the engine is not coupled to the transmission), in reverse, etc.) The transmission status relay **112** may prevent the transmission shifting ECU **100** from initiating engine braking if, for example, the vehicle is not in drive (for example, if the input shaft is not coupled to the transmission).

Some embodiments of the vehicle **10** allow a user to input user preferences for controlling the shift schedule or the operating characteristics of the transmission shifting ECU **100** using a user preferences module **103**. The user preferences module **103** may comprise a touchscreen, such as a center console or other console within the vehicle, or any other means for inputting preferences into the vehicle. Some embodiments of the user preferences module **103** may be smartphone based, such as an app installed on a user's smart phone for inputting user shifting preferences or other data. For example, a user might enable or disable the transmission shifting ECU **100**, or set the transmission shifting ECU **100** to automatically downshift when the vehicle is on a roadway that exceeds a certain grade. Some embodiments of the user preferences allow the user to prevent the transmission shifting ECU **100** from downshifting the transmission if a downshift would cause the engine to exceed a particular RPM or the speed of the vehicle **10** to reduce to a particular speed. In some embodiments of the system, the user may set the transmission shifting ECU **100** to downshift the vehicle **10** when the road grade exceeds a certain level. In some embodiments, the user may set the transmission shifting ECU **100** to downshift the vehicle **10** when the brake level exceeds a particular set point or if a collision detection system detects that a collision is possible. Users might set a particular sensing distance of the road condition sensors **118** or other sensors to activate the transmission shifting ECU **100** based on the output of the sensors.

Referring now to FIG. **3**, a flowchart for shifting a transmission based on vehicle attitude is shown. At block **300**, the one or more attitude sensors **102** may be calibrated based on a zero degree road slope. The calibration may enable accurate measurement of later-encountered non-zero slopes. The calibration may occur at or prior to the sale or lease of a vehicle or before reaching the end user. In some cases, the calibration may occur at some time or various times over the effective life of the vehicle. Not all embodiments of the vehicle **10** or of the one or more attitude sensors **102** will require calibration. For example, if the one or more attitude sensors **102** are calibrated before inclusion in the vehicle **10** or if the one or more attitude sensors **102** are electrolytic tilt sensors. Thus, this step may not be performed in various embodiments described herein.

As shown by block **301**, the vehicle **10** may subsequently encounter a non-zero road grade (i.e., a positive or negative road slope). Upon experiencing such a grade, the one or more attitude sensors **102** may output a signal proportional to the road slope as discussed above and shown by block **302**.

As shown by block **303**, the signal may be received by the one or more processors **116** through the communication path **114**. The one or more processors **116** may then determine the degree of vehicle descent based on the magnitude of the signal received from the one or more vehicle attitude sensors as shown by block **304**. In most cases, the determined vehicle descent will correspond with the slope of the road, and thus, the slope of the road is a factor for determining whether to downshift the vehicle to initiate engine braking or not. However, not all cases of a negative vehicle attitude will correspond with a negative road slope and so, as discussed above, the transmission shifting ECU **100** or the one or more processors **116** may receive additional inputs for determining whether or not to downshift the vehicle in order to initiate engine braking.

For example, it might be that in certain instances the vehicle **10** will encounter a negative grade but not have a positive forward velocity, such as, for example, when the vehicle is being towed, in a reverse gear, or during maintenance. During each of these examples, it is obviously not ideal for the transmission **12** to automatically downshift. Hence the additional inputs to the transmission shifting ECU **100** or one or more processors **116** such as the transmission status relay **112**, the speedometer **106**, and the GPS **110** may prevent the vehicle **10** from unnecessarily downshifting to initiate engine braking.

As shown by block **304***a*, in some embodiments, the transmission shifting ECU **100** or the one or more processors **116** may compare the degree of vehicle descent to a threshold degree of descent to determine whether to shift the transmission **12** to a lower gear or not. The threshold degree of descent may be calculated by the transmission shifting ECU **100** or the one or more processors **116**. In some embodiments the threshold degree of vehicle descent may be stored in one or more of the memory modules **113**, such as in a look up table, or may be provided by or calculated from info provided by the GPS **110** or other vehicle component. The threshold degree of vehicle descent may be based on the vehicle speed, the vehicle attitude, the weather conditions, the road slope as sensed by the one or more attitude sensors **102**, a road slope as relayed by GPS **110**, or some other means. In some embodiments, the current vehicle conditions may be compared to the expected vehicle conditions to determine if the threshold value is met or exceeded.

At block **305**, the vehicle is downshifted based on the degree of vehicle descent. This may occur by generating one or more signals using the transmission shifting ECU **100** or the one or more processors **116** and sending a signal to the transmission **12** to downshift the transmission **12**. Downshifting the transmission may increase the engine braking force thereby reducing the speed of the vehicle (i.e., decelerating) without the use of the friction brakes. Because the brakes are used less frequently and/or at a lesser magnitude, the brakes will wear less quickly resulting in a longer average life span. This may be particularly useful in hilly/mountainous areas where vehicles are routinely driven on down slopes.

In some embodiments, the transmission shifting ECU **100** or the one or more processors **116** may be configured to predict a predicted degree of vehicle descent based on the vehicle route planned into the GPS **110** or using some other method. The predicted degree of vehicle descent may be predicted from data associated with one or more routes in GPS, for example data including the slope of a road along a preplanned route in the GPS. The GPS may use maps stored in the one or more memory modules **113**, downloaded in real time, or received or stored in the vehicle **10** using some other means now known or later developed to generate the route and/or predicted degree of vehicle descent. In such embodiments, the transmission shifting ECU **100** may be configured to shift the transmission **12** when the predicted degree of vehicle descent and the measured degree of vehicle descent exceed the threshold degree of vehicle descent.

In other embodiments, vehicle road grade may be determined, calculated, or predicted using other vehicle conditions such as GPS estimated trajectory, road images from a camera, torque, shock compression, speed, fuel consumption or the like. Additionally, in other embodiments, vehicle road grade may be calculated using methods of calculation currently known in the art or later developed, such as differential equations, linear equations or the like. In some embodiments, the road slope calculation may be based upon acceleration and pedal position. For example, the GPS **110** may provide a road grade based on one or more maps that are stored in the GPS **110** or on an external server and received through the network interface hardware **101** or some other means. This GPS-provided road grade may be sent via the communication path **114** to the transmission shifting ECU **100** and used to shift the transmission **12**. In one or more embodiments, the GPS-provided road grade may be compared to the measured road grade to perform one or more functions. In embodiments of the vehicle **10** with one or more road condition sensors **118**, such as one or more cameras, the road condition sensors **118** may use one or more algorithms, such as a photographic recognition software, alone or in combination with another component of the vehicle **10**, to predict a road grade. The one or more road condition sensors **118** may send this prediction to the transmission shifting ECU **100** to compare to the measured road grade signal or to shift the transmission **12**.

In some embodiments, the transmission shifting ECU **100** may be configured to determine a vehicle speed and to compare the vehicle speed to a threshold vehicle speed. The threshold vehicle speed may be stored in one or more of the memory modules **113**, such as in a look up table, or may be provided by or calculated from info provided by the GPS **110** or some other component of the vehicle **10**. In embodiments wherein the transmission shifting ECU **100** is configured to compare the determined vehicle speed to a threshold vehicle speed, the transmission **12** of the vehicle **10** may be downshifted in response to a comparison between the determined vehicle speed and the threshold vehicle speed. For instance, the transmission shifting ECU **100** may receive an input from the speedometer **106** or the tachometer **104** and the transmission status relay **112** to determine a vehicle speed. In some embodiments, the GPS **110** may send a signal to the transmission shifting ECU **100** that includes vehicle speed. If the transmission shifting ECU **100** determines that vehicle speed exceeds a threshold, programmed, or otherwise desired vehicle speed based on transmission shifting preferences for a given road grade, measured or otherwise, the transmission shifting ECU **100** may shift the transmission **12**.

In some embodiments, the transmission shifting ECU **100** may be configured to calculate a predicted rotational velocity of the engine after a downshift, such as when the vehicle **10** initiates engine braking, based on the various gear ratios, present vehicle speed, present road grade, and other conditions that effect the rotational velocity of the engine. In such embodiments, the transmission shifting ECU **100** may compare the predicted rotational velocity of the engine to a threshold rotational velocity of the engine. The threshold rotational velocity may be stored in one or more of the memory modules **113**, such as in a look up table, or may be provided by or calculated from info provided by some other component or components of the vehicle **10**. In some embodiments, the transmission shifting ECU **100** may prevent a shift of the transmission **12** if the predicted rotational velocity of the engine is too high, such as if it would exceed a limit. Additionally, the predicted rotational velocity of the engine might be used to calculate a predicted decrease in vehicle speed after the shift. The transmission shifting ECU **100** may receive a signal from the brake meter **108** via the communication path **114** to determine such a decrease in speed. The decrease in speed could be used to calculate a resulting speed after the shift, which might be useful, such as, in embodiments having a user preferences module **103**. The information might help users set their preferences for a given road grade and vehicle speed.

In some embodiments, the transmission shifting ECU **100** is configured to predict a predicted degree of vehicle descent based on the vehicle route and to downshift the transmission **12** if the determined degree of vehicle descent exceeds a threshold value and matches the predicted degree of vehicle descent. The predicted degree of vehicle descent may be generated by the GPS **110** or some other component of the vehicle **10** and be based on one or more maps associated with one or more vehicle routes. For example, a user may input an intended route into the GPS **110** to travel from point A to point B. The GPS **110** or the transmission shifting ECU **100** or some other appropriate component might predict one or more grades along the planned route. As the user drives the route, the GPS **110** may send a signal to the transmission shifting ECU **100** of the road grade and the transmission shifting ECU **100** may shift the transmission when that signal exceeds the threshold shifting signal. The threshold shifting signal may be set by the user using the user preferences module **103**. In some embodiments, the GPS **110** may only send a signal to the transmission shifting ECU **100** when the threshold signal is exceeded.

In some embodiments, the transmission shifting ECU **100** is configured to determine a weather condition and a road condition and to downshift the transmission **12** based on, at least in part, the determined degree of vehicle descent, the weather condition, and/or the road condition. The weather condition may be generated by the vehicle **10**, such as by the weather condition sensor **120** or be received by the vehicle by a component such as the GPS **110**. Similarly, the road condition may be sensed and a signal generated by a component of the vehicle, such as the road condition sensor **118**, or received by a component such as the GPS **110**. For example, a user may desire to be limited to a certain speed when a road is wet or covered in precipitation. The user may use the user preferences module **103** to set various set points based on weather conditions such that the user preferences module **103** sends a signal to the transmission shifting ECU **100** when the road is wet as sensed by the one or more road condition sensors **118**. Similarly, the one or more road condition sensors **118** may detect gravel or other foreign objects on the road and shift to a predefined lower threshold for shifting the transmission to ensure that the transmission **12** downshifts appropriately to maintain vehicle speed below user-defined limits.

In some embodiments, the vehicle **10** may determine a rate of change of vehicle attitude and determine whether to shift the transmission based upon the rate of change of vehicle attitude. For example, in certain instances, the vehicle attitude may decrease rapidly and subsequently slowly return to zero, such as when the road grade has a relatively large magnitude negative slope and then slowly begins to level off again. In such cases, a downshift may not be advantageous because the vehicle may be past the relatively large magnitude of negative road grade before the vehicle shifts gears. In such a case, the vehicle **10** may not downshift because, while the instantaneous degree of attitude may temporarily exceed a threshold value, the attitude will not exceed the threshold value for long. Based on the slope getting less negative in magnitude, the transmission shifting ECU **100** may withhold a signal to shift the transmission to initiate engine braking. Similarly, the transmission shifting ECU **100** may have one or more filters to filter out instantaneous, erroneous, or erratic signals that are erroneous or so temporally short that they do not merit a shift to a lower gear to initiate engine braking. The filter may be a component of the transmission shifting ECU **100** or some other component of the system. The filter may be adjustable, such as, for example, by setting a user preference of the system.

FIG. **4** shows a vehicle approaching a stretch of road having different slopes illustrated by sections **401**-**405** of the road. The vehicle **10** may include a transmission shifting ECU **100** configured to perform the engine braking functions as described herein. Of course, FIG. **4** is meant to demonstrate only one example of the infinite number of possible grades along different routes. The purpose is to demonstrate how the system works.

At section **401**, the vehicle is on a flat section of road. The transmission shifting ECU **100** is configured to simply allow the transmission to operate normally. The shift settings of the transmission **12** are unaffected. However, as the vehicle **10** approaches section **402**, the vehicle may downshift the transmission when the vehicle **10** senses the negative slope. In some embodiments, the GPS **110** may predict the upcoming road slope and generate a signal to the transmission shifting ECU **100** regarding the slope. In these embodiments, the vehicle **10** may shift the transmission **12** when the predicted slope is confirmed by the one or more attitude sensors **102**. In this way, the one or more attitude sensors **102** can serve as a check on the GPS **110** and prevent unnecessary shifts of the transmission in the case of faulty or erroneous map data. Additionally, the transmission shifting ECU **100** may generate a signal to downshift the transmission **12** in preparation for the negative slope of section **402** while the vehicle **10** is still in section **401**, shifting the transmission **12** to slow the vehicle **10** to at least partially preempt the effects of gravity that will accelerate the car down the negative slope.

As the vehicle **10** reaches section **403**, the signal generated by the one or more attitude sensors **102** in proportion to the magnitude of the down slope dissipates and the transmission **12** shifts back to its normal gear for the given speed and acceleration. This may happen in a number of ways, for example, the transmission shifting ECU **100** may send a signal to shift the transmission **12** to a higher gear. Conversely, the transmission shifting ECU **100** may simply stop sending a signal to the transmission **12** to downshift the transmission.

Sections **404*a*** and **404*b*** further illustrate the functionality of the system. Section **404*a*** has a noticeably larger negative slope than section **404*b***. Along the length of section **404*a***, one or more portions may have an instantaneous slope of which the magnitude may exceed the magnitude at which point the vehicle would downshift the transmission to initiate engine braking. However, in the example shown, section **404*a*** is a relatively short portion of road. Because section **404*a*** is followed by a section **404*b*** with a relatively smaller magnitude slope, and because no instantaneous slope of section **404*b*** is large enough to trigger a downshift, the transmission **12** may not downshift. In this example, the GPS **110** may send a signal to the transmission shifting ECU **100** to indicate that the magnitude of the negative slope will decrease before the vehicle reaches section **404*a*** or while the vehicle **10** is in section **404*a***. This signal may effectively acknowledge that a downshift would only need to be immediately followed by an up shift and so would be largely ineffective at slowing the speed of the vehicle **10**, so would only result in unnecessary shifting of the transmission.

Regardless of whether the vehicle **10** performs the transmission shifts as described above, at section **405**, as the vehicle **10** again levels off, the transmission will shift back to its normal shift schedule given a desired speed and acceleration.

FIG. **5** shows the vehicle **10** encountering various external conditions that may or may not cause an initiation of engine braking as described herein, for example, ice **501**. A single instance of ice along a roadway may indicate that other instances are possible as an instance of ice generally coincides with temperatures at or below freezing. Such conditions may require precautions such as limitations to speed. One way to limit speed is engine braking and so when external sensors, such as cameras or thermometers, detect conditions that are amenable to ice, the sensors may generate a signal to send to the transmission shifting ECU **100** causing the transmission shifting ECU **100** to shift the transmission to initiate engine braking.

Similarly, various sensors of the vehicle **10** may be configured to detect the presence of liquid **502**, such as water or oil, on the roadway. As described above, the sensors may detect rain, moisture, humidity, or any other type of liquid in the air or on the ground. As with driving on an icy road, a prudent driver might reduce speed to better handle a wet road. The transmission shifting preferences described herein can be entered such that an automatic downshift will result more readily given the detection of liquid on the road. All things being equal, this will result to more engine braking under wet conditions and thus lower vehicle speeds and less wear on friction brakes and other braking systems.

Also shown in FIG. **5** is a speed bump **503**. Speed bump **503** illustrates one possible source of erroneous readings for the gear shifting system described herein. Generally, four-wheeled vehicles will pass over a speed bump **503** one axle at a time. That is, the front wheels will climb and descend the speed bump and then the rear wheels will climb and descend the speed bump. Generally, when the rear wheels are on the speed bump and the front wheels are not, the vehicle will have a negative grade, that is, the rear wheels will be above front wheels and the vehicle will tilt forward. But embodiments of the transmission shifting system can avoid such erroneous results, such as, for example, by requiring a larger magnitude degree of vehicle descent prior to initiating the downshift, by filtering signals from the attitude sensors that are less than a certain magnitude, or by any other appropriate method.

Embodiments of the present disclosure are directed to vehicles, electronic control units, and methods for gear shifting based on vehicle attitude. In some embodiments, electronic control units may receive a signal from one or more vehicle attitude sensors, determine a degree of vehicle descent based on the signal received from one or more vehicle attitude sensors, and downshift the vehicle transmission based on the degree of vehicle descent determined based on the signal received from one or more vehicle attitude sensors, thereby resulting in less brake wear and allowing the use of smaller brake components, which reduces vehicle weight.

It is noted that the terms "substantially" and "about" may be utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. These terms are also utilized herein to represent the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue.

While particular embodiments have been illustrated and described herein, it should be understood that various other changes and modifications may be made without departing from the spirit and scope of the claimed subject matter. Moreover, although various aspects of the claimed subject matter have been described herein, such aspects need not be utilized in combination. It is therefore intended that the appended claims cover all such changes and modifications that are within the scope of the claimed subject matter.

What is claimed is:

1. A vehicle comprising:

an engine;

a plurality of drive wheels;

a vehicle transmission configured to transmit power from the engine to the plurality of drive wheels;

one or more vehicle attitude sensors; and

an electronic control unit communicatively coupled to the one or more vehicle attitude sensors and the vehicle transmission, wherein the electronic control unit is configured to:

receive a signal from the one or more vehicle attitude sensors;

determine a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors;

predict a predicted degree of vehicle descent based on a vehicle route; and

downshift the vehicle transmission when the predicted degree of vehicle descent and the determined degree of vehicle descent exceed a threshold degree of vehicle descent.

2. The vehicle of claim **1**, wherein the electronic control unit is further configured to:

determine a vehicle speed;

compare the determined vehicle speed to a threshold vehicle speed; and

downshift the vehicle transmission in response to comparing the determined vehicle speed to the threshold vehicle speed.

3. The vehicle of claim **1**, wherein the electronic control unit is further configured to:

calculate a predicted rotational velocity of the engine after the downshift;

compare the predicted rotational velocity of the engine to a threshold rotational velocity of the engine; and

downshift the vehicle transmission in response to comparing the predicted rotational velocity of the engine to the threshold rotational velocity of the engine.

4. The vehicle of claim **1**, wherein the electronic control unit is further configured to:

downshift the vehicle transmission when the determined degree of vehicle descent matches the predicted degree of vehicle descent.

5. The vehicle of claim **1**, wherein the electronic control unit is further configured to:

determine at least one of a weather condition and a road condition; and

downshift the vehicle transmission based on the determined degree of vehicle descent and the determined at least one of the weather condition and the road condition.

6. An electronic control unit for a vehicle, wherein the electronic control unit of the vehicle is configured to:

receive a signal from one or more vehicle attitude sensors;

determine a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors;

predict a predicted degree of vehicle descent based on a vehicle route; and

downshift a vehicle transmission when the predicted degree of vehicle descent and the determined degree of vehicle descent exceed a threshold degree of vehicle descent.

7. The electronic control unit of claim **6** further configured to:

determine a vehicle speed;

compare the determined vehicle speed to a threshold vehicle speed; and

downshift the vehicle transmission in response to comparing the determined vehicle speed to the threshold vehicle speed.

8. The electronic control unit of claim **6** further configured to:

calculate a predicted rotational velocity of an engine after the downshift;

compare the predicted rotational velocity of the engine to a threshold rotational velocity of the engine; and

downshift the vehicle transmission in response to comparing the predicted rotational velocity of the engine to the threshold rotational velocity of the engine.

9. The electronic control unit of claim **6** further configured to:

downshift the vehicle transmission when the determined degree of vehicle descent matches the predicted degree of vehicle descent.

10. The electronic control unit of claim **6** further configured to:

determine at least one of a weather condition and a road condition; and

downshift the vehicle transmission based on the determined degree of vehicle descent and the determined at least one of the weather condition and the road condition.

11. A method of downshifting a vehicle transmission configured to transmit power from an engine to a plurality of drive wheels, the method comprising:

receiving a signal from one or more vehicle attitude sensors;

determining a degree of vehicle descent based on the signal received from the one or more vehicle attitude sensors;

predicting a predicted degree of vehicle descent based on a vehicle route; and

downshifting the vehicle transmission when the predicted degree of vehicle descent and the determined degree of vehicle descent exceed a threshold degree of vehicle descent.

12. The method of claim **11**, further comprising:

determining a vehicle speed;

comparing the determined vehicle speed to a threshold vehicle speed; and

downshifting the vehicle transmission in response to comparing the determined vehicle speed to the threshold vehicle speed.

13. The method of claim **11**, further comprising:

calculating a predicted rotational velocity of the engine after the downshift;

comparing the predicted rotational velocity of the engine to a threshold rotational velocity of the engine; and

downshifting the vehicle transmission in response to comparing the predicted rotational velocity of the engine to the threshold rotational velocity of the engine.

14. The method of claim **11**, further comprising:

downshifting the vehicle transmission when the determined degree of vehicle descent matches the predicted degree of vehicle descent.

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