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Adjustable performance for a vehicle

Abstract

A recreational vehicle includes a seatbelt sensor configured to detect when a seatbelt is in an engaged position or a disengaged position and an engine control module in communication with the seatbelt sensor to automatically limit a maximum speed of the vehicle to a reduced maximum speed limit upon detection of the seatbelt is in the disengaged position.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 16/111,892, filed on Aug. 24, 2018, which is a continuation of U.S. patent application Ser. No. 14/571,847, filed on Dec. 16, 2014, which is a continuation of U.S. patent application Ser. No. 13/153,037, filed on Jun. 3, 2011, which claims the benefit of U.S. Provisional Patent Application No. 61/396,817, filed on Jun. 3, 2010, the disclosures of which are expressly incorporated by reference herein.

BACKGROUND AND SUMMARY

(1) The present disclosure relates to electronic throttle control, and more particularly to an electronic throttle control system for recreational and utility vehicles.

(2) In recreational vehicles such as all-terrain vehicles (ATV's), utility vehicles, motorcycles, etc., a mechanical assembly is typically used for controlling the operation of the throttle valve. While many automotive applications utilize electronic throttle control for controlling throttle plate movement, on- and off-road recreational vehicles often link the throttle operator (e.g. thumb lever, twist grip, or foot pedal) directly to the throttle valve via a mechanical linkage such as a cable. As such, separate mechanical devices are necessary for controlling engine idle speed, limiting vehicle speed and power, and setting cruise control.

(3) Recreational vehicles are used for various applications such as navigating trails, pulling loads, plowing, hauling, spraying, mowing, etc. With mechanically controlled throttle valves, the throttle response is often jumpy or hard to control for applications such as plowing or hauling. The throttle valve may open too quickly or too slowly in response to corresponding movement of the throttle operator, resulting in an undesirable torque output at various positions of the throttle operator. In mechanically controlled throttle valves, manually adjusting the rate the throttle valve opens in response to movement of the throttle operator is cumbersome and/or impracticable.

(4) In one exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine, and an engine control module is configured to control the throttle valve. An operator input device is in communication with the engine control module for controlling a position of the throttle valve. A drive mode selection device in communication with the engine control module selects one of a plurality of drive modes, and the plurality of drive modes provide variable movement of the throttle valve in response to a movement of the operator input device.

(5) In another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine, and an engine control module is configured to control the throttle valve. An operator input device is in communication with the engine control module, and the engine control module controls an opening of the throttle valve based on the operator input device. An idle speed control device in communication with the engine control module selects an idle speed of the engine and provides a signal representative of the selected idle speed to the engine control module. The engine control module controls the throttle valve to substantially hold the engine at the selected idle speed.

(6) In yet another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate engine power, and an engine control module is configured to control the throttle valve. A throttle input device is in communication with the engine control module. A location detection device in communication with the engine control module is configured to detect a location of the vehicle. The location detection device is configured to provide a signal to the engine control module representative of the detected location of the vehicle, and the engine control module automatically controls the throttle valve to limit the vehicle speed based on the detected location of the vehicle.

(7) In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate engine power, and a user interface is configured to receive a security code. An engine control module in communication with the user interface is configured to control the throttle valve, and the engine control module is configured to receive the security code from the user interface. A location detection device in

communication with the engine control module is configured to detect a location of the vehicle. The engine control module automatically limits a torque output of the engine upon the security code being received at the engine control module and upon the detected location of the vehicle being outside a predetermined area.
(8) In another exemplary embodiment of the present disclosure, an electronic throttle control method is provided for a vehicle. The method includes the step of providing an engine, a throttle valve configured to control a torque output of the engine, and an engine control module configured to control the throttle valve. The method further includes monitoring at least one of a vehicle speed and an engine speed and receiving a request associated with a maximum vehicle speed. The method includes limiting the vehicle to the maximum vehicle speed upon the at least one of the vehicle speed and the engine speed being less than or equal to a threshold speed. The method further includes limiting the vehicle to a default maximum vehicle speed upon the at least one of the vehicle speed and the engine speed being greater than the threshold speed.
(9) In yet another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. The engine is configured to drive the ground engaging mechanism. A suspension system is coupled between the chassis and the ground engaging mechanism. The vehicle includes at least one of a speed sensor and a position sensor. The speed sensor is configured to detect a speed of the vehicle, and the position sensor is configured to detect a height of the suspension system. A throttle valve is configured to regulate engine power. An engine control module is configured to control the throttle valve. The engine control module is further configured to detect an airborne state of the vehicle and a grounded state of the vehicle based on at least one of the detected speed of the vehicle and the detected height of the suspension system. The engine control module reduces the speed of the vehicle to a target speed upon detection of the airborne state, and the target speed is based on a speed of the vehicle when the vehicle is in the grounded state.
(10) In still another exemplary embodiment of the present disclosure, an electronic throttle control method is provided for a vehicle. The method includes the step of providing an engine, a ground engaging mechanism driven by the engine, a throttle valve configured to control a torque output of the engine, and an engine control module configured to control the throttle valve. The method further includes observing a speed of the vehicle and detecting an airborne state of the vehicle based on an acceleration rate of the vehicle. The acceleration rate is based on the observed speed of the vehicle. The method further includes reducing the torque output of the engine upon detection of the airborne state of the vehicle to reduce the speed of the vehicle to a target speed, the target speed being substantially the same as a speed of the vehicle observed prior to the detection of the airborne state.
(11) In another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a plurality of ground engaging mechanisms configured to support the chassis, and a drive train supported by the chassis. The drive train includes an engine, a transmission, and a final drive. The engine is configured to drive at least one ground engaging mechanism. The drive train includes a first drive configuration wherein the engine drives at least two of the ground engaging mechanisms and a second drive configuration wherein the engine drives at least four of the ground engaging mechanisms. The vehicle further includes at least one sensor configured to detect a parameter of the vehicle and a throttle valve configured to regulate engine power. An engine control module is configured to control the throttle valve. The engine control module is further configured to detect an airborne state of the vehicle based on the detected parameter of the vehicle. The drive train is modulated from the second drive configuration to the first drive configuration upon detection of the airborne state of the vehicle.
(12) In yet another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a plurality of ground engaging mechanisms configured to support the

chassis, and a drive train supported by the chassis. The drive train includes an engine, a transmission, and a final drive. The engine is configured to drive at least one ground engaging mechanism. The vehicle includes a first sensor configured to detect a parameter of the vehicle and a second sensor configured to detect an inclination angle of the vehicle. The vehicle includes a throttle valve configured to regulate engine power. The vehicle further includes an engine control module configured to control the throttle valve. The engine control module is configured to detect an airborne state of the vehicle based on the detected parameter of the vehicle. The engine control module adjusts the torque of the engine upon detection of the airborne state and upon the detected inclination angle of the vehicle being outside a predetermined range. The adjustment of a torque of the engine is configured to adjust the inclination angle of the vehicle to within the predetermined range.

(13) In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine. An engine control module is configured to control an opening of the throttle valve. An operator input device is in communication with the engine control module. The engine control module is configured to control the opening of the throttle valve based on the operator input device. The vehicle further includes a transmission driven by the engine and including a first gear and a second gear. The engine control module opens the throttle valve at a slower rate in the first gear than in the second gear based on a movement of the operator input device.

(14) In another exemplary embodiment of the present disclosure, a vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine. An engine control module is configured to control an opening of the throttle valve. An operator input device is in communication with the engine control module. The engine control module is configured to control the opening of the throttle valve based on the operator input device. The vehicle further includes a load detection device configured to detect a load of the vehicle. The engine control module opens the throttle valve at a first rate based on a movement of the operator input device when the detected load is within a predetermined range and at a second rate based on the movement of the operator input device when the detected load is outside the predetermined range. The first rate is faster than the second rate.

(15) In yet another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine, and the engine generates a torque based on an opening of the throttle valve. An engine control module is configured to control the throttle valve. An operator input device is in communication with the engine control module. The engine control module is configured to control the opening of the throttle valve based on a position of the operator input device. The vehicle further includes a transmission driven by the engine and including a first gear and a second gear. The engine control module automatically reduces the torque of the engine during a shift of the transmission between the first gear and the second gear.

(16) In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a plurality of traction devices configured to support the chassis, and a drive train supported by the chassis. The drive train includes an engine, a transmission, and a final drive. The engine is configured to drive at least a portion of the plurality of traction devices. The drive train includes a first drive configuration wherein the engine drives at least two of the traction devices and a second drive configuration wherein the engine drives at least four of the traction devices. The vehicle further includes a throttle valve configured to regulate engine power and an engine control module configured to control the throttle valve. An operator input device is in communication with the engine control module, and the engine control module is configured to

control the throttle valve based on a position of the operator input device. The engine control module automatically reduces a torque of the engine during a modulation of the drive train between the first drive configuration and the second drive configuration.

(17) In another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine, and the engine generates a torque based on an opening of the throttle valve. An engine control module is configured to control the throttle valve. An operator input device is in communication with the engine control module. The engine control module is configured to control the opening of the throttle valve based on a position of the operator input device. The vehicle further includes an altitude sensor in communication with the engine control module. The altitude sensor is configured to detect an altitude of the vehicle. The engine control module limits the opening of the throttle valve to a first maximum opening upon the vehicle being positioned at a first altitude and to a second maximum opening upon the vehicle being positioned at a second altitude higher than the first altitude. The first maximum opening is different from the second maximum opening.

(18) In yet another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. A throttle valve is configured to regulate air intake into the engine, and the engine generates power based on an opening of the throttle valve. An engine control module is configured to control the throttle valve. An operator input device is in communication with the engine control module. The engine control module is configured to control the opening of the throttle valve based on a position of the operator input device. The vehicle further includes a continuously variable transmission coupled to the engine. The engine is configured to apply a torque to the continuously variable transmission. The engine control module monitors the torque applied to the continuously variable transmission based on at least one of the position of the operator input device and the opening of the throttle valve. The engine control module limits the torque applied to the continuously variable transmission to within a predetermined torque range.

(19) In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and a drive train supported by the chassis. The drive train includes an engine, a transmission, and a final drive. The vehicle includes a throttle valve configured to regulate engine power and a throttle input device configured to adjust the throttle valve. An engine control module is in communication with the throttle input device and the throttle valve. The engine control module automatically controls the throttle valve to provide a torque to the drive train during an idle condition of the engine.

(20) In another exemplary embodiment of the present disclosure, a recreational vehicle is provided including a chassis, a ground engaging mechanism configured to support the chassis, and an engine supported by the chassis. The vehicle includes a speed sensor configured to detect a speed of the vehicle and a safety device configured to support the operator. The safety device is adjustable between an engaged position and a disengaged position. The vehicle includes a throttle valve configured to regulate engine power and a throttle input device configured to control the throttle valve. The vehicle further includes an engine control module in communication with the throttle valve, the safety device, and the speed sensor. The engine control module automatically reduces a torque of the engine upon detection of the safety device being in the disengaged position and upon the detected speed of the vehicle being outside a predetermined range.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a block diagram illustrating an exemplary electronic throttle control system according to one embodiment;

(2) FIG. **2** is a perspective view illustrating an exemplary vehicle incorporating the electronic throttle control system of FIG. **1**;

(3) FIG. **3** is a block diagram illustrating the exemplary vehicle of FIG. **2**;

(4) FIG. **4** is a block diagram illustrating an exemplary configuration of the electronic throttle control system of FIG. **1**;

(5) FIG. **5** is a block diagram illustrating an exemplary drive mode selection device of FIG. **1**;

(6) FIG. **6**A is a graph illustrating a throttle plate position versus a throttle control position in an exemplary normal drive mode;

(7) FIG. **6**B is a graph illustrating a throttle plate position versus a throttle control position in an exemplary plow drive mode;

(8) FIG. **6**C is a graph illustrating a throttle plate position versus a throttle control position in an exemplary work drive mode;

(9) FIG. **6**D is a graph illustrating a throttle plate position versus a throttle control position in an exemplary sport drive mode;

(10) FIG. **7** is a block diagram illustrating an exemplary communication network for the electronic throttle control system of FIG. **1**;

(11) FIGS. **8**A-**8**C are flow charts illustrating an exemplary method of implementing a maximum vehicle speed; and

(12) FIG. **9** is a block diagram illustrating an exemplary maximum speed device of the electronic throttle control system of FIG. **1**.

(13) Corresponding reference characters indicate corresponding parts throughout the several views. The exemplification set out herein illustrates embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE DRAWINGS

(14) The embodiments disclosed herein are not intended to be exhaustive or limit the disclosure to the precise forms disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings.

(15) Referring initially to FIG. **1**, an exemplary electronic throttle control (ETC) system **10** is illustrated for controlling an engine **38** of a recreational vehicle. ETC system **10** includes an engine control module (ECM) **12** in communication with various input devices and sensors for controlling the operation of engine **38**. ETC system **10** may be used to control the engine of any on- or off-road recreational vehicle, such as an ATV, a motorcycle, a utility vehicle, a side-by-side vehicle, a watercraft, and a tracked vehicle, for example. ETC system **10** may also be used to control the engine of an agricultural vehicle or other work vehicle. An exemplary vehicle **100** that incorporates the ETC system **10** of the present disclosure is illustrated in FIG. **2**. Vehicle **100** includes a chassis **110**, a front end **116**, and a rear end **118**. A body portion **124** is supported by the chassis **110**. Front wheels **102** and rear wheels **104** support chassis **110**, although other suitable ground engaging mechanisms may be provided. A front suspension system **120** includes one or more front shock absorbers **112**, and a rear suspension system **122** includes one or more rear shock absorbers **114**. Vehicle **100** further includes a straddle-type seat **106** and a handlebar assembly **108** for steering front wheels **102**.

(16) As illustrated in FIG. **3**, a drive train **60** of vehicle **100** includes engine **38** coupled to a transmission **62**. Transmission **62** may be an automatic or a manual transmission **62**. In one embodiment, a continuously variable transmission (CVT) **62** is provided. A gear selector **88** is provided at user interface **48** for selecting the transmission gear. In one embodiment, gear selector **88** selects between a low gear, a high gear, and a reverse gear, although additional or fewer

transmission gears may be provided.
(17) A pressure sensor **138** in communication with ECM **12** is provided to detect the pressure or suction in a manifold **136** of engine **38**. Based on the detected pressure with sensor **138**, ECM **12** may determine the torque or power output of engine **38**. In particular, ECM **12** calculates the torque output of engine **38** based on the position of throttle control **16** and/or the position of throttle valve **34**, the detected engine speed, and the detected manifold pressure in engine **38**. Based on these inputs, ECM **12** is configured to calculate the instantaneous torque or power output of engine **38**. The amount of fuel injected into or received by engine **38** and the timing of the spark plugs may also contribute to the calculation of engine torque. In one embodiment, the wheel speed measured by wheel speed sensors **30** (FIG. **1**) is further considered in determining engine power.
(18) Power supplied from engine **38** is transferred through transmission **62** to a drive shaft and/or final drive **64** and to wheels **102** and/or wheels **104**. Vehicle **100** may be a four-wheel drive or a two-wheel drive vehicle, although other wheel configurations may be provided. Brakes **66**, **68** are mechanically or hydraulically controlled, and ECM **12** is in communication with the hydraulic/mechanical braking system. In one embodiment, ECM **12** is configured to individually control front brakes **66** and rear brakes **68**. For example, ECM **12** includes anti-lock braking (ABS) and traction control (TCS) functionality, as described herein. Vehicle **100** further includes power steering **70** for steering front wheels **102**. Exemplary power steering **70** includes a hydraulic system configured to assist with steering wheels **102** upon actuation by an operator. Power steering **70** may alternatively include an electric motor or other suitable system providing steering assist. ECM **12** is illustratively in communication with power steering **70**.
(19) Referring again to FIG. **1**, ECM **12** is an electronic controller configured to receive and process electrical signals provided by the input devices and sensors of ETC system **10** to control engine **38**. ECM **12** includes a processor **13** and a memory **15** accessible by processor **13**. Software stored in memory **15** contains instructions for operating ETC system **10**. Memory **15** further stores sensor feedback and results from calculations performed by processor **13**. In the illustrated embodiment, ETC system **10** is configured to control engine idle speed, control maximum vehicle speed, limit engine power upon the occurrence of a specified event, control vehicle ground speed, protect drivetrain components, provide selectable drive modes, and perform other operations involving throttle control. In the illustrated embodiment, ETC system **10** is configured for use with a fuel-injected engine **38**, although other engine types may be provided.
(20) ECM **12** controls movement of a throttle valve assembly **34** based on signals provided to ECM **12** by a throttle input device **14**. As illustrated in FIG. **1**, throttle valve assembly **34** includes a throttle body **35** and a throttle plate **36**. Throttle body **35** may be either a single bore or dual bore type depending on the engine configuration. Adjustment of the throttle plate **36** within throttle body **35** regulates the flow of air into engine **38** to control the speed and power of engine **38** and consequently the speed of the vehicle. In one embodiment, throttle valve assembly **34** is a butterfly valve. A throttle actuator **32** controlled by ECM **12** is coupled to throttle valve assembly **34** for adjusting the position of throttle plate **36** and therefore the air intake into engine **38**. In one embodiment, throttle actuator **32** is a servo motor. In the illustrated embodiment, one or more throttle position sensors **40** coupled to throttle plate **36** detect the position of throttle plate **36** and provide a signal representative of the detected position to ECM **12**. Alternatively, the servo motor of throttle actuator **32** may provide position feedback to ECM **12**. ECM **12** uses the position feedback to control throttle valve assembly **34**.
(21) Throttle input device or throttle operator **14** in electrical communication with ECM **12** is used by an operator to control the operation of throttle valve assembly **34**. Throttle input device **14** includes a throttle control **16** coupled to or positioned in proximity to a position sensor **18**. An exemplary throttle control **16** includes a foot pedal, a twist grip, a thumb or finger lever, or any other suitable device configured to receive input from the operator for adjustment of throttle valve assembly **34**. Position sensor **18** detects movement of throttle control **16** and provides a signal

representative of the position of throttle control **16** to ECM **12**. In response, ECM **12** provides a corresponding throttle plate position command to throttle actuator **32** to cause throttle actuator **32** to adjust the throttle plate position of throttle valve assembly **34** based on the interpreted position of throttle control **16**. As such, the speed and torque of engine **38** is controlled electronically based on the output of throttle input device **14** and ECM **12**. Position sensor **18** may be a potentiometer or a magnetic sensor, for example. In one embodiment, multiple position sensors **18** are used to detect the position of throttle control **16**.

(22) ECM **12** communicates with components on ETC system **10**, such as throttle actuator **32** and throttle input device **14**, using any suitable communication protocol. In one embodiment, controller area network (CAN) protocol is utilized for communication between components on ETC system **10**. Other exemplary communication protocols for communication between components of ETC system **10** include time-triggered protocol (TTP) and FlexRay protocol. In the exemplary embodiment of FIG. **4**, ETC system **10** includes CAN wires **90** electrically coupling ECM **12** to throttle input device **14** and throttle actuator **32**. Other components of ETC system **10**, such as idle speed control device **20**, maximum speed device **22**, ground speed control device **24**, and drive mode selection device **26**, for example, may also communicate with ECM **12** via CAN wires.

(23) ETC system **10** includes an engine speed sensor **28** and a wheel speed sensor **30** in communication with ECM **12**. Engine speed sensor **28** provides a feedback signal to ECM **12** representative of the rotational speed of engine **38**. ECM **12** calculates the rotational speed of engine **38** based on feedback provided by engine speed sensor **28**. Wheel speed sensor **30** provides a feedback signal to ECM **12** representative of the wheel speed of the recreational vehicle, such as the speed of wheels **102** and/or wheels **104** of vehicle **100** (see FIG. **2**), for example. In one embodiment, a wheel speed sensor **30** is coupled to each wheel **102**, **104** for measuring individual wheel speeds. ECM **12** calculates the ground speed of the recreational vehicle based on feedback provided by wheel speed sensors **30**.

(24) In the illustrated embodiment, a suspension sensor **42** in communication with ECM **12** is configured to measure the height of a component of the vehicle suspension system. For example, sensor **42** is configured to measure the height or compression distance of a shock absorber **112**, **114** of vehicle **100** (FIG. **2**). In one embodiment, each shock absorber **112**, **114** of vehicle **100** includes a corresponding sensor **42** for measuring the shock height or longitudinal compression distance. Alternatively, one of front shocks **112** and one of rear shocks **114** each include a height sensor **42**. ECM **12** calculates the shock height based on signals provided with sensor(s) **42**. Sensor(s) **42** may be mounted at other suitable locations of the vehicle suspension system **120**, **122** for measuring a height or compression of the suspension system **120**, **122**.

(25) As illustrated in FIG. **1**, a user interface **48** is coupled to ECM **12** that provides an operator with selectable inputs for controlling ETC system **10**. User interface **48** illustratively includes an idle speed control device **20**, a maximum speed device **22**, a ground speed control device **24**, and a drive mode selection device **26**. User interface **48** further includes a selectable input **50** for switching drive train **60** of vehicle **100** (FIG. **2**) between a two-wheel drive and a four-wheel or all-wheel drive configuration. A display **52** of user interface **48** provides a visual display of the operation state of vehicle **100**, the engine and ground speed, the selected drive mode, the selected drive configuration, and other parameters and measurements of vehicle **100**. Display **52** also notifies the operator of when the ground speed control, the maximum speed control, and the idle speed control functionalities have been activated. In one embodiment, the selected vehicle or engine speed associated with each functionality is also displayed. Display **52** may be a monitor, a touch screen, a series of gauges, or any other suitable device for displaying vehicle parameters to an operator. In one embodiment, user interface **48** is a graphical user interface **48** providing inputs **20**, **22**, **24**, **26**, and **50** via a touchscreen.

(26) Idle speed control device **20** of user interface **48** is a gauge, switch, button, or other selectable input device that allows an operator to select and to adjust the idle speed of engine **38**. Idle speed

control device **20** allows an operator to select between a plurality of discrete engine idle speeds. Alternatively, idle speed control device **20** provides a range of selectable engine idle speeds. In one embodiment, idle speed control device **20** displays the selected idle speed and the actual idle speed on display **52**. Idle speed control device **20** provides a signal representative of the selected engine idle speed setting to ECM **12**. In response, ECM **12** provides a corresponding throttle plate position command to throttle actuator **32** to adjust the throttle plate position of throttle valve assembly **34** based on the engine idle speed setting. In one embodiment, ECM **12** monitors the engine speed feedback from engine speed sensor **28** and adjusts throttle valve assembly **34** accordingly to maintain the engine idle speed at the selected setting.

(27) Maximum speed device **22** allows an operator to set a maximum ground or wheel speed of the recreational vehicle. Maximum speed device **22** is a gauge, switch, button, or other selectable input device that provides a signal representative of the selected maximum ground speed to ECM **12**. In response, ECM **12** limits the torque of engine **38** based on the setting of maximum speed device **22** as well as feedback from wheel speed sensor **30** and/or engine speed sensor **28**. In the illustrated embodiment of FIG. **9**, maximum speed device **22** includes a speed key **80** received in an ignition **82** of vehicle **100**. Speed key **80** includes a transmitter **84** containing maximum vehicle speed information. A transceiver **86** located on vehicle **100** is configured to interrogate the speed key **80** to determine the requested maximum speed. Transceiver **86** receives the maximum speed information from transmitter **84**. Transceiver **86** then provides a signal to ECM **12** representative of the maximum vehicle speed indicated by the transmitter **84**. In one embodiment, transmitter **84** of speed key **80** includes a radio frequency identification (RFID) tag and transceiver **86** includes an RFID reader configured to interrogate the RFID tag. In one embodiment, transceiver **86** interrogates transmitter **84** of speed key **80** upon speed key **80** being received in vehicle ignition **82** and being turned to an ON position. See, for example, the maximum speed control system of U.S. Pat. No. 7,822,514, titled SYSTEM FOR CONTROLLING VEHICLE PARAMETERS, the entire disclosure of which is incorporated herein by reference.

(28) Alternatively, maximum speed device **22** may allow an operator to manually set a maximum vehicle or engine speed of the recreational vehicle. For example, an operator may enter a maximum speed through a keypad or other selectable input of maximum speed device **22**. In one embodiment, the operator enters a security code after adjusting the maximum speed to lock out the maximum speed adjustment feature from other operators. In one embodiment, maximum speed device **22** has a default maximum vehicle speed setting that is adjustable by the operator.

(29) In one embodiment, ECM **12** monitors the vehicle ground speed using wheel speed sensor(s) **30**. Upon detection of the vehicle ground speed approaching or exceeding the maximum speed provided by maximum speed device **22**, ECM **12** provides a throttle command signal to throttle actuator **32** to limit the opening of throttle valve assembly **34**, regardless of a greater throttle demand from throttle control **16**. As such, ECM **12** controls the engine torque based on feedback from wheel speed sensor **30** to maintain a vehicle ground speed approximately at or below the selected maximum speed, despite throttle control **16** being at a position normally corresponding to a vehicle speed greater than the selected maximum speed.

(30) In one embodiment, maximum speed device **22** provides several modes configured to provide several maximum speed levels. For example, each mode is associated with a skill level of the operator of the vehicle. In a first or beginner mode, the maximum speed is limited to a first predetermined speed. In a second or intermediate mode, the maximum speed is limited to a second predetermined speed greater than the first predetermined speed. In a third or expert mode, the maximum speed is limited to a third predetermined speed greater than the second predetermined speed. Alternatively, the restrictions on the maximum speed may be removed in the third mode, and full motor torque and engine speed is available to the operator. Additional modes having different associated maximum speeds may be provided. In one embodiment, each mode has an associated speed key such that the implemented mode is dictated by the speed key used to turn on the vehicle.

Alternatively, the various modes are selected through user interface **48** provided on the vehicle. In one embodiment, the maximum speed in each mode is adjustable by a user. For example, the maximum speed associated with each mode may be programmed into ECM **12** through user interface **48** by a user. In one embodiment, a special code must be entered into ECM **12** to enable modification of the maximum speeds associated with the various modes.

(31) Referring to FIG. **1**, ETC system **10** illustratively includes a global positioning system (GPS) device **44** coupled to ECM **12** for tracking the location of vehicle **100** (FIG. **2**) and communicating the tracked location to ECM **12**. Other suitable satellite navigation systems may be used to track vehicle **100**. In one embodiment, ECM **12** limits the speed or torque of vehicle **100** based on the location of vehicle **100** as detected by GPS device **44**. For example, ECM **12** implements a maximum ground speed or engine speed upon detection of vehicle **100** being located outside of or within a predefined area. In one embodiment, a user programs one or more boundaries into GPS device **44** and/or ECM **12** to identify an area where vehicle **100** is permitted to operate at full capacity. The user also defines a maximum speed of vehicle **100** for all areas outside the defined boundaries. Upon detection with GPS device **44** of vehicle **100** traveling outside the defined area, ECM **12** limits the speed or torque of the engine **38** to the maximum speed. In one embodiment, ECM **12** reduces the throttle opening to limit the vehicle or engine speed to the maximum speed regardless of throttle operator **14** demanding a faster speed. In one embodiment, ECM **12** limits the maximum ground speed of vehicle **100** to about 5 miles per hour (mph) or less, for example, upon vehicle **100** traveling outside the predetermined bounded area. In another embodiment, ECM **12** limits the maximum speed of vehicle **100** to substantially zero mph upon vehicle **100** traveling outside the predetermined bounded area.

(32) Alternatively, a user may program one or more boundaries into GPS device **44** and/or ECM **12** to define an area where the maximum speed of vehicle **100** is to be limited. Upon detection with GPS device **44** of vehicle **100** traveling within the specified area, ECM **12** limits the speed or torque of vehicle **100** to the maximum speed.

(33) In one embodiment, ECM **12** and/or GPS device **44** is in communication with a remote computer via a communication network. Using the remote computer, a user programs the bounded areas into ECM **12** over the communication network. The remote computer is also used to assign maximum speeds for each defined bounded area. See, for example, remote computer **54** and communication network **56** of FIG. **7**. Exemplary communication networks **56** include satellite communication (e.g. through GPS device **44**), the internet, and/or a physical or wireless connection. Although remote computer **54** is illustratively in communication with GPS device **44** in FIG. **7**, remote computer **54** may also communicate directly with ECM **12**.

(34) In one embodiment, ECM **12** is programmed to implement location-based maximum speeds for multiple geographical areas. For example, vehicle **100** may be limited to a first maximum speed when traveling in a first area, to a second maximum speed when traveling in a second area, and to a third maximum speed when traveling in a third area. Each area is defined by programming the respective boundaries into the GPS device **44** and/or ECM **12**. For example, one portion of a property may have speed restrictions of 5 mph or less, and another portion of the property may have speed restrictions of 20 mph or less. A third portion of the property may have no associated speed restrictions. ECM **12** is programmable to limit vehicle **100** to these speed restrictions based on the detected location of vehicle **100** with GPS device **44**. In one embodiment, the location-based maximum speeds for multiple areas are further based on the selected skill-level modes (e.g. beginner, intermediate, expert) described herein. For example, in an intermediate mode, the maximum speeds associated with one or more defined portions of the property may be higher than the maximum speeds in a beginner mode. Similarly, in an expert mode, the maximum speeds associated with one or more defined portions of the property may be higher than the maximum speeds in the intermediate mode.

(35) In one embodiment, ECM **12** includes a security feature configured to limit or to disable

operation of vehicle **100** under certain conditions. In one embodiment, a security code programmable into ECM **12** is configured to disable or reduce functionality of vehicle **100**. For example, the security code may be entered through user interface **48** to disable operation of engine **38** or to limit the speed of engine **38**. Alternatively, a security key or other suitable device may be used to enable a security function that limits or prevents operation of vehicle **100**. In one embodiment, the security feature of ECM **12** is incorporated with GPS device **44** to automatically activate the security function based on the location of vehicle **100**. In particular, the operation of engine **38** is disabled or limited upon detection with GPS device **44** of vehicle **100** being located outside or within a predefined area. In one embodiment, a security code is first entered into ECM **12** to enable the GPS-based security functionality of ECM **12**. An exemplary limited operation of engine **38** includes limiting the maximum speed of vehicle **100** to a minimal speed, such as about 5 mph or less. ECM **12** limits the opening of throttle valve **34** to control the speed of engine **38** and vehicle **100**.
(36) For example, in one embodiment, the security feature of ECM **12** is enabled during transportation of vehicle **100** from a manufacturer to a dealer. Once the manufacturing process is complete, vehicle **100** is loaded onto a carrier, such as a freight truck, for transporting vehicle **100** to the dealer. Prior to or upon loading vehicle **100** onto the carrier, the security feature of ECM **12** is enabled to limit or disable operation of engine **38** and/or other devices of vehicle **100**. Upon arrival of vehicle **100** at the dealer, the security feature is disabled to restore full functionality to vehicle **100** and engine **38**. In one embodiment, the dealer enables the security feature while vehicle **100** remains on the dealer's property, and the security feature is disabled upon a purchaser taking possession of vehicle **100**.
(37) In another example, the security feature is utilized by a private owner to reduce the likelihood of theft of vehicle **100**. The owner may enable the security feature (e.g. with the security code, security key, etc.) as desired when vehicle **100** is not in use and disable the security feature prior to operating vehicle **100**. The owner may also configure ECM **12** to enable the security feature automatically upon vehicle **100** being detected outside a specified property area with GPS device **44**, as described herein.
(38) Referring to FIGS. **8**A-**8**C, an exemplary method of limiting the maximum vehicle speed of vehicle **100** is illustrated. In the illustrated embodiment, an object is stored in memory **15** (FIG. **1**) of ECM **12** indicating whether the speed key functionality is enabled or disabled in ECM **12**. When the speed key functionality is disabled in ECM **12** at block **150**, normal vehicle function is implemented at block **152** regardless of any selected maximum speed. When the speed key functionality is enabled in ECM **12** at block **150** and a key is turned ON in the vehicle ignition at block **154**, the maximum speed function is implemented by ECM **12**. As illustrated at blocks **156** and **158**, the vehicle speed and engine speed are monitored by ECM **12** based on feedback from respective sensors **28**, **30** (FIG. **1**).
(39) At block **162**, ECM **12** determines if there is an error or malfunction with speed sensor **30** (FIG. **1**). If there is no speed feedback error detected at block **162** and speed key **80** is ON at block **154**, ECM **12** monitors the vehicle speed at block **164**. If the vehicle speed is not equal to about zero kilometers per hour (KPH) at block **164** (i.e., if vehicle **100** is not substantially stopped), ECM **12** limits the vehicle speed to a first maximum vehicle speed VSL**1** until the ignition is cycled, as represented at block **166**. In one embodiment, the vehicle ignition (e.g. ignition **82** of FIG. **9**) is cycled by turning the ignition key to the OFF position to shut down vehicle **100** and returning the key to the ON position. If there is a vehicle speed error detected at block **162**, ECM **12** determines the vehicle speed that corresponds to the currently detected engine speed at block **168**. If the correlated vehicle speed is not zero KPH at block **168**, ECM **12** proceeds to block **166** to limit the vehicle speed to the first maximum vehicle speed VSL**1** until ignition **82** is cycled. In one embodiment, the first maximum vehicle speed VSL**1** is the default maximum vehicle speed stored in memory **15** of ECM **12**. For example, as described herein, ECM **12** may have a default

maximum vehicle speed VSL**1** and a plurality of selectable maximum vehicle speeds that are different from the default maximum speed VSL**1**. In one embodiment, the default maximum speed VSL**1** is the lowest maximum speed limit stored in ECM **12**. Once the vehicle ignition is cycled, the implemented default maximum vehicle speed VSL**1** is disabled, and the process of FIGS. **8**A-**8**C repeats when the key is again turned to the ON position.

(40) If the detected vehicle speed at block **164** is about zero KPH, ECM **12** checks the engine speed via engine speed sensor **28** (FIG. **1**). If the detected engine speed is greater than a threshold engine speed ESEL, ECM **12** limits the vehicle speed at block **166** to the first or default maximum vehicle speed VSL**1** until the vehicle ignition is cycled. In one embodiment, the threshold engine speed ESEL is approximately equal to the engine idle speed. Other suitable threshold engine speeds ESEL may be used. If the detected engine speed is less than or equal to the threshold engine speed ESEL at block **170**, ECM **12** proceeds to block **172** to determine if a valid speed limit request has been received. In the illustrated embodiment, the speed limit request is sent to ECM **12** through a user input at user interface **48**, as described herein, or based on the speed key **80** (FIG. **9**) inserted in ignition **82**. In one embodiment, speed key **80** of FIG. **9** includes an RFID transponder **84** configured to provide the maximum speed request to transceiver/RFID reader **86** mounted on vehicle **100**, as described herein. Speed key **80** may provide the maximum speed information directly to transceiver **86** or may provide an identifier that ECM **12** uses to look up the associated maximum speed information in memory **15** (FIG. **1**).

(41) In one embodiment, when an operator selects the maximum speed through user interface **48**, the maximum speed must be selected within a predetermined amount of time after turning the ignition key to the ON position in order for the selected maximum speed to be accepted and implemented by ECM **12**, as described herein.

(42) If a maximum speed is not requested at block **172**, ECM **12** implements the the default maximum speed VSL**1** (block **166**). If a selected maximum speed is received by ECM **12** at block **172**, ECM **12** holds the process flow until a predetermined time delay has expired, as illustrated at block **174**. As such, the maximum vehicle speed may be selected and changed within the allotted time period before ECM **12** proceeds to implement the most recently selected maximum speed at block **176**. In the illustrated embodiment, the time delay is set to ten seconds, although other suitable time delays may be provided.

(43) Once the time delay expires at block **174**, ECM **12** implements the most recently requested maximum vehicle speed limit VSL at block **176**. As long as an error with vehicle speed sensor **30** is not detected at block **178**, the maximum vehicle speed VSL remains in effect until the vehicle ignition is cycled, as illustrated at block **176**. Once ignition **82** is cycled, the selected maximum vehicle speed VSL is disabled, and the process of FIGS. **8**A-**8**C repeats when the ignition key is again turned to the ON position in the vehicle ignition.

(44) If an error with vehicle speed sensor **30** is detected at block **178**, ECM **12** determines if the gear selector is malfunctioning at block **180** based on transmission gear input **160**. See, for example, gear selector **88** of user interface **48** illustrated in FIG. **3**. If an error is not detected with gear selector **88** at block **180**, ECM **12** limits the engine speed based on the requested maximum vehicle speed VSL, as represented at block **184**. In particular, ECM **12** determines an engine speed that corresponds to the selected maximum vehicle speed VSL and limits engine **38** to that determined engine speed. In the illustrated embodiment, ECM **12** determines an engine speed that corresponds to the selected maximum vehicle speed VSL in both the low gear (engine speed CESL) and the high gear (engine speed CESH). If transmission **62** is in the low gear based on transmission gear input **160**, maximum engine speed CESL is implemented at block **184**. If transmission **62** is in the high gear based on transmission gear input **160**, maximum engine speed CESH is implemented at block **184**. If an error is detected with gear selector **88** at block **180**, ECM **12** limits the engine speed to the high gear maximum engine speed CESH at block **182**. The maximum engine speed CESL or CESH implemented in blocks **182**, **184** remain in effect until the vehicle ignition is

cycled, as described herein.
(45) In one embodiment, the method of FIGS. **8**A-**8**C is used in conjunction with a speed key, such as speed key **80** of FIG. **9**. In particular, each speed key **80** has a different associated maximum speed limit that is received by ECM **12** at block **172**. Alternatively, an operator may select a maximum speed using a gauge, switch, touchscreen, or other input device at user interface **48** (FIG. **1**). In one embodiment, a plurality of discrete maximum speeds are selectable by an operator. In another embodiment, any number of maximum speeds may be selected over a vehicle speed range. For example, any speed between 0 KPH and 85 KPH may be selected as the maximum speed.
(46) Referring again to FIG. **1**, ground speed control device **24** of user interface **48** provides for the selection of a vehicle ground speed to be maintained by ECM **12**. Ground speed control may be used to maintain vehicle speed while pulling implements such as sprayers, graders, groomers, seeders, tillers, mowers, etc. or while driving for extended periods on roads or trails, for example. Ground speed control device **24** is a gauge, switch, button, or other selectable input device and provides a signal representative of the selected vehicle ground speed to ECM **12**. For example, upon reaching a desired vehicle speed, ground speed control device **24** is actuated or selected by an operator to maintain that desired vehicle speed. In the illustrated embodiment, ECM **12** maintains the vehicle speed indicated by ground speed control device **24** by maintaining the correct engine torque (i.e., with throttle valve **34**) for that vehicle speed. In one embodiment, ECM **12** monitors feedback from engine speed sensor **28** and/or wheel speed sensor **30** and maintains the vehicle speed with throttle valve **34** using basic proportional-integral-derivative (PID) control. Once activated, ground speed control may be cancelled upon actuation of throttle control **16** or the vehicle brake **66**, **68** (FIG. **3**) or by turning off power to ground speed control device **24**.
(47) In one embodiment, ECM **12** is configured to limit the vehicle speed range in which ground speed control may be applied. For example, ECM **12** may allow activation of ground speed control only within vehicle speeds of 5-30 mph, although any suitable speed range may be used. In one embodiment, the speed ranges permitted by ECM **12** may differ for each transmission configuration (i.e. for each operating gear). For example, a high transmission gear (e.g. third or fourth gear) has a higher allowed vehicle speed range than a low transmission gear (e.g. first or second gear). In one embodiment, ground speed control device **24** provides an input allowing an operator to manually set the range of vehicle speeds in which ground speed control may be applied.
(48) In another embodiment, ground speed control device **24** and ECM **12** cooperate to provide a maximum speed cruise control function to ETC system **10**. In this embodiment, a maximum vehicle speed is requested by an operator with ground speed control device **24** while vehicle **100** is moving. The maximum vehicle speed is set at the speed of vehicle **100** at the time the request is made. With the maximum vehicle speed set, throttle control **16** is used to control vehicle **100** at any speed less than the maximum vehicle speed. When throttle control **16** demands a vehicle speed greater than the maximum vehicle speed, ECM **12** operates to limit the vehicle speed to the maximum vehicle speed. In one embodiment, ECM **12** limits the vehicle speed by reducing the opening of throttle valve **34**. As such, ECM **12** overrides input from throttle control **16** when throttle control **16** demands vehicle speeds greater than the maximum vehicle speed. Vehicle **100** may be slowed to any speed less than the maximum vehicle speed based on reduced input from throttle control **16** without cancelling the maximum vehicle speed setpoint. In one embodiment, the maximum vehicle speed is cancelled upon the ignition of the vehicle being cycled (e.g., upon turning the ignition key to an off position and back to an on position) or upon re-selecting ground speed control device **24**. In one embodiment, the maximum vehicle speed setpoint is retained when engine **38** is stalled, and the maximum vehicle speed remains in effect upon restarting the stalled engine **38**. ECM **12** sends a message to display **52** to notify the operator that the maximum speed cruise control function has been activated and to display the selected maximum speed.
(49) Still referring to FIG. **1**, drive mode selection device **26** of user interface **48** provides several selectable drive modes. In each drive mode, throttle plate **36** opens within throttle valve assembly

34 at a different rate in response to corresponding movement of throttle control **16**. As such, in each drive mode, vehicle **100** has variable acceleration rates or torque output across the displacement range of throttle control **16**. Drive mode selection device **26** may be a gauge, switch, button, or other selectable input device configured to provide a signal to ECM **12** indicating the selected drive mode. In the illustrative embodiment of FIG. **5**, four drive modes are provided—normal mode **92**, sport mode **94**, work mode **96**, and plow mode **98**. In one embodiment, a drive mode is only selectable when vehicle **100** is moving below a predetermined vehicle speed, such as below 10 mph, for example. Other suitable threshold speeds may be provided below which the drive modes may be activated.

(50) FIGS. **6**A-**6**D illustrate exemplary throttle responses or throttle maps for each drive mode. As illustrated in FIGS. **6**A-**6**D, throttle control **16** (shown as “rider input device”) has a range of movement from position A (fully released) to position B (fully engaged), and throttle plate **36** has a range of movement from position X (fully closed throttle) to position Y (fully open throttle). Depending on the design of throttle control **16**, the movement of throttle control **16** may be rotational, along an arc, along a length, or any other appropriate displacement. For example, a hand grip moves rotationally, while a throttle lever moves along an arc. In the illustrated embodiment, throttle valve assembly **34** is a butterfly valve, and throttle plate **36** moves rotationally within a bore of throttle body **35**.

(51) In the normal mode **92** of throttle operation, throttle plate **36** moves linearly with corresponding movement of throttle control **16**. In particular, throttle valve assembly **34** opens at a substantially linear rate in response to corresponding movement of throttle control **16**. As illustrated in the exemplary throttle response of FIG. **6**A, throttle plate **36** moves linearly from position X to position Y as throttle control **16** moves from position A to position B. In other words, the displacement of throttle plate **36** from position X to position Y is substantially linear to the displacement of throttle control **16** from position A to position B.

(52) In the sport mode **94** of throttle operation, throttle plate **36** moves at a faster rate than the rate of corresponding movement of throttle control **16** such that throttle plate **36** reaches a fully or substantially fully open position before throttle control **16** reaches its end of travel. In particular, throttle valve assembly **34** opens at a fast rate initially in response to initial movement of throttle control **16**, as illustrated in FIG. **6**D. Movement of throttle control **16** from position A to position C, which is illustratively about half the full range of movement of throttle control **16**, causes corresponding movement of throttle plate **36** from position X to position Y. In the illustrated embodiment, throttle plate **36** moves from position X to position Y at a substantially logarithmic rate in response to movement of throttle control **16** from position A to position C. Position C may alternatively be at another suitable distance between position A and position B to increase or decrease the displacement of throttle plate **36** in response to a movement of throttle control **16**. In the illustrated embodiment, throttle valve **34** is more responsive to corresponding movement of throttle control **16** in the sport mode **94** as compared to the normal mode **92**.

(53) In the work mode **96** of throttle operation, throttle plate **36** initially moves at a slower rate than the rate of corresponding movement of throttle control **16**. As illustrated in FIG. **6**C, throttle valve assembly **34** opens slowly in response to movement of throttle control **16** from position A to position D, opens rapidly in response to movement of throttle control **16** from position D to position E, and opens slowly in response to movement of throttle control **16** from position E to position B. In the illustrated embodiment, position D is at approximately 40% of the full displacement range of throttle control **16**, and position E is at approximately 60% of the full displacement range of throttle control **16**. Positions D and E may alternatively be at other suitable distances between position A and position B. Put another way, throttle plate **36** moves at a substantially exponential rate in response to movement of throttle control **16** from position A to position C and at a substantially logarithmic rate in response to movement of throttle control **16** from position C to position B. Work mode **96** reduces the sensitivity of throttle valve assembly **34**

to initial movements of throttle control **16** while providing the most torque in the middle of the range of movement of throttle control **16**. Further, work mode **96** reduces the sensitivity of throttle valve assembly **34** to movements of throttle control **16** near the end of the displacement range of throttle control **16** (e.g. from position E to position B). Work mode **96** may be used during towing or hauling applications, for example.

(54) In the plow mode **98** of throttle operation, throttle plate **36** initially moves at a faster rate than the rate of corresponding movement of throttle control **16**. As illustrated in FIG. **6**B, throttle valve assembly **34** opens rapidly in response to movement of throttle control **16** from position A to position F, opens slowly in response to movement of throttle control **16** from position F to position G, and opens rapidly in response to movement of throttle control **16** from position G to position B. In the illustrated embodiment, position F is at approximately 25% of the full displacement range of throttle control **16**, and position G is at approximately 75% of the full displacement range of throttle control **16**. Positions F and G may alternatively be at other suitable distances between position A and position B. Put another way, throttle plate **36** moves at a substantially logarithmic rate in response to movement of throttle control **16** from position A to position C and at a substantially exponential rate in response to movement of throttle control **16** from position C to position B. Plow mode **98** provides increased torque towards the end of the range of movement of throttle control **16** (e.g. from position G to position B). Similarly, plow mode **98** provides decreased torque in the middle of the range of movement of throttle control **16** (e.g. from position F to position G). Plow mode **98** may be used during plowing applications, for example.

(55) In the illustrated embodiment, the normal drive mode **92** is the default drive mode. Upon the selected drive mode being cancelled, ECM **12** defaults to the normal drive mode **92**. In one embodiment, the selected drive mode is cancelled upon the ignition of the vehicle being cycled (e.g., upon turning the ignition key to an off position) or upon disabling the mode with drive mode selection device **26**. In one embodiment, the selected drive mode is retained when engine **38** is stalled, and the selected drive mode remains in effect upon restarting the stalled engine **38**. ECM **12** sends a message to display **52** to notify the operator of the currently selected drive mode.

(56) In one embodiment, each transmission gear of vehicle **100** includes a different set of drive modes. For example, in a transmission **62** with a high gear, a low gear, and a reverse gear, each of these transmission gears has a unique set of drive modes. The low gear has a first normal mode **92**, a first sport mode **94**, a first work mode **96**, and a first plow mode **98**, the high gear has a second normal mode **92**, a second sport mode **94**, a second work mode **96**, and a second plow mode **98**, and the reverse gear has a third normal mode **92**, a third sport mode **94**, a third work mode **96**, and a third plow mode **98**. Each of the normal, work, sport, and plow modes for each transmission gear provides variable movement of the throttle valve **34** in response to corresponding movement of the throttle control **16**. In other words, the exemplary throttle maps illustrated in FIGS. **6**A-**6**D differ for each transmission gear while maintaining similar general plot shapes or contours in each common drive mode. For example, the normal mode **92** for low gear and high gear each have linear throttle maps (see FIG. **6**A), but throttle valve **34** opens at a slower linear rate in the low gear than in the high gear based on a movement of throttle control **16** when in the normal mode **92**. Similarly, the sport mode **94** for low gear and high gear each have substantially logarithmic throttle maps (see FIG. **6**D), but throttle valve **34** opens at a slower logarithmic rate in the low gear than in the high gear based on a movement of throttle control **16** when in the sport mode **94**. Similarly, the work mode **96** and plow mode **98** for the low gear and high gear each have similar shaped throttle maps (see FIGS. **6**C and **6**D), but throttle valve **34** opens at a slower rate in the low gear than in the high gear based on a movement of throttle control **16** for each of the work mode **96** and plow mode **98**. In one embodiment, throttle valve **34** opens slower in the reverse gear than in the low gear and in the high gear based on a movement of throttle control **16** in each of the four corresponding drive modes.

(57) When an operator selects a drive mode with drive mode selection device **26**, the corresponding

drive mode from each set are selected as a group. For example, if work mode **92** is selected by an operator, then the first work mode **92** is implemented when transmission **62** is in the low gear, the second work mode **92** is implemented when transmission **62** is in the high gear, and the third work mode **92** is implemented when transmission **62** is in the reverse gear.

(58) In one embodiment, ECM **12** includes a power limiting feature utilized in the event of engine damage or sensor failure. The power limiting feature limits the power and speed of engine **38** by limiting the degree of the opening of throttle valve assembly **34**. In one embodiment, upon detection with ECM **12** of sensor failure or engine damage, the power limiting feature is activated to reduce the likelihood of further damage to engine **38** or vehicle **100**. Improper or irregular feedback from engine sensors may indicate engine or sensor damage and cause ECM **12** to register a fault. Detection with sensors of engine overheating, improper camshaft movement/position, or improper oxygen levels in the engine exhaust may indicate damage to engine **38**, for example. In one embodiment, the power limiting feature may be disabled by the operator with a switch or other input device at user interface **48**.

(59) In one embodiment, ECM **12** includes a drivetrain component protection feature configured to limit wheel speed by reducing engine torque under certain wheel speed and engine speed combinations. For example, when vehicle **100** of FIG. **1** is airborne, the driven wheels **102**, **104** of vehicle **100** may accelerate rapidly due to the wheels **102**, **104** losing contact with the ground while throttle control **16** is still engaged by the operator. When the wheels **102**, **104** again make contact with the ground upon vehicle **100** landing, the wheel speed decelerates abruptly, possibly leading to damaged or stressed components of drive train **60**. ECM **12** is configured to limit the wheel speed upon detection of vehicle **100** being airborne such that, when vehicle **100** returns to the ground, the wheel speed is substantially the same as when vehicle **100** initially left the ground. In one embodiment, ECM **12** reduces the engine torque, i.e. reduces the throttle valve **34** opening, upon determining vehicle **100** is airborne to reduce or limit the wheel speed, thereby reducing the likelihood of drive train component stress and damage due to over-accelerating wheels **102**, **104**.

(60) In one embodiment, ECM **12** determines that vehicle **100** is airborne upon detection of a sudden acceleration in the wheel speed based on ground speed and engine rpm feedback from the respective wheel speed sensor **30** and engine speed sensor **28**. Vehicle **100** is determined to be airborne when the acceleration in wheel speed exceeds the design specifications of vehicle **100**. For example, vehicle **100** has a maximum wheel acceleration based on available torque from engine **38**, frictional force from the ground, the weight of vehicle **100**, and other design limits. When the driven wheels **102**, **104** accelerate at a faster rate than vehicle **100** is capable under normal operating conditions (i.e., when wheels **102**, **104** are in contact with the ground), ECM **12** determines that wheels **102**, **104** have lost contact with the ground.

(61) In one embodiment, ECM **12** further considers the engine torque and power, along with the detected wheel speed and engine speed, in detecting an airborne state of vehicle **100**. As described herein, the engine torque is determined based on the engine speed, the positions of throttle control **16** and throttle valve **34**, and the pressure of engine manifold **136** (FIG. **3**). Based on the engine speed and engine torque, the power output of engine **38** is determined. Based on the power output of engine **38**, the actual vehicle speed, and the transmission gear, ECM **12** determines whether wheels **102**, **104** are accelerating at a faster rate than normally provided with the corresponding position of throttle control **16** and/or throttle valve **34** when wheels **102**, **104** are in contact with the ground. Upon the wheel speed acceleration exceeding a predetermined level, ECM **12** detects vehicle **100** is airborne and proceeds to limit the wheel speed.

(62) In another embodiment, ECM **12** determines that vehicle **100** is airborne based on an observed change in height or compression distance of one or more shocks of vehicle **100**. For example, referring to vehicle **100** of FIG. **2**, one or more sensors **42** (FIG. **1**) are configured to measure the height or longitudinal compression of shocks **112**, **114**, as described herein. With vehicle **100** positioned on the ground, the combined weight of chassis **110**, body portion **124**, and other

components supported by chassis **110** causes shocks **112**, **114** to compress to a first height. With either or both front wheels **102** and rear wheels **104** of vehicle **100** airborne, the weight of vehicle **100** is removed from respective suspension systems **120**, **122**, and shocks **112**, **114** decompress or extend to a second unloaded height. At the second height, shocks **112**, **114** are in a substantially fully extended state. Based on feedback from sensors **42** (FIG. **1**), ECM **12** determines the vehicle **100** is airborne upon shocks **112**, **114** extending past the first height or upon shocks **112**, **114** substantially extending to the second unloaded height. In one embodiment, the shocks **112**, **114** must be extended for a specified amount of time before ECM **12** determines that vehicle **100** is airborne. In one embodiment, ECM **12** uses the detected shock height in conjunction with the detected wheel speed acceleration to determine that vehicle **100** is airborne.

(63) In some operating conditions, either wheels **102** or wheels **104** become airborne while the other of wheels **102**, **104** remain in contact with the ground. If the wheels **102** or **104** removed from the ground are driven wheels, ECM **12** limits the speed of the driven wheels in the event the wheel speed exceeds a predetermined threshold. For example, in one embodiment, vehicle **100** has a two-wheel drive configuration where wheels **104** are driven by drive train **60** and wheels **102** are not directly driven by drive train **60**. When driven wheels **104** become airborne and non-driven wheels **102** remain in contact with the ground, the possibility exists that the position of throttle control **16** causes wheels **104** to accelerate past the vehicle ground speed (e.g. of wheels **102**) while wheels **104** are away from the ground. In this condition, ECM **12** detects wheels **104** being removed from the ground either based on the height of suspension system **122** or the detected wheel speed of wheels **104**, **102**, as described above. In response to wheels **104** accelerating past a predetermined threshold speed, ECM **12** reduces the speed of wheels **104** to a speed substantially equal to the speed of front wheels **102**. Alternatively, ECM **12** may reduce the speed of wheels **104** to another suitable speed, such as the speed of wheels **104** immediately before wheels **104** left the ground.

(64) In an exemplary method of electronic throttle control, ECM **12** determines whether vehicle **100** is in a grounded state with wheels **102**, **104** in contact with the ground or an airborne state based on the detected shock position and/or the detected wheel speed, as described herein. Upon detection of vehicle **100** in an airborne state, ECM **12** determines the ground speed of vehicle **100** immediately prior to vehicle **100** leaving the ground or when vehicle **100** leaves the ground. In other words, ECM **12** determines the ground speed of vehicle **100** during the transition of the vehicle **100** from the grounded state to the airborne state. In the illustrated embodiment, ECM **12** samples the ground speed during operation of vehicle **100** and stores the sampled values in memory **15** (FIG. **1**). ECM **12** retrieves the ground speed stored in memory **15** that was measured immediately prior to vehicle **100** being airborne. The retrieved ground speed value is set as the target wheel speed. ECM **12** automatically controls throttle valve **34** such that the wheel speed of vehicle **100** is maintained at about the target wheel speed. In particular, when the driven wheels **102**, **104** accelerate when vehicle **100** is airborne due to continued throttle application, ECM **12** automatically reduces the opening of throttle valve **34** to reduce the torque applied to driven wheels **102**, **104**, thereby reducing the wheel speed. As such, driven wheels **102**, **104** contact the ground at approximately the same speed as when vehicle **100** left the ground, thereby reducing stress on components of drivetrain **60**. In one embodiment, the wheel speed is controlled to within about a 10% range of the target ground speed. In one embodiment, ECM **12** applies a brake to the driven wheels to further reduce the wheel speed while vehicle **100** is airborne.

(65) In another embodiment, ECM **12** changes the drive configuration of vehicle **100** under certain airborne conditions. For example, ECM **12** causes vehicle **100** to change from a four-wheel drive configuration to a two-wheel drive configuration when wheels **102**, **104** are detected to be removed from the ground. As such, the non-driven wheels, e.g. wheels **102**, are free spinning upon returning to the ground, thereby reducing the likelihood of stress and/or damage to drive train **60** caused by wheels **102** being at a speed different than the vehicle ground speed. This embodiment is used in conjunction with the airborne speed control embodiments described above. For example, along

with switching from four-wheel drive to two-wheel drive, ECM **12** slows or increases the speed of driven wheels **104** as necessary such that wheels **104** return to the ground at a speed substantially equal to the ground speed of vehicle **100** prior to vehicle **100** leaving the ground, as described herein.

(66) In one embodiment, ECM **12** is configured to adjust the pitch or angle of an airborne vehicle **100** relative to the ground by modulating the throttle operation. ECM **12** automatically adjusts the pitch of airborne vehicle **100** with throttle modulation to improve the levelness of vehicle **100** as vehicle **100** returns to ground. In other words, ECM **12** serves to improve the ability of wheels **102**, **104** of vehicle **100** to contact the ground from an airborne state at substantially the same time. As illustrated in FIG. **1**, vehicle **100** includes one or more inclination or tilt sensors **58** configured to measure the tilt or pitch of vehicle **100**. Upon detection by ECM **12** of vehicle **100** being airborne, as described above, ECM **12** monitors the inclination or pitch of vehicle **100** relative to the ground based on feedback from sensor **58**. Upon the detected inclination of vehicle **100** exceeding a threshold value or being outside a predetermined range, ECM **12** modulates the throttle valve **34** to adjust the speed of the driven wheels, e.g., wheels **104**, thereby altering the pitch of vehicle **100** relative to the ground. As such, vehicle **100** returns to the ground in a more level orientation. The modulation of the throttle valve and the corresponding adjustment of the wheel speed is configured to adjust the inclination of the vehicle to an angle falling within the predetermined range. In one embodiment, the predetermined range includes inclination angles between about −10 degrees and about +10 degrees relative to the horizontal, for example.

(67) For example, upon vehicle **100** being airborne, front end **116** of vehicle **100** may move towards the ground such that front wheels **102** are closer to the ground than rear wheels **104**. In this condition, front wheels **102** are configured to strike the ground before rear wheels **104**, possibly causing instability of the operator and vehicle **100** and/or damage to the vehicle **100**. Upon detection of this non-level condition by ECM **12** with sensors **58**, ECM **12** automatically increases the opening of throttle valve **34** to increase the speed of rear wheels **104**. With wheels **104** accelerating at a faster rate, rear end **118** of vehicle **100** is caused to move down towards the ground. As a result, rear end **118** is brought into better vertical alignment or levelness with front end **116** relative to the ground. As such, when vehicle **100** returns to the ground, wheels **102**, **104** contact the ground at substantially the same time, or wheels **102**, **104** both contact the ground within a shorter amount of time than without the pitch adjustment by ECM **12**.

(68) ECM **12** includes an anti-lock braking system (ABS) configured to provide automatic control of brakes **66**, **68** (FIG. **2**) of vehicle **100**. ABS improves vehicle control by reducing the likelihood of wheels **102**, **104** locking up and losing traction with the ground. ECM **12** monitors the wheel speed of each wheel **102**, **104** with sensors **30** (FIG. **1**) to detect any wheels **102**, **104** approaching a locked state. ECM **12** causes brakes **66**, **68** to selectively reduce the braking force to the individual wheel(s) **102**, **104** that are approaching a locked state. In the illustrated embodiment, ECM **12** also monitors the degree of opening of throttle valve **34** during application of the ABS. In one embodiment, ECM **12** automatically reduces the opening of throttle valve **34** during application of the ABS to reduce the torque being applied to wheels **102**, **104** via engine **38**. For example, when the ABS is activated, ECM **12** reduces the opening of throttle valve **34** to approximately 10%-25%, regardless of throttle operator **14** demanding a greater throttle opening.

(69) ECM **12** further includes a traction control system (TCS) for reducing the traction loss of driven wheels **102**, **104**. ECM **12** detects individual wheels **102**, **104** slipping based on speed feedback from sensors **30**. In particular, when a wheel **102**, **104** is spinning a certain degree faster than the other wheels **102**, **104**, slip is detected at that wheel **102**, **104**. ECM **12** automatically applies the respective brake **66**, **68** to the slipping wheel(s) **102**, **104** to slow the wheel speed and to allow the slipping wheel(s) **102**, **104** to regain traction. In one embodiment, ECM **12** automatically reduces the opening of throttle valve **34** during application of the TCS to reduce the torque being applied to wheels **102**, **104** via engine **38**. For example, when the TCS is activated, ECM **12**

reduces the opening of throttle valve **34** to approximately 10%-25%, regardless of throttle operator **14** demanding a greater throttle opening. Reduction of the throttle further assists the slipping wheel **102**, **104** with regaining traction by reducing torque applied to the slipping wheel **102**, **104**.

(70) ECM **12** further provides vehicle stability control (VCS) to vehicle **100**. VCS incorporates the functionality of the ABS and TCS to improve the stability of vehicle **100** during steering operations. In particular, ECM **12** is configured to reduce oversteer and/or understeer of wheels **102**, **104**. Further, ECM **12** is configured to minimize skids of vehicle **100** during a steering operation. In the illustrated embodiment of FIG. **1**, vehicle **100** includes a yaw rate sensor **46** configured to detect and communicate the angular velocity of vehicle **100** to ECM **12**. Upon detection of skidding or understeer/oversteer based on feedback from sensors **30** and **46**, ECM **12** selectively applies brakes **66**, **68** to individual wheels **102**, **104** as appropriate to counter oversteer or understeer. In addition, ECM **12** limits the opening of throttle valve **34** as appropriate to further reduce the slip angle of vehicle **100**.

(71) ECM **12** also controls the engine torque of vehicle **100** in conjunction with power steering system **70** of FIG. **3**. In particular, ECM **12** instructs power steering system **70** to limit the steering assistance (i.e., tighten up the steering) during periods of high engine torque or increased vehicle speed to reduce the likelihood of over-steering vehicle **100** and causing potential skidding or rollover. In other words, steering assistance from power steering system **70** is reduced when vehicle **100** is accelerating at or above a predetermined rate such that the steering device (e.g. handlebar **108** of FIG. **2**) requires a greater force to steer vehicle **100**. In one embodiment, the steering assistance from power steering **70** is also reduced when vehicle **100** is traveling above a predetermined vehicle speed. In one embodiment, ECM **12** instructs power steering system **70** to provide less steering assistance based on the calculated torque output of engine **38** and/or the detected vehicle speed exceeding a threshold level. In one embodiment, the steering assistance provided with power steering system **70** is proportional to the vehicle speed and the acceleration rate or engine torque of vehicle **100**. In one embodiment, the assistance provided with power steering system **70** is further based on the selected gear or position of transmission **62**, i.e., the steering assistance provided by power steering system **70** is reduced as the operating gear of transmission **62** is increased.

(72) In one embodiment, ECM **12** is configured to tailor the throttle response to the selected gear of operation. For example, in one embodiment, transmission **62** includes a low gear and a high gear in the forward direction. ECM **12** limits the throttle response in the low gear such that throttle valve **34** is less responsive to corresponding movement of throttle operator **14** than when transmission **62** is in the high gear. For example, in response to a movement of the throttle operator **14**, ECM **12** causes throttle valve **34** to open at a slower rate in the low gear than in the high gear, thereby reducing the acceleration rate of vehicle **100** in the low gear as compared to the high gear. As such, vehicle **100** accelerates at a smoother rate in the low forward gear than in the high forward gear. The throttle response may be tailored to transmissions **62** having additional gears. For example, ECM **12** may cause throttle valve **34** to be more responsive in an intermediate gear than in a low gear and more responsive in a high gear than in the intermediate gear.

(73) In a reverse gear, ECM **12** limits the throttle response such that throttle valve **34** is less responsive to corresponding movement of throttle operator **14** than when in a forward gear. For example, ECM **12** causes throttle valve **34** to open at a slower rate than corresponding movement of throttle operator **14** demands, thereby reducing the acceleration rate of vehicle **100** in the reverse direction. As such, vehicle **100** has less acceleration in the reverse direction than in the forward direction. In another embodiment, throttle valve **34** opens at a substantially similar rate in the reverse direction and in the low gear of the forward direction. In one embodiment, ECM **12** also limits the maximum degree of opening of throttle valve **34** when transmission **62** operates in reverse, thereby placing a cap on the amount of engine torque available in the reverse direction. For example, ECM **12** may limit the maximum degree of opening of throttle valve **34** to about 50%

open.

(74) ECM **12** is further configured to reduce the throttle response based on the load being carried, towed, pushed, or otherwise moved by vehicle **100**. For example, ECM **12** may detect the load of vehicle **100** based on suspension sensors **42** (FIG. **1**) or other suitable weight sensors. Upon the detected load exceeding a predetermined threshold weight or being outside a predetermined weight range, ECM **12** is configured to limit the acceleration rate of vehicle **100** by limiting the rate at which throttle valve **34** opens in response to corresponding movement of throttle operator **14**. In one embodiment, the predetermined weight range is between about zero and a threshold weight value. Similarly, ECM **12** is configured to reduce the acceleration rate of vehicle **100** upon detection of vehicle **100** hauling, towing, or pushing an implement, trailer, or other attachment. For example, vehicle **100** includes a sensor coupled to ECM **12** that is configured to detect the presence of an implement attached to chassis **110** (FIG. **2**) of vehicle **100** and to provide a signal to ECM **12** indicative of the detected implement. In one embodiment, the sensor includes a limit switch or a proximity switch, for example, positioned near the chassis attachment point (e.g. hitch, front or rear connection bracket, etc.) for the implement. In one embodiment, ECM **12** implements the load-based throttle control when transmission **62** is in any suitable gear. In one embodiment, a selectable input is provided at user interface **48** for activating the load-based throttle control functionality of ECM **12**. Alternatively, ECM **12** may automatically activate the load-based throttle control under certain operating conditions, i.e, upon transmission **62** being in reverse and an implement being attached to vehicle **100**. In one embodiment, ECM **12** controls throttle valve **34** such that the responsiveness of the throttle is inversely proportional to the weight of the load, i.e., the throttle responsiveness decreases as the weight of the load increases.

(75) In one embodiment, ECM **12** is further configured to limit the throttle when transmission **62** changes operating gears to reduce the engine torque applied to drive train **60**. In an automatic transmission **62**, a transmission controller, such as transmission controller **72** of FIG. **3**, signals to ECM **12** that transmission **62** is changing or is about to change gears. Based on the signal from transmission controller **72**, ECM **12** temporarily reduces the opening of throttle valve **34** to reduce the torque output of engine **38** as transmission **62** modulates between gears. The reduced throttle serves to reduce the grinding or clashing of gears of transmission **62**, the clutch assembly, and/or other components of drive train **60** during the gear modulation. Once the newly selected transmission gear is engaged, ECM **12** returns the throttle valve **34** to the position corresponding to the throttle operator **14**. In one embodiment, ECM **12** resumes normal throttle operation based on a signal from transmission controller **72** that the selected gear is engaged. Alternatively, ECM **12** may resume normal throttle operation upon expiration of a predetermined time delay or based on another suitable trigger.

(76) Similarly, in a manual transmission **62**, engagement of a clutch operator by the operator signals to ECM **12** of an impending gear change, and ECM **12** thereby reduces the throttle opening during the gear change. Alternatively, initial actuation of the gear shifter (e.g., foot shifter, hand shifter, switch, etc.) by the operator may signal to ECM **12** to reduce the throttle. As with the automatic transmission **62**, ECM **12** resumes normal throttle operation upon the selected gear being engaged. For example, the return of the clutch operator to a home position causes normal throttle operation to resume. In one embodiment, in both the manual and automatic transmissions **62**, ECM **12** adjusts throttle valve **34** to reduce the torque output of engine **38** to substantially zero torque or to a minimal positive torque.

(77) In one embodiment, ECM **12** is configured to limit the torque output of engine **38** when drive train **60** switches between a two-wheel drive configuration and a four-wheel or an all-wheel drive configuration, and vice versa. In one embodiment, an operator selects a drive configuration input **50** (FIG. **1**) of user interface **48** to change between two-wheel and four-wheel or all-wheel drive configurations. In another embodiment, ECM **12** is configured to automatically switch between drive configurations in certain operating conditions of vehicle **100**. For example, ECM **12** may

engage all-wheel drive upon detection of slippery road conditions. Upon selection of a new drive configuration by an operator or by ECM **12**, ECM **12** reduces the opening of throttle valve **34** to reduce engine torque and maintains the reduced throttle until the selected drive configuration is implemented. Once the selected drive configuration is engaged, the position of throttle valve **34** is returned to the position corresponding to throttle operator **14**. In one embodiment, ECM **12** reduces the engine torque during the drive configuration change to between about 5% and 30% of the maximum torque capability of engine **38**.

(78) In one embodiment, during implementation of the new drive configuration, ECM **12** further reduces the throttle such that engine **38** or other rotating components of drive train **60** slow to a predetermined speed before the selected drive configuration is implemented. An exemplary engine speed is between about 5% and 30% of the maximum engine speed. In one embodiment, the reduced engine torque and engine rpm during the change between drive configurations serves to reduce the likelihood of damaging the clutch assembly and/or other components of drive train **60** that engage and disengage the four-wheel or all-wheel drive.

(79) In one embodiment, in the four-wheel or all-wheel drive configuration, drive train **60** has torque and speed limits to reduce the likelihood of stress or damage to drive train **60**. ECM **12** further limits the torque and speed of drive train **60** when vehicle **100** is in the four-wheel or all-wheel drive configuration by limiting throttle valve **34** to a reduced maximum opening. In one embodiment, ECM **12** reduces the torque of drive train **60** in the four-wheel or all-wheel drive configuration to about 75% of the maximum torque capability of engine **38**. As such, the likelihood of the speed and torque of drive train **60** exceeding the design limits is reduced.

(80) In one embodiment, ECM **12** is configured to control the torque or horsepower of engine **38** based on the altitude or elevation of vehicle **100**. In the illustrated embodiment, ECM **12** is configured to detect the altitude or the elevation above sea level of vehicle **100** based on the detected pressure in engine manifold **136** with pressure sensor **138**. Alternatively, GPS device **44**, or another suitable device, may be used to calculate the altitude of vehicle **100**. As the altitude of vehicle **100** increases, the density and pressure of the air drawn into engine **38** through throttle valve **34** decreases. In one embodiment, the reduced density of the air drawn into engine **38** causes a reduction in the torque output of engine **38**. For example, for an engine **38** rated at 70 horsepower (HP), engine **38** produces a maximum power output of about 70 HP at sea-level. As the altitude of vehicle **100** increases, the maximum power output of engine **38** may decrease due to the reduced air density. At some altitudes, for example, the maximum power output of the 70 HP rated engine **38** may drop to about 60 HP.

(81) In one embodiment, ECM **12** limits the throttle at lower altitudes such that engine **38** produces substantially the same torque or power output across a range of altitudes. For example, for the engine **38** rated at 70 HP, at a first altitude (e.g. at approximately sea level), ECM **12** limits the opening of throttle valve **34** to a first maximum opening such that the maximum power output of engine **38** is approximately 60 HP. For example, ECM **12** may limit the throttle valve **34** to about 90% of fully open to cause a reduction in maximum engine power to about 60 HP. Upon detection of vehicle **100** reaching a second altitude higher than the first altitude, ECM **12** increases the maximum opening of throttle valve **34** to a second maximum opening that is greater than the first maximum opening. The second maximum opening is based on the second altitude such that engine **38** continues to produce a maximum power output of approximately 60 HP due to the reduced air density at the second altitude. For example, upon vehicle **100** reaching the second altitude, ECM **12** increases the maximum opening limit of throttle valve **34** to approximately 95% such that engine **38** continues to produce 60 HP despite the increased altitude. Similarly, upon detection of vehicle **100** exceeding a third altitude higher than the second altitude, ECM **12** increases the maximum opening of throttle valve **34** to a third maximum opening that is greater than the second maximum opening. The third maximum opening is based on the third altitude such that engine **38** continues to produce a maximum power output of approximately 60 HP as a result of the further reduced air

density at the third altitude. For example, upon vehicle **100** reaching the third altitude, ECM **12** increases the maximum opening limit of throttle valve **34** to approximately 100% such that engine **38** continues to produce 60 HP despite the increased altitude. Additional altitude thresholds and maximum throttle openings may be incorporated. In one embodiment, the maximum opening of throttle valve **34** is directly proportional to the detected altitude and is based on the estimated air density at the various altitudes.

(82) In one embodiment, transmission **62** is a continuously variable transmission (CVT) **62**, and ECM **12** is configured to limit the torque or power applied to CVT **62** to protect the belt or other components of the CVT **62**. Further, by limiting power applied to CVT **62**, the gap between belt elements of CVT **62** and the resulting belt slip may also be reduced. In this embodiment, ECM **12** is configured to detect the gear ratio of CVT **62** based on feedback from a position sensor (e.g. sensor **74** of FIG. **3**) coupled to CVT **62**. ECM **12** further determines the output power or torque from engine **38** based on the position of throttle valve **34** and other inputs, as described herein. Based on the detected gear ratio of CVT **62**, the detected engine speed and wheel speed with respective sensors **28**, **30**, and the torque output of engine **38**, ECM **12** calculates the amount of power being applied to the belt of CVT **62**. ECM **12** limits the power applied to the belt of CVT **62** to a predetermined maximum level by controlling the position of throttle valve **34**, as described herein. The predetermined maximum power level varies according to the detected gear ratio of CVT **62**. For example, a higher gear ratio of CVT **62** may correspond to a higher maximum power level. In one embodiment, the predetermined maximum power level is set based on the stress or strain design limits of the belt of CVT **62** to reduce the likelihood of CVT **62** being damaged. The predetermined maximum power level may be further based on the design limits of the CVT **62** to reduce the likelihood of belt slip. In another embodiment, ECM **12** maintains the power applied to CVT **62** to within a predetermined power range by controlling throttle valve **34**.

(83) In one embodiment, ECM **12** is configured to maintain application of a positive torque on components of drive train **60** during periods of engine idle. For example, ECM **12** adjusts throttle valve **34** to hold the drive train **60** components above a zero-torque level when engine **38** is idling. In one embodiment, ECM **12** maintains the applied torque to drive train **60** at a minimal level such that wheels **102**, **104** are not caused to rotate. In particular, the applied torque to drive train **60** during the engine idle condition is less than the torque required to rotate driven wheels **102**, **104**. ECM **12** monitors the torque applied to drive train **60** based on throttle valve **34**, engine manifold pressure, engine speed, and other inputs, as described herein. In one embodiment, maintaining at least a minimal torque on the components of drive train **60** serves to reduce the likelihood of the components clashing or colliding when drive train **60** is transitioned from an idle condition to a drive condition. In one embodiment, when engine **38** is idling and drive train **60** components are above a zero-torque level, drive train **60** and wheels **102**, **104** are more responsive to initial input from throttle operator **14** due to the reduced “play” in the drive train **60**. In one embodiment, the torque applied to drive train **60** during the idle condition is less than or equal to about 1% of the maximum torque capability of engine **38**.

(84) In one embodiment, engine **38** generates power while vehicle **100** is stationary to drive hydraulics, a power-take-off (PTO), an inverter, or other mechanical or electrical auxiliary systems. The hydraulics and the PTO may be used to manipulate an attachment or an implement, and the inverter may be used to charge an onboard battery or other energy storage device, for example. In one embodiment, when transmission **62** is in a neutral gear, an operator selects an input at user interface **48** to activate engine **38** for generating power to the auxiliary systems. For example, an operator may select an input to activate the hydraulics, the PTO, or the inverter. ECM **12** controls throttle valve **34** to deliver power from engine **38** to the selected system. In one embodiment, ECM **12** maintains engine **38** at a fixed speed to provide constant power output to the selected system.

(85) In the illustrated embodiment of FIG. **3**, vehicle **100** includes a safety net **76** or other suitable platform or device configured to support the operator and to reduce the likelihood of an operator's

feet and/or legs slipping past footrests **126** (FIG. **2**) of vehicle **100**. A safety net sensor or switch **78** is provided at each safety net **76** to detect the attachment of the safety net **76** to vehicle **100**. Switches **78** are configured to provide a signal to ECM **12** indicating whether safety nets **76** are properly attached to vehicle **100**. In one embodiment, vehicle **100** further includes one or more seatbelts **130** or another suitable safety harness configured to help secure the operator within seat **106** (FIG. **2**) of vehicle **100**. For example, seatbelt **130** serves to support the operator from movement away from seat **106**. A seatbelt sensor or switch **132** is provided for each seatbelt **130** and is configured to provide a signal to ECM **12** indicating whether the corresponding seatbelt **130** is properly engaged or secured. Switches **78** and **132** may include proximity sensors or limit switches, for example. In one embodiment, switches **78** and **132** communicate with ECM **12** via CAN communication.
(86) In one embodiment, ECM **12** implements a driver equipment speed limit based on the proper engagement of safety nets **76** and/or seatbelts **130**. When a safety net **76** and/or a seatbelt **130** is not properly attached to vehicle **100** based on feedback from switches **78** and **132**, ECM **12** limits or prevents operation of vehicle **100**. For example, ECM **12** may implement a reduced maximum speed of vehicle **100** (e.g. 5 mph) upon one of safety nets **76** and/or seatbelts **130** being removed or being improperly attached. The driver equipment speed limit feature of ECM **12** may be disabled by an operator (e.g. by entering a disable code into ECM **12**) such that safety nets **76** and seatbelts **130** are not required to be properly engaged for unrestricted operation of vehicle **100**. In one embodiment, a passenger sensor is provided to detect when a passenger is present. Upon detection of a passenger, ECM **12** may limit vehicle operation based on the passenger seatbelt **130** and/or safety nets **76** not being properly engaged.
(87) In one embodiment, when vehicle **100** is traveling above a threshold vehicle speed and one of nets **76** and/or seatbelts **130** is disengaged, ECM **12** causes vehicle **100** to slow to a specified vehicle speed at a specified deceleration rate. In one embodiment, the specified deceleration rate, the threshold vehicle speed, and/or the specified vehicle speed are adjustable by the operator through user interface **48**. In one embodiment, the threshold vehicle speed and the specified vehicle speed are the same. When the vehicle speed is being limited by ECM **12** and the net **76** and/or seatbelt **130** is re-engaged, ECM **12** removes the speed limit and accelerates the vehicle **100** to the speed commanded by throttle control **16** at a specified acceleration rate. The specified acceleration rate may be adjustable by an operator.
(88) ECM **12** sends a message to display **52** of user interface **48** to notify the operator that the safety net **76** and/or seatbelt **130** is disengaged or improperly attached. In one embodiment, if a sensor fault is detected at sensors **78** or **132**, ECM **12** limits the vehicle speed to a predetermined maximum speed until the fault is cleared or corrected. In one embodiment, the predetermined maximum speed is adjustable by an operator through user interface **48**.
(89) While a single ECM **12** is illustrated and described in the present disclosure, additional controllers may be provided to perform the disclosed functions and to provide the disclosed features of ETC system **10**.
(90) While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

Claims

1. A vehicle for traversing a ground surface, comprising: a plurality of ground engaging mechanisms; a chassis supported by the plurality of ground engaging mechanisms; a plurality of vehicle systems supported by the plurality of ground engaging mechanisms, the plurality of vehicle

systems including: a plurality of suspensions operatively coupling the plurality of ground engaging mechanisms to the chassis; and a drive train including an engine, the engine being operatively coupled to at least a portion of the plurality of ground engaging mechanisms to drive the portion of the plurality of ground engaging mechanisms; a seat supported by the plurality of ground engaging mechanisms, the seat having a forwardmost extent, the plurality of ground engaging mechanisms having a first portion positioned forward of the forwardmost extent of the seat and a second portion positioned rearward of the forwardmost extent of the seat; a steering input positioned in front of the seat, the steering input operatively coupled to the first portion of the plurality of ground engaging mechanisms; a plurality of sensors supported by the plurality of ground engaging mechanisms, the plurality of sensors including a first suspension sensor operatively coupled to a first suspension of the plurality of suspensions to monitor a characteristic of the first suspension; and a controller operatively coupled to the plurality of sensors, the controller based on at least one of the plurality of sensors being configured to: determine if the vehicle is airborne; and determining a pitch of the vehicle while the vehicle is airborne; adjust a performance characteristic of at least one of the plurality of vehicle systems based on the vehicle being airborne to adjust the pitch of the vehicle.
2. The vehicle of claim 1, wherein the performance characteristic is a torque of the engine of the drive train.
3. The vehicle of claim 2, wherein the torque of the engine is adjusted to reduce a likelihood of damage to the drive train.
4. The vehicle of claim 2, wherein the torque of the engine is adjusted to alter a movement of at least one of the ground engaging mechanisms.
5. The vehicle of claim 2, wherein the torque of the engine is adjusted to alter a speed of at least one of the ground engaging mechanisms while airborne to be substantially the same as when the vehicle initially left the ground surface.
6. The vehicle of claim 1, wherein the plurality of ground engaging mechanisms are wheels and the plurality of sensors includes a wheel speed sensor and an engine speed sensor and the vehicle is determined to be airborne based on an acceleration detected by the wheel speed sensor exceeding a design specification of the vehicle.
7. The vehicle of claim 1, wherein the first suspension of the plurality of suspensions moveably couples a first ground engaging mechanism to the chassis, the first suspension including a first shock.
8. The vehicle of claim 7, wherein the first suspension sensor monitors a characteristic of the first shock.
9. The vehicle of claim 8, wherein the vehicle is determined to be airborne based on the characteristic of the first shock.
10. The vehicle of claim 7, wherein the first suspension sensor monitors a height characteristic of the first shock.
11. The vehicle of claim 10, wherein the vehicle is determined to be airborne based on the height characteristic of the first shock.
12. The vehicle of claim 7, wherein the first suspension sensor monitors a compression characteristic of the first suspension.
13. The vehicle of claim 12, wherein the vehicle is determined to be airborne based on the compression characteristic of the first suspension.
14. The vehicle of claim 7, wherein the plurality of suspensions further includes a second suspension which movably couples a second ground engaging mechanism to the chassis, the second suspension having a second shock and the plurality of sensors further includes a second suspension sensor operatively coupled to the second suspension.
15. The vehicle of claim 14, wherein the first suspension is positioned forward of the forwardmost extent of the seat and the second suspension is positioned rearward of the forwardmost extent of the seat.

16. The vehicle of claim 15, wherein the seat is a straddle seat.
17. The vehicle of claim 15, wherein the seat is a straddle seat and the steering input is a handlebar.
18. The vehicle of claim 15, wherein the first suspension sensor monitors a characteristic of the first shock and the second suspension sensor monitors a characteristic of the second shock.
19. The vehicle of claim 18, wherein the vehicle is determined to be airborne based on at least one of the characteristic of the first shock and the characteristic of the second shock.
20. The vehicle of claim 15, wherein the first suspension sensor monitors a height characteristic of the first shock and the second suspension sensor monitors a height characteristic of the second shock.
21. The vehicle of claim 20, wherein the vehicle is determined to be airborne based on at least one of the height characteristic of the first shock and the height characteristic of the second shock.
22. The vehicle of claim 15, wherein the first suspension sensor monitors a compression characteristic of the first suspension and the second suspension sensor monitors a compression characteristic of the second suspension.
23. The vehicle of claim 22, wherein the vehicle is determined to be airborne based on at least one of the compression characteristic of the first suspension and the compression characteristic of the second suspension.
24. The vehicle of claim 1, wherein the first suspension is positioned forward of the forwardmost extent of the seat.
25. The vehicle of claim 1, wherein the first suspension is positioned rearward of the forwardmost extent of the seat.
26. The vehicle of claim 1, wherein the plurality of sensors includes a yaw rate sensor and the plurality of vehicle systems includes a plurality of brakes and the controller selectively applies at least a portion of the plurality of brakes to alter a movement of the vehicle based on the yaw rate sensor.
27. The vehicle of claim 1, further comprising a location detection device configured to detect a location of the vehicle and the controller being configured to limit a vehicle speed of the vehicle based on whether the detected location is inside a received geographical area.
28. A method of adjusting vehicle performance, comprising the steps of: providing a vehicle configured to be driven relative to a ground surface by operatively coupling an engine to at least one ground engaging mechanism, the vehicle including a plurality of vehicle systems including at least one suspension and a drive train, the at least one ground engaging mechanism being movably coupled to a chassis of the vehicle through the at least one suspension; monitoring a suspension sensor of the at least one suspension of the vehicle; monitoring a speed sensor operative to determine a speed of the at least one ground engaging mechanism; determining the vehicle is airborne based upon each of the suspension sensor and the speed sensor; and based on determining the vehicle is airborne, adjusting a performance characteristic of a first vehicle system.
29. The method of claim 28, wherein the step of determining the vehicle is airborne includes the step of determining the vehicle is airborne based on the monitored suspension sensor.
30. The method of claim 28, further comprising: monitoring an angular velocity of the vehicle; and adjusting at least one of the plurality of vehicle systems based on the monitored angular velocity.
31. The method of claim 30, wherein the plurality of vehicle systems includes a plurality of brakes and at least a portion of the plurality of brakes is selectively applied based on the monitored angular velocity.
32. The method of claim 28, further comprising: monitoring an inclination angle of the vehicle; and adjusting at least one of the plurality of vehicle systems based on the monitored inclination angle.
33. The method of claim 32, wherein a torque of the engine is altered based on the inclination angle of the vehicle.
34. The method of claim 28, wherein based on determining the vehicle is airborne, adjusting a torque applied to the at least one ground engaging mechanism even during continued application of

a throttle input.

35. The method of claim 34, wherein based on determining the vehicle is airborne, reducing an opening of a throttle valve even during continued application of a throttle input.

36. A method of controlling performance of a vehicle, the method comprising the steps of: receiving a drive mode selection through a user interface supported by the vehicle; adjusting at least one of a plurality of vehicle systems supported by a plurality of ground engaging mechanisms based on the received drive mode selection, the plurality of vehicle systems including a plurality of suspensions operatively coupling the plurality of ground engaging mechanisms to a chassis; and a drive train including an engine, the engine being operatively coupled to at least a portion of the plurality of ground engaging mechanisms to drive the portion of the plurality of ground engaging mechanisms; determining if the vehicle is airborne wherein the plurality of ground engaging mechanisms lose contact with a ground surface; and adjusting the at least one of the plurality of vehicle systems based on the vehicle being airborne such that the engine is operatively coupled to a first portion of the plurality of ground engaging members prior to being airborne and operatively coupled to a second portion of the plurality of ground engaging members while being airborne.

37. The method of claim 36, wherein the step of determining if the vehicle is airborne includes monitoring at least one sensor supported by at least one of the plurality of ground engaging mechanisms.

38. The method of claim 37 wherein the at least one sensor provides an indication of a characteristic of at least one of the plurality of suspensions.

39. The method of claim 38 wherein the at least one sensor provides an indication of a characteristic of a shock of at least one of the plurality of suspensions.