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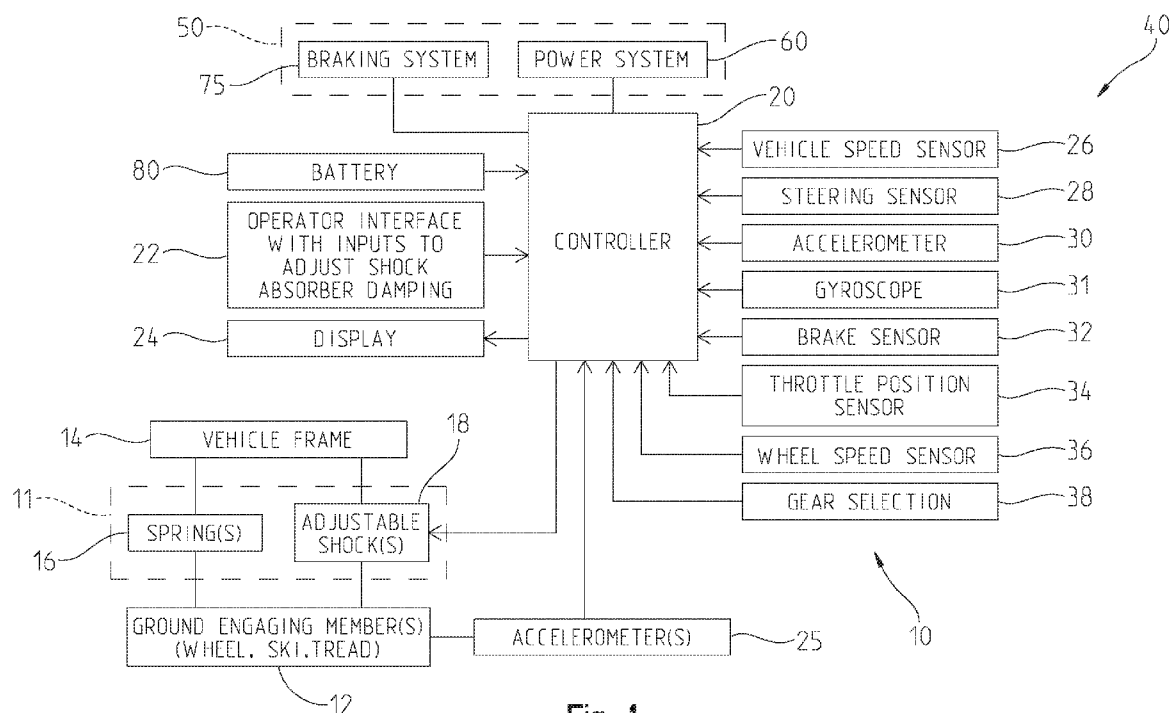


Fig. 1

(57) Abstract: A damping control system for a vehicle having a suspension located between a plurality of ground engaging members and a vehicle frame includes at least one adjustable shock absorber having an adjustable damping profile.

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VEHICLE HAVING ADJUSTABLE SUSPENSION

[0001] The present disclosure relates to improved suspension for a vehicle and in particular to systems and methods of damping control for shock absorbers.

[0002] Currently some off-road vehicles include adjustable shock absorbers. These adjustments include spring preload, high and low speed compression damping and/or rebound damping. In order to make these adjustments, the vehicle is stopped and the operator makes an adjustment at each shock absorber location on the vehicle. A tool is often required for the adjustment. Some on-road automobiles also include adjustable electric shocks along with sensors for active ride control systems. The system of the present disclosure allows an operator to make real time "on-the-go" adjustments to the shocks to obtain the most comfortable ride for given terrain and payload scenarios.

[0003] Exemplary systems are disclosed in US Patent No. 9,010,768 and US Published Patent Application No. 2016/0059660, both assigned to the present assignee and the entire disclosures of each expressly incorporated by reference herein.

[0004] Vehicles often have springs (coil, leaf, or air) at each wheel, track, or ski to support a majority of the load. The vehicle of the present disclosure also has electronic shocks controlling the dynamic movement of each wheel, ski, or track. The electronic shocks have one or more valves that control the damping force of each shock. This valve may control compression damping only, rebound damping only, or a combination of compression and rebound damping. The valve(s) may be connected to a controller having a user interface that is within the driver's reach for adjustment while operating the vehicle. In one embodiment, the controller increases or decreases the damping characteristics of the shock absorbers based on user inputs received from an operator. In another embodiment, the controller has several preset damping modes for selection by the operator. The controller is also coupled to sensors supported by at least one of the suspension and the chassis to provide an actively controlled damping system.

[0005] In an exemplary embodiment of the present disclosure, a recreational vehicle is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least

one suspension including at least one adjustable shock absorber having at least one adjustable damping profile; a driveline torque management system operatively coupled to at least one of the plurality of ground engaging members, the driveline torque management system having at least one adjustable driveline torque management system characteristic; at least one airborne sensor positioned on the recreational vehicle, the at least one airborne sensor monitoring a movement characteristic of the recreational vehicle; and at least one controller operatively coupled to the driveline torque management system, the at least one airborne sensor, and the at least one adjustable shock absorber. The at least one controller determining if the recreational vehicle is in an airborne state and in response to determining the recreational vehicle is in the airborne state altering both the adjustable damping profile of the at least one adjustable shock absorber and altering the at least one adjustable driveline torque management system of the driveline torque management system.

[0006] In another exemplary embodiment of the present disclosure, a recreational vehicle is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors. The at least one controller receives a plurality of inputs from the plurality of vehicle condition sensors. The at least one controller determines if the at least one adjustable shock may be reconfigured from a first ride mode of the plurality of ride modes to a second ride mode of the plurality of ride modes by determining if a first condition is satisfied, if the first condition is satisfied then configuring the at least one shock absorber in the second ride mode, if the first condition is not satisfied then determining if a second condition is satisfied, if the second condition is satisfied then configuring the at least one shock absorber in the second ride mode, if both the first condition and the second condition are not satisfied remaining in the first

ride mode, wherein only one of the first condition and the second condition is based on at least one of a plurality of inputs from the plurality of vehicle condition sensors.

[0007] In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber having at least one adjustable damping profile; a driveline torque management system operatively coupled to at least one of the plurality of ground engaging members, the driveline torque management system having at least one adjustable driveline torque management system characteristic; at least one airborne sensor positioned on the recreational vehicle, the at least one airborne sensor monitoring a movement characteristic of the recreational vehicle; at least one controller operatively coupled to the driveline torque management system, the at least one airborne sensor, and the at least one adjustable shock absorber. The at least one controller determining if the recreational vehicle is in an airborne state and in response to determining the recreational vehicle is in the airborne state altering the adjustable damping profile of the at least one adjustable shock absorber to a first damping profile if the airborne state spans a first time duration and to a second damping profile if the airborne state spans a second time interval, the second time interval being longer than the first time interval.

[0008] In a further exemplary embodiment of the present disclosure, a method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver is provided. The method comprising determining the vehicle is one of cornering and spinning based on a yaw characteristic of the vehicle; and adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the yaw characteristic.

[0009] In yet a further exemplary embodiment of the present disclosure, a method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver is provided. The method comprising (a) receiving a plurality of inputs from a plurality of sensors supported by the vehicle, the plurality of sensors including a first sensor having a first input and a second sensor

having a second input; (b) based on at least the first input from the first sensor, reactively determining if the vehicle is cornering; (c) based on at least the second input from the second sensor, predictively determining if the vehicle is cornering; and (d) adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle when it is determined that the vehicle is cornering in either step (b) or step (c).

[0010] In still another exemplary embodiment of the present disclosure, a recreational vehicle is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members, the plurality of vehicle condition sensors including a yaw characteristic sensor; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors. The at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors and configured to determine when the vehicle is cornering based on an input from the yaw characteristic sensor.

[0011] In still yet a further exemplary embodiment of the present disclosure, a recreational vehicle is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members, the plurality of vehicle condition sensors including an ambient weather sensor; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors. The at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors and adjusting at least one damping characteristic of the at least one adjustable shock based on an input from the ambient weather sensor.

[0012] In yet another exemplary embodiment of the present disclosure, a method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver is provided. The method comprising receiving an indication of an ambient weather condition of an environment surrounding the vehicle; and adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the indication of the received ambient weather condition.

[0013] In yet still another exemplary embodiment of the present disclosure, a method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver is provided. The method comprising sensing a change in a terrain being traversed by the vehicle; and adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the sensed change in the terrain.

[0014] In still another exemplary embodiment of the present disclosure, a method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver is provided. The method comprising storing at least one historical suspension damping characteristic and at least one vehicle location corresponding to the at least one historical suspension damping characteristic; and adjusting the damping characteristic of the at least one adjustable shock absorber at a first vehicle location based on the at least one historical suspension damping characteristic corresponding to the first vehicle location.

[0015] In yet another exemplary embodiment of the present disclosure, a recreational vehicle for operation by an operator is provided. The recreational vehicle comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber having at least one adjustable damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members; at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors, the at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors; and a user interface system supported by the frame. The user interface system including a display. The

display being configurable with the at least one controller to display a screen layout, the screen layout including at least one of (i) at least one numerical indication of at least one damping characteristic of the at least one adjustable shock absorber and (ii) at least one graphical representation of the at least one damping characteristic of the at least one adjustable shock absorber, the screen layout further including at least one of (i) a notification of an active vehicle condition modifier which alters the at least one damping characteristic of the at least one adjustable shock absorber and (ii) a vehicle steering angle indicator.

[0016] In an example thereof, the at least one damping characteristic relates to a compression damping value of the at least one adjustable shock.

[0017] In another example thereof, the at least one damping characteristic relates to a rebound damping value of the at least one adjustable shock.

[0018] In yet another example thereof, the screen layout further includes a vehicle g-force indicator, the vehicle g-force indicator provides a first indication of a magnitude of the g-force being experienced by the vehicle and a second indication of a direction of the g-force being experienced by the vehicle.

[0019] In still another example thereof, the screen layout further a graphical representation of the vehicle, the at least one adjustable shock absorber includes a first shock absorber associated with a first suspension of the at least one suspension and a second shock absorber associated with a second suspension of the at least one suspension, the first shock absorber being positioned on a first side of a vertical longitudinal vehicle centerline plane and the second shock absorber being positioned on a second side of the vertical longitudinal vehicle centerline plane, the second side being opposite the first side. In a variation thereof, a first numerical indication of the at least one numerical indication is associated with the first shock absorber and is positioned on a first side of the graphical representation of the vehicle and a second numerical indication of the at least one numerical indication is associated with the second shock absorber and is positioned on a second side of the graphical representation of the vehicle, the second side of the graphical representation of the vehicle is opposite the first side of the graphical representation of the vehicle. In another variation thereof, a first graphical indication of the at least one graphical indication is associated with the

first shock absorber and is positioned on a first side of the graphical representation of the vehicle and a second graphical indication of the at least one graphical indication is associated with the second shock absorber and is positioned on a second side of the graphical representation of the vehicle, the second side of the graphical representation of the vehicle is opposite the first side of the graphical representation of the vehicle.

[0020] In a further example thereof, the screen layout further a graphical representation of the vehicle, the at least one adjustable shock absorber includes a first shock absorber associated with a first suspension of the at least one suspension and a second shock absorber associated with a second suspension of the at least one suspension, the first suspension being a front suspension of the vehicle and the second suspension being a rear suspension of the vehicle. In a variation thereof, a first numerical indication of the at least one numerical indication is associated with the first shock absorber and is positioned proximate a front portion of the graphical representation of the vehicle and a second numerical indication of the at least one numerical indication is associated with the second shock absorber and is positioned proximate a rear portion of the graphical representation of the vehicle. In another variation thereof, a first graphical indication of the at least one graphical indication is associated with the first shock absorber and is positioned proximate a front portion of the graphical representation of the vehicle and a second graphical indication of the at least one graphical indication is associated with the second shock absorber and is positioned proximate a rear portion of the graphical representation of the vehicle.

[0021] In still a further example thereof, the notification of the active vehicle condition modifier which alters the at least one damping characteristic of the at least one adjustable shock absorber is associated with one of an anti-dive condition, a cornering condition, a ride condition, a squat condition, a brake condition, a roll/cornering condition, and a jump/pitch condition.

[0022] Additional features of the present disclosure will become apparent to those skilled in the art upon consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the invention as presently perceived.

[0023] The foregoing aspects and many additional features of the present system and method will become more readily appreciated and become better understood by reference to the following detailed description when taken in conjunction with the accompanying drawings, where:

[0024] FIG. 1 illustrates a representative view of components of a vehicle of the present disclosure having a suspension with a plurality of continuous damping control shock absorbers and a plurality of sensors integrated with a controller of the vehicle;

[0025] FIG. 2 illustrates an adjustable damping shock absorber coupled to a vehicle suspension;

[0026] FIG. 3 illustrates an x-axis, a y-axis, and a z-axis for a vehicle such as an ATV. ;

[0027] FIG. 4 illustrates a representative view of an exemplary power system for the vehicle of FIG. 1;

[0028] FIG. 5 illustrates a representative view of an exemplary controller of the vehicle of FIG. 1;

[0029] FIG. 6 illustrates a first, perspective view of an exemplary vehicle;

[0030] FIG. 7 illustrates a second, perspective view of the exemplary vehicle of FIG. 6;

[0031] FIG. 8 illustrates a side view of the exemplary vehicle of FIG. 6;

[0032] FIG. 9 illustrates a bottom view of the exemplary vehicle of FIG. 6;

[0033] FIG. 10 illustrates an exemplary representation of an operation of the suspension controller of FIG. 5 and interaction with other vehicle systems;

[0034] FIG. 11 illustrates an exemplary screen layout for a graphical user interface of an operator interface of the vehicle of FIG. 1;

[0035] FIG. 12 illustrates another exemplary screen layout for the graphical user interface of the operator interface of the vehicle of Fig. 1;

[0036] FIG. 12A illustrates a further exemplary screen layout for the graphical user interface of the operator interface of the vehicle of Fig. 1;

[0037] FIG. 12B illustrates a further exemplary screen layout for the graphical user interface of the operator interface of the vehicle of Fig. 1;

[0038] FIG. 12C illustrates a further exemplary screen layout for the graphical user interface of the operator interface of the vehicle of Fig. 1;

[0039] FIG. 13 illustrates a representative view of an operation of a suspension controller of FIG. 5 wherein a requested ride mode change is permitted or denied based on a plurality of inputs based on vehicle condition sensors and/or vehicle condition modifier states;

[0040] FIG. 14 illustrates a representative view of an operation of a suspension controller of FIG. 5 wherein a requested ride mode change is permitted or denied based on a plurality of inputs based on vehicle condition sensors and/or vehicle condition modifier states including a current ride mode, a vehicle speed, vehicle acceleration values, and vehicle inertial values;

[0041] FIG. 15 illustrates an exemplary processing sequence of a ride mode change logic of the suspension controller;

[0042] FIG. 16 illustrates an exemplary processing of the controller of FIG. 1 for a power save condition;

[0043] FIG. 17 illustrates an exemplary processing of the controller of FIG. 1 for handling multiple ride mode change requests;

[0044] FIG. 18 illustrates an exemplary aerial view of a terrain, multiple vehicles on a trail of the terrain, and potential ride mode changes based on the terrain or vehicles;

[0045] FIG. 19A illustrates an exemplary processing sequence of the controller of FIG. 1 related to an airborne detection of the vehicle;

[0046] FIG. 19B illustrates an exemplary processing sequence of the controller of FIG. 1 related to an airborne detection of the vehicle;

[0047] FIG. 20 illustrates exemplary damping control curves for the adjustable shocks of FIG. 1 in response to an airborne detection of the vehicle;

[0048] FIG. 21 illustrates an exemplary processing sequence of the controller of FIG. 1 regarding airborne detection of the vehicle;

[0049] FIG. 22 illustrates an exemplary processing sequence of the controller of FIG. 1 regarding a steering angle of the vehicle;

[0050] FIG. 23A illustrates an exemplary processing sequence of the controller of FIG. 1 regarding airborne detection of the vehicle;

[0051] FIG. 23B illustrates an exemplary processing sequence of the controller of FIG. 1 regarding airborne detection of the vehicle;

[0052] FIG. 24A illustrates an exemplary processing sequence of the controller of FIG. 1 regarding cornering detection of the vehicle;

[0053] FIG. 24B illustrates an exemplary processing sequence of the controller of FIG. 1 regarding cornering detection of the vehicle;

[0054] FIG. 25 illustrates exemplary operator inputs of the operator interface of FIG. 1;

[0055] FIG. 26. Illustrates an exemplary terrain sensing embodiment of the controller of FIG. 1;

[0056] FIG. 27A illustrates an exemplary terrain progression for the vehicle of FIG. 6; and

[0057] FIG. 27B illustrates an exemplary suspension damping level for the terrain progression of FIG. 27A.

[0058] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of various features and components according to the present disclosure, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present disclosure.

[0059] For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, which are described below. The embodiments disclosed below are not intended to be exhaustive or limited to the precise form disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings.

[0060] Referring now to FIG. 1, the present disclosure relates to a vehicle 10 having a suspension system 11 located between a plurality of ground engaging members 12 and a vehicle frame 14. Exemplary ground engaging members 12 include wheels, skis, guide tracks, treads or other suitable devices for supporting the vehicle

relative to the ground. The suspension typically includes springs 16 and shock absorbers 18 coupled between the ground engaging members 12 and the frame 14. The springs 16 may include, for example, coil springs, leaf springs, air springs or other gas springs. The air or gas springs 16 may be adjustable. See, for example, U.S. Patent No. 7,950,486, assigned to the current assignee, the entire disclosure of which is incorporated herein by reference.

[0061] The adjustable shock absorbers 18 are often coupled between the vehicle frame 14 and the ground engaging members 12 through an A-arm linkage 70 (See FIG. 2) or other type linkage. Springs 16 are also coupled between the ground engaging members 12 and the vehicle frame 14. FIG. 2 illustrates an adjustable shock absorber 18 mounted on an A-arm linkage 70 having a first end pivotably coupled to the vehicle frame 14 and a second end pivotably coupled to A-arm linkage 70 which moves with wheel 12. A damping control activator 74 is coupled to controller 20 by wires 71. An exemplary damping control activator is an electronically controlled valve which is activated to increase or decrease the damping characteristics of adjustable shock absorber 18.

[0062] In one embodiment, the adjustable shock absorbers 18 include solenoid valves mounted at the base of the shock body or internal to a damper piston of the shock absorber 18. The stiffness of the shock is increased or decreased by introducing additional fluid to the interior of the shock absorber, removing fluid from the interior of the shock absorber, and/or increasing or decreasing the ease with which fluid can pass from a first side of a damping piston of the shock absorber to a second side of the damping piston of the shock absorber. In another embodiment, the adjustable shock absorbers 18 include a magnetorheological fluid internal to the shock absorber 18. The stiffness of the shock is increased or decreased by altering a magnetic field experienced by the magnetorheological fluid. Additional details on exemplary adjustable shocks are provided in US Published Patent Application No. 2016/0059660, filed November 6, 2015, titled VEHICLE HAVING SUSPENSION WITH CONTINUOUS DAMPING CONTROL, assigned to the present assignee, the entire disclosure of which is expressly incorporated by reference herein.

[0063] In one embodiment, a spring 16 and shock 18 are located adjacent each of the ground engaging members 12. In an ATV, for example, a spring 16 and an adjustable shock 18 are provided adjacent each of the four wheels 12. Some manufacturers offer adjustable springs 16 in the form of either air springs or hydraulic preload rings. These adjustable springs 16 allow the operator to adjust the ride height on the go. However, a majority of ride comfort comes from the damping provided by shock absorbers 18.

[0064] In an illustrated embodiment, adjustable shocks 18 are electrically controlled shocks for adjusting damping characteristics of shocks 18. A controller 20 provides signals to adjust damping of the shocks 18 in a continuous or dynamic manner. Adjustable shocks 18 may be adjusted to provide differing compression damping, rebound damping or both. In one embodiment, adjustable shocks 18 include a first controllable valve to adjust compression damping and a second controllable valve to adjust rebound damping. In another embodiment, adjustable shocks include a combination valve which controls both compression damping and rebound damping.

[0065] In an illustrated embodiment of the present disclosure, a user interface 22 is provided in a location easily accessible to the driver operating the vehicle. Preferably, the user interface 22 is either a separate user interface mounted adjacent the driver's seat on the dashboard or integrated onto a display within the vehicle. User interface 22 includes user input devices to allow the driver or a passenger to manually adjust shock absorber 18 damping during operation of the vehicle based on road conditions that are encountered or to select a preprogrammed active damping profile for shock absorbers 18 by selecting a ride mode. In one embodiment, a selected ride mode alters characteristics of suspension system 11 alone, such as the damping profile for shock absorbers 18. In one embodiment, a selected ride mode alters characteristics of suspension system 11 and other vehicle systems, such as a driveline torque management system 50.

[0066] Exemplary input devices for operator interface 22 include levers, buttons, switches, soft keys, and other suitable input devices. Operator interface 22 may also include output devices to communicate information to the operator. Exemplary output devices include lights, displays, audio devices, tactile devices, and other suitable output

devices. In another illustrated embodiment, the user input devices are on a steering wheel, handle bar, or other steering control of the vehicle 10 to facilitate actuation of the damping adjustment. A display 24 is also provided on or next to the user interface 22 or integrated into a dashboard display of vehicle 10 to display information related to the shock absorber damping settings.

[0067] Controller 20 receives user inputs from operator interface 22 and adjusts the damping characteristics of the adjustable shocks 18 accordingly. The operator may independently adjust front and rear shock absorbers 18 to adjust the ride characteristics of the vehicle. In certain embodiments, each of the shocks 18 is independently adjustable so that the damping characteristics of the shocks 18 are changed from one side of the vehicle to another. Side-to-side adjustment is desirable during sharp turns or other maneuvers in which different damping profiles for shock absorbers 18 on opposite sides of the vehicle improves the handling characteristics of the vehicle. The damping response of the shock absorbers 18 can be changed in a matter of milliseconds to provide nearly instantaneous changes in damping for potholes, dips in the road, or other driving conditions.

[0068] A plurality of vehicle condition sensors 40 are also coupled to the controller 20. For example, a global change accelerometer 25 is coupled adjacent each ground engaging member 12. Each of the accelerometers 25 provides an output signal coupled to controller 20. Accelerometers 25 provide an output signal indicating movement of the ground engaging members and the suspension components 16 and 18 as the vehicle traverses different terrain.

[0069] Additional vehicle condition sensors 40 may include a vehicle speed sensor 26, a steering sensor 28, a chassis supported accelerometer 30, a chassis supported gyroscope 31, and other sensors which monitor one or more characteristics of vehicle 10. Each of vehicle speed sensor 26, steering sensor 28, chassis supported accelerometer 30, and chassis supported gyroscope 31 are operatively coupled to controller 20 and controller 20 receives input from each of vehicle speed sensor 26, steering sensor 28, chassis supported accelerometer 30, and chassis supported gyroscope 31.

[0070] Accelerometer 30 is illustratively a three-axis accelerometer supported on the chassis to provide an indication of acceleration forces of the vehicle during operation. In one embodiment, accelerometer 30 is located at or close to a center position of vehicle 10. In the exemplary vehicle 200 illustrated in FIGS. 6-9, accelerometer 30 is located along a longitudinal centerline plane 122 of vehicle 100. The x-axis, y-axis, and z-axis for a vehicle 10, illustratively an ATV, are shown in FIG. 3.

[0071] Gyroscope 31 is illustratively a three-axis gyroscope supported on the chassis to provide indications of inertial measurements of the vehicle during operation. In one embodiment, accelerometer 30 is not located at a center of gravity of vehicle 10 and the readings of gyroscope 31 are used by controller 20 to determine the acceleration values of vehicle 10 at the center of gravity of vehicle 10. In one embodiment, accelerometer 30 and gyroscope 31 are integrated into suspension controller 86.

[0072] Additional vehicle condition sensors 40 are disclosed herein and illustratively include in FIG. 1 a brake sensor 32, a throttle position sensor 34, a wheel speed sensor 36, and a gear selection sensor 38. Each of these vehicle condition sensors 40 are operatively coupled to controller 20 to provide an output signal coupled to controller 20.

[0073] Referring to FIG. 4, one embodiment of a driveline torque management system 50 of vehicle 10 is illustrated. Driveline torque management system 50 controls the amount of torque exerted by each of ground engaging members 12. Driveline torque management system 50 provides a positive torque to one or more of ground engaging members 12 to power the movement of vehicle 10 through a power system 60. Driveline torque management system 50 further provides a negative torque to one or more of ground engaging members 12 to slow or stop a movement of vehicle 10 through a braking system 75. In one example, each of ground engaging members 12 has an associated brake of braking system 75.

[0074] In the illustrated embodiment of FIG. 4, power system 60 includes a prime mover 62. Exemplary prime movers 62 include internal combustion engines, two stroke internal combustion engines, four stroke internal combustion engines, diesel engines, electric motors, hybrid engines, and other suitable sources of motive force. To start the

prime mover 62, a power supply system 64 is provided. The type of power supply system 64 depends on the type of prime mover 62 used. In one embodiment, prime mover 62 is an internal combustion engine and power supply system 64 is one of a pull start system and an electric start system. In one embodiment, prime mover 62 is an electric motor and power supply system 64 is a switch system which electrically couples one or more batteries to the electric motor.

[0075] A transmission 66 is coupled to prime mover 62. Transmission 66 converts a rotational speed of an output shaft 61 of prime mover 62 to one of a faster rotational speed or a slower rotational speed of an output shaft 63 of transmission 66. It is contemplated that transmission 66 may additionally rotate output shaft 63 at the same speed as output shaft 61.

[0076] In the illustrated embodiment, transmission 66 includes a shiftable transmission 68 and a continuously variable transmission ("CVT") 70. In one example, an input member of CVT 70 is coupled to prime mover 62. An input member of shiftable transmission 68 is in turn coupled to an output member of CVT 70. In one embodiment, shiftable transmission 68 includes a forward high setting, a forward low setting, a neutral setting, a park setting, and a reverse setting. The power communicated from prime mover 62 to CVT 70 is provided to a drive member of CVT 70. The drive member in turn provides power to a driven member through a belt. Exemplary CVTs are disclosed in U.S. Patent No. 3,861,229; U.S. Patent No. 6,176,796; U.S. Patent No. 6,120,399; U.S. Patent No. 6,860,826; and U.S. Patent No. 6,938,508, the disclosures of which are expressly incorporated by reference herein. The driven member provides power to an input shaft of shiftable transmission 68. Although transmission 66 is illustrated as including both shiftable transmission 68 and CVT 70, transmission 66 may include only one of shiftable transmission 68 and CVT 70. Further, transmission 66 may include one or more additional components.

[0077] Transmission 66 is further coupled to at least one differential 72 which is in turn coupled to at least one ground engaging members 12. Differential 72 may communicate the power from transmission 66 to one of ground engaging members 12 or multiple ground engaging members 12. In an ATV embodiment, one or both of a front differential and a rear differential are provided. The front differential powering at

least one of two front wheels of the ATV and the rear differential powering at least one of two rear wheels of the ATV. In a side-by-side vehicle embodiment having seating for at least an operator and a passenger in a side-by-side configuration, one or both of a front differential and a rear differential are provided. The front differential powering at least one of two front wheels of the side-by-side vehicle and the rear differential powering at least one of multiple rear wheels of the side-by-side vehicle. In one example, the side-by-side vehicle has three axles and a differential is provided for each axle. An exemplary side-by-side vehicle 200 is illustrated in FIGS. 6-9.

[0078] In one embodiment, braking system 75 includes anti-lock brakes. In one embodiment, braking system 75 includes active descent control and/or engine braking. In one embodiment, braking system 75 includes a brake and in some embodiments a separate parking brake. Braking system 75 may be coupled to any of prime mover 62, transmission 66, differential 72, and ground engaging members 12 or the connecting drive members therebetween. Brake sensor 32, in one example, monitors when braking system 75 is applied. In one example, brake sensor 32 monitors when a user actuatable brake input, such as brake pedal 232 (see FIG. 7) in vehicle 100, is applied.

[0079] Referring to FIG. 5, controller 20 has at least one associated memory 76. Controller 20 provides the electronic control of the various components of vehicle 10. Further, controller 20 is operatively coupled to a plurality of vehicle condition sensors 40 which monitor various parameters of vehicle 10 or the environment surrounding vehicle 10. Controller 20 performs certain operations to control one or more subsystems of other vehicle components. In certain embodiments, the controller 20 forms a portion of a processing subsystem including one or more computing devices having memory, processing, and communication hardware. Controller 20 may be a single device or a distributed device, and the functions of the controller 20 may be performed by hardware and/or as computer instructions on a non-transitory computer readable storage medium, such as memory 76.

[0080] As illustrated in the embodiment of FIG. 5, controller 20 is represented as including several controllers. These controllers may each be single devices or distributed devices or one or more of these controllers may together be part of a single device or distributed device. The functions of these controllers may be performed by

hardware and/or as computer instructions on a non-transitory computer readable storage medium, such as memory 76.

[0081] In one embodiment, controller 20 includes at least two separate controllers which communicate over a network 78. In one embodiment, network 78 is a CAN network. Details regarding an exemplary CAN network are disclosed in US Patent Application Serial No. 11/218,163, filed September 1, 2005, the disclosure of which is expressly incorporated by reference herein. Of course any suitable type of network or data bus may be used in place of the CAN network. In one embodiment, two wire serial communication is used for some connections.

[0082] Referring to FIG. 5, controller 20 includes an operator interface controller 80 which controls communication with an operator through operator interface 22. A prime mover controller 82 controls the operation of prime mover 62. A transmission controller 84 controls the operation of transmission system 66.

[0083] A suspension controller 86 controls adjustable portions of suspension system 11. Exemplary adjustable components include adjustable shocks 18, adjustable springs 16, and/or configurable stabilizer bars. Additional details regarding adjustable shocks, adjustable springs, and configurable stabilizer bars is provided in US Published Patent Application No. 2016/0059660, filed November 6, 2015, titled VEHICLE HAVING SUSPENSION WITH CONTINUOUS DAMPING CONTROL, assigned to the present assignee, the entire disclosure of which is expressly incorporated by reference herein.

[0084] A communication controller 88 controls communications between a communication system 90 of vehicle 10 and remote devices 500 (see FIG. 17). Exemplary remote devices include other vehicles 10', personal computing devices 502, such as cellphones or tablets, a centralized computer system 504 maintaining one or more databases 506, and other types of devices remote from vehicle 10 or carried by riders of vehicle 10. In one embodiment, communication controller 88 of vehicle 10 communicates with paired devices over a wireless network. An exemplary wireless network is a radio frequency network utilizing a BLUETOOTH protocol. In this example, communication system 90 includes a radio frequency antenna. Communication controller 88 controls the pairing of devices to vehicle 10 and the communications

between vehicle 10 and the remote device. In one embodiment, communication controller 88 of vehicle 10 communicates with remote devices over a cellular network. In this example, communication system 90 includes a cellular antenna and communication controller 88 receives and sends cellular messages from and to the cellular network. In one embodiment, communication controller 88 of vehicle 10 communicates with remote devices over a satellite network. In this example, communication system 90 includes a satellite antenna and communication controller 88 receives and sends messages from and to the satellite network. In one embodiment, vehicle 10 is able to communicate with other vehicles 10 over a Radio Frequency mesh network and communication controller 88 and communication system 90 are configured to enable communication over the mesh network. An exemplary vehicle communication system is disclosed in US Patent Application Serial No. 15/262,113, filed September 12, 2016, titled VEHICLE TO VEHICLE COMMUNICATIONS DEVICE AND METHODS FOR RECREATIONAL VEHICLES, the entire disclosure of which is expressly incorporated by reference herein.

[0085] A steering controller 102 controls portions of a steering system 104. In one embodiment, steering system 104 is a power steering system and includes one or more steering sensors 28. Exemplary sensors and electronic power steering units are provided in U.S. Patent Application Serial No. 12/135,107, assigned to the assignee of the present application, titled VEHICLE, docket PLR-06-22542.02P, the disclosure of which is expressly incorporated by reference herein.

[0086] A vehicle controller 92 controls lights, loads, accessories, chassis level functions, and other vehicle functions.

[0087] A ride height controller 96 controls the preload and operational height of the vehicle. In one embodiment, ride height controller controls springs 16 to adjust a ride height of vehicle 10, either directly or through suspension controller 86. In one example, ride height controller 96 provides more ground clearance in the comfort ride mode compared to the sport ride mode.

[0088] An agility controller 100 controls a braking system of vehicle 10 and the stability of vehicle 10. Control methods of agility controller 100 may include integration into braking circuits (ABS) such that a stability control system can improve dynamic

response (vehicle handling and stability) by modifying the shock damping in conjunction with electronic braking control.

[0089] In one embodiment, controller 20 either includes or is operatively coupled over network 78 to a location determiner 110 which determines a current location of vehicle 10. An exemplary location determiner 110 is a GPS unit which determines the position of vehicle 10 based on interaction with a global satellite system.

[0090] Referring to FIGS. 6-9, an exemplary side-by-side vehicle 200 is illustrated. Vehicle 200, as illustrated, includes a plurality of ground engaging members 12. Illustratively, ground engaging members 12 are wheels 204 and associated tires 206. As mentioned herein one or more of ground engaging members 12 are operatively coupled to power system 60 (see FIG. 4) to power the movement of vehicle 200 and braking system 75 to slow movement of vehicle 200.

[0091] Referring to the illustrated embodiment in FIG. 6, a first set of wheels, one on each side of vehicle 200, generally correspond to a front axle 208. A second set of wheels, one on each side of vehicle 200, generally correspond to a rear axle 210. Although each of front axle 208 and rear axle 210 are shown having a single ground engaging member 12 on each side, multiple ground engaging members 12 may be included on each side of the respective front axle 208 and rear axle 210. As configured in FIG. 6, vehicle 200 is a four wheel, two axle vehicle.

[0092] Referring to FIG. 9, wheels 204 of front axle 208 are coupled to a frame 212 of vehicle 200 through front independent suspensions 214. Front independent suspensions 214 in the illustrated embodiment are double A-arm suspensions. Other types of suspensions systems may be used for front independent suspensions 214. The wheels 204 of rear axle 210 are coupled to frame 212 of vehicle 200 through rear independent suspensions 216. Other types of suspensions systems may be used for rear independent suspensions 216.

[0093] Returning to FIG. 6, vehicle 200 includes a cargo carrying portion 250. Cargo carrying portion 250 is positioned rearward of an operator area 222. Operator area 222 includes seating 224 and a plurality of operator controls. In the illustrated embodiment, seating 224 includes a pair of bucket seats. In one embodiment, seating 224 is a bench seat. In one embodiment, seating 224 includes multiple rows of seats,

either bucket seats or bench seats or a combination thereof. Exemplary operator controls include a steering wheel 226, a gear selector 228, an accelerator pedal 230 (see FIG. 7), and a brake pedal 232 (see FIG. 7). Steering wheel 226 is operatively coupled to the wheels of front axle 208 to control the orientation of the wheels relative to frame 212. Gear selector 228 is operatively coupled to the shiftable transmission 68 to select a gear of the shiftable transmission 68. Exemplary gears include one or more forward gears, one or more reverse gears, and a park setting. Accelerator pedal 230 is operatively coupled to prime mover 62 to control the speed of vehicle 200. Brake pedal 232 is operatively coupled to brake units associated with one or more of wheels 204 to slow the speed of vehicle 200.

[0094] Operator area 222 is protected with a roll cage 240. Referring to FIG. 6, side protection members 242 are provided on both the operator side of vehicle 200 and the passenger side of vehicle 200. In the illustrated embodiment, side protection members 262 are each a unitary tubular member.

[0095] In the illustrated embodiment, cargo carrying portion 250 includes a cargo bed 234 having a floor 256 and a plurality of upstanding walls. Floor 256 may be flat, contoured, and/or comprised of several sections. Portions of cargo carrying portion 250 also include mounts 258 which receive an expansion retainer (not shown). The expansion retainers which may couple various accessories to cargo carrying portion 250. Additional details of such mounts and expansion retainers are provided in US Patent No. 7,055,454, to Whiting et al., filed July 13, 2004, titled "Vehicle Expansion Retainers," the entire disclosure of which is expressly incorporated by reference herein.

[0096] Front suspensions 214A and 214B each include a shock absorber 260, respectively. Similarly, rear suspensions 216A and 216B each include a shock absorber 262. In one embodiment each of shock absorbers 260 and shock absorbers 262 are electronically adjustable shocks 18 which are controlled by a controller 20 of vehicle 200.

[0097] Additional details regarding vehicle 200 are provided in US Patent No. 8,827,019 and US Patent No. 9,211,924, assigned to the present assignee, the entire disclosures of which are expressly incorporated by reference herein. Other exemplary

recreational vehicles include ATVs, utility vehicles, snowmobiles, other recreational vehicles designed for off-road use, on-road motorcycles, and other suitable vehicles.

[0098] Referring to FIG. 10, an exemplary control system 300 for controlling the damping of shock absorbers 18 is provided. Suspension controller 86 is operatively coupled to shock absorbers 18 and controls the damping of shock absorbers 18 based on a plurality of inputs. Exemplary inputs are provided in FIG. 10 and throughout this disclosure. Further, additional exemplary inputs for suspension controller 86 and control processing sequences for suspension controller 86 are provided in US Published Patent Application No. 2016/0059660, filed November 6, 2015, titled **VEHICLE HAVING SUSPENSION WITH CONTINUOUS DAMPING CONTROL**, assigned to the present assignee, the entire disclosure of which is expressly incorporated by reference herein.

[0099] With reference to FIG. 10, steering controller 102 is operatively coupled to a power steering system 302. Steering controller 102 communicates over network 78 values for one or more monitored parameters to suspension controller 86. Exemplary monitored parameters include a steering position, for example a steering angle of steering wheel 226 for vehicle 200, a steering torque, and a steering velocity.

[00100] In some instances, the steering angle of vehicle 100 provided by steering controller 102 may drift over time compared to the actual orientation of the steerable wheels 204 of vehicle 200, illustratively wheels 204 of front axle 208. For example, an operator of vehicle 200 may have to turn a steering device, such as steering wheel 226 for vehicle 200, from its straight line position to maintain vehicle 200 traveling straight along the x-axis (see FIG. 3). As such, steering controller 102 may indicate a slight turn when in reality vehicle 200 is traveling straight. Exemplary reasons for the difference include changes in vehicle 200 as vehicle 200 is broken in and hardware issues, such as a flat or underinflated tire, a bent steering component, or a bent suspension component.

[00101] As mentioned herein, suspension controller 86 may determine vehicle 10 is cornering based on the steering position, such as steering angle, received from steering controller 102. In one embodiment, suspension controller 86 receives the steering position from steering controller 102 and based on inputs from other sensors of

the plurality of sensors 40 determines a revised steering position to use as the input for determining if vehicle 10 is cornering.

[00102] Referring to FIG. 22, an exemplary processing sequence 850 of the logic of suspension controller 86 for determining a revised steering position is illustrated. A steering angle value is received by suspension controller 86 from steering system 104, as represented by block 852. An updated steering angle value is determined by suspension controller 86, as represented by block 854, by applying an offset to the steering angle value. The offset may be applied to the steering angle value in one example by subtracting the offset value and in another example by adding the offset value. The value of the offset is calibrated and stored in a memory accessible by suspension controller 86. In one embodiment, the offset is not actively adapting when a Steering Angle received over the vehicle network 78 is not valid, an Engine Speed received over the vehicle network 78 is not valid, a Vehicle Speed received over the vehicle network 78 is not valid, and/or a y-axis acceleration is not valid, the y-axis acceleration is not valid when it indicates that vehicle 10 is side hilling. The steering angle adaptation processing sequence 850 is also not active when vehicle 10 is determined to be airborne, braking, or accelerating.

[00103] In one example, the offset value is calibrated by the operator of vehicle 10 during operation of vehicle 10. The operator positions the steering wheel 226 of vehicle 10 such that vehicle 10 is traveling straight. The operator selects a steering angle calibrate input of operator input 22. Suspension controller 86 receives the steering angle value from steering system 104 over a period of time and sets the offset equal to the average steering angle value over that period of time. Once set, the operator deselects the calibrate input or suspension controller 86 exits the calibrate routine.

[00104] In another example, the offset value is calibrated by suspension controller 86 based on a plurality of inputs from the plurality of sensors 40. Suspension controller 86 determines a direction of travel of vehicle 10 based on the x-axis and y-axis of accelerometer 30 and/or the rotation rate about the z-axis of gyroscope 31. If suspension controller 86 determines vehicle 10 is traveling straight in the x-axis direction, then vehicle 10 adjusts the offset value in block 854 over time.

[00105] In one embodiment, suspension controller 86 may determine vehicle 10 is cornering based on a Yaw characteristic of vehicle 10. Referring to FIG. 2, when vehicle 10 is cornering, vehicle 10 experiences a rotation about the z-axis. By using a Yaw characteristic, such as rotation about the z-axis, suspension controller 86 may account for cornering events that are not initiated using steering angle or cornering events that are inconsistent with steering angle. Based on the terrain, cornering events are sometimes initiated through a braking of vehicle 10 or an acceleration of vehicle 10. Further, in some scenarios an operator of vehicle 10 will provide a steering angle input of a cornering event to the right to keep vehicle 10 in a cornering event to the left. The Yaw characteristic based cornering processing sequence is able to more accurately detect cornering events in conditions such as over-steer sliding initiated by low friction surfaces, oversteer sliding initiated by braking, oversteer sliding initiated by acceleration, general maneuvers on ice/snow, and any driving situation with counter steer.

[00106] Referring to FIG. 24A, an exemplary processing sequence 790 of suspension controller 86 is shown. Suspension controller 86 receives a first sensor input related to an angular movement of the vehicle, as represented by block 792. In one example, the angular movement of the vehicle is an overall angular movement of the vehicle about the z-axis (see FIG. 2). In one example, the first sensor is a yaw rate sensor which measures a rotation rate about the z-axis of the vehicle (see FIG. 2).

[00107] Suspension controller 86 compares the first sensor input to a first threshold, as represented by block 794. In one example suspension controller 86 compares a magnitude of the first sensor input to the first threshold. In one example, the magnitude of the first sensor value is averaged over a period of time and the averaged value is compared to the first threshold. If the magnitude of the first sensor input exceeds the first threshold, suspension controller 86 determines that a cornering event is occurring, as represented by block 798. Otherwise, suspension controller 86 determines that a cornering event has not occurred, as represented by block 796. If a cornering event has been determined to be occurring, the direction of the cornering event is determined, as represented by block 800. In one example, the sign of the yaw rotation rate indicates the direction of the cornering event.

[00108] In one embodiment, suspension controller 86 further determines if vehicle 10 is spinning by comparing an angular characteristic of the vehicle, such as the yaw rotation rate, to a second threshold. If the magnitude of the yaw rotation rate exceeds the second threshold, then suspension controller 86 determines that vehicle 10 is spinning. In one example, the angular characteristic is the yaw rotation rate and the second threshold is about 100 degrees per second. In another example, the angular characteristic is a change in the direction of travel of the vehicle of at least 90 degrees over a period of time.

[00109] In one embodiment, when suspension controller 86 determines vehicle 10 is cornering to the left the stiffness of the damping characteristic of the adjustable shocks 18 on the right side of vehicle 10 (passenger side) is increased, when suspension controller 86 determines vehicle 10 is cornering to the right the stiffness of the damping characteristic of the adjustable shocks 10 on the left side of vehicle 10 (driver side) is increased, and when suspension controller 86 determines vehicle 10 is spinning the stiffness of all of the adjustable shocks 18 is increased.

[00110] Referring to FIG. 24B, another exemplary processing sequence 810 of suspension controller 86 is shown. Suspension controller 86 receives a first sensor input related to an angular movement of the vehicle and a second sensor input related to a position of a steering device, such as steering wheel 226, of vehicle 200, as represented by block 812. In one example, the angular movement of the vehicle is an overall angular movement of the vehicle about the z-axis (see FIG. 2). In one example, the first sensor is a yaw rate sensor which measures a rotation rate about the z-axis of the vehicle (see FIG. 2) and the second sensor measures an angle of the steering wheel 226.

[00111] Suspension controller 86 compares the second sensor input to a second threshold, as represented by block 814. In one example suspension controller 86 compares a magnitude of the second sensor input to the second threshold. If the magnitude of the second sensor input exceeds the second threshold, suspension controller 86 determines that a cornering event is occurring, as represented by block 816. Otherwise, suspension controller 86 compares the first sensor input to a first threshold, as represented by block 820. In one example suspension controller 86

compares a magnitude of the first sensor input to the first threshold. If the magnitude of the first sensor input exceeds the first threshold, suspension controller 86 determines that a cornering event is occurring, as represented by block 816. Otherwise, suspension controller 86 determines that a cornering event has not occurred, as represented by block 822. If a cornering event has been determined to be occurring, the direction of the cornering event is determined, as represented by block 818. In one example, the sign of the yaw rotation rate indicates the direction of the cornering event. In this manner, the angular characteristic of the overall vehicle, for example the yaw rotation rate, takes priority over the angular characteristic of a steering device of the vehicle, for example the angle of the steering wheel 226. If the steering system indicates the vehicle is turning right and the yaw rate indicates the vehicle is turning left, suspension controller 86 will use the determination of yaw rate sensor to establish the direction of cornering.

[00112] In one embodiment, the yaw angular rate threshold changes as a function of vehicle speed.

[00113] Suspension controller 86 is further operatively coupled to prime mover controller 82, transmission controller 84, communication controller 88, vehicle controller 92, ride height controller 96, and agility controller 100. One or more of prime mover controller 82, transmission controller 84, communication controller 88, vehicle controller 92, ride height controller 96, and agility controller 100 communicates over network 78 values for one or more monitored parameters to suspension controller 86. Exemplary monitored parameters include a vehicle speed, an engine speed, a brake status (brake pedal 232 applied or not applied), a throttle pedal position (accelerator pedal 230 position), a battery voltage of a battery 80 (powers start-up of vehicle 10), and any fault information.

[00114] Suspension controller 86 is further operatively coupled to operator interface controller 80 of user interface 22. Operator interface controller 80, in one embodiment, communicates over network 78 values for parameters selected by an operator of vehicle 10. Exemplary parameters include a number of operators or riders, a ride mode selection for suspension system 11, and other suitable tuning selections for shock absorbers 18 of suspension system 11. In one example, the operator may input

a value for the number of riders and a value estimating a cargo weight through display 24. In one embodiment, vehicle 200 includes sensors associated with seating 224 which provide an indication of whether a rider is positioned in the respective seats or not. Further, vehicle 200 may include additional sensors which monitor an amount of cargo being carried by cargo carrying portion 250. Suspension controller 86 also communicates information to operator interface controller 80. Exemplary information includes a current shock absorber state for shock absorbers 18, a conditional shock absorber state for shock absorbers 18 (for example, "Turning", "Airborne", and "Anti-Dive"), a ride mode selection for suspension system 11, fault information, and vehicle metrics. Exemplary vehicle metrics include values of parameters received by suspension controller 86. In the illustrated embodiment, operator interface controller 80 is operatively coupled to display 24. In one embodiment, display 24 is a touch screen display that presents one or more screens of a graphical user interface 310 to an operator of vehicle 10.

[00115] As shown in FIG. 10, in one embodiment, suspension controller 86 is further operatively coupled to a suspension control rocker switch 312. Rocker switch 312 is connected through a serial connection to suspension controller 86. Rocker switch 312 has three positions. Suspension controller 86 determines whether rocker switch 312 is in a first position corresponding to the suspension being in a comfort mode (described herein), a second position corresponding to the suspension being in a sport mode (described herein), and a third position corresponding to the suspension being in a firm mode (described herein).

[00116] Rocker switch 312 may be used in place of display 24 or in addition to the inputs provided through display 24. In one example, rocker switch 312 selects between multiple ride modes and the inputs of graphical user interface 310 provide operator customization of the vehicle characteristics associated with each of the selectable ride modes as indicated by the configuration/tuning label in FIG. 10. In another example, vehicle 10 does not include rocker switch 312 and the selection of various ride modes and operator customization of the vehicle characteristics associated with each of the selectable ride modes is received by controller 20 through graphical user interface 310 of display 24.

[00117] As mentioned in connection with FIG. 10, in one embodiment, vehicle 10 includes a graphical user interface 310 presented on display 24. Referring to FIG. 11, an exemplary screen 320 of graphical user interface 310 is illustrated. Screen 320 includes a first portion 322 having operator selectable inputs 324 to select a ride mode for suspension system 11 and operator selectable inputs 326 to select the manner in which suspension system 11 is adjusted.

[00118] Operator selectable inputs 324 include a plurality of inputs which permit the operator to select from a plurality of predefined ride modes. Illustratively, exemplary inputs 328, 330, and 332 correspond to a comfort ride mode, a sport ride mode, and a firm ride mode, respectively. Suspension controller 86 has stored damping profiles that correspond to each ride mode. In the following description, inputs 328, 330, and 332 are used to select the various ride modes. However, in one embodiment, the portions of display 24 corresponding to inputs 328, 330, and 332 only provide visual feedback to the operator of the current ride mode and are not selectable inputs. Rather, the ride modes are selected through suspension control rocker switch 312.

[00119] In one embodiment, a comfort ride mode is selected by touching the portion of display 24 at which the comfort button 328 is displayed. A comfort ride mode is generally optimized for comfort and performance. The suspension remains normally soft unless dynamic vehicle conditions sensed by one or more of vehicle condition sensors 40 demand a more firm setting. In one embodiment, a comfort ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the comfort button 328 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the comfort ride mode. In one embodiment, in the comfort mode, suspension controller 86 controls both a compression damping of the adjustable shocks 18 and a rebound damping of the adjustable shocks. Adjustable shocks 18 are set to have a lower compression damping and a lower rebound damping compared to a sport mode. By having a lower rebound damping the suspension will allow the ground engaging members 12 to drop out faster to the terrain. This will create a more comfortable ride for vehicle 10. In one example, the amount of compression damping, rebound damping, or both is dependent on a ground speed of vehicle 10.

[00120] A sport ride mode is selected by touching the portion of display 24 at which the sport button 330 is displayed. The sport ride mode, like other ride modes, may be selected through other inputs of operator interface 22, such as buttons, toggle switches, and other suitable input devices. A sport ride mode increases the baseline damping of shock absorbers 18 compared to the comfort ride mode, more aggressively controls body roll for vehicle conditions such as turning or airborne, and has different speed sensitivity characteristics for increasing the damping of shock absorbers 18. In one embodiment, a sport ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the sport button 330 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the sport ride mode. In one embodiment, in the sport mode, suspension controller 86 controls both a compression damping of the adjustable shocks 18 and a rebound damping of the adjustable shocks. Adjustable shocks 18 are set to have a higher compression damping and a higher rebound damping compared to a comfort mode. In one example, the amount of compression damping, rebound damping, or both is dependent on a ground speed of vehicle 10.

[00121] A firm ride mode is selected by touching the portion of display 24 at which the firm button 332 is displayed. A firm ride mode increases the baseline damping of shock absorbers 18 compared to sports mode. In one example, the firm ride mode provides a maximum damping characteristic of shock absorbers 18. In one embodiment, a firm ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the comfort button 332 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the firm ride mode.

[00122] Below operator selectable inputs 324 is an information panel that provides a textual description of the ride mode selected. Additional ride modes are disclosed in US Published Patent Application No. 2016/0059660 as drive modes, the entire disclosure of which is expressly incorporated by reference herein.

[00123] Operator selectable inputs 326 include a plurality of inputs which permit the operator to select an active suspension management and a passive suspension management. A passive suspension management is selected by touching the portion of

display 24 at which a passive button 334 is displayed. In the passive suspension management, suspension controller 86 adjusts the damping profiles of shock absorbers 18 based on the position of suspension control rocker switch 312. An active suspension management is selected by touching the portion of display 24 at which an active button 336 is displayed. In the active suspension management, suspension controller 86 adjusts the damping profiles of shock absorbers 18 based on logic contained in controller 20 and based on inputs provided through graphical user interface 310 and suspension control rocker switch 312.

[00124] Operator selectable inputs 326 further includes a second portion 350 which provides a graphical feedback to the operator of a steering angle of steering wheel 226 through a rotation orientation of icon 352 and of the firmness of each of shock absorbers 18 through a numerical indicator 354A-D and a graphical indicator 356A-D. A firmness scale is provided below first portion 322 and second portion 350 which provides a graphical representation of a shock firmness from soft on the left to hard on the right. In one embodiment, the graphical representation changes color from green to yellow to red as the firmness increases. In one example, numerical indicators 354A-D and graphical indicators 356A-D provide actual damping values. In another example, numerical indicators 354A-D and graphical indicators 356A-D provide smoothed damping values, such as an average damping value over a time window. In one example, an operator input permits the operator to select whether to display actual damping values or smoothed damping values.

[00125] In one embodiment, each of shock absorbers 18 may have individually set damping profiles which may be set by an operator through graphical user interface 310 of 24 or other suitable operator inputs of user interface 22. In one embodiment, operator inputs of operator interface 22 include at least one input which provides the operator the ability to add a preset damping amount to each of the adjustable shocks 18 (compression, rebound, or both) or to subtract a preset damping amount to each of the adjustable shocks 18 (compression, rebound, or both). In one example, the added or subtracted offset is applied to vehicle speed based damping profiles only. In another example, the added or subtracted offset is applied to one or more selected semi-active modes, such as Cornering, Anti-dive, Anti-squat, Airborne, and other suitable modes.

[00126] In one embodiment, controller 20 may limit power system 60 to maintain vehicle 10 below a set speed, based on the damping parameters of adjustable shocks 10, to ensure suitable vehicle handling and stability. In one embodiment, controller 20 may store damping profiles for each of a plurality of operators which are selectable through graphical user interface 310 of display 24.

[00127] Referring to FIG. 12, an exemplary screen 370 of graphical user interface 310 is illustrated. Screen 370 includes a first portion 372 having operator selectable inputs 374 to select a ride mode for suspension system 11 and operator selectable inputs 376 to select a setting for transmission 66.

[00128] Operator selectable inputs 374 include a plurality of inputs which permit the operator to select from a plurality of predefined ride modes. Illustratively, exemplary inputs 378, 380, and 382 correspond to a trail ride mode, a sport ride mode, and a race ride mode, respectively. Below operator selectable inputs 324 is an information panel that provides a textual description of the ride mode selected. Suspension controller 86 has stored damping profiles that correspond to each ride mode. In the following description, inputs 378, 380, and 382 are used to select the various ride modes. However, in one embodiment, the portions of display 24 corresponding to inputs 378, 380, and 382 only provide visual feedback to the operator of the current ride mode and are not selectable inputs. Rather, the ride modes are selected through suspension control rocker switch 312.

[00129] A trail ride mode is selected by touching the portion of display 24 at which the trail button 378 is displayed. A trail ride mode is generally an aggressive setup of the suspension, transmission, and throttle responses tuned for high performance. In one embodiment, a trail ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the comfort button 378 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the trail ride mode.

[00130] A sport ride mode is selected by touching the portion of display 24 at which the sport button 380 is displayed. A sport ride mode increases the baseline damping of shock absorbers 18 compared to the trail ride mode, more aggressively controls body roll for vehicle conditions such as turning or airborne, and has different

speed sensitivity characteristics for increasing the damping of shock absorbers 18. In one embodiment, a sport ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the sport button 380 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the sport ride mode.

[00131] A race ride mode is selected by touching the portion of display 24 at which the race button 382 is displayed. A race ride mode increases the baseline damping of shock absorbers 18 compared to sports mode. In one example, the race ride mode provides a maximum damping characteristic of shock absorbers 18. In one embodiment, a race ride mode is selected by actuation of suspension control rocker switch 312 and the portion of display 24 at which the race button 328 is displayed is highlighted or otherwise changed in appearance to provide visual feedback to the operator of the selection of the race ride mode.

[00132] Operator selectable inputs 376 include a plurality of inputs which permit the operator to select a setting for transmission 66. A manual setting is selected by touching the portion of display 24 at which a manual button 384 is displayed. An automatic setting is selected by touching the portion of display 24 at which an auto button 386 is displayed. In one embodiment, the manual setting for transmission 66 means the operator has control over the operation of CVT 70 and the auto setting for transmission 66 means CVT 70 functions without operator intervention. Exemplary CVTs 70 which are configurable in both a manual setting and an auto setting are provided in US Patent No. 9,429,235, the entire disclosure of which is expressly incorporated by reference herein.

[00133] Screen 370 further includes a second portion 388 which provides a graphical feedback to the operator of the firmness of each of shock absorbers 18 through a numerical indicator 390A-D and a graphical indicator 392A-D. In one example, a height of the solid portion of the graphical indicator represents a level of a damping characteristic, either a compression damping or a rebound damping. In one example, the height is not linearly related to the damping characteristic to provide a visual emphasis. Additionally color variation may be used for visual emphasis (green, yellow, orange, red). Further, second portion 388 provides a graphical feedback of any

vehicle condition modifiers which are currently active, as represented by icon 394. In one example, an operator input permits the operator to select whether to display an active vehicle condition modifier icon 394 or not. In the illustrated example, an anti-dive icon is displayed. In an anti-dive condition, suspension controller 86 in response to an indication of heavy braking from brake sensor 32 adjusts the damping levels of adjustable shocks 18 adjacent the front axle to be firmer to reduce “dive” of the vehicle. In one embodiment, in the anti-dive condition, suspension controller 86 in response to an indication of heavy braking from brake sensor 32 adjusts the compression damping levels of adjustable shocks 18 adjacent the front axle to be firmer to reduce “dive” of the vehicle, increase the rebound damping of the rear adjustable shocks 18 of vehicle 10 to decrease the rebound speed of the adjustable shocks 18 and provide improved pitch control of vehicle 10, and decrease the rebound damping of the front adjustable shocks 18 of vehicle 10 to allow the ground engaging members 12 to get back to the terrain while braking in chatter (e.g. experiencing a high speed harsh trail). In one example, the amount of compression damping, rebound damping, or both is dependent on a ground speed of vehicle 10.

[00134] Other exemplary vehicle condition modifiers include the Cornering Condition, the Ride Condition, the Squat Condition, the Brake Condition, the Roll/Cornering Condition, the Jump/Pitch Condition, and other factors or combination of factors that cause changes in the damping level of the adjustable shocks in US Published Patent Application No. 2016/0059660, filed November 6, 2015, titled **VEHICLE HAVING SUSPENSION WITH CONTINUOUS DAMPING CONTROL**, assigned to the present assignee, the entire disclosure of which is expressly incorporated by reference herein. In one embodiment, operator interface 22 includes operator inputs whereby an operator may select one or more of the vehicle condition modifiers to deactivate or activate. Deactivated vehicle condition modifiers will not be used by suspension controller 86 in adjusting the damping characteristics of adjustable shocks 18.

[00135] In one embodiment, in the Cornering Condition, suspension controller 86 in addition to changes to the compression damping will increase the rebound damping on adjustable shocks 18 which are inside on the turn, such as the left side adjustable

shocks for a left turn of vehicle 10, thereby decreasing the rebound speed of the adjustable shocks 18 and provide improved roll control. In one example, the amount of compression damping, rebound damping, or both is dependent on a ground speed of vehicle 10. In one embodiment, in the Squat Condition, in response to an indication of an acceleration event of vehicle 10, suspension controller 86 will increase the rebound damping of the front adjustable shocks of vehicle 10 resulting in a decrease of the rebound speed of the adjustable shock 18 and an improved pitch control of vehicle 10. In one example, the amount of compression damping, rebound damping, or both is dependent on a ground speed of vehicle 10.

[00136] Referring to FIGS. 12A-C, additional exemplary screens 340, 342, and 344 of graphical user interface 310 are illustrated. Each of screens 340, 342, and 344 includes a visual feedback representation 346 of a g-force experienced by vehicle 10. G-force representation 346 includes an indication 348 of a steering angle of steering wheel 226 and an indication 349 of the magnitude (distance from a center of visual feedback representation 346) and the direction (angular position of indication 349 relative to the center of visual feedback representation 346) of the g-force experienced. In FIG. 12A, the g-force is towards the driver rear portion of the vehicle. In one embodiment, the screen layouts disclosed herein may be used as part of a demonstration mode wherein the screen functionality is shown while the vehicle is stationary.

[00137] In one embodiment, suspension controller 86 is microprocessor-based and includes processing instructions stored on a non-transitory computer readable medium, such as memory 76, which are executable by the microprocessor of suspension controller 86 to control operation of suspension system 11. Referring to FIG. 13, suspension controller 86 may execute a ride mode change logic 400 which provides control signals to suspension system 11, such as the electronically controlled valves of shock absorbers 18, to achieve various configurations of suspension system 11, such as race, trail, sport, and other suitable configurations. In the case of multi-operator selectable ride modes, ride mode change logic 400 may permit or deny a change from a current, first ride mode to a requested, second ride mode. The term "logic" as used herein includes software and/or firmware executing on one or more

programmable processors, application-specific integrated circuits, field-programmable gate arrays, digital signal processors, hardwired logic, or combinations thereof.

Therefore, in accordance with the embodiments, various logic may be implemented in any appropriate fashion and would remain in accordance with the embodiments herein disclosed. A non-transitory machine-readable medium comprising logic can additionally be considered to be embodied within any tangible form of a computer-readable carrier, such as solid-state memory, magnetic disk, and optical disk containing an appropriate set of computer instructions and data structures that would cause a processor to carry out the techniques described herein. This disclosure contemplates other embodiments in which suspension controller 86 is not microprocessor-based, but rather is configured to control operation of suspension system 11 based on one or more sets of hardwired instructions and/or software instructions stored in memory 76. Further, suspension controller 86 may be contained within a single device or be a plurality of devices networked together to provide the functionality described herein.

[00138] Suspension controller 86 receives multiple inputs that may be used by ride mode logic 400 to determine whether to permit a change from a current, first ride mode to a requested, second ride mode. Suspension controller 86 receives a request 410 to change to a requested, second ride mode. The request 410 is provided by an operator through user interface 22. In one embodiment, graphical user interface 310 displayed on display 24 is used to select a requested, second ride mode. For example, any one of comfort button 328, sport button 330, or firm button 332 of second portion 350 or any one of trail button 378, sport button 380, and race button 382 of second portion 388 may be used to select a requested, second ride mode. In one embodiment, a requested, second ride mode is selected by actuation of rocker switch 312.

[00139] Additionally, suspension controller 86 receives a plurality of inputs 420 based on the operational characteristics of vehicle 10. Suspension controller 86 receives inputs from a plurality of vehicle condition sensors 40. The vehicle condition sensors 40 may either actively provide an indication by sending a sensor signal or passively provide an indication by making available a monitored characteristic, such as a voltage, a temperature, a pressure or other suitable characteristics. Suspension controller 86 further, either receives or initiates based on received inputs from the

plurality of vehicle condition sensors 40, one or more vehicle condition modifier states. Exemplary vehicle condition modifier states are mentioned herein.

[00140] Ride mode change logic 400 determines whether request 410 passes a ride mode change criteria based on the plurality of operational characteristics 420. If the ride mode change criteria are passed, suspension controller 86 permits the requested ride mode change to occur, as represented by block 422. For instance, if the current ride mode was a comfort ride mode (selection input 328 in FIG. 11) and the operator selects a firm ride mode (selection input 332 in FIG. 11), suspension controller 86 would alter suspension 11 to have characteristics based on the firm ride mode. For example, suspension controller 86 would alter a damping profile of shock absorbers 18 to the default damping profile stored in memory 76 for the firm ride mode. If the ride mode criteria fails, suspension controller 86 denies the requested ride mode change, as represented by block 424, and suspension system 11 remains in the current selected ride mode until the operating conditions are resolved and/or there has been another switch state change.

[00141] Referring to FIG. 14, a first exemplary set of operational characteristics 420 includes a current ride mode characteristic 440, a vehicle speed 442, one or more acceleration values 444, and an indication of any active vehicle condition modifier states 446. In one embodiment, vehicle speed 442 is based on an input from vehicle speed sensor 26. In one embodiment, the one or more acceleration values 444 include a z-plane acceleration from chassis supported accelerometer 30, a y-plane acceleration from chassis supported accelerometer 30, and an x-plane acceleration from chassis supported accelerometer 30.

[00142] An exemplary processing sequence 450 of ride mode change logic 400 of suspension controller 86 is illustrated in FIG. 15. Ride mode change logic 400 determines if the requested ride mode is different than the current ride mode, as represented by block 451. Ride mode change logic 400 determines if the requested ride mode has a firmer damping profile than the current ride mode, as represented by block 452. The current ride mode is the active damping profile and may either be a previously selected pre-set ride mode or a custom operator specified damping profile. If the requested ride mode is firmer than the current ride mode, ride mode change logic

400 permits the ride mode change, as represented by block 422. If the requested ride mode is not firmer than the current ride mode, ride mode change logic 400 checks to see if there are any active vehicle condition modifier states, as represented by block 454. If there are active vehicle condition modifier states, ride mode change logic 400 denies the requested ride mode change, as represented by block 424. For example, if vehicle 10 is currently cornering as determined based on a steering angle of the steering wheel, ride mode change logic 400 would not permit a change from a firmer damping profile to a softer damping profile.

[00143] If there are not any active vehicle condition modifier states, ride mode change logic 400 reviews the inputs from vehicle condition sensors 40 to determine whether to permit the ride mode change, as represented by block 456. For example, ride mode change logic 400 may not allow a change to a softer damping profile when a vehicle speed exceeds a vehicle speed threshold. Further, ride mode change logic 400 may not allow a change to a softer damping profile if a x-plane acceleration is greater than a x-plane acceleration threshold or if an absolute value of a y-plane acceleration is greater than a y-plane acceleration threshold. If the inputs from the vehicle sensors are acceptable, ride mode change logic 400 permits the ride mode change as represented by block 422. Otherwise, ride mode change logic 400 denies the ride mode change, as represented by block 424. Referring to Table 1, an exemplary set of conditions based on vehicle sensor values that ride mode change logic 400 uses in deciding whether to permit or deny a ride mode change request. In the examples provided in Table 1,

Table 1

Current Ride Mode	Requested Ride Mode	Conditions
Trail	Sport	No conditions – Sport has a firmer damping profile than Trail
Sport	Trail	- X-plane acceleration value less than X-plane threshold value - Absolute value of Y-plane acceleration less than Y-plane threshold value

Sport	Race	• No conditions – Race has a firmer damping profile than Sport
Race	Sport	• X-plane acceleration value less than X-plane threshold value • Absolute value of Y-plane acceleration less than Y-plane threshold value

the Sport ride mode has a firmer damping profile than the Trail ride mode and the Race ride mode has a firmer damping profile than both of the Sport ride mode and the Trail ride mode.

[00144] A first exemplary damping profile may be a constant value for a ride mode. A second damping profile may be a function or a look-up table that provides a damping value based on one or more static or dynamic inputs. For example, a Sport ride mode may have different damping values for shock absorbers 18 based on a first static input, cargo weight, and/or a second static input, number of riders. In one example, the Sport ride mode has a first damping value for vehicle 10 when vehicle 10 has a single rider and no cargo and a second damping value for vehicle 10 when vehicle 10 has two riders and no cargo, the second damping value being firmer than the first damping value. Further, a Sport ride mode may have multiple different damping values for shock absorbers 18 based on a first dynamic input, a detected vehicle speed. In one example, the Sport ride mode has a first damping value for a first vehicle speed and a second, firmer damping value for a second vehicle speed, the second vehicle speed being greater than the first vehicle speed.

[00145] Ride modes are described herein in connection with the settings of suspension system 11. In one embodiment, a selected ride mode influences other systems of vehicle 10, such as prime mover 62, transmission 66, and other systems of vehicle 10.

[00146] Damping profiles may be altered during the operation of vehicle 10 beyond the values associated with the current ride mode. For example, if the operation of vehicle 10 results in vehicle 10 being placed in a vehicle condition modifier state, suspension controller 86 will alter the current damping profile based on the vehicle

condition modifier state until the vehicle condition modifier state is concluded. In one example, in response to an Anti-Dive modifier state, suspension controller 86 increases the firmness of shock absorbers 18 associated with front axle 208 of vehicle 100.

[00147] As another example, if based on one or more of vehicle condition sensors 40, a power save condition is detected, suspension controller 86 may alter the damping profile of shock absorbers 18. Referring to FIG. 16, controller 20 executes a processing sequence 480 to monitor for a power save condition. In one example, processing sequence 480 is executed by vehicle controller 92, but may be executed by any one or more of the controllers of controller 20 or if controller 20 is a single controller handling the functionality of the controllers listed in FIG. 5 then by controller 20.

[00148] Prime mover controller 82 receives an indication of the voltage of a battery 80 of vehicle 10 from one or more of vehicle condition sensors 40, an indication of an engine speed from one or more of vehicle condition sensors 40, and a current ride mode, as represented by block 482. The measured voltage of the battery is passed through a low pass filter to provide an average measured voltage, as represented by block 484. Based on the measured voltage value, engine speed, and ride mode, prime mover controller 82 determines if a power load shed is required, as represented by block 486. Prime mover controller 82 reduces the power consumption of various vehicle systems to reduce the power drain on battery 80.

[00149] Prime mover controller 82 determines an amount of load shed to be borne by various vehicle systems, as represented by block 488. In one embodiment, the amount of load shed required by each vehicle system depends on the current ride mode of vehicle 10. For example, in a first ride mode suspension controller 86 may have constant damping specified for shock absorbers 18 while in a second ride mode suspension controller 86 may have variable damping for shock absorbers 18. A determined load shed amount or consumption limit is distributed to affected controllers, as represented by block 490. Each controller, in response to the determined load shed or consumption limit, alters its operation. For example, suspension controller 86 may adjust the damping of shock absorbers 18 to be firmer and not permit softer settings to reduce the number of adjustments made to shock absorbers 18. If the consumption limit is below a threshold, suspension controller 86, in one embodiment, defaults the

damping profile of adjustable shocks 18 to be 100% firm. As another example, transmission controller 84 may reduce the number of permitted shifts of transmission 66 in response to the determined load shed or consumption limit.

[00150] Referring to FIG. 17, vehicle controller 92 may receive multiple ride mode requests from various sources. Vehicle controller 92 may receive a first request 520 from user interface 22 and a second request 522 from communication controller 88. Communication controller 88 receives second request 522 from one of remote devices 500. Exemplary remote devices 500 include personal computing devices 502 which may be carried by a rider of vehicle 10 or be spaced apart from vehicle 10. Further, a second vehicle 10' may send second request 522 to vehicle 10. In one embodiment, vehicle 10 and second vehicle 10' are part of a mesh network and second vehicle 10' has altered its ride mode and broadcasts that to vehicle 10 or based on the terrain and/or performance of second vehicle 10' suggestions for preferred ride modes or damping profile adjustments are broadcast to vehicle 10. Further, a centralized computer system 504 may send second request 522 to vehicle 10. In one example, any one of personal computing devices 502, second vehicle 10', or centralized computer system 504 broadcasts second request 522 to any vehicle 10 capable of receiving second request 522. The second request 522 may include location information, such as GPS coordinates, that vehicle controller 92 may use to determine whether second request 522 is pertinent or not based on the current location of vehicle 10 as determined by location determiner 110.

[00151] Vehicle controller 92 receives both first request 520 and second request 522. Vehicle controller 92 determines which one of first request 520 and second request 522 to implement, if either, as represented by block 524. In making this determination, vehicle controller 92 determines whether an auto/manual input 528 of user interface 22 has been set to auto or manual, as represented by block 526. In manual mode, the operator is controlling the damping profile of shock absorbers 18. In the auto mode, the operator is permitting other inputs to control the damping profile of shock absorbers 18. In one embodiment, vehicle controller 92 provides on display 24 an indication of an incoming request from remote devices 500. The operator may actuate an override input 530 of user interface 22 to override the incoming request from

remote devices 500, as represented by block 532. In one example, the override input 530 is displayed as part of graphical user interface 310. Once vehicle controller 92 has determined which of the multiple requests 520, 522 to implement, vehicle controller 92 communicates the request to the system controllers to implement, illustratively prime mover controller 82, transmission controller 84, and suspension controller 86.

[00152] Referring to FIG. 18, an aerial view 600 of a representative trail for vehicles 10 is shown. In one embodiment, aerial view 600 is shown on display 24. The trail starts at location 602, follows a trail path 604 (dashed line), to a trail end 606. A lead vehicle 10A is illustrated along with a follower vehicle 10B. Lead vehicle 10A is traversing the trail first and broadcasts recommendations to vehicle 10B to alter the ride mode, such as altering the damping profile of shock absorbers 18. The trail may also include discrete locations, illustratively locations 608A-608D, at which either lead vehicle 10B or databases 506 accessible by centralized computer system 504, indicates a desired ride mode, such as a damping profile of shock absorbers 18. In one embodiment, controller 20 of vehicle 10A provides visual feedback to the operator of vehicle 10A of an upcoming ride mode change.

[00153] Referring to FIG. 19A, a processing sequence 640 related to vehicle alterations to make in light of vehicle 10 being airborne is provided. Controller 20 determines if vehicle 10 is airborne, as represented by block 652. In one embodiment, controller 20 monitors the output of accelerometer 30 to determine when vehicle 10 is in a freefall. In this manner, accelerometer 30 is a type of airborne sensor in that it is able to provide an indication of when vehicle 10 is airborne.

[00154] In one embodiment, the output of each of the three axes of accelerometer 30 is monitored by controller 20. Controller 20 determines that vehicle 10 is airborne in response to a magnitude of a resultant acceleration vector (based on the x-axis component vector, the y-axis component vector, and the z-axis component vector) being below a first threshold value and, optionally in one example, the magnitude of each of the x-axis acceleration and the magnitude of the y-axis acceleration being below a second threshold.

[00155] Referring to FIG. 23A, an exemplary processing sequence 750 of the logic of controller 20, such as suspension controller 86, is shown. Controller 20 receives the

acceleration values for the x-axis, the y-axis, and the z-axis from accelerometers 30, as represented by block 752. Controller 20 determines the magnitude of the resultant acceleration vector, as represented by block 754. Controller 20 compares the magnitude of the resultant acceleration vector to a first threshold, as represented by block 756. If the magnitude of the resultant acceleration vector is less than the first threshold, controller 20 determines vehicle 10 is experiencing an airborne event, as represented by block 764. Otherwise, controller 20 determines that vehicle 10 is not experiencing an airborne event, as represented by block 760, and the next acceleration values are reviewed, as represented by block 752. In one example, the first threshold value is about 0.3 times the gravitational acceleration on planet Earth (G). As mentioned herein, if accelerometer 30 is not located at the center of gravity of vehicle 10, the inertial values of gyroscope 31 are used in combination with the raw measurement of acceleration values to determine the equivalent acceleration values at the center of gravity of vehicle 10.

[00156] In another embodiment, a magnitude of each of the x-axis acceleration component vector, the y-axis acceleration component vector, and the z-axis acceleration component vector is compared to a respective threshold value. Controller 20 determines that vehicle 10 is airborne in response to each of the magnitude of the x-axis acceleration component vector, the magnitude of the y-axis acceleration component vector, and the magnitude of the z-axis acceleration component vector being less than their respective threshold values. By monitoring each acceleration component magnitude individually instead of a composite acceleration magnitude, controller 20 may provide improved airborne detection in high speed jumping maneuvers and better account for wind resistance.

[00157] Referring to FIG. 22B, an exemplary processing sequence 770 of the logic of controller 20, such as suspension controller 86, is shown. Controller 20 receives the acceleration values for the x-axis, the y-axis, and the z-axis from accelerometers 30, as represented by block 772. Controller 20 compares the x-axis acceleration value to a first threshold, as represented by block 774; the y-axis acceleration value to a second threshold, as represented by block 776; and the z-axis acceleration value to a third threshold, as represented by block 780. In FIG. 22B, blocks 774, 776, and 780 are

illustrated as being executed sequentially. In one embodiment, controller 20 performs the functions of blocks 774, 776, and 780 in parallel. Returning to FIG. 22B, if the x-axis acceleration value is less than the first threshold, controller 20 moves on to block 776. Otherwise, controller 20 determines that vehicle 10 is not experiencing an airborne event, as represented by block 778, and the next acceleration values are reviewed, as represented by block 772. At block 776, controller 20 compares the y-axis acceleration value to a second threshold. If the magnitude of the y-axis acceleration value is less than the second threshold, controller 20 moves on to block 780. Otherwise, controller 20 determines that vehicle 10 is not experiencing an airborne event, as represented by block 778, and the next acceleration values are reviewed, as represented by block 772. At block 780, controller 20 compares the z-axis acceleration value to a third threshold. If the magnitude of the z-axis acceleration value is less than the third threshold, controller 20 determines that vehicle 10 is experiencing an airborne event, as represented by block 782. Otherwise, controller 20 determines that vehicle 10 is not experiencing an airborne event, as represented by block 778, and the next acceleration values are reviewed, as represented by block 772. In one example, the respective threshold values are about 0.3 times the gravitational acceleration on planet Earth (G). In one example, at least two of the first threshold, the second threshold, and the third threshold have the same value. In another example, each of the first threshold, the second threshold, and the third threshold have different values. As mentioned herein, if accelerometer 30 is not located at the center of gravity of vehicle 10, the inertial values of gyroscope 31 are used in combination with the raw measurement of acceleration values to determine the equivalent acceleration values at the center of gravity of vehicle 10.

[00158] Exemplary detection of an airborne event is described in US Published Patent Application No. 2016/0059660, filed November 6, 2015, titled VEHICLE HAVING SUSPENSION WITH CONTINUOUS DAMPING CONTROL, assigned to the present assignee, the entire disclosure of which is expressly incorporated by reference herein. Exemplary detection of an airborne event is described in US Patent No. 9,381,810, filed June 3, 2011, titled ELECTRONIC THROTTLE CONTROL, assigned to

the present assignee, the entire disclosure of which is expressly incorporated by reference herein.

[00159] In response to determining that vehicle 10 is airborne, controller 20 adjusts the damping profile of shock absorbers 18, as represented by block 654. In one embodiment, controller 20 increases a pre-load firmness of shock absorbers 18. In one example, controller 20 increases the firmness of the damping profile of shock absorbers 18 at different rates depending on vehicle characteristics, such as vehicle speed, number of riders, cargo weight, amount of time in the air, and current ride mode. Referring to FIG. 20, an illustrative example 670 is provided. Once it has been detected that vehicle 10 is airborne, controller 20 increases the damping of shock absorbers 18 over time from a current damping value 672 to a maximum damping value 674 in accordance with the vehicle characteristics. Curve 676 represents a first set of vehicle characteristics, such as a single rider and no cargo, and curve 678 represents a second set of vehicle characteristics, such as multiple riders and cargo. In one example, the damping value is increased in a linear fashion from current damping value 672 over time. In one embodiment, in response to the detection of an Airborne condition, suspension controller 86 increases the compression damping of all of adjustable shocks 18 and decreases the rebound damping of all of the adjustable shocks 18. This setup will increase the rebound speed of the adjustable shocks 18 and permit the suspensions of vehicle 10 to drop out faster for the next compression hit to the adjustable shocks 18.

[00160] Referring to FIG. 19B, a processing sequence 650 related to vehicle alterations to make in light of vehicle 10 being airborne is provided. Controller 20 determines if vehicle 10 is airborne, as represented by block 652. In response to determining that vehicle 10 is airborne, controller 20 adjusts the damping profile of shock absorbers 18, as represented by block 654. Further, in response to determining that vehicle 10 is airborne, controller 20 adjusts the adjustable driveline torque management characteristic of the driveline torque management system 50, as represented by block 656.

[00161] Referring to FIG. 21, a processing sequence 700 related to vehicle alterations made by vehicle controller 92 in light of vehicle 10 being airborne is provided. Vehicle controller 92 receives output from accelerometer 30, as represented

by block 702, and monitors the acceleration of vehicle 10. The output is sent through a low pass filter to average the data, as represented by block 704. Vehicle controller 92 executes a freefall algorithm to determine if vehicle 10 is falling, as represented by block 704. In one example, vehicle controller 92 determines if the z-plane acceleration is a negative value indicating a downward movement of vehicle 10. The received data is de-bounced by a delay amount, as represented by block 708. After the de-bounce delay the data is checked again to determine if the z-plane acceleration is a negative value. The data is continued to be checked until a timer expires, as represented by block 710. If the timer expires and the z-plane acceleration continues to be negative, vehicle controller 92 determines that vehicle 10 is airborne, as represented by block 712. In response thereto, vehicle controller 92 or the individual system controllers make adjustments to the vehicle characteristics. If the timer has not expired but a threshold amount of time has passed, controller 92 in response to a positive z-plane acceleration or the detection of gravity determines the vehicle 10 was airborne. The increase in firmness is controlled by the appropriate curve in FIG. 20. In one embodiment, airborne detection is determined by monitoring the output of each of the three axes of accelerometer 30 with controller 20. Controller 20 determines that vehicle 10 is airborne in response to a magnitude of a resultant acceleration vector (based on the x-axis component vector, the y-axis component vector, and the z-axis component vector) being above a first threshold value and the magnitude of each of the x-axis acceleration and the magnitude of the y-axis acceleration being below a second threshold.

[00162] Once the vehicle has been determined to be airborne, suspension controller 86 may increase the suspension damping to provide a firmer suspension for landing, as represented by block 714. Prime mover controller 82 and transmission controller 84 may take steps to protect the driveline of vehicle 10, as represented by block 716. Prime mover controller 82 may limit the torque output of prime mover 62. Transmission controller 84 may prevent shifting transmission 66 to a higher gear.

[00163] Further, the output of power system 60 may be increased or decreased to change the rotational speed of one or more of ground engaging members 12 and change the attitude of vehicle 10 while vehicle 10 is in the air, as represented by block 718. In one example, this is accomplished by adjusting an output of prime mover 62,

altering a speed ratio of transmission 66, or both. Further, braking system 75 may be activated to slow the rotational speed of one or more of ground engaging members 12 to change the attitude of vehicle 10. Controller 20 through changes to driveline torque management system 50 may automatically change the pitch of vehicle 10 while vehicle 10 is airborne.

[00164] Controller 20 may further record information regarding airborne events, as represented by block 720. Exemplary information includes a time duration of each jump, the peak gravitational value experienced by vehicle 10 upon landing, number of jumps in a given period of time, and other information.

[00165] In one embodiment, a position of shock absorbers 18 is used to detect if vehicle 10 is airborne. In one example, if shocks 18 relaxed beyond a calibrated extension value, the vehicle 10 was determined to be airborne. In one variation, a majority of the shocks had to demonstrate a relaxation beyond a calibrated extension value for the vehicle to be considered airborne. Once the shocks compressed beyond a threshold, the dampening profile was adjusted firmer.

[00166] Referring to FIG. 25, in one embodiment, suspension controller 86 is further operatively coupled to a plurality of operable selectable inputs of user interface 22 through which an operator of vehicle 10 may select a terrain ride mode setting for adjustable shocks 18 and/or adjustable springs 16. The selectable inputs may be switches, buttons, touch regions on display 24, dials, and other suitable user inputs. In the illustrated embodiment of FIG. 25, a desert ride mode input 900, an ice ride mode input 902, a sand ride mode input 904, and a trail ride mode input 906 are provided. Other suitable terrain ride mode inputs may be provided.

[00167] In one embodiment, selection of desert ride mode input 900 results in suspension controller 86 adjusting adjustable shocks 18 to a desert setup for desert conditions. In one example, the desert setup may be user defined based on prior vehicle performance in desert conditions.

[00168] In one embodiment, selection of ice ride mode input 902 results in suspension controller 86 adjusting adjustable shocks 18 to an ice setup for ice conditions. In one example, the ice setup may be user defined based on prior vehicle

performance in ice conditions. For instance, an ice setup may alter cornering detection algorithms to provide different operational thresholds for low friction surfaces.

[00169] In one embodiment, selection of sand ride mode input 904 results in suspension controller 86 adjusting adjustable shocks 18 to a sand setup for sand conditions. In one example, the sand setup may be user defined based on prior vehicle performance in sand conditions.

[00170] In one embodiment, selection of trail ride mode input 906 results in suspension controller 86 adjusting adjustable shocks 18 to a trail setup for trail conditions. In one example, the trail setup may be user defined based on prior vehicle performance in trail conditions.

[00171] Referring to FIG. 26, in one embodiment, suspension controller 86 includes terrain sensing logic 912 which based on a plurality of inputs from vehicle condition sensors 40 determines a terrain being experienced by vehicle 10 and adjusts the damping characteristics of one or more of adjustable shocks 18 based thereon. Suspension controller 86 may adjust the compression damping characteristic of one or more of adjustable shocks 18, the rebound damping characteristics of one or more adjustable shocks 18, and/or both the compression and rebound damping of one or more adjustable shocks 18.

[00172] As shown in FIG. 26, terrain sensing logic 912 receives a plurality of inputs from the plurality of sensors 40 including x, y, and z axis acceleration and angular rate information from accelerometer 30 and gyroscope 31, respectively. Additional exemplary sensors include wheel acceleration and displacement sensors. Further, terrain sensing logic 912 receives an indication of a steering angle of the steering device 226, an indication of a steering torque, and an indication of a steering velocity from steering system 104. Additionally, terrain sensing logic 912 receives an indication of an ambient weather event. In the illustrated embodiment, the ambient weather event is an ambient air temperature and the indication is received from a temperature sensor 194. The temperature sensor 194 is supported by vehicle 10. Alternatively, the ambient air temperature may be received from a sensor remote from vehicle 10 and communicated to vehicle 10 over one or more wireless networks, such as over a network from a smartphone, a satellite network, or a cellular network. Terrain sensing

logic may further receive engine speed, accelerator pedal position, and vehicle speed values from one or more of the controllers of vehicle 10. By sensing terrain changes, an operator of vehicle 10 will feel more comfortable driving vehicle 10 in changing terrains without needing to make a ride mode change selection.

[00173] In one embodiment, terrain sensing logic 912 determines vehicle 10 is traversing a harsh trail terrain (chatter) by performing a frequency analysis of incoming inertial measurement information and weighing magnitudes of acceleration at certain frequencies against a calibrated profile. In response thereto, terrain sensing logic 912, adjusts adjustable shocks 18 to optimize either ride or handling based on the weighted observations.

[00174] In one embodiment, terrain sensing logic 912 determines vehicle 10 is traversing a terrain with small hills (whoops) by measuring repeated bottom out events. In response thereto, terrain sensing logic 912, adjusts adjustable shocks 18 to increase compression damping.

[00175] In one embodiment, terrain sensing logic 912 determines vehicle 10 is traversing a terrain with ice by measuring high levels of yaw rate in absence of lateral accelerations. In response thereto, terrain sensing logic 912, adjusts adjustable shocks 18 to increase the damping characteristics, either compression, rebound, or compression and rebound, over current levels.

[00176] In one embodiment, terrain sensing logic 912 determines vehicle 10 is traversing a terrain which causes the vehicle to bottom out by receiving repeated high g-force events in the z-axis (see FIG. 2) from accelerometer 30. In response thereto, terrain sensing logic 912, adjusts adjustable shocks 18 to increase the compression damping of each of the adjustable shocks 18 to reduce the G forces in the z-axis. As the terrain smooths out (i.e. lower G forces in the z-axis), terrain sensing logic 912 decreases the compression damping of each of the adjustable shocks 18 back to a level, such as the current ride mode level.

[00177] In one embodiment, terrain sensing logic 912 adjusts the damping characteristics of adjustable shocks 18 over time based on sensed terrain changes. Referring to FIGS. 27A and 27B, in one example, vehicle 200 is traversing a terrain 940 including a trail terrain 950 followed by a road terrain 952. Exemplary trail terrains

include dirt, off-road trails having uneven surfaces. Exemplary road terrains include asphalt surfaces having a generally smooth surface. In the illustrated example, trail terrain 950 includes a whoops portion 954 which includes a plurality of hills that vehicle 200 must traverse.

[00178] Referring to FIG. 27B, a suspension damping level 960 of at least one of the adjustable shocks 18 is shown over time. At the beginning of the illustrated time period, the suspension damping level remains generally constant as vehicle 200 traverses the trail terrain. Of course, the damping level may be altered by controller 20 if vehicle 200 is cornering, braking, accelerating, or experiencing other conditions. When vehicle 200 enters the whoops region, the terrain sensing logic 912 of controller 20 increases the damping level of the adjustable shock 18. In one example, terrain sensing logic 912 increases the damping level due to an increase in the adjustable shock 18 bottoming out. Once 200 exits the whoops portion, terrain sensing logic 912 of controller 20 begins to reduce the damping level. In one example, terrain sensing logic 912 reduces the damping level due to a decrease in the vertical acceleration measured by accelerometer 30. As shown in FIG. 27B, terrain sensing logic 912 further reduces the damping level when vehicle 200 is traversing road terrain 952.

[00179] In one embodiment, terrain sensing logic 912 stores the suspension damping levels for later recall to proactively adjust the damping level of adjustable shocks 18. As discussed herein, vehicle 200 may include a location determiner 110. In one example, terrain suspension logic 912 stores the suspension damping levels based on vehicle location as determined by location determiner 110. Thus, when vehicle 200 is approaching the stored location, terrain sensing logic 912 will adjust the suspension damping level based on the stored suspension damping level. In a further example, terrain suspension logic 912 will take into account the current vehicle speed when adjusting the suspension damping levels.

[00180] While embodiments of the present disclosure have been described as having exemplary designs, 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 disclosure 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 recreational vehicle, comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber having at least one adjustable damping profile; a driveline torque management system operatively coupled to at least one of the plurality of ground engaging members, the driveline torque management system having at least one adjustable driveline torque management system characteristic; at least one airborne sensor positioned on the recreational vehicle, the at least one airborne sensor monitoring a movement characteristic of the recreational vehicle; and at least one controller operatively coupled to the driveline torque management system, the at least one airborne sensor, and the at least one adjustable shock absorber, the at least one controller determining if the recreational vehicle is in an airborne state and in response to determining the recreational vehicle is in the airborne state altering both the adjustable damping profile of the at least one adjustable shock absorber and altering the at least one adjustable driveline torque management system of the driveline torque management system.
2. The recreational vehicle of claim 1, wherein the at least one airborne sensor is supported by the frame and spaced apart from the at least one adjustable shock.
3. The recreational vehicle of claim 1 or 2, wherein the at least one airborne sensor is positioned generally along a longitudinal centerline plane of the recreational vehicle.
4. The recreational vehicle of any of claims 1-3, wherein the at least one airborne sensor includes an accelerometer.
5. The recreational vehicle of any of claims 1-4, wherein the at least one airborne sensor includes a gyroscope.

6. The recreational vehicle of any of claims 1-5, wherein the at least one adjustable driveline torque management system characteristic of the driveline torque management system is associated with a prime mover of the driveline torque management system.
7. The recreational vehicle of claim 6, wherein the at least one adjustable driveline torque management system characteristic associated with the prime mover of the driveline torque management system is adjusted to alter a pitch of the vehicle.
8. The recreational vehicle of any of claims 1-7, wherein the at least one adjustable driveline torque management system characteristic of the driveline torque management system is associated with a transmission of the driveline torque management system.
9. The recreational vehicle of claim 8, wherein the at least one adjustable driveline torque management system characteristic associated with the transmission of the driveline torque management system is adjusted to alter a pitch of the vehicle.
10. The recreational vehicle of any of claims 1-9, wherein the at least one adjustable driveline torque management system characteristic of the driveline torque management system is associated with a braking system of the driveline torque management system.
11. The recreational vehicle of claim 10, wherein the at least one adjustable driveline torque management system characteristic associated with the braking system of the driveline torque management system is adjusted to alter a pitch of the vehicle.
12. The recreational vehicle of any of claims 1-11, wherein the at least one airborne sensor includes an accelerometer which provides an x-axis acceleration value, a y-axis acceleration value, and a z-axis acceleration value, the at least one controller determining if the recreational vehicle is in an airborne state by comparing a magnitude of a resultant acceleration vector to a first threshold, the resultant acceleration vector being based on the x-axis acceleration value, the y-axis acceleration value, and the z-axis acceleration value.

13. The recreational vehicle of any of claims 1-12, wherein the at least one airborne sensor includes an accelerometer which provides an x-axis acceleration value, a y-axis acceleration value, and a z-axis acceleration value, the at least one controller determining if the recreational vehicle is in an airborne state by comparing the x-axis acceleration value to a first threshold value, the y-axis acceleration value to a second threshold, and the z-axis acceleration value to a third threshold.

14. A recreational vehicle, comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors, the at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors, the at least one controller determining if the at least one adjustable shock may be reconfigured from a first ride mode of the plurality of ride modes to a second ride mode of the plurality of ride modes by determining if a first condition is satisfied, if the first condition is satisfied then configuring the at least one shock absorber in the second ride mode, if the first condition is not satisfied then determining if a second condition is satisfied, if the second condition is satisfied then configuring the at least one shock absorber in the second ride mode, if both the first condition and the second condition are not satisfied remaining in the first ride mode, wherein only one of the first condition and the second condition is based on at least one of a plurality of inputs from the plurality of vehicle condition sensors.

15. The recreational vehicle of claim 14, wherein each of the plurality of ride modes has an associated damping profile.

16. The recreational vehicle of claim 15, wherein the first condition is whether the damping profile of the second ride mode is firmer than the damping profile of the first ride mode.
17. The recreational vehicle of claim 16, wherein the second condition is whether a vehicle condition modifier state is active.
18. The recreational vehicle of claim 16, wherein the second condition is based on at least one of a plurality of inputs from the plurality of vehicle condition sensors.
19. The recreational vehicle of claim 16, wherein the second condition is based on at least a ground speed of the recreational vehicle.
20. The recreational vehicle of any of claims 14-19, further comprising an operator interface, wherein a request change to the second ride mode of the plurality of ride modes is received from the operator interface.
21. The recreational vehicle of any of claims 14-20, further comprising a communication system, wherein a request change to the second ride mode of the plurality of ride modes is received from the communication system.
22. A recreational vehicle, comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber having at least one adjustable damping profile; a driveline torque management system operatively coupled to at least one of the plurality of ground engaging members, the driveline torque management system having at least one adjustable driveline torque management system characteristic; at least one airborne sensor positioned on the recreational vehicle, the at least one airborne sensor monitoring a movement characteristic of the recreational vehicle; and at least one controller operatively coupled to the driveline

torque management system, the at least one airborne sensor, and the at least one adjustable shock absorber, the at least one controller determining if the recreational vehicle is in an airborne state and in response to determining the recreational vehicle is in the airborne state altering the adjustable damping profile of the at least one adjustable shock absorber to a first damping profile if the airborne state spans a first time duration and to a second damping profile if the airborne state spans a second time interval, the second time interval being longer than the first time interval.

23. The recreational vehicle of claim 22, wherein the second damping profile is stiffer than the first damping profile.

24. A method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver, the method comprising:

determining the vehicle is one of cornering and spinning based on a yaw characteristic of the vehicle; and

adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the yaw characteristic.

25. The method of claim 24, wherein the vehicle has a longitudinal centerline vertical plane and the at least one adjustable shock includes a first adjustable shock positioned on a first side of the longitudinal centerline vertical plane and coupled between a frame of the vehicle and a first ground engaging member of the vehicle and a second adjustable shock positioned on a second side of the longitudinal centerline vertical plane and coupled between the frame of the vehicle and a second ground engaging member of the vehicle, the step of adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the yaw characteristic includes the step increasing at least one of a damping characteristic of the first adjustable shock absorber and a damping characteristic of the second adjustable shock absorber, wherein the damping characteristic of the first adjustable shock absorber is increased when the vehicle is rotating in a first direction about a vertical axis and the damping characteristic of the second adjustable shock absorber is increased when the vehicle is

rotating in a second direction about the vertical axis, the second direction being opposite the first direction.

26. The method of claim 25, wherein the step of determining the vehicle is one of cornering and spinning based on the yaw characteristic of the vehicle includes the steps of monitoring an extent associated with the yaw characteristic, determining the vehicle is spinning when the extent has a first value.

27. The method of claim 26, wherein the extent is an angular characteristic and the step of determining the vehicle is spinning includes the steps of comparing the angular characteristic of the yaw characteristic to a threshold value, the threshold value being less than the first value.

28. A method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver, the method comprising:

(a) receiving a plurality of inputs from a plurality of sensors supported by the vehicle, the plurality of sensors including a first sensor having a first input and a second sensor having a second input;

(b) based on at least the first input from the first sensor, reactively determining if the vehicle is cornering;

(c) based on at least the second input from the second sensor, predictively determining if the vehicle is cornering; and

(d) adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle when it is determined that the vehicle is cornering in either step (b) or step (c).

29. The method of claim 28, wherein the step of adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle when it is determined that the vehicle is cornering in either step (b) or step (c) includes the step of adjusting the damping characteristic of the at least one adjustable shock based on step (b) when both step (b) and step (c) indicate that the vehicle is cornering.

30. The method of claim 28 or 29, wherein the first sensor detects an angular characteristic of the vehicle and the second sensor detects an angular characteristic of a steering device of the vehicle.

31. The method of any of claims 28-30, wherein the first sensor is a Yaw rate sensor.

32. A recreational vehicle, comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members, the plurality of vehicle condition sensors including a yaw characteristic sensor; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors, the at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors and configured to determine when the vehicle is cornering based on an input from the yaw characteristic sensor.

33. The recreational vehicle of claim 32, wherein the at least one controller determines a direction the vehicle is cornering based on the input from the yaw characteristic sensor when the vehicle is cornering.

34. The recreational vehicle of claim 32 or 33, wherein the vehicle has a longitudinal centerline vertical plane and the at least one adjustable shock includes a first adjustable shock positioned on a first side of the longitudinal centerline vertical plane and coupled between the frame of the vehicle and a first ground engaging member of the plurality of ground engaging members of the vehicle and a second adjustable shock positioned on a second side of the longitudinal centerline vertical plane and coupled between the frame of the vehicle and a second ground engaging member of the plurality of ground engaging members of the vehicle, wherein the at least one controller adjusts at least

one of a damping characteristic of the first adjustable shock absorber when the at least one controller determines the vehicle is rotating in a first direction about a vertical axis of the vehicle and adjusts at least one damping characteristic of the second adjustable shock absorber when the at least one controller determines the vehicle is rotating in a second direction about the vertical axis, the second direction being opposite the first direction.

35. The recreational vehicle of claim 34, wherein the at least one damping characteristic of the first adjustable shock absorber is increased when the at least one controller determines the vehicle is rotating in the first direction about the vertical axis of the vehicle and the at least one damping characteristic of the second adjustable shock absorber is increased when the at least one controller determines the vehicle is rotating in the second direction about the vertical axis of the vehicle.

36. The recreational vehicle of any of claims 32-35, wherein the at least one controller is further configured to determine when the vehicle is spinning based on an input from the yaw characteristic sensor.

37. The recreational vehicle of claim 36, wherein the vehicle has a longitudinal centerline vertical plane and the at least one adjustable shock includes a first adjustable shock positioned on a first side of the longitudinal centerline vertical plane and coupled between the frame of the vehicle and a first ground engaging member of the plurality of ground engaging members of the vehicle and a second adjustable shock positioned on a second side of the longitudinal centerline vertical plane and coupled between the frame of the vehicle and a second ground engaging member of the plurality of ground engaging members of the vehicle, wherein the at least one controller adjusts at least one of a damping characteristic of the first adjustable shock absorber and adjusts at least one damping characteristic of the second adjustable shock absorber when the at least one controller determines the vehicle is spinning.

38. The recreational vehicle of claim 37, wherein the at least one damping characteristic of the first adjustable shock absorber is increased and the at least one damping characteristic of the second adjustable shock absorber is increased when the at least one controller determines the vehicle is spinning.

39. A recreational vehicle, comprising a plurality of ground engaging members; a frame supported by the plurality of ground engaging members; at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber configurable in a plurality of ride modes each having an associated damping profile; a plurality of vehicle condition sensors supported by the plurality of ground engaging members, the plurality of vehicle condition sensors including an ambient weather sensor; and at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors, the at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors and adjusting at least one damping characteristic of the at least one adjustable shock based on an input from the ambient weather sensor.

40. The recreational vehicle of claim 39, wherein the ambient weather sensor is an ambient air temperature sensor.

41. A method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver, the method comprising:

receiving an indication of an ambient weather condition of an environment surrounding the vehicle; and

adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the indication of the received ambient weather condition.

42. The method of claim 41, wherein the ambient weather condition is an ambient air temperature.

43. A method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver, the method comprising:

sensing a change in a terrain being traversed by the vehicle; and

adjusting the damping characteristic of the at least one adjustable shock absorber of the vehicle based on the sensed change in the terrain.

44. A method of controlling a damping characteristic of at least one adjustable shock absorber of a vehicle being operated by a driver, the method comprising:

storing at least one historical suspension damping characteristic and at least one vehicle location corresponding to the at least one historical suspension damping characteristic; and

adjusting the damping characteristic of the at least one adjustable shock absorber at a first vehicle location based on the at least one historical suspension damping characteristic corresponding to the first vehicle location.

45. A recreational vehicle for operation by an operator, comprising:

a plurality of ground engaging members;

a frame supported by the plurality of ground engaging members;

at least one suspension coupling the plurality of ground engaging members to the frame, the at least one suspension including at least one adjustable shock absorber having at least one adjustable damping profile;

a plurality of vehicle condition sensors supported by the plurality of ground engaging members;

at least one controller operatively coupled to the at least one adjustable shock absorber and the plurality of vehicle condition sensors, the at least one controller receiving a plurality of inputs from the plurality of vehicle condition sensors; and

a user interface system supported by the frame, the user interface system including a display, the display being configurable with the at least one controller to display a screen layout, the screen layout including at least one of (i) at least one numerical indication of at least one damping characteristic of the at least one adjustable

shock absorber and (ii) at least one graphical representation of the at least one damping characteristic of the at least one adjustable shock absorber, the screen layout further including at least one of (i) a notification of an active vehicle condition modifier which alters the at least one damping characteristic of the at least one adjustable shock absorber and (ii) a vehicle steering angle indicator.

46. The recreational vehicle of claim 45, wherein the at least one damping characteristic relates to a compression damping value of the at least one adjustable shock.

47. The recreational vehicle of claim 45 or 46, wherein the at least one damping characteristic relates to a rebound damping value of the at least one adjustable shock.

48. The recreational vehicle of any of claims 45-47, wherein the screen layout further includes a vehicle g-force indicator, the vehicle g-force indicator provides a first indication of a magnitude of the g-force being experienced by the vehicle and a second indication of a direction of the g-force being experienced by the vehicle.

49. The recreational vehicle of any of claims 45-48, wherein the screen layout further a graphical representation of the vehicle, the at least one adjustable shock absorber includes a first shock absorber associated with a first suspension of the at least one suspension and a second shock absorber associated with a second suspension of the at least one suspension, the first shock absorber being positioned on a first side of a vertical longitudinal vehicle centerline plane and the second shock absorber being positioned on a second side of the vertical longitudinal vehicle centerline plane, the second side being opposite the first side.

50. The recreational vehicle of claim 49, wherein a first numerical indication of the at least one numerical indication is associated with the first shock absorber and is positioned on a first side of the graphical representation of the vehicle and a second numerical indication of the at least one numerical indication is associated with the

second shock absorber and is positioned on a second side of the graphical representation of the vehicle, the second side of the graphical representation of the vehicle is opposite the first side of the graphical representation of the vehicle.

51. The recreational vehicle of claim 49 or 50, wherein a first graphical indication of the at least one graphical indication is associated with the first shock absorber and is positioned on a first side of the graphical representation of the vehicle and a second graphical indication of the at least one graphical indication is associated with the second shock absorber and is positioned on a second side of the graphical representation of the vehicle, the second side of the graphical representation of the vehicle is opposite the first side of the graphical representation of the vehicle.

52. The recreational vehicle of any of claims 45-41, wherein the screen layout further a graphical representation of the vehicle, the at least one adjustable shock absorber includes a first shock absorber associated with a first suspension of the at least one suspension and a second shock absorber associated with a second suspension of the at least one suspension, the first suspension being a front suspension of the vehicle and the second suspension being a rear suspension of the vehicle.

53. The recreational vehicle of claim 52, wherein a first numerical indication of the at least one numerical indication is associated with the first shock absorber and is positioned proximate a front portion of the graphical representation of the vehicle and a second numerical indication of the at least one numerical indication is associated with the second shock absorber and is positioned proximate a rear portion of the graphical representation of the vehicle.

54. The recreational vehicle of claim 52, wherein a first graphical indication of the at least one graphical indication is associated with the first shock absorber and is positioned proximate a front portion of the graphical representation of the vehicle and a second graphical indication of the at least one graphical indication is associated with the

second shock absorber and is positioned proximate a rear portion of the graphical representation of the vehicle.

55. The recreational vehicle of any of claims 45-54, wherein the notification of the active vehicle condition modifier which alters the at least one damping characteristic of the at least one adjustable shock absorber is associated with one of an anti-dive condition, a cornering condition, a ride condition, a squat condition, a brake condition, a roll/cornering condition, and a jump/pitch condition.

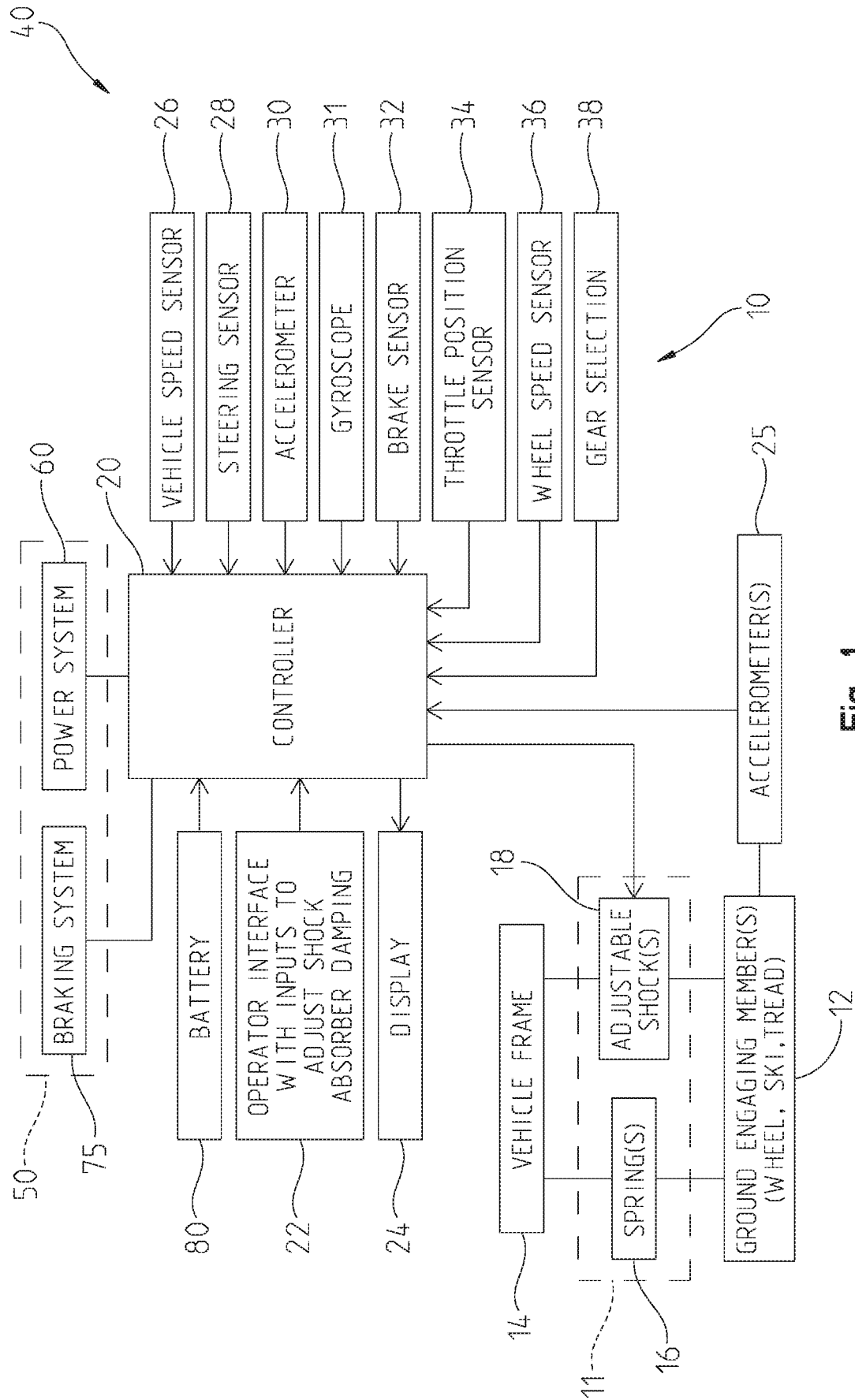


Fig. 1

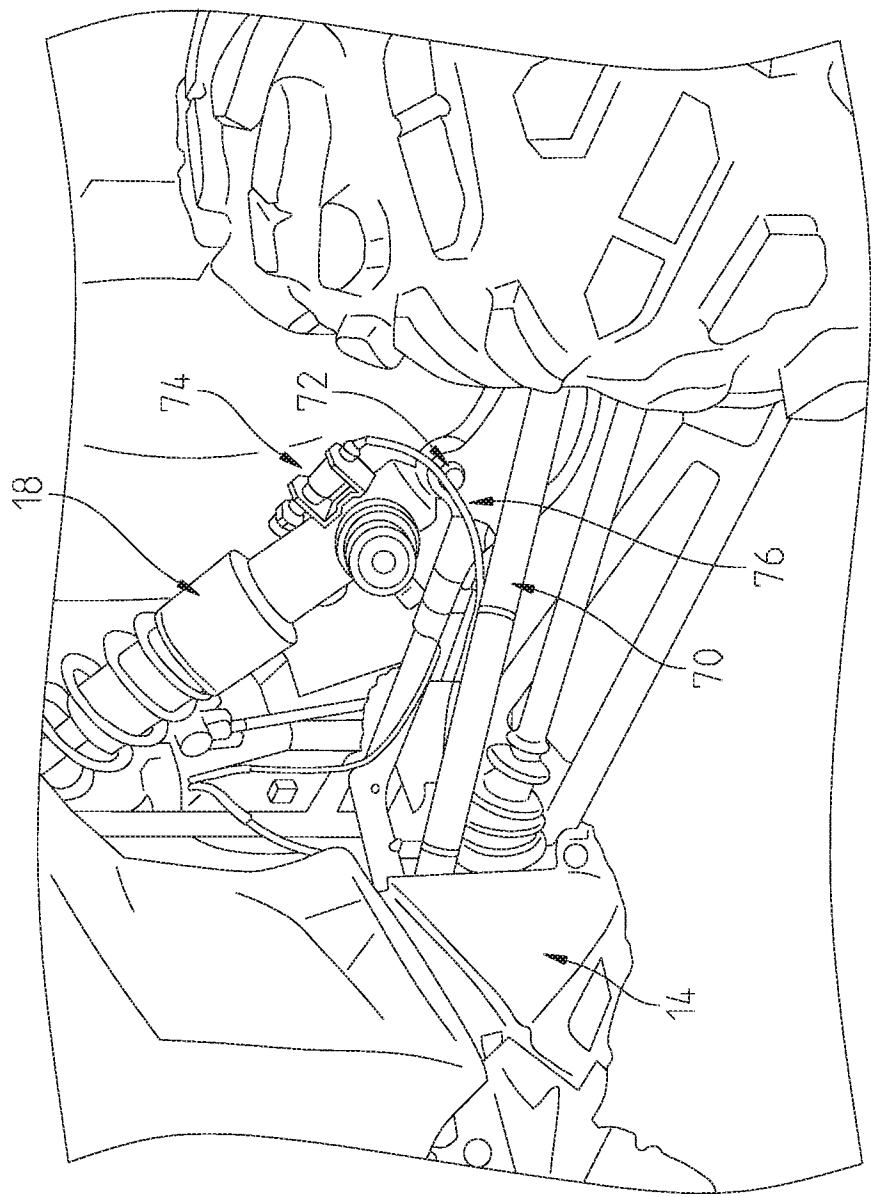


Fig. 2

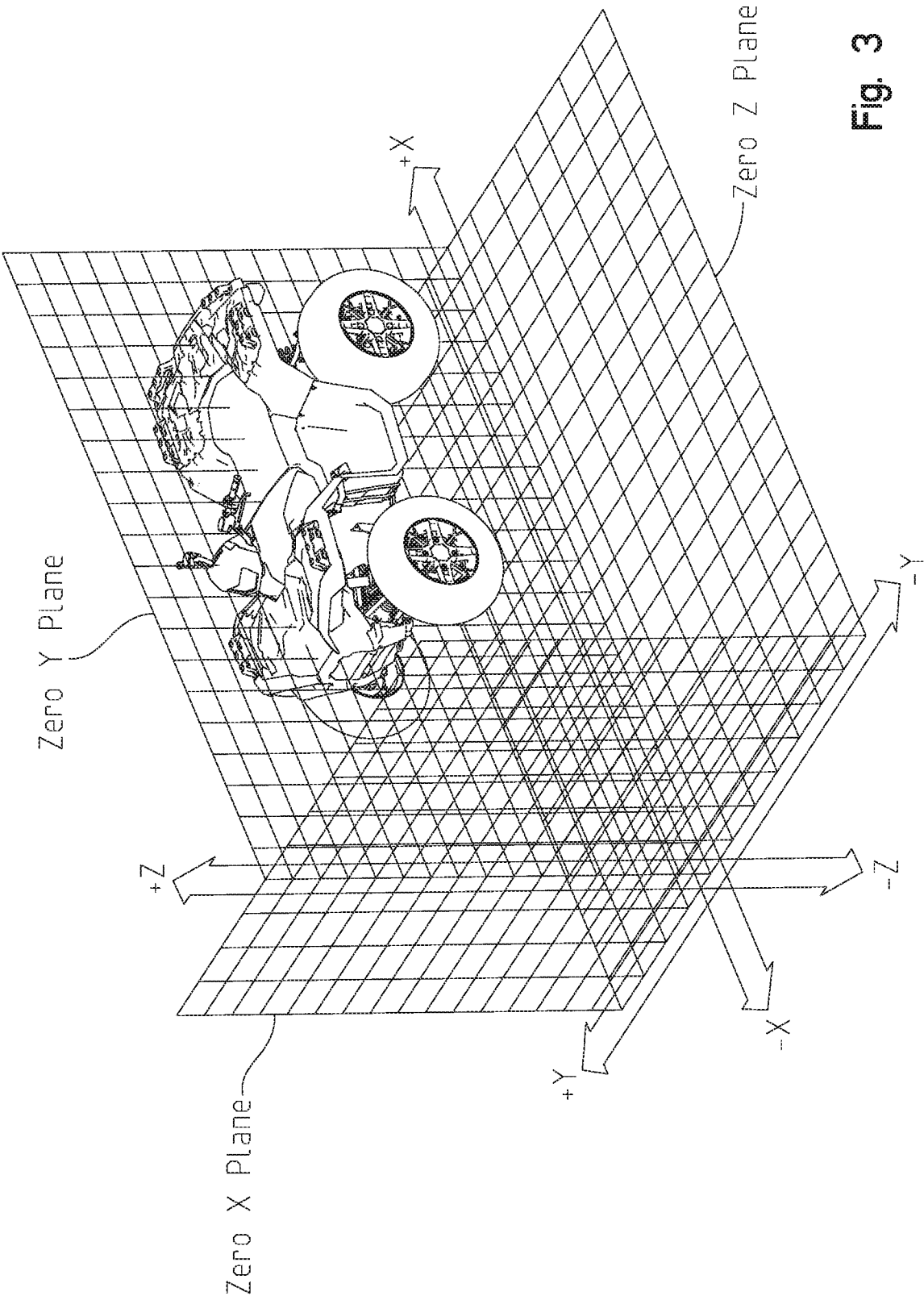


Fig. 3

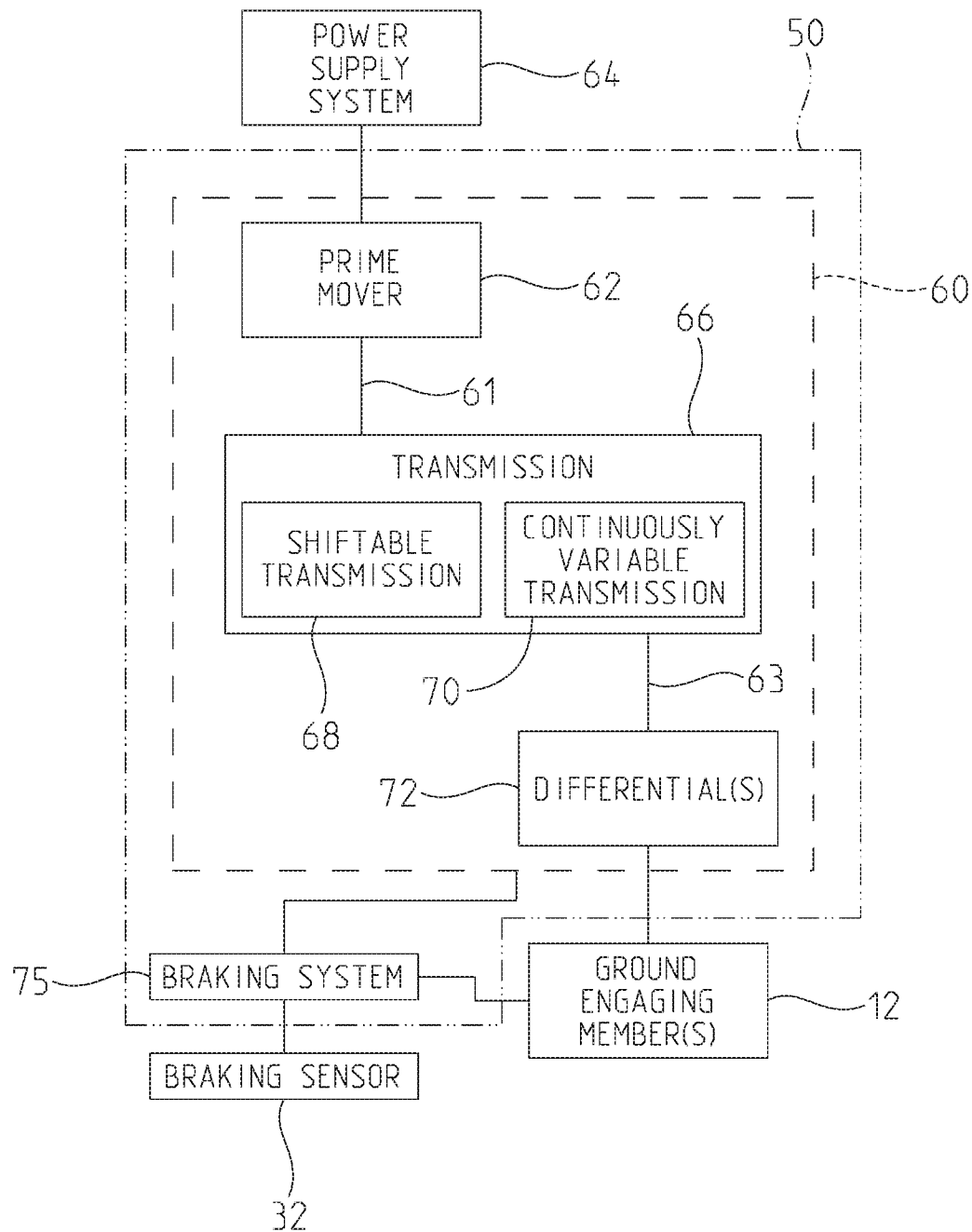


Fig. 4

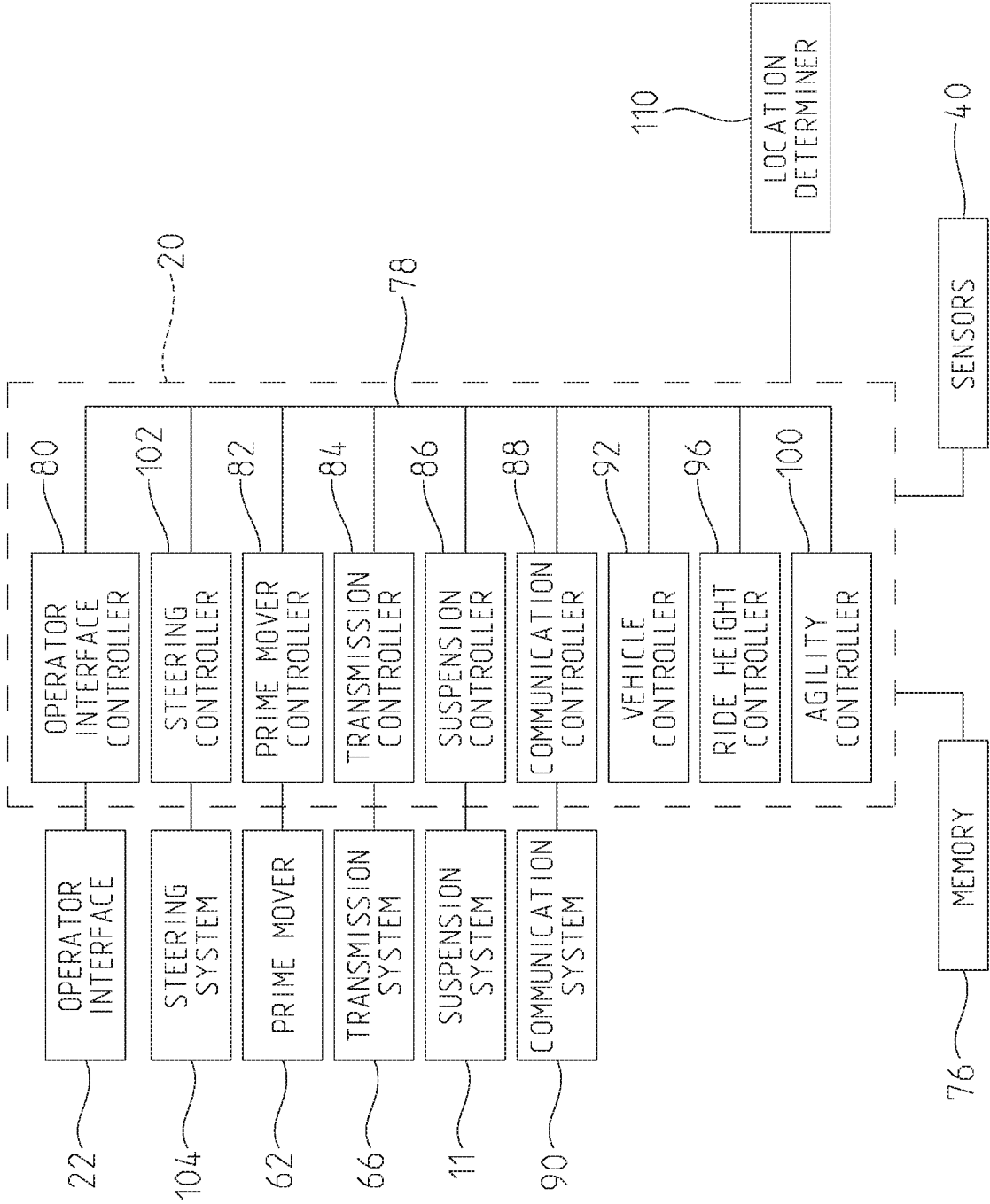


Fig. 5

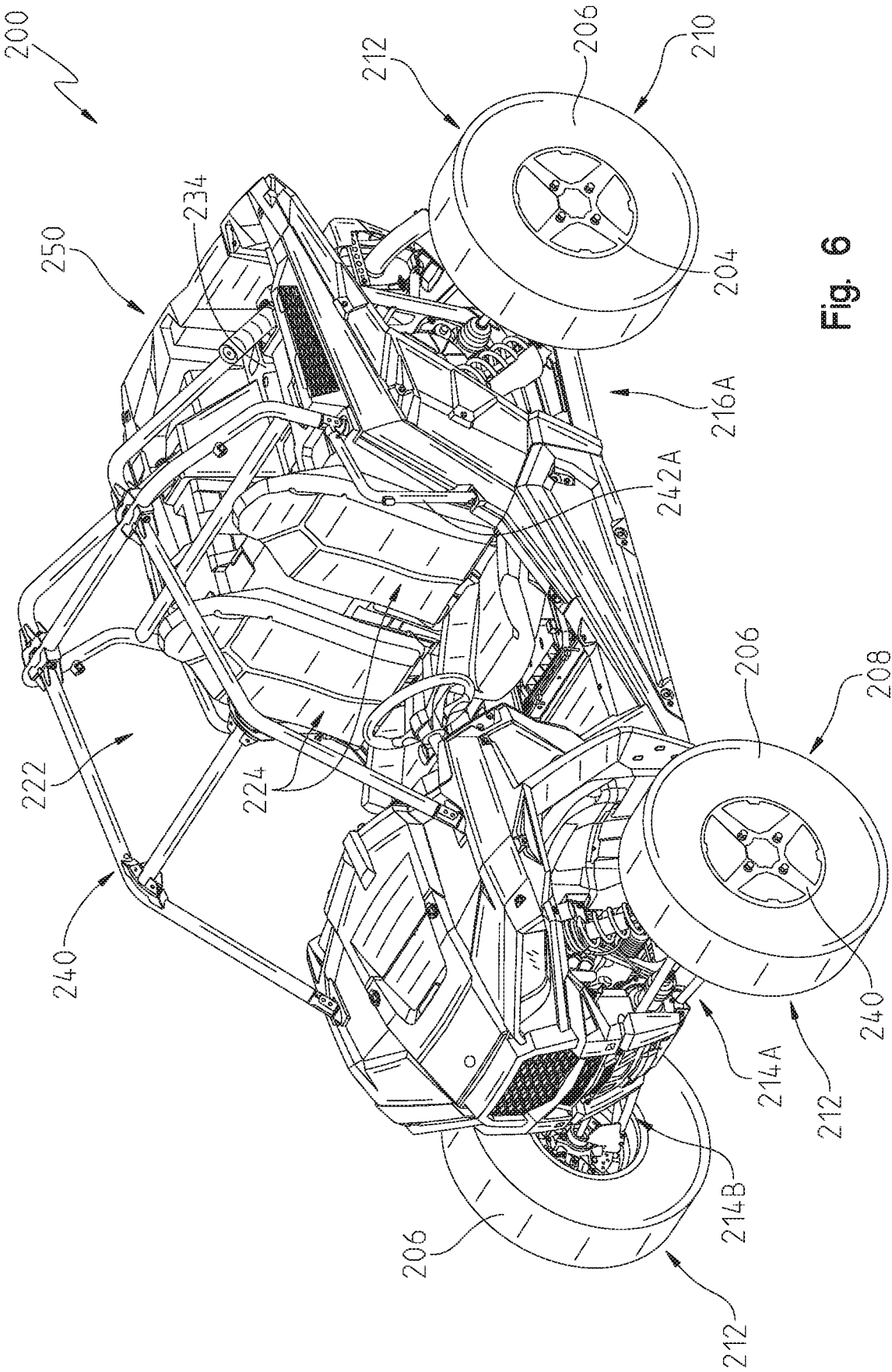


Fig. 6

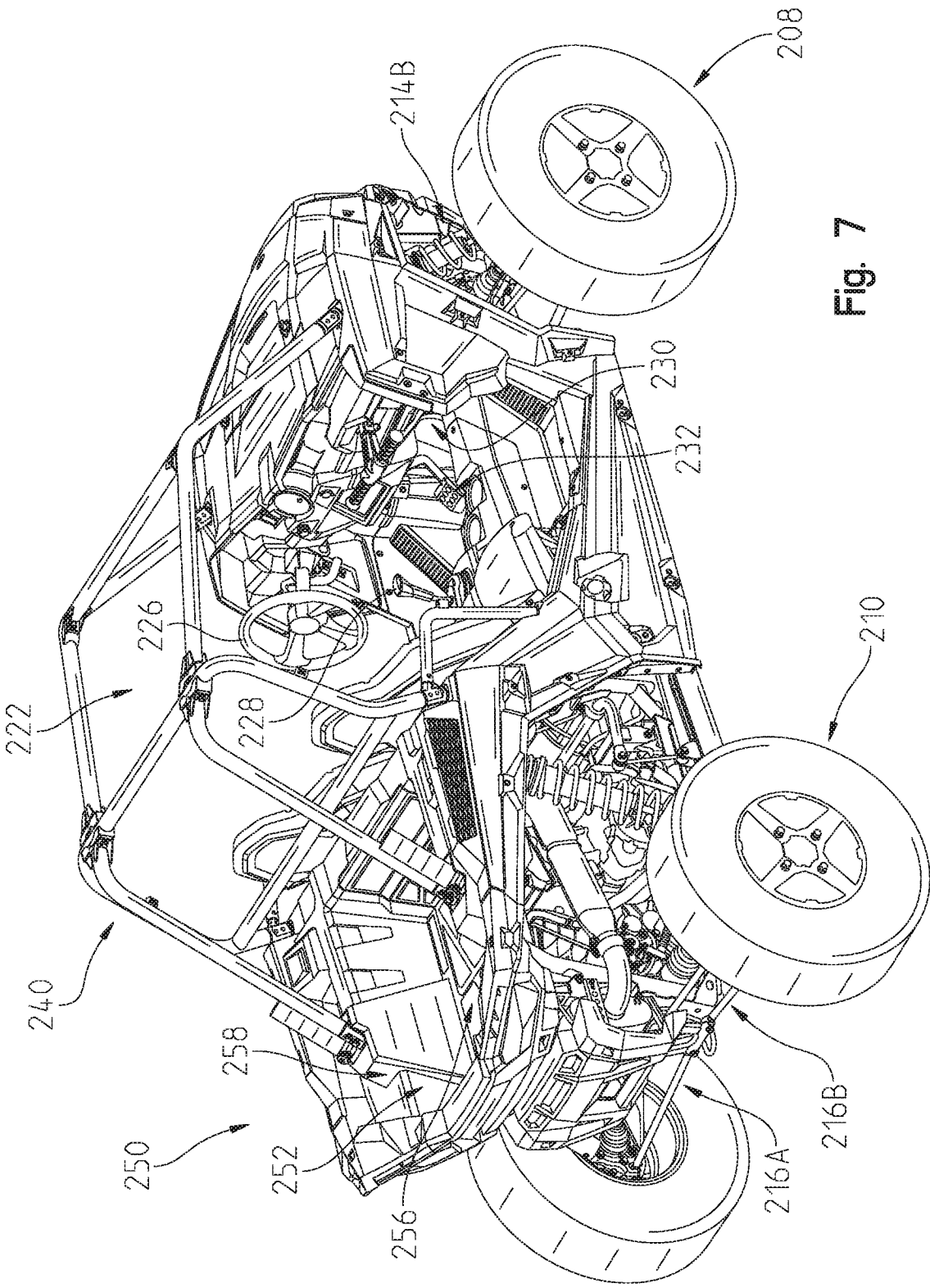


Fig. 7

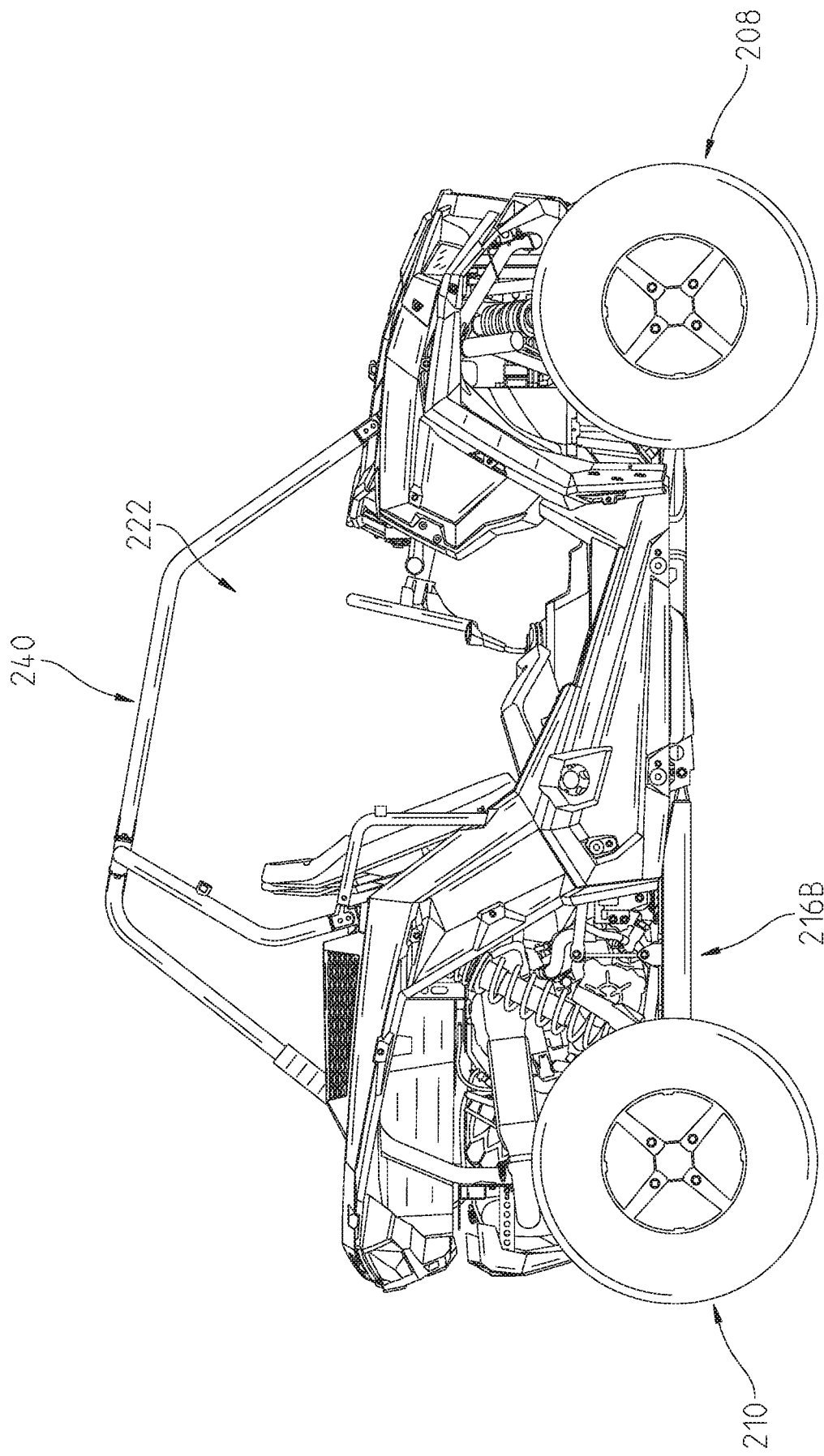


Fig. 8

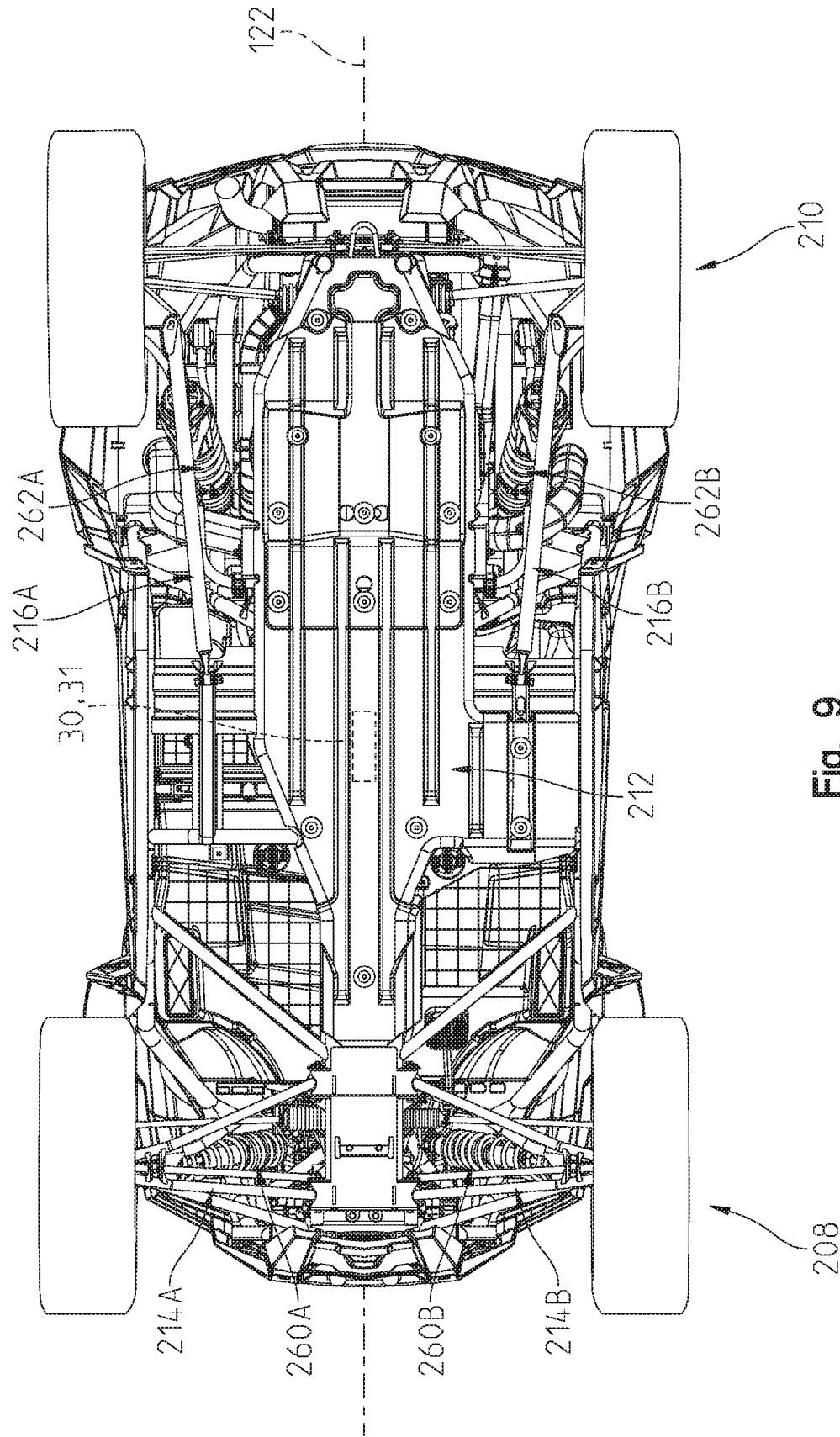
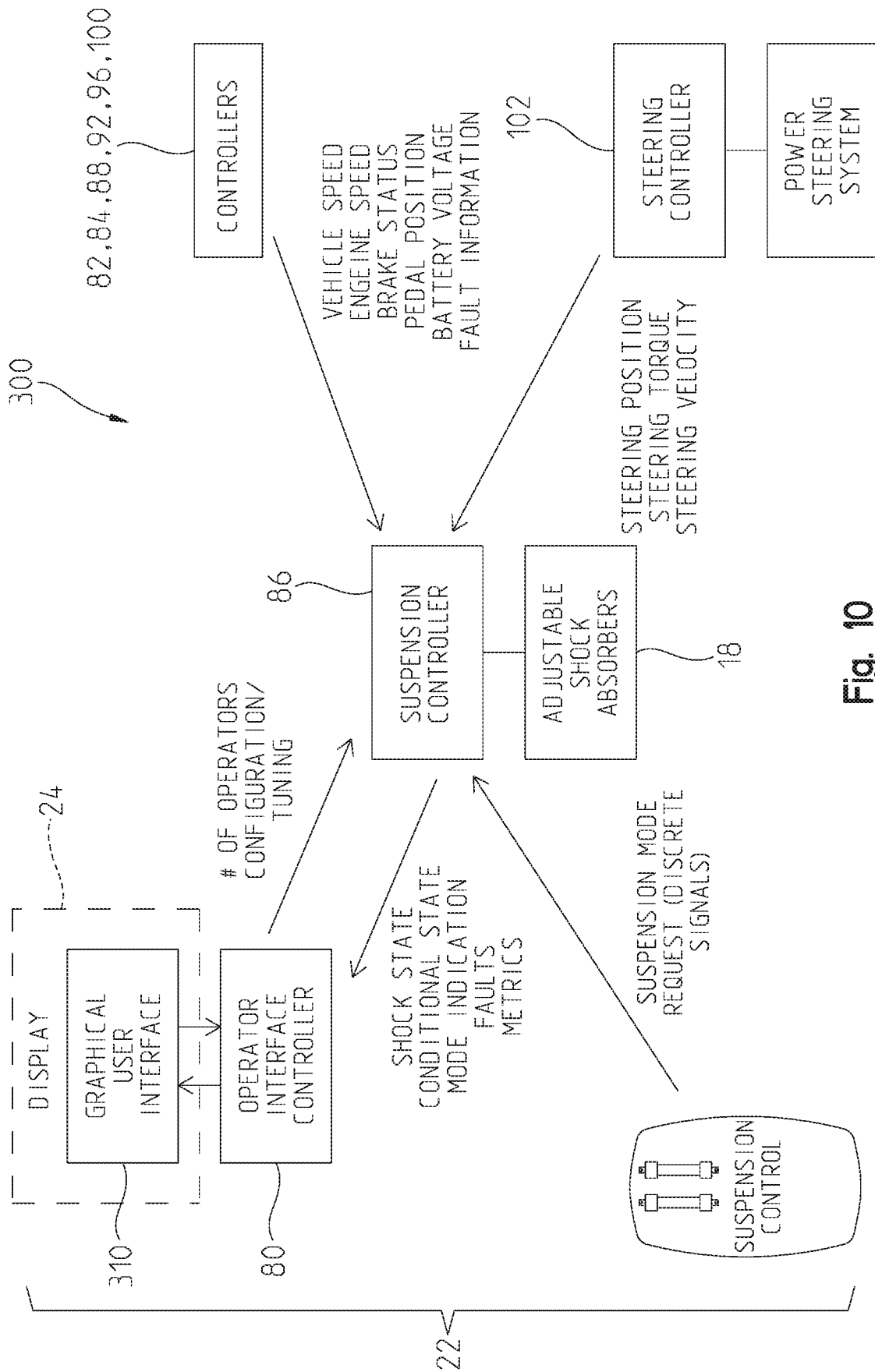


Fig. 9



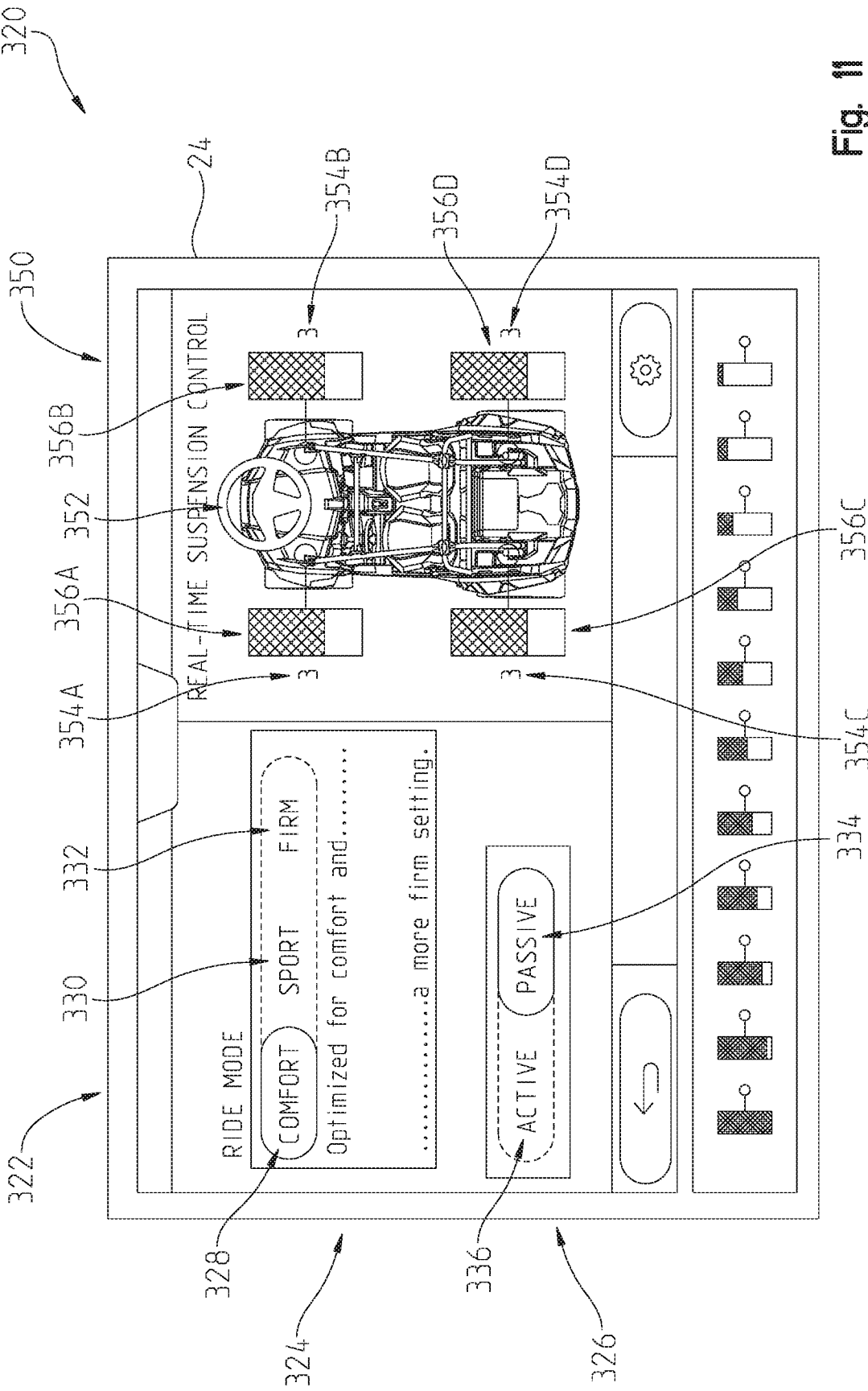


Fig. 11

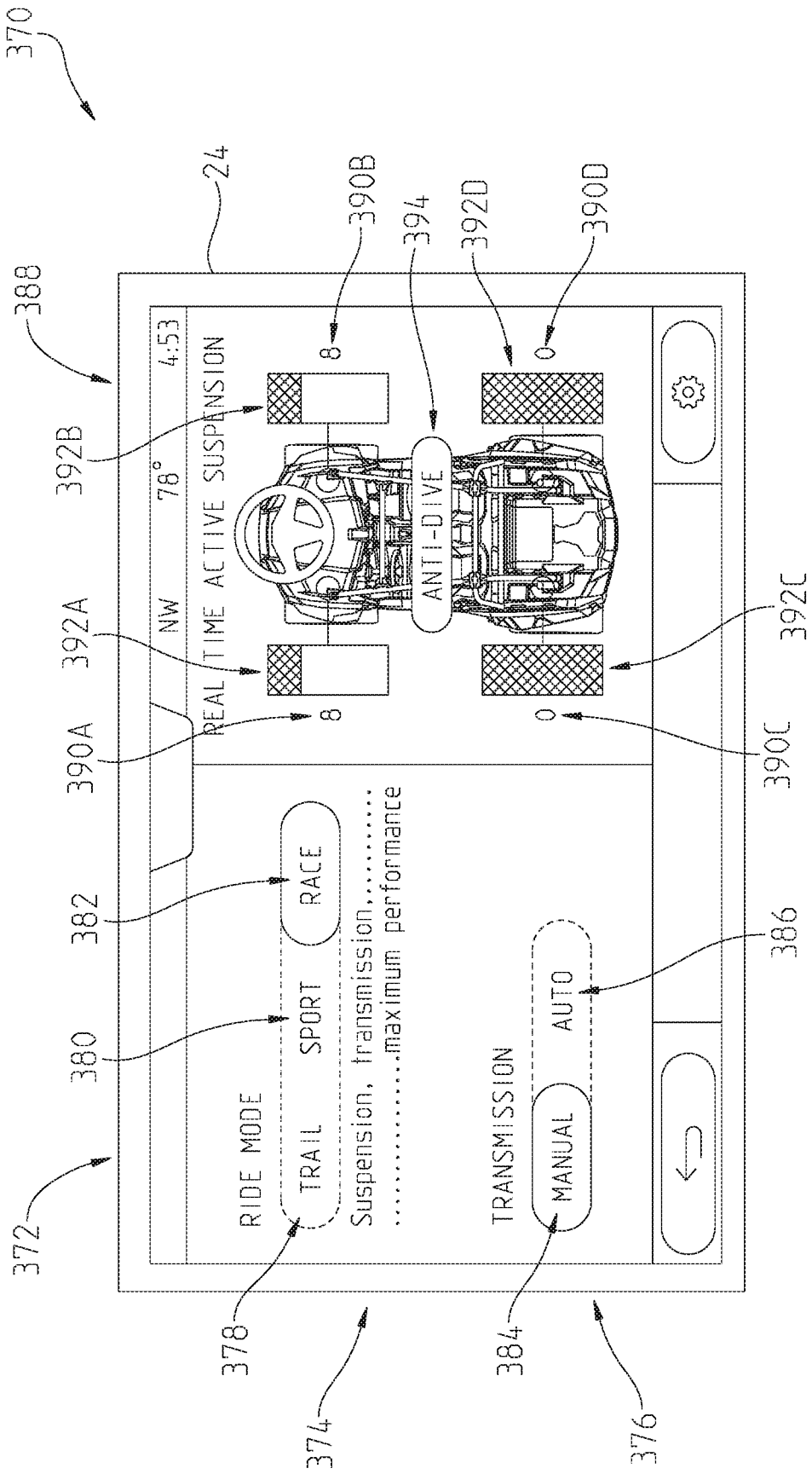


Fig. 12

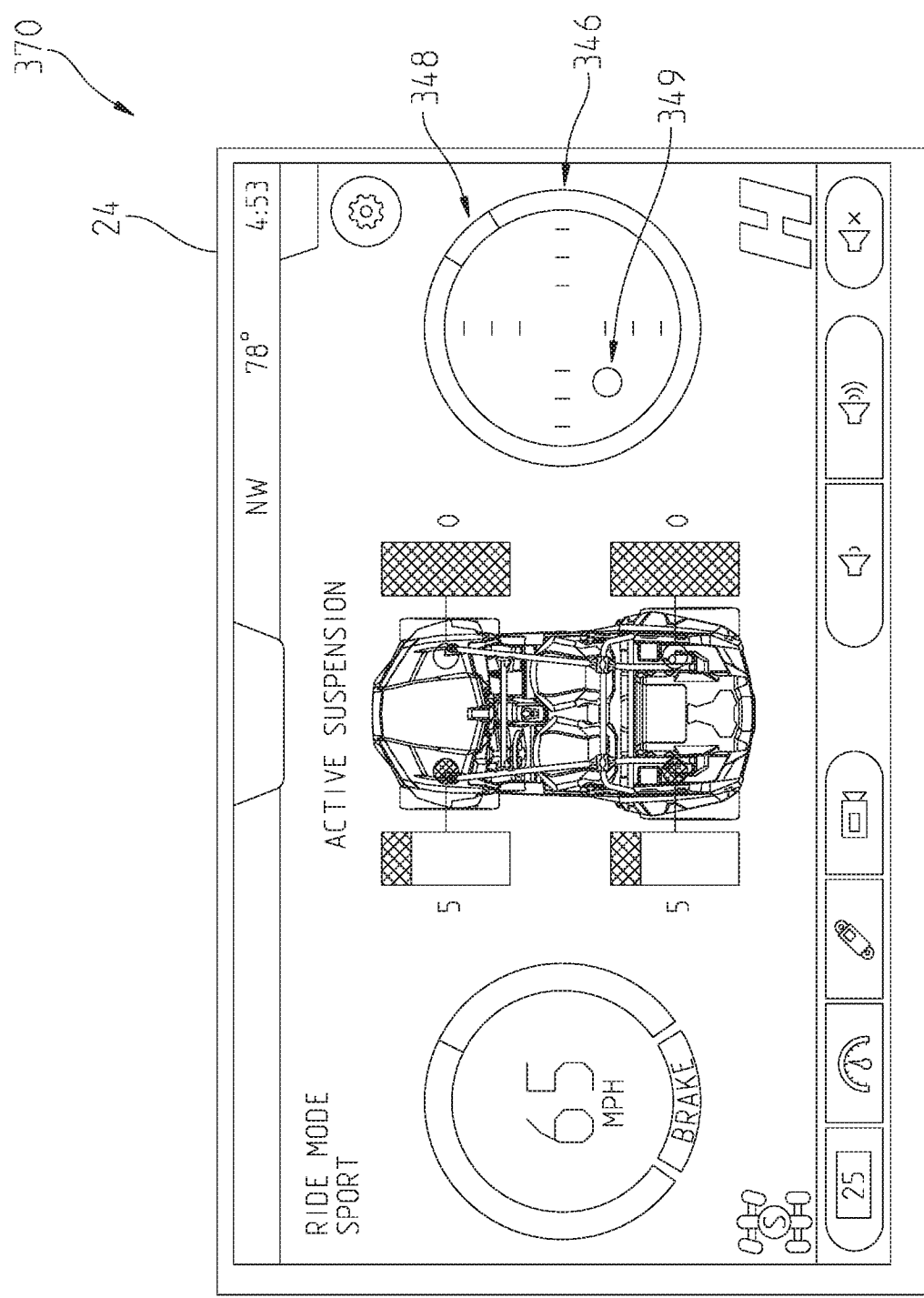


Fig. 12A

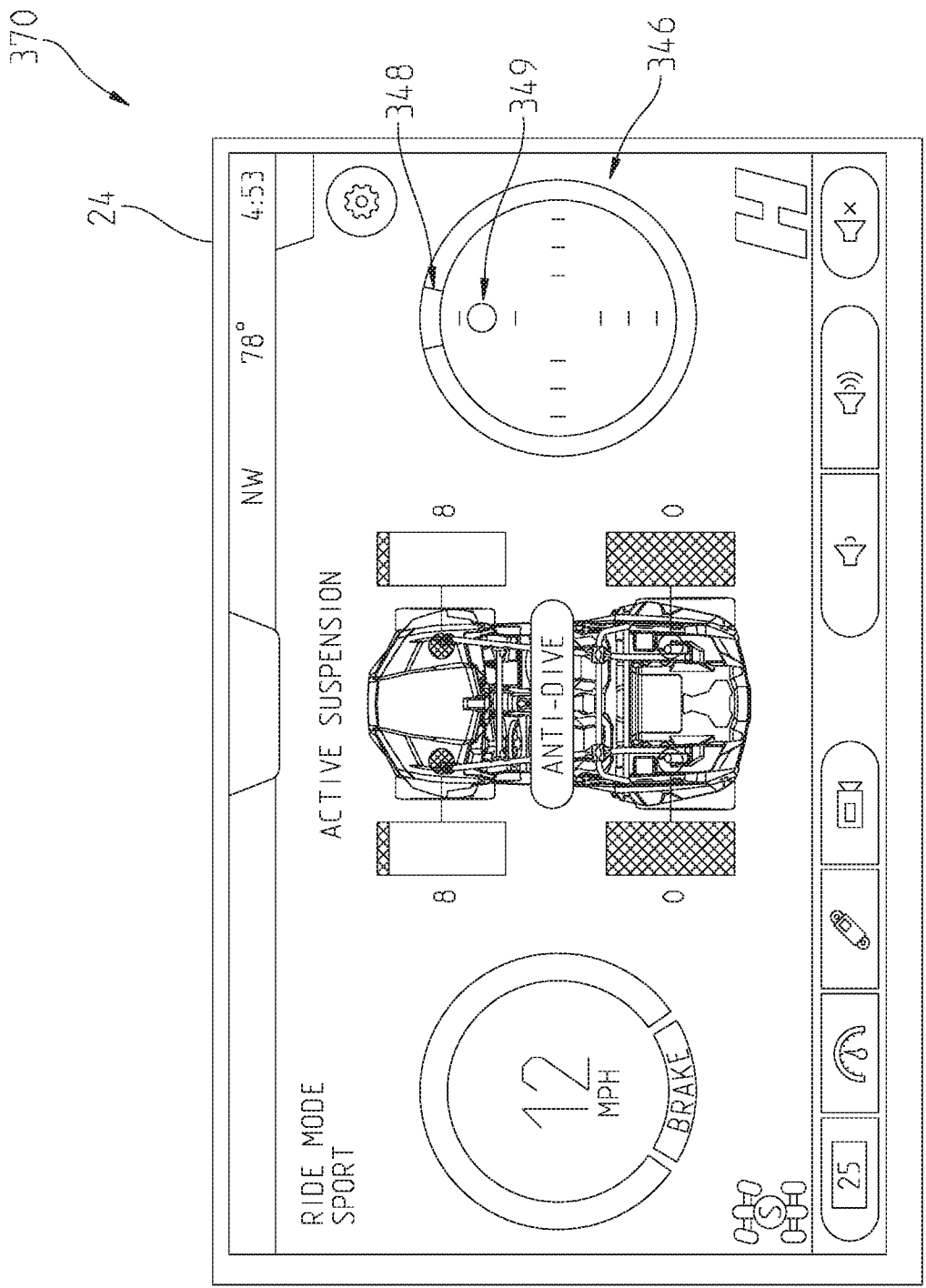


Fig. 12B

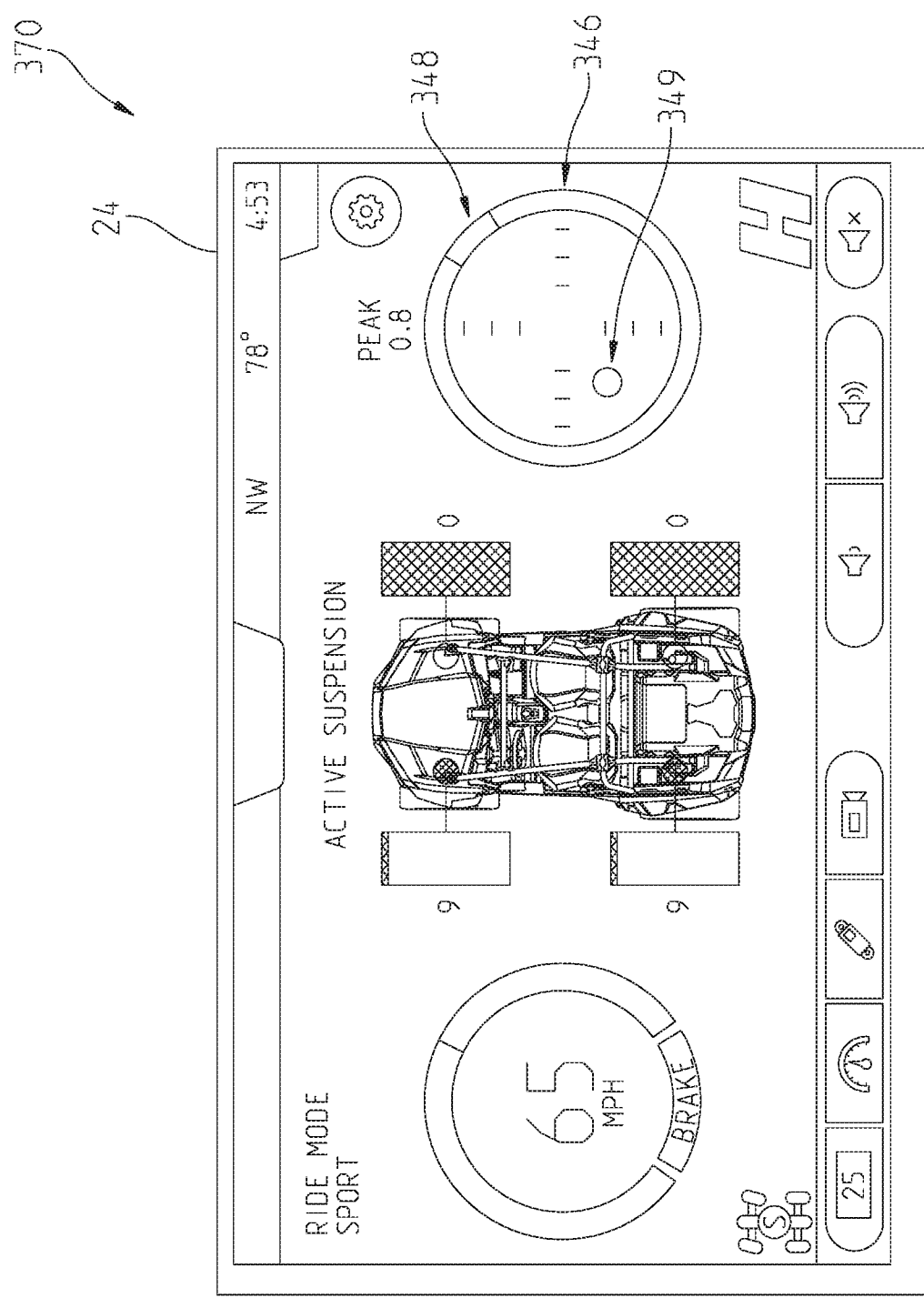


Fig. 12C

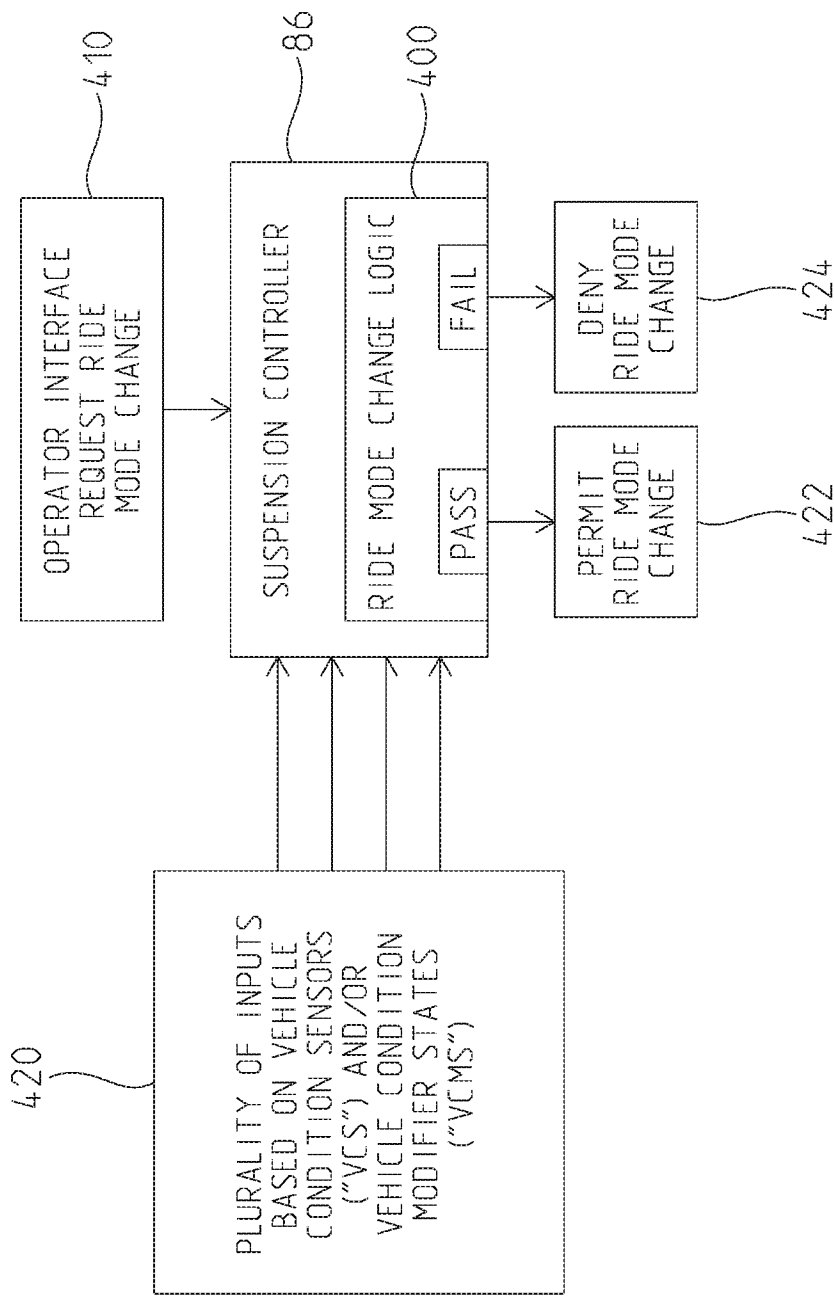


Fig. 13

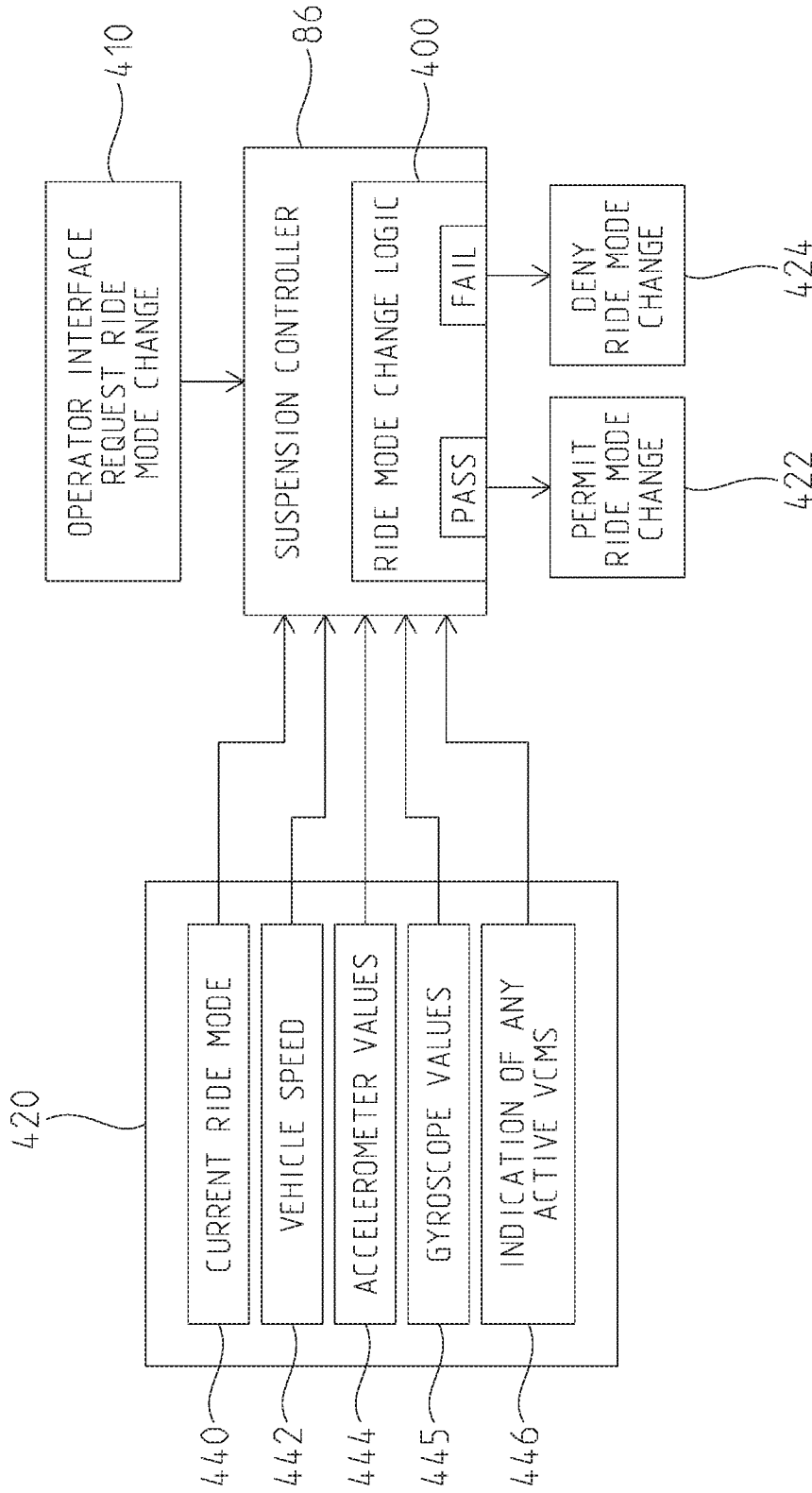


Fig. 14

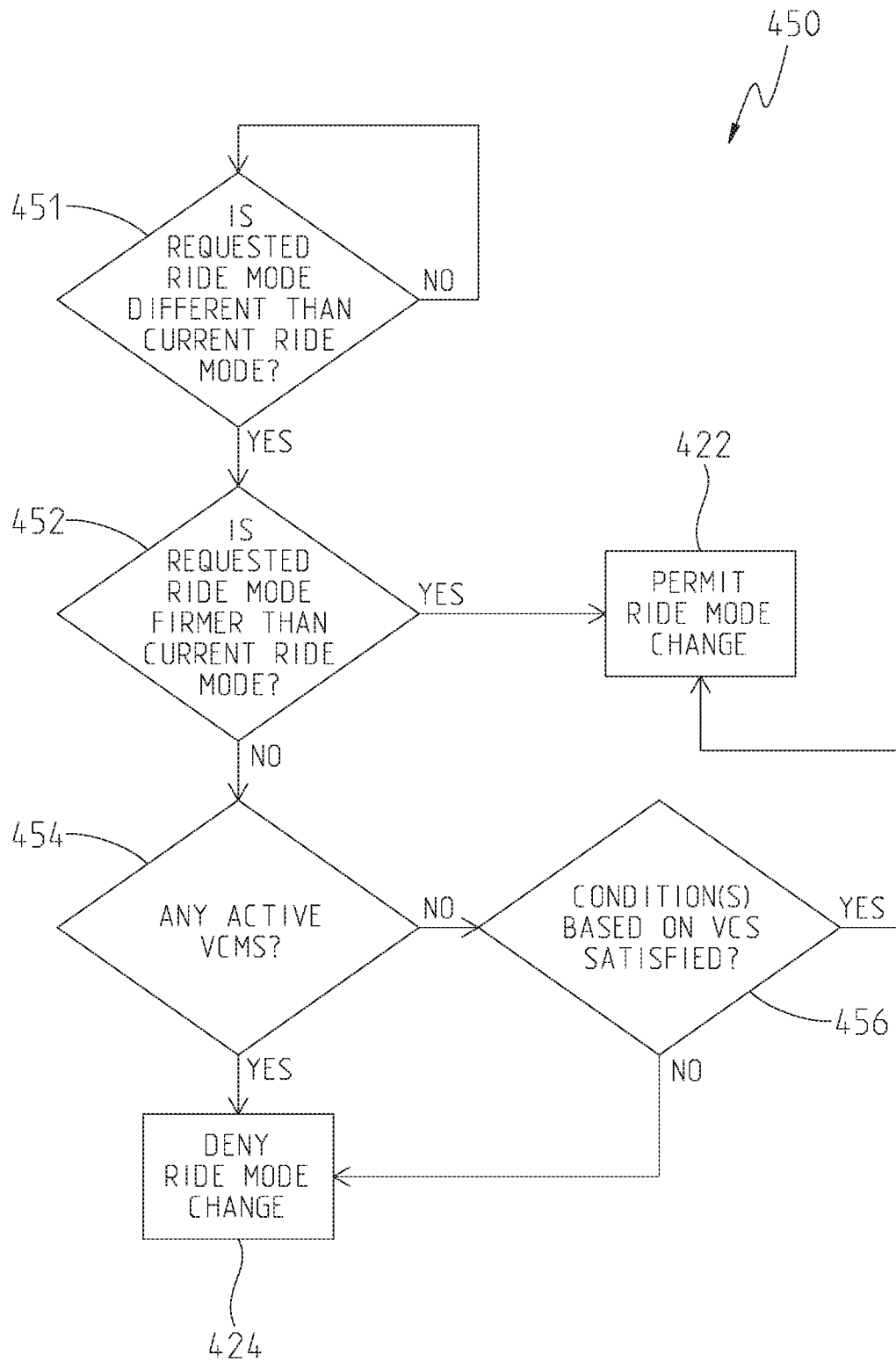


Fig. 15

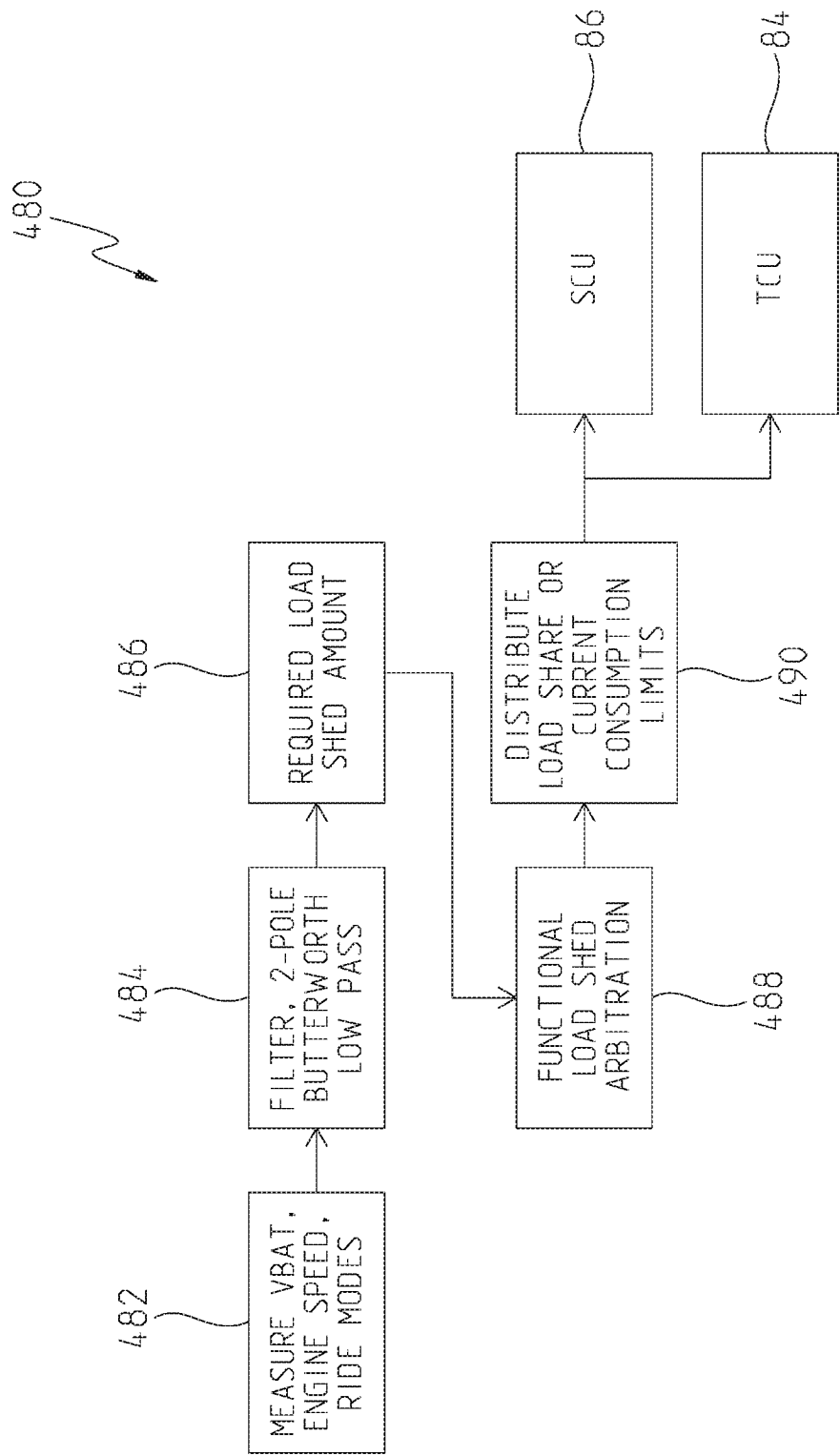


Fig. 16

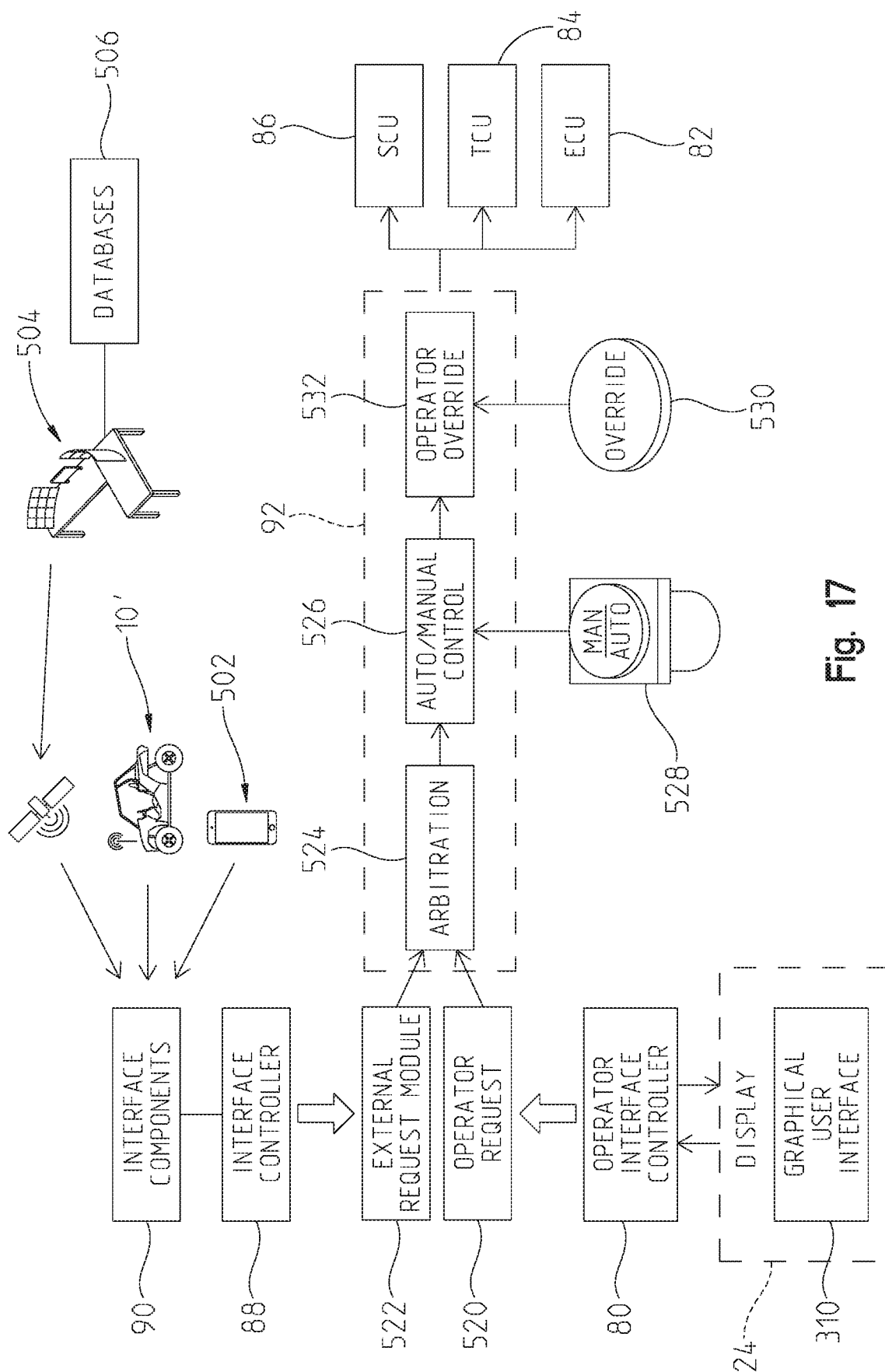


Fig. 17

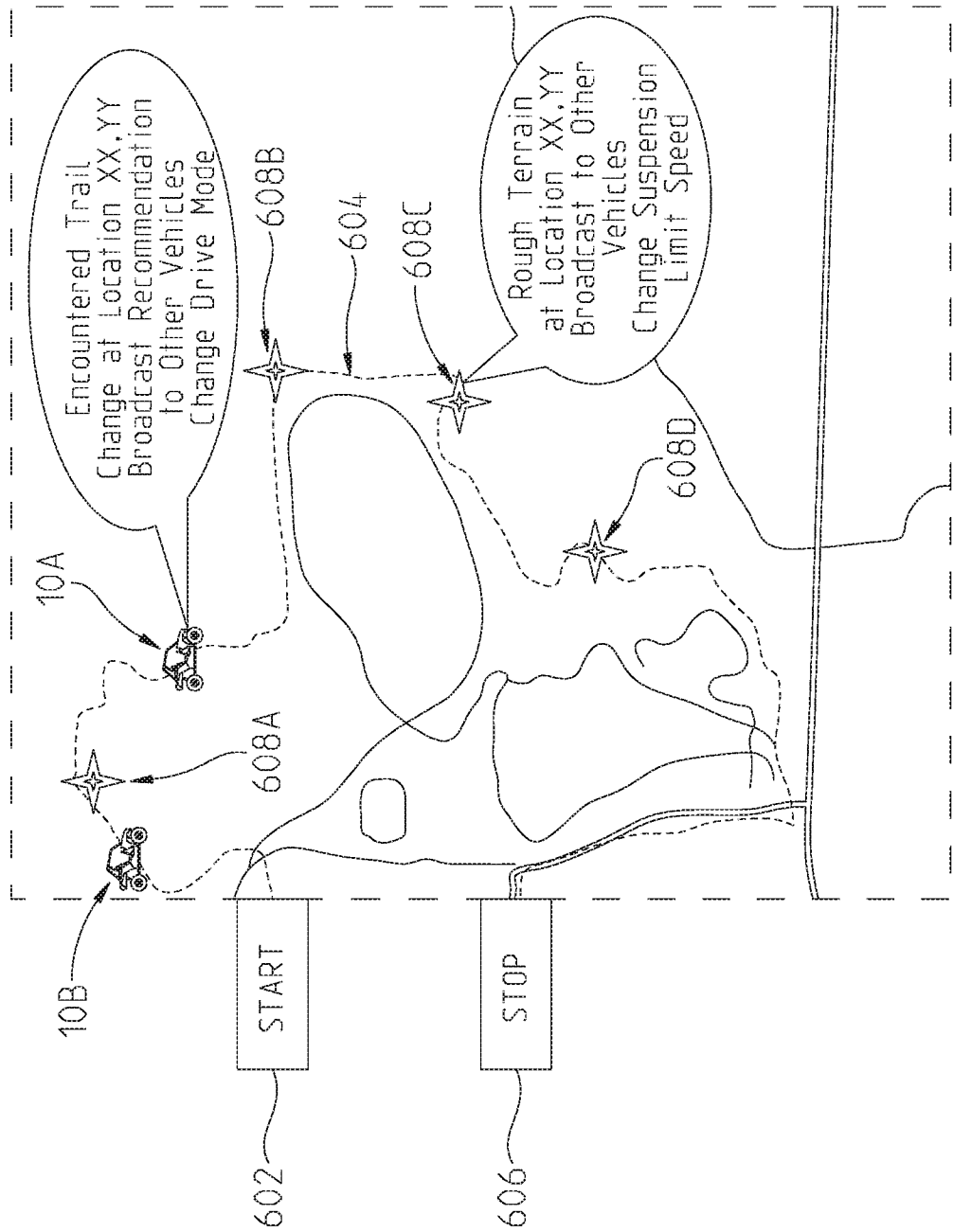


Fig. 18

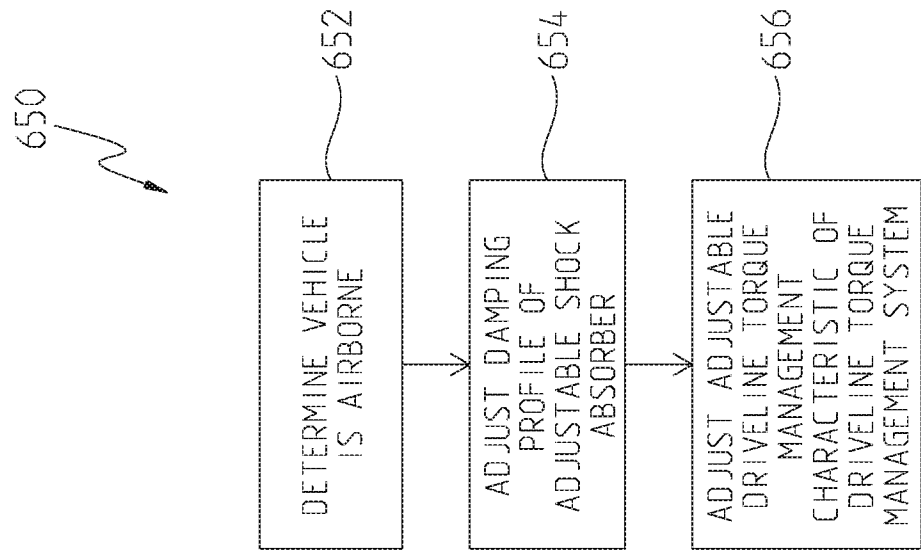


Fig. 19A

Fig. 19B

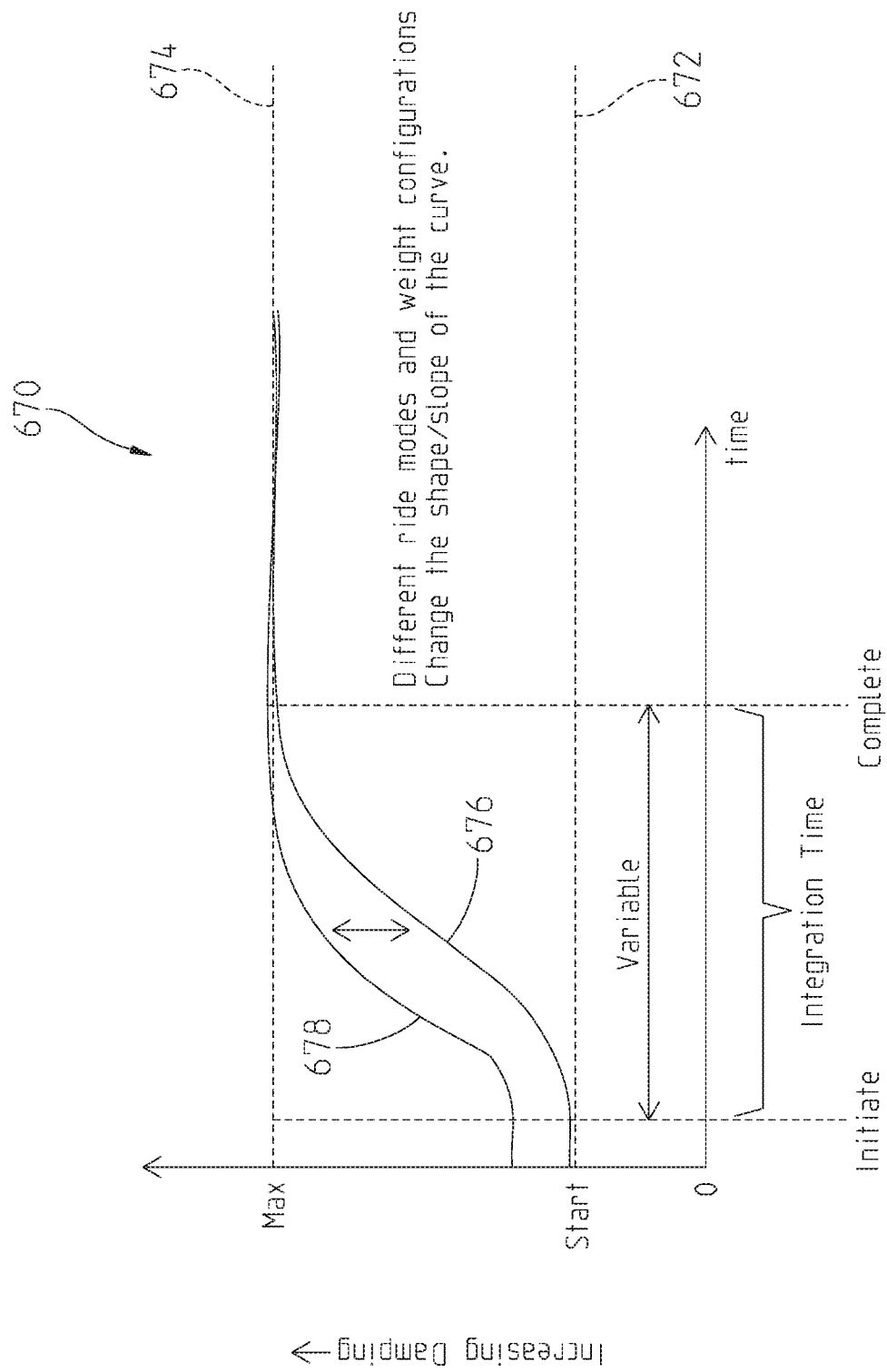


Fig. 20

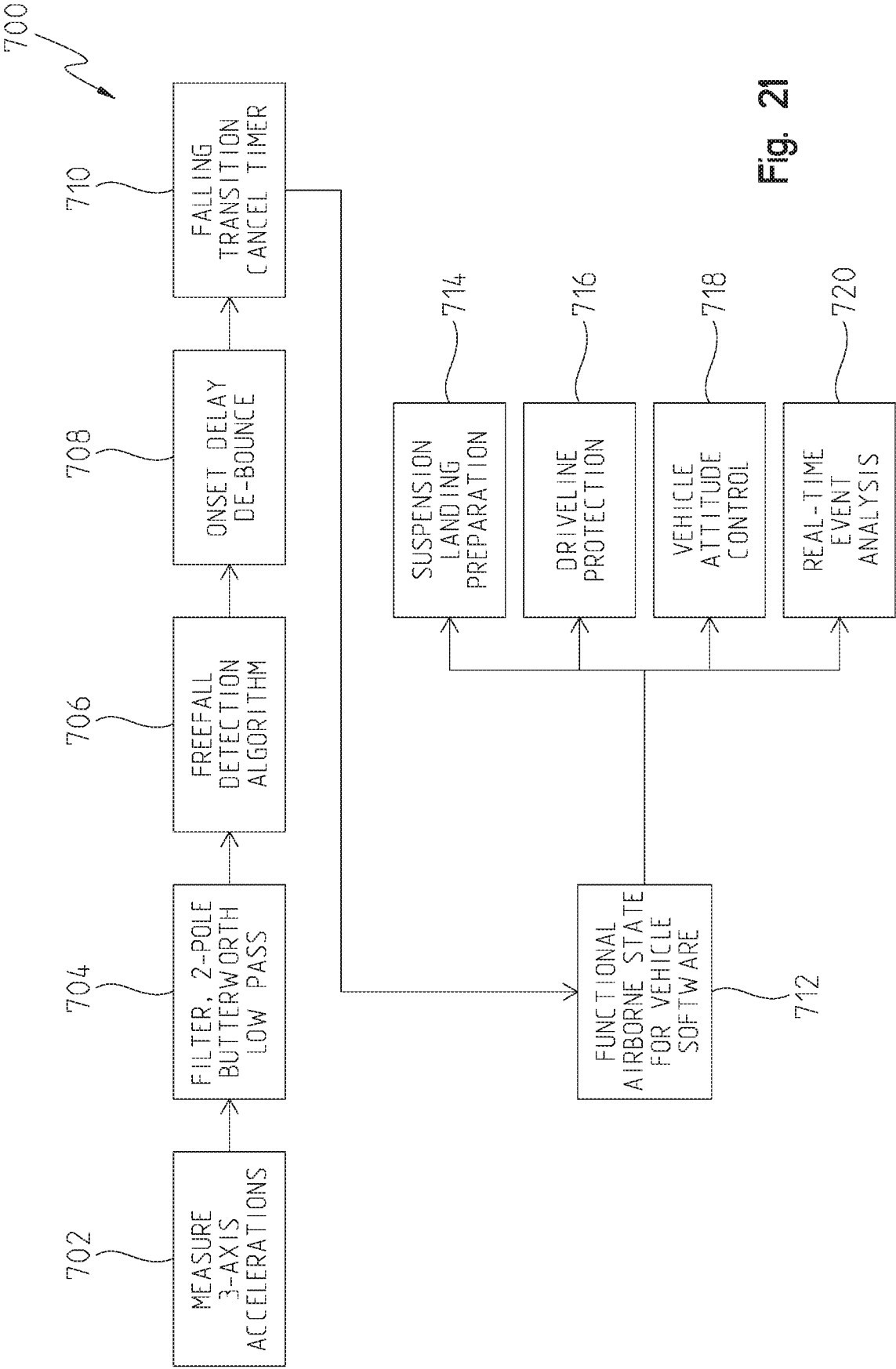


Fig. 21

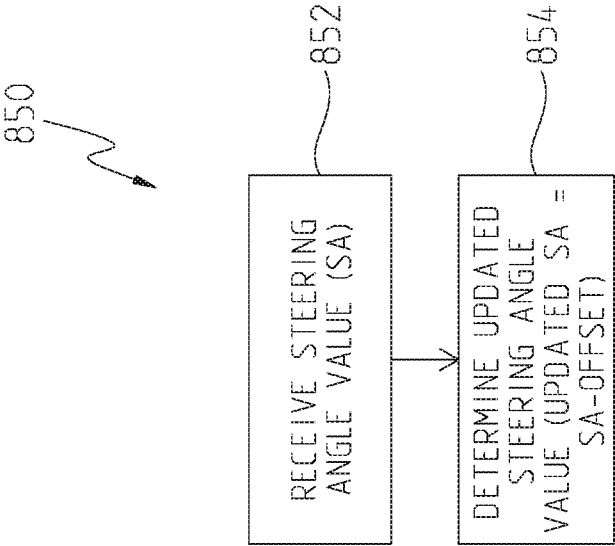


Fig. 22

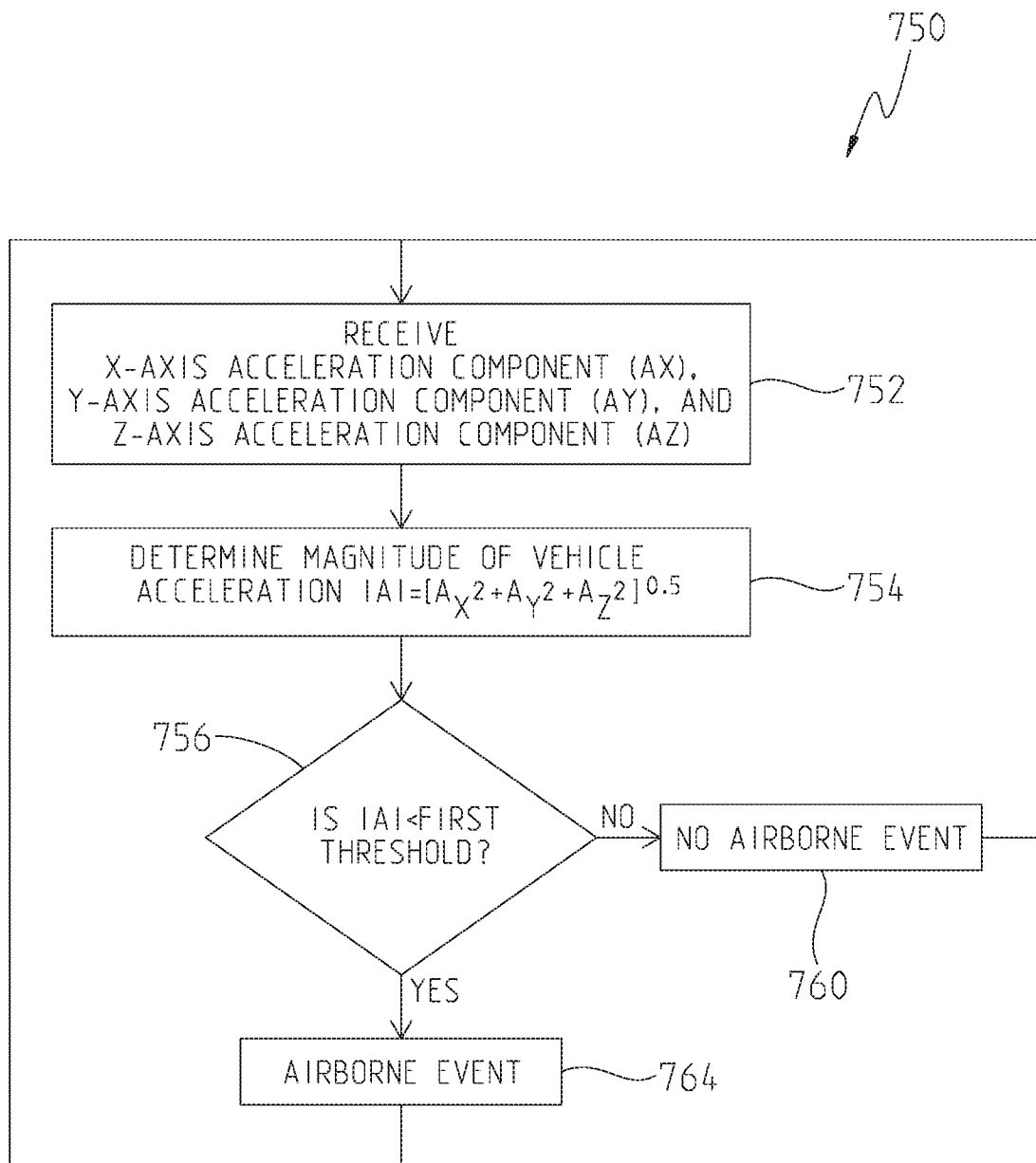


Fig. 23A

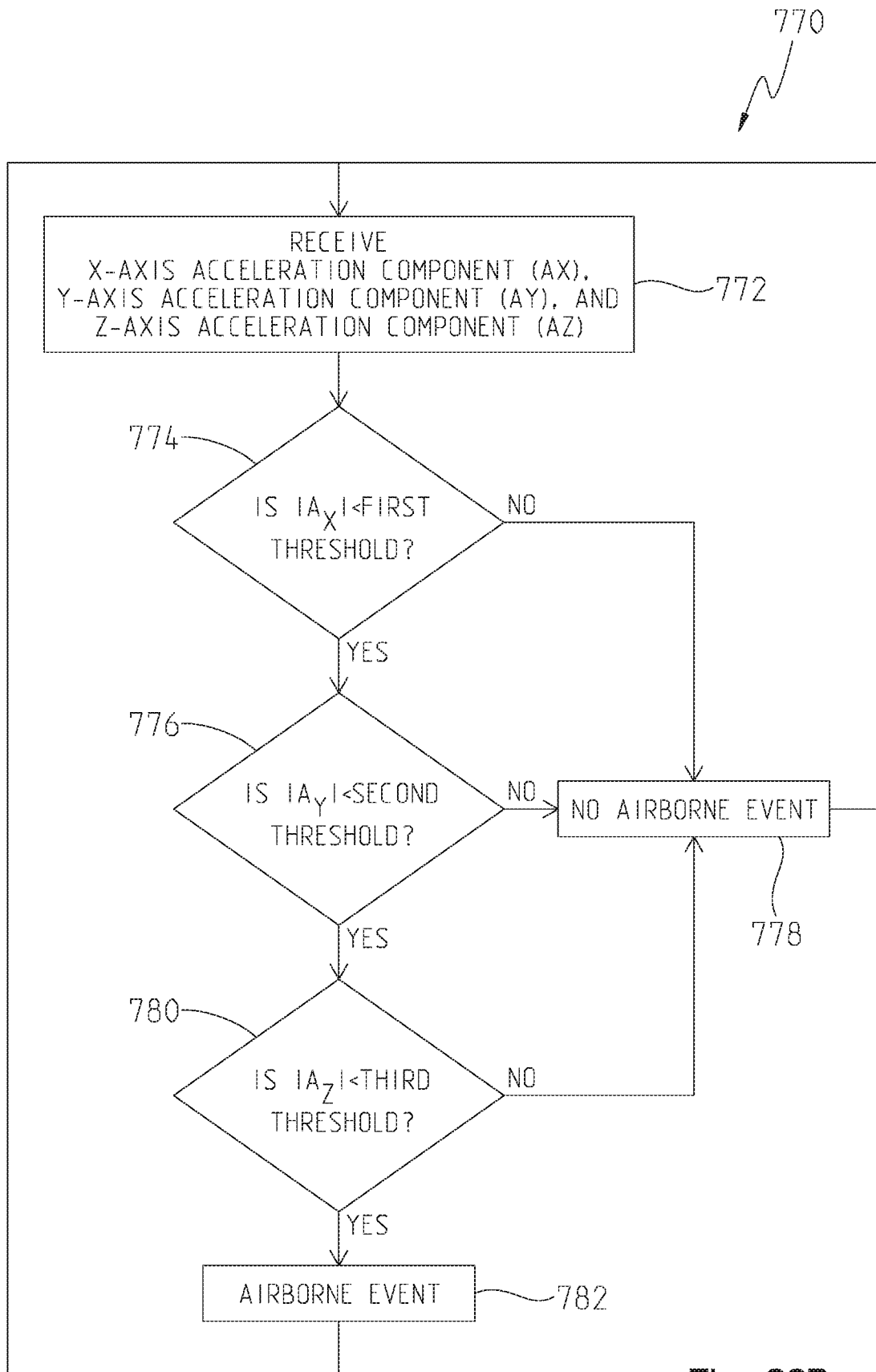


Fig. 23B

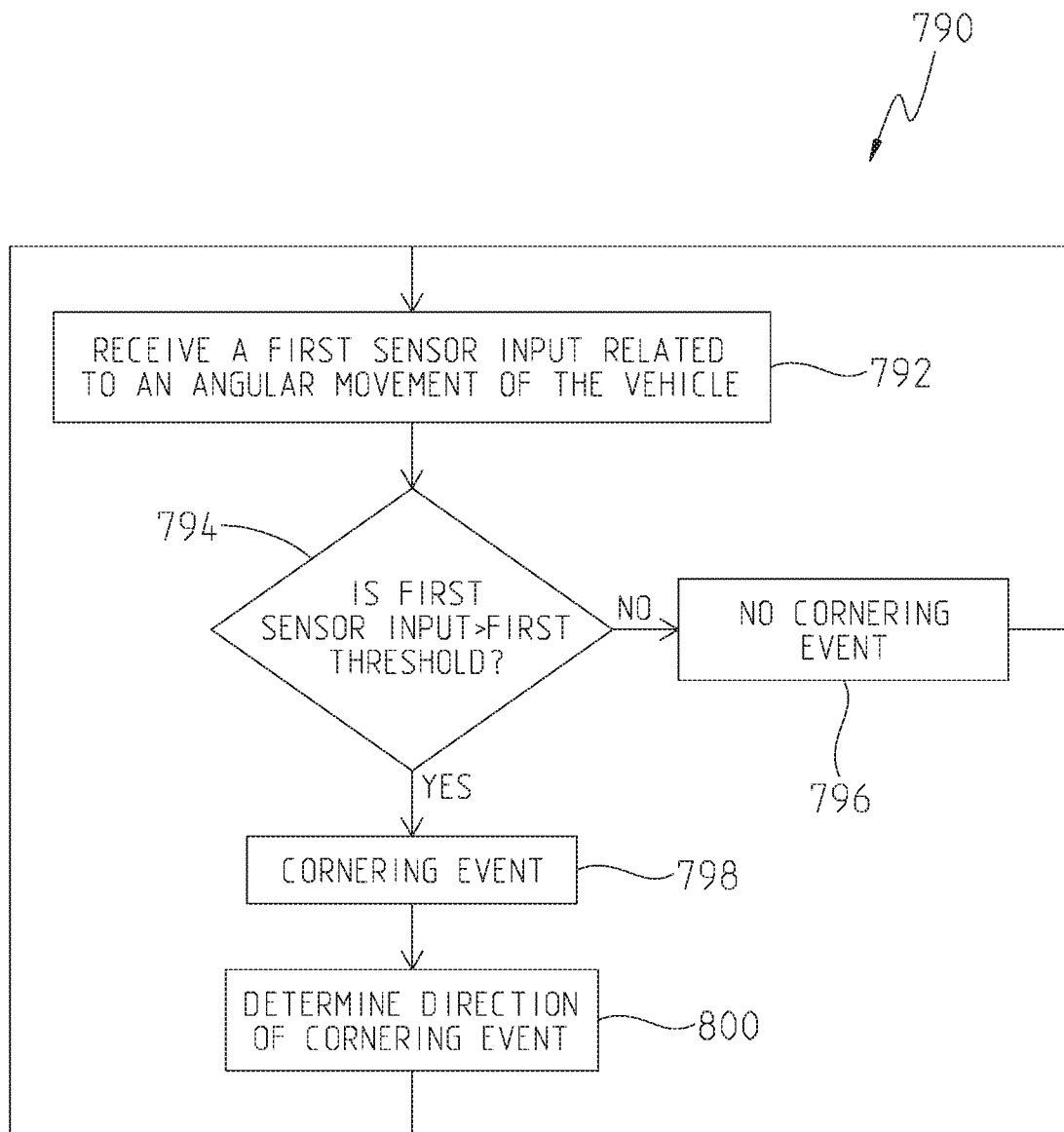


Fig. 24A

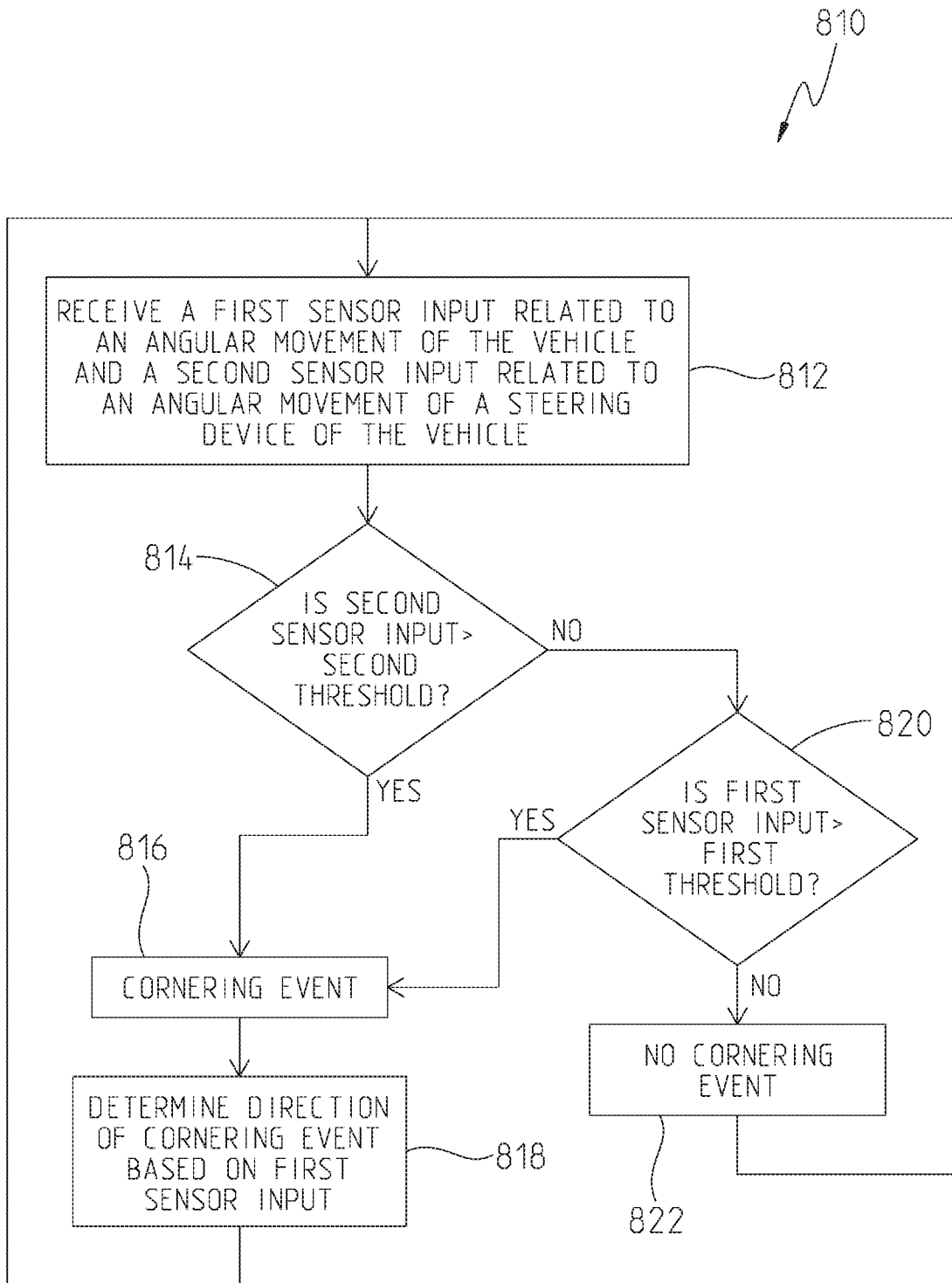


Fig. 24B

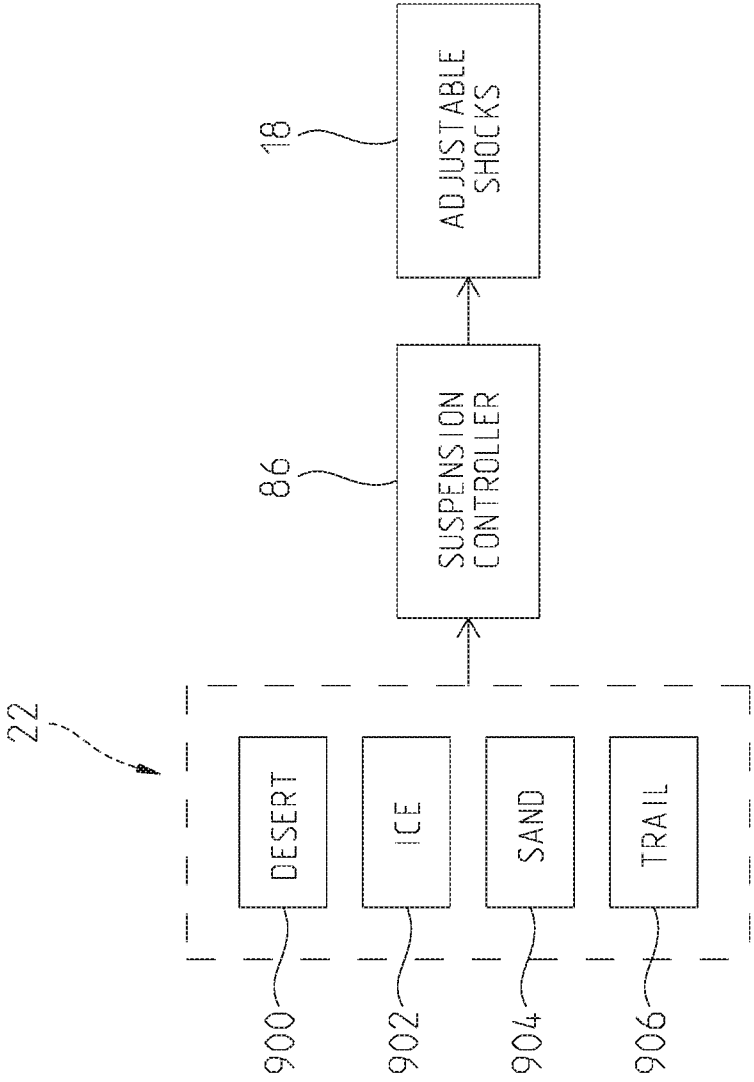


Fig. 25

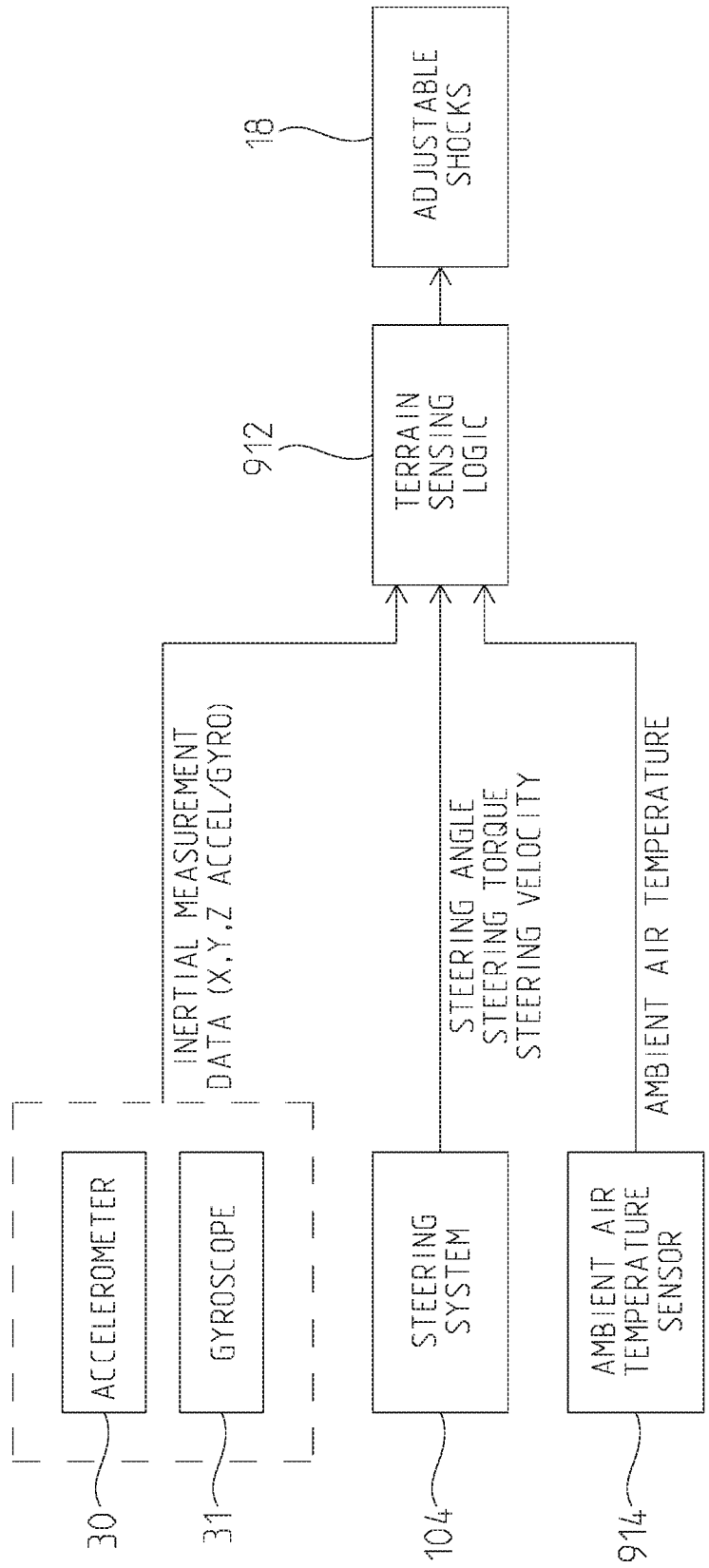


Fig. 26

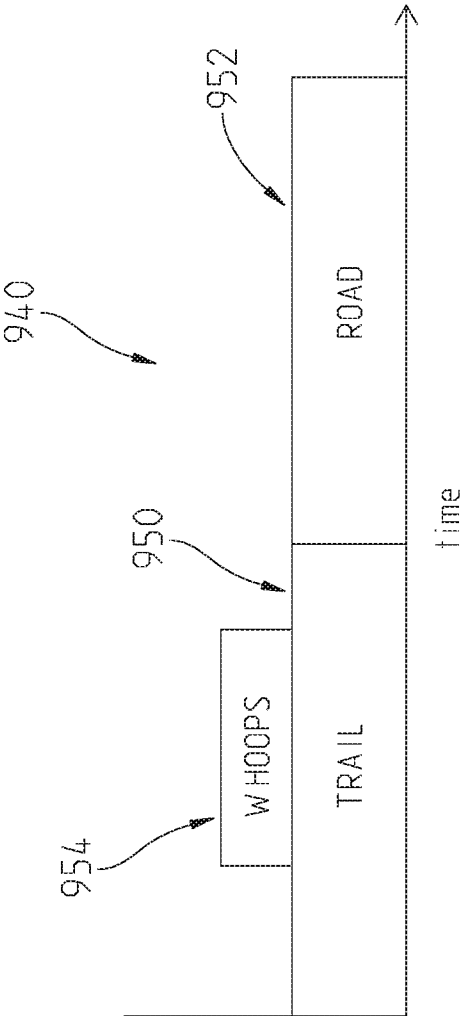


Fig. 27A

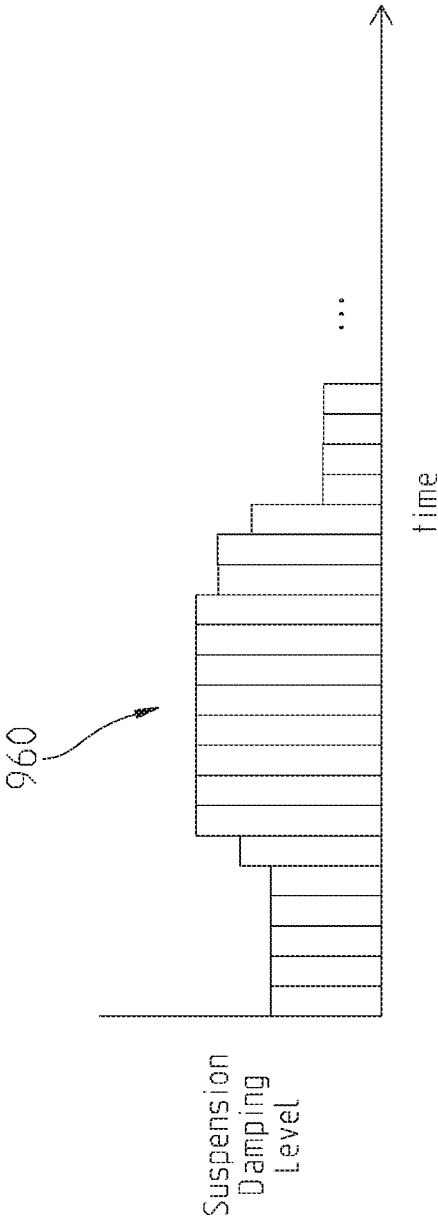


Fig. 27B