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(54) Title: SWITCHABLE ANTI-LOCK BRAKING SYSTEM FOR UTILITY VEHICLE

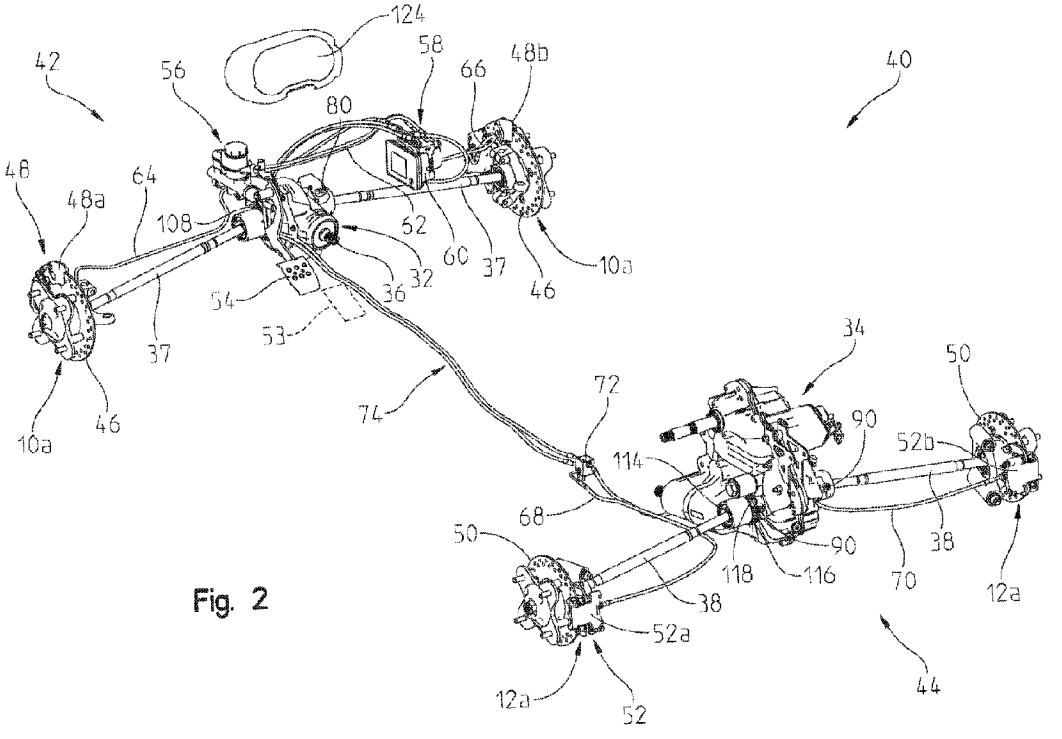


Fig. 2

(57) Abrégé/Abstract:
A utility vehicle (2) includes a frame (4) and a plurality of ground- engaging members (8) supporting the frame (4). Each of the plurality of ground-engaging members (8) is configured to rotate about an axle (37,38). The utility vehicle further includes a powertrain assembly (30) supported by the frame (4) and a braking system (40) configured to operate in a normal run mode and an anti-lock braking mode. The braking system (40) includes an anti-lock braking control module (60) operably coupled to the plurality of ground-engaging members (8) and configured to automatically engage the anti-lock braking mode in response to a predetermined condition, e.g. a vehicle speed condition. Further inventions concern a braking assembly (40) for a utility vehicle (2) and a method of operating a braking assembly (40) of a utility vehicle.

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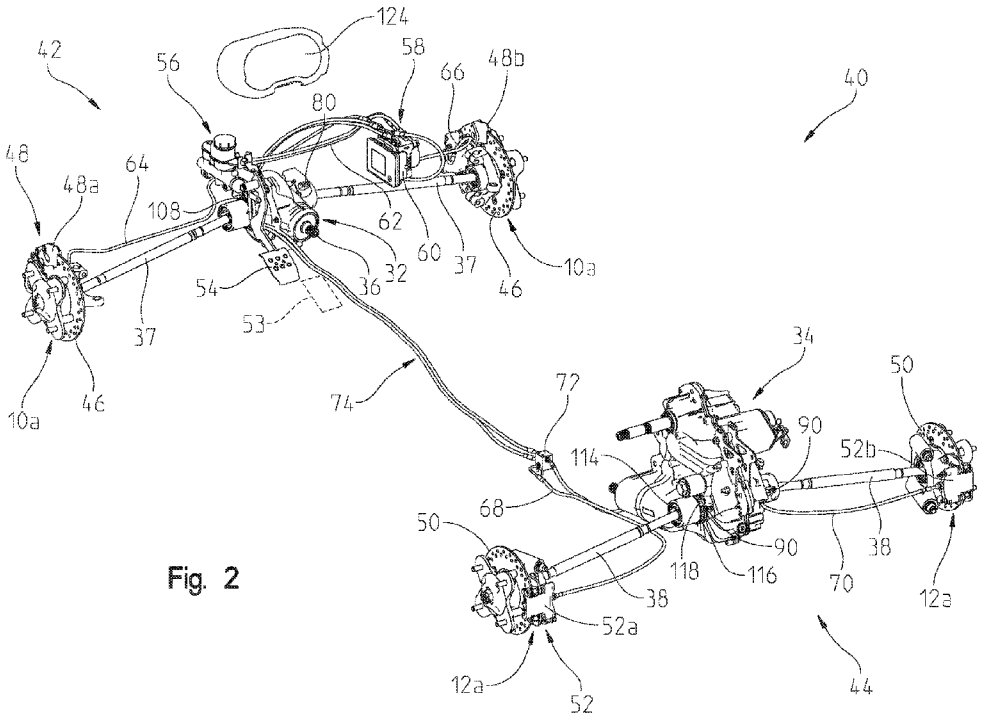


Fig. 2

(57) Abstract: A utility vehicle (2) includes a frame (4) and a plurality of ground- engaging members (8) supporting the frame (4). Each of the plurality of ground-engaging members (8) is configured to rotate about an axle (37,38). The utility vehicle further includes a powertrain assembly (30) supported by the frame (4) and a braking system (40) configured to operate in a normal run mode and an anti-lock braking mode. The braking system (40) includes an anti-lock braking control module (60) operably coupled to the plurality of ground-engaging members (8) and configured to automatically engage the anti-lock braking mode in response to a predetermined condition, e.g. a vehicle speed condition. Further inventions concern a braking assembly (40) for a utility vehicle (2) and a method of operating a braking assembly (40) of a utility vehicle.

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SWITCHABLE ANTI-LOCK BRAKING SYSTEM FOR UTILITY VEHICLE

[0001] The present application claims the benefit of U.S. Provisional Patent Application Serial No. 62/590,041, filed November 22, 2017, and entitled "ANTI-LOCK BRAKING SYSTEM FOR UTILITY VEHICLE," the entirety of which is hereby incorporated herein by reference.

[0002] The present application relates to a braking system for a vehicle and, more particularly, to an anti-lock braking system for a utility vehicle configured for off-road applications.

[0003] Anti-lock braking systems ("ABS") may be used on vehicles to facilitate braking power in response to a user input. For example, the user may depress a brake pedal, thereby enabling the ABS to facilitate braking of the vehicle. The ABS may be configured to facilitate braking of the front wheels, the rear wheels, or both the front and rear wheels.

[0004] In some embodiments, it may be possible to disengage the ABS. However, if a user disengages or turns off the ABS, then the user may have to remember to manually re-engage or turn on the ABS when needed. In such instances, the user must be sufficiently cognizant of the terrain, driving, and other conditions to recognize that the ABS should be turned on before it is needed. As such, there is a need for a system which may automatically engage or turn on the ABS in response to a predetermined driving condition.

[0005] In one embodiment, a utility vehicle comprises a frame and a plurality of ground-engaging members supporting the frame. Each of the plurality of ground-engaging members is configured to rotate about an axle. The utility vehicle further comprises a powertrain assembly supported by the frame and a braking system configured to operate in a normal run mode and an anti-lock braking mode. The braking system comprises an anti-lock braking control module operably coupled to the plurality of ground-engaging members and configured to automatically engage the anti-lock braking mode in response to a predetermined condition.

[0006] In another embodiment, a braking assembly for a utility vehicle configured to operate in a normal run mode and an anti-lock braking mode is disclosed. The braking assembly comprises a user braking member, a plurality of brake calipers operably coupled to the user braking member, a junction member operably coupled to at least two of the plurality of brake calipers, and an anti-lock braking control module operably coupled to at least the user braking

member and junction member. The anti-lock braking control module is configured to automatically engage the anti-lock braking mode at a predetermined condition and disengage the anti-lock braking mode in response to a user input.

[0007] In yet another embodiment, a method of operating a braking assembly of a utility vehicle in one of a normal run mode and an anti-lock braking mode comprises providing a user braking member, providing a plurality of brake calipers operably coupled to the user braking member, providing an anti-lock braking control module operably coupled to the user braking member and the plurality of brake calipers, and automatically engaging the anti-lock braking mode at a predetermined condition.

[0008] Additional features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of the illustrative embodiment exemplifying the best mode of carrying out the invention as presently perceived.

[0009] The foregoing aspects and many of the intended advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description when taken in conjunction with the accompanying drawings.

[0010] Fig. 1 is a left front perspective view of a utility vehicle of the present disclosure;

[0011] Fig. 2 is a left rear perspective view of a braking assembly of the utility vehicle of Fig. 1;

[0012] Fig. 3 is a rear perspective view of the braking assembly of Fig. 2;

[0013] Fig. 4 is a right front perspective view of a front portion of the braking assembly of Fig. 2;

[0014] Fig. 5 is a junction member of the braking assembly of Fig. 2;

[0015] Fig. 6 is a left rear perspective view of a front drive member of the utility vehicle of Fig. 1;

[0016] Fig. 7 is a left rear perspective view of a rear drive member of the utility vehicle of Fig. 1;

[0017] Fig. 8 is a schematic view of a portion of an electrical system of the utility vehicle of Fig. 1;

[0018] Fig. 9 is a schematic view of an electronic braking circuit of the electrical system of Fig. 8;

[0019] Fig. 10A is a schematic view of a hydraulic circuit of the braking assembly of Fig. 2;

[0020] Fig. 10B is a schematic view of an alternative hydraulic circuit of the braking assembly of Fig. 2;

[0021] Fig. 11 is a control diagram of the braking assembly of Fig. 2 operating in a first or ABS On operating mode;

[0022] Fig. 12 is a control diagram of the braking assembly of Fig. 2 operating in a second or ABS On-Off operating mode;

[0023] Fig. 13 is a control diagram of the braking assembly of Fig. 2 operating in a third or ABS Control operating mode;

[0024] Fig. 14 is a control diagram of an adjustable speed limiting feature of the vehicle of Fig. 1.

[0025] Fig. 15 is a control diagram of an electronic stability control ("ESC") assembly of the vehicle of Fig. 1 operating in a first or Normal ESC and ABS Mode;

[0026] Fig. 16 is a control diagram of the ESC assembly operating in a second or Hill Descent Control ("HDC") Mode;

[0027] Fig. 17 is a control diagram of the ESC assembly operating in a third or Hill Assist/Hill Hold Control ("HHC") Mode;

[0028] Fig. 18 is a control diagram of the ESC assembly operating in a fourth or Roll Over Mitigation ("ROM") Mode;

[0029] Fig. 19 is a control diagram of the ESC assembly operating in a fifth or Traction Control System ("TCS") Mode; and

[0030] Fig. 20 is a control diagram of the ESC assembly operating in a sixth or Vehicle Dynamic Control ("VDC") Mode.

[0031] 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. The exemplifications set out herein illustrate embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

[0032] For the purposes of promoting an understanding of the principals of the invention, 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 limit the invention 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. It will be understood that no limitation of the scope of the invention is thereby intended. The invention includes any alterations and further modifications in the illustrative devices and described methods and further applications of the principles of the invention which would normally occur to one skilled in the art to which the invention relates.

[0033] As shown in Fig. 1, a utility vehicle 2 is disclosed and configured for off-road vehicle applications, such that utility vehicle 2 is configured to traverse trails and other off-road terrain. Utility vehicle 2 includes a frame assembly 4 which supports a plurality of body panels 6 and is supported on a ground surface by a plurality of ground-engaging members 8. Illustratively, ground-engaging members 8 include front ground-engaging members 10 and rear ground-engaging members 12. In one embodiment of vehicle 2, each of front ground-engaging members 10 include a wheel assembly 10a and a tire 10b supported thereon. Similarly, each of rear ground-engaging members 12 may include a wheel assembly 12a and a tire 12b supported thereon. A front suspension assembly 27 may be operably coupled to front ground-engaging members 10 and a rear suspension assembly 28 may be operably coupled to rear ground-engaging members 12.

[0034] Referring still to Fig. 1, utility vehicle 2 extends between a front end portion 14 and a rear end portion 16 along a longitudinal axis L and supports an operator area 18 therebetween. Operator area 18 includes seating 20 for at least the operator and also may support one or more passengers. In one embodiment, seating 20 includes side-by-side bucket-type seats while, in another embodiment, seating 20 includes a bench-type seat. A cargo area 22 is positioned rearward of operator area 18 and is supported by frame assembly 4 at rear end portion 16.

[0035] As shown in Fig. 1, operator area 18 includes operator controls 24, such as steering assembly 26, which may be operably coupled to one or more of ground-engaging members 8. Additional operator controls 24 may include other inputs for controlling operation of vehicle 2, as disclosed further herein, such as an accelerator member or pedal 53 and a brake

member or pedal 54 (Fig. 2). More particularly, various operator controls 24 may affect operation of a powertrain assembly 30 of vehicle 2. Powertrain assembly 30 may be supported by rear end portion 16 of vehicle 2 and includes an engine (not shown), a transmission (not shown) operably coupled to the engine, a front final drive member 32 (Fig. 2) operably coupled to front ground-engaging members 10 through front half shafts or axles 37, and a rear final drive member 34 (Fig. 2) operably coupled to rear ground-engaging members 12 through rear half shafts or axles 38. A drive shaft (not shown) may be operably coupled to front final drive member 32 at an input 36 (Fig. 2) for supplying motive power from the engine and/or transmission to front ground-engaging members 10. Rear final drive member 34 is operably coupled the engine and/or transmission to supply power therefrom to rear ground-engaging members 12.

[0036] Referring to Figs. 2-4, vehicle 2 includes a braking assembly 40, illustratively an anti-lock braking system ("ABS"), which includes a front end braking portion 42 positioned generally at front end portion 14 of vehicle 2 and is operably coupled to front ground-engaging members 10 and a rear end braking portion 44 positioned generally at rear end portion 16 of vehicle 2 and is operably coupled to rear ground-engaging members 12. Front end braking portion 42 includes front brake discs 46 and front brake calipers 48 operably coupled to front wheel assemblies 10a. Rear end braking portion 44 includes rear brake discs 50 and rear brake calipers 52 operably coupled to rear wheel assemblies 12a.

[0037] As shown in Figs. 2-4, braking assembly 40 also includes brake member 54, illustratively a brake pedal, positioned within operator area 18 and is defined as one of the operator controls 24 (Fig. 1). Brake member 54 is operably coupled to a brake master cylinder 56 such that braking input from the operator of vehicle 2 is applied to brake member 54 and is transmitted to brake master cylinder 56.

[0038] Referring still to Figs. 2-4, brake master cylinder 56 is operably coupled to a braking control system 58 which includes an anti-lock braking ("ABS") control module 60. More particularly, brake master cylinder 56 is fluidly coupled to ABS control module 60 through conduit(s) or line(s) 62. Illustratively, ABS control module 60 may be hydraulically actuated such that pressurized hydraulic fluid is configured to assist with the operation of braking assembly 40. With the use of ABS control module 60, braking assembly 40 is configured to

operate in a normal run mode, in which an anti-lock braking feature ("ABS feature") is not engaged, and an anti-lock braking mode, in which the ABS feature is engaged.

[0039] ABS control module 60 also is fluidly coupled with brake calipers 48, 52. Illustratively, as shown in Figs. 2-4, braking assembly 40 further includes a front left conduit or line 64, a front right conduit or line 66, a rear left conduit or line 68, and a rear right conduit or line 70 which are all fluidly coupled to ABS control module 60 through four channels, namely a front left channel 140, a front right channel 142, a rear left channel 144, and a rear right channel 146, respectively (Fig. 10). In this way, front left conduit 64 fluidly couples front left brake caliper 48a with ABS control module 60, front right conduit 66 fluidly couples front right brake caliper 48b with ABS control module 60, rear left conduit 68 fluidly couples rear left brake caliper 52a with ABS control module 60, and rear right conduit 70 fluidly couples rear right brake caliper 52b with ABS control module 60. ABS control module 60 also may include a front master cylinder output 148 and a rear master cylinder output 149, both of which are operably coupled to brake master cylinder 56 (Fig. 10), as disclosed herein.

[0040] Referring to Figs. 2-5, with respect to rear end braking portion 44, conduits 68, 70 are fluidly coupled to ABS control module 60 through a junction member or box 72. Illustratively, at least one junction conduit or line 74 (illustratively first and second junction conduits 74a, 74b) extends from ABS control module 60 to junction member 72 such that ABS control module 60 is fluidly coupled with rear brake calipers 52a, 52b through junction conduit 74, junction member 72, and respective rear left and right conduits 68, 70.

[0041] As shown best in Fig. 5, junction member 72 includes a first input 76 fluidly coupled to rear left conduit 68 through first junction conduit 74a and a second input 78 fluidly coupled to rear right conduit 70 through second junction conduit 74b. Junction member 72 facilitates serviceability of braking assembly 40 because if a repair or replacement is needed to rear end braking portion 44, then the repair or replacement may be made at the location of junction member 72, rather than having to fully disassemble all of braking assembly 40 for a repair to only a portion thereof. Additionally, junction member 72 is provided to allow for different braking pressures to be transmitted to rear brake calipers 52a, 52b. For example, a first braking pressure may be provided to rear brake caliper 52a through first junction conduit 74a and rear left conduit 68 while a greater or lesser braking pressure may be provided rear brake caliper 52b through second junction conduit 74b and rear right conduit 70.

[0042] Referring now to Fig. 6, braking control system 58 further includes front wheel speed sensors 80 configured to determine the rotational speed of front ground-engaging members 10 (Fig. 1). Illustratively, each of front ground-engaging members 10 includes an individual wheel speed sensor 80. In one embodiment, wheel speed sensor 80 is coupled to a portion of front final drive member 32 through fasteners 82. As shown in Fig. 6, wheel speed sensor 80 is received through an aperture 84 of a mounting bracket 86. Mounting bracket 86 is coupled to a lateral portion of front final drive member 32 with fasteners 82 which are received within mounting bores 89 on the lateral portions of front final drive member 32. More particularly, fasteners 82 are received within openings 83 on bracket 86, which have an oval or oblong shape, thereby allowing the position of bracket 86 and sensor 80 to be adjustable relative to axle 37. Additional fasteners or couplers 88 are configured to removably couple sensor 80 on mounting bracket 86. It may be appreciated that sensor 80 is generally surrounded by mounting bracket 86 such that mounting bracket 86 conceals at least a portion of sensor 80 from debris and/or objects that may travel towards sensor 80 when vehicle 2 is moving, thereby minimizing damage to sensor 80 during operation of vehicle 2.

[0043] As shown best in Fig. 4, each of front half shafts 37 includes a drive coupling with a splined shaft 106. Splined shaft 106 couples with an output 112 (Fig. 6) of front final drive member 32. Additionally, a gear ring 108 is positioned on the outer surface of each of the drive couplings and is held in position relative to half shafts 37. As such, gear ring 108 is configured to rotate with its corresponding half shaft 37. Each of gear rings 108 includes a plurality of teeth 110 which cooperate with sensor 80 to determine the speed of each half shaft 37. Sensors 80 are positioned in proximity to teeth 110 but do not contact teeth 110; rather sensors 80 count teeth 110 as teeth 110 pass sensor 80 over a specific time period to calculate an angular velocity. Sensors 80 may be speed sensors such as Hall Effect speed sensors.

[0044] Referring to Fig. 7, braking control system 58 also includes rear wheel speed sensors 90 configured to determine the rotational speed of rear ground-engaging members 12 (Fig. 1). Illustratively, each of rear ground-engaging members 12 includes an individual wheel speed sensor 90. In one embodiment, wheel speed sensor 90 is coupled to a portion of rear final drive member 34. As shown in Fig. 7, wheel speed sensor 90 is received through an aperture 92 of a first mounting bracket 94 and is coupled to first mounting bracket 94 with fasteners 95. It may be appreciated that sensor 90 is generally surrounded by first mounting bracket 94 such that

mounting bracket 94 conceals at least a portion of sensor 90 from debris and/or objects that may travel towards sensor 90 when vehicle 2 is moving, thereby minimizing damage to sensor 90 during operation of vehicle 2.

[0045] First mounting bracket 94 is coupled to a second mounting bracket 96 through fasteners 98. More particularly, fasteners 98 are received within openings 97 on first mounting bracket 94, which have an oval or oblong shape, thereby allowing the position of first mounting bracket 94 and sensor 90 to be adjustable relative to axle 38. And, second mounting bracket 96 is coupled to retainer members 100 on lateral portions of rear final drive member 34. Additional fasteners or couplers 102 are configured to removably couple second mounting bracket 96 to retainers 100 because fasteners 102 are received through apertures 104 of retainers 100. It may be appreciated that retainers 100 include a plurality of apertures 104 such that fasteners 102 can be received through any of apertures 104 to adjust the position of second mounting bracket 96 relative to axle 38, thereby also allowing for the position of sensor 90 to be adjustable relative to axle 38.

[0046] As shown best in Figs. 2 and 3, each of rear half shafts 38 includes a drive coupling with a splined shaft 114 (Fig. 3). Splined shaft 114 couples with an output (not shown) of rear final drive member 34. Additionally, a gear ring 116 is positioned on the outer surface of each of the rear drive couplings and is held in position relative to its corresponding rear half shaft 38. As such, gear ring 116 is configured to rotate with its corresponding rear half shaft 38. Each of gear rings 116 includes a plurality of teeth 118 which cooperate with sensor 90 to determine the speed of each rear half shaft 38. Sensors 90 are positioned in proximity to teeth 118 but do not contact teeth 118; rather sensors 90 count teeth 118 as teeth 118 pass sensor 90 over a specific time period to calculate an angular velocity. Sensors 90 may be speed sensors such as Hall Effect speed sensors.

[0047] Referring to Fig. 8, braking control system 58, including ABS control module 60, is electronically coupled or integrated with an overall electrical system 120 of vehicle 2. Electrical system 120 of vehicle 2 includes an engine control module ("ECM") 122 and at least one display or gauge 124. Display 124 is supported within operator area 18 (Fig. 1) and is configured to provide information about vehicle 2 to the operator. In one embodiment, ABS control module 60 may be operated through display 124 such the operator may provide a user input or user selection through display 124, which is transmitted to ABS control module 60, to

turn on/engage or turn off/disengage the ABS feature of braking assembly 40. Illustrative display 124 may include toggle switches, buttons, a touchscreen, or any other type of surface or member configured to receive and transmit a selection made by the user. While ABS control module 60 is configured to engage/disengage the ABS feature through display 124 in the illustrative embodiment, it may be appreciated that vehicle 2 may include other inputs or means for engaging/disengaging the ABS feature.

[0048] Additionally, ABS control module 60 is configured to transmit information about braking assembly 40 to display 124 to provide such information to the operator. For example, ABS control module 60 may be configured to transmit a fault signal to display 124 to indicate to the operator that a fault has occurred within a portion of braking assembly 40, such as a fault of the ABS feature of braking assembly 40. The fault indicator provided on display 124 may be a light, an alphanumeric code or message, or any other indication configured to alert the user of the fault.

[0049] Additionally, display 124 is in electronic communication with ECM 122 to provide information to the operator about the engine (not shown) or other components of powertrain assembly 30. Illustratively, ECM 122 transmits various signals to display 124 to provide information such as engine speed, engine temperature, oil pressure, the driving gear or mode, and/or any other information about powertrain assembly 30. Additionally, as shown in Fig. 8, display 124 is configured to provide inputs and other information to ECM 122. For example, if illustrative vehicle 2 is configured with an adjustable speed limiting device and feature, the user may input speed limits to display 124 which are transmitted to ECM 122 from display 124 to control the speed of vehicle 2, as disclosed further herein.

[0050] Referring to Fig. 9, a schematic view of braking control system 58 and at least a portion of electrical system 120 is disclosed with respect to operation of braking assembly 40. As denoted, front end portion 14 and rear end portion 16 are shown and the left side of vehicle 2 is denoted with "L" and the right side of vehicle 2 is denoted with "R." As shown in Fig. 9, when the operator depresses brake member 54 with a force F, force F is transmitted to brake master cylinder 56, which may be a tandem master cylinder in one embodiment. Brake master cylinder 56 is configured to transmit braking input information to a brake pressure switch 126. Brake pressure switch 126 is then configured to transmit a signal indicative of braking pressure information to a multi-pin connector 128. Multi-pin connector 128 also may be configured to

transmit and/or receive information to and from ECM 122, a steering angle sensor 130 of electrical system 120, display 124, and ABS control module 60. More particularly, ABS control module 60 may include a multi-axis G sensor 132 and a pressure sensor 134, one or both of which may be internal or external sensors and are configured for communication with multi-pin connector 128. Additionally, multi-pin connector 128 is electrically coupled with front wheel speed sensors 80 and rear wheel speed sensors 90.

[0051] Referring still to Fig. 9, in operation, multi-pin connector 128 is configured to receive a user input or user selection from display 124 to indicate if the user has turned on/engaged or turned off/disengaged the ABS feature of braking assembly 40 (e.g., via CAN messages) such that braking assembly 40 is to operate in the anti-lock braking mode or the normal run mode, respectively. Multi-pin connector 128 also may receive signals or other information from ECM 122, steering angle sensor 130, speed sensors 80, 90, multi-axis G sensor 132, and pressure sensor 134 to determine information about the operating conditions of vehicle 2. If the user has engaged the ABS feature of braking assembly 40, for example through display 124, such that braking assembly 40 is to operate in the anti-lock braking mode, then multi-pin connector 128 is configured to electrically communicate with ABS control module 60 to engage the ABS feature of braking assembly 40 when the user provides an input to brake member 54.

[0052] However, if the user has turned off/disengaged the ABS feature of braking assembly 40, for example through a selection on display 124, such that braking assembly 40 is to operate in the normal run mode, then multi-pin connector 128 is configured to determine if the ABS feature should be automatically turned on/engaged based on the vehicle operating conditions. For example, the ABS feature of braking assembly 40 may be automatically turned on/engaged based on a predetermined condition, such a vehicle operating condition, an environmental condition, or any other condition which may affect the driving conditions of vehicle 2. In one embodiment, the predetermined condition may be a predetermined vehicle speed, the steering angle, conditions of the engine, terrain or environmental conditions, or any other condition or factor related to operating conditions of vehicle 2. The predetermined vehicle speed that initiates automatic engagement of the ABS feature of braking assembly 40 may be approximately 30 kph. In this way, even if the user has previously selected to disengage the ABS feature of braking assembly 40, the ABS feature will be automatically engaged, without any user input, via electrical system 120 (e.g., the communication between multi-pin connector

128 and ABS control module 60) when vehicle 2 is operating at the predetermined operating condition, such as a vehicle speed of at least approximately 30 kph.

[0053] It may be appreciated that the ABS feature of braking assembly 40 does not automatically turn off or disengage, but rather, is only disengaged through an operator or user input to display 124. As such, the ABS feature may automatically engage based on vehicle operating conditions but does not automatically disengage and, instead, must be manually disengaged by the operator through display 124. However, the ABS feature can only be disengaged when the vehicle speed is less than the predetermined vehicle speed (e.g., 30 kph). As such, even if the user selects, via display 124, to disengage the ABS feature, ABS control module 60 will not disengage the ABS feature if the vehicle speed is greater than the predetermined vehicle speed. In one embodiment, display 124 may temporarily hide or conceal the user option to disengage the ABS feature when the vehicle speed is greater than the predetermined speed value (e.g., 30 kph).

[0054] Also, even if a fault occurs in braking assembly 40, the ABS feature will not disengage and, instead, a fault indicator will be provided to the operator through display 124. Therefore, the operator will become aware of the fault within braking assembly 40 and may determine, based on the fault indication, if adjustments should be made to the operating conditions of vehicle 2. Yet, the ABS feature will remain engaged throughout the fault condition. Furthermore, the fault indicator will not initiate a slow-down of the vehicle speed such that vehicle 2 may continue to operate at the speed input by the operator even when a fault is indicated.

[0055] Referring now to Fig. 10A, a schematic view of a hydraulic system 150 of vehicle 2 is disclosed with respect to operation of braking assembly 40. Hydraulic system 150 includes a hydraulic reservoir 152 fluidly coupled to ABS control module 60 and also fluidly coupled to junction member 72, and ground-engaging members 10, 12 through any of conduits 64, 66, 68, 70, 74. In operation, as force F is applied to brake member 54 by the operator, brake master cylinder 56 transmits force F to ABS control module 60 through at least brake pressure switch 126. More particularly, brake master cylinder 56 is in communication with front and rear master cylinder outputs 148, 149 which allows hydraulic fluid from hydraulic fluid reservoir 152 to flow to front and rear ground-engaging members 10, 12 through channels 140, 142, 144, 146.

[0056] Illustratively, and still referring to Fig. 10A, as force F is applied to brake member 54, brake master cylinder 56 provides an input to front master cylinder output 148 through brake pressure switch 126 to initiate a flow of hydraulic fluid through front left channel 140 and front left conduit 64 to front left ground-engaging member 10. Additionally, the input provided to front master cylinder output 148 through brake pressure switch 126 also initiates a flow of hydraulic fluid through front right channel 142 and front right conduit 66 to front right ground-engaging member 10. With respect to rear ground-engaging members 12, as force F is applied to brake member 54, brake master cylinder 56 provides an input to rear master cylinder output 149 to initiate a flow of hydraulic fluid through rear left channel 144, first junction conduit 74a, junction member 72, and rear left conduit 68 to rear left ground-engaging member 12. Additionally, the input provided to rear master cylinder output 149 from brake master cylinder 56 also initiates a flow of hydraulic fluid through rear right channel 146, second junction conduit 74b, junction member 72, and rear right conduit 70 to rear right ground-engaging member 12. In this way, a single actuation of braking assembly 40 when the operator depresses brake member 54 allows for braking of all ground-engaging members 10, 12 through the four channels 140, 142, 144, 146 of ABS control module 60. It may be appreciated that, if the ABS feature is engaged, the flow of hydraulic fluid to any of brake calipers 48, 52 may be modulated, temporarily stopped, and/or otherwise adjusted by ABS control module 60 to minimize skidding and maintain steering control of vehicle 2.

[0057] Referring now to Fig. 10B, a schematic view of an alternative hydraulic system 150' of vehicle 2 is disclosed with respect to operation of braking assembly 40, with like components of hydraulic system 150 (Fig. 10A) shown with like reference numbers. In operation, as force F is applied to brake member 54 by the operator, brake master cylinder 56 transmits force F to ABS control module 60. More particularly, as force F is applied to brake member 54, brake master cylinder 56 provides an input to front master cylinder output 148 to initiate a flow of hydraulic fluid through front left channel 140 and front left conduit 64 to front left ground-engaging member 10. Additionally, the input provided to front master cylinder output 148 also initiates a flow of hydraulic fluid through front right channel 142 and a first front right conduit 164 fluidly coupled to a junction block or junction member 162. First front right conduit 164 is fluidly coupled to a first switching member 126' of junction member 162 and

transmits hydraulic fluid or other braking input or signal to front right ground-engaging member 10 through second front right conduit 66.

[0058] With respect to rear ground-engaging members 12, as force F is applied to brake member 54, brake master cylinder 56 provides an input to rear master cylinder output 149 to initiate a flow of hydraulic fluid through rear right channel 146, junction conduit 74, junction member 72, and rear right conduit 70 to rear right ground-engaging member 12. Additionally, the input provided to rear master cylinder output 149 from brake master cylinder 56 also initiates a flow of hydraulic fluid through rear left channel 144 which is fluidly coupled to junction member 162 through a first junction conduit 168. At junction member 162, hydraulic fluid or other braking input or signal is transmitted through a second switching member 126'' and flows through second junction conduit 166, which is fluidly coupled to junction member 72. At junction member 72, hydraulic fluid or other braking input flows through rear left conduit 68 to rear right ground-engaging member 12. In this way, a single actuation of braking assembly 40 when the operator depresses brake member 54 allows for braking of all ground-engaging members 10, 12 through the four channels 140, 142, 144, 146 of ABS control module 60. It may be appreciated that, if the ABS feature is engaged, the flow of hydraulic fluid to any of brake calipers 48, 52 may be modulated, temporarily stopped, and/or otherwise adjusted by ABS control module 60 to minimize skidding and maintain steering control of vehicle 2.

ABS Operating Modes

[0059] With respect to the operation of braking assembly 40, Figs. 11-13 disclose various operating modes which may be used for the ABS feature. As disclosed herein, braking assembly 40 may be configured to automatically turn off the ABS feature when the vehicle speed is below a prescribed or predetermined speed (e.g., 30 kph) and is configured to automatically turn on the ABS feature when the vehicle speed is above the prescribed speed. Alternatively, braking assembly 40 may be configured to allow the user to manually turn on and off the ABS feature.

[0060] Fig. 11 discloses a first operating mode of braking assembly 40 in which the ABS feature always engages when braking is applied by the user (i.e, the "ABS On Mode"). More particularly, if vehicle 2 first begins to operate in the normal run mode (i.e., the ABS feature is

not initially engaged), electrical system 120 may determine if brake member 54 (Fig. 2) has been actuated such that braking has been applied in a Step 200. If no braking has been applied, then vehicle 2 continues to operate in the normal run mode, as controlled by the operator, in Step 202. However, if braking is applied in Step 200, for example through brake member 54, then ABS control module 60 takes control of braking assembly 40 in Step 204 and, because the ABS feature is always engaged in this ABS On Mode, the ABS feature is utilized in the braking process. In Step 204, ABS control module 60 receives inputs from at least pressure sensor 134, brake pressure switch 126, wheel speed sensors 80, 90, ECM 122, and display 124. Display 124 also may receive inputs from a portion of powertrain assembly 30, such as the engine and/or transmission (not shown), regarding information of the operating conditions thereof. With this information, ABS control module 60 modulates cycles of brake pressure, using hydraulic fluid from hydraulic fluid reservoir 152 (Fig. 10A), to distribute pressurized braking fluid to at least some of ground-engaging members 10, 12 in Step 206. During Step 206, ABS control module 60 modulates the pressured braking fluid based on information received by wheel speed sensors 80, 90 to obtain appropriate vehicle deceleration through different wheel slips. Once vehicle 2 properly decelerates and braking has been terminated, vehicle 2 returns to the normal run mode in Step 208 until another braking input is applied, at which time, the ABS feature will automatically be utilized again by ABS control module 60 in the ABS On Mode.

[0061] However, and now referring to Fig. 12, as disclosed herein, the ABS feature of braking assembly 40 may be selectively engaged in a second operating mode (i.e., the "ABS On-Off Mode"). More particularly, in the ABS On-Off Mode, the ABS feature may not always be engaged upon a braking input, but instead, the operator may selectively engage or disengage the ABS feature through display 124. As such, Fig. 12 discloses a Step 210 which allows electrical system 120 to determine if a user input or user selection has been applied to display 124 to engage or disengage the ABS feature such that vehicle 2. If the vehicle 2 is operating in the normal run mode and no input has been provided to display 124, then vehicle 2 continues in the normal run mode and is controlled by the operator, as shown in Step 212.

[0062] However, if display 124 has disengaged the ABS feature of braking assembly 40 in Step 210, then electrical system 120, including ABS control module 60, determines if the vehicle speed is below a predetermined value (e.g., 30 kph) in Step 214 using information from wheel speed sensors 80, 90 (Fig. 9). If the vehicle speed is less than the predetermined speed

threshold (e.g., 30 kph), then ABS control module 60 determines if braking is sensed by an input applied to brake member 54 (Fig. 2) in Step 216. If braking has not been sensed, then vehicle 2 continues to operate in the normal run mode and is controlled by the operator, as shown in Step 218. And, even if braking has been sensed, as long as the vehicle speed is below the predetermined operating condition (e.g., vehicle speed of 30 kph), then ABS control module 60 allows braking to occur without the ABS feature, as shown in Step 220. In Step 222, vehicle 2 will achieve braking deceleration without the ABS feature engaged and will return to the normal run mode. In this way, the ABS feature of braking assembly 40 will not automatically engage if the user has disengaged the ABS feature and the vehicle speed is below the predetermined threshold value. As such, braking may occur but without the ABS feature engaged when braking assembly 40 operates in the ABS On-Off Mode.

[0063] Yet, as shown in Step 224 of Fig. 12, if the vehicle speed is above the predetermined threshold value (e.g., 30 kph), then ABS control module 60 is automatically engaged to take control of operation of braking assembly 40 and engage the ABS feature, despite the user's previous selection through display 124 to disengage the ABS feature. In this way, ABS control module 60 will automatically change from the normal run mode to the anti-lock braking mode in response to the vehicle speed, regardless of the user's previous selection with respect to the ABS feature. At Step 224, ABS control module 60 receives inputs, signals, or other information from a plurality of other components, such as brake pressure switch 126, pressure sensor 134, wheel speed sensors 80, 90, ECM 122, and display 124. Using this information, ABS control module 60 then modulates cycles of brake pressure, using hydraulic fluid from hydraulic fluid reservoir 152 (Fig. 10A), to distribute pressurized braking fluid to each of ground-engaging members 10, 12 in Step 226. During Step 226, ABS control module 60 (e.g., internal solenoids) modulates the pressured braking fluid based on information received by wheel speed sensors 80, 90 to obtain appropriate vehicle deceleration through different wheel slips. Once vehicle 2 properly decelerates, vehicle 2 returns to the normal run mode in Step 228 until another braking input is applied.

[0064] Referring to Fig. 13, a third operating mode of braking assembly 40 is shown as the ABS Control Module Mode. More particularly, as the operator provides an input to brake member 54 (Fig. 2), the brake input is transmitted to brake master cylinder 56 to start the braking process, as shown in Step 230. The braking pressure may be determined by brake pressure

switch 126 and pressure sensor 134 (Fig. 10A) in Step 232 and the speed of ground-engaging members 10, 12 is determined by respective wheel speed sensors 80, 90, as shown in Step 234.

[0065] With this information from Steps 232 and 234, electrical system 120, including ABS control module 60, may determine if the rate of deceleration of any of ground-engaging members 10, 12 is greater than the deceleration rate of the other ground-engaging members 10, 12, as shown in Step 236. If the deceleration rate of one of ground-engaging members 10, 12 is not greater than that of the others, then brake pressure is maintained until brake member 54 is released by the operator, as shown in Step 238.

[0066] However, if the deceleration rate of one of ground-engaging members 10, 12 is greater than that of the others, then, in Step 240, ABS control module 60 (e.g., internal solenoid) may release the brake pressure on the one ground-engaging member 10, 12 which has a greater deceleration rate than the others. In Step 240, ABS control module 60 is configured to release the brake pressure on the one ground-engaging member 10, 12 until the remaining ground-engaging members 10, 12 increase in deceleration rate to equal that of the one ground-engaging member 10, 12. In this way, ABS control module 60 utilizes the ABS feature to minimize wheel slipping on the ground surface and to maintain steering control of vehicle 2.

[0067] Once all ground-engaging members 10, 12 have approximately equal deceleration rates, then ABS control module 60 re-applies braking pressure to the one ground-engaging member 10, 12 with the initially-greater deceleration rate such that braking pressure is now applied to all of ground-engaging members 10, 12, as shown in Step 242.

[0068] It may be appreciated that braking assembly 40 may be pre-set to operate in only one of the three operating modes of Figs. 11-13, as set by a manufacturer or dealer of vehicle 2, or may be configured to operate in any of the operating modes of Figs. 11-13 based on an input from the user. It may be appreciated that, in any of the three operating modes of Figs. 11-13, ABS control module 60 may be automatically engaged to turn on the ABS feature in response to an error of the vehicle speed transmitted by ECM 122 and/or sensors 80, 90. Additionally, depending on the operating mode, the user has the ability to turn on and off the ABS feature during operation of vehicle 2 and, as such, can make adjustments to the performance and handling of vehicle 2 while operating vehicle 2. However, as disclosed herein, electrical system 120 may ignore a user's request to disengage or turn off the ABS feature, depending on the predetermined vehicle condition (e.g., a vehicle speed of at least 30 kph).

[0069] Furthermore, it may be appreciated that both the ABS On Mode and the ABS On-Off Mode may utilize the features of the ABS Control Mode by also modulating the braking pressure, as disclosed best in Fig. 13, in Steps 206 and 226, respectively. As such, when the ABS feature is engaged, ABS control module 60 is configured to monitor the deceleration rate of each of ground-engaging members 10, 12 and may regulate or modulate the flow of hydraulic flow to any brake caliper 48, 52 of a ground-engaging member 10, 12 with a greater deceleration rate than the others.

ASLD Operating Modes

[0070] Referring to Fig. 14, vehicle 2 may be configured with an adjustable speed limiting device or feature ("ASLD") in which the user may selectively define speed limits when vehicle 2 is operating. For example, the user may engage or turn on the adjustable speed limiting feature through display 124, which will allow vehicle 2 to operate at speed limits between a predetermined lower speed limit (e.g., 30 kph) and a predetermined maximum speed limit. When utilizing the adjustable speed limiting feature, the user may adjust the speed limit in predetermined speed intervals or increments (e.g., 5 kph) for each step change.

[0071] As shown in Fig. 14, in Step 170, vehicle 2 operates in the normal run mode. While vehicle 2 operates in the normal run mode, display 124 is in a corresponding normal run mode, as shown in Step 172. In Step 174, the operator or another user enters Display Menu Options by pressing or otherwise providing an input to a "MODE" input of display 124. In Step 176, the user scrolls through the Display Menu Options with inputs, such as "UP" and "DOWN" arrow buttons. In Step 178, the user may select and enter the ASLD Display Menu Options. If the user does not select the ASLD Display Menu Options, then the user may select an "EXIT" input in Step 179. If the user selects the "EXIT" option in Step 179, then display 124 returns to the normal run mode, as shown in Step 172. However, if the user does not select the "EXIT" option in Step 179, then the user is able to continue to scroll through the Display Menu Options, as shown in Step 176.

[0072] If, in Step 178, the user selects and enters the ASLD Display Menu Options, then vehicle 2 begins to operate in accordance with the ASLD feature in Step 180. When utilizing the ASLD feature in Step 180, electrical system 120, such as ABS control module 60, may communicate with display 124, ECM 122, and wheel speed sensors 80, 90 to obtain any

necessary information for operating vehicle 2 according to the ASLD feature. In Step 182, display 124 provides or shows the actual vehicle speed as well as a user selectable speed limit. The user selectable speed may be labeled on display as "Set Speed", "Speed Lim", or any other type of alphanumeric code, label, or information that alerts the user to the location of the user selectable speed limit option on display 124. The user selectable speed limit may be initialized to the maximum speed of vehicle 2, rounded to the nearest 5 kph, in one embodiment.

[0073] In Step 184, the user selectable speed limit variable may be updated to any value selected by the user and stored in ECM 122. In Step 186, ECM 122 provides the updated user selected speed limit to display 124 such that the user is able to quickly determine the speed limit. In Step 188, ECM 122 will not allow vehicle 2 to travel faster than the user selected speed limit.

[0074] In Step 190, an input (e.g., a button) may be actuated (e.g., pressed) on display 124 when the user is operating vehicle 2 in accordance with the ASLD feature. For example, if the "MODE" input is actuated in Step 190, then vehicle 2 continues to operate in accordance with the ASLD feature.

[0075] However, if the "DOWN" input (e.g., arrow button) is actuated in Step 190, then display 124 sends a decrement command to ECM 122 via the CAN bus network for a possible reduction to the user selected speed limit, as shown in Step 191. In Step 192, it is determined if the current user selected speed limit is greater than a predetermined speed value (e.g., 30 kph). If Step 192 determines that the user selected speed limit is greater than the predetermined speed value, then ECM 122 decreases the value of the user selected speed limit by a predetermined incremental amount (e.g., 5 kph), as shown in Step 193. Following Step 193, ECM 122 is updated with the decreased user selected speed limit, as shown in Step 184.

[0076] Yet, if Step 192 determines that the user selected speed limit is not greater than the predetermined speed value, then, as shown in Step 194, the request to modify the user selected speed limit through display 124 is ignored by ECM 122 and the original user selected speed limit continues to be stored in ECM 122, as shown in Step 184.

[0077] However, if in Step 190, if the "UP" input (e.g., arrow button) is actuated, then, as shown in Step 195, display 124 sends an increment command to ECM 122 via the CAN bus network for a possible increase to the user selected speed limit. In Step 196, it is determined if the current user selected speed is less than a calibrated maximum vehicle speed for vehicle 2. If Step 195 determines that the user selected speed limit is less than the calibrated maximum

vehicle speed, then ECM 122 increase the value of the user selected speed limit by a predetermined incremental amount (e.g., 5 kph), as shown in Step 197. Following Step 197, ECM 122 is updated with the increased user selected speed limit, as shown in Step 184.

[0078] Yet, if Step 196 determines that the user selected speed limit is greater than the calibrated maximum vehicle speed, then the request to modify the user selected speed limit through display 124 is ignored by ECM 122, as shown in Step 194.

[0079] Additionally, in one embodiment, if vehicle 2 is operating in various modes (e.g., a farm or ranch mode), the user may first shift to low gear before engaging the adjustable speed limiting feature through display 124. Once the adjustable speed limiting feature is engaged, the predetermined speed increments for each step change may be approximately 1 mph. For example, in an embodiment of vehicle 2 having the farm or ranch operating mode, the predetermined lower speed limit may be approximately 5 mph and the predetermined maximum speed limit may be approximately 12 mph with predetermined speed increments of approximately 1 mph for each step change.

ESC Operating Modes

[0080] Additionally, as shown in at least Fig. 9, with the addition of steering angle sensor 130, ECM 122, ABS control module 60, and/or any other component of electrical system 120 may include an electronic stability control ("ESC") assembly or program 160. ESC assembly 160 may include a yaw rate sensor positioned within a portion of steering assembly 26 (Fig. 1), for example in a portion of an electric power steering module, as well as steering angle sensor 130. ESC assembly 160 may be configured within ECM 122, any other component of electrical system 120, and/or may be a separate module electrically coupled to electrical system 120 and/or ECM 122. In one embodiment, ESC assembly 160 may be selectively engaged by the user through display 124 and/or any other component of vehicle 2; however, in other embodiments, ESC assembly 160 may be automatically engaged by ECM 122 or other components of electrical system 120 based on various operating conditions, such as vehicle conditions, environmental conditions, terrain conditions, etc. Also, it may be appreciated the ESC assembly 160 may always be engaged upon starting vehicle 2 such that ESC assembly 160 is not selectively engaged or disengaged.

[0081] More particularly, and as shown in Figs. 15-20, ESC assembly 160 is configured to operate in various operating modes. With respect to Fig. 15, ESC assembly 160 is configured to operate in a first or ESC and ABS Normal Operating Mode. In the ESC and ABS Normal Operating Mode, when vehicle 2 is operating in the normal run mode, as shown in Step 250, electrical system 120 may determine if brake member 54 (Fig. 2) has been actuated such that braking has been applied in a Step 252. If no braking has been applied, then vehicle 2 continues to operate in the normal run mode, as controlled by the operator, in Step 254.

[0082] However, if braking is applied in Step 252, for example through brake member 54, then ABS control module 60 takes control of braking assembly 40 in Step 256. In Step 256, ABS control module 60 may actively request prescribed drag torque reduction to ECM 122. Additionally, in Step 256, ABS control module 60 communicates with at least pressure sensor 134, brake pressure switch 126, wheel speed sensors 80, 90, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine and/or transmission (not shown), regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2.

[0083] With this information, ABS control module 60 modulates cycles of brake pressure, using hydraulic fluid from hydraulic fluid reservoir 152 (Fig. 10A), to distribute pressurized braking fluid to each brake caliper 48, 52 in Step 258. During Step 258, using information from speed sensors 80, 90, ABS control module 60 modulates the pressured braking fluid based on information received by wheel speed sensors 80, 90 to obtain appropriate vehicle deceleration through different wheel slips. Once vehicle 2 properly decelerates and braking has been terminated, vehicle 2 returns to the normal run mode in Step 260 until another braking input is applied.

[0084] With respect to Fig. 16, ESC assembly 160 is configured to operate in a second or Hill Descent Control ("HDC") Operating Mode. In the HDC Operating Mode, when vehicle 2 is operating in the normal run mode, as shown in Step 262, electrical system 120 may determine if accelerator member 53 (Fig. 2) has been released such that at least no acceleration is being applied in a Step 264. If accelerator member 53 has not been released, then vehicle 2 continues to operate in the normal run mode, as controlled by the operator pressing or otherwise providing an input to accelerator member 53, in Step 266. In Step 266, vehicle 2 continues to operate in

the normal run mode while the operator provides an input to accelerator member 53 as long as the vehicle speed is less than a predetermined speed value (e.g., 4 mph).

[0085] However, if accelerator member 52 has been released in Step 264, then ABS control module 60 takes control of braking assembly 40 in Step 268. In Step 268, ABS control module 60 may monitor inputs from speed sensors 80, 90 to apply an appropriate amount of brake pressure to each caliper 48, 52 to decrease vehicle speed while maintaining a predetermined or specified vehicle speed deceleration rate and proper wheel slips. In one embodiment, the predetermined or specified vehicle speed deceleration rate may be approximately 4 mph when vehicle 2 is traveling down hill. Additionally, in Step 268, ABS control module 60 communicates with at least pressure sensor 134, brake pressure switch 126, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine and/or transmission (not shown), regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2. In one embodiment, in Step 268, ECM 122 communicates with the engine to determine torque and rpm information and also may communicate with accelerator member 53 for electronic throttle control (Fig. 2).

[0086] In Step 270, ESC assembly 160 is configured to maintain speed and/or a speed reduction to the prescribed speed vehicle speed (e.g., 4 mph), until vehicle 2 stops, or until the operator provides an input to accelerator member 53 (i.e., invokes a speed larger than the prescribed vehicle speed (e.g., 4 mph), thereby releasing the braking input).

[0087] With respect to Fig. 17, ESC assembly 160 is configured to operate in a third or Hill Assist/Hill Hold Control ("HHC") Operating Mode. In the HHC Operating Mode, when vehicle 2 is operating in the normal run mode, as shown in Step 272, electrical system 120 may determine if vehicle 2 has stopped moving while in an uphill direction and if brake member 54 (Fig. 2) has been sufficiently applied to retain vehicle 2 in a stationary position while on uphill terrain or in an uphill direction, as shown in Step. 274. If it is determined that vehicle 2 has stopped moved in the uphill direction but the brake torque is insufficient to keep vehicle 2 from rolling backwards in a downhill direction, as shown in Step 276, then the HDC Operating Mode is invoked, as shown in Step 278, to prevent vehicle 2 from moving or rolling backwards in the downhill direction.

[0088] If, however, in Step 274, it is determined that vehicle 2 has stopped moving in the uphill direction but sufficient braking torque is provided to retain vehicle 2 in a stationary position while on the uphill terrain, then ABS control module 60 takes control of braking commands in Step 280. Additionally, in Step 280, ABS control module 60 may monitor inputs of braking pressure applied to brake member 54 by the operator and any sensed changed in the G-force, as sensed by multi-axis g sensor 132 (Fig. 9), in the uphill direction. ABS control module 60 also may monitor any input to acceleration member 53 which may be provided to the engine to increase or change engine torque and speed. Also, in Step 280, ABS control module 60 communicates with at least pressure sensor 134, brake pressure switch 126, speed sensors 80, 90, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine and/or transmission (not shown), regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2. In one embodiment, in Step 268, ECM 122 communicates with the engine to determine torque and rpm information and also may communicate with accelerator member 53 (Fig. 2) for electronic throttle control ("ETC").

[0089] In Step 282, ESC assembly 160 is configured to appropriately maintain static brake pressure, as applied by the operator, which is the same brake pressure sufficient to hold vehicle 2 in a stationary position for a predetermined amount of time (e.g., 1.0-5.0 seconds and, more particularly, 1.5-3.0 seconds). Alternatively, in Step 282, ESC assembly 160 is configured to maintain static brake pressure until engine torque is applied by the operator, for example through accelerator member 53 (Fig. 2), in an amount which overcomes the braking torque. ABS control module 60 may adjust the pressure upon input from ETC, engine torque, and/or engine speed information through the CAN network or messages.

[0090] In Step 284, vehicle 2 may return to the normal run mode in the uphill direction or may roll backwards in the downhill direction if vehicle 2 is maintained on the uphill terrain for a time greater than the predetermined amount of time (e.g., 1.5-3.0 seconds). If vehicle 2 returns to the normal run mode in Step 284, then the HHC Operating Mode returns to Step 272. However, if vehicle 2 begins to roll or move backwards in the downhill direction in Step 284, then the HHC Operating Mode returns to Step 278 to prevent such movement.

[0091] Referring to Fig. 18, ESC assembly 160 is configured to operate in a fourth or Roll Over Mitigation ("ROM") Operating Mode. In the ROM Operating Mode, when vehicle 2

is operating in the normal run mode, as shown in Step 290, electrical system 120 may determine if vehicle 2 is moving, turning to the left or right, and/or operating at an acceleration within the G-force specifications for vehicle 2, as shown in Step 292. If electrical system 120 determines that vehicle is not moving, turning to the left or right, and/or operating at an acceleration within the G-force specifications, then vehicle 2 continues to operate in a normal straight, left-turn, or right-turn driving mode, as shown in Step 294.

[0092] However, if Step 292 determines that vehicle 2 is moving, turning to the left or right, and/or operating at an acceleration within the G-force specifications for vehicle 2, then Step 296 determines if the lateral acceleration of vehicle 2 is greater than the predetermined or set intervention ROM value. In other words, Step 296 determines if vehicle 2 is likely to tip over. If it is determined that vehicle 2 is likely to tip over, then, in Step 298, ABS control module 60 takes control of braking commands and monitors the G forces, wheel speed, steering angle, and steering angle rate of change using sensors 132, 80 and 90, and 130, respectively. Additionally, in Step 298, ABS control module 60 may communicate with at least pressure sensor 134, brake pressure switch 126, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine and/or transmission (not shown), regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2. In one embodiment, in Step 298, ECM 122 communicates with the engine to determine torque and rpm information and also may communicate with accelerator member 53 (Fig. 2) for electronic throttle control ("ETC").

[0093] In Step 300, ABS control module 60 is configured to appropriately administer brake pressure to each of calipers 48, 52 with appropriate amounts of wheel slips to obtain a normal lateral stability value (i.e., a stability value within a predetermined range). In Step 302, vehicle 2 returns to the normal run and steering mode.

[0094] Referring to Fig. 19, ESC assembly 160 is configured to operate in a fifth or Traction Control System ("TCS") Operating Mode. In the TCS Operating Mode, when vehicle 2 is operating in the normal run mode, as shown in Step 310, electrical system 120 may determine if the operator is applying an input to accelerator member 53 (Fig. 2), thereby causing engine torque and speed to cause wheel slips, as shown in Step 312. If Step 312 determines that the operator is not applying an input to accelerator member 53 in a manner resulting in engine torque

and speed causing wheel slips, then vehicle 2 continues to operate in the normal run mode and according to normal driving conditions, as shown in Step 314.

[0095] However, if Step 312 determines that the operator is applying an input to accelerator member 53 in a manner resulting in engine torque and speed causing wheel slips, then, in Step 316, ABS control module 60 takes control of acceleration commands and actively communicates with ECM 122 and wheel speed sensors 80, 90 to reduce engine torque and speed. To reduce engine torque and speed, Step 316 applies an amount of braking pressure to each of brake calipers 48, 52 according to different drive modes, such as a Turf or 4x1 mode, a 4x2 mode, 4x4 mode, reverse, and any other type of mode configured for vehicle 2. Additionally, in Step 316, ABS control module 60 may communicate with at least pressure sensor 134, brake pressure switch 126, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine, transmission, drive shafts, and wheel assemblies 10a, 12a (Fig. 2), regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2.

[0096] In Step 318, ABS control module 60 appropriately modulates the braking pressure distributed to each of brake calipers 48, 52 in combination with appropriate modulations of engine torque reductions. In Step 320, vehicle 2 returns to the normal run mode and operates according to normal driving conditions.

[0097] Referring to Fig. 20, ESC assembly 160 is configured to operate in a sixth or Vehicle Dynamic Control ("VDC") Operating Mode. In the VDC Operating Mode, when vehicle 2 is operating in the normal run mode, as shown in Step 322, electrical system 120 may determine if vehicle 2 is moving, turning to the right or the left, pitching, and/or braking in a manner less than predetermined values for such operations, as shown in Step 324. If Step 324 determines that vehicle 2 is not moving, turning to the right or the left, pitching, and/or braking in a manner less than predetermined values for such operations, then vehicle 2 operates in the normal run mode and/or according to normal driving conditions with regular steering and braking parameters, as shown in Step 326.

[0098] However, if Step 324 determines that vehicle 2 is moving, turning to the right or the left, pitching, and/or braking in a manner less than predetermined values for such operations, then, in Step 328, ABS control module 60 takes control of braking by applying optimum wheel speed parameters using wheel speed sensors 80, 90. More particularly, ABS control module 60

requests engine torque reductions, monitors the steering angle and steering rate using sensor 130, and monitors the changes in G-forces using sensor 132. Additionally, in Step 328, ABS control module 60 may communicate with at least pressure sensor 134, brake pressure switch 126, ECM 122, and display 124. Display 124 also may communicate with a portion of powertrain assembly 30, such as the engine and/or transmission, regarding information of the operating conditions thereof, and ECM 122 may communicate with other components of vehicle 2. In one embodiment, in Step 328, ECM 122 communicates with the engine to determine torque and rpm information and also may communicate with accelerator member 53 (Fig. 2) for electronic throttle control ("ETC").

[0099] In Step 330, ABS control module 60 appropriately applies braking pressure and proper wheel slips to each of ground-engaging members 10, 12 to maintain the intended direction (i.e., steering) and to maintain stability, thereby preventing oversteer or understeer. ABS control module 60 also monitors the lateral, longitudinal, pitch, and/or yaw directions. In Step 332, vehicle returns to the normal run mode and/or normal driving, steering, and braking parameters.

[00100] Additional details of braking assembly 40 may be disclosed in U.S. Patent Application Serial No. 15/471,469, filed March 28, 2017, and entitled "ANTI-LOCK BRAKE SYSTEM FOR ALL-TERRAIN VEHICLE" (Attorney Docket No. PLR-02-27800.00P), the complete disclosure of which is expressly incorporated by reference herein.

[00101] While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

CLAIMS:

1. A utility vehicle comprising a frame; a plurality of ground-engaging members supporting the frame and each of the plurality of ground-engaging members is configured to rotate about an axle; a powertrain assembly supported by the frame; and a braking system configured to operate in a normal run mode and an anti-lock braking mode, the braking system comprising an anti-lock braking control module operably coupled to the plurality of ground-engaging members the vehicle being characterized in that the anti-lock braking control module is configured to automatically engage the anti-lock braking mode in response to a predetermined condition.

2. The utility vehicle of claim 1, characterized in that the anti-lock braking control module is configured to automatically engage the anti-lock braking mode at the predetermined condition without an input from a user.

3. The utility vehicle of claim 1 or 2, further characterized by a user input configured to engage and disengage the anti-lock braking mode in response to a user selection.

4. The all-terrain vehicle of claim 3, wherein the user input is a display positioned on the vehicle.

5. The utility vehicle of claim 4, characterized in that the display is configured to provide an indication of a fault of the anti-lock braking control module and the braking system is configured to maintain a speed of the vehicle when the indication is provided.

6. The utility vehicle of any of claims 3-5, characterized in that only the user selection is configured to disengage the anti-lock braking mode at a predetermined vehicle speed.

7. The utility vehicle of any of claims 1-6, characterized in that the braking system includes a speed sensor operably coupled to at least one of the plurality of ground-engaging members, and a position of the speed sensor is adjustable relative to the axle of the at least one ground-engaging member.

8. The utility vehicle of any of claims 1-7, characterized in that the predetermined condition is a predetermined vehicle speed of approximately 30 kph.

9. The utility vehicle of any of claims 1-8, characterized in that :

the plurality of ground-engaging members includes:

a first front ground-engaging member;

a second front ground-engaging member;

a first rear ground-engaging member; and

a second rear ground-engaging member; and

the braking system includes:

a first front brake caliper operably coupled to the first front ground-engaging member;

a second front brake caliper operably coupled to the second front ground-engaging member;

a first rear brake caliper operably coupled to the first rear ground-engaging member;

a second rear brake caliper operably coupled to the second rear ground-engaging member; and

a single junction member operably coupled to the first and second rear brake calipers.

10. A braking assembly for a utility vehicle configured to operate in a normal run mode and an anti-lock braking mode, comprising a user braking member; a plurality of brake calipers operably coupled to the user braking member; characterized by a junction member operably coupled to at least two of the plurality of brake calipers; and an anti-lock braking control module operably coupled to at least the user braking member and junction member and configured to automatically engage the anti-lock braking mode at a predetermined condition and disengage the anti-lock braking mode in response to a user input.

11. The braking assembly of claim 10, characterized in that the user braking member is a brake pedal and the user input is a display of the utility vehicle.

12. The braking assembly of claim 10 or 11, characterized in that the predetermined condition is a vehicle speed of approximately 30 kph.

13. The braking assembly of any of claims 10-12, characterized in that the plurality of brake calipers includes two rear brake calipers and the junction member defines a single member operably coupled to the two rear brake calipers.

14. The braking assembly of any of claims 10-13, characterized in that the anti-lock braking control module is configured to disengage the anti-lock braking mode only in response to the user input.

15. A method of operating a braking assembly of a utility vehicle in one of a normal run mode and an anti-lock braking mode, comprising providing a user braking member; providing a

plurality of brake calipers operably coupled to the user braking member; providing an anti-lock braking control module operably coupled to the user braking member and the plurality of brake calipers; characterized by automatically engaging the anti-lock braking mode at a predetermined condition.

16. The method of claim 15, further characterized in that disengaging the anti-lock braking mode in response to a user input.

17. The method of claim 16, characterized in that disengaging the anti-lock braking mode occurs only in response to the user input.

18. The method of claim 16 or 17, further characterized in that providing a display of the utility vehicle and selecting the user input through the display.

19. The method of claim 18, further characterized in that providing an indication of a fault of the braking assembly on the display.

20. The method of any of claims 15-19, characterized in that the predetermined condition is a vehicle speed of approximately 30 kph.

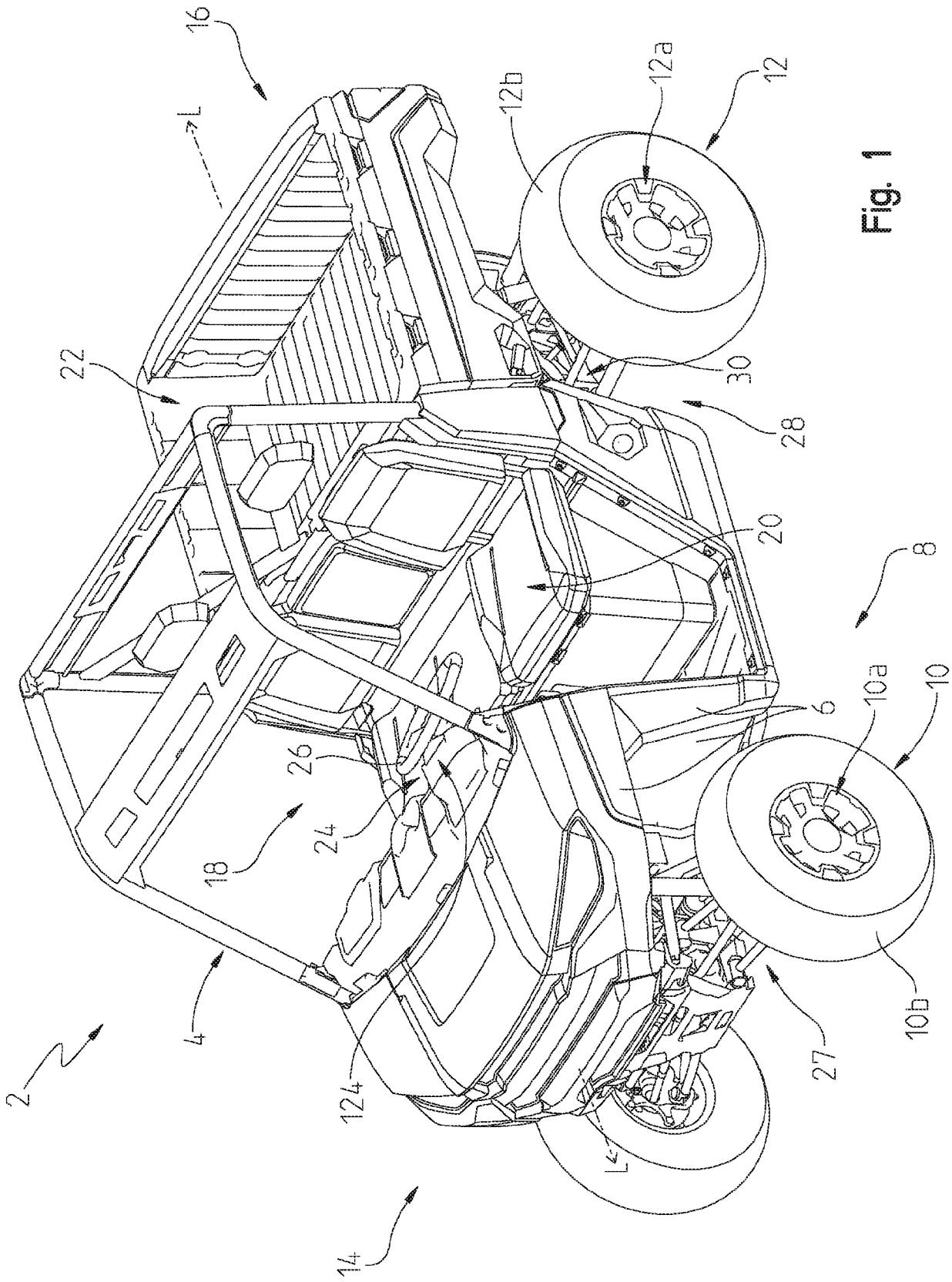


Fig. 1

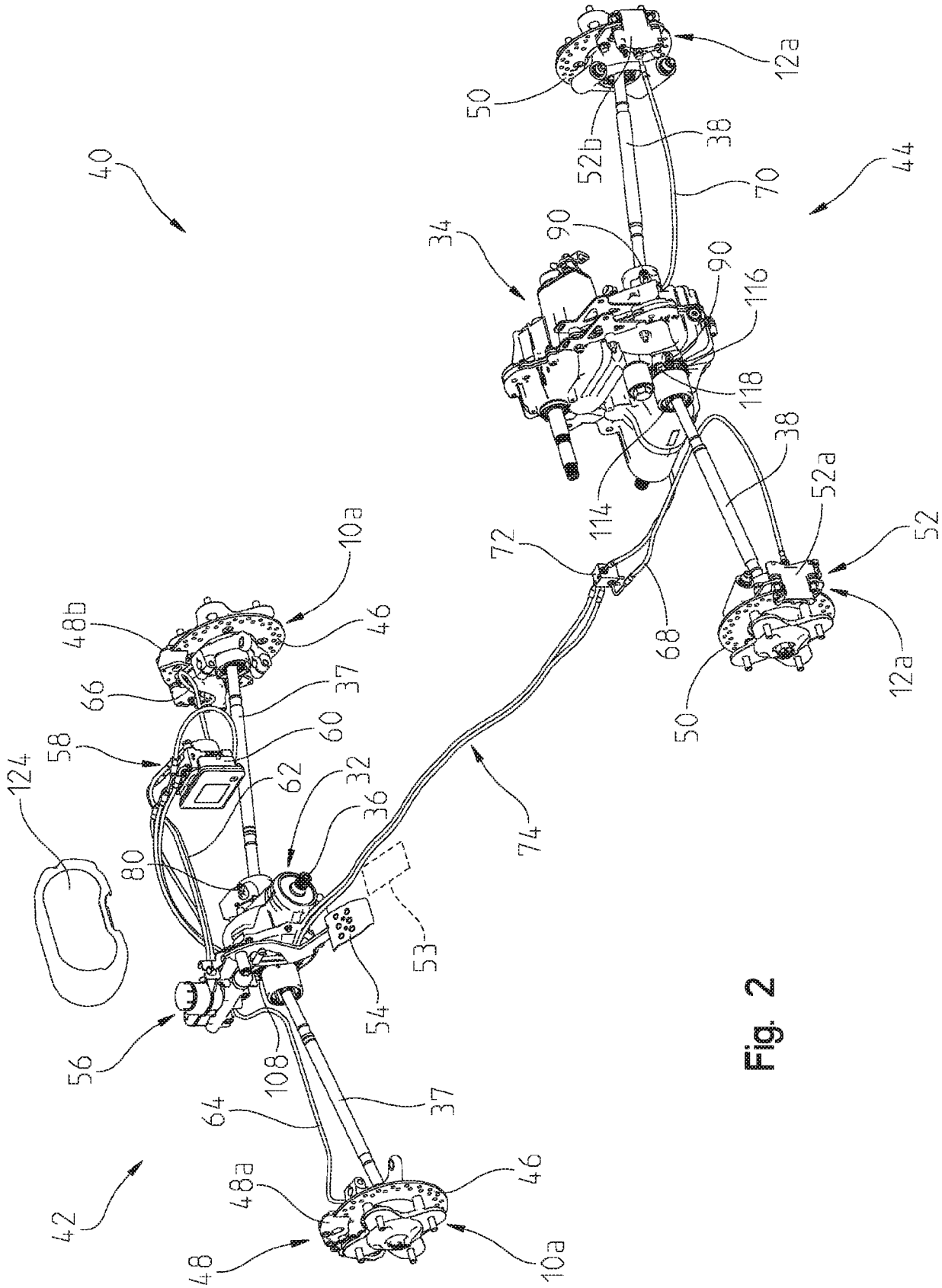

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42
44
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48
48a
48b
50
52
52a
52b
53
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72
74
80
90
108
114
116
118
124
10a
12a
32
34
36
37
38

Fig. 2

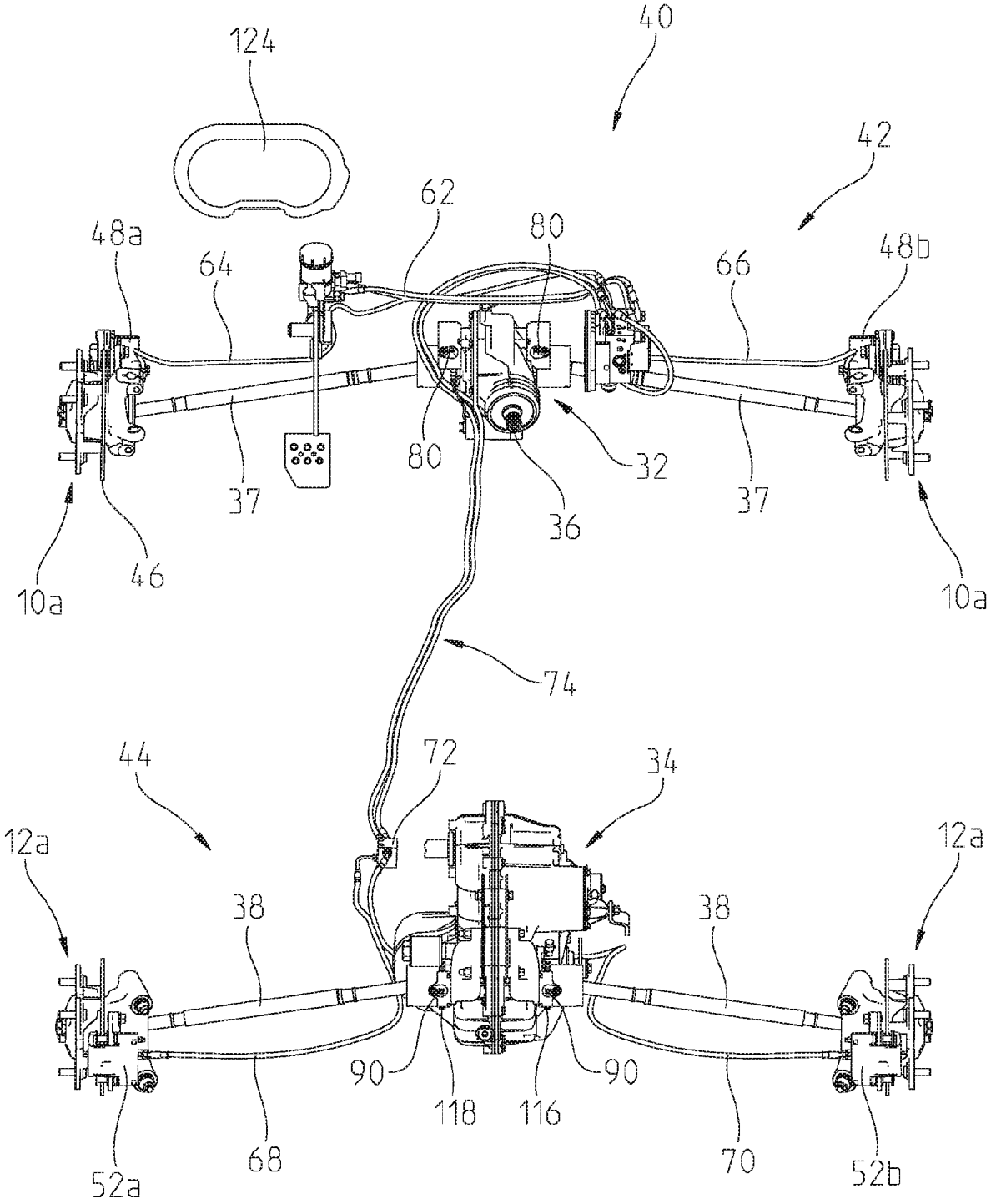

124
40
42
62
48a
64
80
66
48b
80
32
37
37
36
10a
46
10a
74
44
72
34
12a
12a
38
38
90
90
118
116
52a
68
70
52b

Fig. 3

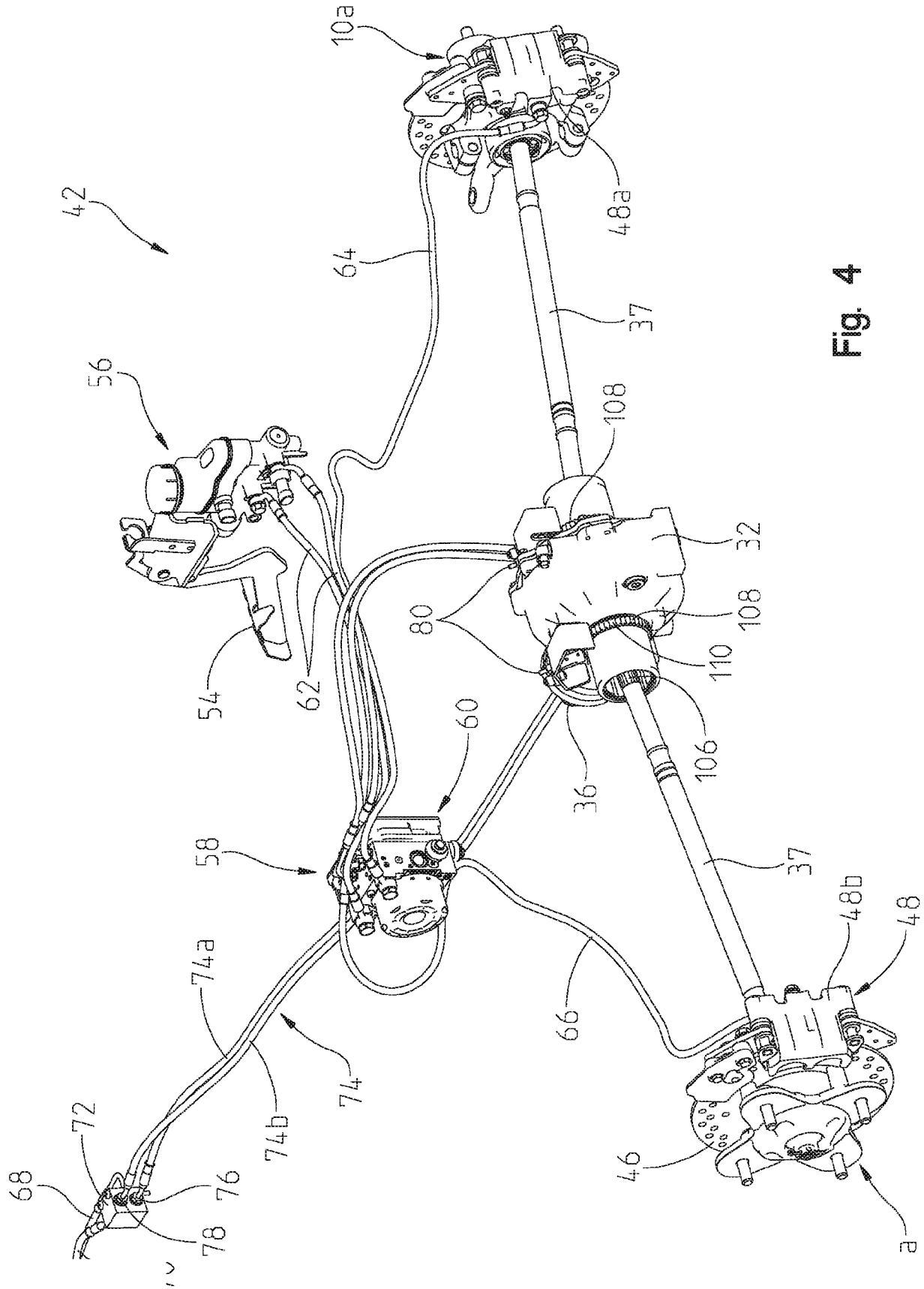

10a
42
64
48a
37
56
108
32
80
108
110
54
62
60
106
36
58
37
48b
48
74a
66
74
74b
72
68
76
78
46
a

Fig. 4

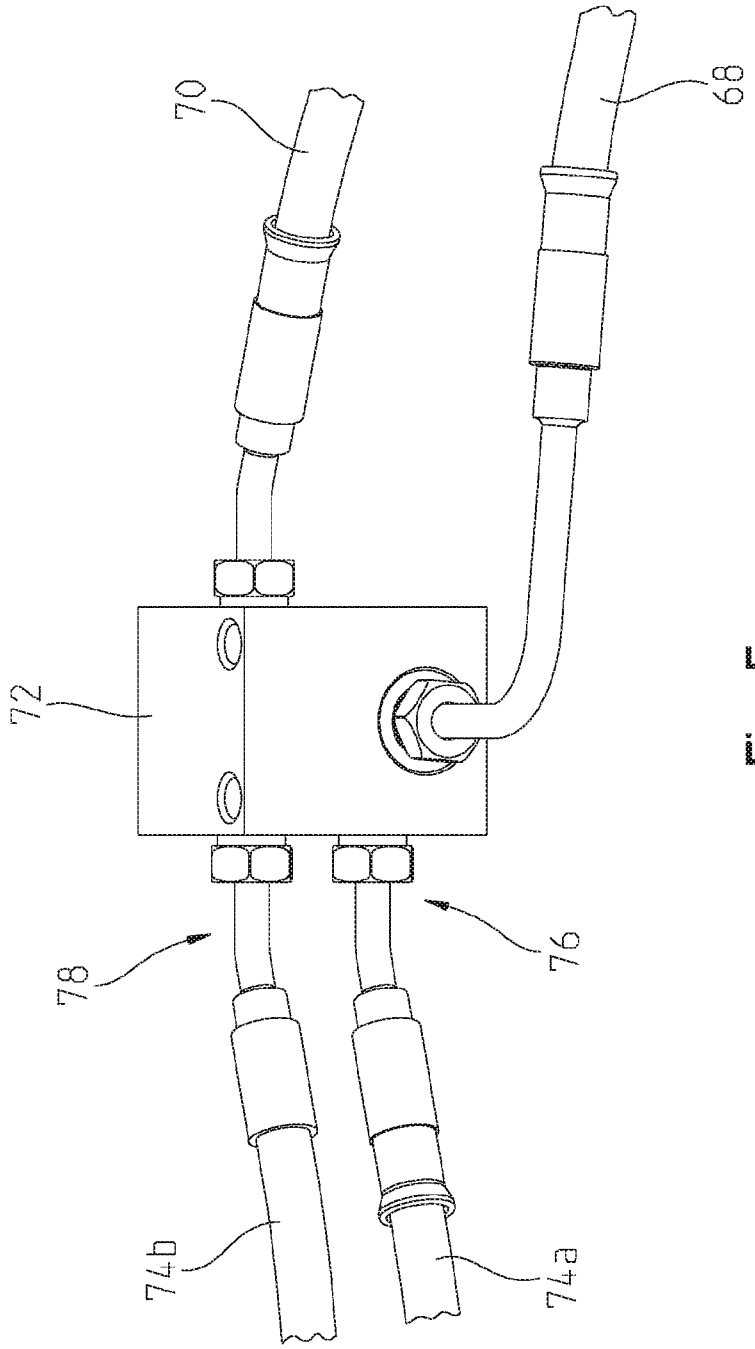


Fig. 5

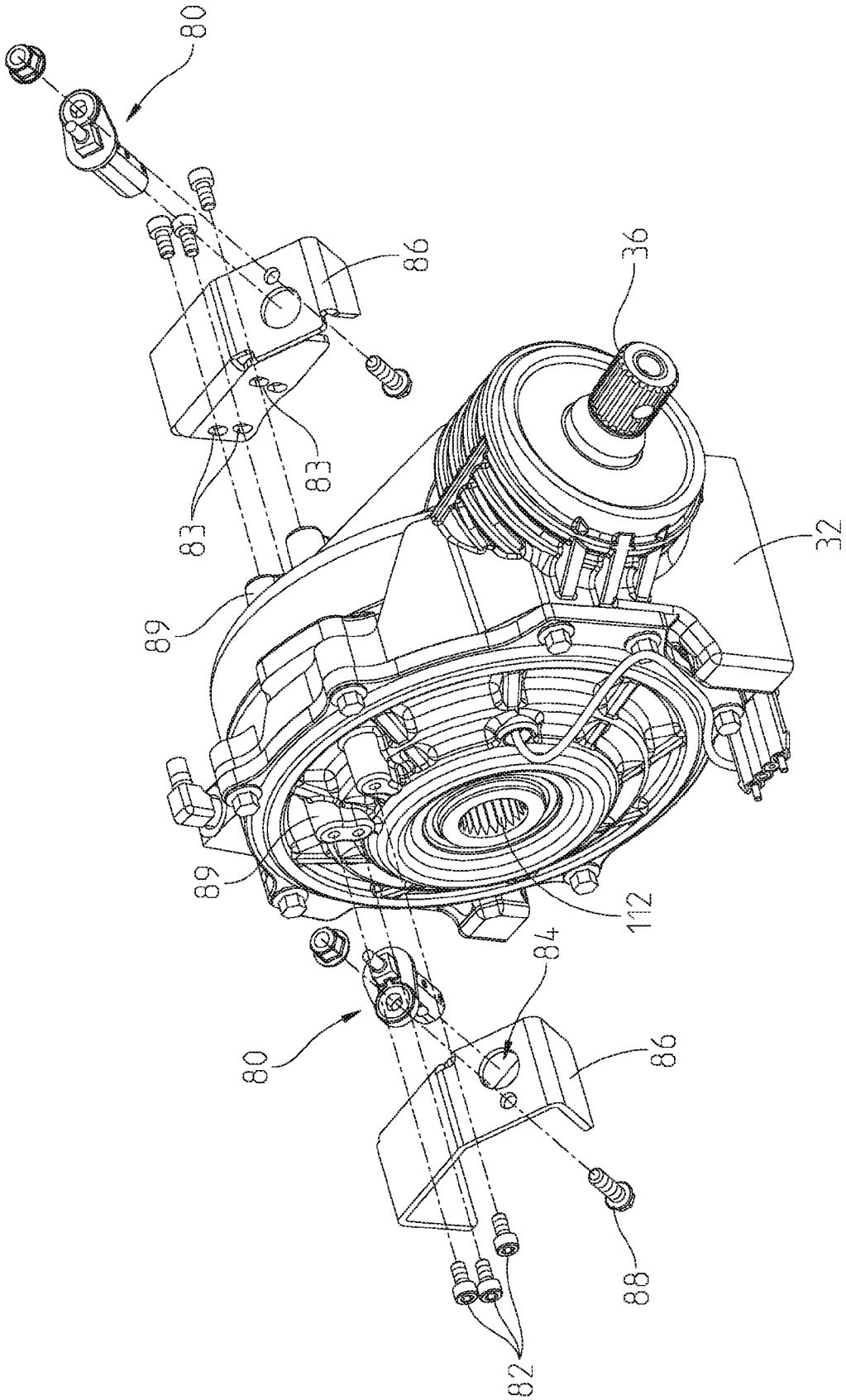


Fig. 6

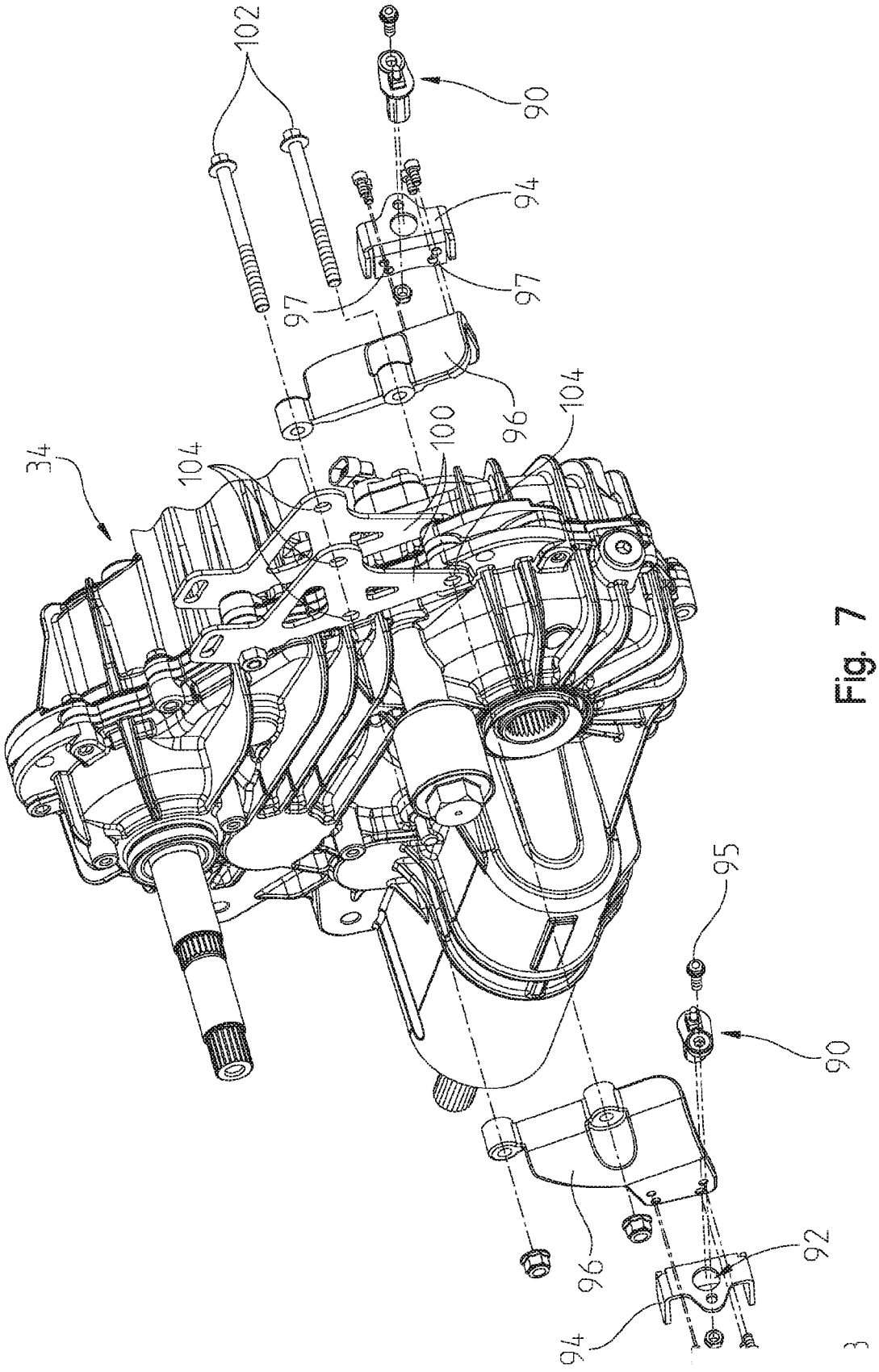


Fig. 7

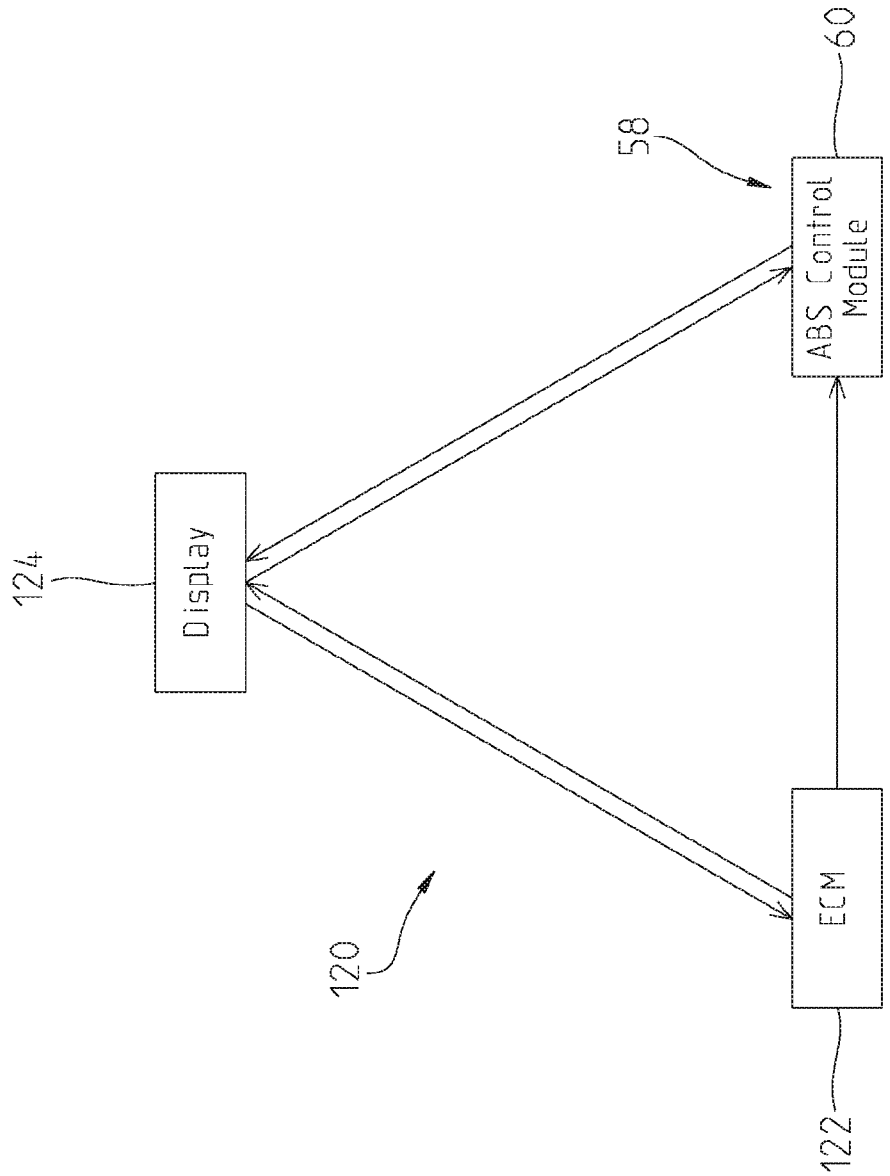


Fig. 8

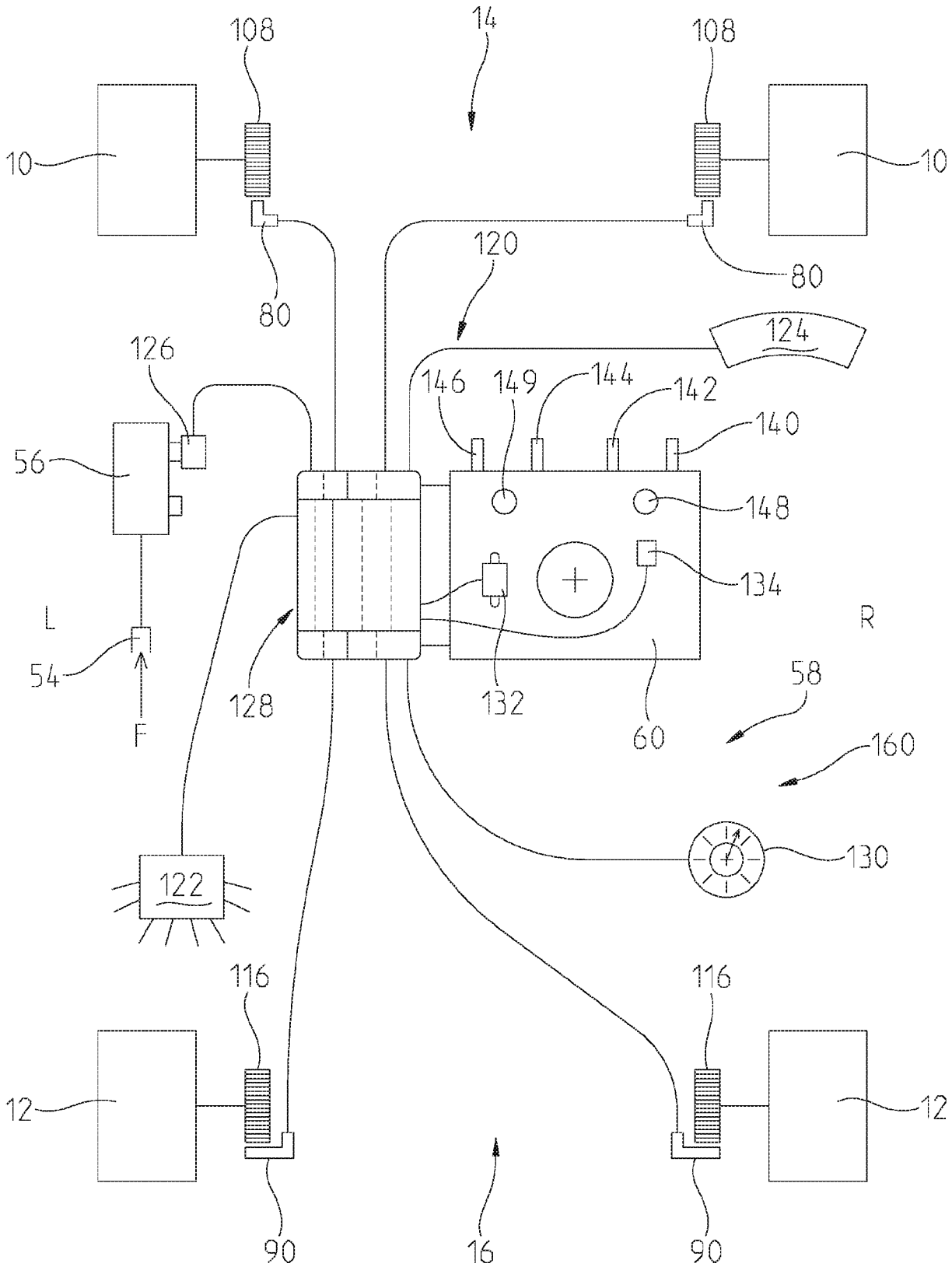

14
108
108
10
10
80
80
120
124
126
146
149
144
142
140
56
148
134
L
R
54
F
128
132
60
58
160
130
122
116
116
12
12
90
16
90

Fig. 9

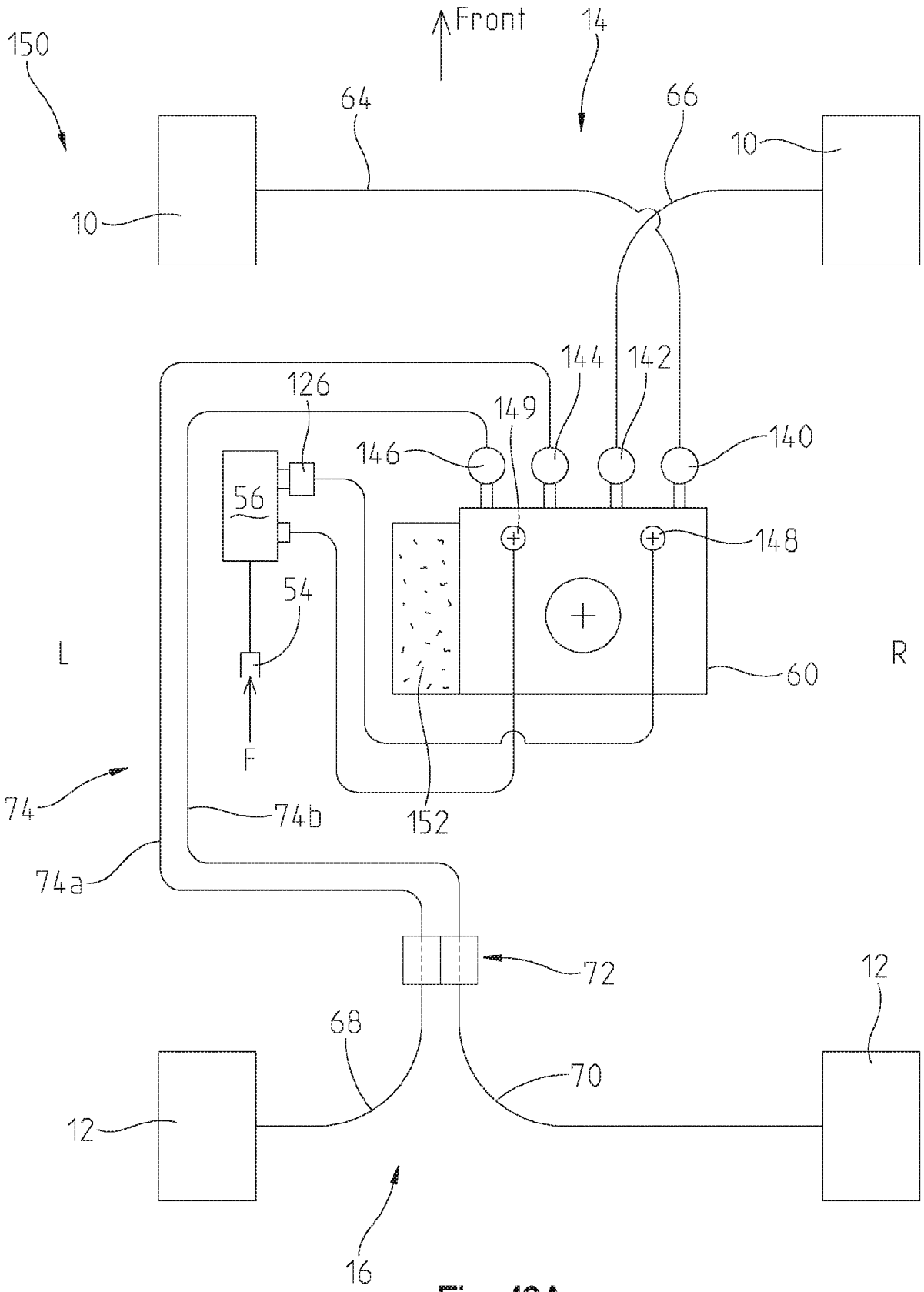

Front
14
150
64
66
10
10
144
142
126
149
146
140
56
148
54
L
R
60
F
74
74b
152
74a
72
12
68
70
12
16

Fig. 10A

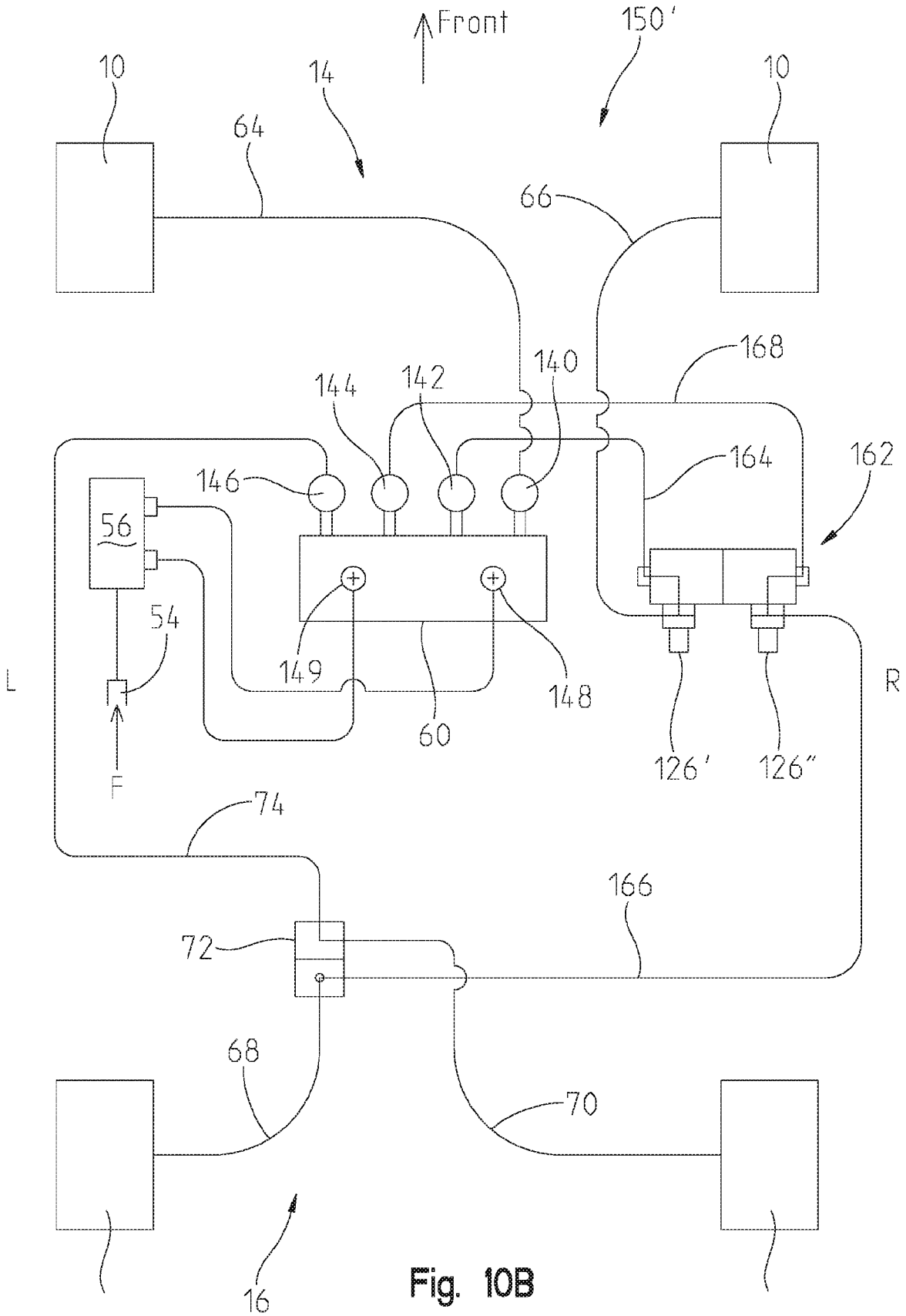

Front
150'
10
14
10
64
66
168
144
142
140
164
162
146
56
54
149
148
60
126'
126"
L
R
F
74
166
72
68
70
16

Fig. 10B

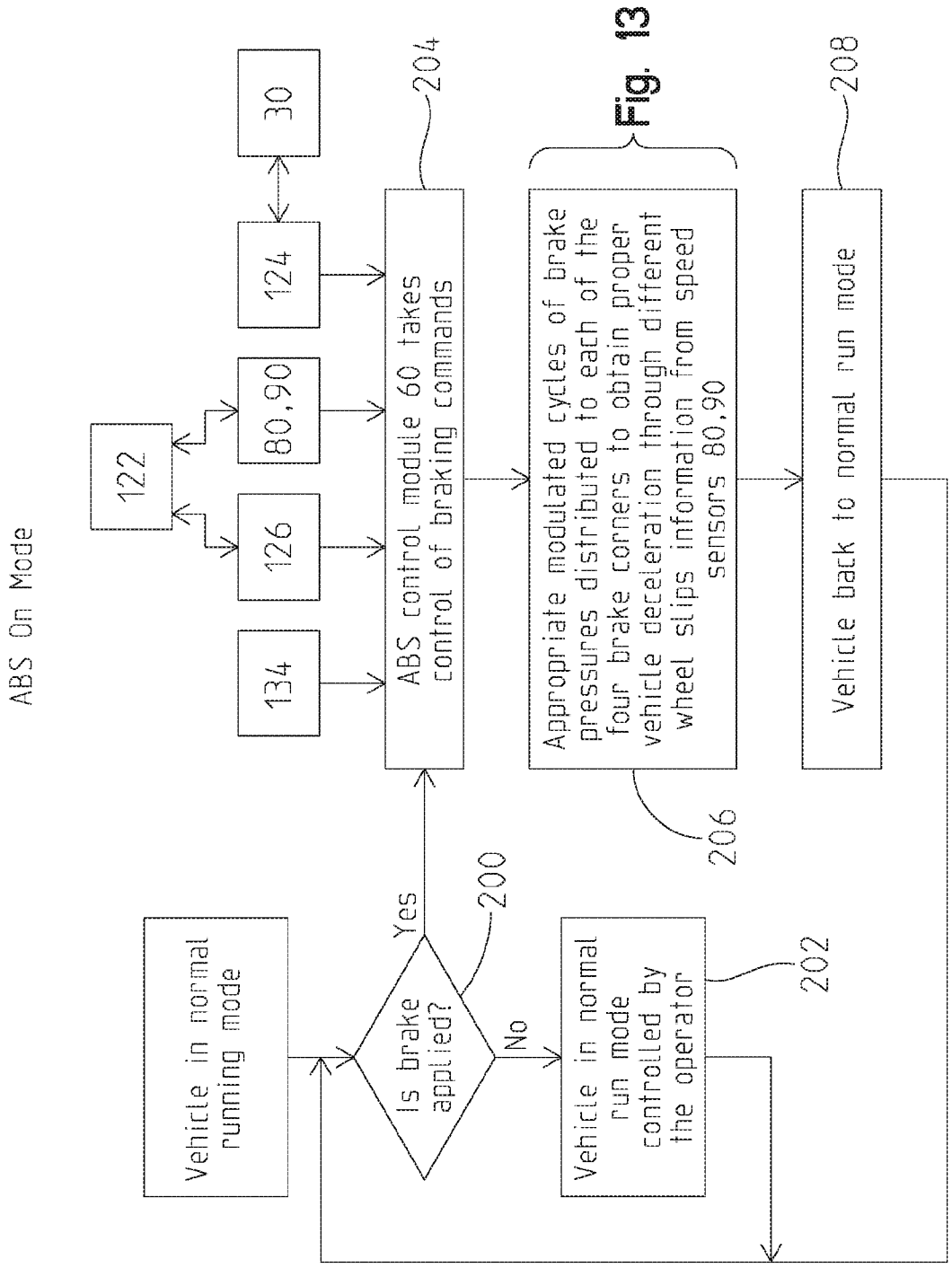

ABS On Mode
Vehicle in normal running mode
Is brake applied?
Yes
No
200
Vehicle in normal run mode controlled by the operator
202
ABS control module 60 takes control of braking commands
204
122
134
126
80,90
124
30
Appropriate modulated cycles of brake pressures distributed to each of the four brake corners to obtain proper vehicle deceleration through different wheel slips information from speed sensors 80,90
206
Vehicle back to normal run mode
208

Fig. 11

Fig. 13

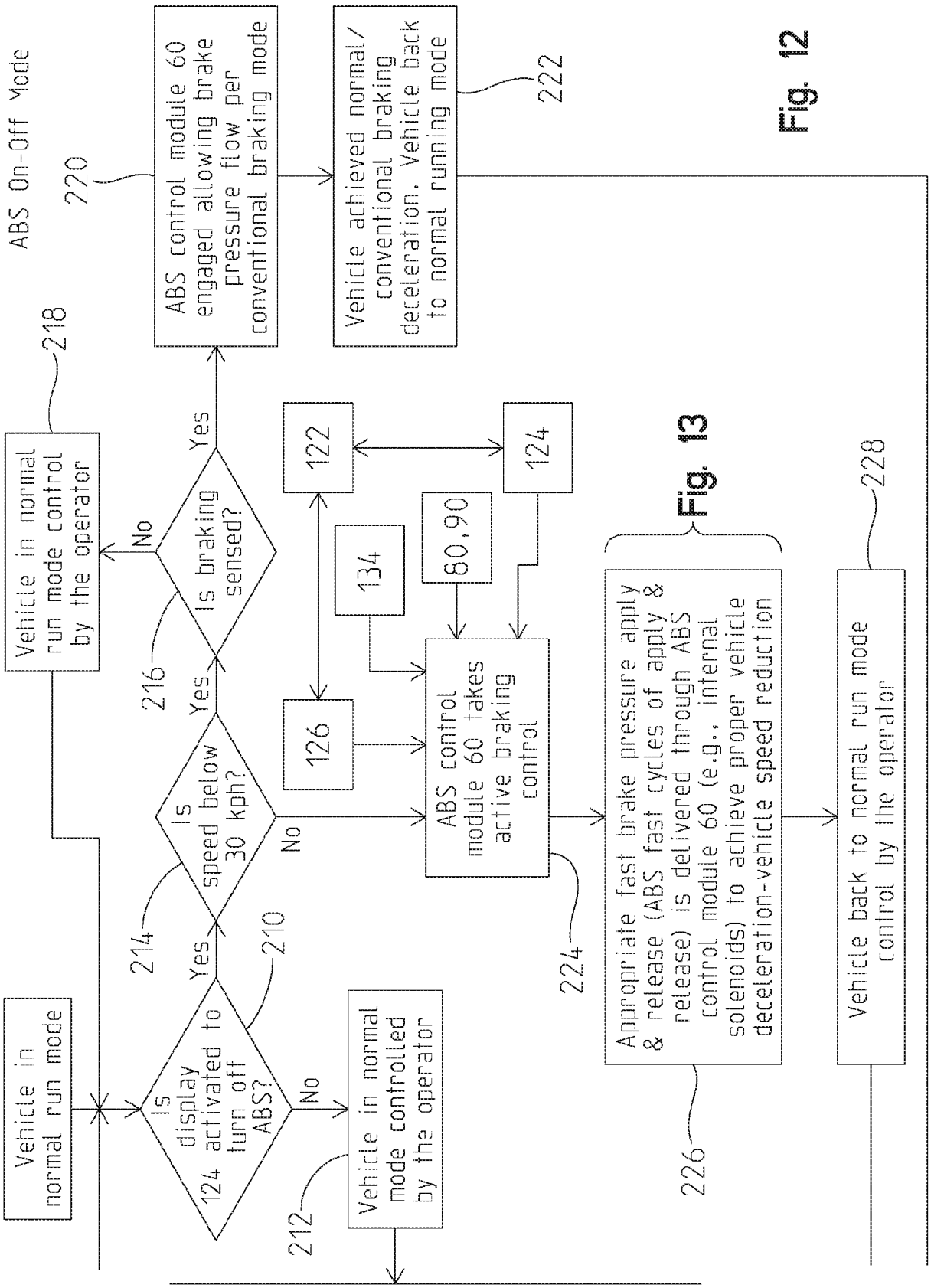

ABS On-Off Mode
220
ABS control module 60 engaged allowing brake pressure flow per conventional braking mode
222
Vehicle achieved normal/ conventional braking deceleration. Vehicle back to normal running mode
218
Vehicle in normal run mode control by the operator
Is braking sensed?
No
Yes
216
122
124
134
80,90
126
Is speed below 30 kph?
Yes
No
214
ABS control module 60 takes active braking control
224
Appropriate fast brake pressure apply & release (ABS fast cycles of apply & release) is delivered through ABS control module 60 (e.g., internal solenoids) to achieve proper vehicle deceleration-vehicle speed reduction
226
228
Vehicle back to normal run mode control by the operator
Vehicle in normal run mode
Is display 124 activated to turn off ABS?
Yes
No
210
212
Vehicle in normal mode controlled by the operator

Fig. 12

Fig. 13

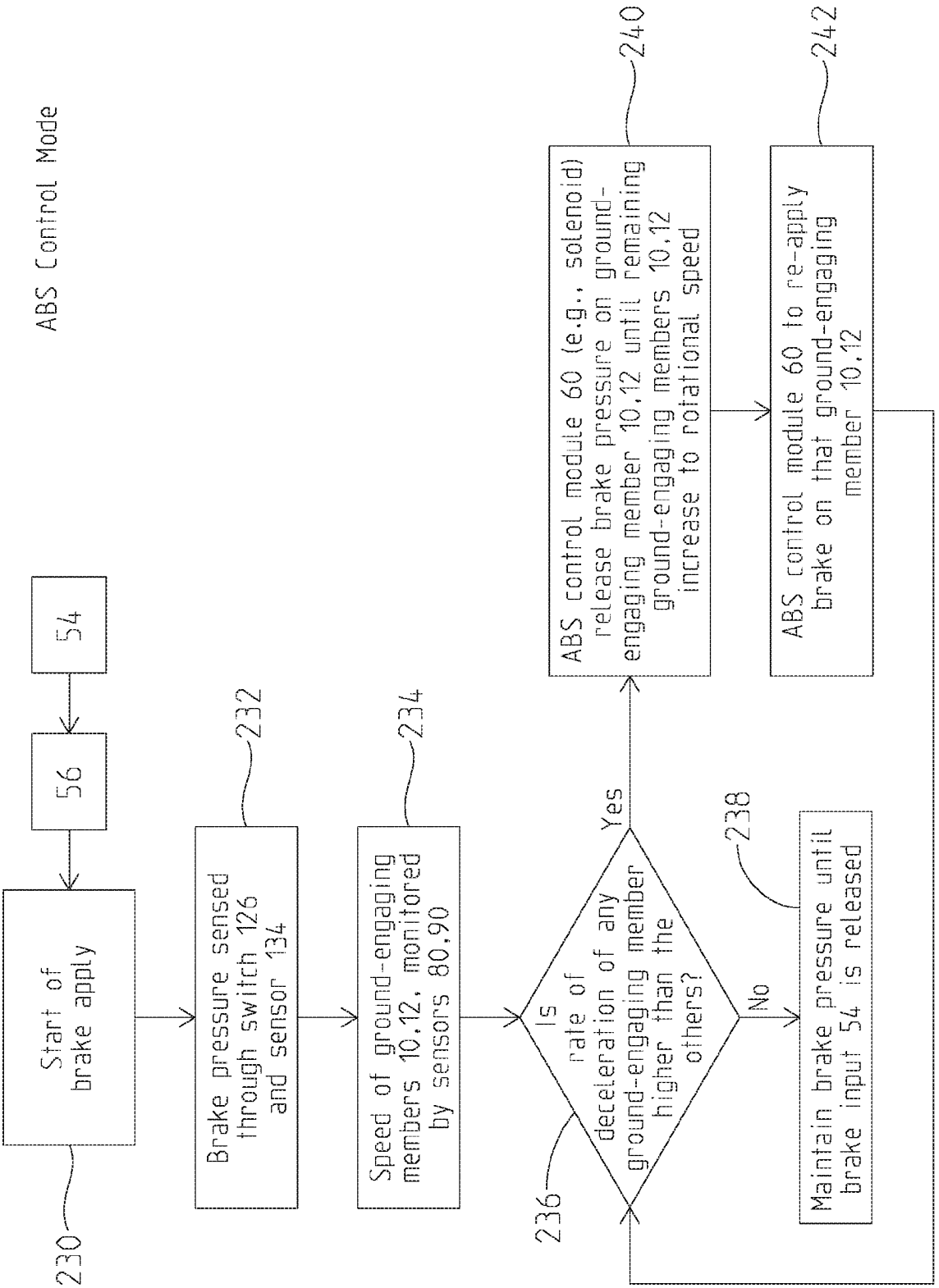

ABS Control Mode
54
56
Start of brake apply
230
Brake pressure sensed through switch 126 and sensor 134
232
Speed of ground-engaging members 10,12, monitored by sensors 80,90
234
Is rate of deceleration of any ground-engaging member higher than the others?
236
Yes
No
238
ABS control module 60 (e.g., solenoid) release brake pressure on ground-engaging member 10,12 until remaining ground-engaging members 10,12 increase to rotational speed
240
ABS control module 60 to re-apply brake on that ground-engaging member 10,12
242
Maintain brake pressure until brake input 54 is released

Fig. 13

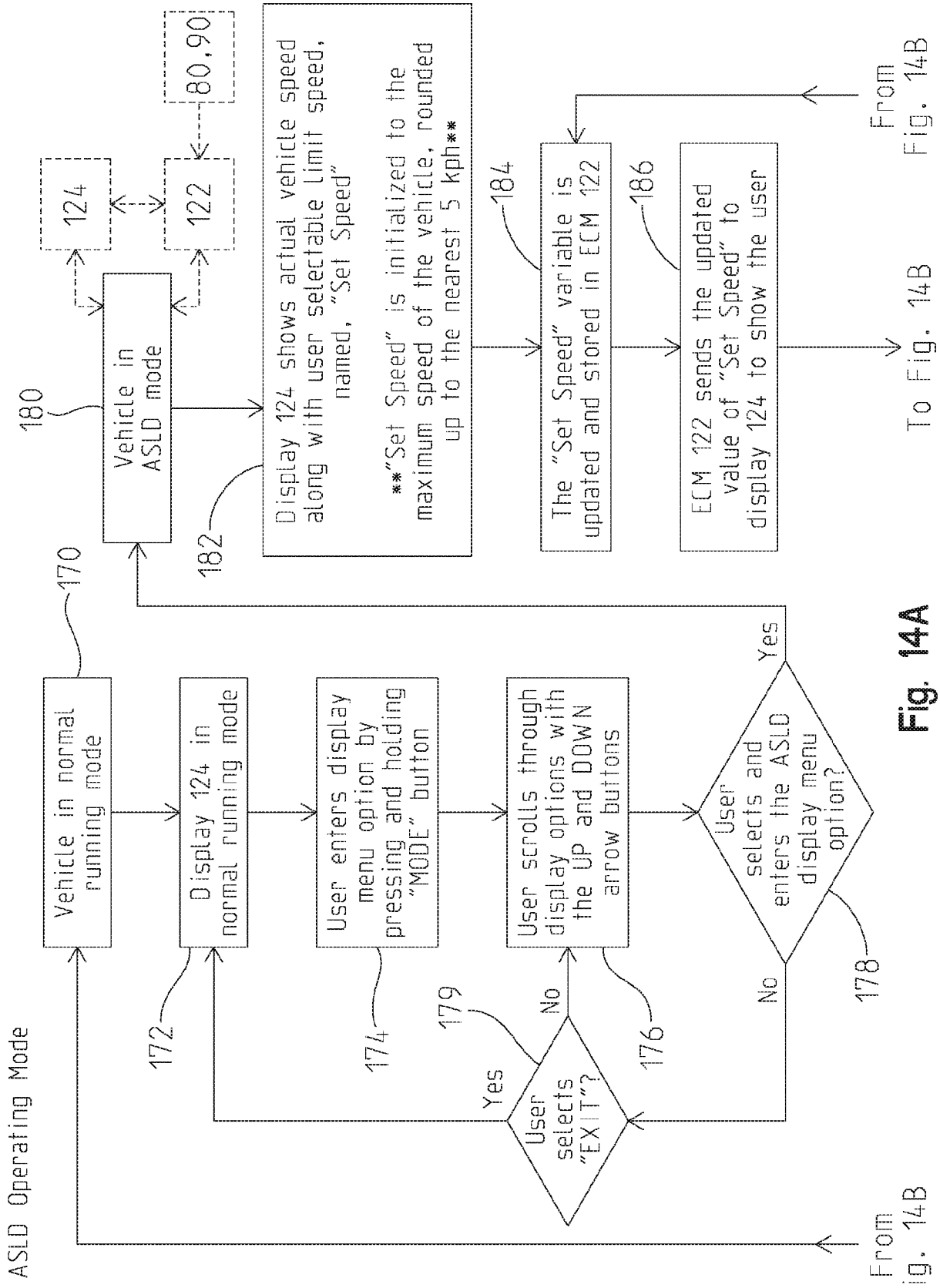

ASLD Operating Mode
From Fig. 14B
Vehicle in normal running mode
Display 124 in normal running mode
User enters display menu option by pressing and holding "MODE" button
User scrolls through display options with the UP and DOWN arrow buttons
User selects and enters the ASLD display menu option?
User selects "EXIT"?
Yes
No
Yes
No
170
172
174
176
178
179
180
Vehicle in ASLD mode
124
122
80,90
182
Display 124 shows actual vehicle speed along with user selectable limit speed, named, "Set Speed"
"Set Speed" is initialized to the maximum speed of the vehicle, rounded up to the nearest 5 kph
184
The "Set Speed" variable is updated and stored in ECM 122
186
ECM 122 sends the updated value of "Set Speed" to display 124 to show the user
To Fig. 14B
From Fig. 14B

Fig. 14A

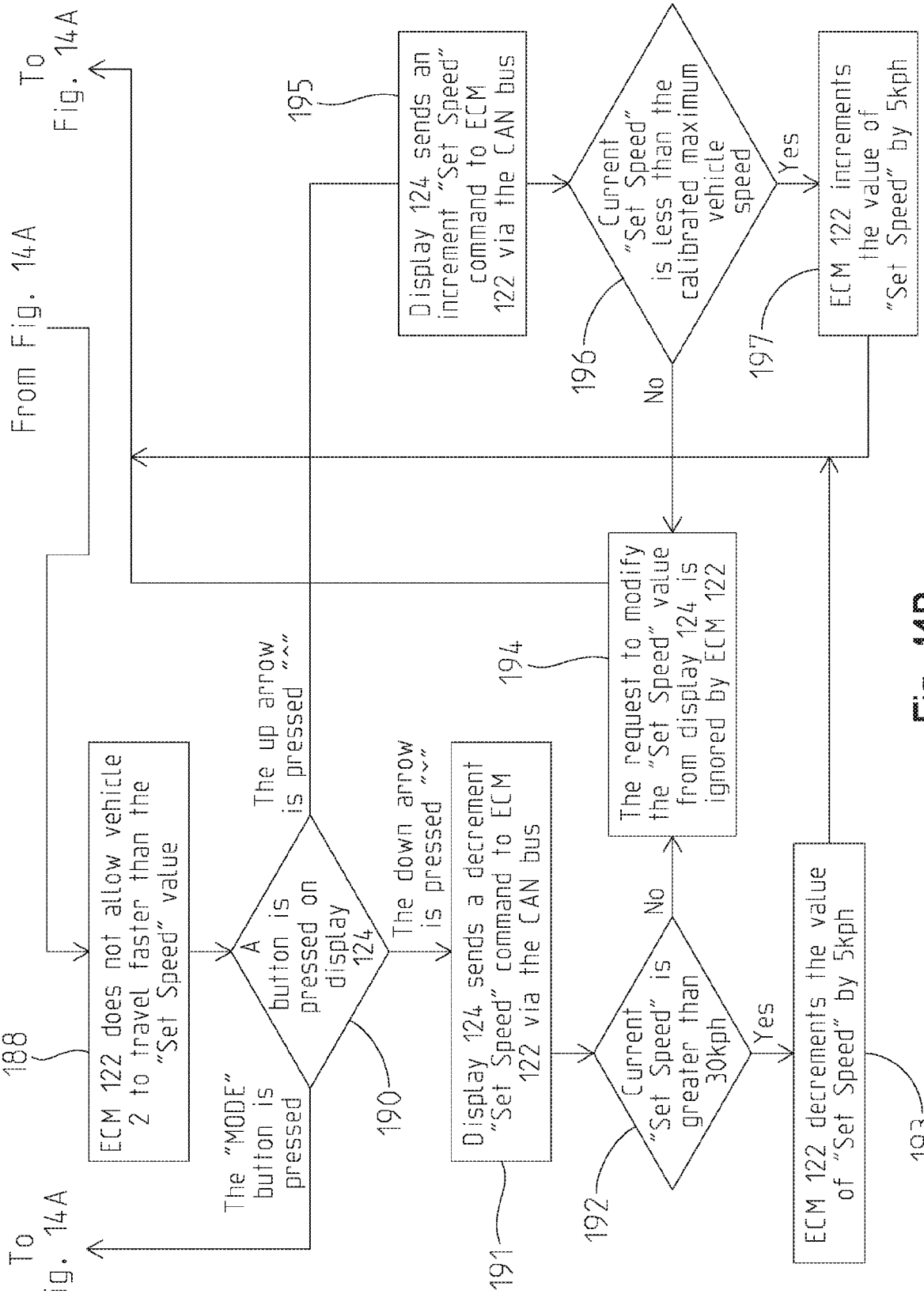

From Fig. 14A
To Fig. 14A
To Fig. 14A
188
ECM 122 does not allow vehicle 2 to travel faster than the "Set Speed" value
A button is pressed on display 124
190
The "MODE" button is pressed
The up arrow is pressed "^"
The down arrow is pressed "v"
191
Display 124 sends a decrement "Set Speed" command to ECM 122 via the CAN bus
192
Current "Set Speed" is greater than 30kph
No
Yes
193
ECM 122 decrements the value of "Set Speed" by 5kph
194
The request to modify the "Set Speed" value from display 124 is ignored by ECM 122
195
Display 124 sends an increment "Set Speed" command to ECM 122 via the CAN bus
196
Current "Set Speed" is less than the calibrated maximum vehicle speed
No
Yes
197
ECM 122 increments the value of "Set Speed" by 5kph

Fig. 14B

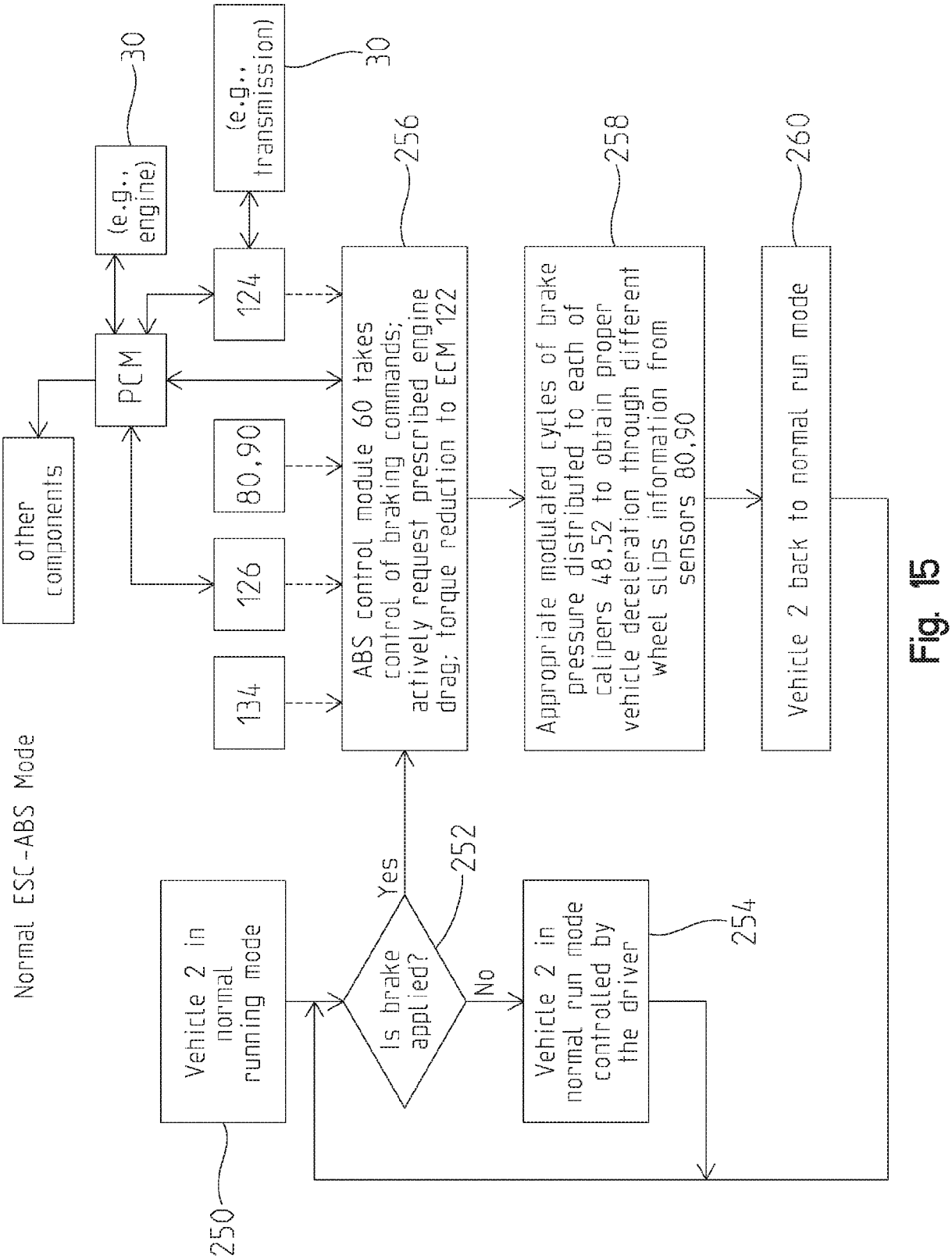

Normal ESC-ABS Mode
Vehicle 2 in normal running mode
250
Is brake applied?
252
Yes
No
Vehicle 2 in normal run mode controlled by the driver
254
ABS control module 60 takes control of braking commands; actively request prescribed engine drag; torque reduction to ECM 122
256
Appropriate modulated cycles of brake pressure distributed to each of calipers 48,52 to obtain proper vehicle deceleration through different wheel slips information from sensors 80,90
258
Vehicle 2 back to normal run mode
260
PCM
other components
134
126
80,90
124
(e.g., engine)
30
(e.g., transmission)
30

Fig. 15

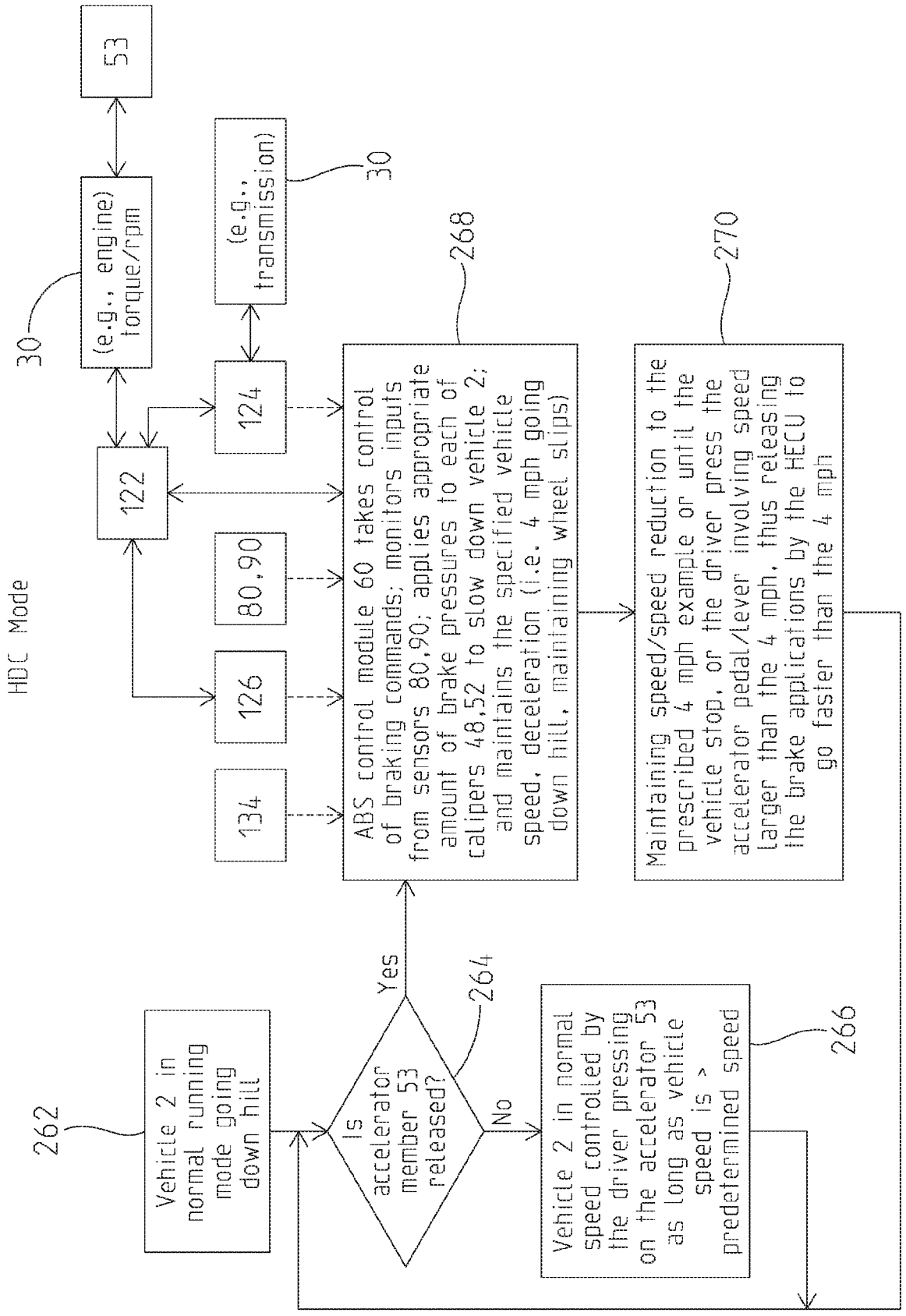

HDC Mode
262
Vehicle 2 in normal running mode going down hill
264
Is accelerator member 53 released?
Yes
No
266
Vehicle 2 in normal speed controlled by the driver pressing on the accelerator 53 as long as vehicle speed is > predetermined speed
268
ABS control module 60 takes control of braking commands; monitors inputs from sensors 80,90; applies appropriate amount of brake pressures to each of calipers 48,52 to slow down vehicle 2; and maintains the specified vehicle speed, deceleration (i.e. 4 mph going down hill, maintaining wheel slips)
270
Maintaining speed/speed reduction to the prescribed 4 mph example or until the vehicle stop, or the driver press the accelerator pedal/lever involving speed larger than the 4 mph, thus releasing the brake applications by the HECU to go faster than the 4 mph
122
124
126
134
80,90
30
(e.g., engine) torque/rpm
30
(e.g., transmission)
53

Fig. 16

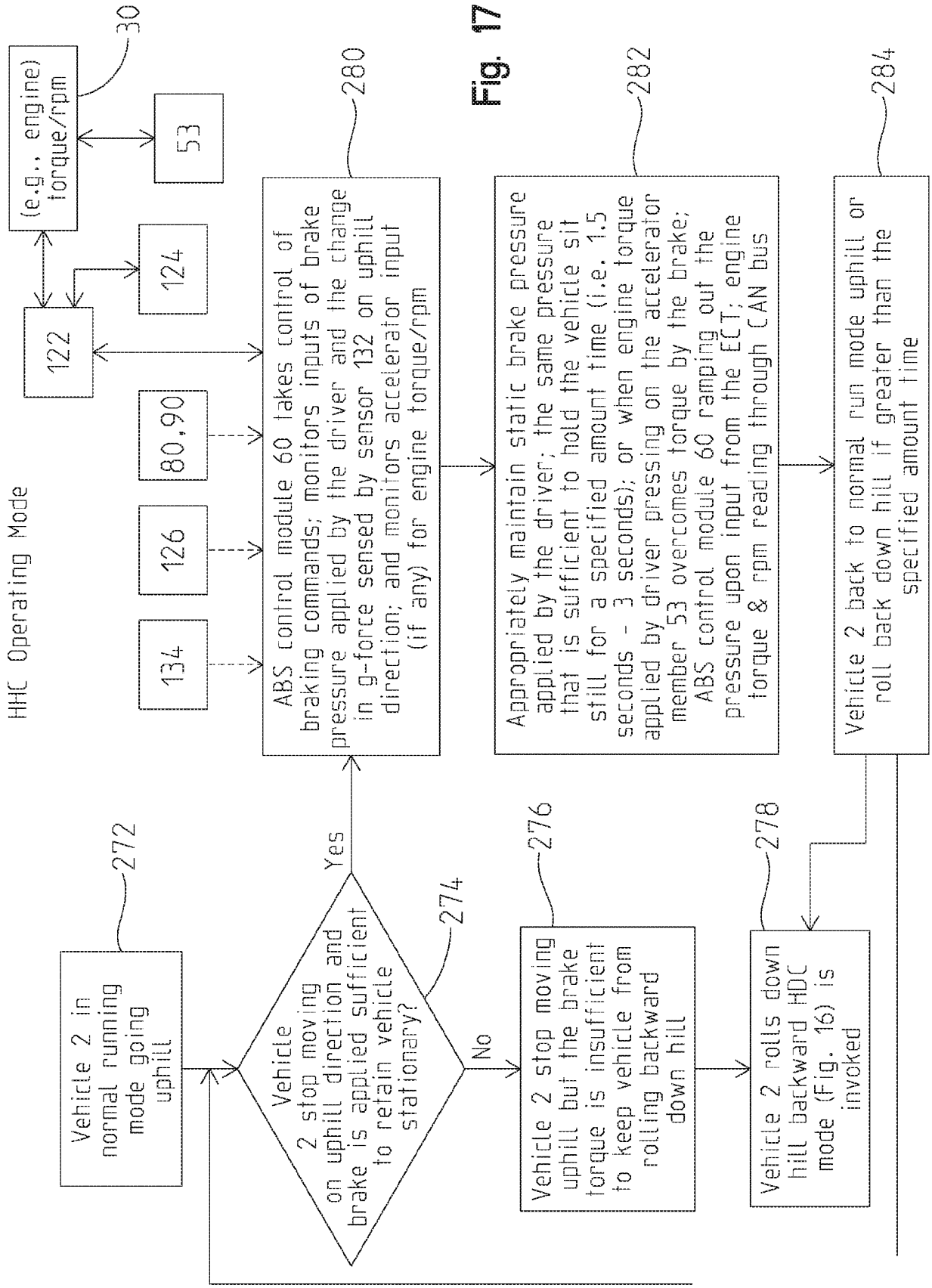

HHC Operating Mode
Vehicle 2 in normal running mode going uphill
272
Vehicle 2 stop moving on uphill direction and brake is applied sufficient to retain vehicle stationary?
274
Yes
No
ABS control module 60 takes control of braking commands; monitors inputs of brake pressure applied by the driver and the change in g-force sensed by sensor 132 on uphill direction; and monitors accelerator input (if any) for engine torque/rpm
280
Appropriately maintain static brake pressure applied by the driver; the same pressure that is sufficient to hold the vehicle sit still for a specified amount time (i.e. 1.5 seconds - 3 seconds); or when engine torque applied by driver pressing on the accelerator member 53 overcomes torque by the brake; ABS control module 60 ramping out the pressure upon input from the ECT; engine torque & rpm reading through CAN bus
282
Vehicle 2 back to normal run mode uphill or roll back down hill if greater than the specified amount time
284
Vehicle 2 stop moving uphill but the brake torque is insufficient to keep vehicle from rolling backward down hill
276
Vehicle 2 rolls down hill backward HDC mode (Fig. 16) is invoked
278
(e.g., engine) torque/rpm
30
53
122
124
80,90
126
134

Fig. 17

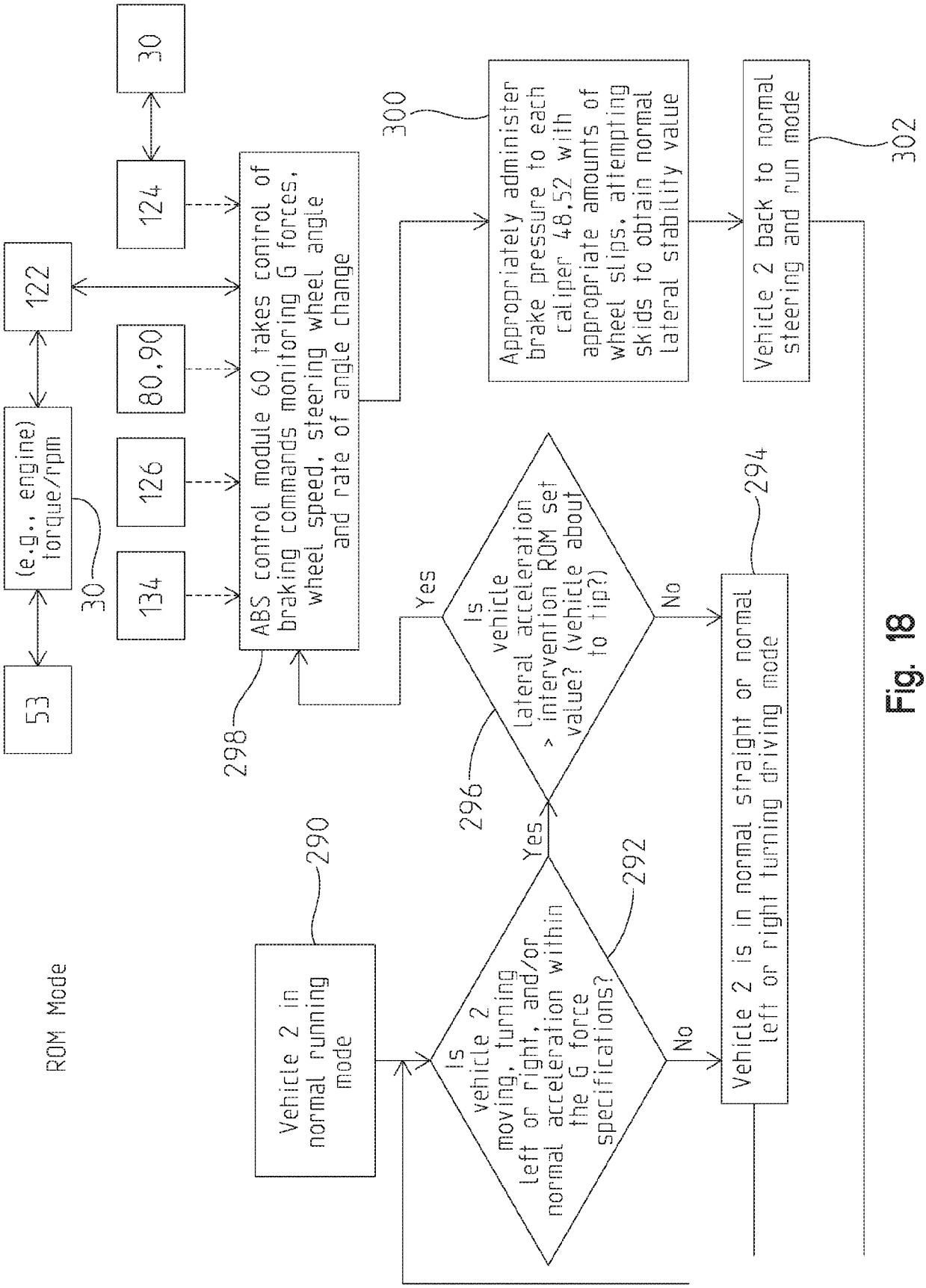

ROM Mode
Vehicle 2 in normal running mode
290
Is vehicle 2 moving, turning Left or right, and/or normal acceleration within the G force specifications?
292
Yes
No
Is vehicle lateral acceleration > intervention ROM set value? (vehicle about to tip?)
296
Yes
No
294
Vehicle 2 is in normal straight or normal left or right turning driving mode
ABS control module 60 takes control of braking commands monitoring G forces, wheel speed, steering wheel angle and rate of angle change
298
Appropriately administer brake pressure to each caliper 48,52 with appropriate amounts of wheel slips, attempting skids to obtain normal lateral stability value
300
Vehicle 2 back to normal steering and run mode
302
53
(e.g., engine) torque/rpm
30
134
126
80,90
124
122
30

Fig. 18

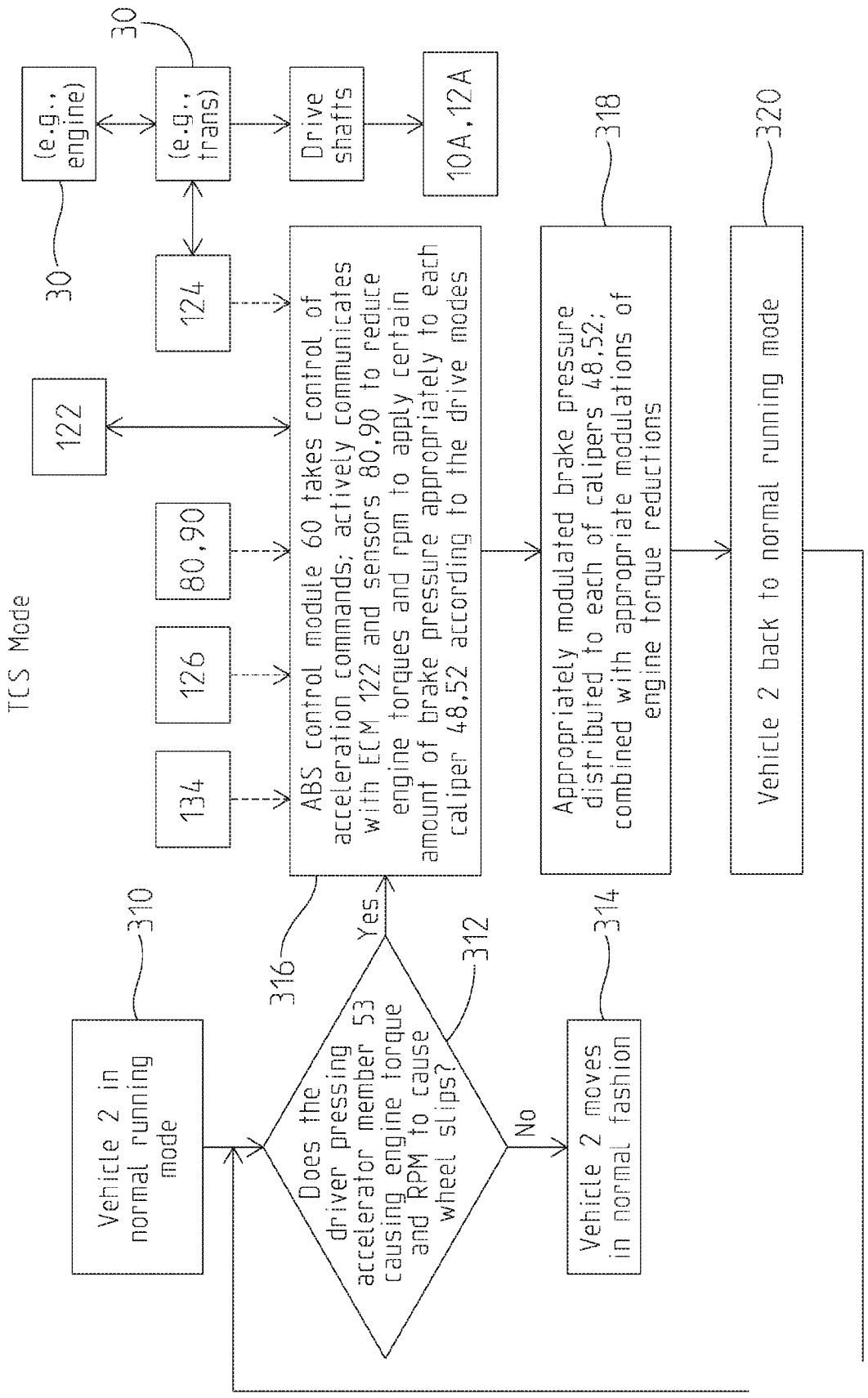

TCS Mode
Vehicle 2 in normal running mode
310
Does the driver pressing accelerator member 53 causing engine torque and RPM to cause wheel slips?
312
Yes
No
316
Vehicle 2 moves in normal fashion
314
ABS control module 60 takes control of acceleration commands; actively communicates with ECM 122 and sensors 80,90 to reduce engine torques and rpm to apply certain amount of brake pressure appropriately to each caliper 48,52 according to the drive modes
Appropriately modulated brake pressure distributed to each of calipers 48,52; combined with appropriate modulations of engine torque reductions
318
Vehicle 2 back to normal running mode
320
134
126
80,90
122
124
30
(e.g., engine)
30
(e.g., trans)
Drive shafts
10A,12A

Fig. 19

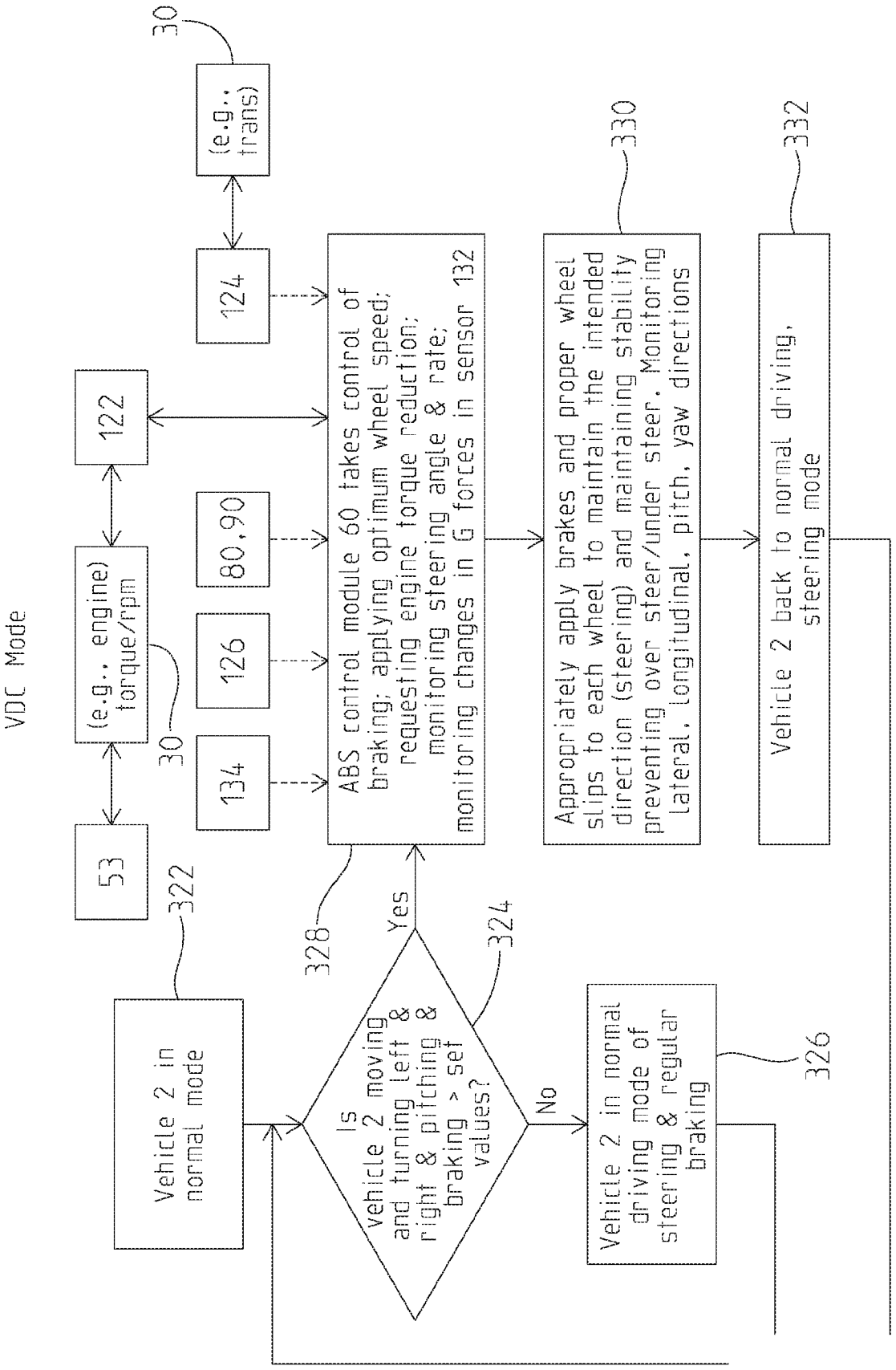

VDC Mode
Vehicle 2 in normal mode
322
Is vehicle 2 moving and turning left & right & pitching & braking > set values?
324
Yes
No
328
ABS control module 60 takes control of braking; applying optimum wheel speed; requesting engine torque reduction; monitoring steering angle & rate; monitoring changes in G forces in sensor 132
Appropriately apply brakes and proper wheel slips to each wheel to maintain the intended direction (steering) and maintaining stability preventing over steer/under steer. Monitoring lateral, longitudinal, pitch, yaw directions
330
Vehicle 2 back to normal driving, steering mode
332
Vehicle 2 in normal driving mode of steering & regular braking
326
53
(e.g., engine) torque/rpm
30
122
124
(e.g., trans)
30
134
126
80,90

Fig. 20

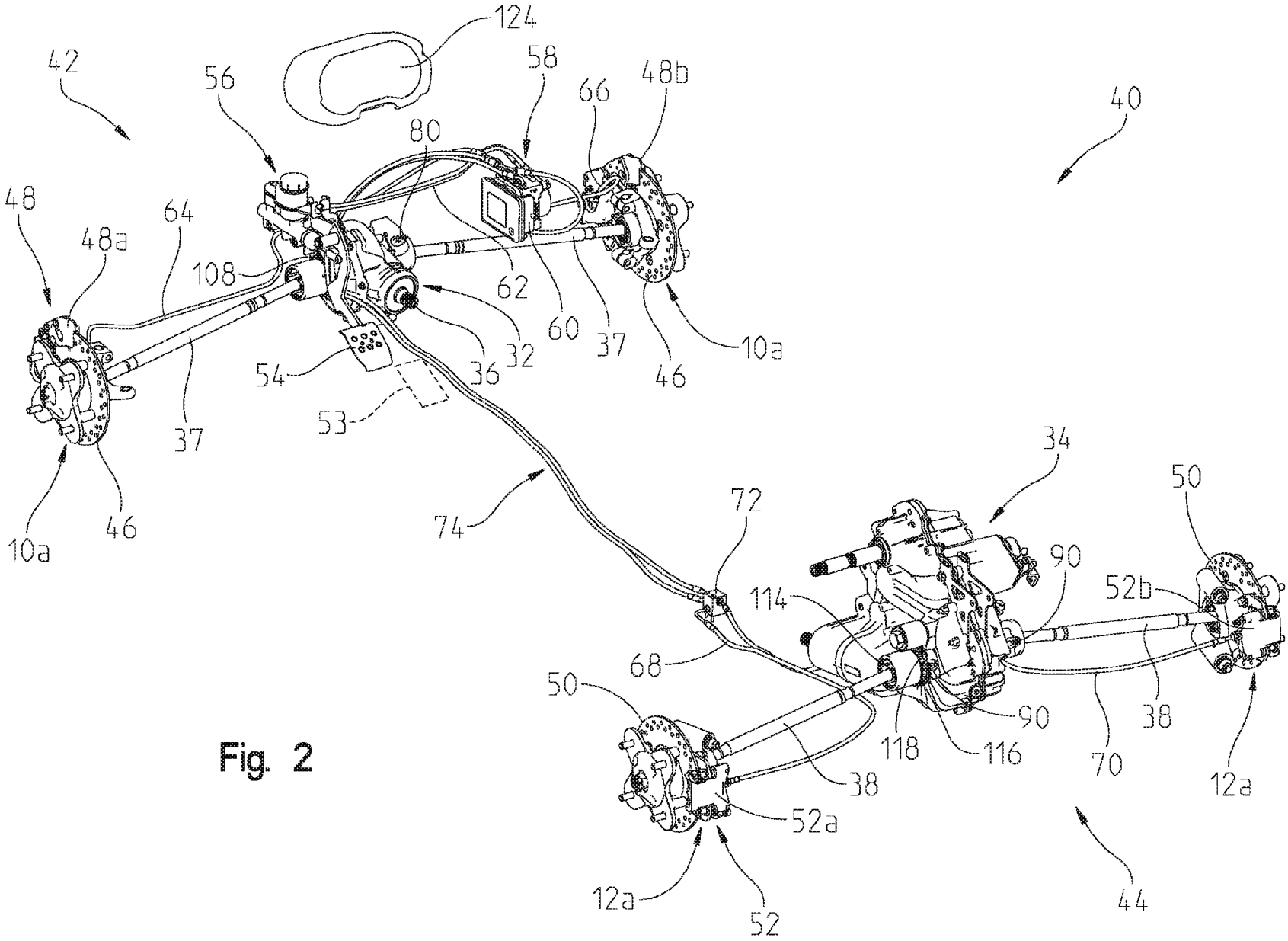

124
42
56
58
66
48b
40
80
48
64
48a
108
62
60
37
32
36
54
53
46
10a
37
10a
46
74
72
34
50
90
114
52b
68
50
118
116
90
38
70
38
12a
52a
12a
52
44

Fig. 2