



(51) International Patent Classification:

B62D 5/04 (2006.01) **B62D 7/14** (2006.01)

(21) International Application Number:

PCT/EP2017/075069

(22) International Filing Date:

03 October 2017 (03.10.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1616968.2 06 October 2016 (06.10.2016) GB
1616966.6 06 October 2016 (06.10.2016) GB

(71) Applicant: **JAGUAR LAND ROVER LIMITED**
[GB/GB]; Abbey Road Whitley, Coventry Warwickshire
CV3 4LF (GB).

(72) Inventors: **GREENWOOD, Jeremy**; c/o Jaguar Land
Rover, Patents Department W/1/073 Abbey Road, Whitley,
Coventry Warwickshire CV3 4LF (GB). **LESBIREL, Rob-
bie**; c/o Jaguar Land Rover, Patents Department W/1/073
Abbey Road, Whitley, Coventry Warwickshire CV3 4LF
(GB).

(74) Agent: **LOCKEY, Robert**; Jaguar Land Rover, Patents
Department W/1/073 Abbey Road, Whitley, Coventry War-
wickshire CV3 4LF (GB).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

(54) Title: STEERING SYSTEM

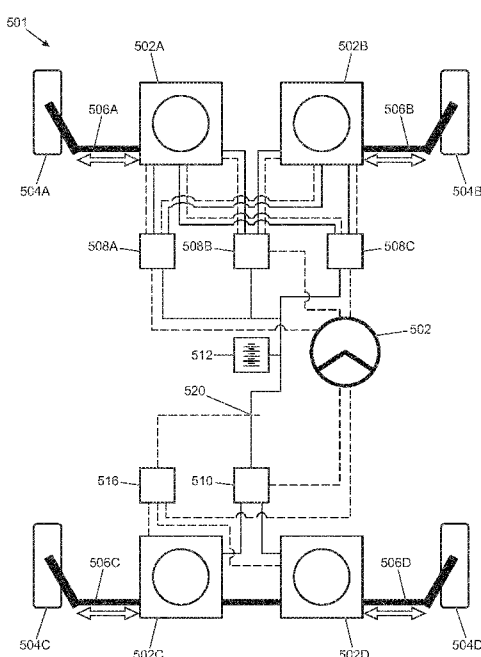


Figure 5

(57) Abstract: Embodiments of the present invention provide steering systems for vehicles (500) in which the wheels (204A, 204B, 204C, 204D, 504A, 504B, 504C, 504D, 604A, 604B, 604C, 604D) on both the front and rear axles are steered by electrical actuators (202A, 202B, 202C, 202D, 502A, 502B, 502C, 502D, 602A, 602B, 602C, 602D) under the control of controllers (208, 210, 508A, 508B, 508C, 510, 608A, 508B, 608C, 640). A watchdog controller (214, 216, 516, 642) is provided to detect error states in the actuators and/or the controllers, and the system (200, 501, 601) is arranged to provide steering by the wheels on only one of the axles if an error state is detected in the controller or actuators associated with the wheels on the other axle.

Published:

— *with international search report (Art. 21(3))*

STEERING SYSTEM

TECHNICAL FIELD

The present disclosure relates to a steering system and particularly, but not exclusively, to a steering control system for a vehicle having a steer-by-wire system. Aspects of the invention relate to a steering control system, to a steering system, to a method, to a controller, to a non-transitory computer-readable medium, to a computer program product, to a processor, and to a vehicle.

BACKGROUND

In conventional wheeled vehicles steering usually is effected by a mechanical connection between a steering wheel which receives steering inputs from the operator of the vehicle and a steering rack which controls the steering position of the road wheels. Power assistance is often provided by electrically or hydraulically powered actuators which generally provide assistive force in dependence on the force provided by the driver. Typically only the front two wheels are steered, although it is also known to steer only the rear wheels or a combination of both the front and rear wheels.

Recently, steer-by-wire systems that do not include a permanent mechanical connection between the steering rack and the steering wheel have been developed. Such systems have the potential to provide significant weight and cost savings as compared to conventional systems, and they may also provide improved crash performance and increased design flexibility regarding steering wheel size and location. This may also provide increased design flexibility regarding the location of other components such as the engine and gearbox, as they may be located in space that was previously required by mechanical steering components. However, the design of steer-by-wire systems for road vehicles must incorporate redundancy, as it is not acceptable for a single failure to have the potential to cause a complete loss of steering. This has led to steer-by-wire systems being provided with duplicate controllers to calculate the required input to the steering actuators and mechanical back-up systems for use in case of a failure of the steering actuators. Such additional components may obviate some or all of the potential advantages that could otherwise be achieved by steer-by-wire systems.

It is an object of embodiments of the invention to at least mitigate one or more of the problems of the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a steering control system, a steering system, a controller, a method, a computer program product, a non-transitory computer readable medium, a processor and a vehicle as claimed in the appended claims.

5

According to an aspect of the present invention there is provided a steering control system for a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the steering control system comprising:

10

a first control means operable to control the first actuation means;

a second control means operable to control the second actuation means; and

15

a watchdog control means operable to inhibit control of the first actuation means by the first control means upon detection of an error state in the first control means and/or the first actuation means. The watchdog control means may be configured to inhibit control of the second actuation means by the second control means upon detection of an error state in the second control means and/or the second actuation means. Such a system is able to provide steering on two separate axles of a vehicle, wherein the steering components on each axle provide redundancy so that steering of the vehicle can be maintained in the event of a failure of the steering components on the other axle. This may facilitate provision of a steer-by-wire system in which mechanical connection between the steering wheel and the steering racks is not required.

20

In an embodiment the first group of wheels is a group of rear wheels and the second group of wheels is a group of front wheels. Optionally, the second control means is operable to communicate with a user input means and the first control means,

25

the second control means being operable to produce a first control signal indicative of a steering contribution required to be provided by the first group of wheels and a second control signal indicative of an amount of current to be sent to the second actuation means,

30

wherein the first control means is operable to produce a third signal indicative of an amount of current to be sent to the first actuation means in dependence on said first signal. Advantageously, such a system may have improved modularity, as the second control means may be operable as part of a system for a vehicle having only one group of steered wheels.

35

Optionally, the system further comprises a first low-level control means and a second low-level control means,

wherein:

the first low-level control means is configured to receive the third signal and to provide a drive current to the first actuation means in dependence on the third signal; and

the second low-level control means is configured to receive the second signal and to provide a drive current to the second actuation means in dependence on the second signal.

In an embodiment the second control means is operable to receive a second signal indicative of an error state having been detected in the first control means and/or the first actuation means, wherein the second control means is operable to adjust at least one control parameter used in the control of the second actuation means in dependence on receipt of said second signal. Advantageously, this allows the second control means to control the second actuator and the second group of wheels compensate for the loss of steering of the first group of wheels.

15

In an embodiment the first control means is operable to receive a first signal indicative of an error state having been detected in the second control means and/or the second actuation means, wherein the first control means is operable to adjust at least one control parameter used in the control of the first actuation means in dependence on receipt of said first signal. Advantageously, this allows the first control means to control the first actuator and the first group of wheels compensate for the loss of steering of the second group of wheels.

20

Optionally, the watchdog control means comprises input means configured to receive a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means, the watchdog control means being operable to detect said error state in the first control means and/or the first actuation means in dependence on the first and second inputs. The watchdog control means may comprise input means configured to receive third input indicative of an output of the second actuation means, the watchdog control means being operable to detect said error state in the second control means and/or the second actuation means in dependence on the first and third inputs. The watchdog control means may calculate an expected range of outputs for the first and second control means based on the driver steering input, and may determine that an error state has occurred if the output of the output of either of the first and second controllers does not fall within the expected range.

25

30

35

In an embodiment the watchdog control means is configured to perform a forced reset of the first control means in response to said detection of an error state in the first control means

and/or the first actuation means. Optionally, the watchdog control means is configured to allow control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset. This may allow the system to resume normal operation if simply resetting the controller corrects the error state.

In an embodiment the watchdog control means is configured to perform a forced reset of the second control means in response to said detection of an error state in the second control means and/or the second actuation means. Optionally, the watchdog control means is configured to allow control of the second actuation means by the second control means in response to a determination that the error state has been corrected by said forced reset. This may allow the system to resume normal operation if simply resetting the controller corrects the error state.

Optionally, the watchdog control means is operable to cause a warning to be issued to a driver of the vehicle upon said detection of an error state in the first control means and/or the first actuation means. This may ensure that the driver is aware that the capabilities of the vehicle are limited. The warning may instruct the driver to drive the vehicle to a safe location and then to stop the vehicle.

Optionally, the watchdog control means is operable to cause a warning to be issued to a driver of the vehicle upon said detection of an error state in the second control means and/or the second actuation means. This may ensure that the driver is aware that the capabilities of the vehicle are limited. The warning may instruct the driver to drive the vehicle to a safe location and then to stop the vehicle.

Optionally, the watchdog control means is operable to cause performance of the vehicle to be limited upon said detection of an error state in the first control means and/or the first actuation means. For example, the speed of the vehicle may be limited. This may increase a likelihood that the driver will drive the vehicle to a safe location and then stop driving the vehicle when an error state is detected.

Optionally, the watchdog control means is operable to cause performance of the vehicle to be limited upon said detection of an error state in the second control means and/or the second actuation means. For example, the speed of the vehicle may be limited. This may increase a likelihood that the driver will drive the vehicle to a safe location and then stop driving the vehicle when an error state is detected.

In an embodiment the watchdog control means is operable to cause an externally visible warning to be issued upon said detection of an error state in the first control means and/or the first actuation means. This may warn other road users that the vehicle has reduced capabilities.

In an embodiment the watchdog control means is operable to cause an externally visible warning to be issued upon said detection of an error state in the second control means and/or the second actuation means. This may warn other road users that the vehicle has reduced capabilities.

Optionally, inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means. Advantageously, this ensures that control of the first actuation means by the first control means is impossible once an error state has been detected by the watchdog control means.

Optionally, inhibiting control of the second actuation means by the second control means comprises interrupting a supply of electrical power to the second control means. Advantageously, this ensures that control of the second actuation means by the second control means is impossible once an error state has been detected by the watchdog control means.

According to another aspect of the invention for which protection is sought there is provided a watchdog control for a steering control system for a vehicle having a steer-by-wire system, the watchdog control operable to inhibit control of a first actuation means by a first control means upon detection of an error state in the first control means and/or the first actuation means, and to inhibit control of a second actuation means by a second control means upon detection of an error state in the second control means and/or the second actuation means.

According to yet another aspect of the invention there is provided a steer-by-wire system and a vehicle having a steer-by-wire system comprising, a watchdog control for a steering control system operable to inhibit control of a first actuation means by a first control means upon detection of an error in at least one of the first control means and/or the first actuation means, and a redundant control means comprising two or more controllers to calculate the required input to a second actuation means. Optionally the first actuation means steers the rear wheels of the vehicle and the second actuation means steers the front wheels of the vehicle.

Redundant control of a steer by wire system is known and may be appropriate for the front wheels of a four wheel steering vehicle which normally provide more steering angle than the rear wheels. In the event of a failure in one of the redundant systems the remaining systems would allow the front wheels to steer normally. In contrast, the rear wheels are likely to steer to a lesser angle and a failure of rear steering is less critical. It is therefore appropriate that the rear wheel steering may be managed by a watchdog which inhibits control of the rear steering in the event of a control system failure. In the event of a rear steering failure the front steering may adapt its response to compensate, for example by increasing the front steering angle for a given steering wheel input.

According to another aspect of the invention for which protection is sought there is provided a steer-by-wire system for a vehicle, the system comprising:

- a first electrically controlled steering actuation means operable to steer a first group of one or more wheels;

- a second electrically controlled steering actuation means operable to steer a second group of one or more wheels; and

- a steering control system as described above.

Optionally, the steer-by-wire system comprises a first biasing means operable to move the first group of wheels to a predetermined position in response to the detection of an error state in the first control means and/or the first actuation means. The predetermined position may correspond to the position of the wheels when the vehicle is driving straight ahead. Advantageously, this may simplify steering with the second group of wheels when steering with the first group of wheels is inhibited.

Optionally, the steer-by-wire system comprises a second biasing means operable to move the second group of wheels to a predetermined position in response to the detection of an error state in the second control means and/or the second actuation means. The predetermined position may correspond to the position of the wheels when the vehicle is driving straight ahead. Advantageously, this may simplify steering with the first group of wheels when steering with the second group of wheels is inhibited.

In an embodiment said first group of wheels comprises a plurality of wheels and the first actuation means comprises a plurality of actuators, each of said actuators being associated with a respective one of said plurality of wheels. Optionally, said second group of wheels comprises a plurality of wheels and the second actuation means comprises a plurality of

actuators, each of said actuators being associated with a respective one of said plurality of wheels. Advantageously, this facilitates individual control of all of the wheels in a steer-by-wire system.

- 5 According to another aspect of the invention for which protection is sought there is provided a vehicle comprising a steer-by-wire system as described above.

Optionally, said first group of one or more wheels comprises at least two front wheels and said second group of wheels comprises at least two rear wheels.

10

According to another aspect of the invention for which protection is sought there is provided a method of controlling a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second
15 group of one or more wheels, the first actuation means being controlled by a first control means and the second actuation means being controlled by a second control means, the method comprising:

detecting an error state in the first control means and/or the first actuation means and, in response to said detection;

20

inhibiting control of the first actuation means by the first control means; and optionally adjusting at least one control parameter used by the second control means in the control of the second actuation means.

25

According to another aspect of the invention for which protection is sought there is provided a method of controlling a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means (202A, 202B) operable to steer a first group of one or more wheels (204A, 204B) and a second electrically controlled steering actuation means (202C, 202D) operable to steer a second group of one or more wheels (204C, 204D), the first actuation means being controlled by a first control means (208) and the second
30 actuation means being controlled by a second control means (210), the method comprising:

receiving an error signal indicating an error state in the first control means and/or the first actuation means and, in response to said signal;

inhibiting control of the first actuation means by the first control means; and

adjusting at least one control parameter used by the second control means in the

35

control of the second actuation means.

Optionally, the method comprises receiving a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means wherein said detection of an error state in the first control means and/or the first actuation means is performed in dependence on the first and second inputs.

5

In an embodiment the method comprises performing a forced reset of the first control means in response to said detection of an error state in the first control means and/or the first actuation means.

10 In an embodiment the method, comprises allowing control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

Optionally the method comprises issuing a warning to a driver of the vehicle in response to
15 said detection of an error state in the first control means and/or the first actuation means.

Optionally the method comprises limiting performance of the vehicle in response to said detection of an error state in the first control means and/or the first actuation means.

20 In an embodiment the method comprises issuing an externally visible warning in response to said detection of an error state in the first control means and/or the first actuation means.

Optionally inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

25

According to another aspect of the invention for which protection is sought there is provided a computer program product executable on a processor so as to implement a method as described above.

30 According to another aspect of the invention for which protection is sought there is provided a non-transitory computer readable medium carrying computer readable code which when executed by a computer causes a vehicle to carry out the method described above.

According to another aspect of the invention for which protection is sought there is provided
35 a processor arranged to implement the method or the computer program product described above.

According to an aspect of the present invention there is provided a steering control system for a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the steering control system comprising:

a first control means operable to control the first actuation means;

a second control means operable to control the second actuation means, the second control means comprising a redundant control means comprising two or more controllers to calculate the required input to a second actuation means; and

a watchdog control means operable to inhibit control of the first actuation means by the first control means upon detection of an error state in the first control means and/or the first actuation means.

Optionally the second control means is operable to receive a signal indicative of an error state having been detected in the first control means and/or the first actuation means, wherein the second control means is operable to adjust at least one control parameter used in the control of the second actuation means in dependence on receipt of said first signal.

Optionally the watchdog control means comprises input means configured to receive a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means, the watchdog control means being operable to detect said error state in the first control means and/or the first actuation means in dependence on the first and second inputs.

Optionally the watchdog control means is configured to perform a forced reset of the first control means in response to said detection of an error state in the first control means and/or the first actuation means.

Optionally the watchdog control means is configured to allow control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

Optionally the watchdog control means is operable to cause a warning to be issued to a driver of the vehicle upon said detection of an error state in the first control means and/or the first actuation means.

Optionally the watchdog control means is operable to cause performance of the vehicle to be limited upon said detection of an error state in the first control means and/or the first actuation means.

- 5 Optionally the watchdog control means is operable to cause an externally visible warning to be issued upon said detection of an error state in the first control means and/or the first actuation means.

10 Optionally inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

15 According to another aspect of the present invention there is provided a watchdog control for a steering control system for a vehicle having a steer-by-wire system, the watchdog control operable to inhibit control of a first actuation means by a first control means upon detection of an error state in the first control means and/or the first actuation means.

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

20 a first electrically controlled steering actuation means operable to steer a first group of one or more wheels;

a second electrically controlled steering actuation means operable to steer a second group of one or more wheels; and

a steering control system and/or a watchdog control as claimed in any preceding claim.

25

Optionally the steer-by-wire system comprises a first biasing means operable to move the first group of wheels to a predetermined position in response to the detection of an error state in the first control means and/or the first actuation means.

- 30 Optionally said first group of wheels comprises a plurality of wheels and the first actuation means comprises a plurality of actuators, each of said actuators being associated with a respective one of said plurality of wheels.

35 According to an aspect of the present invention there is provided a vehicle comprising a steer-by-wire system.

Optionally said first group of one or more wheels comprises at least two rear wheels and said second group of wheels comprises at least two front wheels.

According to an aspect of the present invention there is provided a method of controlling a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means (202A, 202B) operable to steer a first group of one or more wheels (204A, 204B) and a second electrically controlled steering actuation means (202C, 202D) operable to steer a second group of one or more wheels (204C, 204D), the first actuation means being controlled by a first control means (208) and the second actuation means being controlled by a second control means (210), the method comprising:

detecting an error state or receiving an error signal indicating an error state in the first control means and/or the first actuation means and, in response to said detection or said error signal;

inhibiting control of the first actuation means by the first control means; and

adjusting at least one control parameter used by the second control means in the control of the second actuation means.

Optionally the method comprises receiving a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means wherein said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means is performed in dependence on the first and second inputs.

Optionally the method comprises performing a forced reset of the first control means in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

Optionally the method, comprises allowing control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

Optionally the method, comprises issuing a warning to a driver of the vehicle in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

Optionally the method, comprises limiting performance of the vehicle in response to said detection of an error state in the first control means and/or the first actuation means.

Optionally the method, comprises issuing an externally visible warning in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

- 5 Optionally inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

It will be understood that the first control means, the second control means and the watchdog control means may each comprise a controller. Such controllers may comprise a
10 processor having access to an electronic memory, for example a non-transitory computer readable medium. As used herein the terms “first control means”, “second control means” and “watchdog control means” will be each understood to include both a single control means or controller and a plurality of control means or controllers collectively operating to provide the stated control functionality for a first control means, a second control means or a
15 watchdog control means.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

30

Figure 1 shows a schematic diagram of a steering system of vehicle having a steer-by-wire system (PRIOR ART);

Figure 2 shows a schematic diagram of a steering system of vehicle having a steer-by-wire system in an embodiment of the present invention;

35 Figure 3 shows a flow chart illustrating the operation of a watchdog controller in an embodiment of the present invention;

Figure 4 shows a vehicle incorporating a system in an embodiment of the present invention;

Figure 5 shows a schematic diagram of a steering system of vehicle having a steer-by-wire system in a second embodiment of the present invention;

and

Figure 6 shows a schematic diagram of a steering system of vehicle having a steer-by-wire system in a further embodiment of the present invention.

DETAILED DESCRIPTION

Figure 1 shows a known a steer-by-wire system 100 in which steering inputs provided via steering wheel 102 are converted into electrical signals by sensor 104 and transmitted to three separate steering controllers 106A, 106B, 106C. Each of the three steering controllers provides a steering input to the motors 108A, 108B, which control the position of the steering rack 110 and therefore the wheels 114A, 114B. Three separate controllers 106A, 106B, 106C are provided so that if one of the controllers fails or produces an incorrect output then the outputs of the remaining two controllers can be used and the output from the dissenting controller can be discarded. In this way, steering loss as a result of a single controller failure is prevented. It will be understood that a majority gate may be provided to ensure that a controller output that differs from the outputs of the other two controllers is ignored by the actuators.

In the event that more than one of the controllers 106A, 106B, 106C, the sensor 104 or one of the motors 108A, 108B fails or detects an error a clutch 112 is closed, thereby mechanically connecting the steering wheel 102 to the steering rack 110 via steering shaft 116, which controls the steering rack 110 by means of a pinion gear (not shown) when the clutch 112 is closed.

The system shown in figure 1 provides sufficient redundancy to ensure that no single failure can result in a complete loss of steering. However, provision of the mechanical backup and separate controllers increases the cost and weight of the system, and may obviate some of the other potential advantages of steer-by-wire systems. The system shown in figure 1 is for a vehicle having only one pair of steerable wheels. If the steering system shown in figure 1 was to be applied to a vehicle having front and rear axle steering then additional controllers and mechanical backup components would be required, which would increase the cost and weight of the system even further.

Figure 2 shows a schematic diagram of a steering system 200 that is operable to individually steer each of the wheels 204A-D via respective electrical steering control actuators 202A-D, and figure 4 illustrates a wheeled vehicle 500 that may incorporate a steering system 200 as

illustrated in figure 2. Vehicle 500 may be powered by a prime mover such as an internal combustion engine or an electric machine. In some embodiments the vehicle may be a hybrid vehicle powered by a combination of a combustion engine and an electric machine.

5 In the embodiment shown in figure 2 the electrical steering control actuators 202A-D are electric motors having pinion gears operable to move the respective steering racks 206A-D, thereby to change the angle of the wheels 204A-D. However, it will be understood that other electrical steering control actuators, for example electrically controlled hydraulic steering actuators, would also be suitable.

10

Solid lines connecting components in figure 2 illustrate connections for transmitting electrical power, whilst dashed lines connecting components illustrate connections for transmitting control signals. It will be understood that direct electrical connections may not be required for the transmission of control signals, as the required communication may be achieved by
15 wireless connections. Furthermore, although direct connections between components are shown for clarity, it will be understood that in practice the communication of control signals may be facilitated by connection of the components to a common network which the components are able to send and receive signals. A controller area network (CAN) may provide a suitable network over which control signals can be received, and some or all of the
20 sensors, actuators and controllers shown in figure 2 may be connected to a CAN bus rather than each other. It will also be appreciated that other electrical busses are envisaged to convey the control signals, such as IP-based busses for example Ethernet. In this way each component, such as the sensors, actuators and controllers, may represent a network node on the bus.

25

Steering of the front wheels 204A, 204B in the embodiment illustrated in figure 2 is performed by actuators 202A, 202B under the control of front steering controller 208, which is powered by an energy storage device 212, for example a battery. In the illustrated embodiment the battery is a low-voltage (e.g. 12V) battery of the vehicle. Similarly, steering
30 of the rear wheels 204C, 204D is performed by actuators 202C, 202D under the control of rear steering controller 210, which is also powered by battery 212. Front and rear steering controllers 208, 210 are both connected to the battery 212 by respective switches 218, 220, which switches are controlled by watchdog controllers 214, 216. The front and rear steering controllers 208, 210 may each comprise a processor having access to an electronic
35 memory. Instructions for controlling the actuators in dependence on one or more control inputs may be stored on the electronic memories.

When the steering system 200 is operating normally front steering controller 208 receives an input indicative of the position of the steering wheel 102 and may also receive inputs indicative of one or more other vehicle operating parameters including but not limited to a currently selected terrain mode, a vehicle speed, a current position of the steering racks
5 206A, 206B, one or more wheel slip parameters and a vehicle yaw rate. Front steering controller 208 is configured to calculate a required current to send to the steering actuators 202A, 202B to produce the steering effect requested by the user, which calculation may be performed using a predetermined function such as a control map. It will be understood that the calculation of the required current may be continuously updated depending on the
10 current values of the inputs to the controller 208. Under certain circumstances, the current provided to actuator 202A may be different from that provided to actuator 202B.

Under normal operation of the system 200 rear steering controller 210 also receives an input indicative of the position of the steering wheel 102 and optionally other vehicle operating
15 parameters including but not limited to a currently selected terrain mode, a vehicle speed, a current position of the steering racks 206A, 206B, one or more wheel slip parameters and a vehicle yaw rate. A function such as a control map using similar inputs to those used by the function that is used to calculate the current to be provided to the front actuators 202A, 202B by the front steering controller may be implemented on the rear steering controller to
20 calculate the current required by the rear steering actuators 202C, 202D. However, it will be understood that the required current to be provided to the rear actuators 202C, 202D may be quite different from that required by the front actuators 202A, 202B for a given set of input conditions. The functions that are used to calculate the required current to each of the actuators 202A-D based on the input conditions will typically be determined empirically to
25 provide an appropriate balance of vehicle stability and steering responsiveness.

In some embodiments the controllers 208, 210 are operable to receive inputs indicative of the positions of the steering racks 206A-D and to calculate required positions of the steering racks in dependence on the other inputs received by the controllers 208, 210. The
30 controllers may implement feedback control on the current provided to the steering actuators 202A-D to ensure that the actual position of the steering racks matches the required positions as closely as possible. Furthermore, the controllers 208, 210 may control the voltage of the supply to the actuators rather than the current supplied to the actuators.

It will be understood that the functions used to calculate the required current to be passed to the steering actuators 202A-D may take a relatively large number of inputs and may be relatively complex. Accordingly, it is necessary to ensure that the outputs provided by the

functions are not the result of a bug in the functions or of a malfunction of the one or more of the processors that implement the functions.

Watchdog controllers 214, 216 are configured to check that the system 200 is operating normally and to command appropriate corrective action if an error state is detected. The front and rear watchdog controllers 214, 216 may each comprise a processor having access to an electronic memory.

Watchdog controller 214 is configured to receive an input indicative of the position of the steering wheel 102 and inputs indicative of the position of the front steering racks 206A, 206B from the front steering actuators 202A, 202B. Figure 3 shows a flow chart illustrating the control method that is performed by the watchdog controllers 208, 210. The control method begins at step 302 when the vehicle is started and proceeds immediately to step 304, in which the watchdog controller receives inputs P_{R1} , P_{R2} indicative of the positions of the steering racks that are associated with the controller that the watchdog is configured to check the operation of. In the embodiment illustrated in figure 2 watchdog controller 214, which is configured to check the operation of steering controller 208, receives inputs indicative of the positions of steering racks 206A and 206B from steering actuators 202A, 202B. Similarly, watchdog controller 216, which is configured to check the operation of steering controller 210, receives inputs indicative of the positions of steering racks 206C and 206D from steering actuators 202C, 202D.

Once the inputs indicative of the positions of the steering racks have been received the method proceeds to step 306, in which the controller receives an input P_W which is indicative of the current position of the steering wheel. The controller then calculates an expected range of steering rack positions P_{R_MIN} - P_{R_MAX} based on the received steering wheel position P_W in step 308. The control method then proceeds to step 310, in which the controller determines whether or not the received steering rack positions P_{R1} , P_{R2} are within the expected range P_{R_MIN} - P_{R_MAX} . If the received steering rack positions are within the expected range then the control method returns to step 304 and the method is repeated until at least one of the steering rack positions is outside the expected range.

If the controller determines that at least one of the steering rack positions is outside the expected range in step 310 then the method proceeds to step 312, in which it is determined that there is an error either in the steering controller that the watchdog controller is checking the operation of, or in one of the steering actuators. To prevent this error from causing an incorrect steering output the watchdog controller interrupts the flow of electrical power to the

controller that it is checking the operation of by opening a switch between the controller and the battery. In the embodiment illustrated in figure 2 watchdog controller 214 is operable to open switch 218 when an error is detected in controller 208 or one of the front steering actuators 202A, 202B, and watchdog controller 216 is operable to open switch 220 when an error is detected in controller 210 or one of the rear steering actuators 202C, 202D.

Each of the steering racks 206A-D are provided with biasing means that cause them to return to a neutral position when power to the actuator 202A-D associated with the respective steering rack has been cut, for example because an error state has been detected by the watchdog controller. The neutral position may correspond to a straight-ahead position of the wheels. The biasing means may comprise one or more springs arranged to bias the steering rack into the neutral position. Alternatively or in addition, a solenoid may be provided to bias the steering rack into the neutral position, which solenoid may be actuated to stop biasing the steering rack into the neutral position when electrical power is being delivered to the controller associated with the steering rack. Such a solenoid may be operable to lock the steering rack into the neutral position once the steering rack arrives at its neutral position, for example by direct engagement with a recess in steering rack and a component that is fixed relative to the vehicle body.

As shown in figure 2, controller 208 is operable to receive a signal indicative of the position of the switch 220 which can selectively interrupt the flow of electrical power to controller 210. Similarly, controller 210 is operable to receive a signal indicative of the position of the switch 218 which can selectively interrupt the flow of electrical power to controller 208. Under normal operation, both switches 218, 220 are closed and therefore all of the wheels 204A-D may be steered by controllers 208, 210. However, if one of the watchdog controllers 214, 216 detects an error condition then one of the switches 218, 220 will be opened, thereby interrupting the flow of electrical power to one of the controllers 208, 210. When one of the switches 218, 220 is opened the controller that continues to receive electrical power will receive a signal indicating that the switch controlling the flow of power to the other controller has been opened and therefore the wheels that are associated with the other controller will move to their neutral position and are no longer steerable. Accordingly, the remaining controller will adjust at least one control parameter used to calculate the required current to send to the actuators associated with the controller to account for the fact that the wheels associated with the other controller are no longer steerable.

For example, if switch 220 is opened as a result of an error being detected in rear steering controller 210 by watchdog controller 216 then front steering controller 208 may increase the

amount of current that is sent to the front steering actuators 202A, 202B, especially in circumstances where significant steering input from the rear steering actuators 202C, 202D would be expected under normal operation of the vehicle. Similarly, if switch 218 is opened as a result of an error being detected in front steering controller 208 by watchdog controller 5 214 then rear steering controller 210 may change the function that is used to calculate the amount of current that is sent to rear steering actuators to ensure that appropriate steering response is provided by the rear steering actuators 202C, 202D alone when the front steering actuators 202A, 202B are inactive. In this way, each of the steering controllers 208, 210 provides redundancy in the event of failure of the other steering controller. Furthermore, 10 the action of the watchdog controllers 214, 216 ensures that if one of the steering controllers 208, 210 produces an erroneous output then the erroneous output is identified as such and the offending controller is disabled. This ensures that no single failure can lead to a loss of steering or an erroneous steering output.

Watchdog controllers 216, 214 may be operable to perform other verification routines in addition to the routine described above. For example, under normal operation the controllers 208, 210 may send signals to the watchdog controllers (or to a CAN bus which the watchdog controllers are able to receive signals from) at predefined time intervals. The watchdog controllers 214, 216 may be configured to monitor these signals and to identify an error state and disable the controller they are checking if the signal from the controller is not updated 20 within a predefined time interval. Unexpected stoppage of the periodically updating signals may be indicative of the controller being stuck in an infinite loop that is consuming a large proportion of its processing power and therefore preventing normal operation of the controller.

25 It will be understood that when power to one of the steering controllers 208, 210 is interrupted the steering performance of the vehicle may be inferior to that when both of the steering controllers are powered on and functioning correctly. Furthermore, when the system is operating with only one of the steering controllers there is no longer redundancy in the steering system, and a failure of the remaining controller could cause a loss of steering. 30 Accordingly, it is not desirable for the vehicle to be driven for a long period of time when one of the controllers is powered off.

The system 200 may be configured to cause a warning message to be delivered to a driver 35 of the vehicle when one of the steering controllers is powered off. The warning message may inform the driver of which axle the steering has been lost on and may advise them to drive the vehicle to a safe location and then to seek assistance. Furthermore, the system

may be configured to cause a warning message to be issued outside the vehicle so as to warn other road users that the vehicle is not functioning normally. For example, the hazard warning lights may be automatically turned on when an error is detected in one of the steering controllers 208, 210.

5

In some embodiments performance of the vehicle may be limited when one of the steering controllers 208, 210 is powered off. For example the speed of the vehicle may be limited to less than a predetermined value. If the speed of the vehicle is greater than the predetermined value when an error is detected by one of the watchdog controllers 214, 216 then a warning message informing the driver that steering on one of the axles has been lost and instructing them to slow down may be issued. If the driver does not slow down during a predetermined time after warning message being issued then the speed of the vehicle may be automatically reduced to the predetermined value at a gentle deceleration rate.

10

15

In the embodiments described above watchdog controllers 214, 216 are operable to open switches 218, 220 upon detection of an error state. However, in some embodiments when one of the watchdog controllers 214, 216 detects an error in the corresponding controller 208, 210 the watchdog controller is configured to inhibit the controller on which the error is detected from controlling the actuators by disconnecting the controller from the actuators whilst maintaining power to the controller. This may be performed by opening one or more switches between the controller and the actuators. In other embodiments the watchdog controller may be configured to issue an override command to the actuators, which override command causes the actuators to ignore the output of the controller and optionally also causes the actuators to move the steering racks to a predefined position such as a position corresponding to "straight ahead" driving. If an override command that causes the actuators to move the steering racks to the "straight ahead" position is issued by the watchdog controller then it may not be necessary to provide a separate biasing means to move the steering racks to the "straight ahead" position after an error state has been detected.

20

25

30

Once a controller on which an error has been detected has been inhibited from controlling the actuators the watchdog controller that detected the error may be configured to reset the controller. Under some circumstances this may correct the error state. If the watchdog controller determines that resetting the controller has corrected the error state then it may enable the controller to control the actuators again, for example by closing a switch between the controller and the actuators or by ceasing to output the override signal to the actuators.

35

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, memory chips, devices or integrated circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic tape. It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

In the embodiment shown in figure 2 each of the wheels 204A-D is provided with an individual steering rack 206A-D controlled by a respective actuator 202A-D. This allows the steering input to each of the wheels to be individually controlled. However, in some embodiments the front wheels 204A, 204B may be connected to the same steering rack. In such embodiments only a single actuator may be required to control the steering rack of the front wheels. Similarly, rear wheels 204C, 204D may also be connected to the same steering rack, and a single actuator may be used to control the rear steering rack.

Figure 5 shows a schematic diagram of a steering system 501 that is operable to individually steer each of the wheels 504A-D via respective electrical steering control actuators 502A-D, and the wheeled vehicle 500 of figure 4 may alternatively incorporate the steering system 501 as illustrated in figure 5. Vehicle 500 may be powered by a prime mover such as an internal combustion engine or an electric machine. In some embodiments the vehicle may be a hybrid vehicle powered by a combination of a combustion engine and an electric machine.

In the embodiment shown in figure 5 the electrical steering control actuators 502A-D are electric motors having pinion gears operable to move the respective steering racks 506A-D, thereby to change the angle of the wheels 504A-D. However, it will be understood that other electrical steering control actuators, for example electrically controlled hydraulic steering actuators, would also be suitable. Similarly a single actuator may be provided to steer both front wheels or both rear wheels using a rack and steering links in a conventional manner.

Solid lines connecting components in figure 5 illustrate connections for transmitting electrical power, whilst dashed lines connecting components illustrate connections for transmitting control signals. It will be understood that direct electrical connections may not be required for the transmission of control signals, as the required communication may be achieved by wireless connections. Furthermore, although direct connections between components are shown for clarity, it will be understood that in practice the communication of control signals may be facilitated by connection of the components to a common network which the components are able to send and receive signals. A controller area network (CAN) may provide a suitable network over which control signals can be received, and some or all of the sensors, actuators and controllers shown in figure 5 may be connected to a CAN bus rather than each other. It will also be appreciated that other electrical busses are envisaged to convey the control signals, such as IP-based busses for example Ethernet. In this way each component, such as the sensors, actuators and controllers, may represent a network node on the bus.

Steering of the front wheels 504A, 504B in the embodiment illustrated in figure 5 is performed by actuators 502A, 502B under the control of front steering controllers 508A-C, which are powered by an energy storage device 512, for example a battery. In the illustrated embodiment the battery is a low-voltage (e.g. 12V) battery of the vehicle. Steering of the rear wheels 504C, 504D is performed by actuators 502C, 502D under the control of rear steering controller 510, which is also powered by battery 512. Rear steering controller 510 is connected to the battery 512 by respective switch 520, which is controlled by watchdog controllers 516. The front and rear steering controllers 208A-C, 210 may each comprise a processor having access to an electronic memory. Instructions for controlling the actuators in dependence on one or more control inputs may be stored on the electronic memories.

When the steering system 500 is operating normally front steering controllers 508A-C receive an input indicative of the position of the steering wheel 502 and may also receive inputs indicative of one or more other vehicle operating parameters including but not limited to a currently selected terrain mode, a vehicle speed, a current position of the steering racks 506A, 506B, one or more wheel slip parameters and a vehicle yaw rate. Front steering controllers 508A-C are configured to calculate a required current to send to the steering actuators 502A, 502B to produce the steering effect requested by the user, which calculation may be performed using a predetermined function such as a control map. It will be understood that the calculation of the required current may be continuously updated depending on the current values of the inputs to the controllers 508A-C. Under certain

circumstances, the current provided to actuator 502A may be different from that provided to actuator 502B.

Under normal operation of the system 501 rear steering controller 510 also receives an input indicative of the position of the steering wheel 502 and optionally other vehicle operating parameters including but not limited to a currently selected terrain mode, a vehicle speed, a current position of the steering racks 506A, 506B, one or more wheel slip parameters and a vehicle yaw rate. A function such as a control map using similar inputs to those used by the function that is used to calculate the current to be provided to the front actuators 502A, 502B by the front steering controller may be implemented on the rear steering controller to calculate the current required by the rear steering actuators 502C, 502D. However, it will be understood that the required current to be provided to the rear actuators 502C, 502D may be quite different from that required by the front actuators 502A, 502B for a given set of input conditions. The functions that are used to calculate the required current to each of the actuators 502A-D based on the input conditions will typically be determined empirically to provide an appropriate balance of vehicle stability and steering responsiveness.

In some embodiments the controllers 508A-C, 510 are operable to receive inputs indicative of the positions of the steering racks 506A-D and to calculate required positions of the steering racks in dependence on the other inputs received by the controllers 508, 510. The controllers may implement feedback control on the current provided to the steering actuators 502A-D to ensure that the actual position of the steering racks matches the required positions as closely as possible. Furthermore, the controllers 508, 510 may control the voltage of the supply to the actuators rather than the current supplied to the actuators.

It will be understood that the functions used to calculate the required current to be passed to the steering actuators 502A-D may take a relatively large number of inputs and may be relatively complex. Accordingly, it is necessary to ensure that the outputs provided by the functions are not the result of a bug in the functions or of a malfunction of the one or more of the processors that implement the functions.

A watchdog controller 516 is configured to check that the system 501 is operating normally and to command appropriate corrective action if an error state is detected. The watchdog controller 216 may comprise a processor having access to an electronic memory.

Watchdog controller 516 is configured to receive an input indicative of the position of the steering wheel 102 and inputs indicative of the position of the rear steering racks 506C,

506D from the rear steering actuators 502C, 502D. Figure 3 shows a flow chart illustrating the control method that is performed by the watchdog controller 510. The control method begins at step 302 when the vehicle is started and proceeds immediately to step 304, in which the watchdog controller receives inputs P_{R1} , P_{R2} indicative of the positions of the steering racks that are associated with the controller that the watchdog is configured to check the operation of. In the embodiment illustrated in figure 5 watchdog controller 516, which is configured to check the operation of steering controller 510, receives inputs indicative of the positions of steering racks 506C and 506D from steering actuators 502C, 502D.

Once the inputs indicative of the positions of the steering racks have been received the method proceeds to step 306, in which the controller receives an input P_W which is indicative of the current position of the steering wheel. The controller then calculates an expected range of steering rack positions P_{R_MIN} - P_{R_MAX} based on the received steering wheel position P_W in step 308. The control method then proceeds to step 310, in which the controller determines whether or not the received steering rack positions P_{R1} , P_{R2} are within the expected range P_{R_MIN} - P_{R_MAX} . If the received steering rack positions are within the expected range then the control method returns to step 304 and the method is repeated until at least one of the steering rack positions is outside the expected range.

If the controller determines that at least one of the steering rack positions is outside the expected range in step 310 then the method proceeds to step 312, in which it is determined that there is an error either in the steering controller that the watchdog controller is checking the operation of, or in one of the steering actuators. To prevent this error from causing an incorrect steering output the watchdog controller interrupts the flow of electrical power to the controller that it is checking the operation of by opening a switch between the controller and the battery. In the embodiment illustrated in figure 5 watchdog controller 515 is operable to open switch 520 when an error is detected in controller 510 or one of the rear steering actuators 502C, 502D.

Each of the steering racks 506C-D are provided with biasing means that cause them to return to a neutral position when power to the actuator 502C-D associated with the respective steering rack has been cut, for example because an error state has been detected by the watchdog controller. The neutral position may correspond to a straight-ahead position of the wheels. The biasing means may comprise one or more springs arranged to bias the steering rack into the neutral position. Alternatively or in addition, a solenoid may be provided to bias the steering rack into the neutral position, which solenoid

may be actuated to stop biasing the steering rack into the neutral position when electrical power is being delivered to the controller associated with the steering rack. Such a solenoid may be operable to lock the steering rack into the neutral position once the steering rack arrives at its neutral position, for example by direct engagement with a recess in steering rack and a component that is fixed relative to the vehicle body.

As shown in figure 5, watchdog controller 516 is operable to receive a signal indicative of the position of the switch 520 which can selectively interrupt the flow of electrical power to controller 510. Under normal operation, the switch 520 is closed and therefore the rear wheels 504C-D may be steered by controller 510. However, if the watchdog controller 516 detects an error condition then the switch 520 will be opened, thereby interrupting the flow of electrical power to the controller 510. When the switch 520 is opened the front steering controllers 508A-C will receive a signal indicating that the switch controlling the flow of power to the rear steering controller has been opened and therefore the wheels that are associated with that controller will move to their neutral position and are no longer steerable. Accordingly, the front steering controllers 508A-C will adjust at least one control parameter used to calculate the required current to send to the actuators associated with the controllers to account for the fact that the rear wheels are no longer steerable.

As shown in figure 5, the front steering system provides triple redundancy in this embodiment. Each of the front steering controllers 508A-C receives a signal indicative of the position of the steering wheel 502 and provides actuation current to front steering actuators 502A, 502B. The front steering actuators 502A, 502B control the steering angles of front wheels 504A and 504B. In the event of an error or failure of any of the front steering controllers 508A-C, the remaining controllers override the output of the failed controller and maintain steering of the front wheels. The steering of the front wheels is therefore similar to the prior art shown in figure 1 although a control parameter associated with the front steering control system may be modified in the event of a rear steering failure.

The rear steering racks 506C-D are provided with biasing means that cause them to return to a neutral position when power to the actuator 502C-D associated with the respective steering rack has been cut, for example because an error state has been detected by the watchdog controller. The neutral position may correspond to a straight-ahead position of the wheels. The biasing means may comprise one or more springs arranged to bias the steering rack into the neutral position. Alternatively or in addition, a solenoid may be provided to bias the steering rack into the neutral position, which solenoid may be actuated to stop biasing the steering rack into the neutral position when electrical power is being delivered to the

controller associated with the steering rack. Such a solenoid may be operable to lock the steering rack into the neutral position once the steering rack arrives at its neutral position, for example by direct engagement with a recess in steering rack and a component that is fixed relative to the vehicle body.

5

The watchdog controller 516 may be operable to perform other verification routines in addition to the routine described above. For example, under normal operation the controllers 508A-C, 510 may send signals (commonly known as 'alive counters') to the watchdog controllers (or to a CAN bus which the watchdog controllers are able to receive signals from) at predefined time intervals. The watchdog controller 516 may be configured to monitor these signals and to identify an error state and disable the controller they are checking if the signal from the controller is not updated within a predefined time interval. Unexpected stoppage of the periodically updating signals may be indicative of the controller being stuck in an infinite loop that is consuming a large proportion of its processing power and therefore preventing normal operation of the controller.

15

It will be understood that when power to the rear steering controller 510 is interrupted the steering performance of the vehicle may be inferior to that when all of the steering controllers are powered on and functioning correctly. The system 501 may be configured to cause a warning message to be delivered to a driver of the vehicle when the rear steering controller is powered off. The warning message may inform the driver that the steering has been lost on the rear axle and may advise them to drive the vehicle to a safe location and then to seek assistance. Furthermore, the system may be configured to cause a warning message to be issued outside the vehicle so as to warn other road users that the vehicle is not functioning normally. For example, the hazard warning lights may be automatically turned on when an error is detected in one of the steering controllers 508A-C, 510.

20

25

In some embodiments performance of the vehicle may be limited when one of the steering controllers 508A-C, 510 is powered off. For example the speed of the vehicle may be limited to less than a predetermined value. If the speed of the vehicle is greater than the predetermined value when an error is detected by the watchdog controller 516 then a warning message informing the driver that steering on the rear axle has been lost and instructing them to slow down may be issued. If the driver does not slow down during a predetermined time after warning message being issued then the speed of the vehicle may be automatically reduced to the predetermined value at a gentle deceleration rate.

30

35

In the embodiments described above watchdog controller 516 is operable to open a switch 520 upon detection of an error state. However, in some embodiments when the watchdog controller 516 detects an error in the corresponding controller 510 the watchdog controller is configured to inhibit the controller on which the error is detected from controlling the actuators by disconnecting the controller from the actuators whilst maintaining power to the controller. This may be performed by opening one or more switches between the controller and the actuators. In other embodiments the watchdog controller may be configured to issue an override command to the actuators, which override command causes the actuators to ignore the output of the controller and optionally also causes the actuators to move the steering racks to a predefined position such as a position corresponding to "straight ahead" driving. If an override command that causes the actuators to move the steering racks to the "straight ahead" position is issued by the watchdog controller then it may not be necessary to provide a separate biasing means to move the steering racks to the "straight ahead" position after an error state has been detected.

Once a controller on which an error has been detected has been inhibited from controlling the actuators the watchdog controller that detected the error may be configured to reset the controller. Under some circumstances this may correct the error state. If the watchdog controller determines that resetting the controller has corrected the error state then it may enable the controller to control the actuators again, for example by closing a switch between the controller and the actuators or by ceasing to output the override signal to the actuators.

A steering system 601 in another embodiment of the present invention is shown in figure 6. In the embodiment shown in figure 6 the front steering actuators 602A, B are controlled by a redundant control means comprising three controllers 608A-C. Each of the controllers 608A-C is operable to receive a signal indicative of the position of a steering wheel 630 optionally also a signal indicative of an amount of torque applied to the steering wheel 630 from steering wheel motor 632. It will be understood that steering wheel motor 632 is configured to provide feedback to a user of the vehicle, thereby providing a similar "feel" to that experienced when a mechanical connection between the steering wheel 630 and the steering rack 606 is present. The controllers 608A-C may also receive inputs indicative of the speed of the vehicle and other vehicle parameters such as a current driving mode of the vehicle. The controllers 608A-C are arranged to provide a signal indicative of the amount of current to be sent to each of the actuators 608A, 608B to the respective low-level controllers 608AL, 608BL. The low-level controllers 608AL, 608BL are arranged to cause the actuators 608A, 608B to receive an amount of current required by the signal from the controllers 608A-

C from the battery 612. This causes movement of the front steering rack 606F and therefore steering of the front wheels 604A, 604B.

It will be understood that the controllers 608A-C are able to provide redundancy in the calculation of the signals that determine what current should be sent to each of the actuators 608A, B, so that if any one of the controllers 608A-C should fail there would still be two remaining controllers that could safely calculate the signal. Furthermore, the controllers 608A-C are arranged to communicate with one another so as to ensure that if one of the controllers produces a signal that disagrees with that produced by the other two then only the signals that are in agreement with each other are sent to the low-level controllers 608AL, 608BL. This may be referred to as "triple redundancy", and it provides a sufficiently low probability of failure that it can be considered suitable for use in safety-critical systems such as the steering for the front wheels 604A, B.

Typically, all of the steering required by a driver of a vehicle in which the steering system 601 is provided can be performed by steering the front wheels 604A, B. However, the steering system 601 is also operable to steer the rear wheels 604C, D via actuators 602C, D, which can steer the rear wheels 604C, D by moving rear steering rack 606R. The controllers 608A-C are operable to determine when steering by the rear wheels 604C, D is required and to provide a signal indicating the amount of steering required to be performed by the rear wheels to rear steering controller 640. Upon receipt of the signal indicative of the amount of steering to be provided by the rear wheels the rear steering controller 640 is arranged to calculate a signal indicative of an amount of current to be sent to the rear steering actuators 602C, D, which signal is sent to the respective low-level controllers 602CL, 602DL of the rear steering actuators 602C, D. The low-level controllers 602CL, 602DL then cause an amount of current corresponding to that requested by the received signal to be provided to the rear steering actuators 602C, D by the battery 612. This causes movement of the rear steering rack 606R and therefore steering of the rear wheels 604C, D by an amount corresponding to that calculated by the controllers 608A-C.

The signal indicative of the amount of steering required to be performed by the rear wheels is also communicated to a rear watchdog controller 642, which controller is arranged to calculate a range of current values that may be required by the rear actuators 602C, D based on the amount of steering they are required to perform. The rear watchdog controller is also configured to receive an input indicative of the amount of current provided to each of the rear steering actuators 602C, D. In the event that the actual amount of current provided to either of the rear steering actuators 602C, D is outside the range calculated by the rear

watchdog controller 642 the rear watchdog controller is configured to make a determination that an error has occurred in the rear steering controller 640 or one of the low-level controllers 602CL, 602DL of the rear actuators 602C, D. Upon making a determination that an error has occurred the rear watchdog controller is arranged to inhibit control of the rear actuators 602C, D by the rear steering controller 640. This causes the rear wheels 604C, D to return to their "straight ahead" position and causes all of the required steering to be provided by the front wheels 604A, B. It is acceptable to provide a single controller 640 and a watchdog 642 rather than a triple redundant controller for steering the rear wheels, provided that the rear steering system fails to a safe state, as if the rear wheel steering fails steering can still be performed by the front wheels 604A, B without compromising safety.

A particular advantage of the arrangement shown in figure 6 is that it provides a modular system for that can provide appropriate redundancy for a vehicle having rear wheel steering and no mechanical connection between the steering wheel and the steering racks. Such a modular system may have the components associated with the rear wheel steering (i.e. all of the components below line L) omitted when installed in a vehicle that does not have rear wheel steering. In the case of a vehicle without rear wheel steering the wheels 604C, D will be replaced by wheels that are not connected to a steering rack and that are therefore fixed in the straight-ahead position. Accordingly, the system can be used, with appropriate modification, across a vehicle line in which some but not all vehicles are operable to perform rear wheel steering. Furthermore, provision of a rear steering controller 640 that is physically separate from the main controllers 608A-C allows greater flexibility in the design of the system and sourcing of components.

It will also be understood that in figure 6 dashed lines represent connections over which control signals may be transmitted and solid lines represent connections over which electrical power is to be transmitted. Furthermore, although power connections are only shown between the battery 612 and the low-level controllers 602AL, 602BL, 602CL, 602DL, a power connection (either from battery 612 or an alternative power source) will also be provided for each of the other controllers and sensors.

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, memory chips, devices or integrated circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic tape. It will be

appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding
5 claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

10 In the embodiment shown in figure 5 each of the wheels 504A-D is provided with an individual steering rack 506A-D controlled by a respective actuator 502A-D. This allows the steering input to each of the wheels to be individually controlled. However, in some embodiments the front wheels 504A, 504B may be connected to the same steering rack. In such embodiments only a single actuator may be required to control the steering rack of the
15 front wheels. Similarly, rear wheels 504C, 504D may also be connected to the same steering rack, and a single actuator may be used to control the rear steering rack.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may
20 be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or
25 similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention
30 extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

CLAIMS

1. A steering control system for a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the steering control system comprising:
- a first control means operable to control the first actuation means;
 - a second control means operable to control the second actuation means, the second control means comprising a redundant control means comprising two or more controllers to calculate the required input to a second actuation means; and
 - a watchdog control means operable to inhibit control of the first actuation means by the first control means upon detection of an error state in the first control means and/or the first actuation means.
2. A steering system as claimed in claim 1, wherein the first group of wheels is a group of rear wheels and the second group of wheels is a group of front wheels.
3. A steering control system as claimed in claim 1 or claim 2, wherein the second control means is operable to communicate with a user input means and the first control means,
- the second control means being operable to produce a first control signal indicative of a steering contribution required to be provided by the first group of wheels and a second control signal indicative of an amount of current to be sent to the second actuation means, wherein the first control means is operable to produce a third signal indicative of an amount of current to be sent to the first actuation means in dependence on said first signal.
4. A steering control system as claimed in claim 3, wherein the system further comprises a first low-level control means and a second low-level control means,
- wherein:
 - the first low-level control means is configured to receive the third signal and to provide a drive current to the first actuation means in dependence on the third signal; and
 - the second low-level control means is configured to receive the second signal and to provide a drive current to the second actuation means in dependence on the second signal.
5. A steering control system as claimed in any preceding claim, wherein the second control means is operable to receive a signal indicative of an error state having been detected in the first control means and/or the first actuation means, wherein the second

control means is operable to adjust at least one control parameter used in the control of the second actuation means in dependence on receipt of said first signal.

6. A steering control system as claimed in any preceding claim, wherein the watchdog control means comprises input means configured to receive a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means, the watchdog control means being operable to detect said error state in the first control means and/or the first actuation means in dependence on the first and second inputs.

7. A steering control system as claimed in any preceding claim, wherein the watchdog control means is configured to perform a forced reset of the first control means in response to said detection of an error state in the first control means and/or the first actuation means.

8. A steering control system as claimed in claim 7, wherein the watchdog control means is configured to allow control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

9. A steering control system as claimed in any preceding claim, wherein the watchdog control means is operable to cause a warning to be issued to a driver of the vehicle upon said detection of an error state in the first control means and/or the first actuation means.

10. A steering control system as claimed in any preceding claim, wherein the watchdog control means is operable to cause performance of the vehicle to be limited upon said detection of an error state in the first control means and/or the first actuation means.

11. A steering control system as claimed in any preceding claim, wherein the watchdog control means is operable to cause an externally visible warning to be issued upon said detection of an error state in the first control means and/or the first actuation means.

12. A steering control system as claimed in any preceding claim, wherein inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

13. A watchdog control for a steering control system for a vehicle having a steer-by-wire system, the watchdog control operable to inhibit control of a first actuation means by a first control means upon detection of an error state in the first control means and/or the first actuation means.

14. A steer-by-wire system for a vehicle, the system comprising:

a first electrically controlled steering actuation means operable to steer a first group of one or more wheels;

a second electrically controlled steering actuation means operable to steer a second group of one or more wheels; and

a steering control system and/or a watchdog control as claimed in any preceding claim.

15. A steer-by-wire system as claimed in claim 14 and comprising a first biasing means operable to move the first group of wheels to a predetermined position in response to the detection of an error state in the first control means and/or the first actuation means.

16. A steer-by-wire system as claimed in any one of claims 14-15, wherein said first group of wheels comprises a plurality of wheels and the first actuation means comprises a plurality of actuators, each of said actuators being associated with a respective one of said plurality of wheels.

17. A vehicle comprising a steer-by-wire system as claimed in any one of claims 14-16.

18. A vehicle as claimed in claim 17, wherein said first group of one or more wheels comprises at least two rear wheels and said second group of wheels comprises at least two front wheels.

19. A method of controlling a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the first actuation means being controlled by a first control means and the second actuation means being controlled by a second control means, the method comprising:

detecting an error state or receiving an error signal indicating an error state in the first control means and/or the first actuation means and, in response to said detection or said error signal;

inhibiting control of the first actuation means by the first control means; and

adjusting at least one control parameter used by the second control means in the control of the second actuation means.

20. A method as claimed in claim 19, comprising receiving a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means wherein said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means is performed in dependence on the first and second inputs.

5

21. A method as claimed in claim 19 or claim 20, comprising performing a forced reset of the first control means in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

10

22. A method as claimed in claim 21, comprising allowing control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

15

23. A method as claimed in any one of claims 19-22, comprising issuing a warning to a driver of the vehicle in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

20

24. A method as claimed in any one of claims 19-23, comprising limiting performance of the vehicle in response to said detection of an error state in the first control means and/or the first actuation means.

25

25. A method as claimed in any one of claims 19-24, comprising issuing an externally visible warning in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.

26

26. A method as claimed in any one of claims 19-25, wherein inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

30

27. A non-transitory computer readable medium carrying computer readable code which when executed by a computer causes a vehicle to carry out the method of any one of claims 19-26.

35

28. A processor arranged to implement the method of any one of claims 19-26.

29. A steering control system for a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or

more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the steering control system comprising:

a first control means operable to control the first actuation means;

a second control means operable to control the second actuation means; and

5 a watchdog control means operable to inhibit control of the first actuation means by the first control means upon detection of an error state in the first control means and/or the first actuation means, and to inhibit control of the second actuation means by the second control means upon detection of an error state in the second control means and/or the second actuation means.

10 30. A steering control system as claimed in claim 29, wherein the second control means is operable to receive a second signal indicative of an error state having been detected in the first control means and/or the first actuation means, wherein the second control means is operable to adjust at least one control parameter used in the control of the second
15 actuation means in dependence on receipt of said second signal.

31. A steering control system as claimed in claim 29 or claim 30, wherein the first control means is operable to receive a first signal indicative of an error state having been detected in the second control means and/or the second actuation means, wherein the first control
20 means is operable to adjust at least one control parameter used in the control of the first actuation means in dependence on receipt of said first signal.

32. A steering control system as claimed in any one of claims 29-31, wherein the watchdog control means comprises input means configured to receive a first input indicative
25 of a driver steering input and a second input indicative of an output of the first actuation means, the watchdog control means being operable to detect said error state in the first control means and/or the first actuation means in dependence on the first and second inputs.

30 33. A steering control system as claimed in claim 32, wherein the watchdog control means comprises input means configured to receive a third input indicative of an output of the second actuation means, the watchdog control means being operable to detect said error state in the second control means and/or the second actuation means in dependence on the first and third inputs.

35 34. A steering control system as claimed in any one of claims 29-33, wherein the watchdog control means is configured to perform a forced reset of the first control means in

response to said detection of an error state in the first control means and/or the first actuation means.

35. A steering control system as claimed in claim 34, wherein the watchdog control means is configured to allow control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.

36. A steering control system as claimed in any one of claims 29-35, wherein the watchdog control means is operable to cause a warning to be issued to a driver of the vehicle upon said detection of an error state in the first control means and/or the first actuation means.

37. A steering control system as claimed in any in any one of claims 29-36, wherein the watchdog control means is operable to cause performance of the vehicle to be limited upon said detection of an error state in the first control means and/or the first actuation means.

38. A steering control system as claimed in any in any one of claims 29-37, wherein the watchdog control means is operable to cause an externally visible warning to be issued upon said detection of an error state in the first control means and/or the first actuation means.

39. A steering control system as claimed in any in any one of claims 29-38, wherein inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.

40. A watchdog control for a steering control system for a vehicle having a steer-by-wire system, the watchdog control operable to inhibit control of a first actuation means by a first control means upon detection of an error state in the first control means and/or the first actuation means, and to inhibit control of a second actuation means by a second control means upon detection of an error state in the second control means and/or the second actuation means.

41. A steer-by-wire system for a vehicle, the system comprising:
a first electrically controlled steering actuation means operable to steer a first group of one or more wheels;
a second electrically controlled steering actuation means operable to steer a second group of one or more wheels; and

a steering control system and/or a watchdog control as claimed in any preceding claim.

42. A steer-by-wire system as claimed in claim 41 and comprising a first biasing means operable to move the first group of wheels to a predetermined position in response to the detection of an error state in the first control means and/or the first actuation means.

43. A steer-by-wire system as claimed in claim 41 or claim 42 and comprising a second biasing means operable to move the second group of wheels to a predetermined position in response to the detection of an error state in the second control means and/or the second actuation means.

44. A steer-by-wire system as claimed in any one of claims 41-43, wherein said first group of wheels comprises a plurality of wheels and the first actuation means comprises a plurality of actuators, each of said actuators being associated with a respective one of said plurality of wheels.

45. A steer-by-wire system as claimed in any one of claims 41-44, wherein said second group of wheels comprises a plurality of wheels and the second actuation means comprises a plurality of actuators, each of said actuators being associated with a respective one of said plurality of wheels.

46. A vehicle comprising a steer-by-wire system as claimed in any one of claims 41-45.

47. A vehicle as claimed in claim 46, wherein said first group of one or more wheels comprises at least two front wheels and said second group of wheels comprises at least two rear wheels.

48. A method of controlling a vehicle having a steer-by-wire system comprising a first electrically controlled steering actuation means operable to steer a first group of one or more wheels and a second electrically controlled steering actuation means operable to steer a second group of one or more wheels, the first actuation means being controlled by a first control means and the second actuation means being controlled by a second control means, the method comprising:

detecting an error state or receiving an error signal indicating an error state in the first control means and/or the first actuation means and, in response to said detection or said error signal;

inhibiting control of the first actuation means by the first control means; and
adjusting at least one control parameter used by the second control means in the
control of the second actuation means.

- 5 49. A method as claimed in claim 48, comprising receiving a first input indicative of a driver steering input and a second input indicative of an output of the first actuation means wherein said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means is performed in dependence on the first and second inputs.
- 10 50. A method as claimed in claim 48 or claim 49, comprising performing a forced reset of the first control means in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.
- 15 51. A method as claimed in claim 50, comprising allowing control of the first actuation means by the first control means in response to a determination that the error state has been corrected by said forced reset.
- 20 52. A method as claimed in any one of claims 48-51, comprising issuing a warning to a driver of the vehicle in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.
- 25 53. A method as claimed in any one of claims 48-52, comprising limiting performance of the vehicle in response to said detection of an error state in the first control means and/or the first actuation means.
- 30 54. A method as claimed in any one of claims 48-53, comprising issuing an externally visible warning in response to said receipt of an error signal or detection of an error state in the first control means and/or the first actuation means.
- 35 55. A method as claimed in any one of claims 48-54, wherein inhibiting control of the first actuation means by the first control means comprises interrupting a supply of electrical power to the first control means.
56. A non-transitory computer readable medium carrying computer readable code which when executed by a computer causes a vehicle to carry out the method of any one of claims 48-55.

57. A processor arranged to implement the method of any one of claims 48-55.

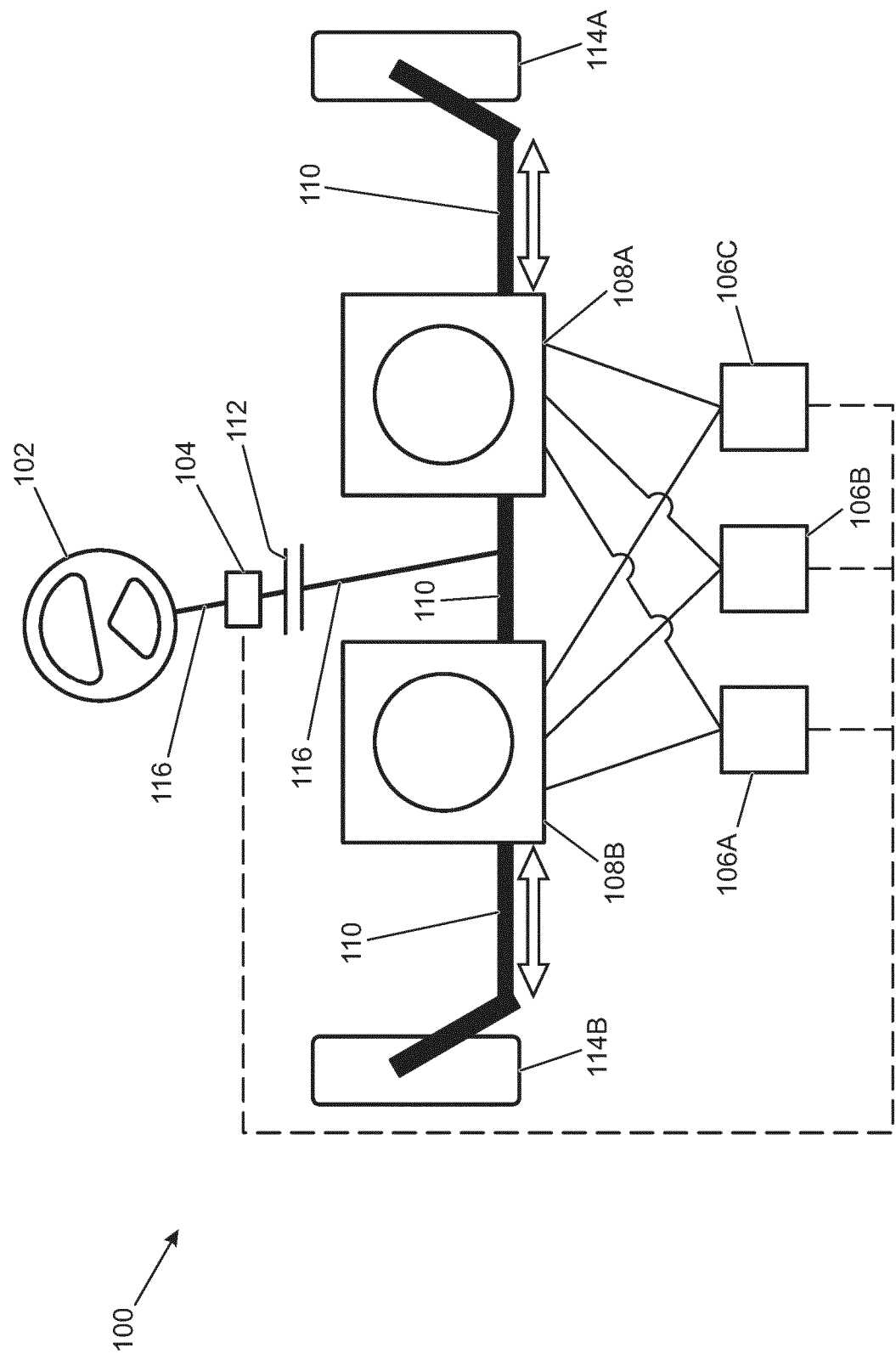


Figure 1 (PRIOR ART)

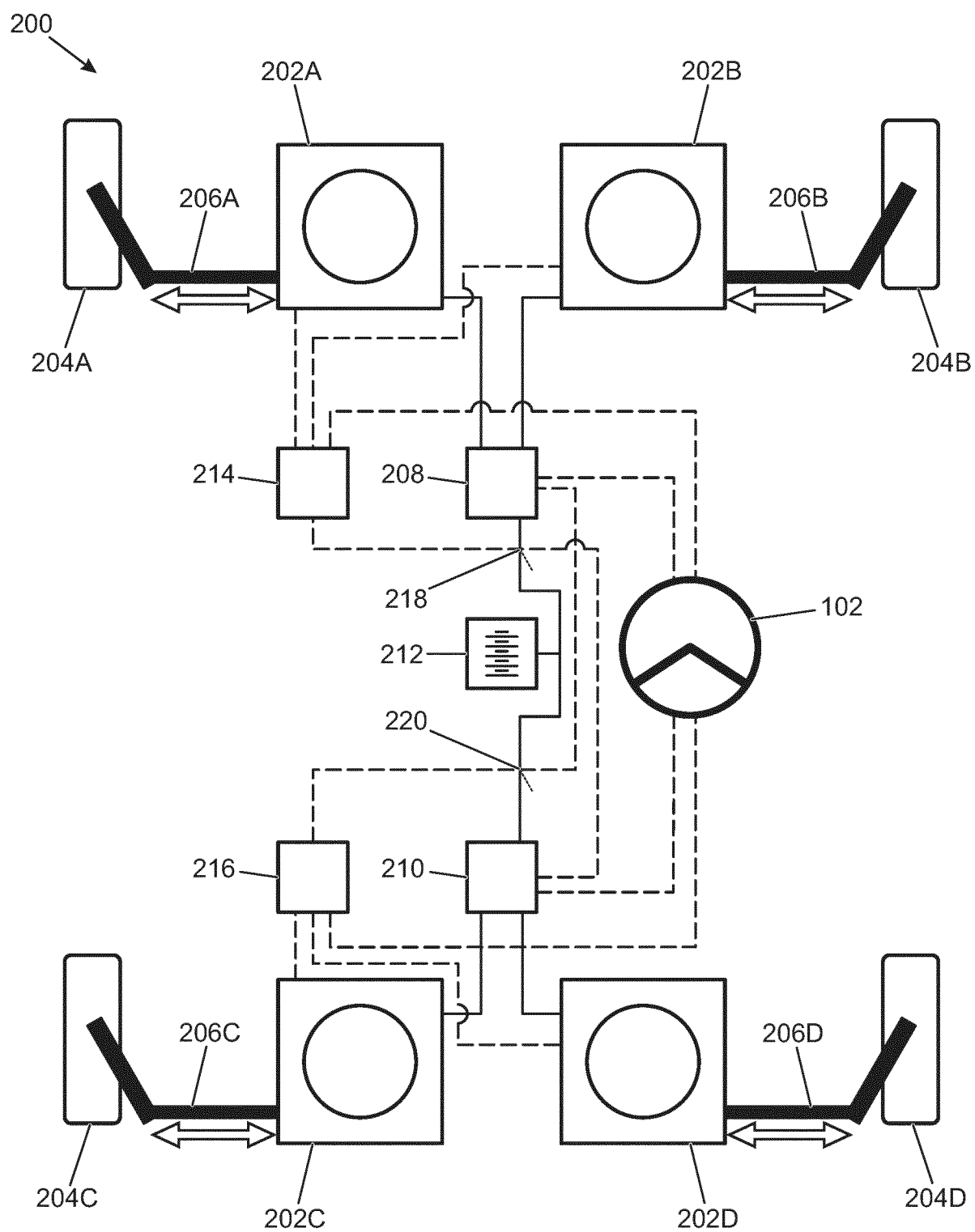


Figure 2

3/6

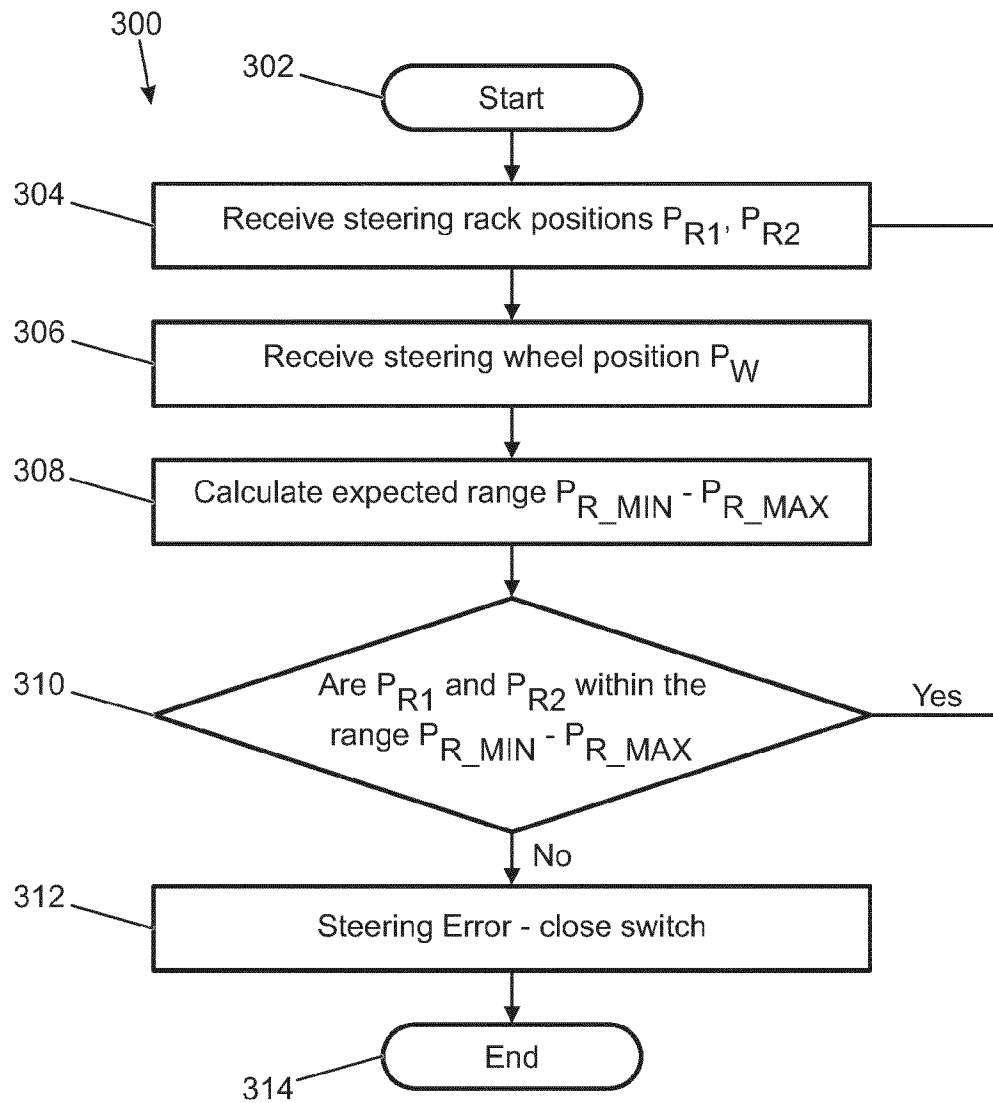


Figure 3

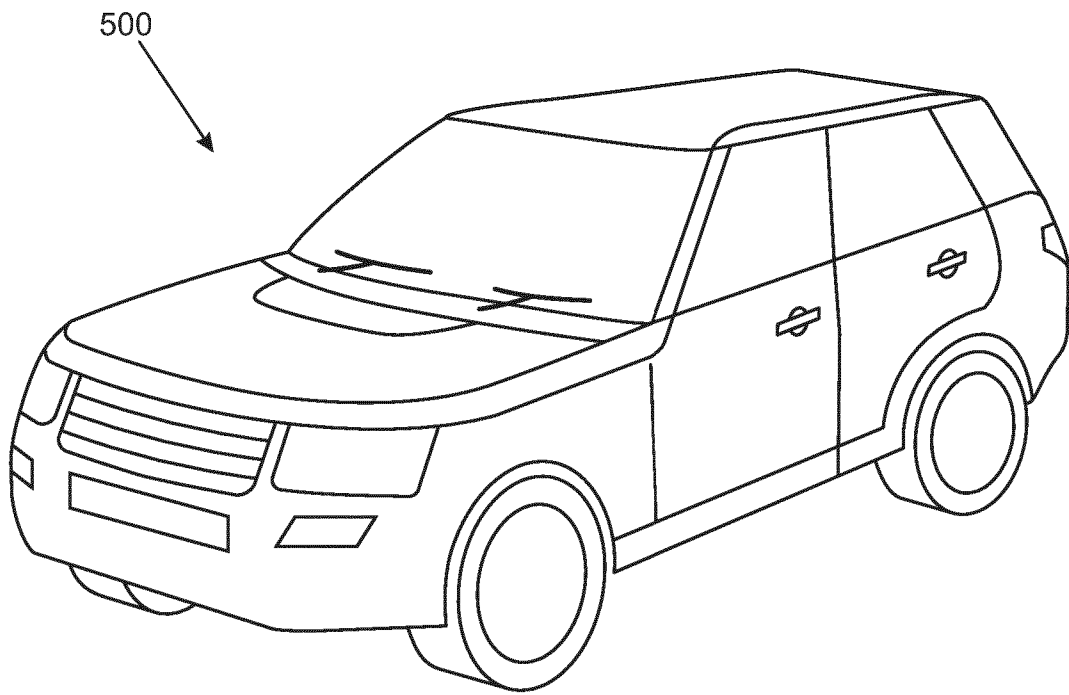


Figure 4

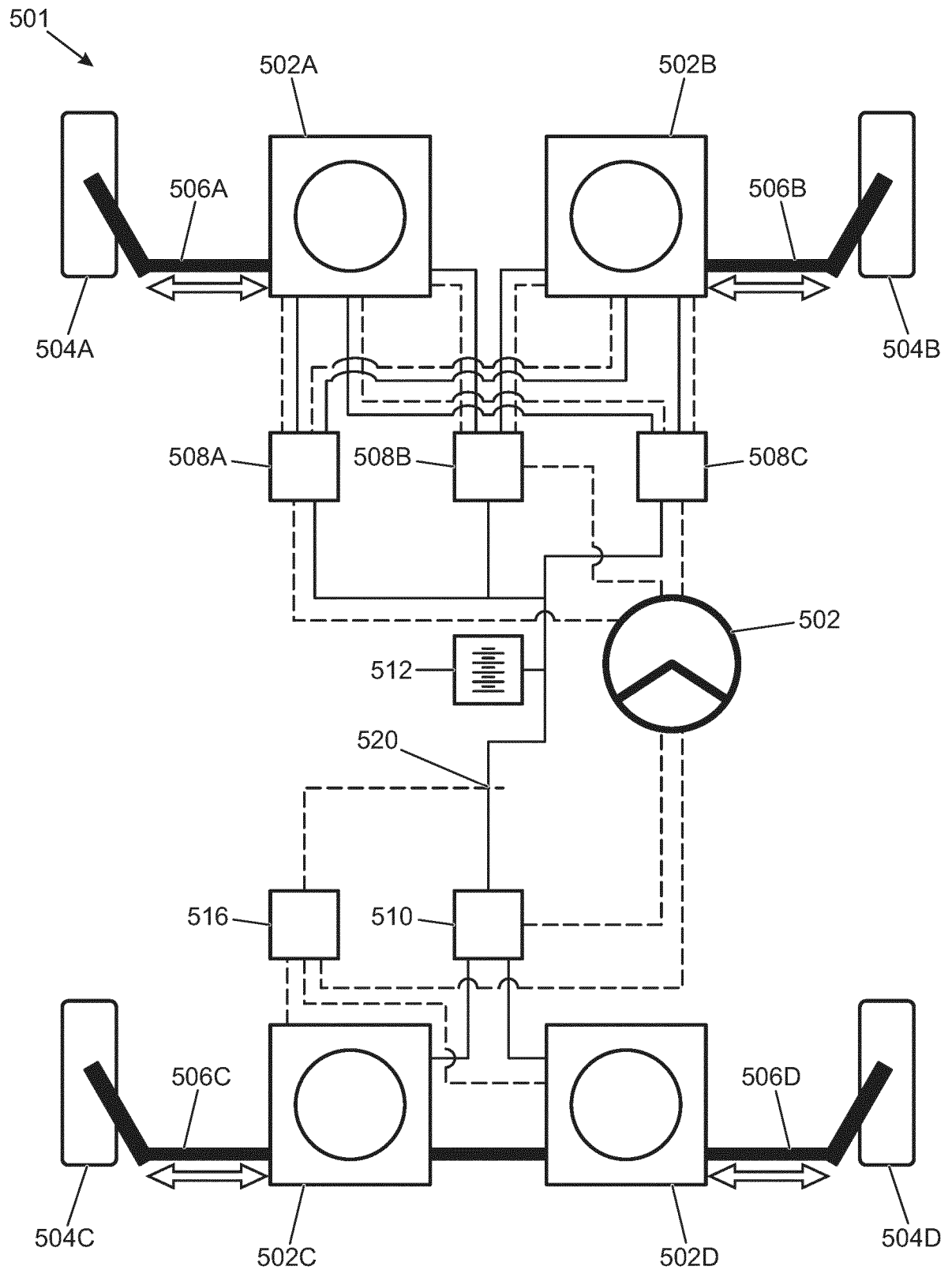


Figure 5

6/6

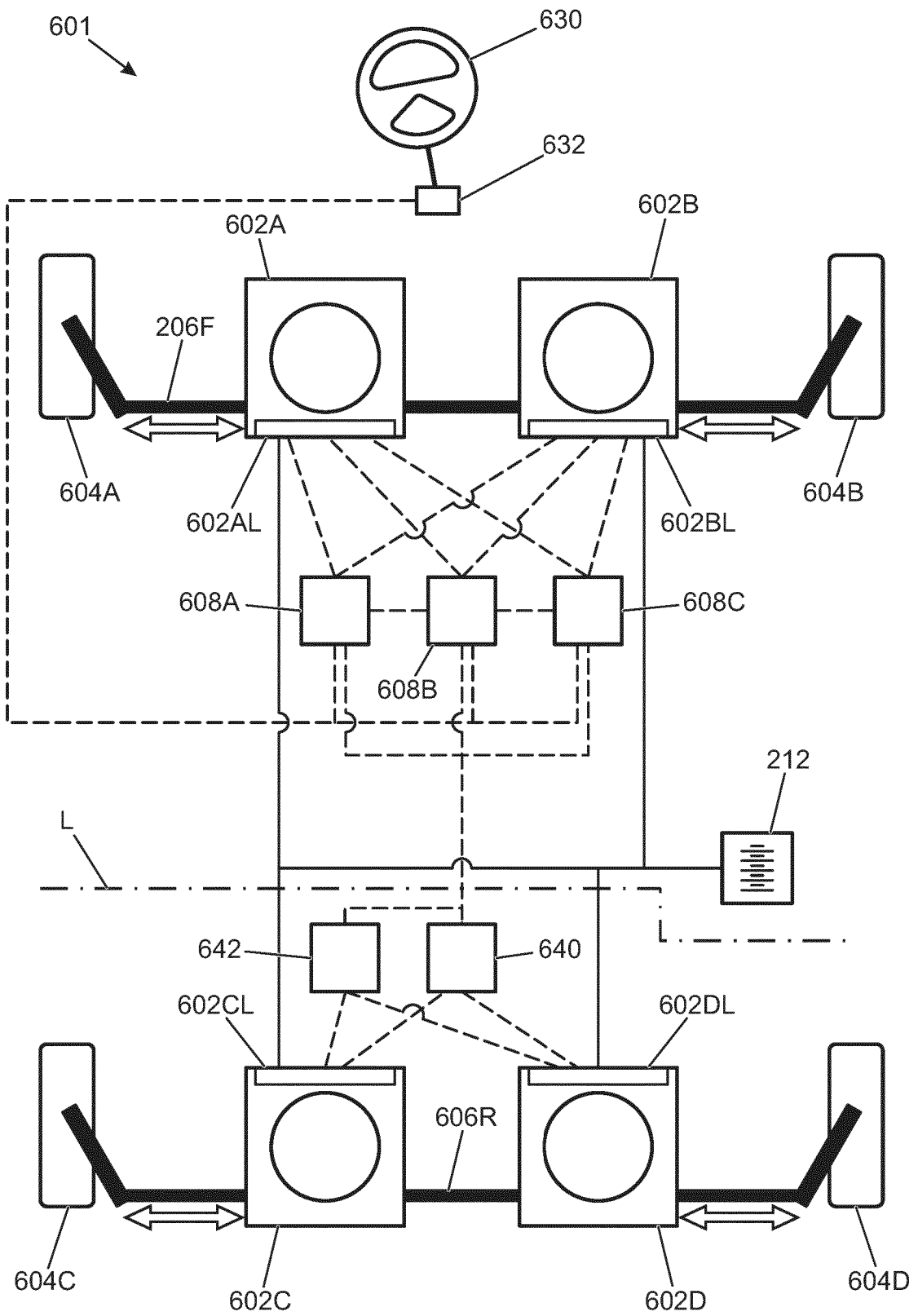


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/075069

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62D5/04 B62D7/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B62D B60W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2015/100207 A1 (YOSHIMURA KENTARO [FR] ET AL) 9 April 2015 (2015-04-09) paragraph [0132] - paragraph [0178] paragraph [0315] - paragraph [0365]; figures 1-28 ----- -/--	13,14, 17,18 1-12,16, 19-30, 32-41, 44-57 15,31, 42,43

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 December 2017

Date of mailing of the international search report

26/01/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Signorini, Luca

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/075069

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007 008242 A (NISSAN MOTOR) 18 January 2007 (2007-01-18) paragraph [0008] - paragraph [0028]; figures 1-18 -----	1,2,4-8, 11,12, 19-22, 25-30, 32-35, 38-41, 48-51, 54-57
Y	US 2005/178606 A1 (HUSAIN MUQTADA [US] ET AL) 18 August 2005 (2005-08-18) paragraph [0027] - paragraph [0084]; figures 1-10 -----	1-12,16, 19-30, 32-41, 44-57
Y	US 2007/246287 A1 (TSUKASAKI YUICHIRO [JP]) 25 October 2007 (2007-10-25) paragraph [0028] - paragraph [0041]; figure 14 -----	45

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/075069

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015100207 A1	09-04-2015	EP 1616746 A2	18-01-2006
		EP 2177413 A2	21-04-2010
		US 2006015231 A1	19-01-2006
		US 2010030421 A1	04-02-2010
		US 2014188343 A1	03-07-2014
		US 2015100207 A1	09-04-2015

JP 2007008242 A	18-01-2007	JP 4821185 B2	24-11-2011
		JP 2007008242 A	18-01-2007

US 2005178606 A1	18-08-2005	DE 102005007725 A1	08-09-2005
		US 2005178606 A1	18-08-2005

US 2007246287 A1	25-10-2007	JP 2007290508 A	08-11-2007
		US 2007246287 A1	25-10-2007
