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(54) Good checking for vehicle wheel speed sensors

Genaue Prüfung für Fahrzeugradgeschwindigkeitssensoren

Processus de vérification pour les capteurs de vitesse de roues de véhicule

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(73) Proprietor: **Robert Bosch GmbH**
70442 Stuttgart (DE)

(72) Inventors:
- **Bechtler, Henrik**
  70182 Stuttgart (DE)
- **Bhadange, Ravi**
  Farmington, Michigan 48335 (US)
- **Patil, Nachiket**
  Farmington Hills, Michigan 48335 (US)
- **Mallmann, Stefan**
  74348 Lauffen (DE)
- **Schwab, Michael**
  70825 Korntal (DE)
- **Tokonaga, Takeshi**
  Yokohama-shi
  Kanagawa-ken, Japan 224-0012 (JP)
- **Stapel, Dietmar**
  48324 Sendenhorst (DE)
- **Klier, Willy**
  Bloomfield Hills, Michigan 48301 (US)
- **Eesmann, Joerg**
  48429 Rheine (DE)

(74) Representative: **DREISS Patentanwälte PartG mbB**
Friedrichstrasse 6
70174 Stuttgart (DE)

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Description

RELATED APPLICATION

[0001] The present application claims the benefit of prior filed co-pending U. S. Provisional Patent Application No. 61/236,393 filed on August 24, 2009.

BACKGROUND

[0002] Modern vehicles include computer systems for controlling engine emissions, vehicle braking, and a variety of other items. Each of these systems requires data in order to function, such as oxygen level data for controlling engine emissions and wheel speed data for controlling braking. This data is generally supplied by sensors located throughout the vehicle. To ensure the integrity of the data provided by the sensors, controllers perform malfunction testing on the sensors (or the signals or data the sensors provide). If a sensor malfunction is detected (e.g., there is an error in the sensor output or sensor data), a warning light or similar indicator can be activated.

[0003] EP 1 227 019 A1 discloses an antilock braking system (ABS) that detects faults in wheel speed sensors and maintains a fault until the wheel speed sensor operates correctly at slow speeds. The ABS lights a fault indicator when the wheel speed sensor is determined to be faulty and the brake is applied by a driver.

SUMMARY

[0004] While current vehicle systems are designed to monitor the functioning or operation of vehicle sensors and determine when a sensor malfunction occurs, such systems lack, at least in general, robust abilities for determining when the sensor malfunction ends. For example, a sensor malfunction might be caused by a powerful source of electromagnetic interference ("EMI"). Such a circumstance might occur if a vehicle passes near an electrical power generation plant, a radar or broadcast installation, or similar location. Once the vehicle moves outside the range of the EMI, the output from the sensor might return to within an acceptable range. However, in many vehicles, once a sensor malfunction occurs, the only way in which the malfunction or error may be cleared is to have a mechanic or technician access the system, check its operation, and perform an act that resets the system or otherwise removes the error.

[0005] A check of the sensor signal based on a re-detection by the failure monitoring function can be used as a mechanism to determine if a sensor has returned to normal operation. However, "good checking" is more than this. In general, malfunction monitoring functions are designed to avoid misdetection. On the other hand, "good check" functions are, according to the invention, designed to avoid a false good check, i.e., a good check function has smaller tolerances for deviations and fewer conditions on the driving situation to perform the evaluation. Or, in other words, the tolerances and conditions used in good checking are different than those used to detect a malfunction.

[0006] The present invention provides a solution to the above stated problem by the features of independent claim 1.

[0007] Embodiments of the invention provide a mechanism for automatically determining whether a malfunctioning sensor has returned to a normal or acceptable operating range. In the parlance of the inventors, embodiments of the invention perform a "good check" on the sensor to determine whether the sensor has returned to normal or acceptable operation after a malfunction has been detected. When a previously-malfunctioning sensor passes the "good check," warning lights (or tell-tale) indicators are shut off and systems that relied upon information from the malfunctioning sensor return to normal operation.

[0008] In one embodiment, the invention provides a controller for determining whether a previously-detected vehicle wheel speed sensor malfunction still exists. The controller includes an electronic, non-volatile memory, and an electronic processing unit connected to the electronic, non-volatile memory. The electronic processing module includes a malfunction monitoring module, a failure handling module, and a signal checking module. The malfunction monitoring module monitors the operation of at least one vehicle sensor and generates a fault signal when the at least one sensor malfunctions. The fault signal contains fault information and causes a tell-tale indicator to be activated and/or a vehicle control system to modify its operation from a first operating state to a second state. The failure handling module causes drive cycle information and the fault information to be stored in the electronic, non-volatile memory. The signal checking module performs a signal check on information from the at least one sensor.

The signal check includes retrieving drive cycle information for a wheel speed sensor from the electronic, non-volatile memory and comparing an output of the wheel speed sensor to a predetermined range. If the output of the wheel speed sensor is within the pre-determined range for a pre-determined amount of time, the wheel speed sensor passes the signal check. If the wheel speed sensor passes the signal check, the controller generates a reset signal, the reset signal causes the tell-tale indicator to be deactivated and/or the vehicle control system to resume operation in the first operating state.

[0009] In some embodiments, the controller is mounted in a vehicle. The previously-detected vehicle wheel speed sensor malfunction is one of an implausible sensitivity of the wheel speed sensor, an interference of the wheel speed sensor, and a stuck signal received from the wheel speed sensor. The wheel speed sensor is one of a plurality of wheel speed sensors and the controller compares a speed detected by each of the plurality of wheel speed sensors, the controller determining that a wheel speed sensor fault still exists if the difference between the fastest speed detected by one of the plurality of wheel speed sensors and the slowest speed detected by one of the plurality of wheel speed sensors exceeds a threshold. The controller checks if the difference between the fastest speed detected by one of the plurality of wheel speed sensors and the slowest speed detected by one of the plurality of wheel speed sensors is less than the threshold for a pre-determined period of time. The controller checks if the speed detected by each of the plurality of wheel speed sensors exceeds a second threshold. The plurality of wheel speed sensors pass the signal check if the controller has not detected interference at the plurality of wheel speed sensors, the speed detected by each of the plurality of wheel speed sensors exceeds the second threshold, and the difference between the fastest speed detected by one of the plurality of wheel speed sensors and the slowest speed detected by one of the plurality of wheel speed sensors is less than the threshold for the pre-determined period of time.

[0010] In some embodiments, the previously-detected vehicle wheel speed sensor malfunction is a wheel speed sensor swapped sensor fault. The signal check is executed only when the vehicle is turning. The controller determines that the vehicle is turning if an absolute value of a yaw rate of the vehicle is greater than a threshold. The controller calculates a wheel speed sensor yaw rate and a lateral acceleration yaw rate. The wheel speed sensor passes the signal check if the difference between the wheel speed sensor yaw rate and the lateral acceleration yaw rate is less than a second threshold for a predetermined period of time.

[0011] In some embodiments, the previously-detected vehicle wheel speed sensor malfunction is a wheel speed sensor missing teeth fault. The controller monitors a signal from the wheel speed sensor and is configured to detect one or more missing teeth in the wheel speed sensor. The wheel speed sensor passes the signal check if the controller does not detect the one or more missing teeth for a pre-determined period of time.

[0012] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a perspective view of a vehicle including a vehicle control system according to one embodiment of the invention.

Fig. 2 schematically illustrates the vehicle control system of Fig. 1 according to one embodiment of the invention.

Fig. 3 schematically illustrates the functional operation of modules of the vehicle control system of Fig. 2 according to one embodiment of the invention.

Fig. 4 is a flow chart illustrating a first wheel-speed-sensor signal check function according to an embodiment of the invention.

Fig. 5 is a flow chart illustrating a second wheel-speed-sensor signal check function according to an embodiment of the invention.

Fig. 6 is a flow chart illustrating a third wheel-speed-sensor signal check function according to an embodiment of the invention.

DETAILED DESCRIPTION

[0014] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

[0015] It should be noted that a plurality of hardware and software based devices, as well as a plurality of different structural components, may be utilized to implement the invention. Further, and as described in subsequent paragraphs, the specific configurations illustrated in the drawings are intended to be exemplary embodiments of the invention. Alternative configurations are possible.

[0016] Fig. 1 illustrates a vehicle 100 including vehicle control system 105. In the example illustrated the vehicle control system is an electronic stability control ("ESC") system. The vehicle control system 105 includes a plurality of wheel speed sensors ("WSS") 110. Each of the WSS's 110 monitor a single wheel of the vehicle and are connected to the bus 115. Each WSS 110 provides information about the speed of rotation of the wheel it monitors. Information obtained by the WSS 110 is transmitted over a connection or network, such as a controller area network ("CAN") bus 115. A controller 120 receives information from the WSS 110 via the bus 115. The controller 120 includes an ESC application or module that is designed to detect instability of the vehicle and help correct the situation. For example, when the controller 120 detects a loss of steering control, the controller 120 may automatically apply one or more individual brakes 125 to help steer the vehicle 100 in a desired direction. In some embodiments, the controller 120 also reduces engine power when it detects a skid or slide of the vehicle 100 until the vehicle operator regains control of the vehicle 100.

[0017] As shown in Fig. 1, the vehicle control system 105 also includes additional sensors such as a yaw rate sensor ("YRS") 130, and a steering angle sensor ("SAS") 135. The YRS 130 is connected to the bus 115 and sends information to other components also connected to the bus 115, such as the controller 120. Information sent by the YRS 130 over the bus 115 includes information about the rotational velocity of the vehicle around a vertical axis at the center of the vehicle. The SAS 135 senses how far and in what direction a steering wheel has been turned, transmitting this data over the bus 115.

[0018] Fig. 2 schematically illustrates the vehicle control system 105 of Fig. 1 in greater detail. The numerous sensors depicted in Fig. 1 are represented generally by boxes 150 (Sensor 1 ... Sensor N). The control system 105 includes the controller 120 and the bus 115. The controller 120 includes an input/output interface 155, an electronic processing unit ("EPU") 160, and one or more memory modules, such as a random access memory ("RAM") module 165 and an electronically erasable programmable read-only memory ("EEPROM") module 170. As shown in Fig. 2, the input/output interface 155 transmits and receives information over the bus 115. The EPU 160 receives the information from the input/output interface 155 and processes the information by executing one or more applications or modules. The applications or modules can be stored in the memory. The EPU 160 also stores information (e.g., information received from the bus 115 or information generated by applications or modules executed by the EPU 160) to the memory. Data stored in the RAM 165 is reset at the start of each new ignition cycle.

[0019] In the embodiment illustrated in Fig. 3, the EPU 160 includes a malfunction monitoring module 200, a failure handling module 205, a vehicle control module 210, and a signal checking module 215. The malfunction monitoring module 200 receives sensor signals from the sensors 150 (e.g., through the input/output interface 155) and saves the sensor signals to the memory. In most embodiments, the malfunction monitoring module 200 saves filtered or compensated sensor signals to the memory. In addition, the malfunction monitoring module 200 can save raw sensor data to the memory. For example, over time a sensor 150 may become dirty or damaged, which can affect the sensor's operation. The malfunction monitoring module 200 applies an offset (positive or negative) to the signals received from a particular sensor 150 to compensate for the sensor's deterioration, and stores the compensated sensor signal to the memory.

[0020] The main function or purpose of the malfunction monitoring module 200 is to determine if a particular sensor is malfunctioning or faulty. For example, if a sensor's offset becomes too large, the malfunction monitoring module 200 may determine that the sensor 150 is no longer reliable, and therefore is malfunctioning. A variety of algorithms and techniques for determining whether a sensor is malfunctioning can also be used, including those disclosed in United States Patent No. 6,834,221.

[0021] When the malfunction monitoring module 200 detects a malfunctioning or faulty sensor, the module 200 generates a fault signal and sends the fault signal to the fault handling module 205. The fault signal includes fault information based on the particular fault or malfunction observed by the malfunction monitoring module 200. The failure handling module 205 stores the fault information and corresponding counter information, (which is referred to as "drive cycle information") in the memory. The drive cycle information indicates what signal check functions should be performed by the signal checking module 215 during the next drive cycle (e.g., the next time during which malfunction testing is performed) to determine whether a previously-detected fault still exists. For example, if the malfunction monitoring module 200 detects that a WSS 110 is malfunctioning and generates a fault signal, the fault or failure handling module 205 saves drive cycle information to the memory, indicating that the signal checking module 215 should check the WSS 110 during a subsequent cycle to determine whether the previously-detected WSS fault still exists.

[0022] Based on faults detected by the malfunction monitoring module 200, the vehicle control module 210 activates one or more warning lights or tell-tales in the vehicle 100 (e.g., on the vehicle's dashboard or instrument panel) that alert the vehicle operator that there is a problem. The vehicle control module 210 may also modify its operation of a particular control system or process, such as ESC functions. For example, if a particular sensor 150 is malfunctioning, the vehicle control module 210 may change the operation of an ESC function from a first operating state (e.g., fully functional and active) to a second operating state (e.g., partial functionality or inactive). In some embodiments, the first operating state includes fully active and functional control where the vehicle control module 210 considers all data from all sensors 150 providing vehicle information relevant to a particular ESC function. The second operating state can include an intermediate functional state where the vehicle control module 210 ignores sensor information from one or more particular malfunctioning sensors, but continues to perform ESC functions using data from other functioning sensors or constants (e.g., when data necessary to perform particular ESC functions cannot be derived from other sensors 150). Alternatively, the second operating state can include a deactivated state. In some embodiments, the vehicle control module 210 can deactivate one or more ESC functions if a sensor 150 important to that function is malfunctioning and, thus, causing a lack of proper information for the ESC to function properly. If the vehicle control module 210 inactivates one or more ESC functions, or other types of vehicle control or monitoring functionality, the vehicle control module 210 activates one or more warning lights or tell-tales that warn the vehicle operator of the modified operating state.

[0023] When ESC functions are operational (e.g., the vehicle control module 210 is monitoring for oversteer and understeer conditions), the vehicle control module 210 obtains current sensor readings from the memory. In some embodiments, the vehicle control module 210 may also or alternatively obtain current sensor readings from the malfunction monitoring module 200, the bus 115 and/or one or more sensors 150 directly (e.g., via the input/output interface 155). If the vehicle control module 210 is ignoring particular sensor information, based on currently detected faults, the vehicle control module 210 does not need to request this sensor information or can simply ignore any such sensor information it receives.

[0024] The signal checking module 215 performs various signal checks to determine whether a previously-detected sensor malfunction still exists. As shown in Fig. 3, as part of a signal check, the signal checking module 215 retrieves drive cycle information stored in the memory. In some embodiments, the signal checking module 215 is initialized during each new ignition cycle, and retrieves the stored drive cycle information upon each initialization. In other embodiments, the signal checking module 215 retrieves stored drive cycle information from the memory at various times while the controller 120 is operating, and the signal checking module 215 performs signal checks based on the stored drive cycle information continuously or at designated times (e.g., a next ignition cycle, or once every 10 milliseconds).

[0025] As described below with respect to Figs. 4-6, after the signal checking module 215 retrieves stored drive cycle information from the memory, the module 215 executes one or more signal check functions to determine whether a previously-detected fault still exists. As part of executing signal check functions, the signal checking module 215 retrieves current sensor readings from the memory (as stored by the malfunction monitoring module 200). In other embodiments, the signal checking module 215 can retrieve current sensor information or readings from the malfunction monitoring module 200 the bus 115 and/or one or more sensors 150 directly (i.e., via the input/output interface 155). The current sensor readings can include compensated or filtered sensor signals or information, raw sensor information, current sensor offsets, and/or other statistical information about a particular sensor 150. The signal checking module 215 uses the current sensor readings when executing a signal check function to determine whether the previously-detected fault still exists. In some embodiments, the signal checking module 215 retrieves current sensor readings from the previously-detected malfunctioning sensor. In other embodiments, the signal checking module 215 also retrieves current sensor readings from sensors other than the previously-detected malfunctioning sensor. For example, the signal checking module 215 can use information from functioning sensors to determine whether a sensor reading from a sensor 150 having a previously-detected fault is implausible.

[0026] As shown in Fig. 3, if the signal checking module 215 performs one or more signal check functions related to a particular fault and determines that the fault doesn't exist anymore, the signal checking module 215 can reset the corresponding fault information and/or drive cycle information in the memory to indicate that the previously-detected malfunction no longer exists. In some embodiments, the signal checking module 215 resets the drive cycle information by generating a reset signal. The failure handling module 205 receives the reset signal and updates the fault information and/or drive cycle information in the memory to indicate that the previously-detected fault no longer exists (e.g., by deleting the previous fault and/or drive cycle information or setting a fault bit or flag to an "okay" or "no fault" value). When the vehicle control module 210 subsequently requests the current faults from the failure handling module 205, the failure handling module 205 informs the vehicle control module 210 that the sensor 150, for which there was a previously-detected fault, is functioning properly. The vehicle control module 210 re-assesses the current faults and, in some embodiments, deactivates a previously-activated warning light or tell-tale within the vehicle 100 and/or returns its operation back to a first or original operating state (e.g., a fully active and functional state).

[0027] If the signal checking module 215 performs one or more signal check functions related to a particular fault and determines that the fault still exists, the signal checking module 215 does not change the corresponding fault and/or drive cycle information in the memory, which retains the fault and/or drive cycle information in the same condition as before the signal checking module 215 performed the required signal checks.

[0028] Particular sensors 150 can experience various malfunctions. For example, the plurality of WSS's 110 may experience a WSS stuck signal malfunction, which occurs when the malfunction monitoring module 200 detects that the WSS signal remains constant for a predetermined period of time or when other detected (i.e., measured or calculated) yaw rates have changed. As described above, when the malfunction monitoring module 200 detects a WSS stuck signal malfunction, the module 200 generates a fault signal and the failure handling module 205 stores corresponding fault information and drive cycle information in the memory. The vehicle control module 210 obtains the current fault information from the failure handling module 205 and activates one or more tell-tales or warning lights and/or modifies operation of a vehicle control (e.g., deactivating ESC function(s)).

[0029] The malfunction monitoring module 200 can detect other WSS malfunctions in addition to the WSS stuck signal malfunction, including a WSS swapped signal malfunction, a WSS implausible sensitivity malfunction, a WSS interference malfunction, and a WSS missing teeth malfunction. Figs. 4-6, illustrate embodiments of methods for determining if previously-detected faults of these types no longer exist.

[0030] Fig. 4 shows an embodiment of the operation of the signal checking module 215 for detecting if a previously-detected first (or generic) WSS error still exists. When the malfunction monitoring module 200 determines that a first WSS fault has occurred, the malfunction monitoring module 200 sets a first WSS drive cycle flag. The signal checking module 215 performs checks on previously-detected faults (e.g., continuously or once each pre-determined time period). One of the checks the signal checking module 215 performs is a first WSS signal check. The signal checking module 215 begins by checking if the first WSS drive cycle flag is set (step 300). If the first WSS drive cycle flag is not set (i.e., a first WSS fault has not been detected), the signal checking module 215 exits the first WSS signal check (step 305).

[0031] If, at step 300, the first WSS drive cycle flag is set (i.e., a first WSS fault has previously been detected), the signal checking module 215 determines if the first WSS fault no longer exists. Generally, the signal checking module 215 compares the readings of each of the plurality of WSS's 110 to each other when the speed of the wheels is above a threshold. If all the readings are all within a desired range for a pre-determined period, and there was no interference in the signal of any of the WSS's 110, the signal checking module 215 determines that the previously-detected generic fault no longer exists. In some embodiments, individual WSS's 110 can be checked against another WSS 110 to identify an individual WSS 110 that is faulty. Thus, an anti-lock braking system that uses data from the WSS 110 can continue to function normally for wheels having non-faulty speed sensors, while operating in an inactive state for the wheel or wheels having a faulty speed sensor.

[0032] Referring back to Fig. 4, the signal checking module 215 determines if the fastest speed detected by one of the WSS's 110 is within an allowable range compared to the slowest speed detected by one of the WSS's 110 (step 310). If the fastest and slowest detected speeds are not within the allowable range (e.g., if the fastest detected speed is greater than the slowest detected speed by more than a threshold such as 0.5% to 30%), the signal checking module 215 resets a first WSS counter (step 315) and a first WSS "OK" flag (step 320), and exits the first WSS signal check (step 305). The first WSS counter tracks the difference between the fastest and slowest detected speeds and determines whether this difference is within the allowable range. The first WSS "OK" flag is used by the controller 120 to reset the first WSS fault and the drive cycle flag.

[0033] If, at step 310, the speeds detected by the WSS's 110 are within the allowable range, the signal checking module 215 checks if the detected speeds have been within the allowable range for a pre-determined time period (e.g., 0.5 to 5.0 seconds) (step 325). If not, the signal checking module 215 increments the first WSS counter (step 330), resets the first WSS "OK" flag (step 320), and exits the first WSS signal check (step 305). If the detected speeds have been within the allowable range for the pre-determined time period, the signal checking module 215 checks if all of the speeds detected by the WSS's 110 exceed a threshold (e.g., 0-100 kilometers per hour) (step 335). If they do not, the signal checking module 215 sets the first WSS "OK" flag (step 320) and exits the first WSS signal check (step 305). If the speeds are all above the threshold, the signal checking module 215 then checks if there has been any interference detected at one of the WSS's 110 (step 340). If interference has been detected, the signal checking module 215 sets the first WSS "OK" flag (step 320) and exits the first WSS signal check (step 305). If there has not been any interference, the signal checking module 215 sets the first WSS "OK" flag (step 345), which causes the first WSS fault and drive cycle flags to be reset and allows the ESC functions using data from the WSS's 110 to return to their fully functional operating state, provided there are no other WSS faults. The signal checking module 215 then exits the first WSS signal check (step 305).

[0034] In some embodiments, when a WSS fault is detected, one or more tell-tale indicators or warning lights can be illuminated (e.g., using one or more colors such as yellow and/or red) to indicate to a driver the status of various ESC functions (e.g., anti-lock braking) which rely on data from the wheel speed sensors. In addition, the warning lights that are illuminated, and their colors, can be modified based on the number of wheels at which a WSS fault has been detected (e.g., one or two wheels versus three or four wheels in a vehicle having four wheels). The states of the warning lights can indicate to the driver which of the ESC functions are compromised, and which remain operational.

[0035] In one exemplary embodiment, when a WSS fault is detected, a brake warning light is off, an ABS warning light is illuminated yellow, an ESC Failure light is also illuminated yellow, and, an ESC off light is off (e.g., the ESC off light is illuminated when the driver manually turns off the ESC functions).

[0036] In another exemplary embodiment, when a WSS fault is detected, a brake warning light is illuminated red, an ABS warning light is illuminated yellow, an ESC failure light is also illuminated yellow, and an ESC off light is off.

[0037] Fig. 5 shows an embodiment for determining whether a previously-detected second (or missing teeth) WSS fault still exists. In some embodiments, the WSS's 110 include "teeth" (e.g., alternating pole magnets, slots, etc.) on a hub that rotates with a wheel. The "teeth" are detected by a sensor and converted to an output signal - generally a square wave signal having a positive half cycle when a "tooth" is detected. The frequency of the signal then indicates the speed at which the wheel is turning. If a "tooth" is missing or becomes dirty, the output signal will miss the positive half cycle associated with that tooth once each revolution of the wheel. The missing signal can impact the calculation of the wheel speed. The wheel speed missing teeth signal checks are performed for each WSS 110 individually.

[0038] When the malfunction monitoring module 200 determines that a second WSS fault has occurred, the malfunction monitoring module 200 sets a second WSS drive cycle flag. The signal checking module 215 performs checks on previously-detected faults (e.g., continuously or once each pre-determined time period). One of the checks the signal checking module 215 performs is a second WSS signal check. The signal checking module 215 begins by checking if the second WSS drive cycle flag is set (step 400). If the second WSS drive cycle flag is not set (i.e., a second WSS fault has not been detected), the signal checking module 215 exits the second WSS signal check (step 405).

[0039] If the second WSS drive cycle flag is set, the signal checking module 215 checks if a missing teeth monitoring function is active (step 410). The missing teeth monitoring function may be inactivated during certain circumstances (e.g., during high-bandwidth computing operations such as when an ABS function is operating). If the missing teeth monitoring function is not active, data related to WSS missing teeth is not valid, and should be ignored. As a consequence, if the function is inactive, the signal checking module 215 resets a second WSS counter (step 415) and exits the second WSS signal check (step 405). If monitoring is active, the signal checking module 215 checks whether any missing teeth have been detected (step 420). If one or more missing teeth have been detected (e.g., by checking a flag or counter updated by the missing teeth monitoring function), the signal checking module 215 resets the second WSS counter (step 415) and exits the second WSS signal check (step 405). If, at step 430, no missing teeth were detected, the signal checking module 215 checks if there have been no missing teeth detected for a pre-determined time period (step 425). If the time period that no missing teeth have been detected is less than the pre-determined time period, the signal checking module 215 increments the counter (step 430) (e.g., updates the time that no missing teeth have been detected) and exits the second WSS signal check (step 405).

[0040] If there have been no missing teeth detected for the entire pre-determined time period, the signal checking module 215 sets a second WSS "OK" flag (step 435), causing the controller 120 to reset the second WSS fault and drive cycle flags, and allowing the ESC functions using data from the WSS's 110 to return to their fully functional operating state, provided there are no other WSS faults. The signal checking module 215 then exits the second WSS signal check (step 405).

[0041] Fig. 6 shows an embodiment of the operation of the signal checking module 215 for detecting if a previously-detected third (or swapped-sensor) WSS fault still exists. In some circumstances, data from individual WSS can be "swapped." For example, the signals from the WSS associated with a right front wheel can be swapped with the signals from the WSS associated with a left front wheel (e.g., by incorrect wiring or sensor addressing). When the sensors are swapped, the data cannot be relied upon by the ESC controller 120.

[0042] When the malfunction monitoring module 200 determines that a third WSS fault has occurred, the malfunction monitoring module 200 sets a third WSS drive cycle flag. The signal checking module 215 performs checks on previously-detected faults (e.g., continuously or once each pre-determined time period). One of the checks the signal checking module 215 performs is a third WSS signal check. The signal checking module 215 begins by checking if the third WSS drive cycle flag is set (step 500). If the third WSS drive cycle flag is not set (i.e., the WSS 110 are not swapped), the signal checking module 215 exits the third WSS signal check (step 505).

[0043] If the third WSS drive cycle flag is set, the signal checking module 215 checks if the vehicle is turning (step 510). In some embodiments, the signal checking module 215 determines the vehicle is turning if a yaw rate from the YRS 130 exceeds a threshold (e.g., 2.0 to 10.0 degrees per second). If the vehicle is not turning, the signal checking module 215 exits the third WSS signal check (step 505).

[0044] If the vehicle is turning, the signal checking module 215 checks if a yaw rate calculated using data from the WSS 110 is within a pre-determined range relative to a yaw rate calculated using data from a lateral acceleration sensor (step 515). A yaw rate is calculated based on the difference in the detected speed of the right and left wheels for both the front and back axles. For example, if the vehicle is traveling straight, there should be little or no difference between the detected speeds of the right and left wheels. However, if the vehicle is turning, the speed of the wheels on the outside of the turn should be faster than the speed of the wheels on the inside of the turn. If the WSS's 110 are swapped between the right and left wheels of the vehicle, the yaw rate calculated using data from the WSS's would be inverse of the actual yaw rate of the vehicle. In addition, if the WSS's 110 are swapped between the front and back axles, the yaw rates calculated for the front axle and the rear axle would likely be out of proportion. A yaw rate is also determined using the lateral acceleration obtained from a lateral acceleration sensor and the speed of the vehicle. In some embodiments, the yaw rates calculated using data from the WSS's must be within a range (e.g., +/- 0.1 to 10.0 degrees per second of the yaw rate calculated using data from the lateral acceleration sensor).

[0045] If, at step 515, the signal checking module 215 determines that the yaw rate calculated using data from the WSS 110 is not within the pre-determined range relative to a yaw rate calculated using data from a lateral acceleration sensor, the signal checking module 215 resets a third WSS counter (step 520) and exits the third WSS signal check (step 505). If the yaw rates are within the pre-determined range, the signal checking module 215 checks if the yaw rates have been within the pre-determined range for a pre-determined time period (step 525) (e.g., 1.0 to 10.0 seconds). If the yaw rates have not been within the pre-determined range for the time period, the signal checking module 215 increments the third WSS counter (step 530) (e.g., updates the time that yaw rates have been within the range) and exits the third WSS signal check (step 505).

[0046] If the yaw rates have been within the range for the entire time period, the signal checking module 215 sets a third WSS "OK" flag (step 535), causing the controller 120 to reset the third WSS fault and drive cycle flags, allowing the ESC functions using data from the

WSS's 110 to return to their fully functional operating state, provided there are no other WSS faults. The signal checking module 215 then exits the third WSS signal check (step 505).

[0047] In some embodiments, the failure handling module 205 detects that a WSS "OK" flag has been set by one of the functions described above. The failure handling module 205 then resets the fault and the drive cycle information in the memory for the respective WSS fault. In other embodiments, the signal checking module 215 sends a reset signal to the failure handling module 205 to reset a respective WSS fault that the signal checking module 215 determines no longer exists.

[0048] Thus, the invention provides, among other things, a controller for determining whether a previously-detected vehicle sensor malfunction still exists by executing various signal checks and signal check functions using sensor-related information. Various features and advantages of the invention are set forth in the following claims.

Claims

1. A controller (120) for determining whether a previously-detected vehicle wheel speed sensor malfunction still exists, the controller (120) comprising: an electronic, non-volatile memory (170); and an electronic processing unit (160) connected to the electronic, non-volatile memory (170), the electronic processing unit (160) including, a malfunction monitoring module (200) that monitors the operation of a wheel speed sensor (110) and generates a fault signal when the wheel speed sensor (110) outputs a signal that is outside of a first predetermined range, the fault signal containing fault information and causing at least one of a tell-tale indicator to be activated and a vehicle control system (105) to modify its operation from a first operating state to a second operating state, a failure handling module (205) that causes drive cycle information and the fault information to be stored in the electronic, non-volatile memory (170), and a signal checking module (215) that performs a signal check on information from the wheel speed sensor (110), the signal check including retrieving drive cycle information for a wheel speed sensor (110) from the electronic, non-volatile memory (170), comparing an output of the wheel speed sensor (110) to a second pre-determined range narrower than the first predetermined range, the wheel speed sensor (110) passing the signal check if the output of the wheel speed sensor (110) is within the second predetermined range for a pre-determined amount of time, generating a reset signal, if the wheel speed sensor (110) passes the signal check, the reset signal causing at least one of the tell-tale indicator to be deactivated and the vehicle control system (105) to resume operation in the first operating state.

2. The controller (120) of claim 1 wherein the previously-detected vehicle wheel speed sensor malfunction is one of an implausible sensitivity of the wheel speed sensor (110), an interference of the wheel speed sensor (110), and a stuck signal received from the wheel speed sensor (110).

3. The controller (120) of claim 2, wherein the wheel speed sensor (110) is one of a plurality of wheel speed sensors (110) and the controller compares a speed detected by each of the plurality of wheel speed sensors (110), the malfunction monitoring module (200) determining that a wheel speed sensor fault still exists if the difference between the fastest speed detected by one of the plurality of wheel speed sensors (110) and the slowest speed detected by one of the plurality of wheel speed sensors (110) exceeds a threshold.

4. The controller (120) of claim 3, wherein the signal checking module (215) checks if the difference between the fastest speed detected by one of the plurality of wheel speed sensors (110) and the slowest speed detected by one of the plurality of wheel speed sensors (110) is less than the threshold for a pre-determined period of time.

5. The controller (120) of claim 4, wherein the controller (120) checks if the speed detected by each of the plurality of wheel speed sensors (110) exceeds a second threshold.

6. The controller (120) of claim 5, wherein the plurality of wheel speed sensors (110) pass the signal check if the controller (120) has not detected interference at the plurality of wheel speed sensors (110), the speed detected by each of the plurality of wheel speed sensors (110) exceeds the second threshold, and the difference between the fastest speed detected by one of the plurality of wheel speed sensors (110) and the slowest speed detected by one of the plurality of wheel speed sensors (110) is less than the threshold for the pre-determined period of time.

7. The controller (120) of claim 1, wherein the previously-detected vehicle wheel speed sensor malfunction is a wheel speed sensor swapped sensor fault.

8. The controller (120) of claim 7, wherein the signal check is executed only when the vehicle is turning.

9. The controller (120) of claim 8, wherein the controller (120) determines that the vehicle is turning if an absolute value of a yaw rate of the vehicle is greater than a threshold.

10. The controller (120) of claim 8, wherein the controller (120) calculates a wheel speed sensor yaw rate and a lateral acceleration yaw rate.

11. The controller (120) of claim 10, wherein the wheel speed sensor (110) passes the signal check if the difference between the wheel speed sensor yaw rate and the lateral acceleration yaw rate is less than a second threshold for a pre-determined period of time.

12. The controller (120) of claim 1, wherein the previously-detected vehicle wheel speed sensor malfunction is a wheel speed sensor missing teeth fault.

13. The controller (120) of claim 12, wherein the controller (120) monitors a signal from the wheel speed sensor (110) and is configured to detect one or more missing teeth in the wheel speed sensor (110).

14. The controller (120) of claim 13, wherein the wheel speed sensor (110) passes the signal check if the controller (120) does not detect the one or more missing teeth for a pre-determined period of time.

Patentansprüche

1. Steuereinheit (120) zum Bestimmen, ob eine früher detektierte Fahrzeugraddrehzahlsensor-Fehlfunktion noch immer vorhanden ist, wobei die Steuereinheit (120) umfasst: einen elektronischen nichtflüchtigen Speicher (170) und eine elektronische Verarbeitungseinheit (160), die mit dem elektronischen nichtflüchtigen Speicher (170) verbunden ist, wobei die elektronische Verarbeitungseinheit (160) enthält: ein Fehlfunktions-Überwachungsmodul (200), das den Betrieb eines Raddrehzahlsensors (110) überwacht und ein Fehlersignal erzeugt, wenn der Raddrehzahlsensor (110) ein Signal ausgibt, das außerhalb eines ersten vorgegebenen Bereichs liegt, wobei das Fehlersignal Fehlerinformationen enthält und bewirkt, dass wenigstens ein Anzeigeindikator aktiviert wird und ein Fahrzeugsteuersystem (105) seinen Betrieb von einem ersten Betriebszustand zu einem zweiten Betriebszustand modifiziert, ein Fehlerhandhabungsmodul (205), das bewirkt, dass Fahrzyklusinformationen und die Fehlerinformationen in dem elektronischen nichtflüchtigen Speicher (170) gespeichert werden, und ein Signalprüfmodul (215), das an Informationen von dem Raddrehzahlsensor (110) eine Signalprüfung ausführt, wobei die Signalprüfung das Wiedergewinnen von Fahrzyklusinformationen für einen Raddrehzahlsensor (110) aus dem elektronischen nichtflüchtigen Speicher (170) und das Vergleichen eines Ausgangs des Raddrehzahlsensors (110) mit einem zweiten vorgegebenen Bereich, der schmäler als der erste vorgegebene Bereich ist, umfasst, wobei der Raddrehzahlsensor (110) die Signalprüfung besteht, wenn der Ausgang des Raddrehzahlsensors (110) für eine vorgegebene Zeitdauer innerhalb des zweiten vorgegebenen Bereichs liegt, und ein Rücksetzsignal erzeugt, falls der Raddrehzahlsensor (110) die Signalprüfung besteht, wobei das Rücksetzsignal bewirkt, dass der Anzeigeindikator deaktiviert wird und/oder das Fahrzeugsteuersystem (105) seinen Betrieb in dem ersten Betriebszustand wieder aufnimmt.

2. Steuereinheit (120) nach Anspruch 1, wobei die früher detektierte Fahrzeugraddrehzahlsensor-Fehlfunktion entweder eine nicht plausible Empfindlichkeit des Raddrehzahlsensors (110) oder eine Störung des Raddrehzahlsensors (110) oder ein von dem Raddrehzahlsensor (110) empfangenes Dauersignal ist.

3. Steuereinheit (120) nach Anspruch 2, wobei der Raddrehzahlsensor (110) einer von mehreren Raddrehzahlsensoren (110) ist und die Steuereinheit eine von jedem der mehreren Raddrehzahlsensoren (110) detektierte Drehzahl vergleicht, wobei das Fehlfunktions-Überwachungsmodul (200) bestimmt, dass ein Raddrehzahlsensor-Fehler noch immer vorhanden ist, falls die Differenz zwischen der durch einen der mehreren Raddrehzahlsensoren (110) detektierten höchsten Drehzahl und der von einem der mehreren Raddrehzahlsensoren (110) detektierten niedrigsten Drehzahl einen Schwellenwert überschreitet.

4. Steuereinheit (120) nach Anspruch 3, wobei das Signalprüfmodul (215) prüft, ob die Differenz zwischen der durch einen der mehreren Drehzahlsensoren (110) detektierten höchsten Drehzahl und der durch einen der mehreren Raddrehzahlsensoren (110) detektierten niedrigsten Drehzahl für eine vorgegebene Zeitdauer niedriger als der Schwellenwert ist.

5. Steuereinheit (120) nach Anspruch 4, wobei die Steuereinheit (120) prüft, ob die von jedem der mehreren Raddrehzahlsensoren (110) detektierte Drehzahl einen zweiten Schwellenwert überschreitet.

6. Steuereinheit (120) nach Anspruch 5, wobei die mehreren Raddrehzahlsensoren (110) die Signalprüfung bestehen, falls die Steuereinheit (120) bei den mehreren Raddrehzahlsensoren (110) keine Störung detektiert hat, die von jedem der mehreren Raddrehzahlsensoren (110) detektierte Drehzahl den zweiten Schwellenwert überschreitet und die Differenz zwischen der von einem der mehreren Raddrehzahlsensoren (110) detektierten höchsten Drehzahl und der von einem der mehreren Raddrehzahlsensoren (110) detektierten niedrigsten Drehzahl für die vorgegebene Zeitdauer niedriger als der Schwellenwert ist.

7. Steuereinheit (120) nach Anspruch 1, wobei die früher detektierte Fahrzeugraddrehzahlsensor-Fehlfunktion ein durch einen Raddrehzahlsensor-Wechsel bedingter Sensorfehler ist.

8. Steuereinheit (120) nach Anspruch 7, wobei die Signalprüfung nur ausgeführt wird, wenn das Fahrzeug eine Kurve fährt.

9. Steuereinheit (120) nach Anspruch 8, wobei die Steuereinheit (120) bestimmt, dass das Fahrzeug eine Kurve fährt, falls ein Absolutwert einer Gierrate des Fahrzeugs größer als ein Schwellenwert ist.

10. Steuereinheit (120) nach Anspruch 8, wobei die Steuereinheit (120) eine Raddrehzahlsensor-Gierrate und eine Querbeschleunigungs-Gierrate berechnet.

11. Steuereinheit (120) nach Anspruch 10, wobei der Raddrehzahlsensor (110) die Signalprüfung besteht, falls die Differenz zwischen der Raddrehzahlsensor-Gierrate und der Querbeschleunigungs-Gierrate für eine vorgegebene Zeitdauer niedriger als ein zweiter Schwellenwert ist.

12. Steuereinheit (120) nach Anspruch 1, wobei die früher detektierte Fahrzeugraddrehzahlsensor-Fehlfunktion ein durch fehlende Zähne im Raddrehzahlsensor bedingter Fehler ist.

13. Steuereinheit (120) nach Anspruch 12, wobei die Steuereinheit (120) ein Signal von dem Raddrehzahlsensor (110) überwacht und konfiguriert ist, einen oder mehrere fehlende Zähne in dem Raddrehzahlsensor (110) zu detektieren.

14. Steuereinheit (120) nach Anspruch 13, wobei der Raddrehzahlsensor (110) die Signalprüfung besteht, falls die Steuereinheit (120) den einen oder die mehreren fehlenden Zähne für eine vorgegebene Zeitdauer nicht detektiert.

Revendications

1. Contrôleur (120) permettant de déterminer la présence d'un fonctionnement défectueux d'un capteur de vitesse de roue de véhicule détecté antérieurement, ce contrôleur (120) comprenant une mémoire non volatile électronique (170) et une unité de traitement électronique (160) connectée à cette mémoire non volatile électronique (170), l'unité de traitement électronique (160) comprenant un module de surveillance de fonctionnement défectueux (200) qui surveille l'activité d'un capteur de vitesse de roue (110) et génère un signal de défaut lorsque ce capteur de vitesse de roue (110) délivre en sortie un signal qui est situé à l'extérieur d'une première plage prédéfinie, ce signal de défaut renfermant une information de défaut et entraînant l'activation d'au moins un indicateur témoin et la modification du fonctionnement d'un système de commande du véhicule (105) d'un premier état opérationnel vers un second état opérationnel, un module de traitement de défaut (205) qui entraîne l'enregistrement d'une information de cycle d'entraînement et de l'information de défaut dans la mémoire non volatile électronique (170) et un module de contrôle de signal (215) qui effectue un contrôle de signal sur l'information provenant du capteur de vitesse de roue (110), ce contrôle de signal comprenant l'extraction de l'information de cycle d'entraînement pour un capteur de vitesse de roue (110) de la mémoire non volatile électronique (170), comparant la sortie du capteur de vitesse de roue (110) à une seconde plage prédéfinie plus étroite que la première plage prédéfinie, le capteur de vitesse de roue (110) passant le contrôle de signal si sa sortie est située dans la seconde plage prédéfinie pendant une durée prédéfinie et générant un signal de remise à zéro si le capteur de vitesse de roue (110) passe le contrôle de signal, la remise à zéro du signal entraînant la désactivation d'au moins l'un des indicateurs témoins et la reprise de l'activité du système de commande du véhicule (105) dans le premier état opérationnel.

2. Contrôleur (120) conforme à la revendication 1, dans lequel le fonctionnement défectueux du capteur de vitesse de roue du véhicule antérieurement détecté est une sensibilité invraisemblable de ce capteur de vitesse de roue (110), ou un brouillage de ce capteur de vitesse de roue (110) ou un signal de panne reçu de ce capteur de vitesse de roue (110).

3. Contrôleur (120) conforme à la revendication 2, dans lequel le capteur de vitesse de roue (110) est un capteur de vitesse de roue parmi un ensemble de capteurs de vitesse de roue (110) et le contrôleur compare la vitesse détectée par chacun des capteurs de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110), le module de surveillance de fonctionnement défectueux (200) déterminant la présence d'un défaut d'un capteur de vitesse de roue si la différence entre la vitesse la plus élevée détectée par l'un des capteurs de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) et la vitesse la plus faible détectée par l'un des capteurs de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) dépasse un seuil.

4. Contrôleur (120) conforme à la revendication 3, dans lequel le module de contrôle de signal (215) contrôle si la différence entre la vitesse la plus élevée détectée par un capteur de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) et la vitesse la plus faible détectée par un capteur de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) est inférieure au seuil pendant une durée prédéfinie.

5. Contrôleur (120) conforme à la revendication 4, dans lequel le contrôleur (120) contrôle si la vitesse détectée par chacun des capteurs de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) dépasse un second seuil.

6. Contrôleur (120) conforme à la revendication 5, dans lequel l'ensemble de capteurs de vitesse de roue (110) passe le contrôle de signal si le contrôleur (120) n'a pas détecté de brouillage sur l'ensemble de capteurs de vitesse de roue (110), la vitesse détectée par chacun des capteurs de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) dépasse le second seuil et la différence entre la vitesse la plus élevée détectée par un capteur de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) et la vitesse la plus faible détectée par un capteur de vitesse de roue (110) parmi l'ensemble de capteurs de vitesse de roue (110) est inférieure au seuil pendant la durée prédéfinie.

7. Contrôleur (120) conforme à la revendication 1, dans lequel le fonctionnement défectueux du capteur de vitesse de roue de véhicule détecté antérieurement est un défaut dû à un échange de capteur du capteur de vitesse de roue.

8. Contrôleur (120) conforme à la revendication 7, dans lequel le contrôle de signal est exécuté uniquement lorsque le véhicule est en virage.

9. Contrôleur (120) conforme à la revendication 8, dans lequel le contrôleur (120) détermine que le véhicule est en virage si la valeur absolue de la vitesse de lacet du véhicule est supérieure à un seuil.

10. Contrôleur (120) conforme à la revendication 8, dans lequel le contrôleur (120) calcule la vitesse de lacet du capteur de vitesse de roue et la vitesse de lacet d'accélération latérale.

11. Contrôleur (120) conforme à la revendication 10, dans lequel le capteur de vitesse de roue (110) passe le contrôle de signal si la différence entre la vitesse de lacet du capteur de vitesse de roue et la vitesse de lacet d'accélération latérale est inférieure à un second seuil pendant une durée prédéfinie.

12. Contrôleur (120) conforme à la revendication 1, dans lequel le fonctionnement défectueux d'un capteur de vitesse de roue de véhicule détecté antérieurement est un défaut dû à des dents manquantes du capteur de vitesse de roue.

13. Contrôleur (120) conforme à la revendication 12, dans lequel le contrôleur (120) surveille un signal provenant du capteur de vitesse de roue (110) et est conformé pour détecter la présence d'une ou de plusieurs dents manquantes dans le capteur de vitesse de roue (110).

14. Contrôleur (120) conforme à la revendication 13, dans lequel le capteur de vitesse de roue (110) passe le contrôle de signal si le contrôleur (120) ne détecte pas la présence d'une ou de plusieurs dents manquantes pendant une durée prédéfinie.

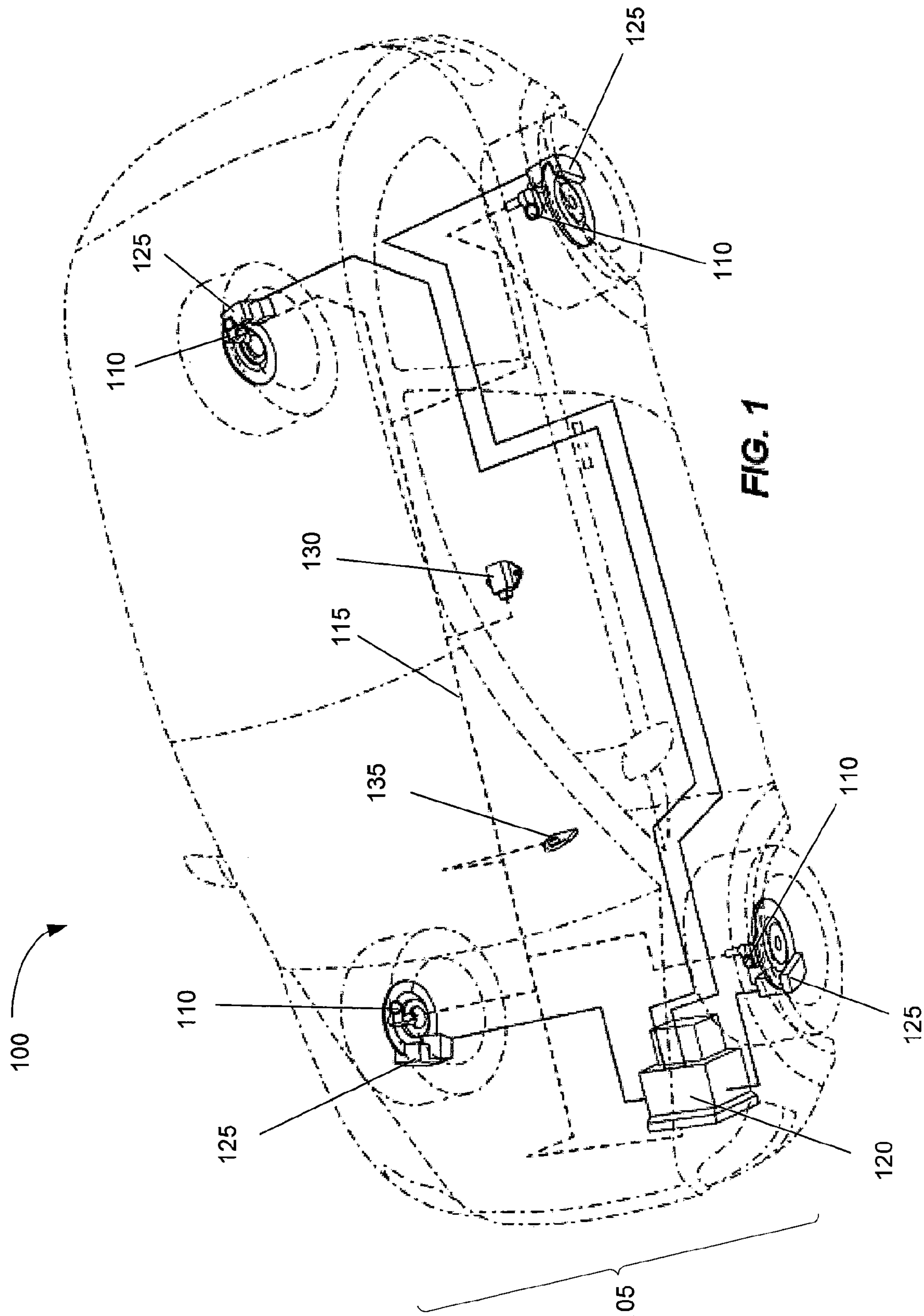

FIG. 1

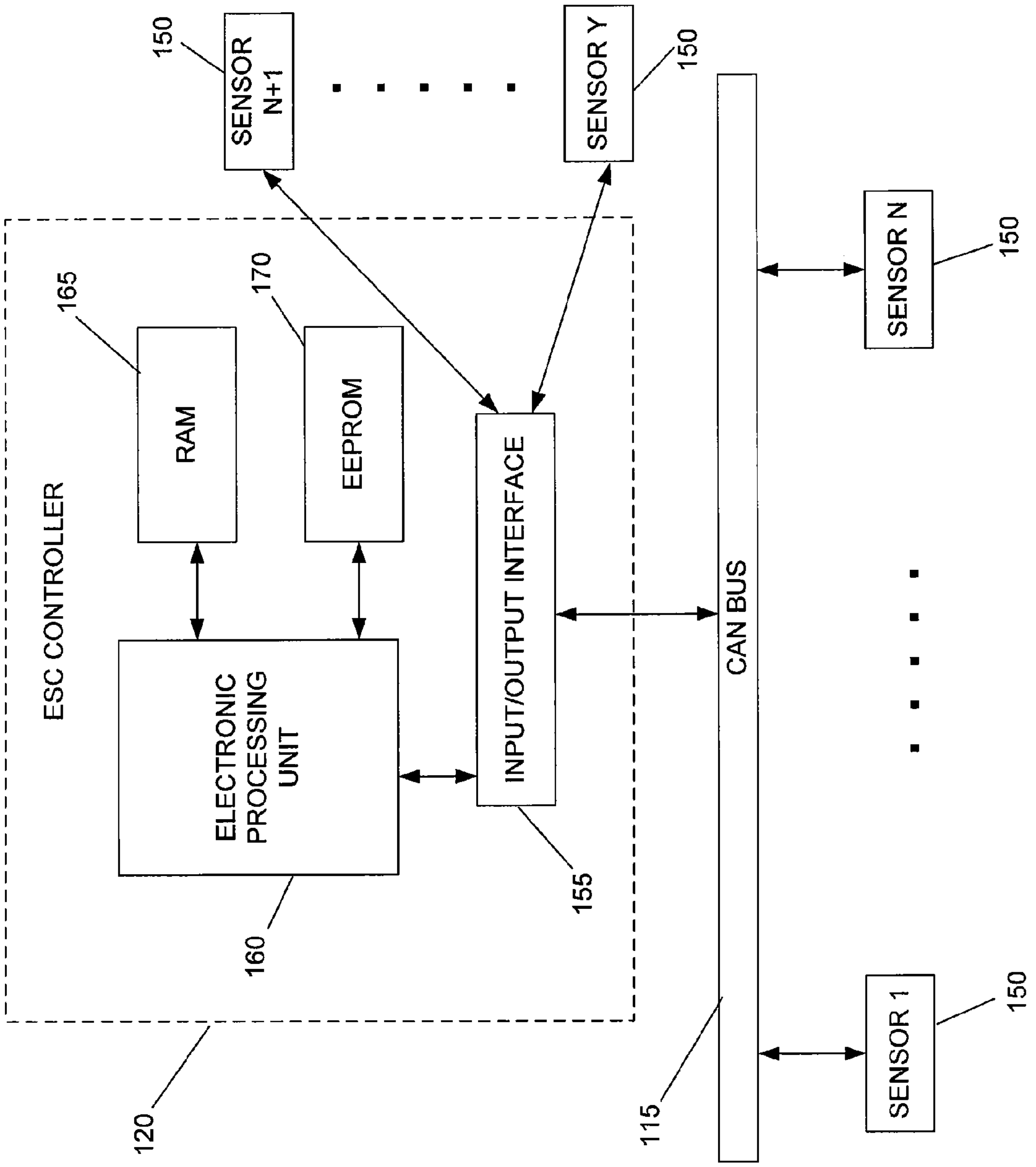
ESC CONTROLLER
RAM
EEPROM
ELECTRONIC PROCESSING UNIT
INPUT/OUTPUT INTERFACE
CAN BUS
SENSOR N+1
SENSOR Y
SENSOR N
SENSOR 1
120
160
155
165
170
115
150

FIG. 2

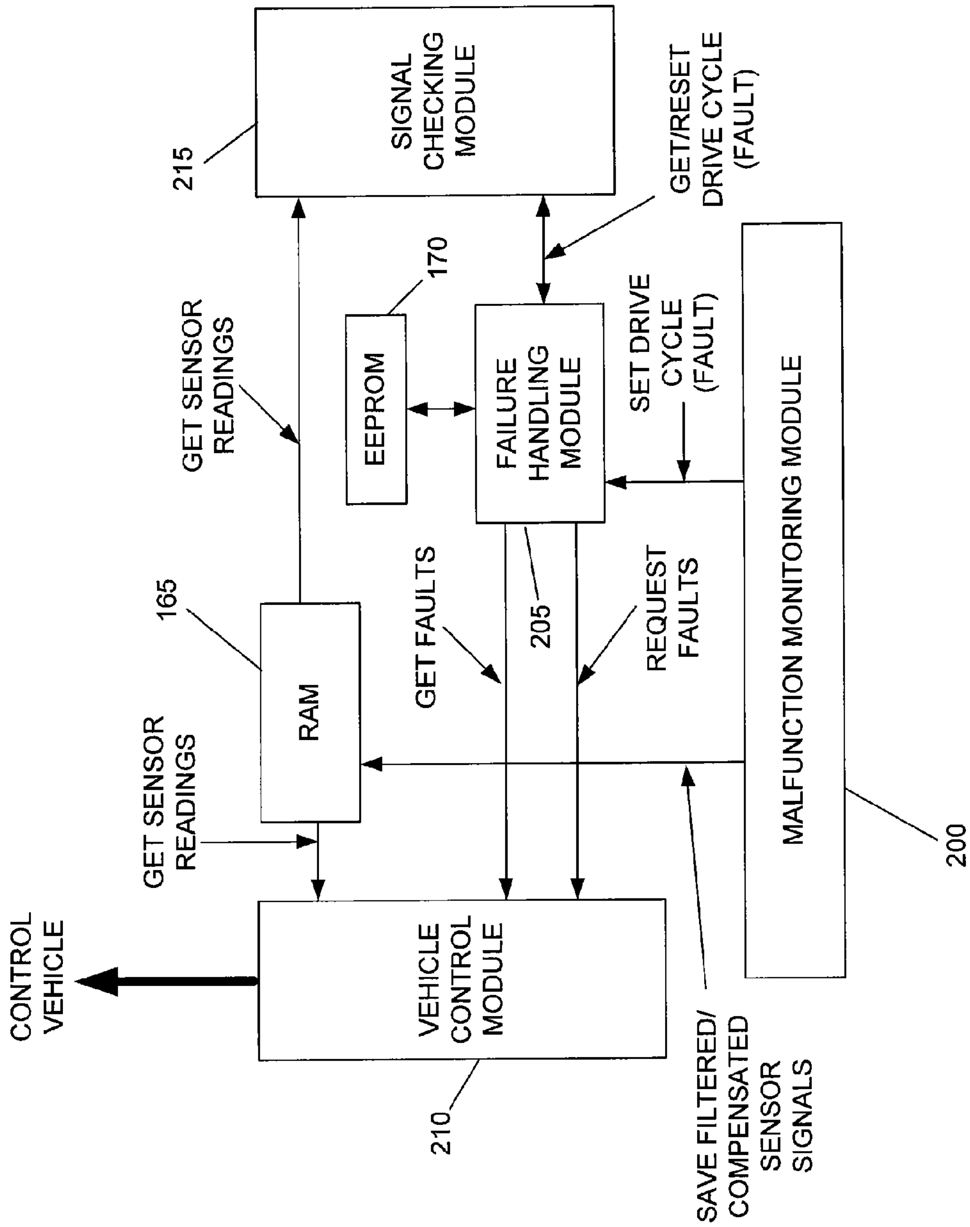
215
SIGNAL CHECKING MODULE
GET/RESET DRIVE CYCLE (FAULT)
GET SENSOR READINGS
170
EEPROM
FAILURE HANDLING MODULE
SET DRIVE CYCLE (FAULT)
165
RAM
GET FAULTS
205
REQUEST FAULTS
MALFUNCTION MONITORING MODULE
GET SENSOR READINGS
200
CONTROL VEHICLE
VEHICLE CONTROL MODULE
210
SAVE FILTERED/ COMPENSATED SENSOR SIGNALS

FIG. 3

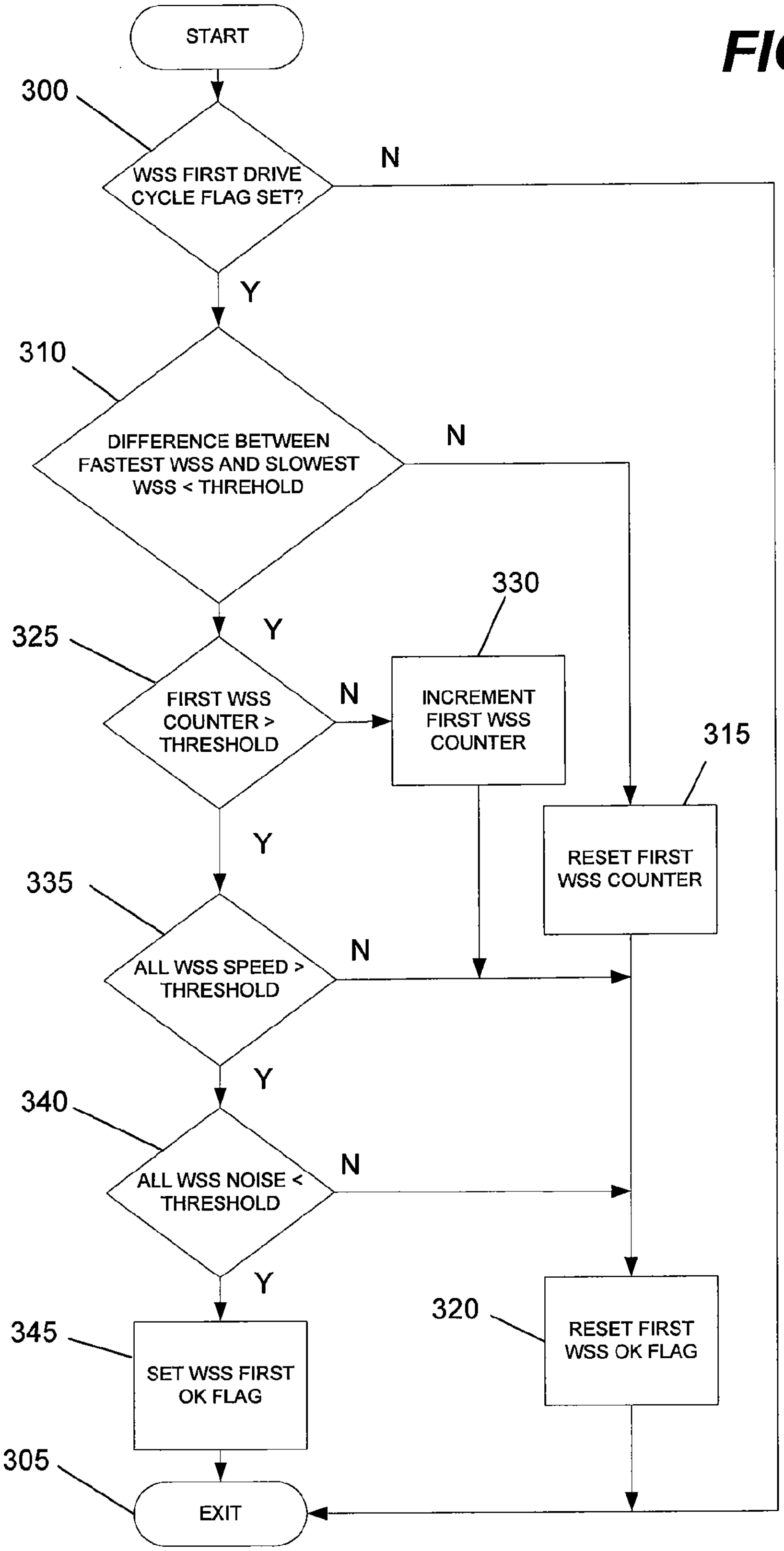
START
300
WSS FIRST DRIVE CYCLE FLAG SET?
N
Y
310
DIFFERENCE BETWEEN FASTEST WSS AND SLOWEST WSS < THREHOLD
N
Y
330
325
FIRST WSS COUNTER > THRESHOLD
N
INCREMENT FIRST WSS COUNTER
315
RESET FIRST WSS COUNTER
Y
335
ALL WSS SPEED > THRESHOLD
N
Y
340
ALL WSS NOISE < THRESHOLD
N
Y
345
SET WSS FIRST OK FLAG
320
RESET FIRST WSS OK FLAG
305
EXIT

FIG. 4

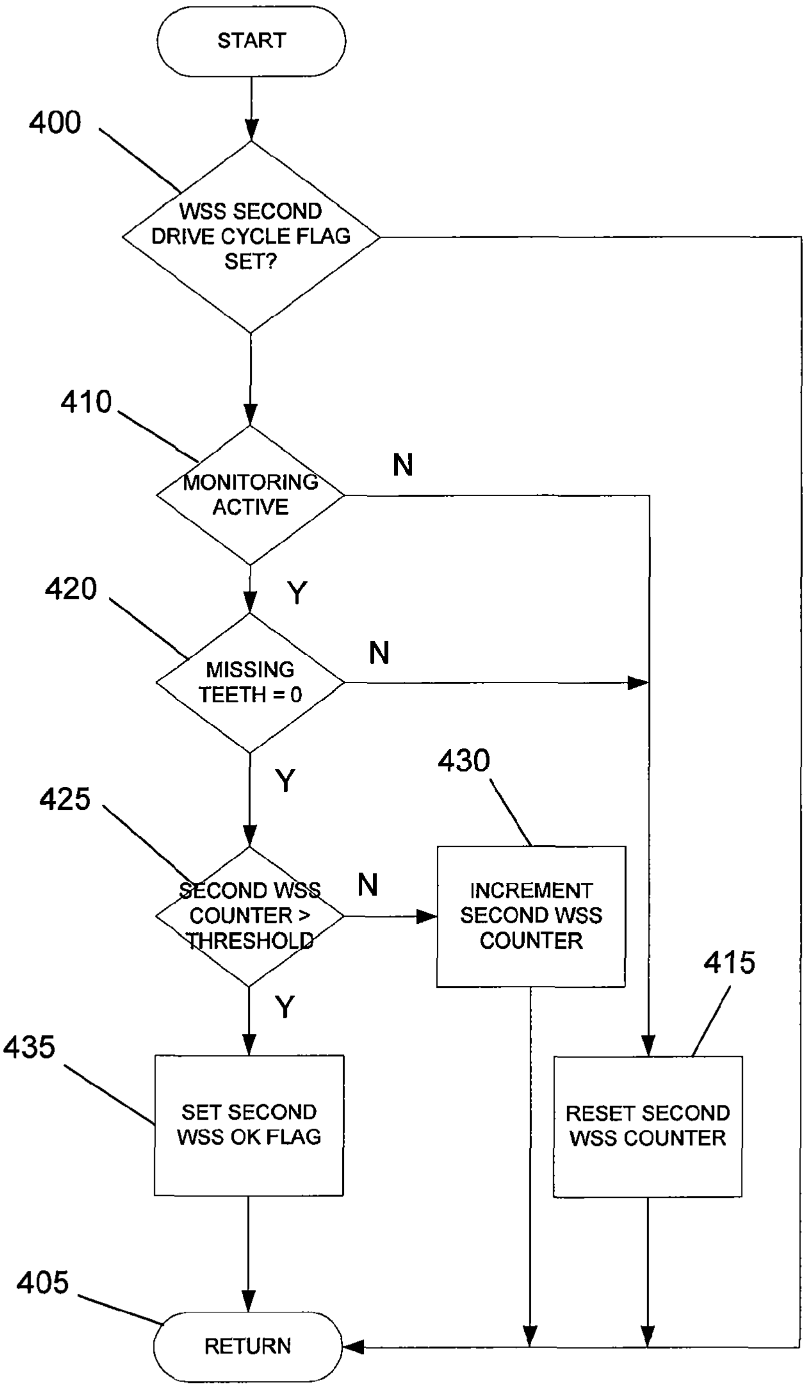
START
400
WSS SECOND DRIVE CYCLE FLAG SET?
410
MONITORING ACTIVE
N
Y
420
MISSING TEETH = 0
N
Y
425
SECOND WSS COUNTER > THRESHOLD
N
430
INCREMENT SECOND WSS COUNTER
Y
415
435
SET SECOND WSS OK FLAG
RESET SECOND WSS COUNTER
405
RETURN

FIG. 5

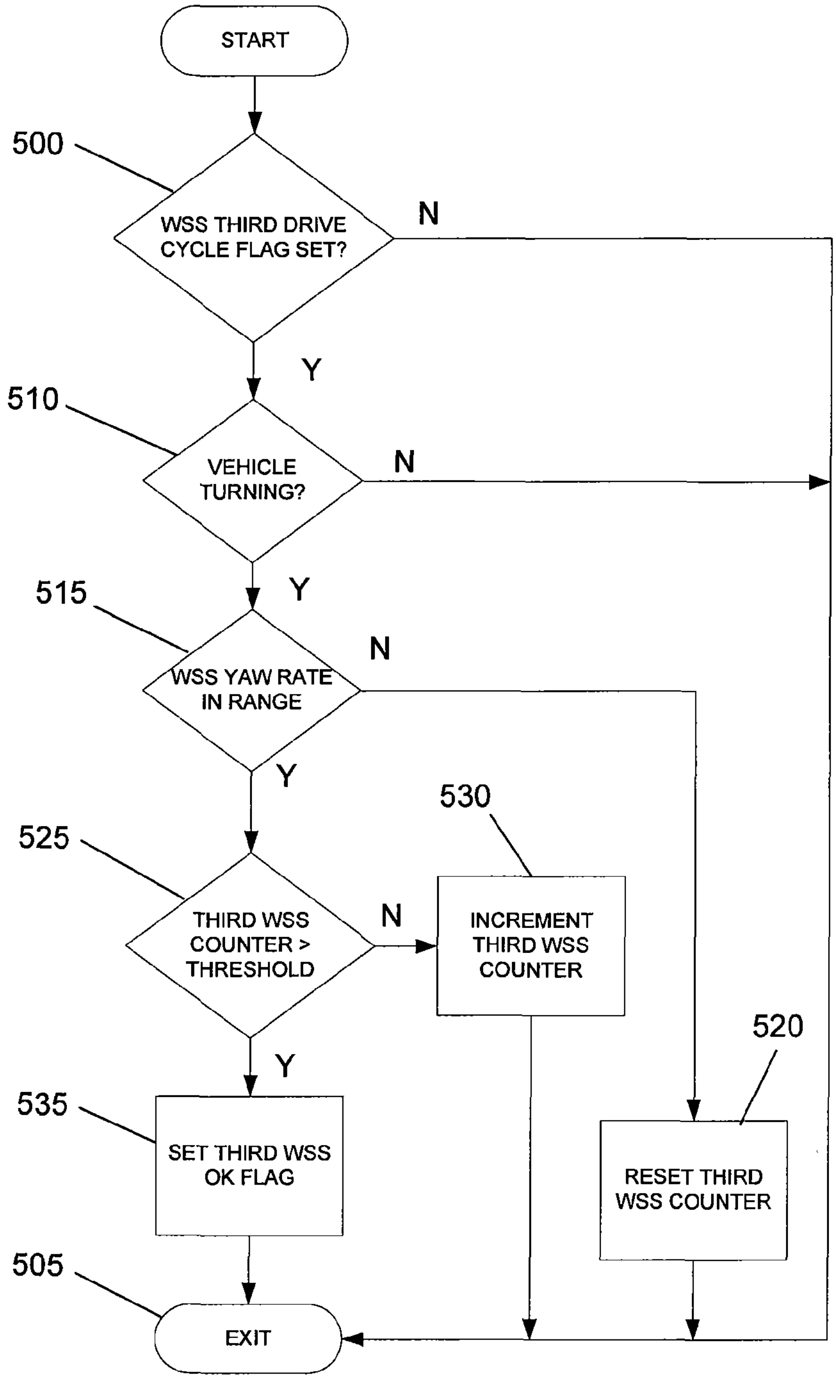
START
500
WSS THIRD DRIVE CYCLE FLAG SET?
N
Y
510
VEHICLE TURNING?
N
Y
515
WSS YAW RATE IN RANGE
N
Y
530
525
THIRD WSS COUNTER > THRESHOLD
N
INCREMENT THIRD WSS COUNTER
520
Y
535
SET THIRD WSS OK FLAG
RESET THIRD WSS COUNTER
505
EXIT

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 61236393 A **[0001]**
- EP 1227019 A1 **[0003]**
- US 6834221 B **[0020]**