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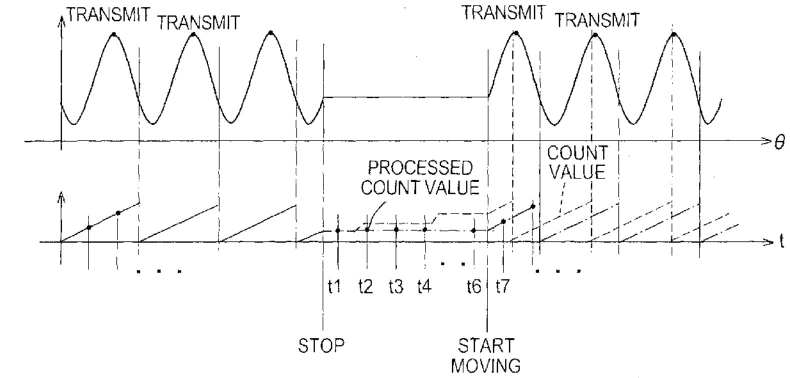
(54) **Title**: WHEEL POSITION IDENTIFYING APPARATUS

FIG. 11C



(57) **Abstract**: A wheel position identifying apparatus includes: wheel-side devices respectively provided at a plurality of wheels of a vehicle, each wheel-side device having a wheel-side rotation sensor configured to detect a rotation position of a corresponding one of the wheels and a transmitting unit that transmits wheel information including at least identification information, a vehicle body-side device having a receiver that receives the wheel information vehicle body-side rotation sensors that outputs a detected value corresponding to the rotation position of a corresponding one of the wheels, and a detected value processing unit that associates the identification information included in the target wheel information with a position of the target wheel and, when the vehicle is placed in a set state during operation of the wheel position identifying unit, process at least one of the detected values of the plurality of vehicle body-side rotation sensors on the basis of the vehicle state.

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WHEEL POSITION IDENTIFYING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a wheel position identifying apparatus that identifies the position of a wheel from which wheel information is transmitted.

2. Description of Related Art

[0002] Japanese Patent Application Publication No. 2010-122023 (JP 2010-122023 A) and Japanese Patent Application Publication No. 2012-111481 (JP 2012-111481 A) describe a wheel position identifying apparatus that associates the position of each wheel with corresponding identification information. In the wheel position identifying apparatus described in JP 2010-122023 A and JP 2012-111481 A, a wheel-side unit including an acceleration sensor, an air pressure sensor, a transmitter, and the like, is provided at each of a plurality of wheels, and a vehicle body-side device including a receiver that receives wheel information, wheel speed sensors that respectively detect rotation positions of the four right and left front and rear wheels, a processing unit mainly formed of a computer, and the like, is provided at a vehicle body. In each of the wheel-side units, a series of pieces of wheel information including identification information (for example, IDx information), air pressure information, and the like, are transmitted when any one of the wheel-side units has reached a predetermined rotation position of the corresponding wheel on the basis of a detected value (an acceleration in the rotation direction or the centrifugal direction) of the corresponding acceleration sensor. In the vehicle body-side device, the detected value of each of the plurality of wheel speed sensors is acquired at timing at which the wheel information including the IDx information has been received by the receiver. In the wheel position identifying apparatus described in JP 2010-122023 A, one of the wheel speed sensors, which has output the detected values having the smallest dispersion, is identified, and the position of the wheel corresponding to the identified one of the wheel speed sensors is associated with the IDx information. In the wheel position identifying apparatus described in JP 2012-111481 A, wheel information is transmitted from each wheel-side unit twice at intervals of a predetermined phase during one rotation of the corresponding wheel, and any one of the wheel speed sensors, which has output two detected values of the interval closest to the interval of the predetermined phase, is identified.

SUMMARY OF THE INVENTION

[0003] The invention provides a wheel position identifying apparatus that is able to further appropriately identify a wheel position.

[0004] A first aspect of the invention provides a wheel position identifying apparatus. The wheel position identifying apparatus includes: wheel-side devices respectively provided at a plurality of wheels of a vehicle, each wheel-side device having a wheel-side rotation sensor configured to detect a rotation position of a corresponding one of the wheels and a transmitting unit configured to transmit wheel information, including at least identification information set for the corresponding one of the wheels, at timing at which a position of the wheel-side rotation sensor with respect to the corresponding one of the wheels, determined on the basis of a detected value of the wheel-side rotation sensor, has reached a predetermined position; and a vehicle body-side device provided at a vehicle body of the vehicle, the vehicle body-side device having a receiver configured to receive the wheel information transmitted from each of the plurality of wheel-side devices, vehicle body-side rotation sensors respectively corresponding to the plurality of wheels and each configured to output a detected value corresponding to the rotation position of a corresponding one of the wheels, and a detected value processing unit configured to, each time target wheel information that is the wheel information transmitted from a target wheel-side device that is one of the plurality of wheel-side devices is received by the receiver, cause each of the vehicle body-side rotation sensors to detect the rotation position of a corresponding one of the plurality of wheels and identify one of the vehicle body-side rotation sensors, which corresponds to a target wheel that is the wheel from which the target wheel information has been transmitted, on the basis of each of the detected values of the rotation positions of the plurality of wheels, associate the identification information included in the target wheel information with a position of the target wheel and, when the vehicle is placed in a set state during operation of the wheel position identifying unit, process at least one of the detected values of the plurality of vehicle body-side rotation sensors on the basis of the state of the vehicle.

[0005] There are a case where the single receiver is provided at the vehicle body or the two or three receivers are provided at the vehicle body. In any cases, the receivers are shared among the plurality of wheel-side devices. The vehicle body-side rotation sensors are respectively provided at the vehicle body at positions corresponding to the plurality of wheels. Each vehicle body-side rotation sensor is configured to detect a rotation angle of a corresponding one of the wheels with respect to a reference position. Each vehicle body-side rotation sensor may be configured to detect an absolute rotation angle of which the reference position is fixed or may be configured to detect a relative rotation angle of which the reference position is variable. When each vehicle body-side rotation sensor is configured to detect a relative rotation angle, the reference position needs to be the same at least during the time the wheel position is identified once.

[0006] In the above aspect, the detected value processing unit may include a correlation change suppressing unit configured to suppress a change of a correlation between each of at least one of the detected values of the plurality of vehicle body-side rotation sensors and a corresponding one of the detected values of the wheel-side rotation sensors corresponding to the vehicle body-side rotation sensors by processing the at least one of the detected values of the plurality of vehicle body-side rotation sensors. It is desirable to keep the correlation between each of the detected values of the vehicle body-side rotation sensors and a corresponding one of the detected values of the wheel-side rotation sensors substantially constant.

[0007] In the above aspect, the detected value processing unit may include one or more of a variation ignoring unit configured to ignore a variation in at least one of the detected values of the plurality of wheel-side rotation sensors, a detected value holding unit configured to keep the at least one of the detected values constant, and a count down unit configured to reduce count values that are the detected values of the plurality of wheel-side rotation sensors. (i) The variation ignoring unit detects whether there is a variation in each of the detected values, and, even when there is a variation, the variation is ignored. *(ii)* The detected value holding unit may detect or not detect whether there is a variation in the detected values. The detected values are regarded as being constant irrespective of whether there is a variation in the detected values. *(iii)* When each of the count values is increased in a forward rotation direction of the corresponding wheel, it is desirable to reduce each of the count values in the reverse rotation direction of the corresponding wheel.

[0008] In the above aspect, the detected value processing unit may include a stopping detected value holding unit configured to keep each of the detected values of the plurality of vehicle body-side rotation sensors constant in at least one of a case where the vehicle is stopped and a case where at least one of a plurality of open-close members provided in the vehicle is open.

[0009] In the above aspect, the detected value processing unit may include a stopping variation ignoring unit configured to, during a predetermined set period of time, when part of the detected values of the plurality of vehicle body-side rotation sensors vary and the remainder of the detected values do not vary, determine that the vehicle is stopped and ignore the variation in each of the detected values of the part of the vehicle body-side rotation sensors.

[0010] In the above aspect, the detected value processing unit may include a variation amount acquisition unit configured to, when at least one of the detected values of the plurality of vehicle body-side rotation sensors has varied while the vehicle is stopped, acquire a variation amount of each of the at least one of the detected values of the plurality of vehicle body-side rotation sensors, and the wheel position identifying unit may include a variation amount dependent wheel position identifying unit configured to identify the wheel position by considering the variation amount of the at least one of the detected values, acquired by the variation amount acquisition unit.

[0011] In the above aspect, the wheel position identifying unit may include a dispersion acquisition unit configured to determine whether each of the detected values of the plurality of vehicle body-side rotation sensors falls within a set range, and the variation amount dependent wheel position identifying unit may include at least one of a set range individual changing unit configured to individually change the set range on the basis of the variation amount of the detected value of the corresponding vehicle body-side rotation sensor and a set range common changing unit configured to uniformly change the set ranges on the basis of at least one variation amount of the at least one of the detected values. Each of the set ranges may be, for example, a range determined on the basis of a degree of dispersion or a range determined on the basis of an error, or the like, of the corresponding detected value.

[0012] In the above aspect, the detected value processing unit may include a variation ignoring unit configured to ignore a variation in part of the detected values of the plurality of vehicle body-side rotation sensors when it has been detected that the vehicle is stopped and when the part of the detected values of the vehicle body-side rotation sensors have varied and the remainder of the detected values of the vehicle body-side rotation sensors have not varied, and a variation amount acquisition unit configured to acquire a variation amount of each of the detected values of the plurality of vehicle body-side rotation sensors when it has been detected that the vehicle is stopped and when all the detected values of the plurality of vehicle body-side rotation sensors have varied. When it has been detected that the vehicle is stopped and when part of the detected values of the vehicle body-side rotation sensors have varied and the remainder of the detected values of the vehicle body-side rotation sensors have not varied, it may be determined that the part of the detected values of the vehicle body-side rotation sensors have been varied due to relative movement between the vehicle body and the wheels and the variation is not due to rotation of the wheels.. However, even when it has been detected that the vehicle is stopped but all the detected values of the plurality of vehicle body-side rotation sensors have varied, the variation may be due to rotation of the wheels. Therefore, in the latter case, it is possible to make it hard for the inconvenience to occur due to the fact that the correlation has been changed by changing the set ranges. In addition, a variation in the detected values is not ignored, so, if it is a variation due to rotation of the wheels, it is possible to appropriately identify the wheel position.

[0013] A second aspect of the invention provides a wheel position identifying apparatus. The wheel position identifying apparatus includes: wheel-side devices respectively provided at a plurality of wheels of a vehicle, each wheel-side device having a wheel-side rotation sensor configured to detect a rotation position of a corresponding one of the wheels and a transmitting unit configured to transmit wheel information, including at least identification information set for the corresponding one of the wheels, at timing at which a position of the wheel-side rotation sensor with respect to the corresponding one of the wheels, determined on the basis of a detected value of the wheel-side rotation sensor, has reached a predetermined position; and a vehicle body-side device provided at a vehicle body of the vehicle, the vehicle body-side device having a receiver configured to receive the wheel information transmitted from each of the plurality of wheel-side devices, vehicle body-side rotation sensors respectively corresponding to the plurality of wheels and each configured to output a detected value corresponding to the rotation position of a corresponding one of the wheels, and a wheel position identification continuing unit configured to, each time target wheel information that is the wheel information transmitted from a target wheel-side device that is one of the plurality of wheel-side devices is received by the receiver, cause each of the vehicle body-side rotation sensors to detect the rotation position of a corresponding one of the plurality of wheels and identify one of the vehicle body-side rotation sensors, which corresponds to a target wheel that is the wheel from which the target wheel information has been transmitted, on the basis of each of the detected values of the rotation positions of the plurality of wheels, associate the identification information included in the target wheel information with a position of the target wheel and, when the vehicle is placed in a set state during operation of the wheel position identifying unit, continue identifying the wheel position by considering the state. The phrase "continue identifying the wheel position by considering the state of the vehicle" corresponds to (a) the set ranges are changed or identification of the wheel position is interrupted when the state of the vehicle is placed in the set state, (b) the set ranges are changed or the detected values are corrected when the state of the vehicle is placed in the set state and the variation in the detected values is large. The wheel position is identified in a mode different from the case where the state of the vehicle is not placed in the set state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a conceptual view that shows the whole of a wheel state acquisition system including a wheel position identifying apparatus according to a first embodiment of the invention;

FIG. 2 is a view that conceptually shows the structures of a wheel-side device and vehicle body-side device that are included in the wheel state acquisition system;

FIG. 3 is a front view of each wheel of which a state is detected by the wheel state acquisition system;

FIG. 4 is a view that shows timing at which wheel information is transmitted from the wheel;

FIG. 5 is a view that conceptually shows the wheel information;

FIG. 6 is a map that shows a wheel position acquisition table stored in a storage unit of a TPMS ECU of the wheel state acquisition system;

FIG. 7 is a flowchart that shows a wheel state acquisition program stored in the storage unit of the TPMS ECU;

FIG. 8 is a flowchart that shows a wheel position identifying program stored in the storage unit of the TPMS ECU;

FIG. 9 is a flowchart that shows a detected value processing program stored in the storage unit of the TPMS ECU;

FIG. 10 is a view that shows a state where a wheel position is identified through execution of the wheel position identifying program;

FIG. 11A is a graph that shows the correlation between each of detected values of wheel-side rotation sensors and a corresponding one of count values that are detected values of vehicle body-side rotation sensors in an existing wheel position identifying apparatus;

FIG. 11B is a graph that shows the correlation between each of detected values of the wheel-side rotation sensors and a corresponding one of count values that are detected values of the vehicle body-side rotation sensors in the existing wheel position identifying apparatus;

FIG. 11C is a graph that shows the correlation between each of detected values of wheel-side rotation sensors and a corresponding one of processed detected values of vehicle body-side rotation sensors in the case where the detected value processing program is executed in the wheel position identifying apparatus according to the first embodiment;

FIG. 12A is a flowchart that shows a count prohibition flag setting program stored in a storage unit of a TPMS ECU of a wheel position identifying apparatus according to a second embodiment of the invention;

FIG. 12B is a flowchart that shows the detected value processing program stored in the storage unit of the TPMS ECU of the wheel position identifying apparatus according to the second embodiment of the invention;

FIG. 13A is a graph that shows the correlation between each of detected values of the wheel-side rotation sensors and a corresponding one of count values that are detected values of the vehicle body-side rotation sensors in the existing wheel position identifying apparatus;

FIG. 13B is a graph that shows the correlation between each of detected values of the wheel-side rotation sensors and a corresponding one of count values that are detected values of the vehicle body-side rotation sensors in the existing wheel position identifying apparatus;

FIG. 13C is a graph that shows the correlation between each of detected values of wheel-side rotation sensors and a corresponding one of processed detected values of vehicle body-side rotation sensors in the case where the detected value processing program is executed in the wheel position identifying apparatus according to the second embodiment;

FIG. 14 is a flowchart that shows the detected value processing program stored in a storage unit of a TPMS ECU of a wheel position identifying apparatus according to a third embodiment of the invention;

FIG. 15 is a flowchart that shows the detected value processing program stored in a storage unit of a TPMS ECU of a wheel position identifying apparatus according to a fourth embodiment of the invention;

FIG. 16 is a flowchart that shows the wheel position identifying program stored in the storage unit of the TPMS ECU;

FIG. 17 is a view that shows a state where a wheel position is identified through execution of the wheel position identifying program; and

FIG. 18 is a flowchart that shows the detected value processing program stored in a storage unit of a TPMS ECU of a wheel position identifying apparatus according to a fifth embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0015] In a wheel position identifying apparatus according to the invention, wheel information is transmitted from each of a plurality of wheels of a vehicle at timing at which a position of a corresponding one of wheel-side rotation sensors in a rotation direction with respect to a corresponding one of the wheels has reached a predetermined set position on the basis of a detected value of the corresponding one of the wheel-side rotation sensors, and, in a vehicle body of the vehicle, detected values of a plurality of vehicle body-side rotation sensors provided in correspondence with the plurality of wheels are acquired at timing at which the wheel information including the same identification information is received, a wheel position is identified on the basis of each of the plurality of detected values, and, when the vehicle is placed in a set state in the process of identifying the wheel position, the wheel position is identified by considering the state or the detected values of the vehicle body-side rotation sensors are processed on the basis of the state. For example, in one target wheel among the plurality of wheels, target wheel information including identification information of IDx is transmitted when a corresponding one of the wheel-side rotation sensors has reached the top dead center, and, in the vehicle body, rotation positions (($\theta a1$, $\theta b1$, $\theta c1$, $\theta d1$), ($\theta a2$, $\theta b2$, $\theta c2$, $\theta d2$), ...) of the right and left front and rear wheels are respectively detected by the plurality of vehicle body-side rotation sensors each time the target wheel information including IDx is received. When the pair of detected values of one vehicle body-side rotation sensor are substantially the same ($\theta c1 \approx \theta c2$) and the pairs of detected values of the other three vehicle body-side rotation sensors are different from each other (($\theta a1 \neq \theta a2$), ($\theta b1 \neq \theta b2$), ($\theta d1 \neq \theta d2$)), the vehicle body-side rotation sensor that has output the detected values ($\theta c1$, $\theta c2$) is identified as the vehicle body-side rotation sensor that detects the rotation position of the target wheel, and the identification information IDx is associated with the position of the wheel (position of the target wheel) corresponding to the identified vehicle body-side rotation sensor. The wheel position is identified on the assumption that (a) the rotation angular velocities are different from one another among the plurality of wheels provided in the vehicle and (b) a certain correlation holds between each of the detected values of the wheel-side rotation sensors and a corresponding one of the detected values of the vehicle body-side rotation sensors. A relative phase of each of the wheel-side rotation sensors with respect to a corresponding one of the wheels is determined on the basis of a corresponding one of the detected values of the wheel-side rotation sensors, and each of the detected values of the vehicle body-side rotation sensors indicates a rotation angle with respect to the reference position of a corresponding one of the wheels, so these are associated with each other. For the above reasons, for example, it is possible to identify the vehicle body-side rotation sensor, which has output the detected values having the smallest dispersion on the basis of the plurality of sets of detected values of the vehicle body-side rotation sensors, as corresponding to the target wheel. Specifically, the plurality of sets of detected values of the plurality of vehicle body-side rotation sensors are acquired, it is determined whether each of the plurality of detected values of them falls within a corresponding one of set ranges, (1) the vehicle body-side rotation sensor that has output the detected value that falls outside the corresponding set range is excluded from identification candidates, and the last remaining vehicle body-side rotation sensor may be identified as corresponding to the target wheel, (2) the vehicle body-side rotation sensor that has output the detected values in which the number of detected values that fall within the corresponding set range is the largest may be identified as corresponding to the target wheel, or the like. On the other hand, the vehicle may stop in the process of identifying the wheel position. While the vehicle is stopped, no wheel information is transmitted from the wheel-side devices, so the detected values of the vehicle body-side rotation sensors are not acquired in order to identify the wheel position. Therefore, when the vehicle has stopped in the process of identifying the wheel position, identification of the wheel position may be interrupted and the wheel position may be identified again after the vehicle starts moving, that is, it is possible to identify the wheel position from the beginning by clearing information, such as the acquired detected values of the vehicle body-side rotation sensors, acquired before the vehicle stops, the determination results as to whether each detected value falls within the corresponding set range, the vehicle body-side rotation sensors excluded from identification candidates and the number of the detected values that fall within the corresponding set range. However, if identification of the wheel position is interrupted each time the vehicle stops, it is not desirable because it requires a long time to identify the wheel position, particularly, in the case of traffic congestion, or the like. Therefore, even when the vehicle stops in the process of identifying the wheel position, it is desirable to continue identifying the wheel position (acquire the detected values of the vehicle body-side rotation sensors, determine whether each detected value falls within the corresponding set range, count the number of the detected values that fall within the corresponding set range, exclude the vehicle body-side rotation sensors from identification candidates, and the like) by, after the vehicle starts moving, keeping the above-described information acquired before the vehicle stops. However, when a passenger gets on or off the vehicle or a baggage is loaded or unloaded while the vehicle is stopped, the vehicle body and the wheels are relatively moved, and the detected values of the vehicle body-side rotation sensors are varied irrespective of a situation that the wheels are not rotating, with the result that the correlation between each of the detected values of the acceleration sensors and a corresponding one of the detected values of the vehicle body-side rotation sensors may change. Therefore, when the wheel position is identified continuously in the case where the vehicle has started moving after stopping, it may not be able to appropriately identify the vehicle body-side rotation sensor. In addition, when each vehicle body-side rotation sensor is of a type of which the count value as a detected value is increased when the corresponding wheel is rotated in the forward direction or in the reverse direction, the correlation between each of the detected values of the wheel-side rotation sensors and a corresponding one of the detected values of the vehicle body-side rotation sensors changes when the vehicle moves backward. Therefore, if the wheel position is identified while the vehicle is traveling backward or travels forward after moving backward, it may not be able to appropriately identify the vehicle body-side rotation sensor. In contrast to this, in the wheel position identifying apparatus according to the invention, for example, in the case where the vehicle is stopped, even when the detected values of the vehicle body-side rotation sensors are varied, the variation may be ignored or, in the case where the vehicle is moving backward, the count values may be reduced. In addition, variation amounts in detected values while the vehicle is stopped may be acquired, and the wheel position after the vehicle starts moving may be identified in consideration of the variation amounts. As a result, it is possible to suppress inconvenience that the wheel position is not appropriately identified due to the change of the correlation between each of the detected values of the acceleration sensors and a corresponding one of the detected values of the vehicle body-side rotation sensors. In addition, even when the vehicle stops in the process of identifying the wheel position, identification of the wheel position is continued after the vehicle starts moving, so it is possible to appropriately avoid extension of a period of time required to identify the wheel position. The phrase "in the process of identifying the wheel position" means a period from when identification of the wheel position is started to when the identification information is associated with the wheel position. Specifically, this is a state where, in order to associate one identification information with the wheel position, a series of operations, such as acquiring the detected values of the vehicle body-side rotation sensors, determining whether each detected value falls within the corresponding set range, counting the number of the detected values that fall within the corresponding set range and determining the vehicle body-side rotation sensor that is excluded from identification candidates, are started but the wheel position is not associated with the identification information. The phrase "continuously identifying the wheel position" means that one or more of the acquired detected values, determination results and number of count values, and determination of the vehicle body-side rotation sensor that is excluded from identification candidates are not cleared and the wheel position is identified with reference to these count values, the vehicle body-side rotation sensor determined to be excluded, and the like.

[0016] Hereinafter, a wheel state acquisition system according to an embodiment of the invention will be described in detail with reference to the accompanying drawings. The wheel state acquisition system includes a wheel position identifying apparatus according to the embodiment of the invention.

First Embodiment

[0017] As shown in FIG. 1, in a vehicle, wheel-side units 12FR, 12FL, 12RR, 12RL that serve as wheel-side devices are respectively provided at right and left front and rear wheels 10FR, 10FL, 10RR, 10RL, and a vehicle body-side device 16 is provided at a vehicle body 14. As shown in FIG. 2, the vehicle body-side device 16 includes a receiver 22, a display 24, a reset switch 25, wheel speed sensors 26FR, 26FL, 26RR, 26RL, a shift position sensor 27, a door open-close detection device 28, a tire pressure monitoring system (TPMS) ECU 30, a brake ECU 32, a navigation system ECU (hereinafter, simply referred to as navi ECU) 34, and the like. The wheel speed sensors 26FR, 26FL, 26RR, 26RL that serve as vehicle body-side rotation sensors are provided in correspondence with the right and left front and rear wheels 10FR, 10FL, 10RR, 10RL. The TPMS ECU 30 is mainly formed of a computer. Hereinafter, when it is required to distinguish the wheels

10, the wheel-side devices 12, the wheel speed sensors 26, and the like, from one another by wheel positions FR, FL, RR, RL, reference signs that indicate the wheel positions are suffixed to the reference numerals; however, for example, when it is not required to distinguish those components from one another or when those components are collectively referred to, the reference signs that indicate the wheel positions may not be suffixed to the reference numbers.

[0018] As shown in FIG. 2, each of the wheel-side units 12 includes an air pressure sensor 40 that serves as a wheel state sensor, an acceleration sensor 42 that serves as a wheel-side rotation sensor, a transmitter 44, and the like. As shown in FIG. 3, each acceleration sensor 42 detects an acceleration that acts on itself (sensor), and is configured such that the acceleration toward the rotation center of the corresponding wheel 10 is positive and the acceleration in the opposite direction (the centrifugal direction of the corresponding wheel 10) is negative. An acceleration G due to gravity and a centrifugal force F act on each wheel 10 that is rotating, so a detected value Y of each acceleration sensor 42 is expressed by the mathematical expression $Y = -F - G\sin\theta$ where an angle θ is defined with reference to a line parallel to a road surface. When the corresponding wheel 10 is rotating at a constant speed, the centrifugal force F is constant, so the detected value Y varies with rotation of the corresponding wheel 10 as shown in FIG. 4.

[0019] In the present embodiment, wheel information 50 is transmitted when the acceleration sensor 42 (wheel-side unit 12) has reached the top dead center, that is, at timing at which the detected value of the acceleration sensor 42 changes from an increasing tendency to a reducing tendency (a derivative value changes from a positive value to 0). In addition, even when braking force or driving force is applied to the wheel 10, the acceleration becomes maximum when the corresponding wheel-side unit 12 has reached the top dead center. In any cases, the wheel information 50 is wirelessly transmitted once during the time the wheel 10 makes one rotation at the timing at which the wheel-side unit 12 has reached the top dead center. The timing at which the wheel information 50 is transmitted may be determined in any way. For example, the wheel information 50 may be transmitted at the timing at which the wheel-side unit 12 has reached a position rotated by 90° from the bottom dead center or the top dead center. In addition, the wheel information 50 may be transmitted twice or more times during the time the wheel 10 makes one rotation. Furthermore, each acceleration sensor 42 may be configured to detect the acceleration in the rotation direction. As shown in FIG. 5, the wheel information 50 is a series of pieces of information including start information 52, identification information 53, air pressure information 54, end information 55, and the like. The identification information 53 is a value individually set for each of the wheel-side units 12FR, 12FL, 12RR, 12RL.

[0020] The single receiver 22 is provided in common among the four front, rear right and left wheel-side units 12FR, 12FL, 12RR, 12RL, and receives the wheel information 50 wirelessly transmitted from each of the wheel-side units 12FR, 12FL, 12RR, 12RL. The display 24 shows an air pressure value indicated by the air pressure information 54 included in the wheel information 50 in association with the wheel position. When the air pressure value P is lower than a normal determination threshold Pth, the air pressure value P is shown in a mode different from a mode when the air pressure value P is higher than or equal to the normal determination threshold Pth. The reset switch 25 is a switch that is configured to be manually operated when tire replacement (including tire rotation; the same applies to the following description), or the like, is conducted. An operation to turn on the reset switch 25 is a trigger for identifying the wheel position. The shift position sensor 27 may be configured to detect a shift position of a transmission or may be configured to detect an operating position of a shift operating member. The door open-close detection device 28 is configured to detect an open-close state of each of doors that serve as a plurality of open-close members provided in the vehicle, and includes door courtesy lamp switches, and the like, provided respectively at the plurality of open-close members. The plurality of open-close members include an open-close member (luggage door) of a luggage room.

[0021] The wheel speed sensors (rotation angular velocity sensors) 26FR, 26FL, 26RR, 26RL are respectively fixedly provided at positions of the vehicle body 14, corresponding to the wheels 10FR, 10FL, 10RR, 10RL, that is, in a state where each sensor portion faces teeth 58 provided in the circumferential direction at the outer periphery of a rotor 56 provided so as to be integrally rotatable with the corresponding wheel 10 as shown in FIG. 3. In each of the wheel speed sensors 26FR, 26FL, 26RR, 26RL, an electric signal is changed with passage of the teeth 58 (strictly, edges that are boundaries between projections and recesses of the teeth 58) facing the sensor portion, and the number of times the electric signal is changed is counted. A count value of the number of the edges that have passed through the position facing the sensor portion from the reference position of the rotor 56 is a detected value, and a rotation angle with respect to the reference position is acquired on the basis of the count value that is the detected value. In the present embodiment, the 48 teeth 58 are formed at the outer periphery of the rotor 56, and a count value in the case where the wheel 10 makes one rotation is Ns (48×2 = 96). The count value is returned to 0 when the count value reaches Ns (96) as shown in FIG. 11A. The reference position may be fixed or variable. For example, the reference position may be set to a position (the tooth 58 located at the position facing the sensor portion corresponds to the tooth that is a reference of the count value) of timing at which an ignition switch switches from an off state to an on state. In addition, as shown in FIG. 4 and FIG. 11A, the rotor 56 is provided so as to be integrally rotatable with the corresponding wheel 10, so the detected value of the corresponding acceleration sensor 42 varies with rotation of the rotor 56, and the count value of the corresponding wheel speed sensor 26 is changed. Therefore, it appears that a predetermined correlation holds between each of the count values of the wheel speed sensors 26 and a corresponding one of the detected values of the acceleration sensors 42. Each wheel speed sensor 26 is connected to the brake ECU 32, and the count values, and the like, acquired in the brake ECU 32 are supplied to the TPMS ECU 30. In the present embodiment, the number of the teeth 58 provided in the rotor 56 is 48; however, the number of the teeth 58 is not limited to this number. In addition, the rotor 56 may be a magnetic rotor. In such a case, magnetic powder is filled in rubber and provided at the outer periphery of the rotor 56 in a state where N poles and S poles are alternately arranged in the circumferential direction.

[0022] The TPMS ECU 30 is mainly formed of a computer. The TPMS ECU 30 acquires the air pressure value or identifies the wheel position by processing the wheel information 50 received in the receiver 22. For example, a wheel position acquisition table and a plurality of programs, such as a wheel state acquisition program, a wheel position identifying program and a detected value processing program, are stored in a storage unit 64. The wheel position acquisition table is shown by the map of FIG. 6. The wheel state acquisition program is shown by the flowchart of FIG. 7. The wheel position identifying program is shown by the flowchart of FIG. 8. The detected value processing program is shown by the flowchart of FIG. 9.

[0023] The operation of the thus configured wheel state acquisition system will be described.

Acquisition of Wheel State

[0024] The wheel state acquisition program shown by the flowchart of FIG. 7 is executed at predetermined set intervals. In step 1 (hereinafter, abbreviated as S1; the same applies to the other steps), it is determined whether the wheel information 50 has been received in the receiver 22. When the wheel information 50 has been received, the identification information 53 and the air pressure information 54 included in the wheel information 50 are loaded in S2, and the position of the wheel 10 from which the wheel information 50 has been transmitted is acquired on the basis of the identification information 53 and the wheel position acquisition table shown by the map of FIG. 6 in S3. In S4, it is determined whether the air pressure value P indicated by the air pressure information 54 is lower than the normal determination threshold Pth. When the air pressure value P is higher than or equal to the normal determination threshold Pth, it is determined that the air pressure is normal. In S5, the air pressure value P is shown on the display 24 in association with the wheel position. In contrast to this, when the air pressure value P is lower than the normal determination threshold Pth, the air pressure value P and the fact that the air pressure value is abnormal are shown in association with the wheel position in S6.

Identification of Wheel Position

[0025] For example, the case where a target wheel that is one of the four right and left front and rear wheels 10FR, 10FL, 10RR, 10RL is the right front wheel 10FR will be described. As described above, the wheel information 50FR is transmitted at the timing at which the detected value of the acceleration sensor 42FR at the right front wheel 10FR changes from an increasing tendency to a reducing tendency (timing at which the derivative value changes from a positive value to 0), that is, the timing at which the wheel-side unit 12FR has reached the top dead center. The rotation position of the wheel 10, determined on the basis of the detected value of the acceleration sensor 42 and the count value of the wheel speed sensor 26 associate with each other in one-to-one correspondence. The rotation position of the wheel 10 may be indicated by the rotation phase (rotation angle) with respect to the reference position of the wheel 10. The rotation angle with respect to the reference position of the wheel 10 (the position of the acceleration sensor 42 in the rotation direction with respect to the wheel 10) is determined on the basis of both the detected value and derivative value of the acceleration sensor 42. Therefore, the count value of the wheel speed sensor 26FR, acquired at the timing at which the wheel information 50FR has been transmitted, that is, the wheel information 50FR has been received in the receiver 22, should be always the same. In contrast to this, the count values of the other wheels 10FL, 10RR, 10RL are usually not always the same. The rotation angular velocities of the right and left front and rear wheels 10FR, 10FL, 10RR, 10RL are usually different from one another. In addition, there occurs a right and left rotation speed difference during cornering or there occurs a slip at part of the wheels during braking. Furthermore, even during traveling straight ahead at a constant speed, the rotation angular velocities differ from one another due to a difference in dynamic loaded radius.

[0026] In the present embodiment, while the vehicle is traveling, that is, while the wheels 10FR, 10FL, 10RR, 10RL are rotating, the count values of the wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired, and one of the wheel speed sensors 26, which has output the count value having the smallest dispersion among these count values, is identified. In addition, when each acceleration sensor 42 is configured to output a detected value when the rotation speed of the corresponding wheel 10 is higher than or equal to a set rotation speed (the centrifugal force is higher than or equal to a set value), the count value of the wheel speed sensor 26 is not acquired when the travel speed of the vehicle is lower than a set speed. As shown in FIG. 10, it is determined whether the count value (a processed count value is used as will be described later) falls within a set range SRc, the wheel speed sensor 26 that has output the count value that falls outside the set range SRc is excluded from identification candidates, and, when one count value determined to fall within the set range SRc is left, the wheel speed sensor 26 that has output that count value is identified. The set range SRc of the count value is determined on the basis of a set range SRθ of the rotation angle and the fact that the count value during the time of one rotation is 96 ($SRc = SR\theta \bullet 96/2\pi$). The set range SRθ of the rotation angle is determined on the basis of an error of the detected value of each acceleration sensor 42, a degree of dispersion, and the like. An upper limit value and lower limit value of the set range may be set or may not be set. For example, it is applicable that the upper limit value and lower limit value of the set range are set on the basis of the detected value, or the like, of the wheel speed sensor 26, detected for the first time in wheel position identification and then it is determined whether the detected value for the second time or later falls between the upper limit value and the lower limit value. It is also applicable that it is determined whether a plurality of detected values fall within a set range from each other without setting the upper limit value and lower limit value of the set range on the basis of the first detected value, or the like. In the latter case, it may be understood that the upper limit value and the lower limit value are set on the basis of the plurality of detected values.

[0027] For example, the count values (Ca1, Cb1, Cc1, Cd1) of the wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired at the timing at which the wheel information 50 including the identification information (IDa) 53 has been received in the receiver 22, and, subsequently, the count values (Ca2, Cb2, Cc2, Cd2) of the wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired at the timing at which the wheel information 50a including the IDa has been received. In this case, when Ca1 and Ca2, Cb1 and Cb2, Cc1 and Cc2 fall within the set range SRc and Cd1 and Cd2 do not fall within the set range SRc, the wheel speed sensor 26 (for example, the wheel speed sensor 26RR) that has output Cd1, Cd2 is excluded from the identification candidates. For the subsequently acquired count values (Ca3, Cb3, Cc3, Cd3) of the wheel speed sensors 26FR, 26FL, 26RR, 26RL, when Ca3 falls within the set range SRc determined by Ca1,Ca2 and Cb3 falls within the set range SRc determined by Cb1, Cb2 but Cc3 does not fall within the set range SRc determined by Cc1, Cc2, the wheel speed sensor 26 (for example, the wheel speed sensor 26FL) that has output Cc1, Cc2, Cc3 is excluded. For the subsequently acquired count values (Ca4, Cb4, Cc4, Cd4) of the wheel speed sensors 26FR, 26FL, 26RR, 26RL, when Ca4 falls within the set range SRc determined by Ca1 to Ca3 but Cb4 does not fall within the set range SRc determined by Cb1 to Cb3, the wheel speed sensor 26 (for example, RL) that has output Cb1 to Cb4 is excluded. The remaining one is the wheel speed sensor 26FR that has output the count values Ca1 to Ca4. As a result, it is possible to identify that the wheel information 50a has been transmitted from the wheel-side unit 12FR corresponding to the wheel speed sensor 26FR, the identification information IDa is associated with the right front wheel 10FR, and the wheel position of the identification information IDa is identified.

[0028] However, during identification of the wheel position, the correlation between each of the count values of the wheel speed sensors 26 and a corresponding one of the detected values of the acceleration sensors 42 may change. The phrase "during identification of the wheel position" means a period from when identification of the wheel position is started, for example, at the timing at which the reset switch 25 has been operated to turn on, to when the identification information is associated with the wheel position. Specifically, the phrase "during identification of the wheel position" means that, in order to associate one identification information with the wheel position, a series of operations, such as acquiring the detected values of the wheel speed sensors 26, determining whether each detected value falls within the corresponding set range and determining the wheel speed sensor 26 that is excluded from the identification candidates but the wheel position is not associated with the identification information. As shown in FIG. 11A, in the case where the vehicle is stopped during identification of the wheel position, when the wheels 10 and the vehicle body 14 are not relatively moved (or relative movement is small) while the vehicle is stopped, the correlation between each of the detected values of the acceleration sensors 42 and a corresponding one of the count values of the wheel speed sensors 26 is kept substantially constant, and the correlation therebetween is substantially the same after the vehicle starts moving. In contrast to this, as shown in FIG. 11B, there is a possibility that the vehicle body moves due to, for example, a situation that a passenger gets on or off or a baggage is loaded or unloaded while the vehicle is stopped. Thus, each wheel speed sensor 26 fixed to the vehicle body 14 and the rotor 56 provided at the corresponding wheel 10 are relatively moved (relative positional correlation changes), and the count values are varied. Thus, the correlation between each of the detected values of the acceleration sensors 42 and a corresponding one of the count values of the wheel speed sensors 26 changes, and it may be not possible to appropriately identify the wheel position. FIG. 11A to FIG. 11C show a state of a variation in each of the detected values of the acceleration sensors 42 with rotation of a corresponding one of the wheels 10 and a state of a variation in a corresponding one of the count values of the wheel speed sensors 26. Strictly, the rotation speed of each wheel decreases immediately before the vehicle stops, and increases after the vehicle starts moving; however, such a variation in rotation speed is not considered. This also applies to FIG. 13A to FIG. 13C.

[0029] In the present embodiment, it is determined whether a variation in each of the count values of the wheel speed sensors 26 is due to relative movement between the wheels 10 and the vehicle body 14 (not due to rotation of the wheels 10 or due to rotation of the wheels 10), and, when it is determined that the variation in each of the count values of the wheel speed sensors 26 is due to relative movement between the wheels 10 and the vehicle body 14, the variation in the count values of the wheel speed sensors 26 is ignored (the count values of the wheel speed sensors 26 are regarded as being not varied). Specifically, the count values of the wheel speed sensors 26 of the four wheels are acquired during a set period of time, and, when there are the wheel speed sensors 26 of which the count value has varied and the wheel speed sensors 26 of which the count value has not varied, it may be understood that, for example, the vehicle body 14 has moved due to a situation that a passenger gets on or off or a baggage is loaded or unloaded, and the wheels 10 and the vehicle body 14 are relatively moved, with the result that the count values of part of the wheel speed sensors 26 have varied. In other words, when there are the wheel speed sensors 26 of which the count value has varied and the wheel speed sensors 26 of which the count value has not varied, it is determined that the variations in the count values are not due to rotation of the wheels 10. In addition, because the variations in the count values of the wheel speed sensors 26 are ignored, processed count values (processed values of the detected values) (described later) Ci* (i = a, b, c, d) are used in identifying the wheel position after the vehicle starts moving. Each of the processed count values after the vehicle starts moving is set to a value shifted by a variation amount by which a count value Ci supplied from the brake ECU 32 is ignored.

[0030] The wheel position identifying program shown by the flowchart of FIG. 8 is, for example, executed when a position identification start condition is satisfied, and is, for example, started when the reset switch 25 is manually operated. In the present embodiment, the case where the wheel position of the identification information IDa is identified will be described. The same applies to the case where the wheel position of another piece of identification information is identified. In S10, it is determined whether the vehicle is traveling. When the vehicle is traveling, it is determined in S11 whether the wheel information 50a including the target identification information IDa has been received. When the wheel information 50a has been received, the processed count values Ci* (descried later) are acquired in S12. It is determined in S13 whether each of the processed count values Ci* falls within the set range SRc, and the wheel speed sensor 26 that has output the processed count value that falls outside the set range SRc is excluded from the identification candidates. It is determined in S14 whether the number of the processed count values determined to fall within the set range SRc is one (the number of the wheel speed sensors 26 remaining as the identification candidates is one). When the number of the processed count values determined to fall within the set range SRc is two or more, S10 to S14 are repeatedly executed. When the number of the remaining wheel speed sensors 26 (processed count values) becomes one, affirmative determination is made in S14. In S15, the position of the wheel corresponding to the remaining one wheel speed sensor 26 is associated with the identification information IDa. It is determined that the wheel information 50a including the identification information IDa has been transmitted from the wheel-side unit 12 of the wheel corresponding to the last remaining one wheel speed sensor 26.

[0031] The detected value processing program shown by the flowchart of FIG. 9 may be, for example, executed by interrupt when the count values Ci are supplied from the brake ECU 32. In S21, count values (values supplied from the brake ECU 32) Can, Cbn, Ccn, Cdn (n = 0, 1, 2, 3, ...) that are the detected values of the wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired. In S22, it is determined whether it is in the process of identifying the wheel position. When it is in the process of identifying the wheel position, it is determined in S23 whether it is in the progress of a set period of time, that is, whether the count values are being acquired. When the count values are not being acquired, it is determined in S24 whether a start condition for acquiring the count values is satisfied. The start condition may be, for example, configured to be satisfied at intervals of the set period of time. When the start condition is satisfied, the count values Can, Cbn, Ccn, Cdn of the wheel speed sensors 26FR, 26FL, 26RR, 26RL of the wheels, acquired in S21, are set to initial values Ca0, Cb0, Cc0, Cd0 and stored in S25. In addition, a count value acquiring flag is set to an on state. Subsequently, when the program is executed, the count value acquiring flag is set to the on state, so affirmative determination is made in S22 and S23. In S26, it is determined whether the set period of time has elapsed. It is determined whether an elapsed time from when the start condition is satisfied has reached the set period of time. Before the set period of time elapses, S21, S22, S23, S26 are repeatedly executed, and the count values Can, Cbn, Ccn, Cdn of the wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired during the set period of time.

[0032] When the set period of time has elapsed, the count value acquiring flag is set to an off state, it is determined whether the plurality of count values Cin output from each of the wheel speed sensors 26FR, 26FL, 26RR, 26RL have varied. That is, it is determined that the count values have not varied when the plurality of count values are equal to each other; whereas it is determined that the count values have varied when part of the plurality of count values are different from each other. It is determined in S27 whether part of the wheel speed sensors 26 have output the not-varied count values, that is, whether there are the wheel speed sensors 26 that have output the varied count values and the wheel speed sensors 26 that have output the not-varied count values among the four wheel speed sensors 26FR, 26FL, 26RR, 26RL. When there are both, processed count values $Ca(n)^*$, $Cb(n)^*$, $Cc(n)^*$, $Cd(n)^*$ of all the wheel speed sensors 26 are set to the initial values Ca0, Cb0, Cc0, Cd0 in S28 ($Ci0 \rightarrow Ci(n)^*$). It may be understood that only the processed count values of the wheel speed sensors 26 of which the count values have varied are set to the initial values of the count values. For example, when the count values ((Ca0, Ca1, Ca2, ...), (Cb0, Cb1, Cb2, ...)) have not varied (($Ca0 = Ca1 = Ca2$, ...), ($Cb0 = Cb1 = Cb2$, ...)) and the count values ((Cc0, Cc1, Cc2, ...), (Cd0, Cd1, Cd2, ...)) have varied (($Cc0 \neq Cc1 \neq Cc2$, ...), ($Cd0 \neq Cd1 \neq Cd2$, ...)), it may be understood that the processed count values ($Cc(n)^*$, $Cd(n)^*$) are set to the initial values (Cc0, Cd0). In contrast to this, when the plurality of count values output from each of all the wheel speed sensors 26 have not varied or the count values output from all the wheel speed sensors 26 have varied, normal processing is executed in S29. The processed count values are set to the count values Can, Cbn, Ccn, Cdn ($Cin \rightarrow Ci(n)^*$) acquired in the preceding S21. For example, this corresponds to, for example, the case where the vehicle is traveling.

[0033] In addition, because the program is repeatedly executed, S28 may be executed after S29 is executed. In such a case, the current processed count values are equal to the previous processed count values ($Ci(n)^* \leftarrow Ci(n-1)^*$), so the processed count values are constant. Furthermore, after the processed count values are returned to the initial values in S28, S29 may be executed. In such a case, in S29, the current processed count values are obtained through a count with reference to the previous processed count values $Ci(n-1)^*$. For example, a variation amount of each of the count values during the set period of time is acquired ($dCi = Cin - Ci0$). By adding the variation amount dCi of each of the count values to a corresponding one of the previous processed count values, a corresponding one of the current processed count values is acquired (Ci(n)* ← Ci(n-1)* + dCi). The set period of time may be set to a period of time shorter than a period of time during which the wheel 10 makes one rotation, for example, a period of time during which the count values of the wheel speed sensors 26 are supplied from the brake ECU 32 multiple times. The set period of time is set to a period of time shorter than the interval at which the processed count values are loaded in identifying the wheel position.

[0034] In this way, in the present embodiment, even when the count values of the wheel speed sensors 26 have varied due to relative movement between the vehicle body 14 and the wheels 10 while the vehicle is stopped although the wheels 10 are not rotating, the variation is regarded as being not varied. As a result, after the vehicle starts moving, identification of the wheel position is continued on the basis of the processed count values of the wheel speed sensors 26 in order to identify the wheel position. However, the correlation between each of the processed count values of the wheel speed sensors 26 and a corresponding one of the detected values of the acceleration sensors 42 is substantially the same before the vehicle stops and after the vehicle starts moving, so it is possible to appropriately identify the wheel position. For example, in FIG. 11C, as in the case of the period between time t1 and time t2 (during the set period of time), when there are the wheel speed sensors 26 of which the count values have varied and the wheel speed sensors 26 of which the count values have not varied, the count values are regarded as being not varied. The processed count values Ci(2)* at time t2 are set to the count values at time t1, that is, the initial values Ci0 of the count values (S28) (Ci(2)* ← Ci0). In addition, as in the case of the period between time t2 and time t3, when the count value of each of all the wheel speed sensors 26 has not varied, the processed count values Ci(3)* at time t3 are equal to the processed count values Ci(2)* at time t2 (S29) (Ci(3)* ← Ci(2)*). Subsequently, as in the case of the period between time t3 and time t4, when there are the wheel speed sensors 26 of which the count values have varied and the wheel speed sensors 26 of which the count values have not varied, the processed count values Ci*(4) are set to the same values at time t4 as the processed count value Ci(3)* at time t3 (S28) (Ci(4)* ← Ci(3)*). As in the case of the period between time t6 and time t7, when the count value of each of all the wheel speed sensors 26 has varied, the count values are counted up with reference to the processed count values Ci(6) at time t6. By adding the variation amount dCi of each of the count values between time t6 and time t7 to a corresponding one of the processed count values Ci(6)* at time t6, the processed count values Ci(7)* are obtained at time t7 (S29) (Ci(7)* ← Ci(6)* + dCi dCi ← Cin - Ci0).

[0035] Thereafter, each of the processed count values is obtained by adding the variation amount dCi of a corresponding one of the count values during the set period of time to a corresponding one of the previous processed count values Ci(n-1)*. As indicated by the points on the alternate long and short dashed line in FIG. 11C, each of the count processed values is a value shifted by the ignored amount of count value from a corresponding one of the count values supplied from the brake ECU 32. In addition, each wheel speed sensor 26 may be of a type that counts up without distinguishing the forward rotation of the rotor 56 from the reverse rotation of the rotor 56 and may be of a type that counts up or counts down depending on the rotation direction of the rotor 56. In any cases, a variation in each of the count values not due to rotation of a corresponding one of the wheels 10 is ignored by executing the program, so it is possible to keep the correlation between each of the detected values of the acceleration sensors 42 and a corresponding one of the processed count values of the wheel speed sensors 26 substantially constant.

[0036] In the present embodiment, a detected value processing unit is formed of a portion of the TPMS ECU 30, which stores the detected value processing program shown by the flowchart of FIG. 9, a portion of the TPMS ECU 30, which executes the detected value processing program, and the like, and a wheel position identifying unit is formed of the detected value processing unit, a portion of the TPMS ECU 30, which stores the wheel position identifying program shown by the flowchart of FIG. 8, a portion of the TPMS ECU 30, which executes the wheel position identifying program, and the like. The detected value processing unit is a correlation change suppressing unit. In addition, a detected value holding unit, a variation ignoring unit and a stopping variation ignoring unit are formed of a portion of the detected value processing unit, which stores S24, S25, S27, S28, a portion of the detected value processing unit, which executes S24, S25, S27, S28, and the like. Furthermore, the wheel position identifying unit also serves as a wheel position identification continuing unit.

Second Embodiment

[0037] When the correlation between each of the detected values of the acceleration sensors 42 and a corresponding one of the count values of the wheel speed sensors 26 may change, for example, while the vehicle is stopped, it is possible to prohibit a variation in each of the count values of the wheel speed sensors 26. A count prohibition flag setting program shown by the flowchart of FIG. 12A is executed at intervals of a predetermined set period of time. In S31, it is determined by the door open-close detection device 28 whether at least one of the plurality of open-close members provided in the vehicle is open. When any one of the luggage door, a passenger seat door, and the like, is open, it is determined that it is highly likely that a passenger gets on or off or a baggage is loaded or unloaded. In S32, it is determined whether the vehicle is stopped on the basis of information from the navi ECU 34 (hereinafter, simply referred to as navi information where appropriate). When at least one of the open-close members is open or when it may be determined that the vehicle is stopped on the basis of the navi information, the count prohibition flag is set to an on state in S33. In contrast to this, when all the open-close members are closed and the vehicle is traveling, the count prohibition flag is set to an off state in S34.

[0038] The detected value processing program shown by the flowchart of FIG. 12B is executed by interrupt. In S41, count values that are the detected values of the four wheel speed sensors 26FR, 26FL, 26RR, 26RL are acquired. In S42, it is determined whether it is in the process of identifying the wheel position. In S43, it is determined whether the count prohibition flag is in the on state. When the count prohibition flag is in the on state, affirmative determination is made in S43. In S44, it is determined whether the count prohibition flag was previously in the off state, that is, it is determined whether the count prohibition flag is set to the on state for the first time. When the count prohibition flag is set to the on state for the first time, the count values of the wheel speed sensors 26FR, 26FL, 26RR, 26RL, acquired in S41, are stored as initial values in S45 (Ca0, Cb0, Cc0, Cd0). Thereafter, in S46, while the count prohibition flag is in the on state, the processed count values Ci(n)* are respectively set to the initial values Ci0. In contrast to this, when the count prohibition flag is not in the on state, normal processing is executed in S47. As a rule, the count values acquired in S41 are set as output values of the corresponding sensors (Ci(n)* ← Cin). In addition, for example, when S46 may be executed after S47 is executed, the current processed count values are equal to the previous processed count values (Ci(n)* ← Ci(n-1)*). In addition, for example, when S47 is executed after S44 to S46 are executed, the processed count values are counted with reference to the previous processed count values, that is, the processed count values Ci(n-1)* at that timing.

[0039] In this way, in the present embodiment, as shown in FIG. 13C, when the vehicle is stopped or when at least one of the open-close members is open, the prohibition flag is set to the on state, and the processed count values of all the wheel speed sensors 26 are kept at constant values. Therefore, even when the count values are varied due to relative movement between the wheels 10 and the vehicle body 14 while the vehicle is stopped, the processed count values remain at the initial values of the count values, and the processed count values are counted with reference to the previous processed count values Ci(n-1)* after the vehicle starts moving. As a result, it is possible to suppress the change of the correlation between each of the detected values of the acceleration sensors 42 and a corresponding one of the processed count values of the wheel speed sensors 26, so it is possible to appropriately identify the wheel position. In the present embodiment, the detected value holding unit and a stopping detected value holding unit are formed of a portion of the TPMS ECU 30, which stores S43 to S46 of the detected value processing program shown by the flowchart of FIG. 12B, a portion of the TPMS ECU 30, which executes S43 to S46, and the like.

Third Embodiment

[0040] The present embodiment is applied to the wheel speed sensors 26 of a type that counts up when the rotor 56 is rotating in the reverse direction or when the rotor 56 is rotating in the forward direction. When the shift position is R and the wheels 10 are rotating in the reverse direction, the wheel speed sensors 26 count down. When the shift position is not R, the process based on the state of the vehicle is executed as in the case of the above-described first and second embodiments. In S51 of the flowchart of FIG. 14 that shows the detected value processing program, the count values Cin of the wheel speed sensors 26FR, 26FL, 26RR, 26RL of the wheels are acquired. When it is not in the process of identifying the wheel position, affirmative determination is made in S52. In S53, it is determined whether the shift position is reverse (R) on the basis of the detected value of the shift position sensor 27. When the shift position is D, N, or the like, the process based on the shift position, for example, a similar process as in the case of the first and second embodiments, is executed in S54. In contrast to this, when the vehicle is traveling backward, backward travel processing is executed. In S55, an amount dCi of increase in each of the count values Cin is acquired. In S56, each of the current processed count values is obtained by subtracting the corresponding amount dCi of increase from a corresponding one of the previous processed count values (Ci(n)* = Ci(n-1)* - dCi). The amount of increase in each of the count values Cin is acquired as a value (for example, Ci2 - Ci1) obtained by subtracting a corresponding one of the previous count values from a corresponding one of the current count values. When the vehicle travels forward after traveling backward, each of the processed count values is counted up with reference to a corresponding one of the previous processed count values Ci(n-1)*.

[0041] In this way, each of the processed count values is counted down from a corresponding one of the previous processed count values when a corresponding one of the wheels 10 is rotated in the reverse direction, so it is possible to appropriately keep the correlation between each of the processed count values of the wheel speed sensors 26 and a corresponding one of the detected values of the acceleration sensors 42. Therefore, even when the vehicle travels forward after traveling backward, it is possible to appropriately continue identification of the wheel position. In the present embodiment, a count down unit is formed of a portion of the TPMS ECU 30, which stores S53 to S57 of the detected value processing program shown by the flowchart of FIG. 14, a portion of the TPMS ECU 30, which executes S53 to S57, and the like.

Fourth Embodiment

[0042] In the present embodiment, when the count values of the wheel speed sensors 26 have varied in a state where the vehicle is stopped, the set range used to identify the wheel position is changed. In S61 of the flowchart of FIG. 15 that shows the detected value processing program, the count values Cin of the wheel speed sensors 26FR, 26FL, 26RR, 26RL of the wheels are acquired. In S62, it is determined whether it is in the process of identifying the wheel position. In S63, it is determined whether the vehicle is stopped on the basis of the navi information. When affirmative determination is made in both S62 and S63, it is determined in S64 whether it is the first time that it is determined that the vehicle is stopped. When it is the first time, the count values Cin of the wheel speed sensors 26FR, 26FL, 26RR, 26RL of the wheels, acquired in S61, are set as the initial values Ci0 and stored in S65. Subsequently, when the program is executed, it is not the first time, so, in S66, a value ΔCi obtained by subtracting a corresponding one of the initial values Ci0 from a corresponding one of the count values Cin of the wheel speed sensors 26FR, 26FL, 26RR, 26RL of the wheels, acquired in S61, is acquired and stored (ΔCi ← Cin - Ci0). The values stored in S66 are updated as needed. A variation amount in each of the count values during the time the vehicle is stopped is acquired and updated. When the vehicle has started moving, negative determination is made in S63. In S67, it is determined whether it is the first time that negative determination is made in S63, that is, it is determined whether the vehicle has started moving after stopping. When the vehicle has started moving after stopping, that is, when it is the first time that S67 is executed, an expanded amount ΔSRci of each set range is obtained on the basis of the variation amount ΔCi acquired in S66, and a corresponding one of changed set ranges (SRci + ΔSRci) is obtained in S68 (ΔSRci ← ΔCi SRci* ← SRci + ΔSRci). The expanded amounts ΔSRci of each set range may be equal to or may be different from a corresponding one of the variation amounts ΔCi of the count values in a state where the vehicle is stopped. In any cases, when the variation amount ΔCi of each of the count values in a state where the vehicle is stopped is large, the expanded amount ΔSRci of a corresponding one of the set ranges is increased larger than when the expanded amount ΔSRci is small.

[0043] The set ranges may be individually changed for each of the wheel speed sensors 26FR, 26FL, 26RR, 26RL or may be changed in common. For example, for the four wheel speed sensors 26, the amount ΔSRc of increase in each set range may be determined on the basis of the maximum value, average value, and the like, of the variation amount of a corresponding one of the count values, and a corresponding one of the changed set ranges SRc* may be determined by uniformly expanding the set ranges of the four wheel speed sensors 26. In addition, each set range may be changed when at least one of the count values of the four wheel speed sensors 26FR, 26FL, 26RR, 26RL has varied in a state where the vehicle is stopped or may be changed when all the count values of the four wheel speed sensors 26 have varied. Even when it has been detected that the vehicle is stopped on the basis of the navi information, the wheels 10 may actually rotate and the vehicle may be slightly moving. Therefore, when all the count values of the four wheel speed sensors 26 are varied, it is not clear whether the variation is due to relative movement between the vehicle body 14 and the wheels 10 (not due to rotation of the wheels 10) or due to rotation of the wheels 10. Therefore, when it may not be determined that the variation is due to relative movement between the wheels 10 and the vehicle body 14, that is, when all the count values of the four wheel speed sensors 26 have varied, not the variations of the count values are ignored but the set ranges are expanded.

[0044] The wheel position is identified on the basis of the changed set ranges, and the wheel position identifying program shown by the flowchart of FIG. 16 is executed at intervals of the predetermined set period of time. While the vehicle is traveling, when the wheel information is received in the receiver 22, the count values Cin of the wheel speed sensors 26 are acquired in S12x. In S13b, the changed set ranges SRi* are loaded. In S13x, it is determined whether each of the count values Cin falls within a corresponding one of the changed set ranges SRi*. Thereafter, as in the case of the above-described embodiments, the wheel position is identified. In the present embodiment, not it is determined whether each of the processed count values falls within a corresponding one of the changed set ranges but it is determined whether each of the count values falls within a corresponding one of the changed set ranges. For example, as shown in FIG. 17, when the count values of the four wheel speed sensors 26 are varied in a state where the vehicle is stopped, the expanded amount ΔSRc for each set range is obtained on the basis of a corresponding one of the variation amounts, and a corresponding one of the changed set ranges is obtained. As a result, even when the correlation changes, it is possible to appropriately identify the wheel position.

[0045] In the present embodiment, a variation amount acquisition unit is formed of a portion of the TPMS ECU 30, which stores S64 to S66, S68 of the detected value processing program shown by the flowchart of FIG. 15, a portion of the TPMS ECU 30, which executes S64 to S66, S68, and the like, a set range changing unit is formed of a portion of the TPMS ECU 30, which stores S69, a portion of the TPMS ECU 30, which executes S69, and the like, and the wheel position identification continuing unit is formed of a portion of the TPMS ECU 30, which stores the wheel position identifying program shown by the flowchart of S15, a portion of the TPMS ECU 30, which executes the wheel position identifying program, and the like.

Fifth Embodiment

[0046] In the present embodiment, while the vehicle is stopped, it is determined whether there are the wheel speed sensors 26 of which the count value has varied and the wheel speed sensors 26 of which the count value has not varied. When there are both, variations of the count values are ignored; whereas, when all the count values of the wheel speed sensors 26 have varied, the set ranges are changed. The detected value processing program shown by the flowchart of FIG. 18 is executed by interrupt, or the like. In S81, the count values Cin are acquired. In S82, it is determined whether it is in the process of identifying the wheel position. When it is in the process of identifying the wheel position, it is determined in S83 whether the vehicle is stopped on the basis of the navi information, or the like. When it is determined that the vehicle is stopped, it is determined in S84 whether it is the first time that it is determined that the vehicle is stopped. When it is the first time, the count values are set to the initial values Ci0 and stored in S85. After that, during the set period of time, S81 to S84, S86 are repeatedly executed, and the count values Cin are acquired. After the set period of time has elapsed, it is determined whether there are the wheel speed sensors 26 that have output varied count values and the wheel speed sensors 26 that have output not-varied count values (S87). When there are both, a variation ignoring flag is set to an on state in S88. In S89, the processed count values are set to initial values (Ci(n)* ← Ci0). The current values of the processed count values may be set to the previous values (Ci(n)* ← Ci(n-1)*). While the vehicle is stopped, the processed count values are kept at constant values by executing S81 to S84, S86 to S89, and the variations of the count values are ignored. When the vehicle has started moving, negative determination is made in S83. In S90, it is determined whether the variation ignoring flag is in the on state. When the variation ignoring flag is in the on state, the processed current values are counted up from the previous processed count values Ci(n-1)* in S91, and the current processed count values Ci(n)* are obtained.

[0047] In contrast to this, when all the count values of the wheel speed sensors 26FR, 26FL, 26RR, 26RL have varied, negative determination is made in S87, so the variation ignoring flag is kept in the off state. S81 to S84, S86, S87 are repeatedly executed while the vehicle is stopped. After that, when the vehicle has started moving, it is determined in S92 whether S92 is executed for the first time, that is, it is determined whether the vehicle has started moving after stopping and S92 is executed for the first time. When it is the first time, the variation amounts ΔCi of the count values in the case where the vehicle is stopped are acquired in S93, the changed amount (expanded amount) of each set range is acquired and a corresponding one of the changed set ranges is acquired in S94.

[0048] When the variations of the count values are ignored, it is determined whether each of the processed count values falls within a corresponding one of the set ranges and the wheel position is identified by executing the wheel position identifying program shown by the flowchart of FIG. 8. When each of the set ranges has been changed, it is determined that each of the count values falls within a corresponding one of the changed set ranges and the wheel position is identified by executing the wheel position identifying program shown by the flowchart of FIG. 16. When part of the count values of the four wheel speed sensors 26FR, 26FL, 26RR, 26RL have not varied and the remainder of the count values have varied, it may be determined that the vehicle is stopped and the count values of part of the wheel speed sensors 26 have varied due to relative movement between the vehicle body 14 and the wheels 10 (not due to rotation of the wheels 10). However, when all the count values of the wheel speed sensors 26 have varied, it is not clear whether the variation is due to rotator of the wheels 10 or not due to rotation of the wheels 10. This is because, even when it is determined that the vehicle is stopped on the basis of the navi information, the vehicle may be slightly moving. Thus, when all the count values of the wheel speed sensors 26 have varied, the wheel position is identified by not ignoring the variations of the count values but changing the set ranges. In this way, the variations of the count values are not ignored when it is not clear whether the variations of the count values are due to rotation of the wheels 10 or not due to rotation of the wheels 10, so, even when the variations are due to rotation of the wheels 10, it is possible to appropriately identify the wheel position.

[0049] The first to fifth embodiments may be implemented in combination as needed. Other than the above-described modes, the invention may be implemented in modes with various controls or improvements on the basis of the knowledge of persons skilled in the art.

[0050] In the invention, the set state may be one of a state where at least one of the detected values of the plurality of vehicle body-side rotation sensors varies when a corresponding one of the wheels is not rotating and a state where the at least one of the detected values may vary.

[0051] In the invention, the set state may be one of a state where at least one of the plurality of wheels and the vehicle body are relatively moved and a state where the at least one of the plurality of wheels and the vehicle body may be relatively moved not due to rotation of the plurality of wheels. When the wheels and the vehicle body are relatively moved not due to rotation of the wheels, the detected values of the vehicle body-side rotation sensors are varied, and the correlation may change. For example, when a passenger gets on or off or a baggage is loaded or unloaded, when the vehicle receives crosswind or when the shift position is changed while the vehicle is stopped, the vehicle body and the wheels may be relatively moved.

[0052] In the invention, the set state may be a state including one or more of (a) a state where the vehicle is stopped, (b) a state where at least one of a plurality of open-close members provided in the vehicle is open and (c) a state where the vehicle is traveling backward. Each vehicle body-side rotation sensor may be of (c-1) a type of which the count value that is the detected value increases in a state where a corresponding one of the wheels is rotating in the forward direction and the count value reduces in a state where a corresponding one of the wheels is rotating in reverse and (c-2) a type of which the count value increases when the wheel rotates in the forward direction or when the wheel rotates in the reverse direction. In the case of the type of (c-2), when the vehicle is traveling backward, the count value of each vehicle body-side rotation sensor is desirably reduced.

[0053] In the invention, the detected value processing unit may include a stop state determination unit configured to determine that the vehicle is stopped as the set state when part of the detected values of the plurality of vehicle body-side rotation sensors have varied and the remainder of the detected values of the vehicle body-side rotation sensors other than the part of the vehicle body-side rotation sensors have not varied. When the plurality of vehicle body-side rotation sensors include the sensors of which the detected value has varied and the sensors of which the detected value has not varied, it is determined that the vehicle is stopped and the correlation is changed as a result of the variations of the detected values of the vehicle body-side rotation sensors due to relative movement between the wheels and the vehicle body.

[0054] In the invention, the detected value processing unit may include a variation amount acquisition unit configured to, when at least one of the detected values of the plurality of vehicle body-side rotation sensors has varied while the vehicle is stopped, acquire the variation of the at least one of the detected values of the plurality of vehicle body-side rotation sensors, and the wheel position identifying unit may include a variation dependent wheel position identifying unit configured to identify the wheel position by considering the variation of the at least one of the detected values, acquired by the variation acquisition unit. The variation of the detected value includes a variation direction, a variation amount, and the like. For example, it is possible to acquire the changed correlation on the basis of a variation in each of the detected values of the vehicle body-side rotation sensors during the time the vehicle is stopped. It may be understood that the correlation has shifted in response to a variation in each of the detected values. For example, it is possible to identify the wheel position by acquiring a corresponding one of the changed set ranges on the basis of the changed correlation. In addition, when the detected values of the vehicle body-side rotation sensors have varied in a state where the vehicle is stopped, it may be understood that an error of each of the detected values of the vehicle body-side rotation sensors is increased accordingly. By understanding in this way, it is possible to expand each of the set ranges on the basis of a variation in a corresponding one of the detected values, and it is possible to identify the wheel position on the basis of each of the expanded set ranges. Changing the set range (including shifting, expanding, or the like, of each set range) may be carried out individually in correspondence with each of the plurality of vehicle body-side rotation sensors or may be carried out in common (uniformly) among the plurality of vehicle body-side rotation sensors. For example, changing the set range may be uniformly carried out on the basis of the maximum value of the variation amount of each of the detected values of the plurality of vehicle body-side rotation sensors, the average value of the variation amount, or the like. In addition, the variation amount (including a shift amount, an expanded amount, and the like) of each set range may be larger when the variation amount of a corresponding one of the detected values is larger than when the variation amount of a corresponding one of the detected values is small. Furthermore, the wheel position may be identified in consideration of the variation amount when the variation amount of a corresponding one of the detected values is large and the wheel position may be identified not in consideration of the variation amount when the variation amount is small.

[0055] In the invention, each wheel-side rotation sensor may be an acceleration sensor configured to detect an acceleration that acts on a corresponding one of the wheel-side rotation sensors, and the transmitter may be configured to transmit the wheel information when a position of a corresponding one of the acceleration sensors, determined on the basis of a corresponding one of the detected values of the acceleration sensor, has reached a predetermined position. Each of the detected values of the acceleration sensors periodically varies with rotation of a corresponding one of the wheels. The wheel information may be, for example, transmitted at timing that is determined by a corresponding one of the detected values of the acceleration sensors or may be transmitted at timing that is determined by a derivative value (a variation in a corresponding one of the detected values). Specifically, the wheel information may be transmitted at timing at which a corresponding one of the detected values of the acceleration sensors has reached a set value (for example, which may be set to 0 or 1G) or may be transmitted at timing at which a corresponding one of the detected values of the acceleration sensors has reached a peak value (for example, timing at which a corresponding one of the detected values has reached a local maximum value or a local minimum value). The wheel information is transmitted a predetermined number of times (for example, once or twice) during the time a corresponding one of the wheels makes one rotation.

[0056] In the invention, each vehicle body-side rotation sensor may include a detecting unit facing an outer peripheral portion of a rotor provided so as to be integrally rotatable with a corresponding one of the wheels and configured to detect a rotation angle of the rotor on the basis of a variation in electrical property of the detecting unit, and the outer peripheral portion of the rotor may be configured to periodically change the electrical property of the detecting unit with rotation of the rotor. For example, the rotor may have a gear shape in which a recess and a protrusion are alternately located at the outer peripheral portion or may be a magnetic rotor in which an N pole and an S pole alternately appear.

[0057] In the invention, the wheel position identifying unit may include a sensor identifying unit configured to identify any one of the vehicle body-side rotation sensors, which has output the detected values having the smallest dispersion.

[0058] In the invention, the sensor identifying unit may include at least one of (a) a first identifying unit configured to exclude the vehicle body-side rotation sensor that has output the detected value that falls outside a corresponding first set range by acquiring whether each of the detected values falls within the corresponding first set range and identify the last remaining one vehicle body-side rotation sensor as the vehicle body-side rotation sensor corresponding to the target wheel and (b) a second identifying unit configured to identify the vehicle body-side rotation sensor that has output the detected values in which the number of the detected values that fall within a corresponding second set range is the largest as the vehicle body-side rotation sensor corresponding to the target wheel. The first set range and the second set range may be the same or may be different from each other.

[0059] In the invention, the vehicle body-side device may include a wheel position identification interrupting unit configured to interrupt identification of the wheel position when a maximum value among at least one of the variation amounts of the detected values of the plurality of vehicle body-side rotation sensors during the time the vehicle is stopped is larger than or equal to a predetermined set value. For example, in the case where the vehicle is stopped in the process of identifying the wheel position, identification of the wheel position may be interrupted when an ignition switch is turned off, and identification of the wheel position may be continued after the vehicle starts moving when the ignition switch remains in an on state. However, in a state where the vehicle is stopped, if any one of the detected values of the vehicle body-side rotation sensors varies not due to rotation of a corresponding one of the wheels, it is difficult to appropriately continue identification of the wheel position. In this case, when identification of the wheel position is always interrupted, it is not desirable because identification of the wheel position delays; however, when the influence of a variation in the any one of the detected values on identification of the wheel position is small, identification of the wheel position is allowed to be continued. Therefore, only when the maximum value of the variation amount is large and the influence on identification of the wheel position is large, continued identification of the wheel position is interrupted.

CLAIMS:

1. A wheel position identifying apparatus comprising:

wheel-side devices respectively provided at a plurality of wheels of a vehicle, each wheel-side device having a wheel-side rotation sensor configured to detect a rotation position of a corresponding one of the wheels and a transmitting unit configured to transmit wheel information, including at least identification information set for the corresponding one of the wheels, at timing at which a position of the wheel-side rotation sensor with respect to the corresponding one of the wheels, determined on the basis of a detected value of the wheel-side rotation sensor, has reached a predetermined position; and

a vehicle body-side device provided at a vehicle body of the vehicle, the vehicle body-side device having a receiver configured to receive the wheel information transmitted from each of the plurality of wheel-side devices, vehicle body-side rotation sensors respectively corresponding to the plurality of wheels and each configured to output a detected value corresponding to the rotation position of a corresponding one of the wheels, and a detected value processing unit configured to, each time target wheel information that is the wheel information transmitted from a target wheel-side device that is one of the plurality of wheel-side devices is received by the receiver, cause each of the vehicle body-side rotation sensors to detect the rotation position of a corresponding one of the plurality of wheels and identify one of the vehicle body-side rotation sensors, which corresponds to a target wheel that is the wheel from which the target wheel information has been transmitted, on the basis of each of the detected values of the rotation positions of the plurality of wheels, associate the identification information included in the target wheel information with a position of the target wheel and, when the vehicle is placed in a set state during operation of the wheel position identifying unit, process at least one of the detected values of the plurality of vehicle body-side rotation sensors on the basis of the state of the vehicle.

2. The wheel position identifying apparatus according to claim 1, wherein

the detected value processing unit includes a correlation change suppressing unit configured to suppress a change of a correlation between each of at least one of the detected values of the plurality of vehicle body-side rotation sensors and a corresponding one of the detected values of the wheel-side rotation sensors corresponding to the vehicle body-side rotation sensors by processing the at least one of the detected values of the plurality of vehicle body-side rotation sensors.

3. The wheel position identifying apparatus according to claim 1 or 2, wherein

the detected value processing unit includes one or more of a variation ignoring unit configured to ignore a variation in at least one of the detected values of the plurality of wheel-side rotation sensors, a detected value holding unit configured to keep the at least one of the detected values constant, and a count down unit configured to reduce count values that are the detected values of the plurality of wheel-side rotation sensors.

4. The wheel position identifying apparatus according to any one of claims 1 to 3, wherein

the detected value processing unit includes a stopping detected value holding unit configured to keep the detected value of each of the plurality of vehicle body-side rotation sensors constant in at least one of a case where the vehicle is stopped and a case where at least one of a plurality of open-close members provided in the vehicle is open.

5. The wheel position identifying apparatus according to any one of claims 1 to 4, wherein

the detected value processing unit includes a stopping variation ignoring unit configured to, during a predetermined set period of time, when part of the detected values of the plurality of vehicle body-side rotation sensors vary and the remainder of the detected values do not vary, determine that the vehicle is stopped and ignore the variation in each of the detected values of the part of the vehicle body-side rotation sensors.

6. The wheel position identifying apparatus according to any one of claims 1 to 5, wherein

the detected value processing unit includes a variation amount acquisition unit configured to, when at least one of the detected values of the plurality of vehicle body-side rotation sensors has varied while the vehicle is stopped, acquire a variation amount of each of the at least one of the detected values of the plurality of vehicle body-side rotation sensors, and

the wheel position identifying unit includes a variation amount dependent wheel position identifying unit configured to identify the wheel position by considering the variation amount of the at least one of the detected values, acquired by the variation amount acquisition unit.

7. The wheel position identifying apparatus according to claim 6, wherein

the wheel position identifying unit includes a dispersion acquisition unit configured to determine whether each of the detected values of the plurality of vehicle body-side rotation sensors falls within a set range, and

the variation amount dependent wheel position identifying unit includes at least one of a set range individual changing unit configured to individually change the set range on the basis of the variation amount of the detected value of the corresponding vehicle body-side rotation sensor and a set range common changing unit configured to uniformly change the set ranges on the basis of at least one variation amount of the at least one of the detected values.

8. The wheel position identifying apparatus according to any one of claims 1 to 7, wherein

the detected value processing unit includes a variation ignoring unit configured to ignore a variation in part of the detected values of the plurality of vehicle body-side rotation sensors when it has been detected that the vehicle is stopped and when the part of the detected values of the vehicle body-side rotation sensors have varied and the remainder of the detected values of the vehicle body-side rotation sensors have not varied, and a variation amount acquisition unit configured to acquire a variation amount of each of the detected values of the plurality of vehicle body-side rotation sensors when it has been detected that the vehicle is stopped and when all the detected values of the plurality of vehicle body-side rotation sensors have varied.

9. A wheel position identifying apparatus comprising:

wheel-side devices respectively provided at a plurality of wheels of a vehicle, each wheel-side device having a wheel-side rotation sensor configured to detect a rotation position of a corresponding one of the wheels and a transmitting unit configured to transmit wheel information, including at least identification information set for the corresponding one of the wheels, at timing at which a position of the wheel-side rotation sensor with respect to the corresponding one of the wheels, determined on the basis of a detected value of the wheel-side rotation sensor, has reached a predetermined position; and

a vehicle body-side device provided at a vehicle body of the vehicle, the vehicle body-side device having a receiver configured to receive the wheel information transmitted from each of the plurality of wheel-side devices, vehicle body-side rotation sensors respectively corresponding to the plurality of wheels and each configured to output a detected value corresponding to the rotation position of a corresponding one of the wheels, and a wheel position identification continuing unit configured to, each time target wheel information that is the wheel information transmitted from a target wheel-side device that is one of the plurality of wheel-side devices is received by the receiver, cause each of the vehicle body-side rotation sensors to detect the rotation position of a corresponding one of the plurality of wheels and identify one of the vehicle body-side rotation sensors, which corresponds to a target wheel that is the wheel from which the target wheel information has been transmitted, on the basis of each of the detected values of the rotation positions of the plurality of wheels, associate the identification information included in the target wheel information with a position of the target wheel and, when the vehicle is placed in a set state during operation of the wheel position identifying unit, continue identifying the wheel position by considering the state.

FIG. 1

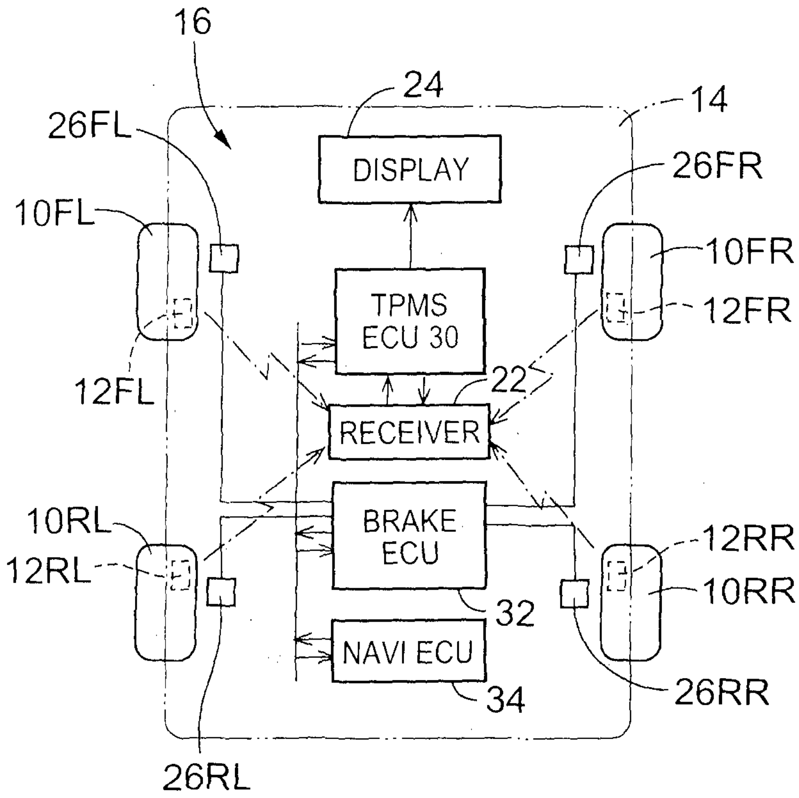

16
24
14
26FL
DISPLAY
26FR
10FL
10FR
TPMS
ECU 30
12FR
12FL
22
RECEIVER
BRAKE
ECU
10RL
12RR
12RL
10RR
32
NAVI ECU
34
26RR
26RL

FIG. 2

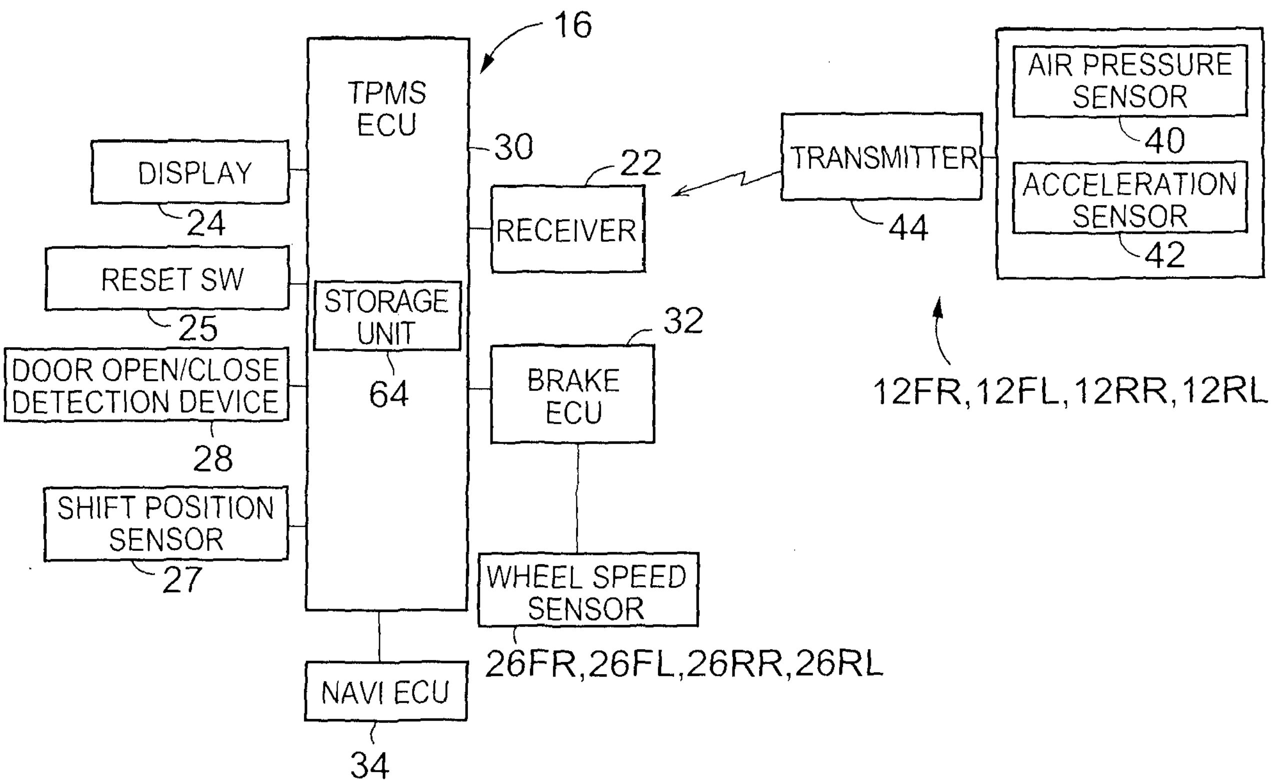

16
TPMS
ECU
AIR PRESSURE
SENSOR
40
TRANSMITTER
DISPLAY
30
22
ACCELERATION
SENSOR
24
RECEIVER
44
42
RESET SW
25
STORAGE
UNIT
32
DOOR OPEN/CLOSE
DETECTION DEVICE
64
BRAKE
ECU
12FR,12FL,12RR,12RL
28
SHIFT POSITION
SENSOR
27
WHEEL SPEED
SENSOR
26FR,26FL,26RR,26RL
NAVI ECU
34

FIG. 3

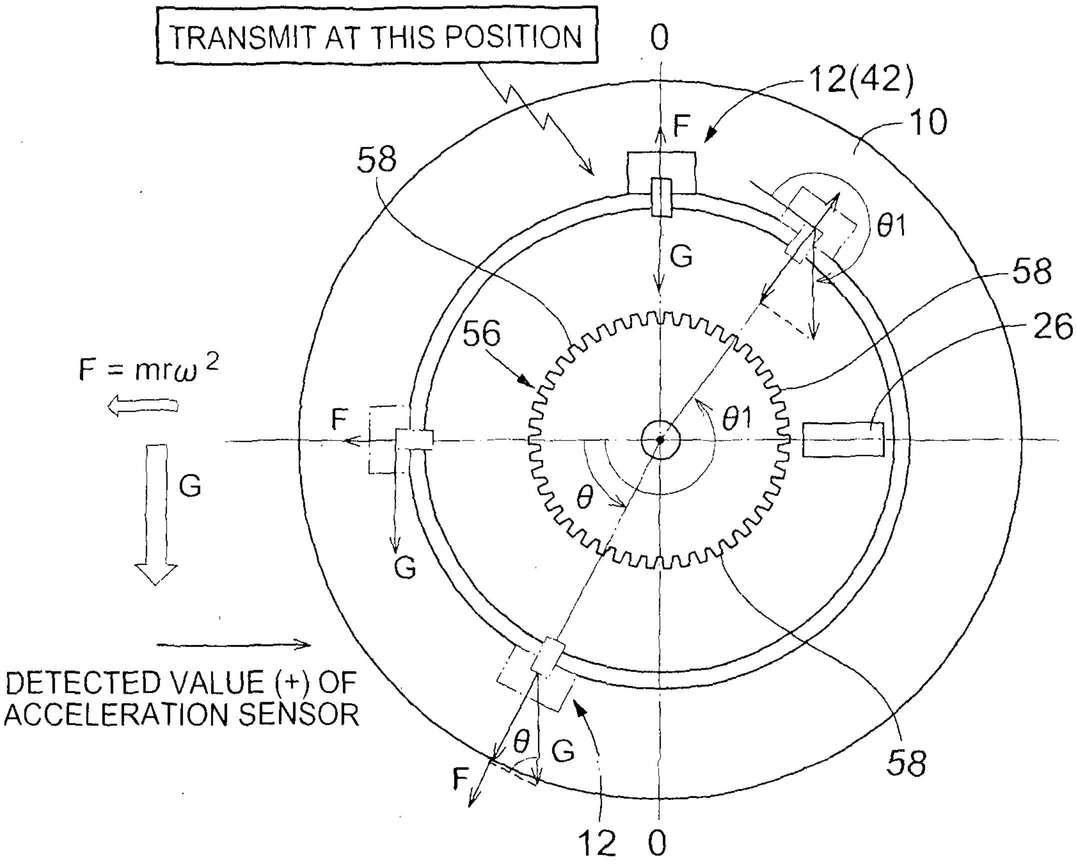

TRANSMIT AT THIS POSITION
0
12(42)
10
F
58
θ1
G
58
26
56
F = mrω 2
θ1
F
θ
G
G
DETECTED VALUE (+) OF
ACCELERATION SENSOR
θ
G
F
58
12
0

FIG. 4

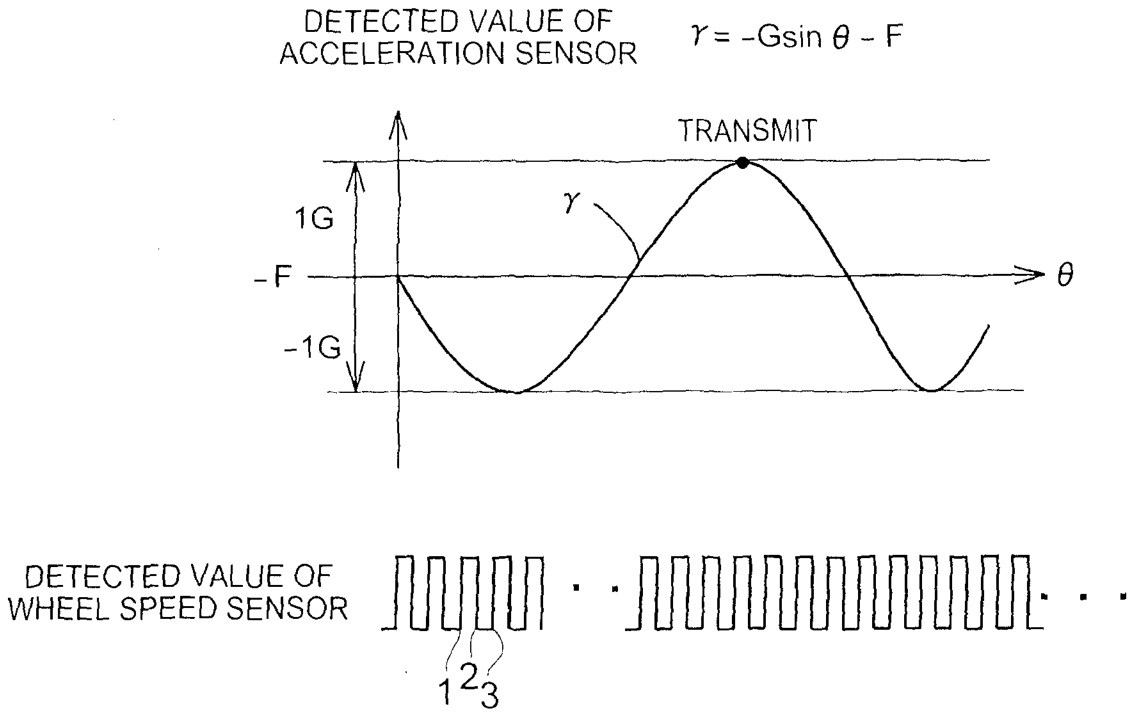

DETECTED VALUE OF
ACCELERATION SENSOR
γ = -Gsin θ - F
TRANSMIT
γ
1G
-F
θ
-1G
DETECTED VALUE OF
WHEEL SPEED SENSOR
1
2
3

FIG. 5

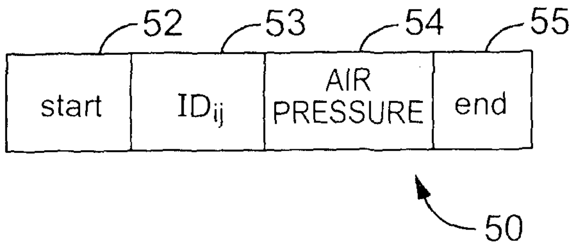


FIG. 6

WHEEL POSITION ACQUISITION TABLE

WHEEL POSITION	ID INFORMATION
FL	IDd
FR	IDa
RL	IDc
RR	IDb

FIG. 7

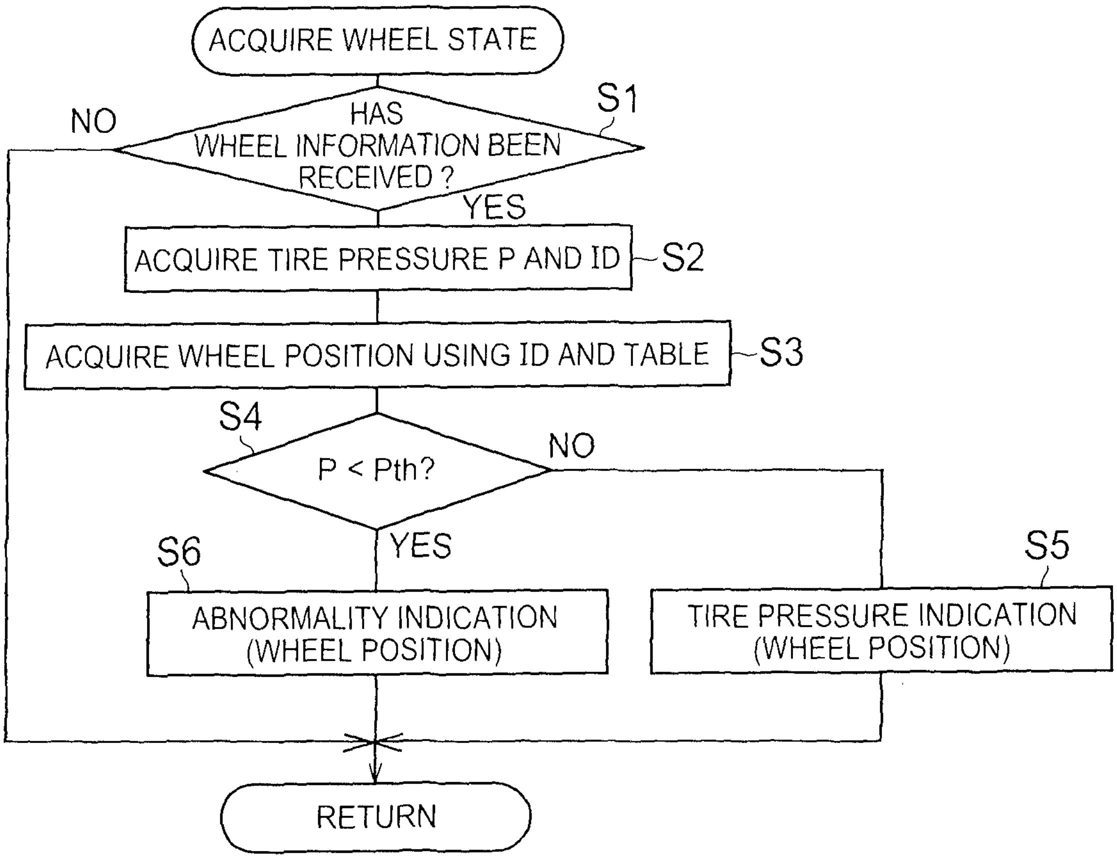


FIG. 8

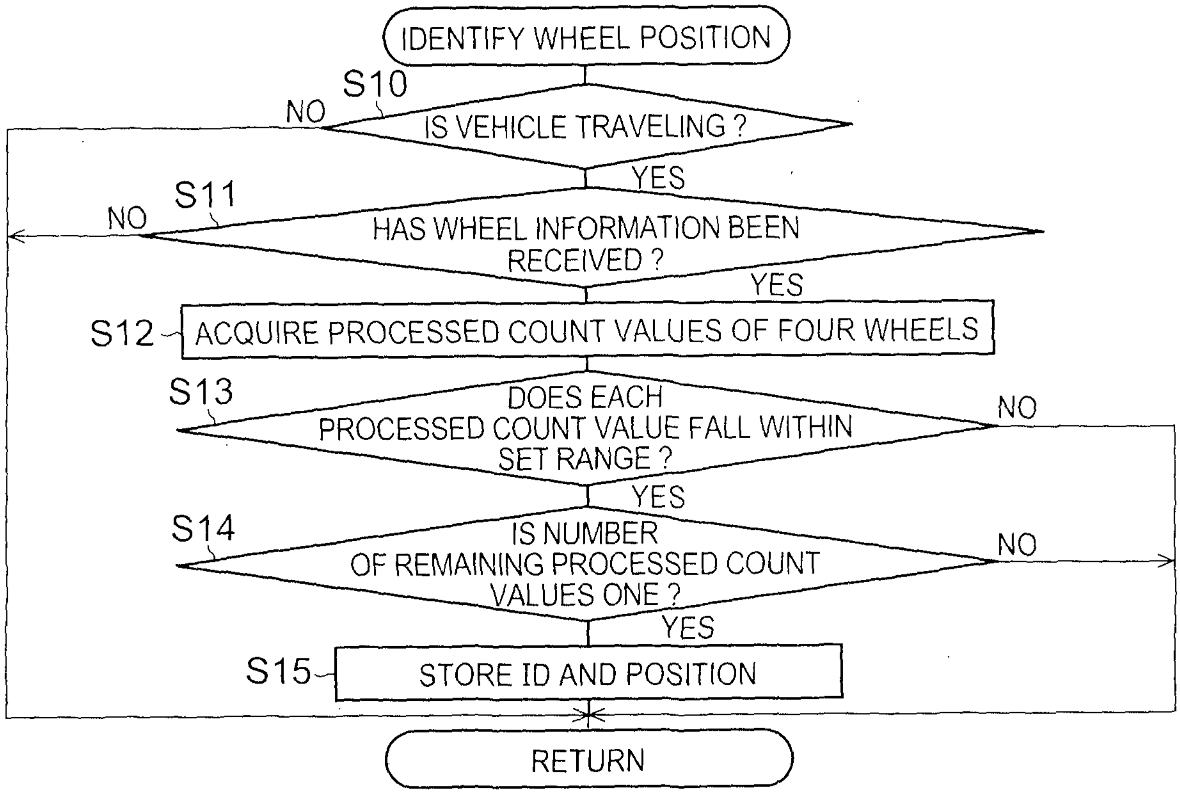

IDENTIFY WHEEL POSITION
S10
IS VEHICLE TRAVELING ?
NO
YES
S11
HAS WHEEL INFORMATION BEEN RECEIVED ?
NO
YES
S12
ACQUIRE PROCESSED COUNT VALUES OF FOUR WHEELS
S13
DOES EACH PROCESSED COUNT VALUE FALL WITHIN SET RANGE ?
NO
YES
S14
IS NUMBER OF REMAINING PROCESSED COUNT VALUES ONE ?
NO
YES
S15
STORE ID AND POSITION
RETURN

FIG. 9

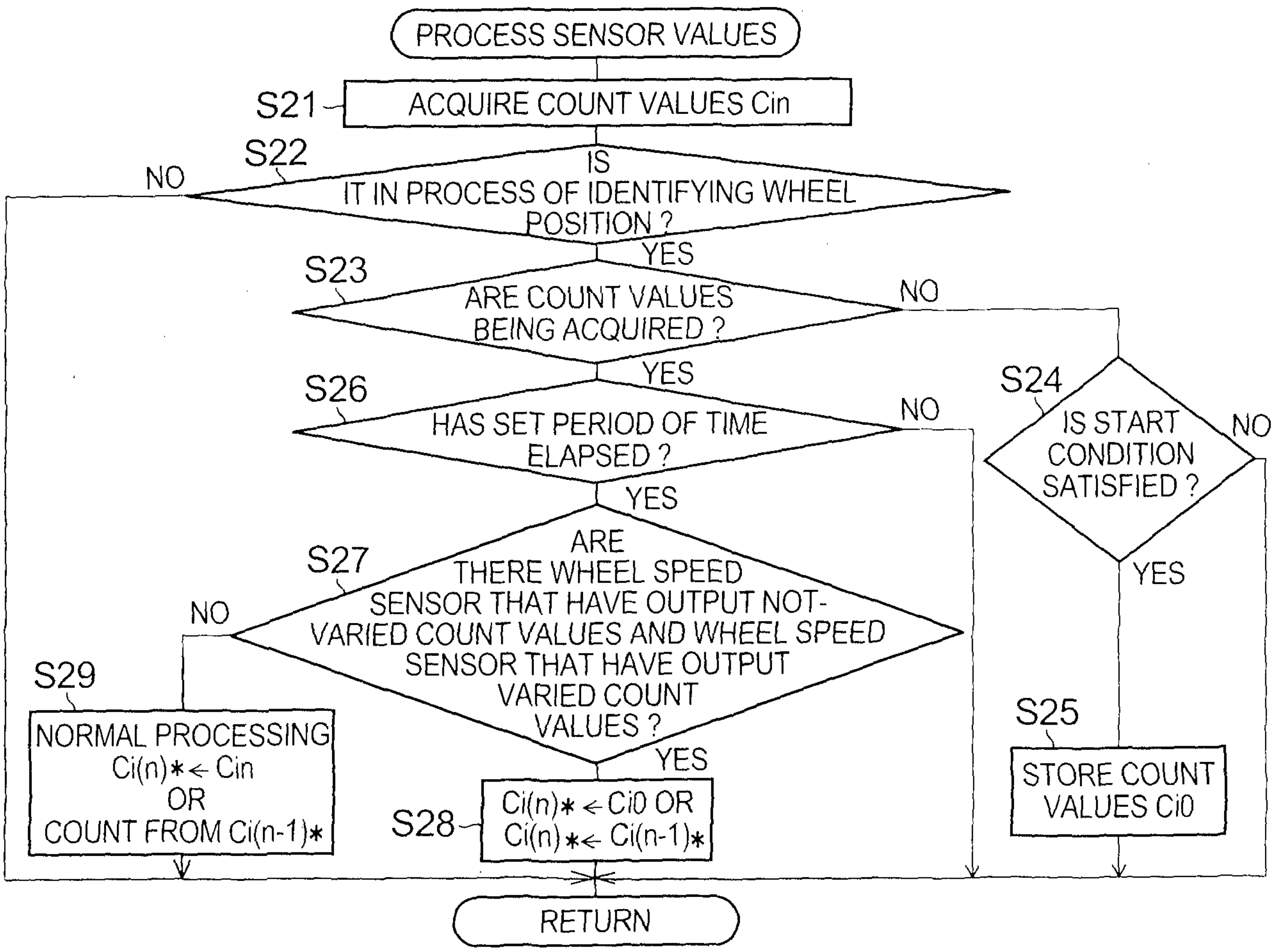

PROCESS SENSOR VALUES
S21
ACQUIRE COUNT VALUES Cin
S22
IS IT IN PROCESS OF IDENTIFYING WHEEL POSITION ?
NO
YES
S23
ARE COUNT VALUES BEING ACQUIRED ?
NO
YES
S24
IS START CONDITION SATISFIED ?
NO
YES
S25
STORE COUNT VALUES Ci0
S26
HAS SET PERIOD OF TIME ELAPSED ?
NO
YES
S27
ARE THERE WHEEL SPEED SENSOR THAT HAVE OUTPUT NOT-VARIED COUNT VALUES AND WHEEL SPEED SENSOR THAT HAVE OUTPUT VARIED COUNT VALUES ?
NO
YES
S29
NORMAL PROCESSING
Ci(n)∗ ← Cin
OR
COUNT FROM Ci(n-1)∗
S28
Ci(n)∗ ← Ci0 OR
Ci(n)∗ ← Ci(n-1)∗
RETURN

FIG. 10

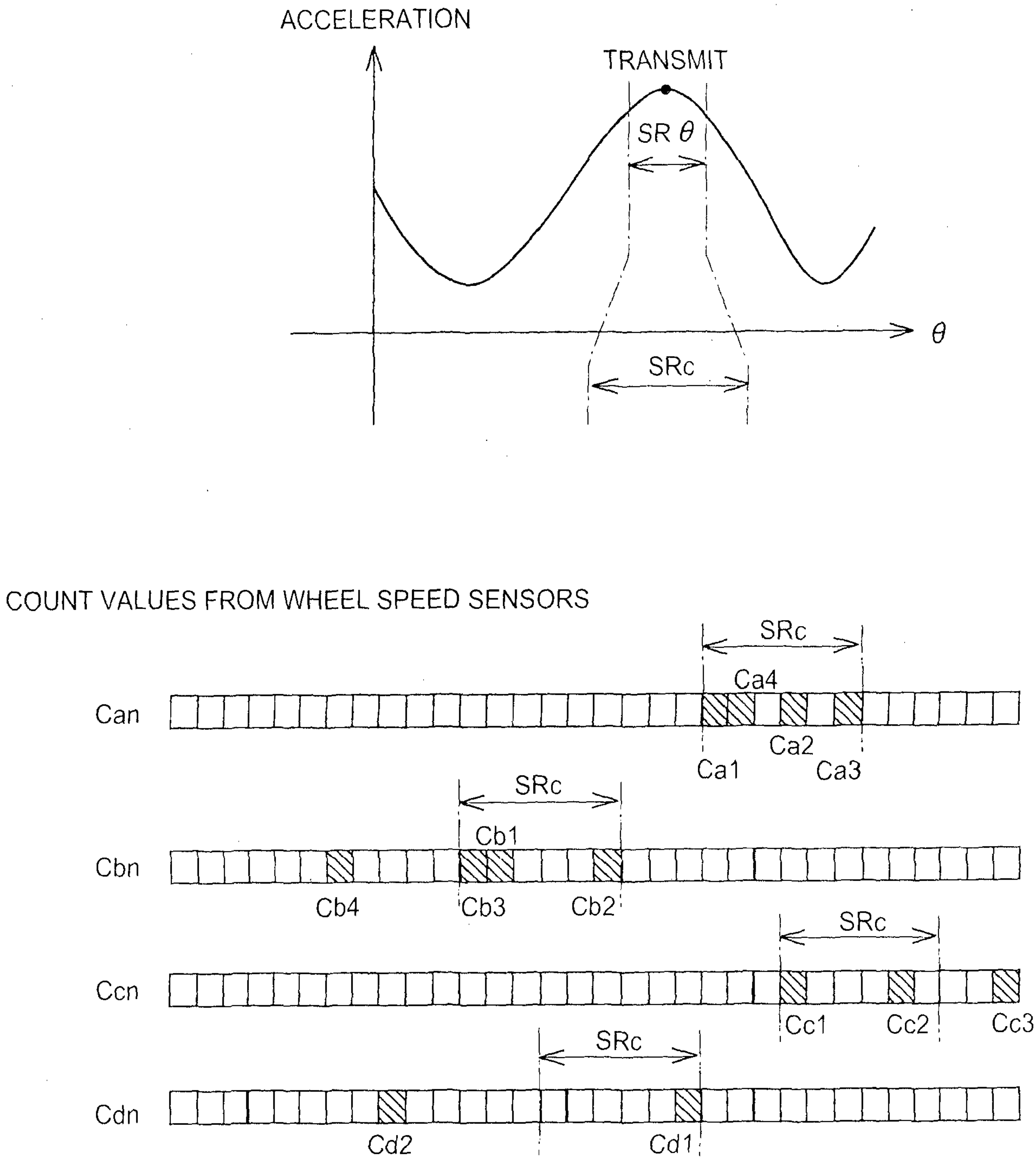

ACCELERATION
TRANSMIT
SR θ
θ
SRc
COUNT VALUES FROM WHEEL SPEED SENSORS
SRc
Ca4
Can
Ca2
Ca1
Ca3
SRc
Cb1
Cbn
Cb4
Cb3
Cb2
SRc
Ccn
Cc1
Cc2
Cc3
SRc
Cdn
Cd2
Cd1

FIG. 11A

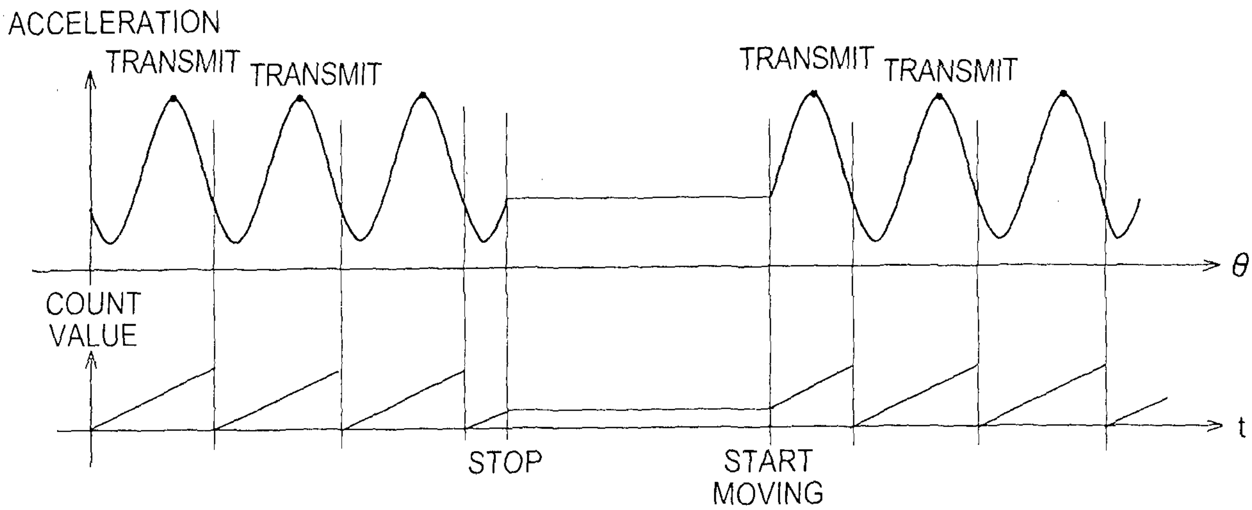


FIG. 11B

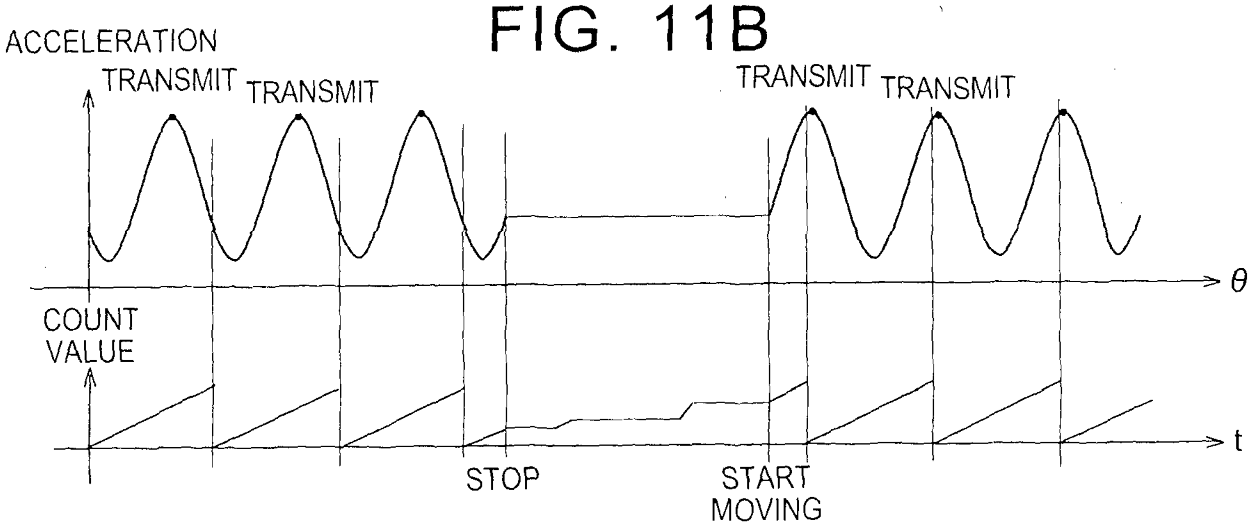


FIG. 11C

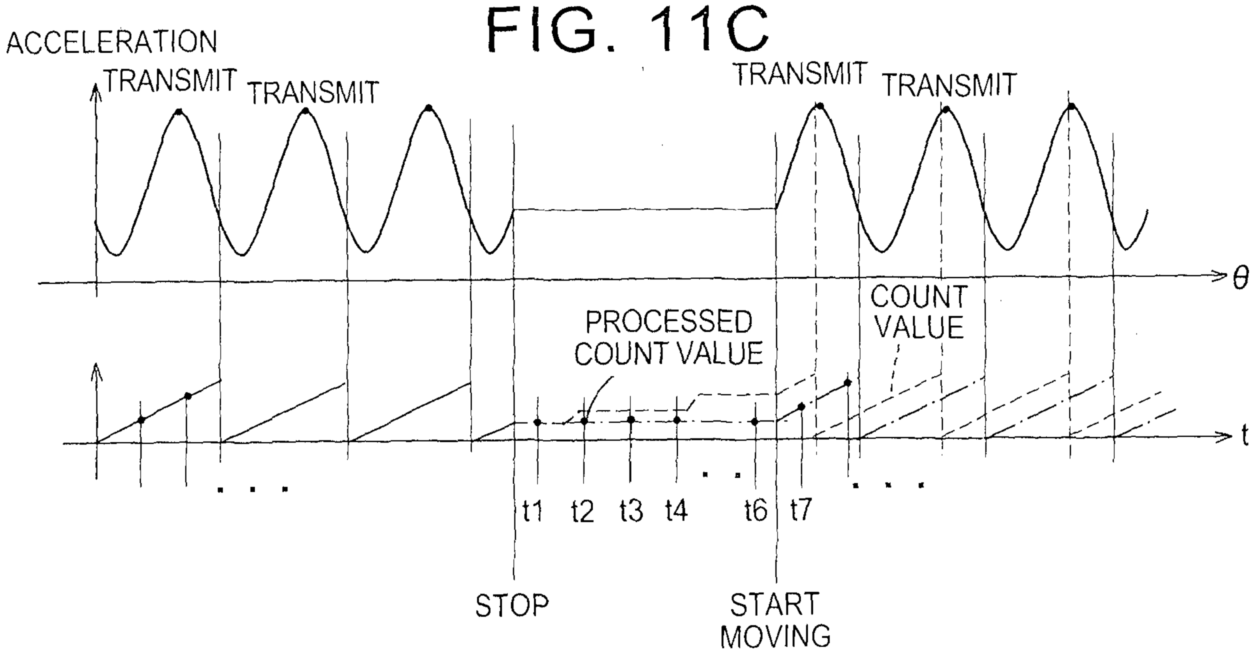


FIG. 12A

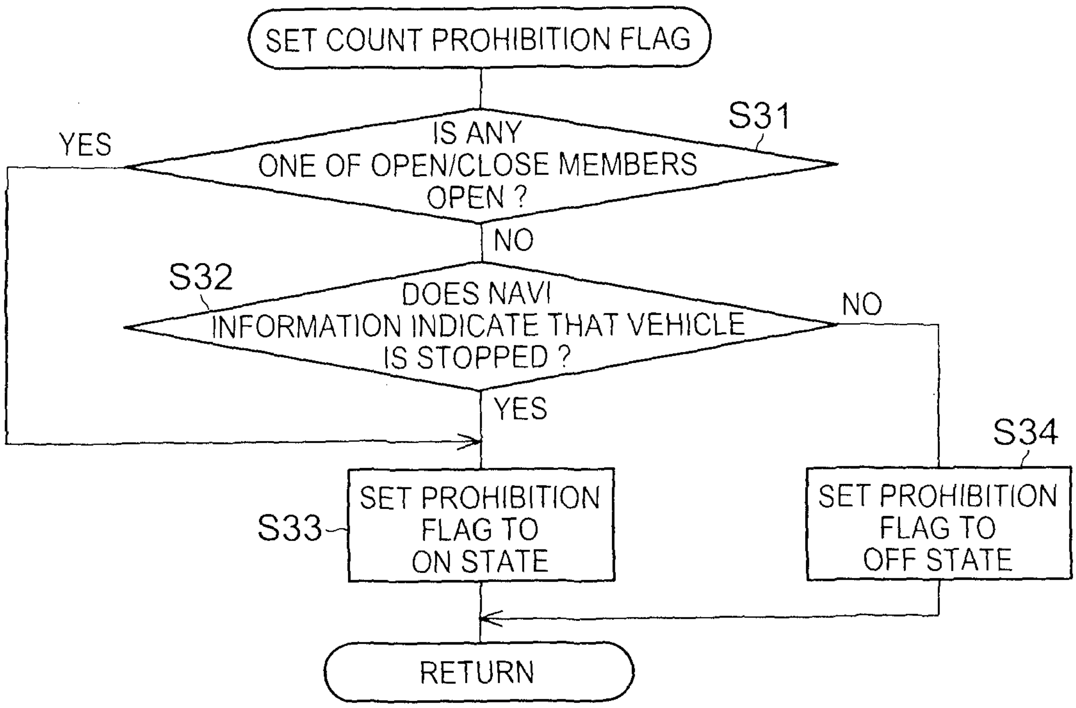


FIG. 12B

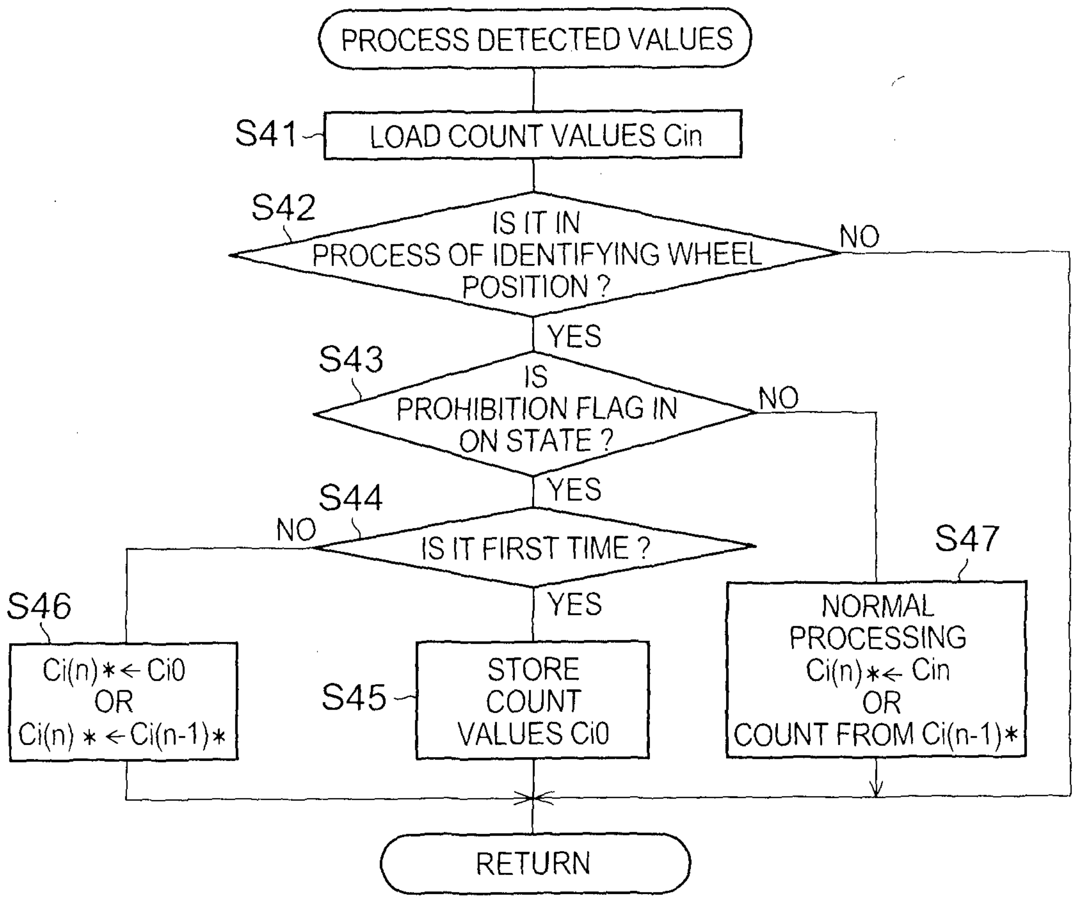


FIG. 13A

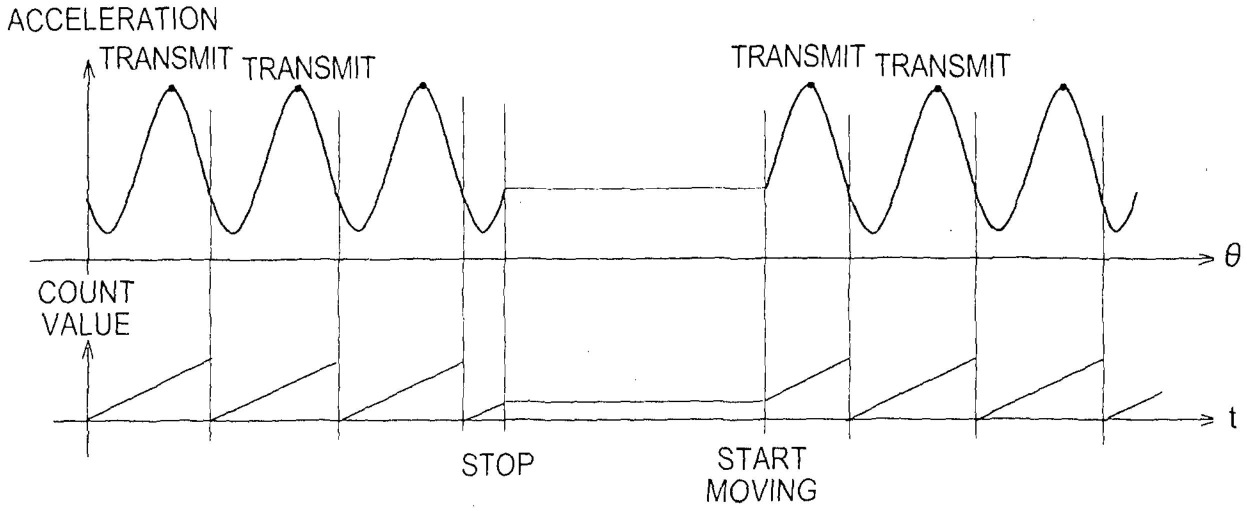


FIG. 13B

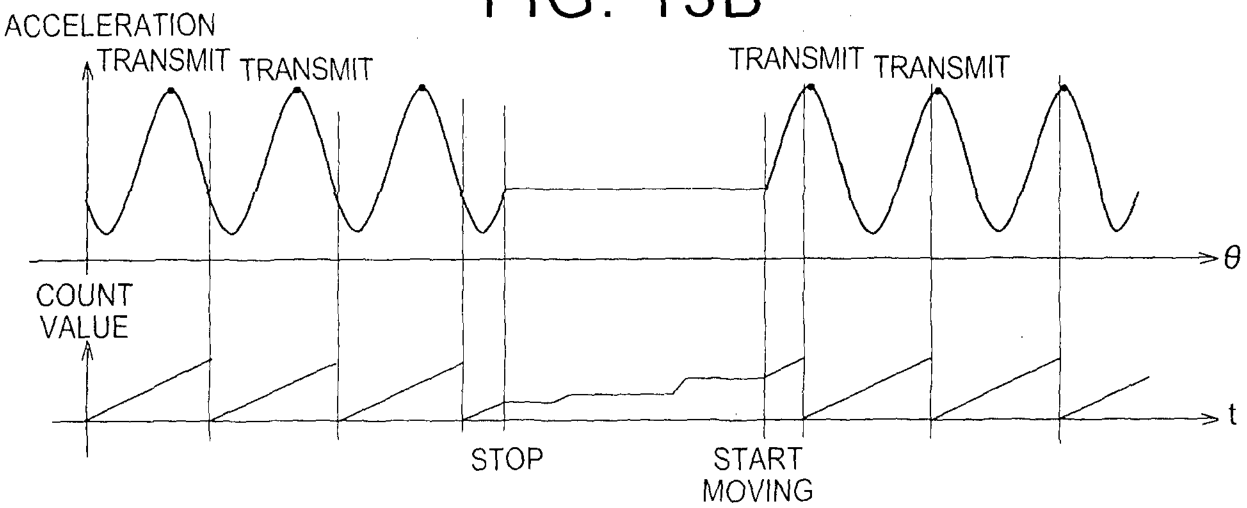


FIG. 13C

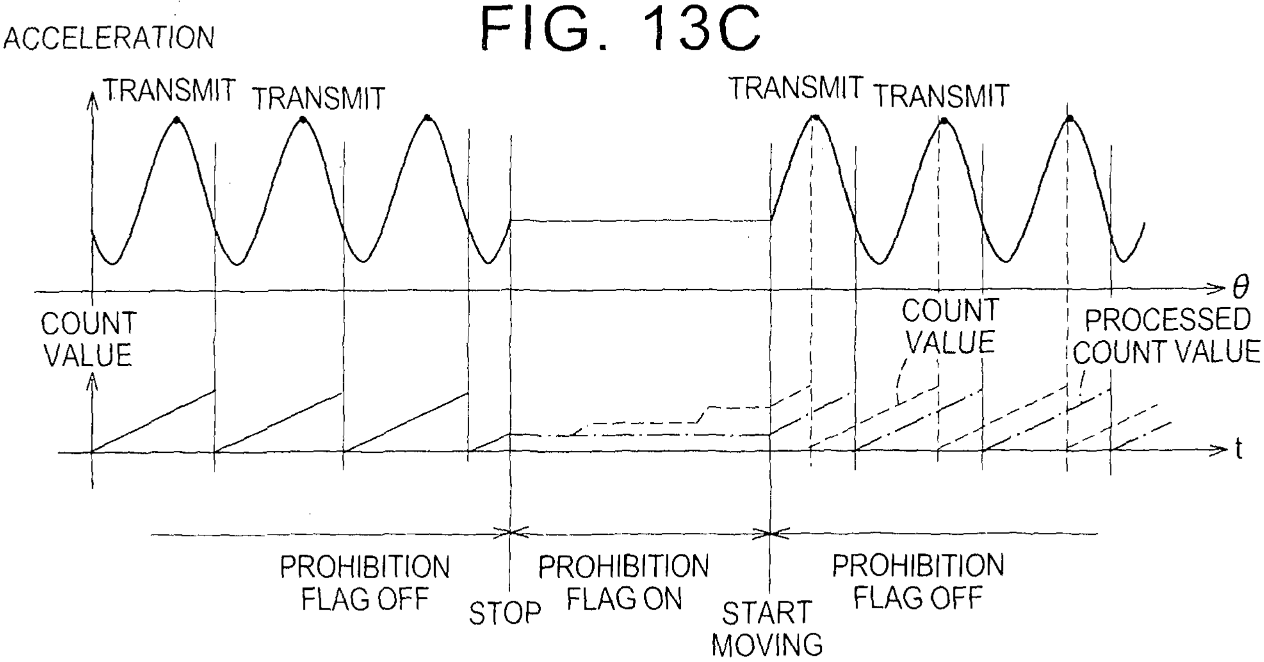


FIG. 14

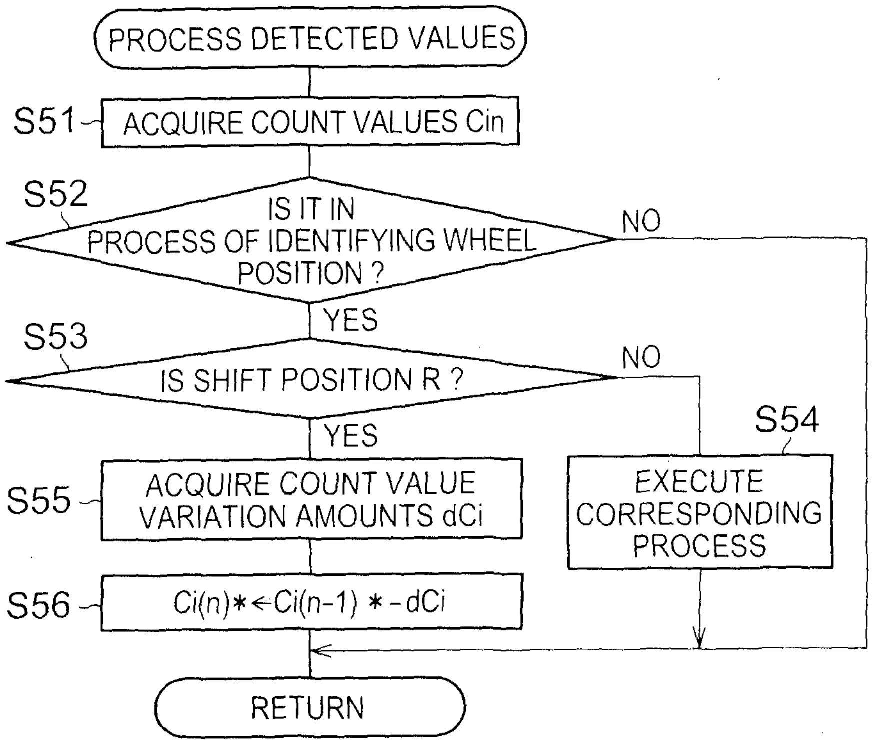

PROCESS DETECTED VALUES
S51
ACQUIRE COUNT VALUES Cin
S52
IS IT IN PROCESS OF IDENTIFYING WHEEL POSITION ?
NO
YES
S53
IS SHIFT POSITION R ?
NO
YES
S54
EXECUTE CORRESPONDING PROCESS
S55
ACQUIRE COUNT VALUE VARIATION AMOUNTS dCi
S56
Ci(n)∗←Ci(n-1) ∗ - dCi
RETURN

FIG. 15

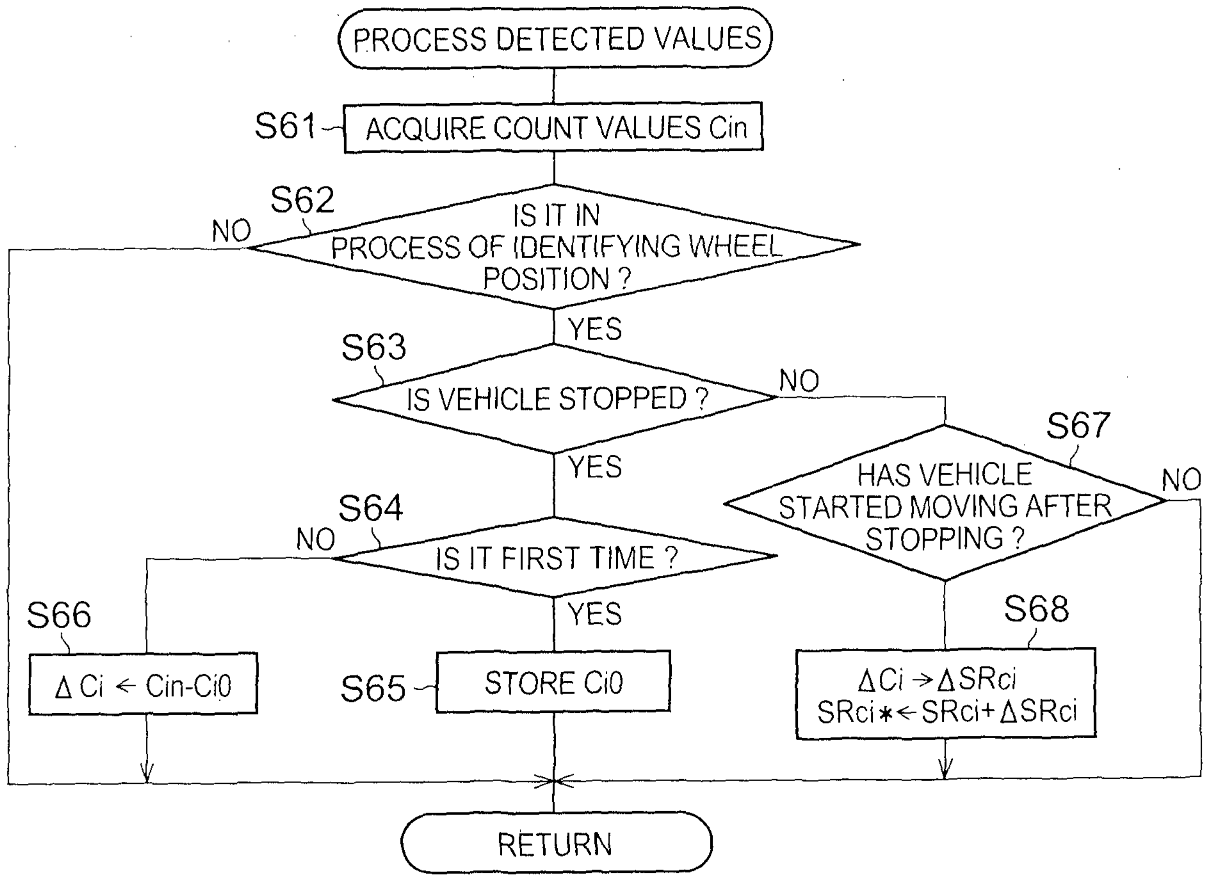

PROCESS DETECTED VALUES
S61
ACQUIRE COUNT VALUES Cin
S62
NO
IS IT IN PROCESS OF IDENTIFYING WHEEL POSITION ?
YES
S63
IS VEHICLE STOPPED ?
NO
S67
HAS VEHICLE STARTED MOVING AFTER STOPPING ?
NO
YES
S64
NO
IS IT FIRST TIME ?
YES
S66
Δ Ci ← Cin-Ci0
S65
STORE Ci0
S68
ΔCi → ΔSRci
SRci∗←SRci+ΔSRci
RETURN

FIG. 16

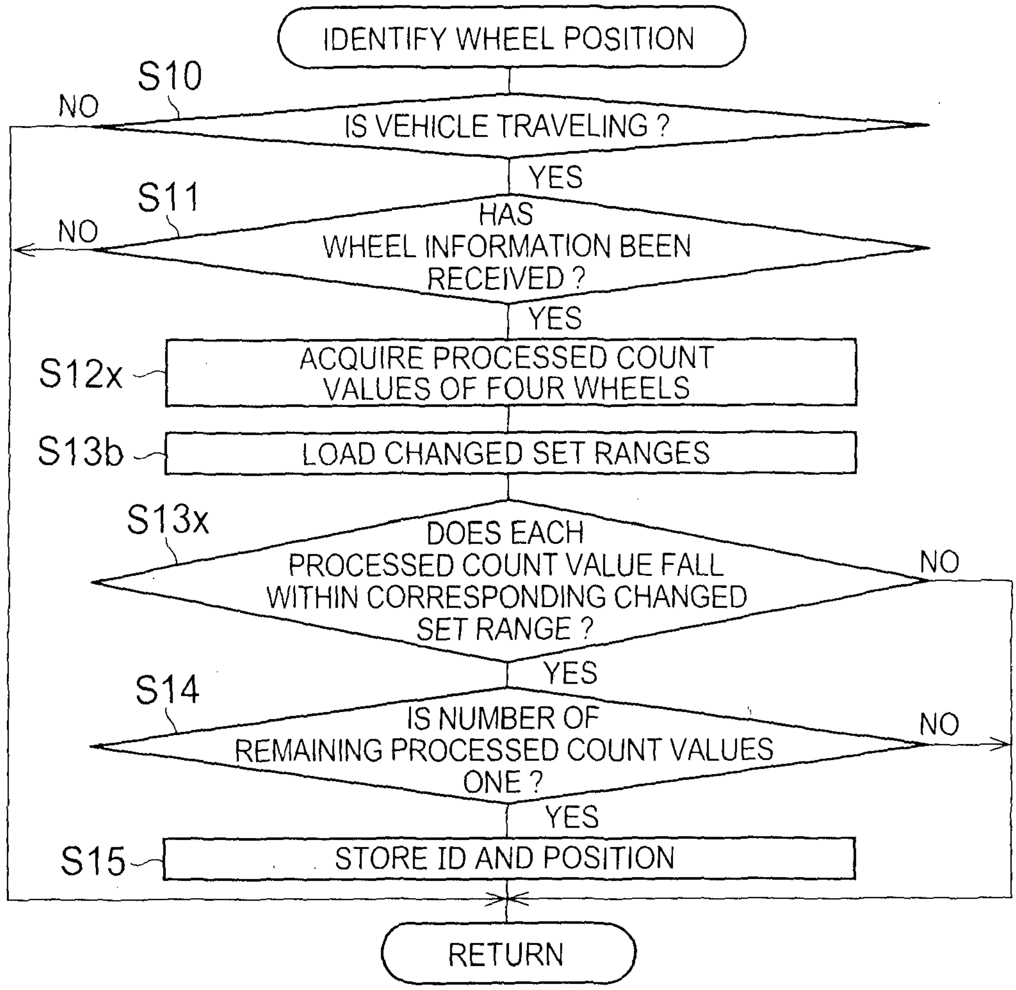

IDENTIFY WHEEL POSITION
S10
NO
IS VEHICLE TRAVELING ?
YES
S11
NO
HAS WHEEL INFORMATION BEEN RECEIVED ?
YES
S12x
ACQUIRE PROCESSED COUNT VALUES OF FOUR WHEELS
S13b
LOAD CHANGED SET RANGES
S13x
DOES EACH PROCESSED COUNT VALUE FALL WITHIN CORRESPONDING CHANGED SET RANGE ?
NO
YES
S14
IS NUMBER OF REMAINING PROCESSED COUNT VALUES ONE ?
NO
YES
S15
STORE ID AND POSITION
RETURN

FIG. 17

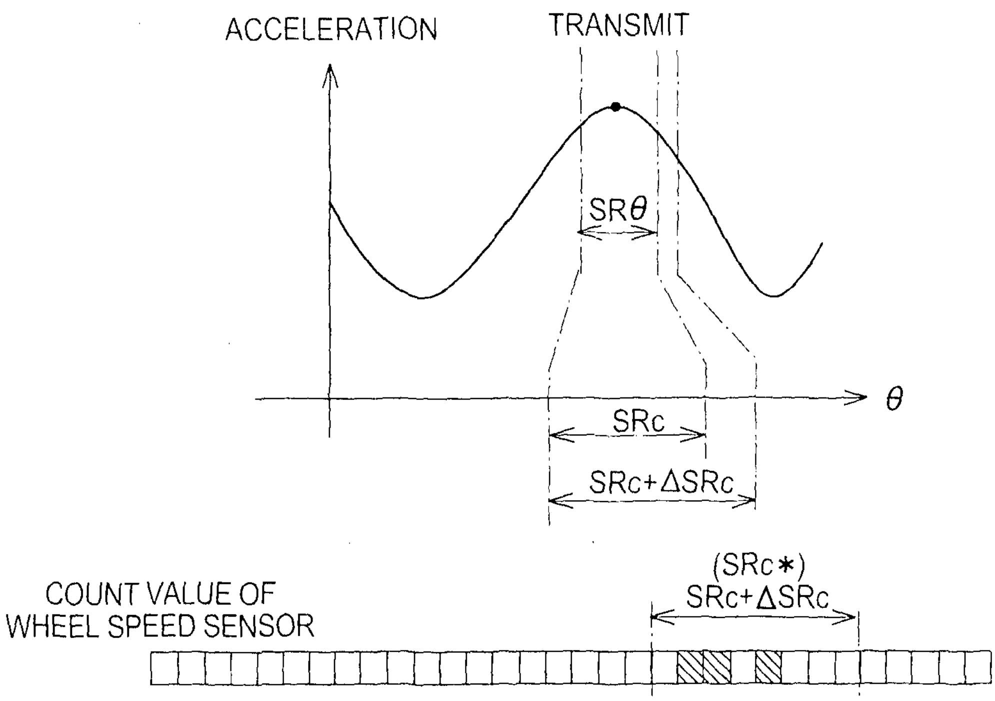
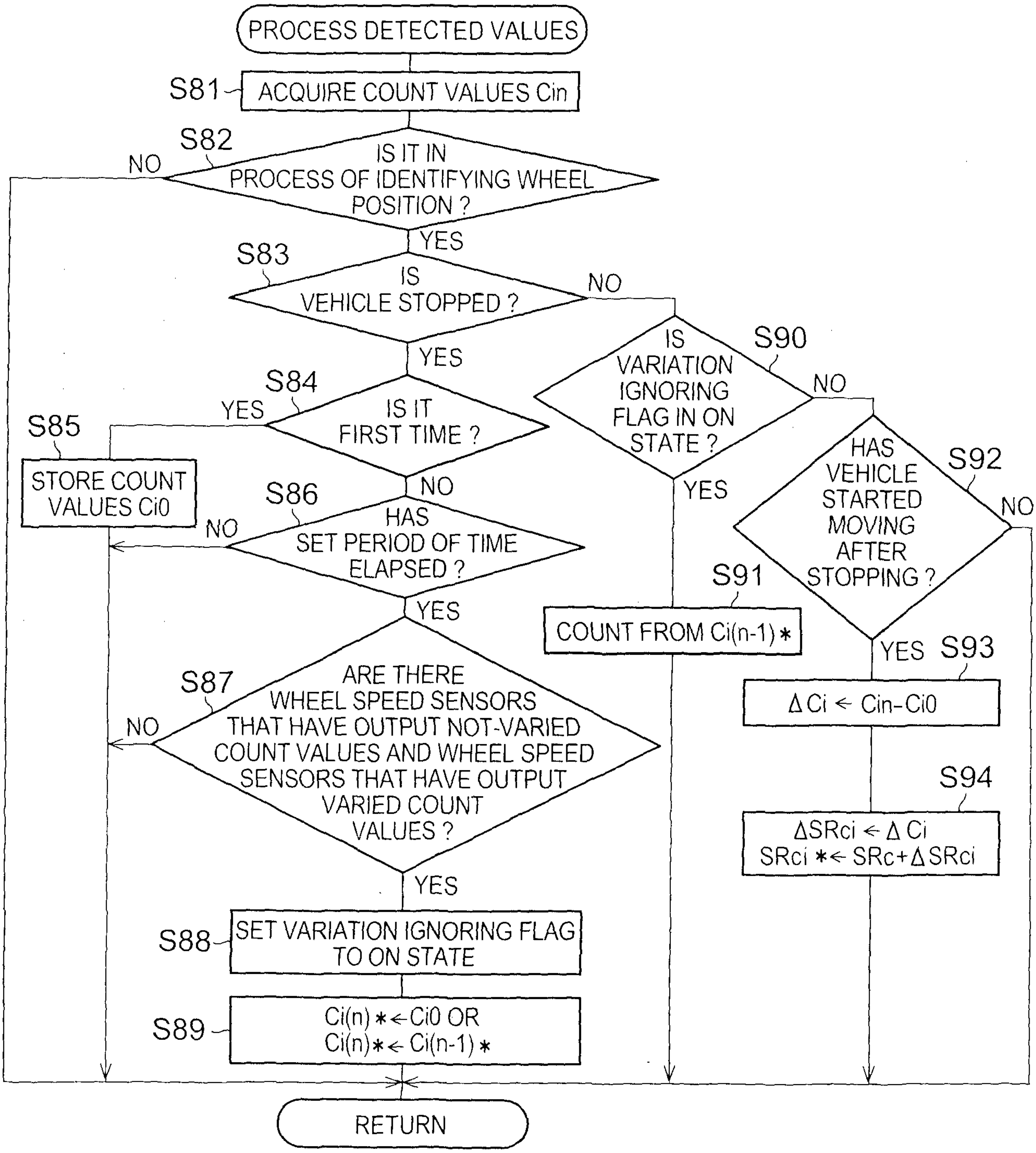

ACCELERATION
TRANSMIT
SRθ
θ
SRc
SRc+ΔSRc
(SRc*)
SRc+ΔSRc
COUNT VALUE OF
WHEEL SPEED SENSOR

FIG. 18


PROCESS DETECTED VALUES
S81
ACQUIRE COUNT VALUES Cin
S82
IS IT IN PROCESS OF IDENTIFYING WHEEL POSITION ?
NO
YES
S83
IS VEHICLE STOPPED ?
NO
YES
S84
IS IT FIRST TIME ?
YES
NO
S85
STORE COUNT VALUES Ci0
S86
HAS SET PERIOD OF TIME ELAPSED ?
NO
YES
S87
ARE THERE WHEEL SPEED SENSORS THAT HAVE OUTPUT NOT-VARIED COUNT VALUES AND WHEEL SPEED SENSORS THAT HAVE OUTPUT VARIED COUNT VALUES ?
NO
YES
S88
SET VARIATION IGNORING FLAG TO ON STATE
S89
Ci(n) ∗ ← Ci0 OR
Ci(n) ∗ ← Ci(n-1) ∗
S90
IS VARIATION IGNORING FLAG IN ON STATE ?
NO
YES
S91
COUNT FROM Ci(n-1) ∗
S92
HAS VEHICLE STARTED MOVING AFTER STOPPING ?
NO
YES
S93
ΔCi ← Cin-Ci0
S94
ΔSRci ← ΔCi
SRci ∗ ← SRc+ΔSRci
RETURN

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/002691

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60C23/04
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)
B60C

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)

EPO-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	WO 2012/140954 A1 (NISSAN MOTOR [JP]; SHIMA TAKASHI; TERADA SYOJI; SAKAGUCHI KAZUO) 18 October 2012 (2012-10-18) the whole document	1-9
E	& EP 2 698 265 A1 (NISSAN MOTOR [JP]) 19 February 2014 (2014-02-19) paragraph [0042] - paragraph [0056] paragraph [0088] - paragraph [0090] figures 1-20 -----	1-9
A	JP 2012 236556 A (NISSAN MOTOR) 6 December 2012 (2012-12-06) the whole document -----	1-9
A	GB 2 385 930 A (LEAR CORP [US]) 3 September 2003 (2003-09-03) page 8, line 20 - page 9, line 5 page 11, line 16 - line 24 figures 1,2 -----	4

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

☒ See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 March 2014	13/03/2014
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 Billen, Karl

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/002691

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 2698265 A1	19-02-2014
		KR 20130128489 A	26-11-2013
		WO 2012140954 A1	18-10-2012
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		JP 2012236556 A	06-12-2012
		KR 20130136583 A	12-12-2013
		WO 2012157307 A1	22-11-2012
GB 2385930 A	03-09-2003	DE 10307291 A1	25-09-2003
		GB 2385930 A	03-09-2003
		US 2003164032 A1	04-09-2003