



(51) International Patent Classification:

B60K 17/35 (2006.01) *B60W 10/02* (2006.01)
B60K 23/08 (2006.01) *B60W 30/045* (2012.01)

(21) International Application Number:

PCT/IB2014/002244

(22) International Filing Date:

28 October 2014 (28.10.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2013-227689 31 October 2013 (31.10.2013) JP
 2013-227690 31 October 2013 (31.10.2013) JP
 2014-211233 15 October 2014 (15.10.2014) JP

(71) Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA** [JP/JP]; 1, Toyota-cho, Toyota-shi, Aichi-ken, 471-8571 (JP).

(72) Inventors: **HASEGAWA, Koichi**; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, 1, Toyota-cho, Toyota-shi, Aichi-ken, 471-8571 (JP). **SHIMIZU, Satoshi**; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, 1, Toyota-

cho, Toyota-shi, Aichi-ken, 471-8571 (JP). **FUKADA, Shunro**; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, 1, Toyota-cho, Toyota-shi, Aichi-ken, 471-8571 (JP).

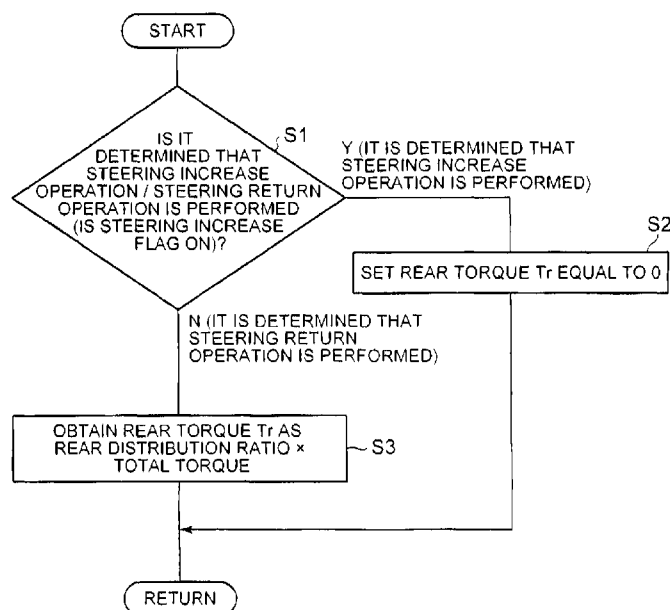
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, KE,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

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

[Continued on next page]

(54) Title: FOUR-WHEEL-DRIVE VEHICLE

FIG. 6



(57) Abstract: A steering device is configured to mechanically transmit rotation of a steering wheel to front wheels. An electronic control unit is configured to determine that operation of the steering wheel by a driver is steering increase operation or determine that the operation of the steering wheel by the driver is steering return operation. The electronic control unit is configured to set the amount or ratio of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation larger than the amount or ratio of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, —
GW, KM, ML, MR, NE, SN, TD, TG).

*before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))*

Published:

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

FOUR-WHEEL-DRIVE VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 **[0001]** The invention relates to a four-wheel-drive vehicle that controls amounts of a driving force distributed to front wheels and rear wheels.

2. Description of Related Art

10 **[0002]** There is well known a four-wheel-drive vehicle in which amounts of a driving force distributed to front wheels and rear wheels are controlled in accordance with operation of a steering wheel by a driver. For example, such a vehicle is described in Japanese Patent Application Publication No. 2007-55476 (JP-2007-55476 A). This Japanese Patent Application Publication No. 2007-55476 (JP-2007-55476 A) proposes an art of swiftly stabilizing the turning behavior during a turn through steering by increasing
15 the amount of a driving force distributed to rear wheels as the differential value of the angle of steering by a driver increases.

SUMMARY OF THE INVENTION

20 **[0003]** By the way, when a tire rolls at a certain slip angle, a torque (hereinafter referred to as a self-aligning torque (abbreviated as the SAT)) is generated on a tread for the tire in such a direction as to reduce the slip angle. This SAT is a characteristic that influences the steering force of the driver. Therefore, the steering force that is needed for the driver to obtain a target turning behavior is changed in accordance with the SAT. The yaw responsiveness of the vehicle is considered to change when the required steering force
25 changes. Accordingly, it is desirable to obtain an appropriate steering force corresponding to the state of steering. The art of Japanese Patent Application Publication No. 2007-55476 (JP-2007-55476 A) aims at stabilizing the turning behavior (e.g., suppressing an understeer state). This art of Japanese Patent Application Publication No. 2007-55476 (JP-2007-55476 A) is unable to meet a request to obtain an appropriate

steering force by controlling the amounts of a driving force distributed to the front wheels and the rear wheels. Incidentally, the problem as mentioned above is unknown, and it still has not been proposed to obtain an appropriate steering force corresponding to the state of steering by controlling the amounts of a driving force distributed to the front wheels and the rear wheels focusing attention on the relationship between the SAT and the driving force.

[0004] The invention provides a four-wheel-drive vehicle that can enhance the yaw responsiveness of the vehicle both when operation of a steering wheel by a driver is steering increase operation and when operation of the steering wheel by the driver is steering return operation.

[0005] An aspect of the invention relates to a four-wheel-drive vehicle. The four-wheel-drive vehicle includes a steering wheel, front wheels, rear wheels, a driving force source, a steering device configured to mechanically transmit rotation of the steering wheel to the front wheels, and an electronic control unit. The electronic control unit is configured to control amount of a driving force distributed to the front wheels and an amount of a driving force distributed to the rear wheels, or ratio of a driving force of the front wheels to the rear wheels, to distribute the driving force from the driving force source to the front wheels and the rear wheels. The electronic control unit is configured to determine whether an operation of the steering wheel by the driver is steering increase operation or steering return operation. The electronic control unit is configured to set the amount of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation larger than the amount of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation, or set the ratio of the driving force of the front wheels to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation larger than the ratio of the driving force of the front wheels to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return

operation.

[0006] In this manner, when operation of the steering wheel is steering increase operation (which means the same as K-turn operation), the amount of the driving force distributed to the front wheels is set larger than when operation of the steering wheel is steering return operation, or the ratio of a driving force of the front wheels to the rear wheels is set larger than when operation of the steering wheel is steering return operation. Therefore, in conjunction with the characteristic that the self-aligning torque (the SAT) decreases as the driving force for the front wheels increases, the SAT decreases and the steering force decreases (i.e., the steering feeling becomes light) during steering increase operation, so the yaw responsiveness of the vehicle can be enhanced. That is, during steering increase operation, the driving force for the front wheels is set large, so the SAT decreases. As a result, a steering amount (a steering angle) for obtaining a target turning behavior (or a target yaw rate) with a small steering force can be realized. Besides, during steering return operation, the SAT increases, but the steering direction is reversed, so the steering force decreases (i.e., the steering feeling becomes light). As a result, the yaw responsiveness of the vehicle can be enhanced. That is, during steering return operation, the driving force for the front wheels is set small, so the SAT increases. As a result, the steering feeling becomes light, and the responsiveness to steering can be enhanced.

[0007] In the above aspect, the electronic control unit may be configured to set the amount of the driving force distributed to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation smaller than the amount of the driving force distributed to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation, or set ratio of a driving force of the rear wheels to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation smaller than the ratio of the driving force of the rear wheels to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return

operation. In this manner, while the amount of the driving force distributed to the front wheels is set relatively large during steering increase operation, the amount of the driving force distributed to the rear wheels is set relatively small during steering return operation. In this manner, while the ratio of the driving force of the rear wheels to the front wheels is set relatively large during steering increase operation, the ratio of the driving force of the rear wheels to the front wheels is set relatively small during steering return operation.

[0008] In the above aspect, the electronic control unit may be configured to set the ratio of the driving force of the rear wheels to the front wheels to zero when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation, and the electronic control unit may be configured to set the ratio of the driving force of the rear wheels to front wheels to a predetermined ratio exceeding zero when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation. In this manner, while no driving force is distributed to the rear wheels and the amount of the driving force distributed to the front wheels or the ratio of the driving force the front wheels to rear wheels is maximized during steering increase operation, a predetermined driving force is distributed to the rear wheels and the amount of the driving force distributed to the front wheels or the ratio of the driving force the front wheels to rear wheels is set small during steering return operation.

[0009] In the above aspect, the electronic control unit may be configured to set a feedforward torque of the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation larger than the feedforward torque of the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation.

[0010] In the above aspect, the electronic control unit may be configured to (i) set a retention value that is a steering angle of a comparative object. The electronic control unit may be configured to calculate a steering angle differential value as a difference between an actual steering angle and a steering angle of the comparative object. The electronic control unit may be configured to determine whether or not a current sign of the

steering angle differential value is different from a sign of last time. The electronic control unit may be configured to determine whether or not a current absolute value of the steering angle differential value exceeds a predetermined value when the electronic control unit determines that the sign of the steering angle differential value is different from the sign of last time. The electronic control unit may be configured to determine that the steering direction changes when the electronic control unit determines that the current absolute value of the steering angle differential value exceeds the predetermined value. The electronic control unit may be configured to set the retention value used in calculating the current steering angle differential value as a retention value used at the time of calculating a subsequent steering angle differential value when the electronic control unit determines that the current absolute value of the steering angle differential value does not exceed the predetermined value. In this manner, in addition to setting a condition that the sign of the steering angle differential value have changed and that the absolute value of the steering angle differential value thereof have exceeded the predetermined value as a condition for determining that the steering direction has changed, when it is determined that the steering direction has not changed because the absolute value of the steering angle differential value has not exceeded the predetermined value in spite of a change in the sign of the steering angle differential value, the retention value used in calculating the steering angle differential value is not updated. Therefore, fine changes in the steering amount during steering are unlikely to exert an influence, and a more accurate and swift determination can be made on steering increase operation of the steering wheel by the driver and steering return operation of the steering wheel by the driver. In this manner, when making a determination on the direction of steering of the steering wheel by the driver, it is possible to suppress the hunting of the determination (an erroneous determination) and restrain the determination from being delayed.

[0011] In the aforementioned four-wheel-drive vehicle, the electronic control unit may be configured to determine that the steering direction has not changed when the electronic control unit determines that the sign of the steering angle differential value has not changed. The retention value setting unit may set the value of the actual steering

angle used in calculating the current steering angle differential value as a retention value used in calculating a subsequent steering angle differential value when the electronic control unit determines that the sign of the steering angle differential value has not changed, or when the electronic control unit determines that the current absolute value of the steering angle differential value has exceeded the predetermined value. In this manner, a more accurate and swift determination can be made on steering increase operation of the steering wheel by the driver and steering return operation of the steering wheel by the driver.

[0012] In the aforementioned four-wheel-drive vehicle, the electronic control unit may be configured to determine whether or not the absolute value of the actual steering angle is within a predetermined range including zero. When the electronic control unit determines that the absolute value of the actual steering angle is within the predetermined range, the electronic control unit may not determine whether or not the sign of the steering angle differential value has changed, the electronic control unit may set the steering direction as a steering direction corresponding to steering increase operation, and the retention value setting unit may set the value of the actual steering angle as the retention value. In this manner, in the case where the absolute value of the actual steering angle is within a predetermined range including zero, the first determination unit does not determine that steering increase operation is performed if the driver performs steering operation of the steering wheel, and the steering direction is set as a steering direction corresponding to steering increase operation. Therefore, preparations can be made in advance for steering increase operation. Besides, a more accurate and swift determination can be made on steering increase operation of the steering wheel by the driver and steering return operation of the steering wheel by the driver.

[0013] In the aforementioned four-wheel-drive vehicle, the electronic control unit may be configured to determine whether or not the actual steering angle has passed zero with respect to a last value. When the electronic control unit determines that the actual steering angle has passed zero with respect to the last value, the electronic control unit may not determine whether or not the sign of the steering angle differential value has changed,

the electronic control unit may set the steering direction as a steering direction corresponding to steering increase operation, and the retention value setting unit may set the value of the actual steering angle as the retention value. In this manner, in the case where the actual steering angle has passed zero, the first determination unit does not
5 determine that the direction of operation of the steering wheel by the driver is steering increase operation in the opposite direction, and the steering direction is set as a steering direction corresponding to steering increase operation. Therefore, steering increase operation can be swiftly coped with. Besides, a more accurate and swift determination can be made on steering increase operation of the steering wheel by the driver and steering
10 return operation of the steering wheel by the driver.

[0014] In the aforementioned four-wheel-drive vehicle, the electronic control unit may control amounts of the driving force distributed to the front wheels and the rear wheels based on a result of a determination on the steering direction. In this manner, the amounts of the distributed driving force are appropriately controlled in accordance with
15 steering increase operation or steering return operation during steering. As a result, the yaw responsiveness of the vehicle is enhanced both during steering increase operation and during steering return operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] 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:
20

FIG. 1 is a view illustrating the schematic configuration of a four-wheel-drive vehicle to which the invention is applied, and is a view illustrating control functions for various
25 kinds of control and an essential part of a control system in the four-wheel-drive vehicle;

FIG. 2 is a view illustrating the schematic configuration of a steering device with which the vehicle is equipped;

FIG. 3 is a view showing a relationship between driving force and self-aligning torque;

FIG. 4A is a view showing a relationship between steering torque and yaw rate during steering increase operation;

FIG. 4B is a view showing a relationship between steering torque and yaw rate in the case where the vehicle runs with an increased front-wheel torque (during FF traveling) and
5 in the case where the vehicle runs with a reduced front-wheel torque (during 4WD traveling);

FIG. 5 is a table summarizing a relationship between driving forces applied to front wheels and rear wheels and steering force;

FIG. 6 is a flowchart illustrating an essential part of the control action of an electronic
10 control unit, namely, the control action for enhancing the yaw responsiveness of the vehicle both when operation of a steering wheel by a driver is steering increase operation and when operation of the steering wheel by the driver is steering return operation;

FIG. 7 is a flowchart illustrating an essential part of the control action of the electronic control unit, namely, the control action for suppressing the hunting of a
15 determination and restraining the determination from being delayed in making the determination on the direction of steering of the steering wheel by the driver;

FIG. 8 is a view illustrating the schematic configuration of a vehicle to which the invention is applied, and this vehicle is designed according to an embodiment of the invention other than that of FIG. 1;

20 FIG. 9 is a schematic view showing an example of a torque distributed to rear wheels during a turn;

FIG. 10 is a graph for illustrating the aim of a method of making a determination on steering direction according to the embodiment; and

FIG. 11 is an example of a time chart when the control action shown in the flowchart
25 of FIG. 7 is executed.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] In the invention, preferably, the four-wheel-drive vehicle is a vehicle that is equipped with a four-wheel-drive system in which a motive power of a driving force

source is distributed, for example, from a motive power transmission path on a main driving wheel side to subsidiary driving wheels via an electronic control coupling or the like, or a vehicle that is equipped with a four-wheel-drive system in which the amounts of a driving force distributed to front wheels and rear wheels are controlled in a driving force source and a motive power transmission path on a main driving wheel side and in a driving force source and a motive power transmission path on a subsidiary driving wheel side that is independent of the main driving wheel side. In the invention, preferably, the vehicle is a four-wheel-drive vehicle that is able to control the amounts of a driving force distributed to the front wheels and the rear wheels. Besides, this four-wheel-drive vehicle is equipped with a transmission that constitutes part of a motive power transmission path between the driving force source and the main driving wheels. This transmission may be a manual transmission such as a known synchronous mesh-type, two parallel shaft-type transmission in which a plurality of pairs of shift gears that are constantly engaged with one another are provided between two shafts, or one of various automatic transmissions (a planetary gear-type automatic transmission, a synchronous mesh-type, two parallel shaft-type automatic transmission, a DCT, a CTV and the like). This automatic transmission is constituted by a single automatic transmission, an automatic transmission having a fluid transmission device, an automatic transmission having a subsidiary transmission or the like. Besides, as the driving force source, a gasoline engine, a diesel engine or the like such as an internal combustion engine or the like in which a motive power is generated through, for example, the combustion of fuel is preferably employed. However, it is also possible to adopt other prime movers such as an electric motor and the like alone or in combination with an engine.

[0017] The embodiments of the invention will be described hereinafter in detail with reference to the drawings.

[0018] FIG. 1 is a view illustrating the schematic configuration of a four-wheel-drive vehicle 10 (hereinafter referred to as the vehicle 10) to which the invention is applied, and is a view illustrating control functions for various kinds of control and an essential part of a control system in the vehicle 10. In FIG. 1, the vehicle 10 is

equipped with an engine 12, front-right and front-left wheels 14R and 14L (hereinafter referred to as the front wheels 14 when no distinction is made in particular therebetween), rear-right and rear-left wheels 16R and 16L (hereinafter referred to as the rear wheels 16 when no distinction is made in particular therebetween), a first motive power transmission path through which a motive power of the engine 12 is transmitted to the front wheels 14 as a motive power transmission path between the engine 12 and the front wheels 14, a second motive power transmission path through which a motive power of the engine 12 is transmitted to the rear wheels 16 as a motive power transmission path between the engine 12 and the rear wheels 16, and the like. The engine 12 is an internal combustion engine, for example, a gasoline engine, a diesel engine or the like, and is a driving force source that generates a driving force. The front wheels 14 are main driving wheels that serve as driving wheels to which a motive power is transmitted from the engine 12 via the first motive power transmission path both in a two-wheel-drive traveling state (a 2WD traveling state) and in a four-wheel-drive traveling state (a 4WD traveling state). The rear wheels 16 are subsidiary driving wheels that serve as driven wheels in the 2WD traveling state and serve as driving wheels to which a motive power is transmitted from the engine 12 via the second motive power transmission path in the 4WD traveling state. Accordingly, the vehicle 10 is an FF-based front/rear-wheel-drive vehicle (a four-wheel-drive vehicle).

[0019] The first motive power transmission path is equipped with a transmission 18, a front differential 20, front-right and front-left axles 22R and 22L (hereinafter referred to as front axles 22 when no distinction is made in particular therebetween), and the like. The second motive power transmission path is equipped with the transmission 18, a transfer 24 as a front/rear wheel motive power distribution device that distributes a motive power of the engine 12 to the rear wheels 16, a propeller shaft 26 as a driving force transmission shaft that transmits the motive power of the engine 12 distributed to the transfer 24 to the rear wheels 16, an electromagnetic driving force distribution coupling (hereinafter referred to as a coupling) 28 as a friction engagement device that is disposed in series with the propeller shaft 26, a rear differential 30, rear-right and rear-left axles 32R and 32L (hereinafter referred to as rear axles 32 when no distinction is made in particular

therebetween), and the like. The vehicle 10 is an example of an electronically controlled torque/split-type four-wheel-drive vehicle that distributes the torque generated by the engine 12 to front wheels and rear wheels in accordance with the traveling situation of the vehicle 10. A drive system (a motive power transmission device) that is fuel-efficient and excellent in traction performance can be provided by the coupling 28.

[0020] The transmission 18 constitutes part of a motive power transmission path that is common to the first motive power transmission path between the engine 12 and the front wheels 14 and the second motive power transmission path between the engine 12 and the rear wheels 16, and transmits the motive power of the engine 12 to the front wheel 14 side and the rear wheel 16 side. The transmission 18 is a known planetary gear-type multiple-stage transmission in which a plurality of shift speeds with different values of a speed ratio γ ($=$ a transmission input rotational speed N_{in} / a transmission output rotational speed N_{out}) are selectively established, a known continuously variable transmission in which the speed ratio γ is steplessly and continuously changed, a known synchronous mesh-type two parallel shaft-type transmission, or the like.

[0021] The coupling 28 is provided between the propeller shaft 26 and the rear differential 30, and transmits a torque between one rotary element 28a that is coupled to the propeller shaft 26 and the other rotary element 28b that is coupled to a drive pinion 34 that meshes with a ring gear of the rear differential 30. The coupling 28 is an electronically controlled coupling that is constituted by, for example, a wet multi-plate clutch, and can continuously change the ratio of the torque distributed to the front wheels and the rear wheels between 100:0 and 50:50 by controlling the torque transmitted to the coupling 28. Specifically, when a current is supplied to an electromagnetic solenoid (not shown) that controls the torque transmitted to the coupling 28, the coupling 28 is engaged with an engagement force that is proportional to the value of the current. For example, when no current is supplied to the electromagnetic solenoid, the engagement force of the coupling 28 is zero, that is, the transmitted torque is zero, and the ratio of the torque distributed to the front wheels and the rear wheels is 100:0. Besides, when the current of the electromagnetic solenoid becomes high and the coupling 28 is completely engaged, the

ratio of the torque distributed to the front wheels and the rear wheels becomes 50:50. In this manner, the ratio of the torque distributed to the rear wheel side increases as the value of the current supplied to the electromagnetic solenoid increases. By controlling this current value, the ratio of the torque distributed to the front wheels and the rear wheels can be continuously changed. Incidentally, the coupling 28 is based on a known art, so the concrete structure and operation thereof will be omitted.

[0022] FIG. 2 is a view illustrating the schematic configuration of a steering device 40 with which the vehicle 10 is equipped. In FIG. 2, the steering device 40 is equipped with a steering shaft 42, a steering gearbox 44, right and left tire rods 46R and 46L (hereinafter referred to as tire rods 46 when no distinction is made in particular therebetween), right and left knuckle arms 48R and 48L (hereinafter referred to as knuckle arms 48 when no distinction is made in particular therebetween), and the like, and mechanically transmits rotation of a steering wheel 49 to the front wheels 14 via those components. Incidentally, for example, a rack-and-pinion-type steering gear mechanism is employed in the steering gearbox 44, etc. The steering device 40 is based on a known art, so the concrete structure and operation thereof will be omitted.

[0023] Returning to FIG. 1, the vehicle 10 is equipped with an electronic control unit 70 that includes control devices for the vehicle 10, for example, a front/rear wheel driving force distribution control device 72 that controls the amounts of a driving force distributed to the front wheels 14 and the rear wheels 16 (that controls an engagement torque of the coupling 28), a steering direction determination control device 74 that determines whether or not operation of the steering wheel 49 by a driver is performed in a steering direction corresponding to steering increase operation or a steering direction corresponding to steering return operation, and the like. The electronic control unit 70 is configured to include a so-called microcomputer that is equipped with, for example, a CPU, a RAM, a ROM, an input/output interface and the like. The CPU performs various kinds of control of the vehicle 10 by performing a signal processing in accordance with a program stored in advance in the ROM while utilizing a temporary storage function of the RAM. For example, the electronic control unit 70 performs output control of the engine

12, changeover control of the drive state of the vehicle 10, and the like, and is configured separately as an electronic control unit for engine control, an electronic control unit for engagement control of the coupling 28, and the like, according to need. Various actual values (e.g., an engine rotational speed N_e , the transmission input rotational speed N_{in} , the transmission output rotational speed N_{out} , respective wheel speeds N_{wfr} , N_{wfl} , N_{wrr} , and N_{wrl} corresponding to rotational speeds (respective wheel speeds) N_w of the respective wheels (i.e., the front wheels 14R and 14L and the rear wheels 16R and 16L), an accelerator opening degree θ_{acc} , a throttle valve opening degree θ_{th} , a longitudinal acceleration G_x of the vehicle 10, a lateral acceleration G_y of the vehicle 10, a yaw rate R_{yaw} as a rotational angular velocity of the vehicle 10 around a vertical axis, a steering angle θ_{sw} of the steering wheel 49 (expressed as a rudder angle θ_{sw} as well), and the like) based on detection signals generated by various sensors (e.g., various rotational speed sensors 50, 52, 54 and 56, an accelerator opening degree sensor 58, a throttle valve opening degree sensor 60, a G sensor 62, a yaw rate sensor 64, a steering sensor 66 and the like) are supplied to the electronic control unit 70 respectively. For example, an engine output control command signal S_e for output control of the engine 12, a torque command signal S_c for controlling the engagement torque of the coupling 28, namely, a 4WD torque control command signal S_c for controlling the torque transmitted (distributed) to the rear wheel 16 side, and the like are output from the electronic control unit 70 to a fuel injection device, an ignition device, engine control devices such as a throttle actuator and the like, the electromagnetic solenoid that drives the coupling 28, and the like, respectively. Incidentally, the electronic control unit 70 calculates a speed V of the vehicle 10 (hereinafter referred to as a vehicle speed V) as one of the various actual values, based on the respective wheel speeds N_w . The electronic control unit 70 adopts, for example, an average wheel speed of the respective wheel speeds N_w as the vehicle speed V .

[0024] The front/rear wheel driving force distribution control device 72 is equipped with vehicle traveling state determination means, namely, a vehicle traveling state determination unit 76, 4WD driving force calculation means, namely, a 4WD driving force calculation unit 78, and actuator output command means, namely, an actuator output

command unit 80.

[0025] The vehicle traveling state determination unit 76 makes a determination on an optimal drive state (an optimal traveling state) of the vehicle 10 based on information such as the various signals and the like. Specifically, if it is determined based on the accelerator opening degree θ_{acc} , the vehicle speed V and the like that there is a steady traveling state in which the change in the driving force of the vehicle 10 is smaller than a driving force change threshold that is obtained in advance experimentally or in view of design and stored (i.e., determined in advance), the vehicle traveling state determination unit 76 determines that the traveling state of the vehicle 10 should be 2WD traveling in which the vehicle runs with the coupling 28 released. On the other hand, if it is determined that the change in the driving force has exceeded the driving force change threshold, the vehicle traveling state determination unit 76 determines that the traveling state of the vehicle 10 should be 4WD traveling in which the vehicle runs with the coupling 28 engaged or slip-engaged. Besides, if it is determined based on the respective wheel speeds N_w that one of rotational speed differences among the respective wheels has exceeded a predetermined rotation difference, the vehicle traveling state determination unit 76 determines that the traveling state of the vehicle 10 should be 4WD traveling. Besides, the vehicle traveling state determination unit 76 determines whether or not the vehicle 10 is turning, based on whether or not respective absolute values of the steering angle θ_{sw} , the lateral acceleration G_y , and the yaw rate R_{yaw} are equal to or larger than respective turning criterial thresholds θ_{swth} , G_{yth} , and R_{yawth} respectively. If it is determined that the vehicle 10 is turning, the vehicle traveling state determination unit 76 determines that the traveling state of the vehicle 10 should be 4WD traveling. The turning criterial thresholds θ_{swth} , G_{yth} , and R_{yawth} are criterial values that are determined in advance to determine, for example, that the vehicle 10 is turning. Incidentally, 4WD traveling should basically be selected when the vehicle 10 is turning. However, 4WD traveling is not absolutely required to be selected when the vehicle is turning.

[0026] The 4WD driving force calculation unit 78 calculates optimal amounts of the driving force distributed (distributed driving force) to the front wheels and the rear

wheels, based on information such as the various signals and the like. Specifically, the 4WD driving force calculation unit 78 calculates an estimated value of an engine torque T_e (an estimated engine torque) T_{ep} based on the engine rotational speed N_e , the throttle valve opening degree θ_{th} , and the like, calculates ratio of the driving force of the front wheels to the rear wheels and ratio of the driving force of the rear wheels to the front wheels (distributed driving force to the front wheels and the rear wheels) such that maximum acceleration performance is secured. The 4WD driving force calculation unit 78 calculates amounts of the driving force distributed to the front wheels and the rear wheels (e.g., a front torque T_f and a rear torque T_r) by multiplying a total torque (a total driving torque) based on the estimated engine torque T_{ep} by the ratio of the driving force of the front wheels to the rear wheels and the ratio of the driving force of the rear wheels to the front wheels respectively. Besides, if it is determined based on the throttle valve opening degree θ_{th} , the vehicle speed V , the respective wheel speeds N_w and the like that the situation of operation by the driver and the change in the driving force of the vehicle are stable, the 4WD driving force calculation unit 78 reduces the amount of the driving force distributed to (or the ratio of the driving force of rear wheels to the front wheels (distributed driving force to the rear wheels)) the rear wheels, creates a situation close to front-wheel drive, and improves fuel economy. Besides, the 4WD driving force calculation unit 78 calculates amounts of the driving force distributed to the front wheels and the rear wheels (or the ratio of the driving force of the front wheels to the rear wheels and the ratio of the driving force of the rear wheels to the front wheels (distributed driving force to the front wheels and the rear wheels)) such that appropriate turning performance is obtained, based on the direction of steering of the steering wheel 49 by the driver, a target yaw rate R_{yawtgt} and the like, during turning. Incidentally, when the vehicle traveling state determination unit 76 determines that the vehicle should be in the 2WD traveling state, the 4WD driving force calculation unit 78 sets the distribution of the driving force to the rear wheels 16 (the ratio of the driving force of rear wheels 16 to the front wheels 14) to zero.

[0027] The actuator output command unit 80 outputs a torque command signal S_c

to the electromagnetic solenoid (not shown) that controls the torque transmitted to the coupling 28, such that the traveling state determined by the vehicle traveling state determination unit 76 and the distribution of the driving force to the front wheels and the rear wheels calculated by the 4WD driving force calculation unit 78 are realized.

5 Specifically, when the vehicle traveling state determination unit 76 determines that the vehicle should be in the 2WD traveling state, the actuator output command unit 80 outputs a command to set the torque transmitted to the coupling 28 to zero, to the aforementioned electromagnetic solenoid. When the vehicle traveling state determination unit 76 determines that the vehicle should be in the 4WD traveling state, the actuator output
10 command unit 80 outputs a command to control the torque transmitted to the coupling 28, to the aforementioned electromagnetic solenoid, such that 4WD traveling is realized with the distribution of the driving force to the front wheels and the rear wheels which is calculated by the 4WD driving force calculation unit 78.

[0028] As described above, when the vehicle traveling state determination unit 76
15 determines that the vehicle 10 is turning, it is determined that the traveling state of the vehicle 10 should be 4WD traveling, and during the turning, the 4WD driving force calculation unit 78 calculates amounts of the driving force distributed to the front wheels and the rear wheels (or the ratio of the driving force of the front wheels to the rear wheels and the ratio of the driving force of the rear wheels to the front wheels) based on the
20 direction of steering of the steering wheel 49 by the driver and the like. The present embodiment of the invention proposes a method of performing control to obtain an appropriate steering torque, as to the distribution of the driving force to the front wheels and the rear wheels during this turning.

[0029] FIG. 3 is a view showing a relationship between the driving force and the
25 self-aligning torque (the SAT; see FIG. 2) generated in a tire at a certain slip angle. It is apparent from FIG. 3 that the SAT tends to decrease as the driving force increases. This SAT is a characteristic that influences an operational force F_{sw} (see FIG. 2) applied to the steering wheel 49 by the driver. For example, in the case of steering increase operation, while the required steering force increases (i.e., the steering feeling becomes heavier) as

the SAT increases, the required steering force decreases (i.e., the steering feeling becomes lighter) as the SAT decreases. This reveals that an increase in the driving force leads to a decrease in the SAT and a decrease in the required steering force in the case of steering increase operation. This demonstrates that only a small steering force is need to realize a target yaw rate (i.e., to reach the same yaw rate (the steering angle θ_{sw})) as shown in FIG. 4A, so the yaw responsiveness of the vehicle improves. On the other hand, it is understood that a decrease in the driving force leads to an increase in the SAT and necessitates a steering force in the case of steering increase operation. This demonstrates that a large steering force is needed to realize the target steering angle θ_{sw} as shown in FIG. 4A, so the yaw responsiveness of the vehicle deteriorates. Besides, in the case of steering return operation that is reverse in direction to steering increase operation, the required steering force increases as the SAT decreases, and the steering force is reduced if the SAT increases. Therefore, as shown in FIG. 4B, the yaw responsiveness of the vehicle deteriorates during steering return operation in the case of traveling with the increased torque for the front wheels (FF traveling), and the yaw responsiveness of the vehicle deteriorates during steering increase operation in the case of traveling with the reduced torque for the front wheels (4WD traveling).

[0030] FIG. 5 is a table summarizing the aforementioned point of observation in such a manner as to correspond to the driving forces of the front wheels and the rear wheels. In FIG. 5, when the front torque T_f is set relatively large (i.e., if the rear torque T_r is set relatively small), the SAT decreases, and only a small steering force is needed (i.e., the steering feeling becomes light) during steering increase operation, so the yaw responsiveness of the vehicle to the steering torque improves. However, a large steering force is needed (i.e., the steering feeling becomes heavy) during steering return operation, so the yaw responsiveness of the vehicle deteriorates. On the other hand, when the front torque T_f is set relatively small (i.e., the rear torque T_r is set relatively large), the SAT increases, and a large steering force is needed (i.e., the steering feeling becomes heavy) during steering increase operation, so the yaw responsiveness of the vehicle deteriorates. However, only a small steering force is needed (i.e., the steering feeling becomes light)

during steering return operation, so the yaw responsiveness of the vehicle to the steering torque improves.

[0031] By the way, it is desirable that the yaw responsiveness of the vehicle to the steering torque be good both during steering increase operation (K-turn operation) of the steering wheel 49 and during steering return operation of the steering wheel 49. In contrast, when the distribution of the torque to the front wheels and the rear wheels is made uniform during steering increase operation and steering return operation that are reverse in the influence of the SAT to each other, it may be impossible to enhance the yaw responsiveness of the vehicle as shown in FIG. 5. Thus, the front/rear wheel driving force distribution control device 72 sets the amount of the driving force distributed to the front wheels 14 when operation of the steering wheel 49 by the driver is performed in a steering direction corresponding to steering increase operation larger than the amount of the driving force distributed to the front wheels 14 when operation of the steering wheel 49 by the driver is performed in a steering direction corresponding to steering return operation. For example, the 4WD driving force calculation unit 78 sets the ratio of the driving force of the rear wheels 16 to the front wheels 14 in the case of a steering direction corresponding to steering increase operation smaller than the ratio of the driving force of the rear wheels 16 to the front wheels 14 in the case of a steering direction corresponding to steering return operation, thereby increasing the amount of the driving force distributed to the front wheels 14. Incidentally, 4WD traveling is basically selected during the turning of the vehicle 10, but the selection of 4WD traveling is not indispensable during turning. Therefore, the 4WD driving force calculation unit 78 sets the ratio of the driving force of the rear wheels 16 to the front wheels 14 to zero in the case of a steering direction corresponding to steering increase operation, and sets the ratio of the driving force of the rear wheels 16 to the front wheels 14 to a predetermined distribution ratio exceeding zero in the case of a steering direction corresponding to steering return operation, and may thereby set the amount of the driving force distributed to the front wheels 14 larger in the case of the steering direction corresponding to steering increase operation than in the case of the steering direction corresponding to steering return operation.

[0032] As described above, the mode of control of the amounts of the driving force distributed to the front wheels and the rear wheels differs depending on whether steering increase operation of the steering wheel 49 or steering return operation of the steering wheel 49 is performed. Therefore, it is desirable to make an appropriate determination on the steering direction during traveling. The real steering angle θ_{sw} (hereinafter referred to as the actual steering angle θ_{sw}) may finely fluctuate contrary to the operational intention of the driver, due to the wobbling of the steering angle θ_{sw} in steering operation by the driver, the wobbling of the steering angle θ_{sw} resulting from a change in road surface resistance transmitted to the steering wheel 49 via the front wheels 14, and the like. Then, when a certain method is adopted in making a determination on the steering direction, hunting occurs in the determination, so the control of making a changeover in control mode in accordance with the determination on the steering direction may become busy. Besides, in a method of making a determination on the steering direction mainly for the purpose of suppressing or preventing the hunting of the determination, a delay in determination may be caused in making a determination on a changeover in the steering direction.

[0033] FIG. 9 is a schematic view showing an example of a torque (rear torque T_r) distributed to the rear wheels 16 during a turn. The rear torque T_r is calculated by the 4WD driving force calculation unit 78 based on the steering direction of the steering wheel 49 by the driver, the target yaw rate R_{yawtgt} , and the like. Specifically, the 4WD driving force calculation unit 78 calculates a rear torque T_r corresponding to a feedforward amount (FF rear torque T_{rff}), distributed from the estimated engine torque T_{ep} at a predetermined distribution of a torque according to the steering angle θ_{sw} , during a turn. The distribution of the torque, corresponding to the feedforward amount, during steering increase operation (K-turn operation) of the steering wheel 49 is set to a relatively small value as shown in FIG. 9 from the viewpoint of the higher turnability (more easy to change the direction) of the vehicle 10 with not being excessively brought close to the 4WD traveling state. On the other hand, the distribution of the torque, corresponding to the feedforward amount, during steering return operation of the steering wheel 49 is set to a

relatively large value as compared to that during steering increase operation as shown in FIG. 9 from the viewpoint of the higher escapability of the vehicle 10 from a curve (or more difficult to become unsteady at the time of returning from cornering to straight-ahead traveling) with being brought close to the 4WD traveling state. In addition, the 4WD driving force calculation unit 78 calculates the target yaw rate R_{yawtgt} , as a target value related to vehicle turning behavior, during a turn based on the vehicle speed V , the steering angle θ_{sw} , and the like, by using a predetermined function f_{yt} as, for example, shown in the following mathematical expression (1). Subsequently, the 4WD driving force calculation unit 78 calculates a rear torque T_r corresponding to a feedback amount (FB rear torque T_{rfb}), which is a feedback control amount for bringing an actual yaw rate R_{yaw} into coincidence with the target yaw rate R_{yawtgt} , by using a predetermined feedback control expression as, for example, shown in the following mathematical expression (2). In this mathematical expression (2), ΔR_{yaw} is a yaw rate deviation ($= R_{yawtgt} - R_{yaw}$) between the target yaw rate R_{yawtgt} and the actual yaw rate R_{yaw} , K_p is a predetermined proportionality coefficient, K_d is a predetermined differential coefficient, and K_i is a predetermined integral action coefficient. The 4WD driving force calculation unit 78 calculates the rear torque $T_r (= T_{rff} + T_{rfb})$ by adding the FF rear torque T_{rff} and the FB rear torque T_{rfb} together during a turn. The actuator output command unit 80 outputs the torque command signal S_c to the electromagnetic solenoid (not shown) that controls the torque transmitted to the coupling 28, such that the rear torque T_r calculated by the 4WD driving force calculation unit 78 is realized during a turn.

$$R_{yawtgt} = f_{yt}(V, \theta_{sw}) \quad (1)$$

$$T_{rfb} = K_p \times \Delta R_{yaw} + K_d \times (d\Delta R_{yaw}/dt) + K_i \times (\int \Delta R_{yaw} dt) \quad (2)$$

[0034] As is apparent from the aforementioned description of control for calculating the rear torque T_r with reference to FIG. 9, the mode of control of the rear torque T_r differs depending on whether steering increase operation (steering increase region) of the steering wheel 49 or steering return operation (steering return region) of the steering wheel 49 is performed. Therefore, it is desirable to make an appropriate determination on the steering direction during traveling. A smooth change in the steering

angle θ_{sw} as shown in FIG. 9 is just for the purpose of illustrating control for calculating the rear torque T_r . The real steering angle θ_{sw} (hereinafter referred to as the actual steering angle θ_{sw}) may finely fluctuate contrary to the operational intention of the driver, due to the wobbling of the steering angle θ_{sw} in steering operation by the driver, the wobbling of the steering angle θ_{sw} resulting from a change in road surface resistance transmitted to the steering wheel 49 via the front wheels 14, and the like (for example, see the steering angle in FIG. 11 (which will be shown later)). Then, when a certain method is adopted in making a determination on the steering direction, hunting occurs in the determination, so the control of making a changeover in control mode in accordance with the determination on the steering direction may become busy. Besides, in a method of making a determination on the steering direction mainly for the purpose of suppressing or preventing the hunting of the determination, a delay in determination may be caused in making a determination on a changeover in the steering direction.

[0035] Furthermore, the present embodiment of the invention also proposes a method of making a determination on the steering direction that makes it possible to suppress the hunting of the determination and restrain the determination from being delayed. FIG. 10 is a graph for illustrating the aim of a method of making a determination on the steering direction according to the present embodiment. In FIG. 10, the aim of the method of making a determination on the steering direction in the present embodiment of the invention consists in, for example, refraining from determining that the steering direction has changed just because the direction of the change in the steering angle θ_{sw} has changed over, and furthermore, determining that the steering direction has changed when the change in the steering angle θ_{sw} has exceeded a predetermined value. Thus, the hunting of the determination as described above is suppressed. In addition, if it is determined that the steering direction has not changed because the change in the steering angle θ_{sw} has not exceeded the predetermined value even when the direction of change in the steering angle θ_{sw} has changed, a retention value θ_{swHld} as a steering angle of a comparative object that is to be compared with the actual steering angle θ_{sw} in calculating the change in the steering angle θ_{sw} is not updated. Thus, in comparison with a case

where the change in the steering angle θ_{sw} is always calculated as a difference between a last value of the steering angle θ_{sw} and an actual value (a current value) of the steering angle θ_{sw} , the change in the steering angle θ_{sw} is more likely to exceed the predetermined value after the direction of change in the steering angle θ_{sw} has changed over. As a result, the determination is restrained from being delayed as described above.

[0036] Specifically, the steering direction determination control device 74 is equipped with retention value setting means, namely, a retention value setting unit 82, steering angle differential value calculation means, namely, a steering angle differential value calculation unit 84, and steering direction determination means, namely, a steering direction determination unit 86.

[0037] The retention value setting unit 82 sets the retention value $\theta_{sw\text{hld}}$ as a steering angle of a comparative object that is to be compared with the actual steering angle θ_{sw} in calculating the change in the steering angle θ_{sw} that is used in making a determination on the steering direction. As will be described later, the change in the steering angle θ_{sw} is a steering angle differential value $\Delta\theta_{sw}$ as a difference between the actual steering angle θ_{sw} and the retention value $\theta_{sw\text{hld}}$. Besides, the steering angle differential value $\Delta\theta_{sw}$ is a value for roughly identifying whether operation of the steering wheel 49 is performed in a steering direction corresponding to steering increase operation or a steering direction corresponding to steering return operation, based on whether the sign of the value is positive or negative. Therefore, in calculating the steering angle differential value $\Delta\theta_{sw}$, the absolute values of both the retention value $\theta_{sw\text{hld}}$ and the actual steering angle θ_{sw} are used. Incidentally, the retention value setting unit 82 sets the retention value $\theta_{sw\text{hld}}$ based on a result of the determination made by the steering direction determination unit 86. Therefore, the concrete setting of this retention value $\theta_{sw\text{hld}}$ will be described later in detail in association with a result of the determination made by the steering direction determination unit 86.

[0038] The steering angle differential value calculation unit 84 calculates the steering angle differential value $\Delta\theta_{sw}$ ($= \theta_{sw\text{hld}} - |\theta_{sw}|$) that is a difference between the retention value $\theta_{sw\text{hld}}$ and the absolute value of the actual steering angle θ_{sw} , as the

change in the steering angle θ_{sw} . The steering angle differential value $\Delta\theta_{sw}$ is calculated as a value that is obtained by subtracting the absolute value of the actual steering angle θ_{sw} from the retention value $\theta_{sw\text{hld}}$. Therefore, the steering angle differential value $\Delta\theta_{sw}$ is a negative value during steering increase operation when the absolute value of the actual steering angle θ_{sw} increases, and is a positive value during steering return operation when the absolute value of the actual steering angle θ_{sw} decreases. From a different point of view, the retention value setting unit 82 sets the retention value $\theta_{sw\text{hld}}$ as an absolute value in order to realize such a state.

[0039] The steering direction determination unit 86 is functionally equipped with first determination means, namely, a first determination unit 88 that determines whether or not the current sign of the steering angle differential value $\Delta\theta_{sw}$ has changed since last time. Specifically, the first determination unit 88 determines whether or not the steering angle differential value $\Delta\theta_{sw}$ is a negative value corresponding to steering increase operation when the steering direction determination unit 86 determines that steering increase operation is performed, thereby determining whether or not the current sign of the steering angle differential value $\Delta\theta_{sw}$ has failed to change since last time. On the other hand, the first determination unit 88 determines whether or not the steering angle differential value $\Delta\theta_{sw}$ is a positive value corresponding to steering return operation when the steering direction determination unit 86 determines that steering return operation is performed, thereby determining whether or not the current sign of the steering angle differential value $\Delta\theta_{sw}$ has failed to change since last time.

[0040] The steering direction determination unit 86 is functionally equipped with second determination means, namely, a second determination unit 90 that determines whether or not the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has exceeded a predetermined value when the first determination unit 88 determines that the current sign of the steering angle differential value $\Delta\theta_{sw}$ has changed since last time. Specifically, the second determination unit 90 determines whether or not the steering angle differential value $\Delta\theta_{sw}$ is larger than a predetermined value $A (> 0)$ if the first determination unit 88 determines that the steering angle differential value $\Delta\theta_{sw}$ is a

positive value corresponding to steering return operation when the steering direction determination unit 86 determines that steering increase operation is performed. On the other hand, the second determination unit 90 determines whether or not the steering angle differential value $\Delta\theta_{sw}$ is smaller than a predetermined value B (< 0) if the first determination unit 88 determines that the steering angle differential value $\Delta\theta_{sw}$ is a negative value corresponding to steering increase operation when the steering direction determination unit 86 determines that steering return operation is performed. The predetermined value A (> 0) or the predetermined value B (< 0) as the aforementioned predetermined value is a steering direction change criterial threshold that is determined in advance to make a determination on, for example, the steering angle differential value $\Delta\theta_{sw}$ that exceeds fine fluctuations contrary to the operational intention of the driver (in other words, that makes it possible to determine that the steering direction has been changed through the operational intention of the driver). The predetermined value A (> 0) is a criterial threshold for determining that a change has been made from steering increase operation to steering return operation, and the predetermined value B (< 0) is a criterial threshold for determining that a change has been made from steering return operation to steering increase operation. The absolute value of the predetermined value B (< 0) may be the same as or different from the predetermined value A (> 0).

[0041] The steering direction determination unit 86 is functionally equipped with third determination means, namely, a third determination unit 92 that determines that the steering direction has changed when the second determination unit 90 determines that the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has exceeded a predetermined value, and determines that the steering direction has not changed when the second determination unit 90 determines that the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has not exceeded the predetermined value. Specifically, the third determination unit 92 determines that the steering direction has changed to a steering direction corresponding to steering return operation and turns a steering increase flag off if the second determination unit 90 determines that the steering angle differential value $\Delta\theta_{sw}$ is larger than the predetermined value A (> 0) when the steering direction determination

unit 86 determines that steering increase operation is performed. On the contrary, the third determination unit 92 determines that the steering direction remains corresponding to steering increase operation and does not change the steering increase flag from on if the second determination unit 90 determines that the steering angle differential value $\Delta\theta_{sw}$ is equal to or smaller than the predetermined value A (> 0) when the steering direction determination unit 86 determines that steering increase operation is performed. On the other hand, the third determination unit 92 determines that the steering direction has changed to a steering direction corresponding to steering increase operation and turns the steering increase flag on if the second determination unit 90 determines that the steering angle differential value $\Delta\theta_{sw}$ is smaller than the predetermined value B (< 0) when the steering direction determination unit 86 determines that steering return operation is performed. On the contrary, the third determination unit 92 determines that the steering direction remains corresponding to steering return operation and does not change the steering increase flag from off if the second determination unit 90 determines that the steering angle differential value $\Delta\theta_{sw}$ is equal to or larger than the predetermined value B (< 0) when the steering direction determination unit 86 determines that steering return operation is performed.

[0042] The retention value setting unit 82 sets the retention value $\theta_{sw\text{hld}}$ that is used when the steering angle differential value calculation unit 84 calculates the current steering angle differential value $\Delta\theta_{sw}$, as the retention value $\theta_{sw\text{hld}}$ that is used when the steering angle differential value calculation unit 84 calculates the subsequent steering angle differential value $\Delta\theta_{sw}$, when the second determination unit 90 determines that the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has not exceeded the predetermined value. That is, the retention value setting unit 82 does not update the retention value $\theta_{sw\text{hld}}$ when the second determination unit 90 determines that the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has not exceeded the predetermined value. Accordingly, while the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has not exceeded the predetermined value after the current sign of the steering angle differential value $\Delta\theta_{sw}$ has changed since last time, a peak value (a

maximum value or a minimum value) is used as the retention value $\theta_{sw\text{hld}}$ (see the maximum value in a peak of the steering angle θ_{sw} and the minimum value in a valley of the steering angle θ_{sw} in FIG. 10).

[0043] As described above, a method of making a determination on the steering direction that makes it possible to suppress the hunting of the determination and restrain the determination from being delayed has been proposed. Furthermore, a preferred mode capable of more accurately and swiftly making a determination on steering increase operation of the steering wheel 49 by the driver and steering return operation of the steering wheel 49 by the driver will be described hereinafter.

[0044] The retention value setting unit 82 sets the value (the absolute value in this case) of the actual steering angle θ_{sw} that is used when the steering angle differential value calculation unit 84 calculates the current steering angle differential value $\Delta\theta_{sw}$, as the retention value $\theta_{sw\text{hld}}$ that is used when the steering angle differential value calculation unit 84 calculates the subsequent steering angle differential value $\Delta\theta_{sw}$, when the second determination unit 90 determines that the current absolute value of the steering angle differential value $\Delta\theta_{sw}$ has exceeded a predetermined value. The actual steering angle θ_{sw} that is set as this retention value $\theta_{sw\text{hld}}$ serves as a last value of the actual steering angle θ_{sw} in calculating the steering angle differential value $\Delta\theta_{sw}$ next time.

[0045] The third determination unit 92 determines that the steering direction has not changed when the first determination unit 88 determines that the sign of the steering angle differential value $\Delta\theta_{sw}$ has not changed. Besides, in this case, the retention value setting unit 82 sets the value (the absolute value in this case) of the actual steering angle θ_{sw} that is used when the steering angle differential value calculation unit 84 calculates the current steering angle differential value $\Delta\theta_{sw}$, as the retention value $\theta_{sw\text{hld}}$ that is used when the steering angle differential value calculation unit 84 calculates the subsequent steering angle differential value $\Delta\theta_{sw}$. Specifically, the third determination unit 92 determines that the steering direction remains corresponding to steering increase operation and does not change the steering increase flag from on, if the first determination unit 88 determines that the steering angle differential value $\Delta\theta_{sw}$ is a negative value

corresponding to steering increase operation when the steering direction determination unit 86 determines that steering increase operation is performed. Besides, in this case, the retention value setting unit 82 sets the absolute value of the actual steering angle θ_{sw} as the retention value θ_{swld} . On the other hand, the third determination unit 92 determines that the steering direction remains corresponding to steering return operation and does not change the steering increase flag from off, if the first determination unit 88 determines that the steering angle differential value $\Delta\theta_{sw}$ is a positive value corresponding to steering return operation when the steering direction determination unit 86 determines that steering return operation is performed. Besides, in this case, the retention value setting unit 82 sets the absolute value of the actual steering angle θ_{sw} as the retention value θ_{swld} .

[0046] Furthermore, the steering direction determination unit 86 is functionally equipped with fourth determination means, namely, a fourth determination unit 94 that determines whether or not the absolute value of the actual steering angle θ_{sw} is within a predetermined range including zero. Then, when the fourth determination unit 94 determines that the absolute value of the actual steering angle θ_{sw} is within the predetermined range, the first determination unit 88 does not determine whether or not the current sign of the steering angle differential value $\Delta\theta_{sw}$ has changed since last time, and the third determination unit 92 determines that the steering direction corresponds to steering increase operation, and turns the steering increase flag on. Besides, in this case, the retention value setting unit 82 sets the absolute value of the actual steering angle θ_{sw} as the retention value θ_{swld} . It should be noted herein that when the driver operates the steering wheel 49 such that the vehicle 10 runs straight forward, the steering direction never fails to correspond to steering increase operation if the steering wheel 49 is thereafter operated with the intention of making a turn. In contrast, the first determination unit 88 does not make a determination (no determinations starting from the first determination unit 88 are made), and the steering direction is made to correspond to steering increase operation, so preparations are made in advance for steering increase operation. Incidentally, it is advisable to determine whether or not the actual steering angle θ_{sw} is zero in order to see if the vehicle 10 traveling straight forward. However, in

consideration of the fact that the actual steering angle θ_{sw} wobbles as described above and that the value detected by the steering sensor 66 has an error (an individual difference), the aforementioned value zero is provided with a certain hysteresis, and it is determined whether or not the absolute value of the actual steering angle θ_{sw} is within the predetermined range including zero. Specifically, the fourth determination unit 94 determines whether or not the absolute value of the actual steering angle θ_{sw} is smaller than a predetermined steering angle as a maximum value of the predetermined range. This predetermined steering angle is also a lower limit of the absolute value of the actual steering angle θ_{sw} that is determined in advance to make it possible to determine, for example, that the driver has operated the steering wheel 49 with the intention of making a turn.

[0047] Furthermore, the steering direction determination unit 86 is functionally equipped with fifth determination means, namely, a fifth determination unit 96 that determines whether or not the actual steering angle θ_{sw} has passed zero with respect to the last value. Then, when the fifth determination unit 96 determines that the actual steering angle θ_{sw} has passed zero with respect to the last value, the first determination unit 88 does not determine whether or not the current sign of the steering angle differential value $\Delta\theta_{sw}$ has changed since last time, and the third determination unit 92 determines that the steering direction corresponds to steering increase operation, and turns the steering increase flag on. Besides, in this case, the retention value setting unit 82 sets the absolute value of the actual steering angle θ_{sw} as the retention value $\theta_{sw\text{hld}}$. It should be noted herein that when the actual steering angle θ_{sw} has passed zero with respect to the last time, the direction of steering of the steering wheel 49 by the driver corresponds to steering increase operation in the opposite direction. In contrast, the first determination unit 88 does not make a determination (no determinations starting from the first determination unit 88 are made), and the steering direction is made to correspond to steering increase operation, so steering increase operation is swiftly coped with. Specifically, the fifth determination unit 96 determines whether or not the actual steering angle θ_{sw} has passed zero with respect to the last value, based on whether or not the product of the actual

steering angle θ_{sw} (the current value) and the last value of the actual steering angle θ_{sw} is a negative value.

[0048] In the present embodiment of the invention, a determination on the steering direction is made according to a method of making a determination on the steering direction as described above. Then, the 4WD driving force calculation unit 78 controls (calculates) the amounts of a driving force distributed to the front wheels and the rear wheels based on a result of a determination on the steering direction by the steering direction determination unit 86 (the third determination unit 92). Thus, the amounts of the distributed driving force are appropriately controlled in accordance with steering increase operation or steering return operation during steering, and the yaw responsiveness of the vehicle 10 is enhanced both during steering increase operation and during steering return operation. Thus, the distributed driving force is controlled in accordance with the steering increase operation or the steering return operation during steering, and the turning performance of the vehicle 10 is improved.

[0049] FIG. 6 is a flowchart illustrating an essential part of the control action of the electronic control unit 70, namely, the control action for enhancing the yaw responsiveness of the vehicle 10 both when operation of the steering wheel 49 by the driver is steering increase operation and when operation of the steering wheel 49 by the driver is steering return operation. This control action is repeatedly executed at intervals of an extremely short cycle time, for example, several milliseconds to several dozens of milliseconds. Besides, this FIG. 6 is an example premised on a state where the vehicle runs based on 2WD traveling.

[0050] In FIG. 6, in S1 corresponding to the steering direction determination unit 86, it is determined whether steering increase operation or steering return operation is performed, based on, for example, whether or not the steering increase flag is on. If the determination in this S1 is positive (i.e., if it is determined that steering increase operation is performed), in step (hereinafter, the word "step" will be omitted) S2 corresponding to the 4WD driving force calculation unit 78, for example, the rear torque T_r is set equal to zero, and the present routine is ended. On the other hand, if the determination in the

aforementioned S1 is negative (i.e., if it is determined that steering return operation is performed), for example, a total torque (a total driving torque) based on an estimated engine torque T_{ep} is multiplied by a predetermined rear distribution ratio (> 0) to calculate the rear torque T_r , in S3 corresponding to the 4WD driving force calculation unit 78.

5 **[0051]** FIG. 7 is a flowchart illustrating an essential part of the control action of the electronic control unit 70, namely, the control action for suppressing the hunting of a determination and restraining the determination from being delayed in making the determination on the direction of steering of the steering wheel 49 by the driver. This control action is repeatedly executed at intervals of an extremely short cycle time, for example, several milliseconds to several dozens of milliseconds. This control action shown in FIG. 7 may be executed, for example, in parallel with the flowchart of FIG. 6 or in S1 of FIG. 6. FIG. 11 is an example of a time chart when the control action shown in the flowchart of FIG. 7 is executed.

15 **[0052]** In FIG. 7, first in S10 corresponding to the fifth determination unit 96, it is determined, for example, whether or not the product of the actual steering angle θ_{sw} (the current value) and the last value of the actual steering angle θ_{sw} is smaller than zero (a negative value). If the determination in this S10 is positive, it is determined that steering increase operation is performed, the steering increase flag is turned on, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value $\theta_{sw\text{hld}}$ in S20 corresponding to the third determination unit 92 and the retention value setting unit 82. If the determination in the aforementioned S10 is negative, it is determined whether or not the absolute value of the actual steering angle θ_{sw} is smaller than a predetermined steering angle close to zero, in S30 corresponding to the fourth determination unit 94. If the determination in this S30 is positive, it is determined that steering increase operation is performed, the steering increase flag is turned on, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value $\theta_{sw\text{hld}}$ in S40 corresponding to the third determination unit 92 and the retention value setting unit 82. If the determination in the aforementioned S30 is negative, it is determined whether or not the steering increase flag is on (i.e., it is determined that steering increase operation is

performed) in S50 corresponding to the steering direction determination unit 86. If the determination in this S50 is positive, it is determined whether or not the steering angle differential value $\Delta\theta_{sw}$ is smaller than zero (i.e., the steering angle differential value $\Delta\theta_{sw}$ is a negative value corresponding to steering increase operation) in S60 corresponding to the first determination unit 88. If the determination in this S60 is positive, it is determined that steering increase operation is still performed, the steering increase flag is not changed from on, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value θ_{swld} in S70 corresponding to the third determination unit 92 and the retention value setting unit 82. If the determination in the aforementioned S60 is negative, it is determined whether or not the steering angle differential value $\Delta\theta_{sw}$ is larger than the predetermined value A (> 0) in S80 corresponding to the second determination unit 90. If the determination in this S80 is positive, it is determined that a change has been made to steering return operation, the steering increase flag is turned off, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value θ_{swld} in S90 corresponding to the third determination unit 92 and the retention value setting unit 82. On the other hand, if the determination in the aforementioned S80 is negative, it is determined that steering increase operation is still performed, the steering increase flag is not changed from on, and the retention value θ_{swld} that is used in calculating the current steering angle differential value $\Delta\theta_{sw}$ is set as the subsequent retention value θ_{swld} (i.e., the retention value θ_{swld} is not updated) in S100 corresponding to the third determination unit 92 and the retention value setting unit 82. Besides, if the determination in the aforementioned S50 is negative, it is determined whether or not the steering angle differential value $\Delta\theta_{sw}$ has exceeded zero (i.e., the steering angle differential value $\Delta\theta_{sw}$ is a positive value corresponding to steering return operation) in S110 corresponding to the first determination unit 88. If the determination in this S110 is positive, it is determined that steering return operation is still performed, the steering increase flag is not changed from off, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value θ_{swld} in S120 corresponding to the third determination unit 92 and the retention value setting unit 82. If the determination in

the aforementioned S110 is negative, it is determined whether or not the steering angle differential value $\Delta\theta_{sw}$ is smaller than the predetermined value B (< 0) in S130 corresponding to the second determination unit 90. If the determination in this S130 is positive, it is determined that a change has been made to steering increase operation, the steering increase flag is turned on, and the absolute value of the actual steering angle θ_{sw} is set as the subsequent retention value θ_{swld} in S140 corresponding to the third determination unit 92 and the retention value setting unit 82. On the other hand, if the determination in the aforementioned S130 is negative, it is determined that steering return operation is still performed, the steering increase flag is not changed from off, and the retention value θ_{swld} that is used in calculating the current steering angle differential value $\Delta\theta_{sw}$ is set as the subsequent retention value θ_{swld} (i.e., the retention value θ_{swld} is not updated) in S150 corresponding to the third determination unit 92 and the retention value setting unit 82.

[0053] In FIG. 11, the comparative embodiment is an example of a steering increase flag that is set, for example, in making a determination on the steering direction based on the differential value of the actual steering angle θ_{sw} . When the actual steering angle θ_{sw} changes as show in the time chart, hunting frequently occurs in the determination as a result of fine fluctuations in the actual steering angle θ_{sw} in the comparative embodiment. In contrast, in the present embodiment, the hunting of the determination is suppressed against fine fluctuations in the actual steering angle θ_{sw} , and the appropriate steering direction is determined. Besides, as indicated by the circled portion, the determination is restrained from being delayed in the present embodiment as compared to the comparative embodiment.

[0054] As described above, according to the present embodiment of the invention, the amount of the driving force distributed to the front wheels 14 is set larger when operation of the steering wheel 49 is steering increase operation than when operation of the steering wheel 49 is steering return operation. Therefore, in conjunction with the characteristic that the self-aligning torque (the SAT) decreases as the driving force of the front wheels 14 increases, during steering increase operation, the SAT decreases, and the

steering force decreases (i.e., the steering feeling becomes light), so the yaw responsiveness of the vehicle 10 can be enhanced. Besides, during steering return operation, the SAT increases, but the steering direction is reversed, so the steering force decreases (i.e., the steering feeling becomes light) and the yaw responsiveness of the vehicle 10 can be enhanced. That is, both during steering increase operation and during steering return operation, the steering angle θ_{sw} for realizing a target turning behavior (or a target yaw rate) with a small steering force can be obtained.

[0055] Besides, according to the present embodiment of the invention, the rear distribution ratio is set smaller during steering increase operation than during steering return operation. Therefore, while the amount of the driving force distributed to the front wheels 14 is set relatively large during steering increase operation, the amount of the driving force distributed to the rear wheels 16 is set relatively large during steering return operation.

[0056] Besides, according to the present embodiment of the invention, while the rear distribution ratio is set zero during steering increase operation, the rear ratio is set to the predetermined distribution ratio exceeding zero during steering return operation. Therefore, during steering increase operation, no driving force is distributed to the rear wheels 16, and the amount of the driving force distributed to the front wheels 14 is maximized. On the other hand, during steering return operation, a predetermined driving force is distributed to the rear wheels 16, and the amount of the driving force distributed to the front wheels 14 is set small.

[0057] Besides, according to the present embodiment of the invention, in addition to setting the condition that the sign of the steering angle differential value $\Delta\theta_{sw}$ have changed and that the absolute value of the steering angle differential value $\Delta\theta_{sw}$ thereof have exceeded the predetermined value as a condition for determining that the steering direction has changed, the retention value θ_{swld} that is used in calculating the steering angle differential value $\Delta\theta_{sw}$ is not updated when it is determined that the steering direction has not changed because the absolute value of the steering angle differential value $\Delta\theta_{sw}$ has not exceeded the predetermined value in spite of a change in the sign of the

steering angle differential value $\Delta\theta_{sw}$. Therefore, fine changes in the actual steering angle θ_{sw} during steering are unlikely to exert an influence, and a more accurate and swift determination can be made on steering increase operation of the steering wheel 49 by the driver and steering return operation of the steering wheel 49 by the driver. In this manner, when a determination is made on the direction of steering of the steering wheel 49 by the driver, it is possible to suppress the hunting of the determination (an erroneous determination) and restrain the determination from being delayed.

[0058] Although the embodiment of the invention has been described in detail based on the drawings, the invention is also applicable to other modes.

[0059] For example, in the foregoing embodiment of the invention, the vehicle 10 is an electronically controlled torque/split-type four-wheel-drive vehicle that distributes the torque generated by the engine 12 to the front wheels and the rear wheels in accordance with the traveling situation by the coupling 28, but the invention is not limited thereto. For example, as in the case of a vehicle 100 shown in FIG. 8, there may be adopted a four-wheel-drive vehicle that is designed to drive the front wheels 14 by the engine 12 and drive the rear wheels 16 by an electric motor M. Besides, there may also be adopted a four-wheel-drive vehicle in which a coupling that is identical in type to the coupling 28 is disposed in series with the respective rear axles 32R and 32L instead of being disposed in series with the propeller shaft 26. Besides, the vehicle 10 is structured such that a motive power is constantly transmitted to the front wheels 14 and that the rear wheels 16 serve as subsidiary driving wheels, but the invention is not limited thereto. For example, the vehicle 10 may also be structured such that a motive power is constantly transmitted to the rear wheels 16 and that the front wheels 14 serve as subsidiary driving wheels. For example, the vehicle 10 may be an FR-based four-wheel-drive vehicle.

[0060] Besides, the flowchart of FIG. 6 in the foregoing embodiment of the invention represents an embodiment in which the rear torque T_r is set to zero during steering increase operation, but the invention is not limited thereto. For example, the predetermined rear torque T_r may be adopted during steering increase operation, and the rear torque T_r obtained by increasing the predetermined rear torque T_r by a predetermined

amount may be adopted during steering return operation. In short, it is sufficient that the rear distribution ratio (or the amount of the driving force distributed to the rear wheels 16) be set smaller during steering increase operation than during steering return operation. In this manner, the respective steps in the flowchart of FIG. 6 can be appropriately changed within an acceptable range.

[0061] Besides, in the foregoing embodiment, control of a driving force distributed to the front wheels and the rear wheels in a four-wheel-drive vehicle is illustrated as control for adopting the result of the determination on the steering direction according to the invention, but the invention is not limited thereto. For example, irrespective of a four-wheel-drive vehicle or a two-wheel-drive vehicle, the result of the determination on the steering direction according to the invention may be adopted to control of a driving force distributed to the right and left wheels in a vehicle. In this manner as well, a distributed driving force is appropriately controlled in accordance with steering increase operation or steering return operation during steering, and the turning performance of the vehicle 10 is improved. In short, the invention may be applied to such control that the control mode is changed based on the result of the determination on the steering direction (whether the steering increase operation of the steering wheel 49 or the steering return operation of the steering wheel 49).

[0062] Besides, in the flowchart of FIG. 7 according to the foregoing embodiment, for example, S10 to S40 are not necessarily required in order to achieve the invention. The steps may be modified as needed without difficulty.

[0063] Incidentally, the foregoing is nothing more than the embodiments of the invention, and the invention can be carried out according to a mode subjected to various alterations and improvements based on the knowledge of those skilled in the art.

CLAIMS

1. A four-wheel-drive vehicle comprising:

a steering wheel;

front wheels;

rear wheels;

a driving force source;

a steering device configured to mechanically transmit rotation of the steering wheel to the front wheels; and

an electronic control unit configured to

(a) control amount of a driving force distributed to the front wheels and an amount of a driving force distributed to the rear wheels, or ratio of a driving force of the front wheels to the rear wheels, to distribute a driving force from the driving force source to the front wheels and the rear wheels,

(b) determine whether an operation of the steering wheel by the driver is steering increase operation or steering return operation, and

(c) set the amount of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation larger than the amount of the driving force distributed to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation, or set the ratio of the driving force of the front wheels to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation larger than the ratio of the driving force of the front wheels to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation.

2. The four-wheel-drive vehicle according to claim 1, wherein

the electronic control unit is configured to set the amount of the driving force distributed to the rear wheels when the electronic control unit determines that the operation

of the steering wheel by the driver is the steering increase operation smaller than the amount of the driving force distributed to the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation, or set ratio of a driving force of the rear wheels to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation smaller than the ratio of the driving force of the rear wheels to the front wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation.

3. The four-wheel-drive vehicle according to claim 1 or 2, wherein

the electronic control unit is configured to set the ratio of the driving force of the rear wheels to the front wheels to zero when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation, and

the electronic control unit is configured to set the ratio of the driving force of the rear wheels to front wheels to a predetermined ratio exceeding zero when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation.

4. The four-wheel-drive vehicle according to claim 1, wherein

the electronic control unit is configured to set a feedforward torque of the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering return operation larger than the feedforward torque of the rear wheels when the electronic control unit determines that the operation of the steering wheel by the driver is the steering increase operation.

5. The four-wheel-drive vehicle according to any one of claims 1 to 4, wherein

the electronic control unit is configured to

- (i) set a retention value that is a steering angle of a comparative object,
- (ii) calculate a steering angle differential value as a difference between an actual

steering angle and a steering angle of the comparative object,

(iii) determine whether or not a current sign of the steering angle differential value is different from a sign of last time ,

(iv) determine whether or not a current absolute value of the steering angle differential value exceeds a predetermined value when the electronic control unit determines that the sign of the steering angle differential value is different from the sign of last time

(v) determine that the steering direction changes when the electronic control unit determines that the current absolute value of the steering angle differential value exceeds the predetermined value, and

(vi) set the retention value used in calculating the current steering angle differential value as a retention value used at the time of calculating a subsequent steering angle differential value when the electronic control unit determines that the current absolute value of the steering angle differential value does not exceed the predetermined value.

FIG. 1

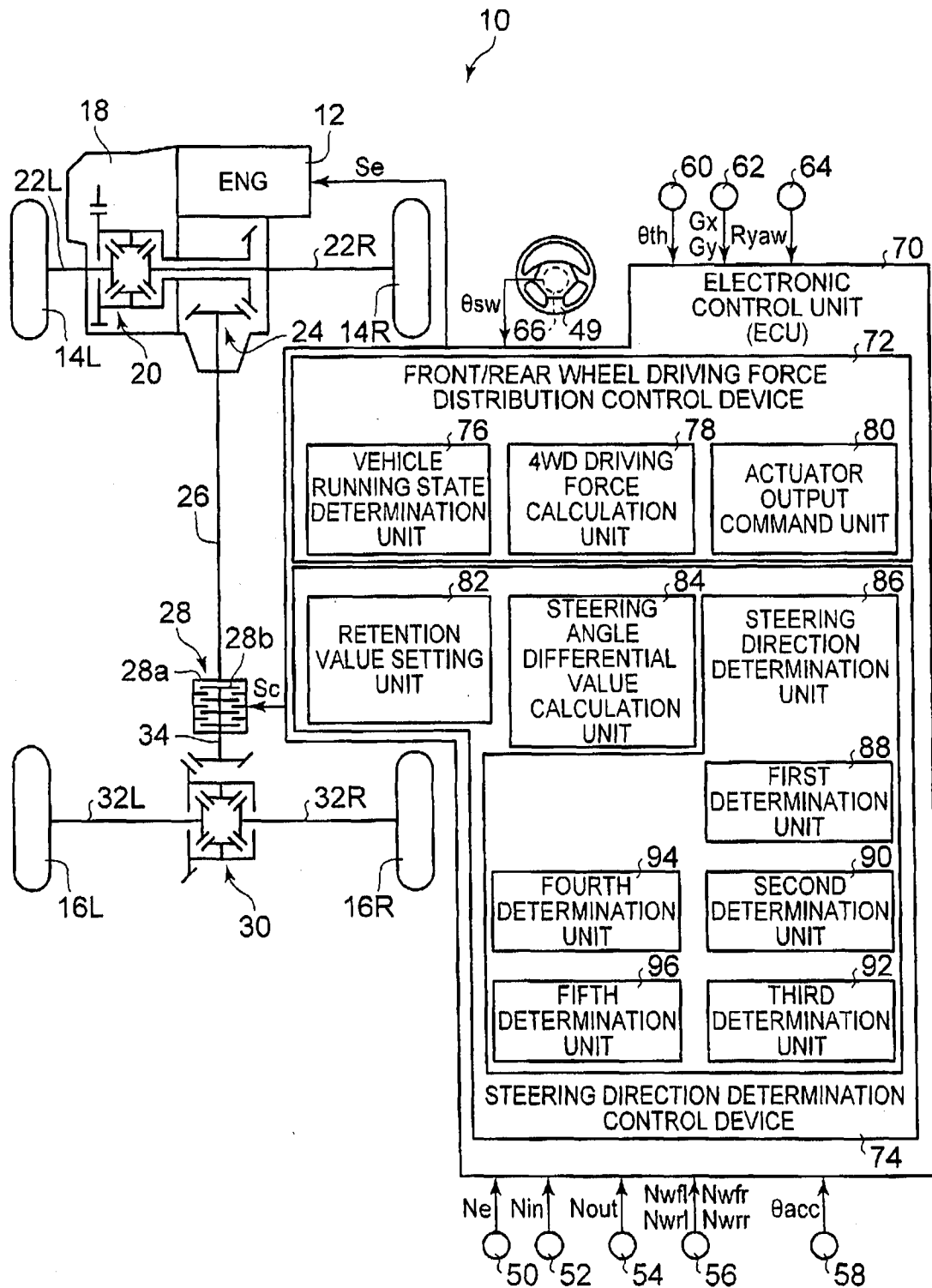


FIG. 2

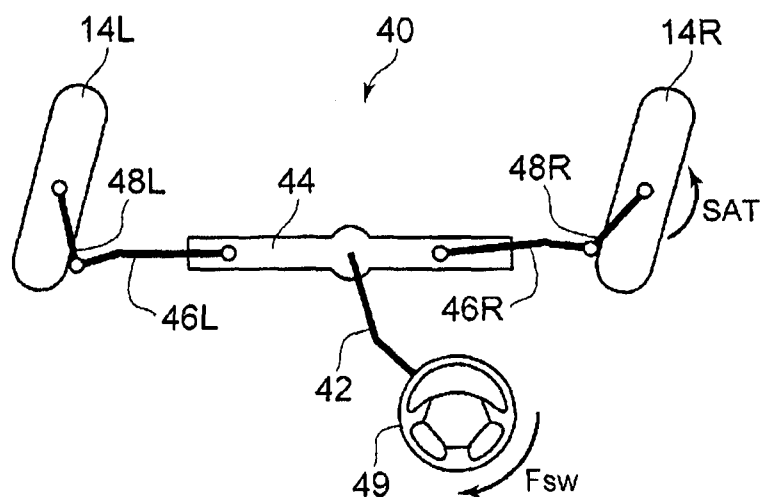


FIG. 3

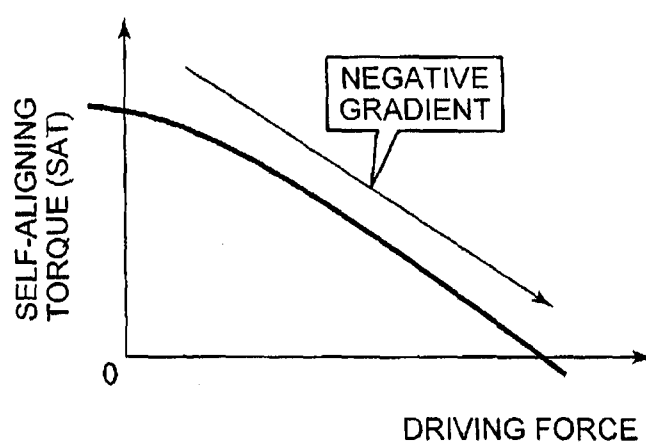


FIG. 4A

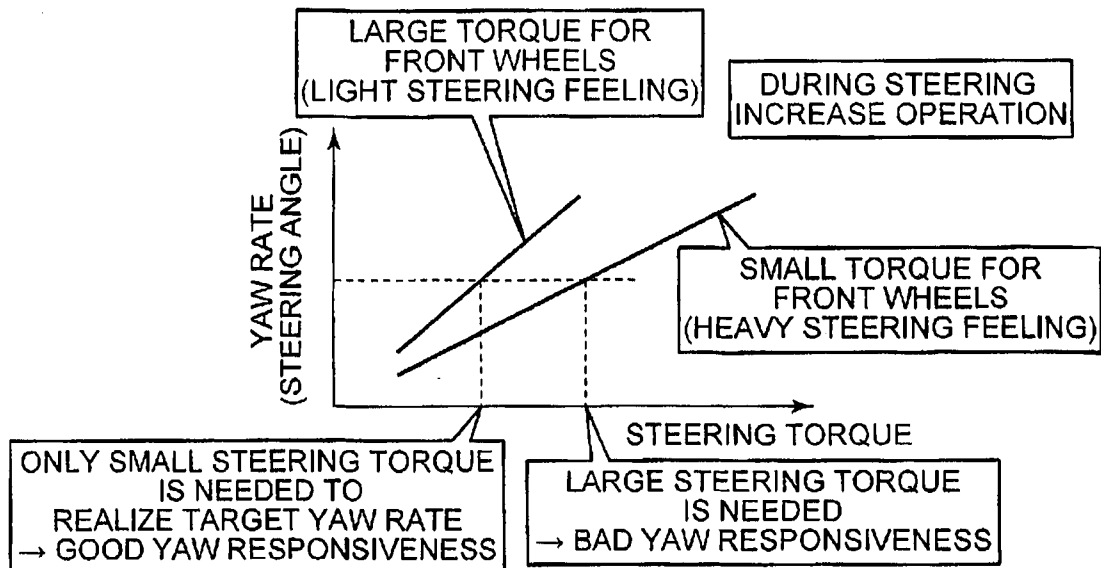


FIG. 4B

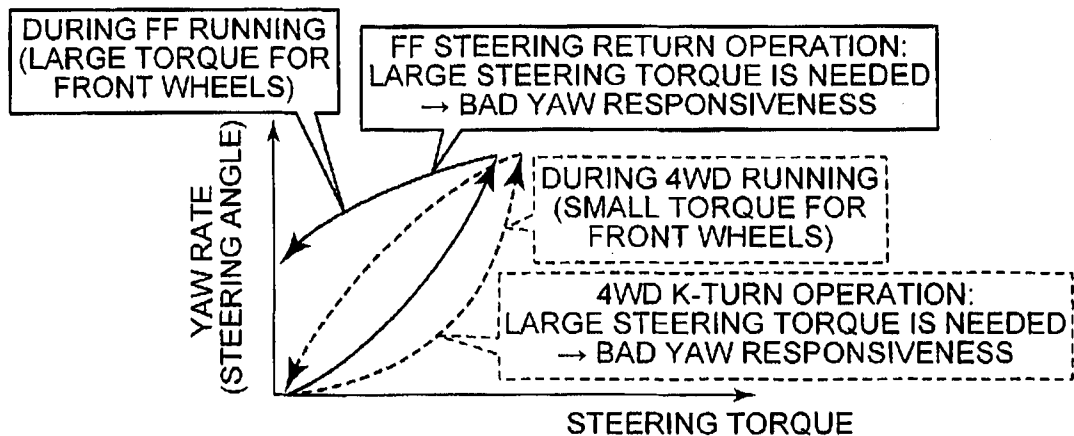


FIG. 5

		K-TURN OPERATION (STEERING INCREASE OPERATION)		STEERING RETURN OPERATION
LARGE TORQUE FOR FRONT WHEELS (SMALL TORQUE FOR REAR WHEELS)	○	LIGHT STEERING FEELING AND GOOD YAW RESPONSIVENESS OF VEHICLE TO STEERING TORQUE	×	HEAVY STEERING FEELING AND POOR YAW RESPONSIVENESS OF VEHICLE TO STEERING TORQUE
SMALL TORQUE FOR FRONT WHEELS (LARGE TORQUE FOR REAR WHEELS)	×	HEAVY STEERING FEELING AND POOR YAW RESPONSIVENESS OF VEHICLE TO STEERING TORQUE	○	LIGHT STEERING FEELING AND GOOD YAW RESPONSIVENESS OF VEHICLE TO STEERING TORQUE

FIG. 6

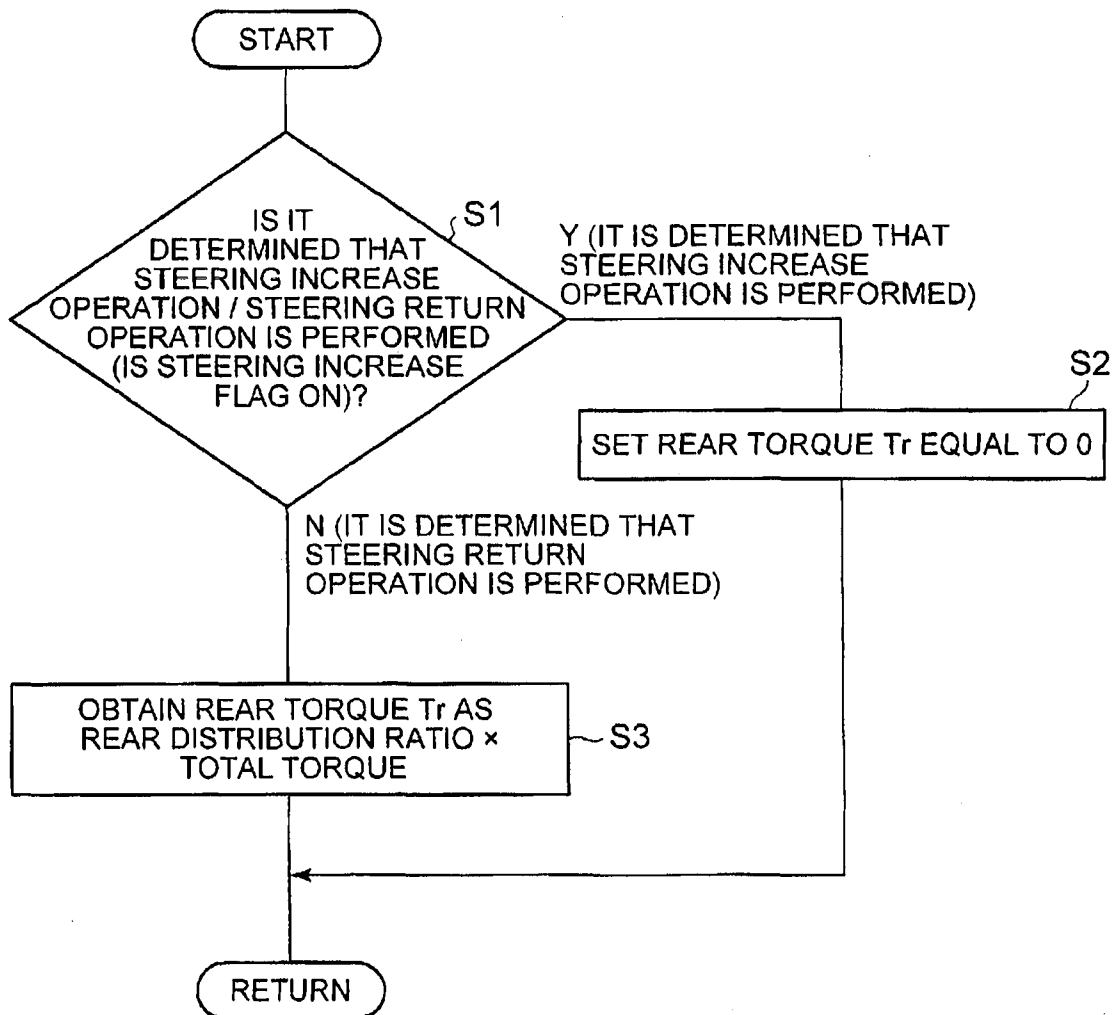


FIG. 7

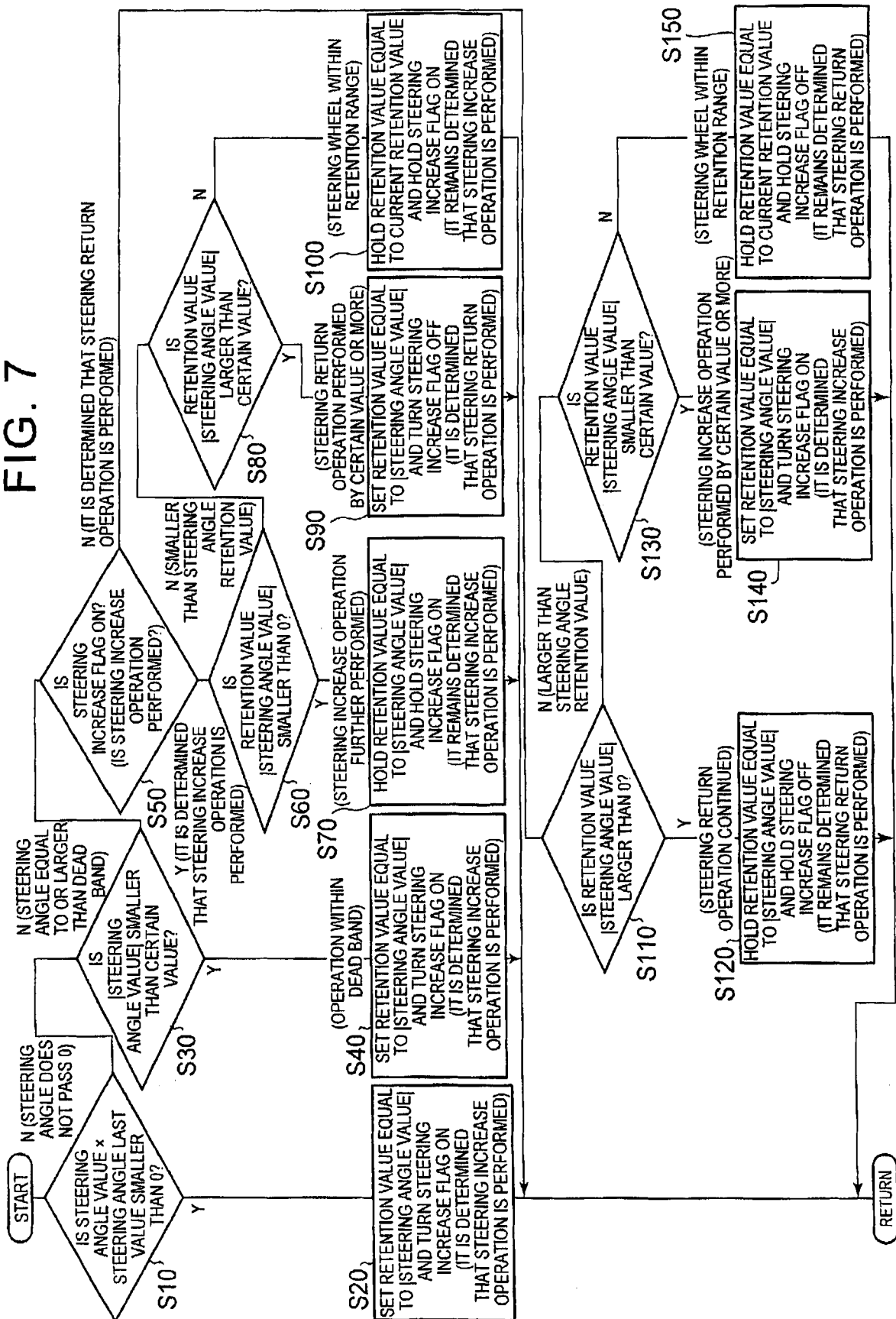


FIG. 8

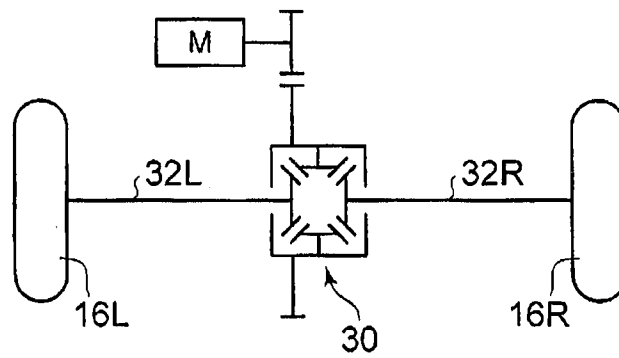
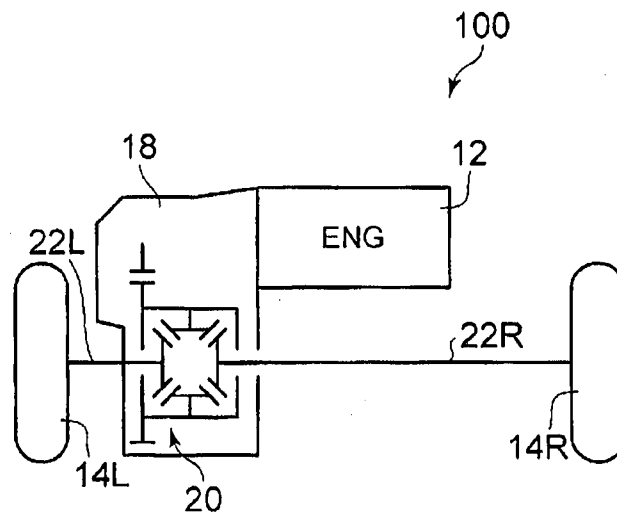


FIG. 9

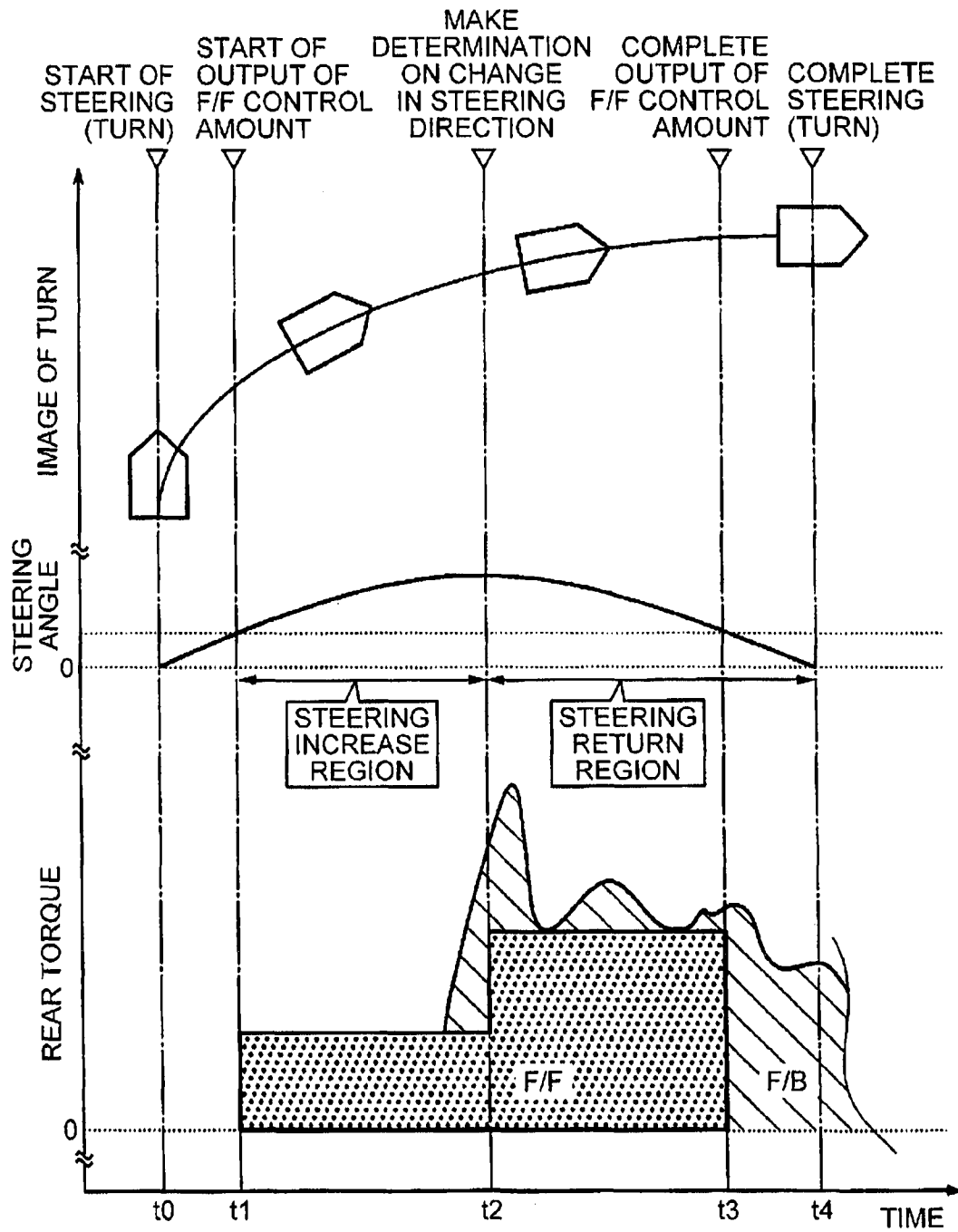


FIG. 10

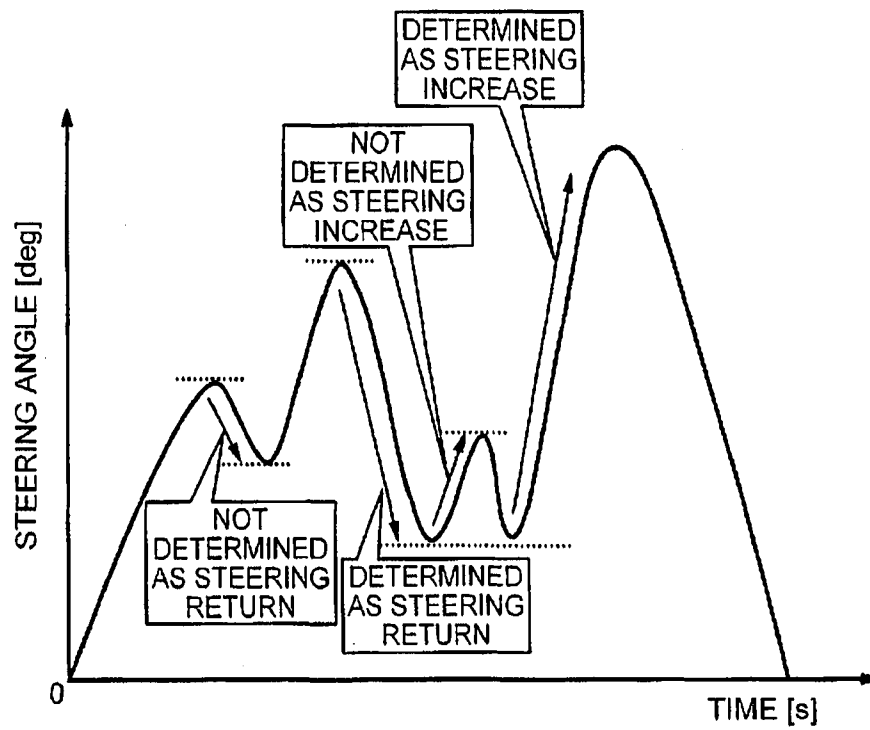
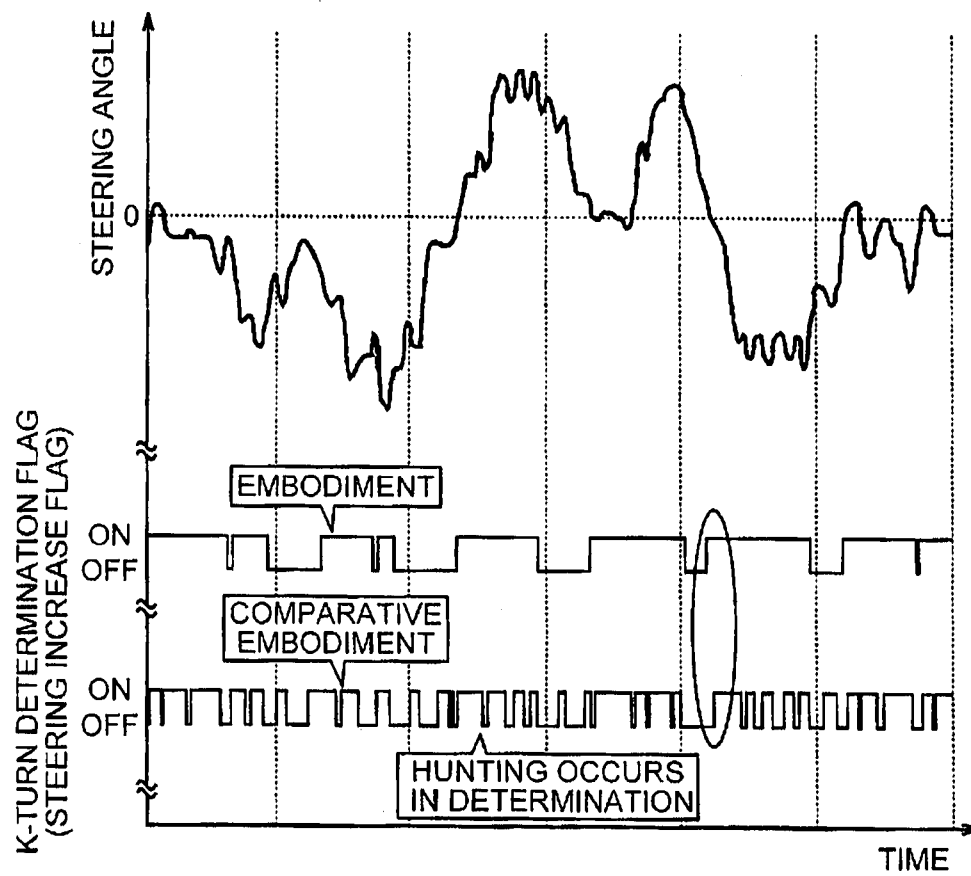


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/002244

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60K17/35 B60K23/08 B60W10/02 B60W30/045
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)

B60K B60W

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 460 547 A2 (MAZDA MOTOR [JP]) 11 December 1991 (1991-12-11) the whole document	1-5
A	----- JP 2007 055476 A (NISSAN MOTOR) 8 March 2007 (2007-03-08) cited in the application the whole document -----	1-5

☐

Further documents are listed in the continuation of Box C.

☒

See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

27 February 2015

Date of mailing of the international search report

09/03/2015

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

Meritano, Luciano

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2014/002244

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0460547	A2	11-12-1991	EP 0460547 A2	11-12-1991
			US 5225984 A	06-07-1993

JP 2007055476	A	08-03-2007	JP 4797513 B2	19-10-2011
			JP 2007055476 A	08-03-2007
