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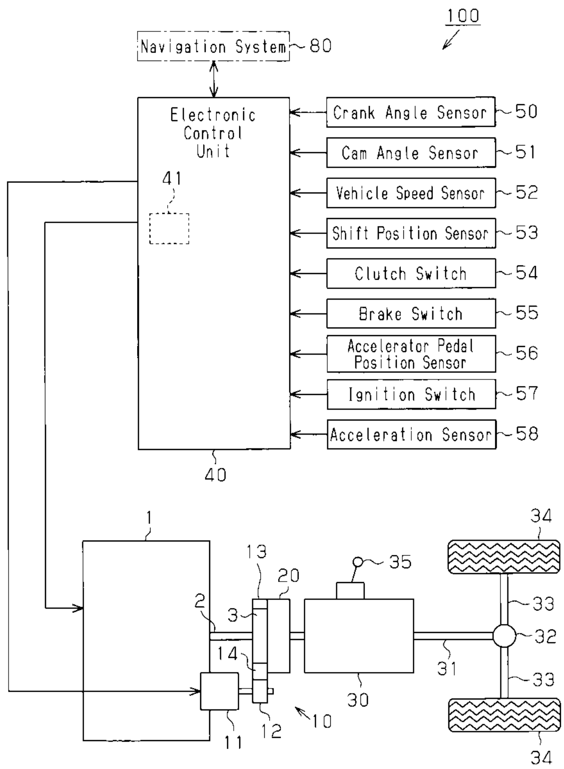
(54) Control apparatus for internal combustion engine

(57) A control apparatus (100) for an internal combustion engine (1) is disclosed. When the engine (1) is started, the apparatus (100) executes starting control in accordance with the stopped crank position. The control apparatus (100) includes inclination state detecting means (40,58,80), shift position detecting means (53), rotation direction determining means (40), and stopped crank position updating means (40). The shift position detecting means (53) detects whether the shift position of a transmission (30) mounted on the vehicle while the engine (1) is off is a neutral position, an advancing position, or a reverse position The rotation direction determining means (40) determines the direction of rotation of the crankshaft accompanying rotation of the vehicle wheels (34) while the engine (1) is off. When an output signal of the crank angle sensor (50) is detected, the stopped crank position updating means (40) updates the stopped crank position, which is stored in the stopped crank position storing means (41), in accordance with the direction of rotation determined by the rotation direction determining means (40).

Fig.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a control apparatus for an internal combustion engine that executes starting control when the engine is started, in accordance with a previously stored stopped position of the crankshaft.

[0002] In recent years, in order to improve the fuel efficiency and exhaust emission, a control apparatus for an internal combustion engine that executes automatic stopping/starting control has been in practical use. In the automatic stopping/starting control, the control apparatus automatically stops the engine when a predetermined automatic stopping condition is met in the engine, and automatically starts the engine when a predetermined automatic starting condition is met.

[0003] In a typical internal combustion engine, the position of the crankshaft (crank position) is detected based on output signals of a crank angle sensor that detects rotation of the crankshaft of the engine. The control apparatus for an internal combustion engine, which executes the automatic stopping/starting control as discussed above, is known to store the crank position (stopped crank position) at the time of the execution of the automatic stopping process, in order to complete the starting of the engine in the automatic starting process at an early stage. Also, the apparatus is known to execute, in the automatic starting process, early-stage starting control, in which the apparatus executes fuel injection and ignition in accordance with the stored stopped crank position.

[0004] When the starting control of the engine in accordance with the stopped crank position is executed in the automatic starting process, unexpected rotation of the crankshaft when the engine is off after being automatically stopped will result in a difference between the position of the crankshaft when started and the stored stopped crank position. This hinders the starting of the engine from being completed in a favorably manner, and degrades the exhaust emission.

[0005] Japanese Laid-Open Patent Publication No. 2005-351210 discloses a control apparatus for an internal combustion engine that deals with the above drawbacks. Specifically, when determining that a stored stopped crank position at the time the engine was stopped is different from a crank position in the next starting, for example, when a vehicle mounting the engine is stopped on a slope, the apparatus does not use the stopped crank position. Instead, the apparatus first determines the crank position in the starting of the engine, and then executes the starting based on the determined crank position.

[0006] However, the control apparatus of the publication determines the crank position, and then executes the starting based on the determined crank position. In this configuration, early-stage starting control cannot be executed in the current starting. Thus, the apparatus still has room for improvement in advancing the completion of the engine starting.

[0007] The above described drawbacks are not only present when an engine that executes automatic stopping/starting control is off after being automatically stopped, but may be found in any configuration in which starting control is executed according to a stopped crank position even if stopping and starting of the engine are executed in response to operation by the driver.

[0008] It is an objective of the present invention to provide a control apparatus for an internal combustion engine, which apparatus is capable of properly executing starting control in accordance with a previously stored stopped position of the crankshaft.

SUMMARY OF THE INVENTION

[0009] The present invention provides a control apparatus for an internal combustion engine. The apparatus includes crank position detecting means that detects the crank position of the engine based on a signal outputted by a crank angle sensor as the crankshaft of the engine rotates, and stopped crank position storing means that stores, as a stopped crank position, the crank position at the time the engine is stopped. When the engine is started, the apparatus executes starting control in accordance with the stopped crank position stored in the stopped crank position storing means. The apparatus further includes inclination state detecting means, shift position detecting means, rotation direction determining means, and stopped crank position updating means. The inclination state detecting means detects the inclination state of a vehicle on which the engine is mounted. The shift position detecting means detects whether the shift position of a transmission mounted on the vehicle while the engine is off is a neutral position, at which rotation of the crankshaft is not transmitted to vehicle wheels, an advancing position, at which rotation of the crankshaft is transmitted to the vehicle wheels after being varied, or a reverse position, at which rotation of the crankshaft is transmitted to the vehicle wheels in a reverse direction. On condition that the shift position detected by the shift position detecting means is the advancing position or the reverse position, the rotation direction determining means determines the direction of rotation of the crankshaft accompanying rotation of the vehicle wheels while the engine is off, based on the detected shift position and the inclination state detected by the inclination state detecting means. When an output signal of the crank angle sensor is detected, the stopped crank position updating means updates the stopped crank position, which is stored in the stopped crank position storing means, in accordance with the direction of rotation determined by the rotation direction determining means.

[0010] Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a schematic diagram illustrating a control apparatus for an internal combustion engine according to a first embodiment of the present invention;
Fig. 2A is a diagram showing a timing rotor and a crank angle sensor provided to the crankshaft of the vehicle shown in Fig. 1;
Fig. 2B is a diagram showing a timing rotor and a cam angle sensor provided to the camshaft of the vehicle shown in Fig. 1;
Fig. 3 is a timing chart showing the relationship among a crank angle signal, a cam angle signal, and the state of stroke of the cylinders;
Fig. 4 is a flowchart illustrating a procedure executed by the control apparatus according to the first embodiment of the present invention;
Fig. 5 is a flowchart illustrating a procedure of a rotation direction determining process executed by the control apparatus according to the first embodiment of the present invention; and
Fig. 6 is a schematic diagram illustrating a navigation system provided in a control apparatus for an internal combustion engine according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] A control apparatus for an internal combustion engine 1 according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 5. Fig. 1 is a schematic diagram showing a vehicle 100 having a control apparatus for an internal combustion engine 1 of the present invention. The internal combustion engine 1, which is mounted on the vehicle 100, includes four linearly arranged cylinders (#1 to #4). Rotational force for driving the vehicle 100 is generated by the internal combustion engine 1 and outputted to a crankshaft 2. The crankshaft 2 is coupled to a flywheel 3, which is fixed to one end of the crankshaft 2. The flywheel 3 is also coupled to a clutch 20, which connects and disconnects the flywheel 3 to and from a transmission 30 in response to operation of a clutch pedal (not shown) by the driver. A propeller shaft 31, which is an output shaft of the transmission 30, is connected via a differential gear 32 to drive shafts 33 each connected to a vehicle wheel 34.

[0013] The transmission 30 is a manual transmission of multiple gears, which is manipulated to switch the shift position by operation of a shift lever 35 by the driver. Specifically, any of the following shift positions is selected by manipulation of the shift lever 35 by the driver: a neutral position, at which rotation of the crankshaft 2 is not transmitted to the vehicle wheels 34; advancing positions (first to fifth speeds), at which rotation of the crankshaft 2 is transmitted to the vehicle wheels 34; and a reverse position, at which rotation of the crankshaft 2 is inverted and transmitted to the vehicle wheels 34.

[0014] When the internal combustion engine 1 outputs rotational force to the crankshaft 2 to cause the vehicle 100 to move, and the shift position of the transmission 30 is the advancing or reverse position, the clutch 20 couples the flywheel 3 and the transmission 30 to each other, so that the rotational force of the crankshaft 2 is ultimately transmitted to the vehicle wheels 34 through the clutch 20, the transmission 30, the propeller shaft 31, the differential gear 32, and the drive shafts 33.

[0015] The internal combustion engine 1 has a constant mesh type starting device 10 for starting the engine 1. Specifically, the starting device 10 includes a starter motor 11 generating torque, a pinion gear 12, a ring gear 13, and a one-way clutch 14. The pinion gear 12 transmits the torque of the starter motor 11 to the crankshaft 2 via the flywheel 3. The ring gear 13 is provided on the outer circumference of the flywheel 3 and constantly meshes with the pinion gear 12. The one-way clutch 14 is provided between the starter motor 11 and the crankshaft 2. The torque of the starter motor 11 is transmitted to the crankshaft 2 via the pinion gear 12 and the ring gear 13. The one-way clutch 14 transmits torque from the starter motor 11 to the crankshaft 2 only when the pinion gear 12 transmits rotational force in the forward direction to the ring gear 13. At the starting of the internal combustion engine 1, the starter motor 11 is driven, and rotational force of the starter motor 11 is transmitted to the crankshaft 2 via the ring gear 13 and the flywheel 3, so that the engine 1 is started. The pinion gear 12 corresponds to a drive gear, and a ring gear 13 corresponds to a driven gear.

[0016] Various types of sensors for detecting the running state of the vehicle 100, the operating state of the engine 1, and operation executed by the driver are provided in various parts of the vehicle 100 and the internal combustion engine 1. These sensors include a vehicle speed sensor 52, which is located near one the vehicle wheels 34 to detect the speed of the vehicle 100, a shift position sensor 53, which detects the position of the shift lever 35 (shift position) manipulated by the drier, a clutch switch 54, which detects that the clutch pedal (not shown) is depressed by the driver, a brake switch 55, which detects that the brake pedal (not shown) is depressed by the driver, an accelerator pedal position sensor 56, which detects the amount of depression of the accelerator pedal (not shown) when depressed by the driver, an ignition switch 57, which is manipulated by the driver to start the engine 1, and an acceleration sensor 58, which detects the acceleration of the vehicle 100.

[0017] A timing rotor 61 shown in Fig. 2A is provided at one end of the crankshaft 2 to rotate integrally with the crankshaft 2. The timing rotor 61 is made of a magnetic substance such as iron. Teeth 62 are arranged at equal angular intervals (10° CA) on the outer circumference of the timing rotor 61. A tooth missing portion 63 for detecting a reference angle is formed on the outer circumference by removing two of the teeth 62. A crank angle sensor 50 is attached to the internal combustion engine 1 at position that faces the teeth 62 of the timing rotor 61. The crank angle sensor 50 outputs signals as the crankshaft 2 rotates.

[0018] The crank angle sensor 50 is a known electromagnetic pickup type, and includes an iron core, a coil provided about the iron core, and a magnet that generates magnetic flux that passes through the coil (none of these are shown).

[0019] When the timing rotor 61 rotates together with the crankshaft 2, recesses and projections that are defined on the outer circumference of the rotor 61 by the teeth 62 cause the distance between the timing rotor 61 and the iron core of the crank angle sensor 50 to vary. As a result, the amount of magnetic flux passing through the coil of the sensor 50 changes, so that electromagnetic induction generates electromotive force (voltage) in the coil. Accordingly, an alternating voltage the frequency of which is proportional to the speed of rotation of the rotor 61 is outputted from the crank angle sensor 50. The outputted voltage is commutated and converted into a crank angle signal, which is a rectangular wave shown in Fig. 3.

[0020] Further, a cam angle sensor 51 for detecting the position of a camshaft (not shown) is attached to the internal combustion engine 1. The camshaft rotates half a turn while the crankshaft 2 rotates one turn. A timing rotor 71 shown in Fig. 2B is attached to one end of the camshaft to rotate integrally with the camshaft. One tooth 72 is provided on the outer circumference of the timing rotor 71. Like the crank angle sensor 50, the cam angle sensor 51 is a known electromagnetic pickup type, is attached to a position that faces the tooth 72 of the timing rotor 71.

[0021] When the timing rotor 71 rotates together with the camshaft, the tooth 72 cause the distance between the timing rotor 71 and the iron core of the cam angle sensor 51 to vary. As a result, the amount of magnetic flux passing through the coil of the sensor 51 changes, so that electromagnetic induction generates electromotive force (voltage) in the coil. The outputted voltage is commutated. Accordingly, as shown in Fig. 3, the cam angle sensor 51 outputs a single rectangular cam angle signal while the timing rotor 71 rotates one turn (720° CA).

[0022] The vehicle 100 has an electronic control unit 40 that collectively controls various devices including the internal combustion engine 1 mounted on the vehicle 100. The electronic control unit 40 receives signals outputted from the above described various sensors. In addition to a non-illustrated central processing unit (CPU), the electronic control unit 40 includes a memory 41 that stores control programs, computation maps, and data obtained during the execution of control processes. Based on signals outputted from the various sensors, the electronic control unit 40 detects the running state of the vehicle 100 and the operating state of the engine 1, and executes various control processes. For example, based on the detected operating state of the engine 1, the electronic control unit 40 executes fuel injection control to inject fuel into the engine 1 and ignition timing control to ignite air-fuel mixture supplied to the engine 1. More specifically, the electronic control unit 40 controls the amount and timing of fuel injection to the engine 1 in the fuel injection control and controls the timing at which air-fuel mixture is ignited in the ignition timing control.

[0023] Further, based on an output signal of the crank angle sensor 50, the electronic control unit 40 detects the position of the crankshaft 2, or the crank position, in a crank position detecting process. The crank position detecting process corresponds to a process executed by crank position detecting means.

[0024] As shown in Fig. 3, since the crank angle sensor 50 outputs the crank angle signal that corresponds to the tooth missing portion 63 once every 360° CA, the electronic control unit 40 detects the crank angle (CA) of the crankshaft 2 using the crank angle signal. However, since the combustion cycle of the internal combustion engine 1 corresponds to 720° CA, whether the piston in each cylinder (#1 to #4) is, for example, at a top dead center in a combustion stroke cannot be directly detected based on the crank angle signal, which corresponds to the tooth missing portion 63 at every 360° CA. Therefore, in the present embodiment, a period corresponding to 720° CA is detected based on the cam signal from the cam angle sensor 51.

[0025] Specifically, a crank counter ccrnk that corresponds to the cam angle signal from the cam angle sensor 51 is used. The initial value of the crank counter ccrnk is set to 0. The crank counter ccrnk is incremented by one every time the crank angle signal is outputted, and reset every 720° CA. Accordingly, as shown in Fig. 3, the electronic control unit 40 is capable of detecting the state of stroke in each cylinder (#1 to #4). That is, in the crank position detecting process of the present embodiment, the output signal from the cam angle sensor 51 is referred in addition to the output signal from the crank angle sensor 50, so that the crank position including the state of stroke in the combustion cycle of each cylinder (#1 to #4) of the internal combustion engine 1 is detected. In the internal combustion engine 1, ignition of air-fuel mixture is executed in the compression stroke. Then, the state of stroke proceeds to the expansion stroke.

[0026] The electronic control unit 40 executes an automatic stopping/starting process, in which the control unit 40 automatically stops the engine 1 when a predetermined automatic stopping condition is met during the operation of the engine 1, and automatically starts the engine 1 when a predetermined automatic starting condition is met when the engine 1 is off after being automatically stopped. When the engine 1 is automatically stopped, the electronic control unit 40 stores the crank position at the time of stopping, that is, the stopped crank position. When the engine 1 is automatically started, the electronic control unit 40 executes starting control in accordance with the stored stopped crank position, or early-stage starting control. Specifically, as the early-stage starting control, fuel injection control, in which fuel is injected according to the stopped crank position, and ignition control, in which ignition is performed according to the stopped crank position, are executed. The automatic stopping/starting process executed by the electronic control unit 40 corresponds to a process executed by automatic stopping/starting means.

[0027] With reference to Figs. 4 and 5, a series of processes executed by the electronic control unit 40 will be described. The series of processes shown by the flowchart of Fig. 4 is repeatedly executed by the electronic control unit 40 at predetermined intervals after then the internal combustion engine 1 is started based on the operation of the ignition switch 57 by the driver.

[0028] In this series of procedure, it is determined whether the engine 1 is off after being automatically stopped (step S101). If it is determined that the engine 1 is not turned off after being automatically stopped (step S101: NO), it is determined whether an automatic stopping condition is met (step S102). Specifically, the automatic stopping condition is met when the speed of the vehicle is 0 km/h, the brake pedal is being depressed, and the acceleration pedal is not depressed. The speed of the vehicle 100 is detected based on the output signal of the vehicle speed sensor 52. The operation of the brake pedal by the driver is detected by the output signal of the brake switch 55. The operation of the accelerator pedal by the driver is detected by the output signal of the accelerator pedal position sensor 56.

[0029] If it is determined that the automatic stopping condition is not met (step S102: NO) through the determining process, the current process is temporarily suspended. On the other hand, if it is determined that the automatic stopping condition is met (step S102: YES), the engine stopping process is executed (step S103). Specifically, fuel supplied to the internal combustion engine 1 is stopped, and ignition of air-fuel mixture is stopped, so that the engine 1 stops running. The crank position when the engine 1 is stopped, that is, the stopped crank position is stored in the memory 41 (step S104). Specifically, the crank position detected based on the crank position detecting process executed by the electronic control unit 40 is stored in the memory as a stopped crank position. The memory 41 corresponds to stopped crank position storing means.

[0030] Then, the rotation direction determining process shown in Fig. 5 is executed (step S105) to determine whether the direction of rotation of the crankshaft 2 caused by rotation of the vehicle wheels 34 when the engine 1 is off is the forward direction or the reverse direction.

[0031] With reference to Fig. 5, the rotation direction determining process executed at step S105 will be described. In this process, the shift position is first detected (step S200). Specifically, based on the output signal of the shift position sensor 53, the position of the shift lever 35 of the transmission 30 is detected. That is, whether the shift lever 35 is at the neutral position, the advancing position, or the reverse position is detected. The process of step S200 corresponds to the process executed by shit position detecting means.

[0032] Then, it is determined whether the detected shift position is the advancing position or the reverse position is detected (step S201). If the detected shift position is determined to be the advancing position or the reverse position (step S201: YES), the electronic control unit 40 determines that rotation of the vehicle wheels 34 with the engine not operating can be transmitted to the crankshaft 2 through the transmission 30 and the clutch 20.

[0033] The electronic control unit 40 is capable of determining rotation of the crankshaft 2 based on the shift position of the transmission 30 and the inclination state of the vehicle 100. Specifically, the inclination state of the vehicle 100 is determined by detecting whether the road surface on which the vehicle 100 is located is an uphill or a downhill, the inclination angle of which is greater than or equal to a predetermined angle α with respect to a plane perpendicular to the direction of gravity. The predetermined angle α is set in advance as an inclination angle of a road surface (inclination angle relative to a plane perpendicular to the direction of gravity), which is suitable for determining whether the vehicle 100 is on an uphill or a downhill. By detecting whether the vehicle 100 is on an uphill or a downhill, the electronic control unit 40 is capable of predicting the moving direction of the vehicle 100 when the engine 1 is off. Specifically, when the vehicle 100 is stopped on an uphill, the moving direction of the vehicle 100 when the engine is off is predicted to be reverse. When the vehicle 100 is stopped on a downhill, the moving direction of the vehicle 100 when the engine is off is predicted to be forward. In accordance with the moving direction of the vehicle 100, the rotation direction of the vehicle wheels 34 are changed. The direction of rotation of the crankshaft 2 accompanying the rotation of the vehicle wheels 34 is changed according to the shift position of the transmission 30, in addition to the rotation direction of the vehicle wheels 34.

[0034] Accordingly, whether the vehicle 100 is stopped on an uphill is determined (step S202). Specifically, based on the output signal of the acceleration sensor 58, it is determined whether the road surface on which the vehicle 100 is located is an uphill having an inclination angle greater than or equal to the predetermined angle α.

[0035] If it is determined that the vehicle 100 is stopped on an uphill through the determining process (step S202: YES), the moving direction of the vehicle 100 when the engine 1 is off is predicted to be reverse.

[0036] It is determined whether the shift position is the advancing position (step S203). The determining process is executed based on the shift position detected at step S200. If it is determined that the shift position is the advancing position (step S203: YES), the rotation direction of the crankshaft 2 is determined to be in a reverse direction (step S204). If it is determined that the shift position is not the advancing position, that is, if the shift position is determined to be the reverse position (step S203: NO), the rotation direction of the crankshaft 2 is determined to be the forward direction (step S205).

[0037] On the other hand, if it is determined that the vehicle 100 is not stopped on an uphill (step S202: NO), it is determined whether the vehicle 100 is stopped on a downhill (step S206). Specifically, as in the determining process at step S202 shown above, based on the output signal of the acceleration sensor 58, it is determined whether the road surface on which the vehicle 100 is located is a downhill having an inclination greater than or equal to the predetermined angle α.

[0038] If it is determined that the vehicle 100 is stopped on a downhill through the determining process (step S206: YES), the moving direction of the vehicle 100 when the engine 1 is off is predicted to be forward.

[0039] It is determined whether the shift position is the advancing position (step S207). The determining process is executed based on the shift position detected at step S200.

[0040] If it is determined that the shift position is the advancing position (step S207: YES) through the determining process, the rotation direction of the crankshaft 2 is determined to be a forward direction (step S208). If it is determined that the shift position is not the advancing position, that is, if the shift position is determined to be the reverse position (step S207: NO), the rotation direction of the crankshaft 2 is determined to be the reverse direction (step S209). The process of steps S202 and 206 corresponds to the process executed by inclination state detecting means. The determination of rotation direction executed in steps S201 to S209 of the rotation direction determining process corresponds to a process executed by rotation direction determining means.

[0041] After the rotation direction of the crankshaft 2 due to rotation of the vehicle wheels 34 is detected, it is determined whether a crank angle signal has been inputted at step S106 of Fig. 4. Specifically, within a predetermined period, it is determined whether a crank angle signal has been inputted from the crank angle sensor 50. If it is determined that a crank angle signal has been inputted (step S106: YES), it is determined that the timing rotor 61 has been rotated by rotation of the crankshaft 2 due to rotation of the vehicle wheels 34, and that the crank angle sensor 50 has outputted the crank angle signal, accordingly.

[0042] Then, in order to update the stopped crank position in accordance with the rotation direction of the crankshaft 2, it is determined whether the rotation direction of the crankshaft 2 is the forward direction or the reverse direction (step S107). Specifically, the rotation direction of the crankshaft 2 is determined to be the forward direction or the reverse direction by the rotation direction determining process executed in step S105.

[0043] If the rotation direction is determined to be forward direction through the determining process (step S107: YES), the stopped crank position is updated to an advanced position (step S108). Specifically, the crank counter ccrnk is incremented by one per input of crank angle signal, so that the crank counter ccrnk is updated.

[0044] On the other hand, if the rotation direction of the crankshaft 2 is determined to be not forward direction, or to be reverse direction (step S107: NO), the stopped crank position is updated to a retarded position (step S109). Specifically, the crank counter ccrnk is decremented by one per input of crank angle signal, so that the crank counter ccrnk is updated. The process of steps S106 through S109 corresponds to the process executed by stopped crank position updating means.

[0045] After the stopped crank position is updated in a direction corresponding to the rotation direction of the crankshaft 2, it is determined whether the automatic starting condition is met (step S110). Specifically, the state in which the driver has released the brake pedal is set as the automatic starting condition, and whether the automatic starting condition is met is determined. The depression of the brake pedal by the driver is detected based on an output signal of the brake switch 55. If no crank signal is inputted in step S106 (step S106: NO), that is, if no crank angle signal has been inputted from the crank angle sensor 50 for a predetermined period, it is determined that the crankshaft 2 has not been rotated. In this case, the stopped crank position is not updated, and the process goes to step S110, where whether the automatic starting condition is met is determined.

[0046] If the decision outcome of step S201 is negative in the rotation direction determining process shown in Fig. 5 (step S201: NO), the electronic control unit 40 determines that the shift position of the transmission 30 is at the neutral position. If the decision outcome of step S206 is negative in the rotation direction determining process shown in Fig. 5 (step S206: NO), it is determined that the vehicle 100 is neither on an uphill nor a downhill. That is, the inclination angle (an inclination angle relative to a plane perpendicular to the direction of gravity) of the road surface on which the vehicle 100 is stopped is less than the predetermined angle α, and the electronic control unit 40 determines that the vehicle 100 is unlikely to move even while the engine 1 is off. In these cases, the direction of the crankshaft 2 due to rotation of the vehicle wheels 34 is not determined, and the process goes to step S110, where whether the automatic starting condition is met is determined.

[0047] If the automatic starting condition is determined to be met through the determining process (step S110: YES), the early-stage starting control in accordance with the stopped crank position is started (step S111). The stopped crank position is a stopped crank position that is stored in the memory 41 when the automatic starting condition is met. Specifically, the stopped crank position corresponds to the stopped crank position stored in step S104 or the stopped crank position that has been updated and stored in the memory in steps S108, S109 based on the fact that the crank angle signal has been inputted. In the early-stage starting control, the fuel injection control for injecting fuel and the ignition control for igniting air-fuel mixture are executed in accordance with the stopped crank position. For example, while the stopped crank position is in a range from 180° CA to 360° CA, it is determined that the cylinder #1 as shown in Fig. 3 is in the compression stroke when the automatic starting process is initiated. The early-stage starting control is executed for ensuring the ignition of air-fuel mixture in the cylinder #1, in which the compression stroke first takes place after the starting of the engine is initiated, or for ensuring the ignition of air-fuel mixture in the cylinder #3, in which the compression stroke takes place after the cylinder #1. This completes the starting of the engine at an early stage.

[0048] If the automatic starting condition is determined to be not met in the determining process of step S110 (step S110: NO), the series of processes is temporarily suspended, and the process from step S101 is executed again. In this case, the decision outcome of step S101 is positive since the engine 1 is still turned off after being automatically stopped (step S101: YES), and the steps subsequent to step S105 is executed. In this manner, until it is determined that the automatic starting condition is met (step S110: YES), the steps subsequent to step S105 is repeated. When it is determined that a crank angle signal has been inputted (step S106: YES), the stopped crank position is repeatedly updated in accordance with the direction of rotation of the crankshaft 2 (step S108, step S109).

[0049] The preferred embodiment has the following advantages.

(1) In the case where the crankshaft 2 rotates as the vehicle wheels 34 rotate while the engine 1 is off, a signal is outputted from the crank angle sensor 50 as the crankshaft 2 rotates. Thus, the rotation of the crankshaft 2 is detected based on the output signal of the crank angle sensor 50. However, the direction of rotation of the crankshaft 2 cannot be detected based only on the output signal of the crank angle sensor 50. However, in the rotation direction determining process of the present embodiment, the direction of rotation of the crankshaft 2 that accompanies rotation of the vehicle wheels 34 when the engine 1 is off is determined. Also, when the crank angle signal is inputted, the stopped crank position is updated in accordance with the determined direction of rotation (step S108, step S109). Therefore, when the crankshaft 2 rotates when the engine 1 is off, the stopped crank position is accurately updated in accordance with the rotation direction of the crankshaft 2. That is, the stopped crank position is accurately updated after the rotation direction of the crankshaft 2 with the engine stopped is determined, and starting control according to the updated stopped crank position will be executed. Therefore, the starting control in accordance with the previously stored stopped crank position is accurately executed.

(2) Since the inclination state of the vehicle 100 is detected based on an output signal of the acceleration sensor 58, there is no need for providing a dedicated senor for detecting the direction of rotation of the crankshaft 2 caused by rotation of the vehicle wheels 34.

(3) The internal combustion engine 1 is provided with the starting device 10, which includes the starter motor 11 generating torque, the pinion gear 12, the ring gear 13, and the one-way clutch 14. The pinion gear 12 transmits the torque of the starter motor 11 to the crankshaft 2 via the flywheel 3. The ring gear 13 is provided on the outer circumference of the flywheel 3 and constantly meshes with the pinion gear 12. The ring gear 13 also transmits the torque to the crankshaft 2. The one-way clutch 14 is provided between the starter motor 11 and the crankshaft 2. The one-way clutch 14 transmits torque between the starter motor 11 and the crankshaft 2 only when the pinion gear 12 transmits rotational force in the forward direction to the ring gear 13. Since the internal combustion engine 1 has the starting device 10 described above, the crankshaft 2 is inhibited from rotating in the reverse direction when the engine 1 is off. Therefore, since the position of the crankshaft 2 when the engine 1 is stopped, that is, the stopped crank position is accurately stored in the memory 41 according to the present embodiment, the starting control according to the stopped crank position is reliably executed.

(4) The internal combustion engine 1 executes an automatic stopping/starting process, in which the engine 1 is automatically stopped when a predetermined automatic stopping condition is met during the operation of the engine 1, and the engine 1 is automatically started when a predetermined automatic starting condition is met when the engine 1 is off after being automatically stopped. Therefore, at the automatic starting process, the early-stage starting control is preferably executed to complete the starting of the engine at an early stage. In this respect, according to the present embodiment, the stopped crank position stored in the memory 41 is accurately updated by detecting the direction of rotation of the crankshaft 2 when the crankshaft 2 rotates while the engine 1 is off after being automatically stopped. Therefore, the early-stage starting control according to the previously stored stopped crank position is properly executed during the automatic starting process, which allows the engine starting to be completed at an early stage.

(5) In the starting device 10 of the internal combustion engine 1, the pinion gear 12 does not come off the ring gear 13, but constantly meshes with the ring

gear 13. Thus, compared to prior art devices, in which a pinion gear meshes with a ring gear only during starting of the engine, the automatic starting process of the engine 1 can be executed at a reliably early stage when the engine 1 is automatically started through the automatic stopping/starting control.

(6) The transmission 30 is a manual transmission of multiple gears. Therefore, compared to an automatic transmission in which rotation of the crankshaft is inputted to the transmission through a torque converter, the crankshaft 2 is easily rotated by rotation of the vehicle wheels 34 when the vehicle wheels 34 rotate in the case where the engine 1 is off and the shift position of the transmission 30 is the advancing position or the reverse position. In this respect, if the crankshaft 2 rotates when the engine 1 that is mounted on the vehicle 100 having the transmission 30 of the present embodiment is off, the stopped crank position is accurately updated in accordance with the direction of rotation of the crankshaft 2.

A control apparatus for an internal combustion engine according to a second embodiment of the present invention will now be described with reference to Figs. 1 to 5, and 6. The second embodiment is different from the first embodiment in the following points. That is, in the first embodiment, the inclination state of the vehicle 100 is detected based on an output signal of the acceleration sensor 58. In the second embodiment, the inclination state of the vehicle 100 is detected by using a navigation system 80. Those processes that are like or the same as the corresponding processes of the first embodiment will not be described.

As indicated by broken line in Fig. 1, the vehicle 100 of the present embodiment has the navigation system 80. As shown in Fig. 6, the navigation system 80 includes a navigation ECU 81 that controls all the processes executed in the system 80, a GPS receiver 82 that receives signals from GPS satellites, a gyro sensor 83 that detects the angular velocity of the vehicle 100, a road data storing device 84 that stores data on the inclination state of roads, an input device 85 through which the driver inputs information related to conditions such as a destination, and a display device 86 that displays the current position and a route to the destination outputted from the navigation ECU 81.

The road data storing device 84 includes a hard disk, a CD-ROM, or a DVD-ROM. The road data storing device 84 stores road map information such as road networks and intersections in relation to latitudes and longitudes. The road data storing device 84 also stores the inclination state of roads, that is, information of inclination angles relative to a plane perpendicular to the direction of gravity.

The navigation ECU 81 includes a CPU that executes computations, a ROM that stores programs for executing calculation of routes to a destination, route guidance, congestion avoidance, and a RAM that temporarily stores processed data. The navigation ECU 81 receives output signals from the GPS receiver 82, the gyro sensor 83, and other various sensors 90. The navigation ECU 81 executes various processes based on the received signals. The navigation ECU 81 executes a process as orientation detecting means to detect the orientation of the vehicle 100 based on the output signal of the gyro sensor 83. The various sensors 90 include, for example, the vehicle speed sensor 52 and the acceleration sensor 58.

When the rotation direction determining process of Fig. 5 is executed in the present embodiment, the inclination state of the vehicle 100 is detected by using the navigation system 80 in steps S202 and S206 for detecting the inclination state of the vehicle 100. Specifically, based on information related to the position of the vehicle 100 that corresponds to a signal received by the GPS receiver 82, and the orientation of the vehicle 100 detected through the output signal from the gyro sensor 83, the inclination state of the vehicle 100 is detected by referring to data on the inclination state of roads stored in the road data storing device 84. That is, based on the position and orientation of the vehicle 100, it is determined whether the vehicle 100 is on an uphill or a downhill.

In addition to the advantages (1) and (3) to (6), the present embodiment has the following advantage.

(7) The vehicle 100 is provided with the navigation system 80 that includes the road data storing device 84 that stores data on the inclination state of roads, the GPS receiver 82 that receives signals from GPS satellites that detect the position of the vehicle 100, the gyro sensor 83 that detects the orientation of the vehicle 100. Based on information related to the position of the vehicle 100 that corresponds to a signal received by the GPS receiver 82, and the orientation of the vehicle 100 detected through the output signal from the gyro sensor 83, the inclination state of the vehicle 100 is detected by referring to data stored in the road data storing device 84. Therefore, the inclination state of the vehicle 100 is detected using the road data storing device 84, the GPS receiver 82, and the gyro sensor 83 of the navigation system 80.

[0050] The control apparatus for an internal combustion engine according to the present invention is not to be restricted to configurations shown in the above embodiments, but may be modified as shown below.

[0051] The rotation direction determining process of Fig. 5 in the above described embodiments is only one example of procedures for determining the direction of rotation, and the order of the determination of the inclination state of the vehicle and the determination of the shift position can be altered as necessary.

[0052] The inclination state of the vehicle 100 is detected based on an output signal of the acceleration sensor 58 in the first embodiment and by using the navigation system 80 in the second embodiment. However, any other configuration that can be used for detecting the inclination state of the vehicle 100 may be used. That is, a sensor for detecting the inclination state of the road may be provided to detect the inclination state of the vehicle 100. Two or more features may be used in combination. Specifically, when the reception of the GPS receiver 82 is poor, for example, when the vehicle 100 is in a tunnel, the inclination state of the vehicle 100 may be detected based on an output signal of other sensors.

[0053] In the illustrated embodiments, the present invention is applied to an in-line four cylinder engine. The number and arrangement of cylinders in the engine are not limited. Even in an internal combustion engine other than an in-line four cylinder type, the state of stroke of each cylinder in the combustion cycle can be detected based on output signals of the crank angle sensor 50 an the cam angle sensor 51, so that the advantages (1) to (7) shown above are achieved.

[0054] The internal combustion engine 1 may be a direct fuel-injection engine, in which fuel is injected directly into the cylinders, or a port-injection engine, in which fuel is injected into the intake passage. The starting control using a previously stored stopped crank position may be executed in different manners in accordance with the type of the engine.

[0055] In the above embodiments, the crank angle sensor 50 is a known electromagnetic pickup type. However, the crank angle sensor 50 is not limited to an electromagnetic pickup type as long as it outputs signals as the crankshaft 2 rotates. For example, the crank angle sensor 50 may be a sensor using a Hall element or a sensor using a magnetoresistive element (MRE), the resistance value of which changes according to changes of the magnetic vector. In this case, the advantages (1) to (7) are also achieved. Compared to a crank angle sensor using an electromagnetic pickup, a crank angle sensor using a magnetoresistive element (MRE) is capable of highly accurately detecting rotation of the crankshaft 2 even in a low rotation speed range of the crankshaft 2.

[0056] Further, the crank angle sensor 50 may be a photoelectric sensor having a light-emitting diode, a phototransistor arranged to face the light-emitting diode, and a disk with slits between the light-emitting diode and the phototransistor. The disk with slits rotates in accordance with rotation of the crankshaft, so that the photoelectric sensor detects rotation of the crankshaft 2.

[0057] The transmission 30 is not limited to a manual transmission of multiple gears. Any other type of transmission may be used as long as it is capable of switching the shift position between a neutral position, at which rotation of the crankshaft 2 is not transmitted to the vehicle wheels 34, and advancing and reverse positions, at which rotation of the crankshaft is transmitted to the vehicle wheels 34. That is, the transmission 30 may be, for example, a multi-gear type automatic transmission (AT), which automatically changes the transmission gear ratio, and a continuously variable transmission (CVT), as long as rotational force is transmitted from the vehicle wheels to the crankshaft to some extent at the advancing position and the reverse position, at which rotation of a crankshaft is transmitted to vehicle wheels. In this case, the advantages (1) to (5), and (7) are achieved.

[0058] The starting device of the internal combustion engine 1 is not limited to the constant mesh type starting device 10. As the starting device of the internal combustion engine 1, a starting device may be used in which, during starting, a pinion gear and a ring gear mesh each other, and torque is generated by a starter. In this case, the advantages (1), (2),(4), (6), and (7) are also achieved.

[0059] The manner in which the automatic stopping/starting control is executed is not limited to those described in the embodiments. However, the automatic stopping condition, the automatic starting condition, and the methods for executing the automatic stopping process and automatic starting process may be changed as necessary. For example, the automatic stopping/starting process may be configured such that the automatic starting condition is met when the driver depresses the clutch pedal. The depression of the clutch pedal by the driver is detected based on an output signal of the clutch switch 54.

[0060] In the crank position detecting process of each of the above embodiments, the position of the crankshaft 2 (crank angle) is detected based on an output signal of the crank angle sensor 50, and the state of stroke of each cylinder (#1 to #4) is detected based on an output signal of the cam angle sensor 51. Accordingly, the crank position including the state of stroke of each cylinder is detected. However, if the state of stroke of each cylinder can be detected regardless of output signals of the cam angle sensor 51, the cam angle sensor 51, which is used for detecting the state of stroke of each cylinder, may be omitted.

[0061] In each of the above embodiments, when the shift position is determined to the neutral position (step S201: NO), the starting control in accordance with the stopped crank position that was stored when the engine was stopped is executed. However, the starting control may be executed in accordance with a stopped crank position that has been estimated through another routine process.

[0062] In the above embodiments, the automatic stopping/starting control is executed in the internal combustion engine 1. However, the present invention may be applied to an internal combustion engine in which such an automatic stopping/starting control is not executed. The advantage (1) can be achieved if the stopped crank position is updated when a crank angle signal is inputted as the crankshaft rotates while the engine is off after being stopped, that is, after the ignition switch is turned off, and the early-stage starting control is executed in accordance with the stopped crank position that is stored in advance when the engine is initially started by turning the ignition switch on. The stopped crank position detection may be executed by monitoring output signals of the crank angle sensor until a predetermined period has elapsed after the internal combustion engine is stopped, that is, after the ignition switch is turned off. If the ignition switch is turned on by the driver before the predetermined period elapses, the early-stage starting control according to a previously stopped crank position is executed. If the ignition switch is turned on by the driver after the predetermined period has elapsed, a normal injection control and ignition control are executed. The normal fuel injection control and ignition timing refer to control in which the position of the crankshaft 2 is determined based on output signals of the crank angle sensor 50 and the cam angle sensor 51 when the starting of the engine 1 is initiated, and each process of control is executed based on the determined position.

Claims

1. A control apparatus for an internal combustion engine (1), comprising crank position detecting means that detects the crank position of the engine (1) based on a signal outputted by a crank angle sensor (50) as the crankshaft (2) of the engine (1) rotates, and stopped crank position storing means that stores, as a stopped crank position, the crank position at the time the engine (1) is stopped, wherein, when the engine (1) is started, the apparatus executes starting control in accordance with the stopped crank position stored in the stopped crank position storing means, **the apparatus being characterized by:**

   inclination state detecting means that detects the inclination state of a vehicle (100) on which the engine (1) is mounted;
   shift position detecting means that detects whether the shift position of a transmission (30) mounted on the vehicle (100) while the engine (1) is off is a neutral position, at which rotation of the crankshaft (2) is not transmitted to vehicle wheels (34), an advancing position, at which rotation of the crankshaft (2) is transmitted to the vehicle wheels (34) after being varied, or a reverse position, at which rotation of the crankshaft (2) is transmitted to the vehicle wheels (34) in a reverse direction;
   rotation direction determining means, wherein, on condition that the shift position detected by the shift position detecting means is the advancing position or the reverse position, the rotation direction determining means determines the direction of rotation of the crankshaft (2) accompanying rotation of the vehicle wheels (34) while the engine (1) is off, based on the detected shift position and the inclination state detected by the inclination state detecting means; and
   stopped crank position updating means, wherein, when an output signal of the crank angle sensor (50) is detected, the stopped crank position updating means updates the stopped crank position, which is stored in the stopped crank position storing means, in accordance with the direction of rotation determined by the rotation direction determining means.

2. The control apparatus according to claim 1, **characterized in that** the inclination state detecting means detects, as the inclination state, whether the vehicle (100) is on an uphill or a downhill,
   wherein the rotation direction determining means determines that the direction of rotation of the crankshaft (2) accompanying rotation of the vehicle wheels (32) is a reverse direction when the inclination state detecting means detects that the vehicle (100) is on an uphill and the shift position detected by the shift position detecting means is the advancing position, and when the inclination state detecting means detects that the vehicle (100) is on a downhill and the shift position detected by the shift position detecting means is the reverse position.

3. The control apparatus according to claim 1 or 2, **characterized in that** the inclination state detecting means detects, as the inclination state, whether the vehicle (100) is on an uphill or a downhill,
   wherein the rotation direction determining means determines that the direction of rotation of the crankshaft (2) accompanying rotation of the vehicle wheels (34) is a forward direction when the inclination state detecting means detects that the vehicle (100) is on an uphill and the shift position detected by the shift position detecting means is the reverse position.

4. The control apparatus according to any one of claims 1 to 3, **characterized in that** the vehicle (100) includes acceleration detecting means that detects acceleration of the vehicle (100),
   wherein the inclination state detecting means detects the inclination state of the vehicle (100) based on the acceleration detected by the acceleration detecting means.

5. The control apparatus according to any one of claims 1 to 3, **characterized in that** the vehicle (100) includes a navigation system (80), wherein the navigation system (80) has road data storing means that stores data on the inclination state of roads, GPS receiving means that receives signals from GPS satellites, which detect the position of the vehicle (100), and orientation detecting means that detects the orientation of the vehicle (100),
   wherein, based on information regarding the position of the vehicle (100) that corresponds to signals re-

ceived by the GPS receiving means and the orientation of the vehicle (100) detected by the orientation detecting means, the inclination state detecting means detects the inclination state of the vehicle (100) by referring to the data stored in the road data storing means.

6. The control apparatus according to any one of claims 1 to 5, **characterized in that** the transmission (30) is a manual transmission of multiple gears.

7. The control apparatus according to any one of claims 1 to 6, **characterized in that** the engine (1) comprises:

    a starter motor (11) generating torque;
    a drive gear (12) receiving the torque from the starter motor (11);
    a driven gear (13) that constantly meshes with the drive gear (12), the driven gear transmitting the torque from the drive gear (12) to the crankshaft (2); and
    a one-way clutch (14) located between the starter motor (11) and the crankshaft (2),

   wherein the one-way clutch (14) transmits torque between the starter motor (11) and the crankshaft (2) only when the drive gear (12) transmits rotational force of rotation in the forward direction to the driven gear (13).

8. The control apparatus according to any one of claims 1 to 7, **characterized by** automatic stopping/starting means that automatically stops the engine (1) when a predetermined automatic stopping condition is met during the operation of the engine (1), and automatically starts the engine (1) when a predetermined automatic starting condition is met when the engine (1) is off after being automatically stopped,
   wherein, when automatically starting the engine (1), the control apparatus executes starting control in accordance with the stopped crank position stored in the stopped crank position storing means.

9. The control apparatus according to any one of claims 1 to 8, **characterized in that** the starting control in accordance with the stopped crank position includes injection and ignition control, in which fuel is injected and ignited in accordance with the stopped crank position stored in the stopped crank position storing means.

Fig.1

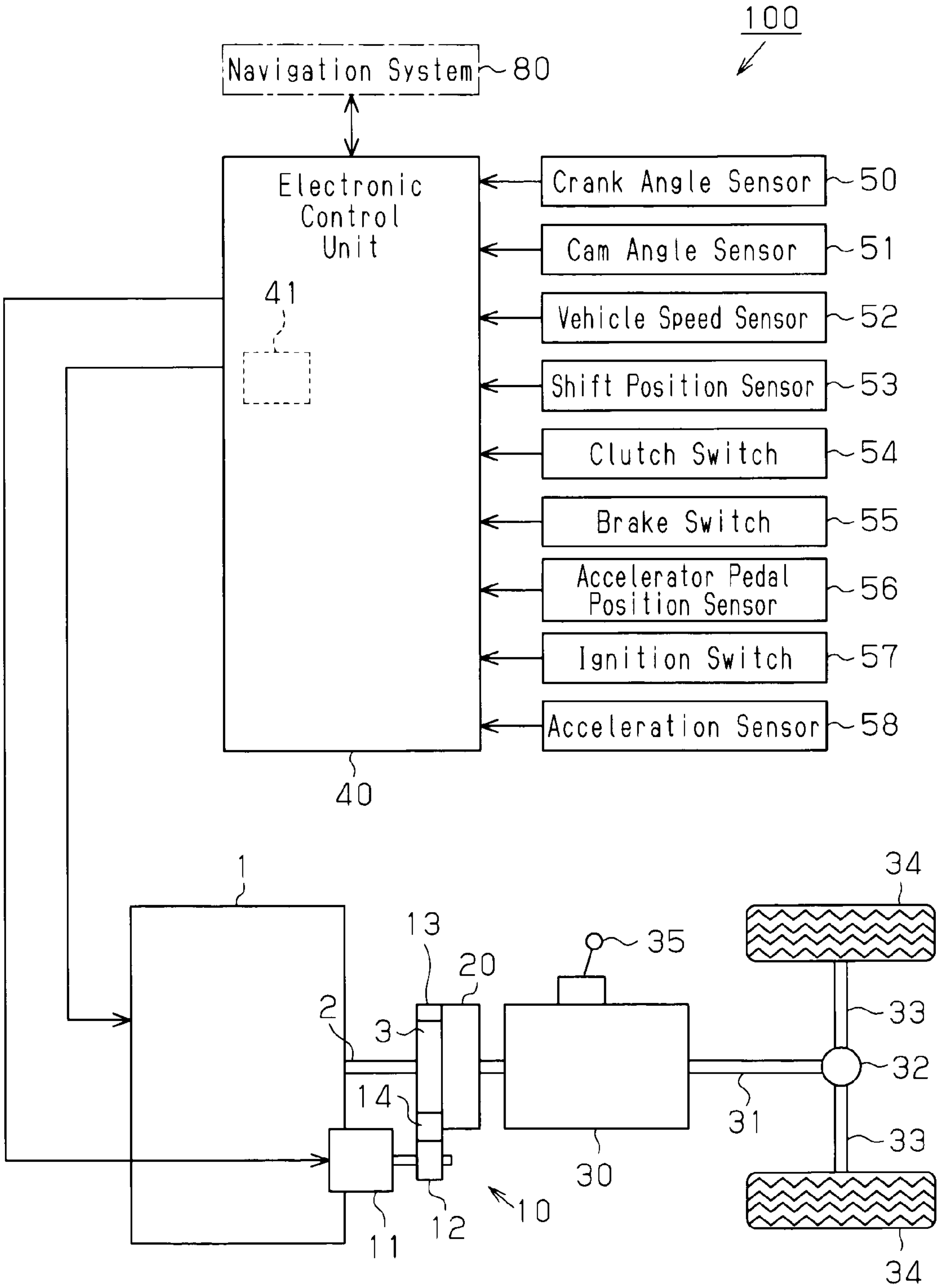

100
Navigation System
80
Electronic Control Unit
41
40
Crank Angle Sensor
50
Cam Angle Sensor
51
Vehicle Speed Sensor
52
Shift Position Sensor
53
Clutch Switch
54
Brake Switch
55
Accelerator Pedal Position Sensor
56
Ignition Switch
57
Acceleration Sensor
58
1
2
3
13
14
20
11
12
10
30
35
31
32
33
34

Fig.2A

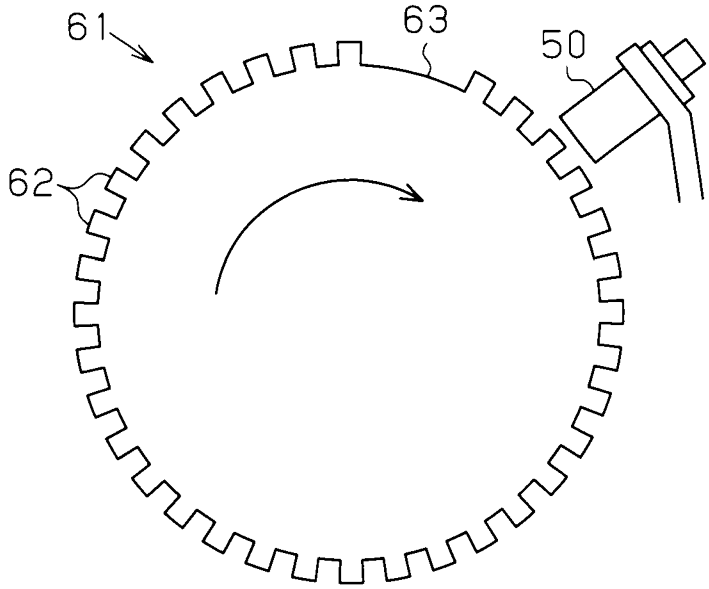


Fig.2B

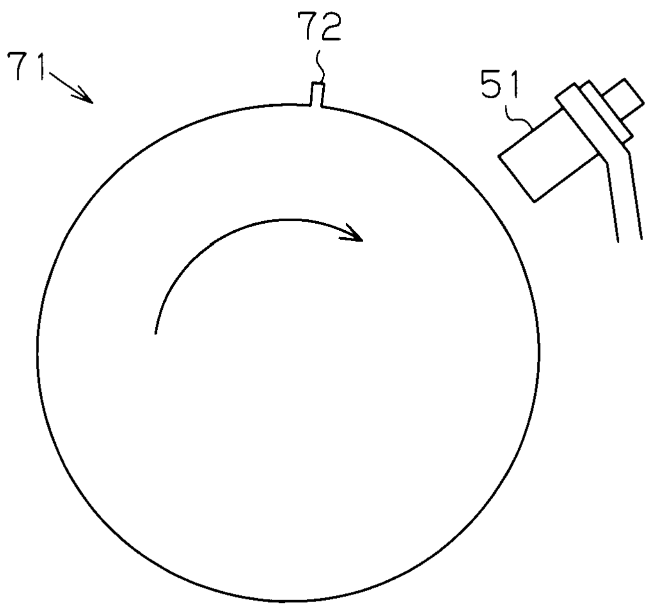


Fig.3

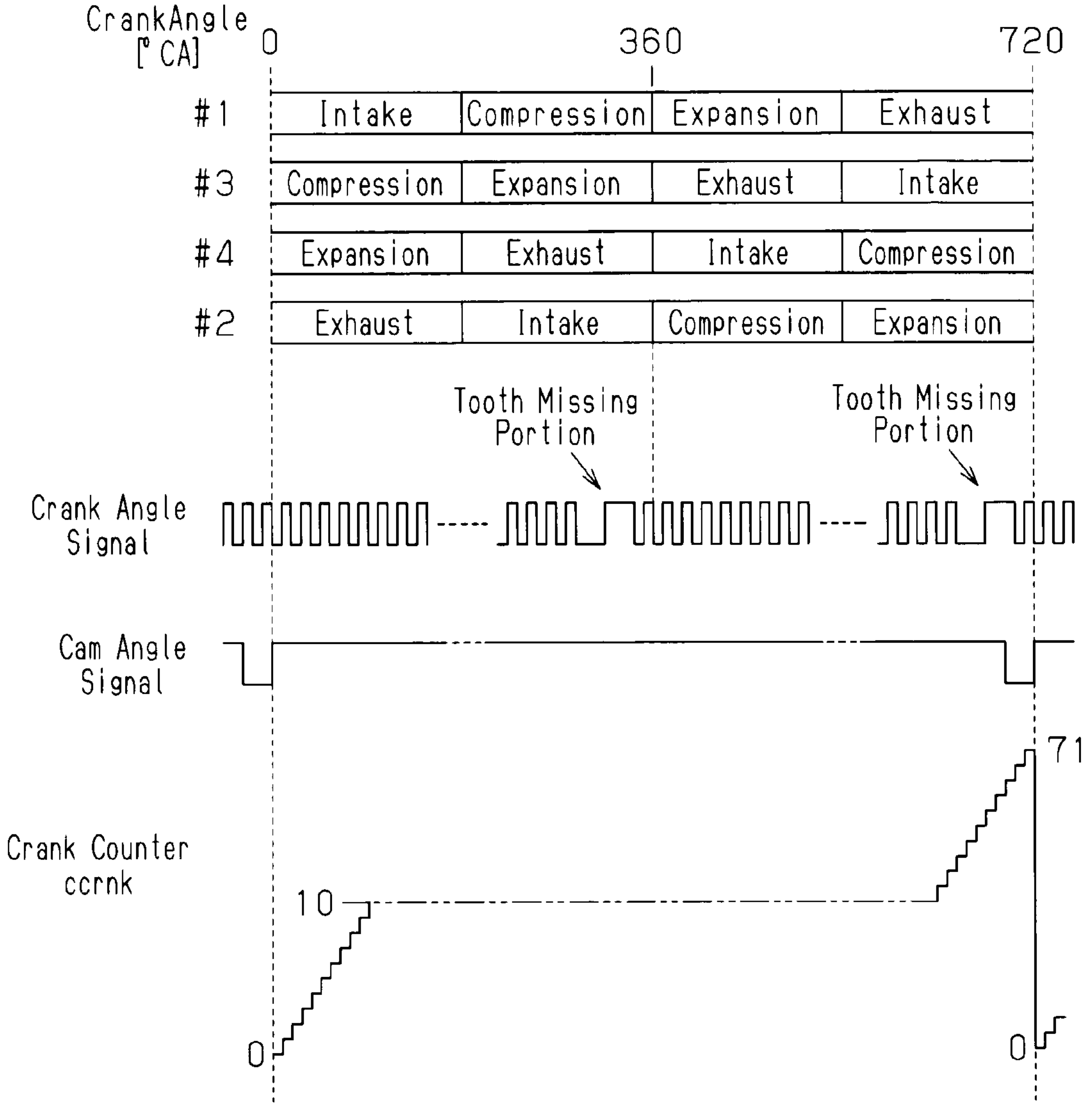

CrankAngle
[° CA]
0
360
720
#1
Intake
Compression
Expansion
Exhaust
#3
Compression
Expansion
Exhaust
Intake
#4
Expansion
Exhaust
Intake
Compression
#2
Exhaust
Intake
Compression
Expansion
Tooth Missing
Portion
Tooth Missing
Portion
Crank Angle
Signal
Cam Angle
Signal
Crank Counter
ccrnk
10
71
0
0

Fig.4

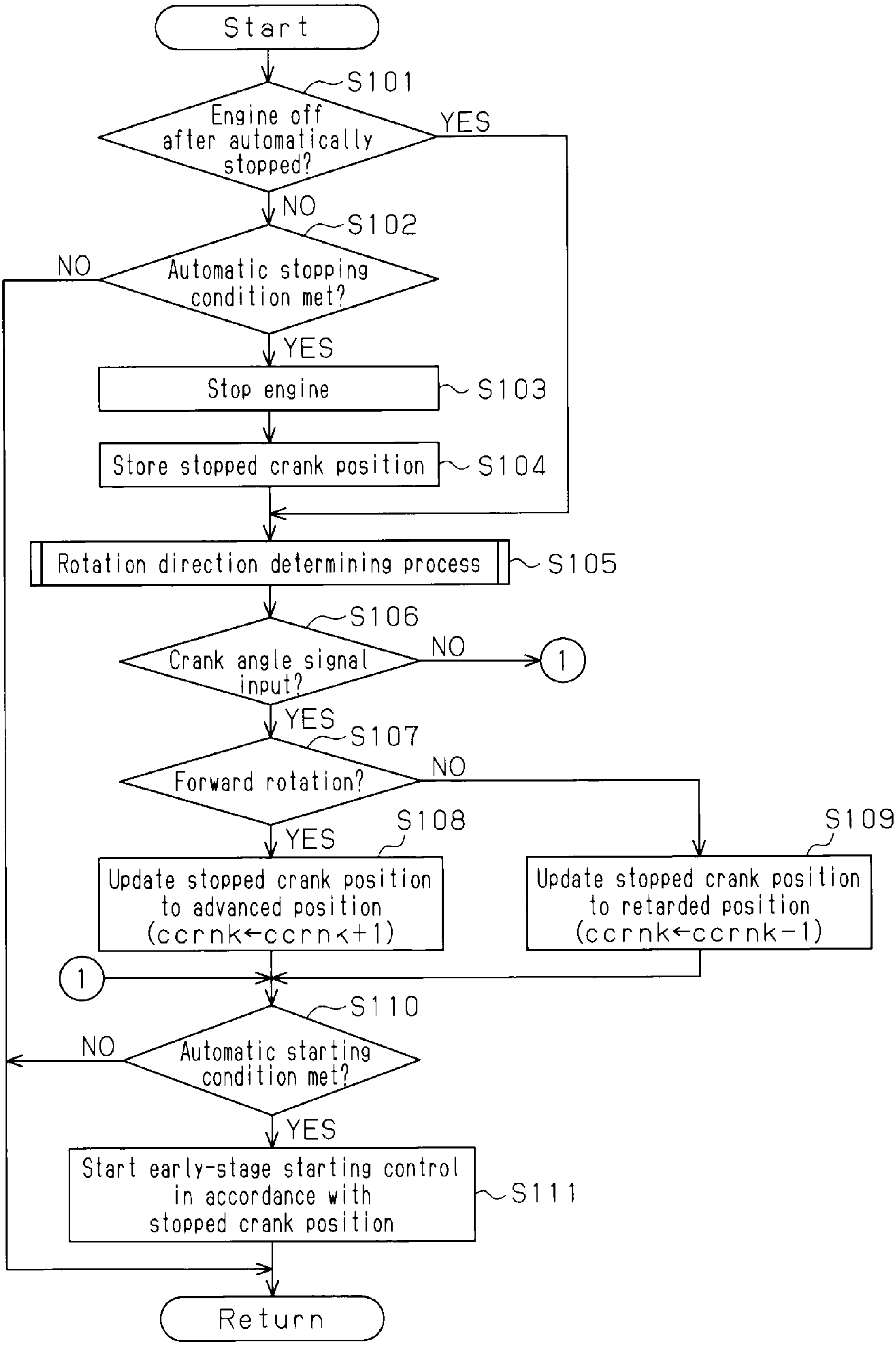

Start
S101
Engine off after automatically stopped?
YES
NO
S102
Automatic stopping condition met?
NO
YES
Stop engine
S103
Store stopped crank position
S104
Rotation direction determining process
S105
S106
Crank angle signal input?
NO
1
YES
S107
Forward rotation?
NO
YES
S108
Update stopped crank position to advanced position (ccrnk←ccrnk+1)
S109
Update stopped crank position to retarded position (ccrnk←ccrnk−1)
1
S110
Automatic starting condition met?
NO
YES
Start early-stage starting control in accordance with stopped crank position
S111
Return

Fig.5

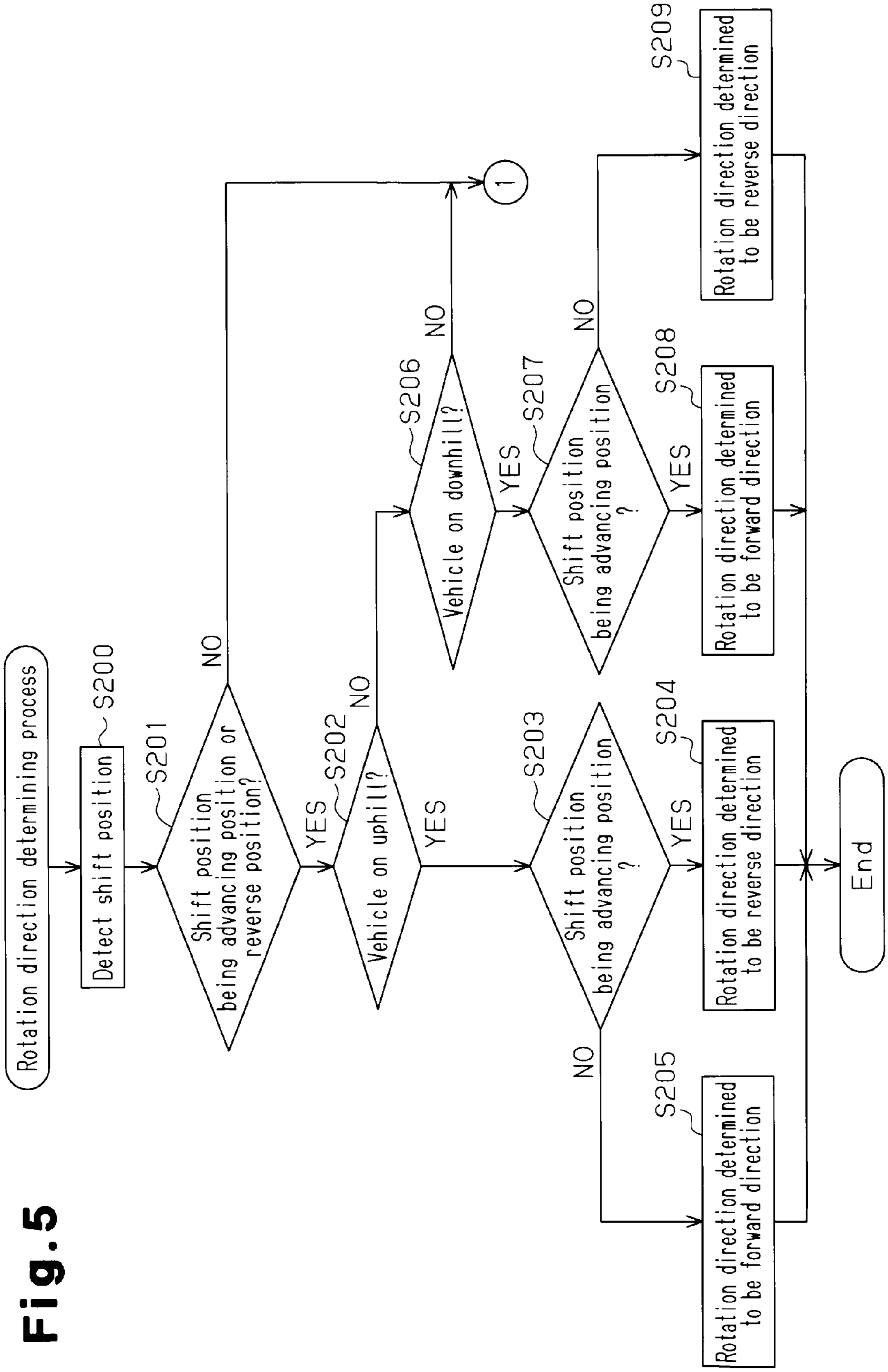
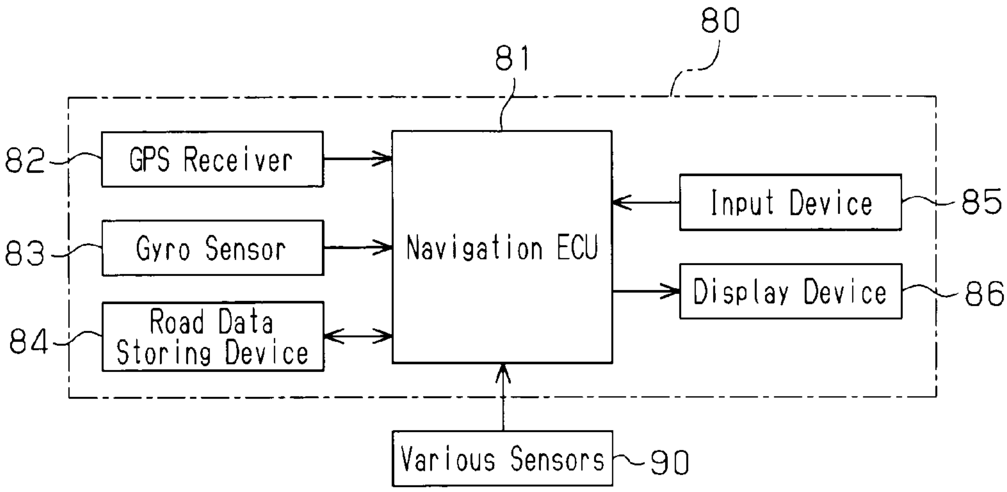

Rotation direction determining process
Detect shift position
S200
S201
Shift position being advancing position or reverse position?
YES
NO
S202
Vehicle on uphill?
YES
NO
S203
Shift position being advancing position ?
YES
NO
S204
Rotation direction determined to be reverse direction
S205
Rotation direction determined to be forward direction
S206
Vehicle on downhill?
YES
NO
1
S207
Shift position being advancing position ?
YES
NO
S208
Rotation direction determined to be forward direction
S209
Rotation direction determined to be reverse direction
End

Fig.6


80
81
82
GPS Receiver
83
Gyro Sensor
84
Road Data
Storing Device
Navigation ECU
Input Device
85
Display Device
86
Various Sensors
90

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2005351210 A **[0005]**