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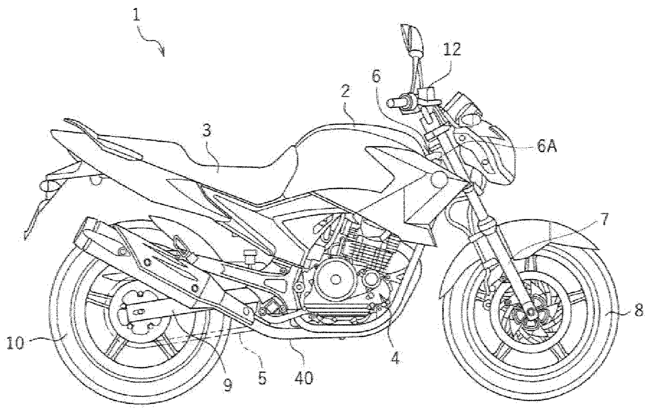
(54) FUEL SHORTAGE DETECTION DEVICE FOR INTERNAL COMBUSTION ENGINE, STRADDLED VEHICLE, AND FUEL SHORTAGE DETECTION METHOD FOR INTERNAL COMBUSTION ENGINE

(57) A fuel shortage detection device for an internal combustion engine capable of detecting fuel shortage based on the air-fuel ratio of the exhaust gas. The fuel shortage detection device for an internal combustion engine includes: an air-fuel ratio determination section 61 that determines whether the air-fuel ratio of the exhaust gas is equal to or greater than a first threshold value TH1 based on the detection result of an O2 sensor 78; an accumulated time calculation section 62 that calculates an accumulated time Ta, which is an amount of time over which the air-fuel ratio is equal to or greater than the first threshold value TH1; an accumulated time reset section 63 that resets the accumulated time Ta at every predetermined time interval B; an accumulated time determination section 64 that determines whether the accumulated time Ta is greater than or equal to a second threshold value TH2; and a fuel shortage determination section 67 that determines that there is fuel shortage when the accumulated time Ta becomes equal to or greater than the second threshold value TH2.

FIG.1



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Description

[0001] The present invention relates to a fuel shortage detection device for an internal combustion engine, a straddled vehicle, and a method for detecting fuel shortage of an internal combustion engine.

[0002] There are devices conventionally known in the art that count the number of times that the air-fuel ratio of the exhaust gas becomes equal to or greater than a predetermined threshold value, and determine that the internal combustion engine is misfiring when the count reaches a predetermined number. While there are various causes of misfires, in the case of fuel shortage, there are times when fuel is injected from the injector and there are other times when fuel is not injected from the injector. Therefore, in the case of fuel shortage, the lean state, in which the air-fuel ratio is equal to or greater than a certain level, may not continue.

[0003] JP 2018-25158 A discloses an engine controller having an air-fuel ratio detection section that detects the air-fuel ratio of the engine, a rotation fluctuation deriving section that derives a rotation fluctuation value of the engine, and a fuel shortage misfire determination section that determines that the engine is misfiring due to shortage of fuel (hereinafter referred to as fuel shortage). The fuel shortage misfire determination section counts the number of times that the engine rotation fluctuation value is equal to or greater than a predetermined rotation fluctuation threshold value, and determines that the engine is misfiring due to fuel shortage when the count is equal to or greater than a predetermined count threshold value.

[0004] The engine controller disclosed in JP 2018-25158 A determines engine fuel shortage based on the engine rotation fluctuation value when a precondition is met, where the precondition is that the air-fuel ratio of the exhaust gas is equal to or greater than an air-fuel ratio threshold value.

[0005] It is an object of the present invention to provide a fuel shortage detection device and method for an internal combustion engine capable of detecting fuel shortage based on the air-fuel ratio of the exhaust gas, and a straddled vehicle having the same.

[0006] According to the present invention said object is solved by a fuel shortage detection device for an internal combustion engine having the features of independent claim 1. Moreover, according to the present invention said object is solved by a fuel shortage detection method for an internal combustion engine having the features of independent claim 7. Preferred embodiments are laid down in the dependent claims.

[0007] A fuel shortage detection device for an internal combustion engine disclosed herein includes: an O2 sensor arranged in an exhaust passage of the internal combustion engine that detects an oxygen concentration of a gas flowing in the exhaust passage; and a determination device, which is a computer connected to the O2 sensor. The determination device includes: an air-fuel ratio determination section that determines whether an air-fuel ratio of the gas is equal to or greater than a first threshold value based on the detection result of the O2 sensor; an accumulated time calculation section that calculates an accumulated time, which is an amount of time over which the air-fuel ratio of the gas is determined to be equal to or greater than the first threshold value by the air-fuel ratio determination section; an accumulated time reset section that resets the accumulated time accumulated by the accumulated time calculation section at every predetermined time interval; an accumulated time determination section that determines whether the accumulated time is equal to or greater than a predetermined second threshold value; and a fuel shortage determination section that determines that there is fuel shortage when the accumulated time becomes equal to or greater than the second threshold value.

[0008] When an internal combustion engine runs short of fuel, the lean state may not necessarily continue, and the lean state and the non-lean state may be repeated. However, even in this case, the lean state is repeated and the accumulated time of the lean state increases. With the fuel shortage detection device described above, it is possible to detect fuel shortage based on the accumulated time of the lean state over which the air-fuel ratio is equal to or greater than the first threshold value. Now, where the fuel supply is unstable or the detection accuracy of the O2 sensor is relatively low, the lean state may be determined temporarily from the detection result of the O2 sensor even when there is no actual fuel shortage. The lean state in such cases does not last long, but as the time of the lean state is accumulated, the accumulated time will eventually become equal to or greater than the second threshold value, leading to false determination of fuel shortage. However, with the fuel shortage detection device described above, the accumulated time is reset at every predetermined time interval. Therefore, it is possible to suppress the influence of the lean state occurring due to causes other than fuel shortage, thus improving the fuel shortage detection accuracy.

[0009] The fuel shortage detection device may include a rotation speed sensor connected to the determination device that detects a rotation speed of the internal combustion engine. The determination device may include: a fluctuation value calculation section that calculates a fluctuation value of the rotation speed of the internal combustion engine; and a fluctuation value determination section that determines whether the fluctuation value of the rotation speed of the internal combustion engine is equal to or greater than a predetermined third threshold value. The fuel shortage determination section may be configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value and the fluctuation value of the rotation speed of the internal combustion engine is equal to or greater than the third threshold value.

[0010] When an internal combustion engine runs short of fuel, the rotation speed of the internal combustion engine fluctuates. With the fuel shortage detection device described above, since the variation of the rotation speed of the internal combustion engine is also taken into consideration, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

[0011] The fuel shortage detection device may include a fuel sensor connected to the determination device that detects whether an amount of fuel stored in a fuel tank is less than or equal to a predetermined fourth threshold value. The fuel shortage determination section may be configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value and the amount of fuel stored in the fuel tank is less than or equal to the fourth threshold value.

[0012] With the fuel shortage detection device described above, since the amount of fuel remaining in the fuel tank is also taken into consideration, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

[0013] The fuel shortage detection device may include: a rotation speed sensor connected to the determination device that detects a rotation speed of the internal combustion engine; and a fuel sensor connected to the determination device that detects whether an amount of fuel stored in a fuel tank is less than or equal to a predetermined fourth threshold value. The determination device may include: a fluctuation value calculation section that calculates a fluctuation value of the rotation speed of the internal combustion engine; and a fluctuation value determination section that determines whether the fluctuation value of the rotation speed of the internal combustion engine is equal to or greater than a predetermined third threshold value. The fuel shortage determination section may be configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value, the fluctuation value of the rotation speed of the internal combustion engine is equal to or greater than the third threshold value, and the amount of fuel stored in the fuel tank is less than or equal to the fourth threshold value.

[0014] With the fuel shortage detection device described above, since the fluctuation of the rotation speed of the internal combustion engine and the amount of fuel remaining in the fuel tank are also taken into consideration, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

[0015] A straddled vehicle disclosed herein includes: an internal combustion engine; a driving wheel; a power transmission mechanism that connects together the internal combustion engine and the driving wheel; and the fuel shortage detection device.

EFFECTS OF INVENTION

[0016] The present invention can provide a fuel shortage detection device for an internal combustion engine capable of detecting fuel shortage based on the air-fuel ratio, and a straddled vehicle having the same.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

FIG. 1 is a side view of a motorcycle according to an embodiment.

FIG. 2 is a conceptual diagram representing an internal combustion engine, various sensors, and an ECU.

FIG. 3 is a block diagram of a determination device.

FIG. 4(a) is a graph showing the relationship between the elapsed time and the engine rotation speed. FIG. 4(b) is a graph showing the relationship between the elapsed time and the air-fuel ratio. FIG. 4(c) is a graph showing the relationship between the elapsed time and the output value of the O2 sensor. FIG. 4(d) is a graph showing the relationship between the elapsed time and the accumulated time over which the air-fuel ratio is detected to be equal to or greater than the first threshold value. FIG. 4(e) is a time chart representing the time interval B.

FIG. 5 is a flow chart of the first determination method.

FIG. 6 is a graph representing the fluctuation value of the engine rotation speed when the motorcycle has fuel shortage while running.

FIG. 7 is a flow chart of the second determination method.

FIG. 8 is a flow chart of the third determination method.

FIG. 9 is a flow chart of the fourth determination method.

FIG. 10 is a block diagram of a determination device according to a variation.

FIG. 11 is a flow chart of a determination method according to a variation.

DESCRIPTION OF EMBODIMENTS

[0018] An embodiment of a fuel shortage detection device for an internal combustion engine and a straddled vehicle will be described with reference to the drawings. FIG. 1 is a side view of a motorcycle 1, which is an example of the straddled vehicle.

[0019] The motorcycle 1 includes a vehicle body frame 6 having a head pipe 6A, an internal combustion engine (hereinafter referred to as an engine) 4, a fuel tank 2, a seat 3, a front wheel 8, and a rear wheel 10. The engine 4, the fuel tank 2 and the seat 3 are supported on the vehicle body frame 6. A steering shaft (not shown) is rotatably supported on the head pipe 6A. A handle bar 12 is fixed to the steering shaft. A front fork 7 is fixed to the steering shaft. The front wheel 8 is linked to the lower end portion of the front fork 7. The rear wheel 10 is a driving wheel that is driven by the engine 4. The engine 4 and the rear wheel 10 are linked together so that power can be transmitted therebetween by a chain 5. The chain 5 is an example of a power transmission mechanism that transmits the power of the engine 4 to the rear wheel 10. Alternatively the power transmission mechanism may be a drive shaft or a transmission belt, etc. A rear arm 9 is pivotally supported on the vehicle body frame 6. The rear wheel 10 is linked to the rear end portion of the rear arm 9.

[0020] As shown in FIG. 2, the engine 4 includes a cylinder 21, a piston 22 arranged in the cylinder 21, a connecting rod 24 connected to the piston 22, and a crank shaft 23 connected to the connecting rod 24. The engine 4 includes a combustion chamber 25, an ignition device 50, an intake valve 32, and an exhaust valve 42. An intake passage 30 including an intake pipe, or the like, and an exhaust passage 40 including an exhaust pipe, or the like, are connected to the engine 4. A throttle valve 34 is arranged in the intake passage 30. A catalyst 44 is arranged in the exhaust passage 40.

[0021] A fuel pump 48 is arranged in the fuel tank 2. A fuel injection valve 52 is attached to the intake passage 30. The fuel pump 48 and a fuel injection valve 52 are connected together by a fuel pipe 46.

[0022] The fuel tank 2 is provided with a fuel sensor 80 that detects whether the amount of fuel is less than or equal to a predetermined threshold value. The intake passage 30 is provided with a pressure sensor 74. The engine 4 includes a rotation speed sensor 70 that detects the rotation speed of the crank shaft 23 (hereinafter referred to as the engine rotation speed). The exhaust passage 40 is provided with an O2 sensor 78 that detects the oxygen concentration.

[0023] The motorcycle 1 includes an ECU (Electronic Control Unit) 90, which is a computer. The ECU 90 includes a CPU 91, a ROM 92, and a RAM 93. The ECU 90 controls the engine 4. In the present embodiment, the ECU 90 functions also as a determination device 60 that determines that the engine 4 has fuel shortage.

[0024] FIG. 3 is a block diagram of the determination device 60. The determination device 60 is communicably connected to the O2 sensor 78, the rotation speed sensor 70, and the fuel sensor 80. The determination device 60 is configured to obtain the air-fuel ratio of the gas flowing in the exhaust passage 40 (hereinafter referred to as exhaust gas) by receiving a signal from the O2 sensor 78. The determination device 60 is configured to obtain the engine rotation speed by receiving a signal from the rotation speed sensor 70. The determination device 60 is configured to obtain the amount of fuel (hereinafter referred to simply as fuel amount) stored in the fuel tank 2 by receiving a signal from the fuel sensor 80.

[0025] The determination device 60 includes an air-fuel ratio determination section 61, an accumulated time calculation section 62, an accumulated time reset section 63, an accumulated time determination section 64, a fluctuation value calculation section 65, a fluctuation value determination section 66, and a fuel shortage determination section 67 by executing a computer program stored in the ROM 92, or the like. The determination device 60 also includes a fuel shortage count storage section 68, which is a nonvolatile memory. The air-fuel ratio determination section 61 determines whether the air-fuel ratio A/F of the exhaust gas is equal to or greater than a predetermined threshold value (hereinafter referred to as the first threshold value) TH1 based on the detection result of the O2 sensor 78. The accumulated time calculation section 62 calculates the accumulated time Ta of the time over which the air-fuel ratio A/F is determined to be equal to or greater than the first threshold value TH1. The accumulated time reset section 63 resets the accumulated time Ta (that is, sets the accumulated time Ta to zero) accumulated by the accumulated time calculation section 62 at every predetermined time interval B. The accumulated time determination section 64 determines whether the accumulated time Ta is equal to or greater than a predetermined threshold value (hereinafter referred to as second threshold value) TH2. The fluctuation value calculation section 65 calculates the fluctuation value DVe of the engine rotation speed. The fluctuation value determination section 66 determines whether the fluctuation value DVe of the engine rotation speed is equal to or greater than a predetermined threshold value (hereinafter referred to as third threshold value) TH3. The fuel shortage determination section 67 determines that there is fuel shortage when a predetermined determination condition is met. The fuel shortage count storage section 68 stores the number of times fuel shortage has been determined.

[0026] FIG. 4(a) to FIG. 4(d) are graphs showing changes in parameters when fuel shortage occurs while the motorcycle 1 is running. The horizontal axis of each graph represents the elapsed time T. FIG. 4(a) is a graph representing the relationship between the elapsed time T and the engine rotation speed Ve. FIG. 4(b) is a graph representing the relationship between the elapsed time T and the air-fuel ratio A/F. FIG. 4(c) is a graph representing the relationship between the elapsed time T and the output value S of the O2 sensor 78. Here, the air-fuel ratio A/F is regarded as being equal to or greater than the first threshold value TH1 when the output value S of the O2 sensor 78 is less than or equal to the threshold value S1. FIG. 4(d) is a graph representing the relationship between the elapsed time T and the accumulated time Ta over which the air-fuel ratio A/F is detected to be equal to or greater than the first threshold value TH1. FIG. 4(e) represents the time interval B.

[0027] In the example shown in FIG. 4(a) to FIG. 4(d), at T=T1, the air-fuel ratio A/F is equal to or greater than the first threshold value TH1, and the exhaust gas is in the lean state (see FIG. 4(b)). In the lean state, the engine rotation speed Ve decreases (see FIG. 4(a)). As shown in FIG. 4(c), the output value S of the O2 sensor 78 may fluctuate even before fuel shortage occurs, and the output value S of the O2 sensor 78 may temporarily be less than or equal to the threshold value S1 indicating that the engine is in the lean state. Note however that it is not actually the lean state (see FIG. 4(b)), the state in which the output value S of the O2 sensor 78 is less than or equal to the threshold value S1 does not continue for a long period of time. Therefore, the accumulated time Ta increases little by little, but will not be equal to or greater than the second threshold value TH2 during the limited time interval B (see FIG. 4(d)). On the other hand, when fuel shortage actually occurs and the lean state occurs, the output value S of the O2 sensor 78 remains less than or equal to the threshold value S1. Therefore, the accumulated time Ta becomes equal to or greater than the second threshold value TH2 during the time interval B. In the example shown in FIG. 4(d), the accumulated time Ta becomes the second threshold value TH2 when T=T2.

[0028] Therefore, in the present embodiment, the fuel shortage determination section 67 determines, as at least one of the determination conditions, whether the accumulated time Ta has become equal to or greater than the second threshold value TH2 during the time interval B. The fuel shortage determination section 67 determines that there is fuel shortage when at least the accumulated time Ta becomes equal to or greater than the second threshold value TH2. Next, some examples of the determination method performed by the determination section 60 will be described.

(First determination method)

[0029] FIG. 5 is a flow chart of the first determination method. In the first determination method, in step S1, the air-fuel ratio determination section 61 determines whether the air-fuel ratio A/F is equal to or greater than the first threshold value TH1. If the air-fuel ratio A/F is equal to or greater than the first threshold value TH1, the process proceeds step S2, and if the air-fuel ratio A/F is less than the first threshold value TH1, the process returns to step S1. In step S2, the accumulated time Ta is calculated by the accumulated time calculation section 62. Then, the process proceeds to step S3, and the accumulated time determination section 64 determines whether the accumulated time Ta is equal to or greater than the second threshold value TH2. If the accumulated time Ta is determined to be equal to or greater than the second threshold value TH2, the process proceeds to step S4, and if the accumulated time Ta is determined to be less than the second threshold value TH2, the process proceeds to step S6. When the process proceeds to step S4, it is determined by the fuel shortage determination section 67 that there is fuel shortage. Thereafter, in step S5, the number of times fuel shortage has been determined is added to the fuel shortage count storage section 68. Note that the count stored in the fuel shortage count storage section 68 (the number of times fuel shortage has been determined) can be transferred as diagnostic data by a service person, or the like, connecting a service tool to the on-board diagnostic device (OBD). In step S6, it is determined whether the count time Ti has become equal to or greater than the time interval B. If it is determined that the count time Ti is equal to or greater than the time interval B, the accumulated time Ta and the count time Ti are reset in step S7, and the process returns to step S1. That is, the accumulated time Ta and the count time Ti are reset to zero, and the process returns to step S1. If it is determined in step S6 that the count time Ti is less than the time interval B, the process returns to step S1.

[0030] As described above, even when there is no fuel shortage, the output value S of the O2 sensor 78 may temporarily be less than or equal to the threshold value S1. There may be cases where even if there is no fuel shortage, it is temporarily considered to be the lean state. Therefore, if fuel shortage is determined based only on the output value S of the O2 sensor 78, there may occur false determination. On the other hand, if there is no fuel shortage, the state considered to be the lean state will not last long, but if there is fuel shortage, the state considered to be the lean state will last long. According to the determination method described above, fuel shortage is determined based on the accumulated time Ta of the state considered to be the lean state (that is, the state in which the air-fuel ratio A/F is equal to or greater than the first threshold value TH1 based on the detection result of the O2 sensor 78). Therefore, it is possible to suppress the influence of a temporary lean state caused by causes other than fuel shortage. Therefore, it is possible to improve the fuel shortage detection accuracy.

(Second determination method)

[0031] FIG. 6 is a graph representing the fluctuation value DVe of the engine rotation speed when fuel shortage occurs while the motorcycle 1 is running. Note that the fluctuation value DVe of the engine rotation speed is DVe=Ve1-Ve2, where Ve1 and Ve2 are the engine rotation speeds before and after a fluctuation for a predetermined period of time, respectively. As shown in FIG. 6, when the lean state is reached at T=T1, the fluctuation value DVe of the engine rotation speed becomes equal to or greater than the threshold value (hereinafter referred to as the third threshold value) TH3. In the second determination method, fuel shortage is determined based on the fluctuation value DVe of the engine rotation speed, in addition to the accumulated time Ta described above.

[0032] FIG. 7 is a flow chart of the second determination method. Also in the second determination method, as in the first determination method, steps S1 to S7 described above are performed. Note however that in the second determination method, if it is determined in step S3 that the accumulated time Ta is equal to or greater than the second threshold value TH2, the process proceeds to step S31, and it is further determined by the fuel shortage determination section 67 whether the fluctuation value DVe of the engine rotation speed equal to or greater than the third threshold value TH3. If the fluctuation value DVe of the engine rotation speed is determined to be equal to or greater than the third threshold value TH3, the process proceeds to step S4, in which it is determined by the fuel shortage determination section 67 that there is fuel shortage. If it is determined in step S31 that the fluctuation value DVe of the engine rotation speed is less than the third threshold value TH3, the process proceeds to step S6. Alternatively to the example as explained with regard to the order of processes of step S3 and step S31, Step S31 may be performed before step S3 or may be performed simultaneously with step S3.

[0033] As described above, according to the second determination method, fuel shortage is determined based on both the accumulated time Ta of the lean state and the fluctuation value DVe of the engine rotation speed. Since the fluctuation of the engine rotation speed is also taken into account, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

(Third determination method)

[0034] As described above, the fuel sensor 80 detects whether the fuel amount in the fuel tank 2 is less than or equal to a threshold value. In the present embodiment, the threshold value is not zero, but is set to a predetermined value as the fuel amount that allows the motorcycle 1 to travel a predetermined distance, so that the passenger can be warned before fuel tank 2 becomes empty. This threshold value will be hereinafter referred to as the fourth threshold value TH4. If the fuel amount M in the fuel tank 2 (hereinafter simply referred to as fuel amount) is greater than the fourth threshold value TH4, no fuel shortage occurs. In the third determination method, fuel shortage is determined based on the detection result of the fuel sensor 80, in addition to the accumulated time Ta described above.

[0035] FIG. 8 is a flow chart of the third determination method. Also in the third determination method, as in the first determination method, steps S1 to S7 described above are performed. Note however that in the third determination method, if it is determined in step S3 that the accumulated time Ta is equal to or greater than the second threshold value TH2, the process proceeds to step S32, and the fuel shortage determination section 67 receives a signal from the fuel sensor 80 to determine whether the fuel amount M is less than or equal to the fourth threshold value TH4. If the fuel amount M is determined to be less than or equal to the fourth threshold value TH4, the process proceeds to step S4, in which the fuel shortage determination section 67 determines that there is fuel shortage. If it is determined in step S32 that the fuel amount M is greater than the fourth threshold value TH4, the process proceeds to step S6. Alternatively to the example as explained with regard to the order of processes of steps S3 and step S32. Step S32 may be performed before step S3 or may be performed simultaneously with step S3.

[0036] According to the third determination method, fuel shortage is determined based on both the accumulated time Ta of the lean state and the fuel amount M in the fuel tank 2. Since the fuel amount M in the fuel tank 2 is also taken into account, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

[0037] Note that the fuel shortage determination method using the fuel sensor 80 may be selectable from among Methods 1 to 3 below, for example.

[0038] Method 1: Based on the resistance value of the fuel sensor 80, fuel shortage is determined when threshold value A ≤ resistance value.

[0039] Method 2: After it is determined by Method 1 that there is fuel shortage, the period of time from when threshold value A > resistance value is reached by refueling until a certain distance is traveled is determined to be fuel shortage.

[0040] Method 3: After it is determined by Method 1 that there is fuel shortage, the distance traveled after the determination is made is accumulated from zero, and fuel shortage is determined when threshold value B ≤ cumulative distance ≤ threshold value C is satisfied for the cumulative distance.

(Fourth determination method)

[0041] FIG. 9 is a flow chart of the fourth determination method. In the fourth determination method, fuel shortage is determined based on the accumulated time Ta, the fluctuation value DVe of the engine rotation speed, and the detection result of the fuel sensor 80. Also in the fourth determination method, as in the first determination method, steps S1 to S7 described above are performed. Note however that in the fourth determination method, if it is determined in step S3 that the accumulated time Ta is equal to or greater than the second threshold value TH2, the process proceeds to step S31, and it is further determined by the fuel shortage determination section 67 whether the fluctuation value DVe of the engine rotation speed is equal to or greater than the third threshold value TH3. If the fluctuation value DVe of the engine rotation speed is determined to be equal to or greater than the third threshold value TH3, the process proceeds to step S32, and the fuel shortage determination section 67 receives a signal from the fuel sensor 80 to determine whether the fuel amount M is less than or equal to the fourth threshold value TH4. If the fuel amount M is determined to be less than or equal to the fourth threshold value TH4, the process proceeds to step S4, in which the fuel shortage determination section 67 determines that there is fuel shortage. If it is determined in step S31 that the fluctuation value DVe of the engine rotation speed is less than the third threshold value TH3, or if it is determined in step S32 that the fuel amount M is greater than the fourth threshold value TH4, the process proceeds step S6. Alternatively to the example as explained with regard to the order of processes of step S3, step S31 and step S32 another order may be taken.

[0042] As described above, according to the fourth determination method, fuel shortage is determined based on the accumulated time Ta of the lean state, the fluctuation value DVe of the engine rotation speed, and the fuel amount M in the fuel tank 2. Since not only the accumulated time Ta of the lean state, but also the fluctuation of the engine rotation speed and the fuel amount in the fuel tank 2 are taken into account, false determination is less likely to occur. Therefore, it is possible to further improve the fuel shortage detection accuracy.

[0043] The fuel shortage detection device and the straddled vehicle according to one embodiment have been described above. The present teaching is also applicable to other embodiments.

[0044] The determination device 60 is the ECU 90 that controls the engine 4 in the embodiment described above. Alternatively, the determination device 60 may be separate from the ECU 90. The determination device 60 may be a computer separate from the ECU 90.

[0045] The number of times fuel shortage is determined is stored in the fuel shortage count storage section 68 when it is determined by the fuel shortage determination section 67 that there is fuel shortage in the embodiment described above. In addition thereto or alternatively, when fuel shortage is determined, the passenger, etc., may be notified of fuel shortage. As shown in FIG. 10, the motorcycle 1 may include a notification device 77 that can communicate with the determination device 60. The first to fourth determination methods described above may include step S51 in which the notification device 77 notifies the passenger, etc., of fuel shortage, instead of step S5 described above (see FIG. 11). Moreover, the notification device 77 may, for example, notify the passenger by lighting a warning lamp, displaying information on a display device, or outputting audio from a speaker, etc.

[0046] A straddled vehicle refers to a vehicle that is straddled by a passenger. The straddled vehicle may be the motorcycle 1. Alternatively, the straddled vehicle may be an auto tricycle, an ATV (All Terrain Vehicle), or a snowmobile, for example.

DESCRIPTION OF REFERENCE SIGNS

[0047] 1: Automobile (straddled vehicle), 4: Internal combustion engine, 5: Chain (power transmission mechanism), 10: Rear wheel (driving wheel), 40: Exhaust passage, 60: Determination device, 61: Air-fuel ratio determination section, 62: Accumulated time calculation section, 63: Accumulated time reset section, 64: Accumulated time determination section, 65: Fluctuation value calculation section, 66: Fluctuation value determination section, 67: Fuel shortage determination section, 70: Rotation speed sensor, 78: O2 sensor, 80: Fuel sensor

Claims

1. A fuel shortage detection device for an internal combustion engine (4), comprising:

an O2 sensor (78) arranged in an exhaust passage (40) of the internal combustion engine (4) and configured to detect an oxygen concentration of a gas flowing in the exhaust passage (40); and
a determination device (60) connected to the O2 sensor (78),
wherein the determination device (60) includes:

an air-fuel ratio determination section (61) configured to determine whether an air-fuel ratio of the gas is equal to or greater than a first threshold value (TH1) based on a detection result of the O2 sensor (78);
an accumulated time calculation section (62) configured to calculate an accumulated time, which is an amount of time over which the air-fuel ratio of the gas is determined to be equal to or greater than the first threshold value (TH1) by the air-fuel ratio determination section (61);
an accumulated time reset section (63) configured to reset the accumulated time calculated by the accumulated time calculation section (62) at every predetermined time interval (B);
an accumulated time determination section (64) configured to determine whether the accumulated time is equal to or greater than a predetermined second threshold value (TH2); and
a fuel shortage determination section (67) configured to determine that there is fuel shortage when the accumulated time becomes equal to or greater than the second threshold value (TH2).

2. The fuel shortage detection device for an internal combustion engine (4) according to claim 1, comprising:

a rotation speed sensor (70) connected to the determination device (60) and
configured to detect a rotation speed of the internal combustion engine (4),
wherein the determination device (60) includes:

a fluctuation value calculation section (65) configured to calculate a fluctuation value of the rotation speed of the internal combustion engine (4); and
a fluctuation value determination section (66) configured to determine whether the

fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than a predetermined third threshold value (TH3),

wherein the fuel shortage determination section (67) is configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2) and the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than the third threshold value (TH3).

3. The fuel shortage detection device for an internal combustion engine (4) according to claim 1, comprising:

a fuel sensor (80) connected to the determination device (60) and configured to detect whether an amount of fuel stored in a fuel tank (2) is less than or equal to a predetermined fourth threshold value (TH4),
wherein the fuel shortage determination section (67) is configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2) and the amount of fuel stored in the fuel tank (2) is less than or equal to the fourth threshold value (TH4).

4. The fuel shortage detection device for an internal combustion engine (4) according to claim 1, comprising:

a rotation speed sensor (70) connected to the determination device (60) and configured to detect a rotation speed of the internal combustion engine (4); and
a fuel sensor (80) connected to the determination device (60) and configured to detect whether an amount of fuel stored in a fuel tank (2) is less than or equal to a predetermined fourth threshold value (TH4),
wherein the determination device (60) includes:

a fluctuation value calculation section (65) configured to calculate a fluctuation value of the rotation speed of the internal combustion engine (4); and
a fluctuation value determination section (66) configured to determine whether the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than a predetermined third threshold value (TH3),

wherein the fuel shortage determination section (67) is configured to determine that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2), the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than the third threshold value (TH3), and the amount of fuel stored in the fuel tank (2) is less than or equal to the fourth threshold value (TH4).

5. The fuel shortage detection device for an internal combustion engine (4) according to at least one of the claims 1 to 4, wherein the determination device (60) is a computer.

6. A straddled vehicle comprising:

an internal combustion engine (4);
a driving wheel (10);
a power transmission mechanism (5) that connects together the internal combustion engine (4) and the driving wheel (10); and
the fuel shortage detection device for an internal combustion engine (4) according to any one of claims 1 to 5.

7. A fuel shortage detection method for an internal combustion engine (4), comprising the steps of:

detecting an oxygen concentration of a gas flowing in an exhaust passage (40) of the internal combustion engine (4),
determining whether an air-fuel ratio of the gas is equal to or greater than a predetermined first threshold value (TH1);
calculating an accumulated time, which is an amount of time over which the air-fuel ratio of the gas is determined to be equal to or greater than the first threshold value (TH1) by the air-fuel ratio determination step;
resetting the accumulated time calculated by the accumulated time calculation step at every predetermined time interval (B);
determining whether the accumulated time is equal to or greater than a predetermined second threshold value (TH2); and
determining that there is fuel shortage when the accumulated time becomes equal to or greater than the second threshold value (TH2).

8. The fuel shortage detection method for an internal combustion engine (4) according to claim 7, comprising:

detecting a rotation speed of the internal combustion engine (4),
calculating a fluctuation value of the rotation speed of the internal combustion engine (4);

determining whether the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than a predetermined third threshold value (TH3), and
determining that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2) and the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than the third threshold value (TH3).

9. The fuel shortage detection method for an internal combustion engine (4) according to claim 7, comprising:

detecting an amount of fuel stored in a fuel tank (2),
determining whether the amount of fuel stored in the fuel tank (2) is less than or equal to a predetermined fourth threshold value (TH4), and
determining that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2) and the amount of fuel stored in the fuel tank (2) is less than or equal to the fourth threshold value (TH4).

10. The fuel shortage detection method for an internal combustion engine (4) according to claim 7, comprising:

detecting a rotation speed of the internal combustion engine (4),
calculating a fluctuation value of the rotation speed of the internal combustion engine (4);
determining whether the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than a predetermined third threshold value (TH3);
detecting an amount of fuel stored in a fuel tank (2),
determining whether the amount of fuel stored in the fuel tank (2) is less than or equal to a predetermined fourth threshold value (TH4), and
determining that there is fuel shortage when the accumulated time is equal to or greater than the second threshold value (TH2), the fluctuation value of the rotation speed of the internal combustion engine (4) is equal to or greater than the third threshold value (TH3), and the amount of fuel stored in the fuel tank (2) is less than or equal to the fourth threshold value (TH4).

FIG.1

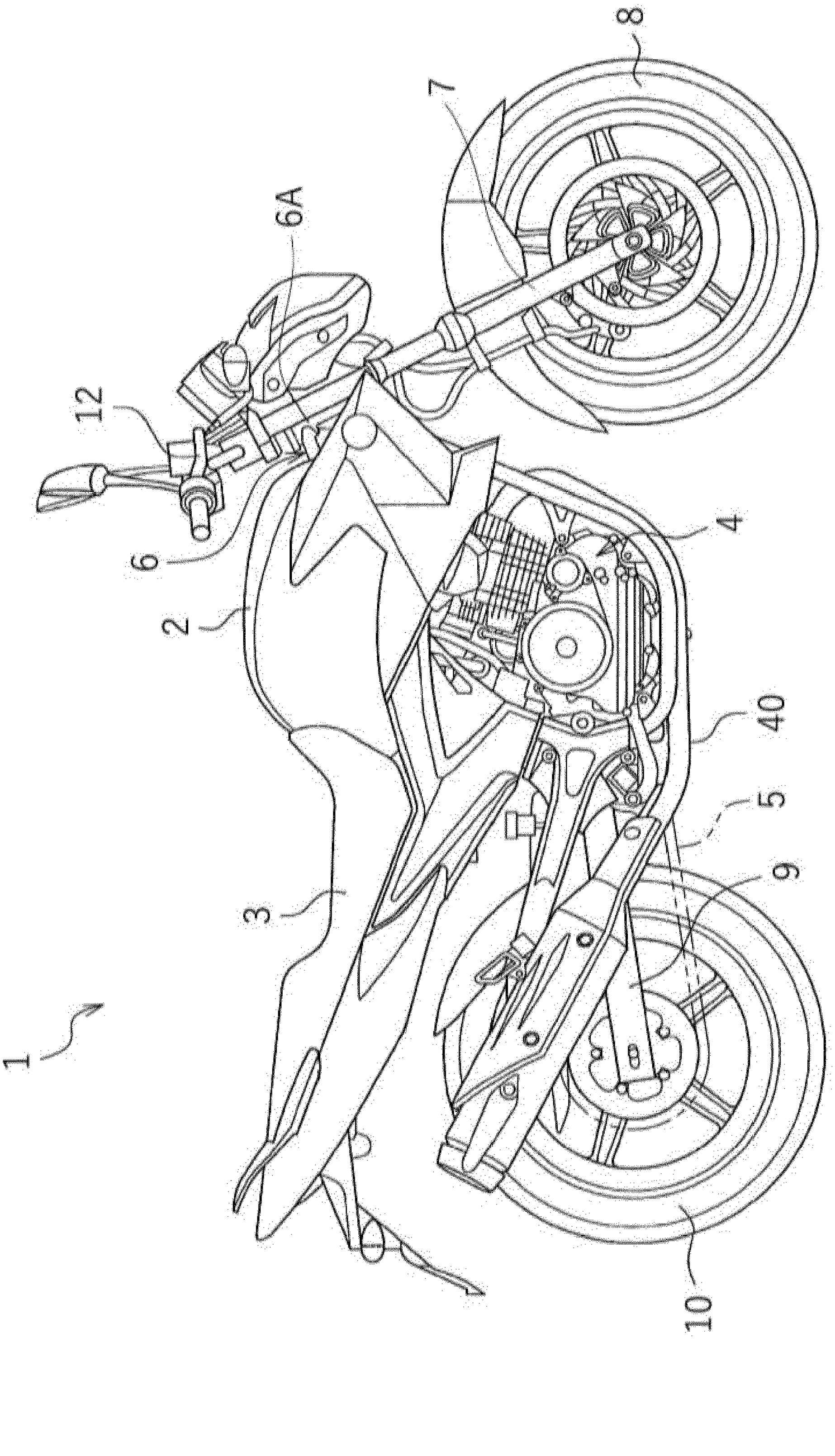


FIG.2

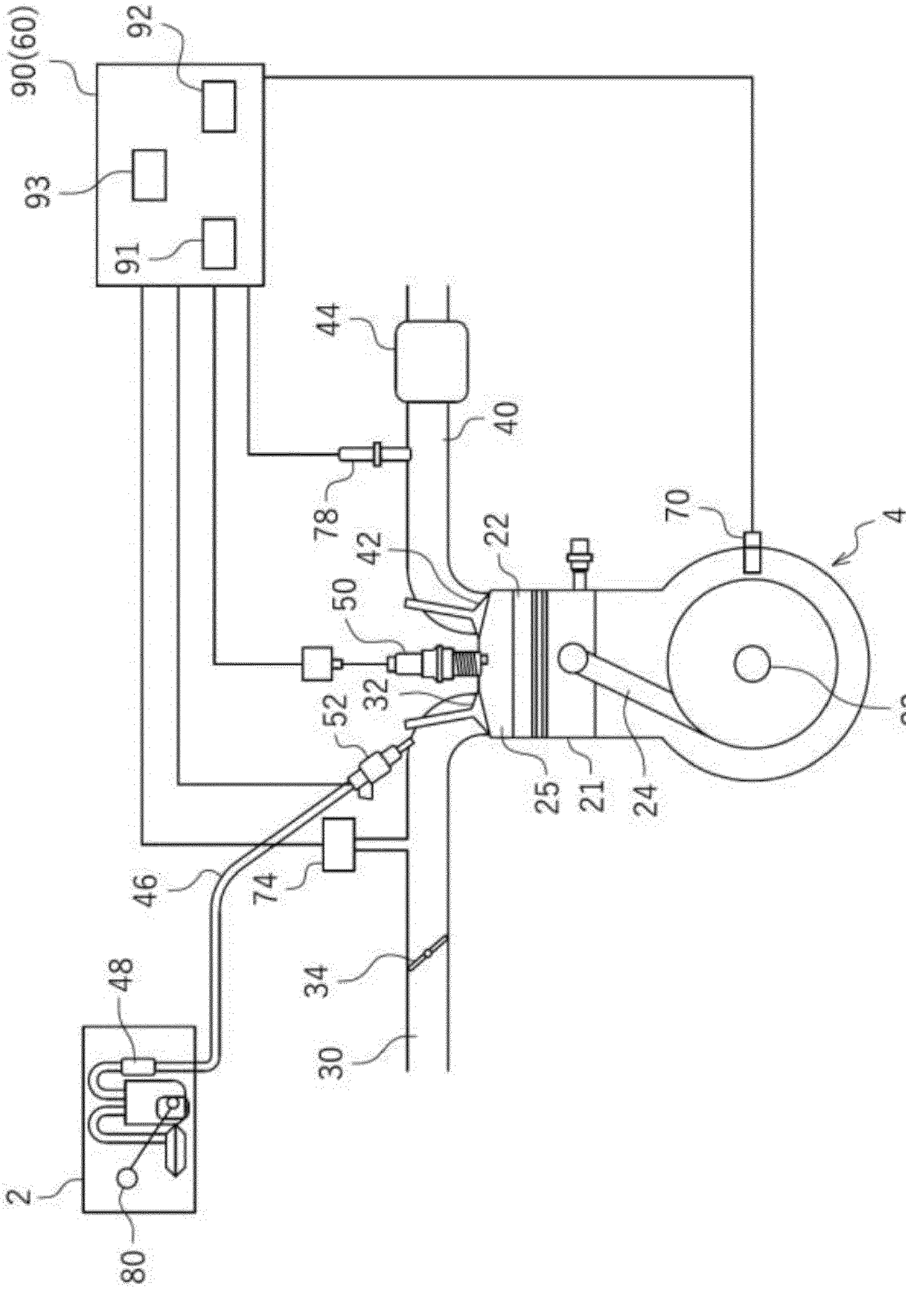

90(60)
92
93
91
44
40
78
42
22
70
4
50
32
52
23
25
21
24
46
74
34
30
48
2
80

FIG.3

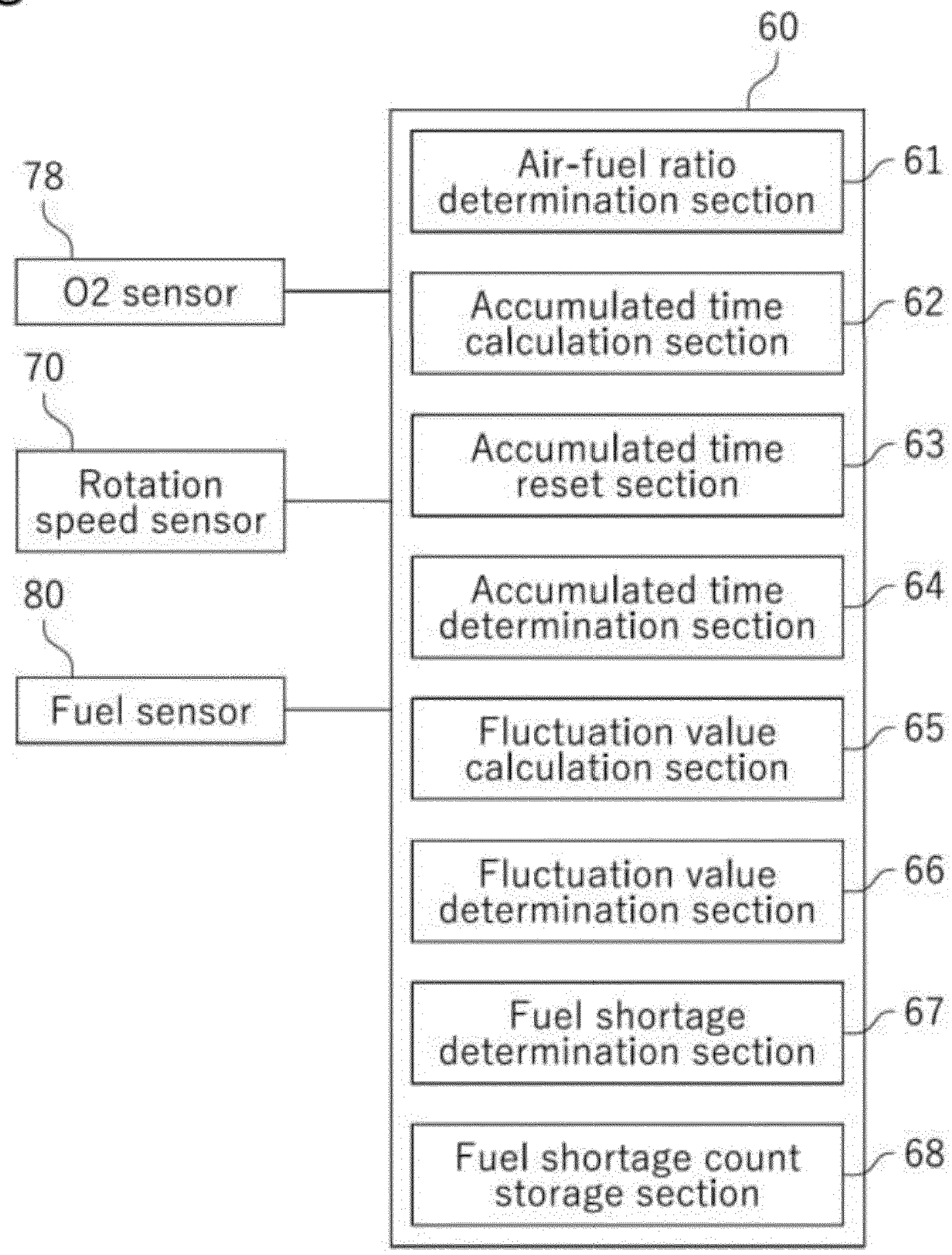

60
78
O2 sensor
70
Rotation speed sensor
80
Fuel sensor
Air-fuel ratio determination section
61
Accumulated time calculation section
62
Accumulated time reset section
63
Accumulated time determination section
64
Fluctuation value calculation section
65
Fluctuation value determination section
66
Fuel shortage determination section
67
Fuel shortage count storage section
68

FIG.4(a)

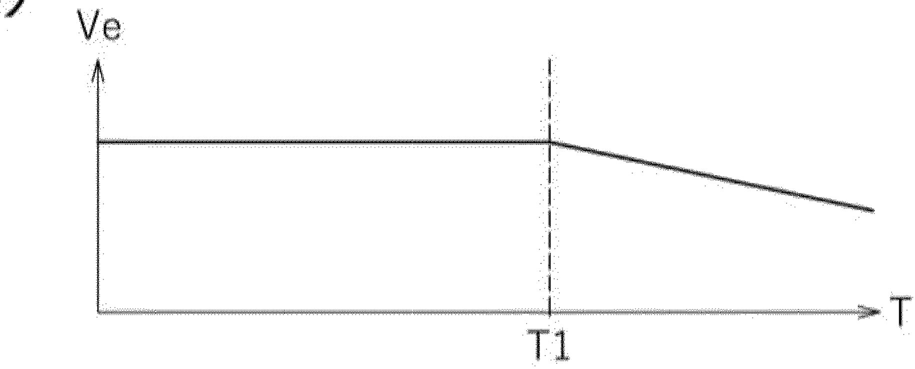


FIG.4(b)

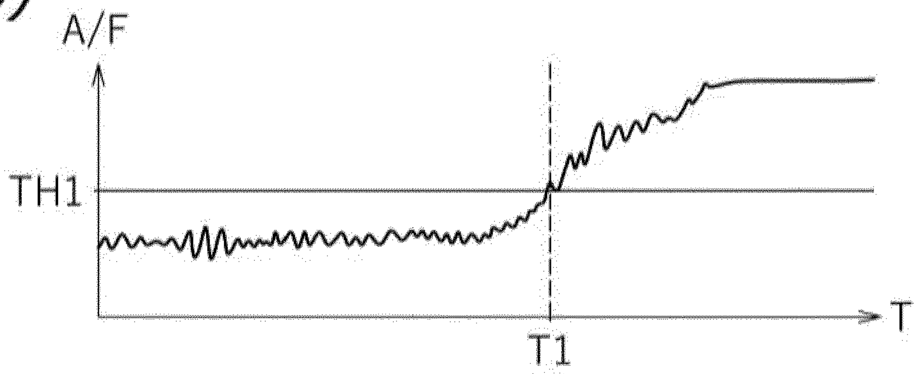


FIG.4(c)

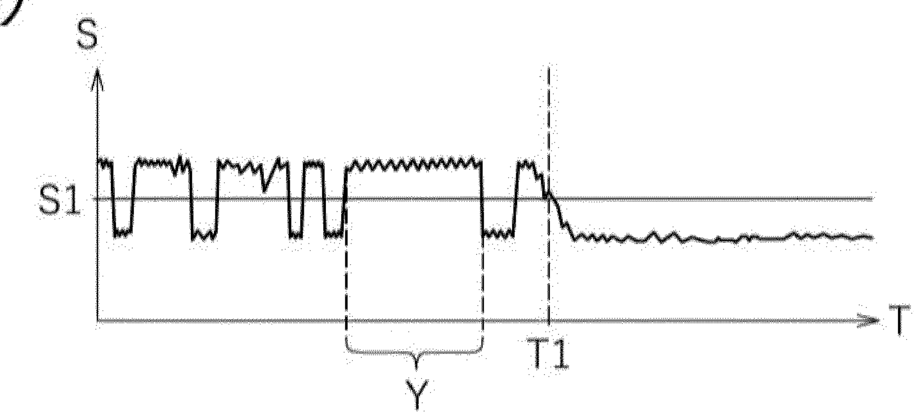


FIG.4(d)

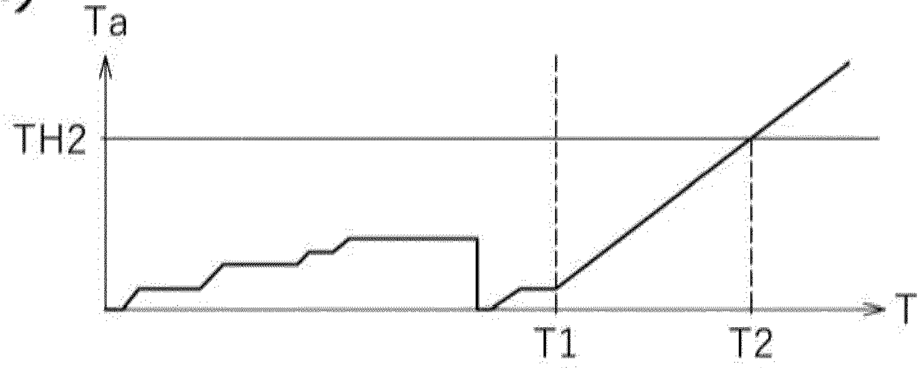


FIG.4(e)

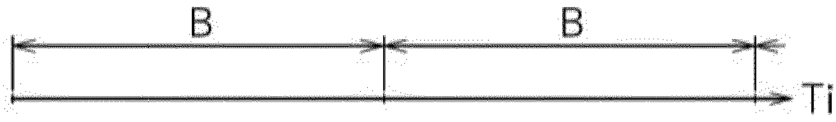


FIG.5

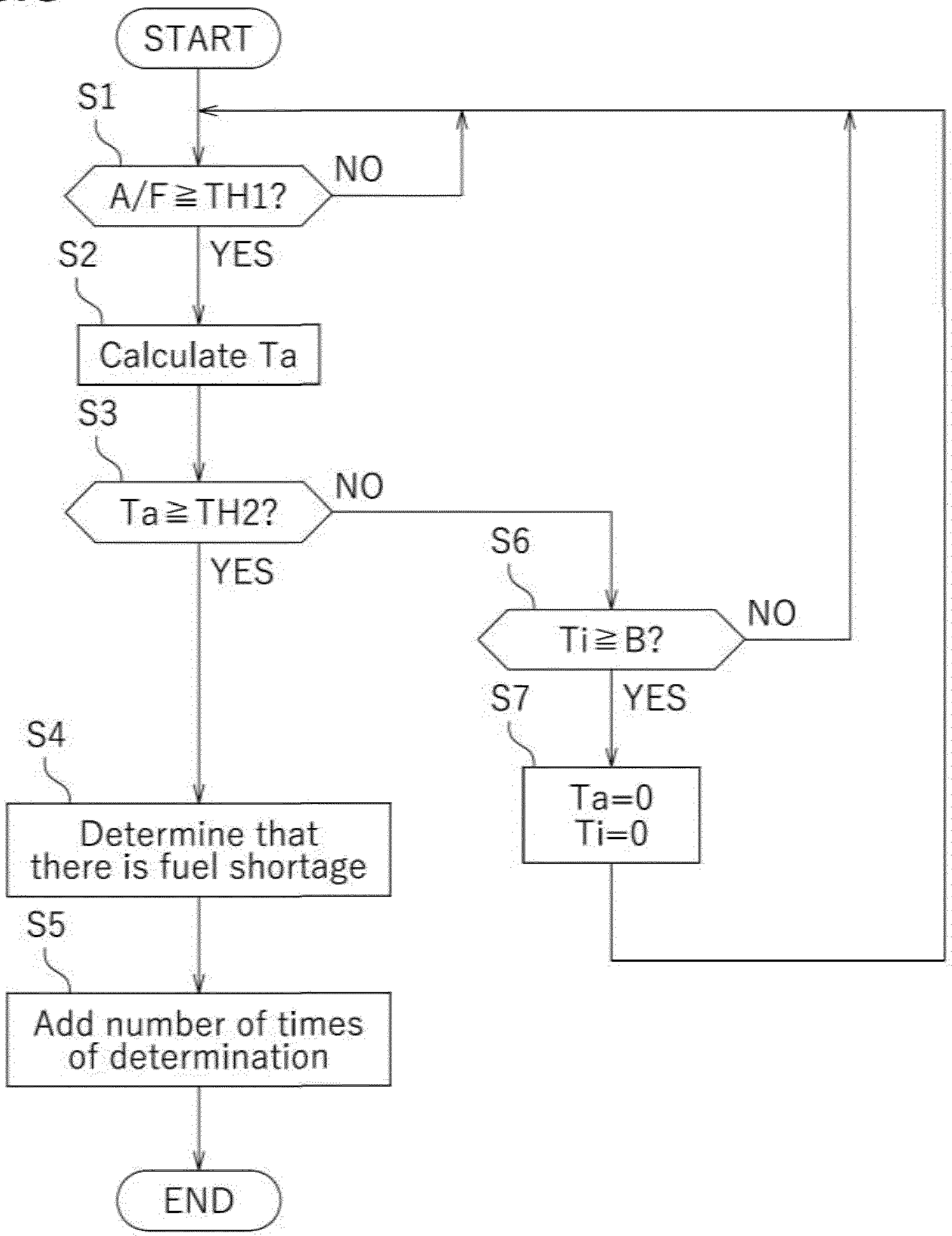

START
S1
A/F≧TH1?
NO
YES
S2
Calculate Ta
S3
Ta≧TH2?
NO
YES
S6
Ti≧B?
NO
S7
YES
S4
Ta=0
Ti=0
Determine that there is fuel shortage
S5
Add number of times of determination
END

FIG.6

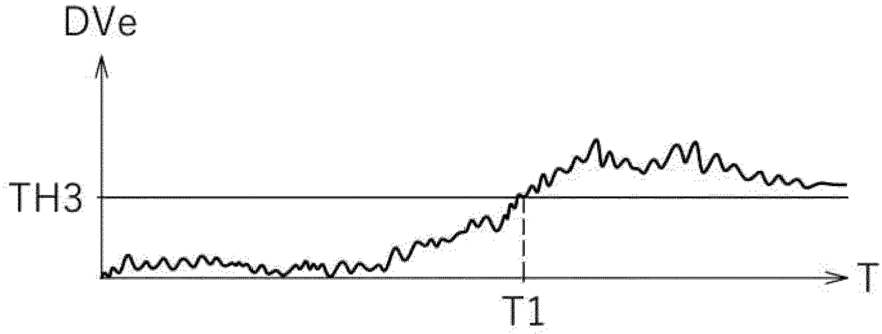


FIG.7

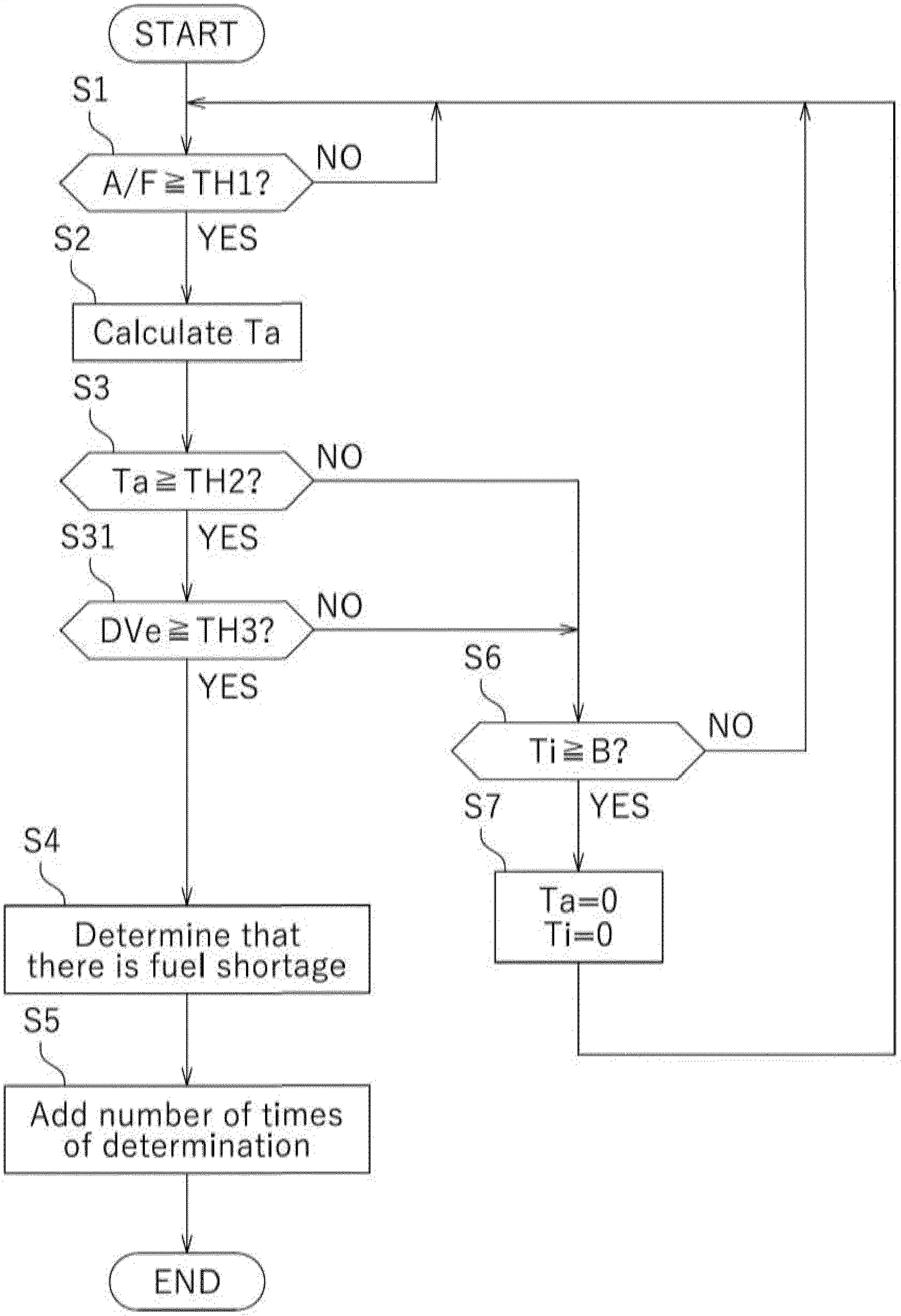

START
S1
A/F ≧ TH1?
NO
YES
S2
Calculate Ta
S3
Ta ≧ TH2?
NO
YES
S31
DVe ≧ TH3?
NO
YES
S6
Ti ≧ B?
NO
YES
S7
Ta=0
Ti=0
S4
Determine that there is fuel shortage
S5
Add number of times of determination
END

FIG.8

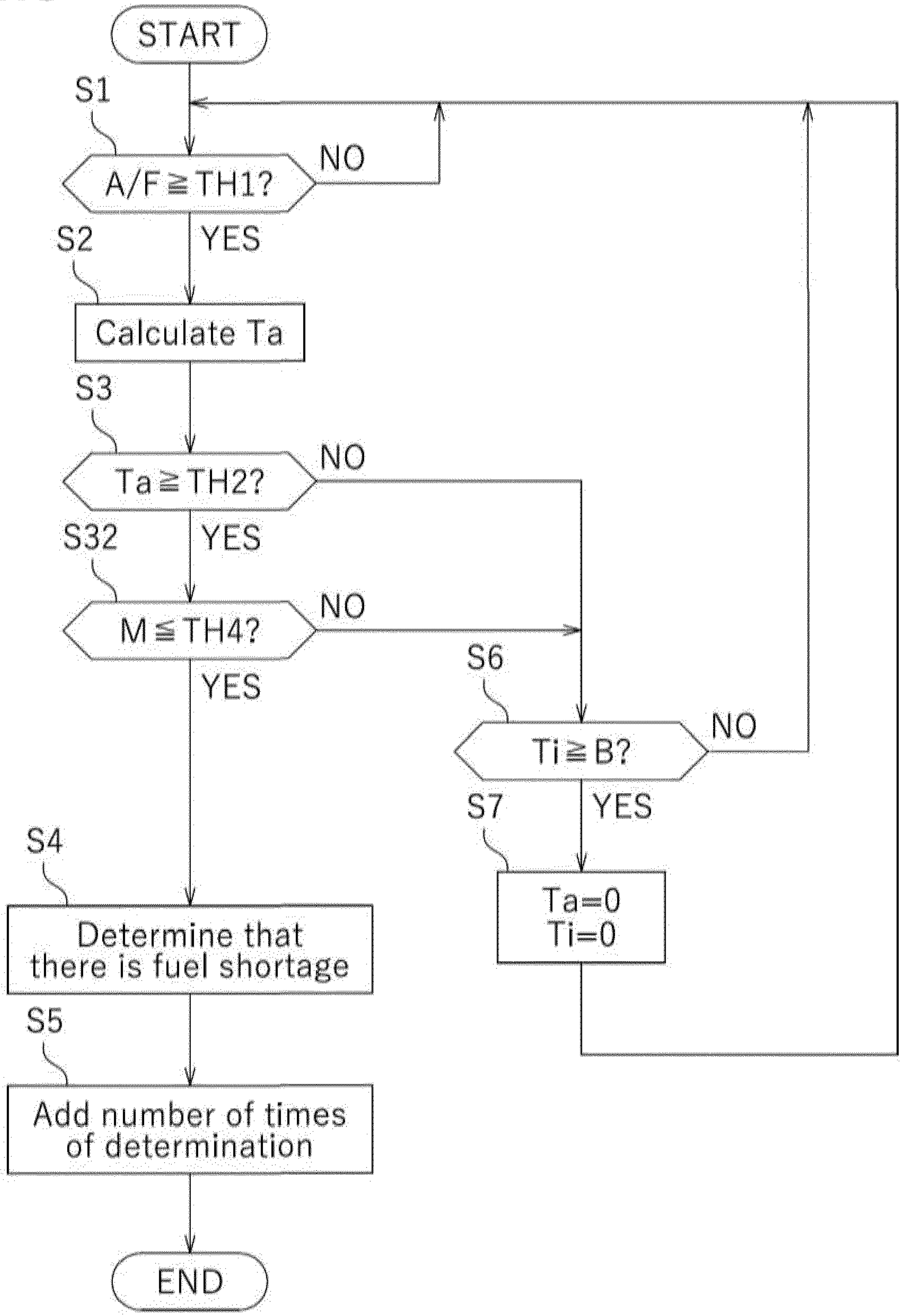

START
S1
A/F ≧ TH1?
NO
YES
S2
Calculate Ta
S3
Ta ≧ TH2?
NO
YES
S32
M ≦ TH4?
NO
YES
S6
Ti ≧ B?
NO
YES
S7
Ta=0
Ti=0
S4
Determine that there is fuel shortage
S5
Add number of times of determination
END

FIG.9

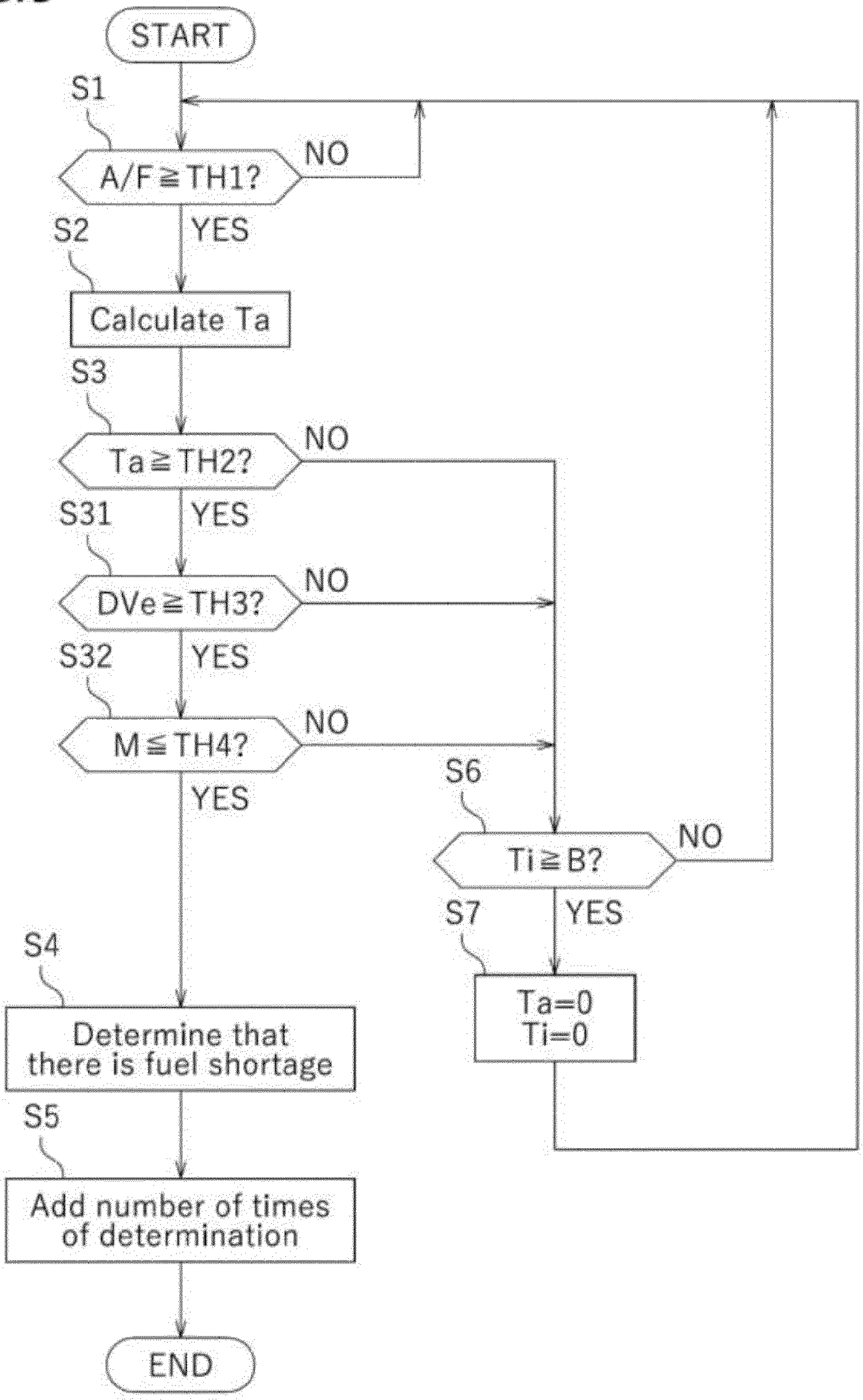

START
S1
A/F ≧ TH1?
NO
YES
S2
Calculate Ta
S3
Ta ≧ TH2?
NO
YES
S31
DVe ≧ TH3?
NO
YES
S32
M ≦ TH4?
NO
YES
S6
Ti ≧ B?
NO
YES
S7
Ta=0
Ti=0
S4
Determine that there is fuel shortage
S5
Add number of times of determination
END

FIG.10

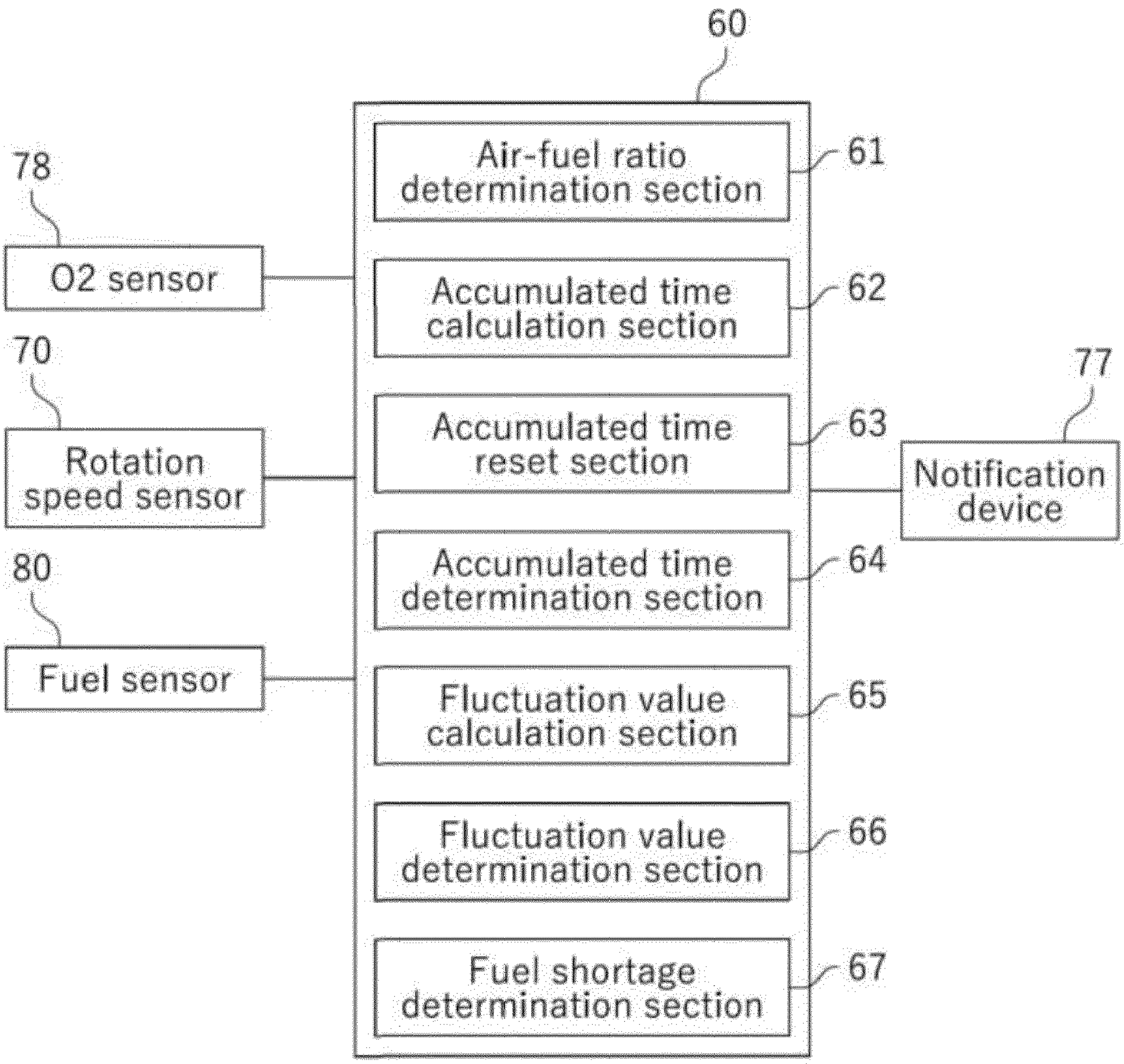
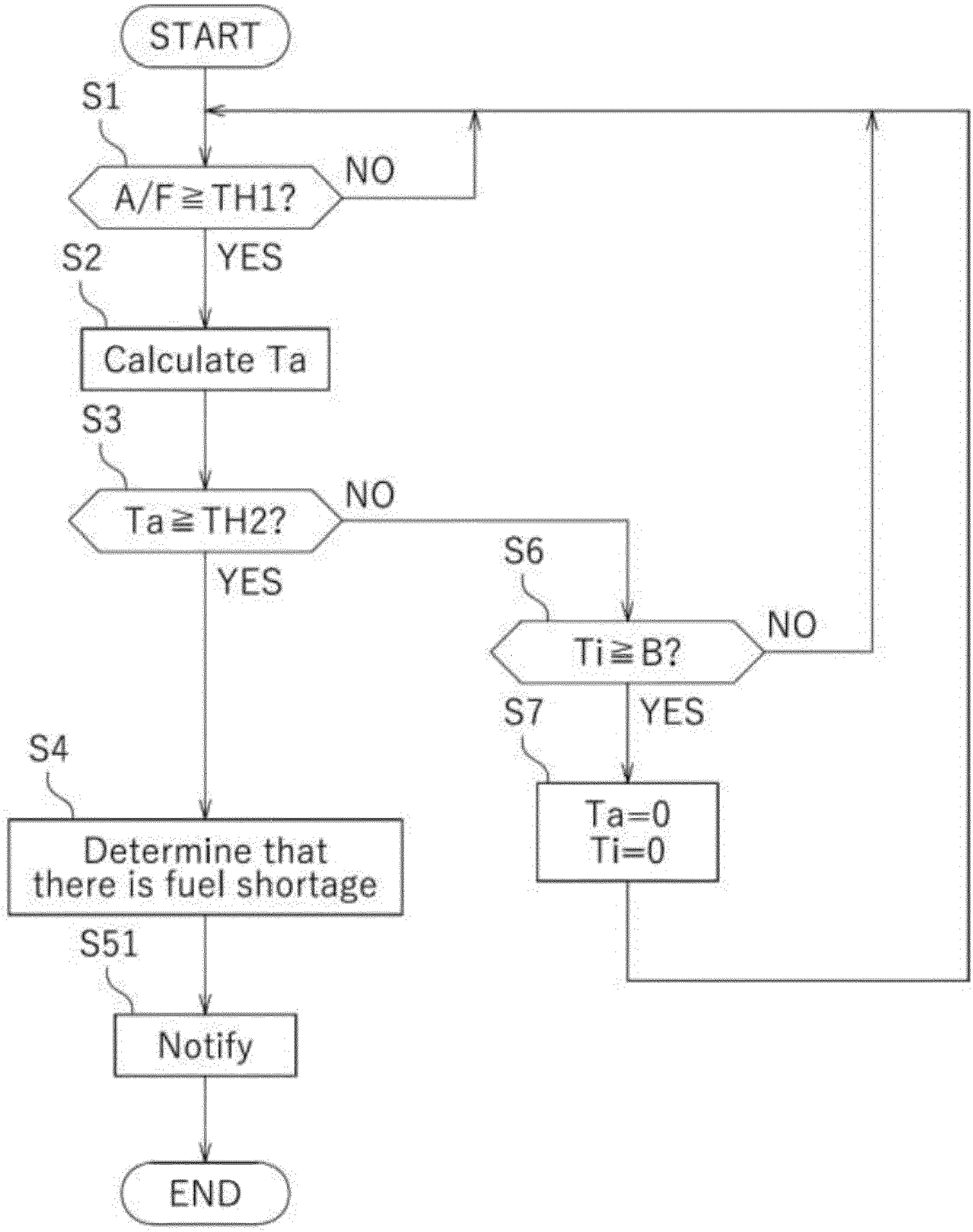

60
Air-fuel ratio determination section
61
Accumulated time calculation section
62
Accumulated time reset section
63
Accumulated time determination section
64
Fluctuation value calculation section
65
Fluctuation value determination section
66
Fuel shortage determination section
67
78
O2 sensor
70
Rotation speed sensor
80
Fuel sensor
77
Notification device

FIG.11


START
S1
A/F ≧ TH1?
NO
YES
S2
Calculate Ta
S3
Ta ≧ TH2?
NO
YES
S6
Ti ≧ B?
NO
YES
S7
Ta=0
Ti=0
S4
Determine that
there is fuel shortage
S51
Notify
END

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EUROPEAN SEARCH REPORT

Application Number
EP 24 19 2092

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2018 025158 A (SUBARU CORP) 15 February 2018 (2018-02-15) * paragraphs [0002] - [0009], [0036] - [0041], [0046] - [0052], [0058]; claims 1-4; figures 1,2 * -----	1-10	INV. F02D41/14 F02D41/24
A	US 9 810 132 B2 (FUJI HEAVY IND LTD [JP]; SUBARU CORP [JP]) 7 November 2017 (2017-11-07) * column 8, lines 24-40; claim 1; figure 1 * * column 9, line 58 - column 10, line 8 * -----	1-10	
A	US 2022/120252 A1 (SUGIMOTO HITOKI [JP]) 21 April 2022 (2022-04-21) * claim 1; figure 1 * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

F02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	17 January 2025	Boye, Michael

CATEGORY OF CITED DOCUMENTS

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17-01-2025

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		US 2022120252 A1	21-04-2022

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