(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 619 098 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
25.01.2006 Bulletin 2006/04

(51) Int Cl.:
B60W 10/06 (2006.01) ***F02D 41/12*** (2006.01)

(21) Application number: **05254489.7**

(22) Date of filing: **19.07.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **20.07.2004 JP 2004211839**

(71) Applicants:
- **Toyota Jidosha Kabushiki Kaisha**
  Toyota-shi, Aichi-ken 471-8571 (JP)
- **Bosch Corporation**
  Shibuya-ku
  Tokyo 150-8360 (JP)

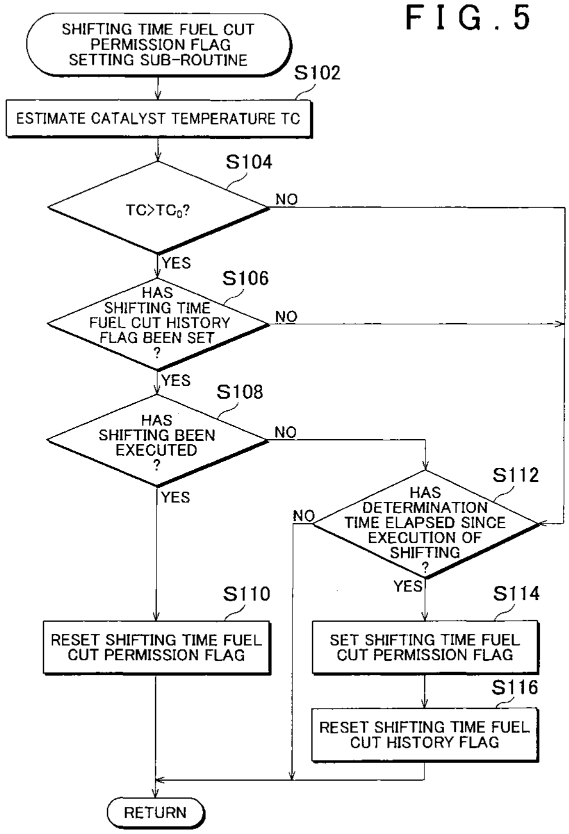
(72) Inventors:
- **Amano, Naoki, c/o Toyota Jidosha K.K.**
  Toyota-shi, Aichi-ken 471-8571 (JP)
- **Otsubo, Massaki, c/o Toyota Jidosha K.K.**
  Toyota-shi, Aichi-ken 471-8571 (JP)
- **Hatakeyama, Tomohiro, c/o Bosch Corporation**
  Tokyo 150-8360 (JP)
- **Yamazaki, Akinori, c/o Bosch Corporation**
  Tokyo 150-8360 (JP)

(74) Representative: **Smith, Samuel Leonard**
J.A. Kemp & Co.,
14 South Square,
Gray's Inn
London WC1R 5JJ (GB)

(54) Control apparatus for internal combustion engine

(57) An ECU performs a program including a step (S110) of resetting a shifting time fuel cut permission flag when shifting is executed before an elapsed time since shifting was executed last time reaches a determination time ("YES" in step S108); and a step (S114) of setting the shifting time fuel cut permission flag when the elapsed time since shifting was executed last time has reached the determination time ("YES" in step S112), in a case where a catalyst temperature TC is higher than a predetermined temperature TC_0 ("YES" in step S104).

F I G . 5



EP 1 619 098 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a control apparatus for an internal combustion engine. More particularly, the invention relates to a control apparatus for an internal combustion engine connected to an automobile transmission which includes a constant-mesh gear train.

2. Description of the Related Art

[0002] A technology is known, in which fuel supply is stopped (i.e., fuel cut is performed) in an internal combustion engine during deceleration of a vehicle. However, when fuel cut is performed, air flows into a catalyst as it is. Therefore, oxidation reaction in the catalyst may be abruptly promoted, and accordingly the catalyst may be deteriorated. Thus, when fuel cut is performed, it is necessary to consider deterioration of the catalyst.

[0003] Japanese Patent Application Publication No. JP 2004-50878A discloses a control apparatus for an internal combustion engine, which can suppress deterioration of the catalyst. The control apparatus disclosed in the Japanese Patent Application Publication No. JP 2004-50878A includes a fuel supply portion which performs fuel supply to an internal combustion engine while an internal combustion engine is operated; a fuel stop portion which stops the fuel supply to the internal combustion engine performed by the fuel supply portion when a predetermined deceleration operation condition is satisfied; a fuel stop prohibition portion which prohibits stop of the fuel supply to the internal combustion engine even when the predetermined deceleration operation condition is satisfied, in a case where a temperature of a catalyst becomes higher than a predetermined temperature; a shifting detection portion which detects a gear ratio in a shifting device; and a fuel supply state control portion which performs control such that the fuel stop prohibition portion continues to prohibit the stop of the fuel supply when the shifting state detection portion detects a change to the highest shift speed before an elapsed time since stop of the fuel supply is prohibited reaches a reference time, and the fuel stop prohibition portion cancels prohibition of stop of the fuel supply, and the fuel stop portion stops the fuel supply when the shifting state detection portion does not detect the change to the highest shift speed before the elapsed time since stop of the fuel supply is prohibited reaches the reference time, in a case where the fuel stop prohibition portion prohibits stop of the fuel supply when the predetermined deceleration operation condition is satisfied and the temperature of the catalyst becomes higher than the predetermined temperature.

[0004] In the control apparatus for an internal combustion engine disclosed in the publication, stop of the fuel supply is prohibited when the predetermined deceleration operation condition is satisfied and the temperature of the catalyst becomes higher than the predetermined temperature. Then, when the change to the highest shift speed performed by the shifting device is detected before the elapsed time reaches the reference time, stop of the fuel supply continues to be prohibited. Also, when the change to the highest shift speed is not detected before the elapsed time reaches the reference time, the fuel supply is stopped. Since it is determined whether stop of the fuel supply continues to be prohibited after stop of the fuel supply is prohibited, it is possible to reliably prevent deterioration of the catalyst from proceeding due to unnecessary fuel cut.

[0005] Recently, vehicles each of which includes an automatic transmission including a constant-mesh gear train have been sold particularly in Europe. In such a vehicle, selection can be made between a mode in which automatic shifting is executed and a mode in which shifting is executed by operation of a shift lever and the like performed by a driver. When shifting is executed, output of an internal combustion engine is decreased in order to disengage a clutch. In the vehicle including such an automatic transmission, it is conceivable to perform fuel cut during shifting in order to increase a region where fuel cut is performed so that fuel efficiency is improved. In this case as well, the catalyst may be deteriorated due to fuel cut. Particularly when the driver intentionally repeats shifting and fuel cut is performed each time shifting is executed, a period during which fuel cut is performed becomes long, and deterioration of the catalyst may proceed. Therefore, it is conceivable to prohibit fuel cut when the temperature of the catalyst becomes higher than the predetermined temperature, and to cancel the prohibition after the elapsed time since fuel cut is prohibited reaches the reference time, as in the control apparatus disclosed in the Japanese Patent Application Publication No. JP 2004-50878A.

[0006] However, in order to prohibit fuel cut in this case, the reference time needs to be set to a long time. If the reference time is set to a long time, the period during which fuel cut is prohibited becomes long, even when the driver does not intentionally perform shifting. Thus, there is a disadvantage in terms of fuel efficiency.

SUMMARY OF THE INVENTION

[0007] It is an object of the invention to provide a control apparatus for an internal combustion engine, which can suppress deterioration of a catalyst due to stop of fuel supply (fuel cut), and can suppress prohibition of stop of the fuel supply for a period longer than necessary.

[0008] A first aspect of the invention relates to a control apparatus for an internal combustion engine which is connected to an automatic transmission including a constant-mesh gear train. Exhaust gas discharged from the internal combustion engine is purified by a catalyst. The control apparatus includes fuel supply means for performing fuel supply to the internal combustion engine; control means for controlling the fuel supply means so as to stop the fuel supply to the internal combustion engine when shifting of the automatic transmission is executed; detection means for detecting a temperature of the catalyst; and determination means for determining whether the control means should be permitted to stop the fuel supply, or the control means should be prohibited from stopping the fuel supply, based on the temperature of the catalyst and an elapsed time since execution of shifting.

[0009] According to the first aspect of the invention, the fuel supply means performs fuel supply to the internal combustion engine. The control means controls the fuel supply means so as to stop the fuel supply to the internal combustion engine when shifting of the automatic transmission is executed. The detection means detects the temperature of the catalyst. For example, when the temperature of the catalyst is higher than a predetermined temperature, the determination means determines whether the control means should be permitted to stop the fuel supply, or the control means should be prohibited from stopping the fuel supply, based on the elapsed time since execution of shifting. Thus, for example, it can be determined that the control means should be permitted to stop the fuel supply after a predetermined determination time has elapsed since shifting was executed last time, and the control means should be prohibited from stopping the fuel supply before the predetermined determination time elapses. Thus, stop of the fuel supply can be prohibited so as to suppress an increase in the temperature of the catalyst until the determination time elapses. Also, the fuel supply can be stopped after the determination time has elapsed. In this case, if the determination time is set to a short time, stop of the fuel supply can be prohibited when shifting is repeated at time intervals each of which is shorter than the determination time, and stop of the fuel supply can be permitted promptly when shifting is not repeated. Also, it can be determined that stop of the fuel supply should be permitted after the determination time has elapsed since stop of the fuel supply is cancelled, and stop of the fuel supply should be prohibited before the determination time elapses. Therefore, stop of the fuel supply can be prohibited so as to suppress an increase in the temperature of the catalyst until the determination time elapses, and the fuel supply can be stopped when shifting is executed even if shifting is repeated, after the determination time has elapsed. As a result, it is possible to provide the control apparatus for an internal combustion engine which can suppress deterioration of a catalyst due to stop of fuel supply (fuel cut), and can suppress prohibition of stop of the fuel supply for a period longer than necessary.

[0010] The determination means may further include means for determining that the control means should be permitted to stop the fuel supply after a predetermined time has elapsed since shifting was executed last time, and determining that the control means should be prohibited from stopping the fuel supply before the predetermined determination time elapses since shifting was executed last time, in a case where the temperature of the catalyst is higher than a predetermined temperature.

[0011] In this case, it is determined that stop of the fuel supply should be permitted after the determination time has elapsed since shifting was executed last time, and stop of the fuel supply should be prohibited before the determination time elapses, in a case where the temperature of the catalyst is higher than the predetermined temperature. If the determination time is set to a short time, stop of the fuel supply can be prohibited when shifting is repeated at short time intervals, and stop of the fuel supply can be permitted promptly when shifting is not repeated. Thus, it is possible to successively stop the fuel supply so as to suppress an increase in the temperature of the catalyst, and to suppress prohibition of stop of the fuel supply for a period longer than necessary.

[0012] The determination means may further include means for determining that the control means should be permitted to stop the fuel supply after a predetermined determination time has elapsed since the control means cancels stop of the fuel supply, and determining that the control means should be prohibited from stopping the fuel supply before the predetermined determination time elapses since the control means cancels stop of the fuel supply, in a case where the temperature of the catalyst is higher than a predetermined temperature.

[0013] In this case, it is determined that the control means should be permitted to stop the fuel supply after the determination time has elapsed since stop of the fuel supply is cancelled, in the case where the temperature of the catalyst is higher than a predetermined temperature. It is determined that the control means should be prohibited from stopping the fuel supply before the determination time elapses. Thus, it is possible to prohibit stop of the fuel supply so as to suppress an increase in the temperature of the catalyst until the determination time elapses, and to stop the fuel supply during shifting after the determination time elapses even if shifting is repeated.

[0014] The control apparatus for an internal combustion engine according to the first aspect of the invention may further include means for calculating requested torque which the automatic transmission requests the internal combustion engine to output; and torque determination means for determining whether the control means should be permitted to stop the fuel supply, or the control means should be prohibited from stopping the fuel supply, based on the requested torque.

[0015] In this case, the requested torque which the automatic transmission requests the internal combustion engine to output is calculated. For example, when the requested torque is lower than the lowest torque of the internal combustion engine, it is determined that stop of the fuel supply should be permitted. When the requested torque is equal to or higher than the lowest torque of the internal combustion engine, it is determined that stop of the fuel supply should be prohibited. Thus, the fuel supply is performed in a region where the internal combustion engine can control the torque. Accordingly, it is possible to suppress deterioration of the catalyst due to stop of the fuel supply for a period longer than necessary.

[0016] The torque determination means may further include means for determining that the control means should be permitted to stop the fuel supply when the requested torque is lower than predetermined torque, and determining that the control means should be prohibited from stopping the fuel supply when the requested torque is equal to or higher than the predetermined torque.

[0017] In this case, when the requested torque is lower than the predetermined torque of the internal combustion engine, it is determined that stop of the fuel supply should be permitted. When the requested torque is equal to or higher than the predetermined torque of the internal combustion engine, it is determined that stop of the fuel supply should be prohibited. Thus, the fuel supply is performed in a region where the internal combustion engine can control the torque. Accordingly, it is possible to suppress deterioration of the catalyst due to stop of the fuel supply for a period longer than necessary.

[0018] The predetermined torque may be the lowest torque that the internal combustion engine can output.

[0019] In this case, when the requested torque is lower than the lowest torque of the internal combustion engine, it is determined that stop of the fuel supply should be permitted. When the requested torque is equal to or higher than the lowest torque of the internal combustion engine, it is determined that stop of the fuel supply should be prohibited. Thus, the fuel supply is performed in a region where the internal combustion engine can control the torque. Accordingly, it is possible to suppress deterioration of the catalyst due to stop of the fuel supply for a period longer than necessary.

[0020] Further, the internal combustion engine may be connected to the automatic transmission via a clutch. The control apparatus may further include means for determining that the control means should be permitted to stop the fuel supply when the clutch is in a disengaged state, determining that the control means should be permitted to successively stop the fuel supply when the clutch is in an engaged state and the fuel supply is being stopped, and determining that the control means should be prohibited from stopping the fuel supply when the clutch is in the engaged state and the fuel supply is being performed.

[0021] In this case, when the clutch is in the disengaged state, it is determined that stop of the fuel supply should be permitted. Thus, when the torque is suddenly decreased due to stop of the fuel supply, it is possible to suppress occurrence of shock. When the clutch is in the engaged state and the fuel supply is being stopped, it is determined that the control means should be permitted to stop the fuel supply. Thus, it is possible to suppress occurrence of shock when the torque is suddenly increased due to prohibition of stop of the fuel supply, and to continue to stop the fuel supply. When the clutch is in the engaged state and the fuel supply is being performed, it is determined that the control means should be prohibited from stopping the fuel supply. Thus, in the case where there is a possibility that shock is caused if the torque is suddenly changed, it is possible to prohibit stop of the fuel supply, thereby suppressing occurrence of shock due to a sudden change in the torque.

[0022] A second aspect of the invention relates to a control method for an internal combustion engine which is connected to an automatic transmission including a constant-mesh gear train, the control method including a step of detecting a temperature of a catalyst that purifies exhaust gas discharged from the internal combustion engine. This method includes the steps of measuring an elapsed time since shifting of the automatic transmission is executed; and determining whether stop of fuel supply should be permitted or prohibited, based on the detected temperature of the catalyst and the measured elapsed time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of exemplary embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a control block diagram showing a vehicle including a control apparatus for an internal combustion engine according to a first embodiment of the invention;

FIG. 2 is a control block diagram showing an engine controlled by the control apparatus for an internal combustion engine according to the first embodiment of the invention;

FIG. 3 is a diagram showing a clutch;

FIG. 4 is a first flowchart showing a control structure of a program performed by an ECU of the control apparatus for an internal combustion engine according to the first embodiment of the invention;

FIG. 5 is a flowchart showing a second flowchart showing a control structure of a program performed by the ECU of the control apparatus for an internal combustion engine according to the first embodiment of the invention;

FIG. 6 is a third flowchart showing a control structure of a program performed by the ECU of the control apparatus for an internal combustion engine according to the first embodiment of the invention;

FIG. 7 is a fourth flowchart showing a control structure of a program performed by the ECU of the control apparatus for an internal combustion engine according to the first embodiment of the invention;

FIG. 8 is a first flowchart showing a control structure of a program performed by an ECU of a control apparatus for an internal combustion engine according to a second embodiment of the invention;

FIG. 9 is a second flowchart showing a control structure of a program performed by the ECU of the control apparatus for an internal combustion engine according to the second embodiment of the invention;

FIG. 10 is a first flowchart showing a control structure of a program performed by an ECU of a control apparatus for an internal combustion engine according to a third embodiment of the invention; and

FIG. 11 is a second flowchart showing a control structure of a program performed by the ECU of the control apparatus for an internal combustion engine according to the third embodiment of the invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0024] Hereinafter, embodiments of the invention will be described with reference to the drawings. In the following description, the same components are denoted by the same reference numerals. The names and functions of the same components are the same. Accordingly, detailed description thereof will not be repeated.

[0025] First embodiment

Referring to FIG. 1, a vehicle including a control apparatus for an internal combustion engine according to a first embodiment of the invention will be described. This vehicle runs when driving force generated in an engine 100 is transmitted to a wheel 404 via a clutch 200, a transmission 300, a differential gear 400, and a drive shaft 402. An electronic control unit (hereinafter, referred to as "ECU") 500 controls the engine 100, the clutch 200, and the transmission 300. Control of an internal combustion engine according to the embodiment is realized, for example, by a program performed by the ECU 500.

[0026] The engine 100 is a gasoline engine. The engine 100 may be a diesel engine, instead of a gasoline engine. The clutch 200 is connected to a crankshaft 600 of the engine 100. A clutch output shaft 202 is connected to an input shaft 302 of the transmission 300 via a spline 310.

[0027] The transmission 300 includes a constant-mesh gear train. In the transmission 300, a shift speed is selected by sliding a shift fork shaft by an actuator 304. The actuator 304 may be hydraulically operated or may be electrically operated. The shift speed may be selected by an actuator using a concentric slave cylinder.

[0028] The ECU 500 includes an engine ECU 502, a transmission ECU 504, memory 506, and a counter 508. The engine ECU 502 controls the engine 100. The transmission ECU 504 controls the clutch 200 and the transmission 300. Signals are sent and received between the engine ECU 502 and the transmission ECU 504. The memory 506 stores programs performed by the ECU 500, maps used by the ECU 500, and the like. The counter 508 measures an elapsed time since shifting of the transmission 300 is executed.

[0029] The ECU 500 receives signals from a position sensor 510, an accelerator pedal operation amount sensor 512, a brake switch 514, a vehicle speed sensor 516, an input shaft rotational speed sensor 518, an output shaft rotational speed sensor 520, and a crank position sensor 524 provided so as to be opposed to an outer periphery of a timing rotor 522.

[0030] The position sensor 510 detects a shift position of the shift lever. The accelerator pedal operation amount sensor 512 detects an accelerator pedal operation amount of an accelerator pedal. The brake switch 514 detects whether a brake pedal is depressed. The vehicle sensor 516 detects a vehicle speed. The input shaft rotational speed sensor 518 detects a rotational speed of the input shaft of the transmission 300. The output shaft rotational speed sensor 520 detects a rotational speed of an output shaft of the transmission 300. The crank position sensor 524 detects an engine rotational speed.

[0031] The ECU 500 performs computations based on the signals sent from the sensors, the elapsed time measured by the counter 508, the programs and maps stored in the memory 506, and the like. In this embodiment, the ECU 500 performs shifting (upshifting and downshifting) based on operation of the shift lever performed by a driver. Shifting may be performed based on operation of a switch provided in a steering wheel (not shown), instead of the operation of the shift lever.

[0032] Referring to FIG. 2, the engine 100 will be further described. Air taken into the engine 100 is filtered by an air cleaner 102. Then, the air passes through an intake pipe 104 and an intake manifold 106, and is introduced into a combustion chamber together with fuel injected from an injector 108.

[0033] In the combustion chamber, air-fuel mixture is ignited by an ignition plug 110, and is burned. When the air-fuel mixture is burned, driving force is generated in the engine 100. The burned air-fuel mixture, that is, exhaust gas is guided to an exhaust manifold 112, and purified by a catalyst 144. Then, the exhaust gas is discharged to the outside of a vehicle.

[0034] The air introduced in the combustion chamber is controlled by a throttle valve 114. An amount of air is detected by an air flow meter 526, and a signal indicative of a result of detection is sent to the ECU 500. An opening amount of the throttle valve 114 is detected by a throttle opening amount sensor 528, and a signal indicative of a result of detection is sent to the ECU 500.

[0035] Referring to FIG. 3, the clutch 200 will be further described. The clutch 200 is a dry type single plate friction clutch. As shown in FIG. 3, the clutch 200 includes a clutch output shaft 202, a clutch disk 204 provided on the clutch output shaft 202, a clutch housing 206, a pressure plate 208 provided in the clutch housing 206, a diaphragm spring 210, a clutch release cylinder 212, a release fork 214, and a release sleeve 216.

[0036] When the diaphragm spring 210 applies force to the pressure plate 208 rightward in FIG. 3, the clutch disk 204 is pressed to a fly wheel 602 fitted to the crankshaft of the engine 100, and thus the clutch is engaged.

[0037] When the clutch release cylinder 212 moves the release sleeve 216 rightward in FIG. 3 via the release fork 214, an inner end portion of the diaphragm spring 210 is moved rightward in FIG. 3. When the inner end portion of the diaphragm spring 210 is moved rightward in FIG. 3, the pressure plate 208 is moved leftward in FIG. 3, and the clutch disk 204 is separated from the fly wheel 602 and thus the clutch is disengaged.

[0038] The clutch release cylinder 212 is operated when hydraulic pressure of hydraulic oil pumped up by a hydraulic pump 220 from a reservoir 218 is supplied to the clutch release cylinder 212 via a clutch solenoid valve 222. The clutch solenoid valve 222 switches between supply of the hydraulic pressure to the clutch release cylinder 212 and discharge of the hydraulic pressure from the clutch release cylinder 212. The clutch solenoid valve 222 is controlled by the ECU 500.

[0039] When the hydraulic pressure is supplied to the clutch release cylinder 212, a piston of the clutch release cylinder 212 is moved leftward in FIG. 3, and the release sleeve 216 is moved rightward in FIG. 3. Thus, the clutch is disengaged. The position of the piston of the clutch release cylinder 212 (i.e., clutch stroke) is detected by a clutch stroke sensor 532. A signal indicative of a result of detection performed by the clutch stroke sensor 532 is sent to the ECU 500.

[0040] The ECU 500 detects whether the clutch 200 is in a disengaged state, in an engaged state, or in a semi-engaged state, based on the signal sent from the clutch stroke sensor 532. The clutch 200 may be operated by electric power.

[0041] Referring to FIG. 4, description will be made of a control structure of a program performed by the ECU 500 of the control apparatus for an internal combustion engine according to the embodiment.

[0042] In step S300, the ECU 500 determines whether shifting needs to be executed. The ECU 500 may determine whether shifting needs to be executed, for example, based on a shift diagram and the like stored in the memory 506, or the ECU 500 may determine whether shifting needs to be executed based on whether the driver has performed operation of the shift lever. When shifting needs to be executed ("YES" in step S300), the ECU 500 performs step S100. When shifting does not need to be performed ("NO" in step S300), the ECU 500 finishes the routine.

[0043] In step S100, the ECU 500 performs a shifting time fuel cut permission flag setting sub-routine. In step S200, the ECU 500 performs a shifting time fuel cut performing flag setting sub-routine.

[0044] In step S400, the ECU 500 determines whether the shifting time fuel cut performing flag has been set. When the shifting time fuel cut performing flag has been set ("YES" in step S400), the ECU 500 performs step S500. When the shifting time fuel cut performing flag has not been set ("NO" in step S400), the ECU 500 performs step S700.

[0045] In step S500, the ECU 500 performs shifting and fuel cut. In step S600, the ECU 500 sets a shifting time fuel cut history flag. In step S700, the ECU 500 performs shifting without performing fuel cut. In step S800, the ECU 500 starts to measure the elapsed time since execution of shifting, using the counter 508.

[0046] Referring to FIG. 5, the shifting time fuel cut permission flag setting sub-routine will be described.

[0047] In step S102, the ECU 500 estimates a catalyst temperature TC based on the engine rotational speed, an engine load, and the like. In step S104, the ECU 500 determines whether the catalyst temperature TC is higher than a predetermined temperature TC_0. When the catalyst temperature TC is higher than the predetermined temperature TC_0 ("YES" in step S104), the ECU 500 performs step S106. When the catalyst temperature TC is equal to or lower than the predetermined temperature TC_0 ("NO" in step S104), the ECU 500 performs step S 114.

[0048] In step S106, the ECU 500 determines whether the shifting time fuel cut history flag has been set. When the shifting time fuel cut history flag has been set ("YES" in step S106), the ECU 500 performs step S108. When the shifting time fuel cut history flag has not been set ("NO" in step S106), the ECU 500 performs step S 114.

[0049] In step 108, the ECU 500 determines whether a shift lever position when the shifting time fuel cut permission flag setting sub-routine was performed last time (i.e., a shift speed after shifting in step S500) is different from the shift lever position when the shifting time fuel cut permission flag setting sub-routine is performed this time (i.e., a shift speed when step S108 is performed). That is, shifting has been performed. When shifting has been performed ("YES" in step S108), the ECU 500 performs step S110. When shifting has not been performed ("NO" in step S108), the ECU 500 performs step S 112. In step S110, the ECU 500 resets the shifting time fuel cut permission flag.

[0050] In step S 112, the ECU 500 determines whether the elapsed time since shifting was executed while fuel cut was being performed has reached a predetermined determination time. When the elapsed time has reached the predetermined determination time ("YES" in step S112), the ECU 500 performs step S114. When the elapsed time has not reached the predetermined determination time ("NO" in step S 112), the ECU 500 finishes the routine. In step S 114, the ECU 500 sets the shifting time fuel cut permission flag. In step S 116, the ECU 500 resets the shifting time fuel cut history flag.

[0051] Referring to FIG. 6 and FIG. 7, the shifting time fuel cut performing sub-routine will be described.

[0052] In step S202, the ECU 500 calculates requested net torque TS which the transmission 300 requests the engine 100 to output. The net torque is torque that is actually input to the transmission 300. The requested net torque TS is calculated using an ordinary known method. Therefore, detailed description of the method of calculating the requested net torque TS will be omitted.

[0053] In step S204, the ECU 500 determines whether the requested net torque TS is lower than predetermined requested net torque TS_0. The requested net torque TS_0 is set to a value (for example, a negative value) such that the requested net torque TS_0 cannot be output if fuel cut is not performed. For example, when the clutch 200 is disengaged, the requested net torque TS becomes lower than the predetermined requested net torque TS_0 in order to suppress racing of the engine 100 due to a decrease in a load. That is, when there is a request for disengaging the clutch, the requested net torque TS becomes lower than the predetermined requested net torque TS_0. When the requested net torque TS is lower than the predetermined requested net torque TS_0 ("YES" in step S204), the ECU 500 determines that the transmission 300 requests an instantaneous decrease in the torque caused by fuel cut, and the ECU 500 performs step S206. When the requested net torque TS is equal to or higher than the predetermined requested net torque TS_0 ("NO" in step S204), the ECU 500 performs step S224 in FIG. 7.

[0054] Referring back to FIG. 6, in step S206, the ECU 500 converts the requested net torque TS to requested indicated torque TZ. The indicated torque is torque that is actually output by the engine 100. The requested indicated torque TZ is calculated by adding friction torque of machine parts and the like and load torque of auxiliary machinery such as an alternator (not shown) to the requested net torque TS. The requested indicated torque TZ is calculated using an ordinary known method. Therefore, detailed description of the method of calculating the requested indicated torque TZ will be omitted.

[0055] In step S208, the ECU 500 determines whether the requested indicated torque TZ is lower than predetermined requested indicated torque TZ_0. The predetermined requested indicated torque TZ_0 is set to the lowest torque that can be output by the engine 100 by decreasing an amount of intake air, or delaying ignition timing. The lowest torque that can be output is the lowest torque at which misfire, an engine stall, or the like does not occur and the engine-can be normally operated, and is not a functional limit. When the requested indicated torque TZ is lower than the predetermined requested indicated torque TZ_0 ("YES" in step S208), the ECU 500 performs step S210. When the requested indicated torque TZ is equal to or higher than the predetermined requested indicated torque TZ_0 ("NO" in step S208), the ECU 500 performs step S224 in FIG. 7.

[0056] Referring back to FIG. 6, in step S210, the ECU 500 determines whether a fuel cut prohibition request signal has been unsent. The fuel cut prohibition request signal is a signal that is sent from the transmission ECU 504 to the engine ECU 502 when the clutch 200 is in the engaged state. When the fuel cut prohibition request signal has been unsent ("YES" in step S210), that is, when the clutch 200 is in the disengaged state, the ECU 500 performs step S216. When the fuel cut prohibition request signal has been sent ("NO" in step S210), that is, when the clutch 200 is in the engaged state, the ECU 502 performs step S214.

[0057] In step S214, the ECU 500 determines whether idling time fuel cut is being performed. The idling time fuel cut is fuel cut performed when the engine 100 is idling during deceleration of the vehicle. When the idling time fuel cut is being performed ("YES" in step S214), the ECU 500 performs step S216. When the idling time fuel cut is not being performed ("NO" in step S214), the ECU 500 performs step S224 in FIG. 7.

[0058] Referring back to FIG. 6, in step S216, the ECU 500 determines whether the engine rotational speed is higher than an idling time fuel cut return rotational speed. The idling time fuel cut return rotational speed is a rotational speed at which a state where the idling time fuel cut is performed is returned to a state where the engine 100 is driven by injecting fuel. When the engine rotational speed is higher than the idling time fuel cut return rotational speed ("YES" in step S216), the ECU 500 performs step S218 in FIG. 7. When the engine rotational speed is equal to or lower than the idling time fuel cut return rotational speed ("NO" in step S216), the ECU 500 performs step S224.

[0059] In step S218, the ECU 500 determines whether the shifting time fuel cut permission flag has been set. When the shifting time-fuel cut permission flag has been set ("YES" in step S218), the ECU 500 performs step S220. When the shifting time fuel cut permission flag has not been set ("NO" in step S218), the ECU 500 performs step S224.

[0060] In step S220, the ECU 500 determines whether an idling time fuel cut performing condition other than a condition that the engine 100 is idling is satisfied. The idling time fuel cut performing condition is the condition for performing the idling timing fuel cut. For example, the idling time fuel cut performing condition includes a condition that a temperature of a catalyst is high, and a shift speed is not the highest shift speed. As the idling time fuel cut performing condition, a condition in ordinary known art is used. Therefore, detailed description of the idling time fuel cut performing condition will be omitted. When the idling time fuel cut performing condition is satisfied ("YES" in step S220), the ECU 500 performs step S222. When the idling fuel cut performing condition is not satisfied ("NO" in step S220), the ECU 500 performs 224. In step S222, the ECU 500 sets the shifting time fuel cut performing flag. In step S224, the ECU 500 resets the shifting time fuel cut performing flag.

[0061] Hereinafter, description will be made of operation of the ECU 500 of the control apparatus for an internal combustion engine according to the embodiment of the invention, based on the aforementioned structure and the aforementioned flowchart. The following description will be made on the assumption that fuel cut was performed when a present shift speed was achieved (i.e., when shifting was executed last time) in step S500, and the shifting time fuel cut history flag was set in step S600.

[0062] After fuel cut is performed during shifting in step S500, the shifting time fuel cut history flag is set in step

S600, and the counter 508 starts to measure the elapsed time since the shifting in step S800, the shifting time fuel cut permission flag setting sub-routine is performed again in step S100.

[0063] In the shifting time fuel cut permission flag setting sub-routine, a catalyst temperature TC is detected in step S102. Then, it is determined whether the catalyst temperature TC is higher than the predetermined temperature TC_0 in step S104.

[0064] When the catalyst temperature TC -is equal to or lower than the predetermined temperature TC_0 ("NO" in step S104), it can be determined that no problem may be caused if the catalyst temperature is increased by fuel cut. In this case, the shifting time fuel cut permission flag is set in step S 114, and fuel cut is permitted to be successively performed when shifting is executed. In this case, the shifting time fuel cut history flag is reset in step S 116.

[0065] Meanwhile, when the catalyst temperature TC is higher than the predetermined temperature TC_0 ("YES" in step S104), it is necessary to suppress an increase in the catalyst temperature caused by fuel cut. In this case, in step S106, it is determined whether the shifting time fuel cut history flag has been set. That is, in step S106, it is determined whether fuel cut was performed when shifting was executed last time.

[0066] Since fuel cut was performed when shifting was executed last time in step S500, and the shifting time fuel cut history flag was set in step S600 ("YES" in step S106), it is necessary to prohibit fuel cut from being successively performed when shifting is executed, at this time.

[0067] In the case where shifting was executed in step S500 after the shifting time fuel cut permission flag setting sub-routine was performed last time ("YES" in step S108), the shifting time fuel cut permission flag is reset in step S110. That is, every time shifting is executed while fuel cut is being performed in step S500, the shifting time fuel cut permission flag is reset in step S 110 in the shifting time fuel cut permission flag setting sub-routine which is performed immediately after shifting is executed in step S500.

[0068] After the shifting time fuel cut permission flag is reset in step S 110, it is determined whether the elapsed time since execution of shifting has reached the determination time in step S112, as long as shifting continues to be unperformed ("NO" in step S300, or "NO" in step S108).

[0069] When the elapsed time since shifting was executed in step S500 last time (i.e., since a present shift speed was achieved) has reached the determination time ("YES" in step S 112), it can be determined that the catalyst temperature TC may not be abnormally increased and no problem may be caused even if fuel cut is performed. In this case, the shifting time fuel cut permission flag is set in step S 114, and fuel cut is permitted to be successively performed when shifting is executed, and the shifting time fuel cut history flag is reset in step S 116.

[0070] When the elapsed time since shifting was executed in step S500 last time has not reached the determination time ("NO" in step S 112), the shifting time fuel cut permission flag remains in the reset state after being reset in step S110. Therefore, the shifting time fuel cut permission flag remains in the reset state after being reset in step S110 as long as shifting is repeated, for example, by operation of the shift lever performed by the driver (i.e., YES in step S300 and step S700 is performed) until the elapsed time reaches the determination time. Since the determination time is compared with the elapsed time since execution of shifting, fuel cut can be prohibited by setting the determination time to a short time when shifting is repeated at short time intervals. Therefore, when shifting is repeated at normal time intervals, fuel cut can be permitted promptly, whereby fuel efficiency can be improved.

[0071] After the shifting time fuel cut permission flag setting sub-routine in step S100 is finished, the shifting time fuel cut performing flag setting sub-routine is performed in step S200. In the shifting time fuel cut performing flag setting sub-routine in step S200, the requested net torque TS is calculated in step S202, and it is determined whether the requested net torque TS is lower than the predetermined requested net torque TS_0 in step S204.

[0072] When the requested net torque TS is equal to or higher than the predetermined requested net torque TS_0 ("NO" in step S204), it can be determined that the transmission 300 does not request an instantaneous decrease in the torque caused by fuel cut. In this case, the shifting time fuel cut performing flag is reset in step S224. Thus, even when shifting needs to be executed ("YES" in step S300), shifting is executed without performing fuel cut (i.e., NO in step S400, and step S700 is performed). When shifting is executed without performing fuel cut in step S700, the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0073] Meanwhile, when the requested net torque TS is lower than the predetermined requested net torque TS_0 ("YES" in step S204), it can be determined that the transmission 300 requests an instantaneous decrease in the torque caused by fuel cut. In this case, the requested net torque TS is converted to the requested indicated torque TZ in step S206, and it is determined whether the requested indicated torque TZ is lower than the predetermined requested indicated torque TZ_0 in step S208. Thus, it is determined whether the engine 100 can output the torque requested by the transmission 300 by decreasing the amount of intake air or delaying ignition timing, even if fuel cut is not performed.

[0074] When the requested net torque TS is equal to or higher than the predetermined requested net torque TS_0 ("NO" in step S204), that is, when the engine 100 can output the torque requested by the transmission 300 even if fuel cut is not performed, the shifting time fuel cut performing flag is reset in step S224. Accordingly, even when shifting needs to be executed ("YES" in step S300), shifting is executed without performing fuel cut ("NO in step S400, and step S700 is performed). Thus, it is possible to reduce the possibility that fuel cut is performed in a region where the torque of the engine 100 can be controlled. When shifting is executed without performing fuel cut in step S700, the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0075] When the requested indicated torque TZ is lower than the predetermined requested indicated torque TZ_0 ("YES" in step S208), that is, when the engine 100 cannot output the torque requested by the transmission 300 if fuel cut is not performed, it is determined whether the fuel cut prohibition request signal has been unsent in step S210.

[0076] When the clutch 200 is in the engaged state, and the fuel cut prohibition request signal has been sent from the transmission ECU 504 to the engine ECU 502 ("NO" in step S210), it is determined whether the idling time fuel cut is being performed in step S214.

[0077] In the case where the clutch 200 is in the engaged state ("NO" in step S210), when the idling time fuel cut is not being performed ("NO" in step S214), it can be determined that shock may be caused by a sudden decrease in the torque if fuel cut is performed during shifting. In this case, the shifting time fuel cut performing flag is reset in step S224. Even when shifting needs to be executed ("YES" in step S300), shifting is executed without performing fuel cut ("NO" in step S400, and step S700 is performed). Thus, it is possible to reduce the possibility that shock is caused by fuel cut, and therefore driveability is deteriorated. When shifting is executed without performing fuel cut in step S700, the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0078] When the clutch 200 is in the disengaged state, that is, when the fuel cut prohibition request signal has been unsent from the transmission ECU 504 to the engine ECU 502 ("YES" in step S210), it can be determined that shock may not be caused even if fuel cut is performed.

[0079] Also, even when the clutch 200 is in the engaged state ("NO" in step S210), if the idling time fuel cut is being performed ("YES" in step S214), it can be determined that shock may not be caused even if fuel cut is successively performed when shifting is executed.

[0080] In these cases (i.e., in the case of "YES" in step S210, and in the case of "YES" in step S214), it is determined whether the engine rotational speed is higher than the idling time fuel cut return rotational speed in step S216.

[0081] When the engine rotational speed is equal to or lower than the idling time fuel cut return rotational speed ("NO" in step S216), an engine stall may occur if fuel cut is performed during shifting. In this case, the shifting time fuel cut performing flag is reset in step S224, and even if shifting needs to be executed ("YES" in step 5300), shifting is executed without performing fuel cut ("NO" in step S400, and step S700 is performed). Thus, it is possible to suppress occurrence of an engine stall due to fuel cut. When shifting is executed without performing fuel cut in step S700, the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0082] When the engine rotational speed is higher than the idling time fuel cut return rotational speed ("YES" in step S216), it can be determined that an engine stall may not be caused even if fuel cut is performed during shifting. In this case, it is determined whether the shifting time fuel cut permission flag has been set in step S218.

[0083] When the shifting time fuel cut permission flag has not been set ("NO" in step S218), fuel cut is being prohibited from being performed at short time intervals even if shifting is executed at short time intervals. In this case, the shifting time fuel cut performing flag is reset in step S224, and even if shifting can be executed while fuel cut is being performed without causing an engine stall, shifting is executed without performing fuel cut ("NO" in step S400, and step S700 is performed). Thus, fuel cut is prohibited from being repeated at short time intervals. Accordingly, an increase in the catalyst temperature is suppressed, and deterioration of the catalyst is suppressed. When shifting is executed without performing fuel cut in step S700, the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0084] If the shifting time fuel cut permission flag has been set ("YES" in step S218), it can be determined that the catalyst 144 may not be deteriorated even if fuel cut is performed during shifting. In this case, it is determined whether the idling time fuel cut performing condition other than the condition that the engine 100 is idling is satisfied in step S220.

[0085] When the idling time fuel cut performing condition is not satisfied ("NO" in step S220), the shifting time fuel cut performing flag is reset in step S224. Even if shifting can be performed while fuel cut is being performed without deteriorating the catalyst 144, shifting is executed without performing fuel cut in step 700.

[0086] When the idling time fuel cut performing condition is satisfied ("YES" in step S220), the shifting time fuel cut performing flag is set in step S222. When shifting needs to be executed ("YES" in step S300), shifting is executed while fuel cut is performed in step S500. When shifting is executed while fuel cut is being performed in step S500, the shifting time fuel cut history flag is set in step S600, and the counter 508 starts to measure the elapsed time since execution of shifting, in step S800.

[0087] As described above, the ECU of the control apparatus for an internal combustion engine according to the embodiment of the- invention resets the shifting time fuel cut permission flag when fuel cut is performed during shifting. In the case where shifting is executed next time before the elapsed time since execution of shifting reaches the determination time, the shifting time fuel cut permission flag remains in the reset state. In the case where the shifting time fuel cut permission flag is in the reset state, fuel cut is not performed when shifting is executed next time. Thus, in the case where shifting is repeated at short time intervals, it is possible to reduce that possibility that fuel cut is successively performed. Therefore, it is possible to suppress an increase in the catalyst temperature. As a result, it is possible to suppress deterioration of the catalyst due to fuel cut.

[0088] Also, because the elapsed time since execution of shifting is measured, fuel cut can be suppressed when shifting is repeated at short time intervals, and fuel cut can be permitted promptly when shifting is not repeated, by setting the determination time to a short time. Thus, fuel efficiency can be improved.

[0089] Second embodiment

A second embodiment of the invention will be described with reference FIG. 8 and FIG. 9. In the aforementioned first embodiment, the shifting time fuel cut permission flag remains in the reset state as long as shifting is repeated. However, in the second embodiment, after the elapsed time reaches the determination time, the shifting time fuel cut permission flag is set even if shifting is executed. Other portions of the control structure and functions thereof are the same as in the first embodiment. Therefore, detailed description thereof will be omitted.

[0090] Referring to FIG. 8, description will be made of control running using a program performed by the ECU 500 of a control apparatus for an internal combustion engine according to the second embodiment of the invention.

[0091] As shown in FIG. 8, in the second embodiment, another shifting time fuel cut permission flag setting sub-routine is performed in step S900, instead of performing the shifting time fuel cut permission flag setting sub-routine in the first embodiment. The shifting time fuel cut performing flag setting sub-routine is the same as in the first embodiment. The same steps as in the first embodiment are denoted by the same step numbers. Accordingly, detailed description thereof will be omitted.

[0092] As shown in FIG. 8, in step S802, the ECU 500 measures the elapsed time since shifting is executed while fuel cut is being performed, using the counter 508.

[0093] Referring to FIG. 9, the shifting time fuel cut permission flag setting sub-routine according to the second embodiment will be described.

[0094] In step S902, the catalyst temperature TC is detected. In step S904, the ECU 500 determines whether the catalyst temperature TC is higher than the predetermined temperature TC_0. When the catalyst temperature TC is higher than the predetermined temperature TC_0 ("YES" in step S904), the ECU 500 performs step S906. When the catalyst temperature TC is equal to or lower than the predetermined temperature TC_0 ("NO" in step S904), the ECU 500 performs step S920.

[0095] In step S906, the ECU 500 determines whether the shifting time fuel cut performing flag is in the reset state. When the shifting time fuel cut performing flag is in the reset state ("YES" in step S906), the ECU 500 performs step S908. When the shifting time fuel cut performing flag is not in the reset state ("NO" in step S906), the ECU 500 finishes the sub-routine.

[0096] In step S908, the ECU 500 determines whether the shifting time fuel cut performing flag was set when the shifting time fuel cut permission flag setting sub-routine was performed last time. When the shifting time fuel cut performing flag was set ("YES" in step S908), the ECU 500 performs step S910. When the shifting time fuel cut performing flag was not set ("NO" in step S908), the ECU 500 performs step S912.

[0097] In step S910, the ECU 500 resets the value of the counter 508. In step S912, the ECU 500 calculates a fuel cut prohibition period TP based on the value of the counter 508.

[0098] In step S914, the ECU 500 determines whether the fuel cut prohibition period TP is shorter than a predetermined period TP_0. When the fuel cut prohibition period TP is shorter than the predetermined period TP_0 ("YES" in step S914), the ECU 500 performs step S918. When the fuel cut prohibition period TP is equal to or longer than the predetermined period TP_0 ("NO" in step S914), the ECU performs step S920.

[0099] In step S918, the ECU 500 resets the shifting time fuel cut permission flag. In step S920, the ECU 500 sets the shifting time fuel cut permission flag.

[0100] Description will be made of operation of the ECU 500 of the control apparatus for an internal combustion engine according to the second embodiment of the invention, based on the aforementioned structure and the aforementioned flowchart.

[0101] While the vehicle is running, the catalyst temperature TC is detected in step S902. When the catalyst temperature TC is equal to or lower than the predetermined temperature TC_0 ("NO" in step S904), it can be determined that the catalyst 144 may not be deteriorated even if the catalyst temperature is increased by fuel cut. In this case, the shifting time fuel cut permission flag is set in step S920, and fuel cut is permitted during shifting.

[0102] Meanwhile, when the catalyst temperature TC is higher than the predetermined temperature TC_0 ("YES" in step S904), the catalyst 144 may be deteriorated. Therefore, fuel cut needs to be suppressed. In this case, if the shifting time fuel cut performing flag is in the reset state ("YES" in step S906), it is determined whether the shifting time fuel cut performing flag was in the set state when the shifting time fuel cut permission flag setting sub-routine was started last time, in step S908.

[0103] In the case where the shifting time fuel cut performing flag was in the set state when the shifting time fuel cut permission flag setting sub-routine was started last time ("YES" in step S908), it can be determined that the state of the shifting time fuel cut performing flag has been changed from the set state to the reset state. In this case, the value of the counter 508 is reset in step S910.

[0104] Meanwhile, in the case where the shifting time fuel cut performing flag was in the reset state when the shifting time fuel cut permission flag setting sub-routine was started last time ("NO" in step S908), the counter 508 continues to measure the elapsed time. The fuel cut prohibition period TP is calculated based on the value of the counter 508 in step S912.

[0105] When the fuel cut prohibition period TP is shorter than the predetermined period TP_0 ("YES" in step S914), the shifting time fuel cut permission flag is reset in step S918. Thus, in the case where fuel cut during shifting is requested before the predetermined period TP_0 elapses since fuel cut was performed last time while fuel cut was being performed, fuel cut is prohibited.

[0106] When the fuel cut prohibition period TP becomes equal to or longer than the predetermined period TP_0 ("NO" in step S914), the shifting time fuel cut permission flag is set in step S920. Thus, in the case where the predetermined period TP_0 has elapsed since shifting is executed while fuel cut is being performed and the same shift speed has been maintained for the predetermined period TP_0, fuel cut during shifting is permitted thereafter. Therefore, fuel efficiency can be improved.

[0107] As described above, in the case where the predetermined period TP_0 has elapsed since shifting is executed while fuel cut is being performed and the same shift speed has been maintained for the predetermined period TP_0, the shifting time fuel cut permission flag is set. Thus, after the predetermined period TP_0 has elapsed, fuel cut is performed even if the driver intentionally repeats shifting. Thus, fuel efficiency can be improved.

[0108] Third embodiment

Referring to FIG. 10 and FIG. 11, a third embodiment of the invention will be described. In the first embodiment, fuel cut is performed during shifting. However, in the third embodiment, when the engine is brought into the idling state during shifting, idling time fuel cut is performed in addition to fuel cut during shifting. Other portions of the control structure and functions thereof are the same as in the first embodiment. Therefore, detailed description thereof will be omitted.

[0109] Referring to FIG. 10, description will be made of a control structure of a program performed by the ECU 500 of a control apparatus for an internal combustion engine according to the third embodiment.

[0110] In step S1000, the ECU 500 determines whether shifting of the transmission 300 is being executed. When shifting is being executed ("YES" in step S1000), the ECU 500 performs step S1100. When shifting is not being executed ("NO" in step S1000), the ECU 500 finishes the routine.

[0111] In step S1100, the ECU 500 performs an idling time fuel cut permission flag setting sub-routine. In step S1200, the ECU 500 determines whether the idling time fuel cut performing condition is satisfied. When the idling time fuel cut performing condition is satisfied ("YES" in step S1200), the ECU 500 performs step S1300. When the idling time fuel cut performing condition is not satisfied ("NO" in step S1200), the ECU 500 finishes the routine.

[0112] In step S1300, the ECU 500 determines whether an idling time fuel cut permission flag has been set. When the idling time fuel cut permission flag has been set ("YES" in step S 1300), the ECU 500 performs step S1400. When the idling time fuel cut permission flag has not been set ("NO" in step S1300), the ECU 500 finishes the routine. In step S1400, the ECU 500 performs fuel cut.

[0113] Referring to FIG. 11, the idling time fuel cut permission flag setting sub-routine will be described.

[0114] In step S 1102, the ECU 500 determines whether the fuel cut prohibition request signal has been sent from the transmission ECU 504 to the engine ECU 502. When the fuel cut prohibition request signal has been sent ("YES" in step S 1102), that is, when the clutch 200 is in the engaged state, the ECU 500 performs step S1104. When the fuel cut prohibition request signal has not been sent ("NO" in step S 1102), that is, when the clutch 200 is in the disengaged state, the ECU 500 performs step S1108.

[0115] In step S 1104, the ECU 500 determines whether the idling time fuel cut is unperformed. When the idling time fuel cut is unperformed, that is, when the idling time fuel cut is not being performed ("YES" in step S 1104), the ECU 500 performs step S 1106. When the idling time fuel cut is being performed ("NO" in step S 1104), the ECU 500 performs step S 1108. In step S 1106, the ECU 500 resets the idling time fuel cut permission flag.

[0116] In step S1108, the ECU 500 determines whether a torque priority request signal has been sent from the transmission ECU 504 to the engine ECU 502. The torque priority request signal is a signal that is sent from the transmission ECU 504 to the engine ECU 502, for example, when the engine rotational speed needs to be synchronized with an input rotational speed of the transmission 300, by causing the engine 100 to race during shifting. While the torque priority request signal is sent, the engine 100 increases the torque according to the request from the transmission 300. When the torque priority request signal has been sent ("YES" in step S 1108), the ECU 500 performs step S1110. When the torque priority request signal has not been sent ("NO" in step S1108), the ECU 500 performs step S1118.

[0117] In step S1110, the ECU 500 calculates the requested net torque TS. In step S1112, the ECU 500 determines whether the requested net torque TS is lower than the predetermined torque TS_0. When the requested net torque TS is lower than the predetermined torque TS_0 ("YES" in step S1112), the ECU 500 performs step S1114. When the requested net torque TS is equal to or higher than the predetermined torque TS_0 ("NO" in step S1112), the ECU 500 performs step S 1106.

[0118] In step S 1114, the ECU 500 converts the requested net torque TS to the requested indicated torque TZ. In step S1116, the ECU 500 determines whether the requested indicated torque TZ is lower than the predetermined torque TZ_0. When the requested indicated torque TZ is lower than the predetermined torque TZ_0 ("YES" in step S 1116), the ECU 500 performs step S 1118. When the requested indicated torque TZ is equal to or higher than the predetermined torque TZ_0 ("NO" in step S1116), the ECU 500 performs step S1106. In step S1118, the ECU 500 sets the idling time fuel cut permission flag.

[0119] Description will be made of operation of the ECU 500 according to the third embodiment, based on the aforementioned structure and the aforementioned flowchart.

[0120] When shifting of the transmission 300 is being executed while the vehicle is running ("YES" in step S1000), the idling time fuel cut permission flag setting sub-routine is performed in step S1100. In the idling time fuel cut permission flag setting sub-routine performed in step S1100, it is determined whether the fuel cut prohibition request signal has been sent from the transmission ECU 504 to the engine ECU 502, in step 1102. In the case where the clutch 200 is in the engaged state, the fuel cut prohibition request signal has been sent ("YES" in step S1102), and the idling time fuel cut is unperformed, that is, the idling time fuel cut is not being performed ("YES" in step S1104), the torque may be suddenly changed by fuel cut, and shock may be caused. In this case, the idling time fuel cut permission flag is reset in step S1106. After the idling time fuel cut permission flag is reset in step S1106, even when the idling time fuel cut performing condition is satisfied ("YES" in step S1200), fuel cut is not performed ("NO" in step S 1300).

[0121] Meanwhile, when the fuel cut prohibition request signal has not been sent ("NO" in step S 1102), that is, when the clutch 200 is in the disengaged state, it can be determined that shock may not be caused even if the torque is suddenly changed by fuel cut.

[0122] Also, even when the fuel cut prohibition request signal has been sent ("YES" in step S1102), that is, even when the clutch 200 is in the engaged state, if fuel cut is being performed ("NO" in step S1104), it can be determined that shock may not be caused.

[0123] In this case ("NO" in step S1102, or "NO" in step 1104), it is determined whether the torque priority request signal has been sent from the transmission ECU 504 to the engine ECU 502, in step S1108.

[0124] When the torque priority request signal has not been sent ("NO" in step S 1108), it can be determined that, for example, the engine rotational speed does not need to be synchronized with the input shaft rotational speed of the transmission 300 by causing the engine 100 to race. In this case, the idling time fuel cut permission flag is set in step S1118. After the idling time fuel cut permission flag is set in step S1118, when the idling time fuel cut performing condition is satisfied ("YES" in step S1200), fuel cut is performed ("YES" in step S1300, and step S1400 is performed).

[0125] When the torque priority request signal has been sent ("YES" in step S1108), it can be determined, for example, that the engine rotational speed needs to be synchronized with the input shaft rotational speed of the transmission 300, by causing the engine 100 to race. In this case, the requested net torque TS is calculated in step S1110, and it is determined whether the requested net torque TS is lower than the predetermined torque TS_0 in step S1112.

[0126] When the requested net torque TS is equal to or higher than the predetermined torque TS_0 ("NO" in step S1112), it can be determined that the transmission 300 does not request a decrease in the torque caused by fuel cut. In this case, the idling time fuel cut permission flag is reset in step S 1106. After the idling time fuel cut permission flag is reset in step S1106, even when the idling time fuel cut performing condition is satisfied ("YES" in step S1200), fuel cut is not performed ("NO" in step S1300).

[0127] When the requested net torque TS is lower than the predetermined torque TS_0 ("YES" in step S1112), it can be determined that the transmission 300 is requesting fuel cut. Then, the requested net torque TS is converted to the requested indicated torque TZ in step S1114, and it is determined whether the requested indicated torque TZ is lower than the predetermined torque TZ_0 in step S 1116.

[0128] When the requested indicated torque TZ is equal to or higher than the predetermined torque TZ_0 ("NO" in step S1116), it can be determined that the engine 100 can output the torque requested by the transmission 300 by decreasing the amount of intake air, or by delaying the ignition timing, even if fuel cut is not performed. In this case, the idling time fuel cut permission flag is reset in step S1106. After the idling time fuel cut permission flag is reset in step S1106, even when the idling time fuel cut performing condition is satisfied ("YES" in step S1200), fuel cut is not performed ("NO" in step S1300).

[0129] When the requested indicated torque TZ is lower than the predetermined torque TZ_0 ("YES" in step S 1116), it can be determined that the engine 100 cannot output the torque requested by the transmission 300 if fuel cut is not performed. In this case, the idling time fuel cut permission flag is set in step S1118. After the idling time fuel cut permission flag is set in step S1118, when the idling time fuel cut performing condition is satisfied ("YES" in step S1200), fuel cut is performed ("YES" in step S1300, and step S 1400 is performed).

[0130] As described above, when the torque priority signal has not been sent from the transmission ECU to the engine ECU during shifting, the ECU of the control apparatus for an internal combustion engine according to the third embodiment sets the idling time fuel cut permission flag. Also, even when the torque priority signal has been sent, if the engine cannot output the torque requested by the transmission if fuel cut is not performed, the idling time fuel cut permission flag is set. After the idling time fuel cut permission flag is set, when the idling time fuel cut performing condition is satisfied, fuel cut is performed. Thus, the region where idling time fuel cut is performed can be increased, and fuel efficiency can be improved.

[0131] Thus, the embodiment of the invention that has been disclosed in the specification is to be considered in all respects as illustrative and not restrictive. The technical scope of the invention is defined by claims, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

Claims

1. A control apparatus for an internal combustion engine which is connected to an automatic transmission (300) including a constant-mesh gear train, wherein exhaust gas discharged from the internal combustion engine (100) is purified by a catalyst, and the control apparatus includes fuel supply means (108) for performing fuel supply to the internal combustion engine (100); control means for controlling the fuel supply means (108) so as to stop the fuel supply to the internal combustion engine (100) when shifting of the automatic transmission (300) is executed; and detection means for detecting a temperature of the catalyst, **characterized in that** the control apparatus includes determination means for determining whether the control means should be permitted to stop the fuel supply, or the control means should be prohibited from stopping the fuel supply, based on the temperature of the catalyst and an elapsed time since execution of shifting.

2. The control apparatus according to claim 1, wherein the determination means further includes means for determining that the control means should be permitted to stop the fuel supply after a predetermined determination time has elapsed since shifting was executed last time, and determining that the control means should be prohibited from stopping the fuel supply before the predetermined determination time elapses since shifting was executed last time, in a case where the temperature of the catalyst is higher than a predetermined temperature.

3. The control apparatus according to claim 1, wherein the determination means further includes means for determining that the control means should be permitted to stop the fuel supply after a predetermined determination time has elapsed since the control means cancels stop of the fuel supply, and determining that the control means should be prohibited from stopping the fuel supply before the predetermined determination time elapses since the control means cancels stop of the fuel supply, in a case where the temperature of the catalyst is higher than a predetermined temperature.

4. The control apparatus according to any one of claims 1 to 3, wherein the control apparatus further includes means for calculating requested torque which the automatic transmission requests the internal combustion engine to output; and torque determination means for determining whether the control means should be permitted to stop the fuel supply, or the control means should be prohibited from stopping the fuel supply, based on the requested torque.

5. The control apparatus according to claim 4, wherein the torque determination means further includes means for determining that the control means should be permitted to stop the fuel supply when the requested torque is lower than predetermined torque, and determining that the control means should be prohibited from stopping the fuel supply when the requested torque is equal to or higher than the predetermined torque.

6. The control apparatus according to claim 5, wherein the predetermined torque is lowest torque that the internal combustion engine can output.

7. The control apparatus according to any one of claims 1 to 6, wherein the internal combustion engine is connected to the automatic transmission via a clutch (200); and the control apparatus further includes means for determining that the control means should be permitted to stop the fuel supply when the clutch (200) is in a disengaged state, determining that the control means should be permitted to successively stop the fuel supply when the clutch (200) is in an engaged state and the fuel supply is being stopped, and determining that the control means should be prohibited from stopping the fuel supply when the clutch (200) is in the engaged state and the fuel supply is being performed.

8. A control method for an internal combustion engine which is connected to an automatic transmission (300) including a constant-mesh gear train, the control method including the step of detecting a temperature of a catalyst that purifies exhaust gas discharged from the internal combustion engine (100), the control method being **characterized by** comprising the steps of:

   measuring an elapsed time since shifting of the automatic transmission (300) is executed; and
   determining whether stop of fuel supply should be permitted or prohibited, based on the detected temperature of the catalyst and the measured elapsed time.

FIG. 1

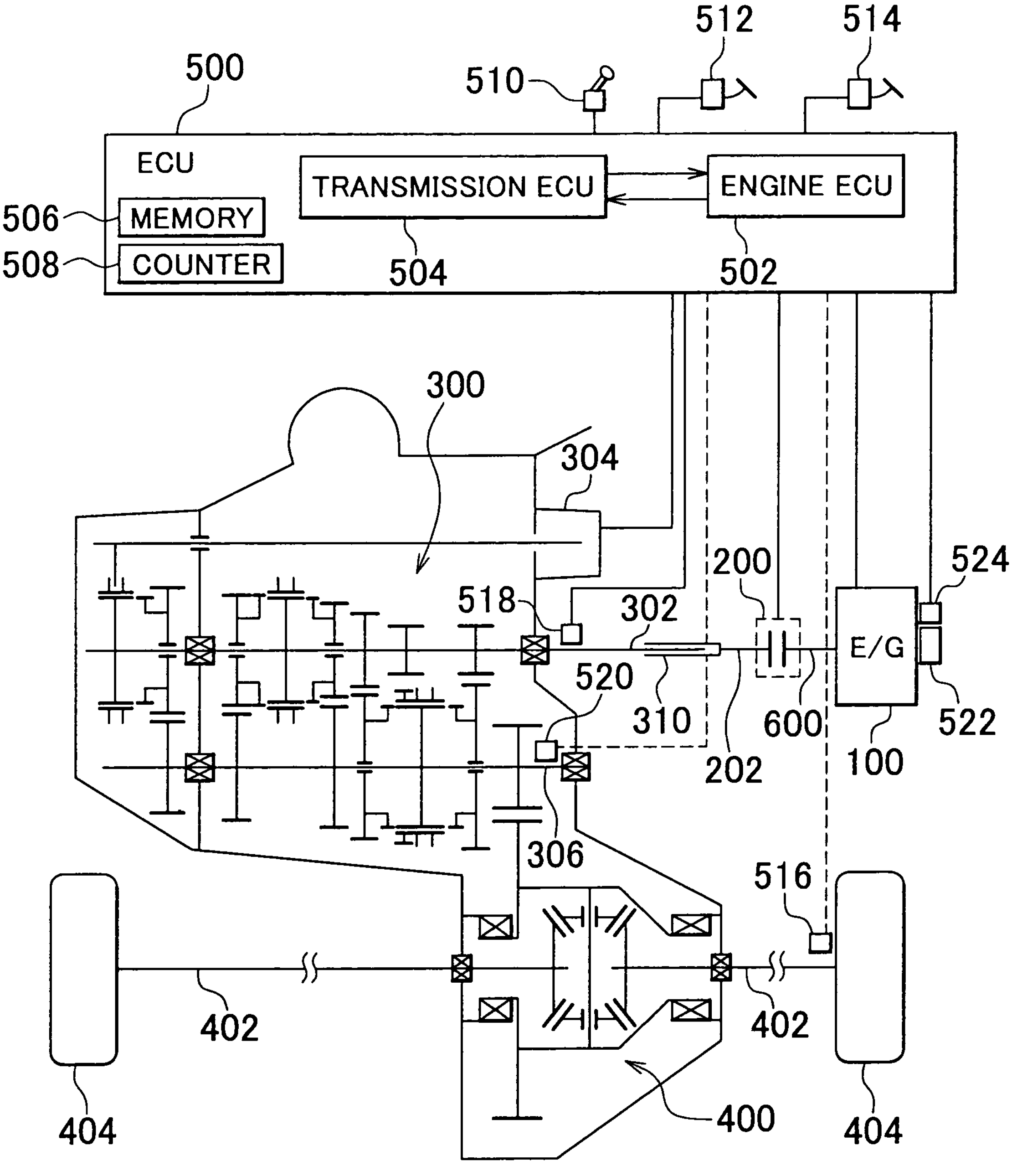

500
ECU
MEMORY
COUNTER
TRANSMISSION ECU
ENGINE ECU
506
508
504
502
510
512
514
300
304
200
302
518
520
310
600
202
100
E/G
524
522
306
516
402
402
404
404
400

FIG. 2

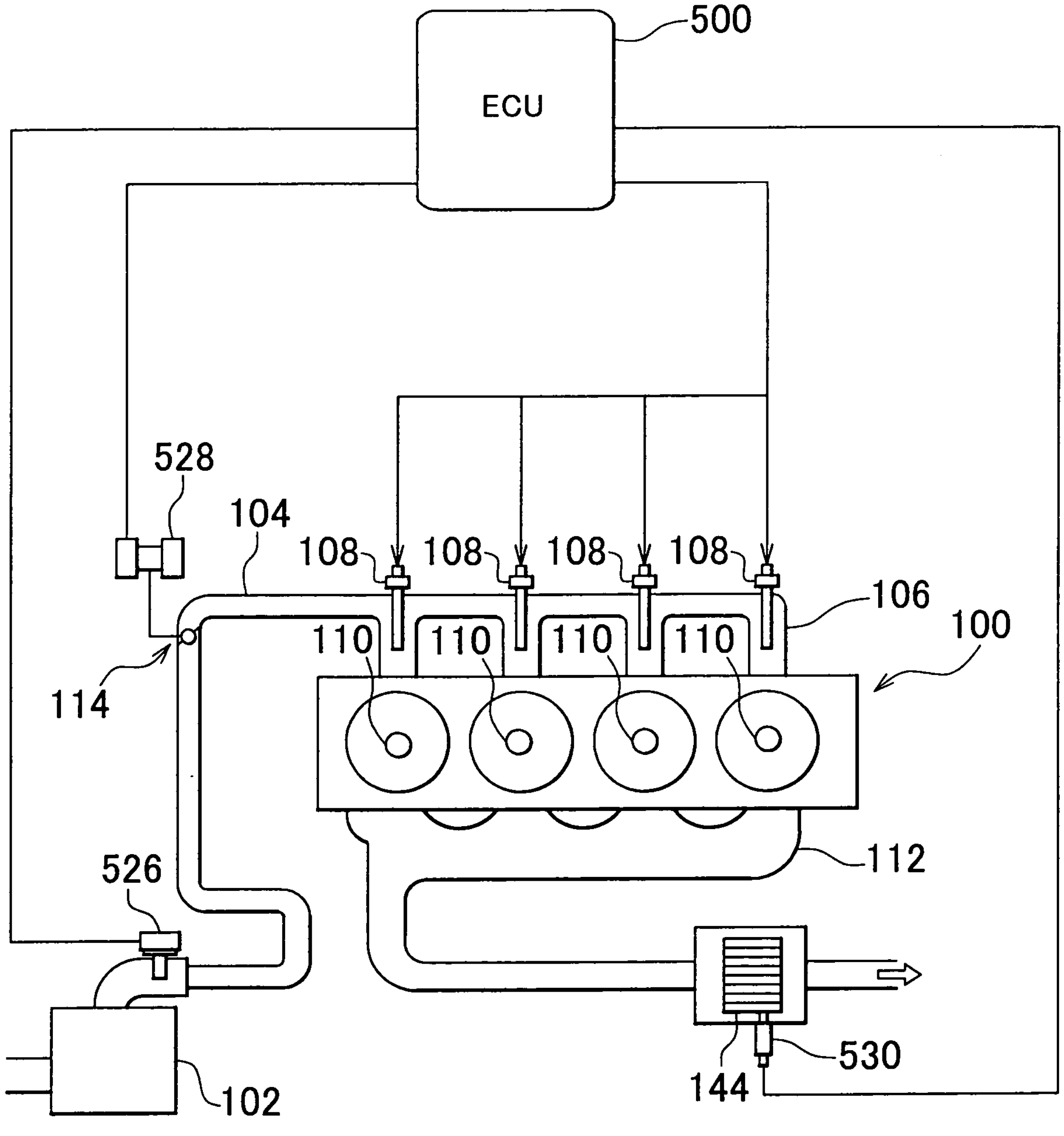

500
ECU
528
104
108
108
108
108
106
100
110
110
110
110
114
112
526
530
144
102

FIG. 3

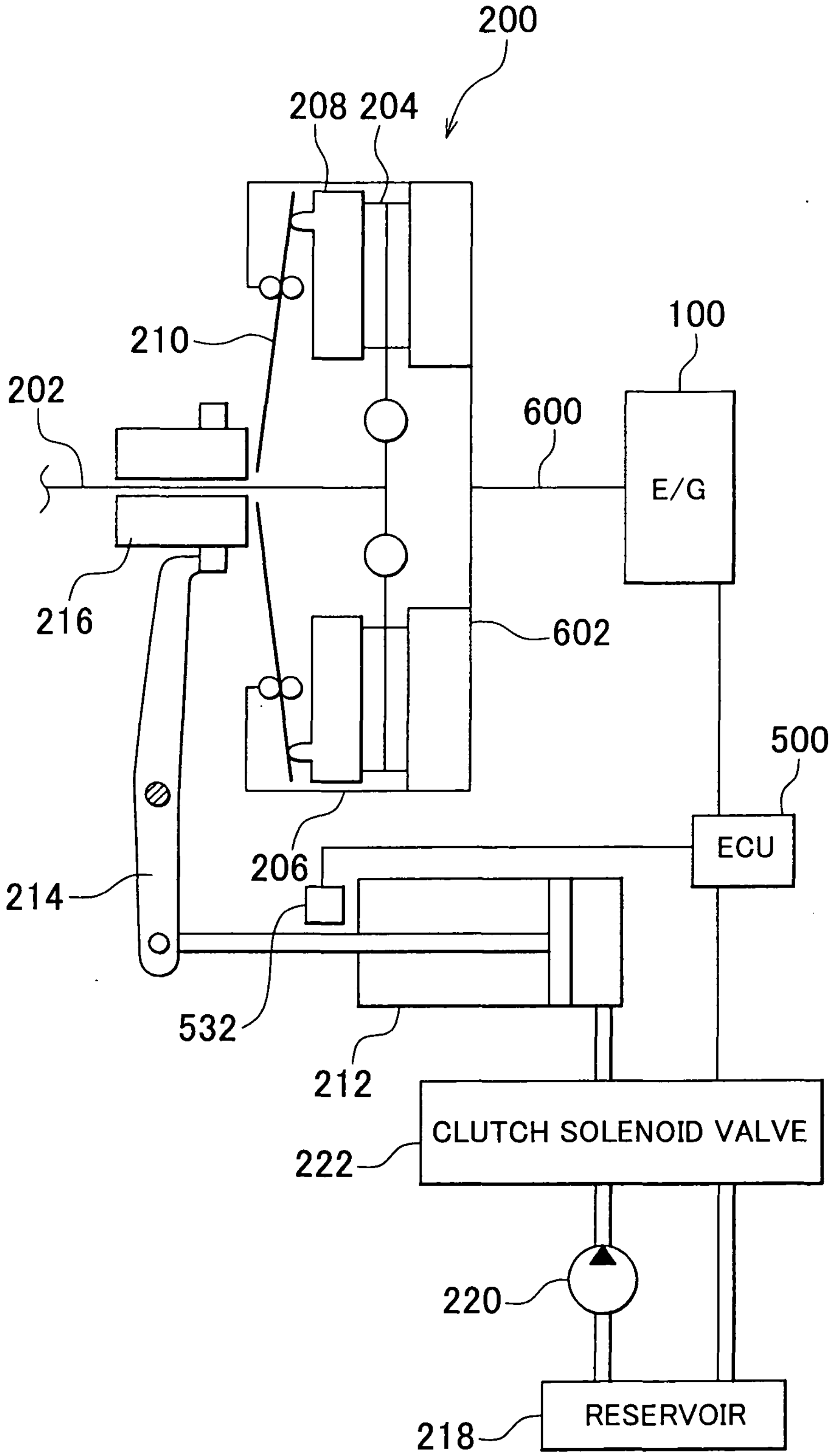

200
208 204
210
100
202
600
E/G
216
602
500
ECU
206
214
532
212
CLUTCH SOLENOID VALVE
222
220
RESERVOIR
218

FIG. 4

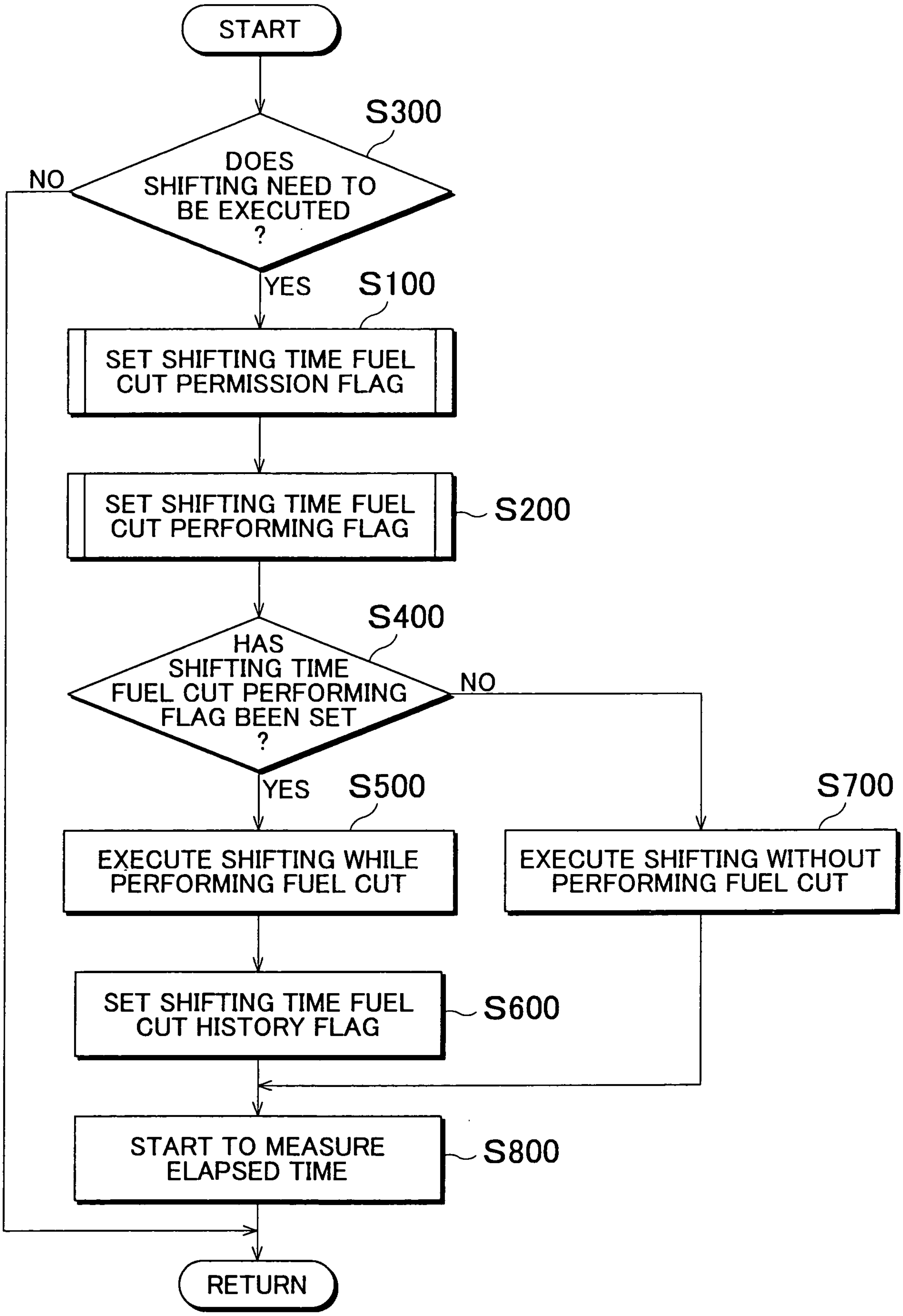

START
S300
DOES SHIFTING NEED TO BE EXECUTED ?
NO
YES
S100
SET SHIFTING TIME FUEL CUT PERMISSION FLAG
S200
SET SHIFTING TIME FUEL CUT PERFORMING FLAG
S400
HAS SHIFTING TIME FUEL CUT PERFORMING FLAG BEEN SET ?
NO
YES
S500
EXECUTE SHIFTING WHILE PERFORMING FUEL CUT
S700
EXECUTE SHIFTING WITHOUT PERFORMING FUEL CUT
S600
SET SHIFTING TIME FUEL CUT HISTORY FLAG
S800
START TO MEASURE ELAPSED TIME
RETURN

FIG. 5

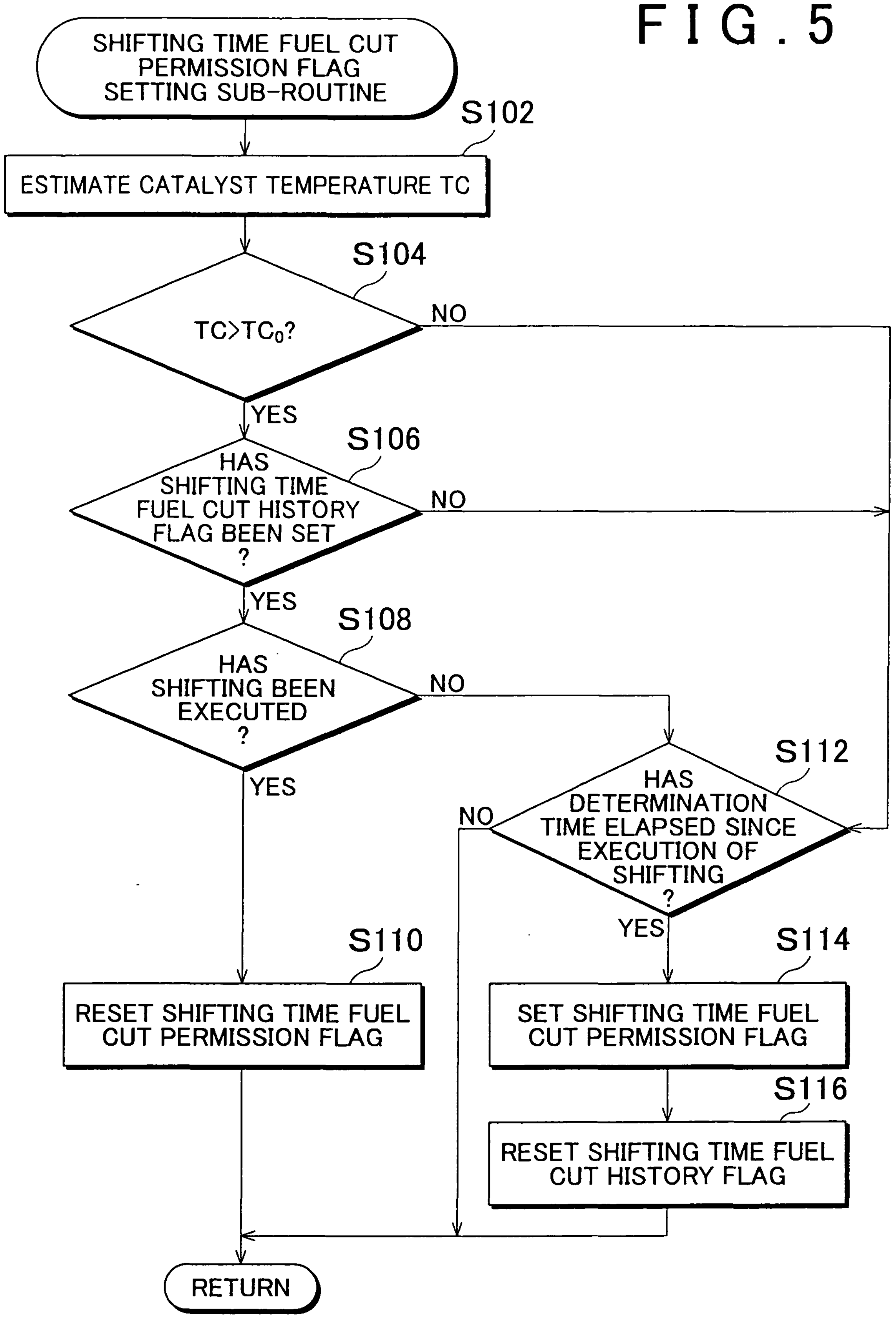

SHIFTING TIME FUEL CUT PERMISSION FLAG SETTING SUB-ROUTINE
S102
ESTIMATE CATALYST TEMPERATURE TC
S104
$TC>TC_0$?
NO
YES
S106
HAS SHIFTING TIME FUEL CUT HISTORY FLAG BEEN SET ?
NO
YES
S108
HAS SHIFTING BEEN EXECUTED ?
NO
YES
S112
HAS DETERMINATION TIME ELAPSED SINCE EXECUTION OF SHIFTING ?
NO
YES
S110
RESET SHIFTING TIME FUEL CUT PERMISSION FLAG
S114
SET SHIFTING TIME FUEL CUT PERMISSION FLAG
S116
RESET SHIFTING TIME FUEL CUT HISTORY FLAG
RETURN

FIG. 6

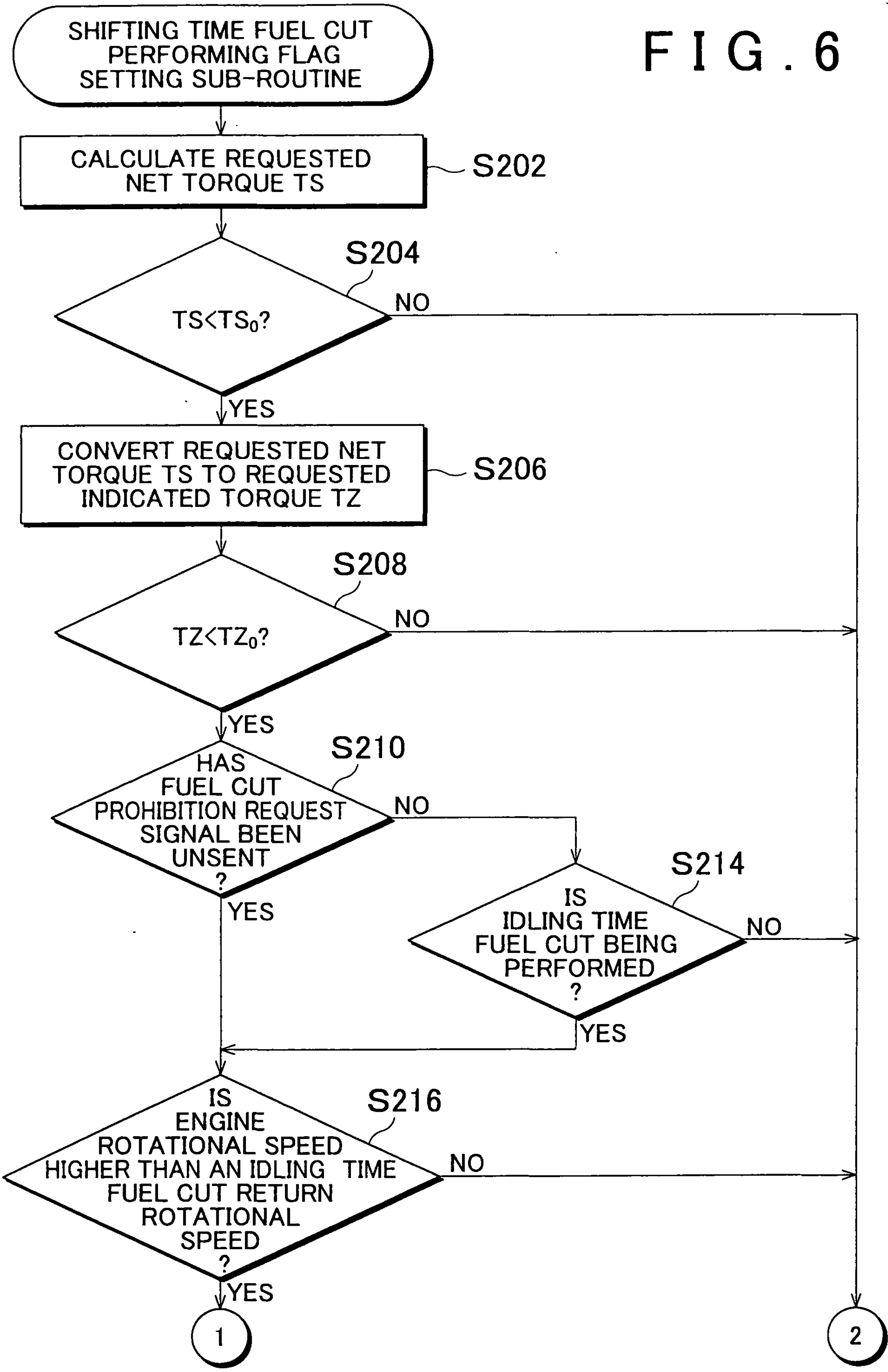

SHIFTING TIME FUEL CUT PERFORMING FLAG SETTING SUB-ROUTINE
CALCULATE REQUESTED NET TORQUE TS
S202
S204
TS<TS0?
NO
YES
CONVERT REQUESTED NET TORQUE TS TO REQUESTED INDICATED TORQUE TZ
S206
S208
TZ<TZ0?
NO
YES
S210
HAS FUEL CUT PROHIBITION REQUEST SIGNAL BEEN UNSENT ?
NO
YES
S214
IS IDLING TIME FUEL CUT BEING PERFORMED ?
NO
YES
S216
IS ENGINE ROTATIONAL SPEED HIGHER THAN AN IDLING TIME FUEL CUT RETURN ROTATIONAL SPEED ?
NO
YES
1
2

FIG.7

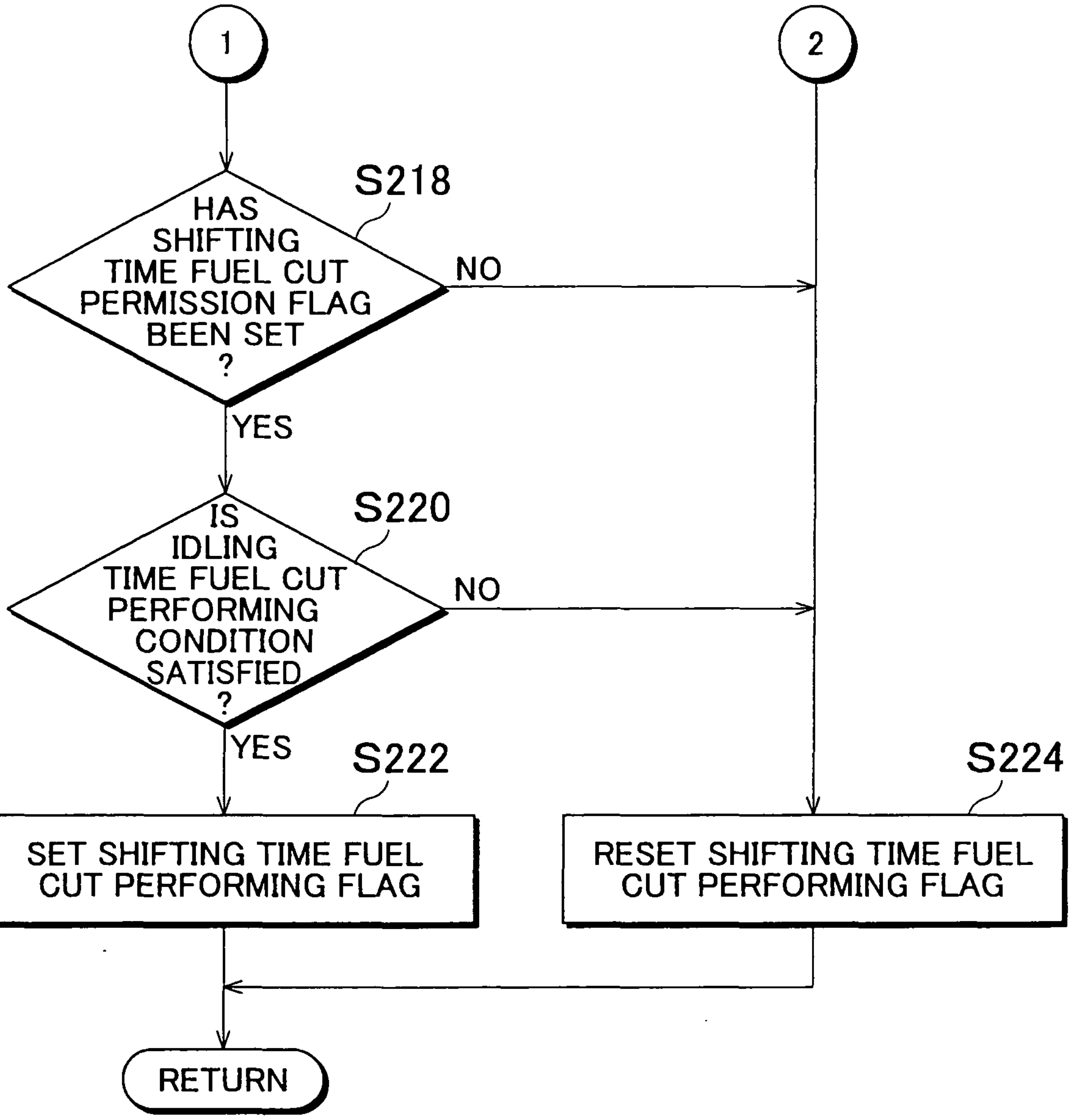

1
2
S218
HAS SHIFTING TIME FUEL CUT PERMISSION FLAG BEEN SET ?
NO
YES
S220
IS IDLING TIME FUEL CUT PERFORMING CONDITION SATISFIED ?
NO
YES
S222
SET SHIFTING TIME FUEL CUT PERFORMING FLAG
S224
RESET SHIFTING TIME FUEL CUT PERFORMING FLAG
RETURN

FIG. 8

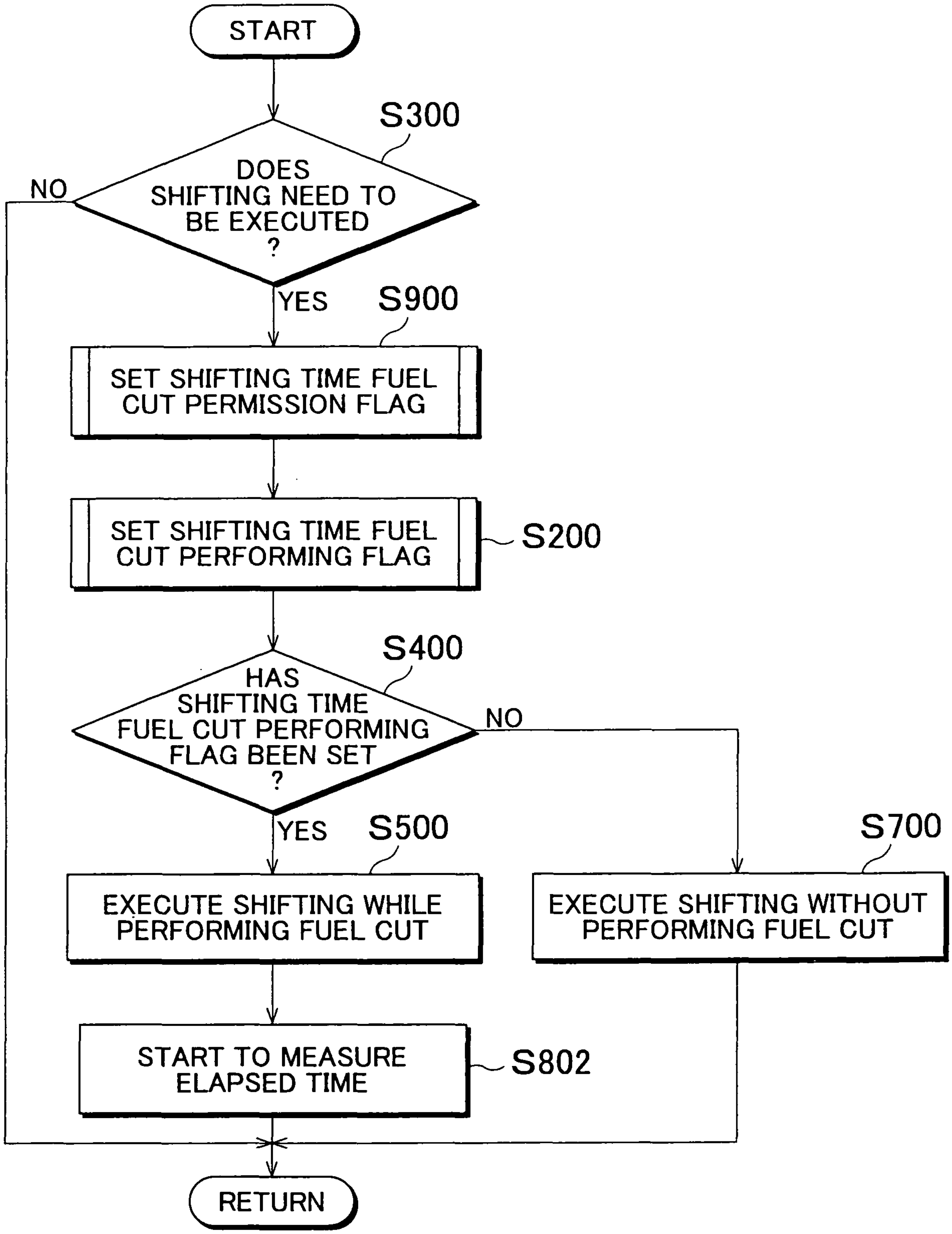

START
S300
DOES SHIFTING NEED TO BE EXECUTED ?
NO
YES
S900
SET SHIFTING TIME FUEL CUT PERMISSION FLAG
SET SHIFTING TIME FUEL CUT PERFORMING FLAG
S200
S400
HAS SHIFTING TIME FUEL CUT PERFORMING FLAG BEEN SET ?
NO
YES
S500
EXECUTE SHIFTING WHILE PERFORMING FUEL CUT
S700
EXECUTE SHIFTING WITHOUT PERFORMING FUEL CUT
START TO MEASURE ELAPSED TIME
S802
RETURN

FIG. 9

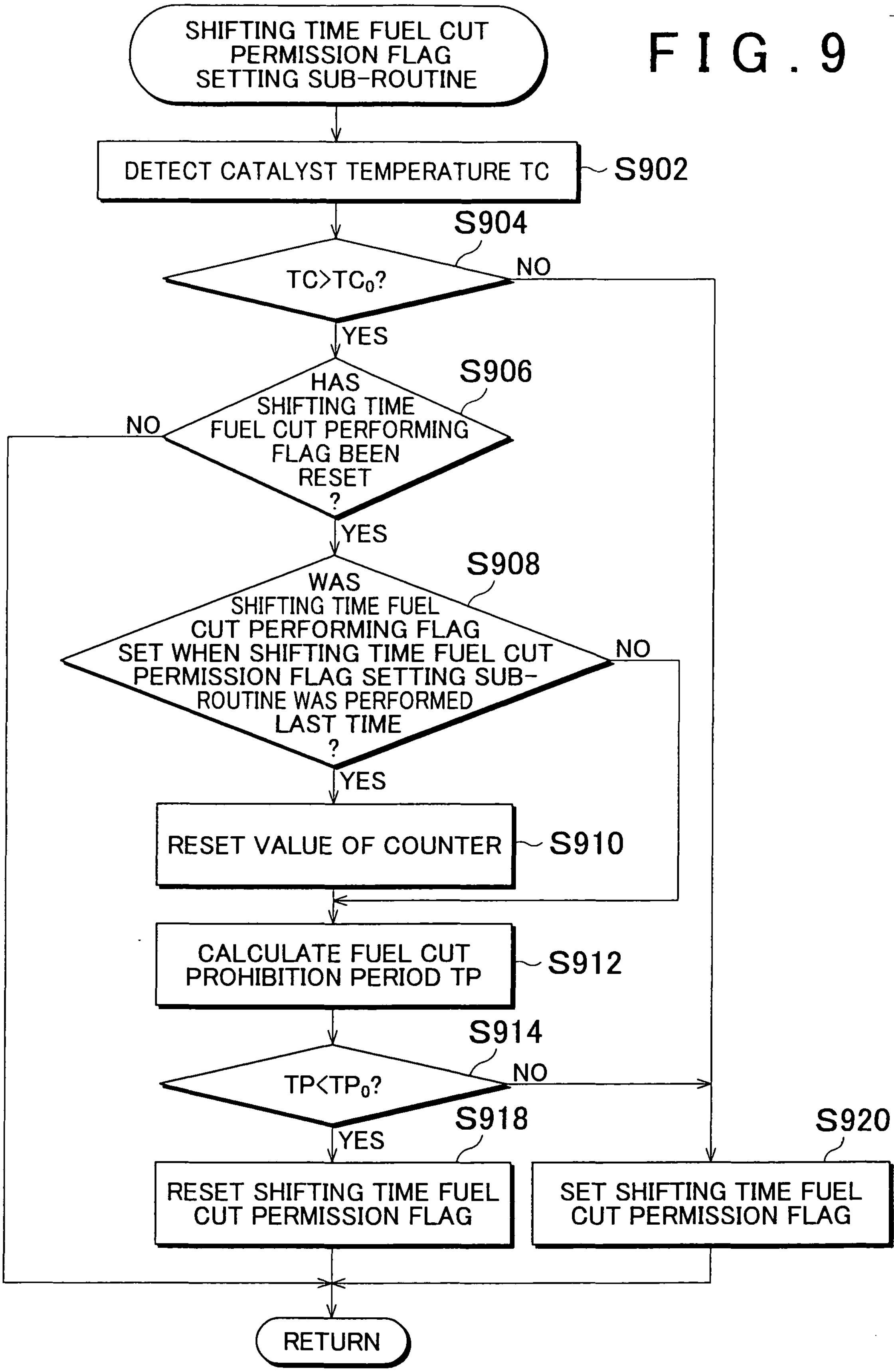

SHIFTING TIME FUEL CUT PERMISSION FLAG SETTING SUB-ROUTINE
DETECT CATALYST TEMPERATURE TC
S902
S904
TC>TC0?
NO
YES
S906
HAS SHIFTING TIME FUEL CUT PERFORMING FLAG BEEN RESET ?
NO
YES
S908
WAS SHIFTING TIME FUEL CUT PERFORMING FLAG SET WHEN SHIFTING TIME FUEL CUT PERMISSION FLAG SETTING SUB-ROUTINE WAS PERFORMED LAST TIME ?
NO
YES
RESET VALUE OF COUNTER
S910
CALCULATE FUEL CUT PROHIBITION PERIOD TP
S912
S914
TP<TP0?
NO
YES
S918
RESET SHIFTING TIME FUEL CUT PERMISSION FLAG
S920
SET SHIFTING TIME FUEL CUT PERMISSION FLAG
RETURN

FIG. 10

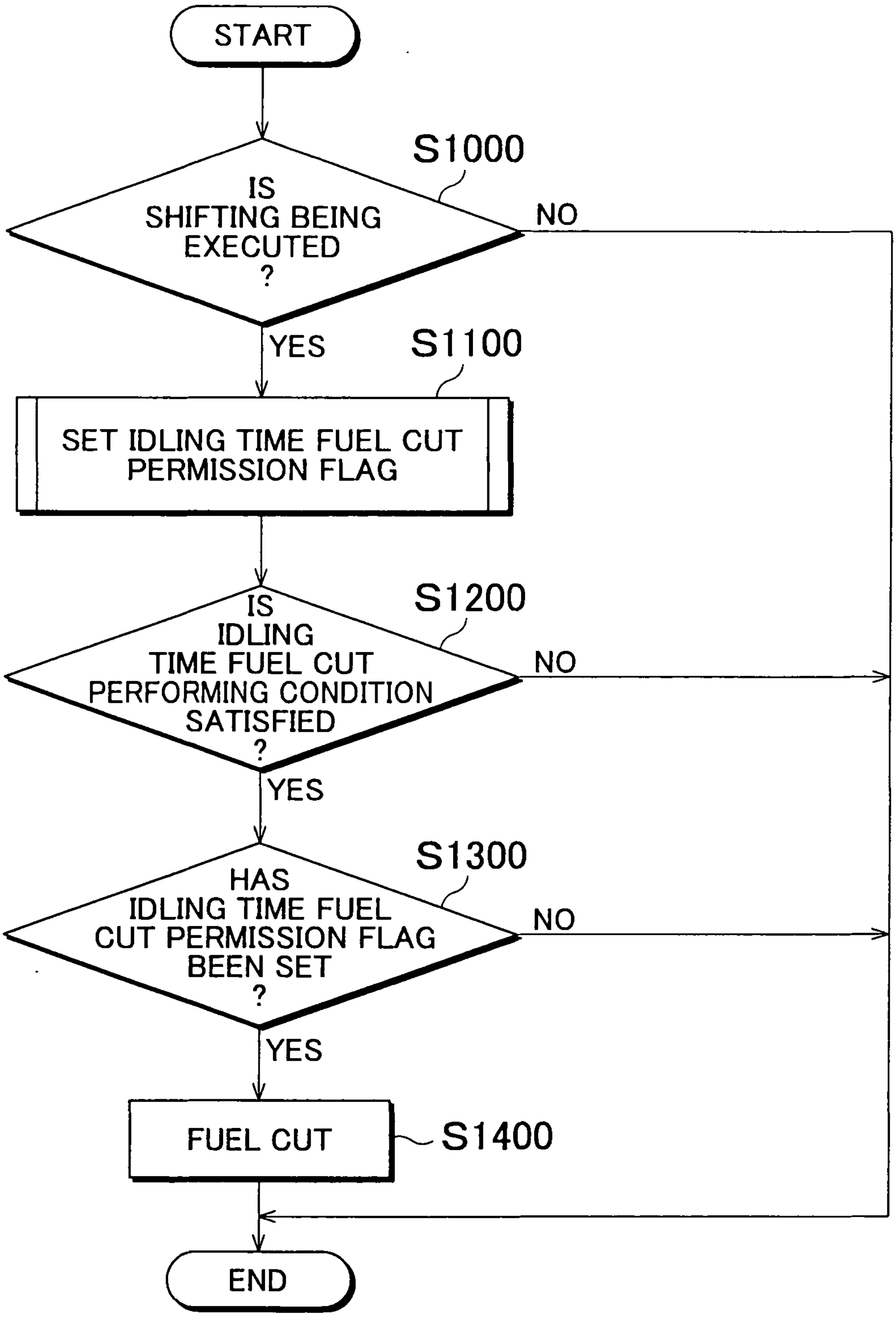
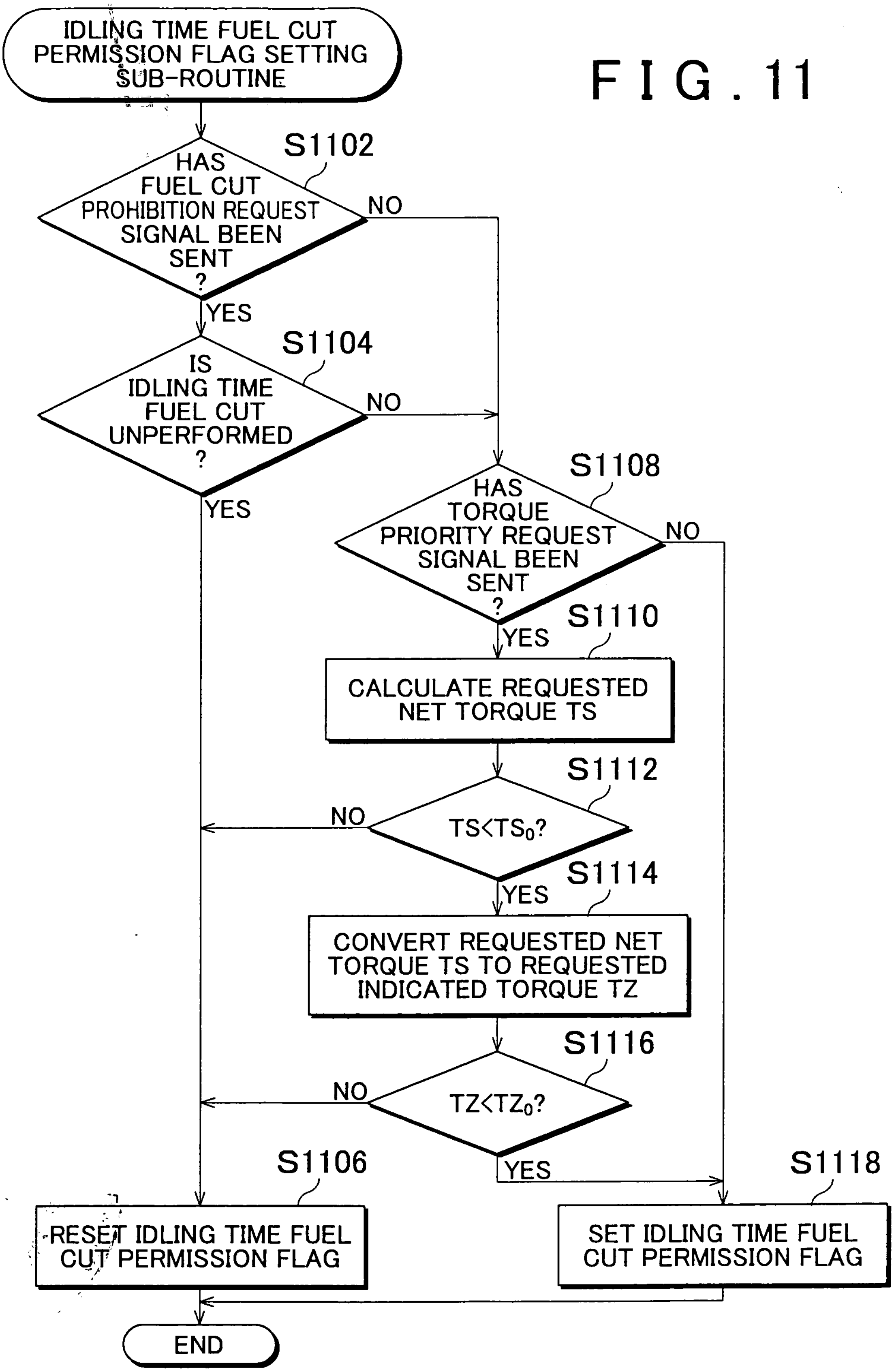

START
S1000
IS SHIFTING BEING EXECUTED ?
NO
YES
S1100
SET IDLING TIME FUEL CUT PERMISSION FLAG
S1200
IS IDLING TIME FUEL CUT PERFORMING CONDITION SATISFIED ?
NO
YES
S1300
HAS IDLING TIME FUEL CUT PERMISSION FLAG BEEN SET ?
NO
YES
FUEL CUT
S1400
END

FIG. 11


IDLING TIME FUEL CUT PERMISSION FLAG SETTING SUB-ROUTINE
S1102
HAS FUEL CUT PROHIBITION REQUEST SIGNAL BEEN SENT ?
NO
YES
S1104
IS IDLING TIME FUEL CUT UNPERFORMED ?
NO
YES
S1108
HAS TORQUE PRIORITY REQUEST SIGNAL BEEN SENT ?
NO
YES
S1110
CALCULATE REQUESTED NET TORQUE TS
S1112
TS<TS0?
NO
YES
S1114
CONVERT REQUESTED NET TORQUE TS TO REQUESTED INDICATED TORQUE TZ
S1116
TZ<TZ0?
NO
YES
S1106
RESET IDLING TIME FUEL CUT PERMISSION FLAG
S1118
SET IDLING TIME FUEL CUT PERMISSION FLAG
END