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(54) **CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE**

(57) [Problem] To securely perform determinations of strokes of an engine.

[Solving Means] A control apparatus for an engine measures a maximum pressure P2 and a minimum pressure P1 in an intake pipe during one revolution of a crankshaft and calculates a difference between the maximum pressure P2 and the minimum pressure P1 as an intake-air-pressure fluctuation range DPMTDC. The control apparatus compares, with respect to a magnitude relation, a previous intake-air-pressure fluctuation range with a current intake-air-pressure fluctuation range. When variations in the magnitude relation between the intake-air-pressure fluctuation ranges DPMTDC occur three consecutive times, the control apparatus makes a stroke determination, and determines that the engine is in expansion and exhaust strokes when a variation in the intake-air-pressure fluctuation ranges DPMTDC is from large to small.

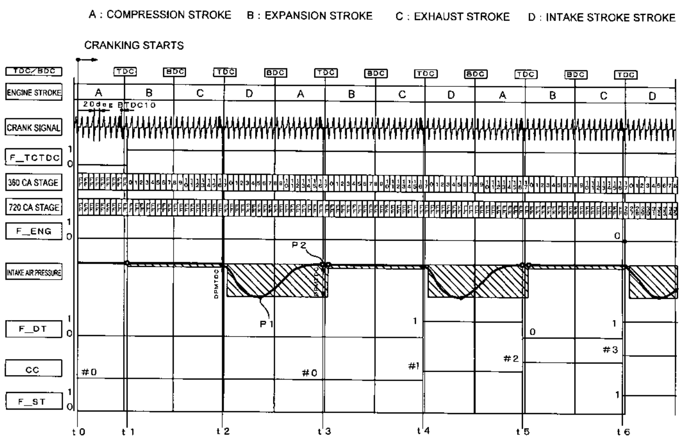

FIG. 8

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Description

Technical Field

[0001] The present invention relates to a control apparatus for an internal combustion engine.

Background art

[0002] An internal combustion engine, for example, a four-stroke cycle single cylinder engine outputs power by repeating four strokes, which are intake strokes, compression strokes, expansion strokes, and exhaust strokes. A control apparatus for an engine measures a timing of injection or ignition of fuel by determining these strokes of the engine.

[0003] As a method applied by a control apparatus for determining engine strokes, for example, there has been known a method of comparing pressure characteristics in an intake pipe during a first revolution of a crankshaft with those between first and second revolutions thereof, that is, at 720 CA (Crank Angle) at the start of an engine, thereby determining the engine strokes.

[0004] As a specific example of determining strokes at the start of an engine, for example, the following method has been known. A minimum pressure in an intake pipe is measured for every one revolution of a crankshaft. The minimum pressure at a first revolution of the crankshaft is compared with a minimum pressure at a second revolution thereof. With this stroke determination method, engine strokes are determined at the second revolution of the crankshaft. There is another example of determining strokes as follows. That is, pressures in an intake pipe of an engine are accumulated for every pulse signal output regularly in response to the revolution of a crankshaft. With this stroke determination method, engine strokes are determined by comparing an accumulated pressure in the intake pipe at a first revolution of the crankshaft with that at a second revolution thereof when the crankshaft revolves twice.

Prior Art Documents

Patent Documents

[0005]

Patent Document 1: Japanese Patent Application Laid-open No. 2000-265894

Patent Document 2: Japanese Patent Application Laid-open No. 2003-3887

Summary of the Invention

Problem to be Solved by the Invention

[0006] However, when pressure characteristics in the intake pipe during one revolution of the crankshaft are compared with those at 720 CA, in some cases, the magnitude relation between the minimum pressure or accumulated pressure in the intake pipe at the first revolution and the minimum pressure or accumulated pressure in the intake pipe at the second revolution does not match the engine strokes, resulting in an error in the stroke determination. For example, such a phenomenon occurs when a throttle valve that regulates the amount of intake air is operated to be opened or closed or when the engine rotates at a high rotational speed and the throttle valve is open at a high opening degree (fully open, for example), at the start of the engine or while the engine is running in a transient operation.

The present invention has been achieved in view of the above problems, and a primary object of the present invention is to securely perform determinations of strokes of an engine.

Means for Solving the Problem

[0007] One aspect of the present invention provides a control apparatus for an internal combustion engine, comprising: an intake-air-pressure calculating unit that acquires a pressure in an intake pipe, which supplies air into a combustion chamber of the internal combustion engine, and measures the maximum pressure and the minimum pressure in the intake pipe during one revolution of an output shaft of the internal combustion engine; a fluctuation-range calculating unit that calculates a pressure fluctuation range during one revolution of the output shaft from a difference between a maximum pressure and a minimum pressure in the intake pipe; a fluctuation-range comparing unit that compares, with respect to a magnitude relation, a previous pressure fluctuation range with a current pressure fluctuation range obtained during two revolutions of the crankshaft; a stroke determining unit that compares, with respect to a magnitude relation, a previous pressure fluctuation range with a current pressure fluctuation range, and determines strokes of the internal combustion engine; and an output processing unit that executes a fuel injection output and an ignition output once for every two revolutions of the output shaft after strokes of the internal combustion engine are determined.

[0008] Another aspect of the present invention provides the control apparatus for an internal combustion engine according to claim 1, wherein the stroke determining unit compares, with respect to a magnitude relation, the previous pressure fluctuation range with the current pressure fluctuation range, and determines strokes of an engine when variations in the magnitude relation between the pressure fluctuation ranges in the intake pipe occur alternately and consecutively in a period of revolutions of the output shaft with a predetermined number of times.

[0009] Still another aspect of the present invention provides the control apparatus for an internal combustion engine according to claim 2, wherein the stroke determining unit determines strokes of an engine when variations in a magnitude relation between the pressure fluctuation ranges in the intake pipe occur three consecutive times.

[0010] Still another aspect of the present invention provides the control apparatus for an internal combustion engine according to any one of claims 1 to 3, wherein when a variation from the previous pressure fluctuation range to the current pressure fluctuation range is from large to small, the stroke determining unit determines that strokes corresponding to the current pressure fluctuation range are expansion and exhaust strokes.

Effect of the Invention

[0011] According to the present invention, the control apparatus determines strokes according to variations in fluctuation ranges of a pressure in an intake pipe. Therefore, the control apparatus can accurately determine strokes even in conditions in which an error can occur to determinations in conventional techniques. Because ignition or the like can be executed based on a correct result of stroke determinations, the durability of constituent elements that constitute an ignition system can be improved.

Brief Description of the Drawings

[0012]

[FIG. 1] FIG. 1 shows a configuration of an internal combustion engine and a control apparatus according to an embodiment of the present invention.
[FIG. 2] FIG. 2 is a block diagram of the control apparatus.
[FIG. 3] FIG. 3 is a flowchart of control of the internal combustion engine.
[FIG. 4] FIG. 4 is an explanatory diagram of a process of detecting a crank angle using a timing rotor.
[FIG. 5] FIG. 5 is a flowchart of a calculating process of an intake air pressure for engine stroke determination (part 1).
[FIG. 6] FIG. 6 is a flowchart of an engine-stroke determining process (part 1).
[FIG. 7] FIG. 7 is a flowchart of the engine-stroke determining process (part 2).
[FIG. 8] FIG. 8 is a timing chart at the time of performing an engine-stroke determining process (part 1).
[FIG. 9] FIG. 9 is a timing chart at the time of performing the engine-stroke determining process (part 2).
[FIG. 10] FIG. 10 shows experiment results of stroke determinations (part 1).
[FIG. 11] FIG. 11 shows experiment results of stroke determinations (part 2).

Best Mode for Carrying Out the Invention

[0013] A mode for carrying out the present invention is explained below in detail.
FIG. 1 is a schematic configuration diagram of a system including an internal combustion engine and a control apparatus for the internal combustion engine.
An engine 1 that is an internal combustion engine includes an intake pipe 2 that takes in air. The intake pipe 2 includes an intake port 2A at an upstream of the intake pipe 2 and an air cleaner 3 is attached to the intake port 2A. After an intake-air temperature sensor 4 is provided thereto, a throttle valve 5 can regulate a pipe line area. A throttle opening-degree sensor 6 monitors the opening degree of the throttle valve 5. An intake-air pressure sensor 7 and an injector 8 for fuel injection are provided in this order at a downstream of the throttle valve 5 and connected to a combustion chamber 13 formed out of a cylinder head 12 and a cylinder block 11. An intake valve 14 is inserted between the intake pipe 2 and the combustion chamber 13 so as to freely open or close a pipe line.

[0014] A piston 15 is slidably inserted into the cylinder block 11. The piston 15 is coupled to a crankshaft 17 via a crank arm 16, and is configured to convert a linear reciprocating motion of the piston 15 into a revolving motion of the crankshaft 17 that serves as an output shaft. The crankshaft 17 is rotatably supported by the cylinder block 11 and a timing rotor 18 is fixed to the crankshaft 17 for detecting the number of revolutions of the crankshaft 17. A crank angle sensor 19 is arranged near the timing rotor 18. Furthermore, a channel 20 that circulates coolant is formed in the cylinder block 11 and a coolant temperature sensor 21 that measures the temperature of the coolant is attached to the cylinder block 11.

[0015] An ignition plug 24 and an exhaust pipe 25 as well as the intake pipe 2 are attached to the cylinder head 12. The ignition plug 24 is electrically connected to an ignition coil 27 so as to apply a high voltage to the ignition coil 27. Furthermore, an exhaust valve 28 is attached to an opening of the exhaust pipe 25 continuous to the combustion chamber 13 so as to freely open or close it. In addition, a catalytic converter 29 is provided halfway along the exhaust pipe 25.

[0016] A configuration of a control apparatus 41 that controls the engine 1 mentioned above is explained next with reference to FIG. 2. The control apparatus 41 is also referred to as "ECU (Electronic Control Unit)".
The control apparatus 41 is connected to a battery 42, and is configured such that signals can be input to the control apparatus 41 from the crank angle sensor 19, the throttle opening-degree sensor 6, the intake-air pressure sensor 7, the coolant temperature sensor 21, and the intake-air temperature sensor 4. The control apparatus 41 is also configured to be able to output signals to the ignition coil 27 and the injector 8.

[0017] The control apparatus 41 includes a waveform shaping circuit 51 that shapes digital signals output from the crank angle sensor 19 and an A/D (Analog/Digital) converter 52 that converts analog signals output from the four sensors 4, 6, 7, and 21 into digital signals. The waveform shaping circuit 51 and the A/D converter are connected to a CPU (Central Processing Unit) 53. A ROM (Read Only Memory) 54, a RAM (Random Access Memory) 55, and a timer 56 are also connected to the CPU 53. Furthermore, an output of the CPU 53 is connected to an ignition circuit 57 and a drive circuit 58. The ignition circuit 57 is configured to output signals to the ignition coil 27 at a predetermined timing. The drive circuit 58 is configured to output signals for driving the injector 8 at a predetermined timing.

[0018] Furthermore, in the embodiment of the present invention, the CPU 53 can be functionally divided into a crank signal processing unit 61, a throttle signal processing unit 62, an intake-air-pressure calculating unit 63, a fluctuation-range calculating unit 64, a fluctuation-range comparing unit 65, a stroke determining unit 66, and an output processing unit 67.

[0019] The crank signal processing unit 61 calculates a rotation angle of the crankshaft 17 and an engine speed. The throttle signal processing unit 62 calculates a throttle opening degree. The intake-air-pressure calculating unit 63 calculates pressures in the intake pipe and also calculates a maximum pressure and a minimum pressure. The fluctuation-range calculating unit 64 calculates a fluctuation range of the pressures in the intake pipe 2 during one revolution of the crankshaft 17. The fluctuation-range comparing unit 65 compares a previous pressure fluctuation range and a current pressure fluctuation range calculated during two revolutions of the crankshaft 17. The stroke determining unit 66 determines strokes of the engine 1 according to variations in the pressure fluctuation ranges. The output processing unit 67 performs an fuel injection output and an ignition output in response to the result of stroke determinations.

Control of the internal combustion engine according to the present embodiment is explained next.

[0020] First, as shown in the flowchart of FIG. 3, in Step S101, the control apparatus 41 detects a crank-angle reference position. For example, as shown in FIG. 4, the timing rotor 18 has 18 protrusions 71 formed at an interval of a rotation angle of 20°, and one of the protrusions 71 is defined as a reference protrusion 71A and it is formed to be circumferentially longer than other protrusions 71. When detecting the next protrusion 71 to the reference protrusion 71A, the crank signal processing unit 61 of the control apparatus 41 sets the number of 360 CA (Crank Angle) stages to "0". The crank signal processing unit 61 increments the number of stages starting from "0" whenever detecting the protrusion 71. The crank signal processing unit 61 then sets the number of stages when detecting the reference protrusion 71 A to "17". Thereafter, when detecting the next protrusion 71 to the reference protrusion 71A, the crank signal processing unit 61 resets the number of stages to "0" and repeatedly counts up again from "0". A top dead center (TDC) of the piston 15 is located between the reference protrusion 71 A and the next protrusion 71. An end point of the reference protrusion 71 A is located at a position (BTDC 10°) advanced from the top dead center by 10°. In addition, an end point of the next protrusion 71 to the reference protrusion 71A is located at a position (ATDC 10°) lagging behind the top dead center by 10°.

[0021] Detection of the reference position of the crank angle 17 is performed by measuring the length of each of the protrusions 71 formed cyclically on the outer circumference of the timing rotor 18 and the time required until the next protrusion 71 appears. As described above, only the reference protrusion 71 A of the timing rotor 18 is formed longer in a rotational direction. Accordingly, the crank angle sensor 19 is used to measure the length of the protrusion 71 and the time required until the next protrusion 71 appears, and calculates a ratio of the length and the time. The protrusions 71 other than the reference protrusion 71A have a constant ratio and a ratio of the reference protrusion 71A is relatively higher than that of other protrusions 71. Therefore, it is possible to determine whether a certain protrusion 71 is the reference protrusion 71 A or the protrusion 71 other than the reference protrusion 71 A by measuring the difference between previous and current ratios.

[0022] Next, in Step S102, the control apparatus 41 checks whether a crank rear-end-position signal indicating detection of a rear end position of the reference protrusion 71A of the timing rotor 18 is output. When the crank rear-end-position signal is not detected, this process is finished. On the other hand, when the crank rear-end-position signal is output, the process proceeds to Step S 104. In Step S104, the control apparatus 41 checks whether the crank-angle reference position has been detected. When the crank-angle reference position is not detected, the process proceeds to Step S105, and the control apparatus 41 resets parameters for engine stroke determination. Thereafter, the control apparatus 41 finishes this process.

[0023] On the other hand, when the crank-angle reference position has been already detected in Step S104, the control apparatus 41 calculates the engine speed in Step S106. For example, the engine speed is calculated based on a sum of a measured time corresponding to 360 CA for the protrusions 71 provided on the timing rotor 18. Next, in Step S107, the throttle signal processing unit 62 of the control apparatus 41 calculates the throttle opening degree based on an output from the throttle opening-degree sensor 6. Further, in Step S108, the intake-air-pressure calculating unit 63 calculates an intake air pressure PMB based on an output from the intake-air-pressure sensor.

[0024] Thereafter, in Step S109, the intake-air-pressure calculating unit 63 and the fluctuation-range calculating unit 64 of the control apparatus 41 calculate an intake air pressure for determination used to determine engine strokes according to the intake air pressure. In this case, the control apparatus 41 decides the maximum intake air pressure and the minimum intake air pressure, and calculates the difference between the maximum and minimum intake air pressures for every one revolution of the crankshaft 17. This process is explained later in detail. Furthermore, in Step S110, the fluctuation-range comparing unit 65 and the stroke determining unit 66 of the control apparatus 41 determine engine strokes based on the intake air pressure for determination. In the present embodiment, the control apparatus 41 acquires pieces of data corresponding to four revolutions, each data of which is on the difference between the maximum and minimum intake air pressures during one revolution of the crankshaft 17. When the variation in differences is either "large → small → large → small" or "small → large → small → large" and the variation in the differences at or after the fourth revolution is smaller than the previous variation, the control apparatus 41 determines that the engine 1 is in expansion and exhaust strokes. This process is explained later in detail.

[0025] Next, in Step S111, the output processing unit 67 of the control apparatus 43 calculates an ignition timing from the determination result of the strokes of the engine 1, the engine speed, and the throttle opening degree. Furthermore, in Step S 112, the output processing unit 67 decides a fuel injection amount and the timing of starting fuel injection from the determination result of the strokes of the engine 1, the engine speed, and the throttle opening degree.

[0026] Further, in Step S 113, the output processing unit 67 performs an ignition output process to discharge the ignition plug 24, thereby igniting a combustible air-fuel mixture in the combustion chamber 13. After the strokes of the engine 1 are determined, the output processing unit 67 performs the ignition output process only in intake and compression strokes and performs one ignition output for every two revolutions of the crankshaft 17. On the other hand, when the strokes of the engine 1 have not been determined yet, the output processing unit 67 performs one ignition output for every one revolution of the crankshaft 17.

[0027] In Step S 114, the output processing unit 67 then performs a fuel injection process to inject fuel into the air drawn into the intake pipe 2, thereby producing the combustible air-fuel mixture. After the strokes of the engine 1 are determined, the output processing unit 67 performs the fuel injection process of injecting the fuel once for every two revolutions of the crankshaft 17. On the other hand, when the strokes of the engine 1 have not been determined yet, the output processing unit 67 performs the fuel injection process of injecting the fuel once for every one revolution of the crankshaft 17.

Details of a calculating process of the intake air pressure for stroke determination in Step 109 of FIG. 3 are explained next with reference to the flowchart of FIG. 5.

[0028] First, in Step S201, the control apparatus 41 checks the number of stages calculated along with the rotation of the timing rotor 18. When the number of stages specified by the rotation angle of the crankshaft 17 indicates a stage just after the top dead center, that is, the number of stages is 0 (zero), the process proceeds to Step S202. In Step S202, the intake-air-pressure calculating unit 63 resets an intake-air-pressure bottom value and sets the intake-air-pressure bottom value PMB to a current intake air pressure. In Step S203, the intake-air-pressure calculating unit 63 resets an intake-air-pressure top value and sets an intake-air-pressure top value PMT to the current intake air pressure. Further, in Step S204, the fluctuation-range calculating unit 64 resets an intake-air-pressure fluctuation range DPMTDC and sets a current value to zero. Thereafter, the process proceeds to Step S210 to be explained later.

[0029] On the other hand, when it is determined in Step S201 that the current stage is not the stage right after the top dead center, the process proceeds to Step S205, and the intake-air-pressure calculating unit 63 checks whether the intake-air-pressure bottom value PMB has been measured. When the current intake air pressure is equal to or lower than the intake-air-pressure bottom value PMB, the intake-air-pressure calculating unit 63 assumes that a new intake-air-pressure bottom value PMB has been detected. The process proceeds to Step S206, in which the intake-air-pressure calculating unit 63 updates the intake-air-pressure bottom value PMB to the current intake air pressure, and then the process proceeds to Step S207.

Meanwhile, if it is determined in Step S205 that the current intake air pressure is higher than the intake-air-pressure bottom value PMB, the intake-air-pressure calculating unit 63 does not update the intake-air-pressure bottom value PMB and the process proceeds to Step S207.

[0030] Further, in Step S207, the intake-air-pressure calculating unit 63 checks whether the intake-air-pressure top value PMT has been measured. When the current intake air pressure is equal to or higher than the intake-air-pressure top value PMT, the intake-air-pressure calculating unit 63 assumes that a new intake-air-pressure top value PMT has been detected and the process proceeds to Step S208. In Step S208, the intake-air-pressure calculating unit 63 updates the intake-air-pressure top value PMT to the current intake air pressure. When it is determined in Step S207 that the current intake air pressure is lower than the intake-air-pressure top value PMT, the intake-air-pressure calculating unit 63 does not update the intake-air-pressure top value PMT and the process proceeds to Step S209.

[0031] Next, in Step S209, the fluctuation-range calculating unit 64 calculates the intake-air-pressure fluctuation range DPMTDC. The intake-air-pressure fluctuation range DPMTDC can be obtained by subtracting the intake-air-pressure bottom value PMB from the intake-air-pressure top value PMT.

[0032] The process in Step S210 is performed next. When the current stage is not the stage just before the top dead center, this process is finished. In this way, while the stage reaches a next stage corresponding to the top dead center after passing the stage corresponding to the top dead center, the processes from Steps S201 to S209 are repeated, thereby repeatedly updating the intake-air-pressure bottom value PMB, updating the intake-air-pressure top value PMT, and calculating the intake-air-pressure fluctuation range DPMTDC.

[0033] On the other hand, when it is determined in Step S210 that the current stage has reached the stage just before the top dead center, the process proceeds to Step S211, and the fluctuation-range calculating unit 64 stores a current intake-air-pressure fluctuation range DPMTDC 1 already stored in a memory as a previous intake-air-pressure fluctuation range DPMTDC2. In Step S212, the fluctuation-range calculating unit 64 then stores the present intake-air-pressure fluctuation range DPMTDC as the current intake-air-pressure fluctuation range DPMTDC1. In Step S213, the fluctuation-range calculating unit 64 calculates an intake-air-pressure fluctuation range variation amount DDPMTDC by subtracting the current intake-air-pressure fluctuation range DPMTDC 1 from the previous intake-air-pressure fluctuation range DPMTDC2. The process performed so far calculates the intake-air-pressure bottom value PMB and the intake-air-pressure top value PMT during one revolution of the crankshaft 17, the current intake-air-pressure fluctuation range (DPMTDC1), and the intake-air-pressure fluctuation range variation amount DDPMTDC that is the difference between the previous intake-air-pressure fluctuation range and the current intake-air-pressure fluctuation range. This process is then finished.

Details of an engine-stroke determining process in Step S110 of FIG. 3 are explained next with reference to the flowcharts of FIGS. 6 and 7.

[0034] First, in Step S301, the fluctuation-range calculating unit 64 of the control apparatus 41 checks the current stage. When the stage is not the stage just before the top dead center, Step S320 in FIG. 7 via a terminal A is performed. On the other hand, when it is determined in Step S301 that the stage is just before the top dead center, the process proceeds to Step S302. In Step S302, the fluctuation-range comparing unit 65 checks whether the variation amount DDPMTDC in the intake-air-pressure fluctuation ranges DPMTDC is equal to or greater than a predetermined value. For example, the predetermined value is defined as about 5 kPa although the value differs according to the displacement or the like of the engine 1.

[0035] When it is determined in Step S302 that the variation amount in the intake-air-pressure fluctuation ranges DPMTDC is smaller than the predetermined value, the process proceeds to Step S303, and the fluctuation-range calculating unit 64 resets a previous intake-air-pressure fluctuation flag. Further, in Step S304, the fluctuation-range calculating unit 64 resets a current intake-air-pressure fluctuation flag. In Step S305, an intake-air-pressure fluctuation cycle counter CC is reset. Thereafter, Step S312 in FIG. 7 via a terminal B is performed.

[0036] On the other hand, when it is determined in Step S302 that the variation amount in the intake-air-pressure fluctuation ranges DPMTDC is equal to or greater than the predetermined value, the process proceeds to Step S306, and the fluctuation-range calculating unit 64 updates a previous intake-air-pressure fluctuation flag F_DB. Specifically, the fluctuation-range calculating unit 64 updates the previous intake-air-pressure fluctuation flag F_DB to a current intake-air-pressure fluctuation flag F_DT.

Further, in Step S307, the fluctuation-range comparing unit 65 checks the magnitude relation between the previous intake-air-pressure fluctuation range DMPTDC2 and the current intake-air-pressure fluctuation range DMPTDC1, and sets the current intake-air-pressure fluctuation flag F_DT accordingly. For example, when the previous intake-air-pressure fluctuation range DMPTDC2 is equal to or greater than the current intake-air-pressure fluctuation range DMPTDC1, the variation in the intake-air-pressure fluctuations is from large to small. Therefore, the current intake-air-pressure fluctuation flag F_DT is set to "1". When the previous intake-air-pressure fluctuation range DMPTDC2 is smaller than the current intake-air-pressure fluctuation range DMPTDC1, the variation in the intake-air-pressure fluctuations is from small to large. Therefore, the current intake-air-pressure fluctuation flag F_DT is set to "0".

[0037] In Step S308, if it is not assumed that the intake air pressure fluctuations are generated cyclically, the process proceeds to Step S309. The case where it is not assumed that the intake air pressure fluctuations are generated cyclically means a case where the value of the intake-air-pressure fluctuation cycle counter CC is smaller than "1". In Step S309, the fluctuation-range comparing unit 65 checks the magnitude relation between the previous intake-air-pressure fluctuation range DPMTDC2 and the current intake-air-pressure fluctuation range DPMTDC 1. When the variation from the previous intake-air-pressure fluctuation range DPMTDC2 to the current intake-air-pressure fluctuation range DPMTDC1 is from large to small, the process proceeds to Step S310. In Step S310, when the current intake-air-pressure fluctuation flag (F_DT) is inverted with respect to the previous intake-air-pressure fluctuation flag (F_DB), the process proceeds to Step S311, and the intake-air-pressure fluctuation cycle counter CC is incremented. Thereafter, the process proceeds to Step S312 in FIG. 7 via the terminal B.

[0038] On the other hand, when it is determined in Step

S309 that the variation from the previous intake-air-pressure fluctuation range DPMTDC2 to the current intake-air-pressure fluctuation range DPMTDC1 is from small to large, the process proceeds to Step S305. In Step S305, the intake-air-pressure fluctuation cycle counter CC is reset to "0". Thereafter, the process proceeds to Step S312 in FIG. 7 via the terminal B. Furthermore, when it is determined in Step S310 that the intake-air-pressure fluctuation flag is not inverted, for example, when the previous intake-air-pressure fluctuation flag F_DB and the current intake-air-pressure fluctuation flag F_DT are both "1" or "0", the process proceeds to Step S305. In Step S305, the intake-air-pressure fluctuation cycle counter CC is reset to "0". Thereafter, the process proceeds to Step S312 in FIG. 7 via the terminal B.

[0039] Meanwhile, when it is determined in Step S308 that the intake-air-pressure fluctuations are generated cyclically, that is, the value of the intake-air-pressure fluctuation cycle counter CC is equal to or greater than "1", the process proceeds to Step S310. In Step S310, when the current intake-air-pressure fluctuation flag F_DT is inverted with respect to the previous intake-air-pressure fluctuation flag F_DB, the process proceeds to Step S311. In Step S311, the intake-air-pressure fluctuation counter CC is incremented. Thereafter, the process proceeds to Step S312. When it is determined in Step S310 that the intake-air-pressure fluctuation flag is not inverted, the intake-air-pressure fluctuation cycle counter CC is reset in Step S305. The process then proceeds to Step S312 in FIG. 7 via the terminal B.

[0040] In Step S312 shown in FIG. 7, the stroke determining unit 66 checks the value of the intake-air-pressure fluctuation cycle counter CC. When the value of the intake-air-pressure fluctuation cycle counter CC is equal to or greater than "3", the process proceeds to Step S313. In Step S313, it is checked whether the variation in the intake-air-pressure fluctuations is from large to small. That is, the current intake-air-pressure fluctuation flag F_DT is checked and when the intake-air-pressure fluctuation flag F_DT is "1", the process proceeds to Step S314. When the strokes of the engine 1 have been already determined in Step pS314, the process proceeds to Step S315. In Step S315, when the number of stages of the 720 CA is "25", the process proceeds to Step S316. Similarly, in Step S314, when the strokes of the engine 1 have not been determined yet, the process proceeds to Step S316.

[0041] In Step S316, a stroke determination flag F_ST is set to "1" on an assumption that the strokes of the engine 1 have been determined. In Step S317, the 720 CA stage is set to "26". The 720 CA stage is a numeral incremented whenever the position of the protrusion 71 of the timing rotor 18 is detected while the crankshaft revolves by 720°.

[0042] When it is determined in Step S312 that the value of the intake-air fluctuation cycle counter CC is smaller than "3", or it is determined in Step S313 that the variation in the intake-air-pressure fluctuation ranges is from small to large, the process proceeds to Step S320. In Step S320, the stroke determining unit 66 checks whether the strokes of the engine 1 have been determined while referring to the stroke determination flag F_ST. When the strokes have not been determined yet in Step S320, the stroke determining unit 66 decides that the strokes of the engine 1 cannot be determined. At this time, "0" is assigned to the stroke determination flag F_ST. Furthermore, in Step S320, the 720 CA stage is reset. Further, when the 720 CA stage does not match the engine strokes in Step S315, the process proceeds to Steps S321 and S322.

[0043] When it is determined in Step S320 that the strokes have been determined, that is, the stroke determination flag F_ST is "1", the process proceeds to Step S323. When it is determined in Step S323 that the 720 CA stage reaches a maximum value, the process proceeds to Step S324, in which the 720 CA stage is set to zero. In other cases, the process proceeds to Step S25, in which the 720 CA stage is incremented by one.

[0044] After the 720 CA stage is set in Step S317, S322, S325 or S324, the process in and after Step S326 differs depending on whether the strokes of the engine 1 have been determined.
That is, when it is determined in Step S326 that the stroke determination flag F_ST is "0", that is, the strokes have not been determined yet, the process proceeds to Step S327. In Step S327, "0" is assigned to an engine stroke flag F_ENG and this process is finished. On the other hand, when it is determined in Step S326 that the strokes have been determined, the process proceeds to Step S328. When it is determined in Step S328 that the 720 CA stage is "9", the stroke determining unit 66 assumes that the engine 1 is in expansion and exhaust strokes and sets the engine stroke flag F_ENG to "1" in Step S329. Thereafter, this process is finished.

[0045] When it is determined in Step S328 that the 720 CA stage is not "9", the process proceeds to Step S320. When it is determined in Step S320 that the 720 CA stage is "27", the stroke determining unit 66 assumes that the engine 1 is in the intake and compression strokes and sets the engine stroke flag F_ENG to "0" in Step S311. Thereafter, this process is finished. When it is determined in Step S328 that the 720 CA stage is not "9" and it is determined in Step S330 that the 720 CA stage is not "27" either, this process is finished without setting the engine stroke flag F_ENG.

[0046] An ignition-timing calculating process in Step S111, a fuel-injection-amount calculating process in Step S 112, the ignition output process in Step S 113, and the fuel injection process in Step S114 shown in the flowchart of FIG. 3 are performed so as to execute fuel injection or the like once for every two resolutions of the crankshaft 17 when the stroke determination flag F_ST is "1". Furthermore, the fuel injection or the like is executed at an optimum timing according to the respective strokes of the engine 1 by referring to the engine determination flag F_ENG.

[0047] A process at the start of the engine 1 is explained next in detail mainly with reference to the timing chart of FIG. 8. In FIG. 8, the horizontal axis indicates time. The following parameters are shown on the vertical axis from above. "TDC/BDC" indicates that the piston 15 is at the top dead center (TDC) or a bottom dead center (BDC). "Engine stroke" indicates which stroke the engine 1 is in. "Crank signal" indicates an analog signal output from the crank angle sensor 19 along with the rotation of the timing rotor 18. "F_TCTDC" is a flag that indicates detection of the reference position. "360 CA stage" is data incremented whenever the protrusion 71 on the timing rotor 18 is detected during one revolution (360°) of the crankshaft 17. A value from 0 to 17 is repeatedly allocated to the 360 CA stage. "720 CA stage" is data incremented whenever the protrusion 71 on the timing rotor 18 is detected during two revolutions (720°) of the crankshaft 17. A value from 0 to 35 is repeatedly allocated to the 720 CA stage. If no protrusion 71 is detected, "FF" is allocated to the 360 CA stage or the 720 CA stage. "F_ENG" is the engine stroke flag, and "intake air pressure" is the pressure in the intake pipe 2. "F_DT" is the current intake-air-pressure fluctuation flag and "CC" is the value of the intake-air-pressure fluctuation counter CC. "F_ST" indicates the stroke determination flag of the engine 1.

[0048] At a time t0 when cranking starts, the crank angle sensor 19 outputs an analog crank signal along with the revolution of the crankshaft 17. The crank signal peaks cyclically at an interval of 20°, for example.

At a time t1 when the reference position of the timing rotor 18 that rotates in proportion to the crankshaft 17 is detected, the flag F_TCTDC indicating the detection of the reference position is set to "1". The value of the 360 CA stage is thereby updated and the value from 0 to 17 is thereafter repeatedly allocated to the 360 CA stage. Reading of an intake air pressure PM is then started. Furthermore, the calculating process of the intake air pressure for determination as shown in the flowchart of FIG. 5 is performed to start calculating the intake-air-pressure bottom value PMB, the intake-air-pressure top value PMT, and the intake-air-pressure fluctuation range DPMTDC.

[0049] Whenever a peak of the crank signal is detected, the 360 CA stage is incremented. At a time t2 when the 360 CA stage is "17" corresponding to a state just before the top dead center, the intake-air-pressure fluctuation range at this time is stored as the current intake-air-pressure fluctuation range DPMTDC 1. The current intake-air-pressure fluctuation range DPMTDC 1 having already been stored is stored as the previous intake-air-pressure fluctuation range DPMTDC2. The variation DDPMTDC between the current intake-air-pressure fluctuation range DPMTDC 1 and the previous intake-air-pressure fluctuation range DPMTDC2 is calculated. Nevertheless, at the time t2, the intake-air-pressure fluctuation range variation DDPMTDC is 0 because it is the first process.

[0050] Thereafter, the 360 CA stage is reset and counted again from "0". Along with the counting, the calculating process of the intake air pressure for determination as shown in the flowchart of FIG. 5 is performed to start calculating the intake-air-pressure bottom value PMB, the intake-air-pressure top value PMT, and the intake-air-pressure fluctuation range DPMTDC. In a process from the time t2 to a time t3, the intake air pressure gradually decreases as the stage is closer to "5". Therefore, the initial intake-air-pressure top value PMT is kept as the PMT. On the other hand, the intake-air-pressure bottom value PMB is appropriately updated according to a decrease in the intake air pressure and reaches a minimum value P1 when the stage is "5". Thereafter, while the intake air pressure gradually increases as the stage is closer to "17", the intake-air-pressure bottom value PMB is kept P1. When the stage is "17", the intake-air-pressure top value PMT reaches a maximum value P2. As a result, the intake-air-pressure fluctuation range DPMTDC corresponds to the height of a range surrounded by a rectangle in FIG. 8 or becomes equal to P2-P1.

[0051] It is assumed here that this intake-air-pressure fluctuation range DPMTDC is greater than the predetermined value indicated in Step S302 of FIG. 6. In this case, when the previous intake-air-pressure fluctuation range DPMTDC2 is compared with the current intake-air-pressure fluctuation range DPMTDC1, the variation in the fluctuation ranges is from small to large. Therefore, the current intake-air-pressure fluctuation flag F_DT is set to "0". At this point, the stroke determination has not been made yet and thus it is not confirmed that the intake-air-pressure fluctuation flag is inverted. Due to this, the intake-air-pressure fluctuation cycle counter CC remains as "0".

[0052] In the subsequent period from the time t3 to a time t4, similar processes are performed. In this period, the previous intake-air-pressure fluctuation range DPMTDC2 (between the time t2 and the time t3) is compared with the current intake-air-pressure fluctuation range DPMTDC 1 (between the time t3 and the time t4). The current intake-air-pressure fluctuation range DPMTDC1 at the time t4 is smaller than the previous range DPMTDC2 at the time t3. That is, the variation in the fluctuation ranges is from large to small from the time t3 to the time t4, so that the current intake-air-pressure fluctuation flag F_DT is set to "1". At this point, the current intake-air-pressure fluctuation flag F_DT is inverted from "0" to "1" although the stroke determination has not been made yet. That is, it can be assumed that the intake-air-pressure fluctuations are cyclic from the previous top dead center to the current top dead center, so that the intake-air-pressure fluctuation cycle counter CC is incremented to "1".

[0053] In a period from the time t4 to a time t5, the current intake-air-pressure fluctuation range DPMTDC is calculated. Because the variation between the previous fluctuation range (from the time t3 to the time t4) and the current fluctuation range (from the time t4 to the time t5) is from small to large, the current intake-air-pressure fluctuation flag F_DT is set to "0". Although the stroke determination has not been made yet, it is confirmed that the intake-air-pressure fluctuation flag is inverted (from "1" to "0"). Therefore, the intake-air-pressure fluctuation cycle counter CC is incremented to "2".

[0054] Furthermore, in a period from the time t5 to a time t6, the current intake-air-pressure fluctuation range DPMTDC is calculated. Because the variation in the intake-air-pressure fluctuation ranges DPMTDC is from large to small, the current intake-air-pressure fluctuation flag F_DT is inverted with respect to the previous value. Therefore, the intake-air-pressure fluctuation cycle counter CC is incremented to "3".

[0055] After these steps, the intake-air-pressure fluctuation cycle counter CC becomes equal to or greater than "3". That is, in a period corresponding to the four revolutions of the crankshaft 17, the variations in the intake-air-pressure fluctuation ranges occur alternately and consecutively from one 720 CA stage to the next 720 CA stage. Therefore, the stroke determination can be made.

Furthermore, at this time, the variation in the intake-air-pressure fluctuations DPMTDC is from large to small. Therefore, it is determined that the strokes during one revolution (360 CA) just before the time t6 are the expansion and exhaust strokes.

Accordingly, the stroke determination flag F_ST at the 720 CA stage is set to "1" and "26" is set to the 720 CA stage at this time.

Thereafter, based on the determination result of the strokes of the engine 1, fuel injection and ignition are performed once for every two revolutions.

[0056] A process of stroke determination when a vehicle state changes from deceleration to acceleration is explained next mainly with reference to the timing chart of FIG. 9. It is assumed that at a time t10, the engine 1 is running in a decelerating state at the engine speed of 5000 rpm and the throttle opening degree is an idling opening degree, for example. It is also assumed that the stroke determination is made before the time t10, the variation in the intake-air-pressure fluctuation ranges DPMTDC is from small to large, and that the intake-air-pressure fluctuations cycle counter CC is "255". This indicates that the variations occur cyclically, alternately, and consecutively 255 or more times because the upper limit of the intake-air-pressure fluctuation cycle counter CC is "255".

[0057] At a time t11, a running state of the engine 1 changes from the decelerating state to an accelerating state by operating the throttle valve 5 open. Because the engine 1 is in the expansion and exhaust strokes at this time, the engine 1 causes no effect on the intake pipe 2. By opening the throttle valve 5, a downstream side of the throttle valve 5 is continuous to an upstream side, that is, to the atmosphere. As a result, the pressure in the intake pipe in the expansion and exhaust strokes varies to an approximate atmospheric pressure and the intake-air-pressure fluctuation range DPMTDC in the expansion and exhaust strokes is greater than the previous intake-air-pressure fluctuation range DPMTDC.

[0058] At a time t12 when the 360 CA stage reaches a stage before the top dead center, the intake-air-pressure fluctuation range DPMTDC in a period from the stage after the time t10 to a time t12 is calculated. Because the variation from the previous intake-air-pressure fluctuation range DPMTDC to the current range DPMTDC is from small to large, the current intake-air-pressure fluctuation flag F_DT is set to "0". The intake-air-pressure fluctuation flag is kept "0", so that cyclic nature of the intake-air-pressure fluctuations is lost from the previous top dead center to the current top dead center. The intake-air-pressure fluctuation cycle counter CC is thereby reset to "0".

[0059] At a time t13 when the 360 CA stage reaches the stage before the top dead center, the intake-air-pressure fluctuation range DPMTDC in a period from the stage after the time t12 to the time t13 is calculated. Because the variation from the previous intake-air-pressure fluctuation range DPMTDC to the current range DPMTDC is from large to small, the current intake-air-pressure fluctuation flag F_DT is set to "1". The intake-air-pressure fluctuation cycle counter CC is "0". Therefore, because the intake-air-pressure fluctuation flag is inverted with respect to the previous value, the cyclic nature of the intake-air-pressure fluctuations is maintained from the previous top dead center to the current top dead center. The intake-air-pressure fluctuation cycle counter CC is thereby incremented to "1".

[0060] At the time t14 when the 360 CA stage reaches the stage before the top dead center, the intake-air-pressure fluctuation range DPMTDC in a period from the stage after the time t13 to the time t14 is calculated. Because the variation from the previous intake-air-pressure fluctuation range DPMTDC to the current range DPMTDC is from large to small, the current intake-air-pressure fluctuation flag F_DT is set to "1". The intake-air-pressure fluctuation flag is kept "1", so that the cyclic nature of the intake-air-pressure fluctuations is lost from the previous top dead center to the current top dead center. The intake-air-pressure fluctuation cycle counter CC is thereby reset to "0".

[0061] At a time t15 when the 360 CA stage reaches a stage before the top dead center, the intake-air-pressure fluctuation range DPMTDC in a period from the stage after the time t14 to the time t15 is calculated. The variation from the previous intake-air-pressure fluctuation range DPMTDC to the current range DPMTDC is from small to large. Because the air-pressure fluctuation cycle counter CC is "0" at this point, the intake-air-pressure fluctuation cycle counter CC is reset again to "0".

[0062] At a time t16 when the 360 CA stage reaches the stage before the top dead center, the intake-air-pressure fluctuation range DPMTDC in a period from the stage after the time t15 to the time t16 is calculated. Because the variation from the previous intake-air-pressure fluctuation range DPMTDC to the current range DPMTDC is from large to small, the current intake-air-pressure fluctuation flag F_DT is set to "1". The intake-air-pressure fluctuation cycle counter CC is "0" and the intake-air-pressure fluctuation flag is inverted with respect to the previous value. Therefore, the cyclic nature of the intake-air-pressure fluctuations is maintained from the previous top dead center to the current top dead center. The intake-air-pressure fluctuation cycle counter CC is thereby incremented to "1".

[0063] Thereafter, whenever the 360 CA stage reaches the stage before the top dead center, the processes described above are repeated. At a time t17, the intake-air-pressure fluctuation cycle counter CC is "1" and the fluctuation range is inverted. Therefore, the intake-air-pressure fluctuation cycle counter CC is incremented to "2". At a time t18, the intake-air-pressure fluctuation cycle counter CC is "2" and the fluctuation range is inverted. Due to this, the intake-air-pressure fluctuation cycle counter CC is incremented to "3".

[0064] After the process at and before the time t18, the intake-air-pressure fluctuation cycle counter C becomes "3" and the variation is from large to small, so that the stroke determination is made. That is, in the period of the four revolutions of the crankshaft, the variations in the intake-air-pressure fluctuations occur alternately and consecutively during the two revolutions of the crankshaft (720 CA) and the variation in the intake-air-pressure fluctuations DPMTDC is from large to small at this time. Therefore, it is determined that the strokes during one revolution (360 CA) just before the time t18 are the expansion and exhaust strokes.

As a result, the stroke determination flag F_ST is set to "1" and #26 is set to the 720 CA stage.

[0065] In this way, when the throttle valve 5 is operated to open while the engine is running in the decelerating state, that is, when the running state of the engine 1 changes from the decelerating state to the accelerating state, the cyclic nature of the intake-air-pressure fluctuation ranges DPMTDC is lost. Conventional control apparatuses erroneously determine strokes if the cyclic nature is lost as described above. On the other hand, the control apparatus 41 can determine strokes even after the cyclic nature is lost by setting, as conditions for the engine stroke determination, alternate and consecutive occurrence of the variations in the intake-air-pressure fluctuations range during the four revolutions of the crankshaft 17.

[0066] Furthermore, an intake-air-pressure signal after the t14 has a signal waveform under a high load, for example, when the throttle fully opens. Under the high load, the intake air pressure pulsates in the intake pipe as seen in the period from the time t11 to the time t12 shown in FIG. 9. This may cause malfunction of determinations or erroneous determinations in the engine stroke determination by the comparison using minimum intake air pressures or accumulated intake air pressures according to conventional techniques. The control apparatus 41 compares the intake-air-pressure fluctuation ranges during the two revolutions of the crankshaft (720 CA). Therefore, even when the engine is running in a state where the intake air pressure pulsates under a high load, the control apparatus 41 can accurately determine the engine strokes.

[0067] As described above, the control apparatus 41 compares the current intake-air-pressure fluctuation range with the previous intake-air-pressure fluctuation range during one revolution of the crankshaft 17 (360 CA). Therefore, it is possible to accurately determine the engine strokes even in conditions in which the engine 1 is running at a high speed under a high load and the intake air pressure has a high pulsation.

Because the control apparatus 41 makes an engine stroke determination by the comparison to determine whether one intake-air-pressure fluctuation range is equal to or greater than the next intake-air-pressure fluctuation range, it is possible to detect a high deviation between the intake air pressures and enlarge a range in which the engine stroke determination can be made in an engine running range constituted by the engine speed, as compared to conventional techniques.

[0068] Furthermore, the control apparatus 41 makes an engine stroke determination while paying attention to the nature of the cycles in which the variations in the intake-air-pressure fluctuation ranges occur alternately and consecutively. Therefore, even when the throttle valve 5 that regulates the amount of intake air is operated to open or close, the control apparatus 41 can make an engine stroke determination more accurately.

The control apparatus 41 makes a stroke determination when the variations in the intake-air-pressure fluctuation ranges occur three times. Therefore, even when the throttle valve 5 is operated to open or close, the control apparatus 41 can make an engine stroke determination accurately in a short time.

[0069] Due to the above configurations, the control apparatus 41 can prevent engine failure due to the erroneous determination of the engine strokes, and execute fuel injection and ignition once for every two revolutions of the crankshaft 17 (720 CA) based on the engine strokes. This can reduce energy loss (consumption) and improve the durability of constituent elements, such as a capacitor and a coil, that constitute the ignition system.

[0070] When the opening degree of the throttle valve 5 is stably constant while the engine 1 is running, the intake-air-pressure fluctuation range in the expansion and exhaust strokes is greater than the previous fluctuation range. However, when the throttle valve 5 is operated to open in the expansion and exhaust strokes, the engine 1 causes no effect on the intake pipe 2. Therefore, the intake pipe 2 at the downstream of the throttle valve 5 is continuous to the upstream intake pipe, that is, to the atmosphere, the intake air pressure in the expansion and exhaust strokes changes to the approximate atmospheric pressure, and the intake-air-pressure fluctuation range in the expansion and exhaust strokes is greater than the intake-air-pressure fluctuation range in the intake and compression strokes. Moreover, the intake-air-pressure fluctuation range in the strokes right after the expansion and exhaust strokes is smaller than that in the expansion and exhaust strokes. On the other hand, even when the throttle valve 5 is operated closed in the expansion and exhaust strokes, the intake-air-pressure fluctuation range in these strokes is not greater than that in the intake and compression strokes just before the expansion and exhaust strokes. That is, even when the throttle valve 5 is operated to open or close, the state where the intake-air-pressure fluctuation range in the expansion and exhaust strokes is greater than that in the intake and compression stroke does not occur consecutively during four or more revolutions of the crankshaft 17.

[0071] FIGS. 10 and 11 show results of experiments. FIG. 10 shows respective parameters and a determination result when the running state of the engine 1 changes from a high load state (for example, at the engine speed of about 9000 rpm) to the decelerating state. FIG. 11 shows respective parameters and a determination result when the running state of the engine 1 changes from the decelerating state to the accelerating state (for example, at the engine speed up to about 9000 rpm).

FIG. 10 shows variations in the intake air pressure when the running state of the engine 1 changes from the high load to the decelerating state. When the intake-air-pressure fluctuation range at the current top dead center and that at the previous top dead center are compared during the two revolutions of the crankshaft 17 (720 CA), the comparison indicates that the variations occur alternately and consecutively. Conventional determination methods pay attention to the intake-air-pressure bottom values PMB. Therefore, when the difference between the intake-air-pressure bottom values PMB is small during two consecutive strokes, an error possibly occurs to the determination. On the other hand, according to the present embodiment, attention is paid to the variation between the intake-air-pressure top value PMT and the intake-air-pressure bottom value PMB. Accordingly, even when the difference between the intake-air-pressure bottom values PMB is small, it is possible to discriminate the intake and compression strokes from the expansion and exhaust strokes.

[0072] FIG. 11 shows variations in the intake air pressure when the running state of the engine 1 changes from the decelerating state to the accelerating state. When the throttle 5 starts to open at around 40 msec, the variations in the intake-air-pressure fluctuation ranges do not occur alternately, but the variations occur soon afterwards. In the period corresponding to the four revolutions of the crankshaft 17, the variations occur alternately and consecutively. This means that the control apparatus 41 can accurately determine engine strokes even while the engine is accelerating.

[0073] When the intake-air-pressure fluctuation range of the engine 1 at the current top dead center and that at the previous top dead center are compared during the two revolutions of the crankshaft 17 (720 CA), the variations occur alternately and consecutively in the period corresponding to the four revolutions of the crankshaft 17. In addition, when the current variation in the intake-air-pressure fluctuation ranges is from large to small, the control apparatus 41 determines that the strokes during one revolution (360 CA) just before the variation are the expansion and exhaust strokes. Even when the throttle opening degree is operated to close (to decelerate) the throttle valve or to open (to accelerate) it, the control apparatus 41 can accurately determine the engine strokes.

[0074] It should be understood that the present invention is not limited to the examples and conditions mentioned in the above embodiment. The present invention can be variously changed or modified without departing from the spirit and scope of the invention.

The present invention is not limited to the above embodiment and can be applied to a wide range of technical fields.

For example, the above embodiment can be also applicable to multi-cylinder engine. In addition, the internal combustion engine is not limited to the engine 1 shown in FIG. 1.

Furthermore, the control apparatus can make a stroke determination when variations in the intake-air-pressure fluctuation ranges occur four or more times.

Explanations of Reference Numerals

[0075]

1	Engine (Internal combustion engine)
2	Intake pipe
17	Crankshaft (Output shaft)
41	Control apparatus
53	CPU
61	Crank signal processing unit
62	Throttle signal processing unit
63	Intake-air-pressure calculating unit
64	Fluctuation-range calculating unit
65	Fluctuation-range comparing unit
66	Stroke determining unit
67	Output processing unit

Claims

1. A control apparatus for an internal combustion engine, comprising:

an intake-air-pressure calculating unit that acquires a pressure in an intake pipe, which supplies air into a combustion chamber of the internal combustion engine, and measures a maximum pressure and a minimum pressure in the intake pipe during one revolution of an output shaft of the internal combustion engine;

a fluctuation-range calculating unit that calculates a pressure fluctuation range during one revolution of the output shaft from a difference between the maximum pressure and the minimum pressure in the intake pipe;
a fluctuation-range comparing unit that compares, with respect to a magnitude relation, a previous pressure fluctuation range with a current pressure fluctuation range obtained during two revolutions of the crankshaft;
a stroke determining unit that compares, with respect to a magnitude relation, a previous pressure fluctuation range with a current pressure fluctuation range, and determines strokes of the internal combustion engine; and
an output processing unit that executes a fuel injection output and an ignition output once for every two revolutions of the output shaft after strokes of the internal combustion engine are determined.

2. The control apparatus for an internal combustion engine according to claim 1, wherein the stroke determining unit compares, with respect to a magnitude relation, the previous pressure fluctuation range with the current pressure fluctuation range, and determines strokes of an engine when variations in the magnitude relation between the pressure fluctuation ranges in the intake pipe occur alternately and consecutively in a period of revolutions of the output shaft with a predetermined number of times.

3. The control apparatus for an internal combustion engine according to claim 2, wherein the stroke determining unit determines strokes of an engine when variations in a magnitude relation between the pressure fluctuation ranges in the intake pipe occur three consecutive times.

4. The control apparatus for an internal combustion engine according to any one of claims 1 to 3, wherein when a variation from the previous pressure fluctuation range to the current pressure fluctuation range is from large to small, the stroke determining unit determines that strokes corresponding to the current pressure fluctuation range are expansion and exhaust strokes.

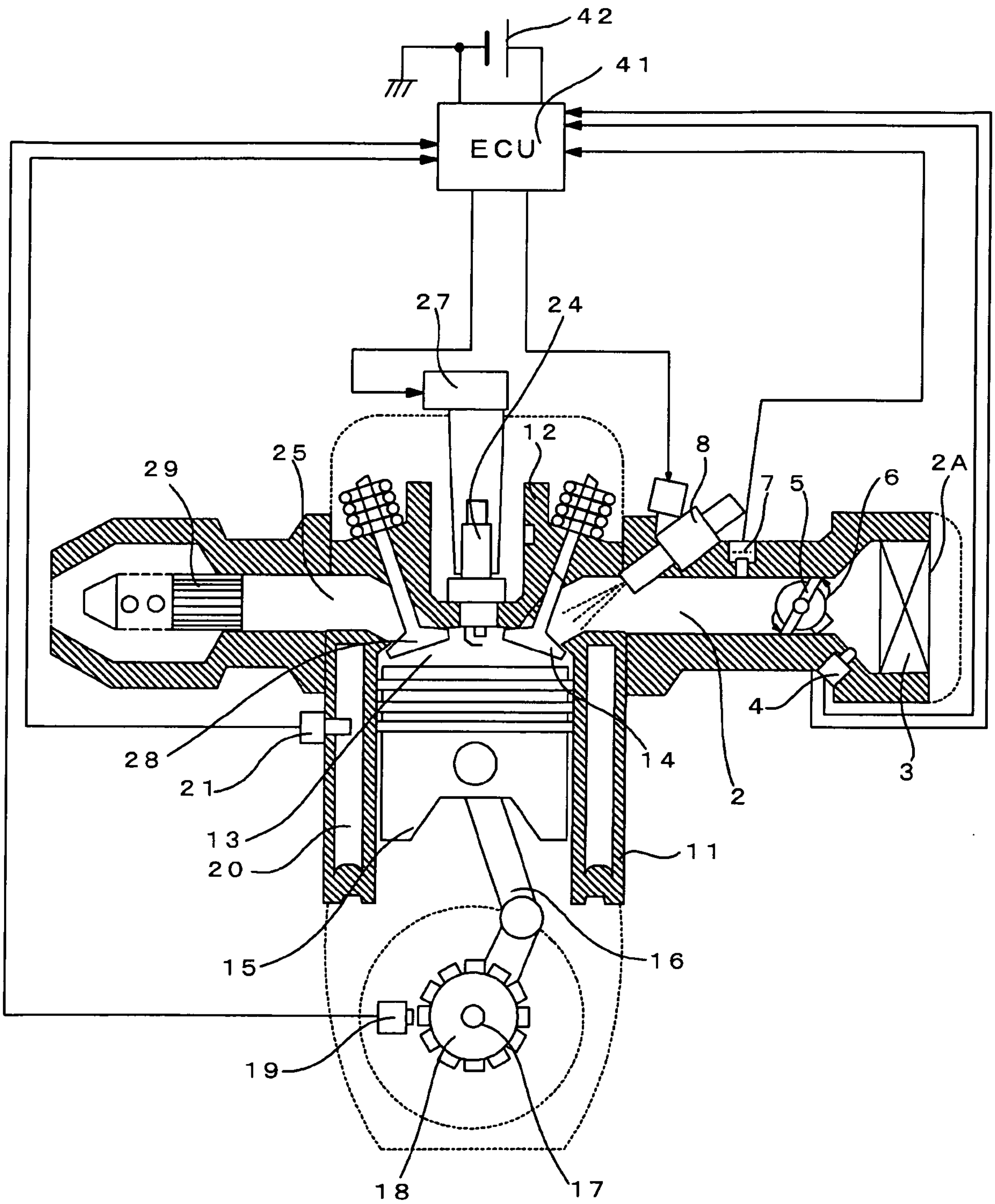

FIG. 1

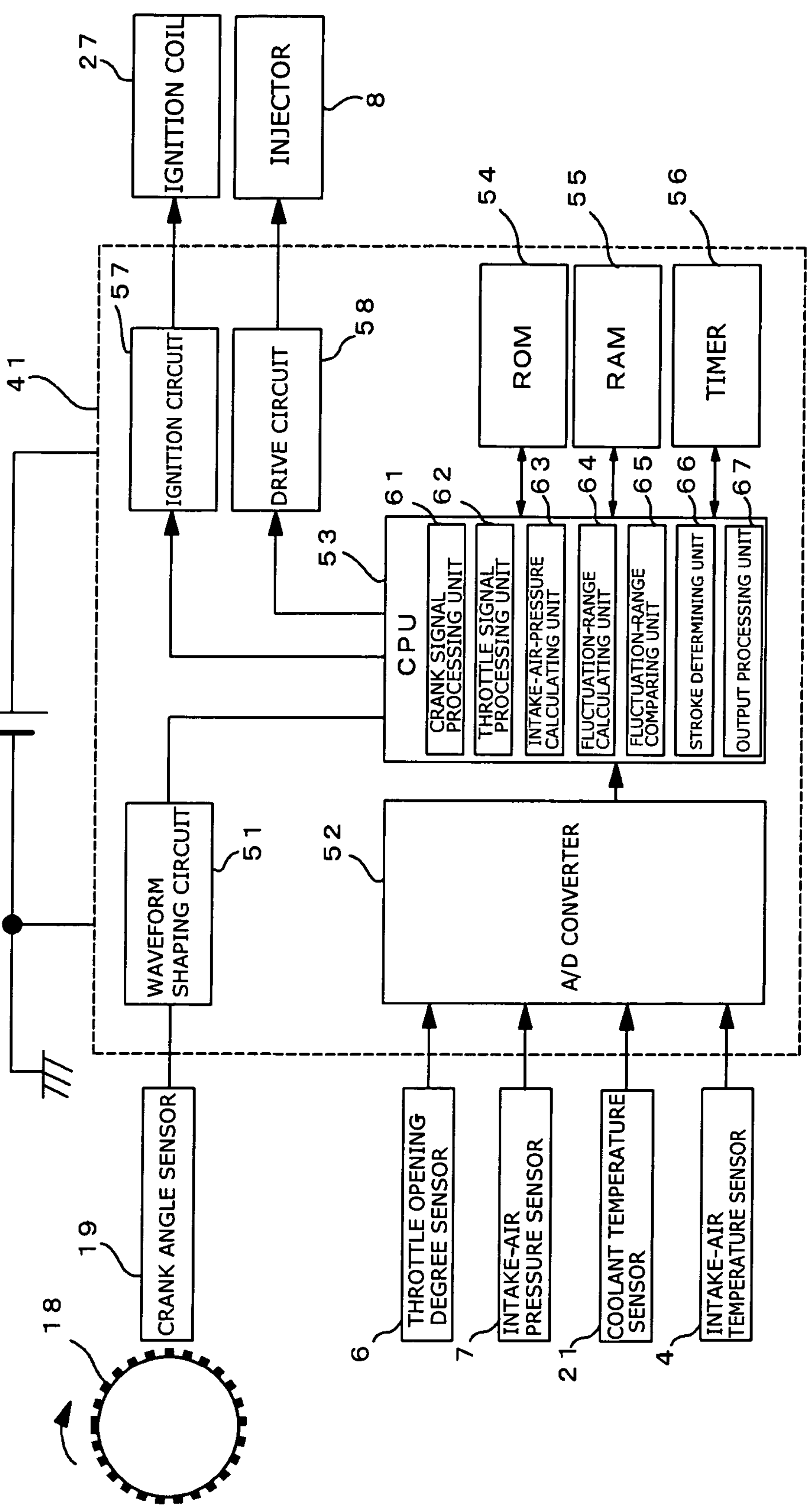
IGNITION COIL
INJECTOR
IGNITION CIRCUIT
DRIVE CIRCUIT
ROM
RAM
TIMER
CPU
CRANK SIGNAL PROCESSING UNIT
THROTTLE SIGNAL PROCESSING UNIT
INTAKE-AIR-PRESSURE CALCULATING UNIT
FLUCTUATION-RANGE CALCULATING UNIT
FLUCTUATION-RANGE COMPARING UNIT
STROKE DETERMINING UNIT
OUTPUT PROCESSING UNIT
WAVEFORM SHAPING CIRCUIT
A/D CONVERTER
CRANK ANGLE SENSOR
THROTTLE OPENING DEGREE SENSOR
INTAKE-AIR PRESSURE SENSOR
COOLANT TEMPERATURE SENSOR
INTAKE-AIR TEMPERATURE SENSOR
27
8
41
42
51
52
53
54
55
56
57
58
61
62
63
64
65
66
67
18
19
6
7
21
4

FIG. 2

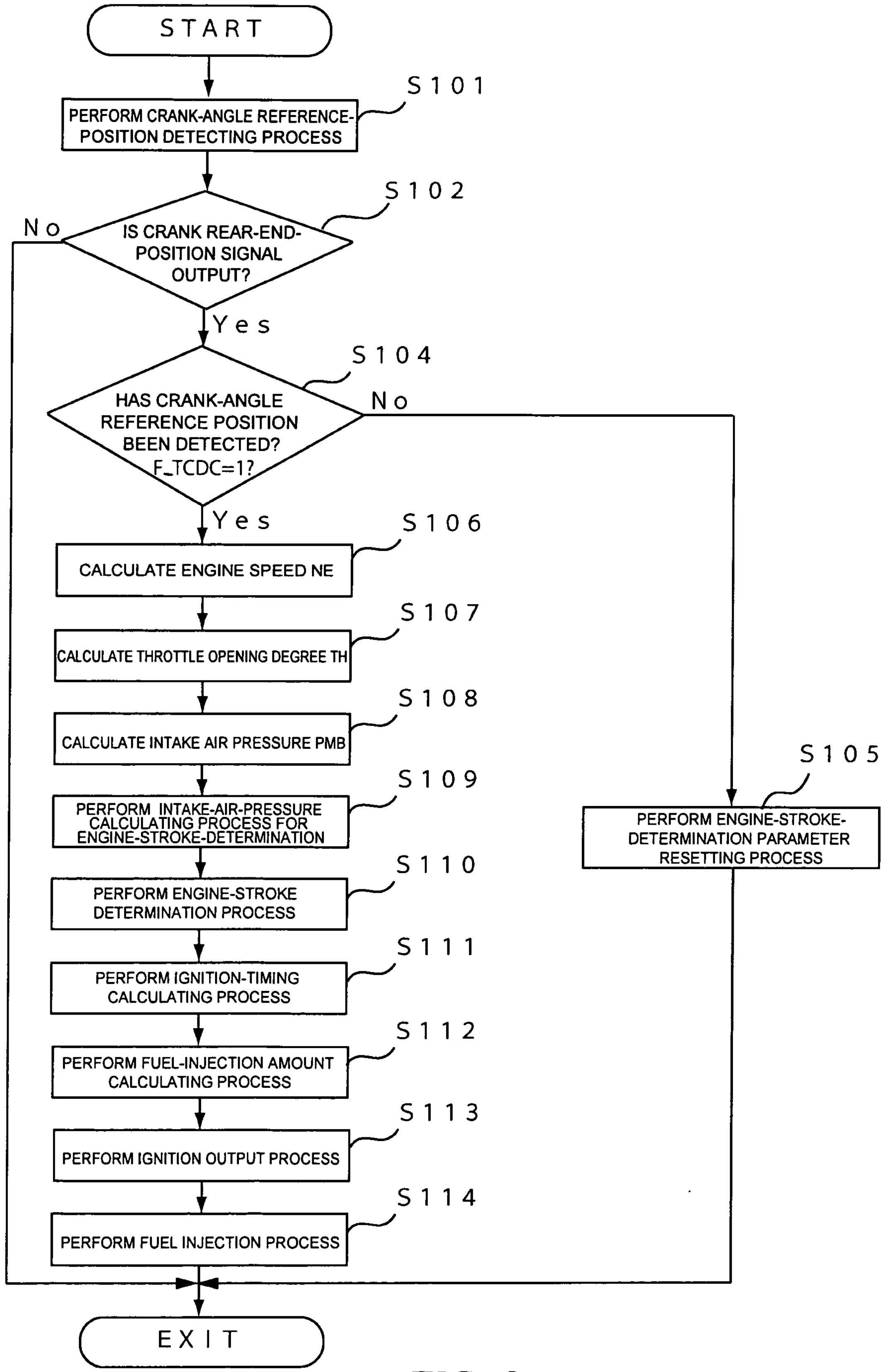
START
S101
PERFORM CRANK-ANGLE REFERENCE-POSITION DETECTING PROCESS
S102
IS CRANK REAR-END-POSITION SIGNAL OUTPUT?
No
Yes
S104
HAS CRANK-ANGLE REFERENCE POSITION BEEN DETECTED? F_TCDC=1?
No
Yes
S106
CALCULATE ENGINE SPEED NE
S107
CALCULATE THROTTLE OPENING DEGREE TH
S108
CALCULATE INTAKE AIR PRESSURE PMB
S109
PERFORM INTAKE-AIR-PRESSURE CALCULATING PROCESS FOR ENGINE-STROKE-DETERMINATION
S110
PERFORM ENGINE-STROKE DETERMINATION PROCESS
S111
PERFORM IGNITION-TIMING CALCULATING PROCESS
S112
PERFORM FUEL-INJECTION AMOUNT CALCULATING PROCESS
S113
PERFORM IGNITION OUTPUT PROCESS
S114
PERFORM FUEL INJECTION PROCESS
S105
PERFORM ENGINE-STROKE-DETERMINATION PARAMETER RESETTING PROCESS
EXIT

FIG. 3

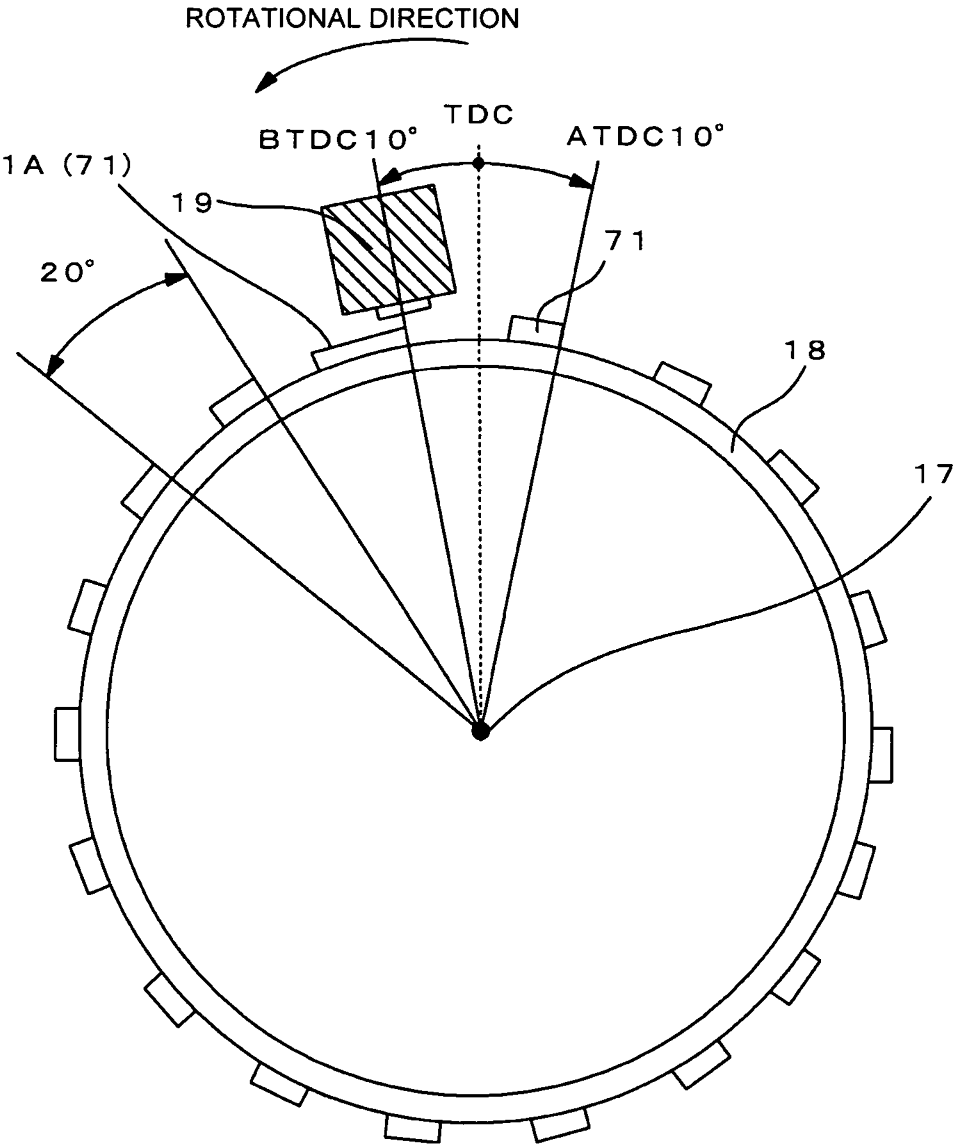

FIG. 4

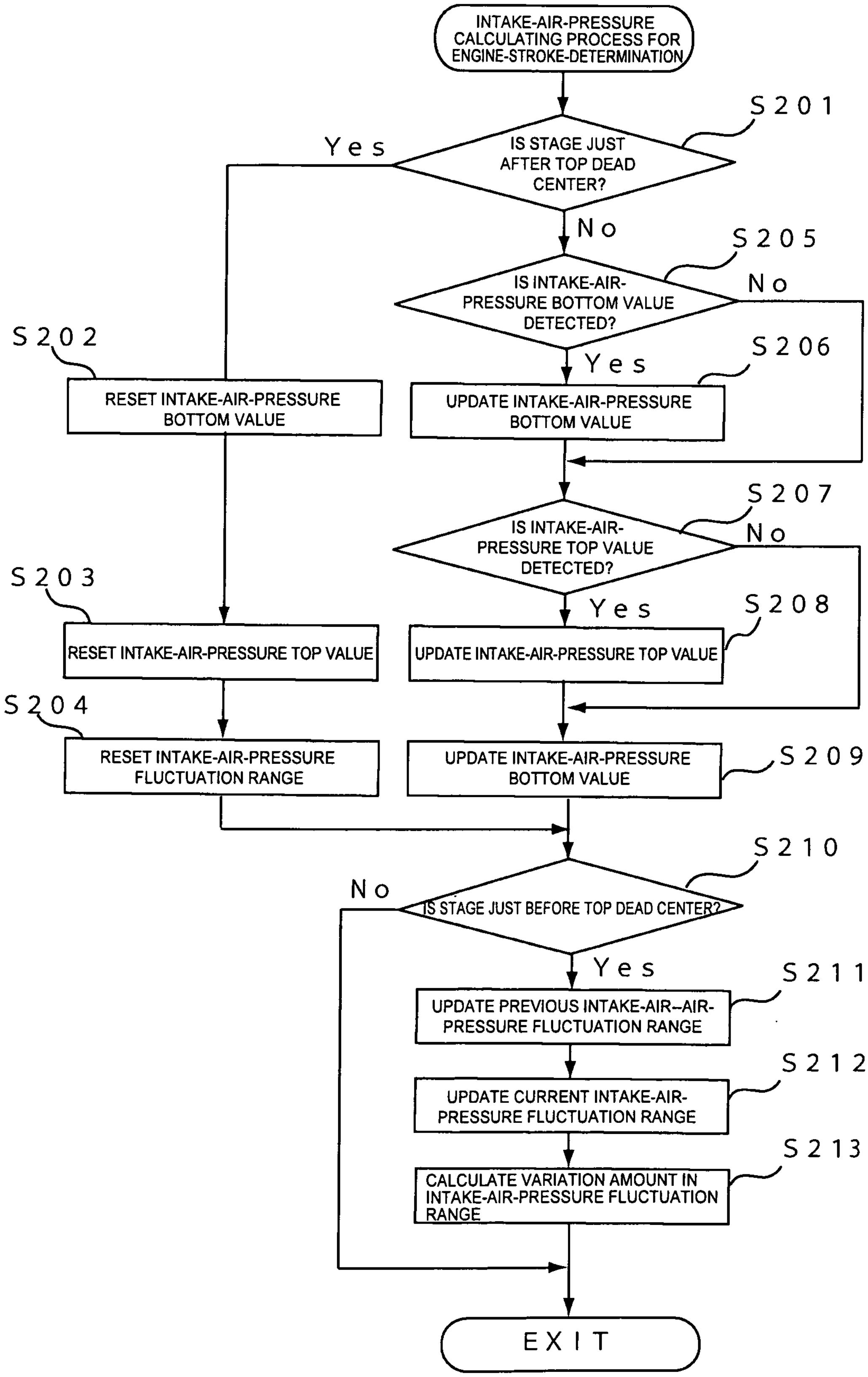
INTAKE-AIR-PRESSURE CALCULATING PROCESS FOR ENGINE-STROKE-DETERMINATION
S201
IS STAGE JUST AFTER TOP DEAD CENTER?
Yes
No
S202
RESET INTAKE-AIR-PRESSURE BOTTOM VALUE
S205
IS INTAKE-AIR-PRESSURE BOTTOM VALUE DETECTED?
No
Yes
S206
UPDATE INTAKE-AIR-PRESSURE BOTTOM VALUE
S207
IS INTAKE-AIR-PRESSURE TOP VALUE DETECTED?
No
Yes
S203
RESET INTAKE-AIR-PRESSURE TOP VALUE
S208
UPDATE INTAKE-AIR-PRESSURE TOP VALUE
S204
RESET INTAKE-AIR-PRESSURE FLUCTUATION RANGE
UPDATE INTAKE-AIR-PRESSURE BOTTOM VALUE
S209
S210
IS STAGE JUST BEFORE TOP DEAD CENTER?
No
Yes
S211
UPDATE PREVIOUS INTAKE-AIR--AIR-PRESSURE FLUCTUATION RANGE
S212
UPDATE CURRENT INTAKE-AIR-PRESSURE FLUCTUATION RANGE
S213
CALCULATE VARIATION AMOUNT IN INTAKE-AIR-PRESSURE FLUCTUATION RANGE
EXIT

FIG. 5

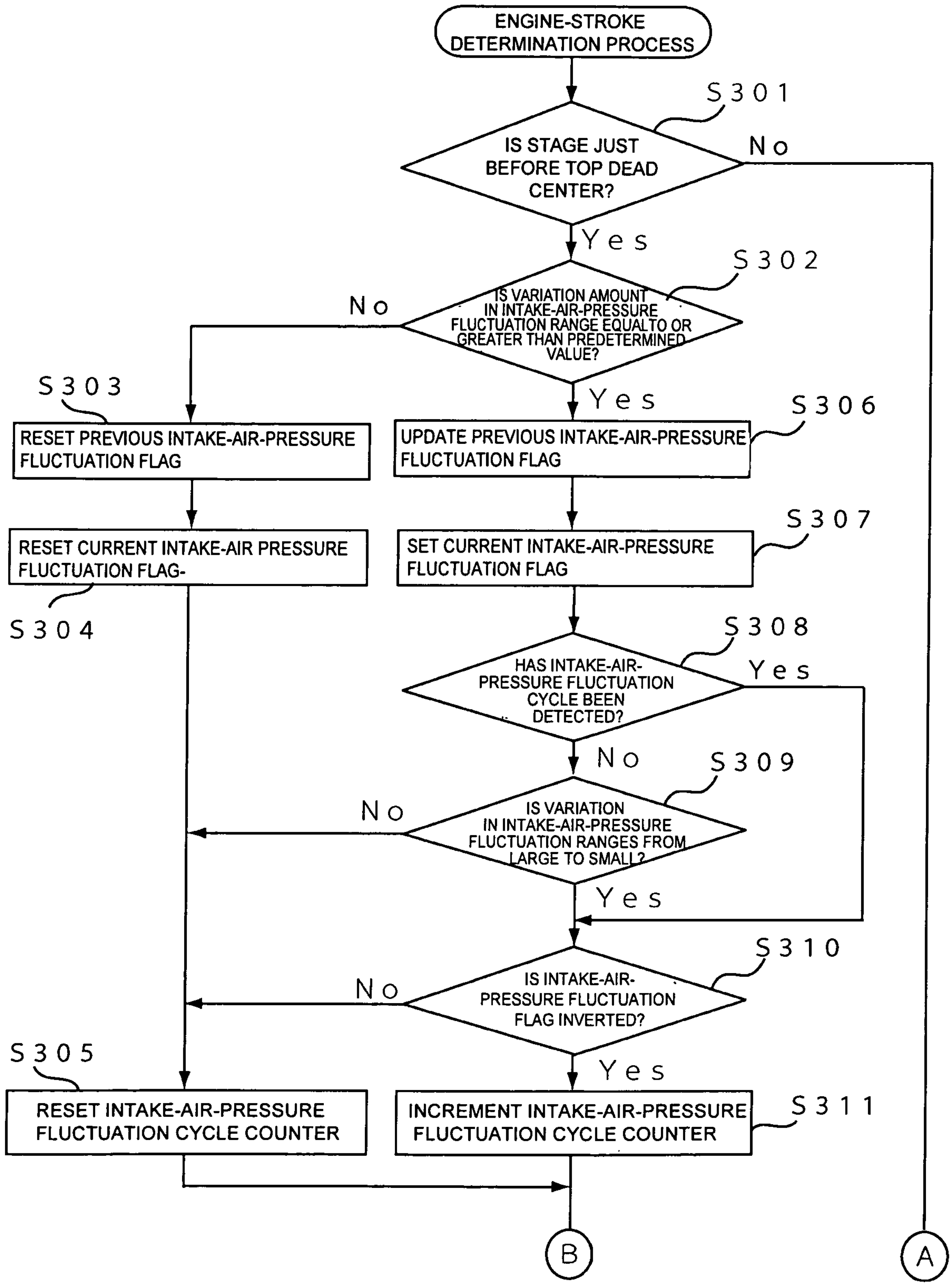
ENGINE-STROKE DETERMINATION PROCESS
S301
IS STAGE JUST BEFORE TOP DEAD CENTER?
No
Yes
S302
IS VARIATION AMOUNT IN INTAKE-AIR-PRESSURE FLUCTUATION RANGE EQUALTO OR GREATER THAN PREDETERMINED VALUE?
No
Yes
S303
RESET PREVIOUS INTAKE-AIR-PRESSURE FLUCTUATION FLAG
S306
UPDATE PREVIOUS INTAKE-AIR-PRESSURE FLUCTUATION FLAG
RESET CURRENT INTAKE-AIR PRESSURE FLUCTUATION FLAG-
S304
S307
SET CURRENT INTAKE-AIR-PRESSURE FLUCTUATION FLAG
S308
HAS INTAKE-AIR-PRESSURE FLUCTUATION CYCLE BEEN DETECTED?
Yes
No
S309
IS VARIATION IN INTAKE-AIR-PRESSURE FLUCTUATION RANGES FROM LARGE TO SMALL?
No
Yes
S310
IS INTAKE-AIR-PRESSURE FLUCTUATION FLAG INVERTED?
No
Yes
S305
RESET INTAKE-AIR-PRESSURE FLUCTUATION CYCLE COUNTER
INCREMENT INTAKE-AIR-PRESSURE FLUCTUATION CYCLE COUNTER
S311
B
A

FIG. 6

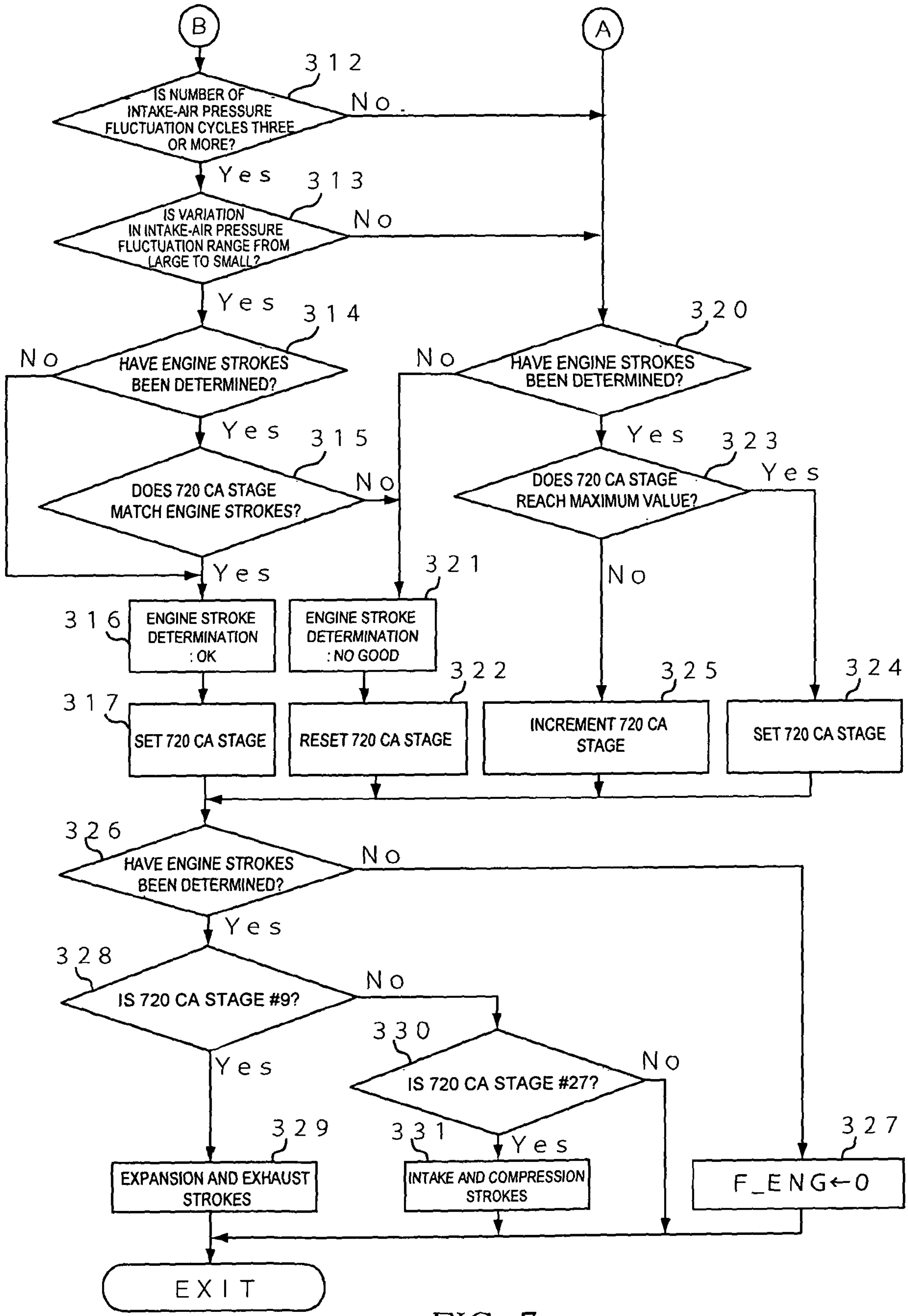
B
A
312
IS NUMBER OF INTAKE-AIR PRESSURE FLUCTUATION CYCLES THREE OR MORE?
No
Yes
313
IS VARIATION IN INTAKE-AIR PRESSURE FLUCTUATION RANGE FROM LARGE TO SMALL?
No
Yes
314
HAVE ENGINE STROKES BEEN DETERMINED?
No
Yes
315
DOES 720 CA STAGE MATCH ENGINE STROKES?
No
Yes
320
HAVE ENGINE STROKES BEEN DETERMINED?
No
Yes
323
DOES 720 CA STAGE REACH MAXIMUM VALUE?
Yes
No
316
ENGINE STROKE DETERMINATION : OK
321
ENGINE STROKE DETERMINATION : NO GOOD
317
SET 720 CA STAGE
322
RESET 720 CA STAGE
325
INCREMENT 720 CA STAGE
324
SET 720 CA STAGE
326
HAVE ENGINE STROKES BEEN DETERMINED?
No
Yes
328
IS 720 CA STAGE #9?
No
Yes
330
IS 720 CA STAGE #27?
No
Yes
329
EXPANSION AND EXHAUST STROKES
331
INTAKE AND COMPRESSION STROKES
327
F_ENG←0
EXIT

FIG. 7

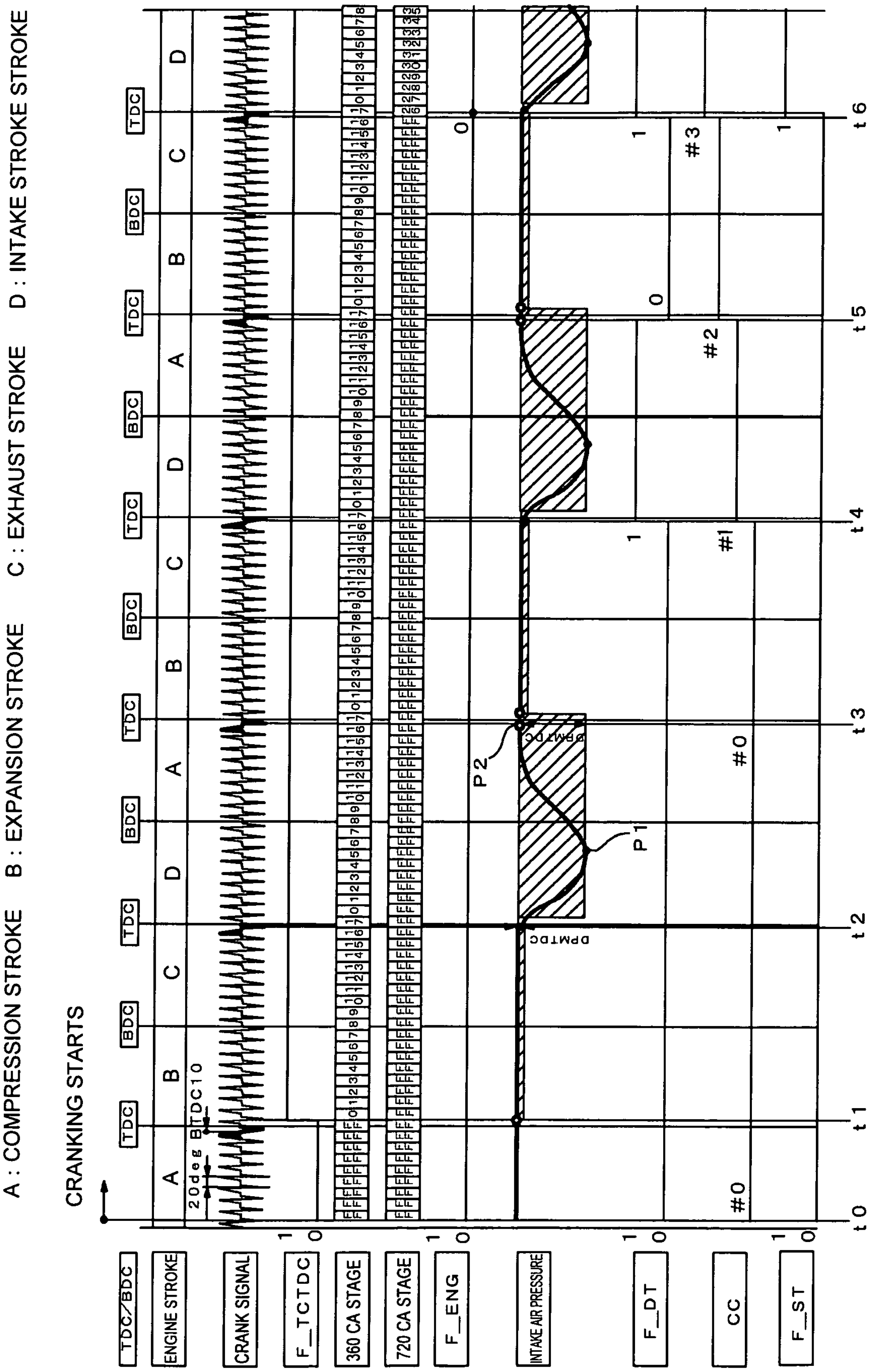
A : COMPRESSION STROKE
B : EXPANSION STROKE
C : EXHAUST STROKE
D : INTAKE STROKE
CRANKING STARTS
TDC/BDC
ENGINE STROKE
CRANK SIGNAL
F__TCTDC
360 CA STAGE
720 CA STAGE
F__ENG
INTAKE AIR PRESSURE
F__DT
CC
F__ST
20deg
BTDC10
DPMTDC
P1
P2
#0
#1
#2
#3
t0
t1
t2
t3
t4
t5
t6

FIG. 8

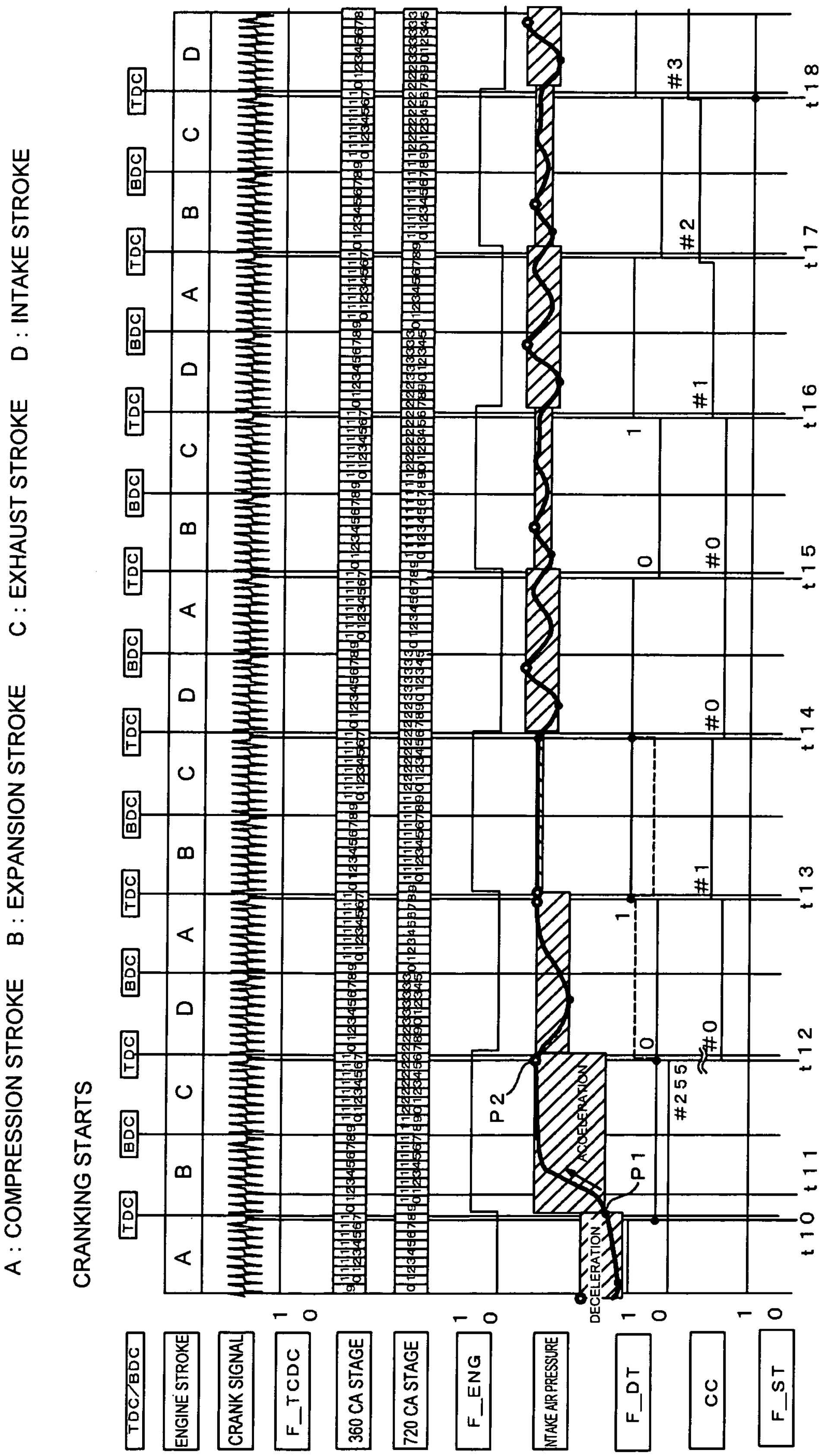
A : COMPRESSION STROKE B : EXPANSION STROKE C : EXHAUST STROKE D : INTAKE STROKE
CRANKING STARTS
TDC/BDC
ENGINE STROKE
CRANK SIGNAL
F_TCDC
360 CA STAGE
720 CA STAGE
F_ENG
INTAKE AIR PRESSURE
F_DT
CC
F_ST
DECELERATION
ACCELERATION
P1
P2
#255
#0
#1
#2
#3
t10
t11
t12
t13
t14
t15
t16
t17
t18

FIG. 9

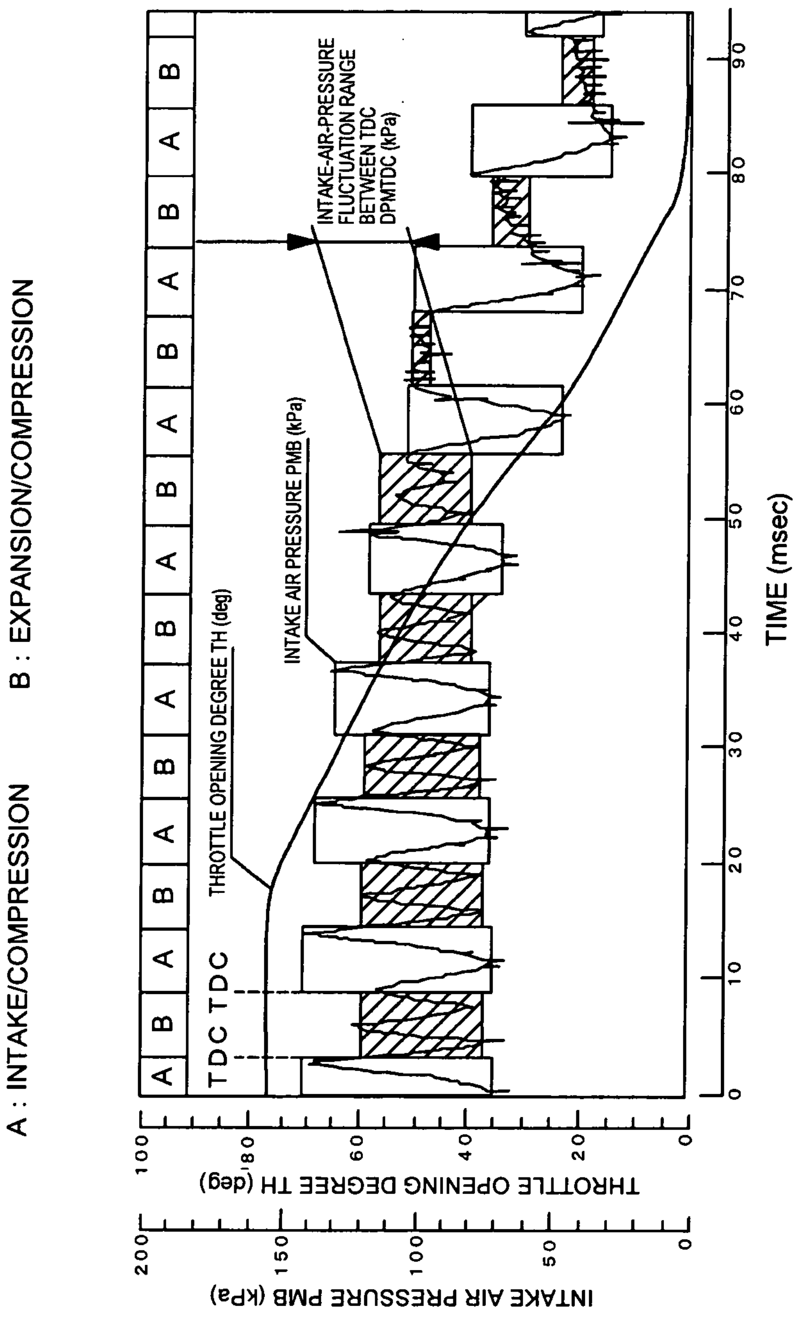
A : INTAKE/COMPRESSION
B : EXPANSION/COMPRESSION
A B A B A B A B A B A B A B A B
TDC TDC
THROTTLE OPENING DEGREE TH (deg)
INTAKE AIR PRESSURE PMB (kPa)
INTAKE-AIR-PRESSURE FLUCTUATION RANGE BETWEEN TDC DPMTDC (kPa)
THROTTLE OPENING DEGREE TH (deg)
100
80
60
40
20
0
INTAKE AIR PRESSURE PMB (kPa)
200
150
100
50
0
TIME (msec)
0
10
20
30
40
50
60
70
80
90

FIG. 10

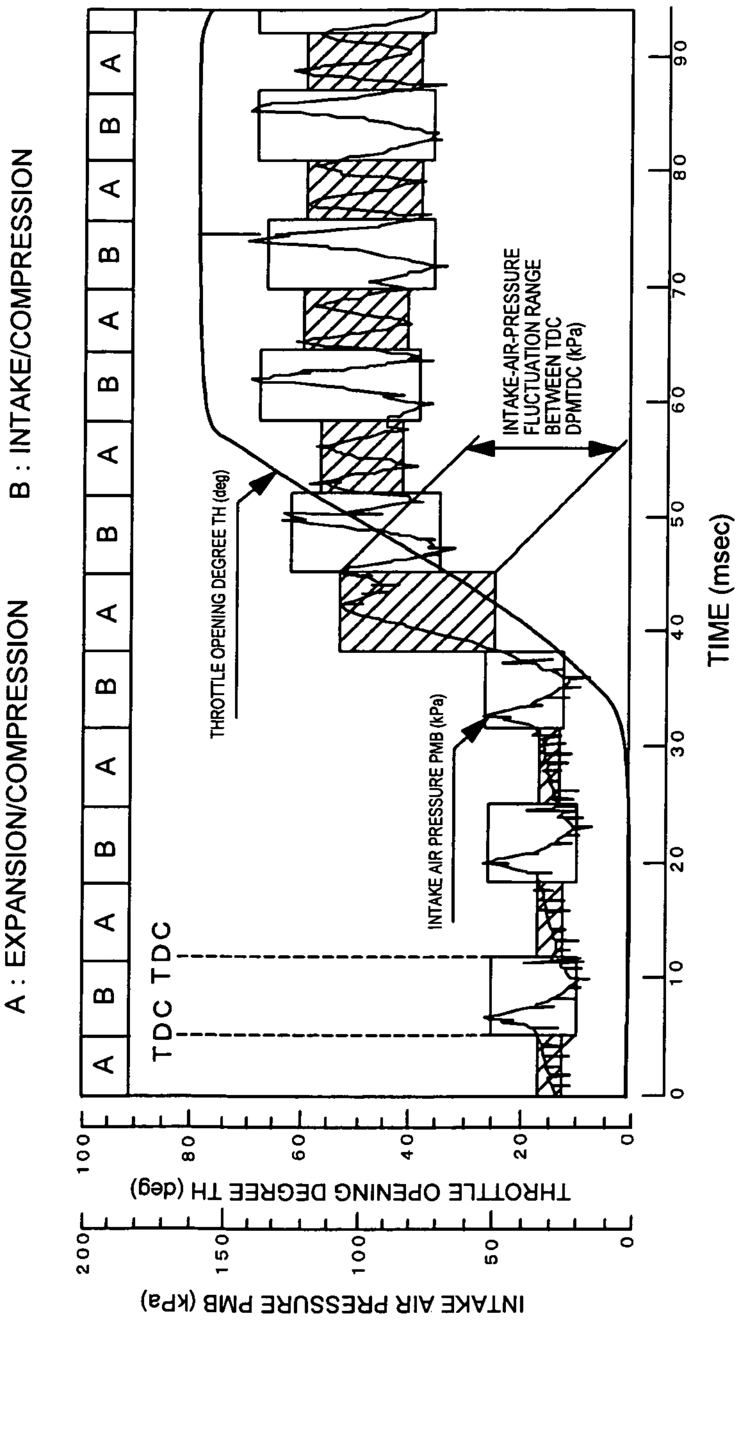
A : EXPANSION/COMPRESSION
B : INTAKE/COMPRESSION
TDC TDC
THROTTLE OPENING DEGREE TH (deg)
INTAKE AIR PRESSURE PMB (kPa)
INTAKE-AIR-PRESSURE FLUCTUATION RANGE BETWEEN TDC DPMTDC (kPa)
TIME (msec)
THROTTLE OPENING DEGREE TH (deg)
INTAKE AIR PRESSURE PMB (kPa)

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/062206

A. CLASSIFICATION OF SUBJECT MATTER
F02D45/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D45/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2002-339792 A (Kokusan Denki Co., Ltd.), 27 November 2002 (27.11.2002), abstract; claims 1 to 5; paragraphs [0052] to [0083]; fig. 2 to 4 (Family: none)	1-3 4
Y A	JP 2000-265894 A (Honda Motor Co., Ltd.), 26 September 2000 (26.09.2000), abstract; claim 6; paragraphs [0017] to [0042], [0044]; fig. 1 to 6 & CN 1266943 A	1-3 4
A	JP 10-227252 A (Honda Motor Co., Ltd.), 25 August 1998 (25.08.1998), abstract; claim 1; paragraphs [0006], [0019] to [0020]; fig. 3 & US 6170322 B1 & DE 19804816 A	1-4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 09 August, 2010 (09.08.10)	Date of mailing of the international search report 17 August, 2010 (17.08.10)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/062206

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-274936 A (Honda Motor Co., Ltd.), 12 October 2006 (12.10.2006), abstract; paragraphs [0003] to [0005], [0024] to [0037]; fig. 2 to 4 & US 2006/0218998 A1 & EP 1707937 A1 & CA 2537522 A	1-4
A	JP 2005-233035 A (Denso Corp.), 02 September 2005 (02.09.2005), abstract; paragraph [0003]; fig. 3 (Family: none)	1-4
A	JP 2003-307150 A (Denso Corp.), 31 October 2003 (31.10.2003), abstract; fig. 3 & CN 1438411 A	1-4
A	JP 2007-198366 A (Denso Corp.), 09 August 2007 (09.08.2007), paragraph [0092] & US 2007/0144487 A1	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000265894 A **[0005]**
- JP 2003003887 A **[0005]**