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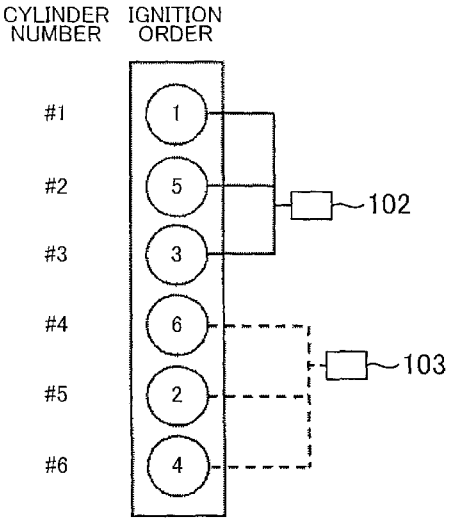
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(54) Title: CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINE WITH A DUAL-CORE CONTROL UNIT

(57) Abstract: A control system for an internal combustion engine, the internal combustion engine includes a plurality of cylinders configured to perform combustion in a firing order set in advance. The number of the plurality of cylinders is an even number equal to or larger than four. The control system includes actuators, and at least one arithmetic unit with at least two cores. The actuators are respectively provided in the plurality of cylinders. The two cores are configured to respectively control the operations of the actuators of the plurality of cylinders. One of the two cores is allocated to the actuators of a first cylinder group. The other of the two cores is allocated to the actuators of a second cylinder group. The first cylinder group is a group formed by the cylinders, the firing order of which is odd number order. The second cylinder group is a group formed by the cylinders, the firing order of which is even number order.

FIG. 2



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CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINE WITH A DUAL-CORE CONTROL UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

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

2. Description of Related Art

[0002] For example, Japanese Patent Application Publication No. 4-318253 (JP 4-318253 A) discloses a conventional control system in which six arithmetic units respectively corresponding to cylinders of a six-cylinder engine are provided. With the control system, the operations of actuators such as a fuel injection valve, an exhaust valve, a starting valve, and a cylinder lubricating device provided for each of the cylinders can be controlled in units of the cylinders. Therefore, even when the arithmetic unit allocated to the actuator of a certain cylinder breaks down, the operation of the internal combustion engine can be continued by the other normal arithmetic units.

SUMMARY OF THE INVENTION

[0003] Incidentally, the order of combustion performed in the cylinders and timing of the combustion are set such that intervals of the combustion are fixed when all the actuators and the arithmetic units are normally operated. Therefore, in the control system, it is likely that the intervals of the combustion are not fixed when the actuation of the arithmetic unit allocated to the broken-down cylinder is stopped. Specifically, when the arithmetic unit allocated to one cylinder in the six-cylinder engine breaks down, the actuation of the arithmetic units of the other five cylinders is continued. Then, since the intervals of the combustion are not fixed after the breakdown, engine vibration increases and affects drivability of a driver.

[0004] The invention provides a control system for an internal combustion engine capable of continuing operation without increasing engine vibration even when the actuation of a part of a plurality of arithmetic units is stopped.

[0005] A control system for an internal combustion engine according to a first aspect of the invention, the internal combustion engine includes a plurality of cylinders configured to perform combustion in a firing order set in advance. The number of the plurality of

cylinders is an even number equal to or larger than four. The control system includes actuators, and two arithmetic units. The actuators are respectively provided in the plurality of cylinders. The two arithmetic units are configured to respectively control the operations of the actuators of the plurality of cylinders. One of the two arithmetic units is allocated to the actuators of a first cylinder group. The other of the two arithmetic units is allocated to the actuators of a second cylinder group. The first cylinder group is a group formed by the cylinders, the firing order of which is odd number order. The second cylinder group is a group formed by the cylinders, the firing order of which is even number order.

[0006] According to this aspect, even when the actuation of the arithmetic unit allocated to the cylinder belonging to one cylinder group of the first cylinder group and the second cylinder group is stopped, it is possible to keep intervals of the combustion fixed with the arithmetic units allocated to the cylinders belonging to the other cylinder group. Therefore, it is possible to reduce engine vibration that occurs when the intervals of the combustion are non-uniform.

[0007] In the control system according to the first aspect of the invention, the internal combustion engine may be a V-6 engine including two banks or a horizontally opposed six-cylinder engine including two banks. The cylinders belonging to the first cylinder group may be provided in the bank different from the bank in which the cylinders belonging to the second cylinder group are provided.

[0008] According to this aspect, in the V-6 engine or the horizontally opposed six-cylinder engine including the two banks, when the actuation of the arithmetic unit allocated to the cylinder belonging to one cylinder group of the first cylinder group and the second cylinder group is stopped, it is possible to stop the combustion in the bank corresponding to the arithmetic unit. That is, it is possible to perform combustion control in units of the banks.

[0009] In the control system according to the first aspect of the invention, the internal combustion engine may be a V-8 engine including two banks or a horizontally opposed eight-cylinder engine including two banks. The cylinders belonging to the first cylinder group and the cylinders belonging to the second cylinder group may be provided in each of the two banks, the cylinders belonging to the first cylinder group and the cylinders belonging to the second cylinder group being the same in number.

[0010] According to this aspect, in the V-8 engine or the horizontally opposed eight-cylinder engine including the two banks, when the actuation of the arithmetic unit allocated to the cylinder belonging to one cylinder group of the first cylinder group and the second cylinder group is stopped, it is possible to cancel engine vibration between the two banks.

[0011] A control system for an internal combustion engine according to a second aspect of the invention, the internal combustion engine includes a plurality of cylinders configured to perform combustion in a firing order set in advance. The control system includes actuators, and a plurality of arithmetic units. The actuators are respectively provided in the plurality of cylinders. The number of the plurality of arithmetic units is an even number satisfying a condition that the number is larger than 2 and equal to or smaller than n/2. Here, n is the number of the plurality of cylinders. The plurality of arithmetic units are configured to respectively control the operations of the actuators of the plurality of cylinders. The plurality of arithmetic units are divided into arithmetic units belonging to a first arithmetic unit group and arithmetic units belonging to a second arithmetic unit group different from the first arithmetic unit group. The arithmetic units belonging to the first arithmetic unit group are allocated to the actuators of a first cylinder group. The arithmetic units belonging to the second arithmetic unit group are allocated to the actuators of a second cylinder group. The first cylinder group is a group formed by the cylinders, the firing order of which is an odd number order. The second cylinder group is a group formed by the cylinders, the firing order of which is an even number order. The plurality of arithmetic units are configured to, when the actuation of a specific arithmetic unit belonging to the first arithmetic unit group or the second arithmetic unit group is stopped, stop the actuation of the arithmetic units belonging to the arithmetic unit group the same as the arithmetic unit group to which the specific arithmetic unit belongs and continue the actuation of the arithmetic units belonging to the arithmetic unit group different from the arithmetic unit group to which the specific arithmetic unit belongs.

[0012] According to the aspect, even when the actuation of a specific arithmetic unit among m arithmetic units is stopped, it is possible to keep intervals of combustion fixed with the arithmetic units belonging to an arithmetic unit group different from an arithmetic unit group to which the specific arithmetic unit belongs. Therefore, it is possible to reduce engine vibration that occurs when the intervals of the combustion are non-uniform.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a diagram schematically showing the configuration of a parallel arithmetic unit;

FIG. 2 is a diagram for explaining allocation of cores in a first embodiment;

FIG. 3A is a diagram for explaining intervals of combustion during normal operation;

FIG. 3B is a diagram for explaining intervals of combustion in the case of a breakdown of a second core;

FIG. 4A is a diagram for explaining allocation of cores to an inline four cylinder engine;

FIG. 4B is a diagram for explaining allocation of cores to a V-6 engine;

FIG. 4C is a diagram for explaining allocation of cores to a V-8 engine;

FIG. 4D is a diagram for explaining allocation of cores to a W-12 engine;

FIG. 5 is a diagram for explaining allocation of cores in a second embodiment;

FIG. 6 is a diagram for explaining intervals of combustion in the case of a breakdown of a second core; and

FIG. 7 is a diagram for explaining allocation of four cores to a W-12 engine.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] Control systems in embodiments of the invention are explained below with reference to the drawings. Note that common components in the figures are denoted by the same reference numerals and signs and redundant explanation of the components is omitted. The invention is not limited by the embodiments explained below.

[0015] First, a first embodiment is explained. A control system for an internal combustion engine in the first embodiment includes an inline six-cylinder engine mounted on a vehicle or the like and a parallel arithmetic unit configured to calculate a control target value of an actuator for control of the engine. There is no limitation on types of engines to which the control system in this embodiment is applied. The control system in this embodiment can be applied to various engines such as a gasoline engine, a diesel engine, a natural intake engine, and a supercharging engine. An injector (a control target value: a fuel injection amount, a fuel injection period) provided for each of the cylinders of the engine is included in the actuator in the control system in this embodiment. In an engine in which an ignition plug is provided for each of the cylinders, the ignition plug (a control

target value: an ignition period) is also included in the actuator. In an engine in which a throttle valve of an electromagnetic drive type, a tumble control valve (TCV), or a swirl control valve (SCV) is provided for each of cylinders, the throttle valve (a control target value: throttle opening), the TCV (a control target value: TCV opening), or the SCV (a control target value: SCV opening) is also included in the actuator.

[0016] FIG. 1 is a diagram schematically showing the configuration of the parallel arithmetic unit. Various kinds of information concerning an operation state and an operation environment of the engine are input to a parallel arithmetic unit 100 from a plurality of sensors included in the engine. The parallel arithmetic unit 100 calculates, on the basis of the information, control target values instructed to actuators. The parallel arithmetic unit 100 is a parallel arithmetic unit of a dual core type including two cores (arithmetic units), i.e., a first core 102 and a second core 103. The cores 102 and 103 include central processing units (CPUs) 104 and 105 and caches 106 and 107. In local memories 108 and 109, various computer programs to be executed by the CPUs 104 and 105 and various data to be used during execution of the computer programs are stored. The cores 102 and 103 are connected to each other by a bus 110. Communication is performed between the cores 102 and 103 through the bus 110. Although not shown in the figure, a cache shared between the cores is also connected to the bus 110.

[0017] FIG. 2 is a diagram for explaining allocation of the cores 102 and 103. Note that, in this embodiment, like a general inline six-cylinder engine, the engine is set such that a first cylinder, a fifth cylinder, a third cylinder, a sixth cylinder, a second cylinder, and a fourth cylinder fire in this order. In FIG. 2, #1 to #6 represent cylinder numbers of the engine. As shown in FIG. 2, the first core 102 is allocated to the first, second, and third cylinders that fire in odd numbered places and the second core 103 is allocated to the fourth, fifth, and sixth cylinders that fire in even numbered places. That is, control target values of the actuators provided in the cylinders that fire in odd numbered places are calculated by the first core 102 and control target values of the actuators provided in the cylinders that fire in even numbered places are calculated by the second core 103. Note that, in this embodiment, the "even numbered places" and the "odd numbered places" are set on the basis of the first cylinder. However, the "even numbered places" and the "odd numbered places" can also be set on the basis of any cylinder among the second to sixth cylinders.

[0018] With the parallel arithmetic unit 100 including the first core 102 and the second core 103, it is possible to reduce a calculation load per one core. Therefore, it is possible to improve calculation speed of the arithmetic unit as a whole. In particular, in the parallel arithmetic unit 100, the core allocated to the cylinders (the first, second, and third cylinders) that fire in odd numbered places and the core allocated to the cylinders (the fourth, fifth, and sixth cylinders) that fire in even numbered places are different. Therefore, calculations of control target values of the actuators provided in the cylinders that fire in adjacent firing periods are performed in the different cores. There is an advantage that a reduction effect of the calculation load is high. If calculations of the same amount are processed, calculation frequencies of the cores can be reduced in the parallel arithmetic unit of a dual core type compared with an arithmetic unit of a single core type. Power efficiency of the cores is further deteriorated as calculation frequencies are higher. Therefore, with the parallel arithmetic unit 100, it is also possible to further improve power efficiency of the arithmetic unit as a whole than the arithmetic unit of the single core type.

[0019] In addition, with the control system in the first embodiment, it is possible to keep the intervals of the combustion fixed. FIGS. 3A and 3B are diagrams for explaining the intervals of the combustion. FIG. 3A shows combustion intervals during normal operation. During the normal operation, the first core 102, the second core 103, the sensors, and the actuators normally operate. Therefore, the cylinders fire in the order explained above and combustion intervals of the cylinders are fixed. FIG. 3B shows combustion intervals in the case of a breakdown of the second core 103. As shown in FIG. 3B, when the second core 103 breaks down, although the calculation of a control target value by the second core 103 is not performed, the calculation of a control target value by the normal first core 102 is continued. That is, reduced cylinder operation by the cylinders (the first, second, and third cylinders) allocated with the first core 102 is performed. During the reduced cylinder operation, the combustion intervals of the cylinders are fixed, although wider than the combustion intervals during the normal operation. Therefore, it is possible to reduce engine vibration that occurs when the intervals of the combustion is non-uniform, and to minimize deterioration in drivability. Note that the effect shown in FIG. 3B can also be obtained when the actuation of one of the two cores is actively stopped. In this case, an effect can also be obtained that it is

possible to reduce the number of the cores, which calculate control target values, and reduce power consumption of the arithmetic unit as a whole.

[0020] Note that, in the first embodiment, the first core 102 and the second core 103 are equivalent to the "arithmetic unit" in the first aspect.

[0021] Incidentally, in the example explained in the first embodiment, the inline six-cylinder engine is used. However, other engines in which the number and the array of cylinders are varied can also be used. FIGS. 4A to 4D are diagrams for explaining modifications of the first embodiment. Note that, in FIGS. 4A to 4D, #1 to #12 represent cylinder numbers of various engines. FIG. 4A is a diagram for explaining allocation of cores to an inline four cylinder engine. Note that, in the engine, a first cylinder, a third cylinder, a fourth cylinder, and a second cylinder fire in this order. In this case, the first core 102 is allocated to the first and fourth cylinders that fire in odd numbered places and the second core 103 is allocated to the second and third cylinders that fire in even numbered places. Consequently, it is possible to keep the intervals of the combustion fixed in both of the normal operation and the reduced cylinder operation. Therefore, the same effects as those of the first embodiment can be obtained. FIG. 4B is a diagram for explaining allocation of corers to a V-6 engine. Note that, in the engine, a first cylinder, a fifth cylinder, a third cylinder, a sixth cylinder, a second cylinder, and a fourth cylinder fire in this order. In this case, the first core 102 is allocated to the first to third cylinders that fire in odd numbered places and the second core 103 is allocated to the fourth to sixth cylinders that fire in even numbered places. Consequently, the same effects as those of the first embodiment can be obtained. In addition, it is possible to perform control in units of banks (a first bank 121 and a second bank 122). Therefore, when the control is combined with the active reduced cylinder operation, it is possible to efficiently reduce power consumption of the arithmetic unit as a whole. Note that the allocation of the cores shown in the figure can also be applied to a horizontally opposed six-cylinder engine. FIG. 4C is a diagram for explaining allocation of cores to a V-8 engine. Note that, in the engine, a first cylinder, an eighth cylinder, a sixth cylinder, a second cylinder, a seventh cylinder, a third cylinder, a fourth cylinder, and a fifth cylinder fire in this order. In this case, the first core 102 is allocated to the first, fourth, sixth, and seventh cylinders that fire in odd numbered places and the second core 103 is allocated to the second, third, fifth, and eight cylinders that fire in even numbered places. Consequently, the same effects as those of the embodiment can be obtained. In this case, in the left and right banks (the first bank

121 and the second bank 122), the number of cylinders that fire in odd numbered places is set equal to the number of cylinders that fire in even numbered places. Consequently, vibration can be cancelled between the left and right banks (the first bank 121 and the second bank 122) during the reduced cylinder operation. Note that the allocation of the cores shown in the figure can also be applied to a horizontally opposed eight-cylinder engine. FIG. 4D is a diagram for explaining allocation of cores to a W-12 engine. Note that, in the engine, a first cylinder, an eighth cylinder, a third cylinder, a ninth cylinder, a second cylinder, a seventh cylinder, a tenth cylinder, a fifth cylinder, an eleventh cylinder, a sixth cylinder, a twelfth cylinder, and a fourth cylinder fire in this order. In this case, the first core 102 is allocated to the first to third and tenth to twelfth cylinders that fire in odd numbered places and the second core 103 is allocated to the fourth to ninth cylinders that fire in even numbered places. Consequently, the same effects as those of the embodiment can be obtained. In this case, in left and right banks (a left first bank 121, a left second bank 122, a right first bank 123, and a right second bank 124), the number of cylinders that fire in odd numbered places is set equal to the number of cylinders that fire in even numbered places. Consequently, vibration can be cancelled between the left and right banks (the left first bank 121, the left second bank 122, the right first bank 123, and the right second bank 124) during the reduced cylinder operation.

[0022] In the first embodiment, the parallel arithmetic unit 100 includes the two cores, i.e., the first core 102 and the second core 103. However, the parallel arithmetic unit 100 may further include cores for performing calculations other than the calculation of the control target values. Note that this modification can also be applied to a second embodiment explained below.

[0023] The first embodiment is based on the parallel arithmetic unit 100 of the dual core type. However, the invention can also be realized by two arithmetic units of a single core type. That is, the same effects as those of the embodiment can be obtained if, on the basis of a firing order set in advance, one of the two arithmetic units of the single core type is allocated to cylinders belonging to a cylinder group (a first cylinder group) that fire in odd numbered places and the other of the two arithmetic units of the single core type is allocated to cylinders belonging to a cylinder group (a second cylinder group) that fire in even numbered places. Note that this modification can also be applied to the second embodiment explained below.

[0024] The second embodiment is explained. In the example explained in the first embodiment, the parallel arithmetic unit of the dual core type including the two cores, i.e., the first core 102 and the second core 103 is used. The second embodiment is different from the first embodiment in that a parallel arithmetic unit of a quad core type including four cores is used.

[0025] FIG. 5 is a diagram for explaining allocation of cores in the second embodiment. Note that a firing order of the engine is the same as the firing order shown in FIG. 4C. In this case, the first core 102 is allocated to the first and fourth cylinders, the second core 103 is allocated to the second and third cylinders, a third core 111 is allocated to the sixth and seventh cylinders, and a fourth core 112 is allocated to the fifth and eighth cylinders. The cores (the first core 102 and the third core 111) allocated to the cylinders that fire in odd numbered places and the cores (the second core 103 and the fourth core 112) allocated to the cylinders that fire in even numbered places are set in separate core groups. The actuation of the cores during the reduced cylinder operation is controlled in units of the set core groups.

[0026] FIG. 6 is a diagram for explaining combustion intervals in the case of a breakdown of the second core 103 in the configuration shown in FIG. 5. When the second core 103 breaks down, the actuation of the fourth core 112 belonging to the core group the same as the core group to which the second core 103 belongs is forcibly stopped. If the actuation of the fourth core 112 is forcibly stopped during the breakdown of the second core 103, the calculation of control target values by the second core 103 and the fourth core 112 is not performed. On the other hand, the calculation of control target values by the cores (the first core 102 and the third core 111) belonging to the core group different from the core group to which the second core 103 belongs is continued. That is, the reduced core operation by the cylinders (the first, fourth, sixth, and seventh cylinders) allocated with the first core 102 and the third core 111 is performed. Consequently, it is possible to keep the intervals of the combustion fixed even during the reduced cylinder operation. Note that the effect shown in FIG. 6 is not limitedly obtained during the breakdown of the second core 103 and is also obtained when the actuation of the second core 103 is actively stopped.

[0027] Note that, in the second embodiment, the first core 102, the second core 103, the third core 111, and the fourth core 112 are equivalent to the "arithmetic unit" in the second aspect.

[0028] Incidentally, in the second embodiment, the first core 102 is allocated to the first and fourth cylinders and the third core 111 is allocated to the sixth and seventh cylinders. However, the first core 102 may be allocated to only the first cylinder and the third core 111 may be allocated to the fourth, sixth, and seventh cylinders. Alternatively, the first core 102 may be allocated to only the sixth cylinder and the third core 111 may be allocated to the first, fourth, and seventh cylinders. That is, the first core 102 may be allocated to a part of the cylinders of the cylinder group (the first cylinder group) that fire in odd numbered places and the third core 111 may be allocated to the remaining cylinders of the first cylinder group. This relation also applies between the second core 103 and the fourth core 112 and the cylinders of the cylinder group that fire in even numbered places. That is, the second core 103 may be allocated to a part of the cylinders of the cylinder group (the second cylinder group) that fire in even numbered places and the fourth core 112 may be applied to the remaining cylinders of the second cylinder group.

[0029] In the example explained in the second embodiment, the V-8 engine is used. However, other engines in which the number and the array of cylinders are varied can also be used. FIG. 7 is a diagram for explaining allocation of four cores to a W-12 engine. Note that combustion order of the engine is the same as the combustion order shown in FIG. 4D. In this case, the first core 102 is allocated to first to third cylinders, the second core 103 is allocated to fourth to sixth cylinders, the third core 111 is allocated to seventh to ninth cylinders, and the fourth core 112 is allocated to tenth to twelfth cylinders. Core groups are set such that the cores (the first core 102 and the third core 111) allocated to the cylinders that fire in odd numbered places belong to a group different from a group to which the cores (the second core 103 and the fourth core 112) allocated to the cylinders that fire in even numbered places belong. As in FIG. 6, when the second core 103 breaks down, the actuation of the fourth core 112 belonging to the core group the same as the core group to which the second core 103 belongs is forcibly stopped and the reduced cylinder operation by the cylinders applied with the first core 102 and the third core 111 is performed. Consequently, it is possible to keep the intervals of the combustion fixed even during the reduced cylinder operation.

[0030] In the example explained in the second embodiment, the parallel arithmetic unit of the quad core type including the four cores is used. However, the number m of the cores allocated to the cylinders does not always need to be four. The number m may be an even number that satisfies a relation $2<m\leq n/2$ with respect to the number of cylinders n

(n is an even number equal to or larger than 8). In this case, core groups are set such that the cores allocated to the cylinders that fire in odd numbered places belong to a group different from a group to which the cores allocated to the cylinders that fire in even numbered places belong. The actuation of the remaining cores belonging to the core group the same as the core group to which a broken-down specific core (or a specific core actively stopped to be actuated) is forcibly stopped. The reduced cylinder operation by the cylinders allocated with the cores belonging to the core group different from the core group to which the broken-down core belongs is performed. Consequently, it is possible to obtain the same effects as those of the second embodiment.

CLAIMS:

1. A control system for an internal combustion engine, the internal combustion engine including a plurality of cylinders configured to perform combustion in a firing order set in advance, the number of the plurality of cylinders being an even number equal to or larger than four, the control system comprising:

actuators respectively provided in the plurality of cylinders; and

two arithmetic units configured to respectively control operations of the actuators of the plurality of cylinders, one of the two arithmetic units being allocated to the actuators of a first cylinder group, the other of the two arithmetic units being allocated to the actuators of a second cylinder group,

the first cylinder group being a group formed by the cylinders, the firing order of which is an odd number order, and

the second cylinder group being a group formed by the cylinders, the firing order of which is an even number order.

2. The control system according to claim 1, wherein

the internal combustion engine is a V-6 engine including two banks or a horizontally opposed six-cylinder engine including two banks, and

the cylinders belonging to the first cylinder group are provided in the bank different from the bank in which the cylinders belonging to the second cylinder group are provided.

3. The control system according to claim 1, wherein

the internal combustion engine is a V-8 engine including two banks or a horizontally opposed eight-cylinder engine including two banks, and

the cylinders belonging to the first cylinder group and the cylinders belonging to the second cylinder group are provided in each of the two banks, the cylinders belonging to the first cylinder group and the cylinders belonging to the second cylinder group being the same in number.

4. A control system for an internal combustion engine, the internal combustion engine including a plurality of cylinders configured to perform combustion in a firing order set in advance, the number of the plurality of cylinders being an even number equal to or larger than eight, the control system comprising:

actuators respectively provided in the plurality of cylinders; and

a plurality of arithmetic units, the number of the plurality of arithmetic unit being an even number satisfying a condition that the number is larger than 2 and equal to or smaller than n/2, where n is the number of the plurality of cylinders, the plurality of arithmetic units being configured to respectively control operations of the actuators of the plurality of cylinders,

the plurality of arithmetic units being divided into arithmetic units belonging to a first arithmetic unit group and arithmetic units belonging to a second arithmetic unit group different from the first arithmetic unit group, the arithmetic units belonging to the first arithmetic unit group being allocated to the actuators of a first cylinder group, the arithmetic units belonging to the second arithmetic unit group being allocated to the actuators of a second cylinder group,

the first cylinder group being a group formed by the cylinders, the firing order of which is odd number order,

the second cylinder group being a group formed by the cylinders, the firing order of which is even number order, and

the plurality of arithmetic units being configured to, when actuation of a specific arithmetic unit belonging to the first arithmetic unit group or the second arithmetic unit group is stopped, stop operation of the arithmetic units belonging to the arithmetic unit group the same as the arithmetic unit group to which the specific arithmetic unit belongs and continue operation of the arithmetic units belonging to the arithmetic unit group different from the arithmetic unit group to which the specific arithmetic unit belongs.

FIG. 1

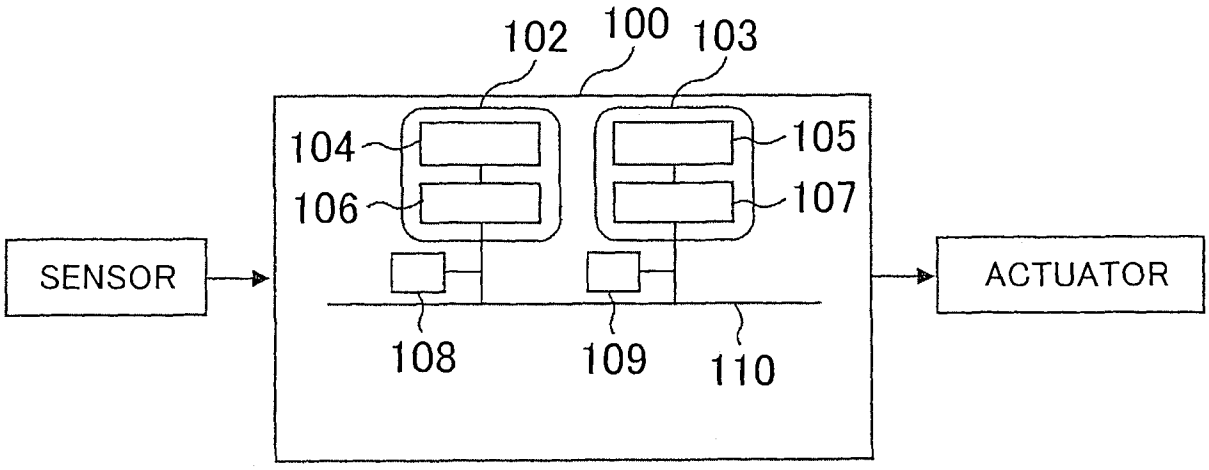


FIG. 2

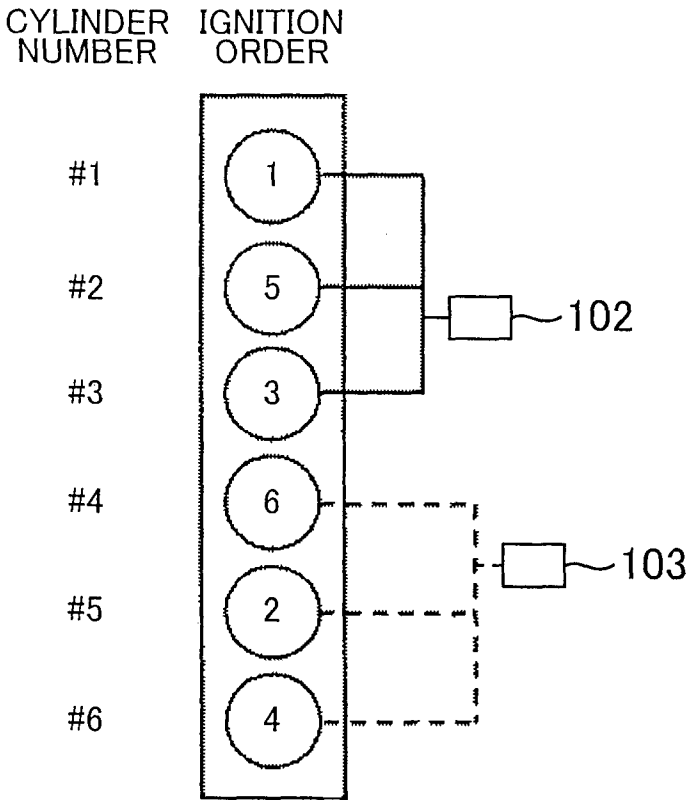


FIG. 3A

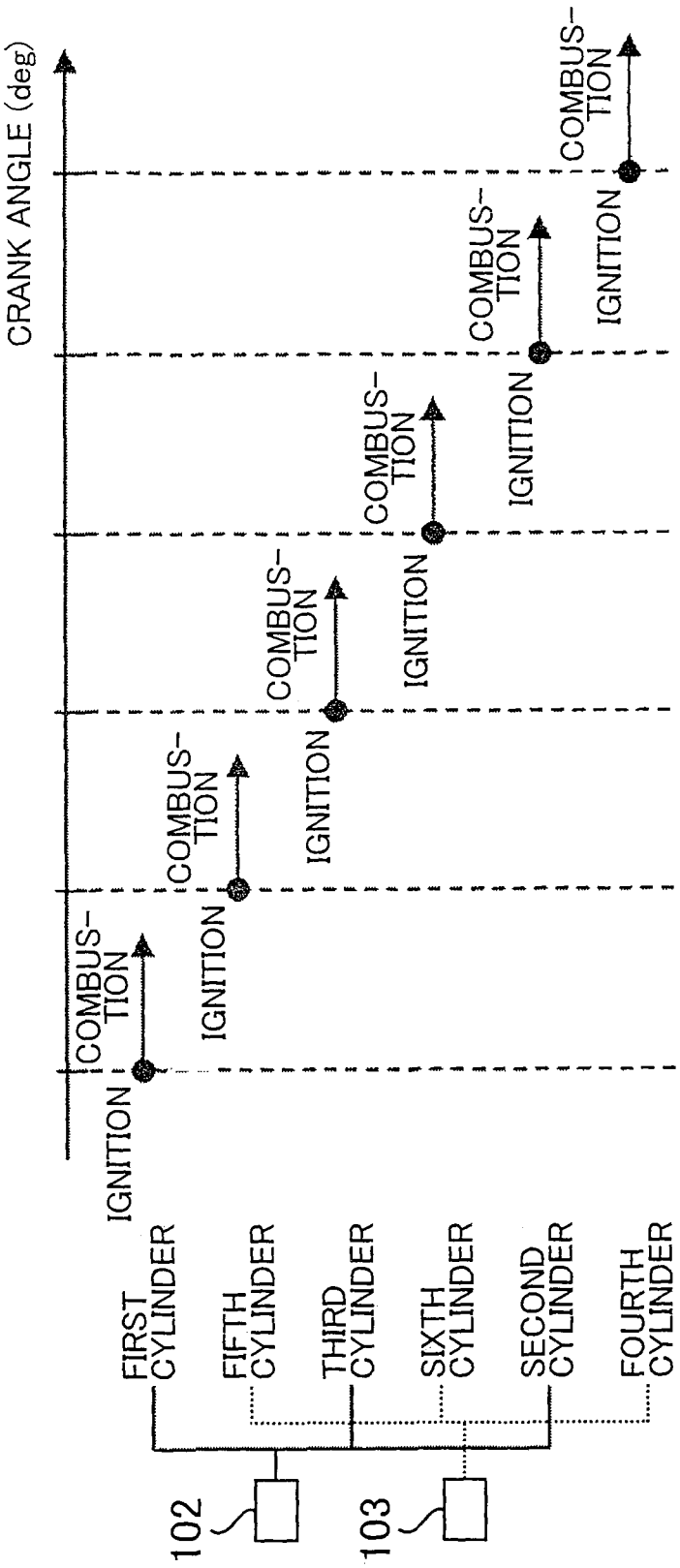

CRANK ANGLE (deg)
IGNITION
COMBUS-TION
FIRST CYLINDER
IGNITION
COMBUS-TION
FIFTH CYLINDER
IGNITION
COMBUS-TION
THIRD CYLINDER
IGNITION
COMBUS-TION
SIXTH CYLINDER
IGNITION
COMBUS-TION
SECOND CYLINDER
IGNITION
COMBUS-TION
FOURTH CYLINDER
102
103

FIG. 3B

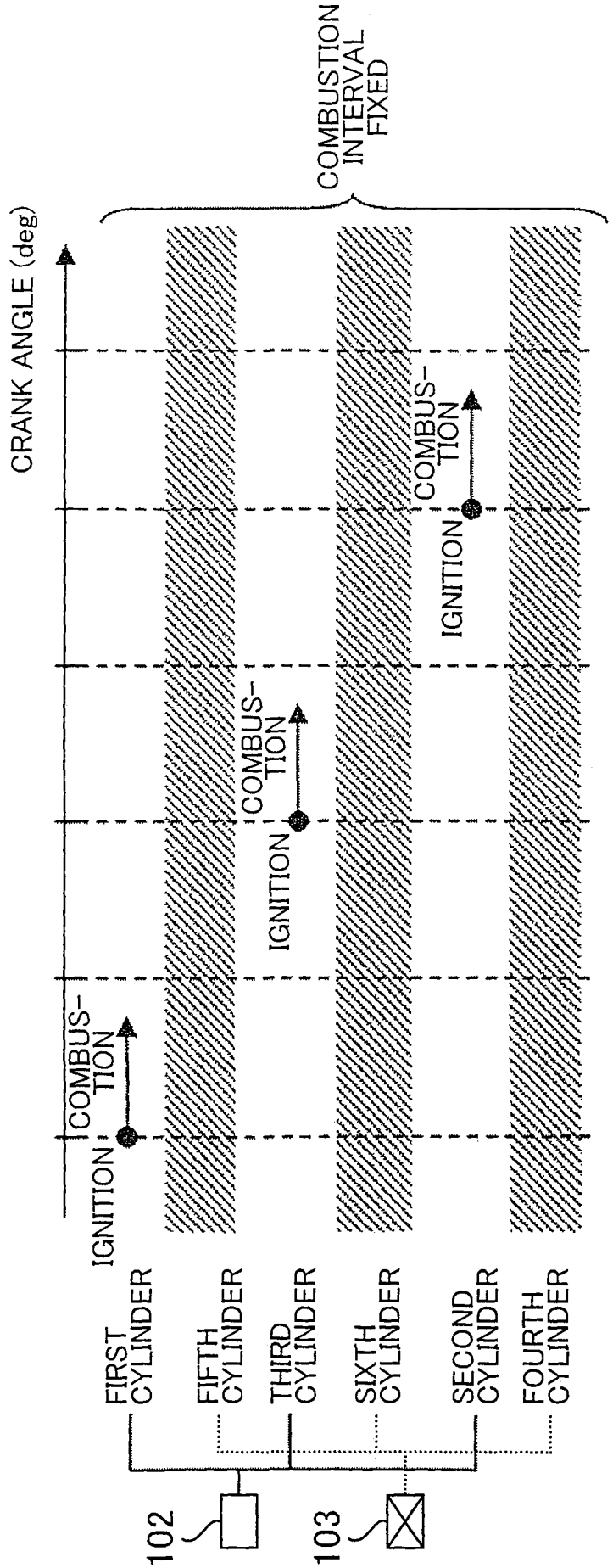

COMBUSTION INTERVAL FIXED
CRANK ANGLE (deg)
IGNITION
COMBUS-TION
IGNITION
COMBUS-TION
IGNITION
COMBUS-TION
FIRST CYLINDER
FIFTH CYLINDER
THIRD CYLINDER
SIXTH CYLINDER
SECOND CYLINDER
FOURTH CYLINDER
102
103

FIG. 4B

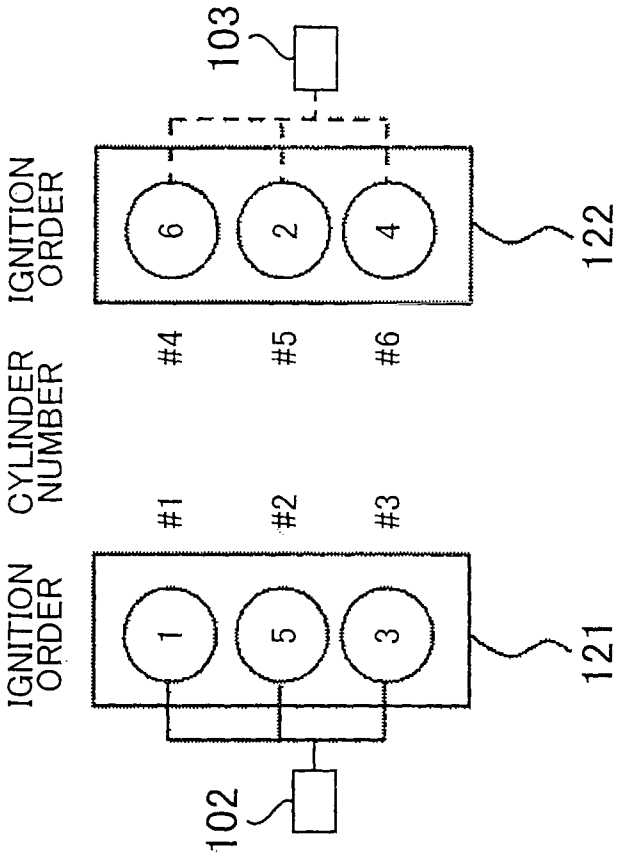

CYLINDER NUMBER
IGNITION ORDER
#1
#2
#3
#4
#5
#6
1
5
3
6
2
4
102
103
121
122

FIG. 4A

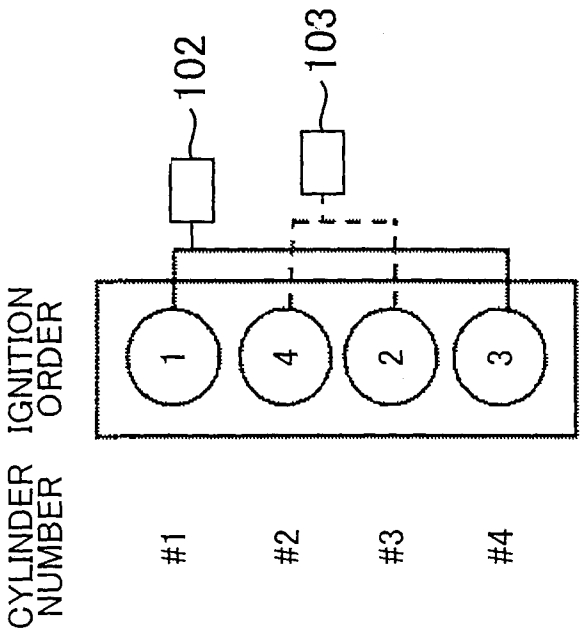

CYLINDER NUMBER
IGNITION ORDER
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#2
#3
#4
1
4
2
3
102
103

FIG. 4C

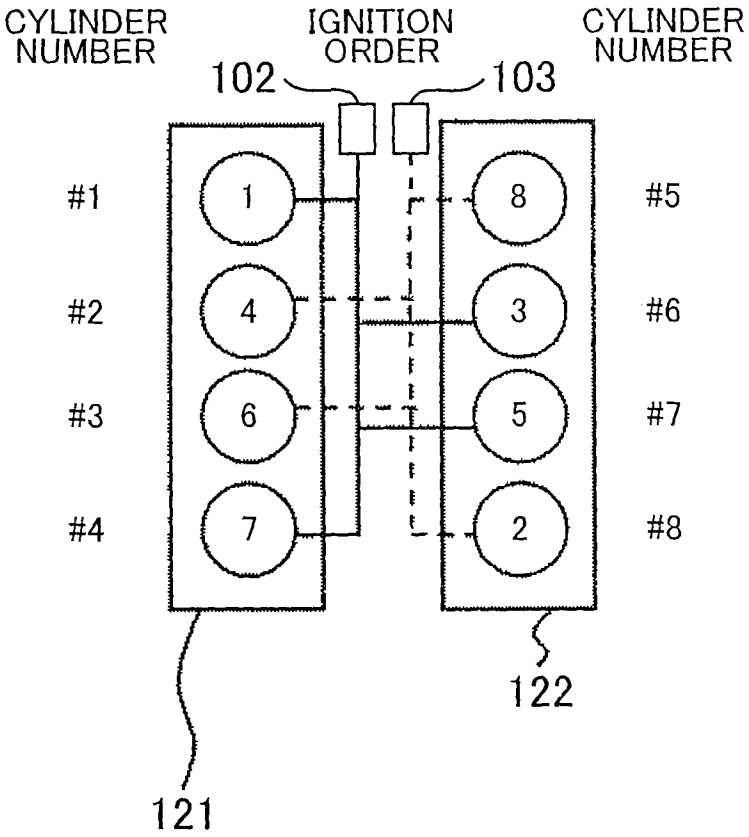

CYLINDER NUMBER
IGNITION ORDER
CYLINDER NUMBER
102
103
#1
#2
#3
#4
1
4
6
7
8
3
5
2
#5
#6
#7
#8
121
122

FIG. 4D

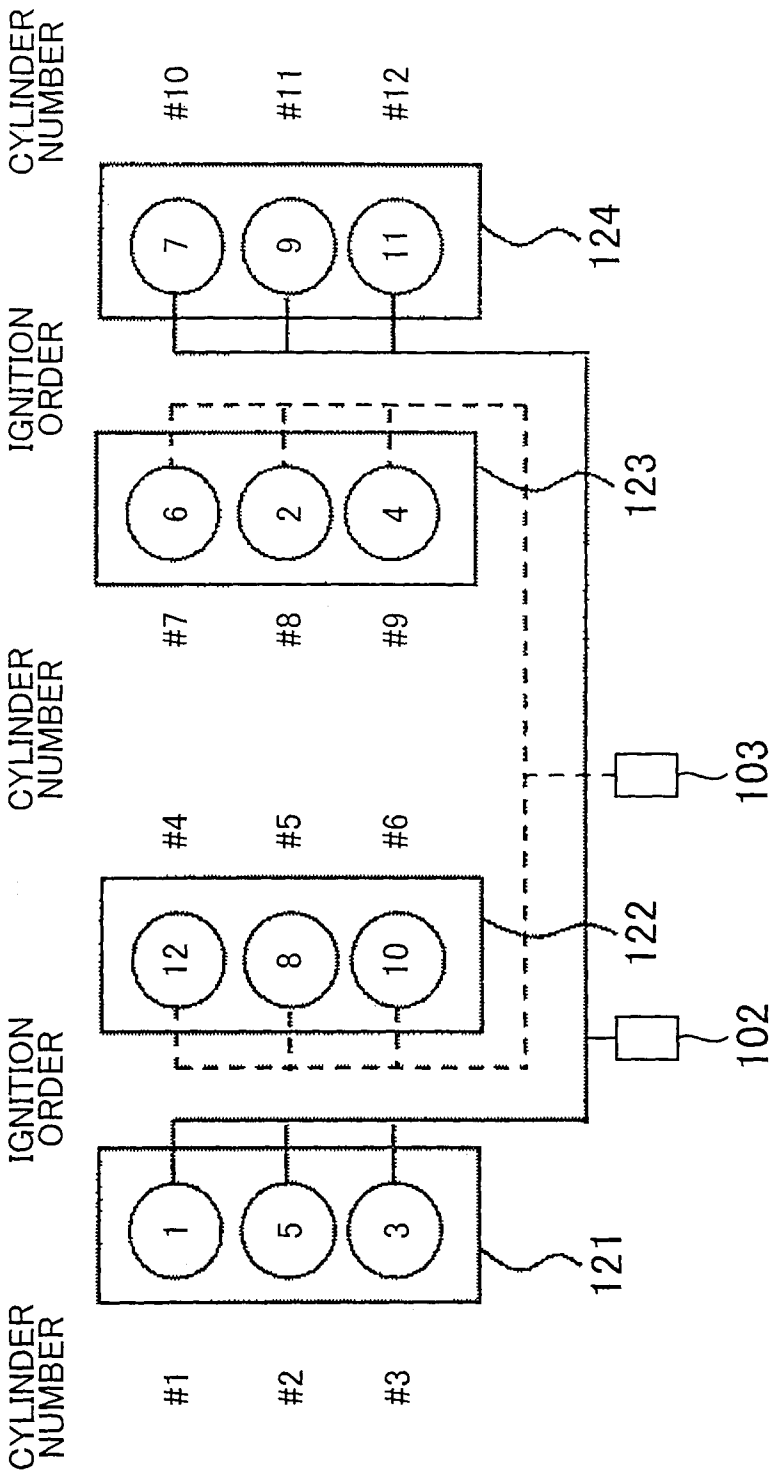

CYLINDER NUMBER
#1
#2
#3
IGNITION ORDER
1
5
3
121
CYLINDER NUMBER
#4
#5
#6
IGNITION ORDER
12
8
10
122
CYLINDER NUMBER
#7
#8
#9
IGNITION ORDER
6
2
4
123
CYLINDER NUMBER
#10
#11
#12
IGNITION ORDER
7
9
11
124
102
103

FIG. 5

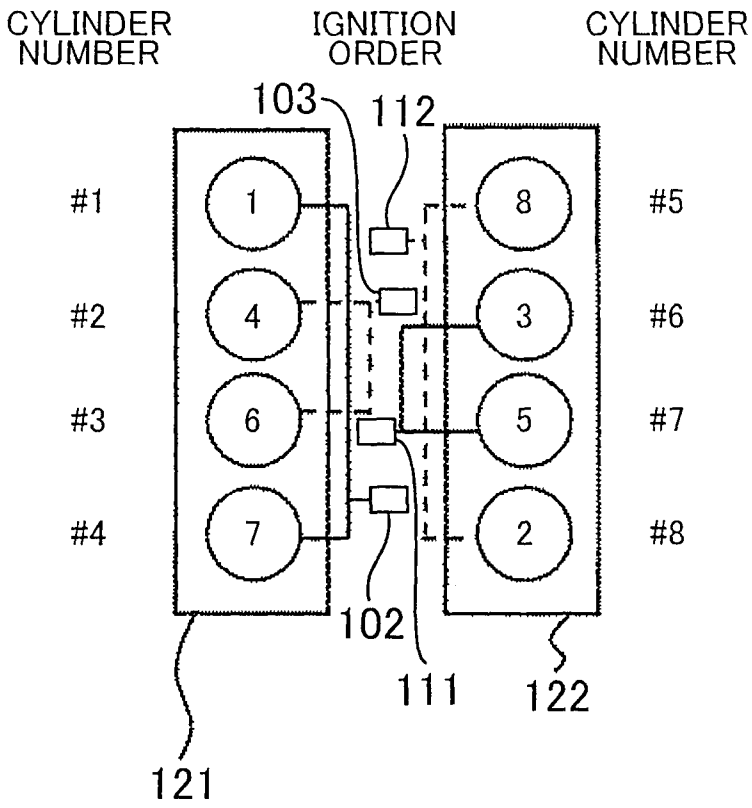

CYLINDER NUMBER
IGNITION ORDER
CYLINDER NUMBER
103
112
#1
#2
#3
#4
1
4
6
7
8
3
5
2
#5
#6
#7
#8
102
111
122
121

FIG. 6

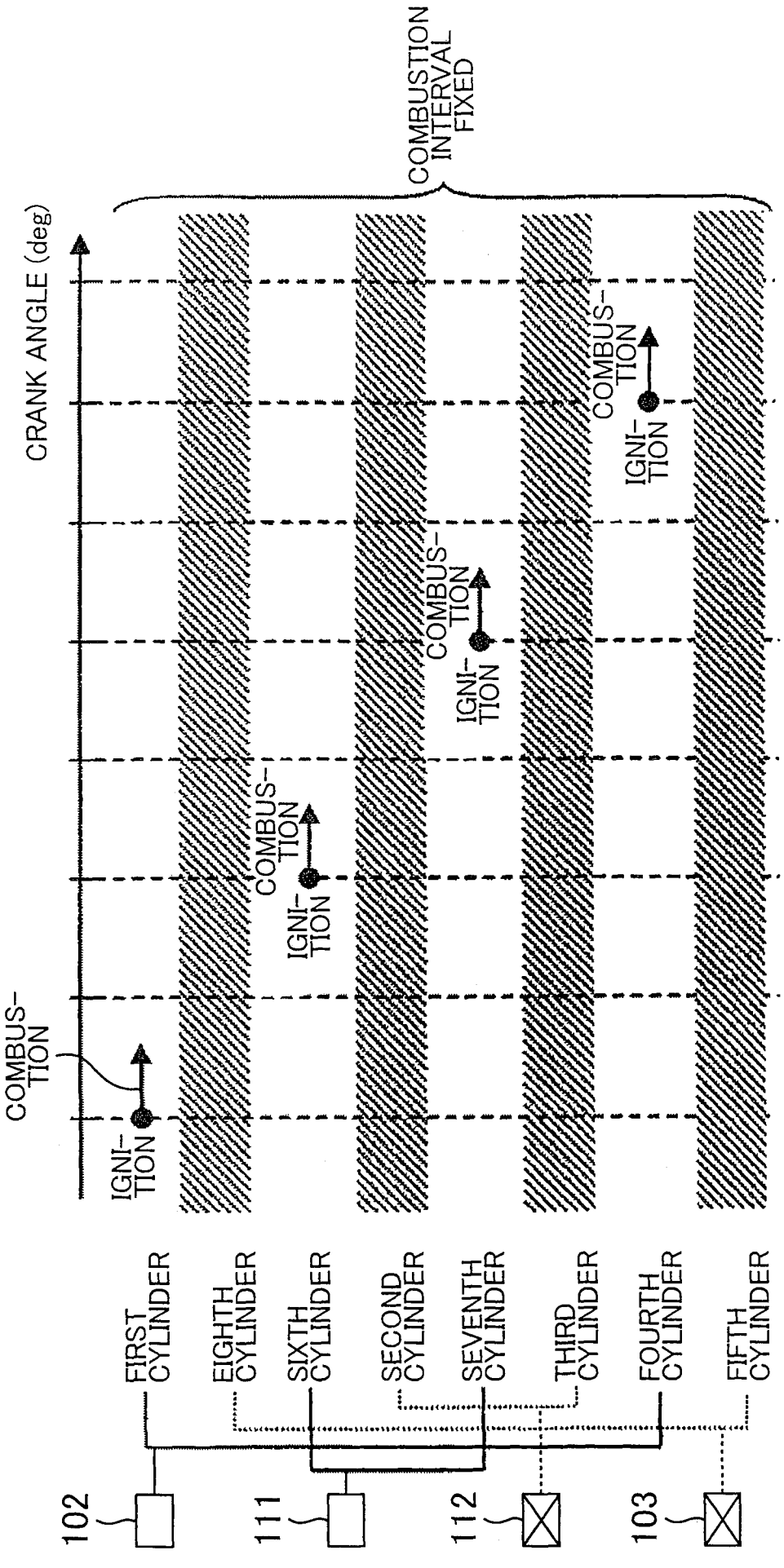
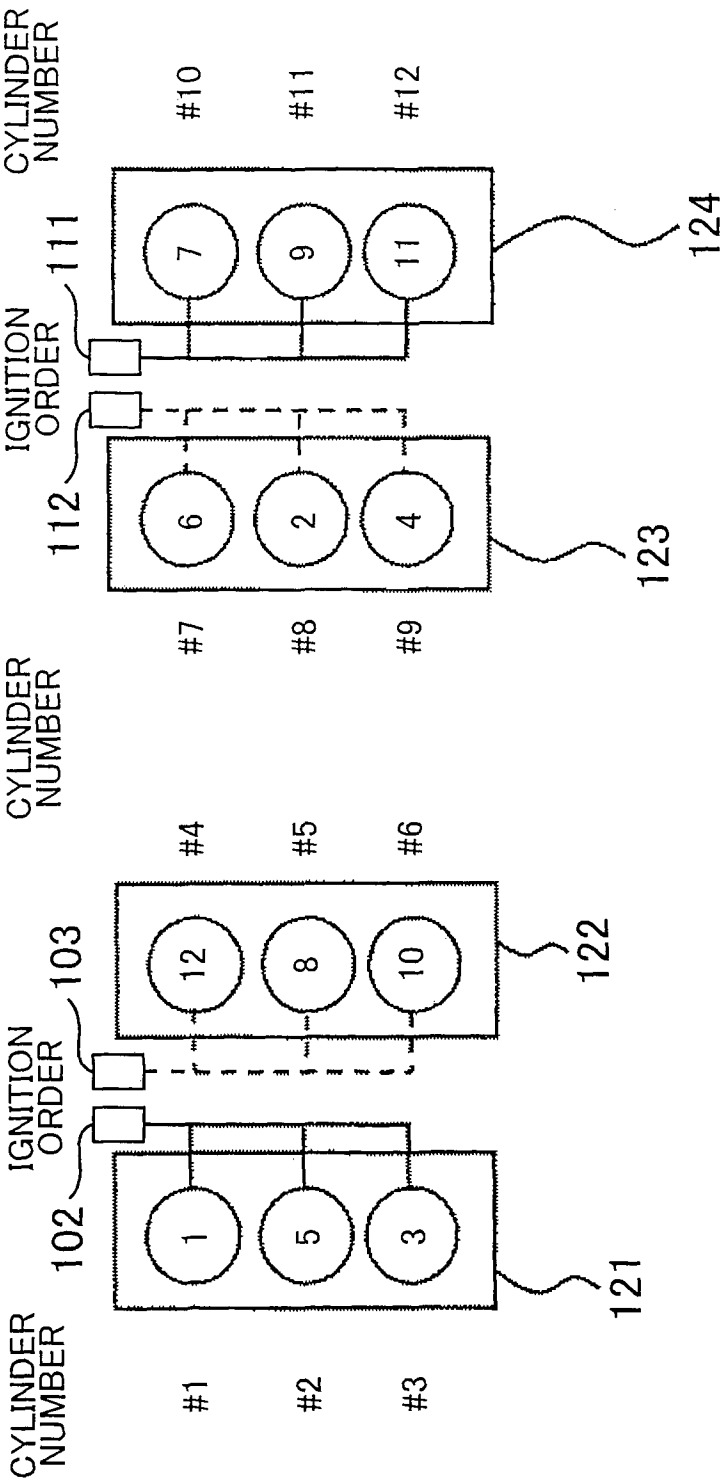

COMBUSTION INTERVAL FIXED
CRANK ANGLE (deg)
COMBUS-TION
IGNI-TION
COMBUS-TION
IGNI-TION
COMBUS-TION
IGNI-TION
COMBUS-TION
IGNI-TION
FIRST CYLINDER
EIGHTH CYLINDER
SIXTH CYLINDER
SECOND CYLINDER
SEVENTH CYLINDER
THIRD CYLINDER
FOURTH CYLINDER
FIFTH CYLINDER
102
111
112
103

FIG. 7


CYLINDER NUMBER
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
IGNITION ORDER
102
103
111
112
1
5
3
12
8
10
6
2
4
7
9
11
121
122
123
124

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/001898

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/26 F02D41/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02B F02D G06F G05B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2007 006174 A1 (FORD GLOBAL TECH LLC [US]) 16 August 2007 (2007-08-16) abstract; figures 1-6 paragraphs [0001] - [0002], [0006] - [0008] -----	1-4
X	WO 2004/065768 A2 (KAREM ABRAHAM E [US]) 5 August 2004 (2004-08-05) abstract; figure 1 page 6, line 19 - page 7, line 11 page 16, line 21 - page 17, line 20 -----	1-4
X	DE 10 2012 201894 A1 (BOSCH GMBH ROBERT [DE]) 14 August 2013 (2013-08-14) abstract; figure 1 paragraphs [0002] - [0009], [0024] -----	1-4

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 January 2015	05/02/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Mineau, Christophe

2

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/001898

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	DE 10 2005 036441 A1 (BOSCH GMBH ROBERT [DE]) 8 February 2007 (2007-02-08) abstract; figure 1 paragraphs [0020] - [0021]	1-4
A	PATRICK LETEINTURIER ET AL: "MultiCore Benefits & Challenges for Automotive Applications", SAE TECHNICAL PAPER SERIES, 17 April 2008 (2008-04-17), pages 776-4841, XP055164401, 2008 World Congress Detroit, Michigan abstract	1-4

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/001898

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