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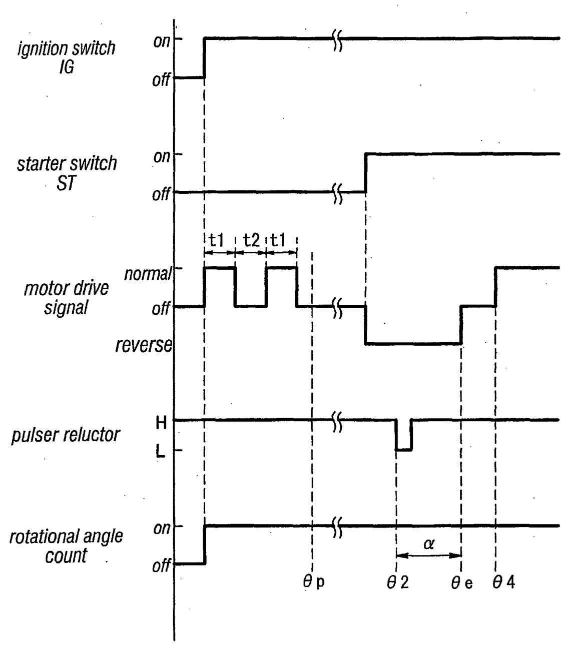
(54) **ENGINE STARTER**

(57) In engine starter system adapted to crank an engine first in a reverse direction, and finally in a normal direction with an electric motor that is connected to a crankshaft of an engine, to ensure a successful cranking at all times, an electric current is supplied to the electric motor for a normal rotation prior to cranking the engine in the reverse direction to move the crankshaft to a suitable angular position at least under a prescribed condition. This control can be accomplished without requiring any special angle sensor.

Fig.12



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Description

TECHNICAL FIELD

[0001] The present invention relates to an engine starter system.

BACKGROUND OF THE INVENTION

[0002] Conventionally, in motor vehicles, an engine is cranked by an electric motor, and the electric motor is sometimes used also as an electric generator. By doing so, the electric motor serves both for cranking the engine and generating electricity, and the accessory equipment for the engine can be simplified.

[0003] In an engine starter system, because the position of the piston is indeterminate at the start of cranking the engine, the rated output of the starter motor needs to be high enough to be able to crank the engine even when the piston is at the beginning of a compression stroke and/or when the engine is cold and therefore involves a high level of viscous resistance. However, it is not desirable to increase the size of the starter motor.

[0004] A swing engine starter system is also known which cranks the engine in the normal direction after slightly turning the crankshaft in the reverse direction to ensure a successful cranking of the engine under any condition even when the rated output of the starter motor is relatively small. This swing action provides an approach run and allows the spring back force of a compression pressure to be utilized to help the cranking speed to reach an adequate level to overcome the compression stroke.

[0005] In such a swing start engine starter system, for a small electric motor to be able to successfully crank the engine without fail, it is necessary to place the crankshaft at a position which provides an adequate approach run distance directed toward the expansion stroke in the reverse direction such as a position in the compression stroke or a position in the intake stroke near the compression stroke before cranking the engine. Otherwise the crankshaft may stop before reaching the expansion stroke if the engine load is high as is the case when the engine is cold (due to viscous resistance). On the other hand, if the engine temperature is normal, the crankshaft can rotate in the reverse direction to an intermediate point of the expansion stroke by opposing the compression pressure. Conversely, if the engine temperature is high and the engine load is light, the crankshaft could rotate in the reverse direction beyond the top dead center of the expansion stroke.

[0006] However, the angular position of the crankshaft (or the position of the piston) before cranking the engine can only be estimated, and may not be the same each time. Therefore, if the reverse drive is defined so as to accommodate such variations, the necessary approach run distance may not necessarily be ensured, and it does not lead to the minimization of the rated output of the electric motor. The piston position can be detected by using a rotary encoder or the like, but it leads to the rise in the cost of the system.

BRIEF SUMMARY OF THE INVENTION

[0007] In view of such problems of the prior art, a primary object of the present invention is to provide an engine starter system which can perform the swing start action by moving the crankshaft (piston) to an optimum position when necessary so that a reliable cranking action can be effected at all times.

[0008] A second object of the present invention is to provide an engine starter system which can start an engine reliably with a minimum consumption of electric power.

[0009] A third object of the present invention is to provide an engine starter system which allows the crankshaft angular position sensor used for such an engine starter system to be simplified and minimized in cost.

[0010] A fourth object of the present invention is to provide an engine starter system which is suitable for use with an idle stop system which requires frequent restarting of the engine.

[0011] A fifth object of the present invention is to provide an engine starter system which is suited to use an electric motor that serves also as an electric generator.

[0012] According to the present invention, such objects can be accomplished by providing an engine starter system adapted to crank an engine first in a reverse direction, and finally in a normal direction with an electric motor that is connected to a crankshaft of an engine, comprising: an electric motor connected to the crankshaft; a sensor for detecting an angular position of the crankshaft; and a controller for controlling a supply of electric current to the electric motor according an output signal of the sensor; the controller being adapted to supply an electric current to the electric motor for a normal rotation prior to cranking the engine in the reverse direction at least under a prescribed condition.

[0013] Thus, by temporarily stopping the crankshaft when it has rotated in the normal direction to a position inside the compression stroke in advance, the final cranking in the normal direction can be performed after rotating the crankshaft in the reverse direction so as to provide an adequate approach run distance and allow the spring back of the compression pressure to be utilized so that a reliable cranking action can be ensured. In particular, by rotating the crankshaft in the normal direction in an intermittent manner as a preliminary action, even when the engine temperature is high and the friction loss is small as is the case when stopping the engine on a red signal (idle stop) or restarting the vehicle after a short stop, it is possible to prevent the crankshaft from rotating beyond the top dead center due to an excessive rotational speed, and to prevent an excessive spring back of the crankshaft which can be produced when the crankshaft is rotated against the compression pressure to a point near the top dead center. In either case, the position from which to start the subsequent cranking can deviate significantly from a proper position.

[0014] If a crankshaft angular position at which the intermittent supply of electric current to the electric motor is changed to the supply of electric current for the reverse cranking is determined as a position at which the crankshaft is pushed back in the reverse direction by more than a prescribed angle a prescribed number of times during a power off period in the supply of electric current to the electric motor in an intermittent manner or as a position at which the crankshaft fails to rotate in the normal direction by more than a prescribed angle a prescribed number of times during a power on period in the supply of electric current to the electric motor in an intermittent manner, the crankshaft angular position at which the reverse cranking should be started can be determined both simply and economically.

[0015] If the crankshaft angular position sensor is capable of providing the necessary angular information, a crankshaft angular position at which the intermittent supply of electric current to the electric motor for the normal cranking is changed to the supply of electric current to the electric motor for the reverse cranking may be predetermined, and the electric motor may be brought to the reverse drive condition when the output signal of the crankshaft angular position sensor has detected the predetermined angular position is detected.

[0016] When the first preliminary cranking in the normal direction is not performed, the reverse drive is performed in an intermittent manner so that the crankshaft may be prevented from rotating beyond the top dead center after reversing the expansion stroke or from being kicked back by the compression pressure of the expansion stroke in the same manner as in the case of the preliminary cranking in the normal direction.

[0017] If a sensor for detecting at least one of a battery voltage and an engine temperature is provided, the supply of electric current to the electric motor in an intermittent manner may be performed only when the output signal of the sensor indicates that at least one of the battery voltage and engine temperature falls below a prescribed value. Thus, the crankshaft is rotated in the normal direction before being cranked in the reverse direction only when the battery voltage is low and/or when the engine temperature is low so that the crankshaft is prevented from being kicked back by the compression pressure when reversing the expansion stroke, and the cranking of the engine can be accomplished quickly and with a minimum consumption of electric power according to the particular given condition.

[0018] When restarting the engine in a fully warmed up state as is the case of an idle stop operation or restarting the vehicle after a short stop, there is an increased tendency for the crankshaft to be kicked back by the compression pressure due to the reduced frictional loss, and merely intermittently cranking the engine in the normal direction may not be enough to effectively bring the crankshaft angular position to the prescribed position in the compression stroke. In such a case, the supply of electric current in an intermittent manner may be repeated. For more effectively bringing the crankshaft angular position to the prescribed position in the compression stroke, a duty ratio of the supply of electric current in an intermittent manner may be decreased when repeating the supply of electric current to the electric motor in an intermittent manner.

[0019] To allow the necessary angular information to be obtained without using an expensive encoder or the like, the crankshaft angular position sensor may comprise an absolute position sensor for detecting an absolute position of the crankshaft and a relative position sensor for detecting an angular positional change of the crankshaft at a higher resolution, detection of an absolute angle of the crankshaft at a high resolution being enabled by combining the sensors. For instance, the absolute position sensor may comprise an ignition timing sensor. The electric motor may comprise a brushless motor, and the relative position sensor may comprise a commutating signal sensor of the brushless motor.

[0020] In such a case, a crankshaft angular position at which the reverse cranking is taken over by the final normal cranking may be determined according to an output of the relative position sensor using an output of the ignition timing sensor in an exhaust stroke of the engine as a reference. This allows the absolute angular position of the crankshaft to be known at a high resolution, and the obtained absolute angular position of the crankshaft can be used for the ignition control and fuel injection control as well as for the cranking control.

[0021] Because an ignition timing sensor typically produces an output signal both in the compression stroke and exhaust stroke, it is necessary to distinguish them to allow the absolute angle of the crankshaft to be determined. Based on such considerations, an output of the ignition timing sensor may be disregarded for a prescribed angle after the reverse cranking has started following the supply of electric current in an intermittent manner for the first preliminary normal drive.

[0022] If the relative position sensor is adapted to detect a rotational direction as is the case with a commutating signal sensor of a brushless motor, an output of the ignition timing sensor during an exhaust stroke of the engine may be identified to provide a reference for a timing of starting the final normal cranking according to a detected rotational angle and the output of the ignition timing sensor. Also, an output of the ignition timing sensor during an exhaust stroke of the engine may be identified to provide a reference for a timing of starting the final normal cranking according to a point of change in the rotational direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Now the present invention is described in the following with reference to the appended drawings, in which:

Figure 1 is a schematic diagram of an engine starter system embodying the present invention;
Figure 2 is a fragmentary sectional side view of the engine starter system;
Figure 3 is a fragmentally end view partly in section as seen in the direction indicated by arrows III-III in Figure 2;
Figure 4 is a simplified circuit diagram of the engine starter system embodying the present invention;
Figure 5 is a time chart showing the commutating signal of the electric motor (brushless motor);
Figure 6 is a flow chart showing the control flow according to the present invention;
Figure 7 is a diagram showing the change in the strokes of the four stroke engine embodying the present invention when the preliminary normal drive is not effected;
Figure 8 is a diagram showing the control procedure for the control action shown in Figure 7;
Figure 9 is a time chart showing the control procedure for the control action shown in Figure 7;
Figure 10 is a diagram showing the change in the strokes of the four stroke engine embodying the present invention when the preliminary normal drive is effected;
Figure 11 is a diagram showing the control procedure for the control action shown in Figure 10;
Figure 12 is a time chart showing the control procedure for the control action shown in Figure 10;
Figure 13 is a diagram showing the change in the strokes of the four stroke engine to illustrate the arrangement for avoiding an erroneous detection of the output of the ignition timing sensor when the preliminary normal drive is effected;
Figure 14 is a diagram showing the control procedure for the control action shown in Figure 13;
Figure 15 is a time chart showing the control procedure for the control action shown in Figure 13;
Figures 16 to 18 are time charts showing another arrangement for avoiding an erroneous detection of the output of the ignition timing sensor when the preliminary normal drive is effected;
Figure 19 is a time chart showing yet another arrangement for avoiding an erroneous detection of the output of the ignition timing sensor when the preliminary normal drive is effected;
Figure 20 is a time chart showing yet another arrangement for avoiding an erroneous detection of the output of the ignition timing sensor when the preliminary normal drive is effected; and
Figure 21 is a time chart showing yet another arrangement for avoiding an erroneous detection of the output of the ignition timing sensor when the preliminary normal drive is effected;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Figure 1 is a schematic diagram showing an engine starter system embodying the present invention. As shown in Figure 1, this starter system includes an electric motor (generator) 1 which is coaxially and directly connected to a crankshaft 2 of an engine ENG, and is adapted not only to crank the engine but also to function as an electric generator during the operation of the engine. A controller ECU controls the electric motor 1 as well as the engine ENG by receiving signals from an ignition switch IG and a starter switch ST.

[0025] An exemplary structure of the electric motor 1 is now described in the following with reference to Figures 2 and 3. As shown in the drawings, an outer rotor 3 having the shape of a shallow cup and serving also as a flywheel is coaxially attached to the crankshaft 2 of the engine ENG, and includes a prescribed number of arcuate magnet pieces 4 that are attached to the inner circumferential surface of the outer rotor 3 in such a manner that the magnetic poles of the magnet pieces 4 alternate between N and S along the circumferential direction.

[0026] The electric motor 1 is additionally provided with an inner stator 5 which is coaxially disposed with respect to the outer rotor 3 and cooperates with the latter. The inner stator 5 is provided with a same number of stator cores 7 as the magnet pieces 4 which are disposed radially with respect to the crankshaft 2 inside the peripheral wall of the outer rotor 3 opposite the magnetic poles of the magnet pieces 4, and stator coils 6 which are wound around the corresponding stator cores 7. The inner stator 5 is fixedly attached to an end surface of the engine ENG with threaded bolts 11. Each stator coil 6 is connected to a drive device such as an FET in a motor driver circuit 14 for driving the electric motor 1 according to an electric motor control signal from a CPU provided in the controller ECU as shown in Figure 4 also. The electric motor of this ACG starter system consists of a brushless motor, and the motor driver circuit 14 include a pair of FETs for each of the U, V and W phases to drive the corresponding phase into high and low states. An intermediate node between each pair of the FETs is connected to the stator coil 6 of the corresponding phase.

[0027] To the outer circumferential surface of the outer peripheral wall of the outer rotor 3 is attached a reluctor 8 consisting of a magnetic member. A pulser (magnetic detection coil) 9 is fixedly attached to an end surface of the engine ENG via a bracket 10 which is integrally formed with the pulser 9 with a threaded bolt 12 so as to oppose the outer peripheral surface of the peripheral wall of the outer rotor 3. The pulser 9 forms an ignition timing sensor in cooperation with the reluctor 8 by detecting magnetic changes as the reluctor 8 passes the pulser 9. Three Hall devices 13 are provided in the inner stator 5 of the electric motor 1 to form a commutating position sensor. The outer rotor 3 is provided with an annular sensor magnet 15 serving as an object of detection around a boss projecting toward the engine main body. The Hall devices 13 are placed on suitable locations of the inner stator 5 via a positioning case so as to detect the positional changes in the magnetic poles of the sensor magnet 15. The Hall devices 13 are arranged at a regular interval along the circumferential direction so as to correspond to the U, V and W phases as shown in Figure 3.

[0028] Referring to Figure 1 and 4, the controller ECU monitors the engine temperature TE and the battery voltage BT. According to the monitored values, a preliminary action can be started by selecting a control action which is both efficient and appropriate according to a data table stored in ROM in advance. The engine temperature TE may include the cooling water temperature in a water cooled engine, the ambient temperature inside the engine room, the temperature of the electric motor (electric generator) 1, the temperature of the controller ECU when it is mounted inside the engine room, or any data that would give a measure of the temperature of any part of the engine.

[0029] The mode of cranking the engine with this engine starter system is described in the following. As the electric motor 1 consists of a three phase brushless motor in this embodiment, the Hall devices 13 are arranges so as to detect the timings of the rise (L→H) and fall (H→L) of each of the U, V and W phases as shown in Figure 5, and the rotational angle can be detected by an increment of 10 degrees according to the combinations of the states of the three phases. As there are six possible combinations of these states, the same combination repeats itself for every 60 degrees. Therefore, this sensor can detects relative angular changes, but cannot measure the absolute angular position by itself.

[0030] Because the engine consists of a four stroke engine, for each two revolutions or for each rotation of 720 degrees, the compression, expansion, exhaust and intake strokes take place as illustrated in Figure 7. The pulser 9 detects the passage of the reluctor 8 at a position ($\theta 1$) slightly before the top dead center between the compression and expansion strokes, and at a position ($\theta 2$) slightly before the top dead center between the exhaust and intake strokes or at a position separated from position $\theta 1$ by 360 degrees. Positions $\theta 1$ and $\theta 2$ are referred to as "ignition timing reference position" and "angle computing reference position" in the following description. Because the reluctor 8 has a certain width, the pulser 9 produces pulses of mutually opposite polarities as the leading edge and trailing edge of the reluctor 8 passes the pulser 9. Therefore, the pulser 9 can determine the absolute angular position, but can determine only one point out of 360 degrees, and cannot distinguish between the compression stroke and exhaust stroke.

[0031] When the engine ENG is stationary, it can be estimated that that the crankshaft is somewhere in the exhaust or intake stroke, but cannot be determined for certain under normal condition. Therefore, when an attempt is made to successfully crank the engine by rotating the crankshaft in the reverse direction before finally cranking the engine in the normal direction (swing start action), it cannot be determined how far back the crankshaft should be rotated in the reverse direction. In other words, depending on the position of the crankshaft before cranking the engine, the reverse drive may not able to rotate the crankshaft in the reverse direction to a sufficient extent to provide an adequate approach run distance and adequate swing action when finally cranking the engine in the normal direction due to the compression resistance that is encountered when reversing the expansion stroke. It is also possible for the reverse drive to rotate the crankshaft beyond the top dead center from the side of the expansion stroke. Therefore, in the illustrated embodiment, prior to the final cranking action, the crankshaft is rotated in the normal direction (preliminary normal drive), when necessary, to such an extent as not to go beyond the top dead center between the compression and expansion strokes so that the swing start action can be effected with an adequate approach run distance for the reverse drive.

[0032] When restarting the engine after each idle stop, or when starting the engine in a fully warmed up state, the friction loss is so small that such a preliminary normal drive would not be necessary. Even when a preliminary normal drive is omitted, the reverse drive could be excessive enough for the crankshaft to rotate beyond the top dead center from the expansion stroke.

[0033] According to the starter system of the present invention, the ignition switch IG is turned on at first, and a preliminary action is performed before the switch ST is turned on to crank the engine. The cranking may consist of a simple normal drive or a swing action drive combining both a reverse drive and a normal drive. This action takes place in an automatic manner as the vehicle operator turns on the ignition switch IG and then turn on the starter switch ST.

[0034] Referring to Figure 6, it is determined if the battery voltage BT is lower than a prescribed lower limit value BTL in step 1 (ST1). If higher, the program flow advances to step 2 (ST2). It is then determined if the engine temperature TE is lower than a prescribed lower limit TEL, and if higher, the program flow advances to step 3 (ST3).

[0035] In step 3 (ST3), as it is determined that a preliminary normal drive is not necessary, an intermittent drive in the reverse direction is performed as a preliminary reverse drive preceding the turning on of the starter switch ST as indicated by arrow in Figures 7 and 8. As shown in Figure 9, the power on time period t1 during the intermittent drive is for instance in the order of 50 ms, and the power off time period t2 may be in the same range. The reverse drive in this case is effected in an intermittent manner to avoid the reverse drive from becoming excessive and rotating the crankshaft in the reverse direction beyond the top dead center from the expansion stroke because the battery voltage is high and/or because the friction loss is small as is the case when the engine is fully warmed up or is being restarted after an idle stop. Therefore, if there is no fear of rotating the crankshaft beyond the top dead center from the side of the expansion stroke by taking a suitable measure to prevent the reverse drive from becoming excessive, the intermittent drive may be replaced with a continuous drive.

[0036] In step 4 (ST4), it is determined if a compression start position θe defined in an intermediate point of the expansion stroke has been reached as shown in Figures 7 and 8. The detection of the compression start position θe can be accomplished by detecting the spring back of the compression pressure which is produced as a result of reversing the expansion stroke. More specifically, based upon the commutating position signal from the Hall devices 13, the compression start position θe may be defined as a position at which the crankshaft is pushed back in the normal direction by more than a prescribed angle (20 degrees, for instance) during a power off interval of the electric motor a prescribed number of times (which may be once or more), or at a position at which the crankshaft fails to rotate in the reverse direction by more than a prescribed angle (20 degrees, for instance) during a power on interval of the electric motor a prescribed number of times (which may be once or more). However, if the absolute angular position of the crankshaft and the current stroke are known or an angle sensor provides such information, it is possible to terminate the reverse drive when it is actually detected that the angular position of the crankshaft has reached the compression start position θe.

[0037] When the compression start position θe is detected in step 4 (ST4), the program flow advances to step 5 (ST5). Because the compression start position as detected in step 4 (ST4) may not be accurate, this position is set as a provisional compression start position θe, and the program flow advances to step 6 (ST6).

[0038] The final normal drive cranking control is conducted in step 6 (ST6). When the compression start position θe is detected, the crankshaft is stationary in the expansion stroke as shown in Figures 7 and 8. When the starter switch ST is turned on at this time, the cranking in the normal direction is started from this preparatory position by continually supplying electric current to the electric motor 1 as indicated by arrow B in Figure 7 and 8. This corresponds to a case where the rotational speed can be increased enough to rotate the crankshaft beyond the top dead center when cranking the engine because an adequate approach run distance extending from a point in the expansion stroke to the compression stroke is ensured and the spring back force of the compression pressure can be utilized. During this normal rotation, the passage of the reluctor 8 in the exhaust stroke in the normal direction can be detected as a pulser output signal, and the detected position is set as an angle computing reference position θ2 that can be used as a reference of angular position instead of the provisional compression start position θe as shown in Figures 7 and 8. This angular position can be used as a reference in determining the absolute angle for timing control in cranking, ignition and fuel injection controls.

[0039] According to this embodiment, the condition for anticipating a sufficient rise in the rotational speed is determined form the battery voltage BT and engine temperature ET in steps 1 and 2 (ST1 and ST2). The drive torque of the engine 1 is low when the battery voltage BT is lower than the lower limit value BTL. The friction loss is great due to a high viscous resistance when the engine temperature TE is lower than the lower limit value TEL. In either case, a sufficient rise in the rotational speed cannot be anticipated, and the program flow advances to step 7 (ST7).

[0040] In step 7 (ST7), the crankshaft is driven in the normal direction in an intermittent manner as a preliminary normal drive as indicated by arrow C in Figures 10 and 11, as opposed to step 3 (ST3). In this case, as long as a necessary measure is taken so as to prevent the crankshaft from rotating beyond the top dead center from the compression stroke and to place the crankshaft in a point in the compression stroke before starting the reverse cranking action, the preliminary normal cranking may be performed continuously instead of being performed an intermittent manner.

[0041] In step 8 (ST8), it is determined if the compression start position θp in the compression stroke has been reached as shown in Figures 10 and 11, in a similar manner as in step 4 (ST4). In other words, based upon the commutating position signal from the Hall devices 13, the compression start position θp may be defined as a position at which the crankshaft is pushed back in the reverse direction by more than a prescribed angle (20 degrees, for instance) during a power off interval of the electric motor a prescribed number of times (which may be once or more), or at a position at which the crankshaft fails to rotate in the normal direction by more than a prescribed angle (20 degrees, for instance) during a power on interval of the electric motor a prescribed number of times (which may be once or more). Once the compression start position θp has been detected, the program flow advances to step 9 (ST9) where this position is set as a provisional compression start position θp in a similar manner as in step 5 (ST5) before the program flow advances to step 10. In this case also, if the absolute angular position of the crankshaft and the current stroke are known or an angle sensor provides such information, it is possible to terminate the normal drive when it is actually detected that the angular position of the crankshaft has reached the compression start position θp.

[0042] A swing cranking action is started in step 10 (ST10). When the compression start position θp has been detected, the engine is stationary at a point inside the compression stroke as shown in Figures 10 and 11. As the starter switch ST is turned on, the electric motor

1 is continually supplied with electric current so as to drive the engine from this stationary position in the reverse direction (Figure 12). During this reverse rotation, upon detecting the passage of the reluctor 8 in the exhaust stroke as a pulser output signal as shown in Figures 10 and 11, the detected position is set as an angle computing reference position θ2 which serves as the final reference for determining the angular position, instead of the provisional compression start position θp. This angular position can be used as a reference in determining the absolute angle for timing control in cranking, ignition and fuel injection controls.

[0043] The proper compression start position θe when reversing the expansion stroke can be obtained by using the angle computing reference position θ2 as a reference. When this proper compression start position θe is reached, the supply of electric current to the electric motor 1 is terminated similarly as the case mentioned above, and the expansion stroke is reversed under the inertia. When the crankshaft has come to a stop during the expansion stroke (θ4) and started rotating back in the normal direction, electric current is then continually supplied to the electric motor 1 to drive it in the normal direction and crank the engine. By starting the normal drive only when the crankshaft has come to a stop due to the balancing of the inertia of the crankshaft with the compression pressure produced by the reversing of the expansion stroke, the power consumption can be reduced as compared to the case where the normal drive is started immediately after the termination of the reverse drive.

[0044] By so doing, even when the temperature is low, and the friction loss is significant due to viscous resistance, because the crankshaft is at first rotated in the normal direction into the compression stroke before rotating in the reverse direction, and a relatively long approach run distance can be ensured in addition to the continued supply of electric current to the electric motor when reversing the expansion stroke, the rotational speed of the crankshaft as it reverses the expansion stroke can be increased to a sufficient level. Furthermore, the spring back force due to the rise in the compression pressure when reversing the expansion stroke pushes back the piston, and the relatively long approach run distance in the normal direction helps the rotational speed to increase to a sufficient level. Therefore, a sufficient torque is produced for rotating the crankshaft in the normal direction beyond the top dead center of the compression stroke, and an electric motor having a relatively small rated output can successfully crank the engine even when the friction loss is significant.

[0045] For instance, when stopping the engine on a red signal or the like or in an idle stop situation, because the ignition switch IG remains on, and the absolute angle of the crankshaft is kept in memory, the re-starting control can be conducted in a favorable manner according to the stored angle computing reference position θ2. This angular position can be used for ignition and fuel injection controls during the startup and/or the normal operation.

[0046] In this case, the absolute angular position based upon the angle computing reference position θ2 can be used as an accurate absolute angular position. On the other hand, when the reference angle is obtained from the change in the rotational speed of the crankshaft 2 as its rotation is opposed by the compression stroke, the obtained reference value is treated as a provisional absolute value. However, this value does not substantially deviate from the true reference value, and it can be safely used for finding the optimum position for changing the rotational direction of the crankshaft in a swing cranking action making use of the compression pressure obtained by reversing the expansion stroke, for performing the ignition control and fuel ignition control during the cranking process.

[0047] Upon completion of the aforementioned preliminary action, when the engine is cut to prevent the engine from idling, or when the engine is cut for any reason, the engine may come to a stop at a position which is remote from the compression start position θe (θp) by more than a prescribed separation angle (20 degrees, for instance). In such a case, according to the present invention, a preliminary action is repeated so that a favorable cranking with an adequate approach run can be effected either with a normal rotation or reverse rotation cranking control.

[0048] The case of the engine coming to a stop at a position remote (for instance 20 degrees away) from the compression start position θe (θp) typically occurs when the spring back force of the compression pressure in the compression stroke or expansion stroke is excessive. Therefore, when conducting the preliminary action once more, it is preferable to set the power on period longer than that used for the preceding preliminary action. This allows the spring back force to be reduced, and the crankshaft to come to a stop near the expansion stroke or compression stroke.

[0049] It is preferable to change the power on period t1 and power off period t2 during the preliminary action in dependence on at least one of the battery voltage BT and engine temperature TE. For instance, the power on period t1 may be extended while the power off period t2 is diminished when the battery voltage is low and/or when the engine temperature is low. Conversely, for instance, the power period t1 may be diminished while the power off period t2 is extended when the battery voltage is high and/or when the engine temperature is high. Thus, an optimum cranking control can be effected which adapts itself to changes in the engine cranking condition.

[0050] Following the detection of the compression start position during a preliminary action, if the crankshaft would not come to a stop within a prescribed angle (20 degrees, for instance), a regenerative braking may be applied to the electric motor 1 by turning on all of the drive devices (FETs) of the motor driver circuit 14 upon detecting the prescribed angle so that the crankshaft may be caused to come to a stop within a prescribed angle from the compression start position. This eliminates the need to repeat the preliminary cranking action over and over again.

[0051] A second embodiment of the present invention is described in the following. In the second embodiment, the ignition switch IG is turned on at first, and the starter switch ST is then turned on to crank the engine. At this time, as shown in Figure 15, as soon as the ignition switch IG is turned on, the electric motor 1 is rotated in the normal direction in an intermittent manner as a preliminary normal drive. The duration of each intermittent operation T1 may be 50 ms, for instance. In this case also, as long as a necessary measure is taken so as to prevent the crankshaft from rotating beyond the top dead center from the compression stroke and to have the crankshaft placed in a point in the compression stroke before starting the reverse cranking action, the preliminary normal cranking may be performed continuously instead of being performed an intermittent manner.

[0052] Once the ignition switch IG is turned on, the counting of the rotational angle of the crankshaft 2 (or the outer rotor 3) based on the commutating position signal of the brushless motor is enabled, and the actual counting is started upon receiving a reference signal which is described hereinafter. In the illustrated embodiment, the electric motor 1 consists of a three-phase bushless motor, and can serve as a rotational angle detecting means with the Hall devices 13 detecting the timing of the rise (L - H) and fall (L - H) of each phase U, V or W as shown in Figure 6. It can count the rotational angle by the increment of 10 degrees, for instance.

[0053] During this preliminary normal drive operation, the crankshaft 2 is turned to an angle which is immediately before the top dead center of a compression stroke of a four-stroke engine as shown in arrow A in Figures 13 and 14. Such a control action can be effected by noting the possibility of computing the rotational speed from the count of the rotational angle. When the rotational speed has dropped to zero during the non-drive period of the intermittent operation, it can be judged that the piston has risen to a point close to the top dead center, and the resulting rise in the compression pressure has resisted any further rise of the piston. The normal drive is therefore terminated at this point. The intermittent operation is conducted for the purpose that the crankshaft 2 can be rotated to a position substantially coinciding with a ignition timing reference position (a certain angle before the top dead center which is used for the ignition timing control) $\theta 1$ but not to the extent to reach the top dead center (by producing a torque that would not overcome the compression resistance).

[0054] Then, the starter switch ST is turned on to turn the electric motor 1 in the reverse direction (arrow B in Figures 13 and 14). At this time, the pulser 9 detects the passage of the reluctor 8 (ignition timing reference position $\theta 2$) during the exhaust stroke of the illustrated four-stroke engine, and produces a signal similar to that is produced at the ignition timing reference position $\theta 1$. The rotational angle is counted anew from this ignition timing reference position $\theta 2$. When this count has reached angle α, and a reverse drive terminate position $\theta 3$ defined within the expansion stroke is reached, the drive of the electric motor 1 in the reverse direction is terminated, and the normal drive of the electric motor 1 is started when a normal drive reversing position $\theta 4$ is reached at which the inertia force in the normal direction balances with the compression force that increases progressively as the expansion stroke is reversed, (arrow C in Figures 13 and 14). By thus starting the normal drive only when ($\theta 4$) the inertia force of the crankshaft has balanced with the compression pressure caused by the reversing of the expansion stroke, the power consumption can be reduced as compared to the case the normal drive is started immediately after the reverse drive has been terminated ($\theta 3$).

[0055] The reversing of the expansion stroke produces a rise in the compressive pressure which tends to push back the piston, and this produces an assist force for the normal rotation which, combine with the adequate approach distance that is ensure, contributes to the increase in the rotational speed in the normal direction. This provides an adequate torque for getting over the top dead center during the compression stroke in the normal direction, and allows the required output of the electric motor of the starter system to be minimized.

[0056] During the period of the first normal drive, when the crankshaft 2 has rotated in the normal direction far enough to detect the first edge of the reluctor 8 (as indicated by the imaginary line D in Figures 13 and 14), the same edge will be detected again when the crankshaft rotates in the reverse direction, and this causes a detection of an erroneous signal G as indicated by the imaginary lines in Figure 15. As a result, the erroneous detection signal G would be confused with the angle computing reference position signal $\theta 2$, and the reverse drive would be terminated at an erroneous reversing position $\theta 5$ (see Figure 13) which is separated from the ignition timing reference position $\theta 1$ by the angle α. Therefore, the crankshaft 2 would rotate in the normal direction after a small travel from the erroneous reversing position $\theta 5$ under the inertia as indicated by imaginary line arrow E in Figure 13, and the resulting absence of the assist force and reduction in the approach run distance for the normal drive (reduction by half) may prevent the increase in the rotational speed that is required for the crankshaft 2 to rotate beyond the top dead center.

[0057] On the other hand, according to the present invention, a prescribed angle in the reverse direction from the point at which the rotational angle of the electric motor 1 changes from the normal direction to the reverse direction is defined as a mask interval M for disregarding the signal detection by the pulser 9. The mask interval

M should be greater than the angle by which the reluctor 8 extends as detected by the pulser 9, but should be small enough to stay clear from the angle computing reference positional signal θ2, and may be an angle somewhat smaller than 360 degrees such as 200 degrees.

[0058] Another embodiment for preventing the pulser 9 from erroneously detecting the reluctor 8 in finding a reference point for the determination of an absolute angle is described in the following with reference to Figures 16 to 18. The pulser 9 of the engine starter system of the present invention produces a detection signal when passing the front edge and rear edge of the reluctor 8. The detection signal for the normal rotation includes a negative first reference pulse P1 that is produced as the front edge of the reluctor 8 passes, and a positive second reference pulse P2 that is produced as the rear edge of the reluctor 8 passes as shown in Figure 16. By integrating these pulses, a rectangular pulser output signal (pulser reluctor) corresponding to the position of the reluctor 8 can be produced. In the following control, no distinction is made between the positive and negative polarity of the reference pulses P1 and P2.

[0059] When detecting the passage of the reluctor 8 when the crankshaft is rotating in the reverse direction in the exhaust stroke during the cranking control, the second reference pulse P2 is first produced, and the first reference pulse P1 is then produced so that a pulser output signal similar to that mentioned above is produced as shown in Figure 17. This allows the detected angle computing reference positional signal θ2 to be judged as genuine. During the preliminary normal drive, if position θ1 is not reached, the second reference pulse P2 appearing first can be identified as the angle computing reference position signal θ2 for the reverse rotation.

[0060] On the other hand, when the crankshaft 2 has turned far enough to detect the first edge of the reluctor 8 during the first preliminary normal rotation, and the crankshaft starts rotating in the reverse direction from an intermediate point of the reluctor 8 as shown in Figure 18, the rise of the first reference pulse P1 would be detected during the first normal rotation, and the rise of the first reference pulse P2 would be detected again during the subsequent reverse rotation. Because the two references pulses are produced during the normal rotation and reverse rotation, respectively, the difference from the case of Figure 17 can be detected, and an erroneous detection can be avoided. The normal and reverse rotations can be distinguished by monitoring the order of appearance of the U, V and W phases as shown in Figure 5.

[0061] According to a modified method of avoiding an erroneous detection based on the identification of the rotational direction at the time of the generation of the reference pulse, because the rotational angle α is counted from the angle computing reference position θ2 to determine the rotational angle by which the reverse drive should be continued from the angle computing reference position θ2 on when the crankshaft is rotating in the reverse direction, the counting of the rotational angle may be limited to the time when the crankcase is rotating in the reverse direction. Therefore, if the crankshaft is rotating in the normal direction when the first reference pulse P1 is produced as shown in Figure 18, it may be identified as a pulse not corresponding to the angle computing reference position θ2 for counting the rotational angle so that an erroneous detection can be avoided.

[0062] Yet another embodiment for preventing the pulser 9 from erroneously detecting the reluctor 8 in finding a reference point for the determination of an absolute angle is described in the following with reference to Figure19. In this embodiment, the timing of the two reference pulses P1 and P2 is associated with the states of the U, V and W phases in advance to determine if the current state is normal or not. When the crankshaft is rotating in the normal direction, the state of the U, V and W phases is LLH when the first reference pulse P1 is produced at time T1, and LHL when the second reference pulse P2 is produced at T2. In other words, when such a state is detected, it can be judged that the crankshaft is rotating in the normal direction.

[0063] When detecting the passage of the reluctor 8 while the crankshaft is rotating in the reverse direction, as opposed to the above example, the state of the U, V and W phases is LHL when the second reference pulse P2 is produced at time T3 as indicated by the imaginary lines in Figure 19, and LLH when the first reference pulse P1 is produced at time T4 as indicated by the imaginary lines. In other words, it can be judged that the passage of the reluctor 8 has been detected while the crankshaft is rotating in the reverse direction.

[0064] The state of reversing the rotational direction shown in Figure 19 is produced when the first reference pulse P1 is produced during the first rotation in the normal direction, and the rotational direction is reversed before the second reference pulse P2 is produced. In this case, the state of the U, V and W phases when the first pulse P1 is produced at time T1 is LLH, and is then LLH when the first pulse P1 is produced at time T4 while the crankshaft 2 is rotating in the reverse direction as indicated by the imaginary lines. This change in the state does not correspond to either of the two states (normal/reverse rotation), and can be therefore judged to correspond to no normal state. This therefore prevents an erroneous detection.

[0065] However, if the state of any of the U, V and W phases changes while a reference pulse is being produced, it may become impossible to determine if the normal/reverse rotation has properly taken place. For instance, suppose the timing of the reference pulses P1 and P2 and the states of the U, V and W phases are associated with each other in such a manner that the state of the U phase changes during the time the first reference pulse P1 is produced, and the state of V phase changes during the time the second reference pulse P2 is produced. In other words, each cycle of the U, V and

W phases consists of 60 degrees while the width of the reluctor 8 corresponds to an angle of 50 degrees. Therefore, the state of the U, V and W phases is LLH when the first reference pulse P1 is produced at time T1, and is then LHH when the second pulse P2 is produced at time T2 when the crankshaft is rotating in the normal direction. Similarly, the state of the U, V and W phases is LLH when the second reference pulse P2 is produced at time T3, and is then HLH when the first pulse P1 is produced at time T4 when the crankshaft is rotating in the reverse direction. When the first edge of the reluctor 8 passes the pulser 9 during the normal rotation and after a change in the rotational direction again passes the pulser 9 during the reverse rotation, the state of the U, V and W phases is LLH at time T1, and is then HLH at time T4 . Therefore, if the crankshaft changes the direction of rotation when the pulser 9 is an intermediate point of the reluctor 8, it is not possible to distinguish whether the crankshaft is simply rotating in the normal direction or has changed the direction of rotation.

[0066] Such a problem can be avoided if the point of detecting each reference pulse is at least partly based on the falling edge of the pulse instead of the rising edge of the pulse. If the detection is based on the falling edge, the state of the U, V and W phases changes from HLH at time T4 to LLH at time T3 when the crankshaft is rotating in the normal direction, from LHH at time T2 to LLH at time T1 when the crankshaft is rotating in the reverse direction, and from HLH at time T4 to LLH at time T1 when the crankshaft has changed the direction of rotation. Therefore, the case of changing the direction of rotation cannot be distinguished from the case of a normal direction, but can be distinguished from the case of a reverse direction so that the possibility of confusing the ignition timing reference position θ1 with the angle computing reference position θ2 during the reverse rotation can be avoided.

[0067] Yet another embodiment for preventing the pulser 9 from erroneously detecting the reluctor 8 in finding a reference point for the determination of an absolute angle is described in the following with reference to Figure19. In this embodiment, the rotational direction is determined by monitoring the change in the state of the U, V and W phases. The state changes at the time of each rise or fall of each phase at an interval of 10 degrees, and the change in the state can be detected.

[0068] In the illustrated embodiment, as shown in Figure 21, the change in the state is monitored for each of the intervals Ta through Tg defined between each adjacent detection timing (at the interval of 10 degrees). Thus, as the crankshaft rotates in the normal direction, the state of the U, V and W phases changes in the order of LHH, LLH, HLH, HLL, HHL, LHL and LHH. This order reverses when the crankshaft rotates in the reverse direction. However, if the leading edge of the reluctor 8 passes the pulser 9 in the normal direction, and the crankshaft changes the rotational direction so that the leading edge of the reluctor 8 then passes the leading edge of the pulser 9 this time in the reverse direction, such an order disappears. For instance, if the change in the rotational direction occurs in the interval Td, the state of the U, V and W phases changes in the order of LHH, LLH, HLH, HLL, HLH, LLH and LHH, and it is therefore possible to distinguish the case of changing the rotational direction from the case of a revere rotation. In this case, because it is not necessary to consider the timing of the reference pulses P1 and P2, an erroneous detection can be avoided without regard to the timing relationship between the reference pulses and the commutating position pulses (changes in the state of the phases) or without requiring any accuracy in the positional relationship when assembling the corresponding parts.

[0069] The foregoing description was directed to a four-stroke engine, but the present invention is equally applicable to two-stroke engines also if a similar reluctor is additionally provided on the side of the bottom dead center.

[0070] Although the present invention has been described in terms of preferred embodiments thereof, it is obvious to a person skilled in the art that various alterations and modifications are possible without departing from the scope of the present invention which is set forth in the appended claims.

Claims

1. An engine starter system adapted to crank an engine first in a reverse direction, and finally in a normal direction with an electric motor that is connected to a crankshaft of an engine, comprising:

    an electric motor connected to said crankshaft;
    a sensor for detecting an angular position of said crankshaft; and
    a controller for controlling a supply of electric current to said electric motor according an output signal of said sensor;
    said controller being adapted to supply an electric current to said electric motor for a normal rotation prior to cranking said engine in the reverse direction at least under a prescribed condition.

2. An engine starter system according to claim 1, wherein said electric current is supplied to said electric motor in an intermittent manner.

3. An engine starter system according to claim 2, wherein a crankshaft angular position at which the intermittent supply of electric current to the electric motor is changed to the supply of electric current for the reverse cranking is determined as a position at which the crankshaft is pushed back in the reverse direction by more than a prescribed angle a

prescribed number of times during a power off period in the supply of electric current to the electric motor in an intermittent manner or as a position at which the crankshaft fails to rotate in the normal direction by more than a prescribed angle a prescribed number of times during a power on period in the supply of electric current to the electric motor in an intermittent manner.

4. An engine starter system according to claim 2, wherein a crankshaft angular position at which the supply of electric current to said electric motor in an intermittent manner is changed to that for said reverse cranking is determined as a position at which said crankshaft fails to rotate by more than a prescribed angle a prescribed number of times during a power on period in the supply of electric current to said electric motor in an intermittent manner.

5. An engine starter system according to claim 2, wherein a crankshaft angular position at which the intermittent supply of electric current to the electric motor for the normal cranking is changed to the supply of electric current to the electric motor for the reverse cranking may be predetermined.

6. An engine starter system according to claim 2, wherein said reverse drive is performed in an intermittent manner when said first cranking in the normal direction is not performed.

7. An engine starter system according to claim 2, further comprising a sensor for detecting at least one of a battery voltage and an engine temperature, and the supply of electric current to said electric motor in an intermittent manner is performed only when the output signal of said sensor indicates that at least one of said battery voltage and engine temperature falls below a prescribed value.

8. An engine starter system according to claim 2, wherein the supply of electric current to said electric motor in an intermittent manner is performed repeatedly until said crankshaft angular position reaches a prescribed position in an compression stroke.

9. An engine starter system according to claim 2, wherein a duty ratio of the supply of electric current in an intermittent manner is decreased when repeating the supply of electric current to said electric motor in an intermittent manner.

10. An engine starter system according to claim 2, wherein said reverse drive is started after an interval of regenerative braking when the supply of electric current to said electric motor in an intermittent manner is performed repeatedly.

11. An engine starter system according to claim 1, wherein said crankshaft angular position sensor comprises an absolute position sensor for detecting an absolute position of said crankshaft and a relative position sensor for detecting an angular positional change of said crankshaft at a higher resolution, detection of an absolute angle of said crankshaft at a high resolution being enabled by combining said sensors.

12. An engine starter system according to claim 11, wherein said absolute position sensor comprises an ignition timing sensor.

13. An engine starter system according to claim 11, wherein said electric motor comprises a brushless motor, and said relative position sensor comprises a commutating signal sensor of said brushless motor.

14. An engine starter system according to claim 12, wherein a crankshaft angular position at which said reverse cranking is taken over by said final normal cranking is determined according to an output of said relative position sensor using an output of said ignition timing sensor in an exhaust stroke of said engine as a reference.

15. An engine starter system according to claim 14, wherein an output of said ignition timing sensor is disregarded for a prescribed angle after said reverse cranking has started following the supply of electric current following said first normal drive.

16. An engine starter system according to claim 14, wherein said relative position sensor is adapted to detect a rotational direction, and an output of said ignition timing sensor during an exhaust stroke of the engine is identified to provide a reference for a timing of starting said final normal cranking according to a detected rotational angle and the output of said ignition timing sensor.

17. An engine starter system according to claim 14, wherein said relative position sensor is adapted to detect a rotational direction, and an output of said ignition timing sensor during an exhaust stroke of the engine is identified to provide a reference for a timing of starting said final normal cranking according to a point of change in the rotational direction.

Fig.1

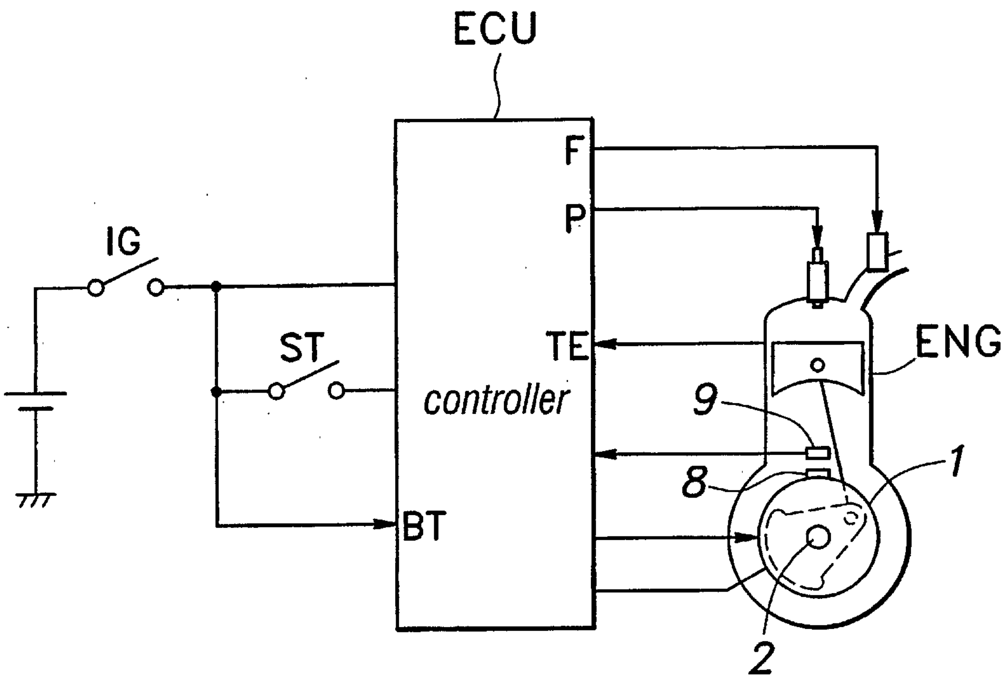

ECU
F
P
IG
TE
ENG
ST
controller
9
1
8
BT
2

Fig.5

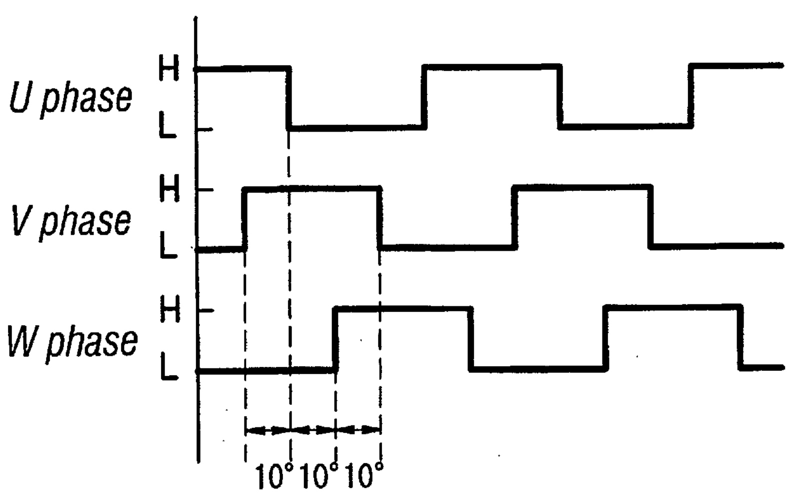

U phase
H
L
V phase
H
L
W phase
H
L
10°
10°
10°

Fig.2

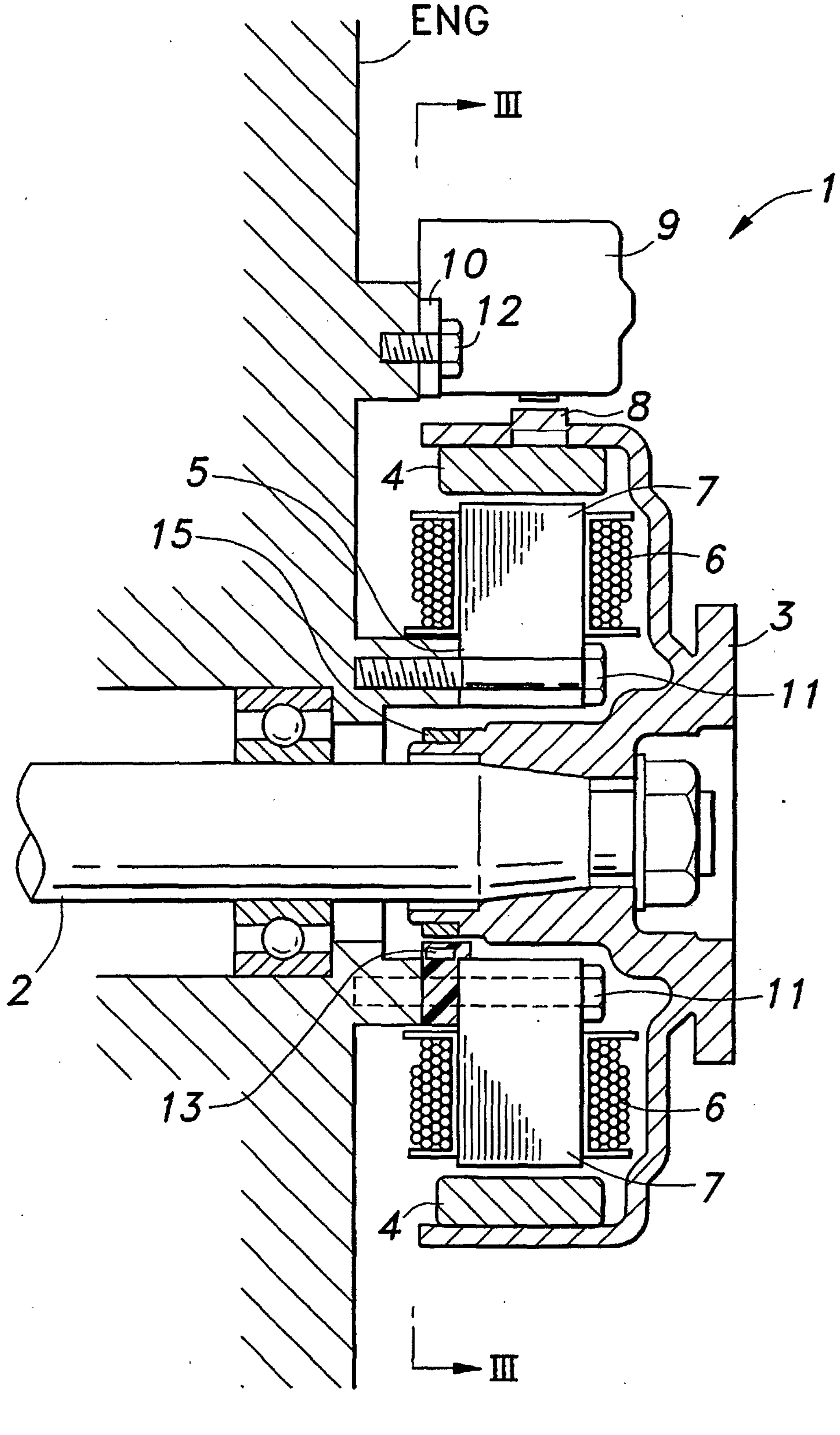


Fig.3

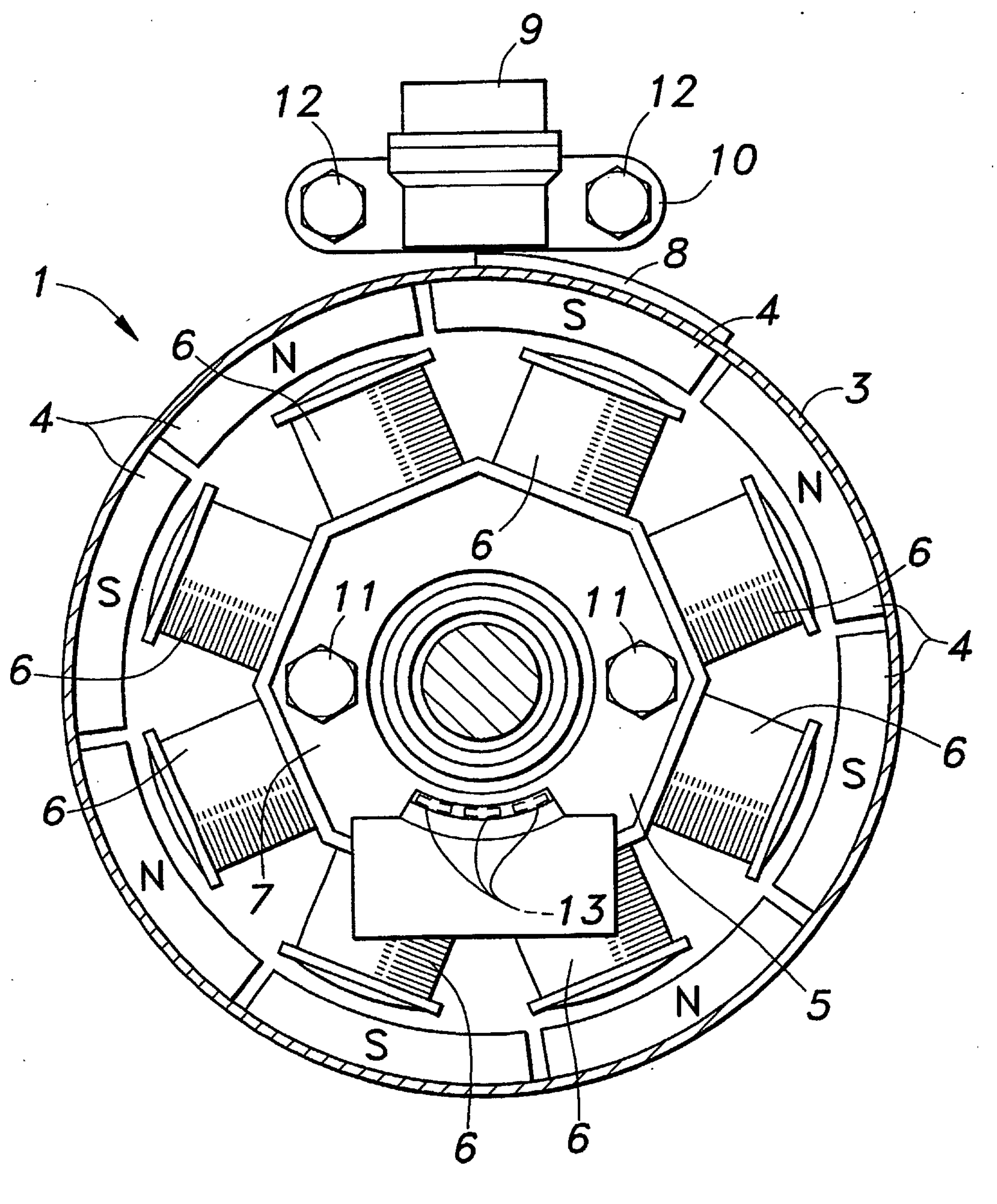


Fig.4

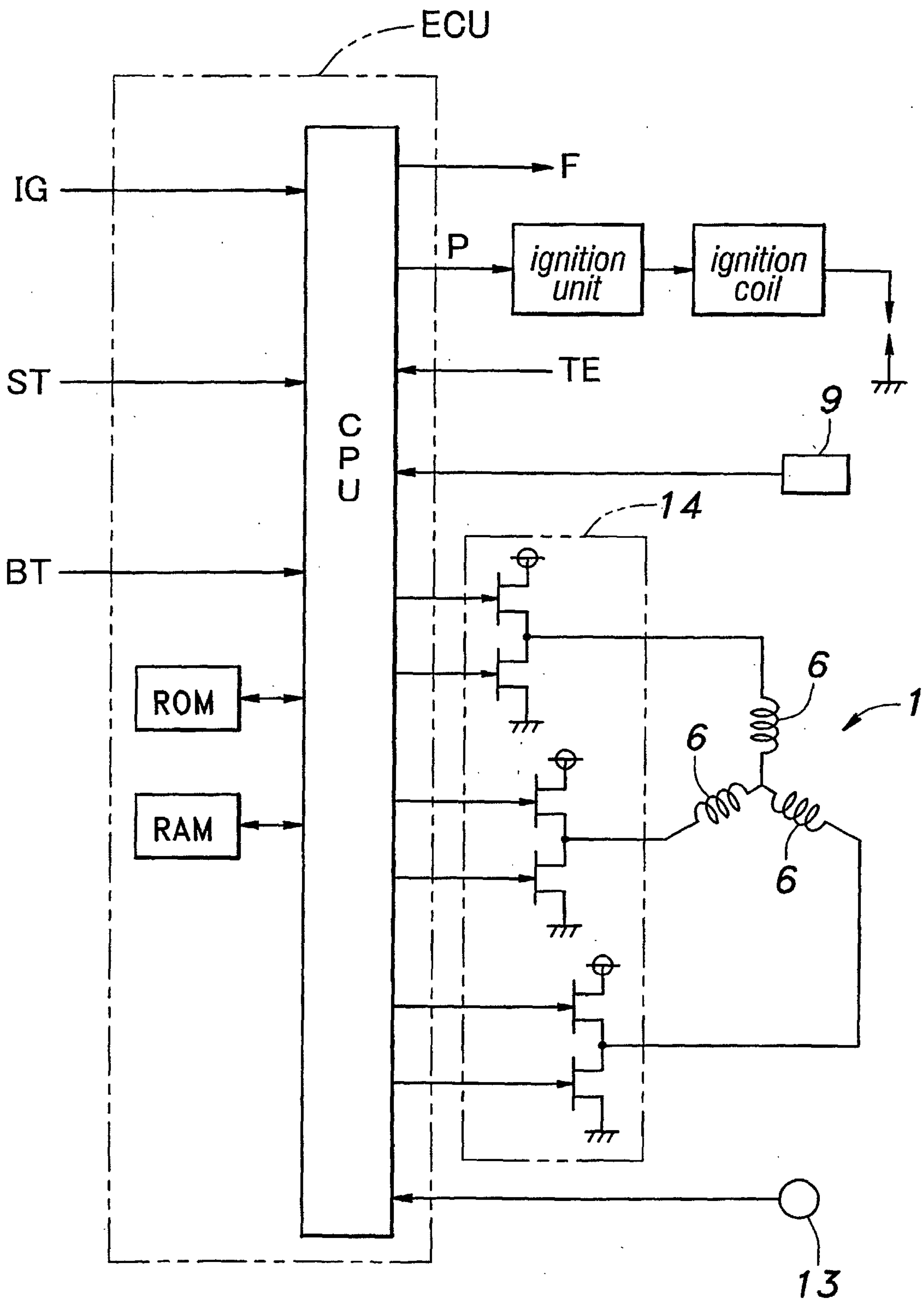

ECU
IG
ST
BT
F
P
ignition unit
ignition coil
TE
9
C P U
14
ROM
RAM
6
6
6
1
13

Fig.6

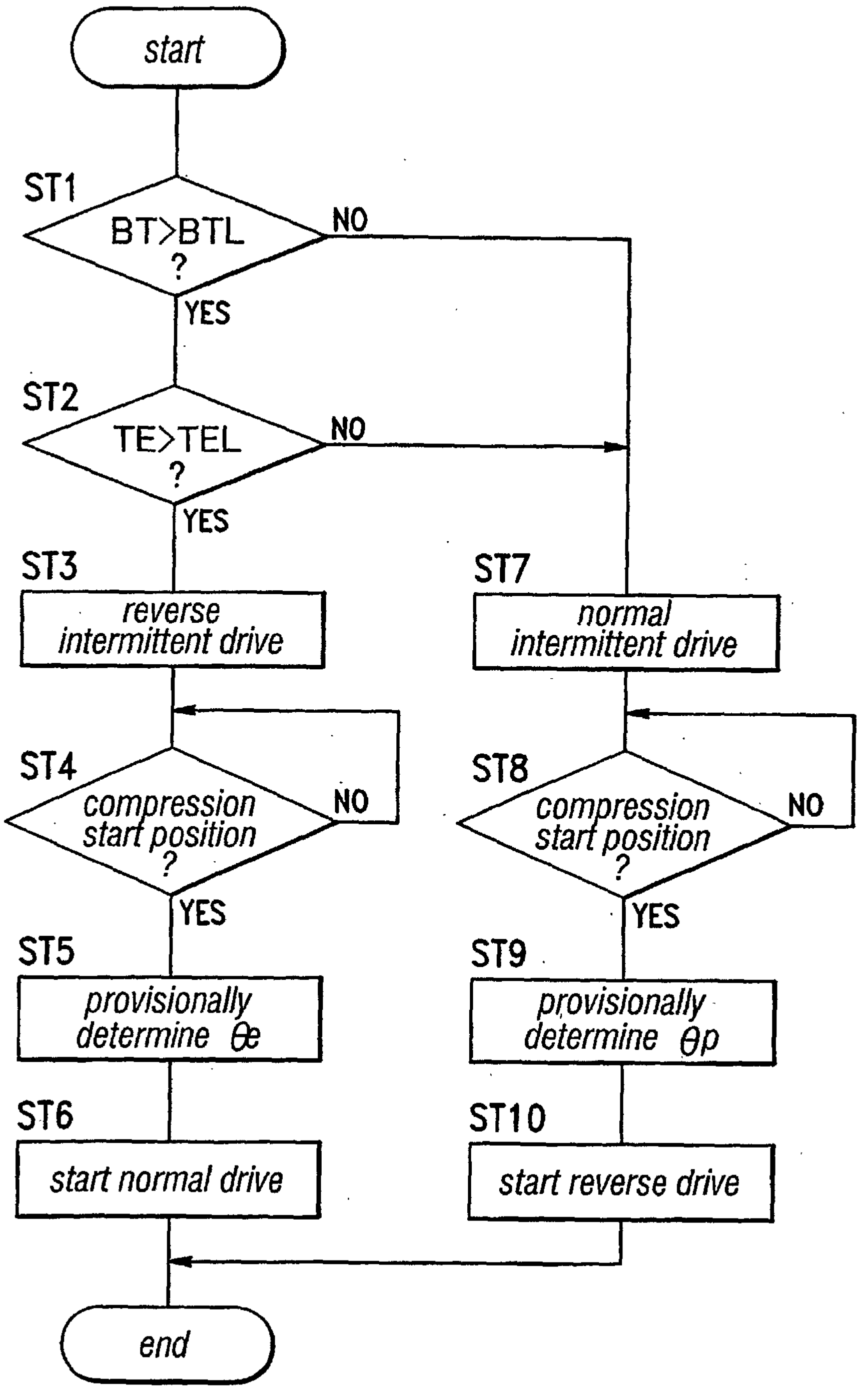

start
ST1
BT>BTL ?
NO
YES
ST2
TE>TEL ?
NO
YES
ST3
reverse intermittent drive
ST7
normal intermittent drive
ST4
compression start position ?
NO
YES
ST8
compression start position ?
NO
YES
ST5
provisionally determine θe
ST9
provisionally determine θp
ST6
start normal drive
ST10
start reverse drive
end

Fig.7

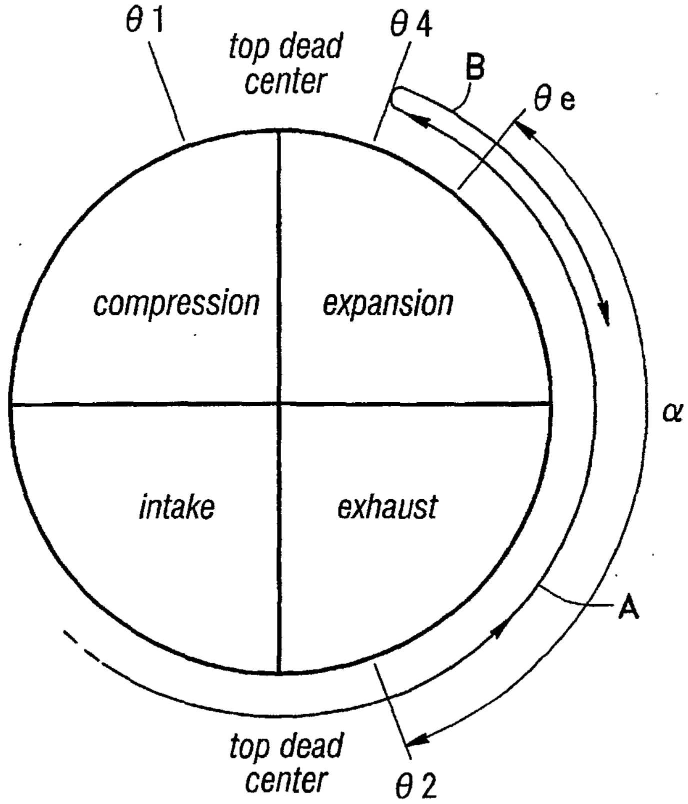

θ1
top dead center
θ4
B
θe
compression
expansion
intake
exhaust
α
A
top dead center
θ2

Fig.10

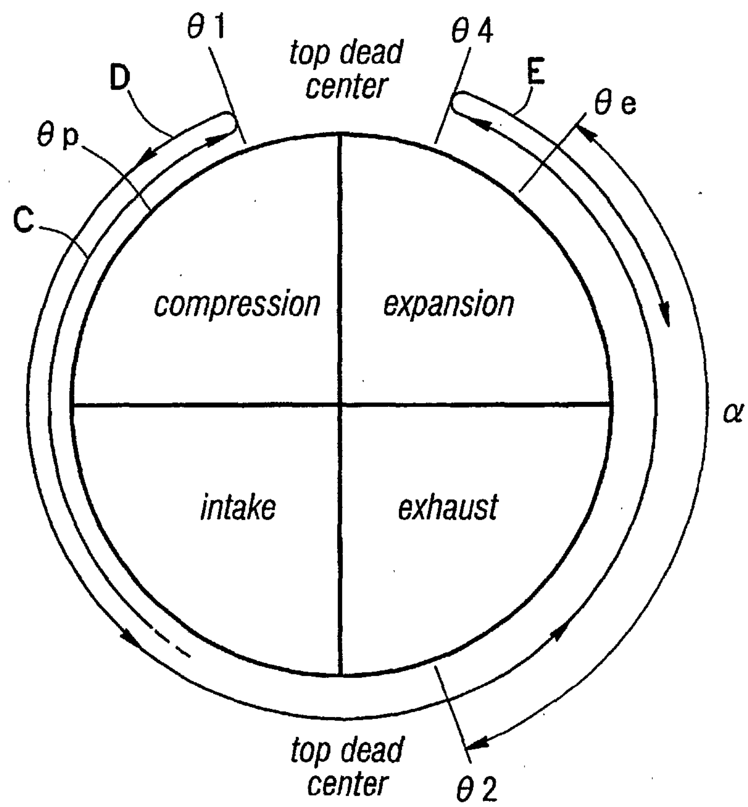

θ1
top dead center
θ4
D
E
θe
θp
C
compression
expansion
intake
exhaust
α
top dead center
θ2

Fig.8

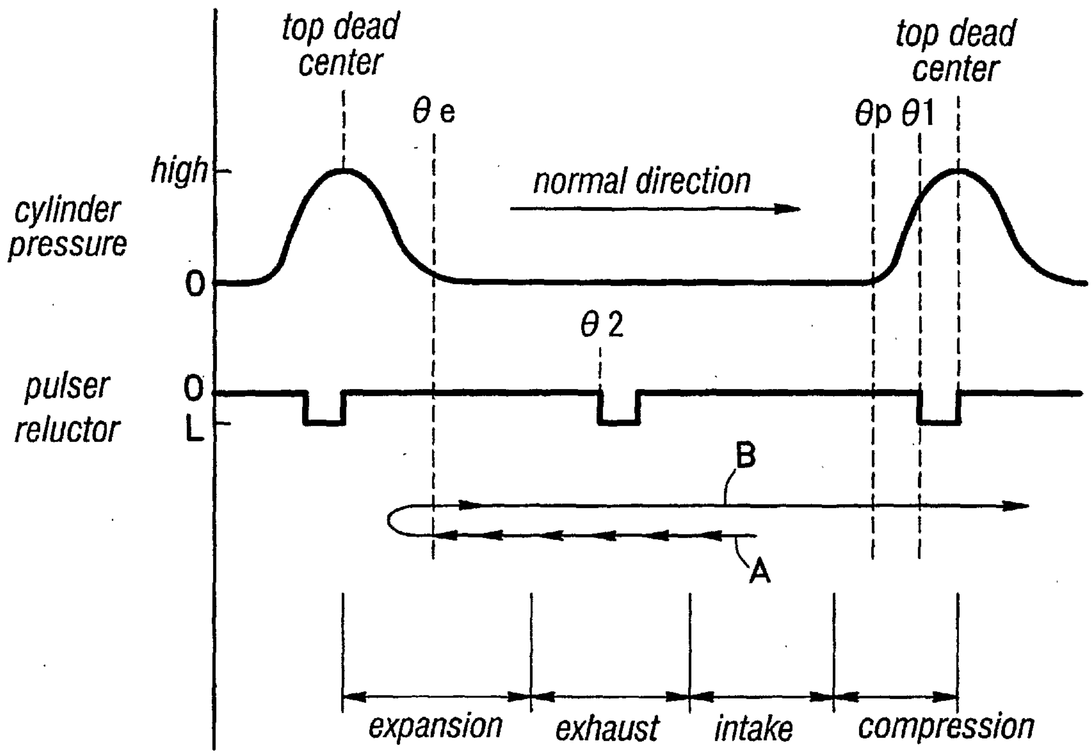

top dead center
θ e
top dead center
θp θ1
high
cylinder pressure
0
normal direction
θ 2
pulser reluctor
0
L
B
A
expansion
exhaust
intake
compression

Fig.9

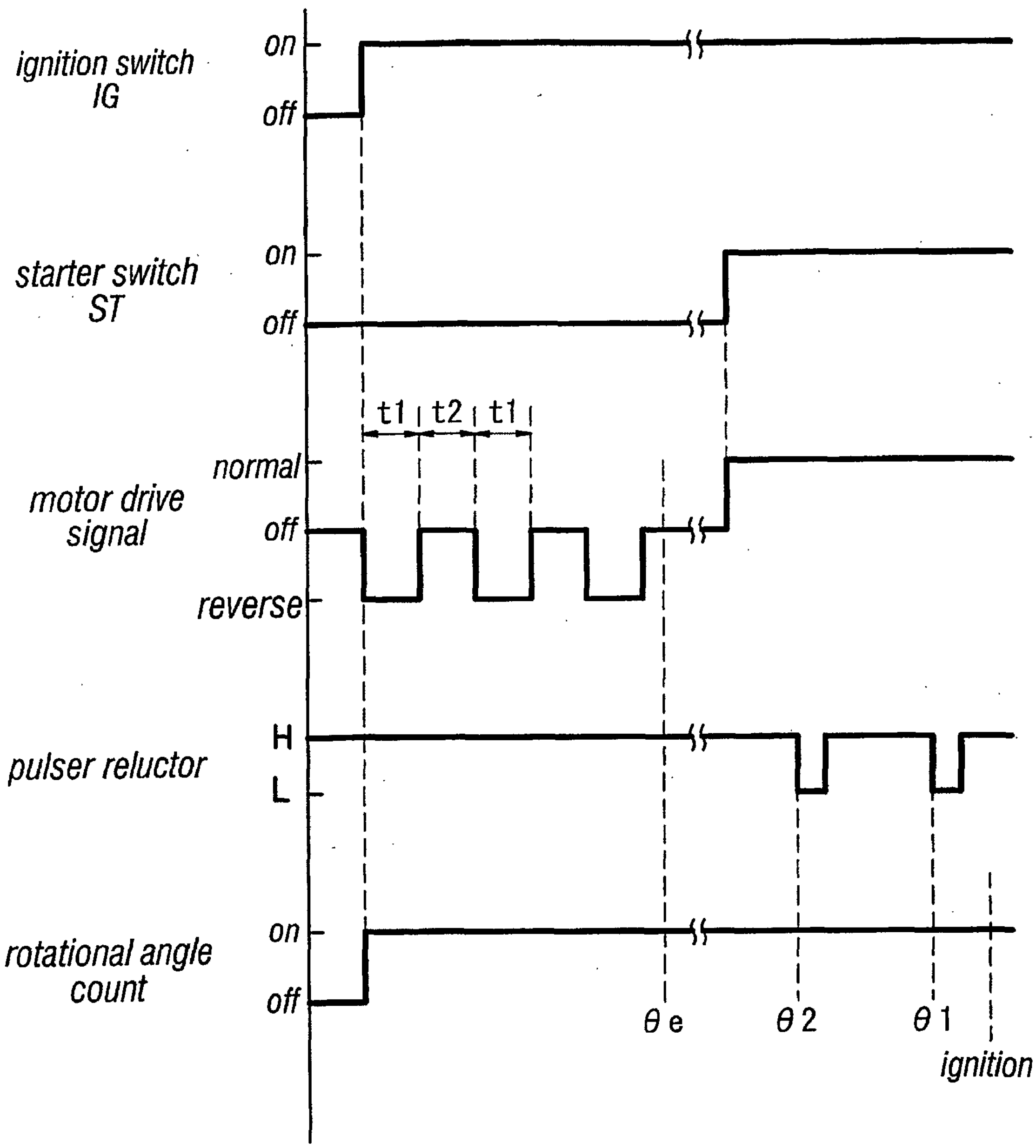

ignition switch
IG
on
off
starter switch
ST
on
off
t1
t2
t1
motor drive
signal
normal
off
reverse
pulser reluctor
H
L
rotational angle
count
on
off
θe
θ2
θ1
ignition

Fig.11

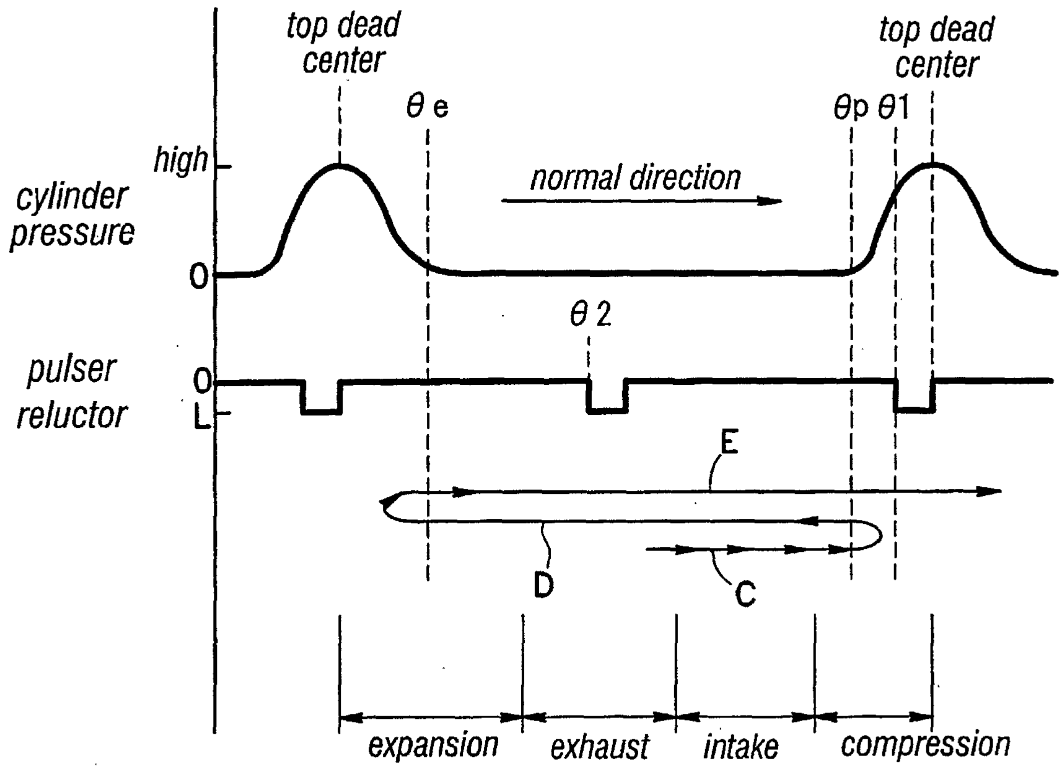

top dead center
θe
θp θ1
top dead center
high
cylinder pressure
0
normal direction
θ2
pulser reluctor
0
L
E
D
C
expansion
exhaust
intake
compression

Fig.14

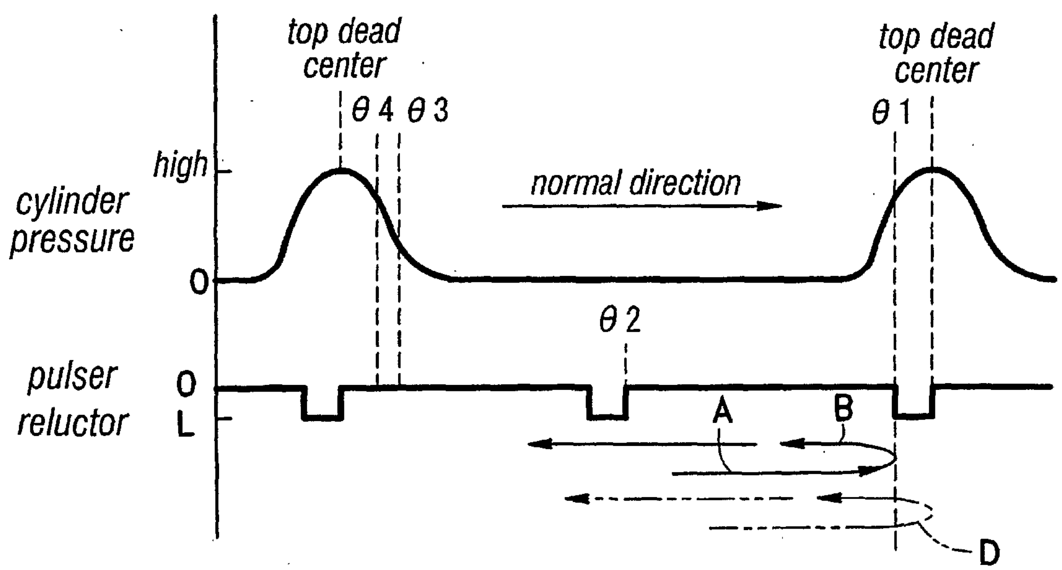

top dead center
θ4 θ3
top dead center
θ1
high
cylinder pressure
0
normal direction
θ2
pulser reluctor
0
L
A
B
D

Fig. 12

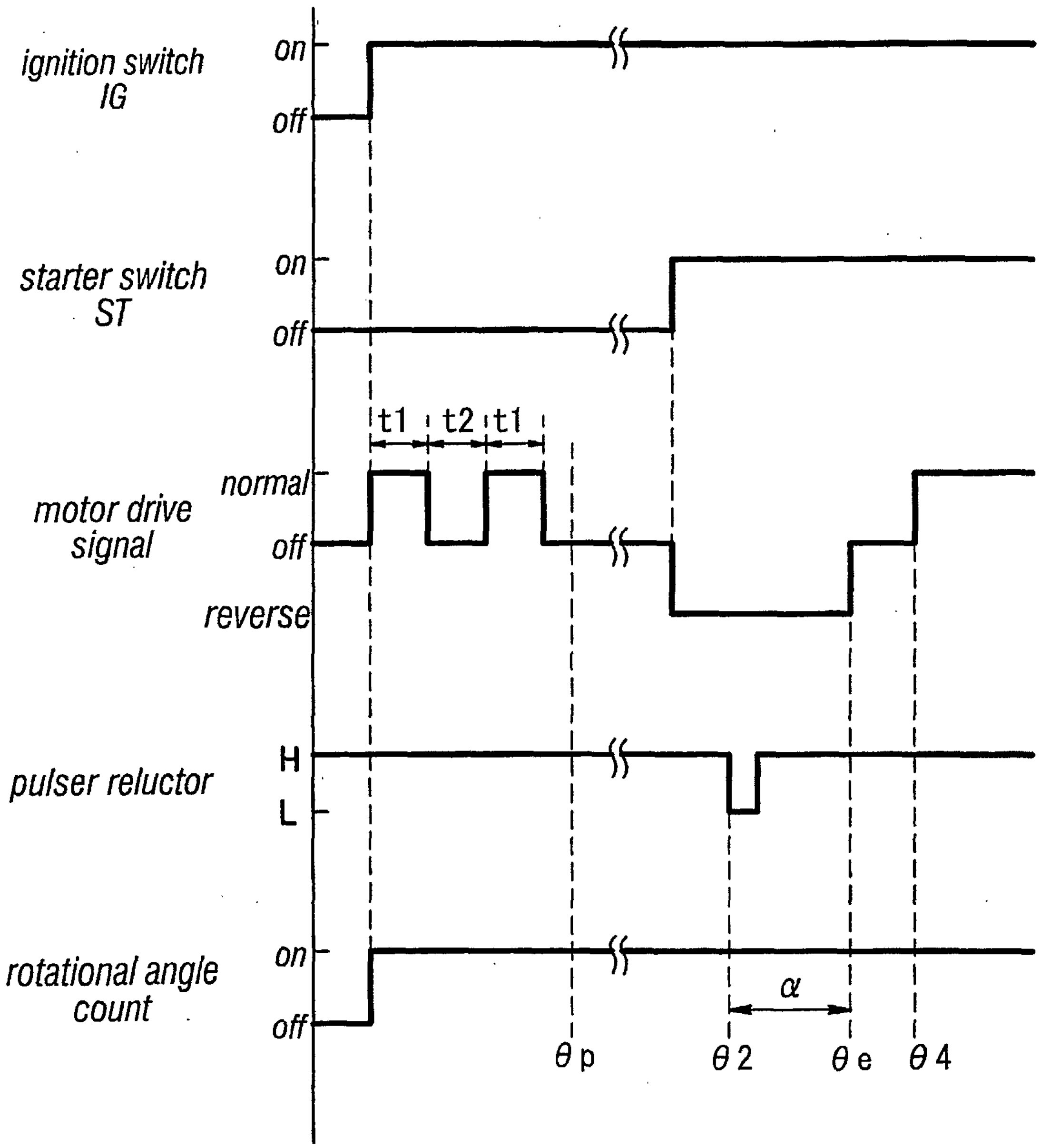

ignition switch IG
on
off
starter switch ST
on
off
t1
t2
t1
motor drive signal
normal
off
reverse
pulser reluctor
H
L
rotational angle count
on
off
α
θp
θ2
θe
θ4

Fig. 13

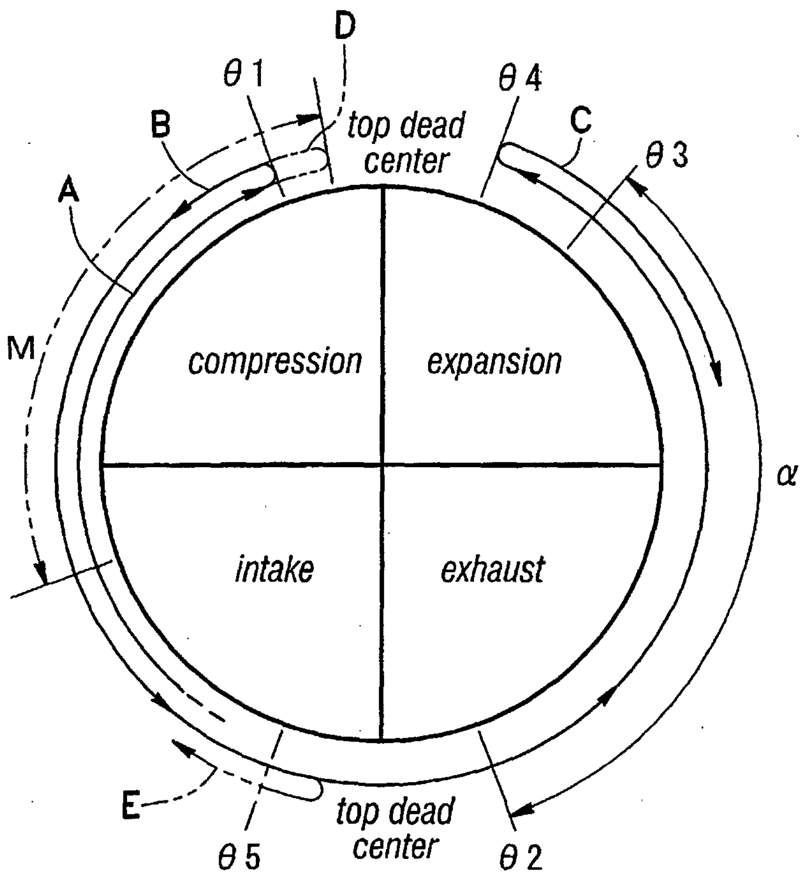

D
θ1
θ4
B
top dead center
C
θ3
A
M
compression
expansion
α
intake
exhaust
E
top dead center
θ5
θ2

Fig.15

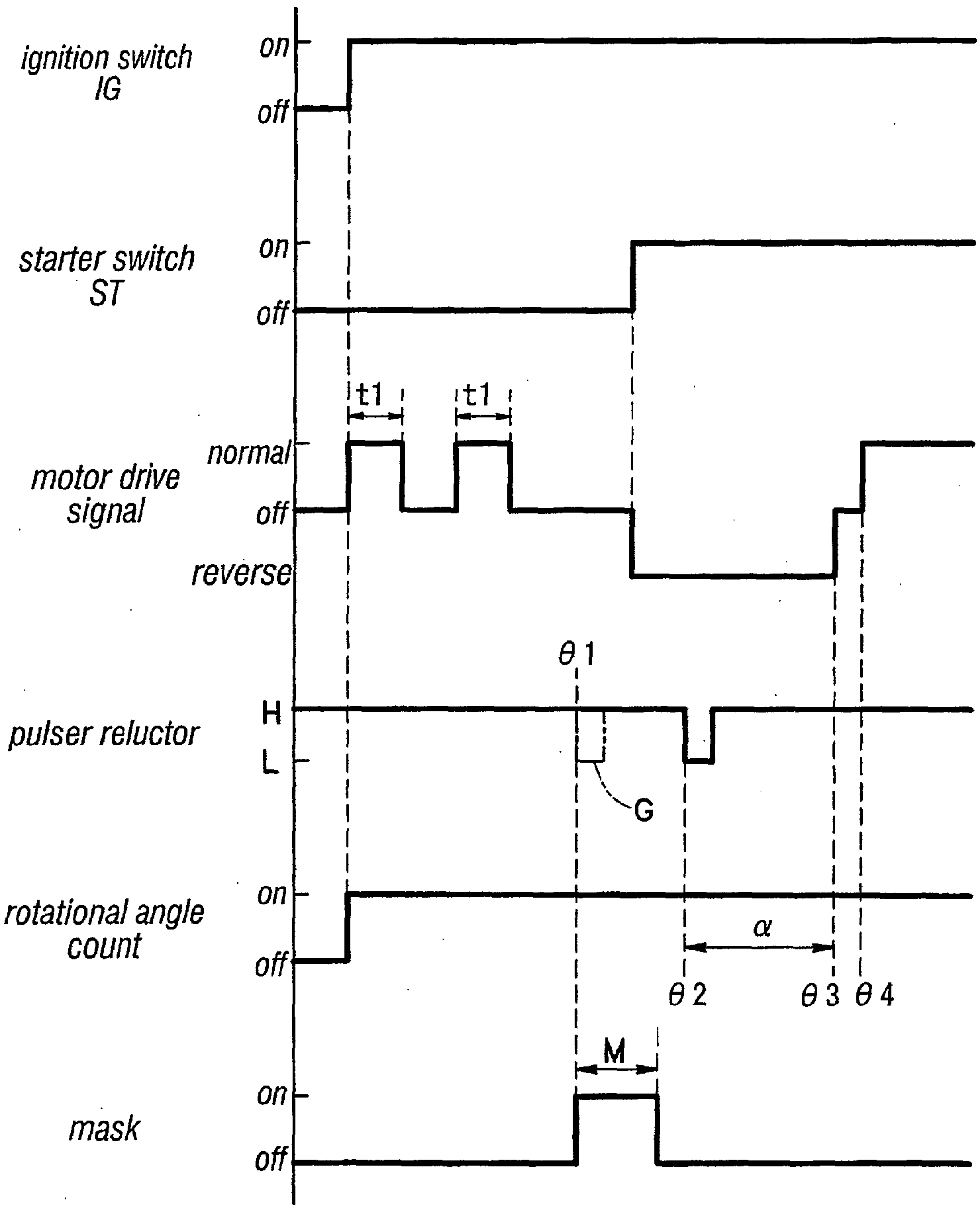

ignition switch IG
on
off
starter switch ST
on
off
t1
t1
motor drive signal
normal
off
reverse
θ1
pulser reluctor
H
L
G
rotational angle count
on
off
α
θ2
θ3
θ4
M
mask
on
off

Fig. 16

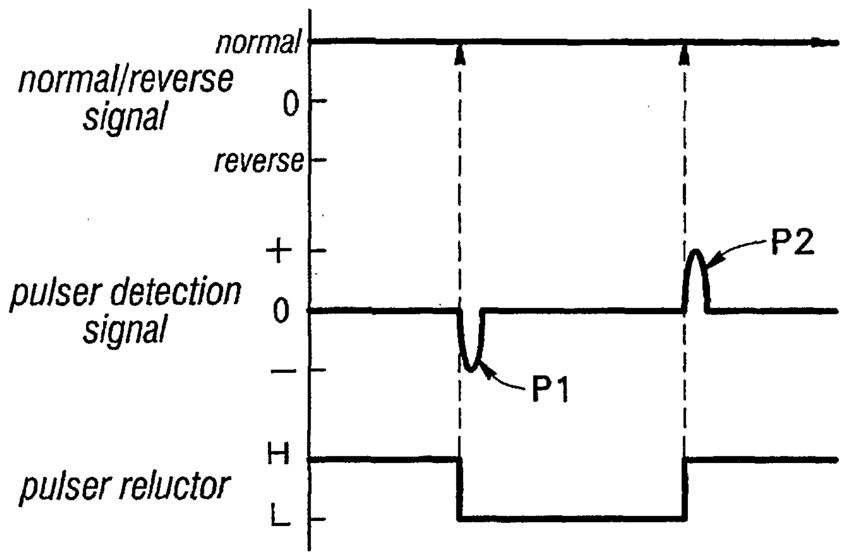


Fig. 17

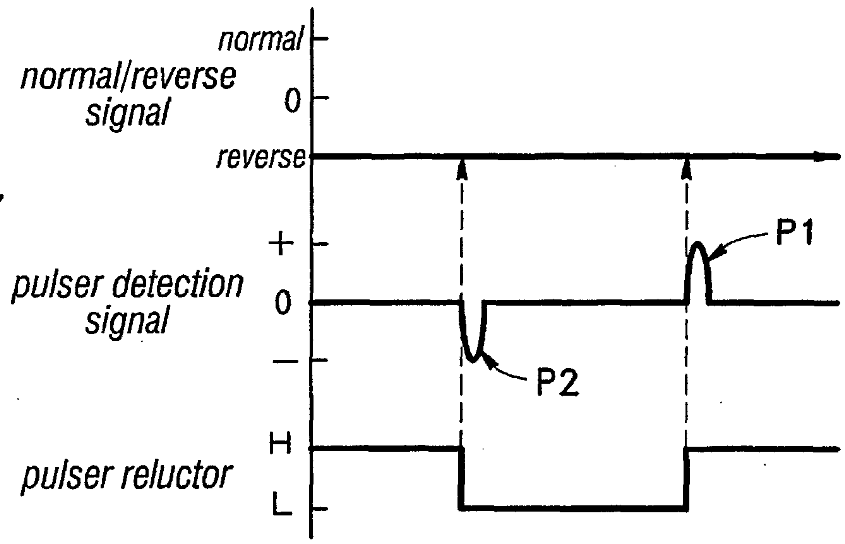


Fig. 18

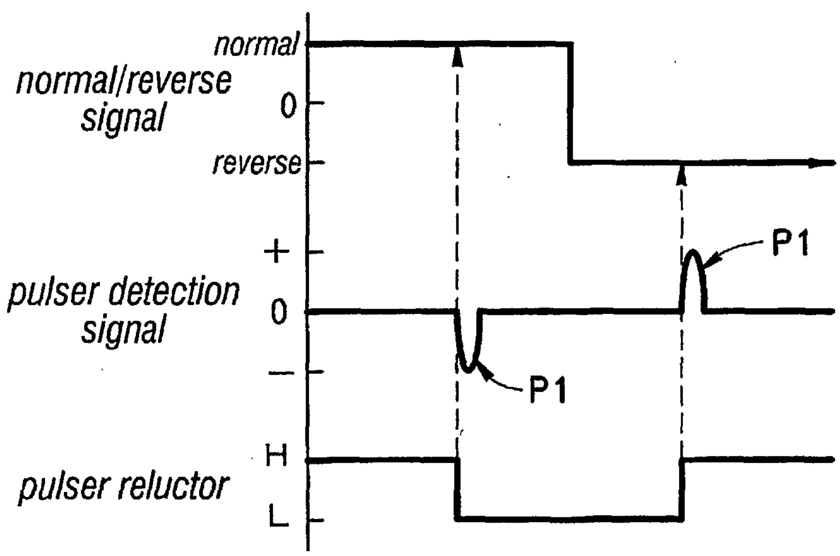


Fig. 19

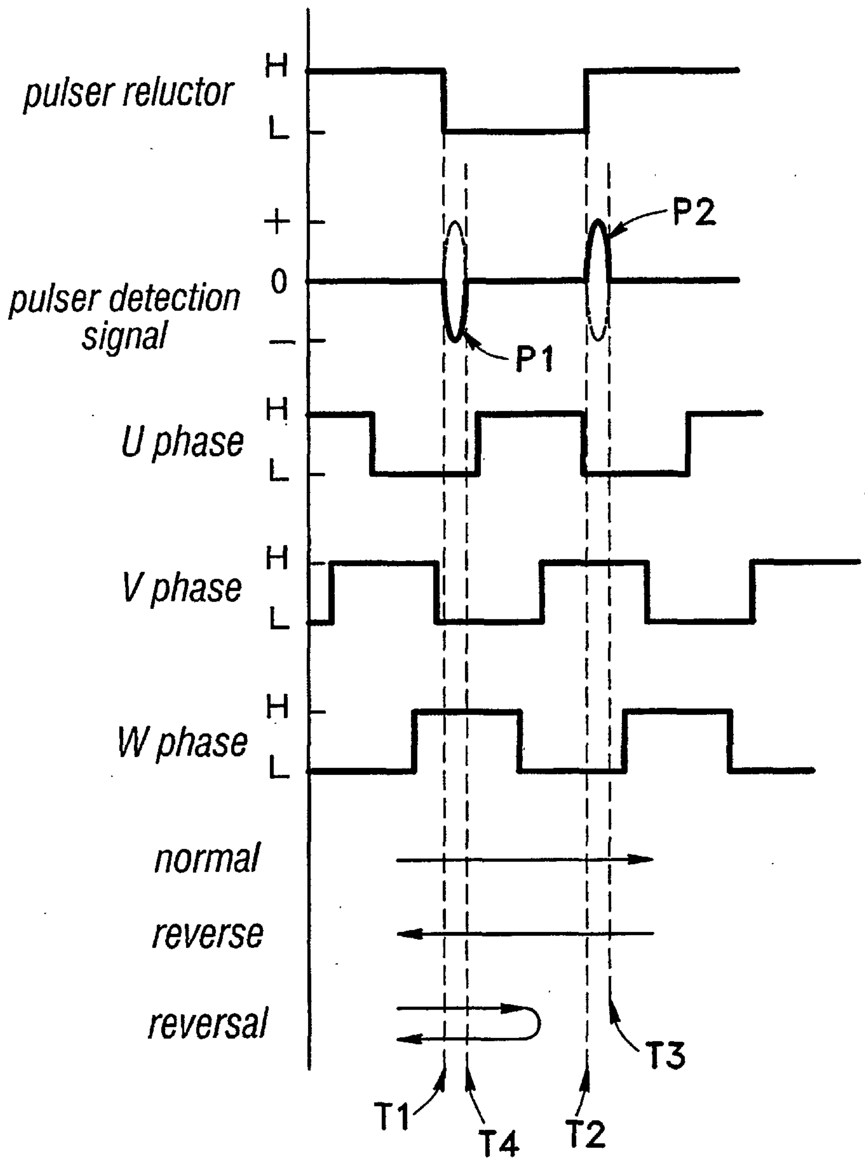

pulser reluctor
H
L
pulser detection signal
+
0
−
P1
P2
U phase
H
L
V phase
H
L
W phase
H
L
normal
reverse
reversal
T1
T4
T2
T3

Fig.20

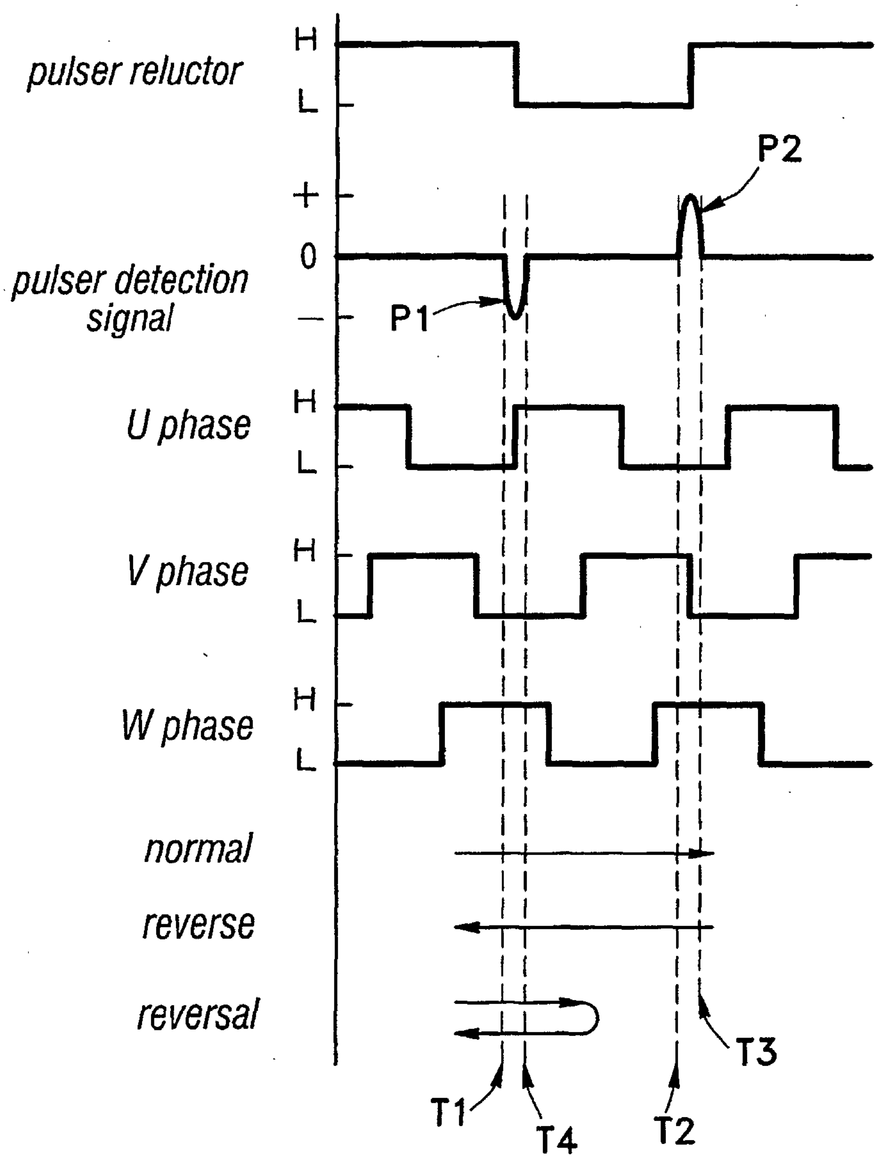
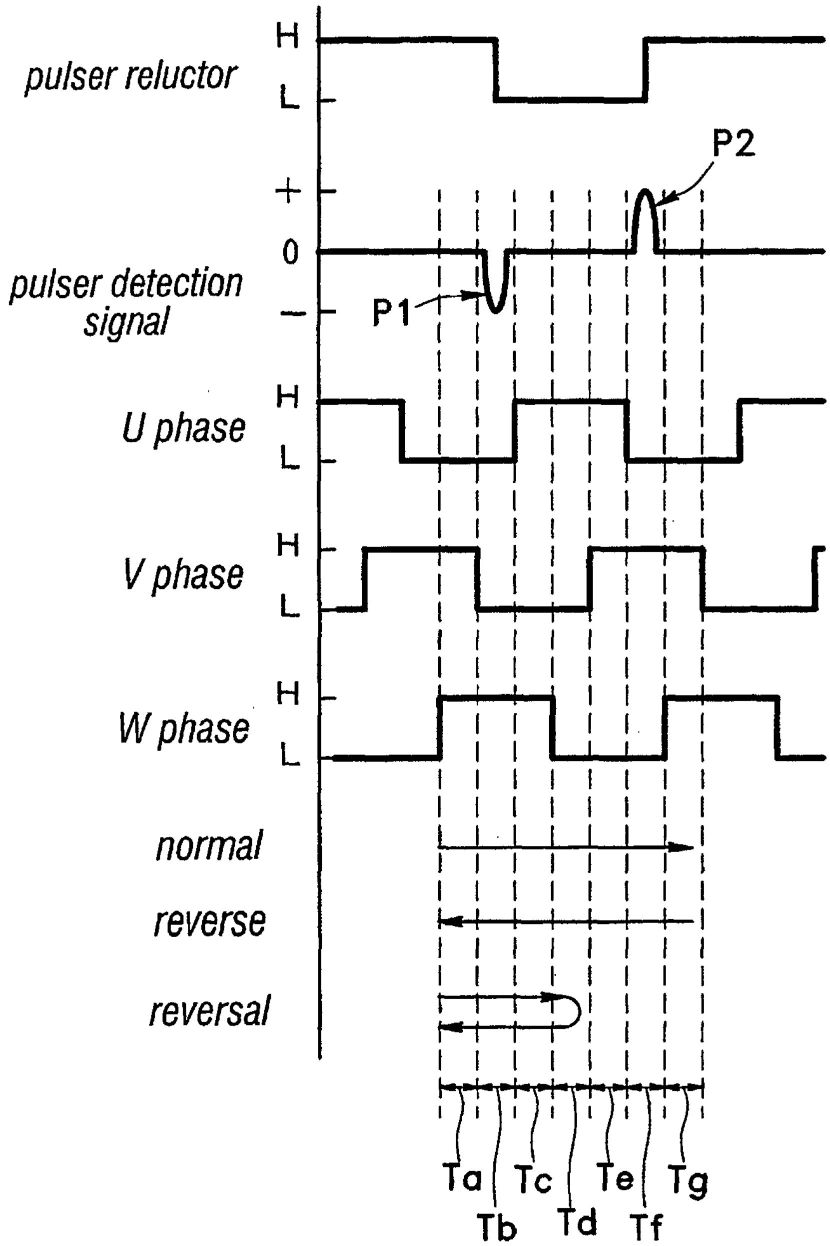

pulser reluctor
H
L
pulser detection signal
+
0
−
P1
P2
U phase
H
L
V phase
H
L
W phase
H
L
normal
reverse
reversal
T1
T4
T2
T3

Fig.21


pulser reluctor
H
L
P2
+
0
pulser detection signal
P1
−
U phase
H
L
V phase
H
L
W phase
H
L
normal
reverse
reversal
Ta
Tb
Tc
Td
Te
Tf
Tg

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/08518

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ F02N11/08

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)
Int.Cl⁷ F02N11/08, F02N17/08

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

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Kokai Jitsuyo Shinan Koho	1971-2001	Jitsuyo Shinan Toroku Koho	1996-2001

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.
X	JP 3-3969 A (Mazda Motor Corporation), 10 January, 1991 (10.01.91), Full text; Figs. 1 to 8 (Family: none)	1,2,6,8
A	JP 7-71350 A (Nippon Denso Co., Ltd.), 14 March, 1995 (14.03.95), Full text; Figs. 1 to 6 & DE 4430651 A & US 5458098 A	1-17
EA	JP 2000-283010 A (Honda Motor Co., Ltd.), 10 October, 2000 (10.10.00), Full text; Figs. 1 to 24 & CN 1269466 A	1-17
EA	JP 2000-303938 A (Honda Motor Co., Ltd.), 31 October, 2000 (31.10.00), Full text; Figs. 1 to 20 & EP 1046813 A & CN 1271813 A	1-17

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search 20 December, 2001 (20.12.01)	Date of mailing of the international search report 15 January, 2002 (15.01.02)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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