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

(11) EP 1 596 055 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 158(3) EPC

(43) Date of publication:
16.11.2005 Bulletin 2005/46

(21) Application number: **04706791.3**

(22) Date of filing: **30.01.2004**

(51) Int Cl.[7]: **F02D 41/20**, F02M 51/02

(86) International application number:
PCT/JP2004/000889

(87) International publication number:
WO 2004/070182 (19.08.2004 Gazette 2004/34)

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

(30) Priority: **03.02.2003 JP 2003026167**

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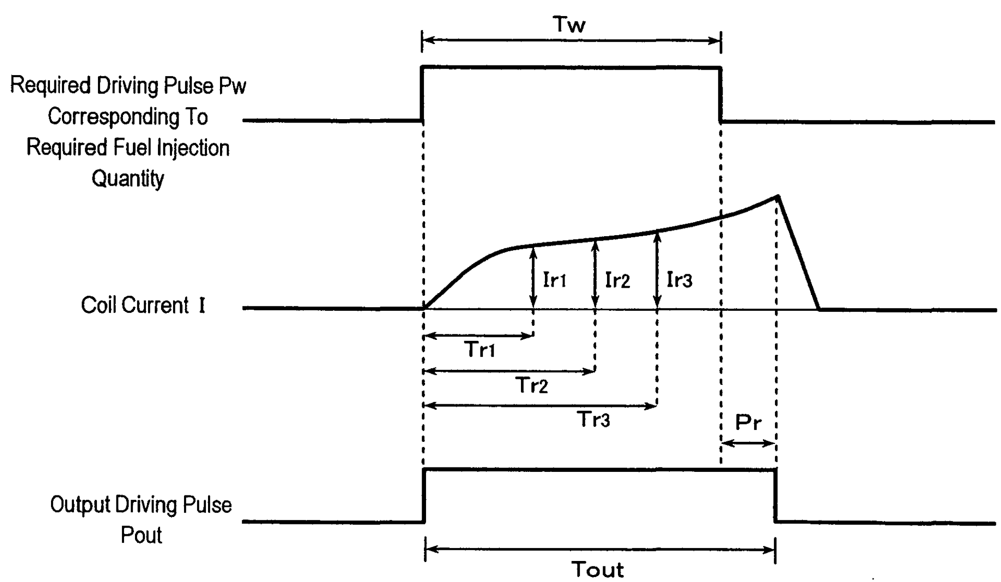
(54) METHOD AND DEVICE FOR FUEL INJECTION

(57) There are provided a fuel injection control method and control apparatus enabling a proper amount of fuel injection in response to a required fuel injection quantity from the engine side. A coil current passed through a fuel injection solenoid is measured at one or more points at each of which respective predetermined time has elapsed since the start of driving of the solenoid, and based on a measured value of the coil current, timing for halting the driving of the solenoid is corrected and adjusted. Correction values are determined in advance based on a value of the coil current and required fuel injection quantity for the solenoid or corresponding to various combinations of the value of the coil current and the required fuel injection quantity for the solenoid, and the correction is performed using the correction value selected corresponding to one of the combinations.

FIG.3



Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to an electronic fuel injection control method and control apparatus for supplying fuel to an engine, etc, and more particularly, to a fuel injection control method and control apparatus for injecting a required fuel injection quantity accurately while eliminating effects of variations in coil resistance of a fuel injection solenoid caused by variations in power supply voltage and temperature, etc.

Background Art

[0002] With respect to an internal combustion such as an engine of a vehicle including a two-wheeled vehicle, it is extremely an important factor that affects the performance of the internal combustion to supply a required fuel injection quantity varying every instance appropriately at proper timing. Therefore, conventionally, the fuel injection time in starting an engine is corrected corresponding to inlet air temperature of the engine and battery voltage (JP S58-28537).

[0003] FIG.18 illustrates a specific example of a control circuit of such a conventional fuel injection apparatus that detects the power supply voltage. In this example, a fuel injection quantity per unit time injected from the fuel injection apparatus varies due to variations in power supply voltage (battery voltage), in view of which, the fuel injection time is adjusted using a level of the power supply voltage. In other words, the power supply voltage V_B applied to a power supply terminal 11 is input to a microcomputer 13 of ECU (Electronic Control Unit) via a power supply voltage input circuit 12. When the power supply voltage V_B is low, the microcomputer 13 outputs a driving pulse with a longer ON time of a FET 14 to a FET driving circuit 15 so as to adjust the driving time (fuel injection time) of a fuel injection solenoid 16 to be longer. Meanwhile, when the power supply voltage V_B is high, the microcomputer 13 outputs a driving pulse with a shorter ON time of the FET 14 to the FET driving circuit 15 so as to adjust the driving time of the fuel injection solenoid 16 to be shorter. In this way, the fuel injection quantity is controlled so that a required proper quantity of fuel is supplied without being affected by variations in power supply voltage.

[0004] Further, stabilization is performed conventionally on driving current of the fuel injection solenoid. FIG. 19 is a view for illustrating a control circuit of a fuel injection apparatus of a conventional type of performing constant current control. In this circuit, the power supply voltage V_B applied to the power supply terminal 11 is detected in a power supply voltage detecting circuit 21, while the coil current is detected in resistance 22 and a current detecting circuit 23 provided for current detection. Then, the microcomputer 13 and constant current driving circuit 24 control so that the coil current does not vary with variations in power supply voltage V_B.

[0005] A method is further performed for detecting a fuel temperature corresponding to a temperature of an electromagnetic coil, setting a correction pulse width for correcting an operation delay time of a fuel injection valve based on the fuel temperature and battery voltage, and using a value of the sum of an effective injection pulse width corresponding to a fuel quantity to supply to an engine and the correction pulse width as a final injection pulse width (JP H08-4575).

[0006] Further, an idling control apparatus of an internal combustion is also known which is not to adjust a fuel injection quantity to the internal combustion, but to stabilize rotation speed at idling operation of the internal combustion, detects an operation state of the internal combustion, provides a control signal to an opening area adjustment apparatus of a bypass passage that bypasses a throttle valve to feed air to the internal combustion to detect an actual driving current of the opening area adjustment apparatus, calculates a correction amount of the control signal subsequent to startup of the opening area adjustment apparatus based on the detection result of the actual driving current, and using the correction amount, corrects a control signal that is calculated in advance before the startup (JP H09-126023).

[0007] However, for example, in the control method of correcting the fuel injection time based on the power supply voltage as shown in FIG.18, when the temperature of the coil constituting the solenoid 16 increases, the resistance of the coil varies, the coil current thus varies even when the power supply voltage V_B is the same, and it is difficult to supply a required fuel injection quantity accurately. This is because a fuel injection quantity per unit time of the solenoid 16 varies with the coil current value.

[0008] Therefore, as shown in FIG.19, it is considered driving the solenoid 16 with constant current. However, operation characteristics including the operation start time of the solenoid 16 vary largely with temperature, thereby leading to increases in complexity in control circuit and software processing, and the cost is thus increased. Further, since the solenoid driving current has characteristics of rising gradually by its selfinductance after starting the driving, stabilizing the solenoid driving current simply means a limitation of the driving current (setting of a maximum current value).

[0009] Meanwhile, in the driving control apparatus of an engine fuel injection valve disclosed in JP H08-4575, the temperature of the electromagnetic coil whose fuel injection characteristics vary with temperature does not agree with the fuel temperature always, and it is necessary to place a driving control apparatus of the engine fuel injection valve inside a fuel tank with a limited capacity to detect the fuel temperature, resulting in a problem of decreasing the fuel storage capacity of the fuel tank corresponding to such placement.

[0010] Further, the control apparatus as disclosed in JP H09-126023 adjusts an air amount to supply to the internal combustion to stabilize the idling rotation speed of the internal combustion to predetermined speed to prevent hunting, falling or stall in the number of idling rotations, and to adjust a fuel supply quantity varying every instant from the internal combustion side, requires a regulator or the like to adjust a fuel supply quantity independently of the opening area adjustment apparatus that adjusts the air amount, resulting in problems of increased complexity in the entire apparatus and increased cost.

[0011] Recently, the inventors of the present invention have developed a fuel injection system (hereinafter, referred to as an "electromagnetic fuel injection system") using an electromagnetic fuel injection pump that pressurizes and injects fuel, as distinct from the conventional type of fuel injection apparatus or fuel injection system that injects fuel pressurized and fed in/from a fuel pump or regulator.

[0012] This electromagnetic fuel injection system has a significant advantage of capable of implementing miniaturization and cost reduction as compared to the conventional type of fuel injection system, but a characteristic that an injection quantity is affected by a coil current for driving a fuel injection solenoid, and therefore, a problem that it is not possible to perform proper correction of the fuel injection quantity in response to a required quantity only by simply increasing/decreasing a driving pulse width based on the power supply voltage of the battery as described above.

[0013] The present invention aims to solve various issues of the conventional fuel injection control apparatuses and control methods as described above, and it is an object of the present invention to provide a fuel injection control method and control apparatus capable of adjusting a fuel injection quantity corresponding to a state of the fuel injection solenoid in response to a fuel injection quantity required from the engine side varying every instance.

Disclosure of Invention

[0014] In view of the issues of the conventional techniques of fuel injection apparatus and method, the present invention provides a fuel injection control method for measuring a coil current passed through a fuel injection solenoid at one or more points at each of which respective predetermined time has elapsed since the start of driving of the solenoid, and correcting and adjusting timing for halting the driving of the solenoid based on a measured value of the coil current.

[0015] Thus, in the present invention, since the timing for halting the driving of the solenoid is corrected and adjusted based on the measured value of the coil current that has a significant effect on an increase in temperature of the fuel injection solenoid, it is possible to perform fuel injection control to obtain a required proper quantity. The coil current is measured at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the fuel injection solenoid, thereby enabling recognition of transition of the coil current as well as an absolute value of the coil current at some point, and it is thus possible to perform fuel injection control in response to a required fuel injection quantity with more accuracy than in correcting the timing for halting the driving of the solenoid based on the measured value of the coil current at a single point.

[0016] The fuel injection control method according to the present invention has the steps of starting driving of a fuel injection solenoid, measuring a coil current passed through the solenoid at one or more points at each of which respective predetermined time has elapsed since the start of the driving of the solenoid, and obtaining a correction value to correct timing for halting the driving of the solenoid based on a measured value of the coil current.

[0017] The correction is performed using a correction value determined based on the measured value of the coil current and a required fuel injection quantity for the solenoid. Further, correction values are determined in advance corresponding to various combinations of the measured value of the coil current and the required fuel injection quantity for the solenoid, and a correction value selected corresponding to one of the combinations is used.

[0018] Further, the correction of the timing for halting the driving of the solenoid is comprised of the steps of obtaining a gradient correction value indicated by a ratio between an increase in the required fuel injection quantity and an increase in output driving pulse width of the solenoid, determined based on either or both of the measured value of the coil current and the required fuel injection quantity for the solenoid, further obtaining a corrected inoperative time elapsing until fuel injection is started after starting the driving of the solenoid where the inoperative time is determined corresponding to the measured value of the coil current, and calculating a correction value by adding the corrected inoperative time to a value of multiplication of a required driving pulse corresponding to the required fuel injection quantity by the gradient correction value, so as to adjust the timing for halting the solenoid using the correction value, thus enabling precise fuel injection control.

[0019] Furthermore, in the present invention, at the time of starting the engine or at the first driving time to resume once halted fuel injection, the power supply voltage to apply to the solenoid is measured, and based on the power supply voltage, the timing for halting the driving of the solenoid is corrected. Then, in next or subsequent driving cycle of the solenoid, a correction value to correct the timing for halting the driving of the solenoid is obtained based on the currently measured value of the coil current.

[0020] Moreover, the present invention provides a fuel injection control apparatus having means for driving a fuel injection solenoid, current measuring means for measuring a coil current passed through the solenoid at one or more points at each of which respective predetermined time has elapsed since the start of the driving of the solenoid, and control means for obtaining a correction value to correct timing for halting the driving of the solenoid based on a measured value of the coil current, and adjusting the timing for halting the driving of the solenoid using the correction value.

[0021] Herein, a feedback circuit may be provided to reuse energy released from the solenoid at the time of halting the driving of the solenoid, as energy for driving the solenoid. The feedback circuit includes a capacitor to charge the energy released from the solenoid at the time of halting the driving of the solenoid. It is thereby possible to reduce power consumption of the battery and further reduce the capacity of the battery.

[0022] The fuel injection control method and apparatus according to the present invention are to correct and adjust the timing for halting driving of the solenoid based on a measured value of the coil current that has a significant effect on an increase in temperature of the fuel injection solenoid, and thus enable fuel injection control with required proper quantity. Further, it is possible to recognize the transition of the coil current by measuring the coil current at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the fuel injection solenoid, thereby achieving fuel injection control that more accurately responds to a required fuel injection quantity.

Brief Description of Drawings

[0023]

FIG.1 shows an example of a configuration where a fuel injection control method and fuel injection control apparatus according to the present invention are applied to an electromagnetic fuel injection system;

FIG.2 shows an example of a control mechanism of a fuel injection control apparatus according to a first embodiment of the present invention;

FIG.3 shows a waveform chart of a waveform of each of a required driving pulse corresponding to a required fuel injection quantity, coil current and output driving pulse in an electromagnetic fuel injection system to which is applied a fuel injection control method according to the first embodiment;

FIG.4 is a conceptual view for illustrating a scheme of obtaining a pulse width of the output driving pulse in the first embodiment of the present invention;

Fig. 5 is a chart for conceptually illustrating a scheme of obtaining a correction value Pr of the output driving pulse of a solenoid;

FIG.6 shows the relationship between fuel flow rate Q and output driving pulse width Tout of the solenoid in a fuel injection control system according to a second embodiment of the present invention;

FIG.7 is a graph indicating injection quantity characteristics in a fuel injection apparatus;

FIG.8 is a characteristic chart showing an example of characteristics of corrected inoperative time in a fuel injection control method and fuel injection control apparatus in the second embodiment;

FIG.9 is a characteristic chart showing an example of characteristics of gradient correction value in the fuel injection control method and fuel injection control apparatus in the second embodiment;

FIG.10 is a conceptual view for illustrating a scheme of obtaining a corrected output driving pulse width Tout in the second embodiment of the present invention;

FIG.11 shows an example of a control mechanism of a fuel injection control apparatus including a power supply voltage detecting circuit according to a third embodiment of the present invention;

FIG.12 shows an example of correction processing control flow in the third embodiment of the present invention;

FIG.13 is a characteristic view schematically showing fuel injection characteristics in a fuel injection control method and the fuel injection control apparatus according to the third embodiment of the present invention;

FIG.14 shows a flowchart of processing procedures of a fuel injection control method according to a fourth embodiment of the present invention;

FIG. 15 shows a timing chart of software processing to detect a coil current in the fourth embodiment;

FIG.16 shows a timing chart of a case where detection timing is shifted in the software processing to detect a coil current in the fourth embodiment;

FIG.17 shows a waveform chart of a waveform of each of output driving pulse and coil current in the case where detection timing is shifted in the software processing to detect a coil current in the fourth embodiment;

FIG. 18 shows a first example of a control mechanism of a conventional fuel injection control apparatus; and

FIG.19 shows a second example of the control mechanism of the conventional fuel injection control apparatus.

Best Mode for Carrying Out the Invention

[0024] Embodiments of the present invention will be described specifically below with reference to accompanying drawings.

(1) First embodiment of the present invention

[0025] FIG.1 shows an example of an entire schematic configuration of a fuel injection system including a fuel injection control apparatus according to the present invention.

[0026] As shown in FIG.1, the electromagnetic fuel injection system has as its basic configuration a plunger pump 32 that is an electromagnetically driven pump which pressurizes and feeds fuel inside a fuel tank 31, an inlet orifice nozzle 33 having an orifice portion through which is passed the fuel with the predetermined pressure pressurized and fed in/from the plunger pump 32, an injection nozzle 34 that injects the fuel passed through the inlet orifice nozzle 33 with the pressure higher than a predetermined value to an intake passage (of an engine), and a control unit (ECU) 36 configured to output a control signal to the plunger pump 32 or the like based on operation information of the engine and on a coil current flowing through a solenoid (fuel injection solenoid in the present invention) of the plunger pump 32. The control means in the fuel injection control apparatus according to the present invention corresponds to the control unit 36.

[0027] FIG.2 is to explain a configuration of the fuel injection control apparatus according to the first embodiment of the present invention. In FIG.2, a fuel injection solenoid (hereinafter, referred to as a "solenoid" or "coil" as appropriate) 46 constitutes the plunger pump 32. The plunger pump 32 is driven by driving means composed of switching elements to drive the fuel injection solenoid 46 such as, for example, an N-channel FET 44, FET 48 and FET driving circuit 45.

[0028] The fuel injection apparatus according to the present invention is provided with a capacitor 50 and diode 42 to charge energy released from the solenoid 46 in halting driving of the solenoid 46. It is thereby possible to achieve both reductions in power consumption and capacity of a battery 41. This is because the energy stored in the solenoid 46 is reused as driving energy for the solenoid 46. Further, since the voltage higher than the power supply voltage (for example, 12V) is charged in the capacitor 50, the coil current rises steeply in starting driving of the solenoid 46, and there is obtained an advantage of reducing the operation start time (inoperative time) of the plunger pump 32.

[0029] As shown in FIG.2, the control apparatus is further provided with a current detecting circuit 6 that measures a coil current Ir passed through the solenoid 46 at one or more points at each of which respective predetermined time has elapsed since the start of driving of the fuel injection solenoid 46, and control means including driving driver and microcomputer 43 which obtain a correction value to correct timing for halting the driving of the solenoid 46 based on one or more measured values of the coil current, and based on the correction value, adjust the timing for halting the driving of the solenoid 46 in next and subsequent driving .

[0030] The power supply voltage (V_B) of the battery 41 is applied to one end of the solenoid 46 via a diode 57. The other end of the solenoid 46 is connected to the drain of the FET 44. As described above, the other end may be connected to the capacitor 50 to charge the energy released from the solenoid 46 via the diode 42.

[0031] To the gate of the FET 44 is supplied an output driving pulse based on an operation signal output from the microcomputer 43 via the FET driving circuit (driver circuit) 45. The ON/OFF operation of the FET 48 may be the same as in the FET 44, or the FET 48 may be ON prior to driving (ON of the FET 44) of the solenoid 46. The FET 48 is switched off before the FET 44 is switched off.

[0032] A source terminal of the FET 44 is grounded via resistance 52 for current detection. When the FET 44 becomes ON by the driving pulse, the power supply voltage is supplied to the solenoid 46 from the battery 41 and driving of the solenoid 46 is started. Then, the current passed through the solenoid 46 is measured in the current detecting circuit 6.

[0033] In the current detecting circuit 6, a voltage drop ("R_{52}" x "coil current value") generated between opposite terminals of current detection resistance 52 (low resistance) is amplified in an amplifying circuit composed of series resistance 7, feedback resistance 8 and operational amplifier 9 and output to an analog input terminal of the microcomputer 43.

The microcomputer 43 converts the input analog current value into a digital value to store in an internal memory. In the present invention, timing for halting driving of the solenoid 46 is corrected based on a measured value of the coil current stored in the memory in the control means, whereby fuel injection is carried out which suitably responds to a required fuel injection quantity.

[0034] In addition, the energy released from the solenoid 46 in halting driving of the solenoid 46 is charged in the capacitor 50 to reuse in FIG.2, but may be consumed in, for example, a sunaber circuit as shown in FIG.18 as in the conventional technique. Further, a configuration is available where the other end of the solenoid 46 is connected to the battery 41 via the diode 42 to charge the battery 41.

[0035] FIG.3 shows the mutual relationship between required driving pulse Pw of the solenoid 46 corresponding to required fuel injection quantity Qc, pulse width Tw of the required driving pulse Pw, driving time Tr until a measured value Ir of the coil current is detected after starting driving of the solenoid 46, and output driving pulse Pout actually output to the FET 44 for driving the solenoid 46. The coil current is measured at predetermined one or more points at each of which respective predetermined time has elapsed since the start of driving of the solenoid 46. In FIG.3, measured values of the coil current passed through the solenoid 46 after a lapse of Tr1, Tr2, Tr3...Trn since the time of starting driving of the solenoid 46 are indicated by Ir1, Ir2, Ir3...Irn, respectively.

[0036] In the present invention, with respect to the required driving pulse Pw, the correction value Pr of the required driving pulse Pw is obtained based on the coil current Ir (one or more measured values) obtained principally in the last driving (or before the last driving) of the solenoid during the time the solenoid 46 is actually driven, and based on the correction value Pr, adjustment is carried out such as an increase or decrease in driving time of the solenoid 46.

[0037] As shown in FIG.3, in the fuel injection control method, the output driving pulse Pout rises in synchronization with a rising edge of the required driving pulse Pw, the solenoid 46 is thereby driven, and the coil current I starts flowing. Then, at predetermined one or more points at each of which respective predetermined time, for example, 2ms, or 2ms, 4ms or 6ms has elapsed since the start of driving of the solenoid 46, measured values Ir (Ir1, Ir2 and Ir3) of the coil current are measured. After the driving of the solenoid 46 is halted, the measured values Ir (Ir of one point, or Ir1, Ir2 and Ir3 of three points) are read from the memory, and based on the measured values Ir of the coil current and the required fuel injection quantity Qc, the correction value Pr is obtained with respect to the required fuel injection quantity Qc. The required driving pulse width Tw corresponding to the required fuel injection quantity Qc is corrected based on the correction value Pr, and the output driving pulse Pout is supplied to the gate of the FET 44. In this way, appropriate adjustment of fuel injection quantity is carried out in the fuel injection apparatus where the fuel injection quantity is affected by the coil current for driving the fuel injection solenoid.

[0038] In the case where the correction value Pr is obtained based on a plurality of coil current values (Ir1, Ir2, Ir3...Irn) at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the solenoid 46, the correction value Pr is obtained from the Ir axis of n dimensions, or a first correction value Pr is obtained based on a first measured value Ir1 of the coil current, corrected successively based on a subsequent measured value Ir, thereby obtaining Pr2, Pr3...Prn, and Prn is set as a final correction value. Further, it may be possible to calculate the average of correction values Prn in a plurality of coil current values (Ir1, Ir2, Ir3...Irn) at a plurality of points and set Prn as a final correction value.

[0039] In descriptions in FIG.4 and subsequent descriptions, the foregoing is the same as in the case where the correction value Pr is obtained based on a plurality of coil current values at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the solenoid 46.

[0040] FIG.4 is a view showing the concept of obtaining the pulse width Tout of the output driving pulse Pout in the first embodiment of the present invention. As shown in the figure, a correction pulse width calculation processing section 71 obtains the correction value Pr of the required driving pulse Pw corresponding to the required fuel injection quantity Qc, based on the required fuel injection quantity Qc and measured value Ir of the coil current. A calculator 72 (for example, adder/subtracter) adds or subtracts the correction value Pr to/from the required driving pulse width Tw corresponding to the required fuel injection quantity Qc, and thereby obtains the output driving pulse width Pout for next time (or next and subsequent time). The microcomputer 43 includes the correction pulse width calculation processing section 71 and adder 72. As described above, in the case where the correction value Pr is obtained based on a plurality of coil current values (Ir1, Ir2, Ir3...Irn) at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the solenoid 46, the correction value Pr is obtained from the Ir axis of n dimensions, or a first correction value Pr is obtained based on a first measured value Ir1 of the coil current, corrected successively based on a subsequent measured value Ir, thereby obtaining Pr2, Pr3...Prn, and Prn is set as a final correction value.

[0041] In addition, the coil current sometimes varies largely in measurement due to multiplexing of noise or the like caused by temperature and coil resistance, etc. When the output driving pulse Pout is output which is corrected using the correction value varying every measurement, the fuel injection quantity is not stabilized and the inconvenience arises in driving the engine.

[0042] Therefore, the microcomputer 43 calculates a plurality (a predetermined number) of last correction values and an average correction value of the plurality of last correction values to store. When a currently measured and calculated correction value exceeds a predetermined allowance of the average correction value, correction processing is performed to obtain the pulse width Tout of the next output driving pulse Pout. Meanwhile, when the correction value is within the allowance, the correction processing is not performed.

[0043] FIG.5 is a chart for conceptually showing a scheme of obtaining the correction value Pr of the solenoid driving pulse in the correction processing based on a measured value Ir of the coil current during the driving of the solenoid according to the present invention as described earlier. As shown in the figure, a correction map is prepared in a memory 8 in the microcomputer constituting the present invention. For example, on the map, the measured value Ir of the coil current is plotted on the horizontal axis (when the correction value Pr is obtained based on n coil current values at a plurality of points at each of which respective predetermined time has elapsed, Ir axis of n dimensions), the required fuel injection quantity Qc is plotted on the vertical axis, and correction values Pr are mapped in relation to various combinations of the measured value Ir of the coil current and required fuel injection quantity Qc. The correction values Pr in relation to the combinations of the measured value Ir of the coil current and required fuel injection quantity Qc are obtained beforehand by experiment or the like. Such a correction value map may be a multidimensional map exceeding n dimensions when there is a plurality of variable elements as described later.

[0044] According to the first embodiment as described above, since the output driving pulse Pout for actually switching between ON and OFF of the FET 44 for driving the solenoid 46 is corrected based on the measured values Ir of the coil current at one or more points after a lapse of predetermined time since the start of driving of the solenoid 46 and on the required driving pulse Pw corresponding to the required fuel injection quantity, the relationship is linear between the required fuel injection quantity and actual fuel injection quantity in the electromagnetic fuel injection pump that pressurizes the fuel to inject, and it is possible to correct a required quantity of fuel injection accurately.

(2) Second embodiment of the present invention

[0045] A fuel injection method according to the second embodiment of the present invention will be described below using as an example the case of applying the electromagnetic fuel injection system with the configuration as shown in FIG.1. Descriptions of the configuration of the electromagnetic fuel injection system overlap the first embodiment and are omitted.

[0046] In the second embodiment, using a gradient correction value indicated by a ratio between an increase in required fuel injection quantity Qc and an increase in output driving pulse width Tout of the solenoid, and a corrected inoperative time elapsing until fuel injection is started after starting driving of the solenoid, the output driving pulse width Tout is obtained by adding the corrected inoperative time to a value of multiplication of the required driving pulse corresponding to the required fuel injection quantity Qc by the gradient correction value.

[0047] FIG.6 shows the relationship between the fuel injection quantity Q and output driving pulse width Tout of the solenoid in a fuel injection control system according to the second embodiment of the present invention. As shown in FIG.6, the fuel injection quantity Q is zero during the time for the pulse width to rise from zero to some value (Toffset), and then increases with some gradient Td as the pulse width increases.

[0048] A predetermined period of time (Toffset) after starting driving the solenoid 46 is the time during which actual fuel injection is not started, and is called inoperative time because the time does not affect the injection quantity. The inoperative time Toffset is also a variable value affected by the measured value Ir of the coil current. Accordingly, in the case of performing more proper fuel injection in response to the fuel injection quantity Q, it is necessary to also correct Toffset. In FIG.6, the gradient Td is a ratio between an increase in the required fuel injection quantity Qc and an increase in the output driving pulse width of the solenoid, and is called gradient correction value Td in the specification of the present invention. Using the Td and Toffset, the output driving pulse width Tout required to inject the required fuel injection quantity Qc accurately is expressed by an equation of [Tout=QcxTd+Toffset].

[0049] The inoperative time Toffset varies with level of the coil current as described above, and therefore, is expressed as the function of measured value Ir of the coil current. In other words, a value of corrected inoperative time Toffset is obtained corresponding to the measured value Ir of the coil current. The value of corrected inoperative time Toffset is obtained from, for example, a two-dimensional map on which values of Toffset are mapped in relation to measured values Ir1 of the coil current at the first point of the coil current after a lapse of time Tr1. The map is obtained in advance by experiment or the like.

[0050] When the relationship is linear between the required fuel injection quantity Qc and output driving pulse width Tout, the gradient correction value Td is the function of the measured value Ir (for example, Ir1) of the coil current, as in inoperative time Toffset. Accordingly, the value of gradient correction value Td is obtained, for example, from the two-dimensional map where values of Td are mapped in relation to Ir. However, when the relationship between the required fuel injection quantity Qc and output driving pulse width Tout is not linear, the gradient correction value Td is the function of the measured value Ir of the coil current and required fuel injection quantity Qc. Accordingly, in this case, the gradient correction value Td is obtained using a three-dimensional map where values of gradient correction value Td are mapped in relation to the measured value Ir of the coil current and required fuel injection quantity Qc. These maps are obtained in advance by experiment or the like.

[0051] FIG.7 shows an example of an injection quantity characteristics graph indicating the relationship between actual fuel injection quantity Qout and output driving pulse width Tout for final fuel injection with respect to various measured values Ir of the coil current. The injection quantity characteristics graph as shown in FIG. 7 indicates that as the measured value Ir of the coil current increases, the inoperative time decreases and a more amount of fuel injection is carried out with respect to the same output driving pulse width.

[0052] FIG.8 shows an example of the relationship between the inoperative time Toffset and measured value Ir of the coil current. FIG.9 shows an example of the relationship between gradient correction value Td and measured value Ir (for example, Ir1) of the coil current. When the relationship is linear between the required fuel injection quantity Qc and output driving pulse width Tout, irrespective of the value of required fuel injection quantity Qc, the relationship between the gradient correction value Td and measured value Ir of the coil is only the relationship as shown in FIG.9.

[0053] However, when the relationship is not linear between the required fuel injection quantity Qc and output driving pulse width Tout, the relationship as shown in FIG.9 is present with respect to each of various required fuel injection quantities Qc.

[0054] FIG. 10 is a second conceptual view for illustrating a scheme of obtaining a corrected output driving pulse width Tout in the second embodiment. As shown in FIG.10, first, a multiplier 75 multiplies the required driving pulse Pw corresponding to the required fuel injection quantity Qc by the gradient correction value Td.

The gradient correction value Td is obtained from a map 81 based on the measured value Ir of the coil current.

[0055] The gradient correction value Td can be obtained also based on a plurality of coil current values (Ir1, Ir2, Ir3...Irn) at a plurality of points at each of which respective predetermined time has elapsed since the start of driving of the solenoid 46. In this case, the gradient correction value Td is obtained from the Ir axis of n dimensions, or a first gradient correction value Td_1 is obtained based on a first measured value Ir1 of the coil current, corrected successively based on a subsequent measured value Ir, thereby obtaining Td2, Td3...Tdn, and Tdn is set as a final correction value.

[0056] Then, an adder 76 adds the inoperative time Toffset to a value of Qc x Td. Used as the inoperative time Toffset is a corrected inoperative time Toffset obtained from a map 82 based on the measured value Ir of the coil current. Thus, the output driving pulse width Tout for final fuel injection is obtained. The microcomputer 43 includes the multiplier 75 and adder 76. Maps 81 and 82 are stored in a data storage in the microcomputer 43.

[0057] According to the second embodiment as described above, the gradient correction value Td is obtained based on one or more measured values Ir of the coil current, or on the measured value Ir of the coil current and required fuel injection quantity Qc, the corrected inoperative time Toffset is obtained based on the measured value Ir of the coil current, and the output driving pulse width Tout for the final fuel injection is corrected using the corrected inoperative time Toffset and gradient correction value Td.

[0058] Therefore, in the electromagnetic fuel injection pump that pressurizes fuel to inject, even when the relationship is not linear between the required driving pulse Pw corresponding to the required fuel injection quantity Qc and fuel injection quantity Q, it is possible to correct the fuel injection quantity Q properly. Further, in the fuel injection apparatus where the relationship is linear between the driving pulse width and fuel injection quantity, since the gradient correction value Td and corrected inoperative time Toffset are obtained from respective two-dimensional maps, there are advantages that calculation to obtain correction values is simplified and that a memory usage amount by the maps is reduced, as compared to the case of using three-dimensional maps for correction.

(3) Third embodiment of the present invention

[0059] FIG.11 is a view for illustrating a control mechanism in a fuel injection control apparatus according to the third embodiment of the present invention. As shown in FIG.11, the control mechanism has a configuration with the electromagnetic fuel injection system as illustrated in FIG.2 and further a power supply voltage detecting circuit 49 that detects the power supply voltage V_B and supplies the detected value to the microcomputer 43. The other structure is the same as the configuration as illustrated in FIG.2.

[0060] FIG.12 shows an example of correction processing control flow in the third embodiment. At the time of starting an engine, i.e. at the time of first driving the fuel injection solenoid 46, the last fuel injection cycle is not present, and therefore, there is no data of measured values Ir of the coil current at one or more points after starting fuel injection in the last fuel injection cycle to be referred to so as to obtain the gradient correction value Td and corrected inoperative time Toffset. The same situation occurs in the case of resuming driving of the solenoid 46 after the fuel injection is halted due to a fuel cut occurring when a vehicle mounted with the engine drives down a hill or a fuel cut for an idling stop in waiting at traffic lights. Further, there are cases that in starting an engine with a battery of small capacity, the power supply voltage V_B decreases extremely, the microcomputer is thereby reset, and it is not possible to refer to data of Ir of the last fuel injection.

[0061] Hence, in the third embodiment, at the time of starting the engine, or only at the first driving time to drive the solenoid 46 again after a halt of fuel injection due to a fuel cut, etc., the power supply voltage detecting circuit 49 detects the power supply voltage V_B, and based on the detected value, the gradient correction value Td and corrected inoperative time Toffset are obtained.

[0062] Further, a map on which the corrected inoperative time Toffset is mapped in relation to the power supply voltage V_B and another map on which the gradient correction value Td is mapped in relation to the power supply voltage V_B are obtained in advance by experiment or the like and stored in a storage section in the microcomputer, which is not shown in the figure particularly.

[0063] As in the second embodiment, the output driving pulse width Pout is obtained by the equation of [Tout=QcxTd+Toffset] described earlier using the gradient correction value Td and corrected inoperative time Toffset obtained based on the detected value of the power supply voltage V_B.

[0064] According to the third embodiment as described above, since the output driving pulse width Tout for final fuel injection is corrected based on the detection of the power supply voltage V_B at the time of starting the engine and at the first driving time to drive the solenoid 46 again after a halt of fuel injection, for example, due to a fuel cut, while being corrected based on the detected value Ir of the coil current detected in the last fuel injection in other cases, as in the third embodiment, it is possible to correct the fuel injection quantity Q accurately in the electromagnetic fuel injection system that pressurizes fuel to inject.

[0065] Further, when the relationship is linear between the output driving pulse width Tout and fuel injection quantity Q, since the maps for use in correction calculation are two-dimensional maps, there are advantages that the correction calculation is simplified and that a memory usage amount by the maps is reduced.

(4) The fourth embodiment of the present invention

[0066] A fuel injection control method according to the fourth embodiment of the present invention is a method for preventing the measured value Ir of the coil current from differing from an original value due to a shift of the measurement timing in measuring the coil current after a lapse of predetermined time since the start of driving of the solenoid 46 in the first to third embodiments as described above.

[0067] For example, it is assumed that the electromagnetic fuel injection system with the configuration as illustrated in FIG.2 or 11 performs software processing, as shown in FIG.15, where a timer to count the detection time Tr of the coil current starts at an interrupt 92 for switching ON an output driving pulse 91, thereby the state becomes interrupt wait 93, a current detection A/D converter starts at a count up interrupt 94 of the timer, thereby the state becomes interrupt wait 95, and an A/D conversion value is read at an A/D conversion finish interrupt 96. Herein, the timer and current detection A/D converter are integrally provided in the microcomputer 43.

[0068] In such software processing, as shown in FIG. 16, when the count up interrupt 94 of the timer occurs while other interrupt processings 97 are executed, the current detection A/D converter is started after the processings 97 are finished. Therefore, the sampling timing of the coil current is shifted by T_s, and the coil current is detected at the time a time $Tr+T_s$ has elapsed since the start of driving of the solenoid 46.

[0069] Accordingly, as shown in FIG.17, a detected value 98 of the coil current differs from an original value, i.e. the measured value Ir of the coil current at the time the time Tr has elapsed since the start of driving by I_s. Such a shift occurs also in a case where other interrupt processings are being executed when the interrupt 92 occurs to switch ON the output driving pulse 91, and therefore, the timer starts a few moments later after the output driving pulse 91 is switched ON. Then, in the fourth embodiment, the coil current is measured in procedures as described below.

[0070] FIG. 14 is a flowchart illustrating an example of processing procedures in the fuel injection control method according to the fourth embodiment of the present invention. When solenoid driving ON interrupt processing is started, time T_1 (a value of output compare) the output driving pulse is switched ON is stored (step S131), and the current detection timer is started (step S132).

[0071] Then, other processings are executed (step S133), and when the count up interrupt of the timer occurs, current detection timer processing is started. When the processing is started, the present time, i.e. time T_2 A/D conversion is scheduled to execute is measured (step S134), and an elapsed time T_2-T_1 between time T_1 and time T_2 is obtained (step S135).

[0072] Herein, the elapsed time T_2-T_1 is compared with a beforehand set time (step S136). As a result of comparison, when the elapsed time T_2-T_1 is within the set time, the current detection A/D converter is started to start A/D conversion (step S137), and the current detection timer processing is finished.

[0073] Then, when the A/D conversion finish interrupt occurs, an A/D conversion value is read in the A/D conversion processing, the measured value Ir of the coil current is updated using the read value (step S138), and all the processing is finished. In this case, based on the updated measured value Ir of the coil current, the output driving pulse width of the solenoid is corrected as described in the first to third embodiments.

[0074] Meanwhile, as a result of comparison in step S136, when the elapsed time (T_2-T_1) exceeds the set time, the current detection A/D converter is not started, and all the processing is finished. In this case, based on a measured value Ir of the coil current that is not updated, i.e. a measured value Ir of the coil current (for example, stored in RAM in the microcomputer 43) that is last measured, the output driving pulse width of the solenoid is corrected. The same processing as described above is carried out in the case of control based on n measured values Ir of the coil current at a plurality of points after starting fuel injection.

[0075] According to the fourth embodiment as described above, since a measured value Ir of the coil current is prevented from being measured at measurement timing largely shifted due to other interrupt processings or the like, it is possible to suppress A/F variations occurring due to correction based on a measured value Ir of the coil current differing from the original value.

[0076] The present invention is not limited to the aforementioned embodiments, and is capable of being carried out with various modifications thereof. For example, in the first embodiment, the calculator, which applies the correction value Pr of the pulse width to the required driving pulse Pw corresponding to the required fuel injection quantity Qc, is not limited to an adder, and may be a subtracter, multiplier, divider, a combination thereof, or device for performing other calculation.

[0077] Further, the present invention is not limited to the electromagnetic fuel injection system described in the above-mentioned embodiments, and applicable to a fuel injection apparatus provided with a fuel supply pressure regulator having characteristics such that the relationship between the output driving pulse width of the solenoid and fuel injection quantity is relatively linear. This is because operation characteristics such as operation start time (inoperative time) for driving the solenoid vary with coil current value, temperature or the like in such a fuel injection apparatus.

Industrial Applicability

[0078] The present invention is related to an electronic fuel injection control method and control apparatus to supply fuel to an engine, etc., and has industrial applicability.

Claims

1. A fuel injection control method for measuring a coil current passed through a fuel injection solenoid at one or more points at each of which respective predetermined time has elapsed since the start of driving of the solenoid, and correcting and adjusting timing for halting the driving of the solenoid based on a measured value of the coil current.

2. A fuel injection control method comprising the steps of:

   starting driving of a fuel injection solenoid,
   measuring a coil current passed through the solenoid at one or more points at each of which respective predetermined time has elapsed since the start of the driving of the solenoid; and
   obtaining a correction value to correct timing for halting the driving of the solenoid based on a measured value of the coil current,

   wherein the timing for halting the driving of the solenoid is adjusted using the correction value.

3. The fuel injection control method according to claim 1 or 2, wherein correction is carried out using a correction value determined based on the measured value of the coil current and a required fuel injection quantity for the solenoid.

4. The fuel injection control method according to claim 1 or 2, wherein correction values are determined in advance corresponding to various combinations of the measured value of the coil current and the required fuel injection quantity for the solenoid, and correction is carried out using a correction value selected corresponding to one of the combinations.

5. The fuel injection control method according to claim 1 or 2, wherein correction of the timing for halting the driving of the solenoid comprises the steps of:

   obtaining a gradient correction value indicated by a ratio between an increase in required fuel injection quantity and an increase in output driving pulse width of the solenoid, determined based on either or both of the measured value of the coil current and the required fuel injection quantity for the solenoid;
   further obtaining a corrected inoperative time elapsing until fuel injection is started after starting the driving of the solenoid, the corrected inoperative time being determined corresponding to the measured value of the coil current; and
   calculating the correction value by adding the corrected inoperative time to a value of multiplication of a required driving pulse corresponding to the required fuel injection quantity by the gradient correction value,

   wherein the timing for halting the solenoid is adjusted using the correction value.

6. The fuel injection control method according to claim 1 or 2, wherein in setting a driving time of the solenoid at the time of starting the engine or at the first driving time to resume once halted fuel injection, a power supply voltage to apply to the solenoid is measured, and based on a measured value of the power supply voltage, the timing for halting the driving of the solenoid is corrected.

7. A fuel injection control apparatus comprising:

   means for driving a fuel injection solenoid;
   current measuring means for measuring a coil current passed through the solenoid at one or more points at each of which respective predetermined time has elapsed since the start of the driving of the solenoid; and
   control means for obtaining a correction value to correct timing for halting the driving of the solenoid based on a measured value of the coil current, and adjusting the timing for halting the driving of the solenoid using the correction value.

8. The fuel injection control apparatus according to claim 7, further comprising:

   a feedback circuit to reuse energy released from the solenoid at the time of halting the driving of the solenoid, as energy for driving the solenoid.

9. The fuel injection control apparatus according to claim 8, wherein the feedback circuit includes a capacitor to charge the energy released from the solenoid at the time of halting the driving of the solenoid.

10. The fuel injection control apparatus according to any one of claims 7 to 9, wherein the correction value is determined based on the measured value of the coil current and a required fuel injection quantity for the solenoid.

11. The fuel injection control apparatus according to any one of claims 7 to 9, wherein correction values are determined in advance corresponding to various combinations of the measured value of the coil current and the required fuel injection quantity for the solenoid, and the correction value is selected corresponding to one of the combinations.

12. The fuel injection control apparatus according to any one of claims 7 to 9, further comprising:

storing means for storing a measured value of the coil current;
means for obtaining a gradient correction value indicated by a ratio between an increase in the required fuel injection quantity and an increase in output driving pulse width of the solenoid, determined based on either or both of the measured value of the coil current stored in the storing means and the required fuel injection quantity for the solenoid;
means for obtaining a corrected inoperative time elapsing until fuel injection is started after starting the driving of the solenoid, the corrected inoperative time being determined corresponding to the measured value of the coil current stored in the storing means; and
means for obtaining the correction value by adding the corrected inoperative time to a value of multiplication of a required driving pulse corresponding to the required fuel injection quantity by the gradient correction value,

wherein the timing for halting the solenoid is adjusted using the correction value.

FIG.1

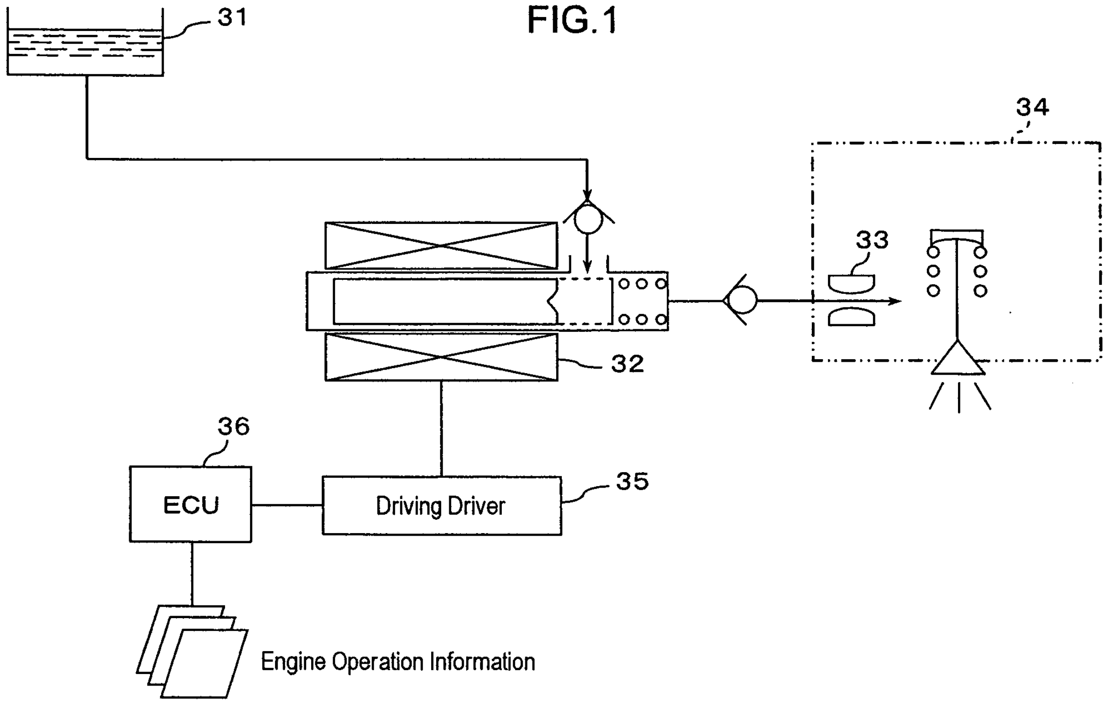

31
34
33
32
36
ECU
Driving Driver
35
Engine Operation Information

FIG.2

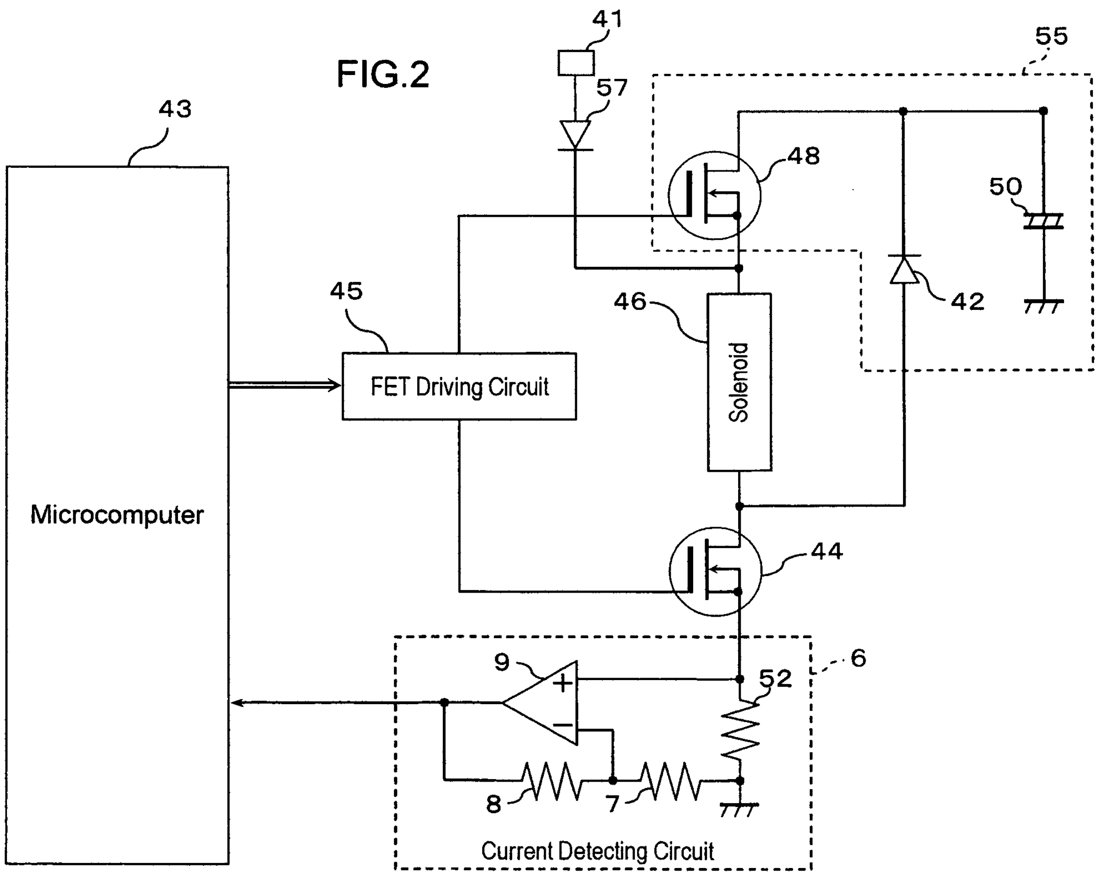

41
55
57
43
48
50
45
46
42
FET Driving Circuit
Solenoid
Microcomputer
44
9
6
52
8
7
Current Detecting Circuit

FIG.3

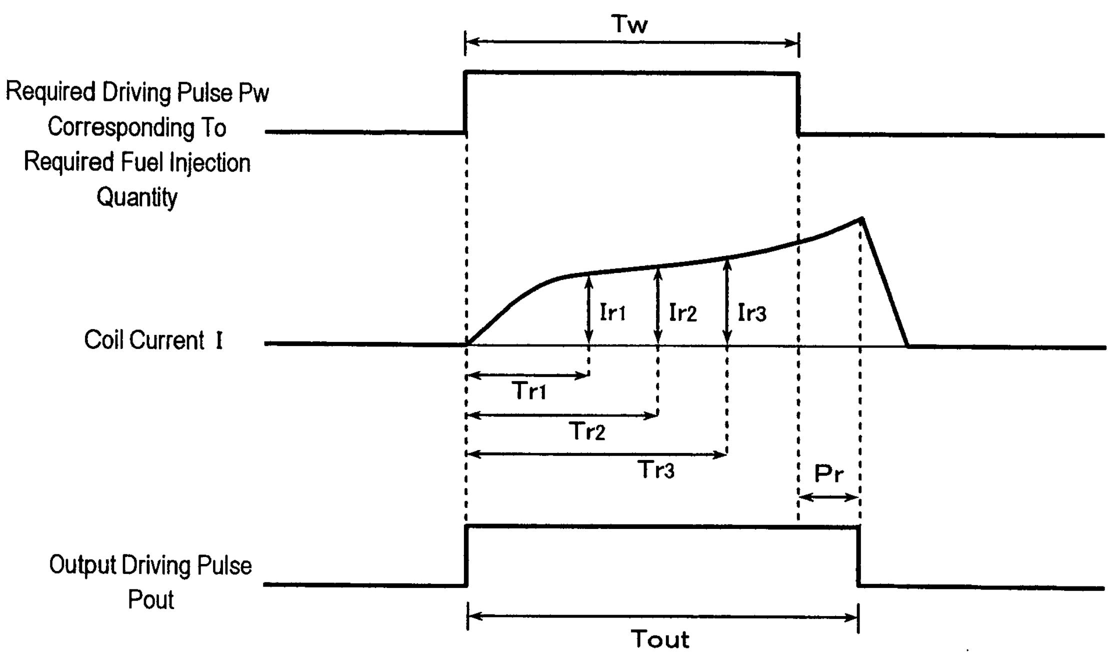

Tw
Required Driving Pulse Pw
Corresponding To
Required Fuel Injection
Quantity
Coil Current I
Ir1
Ir2
Ir3
Tr1
Tr2
Tr3
Pr
Output Driving Pulse
Pout
Tout

FIG.4

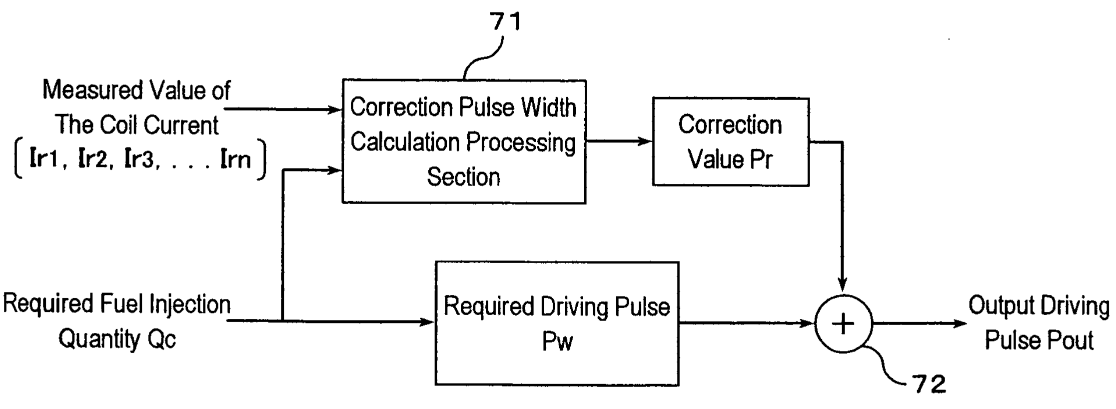

71
Measured Value of
The Coil Current
[Ir1, Ir2, Ir3, . . . Irn]
Correction Pulse Width
Calculation Processing
Section
Correction
Value Pr
Required Fuel Injection
Quantity Qc
Required Driving Pulse
Pw
+
Output Driving
Pulse Pout
72

FIG.5

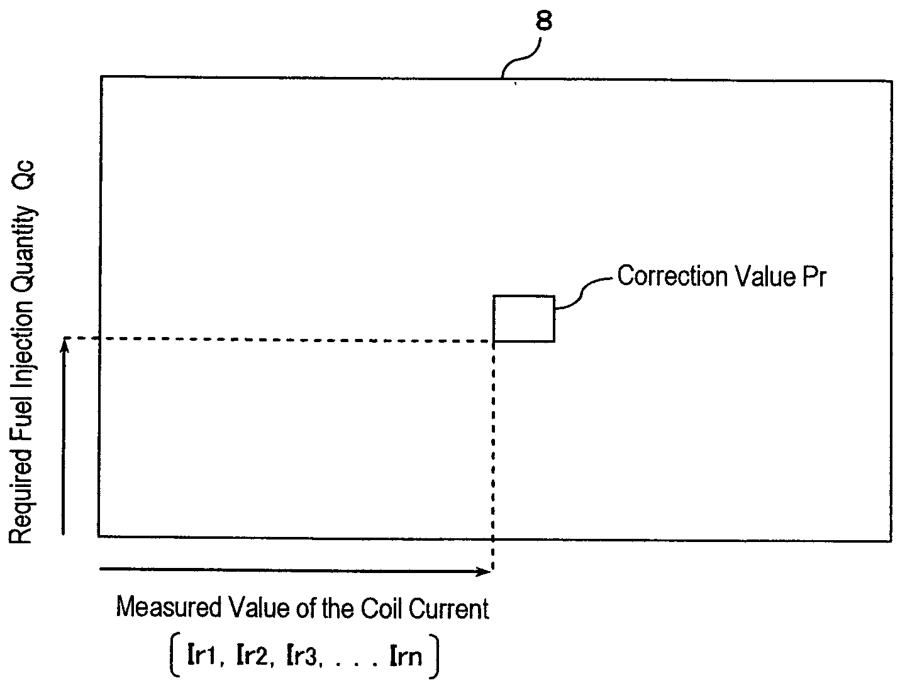

8
Required Fuel Injection Quantity Qc
Correction Value Pr
Measured Value of the Coil Current
[Ir1, Ir2, Ir3, . . . Irn]

FIG.6

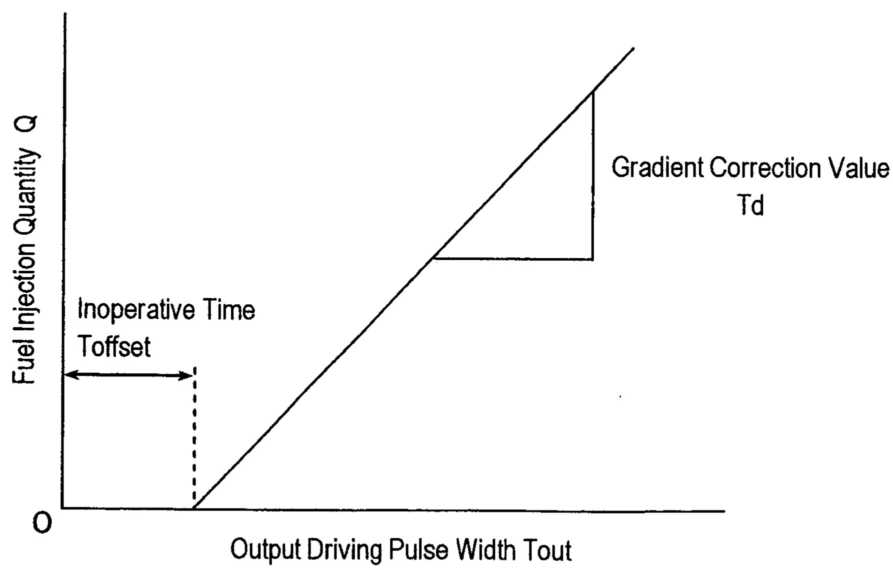

Fuel Injection Quantity Q
Gradient Correction Value
Td
Inoperative Time
Toffset
O
Output Driving Pulse Width Tout

FIG.7

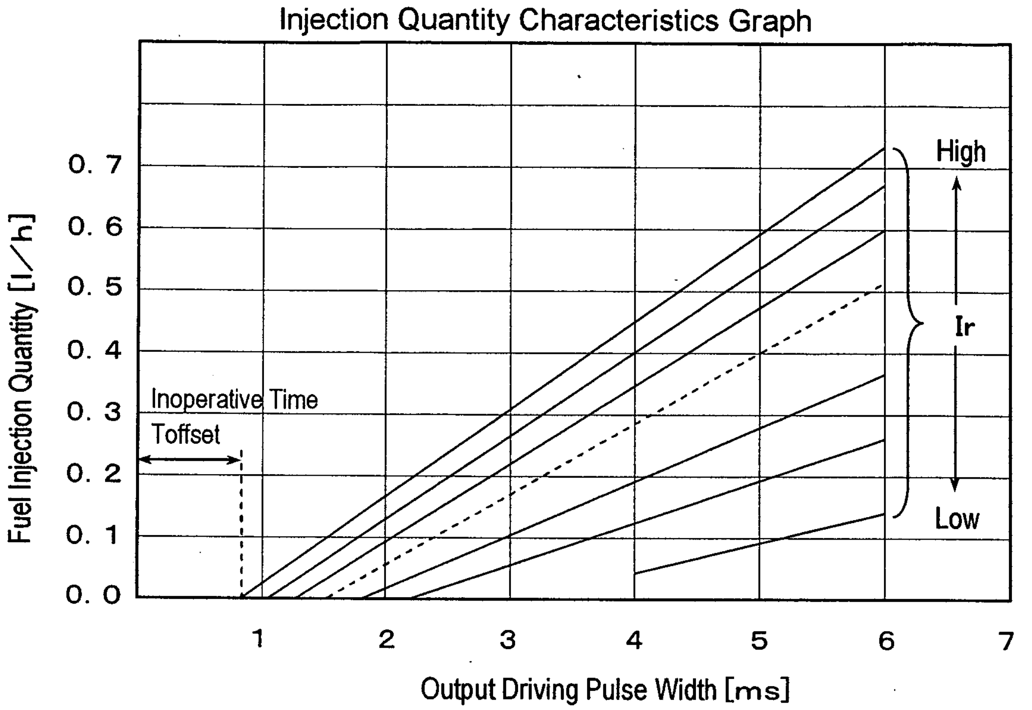

Injection Quantity Characteristics Graph
Fuel Injection Quantity [l/h]
0. 7
0. 6
0. 5
0. 4
0. 3
0. 2
0. 1
0. 0
Inoperative Time
Toffset
High
Ir
Low
1
2
3
4
5
6
7
Output Driving Pulse Width [ms]

FIG.8

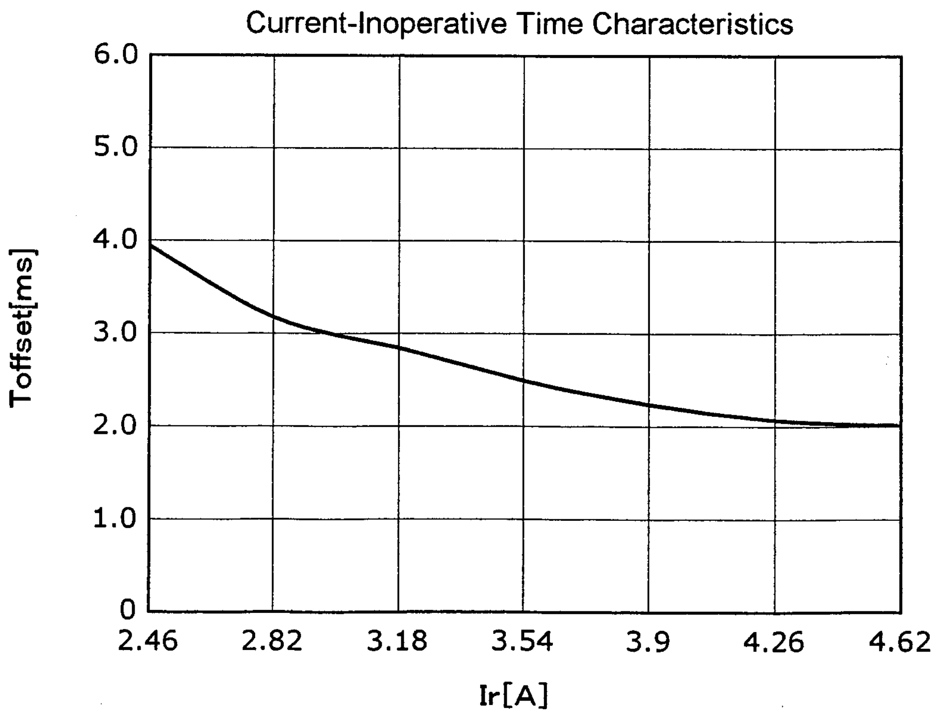

Current-Inoperative Time Characteristics
Toffset[ms]
6.0
5.0
4.0
3.0
2.0
1.0
0
2.46
2.82
3.18
3.54
3.9
4.26
4.62
Ir[A]

FIG.9

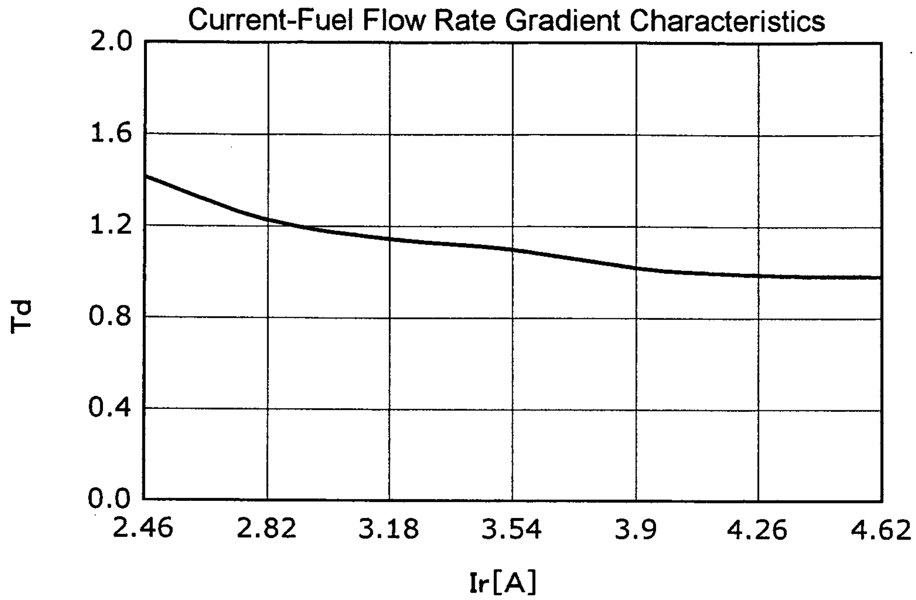

Current-Fuel Flow Rate Gradient Characteristics
2.0
1.6
1.2
0.8
0.4
0.0
Td
2.46
2.82
3.18
3.54
3.9
4.26
4.62
Ir[A]

FIG.10

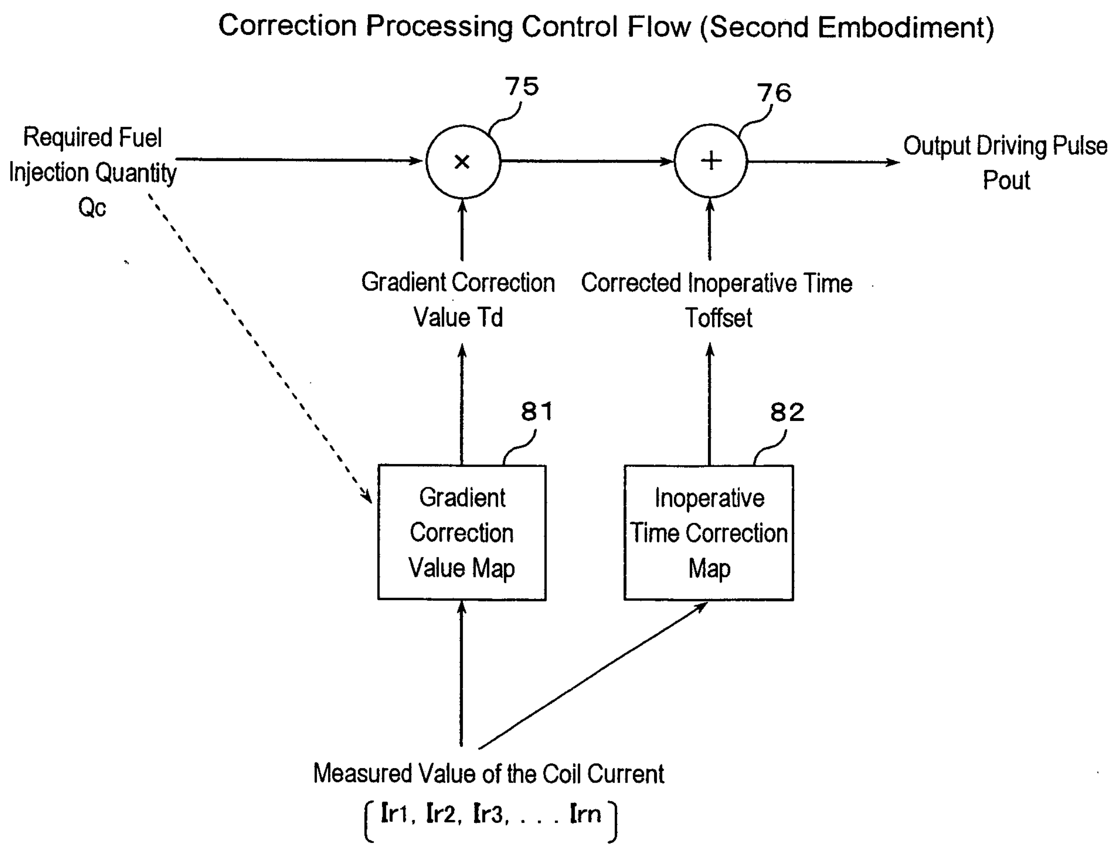
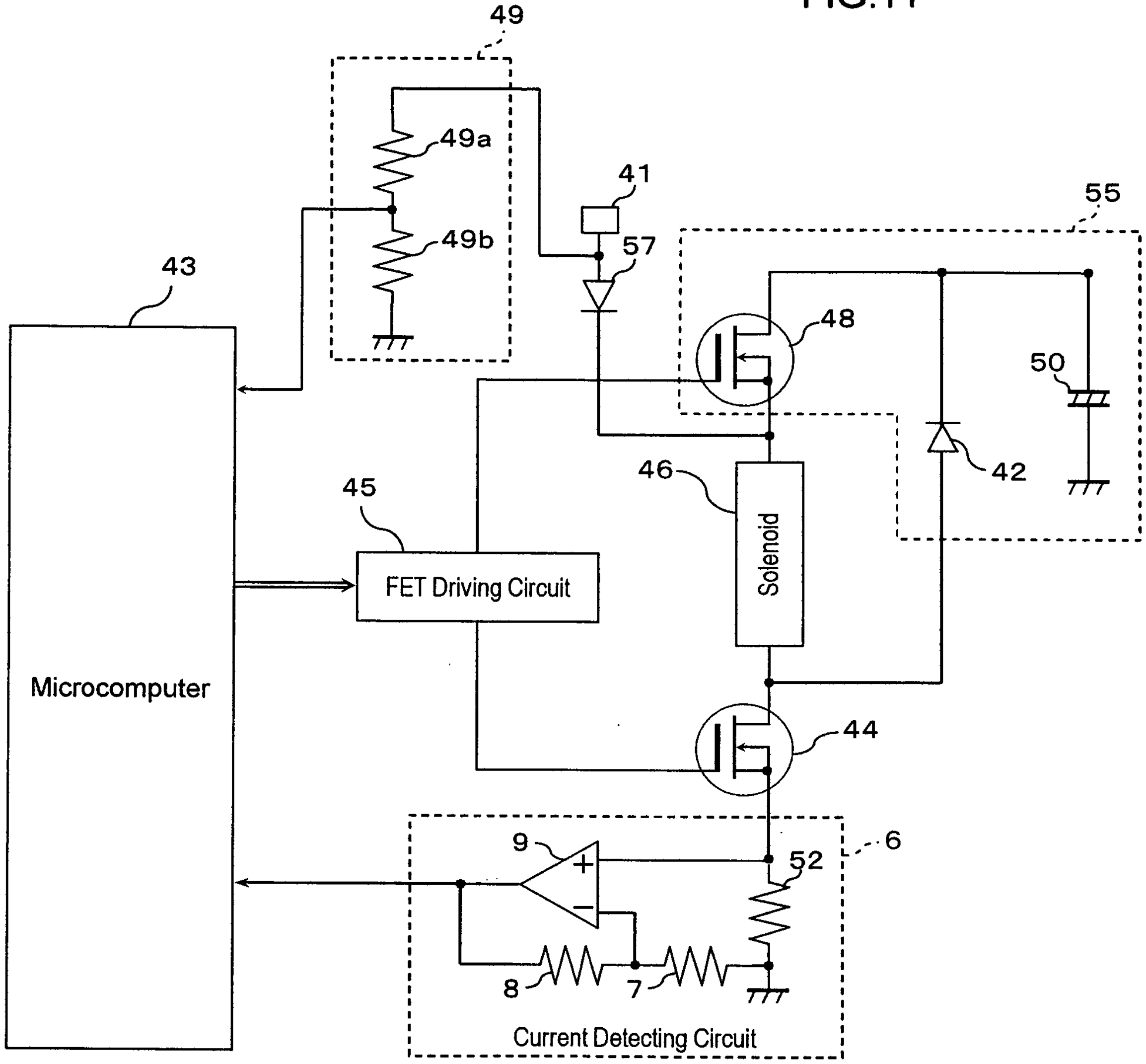

Correction Processing Control Flow (Second Embodiment)
75
76
Required Fuel Injection Quantity Qc
×
+
Output Driving Pulse Pout
Gradient Correction Value Td
Corrected Inoperative Time Toffset
81
82
Gradient Correction Value Map
Inoperative Time Correction Map
Measured Value of the Coil Current
[Ir1, Ir2, Ir3, . . . Irn]

FIG.11


49
49a
49b
41
57
55
43
48
50
45
46
42
Solenoid
FET Driving Circuit
Microcomputer
44
9
6
52
8
7
Current Detecting Circuit

Correction Processing Control Flow Using Measured Values of the Coil Current and Power Supply Voltage (Third Embodiment)

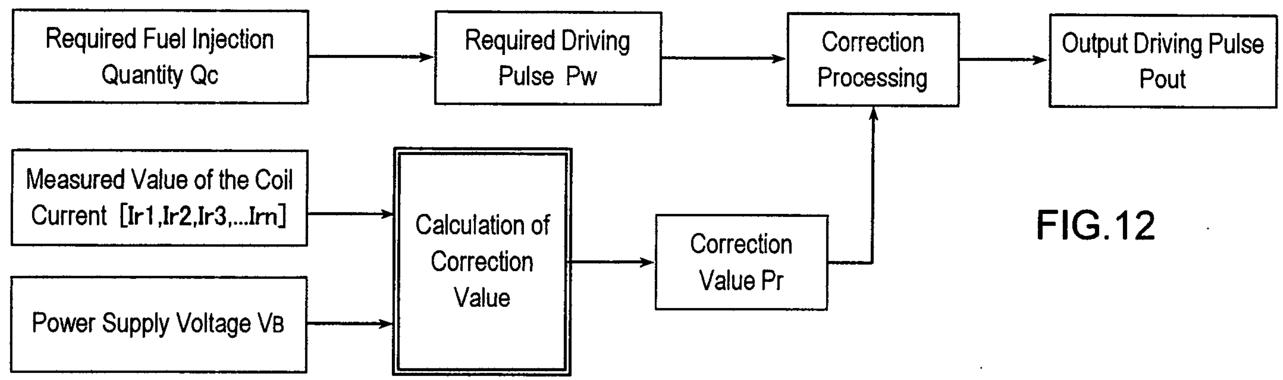


FIG.12

FIG.13

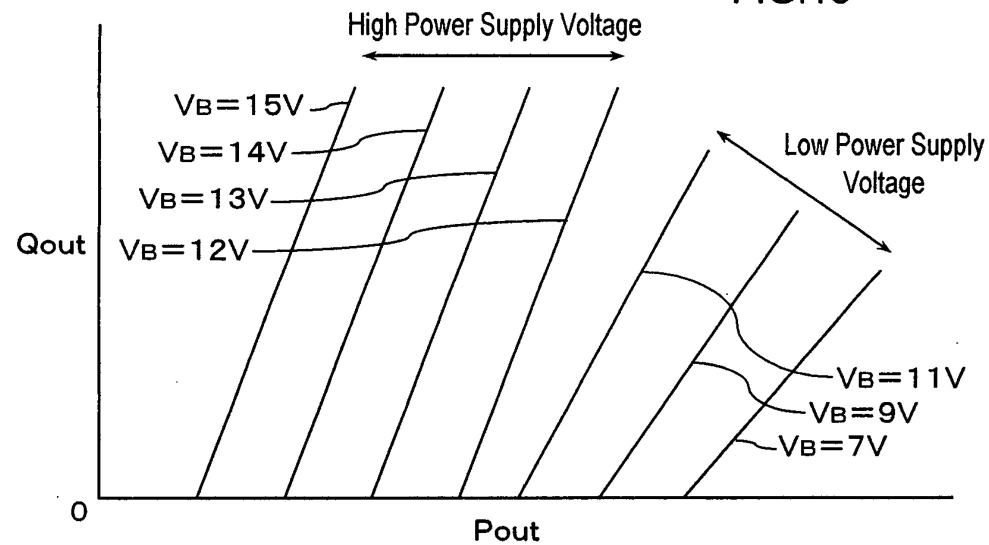
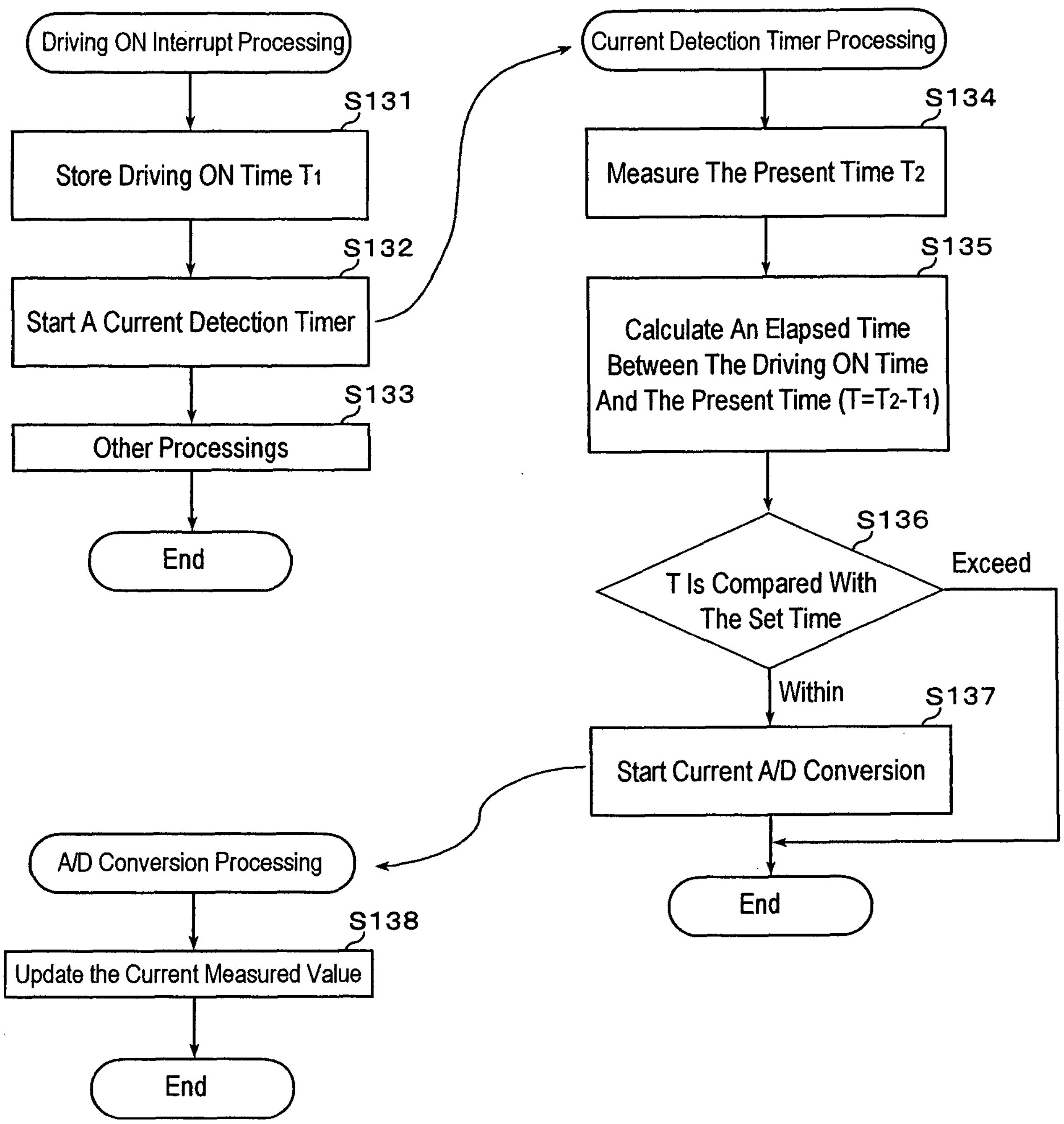


FIG.14



Driving ON Interrupt Processing
S131
Store Driving ON Time T1
S132
Start A Current Detection Timer
S133
Other Processings
End
Current Detection Timer Processing
S134
Measure The Present Time T2
S135
Calculate An Elapsed Time Between The Driving ON Time And The Present Time (T=T2-T1)
S136
T Is Compared With The Set Time
Exceed
Within
S137
Start Current A/D Conversion
End
A/D Conversion Processing
S138
Update the Current Measured Value
End

FIG.15

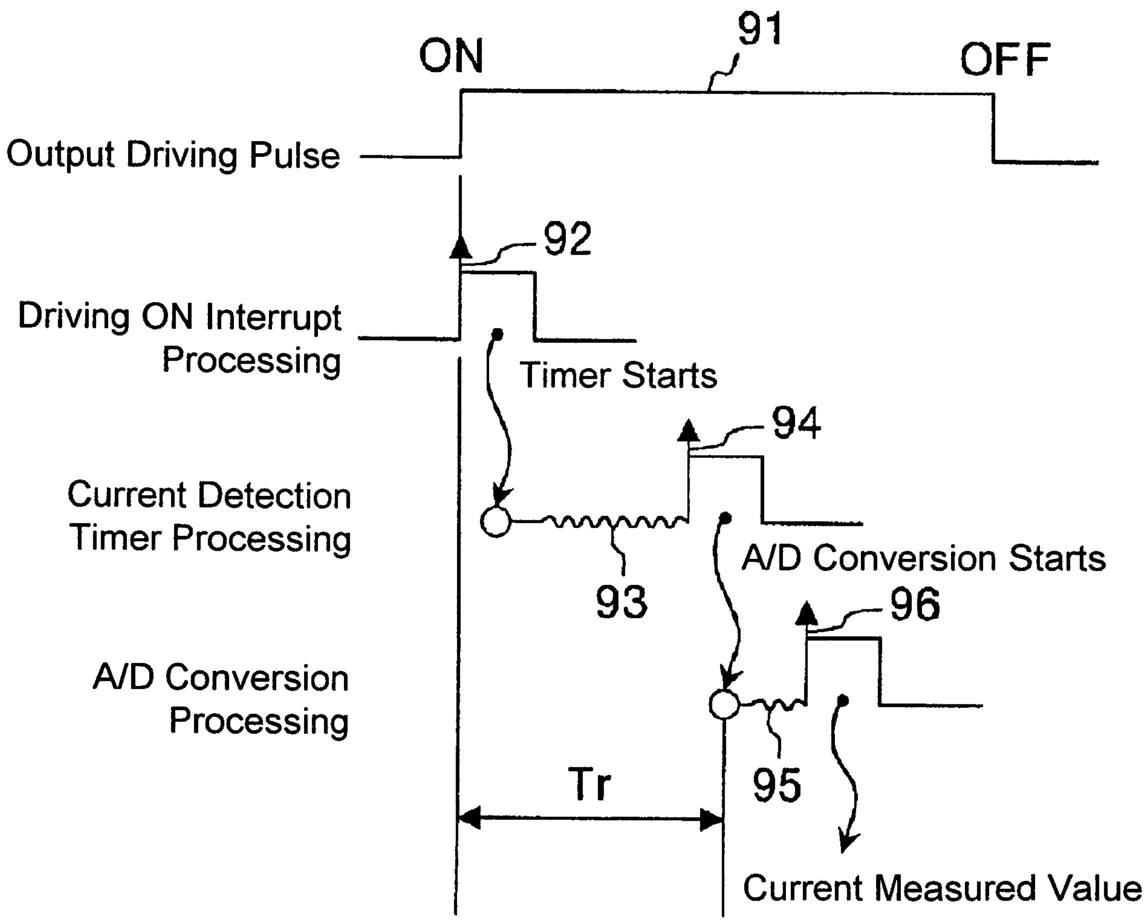

ON
91
OFF
Output Driving Pulse
92
Driving ON Interrupt Processing
Timer Starts
94
Current Detection Timer Processing
A/D Conversion Starts
93
96
A/D Conversion Processing
Tr
95
Current Measured Value

FIG.16

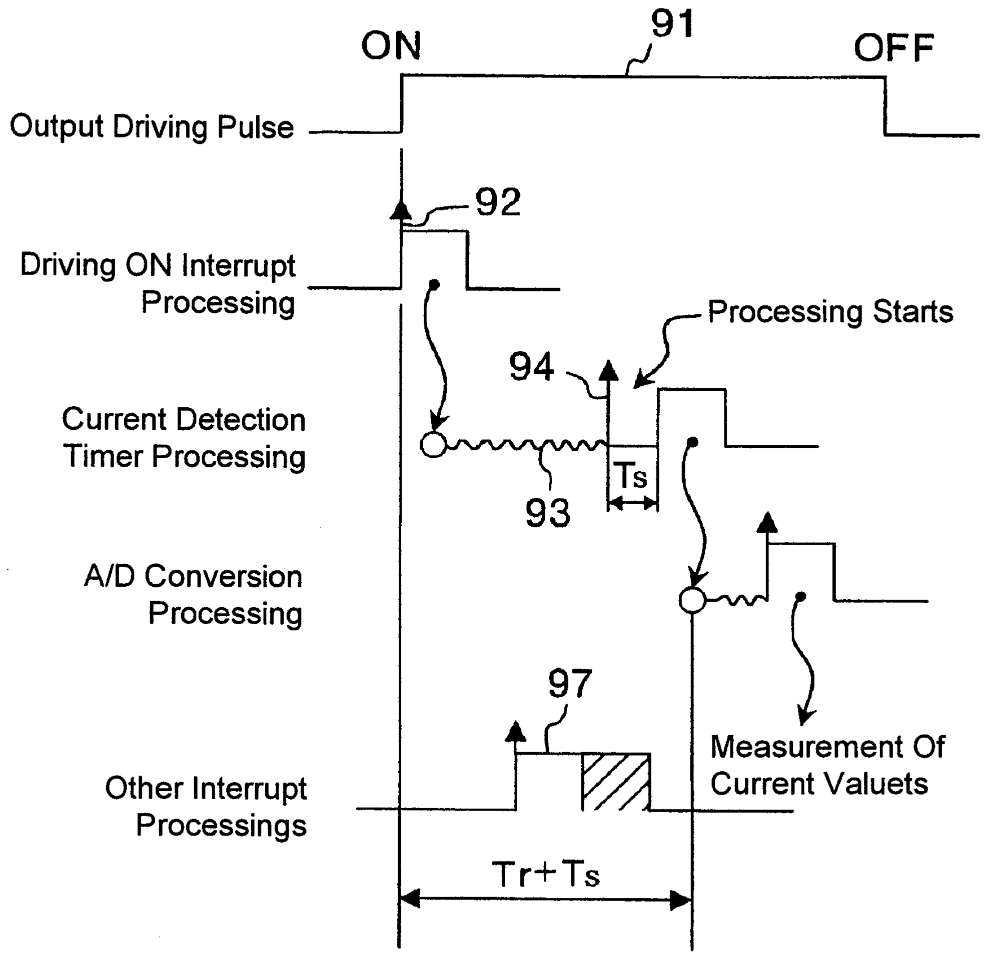

ON
91
OFF
Output Driving Pulse
92
Driving ON Interrupt Processing
Processing Starts
94
Current Detection Timer Processing
Ts
93
A/D Conversion Processing
97
Measurement Of Current Valuets
Other Interrupt Processings
Tr+Ts

FIG.17

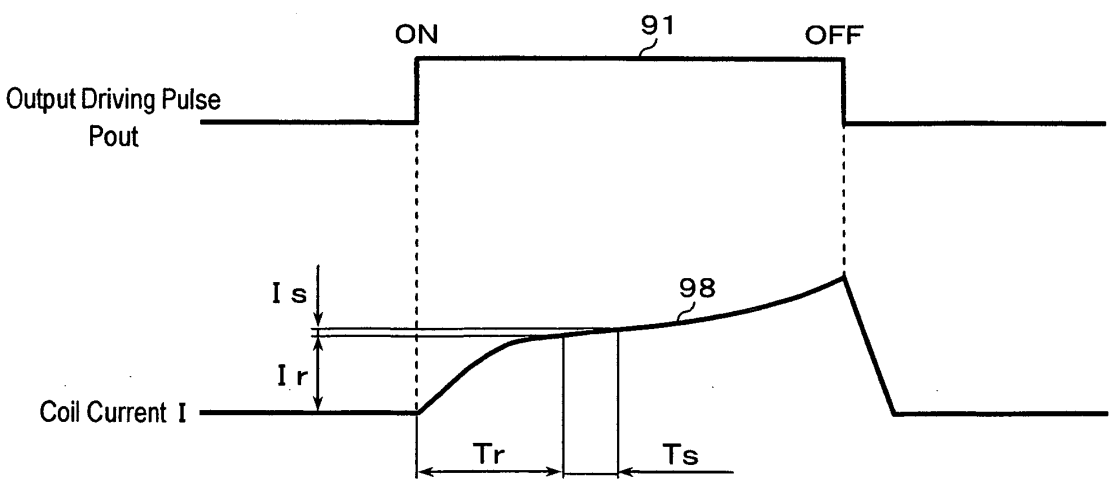

ON
91
OFF
Output Driving Pulse Pout
I s
98
I r
Coil Current I
Tr
Ts

FIG.18

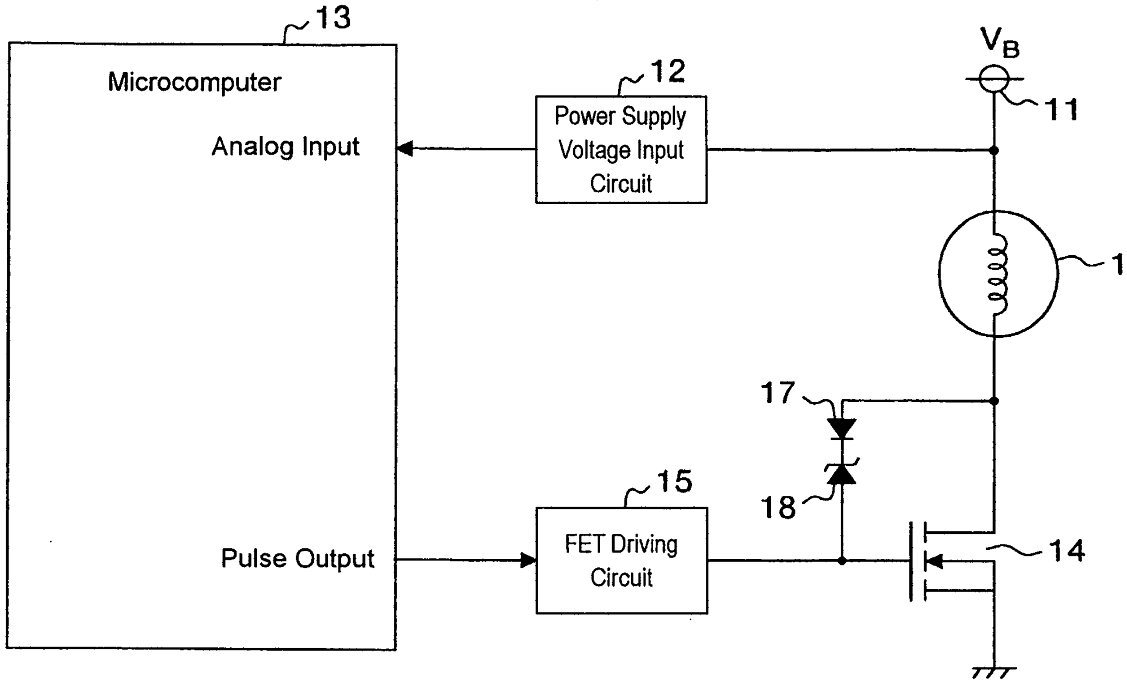
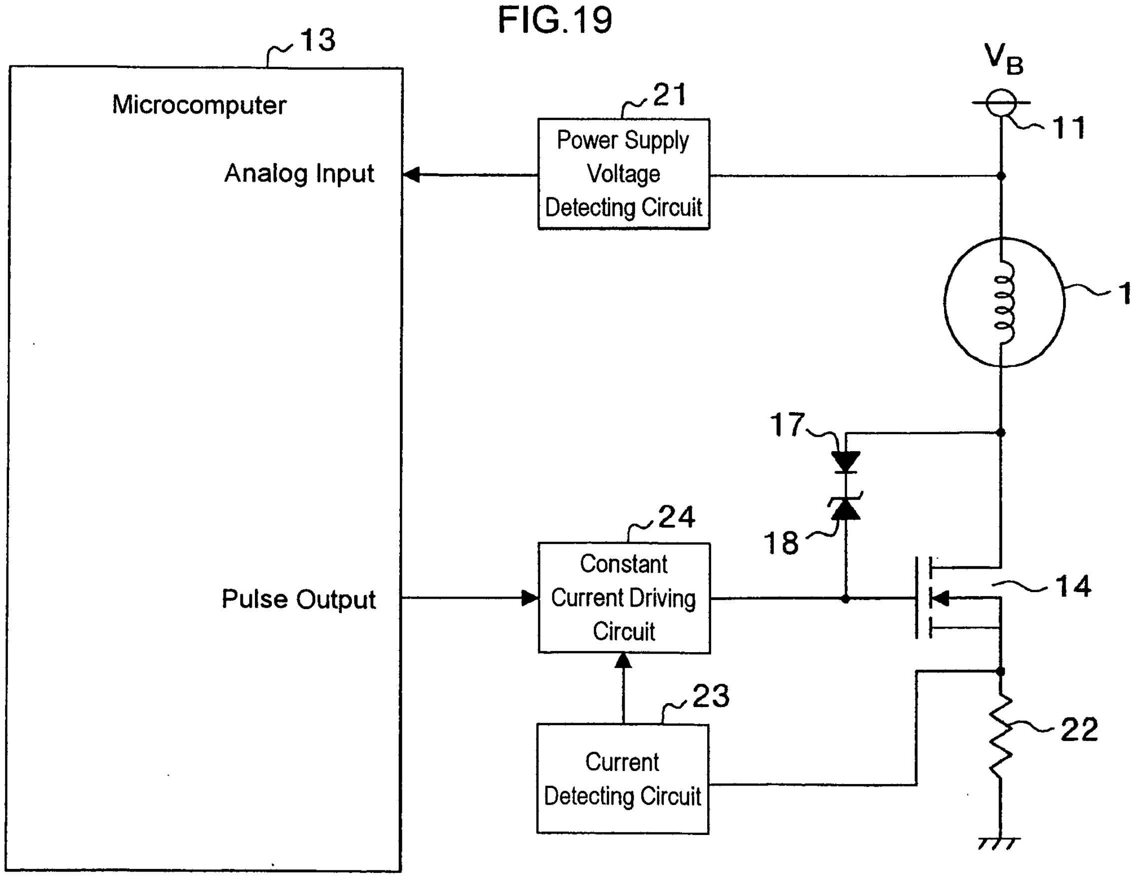

13
Microcomputer
Analog Input
Pulse Output
12
Power Supply Voltage Input Circuit
15
FET Driving Circuit
VB
11
17
18
14

FIG.19


13
Microcomputer
Analog Input
Pulse Output
21
Power Supply Voltage Detecting Circuit
24
Constant Current Driving Circuit
23
Current Detecting Circuit
VB
11
17
18
14
22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/000889

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 F02D41/20, F02M51/02

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.Cl^7 F02D41/20, F02M51/02, H01F7/18

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

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

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 Y A	JP 2000-337224 A (Hitachi, Ltd.), 05 December, 2000 (05.12.00), Full text; all drawings (Family: none)	1,2,7 3,4,8-11 5,6,12
Y A	JP 2001-193588 A (Mitsubishi Electric Corp.), 17 July, 2001 (17.07.01), Full text; all drawings (Family: none)	3,4,10,11 5,6,12
Y	US 4603669 A (Nippondenso Co., Ltd.), 05 August, 1986 (05.08.86), Full text; all drawings & JP 7-111151 B2	4,11

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March, 2004 (10.03.04)	23 March, 2004 (23.03.04)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/000889

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-110593 A (Nissan Motor Co., Ltd.), 18 April, 2000 (18.04.00), Full text; all drawings (Family: none)	8,9

Form PCT/ISA/210 (continuation of second sheet) (July 1998)