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

(11) **EP 1 139 444 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.10.2001 Bulletin 2001/40

(51) Int Cl.[7]: **H01L 41/04**, F02D 41/20, F02M 51/06

(21) Application number: **00106989.7**

(22) Date of filing: **01.04.2000**

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

(71) Applicant: **Robert Bosch GmbH**
70469 Stuttgart (DE)

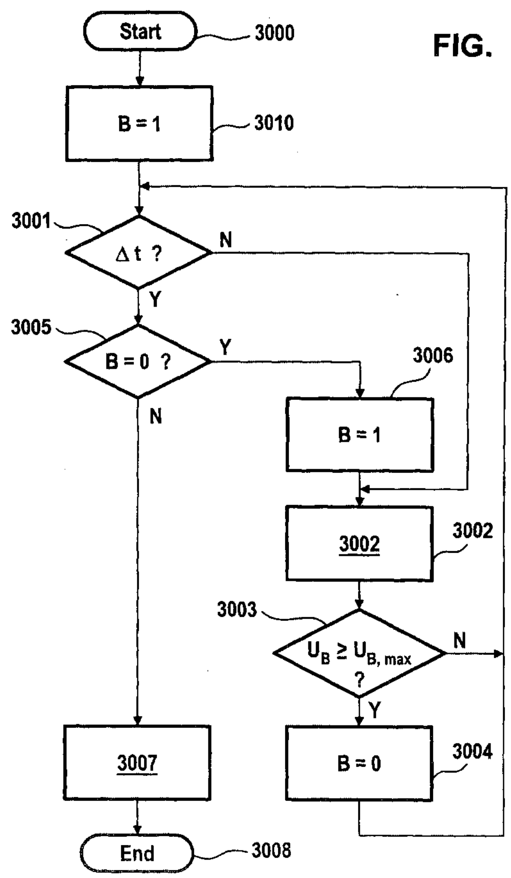
(72) Inventors:
- **Rueger, Johannes-Joerg**
  71665 Vaihingen/Enz (DE)
- **Hock, Alexander**
  71229 Leonberg (DE)
- **Schulz, Udo**
  71665 Vaihingen/Enz (DE)

(74) Representative:
Dreiss, Fuhlendorf, Steimle & Becker
Patentanwälte,
Postfach 10 37 62
70032 Stuttgart (DE)

(54) **Fuel injection system**

(57) Fuel injection system comprising a piezoelectric element for controlling the amount of injected fuel into a combustion engine, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element, the driving circuitry comprising a buffer capacitor, wherein the voltage across the buffer capacitor and/or the charge the buffer capacitor is carrying is measured.

FIG. 6



EP 1 139 444 A1

Description

[0001] The present invention relates to fuel injection system having piezoelectric elements.

[0002] Piezoelectric elements can be used for such purposes because they possess the property of contracting or expanding as a function of a voltage applied thereto or occurring therein. Fuel injection systems using piezoelectric elements are characterized by the fact that, to a first approximation, piezoelectric elements exhibit a proportional relationship between applied voltage and the linear expansion.

[0003] In a fuel injection nozzle, for example, implemented as a double acting, double seat valve to control the linear stroke of a needle for fuel injection into a cylinder of an internal combustion engine, the amount of fuel injected into a corresponding cylinder is a function of the time the valve is open, and where a piezoelectric element is used, the activation voltage applied to the piezoelectric element.

[0004] Fig. 7 is a schematic representation of a fuel injection system using a piezoelectric element 2010 as an actuator. Referring to Fig. 7, the piezoelectric element 2010 is electrically energized to expand and contract in response to a given activation voltage. The piezoelectric element 2010 is coupled to a piston 2015. In the expanded state, the piezoelectric element 2010 causes the piston 2015 to protrude into a hydraulic adapter 2020 which contains a hydraulic fluid, for example fuel. As a result of the piezoelectric element's expansion, a double acting control valve 2025 is hydraulically pushed away from hydraulic adapter 2020 and the valve plug 2035 is extended away from a first closed position 2040. The combination of double acting control valve 2025 and hollow bore 2050 is often referred to as double acting, double seat valve for the reason that when piezoelectric element 2010 is in an unexcited state, the double acting control valve 2025 rests in its first closed position 2040. On the other hand, when the piezoelectric element 2010 is fully extended, it rests in its second closed position 2030. The later position of valve plug 2035 is schematically represented with ghost lines in Fig. 7.

[0005] The fuel injection system comprises an injection needle 2070 allowing for injection of fuel from a pressurized fuel supply line 2060 into the cylinder (not shown) . When the piezoelectric element 2010 is unexcited or when it is fully extended, the double acting control valve 2025 rests respectively in its first closed position 2040 or in its second closed position 2030. In either case, the hydraulic rail pressure maintains injection needle 2070 at a closed position. Thus, the fuel mixture does not enter into the cylinder (not shown). Conversely, when the piezoelectric element 2010 is excited such that double acting control valve 2025 is in the so-called mid-position with respect to the hollow bore 2050, then there is a pressure drop in the pressurized fuel supply line 2060. This pressure drop results in a pressure differential in the pressurized fuel supply line 2060 between the top and the bottom of the injection needle 2070 so that the injection needle 2070 is lifted allowing for fuel injection into the cylinder (not shown).

[0006] In driving the piezoelectric element, power could be supplied directly from the battery. However, because of the fluctuating demands of the injection system it has been proposed to charge a buffer capacitor which would supply power to the injectors. In this model, a DC/DC converter converts the battery voltage to the desired voltage and ensures that the buffer capacitor remains adequately charged so as to meet the engine's demand. Bosch patent application "Fuel Injection System", attorney docket No. 10744/55, filed concurrently herewith and incorporated by reference in its entirety, discloses one such system.

[0007] To implement the DC/DC converter in a cost-effective manner, the converter is designed such that the drive signal is provided by an analog integrated circuit for driving the piezoelectric actuators. Thus, the voltage across a buffer capacitor is sensed by means of a voltage divider. The converter's current can be detected in the same way, although one skilled in the art would appreciate that other implementations are also feasible.

[0008] The drive system is always voltage controlled. That is, as long as the voltage of the buffer capacitor is below a predetermined level (*e.g.*, 250 V), the switch that is part of the DC/DC converter is cycled ON. Once the desired voltage has been reached, the switch, and thus the converter, are switched OFF. A problem arises when the voltage-sensing system fails. This failure can be caused by, for example, a short circuit involving a sensor lead. Another reason for failure can be that, as a low-side resistor gradually loses resistance, the voltage-sensing system can become more and more defective, until it finally and fails. If any of these failures occur, the activation IC (discussed in greater detail below) will not recognize that the desired voltage is reached. As a result, the switch is activated again, thereby charging the buffer again. This will continue until the buffer finally bursts, leading to destruction of the control unit.

[0009] It is an object of the present invention to avoid above-mentioned problems.

[0010] This object is achieved by a fuel injection system according to claim 1 and a method according to claim 12.

[0011] An inventive fuel injection system comprises a piezoelectric element for controlling the amount of injected fuel into a combustion engine, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element, the driving circuitry comprising a buffer capacitor, wherein the fuel injection system comprises a voltage measuring device for measuring or determining the voltage across the buffer capacitor.

[0012] In a preferred embodiment of the invention the voltage measuring device determines the voltage across the buffer capacitor at a predetermined time.

[0013] In a further preferred embodiment of the invention the voltage measuring device determines whether the voltage across the buffer capacitor reaches a predefined maximum voltage within a predetermined time interval.

[0014] In a further preferred embodiment of the invention the voltage measuring device determines whether the voltage across the buffer capacitor reaches a predefined maximum voltage at least once within a predetermined time interval.

[0015] The object is further achieved by a fuel injection system according to claim 5. Such a fuel injection system comprises a piezoelectric element for controlling the amount of injected fuel into a combustion engine, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element, the driving circuitry comprising a buffer capacitor capable of carrying a charge, wherein the fuel injection system comprises a charge measuring device for measuring the charge the buffer capacitor is carrying.

[0016] In a preferred embodiment of the invention the charge measuring device determines whether the charge reaches a predefined maximum charge within a predetermined time interval.

[0017] In a preferred embodiment of the invention the charge measuring device determines whether the charge reaches a predefined maximum charge at least once within a predetermined time interval.

[0018] In a further preferred embodiment of the invention the buffer capacitor having a capacitance of at least 25μF.

[0019] In a further preferred embodiment of the invention the predetermined time interval being equal to or less than ten cycles of injecting fuel by driving the piezoelectric element.

[0020] In a further preferred embodiment of the invention the predetermined time interval being equal to or less than five cycles of injecting fuel by driving the piezoelectric element.

[0021] In a further preferred embodiment of the invention the predetermined time interval being equal to one cycle of injecting fuel by driving the piezoelectric element.

[0022] Advantageous developments of the present invention are evident from the dependent claims, the description below, and with reference to the figures in which:

Fig. 1 shows a graph depicting the relationship between activation voltage and injected fuel volume in a fixed time period for the example of a double acting control valve;

Fig. 2 shows a schematic profile of an exemplary control valve stroke and a corresponding nozzle needle lift for the example of a double acting control valve;

Fig. 3 shows a block diagram of an exemplary embodiment of an arrangement in which the present invention may be implemented;

Fig. 4A shows a depiction to explain the conditions occurring during a first charging phase (charging switch 220 closed) in the circuit of Fig. 3;

Fig. 4B shows a depiction to explain the conditions occurring during a second charging phase (charging switch 220 open again) in the circuit of Fig. 3;

Fig. 4C shows a depiction to explain the conditions occurring during a first discharging phase (discharging switch 230 closed) in the circuit of Fig. 3;

Fig. 4D shows a depiction to explain the conditions occurring during a second discharging phase (discharging switch 230 open again) in the circuit of Fig. 3;

Fig. 5 shows a block diagram of components of the activation IC E which is also shown in Fig. 3;

Fig. 6 is a flowchart representation of a method of practicing the present invention; and

Fig. 7 schematically represents a fuel injector using a piezoelectric element as an actuator.

[0023] Fig. 1 shows a graph depicting the relationship between activation voltage U and injected fuel volume m_E during a preselected fixed time period, for an exemplary fuel injection system using piezoelectric elements acting upon double acting control valves. The y-axis represents volume m_E of fuel injected into a cylinder chamber during the preselected fixed period of time. The x-axis represents the activation voltage U applied to or stored in the corresponding piezoelectric element, used to displace a valve plug of the double acting control valve.

[0024] At x=0, y=0, the activation voltage U is zero, and the valve plug is seated in a first closed position to prevent the flow of fuel during the preselected fixed period of time. For values of the activation voltage greater than zero, up to the x-axis point indicated as U_{opt}, the represented values of the activation voltage U cause the displacement of the valve plug away from the first seat and towards the second seat, in a manner that results in a greater volume m_E of injected fuel for the fixed time period, as the activation voltage U approaches U_{opt}, up to the value for volume indicted on the y-axis by $m_{E,max}$. The point $m_{E,max}$, corresponding to the greatest volume for the injected fuel during the fixed period of time, represents the value of the activation voltage for application to or charging of the piezoelectric element, that results in an optimal displacement of the valve plug between the first and second valve seats.

[0025] As shown on the graph of Fig. 1, for values of the activation voltage greater than U_{opt}, the volume of fuel injected during the fixed period of time decrease until it reaches zero. This represents displacement of the valve plug from the optimal point and toward the second seat of the double seat valve until the valve plug is seated against the second valve seat. Thus, the graph of Fig. 1 illustrates that a maximum volume of fuel injection occurs when the activation voltage causes the piezoelectric element to displace the valve plug to the optimal point.

[0026] The present invention teaches that the value for U_{opt} at any given time for a particular piezoelectric element is influenced by the operating characteristics of the particular piezoelectric element at that time. That is, the amount of displacement caused by the piezoelectric element for a certain activation voltage varies as a function of the operating characteristics of the particular piezoelectric element. Accordingly, in order to achieve a maximum volume of fuel injection, $m_{E,max}$, during a given fixed period of time, the activation voltage applied to or occurring in the piezoelectric element should be set to a value relevant to current operating characteristics of the particular piezoelectric element, to achieve U_{opt}.

[0027] Fig. 2 shows a double graph representing a schematic profile of an exemplary control valve stroke, to illustrate the double seat valve operation discussed above. In the upper graph of Fig. 2, the x-axis represents time, and the y-axis represents displacement of the valve plug (valve lift). In the lower graph of Fig. 2, the x-axis once again represents time, while the y-axis represents a nozzle needle lift to provide fuel flow, resulting from the valve lift of the upper graph. The upper and lower graphs are aligned with one another to coincide in time, as represented by the respective x-axises.

[0028] During an injection cycle, the piezoelectric element is charged resulting in an expansion of the piezoelectric element, as will be described in greater detail, and causing the corresponding valve plug to move from the first seat to the second seat for a pre-injection stroke, as shown in the upper graph of Fig. 2. The lower graph of Fig. 2 shows a small injection of fuel that occurs as the valve plug moves between the two seats of the double seat valve, opening and closing the valve as the plug moves between the seats. In general, the charging of the piezoelectric element can be done in two steps: the first one is to charge it to a certain voltage and cause the valve to open and the second one is to charge it further and cause the valve to close again at the second seat. Between these steps, in general, there can be a certain time delay.

[0029] After a preselected period of time, a discharging operation is then performed, as will be explained in greater detail below, to reduce the charge within the piezoelectric element so that it contracts, as will also be described in greater detail, causing the valve plug to move away from the second seat, and hold at a midway point between the two seats. As indicated in Fig. 1, the activation voltage within the piezoelectric element is to reach a value that equals U_{opt} to correspond to an optimal point of the valve lift, and thereby obtain a maximum fuel flow, $m_{E,max}$, during the period of time allocated to a main injection. The upper and lower graphs of Fig. 2 show the holding of the valve lift at a midway point, resulting in a main fuel injection.

[0030] At the end of the period of time for the main injection, the piezoelectric element is discharged to an activation voltage of zero, resulting in further contraction of the piezoelectric element, to cause the valve plug to move away from the optimal position, towards the first seat, closing the valve and stopping fuel flow, as shown in the upper and lower graphs of Fig. 2. At this time, the valve plug will once again be in a position to repeat another pre-injection, main injection cycle, as just described above, for example. Of course, any other injection cycle can be performed.

[0031] Fig. 3 provides a block diagram of an exemplary embodiment of an arrangement in which the present invention may be implemented.

[0032] In Fig. 3 there is a detailed area A and a non-detailed area B, the separation of which is indicated by a dashed line c. The detailed area A comprises a circuit for charging and discharging piezoelectric elements 10, 20, 30, 40, 50 and 60. In the example being considered these piezoelectric elements 10, 20, 30, 40, 50 and 60 are elements in fuel injection nozzles (in particular in so-called common rail injectors) of an internal combustion engine. Piezoelectric elements can be used for such purposes because, as is known, and as discussed above, they possess the property of contracting or expanding as a function of a voltage applied thereto or occurring therein. The reason to take six piezoelectric elements 10, 20, 30, 40, 50 and 60 in the embodiment described is to independently control six cylinders within a combustion engine; hence, any other number of piezoelectric elements might match any other purpose.

[0033] The non-detailed area B comprises a control unit D and a activation IC E by both of which the elements within the detailed area A are controlled, as well as a measuring system F for measuring system operating characteristics such as, for example, fuel pressure and rotational speed (rpm) of the internal combustion engine for input to and use by the control unit D, according to the present invention, as will be described in detail below. According to the present invention, the control unit D and activation IC E are programmed to control activation voltages for piezoelectric elements as a function of operating characteristics of the each particular piezoelectric element.

[0034] The following description firstly introduces the individual elements within the detailed area A. Then, the procedures of charging and discharging piezoelectric elements 10, 20, 30, 40, 50, 60 are described in general. Finally, the ways both procedures are controlled by means of control unit D and activation IC E, according to the present invention, are described in detail.

[0035] The circuit within the detailed area A comprises six piezoelectric elements 10, 20, 30, 40, 50 and 60.

[0036] The piezoelectric elements 10, 20, 30, 40, 50 and 60 are distributed into a first group Gl and a second group G2, each comprising three piezoelectric elements (i.e. piezoelectric elements 10, 20 and 30 in the first group Gl resp. 40, 50 and 60 in the second group G2). Groups G1 and G2 are constituents of circuit parts connected in parallel with one another. Group selector switches 310, 320 can be used to establish which of the groups G1, G2 of piezoelectric elements 10, 20 and 30 resp. 40, 50 and 60 will be discharged in each case by a common charging and discharging apparatus (however, the group selector switches 310, 320 are meaningless for charging procedures, as is explained in further detail below).

[0037] The group selector switches 310, 320 are arranged between a coil 240 and the respective groups G1 and G2 (the coil-side terminals thereof) and are implemented as transistors. Side drivers 311, 321 are implemented which transform control signals received from the activation IC E into voltages which are eligible for closing and opening the switches as required.

[0038] Diodes 315 and 325 (referred to as group selector diodes), respectively, are provided in parallel with the group selector switches 310, 320. If the group selector switches 310, 320 are implemented as MOSFETs or IGBTs, these group selector diodes 315 and 325 can be constituted by the parasitic diodes themselves. The diodes 315, 325 bypass the group selector switches 310, 320 during charging procedures. Hence, the functionality of the group selector switches 310, 320 is reduced to select a group G1, G2 of piezoelectric elements 10, 20 and 30, resp. 40, 50 and 60 for a discharging procedure only.

[0039] Within each group G1 resp. G2 the piezoelectric elements 10, 20 and 30, resp. 40, 50 and 60 are arranged as constituents of piezoelectric branches 110, 120 and 130 (group G1) and 140, 150 and 160 (group G2) that are connected in parallel. Each piezoelectric branch comprises a series circuit made up of a first parallel circuit comprising a piezoelectric element 10, 20, 30, 40, 50 resp. 60 and a resistor 13, 23, 33, 43, 53 resp. 63 (referred to as branch resistors) and a second parallel circuit made up of a selector switch implemented as a transistor 11, 21, 31, 41, 51 resp. 61 (referred to as branch selector switches) and a diode 12, 22, 32, 42, 52 resp. 62 (referred to as branch diodes).

[0040] The branch resistors 13, 23, 33, 43, 53 resp. 63 cause each corresponding piezoelectric element 10, 20, 30, 40, 50 resp. 60 during and after a charging procedure to continuously discharge themselves, since they connect both terminals of each capacitive piezoelectric element 10, 20, 30, 40, 50, resp. 60 one to another. However, the branch resistors 13, 23, 33, 43, 53 resp. 63 are sufficiently large to make this procedure slow compared to the controlled charging and discharging procedures as described below. Hence, it is still a reasonable assumption to consider the charge of any piezoelectric element 10, 20, 30, 40, 50 or 60 as unchanging within a relevant time after a charging procedure (the reason to nevertheless implement the branch resistors 13, 23, 33, 43, 53 and 63 is to avoid remaining charges on the piezoelectric elements 10, 20, 30, 40, 50 and 60 in case of a breakdown of the system or other exceptional situations). Hence, the branch resistors 13, 23, 33, 43, 53 and 63 may be neglected in the following description.

[0041] The branch selector switch/branch diode pairs in the individual piezoelectric branches 110, 120, 130, 140, 150 resp. 160, i.e. selector switch 11 and diode 12 in piezoelectric branch 110, selector switch 21 and diode 22 in piezoelectric branch 120, and so on, can be implemented using electronic switches (i.e. transistors) with parasitic diodes, for example MOSFETs or IGBTs (as stated above for the group selector switch/diode pairs 310 and 315 resp. 320 and 325).

[0042] The branch selector switches 11, 21, 31, 41, 51 resp. 61 can be used to establish which of the piezoelectric elements 10, 20, 30, 40, 50 or 60 will be charged in each case by a common charging and discharging apparatus: in each case, the piezoelectric elements 10, 20, 30, 40, 50 or 60 that are charged are all those whose branch selector switches 11, 21, 31, 41, 51 or 61 are closed during the charging procedure which is described below. Usually, at any time only one of the branch selector switches is closed.

[0043] The branch diodes 12, 22, 32, 42, 52 and 62 serve for bypassing the branch selector switches 11, 21, 31, 41, 51 resp. 61 during discharging procedures. Hence, in the example considered for charging procedures any individual piezoelectric element can be selected, whereas for discharging procedures either the first group G1 or the second group G2 of piezoelectric elements 10, 20 and 30 resp. 40, 50 and 60 or both have to be selected.

[0044] Returning to the piezoelectric elements 10, 20, 30, 40, 50 and 60 themselves, the branch selector piezoelectric terminals 15, 25, 35, 45, 55 resp. 65 may be connected to ground either through the branch selector switches 11, 21, 31, 41, 51 resp. 61 or through the corresponding diodes 12, 22, 32, 42, 52 resp. 62 and in both cases additionally through resistor 300.

[0045] The purpose of resistor 300 is to measure the currents that flow during charging and discharging of the piezoelectric elements 10, 20, 30, 40, 50 and 60 between the branch selector piezoelectric terminals 15, 25, 35, 45, 55 resp. 65 and the ground. A knowledge of these currents allows a controlled charging and discharging of the piezoelectric elements 10, 20, 30, 40, 50 and 60. In particular, by closing and opening charging switch 220 and discharging switch 230 in a manner dependent on the magnitude of the currents, it is possible to set the charging current and discharging current to predefined average values and/or to keep them from exceeding or falling below predefined maximum and/or minimum values as is explained in further detail below.

[0046] In the example considered, the measurement itself further requires a voltage source 621 which supplies a voltage of 5 V DC, for example, and a voltage divider implemented as two resistors 622 and 623. This is in order to prevent the activation IC E (by which the measurements are performed) from negative voltages which might otherwise occur on measuring point 620 and which cannot be handled by means of activation IC E: such negative voltages are changed into positive voltages by means of addition with a positive voltage setup which is supplied by voltage source 621 and voltage divider resistors 622 and 623.

[0047] The other terminal of each piezoelectric element 10, 20, 30, 40, 50 and 60, i.e. the group selector piezoelectric terminal 14, 24, 34, 44, 54 resp. 64, may be connected to the plus pole of a voltage source via the group selector switch 310 resp. 320 or via the group selector diode 315 resp. 325 as well as via a coil 240 and a parallel circuit made up of a charging switch 220 and a charging diode 221, and alternatively or additionally connected to ground via the group selector switch 310 resp. 320 or via diode 315 resp. 325 as well as via the coil 240 and a parallel circuit made up of a discharging switch 230 or a discharging diode 231. Charging switch 220 and discharging switch 230 are implemented as transistors, for example, which are controlled via side drivers 222 resp. 232.

[0048] The voltage source comprises an element having capacitive properties which, in the example being considered, is the (buffer) capacitor 210. Capacitor 210 is charged by a battery 200 (for example a motor vehicle battery) and a DC voltage converter 201 downstream therefrom. DC voltage converter 201 converts the battery voltage (for example, 12 V) into substantially any other DC voltage (for example, 250 V), and charges capacitor 210 to that voltage. DC voltage converter 201 is controlled by means of transistor switch 202 and resistor 203 which is utilized for current measurements taken from a measuring point 630.

[0049] For cross check purposes, a further current measurement at a measuring point 650 is allowed by activation IC E as well as by resistors 651, 652 and 653 and a 5 V DC voltage, for example, source 654; moreover, a voltage measurement at a measuring point 640 is allowed by activation IC E as well as by voltage dividing resistors 641 and 642.

[0050] Finally, a resistor 330 (referred to as total discharging resistor), a stop switch implemented as a transistor 331 (referred to as stop switch), and a diode 332 (referred to as total discharging diode) serve to discharge the piezoelectric elements 10, 20, 30, 40, 50 and 60 (if they happen to be not discharged by the "normal" discharging operation as described further below). Stop switch 331 is preferably closed after "normal" discharging procedures (cycled discharging via discharge switch 230). It thereby connects piezoelectric elements 10, 20, 30, 40, 50 and 60 to ground through resistors 330 and 300, and thus removes any residual charges that might remain in piezoelectric elements 10, 20, 30, 40, 50 and 60. The total discharging diode 332 prevents negative voltages from occurring at the piezoelectric elements 10, 20, 30, 40, 50 and 60, which might in some circumstances be damaged thereby.

[0051] In such systems, it is desirable that the load on the battery voltage is as uniform as possible so that the battery voltage fluctuations are minimized. In the system described above, there is no direct drive of the elements 10, 20, 30, 40, 50 and 60 from the battery 200 voltage. Therefore, when driving the elements 10, 20, 30, 40, 50 and 60, there are no direct effects on battery voltage. The battery supplies power to the DC converter 201 until the desired voltage is reached (for example, 250V) at which point the battery voltage drops somewhat (for example, .5V) below what it would be in an unloaded condition. Such a voltage drop effects the entire electrical system to which the battery is supplying power. Other sensors, and in particular, elements such as those used for rail pressure regulation, exhibit voltage dependence. If the voltage collapses, this effects the accuracy with which those elements operate.

[0052] It is desirable to provide for charging the primary side (battery side) current limit of the converter 201 as a function of the operating, or output, side voltage value so that the drive of the converter will operate continuously, or almost continuously and provide approximately just enough power to drive the elements 10, 20, 30, 40, 50 and 60. Such a scenario is possible because the information regarding the number of fuel injection operations planned is present in the control unit. In other words, the energy requirement of the output stage is known. Moreover, the current limit on the primary side can be updated continuously by way of the SPI in the activation IC E.

[0053] The control described above could be performed by a converter control unit (not shown, but described in greater detail below) that would determine the energy requirement of the output stage per unit of time from the engine speed, number of cylinders in the engine, number of drive operations, and maximum voltage used for the drive operation. From this energy requirement, the necessary DC/DC current can be determined by means of a characteristic curve. This is the maximum primary side current wherein the converter 201 operates at a fixed frequency. If the primary side current is increased, the converter supplies more power and vise versa.

[0054] The value can be determined by multiplying the number of cylinders by the number of drive operations per 720° of crankshaft angle. This value is then multiplied by the energy required for charging to the maximum voltage used for the drive operation. This is a function of the efficiency of the DC/DC converter, the efficiency of the output stage, and the efficiency of the piezoelectric elements 10, 20, 30, 40, 50 and 60. This product is divided by the engine speed to provide the energy required by the output stage. In order to ensure that the energy required by the output stage is provided reliably, a safety factor can be included (for example, multiplying by 1.1).

[0055] Charging and discharging of all the piezoelectric elements 10, 20, 30, 40, 50 and 60 or any particular one is accomplished by way of a single charging and discharging apparatus (common to all the groups and their piezoelectric elements). In the example being considered, the common charging and discharging apparatus comprises battery 200, DC voltage converter 201, capacitor 210, charging switch 220 and discharging switch 230, charging diode 221 and discharging diode 231 and coil 240.

[0056] The charging and discharging of each piezoelectric element works the same way and is explained in the following while referring to the first piezoelectric element 10 only.

[0057] The conditions occurring during the charging and discharging procedures are explained with reference to Figs. 4A through 4D, of which Figs. 4A and 4B illustrate the charging of piezoelectric element 10, and Figs. 4C and 4D the discharging of piezoelectric element 10.

[0058] The selection of one or more particular piezoelectric elements 10, 20, 30, 40, 50 or 60 to be charged or discharged, the charging procedure as described in the following as well as the discharging procedure are driven by activation IC E and control unit D by means of opening or closing one or more of the above introduced switches 11, 21, 31, 41, 51, 61; 310, 320; 220, 230 and 331. The interactions between the elements within the detailed area A on the one hand and activation IC E and control unit D on the other hand are described in detail further below.

[0059] Concerning the charging procedure, firstly any particular piezoelectric element 10, 20, 30, 40, 50 or 60 which is to be charged has to be selected. In order to exclusively charge the first piezoelectric element 10, the branch selector switch 11 of the first branch 110 is closed, whereas all other branch selector switches 21, 31, 41, 51 and 61 remain opened. In order to exclusively charge any other piezoelectric element 20, 30, 40, 50, 60 or in order to charge several ones at the same time they would be selected by closing the corresponding branch selector switches 21, 31, 41, 51 and/or 61.

[0060] Then, the charging procedure itself may take place:

[0061] Generally, within the example considered, the charging procedure requires a positive potential difference between capacitor 210 and the group selector piezoelectric terminal 14 of the first piezoelectric element 10. However, as long as charging switch 220 and discharging switch 230 are open no charging or discharging of piezoelectric element 10 occurs: In this state, the circuit shown in Fig. 3 is in a steady-state condition, i.e. piezoelectric element 10 retains its charge state in substantially unchanged fashion, and no currents flow.

[0062] In order to charge the first piezoelectric element 10, charging switch 220 is closed. Theoretically, the first piezoelectric element 10 could become charged just by doing so. However, this would produce large currents which might damage the elements involved. Therefore, the occurring currents are measured at measuring point 620 and switch 220 is opened again as soon as the detected currents exceed a certain limit. Hence, in order to achieve any desired charge on the first piezoelectric element 10, charging switch 220 is repeatedly closed and opened whereas discharging switch 230 remains open.

[0063] In more detail, when charging switch 220 is closed, the conditions shown in Fig. 4A occur, i.e. a closed circuit comprising a series circuit made up of piezoelectric element 10, capacitor 210, and coil 240 is formed, in which a current $i_{LE}(t)$ flows as indicated by arrows in Fig. 4A. As a result of this current flow both positive charges are brought to the group selector piezoelectric terminal 14 of the first piezoelectric element 10 and energy is stored in coil 240.

[0064] When charging switch 220 opens shortly (for example, a few µs) after it has closed, the conditions shown in Fig. 4B occur: a closed circuit comprising a series circuit made up of piezoelectric element 10, charging diode 221, and coil 240 is formed, in which a current $i_{LA}(t)$ flows as indicated by arrows in Fig. 4B. The result of this current flow is that energy stored in coil 240 flows into piezoelectric element 10. Corresponding to the energy delivery to the piezoelectric element 10, the voltage occurring in the latter, and its external dimensions, increase. Once energy transport has taken place from coil 240 to piezoelectric element 10, the steady-state condition of the circuit, as shown in Fig. 3 and already described, is once again attained.

[0065] At that time, or earlier, or later (depending on the desired time profile of the charging operation), charging switch 220 is once again closed and opened again, so that the processes described above are repeated. As a result of the re-closing and re-opening of charging switch 220, the energy stored in piezoelectric element 10 increases (the energy already stored in the piezoelectric element 10 and the newly delivered energy are added together), and the voltage occurring at the piezoelectric element 10, and its external dimensions, accordingly increase.

[0066] If the aforementioned closing and opening of charging switch 220 are repeated numerous times, the voltage occurring at the piezoelectric element 10, and the expansion of the piezoelectric element 10, rise in steps.

[0067] Once charging switch 220 has closed and opened a predefined number of times, and/or once piezoelectric element 10 has reached the desired charge state, charging of the piezoelectric element is terminated by leaving charging switch 220 open.

[0068] Concerning the discharging procedure, in the example considered, the piezoelectric elements 10, 20, 30, 40, 50 and 60 are discharged in groups (G1 and/or G2) as follows:

[0069] Firstly, the group selector switch(es) 310 and/or 320 of the group or groups G1 and/or G2 the piezoelectric elements of which are to be discharged are closed (the branch selector switches 11, 21, 31, 41, 51, 61 do not affect the selection of piezoelectric elements 10, 20, 30, 40, 50, 60 for the discharging procedure, since in this case they are bypassed by the branch diodes 12, 22, 32, 42, 52 and 62). Hence, in order to discharge piezoelectric element 10 as a part of the first group G1, the first group selector switch 310 is closed.

[0070] When discharging switch 230 is closed, the conditions shown in Fig. 4C occur: a closed circuit comprising a series circuit made up of piezoelectric element 10 and coil 240 is formed, in which a current $i_{EE}(t)$ flows as indicated by arrows in Fig. 4C. The result of this current flow is that the energy (a portion thereof) stored in the piezoelectric element is transported into coil 240. Corresponding to the energy transfer from piezoelectric element 10 to coil 240, the voltage occurring at the piezoelectric element 10, and its external dimensions, decrease.

[0071] When discharging switch 230 opens shortly (for example, a few µs) after it has closed, the conditions shown in Fig. 4D occur: a closed circuit comprising a series circuit made up of piezoelectric element 10, capacitor 210, discharging diode 231, and coil 240 is formed, in which a current $i_{EA}(t)$ flows as indicated by arrows in Fig. 4D. The result of this current flow is that energy stored in coil 240 is fed back into capacitor 210. Once energy transport has taken place from coil 240 to capacitor 210, the steady-state condition of the circuit, as shown in Fig. 3 and already described, is once again attained.

[0072] At that time, or earlier, or later (depending on the desired time profile of the discharging operation), discharging switch 230 is once again closed and opened again, so that the processes described above are repeated. As a result of the re-closing and re-opening of discharging switch 230, the energy stored in piezoelectric element 10 decreases further, and the voltage occurring at the piezoelectric element, and its external dimensions, also accordingly decrease.

[0073] If the aforementioned closing and opening of discharging switch 230 are repeated numerous times, the voltage occurring at the piezoelectric element 10, and the expansion of the piezoelectric element 10, decrease in steps.

[0074] Once discharging switch 230 has closed and opened a predefined number of times, and/or once the piezoelectric element has reached the desired discharge state, discharging of the piezoelectric element 10 is terminated by leaving discharging switch 230 open.

[0075] The interaction between activation IC E and control unit D on the one hand and the elements within the detailed area A on the other hand is performed by control signals sent from activation IC E to elements within the detailed area A via branch selector control lines 410, 420, 430, 440, 450, 460, group selector control lines 510, 520, stop switch control line 530, charging switch control line 540 and discharging switch control line 550 and control line 560. On the other hand, there are sensor signals obtained on measuring points 600, 610, 620, 630, 640, 650 within the detailed area A which are transmitted to activation IC E via sensor lines 700, 710, 720, 730, 740, 750.

[0076] The control lines are used to apply or not to apply voltages to the transistor bases in order to select piezoelectric elements 10, 20, 30, 40, 50 or 60, to perform charging or discharging procedures of single or several piezoelectric elements 10, 20, 30, 40, 50, 60 by means of opening and closing the corresponding switches as described above. The sensor signals are particularly used to determine the resulting voltage of the piezoelectric elements 10, 20 and 30, resp. 40, 50 and 60 from measuring points 600 resp. 610 and the charging and discharging currents from measuring point 620. The control unit D and the activation IC E are used to combine both kinds of signals in order to perform an interaction of both as will be described in detail now while referring to Figs. 3 and 5.

[0077] As is indicated in Fig. 3, the control unit D and the activation IC E are connected to each other by means of a parallel bus 840 and additionally by means of a serial bus 850. The parallel bus 840 is particularly used for fast transmission of control signals from control unit D to the activation IC E, whereas the serial bus 850 is used for slower data transfer.

[0078] In Fig. 5 some components are indicated, which the activation IC E comprises: a logic circuit 800, RAM memory 810, digital to analog converter system 820 and cooperator system 830. Furthermore, it is indicated that the fast parallel bus 840 (used for control signals) is connected to the logic circuit 800 of the activation IC E, whereas the slower serial bus 850 is connected to the RAM memory 810. The logic circuit 800 is connected to the RAM memory 810, to the cooperator system 830 and to the signal lines 410, 420, 430, 440, 450 and 460; 510 and 520; 530; 540, 550 and 560. The RAM memory 810 is connected to the logic circuit 800 as well as to the digital to analog converter system 820. The digital to analog converter system 820 is further connected to the cooperator system 830. The cooperator system 830 is further connected to the sensor lines 700 and 710; 720; 730, 740 and 750 and -as already mentioned-to the logic circuit 800.

[0079] The above listed components may be used in a charging procedure for example as follows:

[0080] By means of the control unit D a particular piezoelectric element 10, 20, 30, 40, 50 or 60 is determined which is to be charged to a certain target voltage. Hence, firstly the value of the target voltage (expressed by a digital number) is transmitted to the RAM memory 810 via the slower serial bus 850. The target voltage can be, for example, the value for U_{opt} used in a main injection, as described above with respect to Fig. 1. Later or simultaneously, a code corresponding to the particular piezoelectric element 10, 20, 30, 40, 50 or 60 which is to be selected and the address of the desired voltage within the RAM memory 810 is transmitted to the logic circuit 800 via the parallel bus 840. Later on, a strobe signal is sent to the logic circuit 800 via the parallel bus 840 which gives the start signal for the charging procedure.

[0081] The start signal firstly causes the logic circuit 800 to pick up the digital value of the target voltage from the RAM memory 810 and to put it on the digital to analog converter system 820 whereby at one analog exit of the converters 820 the desired voltage occurs. Moreover, said analog exit (not shown) is connected to the cooperator system 830. In addition hereto, the logic circuit 800 selects either measuring point 600 (for any of the piezoelectric elements 10, 20 or 30 of the first group G1) or measuring point 610 (for any of the piezoelectric elements 40, 50 or 60 of the second group G2) to the cooperator system 830. Resulting thereof, the target voltage and the present voltage at the selected piezoelectric element 10, 20, 30, 40, 50 or 60 are compared by the cooperator system 830. The results of the comparison, i.e. the differences between the target voltage and the present voltage, are transmitted to the logic circuit 800. Thereby, the logic circuit 800 can stop the procedure as soon as the target voltage and the present voltage are equal to one another.

[0082] Secondly, the logic circuit 800 applies a control signal to the branch selector switch 11, 21, 31, 41, 51 or 61 which corresponds to any selected piezoelectric element 10, 20, 30, 40, 50 or 60 so that the switch becomes closed (all branch selector switches 11; 21, 31, 41, 51 and 61 are considered to be in an open state before the onset of the charging procedure within the example described). Then, the logic circuit 800 applies a control signal to the charging switch 220 so that the switch becomes closed. Furthermore, the logic circuit 800 starts (or continues) measuring any currents occurring on measuring point 620. Hereto, the measured currents are compared to any predefined maximum value by the cooperator system 830. As soon as the predefined maximum value is achieved by the detected currents, the logic circuit 800 causes the charging switch 220 to open again.

[0083] Again, the remaining currents at measuring point 620 are detected and compared to any predefined minimum value. As soon as said predefined minimum value is achieved, the logic circuit 800 causes the charging switch 220 to close again and the procedure starts once again.

[0084] The closing and opening of the charging switch 220 is repeated as long as the detected voltage at measuring point 600 or 610 is below the target voltage. As soon as the target voltage is achieved, the logic circuit stops the continuation of the procedure.

[0085] The discharging procedure takes place in a corresponding way: Now the selection of the piezoelectric element 10, 20, 30, 40, 50 or 60 is obtained by means of the group selector switches 310 resp. 320, the discharging switch 230 instead of the charging switch 220 is opened and closed and a predefined minimum target voltage is to be achieved.

[0086] The timing of the charging and discharging operations and the holding of voltage levels in the piezoelectric elements 10, 20, 30, 40, 50 or 60, as for example, the time of a main injection, can be according to a valve stroke, as shown, for example, in Fig. 2.

[0087] It is to be understood that the above given description of the way charging or discharging procedures take place are exemplary only. Hence, any other procedure which utilizes the above described circuits or other circuits might match any desired purpose and any corresponding procedure may be used in place of the above described example.

[0088] As stated above, in order to improve voltage uniformity the piezoelectric elements are charged by using buffer capacitor 210. A DC/DC converter 201 is disposed between buffer capacitor 210 and battery 200 and is responsible for providing adequately charging buffer capacitor 210. Thus, there is no direct effect on the battery even when the piezoelectric elements are charged. In addition, the primary side of converter 201 can be controlled as a function of the engine's demands (or anticipated demand) to provide an even more uniform voltage to buffer capacitor 210. A drive signal is provided by IC E to DC/DC converter. In addition, as described the voltage across buffer capacitor 210 is measured by means of voltage divider. As long as the buffer voltage is below a set level (*e.g.*, 250 V) the switch that is part of the DC/DC converter is cycled ON and OFF. Once the desired voltage is reached, the switch and consequently the converter 201 are turned OFF. In order to detect a possible voltage sensor failure, the present invention provides for a secondary method to stop charging buffer capacitor 210.

[0089] More specifically, in the above-described sensor failure case, the DC/DC converter switch is permanently activated or the desired voltage is never reached. If there is no failure, DC/DC converter 201 must be switched off at least once per every 720° rotation of the crankshaft angle (in the stationary operation). Accordingly, an embodiment of the present invention provides for sending a signal over the TPU interface of the activation IC E, signaling the IC that 720° of crankshaft angle has passed. At the same time a bit is to be provided in the IC that is set when the "720° of crankshaft angle signal" arrives and is reset by the DC/DC converter system once the buffer voltage reaches the desired value. If the bit is not set when the "720° of crankshaft angle signal" arrives, there is an indication of a system failure. This situation can be entered in the diagnostic register of the IC and can be read by way of the SPI interface.

[0090] Therefore, the diagnostic action can detect at least the following failures:

(i) Failure of the voltage-sensing system;

(ii) defective voltage sensing system (e.g., low resistance);

(iii) too many fuel injection actions programmed or incorrect voltage, or an application error in which the drive system requires more energy than listed in the performance specifications;

(iv) unfavorable operating conditions (for example, low temperature), such that the voltage across the buffer electrolytic capacitor drops during the drive operation to a greater degree than specified, for example, -40° C. For lower temperatures the system can still attempt operation and problems can be detected; and

(v) The Electrical Serial Resistance of a building part ("ESR") of the buffer electrolytic capacitor is too large (for example, because of a long service life).

[0091] A failure by the voltage-sensing system always results in system failure. In response, the output stage can be switched OFF.

[0092] In the cases (iii), (iv) and (v) , the failure is either temporarily or permanently caused by the application software. In these cases, the load on the converter can be reduced, for example, by omitting certain fuel injection operations. This affects both the pre-injection and post injection drive operations. Because the drive voltage for the common rail system also depends on the rail pressure, the desired rail pressure can be decreased as an alternative to reducing the drive power. If these measures have no effect, this indicates that the voltage-sensing system has likely failed. As a result the output stage must be switched OFF.

[0093] Fig. 6 shows a flowchart representation of one method for practicing the present invention which can be implemented on control unit D. The start of the flow chart and the end of the flow chart are denoted with reference numbers 3000 and 3008 respectively. The program starts with an initialization step 3010 setting a bit B to 1. Step 3010 is followed by a step 3001 checking whether a certain time limit Δt is expired. In the present invention this time limit Δt relates to 720° of crank shaft angle rotation. If Δt has not expired (the crank shaft angle has not passed 720°) decision block 3001 is followed by step 3002 measuring the voltage U_B across the buffer capacitor 210. Alternatively, the charge of the buffer capacitor 210 is measured in step 3002 and used to calculate the voltage U_B across buffer capacitor 210. Step 3002 is followed by decision block 3003 deciding whether the voltage U_B across the buffer capacitor 210 is greater than or equal to a target value $U_{B,max}$ for the voltage U_B across the buffer capacitor 210, i.e., it is checked whether the voltage U_B across the capacitor 210 has reached the target value $U_{B,max}$. If the target value $U_{B,max}$ is reached the bit B is reset, *i.e.,* B = 0 (step 3004). Step 3004 is followed by decision block 3001. If the target value $U_{B,max}$ is not reached, decision block 3003 is followed by decision block 3001.

[0094] If Δt is expired, *i.e.*, the crank shaft angle has reached or passed 720° the decision block 3001 is followed by decision block 3005. Decision block 3005 checks whether the bit B has been reset, *i.e.*, whether B = 0. If this condition is fulfilled, decision block 3005 is followed by step 3006 setting the bit B again, *i.e.*, B = 1. Also Δt is reset. Step 3006 is followed by step 3002. If the bit B has not been reset, decision block 3005 is followed by step 3007 defining that a failure has occurred.

Claims

1. Fuel injection system comprising a piezoelectric element (10, 20, 30, 40, 50 or 60) for controlling the amount of injected fuel into a combustion engine, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element (10, 20, 30, 40, 50 or 60), the driving circuitry comprising a buffer capacitor (210),
characterized in that
the fuel injection system comprises a voltage measuring device for measuring or determining the voltage across the buffer capacitor (210).

2. Fuel injection system according to claim 1,
characterized in that
the voltage measuring device determines the voltage across the buffer capacitor (210) at a predetermined time.

3. Fuel injection system according to claim 1 or 2,
characterized in that
the voltage measuring device determines whether the voltage across the buffer capacitor (210) reaches a predefined maximum voltage within a predetermined time interval.

4. Fuel injection system according to claim 1 or 2,
characterized in that
the voltage measuring device determines whether the voltage across the buffer capacitor (210) reaches a predefined maximum voltage at least once within a predetermined time interval.

5. Fuel injection system comprising a piezoelectric element (10, 20, 30, 40, 50 or 60) for controlling the amount of injected fuel into a combustion engine, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element (10,

20, 30, 40, 50 or 60), the driving circuitry comprising a buffer capacitor (210) capable of carrying a charge,
characterized in that
the fuel injection system comprises a charge measuring device for measuring the charge the buffer capacitor (210) is carrying.

6. Fuel injection system according to claim 5,
characterized in that
the charge measuring device determines whether the charge reaches a predefined maximum charge within a predetermined time interval.

7. Fuel injection system according to claim 5,
characterized in that
the charge measuring device determines whether the charge reaches a predefined maximum charge at least once within a predetermined time interval.

8. Fuel injection system according to one of the foregoing claims,
characterized in that
the buffer capacitor (210) has a capacitance of at least 25μF.

9. Fuel injection system according to claim 3, 4, 6 or 7,
characterized in that
the predetermined time interval is equal to or less than ten cycles of injecting fuel by driving the piezoelectric element (10, 20, 30, 40, 50 or 60).

10. Fuel injection system according to claim 9,
characterized in that
the predetermined time interval is equal to or less than five cycles of injecting fuel by driving the piezoelectric element (10, 20, 30, 40, 50 or 60).

11. Fuel injection system according to claim 10,
characterized in that
the predetermined time interval is equal to one cycle of injecting fuel by driving the piezoelectric element (10, 20, 30, 40, 50 or 60).

12. Method for operating a fuel injection system comprising a piezoelectric element (10, 20, 30, 40, 50 or 60) for controlling the amount of injected fuel into a combustion engine, in particular for operating a fuel injection system according to one of the foregoing claims, the fuel injection system further comprising a driving circuitry for driving the piezoelectric element (10, 20, 30, 40, 50 or 60), the driving circuitry comprising a buffer capacitor (210),
characterized in that
the voltage across the buffer capacitor (210) and/or the charge the buffer capacitor (210) is carrying is measured.

FIG. 1

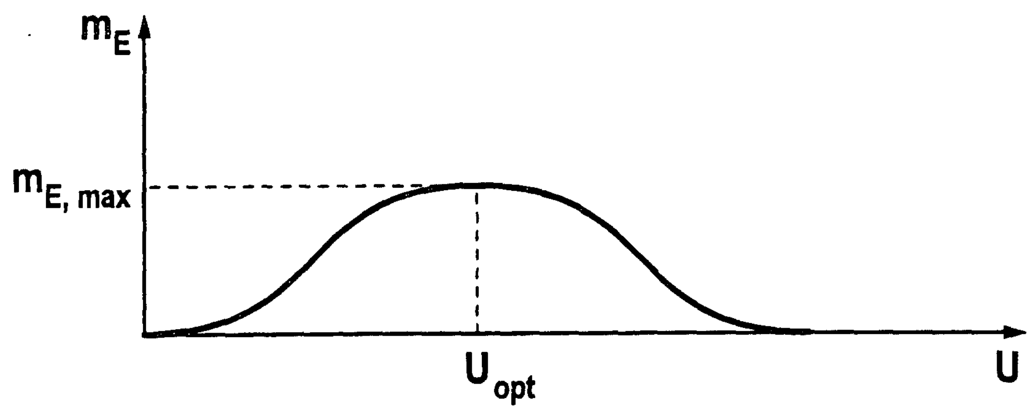
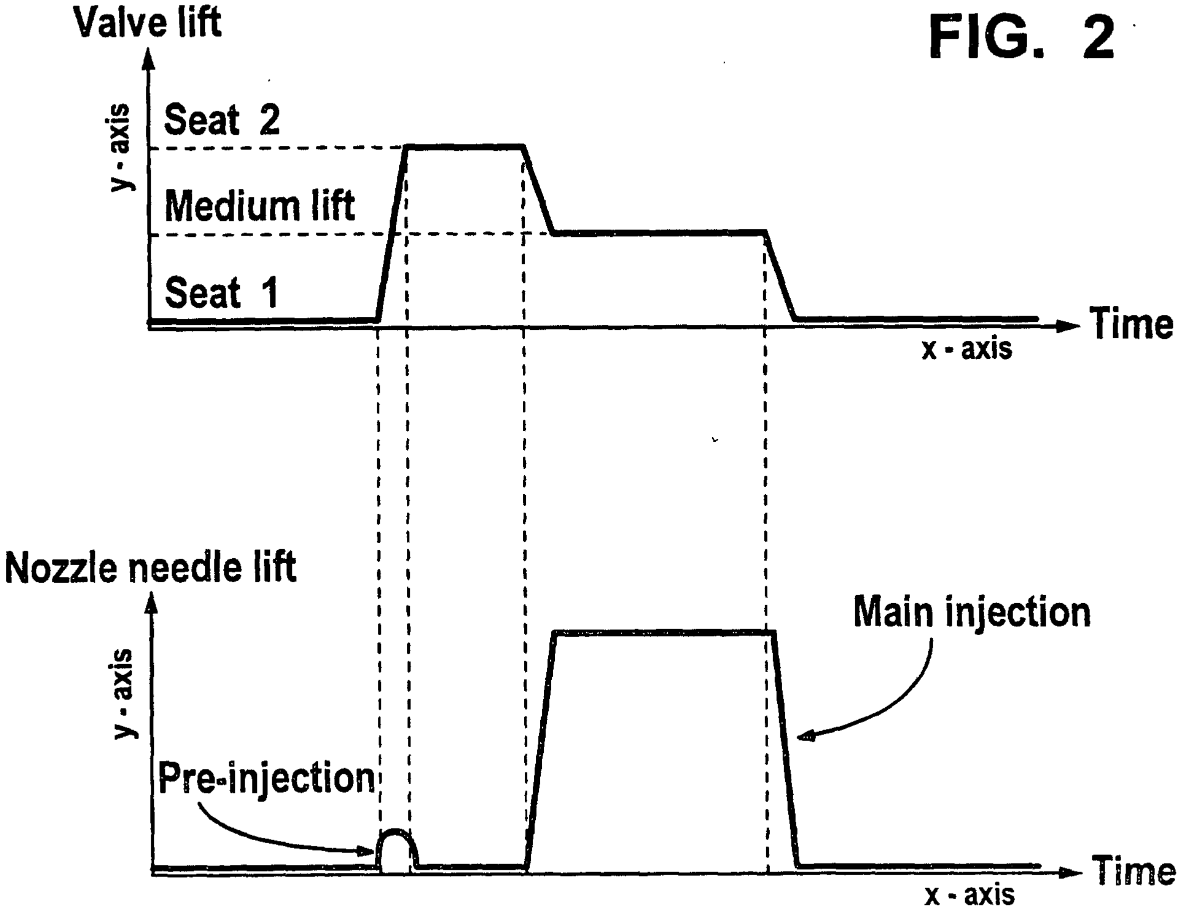

m_E
$m_{E, max}$
U_{opt}
U

FIG. 2


Valve lift
y - axis
Seat 2
Medium lift
Seat 1
Time
x - axis
Nozzle needle lift
Main injection
y - axis
Pre-injection
Time
x - axis

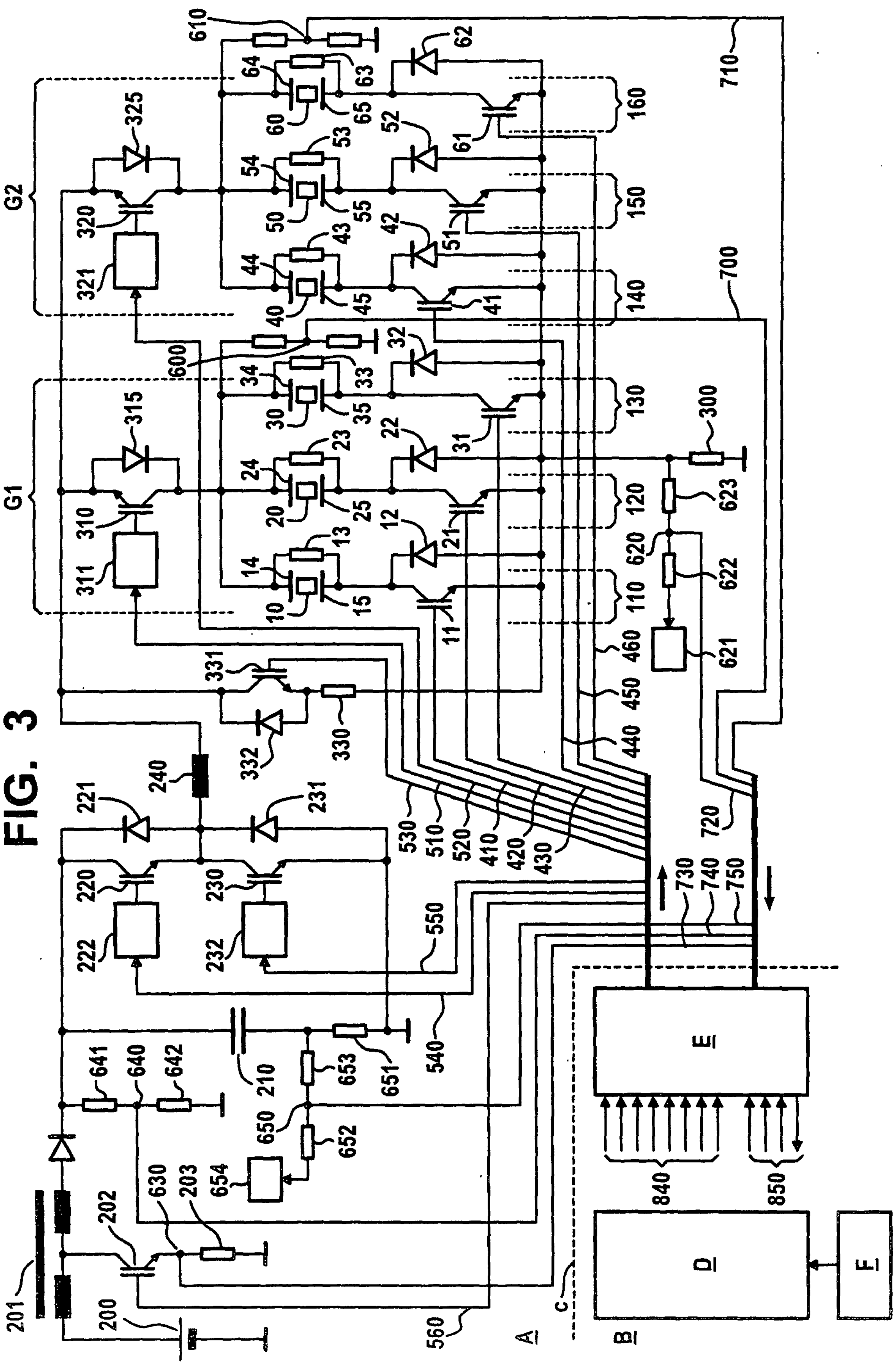


FIG. 3

FIG. 4A

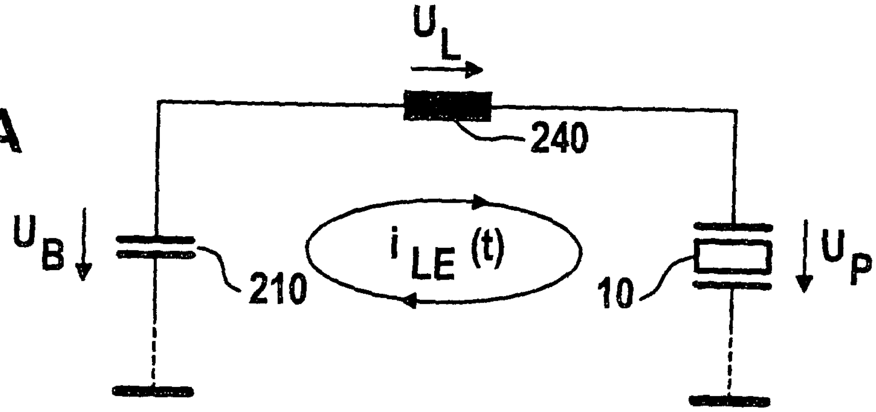


FIG. 4B

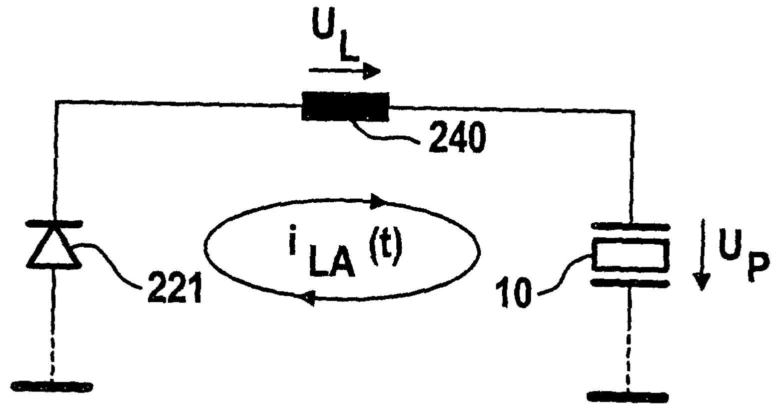


FIG. 4C

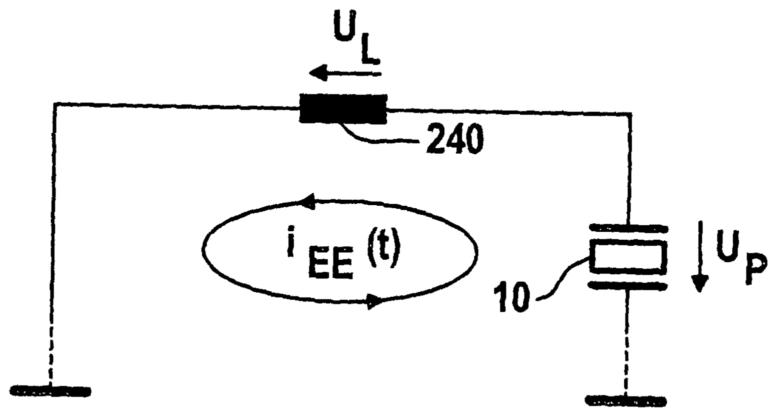
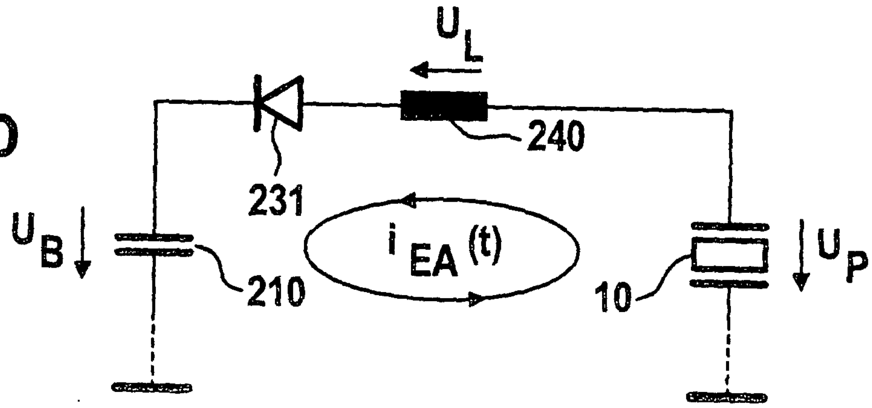


FIG. 4D



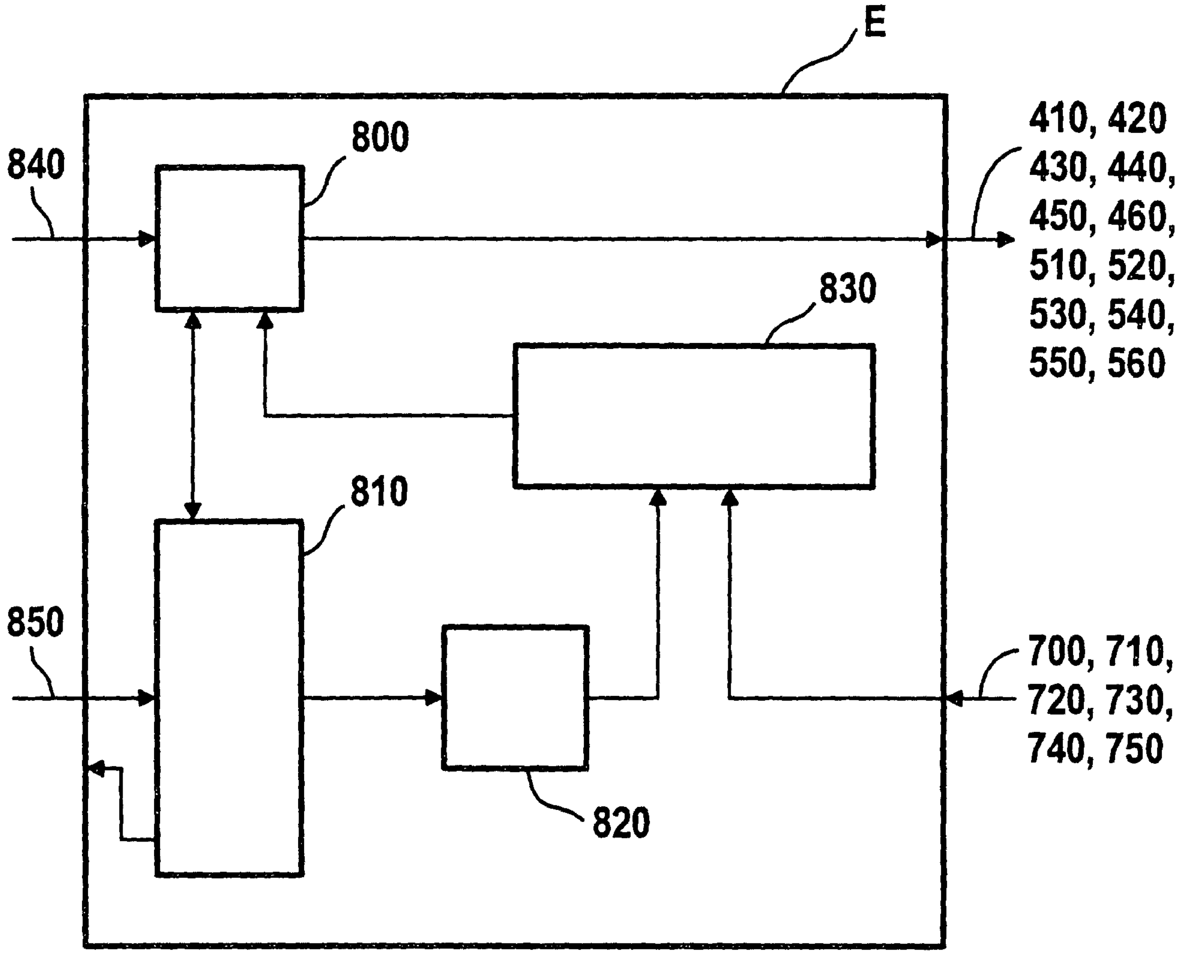

E
800
840
410, 420
430, 440,
450, 460,
510, 520,
530, 540,
550, 560
830
810
850
700, 710,
720, 730,
740, 750
820

FIG. 5

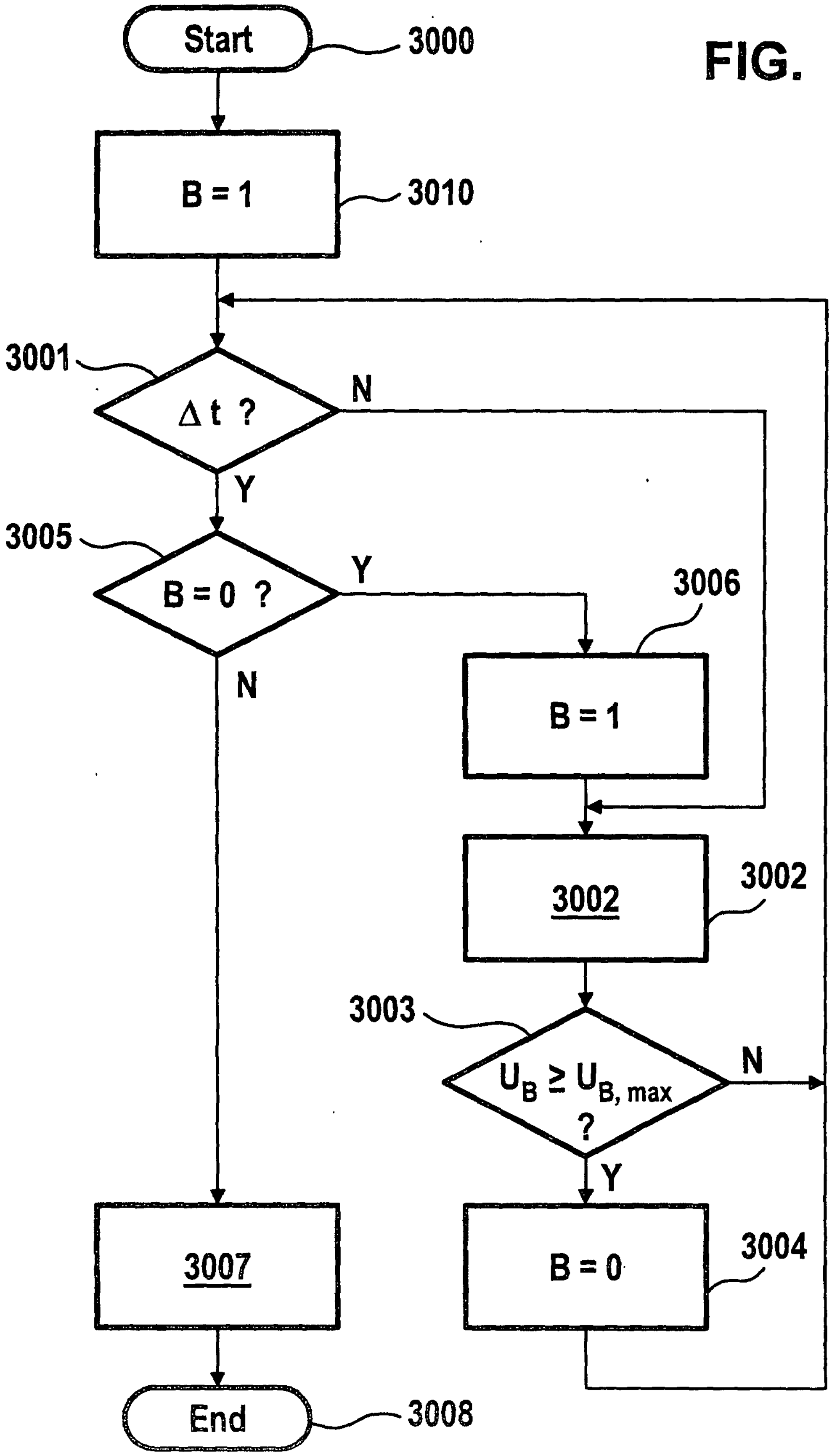
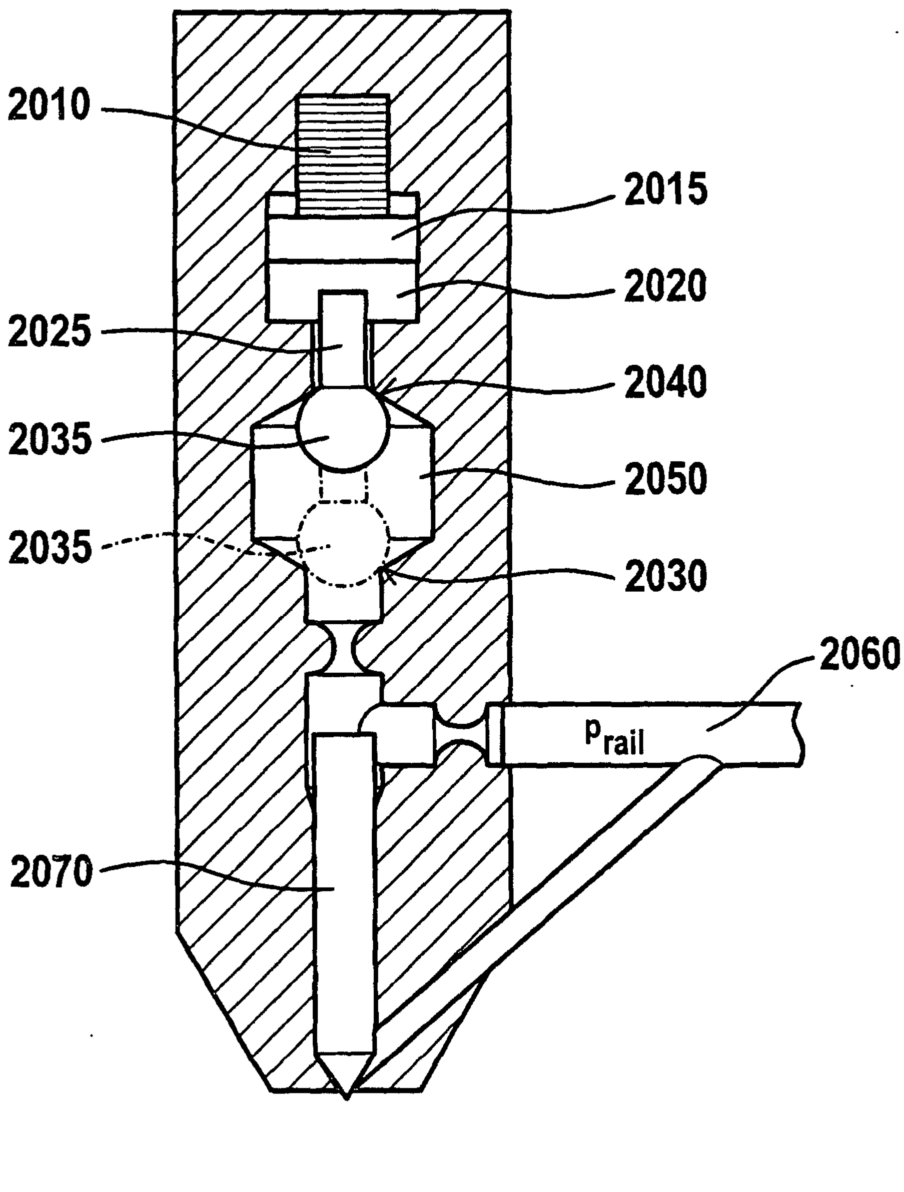

Start
3000
B = 1
3010
3001
Δt ?
N
Y
3005
B = 0 ?
Y
N
3006
B = 1
3002
3002
3003
$U_B \geq U_{B, max}$?
N
Y
3007
B = 0
3004
End
3008

FIG. 6

FIG. 7



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 10 6989

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	DE 198 41 460 A (SIEMENS AG) 16 March 2000 (2000-03-16) * abstract * * column 1, line 3 - column 2, line 57 * * column 3, line 63 - column 4, line 20 * * column 4, line 59 - column 5, line 7 * * figure 1 * ---	1,2,5,12 3,4,6-11	H01L41/04 F02D41/20 F02M51/06
X A	EP 0 371 469 A (TOYOTA MOTOR CO LTD) 6 June 1990 (1990-06-06) * column 12, line 56 - column 13, line 13 * * column 13, line 41 - line 47 * * column 15, line 16 - line 58 * * figures 9,11 * ---	1,2,5,12 3,4,6-11	
X A	US 5 986 360 A (FREUDENBERG HELLMUT ET AL) 16 November 1999 (1999-11-16) * column 1, line 46 - column 2, line 57 * * column 3, line 32 - line 40 * * column 4, line 3 - column 5, line 7 * -----	1,2,5,12 3,4,6-11	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01L F02D F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 June 2000	Libeaut, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 10 6989

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

30-06-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19841460 A	16-03-2000	FR 2784204 A	07-04-2000
EP 0371469 A	06-06-1990	JP 2185649 A	20-07-1990
		JP 2513011 B	03-07-1996
		DE 68921047 D	23-03-1995
		DE 68921047 T	14-06-1995
		US 5057734 A	15-10-1991
US 5986360 A	16-11-1999	DE 19734895 A	25-02-1999
		FR 2767355 A	19-02-1999

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82