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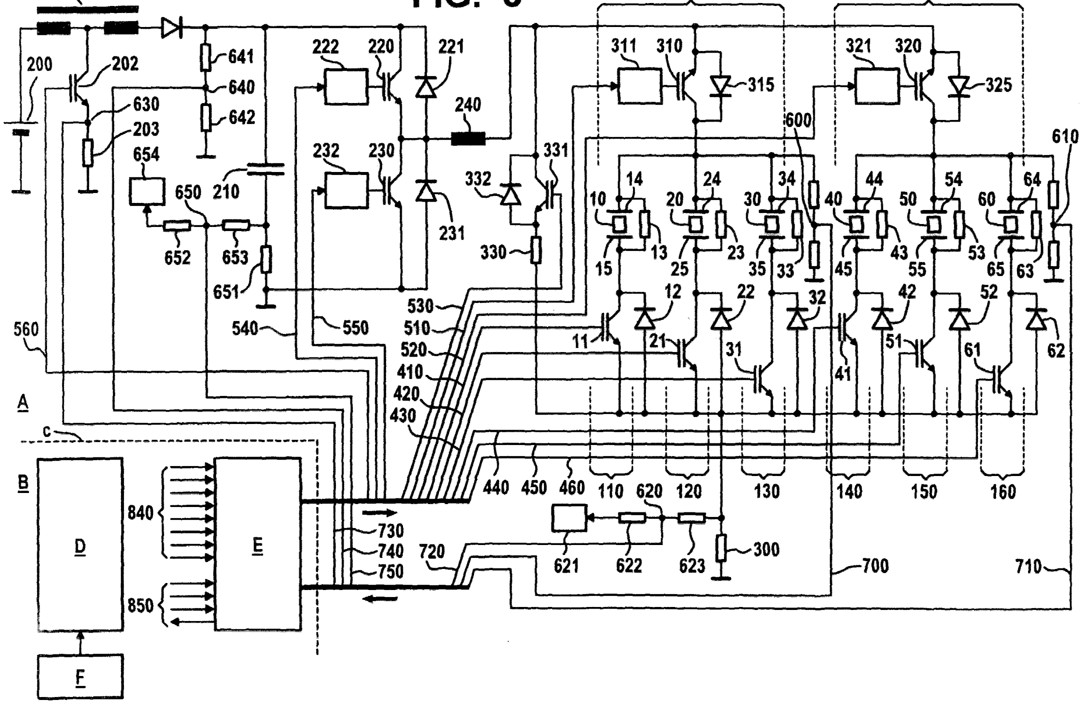
(54) **Fuel injection system**

(57) Fuel injection system having a piezoelectric element for controlling the amount of injected fuel into a combustion engine, wherein electric power for driving the piezoelectric element is supplied by an electric power source, and wherein the fuel injection system comprises a controllable voltage converter disposed between the piezoelectric element and the electric power source and a control unit for adjusting a current between the electric power source and the controllable voltage converter to a value between 0 ampere and a maximum current.

**FIG. 3**

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## Description

**[0001]** The present invention relates to a fuel injection system having a piezoelectric element for controlling the amount of injected fuel into a combustion engine, wherein electric power for driving the piezoelectric element is supplied by an electric power source. The present invention further relates to a method for operating such a fuel injection system.

**[0002]** The practical implementation of elements using piezoelectric elements proves to be advantageous in particular if the element in question must perform rapid and/or frequent movements, such as those used in fuel injection nozzles for internal combustion engines. Reference is made, for example, to EP 0 371 469 B1 and to EP 0 379 182 B1 regarding the usability of piezoelectric elements in fuel injection nozzles.

**[0003]** In the example of a fuel injection nozzle, expansion and contraction of piezoelectric elements is used to control valves that manipulate the linear strokes of injection needles. German patent applications DE 197 42 073 A1 and DE 197 29 844 A1, which are described below and are incorporated herein by reference in their entirety, disclose piezoelectric elements with double acting, double seat valves for controlling injection needles in a fuel injection system.

**[0004]** 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 in the case of the use of a piezoelectric element, the activation voltage applied to the piezoelectric element.

**[0005]** Fig. 8 is a schematic representation of a fuel injection system using a piezoelectric element 2010 as an actuator. Referring to Fig. 8, 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. 8.

**[0006]** 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).

**[0007]** An object of the present invention is to increase the accuracy of a fuel injection system.

**[0008]** This is achieved by way of the features claimed in claim 1 and claim 9. An inventive fuel injection system has at least one piezoelectric element for controlling the amount of injected fuel into a combustion engine, wherein electric power for driving the piezoelectric element is supplied by an electric power source, and wherein the fuel injection system comprises a controllable voltage converter disposed between the piezoelectric element and the electric power source and a control unit for adjusting a current between the electric power source and the controllable voltage converter to a value between 0 ampere and a maximum current. In particular when a voltage is applied to the piezoelectric element (especially if the fuel injection system comprises several piezoelectric elements) there is an AC component flowing between the electric power source and the controllable voltage converter, even though the controllable voltage converter is in a preferred embodiment DC/DC converter. In this case adjusting the current between the electric power sources and the controllable voltage converter to a value between 0 ampere and a maximum current means in particular that the effective value or the amplitude of the current between the electric power source and the controllable voltage converter is adjusted to a value between 0 ampere and a maximum current. Adjusting the current to a value between 0 ampere and a maximum current means in particular that the current is controlled in such a manner that it can be adjusted to more than one of two values, where in particular one value is set to 0 ampere and the other value is set to a value which in particular relates to a maximum value of power which can be necessary to drive the piezoelectric elements. It turns out that the invention is very advantageous as voltage drops between the electric power supply and the controllable voltage converter which occur due to driving the piezoelectric elements are compensated or almost compensated. It turned out that this way a sensor for measuring rail pressure in the fuel supply system provides more accurate measured values resulting in a more precise fuel injection.

**[0009]** In a preferred embodiment of the invention the control unit adjusts the current between the electric power source and the controllable voltage converter based upon a speed of the combustion engine.

**[0010]** In a further preferred embodiment of the invention the control unit adjusts the current between the electric power source and the controllable voltage converter based upon the number of cylinders z, in particular based upon the number of cylinders z and the number j of injections per cylinder.

**[0011]** In a further preferred embodiment of the invention the electric power source is a battery.

**[0012]** In a further preferred embodiment of the invention the fuel injection system further comprises a driving circuitry for driving the piezoelectric element, wherein the driving circuitry comprises a buffer capacitor, in particular a buffer capacitor or a bank or capacitors of at least 25μF.

**[0013]** In a further preferred embodiment of the invention the buffer capacitor is disposed between the piezoelectric element and the controllable voltage converter.

**[0014]** In another preferred embodiment of the invention the fuel injection system further comprises a voltage sensor for measuring a voltage across the buffer capacitor.

**[0015]** In a further preferred embodiment of the invention the control unit adjusts the current between the electric power source and the controllable voltage converter based upon the voltage across the buffer capacitor.

**[0016]** Further advantageous developments of the present invention are evident from the dependent claims, the description below, and the figures.

**[0017]** One advantage of the present invention lies in the reduction of the battery voltage fluctuation.

**[0018]** Another advantage of the present invention is the substantial increase in the accuracy of the fuel injection system and its independence from the voltage fluctuations.

**[0019]** The invention will be explained below in more detail with reference to exemplary embodiments, referring to the figures in which:

Fig. 1 shows a graph depicting the relationship between activation voltage and injected fuel volume;

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 shows one configuration for controlling a combustion engine;

Fig. 7 represents an embodiment of the present invention for reducing voltage fluctuations in systems having piezoelectric elements; and

Fig. 8 schematically represents a fuel injection system using a piezoelectric element as an actuator.

**[0020]** 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.

**[0021]** 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 U greater than zero, up to the x-axis point indicated as $U_{opt}$, the represented values of the activation voltage cause the displacement of the valve plug away from the first closed position and towards the second closed position, in a manner that results in a greater volume of injected fuel for the fixed time period, as the activation voltage approaches $U_{opt}$, up to the value for volume indicated 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.

**[0022]** As shown on the graph of Fig. 1, for values of the activation voltage U greater than $U_{opt}$, the volume $m_E$ of fuel injected during the fixed period of time decreases until it reaches zero. This represents displacement of the valve plug from the optimal point and toward the second closed position of the double acting control valve until the valve plug is seated in its second closed position. 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.

**[0023]** 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 $U_{opt}$.

**[0024]** Fig. 2 shows a double graph representing a schematic profile of an exemplary control valve stroke, to illustrate the double acting control 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.

**[0025]** 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 closed position to the second closed position 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 closed position. Between these steps, in general, there can be a certain time delay.

**[0026]** 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 closed position, 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.

**[0027]** 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 closed position, 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.

**[0028]** Fig. 3 provides a block diagram of an exemplary embodiment of an arrangement in which the present invention may be implemented.

**[0029]** 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.

**[0030]** 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.

**[0031]** 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.

**[0032]** The circuit within the detailed area A comprises six piezoelectric elements 10, 20, 30, 40, 50 and 60.

**[0033]** The piezoelectric elements 10, 20, 30, 40, 50 and 60 are distributed into a first group G1 and a second group G2, each comprising three piezoelectric elements (i.e. piezoelectric elements 10, 20 and 30 in the first group G1 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).

**[0034]** 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.

**[0035]** 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.

**[0036]** 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).

**[0037]** 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.

**[0038]** 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).

**[0039]** 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.

**[0040]** 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.

**[0041]** 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.

**[0042]** 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.

**[0043]** 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.

**[0044]** 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.

**[0045]** 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.

**[0046]** 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.

**[0047]** 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.

**[0048]** 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/DC converter 201 until the desired voltage is reached (for example, 250V) at which point the battery voltage drops somewhat (for example, 0.5V) 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.

**[0049]** It is desirable to provide for charging the primary side (battery side) current limit of the DC/DC converter 201 as a function of the operating, or output, side voltage value so that the drive of the DC/DC converter 201 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 D. 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.

**[0050]** 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 current can be determined by means of a characteristic curve. This is the maximum primary side current wherein the DC/DC converter 201 operates at a fixed frequency. If the primary side current is increased, the converter supplies more power and vise versa.

**[0051]** 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 201, 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).

**[0052]** 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/DC converter 201, capacitor 210, charging switch 220 and discharging switch 230, charging diode 221 and discharging diode 231 and coil 240.

**[0053]** 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.

**[0054]** 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.

**[0055]** 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.

**[0056]** 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.

**[0057]** Then, the charging procedure itself may take place:

**[0058]** 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.

**[0059]** 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.

**[0060]** 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.

**[0061]** 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.

**[0062]** 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.

**[0063]** 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.

**[0064]** 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.

**[0065]** 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:

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.

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.

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.

**[0066]** 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.

**[0067]** 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.

**[0068]** 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.

**[0069]** 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.

**[0070]** 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.

**[0071]** 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.

**[0072]** 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.

**[0073]** The above listed components may be used in a charging procedure for example as follows:

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.

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.

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.

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.

**[0074]** 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.

**[0075]** 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.

**[0076]** 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.

**[0077]** 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.

**[0078]** within the detailed area A via the signal lines 410, 420, 430, 440, 450, 460, 510, 520, 530, 540, 550, 560, 700, 710, 720, 730, 740, and 750. The fuel injection into the combustion engine 2505 is controlled via the piezoelectric elements 10, 20, 30, 40, 50, and 60, of the circuit within the detailed area A shown in Fig. 4. The rotational speed of the combustion engine 2505 is measured and fed into a fuel correction unit 2506. The fuel correction unit 2506 comprises a frequency analyzer which evaluates the frequency of the rotational speed. The fuel correction unit 2506 calculates a fuel correction value $\triangle m_E$ upon this frequency analysis for each individual cylinder o the combustion engine 2505.

**[0079]** The configuration shown in Fig. 6 also comprises a fuel volume calculation unit 2507 calculating a desired fuel volume $m_E$. The desired fuel volume is added to the fuel volume correction value $\triangle m_E$ via an adder 2508. The sum of the desired fuel volume $m_E$ and the fuel volume correction value $\triangle m_E$ is fed into a fuel metering unit 2509. The fuel metering unit calculates the time a voltage has to be applied to the piezoelectric elements 10, 20, 30, 40, 50 and 60, to inject fuel into the combustion engine 2505. The fuel correction unit 2506, the adder 2508, the fuel volume calculation unit 2507, and the fuel metering unit 2509 are implemented in the control unit D. Time signals to signaling when a voltage has to be applied to the piezoelectric elements 10, 20 , 30, 40, 50 and 60, to inject fuel into the combustion engine 2505 are transferred from the fuel metering unit 2509 to the activation IC E via the parallel bus 840.

**[0080]** The online correction value $K_o$ is calculated by an online optimization unit 2510. The online optimization unit 2510 calculates the online correction value $K_o$ based upon the fuel correction value $\triangle m_E$ calculated by the fuel correction unit 2506.

**[0081]** On average, a voltage of 250 V is required to drive the piezoelectric elements. In contrast to a drive system using solenoid valves which were driven directly by the car battery, in injection systems using piezoelectric elements there is no direct drive of the elements from the battery voltage. Instead, the voltage is generated from the battery by means of a DC/DC converter 201 and then supplied to the piezoelectric elements. The system used to increase the voltage and maintain a substantial voltage uniformity separates the battery voltage network and the drive system of the elements. As a result, when the elements are driven, there is no direct effect on the battery voltage (*i.e.*, the battery is not drained directly). Thus, since the battery voltage is drawn only through the DC/DC converter 201 a more uniform load profile can be established. The DC/DC converter 201 is charged until the desired voltage, for example 250 V, is reached. During this time the battery voltage, in extreme cases, drops, e.g. 0.5 V, below an unloaded power system.

**[0082]** To improve the voltage uniformity even further, an embodiment of the present invention provides for charging the primary-side current limit of the DC/DC converter 201 as a function of the engine speed so that the drive of the DC/DC converter 201 is substantially uniform. Otherwise, there could be a gap in the voltage consistency supplied to the piezoelectric element. If the desired voltage is not attained, the piezoelectric element will not be properly charged resulting in an inaccurate fuel injection.

**[0083]** Therefore, according to one embodiment of the present invention the DC/DC converter 201 will operate substantially continuously to provide just enough power for driving the piezoelectric elements. According to this embodiment, power is not provided directly from the battery, rather from a buffer capacitor which is in turn fed from the battery through a DC/DC converter 201.

**[0084]** Referring to Fig. 3, battery 200 is connected to DC/DC converter 201 which supplies power to buffer capacitor 210. Activation IC E contains therein a threshold frequency value for the capacitor 210 of, for example, 10 Amp.

**[0085]** Hence, if the battery voltage changes very frequently, for example, due to the load from driving injectors, the duty cycles of the elements must be readjusted as frequently to ensure the desired average current. If the readjustment does not take place frequently or completely the fuel injection quantity will be affected.

**[0086]** Therefore, according to an embodiment of the present invention, the feedback is minimized by determining the energy requirement of the output stage as a function of time, engine speed, number of cylinders, number of drive operations and the maximum voltage used for the drive operation. This value can be calculated from the engine's operating parameters that are supplied to control unit D shown in Fig. 3 and the result is communicated with the activation IC E. By controlling the current limit on the primary side of the DC/DC converter 201, the output of the DC/DC converter 201 can be controlled and updated with the most recent engine performance requirements by way of the SPI in the activation IC E. In this manner, the DC/DC converter is continuously providing voltage to the buffer capacitor 210, which in turn attends to charging the piezoelectric elements.

**[0087]** In another embodiment of the invention, the data comprising the characteristic curve can be compiled under laboratory conditions and stored, for example, in the RAM memory module 810. Such characteristic curve correlates data for energy requirement to DC/DC current. The value for the frequency is constant and can be stored in the activation IC E. Thus, the energy requirement establishes the maximum primary-side current wherein the DC/DC converter 201 operates at a fixed frequency and vice versa.

**[0088]** Fig. 7 represents an embodiment of the present invention for reducing voltage fluctuations in systems having piezoelectric elements. Referring to Fig. 7, the number of cylinders z is multiplied (using a multiplier 7055) by the number j of injections per cylinder. The outcome is then multiplied (using a multiplier 7050) by an energy value S. The energy value S is determined by obtaining the maximum voltage $U_{max}$ as normalized by the energy required for charging $U_{max}$. Reference number 7045 denotes a characterizing curve depicting the relationship between activation voltage U and the energy S needed to charge the piezoelectric element 10. Such data can be compiled from laboratory measurement and stored in RAM memory 810. The result, denoted as $S_z$ in Fig. 7, is divided via a divider 7060 by the time $t_n$ which it takes for 720° of crankshaft rotation, i.e. the speed n of the engine. The time $t_n$ is calculated via an block 7010 based upon the speed n of the engine. The term $S_z/t_n$, is into DC/DC a second characteristic curve 7070. The result is a minimal converter's primary side current $I_{DO/DC,min}$.

**[0089]** Finally, to ensure that the energy required by the output stage is provided reliably, the DC/DC converter's primary side current $I_{DC/DC,min}$ is multiplied (using a multiplier 7075) by a safety factor e. A safety factor e of 1.1 is exemplary and it would be within the scope of the present invention to apply other values that satisfy the safety factor requirement. The result of the multiplication, $I^*_{DC/DC}$, is a desired value for the current between the battery 200 and the DC/DC-converter 201. Thus, in the above embodiment if the primary-side current is increased, the DC/DC converter 201 supplies more power and vice versa. This enables the buffer capacitor to stay charged continuously throughout the engine's operation while substantially eliminating voltage fluctuations.

**[0090]** In one embodiment of the present invention, data relating to engine speed n, number z of cylinders and number j of injections per cylinder can be measured by the measuring system F. The data is then transmitted to control unit D and thereafter to activation IC E. Accordingly, the primary side current of the DC/DC converter 201, i.e. the current between the DC/DC converter 201 (controllable voltage converter), is continuously updated by the activation IC E. Other information such as the characteristic curve depicting the characteristic curve 7045 between maximum voltage $U_{max}$ and energy s needed to charge a piezoelectric element and the characteristic curve 7070 can be stored, for example, in RAM 810. The desired value $I^*_{DC/DC}$ for the current between the battery 200 and the DC/DC-converter 201 is adjusted via the transistor switch 202.

**[0091]** The embodiments of the present invention provide a means for obtaining the maximum primary side current at which the DC/DC converter 201 operates at a fixed frequency. If the primary side current is increased, the DC/DC converter 201 supplies more power to the buffer capacitor 210. Conversely, if the primary side current is decreased, the DC/DC converter 201 supplies less power.

## Claims

**1.** Fuel injection system having a piezoelectric element (10, 20, 30, 40, 50 or 60) for controlling the amount of injected fuel into a combustion engine, wherein electric power for driving the piezoelectric element (10, 20, 30, 40, 50 or 60) is supplied by an electric power source (200),
**characterized in that**

the fuel injection system comprises a controllable voltage converter (201) disposed between the piezoelectric element (10, 20, 30, 40, 50 or 60) and the electric power source (200); and
a control unit (D) for adjusting a current between the electric power source (200) and the controllable voltage converter (201) to a value between 0 ampere and a maximum current.

**2.** Fuel injection system according to claim 1,
**characterized in that**
the control unit (D) adjusts the current between the electric power source (200) and the controllable voltage converter (201) based upon a speed (n) of the combustion engine.

**3.** Fuel injection system according to claim 1 or 2,
**characterized in that**
the control unit (D) adjusts the current between the electric power source (200) and the controllable voltage converter (201) based upon the number (z) of cylinders, in particular based upon the number of cylinders (z) and the number (j) of injections per cylinder.

**4.** Fuel injection system according to claim 1, 2 or 3,
**characterized in that**
the electric power source (200) is a battery.

**5.** Fuel injection system according to claim 1, 2, 3 or 4 further comprising a driving circuitry for driving the piezoelectric element (10, 20, 30, 40, 50 or 60),
**characterized in that**
the driving circuitry comprises a buffer capacitor (210), in particular of at least 25µF.

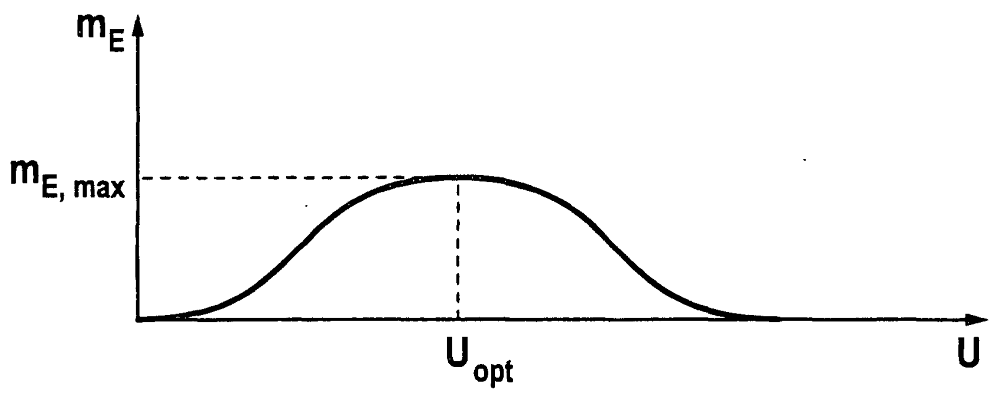
**6.** Fuel injection system according to claim 5,
**characterized in that**
the buffer capacitor (210) is disposed between the piezoelectric element (10, 20, 30, 40, 50 or 60) and the controllable voltage converter (201).

**7.** Fuel injection system according to claim 5 or 6,
**characterized in that**
the fuel injection system further comprises a voltage sensor for measuring a voltage across the buffer capacitor (210).

**8.** Fuel injection system according to claim 5, 6 or 7,
**characterized in that**
the control unit (D) adjusts the current between the electric power source (200) and the controllable voltage converter (201) based upon the voltage across the buffer capacitor (210).

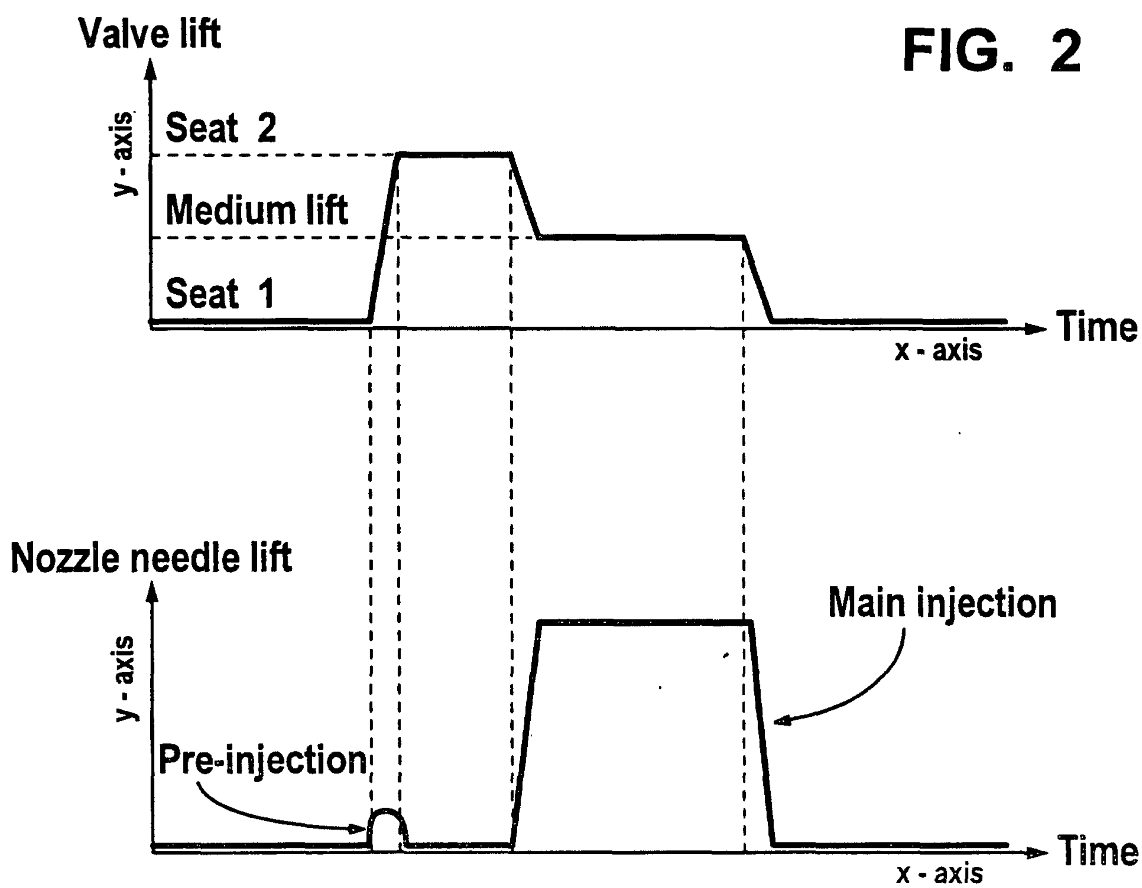
**9.** Method for operating a fuel injection system having a piezoelectric element (10, 20, 30, 40, 50 or 60) for controlling the amount of injected fuel into a combustion engine, in particular for operating a fuel injection system according to one of the foregoing claims, wherein electric power for driving the piezoelectric element (10, 20, 30, 40, 50 or 60) is supplied by an electric power source (200),
**characterized in that**
a current between the electric power source (200) and controllable voltage converter (201) disposed between the piezoelectric element (10, 20, 30, 40, 50 or 60) and the electric power source (200) is adjusted to a value between 0 ampere and a maximum current.

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
y - axis
Pre-injection
Main injection
Time
x - axis

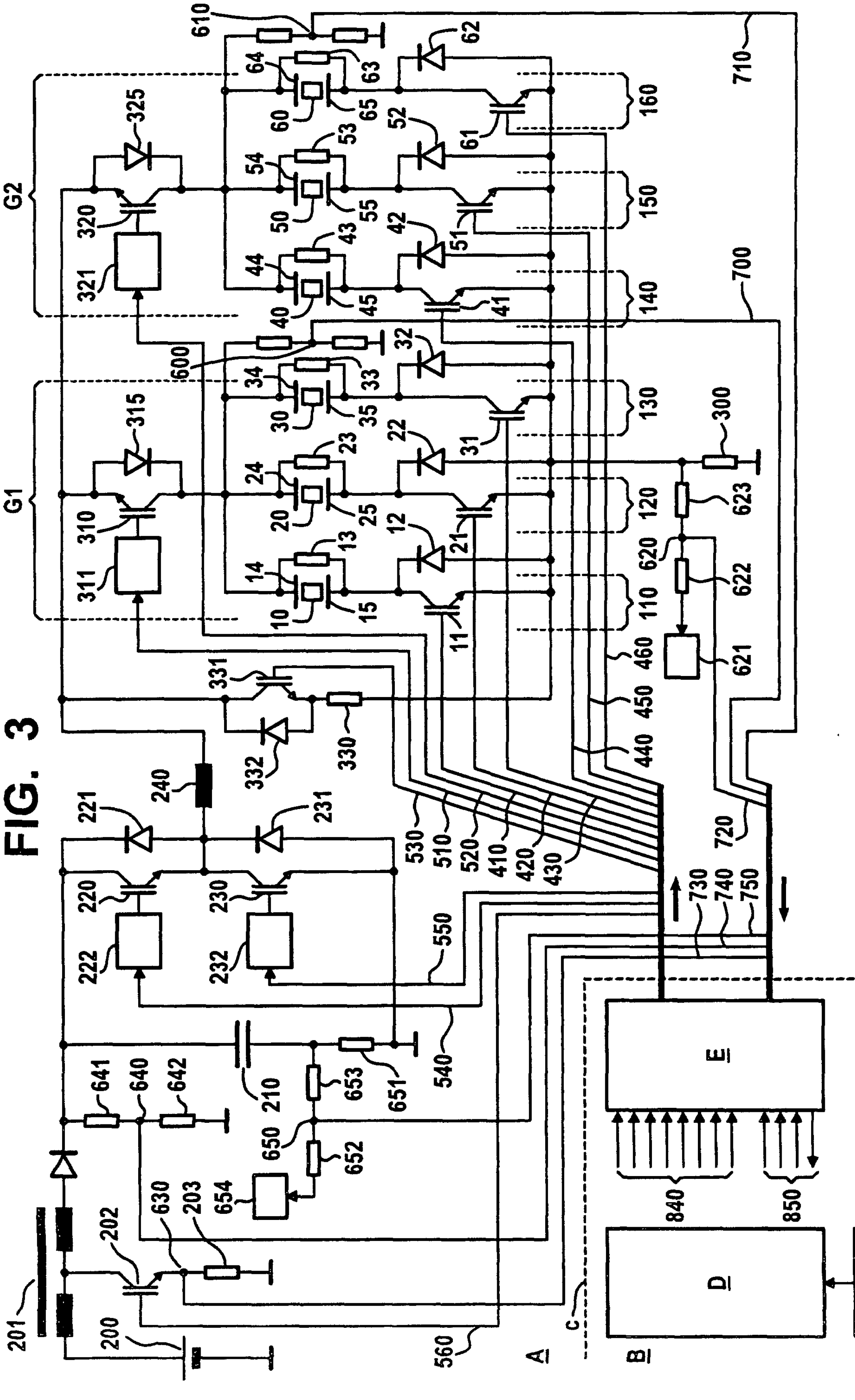



FIG. 3

FIG. 4a

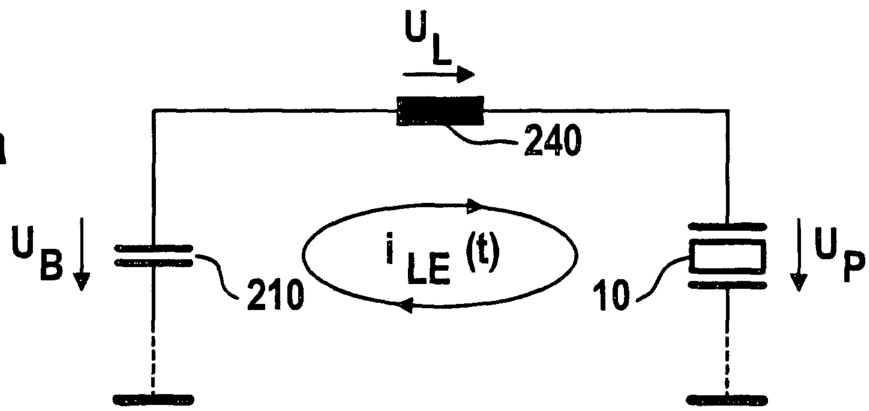



FIG. 4b

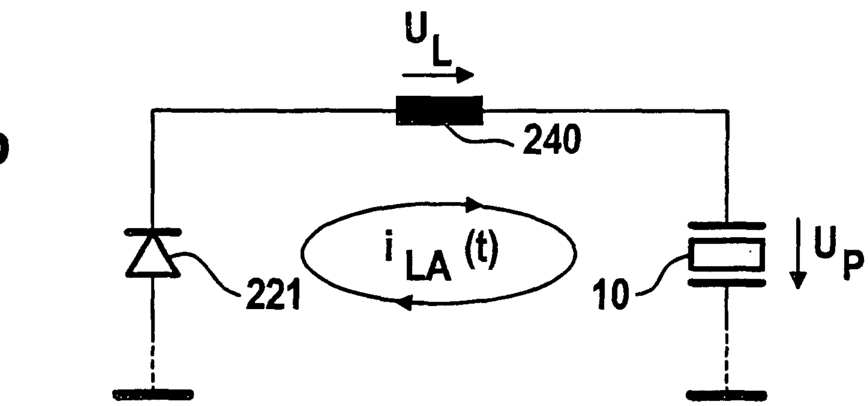



FIG. 4c

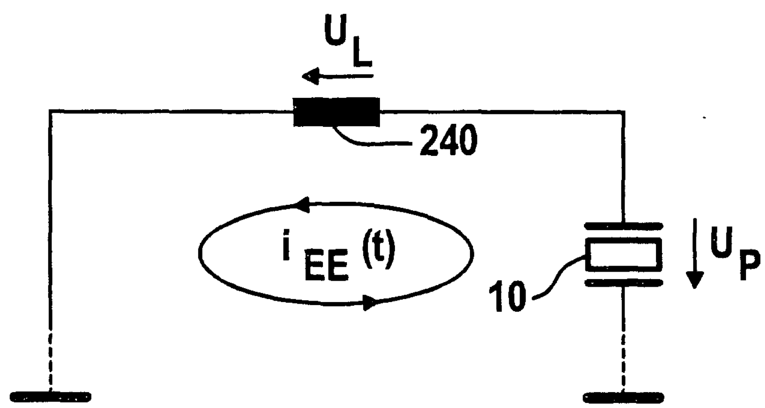
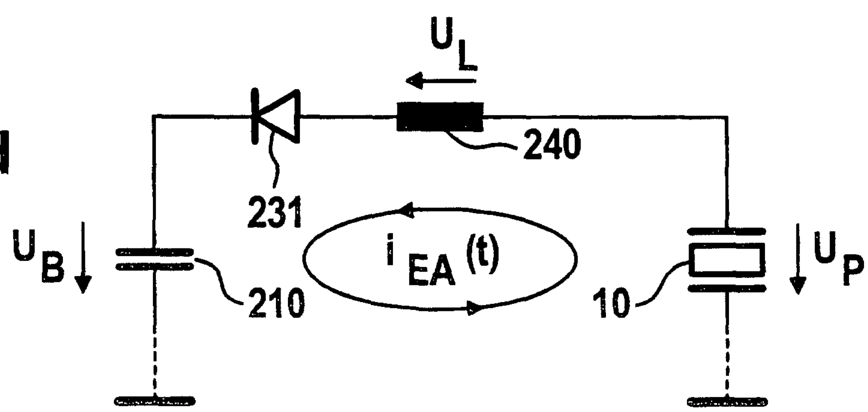



FIG. 4d



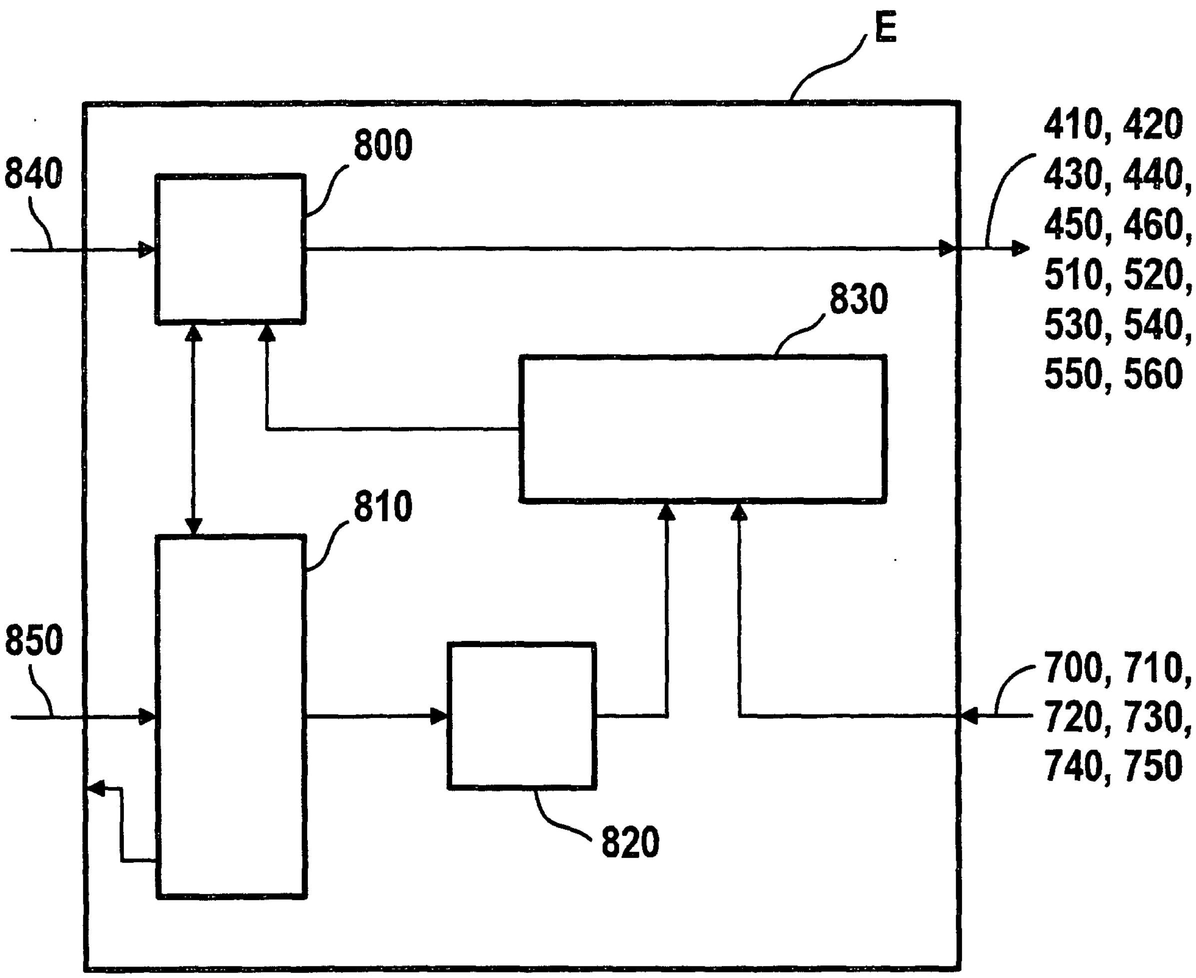

E
800
840
410, 420
430, 440,
450, 460,
510, 520,
530, 540,
550, 560
830
810
850
700, 710,
720, 730,
740, 750
820

FIG. 5

FIG. 6

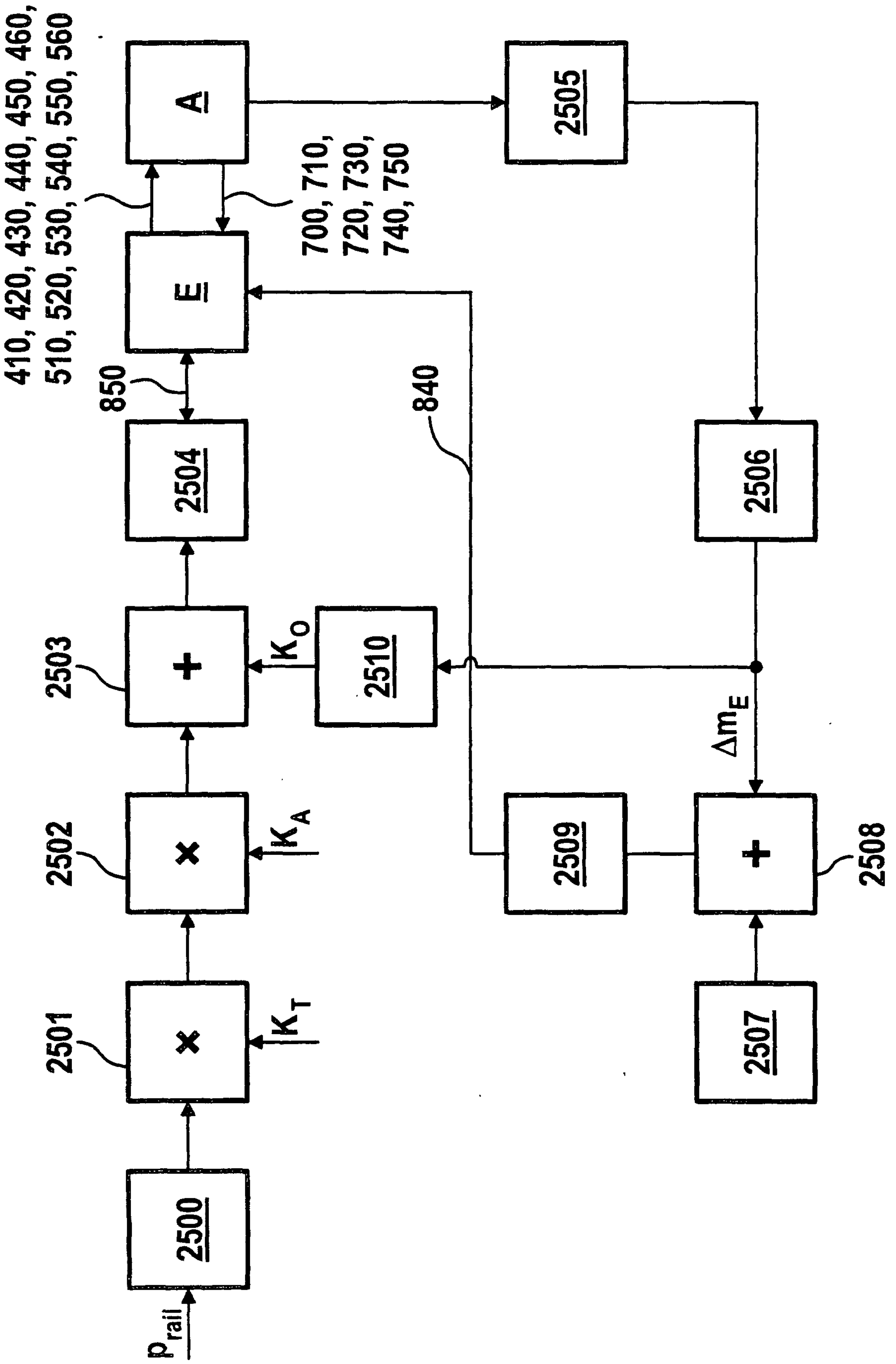

410, 420, 430, 440, 450, 460,
510, 520, 530, 540, 550, 560
A
E
700, 710,
720, 730,
740, 750
850
840
2500
2501
2502
2503
2504
2505
2506
2507
2508
2509
2510
$p_{rail}$
$K_T$
$K_A$
$K_O$
$\Delta m_E$

FIG. 7

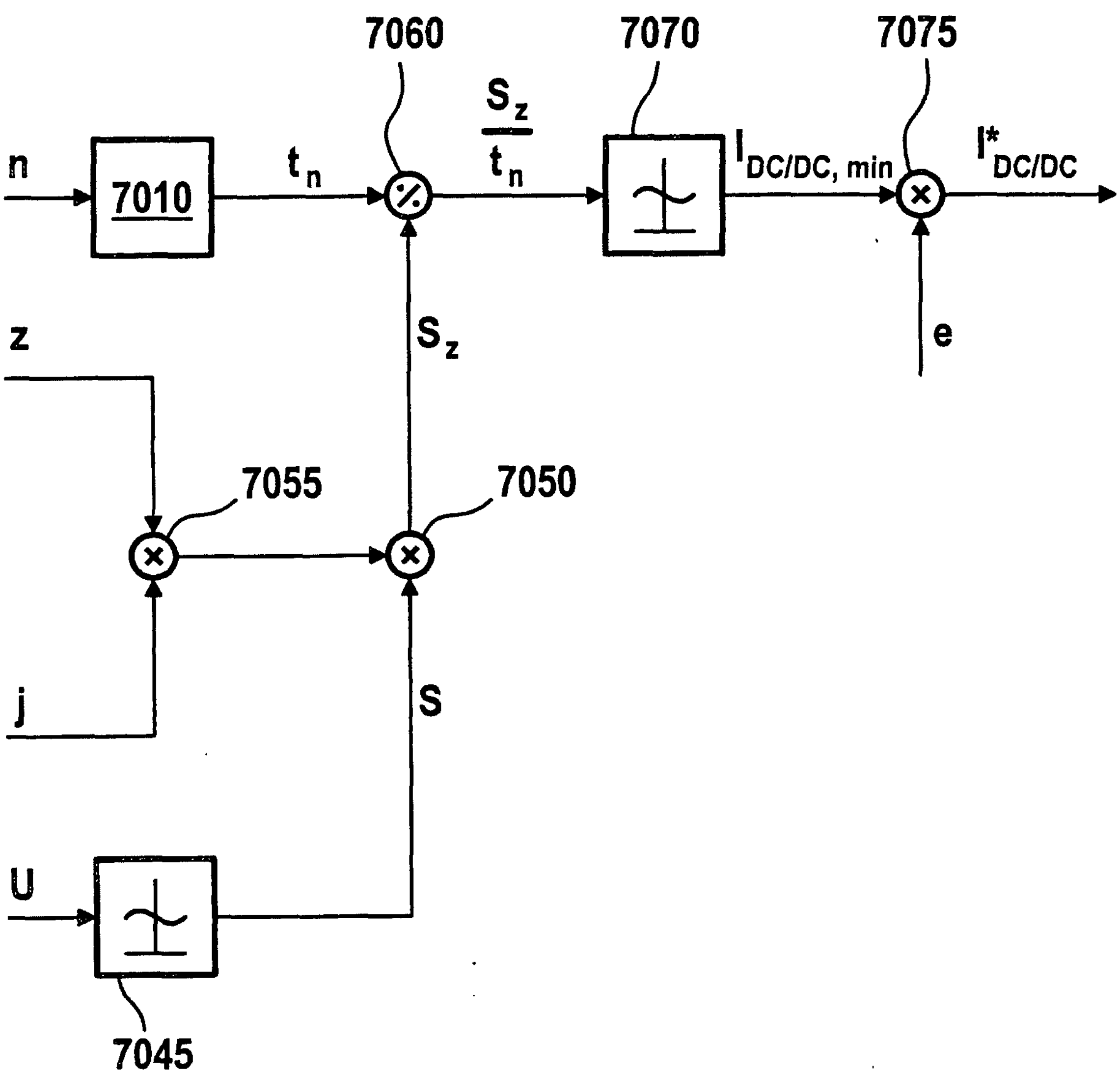
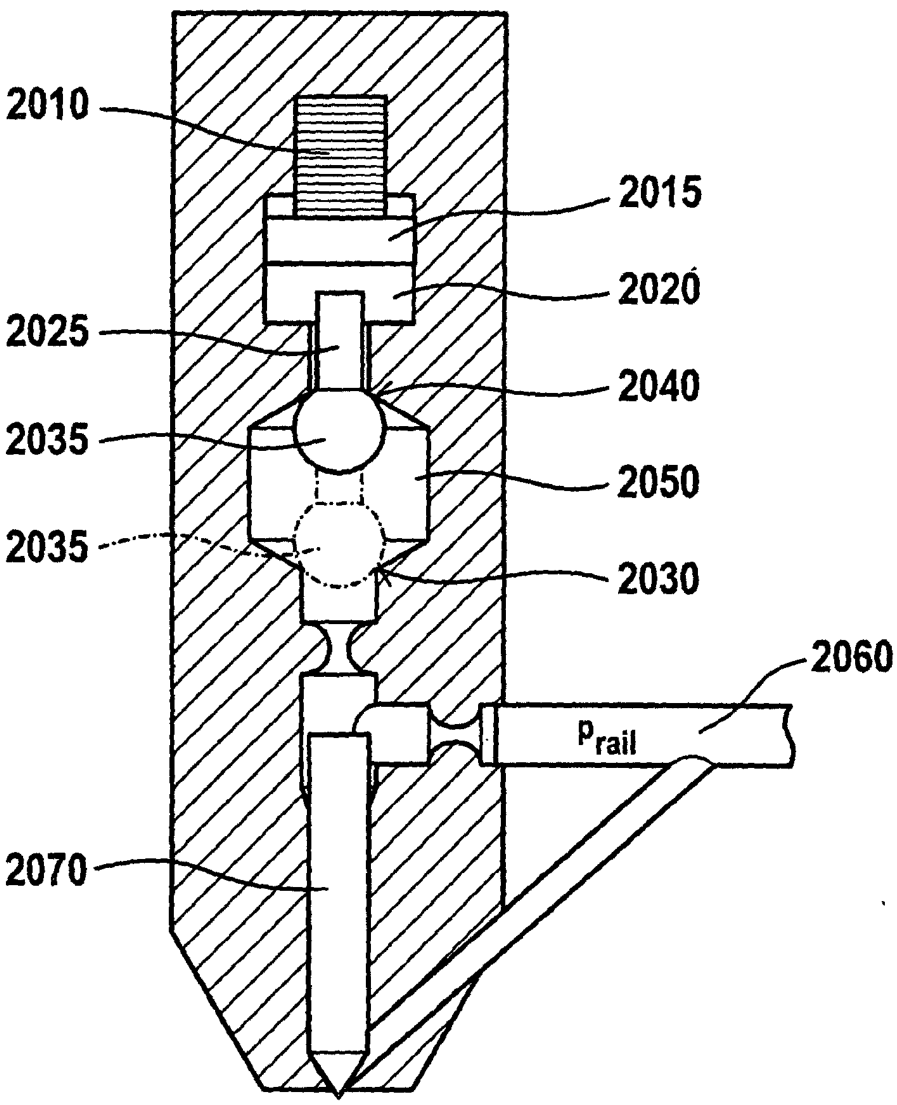

7060
7070
7075
n
7010
$t_n$
$\frac{S_z}{t_n}$
$I_{DC/DC, min}$
$I^*_{DC/DC}$
z
$S_z$
e
7055
7050
j
S
U
7045

FIG. 8



European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 00 10 7203

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| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
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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

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30-06-2000

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