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(54) ## FUEL INJECTOR WITH VALVE POSITION DETECTION CIRCUIT

(57) A fuel injector for an internal combustion engine comprises a nozzle (12) with a body (16) and a needle (14), a control chamber (52) and a control valve (20).

A detection circuit (64) is provided for detecting the position of both the needle (14) and the valve member (28) of the control valve (20), the detection circuit including first and second circuit branches (64.1, 64.2), both connected at one end to a common detection voltage terminal (66). The first circuit branch (64.1) includes a first electric link associated with the needle (14) and configured so that the needle forms a first switch member that closes the first circuit branch when the needle rests on its seat (42), the first circuit branch having a first predetermined resistance value (R_1). The second circuit branch (64.2) includes a second electric link associated with the control valve (20) and configured so that the valve member (28) forms a second switch member that closes the second circuit branch when said valve member rests on its seat (26), the second circuit branch having a predetermined resistance value (R_2) different from that of the first circuit branch.

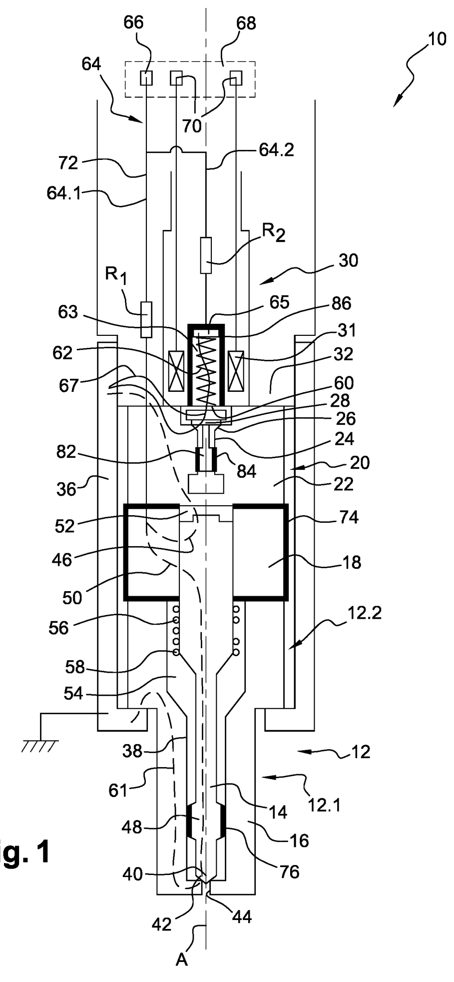

Fig. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to fuel injection and more specifically to fuel injectors, in particular for internal combustion engines.

BACKGROUND OF THE INVENTION

[0002] The contemporary design of internal combustion engines must cope with the increasingly stringent regulations on pollutant emissions. Accordingly, automotive engineers strive for designing engines with low fuel consumption and low emission of pollutants, which implies including electronic devices capable of monitoring the combustion performance and emissions.

[0003] In order to comply with this emissions standard, a proper operation of a fuel-injected engine requires that the fuel injectors and their controller allow for a timely, precise and reliable fuel injection, whatever the operating condition and during all injector lifecycle (at least 240 000 km). Indeed, it is well known that problems arise when the performance, or more particularly the timing, and the quantity of fuel delivered by the injectors diverge beyond acceptable limits. For example, injector performance deviation or variability will cause different torques to be generated between cylinders due to unequal fuel amounts being injected, or from the relative timing of such fuel injection. This problem is particularly acute when injecting small fuel quantities, due to response delays at opening and closing. The injector performance is also affected by a number of uncontrolled parameters such as for example: injector ageing, deposit, fuel properties (especially viscosity)...

[0004] In order to take into account the individual specificities of a fuel injector, it has been proposed to associate to a given fuel injector a number of performance parameters thereof. These performance parameters are, e.g., encoded in a bar code applied to the injector, so that the performance parameters can be retrieved by a bar code scanner at the time of installation in the engine and transferred to the engine control unit (ECU). Such method for fuel injector parameters installation is for example described in US 7,136,743.

[0005] Another method of fuel injector installation has been disclosed in WO2011/073147, which uses a segmented master performance curve. Each fuel injector to be installed in the engine is provided with specific fuel injector parameters in a machine-readable format, and these parameters are transferred to the engine ECU. Fitting information, preferably coefficients for a characteristic equation attributed to each respective segment of the master flow curve, are contained in these fuel injector specific parameters.

[0006] EP 2 375 036 discloses a method for determining an injector closing time based on the voltage trace measured at the coil of the electromagnetic actuator of the injector. There voltage trace gives the closing timing of the valve in a servo-injector design. It gives the information on the moving part in the electromagnetic circuit, i.e. the valve meber of the control valve in the case of a common rail injector, and not the needle of the injector nozzle.

[0007] Another approach is described in WO2017/167627, where fuel injector is designed with a switch function for detecting needle opening and closing. The needle is axially guided in its upper region by a guide member that is set to a predetermined electric potential. The needle is mounted in the nozzle body so as to be able to move therein while being electrically isolated from the nozzle body, except for the region of the nozzle body seat, so that the needle is in electric contact with the nozzle body only in closed position.

[0008] Although the above-mentioned methods and designs are beneficial in that they allow more appropriately describing the flow performance per injector and provide finer control in the ballistic zone, it is still desirable to find ways of obtaining injector feedback in order to improve the control of fuel injection.

SUMMARY OF THE INVENTION

[0009] The present invention has been developed on the basis of the switch function disclosed in WO2017/167627. The clear benefit of a detection system using the injector needle as switch is that it gives a very precise timing of the events when the needle leaves or reaches the closed position.

[0010] For a better knowledge of the injector operating status, it is also desirable to obtain feedback from the control valve. Similar to the needle, the valve member of the control valve can be used as mobile contact member of a switch.

[0011] Unfortunately, the simple transposition of the switch detection principle disclosed in WO2017/167627 to the control valve, for use in addition to the needle detection, is not helpful and/or cumbersome. Indeed, this would amount to having two detection circuits linked to a same detection terminal, one with the needle switch and the other with the valve switch. Since both switches are pulling the signal down when closed, it would not be possible to observe the desired events, save for relatively rare cases where both switches are concurrently open. Alternatively one could design two parallel detection circuits with two wires and two terminals, one for the control valve and one for the nozzle, which would then require two separate measuring circuits in the ECU.

[0012] Against these considerations, the present invention uses a detection circuit with two parallel detection branches, and is remarkable in that each circuit branch is designed to have a distinct predetermined ohmic resistance value.

[0013] Accordingly, the present invention proposes a fuel injector comprising:

a nozzle with a body in which a needle is moveable between a closed position, in which a first end of the needle rests on a valve seat to prevent fuel injection through one or more injection orifices of the nozzle, and an open position in which the needle is lifted from its seat to allow injection;

a control chamber filled, in use, with fuel in order to exert a pressure on the second end of the needle;

a control valve associated with the control chamber allowing to selectively vary the pressure in the control chamber and thereby control an opening or closing move of the needle, the control valve being associated to an actuator;

a detection circuit, inside the injector, for detecting the position of both the needle and the valve member, the detection circuit including first and second circuit branches, both connected at one end to a common detection voltage terminal;

the first circuit branch including a first electric link associated with said the and configured so that the needle forms a first switch member that closes the first circuit branch when the needle rests on its seat, the first circuit branch having a first predetermined resistance value;

the second circuit branch including a second electric link associated with the control valve and configured so that the valve member forms a second switch member that closes the second circuit branch when the valve member rests on its seat, the second circuit branch having a predetermined resistance value different from that of the first circuit branch.

[0014] Since the two circuit branches are in parallel and each has a switch function and a given resistance (different from the other branch), the detection circuit will exhibit four different resistance values depending on the configuration of the switches:

- resistance of second circuit branch when the switch of the first branch only is open
- resistance of the second circuit branch when the switch of the first branch only is open;
- the resistance of the parallel mounting when the two switches are closed
- infinite resistance when the two switches are open.

[0015] As it will be understood, the voltage at the detection voltage terminal will vary depending on the resistance offered by the detection circuit. This makes it possible to discriminate between the different states (open/closed) of the switches and hence makes it possible to decode the sequence of events in the nozzle and control valve.

[0016] It shall be appreciated that only one terminal is required in the injector connector for obtaining feedback of both the nozzle and the control valve. The implementation of the detection circuit in an injector can be easily carried with slight modifications that do not alter the hydraulic behavior of the injector. Furthermore, the present detection circuit can be easily implemented in fuel injectors equipped with an electromagnetic or piezo-electric actuator.

[0017] The respective resistance values are selected for an enhanced readability, i.e. so that the signal magnitude is sufficiently different to allow properly discriminating between each position. For example, the voltage difference between each configuration is preferably of at least about 0.5 V to 1 V, preferably of at least 1.5 to 2 V, or larger.

[0018] Preferably, the resistance of each circuit branch is of at least 500 Ω, more preferably at least 1 kΩ. The ratio between the two resistors is preferably of 1.4 or 1.5, or higher).

[0019] The resistance of each circuit branch can be easily set to a desired value by adding a resistor. The first or second link may typically be a coated (insulated) conductor (wire) running from the detection voltage terminal down to the desired region of the nozzle, respectively of the control valve. A resistor can easily be serially inserted in each electrical link. Alternatively, the first or second link can be manufactured in a material of predetermined resistivity, so that the link itself forms the resistor.

[0020] Preferably, each circuit branch is designed such that the circuit is closed only when the respective mobile contact member is in an end position, i.e. seat position or full lift position, the circuit branch being open when the mobile contact member is in-between said end positions. In other words, the first circuit branch is designed to be only closed when the valve member is in its closed or fully open position. Similarly, the second circuit branch is designed to be only closed when the valve member is in its closed or fully open position.

[0021] In embodiments, the second electric link is connected to a valve member biasing means that is electrically insulated from a control valve body, and the valve member is axially guided by a valve stem that is electrically insulated from the valve body. The actuator may comprise a coil and a moveable armature that is rigidly linked to the valve member. The valve member biasing means comprises a valve spring arranged in a spring bore in an actuator body. The valve spring is electrically insulated from the actuator body and in electrical contact with the armature.

[0022] With such configuration, the second circuit branch includes the second link, the valve spring, the armature and the valve member, as well as the valve body and/or the actuator body.

[0023] The first circuit branch may generally include the first electric link, the upper guide member, the needle, the nozzle body or the valve body.

[0024] As it will be understood by those skilled in the art, in both circuit branches the valve body, nozzle body or actuator body are generally electrically linked with an engine component at chassis ground, e.g. via the capnut or injector body in contact with the cylinder head or fuel rail.

[0025] The above-mentioned four different resistance values for the fuel injector will allow, with a suitable algorithm in the ECU, decoding eight events of interest.

[0026] That is, four events for the needle:

- needle detachment from seat (Start of Injection)
- needle arrival on control valve body (Full Lift Start)
- needle leaving the control valve body (Full Lift End)
- needle landing on seat (End of Injection)

[0027] And similarly four events for the control valve:

- valve member detachment from seat;
- valve member in upper abutment (full stroke - control valve fully open);
- valve member leaving fully open position (start of closing stroke);
- valve member landing on seat (control valve closed).

[0028] According to another aspect, the invention concerns a method of monitoring injector status, comprising measuring a detection voltage at the common detection voltage terminal of the above-mentioned injector, and determining the sequence of control valve and nozzle events based on the voltage evolution at said common detection voltage terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1: is a schematic illustration of an embodiment of the present fuel injector;

Figure 2: is a simplified diagram illustrating the detection circuit in the fuel injector of Fig.1 and the detection function in the ECU;

Figures 3 and 4: are two graphs of detection voltage vs. time for different fuel injector events.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] An embodiment of the present fuel injector 10 is schematically illustrated in Figure 1. The fuel injector 10 is suitable for use in a fuel injection system of an internal combustion engine, and particularly a diesel engine in which fuel is typically injected into the engine at high pressure levels in excess of several hundred bar, and commonly as high as 2000 to 3000 bar.

[0031] Fuel injector 10 extends along longitudinal axis A and comprises, from bottom to top, a nozzle 12 with a needle 14 arranged in a nozzle body 16; an upper guide member 18 for the needle 14; a control valve 20 comprising a valve body 22 with a fuel passage 24 including a seat 26 and a valve member 28; and a solenoid-type actuator 30 having an actuator body 32 with a coil 31 and moveable armature 31. The nozzle body 16, upper guide member 18, control valve body 22 and actuator body 32 are stacked and maintained by any appropriate means. For example, reference sign 36 designates a nut-shaped body referred to as cap-nut, that engages a shoulder of the nozzle body 16 and is screwed on the injector body 32.

[0032] The nozzle 12 includes a first region 12.1 of relatively narrow diameter and a second, enlarged region 12.2. The nozzle body 16 is provided with a bore 38 which extends through both the first and second regions, the bore 38 terminating at a position spaced from the free end of the first region 12.1. The elongate injector needle 14 is slideable within the bore 38, the injector needle 16 including a tip 40 which is arranged to engage a nozzle seat 42 defined by the inner surface of the nozzle body 16 adjacent the tip (free end) of the nozzle 12. At its tip, the nozzle 12 is provided with one or more apertures 44 downstream of the nozzle seat 42, the apertures 44 being positioned such that engagement of the needle tip 40 with the nozzle seat 42 prevents fluid escaping from the injector body 16 through the apertures 44, and when the tip 40 is lifted from the seat 42, fluid may be delivered through the apertures 44.

[0033] Needle 12 has a generally cylindrical shape and extends axially from the needle tip (featuring a needle seat cooperating with valve seat 42) to an upper, needle head 46. The needle 14 is advantageously axially guided. In the lower region, the needle 14 includes an annular protrusion 48 that slides against the inner surface of the bore 38, which forms a cylindrical guide. In the upper region, the needle head 46 is guided by the upper guide member 18, which is an independent element in-between the nozzle body 16 and control valve body 22. Upper guide member 18 is fixedly maintained in the injector stack, namely through the axial compression exerted by the cap-nut 36. The needle head 38 is guided in an axial guiding bore 50 provided in upper guide element 18. The needle head 46, together with the guiding bore 50 and control valve body 22 define a control chamber 52.

[0034] Although not shown, the injector 10 includes a fuel supply line which is arranged to receive high pressure fuel from an accumulator (e.g. common rail) of an associated fuel delivery system and which communicates with an annular gallery 54. In order to permit fuel to flow from the gallery 54 towards the tip region of the nozzle body 16, a number of calibrated orifices or grooves (straight or helicoidal - not shown) are provided in the protrusion 48.

[0035] In the configuration shown in Figure 1, the needle 14 sealingly rests on the nozzle seat 42; it is in the closed position (CP), preventing the flow of fuel through orifice(s) 44. The needle 14 can be lifted from this closed position by adjusting (i.e. reducing) the pressure in the control chamber 52 -thereby permitting fuel flow towards the injection orifices 44- typically up to fully open position O (generally in upper abutment against control valve body 22). Between the CP and OP the needle 14 is said to be "ballistic", which generally also permits fuel flow to the injection orifices.

[0036] Needle 14 is typically biased in closed position by means of a spring 56 that rests, at one end, on an annular bearing surface 58 surrounding the needle head 46, and at the other end against a lower surface of the upper guide member 18.

[0037] As is well-know, the actuation of the needle 14 is operated by adjusting the pressure in the control chamber 52. Therefore, the high pressure supply side includes a derivation channel (not shown) opening into the control chamber 52. The latter is also connected to a low pressure circuit via an outlet channel (not shown), the flow through the outlet channel being controlled by the control valve 20. When the coil 31 of the actuator 30 is energized, it attracts the armature 60 that is rigidly linked to the valve member 28, which is lifted from its seat 26. This opens the outlet channel and allows fuel to flow from the control chamber 52 to the low pressure circuit. As a consequence, the pressure in the control chamber 52 decreases and the needle 14 lifts from its seat in direction of the OP, allowing fuel to flow towards orifice 44 and, hence, allowing fuel injection into the combustion chamber.

[0038] When actuator 30 is no longer energized, the armature 60 and valve member 28 assembly is biased in closed position (valve member 28 on seat 26) by a valve spring 62, thereby closing the outlet channel and retaining the inflow of high pressure fuel in the control chamber 32. The fuel pressure therein builds-up again and the needle 14, under the pressure exerted by the fuel and the needle spring 56, moves towards the CP in which the needle tip 40 sealingly engages the seat 42 (spaced from the ceiling of the control chamber) and impedes the flow of fuel downstream thereof.

[0039] The operating principle and injector design explained above are well known in the art and have only been briefly described since it is not the focus of the invention. The general injector design presented herein above is illustrative and should not be construed as limiting.

[0040] It shall be appreciated that the present injector 10 comprises detection means for detecting the position of both the needle 14 and the valve member 28. The detection means includes a detection circuit, generally indicated 64, with first 64.1 and second 64.2 detection branches, both with a switch function where the needle 14 and valve member 28 respectively form a movable contact element.

[0041] The detection circuit 64 is electrically connected to a detection terminal 66 in a connector 68 (represented by the dash-lined square) that also typically includes a pair of terminals 70 that are used for supplying power to the actuator coil. Conventionally the connector 68 is mounted on the injector end opposite the injection tip.

[0042] As will be understood from Fig.1, the two circuit branches 64.1 and 54.2 are connected at one end to the detection terminal 66 and will be grounded at the other end, i.e. linked to the chassis or possibly another reference potential, when the branch is closed by the respective switch.

[0043] As will be clear, such switch function is possible since the involved injector components are typically metallic and hence electrically conductive, namely the upper guide 18, needle 14, nozzle body 16, valve body 22, valve member 28, armature 60, actuator body 32 and cap-nut 36.

[0044] To enable proper detection of both needle and valve events, each circuit branch is designed to exhibit a predetermined ohmic resistance, different from the other branch. In this embodiment, the resistance of each branch is set by providing a resistor in each branch.

[0045] The first detection branch 64.1 includes a first electric link, indicated 72 , that extends axially through the injector down to the upper guide member 18, to which it is electrically connected, the needle 14, the nozzle body 16 or the valve body 22, and finally the cap-nut 36 which is contact with the chassis ground. It may be noted here that classical electrical path is needle/ nozzle body/ capnut, since the capnut is generally in contact with the cyclinder head which is at the engine electrical ground. Also, the capnut is in contact with injector body 32, which is generally also in contact with the high pressure pipe in communication with the fuel rail, also at the engine ground. These are possible return paths from the capnut.

[0046] It may be noted that for this function, the first link 72, typically a coated wire, is guided through the injector in an electrically insulated manner. A first resistor R_1 is provided in the first link, i.e. serially mounted between two wire sections. The upper guide member 18 is also electrically insulated from the surrounding components in contact therewith, except for the surface of the guide bore 50 in contact with the needle 14. For example, the upper, lower and outer surfaces of the upper guide member 18 may be covered by an electrically insulating coating 74. Also, the needle 14 is insulated from the nozzle body 16, except at the nozzle seat 42. An insulating coating 76 is provided around annular protrusion 48 at the interface with the bore.

[0047] Current flow paths for the nozzle detection are represented by dashed lines 61 and summarized below :

- The circuit branch 64.1 is closed when the needle 14 is in CP, where the current can flow from the upper guide member 18 through the needle 14 into the nozzle body 16 at the seat contact, and from there to the cap-nut 36.
- The circuit branch is also closed when the needle 14 is fully open OP and hence the needle head 46 is in contact with the bottom wall of the valve body 22, which forms the ceiling of the control chamber 52. In such case the current will flow from the upper guide 18 via the needle head 46 into the valve body 22, and further to the actuator body 32 and cap-nut 36.

[0048] Apart from the OP and CP, when the needle 14 is not in an end position, i.e. is ballistic, the circuit in the first branch is open and no current flows therethrough.

[0049] The second detection branch 64.2 is associated with the control valve 20. It includes a second link 80 that is connected to the valve spring 62, the armature 60 biased by the spring 62 and rigidly connected to the valve member 28, the valve body 22, the actuator body 32 and the cap-nut 36. It may be noted here that whereas there is a mounting clearance between the valve body 22 and capnut 36, in other embodiments they may be in contact and current can flow directly from valve body 22 into cap-nut 36.

[0050] It may be noted that in this embodiment, the valve stem 82, by which the valve member 28 is axially guided in the valve body 22, is electrically insulated from the valve body, e.g. by way of a coating 84. Also, the valve spring 62 is electrically insulated from the spring bore 63 in which it is arranged. For example, an insulating coating 86 can be applied onto the internal surface of the spring bore 63.

[0051] The second link 80, again typically a coated wire, can be introduced via an end orifice into the spring bore 63 to connect a contact plate 65 which is in contact with the valve spring 62. A second resistor R_2 is provided in the second link, i.e. serially mounted between two wire sections.

[0052] Current flow paths for the control valve detection are represented by line 67 and summarized below:

- The circuit branch 64.2 is closed when the valve member 28 rests on the valve seat 24, where the current can flow from the second link 80 via valve spring 62 into the armature 60 and valve member 28, and into the valve body 22 at the seat contact, and from there to the cap-nut 36 via the actuator body 32.
- The circuit branch is also closed when the valve member 28 is in its fully open position, the armature 60 being in contact with the actuator body 32. In such case the current can flow from the second link 80 via valve spring 62 into the armature 60, and further via the actuator body 32 into the capnut 36.

[0053] If the valve member is in a position other than these closed and fully open positions, the circuit in the second branch is open and no current flows therethrough.

[0054] The electrically insulating coatings 74, 76, 84 and 86 may consist of any appropriate materials. Suitable materials are e.g. DLC coatings (Diamond-like carbon coatings, known for properties of electrical insulation, high hardness, low friction and chemical inertness) or aluminum oxide coatings.

[0055] It may be noticed that although the present embodiment concerns a solenoid injector, it is also possible to implement the second detection branch with a piezo-electric actuator.

[0056] Fig.2 is a simplified model of the electric circuit 64 representing the two detection branches of the detection circuit in the injector 10. One will recognize the two parallel branches of the detection circuit, namely the first branch 64.1 with resistor R_1 and switch SW1 formed by the needle, and the second branch 64.2 with resistor R_2 and switch SW2 formed by the valve member. A supply voltage Vs is applied by the ECU at the detection terminal 70 of the connector, whereby the same potential is applied to both branches. A measuring resistor R_0 is preferably integrated in the ECU in the detection line and the injector status is monitored by measuring the voltage after resistor Ro, referred to as detection voltage V_D. The measuring resistor R_0 may generally be in the same range as resistors R_1 and R_2. The detection voltage V_D evolves depending on the status (open/closed) of the switches SW1 and SW2. When both switches are open, no current can flow and the detection voltage V_D will be equal to the supply voltage Vs. In the other cases, V_D will depend on the resistance offered by the fuel injector, i.e. R_1, R_2 or both (resistances in parallel). The theoretic voltage V_D can thus be calculated by using the voltage divider formula.

[0057] The ECU measuring circuit illustrated in Fig.2 is only a simplified example for the purpose of illustrating the invention; it should not be construed as limiting. Those skilled in the art may devise any other appropriate measuring circuit to determine the current or voltage at the detection terminal 70.

[0058] In practice, the detection voltage may evolve as summarized in table 1 below. For this example, the fixed parameters are:

V_S = 20 V; R_0 = 2 kΩ; R_1= 1.3 kΩ; R_2 = 2 kΩ

[0059] In the table, the injector resistance is given for each combination of the switches, reflecting the corresponding positions of the needle and valve. The corresponding resistance of the injector is given, as well as the detection voltage.

Table1

SW1 - needle	**SW2 - valve**	**Injector resistance**	**Detection voltage V_D**
Closed	Closed	790 Ω	5.6 V
Closed	Open	1.3 kΩ	7.8 V
Open	Closed	2 kΩ	10 V
Open	Open	infinite	20 V

[0060] As can be seen, the proposed detection circuit with its resistors leads to different voltage signals that allow identifying the different states of the needle and control valve.

[0061] As it will be clear to those skilled in the art, a proper selection of the various resistor values allows better differentiation between the voltage levels.

[0062] Let us now turn to Figures 3 and 4, which show two graphs (simulations) illustrating the evolution of the detection voltage in function of time. As it will be seen, the proposed detection scheme with four different signal magnitudes for detection voltage V_D permits decoding all 8 events relating to the needle and valve operation.

[0063] The different events corresponding to the timings t_1 to ts in Fig.3 are listed below:

- t_1: start of valve opening stroke
- t_2: valve fully open
- t_3: start of needle opening stroke
- t_4: needle fully open
- t_5: start of valve closing stroke
- t_6: valve in closing position
- t_7: start of needle closing stroke
- t_8: needle in closing position

[0064] The different events corresponding to timings t_1 to ts in Fig.4 are listed below:

- t_1: start of valve opening stroke
- t_2: valve fully open
- t_3: start of needle opening stroke
- t_4: start of valve closing stroke
- t_5: valve in closed position
- t_6: needle fully open
- t_7: start of needle closing stroke
- t_8: needle in closing position

[0065] As can be seen, with a fuel injector equipped with the present detection circuit, all 8 events of interest are clearly visible and measurable by ECU.

[0066] The implementation of the detection circuit is easy and does not affect the general design of the injector, in particular does not affect the hydraulic and dynamic properties. It simply requires drawing the two electric links through the injector and insulating some surfaces.

Claims

1. A fuel injector, in particular for an internal combustion engine, comprising
a nozzle (12) with a body (16) in which a needle (14) is moveable between a closed position, in which a first end (40) of said needle rests on a valve seat (42) to prevent fuel injection through one or more injection orifices (44) of said nozzle, and an open position in which said needle (14) is lifted from its seat to allow injection;
a control chamber (52) filled, in use, with fuel in order to exert a pressure on the second end (46) of said needle;
a control valve (20) associated with said control chamber (52) allowing to selectively vary said pressure in said control chamber and thereby control an opening or closing move of said needle (14), said control valve being associated with an actuator (30);
characterized by a detection circuit (64) for detecting the position of both the needle (14) and a valve member (28) of said control valve (20), said detection circuit including first and second circuit branches (64.1, 64.2), both connected at one end to a common detection voltage terminal (66);
said first circuit branch (64.1) including a first electric link associated with said nozzle (14) and configured so that said needle forms a first switch member that closes the first circuit branch when said needle rests on its seat (42), said first circuit branch having a first predetermined resistance value (Ri);
said second circuit branch (64.2) including a second electric link associated with said control valve (20) and configured so that said valve member (28) forms a second switch member that closes the second circuit branch when said valve member rests on its seat (26), said second circuit branch having a predetermined resistance value (R_2) different from that of said first circuit branch; and wherein said first and second circuit branches are in parallel.

2. The fuel injector according to claim 1 wherein said detection circuit is configured to take four different resistance values depending on the configurations of the first and second switch members.

3. The fuel injector according to any one of the preceding claims, wherein each circuit branch has a resistance of at least 500 Ω, preferably at least 1 kΩ.

4. The fuel injector according to any one of the preceding claims, wherein each of said first and second circuit branches includes a respective resistor having a resistance different from that in the other branch.

5. The fuel injector according to any one of the preceding claims, wherein said second circuit branch is only closed when said valve member is in its closed or fully open position.

6. The fuel injector according to claim 4, wherein said second electric link is connected to a valve member biasing means that is electrically insulated from a control valve body, and said valve member is axially guided by a valve stem that is electrically insulated from the valve body.

7. The fuel injector according to claim 5, wherein said actuator comprises a coil and a moveable armature that is rigidly linked to said valve member, said valve member biasing means comprising a valve spring arranged in a spring bore in an actuator body; and wherein said valve spring is electrically insulated from the actuator body and in electrical contact with said armature.

8. The fuel injector according to claim 6, wherein said second circuit branch 64.2 includes said second link 80, said valve spring 62, said armature 60 and said valve member 28, as well as the valve body 22 and/or the actuator body 32.

9. The fuel injector according to any one of the preceding claims, wherein said first circuit branch is only closed when said valve member is in its closed or fully open position.

10. The fuel injector according to any one of the preceding claims, wherein said first circuit branch includes said first electric link (72), said upper guide member (18), said needle (14), said nozzle body (16) or said valve body (22).

11. The fuel injector according to any one of the preceding claims, comprising a connector with terminals for energizing said actuator, said connector further comprising one terminal that connects said detection circuit.

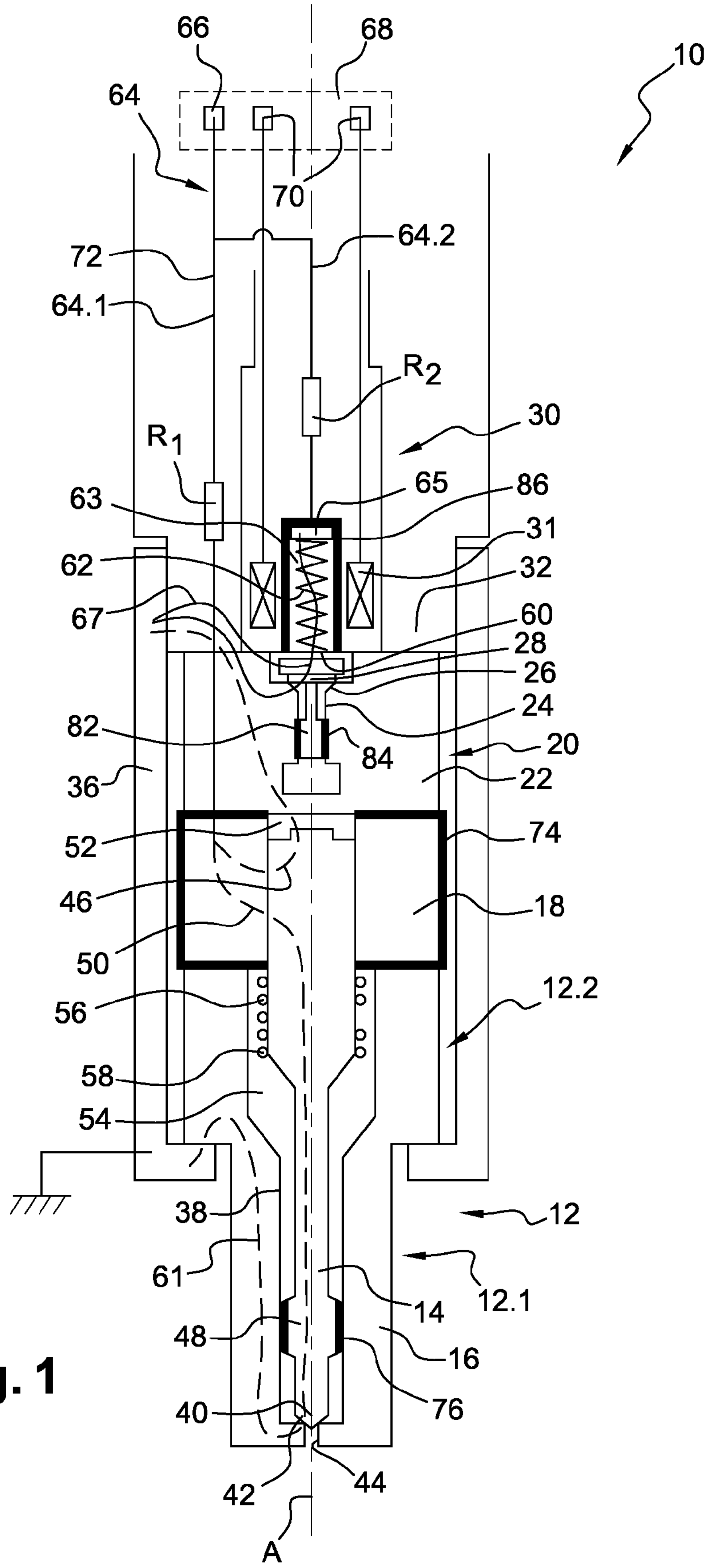
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Fig. 1

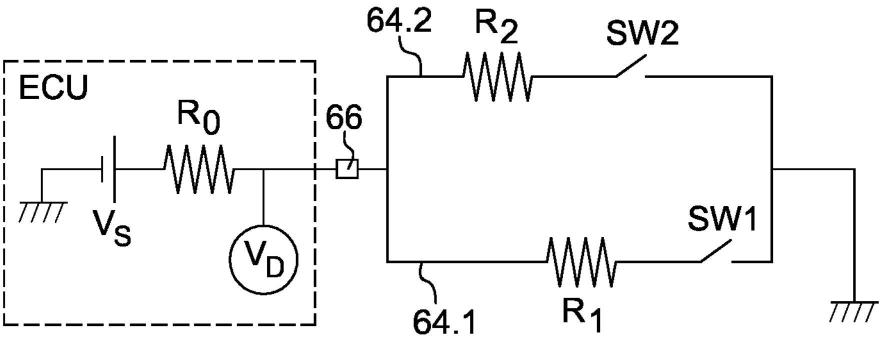

Fig. 2

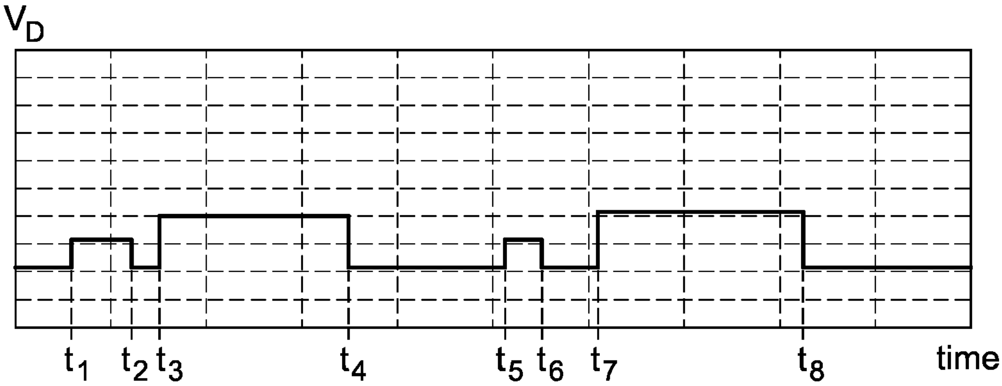

Fig. 3

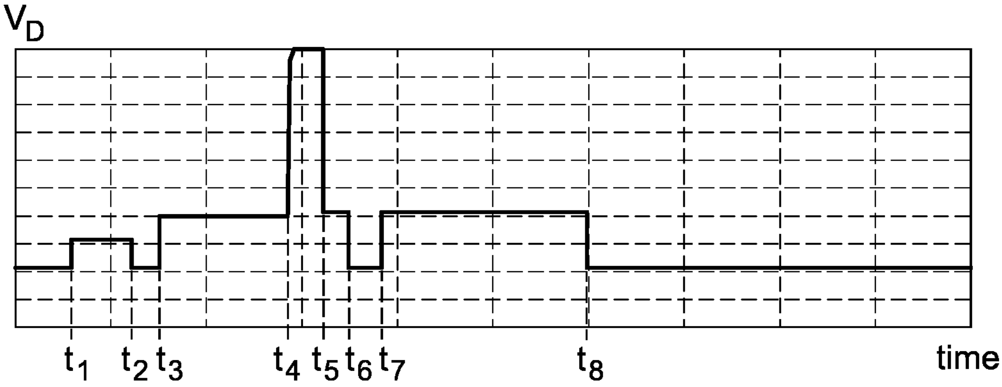

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 3633

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	22 May 2019	Hermens, Sjoerd

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