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(54) Method for controlling a solenoid injector

(57) A solenoid injector (1) has an actuator (11) comprising a ferromagnetic coil (13). The actuator acts on a needle (5), which prevents an injection of a fluid in a closing position of the needle (5) and otherwise enables the injection of the fluid. In a first step the ferromagnetic coil (13) is energized for moving the needle (5) out of the closing position. In a second step the ferromagnetic coil (13) is de-energized until an electrical current through the ferromagnetic coil (13) reaches a zero value for moving the needle (5) back to the closing position. In a third step a negative electrical current is controlled through the ferromagnetic coil (13) with respect to the electrical current of the second step for a given time (DT).

FIG 1

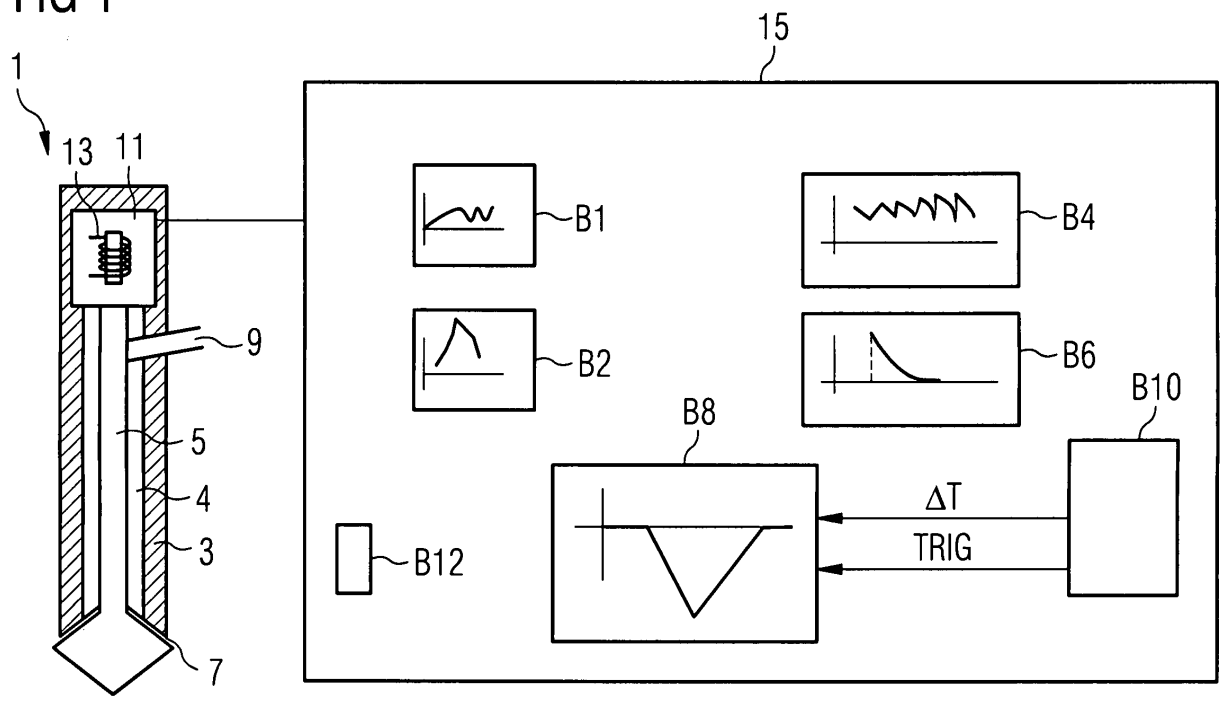

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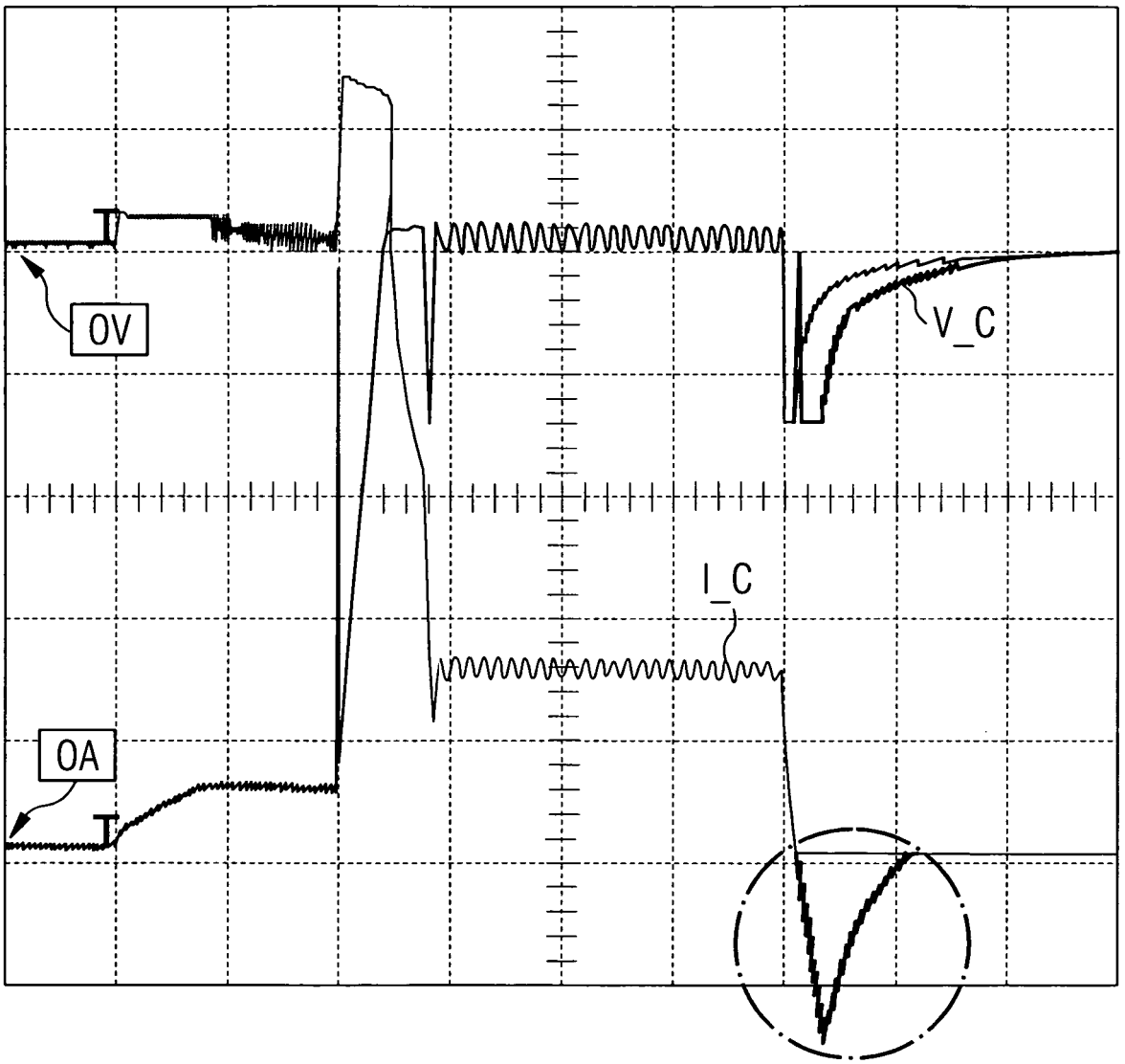
FIG 3



Description

[0001] The invention relates to a method for controlling a solenoid injector.

[0002] Increasingly strict regulations concerning exhaust emissions of internal combustion engines, which are located in vehicles, make it necessary to provide some measures, which reduce the exhaust emissions. One way of assessing this is to reduce the exhaust emissions produced by the internal combustion engine during the combustion process. Another way of assessing this challenge is to use exhaust after treatment systems to transform the unwanted emissions into harmless substances. For reducing the exhaust emissions created during the combustion process it is necessary to provide a very good mixture between air and fuel, which is injected by an injector. For achieving such a good mixture preparation multiple injections of fuel during one working cycle of the internal combustion engine are provided in certain engine states. This renders a precise dosing of extremely small amounts of fuel via the injector necessary. Also in very low load engine states of the engine extremely small quantities of fuel need to be dosed into the cylinder of the internal combustion engine. A precise dosing of as small as possible amounts of fluid therefore improves the engine's exhaust emission production in a positive way.

[0003] The object of the invention is to create a method and a device for controlling a solenoid injector, which enables a precise dosing of small quantities of fluid.

[0004] The object is achieved by the features of the independent claims. Advantageous embodiments of the invention are given in the subclaims.

[0005] The invention is distinguished by a method and a respective device for controlling a solenoid injector with an actuator comprising a ferromagnetic coil. The actuator acts on a needle, which prevents an injection of a fluid in a closing position of the needle and otherwise enables the injection of the fluid. In a first step the ferromagnetic coil is energized for moving the needle out of the closing position. In a second step the ferromagnetic coil is de-energized until an electrical current through the coil reaches a zero value for moving the needle back into the closing position. In a third step a negative electrical current through the coil is controlled with respect to the electrical current of the second step for a given time. In that way by properly choosing the given time a remanence magnetic flux density remaining in the actuator when the electrical current through the coil reaches zero may be further reduced, which surprisingly results in a faster closing of the needle, that is a faster movement into its closing position. This then results in a decreased amount of fluid being at a minimum possibly dosed by the solenoid injector. At the same time this also results in a more precise dosing of the fluid. Preferably the third step may only be conducted, when the amount of fluid to be dosed by the solenoid injector is below a given threshold value.

[0006] In an advantageous embodiment of the invention the third step comprises applying a voltage of opposite polarity in respect of a voltage for energizing a ferromagnetic coil in the first step. This has the advantage, that such a voltage may be controlled in a simple way.

[0007] Exemplary embodiments of the invention are explained in the following with the aid of schematic drawings. These are as follows:

Figure 1: a solenoid injector and a device for controlling the solenoid injector,

Figure 2A: a current through a ferromagnetic coil of an actuator of the injector plotted over the time,

Figure 2B: an historesis curve, and

Figure 3: measurement signals of the current through the coil and a voltage applied to the coil plotted versus the time.

[0008] An injector 1 (Figure 1) comprises a housing 3 with a recess 4. A needle 5 is taken in the recess 4 of the housing 3. In its closing position the needle 5 prevents an injection of a fluid, in particular of fuel and in other positions the needle 5 enables the injection of fluid through a nozzle 7. Preferably a tensioning means is provided, which is preferably a spring, which is pretensioned in a way that the needle 5 rests in its closing position, where no forces or no respective high forces are being exerted by an actuator 11.

[0009] The injector comprises the actuator 11. The actuator 11 comprises a ferromagnetic coil 13, which is controlled by a control device 15. Depending on a magnetic flux density B a force is exerted on the needle 5, for example via an armature being coupled to the needle 5. Depending on the control signals being applied to the ferromagnetic coil 13 the position of the needle 5 may be influenced and respectively the needle 5 may be moved out of its closing position or back into its closing position or being held in a given opening position in order to achieve the desired dosing of fluid through the solenoid injector 1.

[0010] The injector 1 is provided with a fuel inlet which is preferably connected to a fluid supply of an internal combustion engine. The injector 1 is also preferably arranged in an internal combustion engine. It is preferably arranged in a way in the internal combustion engine, that it can dose fluid directly into a cylinder of the internal combustion engine. The fluid

supply provides fluid under high pressure, in the case of gasoline as fluid, for example with a pressure of up to 200 bars. The injector may, however, also be arranged in an intake manifold, which communicates with the respective cylinders of the internal combustion engine. The control device 15 is provided, which may also be referred to as device for controlling the solenoid injector 1.

[0011] The control device 15 comprises a block B1, which incorporates a premagnetizing unit. The premagnetizing unit is designed to control a current I_C through the ferromagnetic coil 13 in a first phase PH1 (Figure 2A) in order to premagnetize the ferromagnetic circuit, which also includes, besides the ferromagnetic coil, the armature and other ferromagnetic devices.

[0012] A block B2 is further provided, which is designed for providing a current through the ferromagnetic coil 13 rising very quickly and resulting in a current I_C with a high amplitude, which then results in a high magnetic force moving the needle 5 away from its closing position into the opening position. The control is performed via the block B2 during a second phase PH2. At the end of the second phase PH2 the current I_C through the ferromagnetic coil 13 is again reduced to a holding current level.

[0013] During controlling of the current through the ferromagnetic coil 13 to the holding current level a block B4, which incorporates a hold-unit, takes over control of the current through the ferromagnetic coil 13. This is shown by the third phase PH3 in Figure 2A. During the third phase PH3 the needle remains in its opening position and therefore fluid is dosed through the nozzle 7, preferably into a combustion chamber of a cylinder of an internal combustion engine.

[0014] At the end of the third phase PH3, it is desired to close the needle again, that means to move the needle 5 back into its closing position. A block B6 is provided, which comprises a first closing unit. This first closing unit preferably comprises electronic circuitry 3 comprising a capacitor, which is used to store the energy being provided to the ferromagnetic coil 13 during the first three phases PH1-PH3. Therefore an appropriate voltage is applied to the ferromagnetic coil 13 during a fourth phase PH4, during which block B6 takes over control in order to reduce the magnetic flux density within the ferromagnetic coil 13.

[0015] The fourth phase PH4 is terminated when the current through the ferromagnetic coil 13 has reached a zero value coming from a positive value during the first to fourth phases PH1 to PH4.

[0016] When the fourth phase PH 4 is terminated a remanence magnetic flux density B_R remains in the ferromagnetic parts of the actuator 11, which reduces the speed of the needle 5 while moving back into its closing position. In order to speed up this process a block B8 is provided which comprises a second closing unit. The control of the current of the ferromagnetic coil 13 is conducted via the block B8 when the fourth phase PH4 has been terminated.

[0017] In order to detect the zero crossing of the current I_C through the ferromagnetic coil a block B12 is provided, which comprises a current measuring or determining unit for determining the current through the ferromagnetic coil 13. The block B8 is designed for controlling a negative electrical current through the ferromagnetic coil 13 for a given time DT. The control is given to the block B8, when a triggering signal TRIG is generated by a block B10 comprising a scheduling unit for determining which of the blocks B1, B2, B4, B6, B8 currently takes over control of the current through the ferromagnetic coil 13.

[0018] The block B8 is designed to provide a voltage of opposite polarity in respect of a voltage for energizing the ferromagnetic coil 13 during the first to third phases PH1-PH3. This voltage of opposite polarity results in the negative current through the ferromagnetic coil 13 and in this way reduces the magnetic flux density B within the actuator 11.

[0019] The given time DT is preferably chosen in a way, that the magnetic flux density B is reduced from its remanence magnetic flux density B_R to a basically zero magnetic flux density B. For that purpose the given time DT is stored in the control device and is determined before operation of the control device by way of experiments or simulations.

[0020] The given time DT is preferably that duration of time, during which the given voltage of opposite polarity is applied to the ferromagnetic coil 13. During the fifth phase PH5 the needle 5 reaches its closing position again. After that the needle 5 remains in its closing position until the next injection event is controlled. This time is usually significantly larger than the time for the phases PH1 to PH3. For that reason during phase PH1 the hystheresis curve between the magnetic flux density B and the magnetic field strength H is started again from the value of zero each for the magnetic flux density B and the magnetic field strength H.

[0021] Figure 3 shows respective plots of the current I_C and the voltage V_C being applied to the ferromagnetic coil 13.

Claims

1. Method for controlling a solenoid injector (1) with an actuator (11) comprising a ferromagnetic coil (13), the actuator (11) acting on a needle (5), which prevents an injection of a fluid in a closing position of the needle (5) and otherwise enables the injection of fluid, comprising

   - a first step of energizing the ferromagnetic coil (13) for moving the needle (5) out of the closing position,
   - second step of de-energizing the ferromagnetic coil (13) until an electrical current (I_C) through the ferromag-

netic coil (13) reaches a zero value for moving the needle (5) back in the closing position and
- a third step of controlling a negative electrical current through the ferromagnetic coil (13) with respect to the electrical current (I_C) of the second step for a given time (DT).

2. A method according to claim 1, with the third step comprising applying a voltage of opposite polarity in respect to a voltage for energizing the ferromagnetic coil (13) in the first step.

3. Device for controlling a solenoid injector (1) with an actuator (11) comprising a ferromagnetic coil (13), the actuator (11) acting on a needle (5), which prevents an injection of a fluid in a closing position of the needle (5) and otherwise enables the injection of fluid, the device being designed for

- energizing in a first step the ferromagnetic coil (13) for moving the needle (5) out of the closing position,
- for de-energizing the ferromagnetic coil in a second step until an electrical current through the ferromagnetic coil (13) reaches a zero value for moving the needle (5) back in the closing position,
- for controlling in a third step a negative electrical current through the ferromagnetic coil (13) with respect to the electrical current of the second step for a given time.

FIG 1

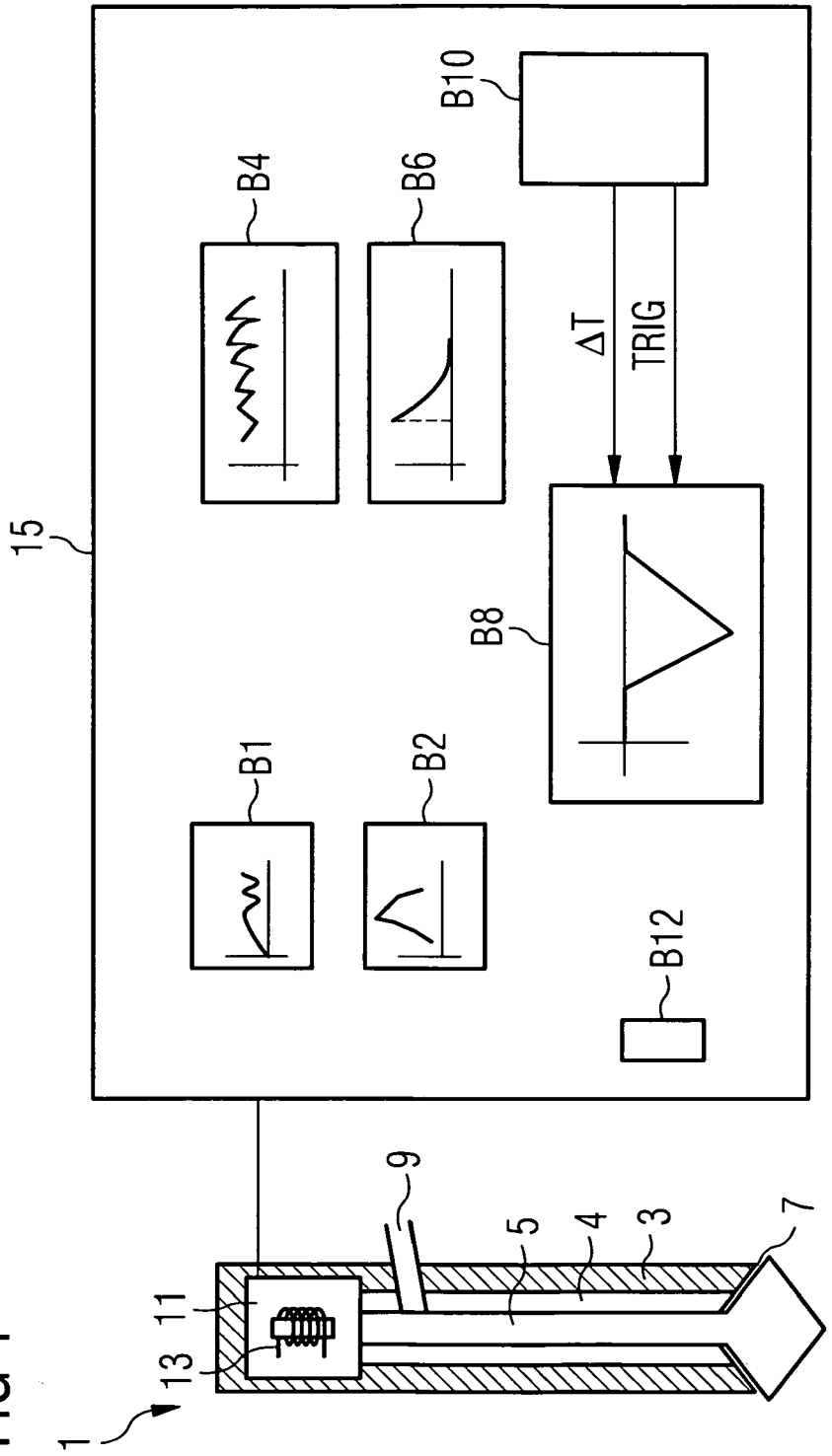


FIG 2B

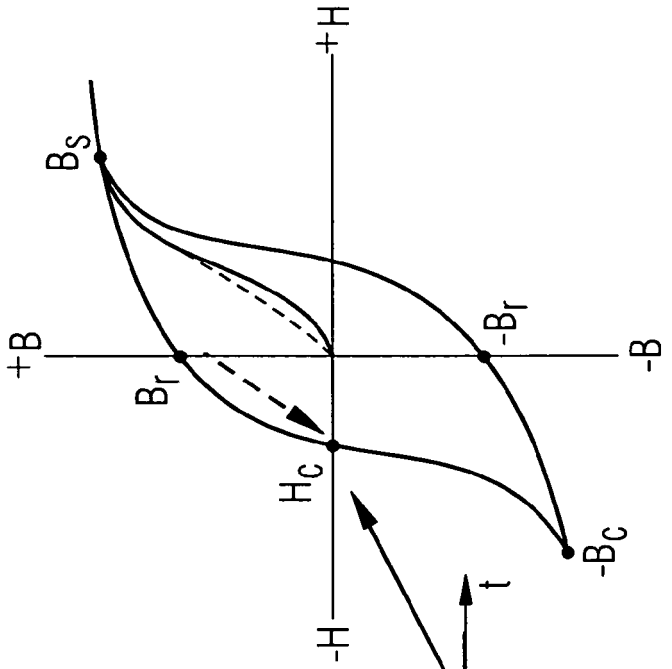


FIG 2A

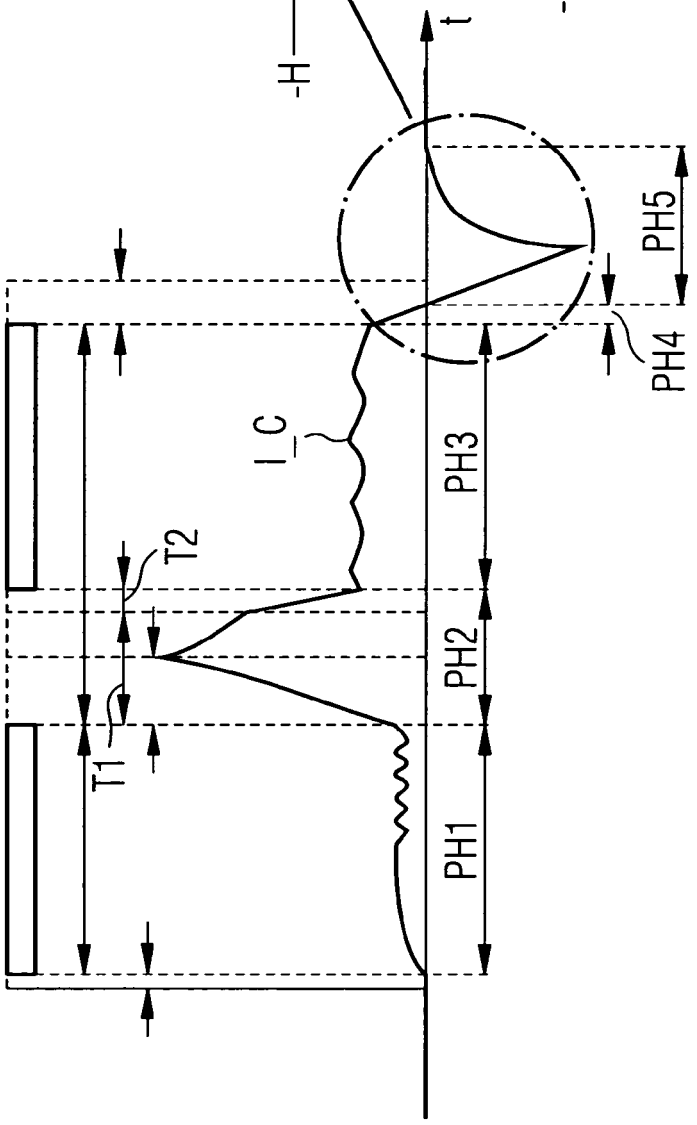
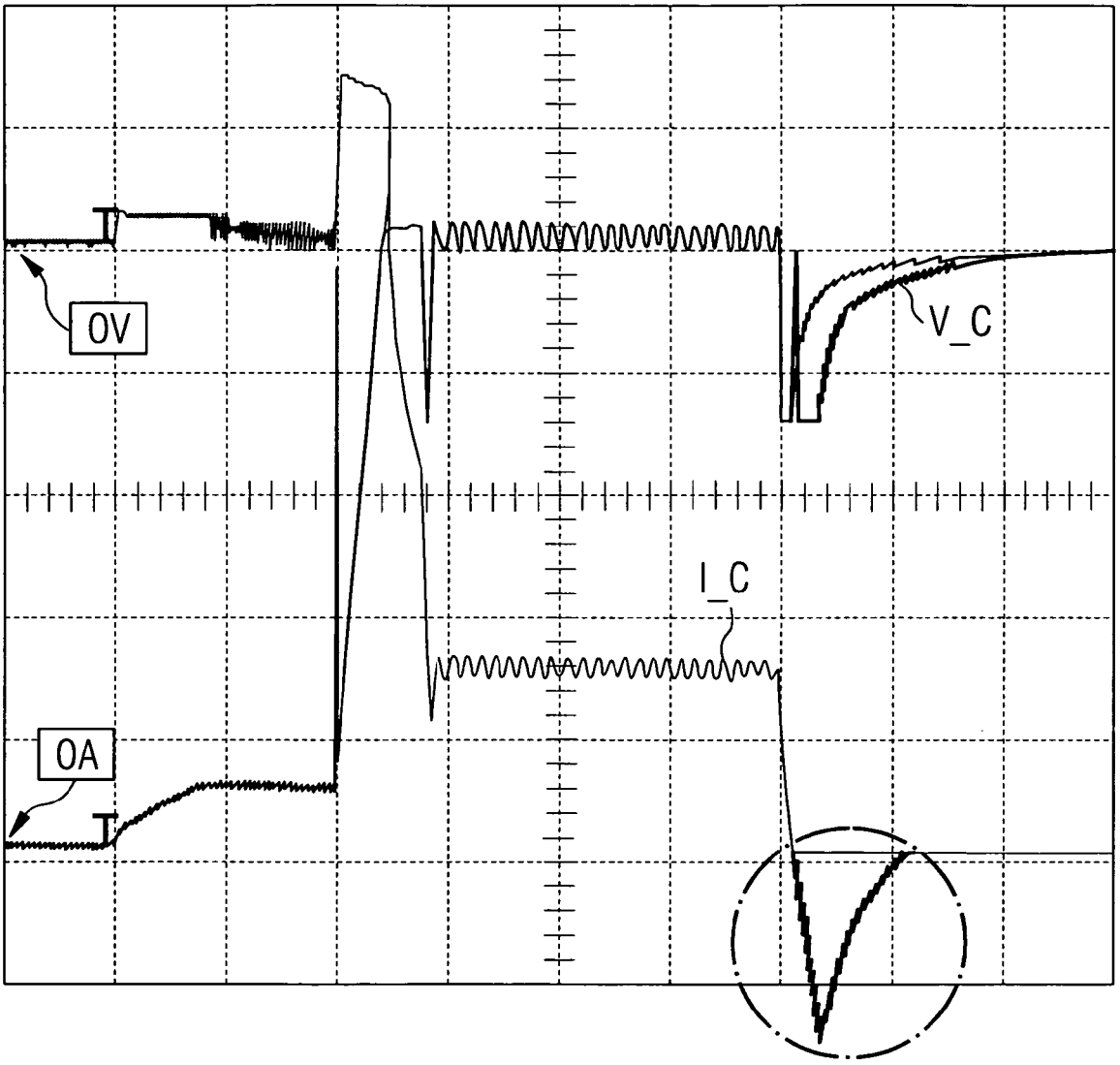


FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 05 00 5166

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 4 385 339 A (TAKADA ET AL) 24 May 1983 (1983-05-24) * abstract; figures 10,11 * -----	1-3	F02D41/20 F02M51/06 F02M61/08 H01F7/18
X	GB 2 150 368 A (* SOLEX) 26 June 1985 (1985-06-26) * page 1, lines 69-82,88-91,94-97,101-105,109-112,119-121 * -----	1-3	
X	GB 1 428 353 A (HITACHI LTD) 17 March 1976 (1976-03-17) * page 2, lines 11-18,23-32; figure 4 * -----	1-3	
X	GB 1 427 995 A (HITACHI LTD) 10 March 1976 (1976-03-10) * page 1, lines 78-95 * * page 2, lines 55-65,68-72 * * page 3, lines 85-88 * * page 4, lines 34-53 * * figures 3,9 * -----	1-3	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F02D
F02M
H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	28 July 2005	Boye, M

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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28-07-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4385339 A	24-05-1983	JP 1021342 B	20-04-1989
		JP 1546008 C	28-02-1990
		JP 56081232 A	03-07-1981
		DE 3045639 A1	27-08-1981
GB 2150368 A	26-06-1985	NONE	
GB 1428353 A	17-03-1976	NONE	
GB 1427995 A	10-03-1976	JP 818865 C	30-06-1976
		JP 48088320 A	19-11-1973
		JP 50032897 B	25-10-1975
		DE 2306007 A1	06-09-1973
		US 4078528 A	14-03-1978

EPO FORM P0459

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