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

(11) EP 3 712 418 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.09.2020 Bulletin 2020/39

(21) Application number: **19164188.5**

(22) Date of filing: **20.03.2019**

(51) Int Cl.:
F02D 41/38 *(2006.01)*
F02D 41/20 (2006.01)
F02D 41/22 (2006.01)
F02M 55/02 (2006.01)
F02M 63/00 (2006.01)
F02M 63/02 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Vitesco Technologies GmbH**
30165 Hannover (DE)

(72) Inventor: **Chia, Tet Kong Brian**
93053 Regensburg (DE)

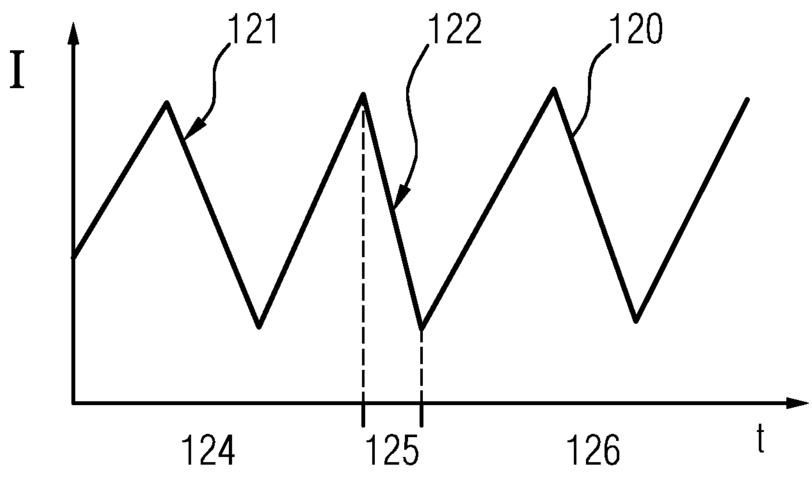
(74) Representative: **Waldmann, Georg Alexander**
Continental Automotive GmbH
Patente und Lizenzen
Postfach 22 16 39
80506 München (DE)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) METHOD FOR OPERATING A PRESSURE CONTROL VALVE, METHOD FOR OPERATING A FLUID SUPPLY SYSTEM AND DEVICE FOR OPERATING A FLUID SUPPLY SYSTEM

(57) A method for operating a pressure control valve (110) of a fluid supply system (100) for a vehicle comprises:
- applying a control signal (120) for the valve (110) to hold the valve (110) in a closed state dependent on a given opening pressure for the valve (110),
- detecting a first frequency (121) of the control signal (120) in a first period (124) of oscillation,
- detecting a second frequency (122) of the control signal (120) in a second period (125) of oscillation, the second period (125) being adjacent to the first period (124),
- comparing the first frequency (121) with the second frequency (122),
- determining an opening of the valve (110), if the second frequency (122) is different from the first frequency (121).

FIG 3



EP 3 712 418 A1

Description

Field of Technology

[0001] The disclosure relates to a method for operating a pressure control valve of a fluid supply system for a vehicle. The disclosure further relates to a method for operating a fluid supply system for a vehicle, in particular for a fluid supply system with a pressure control valve. The disclosure further relates to a corresponding device for operating a fluid supply system for a vehicle.

Background

[0002] Fluid supply systems for diesel engines or gasoline engines may work with high pressure. So-called common rail direct fuel injection systems comprise a high pressure pump for feeding a common fuel rail. For example, pressure in the rail is determined with the aid of a pressure sensor. The pump feeds fuel to the common rail dependent on a desired pressure and the signal of the pressure sensor.

[0003] It is desirable to provide methods and devices for operating a pressure control valve of a fluid supply system for a vehicle and the fluid supply system that allow reliable operation.

Summary of the Invention

[0004] Exemplary embodiments herein provide a method for operating a pressure control valve of a fluid supply system for a vehicle.

[0005] In particular, the method comprises: operating a pressure control valve of a fluid supply system for a vehicle, comprising:

- applying a control signal for the valve to hold the valve in a closed state dependent on a given opening pressure for the valve,
- detecting a first frequency of the control signal in a first period of oscillation,
- detecting a second frequency of the control signal in a second period of oscillation, the second period being adjacent to the first period,
- comparing the first frequency with the second frequency,
- determining an opening of the valve, if the second frequency is different from the first frequency.

[0006] The method allows to use the pressure control valve as an indicator of the given opening pressure of the valve being exceeded. For example, the given opening pressure equals a maximum system pressure of the fluid supply system. The opening pressure of the valve may be slightly higher than the maximum system pressure. If the valve opens, the system pressure is higher than the opening pressure of the valve. Due to the detection of the frequency change in the control signal, the opening of the valve is easy and reliable to detect. The change in the frequency of the control system results from a movement of an armature of the pressure control valve from a closed state to the open state. For example, the change in the frequency is due to the pole distance variation during opening and closing of the valve and the voltage induced due to the movement of the armature. The frequency change indicates the opening of the pressure control valve which also means that the rail pressure is above the opening pressure of the pressure control valve. This information can be used to indicate that the supply system has an overpressure. A corresponding failure reaction is possible to prevent a system burst. Thus, an overpressure can be avoided even if there is a malfunction of the rail pressure sensor. If the rail pressure sensor delivers a faulty signal, e.g. a stack signal, the overpressure in the system may not be determined depending on the signal of the rail pressure sensor. By detecting the frequency change of the control signal of the pressure control valve damage to the system due to overpressure can still be avoided.

[0007] According to further embodiments, the second period follows directly after the first period. Thus, a relative change in the signal is detectable. Therefore other influencing factors like temperature can be disregarded.

[0008] According to further embodiments, the opening of the valve is detected if the second frequency is greater than the first frequency depending on the movement of the armature and/or the pole piece of the valve relative to a coil of the valve. According to further embodiments, the opening of the valve is detected if the second frequency is smaller than the first frequency depending on the movement of the armature and/or the pole piece of the valve relative to a coil of the valve.

[0009] The movement of the armature and/or the pole piece has an effect on the signal applied to the pressure control valve. The pole distance has an effect on the signal applied to the pressure control valve. In particular, the transition from closed to open has an effect on the current applied on the pressure control valve due to the movement of the armature. In particular, the transition from closed to open has an effect on the frequency with which the intensity of the current changes. The frequency is higher or lower when the pressure control valve opens dependent on the design of pressure control valve itself. A frequency increase or a frequency decrease can be detected depending on the design of the pressure control valve. In particular, the frequency change is detectable when the current of the pressure control valve is controlled via a current close loop control. The frequency change is due to the change of current gradient which is in particular based on the combination of two physical event: a current induction due to the movement of the anchor and an inductivity change due to a change in the pole distance (air gap). If the current of the pressure control valve is controlled via a PWM (pulse-width modulation) based control, in particular a fixed PWM control, a current change due to the change in current gradient can be detected. For example, a change in an average current is detected, if the pressure control valve opens. For example, a change in an average current is detected, if the pressure control valve closes.

[0010] According to further embodiments, the method comprises:

- applying the control signal to hold the valve in a closed state with an opening pressure greater than the given opening pressure for the valve in a third period of oscillation, the third period being subsequent to the second period,
- detecting a third frequency of the control signal in the third period,
- comparing the third frequency with the first frequency,
- determining a closing of the valve, if the third frequency is smaller than the first frequency.

[0011] Thus, it is possible to have a further transition from the open state to the closed state of the pressure control valve. By increasing the opening pressure, the pressure control closes. If there is a change in the frequency after the opening pressure has been increased, this is a sign that the pressure control valve has moved from the open state to the closed state. That confirms that the pressure control valve has opened in the second period. Thus a more robust detection is possible.

[0012] According to further embodiments, a control signal to hold the valve in a closed state with an opening pressure smaller than the given opening pressure is applied in response to determining the opening of the valve. Thus, it is possible to reduce the pressure in the supply system to avoid an overpressure and a system burst.

[0013] According to a further aspect, a method for operating a fluid supply system for a vehicle comprises determining an overpressure in the fluid supply system if an opening of the pressure control valve has been detected.

[0014] According to further embodiments, an overpressure in a common rail of the supply system is determined dependent on the detection of the opening of the valve. The overpressure in the common rail is detected independent of the signal of a pressure signal of the common rail. According to further embodiments, a fluid delivery of a pump of the supply system is limited in response to determining the opening of the valve. Thus, it is possible to lower the system pressure.

[0015] According to further embodiments, a malfunction of the pressure sensor of the supply system is determined depending on the opening of the valve. If the opening of the pressure control valve has been detected and a signal of the pressure sensor indicates a pressure below the maximum system pressure, this indicates a malfunction of the pressure sensor.

[0016] According to a further aspect, a device for operating a fluid supply system for a vehicle is described, wherein the device is configured to execute a method according to at least one of the embodiments explained above.

[0017] By detecting an overpressure in a fluid supply system in response to an opening of the pressure control valve, a low cost software solution is possible. The described methods allow a low cost strategy to detect system overpressure and prevent an eventual system burst. Furthermore, the detection is based on the relative change of frequency which is not affected by component tolerances and other environmental influences.

Brief Description of the Drawings

[0018] The present invention will be further described with reference to the accompanying drawings, wherein:

Figure 1 shows a schematic diagram of a fluid supply system according to an embodiment;

Figure 2 shows a schematic diagram of a pressure control valve according to an embodiment;

Figures 3 and 4 each show a schematic signal path according to embodiments; and

Figure 5 shows a flowchart of a method according to an embodiment.

[0019] While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail.

Detailed Description of the Drawings

[0020] In the following detailed description of embodiments, reference is made to the accompanying drawings, which form a part hereof and in which are shown, by way of illustration, specific embodiments in which the invention may be practiced. The illustrated embodiments are not intended to be exhaustive of all embodiments according to the invention.

[0021] Figure 1 shows a fluid supply system 100 according to an embodiment. In particular, the supply system 100 is a common rail fuel injection system for diesel or gasoline engines of a vehicle.

[0022] The supply system 100 comprises a high pressure pump that feeds the fuel to a common rail 102 which acts as a pressure reservoir. Out of the common rail 102 the fuel can be injected to an engine wire injector 103.

[0023] A pressure sensor 104 may be assigned to the common rail 102 to measure the pressure inside the common rail 102.

[0024] The supply system 100 comprises a pressure control valve 110 that is an electrovalve with a variable opening pressure. The electrovalve comprises an electromagnet. The pressure control valve may be a solenoid valve. Depending on a given opening pressure for the pressure control valve 110 a maximum system pressure for the supply system 100 inside the common rail 102 can be set.

[0025] For example, the pressure sensor 104 is an analog high pressure sensor which is mounted to the common rail 102. The rail pressure sensor 104 provides an output signal in the form of a signal voltage to an engine control unit (ECU). The measured signal voltage by the ECU might drift away. That means that the measured value could differ from the actual pressure value inside the common rail 102. Such a signal drift may lead to a system overpressure and possibly to a system burst.

[0026] Figure 2 shows the pressure control valve 110 according to an embodiment.

[0027] The pressure control valve 110 comprises a valve pin 114. To close the pressure control valve 110 the valve pin 114 is pressed against a valve seat 115. The valve pin 114 is coupled to a pole piece 112 and an armature 113. A coil 111 surrounds the armature 113. Thus, by applying a current to coil, the valve pin 114 can be moved. The value of the current define an opening pressure of the pressure control valve 110.

[0028] The pressure control valve 110 is used as an active pressure decrease during engine coasting mode. Most of the time, the pressure control valve 110 is controlled via open loop mode. A current is applied on the pressure control valve 110 so that the opening pressure is above the rail pressure set point or at the maximum system pressure. A safety margin may be added to the given rail pressure set point or the maximum system pressure. This means that the pressure control valve is always in a closed position during normal operation. In the case of a malfunction of the rail pressure sensor 104, e.g. a signal stuck, the pressure control valve 110 will open when the pressure inside the common rail 102 is above the opening pressure of the pressure control valve 110. The opening pressure of the pressure control valve 110 depends on the applied current. However, the expectation that the pressure will stay around the opening pressure will not be fulfilled. The reason for this is that the pressure control valve 110 does not have the pressure-limiting function like a pressure-limiting valve. Unless a system overpressure is detected and further action is taken, the high pressure system 100 runs the risk of overpressure and eventual system burst. This is because a controlled pressure control valve acts as a throttle and restricts the fluid flow out of the common rail 102. The pressure control valve, which is supplied with current and/or magnetic force, pushes the valve against the valve seat. Therefore, the pressure inside the common rail 102 cannot be limited through the pressure control valve 110.

[0029] Figure 3 shows a control signal 120 to control the pressure control valve 110 according to an embodiment. During a first period 124 the control signal comprises a first frequency 121. During the first period 124 the system 100 is in a normal operation.

[0030] If the pressure inside the common rail 102 rises up over the given opening pressure of the pressure control valve 110, the pressure control valve 110 opens. This can be detected in a frequency change of the control signal 120. In Figure 3 this is shown by an increased second frequency 122 during a second period 125. During the second period 125 the valve pin 114 moves together with the pole piece 112 and the armature 113 relative to the coil 111. This induces a voltage. The voltage induced due to the movement of armature 113 leads to the change in the frequency between the first frequency 121 and the second frequency 122. By comparing the second frequency 122 with the first frequency 121 the opening of the pressure control valve 110 is detectable.

[0031] According to further embodiments, the detected frequency change of the control signal 120 is a decreased second frequency 122 during a second period 125. The kind of frequency change is dependent on the design and type of the pressure control valve 110.

[0032] According to embodiments, the second period 125 follows directly after the first period 124. The first frequency 121 and the second frequency 122 that belong to directly adjacent periods of oscillation are compared. Thus, component tolerance and other environmental influences like temperature can be disregarded.

[0033] In particular, if there is a malfunction of the rail pressure sensor 104, the pressure inside the common rail 102 rises over the opening pressure of the pressure control valve 110. The frequency of the control signal 110 defines the opening pressure of the pressure control valve. In particular, the current applied to the pressure control valve 110 specifies the opening pressure of the pressure control valve 110. In response to the pressure inside the common rail 102 being higher than the opening pressure of the pressure control valve 110, the pressure control valve 110 opens. The transition from the closed state to the open state has an effect on the current applied on the pressure control valve 110 due to the movement of the armature 113 relative to the coil 111. The transition from the closed state to the open position has an effect on the frequency of the control signal 120 applied on the pressure control valve 110. The change in the frequency is due to the pole distance variation during opening and closing of the pressure control valve 110 and the voltage induced due to the movement of the armature 113. Thus, an opening of the pressure control valve is detectable dependent on the frequency of the control signal 120. The detection of an opening of the pressure control valve 110 can be used an indicator for a system overpressure in the common rail 102. Further failure reaction is possible to prevent a system burst, for example lowering the current applied to the pressure control valve to decrease the opening pressure. Furthermore, a limitation of the pump delivery of the pump 101 is possible or a limp home mode for the vehicle is possible.

[0034] Figure 4 shows the control signal 120 according to a further embodiment.

[0035] After detection of the opening of the pressure control valve 110 during the second period 125 the applied current is increased. Thus, in a third period 126 after the second period 125 a third frequency 123 is detectable. The third frequency 123 is different to the second frequency 122 and different to the first frequency 121. In particular, the third frequency 123 is smaller than the first frequency 121 and smaller than the second frequency 122. The applied current is increased after an initial frequency change detection in the second period 125. The increased applied current leads to a transition to a closed pressure control valve 110. The increased current defines an increased opening pressure and thus the pressure control valve 110 closes. The closing must lead to a change of the frequency of the control signal 120. This change from the second frequency 122 or the first frequency 121 to the third frequency 123 confirms that the pressure control valve 110 has indeed opened during the first period 124. Thus, a more robust detection of a system overpressure is realized.

[0036] According to further embodiments, the third frequency 123 is greater than the first frequency 121 and greater than the second frequency 122. The kind of frequency change is dependent on the design and type of the pressure control valve 110.

[0037] Figure 5 shows a flowchart of a method according to an embodiment.

[0038] During step 201 the pressure control valve 110 is applied with a constant current dependent on a desired opening pressure and/or a desired maximum system pressure.

[0039] In step 202 a system overpressure detection is executed. The overpressure is detected dependent on a detection of an opening of the pressure control valve 110. The opening of the pressure control valve 110 is detected dependent on a frequency change of the control signal 120. The valve opening is detected via a frequency change on the applied current.

[0040] In step 203 a system burst prevention is started. For example the current applied to the pressure control valve 110 is lowered. Alternatively or in addition a pump delivery is limited, for example via a volume control valve intervention. Alternatively or in addition a limp home mode for the vehicle is initiated to prevent a further increase of the pressure inside the common rail 102.

[0041] The proposed methods realize a low cost strategy to detect a system overpressure. The system overpressure is detectable via a software solution via hardware that is usually installed in the supply system 100. Thus, even with a malfunctioning pressure sensor 104 a system burst can be prevented.

Claims

1. Method for operating a pressure control valve (110) of a fluid supply system (100) for a vehicle, comprising:

- applying a control signal (120) for the valve (110) to hold the valve (110) in a closed state dependent on a given opening pressure for the valve (110),
- detecting a first frequency (121) of the control signal (120) in a first period (124) of oscillation,
- detecting a second frequency (122) of the control signal (120) in a second period (125) of oscillation, the second period (125) being adjacent to the first period (124),
- comparing the first frequency (121) with the second frequency (122),
- determining an opening of the valve (110), if the second frequency (122) is different from the first frequency (121).

2. Method according to claim 1, wherein the second period (125) follows directly after the first period (124).

3. Method according to claim 1 or claim 2, comprising:

- determining the opening, if the second frequency (122) is greater than the first frequency (121) or smaller than the first frequency (121), dependent on a movement of an armature (113) and/or a pole piece (122) of the valve (110) relative to a coil (111) of the valve (110).

4. Method according to any one of claims 1 to 3, comprising:

- applying the control signal (120) to hold the valve (110) in a closed state with an opening pressure greater than the given opening pressure for the valve (110) in a third period (126) of oscillation, the third period (126) being subsequent to the second period (122),
- detecting a third frequency (123) of the control signal (120) in the third period (126),
- comparing the third frequency (123) with the first frequency (121),
- determining a closing of the valve (110), if the third frequency (123) is smaller than the first frequency (121).

5. Method according to any one of claims 1 to 4, comprising:

- applying the control signal (120) to hold the valve (110) in a closed state with an opening pressure smaller than the given opening pressure in response to determining the opening of the valve (110).

6. Method for operating a fluid supply system (100) for a vehicle, wherein the fluid supply system (100) comprises a pressure control valve (110), comprising:

- if an opening of the valve (110) has been detected with a method according to any one of claims 1 to 5, determining an overpressure in the fluid supply system (100).

7. Method according to claim 6, comprising:

- determining an overpressure in a common rail (102) of the supply system (100) dependent on the detection of the opening of the valve (110).

8. Method according to claim 6 or claim 7, comprising:

- limiting of a fluid delivery of a pump (101) of the supply system (100) in response to determining the opening of the valve (110).

9. Method according to any one of claims 6 to 8, comprising:

- determining a malfunction of a pressure sensor (104) of the supply system (100) dependent on the opening of the valve (110) .

10. Device for operating a fluid supply system (100) for a vehicle, wherein the device is configured to execute a method according to any one of the claims 1 to 9.

Amended claims in accordance with Rule 137(2) EPC.

1. Method for operating a pressure control valve (110) of a fuel supply system (100) for a vehicle, comprising:

- applying a control signal (120) for the valve (110) to hold the valve (110) in a closed state dependent on a given opening pressure for the valve (110), wherein the valve (110) opens if a pressure rises up over the given opening pressure,- detecting a first frequency (121) of the control signal (120) in a first period (124) of oscillation,
- detecting a second frequency (122) of the control signal (120) in a second period (125) of oscillation, the second period (125) being adjacent to the first period (124),
- comparing the first frequency (121) with the second frequency (122),
- determining a transition from the closed state to an open state of the valve (110) and thus an opening of the valve (110), if the second frequency (122) is different from the first frequency (121).

2. Method according to claim 1, wherein the second period (125) follows directly after the first period (124).

3. Method according to claim 1 or claim 2, comprising:

- determining the opening, if the second frequency (122) is greater than the first frequency (121) or smaller than the first frequency (121), dependent on a movement of an armature (113) and/or a pole piece (122) of the valve (110) relative to a coil (111) of the valve (110).

4. Method according to any one of claims 1 to 3, comprising:

- applying the control signal (120) to hold the valve (110) in a closed state with a further opening pressure greater than the given opening pressure for the valve (110) in a third period (126) of oscillation, the third period (126) being subsequent to the second period (122),
- detecting a third frequency (123) of the control signal (120) in the third period (126),
- comparing the third frequency (123) with the first frequency (121),
- determining a closing of the valve (110), if the third frequency (123) is smaller than the first frequency (121).

5. Method according to any one of claims 1 to 4, comprising:

- applying the control signal (120) to hold the valve (110) in a closed state with a further opening pressure smaller than the given opening pressure in response to determining the opening of the valve (110).

6. Method for operating a fuel supply system (100) for a vehicle, wherein the fuel supply system (100) comprises a pressure control valve (110), comprising:

- if an opening of the valve (110) has been detected with a method according to any one of claims 1 to 5, determining an overpressure in the fuel supply system (100).

7. Method according to claim 6, comprising:

- determining an overpressure in a common rail (102) of the supply system (100) dependent on the detection of the opening of the valve (110).

8. Method according to claim 6 or claim 7, comprising:

- limiting of a fuel delivery of a pump (101) of the supply system (100) in response to determining the opening of the valve (110) .

9. Method according to any one of claims 6 to 8, comprising:

- determining a malfunction of a pressure sensor (104) of the supply system (100) dependent on the opening of the valve (110).

10. Device for operating a fuel supply system (100) for a vehicle, wherein the device is configured to execute a method according to any one of the claims 1 to 9.

FIG 1

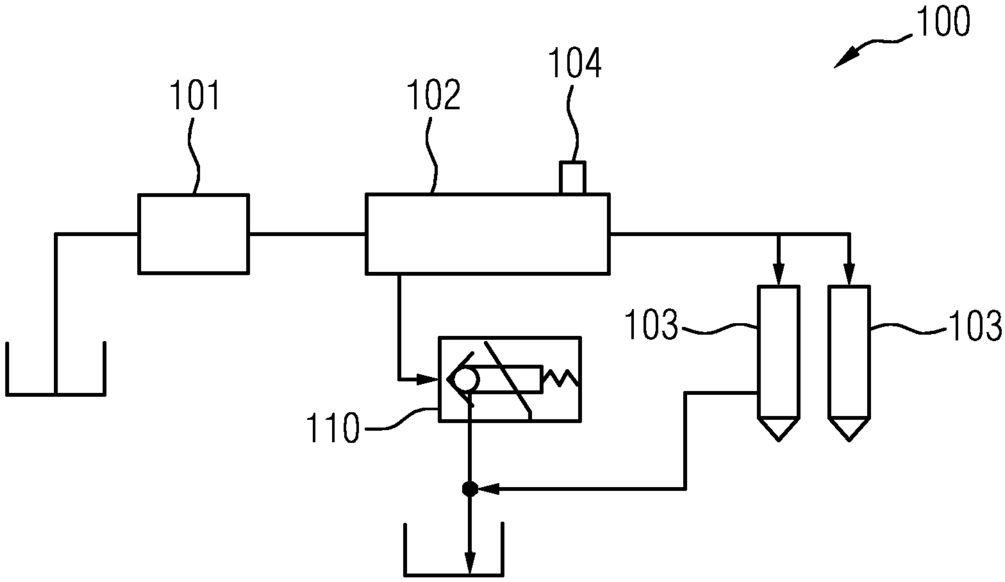


FIG 2

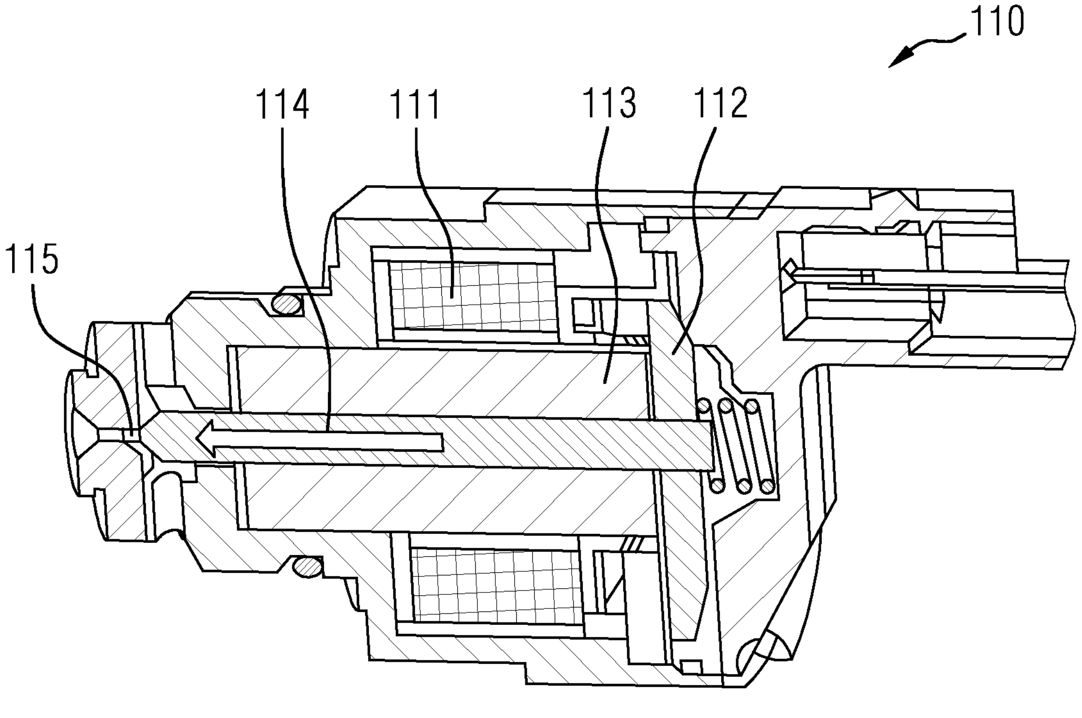


FIG 3

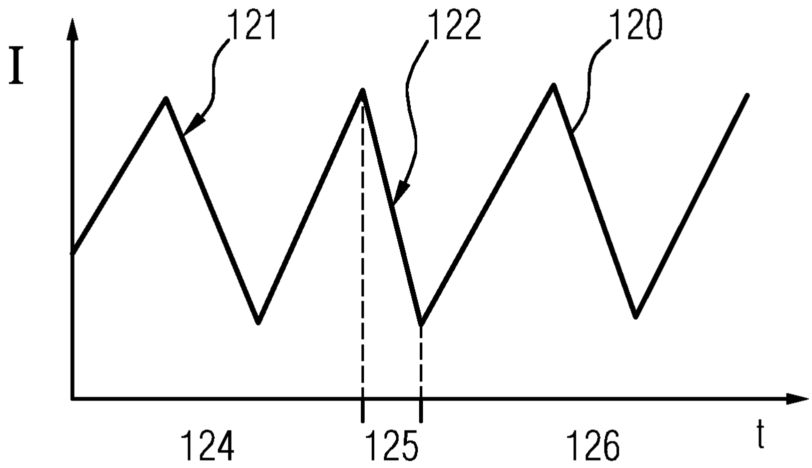


FIG 4

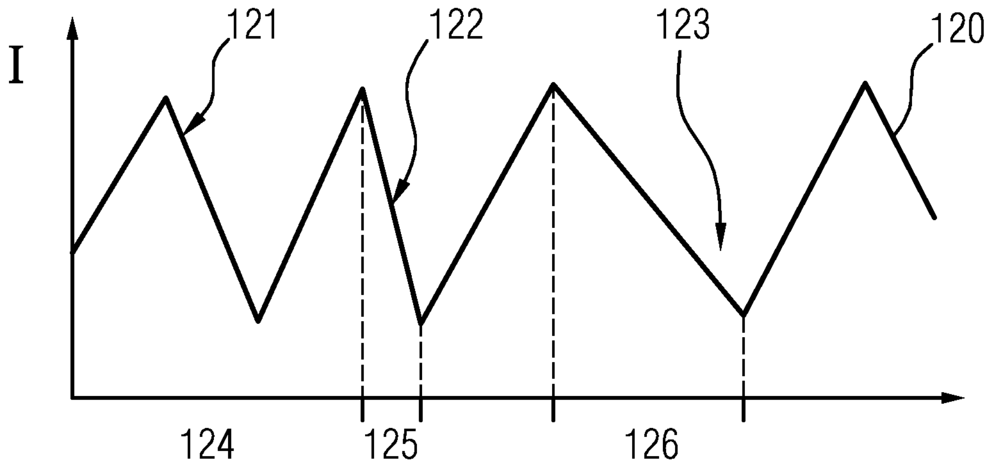
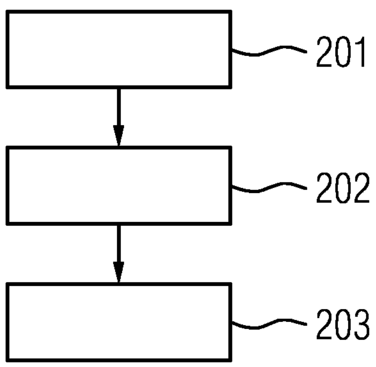


FIG 5



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 16 4188

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	EP 3 385 527 A1 (CONTINENTAL AUTOMOTIVE GMBH [DE]) 10 October 2018 (2018-10-10) * paragraph [0014]; figures 1-3 * * paragraph [0020] * * paragraph [0031] - paragraph [0035] * -----	1-3,10 5-9 4	INV. F02D41/38 ADD. F02D41/20 F02D41/22 F02M55/02 F02M63/00 F02M63/02
Y	DE 10 2013 202266 A1 (BOSCH GMBH ROBERT [DE]) 14 August 2014 (2014-08-14) * paragraph [0002] - paragraph [0003] * * paragraph [0020] * * paragraph [0025] - paragraph [0034] * -----	5-9	
A	DE 10 2012 203283 A1 (CONTINENTAL AUTOMOTIVE GMBH [DE]) 5 September 2013 (2013-09-05) * paragraph [0048] - paragraph [0049] * -----	1-10	
A	US 2017/107931 A1 (ANETSBERGER DANIEL [DE] ET AL) 20 April 2017 (2017-04-20) * paragraph [0023] - paragraph [0050] * -----	1-10	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 3 385 528 A1 (CONTINENTAL AUTOMOTIVE GMBH [DE]) 10 October 2018 (2018-10-10) * paragraph [0015] * * paragraph [0029] - paragraph [0036]; figures 2-3 * -----	1-10	F02D F02M

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	2 August 2019	Rocabruna Vilardell

CATEGORY OF CITED DOCUMENTS

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

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

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 16 4188

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

02-08-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3385527 A1	10-10-2018	NONE	
DE 102013202266 A1	14-08-2014	NONE	
DE 102012203283 A1	05-09-2013	NONE	
US 2017107931 A1	20-04-2017	CN 106460755 A	22-02-2017
		DE 102014206442 A1	08-10-2015
		KR 20160140923 A	07-12-2016
		US 2017107931 A1	20-04-2017
		WO 2015150016 A1	08-10-2015
EP 3385528 A1	10-10-2018	NONE	

EPO FORM P0459

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