



- (51) International Patent Classification:
F16K 31/00 (2006.01)
- (21) International Application Number:
PCT/US2014/067398
- (22) International Filing Date:
25 November 2014 (25.11.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant: AEROJET ROCKETDYNE, INC. [US/US];
P.O. Box 13222, Sacramento, CA 95813-6000 (US).
- (72) Inventors: SWANSON, Jon, Darel; 22034 West Conway
Pl, Saugus, CA (US). DAREJEH, Hadi; 985 Triunfo Cyn
Road, Westlake Village, CA (US).
- (74) Agent: THORSTAD-FORSYTH, Carol, E.; Fox Roth-
schild LLP, 222 Lakeview Avenue, Suite 700, West Palm
Beach, FL 33401 (US).
- (81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published: — with international search report (Art. 21(3))

(54) Title: ACTUATOR CONTROLLER

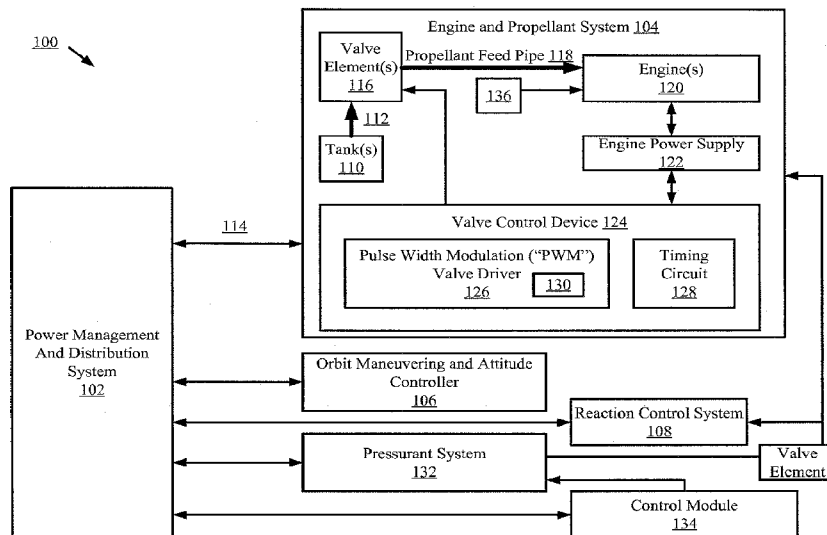


FIG. 1

(57) Abstract: Systems (100) and methods (300, 500) for controlling an electromechanical valve element (116). The methods involve: building up a magnetic flux through a valve (206) of the electromechanical valve element by supplying a PWM signal to an electromechanically inductive coil (202) of the electromechanical valve element at a power level lower than a power level needed to actuate the valve. When the valve needs to be opened, an amplitude of the PWM signal is increased such that the power provided to the electromechanically inductive coil rises to a power level sufficient to actuate the valve. Notably, the valve opens when a power cycling time of the PWM signal increases beyond a minimum power required to open the valve.

WO 2016/085476 A1

ACTUATOR CONTROLLER

BACKGROUND

Statement of the Technical Field

5 The disclosure relates to electronic systems comprising controllers for actuators. More particularly, the disclosure concerns systems and methods for controlling actuators using Pulse Width Modulation (“PWM”) frequency power control.

Description of the Related Art

10 In an orbital launch vehicle, a separation system is provided for a crew capsule. The separation system is typically a solid rocket system that pulls the crew capsule away from the launch vehicle. During operation, power flows from one or more power sources to a Power Management and Distribution (“PMD”) system of the orbital launch vehicle. From there, the power is distributed to all loads. The loads include, but are not limited to, bus loads, payloads and a Service Module Propulsion (“SMP”) system. A PMD system may include a collection
15 of circuits comprising filters, batteries, converters, isolation circuits and regulators. During operation, the PMD system outputs a regulated bus voltage that is distributed throughout the bus to the SMP system, bus loads, payloads, and battery chargers. The SMP system comprises engines, an engine power supply, and propellant tank(s). In general, the engines are configured for use on the orbital launch vehicle to assist in adjusting its position when in
20 flight. Various valves may control the provision of propellant from one or more propellant tanks to the engines.

SUMMARY

25 The present disclosure concerns systems and methods for controlling an electromechanical valve element. The methods comprise building up a magnetic flux through a valve by supplying a PWM signal to an electromechanically inductive coil of the electromechanical valve element at an average PWM current level lower than a current level needed to actuate the valve. When the valve needs to be opened, an amplitude of the PWM signal is increased such that the current provided to the electromechanically inductive coil rises to a level

sufficient to actuate the valve. Notably, the valve opens when a power cycling time of the PWM signal increases beyond a minimum power required to open the valve.

Once the valve has opened, the amplitude of the PWM signal is reduced. The amplitude is reduced such that a magnetic field applied to the valve is still of a strength sufficient to retain the valve in an open position. The valve is closed by further reducing the amplitude of the PWM signal such that the magnetic field applied to the valve drops to a strength that is not sufficient to retain the valve in its open position. The supply of the PWM signal to the electromechanically inductive coil is entirely removed when the valve does not need to be actuated for a given period of time.

10 The present disclosure also concerns an actuator controller including an actuator and a PWM circuit interfacing with the actuator. The actuator has a pull-in average current which causes actuation of the actuator when supplied thereto. During operation, the PWM circuit may be operable to hold steady a pre-pull-in average current which has a positive non-zero value lower than the pull-in average current. The term “hold steady”, as used herein, means to supply a PWM signal which has an average current of a particular value during a given period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will be described with reference to the following drawing figures, in which like numerals represent like items throughout the figures, and in which:

20 FIG. 1 is a schematic illustration of an exemplary power system for a space vehicle.

FIG. 2 is a schematic illustration of an exemplary architecture for a valve element.

FIG. 3 is a flow diagram of an exemplary method for controlling the opening and closing of the valve of the valve element shown in FIG. 1.

FIG. 4 is a graph showing two signals useful for understanding the present disclosure.

25 FIG. 5 is a flow diagram of another exemplary method for controlling an actuator.

DETAILED DESCRIPTION

The present disclosure is directed to implementing systems and methods for controlling an actuator. The speed at which the actuator (e.g., coil) engages with another mechanical element (e.g., a valve) may be faster as compared to that of conventional systems. The term “actuator”, as used herein, refers to an electro-mechanical device that moves a mechanism. In some scenarios, an element of an actuator may be a coil based solenoid, the coil of which may be moved via electromagnetic induced force. The actuator controller system may be employed in any application where fast reacting mechanical components are needed. For example, the present disclosure can also be used in medical applications, combustion systems (e.g., automotive, industrial equipment or similar industries), food processing applications and/or drug manufacturing applications. This concept can be used as a technique for an improvement of precise mass transfer of gas or liquid media by accelerating the valve to its open position (flow controlled).

Referring now to FIG. 1, there is provided a schematic illustration of an SMP system **100** for a space vehicle that facilitates activities in a space environment, such as service to a space station, maintenance of existing satellites, placement of equipment in orbit and other activities. In this regard, the SMP system is configured to develop sufficient thrust so that the space vehicle can be maneuvered away from or toward other object.

As shown in FIG. 1, the SMP system **100** comprises a Power Management and Distribution (“PMD”) system **102**, an Engine and Propellant (“E/P”) system **104**, an Orbit Maneuvering and Attitude Controller (“OMAC”) **106**, a Reaction Control System (“RCS”) **108**, a pressurant system **132** and a control module **134**. The listed components **106**, **108**, **132** and **134** are well known in the art, and therefore will not be discussed herein.

During operation, power flows from one or more power sources (not shown) to the PMD system **102**. The power sources can include, but are not limited to, batteries, fuel cells, and/or solar cells. The PMD system **102** distributes the power to all loads **104**, **106**, **108**, **132**, **134** of the SMP system **100**. In this regard, the PMD system **102** includes a collection of circuits comprising filters, batteries, converters, isolation circuits and/or regulators. The circuits are

arranged to output a regulated bus voltage that is distributed throughout the bus to the loads **104, 106, 108, 132, 134**, as well as battery chargers.

The E/P system **104** may include one or more engines **120** and an engine power supply **122**. The engine power supply **122** is generally configured to supply power to the engine(s) **120** so as to turn it(them) “on” and “off”. In this regard, the regulated bus voltage output from the PMD system **102** is distributed to the engine power supply **122**, as shown by reference number **114**. The regulated bus voltage is used by the engine power supply **122** to start the engine(s) **120**. At start time, the engine(s) **120** is(are) supplied propellant which is stored in one or more tanks **110**. At least one valve element **116** is provided for controlling the provision of propellant from the tank(s) to the engine(s).

The valve element **116** includes, but is not limited to, an electromechanical valve (e.g., a solenoid valve). Electromechanical and solenoid valves are well known in the art, and therefore will not be described in detail herein. A schematic illustration of an exemplary architecture for the valve element **116** is provided in FIG. 2. The valve element **116** is described herein as comprising a normally closed valve. However, the valve element **116** may alternatively comprise a normally open valve.

As shown in FIG. 2, the valve element **116** comprises an electromagnetically inductive coil **202**, a conductive rod **204** and a valve **206**. The valve element **116**, inductive coil **202** and/or conductive rod **204** is(are) also referred to herein as (an) actuator(s). The valve **206** is normally in a closed position. The valve **206** transitions to an open position in response to an electrical signal received from a Valve Control Device (“VCD”) **124**. In this scenario, propellant is allowed to flow from the tank **110** to the engine **120** via propellant feed pipes **112** and **118**. The opening and closing of the valve **206** is thereafter also controlled by the VCD **124** to regulate the flow of propellant to the engine **120** throughout its operation.

Notably, the VCD **124** implements a novel method for controlling the opening and closing of the valve of the valve element **116**. A schematic illustration of the novel method **300** is provided in FIG. 3. Method **300** is described in relation to a normally closed solenoid valve scenario. As should be understood, the actuator control technique employed herein may also be used with normally open valves. In this case, method **300** may be revised accordingly.

The method **300** generally involves providing power to the electromagnetically inductive coil **202** of the valve element **116** at a cyclic on/off rate faster than the speed at which the valve **206** opens. As should be understood, the electromagnetically inductive coil **202** is wound around a conductive rod **204** which moves in and out of the coil **202** as shown by arrow **214** so as to alter the coil's inductance, and thereby provide an electromagnet. When a magnetic field of a particular strength is applied to the valve **206** by the electromagnet, the valve is caused to move in a direction shown by arrow **208** whereby the valve is transitioned from a closed state to an open state. When the strength of the magnetic field is reduced by a certain amount, the valve **206** is caused to move in a direction shown by arrow **210** whereby the valve is transitioned from the open state to the closed state.

As shown in FIG. 3, the method **300** begins with step **302** and continues with step **304** where an electrical PWM signal (e.g., electrical PWM signal **406** of FIG. 4) is supplied to the electromagnetically inductive coil **202** at an PWM average current level lower than the actual PWM current level required to actuate the valve **206** of the valve element **116**. This allows a buildup of magnetic flux through the valve **206**, as shown by step **306**.

When the valve **206** does not need to be actuated or opened within a given period of time [**308:NO**], step **314** is performed where the supply of power to the valve element **116** is removed. In contrast, when the valve **206** needs to be actuated or opened within a given period of time [**308:YES**], method **300** continues with steps **312-320** in which the valve is opened and closed at the appropriate times.

In this regard, step **312** involves determining when the valve **206** needs to be opened. At the time the valve **206** needs to be open [**312:YES**], step **314** is performed. Step **314** involves increasing the current (or amplitude) of the electrical PWM signal such that the power provided to the electromagnetically inductive coil **202** rises to the actual power level required to actuate the valve (e.g., as shown by peak **402** of FIG. 4). As shown by step **316**, the valve **206** opens when the powered cycling time increases beyond the valve's required opening time. Once the valve has been opened, the valve is held in its open position. In this regard, the amplitude of the electrical PWM signal is decreased for power saving and heat reduction reasons, as shown by step **318**. The amplitude is decreased so that the power provided to the

electromagnetically inductive coil **202** falls below the power level required to actuate the valve **206**, but the magnetic field is still of a strength to retain the valve in its open position. The amplitude reductions can be achieved by lowering the voltage and/or current of the PWM signal.

- 5 When the valve needs to be closed [**320:YES**], then step **322** is performed where the amplitude of the PWM signal is further decreased. More specifically, the amplitude of the PWM signal is decreased to a value in which the magnetic field applied to the valve **206** is of a strength that is not strong enough to retain the valve in its open position. Thereafter, method **300** returns to step **308**.
- 10 As a result of the implementation of this method, the actuation speed (or opening speed) of the valve **206** is increased greatly as compared that of conventional valves (e.g., as shown by time period **404** of FIG. 4). For example, a conventional valve typically opens at 100 msec, while the valve may open at 74 to 84 msec using this method. This example reflects a 16 to 26 percent improvement in opening time of the valve. The increased actuation speed of the
- 15 valve facilitates a more precise flow of propellant to the engine **120**, thereby increasing the efficiency of propellant use. Additionally, such lower cost valves may be used in propulsion or engine applications. Furthermore, the electrical power surge experienced in the valve element **116** is reduced as compared to that of conventional valve circuits.

Referring again to FIG. 1, the electrical PWM signal is generated by a PWM valve driver (or

20 PWM circuit) **126** of the VCD **124**. The PWM valve driver **126** includes hardware and/or software implementing a modulation technique. The hardware can include, but is not limited to, an electronic circuit. Modulation techniques are well known in the art, and therefore will not be described herein. Any known or to be known modulation technique can be used herein without limitation. In all cases, the modulation technique controls the width of an electrical

25 signal's pulse based on modulator signal information. The PWM signal resulting from such modulation generally comprises a chopped square wave with a fixed pulse width and frequency (e.g., of about 16 kilohertz). Notably, the frequency of the PWM signal may not be the same for two different valve control applications.

The modulation technique allows the control of the power supplied to the valve element **116**. In some scenarios, the supplied power is controlled using a switch **130** disposed between the engine power supply **122** and the valve element **116**. The switch **130** can include, but is not limited to, a semiconductor switch. Semiconductor switches are well known in the art, and therefore will not be described herein. Any known or to be known semiconductor switch can be used herein without limitation. The switch **130** is turned “on” and “off” at a relatively fast pace. The longer the switch **130** is “on” as compared to the “off” periods, the higher the power supplied to the valve element **116**. The switching frequency is selected to be faster than the rate at which the valve **206** can open. A timing circuit **128** is provided to facilitate the turning “on” and “off” of the switch **330** at the proper times. The timing circuit **128** is designed to oscillate at a speed faster than the opening/closing speed of the valve **206**.

Referring now to FIG. 5, there is provided a flow diagram of another novel method **500** for controlling an actuator (e.g., the opening and closing of the valve of the valve element **116**). Method **500** begins with step **502** and continues with step **504** where a PWM circuit (e.g., the PWM valve driver **126** of FIG. 1) is interfaced with an actuator (e.g., valve element **116** of FIG. 1). The actuator has a pull-in average current (e.g., pull-in average current **408** of FIG. 4) with a value sufficient to cause actuation of the actuator when supplied thereto.

During operation, the PWM circuit holds steady a pre-pull-in average current (e.g., pre-pull-in average current **410** of FIG. 4) which has a positive non-zero value lower than the pull-in average current, as shown by step **506**. The term “hold”, as used herein, refers to maintaining or limit an amount of variation. The term “steady”, as used herein, refers to not fluctuating or varying widely. The pre-pull-in average current causes a magnetic flux to build up through the actuator. The magnetic flux is not of a sufficient amount to actuate the actuator, but is of a sufficient amount to increase the actuation time of the actuator (e.g., the opening/closing time of a valve). The magnetic flux is built up through the actuator by supplying a PWM signal (e.g., signal **406** of FIG. 4) to the actuator at a power level lower than a power level needed to actuate the actuator. The valve opens when the power cycling time of the PWM signal increases beyond the valve’s required power level to open, as described above and as shown by step **507**.

At some time later, step **508** is performed where the PWM circuit reduces the amplitude of the PWM signal such that a magnetic field applied to the actuator is still of a strength sufficient to retain the actuator in an actuated position (e.g., an open position). The amplitude can be further reduced in step **510** such that the magnetic field applied to the actuator is not of a strength sufficient to retain the actuator in the actuated position, whereby the actuator is caused to transition from the actuated position (e.g., an open position) to a non-actuated position (e.g., a closed position). The supply of a PWM signal to the actuator can be removed when a determination is made that the actuator does not need to be in an actuated position within a given period of time, as shown by step **512**. Upon completing step **512**, step **514** is performed where method **500** ends or other processing is performed.

15

20

25

CLAIMS

We claim:

1. A method for controlling an electromechanical valve element, comprising:
5 building up a magnetic flux through a valve of the electromechanical valve element by supplying a Pulse Width Modulation (“PWM”) signal to an electromechanically inductive coil of the electromechanical valve element at a PWM average current level lower than a PWM current level needed to actuate the valve; and
increasing an amplitude of the PWM signal when the valve needs to be opened such
10 that an average power provided to the electromechanically inductive coil rises to a power level sufficient to actuate the valve.
2. The method according to claim 1, further comprising removing the supply of the PWM signal to the electromechanically inductive coil when a determination is made that the valve does not need to be opened within a given period of time.
- 15 3. A method for controlling an electromechanical valve element of a propulsion system, comprising:
building up a magnetic flux through a valve of the electromechanical valve element by supplying a Pulse Width Modulation (“PWM”) signal to an electromechanically inductive coil of the electromechanical valve element at a PWM average current level lower than a PWM
20 current level needed to actuate the valve; and
allowing propellant to flow to an engine of the propulsion system by increasing an amplitude of the PWM signal such that an average power provided by the electromechanically inductive coil rises to a power level sufficient to actuate the valve.
4. The method according to claim 3, wherein the amplitude of the PWM signal is
25 increased when it is determined that the valve needs to be opened.

5. The method according to claim 5, further comprising removing the supply of the PWM signal to the electromechanically inductive coil when it is determined that the valve does not need to be opened within a given period of time.
6. A system, comprising:
5 an actuator having a pull-in average current that causes actuation of the actuator when supplied thereto; and
a Pulse Width Modulation (“PWM”) circuit interfacing with the actuator;
wherein the PWM circuit holds steady a pre-pull-in average current which has a positive non-zero value lower than the pull-in average current.
- 10 7. The system according to claim 6, wherein the pre-pull-in average current causes a magnetic flux to build up through the actuator which is not of a sufficient amount to actuate the actuator, but is of a sufficient amount to decrease the actuation time of the actuator.
8. The system according to claim 7, wherein the magnetic flux is built up through the actuator by supplying a PWM signal to the actuator at a power level lower than a power level
15 need to actuate the actuator.
9. The system according to claim 6, wherein the PWM circuit further removes a supply of a PWM signal to the actuator when a determination is made that the actuator does not need to be in an actuated position within a given period of time.
10. The system according to claim 6, wherein actuation of the actuator causes propellant
20 to flow to an engine of the system.

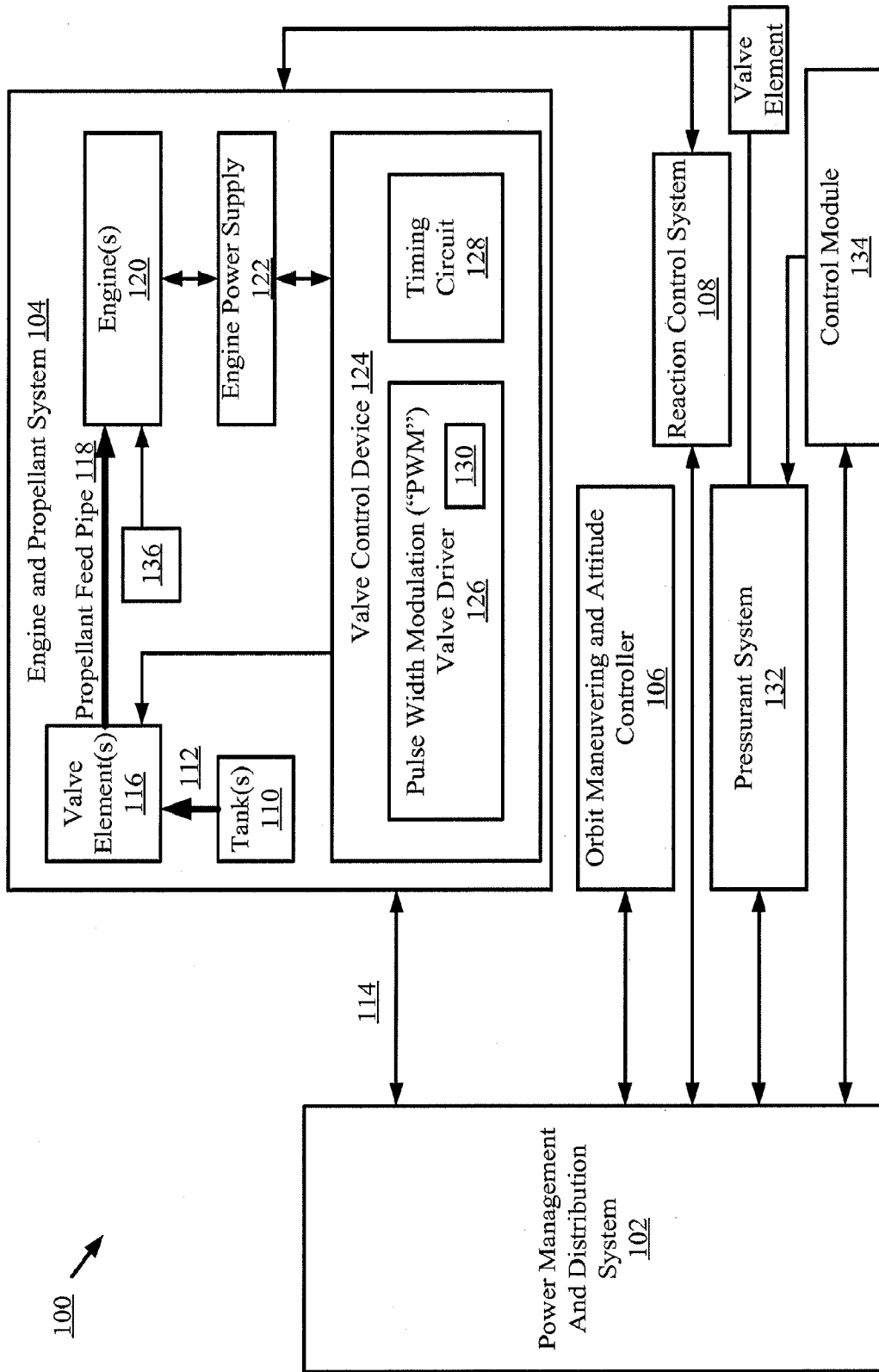


FIG. 1

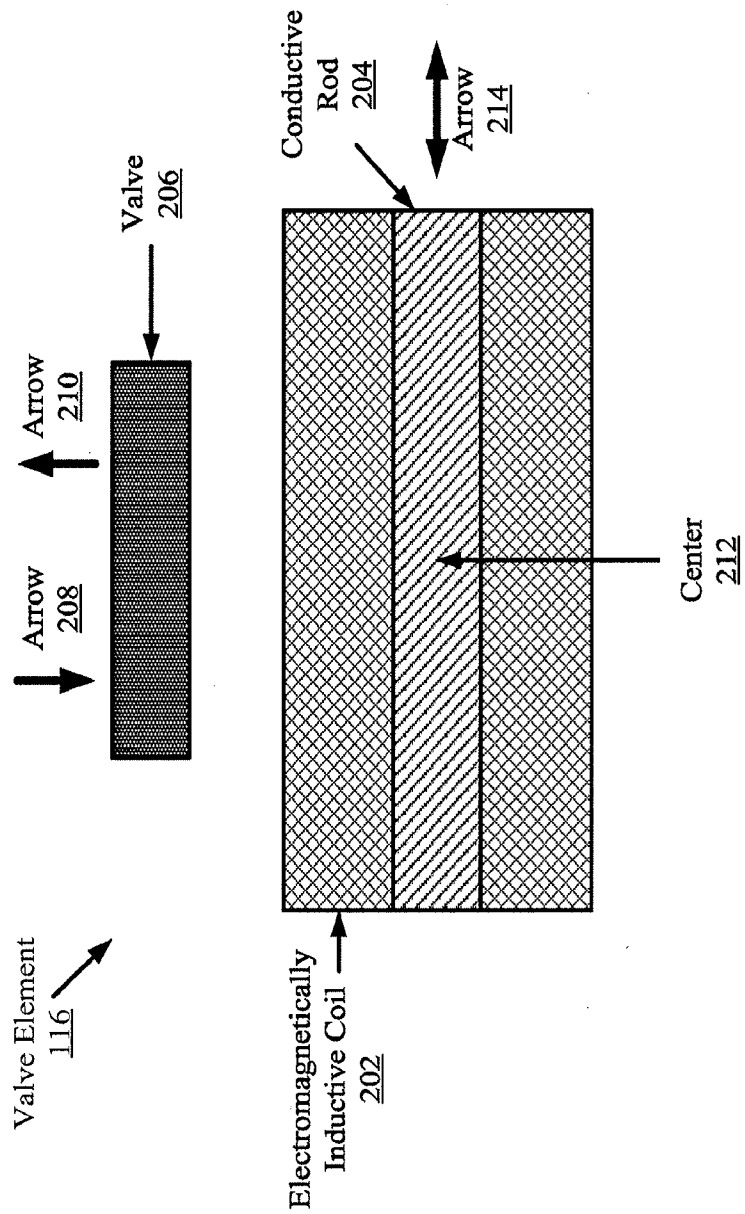


FIG. 2

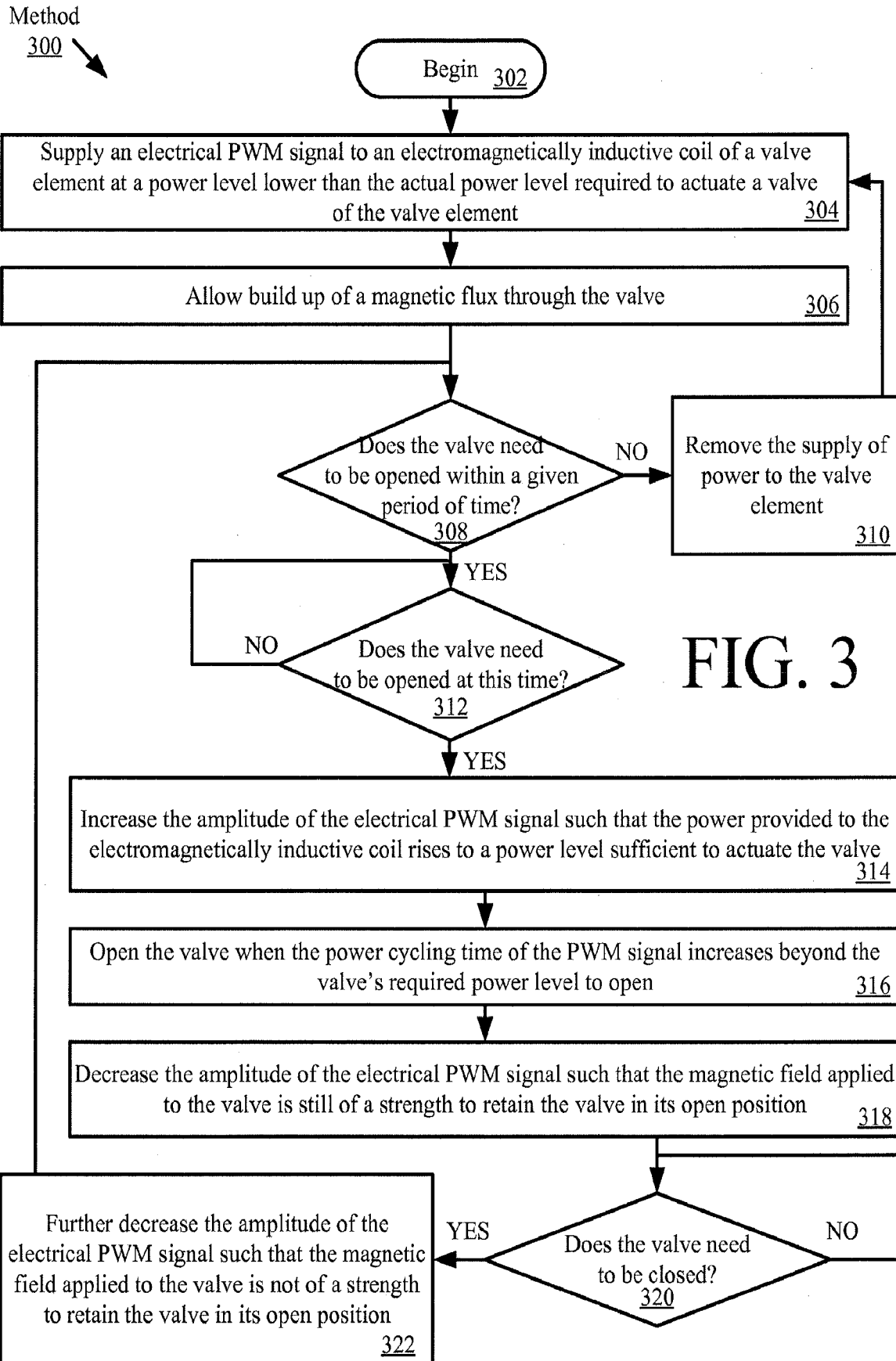


FIG. 3

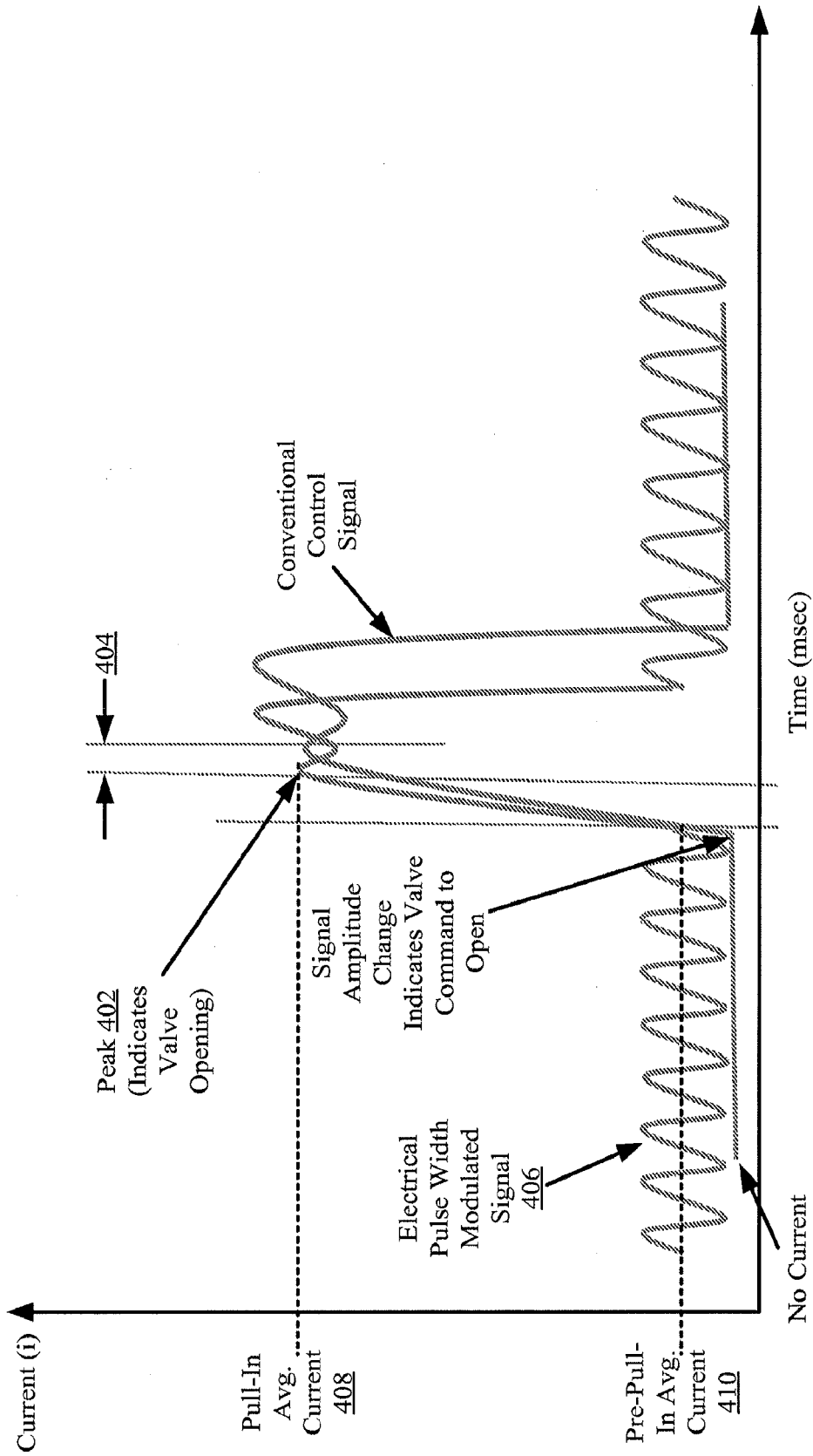


FIG. 4

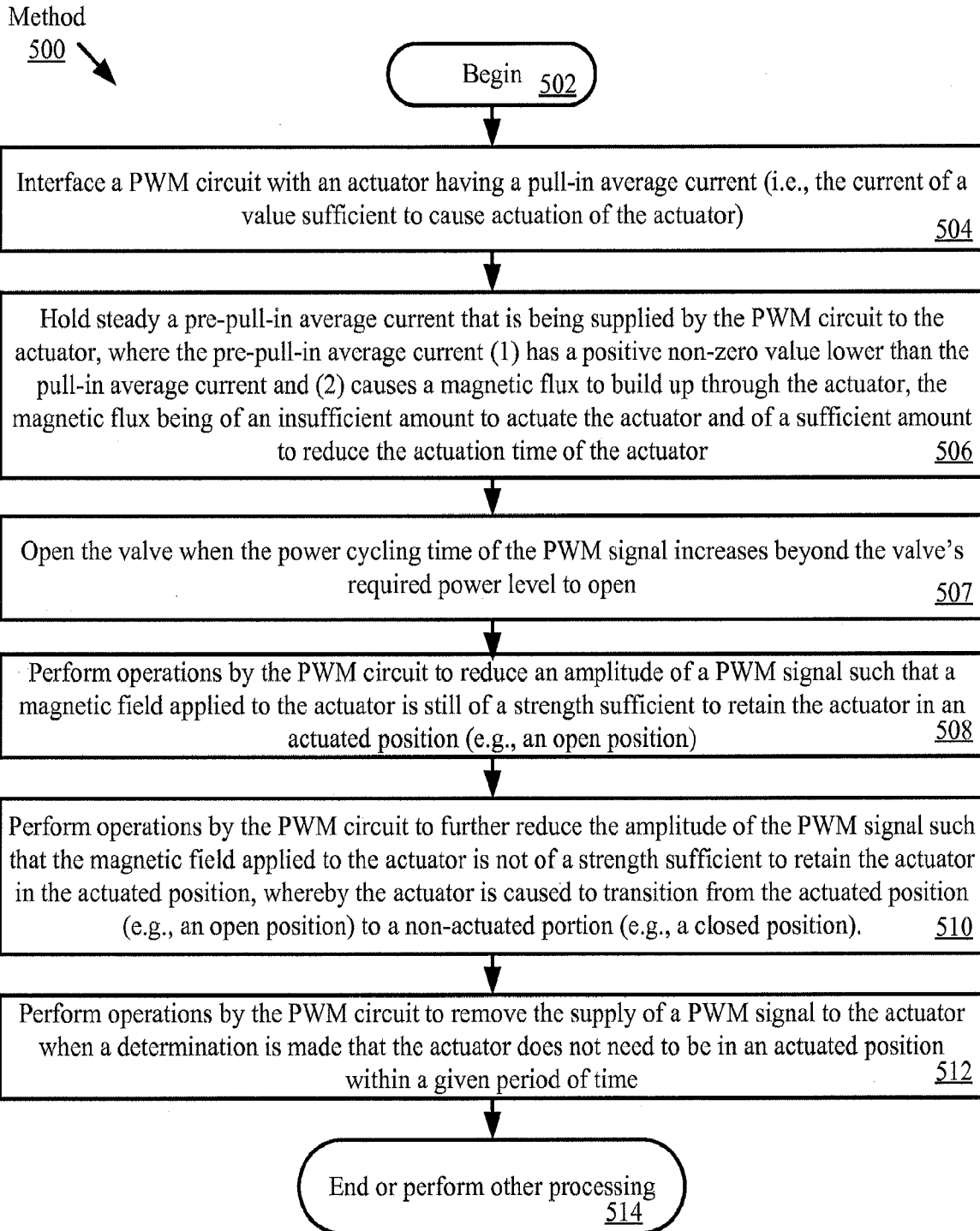



FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/067398

<p>A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - F16K 31/00 (2015.01) CPC - F16K 31/00 (2014.12) According to International Patent Classification (IPC) or to both national classification and IPC</p>																	
<p>B. FIELDS SEARCHED</p> <p>Minimum documentation searched (classification system followed by classification symbols) IPC(8) - F16K 31/00, F16K 31/02, F16K 31/06, H01H 47/22 (2015.01) USPC - 251/129.04, 251/129.15, 361/154, 361/160, 361/170</p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched CPC - F16K 31/00, F16K 31/02, F16K 31/06, H01F 7/06, H01F 2007/1888, H01H 47/22 (2014.12) (keyword delimited)</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Orbit, Google Patents, Google, ProQuest Search terms used: electromechanical valve, PWM, pulse width modulation, actuator, pull-in, hold, magnetic flux, propellant</p>																	
<p>C. DOCUMENTS CONSIDERED TO BE RELEVANT</p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X -- Y</td> <td>US 2009/0026397 A1 (EVERS) 29 January 2009 (29.01.2009) entire document</td> <td>1,2 --- 3-5,9</td> </tr> <tr> <td>Y</td> <td>US 2,794,318 A (ZUCROW et al) 04 June 1957 (04.06.1957) entire document</td> <td>3-5,10</td> </tr> <tr> <td>X -- Y</td> <td>US 6,671,158 B1 (UNDERWOOD) 30 December 2003 (30.12.2003) entire document</td> <td>6 -- 7-10</td> </tr> <tr> <td>Y</td> <td>US 2007/0188967 A1 (SMITH et al) 16 August 2007 (16.08.2007) entire document</td> <td>7,8</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X -- Y	US 2009/0026397 A1 (EVERS) 29 January 2009 (29.01.2009) entire document	1,2 --- 3-5,9	Y	US 2,794,318 A (ZUCROW et al) 04 June 1957 (04.06.1957) entire document	3-5,10	X -- Y	US 6,671,158 B1 (UNDERWOOD) 30 December 2003 (30.12.2003) entire document	6 -- 7-10	Y	US 2007/0188967 A1 (SMITH et al) 16 August 2007 (16.08.2007) entire document	7,8
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.															
X -- Y	US 2009/0026397 A1 (EVERS) 29 January 2009 (29.01.2009) entire document	1,2 --- 3-5,9															
Y	US 2,794,318 A (ZUCROW et al) 04 June 1957 (04.06.1957) entire document	3-5,10															
X -- Y	US 6,671,158 B1 (UNDERWOOD) 30 December 2003 (30.12.2003) entire document	6 -- 7-10															
Y	US 2007/0188967 A1 (SMITH et al) 16 August 2007 (16.08.2007) entire document	7,8															
<p><input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/></p>																	
<p>* Special categories of cited documents:</p> <table border="0"> <tr> <td style="vertical-align: top;"> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </td> <td style="vertical-align: top;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p> </td> </tr> </table>			<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>													
<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>																
<p>Date of the actual completion of the international search 28 January 2015</p>		<p>Date of mailing of the international search report 03 MAR 2015</p>															
<p>Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201</p>		<p>Authorized officer: Blaine R. Copenheaver </p> <p>PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774</p>															