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

(11) **EP 3 561 316 A1**

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.10.2019 Bulletin 2019/44

(51) Int Cl.:
F15B 13/08 *(2006.01)*

(21) Application number: **19168449.7**

(22) Date of filing: **10.04.2019**

(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

(30) Priority: **23.04.2018 IT 201800004796**

(71) Applicant: **Camozzi Automation S.p.A.**
25126 Brescia (IT)

(72) Inventors:
- **KOLVENBACH, Hansgeorg**
  25136 Brescia (IT)
- **FERRARINI, Dario**
  25136 Brescia (IT)

(74) Representative: **Chimini, Francesco**
Jacobacci & Partners S.p.A.
Piazza della Vittoria 11
25122 Brescia (IT)

(54) PNEUMATIC MODULES AND SYSTEM FOR PROPORTIONAL CONTROL

(57) A pneumatic master module for pressure or flow proportional control comprises a master module valve body, a master proportional electrovalve, a relative pressure sensor for detecting the pressure of the regulated flow of pressurized air downstream the master proportional electrovalve, an electronic control unit adapted to drive the master proportional electrovalve and a slave proportional or on/off electrovalve of a respective slave module according to a pressure signal provided by the relative pressure sensor, the electronic control unit being further configured to implement a digital communication bus interface for data exchanging with other master modules. The relative pressure sensor and the electronic control unit are mounted on an electronic printed circuit board. A master male-type inlet electronic connector and a master female-type outlet connector are mounted on parallel opposite sides of the master electronic printed circuit board. [Fig. 4]

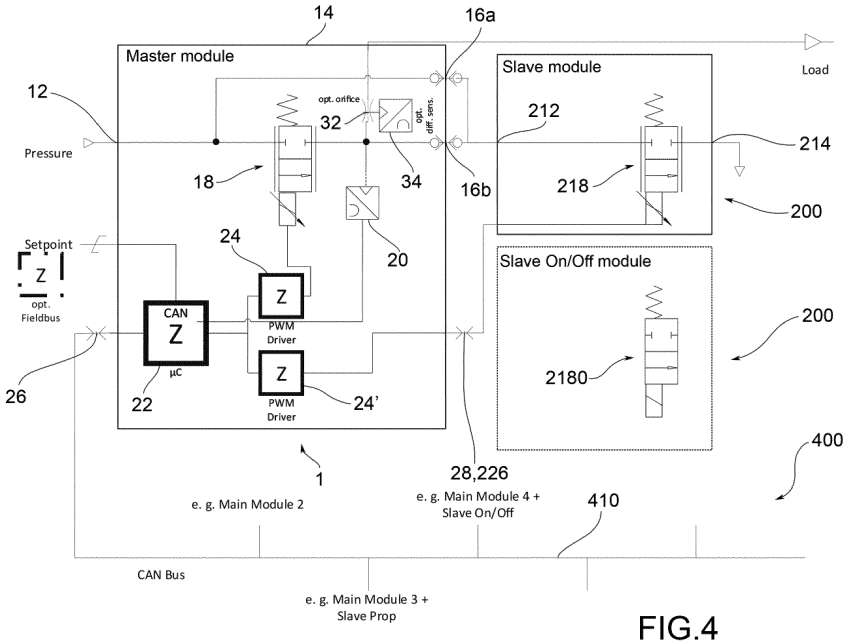

FIG.4

EP 3 561 316 A1

Description

[0001] The present invention relates to pneumatic modules and a system for pressure or flow proportional control.

[0002] Several products are already known for specifically performing proportional pneumatic tasks. For example, the following control valves are already available on the market:

- 2/2 way proportional valves to provide variable flow;
- 2 way pressure control valves with integrated gauge sensor and closed loop electronics;
- 3 way pressure control valves with integrated gauge sensor and closed loop electronics.

[0003] Depending on the dedicated task within an application, these valves can be used as standalone products or need to be combined with, or on, additional manifolds.

[0004] In addition, for the special task of a closed loop flow control, external flow sensors need to be combined with valves and electronics individually.

[0005] To exchange process data between such combinations, diverse digital bus protocols are available, that need to be connected by special wires and controlled by field bus master devices.

[0006] It is one object of the present invention to integrate some proportional control functions, such as those mentioned above, into one modular and stackable system.

[0007] Another object of the invention is to provide a proportional control system in which pneumatic modules are interconnected without any external wiring or external dedicated communication device.

[0008] These objects are achieved by a pneumatic master module according to claim 1, a master-slave module according to claim 7, and with a system according to claim 11. The dependent claims describe preferred embodiments of the invention.

[0009] The characteristics and advantages of the modules and system according to the invention will be evident from the description given below of its preferred embodiments, made by way of non-limiting examples with reference to the appended drawings, wherein:

- figures 1 and 1a are a perspective view and a side elevation view of a pneumatic master module according to the invention;
- figure 1b is a block diagram of the closed loop flow control function of the master module;
- figures 2 and aa are a perspective view and a side elevation view of a pneumatic slave module adapted to be connected to the master module of figure 1;
- figures 3, 3a and 3b are a perspective view, a side elevation view and a front elevation view of a master-slave module according to the invention;
- figure 4 is a block diagram of the master-slave module; and
- figure 5 is an example of a stackable system formed by two master-slave modules.

[0010] Figures 1, 1a and 1b show a pneumatic master module 1 for pressure or flow proportional control.

[0011] The master module 1 comprises a master module valve body 10 in which passages for a flow of pressurized air are formed. In one preferred embodiment, the master module valve body 10 has a rectangular parallelepiped shape.

[0012] These passages connects a master pneumatic inlet port 12 to a first master pneumatic outlet port 14 for a direct pneumatic connection to a load and to a second master pneumatic outlet port 16 for the pneumatic connection to a pneumatic inlet port of a slave module which can be connected to the master module, and which will be hereinafter described.

[0013] A master proportional electrovalve 18 is mounted on the master module valve body 10. In one embodiment, the master proportional electrovalve 18 is mounted on a face 10a of the parallelepiped body 10, for example one of the smaller bases.

[0014] The master proportional electrovalve 18 is adapted to supply the first and second master pneumatic outlet ports 14, 16 with a regulated flow of pressurized air entering the master module through the pneumatic inlet port 12.

[0015] The master module 1 further comprises a relative pressure sensor 20 for detecting the pressure of the regulated flow of pressurized air downstream the master proportional electrovalve 18.

[0016] The master proportional electrovalve 18 is electrically driven by an electronic control unit 22, for example implemented by a microprocessor. The electronic control unit 22 is further configured to drive a slave proportional or on/off electrovalve of a respective slave module.

[0017] In one embodiment, the master and slave proportional electrovalves are driven by respective PWM drivers 24, 24' .

[0018] The master and slave proportional electrovalves are driven according to a pressure signal provided by the relative pressure sensor 20, so as to implement a closed loop flow or pressure control.

[0019] The electronic control unit 22 is further configured to implement a digital communication bus interface for data exchanging with other master modules. In one embodiment, Can-bus protocol is used for the digital communication bus.

[0020] The master module 1 is provided with a master male-type inlet electronic connector 26 and a master female-type outlet connector 28 for receiving and transmitting analog and digital electronic signals.

[0021] The relative pressure sensor 20 and the electronic control unit 22 are mounted on an electronic printed circuit board 30.

[0022] The master male-type inlet electronic connector and the master female-type outlet connector 26, 28 are

mounted on parallel opposite sides of the master electronic printed circuit board 30.

[0023] In one embodiment, the master module 1 further comprises, downstream the master proportional electrovalve 18, a nozzle or orifice 32 for a flow control of the regulated flow of pressurized air. In particular, the combination of the relative pressure 20 and of the nozzle or orifice 32 allows to perform, in addition to the pressure control, a simplified flow control.

[0024] In one embodiment, the master module 1 is further provided with a differential pressure sensor 34 for detecting the difference of pressure upstream and downstream the nozzle or orifice 32.

[0025] Preferably, the differential pressure sensor 34 is also operatively connected to the electronic control unit 22, for example to perform a full closed loop flow control.

[0026] In one preferred embodiment, the master inlet and outlet electronic connectors 26, 28 and the electronic circuit board 30 are configured to receive and transmit power supply signals and digital communication bus signals. In one embodiment, the power supply for the electronic component of the printed circuit board 30 (5 V) is separated from the power supply of the proportional electrovalves (for example 12 V or 24 V).

[0027] In one embodiment, the electronic interface of the master module further includes a terminal for inputting an analogue setpoint and a terminal for outputting a feedback signal.

[0028] According to one embodiment, the master electronic printed circuit board 30 is directly connected to the electric pins 18' of the solenoid 18a of the master proportional electrovalve 18.

[0029] The master electronic printed circuit board 30 extends parallel to the master module valve body 10.

[0030] In one embodiment, the master electronic printed circuit board 30 is supported by the electric pins 18' and, at the opposite side, by supporting pillars 19 extending from the master module valve body 10.

[0031] In addition, the inlet and outlet electronic connectors 26, 28 are configured to be connected to electronic printed circuit board of another pneumatic master module or of a slave module such that all the electronic printed circuit boards lie in the same plane.

[0032] In order to allow to stack side by side more master modules, or a master module and a slave module, as will be described hereinafter, the pneumatic master inlet port 12 and the first master pneumatic outlet port 14 are formed in the face 10b of the master module valve body 10 opposite to the master proportional electrovalve (figure 5) or in the face 10c opposite to the electronic printed circuit board 30 (Figures 1, 1a). The second master pneumatic outlet port 16 is formed on one (10d) of the lateral faces of the master module valve body perpendicular to the electronic printed circuit board 30.

[0033] In one embodiment, the second master pneumatic outlet port 16 is divided into two outlet ducts 16a and 16b: a first outlet duct 16 bypasses the master proportional electrovalve 18 and is directly connected to the inlet port 12; the second outlet duct 16b is connected to the outlet of the master proportional electrovalve 18, as shown in figure 4. This way, it is possible to chose between a series or parallel pneumatic connection between the master module 1 and the respective slave module. In fact, if the first outlet duct 16a is plugged and the second outlet 16b is left open, a series operation of the master-slave assembly is obtained. If the first outlet duct 16a is open and the second outlet duct 16b is plugged, a parallel operation is obtained in order to double the flow capability.

[0034] In one embodiment, the master electronic printed circuit board 30 has substantially the same width of the master module valve body 10.

[0035] Figures 2, 2a show a slave module 200 adapted to be connected to and driven by a respective master module 1 so as to form a master-slave module 300.

[0036] The slave module 200 comprises a slave module valve body 210 in which passages for a flow of pressurized air are formed. These passages connects a slave pneumatic inlet port 212 to a slave pneumatic outlet port 214.

[0037] The slave module 200 can be provided with a slave proportional electrovalve 218 or with a slave on/off electrovalve 2180. In each case, the slave electrovalve 218; 2180 is connected between the slave pneumatic inlet port 212 and the slave pneumatic outlet port 214. Each of the proportional or on/off electrovalve 218; 2180 is driven by a control signal provided by the master module 1.

[0038] The slave module 200 is provided with a slave male-type inlet electronic connector 226 adapted to be releasably connected to the master female-type outlet connector 28 of the master module and a slave female-type outlet connector 228 suitable for being releasably connected to a master male-type inlet electronic connector 26 of another master module 1.

[0039] The slave inlet and outlet electronic connectors 226, 228 are adapted for receiving and transmitting analog and digital electronic signals, in particular power supply signals and digital communication bus signals.

[0040] The slave male-type inlet electronic connector 226 and the slave female-type outlet connector 228 are mounted on parallel opposite sides of a slave electronic printed circuit board 230, so that the master electronic printed circuit board 30 and the slave electronic printed circuit board 230 lie in the same plane.

[0041] Furthermore, the slave valve body 210 has a lateral face 210d in which the slave pneumatic inlet port 212 is formed and which is adapted to abut against a lateral face 10d of the master valve body, so that the second master pneumatic outlet port 16 and the slave pneumatic inlet port 212 can be are directly and sealingly connected, for example with the interposition of a sealing element 40.

[0042] In one preferred embodiment, the slave module valve body 210 as the same external shape and sizes of the master module valve body 10.

[0043] In one embodiment, the slave electronic printed circuit board 230 has substantially the same width of the slave module valve body 210.

[0044] In one preferred embodiment, the whole slave module 200 has the same external shape and sizes of the master module 1.

[0045] Figures 3, 3a and 3b show the master module 1 and the slave module 200 connected together to form a master-slave module 300.

[0046] As explained above, the master module 1 and the slave module 200 are placed side by side so that the master second pneumatic outlet port 16 is aligned and in direct communication with the slave inlet port 212, without the interposition of any external connection element, apart the sealing element.

[0047] The master module 1 and the slave module 200 are connected by the coupling of the respective electric connectors 28, 226.

[0048] In one embodiment, the master proportional electrovalve 18 is a 2-way valve and the slave electrovalve 218; 2180 is also a 2-way valve.

[0049] Therefore, the master module 1 alone can perform 2-way functions, while the master-slave module 300 can perform 3-way functions.

[0050] Master modules 1 and/or master-slave modules 300 can be connected to form a system 400 of stackable control modules.

[0051] The system 400 comprises a digital communication bus 410, at least one pneumatic master module 1 and/or at least one pneumatic master-slave module 300, each master module 1 or master-slave module 300 exchanging data through the digital communication bus 410.

[0052] In the system 400, at least two identical master modules 1 are directly connected each other through the electronic master outlet 28 and inlet 26 connectors.

[0053] In the system 400, one master module 1 is electrically connected to the slave outlet electronic connector 228 of a slave module 200 of a master-slave module 300. In this case, the slave module 200 acts as a bridge for transmitting to the downstream master module 1 at least the electric signals of the digital communication bus 410.

[0054] To sum up, such a system of stackable control modules can include:

- master modules with proportional electrovalve, sensors and control unit;
- slave modules with proportional or on/off electrovalve only.

[0055] The system can perform:

- 2-way functions with master module only;
- 3-way functions with master and slave module;
- series or parallel operation, selectable according to the needs;
- pressure control by relative (gauge) pressure sensor;
- simplified flow control by nozzle and relative (gauge) pressure sensor;
- true flow control by nozzle and relative (gauge) and differential pressure sensors;
- position control by external feedback sensor;
- combinations of all above mentioned.

[0056] As for the position control by external feedback sensor, for example, with the combined use of a master-slave module connected to the rod side of a pneumatic cylinder and a master-slave module connected to the bore side of the cylinder, it is possible to control this cylinder in closed loop positioning mode by reading in an analog input signal that contains information about the position of the cylinder and intercommunicating via the digital communication bus between the two master-slave modules.

[0057] A person skilled in the art may make modifications and variations to the embodiments of the modules and system according to the invention, replacing elements with others functionally equivalent so as to satisfy contingent requirements while remaining within the scope of protection of the following claims.

[0058] Each of the characteristics described as belonging to a possible embodiment may be realised independently of the other embodiments described.

Claims

1. Pneumatic master module for pressure or flow proportional control, comprising:

   - a master module valve body in which passages for a flow of pressurized air are formed, said passages connecting a master pneumatic inlet port to a first master pneumatic outlet port for a direct pneumatic connection to a load and to a second master pneumatic outlet port for the pneumatic connection to a pneumatic inlet port of a slave module which can be connected to the master module;
   - a master proportional electrovalve adapted to supply the first and second master pneumatic outlet ports with a regulated flow of pressurized air entering the master module through the pneumatic inlet port;
   - a relative pressure sensor for detecting the pressure of the regulated flow of pressurized air downstream the master proportional electrovalve;
   - an electronic control unit adapted to drive the master proportional electrovalve and a slave proportional or on/off electrovalve of a respective slave module according to a pressure signal provided by the relative pressure sensor, the electronic control unit being further configured to implement a digital communication bus inter-

face for data exchanging with other master modules;

- a master male-type inlet electronic connector and a master female-type outlet connector for receiving and transmitting analog and digital electronic signals, wherein the relative pressure sensor and the electronic control unit are mounted on an electronic printed circuit board, the master male-type inlet electronic connector and the master female-type outlet connector being mounted on parallel opposite sides of the master electronic printed circuit board.

2. Pneumatic master module according to claim 1, further comprising, downstream the master proportional electrovalve, a nozzle or orifice for a flow control of the regulated flow of pressurized air.

3. Pneumatic master module according to claim 2, further comprising a differential pressure sensor for detecting the difference of pressure upstream and downstream the nozzle or orifice, the differential pressure sensor being operatively connected to the electronic control unit.

4. Pneumatic master module according to anyone of the previous claims, wherein the master inlet and outlet electronic connectors and the electronic circuit board are configured to receive and transmit power supply signals and digital communication bus signals.

5. Pneumatic master module according to anyone of the previous claims, wherein:

- the master module valve body has a rectangular parallelepiped shape;
- the master proportional electrovalve is mounted on one of the faces of the master module valve body;
- the master electronic printed circuit board is supported by the electric pins of the master proportional electrovalve and extends parallel to the master module valve body, the inlet and outlet electronic connectors being configured to be connected to electronic printed circuit board of another pneumatic master module or of a slave module such that all the electronic printed circuit boards lie in the same plane;
- the pneumatic master inlet port and the first master pneumatic outlet port are formed in the face of the master module valve body opposite to the master proportional electrovalve or to the electronic printed circuit board;
- the second master pneumatic outlet port is formed on one of the lateral faces of the master module valve body perpendicular to the electronic printed circuit board.

6. Pneumatic master module according to anyone of the previous claims, wherein the master electronic printed circuit board has substantially the same width of the master module valve body.

7. Pneumatic master-slave module for pressure or flow proportional control, comprising a master module according to anyone of the previous claims and a slave module electronically and pneumatically connected to the master module and comprising:

- a slave module valve body in which passages for a flow of pressurized air are formed, said passages connecting a slave pneumatic inlet port to a slave pneumatic outlet port, the slave pneumatic inlet port being connected to the second pneumatic outlet port of the master module;
- a slave proportional electrovalve or a slave on/off electrovalve connected between the slave pneumatic inlet port and the slave pneumatic outlet port, said proportional or on/off electrovalve being driven by a control signal provided by the master module;
- a slave male-type inlet electronic connector releasably connected to the master female-type outlet connector of the master module and a slave female-type outlet connector suitable for being releasably connected to a master male-type inlet electronic connector of another master module, the slave inlet and outlet electronic connector being adapted for receiving and transmitting analog and digital electronic signals, wherein the slave male-type inlet electronic connector and the slave female-type outlet connector being mounted on parallel opposite sides of a slave electronic printed circuit board, so that the master electronic printed circuit board and the slave electronic printed circuit board lie in the same plane,

and wherein the slave valve body has a lateral side in which the slave pneumatic inlet port is formed and which abuts against a lateral side of the master valve body, so that the second master pneumatic outlet port and the slave pneumatic inlet port are directly and sealingly connected.

8. Pneumatic master-slave module according to claim 7, wherein the inlet and outlet slave electronic connectors and the slave electronic circuit board are configured to receive and transmit power supply signals and digital communication bus signals.

9. Pneumatic master-slave module according to any of the claims 7 or 8, wherein the slave module valve body as the same external shape and sizes of the master module valve body.

10. Pneumatic master-slave module according to any of the claims 7-9, wherein the slave electronic printed circuit board has substantially the same width of the slave module valve body.

11. System for pressure or flow control, comprising:

- a digital communication bus;
- at least one pneumatic master module according to any of the claims 1-6 and/or at least one pneumatic master-slave module according to any of the claims 7-10, each master module or master-slave module exchanging data through the digital communication bus.

12. System according to claim 10, wherein at least two identical master modules are directly connected each other through the electronic master outlet and inlet connectors.

13. System according to claim 10, wherein one master module is electrically connected to the slave outlet electronic connector of slave module of a master-slave module, said slave module acting as a bridge for transmitting to the downstream master module at least the electric signals of the digital communication bus.

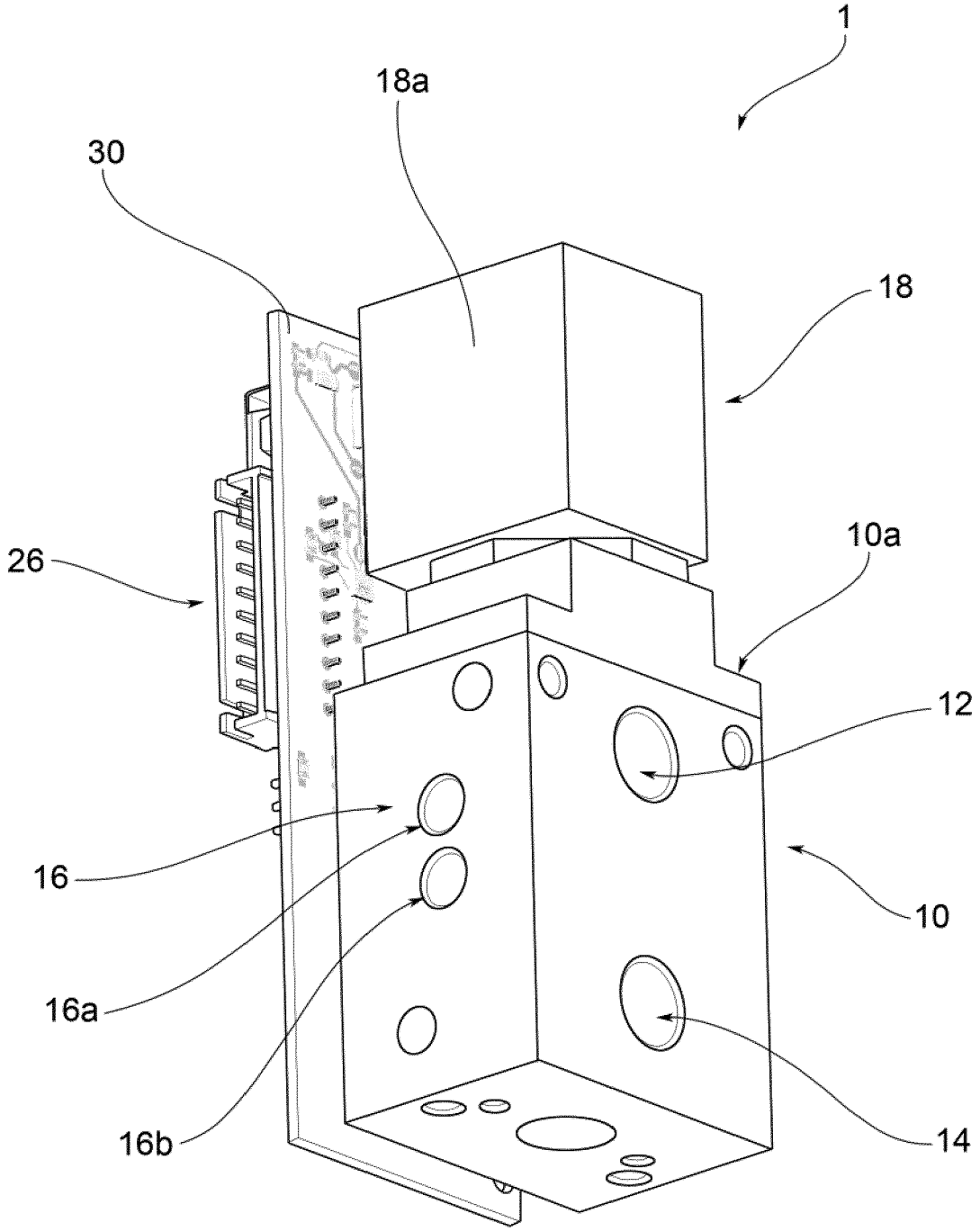

FIG.1

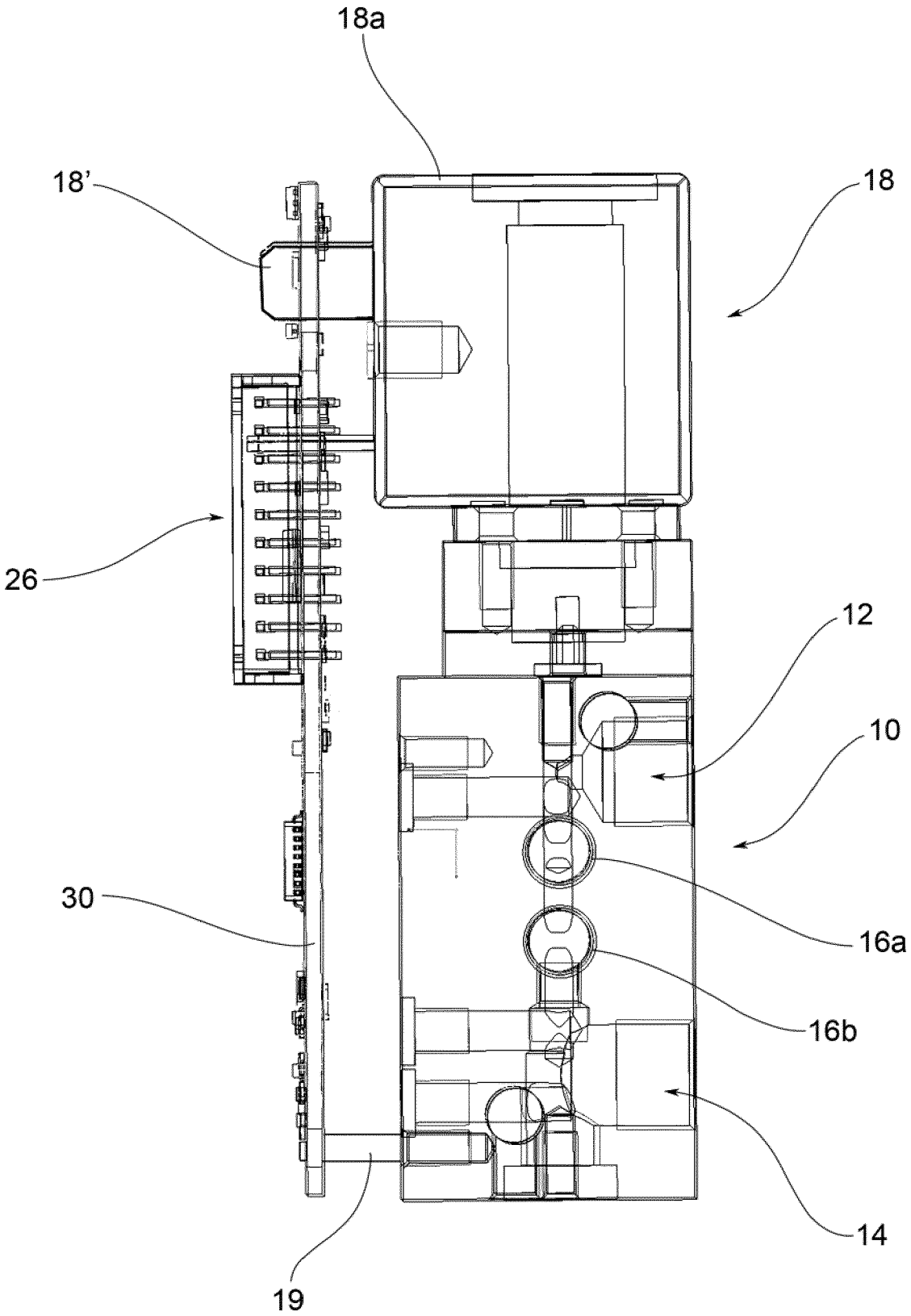

FIG.1a

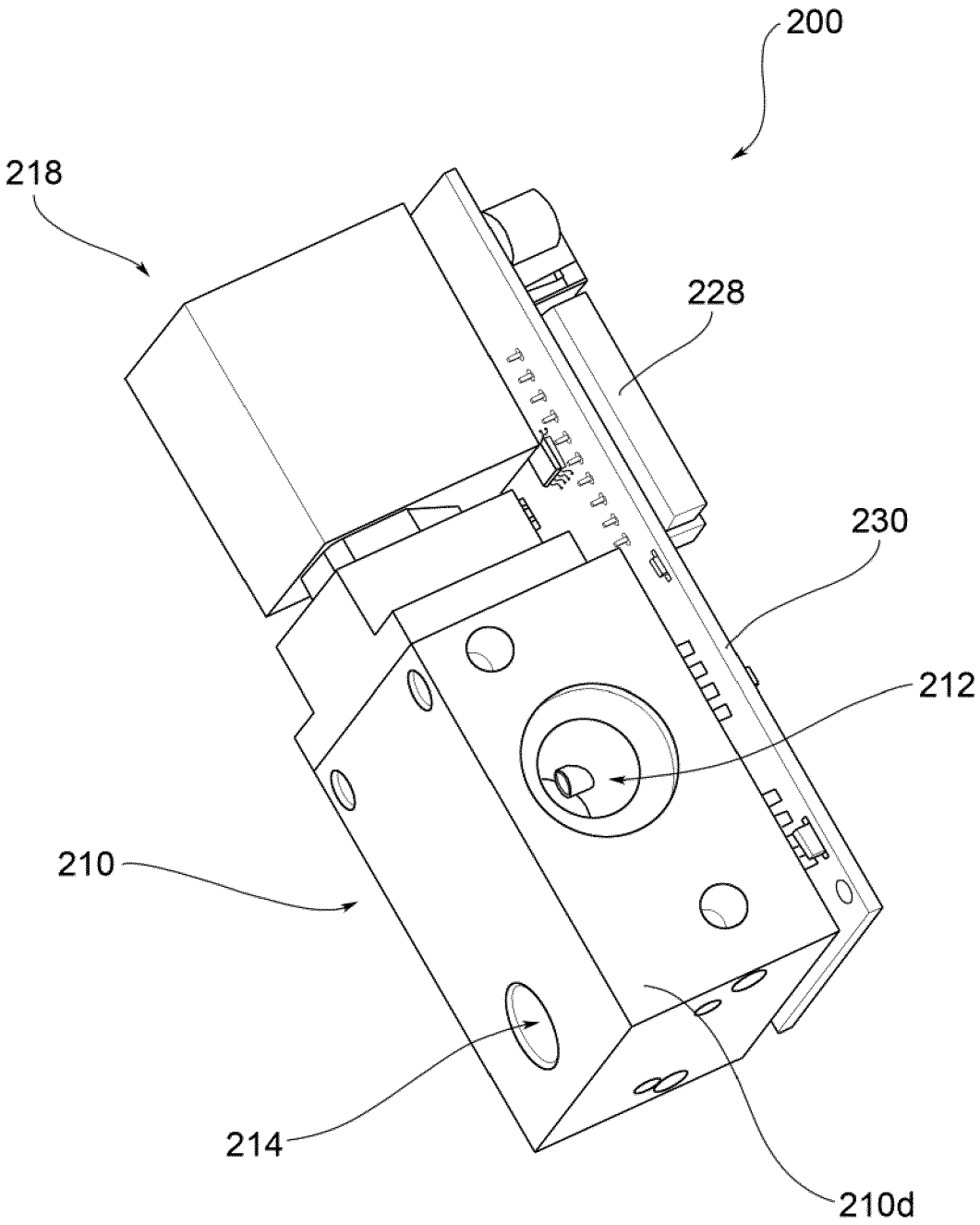

FIG.2

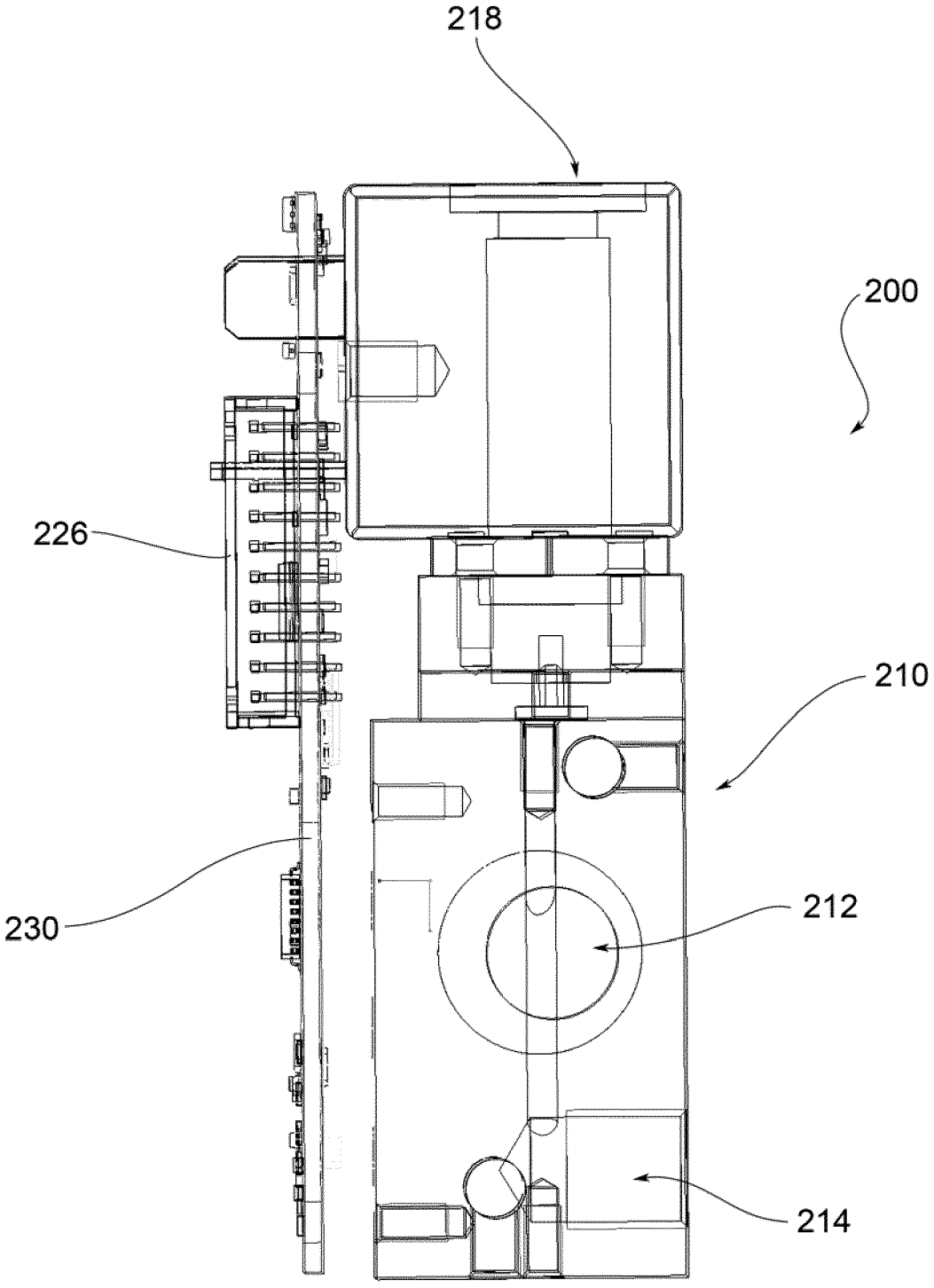

FIG.2a

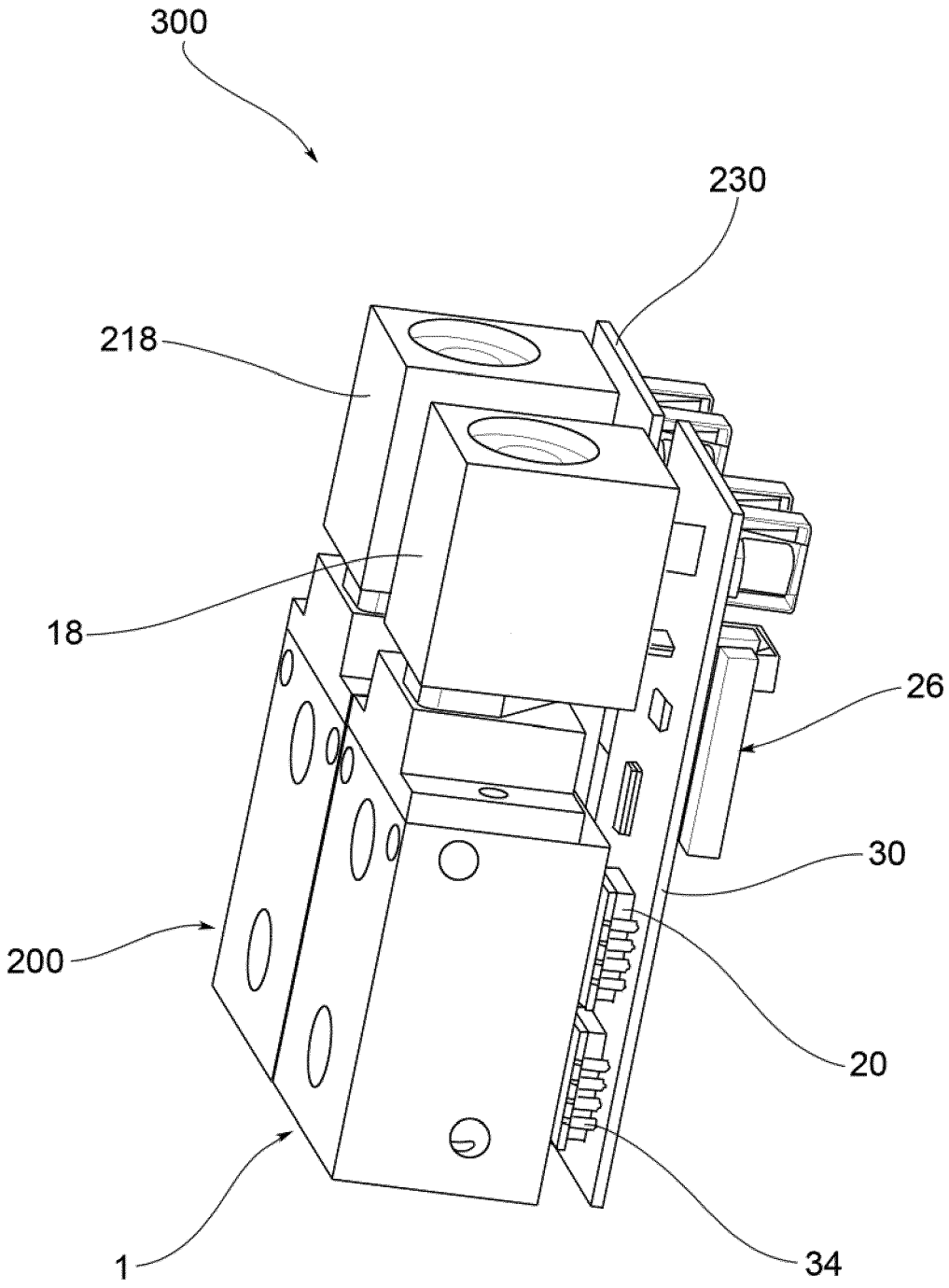

FIG.3

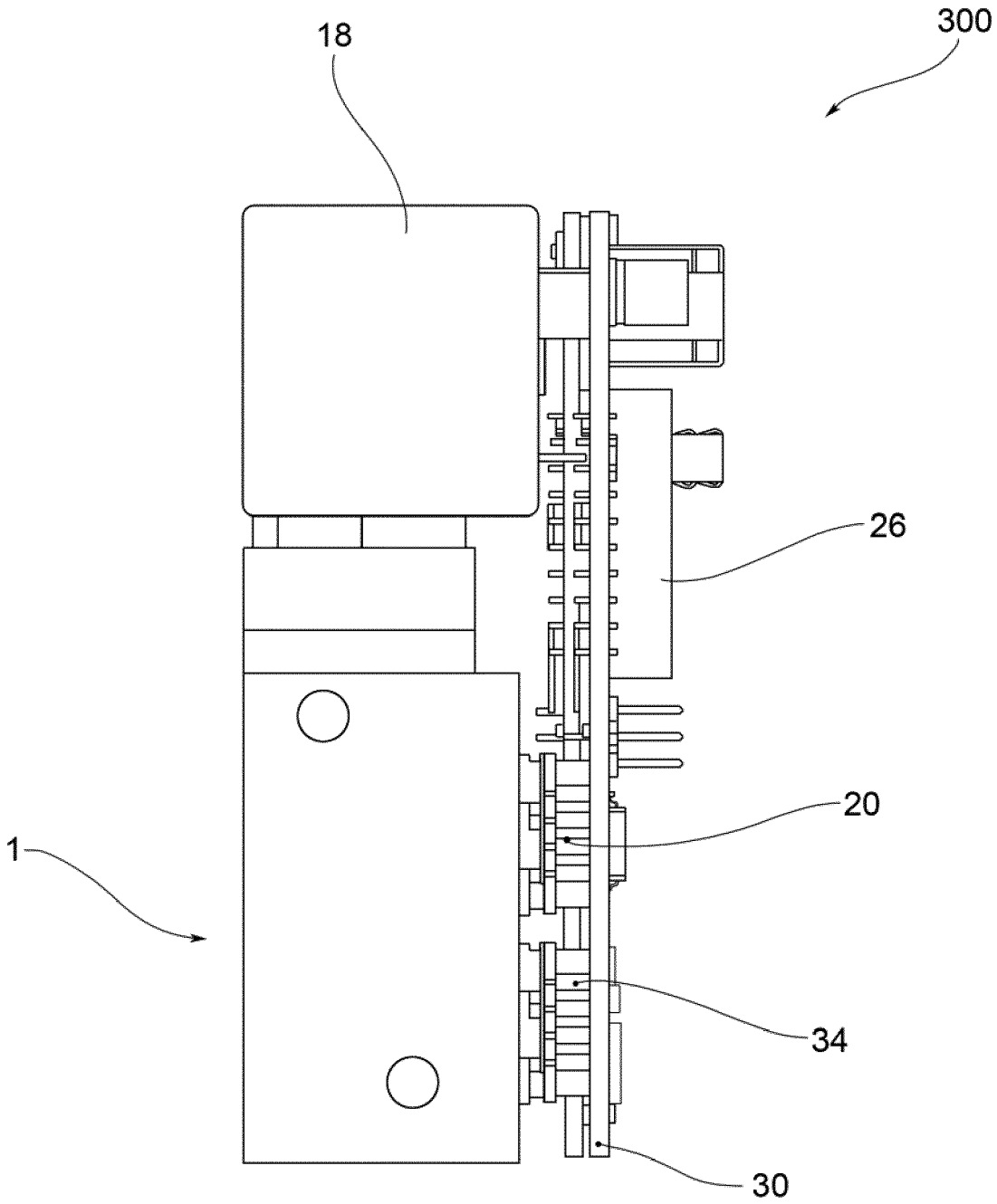

FIG.3a

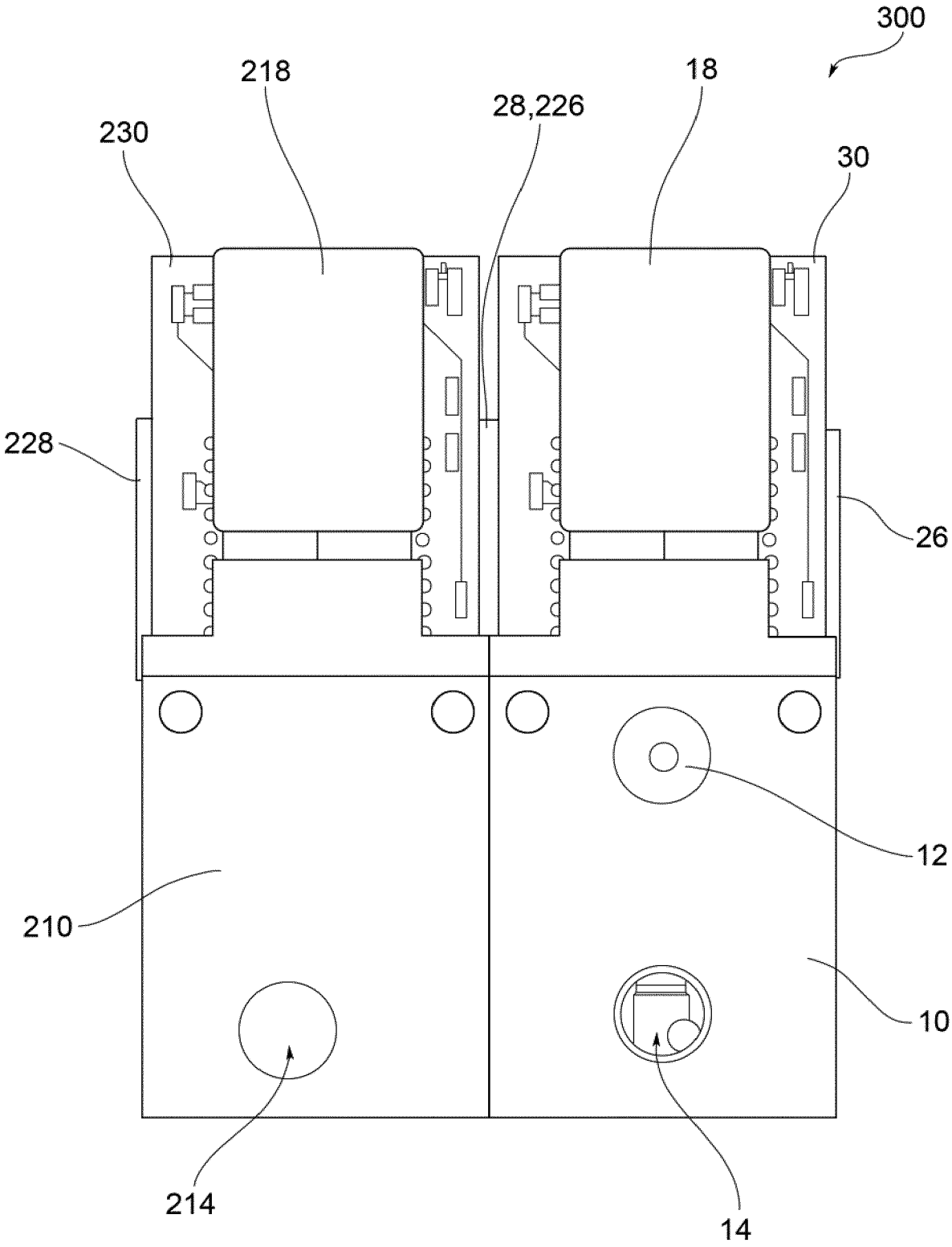

FIG.3b

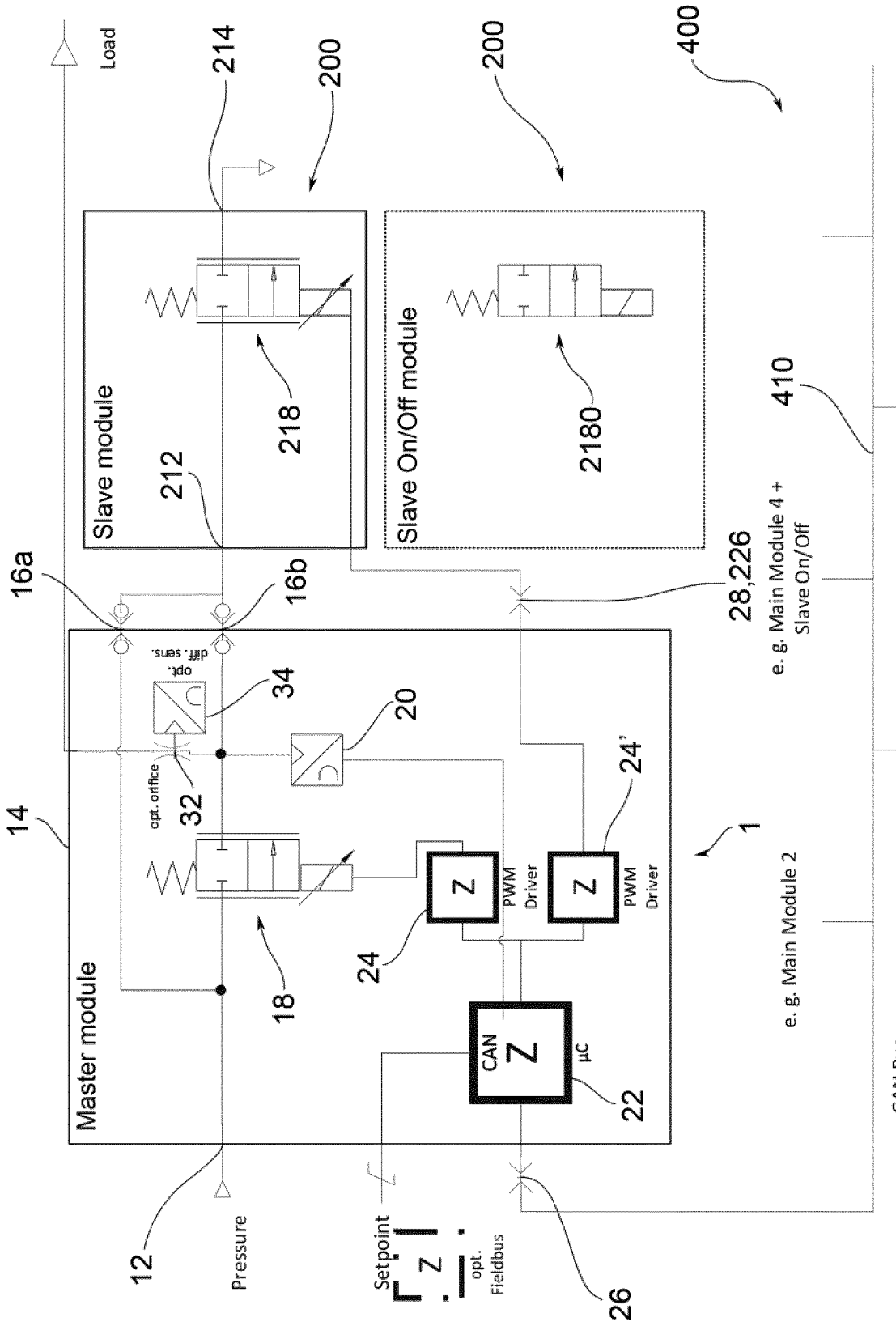
Load
214
200
200
400
Slave module
212
218
Slave On/Off module
2180
410
16a
16b
28,226
e. g. Main Module 4 + Slave On/Off
opt. diff. sens.
34
20
opt. orifice
32
14
24'
1
Master module
PWM Driver
PWM Driver
24
18
CAN
µC
22
e. g. Main Module 2
e. g. Main Module 3 + Slave Prop
CAN Bus
12
Pressure
Setpoint
opt. Fieldbus
26

FIG.4

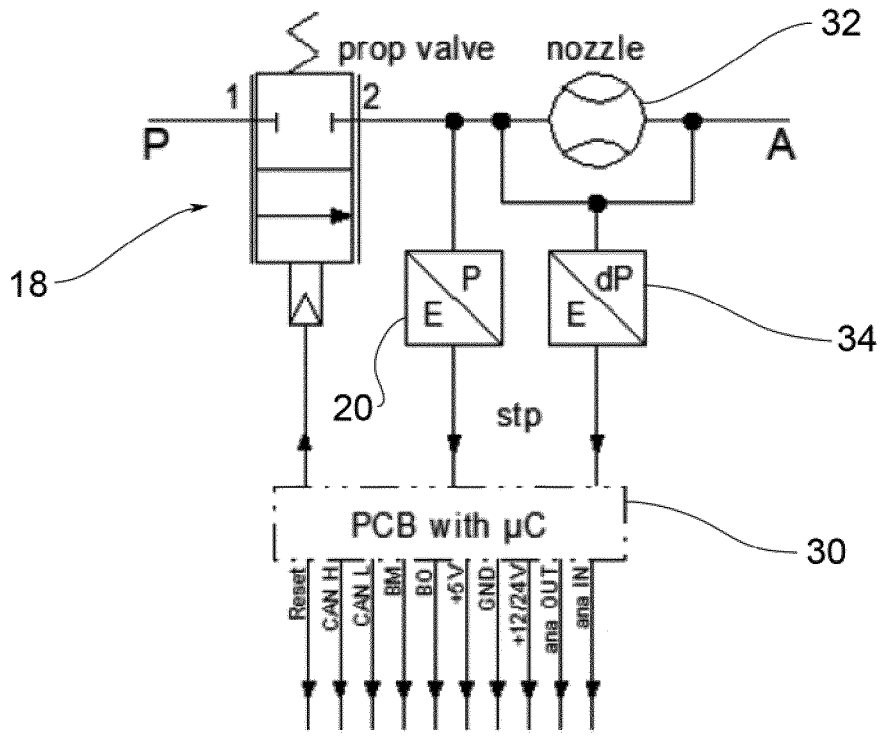
prop valve
nozzle
32
1
2
P
A
18
P
E
dP
E
34
20
stp
PCB with µC
30
Reset
CAN H
CAN L
BM
BO
+5V
GND
+12/24V
ana OUT
ana IN

FIG.1b

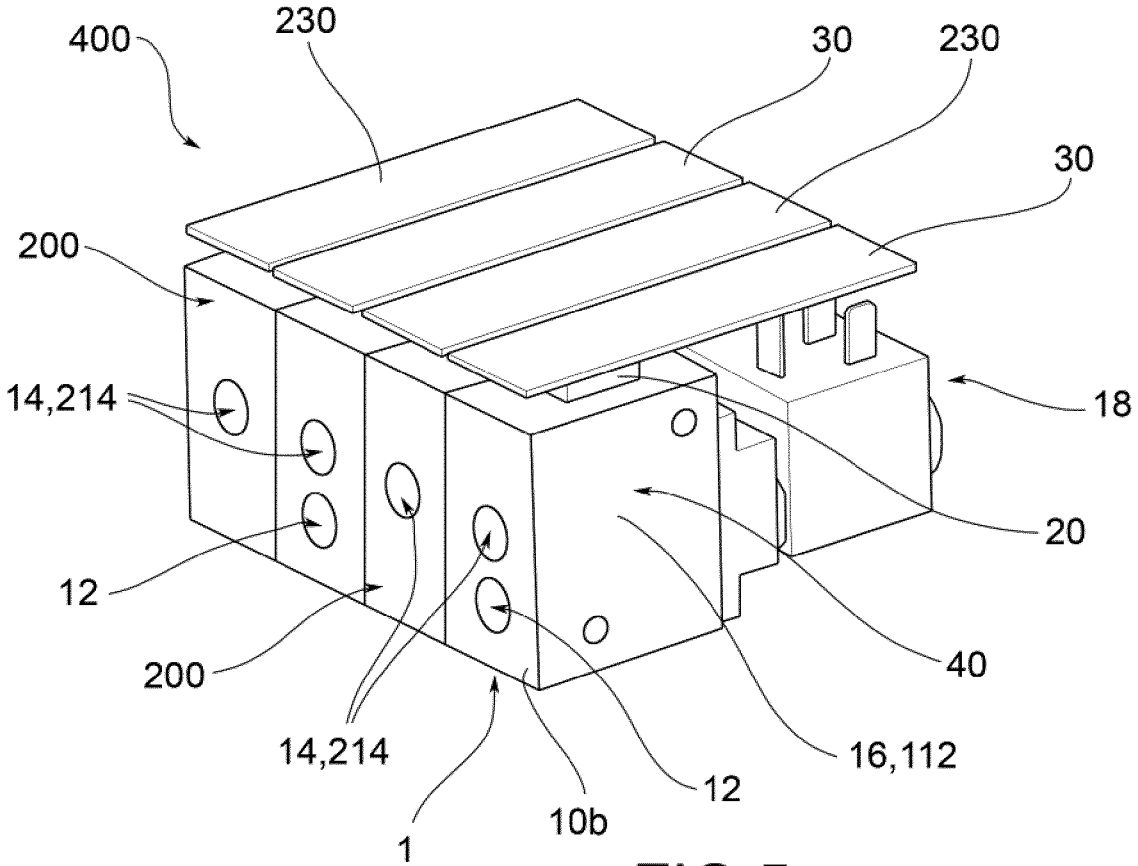
400
230
30
230
30
200
14,214
18
20
12
40
200
16,112
14,214
12
10b
1

FIG.5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 16 8449

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 458 048 A (HOHNER HEINZ [DE]) 17 October 1995 (1995-10-17) * column 3, lines 9-55 * * column 4, line 52 - column 5, line 10 *	1-13	INV. F15B13/08
A	DE 10 2010 035747 A1 (FESTO AG & CO KG [DE]) 1 March 2012 (2012-03-01) * paragraph [0033] *	1,7	
A	US 6 701 962 B2 (FESTO CORP [US]) 9 March 2004 (2004-03-09) * column 7, line 43 - column 8, line 18 *	1	
A	DE 10 2004 044497 B3 (FESTO AG & CO [DE]) 27 April 2006 (2006-04-27) * paragraphs [0035] - [0043] *	1	

TECHNICAL FIELDS SEARCHED (IPC)

F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 August 2019	Toffolo, Olivier

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 8449

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.

26-08-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5458048 A	17-10-1995	DE 59207345 D1	14-11-1996
		EP 0608245 A1	03-08-1994
		ES 1027702 U	16-09-1994
		JP H07500408 A	12-01-1995
		KR 0157097 B1	18-02-1999
		US 5458048 A	17-10-1995
		WO 9404831 A1	03-03-1994
DE 102010035747 A1	01-03-2012	NONE	
US 6701962 B2	09-03-2004	DE 10216703 A1	28-11-2002
		JP 2002323160 A	08-11-2002
		US 2002174905 A1	28-11-2002
DE 102004044497 B3	27-04-2006	NONE	

EPO FORM P0459

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