

(19)



(11)

EP 3 340 259 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.06.2018 Bulletin 2018/26

(51) Int Cl.:
H01F 7/06 (2006.01) **H01F 7/127** (2006.01)
H01F 7/128 (2006.01) **H01F 7/18** (2006.01)
F16K 31/00 (2006.01)

(21) Application number: **16465562.3**

(22) Date of filing: **21.12.2016**

(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:
MA MD

(71) Applicant: **Conti Temic microelectronic GmbH
90411 Nürnberg (DE)**

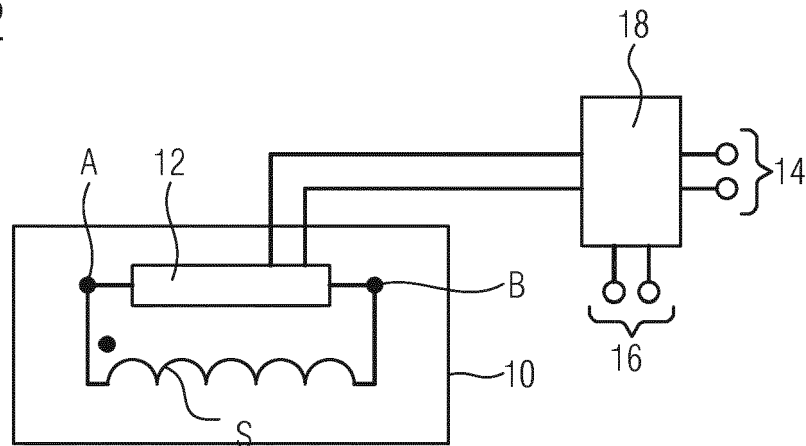
(72) Inventor: **Dabuleanu, Marius
550046 Sibiu (RO)**

(54) **SOLENOID DEVICE**

(57) The invention relates to a solenoid device, in particular for a solenoid valve, with a solenoid coil (S) having a housing (10) and with a driving unit (12) for the

solenoid coil (S), wherein the driving unit (12) is arranged within the housing (10) of the solenoid coil (S).

Fig.2



Description

[0001] The invention relates to a solenoid device, in particular for a solenoid valve.

[0002] Solenoid devices are used in a multitude of technical applications, for example to provide electromechanical control for valves in fluidic systems. A solenoid coil in such a valve generates a magnetic field which actuates a valve piston, diaphragm or the like, in order to switch the valve between an open and closed state.

[0003] In order to control the solenoid, a driving unit is necessary which provides the needed voltage and current to put the solenoid in a predefined state. Such driving units are usually placed external to the solenoid itself, which is usually housed in a separate housing. Generally, the driving unit is provided on a printed circuit board (PCB).

[0004] An example for a solenoid device according to the prior art is shown in Fig. 1. A solenoid S is arranged in a housing 10. Terminal contacts A, B of the solenoid S are connected to an external driving unit 12 in form of a PCB. The driving unit 12 comprises connectors 14 for a power supply and connectors 16 for a communication connection with further external controller components.

[0005] In more complex application containing multiple solenoids, any change in the solenoid layout during the design phase necessitates a redesign of the PCB of the driving unit 12 to accommodate changed, added or removed solenoids S. Moreover, such a PCB takes up considerable room, which can be problematic in many applications with restricted installation space, as it is the case for example in automotive applications.

[0006] It is thus the technical problem underlying the present invention to provide a solenoid device which is easily adaptable and particularly compact.

[0007] This problem is solved by the subject matter of claim 1.

[0008] According to the invention, a solenoid device, in particular for a solenoid valve, comprises a solenoid coil having a housing and a driving unit for the solenoid coil, wherein the driving unit is arranged within the housing of the solenoid coil.

[0009] By integrating the driving unit into the solenoid housing, the need for external circuits is reduced, allowing for a compact configuration. Moreover, since each solenoid device carries its own driving unit, the external circuitry, if present at all, does not have to be redesigned if any changes regarding the solenoid layout of a particular apparatus are made during the design phase or during later overhauls.

[0010] In a preferred embodiment of the invention, the driving unit comprises a high side switch driver circuit and a first transistor, in particular a MOSFET (metal-oxide-semiconductor field effect transistor), wherein the first transistor is adapted to apply a first potential to the solenoid when activated by the high side switch driver circuit.

[0011] High side switch is to be understood in that the

first transistor is arranged between high potential, i.e. the power supply, and the solenoid. High side drivers are robust against faults to ground, which are the most common fault type in automotive applications.

[0012] In a further preferred embodiment, the driving unit comprises a free wheeling diode driver circuit and a second transistor, in particular a MOSFET, wherein the second transistor is adapted to apply a second potential to the solenoid when activated by the free wheeling diode driver circuit.

[0013] In other words, the second transistor acts like a protective diode eliminating fly back voltage spikes as caused by loss or disruption of the power supply for the inductive load of the solenoid. To this end, the second transistor is preferably arranged in parallel to the solenoid. Furthermore, the second transistor can be applied to maintain current flow through the solenoid.

[0014] In a further preferred embodiment of the invention, the driving unit comprises a low side switch driver circuit and a third transistor, in particular a MOSFET, wherein the third transistor is adapted to apply a third potential to the solenoid when activated by the low side switch driver circuit.

[0015] A low side switch driver comprises the switching transistor being arranged between the solenoid and ground. Low side drivers are generally easier to control but lack protection from faults to ground compared to high side drivers.

[0016] It is further preferred for the first, second and third transistor to be connected in series. In such an embodiment, the driving offers the option to select between the high side and low side driver to control the solenoid, while the second transistor provides power surge protection when switching the solenoid in both of these cases.

[0017] In a further embodiment, the first and/or second and/or third potential is a pulse-width modulated signal. Pulse-width modulation (PWM) is based on providing a rectangular signal switching between a HIGH potential state and a LOW potential state with varying pulse lengths. It allows for setting the magnetic field strength of the solenoid in an analog manner while providing a digital control signal. Due to the low-pass filtering characteristics of the solenoid, the resulting average magnetic field strength depends on the duty cycle of the PWM signal applied to the solenoid, i.e. the ratio between the times the PWM signal is in the HIGH state and the LOW state.

[0018] In a further preferred embodiment, the solenoid is connected in series to a measuring shunt and the driving unit comprises a measurement circuit to measure a potential drop over the measuring shunt. This allows for monitoring of the load applied to the solenoid.

[0019] It is further preferred if the solenoid and the measuring shunt are connected in parallel with the second transistor, in order to provide protection against fly back voltage spikes.

[0020] In another preferred embodiment, the driving unit comprises an interface for receiving command in-

structions for the solenoid device and/or sending status information about the solenoid device, in particular via a field bus, preferably a CAN-bus or FlexRay-bus. This allows for connecting the solenoid device to other controller devices, in particular for automotive applications, in a standardized way.

[0021] It is further preferred that driving unit in the solenoid's housing comprises a communication circuit providing the interface, said interface being in particular in form of a CAN-bus or FlexRay-bus socket. The communications circuit can translate external control commands to internal commands for the drivers and relate internal status information of the driving unit to external devices.

[0022] In a further preferred embodiment, the driving unit is constructed as an integrated circuit. This allows for a particularly compact form of the driving unit, and thus of the overall solenoid device.

[0023] Embodiments of the invention are now described in further detail with reference to the drawings, wherein:

Fig. 1 shows a solenoid device according to the prior art;

Fig. 2 shows a schematic depiction of a solenoid device according to an embodiment of the invention; and

Fig. 3 shows a schematic circuit diagram of a solenoid device according to an embodiment of the invention.

[0024] The solenoid device shown in Fig. 2 comprises a solenoid S, which is arranged in a housing 10. A driving unit 12 is connected to terminal connectors A, B of the solenoid S and arranged in the housing 10 together with the solenoid S. The driving unit 12 is connected to an external printed circuit board, PCB, 18, which provides connectors 14 for a power supply and connectors 16 for control signals. Since the driving unit 12 is integrated with the solenoid housing 10, the external circuit board 18 can be smaller than in case of the prior art shown in Fig. 1 and can be independent from the type of solenoid S.

[0025] As shown in Fig. 3, the driving unit 12 comprises a high side switch driver 20 connected to a MOSFET T1. When the high side switch driver 20 activates the MOSFET T1, the terminal connector A of the solenoid S is connected to the high potential level of the power supply (usually between 10 V and 15 V), while the terminal connector B is connected to ground via a measuring shunt R_S .

[0026] A further MOSFET T2 can be activated via a free wheeling diode driver 22. The MOSFET T2 is connected in parallel to the solenoid S and the measuring shunt R_S and acts as a flyback diode preventing flyback voltage spikes upon deactivation of the solenoid S. It can further be utilized to maintain current flow through the solenoid S.

[0027] A low side switch driver 24 controls a third MOSFET T3. When activated, the MOSFET T3 connects the

terminal connector B of the solenoid to ground via the measuring shunt R_S , while the terminal connector A of the solenoid is connected to the high potential level of the power supply.

[0028] This arrangement allows driving the solenoid S either in high side mode or in low side mode. Which mode is chosen depends on the particular application of the solenoid S. A connector pin 19 of the driving unit 20 can receive an external signal to control the driving mode or can be hardwired to either ground or high potential to set a fixed driving mode for the solenoid S.

[0029] When in high side mode, the first MOSFET T1 provides control for the solenoid S. The MOSFET T3 is not used for control purposes in this arrangement, but rather provides a protective function by disconnecting the solenoid from ground in case of a malfunction, like an overcurrent, a short circuit on the solenoid or a defect of the low side switch driver 24.

[0030] The drivers 20, 22, 24 provide pulse-width modulated (PWM) signals to the respective gates of MOSFETS T1, T2, T3 in order to activate or deactivate them. Since the MOSFETS are activated and deactivated in synchronization with the PWM signal, the resulting potential to the solenoid S also follows the PWM signal. Due to the inductivity of the solenoid S, the signal is smoothed, so that the resulting magnetic field is largely constant. The resulting field strength can be modulated by changing the duty cycle of the PWM signal.

[0031] A current measurement block 26 can monitor the voltage drop over the measuring shunt R_S in order to determine the load applied to the solenoid S.

[0032] Control signals for the drivers 20, 22, 24 can be received via a communication circuit 28, which also can relay back internal information of the driving unit 12 to external devices. The communication circuit 28 is coupled to the connectors 16, which preferably provide a CAN- or FlexRay-bus interface for automotive applications.

Claims

1. Solenoid device, in particular for a solenoid valve, with a solenoid coil (S) having a housing (10) and with a driving unit (12) for the solenoid coil (S), wherein the driving unit (12) is arranged within the housing (10) of the solenoid coil (S).
2. Solenoid device according to claim 1, characterized in that the driving unit (12) comprises a high side switch driver circuit (20) and a first transistor (T1), in particular a MOSFET, wherein the first transistor (T1) is adapted to apply a first potential to the solenoid (S) when activated by the high side switch driver circuit (20).
3. Solenoid device according to claim 1 or 2,

characterized in that

the driving unit (12) comprises a free wheeling diode driver circuit (22) and a second transistor (T2), in particular a MOSFET, wherein the second transistor (T2) is adapted to apply a second potential to the solenoid (S) when activated by the free wheeling diode driver circuit (22). 5

4. Solenoid device according to any of claims 1 to 3,
characterized in that 10
the driving unit (12) comprises a low side switch driver circuit (24) and a third transistor (T3), in particular a MOSFET, wherein the third transistor (T3) is adapted to apply a third potential to the solenoid (S) when activated by the low side switch driver circuit (24). 15
5. Solenoid device according to claims 2 to 4,
characterized in that
the first (T1), second (T2) and third transistor (T3) are connected in series. 20
6. Solenoid device according to any of claims 2 to 5,
characterized in that
the first and/or second and/or third potential is a pulse-width modulated signal. 25
7. Solenoid device according to any of claims 1 to 6,
characterized in that
the solenoid (S) is connected in series to a measuring shunt (R_S) and the driving unit (12) comprises a measurement circuit (26) to measure a potential drop over the measuring shunt (R_S). 30
8. Solenoid device according to claim 7,
characterized in that 35
the solenoid (S) and the measuring shunt (R_S) are connected in parallel with the second transistor (T2).
9. Solenoid device according to any of claims 1 to 8,
characterized in that 40
the driving unit (12) comprises an interface (16) for receiving command instructions for the solenoid device and/or sending status information about the solenoid device, in particular via a field bus, preferably a CAN-bus or FlexRay-bus. 45
10. Solenoid device according to claim 9,
characterized in that
the driving unit (12) comprises a communication circuit (28) providing the interface, said interface being in particular in form of a CAN-bus or FlexRay-bus socket. 50
11. Solenoid device according to any of claims 1 to 10,
characterized in that 55
the driving unit (12) is constructed as an integrated circuit.

Fig.1

PRIOR ART

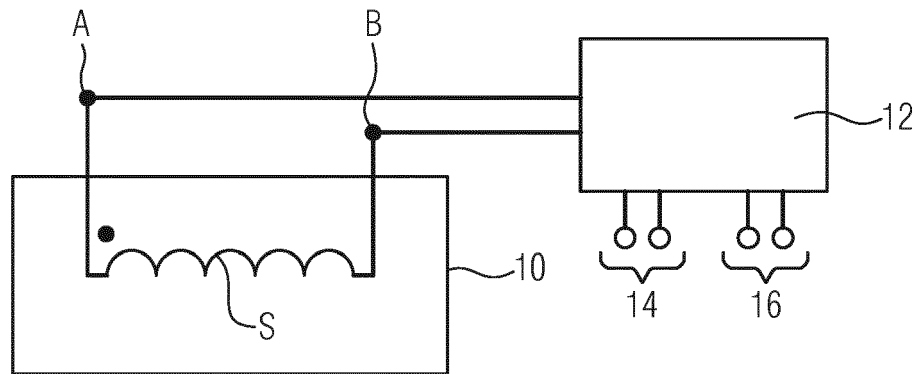
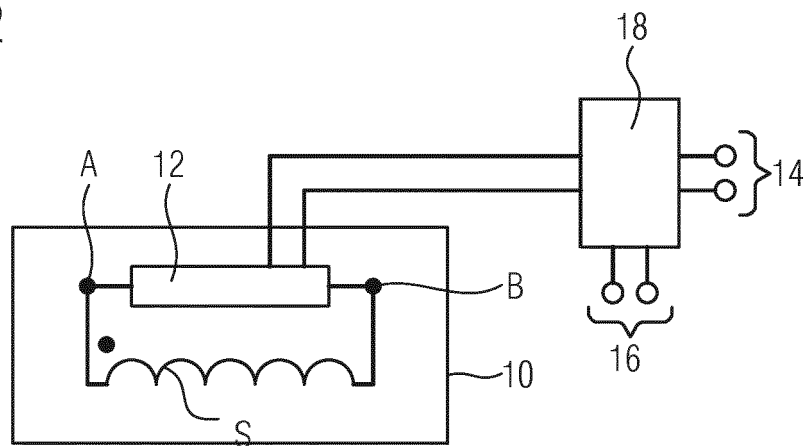


Fig.2



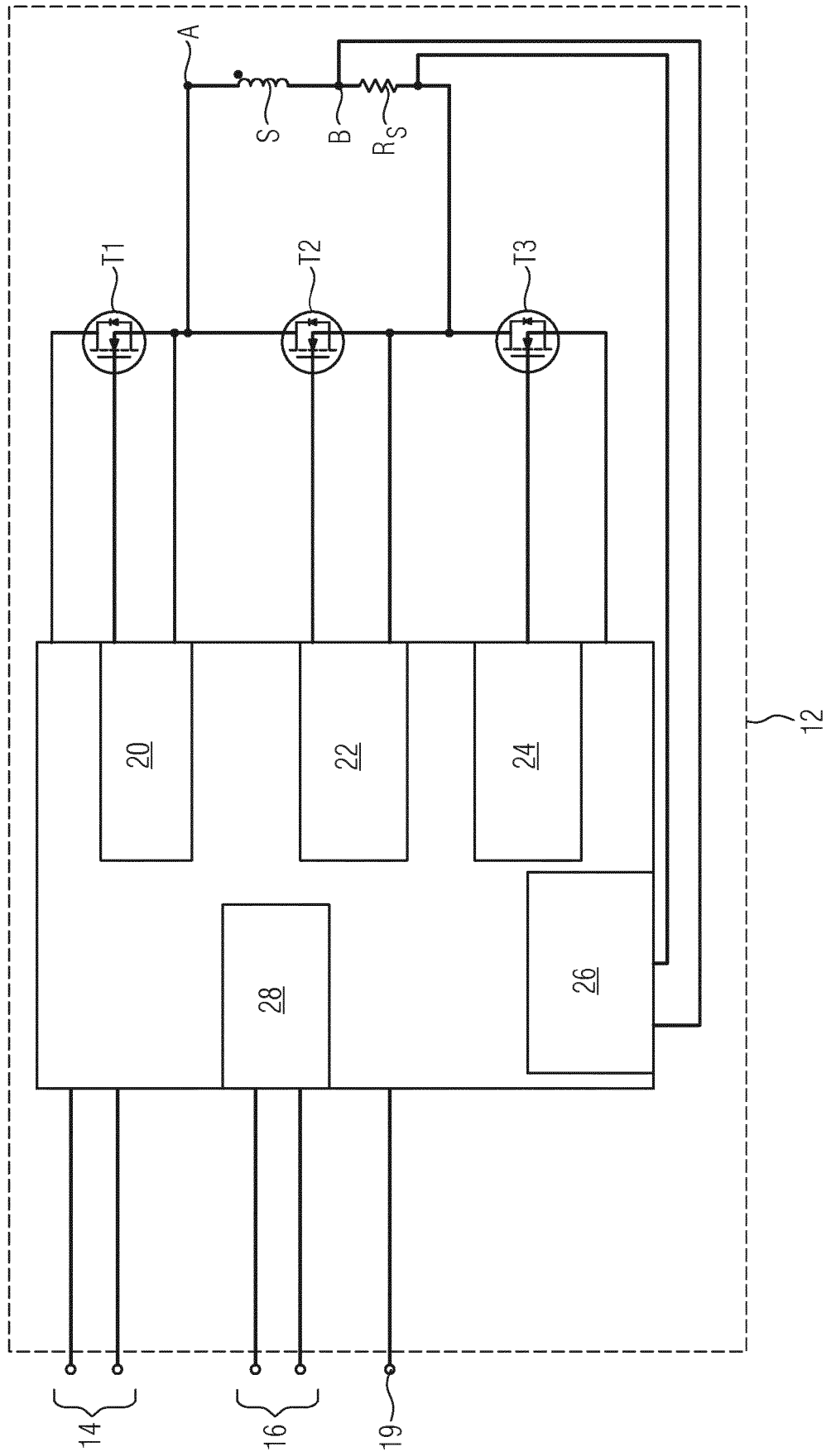


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 16 46 5562

5

10

15

20

25

30

35

40

45

50

55

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	US 5 538 220 A (LAMARCA DREW [US]) 23 July 1996 (1996-07-23)	1-4,6-11	INV. H01F7/06 H01F7/127 H01F7/128 H01F7/18 F16K31/00	
A	* column 4, paragraph 3; figure 1 et 2 * * column 3, paragraph 2 *	5		
X	FR 2 352 381 A1 (TELEMECANIQUE ELECTRIQUE [FR]) 16 December 1977 (1977-12-16) * figure 5 *	1,11		
X	WO 2014/134500 A1 (TENNECO AUTOMOTIVE OPERATING [US]) 4 September 2014 (2014-09-04) * figures 6,7 *	1,11		
X	EP 1 903 581 A2 (EATON CORP [US]) 26 March 2008 (2008-03-26) * figure 4 *	1,11		
X	WO 2010/029133 A1 (CONTINENTAL AUTOMOTIVE GMBH [DE]; JAKLIN RALF [DE]) 18 March 2010 (2010-03-18) * abstract; figure 3 *	1,11		TECHNICAL FIELDS SEARCHED (IPC)
X	EP 0 883 142 A2 (SMC CORP [JP]) 9 December 1998 (1998-12-09) * abstract; figure 5 *	1,11		H01F F16K
X	EP 0 947 408 A2 (SIEMENS AG [DE]) 6 October 1999 (1999-10-06) * paragraph [0016]; figure 1 *	1,11		
X	US 6 059 382 A (SCHOETTL JOHANNES [DE]) 9 May 2000 (2000-05-09) * figure 2 *	1,11		
A	EP 2 110 820 A2 (SIEMENS ENERGY & AUTOMAT [US]) 21 October 2009 (2009-10-21) * paragraph [0015]; figure 1 *	2		
		-/--		
The present search report has been drawn up for all claims				
Place of search Munich		Date of completion of the search 1 June 2017	Examiner Rouzier, Brice	
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)



EUROPEAN SEARCH REPORT

 Application Number
 EP 16 46 5562

5

10

15

20

25

30

35

40

45

50

55

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	WO 2012/125102 A1 (DIGISIGN AB [SE]; WIRGART BENGT [SE]) 20 September 2012 (2012-09-20) * page 10, line 11 - line 23; figures 6,7 *	3,6	
A	DE 10 2011 087368 A1 (INFINEON TECHNOLOGIES AG [DE]) 31 May 2012 (2012-05-31) * figure 1a * * paragraph [0019] *	4	
A	DE 196 47 215 A1 (FESTO KG [DE]) 24 July 1997 (1997-07-24) * abstract *	7,8	
A	US 2014/290771 A1 (KERBER JOSEF [DE] ET AL) 2 October 2014 (2014-10-02) * paragraph [0024]; figure 2 *	9,10	
A	US 2014/238494 A1 (SCHWEIKERT CHRISTIAN [DE] ET AL) 28 August 2014 (2014-08-28) * paragraph [0040] * * paragraph [0041] * * paragraph [0036] *	4	
A	US 2006/070591 A1 (MERWIN JEFFREY D [US]) 6 April 2006 (2006-04-06) * figure 2 *	2,4	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 1 June 2017	Examiner Rouzier, Brice
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 16 46 5562

5

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.

01-06-2017

10

15

20

25

30

35

40

45

50

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5538220 A	23-07-1996	AU 688992 B2	19-03-1998
		BR 9506421 A	09-09-1997
		CA 2177277 A1	02-05-1996
		JP H10503829 A	07-04-1998
		US 5538220 A	23-07-1996
		WO 9612905 A1	02-05-1996
FR 2352381 A1	16-12-1977	NONE	
WO 2014134500 A1	04-09-2014	CN 105026788 A	04-11-2015
		EP 2962010 A1	06-01-2016
		JP 2016514239 A	19-05-2016
		KR 20150121020 A	28-10-2015
		US 2014238797 A1	28-08-2014
		US 2015247544 A1	03-09-2015
		WO 2014134500 A1	04-09-2014
EP 1903581 A2	26-03-2008	EP 1903581 A2	26-03-2008
		US 2008074219 A1	27-03-2008
WO 2010029133 A1	18-03-2010	DE 102008046906 A1	25-03-2010
		EP 2334963 A1	22-06-2011
		WO 2010029133 A1	18-03-2010
EP 0883142 A2	09-12-1998	CN 1193803 A	23-09-1998
		DE 69817677 D1	09-10-2003
		DE 69817677 T2	29-07-2004
		EP 0883142 A2	09-12-1998
		JP 4395548 B2	13-01-2010
		JP H10256035 A	25-09-1998
		TW 415627 U	11-12-2000
		US 6095489 A	01-08-2000
EP 0947408 A2	06-10-1999	NONE	
US 6059382 A	09-05-2000	DE 19704152 A1	06-08-1998
		EP 0856447 A2	05-08-1998
		US 6059382 A	09-05-2000
EP 2110820 A2	21-10-2009	EP 2110820 A2	21-10-2009
		US 2009323247 A1	31-12-2009
WO 2012125102 A1	20-09-2012	NONE	
DE 102011087368 A1	31-05-2012	CN 102570782 A	11-07-2012
		DE 102011087368 A1	31-05-2012

EPO FORM P0459

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

55

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 46 5562

5

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.

01-06-2017

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2012133420 A1	31-05-2012
		US 2014035626 A1	06-02-2014

DE 19647215 A1	24-07-1997	DE 19647215 A1	24-07-1997
		DE 29600866 U1	07-03-1996

US 2014290771 A1	02-10-2014	CN 104074819 A	01-10-2014
		DE 102013005478 B3	30-01-2014
		US 2014290771 A1	02-10-2014

US 2014238494 A1	28-08-2014	CN 104006203 A	27-08-2014
		DE 102014002420 A1	28-08-2014
		US 2014238494 A1	28-08-2014

US 2006070591 A1	06-04-2006	DE 112005002447 T5	18-10-2007
		US 2006070591 A1	06-04-2006
		WO 2006041709 A1	20-04-2006

EPO FORM P0459

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