



- (51) International Patent Classification:  
*H05K 1/02* (2006.01)
- (21) International Application Number:  
PCT/EP2012/062563
- (22) International Filing Date:  
28 June 2012 (28.06.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant (for all designated States except US): **AK-TIEBOLAGET ELECTROLUX** [SE/SE]; S:t Göransgatan 143, S-105 45 Stockholm (SE).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **KJELLSTRÖM, Claes** [SE/SE]; Hallestagan 13, S-617 30 Hälleblacker (SE).
- (74) Agent: **BODIN, Henrik**; S:t Göransgatan 143, S-105 45 Stockholm (SE).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

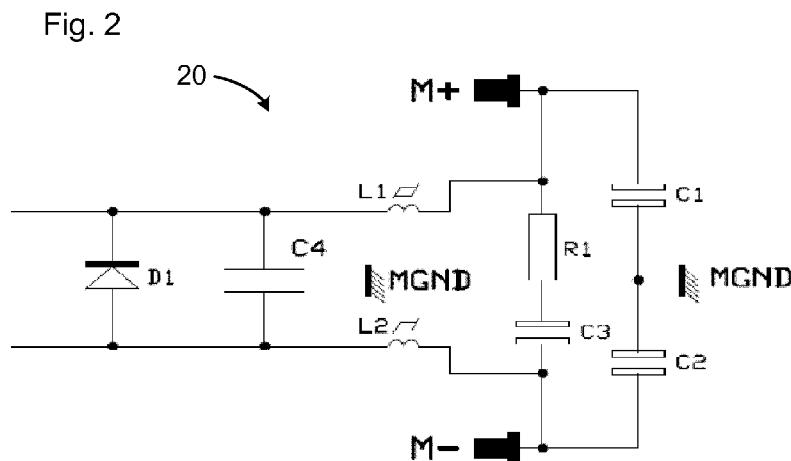
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, 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, 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, ML, MR, NE, SN, TD, TG).

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

WO 2014/000800 A1

(54) Title: PRINTED CIRCUIT BOARD AND ELECTRIC FILTER



(57) Abstract: The present invention relates to a printed circuit board (30) and an electric filter (20). The printed circuit board is arranged to accommodate electric circuitry on one side, the other side of the printed circuit board being arranged with an electrically conductive material via which a ground point common to the electric circuitry and a device contacting the conductive material is accomplished. The electric filter for filtering electric signals of a DC motor (40) comprises a freewheeling diode (D1) coupled in parallel to the motor, an X2Y capacitor (C4) coupled in parallel to the motor, wherein a ground terminal (MGND) of the X2Y capacitor is coupled to a chassis of the motor, a low pass filter comprising a ferrite bead (L1, L2) and a capacitor (C1, C2) connected to each motor terminal (M+, M-), and a resistor-capacitor (RC) filter (R1, C3) coupled in parallel to the motor.

## **PRINTED CIRCUIT BOARD AND ELECTRIC FILTER**

### ***TECHNICAL FIELD***

The present invention relates to a printed circuit board and an electric filter.

### ***BACKGROUND***

- 5 In electric devices arranged with electric motors, such as household appliances in the form of e.g. vacuum cleaners, requirements pertaining to motor noise and electromagnetic interference (EMI) are strict. These requirements are for instance set forth in standard BS EN 55014-2:1997.

10 It is thus a general problem in the art in the field of household appliances to provide products which are acceptable from a noise and EMI viewpoint.

### ***SUMMARY***

An object of the present invention is to solve, or at least mitigate this problem in the art and provide an improved printed circuit board and electric filter for removing noise emission of a motor.

- 15 This object is attained in a first aspect of the present invention by a printed circuit board arranged to accommodate electric circuitry on one side, the other side of the printed circuit board being arranged with an electrically conductive material via which a ground point common to the electric circuitry and a device contacting the conductive material is accomplished.
- 20 Advantageously, by arranging on side of the board for accommodating electric circuitry exemplified in the form of an electric filter for filtering electric signals of a direct current (DC) motor, and the other side of the board with a conductive material via which a ground point common the electric filter and a chassis of the motor is accomplished, grounding problems for the
- 25 electric filter are overcome, or at least considerably mitigated.

In an embodiment of the present invention, the side of the printed circuit board having the conductive material is completely coated with the material in the form of e.g. zinc, copper or any other appropriate conductive material.

When setting the coated side of the printed circuit board in contact with the motor chassis, the chassis will act as a shield for noise emissions of the motor, since the printed circuit board is arranged at an end of the motor, which motor typically being cylindrically shaped, and thus completely covers the end of the motor on which it is mounted by means of e.g. soldering.

In a further embodiment of the present invention, since the printed circuit board is mounted directly to the motor chassis, it is advantageous to provide the board with ventholes for dissipating heat from the motor.

In yet a further embodiment of the present invention, the ventholes are circular, which is advantageous since problems relating to standing waves and resonance can be avoided or at least mitigated.

In another embodiment of the present invention, the physical layout of the electric circuitry arranged to be accommodated on the board is such that it is symmetrically arranged around a central axis of the board. This is advantageous since signals passing through the filter will have the same propagation time, which further reduces noise.

This object is further attained in a second aspect of the present invention by an electric filter for filtering electric signals of a DC motor, which electric filter comprises a freewheeling diode coupled in parallel to the motor, an X2Y capacitor coupled in parallel to the motor, wherein a ground terminal of the X2Y capacitor is coupled to a chassis of the motor, a low pass filter comprising a ferrite bead and a capacitor connected to each motor terminal, and a resistor-capacitor (RC) filter coupled in parallel to the motor.

Advantageously, a freewheeling diode is coupled in parallel to the motor and is used to provide a path for the release of energy stored in the inductive motor when the motor is turned off. As long as the motor is running, the freewheeling diode is reverse-biased with respect to an operating voltage applied to the motor. When the motor is turned off, the diode becomes forward-biased with respect to the inductive motor and will conduct current until the energy stored in the inductive motor is dissipated.

Further advantageous is that the X2Y capacitor is coupled in parallel to the motor, wherein any common-mode noise appearing on the motor terminals advantageously is filtered to the common ground formed by the motor chassis by the two capacitors comprised in the X2Y capacitor.

- 5 A low pass filter comprising a ferrite bead and a capacitor is coupled to each motor terminal. A ferrite bead is an inductor which is constructed to become highly resistive at a design frequency range and current induced in the bead is advantageously dissipated as heat instead of inducing an opposing current back in the electric filter, as in the case of the inductive motor discussed  
10 hereinabove.

An RC filter occasionally referred to as an RC snubber, i.e. a resistor coupled in series to a capacitor, is coupled across the motor to advantageously reduce voltage overshoot of the motor. When the motor charges to an intended voltage potential, the remaining energy in leads to the motor continues to  
15 charge the motor voltage and causes voltage overshoot, which is sometimes referred to as ringing.

Thus, the electric filter advantageously reduces noise emission of the DC motor, the motor being for example a nozzle motor of an upright vacuum cleaner. Given the strict requirements on motor noise for household  
20 appliances, the filter of the present invention facilitates lowering noise levels of the motor such that specified requirements are complied with.

In a further embodiment of the present invention, a printed circuit board assembly is provided. That is, a printed circuit board assembly is provided not only comprising the printed circuit board discussed with reference to the  
25 first aspect of the present invention herein above but further the electric filter of the second aspect of the present invention mounted to the printed circuit board. Thus, the electric filter is mounted on one side of the board and ground wiring is performed from that side of the board to the conductive material arranged on the other side of the board, which conductive material

is grounded via the motor chassis such that a common ground is accomplished for the electric filter and the motor.

In yet a further embodiment of the present invention, a DC motor arrangement is provided comprising the printed circuit board assembly  
5 mounted with the conductive material of the printed circuit board contacting the motor chassis.

In still a further embodiment of the present invention a vacuum cleaner is provided comprising the DC motor arrangement

In further embodiments, the DC motor arrangement is arranged in a nozzle  
10 of the vacuum cleaner and/or in a fan unit of the vacuum cleaner.

It is noted that the invention relates to all possible combinations of features recited in the claims. Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. Those skilled in the art realize that different features of  
15 the present invention can be combined to create embodiments other than those described in the following.

### ***BRIEF DESCRIPTION OF THE DRAWINGS***

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

20 Fig 1 shows a battery-driven vacuum cleaner of an upright model in which the present invention can be implemented;

Figure 2 shows a circuit diagram of an electric filter according to an aspect of the present invention;

Figure 3 illustrates a printed circuit board according to a further aspect of the  
25 present invention;

Figure 4 shows a side view of a vacuum cleaner nozzle motor arranged with a printed circuit board assembly according to an embodiment of the present invention; and

5 Figure 5 shows a further view of the vacuum cleaner nozzle motor arranged with a printed circuit board assembly according to the embodiment of the present invention shown in Figure 4.

### ***DETAILED DESCRIPTION***

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different  
10 forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

15 Figure 1 illustrates a battery-driven vacuum cleaner 1 of an upright model comprising a nozzle 2 provided with a rotatable member 3, like a brush roll, for picking up particles from a surface to be cleaned. In a main body 4 of the vacuum cleaner 1, a fan motor 5 generally having the shape of a cylinder is arranged for creating a suction flow such that particles can be transported to  
20 a dust bag or container (not shown).. Further, as is illustrated with dashed lines, a nozzle motor 6 is arranged in the nozzle for rotating the brush roll 3 such that particles can be picked up from the surface to be cleaned. The present invention can be implemented in the fan motor 5 as well as in the nozzle motor 6. Even though Figure 1 shows an upright/stick vacuum cleaner,  
25 the present invention can be applied in other types of vacuum cleaners, such as e.g. a handheld vacuum cleaner, a robotic vacuum cleaner or a canister vacuum cleaner.

Figure 2 shows a circuit diagram of an electric filter according to an aspect of the present invention, the filter 20 being connected to a DC motor via motor  
30 terminals M+ and M-. The filter 20 comprises a freewheeling diode D1

coupled in parallel to the motor, an X2Y capacitor C4 coupled in parallel to the motor, wherein a ground terminal MGND of the X2Y capacitor is coupled to a chassis of the motor, a low pass filter comprising a ferrite bead L1, L2 and a capacitor C1, C2 respectively connected to each motor terminal M+ and M-, and an RC filter consisting of resistor R1 and capacitor C3 coupled in parallel to the motor. As previously has been discussed, the freewheeling diode D1 is used to provide a path for the release of energy stored in the inductive motor when the motor is turned off. As long as the motor is running, the freewheeling diode D1 is reverse-biased with respect to an operating voltage applied to the motor. When the motor is turned off, the diode D1 becomes forward-biased with respect to the inductive motor and will conduct current until the energy stored in the inductive motor is dissipated. To filter common-mode noise appearing on the motor terminals M+ and M- to the ground MGND common to the filter and the motor the X2Y capacitor C4 is used. Further, to dissipate current as heat, the low pass filters of L1, C1 and L2, C2 are connected to the motor terminals M+ and M-, where the inductances L1, L2 are realized in the form of ferrite beads. Finally, the RC filter R1, C3 is used to reduce voltage overshoot – aka. ringing - of the motor.

Figure 3 illustrates a printed circuit board according to a further aspect of the present invention. The top view of Figure 3 shows one side of the printed circuit board 30 indicating the placement of the electric filter comprising the components D1, C4, L1, L2 R1, C3, C1 and C2 as was discussed in connection to Figure 2. Thus, the top view of Figure 3 shows the side of the board 30 arranged to accommodate the electric filter 20 of Figure 2.

As can be seen in Figure 3, in an embodiment of the present invention, the physical layout of the filter arranged to be accommodated on the board 30 is such that it is symmetrically arranged around a central axis CA of the board. This is advantageous since signals passing through the filter will have the same propagation time, which further reduces noise.

The bottom view of Figure 3 shows the other side of the printed circuit board 30 being arranged with an electrically conductive material via which a ground point common to the electric filter and e.g. a motor chassis on which the board 30 can be mounted is accomplished. In this particular embodiment, 5 the complete side of the board 30 arranged with the conductive material is coated with the material.

In a further embodiment of the present invention, since the printed circuit board 30 is mounted directly to the motor chassis, as will be shown in the following it is advantageous to provide the board with circular ventholes 31, 10 32, 33, 34 for dissipating heat from the motor.

Figure 4 shows a side view of a vacuum cleaner nozzle motor arranged with a printed circuit board assembly according to an embodiment of the present invention comprising the printed circuit board 30 described with reference to Figure 3 and the electric filter shown in Figure 2 mounted on the printed 15 circuit board (the filter not being shown in Figure 4). For a detailed view of the actual placement of filter components onto the board, reference is made to Figure 3. At one end of the cylindrically shaped motor 40, the side of the printed circuit board 30 being arranged with a conductive material is soldered to the motor chassis to create the common grounding point.

20 Figure 5 shows a further view of the vacuum cleaner nozzle motor arranged with the printed circuit board assembly comprising the printed circuit board 30 and the electric filter shown in Figure 4 (the filter not being shown in Figure 4), which printed circuit board assembly is mounted to one end of the cylindrically shaped motor 40. Further shown in Figure 5 are cables 51, 52 25 connected to the motor terminals such that pulse width modulation (PWM) signals can be supplied for motor control. In an embodiment of the present invention, the cables are intertwined in order to further reduce noise emission. By achieving symmetry in noise for signals transported on the cables, interference may be cancelled due to phase shift of interfering signals. 30 Crosstalk may further be reduced.



Even though the invention has been described with reference to specific exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art. The described embodiments are therefore not intended to limit the scope of the invention,  
5 as defined by the appended claims.

## claims

1. A printed circuit board (30) arranged to accommodate electric circuitry on one side, the other side of the printed circuit board being arranged with an electrically conductive material via which a ground point common to the electric circuitry and a device contacting the conductive material is accomplished.
2. The printed circuit board (30) of claim 1, wherein said other side of the printed circuit board is coated with the electrically conductive material.
3. The printed circuit board (30) of claims 1 or 2, wherein the electric circuitry is an electric filter (20) for filtering electrical signals of a direct current, DC, motor (40), and said other side is arranged with the conductive material for contacting a chassis of the motor in order to accomplish a ground point common to the chassis and the electric filter.
4. The printed circuit board (30) of any one of the preceding claims, further being arranged such that the side of the board arranged with a conductive material fully contacts the device which the board is arranged to contact.
5. The printed circuit board (30) of any one of the preceding claims, further being arranged with ventholes (31, 32, 33, 34) for dissipating heat from the device arranged to contact the conductive material.
6. The printed circuit board (30) of claim 5, wherein the ventholes (31, 32, 33, 34) are circular.
7. The printed circuit board (30) of any one of the preceding claims, wherein physical layout of the electric circuitry arranged to be accommodated on the board is such that it is symmetrically arranged around a central axis (CA) of the board.
8. An electric filter (20) for filtering electric signals of a direct current, DC, motor (40), which electric filter comprises:

a freewheeling diode (D1) coupled in parallel to the motor;

an X2Y capacitor (C4) coupled in parallel to the motor, wherein a ground terminal (MGND) of the X2Y capacitor is coupled to a chassis of the motor;

5 a low pass filter comprising a ferrite bead (L1, L2) and a capacitor (C1, C2) connected to each motor terminal (M+, M-); and

a resistor-capacitor, RC, filter (R1, C3) coupled in parallel to the motor.

9. A printed circuit board assembly comprising the printed circuit board (30) of any one of claims 1-7, wherein the electric filter (20) of claim 8 is  
10 mounted to said one side of the printed circuit board for filtering electric signals of the DC motor (40), a chassis of which motor is arranged to contact the conductive material arranged on said other side of the printed circuit board.

10. A DC motor arrangement comprising the printed circuit board assembly  
15 of claim 9 mounted with the conductive material of the printed circuit board (20) contacting the motor chassis.

11. The DC motor arrangement of claim 10, further comprising a pair of cables (51, 52) connected to the printed circuit board (30) and further to the respective motor terminal (M+, M-) for pulse width modulation, PWM,  
20 signal supply, said cables being intertwined with each other.

12. A vacuum cleaner (1) comprising the DC motor arrangement of any one of claims 10-11.

13. The vacuum cleaner (1) of claim 12, the DC motor arrangement being arranged in a nozzle (2) of the vacuum cleaner.

25 14. The vacuum cleaner (1) of claims 12 or 13, the DC motor arrangement being arranged in a fan unit of the vacuum cleaner.

1/4

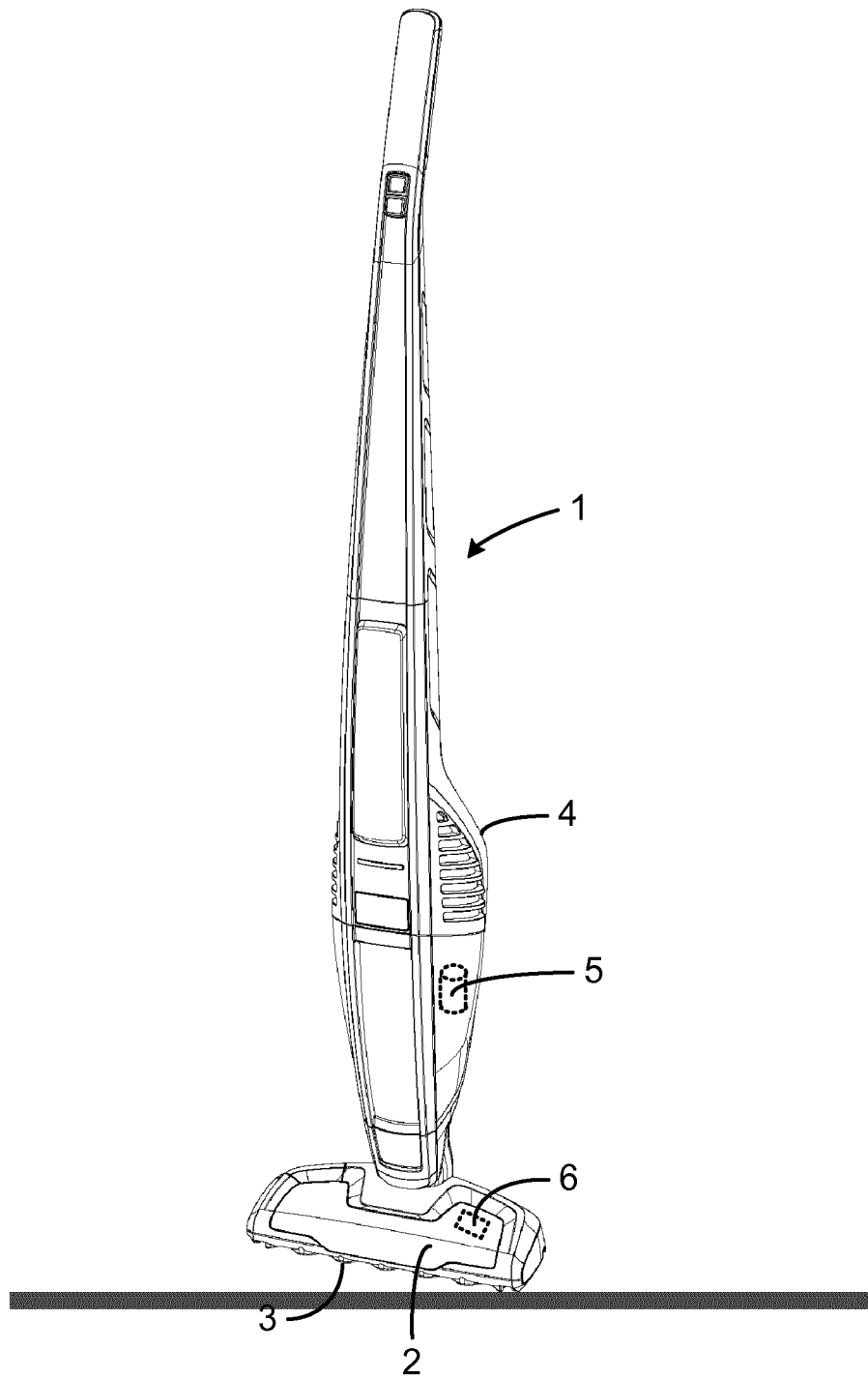


Fig. 1

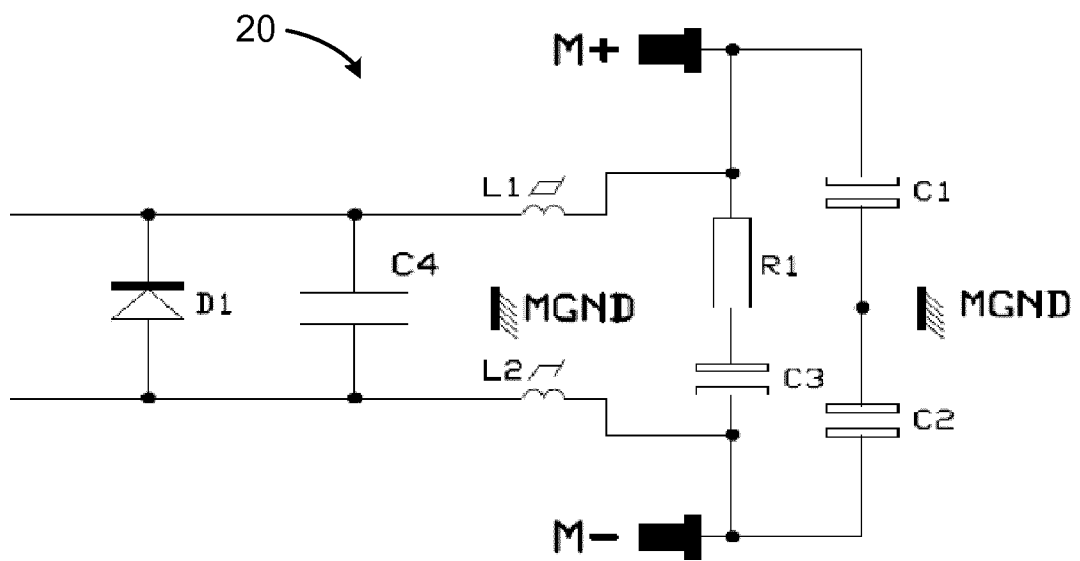


Fig. 2

3/4

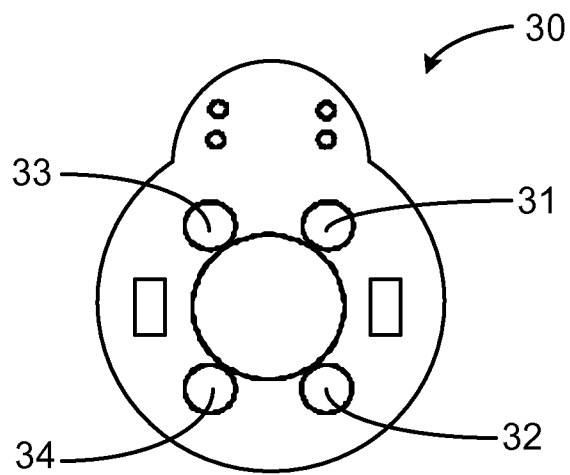
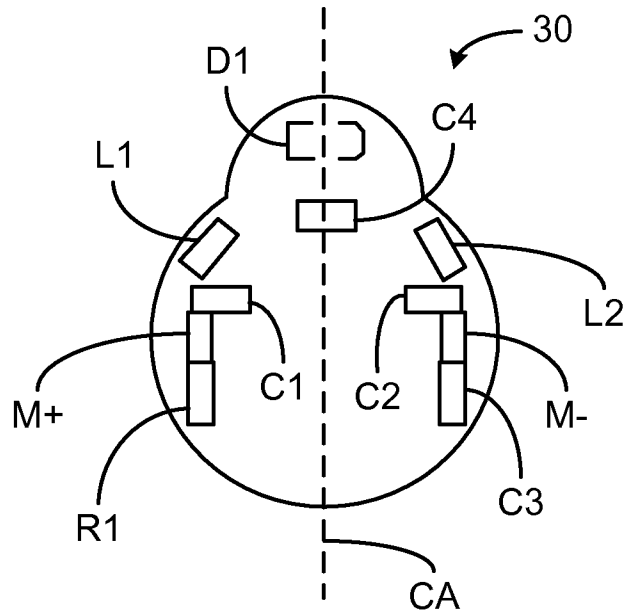


Fig. 3

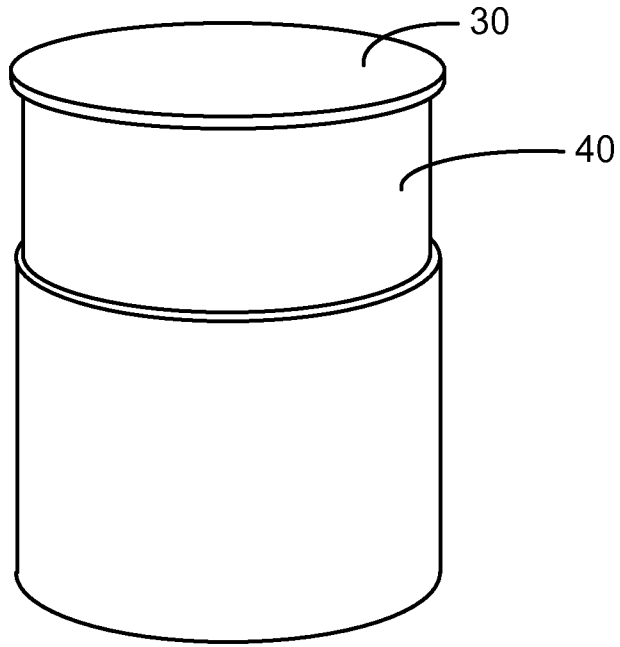


Fig. 4

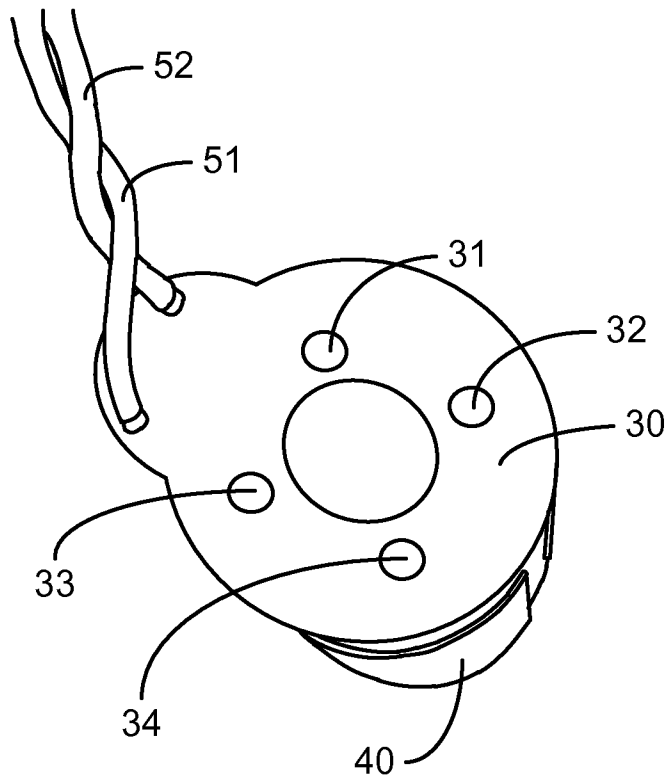


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2012/062563

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H05K1/02  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Anonymous: "DC Motor Design with X2Y Technology", Johanson Dielectrics 29 April 2005 (2005-04-29), pages 1-17, XP002692858, Retrieved from the Internet: URL: <a href="http://www.johansondielectrics.com/images/stories/tech-notes/x2y/mfb/JDI_X2Y_DC_Motor_Filtering_Basics.pdf">http://www.johansondielectrics.com/images/stories/tech-notes/x2y/mfb/JDI_X2Y_DC_Motor_Filtering_Basics.pdf</a> [retrieved on 2013-02-26]	1-4
Y	page 1, line 1 - page 14, line 10; figures ----- -/--	5-14

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "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)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "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
- "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
- "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
- "&" document member of the same patent family

Date of the actual completion of the international search  27 February 2013	Date of mailing of the international search report  18/04/2013
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Geoghegan, C



## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2012/062563

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	J. Muccioli et al.: "Suppression techniques using X2Y as a broadband EMI filter", 2003 IEEE International Symposium on EMC 23 August 2003 (2003-08-23), pages 1-31, XP002692859, Boston, MA, USA Retrieved from the Internet: URL: <a href="http://www.x2y.com/publications/emi/au-g23-03.pdf">http://www.x2y.com/publications/emi/au-g23-03.pdf</a> [retrieved on 2013-02-26] page 4 - page 10; figures	5-14
A	US 4 673 851 A (DISSER ROBERT J [US]) 16 June 1987 (1987-06-16) column 1, line 34 - column 3, line 25; figures	8-14
A	Anonymous: "X2Y EMI Filter Devices for Appliances", X2Y Technology in Balance 1 November 2008 (2008-11-01), pages 1-6, XP002692860, Retrieved from the Internet: URL: <a href="http://www.x2y.com/publications/emi/applfilter.pdf">http://www.x2y.com/publications/emi/applfilter.pdf</a> [retrieved on 2013-02-26] page 1, line 1 - page 2, line 5; figures	12-14
A	EP 1 780 867 A2 (BLACK & DECKER INC [US]) 2 May 2007 (2007-05-02) page 6, paragraph 44 - paragraph 47; figure 1B page 12, paragraph 98 - paragraph 100; figure 6	1,8

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No

PCT/EP2012/062563

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4673851	A	16-06-1987	DE 3768036 D1 28-03-1991
			EP 0240172 A2 07-10-1987
			JP 62236382 A 16-10-1987
			US 4673851 A 16-06-1987
-----			
EP 1780867	A2	02-05-2007	CN 201048140 Y 16-04-2008
			EP 1780867 A2 02-05-2007
			US 2008238370 A1 02-10-2008
			US 2010213900 A1 26-08-2010
			US 2011163701 A1 07-07-2011
-----			