

(51) International Patent Classification:
H05B 6/06 (2006.01)(21) International Application Number:
PCT/EP2017/054845(22) International Filing Date:
2 March 2017 (02.03.2017)

(25) Filing Language: English

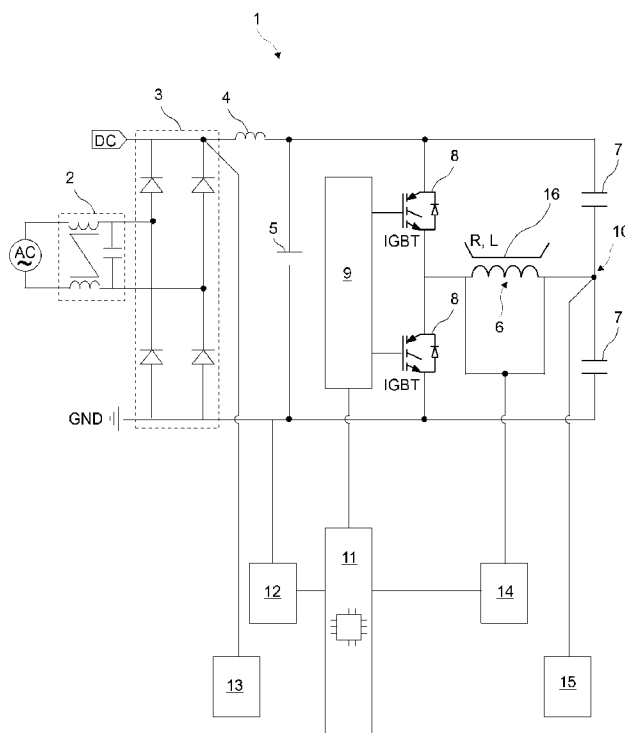
(26) Publication Language: English

(30) Priority Data:
A 2016/02875 4 March 2016 (04.03.2016) TR(71) Applicant: **ARCELIK ANONIM SIRKETI** [TR/TR]; E5
Ankara Asfalti Uzeri, Tuzla, 34950 Istanbul (TR).(72) Inventors: **OZTURK, Metin**; E5 Ankara Asfalti Uzeri,
Tuzla, 34950 Istanbul (TR). **SARIOGLU, Atakan**; E5
Ankara Asfalti Uzeri, Tuzla, 34950 Istanbul (TR). **OK-
TAY, Ulas**; E5 Ankara Asfalti Uzeri, Tuzla, 34950 Istanbul
(TR). **SINIRLIOGLU, Sercan**; E5 Ankara Asfalti
Uzeri, Tuzla, 34950 Istanbul (TR).(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, DJ, 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, KH, KN,
KP, KR, KW, 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).

[Continued on next page]

(54) Title: INDUCTION HEATING COOKER POWER CONTROL CIRCUIT

Figure 1



(57) Abstract: The present invention relates to a power control circuit (1) suitable to be used in induction heating cookers, comprising an AC filter circuit (2) that filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8), for example an IGBT (Insulated Gate Bipolar Transistor) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive voltage (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9), the power control circuit (1) determining whether or not the ferromagnetic characteristics of the vessel (16) placed on the induction coil (6) are suitable for induction heating.

WO 2017/149055 A1



Published:

— *with international search report (Art. 21(3))*

Description**INDUCTION HEATING COOKER POWER CONTROL CIRCUIT**

- [0001] The present invention relates to an induction heating cooker that detects the ferromagnetic properties of the vessel placed thereon.
- [0002] The induction heating cooker functions according to the principle of heating a cast iron or steel ferromagnetic cooking vessel with the magnetic field generated by the induction coil. In order to drive the induction coils generating the magnetic field, a high-level electric current is passed through the power switch (such as IGBT (Insulated Gate Bipolar Transistor), diode, MOSFET, etc.) on the electronic circuit. In the state of the art, half bridge series resonant (HBSR) circuits formed by using two power switches and two resonant capacitors are used for driving a single induction coil.
- [0003] In the market, vessels suitable to be used on the induction heating cookers have different characteristics depending on the alloy they comprise. In other words, the ferromagnetic characteristics of the vessels are different. While aluminum alloy pots have low inductance values, cast iron vessels have high inductance values. Therefore, it is important to know the ferromagnetic characteristics of a vessel placed onto the induction heating cooker. When a vessel that has a low ferromagnetic quality, meaning that has a low capacity of converting magnetic energy into thermal energy is placed onto the induction heating cooker, the vessel cannot be heated in accordance with the selected power setting, causing increase in power consumption and damaging the electronic circuit.
- [0004] The European Patent No. EP2034801 relates to an induction heating appliance that enables the user to be informed of the cooking capabilities of cookware suitable for induction heating.
- [0005] The European Patent No. EP2282606 relates to an induction heating appliance control method. By comparing the resonant voltage with a constant reference voltage predetermined by the control unit, the presence or absence of a vessel present on the induction coil, and the resistivity and the amplitude thereof is determined.
- [0006] In the European Patent No. EP1629698, an induction cooking system

comprising a power inverter, a microprocessor, a protection circuit and a pan detection circuit is disclosed.

- [0007] The aim of the present invention is the realization of a power control circuit that detects the ferromagnetic characteristics of the vessel placed onto the induction coil.
- [0008] The induction heating cooker power control circuit realized in order to attain the aim of the present invention, explicated in the first claim and the respective thereof, comprises a microcontroller that calculates the vessel resistance and inductance according to the power drawn from the mains and to the current passing through the induction coil while the induction coil is energized at any power setting selected via the user interface and that decides whether or not the vessel is present by checking if the vessel inductance is between the predetermined lower and upper limit values, and the microcontroller deciding if the ferromagnetic characteristics of the vessel are suitable for induction cooking in the case that the vessel is present.
- [0009] The microcontroller decides that the ferromagnetic characteristics of the vessel is not suitable if the inductance of the vessel is below the lower limit value.
- [0010] The microcontroller decides that the vessel is not present on the induction heating cooker if the vessel inductance is above the upper limit value.
- [0011] By using the calculated vessel inductance, the microcontroller determines the resonant frequency that provides the maximum power to be transmitted to the vessel.
- [0012] The power control circuit of the present invention furthermore comprises a mains current monitoring circuit, an input voltage monitoring circuit, a coil current monitoring circuit that monitors the current of the induction coil and a capacitance voltage monitoring circuit that together provide the data required for the microcontroller to calculate the said vessel inductance.
- [0013] The induction heating cooker power control circuit of the present invention quickly and correctly detects if the vessel is present on the cooker when the induction coil is energized and if the vessel is present, detects if the ferromagnetic characteristics thereof are suitable. The power control circuit

determines the resonant frequency suitable for the vessel type, thus decreasing the power consumption and preventing the electronic circuit components from being damaged.

[0014] The induction heating cooker realized in order to attain the aim of the present invention is illustrated in the attached figure, where:

[0015] Figure 1 – is the schematic view of the induction heating cooker power control circuit

[0016] The elements illustrated in the figures are numbered as follows:

[0017] 1 - Power control circuit

[0018] 2 - AC filter circuit

[0019] 3 - Bridge rectifier

[0020] 4 - Filter inductor

[0021] 5- Filter capacitor

[0022] 6 - Induction coil

[0023] 7 - Resonant capacitor

[0024] 8 - Power switch

[0025] 9 - Drive circuit

[0026] 10 - Collector node

[0027] 11 - Microcontroller

[0028] 12 - Mains current monitoring circuit

[0029] 13 - Input voltage monitoring circuit

[0030] 14 - Coil current monitoring circuit

[0031] 15 - Capacitance voltage monitoring circuit

[0032] 16 - Vessel

[0033] R: Vessel resistance

[0034] L: Vessel inductance

[0035] L-lower: Vessel inductance lower limit value

[0036] L-upper: Vessel inductance upper limit value

[0037] AC: Mains current (alternative current) input

[0038] The power control circuit (1) (also referred to as the inverter circuit) that is suitable to be used in induction heating cookers and that provides the generation of magnetic energy for heating a vessel (16) placed onto the induction heating cooker surface, comprises an AC filter circuit (2) that

filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8), for example an IGBT (Insulated Gate Bipolar Transistor) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive voltage (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9).

[0039] The induction heating cooker is operated by means of an on-off button (not shown in the figures) and first electronic components such as the microcontroller (11) and the user interface (not shown in the figures) are activated. Afterwards, in order to heat the vessel at the desired power setting, the heating setting is selected via the user interface and the induction coil (6) is energized by the power control circuit (1).

[0040] The power control circuit (1) of the present invention comprises the microcontroller (11) that calculates the vessel resistance (R) depending on the power drawn from the mains and on the current passing through the induction coil (6) and calculates the vessel inductance (L) depending on the vessel resistance (R) while the induction coil (6) is energized during the power transmission from the induction heating cooker to the vessel (16) at any power setting selected via the user interface and that decides that the ferromagnetic characteristics of the vessel (16) are suitable for induction cooking and that continues induction heating if the vessel inductance (L) is between the predetermined vessel inductance lower limit (L-lower) and upper limit (L-upper) prerecorded in its memory ($L\text{-lower} < L < L\text{-upper}$).

[0041] The microcontroller (11) decides that the ferromagnetic characteristics of

the vessel (16) are not suitable if the calculated vessel inductance (L) is below the vessel inductance lower limit (L-lower) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.

- [0042] The microcontroller (11) decides that the vessel (16) is not present on the induction heating cooker if the calculated vessel inductance (L) is above the vessel inductance upper limit (L-upper) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.
- [0043] Moreover, by using the calculated actual vessel inductance (L), the microcontroller (11) determines the resonant frequency, in other words the minimum operation frequency, that provides the maximum power to be transmitted to the vessel (16). When the user selects the highest power setting, for example selects "9" on the power setting knob marked from 1 to 9, the resonant frequency determined by the microcontroller (11) by using the vessel inductance (L) is applied. Different resonant frequencies are determined for vessels (16) with different magnetic properties placed on the induction heating cooker. Thus, the vessels (16) of different types are enabled to be heated in accordance with the vessel inductance (L), decreasing the energy consumption.
- [0044] In an embodiment of the present invention, the power control circuit (1) comprises a mains current monitoring circuit (12) connected to the DC line and an input voltage monitoring circuit (13) connected to the outlet of the bridge rectifier (3) that together provide the calculation of the power drawn from the mains in order to determine the vessel resistance (R).
- [0045] The microcontroller (11) calculates the power drawn from the mains by calculating and using the root means square of the current values drawn from the mains according to the data received from the mains current monitoring circuit (12) and the root mean square of the input voltage values according to the data received from the input voltage monitoring circuit (13).
- [0046] In this embodiment, the power control circuit (1) furthermore comprises a coil current monitoring circuit (14) that provides the calculation of the

vessel resistance (R) by the microcontroller (11), that is connected to the induction coil (6) and that monitors the current passing through the induction coil (6).

- [0047] The microcontroller (11) calculates the maximum current value passing through the induction coil (6) according to the data received from the coil current monitoring circuit (14) and also calculates the vessel resistance (R) by using the ratio of the power drawn from the mains to the said maximum current value.
- [0048] In another embodiment of the present invention, the power control circuit (1) comprises a capacitance voltage monitoring circuit (15) that provides the calculation of the vessel inductance (L) by the microcontroller (11) and that is connected to the collector node (10).
- [0049] The microcontroller (11) determines the maximum capacitance voltage according to the data received from the capacitance voltage monitoring circuit (15) and calculates the vessel inductance (L) by using the previously calculated vessel resistance (R).
- [0050] In another embodiment of the present invention, the power control circuit (1) is a half bridge series resonant (HBSR) circuit comprising a pair of resonant capacitors (7) and a pair of power switches (8).
- [0051] In another embodiment of the present invention, the power control circuit (1) is a single switch quasi resonant (SSQR) circuit comprising a single resonant capacitor (7) and a single power switch (8). In some embodiments, it is known as single-ended inverter circuit.
- [0052] In the induction heating cooker power control circuit (1) of the present invention, the microcontroller (11) decides whether or not the ferromagnetic characteristics of the vessel (16) are suitable by calculating the vessel inductance (L) when the induction coil (6) is energized. If the vessel inductance (L) is between the predetermined lower and upper limit values (L-lower and L-upper), the heating process is continued, providing an efficient transmission of power in accordance with the characteristics of the vessel (16). If the vessel (16) is not suitable, the energy transmission is terminated, thus preventing the electronic circuit components from being damaged with high current.

Claims

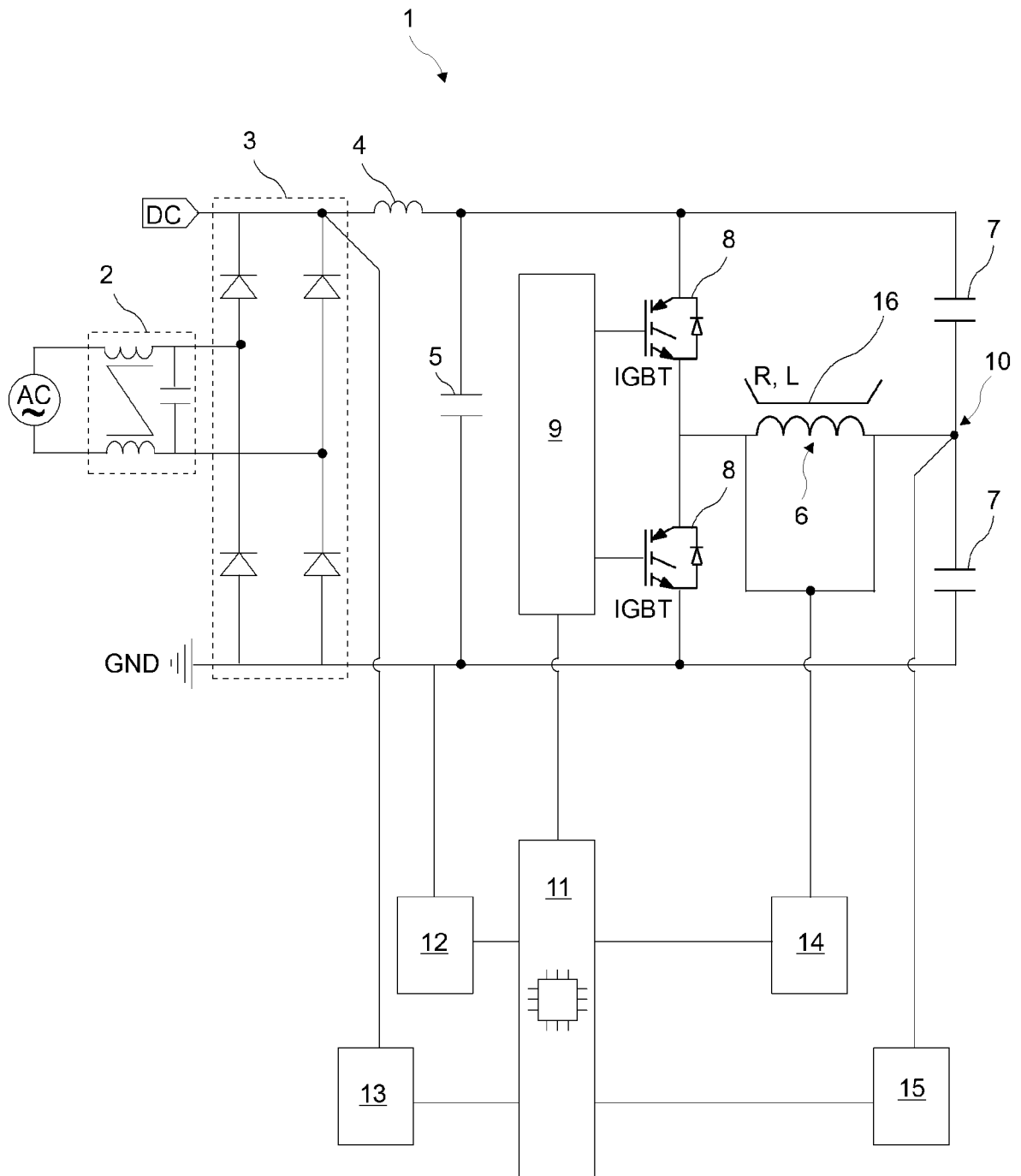
1. A power control circuit (1) suitable to be used in induction heating cookers, **comprising** an AC filter circuit (2) that filters the mains current; a bridge rectifier (3) that converts the alternative current received from the mains into direct current; a DC filter inductor (4) and a DC filter capacitor (5) that are disposed at the outlet of the bridge rectifier (3) on the DC line; an induction coil (6) that is energized for heating the vessel (16) placed onto the induction heating cooker; at least one resonant capacitor (7) that energizes the induction coil (6); at least one power switch (8) that enables the resonant capacitor (7) to be charged/discharged and that provides the transmission of power from the induction coil (6) to the vessel (16); a drive circuit (9) that enables the power switch (8) to be driven with a drive voltage at the desired level; a collector node (10) whereon the resonant voltage is generated, and a microcontroller (11) that regulates the operation of the power switch (8) by means of the drive circuit (9), **characterized by** the microcontroller (11) that calculates the vessel resistance (R) depending on the power drawn from the mains and on the current passing through the induction coil (6) and calculates the vessel inductance (L) depending on the vessel resistance (R) while the induction coil (6) is energized at any power setting selected via the user interface and that decides that the ferromagnetic characteristics of the vessel (16) are suitable for induction cooking and that continues induction heating if the vessel inductance (L) is between the predetermined vessel inductance lower limit (L-lower) and upper limit (L-upper) prerecorded in its memory.
2. A power control circuit (1) as in Claim 1, **characterized by** the microcontroller (11) that decides that the ferromagnetic characteristics of the vessel (16) are not suitable if the vessel inductance (L) is below the lower limit (L-lower) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.
3. A power control circuit (1) as in Claim 1, **characterized by** the microcontroller (11) that decides that the vessel (16) is not present on the induction heating cooker if the vessel inductance (L) is above the upper limit (L-upper) and ends the heating process, enabling the user to be warned audibly and/or visually by means of the user interface.

4. A power control circuit (1) as in any one of the Claims 1 to 3, **characterized by** the microcontroller (11) that determines the resonant frequency providing the maximum power to be transmitted to the vessel (16) by using the calculated vessel inductance (L).
5. A power control circuit (1) as in Claim 1, **characterized by** a mains current monitoring circuit (12) connected to the DC line and an input voltage monitoring circuit (13) connected to the outlet of the bridge rectifier (3) that together provide the calculation of the power drawn from the mains in order to determine the vessel resistance (R).
6. A power control circuit (1) as in Claim 5, **characterized by** the microcontroller (11) that calculates the power drawn from the mains by calculating and using the root mean square of the current values drawn from the mains according to the data received from the mains current monitoring circuit (12) and the root mean square of the input voltage values according to the data received from the input voltage monitoring circuit (13).
7. A power control circuit (1) as in Claim 1, **characterized by** a coil current monitoring circuit (14) that provides the calculation of the vessel resistance (R) by the microcontroller (11), that is connected to the induction coil (6) and that monitors the current of the induction coil (6).
8. A power control circuit (1) as in Claim 7, **characterized by** the microcontroller (11) that calculates the maximum current value passing through the induction coil (6) according to the data received from the coil current monitoring circuit (14) and also calculates the vessel resistance (R) by using the ratio of the power drawn from the mains to the said maximum current value.
9. A power control circuit (1) as in Claim 1, **characterized by** a capacitance voltage monitoring circuit (15) that provides the calculation of the vessel inductance (L) by the microcontroller (11) and that is connected to the collector node (10).
10. A power control circuit (1) as in Claim 9, **characterized by** the microcontroller (11) that determines the maximum capacitance voltage value according to the data received from the capacitance voltage monitoring circuit (15) and calculates the vessel inductance (L) by using the vessel resistance (R).
11. A power control circuit (1) as in Claim 1, **characterized by** being a half bridge

series resonant circuit comprising a pair of resonant capacitors (7) and a pair of power switches (8).

12. A power control circuit (1) as in Claim 1, **characterized by** being a single switch quasi resonant circuit comprising a single resonant capacitor (7) and a single power switch (8).
13. An induction heating cooker, **characterized by** a power control circuit (1) as in Claim 1.

Figure 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/054845

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B6/06
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)
H05B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2 437 573 A1 (MITSUBISHI ELECTRIC CORP [JP]; MITSUBISHI ELECTRIC HOME APPL [JP]) 4 April 2012 (2012-04-04) abstract; claim 1; figures 1-14 -----	1-13
A	EP 2 034 801 A1 (WHIRLPOOL CO [US]; TEKA IND SA [ES]) 11 March 2009 (2009-03-11) cited in the application abstract; claim 1; figures 1-6 -----	1-13
A	US 2015/060439 A1 (PANKRATZ HARRI [DE] ET AL) 5 March 2015 (2015-03-05) abstract; claims 1,8; figures 1-3 -----	1-13



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

17 May 2017

Date of mailing of the international search report

26/05/2017

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

Garcia, Jesus

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/054845

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2437573	A1	04-04-2012	CN 102428750 A 25-04-2012
		EP 2437573 A1	04-04-2012
		ES 2557329 T3	25-01-2016
		JP 5225465 B2	03-07-2013
		WO 2010137498 A1	02-12-2010

EP 2034801	A1	11-03-2009	BR PI0803658 A2 29-09-2009
		CA 2639157 A1	05-03-2009
		EP 2034801 A1	11-03-2009
		ES 2398290 T3	15-03-2013
		US 2009057299 A1	05-03-2009

US 2015060439	A1	05-03-2015	CA 2870241 A1 14-11-2013
		CN 104272863 A	07-01-2015
		DE 102012207847 A1	14-11-2013
		DE 112013002397 A5	22-01-2015
		EP 2848088 A2	18-03-2015
		JP 2015517715 A	22-06-2015
		KR 20150011827 A	02-02-2015
		US 2015060439 A1	05-03-2015
		WO 2013167686 A2	14-11-2013
