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(54) **INDUCTION COOKER AND A METHOD OF OPERATION**

(57) An induction cooker (10) has an induction coil (12). A power circuit provides a varying electric current to the induction coil (12). The power circuit has at least a first transistor (24) and a second transistor (26). A first current sensor (28) senses the current flowing through the first transistor (24). A second current sensor (30)

senses the current flowing through the second transistor (26). An indication is output in the case that the current flowing through the first transistor (24) and the current flowing through the second transistor (26) differ by more than a threshold.

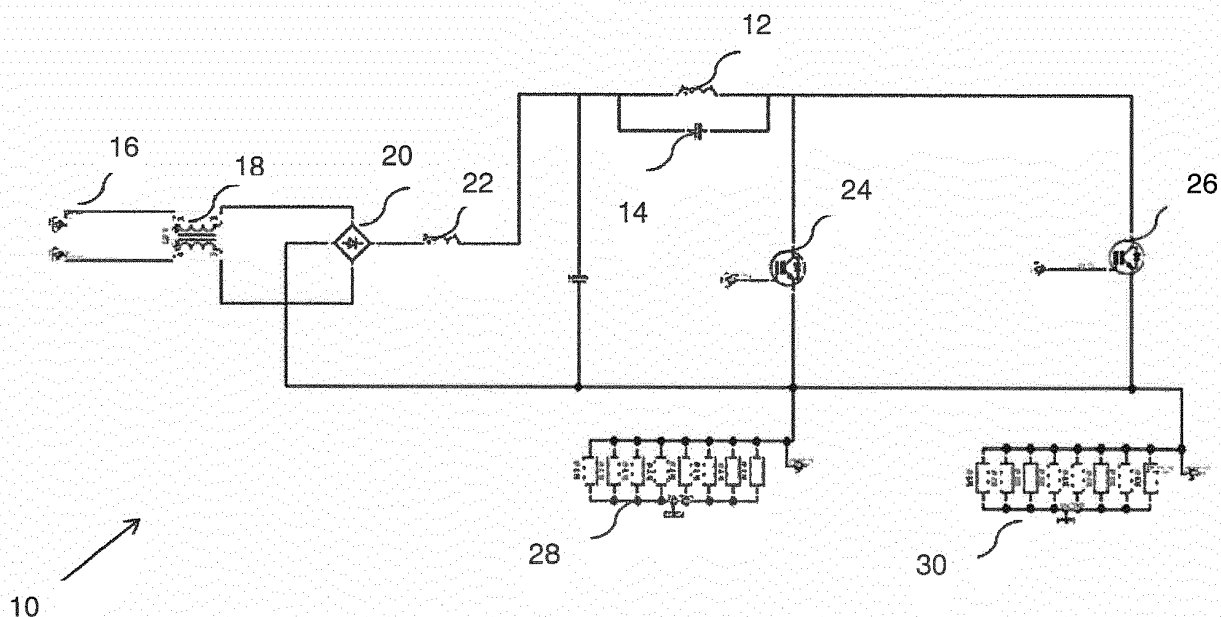


Fig. 1

Description

Technical Field

[0001] The present disclosure relates to an induction cooker and a method of operating an induction cooker.

Background

[0002] Induction cookers are known in which a varying electric current is passed through an induction coil, the coil therefore producing a corresponding varying electromagnetic field. The varying electromagnetic field induces a varying eddy current in a ferromagnetic cooking vessel or the like when the cooking vessel placed in close proximity to the induction coil, which in turn heats the cooking vessel and therefore the contents of the cooking vessel. One or more transistors may be used to control the power that is provided to the induction coil by varying the current that is provided to the induction coil.

Summary

[0003] According to a first aspect disclosed herein, there is provided an induction cooker, the induction cooker comprising:

an induction coil arranged to receive a varying electric current and to produce a corresponding varying electromagnetic field;
 a power circuit constructed and arranged to provide the varying electric current;
 the power circuit comprising at least a first transistor and a second transistor which are each arranged in series with the induction coil and which are arranged in parallel to each other, the transistors being controllable so as to control the current that is provided to the induction coil by the power circuit;
 a first current sensor for sensing the current flowing through the first transistor;
 a second current sensor for sensing the current flowing through the second transistor; and
 a controller for controlling the power circuit, the controller being arranged to compare a current flowing through the first transistor and a current flowing through the second transistor, and to cause an indication to be output in the case that the current flowing through the first transistor and the current flowing through the second transistor differ by more than a threshold.

[0004] In an example, the transistors of the power circuit are power transistors.

[0005] In an example, the transistors of the power circuit are insulated-gate bipolar transistors.

[0006] In an example, the induction coil is a coil of a resonant converter, the resonant converter comprising a capacitor in parallel with the induction coil.

[0007] In an example, the induction cooker comprises a display device, wherein the controller is arranged such that the indication is a visual indication that is provided to the display device for display.

[0008] According to a second aspect disclosed herein, there is provided a method of operating an induction cooker, the induction cooker comprising a power circuit constructed and arranged to provide a varying electric current to an induction coil of the induction cooker, the power circuit comprising at least a first transistor and a second transistor which are each arranged in series with the induction coil and which are arranged in parallel to each other, the transistors being controllable so as to control the current that is provided to the induction coil by the power circuit, the method comprising:

sensing a current flowing through the first transistor;
 sensing a current flowing through the second transistor;
 comparing the current flowing through the first transistor and the current flowing through the second transistor; and
 outputting an indication in the case that the current flowing through the first transistor and the current flowing through the second transistor differ by more than a threshold.

Brief Description of the Drawings

[0009] To assist understanding of the present disclosure and to show how embodiments may be put into effect, reference is made by way of example to the accompanying drawings in which:

Figure 1 shows schematically a circuit diagram of an example of an induction cooker according to an aspect disclosed herein;

Figure 2 shows schematically a plan view of an induction coil; and

Figures 3A and 3B show examples of differences in currents flowing through switching transistors.

Detailed Description

[0010] Referring to Figure 1, there is shown a circuit diagram of an example of an induction cooker 10 according to an aspect disclosed herein. The induction cooker 10 has an induction coil 12. As will be discussed further below, a varying electric current is provided to the induction coil 12, which therefore produces a corresponding varying electromagnetic field. When a ferromagnetic object is placed close to the induction coil 12 and therefore in the varying electromagnetic field, a corresponding varying eddy current is induced in the ferromagnetic object, which therefore heats the ferromagnetic object. The ferromagnetic object may be a cooking vessel such as a

cooking pot or saucepan or frying pan, etc., etc.

[0011] In the example shown, the induction coil 12 is in parallel with a capacitor 14. The induction coil 12 and the capacitor 14 form a resonant converter (which term as used herein includes so-called "quasi-resonant" converters unless the context requires otherwise) which resonates at a specific frequency.

[0012] Many induction cookers are intended to be run from an AC (alternating current) mains electric power supply. However, the current is not used directly from the mains power supply as the mains power supply is typically at a frequency of between 50 to 60 Hz or so, which can cause an unpleasant audible hum if used directly to power the induction coil 12. Accordingly, in this example, the incoming AC mains power 16 is passed through a filter 18 and then to a rectifier 20, which may for example be a diode bridge rectifier, which rectifies the AC to DC (direct current). In the example shown, the direct current is then provided via a series choke coil 22 to the induction coil 12.

[0013] As mentioned, a varying current must be provided to the induction coil 12 in order to produce the required varying electromagnetic field. This is often achieved by regulating or varying the current at a constant voltage. This is often achieved in practice by using a converter having a transistor which is controlled to switch on and off as necessary to produce a varying electric current. Because the power levels are high, the switching transistor that is used is typically a "power" transistor which is capable of withstanding the high voltages and/or high currents that are used. By way of example only, the total power of the induction cooker 10 may be say 3500W and the currents flowing through the switching transistor(s) may be say 15A.

[0014] Power transistors are relatively expensive components, and a power transistor that can withstand very high currents is very expensive. Accordingly, two or more transistors, such as power transistors, may be used in parallel in the converter effectively to "share" the current that is being supplied, which helps to keep down the costs as transistors having a lower specification may be used instead of a single, high specification transistor.

[0015] The use of two switching transistors in the converter portion in the present example is indicated in Figure 1, it being understood that other examples may use more than two switching transistors. In particular, there is shown two switching transistors 24, 26. Each switching transistor 24, 26 is connected in series with the induction coil 10 on the return line to the rectifier 20. The switching transistors 24, 26 are in parallel with each other. The switching transistors 24, 26 are controlled by a main controller (not shown in Figure 1) to switch on and off at the necessary times in order to provide the desired power to the induction coil 12.

[0016] The switching transistors 24, 26 may be for example so-called power transistors. Suitable examples include MOSFETs (metal-oxide-semiconductor field-effect transistors) and IGBTs (insulated-gate bipolar transis-

tors). As is known, MOSFETs are typically described in terms of the gate, source and drain of the MOSFET and IGBTs are typically described in terms of the base, collector and emitter of the IGBT. For present purposes, these terms are in essence equivalent to each other. Thus, in the present specification, which is given in terms of using IGBTs as specific examples of the switching transistors 24, 26, the language of "base, collector and emitter" will be used, it being understood that this will be interpreted as "gate, source and drain" in the case of MOSFETs being used as the switching transistors 24, 26.

[0017] Given the symmetry in their layout and connections, it would be expected that the current flowing through the two switching transistors 24, 26 would be the same. However it has been found that in practice the current flowing through the two switching transistors 24, 26 may be different, for example because of variations in manufacturing tolerances of various components or errors during manufacture. This is undesirable as it is likely to mean that one of the switching transistors 24, 26 may be subjected to a greater load than the other and is therefore more likely to fail over time, leading to a shortened lifetime before repair or replacement is necessary.

[0018] Accordingly, in accordance with examples of aspects described herein, the induction cooker 10 is arranged so that the currents flowing through the two switching transistors 24, 26 are compared. In the case that the currents flowing through the switching transistors 24, 26 differ by more than a threshold, then an indication may be output. The indication may be for the benefit of the user (owner) of the induction cooker 10 as it may effectively indicate that some repair or replacement will be required. The indication may be for the benefit of the manufacturer of the induction cooker 10 as it may be used during final testing of the induction cooker 10 following manufacture to effectively indicate that some modification of the components or circuit of the induction cooker 10 is required.

[0019] In the example shown, a current detector 28, 30 is provided for each switching transistor 24, 26 to measure the current flowing through the switching transistors 24, 26. The current detectors 28, 30 are connected in series with the respective switching transistors 24, 26. The measured current from each current detector 28, 30 is passed to a comparator, which may be implemented as part of the main controller or by a separate comparator component. If it is determined that the currents flowing through the switching transistors 24, 26 differ by more than a threshold, then a corresponding indication is caused to be output by the controller. The indication may be output as for example a warning or alarm sound. Alternatively or additionally, the indication may be output as for example a visual display on a display device, such as a display device of the induction cooker 10. An appropriate value for the threshold can be set by the manufacturer. The threshold may be for example some percentage, such that an indication is output if the two currents differ by more than 5% or 10% or 15%, etc.

[0020] The currents flowing through the switching transistors 24, 26 may be measured continuously by the current detectors 28, 30. Alternatively, the currents may be measured at intervals, such as for example every 10ms, which would be particularly appropriate in the case that the mains power supply is a 50Hz AC. The currents may be measured during the zero-crossing points of the 10ms period, which is advantageous as there should be no or little noise at the noise zero-crossing points. The comparison between the two currents flowing through the switching transistors 24, 26 may be such that it is not initially carried for a time period following initial powering of the induction coil 12. This is to enable the powering of the induction coil 12 to settle down after first being powered. It can happen for example that noise levels in the detected currents are high during this initial period. The initial time period when no comparison is made may for example be around 1 second or so. The comparison between the two currents flowing through the switching transistors 24, 26 may be such that it is only carried out for a time period following initial powering of the induction coil 12. In the case that no comparison is made for an initial time period, this time period when a comparison is made may follow that initial time period. The time period when a comparison is made may be for example a few seconds, such as for example 5 seconds. In this time in this example where the currents are measured every 10ms, the controller receives approximately 3000 sensed current values, which provides a good measure and averaging of the current difference.

[0021] The current detectors 28, 30 may be or comprise one or more current shunt resistors. A shunt resistor is a low resistance, precision resistor which may be used to measure AC or DC electrical currents by the voltage drop those currents create across the resistance. The resistance may be for example in the region of a few milliohm.

[0022] The current detectors 28, 30 for detecting the currents in the switching transistors 24, 26 may be provided as part of the induction cooker 10 for other purposes. For example, in induction cookers, a feedback system may be used for controlling the switching on and off of the switching transistors 24, 26 to achieve the desired power output. Such a feedback system uses measured values of the currents flowing through the switching transistors 24, 26. Such a feedback system may also be used to detect when a cooking vessel has been removed from the induction cooker 10 as removal of the cooking vessel causes rapid and significant changes in the current flowing through the switching transistors 24, 26.

[0023] As a particular example of errors that may occur during manufacture of the induction cooker 10, the switching transistors 24, 26 may be in thermal contact with respective heat sinks for removing excess heat from the switching transistors 24, 26 during operation, and it can happen that the thermal contact between one or both of the switching transistors 24, 26 and the heat sinks is poor. This will manifest itself by different currents flowing

through the switching transistors 24, 26, which will therefore be brought to the attention of the manufacturer during testing.

[0024] As another example of errors that may occur during manufacture of the induction cooker 10, errors may arise in the induction coil 12, either during manufacture of the induction coil 12 itself or during assembly of the induction coil 12 into the induction cooker 10. An example of an induction coil 12 is shown schematically in Figure 2. The induction coil 12 of this example has inner, middle and outer portions. First and second electrical connectors 122, 124 are provided at the two ends of the coil 12 for connecting the coil 12 into the circuit of the induction cooker 10. It is important that the induction coil 12 is inserted in the correct direction or orientation into the induction cooker 10, and in particular that the two electrical connectors 122, 124 are connected the right way round to the resonant capacitor 14 and the switching transistors 24, 26. If for some reason the induction coil 12 has not been manufactured correctly, such as not having a uniform direction for the winding of the coil, or is installed incorrectly into the induction cooker 10, this will manifest itself by different currents flowing through the switching transistors 24, 26.

[0025] This difference in the currents through the switching transistors 24, 26 in the case that the induction coil 12 has been manufactured or installed correctly and incorrectly are illustrated in Figures 3A and 3B. Figure 3A shows the difference (measured as a percentage) between the measured currents passing through the switching transistors 24, 26 in the case that the induction coil 12 has been manufactured and installed correctly. As can be seen, the difference is less than around 1.7% of the value of the current flowing through one or other of the switching transistors 24, 26. In contrast, Figure 3B shows the difference (measured as a percentage) between the measured currents passing through the switching transistors 24, 26 in the case that the induction coil 12 has been manufactured and/or installed incorrectly. As can be seen, the current difference is large, typically above around 15% in this example. As such, the controller of the induction cooker 10 quickly turns off the current through the switching transistors 24, 26 (at just less than 58 ms from when the comparison is first made in the example shown). An indication is also provided, which in this case is likely to be for the attention of the manufacturer as this is ideally carried out during testing following manufacture.

[0026] It will be understood that the processor or processing system or circuitry referred to herein may in practice be provided by a single chip or integrated circuit or plural chips or integrated circuits, optionally provided as a chipset, an application-specific integrated circuit (ASIC), field-programmable gate array (FPGA), digital signal processor (DSP), graphics processing units (GPUs), etc. The chip or chips may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or processors and a digital

signal processor or processors, which are configurable so as to operate in accordance with the exemplary embodiments. In this regard, the exemplary embodiments may be implemented at least in part by computer software stored in (non-transitory) memory and executable by the processor, or by hardware, or by a combination of tangibly stored software and hardware (and tangibly stored firmware).

[0027] The examples described herein are to be understood as illustrative examples of embodiments of the invention. Further embodiments and examples are envisaged. Any feature described in relation to any one example or embodiment may be used alone or in combination with other features. In addition, any feature described in relation to any one example or embodiment may also be used in combination with one or more features of any other of the examples or embodiments, or any combination of any other of the examples or embodiments. Furthermore, equivalents and modifications not described herein may also be employed within the scope of the invention, which is defined in the claims.

Claims

1. An induction cooker, the induction cooker comprising:

an induction coil arranged to receive a varying electric current and to produce a corresponding varying electromagnetic field;
 a power circuit constructed and arranged to provide the varying electric current;
 the power circuit comprising at least a first transistor and a second transistor which are each arranged in series with the induction coil and which are arranged in parallel to each other, the transistors being controllable so as to control the current that is provided to the induction coil by the power circuit;
 a first current sensor for sensing the current flowing through the first transistor;
 a second current sensor for sensing the current flowing through the second transistor; and
 a controller for controlling the power circuit, the controller being arranged to compare a current flowing through the first transistor and a current flowing through the second transistor, and to cause an indication to be output in the case that the current flowing through the first transistor and the current flowing through the second transistor differ by more than a threshold.

2. An induction cooker according to claim 1, wherein the transistors of the power circuit are power transistors.

3. An induction cooker according to claim 1 or claim 2,

wherein the transistors of the power circuit are insulated-gate bipolar transistors.

4. An induction cooker according to any of claims 1 to 3, wherein the induction coil is a coil of a resonant converter, the resonant converter comprising a capacitor in parallel with the induction coil.

5. An induction cooker according to any of claims 1 to 4, comprising a display device, wherein the controller is arranged such that the indication is a visual indication that is provided to the display device for display.

6. A method of operating an induction cooker, the induction cooker comprising a power circuit constructed and arranged to provide a varying electric current to an induction coil of the induction cooker, the power circuit comprising at least a first transistor and a second transistor which are each arranged in series with the induction coil and which are arranged in parallel to each other, the transistors being controllable so as to control the current that is provided to the induction coil by the power circuit, the method comprising:

sensing a current flowing through the first transistor;
 sensing a current flowing through the second transistor;
 comparing the current flowing through the first transistor and the current flowing through the second transistor; and
 outputting an indication in the case that the current flowing through the first transistor and the current flowing through the second transistor differ by more than a threshold.

7. A method according to claim 6, wherein the transistors of the power circuit are power transistors.

8. A method according to claim 6 or claim 7, wherein the transistors of the power circuit are insulated-gate bipolar transistors.

9. A method according to any of claims 6 to 8, comprising outputting the indication as a visual indication on a display device.

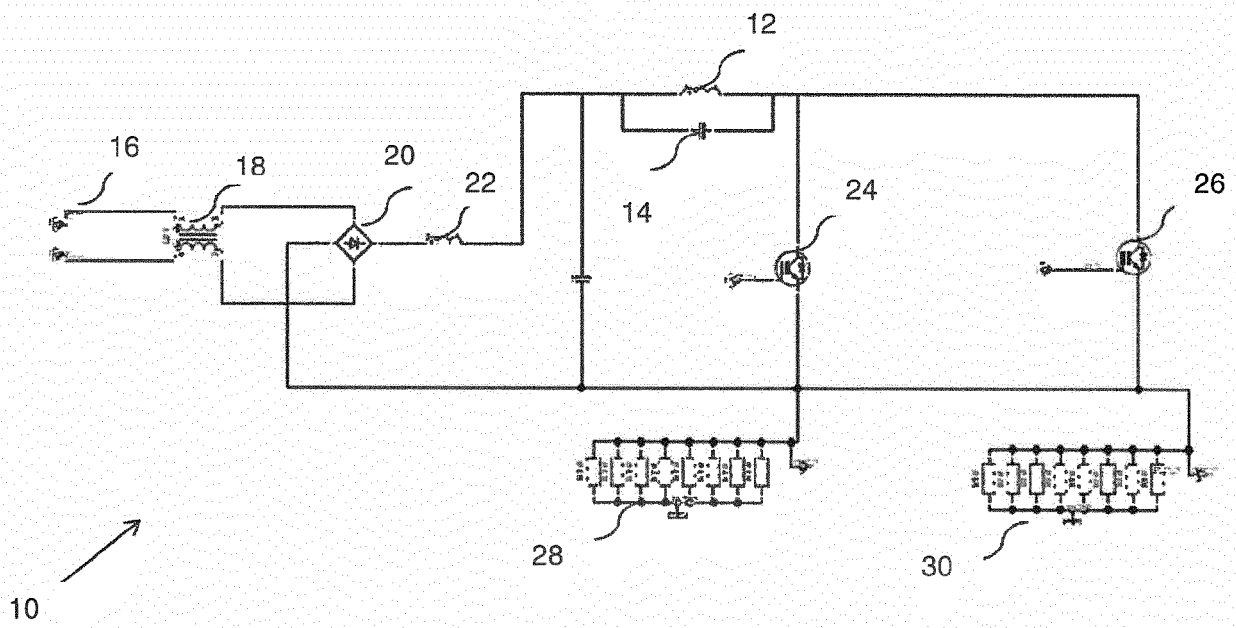


Fig. 1

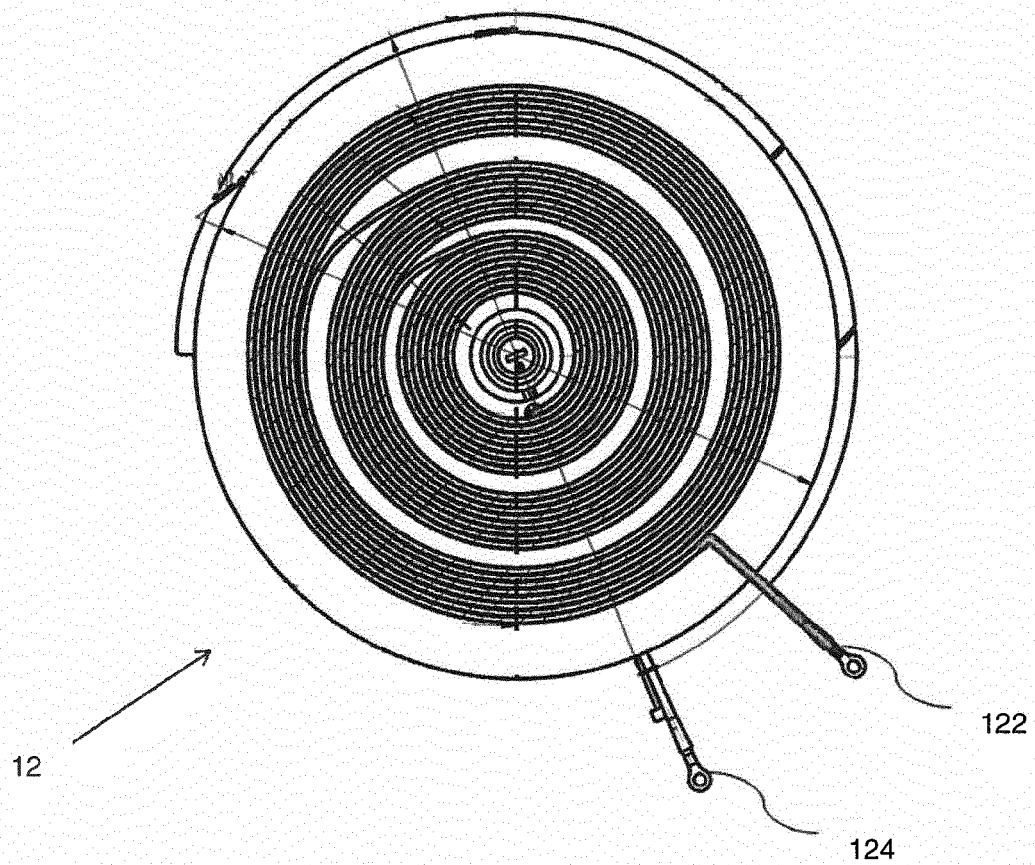


Fig. 2

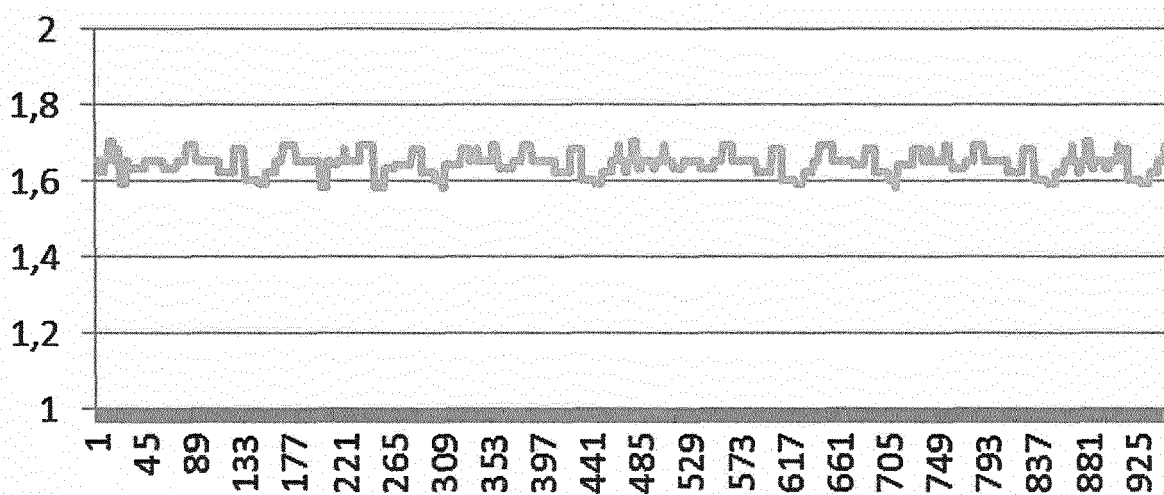


Fig. 3A

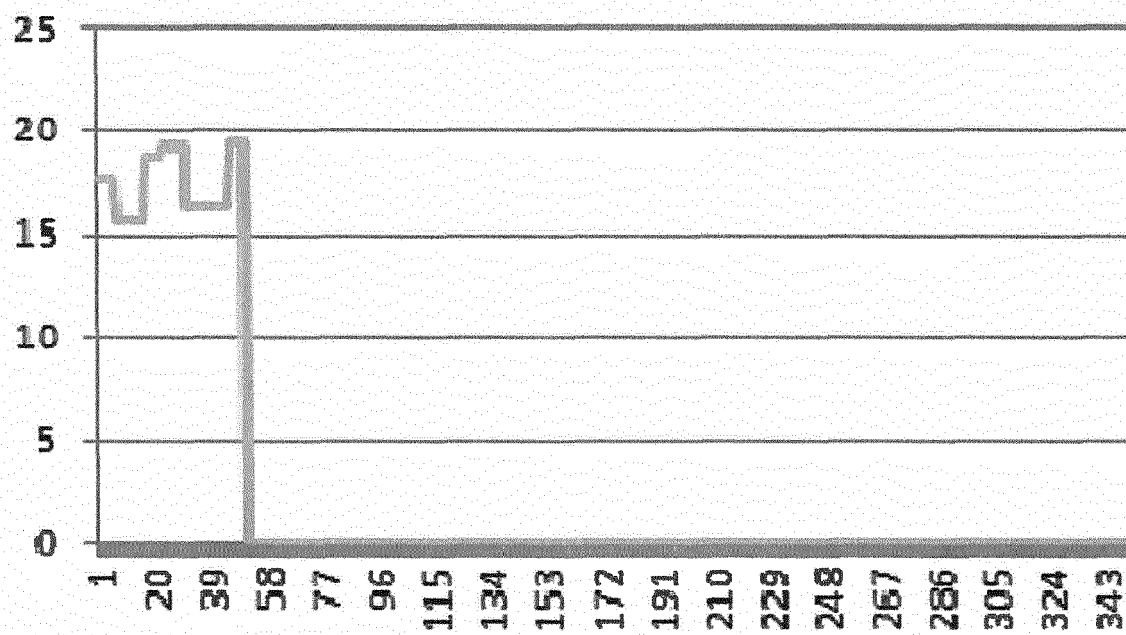


Fig. 3B



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Application Number
EP 17 17 7729

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Place of search Munich		Date of completion of the search 5 December 2017	Examiner Pierron, Christophe
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	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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