The present invention relates to an induction heating cooker (1) comprising a full-wave rectifier (7) rectifying the alternative signal, a filter inductance (2) and a filter capacitor (3) at the output of the full-wave rectifier (7), a parallel resonant circuit (8) having a resonant inductor (5) and a resonant capacitor (6) disposed in parallel, a power switching device (4) in parallel with a reverse-biased freewheeling diode (8), said device operating such that the resonant inductor (5) and the resonant capacitor (6) involve in energy exchange, the power switching device (4) being connected to a collector node (10) whereon a resonant voltage (V_red) is generated, the induction heating cooker (1) further comprising a control unit regulating the operation of the power switching device (4) and a drive circuit that drives the same.
Description

QUASI-RESONANT INDUCTION HEATER HAVING COOKWARE POSITION SENSING CIRCUIT

[0001] The present invention relates to an improved quasi-resonant induction heater having a cookware presence and position detection circuit.

[0002] It is well-known that the induction heating cooker operates based on the process of heating a ferromagnetic material by electromagnetic induction where eddy currents are to be induced and resistance provides heat dissipation within said ferromagnetic material, i.e. a cooking vessel in the form of a pot or pan.

[0003] By induction heating, high-frequency alternating current is passed through a coil upon which a magnetic field of the same frequency is induced. The internal resistance of the pan causes heat dissipation due to Joule effect and energy transfer is interrupted once the pan is removed from the cooktop. The energy efficiency of induction heating cookers is considerably high since there is no transfer of heat energy between the hob and the cookware and heat energy lost in the air is minimal.

[0004] A resonant converter in an induction heater circuit topology typically consists of a capacitor, an inductor and resistance. To this end, when power is supplied to the resonant tank, electric energy is stored in the inductor and transferred to the capacitor. Resonance therefore occurs while the inductor and the capacitor involve in energy exchange. The resonant converter can be a half-bridge series resonant converter or a quasi-resonant converter.

[0005] A quasi-resonant converter exhibits certain advantages over a half-bridge series resonant converter especially due to its simpler circuit design having only one power switching device compared to the half-bridge series resonant converter whose overall operation is more complex. The circuit design parameters in a quasi-resonant converter are regarded as a serious cost advantage in this regard. In order to drive the resonant inductor generating magnetic field and in turn inducing eddy currents on the skin depth of a cooking vessel, a high-frequency power switch such as an IGBT is accordingly used.
The disadvantage of a quasi-resonant converter is that it operates in a much narrower power frequency range and the maximum frequency value is limited. A further drawback can be viewed as relevance of the additional parameters such as the ambient temperature, physical and ferromagnetic characteristics of the cooking container or mains voltage fluctuations. These are of critical importance to reach a proper assessment of the presence of the cooking vessel or the correct position thereof. Reliability of the position assessment data is also important in case a multitude of resonant coils are used so that only certain coils can be energized.

An inherent problem associated with cookware position sensing arrangements is that electronic circuits in this regard are costly and complex to implement. An electronic circuit designed to monitor the resonant current or the IGBT voltage can be considered in this respect. The solution of the present invention, on the other hand, provides a substantially simpler solution to the above-mentioned problem by which cookware position sensing can be done practically and accurately.

Among others, a prior art publication in the technical field of the invention may be referred to as EP 1 629 698 B1, which discloses an induction cooking system including a power inverter, a microprocessor, a protection circuit and a pan detection circuit.

The present invention, on the other hand, provides a simpler and cheaper circuit solution by which presence and correct position of a cookware on the cooktop can be accurately detected.

The present invention provides a quasi-resonant converter circuit for an induction heating cooker having cookware presence and correct position detecting capabilities as provided by the characterizing features defined in Claim 1.

Primary object of the present invention is to provide an improved quasi-resonant induction heater having a cookware presence and position detection circuit.

The present invention proposes an induction heating cooker capable of sensing presence and correct placement of a ferromagnetic cooking container in an induction heating cooker. It has a bridge rectifier, a DC-line
inductance and a DC-line capacitor. A resonant inductor and a resonant capacitor are disposed in parallel so as to be powered by a high-frequency switching device such as an IGBT. The latter is in parallel with a diode as an anti-parallel diode.

[0013] The induction heating cooker comprises senses presence and appropriate placement of a cooking vessel by monitoring the zero-cross of the freewheeling diode current. A charging diode in parallel with said freewheeling diode in this respect is forward-biased when the freewheeling diode starts conduction. The charging diode charges a charge reference capacitor and the voltage between the terminals of the latter is monitored by means of a charge detection circuit. This latter circuit generates a voltage output, the duration of the square-wave voltage of which in a cycle is indicative of the electrical load associated with the induction coil.

[0014] Accompanying drawings are given solely for the purpose of exemplifying a circuit whose advantages over prior art were outlined above and will be explained in brief hereinafter.

[0015] The drawings are not meant to delimit the scope of protection as identified in the claims nor should they be referred to alone in an effort to interpret the scope identified in the claims without recourse to the technical disclosure in the description of the present invention.

[0016] Fig. 1 demonstrates a simplified circuit block diagram representation of a power control circuit of an induction heating cooker according to the present invention.

[0017] Fig. 2 demonstrates a circuit diagram of the power control circuit of an induction heating cooker according to the present invention.

[0018] Fig. 3 demonstrates the waveforms of the zero-cross of the anti-parallel diode current and the corresponding voltage signal of the charge detection circuit according to the present invention.

[0019] The following numerals are used in the detailed description:

1. induction heating cooker
2. Filter Inductance
3. Filter capacitor
4. Power switching device
The present invention proposes a power circuit by which heat energy is induced within a magnetically responsive cooking container.

The induction heating cooker (1) of the present invention is supplied with a source of AC voltage. A full-wave bridge rectifier (7) is connected between the AC source and power stage of a resonant inductor (5). The resonant inductor (5) is connected between the output of said full-wave rectifier (7) and a power switching device (4) including a gate (G), a collector (C) and an emitter (E). The resonant capacitor (6) is parallel to the resonant inductor (5) and an anti-parallel diode, i.e. a freewheeling diode (8) is connected parallel to said power switching device (4).

The induction heating cooker (1) conventionally comprises an AC signal filtering circuit. Power passing through a filter capacitor (3) serves to the purpose of filtering high frequency current. The voltage of said filter capacitor (3) is converted into a square wave by said high-frequency power switching device (4). According to Ampere’s Law, the square wave provides resonance creating a magnetic field around the resonant inductor (5), that is, the induction coil. The resonant capacitor (6) provided in parallel with said resonant inductor (5) therefore compensates the inductive nature of the latter.

The quasi-resonant converter’s power switching device (4) is an insulated gate bipolar transistor (IGBT). The operating principle of the quasi-resonant converter typically relies on the storage of energy in the
resonant inductor (5) when the power switching device (4) is turned on, and transfer of energy from said resonant inductor (5) to a cooking container when the power switching device (4) is turned off. More particularly, when the power switching device (4) is turned off, the resonant voltage \( V_{ce} \) increases on the collector node (10) as the resonant capacitor (6) is being discharged. When the resonant voltage \( V_{ce} \) is equal to the input voltage \( V_{dc} \) at the input node (9), the energy stored in the resonant inductor (5) begins to be transferred to the resonant capacitor (6). The resonant current gradually decreases to zero when the resonant voltage reaches its maximum, meaning that energy transfer from the resonant inductor (5) to the resonant capacitor (6) is terminated. Thereupon, the resonant capacitor (6) starts discharging the energy to the resonant inductor (5). The current completes its cycle by passing through the freewheeling diode (8) connected in parallel to the IGBT.

[0024] The cookware presence and correct position detection method of the present invention relies on the use of an electronic circuit that generates an output at the moment which said freewheeling diode (8) starts conduction. It is established that the presence and correct position of a cookware can be accurately detected by means of a charge detection circuit (12) detecting the zero-cross of the current of the freewheeling diode (8). Fig. 3 demonstrates the waveforms of the zero-cross of the anti-parallel freewheeling diode (8) current and the corresponding output voltage signal of the charge detection circuit (12) according to the present invention.

[0025] The resonance diode or the freewheeling diode (8) is forward-biased when the collector voltage of the IGBT, i.e. the resonant voltage \( V_{ce} \) becomes negative. Accordingly, when said anti-parallel freewheeling diode (8) is in conduction, a charging diode D1 (13) in parallel with the latter charges a charge reference capacitor C6 (14), by means of which said charge detection circuit (12) generates a voltage output indicative of the zero-cross of the current of the freewheeling diode (8). It is established that the duration of the positive voltage waveform in the voltage output of the charge detection circuit (12) in a cycle varies according to the electrical
load. In other words, it is observed that the electrical resistance of the load (the internal resistance of the induction coil) is calculated as $R = 0.2R$ (0.2 ohms) and the duration of the square wave signal in a cycle is more than 6 $\mu$s. In contrast, when there is a correctly positioned ferromagnetic cooking container on the hob, the resistance of the load is calculated as 2.5R-3.5R and the duration of the square wave signal in a cycle is around 3 $\mu$s. Therefore any deviation from this duration will be interpreted as an incorrect position of the cooking container on the induction coil.

[0026] The charge reference capacitor (14) of the charging circuit (11) is connected to the base of an NPN BJT (bipolar junction transistor) transistor Q1 in the charge detection circuit (12) through base-bias resistors R1, R2 and R3, said transistor Q1 having a load resistor R5. The charge detection circuit (12) comprises a PNP BJT transistor Q2, whose emitter is connected to the positive terminal $V_{cc}$. The collector of Q1 is connected to the base of Q2. Q2 generates an amplified output signal to be processed by an electronic control unit (not shown), which in turn operates an IGBT driving circuit.

[0027] It is to be noted that the current zero-cross and turn-on time of the freewheeling diode (8) and the duration of the square-wave voltage signal at the output of the charge detection circuit (12) therefrom is indicative of the electrical load condition. In a nutshell, the present invention proposes an induction heating cooker (1) comprising a full-wave rectifier (7) rectifying the alternative signal, a filter inductance (2) and a filter capacitor (3) at the output of the full-wave rectifier (7), a parallel resonant circuit having a resonant inductor (5) and a resonant capacitor (6) disposed in parallel and a power switching device (4) in parallel with a reverse-biased freewheeling diode (8). The power switching device (4) is connected to a collector node (10) whereon a resonant voltage ($V_{ce}$) is generated and operates such that the resonant inductor (5) and the resonant capacitor (6) involve in energy exchange. Said induction heating cooker (1) further comprises a control unit (not shown) regulating the operation of the power switching device (4) and a drive circuit (15) that drives the same.

[0028] The induction heating cooker (1) comprises a charging circuit (11) having
a charging diode (13) in parallel with the freewheeling diode (8) and which is forward-biased when the freewheeling diode (8) is in conduction, the charging diode (13) charging a charge reference capacitor (14). The cooker further comprises a charge detection circuit (12) detecting the voltage between the terminals of said charge reference capacitor (14) and generating a voltage output indicative of the electrical load associated with the resonant inductor (5).

[0029] The method of sensing presence and correct placement of a ferromagnetic cooking container in an induction heating cooker (1) according to the present invention comprises the steps of: a) monitoring the zero-cross of the freewheeling diode (8) current by means of a charging diode (13) in parallel with the freewheeling diode (8) and which is forward-biased when the freewheeling diode (8) is in conduction, the charging diode (13) charging a charge reference capacitor (14) and, b) monitoring the voltage between the terminals of the charge reference capacitor (14) by means of a charge detection circuit (12) generating a voltage output, the duration of the square-wave voltage of which in a cycle is indicative of the electrical load associated with the induction coil.

[0030] As the cookware presence and correct position sensing method of the present invention does not require monitoring of the resonant current, which necessitates a current transformer with a more sensitive electronic circuit, the simplistic yet efficient and accurate method of the invention advantageously provides protection against hazardous conditions, such as no load, over current and over voltage. Another principal advantage of the present method stems from the fact that fluctuations in the input parameters such as for instance mains voltage or ambient temperature have no direct impact on the accuracy of the sensing assessment.
Claims

1. An induction heating cooker (1) comprising a full-wave rectifier (7) rectifying the alternative signal, a filter inductance (2) and a filter capacitor (3) at the output of the full-wave rectifier (7), a parallel resonant circuit having a resonant inductor (5) and a resonant capacitor (6) disposed in parallel, a power switching device (4) in parallel with a reverse-biased freewheeling diode (8), said power switching device (4) being connected to a collector node (10) whereon a resonant voltage \(V_{ce}\) is generated and operating such that the resonant inductor (5) and the resonant capacitor (6) involve in energy exchange, said induction heating cooker (1) further comprising a control unit regulating the operation of the power switching device (4) and a drive circuit (15) that drives the same characterized in that

- a charging circuit (11) having a charging diode (13) in parallel with said freewheeling diode (8) and which is forward-biased when said freewheeling diode (8) is in conduction, said charging diode (13) charging a charge reference capacitor (14),

- a charge detection circuit (12) detecting the voltage between the terminals of said charge reference capacitor (14) and generating a voltage output the duration of the square-wave voltage of which in a cycle is indicative of the electrical load associated with said resonant inductor (5).

2. The induction heating cooker (1) as in Claim 1, characterized in that the power switching device (4) is an IGBT on a collector node (10) of which the resonant voltage \(V_{ce}\) is generated.

3. The induction heating cooker (1) as in Claim 1 or 2, characterized in that the charge reference capacitor's (14) positive terminal is connected to the base of an NPN bipolar junction transistor (Q1), the collector of which is connected to the base of a PNP bipolar junction transistor (Q2), whose emitter is connected to the positive terminal \(V_{cc}\).

4. A method of sensing presence and correct placement of a ferromagnetic cooking container in an induction heating cooker (1), said induction heating cooker (1) comprising a full-wave rectifier (7), a filter inductance (2) and a filter capacitor (3), a parallel resonant circuit having a resonant inductor (5) and a resonant capacitor (6) disposed in parallel, an IGBT in parallel with a
reverse-biased freewheeling diode (8), said IGBT being connected to a collector node (10) whereon a resonant voltage \( V_{ce} \) is generated and operating such that the resonant inductor (5) and the resonant capacitor (6) involve in energy exchange, the induction heating cooker (1) further comprising a control unit regulating the operation of said power switching device (4) and a drive circuit that drives the same, the method of sensing presence and correct placement of a ferromagnetic cooking container in an induction heating cooker (1) comprises the steps of:

- monitoring the zero-cross of the freewheeling diode (8) current by means of a charging diode (13) in parallel with the freewheeling diode (8) and which is forward-biased when the freewheeling diode (8) is in conduction, the charging diode (13) charging a charge reference capacitor (14) and,
- monitoring the voltage between the terminals of the charge reference capacitor (14) by means of a charge detection circuit (14) generating a voltage output, the duration of the square-wave voltage of which in a cycle is indicative of the electrical load associated with the induction coil.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05B6/06

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 database 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

<table>
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