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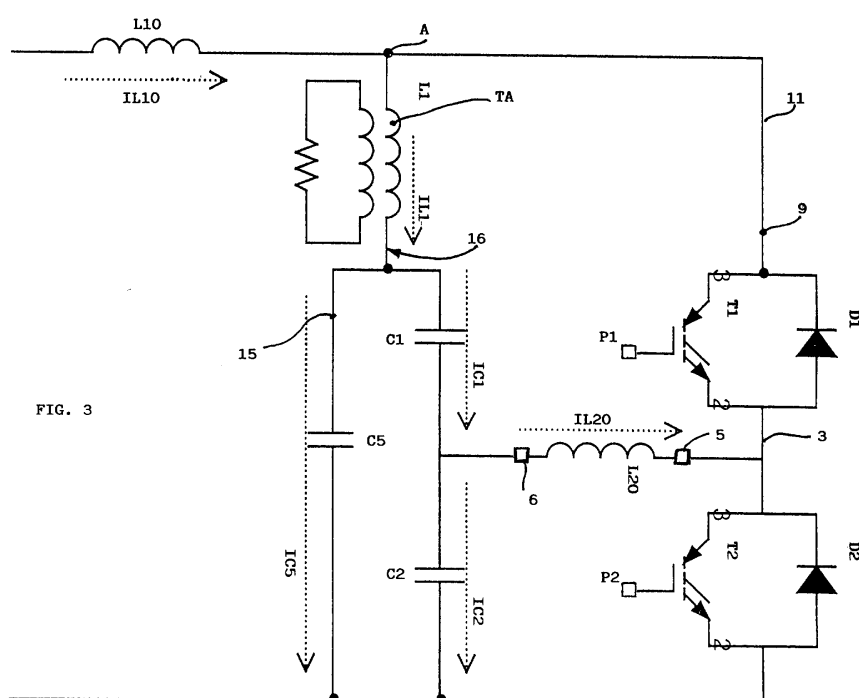
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(54) **Induction cooktop**

(57) Induction cooktop comprising an inverter circuit with a first bridge and a second bridge connected with each other through an appropriate connection, a resonant circuit with a coil having a terminal thereof connected to said connection and the other terminal thereof connected to the terminals of two distinct resonance capacitors, the respective other polarities of which are connected to respective terminals of said two bridges; a fil-

ter capacitor is provided between said respective terminals, wherein there are provided means adapted to solely measure the sum of the currents in said filter capacitor and one of said resonance capacitors.

A common connection is provided between a terminal of the resonance capacitor and a terminal of the filter capacitor, while an appropriate connection including a current transformer is provided between said common connection and one of said bridges.



Description

[0001] The present invention refers to an improved kind of induction cooktop that uses an inverter circuit (or, more simply, an inverter) which generates a variable magnetic field in order to heat up a metal object, usually the bottom of a pan or pot.

[0002] The above-mentioned inverter circuit is provided with an induction coil and a resonance capacitor, which is adapted to resonate with said induction coil.

[0003] In "consumer" applications, i.e. when these induction cooktops are intended for use in applications that generally and specifically involve the so-called electric home appliances, said cooktops simply cannot escape from the general requirements that peculiarly apply to this special market, in which the products intended therefore shall among other things have absolutely competitive costs and prices combined with a reliability that must not only be substantial and sizeable, but also capable of being guaranteed throughout the first years of the product life.

[0004] In the light of these considerations, one of the basic requirements that most of all seems to demand appropriate compliance in connection with these kinds of cooktops relates to the capability for both the current flowing through the heating or resonance coil and the total current entering the circuit to be measured to an adequate extent of accuracy to properly meet both operating, i.e. practical and safety needs.

[0005] Various solutions have been found and proposed in the art in view of complying with this requirement; a typical one among such solutions is illustrated in the accompanying Figure 1A, in which the currents in said respective circuits are measured conventionally by means of respective current transformers (CT1, CT2).

[0006] While such a solution turns out to be fully satisfactory from a point of view of general performance capabilities, it is certainly less so from an economic point of view, since the presence of two current transformers, which are inherently rather expensive devices, practically thwarts the general effort aimed at reducing costs.

[0007] In view of overcoming such a drawback, the circuit solution illustrated symbolically in the accompanying Figure 1B is therefore been adopted. This solution provides for a single current transformer to be connected in series with the filter capacitor C_f , and further provides for the resonance coil to be connected in series with a single resonance capacitor C_{r1} .

[0008] Although it seemingly appears to be capable of ensuring an adequate compliance with the above-cited requirements, when a closer look is taken at it this particular solution turns however out as being still too costly, since it has been found experimentally that, for the same general conditions and parameters and, in particular, for the same the power output, said filter capacitor must be rated at a capacitance that is substantially twice as much as the capacitance rating of the filter capacitor used in the previously cited circuit with two

resonance capacitors.

[0009] It would therefore be desirable, and is actually a main purpose of the present invention, to provide an induction cooktop which is capable of operating and being controlled with a single current transformer and, at the same time, does not involve any unsustainable increase in costs and/or in the electric and thermal load imposed to the other component parts.

[0010] According to the present invention, the above-indicated aim is reached in a particular kind of induction cooktop that incorporates the characteristics as recited in the appended claims and is described below by way of non-limiting example with reference to the accompanying drawings, in which:

- Figure 2 is a schematic view of a circuit arrangement of an embodiment of the induction cooktop according to the present invention;
- Figure 3 is a schematic view of the same circuit arrangement shown in Figure 2, in which the arrangement of the current transformer according to the present invention is however shown more explicitly;
- Figures 4, 5, 6 and 7 are diagrammatical views showing the flow pattern of the currents in the circuit arrangement of Figure 2 in four successive operating phases of the induction cooktop, respectively;
- Figure 8 is a diagrammatical view of the pattern followed by some currents of the circuit of the invention during a specific operating phase; and
- Figure 9 is a diagrammatical view of the pattern followed by some other currents of the circuit of the invention during another specific operating phase.

[0011] The invention is substantially based on the experimentally verified consideration that, in some portions of the power-supply circuit, the high-frequency alternating current of the heating coil is not constant, but is rather subject to significant variations during the different phases of which each single complete cycle of operation is formed. Therefore, an attempt has been made to improve the circuit according to the prior-art by modifying and/or expanding it, and to identify, within the various phases making up the complete cycle, current values that are individually capable of being correlated with both the power-supply current and the resonance current.

[0012] In substance, the attempt has been made to sample the current in a particular portion of the circuit at specific instants, and to process the results of such a sampling so as to calculate, or directly measure, the currents being investigated.

[0013] These attempts have led to an absolutely positive outcome and the peculiarities, i.e. ways and means of the resulting solution are described below.

[0014] With reference to Figure 2, an induction cook-top according to the present invention comprises:

- a half-bridge inverter circuit with a first and a second electronic switch or diamond circuit (E.S.C.) D1 - T1 and D2 - T2, for instance of the IGBT (Insulated Gate Bipolar Transistor) type, connected in series via a connection 3 between two common terminals G1, G2, and controlled by means of respective driving signals that are sent to respective circuits P1, P2;
- a heating coil L20 for a high-frequency electric current adapted to inductively heat up an appropriate object to flow therethrough, this coil being connected with a first terminal 5 thereof to said connection 3;
- the second terminal 6 of this coil being connected to the terminal of a first resonance capacitor C2;
- a filter capacitor C5 connected with a first terminal G4 to an extreme 7 (not connected to said connection 3) of said electronic switch circuits and with the respective second terminal 15 to a first terminal 10 of a filter inductor L10, the opposite terminal of which is connected to the power supply;
- a connection 11 that connects the second extreme 9 (not connected to said connection 3) of said electronic switch circuits to said first extreme 10 of said filter inductor L10.

[0015] According to the present invention, a second resonance capacitor C1 is provided between said second terminal 6 of said heating coil L20 and said second terminal 15 of said filter capacitor C5; in addition, the current-conducting link 16 between said second terminal 15 and said connection 11 (which connects the second extreme 9 of said electronic switch circuits at a branch point A, to which there is connected also the connection with said first terminal 10 of said filter inductor L10) is provided with a current transformer TA, whose primary winding is represented by the coil L1 illustrated in Figure 3.

[0016] Owing to the effect of such a capacitor C1, the individual complete cycle may be broken down into four distinct phases 1, 2, 3 and 4, in which the current pattern is as symbolically represented in Figures 4, 5, 6 and 7, respectively.

[0017] Let us now consider the phase 1 of said complete cycle: throughout the extensive experimental work that has been carried out in this connection, it has been found, on the basis of the measurements performed, that the pattern of the driving currents, the resonance current I (L20), the current of the filter coil I (L10), and the current in the current transformer I (L1) is as represented in the diagram appearing in Figure 8; from this

diagram it may be noticed that, as far as the sole phase 1 is concerned, the following experimental relation applies:

$$I(L20) = I(L1) - I(L10)$$

wherein the indicated currents shall be intended as being instantaneous currents.

[0018] The fact shall however be taken into due consideration that the current I(L10) is sensibly constant and, furthermore, of known magnitude owing to its being measured during the afore defined phase 3 of the cycle; as a result, by measuring the current I(L1) during this phase 1 it is possible for the desired resonance current I(L20) to be found out by calculation according to the above-indicated relation.

[0019] The possibility is in this way fully demonstrated for said resonance current to be calculated provided that the measurement, i.e. the sampling is carried out at a point lying precisely and surely within this defined phase 1. Anyway, such a requirement is readily and quite easily complied with through an accurate synchronization of such a current measurement with the driving signals of the electronic switch circuits on the driving circuits P1 and P2.

[0020] The phase 3 of the cycle shall be considered next. Following a logic and methodological procedure fully similar to the afore explained one, during the various experiments that have been conducted it has been found by measurement that the pattern of the driving currents, the input current I (L10), the current on the capacitor C5, and the current on the capacitor C1 is as represented in the diagram appearing in Figure 9; from this diagram it may be noticed that, as far as the sole phase 3 is concerned, the following experimental relation applies:

$$I(L10) = I(C5) + I(C1)$$

wherein the indicated currents shall again be intended as being instantaneous currents.

[0021] However, owing to the fact that the currents in C5 and C1 practically deplete the current flowing through the primary coil of the transformer TA, it ensues that there is no current in the branch of the electronic switch circuits. Therefore, the current that is to be measured in the secondary coil of the transformer TA provides an accurate measure of the input current I(L10).

[0022] Again, the possibility is in this way fully demonstrated for said input current to be directly measured provided that the measurement, i.e. the sampling is carried out at a point lying precisely and surely within this defined phase 3, wherein such a requirement is readily and quite easily complied with through an accurate synchronization of such a current measurement with the driving signals of the electronic switch circuits on the

driving circuits P1 and P2.

[0023] The electronic techniques to be used and the procedures to be followed in order to carry out such current samplings in a synchronized manner as indicated above are fully within the abilities of those skilled in the art, so that they shall not be explained here any closer.

Claims

1. Induction cooktop, in particular for home use, comprising:

- a half-bridge inverter circuit with a first and a second electronic switch or diamond circuit (D1 - T1, D2 - T2) connected in series via a connection (3) between two common terminals (G1, G2) of said electronic switch circuits;
- a resonant heating coil (L20) for a high-frequency electric current adapted to inductively heat up an appropriate object to flow there-through, this coil being connected with a first terminal (5) thereof to said connection (3), and with the second terminal (6) thereof to the terminal of a first resonance capacitor (C2);
- a filter capacitor (C5) connected with a first terminal (G4) thereof to an extreme (7), not connected to said connection (3), of said electronic switch circuits, and with the second terminal (15) thereof to a first terminal (10) of a filter inductor (L10), the opposite terminal of which is connected to the power supply;
- a connection (11) that connects the second extreme (9), not connected to said connection (3), of said electronic switch circuits to said first terminal (10) of said filter inductor (L10),

characterized in that a second resonance capacitor (C1) is provided

- between said second terminal (6) of said heating coil (L20)
- and said second terminal (15) of said filter capacitor (C5);
- and in that**
- the current-conducting link (16) between said second terminal (15) and said connection (11) connects the second extreme (9) of said electronic switch circuits at a branch point (A), to which there is connected also the connection with said first terminal (10) of said filter inductor (L10).

2. Induction cooktop according to claim 1, **characterized in that** there is provided a current transformer (TA) connected in series to said current-conducting link (16).

3. Induction cooktop according to claim 1 or 2, **characterized in that** the input current (IL10) and the resonance current (IL20) of said induction cooktop are calculated and/or measured on the basis of distinct readings of the current measured by said current transformer (TA).

4. Induction cooktop according to claim 3, **characterized in that** said current readings on said current transformer (TA) are selectively synchronized with two respective driving signals on respective driving circuits (P1, P2) of said electronic switch circuits (D1-T1, D2-T2).

5. Induction cooktop according to claim 4, **characterized in that** said two driving signals correspond to the conditions of:

T1 = OFF, T2 = ON (Phase 3) and
T1 = ON, T2 = OFF (Phase 1), respectively.

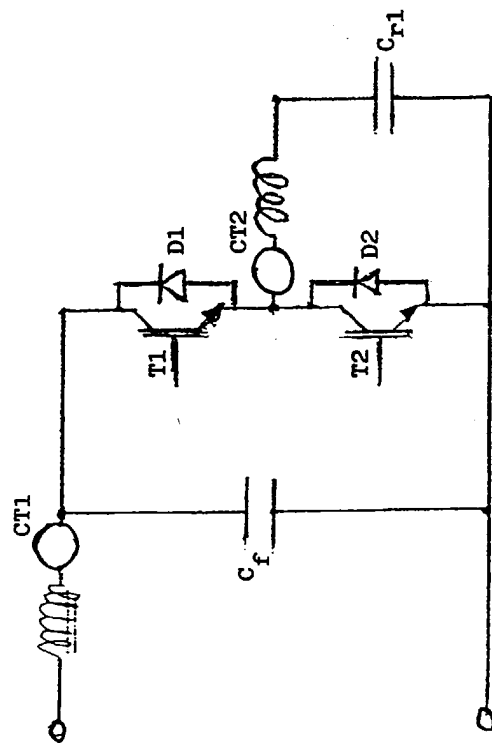


FIG. 1A

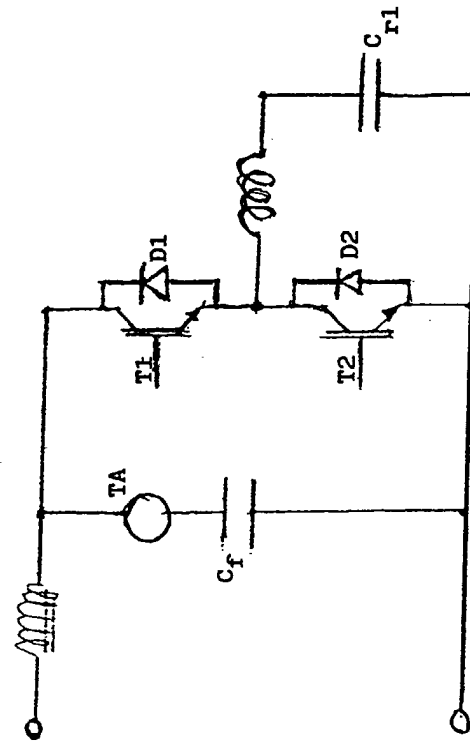


FIG. 1B

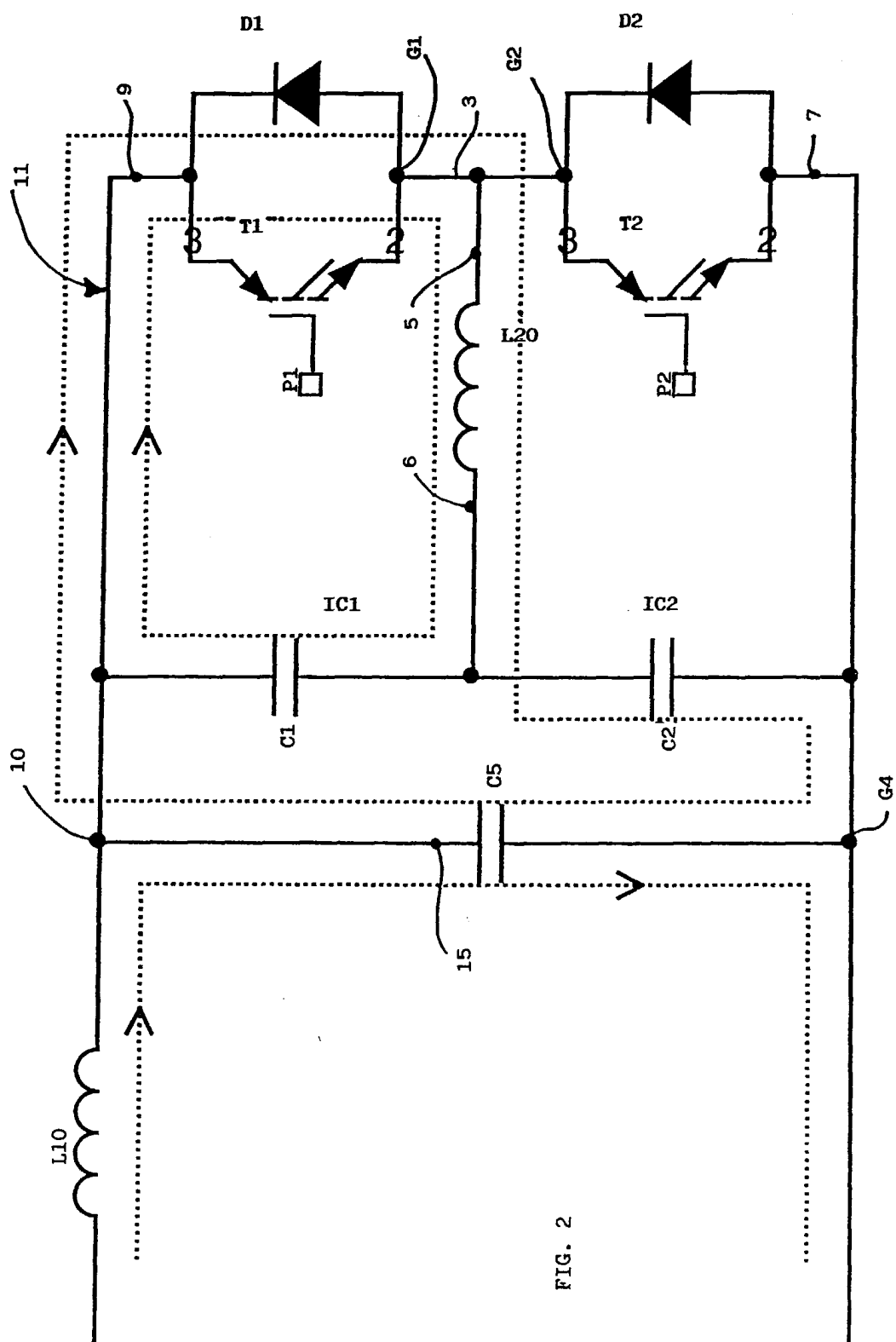


FIG. 2

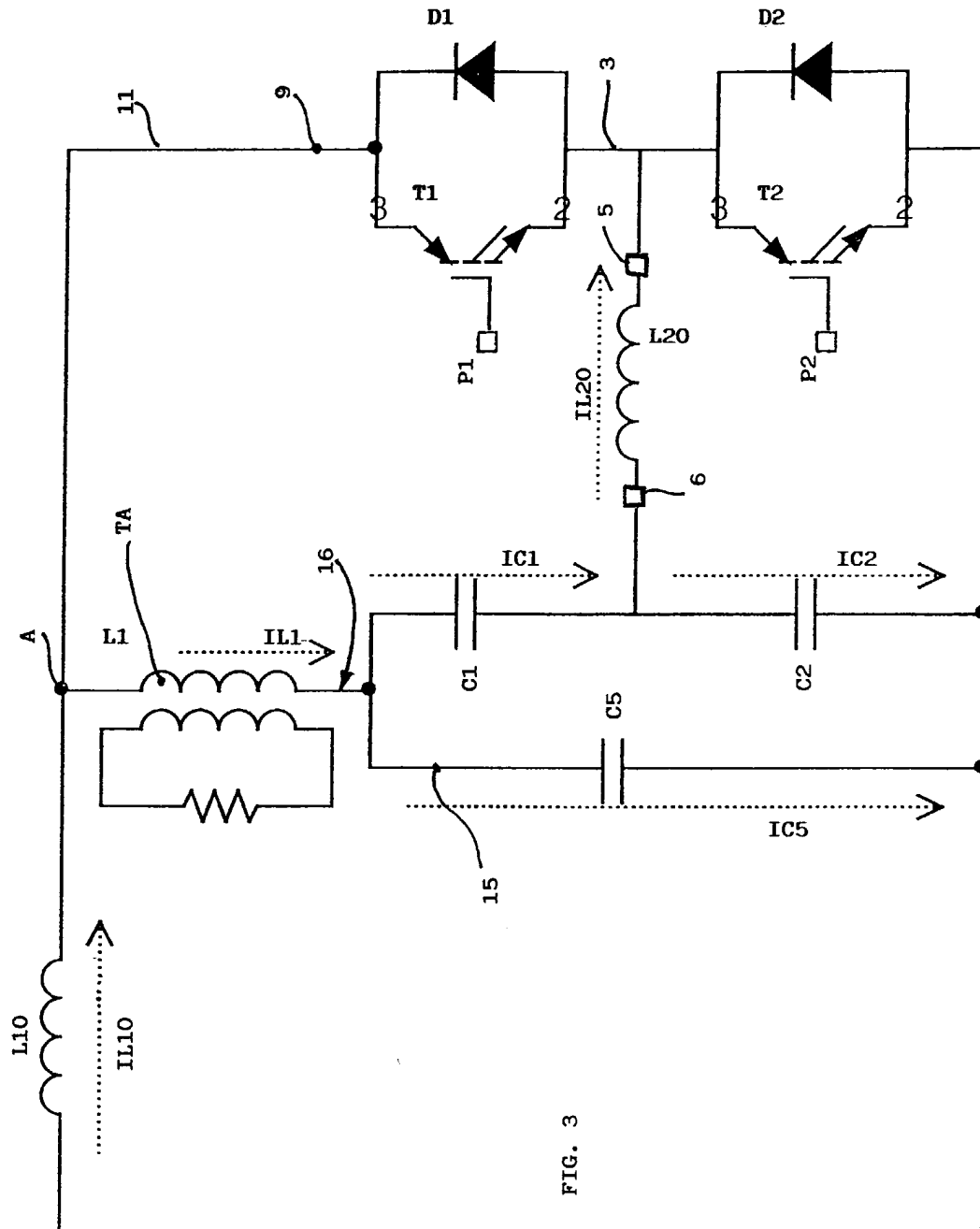


FIG. 3

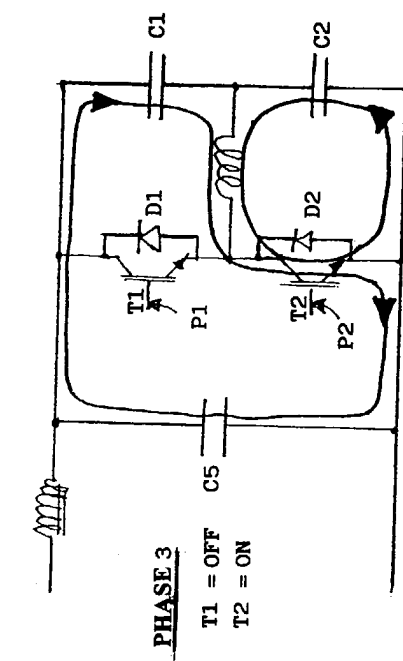


FIG. 6

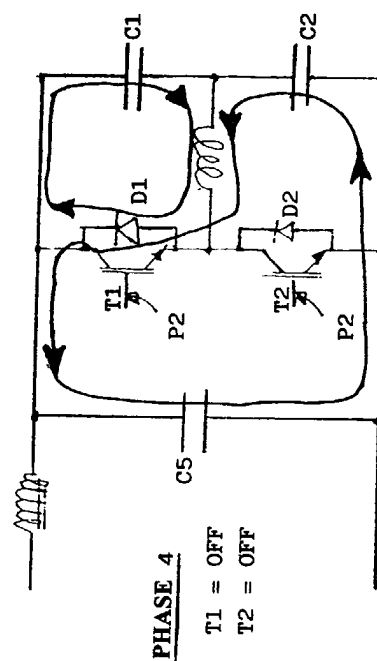


FIG. 7

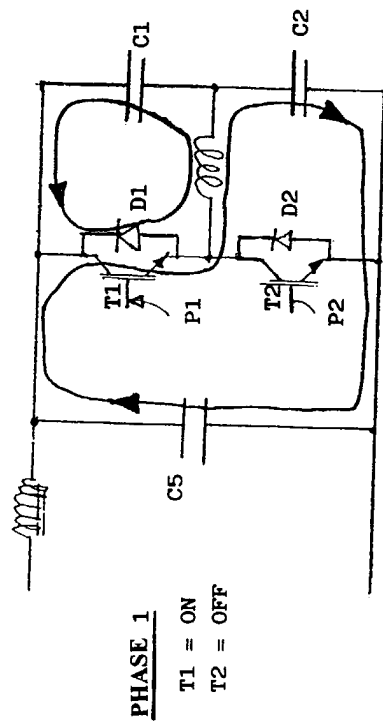


FIG. 4

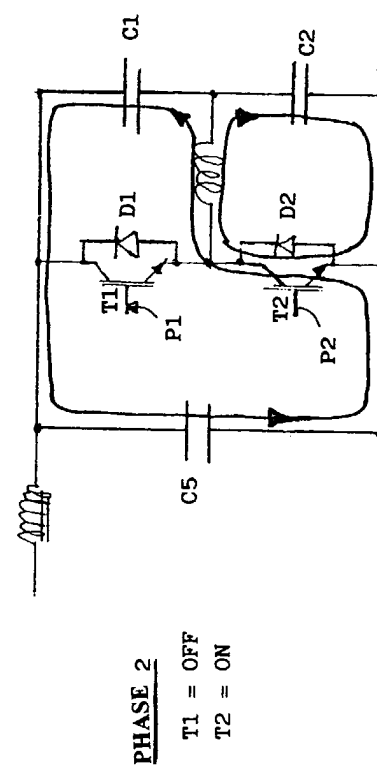
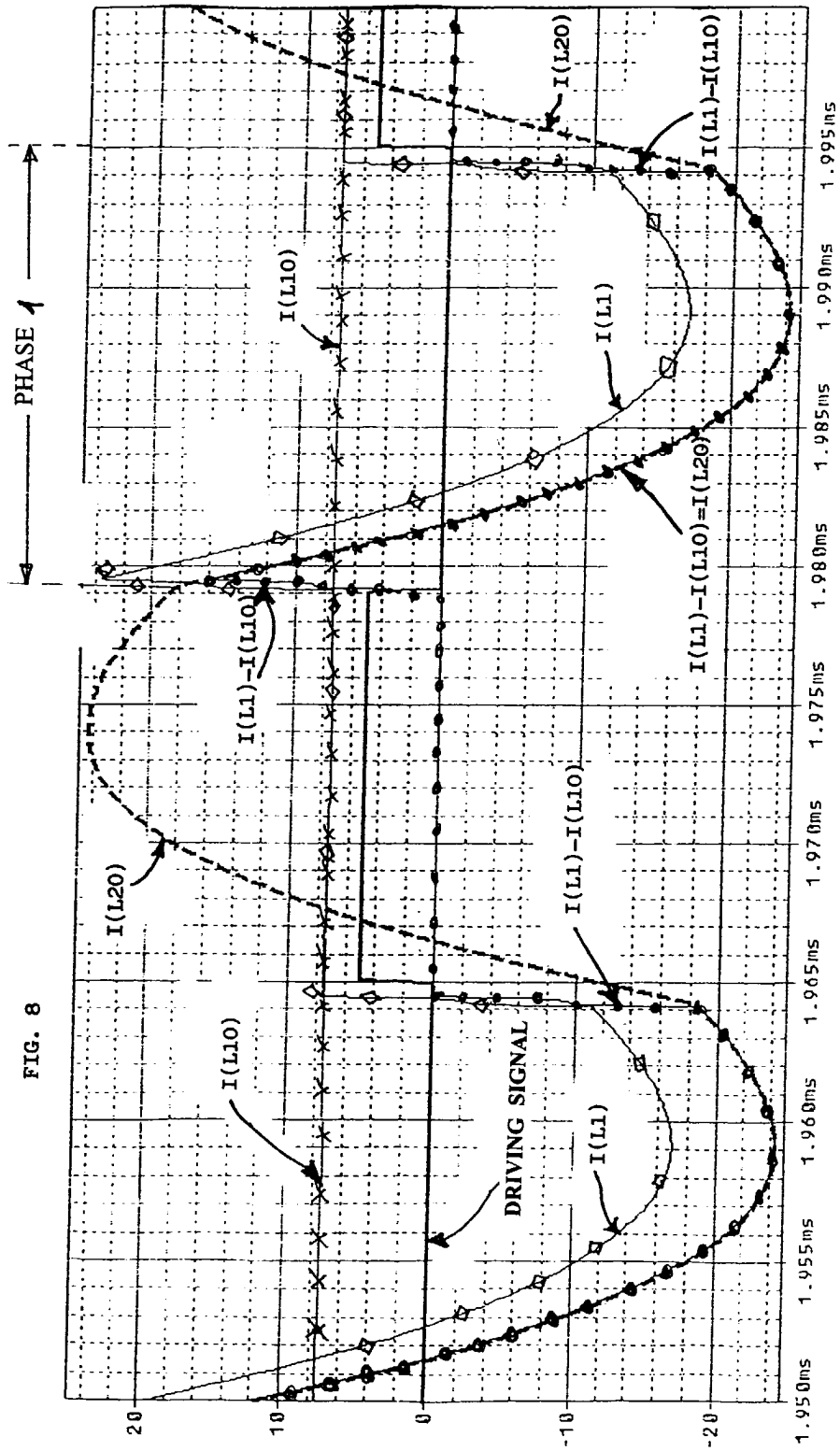
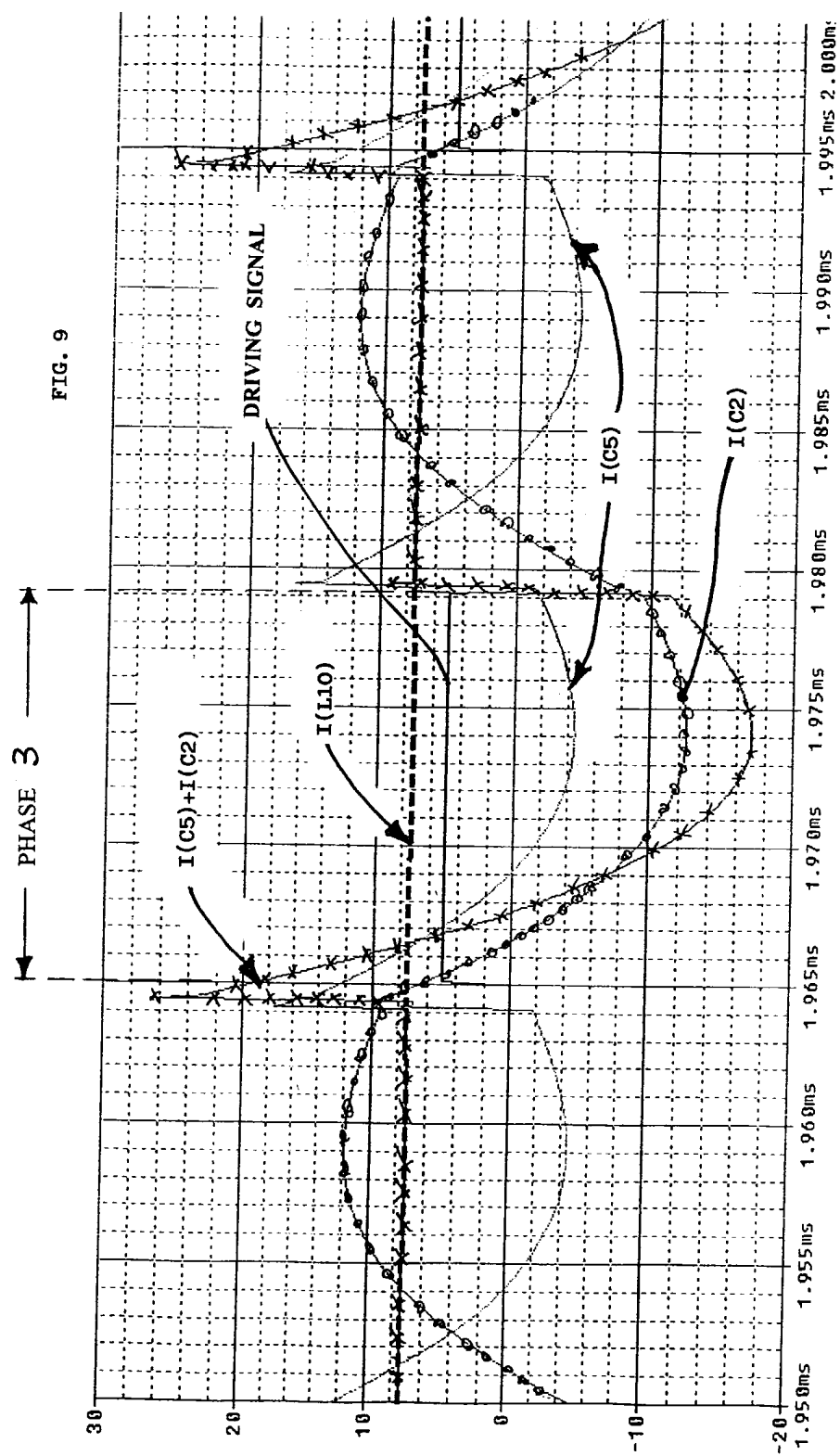


FIG. 5







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EUROPEAN SEARCH REPORT

Application Number
EP 03 01 0965

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	KOERTZEN H W ET AL: "Design of the half-bridge, series resonant converter for induction cooking" POWER ELECTRONICS SPECIALISTS CONFERENCE, 1995. PESC '95 RECORD., 26TH ANNUAL IEEE ATLANTA, GA, USA 18-22 JUNE 1995, NEW YORK, NY, USA, IEEE, US, 18 June 1995 (1995-06-18), pages 729-735, XP010150634 ISBN: 0-7803-2730-6	1	H05B6/12 H05B6/02
A	* the whole document *	2	
X	KOERTZEN H W ET AL: "Single shot surface heating series resonant converter with ZCS and an uncontrolled DC link voltage" INDUSTRY APPLICATIONS CONFERENCE, 1995. THIRTIETH IAS ANNUAL MEETING, IAS '95., CONFERENCE RECORD OF THE 1995 IEEE ORLANDO, FL, USA 8-12 OCT. 1995, NEW YORK, NY, USA, IEEE, US, 8 October 1995 (1995-10-08), pages 1957-1963, XP010193309 ISBN: 0-7803-3008-0	1	
A	* the whole document *	2	
A	PALMER P R ET AL: "AN MCT BASED INDUSTRIAL INDUCTION COOKER CIRCUIT USING ZERO CURRENTSWITCHING" EPE '95: 6TH. EUROPEAN CONFERENCE ON POWER ELECTRONICS AND APPLICATIONS. SEVILLA, SEPT. 19 - 21, 1995, EUROPEAN CONFERENCE ON POWER ELECTRONICS AND APPLICATIONS, BRUSSELS, EPE ASSOCIATION, B, vol. 2 CONF. 6, 19 September 1995 (1995-09-19), pages 2677-2682, XP000537803 * abstract *	1	
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 20 October 2003	Examiner Garcia, J
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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EUROPEAN SEARCH REPORT

Application Number
EP 03 01 0965

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 0 817 531 A (BALAY SA) 7 January 1998 (1998-01-07) * abstract *	1	
A	US 6 288 378 B1 (PATRIDGE DONALD F ET AL) 11 September 2001 (2001-09-11) * abstract; figure 1 *	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
Place of search MUNICH		Date of completion of the search 20 October 2003	Examiner Garcia, J
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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ON EUROPEAN PATENT APPLICATION NO.**

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20-10-2003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0817531 A	07-01-1998	ES 2128941 A1	16-05-1999
		EP 0817531 A2	07-01-1998

US 6288378 B1	11-09-2001	US 6211498 B1	03-04-2001
		US 2002011913 A1	31-01-2002
		AU 3709500 A	21-09-2000
		WO 0052967 A1	08-09-2000
