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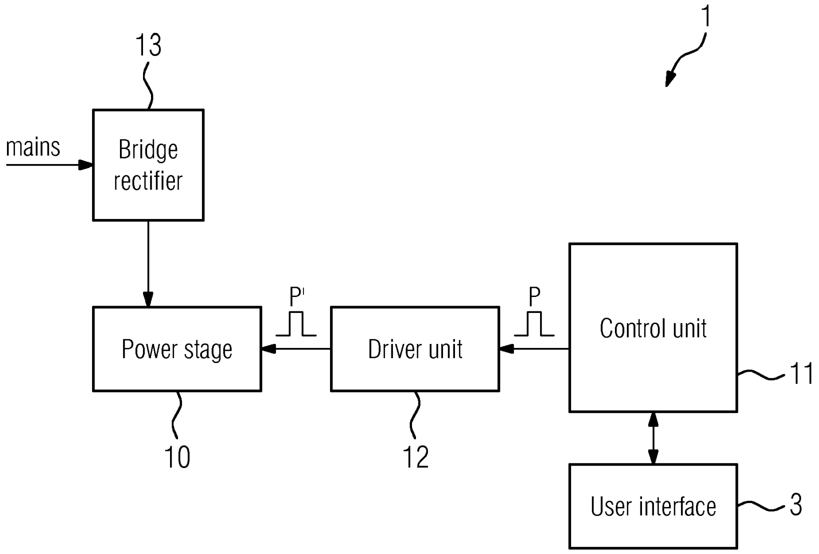
(54) INDUCTION HOB AND METHOD FOR OPERATING AN INDUCTION HOB

(57) The invention relates to an induction hob comprising a power stage (10) with at least one switching element (20) for enabling an alternating current flow through an induction element (21) and a control unit (11) providing enabling signal (P) comprising pulses with a variable pulse duration to the switching element (20) for enabling said current flow through said induction element (21), wherein the pulse duration (ΔP) is changed between a minimum value (ΔP_{min}) and a maximum value (ΔP_{max}) in order to adjust the power provided to the induction element (21). The control unit (11) is adapted to reduce the pulse duration (ΔP) of a set of enabling signal pulses (P) to a reduced pulse duration (ΔP_{red}) lower than minimum value (ΔP_{min}) when starting the heating process in order to reduce acoustic noise.

FIG 2



Description

[0001] The present invention relates generally to the field of induction hobs. More specifically, the present invention is related to an induction hob configured to reduce acoustic noise during start-up of power stage.

BACKGROUND OF THE INVENTION

[0002] Induction hobs for preparing food are well known in prior art. Induction hobs typically comprise at least one heating zone which is associated with at least one induction element. For heating a piece of cookware placed on the heating zone, the induction element is coupled with electronic driving means comprising a switching element for driving an AC current through the induction element. Said AC current generates a time varying magnetic field. Due to the inductive coupling between the induction element and the piece of cookware placed above the induction element, the magnetic field generated by the induction element causes eddy currents circulating in the piece of cookware. The presence of said eddy currents generates heat within the piece of cookware due to the electrical resistance of said piece of cookware.

[0003] Typically, the switching element receives a pulsed enabling signal in order to enable a current flow through the induction element according to the enabling signal. When starting the power stage, the current flowing through the induction element may be significantly higher than after a certain operating time of powering the power stage. Said increased switch-on current may lead to significant acoustic noise which might be disturbing for a user of the induction hob.

SUMMARY OF THE INVENTION

[0004] It is an objective of the embodiments of the invention to provide an induction hob generating reduced acoustic noise when starting the power stage. The objective is solved by the features of the independent claims. Preferred embodiments are given in the dependent claims. If not explicitly indicated otherwise, embodiments of the invention can be freely combined with each other.

[0005] According to an aspect of the invention, the invention relates to an induction hob comprising a power stage with at least one switching element for enabling an alternating current flow through an induction element and a control unit providing an enabling signal comprising pulses with a variable pulse duration to the switching element for enabling said alternating current flow through said induction element. The pulse duration of the pulses is changed between a minimum value and a maximum value in order to adjust the power provided to the induction element. Said minimum value and maximum value may be nominal minimum and maximum values defining a nominal range of pulse duration values. In addition, the control unit is adapted to reduce the pulse duration of a set of enabling signal pulses to a reduced pulse duration lower than said minimum value when starting the heating process in order to reduce acoustic noise. Surprisingly, the Applicant found out that the acoustic noise can be significantly reduced by upper-mentioned reduction of pulse duration without any significant lowering of the lifetime of the switching element, although the switching element is driven in hard switching region due to the reduced pulse duration, i.e. there are hard voltage/current transitions within the switching element in the switching moment. Thus, acoustic noise can be avoided or reduced without any additional circuit components for reducing said acoustic noise.

[0006] According to preferred embodiments, the switching element is an insulated-gate bipolar transistor. Said insulated-gate bipolar transistor may be arranged in a quasi-resonant architecture.

[0007] According to embodiments, the power stage comprises a quasi-resonant architecture comprising a single switching element. In other words, there is no further switching element needed which may reduce the acoustic noise by lowering the charge of a capacitor providing electric power to the induction element.

[0008] According to embodiments, the pulse duration is reduced during a first set of half-waves of mains provided by a bridge rectifier to the power stage immediately after start-up of the power stage. During said first set of half-waves of mains, the electric charges accumulated at a capacitor are significantly reduced. Therefore, also the current provided to the induction element is significantly decreased. Thus, after said first set of half-waves, the power stage may be driven within the nominal range of pulse duration, i.e. with a pulse duration between minimum pulse duration and maximum pulse duration because the risk of causing acoustic noise is eliminated during the period of said first set of half-waves. According to embodiments, the first set of half-waves of mains comprises 1 to 20 half-waves.

[0009] According to embodiments, the reduced pulse duration is between half of the minimum pulse duration and minimum pulse duration. By using a reduction of pulse width in the upper-mentioned range, a significant reduction of acoustic noise can be obtained.

[0010] According to embodiments, the reduced pulse duration is in the range between $5\mu s$ and $9\mu s$, preferably $7\mu s$, and the minimum pulse duration is at least $10\mu s$.

[0011] According to embodiments, after starting the heating process, the control unit is configured to increase the pulse duration of the enabling signal pulses with each enabling signal pulse by a predefined pulse duration step until said minimum value of pulse duration is reached. So, in other words, starting at a reduced pulse duration starting value, the pulse duration is stepwise increased until said minimum value of pulse duration is reached. The step width may be chosen such that said minimum value of pulse duration is reached as quick as possible without a significant generation of acoustic noise. Thereby, a return to the nominal range of pulse duration as soon as possible is achieved.

[0012] According to embodiments, after reaching said minimum value of pulse duration, the control unit is configured to adapt the pulse duration of the enabling signal pulses according to the requested power. So, after performing the noise reduction routine, the control unit is driving the power stage in the normal power regulation mode, wherein the pulse duration is between minimum and maximum pulse duration value in order to power the induction element according to the power setting chosen by the user.

[0013] According to a second aspect, the invention relates to a method for operating an induction hob, the induction hob comprising a power stage with at least one switching element for enabling an alternating current flow through an induction element and a control unit providing an enabling signal comprising pulses with a variable pulse duration to the switching element for enabling said current flow through said induction element, wherein the pulse duration is changed between a minimum value and a maximum value in order to adjust the power provided to the induction element. The pulse duration of a set of enabling signal pulses is reduced to a reduced pulse duration lower than said minimum value when starting the heating process in order to reduce acoustic noise.

[0014] The term "essentially" or "approximately" as used in the invention means deviations from the exact value by +/- 10%, preferably by +/- 5% and/or deviations in the form of changes that are insignificant for the function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The various aspects of the invention, including its particular features and advantages, will be readily understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 shows a schematic view of an induction hob according to the current invention;

Fig. 2 shows an example schematic diagram of the electrical components comprised within the induction hob;

Fig. 3 shows an example circuit diagram of the bridge rectifier, the power stage and the driver unit according to Fig. 2;

Fig. 4 shows a first section of a signal diagram illustrating the voltage values of the enabling signal, the collector voltage of the switching element, the capacitor voltage and the trigger signal; and

Fig. 5 shows a second section of a signal diagram according to Fig. 4 wherein the signal representations of Fig. 5 directly follow after the signal representations of Fig. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] The present invention will now be described more fully with reference to the accompanying drawings, in which example embodiments are shown. However, this invention should not be construed as limited to the embodiments set forth herein. Throughout the following description similar reference numerals have been used to denote similar elements, parts, items or features, when applicable.

[0017] Fig. 1 shows a schematic illustration of an induction hob 1 according to the invention. The induction hob 1 may comprise multiple heating zones 2 preferably provided at a common hob plate. Each heating zone is correlated with at least one induction element placed beneath the hop plate. The induction hob 1 further comprises a user interface 3 for receiving user input and/or providing information, specifically graphical information to the user. The induction hob 1 may comprise at least one switching element associated with a respective induction element for enabling a current flow through said induction element. The switching element may be controlled by an enabling signal, said enabling signal enabling a current flow through said induction element in order to induce eddy currents within the piece of cookware placed above the induction element.

[0018] Fig. 2 shows a schematic block diagram of an induction hob 1 being adapted to perform a noise reduction routine for reducing acoustic noise after starting a heating process.

[0019] The induction hob 1 comprises a power stage 10, a control unit 11 and a user interface 3, said user interface 3 being coupled with the control unit 11 in order to provide information to the user and/or to receive information from the user via the user interface 3. Furthermore, the induction hob 1 may comprise a bridge rectifier 13, said bridge rectifier 13 being coupled with the power stage 10 for providing electrical power to the induction element comprised within the power stage 10. The bridge rectifier 13 may be coupled with one or more phases of the mains supply network.

[0020] According to embodiments, the control unit 11 is coupled with the power stage 10 via a driver unit 12, said driver unit 12 being adapted to receive an enabling signal P comprising electrical pulses provided by the control unit 11, modify said received enabling signal P and provide a modified enabling signal P' to the power stage 10. According to other embodiments, the control unit 11 may be directly coupled with the power stage 10, i.e. may provide the enabling signal P directly to the power stage 10. The control unit 11 is adapted to modify the pulse duration ΔP according to the requested power. The requested power may be provided to the control unit 11 according to a power demand entered by a user at the user interface 3. The pulse duration ΔP may vary between a minimum pulse duration ΔP_{min}, which corresponds to a minimum of requested power, and a maximum pulse duration ΔP_{max}, which corresponds to a maximum of requested power. Said minimum pulse duration ΔP_{min} and maximum pulse duration ΔP_{max} may be chosen in order to guarantee a certain lifetime of a switching element enabling an alternating current flow through an induction element based on the enabling signal P.

[0021] In order to reduce the generation of acoustic noise when providing heat to the piece of cookware placed above the induction element, the control unit 11 is adapted to perform a noise reduction mechanism. When performing said noise reduction mechanism, the pulse duration ΔP is lowered below the minimum pulse duration ΔP_{min} after start-up of the power stage 10. Thereby, the acoustic noise can be significantly reduced.

[0022] Fig. 3 shows the driver unit 12, the power stage 10 and the bridge rectifier 13 in closer detail. The driver unit 12 receives at input I1 the enabling signal P for enabling an alternating current flow through the power stage 10. The driver unit 12 comprises an electrical circuitry configured to adapt the received enabling signal P according to the needs of the power stage 10. For example, the driver unit may amplify the received enabling signal P and/or may change the signal level of the enabling signal P by adding a certain offset voltage value to said received enabling signal P in order to derive a modified enabling signal P'. Said modified electrical pulse P' may be provided to the gate of the switching element 20. Said switching element 20 may be, for example, an IGBT.

[0023] The collector (node 23) of the switching element 20 may be coupled via a filtering circuitry (comprising one or more capacitors) to an oscillating circuit 25, said oscillating circuit 25 comprising the induction element 21, preferably constituted by an induction coil, and a capacitor 22. The power stage 10 may comprise quasi-resonant power stage architecture. On the opposite side of the capacitor 22, the induction element 21 may be coupled with the bridge rectifier 13 in order to power the oscillating circuit 25 by the mains supply network.

[0024] During turn-off time of the switching element 20, the capacitor 22 is charged, i.e. electric energy provided by the bridge rectifier 13 is stored in the capacitor 22. Thereby, the electric voltage Vcap at node 24 is the rising. For example, the electric voltage Vcap of node 24 may be up to 1.41* V_{mains}, wherein V_{mains} is the mains voltage. When starting the power stage 10 after such turn-off time, a high current may flow through the induction element 21 thereby causing acoustic noise. The electric current value flowing at start-up of the power stage 10 may depend on the electric voltage of node 24 and the pulse duration ΔP of the enabling signal P. The electric voltage Vcap of node 24 is correlated with the amount of electric energy stored in the capacitor 22 which may be used for providing current flow through the induction element 21. The pulse duration ΔP of the enabling signal P may be indicative for the amount of electric charge which will be used for creating said current flow through the induction element 21. In other words, at a fixed electric voltage Vcap of node 24, the longer the pulse duration ΔP is, the higher is the current flowing through the induction element 21 and the stronger the acoustic noise generated by said electric current flow. However, it is not possible to decrease pulse duration ΔP in an arbitrary way below a certain threshold, e.g. below ΔP_{min} because when reducing pulse duration ΔP below said threshold, the switching element is driven in hard switching condition which can destroy the switching element. Surprisingly, the Applicant found out that when driving the switching element below said threshold pulse duration or below said minimum pulse duration ΔP_{min} for a limited period of time after starting the power stage 10, the lifetime of the switching element 21 is not or not significantly reduced.

[0025] For example, the normal range of pulse duration ΔP may be 10μs to 22μs, wherein the lower value corresponds to the minimum power setting and the upper value corresponds to the maximum power setting. In order to avoid the occurrence of acoustic noise, the pulse duration ΔP may be lowered to a reduced pulse duration ΔP_{red} wherein $0.5 \cdot \Delta P_{min} \leq \Delta P_{red} < \Delta P_{min}$. For example, the reduced pulse duration ΔP_{red} is in the range between 5μs and 9μs, preferably 7μs. Said reduction of pulse duration ΔP may be only obtained for a short period of time. The pulse duration reduction may be obtained for a certain number of half wave cycles of the mains supply voltage provided by the bridge rectifier 13. For example, the pulse duration reduction may be obtained for 1 to 20 half wave cycles of the mains supply voltage.

[0026] During the first half wave cycles, the voltage drop over capacitor 22 (i.e. voltage Vcap at node 24) is significantly decreasing. Thus, starting at reduced pulse duration ΔP_{red}, the pulse duration ΔP can be stepwise increased without producing more acoustic noise. For example, the pulse duration ΔP may be increased by a certain step width every half wave cycle after starting the power stage 10. For example, the step width may be in the range of 0.2μs to 1μs, specifically 0.5μs. The choosen step width may depend on the reduction ratio, i.e. the ratio by which the reduced pulse duration ΔP_{red} is lower than the minimum pulse duration ΔP_{min}. The pulse duration ΔP may be increased as long as the minimum power duration ΔP_{min} (which corresponds to the minimum power setting) is reached.

[0027] After reaching the minimum power duration ΔP_{min}, the control unit 11 may adapt the power duration ΔP according to the requested power provided by the user via the user interface 3 in order to heat the piece of cookware placed above the induction element 21 according to the chosen power setting.

[0028] Fig. 4 and 5 show signal diagrams of the enabling signal P, the capacitor voltage Vcap at node 24, the collector voltage Vc at node 23 and a trigger signal TS causing the generation of the next pulse of the enabling signal P. It is worth mentioning that the signal illustrations of the enabling signal P and the trigger signal TS are shifted against the collector voltage Vc and the capacitor voltage Vcap for the sake of a better recognisability. Thereby, fig. 5 shows the signals following on the signals of fig. 4. As can be seen from the length of the pulses of enabling signal P, the pulse duration is increasing with every occurrence of a further enabling signal pulse, wherein the step width for increasing the pulse duration ΔP of the enabling signal P is 0.5μs in the present embodiment.

[0029] It should be noted that the description and drawings merely illustrate the principles of the proposed methods and systems. Those skilled in the art will be able to implement various arrangements that, although not explicitly described or shown herein, embody the principles of the invention.

List of reference numerals

[0030]

1	induction hob
2	heating zone
3	user interface
10	power stage
11	control unit
12	driver unit
13	bridge rectifier
20	switching element
21	induction element
22	capacitor
23	node
24	node
25	oscillating circuit

I1	Input
P	enabling signal
P'	modified enabling signal
ΔP	pulse duration
ΔP_{min}	minimum pulse duration
ΔP_{max}	maximum pulse duration
ΔP_{red}	reduced pulse duration
TS	trigger signal
Vc	collector voltage
Vcap	capacitor voltage

Claims

1. Induction hob comprising a power stage (10) with at least one switching element (20) for enabling an alternating current flow through an induction element (21) and a control unit (11) providing enabling signal (P) comprising pulses with a variable pulse duration to the switching element (20) for enabling said current flow through said induction element (21), wherein the pulse duration (ΔP) is changed between a minimum value (ΔP_{min}) and a maximum value (ΔP_{max}) in order to adjust the power provided to the induction element (21), **characterised in that,**
the control unit (11) is adapted to reduce the pulse duration (ΔP) of a set of enabling signal pulses (P) to a reduced pulse duration (ΔP_{red}) lower than minimum value (ΔP_{min}) when starting the heating process in order to reduce acoustic noise.

2. Induction hob according to claim 1, wherein the switching element (20) is an insulated-gate bipolar transistor (IGBT).

3. Induction hob according to claim 1 or 2, wherein the power stage (10) comprises a quasi-resonant architecture comprising a single switching element (20).

4. Induction hob according to anyone of the preceding claims, wherein the pulse duration (ΔP) is reduced during a set of first half-waves of mains provided by a bridge rectifier (13) to the power stage (10) immediately after start-up of the power stage (10).

5. Induction hob according to claim 4, wherein the number of first half-waves of mains is between 1 and 20.

6. Induction hob according to anyone of the preceding claims, wherein the reduced pulse duration is $\Delta P_{red} \geq 0.5 \cdot \Delta P_{min}$.

7. Induction hob according to anyone of the preceding claims, wherein the reduced pulse duration (ΔP_{red}) is in the range between 5μs and 9μs, preferably 7μs.

8. Induction hob according to anyone of the preceding claims, wherein, after starting the heating process, the control unit (11) is configured to increase the pulse duration (ΔP) of the enabling signal pulses (P) with each enabling signal pulse by a predefined pulse duration step until said minimum value (ΔP_{min}) of pulse duration is reached.

9. Induction hob according to claim 8, wherein, after reaching said minimum value (ΔP_{min}) of pulse duration, the control unit (11) is configured to adapt the pulse duration (ΔP) of the enabling signal pulses (P) according to the requested power.

10. Method for operating an induction hob (1), the induction hob (1) comprising a power stage (10) with at least one switching element (20) for enabling an alternating current flow through an induction element (21) and a control unit (11) providing enabling signal (P) comprising pulses with a variable pulse duration (ΔP) to the switching element (20) for enabling said current flow through said induction element (21), wherein the pulse duration (ΔP) is changed between a minimum value (ΔP_{min}) and a maximum value

(ΔP_{max}) in order to adjust the power provided to the induction element (21), **characterised in that,** the pulse duration (ΔP) of a set of enabling signal pulses (P) is reduced to a reduced pulse duration (ΔP_{red}) lower than minimum value (ΔP_{min}) when starting the heating process in order to reduce acoustic noise.

FIG 1

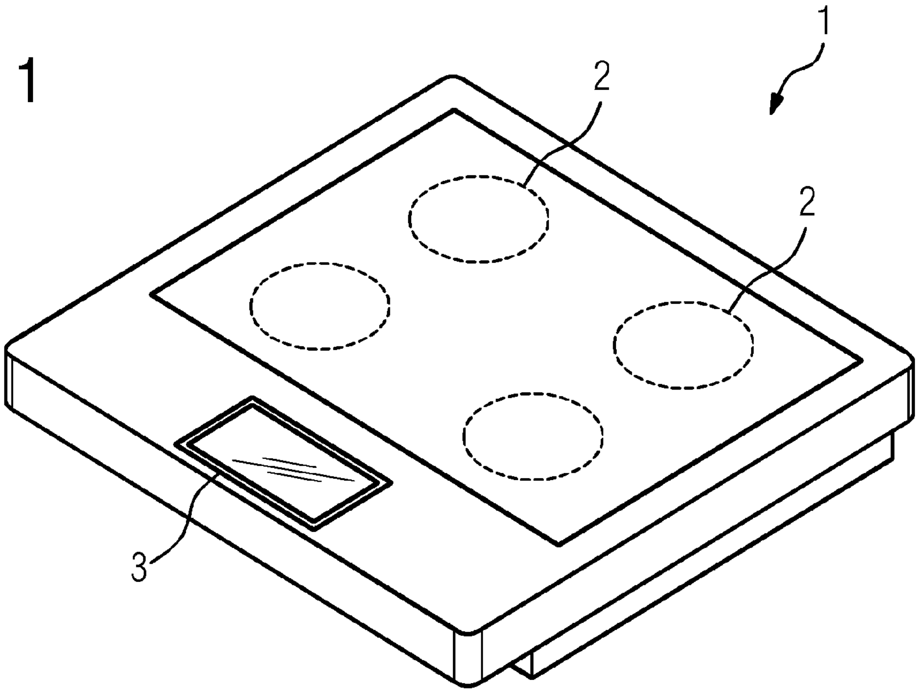

1
2
2
3

FIG 2

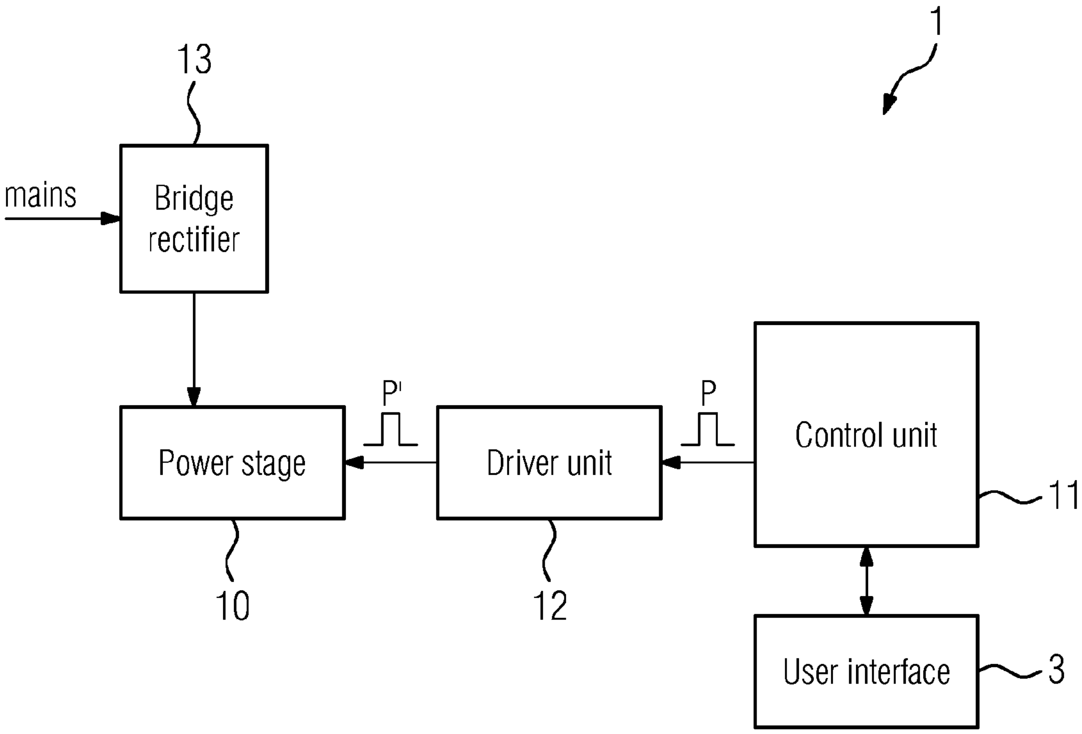

1
13
mains
Bridge rectifier
Power stage
P'
Driver unit
P
Control unit
11
10
12
User interface
3

FIG 3

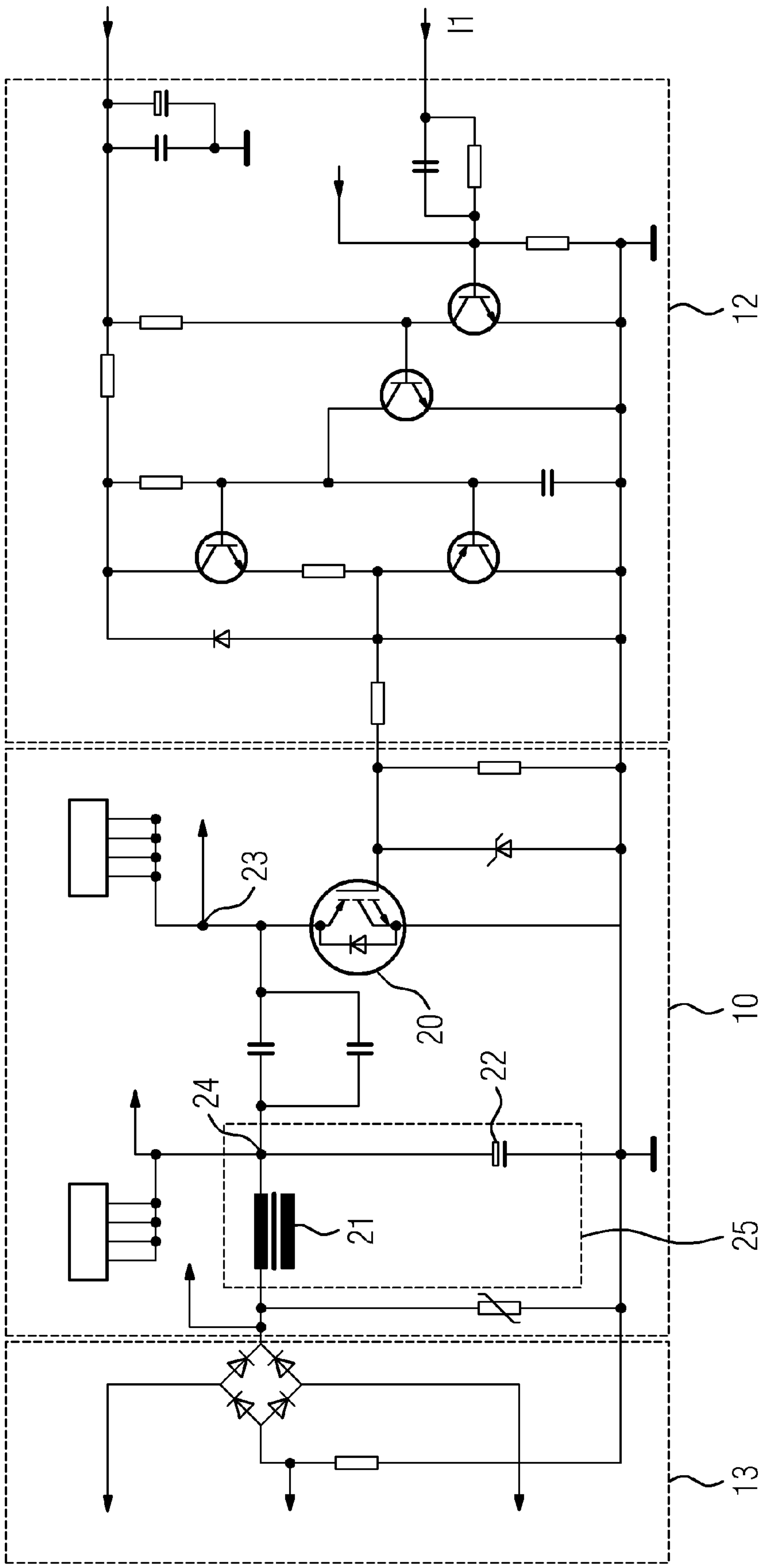


FIG 4

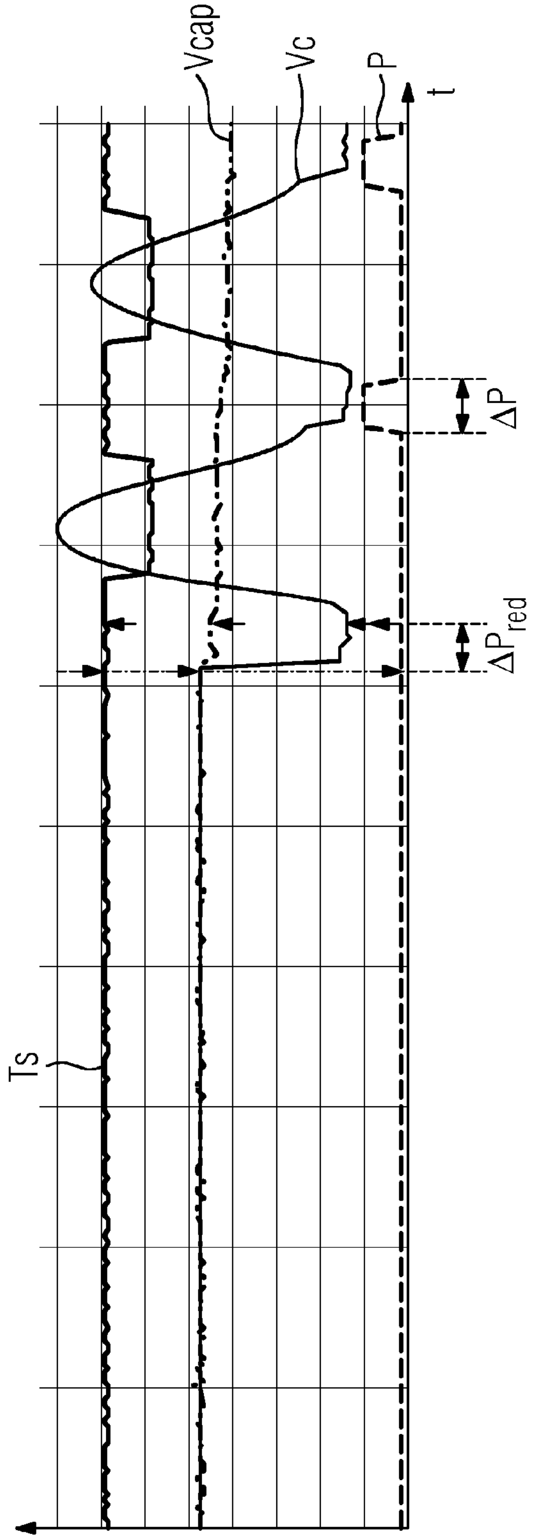
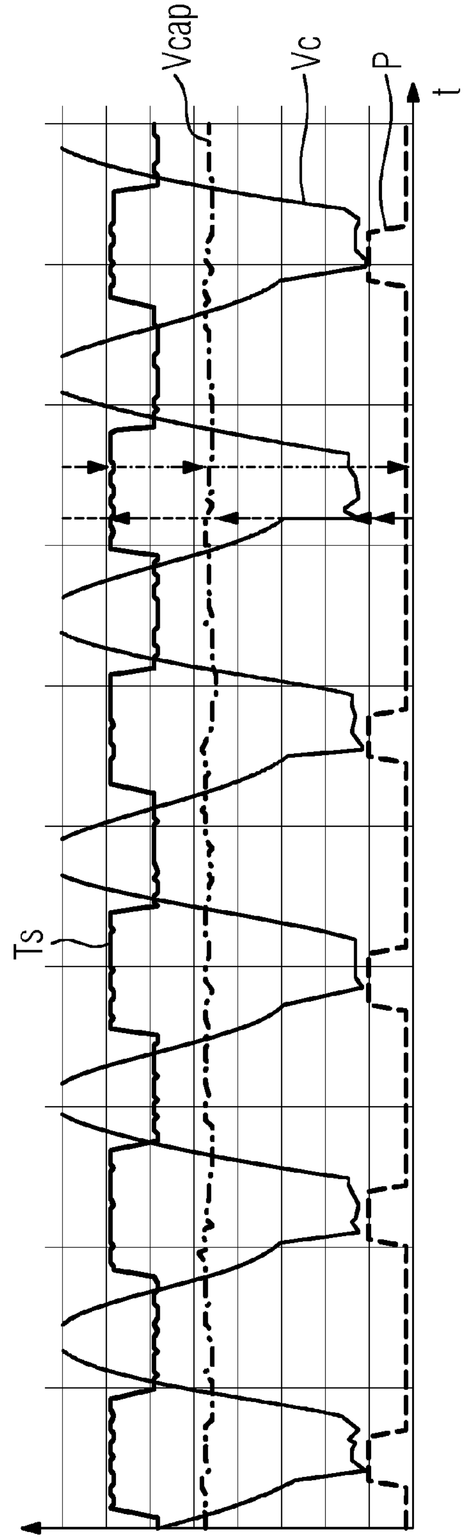


FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 6589

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	GB 2 108 786 A (SANYO ELECTRIC CO) 18 May 1983 (1983-05-18) * page 3, line 63 - page 4, line 5; claims 23,24; figures 17-19 * * page 5, line 35 - line 46 * * page 8, line 63 - page 9, line 10 * * page 9, line 41 - line 49 *	1-10	
A	JP 2009 295392 A (TOSHIBA HOME TECH CORP) 17 December 2009 (2009-12-17) * abstract; figure 1 *	1-10	
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TECHNICAL FIELDS SEARCHED (IPC)
H05B

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	25 January 2016	Gea Haupt, Martin

CATEGORY OF CITED DOCUMENTS

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