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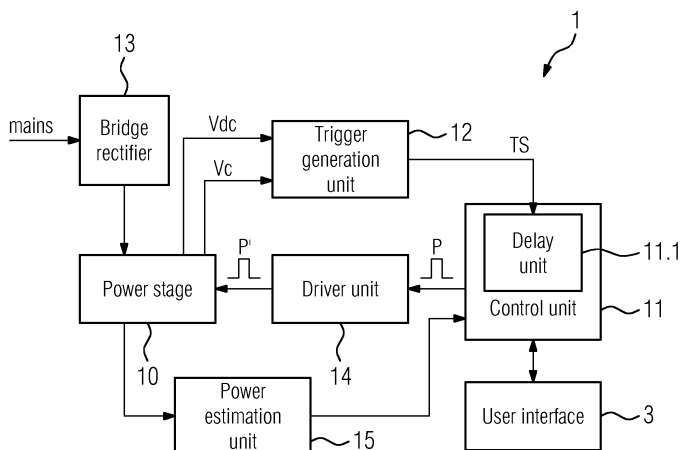
INDUCTION HOB AND METHOD FOR OPERATING AN INDUCTION HOB

(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 an enabling signal (P) to the switching element (20) for enabling said current flow through said induction element (21). The induction hob further comprises a trigger generation unit (12), said trigger generation unit (12) receiving an oscillating voltage (Vc) provided at a first monitoring point (23) of the power stage (10) and a reference voltage (Vdc) provided at a second monitoring

point (24) of the power stage (10), the trigger generation unit (12) being adapted to derive a trigger signal (TS) based on the oscillating voltage (Vc) and the reference voltage (Vdc). In addition, the trigger generation unit (12) is coupled with the control unit (11) for transmitting said trigger signal (TS) to the control unit (11). The control unit (11) comprises a delay unit (11.1), said delay unit (11.1) being triggered by the trigger signal (TS), wherein the delay unit (11.1) is configured to control the provision of an enabling signal (P) to the switching element (20) after elapsing of a delay time (Δt).

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 switching losses of the switching element within the 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. The switching losses of the switching element significantly depend on the voltage values applied to the switching element.

SUMMARY OF THE INVENTION

[0004] It is an objective of the embodiments of the invention to provide an induction hob with reduced switching losses of the switching element. 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 to the switching element for enabling said current flow through said induction element. The induction hob further comprises a trigger generation unit, said trigger generation unit receiving an oscillating voltage provided at a first monitoring point of the power stage and a reference voltage provided at a second monitoring point of the power stage. The trigger generation unit is adapted to derive a trigger signal based on the oscillating voltage and the reference voltage. Furthermore, the trigger generation unit is coupled with the control unit for transmitting said trigger signal to the control unit. In addition, the control unit comprises

a delay unit, said delay unit being triggered by the trigger signal, wherein the delay unit is configured to control the provision of an enabling signal to the switching element after elapsing of a delay time. Thereby, an appropriate timing of the provision of the enabling signal, specifically an appropriate timing of the provision of a pulse of the enabling signal to the power stage may be achieved. Said timing may be chosen such that the voltage drop across the switching element is minimized when the enabling signal is applied to the switching element.

[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 preferred embodiments, the first monitoring point is arranged at the collector of the switching element. Said arrangement is advantageous because the voltage at the collector directly corresponds to the voltage drop across the switching element and therefore comprises information regarding the appropriate timing of launching the next enabling signal pulse.

[0008] According to preferred embodiments, the second monitoring point is directly coupled with the electrical connection between the induction element and a capacitor, said capacitor being directly coupled with the induction element, wherein said induction element and said capacitor forming a resonant oscillating circuit of the induction hob. Said capacitor may have a high capacity value leading to an oscillation-free or essentially oscillation-free voltage signal at said electrical node between the induction element and said at least one capacitor. In other words, the voltage of said electrical node may be only slowly varying. Thus, the minimum voltage value of the oscillating voltage may be derived by comparing said oscillating voltage with said slowly varying reference voltage.

[0009] According to preferred embodiments, the trigger generation unit comprises a comparator adapted to derive said trigger signal based on the comparison of the voltage level of the oscillating voltage and the voltage level of the reference voltage level. The trigger signal may be a digital signal with a high level and a low level and steep edges between said high levels and said low levels. The level of the trigger signal may directly depend on the voltage ratio of the oscillating voltage and the reference voltage.

[0010] According to preferred embodiments, the delay unit is configured to start a delay timer based on the rising or falling edge of the trigger signal. Preferably, the edge may be chosen which is in close proximity to the minimum of the oscillating voltage.

[0011] According to preferred embodiments, the delay unit is configured to determine the delay time based on the pulse duration of the enabling signal. The oscillating voltage and the reference voltage may depend on the pulse duration of the enabling signal because said pulse duration changes the powering of the induction coil, i.e. the electrical load of the power stage. Thereby the period

of time between the crossing of the voltage values of the oscillating voltage and the reference voltage may also vary dependent on the pulse duration of the enabling signal. Said variation may be compensated by providing the pulse duration of the enabling signal or an information derived from the pulse duration to the delay unit in order to control the delay time based on the pulse duration of the enabling signal.

[0012] According to preferred embodiments, the induction hob comprises a power estimation unit for determining or estimating the electrical power consumption of the power stage. The power estimation unit may receive information regarding electrical voltage and/or current values from the power stage in order to determine or estimate the power consumption of said power stage.

[0013] According to preferred embodiments, the control unit is adapted to compare the estimated power consumption provided by the power estimation unit with the power requested by the user in order to adapt the power consumption of the power stage to the requested power. In other words, a control loop is provided which may adapt the power consumption of the power stage according to the power requested by a user.

[0014] According to preferred embodiments, the control unit is configured to adapt the pulse duration of the enabling signal based on the comparison result between the requested power and the estimated power consumption. By changing the pulse duration, the energy transferred to the piece of cookware placed above the induction element may be increased thereby also increasing the power consumption of the power stage. Therefore, in case that the power consumption of the power stage is below the requested power, the pulse duration may be increased. On the other hand, the pulse duration may be decreased if the power consumption of the power stage is above the requested power.

[0015] 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 to said switching element for enabling said current flow through said induction element. The induction hob comprises a trigger generation unit, said trigger generation unit receiving an oscillating voltage provided at a first monitoring point of the power stage and a reference voltage provided at a second monitoring point of the power stage. The trigger generation unit derives a trigger signal based on the oscillating voltage and the reference voltage and transmits said trigger signal to the control unit. Furthermore, the control unit comprises a delay unit, said delay unit being triggered by the trigger signal, wherein the delay unit provides an enabling signal to the switching element after elapsing of a delay time.

[0016] 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 func-

tion.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0017]** 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 an example signal diagram illustrating the voltage values of the enabling signal, the oscillating voltage, the reference voltage and the trigger signal; and
 - Fig. 5 shows a detailed illustration of a section of the signal diagram according to Fig. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] 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.

[0019] 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 hob 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.

[0020] Fig. 2 shows a schematic block diagram of an induction hob 1 being adapted to perform an improved timing for providing an enabling signal P to the switching element thereby lowering the switching losses of the switching element.

[0021] 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.

[0022] According to embodiments, the control unit 11 is coupled with the power stage 10 via a driver unit 14, said driver unit 14 being adapted to receive the enabling signal P 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.

[0023] In order to improve the timing for providing the enabling signal P, the induction hob 1 comprises a trigger generation unit 12. Said trigger generation unit 12 is coupled with the power stage 10 in order to receive two different electrical signals. The trigger generation unit 12 is adapted to derive a trigger signal TS based on said electrical signals. More in detail, the trigger generation unit receives an oscillating voltage Vc provided at the first monitoring point 23 of the power stage 10. Said first monitoring point 23 may be associated with the switching element of the power stage 10 in order to derive information regarding the voltage drop at the switching element. Specifically, the first monitoring point 23 may be arranged at the collector of the switching element, i.e. the oscillating voltage Vc measured at the first monitoring point 23 corresponds to the voltage at the collector of the switching element. For example, the switching element may be an insulated-gate bipolar transistor (IGBT) and the power stage comprises quasi-resonant architecture, i.e. uses a single switching element.

[0024] In addition, the trigger generation unit 12 receives a reference voltage signal provided at a second monitoring point 25 of the power stage 10. Said second monitoring point 25 may be associated with a capacitor, said capacitor forming together with the induction element an oscillating circuit within the power stage 10. The capacitor may have a high capacity value. Therefore, the reference voltage Vdc may be only slowly varying with respect to the oscillating voltage Vc.

[0025] The trigger generation unit 12 may comprise a comparator, said comparator receiving the oscillating voltage Vc and the reference voltage Vdc provided by the power stage 10. Said comparator may provide the trigger signal TS by comparing the voltage value of the oscillating voltage Vc with the voltage value of the reference voltage Vdc. The comparator may provide an rectangular trigger signal TS. For example, the trigger signal may comprise a low level in case that the oscillating voltage Vc is greater than the reference voltage Vdc and the trigger signal may comprise a high level in case that the

oscillating voltage Vc is lower than the reference voltage Vdc with steep edges between said high level and said low level. The trigger generation unit 12 is coupled with the control unit 11 for transmitting the trigger signal TS to said control unit 11.

[0026] The control unit 11 comprises a delay unit 11.1 configured to receive said trigger signal TS. The delay unit 11.1 may be triggered by the rising or falling edge of said trigger signal TS and may start a delay timer. Said delay timer may start a delay mechanism by counting down a delay time Δt . After expiry of said delay time Δt , the control unit may transmit a new enabling signal P to the power stage 10 in order to power the induction element. By performing said delay mechanism, the oscillating voltage Vc may reach the minimum value or a value close to minimum value. The oscillating voltage Vc corresponds to the voltage drop over the switching element and therefore also said voltage dropping over the switching element reaches a minimum value or a value close to minimum value. Thereby, the switching losses of the switching element are significantly reduced.

[0027] Fig. 3 shows the driver unit 14, the power stage 10 and the bridge rectifier 13 in closer detail. The driver unit 14 receives at Input I1 the enabling signal P for enabling an alternating current flow through the power stage 10. The driver unit 14 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.

[0028] The collector of the switching element 20 may be coupled via a filtering circuitry (comprising one or more capacitors) to the oscillating circuit 25, said oscillating circuit 25 comprising the induction element 21, preferably constituted by an induction coil, and the capacitor 22. The power stage 10 may comprise a 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.

[0029] When receiving the modified enabling signal P' at the switching element 20, the voltage at the collector of the switching element 20 is suddenly decreasing and after closing the switching element 20, the electrical voltage of the collector of the switching element 20 is oscillating. Preferably, the collector of the switching element 20 is chosen as first monitoring point 23 to derive the oscillating voltage Vc, because the voltage of the collector of the switching element 20 directly corresponds to the voltage drop over the switching element 20. In preferred embodiments, the emitter of said switching element 20 is directly coupled to ground.

[0030] The second monitoring point 24 for deriving the

reference voltage V_{dc} may be the electrical node between the induction element 21 and the capacitor 22. In other words, the second monitoring point 24 is constituted by the direct electrical connection between the induction element 21 and the capacitor 22. In contrary to the oscillating voltage V_c , the reference voltage does not show a significant oscillation behaviour but is only slowly varying according to the load of the induction element 21. Therefore, the reference voltage V_{dc} forms an appropriate signal for deriving the trigger signal TS by comparing the oscillating voltage V_c with the reference voltage V_{dc} .

[0031] Fig. 4 and 5 show signal diagrams of the enabling signal P, the reference voltage V_{dc} , the oscillating voltage V_c and the trigger signal TS. It is worth mentioning that the signal illustrations of the enabling signal P and the trigger signal TS are shifted against the oscillating voltage V_c and the reference voltage V_{dc} for the sake of a better recognisability.

[0032] After the provision of an enabling signal P (e.g. a single pulse comprising certain pulse duration) the oscillating voltage V_c is sharply decreasing until the enabling signal P (i.e. the positive pulse of the enabling signal P) is low because the enabling signal P enables a current flow through the switching element 20. After closing the switching element 20 (i.e. after the falling edge of the enabling signal P), the oscillating voltage V_c starts an oscillating cycle, i.e. the oscillating voltage V_c is rising to a maximum value and after passing the maximum value decreasing. During the oscillating cycle, the oscillating voltage V_c comprises in a first period of time t_1 a voltage value lower than the reference voltage V_{dc} , in a second period of time t_2 voltage value higher than the reference voltage V_{dc} and in a third period of time t_3 of voltage value lower than the reference voltage V_{dc} .

[0033] The trigger generation unit receiving said oscillating voltage V_c and said reference voltage V_{dc} may generate said trigger signal TS by comparing the voltage values of the oscillating voltage V_c and said reference voltage V_{dc} . For example, the trigger generation unit 12 may comprise a comparator providing a trigger signal TS with a high level when the oscillating voltage V_c is lower than the reference voltage V_{dc} . Conversely, the comparator may provide a trigger signal TS with a low level when the oscillating voltage V_c is higher than the reference voltage V_{dc} . According to another embodiment, also the inverse generation of the trigger signal TS may be possible, i.e. the comparator may provide a trigger signal TS with a high level when the oscillating voltage V_c is higher than the reference voltage V_{dc} and may provide a trigger signal TS with a low level when the oscillating voltage V_c is lower than the reference voltage V_{dc} .

[0034] Still referring to figures 4 and 5, according to the present embodiment, the rising edge of the trigger signal TS is shortly before the minimum value of the oscillating voltage V_c . Therefore, the delay unit 11.1 may use said rising edge of the trigger signal TS for starting a delay timer. Said delay timer may count down a certain

delay time Δt in order to launch the next pulse of the enabling signal P in close proximity to the minimum value of the oscillating voltage V_c . After expiration of the delay time Δt , the delay unit 11.1 may provide a trigger to the control unit 11 in order to launch the next pulse of the enabling signal P.

[0035] The control unit 11.1 may be configured to adapt the pulse duration ΔP of the pulses of the enabling signal P based on the power request of the user for the respective heating zone 2 correlated with the induction element 21. The longer the pulse duration ΔP is, the more heating power is provided to the piece of cookware placed above the induction element 21.

[0036] The pulse duration ΔP of the pulses of the enabling signal P has also strong effect on the amplitude of the oscillating voltage V_c . In case that a fixed delay time Δt would be used, the timing of launching the following pulse of the enabling signal P may be inappropriate in most cases. Thus, the delay unit 11.1 may be configured to adapt the delay time Δt according to the requested power, respectively, according to the pulse duration ΔP . For example, the control unit 11 may receive a power request of the user interface 3 and may adapt the pulse duration ΔP according to the requested power. The control unit 11 may provide the requested power value and/or the pulse duration ΔP derived from said requested power value to the delay unit 11.1. The delay unit may comprise a processing unit adapted to calculate an appropriate delay time Δt based on the received requested power value and/or the pulse duration ΔP . According to other embodiments, the delay unit may comprise a look-up table comprising a plurality of table entries, each table entry correlating a certain delay time value with a requested power value and/or a pulse duration value. Thereby, the delay unit 11.1 is able to adapt the delay time Δt based on the received requested power value and/or the pulse duration value.

[0037] Referring back to fig. 2, the induction hob further comprises a power estimation unit 15. Said power estimation unit 15 may be adapted to derive information regarding the energy consumed by the power stage 10. The power estimation unit 15 may be coupled with the power stage 10 in order to receive information about the power consumption of the power stage 10 and may further be coupled with the control unit 11 in order to provide information regarding the power consumption of the power stage 10 to the control unit. For example, the power estimation unit 15 may receive information regarding the electrical current flowing through the induction element 21 in order to determine or estimate the power consumption of the power stage 10. The information regarding the power consumption of the power stage 10 may be transmitted to the control unit 11 in order to compare the power consumption determined by the power estimation unit 15 with the power request according to the user demand. Based on the comparison of the power consumption value provided by the power estimation unit 15 and the requested power, the control unit 11 may adapt the pulse

duration ΔP in order to adjust the power consumption of the power stage 10 to the requested power. In other words, by means of the power estimation unit 15 a feed-back control loop is provided for adapting the power consumption of the power stage 10 according to the power requested by the user via the user interface 3.

[0038] 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

[0039]

1	induction hob
2	heating zone
3	user interface
10	power stage
11	control unit
11.1	delay unit
12	trigger generation unit
13	bridge rectifier
14	driver unit
15	power estimation unit
20	switching element
21	induction element
22	capacitor
23	first monitoring point
24	second monitoring point
25	oscillating circuit
I1	Input
P	enabling signal
P'	modified enabling signal
ΔP	pulse duration
TS	trigger signal
Δt	delay time
Vc	oscillating voltage
Vdc	reference 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 an enabling signal (P) to the switching element (20) for enabling said current flow through said induction element (21), **characterised in that,** the induction hob comprises a trigger generation unit (12), said trigger generation unit (12) receiving an oscillating voltage (Vc) provided at a first monitoring point (23) of the power stage (10) and a reference

voltage (Vdc) provided at a second monitoring point (24) of the power stage (10), the trigger generation unit (12) being adapted to derive a trigger signal (TS) based on the oscillating voltage (Vc) and the reference voltage (Vdc);

the trigger generation unit (12) being coupled with the control unit (11) for transmitting said trigger signal (TS) to the control unit (11);

the control unit (11) comprising a delay unit (11.1), said delay unit (11.1) being triggered by the trigger signal (TS), wherein the delay unit (11.1) is configured to control the provision of an enabling signal (P) to the switching element (20) after elapsing of a delay time (Δt).

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 first monitoring point (23) is arranged at the collector of the switching element (20).

4. Induction hob according to anyone of the preceding claims, wherein the second monitoring point (24) is the electrical connection between the induction element (21) and a capacitor (22), said capacitor (22) being directly coupled with the induction element (21), wherein said induction element (21) and said capacitor (22) forming a resonant oscillating circuit (25) of the induction hob (1).

5. Induction hob according to anyone of the preceding claims, wherein the trigger generation unit (12) comprises a comparator adapted to derive said trigger signal (TS) based on the comparison of the voltage level of the oscillating voltage level (Vc) and the voltage level of the reference voltage level (Vdc).

6. Induction hob according to anyone of the preceding claims, wherein the delay unit (11.1) is configured to start a delay timer based on the rising or falling edge of the trigger signal (TS).

7. Induction hob according to anyone of the preceding claims, wherein the delay unit (11.1) is configured to determine the delay time (Δt) based on the pulse duration of the enabling signal (P).

8. Induction hob according to anyone of the preceding claims, comprising a power estimation unit (15) for estimating the electrical power consumption of the power stage (10).

9. Induction hob according to claim 8, wherein the con-

trol unit (11) is adapted to compare the estimated power consumption provided by the power estimation unit (15) with the power requested by the user in order to adapt the power consumption of the power stage (10) to the requested power.

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10. Induction hob according to claim 9, wherein the control unit (11) is configured to adapt the pulse duration of the enabling signal (P) based on the comparison result between the requested power and the estimated power consumption.
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11. 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 an enabling signal (P) to said switching element (20) for enabling said current flow through said induction element (21),
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- characterised in that,**
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- the induction hob (1) comprises a trigger generation unit (12), said trigger generation unit (12) receiving an oscillating voltage (Vc) provided at a first monitoring point (23) of the power stage (10) and a reference voltage (Vdc) provided at a second monitoring point (23) of the power stage (10), the trigger generation unit (12) deriving a trigger signal (TS) based on the oscillating voltage (Vc) and the reference voltage (Vdc) and transmitting said trigger signal (TS) to the control unit (11);
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- the control unit (11) comprising a delay unit (11.1), said delay unit (11.1) being triggered by the trigger signal (TS), wherein the delay unit (11.1) controls the provision of an enabling signal (P) to the switching element (20) after elapsing of a delay time (At).
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FIG 1

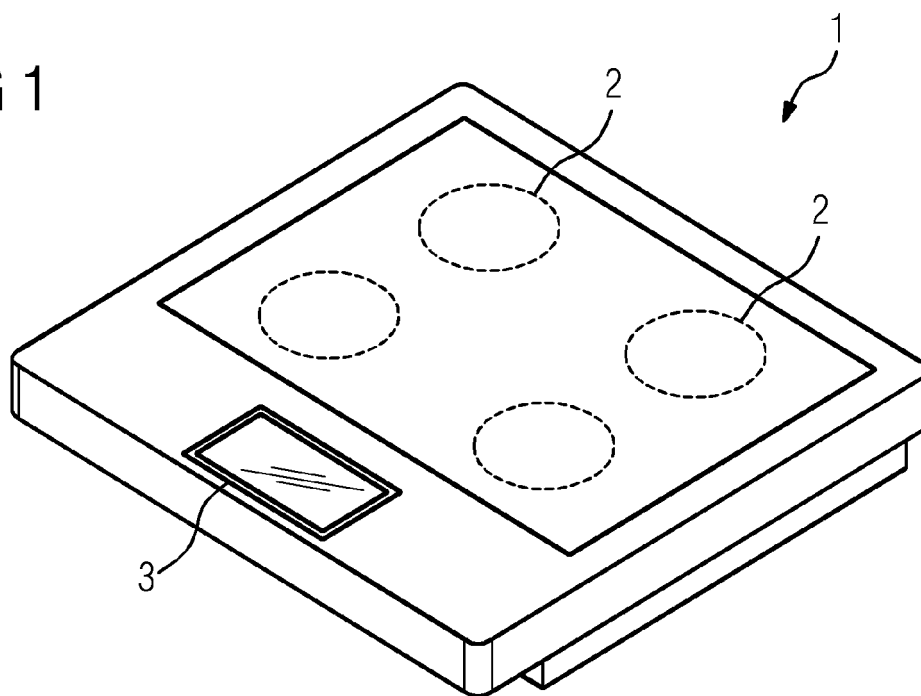


FIG 2

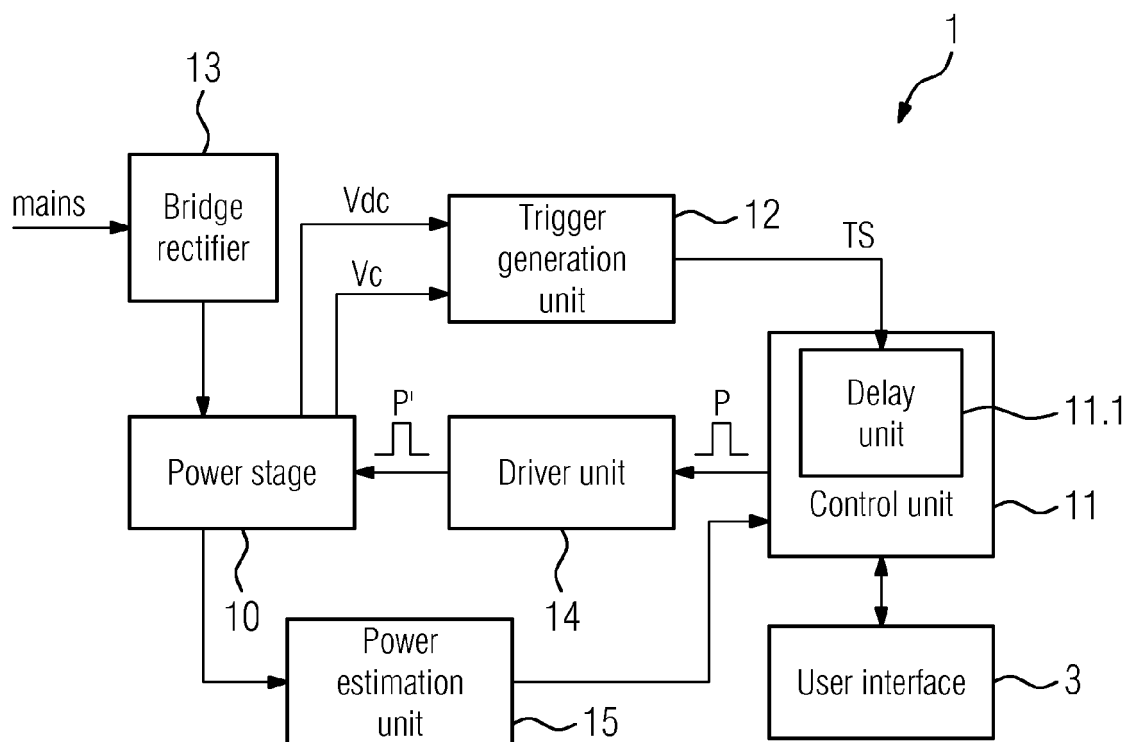


FIG 3

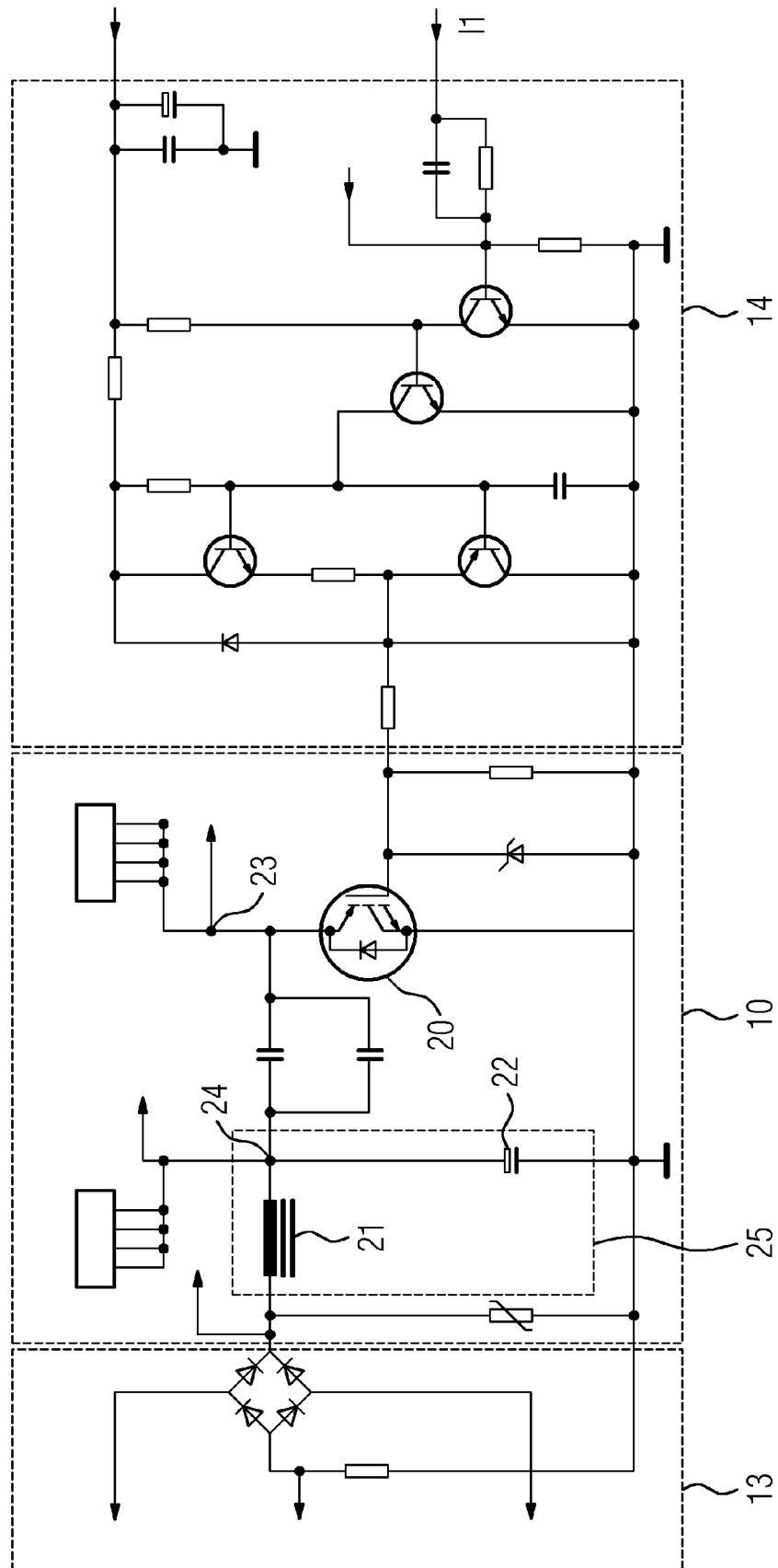


FIG 4

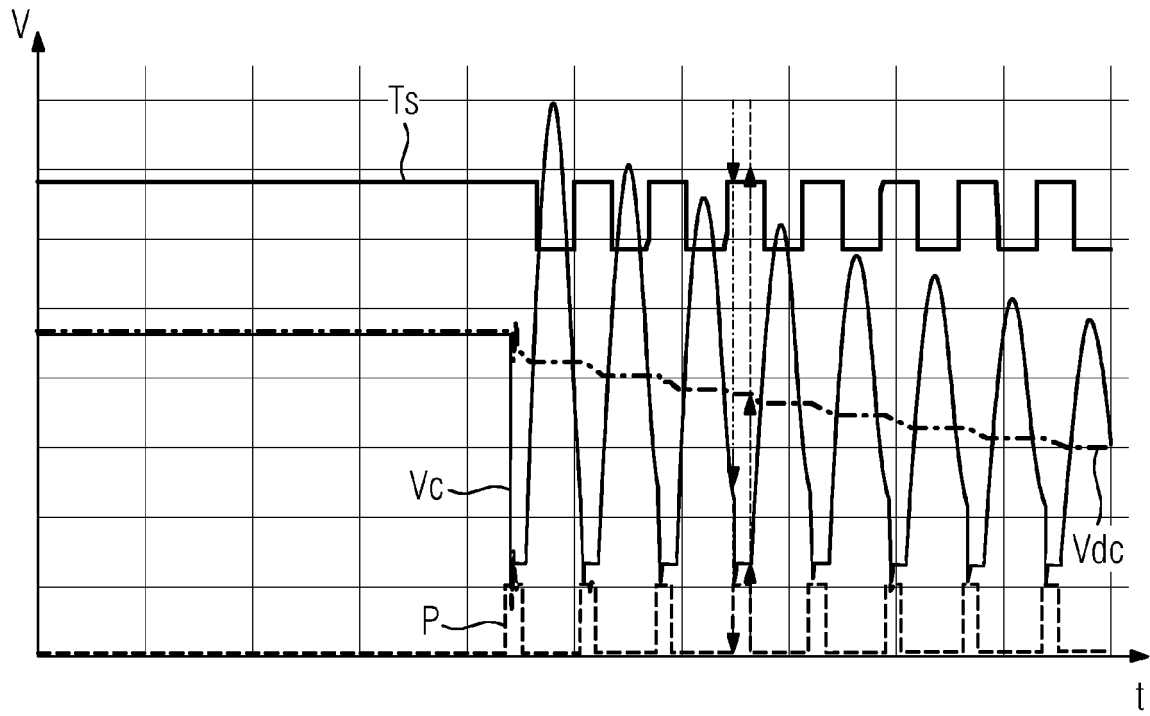
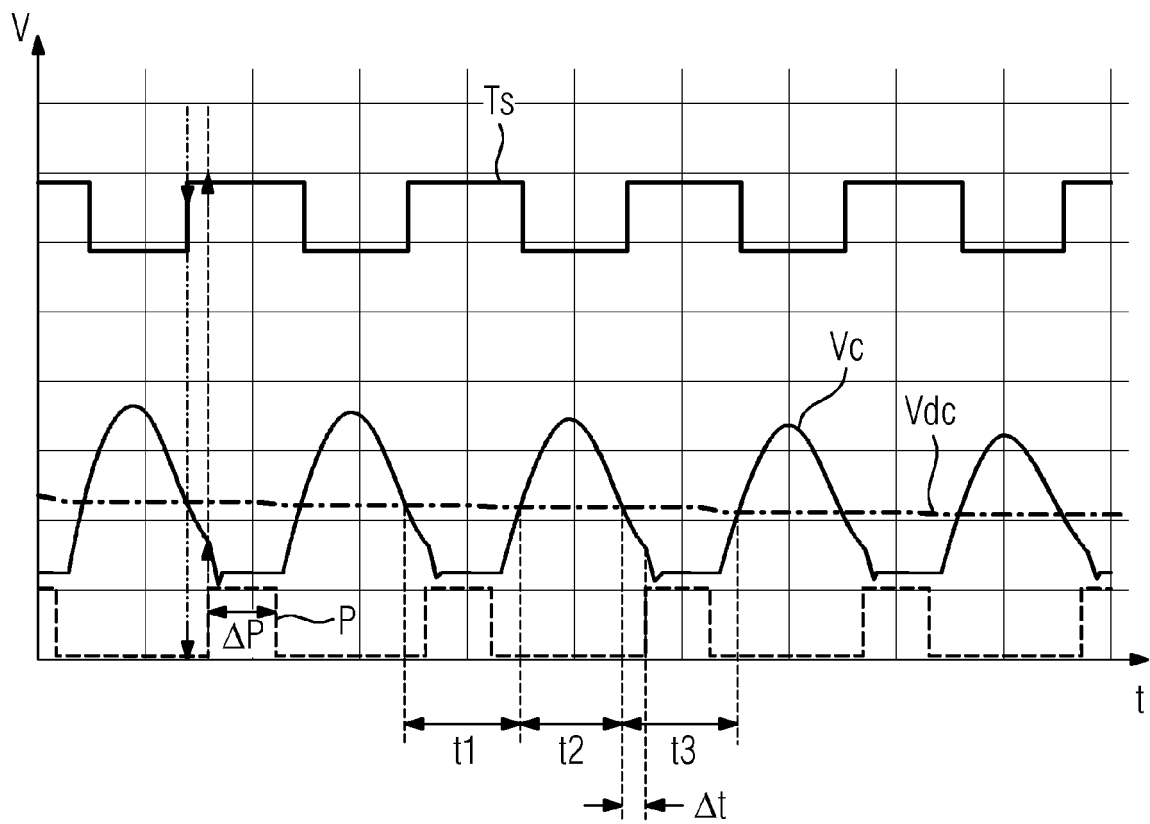


FIG 5





EUROPEAN SEARCH REPORT

Application Number
EP 15 17 6584

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 15 17 6584

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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