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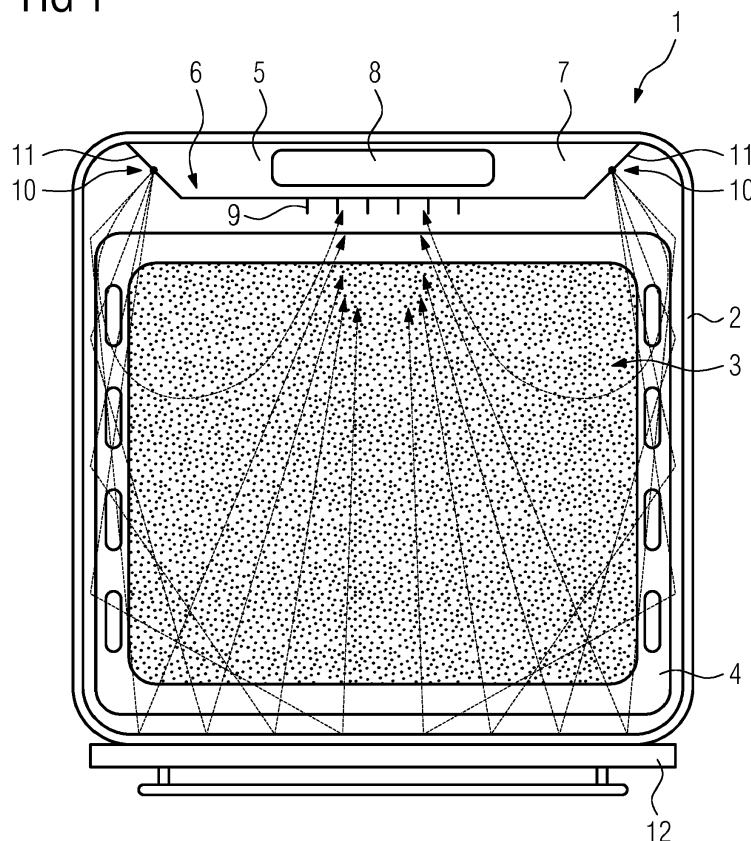
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(54) **Method of operating an air convection fan of a cooking oven and cooking oven**

(57) The underlying invention is directed to a method of operating a fan (8) during a forced air convection cooking phase of a cooking oven(1). The convection fan (8) in at least one forced convection operational phase is

operated such that the rotary speed of the fan (8) uniformly and continuously oscillates between periods of increasing and decreasing rotary speed (RPM).

FIG 1



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Description

[0001] The present invention in particular relates to a method of operating an air convection fan of a cooking oven in which food may be cooked or baked by forced air ventilation, in particular forced hot air ventilation or convection.

[0002] In forced air ventilation or convection ovens, different approaches for optimizing or improving convection cooking have been proposed. In particular methods have been proposed for optimizing heat transfer from forced air convection heating elements to food products to be cooked. In particular, cooking modes in forced air convection cooking are known from EP 2 282 128 A1, EP 1 965 137 A1, US 2010/0092275 A1 and US 2005/0236388 A1, for example.

[0003] However, the known solutions still leave room for further optimization of heat transfer in convection cooking appliances and convection cooking processes.

[0004] Therefore, it is an object of the invention to provide a solution for further optimizing heat transfer between a heating unit and one or several cooking products placed in a corresponding cooking cavity of an oven.

[0005] This object is solved by the features of claims 1, 11 and 12. Embodiments in particular result from respective dependent claims.

[0006] According to claim 1 a method of operating an air convection fan during a forced air convection cooking phase of a cooking oven is provided. A forced air convection cooking phase in particular shall mean a cooking phase in which air within an cooking chamber, in particular an oven cavity, of the oven is forced to circulate therein by the operation of a convection fan.

[0007] The convection fan is arranged, positioned and adapted such that air from within the cooking chamber can be sucked in and blown out again into the cooking chamber. The convection fan may for example be integrated in a vertical rear wall of the cooking chamber, and adapted such air is sucked in at a center region of the rear wall and is blown out at lateral sides in an air stream with an orientation which is tilted laterally outwards and comprises an airflow component directed towards the front wall of the cooking chamber.

[0008] The air stream during forced air convection may pass or be passed through a heating element arranged in the exhaust and/or inlet port of the convection fan. The heating element may be a circular heating element adapted to heating the incoming and/or exhausting air. However, the heating element may in variants also be arranged in or at other locations, such that the circulating air in its convection pathway passes or sweeps by the heating element and thus can be heated.

[0009] The oven may be any type of cooking oven, in particular a conventional electric oven, microwave oven and the like.

[0010] According to the invention, the convection fan in at least one forced convection operational phase is operated such that the rotary speed of the convection

fan uniformly, i.e. steadily, and continuously oscillates or alternates between periods of increasing and decreasing rotary speed.

[0011] This operational mode in particular has the advantage that the pattern of the airflow, the airflow distribution and/or the airflow velocity distribution within a cooking chamber of the oven can be steadily and continuously varied.

[0012] This in particular shall mean that, with respect to the airflow patterns, essentially no steady states with constant rotary speed occur. Therefore, a dynamic airflow rather than a steady state airflow pattern can be established within the cooking chamber during the forced convection operational phase. This in particular has the advantage, that heat within the cooking chamber can be distributed more efficiently and uniformly, and in particular uniform heating of the objects, i.e. food items, contained in the cooking chamber, can be obtained.

[0013] The oscillating operation of the convection fan may be provided or sub-divided in at least a first and second period, wherein in the first period, the convection fan is operated in an accelerating manner, and wherein the convection fan in the second period is operated in a decelerating manner. The first and second periods may be conducted alternately.

[0014] The term oscillating in the meaning of the present invention in particular shall mean or relate to conditions in which the convection fan is operated such that the rotary speed under ideal conditions changes steplessly, in particular without any discontinuities or plateaus of constant rotary speed. In particular a continuous stepless oscillatory variation of the fan rotary speed, which variation may be cyclically changed and/or repeated, can be obtained.

[0015] Note that operating the convection fan in a period with increasing rotary speed essentially corresponds to an operation in an accelerating mode, as increasing the rotary speed goes along with accelerating the fan motor and/or fan blades. Similarly, operating the convection fan in a period with decreasing rotary speed corresponds to an operation in a decelerating mode, as decreasing the rotary speed means, either actively or passively by the action of friction and inertia, decelerating the fan motor and/or fan blades.

[0016] The proposed uniform and steady oscillatory operation of the conduction fan in particular shall mean, that the rotary speed, in particular the speed of the fan, or the fan blades, the movement pattern of the fan, or the motor pattern of the fan motor are free from plateaus of constant rotary speed. A plateau shall mean a time interval in which the rotary speed is constant. This in particular shall mean that the motion or movement pattern in rotary speed of fan, fan motor and/or blades are free from steady states time intervals, in which no acceleration or deceleration occurs. In such operational modes, deceleration and acceleration may occur only in specific, i.e. singular, points of time in between a first period and a second period, i.e. in between an accelerating and de-

celerating phase. In mathematical terms, the proposed operational mode in particular means that the derivative of the fan speed has only singular zero-points, i.e. only singular points of zero acceleration occur.

[0017] As already mentioned, the movement or motion pattern related or generated at the fan is transferred into a specific airflow pattern within the cooking chamber. Hence, at least a corresponding bulk or main airflow pattern in the cooking chamber may be free from steady airflow states, i.e. free from constant airflow patterns. This in particular shall mean that in a bulk or main airflow area within the cooking chamber, i.e. an area in which the main or relevant convection airflow is generated or occurs, is free from steady or constant airflow patterns. Or, in other words, at least in the main airflow area, in particular in a main bulk airflow area, a dynamic airflow pattern can be obtained or generated. Due to the inventive control of the convection fan, the airflow pattern changes continuously and steadily in concert with the convection fan operation.

[0018] Therefore, the present invention in particular provides a method in which the convection fan is operated such that the airflow pattern generated by the fan within the cooking chamber is continuously and steadily changing, i.e. represents a dynamic airflow pattern.

[0019] In embodiments of the invention, the convection fan may be operated such that the rotary speed has a sinusoidal shape or sinusoidal temporal progression, relative to its average. In particular the rotary speed can be continuously oscillated to obtain in the end a sine curve graph form, i.e. a sine-shaped graph or progression over time.

[0020] Such smooth and uniform oscillations in sinusoidal shape in particular are suitable for obtaining adequate, optimal and in particular unique airflow pattern dynamics within the cooking chamber, avoiding steady states.

[0021] In embodiments of the invention, the convection fan may be controlled such that the rotary speed oscillates between upper and lower limits, wherein at least one of the upper and lower limit changes over time according to a predefined course or pathway.

[0022] In particular, the rotary speed may oscillate, in particular sweep, between the upper and lower limits, for example in a sinusoidal manner. The upper and lower limits may be selected such that the difference between them remains constant over time. However it is also possible that the upper and lower limits are selected such that the difference between them varies, in particular increases, decreases, or alternately increases and decreases. The distance between upper and lower limits preferably kept at a certain percentage of the minimum or maximum rotatory speed of the convection fan.

[0023] In variants of the invention, at least one of the lower limits and upper limits, i.e. the lower limits and/or the upper limits respectively, span a lower and/or upper envelope, respectively, for the rotary speed. This in particular means that actual rotary speed oscillates between

the lower envelope and the upper envelope.

[0024] At least one of the upper and lower envelopes, at least in sections, has a linear or curved shape. This in particular shall mean that a respective envelope develops over time in a linear and/or curved fashion, which in particular may mean that the envelopes at least in sections can be linear and in other sections can be curved. As an example for a curved progression, it may be that a respective envelope can have a sinusoidal and/or pulsating shape.

[0025] The development over time in particular may be such that the upper and/or lower limit has/have an increasing, decreasing and/or constant trend, which in particular shall mean that the trend or average value can be in sections increasing, in other sections decreasing and can be constant in yet further sections.

[0026] In particular the upper and lower limits and the trend, as well as the rotary speed average, can be selected and fixed such that by sweeping the rotary speed of the fan between the upper and lower envelope, an optimal and favourable dynamic airflow pattern distribution or progression can be obtained within the cooking chamber.

[0027] In further embodiments of the invention it may be provided that a rotary speed difference between upper and lower limits, in particular upper and lower envelopes, is constant over time, which may mean that the difference between upper and lower limits essentially is invariable. This in particular may be applied if a corresponding heating element is operated at a constant heating power.

[0028] In other embodiments, it may be provided that a rotary speed difference between upper and lower limits, in particular upper and lower envelopes, has a pulsative, in particular sinusoidal, course over time. This in particular may be applied if a heating element related to the convection fan is operated with a corresponding progression over time. The progression over time of the heating power of the heating element/s may correspond to a pulsed operation, which may be used in order to obtain defined heat output values.

[0029] Or, in other words, the convection air output of the fan, i.e. the convection airstream, may be adapted in correspondence to the heat output of the heating element/s. In this way a comparatively unique heating and gentle cooking may be obtained.

[0030] In further embodiments of the invention, the convection fan may be controlled such that the temporal average of the rotary speed, at least in subsections of the forced convection operational phase has a linear or curved shape. The curved shape in particular may be sinusoidal and/or pulsating, in particular according to a manner as already described beforehand. A trend of the temporal average of the rotary speed may at least in subsections be increasing, decreasing, or be constant over time.

[0031] As can be seen, the shape or progression of the rotary speed as well as of the temporal average of the rotary speed can be varied within comparatively wide

boundaries.

[0032] In particular the shape or progression of the rotary speed and temporal average may be selected to obtain an optimal and unique heat transfer for a given set of operational parameters, such as cooking temperature, size of the cooking chamber, number and/or volume and/or size of the food product contained within the cooking chamber, cooking program, number of cooking trays contained in the cooking chamber and so on.

[0033] In embodiments it is provided, that for obtaining a rotary speed time course or pattern as mentioned in any embodiment and/or configuration above and further above, at least a signal component of the power signal for powering the convection fan is a pulse width modulated (PWM), pulse frequency modulated (PFM) and/or pulse phase modulated (PPM) power signal.

[0034] PWM, PFM and PPM represent comparatively robust and exact options for controlling the rotary speed of the convection fan to obtain a desired dynamic airflow pattern. PWM, PFM or PPM may be used only for a signal component, which shall mean that the total signal may be a combination or superposition of power supply signals, in particular a superposition of a constant or base power supply signal component and a PWM, PFM and/or PPM signal component.

[0035] In embodiments of the invention, and as already indicated further above, the rotary speed of the fan may be correlated with a heating power cycle of a convection heating element of the cooking oven. In particular the rotary speed and heating element may be operated to have similar or even equal duty cycles and/or clock cycles. The signal behaviour of the rotary speed value and the heating power may either be cyclic or anticyclic. Adapting the operational cycles of the convection fan and heating element to each other may be used to further improve uniformity of heating.

[0036] In further embodiments and as already mentioned in the description above, the convection fan may be operated in order to obtain, during the forced convection operational phase, a dynamically changing, in particular repetitive, airflow pattern within the cooking chamber of the cooking oven. In this way, unique heating and heat distributions within the cooking chamber can be obtained.

[0037] According to claim 11, a controller unit for controlling at least one convection fan of a cooking oven during a forced air convection cooking phase is proposed. The proposed controller unit is adapted to generate control signals to operate the fan according to a method as described in any embodiment and variant further above and further below. As to advantages of such a controller module, reference is made to the description above.

[0038] According to claim 12, a cooking oven is provided, comprising a cooking chamber and a convection fan adapted to circulate air within the cooking chamber. The cooking oven further comprises a controller unit as described and set out beforehand. The controller unit in

particular is adapted to operate the cooking oven according to any embodiment and variant as described further above and below. As to advantages and advantageous effects, reference is made to the description further above and below.

[0039] In a variant of the cooking oven, the convection fan may be positioned at a vertical rear wall of the cooking chamber. Such a position in connection with the proposed operational method according to the invention in particular may lead to unique and homogenous airflow patterns, and therefore heat distribution patterns, within the cooking chamber. Preferably, air outlets of a fan casing, which air outlets are adapted to specifically control the exhaustion of convection air into the cooking chamber, are positioned and oriented to generate an output airflow directed laterally frontwards. In particular, the openings may be adapted such that the exhaustion airstream is directed towards the lateral sidewalls, from where it is reflected towards the inner of the cooking chamber or towards the front wall to finally be sucked in again at an air suction opening of the convection fan.

[0040] The air suction opening of the convection fan in particular may be positioned in a center region of the lateral back wall of the cooking chamber.

[0041] Note that the fan, together with exhaustion ports and suction opening and port, may also be arranged at or integrated with a top wall or lateral side wall of the cooking chamber.

[0042] In particular in order to obtain a uniform air distribution and airflow pattern within the cooking chamber air exhaustion ports may be directed laterally outwards, and air suction ports of the convection fan may be arranged in a central region relative to a wall to or at which the convection fan is mounted to or implemented.

[0043] In all, it can be seen that the present invention is suitable for providing a method of enhanced convection cooking possibilities.

[0044] Embodiments of the invention will now be described in connection with the annexed figures, in which:

- FIG. 1 a sectional top view of a cooking oven;
- FIG. 2 a graph of the rotary fan speed over time during a convection cooking phase;
- FIG. 3 a graph of the fan acceleration during the cooking phase;
- FIG. 4 a schematic layout of a convection fan controller;
- FIG. 5 a graph of the power supply voltage for the convection fan in a pulsed operational mode;
- FIG. 6 a graph of the rotary speed of the fan operated according to the supply voltage indicated in FIG. 5;

- FIG. 7 an electric diagram of a first variant of oven electronics;
- FIG. 8 an electric diagram of a second variant of oven electronics;
- FIG. 9 operating graphs of fan and heater during a convection heating phase;
- FIG. 10 a further schematic layout of a convection fan controller;
- FIG. 11 graphs of operational parameters in a pulse width modulation operational mode of the fan; and
- FIG. 12 graphs of operational parameters in a pulse frequency modulation operational mode;

[0045] FIG. 1 shows a sectional top view of a baking or cooking oven 1. The cooking oven 1 may be a conventional electric baking or cooking oven, but may in embodiments also be implemented as a microwave oven and similar, respectively provided with a forced convection operational mode.

[0046] The cooking oven comprises an outer casing 2 defining therein a cooking chamber 3. In the present figure, a baking tray 4 is accommodated in the cooking chamber 3 having thereon a cake dough intended to be baked with the cooking oven 1.

[0047] At a rear wall 5 of the cooking chamber 3 a convection fan unit 6 is arranged. The convection fan unit 6 comprises a casing 7 attached to the rear wall 5. Further, the convection fan unit 6 comprises a convection fan 8 accommodated within the casing 7.

[0048] The convection fan unit may further comprise a fan controller (not shown) adapted to operate the cooking oven in a forced air convection cooking or baking mode. Such operation procedures are generally known and a basic description thereof is omitted.

[0049] However, in the forced air convection operational modes, air is circulated within the cooking chamber in order to uniquely distribute the heat generated by a heating element (not shown) within the cooking chamber 3.

[0050] The convection fan 8 and the casing 7 are implemented and adapted to each other such that the convection fan 8 can suck in air at an input port 9 arranged in the present embodiment in the center of the rear wall 5.

[0051] Exhaustion ports 10 of the casing 7 are provided at bevelled lateral edges 11 of the casing 7. The bevelled lateral edges 11 in the present case run vertically, wherein the exhaustion ports 10 are arranged and adapted such that air blown out from the casing 7 is directed laterally outwards with a frontward component in order to impinge a respective side wall of the cooking chamber 3.

[0052] The exhaustion ports 10 in particular are adapted and arranged such that the exhausted airflow has a velocity component not only towards a respective side

wall, but also towards the front side or wall, i.e. front door 12, of the cooking chamber 3.

[0053] The fan controller is adapted to operate the air convection fan 8 during a forced air convection cooking phase of the cooking oven 1 such that the convection fan 8 in at least one forced convection operational phase is operated such that the rotary speed of the convection fan 8 uniformly and continuously oscillates between periods of increasing and decreasing rotary speed.

[0054] Such operational modes will be explained in more details further below. However, the proposed operational mode is adequate for obtaining optimized, and as compared to conventional convection cooking improved, heat transfer between the heating element and the item to be cooked or baked, in particular the cake dough.

[0055] The optimized and improved heat transfer in particular is obtained for the reason that the airflow pathway within the cooking chamber 3 is not static but rather varies and changes dynamically over time. This is indicated in FIG. 1 by a number of dashed arrows, respectively starting at the exhaustion ports 10 and leading to the input port 9. Each of the dotted arrowed lines is representative of a main bulk airflow of one of different airflow patterns generated by the convection fan 8.

[0056] As can be seen from FIG. 1, a variety of different airflow pathways, in particular main bulk airflow pathways or patterns, during forced air convection cooking can be obtained by steadily and continuously oscillating the rotary speed of the convection fan 8. This variation in airflow pattern in the end leads to improved cooking and baking results.

[0057] Note, that air exhausted from the convection fan 8 in some of the airflow patterns strikes the sidewalls and front wall before returning to the input port 9.

[0058] FIG. 2 shows a graph of the rotary speed RPM of the convection fan 8 over time. As can be deduced from FIG. 2, the rotary speed RPM continuously alternates between increasing and decreasing phases, without any plateaus and steps of constant rotary speed. The rotary speed therefore is a stepless, continuously and steadily changing function of time. By this, respective alternating or changing airflow patterns within the cooking chamber 3 can be obtained which leads to improved cooking and baking results.

[0059] The steady, continuous and stepless as well as plateau-free time course of the rotary speed goes along with the fact that the convection fan 8, in particular a fan blade or fan blades thereof, is constantly accelerated and decelerated without any time intervals of zero acceleration. Only singular points of zero acceleration occur, where the movement pattern of the convection fan 7 changes from increasing rotary speed RPM to decreasing rotary speed RPM. This in particular can be seen from FIG. 3 showing a graph of the convection fan acceleration ($\delta v/\delta t$) over time during the forced air convection cooking phase.

[0060] It can be seen from FIG. 2, that, except an initial

pre-heating phase P, a mean value or average, or trend T of the rotary speed RPM in the present case is constant over time, i.e. runs parallel to the abscissa. Note that this is just an option to operate the convection fan 7 to obtain at least in a main cooking phase a linear and constant trend T of the rotary speed RPM. Other examples are possible and some will be explained further below.

[0061] FIG. 4 shows a schematic layout of a convection fan controller 13 of the cooking oven 1. The convection fan controller 13 is coupled to an oven switch 14 for activation. The controller 13 comprises a pulse generator 15 for generating a pulsed operating voltage signal for operating the convection fan 8. The pulsed operating voltage signal is supplied to the fan motor 16 via an electronic key 15.1. The electronic key 15.1 in particular may be adapted to transform pulse-width-modulated or pulse-phase-modulated input signals generated by a pulse generator into corresponding power supply signals to the fan motor 16.

[0062] By using such a layout of the convection fan controller 13, an operational mode in which the rotary speed continuously and steadily oscillates between increasing and decreasing phases is possible. An example of corresponding operational parameters of such a pulsed operation are shown in FIG. 5 and FIG. 6.

[0063] FIG. 5 shows a graph of the power supply voltage V for the convection fan 8 in the pulsed operational mode, while FIG. 6 shows a graph of the rotary speed RPM of the convection fan 8 operated according to the supply voltage indicated in FIG. 5.

[0064] The supply voltage as shown in FIG. 5 comprises single voltage pulses VP1, VP2, VP3, VP4 and so on, output respectively in a corresponding period W1, W2, W3, W4 The pulses VP and Periods W in the present example are equal to each other, i.e. are identical. This means, that the lengths of the periods W are the same, and that the lengths of the pulses VP are the same, in particular the duty cycles of the periods do not change.

[0065] FIG. 6 shows the graph of the convection fan speed RPM operated with the pulsed supply voltage of FIG. 5. Each pulse W causes the rotary speed RPM of the convection fan 8 to increase, whereas in the pulseless phase of each period W the rotary speed of the convection fan 8 decreases, in particular due to friction and inertia, wherein the graph of the rotary speed RPM represents a continuous and steady function of time.

[0066] In a steady state condition of the convection fan operation, which essentially corresponds to the situation in FIG. 5 and FIG. 6, the rotary speed RPM continuously or alternately oscillates between an upper rotary speed limit RPM(U) and a lower rotary speed limit RPM(L).

[0067] The upper rotary speed limit RPM(U) and lower rotary speed limit RPM(L) in the present case are constant respectively, and in particular can be described by a respective linear envelope running parallel to the abscissa.

[0068] As an overall movement pattern of the convection fan 8 in the operational mode according to FIG. 5,

the rotary speed RPM of the convection fan 8 follows or makes up a sinusoidal curve, which of course is continuous, steady, stepfree and does not contain any plateaus. In particular sinusoidal rotary speed curves are appropriate for obtaining favourable dynamic airflow patterns within the cooking chamber, in order to obtain uniform heat distribution and cooking results.

[0069] FIG. 7 shows an electric diagram of a first variant of oven electronics. A first electronic block 17 comprises a heater 17.1, an alternating voltage power supply 17.2, and a thermostat 17.3.

[0070] The first electronic block 17 is adapted and configured in order to thermostat controlled heating the cooking chamber 3. If the thermostat 17.3 detects a temperature that is below a given threshold the heater 17.1 powered by the power supply 17.2 will be activated and heat can be supplied to the cooking chamber 3, in particular via the convection fan 3. If the thermostat 17.3 detects a temperature above an upper threshold, the heater 17.1 will be disconnected from the power supply 17.2 in order to avoid overtemperatures within the cooking chamber.

[0071] A second electronic block 18 of the first variant of oven electronics comprises a pulse generation unit 18.1, an oven switch 18.2, and an electronic switch 18.3. In operation, the second electronic block generates a pulsed power signal with a frequency ω_1 and supplies the pulsed power signal to the fan motor 16, in such a way that the fan motor 16 operates in a fashion as described above, i.e. that the rotary speed RPM of the convection fan 8 continuously and steadily increases and decreases without any plateaus or intervals of constant rotary speed.

[0072] The oven switch 18.2 in particular makes electrical connections between several components of the oven. In the present example, the oven switch is, for sake of simplicity, implemented as a simple switch. The oven switch 18.2 as shown in the figure in particular may be adapted to close an electrical circuit that creates conditions to power the hole assembly to operate the oven in a dynamic forced air convection.

[0073] FIG. 8 shows an electric diagram of a second variant of oven electronics. The second variant is similar to the first variant, and also comprises a first electronic block 17 and a second electronic block 18.

[0074] The first and second electronic blocks 17 and 18 differ from that of FIG. 7 in that the first electronic block in the second variant additionally comprises a relay 18.4 adapted to switch the pulse generator 18.1 between a first pulse frequency ω_1 and a second pulse frequency ω_2 . Here, a further difference between the first and second variant becomes obvious, viz, the pulse generator 18.1 in the second variant is adapted to generate pulsed power supply signals of different pulse frequencies ω_1 and ω_2 , instead of using just a single pulse frequency.

[0075] The difference in operation of the second variant relative to the first variant may exemplarily be extracted from FIG. 9, showing operating graphs of convection fan 8 and heater 17.1 when operated with a controller

implemented according to the electric diagram in FIG. 8.

[0076] Regarding the heater activity shown in the lower graph of FIG. 9 it can be seen that the heater is switched by the thermostat between on (1) and off states (0). The operation of the heater, depicted in FIG. 9 in an idealized manner, can be described by a stepwise constant function alternating repeatedly between an on and off state.

[0077] Coupling of the heater 17.1 via the relay 18.4 with the pulse generator 18.1 in the present case is such, that in the on state of the heater 17.1, the pulse generator 18.1 generates a power supply voltage with the second frequency ω_2 , while in the off state the pulse generator 18.1 generates a power supply voltage with the first frequency ω_1 .

[0078] Such an operation leads to a yet more dynamic variation of the airflow pattern within the cooking chamber 3. A corresponding course of the rotary speed RPM of the fan motor 16 can be seen in the upper graph in FIG. 9. Also in this case, the rotary speed RPM of the convection fan 8 continuously and steadily varies or oscillates without showing any plateaus.

[0079] It shall be mentioned, that the trend T of the rotary speed, in particular the average value of the rotary speed RPM of the convection fan 8 in the present case has a sinusoidal shape. Similarly, the upper and lower envelopes of the rotary speed values have a sinusoidal shape. However, in the present case the distance between the upper envelope and lower envelope of the rotary speed signal changes with time, which is due to the frequency variation of the pulsed power supply.

[0080] FIG. 10 shows a further schematic layout of a convection fan controller 13. From FIG. 10 it can be seen, that the controller may comprise a PWM module 20, i.e. a pulse width modulation module, and/or a PFM module 21, i.e. a pulse frequency modulation module. In FIG. 10, both modules are shown; however, the controller may comprise either the PWM module 20 or the PFM module 21, or the controller may comprise both the PWM and PFM module.

[0081] Using the PWM module 20, the controller can generate a pulsed power signal for the convection fan 8 in form of a pulse width modulated signal. Using the PFM module 21, the controller can generate a pulsed power signal for the convection fan 8 in form of a pulse frequency modulated signal. Note that also PPM modules may be used, i.e. pulse phase modulation modules.

[0082] It is possible to use a combination of PWM and PFM, in which case an exponential or a logarithmic variation of the rotary speed of the convection fan 8 may be obtained.

[0083] As can in particular be seen from the different possibilities described so far, the proposed control method allows a great variety of different operational modes and configurations leading in each case to specific convection fan 8 operational modes and corresponding airflow patterns within the cooking chamber 3.

[0084] The great variety in generating specific airflow patterns makes it possible to specifically adapt the oper-

ational mode of the convection fan 8 in forced convection operational cycles to a variety of different conditions prevailing within the cooking chamber 3, such for example the number of trays, number of objects within cooking chamber, size of product, temperature, moisture, and so on.

[0085] FIG. 11 exemplarily shows graphs of operational parameters in a PWM operational mode of the convection fan 8. The upper graph shows exemplary single voltage pulses VP1 to VP 4 in respective periods W1 to W4. The length of the voltage pulses in FIG. 11 increases from voltage pulse VP1 to VP 4. The periods W1 to W4 have the equal length, and therefore the duty cycle increases.

[0086] The lower graph in FIG. 11 shows the rotary speed of the convection fan 8 over time as operated in PWM mode according to the upper graph in FIG. 11. As the pulse width of the supply voltage gradually increases (see upper graph in FIG. 11), the average value, i.e. the trend T, of the rotary speed RPM of the convection fan 8 also increases.

[0087] In the present example, the trend T increases in accordance with a linear relationship over time. In each period W, the convection fan 8 first accelerates and then decelerates. Relative to the average value, i.e. the trend T, the rotary speed RPM of the convection fan 8 has a sinusoidal form.

[0088] The pulse width modulation in the present case is implemented such that a difference between successive wave crests 22 and wave troughs 23 essentially is constant. This in particular may mean that the upper and lower envelopes RPM(U) and RPM(L) essentially are parallel to each other and to the trend T.

[0089] FIG. 12 shows graphs of operational parameters in a pulse frequency modulation PFM operational mode of the convection fan 8. The upper graph in FIG. 12 shows exemplary single voltage pulses VP1 to VP4 in respective periods W1 to W4. The length of the voltage pulses in FIG. 12 increases from voltage pulse VP1 to VP 4, which is similar to the situation in FIG. 11. However, the periods W1 to W4 have, in contrast to the situation in FIG. 11, increasing lengths, in particular such that the duty cycle remains constant.

[0090] The lower graph in FIG. 12 shows the rotary speed of the convection fan 8 over time as operated in PFM mode according to the upper graph in FIG. 12. In the present situation, the pulse frequency of the supply voltage decreases while the pulse length increases (see upper graph in FIG. 12).

[0091] The pulse phase modulation PFM in the example of FIG. 12 is adapted such that the average value, i.e. the trend T, of the rotary speed RPM of the convection fan 8 increases according to a linear function of time. The difference to the situation in FIG. 11 is that the lower envelope RPM(L) of the rotary speed RPM remains constant while the upper envelope RPM(U) of the rotary speed RPM increases linear with time. In this constitution, the difference between wave crests 22 and wave

troughs 23 increases with time.

[0092] Similar to the situation in FIG. 11, the convection fan 8 in each period W first accelerates and then decelerates. The rotary speed RPM of the convection fan 8 has a sinusoidal form with increasing amplitude. As the rotary speed values over time are different from the situation in FIG. 11, the operation according to FIG. 12 leads to a different airflow pattern as compared to the situation in FIG. 11.

[0093] It shall be noted, that the situations in FIG. 11 and FIG. 12 are exemplary operational modes in accordance with the invention as proposed herein. Clearly, the graphs only show short sections of the overall operational forced convection operation, and a great variety of different possibilities and rotary speed graphs or forms can be generated by operating the cooking oven according to the invention.

[0094] As an example, in other operational phases, the trend T may be decreasing while the sinusoidal behaviour of the rotary speed RPM is maintained. With regard to the situation in FIG. 11, this would require to use pulses with decreasing length. With regard to the situation in FIG. 12 this would require to gradually reduce the lengths of the periods W.

[0095] Many other different operational modes are available for the invention as proposed herein, and the examples as given in the figures shall not be limiting for the scope of the invention.

[0096] In all, it should become clear, that the invention as proposed herein provides a solution for optimizing heat transfer between a heating unit and one or several cooking products placed in a corresponding cooking cavity of an oven.

[0097] Further information relating to the invention as proposed herein are given below.

[0098] One feature of the present invention is that the average fan speed profile may have different values during the entire cooking process without stagnation points. The invention may also represent an application of an active technique with respect to heat transfer enhancement within the cooking chamber by using or combining geometrical properties of the fan cover and/or oven cavity walls with the dynamic control of the fan operation.

[0099] The operational patterns, as possible with the proposed invention, make it possible to agitate in a turbulent way the hot air molecules within the oven cavity or enclosure, i.e. cooking chamber. In this way, the heat may be transferred from the heat generator with more efficiency as compared to conventional solutions.

[0100] In general, the proposed invention allows a great variety with respect to the trends of the rotary speed of the fan and the mean velocity, acceleration and/or deceleration profiles during a complete operational cycle.

[0101] The speed, acceleration and/or deceleration trend as well as the way or form of increase and decrease of the rotary speed can vary according to a desired cooking or baking program configuration which matches to a cooking mode or to a cooking function.

[0102] The speed, acceleration and/or deceleration of the convection fan 8 may have also a triangle shape, trapezoidal shape, saw teeth profile and so on; in particular a multitude of different geometrical configurations, even curved shapes and linear shapes or combinations thereof are possible.

[0103] The proposed invention allows a great dynamism of the airflow within the cooking chamber, i.e. oven cavity, wherein the airflow and airflow pattern at every second or time interval may have a different configuration by following different paths due to a multitude of fan speeds.

[0104] Operation of the convection fan may be conducted in repetitive cycles, wherein in 1 to n cycles, the rotary speed may be gradually increased and wherein in another n cycles, the rotary speed may be decreased again.

[0105] A respective one of the cycles may be finished as soon as the fan speed reaches a maximum limit or minimum limit for a given operating time, and the respective subsequent cycle may be conducted thereafter. This means that the cycles can be cyclically repeated until the end of the overall forced convection operational mode. Other modes are conceivable.

[0106] In any technical embodiment of the invention, the fan may be powered by using resistors in order to drop the voltage on its coil, and therefore reduce the fan speed or to regulate the fan power. In other solutions power switches such as thyristors, triacs or any other electronic device may be used, which serve as the electronic key in order to control the main phase for a power drop effect. All of these possibilities may be specifically selected in dependence of the circumstances in which the oven operates and is configured.

[0107] According to embodiments of the present invention and for the operational mode as proposed by the invention, the fan may be powered in any variant of these embodiments (only) with the effective voltage recommended by its manufacturer.

[0108] Usually for EU (European Union) the normative 230-240 Vac is used. However, the present invention does not exclude and is not limited in other applications by using different voltage values.

[0109] With the proposed invention it is not mandatory to provide special devices for specifically regulating the voltage of the fan and/or for adjusting the power on the fan coil, rather it may use the electronic keys in order to switch on or off the voltage of the fan.

[0110] The technical solution as proposed herein may also make use of the mechanical properties of the fan (shaded pole type) and of its impeller or wheel blade, where the oscillating effect occurs due to friction and the inertial forces accumulated within the fan axle during the "On" stage, when it is energized.

[0111] The wheel blade/s of the fan 8 may have a considerable weight, usually comprised between 90 grams and 110 grams, and a have large diameter, usually comprised between 150 mm and 180 mm.

[0112] The profile of the wheel blade preferably is of a "backward inclined" configuration, which has shown to give comparatively good results with respect to uniformly distributing the heat within the cooking chamber. This in particular is due to the fact that this type of blade enables a sliding effect during a comparatively long time after the fan was energized, i.e. during an off cycle of the fan motor.

[0113] The effective fan power may for example be between 19 W and 35 W, in particular depending on the impeller or wheel blade type other characteristics. According to the present invention it is possible that an additional weight is fixed on the fan impeller or wheel blade in order to reach the similar results as mentioned beforehand, in particular to obtain a favorable sliding effect.

[0114] As an example, an initial fan speed in the above mentioned example is comprised between 1200 RPM and 2000 RPM at room temperature, in particular between 18° C and 25° C, when is energized at the nominal voltage.

[0115] The operating mode of the fan motor may consist in powering its coil with pulses by 230 - 240 Vac (voltage alternating current) without the necessity to be synchronized with the main phase. However, the present invention doesn't exclude such a synchronized operating mode.

[0116] The pulses may be generated by using any suitable methods or electronic device. However, for a favourable efficiency for obtaining the desired effects it may be good to exactly control the fan by using for example the PWM method, the PFM method, or the PPM method or any combination thereof.

[0117] In PWM mode, the switching frequency is fixed and the varying duty cycle of the pulses controls the output time when the voltage is delivered to the fan. The duty cycle is defined as the "on" time of the pulse divided by the total pulse period.

[0118] In PFM mode, or similar in PPM mode, the switching frequency, or phase, respectively, varies, and the switching frequency is proportional to the output time when the pulse is "on". Therefore, the fan motor is energized with pulses by using a similar technique as the SMPS mode (switch mode power supply mode) but keeping a nominal value on its coil, or 230-240 Vac during the switching mode.

[0119] Just for giving some examples, pulses in pulsed operational modes may have period length in the range of 1 to 10 seconds, and duty cycles may be chosen to cover as large as possible pulse periods between 5% and 99%. Depending on the fan power and its wheel blade, in particular its weight, diameter, form and/or geometry, the periods may in embodiments vary between 1 second and 10 seconds or up to 20 seconds having a duty cycle range comprised between 5% and 99%.

[0120] When the convection fan operates with PWM pulses the duty cycle of the pulses may be responsible to the fan speed changes and its trend. This shall be explained by use of an example operation as given below.

[0121] Starting with an initial pulse, the fan blade is

accelerated and the rotary speed increases. During subsequent "off" times, the fan is not energized, and in this "off" times frictional and inertial forces accumulated in the fan impeller and wheel blade act, resulting in a decelerating motion. The decelerating motion or movement is kept until a following, subsequent pulse is applied to the fan.

[0122] The subsequent pulse in PWM mode has a larger pulse length and the fan is energized again during this given time and starts a new increase of its speed. After the subsequent pulse the fan rotary speed is greater than the previously RPM value from the previous pulse. This leads to an increasing effect on the fan rotary speed, which is continued until the rotary speed reaches a desired value. Thereafter the fan may be operated to in a declining profile, or may remain in a steady state with that last speed value of the PWM cycle.

[0123] In tests it could be observed, that a difference between upper rotary speed limits and lower rotary speed limits or thresholds should be kept between 10% and 45% from the maximum RPM value of the fan rotary speed under same operating conditions. Respective tests were performed at room temperature. For example, the values in terms of rotary speed may be between 200 RPM and 700 RPM for a motor fan which under normal operational conditions (wheel blade / counterweight) operates at 1500 RPM as maximum speed value.

[0124] In the following paragraphs, an example of a PFM or PPM mode is described. When the convection fan operates with PFM or PPM pulses the frequency of the pulses is responsive to the fan speed changes and its trend. This time the duty cycle remains constant as percentage of any given period and its value is responsible for the minimum fan rotary speed which gives the inferior threshold of the fan rotary speed.

[0125] Upon a first pulse, the fan is powered and it reaches a given rotary speed at the upper envelope. Thereafter, the fan is operated in the "off" time of the same period, in which the fan is not energized. In this "off" time, the inertial force accumulated into the fan impeller and wheel blade acts and causes the rotary speed to decrease until a subsequent pulse is applied to the fan. The subsequent pulse is issued with a larger period, i.e. with a lower frequency as compared to a former period, but with the same duty cycle, and the fan is energized again by the subsequent pulse duration and starts a new increase of its speed.

[0126] Because of the subsequent pulse being longer, the fan will be powered longer than in the previous stage with the effect that the subsequent upper rotary speed value of the fan is greater and that relative to the previous pulse. When the rotary speed falls again it will take a longer time than in the previous stage because of a larger pulse period, and the speed of the fan will reach the common lower rotary speed limit also after the subsequent pulse. The PFM algorithm as described beforehand in PFM mode may be repeated during a preset time period in order to reach desired average values of the fan rotary

speed.

[0127] Similar to the PWM mode, there may be a useful range of fan rotary speeds but also restrictions may apply. Further the frequency values may require careful selection in order to cover as large as possible a multitude of the fan rotary speeds, which in turn result in large airflow oscillation characteristics.

[0128] It shall be noted, that the duty cycle of the PFM or PPM mode shall be adjusted in such manner that the lower rotary speed limit or value is be above zero, which means that the rotary speed will have no plateaus of stagnation. Further, care should be taken to avoid that the upper rotary speed limit reaches or even exceeds the maximum speed value of the fan when it operates in the classical mode.

[0129] Tests showed that in PFM or PPM the range above 600 RPM as a lower rotary speed limit and 1200-1300 RPM as an upper rotary speed limit is adequate, effective and efficient. Note that the tests were performed at the room temperature. However, the rotary speed range is not limited to the previous mentioned values but should be kept between 40% and 80% from the maximum RPM value of the fan speed in the same operating conditions. These values in terms of speed may for example lie between 600 RPM and 1200 RPM for a motor fan which under normal load (wheel blade / counterweight) conditions operates at 1500 RPM as maximum speed value.

[0130] In addition to the above, it shall be noted, that

- the technical solution of the present invention can be combined with an operating mode of one or more heaters of the oven in order to operate different cooking modes or any other functions of the oven;
- the proposed solution can be a part of an operating algorithm of any kind of a cooking appliance;
- the proposed dynamic operating mode of the convection fan can be also in relationship with other parameters supplied by different sensors like the oven temperature, in which for reaching the maximum effects or the superior cooking efficiency, the oven temperature parameter can be an input for the fan control unit;
- the present invention also is not limited to the number of the fan motors which operate within an oven, the voltage supply value, the power, or to the operating sequences thereof.

[0131] Technical advantages and characteristics of the present invention in particular relate to:

- the dynamic control of the forced air convection, in particular to the characteristic of an oven in which the motor fan and technical procedure for the controlling of its speed is able to allow a high dynamism

of the airflow within the oven cavity, in particular to generate more than one airflow path or pattern;

- the technical procedure in which the convection fan is forced to operate with acceleration and deceleration during of given periods, or during an entire period of a cooking procedure.
- the technical procedure in which the convection fan may operate without rotary speed stagnation points;
- a cooking algorithm or electric, electronic or electro-mechanical device which takes account of the derivative function of the convection fan rotary speed, during its active or passive operational time
- the fact that time intervals in which the pulses are generated, in particular for 1 to 10 seconds, the corresponding duty cycle percentages, in particular ranges from 5% to 99%
- the speed oscillation ranges in which the airflow behavior within the oven cavity becomes more efficient (for PWM: the values between 200 RPM and 700 RPM; for PFM, or PPM: the values between 600 RPM and 1200 RPM)
- the threshold differences as percentages; for PWM: from 10% to 45% from the maximum RPM value of the motor fan; for PFM, or PPM: from 40% to 80% from the maximum RPM value of the motor fan;
- the associated speed trend, or the average of the trace of the speed, which can be lead to different geometrical shapes, like a triangle, saw teeth profile, sinusoidal, or a polynomial shape, wherein the shapes may be created by controlling the fan motor with acceleration and deceleration during a given period, or during the entire period of cooking performance.
- an enhanced oven performance due to the new concept of operation of the convection fan;
- a considerable range of energy saving possibilities, where the efficiency enhancement may be between 30 Wh and 70 Wh;
- the dynamic control of the forced air convection may open the way to new, yet unknown operating algorithms of the electric ovens.

List of reference numerals

[0132]

- 1 cooking oven

2 outer casing
 3 cooking chamber
 4 baking tray
 5 rear wall
 6 convection fan unit
 7 casing
 8 convection fan
 9 input port
 10 exhaustion port
 11 lateral edges
 12 front door
 13 convection fan controller
 14 oven switch
 15 pulse generator
 15.1 electronic key
 16 fan motor
 17 first electronic block
 17.1 heater
 17.2 power supply
 17.3 thermostat
 18 second electronic block
 18.1 pulse generator
 18.2 oven switch
 18.3 electronic switch
 18.4 relay
 19 fan power supply
 20 PWM module
 21 PFM module
 22 wave crest

23 wave trough
 RPM rotary speed
 5 RPM(U) upper rotary speed limit
 RPM(L) lower rotary speed limit
 P pre-heating phase
 10 T trend
 V supply voltage
 15 VP voltage pulse
 W Period
 ω frequency
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Claims

1. Method of operating an air convection fan (8) during a forced air convection cooking phase of a cooking oven (1), wherein the convection fan (8) in at least one forced convection operational phase is operated such that the rotary speed of the fan (8) uniformly and continuously oscillates between periods of increasing and decreasing rotary speed (RPM) .
2. Method according to claim 1, wherein the fan (8) is operated such that the rotary speed (RPM) has a sinusoidal shape relative to its average speed (T).
3. Method according to one of claims 1 or 2, wherein the fan (8) is controlled such that the rotary speed (RPM) oscillates between upper (RPM(U)) and lower limits (RPM(L)), wherein at least one of the upper and lower limit (RPM(U), RPM(L)) changes over time according to a predefined course.
4. Method according to claim 3, wherein at least one of the lower limits (RPM(L)) and upper limits (RPM(U)) span a lower or upper envelope, respectively, for the rotary speed (RPM), wherein at least one of the upper and lower envelope at least in sections has a linear or curved, in particular sinusoidal and/or pulsating, shape, in particular with an increasing, decreasing and/or constant trend (T).
5. Method according to claim 3 or 4, wherein a rotary speed difference between upper and lower limits (RPM(U), RPM(L)) is constant over time.
6. Method according to 3 or 4, wherein a rotary speed difference between upper and lower limits (RPM(U), RPM(L)) has a pulsative, in particular sinusoidal,

course over time.

7. Method according to at least one of claims 1 to 6, wherein the convection fan (8) is controlled such that the temporal average (T) of the rotary speed (RPM) at least in subsections of the forced convection operational phase has a linear or curved, in particular sinusoidal and/or pulsating, shape, in particular with an increasing, decreasing or constant trend (T).

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8. Method according to at least one of claims 1 to 7, wherein for obtaining a rotary speed time course according to at least one of claims 1 to 7, at least a signal component of the power supply signal for powering the convection fan (8) is a pluse width modulated (PWM), pulse frequency modulated (PFM) and/or pulse phase modulated (PPM) power signal.

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9. Method according to at least one of claims 1 to 8, wherein oscillation of the rotary speed of the fan (8) is correlated with a heating power cycle of a convection heating element (17.1) of the cooking oven (1).

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10. Method according to at least one of claims 1 to 9, wherein the convection fan (8) is operated according to a time course of at least one of claims 1 to 9 in order to obtain, during the forced convection operational phase, a dynamically changing, in particular repetitive, airflow pattern within a cooking chamber (3) of the cooking oven (1).

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11. Controller unit (18) configured for controlling at least one convection fan (8) of a cooking oven (1) during a forced air convection cooking phase, wherein the controller (18) is adapted to generate control signals to operate the convection fan (8) according to at least one of claims 1 to 10.

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12. Cooking oven (1) comprising a cooking chamber (3) and a convection fan (8) adapted to circulate air within the cooking chamber (3), wherein the cooking oven (1) comprises a controller unit (18) according to claim 11 adapted for operating the cooking oven (1) in a forced convection cooking phase or mode.

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13. Cooking oven (1) according to claim 12, wherein the convection fan (8) is positioned at a vertical rear wall (5) of the cooking chamber (3), and wherein air outlets (10) of a fan casing (7), adapted to specifically control the exhaustion of convection air into the cooking chamber (3), are positioned and oriented to generate an output airflow directed laterally frontwards.

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FIG 1

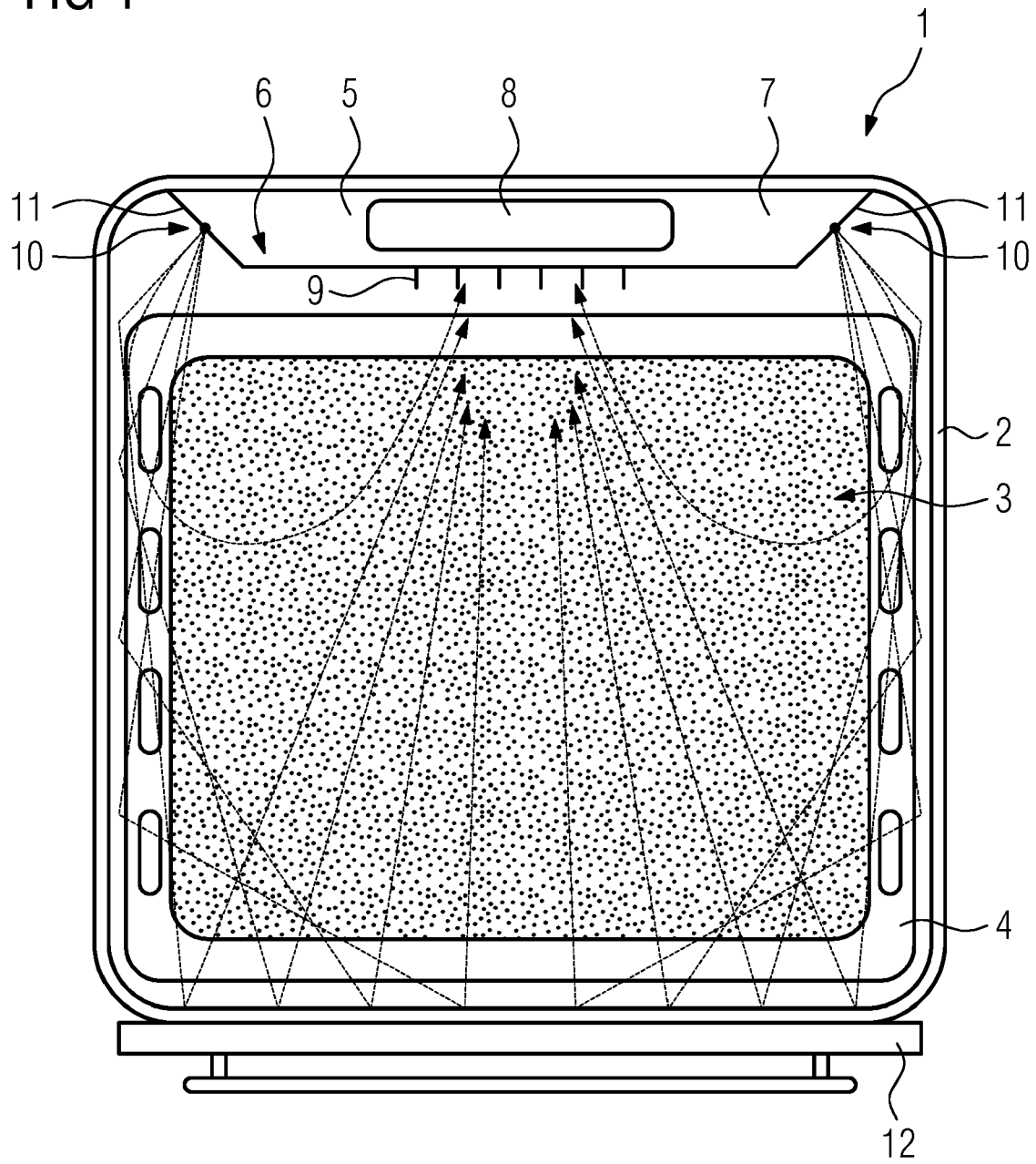


FIG 2

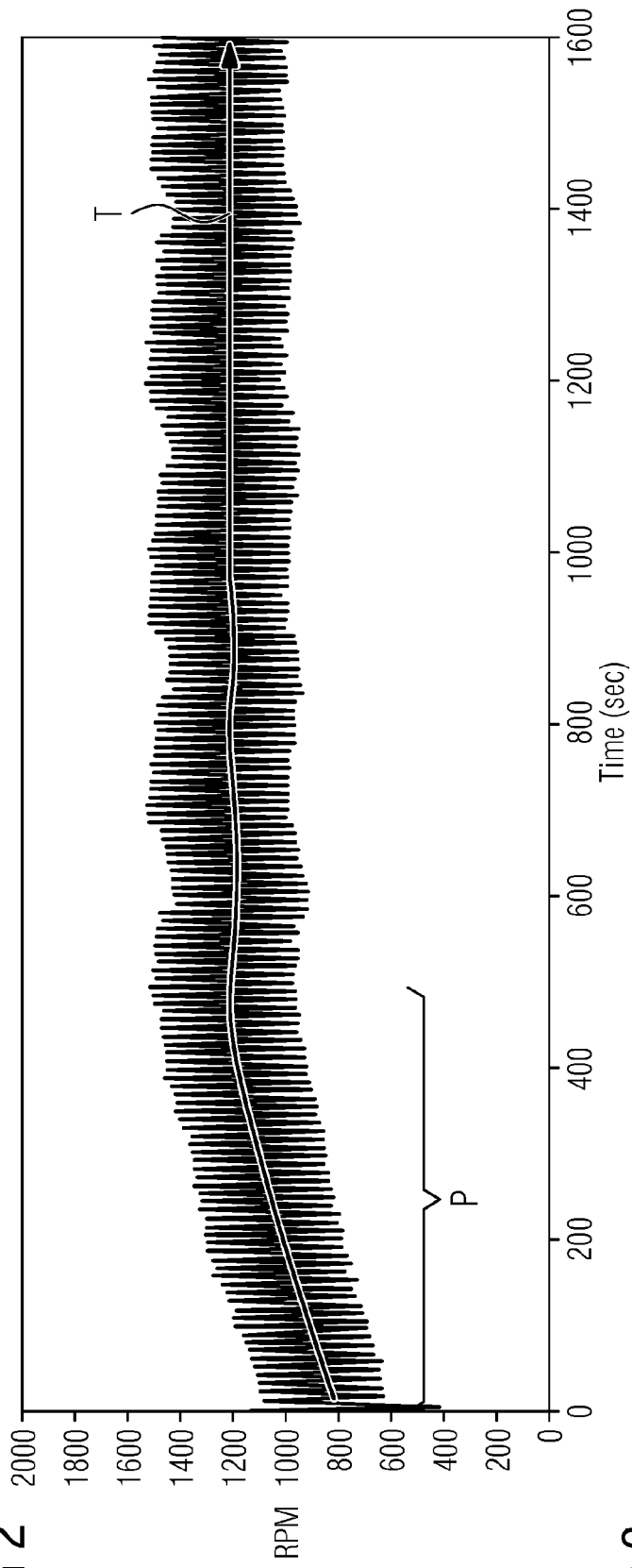


FIG 3

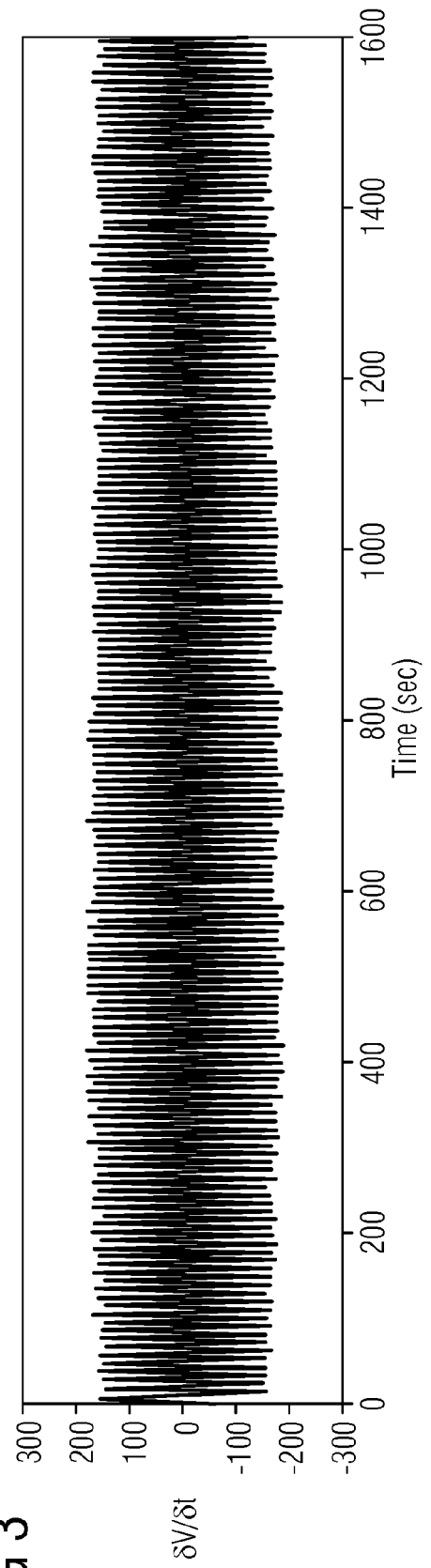


FIG 4

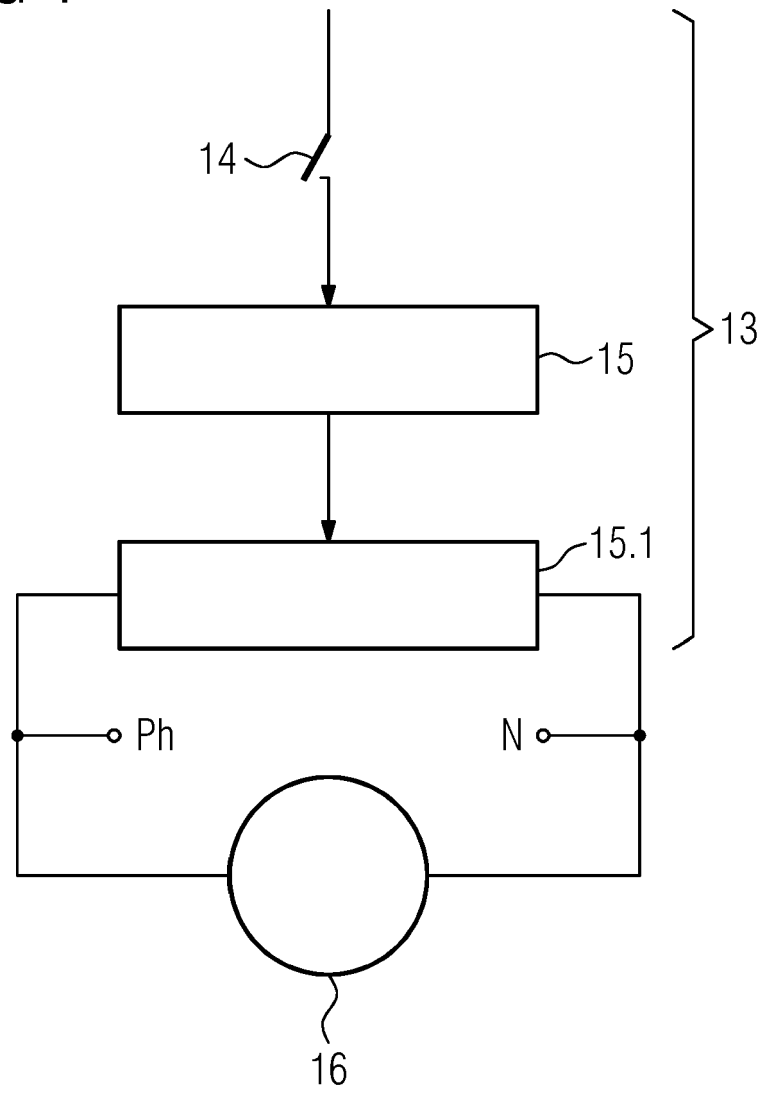


FIG 5

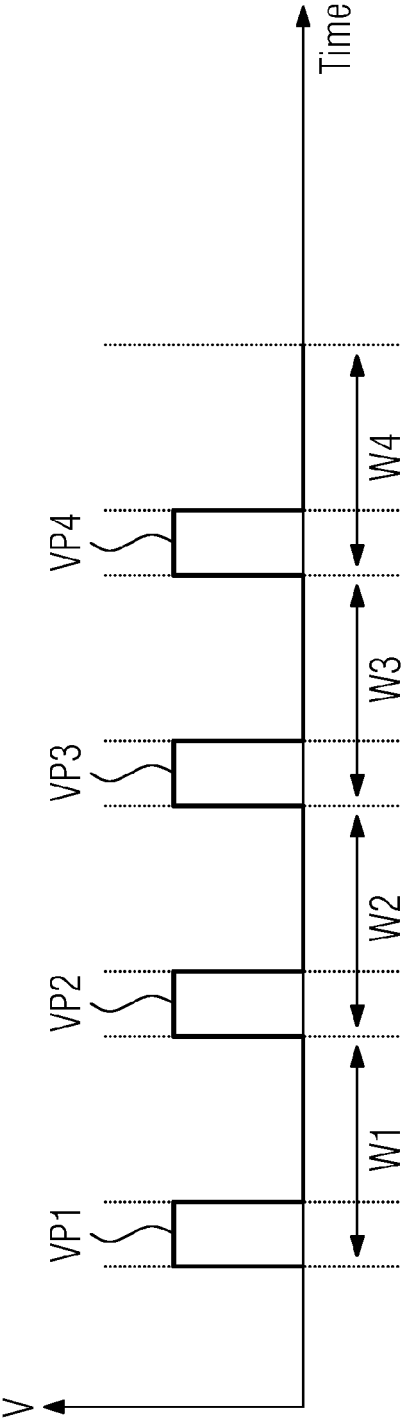


FIG 6

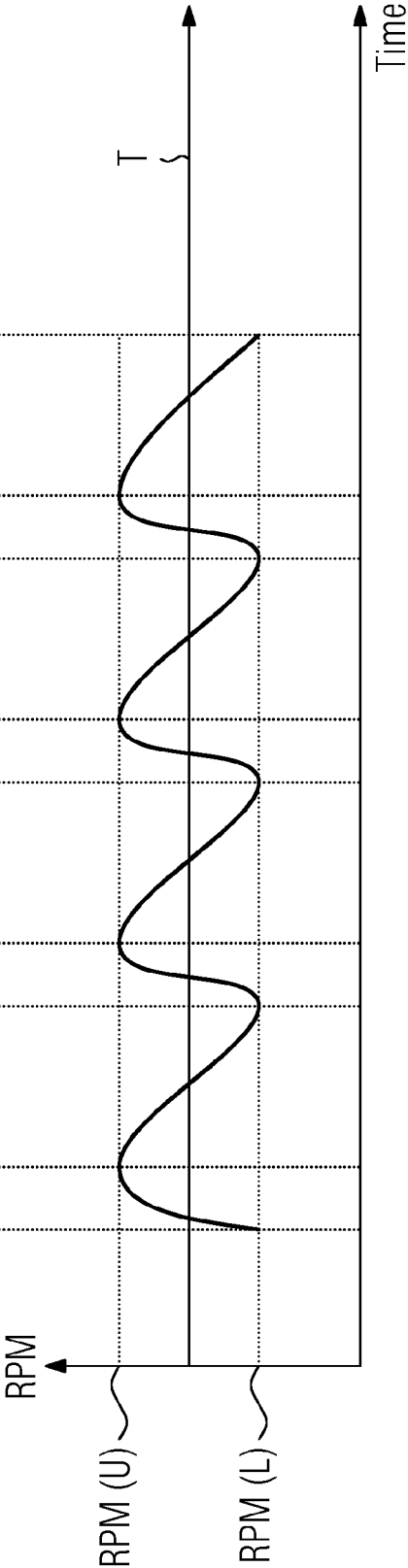


FIG 7

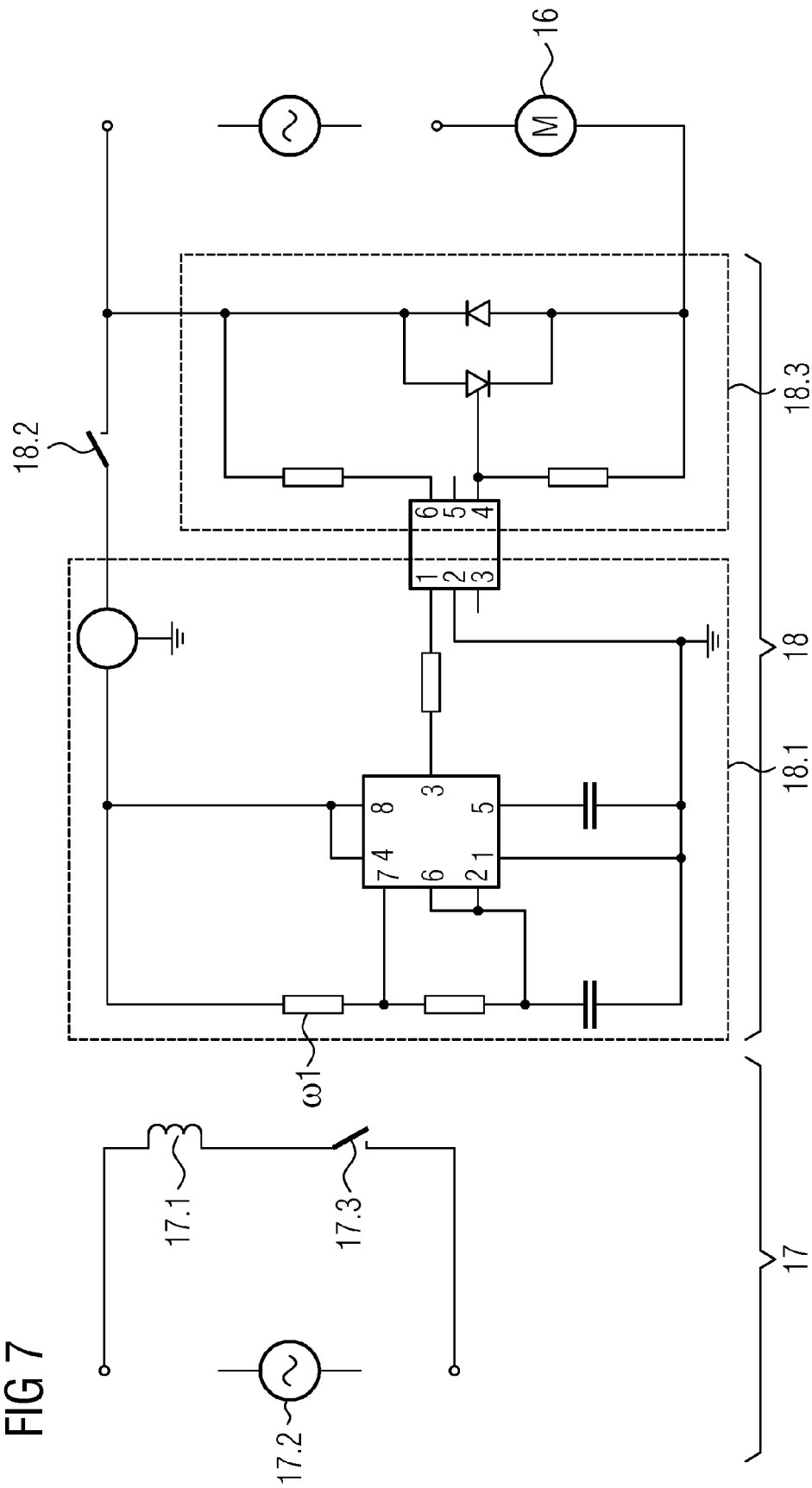


FIG 8

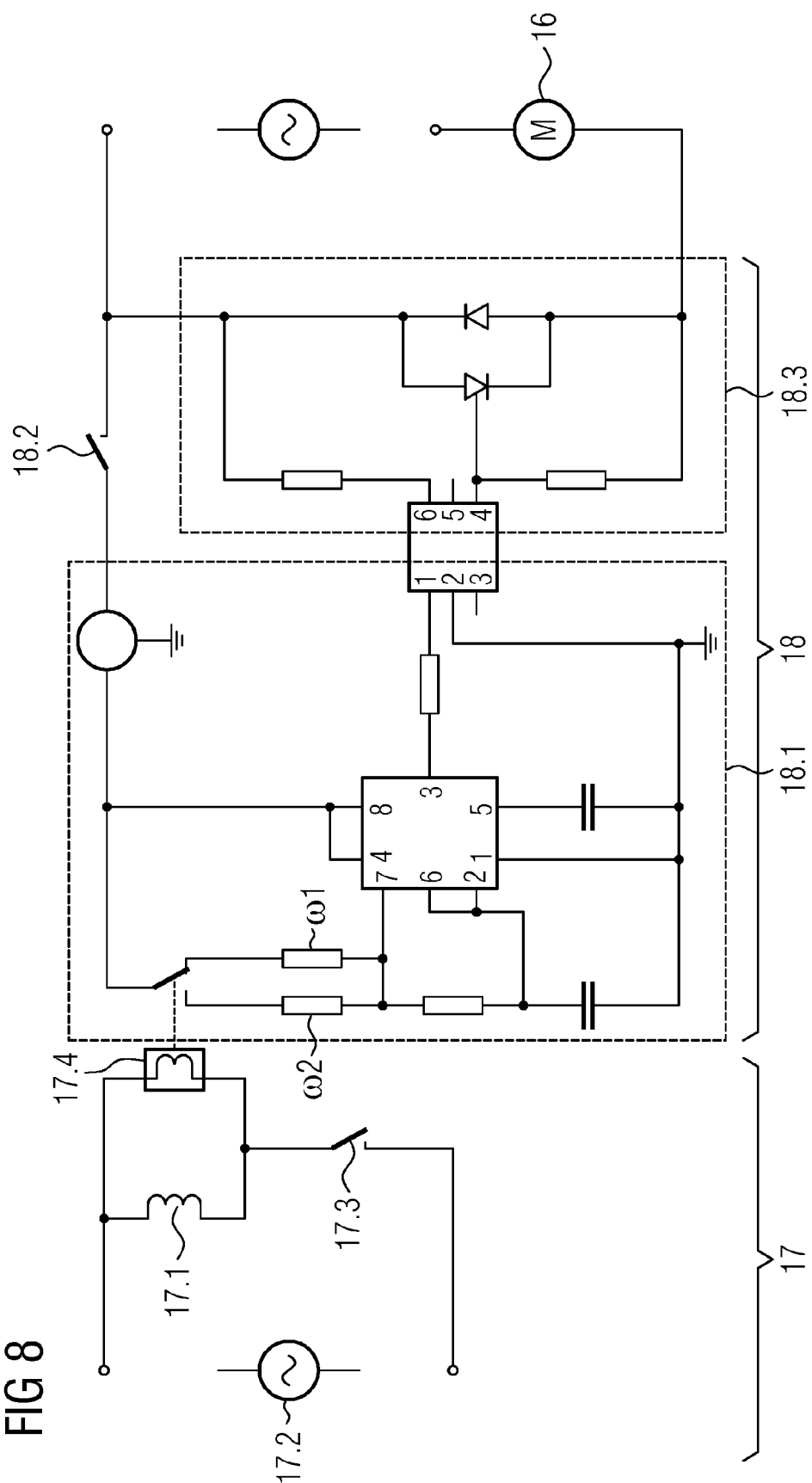


FIG 9

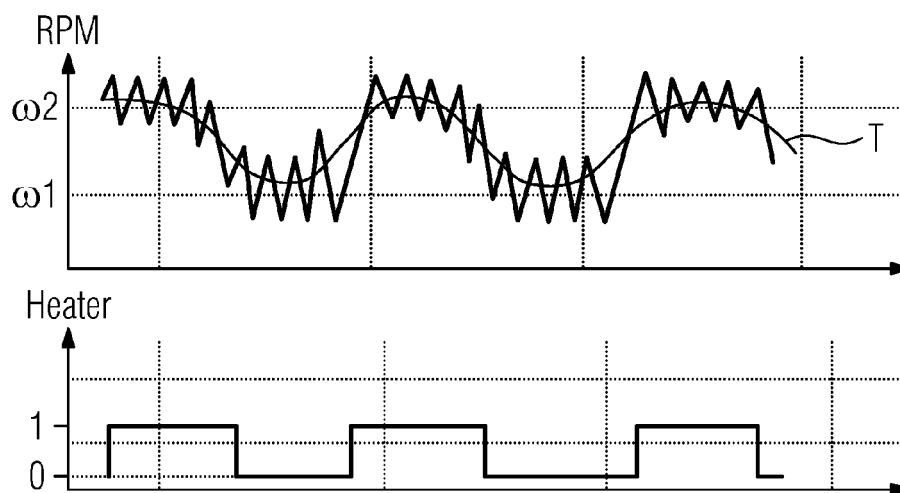


FIG 10

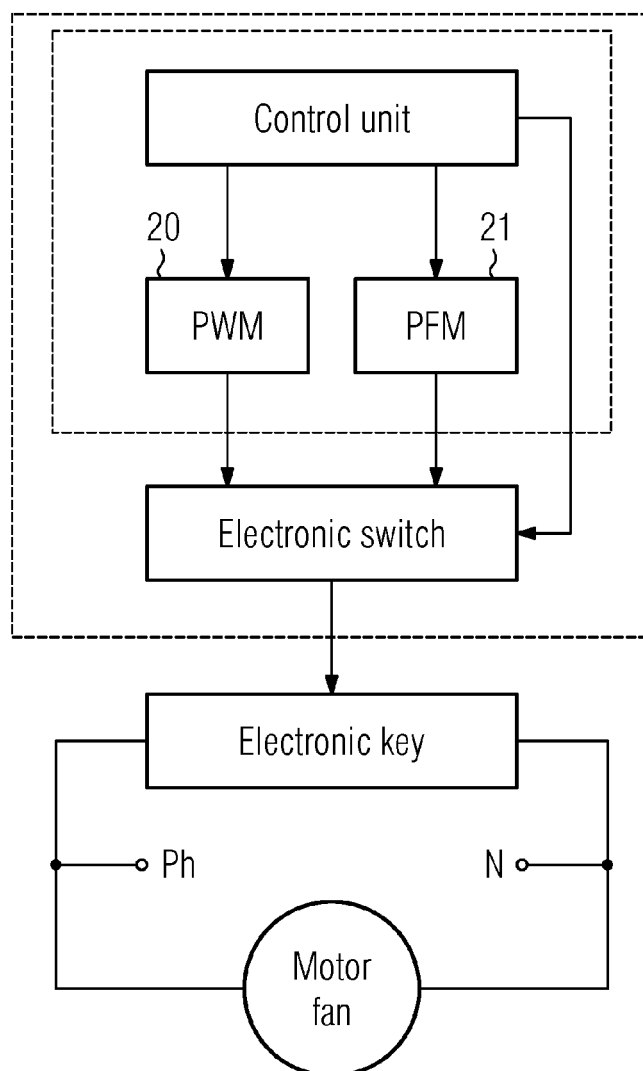


FIG 11

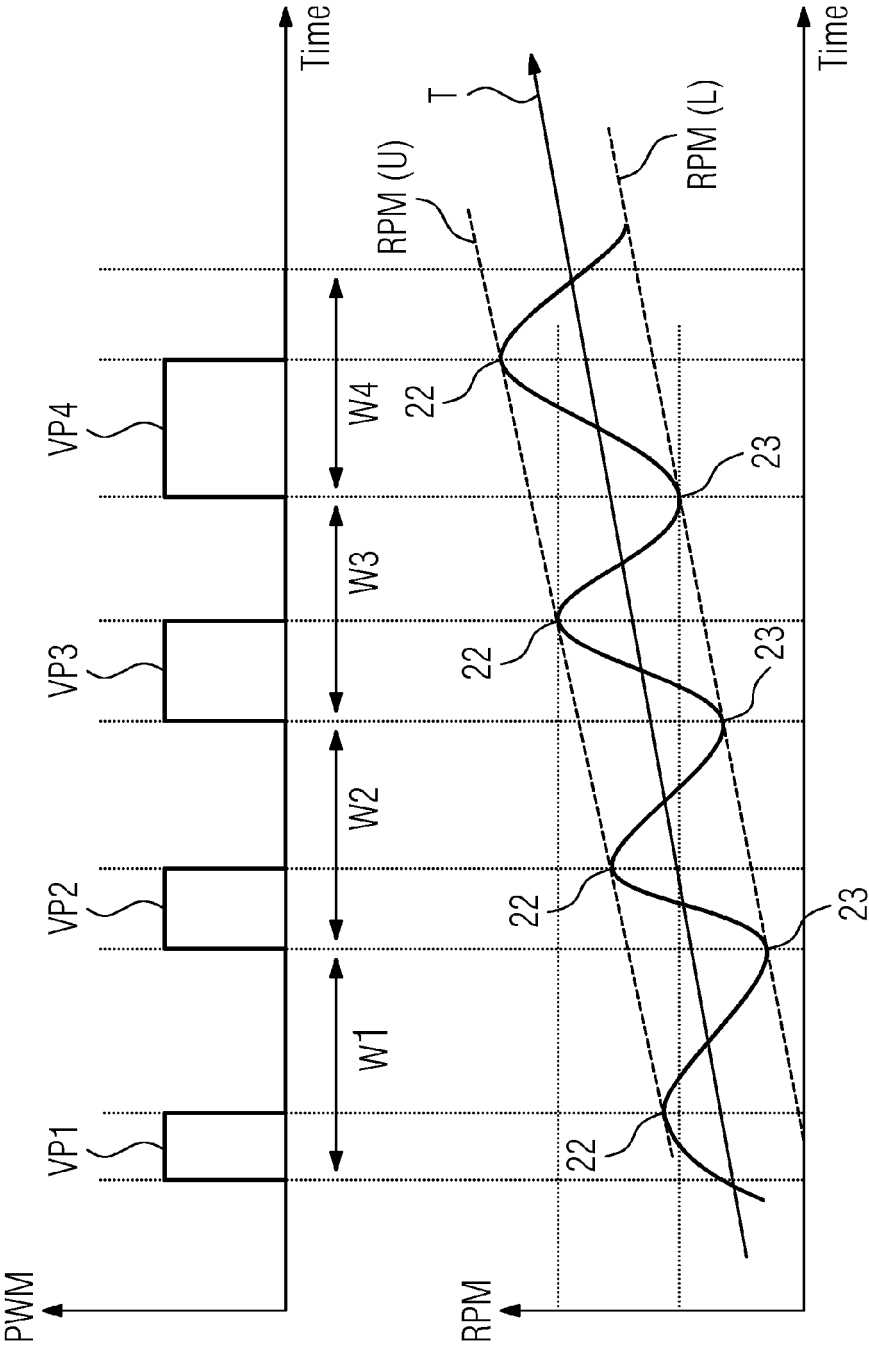
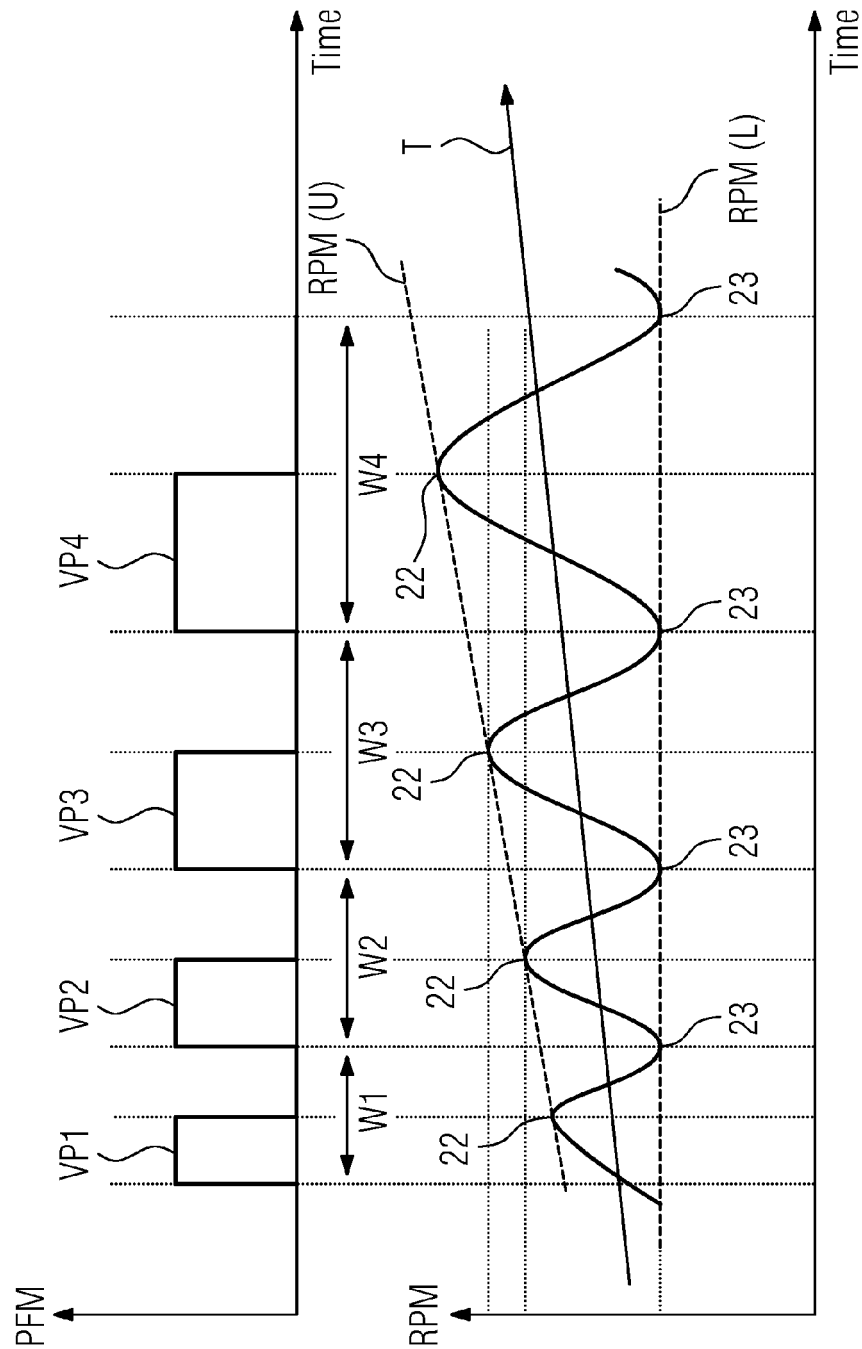


FIG 12





EUROPEAN SEARCH REPORT

Application Number
EP 14 15 1512

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Place of search The Hague		Date of completion of the search 2 June 2014	Examiner Rodriguez, Alexander
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