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Field of the invention

5 The invention relates to a microwave oven with a magnetron comprising a cathode, an anode and a cathode heating and with a controller circuit for the magnetron. The invention also relates to a method for operating such a microwave oven.

Background

10 Normally, a microwave oven has a transformer with two secondary windings. The one secondary winding serves to drive the cathode heating of the magnetron while the other secondary winding is used for generating the high voltage between the cathode and the anode. If such a device is active, an alternating voltage is applied to the transformer on its primary. The result of this is that the high voltage is present before the cathode has reached a temperature of operation, thus leading to a badly controlled switch on process. Particularly, the voltage across the magnetron is very excessive before firing, such that the respective components have to be dimensioned with an excessive dielectric rigidity.

25 US 4 742 442 describes a device in which the driving circuit has a heating current generator which can be switched on separately from the high voltage generator. Particularly, two separate transformers for the heating current and the high voltage are provided. After activating the device, an alternating voltage is applied to the heating current transformer in order to heat up the cathode. After a certain time, e.g. five seconds, also an alternating voltage is subsequently generated for the high voltage transformer, such that the high voltage is applied to the magnetron only after pre-

heating the cathode. The disadvantage of this solution is the additional time necessary for preheating and which may delay the switching on procedure of the device.

US 4 825 028 describes a device in case of
5 which the magnetron is charged with low high voltage during preheating of the cathode, while the current through the heating is measured. When a threshold current is reached, preheating is terminated and the voltage applied to the magnetron is increased.

10

Description of the invention

It is therefore the objective of the invention to provide a microwave oven and a method of the
15 type mentioned at the beginning, in case of which a fast yet controlled switching on procedure is made possible. This objective is met by the subject matter of the independent claims.

According to this, the driving circuit of the
20 magnetron has a high voltage generator for generating the high voltage between the anode and the cathode, as known, as well as a heating current generator for generating the heating current for the cathode heating. Furthermore, a controller is provided, which controls these components.
25 The controller is adapted in such a way that for activating the device (i.e. for switching on the magnetron) first the heating current generator is activated. Only later (i.e. after activating the heating current generator) the high voltage generator is
30 activated. In this way, as described above, a defined switching on procedure is reached.

Furthermore, a measurement circuit is provided, which is adapted to determine a parameter depending on the electric resistance of the cathode
35 heating. The controller is adapted to set the switching on instant (i.e. the instant of activation) of the high voltage generator depending on said parameter. In other

words, the instant of activation of the high voltage generator is a function of the measured parameter and changes depending on how the parameter varies.

Consequently, the invention also relates to a method for operating a microwave oven, wherein the microwave oven has a magnetron having a cathode, an anode and a cathode heating. For activating the microwave oven, at least the following steps are carried out in the method:

10 (A) Generating the heating current through the cathode heating. This is done during a preheating phase during a preheating duration.

(B) Only after termination of the preheating phase, applying a high voltage between the anode and the cathode.

15 Additionally, a parameter depending on the electric resistance of the cathode heating is measured, and the preheating duration, i.e. the instant when the high voltage is applied between cathode and anode, is determined depending on said parameter.

20 The invention is based on the recognition that the resistance of the cathode heating depends on the temperature of the cathode heating. By now measuring a parameter depending on the resistance, it is hence possible to determine a measure for the cathode temperature. This makes it possible to choose the preheating duration depending on the cathode temperature, wherein this creates the basis for switching on the high voltage when a sufficient cathode temperature has been reached. In this way, it is possible to reduce the preheating duration if the initial cathode temperature is already relatively high. Additionally, the switching on of the high voltage can be done when the cathode temperature is well defined, such that a precisely defined behaviour and an initial oscillation of the magnetron are made possible with very high probability.

Furthermore, a power controller is provided, being adapted to regulate the power absorbed by the cathode heating to a target value. In this case, the controller is adapted to regulate the heating power
5 during the preheating phase to a prescribed, particularly fixed, first target value. This has the advantage, as compared to a constant heating voltage or a constant heating current, that the power absorption is not too high - because the cathode heating has a lower resistance
10 at low temperatures than at high temperatures, it would otherwise be possible that in case of a cold cathode an excessive power absorption and consequently damage of the components occurs.

Advantageously, in this case, after
15 termination of the preheating phase, the heating power is reduced to a prescribed, particularly fixed, second (lower) target value, because when the magnetron starts operating, the cathode is supplied with power also by the high voltage. Without reducing power of the cathode
20 heating, the cathode temperature would consequently further increase, such that lifetime of the cathode heating is affected.

The measured parameter is advantageously the current through the cathode heating, or the duration of
25 the power-regulated heating pulses. These variables form a good measure for the heating resistance.

In a particularly preferred embodiment, the controller is adapted to terminate the preheating phase when the variation speed of the parameter falls below a
30 variation threshold value. In other words, preheating is terminated and the high voltage is switched on when the temperature of the cathode substantially does not vary anymore. This procedure has the advantage that it is based on measurement of relative values and that it is
35 independent of absolute values, e.g. the absolute resistance of the cathode heating, such that stray and

ageing effects of the components have little effect on operation.

5

Short description of the drawings

Further embodiments, advantages and applications of the invention result from the dependent claims and the now following description by means of the drawings. It is shown in:

Fig. 1 a section through the parts of a microwave oven that are most important for the present context,

15 Fig. 2 a simplified circuit diagram of the microwave oven and

Fig. 3 a diagram of a number of signals of the driving circuit for the cathode heating.

20

Ways for carrying out the invention

Definitions:

In the present context, high voltage is understood as the voltage required as anode-cathode-voltage for operating the magnetron. Practically, this voltage amounts in most cases to at least 1 kV, normally a number of kilovolts.

A push-pull stage is a series circuit of two electronic components that can be alternately switched conductive such that a time-varying voltage is present at the center tap of both components.

A half-bridge configuration is a circuit with precisely one push-pull stage.

A full bridge configuration (H-circuit, H-bridge) is a circuit with two push-pull stages connected in parallel, wherein the load is located between the center taps of both push-pull stages.

Basic configuration:

The invention relates to a microwave oven as exemplarily shown in Fig. 1. The microwave oven has a cooking space 1 for receiving the food to be heated, which can be closed towards the used by a user door 2. A magnetron 3 is additionally arranged inside the device, which is connected to the cooking space 1 via a waveguide 4. A controller 5 controls the function of the device.

Fig. 2 shows the components of the controller 5 that are most important in the present context.

The grid voltage of e.g. 230 volts at 50 Hz is rectified in a rectifier 10. The first intermediary voltage U_z generated in this way is then slightly filtered via a first capacitor C1, wherein the capacitor C1 is dimensioned such that on load the value of the first intermediary voltage U_z fluctuates with the double grid frequency by at least 50%. The intermediary voltage U_z is additionally tapped via a diode D1 and further filtered via a second capacitor C2 in order to generate a second intermediary voltage U_z' .

The first intermediary voltage U_z is supplied to a high voltage generator 11, by means of which the high voltage described below is generated for driving the magnetron 3. The second intermediary voltage U_z' is supplied to a heating current generator 12 by means of which the heating current for the cathode heating of the magnetron 3 is generated as described below.

The operation of the high voltage generator 11 and of the heating current generator 12 is controlled by a controlling unit 13, e.g. as microprocessor.

A value that is proportional to the intermediary voltage U_z is supplied to an analog-digital-converter of the controlling unit 13 via a voltage divider R5, R6, such that the controller unit can determine the intermediary voltage U_z .

High voltage generator:

The high voltage generator 11 comprises a full-bridge-circuit with four electronic switching elements T3 - T6, particularly IGBT-transistors, each one having a free-wheel diode. The switching elements T3 - T6 are arranged, as known, in two branches T3 and T4 or T5 and T6, respectively, wherein the switching elements of each branch are arranged in series between the first intermediary voltage U_z and ground. A center tap is provided between the switching elements of each branch, wherein both center taps are connected to both connectors of the primary winding of a high voltage transformer 14. The high voltage transformer 14 has a secondary winding with a substantially higher number of turns than the primary winding, for generating the high voltage. The high voltage is rectified via two diodes D2 and D3, doubled and filtered via two capacitors C3 and C4. The high voltage U_h generated in this way is applied between the cathode K and the anode A of the magnetron 3.

A driving circuit 16 is provided for driving the switching elements T3 - T6, which is controlled by the controller unit 13. The driving circuit 16 generates the control voltages (gate voltages or base voltages) U_{G3} - U_{G6} for the switching elements T3 - T6. The controller unit 13 is adapted to switch the two branches of the full-bridge-circuit T3 - T6 alternately. The driving is carried out in such a way that during a switching cycle the primary winding of the high voltage transformer 14 is not all the time between the first intermediary voltage U_z and ground, but that the primary winding is uncoupled from the intermediary voltage U_z during a time period chosen by the controller unit 13, i.e. the circuit is clocked with pulse width modulation, such that the value of the high voltage U_h can be controlled.

In order to monitor the high voltage U_h it can be divided via a voltage divider R10 - R13 and R14 and supplied to an optocoupler 17, the output signal of

which is transferred to the controller unit 13. For example, an absence or no-firing of the magnetron can be detected in this way.

Furthermore, a resistor R20 is provided
5 between both branches T3, T4 or T5, T6, respectively, and a fixed reference potential, particularly ground. The initial rise of the voltage drop across this resistor at the beginning of a current pulse is a measure for the anode current of the magnetron 3 and it is supplied to
10 the controller unit 13 via an amplifier 18 for measurement purposes. This will be described in more detail below.

Heating current generator:

15 The heating current generator 12 is formed in the present embodiment by a half-bridge with two switching elements T1 and T2 operated as push-pull stage. The switching elements T1 and T2, which are themselves formed e.g. as IGBT-transistors and each of which is
20 equipped with a free-wheel diode, are arranged in series between the second intermediary voltage U_z' and ground.

The center tap between the two switching elements T1, T2 is connected to the one connector of the primary winding of a heating transformer 15. The second
25 connector of the primary winding of the heating transformer 15 is connected to the center tap of a capacitive voltage divider consisting of two capacitors C5 and C6. The two capacitors C5 and C6 are arranged in series between the second intermediary voltage U_z' and
30 ground.

The diode D1 avoids that current is diverted from the capacitors C5, C6 when the high voltage generator 11 connected to the intermediary voltage U_z takes current.

35 The secondary winding of the heating transformer 15 is connected to the cathode heating, i.e.

the filament, of the magnetron 3 and supplies it with current.

For driving the switching elements T1 and T2 a driving circuit 20 is provided, which is controlled by the controller unit 13. The driving circuit 20 generates the control voltages (gate voltages or base voltages) UG1, UG2 for the switching elements T1 or T2, respectively. The type of driving is described below in more detail.

10 A resistor R21 is arranged between the push-pull stage formed by the switching elements T1, T2 and ground (or another fixed reference potential), by means of which the current flows towards ground (or the reference potential, respectively) from the push-pull stage T1, T2 through the heating transformer. The voltage drop across this resistor is a measure for the current flowing from the second intermediary voltage U_z' through the primary coil of the high voltage transformer 15 towards ground (or reference potential, respectively). It is tapped by an amplifier 21 and supplied to an analog-digital-converter of the control unit 13.

Driving the heating current generator:

In the following it is described by Fig. 3 how the control unit 13 drives the switching elements of the heating current generator 12. The figure shows the course of the voltages UG1 and UG2, which are present at the control inputs of the switching elements T1 and T2, as well as the course of the voltage Uih that drops across the resistor R21.

The control unit 13 is adapted to switch on both switching elements T1 and T2 in a cyclic and alternating manner. A typical cycle period T_z is preferably in the range of 10 - 50 μ s.

35 The time periods during which one of the switching elements T1 and T2 is switched on are called heating phases H1 or H2, respectively, in the following,

and they are drawn in Fig. 3, wherein the first switching element T1 is switched on in heating phase H1 and the second switching element T2 is switched on in heating phase H2. Both switching elements T1, T2 are switched off
5 between the heating phases H1 and H2 or H2 and H1, respectively. The phases during which both switching elements T1, T2 are switched off are called idle phases R1 and R2 and they are also drawn in Fig. 3. The heating phases have a duration t_h , the idle phases have a
10 duration t_r .

In a simple embodiment, the time t_h may be chosen identic for both switching elements T1, T2, equally t_r .

In this way an alternating current is
15 generated in the primary winding of the heating transformer 15, which is supplied as heating power to the cathode heating of the magnetron 3 (except losses in the components, particularly in the heating transformer 15). The averaged value of the heating power is a function of
20 the duty cycle, i.e. of the quotient t_h/t_z .

As can be seen in Fig. 3, after switching on the switching elements T1, T2, the current through the primary winding of the heating transformer 15 increases and therefore also the voltage drop U_{ih} across the
25 resistor R21 can be measured by the control unit 13 via the amplifier 21.

The voltage drop U_{ih} forms a parameter that depends on the resistance of the cathode heating of the magnetron 3. Under the assumption that no losses occur in
30 the heating transformer 15, U_{ih} is inversely proportional to the resistor of the cathode heating towards the end of the heating pulse. Thus, the resistor R21 forms together with the amplifier 21 a measurement circuit adapted to determine a parameter depending on the resistance of the
35 cathode heating.

In Fig. 3 a time instant t_m is drawn, in which the controller 13 measures the voltage drop U_{ih} .

This time instant t_m is preferably shortly before the end t_x of the respective heating phase H1 or H2, e.g. maximally 1 μs before the end t_x of the heating phase. Advantageously, a measurement takes place in every
5 heating phase.

The control unit 13 is adapted to keep the product $P = U_{z'} \cdot U_{ih}(t_m) \cdot t_h$ constant by varying the duration t_h of the heating phases depending on the values $U_{ih}(t_m)$ and $U_{z'}$. The product P is at least approximately
10 proportional to the power supplied to the cathode heating.

Approximately the value of the intermediary voltage U_z can be used for the value of the intermediary voltage $U_{z'}$, as it is determined by the control unit via
15 the voltage divider R5, R6. As long as (during the pre-heating phase) the high voltage generator 11 is not in operation, $U_{z'}$ corresponds to the value of U_z except for the voltage drop across D1. After that $U_{z'}$ is partly a little higher than U_z , however the difference remains
20 small if the components are dimensioned in a suitable way. If $U_{z'}$ shall be determined precisely, a second voltage divider can be provided additionally or alternatively to R5, R6, which supplies the second intermediary voltage $U_{z'}$ for measurement by the control
25 unit 13.

Preferably, P is averaged during a filtering time, which amounts to at least half of a cycle period of the grid voltage, i.e. at least 10 ms. An adjustment of the pulse width t_h is only done after the filtering time
30 has passed.

P is a direct measure for the power given by the push-pull stage T1, T2 and therefore (not taking into account the losses, particularly in the heating transformer 15) also a measure for the heating power of
35 the cathode heating of the magnetron 3. Thus, the controller unit 13 also forms a power regulator by means

of which the power received by the cathode heating can be regulated to a target value.

Operation:

5 When the user activates the microwave oven, i.e. when he has given the command to supply the food in the cooking space with energy, the controller 13 first starts a pre-heating phase. In this pre-heating phase the switching elements T3 - T6 remain all switched off, such
10 that no high voltage falls across the magnetron 3. After the pre-heating phase there is an operation phase, during which also the switching elements T3 - T6 are taken into operation alternately in order to apply the high voltage to the magnetron and to generate the desired
15 microwave radiation.

 The switching elements T1 and T2 are operated in the way shown in Fig. 3 and described above, that is, in the preheating phase as well as (with slightly different operation parameters) in the subsequent
20 operating phase.

 During the preheating phase, the controller provides itself with a first target value for the power of the cathode heating. It lies e.g. between 80 - 120 watts (wherein the value to be chosen practically
25 certainly depends on the size and power of the magnetron).

 During the preheating phase the temperature of the cathode rises. Because the cathode heating is a cold conductor (i.e. a PTC-resistor), its resistance
30 increases with increasing temperature. Due to this, the voltage U_{ih} decreases. Because the controller unit 13 tries to regulate the product $P = U_{z'} \cdot U_{ih}(t_m) \cdot t_h$ to a constant value, the duration t_h of the heating phases increases in order to keep the product constant.
35 Consequently, the current pulses generated by the push-pull amplifier T1, T2 get longer and the provided power remains approximately constant.

After a certain time the cathode reaches a temperature balance. This time depends primarily on the initial temperature of the cathode. When the balance state is reached, the measured value $U_{ih}(t_m)$ does change
5 anymore. Thus, the controller unit can detect the balance state in such a way that the variation speed of the measured parameter $U_{ih}(t_m)$ falls below a variation threshold value. The smaller this threshold value is chosen, the better is the balance, but the longer takes
10 the preheating phase. The threshold value can e.g. be given in percent per 10 ms, i.e. a threshold value falls below $x\%/10\text{ms}$ when the measured parameter $U_{ih}(t_m)$ doesn't vary more than $x\%$ during 10 ms. Preferably, the threshold value is smaller than $10\%/10\text{ms}$ (i.e. 10% above the half
15 wave time of 10 ms).

As soon as the variation speed of the parameter falls below said threshold value, which happens after two to eight second depending on the initial temperature of the cathode, the controller unit 13
20 terminates the preheating phase and initiates the operating phase:

- For this, it starts operating the bridge circuit T3 - T6 by alternately activating the switching elements T3 and T6 or T4 and T5, respectively, in order
25 to generate an alternating current in the primary winding of the high voltage transformer 14, the result of which is that the high voltage across the cathode and the anode of the magnetron 3 is built up.

- Furthermore, the controller unit 13 reduces
30 the target value for the heating power because the cathode is now also supplied with power of the cathode heating via the high voltage. Advantageously, the target value is reduced by at least 30%, e.g. to 30 - 40 watts.

In the operating phase, the controller unit
35 can e.g. regulate or limit the high voltage by monitoring the signal of the optocoupler 17, and/or it can regulate or limit the current through the bridge circuit T3 - T6

towards ground by measuring the signal of the amplifier 18. This regulation or limitation, respectively, can be carried out independently of the regulation of the heating power.

5

Notes:

In the above embodiment, the voltage drop U_{ih} across R21 is used as parameter depending on the resistance of the cathode heating. Alternatively, also 10 the quotient $U_{ih}/U_{z'}$ can e.g. be used because it is independent of fluctuations of the second intermediary voltage $U_{z'}$, or the value U_{ih} may e.g. be averaged over at least half a grid period in order to compensate for the corresponding periodic fluctuations of $U_{z'}$.

15 Basically, any parameter can be used which depends on the resistance of the cathode heating, particularly the current through the cathode heating or (like in the above embodiment) the primary-side current of the heating transformer 15. The duration t_h of the 20 heating phases may also be used as parameter because they are also depending on the heating resistance due to the rule described above.

The sequence controlling of the described method steps may be implemented in the controller unit 13 25 as hardware and/or software.

To sum up, a controller circuit for a microwave oven is described. It has a push-pull stage T1, T2 for driving a heating transformer 15, by means of which the cathode heating of the magnetron 3 is operated. 30 A separate high voltage transformer 14 is provided for the generation of the high voltage, which is supplied by a bridge circuit T3 - T6. The controller unit 13 of the device is adapted to preheat the cathode during a preheating phase before switching on the high voltage. It 35 measures the current through the push-pull amplifier T1, T2 towards ground and the power of the cathode heating by varying the width of the pulses generated by the push-

pull amplifier T1, T2. As soon as the current doesn't vary anymore, the high voltage is switched on. In this way, the duration of the preheating phase can be kept short.

5 While preferred embodiments of the invention are described in this application, it has to be clearly noted that the invention is not limited thereto and may be executed in other ways within the scope of the now following claims.

10

Patentkrav

1. Mikrobølgeovn med en magnetron (3) omfattende en katode (K), en anode (A) og et katodevarmelegeme og med et styrekredsløb til magnetronen (3),
5 hvor styrekredsløbet omfatter:
en højspændingsgenerator (11) til generering af en højspænding mellem anoden (A) og katoden (K),
en varmestrømsgenerator (12) til generering af en varmestrøm til katodevarmelegemet og
10 en styreenhed (13),
hvor styreenheden (13) er indrettet til efter aktivering af mikrobølgeovnen i en foropvarmningsfase i et foropvarmningstidsrum først at aktivere varmestrømsgeneratoren (12) og først senere højspændingsgeneratoren (11),
hvor mikrobølgeovnen omfatter et målekredsløb (21, R21), der er indrettet til
15 at bestemme et parameter, der afhænger af en modstand af katodevarmelegemet, hvor styreenheden (13) er indrettet til at fastsætte et tilkoblingstidspunkt af højspændingsgeneratoren (11) afhængigt af det nævnte parameter, og hvor mikrobølgeovnen omfatter en effektregulator (13, 21, R21), hvormed en varmeeffekt, der optages af katodevarmelegemet, kan reguleres, hvor
20 styreenheden (13) er indrettet til at regulere varmeeffekten til en første indstillingsværdi under foropvarmningsfasen.
2. Mikrobølgeovn ifølge krav 1, hvor styreenheden (13) er indrettet til at regulere varmeeffekten fra udløb af foropvarmningsfasen til en anden indstillingsværdi, hvor den anden indstillingsværdi ligger lavere end den første indstillingsværdi, især mindst 30% lavere.
- 25
3. Mikrobølgeovn ifølge et af de foregående krav, med en varmetransformator (15), til hvilken katodevarmelegemet er tilsluttet på sekundærsiden, og
30 med et modtakt-sluttrin med to serieforbundne koblingselementer (T1, T2), der kan tilkobles skiftevist af styreenheden (13), hvor modtakt-sluttrinnet på primærsiden er tilsluttet til varmetransformatoren (15).
4. Mikrobølgeovn ifølge krav 3, hvor målekredsløbet (21, R21) omfatter en
35 modstand (R21), som strømmen løber gennem fra modtakt-sluttrinnet gen-

nem varmetransformatoren (15) mod et referencepotential, især mod masse.

- 5 **5.** Mikrobølgeovn ifølge krav 4 og krav 5, hvor styreenheden (13) er indrettet til at tilkoble de to koblingselementer (T1, T2) skiftevis under varrefaserne (H1, H2), og derimellem under hvilefaserne (R1, R2) at holde de to koblingselementer (T1, T2) frakoblet, hvor effektregulatoren (13, 21, R21) styrer varrefasernes (H1, H2) varighed (th).
- 10 **6.** Mikrobølgeovn ifølge krav 5, hvor effektregulatoren er indrettet til at holde et produkt $P = U_{z'} \cdot U_{ih(tm)} \cdot t_h$ konstant, hvor $U_{z'}$ er en spænding, der er påtrykt modtakt-sluttrinnet, U_{ih} er en spænding, der falder over modstanden R21, og t_h er varrefasernes varighed.
- 15 **7.** Mikrobølgeovn ifølge et af kravene 5 eller 6, hvor parametret er varrefasernes varighed (th).
- 20 **8.** Mikrobølgeovn ifølge et af kravene 3 til 6, hvor parametret er en strøm, der løber fra modtakt-sluttrinnet gennem varmetransformatoren (15) mod et referencepotential, især mod masse.
- 25 **9.** Mikrobølgeovn ifølge et af de foregående krav, hvor styreenheden (13) er indrettet til at afslutte foropvarmningsfasen, når en ændringshastighed af parametret falder til under en ændringstærskelværdi, og især hvor ændringstærskelværdien ligger under 10%/10ms.
- 30 **10.** Fremgangsmåde til drift af en mikrobølgeovn med en magnetron (3) omfattende en katode (K), en anode (A) og et katodevarmelegeme, hvor i det mindste de følgende trin udføres til aktivering af mikrobølgeovnen:
at generere en varmestrøm ved hjælp af katodevarmelegemet i en foropvarmningsfase under et foropvarmningstidsrum og
efter foropvarmningstidsrummet er gået, at anlægge en højspænding mellem anoden (A) og katoden (K),
hvor et parameter, der afhænger af katodevarmelegemets modstand, måles, og foropvarmningstidsrummet bestemmes afhængigt af det nævnte parameter,
35 og hvor katodevarmelegemets varmeeffekt reguleres til en første indstillings-

værdi under foropvarmningsfasen.

- 5 **11.** Fremgangsmåde ifølge krav 10, hvor varmeeffekten reguleres til en anden indstillingsværdi fra udløb af foropvarmningsfasen, hvor den anden indstillingsværdi ligger lavere end den første indstillingsværdi, især mindst 30% lavere.
- 10 **12.** Fremgangsmåde ifølge et af kravene 10 til 11, hvor foropvarmningsfasen afsluttes, når en ændringshastighed af parametret falder til under en ændringstærskelværdi, og især hvor ændringstærskelværdien ligger under 10%/10ms.

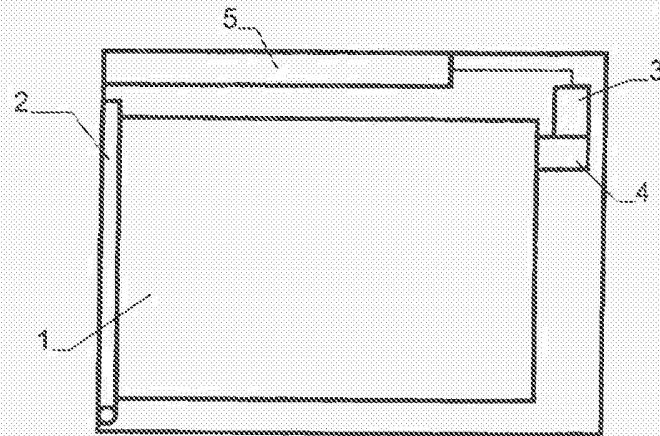


Fig. 1

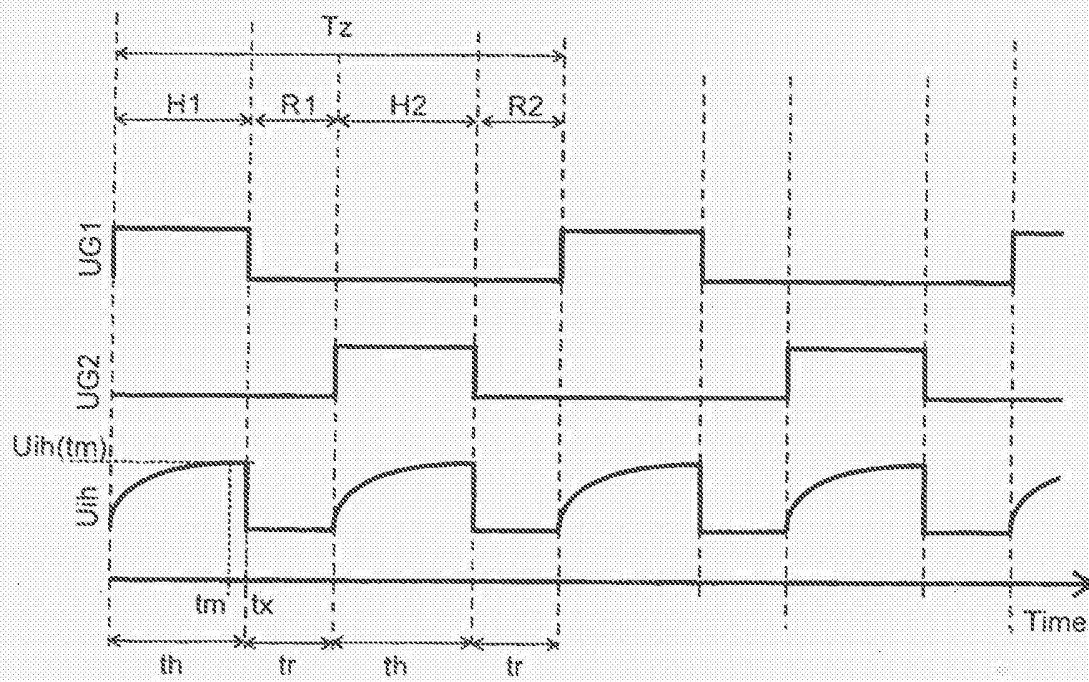


Fig. 3

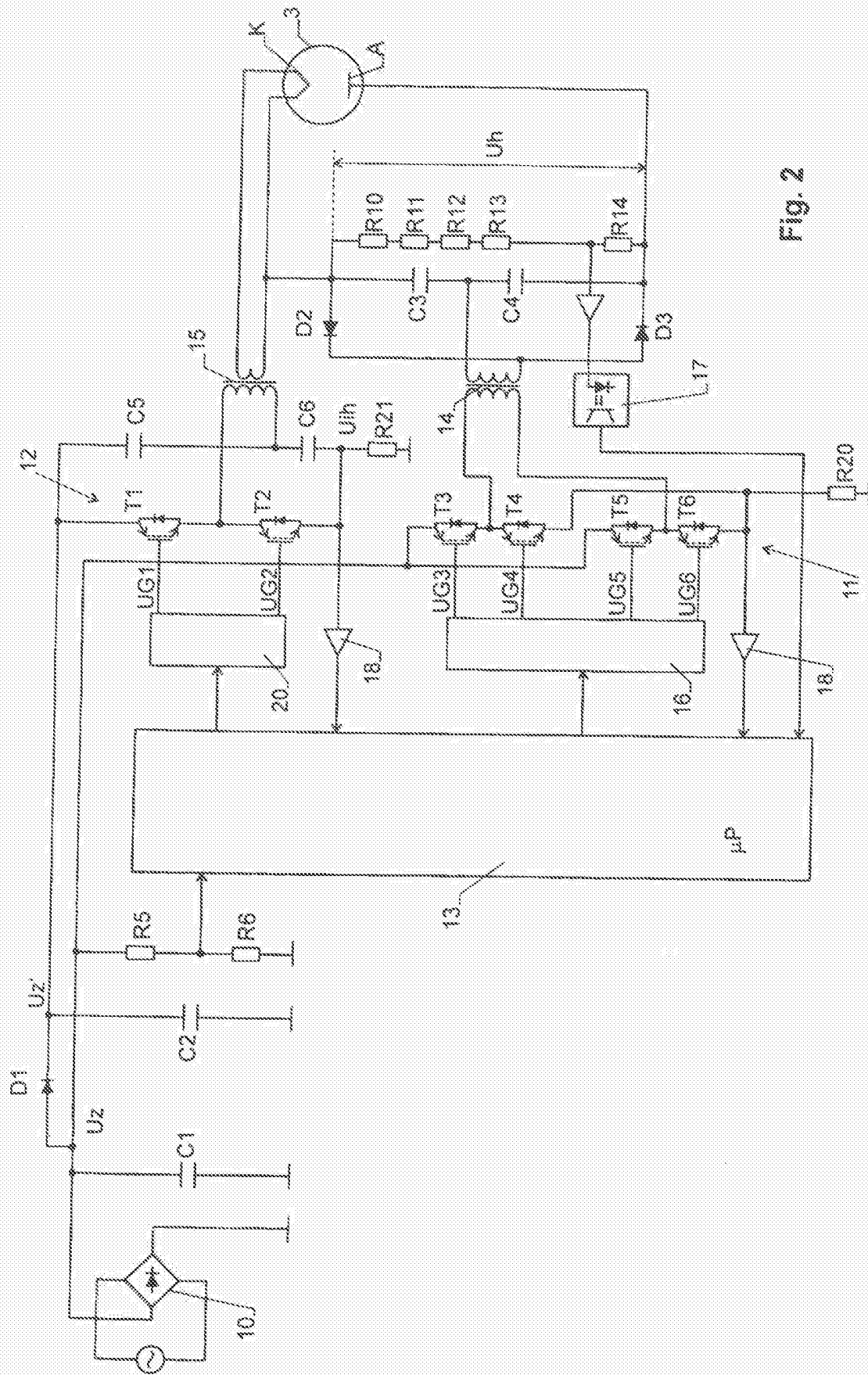


Fig. 2