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(54) Laundry treatment appliance with a universal motor

(57) A laundry treatment appliance **(100)** is proposed. The laundry treatment appliance **(100)** comprises:
a drum **(115)** for housing a laundry load to be treated,
a universal motor **(140)** adapted to be powered by an electric voltage ($V_{MOTOR,A}$, $V_{MOTOR,B}$) for causing drum **(115)** rotation,
an operating condition detecting unit **(160)** adapted to detect the occurrence of an operating condition of said appliance **(100)**, and
a power supply apparatus **(200)** configured to power the universal motor **(140)** in a first driving mode if a first operating condition is detected, and in a second driving mode if a second operating condition is detected, wherein in the first driving mode the voltage ($V_{MOTOR,A}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a first waveform, and in the second driving mode the voltage ($V_{MOTOR,B}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a second waveform different from said first waveform.

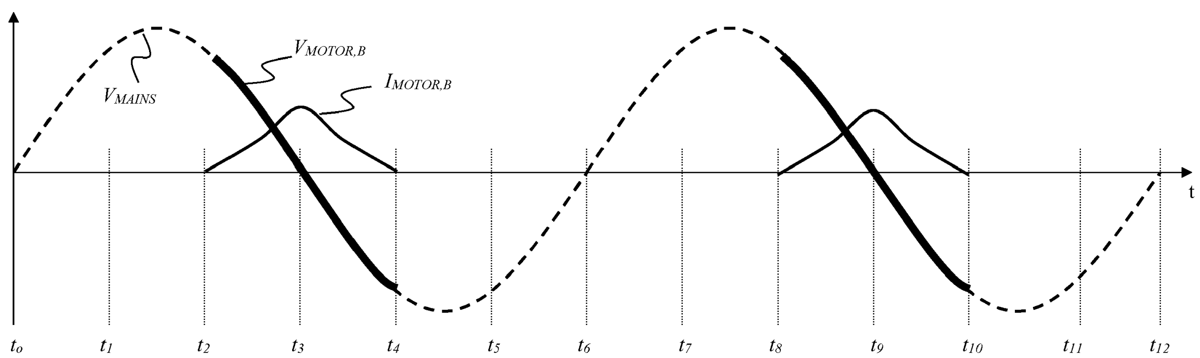


Figure 3B

EP 3 023 535 A1

Description

Field of the invention

[0001] The present invention generally relates to a laundry treatment appliance (e.g., a laundry washing and/or drying appliance), both for domestic and professional use. More particularly, the present invention relates to a laundry treatment appliance provided with a universal motor for causing a rotatable drum rotation during laundry load treatment, and a method and system for efficiently feeding electric power to the universal motor based on appliance operating conditions.

Background of the invention

[0002] Nowadays most of laundry treatment appliances, e.g. laundry washing appliances, laundry washing/drying appliances and laundry drying appliances, hereinafter laundry appliances, make use of a universal motor for rotating their rotatable drum, called also simply "drum" (*i.e.* the rotatable container arranged inside the laundry appliance wherein a laundry load is placed/housed in order to be washed and/or dried).

[0003] Universal motor is an electric motor very similar, in construction, to a DC series motor, but, unlike the latter, it can be operated by both AC and DC power supplies (both of them typically derived by a mains power supply).

[0004] Universal motors feature high starting torque and speed, as well as lightweightness and compactness.

[0005] Universal motors which nowadays laundry appliances are equipped with, are mostly operated by an AC electric power, typically by means of a power supply/feeding apparatus comprising a thyristor device *(e.g.,* a TRIAC device) selectively allowing/preventing AC electric power from the mains power supply to be fed to the universal motor.

[0006] An example of laundry appliance using a universal motor for rotating the drum is shown for example in US2004139767A and in CN2873847Y.

Summary of the Invention

[0007] Applicant has found that although operating the universal motor of a laundry treatment appliance by mainly an AC electric power leads to power supply/feeding apparatus that are easy and cheap to implement, the resulting universal motor operation could be not satisfactory for modem technological requirements.

[0008] Indeed, Applicant has ascertained that some conditions may determine incorrect/not-optimal operation of the laundry appliance, and especially of the universal motor. An example of such conditions is a significant reductions in the mains power supply below values deemed acceptable for proper operation of the laundry appliance, both frequent (as in geographical areas, such East Europe and Asian countries, wherein the mains power supply is highly unstable and may have fluctuations below nominal values for relatively long period of time), and sporadic *(e.g.,* due to temporary mains power supply failures). A reduction in the mains power supply determines poor starting torque of the universal motor (which may lead to a rotation failure of the drum) or a slowing down of the universal motor speed.

[0009] In addition, if the laundry load within the drum is too much, the torque generated by the universal motor may be not high enough to rotate the drum at the desired speed, or to take it into rotation at all.

[0010] Last but not least, high peak to peak currents passing through the universal motor when driven by the AC electric power result in a poor universal motor efficiency, as well as in high brushes temperature (which leads to limited universal motor lifetime).

[0011] Applicant has faced the problem of devising a satisfactory solution able to overcome the above-discussed, as well as other, drawbacks.

[0012] Applicant has found that by providing a laundry treatment appliance with an operating condition detecting unit adapted to detect the occurrence of an operating condition of the appliance, and with a power supply apparatus configured to power an universal motor rotating the rotatable drum of the appliance in a first driving mode if a first operating condition is detected, and in a second driving mode if a second operating condition is detected, wherein in the first driving mode the electric voltage provided to the universal motor has a first waveform, and in the second driving mode the electric voltage provided to the universal motor has a second waveform, different from the first waveform, it is possible to effectively rotate the drum even in case of hard working conditions, such as significant reductions in the mains power supply or high amount of laundry loaded in the drum.

[0013] In particular, one or more aspects of the present invention are set out in the independent claims, with advantageous features of the same solution that are indicated in the dependent claims (with any advantageous feature provided with reference to a specific aspect of the solution according to an embodiment of the invention that applies *mutatis mutandis* to any other aspect thereof).

[0014] An aspect of the present invention relates to a laundry treatment appliance. The laundry treatment appliance comprises:

- a drum for housing a laundry load to be treated,
- a universal motor adapted to be powered by an electric voltage for causing drum rotation,
- an operating condition detecting unit adapted to detect the occurrence of an operating condition of said appliance, and
- a power supply apparatus configured to power the universal motor in a first driving mode if a first operating condition is detected, and in a second driving mode if a second operating condition is detected, wherein in the first driving mode the voltage provided by said power supply apparatus to the universal mo-

tor has a first waveform, and in the second driving mode the voltage provided by said power supply apparatus to the universal motor has a second waveform different from said first waveform.

[0015] According to an embodiment of the present invention, said second waveform is a partialized version of said first waveform.

[0016] According to an embodiment of the present invention, said voltage provided by said power supply apparatus to the universal motor in the second driving mode is an alternating voltage, said voltage provided by said power supply apparatus to the universal motor in the second driving mode having a direct component for increasing a starting torque of the universal motor when the second operating condition is detected.

[0017] According to an embodiment of the present invention, said power supply apparatus is connected or connectable to a mains power supply providing a sinusoidal mains voltage, and wherein said first waveform comprises a sequence of positive-slope and negative-slope sinusoidal portions of said sinusoidal mains voltage, said second waveform comprising the positive-slope or the negative-slope sinusoidal portions of said first waveform.

[0018] According to an embodiment of the present invention, said power supply apparatus is connected or connectable to a mains power supply providing a sinusoidal mains voltage, and wherein said second operating condition occurs if the amplitude of said sinusoidal mains voltage is below a first threshold amplitude value.

[0019] According to an embodiment of the present invention, said first operating condition occurs if the amplitude of said sinusoidal mains voltage is above a second threshold amplitude value higher than said first threshold amplitude value.

[0020] According to an embodiment of the present invention, said second operating condition occurs if the amplitude of said sinusoidal mains voltage drops below the first threshold amplitude value and said first operating condition occurs if the amplitude of said sinusoidal mains voltage rises above said second threshold amplitude value, the universal motor being powered in the current, first or second, driving mode when the amplitude of said sinusoidal mains voltage is between said first and second threshold amplitude values.

[0021] According to an embodiment of the present invention, said power supply apparatus is configured to interrupt the powering of said universal motor if the amplitude of said sinusoidal mains voltage is below a third threshold amplitude value lower than said first threshold amplitude value.

[0022] According to an embodiment of the present invention, said second operating condition occurs when the amount of laundry load is above a threshold laundry load weight.

[0023] According to an embodiment of the present invention, said second operating condition occurs when a water discharge phase is started.

[0024] According to an embodiment of the present invention, said second operating condition occurs when the rotation speed of the drum is below a threshold rotation speed.

[0025] According to an embodiment of the present invention, the driving apparatus comprises:

a thyristor device comprising a first anode terminal coupled to a first mains power supply terminal and a second anode terminal coupled to a first universal motor terminal, a second universal motor terminal being coupled with a second mains power supply terminal;

a control unit configured to generate first or second control signals for allowing powering the universal motor in the first or second driving modes, respectively, and

a triggering circuit configured to activate the thyristor device by providing first or second triggering pulse signals to a gate terminal of the thyristor device based on the first or second control signals, respectively.

[0026] According to an embodiment of the present invention, the appliance comprises a laundry washing appliance or a laundry washing/drying appliance or a laundry drying appliance.

[0027] Another aspect of the present invention relates to a method for operating a laundry treatment appliance comprising a drum for housing a laundry load to be treated, a universal motor adapted to be powered by a voltage for causing drum rotation, an operating condition detecting unit adapted to detect the occurrence of an operating condition of said appliance, a power supply apparatus configured to power the universal motor in a first driving mode in which the voltage provided by said power supply apparatus to the universal motor has a first waveform, and in a second driving mode in which the voltage provided by said power supply apparatus to the universal motor has a second waveform different from said first waveform, said method comprising the steps of:

- detecting the current operating condition of said appliance;
- powering said universal motor in said first driving mode if a first operating condition is detected;
- powering said universal motor in said second driving mode if a second operating condition is detected.

Brief Description of the Drawings

[0028] These and other features and advantages of the present invention will be better understood with reference to the following detailed description, given purely by way of a non-restrictive indication, to be read in conjunction with the accompanying drawings (wherein corresponding elements are denoted with equal or similar references, and their explanation is not repeated for the sake of exposition brevity). In this respect, it is expressly understood that the figures are not necessarily drawn to scale (with some details that may be exaggerated and/or simplified) and that, unless otherwise indicated, they are simply used to conceptually illustrate the described structures and procedures. In particular:

Figure **1A** shows an isometric view of a laundry appliance according to an embodiment of the present invention;

Figure 1B shows a schematic cross-sectional view of the laundry appliance of Figure **1A;**

Figure 2 shows, in terms of circuit elements, a power supply apparatus of said laundry appliance according to an embodiment of the present invention, and

Figures 3A-3B show, according to an embodiment of the present invention, qualitative waveforms resulting from first and second motor driving modes, respectively, of the power supply apparatus of **Figure 2.**

Detailed description of preferred embodiments

[0029] With reference to the drawings, Figures **1A** and **1B** show isometric and cross-sectional views, respectively, of a laundry appliance **100** according to an embodiment of the present invention.

[0030] The laundry appliance **100** is an appliance for treating a laundry load *(e.g.,* a laundry washing appliance or a laundry washing/drying appliance), for example of the front-loading type - anyway, as should be apparent from the following description, laundry appliances of the top-loading type may also benefit from the present invention.

[0031] The laundry appliance **100** preferably comprises a substantially parallepiped-shaped cabinet **105,** which encloses an inner compartment.

[0032] The inner compartment accommodates a number of well-known electronic, electro-hydraulic, mechanical and/or electro-mechanical components (only the relevant ones to the understanding of the present invention being introduced and discussed in the following).

[0033] As usual, the inner compartment accommodates a tub **110** (shown in **Figure 1B),** preferably substantially cylindrically-shaped, and, within the tub **110,** a rotatable drum **115,** preferably substantially cylindrically-shaped, intended to house a laundry load to be washed and/or dried and to rotate (when the laundry appliance **100** operation so requires) about an axis **A** in order to tumble the laundry load housed therein.

[0034] The rotatable drum **115** is accessible through an access door **120** (shown in an opened configuration in **Figure 1A** and in a closed configuration in **Figure 1B),** preferably provided on a front panel of the cabinet **105** for selectively allowing laundry loading into/unloading from the rotatable drum **115** through a cabinet opening $\mathbf{105_O}$ (visible in **Figure 1A),** and tub $\mathbf{110_O}$ and drum $\mathbf{115_O}$ openings (visible in **Figure 1B).** Preferably, in order to achieve a watertight connection between the cabinet opening $\mathbf{105_O}$ and the tub opening $\mathbf{110_O}$ (thus avoiding washing/cleaning liquids leakages within the inner compartment, outside the tub **110),** a bellows **125,** preferably made of an elastomeric and waterproof material, is mounted in a watertight manner (*e.g.*, by gluing, by welding, or by interference fitting) between respective edges of the cabinet opening $\mathbf{105_O}$ and of the tub opening $\mathbf{110_O}$.

[0035] In the exemplary illustrated embodiment, the laundry appliance **100** comprises, preferably at a cabinet top $\mathbf{105_T}$, a drawer **130** for loading laundry-treating products (*e.g.*, detergents, softeners, bleachers, and the like), and, preferably aside the drawer **130,** a user interface **135.**

[0036] The user interface **135** preferably comprises a control panel $\mathbf{135_A}$ (*e.g.*, comprising buttons, rotative knobs, displays) for user selection of a desired laundry treatment to be carried out and options thereof, and a control system $\mathbf{135_B}$ (*e.g.*, comprising electronic devices such as one or more microcontrollers) adapted to control operation of the laundry appliance **100** according to user selection on the control panel $\mathbf{135_A}$ (and, according to the present invention, as discussed below, according to occurrence/detection of one or more predetermined operating conditions that may lead to incorrect/not-optimal operation of the laundry appliance **100**). As can be best appreciated in **Figure 1B,** the control system $\mathbf{135_B}$ is preferably arranged within the inner compartment, even more preferably at a top thereof *(e.g.,* close to the cabinet top $\mathbf{105_T}$**)** in order to be less prone to contacts with liquids or humidity possibly leaking from the tub **110.**

[0037] As visible in **Figure 1B,** the inner compartment also accommodates a universal motor **140** (*i.e.*, an electric motor very similar, in construction, to a DC series motor, but operable by both AC and DC electric power supplies) adapted to be powered/fed for causing drum rotation when laundry appliance **100** operation so requires. In order achieve that, preferably, a rotor shaft $\mathbf{145_A}$ is connected to the rotatable drum **115** through a rear tub opening $\mathbf{110_{OR}}$ provided at a tub backside or backwall $\mathbf{110_R}$, and to the universal motor **140** by means of a transmission apparatus **150** comprising pulleys (such as the pulleys $\mathbf{150_A}$ and $\mathbf{150_B}$ mounted to the rotor shaft $\mathbf{145_A}$ and to a motor shaft $\mathbf{145_B}$, respectively) as well as a transmission belt or chain **150c** coupled thereto.

[0038] As exemplary illustrated in **Figure 1B,** the universal motor **140** is preferably arranged at a cabinet bottom $\mathbf{105_B}$, together with a driving circuit **155** for driving the universal motor **140 -** *i.e.*, for powering/feeding the universal motor **140** with an electric voltage (and a corresponding electric current) capable of causing drum rotation based on the user setting and, as discussed below, on the detected operating condition/conditions of the laundry appliance **100.**

[0039] Universal motor **140** driving takes place according to proper control signals from the control system $\mathbf{135_B}$

(electrical connection between the driving circuit 155 and the control system **135_B** not shown for the sake of illustration ease). In the following, only control signals based on detection of the operating condition/conditions of the laundry appliance **100** will be considered, it being understood that, although not discussed, control signals based (as usual) on desired setting of the laundry appliance **100** (*e.g.*, according to user selection on the control panel **135_A**) may be provided.

[0040] Detection of each operating condition (or of a set of operating conditions) is achieved by means of a respective operating condition detecting unit (hereinafter, OCD unit) **160,** only one depicted in the figure, whose implementation and arrangement depend on the operating condition/conditions it is intended to detect. Broadly speaking, the operating conditions detected by the OCD unit **160** (or more thereof) are preferably (although not necessarily) those ones that may determine incorrect/not-optimal operation of the laundry appliance **100,** and especially faults, malfunctions, criticalities or inefficiencies of the universal motor **140,** as progressively detailed when discussing embodiments of the present invention.

[0041] The driving circuit **155** and the control system **135_B** *(i.e.,* components thereof that are communicably coupled to the driving circuit **155)** define, as a whole, a power supply apparatus configured to power/feed the universal motor **140** in different driving modes according to the detected operating condition/conditions.

[0042] A power supply apparatus according to an embodiment of the present invention is illustrated (in terms of circuit elements) in **Figure 2,** and denoted by the number reference **200.**

[0043] The power supply apparatus **200,** connected or connectable to line **T_L** and neutral **T_N** terminals of a mains power supply providing an AC mains voltage V_{MAINS}, preferably comprises a thyristor device *(e.g.,* a TRIAC device) **205_T** *(e.g.,* part of the driving circuit **155)** having a first anode terminal coupled (*e.g.*, directly connected) to the neutral terminal **T_N** of the mains power supply, a second anode terminal coupled *(e.g.,* directly connected) to a first terminal of the universal motor **140,** and a gate terminal coupled *(e.g.,* directly connected) to a triggering circuit *(e.g.,* part of the driving circuit 155 as well) adapted to generate triggering pulse signals for activating the thyristor device **205_T** according to the control signals. The universal motor 140 comprises a second terminal coupled (*e.g.*, directly connected) to the line terminal **T_L** of the mains power supply. Although not shown, the first anode terminal of the thyristor device **205_T** and/or the second terminal of the universal motor 140 may be coupled to the neutral **T_N** and line **T_L** terminals, respectively, of the mains power supply by means of proper electric components (*e.g.*, switches or relays).

[0044] An AC-DC conversion circuit (only conceptually illustrated in the figure and denoted, as a whole, by the number reference 210) is provided (preferably arranged at control system **135_B** side) that comprises transforming, rectifying and regulation components for receiving the mains voltage V_{MAINS} across the line **T_L** and neutral **T_N** terminals of the mains power supply and providing a (DC) ground voltage *GND* and a (DC) supply voltage *Vcc (e.g.,* a 3V, 5V or 12V DC voltage with respect to the ground voltage *GND*). The ground *GND* and supply *Vcc* voltages generated by the AC-DC conversion unit **210** are used, amongst other things, for supplying the electric and electronic components included in the power supply apparatus **200,** such as a control unit **215** *(e.g.,* a microcontroller or a microprocessor preferably arranged at control system **135_B** side) intended to manage the operation of the laundry appliance **100** (in the following, for the sake of exposition brevity, only functionalities of the control unit **215** pertinent to universal motor **140** power supplying/feeding will be considered). For this purpose, the control unit **215** is connected between a supply terminal Vcc providing the supply voltage *Vcc* and a ground terminal **GND** providing the ground voltage *GND.*

[0045] The triggering circuit for activating the thyristor device **205** is controlled by the control unit **215** by means of the control signals, such as the control signal V_{CTRL}, each one associated with the detection of a respective operating condition (or of a respective set of operating conditions) of the laundry appliance **100.** Preferably, the control signals, such as the control signal V_{CTRL}, are generated internally to the control unit **215,** even more preferably the control signals, such as the control signal V_{CTRL}, are digital voltage signals capable of selectively taking a high logic value *(e.g.,* corresponding to the supply voltage *Vcc*) and a low logic value *(e.g.,* corresponding to the ground voltage *GND*).

[0046] According to the exemplary illustrated embodiment, the triggering circuit comprises a resistor **205_R** and a transistor **205_B.** The transistor **205_B,** preferably a BJT (*"Bipolar Junction Transistor*") transistor, has a base terminal coupled *(e.g.,* directly connected) to the control unit **215** for receiving the control signal V_{CTRL}, an emitter terminal coupled (*e.g.*, directly connected) to the ground terminal **GND** for receiving the ground voltage *GND*, and a collector terminal coupled *(e.g.,* directly connected) to a first terminal of the resistor **205_R -** a second terminal of the resistor **205_R** being instead coupled (*e.g.*, directly connected) to the gate terminal of the thyristor device **205_T.**

[0047] According to this circuit implementation, which is however not limiting for the present invention, when the control unit **215** sets the control signal V_{CTRL} at the low logic value, the transistor **205_B** is off, and the gate terminal of the thyristor device **205_T** is floating. In this condition, the thyristor device **205_T,** and hence the universal motor **140,** are off. When, instead, the control unit **215** sets the control signal V_{CTRL} at the high logic value, the transistor **205_B** is on, and a current pulse flows from the gate terminal to the ground terminal **GND**, and hence across the resistor **205_R** and the transistor **205_B,** thus triggering the activation of the thyristor device **205_T** that enable an AC electric voltage to be fed across (and a corresponding AC electric current to flow through) the universal motor **140.** As will be better understood from the following description, the AC electric voltage fed across the universal motor **140** is preferably derived from the AC mains voltage V_{MAINS}, whereas the AC electric current flowing through the universal motor **140** substantially (*i.e.*, approximately) depends on the AC electric voltage, on an equivalent impedance exhibited by the universal motor **140** and on universal motor **140** components/parts introducing (capacitive and/or inductive) non-linearity.

[0048] As usual in laundry appliances, in order to control the amount of AC electric voltage that is allowed to be fed across (and, accordingly, the amount of electric current that is allowed to flow through) the thyristor device **205$_T$** and the universal motor **140** (so as to control, for example, rotation speed and acceleration and deceleration profiles of the rotatable drum **115),** the control signal V_{CTRL} is such that activation of the thyristor device **205$_T$** is triggered after a predefined delay time (corresponding to a predefined phase angle of the mains voltage V_{MAINS}) and over a predefined activation time (corresponding to a predefined conduction angle of the mains voltage V_{MAINS}). In this respect, from now on reference will be also made to **Figure 3A,** which shows, according to an embodiment of the present invention, qualitative waveforms of the mains voltage V_{MAINS}, of the electric voltage across the universal motor **140** in a first driving mode of the power supply apparatus **200** (hereinafter, motor voltage $V_{MOTOR,A}$), and of the current flowing through the universal motor **140** in the first driving mode of the power supply apparatus **200** (hereinafter, motor current $I_{MOTOR,A}$) - the first driving mode being the only driving mode available in conventional laundry appliances making use of universal motors.

[0049] As visible in this figure, the mains voltage V_{MAINS} is an alternating voltage having a full-wave periodic, e.g. sinusoidal, waveform (and, as usual, an amplitude of 230V or 125V and a frequency of 50Hz or 60Hz). As illustrated, assuming, for each half-wave of the mains voltage V_{MAINS}, conduction angles between 0 and $\pi/4$ (corresponding to activation time intervals t_0-t_1, t_3-t_4, t_6-t_7, t_9-t_{10}) and between $3/4\pi$ and π (corresponding to activation time intervals t_2-t_3, t_5-t_6, t_8-t_9, t_{11}-t_{12}) - *i.e.,* phase angle between $\pi/4$ and $3/4\pi$ (corresponding to delay time intervals t_1-t_2, t_4-t_5, t_7-t_8, t_{10}-t_{11}) - the motor voltage $V_{MOTOR,A}$ is an alternating voltage defined by a sequence of positive-slope and negative-slope sinusoidal portions of (or, when possible non-idealities are considered, approximately matching the waveform/trend of) the mains voltage V_{MAINS} at the conduction angles, and the motor current $I_{MOTOR,A}$ is an alternating current having a sequence of positive and negative sinusoidal (or substantially sinusoidal) waveforms. The sinusoidal portions of (or approximately matching the waveform/trend of) the mains voltage V_{MAINS} that define the motor voltage $V_{MOTOR,A}$ derive from activation of the thyristor device **205$_T$** at the above conduction angles. Instead, the substantially sinusoidal waveform of the motor current $I_{MOTOR,A}$ is due, ideally (*i.e.* without taking into account delay time intervals and non-idealities introduced by universal motor 140 components/parts, as herein assumed), to inductive nature of the universal motor 140 (so that the motor current $I_{MOTOR,A}$ waveform results from the full-wave sinusoidal waveform of the mains voltage V_{MAINS} over the activation time intervals, or otherwise stated, from the positive-slope and negative-slope sinusoidal portions of the mains voltage V_{MAINS}). Broadly speaking, the power supply apparatus 200 is configured to power the universal motor 140 in the first driving mode if a first operating condition is detected, and in a second driving mode if a second operating condition is detected, wherein the electric voltage across the universal motor 140 in the first driving mode (*i.e.*, the motor voltage $V_{MOTOR,A}$) and the electric current through the universal motor **140** in the first driving mode (*i.e.*, the motor current $I_{MOTOR,A}$) have the waveforms illustrated in **Figure 3A,** and the electric voltage across the universal motor **140** in the second driving mode (hereinafter, motor voltage $V_{MOTOR,B}$) and the electric current through the universal motor **140** in the second driving mode (hereinafter, motor current $I_{MOTOR,B}$) have different waveforms (illustrated in **Figure 3B,** discussed herebelow).

[0050] Advantageously, the second operating condition may be the occurrence of an incorrect/not-optimal or critical condition of the laundry appliance **100** (reason why, in the following, the second operating condition will be referred to as critical operating condition and the second driving mode, intended to support laundry appliance **100** operation for forestalling potential faults or malfunctioning arising from the critical operating condition, will be referred to as support driving mode), whereas the first operating condition may be the non-occurrence of the critical operating condition, preferably indicative of a default/normal operation of the laundry appliance **100** (reason why, in the following, the first operating condition will be referred to as normal operating condition and the first driving mode, intended to ensure normal laundry appliance **100** operation, will be referred to as normal driving mode).

[0051] From now on, reference will be also made to **Figure 3B,** which shows, according to an embodiment of the present invention, qualitative waveforms of the mains voltage V_{MAINS}, of the motor voltage $\mathbf{V}_{MOTOR,B}$ and of the motor current $I_{MOTOR,B}$ in the support driving mode of the power supply apparatus **200.** As mentioned above, the support driving mode is started upon detection (and communication to the control unit **215)** of a critical operating condition by the OCD unit **160,** and is enabled by generation of the corresponding control signal V_{CRTL} by the control unit **215** (the control signal V_{CRTL}, and the resulting triggering pulse signal, in the support driving mode associated with a critical operating condition being thus different from the control signal V_{CRTL}, and the resulting triggering pulse signal, in the normal driving mode, and, preferably, also from the control signal V_{CRTL}, and the resulting triggering pulse signal, in the support driving mode associated with a different critical operating condition, when detection of more critical operating conditions is provided).

[0052] Preferably, the motor votlage $V_{MOTOR,B}$ (and, accordingly, the motor current $I_{MOTOR,B}$) waveform is a partialized version of the motor voltage $V_{MOTOR,A}$ waveform (and, respectively, of the motor current $I_{MOTOR,A}$) - in the following, for the sake of exposition ease and conciseness, due to the close correlation between the motor current and the motor votlage above mentioned, and unless otherwise specified, the motor current $I_{MOTOR,B}$ should be considered having the same features/properties of the motor votlage $V_{MOTOR,B}$.

[0053] Additionally or alternatively, the motor voltage $V_{MOTOR,B}$, which is an alternating electric voltage, advantageously has a direct component for increasing a starting torque of the universal motor **140** in the support driving mode. Thus, the motor votlage $V_{MOTOR,B}$ in the support driving mode features, unlike the motor votlage $V_{MOTOR,A}$ in the normal driving mode, a non-zero direct component, which provides an improved starting torque of the universal motor **140** that allows it to correctly operate even when a critical operating condition occurs (as detailed below).

[0054] In order to obtain said direct component, preferably, as visible in **Figure 3B,** the motor voltage $V_{MOTOR,B}$ waveform (in the support driving mode) comprises the negative-slope sinusoidal portions (as exemplary illustrated) or the positive-slope sinusoidal portions of the motor voltage $V_{MOTOR,A}$ waveform (in the normal driving mode). This is preferably achieved, similarly to former discussion, by generating (at the control unit **215** side) a control signal V_{CTRL} such that the phase and conduction angles of the mains voltage V_{MAINS} allow "suppressing", with respect to the motor voltage $V_{MOTOR,A}$ waveform, the positive-slope sinusoidal portions (as herein exemplary illustrated) or the negative-slope sinusoidal portions. In the example illustrated, for each period of the mains voltage V_{MAINS}, conduction angles between $3/4\pi$ and $5/4\pi$ (corresponding to activation time intervals t_2-t_4, t_8-t_{10}), and, hence, phase angles between 0 and $3/4\pi$ and between $5/4\pi$ and 2π, are provided, so that the motor voltage $V_{MOTOR,B}$ in the support driving mode is an alternating votlage having a sequence of only negative-slope sinusoidal portions (as herein exemplary assumed) or only positive-slope sinusoidal portions waveforms. In the example at issue, this translates into a motor current $I_{MOTOR,B}$ in the support driving mode having a sequence of only positive (as herein exemplary assumed and illustrated in **Figure 3B)** or only negative sinusoidal (or substantially sinusoidal) waveforms with respect to the motor current $I_{MOTOR,A}$ in the normal driving mode.

[0055] Obtaining said direct component by provision of only positive or only negative half-waves is particularly advantageous as the resulting support driving mode features, unlike the normal driving mode, a reduced peak to peak motor current passing through the universal motor **140.** This advantageously results in a high universal motor efficiency, as well as in low brushes temperature (and, hence, in extended universal motor lifetime).

[0056] According to an embodiment of the present invention, the critical operating condition occurs if the amplitude of the mains voltage V_{MAINS} is below a lower threshold amplitude value (in which case the OCD unit **160** may comprise a sensing unit, preferably a voltage divider, even more preferably a resistive voltage divider). Thus, powering the universal motor **140** in the support driving mode (with the motor voltage $V_{MOTOR,B}$ and with the motor current $I_{MOTOR,B}$) avoids poor starting torque of the universal motor **140** (and resulting rotation failure of the drum **115** or slowing down of the universal motor **140** speed) arising (as in known laundry appliances equipped with universal motors) from significant reductions in the mains voltage V_{MAINS} - both frequent (as in geographical areas, such East Europe and Asian countries, wherein the mains voltage V_{MAINS} is highly unstable and may have fluctuations below nominal values for relatively long period of time), and sporadic *(e.g.,* due to temporary mains voltage V_{MAINS} failures). Indeed, as mentioned above, the motor voltage $V_{MOTOR,B}$ in the support driving mode features, unlike the motor voltage $V_{MOTOR,A}$ in the normal driving mode, a non-zero direct component, which provides an improved starting torque of the universal motor **140** that allows it to correctly operate even when the mains power supply is significantly reduced.

[0057] Preferably, the normal operating condition (and the normal driving mode of the universal motor 140) is set, or restored, when the amplitude of the mains voltage V_{MAINS} is above an upper threshold amplitude value higher than the lower threshold amplitude value - anyway, nothing prevents from providing implementations wherein the lower and upper threshold amplitude values are a same single threshold amplitude value (in which case the critical and normal operating conditions occurring if the amplitude of the mains voltage V_{MAINS} is below and above, respectively, said single threshold amplitude value).

[0058] Even more preferably, switching between normal and support operating conditions is achieved by means of hysteresis (and, hence, of directionality of lower and upper threshold amplitude values crossing). According to an exemplary embodiment making use of hysteresis, the critical operating condition occurs as soon as (and only when) the amplitude of the mains voltage V_{MAINS} drops below the lower threshold amplitude value and the normal operating occurs as soon as (and only when) the amplitude of the mains voltage V_{MAINS} rises above the upper threshold amplitude value, so that the universal motor **140** is driven in the current (first or second) driving mode when the amplitude of the mains voltage V_{MAINS} is between the lower and upper threshold amplitude values.

[0059] Additionally or alternatively to the above, the power supply apparatus **200** is advantageously configured to interrupt the powering of the universal motor **140** if the amplitude of the mains voltage V_{MAINS} is below a limit threshold amplitude value, *e.g.* lower than the upper threshold amplitude value (or of the single threshold amplitude value, as the case may be), so that the universal motor **140** is driven in the support driving mode when the amplitude of the mains voltage V_{MAINS} is between the limit and lower threshold amplitude values.

[0060] According to another embodiment, not necessarily alternative to the previous embodiments, the critical operating condition occurs when the amount of laundry load within the rotatable drum **115** is above a threshold laundry load weight (in which case, the OCD unit **160** may be a known weight sensing unit). Thus, powering the universal motor **140** in the support driving mode avoids that excessive laundry load within the drum **115** results (as typically is in known laundry appliances equipped with universal motors) in a generated torque not high enough to rotate the drum **115** at the desired speed, or to take it into rotation at all.

[0061] Additionally or alternatively, the critical operating condition may occur when the rotation speed of the rotatable drum **115** is below a threshold rotation speed (in which case the OCD unit **160** may be, or may comprise, a tachometer unit). Thus, in this case as well, powering the universal motor **140** in the support driving mode avoids that a reduced rotation speed of the rotatable drum **115** impairs the laundry treatment (as typically is in known laundry appliances equipped with universal motors).

[0062] According to another embodiment, not necessarily alternative to the previous embodiments, the critical operating condition occurs when a water discharge phase is started - indeed, the water-laden laundry load makes the rotatable drum **115** heavier, so that the improved starting torque provided by powering the universal motor **140** in the support driving mode allows avoiding laundry treatment being compromised.

[0063] From the above, it should be understood that other critical operating conditions may be provided without affecting the principles of the present invention.

Claims

1. Laundry treatment appliance **(100)** comprising:

   a drum **(115)** for housing a laundry load to be treated,
   a universal motor **(140)** adapted to be powered by an electric voltage ($V_{MOTOR,A}$, $_{MOTOR,B}$) for causing drum **(115)** rotation,
   an operating condition detecting unit **(160)** adapted to detect the occurrence of an operating condition of said appliance **(100),** and
   a power supply apparatus **(200)** configured to power the universal motor **(140)** in a first driving mode if a first operating condition is detected, and in a second driving mode if a second operating condition is detected, wherein in the first driving mode the voltage ($V_{MOTOR,A}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a first waveform, and in the second driving mode the voltage ($V_{MOTOR,B}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a second waveform different from said first waveform.

2. Laundry treatment appliance **(100)** according to Claim 1, wherein said second waveform is a partialized version of said first waveform.

3. Laundry treatment appliance **(100)** according to Claim 1 or 2, wherein said voltage ($V_{MOTOR,B}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** in the second driving mode is an alternating voltage, said voltage ($V_{MOTOR,B}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** in the second driving mode having a direct component for increasing a starting torque of the universal motor **(140)** when the second operating condition is detected.

4. Laundry treatment appliance **(100)** according to Claim 2 or 3, wherein said power supply apparatus **(200)** is connected or connectable to a mains power supply providing a sinusoidal mains voltage (V_{MAINS}), and wherein said first waveform comprises a sequence of positive-slope and negative-slope sinusoidal portions of said sinusoidal mains voltage (V_{MAINS}), said second waveform comprising the positive-slope or the negative-slope sinusoidal portions of said first waveform.

5. Laundry treatment appliance **(100)** according to any of the preceding Claims, wherein said power supply apparatus **(200)** is connected or connectable to a mains power supply providing a sinusoidal mains voltage (V_{MAINS}), and wherein said second operating condition occurs if the amplitude of said sinusoidal mains voltage (V_{MAINS}) is below a first threshold amplitude value.

6. Laundry treatment appliance **(100)** according to Claim 5, wherein said first operating condition occurs if the amplitude of said sinusoidal mains voltage (V_{MAINS}) is above a second threshold amplitude value higher than said first threshold amplitude value.

7. Laundry treatment appliance **(100)** according to Claim 6, wherein said second operating condition occurs if the amplitude of said sinusoidal mains voltage (V_{MAINS}) drops below the first threshold amplitude value and said first operating condition occurs if the amplitude of said sinusoidal mains voltage

(V_{MAINS}) rises above said second threshold amplitude value, the universal motor (140) being powered in the current, first or second, driving mode when the amplitude of said sinusoidal mains voltage (V_{MAINS}) is between said first and second threshold amplitude values.

8. Laundry treatment appliance **(100)** according to Claim 5, 6 or 7, wherein said power supply apparatus **(200)** is configured to interrupt the powering of said universal motor **(140)** if the amplitude of said sinusoidal mains voltage (V_{MAINS}) is below a third threshold amplitude value lower than said first threshold amplitude value.

9. Laundry treatment appliance **(100)** according to any Claim from 1 to 4, wherein said second operating condition occurs when the amount of laundry load is above a threshold laundry load weight.

10. Laundry treatment appliance **(100)** according to any Claim from 1 to 4, wherein said second operating condition occurs when a water discharge phase is started.

11. Laundry treatment appliance **(100)** according to any Claim from 1 to 4, wherein said second operating condition occurs when the rotation speed of the drum **(115)** is below a threshold rotation speed.

12. Laundry treatment appliance **(100)** according to any of the preceding claims, wherein the driving apparatus **(200)** comprises:

a thyristor device **(205_T)** comprising a first anode terminal coupled to a first mains power supply terminal **(T_N)** and a second anode terminal coupled to a first universal motor terminal, a second universal motor terminal being coupled with a second mains power supply terminal **(T_L);**
a control unit **(215)** configured to generate first or second control signals for allowing powering the universal motor **(140)** in the first or second driving modes, respectively, and
a triggering circuit **(205_R,205_B)** configured to activate the thyristor device **(205_T)** by providing first or second triggering pulse signals to a gate terminal of the thyristor device **(205_T)** based on the first or second control signals, respectively.

13. Laundry treatment appliance **(100)** according to any of the preceding Claims, wherein the appliance comprises a laundry washing appliance or a laundry washing/drying appliance or a laundry drying appliance.

14. Method for operating a laundry treatment appliance **(100)** comprising a drum **(115)** for housing a laundry load to be treated, a universal motor **(140)** adapted to be powered by a voltage ($V_{MOTOR,A}$,$V_{MOTOR,B}$) for causing drum **(115)** rotation, an operating condition detecting unit **(160)** adapted to detect the occurrence of an operating condition of said appliance **(100),** a power supply apparatus **(200)** configured to power the universal motor **(140)** in a first driving mode in which the voltage ($V_{MOTOR,A}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a first waveform, and in a second driving mode in which the voltage ($V_{MOTOR,B}$) provided by said power supply apparatus **(200)** to the universal motor **(140)** has a second waveform different from said first waveform,
said method comprising the steps of:

- detecting the current operating condition of said appliance;
- powering said universal motor **(140)** in said first driving mode if a first operating condition is detected;
- powering said universal motor **(140)** in said second driving mode if a second operating condition is detected.

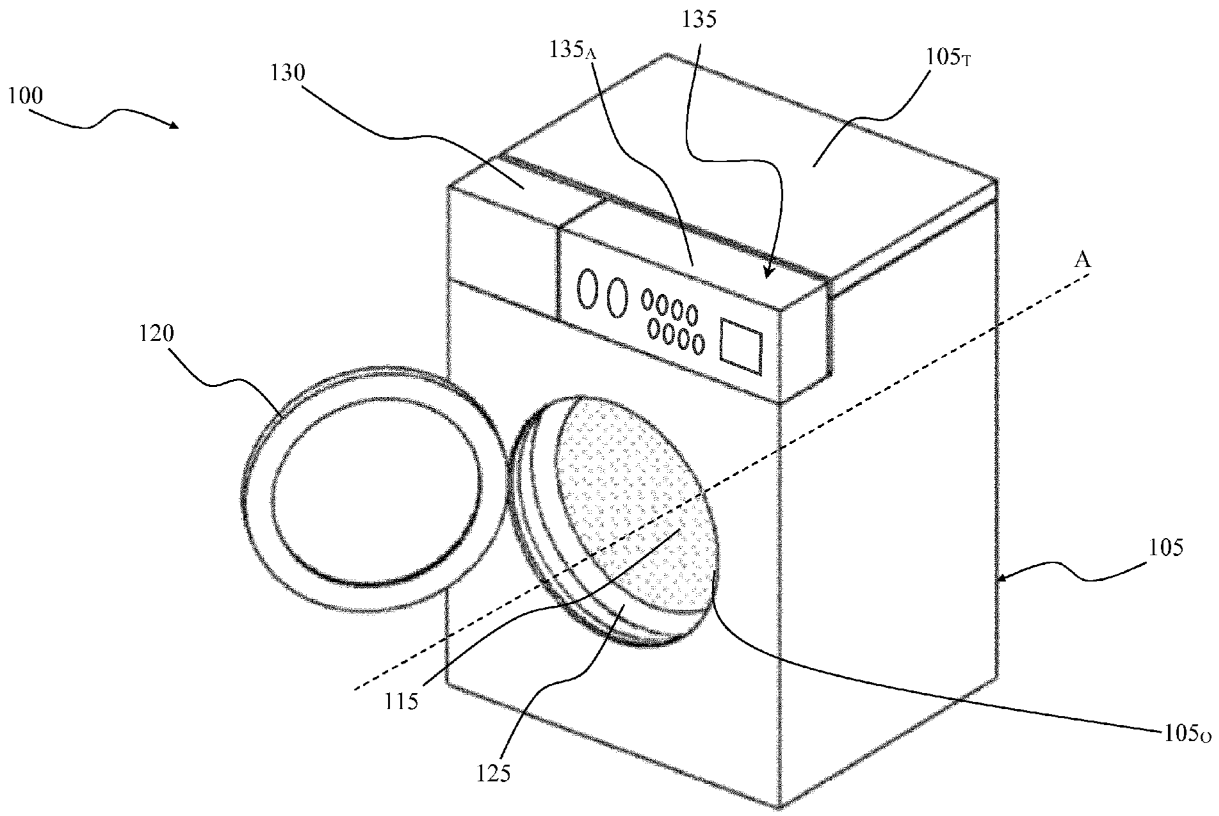
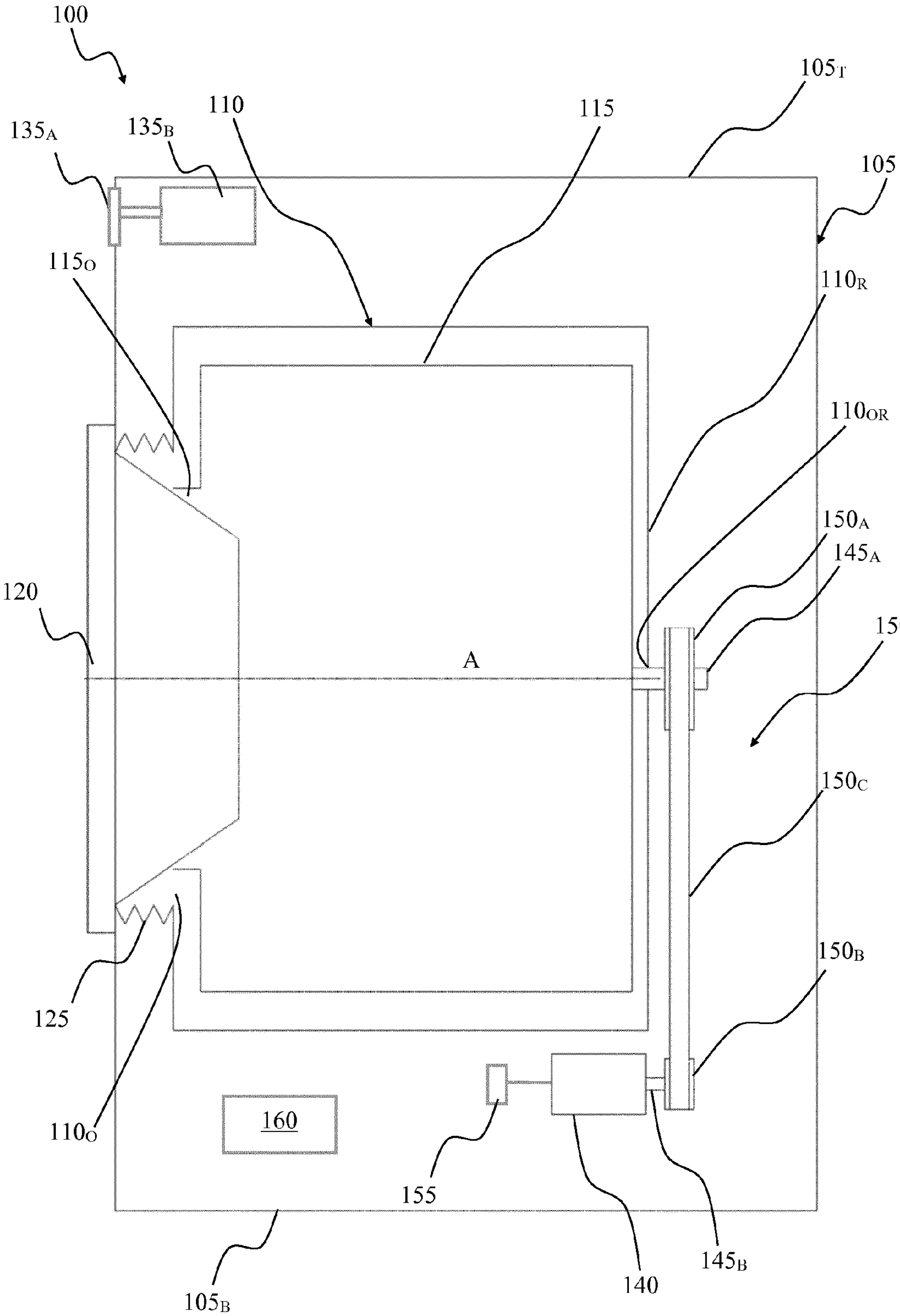


Figure 1A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115
105_T
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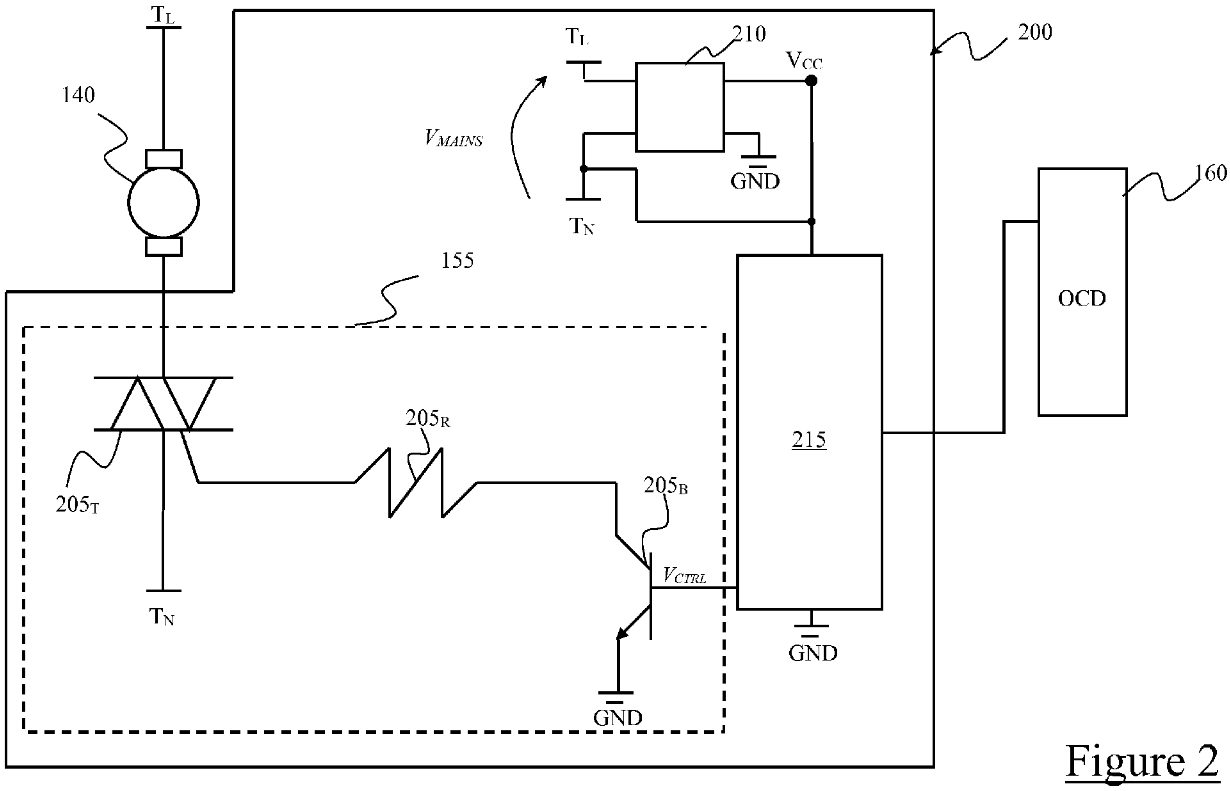
140
145_B
105_B

Figure 1B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200
T_L
210
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V_{MAINS}
GND
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155
OCD
205_R
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205_T
205_B
V_{CTRL}
T_N
GND
GND

Figure 2

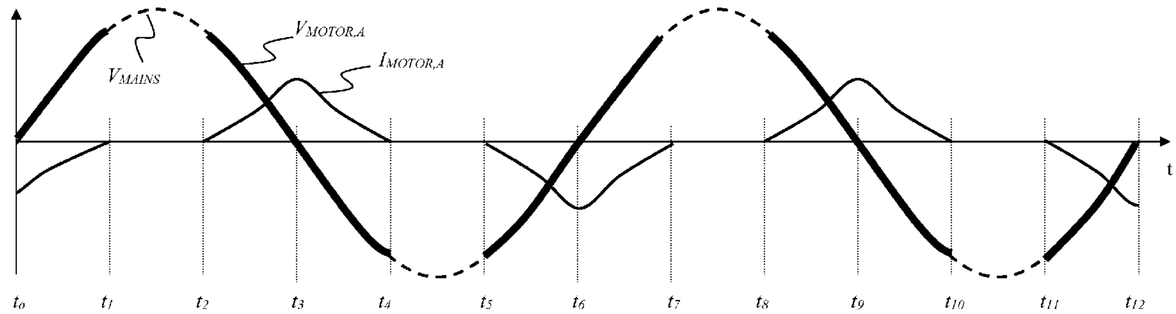

Figure 3A

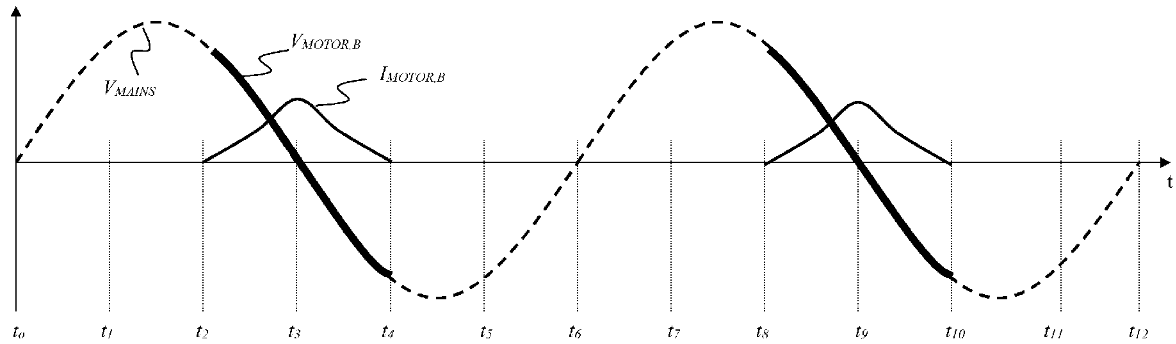

Figure 3B

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EUROPEAN SEARCH REPORT

Application Number
EP 14 19 3812

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	DE 10 2008 044283 A1 (BSH BOSCH SIEMENS HAUSGERAETE [DE]) 10 June 2010 (2010-06-10) * the whole document * -----	1-8, 12-14 9-11	INV. D06F58/28 D06F33/02 D06F37/30
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TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	21 April 2015	Jezierski, Krzysztof

CATEGORY OF CITED DOCUMENTS

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21-04-2015

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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