(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 January 2015 (29.01.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/011128 A1

(51) International Patent Classification:
H05B 33/08 (2006.01)

(21) International Application Number:
PCT/EP2014/065696

(22) International Filing Date:
22 July 2014 (22.07.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13306052.5 22 July 2013 (22.07.2013) EP

(71) Applicant: **KONINKLIJKE PHILIPS N.V.** [NL/NL]; High Tech Campus 5, NL-5656 AE Eindhoven (NL).

(72) Inventors: **VAN HELVOORT, Jeroen, Johannes, Michiel**; c/o High Tech Campus 5, NL-5656 AE Eindhoven (NL). **RICHARDSON, Angelica, Margarita, Nava**; c/o High Tech Campus 5, NL-5656 AE Eindhoven (NL).

(74) Agents: **BOURDAT, Laurent** et al.; Philips IP&S, P.O. Box 220, NL-5600 AE Eindhoven (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: DEVICE AND METHOD FOR DAMPENING OSCILLATIONS IN THE DIMMER-ATTACH PHASE WHEN A DIMMER IS USED WITH A LOW POWER LAMP

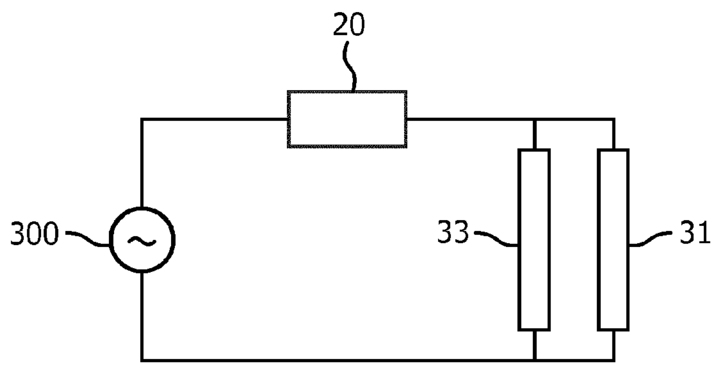

FIG. 3

(57) Abstract: Device for dampening oscillations (31) caused by a leading edge dimmer (20) comprising a Triac switch when used with a low-power load (33), the dampening device (31) being characterized in that it comprises at least a controller module comprising a resistive element having a resistance value that is variable over time, so as to draw a time-varying quantity of energy away from the oscillations in the dimmer attach phase, in such a way as to dampen the oscillations by preventing the current through the Triac from falling below a predetermined value, the resistive element being configured to be driven by a control signal.

WO 2015/011128 A1

DEVICE AND METHOD FOR DAMPENING OSCILLATIONS IN THE DIMMER-ATTACH PHASE WHEN A DIMMER IS USED WITH A LOW POWER LAMP

Technical Field

[0001] The present invention is directed to a device and a method for dampening oscillations that may occur when a driver for a low power lamp is connected to a dimmer. The present invention also relates to a driver for a light emitting device, comprising such a device.

Background

[0002] Many homes and office buildings nowadays are equipped with dimmers, that is: devices allowing regulating the light output of light emitting devices such as lamps. A widely used type of dimmer is so-called Leading Edge (LE) phase-cut dimmer, which benefits from a simple design.

[0003] An LE dimmer limits the power that is supplied over time to the lamp by an Alternating Current (AC) voltage supply such as mains, by blocking the voltage over an adjusted period of time during the start, or leading edge, of each line-voltage half cycle. The adjusted time determines the dimming level of the light output. A typical voltage delivered by an LE dimmer over time is illustrated by Figure 1. As shown in Figure 1, for each half cycle of the periodic signal, whichever the polarity, the voltage is blocked by the dimmer, meaning that the voltage across the terminals of the lamp is null over said adjusted period of time T_{off}. At time offset t_{edge}, the voltage is no longer blocked by the dimmer and thereafter the voltage at the lamp presents a typical sine shape during a period of time T_{on} until time offset t_{null}. The period of time (in the order of 200 µs) directly following the time offset t_{edge} is referred to as the dimmer-attach phase T_{attach}.

[0004] Typically, the voltage blocking effect of an LE dimmer is produced by a Triac switch, which is closed by means of a timing circuit. A simplified structure of a typical LE dimmer 20 is illustrated by Figure 2. As illustrated in Figure 2, the LE dimmer 20 is placed along the mains line LN. A load 22 is connected between the output of the LE dimmer 20 and the mains neutral NE. The switch opens once the current through it drops below a threshold, usually called “holding current”. For a purpose of compliance with international standards related to ElectroMagnetic Compatibility (EMC), EMEA LE dimmers typically comprise an output filter, with a typical operating range between 10 and 25 kHz, consisting of an inductance L in series with the Triac Tr, and a capacitance CF in parallel to the Triac Tr and the inductance LF, as illustrated in Figure 2. A timer module 201, also comprising a power supply, allows controlling switching on and off of the Triac Tr.

[0005] Such conventional dimmers as LE dimmers have been designed for being used with incandescent lamps. However, there is an increasing demand for low-power replacement lamps, based on technologies such as Compact Fluorescent Lamps (CFL) or Light Emitting Diodes (LED). When conventional dimmers such as LE dimmers are used with such low-power lamps, undesirable effects can occur, notably: flickering effects and possibly acoustic noise, which significantly hamper performance and lifetime of the lamp.

[0006] When a low-power lamp such as a LED lamp is connected to a LE dimmer, two main issues arise: a first issue, that is due to the substantially lower power consumption of the LED lamp, results in the steady state current of the LED being closer to the Triac holding current; a second issue lies in oscillations occurring when the Triac is closed, due to the presence of the capacitance and inductance in the LE dimmer. The frequency, amplitude and damping ratio of these oscillations are determined by the EMC output filter in the dimmer and the energy draw of the load (“dissipation”). Though a conventional incandescent light exhibits ample dissipation, thereby damping such oscillations, the dissipation, thus the damping, is substantially less with a LED lamp.

[0007] If the oscillations are not sufficiently damped, then the current through the Triac falls below the holding current and the Triac is then switched off too early, resulting in refiring.

[0008] Solutions have been proposed to overcome the oscillations. Such solutions consist of extension circuits such as bleeders or RC latches that allow drawing a predefined current during the leading edge phase. This current, hereinafter referred to as feed-forward current, draws energy from the oscillations to dampen them, and temporarily raises the steady state current, in order to prevent the current through the Triac to drop down to a too low strength. One drawback of such existing solutions is that the feed-forward current is independent from the actual circumstances, notably from the characteristics of the system, i.e. from the characteristics of the dimmer itself, but also the characteristics of the load or plurality of loads attached to the dimmer, the dimmer's output signals being dependent on the loads, which makes such solutions not optimally power-efficient in most operational configurations.

Summary

[0009] One aim of the present invention is to solve the above-mentioned problems, by allowing the current in the attach phase to be adapted to the actual operational configuration. Since the current in the attach phase responds to the operational conditions, it is being hereinafter referred to as "feedback current", in opposition to the feed-forward current produced by known solutions.

[0010] More specifically, the present invention proposes that the current in the attach phase is shaped thanks to a controller module comprising an impedance element with an impedance that is variable over time, for example a resistive element with a variable resistance, or a capacitive element with a variable capacitance, or a combination of a resistive element and a capacitive element with respectively variable resistance and capacitance, the variable resistance or capacitance being determined by a Pulse Width Modulation (PWM) signal duty cycle.

[0011] For the sake of clarity, it will be hereinafter referred to exemplary embodiments wherein the impedance element is a resistive element, though it shall be observed that the following description can also be applied to embodiments wherein the impedance element is a capacitive element or a combination of a resistive element and a capacitive element.

[0012] As a result, the feedback current can be much lower than the feed-forward current; moreover, the feedback current can be shaped accordingly with the properties of the used dimmer, therefore reducing the current in the attach phase even further.

[0013] For that purpose, the present invention proposes a device for dampening oscillations caused by a leading edge dimmer comprising a Triac switch when used with a low-power load, the dampening device being characterized in that it comprises at least a controller module comprising an impedance element having an impedance value that is variable over time, so as to draw a time-varying quantity of energy away from the oscillations during the attach phase of the dimmer, in such a way as to dampen the oscillations by preventing the current through the Triac switch from falling below a predetermined value, the impedance element being configured to be driven by a control signal.

[0014] In an exemplary embodiment of the invention, the impedance element can be at least one among the group consisting of a resistive element having a resistance value that is variable over time, and a capacitive element having a capacitance value that is variable over time.

[0015] In an exemplary embodiment of the invention, the impedance element can comprise a switching element in series with a resistor, the control signal being a Pulse Width Modulation signal of a determined frequency, the control signal being controlling the switching element, the duty cycle of the control signal thereby determining a variable resistance.

[0016] In an exemplary embodiment of the invention, the impedance element can comprise a switching element in series or in parallel with a capacitor, the control signal being a Pulse Width Modulation signal of a determined frequency, the control signal being controlling the switching element, the duty cycle of the control signal thereby determining a variable capacitance.

[0017] In an exemplary embodiment of the invention, the dampening device can further comprise a memory configured for storing at least one driving table comprising a plurality of values of the duty cycle of the control signal, the dampening device being configured for varying the duty cycle of the control signal as a function of the values comprised in said at least one driving table.

[0018] In an exemplary embodiment of the invention, a driving table may comprise a control word, comprising a series of values of the duty cycle of the control signal, each value of the series of values being applied to the control signal over a predetermined plurality of cycles of the control signal.

[0019] In an exemplary embodiment of the invention, the dampening device can be configured for being put in parallel with the low-power load.

[0020] In an exemplary embodiment of the invention, the dampening device can be configured for being put in parallel with the leading edge dimmer.

[0021] In an exemplary embodiment of the invention, the dampening device may further comprise an adaptive module, configured for identifying at least one characteristic of the dimmer and selecting an appropriate controller module as a function of the identified dimmer characteristics.

[0022] In an exemplary embodiment of the invention, the adaptive module may comprise an identification module configured for delivering an output signal representative of identified characteristics of the dimmer as a function of at least one signal delivered by the dimmer.

[0023] In an exemplary embodiment of the invention, the adaptive module may comprise a selection module configured for receiving as an input said signal representative of identified dimmer characteristics, determining an appropriate controller module among a plurality of controller modules as a function of the identified dimmer characteristics, and outputting a corresponding control signal.

[0024] In an exemplary embodiment of the invention, the dampening device may further comprise a switching module configured for selecting the appropriate controller module as a function of the control signal output by the selection module.

[0025] Another aspect of the current invention is a light emitting device characterized in that it comprises a dampening device following one of the described embodiments.

[0026] Another aspect of the current invention is a driver for a light emitting device characterized in that it comprises a dampening device following one of the described embodiments.

[0027] Another aspect of the current invention is a method for dampening oscillations caused by a leading edge dimmer comprising a Triac switch when used with a low-power load, characterized in that it comprises at least a step of applying a control signal to a controller module for controlling a variable resistance over time so as to draw a time-varying quantity away from the oscillations in such a way as to dampen the oscillations by preventing the current through the Triac switch from falling below a predetermined value.

[0028] Another advantage of the present invention is that the feedback current automatically adapts to the actual operational circumstances, such as dimming angle, dimmer characteristics, use of parallel light emitting devices, etc.

[0029] Another advantage of the present invention in some of its embodiments is that the feedback current can be minimized through a selection of an optimal PWM signal driving table among a plurality of driving tables, a driving table comprising a set of values defining the shape of the PWM signal, as described further in detail hereinafter.

Brief Description of the Drawings

[0030] These and other characteristics and advantages of the invention will be made clearer in view of the detailed description given below of a preferred embodiment, provided by way of an illustrative and non-limiting example only, as well as the accompanying drawings which represent:

[0031] Figure 1, described above, a curve showing a typical voltage delivered by a LE dimmer over time;

[0032] Figure 2, described above, a sketch drawing showing a typical LE dimmer;

[0033] Figure 3, a sketch drawing illustrating a dampening device in combination with a power supply, a dimmer and a load, in an exemplary embodiment of the invention;

[0034] Figure 4, a sketch drawing illustrating a controller module that is part of a dampening device, and an exemplary mode of operation thereof, in an exemplary embodiment of the invention;

[0035] Figure 5, curves illustrating typical oscillations occurring when a leading edge dimmer is used with a low-power load, respectively with and without a dampening device according to the invention;

[0036] Figures 6A and 6B, curves illustrating exemplary variations of feedback current, and corresponding variations of the resistance of a resistive element in a dampening device according to an exemplary embodiment of the invention;

[0037] Figure 7, curves illustrating the variations of the duty cycle of a PWM signal applied for controlling the resistance of a resistive element, in a dampening device according to an exemplary embodiment of the invention;

[0038] Figure 8, a sketch drawing illustrating a dampening device in combination with a power supply, a dimmer and a load, in an alternative exemplary embodiment of the invention;

[0039] Figure 9, a sketch drawing illustrating an adaptive module following an exemplary embodiment of the invention.

Detailed Description

[0040] In the following detailed description, for purposes of explanation and not limitation, representative embodiments disclosing specific details are set forth in order to provide a thorough understanding of the present teachings. However, it will be apparent to one having ordinary skill in the art having had the benefit of the present disclosure that other embodiments according to the present teachings that depart from the specific details disclosed herein remain within the scope of the appended claims. Moreover, descriptions of well-known apparatuses and methods may be omitted so as to not obscure the description of the representative embodiments. Such methods and apparatuses are clearly within the scope of the present teachings.

[0041] Figure 3 shows a sketch drawing illustrating a dampening device in combination with a power supply, a dimmer and a load, in an exemplary embodiment of the invention.

[0042] A load 33, for example a low-power lamp such as a LED or a plurality of LEDs, can be supplied by a voltage source 300, for example mains voltage, through a dimmer 20, such as a LE dimmer comprising a Triac, not shown in Figure 3. In the exemplary embodiment of the invention depicted by Figure 3, a dampening device 31 can be put in parallel with the load 33. As detailed hereinafter, other configurations are possible, the dampening device 31 being not necessarily put in parallel with the load 33. The dampening device 31 allows drawing energy from the oscillations in order to dampen them, and temporarily raises the steady state current, in order to prevent the current in the Triac to drop too low.

[0043] The dampening device 31 notably comprises at least a controller module comprising a resistive element, whose resistance can be varied so that the current in the attach phase can be shaped in order to dampen the oscillation and prevent from misfiring of the Triac. The resistive element can be controlled through a control signal. A detailed structure of a controller module as part of a dampening device 31 is described below in reference to Figure 4.

[0044] In reference to Figure 4, the dampening device can comprise a controller module 41 comprising a resistive element formed by a resistor 412 in series with a switching element 414. The switching element 414 can be driven by a control signal 416. The control signal 416 can for example be a PWM signal, that is: a logical signal with a determined frequency and varying duty cycle. In the non-limiting exemplary embodiment illustrated by Figure 4, the control signal 416 is formed by a first series of pulses with a duty cycle equal to 0.9, followed by a series of pulses with a duty cycle of 0.5, followed by a series of pulses with a duty cycle of 0.1. The control signal 416 can be determined by a driving table, or a control word defined as [0.9; 0.5; 0.1; 0].

[0045] The control signal 416 can be realized by means of a control signal generation module, not represented in Figure 4, allowing generating the control signals, for example based upon control words as described above, which can be stored in a memory. For example, a plurality of control words can be stored in a look-up table. In advantageous embodiments described hereinafter, in reference to Figure 9, an additional adaptive module can allow selecting a control scheme depending on the identified operating configuration.

[0046] The resistor 412 can be formed by an actual resistor, a plurality of resistors in series or in parallel, or a resistive network, or any plurality of components known to form a resistive element. The switching element 414 can for example be formed by a Field Effect Transistor (FET) or an Insulated-Gate Bipolar Transistor, or any known component allowing switching, preferably at high frequencies.

[0047] When switching occurs at a relatively high frequency, as detailed hereinafter in reference to Figure 7, the resistive element can be considered as having a time-averaged effective resistance R_{var} that is determined by the duty cycle and the nominal resistance value of the resistor 412, denoted as R_{closed}. The effective resistance can be determined by relation (1) below:

[0048] $$\frac{1}{R_{\text{var}}} = \eta \frac{1}{R_{closed}} + (1-\eta)\frac{1}{R_{opened}} \quad (1),$$

[0049] wherein R_{opened} stands for the resistance value of the resistive element when the switching element 414 is opened; the value of resistance R_{opened} can be considered as being infinite, therefore the duty cycle can be formulated as a function of the effective resistance and nominal resistance of the resistor 412, as per relation (2) below:

[0050] $$\eta = \frac{R_{closed}}{R_{\text{var}}} \quad (2).$$

[0051] For the relations (1) and (2) above to be relevant, the frequency of the PWM control signal should be significantly higher than the frequency of the dynamics in the system, which is typically between 10 and 25 kHz. For instance, a frequency of the PWM signal can be 40 kHz or above, as detailed further below.

[0052] Figure 5 shows curves illustrating typical oscillations occurring when a leading edge dimmer is used with a low-power load, respectively with and without a dampening device according to the invention.

[0053] Figure 5 depicts a bi-dimensional orthonormal frame wherein the abscissae give time expressed in seconds, and the ordinates give the amplitude of the current through the dimmer, flowing through the Triac.

[0054] A first curve 501 displays the amplitude of the current through the Triac of the dimmer, in a case when the dimmer is connected to a low-power lamp. The first curve 501 is typical of the oscillations that occur in such a configuration, which phenomenon being also designated as “ringing”. Resonance between inductor and capacitors within the LE dimmer results in ringing of the current through the dimmer. Such ringing may typically occur when leading edge Triac dimmers are used to dim low-power lamps such as LED lamps. As the ringing becomes large, the resulting minimum current through the Triac will be lower than the holding current necessary to maintain the Triac conductive, causing the Triac to turn off or “misfire”. The misfiring causes the lighting current provided from dimmer to the load lamp to repeatedly spike (or “multifire”) during waveform half cycles. As a result, the lamp driver turns on and off, and the lamp consequently flickers on and off. The first curve 501 results from a simulation and actually does not show the turning off of the Triac, for example at 45 µs, for the sake of clarity. Even dimmers that include prolonged or repeated firing of the Triac, i.e. dimmers that actively force the Triac in the conductive state during a prolonged period of time, are affected by the repeated drops in the current below the holding current.

[0055] In the non-limiting example illustrated by Figure 5, zero-crossing of the first curve 501 occurs approximately 45 µs after the Triac of the dimmer turns on.

[0056] Still in reference to Figure 5, a second curve 502 displays the amplitude of the current through the Triac of the dimmer, in a case when the dimmer is connected to a higher power lamp, such as an incandescent light source. In such a case, the high power that is dissipated by the lamp brings a dampening effect to the oscillation of the input current, and no drops below the holding current of the second curve 502 occurs. In steady state, still a relatively high current flows.

[0057] A third curve 503 displays the amplitude of the current in the Triac of the dimmer, in a case when the dimmer is connected to a low-power lamp, the dimmer being this time associated with a dampening device as per the invention. The dampening device shall be configured so that no drop below the holding current of the third curve 503 occurs.

[0058] With the exemplary configuration shown in Figure 5, the dampening device can be configured in such a way that much power is drawn away from the load, at least during a first period of time essentially corresponding to the time interval between the first positive peak of first curve 501 and its first negative peak; then power shall still been drawn away from the load, but in lower proportions compared with the first period of time; then less power shall be drawn over time. Such a time sequence defines a feedback current bleeding profile over time, which can be directly translated in a time profile of the variations of the effective resistance of the resistive element, as detailed hereinafter in reference to Figures 6A and 6B.

[0059] Figures 6A and 6B show curves illustrating exemplary variations of feedback current, and corresponding variations of the resistance of a resistive element in a dampening device according to an exemplary embodiment of the invention.

[0060] In reference to Figure 6A, a first curve 601 displays the feedback current as a function of time, in an exemplary configuration corresponding to that of Figure 5. A second curve 602 displays the corresponding load voltage, also as a function of time. As mentioned above, and as shown by first curve 601, the feedback current rapidly increases during a first period of time during which most of the energy shall be drawn so as to dampen the oscillations; the feedback current is then rapidly decreased to a lower level where still some energy is drawn away from the load; the feedback current then tends toward a null value. This variation scheme of the feedback current allows a fast increase of the load voltage, as shown by second curve 602, and a fast stabilization of the load voltage.

[0061] Now in reference to Figure 6B, a third curve 603 displays the corresponding profile of variations of the resistance of the resistive element allowing a feedback current profile as displayed by the first curve 601 in Figure 6A, as a function of time, in a dilated scale compared to Figure 6A. In this exemplary configuration, the nominal resistance R_{closed} of the resistive element is 500 Ohms. The variable resistance R_{var} is initially infinite, the switching element being then opened, and rapidly decreases to a low value, in the example lower than 1 kOhm, allowing drawing most energy away from the load. Then the resistance is increased to an intermediate level, in the example around 7 kOhms, so that some energy can still be drawn away from the load. Finally, the resistance increases to an infinite value.

[0062] In practice, this variation profile of the variable resistance is repeated for each leading edge of the signal that is output by the dimmer, that is: typically at mains frequency, that is: at a frequency of 50 or 60 Hz.

[0063] Figure 7 shows curves illustrating the variations of the duty cycle of a PWM signal applied for controlling the resistance of a resistive element, in a dampening device according to an exemplary embodiment of the invention.

[0064] As mentioned herein below, the value of the variable resistance can be determined by the duty cycle of a PWM control signal. In Figure 7, a first curve 701 displays the variations of the duty signal of the control signal as a function of time, in an exemplary configuration corresponding to that of Figures 5, 6A and 6B.

[0065] The duty cycle is adjusted so that a low impedance path is provided during the period of time T_{off} during which the dimmer blocks the AC voltage supply, starting from a low initial value.

[0066] In practice, discrete values of the duty cycle can be applied to a few consecutive cycles of the control signal. In the exemplary configuration illustrated by figures 5 to 7, the control signal can have a frequency of 120 kHz, and the update rate of the duty cycle can for example be of 40 kHz, allowing a given discrete value of the duty cycle to be applied over a period of 0.025 ms, as displayed by a second curve 702 in Figure 7.

[0067] In the illustrated exemplary configuration, a first duty cycle of 0.82 is applied, followed by following values of the duty cycle: 0.74, 0.36, 0.09, 0.07, 0.04, 0.01, 0. Therefore a control word in this exemplary configuration can be formulated as [0.82, 0.74, 0.36, 0.09, 0.07, 0.04, 0.01, 0].

[0068] Figure 8 a sketch drawing illustrating a dampening device in combination with a power supply, a dimmer and a load, in an alternative exemplary embodiment of the invention.

[0069] As shown in Figure 8, in an alternative embodiment, a dampening device 81 can be put in parallel with the dimmer 20, instead of being put in parallel with the load 33 as in the previously described embodiments.

[0070] The design of a dampening device as per any of previously described embodiments can be optimized to one specific dimmer, resulting in minimal energy use. Optimization can be carried out by a user, who can select an appropriate control scheme of the resistive element depending on the operational configuration, for example by selecting the most appropriate control word among a plurality of control words stored in a memory.

[0071] However, the installed base consists of dimmers with different characteristics, all having different values for internal inductance and capacitance. As mentioned above, in advantageous embodiments thereof, the current invention can further provide an adaptive module that allows selecting a control scheme depending on an identified actual operational configuration. The adaptive module can be included in the dampening device, or external to the dampening device. It will hereinafter be considered that the dampening device, in the following described embodiments of the invention, comprises the adaptive module.

[0072] The adaptive module can comprise an identification module that allows identifying at least one characteristic of the dimmer actually used in combination with the lamp, and a selection module; the identification of the dimmer can be input to the selection module for a selection of the most appropriate controller module, as illustrated in Figure 9 described hereinafter.

[0073] For example, the adaptive module can be based on a so-called “Multiple Model Adaptive Controller” architecture (MMAC), which brings the advantage of being robust against variations in dimmer oscillation frequencies. In an MMAC architecture, the identification module can be formed by a supervisor module that can select from a set of controller modules which controller module shall be used, based on observed signals of the identification module.

[0074] The adaptive module can be configured for implementing a selection method comprising an initiation step, wherein a first controller module can be selected with an arbitrary small resistance, mimicking the load of an incandescent light bulb, making it robust for oscillation frequencies in a very large frequency window. Although being robust, the first controller module implies a large dissipation. Once the identification module has identified the characteristics of the dimmer used, for example by measuring the frequency of the oscillations, or the damping level, or a rising time, a selection step can allow selecting the most appropriate controller module as a function of the detected frequency window of the oscillations during the attach phase. The selection module can comprise hardware elements allowing implementing the selection method, such as a microcontroller and a memory, for instance.

[0075] The applicant indeed has noticed that among the many LE dimmers available on the market, each of them provides different operating characteristics, which also depend on operating conditions, such as the actual dimming level. The identification module can for instance comprise means for identifying the frequency of oscillations, the damping level, or rising time.

[0076] For instance, one first type of commercially available dimmer has an oscillation frequency in the range of 12.5 to 15.0 kHz, this oscillation frequency being dependent upon the actual dimming setting; another type of commercially available dimmer has an oscillation frequency in the range of 16.6 to 20.0 kHz, while a third type of commercially available dimmer has an oscillation range of 10.4 to 20.0 kHz.

[0077] For example, the current oscillations occurring in the dimmer can be measured through measuring the voltage across the lamp, as the current oscillations translate into voltage oscillations across the lamp. One possible way for identifying the frequency of the voltage oscillations across the lamp is to use a bank of Kalman filters, or an approximation/simplification thereof. Prior to identifying the frequency of the voltage oscillations, the voltage can for example be scaled down, and the low-frequency components of the signal can then be filtered out. Frequency of the resulting high-frequency signal can then be determined by digital means.

[0078] Similarly, the damping of the oscillations can be determined based on analyzing the voltage oscillations across the lamp, for example using digital means.

[0079] Alternatively, the frequency and damping can be determined with a Fast Fourier Transform of the driver voltage, or a peak-detection scheme.

[0080] Similarly, the rising time of the dimmer output voltage is translated into a rise time of the voltage across the lamp. Analyzing the voltage across the lamp can thus allow determining the rising time of the dimmer’s phase cut signal.

The rising time can for example be defined as the time period that is required for the magnitude of the signal to reach 90% of its instantaneous maximum value starting from 10% of the maximum value.

[0081] Advantageously, the selection method can be iterated in order to allow selecting a smaller frequency window, so as to minimize energy dissipation in the controller module. In general it can be stated that the smaller the identified frequency window is, the less robust the controller has to be, and the less energy is dissipated. Several frequency windows can be defined, one for the entire operating window and arbitrary many for smaller regions. Each frequency window corresponds to a control word, i.e. a driving table comprising PWM duty cycle values, as described further above, which can have been designed offline and can be adapted online.

[0082] Besides, the level of damping that is required to dampen the dimmer-lamp oscillations varies depending on the dimmer and on the presence of lamps connected in parallel. Additional lamps can offer a lot of damping if they are incandescent lamps, or low damping if they are low-power lamps such as LEDs of CFLs. If less damping is required, the PWM duty cycle values can be scheduled accordingly, providing additional freedom to save energy and limit current in the attach phase.

[0083] Figure 9 shows a sketch drawing illustrating an adaptive module following a non-limiting exemplary embodiment of the invention.

[0084] An adaptive module 900 can comprise an identification module 901 for example receiving as input the output signals of the dimmer, for example a dimmer output voltage or current, and providing an output signal that is representative of an identified type of dimmer, for example an output signal representative of system characteristics, such as for instance signals that are representative of the identified frequency of the input signal coming from the dimmer, its rising time and/or its damping level. . The adaptive module 900 can further comprise a selection module 902, receiving as an input the output signal of the identification module 901. Based on the identified frequency and on the signal ouput by the identification module 901, the selection module 902 can then determine an appropriate frequency window to make the controller match the characteristics of the system, and determine an appropriate controller module among a plurality of controller modules C_1, C_2, ..., C_{N-1}, C_N, and output a control signal corresponding to the determined appropriate controller module to a switching module 903, actually selecting the determined controller module. The plurality of controller modules does not necessarily correspond to physically distinct controller modules, but can correspond to a plurality of driving tables, or control words as defined below.

[0085] The identification module 901, selection module 902 and switching module 903 do not necessarily correspond to separate physical modules, and all of them can for instance be implemented in an electronic circuit or in a microcontroller.

[0086] In other embodiments, the controller module can be further selected as a function of the lamp characteristics, such as, for instance, as a function of characteristics of the load voltage, such as notably damping level, rising time, decay rate of the oscillation, peak-peak amplitude, minimum and maximum voltage, etc. An advantage of such embodiments is that they allow improving the cooperation between multiple lamps, by sharing the burden between the lamps, which can prevent from having to derate the dimmer.

[0087] A dampening device following any of the described embodiments can be located in the lamp. For example, a LED retrofit lamp can comprise a dampening device following any of the described embodiments, and can therefore advantageously replace an incandescent lamp or any other type of lamp, without requiring any intervention by the user on the existing installation. The dampening device can for example be comprised in the lamp driver, for example upstream or downstream the bridge rectifier of the driver, or upstream or downstream the ElectroMagnetic Interference (EMI) filter of the driver, if it is thus equipped.

[0088] In other embodiments, a dampening device following any of the described embodiments can be added to an existing installation, for example in parallel with the dimmer, as described above.

[0089] While the invention has been illustrated and described in detail in the drawings and foregoing description, it should be clear to a person skilled in the art that such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments; rather, several variations and modifications are possible within the protective scope of the invention as defined in the appending claims.

[0090] All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

[0091] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed at limiting the scope.

CLAIMS

1. Device for dampening oscillations (31) caused by a leading edge dimmer (20) comprising a Triac switch when used with a low-power load (22, 33), the dampening device (31) being characterized in that it comprises at least a controller module (41) comprising an impedance element having an impedance (R_{var}) value that is variable over time, so as to draw a time-varying quantity of energy away from the oscillations during the attach-phase of the dimmer (20) in such a way as to dampen the oscillations by preventing the current through the Triac switch from falling below a predetermined value, the impedance element being configured to be driven by a control signal (416).

2. Dampening device (31) as claimed in Claim 1, wherein the impedance element is at least one among the group consisting of a resistive element having a resistance (R_{var}) value that is variable over time, and a capacitive element having a capacitance value that is variable over time.

3. Dampening device (31) as claimed in Claim 1, characterized in that the impedance element comprises a switching element (414) in series with a resistor (412), the control signal being a Pulse Width Modulation (PWM) signal of a determined frequency higher than 10 kHz, the control signal (416) being controlling the switching element (414), the duty cycle of the control signal (416) thereby determining a variable resistance (R_{var}).

4. Dampening device (31) as claimed in Claim 1, characterized in that the impedance element comprises a switching element (414) in series or in parallel with a capacitor (412), the control signal being a Pulse Width Modulation (PWM) signal of a determined frequency, the control signal (416)

being controlling the switching element (414), the duty cycle of the control signal (416) thereby determining a variable capacitance.

5. Dampening device (31) as claimed in any of preceding claims, characterized in that it comprises a memory storing at least one driving table comprising a plurality of values of the duty cycle of the control signal (416), the dampening device being configured for varying the duty cycle of the control signal (416) as a function of the values comprised in said at least one driving table.

6. Dampening device (31) as claimed in Claim 5, characterized in that a driving table comprises a control word, comprising a series of values of the duty cycle of the control signal (416), each value of the series of values being applied to the control signal (416) over a predetermined plurality of cycles of the control signal (416).

7. Dampening device (31) as claimed in any of preceding claims, characterized in that it is configured for being put in parallel with the low-power load (22, 33).

8. Dampening device (31) as claimed in any of preceding Claims 1 to 6, characterized in that it is configured for being put in parallel with the leading edge dimmer (20).

9. Dampening device (31) as claimed in any of preceding claims, characterized in that it comprises an adaptive module (900), configured for identifying at least one characteristic of the dimmer (20) by identifying at least one in the group consisting of frequency of the oscillations, damping level and rising time, and

selecting an appropriate controller module (41) as a function of the at least one identified characteristic of the dimmer (20).

10. Dampening device (31) as claimed in Claim 9, characterized in that the adaptive module (900) comprises an identification module (901) delivering an output signal representative of at least one identified characteristic of the dimmer (20) as a function of at least one signal delivered by the dimmer (20).

11. Dampening device (31) as claimed in Claim 10, characterized in that the adaptive module (900) comprises a selection module (902) configured for receiving as an input said signal representative of at least one identified characteristic of the dimmer (20), determining an appropriate controller module among a plurality of controller modules (C_1, C_2, ..., C_{N-1}, C_N) as a function of the at least one identified characteristic of the dimmer (20), and outputting a corresponding control signal.

12. Dampening device (31) as claimed in Claim 11, characterized in that it further comprises a switching module (903) configured for selecting the appropriate controller module as a function of the control signal output by the selection module (902).

13. Light emitting device characterized in that it comprises a dampening device (31) as claimed in any of preceding claims.

14. Driver for a light emitting device characterized in that it comprises a dampening device (31) as claimed in any of preceding claims 1 to 12.

15. Method for dampening oscillations caused by a leading edge dimmer (20) comprising a Triac switch when used with a low-power load (22, 33), characterized in that it comprises at least a step of applying a control signal (416) to a controller module (41) for controlling a variable resistance over time so as to draw a time-varying quantity away from the oscillations in such a way as to dampen the oscillations by preventing the current through the Triac switch from falling below a predetermined value.

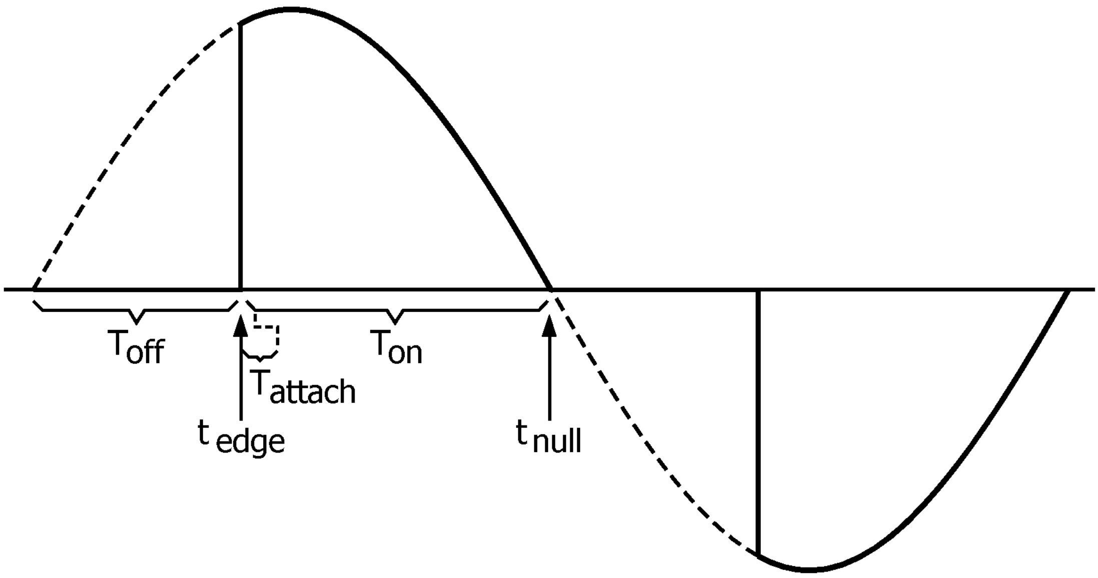

FIG. 1

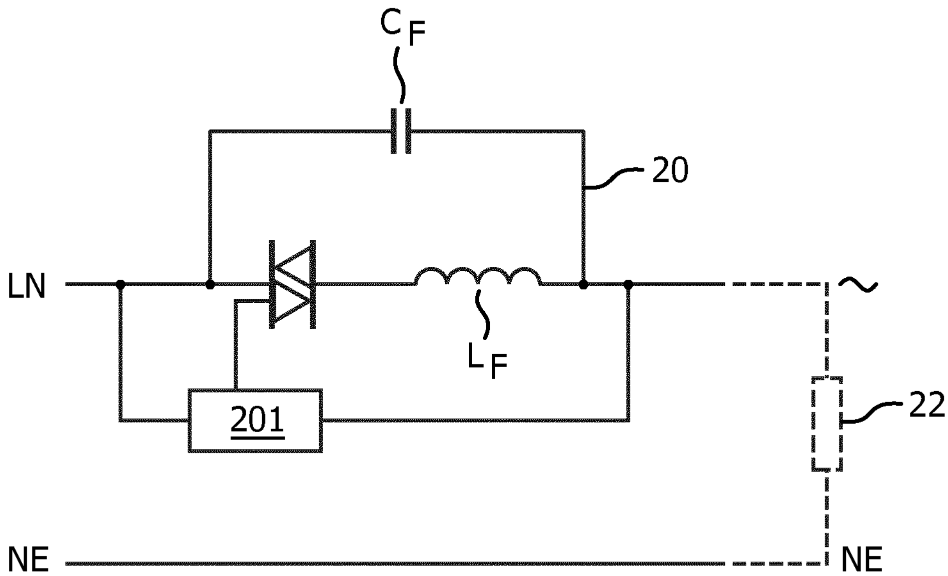

FIG. 2

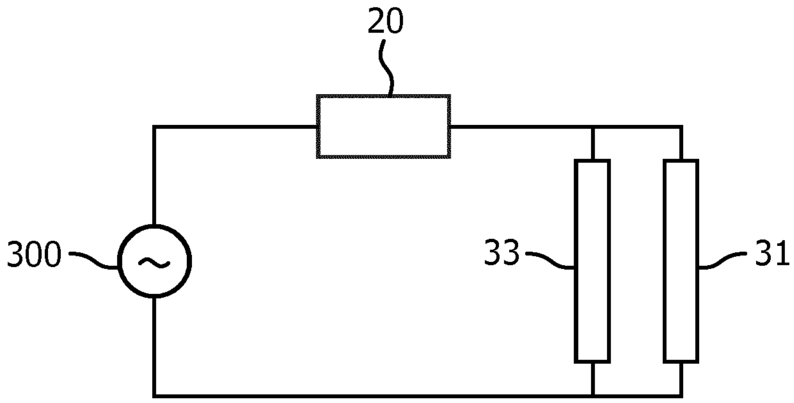

FIG. 3

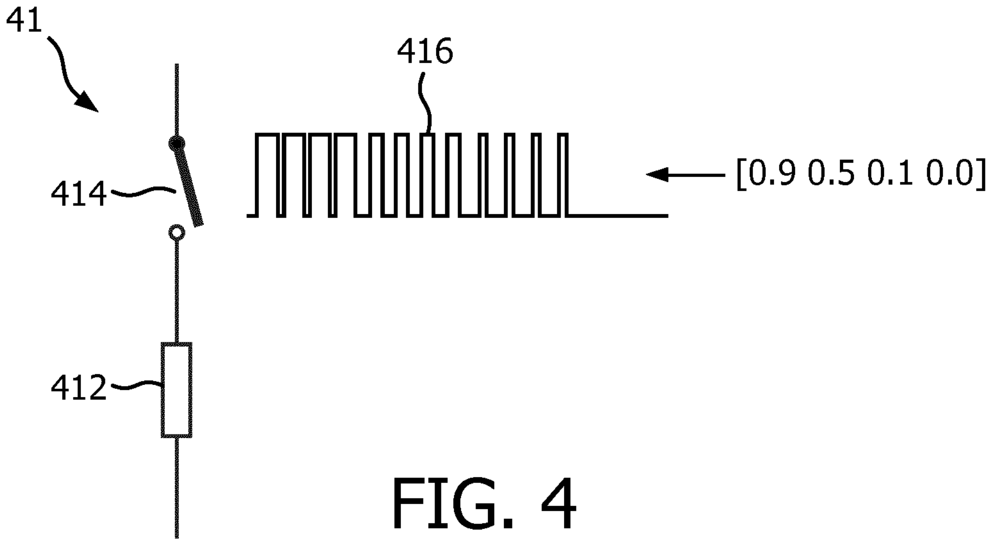

FIG. 4

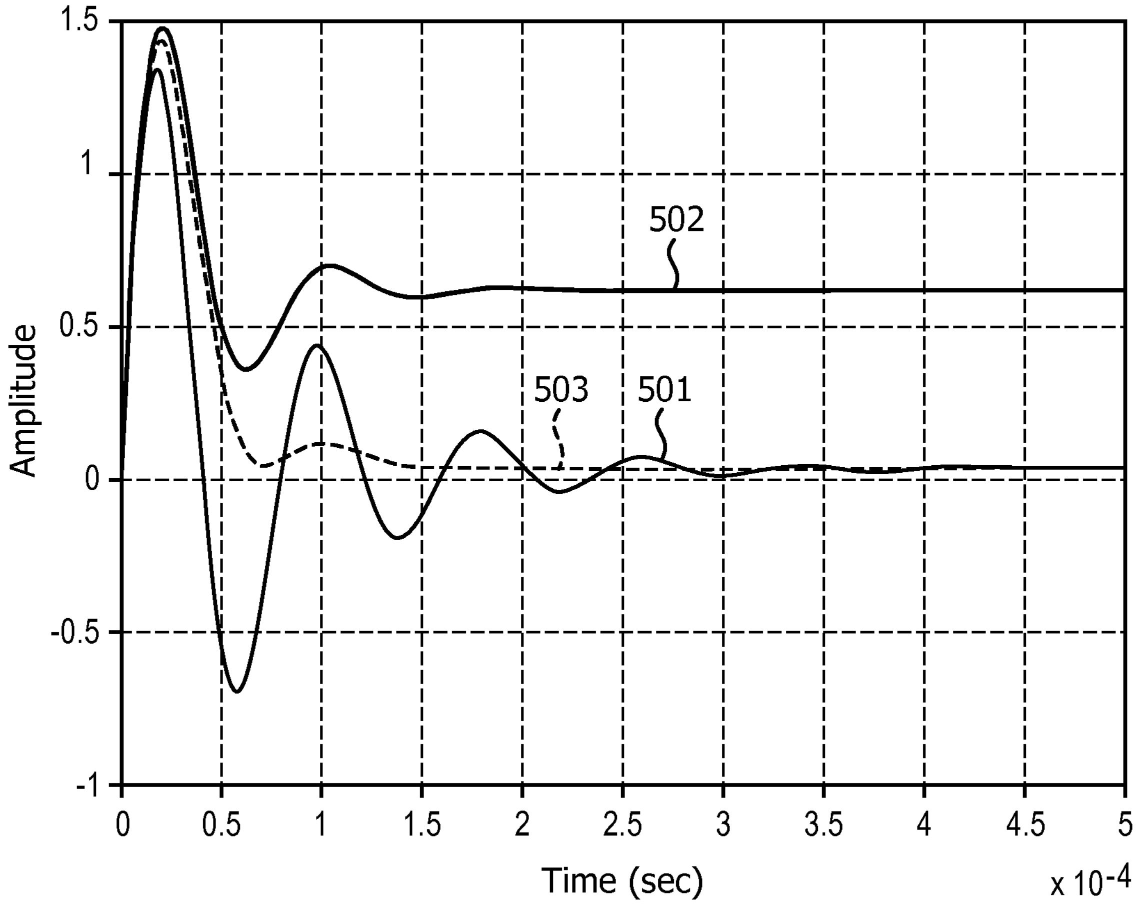
1.5
1
0.5
0
-0.5
-1
Amplitude
502
503
501
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)
x 10-4

FIG. 5

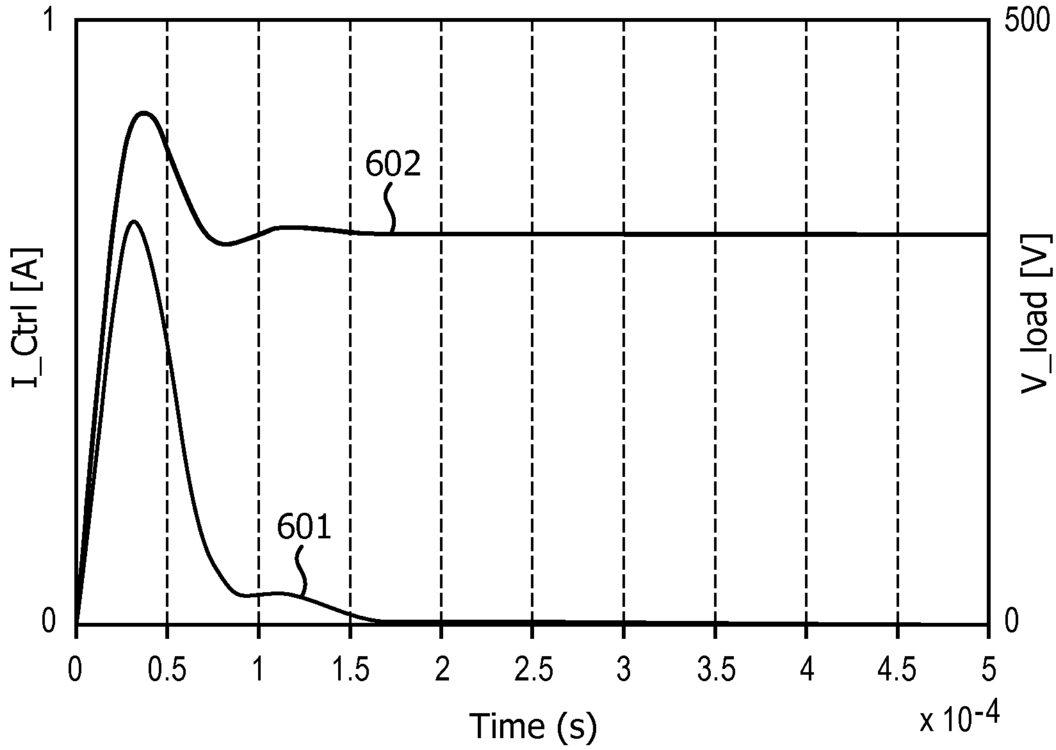
1
500
602
601
0
0
I_Ctrl [A]
V_load [V]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (s)
x 10-4

FIG. 6A

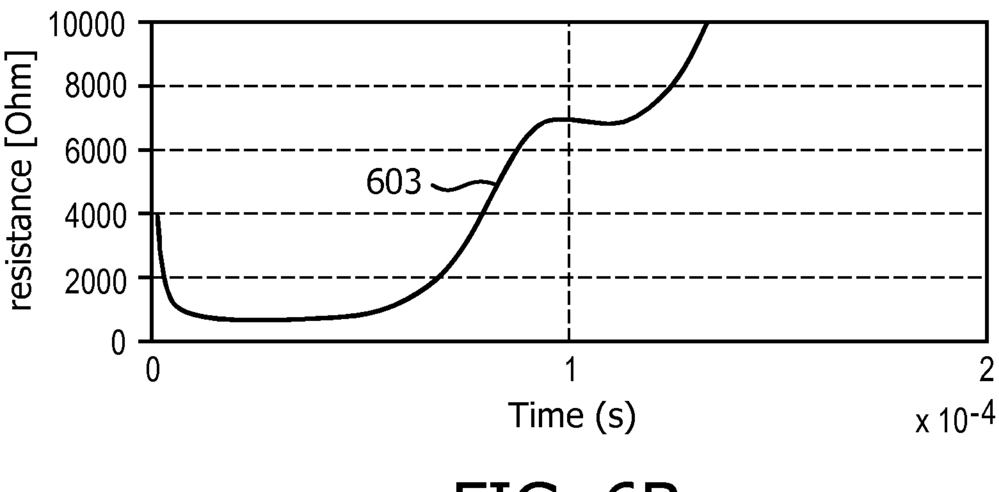
10000
8000
6000
4000
2000
0
resistance [Ohm]
603
0
1
2
Time (s)
x 10-4

FIG. 6B

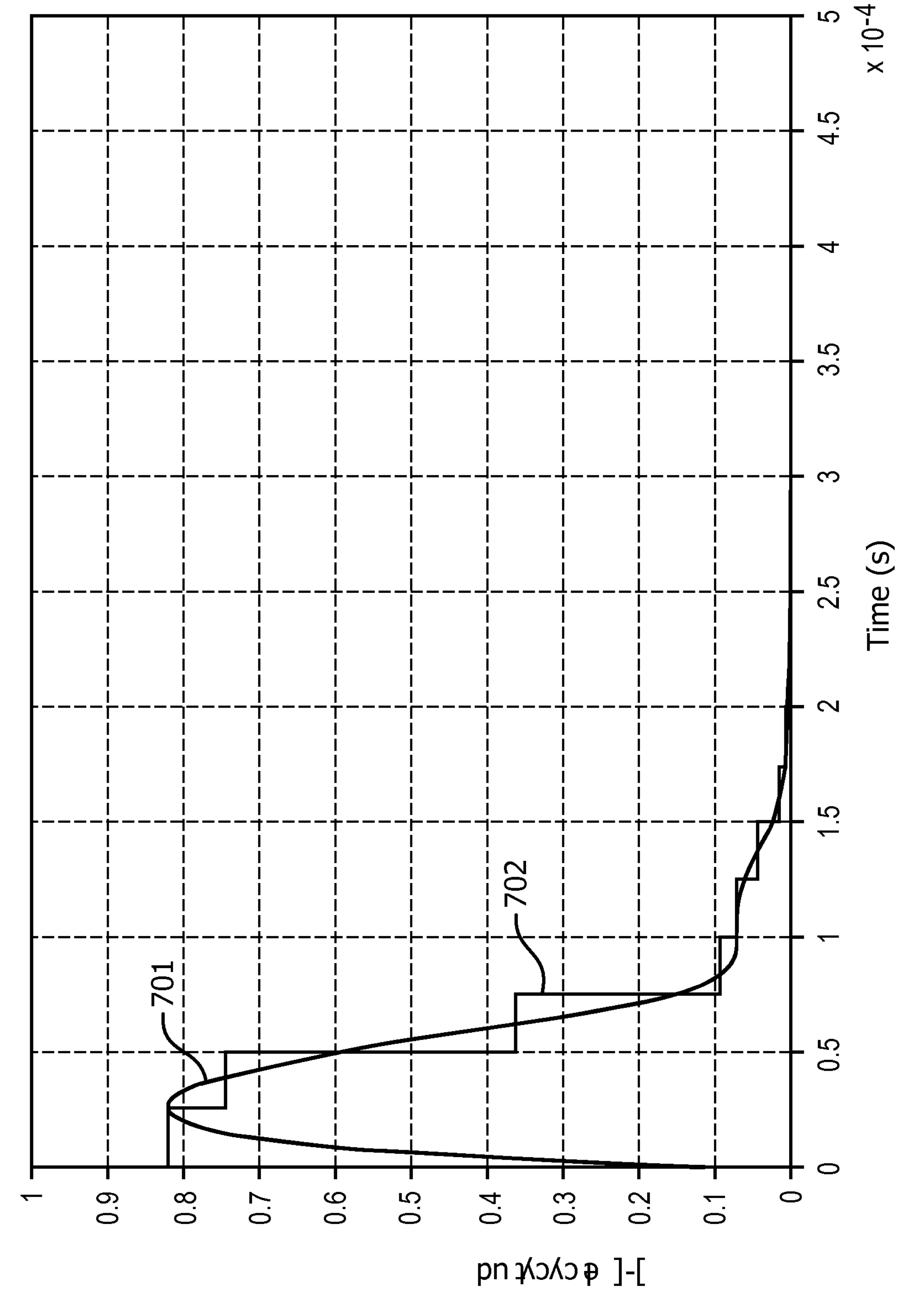
701
702
Time (s)
x 10^-4
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG. 7

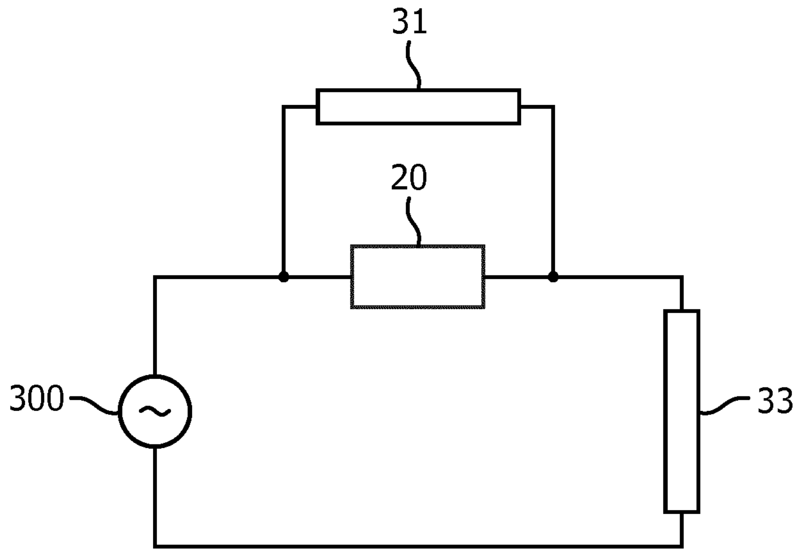
31
20
300
33

FIG. 8

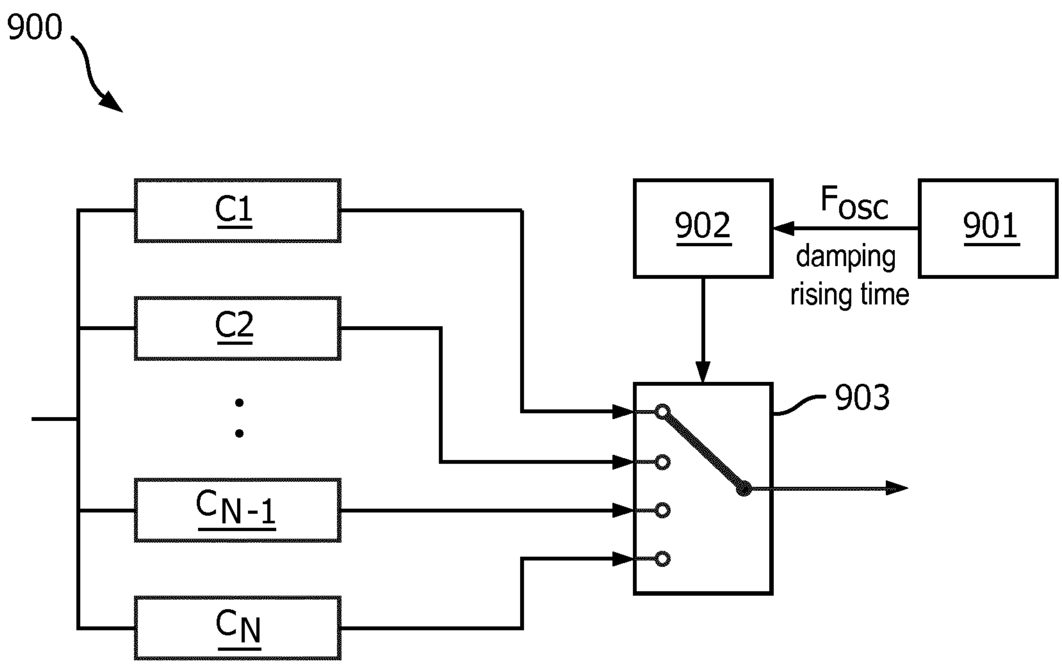
900
C1
C2
CN-1
CN
902
Fosc
damping
rising time
901
903

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/065696

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B33/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2011/045371 A1 (TRIDONIC UK LTD [GB]; WILSON IAN [GB]; FRANKLAND JAMES [GB]) 21 April 2011 (2011-04-21) claims 1,3,6	1-3,5-7, 9-15 4,8
Y	US 2012/274230 A1 (KANAMORI ATSUSHI [JP] ET AL) 1 November 2012 (2012-11-01) figures 1,2,5,7	4
Y	US 2012/319610 A1 (YOSHINAGA MITSUTOMO [JP]) 20 December 2012 (2012-12-20) figure 2	8
X	US 2011/057578 A1 (OTAKE HIROKAZU [JP] ET AL) 10 March 2011 (2011-03-10) abstract	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 October 2014	19/11/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Boudet, Joachim

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/065696

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011045371 A1	21-04-2011	CN 102598856 A	18-07-2012
		DE 112010004051 T5	07-02-2013
		EP 2489241 A1	22-08-2012
		WO 2011045371 A1	21-04-2011
US 2012274230 A1	01-11-2012	CN 102762012 A	31-10-2012
		EP 2519078 A1	31-10-2012
		JP 5331154 B2	30-10-2013
		JP 2012230858 A	22-11-2012
		US 2012274230 A1	01-11-2012
US 2012319610 A1	20-12-2012	CN 202652643 U	02-01-2013
		JP 2013020931 A	31-01-2013
		US 2012319610 A1	20-12-2012
US 2011057578 A1	10-03-2011	CN 102014546 A	13-04-2011
		EP 2302980 A2	30-03-2011
		JP 5333768 B2	06-11-2013
		JP 2011054537 A	17-03-2011
		US 2011057578 A1	10-03-2011