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(54) **Title:** MOTOR CONTROL DEVICE

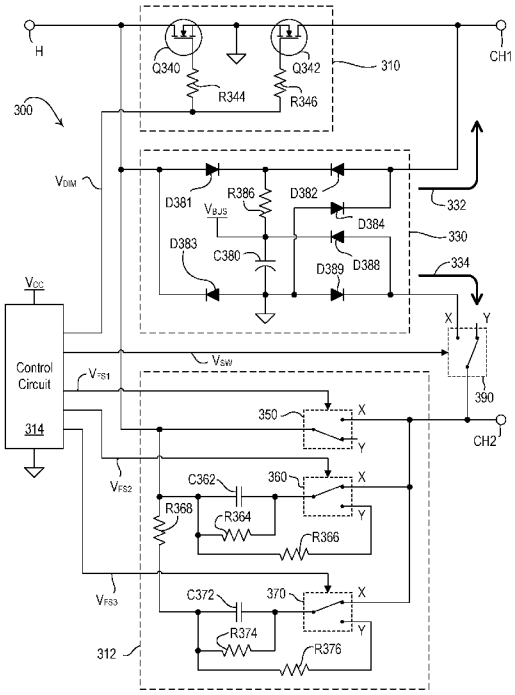


FIG. 3

(57) **Abstract:** A load control device may control power delivered from a power source, such as an alternating-current (AC) power source, to at least two electrical loads, such as a lighting load and a motor load. The load control device may include multiple load control circuit, such as a dimmer circuit and a motor drive circuit, for controlling the power delivered to the lighting load and the motor load, respectively. The load control device may adjust the rotational speed of the motor load in a manner so as to minimize acoustic noise generated by the load control device and reduce the amount of time required to adjust the rotational speed of the motor load. The load control device may remain powered when one of the electrical loads (e.g., the lighting load) has been removed (e.g., electrically disconnected or uninstalled) and/or has failed in an open state (has "burnt out" or "blown out").

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MOTOR CONTROL DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/517,478, filed June 9, 2017, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

[0002] Ceiling fans often include a motor for rotating the fan blades as well as a light source for illuminating the space in which the ceiling fan is mounted. In some installations, the ceiling fan may receive a single power feed and a single switch (*e.g.*, a mechanical toggle switch installed in an electrical wallbox) may be used to control the power delivered from an alternating-current (AC) power source to both the motor and the light source. In other installations, the motor and the light source may receive separate power feeds and may be controlled independently by a wall-mounted control device. For example, a wall-mounted dual load control device may comprise a motor drive circuit connected to the motor of the ceiling fan via a first electrical wiring and a dimming circuit connected to the light source of the ceiling fan via a second electrical wiring.

[0003] The motor drive circuit may comprise one or more capacitors that may be electrically coupled in series with the motor to adjust the rotational speed of the motor to one or more rotational speeds (*e.g.*, rotational speeds less than a maximum rotational speed). In some cases, the capacitors may be electrically coupled in parallel to provide one or more additional rotational speeds. If the capacitors are coupled in parallel when the voltages across the capacitors have different magnitudes, acoustic noise may be generated in the load control device (*e.g.*, due to a large circulating current being generated in the capacitors), which can be bothersome to a user of the load control device. In addition, repetitive occurrences of the large circulating current may damage the capacitors and other electrical components of the load control device.

[0004] Some wall-mounted dual load control devices include digital control circuits (*e.g.*, a processing circuit, such as a microprocessor) for controlling the motor drive circuit and the dimming circuit (*e.g.*, using a phase-control dimming technique) and/or for providing advanced features or feedback to a user. Such wall-mounted dual load control devices typically each include a power supply for generating a supply voltage for powering the processing circuit. The power supply may be coupled in parallel with the dimming circuit and may be configured to conduct current through the light source to generate a direct-current (DC) supply voltage when a controllably conductive device of the dimming circuit is non-conductive each half-cycle of the AC power source. Since it may be undesirable to conduct current through the motor load when the motor is off, the power supply may be configured to conduct current through the light source in order to generate the supply voltage. If the light source is removed from the ceiling fan and/or has failed in an open circuit (*e.g.*, is "burnt out" or "blown out"), the power supply will not be able to conduct current through the light source to generate the supply voltage and the microprocessor will be unpowered. As a result, the wall-mountable smart dual load control device become unpowered and thus will not be able to control the power delivered to the motor when the light source is removed from the ceiling fan and/or has failed in an open circuit.

SUMMARY

[0005] As described herein, a load control device (*e.g.*, a dual load control device) may control power delivered from a power source, such as an alternating-current (AC) power source, to at least two electrical loads, such as a lighting load and a motor load. The load control device may comprise a first load control circuit (*e.g.*, a dimmer circuit) for controlling the power delivered to the lighting load and a second load control circuit (*e.g.*, a motor drive circuit) for controlling the power delivered to the motor load. The load control device may also comprise a control circuit that may control the first and second load control circuits to control the power delivered to the first and second electrical loads, respectively.

[0006] The load control device may adjust the rotational speed of the motor load in a manner so as to minimize acoustic noise generated by the load control device and reduce the amount of time required to adjust the rotational speed of the motor load. The motor drive circuit may comprise first and second capacitors, and first and second controllable switching circuits coupled in series with the

first and second capacitors, respectively. The control circuit may control the first controllable switching circuit to electrically couple the first capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a first rotational speed, and to control the second controllable switching circuit to electrically couple the second capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a second rotational speed. The motor drive circuit may further comprise first and second resistors configured to be coupled in parallel with the first and second capacitors, respectively, when the respective capacitor is electrically coupled in series between the AC power source and the motor load.

[0007] When the control circuit receives a command to change the motor load from the first rotational speed to the second rotational speed, the control circuit is configured to control the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a first zero-crossing of the AC power source, wait for a wait time period to allow the first capacitor to discharge through the first resistor; and subsequently control the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a second zero-crossing of the AC power source. In addition, the control circuit may be configured to cause the motor load to rotate at a third rotational speed by controlling the first and second controllable switching circuits to electrically couple the first and second capacitors in parallel electrical connection, where the parallel combination of the first and second capacitors is coupled in series electrical connection between the AC power source and the motor load. As a result of controlling the first and second switching circuits in this manner, the magnitude of a circulating current that may be conducted through the first and second capacitors when the first and second controllable switching circuit are rendered conductive may be reduced, which may prevent damage to the first and second capacitors and the first and second controllable switching devices.

[0008] In addition, the load control device may remain powered when one of the electrical loads (*e.g.*, the lighting load) has been removed (*e.g.*, electrically disconnected or uninstalled) and/or has failed in an open state (has "burnt out" or "blown out"). The load control device may comprise a power supply that may be coupled to conduct a charging current through the first electrical load (*e.g.*, the lighting load) for generating a supply voltage. The load control device may further

comprise a controllable switching circuit coupled to the power supply and configured to conduct the charging current through the second electrical load (*e.g.*, the motor load). In response to determining that the charging current is not being conducted through the first electrical load, the control circuit may be configured to render the controllable switching circuit conductive to allow the power supply to conduct the charging current through the second electrical load. In addition, the control circuit may enter an error state and may turn off the second electrical load in response to determining that the charging current is not being conducted through the first electrical load. The control circuit may store present states of the first and second load control circuits in the memory when operating in the error state, and may to the first and second load control circuits according to the states stored in the memory when exiting the error state.

[0009] In addition, a method of controlling power delivered from an alternating-current (AC) power source to a motor load is disclosed herein. The method may comprise: (1) controlling a first controllable switching circuit to electrically couple a first capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a first rotational speed; (2) controlling a second controllable switching circuit to electrically couple a second capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a second rotational speed; and (3) changing the motor load from the first rotational speed to the second rotational speed by controlling the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a first zero-crossing of the AC power source, waiting for a wait time period to allow the first capacitor to discharge through a first resistor, and subsequently controlling the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a second zero-crossing of the AC power source.

[0010] Further, a method of controlling power delivered from a power source to at least two electrical loads may comprise: (1) controlling first and second load control circuits to control the power delivered to the first and second electrical loads, respectively; (2) generating a supply voltage by conducting a charging current through the first electrical load; (3) determining that the charging current is not being conducted through the first electrical load; and (4) rendering a first controllable switching circuit conductive to allow the charging current to be conducted through the second

electrical load in response to determining that the charging current is not being conducted through the first electrical load.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a diagram of an example load control system for controlling the operation of an electrical device, such as a ceiling fan.

[0012] FIG. 2 is a simplified block diagram of an example dual load control device.

[0013] FIG. 3 is a simplified schematic diagram of an example dual load control device.

[0014] FIG. 4 is a simplified flowchart of an example actuator procedure.

[0015] FIG. 5 is a simplified flowchart of an example fault mode procedure.

[0016] FIG. 6 is a simplified schematic diagram of another example dual load control device.

DETAILED DESCRIPTION

[0017] FIG. 1 is a diagram of an example load control system 100 for controlling the operation of an electrical device, such as a ceiling fan 110. The ceiling fan 110 may receive power from a power source, such as an alternating-current (AC) power source or a direct-current (DC) power source. The ceiling fan 110 may be installed on the ceiling of a room 101 or space in a building. The ceiling fan 110 may comprise a motor load (*e.g.*, a first electrical load), such as a fan motor 112, for rotating a plurality of blades 114 (*e.g.*, three blades as shown in FIG. 1) to circulate the air in the room 101. The ceiling fan 110 may comprise a lighting load (*e.g.*, a second electrical load), such as a light source 116, for illuminating the room 101. The ceiling fan 110 may also include a control device or circuit that may be housed in a base portion 118 and may control the motor 112 (*e.g.*, to turn on and off, adjust the rotational speed, and/or control the direction of rotation of the motor) and the light source 116 (*e.g.*, to turn on and off and/or adjust the intensity of the light source).

[0018] The load control system 100 may also comprise a dual load control device 120 for controlling (*e.g.*, individually controlling) the motor 112 and the light source 116 of the ceiling

fan 110. The dual load control device 120 may be configured to be electrically coupled between the power source and the ceiling fan 110. For example, the dual load control device 120 may be configured to receive a hot wiring 102 from a hot side of an AC power source as shown in FIG. 1. The dual load control device 120 may comprise first and second controlled outputs (*e.g.*, a motor control output and a lighting control output) that may be coupled to the ceiling fan 110 through a motor control wiring 104 and a lighting control wiring 106, respectively, for individually controlling the motor 112 and the light source 116 of the ceiling fan. The ceiling fan 110 may also be coupled to a neutral side of the AC power source through a neutral wiring 108. The dual load control device may comprise one or more actuators for controlling the motor 112 (*e.g.*, the on and off state and/or the rotational speed of the motor) and the light source 116 (*e.g.*, the on and off state and/or the intensity of the light source).

[0019] The dual load control device 120 may be configured to receive wired or wireless signals, such as radio-frequency (RF) signals 109, for controlling the motor 112 and/or the light source 116 of the ceiling fan 110. The load control system 100 may comprise a remote control device 130 (*e.g.*, a battery-powered RF remote control) for transmitting RF signals 109 including commands for controlling the motor 112 and/or the light source 116 of the ceiling fan 110 in response to actuations of a plurality of buttons, *e.g.*, an increase-light-intensity button 132, a decrease-light-intensity button 134, an increase-rotational-speed button 136, and a decrease-rotational-speed button 138. The control device of the ceiling fan 110 may be configured to turn on and/or raise the intensity of the light source 116 in response to actuations of the increase-light-intensity button 132. The control device of the ceiling fan 110 may be configured to turn off and/or lower the intensity of the light source 116 in response to actuations of the decrease-light-intensity button 134. The control device of the ceiling fan 110 may be configured to turn on and/or increase the rotational speed of the motor 112 in response to actuations of the increase-rotational-speed button 136. The control device of the ceiling fan 110 may be configured to turn off and/or decrease the rotational speed of the motor 112 in response to actuations of the decrease-rotational-speed button 138. The remote control device 130 may comprise additional buttons for selecting presets and/or separately turning on and off and/or adjusting the power delivered to the motor 112 and the light source 114. One will recognize that the control device of the ceiling fan 110 may also and/or

alternatively be configured to receive control signals from a control device via a wired communication link.

[0020] The operation of the load control system 100 (*e.g.*, the operation of the ceiling fan 110) may be programmed and configured using, for example, the mobile device or other network device (*e.g.*, when the mobile device is a personal computing device). The mobile device may execute a graphical user interface (GUI) configuration software for allowing a user to program how the load control system 100 will operate. For example, the configuration software may run as a PC application or a web interface. Examples of configuration procedures for load control systems are described in greater detail in commonly-assigned U.S. Patent No. 7,391,297, issued June 24, 2008, entitled HANDHELD PROGRAMMER FOR A LIGHTING CONTROL SYSTEM; U.S. Patent Application Publication No. 2008/0092075, published April 17, 2008, entitled METHOD OF BUILDING A DATABASE OF A LIGHTING CONTROL SYSTEM; and U.S. Patent Application Publication No. 2014/0265568, filed March 14, 2013, entitled COMMISSIONING LOAD CONTROL SYSTEMS, the entire disclosures of which are incorporated by reference herein.

[0021] FIG. 2 is a simplified block diagram of an example load control device 200 (*e.g.*, a dual load control device), which may be deployed as the dual load control device 120 of the load control system 100 shown in FIG. 1. The load control device 200 may be configured to control the power (*e.g.*, the amount of power) delivered to first and second electrical loads 202, 204 (*e.g.*, a light source and a motor, respectively, of a ceiling fan, such as the ceiling fan 110 shown in FIG. 1). The load control device 200 may have a hot terminal H adapted to be coupled to an alternating-current (AC) power source 206 for receiving an AC mains line voltage V_{AC}. The load control device 200 may also comprise a first controlled-hot terminal CH1 (*e.g.*, a light control or dimmed hot terminal) adapted to be coupled to the first electrical load 202 and a second controlled-hot terminal CH2 adapted to be coupled to the second electrical load 204.

[0022] The load control device 200 may comprise a first load control circuit 210 (*e.g.*, a dimmer circuit) coupled between the hot terminal H and the first controlled hot terminal CH1 for controlling the power delivered to the first electrical load 202 (*e.g.*, the light source). The load control device 200 may comprise a second load control circuit 212 (*e.g.*, a motor control circuit) coupled between the hot terminal H and the second controlled hot terminal CH2 for controlling the

power delivered to the second electrical load 204 (*e.g.*, the motor). The load control device 200 may also comprise a control circuit 214 coupled to the first and second load control circuits 210, 212, for controlling the respective electrical loads. The control circuit 214 may include one or more of a processor (*e.g.*, a microprocessor), a microcontroller, a programmable logic device (PLD), a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), or any suitable controller or processing device. The load control device 200 may comprise a memory (not shown) configured to store operational characteristics of the load control device (*e.g.*, present states of the first and second load control circuits 210, 212, *etc.*). The memory may be implemented as an external integrated circuit (IC) or as an internal circuit of the control circuit 214.

[0023] The load control device 200 may further comprise a zero-cross detect circuit 216 coupled in parallel with the first load control circuit 210. The zero-cross detect circuit 216 may generate a zero-cross control signal V_{ZC} representative of the zero-crossing points of the AC line voltage V_{AC} of the AC power source 206 in response to a voltage developed across the first load control circuit 210. The control circuit 214 may receive the zero-cross control signal V_{ZC} for controlling the first and second load control circuits 210, 212 relative to the zero-crossings of the AC line voltage V_{AC}.

[0024] The control circuit 214 may generate a first drive signal V_{DR1} (*e.g.*, one or more drive signals) for controlling the first load control circuit 210. The first load control circuit 210 may comprise a controllably conductive device, for example, a relay and/or a bidirectional semiconductor switch, such as, a triac, a field-effect transistor (FET) in a rectifier bridge, two FETs in anti-series connection, one or more insulated-gate bipolar junction transistors (IGBTs), or other suitable semiconductor switching circuit. The control circuit 214 may be configured to control the first load control circuit 210 to turn the first electrical load 202 on and off. The control circuit 214 may be configured to render the controllably conductive device of the first load control circuit 210 conductive and/or non-conductive at predetermined times relative to the zero-crossing points of the AC waveform (*e.g.*, in response to the zero-cross control signal V_{ZC}) using a phase-control dimming technique (*e.g.*, a forward phase-control dimming technique and/or a reverse phase-control dimming technique) to adjust the amount of power delivered to the first electrical load (*e.g.*, to adjust the intensity of a light source).

[0025] The control circuit 214 may generate a second drive signal V_{DR2} (*e.g.*, one or more drive signals) for controlling the second load control circuit 212. The control circuit 214 may be configured to control the second load control circuit 212 to turn the second electrical load 204 on and off. The control circuit 214 may be configured to control the second load control circuit 212 to control the amount of power delivered to the second electrical load 204. For example, the control circuit 214 be configured to control the second load control circuit 212 to control the rotational speed and/or direction of the motor. The control circuit 214 may be configured to control the rotational speed to one or more discrete motor speeds between a minimum speed and a maximum speed. In addition, the control circuit 214 may be configured to continuously vary the rotational speed of the motor between the minimum speed and the maximum speed. The control circuit 214 may be configured to control the second load control circuit 212 relative to the zero-crossings of the AC line voltage V_{AC}.

[0026] The load control device 200 may further comprise one or more actuators 218 for receiving user inputs. The control circuit 214 may be configured to control the first and second load control circuits 210, 212 in response to actuations of the actuators 218. For example, the control circuit 214 may be configured to turn on and off and/or adjust an intensity of a light source controlled by the first load control circuit 210 in response to actuations of the actuators 218. In addition, the control circuit 214 may be configured to control the rotational speed and/or direction of a motor controlled by the second load control circuit 212 in response to actuations of the actuators 218. The control circuit 214 may wait for a timeout period $T_{TIMEOUT}$ (*e.g.*, approximately 500 milliseconds) after the last command for controlling the motor was received (*e.g.*, after the last actuation of the actuators) to adjust the rotational speed of the motor before controlling the second load control circuit 212 to adjust the rotational speed of the motor.

[0027] The load control device 200 may further comprise one or more visual indicators, such as light-emitting diodes (LEDs) 220, for providing visual feedback to a user of the load control device. For example, the control circuit 214 may be configured to illuminate the LEDs 220 to provide feedback of a present intensity of a light source controlled by the first load control circuit 210 and/or a present rotational speed of a motor controlled by the second load control circuit 212.

[0001] The load control device 200 may comprise a communication circuit 222. The communication circuit 222 may comprise a wireless communication circuit, such as, for example, a radio-frequency (RF) transceiver coupled to an antenna for transmitting and/or receiving RF signals, an RF transmitter for transmitting RF signals, an RF receiver for receiving RF signals, or an infrared (IR) transmitter and/or receiver for transmitting and/or receiving IR signals. The communication circuit 222 may also comprise a wired communication circuit configured to be coupled to a wired control link, for example, a digital communication link and/or an analog control link, such as a 0-10V control link or a pulse-width modulated (PWM) control link. The communication circuit 222 of the load control device 200 may also be responsive to one or more maintained switches and/or momentary switches. In addition, the communication circuit 222 may be coupled to the electrical wiring connected to the load control device 200 for transmitting a control signal via the electrical wiring using, for example, a power-line carrier (PLC) communication technique. An example of a load control system having control device configured to transmit control signals via electrical wiring is described in greater detail in commonly-assigned U.S. Patent No. 8,471,687, issued June 25, 2013, entitled METHOD AND APPARATUS FOR COMMUNICATING MESSAGE SIGNALS IN A LOAD CONTROL SYSTEM, the entire disclosure of which is incorporated by reference herein.

[0028] The load control device 200 may also include a power supply 230. The power supply 230 may generate a direct-current (DC) supply voltage V_{CC} for powering the control circuit 214 and the other low-voltage circuitry of the load control device 200. The power supply 230 may be coupled in parallel with the first load control circuit 210. The power supply 230 may be configured to conduct a charging current through the first electrical load 202 to generate the supply voltage V_{CC} (*e.g.*, through a first charging path 232 as shown in FIG. 2). When the power supply 222 is conducting the charging current through the first electrical load 202, the zero-cross detect circuit 216 will generate indications of the zero-crossings of the AC waveform in the zero-cross control signal V_{ZC}.

[0029] If the first electrical load 202 fails as an open circuit (*e.g.*, the light source is "burnt out" or "blown out") and/or the first electrical load 202 is removed, the first charging path 232 may be interrupted and the power supply 230 may not be able to charge through the first electrical load.

The control circuit 214 may be configured to detect if the first electrical load 202 is failed or missing in response to the zero-cross detect signal V_{ZC} since the charging current cannot be conducted through the first electrical load. For example, if the control circuit 214 determines at the zero-crossings are not present in the zero-cross detect signal V_{ZC} for a predetermined number of consecutive half-cycles (*e.g.*, four consecutive half-cycles), the control circuit 214 may determine that the first electrical load 202 is failed or missing.

[0030] The load control device 200 may further comprise a switching circuit 234 coupled between the power supply 230 and the second controlled hot terminal CH2. The control circuit 214 may generate a switch control signal V_{SW} for rendering the switching circuit 234 conductive and non-conductive. During normal operation (*e.g.*, when the first electrical load 202 is present), the control circuit 214 may render the switching circuit 234 non-conductive to allow the power supply to conduct the charging current through the first electrical load 202 (*e.g.*, through the first charging path 232). When the control circuit 214 determines that the first electrical load 202 is failed or missing, the control circuit may be configured to close the switching circuit 234 to allow the power supply 230 to conduct the charging current through the switching circuit 234 and the second electrical load 204 (*e.g.*, through a second charging path 236 as shown in FIG. 2). Since the second electrical load 204 may be a motor, the control circuit 214 may be configured to turn the second electrical load off when the switching circuit 234 is conductive and the charging current is being conducted through the second electrical load 204.

[0031] FIG. 3 is a simplified schematic diagram of an example load control device 300 (*e.g.*, the dual load control device 120 of FIG. 1 and/or the load control device 200 of FIG. 2) for controlling the amount of power delivered to multiple electrical loads (*e.g.*, a light source and a motor, respectively, of a ceiling fan). The load control device 300 may have a hot terminal H adapted to be coupled to a power source (*e.g.*, the AC power source 206) for receiving an AC mains line voltage. The load control device 300 may also comprise a first controlled-hot terminal CH1 (*e.g.*, a light control or dimmed hot terminal) adapted to be coupled to a first electrical load (*e.g.*, the first electrical load 202, such as a light source) and a second controlled-hot terminal CH2 adapted to be coupled to a second electrical load (*e.g.*, the second electrical load 204, such as a motor).

[0032] The load control device 300 may comprise a first load control circuit 310 (*e.g.*, a dimmer circuit) electrically coupled between the hot terminal H and the first controlled hot terminal CH1 for controlling the power delivered to the first electrical load (*e.g.*, the light source). The load control device 300 may comprise a second load control circuit 312 (*e.g.*, a motor control circuit) electrically coupled between the hot terminal H and the second controlled hot terminal CH2 for controlling the power delivered to the second electrical load (*e.g.*, the motor). The load control device 300 may also comprise a control circuit 314 coupled to the first and second load control circuits 310, 312, for controlling the respective electrical loads. The control circuit 314 may include one or more of a processor (*e.g.*, a microprocessor), a microcontroller, a programmable logic device (PLD), a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), or any suitable controller or processing device. The load control device 300 may further comprise a zero-cross detect circuit (not shown) coupled in parallel with the first load control circuit 310 for generating a zero-cross control signal representative of the zero-crossing points of the AC line voltage of the AC power source.

[0033] The first load control circuit 310 may comprise a controllably conductive device, such as two field-effect transistors (FETs) Q340, Q342 that are coupled in anti-series connection between the hot terminal H and the first controlled hot terminal CH1. The junction of the FETs Q340, Q342 may be coupled to circuit common. The controllably conductive device of the first load control circuit 310 may further comprise, for example, a thyristor (such as a triac), a field-effect transistor (FET) in a rectifier bridge, one or more insulated-gate bipolar junction transistors (IGBTs), or other suitable bidirectional semiconductor switch. The control circuit 314 may generate a dimming control signal V_{DIM} for controlling the FETs Q340, Q342 of the first load control circuit 310 to conduct a first load current I_{LOAD1} through the first electrical load. The dimming control signal V_{DIM} may be coupled to the gates of the FETs Q340, Q342 via respective gate resistors R344, R346. The control circuit 314 may be configured to render the FETs Q340, Q342 conductive and/or non-conductive at predetermined times relative to the zero-crossing points of the AC waveform (*e.g.*, in response to the zero-cross detect circuit) using a forward phase-control dimming technique and/or a reverse phase-control dimming technique to adjust the amount of power delivered to the first electrical load (*e.g.*, to adjust the intensity of a light source). During the positive half-cycles of the AC power source, the first load current I_{LOAD1} may be conducted through

the drain-source channel of the first FET Q340 and a body diode of the second FET Q342. During the negative half-cycles of the AC power source, the first load current I_{LOAD1} may be conducted through the drain-source channel of the second FET Q342 and a body diode of the first FET Q340.

[0034] The control circuit 314 may generate a plurality of fan speed control signals V_{FS1}, V_{FS2}, V_{FS3} for controlling the second load control circuit 312 to control the second electrical load to a plurality of discrete power levels (*e.g.*, a plurality of discrete rotational speeds of a motor, such as a motor of a ceiling fan). The second load control circuit 312 may comprise a first switching circuit, such as a first single-pole double-throw (SPDT) relay 350, coupled between the hot terminal H and the second controlled hot terminal CH2. The control circuit 314 may generate the first fan speed control signal V_{FS1} for switching the first relay 350 between a first position X (*e.g.*, in which a movable contact of the relay is connected to a first stationary contact) and a second position Y (*e.g.*, in which the movable contact of the relay is connected to a second stationary contact). When the first relay 350 is controlled to the first position X, the AC line voltage may be coupled across the second electrical load, such that the second electrical load is controlled to a full power level (*e.g.*, the motor of the ceiling fan is controlled to a maximum rotational speed or full speed). While the first relay 350 is shown as a SPDT relay in FIG. 3, the first relay could be replaced by a single-pole single-throw (SPST) relay.

[0035] The second load control circuit 312 may further comprise second and third switching circuits, such as respective SPDT relays 360, 370, that are coupled in series with respective capacitors C362, C372 between the hot terminal H and the second controlled hot terminal CH2. The control circuit 314 may generate the second and third fan speed control signals V_{FS2}, V_{FS3} for switching each of the respective relays 360, 370 between a first position X and a second position Y. The first and second capacitors C362, C372 may have different capacitances, *e.g.*, 3.3 μF and 5.6 μF, respectively. When the second relay 360 is controlled to the first position X, the first capacitor C362 may be coupled in series electrical connection between the AC power source and the second electrical load. When the third relay 370 is controlled to the first position X, the second capacitor C372 may be coupled in series electrical connection between the AC power source and the second electrical load.

[0036] When only the first capacitor C362 is coupled in series with the second electrical load (*e.g.*, the second relay is in position X and the first and third relays 350, 370 are in position Y), the second electrical load may be controlled to a first intermediate power level (*e.g.*, the motor of the ceiling fan may be controlled to a first intermediate rotational speed). When only the second capacitor C372 is coupled in series with the second electrical load (*e.g.*, the third relay is in position X and the first and second relays 350, 370 are in position Y), the second electrical load may be controlled to a second intermediate power level (*e.g.*, the motor of the ceiling fan may be controlled to a second intermediate rotational speed). When both of the first and second capacitors C362, C372 are coupled in series with the second electrical load (*e.g.*, the second and third relays are in position X and the first relay 350 is in position Y), the second electrical load may be controlled to a third intermediate power level (*e.g.*, the motor of the ceiling fan may be controlled to a third intermediate rotational speed). The control circuit 314 may be configured to turn off the second electrical load by controlling all of the relays 350, 360, 370 of the second load control circuit 310 to the second position Y.

[0037] The second load control circuit 310 may comprise resistors R364, R374 coupled in parallel with the capacitors C362, C372, respectively, for allowing the capacitors C362, C372 to discharge when the relays 360, 370 are in either the first position X or the second position Y. The second load control circuit 310 may further comprise resistors R366, R376, that may be coupled in parallel with the capacitors C362, C372, respectively, when the respective relays 360, 370 are in the second position Y. The resistors R366, R376 may have smaller resistances than the resistors R364, R374 to allow the respective capacitors C362, C372 to discharge at a faster rate when the relays 360, 370 are in the second position Y. The resistors R366, R376 may be coupled in parallel with the respective capacitors C362, C372 to discharge the capacitors when the capacitors are not electrically coupled in series between the between the AC power source and the second electrical load (*e.g.*, when the relays 360, 370 are in the second position Y). The second load control circuit 310 may further comprise a resistor R368 coupled between the first and second capacitors C362, C372 for limiting the magnitude of a circulating current that may flow through the capacitor C362, C372 when both of the relays 360, 370 are controlled to the first position X.

[0038] The SPDT relays 360, 370 could each be replaced by two SPST relays. The first SPST relay of each pair may be controlled by one of the second and third fan speed control signals V_{FS2}, V_{FS3} and the second SPST relay may be controlled by the inverse of the one of the second and third fan speed control signals V_{FS2}, V_{FS3}. In addition, the control circuit 314 may generate additional fan speed control signals for controlling the SPST relays.

[0039] The control circuit 314 may control the relays 360, 370 to attempt to couple the first and second capacitor C362, C372 in and out of the second load control circuit 310 (*e.g.*, by changing the relays between the first position X and the second position Y) at approximately the zero-crossings of the AC power source. This may reduce the magnitudes of the currents conducted through the capacitors C362, C372 when the relays are changed to from the first position X to the second position Y and vice versa. The control circuit 314 may be configured to determine the timing of when to control the relays 360, 370 in response to the zero-crossings of the AC power source as determined from the zero-cross detect circuit. For example, when turning off the second electrical load, the control circuit 314 may control all of the relays 350, 360, 370 to position Y at a subsequent zero-crossing. When turning on the second electrical load (*e.g.*, to one of the speeds, such as the maximum rotational speed or the first, second, or third intermediate rotational speeds), the control circuit 314 may control the appropriate relays for the desired rotational speed to position X at a subsequent zero-crossing.

[0040] When changing the power level of the second electrical load from one level to another (*e.g.*, to change the rotational speed of the motor from one speed to another speed), the control circuit 314 may first control all of the relays 350, 360, 370 to position Y at a subsequent zero-crossing. The control circuit 314 may then wait for a wait time period T_{WAIT} (*e.g.*, approximately 0.5 seconds) to allow the capacitors C362, C374 to discharge through the resistors R366, R376 (*e.g.*, at the faster rate than the capacitors could discharge through the respective resistors R364, R374). After the wait time period T_{WAIT}, the control circuit 314 may control the appropriate relays for the desired rotational speed to position X at a subsequent zero-crossing.

[0041] The load control device 300 may comprise a power supply 330 for generating a direct-current (DC) supply voltage V_{CC} for powering the control circuit 314 and the other

low-voltage circuitry of the load control device 300. The power supply 330 may be coupled in parallel with the first load control circuit 310 to conduct a charging current through the first load electrical load (*e.g.*, through a first charging path 332 as shown in FIG. 3) to charge an energy storage capacitor C380 of the power supply 330 when the FETs Q340, Q342 of the first load control circuit 310 are non-conductive each half-cycle. The energy storage capacitor C380 may be coupled to the hot terminal H and the first controlled hot terminal CH1 through a full-wave rectifier bridge that includes diodes D381, D382, D383, D384. The diodes D383, D384 could be the body diodes of the FETs Q340, Q342, respectively, of the first load control circuit 310. The energy storage capacitor C380 may also be coupled in series with a resistor R386 on the DC side of the rectifier bridge and may produce a DC bus voltage V_{BUS} (*e.g.*, approximately 170V). The power supply may comprise a second stage (not shown) for generating the supply voltage V_{CC} from the bus voltage V_{BUS} (*e.g.*, a linear regulator, a switching power supply, such as a buck converter, or other suitable power supply circuit for generating a low-magnitude DC supply voltage).

[0042] The load control device 300 may further comprise a switching circuit, such as a SPDT relay 390 coupled between the power supply 330 and the second controlled hot terminal CH2. The control circuit 314 may generate a switch control signal V_{SW} for switching the relay 390 between a first position X and a second position Y. When the relay 390 is controlled to the first position X, the energy storage capacitor C380 of the power supply 380 may be configured to charge through the second controlled hot terminal CH2 and the second electrical load via diodes D388, D389 of the power supply 330 (*e.g.*, through a second charging path 334 as shown in FIG. 3). While the relay 390 is shown as a SPDT relay in FIG. 3, the first relay could be replaced by a SPST relay.

[0043] The control circuit 314 may be configured to determine if the first electrical load is failed or missing (*e.g.*, in response to the zero-cross detect circuit coupled across the first load control circuit 310) and control the relay 390 to allow the energy storage capacitor C380 of the power supply 330 to charge through the second electrical load. When the first electrical load is present, the control circuit 314 may control the relay 390 to the second position Y to allow the power supply 330 to conduct the charging current through the first electrical load. In response to determining that the first electrical load is failed or missing, the control circuit 314 may be configured to control the relay 390 to the first position X to allow the energy storage capacitor C380

power supply 330 to conduct the charging current through the relay 390 and the second electrical load (*e.g.*, through the second charging path 334).

[0044] FIG. 4 is a simplified flowchart of an example actuator procedure 400 that may be executed by a control circuit of a load control device (*e.g.*, a control circuit of the dual load control device 120, the control circuit 214 of the load control device 200, and/or the control circuit 314 of the load control device 300). The control circuit may execute the actuator procedure 400 to control a plurality of relays of a load control circuit (*e.g.*, the relays 350, 360, 370 of the second load control circuit 312 shown in FIG. 3) to control an electrical load, such as a motor of a ceiling fan in response to actuations of one or more of a plurality of actuators (*e.g.*, the actuators 218). For example, the control circuit may execute the actuator procedure 400 in response to detecting an actuation of one the actuators at 410. The control circuit may first wait for a timeout period $T_{TIMEOUT}$ (*e.g.*, approximately 500 milliseconds) after the last actuation of the actuators at 412 before attempting to adjust the rotational speed of the motor.

[0045] When the timeout period $T_{TIMEOUT}$ since the last actuation expires at 412 and the last actuation indicated a command to turn the motor on at 414 (*e.g.*, to turn the motor on from off), the control circuit may control the appropriate relays for the desired rotational speed (*e.g.*, such as a maximum rotational speed or an intermediate rotational speeds) to position X at a subsequent zero-crossing at 416, before the actuator procedure 400 exits. If the last actuation indicated a command to change the rotational speed of the motor at 418 (*e.g.*, to change the speed of the motor from a first non-off speed to a second non-off speed), the control circuit may control all of the relays to position Y at a subsequent zero-crossing at 420. The control circuit may wait for a wait time period T_{WAIT} (*e.g.*, approximately 0.5 seconds) at 422 and then control the appropriate relays for the desired rotational speed to position X at a subsequent zero-crossing at 424, before the actuator procedure 400 exits. If the last actuation indicated a command to turn off the motor at 426 (*e.g.*, to turn the motor off from on), the control circuit may control all of the relays to position Y at a subsequent zero-crossing at 428 and the actuator procedure 400 may exit.

[0046] As illustrated in FIG. 4, the control procedure 400 may only require two switching events of the relays (*e.g.*, at 420 and 424) and a single wait period (*e.g.*, at 422) to change the motor from a first rotational speed to a second rotational speed independent of the specific values of each

rotational speed and the relays required to change between the rotational speeds. The resistance of resistors R366, R376 of the load control device 300 shown in FIG. 3 may be decreased to decrease the length of the wait time period T_{WAIT} to decrease the time required to change between the rotational speeds.

[0047] FIG. 5 is a simplified flowchart of an example fault mode procedure 500 that may be executed by a control circuit of a dual load control device (*e.g.*, a control circuit of the dual load control device 120, the control circuit 214 of the load control device 200, and/or the control circuit 314 of the load control device 300). The dual load control device may comprise first and second load control circuits (*e.g.*, the first and second load control circuits 210, 212, 310, 312) for controlling first and second electrical loads (*e.g.*, a light source and a motor), respectively. The control circuit may execute the fault mode procedure 500 to enter an error state if the control circuit detects that current is not flowing through one of multiple electrical loads controlled by the load control device. For example, the control circuit may execute the fault mode procedure 500 periodically at 510.

[0048] The control circuit may first determine if current is flowing through the first electrical load at 512. For example, the control circuit may determine if zero-crossings were not detected for a predetermined number of half-cycles (*e.g.*, four consecutive half-cycles). If current is not flowing through the first electrical load at 514 and the error state is not set yet at 516, the control circuit may enter the error state at 518 and store the previous states of the first and second load control circuits in memory at 520. The control circuit may turn off the first load control circuit at 522 (*e.g.*, by rendering the FETs Q340, Q342 non-conductive) and turn off the second load control circuit at 524 (*e.g.*, by controlling all of the relays 350, 360, 370 of the second load control circuit 310 to the second position Y). The control circuit may engage an alternate charging path for an internal power supply through the second electrical load at 526 (*e.g.*, by controlling the relay 390 to position X). The control circuit may then provide visual feedback of the error state at 528 (*e.g.*, by illuminating one or more of the visual indicators, such as the LEDs 220), before the fault mode procedure 500 exits. If the control circuit is in the error state at 516, the control circuit may simply continue to provide the visual feedback of the error state at 528 and the fault mode procedure 500 may exit.

[0049] If current is flowing through the first electrical load at 514 and the control circuit is in the error state at 530 (*e.g.*, the light source has been re-installed in series with the first load control circuit and/or the fault condition has been resolved), the control circuit may exit the error state at 532 and disengage the alternate charging path for the internal power supply through the second electrical load at 534 (*e.g.*, by controlling the relay 390 to position Y). At 536, the control circuit may turn on the first load control circuit and control the first load control circuit according to the previous state of the first load control circuit stored in the memory (*e.g.*, as stored at 520). At 538, the control circuit may turn on the second load control circuit and control the second load control circuit according to the previous state of the second load control circuit stored in the memory (*e.g.*, as stored at 520), before the fault mode procedure 500 exits. If current is flowing through the first electrical load at 514 and the control circuit is not in the error state at 530, the fault mode procedure 500 may simply exit.

[0050] FIG. 6 is a simplified schematic diagram of another example load control device 600 (*e.g.*, the dual load control device 120 of FIG. 1 and/or the load control device 200 of FIG. 2) for controlling the amount of power delivered to multiple electrical loads (*e.g.*, a light source and a motor, respectively, of a ceiling fan). The load control device 600 may be similar to the load control device 300 shown in FIG. 3. However, the load control device 600 of FIG. 6 has three double-pole double-throw (DPDT) relays 650, 660, 670 rather than the SPDT relays 350, 360, 370, 390 of the load control device 300 shown in FIG. 3. The first DPDT relay 650 is illustrated by two separate SPDT switches 650A and 650B that are controlled between positions X and Y in response to a first relay control signal V_{R1}. The second DPDT relay 660 is illustrated by two separate SPDT switches 660A and 660B that are controlled between positions X and Y in response to a second relay control signal V_{R2}. The third DPDT relay 670 is illustrated by two separate SPDT switches 670A and 670B that are controlled between positions X and Y in response to a third relay control signal V_{R3}. The first, second, and third relay control signals V_{R1}, V_{R2}, V_{R3} may be generated by a control circuit 614. The control circuit 614 may include one or more of a processor (*e.g.*, a microprocessor), a microcontroller, a programmable logic device (PLD), a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), or any suitable controller or processing device.

[0051] The load control device 600 may comprise a second load control circuit 612 that includes the first SPDT switches 650A, 660A, 670A of each of the DPDT relays 650, 660, 670. The first SPDT switch 650A of the first DPDT relay 650 may be coupled between the hot terminal H and the second controlled hot terminal CH2. When the first SPDT switch 650A of the first DPDT relay 650 is controlled to the first position X, the AC line voltage may be coupled across the second electrical load, such that the second electrical load is controlled to a full power level (*e.g.*, the motor of the ceiling fan is controlled to a maximum rotational speed or full speed). The first SPDT switch 660A of the second DPDT relay 660 and the first SPDT switch 670A of the third DPDT relay 670 may be coupled in series with the first and second capacitor C362, C372, respectively. When the first SPDT switch 660A of the second DPDT relay 660 is controlled to the first position X, the first capacitor C362 may be coupled in series electrical connection between the AC power source and the second electrical load. When the first SPDT switch 670A of the third DPDT relay 670 is controlled to the first position X, the second capacitor C372 may be coupled in series electrical connection between the AC power source and the second electrical load. When the first SPDT switches 650A, 650A, 670A of all of the DPDT relays 650A, 660A, 670A are in position Y, the second electrical load may be controlled off.

[0052] The second SPDT switches 650B, 660B, 670B of each of the DPDT relays 650, 660, 670 may form a switching circuit for allowing the power supply 330 to conduct the charging current through the second electrical load. The second SPDT switches 650B, 660B, 670B of each of the DPDT relays 650, 660, 670 may be coupled between the power supply 330 and the second controlled hot terminal CH2 to provide the second charging path 334 through the second electrical load (*e.g.*, when the second SPDT switches 650B, 660B, 670B are each in the second position Y). The first switch 650A of the first DPDT relay 650 may also be electrically connected so as to conduct the charging current through the second electrical load when in the second position Y (*e.g.*, in parallel with the second switch 650B when in the second position Y). The second switch 650B of the first DPDT relay 650 may also be electrically connected so as to be coupled between the hot terminal H and the second controlled hot terminal CH2 when in the first position X (*e.g.*, in parallel with the first switch 650A when in the first position X). When any of the first SPDT switches 650A, 650A, 670A of each of the DPDT relays 650, 660, 670 may be in the first position X (*e.g.*, the second electrical load is on), the second SPDT switches 650B, 660B, 670B may also be in the first

position X and the power supply 330 may not be able to charge through the second electrical load. When the first SPDT switches 650A, 650A, 670A of all of the DPDT relays 650A, 660A, 670A are in the second position Y (*e.g.*, the second electrical load is off), the second SPDT switches 650B, 660B, 670B may also be in the second position Y and the power supply 330 may be able to charge through the second electrical load.

What is claimed is:

CLAIMS

1. A load control device for controlling power delivered from an alternating-current (AC) power source to a motor load, the load control device comprising:

first and second capacitors;

first and second controllable switching circuits coupled in series with the first and second capacitors, respectively;

a control circuit configured to control the first controllable switching circuit to electrically couple the first capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a first rotational speed, the control circuit configured to control the second controllable switching circuit to electrically couple the second capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a second rotational speed; and

first and second resistors configured to be coupled in parallel with the first and second capacitors, respectively, when the respective capacitor is not electrically coupled in series between the AC power source and the motor load;

wherein, when the control circuit receives a command to change the motor load from the first rotational speed to the second rotational speed, the control circuit is configured to:

control the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a first zero-crossing of the AC power source;

wait for a wait time period to allow the first capacitor to discharge through the first resistor; and

subsequently control the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a second zero-crossing of the AC power source.

2. The load control device of claim 1, wherein the control circuit is configured to wait for a timeout period after receiving a previous command for controlling the motor load before controlling the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately the first zero-crossing of the AC power source.

3. The load control device of claim 2, further comprising:

an actuator configured to receive a user input;

wherein the control circuit is configured to receive the command to change the motor load from the first rotational speed to the second rotational speed in response to an actuation of the actuator.

4. The load control device of claim 2, further comprising:

a communication circuit configured to receive signals;

wherein the control circuit is configured to receive the command to change the motor load from the first rotational speed to the second rotational speed in response to a signal received via the communication circuit.

5. The load control device of claim 1, wherein the control circuit is configured to cause the motor load to rotate at a third rotational speed by controlling the first and second controllable switching circuits to electrically couple the first and second capacitors in parallel electrical connection, where the parallel combination of the first and second capacitors is coupled in series electrical connection between the AC power source and the motor load.

6. The load control device of claim 5, wherein, when the control circuit receives a command to change the motor load from the first rotational speed to the third rotational speed, the control circuit is configured to:

control the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source;

wait for the wait time period to allow the first capacitor to discharge through the first resistor; and

subsequently control the first and second controllable switching circuits to connect the parallel combination of the first and second capacitors in series electrical connection between the AC power source and the motor load at approximately a fourth zero-crossing of the AC power source.

7. The load control device of claim 1, wherein, when the control circuit receives a command to change the motor load from off to the second rotational speed, the control circuit is configured to:

control the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source.

8. The load control device of claim 1, wherein, when the control circuit receives a command to change the motor load from the first rotational speed to off, the control circuit is configured to:

control the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source.

9. The load control device of claim 1, further comprising:

a third controllable switching circuit coupled in parallel electrical connection with the series combination of the first capacitor and the first switching circuit;

wherein the control circuit configured to control the third controllable switching circuit to electrically couple the AC power source to the motor load to cause the motor load to rotate at a maximum rotational speed.

10. The load control device of claim 1, wherein the first controllable switching circuit comprises a single-pole double-throw relay having a movable contact electrically coupled to the first

capacitor, and

wherein the first capacitor is connected in series electrical connection between the AC power source and the motor load when the movable contact is connected to a first stationary contact of the relay, and the first capacitor is connected in parallel electrical connection with the first resistor when the movable contact is connected to a second stationary contact of the relay.

11. The load control device of claim 1, further comprising:

a zero-cross detect circuit configured to generate a zero-cross detect signal that indicates zero-crossings of the AC power source;

wherein the control circuit is configured to control the first and second controllable switching circuits to connect and disconnect the respective capacitors from series electrical connection between the AC power source and the motor load at approximately zero-crossings of the AC power source in response to the zero-cross detect signal received from the zero-cross detect circuit.

12. A method of controlling power delivered from an alternating-current (AC) power source to a motor load, the method comprising:

controlling a first controllable switching circuit to electrically couple a first capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a first rotational speed;

controlling a second controllable switching circuit to electrically couple a second capacitor in series between the AC power source and the motor load to cause the motor load to rotate at a second rotational speed; and

changing the motor load from the first rotational speed to the second rotational speed by controlling the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a first zero-crossing of the AC power source, waiting for a wait time period to allow the first capacitor to discharge through a first resistor, and subsequently controlling the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a second zero-crossing of the AC power source.

13. The method of claim 12, further comprising:

receiving a present command to change the motor load from the first rotational speed to the second rotational speed;

wherein changing the motor load from the first rotational speed to the second rotational speed comprises changing the motor load from the first rotational speed to the second rotational speed in response to receiving the present command.

14. The method of claim 13, further comprising:

receiving a previous command for controlling the motor load; and

waiting for a timeout period after receiving the previous command before changing the motor load from the first rotational speed to the second rotational speed in response to the present command.

15. The method of claim 12, further comprising:

controlling the first and second controllable switching circuits to electrically couple the first and second capacitors in parallel electrical connection to cause the motor load to rotate at a third rotational speed, where the parallel combination of the first and second capacitors is coupled in series electrical connection between the AC power source and the motor load.

16. The method of claim 15, further comprising:

changing the motor load from the first rotational speed to the third rotational speed by controlling the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source, waiting for the wait time period to allow the first capacitor to discharge through the first resistor through the first resistor, and subsequently controlling the first and second controllable switching circuits to connect the parallel combination of the first and second capacitors in series electrical connection between the AC power source and the motor load at approximately a fourth zero-crossing of the AC power source.

17. The method of claim 12, further comprising:

changing the motor load from off to the second rotational speed by controlling the second controllable switching circuit to connect the second capacitor in series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source.

18. The method of claim 12, further comprising:

changing the motor load from the first rotational speed to off by controlling the first controllable switching circuit to disconnect the first capacitor from the series electrical connection between the AC power source and the motor load at approximately a third zero-crossing of the AC power source.

19. The method of claim 12, further comprising:

controlling a third controllable switching circuit coupled in parallel electrical connection with the series combination of the first capacitor and the first switching circuit to electrically couple the AC power source to the motor load to cause the motor load to rotate at a maximum rotational speed.

20. The method of claim 12, further comprising:

generating a zero-cross detect signal that indicates zero-crossings of the AC power source; and

determining times of the first and second zero-crossings based on the zero-cross detect signal.

21. A load control device for controlling power delivered from a power source to at least two electrical loads, the load control device comprising:

a first load control circuit configured to control the power delivered to a first electrical load of the at least two electrical loads;

a second load control circuit configured to control the power delivered to a second electrical load of the at least two electrical loads;

a control circuit configured to control the first and second load control circuits to control the power delivered to the first and second electrical loads, respectively;

a power supply configured to generate a supply voltage, the power supply coupled to conduct a charging current through the first electrical load; and

a first controllable switching circuit coupled to the power supply and configured to conduct the charging current through the second electrical load;

wherein, in response to determining that the charging current is not being conducted through the first electrical load, the control circuit is configured to render the first controllable switching circuit conductive to allow the power supply to conduct the charging current through the second electrical load.

22. The load control device of claim 21, wherein the control circuit is configured to enter an error state in response to determining that the charging current is not being conducted through the first electrical load.

23. The load control device of claim 22, wherein the control circuit is configured to exit the error state and render the first controllable switching circuit non-conductive in response to determining that the charging current is being conducted through the first electrical load.

24. The load control device of claim 23, further comprising:

a memory configured to store operational characteristics of the load control device;

wherein, in response to determining that the charging current is not being conducted through the first electrical load, the control circuit is configured to store present states of the first and second load control circuits in the memory.

25. The load control device of claim 24, wherein, in response to determining that the charging current is being conducted through the first electrical load, the control circuit is configured to control the first and second load control circuits according to the states stored in the memory.

26. The load control device of claim 22, wherein the control circuit is configured to control the second load control circuit to turn off the second electrical load when operating in the error state.

27. The load control device of claim 26, wherein the first load control circuit comprises a controllably conductive device adapted to be coupled between an AC power source and the first electrical load, the control circuit configured to control the first load control circuit to render the controllably conductive device non-conductive when operating in the error state.

28. The load control device of claim 27, wherein, in response to determining that the charging current is being conducted through the first electrical load, the control circuit is configured to render the controllably conductive device of the first load control circuit conductive, and turn the second load control circuit on.

29. The load control device of claim 22, further comprising:

at least one visual indicator configured to be illuminated to provide visual feedback;

wherein the control circuit is configured to cause the visual indicator to provide the visual feedback when operating in the error state.

30. The load control device of claim 21, further comprising:

a hot terminal adapted to be coupled to the power source;

a first controlled-hot terminal adapted to be coupled to the first electrical load; and

a second controlled-hot terminal adapted to be coupled to the second electrical load;

wherein the first load control circuit is coupled between the hot terminal and the first controlled-hot terminal, the second load control circuit is coupled between the hot terminal and the second controlled-hot terminal, and the first controllable switching circuit is coupled between the power supply and the second controlled-hot terminal.

31. The load control device of claim 30, wherein the second load control circuit comprises a second controllable switching circuit coupled between the hot terminal and the second

controlled-hot terminal, the control circuit configured to render the second controllable switching circuit conductive and non-conductive to turn the second electrical load on and off, respectively.

32. The load control device of claim 31, wherein the second electrical load comprises a motor, and the second load control circuit comprises a capacitor and a third controllable switching circuit coupled in series with the capacitor, the series combination of the capacitor and the third controllable switching circuit coupled in parallel with the second controllable switching circuit, the control circuit configured to render the second controllable switching circuit non-conductive and render the third switching circuit conductive to adjust a rotational speed of the motor.

33. The load control device of claim 32, wherein the third controllable switching circuit comprises a first single-pole double-throw switch of a double-pole double-throw relay and the first controllable switching circuit comprises a second single-pole double-throw switching of the double-pole double-throw relay.

34. The load control device of claim 31, wherein the first and second controllable switching circuits comprise single-pole double-throw relays.

15. The load control device of claim 10, wherein the power supply comprises a capacitor and four diodes configured as a full-wave rectifier bridge with an DC side of the rectifier bridge coupled across the capacitor and an AC side of the rectifier bridge coupled to the hot terminal and to the second controlled-hot terminal via the first controllable switching circuit.

36. The load control device of claim 21, further comprising:

a zero-cross detect circuit coupled in parallel with the first load control circuit, the zero-cross detect circuit configured to generate a zero-cross detect signal that indicates zero-crossings of an alternating-current voltage generated by the power source when at least the charging current is conducted through the first electrical load;

wherein the control circuit is configured to determine that the charging current is not being conducted through the first electrical load in response to the zero-cross detect signal.

37. The load control device of claim 36, wherein the control circuit is configured to determine that the charging current is not being conducted through the first electrical load if the zero-cross detect signal does not indicate zero-crossings of the alternating-current voltage for a predetermined number of half-cycles of the alternating-current voltage.

38. The load control device of claim 21, wherein the first electrical load comprises a light source and the second electrical load comprises a motor.

39. A method of controlling power delivered from a power source to at least two electrical loads, the method comprising:

controlling first and second load control circuits to control the power delivered to the first and second electrical loads, respectively;

generating a supply voltage by conducting a charging current through the first electrical load;

determining that the charging current is not being conducted through the first electrical load; and

rendering a first controllable switching circuit conductive to allow the charging current to be conducted through the second electrical load in response to determining that the charging current is not being conducted through the first electrical load.

40. The method of claim 39, further comprising:

receiving a zero-cross detect signal that indicates zero-crossings of an alternating-current voltage generated by the power source when at least the charging current is conducted through the first electrical load; and

wherein determining that the charging current is not being conducted through the first electrical load further comprises determining that the charging current is not being conducted through the first electrical load in response to the zero-cross detect signal.

41. The method of claim 40, wherein determining that the charging current is not being conducted through the first electrical load further comprises determining that the charging

current is not being conducted through the first electrical load if the zero-cross detect signal does not indicate zero-crossings of the alternating-current voltage for a predetermined number of half-cycles of the alternating-current voltage.

42. The method of claim 39, further comprising:

rendering a second controllable switching circuit of the second load control circuit conductive and non-conductive to turn the second electrical load on and off, respectively, the second controllable switch circuit adapted to be coupled between the power source and the second electrical load.

43. The method of claim 42, wherein the second electrical load comprises a motor, the method further comprising adjusting a rotational speed of the motor by rendering the second controllable switching circuit non-conductive and rendering a third switching circuit of the second load control circuit conductive, the third controllable switching circuit coupled in series with a capacitor, the series combination of the capacitor and the third controllable switching circuit coupled in parallel with the second controllable switching circuit.

44. The method of claim 39, further comprising:

controlling the second load control circuit to turn off the second electrical load when the first controllable switching circuit is rendered conductive.

45. The method of claim 44, further comprising:

rendering a controllably conductive device of the first load control circuit non-conductive when the first controllable switching circuit is rendered conductive.

46. The method of claim 19, further comprising:

illuminating a visual indicator to provide the visual feedback in response to determining that the charging current is not being conducted through the first electrical load.

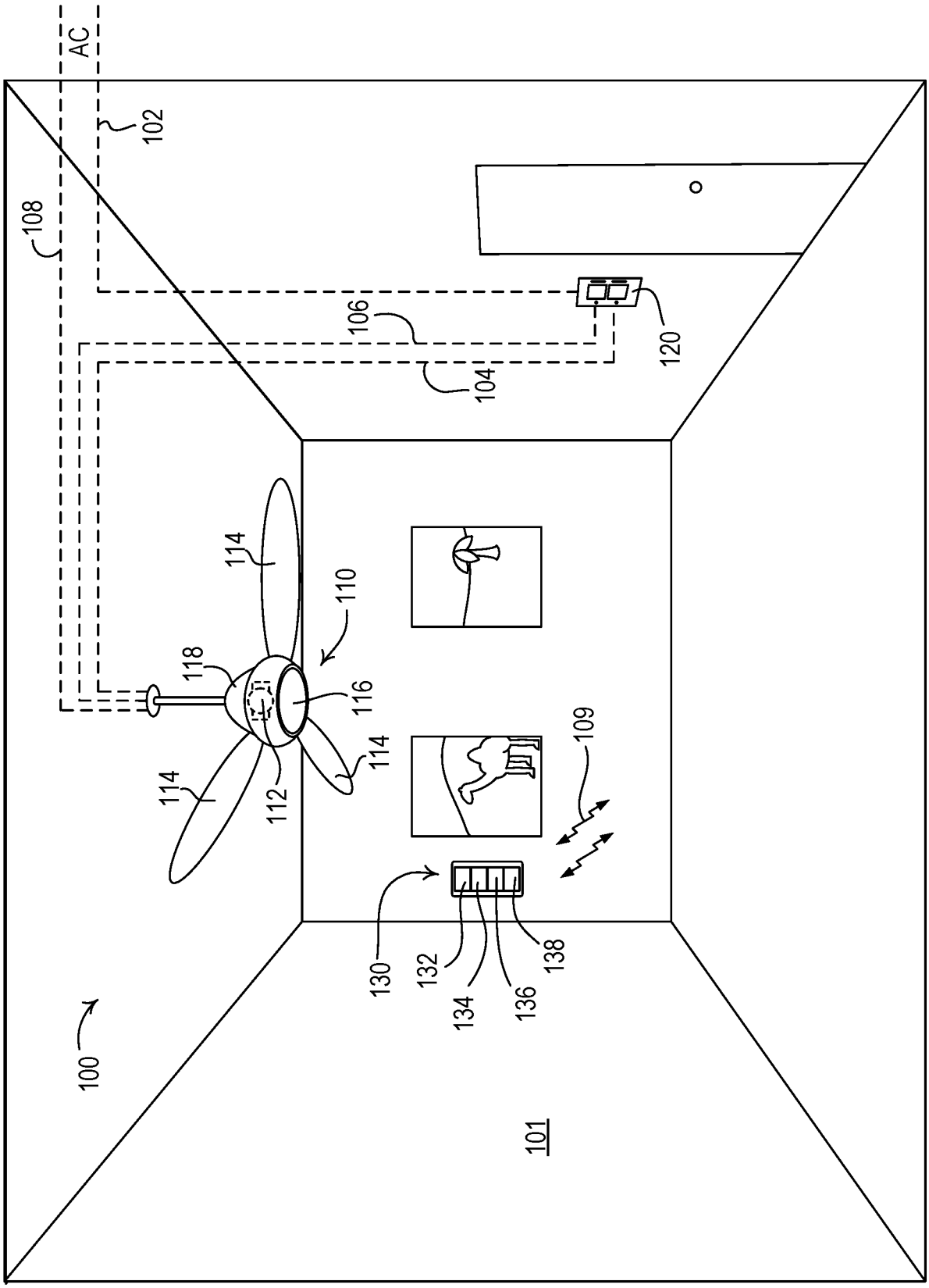

AC
102
108
106
104
120
114
110
118
116
114
112
114
109
130
132
134
136
138
100
101

FIG. 1

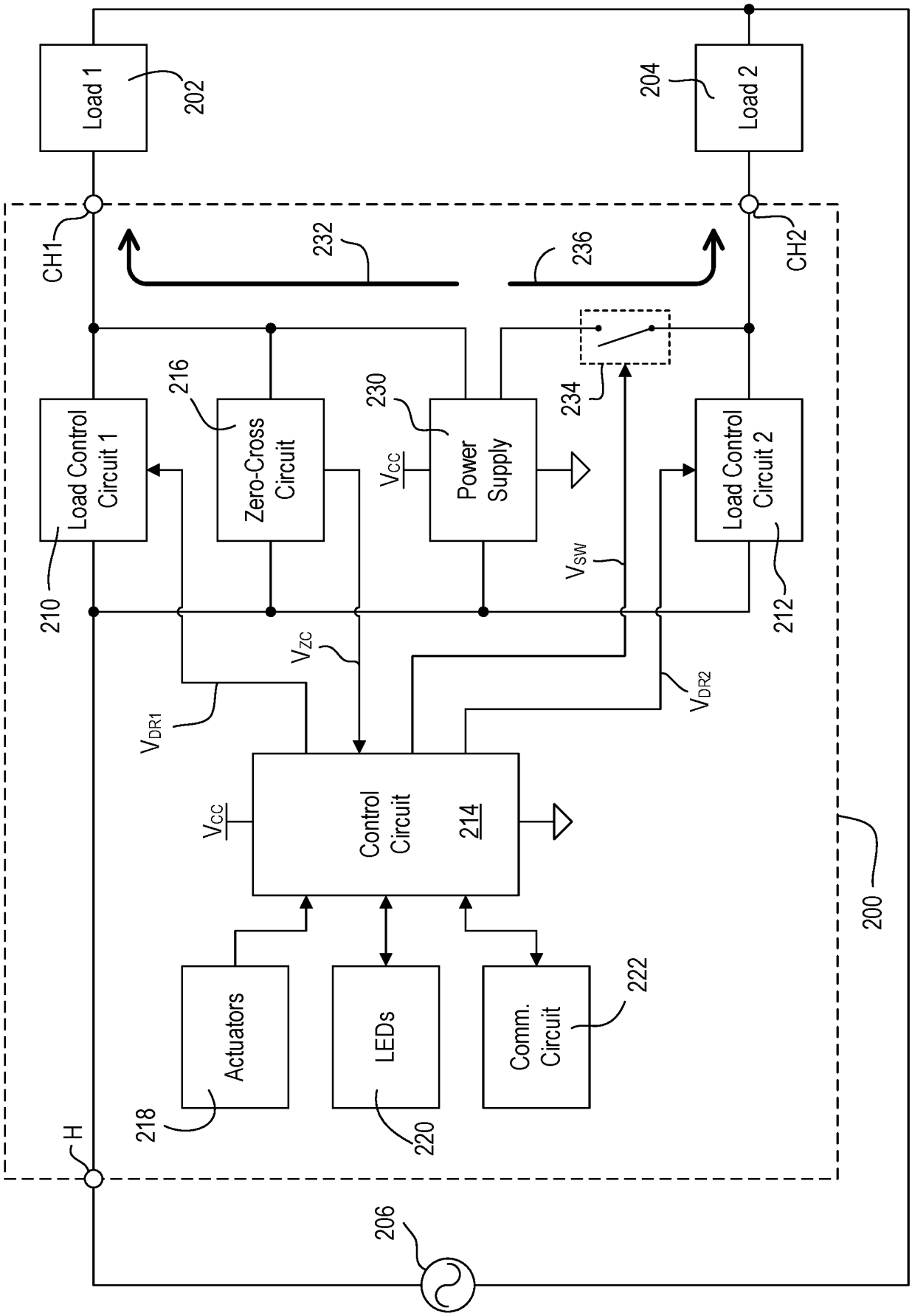

Load 1
202
204
Load 2
CH1
CH2
232
236
Load Control Circuit 1
216
Zero-Cross Circuit
230
Power Supply
234
Load Control Circuit 2
210
212
V_{CC}
V_{SW}
V_{ZC}
V_{DR1}
V_{DR2}
Control Circuit
214
200
Actuators
LEDs
Comm. Circuit
222
218
220
H
206

FIG. 2

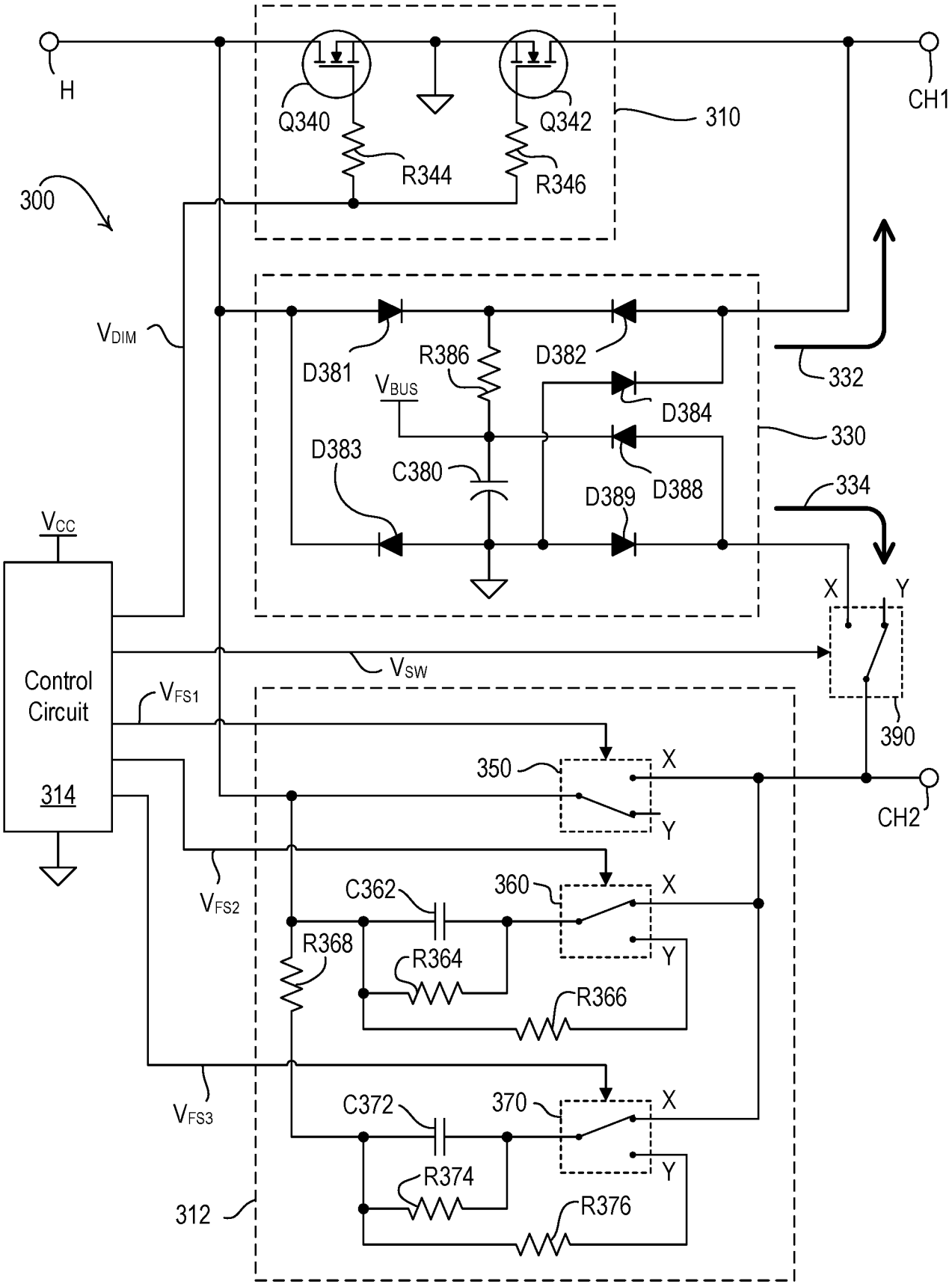

H
CH1
Q340
Q342
310
R344
R346
300
VDIM
D381
R386
D382
VBUS
D384
332
330
D383
C380
D389
D388
334
VCC
X
Y
Control Circuit
VSW
VFS1
390
350
X
Y
CH2
314
VFS2
C362
360
X
R368
R364
Y
R366
VFS3
C372
370
X
R374
Y
312
R376

FIG. 3

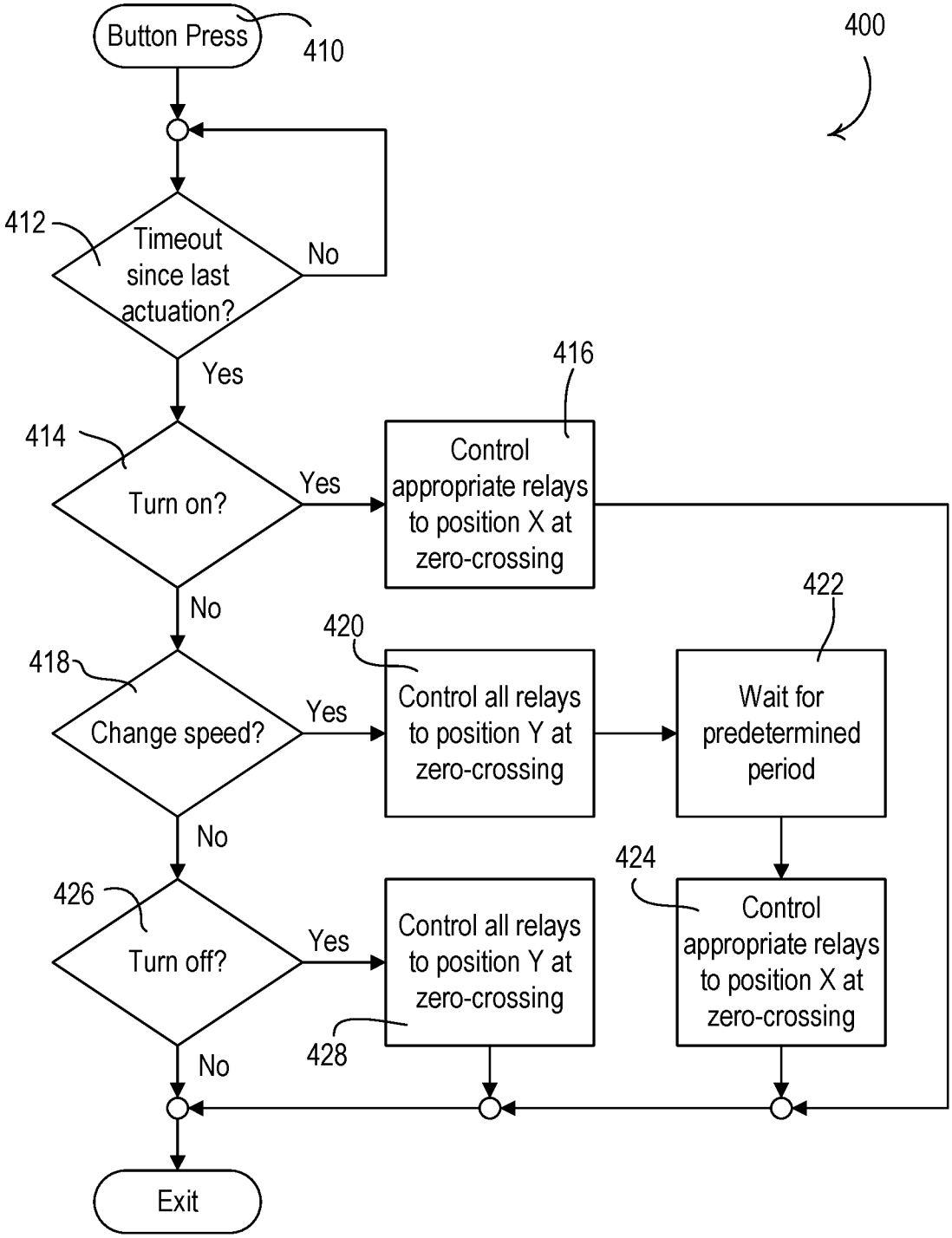

400
Button Press
410
412
Timeout since last actuation?
No
Yes
414
Turn on?
Yes
416
Control appropriate relays to position X at zero-crossing
No
418
Change speed?
Yes
420
Control all relays to position Y at zero-crossing
422
Wait for predetermined period
No
424
Control appropriate relays to position X at zero-crossing
426
Turn off?
Yes
Control all relays to position Y at zero-crossing
428
No
Exit

FIG. 4

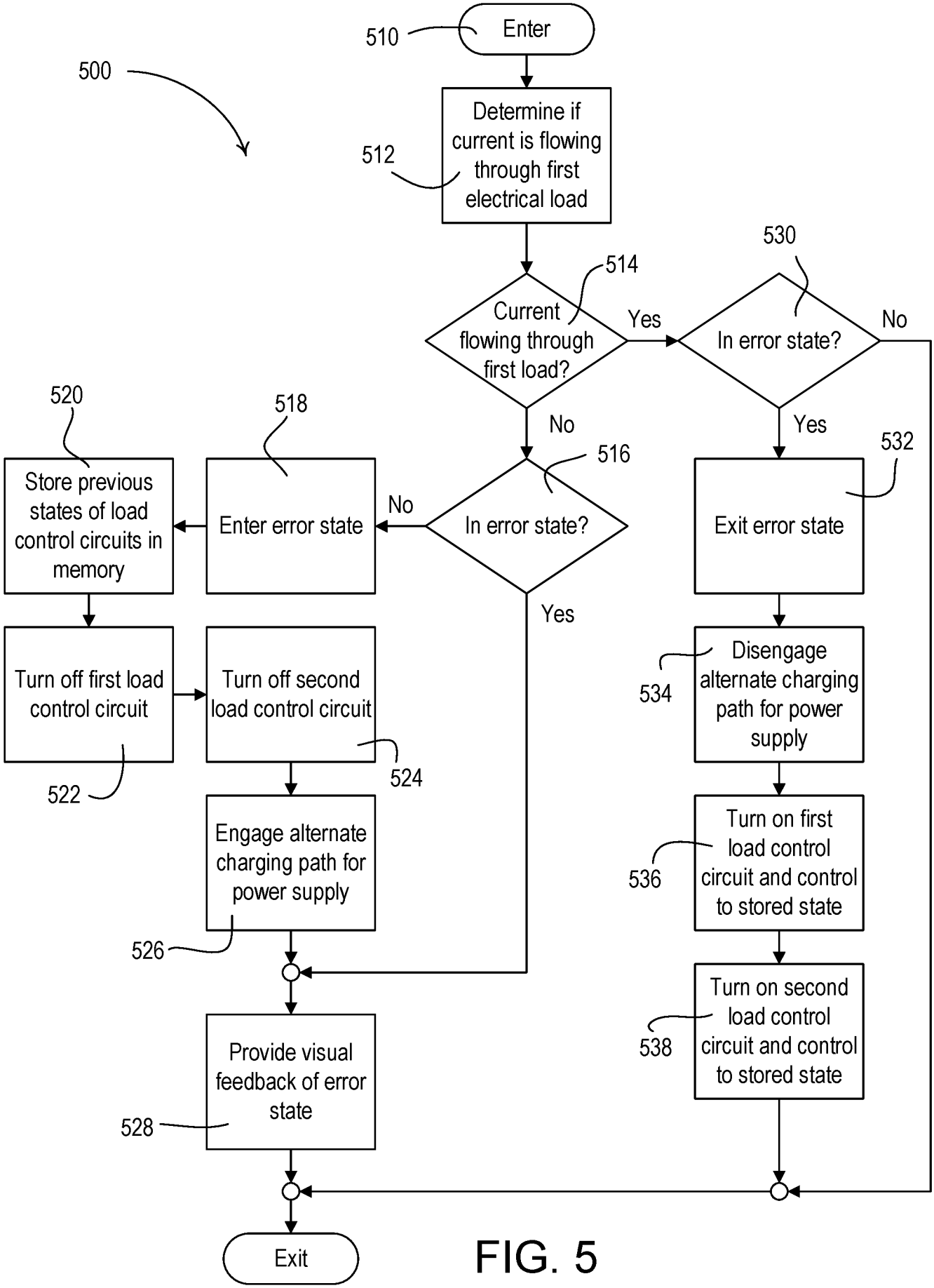

500
510
Enter
512
Determine if current is flowing through first electrical load
514
Current flowing through first load?
Yes
530
In error state?
No
Yes
No
516
In error state?
No
Yes
518
Enter error state
520
Store previous states of load control circuits in memory
522
Turn off first load control circuit
524
Turn off second load control circuit
526
Engage alternate charging path for power supply
528
Provide visual feedback of error state
532
Exit error state
534
Disengage alternate charging path for power supply
536
Turn on first load control circuit and control to stored state
538
Turn on second load control circuit and control to stored state
Exit

FIG. 5

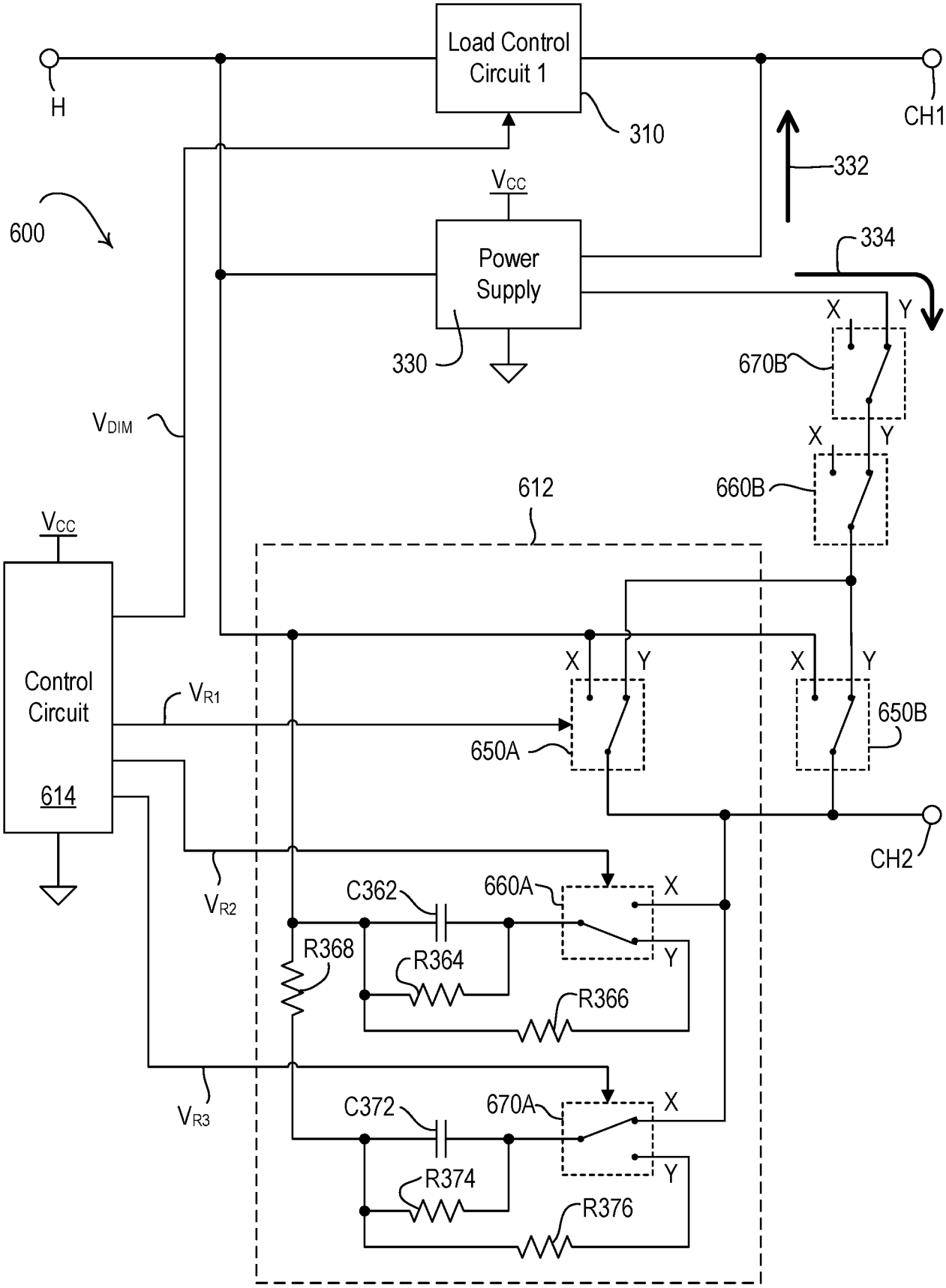

Load Control Circuit 1
310
H
CH1
332
600
V_{CC}
Power Supply
334
330
X
Y
670B
V_{DIM}
660B
612
V_{CC}
Control Circuit
614
V_{R1}
650A
650B
CH2
V_{R2}
C362
660A
R368
R364
R366
V_{R3}
C372
670A
R374
R376

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/036708

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02P25/04 H02P1/24 H02P27/16
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)
H02P

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	US 2007/114963 A1 (STEINER JAMES P [US] ET AL) 24 May 2007 (2007-05-24) abstract figures 1-6C paragraphs [0005], [0016], [0034] table 1 claims 1,15,23	1-20,32, 33
A	CN 105 763 130 A (GREE ELECTRIC APPLIANCES INC ZHUHAI) 13 July 2016 (2016-07-13) abstract; figure 1	1-20
A	US 4 352 993 A (HANNAS JAMES R) 5 October 1982 (1982-10-05) abstract figures 1-2C	1-20

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[X] Further documents are listed in the continuation of Box C.

[X] 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
31 August 2018	12/11/2018

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	Vanata, Daniela

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/036708

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CA 2 178 026 A1 (NEIGER BENJAMIN [US]; GERSHEN BERNARD [US]; KRAJCI EDWARD [US]) 15 December 1996 (1996-12-15) abstract figures 1-3 claims 1,2	1-20
A	DE 44 21 976 A1 (GOLD STAR CO [KR]) 5 January 1995 (1995-01-05) abstract figure 1 column 1 - column 4	1-20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/036708

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-20, 32, 33

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-20, 32, 33

Motor speed control

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2. claims: 21-31, 34-46

Power control for two loads

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2018/036708

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007114963 A1	24-05-2007	AT 487270 T	15-11-2010
		BR PI0619700 A2	11-10-2011
		CA 2628529 A1	31-05-2007
		CN 101473526 A	01-07-2009
		EP 1952527 A2	06-08-2008
		HK 1132099 A1	15-04-2011
		JP 2009520451 A	21-05-2009
		US 2007114963 A1	24-05-2007
		US 2009072775 A1	19-03-2009
		US 2010109597 A1	06-05-2010
		WO 2007061901 A2	31-05-2007
CN 105763130 A	13-07-2016	NONE	
US 4352993 A	05-10-1982	NONE	
CA 2178026 A1	15-12-1996	NONE	
DE 4421976 A1	05-01-1995	CN 1107625 A	30-08-1995
		DE 4421976 A1	05-01-1995
		JP H0715993 A	17-01-1995
		KR 950001580 U	04-01-1995