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(54) ELECTRONIC DEVICE INCLUDING A POWER FACTOR CORRECTION CIRCUIT AND METHOD FOR CONTROLLING THE POWER FACTOR CORRECTION CIRCUIT

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(57) **ABSTRACT**

An electronic device is provided. The electronic device includes: a power factor correction (PFC) circuit; a rectifier circuit configured to rectify an alternating current voltage to obtain an input voltage having a negative polarity and provide the input voltage to the PFC circuit; and a protecting circuit configured to protect the PFC circuit. The PFC circuit includes: a first diode; an inductor configured to store energy based on the input voltage provided by the rectifier circuit while a switching circuit is turned on and provide energy while the switching circuit is turned off; and an output capacitor connected to the inductor through the first diode, and configured to provide an output voltage having a positive polarity by using the energy provided by the inductor while the switching circuit is turned off.

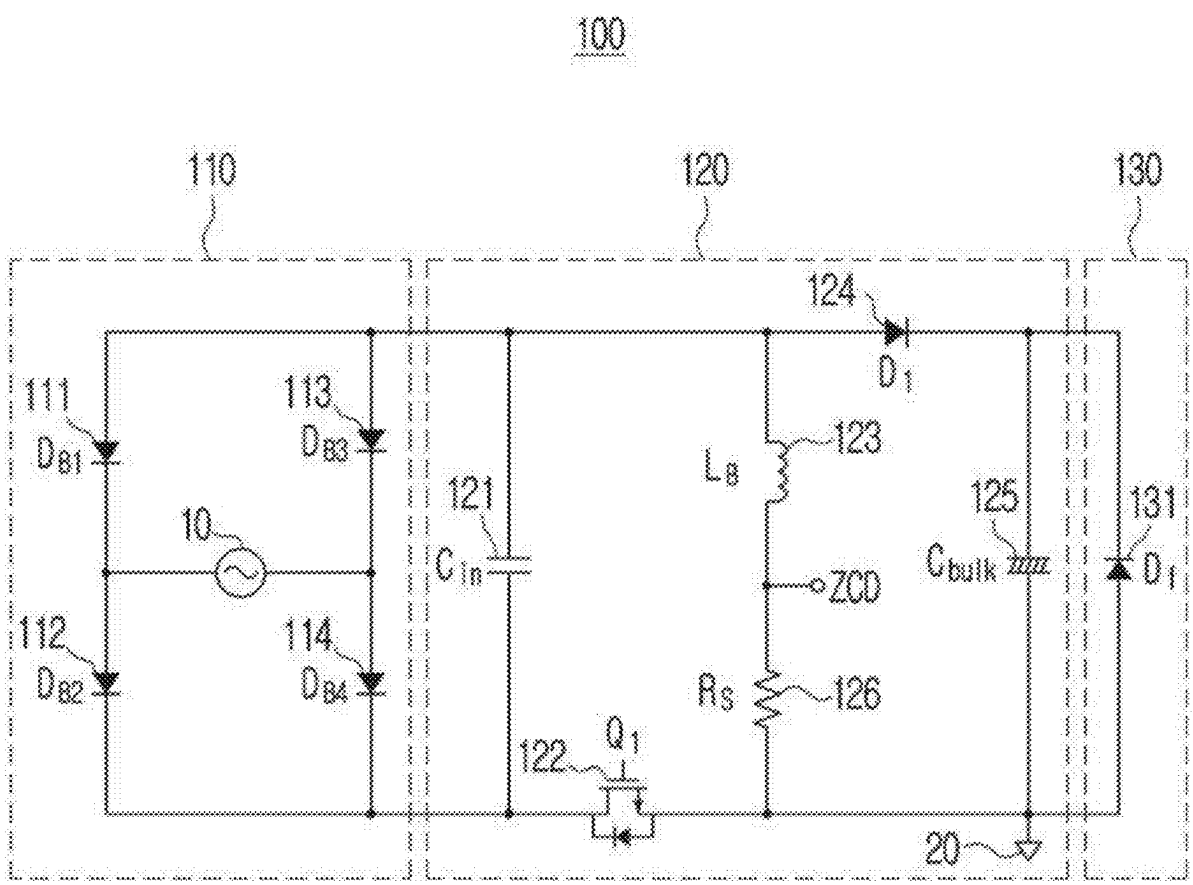


FIG. 1A

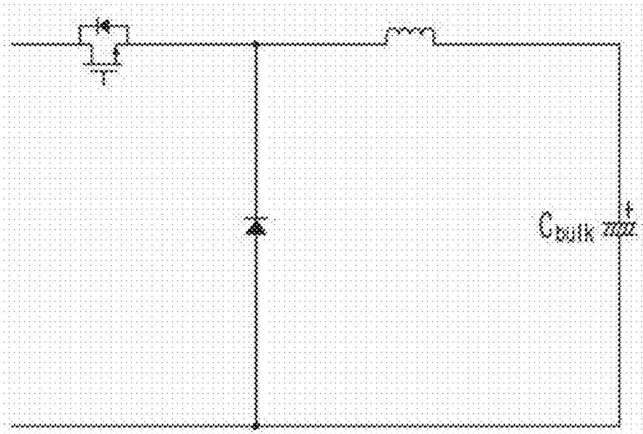


FIG. 1B

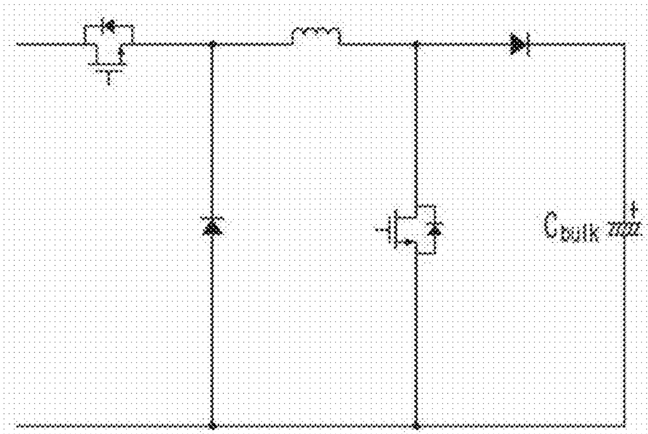


FIG. 1C

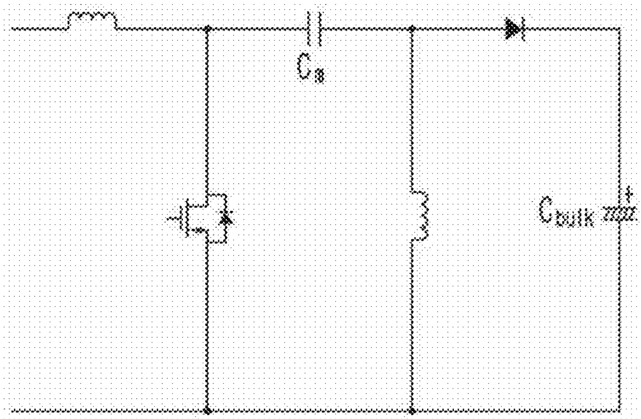


FIG. 2

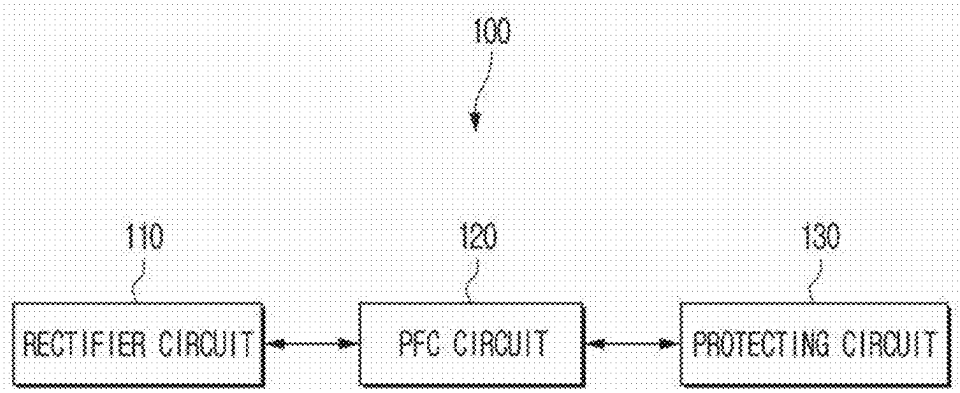

100
110
120
130
RECTIFIER CIRCUIT
PFC CIRCUIT
PROTECTING CIRCUIT

FIG. 3

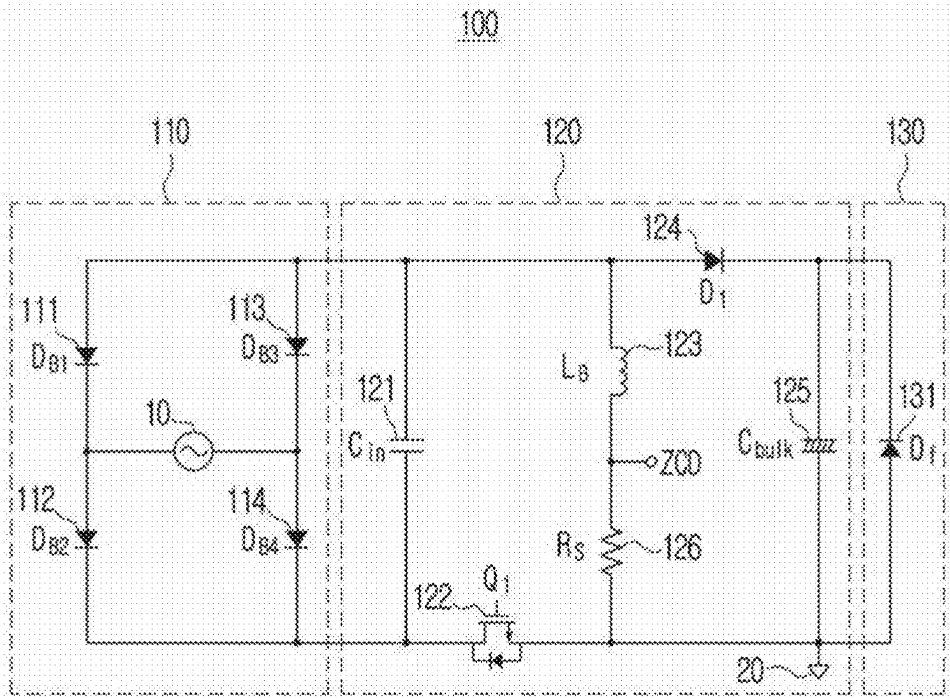

100
110
120
130
124
D_1
111
D_{B1}
113
D_{B3}
10
112
D_{B2}
114
D_{B4}
121
C_{in}
L_S
123
ZCD
R_S
126
Q_1
122
125
C_{bulk}
131
D_f
20

FIG. 4A

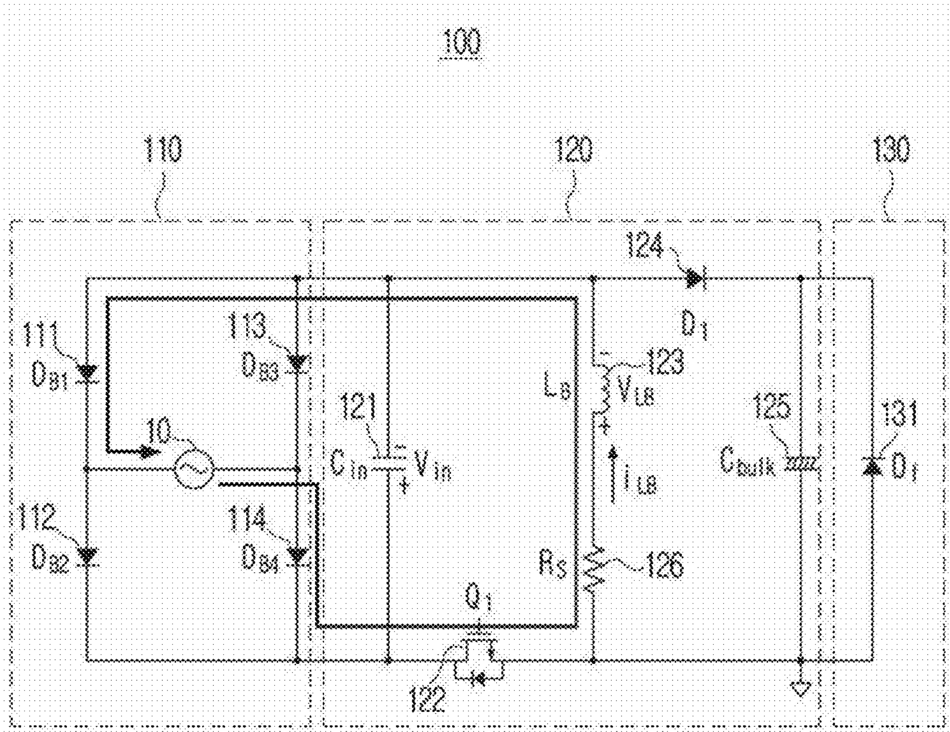

100
110
120
130
124
D_1
111
D_{B1}
113
D_{B3}
123
L_B
V_{LB}
121
125
131
10
C_{in}
V_{in}
i_{LB}
C_{bulk}
D_f
112
D_{B2}
114
D_{B4}
R_S
126
Q_1
122

FIG. 4B

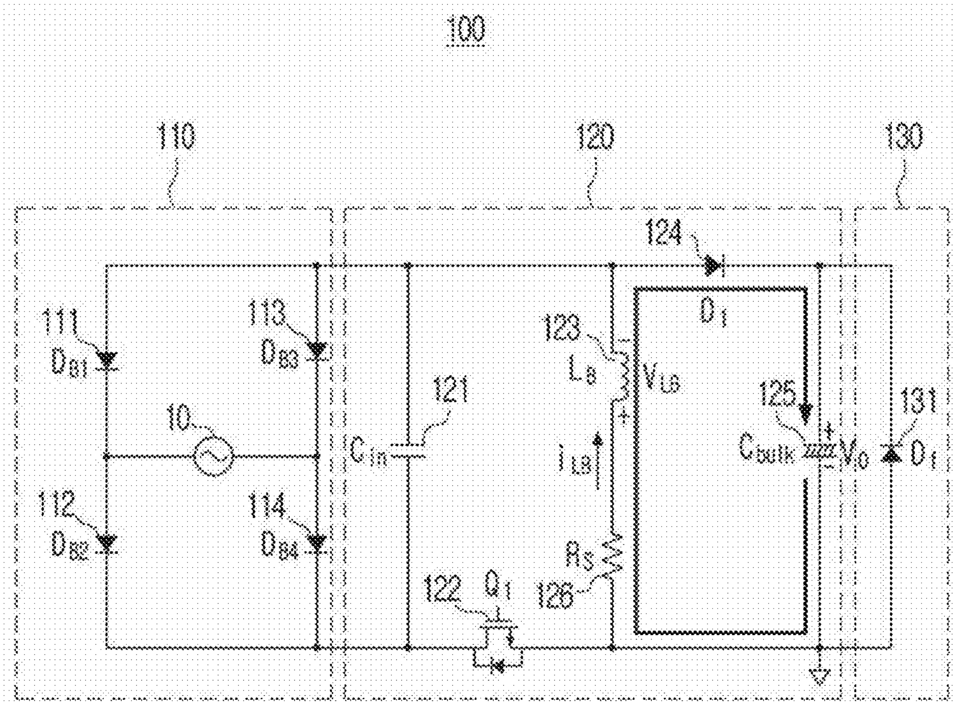

100
110
120
130
124
D_1
111
D_{B1}
113
D_{B3}
123
L_B
V_{LB}
121
125
131
10
C_{in}
i_{LB}
C_{bulk}
V_O
D_f
112
D_{B2}
114
D_{B4}
R_S
122
Q_1
126

FIG. 5A

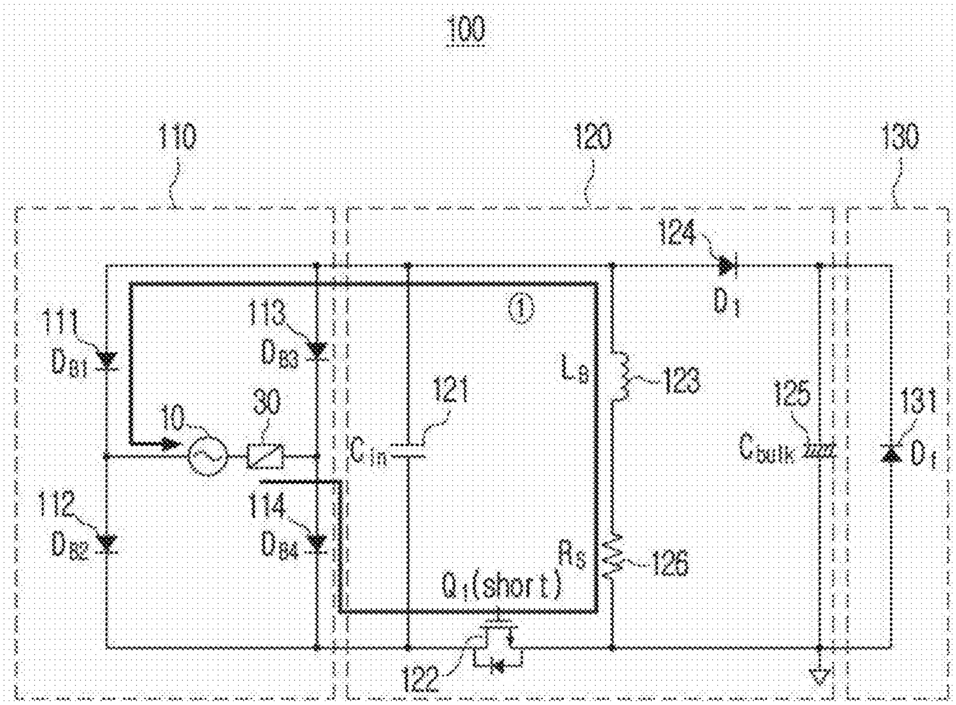

100
110
120
130
124
D_1
111
D_{B1}
113
D_{B3}
①
L_B
123
121
125
131
10
30
C_{in}
C_{bulk}
D_f
112
D_{B2}
114
D_{B4}
R_S
126
Q_1(short)
122

FIG. 5B

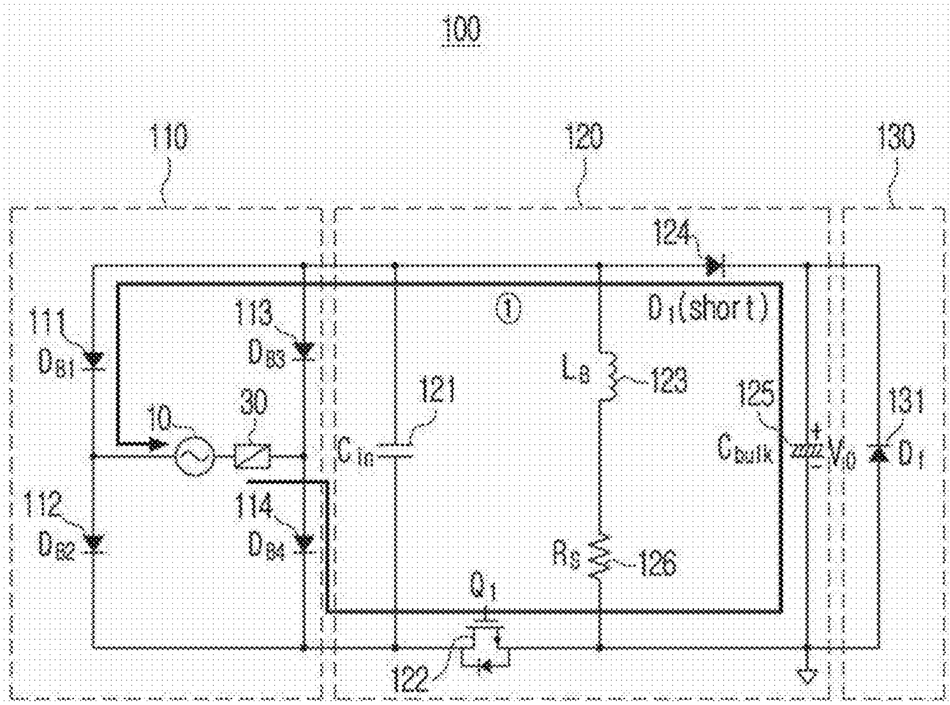

100
110
120
130
124
①
D_1(short)
111
D_{B1}
113
D_{B3}
10
30
121
C_{in}
L_B
123
125
C_{bulk}
V_O
131
D_f
112
D_{B2}
114
D_{B4}
R_S
126
Q_1
122

FIG. 5C

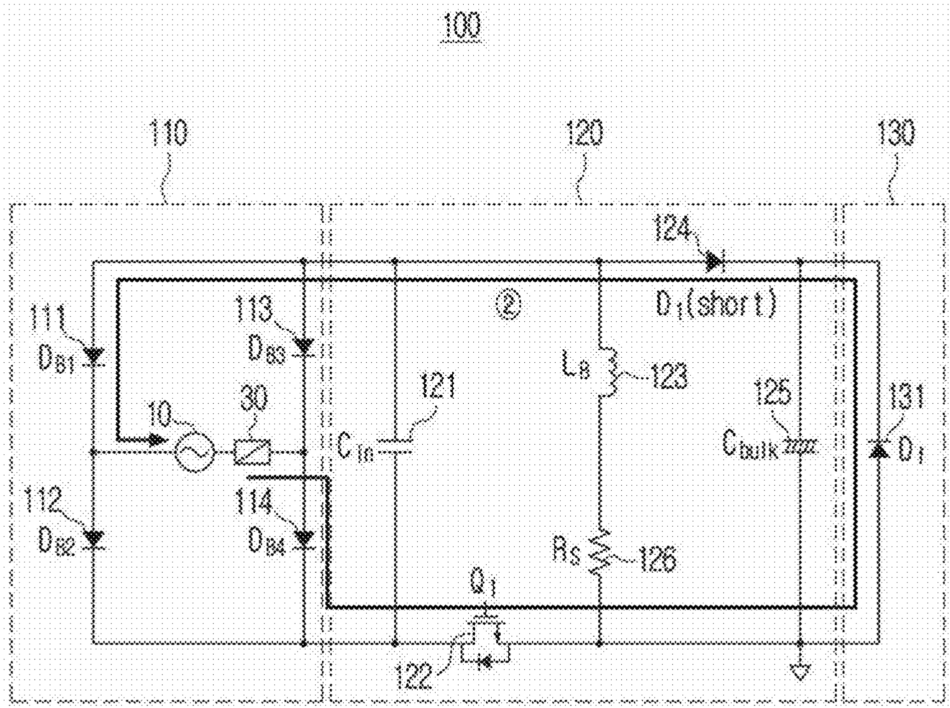

100
110
120
130
124
D1(short)
②
111
DB1
113
DB3
LB
123
121
125
131
10
30
Cin
Cbulk
D1
112
DB2
114
DB4
RS
126
Q1
122

FIG. 6

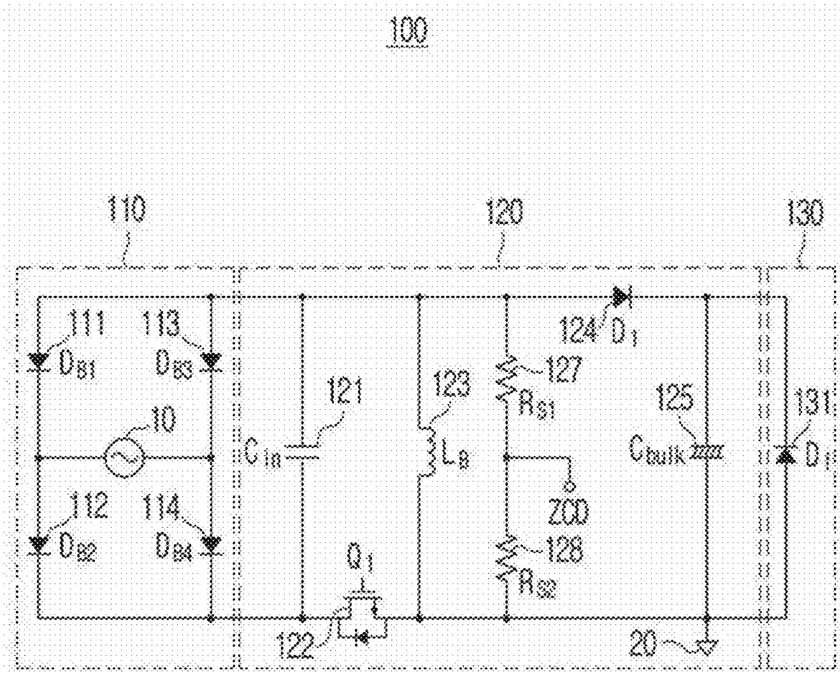

100
110
120
130
111
113
112
114
D_{B1}
D_{B3}
D_{B2}
D_{B4}
10
121
C_{in}
122
Q_1
123
L_B
124
D_1
127
R_{S1}
128
R_{S2}
ZCD
125
C_{bulk}
131
20

FIG. 7

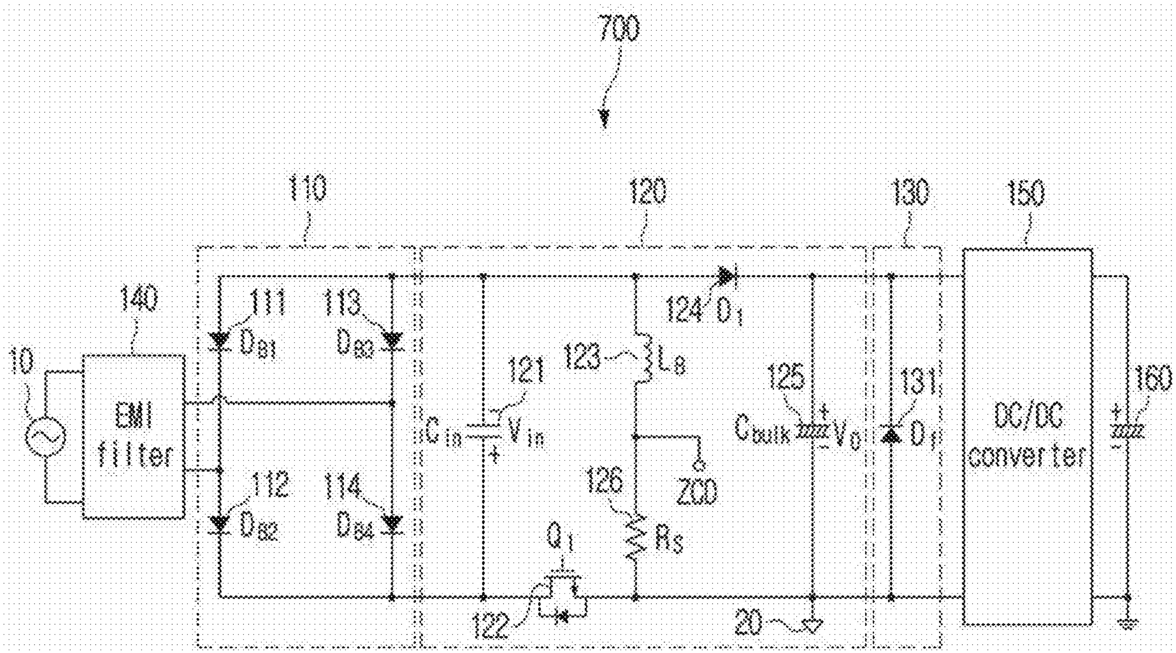
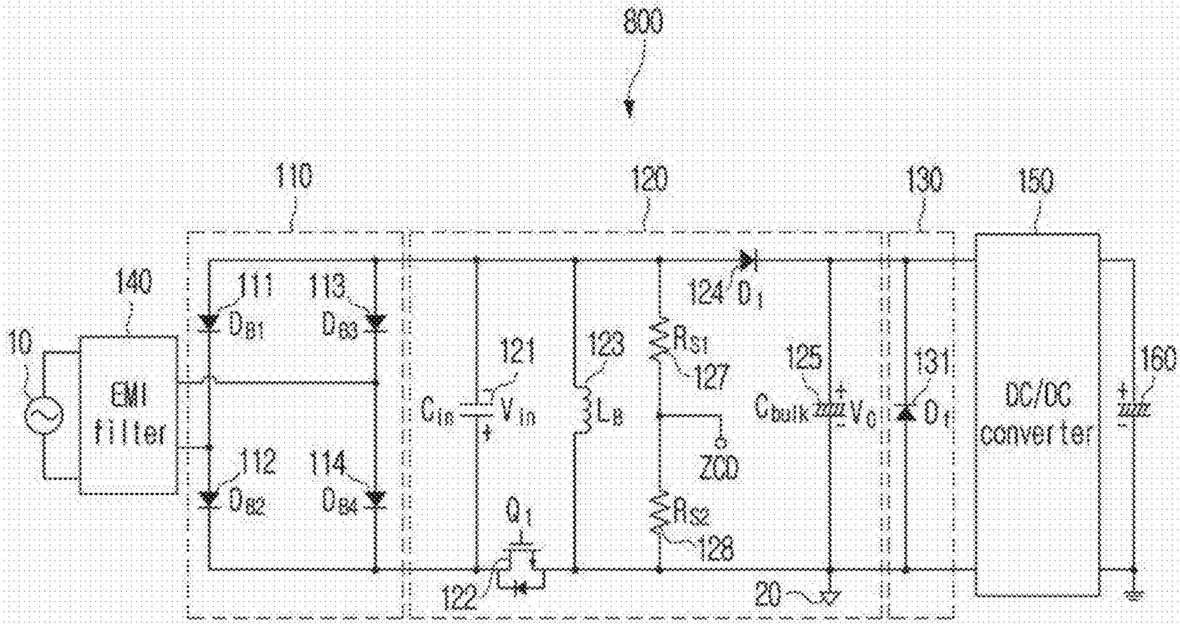

700
110
120
130
150
140
10
EMI filter
111
D_{B1}
112
D_{B2}
113
D_{B3}
114
D_{B4}
121
C_{in}
V_{in}
122
Q_1
123
L_B
124
D_1
125
C_{bulk}
V_O
126
R_S
ZCD
20
131
D_f
DC/DC converter
160

FIG. 8



800
110
120
130
150
140
10
EMI filter
111
D_{B1}
113
D_{B3}
112
D_{B2}
114
D_{B4}
121
C_{in}
V_{in}
123
L_B
124
D_1
R_{S1}
127
ZCD
R_{S2}
128
Q_1
122
125
C_{bulk}
V_C
20
131
D_f
DC/DC converter
160

FIG. 9

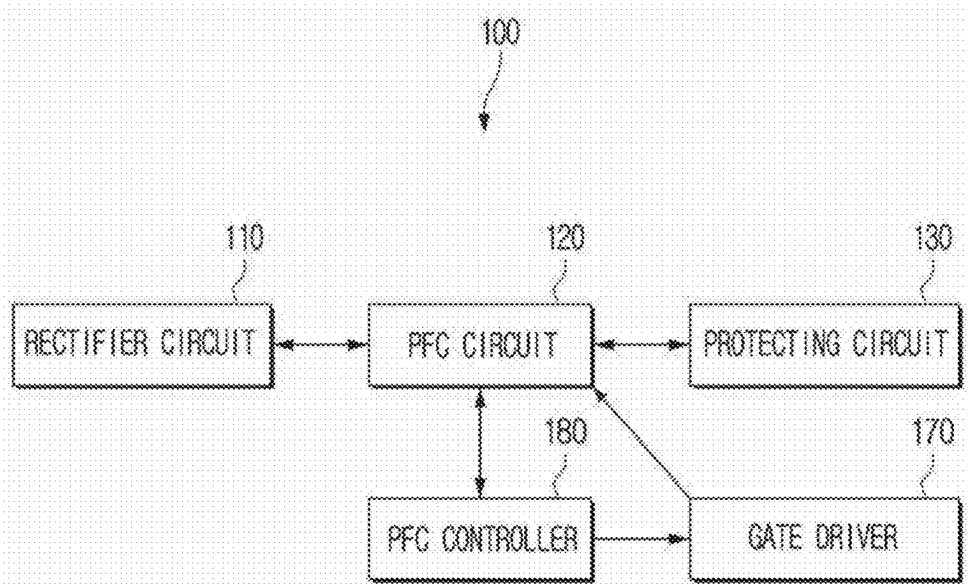

100
110
120
130
RECTIFIER CIRCUIT
PFC CIRCUIT
PROTECTING CIRCUIT
180
170
PFC CONTROLLER
GATE DRIVER

FIG. 10

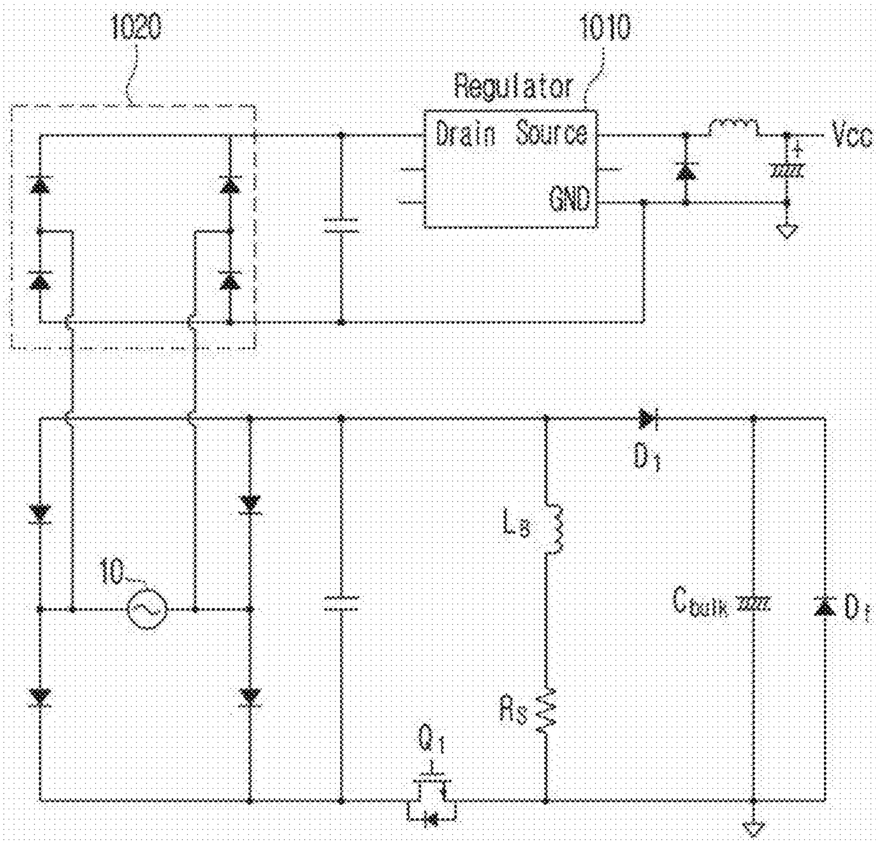

1020
1010
Regulator
Drain
Source
GND
Vcc
D1
Ls
10
Cbulk
Df
Rs
Q1

FIG. 11

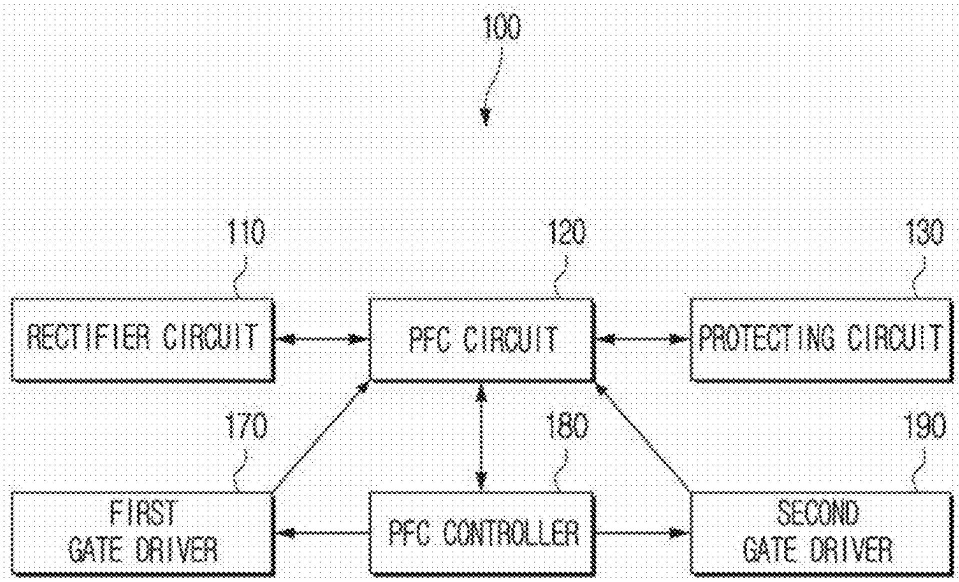

100
110
120
130
RECTIFIER CIRCUIT
PFC CIRCUIT
PROTECTING CIRCUIT
170
180
190
FIRST
GATE DRIVER
PFC CONTROLLER
SECOND
GATE DRIVER

FIG. 12

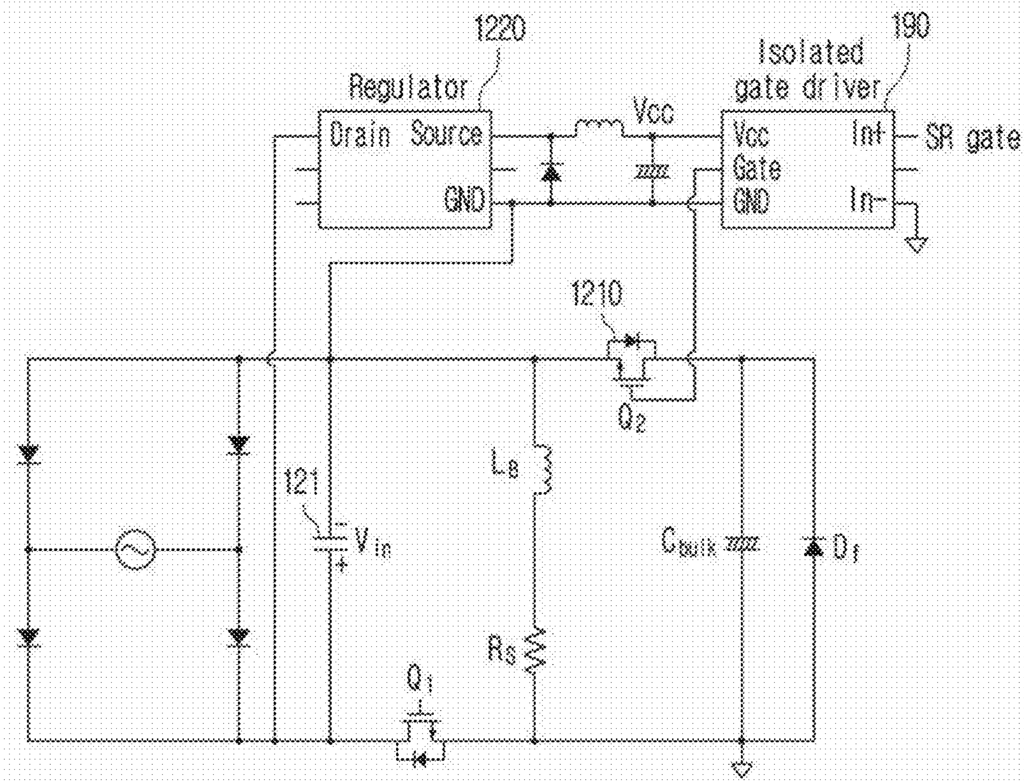

1220
Regulator
Drain
Source
GND
Vcc
190
Isolated gate driver
Vcc
Gate
GND
Int
In-
SR gate
1210
Q_2
121
V_{in}
L_B
C_{bulk}
D_f
R_S
Q_1

FIG. 13A

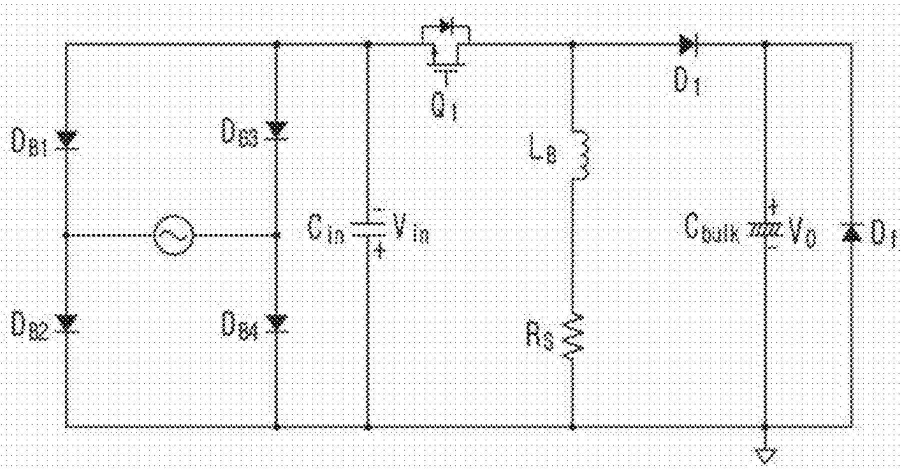


FIG. 13B

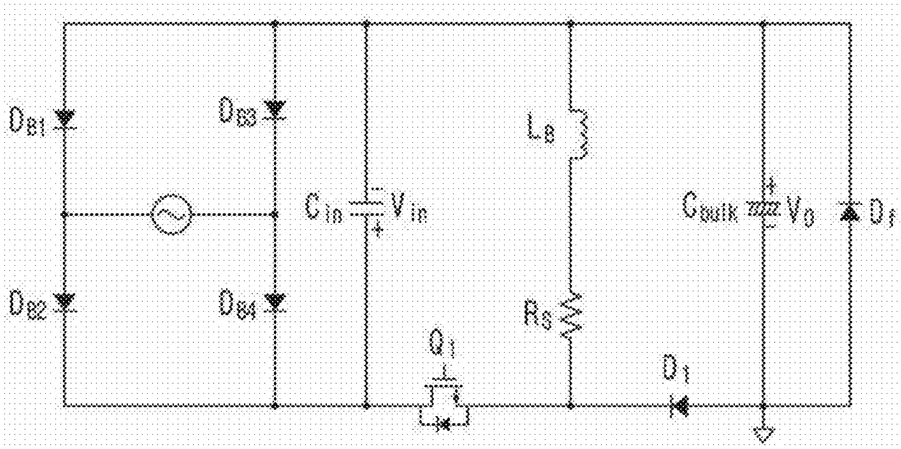


FIG. 14A

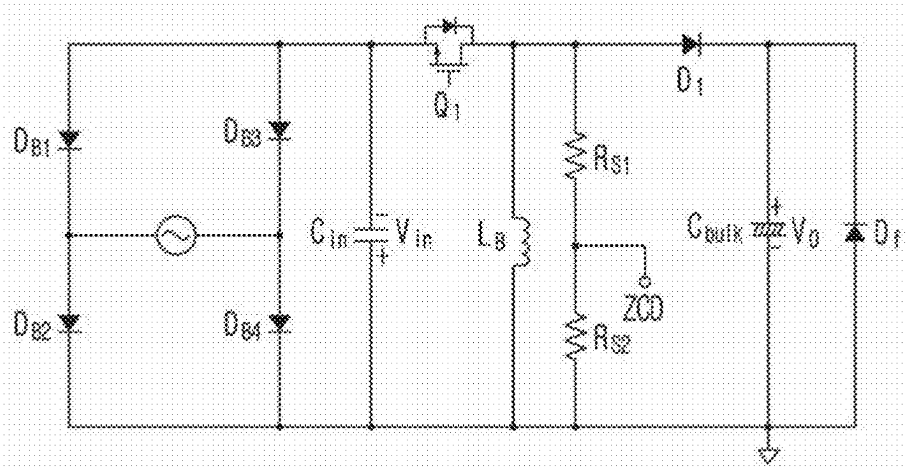


FIG. 14B

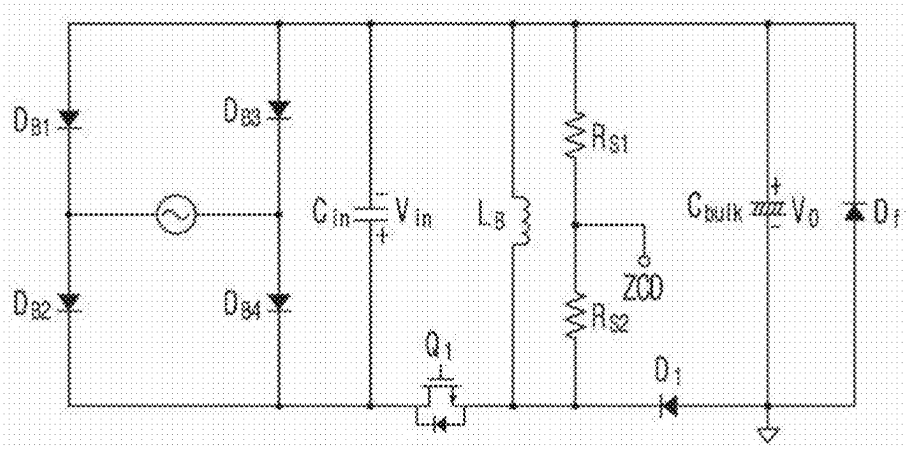
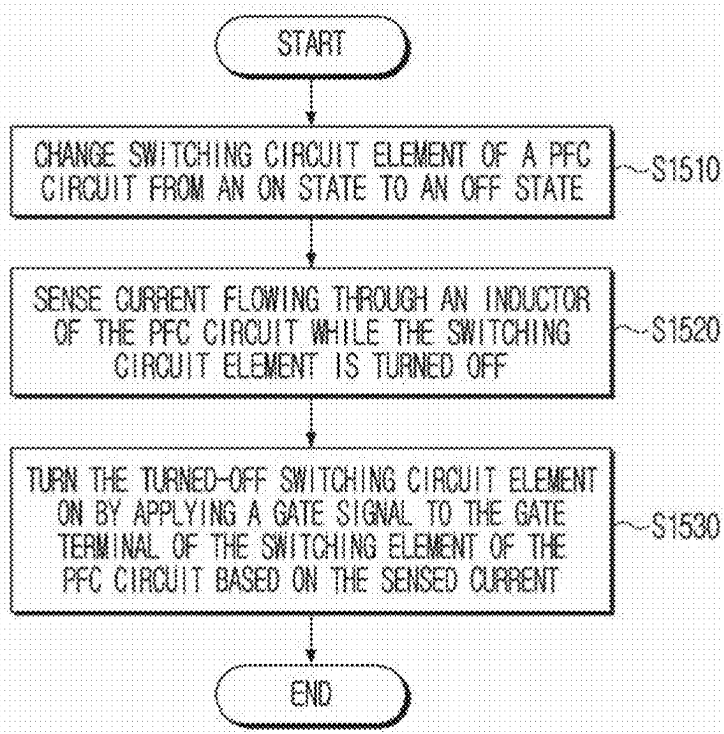


FIG. 15


START
CHANGE SWITCHING CIRCUIT ELEMENT OF A PFC CIRCUIT FROM AN ON STATE TO AN OFF STATE
S1510
SENSE CURRENT FLOWING THROUGH AN INDUCTOR OF THE PFC CIRCUIT WHILE THE SWITCHING CIRCUIT ELEMENT IS TURNED OFF
S1520
TURN THE TURNED-OFF SWITCHING CIRCUIT ELEMENT ON BY APPLYING A GATE SIGNAL TO THE GATE TERMINAL OF THE SWITCHING ELEMENT OF THE PFC CIRCUIT BASED ON THE SENSED CURRENT
S1530
END

ELECTRONIC DEVICE INCLUDING A POWER FACTOR CORRECTION CIRCUIT AND METHOD FOR CONTROLLING THE POWER FACTOR CORRECTION CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a bypass continuation application of International Application No. PCT/KR2025/001855, filed on Feb. 7, 2025, which claims priority to Korean Patent Application No. 10-2024-0019432, filed on Feb. 8, 2024, in the Korean Intellectual Property Office, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND

1. Field of the Invention

[0002] The present disclosure relates to an electronic device including a power factor correction (PFC) circuit and a method for controlling the PFC circuit.

2. Description of the Related Art

[0003] Various types of electronic devices have been developed, including low-profile electronic devices such as an ultra-slim TV.

[0004] Electronic devices may include a power circuit which supplies power to components of the electronic devices. The power circuit may include a PFC to satisfy power factor and harmonic wave regulations.

[0005] Accordingly, there is a need for a PFC circuit suitable for low-profile electronic devices.

SUMMARY OF THE INVENTION

[0006] In accordance with an aspect of the disclosure, an electronic device includes: a power factor correction (PFC) circuit; a rectifier circuit configured to rectify an alternating current voltage to obtain an input voltage having a negative polarity and provide the input voltage to the PFC circuit; and a protecting circuit configured to protect the PFC circuit. The PFC circuit includes: a first diode; an inductor configured to store energy based on the input voltage provided by the rectifier circuit while a switching circuit is turned on and provide energy while the switching circuit is turned off; and an output capacitor connected to the inductor through the first diode, and configured to provide an output voltage having a positive polarity by using the energy provided by the inductor while the switching circuit is turned off. Based on the first diode being short-circuited, the PFC circuit is protected by a current path formed by the protecting circuit while the switching circuit is turned on.

[0007] The protecting circuit may include a second diode which is connected to the output capacitor in parallel.

[0008] The rectifier circuit may include a diode bridge, and the PFC circuit may further include an input capacitor configured to receive the input voltage from the diode bridge.

[0009] A first end of the switching circuit may be connected to one end of the input capacitor, one end of the inductor may be connected to another end of the input capacitor and an anode of the first diode, another end of the inductor may be connected to one end of a resistor, one end of the output capacitor may be connected to a cathode of the first diode and a cathode of the second diode, another end of the output capacitor may be connected to the other end of the resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and the resistor may be used to sense current flowing through the inductor.

[0010] The PFC circuit may be driven in a critical conduction mode (CrM) based on the current flowing through the inductor, and the current may be sensed using the resistor.

[0011] A first end of the switching circuit may be connected to one end of the input capacitor, one end of the inductor may be connected to another end of the input capacitor, an anode of the first diode, and one end of a first resistor, another end of the first resistor may be connected to one end of a second resistor, one end of the output capacitor may be connected to a cathode of the first diode and a cathode of the second diode, another end of the output capacitor may be connected to another end of the inductor, another end of the second resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and the first resistor and the second resistor may be used to sense current flowing through the inductor.

[0012] The PFC circuit may be driven in a CrM based on the current of the inductor sensed using the first resistor and the second resistor.

[0013] Based on the switching circuit being turned on in a state where the first diode is short-circuited due to a failure, a voltage charged in the output capacitor by the input voltage may be discharged, and based on the voltage of both ends of the output capacitor becoming zero according to the discharge, the current path may flow through the second diode.

[0014] The electronic device may further include a fuse. The fuse may be disconnected by current flowing through the current path to terminate an operation of the PFC circuit.

[0015] The electronic device may further include a fuse. Based on the switching circuit being short-circuited due to a failure, the fuse may be disconnected by current flowing through the switching circuit to terminate and an operation of the PFC circuit.

[0016] The electronic device may further include: an electromagnetic interference (EMI) filter configured to filter a source alternating current voltage and provide the alternating current voltage to the rectifier circuit; and a DC/DC converter to which the output voltage is applied.

[0017] In accordance with an aspect of the disclosure, a method for controlling a PFC circuit of an electronic device, including a PFC circuit, a rectifier circuit configured to apply an input voltage having a negative polarity to the PFC circuit by rectifying an alternating current voltage, and a protecting circuit configured to protect the PFC circuit, is provided. The method includes: controlling a switching circuit from an on state to an off state by applying a gate signal to a gate terminal of the switching circuit of the PFC circuit; sensing current flowing through an inductor of the PFC circuit while the switching circuit is in the off state; controlling the switching circuit from the off state to the on state by applying the gate signal to the gate terminal of the switching circuit of the PFC circuit based on the sensed current; storing energy in the inductor based on the input voltage applied from the rectifier circuit while the switching circuit is in the on state; and providing, while the switching circuit is in the off state, an output voltage having a positive polarity using an output capacitor of the PFC circuit that is connected to the inductor through a first diode. Based on the first diode being short-circuited, the PFC circuit is protected by a current path formed by the protecting circuit while the switching circuit is turned on.

[0018] The protecting circuit may include a second diode which is connected to the output capacitor in parallel.

[0019] The rectifier circuit may include a diode bridge, and the method may further include receiving the input voltage from the rectifier circuit at an input capacitor of the PFC circuit.

[0020] One end of the switching circuit may be connected to one end of the input capacitor, one end of the inductor may be connected to another end of the input capacitor and an anode of the first diode, another end of the inductor may be connected to one end of a resistor, one end of the output capacitor may be connected to a cathode of the first diode and a cathode of the second diode, another end of the output capacitor may be connected to another end of the resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and the method may further include sensing current flowing through the inductor using the resistor.

[0021] In accordance with an aspect of the disclosure, an electronic device includes: a PFC circuit; a protecting circuit including: a first diode; an inductor configured to store energy based on an input voltage while a switching circuit is turned on and provide energy while the switching circuit is turned off; and an output capacitor connected to the inductor through the first diode, and configured to provide an output voltage having a positive polarity by using the energy provided by the inductor while the switching circuit is turned off; and a PFC controller configured to control the switching circuit to turn on and off based on current flowing through the inductor.

[0022] The PFC controller may be further configured to control the switching circuit to turn on based on the current flowing through the inductor being zero.

[0023] The PFC controller may be further configured to control the switching circuit to turn off based on a threshold time passing after controlling the switching circuit to turn on.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The above and other aspects, features, and advantages of certain embodiments of the present disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

[0025] FIGS. **1**A, **1**B and **1**C are views illustrating an example of a power factor correction (PFC) circuit;

[0026] FIG. **2** is a block diagram illustrating a configuration of an electronic device according to an embodiment;

[0027] FIG. **3** is a view illustrating a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment;

[0028] FIGS. **4**A and **4**B are views illustrating operations of a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment;

[0029] FIGS. **5**A, **5**B, and **5**C are views illustrating operations for protecting the PFC circuit according to an embodiment;

[0030] FIG. **6** is a view illustrating a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment;

[0031] FIGS. **7** and **8** are views illustrating an example of power circuits according to embodiments;

[0032] FIG. **9** is a block diagram illustrating a configuration of an electronic device according to an embodiment;

[0033] FIG. **10** is a view illustrating a method of providing power to a PFC controller according to an embodiment;

[0034] FIG. **11** is a block diagram illustrating a configuration of an electronic device according to an embodiment;

[0035] FIG. **12** is a view illustrating a method of providing power to a second gate driver according to an embodiment;

[0036] FIGS. **13**A, **13**B, **14**A, and **14**B are views illustrating a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment; and

[0037] FIG. **15** is a flow chart illustrating a method of controlling a PFC circuit of an electronic device according to an embodiment.

DETAILED DESCRIPTION

[0038] Embodiments are described below with reference to the accompanying drawings. Embodiments described herein are examples, and thus, the present disclosure is not limited thereto, and may be realized in various other forms. Each embodiment provided in the following description is not excluded from being associated with one or more features of another example or another embodiment also provided herein or not provided herein but consistent with the present disclosure. Expressions such as "at least one of a, b, or c" may designate "a", "b", "c", "a and b", "a and c", "b and c", "all of a, b, and c", or variants thereof.

[0039] The terms used herein are selected to be general terms which are currently and widely used as much as possible in consideration of functions in the disclosure. However, the terms may be varied according to intention of those skilled in the art or precedents, emergence of new technologies, etc. Also, there may be a term arbitrarily selected by the applicant in a specific case. In this case, the meaning of the term is specifically described in the corresponding part of the description. Therefore, the term used in the disclosure should be defined based on the meaning of the term and the contents throughout an entire specification other than the simple name of the term.

[0040] The singular expression may include the plural expression unless otherwise explicitly noted in the context. The terms used herein including technical or scientific terms may have the same meaning as that generally understood by those skilled in the art described in the specification. As used herein, the terms "1st" or "first" and "2nd" or "second" may use corresponding components regardless of importance or order and are used to distinguish a component from another component without limiting the components.

[0041] Throughout the specification, unless explicitly described to the contrary, the expression that a part "comprises" a component will be understood to imply the inclusion of the stated component but not the exclusion of the component. In addition, terms such as "part", "module", etc., which are described in the specification, indicate a unit that processes at least one function or operation. The unit may be realized by hardware.

[0042] The term "and/or" include combinations of a plurality of related described components or any component of the plurality of related described components.

[0043] Various elements and areas of the drawings are schematically depicted. Therefore, embodiments are not limited by the relative size or spacing depicted in the attached drawings.

[0044] Hereinafter, the disclosure is described with reference to the attached drawings.

[0045] FIGS. **1**A to **1**C are views illustrating an example of a power factor correction (PFC) circuit.

[0046] A power circuit having 75 W or more of output power is to use a PFC circuit to satisfy power factor-related and high frequency-related regulations (e.g., regulatory conditions related to total harmonic distortion (THD)). For example, the PFC circuit may include a boost converter-based PFC circuit

[0047] However, it is difficult to use the boost converter-based PFC circuit in the electric device (e.g., an ultra-slim TV, etc.) in which a power circuit is required in an ultra-slim form (or a slim form).

[0048] Specifically, the boost converter is a step-up converter, wherein an input voltage is higher than an output voltage. Therefore, an output capacitor of the boost converter is to be an electrolytic capacitor having a high internal pressure. However, a capacitor having a high internal pressure has a great diameter, which is not suitable for an ultra-slim power circuit. Also, when an additional winding is used for zero current detection (ZCD), a large inductor is used.

[0049] To overcome this problem, a step-down converter in which an output capacitor having a low internal pressure may be used for a PFC circuit. The step-down converter may be a buck converter, a two switching buck-boost converter, a single-ended primary-inductor converter (SEPIC converter), etc.

[0050] FIG. **1**A is a view illustrating an example of a buck converter. The buck converter has advantages of a simple structure and a small number of elements. However, based on a switching circuit element (e.g., a switch circuit, such as a metal oxide semiconductor field effect transistor (MOSFET)) being short-circuited due to a failure, there is a problem that the input voltage may be applied to the output capacitor (e.g., C_{bulk}), which may cause the output capacitor to explode.

[0051] FIG. **1**B is a view illustrating an example of the two switching buck-boost converter. The two switching buck-boost converter is a converter in which both step-up and step-down are possible. Accordingly, there is an advantage of being capable of controlling an output voltage regardless of a magnitude of the input voltage. However, similar to the buck converter, there is a problem that based on the switching circuit element being short-circuited due to a failure, the output capacitor (e.g., C_{bulk}) may explode.

[0052] FIG. **1**C is a view illustrating an example of the SEPIC converter. An input and output of the SEPIC converter are separated due to the capacitor (Cm). In this regard, even though the switching circuit element is short-circuited, the output capacitor (e.g., C_{bulk}) may be protected. However, the SEPIC converter has a topology of requiring two inductors and thus has a disadvantage that increased size and cost of the converter is required.

[0053] Also, each of the aforementioned step-down converters require additional winding for ZCD. Thus, similar to the boost converter, there is problem that a magnitude of the inductor is great.

[0054] FIG. **2** is a block diagram illustrating a configuration of an electronic device according to an embodiment.

[0055] The electronic device **100** may include a power circuit for receiving external power (e.g., commercial power) and providing power to each component of the electronic device **100**. The power circuit may include a buck boost converter based-power factor correction (PFC) circuit.

[0056] For example, with reference to FIG. **2**, the electronic device **100** includes a rectifier circuit **110**, a PFC circuit **120**, and a protecting circuit **130**.

[0057] The rectifier circuit **110** receives an external voltage. The external voltage may be an AC voltage applied from the external power. The rectifier circuit **110** may rectify the input AC voltage.

[0058] The PFC circuit **120** may improve a power factor. For this, the PFC circuit **120** may include the buck boost converter. The buck boost converter may operate as a step-up converter or operate as a step-down converter according to a duty ratio of the switching circuit element.

[0059] In the disclosure, the duty ratio of the switching circuit element may be set such that the buck boost converter operates as the step-down converter. The PFC circuit **120** may operate as the step down converter and generate an output voltage lower than an input voltage according to a switching operation of the switching circuit element.

[0060] Due to a circuit structure of the PFC circuit **120**, a polarity of the output voltage of the PFC circuit **120** may be opposite to a polarity of the input voltage thereof. According to the disclosure, in consideration of this, an input voltage having a negative polarity may be applied to the PFC circuit **120** by using the rectifier circuit **110**. For example, the rectifier circuit **110** may rectify an AC voltage and apply an input voltage having a negative polarity to the PFC circuit **120**.

[0061] The PFC circuit **120** may include a switching circuit element, an inductor, a first diode, and an output capacitor.

[0062] The switching circuit element may be, for example, a MOSFET. The inductor may store energy based on the input voltage applied from the rectifier circuit **110** while the switching circuit element is turned on. The output capacitor may be connected to the inductor through the first diode. Further, the output capacitor may provide an output voltage having a positive polarity by using energy stored in the inductor while the switching circuit element is turned off.

[0063] The protecting circuit **130** may be a circuit for protecting the PFC circuit **120**. The protecting circuit may be referred to as, for example, a short-circuit protecting circuit, a short-circuit fault protecting circuit, etc.

[0064] Protection provided by the PFC circuit **120** may, based on an element of the PFC circuit **120** being short-circuited, protect malfunction in another element of the PFC circuit **120**.

[0065] As aforementioned, the inductor and the output capacitor may be connected through the first diode. Therefore, based on the switching circuit element being turned on in a state where the first diode is short-circuited by a failure, the input voltage may be applied to the output capacitor. The input voltage has a negative polarity. Therefore, based on the input voltage being applied to the output capacitor, there may be a problem that a voltage having an opposite polarity is applied to the output capacitor, which may result in the output capacitor being damaged and exploding. According to the disclosure, the protecting circuit **130** may form a current path according to a voltage of both ends of the output capacitor based on the switching circuit element being turned on in a state where the first diode is short-circuited due to a failure. Accordingly, the protecting circuit **130** prevents a voltage having an opposite polarity from being applied to the output capacitor and thus the output capacitor may be protected.

[0066] Hereinafter, structures and operations of circuits are more specifically described.

[0067] FIG. **3** is a view illustrating a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment.

[0068] With reference to FIG. **3**, the rectifier circuit **110** may include diode bridge include diodes **111**, **112**, **113**, **114** connected in a bridge form. The diode bridge may be referred to as, for example, a bridge rectifier, etc.

[0069] An anode of a diode D_{B1} **111** may be connected to an anode of a diode D_{B3} **113** and a cathode of the diode D_{B1} **111** may be connected to an anode of a diode D_{B2} **112**.

[0070] The anode of the diode D_{B2} **112** may be connected to the cathode of the diode D_{B1} **111** and a cathode of the diode D_{B2} **112** may be connected to a cathode of the diode D_{B4} **114**.

[0071] The anode of the diode D_{B3} **113** may be connected to the anode of the diode D_{B1} **111** and a cathode of the diode D_{B3} **113** may be an anode of the diode D_{B4} **114**.

[0072] The anode of the diode D_{B4} **114** may be connected to the cathode of the diode D_{B3} **113** and the cathode of the diode D_{B4} **114** may be connected to the cathode of the diode D_{B2} **112**.

[0073] Also, the cathode of the diode D_{B1} **111** and the anode of the diode D_{B2} **112** may be connected to an AC voltage source **10** (e.g., one end (i.e., one terminal) of the AC voltage source **10**) and the cathode of the diode D_{B3} **113** and the anode of the diode D_{B4} **114** may be connected to the AC voltage source **10** (e.g.: the other end (i.e., the other terminal) of the AC voltage source **10**).

[0074] The PFC circuit **120** may include an input capacitor C_{in} **121**, a switching circuit element Q_1 **122**, an inductor L_B **123**, a first diode D_1 **124**, an output capacitor C_{bulk} **125**, and a resistor R_s **126**.

[0075] The input capacitor C_{in} **121** may receive an input voltage from the diodes **111**, **112**, **113**, **114** of the diode bridge. For example, one end of the input capacitor C_{in} **121** may be connected to the cathode of the diode D_{B2} **112** and the cathode of the diode D_{B4} **114** and the other end of the input capacitor C_{in} **121** may be connected to the anode of the diode D_{B1} **111** and the anode of the diode D_{B3} **113**.

[0076] Also, one end of the input capacitor C_{in} **121** may be connected to a first end of a switching circuit element Q_1 **122**. A first end of the switching circuit element Q_1 **122** may be a drain terminal. The other end of the input capacitor C_{in} **121** may be connected to one end of the inductor L_B **123** and the anode of the first diode D_1 **124**. The other end of the inductor L_B **123** may be connected to one end of the resistor R_S **126**. The resistor R_S **126** may be a resistor for sensing current flowing through the inductor L_B **123**.

[0077] Also, one end of the output capacitor C_{bulk} **125** may be connected to a cathode of the first diode D_1 **124** and the other end of the output capacitor C_{bulk} **125** may be connected to the other end of the resistor R_S **126**, a second end of the switching circuit element Q_1 **122**, and a ground voltage **20**. The second end of the switching circuit element Q_1 **122** may be a source terminal of the switching element Q_1 **122**.

[0078] The protecting circuit **130** may include a second diode D_f **131**. The second diode D_f **131** may be connected to the output capacitor C_{bulk} **125** in parallel. For example, the cathode of the second diode D_f **131** may be connected to one end of the output capacitor C_{bulk} **125** and the anode of the second diode D_f **131** may be connected to the other end of the output capacitor C_{bulk} **125**.

[0079] FIGS. **4**A and **4**B are views illustrating operations of a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment.

[0080] The rectifier circuit **110** may rectify an AC voltage provided from the AC voltage source **10** by using the diodes **111**, **112**, **113**, **114** of the diode bridge, and may apply an input voltage to the PFC circuit **120**. For example, with reference to FIG. **4**A, based on the switching circuit element Q_1 **122** being turned on, a negative input voltage—V_{in} may be applied to the input capacitor C_{in} **121** by the diodes **111**, **112**, **113**, **114** of the diode bridge. A magnitude of a resistor value of the resistor R_s **126** is small and thus V_{in} may be applied to the inductor L_B **123**. Accordingly, a current i_{LB} of the inductor L_B **123** may increase and energy may be stored in the inductor L_B **123**. The operation as the above may be referred to as a build-up operation.

[0081] With reference to FIG. **4**B, based on the switching circuit element Q_1 **122** being turned off, a magnitude of a resistor value of the resistor R_s **126** is small and thus a negative output voltage (e.g., $-V_o$) may be applied to the inductor L_B **123**. Accordingly, the current i_{LB} of the inductor L_B **123** may decrease, the output capacitor C_{bulk} **125** may be charged by energy stored in the inductor L_B **123** and power may be supplied to an output side. An operation as the above may be referred to as a powering operation.

[0082] As the above, the PFC circuit **120** may provide power to an output side according to turn-on/turn-off of the switching circuit element.

[0083] According to the disclosure, the PFC circuit **120** may be realized as a critical conduction mode (CrM) PFC circuit. That is, the PFC circuit **120** may be controlled in a CrM method. The CrM method may include a method of sensing current flowing through the inductor L_B, turning the switching circuit element on whenever current flowing through the inductor L_B arrive at zero, and driving the PFC circuit **120**.

[0084] For example, the electronic device **100** may include a PFC controller and a gate driver. The PFC controller may include an integrated circuit (IC) chip. The controller may control a gate driver and apply a gate signal for turning the switching circuit element Q_1 **122**, to a gate terminal of the switching circuit element Q_1 **122** which is in a state of turn-on.

[0085] Based on the switching circuit element Q_1 **122** being turned off, current flowing through the inductor L_B **123** may decrease. The PFC controller may sense current flowing through the inductor L_B **123** and may apply a gate signal for turning the switching circuit element Q_1 **122** on, to the gate terminal of the switching circuit element Q_1 **122** based on current flowing through the inductor L_B **123** arriving at zero. Further, the PFC controller may apply a gate signal for turning the switching circuit element Q_1 **122** off, to a gate terminal of the switching circuit element Q_1 **122** based on threshold time passing from a time point that the switching circuit element Q_1 **122** is turned on

[0086] The PFC controller may repetitively perform these operations and drive the PFC circuit in the CrM method.

[0087] The PFC circuit **120** shown in FIG. **3** may be driven in the CrM method based on of the inductor L_B **123** sensed by using the resistor R_s **126**. That is, the PFC controller may sense current flowing through the inductor L_B **123** by using the resistor R_s **126** connected to the inductor L_B **123** in series and detect a time point where current flowing through the inductor L_B **123** is zero. Further, the

PFC controller may turn the switching circuit element Q_1 **122** on based on current flowing through the inductor L_B **123** being zero. That is, the PFC controller may perform ZCD by using the resistor R_s **126**. The ZCD may refer to detecting a time point where current flowing through the inductor of the converter is zero. Current passing through the node ZCD, which is connected between the inductor L_B **123** and the resistor R_s **126**, may be monitored for ZCD.

[0088] FIGS. **5**A, **5**B, and **5**C are views illustrating operations for protecting the PFC circuit according to an embodiment.

[0089] As aforementioned, the PFC circuit **120** may operate as a step-down converter. In this case, there may be a problem that the output capacitor C_{bulk} **125** explodes based on an active element (e.g., the switching circuit element Q_1 **122**, the first diode D_1 **124**) of the PFC circuit **120** being short-circuited by a failure. According to the disclosure, based on the active element (specifically, the first diode D_1 **124**) being short-circuited, the output capacitor C_{bulk} **125** may be protected by using the protecting circuit **130**.

[0090] With reference to FIGS. **5**A and **5**B, the electronic device **100** may include a fuse **30**. One end of the fuse **30** may be connected to the other end of the AC voltage source **10** (e.g., the other end of the AC voltage source **10**) and the other end of the fuse **30** may be connected to the cathode of the diode D_{B3} **113** and the anode of the diode D_{B4} **114**. The embodiments are not limited thereto and the fuse **30** may be connected to various positions. For example, one end of the fuse **30** may be connected to the AC voltage source **10** (e.g., one end of the AC voltage source **10**) and the other end of the fuse **30** may be connected to the cathode of the diode D_{B1} **111** and the anode of the diode D_{B2} **112**. As the above, the fuse **30** may be disposed in various positions on a current path where current output from the AC voltage source **10** flow or a current path where current input to the AC voltage source **10** flow.

[0091] FIG. **5**A is a view illustrating a case that the switching circuit element Q_1 **122** is short-circuited due to a failure.

[0092] Based on the switching circuit element Q_1 **122** being short-circuited due to a failure, the fuse **30** opens due to current of the switching circuit element Q_1 **122**, and the operation of the PFC circuit **120** may be terminated.

[0093] With reference to FIG. **5**A, based on the switching circuit element Q_1 **122** being short-circuited due to a failure, current of the output capacitor C_{bulk} **125** are blocked by the first diode D_1 **124**. Therefore, current flowing through the inductor L_B **123** (1 of FIG. **5**A) may increase due to a voltage of an input side and the fuse **30** may be disconnected as current increase. Accordingly, the operation of the PFC circuit **120** may be stably terminated and elements of the PFC circuit **120** may be protected.

[0094] FIGS. **5**B and **5**C are views illustrating cases that the first diode D_1 **124** is short-circuited due to a failure.

[0095] With reference to FIG. **5**B, based on the switching circuit element Q_1 **122** being turned on in a state where the first diode D_1 **124** is short-circuited due to a failure, a voltage charged in the output capacitor C_{bulk} **125** may be discharged by the input voltage. That is, current may flow to the first diode D_1 **124** and the output capacitor C_{bulk} **125**, by the input voltage (1 of FIG. **5**B) and electric charges charged in the output capacitor C_{bulk} **125** may be discharged by current.

[0096] Accordingly, a voltage (V_o) of both ends of the output capacitor C_{bulk} **125** may be lowered.

[0097] With reference to FIG. **5**C, based on a voltage of both ends of the output capacitor C_{bulk} **125** becoming zero (or a threshold voltage of the first diode D_1 **124**), a current path may be formed by the second diode D_f **131** and current may flow through the current path (2 of FIG. **5**C). Current flowing through the current path may increase and thus the fuse **30** may be disconnected as current increase. Accordingly, the operation of PFC circuit **120** may be stably terminated and elements of the PFC circuit **120** may be protected.

[0098] As the above, according to the disclosure, based on the active element (specifically, the first diode D_1 **124**) being short-circuited due to a failure, it is prevented that a negative voltage is applied to the output capacitor C_{bulk} **125** thanks to the second diode D_f **131** and thus explosion of the output capacitor C_{bulk} **125** may prevented.

[0099] FIG. **6** is a view illustrating a rectifier circuit, a PFC circuit, and a protecting circuit according to an embodiment.

[0100] With reference to FIG. **6**, the rectifier circuit **110** may include a diode bridge including diodes **111**, **112**, **113**, **114** connected in a bridge form.

[0101] The anode of the diode D_{B1} **111** may be connected to the anode of the diode D_{B3} **113** and the cathode of the diode D_{B1} **111** may be connected to the anode of the diode D_{B2} **112**.

[0102] The anode of the diode D_{B2} **112** may be connected to the cathode of the diode D_{B1} **111** and the cathode of the diode D_{B2} **112** may be connected to the cathode of the diode D_{B4} **114**.

[0103] The anode of the diode D_{B3} **113** may be connected to the anode of the diode D_{B1} **111** and the cathode of the diode D_{B3} **113** may be connected to the anode of the diode D_{B4} **114**.

[0104] The anode of the diode D_{B4} **114** may be connected to the cathode of the diode D_{B3} **113** and the cathode of the diode D_{B4} **114** may be connected to the cathode of the diode D_{B2} **112**.

[0105] Also, the cathode of the diode D_{B1} **111** and the anode of the diode D_{B2} **112** may be connected to the AC voltage source **10** (e.g., one end of the AC voltage source **10**) and the cathode of the diode D_{B3} **113** and the anode of the diode D_{B4} **114** may be connected to the AC voltage source **10** (e.g., the other end of the AC voltage source **10**).

[0106] The PFC circuit **120** may include the input capacitor C_{in} **121**, the switching circuit element Q_1 **122**, the inductor L_B **123**, the first diode D_1 **124**, the output capacitor C_{bulk} **125**, a first resistor R_{s1} **127**, and a second resistor R_{s2} **128**.

[0107] The input capacitor C_{in} **121** may receive an input voltage from the diodes **111**, **112**, **113**, **114** of the diode bridge. For example, one end of the input capacitor C_{in} **121** may be connected to the cathode of the diode D_{B2} **112** and the cathode of the diode D_{B4} **114** and the other end of the input capacitor C_{in} **121** may be connected to the anode of the diode D_{B1} **111** and the anode of the diode D_{B3} **113**.

[0108] Also, one end of the input capacitor C_{in} **121** may be connected to a first end of the switching circuit element Q_1 **122**. The first end of the switching circuit element Q_1 **122** may be a drain terminal. The other end of the input capacitor C_{in} **121** may be connected to one end of the inductor L_B **123**, the anode of the first diode D_1 **124**, and one end of the first resistor R_{s1} **127**.

[0109] The first resistor R_{s1} **127** and the second resistor R_{s2} **128** may be connected in series. For example, the other end of the first resistor R_{s1} **127** may be connected to one end of the second resistor R_{s2} **128**.

[0110] Also, one end of the output capacitor C_{bulk} **125** may be connected to the cathode of the first diode D_1 **124** and the other end of the output capacitor C_{bulk} **125** may be connected to the other end of the inductor L_B **123**, the other end of the second resistor R_{s2} **128**, a second end of the switching circuit element Q_1 **122**, and a ground voltage **20**. The second end of the switching circuit element Q_1 **122** may be a source terminal of the switching circuit element Q_1 **122**.

[0111] The protecting circuit **130** may include the second diode D_f **131**. The second diode D_f **131** may be connected to the output capacitor C_{bulk} **125** in parallel. For example, the cathode of the second diode D_f **131** may be connected to one end of the output capacitor C_{bulk} **125** and the anode of the second diode D_f **131** may be connected to the other end of the output capacitor C_{bulk} **125**.

[0112] With reference to FIGS. **3** and **6**, connection structures of other elements except connection structures of resistors are substantially similar. Therefore, the contents described in FIGS. **4**A, **4**B, **5**A, **5**B, and **5**C may be applied to a circuit shown in FIG. **6**.

[0113] With reference to FIG. **3**, the resistor R_s **126** may be used for ZCD. The resistor R_s **126** may be connected to the inductor L_B **123** in series with the node ZCD connected therebetween. With reference to FIG. **6**, the first resistor R_{s1} **127** and the second resistor R_{s2} **128** connected in series may be used for ZCD. In this regard, the node ZCD may be connected in series between the first resistor R_{s1} **127** and the second resistor R_{s2} **128**. The first resistor R_{s1} **127** and the second resistor R_{s2} **128** connected in series may be connected to the inductor L_B **123** in parallel.

[0114] The PFC circuit **120** shown in FIG. **6** may be driven in the CrM method based on current of the inductor L_B **123** sensed by using the first resistor R_{s1} **127** and the second resistor R_{s2} **128**. That is, the PFC controller may sense a voltage of both ends of the inductor L_B **123** by using the first resistor R_{s1} **127** and the second resistor R_{s2} **128** connected to the inductor L_B **123** in parallel to sense current flowing through the inductor L_B **123**, and detect a time point where current flowing through the inductor L_B **123** is zero. Further, the PFC controller may turn the switching circuit element Q_1 **122** on based on current flowing through the inductor L_B **123** becoming zero. That is, the PFC controller may perform ZCD by using the first resistor R_{s1} **127** and the second resistor R_{s2} **128**.

[0115] As the above, the ZCD operation may be performed by sensing current or voltages of the inductor by using resistors without an additional winding of the inductor for the ZCD operation. Accordingly, an ultra-slim power supply may be provided by using the PFC circuit **120**.

[0116] FIGS. **4**A, **5**A, **5**B, and **5**C illustrate that a voltage of one polarity of the AC voltage source (e.g., a voltage having a (+) polarity) is input to the rectifier circuit **110** but embodiments are not limited thereto. That is, even though a voltage having another polarity of the AC voltage source (e.g., a voltage having a (−) polarity) is input to the rectifier circuit **110**, the aforementioned contents may be similarly applied.

[0117] FIGS. **7** and **8** are views of an example of power circuits according to embodiments.

[0118] The electronic device **100** may include a power circuit **700** shown in FIG. **7** or a power circuit **800** shown in FIG. **8**.

[0119] The power circuit **700** shown in FIG. **7** may include the rectifier circuit **110**, the PFC circuit **120**, and the protecting circuit **130** described in FIG. **3**. The contents described to structures and operations of theses circuits may be applied to the power circuit **700** shown in FIG. **7**.

[0120] The power circuit **800** shown in FIG. **8** may include the rectifier circuit **110**, the PFC circuit **120**, and the protecting circuit **130** described in FIG. **6**. The contents described to structures and operations of theses circuits may be applied to the power circuit **800** shown in FIG. **8**.

[0121] With respect to FIGS. **7** and **8**, an electromagnetic interference (EMI) filter **140** may receive an AC voltage from the AC voltage source **10**. Further, the EMI filter **140** may remove a noise from the AC voltage. The EMI filter **140** may include various elements such as a capacitor, an inductor, and a reactor. For example, the EMI filter **140** may discharge power to a spike through a resistor, discharge a noise through a capacitor, or remove a noise through an inductor. Embodiments are not limited thereto and the EMI filter **140** may remove a noise by using various methods.

[0122] Further, the EMI filter **140** may apply the AC voltage where a noise is removed (i.e., a filtered AC voltage) to the rectifier circuit **110**. The rectifier circuit **110** may receive the AC voltage in which a noise is removed by the EMI filter **140** and apply a negative input voltage (e.g., $-V_{in}$) to the PFC circuit **120** by rectifying the AC voltage.

[0123] A DC/DC converter **150** may output a direct current (DC) voltage having a voltage range in which an operation of various configurations of the electronic device **100** are possible. For example, the output voltage (e.g., V_o) of the PFC circuit **120** may be applied to the DC/DC converter **150**. The DC/DC converter **150** may convert an input voltage to a voltage suitable for configurations of the electronic device **100** and may output the voltages. An output voltage of the DC/DC converter **150** may be applied to an output capacitor **160**.

[0124] FIG. **9** is a block diagram illustrating a configuration of the electronic device according to an embodiment.

[0125] With reference to FIG. **9**, the electronic device **100** may include the rectifier circuit **110**, the PFC circuit **120**, the protecting circuit **130**, a gate driver (i.e., a gate driver circuit) **170**, and a PFC controller (i.e., a PFC control circuit) **180**. Among configurations shown in FIG. **9**, the aforementioned contents may be applied to the rectifier circuit **110**, the PFC circuit **120**, and the protecting circuit **130**. Therefore, the repetitive description thereof is omitted for conciseness.

[0126] The gate driver **170** may generate a gate signal for controlling a switching operation of the switching circuit element Q_1 **122** of the PFC circuit **120** and apply the gate signal to a gate terminal of the switching circuit element Q_1 **122**.

[0127] The PFC controller **180** may control a gate driver **170** to drive the PFC circuit **120** in a CrM method.

[0128] For example, the PFC controller **180** may apply a gate signal for turning the switching circuit element Q_1 **122** on to a gate terminal of the switching circuit element Q_1 **122** by controlling the gate driver **170**. The switching circuit element Q_1 **122** may be turned on based on the gate signal being applied from the gate driver **170**.

[0129] Further, the PFC controller **180**, based on a threshold time passing from a time point that the switching circuit element Q_1 **122** is turned on, may apply a gate signal for turning the switching circuit element Q_1 **122** off, to a gate terminal of the switching circuit element Q_1 **122** by controlling the gate driver **170**. The switching circuit element Q_1 **122** may be turned off based on the gate signal being applied from the gate driver **170**.

[0130] Based on the switching circuit element Q_1 **122** being turned off, current flowing through the inductor L_B **123** may be reduced. The PFC controller **180** may sense current flowing through the inductor L_B **123** by using the resistor **126** connected to the inductor L_B **123** in series or sense current flowing through the inductor L_B **123** by using the resistors **126**, **127** connected to the inductor L_B **123** in parallel, thereby sensing whether current flowing through the inductor L_B **123** arrive at zero.

[0131] Further, the PFC controller **180** may apply a gate signal for turning the switching circuit element Q_1 **122** on, to a gate terminal of the switching circuit element Q_1 **122** by controlling the gate driver **170** based on current flowing through the inductor L_B **123** being zero.

[0132] Thereafter, the PFC controller **180**, based on a threshold time passing from a time point that the switching circuit element Q_1 **122** is turned on, may apply a gate signal for turning the switching circuit element Q_1 **122** off, to a gate terminal of the switching circuit element Q_1 **122** by controlling the gate driver **170**. Further, the PFC controller **180** may sense current flowing through the inductor L_B **123** and based on current flowing through the inductor L_B **123** being zero, may apply a gate signal for turning the switching circuit element Q_1 **122** on, to a gate terminal of the switching circuit element **122**.

[0133] The PFC controller **180** may drive the PFC circuit in the CrM method by repetitively performing these operations.

[0134] FIG. **10** is a view illustrating a method of providing power to the PFC controller according to an embodiment.

[0135] With reference to FIG. **10**, according to the disclosure, a power voltage Vcc for the PFC controller **180** may be generated through a regulator **1010** by connecting the regulator **1010** to the AC voltage source **10** through a rectifying circuit **1020**.

[0136] FIG. **10** illustrates a buck regulator but embodiments are not limited thereto. The regulator may be realized as, for example, a linear regulator, etc.

[0137] Also, FIG. **10** illustrates a circuit shown in FIG. **3** as an example but embodiments are not limited thereto. As shown in FIG. **10**, a circuit of generating power for the PFC controller **180** may be configured by connecting a rectifier circuit, a capacitor, a regulator, a diode, an inductor, etc., to the circuit shown in FIG. **6**.

[0138] According to an embodiment, the first diode D_1 **124** may be substituted with a synchronous rectifier (SR). In this case, the electronic device **100** may further include a gate driver for controlling a switching operation of the synchronous rectifier. An example in which the first diode D_1 **124** is substituted with the synchronous rectifier is more specifically described in FIG. **11**.

[0139] FIG. **11** is a block diagram illustrating a configuration of an electronic device according to an embodiment.

[0140] With reference to FIG. **11**, an electronic device **100** may include a rectifier circuit **110**, a PFC circuit **120**, a protecting circuit **130**, a first gate driver (i.e., first gate driver circuit) **170**, a PFC controller (i.e., a PFC control circuit) **180**, and a second gate driver (i.e., second gate driver circuit) **190**.

[0141] In FIG. **11**, the first diode D_1 **124** of the PFC circuit **120** shown in FIG. **10** may be substituted with a synchronous rectifier. The synchronous rectifier may be realized with a switching circuit element such as, for example, MOSFET.

[0142] For example, in the PFC circuit **120** shown in FIG. **3**, a source terminal of the synchronous rectifier may be connected to the other end of the input capacitor C_{in} **121** and one end of the inductor L_B **123**. A drain terminal of the synchronous rectifier may be connected to one end of the output capacitor C_{bulk} **125** and a cathode of the second diode D_f **131**.

[0143] For example, in the PFC circuit **120** shown in FIG. **6**, a source terminal of the synchronous rectifier may be connected to the other end of the input capacitor C_{in} **121**, one end of the inductor L_B **123** and one end of the first resistor (R_{s1}) **127**. A drain terminal of the synchronous rectifier may be connected to one end of the output capacitor C_{bulk} **125** and a cathode of the second diode D_f **131**.

[0144] In FIG. **11**, a gate driver **170** for controlling a switching circuit element Q_1 **122** is described as the first gate driver **170** and a gate driver for controlling the synchronous rectifier is described as a second gate driver **190**. The aforementioned contents may be applied to the rectifier circuit **110**, the PFC circuit **120**, the protecting circuit **130**, the PFC controller **180**, and the first gate driver **170** among configurations shown in FIG. **11**. Therefore, the repetitive description thereof is omitted for conciseness.

[0145] The second gate driver **190** may generate a gate signal for controlling a switching operation of the synchronous rectifier and apply a gate signal to a gate terminal of the synchronous rectifier.

[0146] The PFC controller **180** may control the second gate driver **190**. For example, the PFC controller **180** may apply a gate signal for turning the synchronous rectifier off to a gate terminal of the synchronous rectifier at a time point in which the switching circuit element Q_1 **122** is turned on by controlling the second gate driver **190**. Also, the PFC controller **180** may apply a gate signal for turning the synchronous rectifier on to the gate terminal of the synchronous rectifier at a time point in which the switching circuit element Q_1 **122** is turned off by controlling the second gate driver **190**.

[0147] Therefore, the synchronous rectifier is turned off while the switching circuit element Q_1 **122** is turned on, and the synchronous rectifier is turned on while the switching circuit element Q_1 **122** is turned off. Accordingly, the synchronous rectifier may perform the same function as that of the diode **124**.

[0148] FIG. **12** is a view illustrating a method of providing power to the second gate driver according to an embodiment.

[0149] With reference to FIG. **12**, if the diode **124** is substituted with the synchronous rectifier, a source terminal of a synchronous rectifier Q2 **1210** is separated from a ground and floats. In this regard, the second gate driver **190** may be realized as an isolated gate driver. In this regard, as shown in FIG. **12**, a circuit for providing power to the second gate driver **190** may be provided.

[0150] With reference to FIG. **12**, because the other end (e.g., a (−) polarity of an input voltage V_{in}) of the input capacitor **121** and a source terminal of the synchronous rectifier Q_2 **1210** are the same nodes, a power voltage Vcc generated by the regulator **1220** which receives the input voltage may be used as power for driving the second gate driver **190**.

[0151] FIG. **12** illustrates a buck regulator but embodiments are not limited thereto. The regulator may be realized as, for example, a linear regulator, etc.

[0152] Also, in FIG. **12**, the circuit shown in FIG. **3** is illustrated as an example but embodiments are not limited thereto. A circuit of generating power for the second gate driver **190** may be configured by connecting a regulator, a diode, an inductor, a capacitor, etc., to the circuit shown in FIG. **6**, as shown in FIG. **12**.

[0153] According to an embodiment, a connection structure of the switching circuit element Q_1 **122** and the first diode D_1 **124** may be variously changed in the PFC circuit **120**.

[0154] For example, the connection structure of the switching circuit element Q_1 **122** and the first diode D_1 **124** in the PFC circuit **120** shown in FIG. **3** may be changed to that as shown in FIGS. **13**A and **13**B.

[0155] Also, the connection structure of the switching circuit element Q_1 **122** and the first diode D_1 **124** in the PFC circuit **120** shown in FIG. **6** may be changed to that as shown in FIGS. **14**A and **14**B.

[0156] Referring to FIGS. **13***a*, **13***b*, **14***a*, and **14***b*, the switching element Q_1 **122** and the first diode L_B **124** may be arranged on the same line, and accordingly, the EMI characteristics can be improved.

[0157] Circuits shown in FIGS. **13**A, **13**B, **14**A, and **14**B operate substantially similar to circuits shown in FIGS. **3** and **6**. In this regard, the aforementioned contents may be applied to the circuits shown in FIGS. **13**A, **13**B, **14**A, and **14**B. Also, in the circuits shown in FIGS. **13**A, **13**B, **14**A, and **14**B, the first diode D_1 **124** may be substituted with the synchronous rectifier. Also, a power circuit may be configured by connecting the EMI filter **140**, the DC/DC converter **150**, and the output capacitor **160** to the circuits shown in FIGS. **13**A, **13**B, **14**A, and **14**B.

[0158] FIG. **15** is a flow chart illustrating a method of controlling a PFC circuit of an electronic device according to an embodiment.

[0159] The electronic device includes a PFC circuit, a rectifier circuit configured to rectify an AC voltage and applying an input voltage having a negative polarity to a PFC circuit, and a protecting circuit for protecting the PFC circuit.

[0160] In operation S**1510**, a switching circuit element is changed from an on state to an off state by applying a gate signal to a gate terminal of a switching circuit element of the PFC circuit.

[0161] In operation S**1520**, current flowing through the inductor of the PFC circuit are sensed while the switching circuit element is turned off.

[0162] In operation S**1530**, the turned-off switching circuit element is turned on by applying a gate signal to a gate terminal of the switching circuit element of the PFC circuit based on the sensed current.

[0163] The PFC circuit includes an inductor in which energy is stored based on the input voltage applied from the rectifier circuit while the switching circuit element is turned on, and an output capacitor which is connected to the inductor through the first diode and provides an output voltage having a positive polarity by using the stored energy while the switching circuit element is turned off. Further, based on the first diode being short-circuited, the PFC circuit is protected by the current path formed by the protecting circuit while the switching circuit element is turned on.

[0164] Also, the protecting circuit may include a second diode connected to the output capacitor in parallel.

[0165] Also, the rectifier circuit may include a diode bridge. The PFC circuit further include an input capacitor which receives the input voltage from the diode bridge.

[0166] For example, the first end of the switching circuit element may be connected to one end of the input capacitor. One end of the inductor may be connected to the other end of the input capacitor and an anode of the first diode. The other end of the inductor may be connected to one end of a resistor. Also, one end of the output capacitor may be connected to a cathode of the first diode and a cathode of the second diode and the other end of the output capacitor may be connected to the other end of the resistor, the second end of the switching circuit element, a ground voltage, and an anode of the second diode.

[0167] In this case, the resistor may be a resistor for sensing current flowing through the inductor. In the operation S**1520**, current of the inductor may be sensed by using the resistor.

[0168] For example, the first end of the switching circuit element may be connected to one end of the input capacitor. One end of the inductor may be connected to the other end of the input capacitor, the anode of the first diode, and one end of the first resistor. The other end of the first resistor may be connected to one end of the second resistor. Also, one end of the output capacitor may be connected to the cathode of the first diode and the cathode of the second diode. The other end of the output capacitor may be connected to the other end of the inductor, the other end of the second resistor, the second end of the switching circuit element, a ground voltage, and the anode of the second diode.

[0169] In this case, the first and second resistors may be used for sensing current flowing through the inductor. In the operation S**1520**, current of the inductor may be sensed by using the first and second resistors.

[0170] Also, based on the switching circuit element being turned on in a state where the first diode is short-circuited due to a failure, a voltage charged by the input voltage in the output capacitor is discharged. Based on a voltage of both ends of the output capacitor becoming zero according to the discharge, a current path may be formed by the second diode.

[0171] Also, the rectifier circuit may further include a fuse. In this case, an operation of the PFC circuit may be terminated by disconnection of the fuse due to current flowing through the current path.

[0172] Various examples of the disclosure may be realized within a recording medium which may be read by a computer or a device similar with the same by using hardware, or combinations thereof. In some cases, embodiments described in the disclosure may be realized by a processor itself.

[0173] According to various embodiments of the disclosure as the above, computer instructions to perform a processing operation of the electronic device may be stored in a non-transitory computer-readable medium.

[0174] The non-transitory computer-readable medium does not refer to a medium which may store data for a short period such as a register, a cache, and memory but refers to a medium which may semipermanently store data and be read by the machine. Specific examples of the non-transitory computer-readable medium may be a compact disc (CD), a digital video/versatile disc (DVD, a hard disk, a blue-ray disk, a Universal Serial Bus (USB) storage device, a memory card, a read-only memory (ROM), etc.

[0175] While aspects of embodiments have been particularly shown and described, it will be understood that various changes in form and details may be made therein without departing from the spirit and scope of the following claims.

What is claimed is:

1. An electronic device, comprising:

a power factor correction (PFC) circuit;

a rectifier circuit configured to rectify an alternating current voltage to obtain an input voltage having a negative polarity and provide the input voltage to the PFC circuit; and

a protecting circuit configured to protect the PFC circuit, wherein the PFC circuit comprises:

a first diode;

an inductor configured to store energy based on the input voltage provided by the rectifier circuit while a switching circuit is turned on and provide energy while the switching circuit is turned off; and

an output capacitor connected to the inductor through the first diode, and configured to provide an output voltage having a positive polarity by using the energy provided by the inductor while the switching circuit is turned off, and

wherein based on the first diode being short-circuited, the PFC circuit is protected by a current path formed by the protecting circuit while the switching circuit is turned on.

2. The electronic device of claim **1**, wherein the protecting circuit comprises a second diode which is connected to the output capacitor in parallel.

3. The electronic device of claim **2**, wherein the rectifier circuit comprises a diode bridge, and

wherein the PFC circuit further comprises an input capacitor configured to receive the input voltage from the diode bridge.

4. The electronic device of claim **3**, wherein a first end of the switching circuit is connected to one end of the input capacitor,

wherein one end of the inductor is connected to another end of the input capacitor and an anode of the first diode,

wherein another end of the inductor is connected to one end of a resistor,

wherein one end of the output capacitor is connected to a cathode of the first diode and a cathode of the second diode,

wherein another end of the output capacitor is connected to the other end of the resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and

wherein the resistor is used to sense current flowing through the inductor.

5. The electronic device of claim **4**, wherein the PFC circuit is driven in a critical conduction mode (CrM) based on the current flowing through the inductor, and

wherein the current is sensed using the resistor.

6. The electronic device of claim **3**, wherein a first end of the switching circuit is connected to one end of the input capacitor,

wherein one end of the inductor is connected to another end of the input capacitor, an anode of the first diode, and one end of a first resistor,

wherein another end of the first resistor is connected to one end of a second resistor,

wherein one end of the output capacitor is connected to a cathode of the first diode and a cathode of the second diode,

wherein another end of the output capacitor is connected to another end of the inductor, another end of the second resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and

wherein the first resistor and the second resistor are used to sense current flowing through the inductor.

7. The electronic device of claim **6**, wherein the PFC circuit is driven in a CrM based on the current of the inductor sensed using the first resistor and the second resistor.

8. The electronic device of claim **2**, wherein based on the switching circuit being turned on in a state where the first diode is short-circuited due to a failure, a voltage charged in the output capacitor by the input voltage is discharged, and

wherein based on the voltage of both ends of the output capacitor becoming zero according to the discharge, the current path flows through the second diode.

9. The electronic device of claim **8**, further comprising a fuse,

wherein the fuse is disconnected by current flowing through the current path to terminate an operation of the PFC circuit.

10. The electronic device of claim **2**, further comprising a fuse,

wherein based on the switching circuit being short-circuited due to a failure, the fuse is disconnected by current flowing through the switching circuit to terminate and an operation of the PFC circuit.

11. The electronic device of claim **1**, further comprising:

an electromagnetic interference (EMI) filter configured to filter a source alternating current voltage and provide the alternating current voltage to the rectifier circuit, and

a DC/DC converter to which the output voltage is applied.

12. A method for controlling a power factor correction (PFC) circuit of an electronic device, including a PFC circuit, a rectifier circuit configured to apply an input voltage having a negative polarity to the PFC circuit by rectifying an alternating current voltage, and a protecting circuit configured to protect the PFC circuit, the method comprising:

controlling a switching circuit from an on state to an off state by applying a gate signal to a gate terminal of the switching circuit of the PFC circuit;

sensing current flowing through an inductor of the PFC circuit while the switching circuit is in the off state;

controlling the switching circuit from the off state to the on state by applying the gate signal to the gate terminal of the switching circuit of the PFC circuit based on the sensed current;

storing energy in the inductor based on the input voltage applied from the rectifier circuit while the switching circuit is in the on state; and

providing, while the switching circuit is in the off state, an output voltage having a positive polarity using an output capacitor of the PFC circuit that is connected to the inductor through a first diode, wherein based on the first diode being short-circuited, the PFC circuit is protected by a current path formed by the protecting circuit while the switching circuit is turned on.

13. The method of claim **12**, wherein the protecting circuit includes a second diode which is connected to the output capacitor in parallel.

14. The method of claim **13**, wherein the rectifier circuit comprises a diode bridge, and

wherein the method further comprises receiving the input voltage from the rectifier circuit at an input capacitor of the PFC circuit.

15. The method of claim **14**, wherein one end of the switching circuit is connected to one end of the input capacitor,

wherein one end of the inductor is connected to another end of the input capacitor and an anode of the first diode,

wherein another end of the inductor is connected to one end of a resistor, wherein one end of the output capacitor is connected to a cathode of the first diode and a cathode of the second diode,

wherein another end of the output capacitor is connected to another end of the resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and

wherein the method further comprises sensing current flowing through the inductor using the resistor.

16. The method of claim **15**, wherein the PFC circuit is driven in a critical conduction mode (CrM) based on the current flowing through the inductor, and

wherein the current is sensed using the resistor.

17. The method of claim **14**, wherein a first end of the switching circuit is connected to one end of the input capacitor;

wherein one end of the inductor is connected to another end of the input capacitor, an anode of the first diode, and one end of a first resistor,

wherein another end of the first resistor is connected to one end of a second resistor, wherein one end of the output capacitor is connected to a cathode of the first diode and a cathode of the second diode,

wherein another end of the output capacitor is connected to another end of the inductor, another end of the second resistor, a second end of the switching circuit, a ground voltage, and an anode of the second diode, and

wherein the first resistor and the second resistor are used to sense current flowing through the inductor.

18. An electronic device, comprising:

a power factor correction (PFC) circuit;

a protecting circuit comprising:

a first diode;

an inductor configured to store energy based on an input voltage while a switching circuit is turned on and provide energy while the switching circuit is turned off; and

an output capacitor connected to the inductor through the first diode, and configured to provide an output voltage having a positive polarity by using the energy provided by the inductor while the switching circuit is turned off; and

a PFC controller configured to control the switching circuit to turn on and off based on current flowing through the inductor.

19. The electronic device of claim **18**, wherein the PPC controller is further configured to control the switching circuit to turn on based on the current flowing through the inductor being zero.

20. The electronic device of claim **19**, wherein the PPC controller is further configured to control the switching circuit to turn off based on a threshold time passing after controlling the switching circuit to turn on.

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