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(54) **Title:** BOOST CONVERTER SHORT CIRCUIT PROTECTION

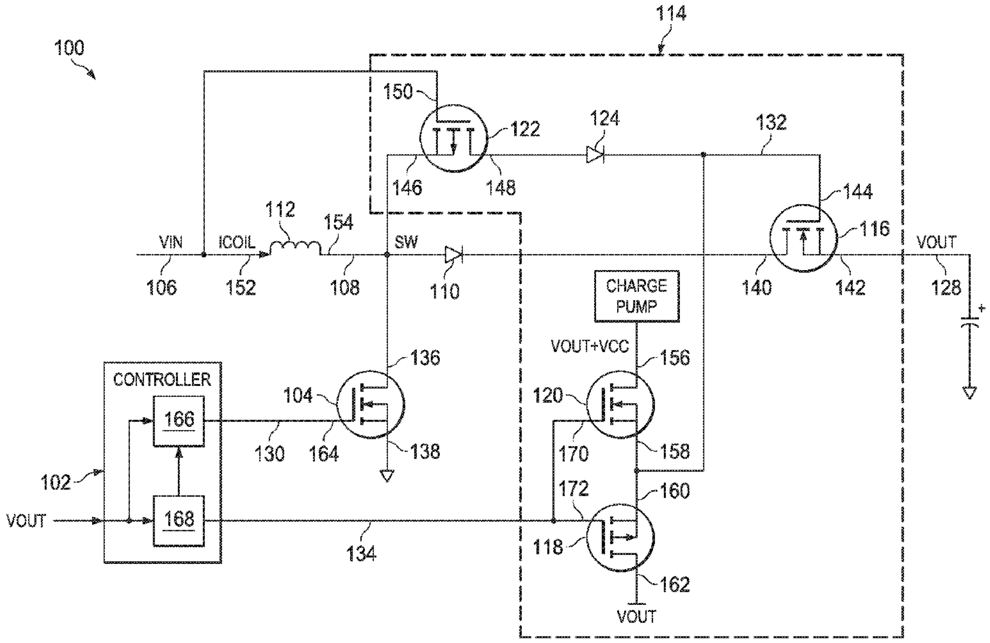

FIG. 1

(57) **Abstract:** A boost converter (100) includes a voltage output terminal (128), a power transistor (104), and short circuit protection circuitry (114). The voltage output terminal (128) is configured to provide a boosted output voltage generated by the boost converter (100). The power transistor (104) is configured to draw current through an inductor (112). The short circuit protection circuitry (114) is configured to control current flow through the inductor (112) responsive to detection of a short circuit at the voltage output terminal (128). The short circuit protection circuitry (112) includes an output switch (116) coupled to an input terminal (136) of the power transistor (104) and connected to the voltage output terminal (128). The output switch (116) is configured to switch current flow from the inductor (112) to the voltage output terminal (128). The output switch (112) is a negative (N) channel metal oxide semiconductor field effect transistor (MOSFET).

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[Continued on next page]

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Boost Converter Short Circuit Protection

BACKGROUND

[0001] Boost converters are switch-mode power supplies that generate an output voltage that is higher than the input voltage. Boost converters are widely used in applications that operate with a low input voltage, such as battery powered applications. The boost converter produces the stepped up output voltage by switching to ground the output of an inductor coupled to the voltage input at a duty cycle selected to produce the boosted output voltage.

SUMMARY

[0002] Circuitry and a method for using a negative (N) channel metal oxide semiconductor field effect transistor (MOSFET) for short circuit protection in a boost converter. In one example, a boost converter includes an inductor connection terminal, a voltage output terminal, a power transistor, and a first N channel MOSFET. The power transistor includes an input terminal coupled to the inductor connection terminal, and an output terminal coupled a ground reference. The first N channel MOSFET includes a drain terminal coupled to the inductor connection terminal, and a source terminal coupled to the voltage output terminal.

[0003] In another example, a boost converter includes a voltage output terminal, a power transistor, and short circuit protection circuitry. The voltage output terminal is configured to provide a boosted output voltage generated by the boost converter. The power transistor is configured to draw current through an inductor. The short circuit protection circuitry is configured to control current flow through the inductor responsive to detection of a short circuit at the voltage output terminal. The short circuit protection circuitry includes an output switch coupled to an input terminal of the power transistor and connected to the voltage output terminal. The output switch is configured to switch current flow from the inductor to the voltage output terminal. The output switch is an N channel MOSFET.

[0004] In a further example, a method for boost converter short circuit protection includes determining whether there is a short circuit at a voltage output terminal of the boost converter. Responsive to determining that there is a short circuit at the voltage output terminal, a first N channel MOSFET that draws current from an inductor is turned off, and a second N channel MOSFET that is connected to the voltage output terminal and couples the inductor to the voltage output terminal is turned off.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] For a detailed description of various examples, reference will now be made to the accompanying drawings in which:

[0006] Figure 1 shows an example of a boost converter that includes a negative (N) channel metal oxide semiconductor field effect transistor (MOSFET) for output voltage short circuit protection in accordance with the present disclosure;

[0007] Figure 2 shows a timing diagram for operation of a boost converter that includes an N channel MOSFET for output voltage short circuit protection in accordance with the present disclosure; and

[0008] Figure 3 shows a flow diagram for a method for using an N channel MOSFET for output voltage short circuit protection in a boost converter in accordance with the present disclosure.

DETAILED DESCRIPTION

[0009] Certain terms have been used throughout this description and claims to refer to particular system components. As one skilled in the art will appreciate, different parties may refer to a component by different names. This document does not intend to distinguish between components that differ in name but not function. In this disclosure and claims, the terms “including” and “comprising” are used in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to… .” Also, the term “couple” or “couples” is intended to mean either an indirect or direct wired or wireless connection. Thus, if a first device couples to a second device, that connection may be through a direct connection or through an indirect connection via other devices and connections. The recitation “based on” is intended to mean “based at least in part on.” Therefore, if X is based on Y, X may be a function of Y and any number of other factors.

[0010] If a boost converter lacks output short circuit protection, a short to ground on the output terminal of the boost converter can short the boost converter input voltage to ground through the inductor and other uncontrolled components in the path between the converters input and output voltage terminals. Under such conductions, the inductor, conductors, and/or other components of the boost converter may be damaged. Boost converter output short circuit protection includes adding a switching device between the inductor and the boost converter output terminal. Some implementations add a positive (P) channel metal oxide semiconductor field effect transistor (MOSFET) between the inductor and the boost converter output terminal, and circuitry to detect output short circuits and control the P channel MOSFET responsive to detected short. P channel MOSFETs are relatively easy to control, but are less efficient than negative (N) channel MOSFETs of equivalent size.

[0011] The boost converters and associated control circuitry disclosed herein include an N channel MOSFET as an over current protection switch between the inductor and the output voltage terminal of the boost converter. Because fully opening the over current protection switch immediately on detection of an output short circuit may cause a high voltage transient (due to an increase in voltage as the inductor discharges) that can damage components of the boost converter, the circuitry controlling the operation of the N channel MOSFET allows for current to flow from the inductor through the N channel MOSFET until the voltage across the inductor is substantially zero. Thereafter, the N channel MOSFET is fully turned off to isolate the boost converter from the short circuit.

[0012] Figure 1 shows an example of a boost converter 100 that includes an N channel MOSFET for output voltage short circuit protection in accordance with the present disclosure. The boost converter 100 includes a controller 102, a power transistor 104, an voltage input terminal 106, an inductor connection terminal 108, a diode 110, an inductor 112, short circuit protection circuitry 114, and a voltage output terminal 128. The power transistor 104 may be an N channel MOSFET or a bipolar transistor capable of conducting substantial current. The power transistor 104 includes a control terminal (e.g., a gate terminal) 164 that is coupled to the controller 102, an input terminal (e.g., a drain terminal) 136 that is coupled to the inductor connection terminal 108, and an output terminal (e.g., a source terminal) 138 that is coupled to ground.

[0013] The controller 102 includes pulse generation circuitry 166 that generates a pulse signal 130 to turn the power transistor 104 on and off. For example, the pulse generation circuitry 166 may include pulse width modulation circuitry or pulse frequency modulation circuitry that generates the pulse signal 130 based on a comparison of voltage at the voltage output terminal 128 to a reference voltage (e.g., a voltage generated by a band-gap circuit of the controller 102). The pulse generation circuitry 166 is coupled to the control terminal 164 of the power transistor 104. The controller 102 also includes short circuit detection circuitry 168 that detects a short circuit at the voltage output terminal 128. For example, the short circuit detection circuitry 168 may include a comparator that compares the voltage at the voltage output terminal 128 to the voltage at the voltage input terminal 106. If the voltage at the voltage output terminal 128 falls below the voltage at the voltage input terminal 106, then a short circuit may be present at the voltage output terminal 128. When a short circuit at the voltage output terminal 128 is detected, the controller 102 may turn off the power transistor 104.

[0014] The inductor 112 includes a terminal 152 that is coupled to the voltage input terminal 106 and a terminal 154 that is coupled to the inductor connection terminal 108. When turned on, the power transistor 104 induces current flow in the inductor 112. When the power transistor 104 is turned off the magnetic field about the inductor 112, produced by current flow while the power transistor 104 is turned on, collapses and the voltage at the inductor connection terminal 108 rises above the voltage at the voltage input terminal 106. The diode 110 couples the inductor connection terminal 108 to the short circuit protection circuitry 114. In some implementations of the boost converter 100, the diode 110 may be replaced by an N channel MOSFET.

[0015] The short circuit protection circuitry 114 includes an N channel MOSFET 116 (also referred to herein as an "output switch"), a P channel MOSFET 118, an N channel MOSFET 120, a P channel MOSFET 122 (also referred to herein as a "control transistor"), and a diode 124. When no short circuit is present at the output of the boost converter 100, the N channel MOSFET 116 is fully turned on to provide a path for current flow from the inductor connection terminal 108, via the diode 110, to the voltage output terminal 128. When a short circuit is detected at the voltage output terminal 128, the N channel MOSFET 116 operates as an output switch to protect the boost converter 100. The N channel MOSFET 116 protects the boost converter during an output short in two ways. First, on detection of a short at the voltage output terminal 128, turn-off of the N channel MOSFET 116 is initiated, but the N channel MOSFET 116 is kept partially on to allow the inductor 112 to discharge through the N channel MOSFET 116. By providing a path for discharge of the inductor 112, the N channel MOSFET 116 prevents a high-voltage transient at the inductor connection terminal 108 that may damage components of the boost converter 100. The time required to discharge the inductor 112 may be in a range of a few milliseconds. Finally, after the inductor 112 has been discharged the N channel MOSFET 116 is fully turned off to prevent flow of current through the inductor 112 to the voltage output terminal 128 thereby isolating the boost converter 100 from the short circuit at the voltage output terminal 128.

[0016] The N channel MOSFET 116 includes an input terminal (e.g., a drain terminal) 140 that is coupled to the inductor connection terminal 108 via the diode 110, and an output terminal (e.g., a source terminal) 142 that is coupled to the voltage output terminal 128. The N channel MOSFET 116 is controlled by the P channel MOSFET 118, the N channel MOSFET 120, and the P channel MOSFET 122.

[0017] The P channel MOSFET 118 and the N channel MOSFET 120 are connected to form a pull-up/pull-down circuit that drives the control terminal 144 of the N channel MOSFET 116. Because the impedance of the control terminal 144 of the N channel MOSFET 116 is relatively high, the P channel MOSFET 118 and the N channel MOSFET 120 may be relatively weak drivers. The P channel MOSFET 118 (low-side transistor) and the N channel MOSFET 120 (high-side transistor) are controlled by a signal 134 generated by the controller 102. The signal 134 may be generated based on the state of the voltage output terminal 128 as determined by the short circuit detection circuitry 168 of the controller 102. A control terminal (e.g., a gate terminal) 172 of the P channel MOSFET 118 and a control terminal (e.g., a gate terminal) 170 of the N channel MOSFET 120 are coupled to the short circuit detection circuitry 168.

[0018] When no short is detected at the voltage output terminal 128, the signal 134 turns on the N channel MOSFET 120 and turns off the P channel MOSFET 118. An input terminal (e.g., a source terminal) 160 of the P channel MOSFET 118 is coupled to an output terminal (e.g., a source terminal) 158 of the N channel MOSFET 120. The input terminal 160 of the P channel MOSFET 118 and the output terminal 158 of the N channel MOSFET 120 are coupled to the control terminal (e.g., gate terminal) 144 of the N channel MOSFET 116. When turned on, the N channel MOSFET 120 drives the control signal 132, the control voltage applied to the N channel MOSFET 116, to a voltage higher than the voltage at the voltage output terminal 128 to turn on the N channel MOSFET 116. For example, the boost converter 100 may include a charge pump that generates a voltage higher than the voltage at the voltage output terminal 128 when no short is present at the output terminal 128. An input terminal (e.g., a drain terminal) 156 of the N channel MOSFET 120 is coupled to the charge pump.

[0019] When a short at the voltage output terminal 128 is detected, the signal 134 turns on the P channel MOSFET 118 and turns off the N channel MOSFET 120. When the N channel MOSFET 120 is turned off, and the P channel MOSFET 118 is turned on, the P channel MOSFET 118 drives the control signal 132 to the voltage present on the voltage output terminal 128 to turn off the N channel MOSFET 116. An output terminal (e.g., a drain terminal) 162 of the P channel MOSFET 118 is coupled to the voltage output terminal 128. Because the P channel MOSFET 118 may be relatively small and weak, the P channel MOSFET 118 may turn off the N channel MOSFET 116 relatively slowly. Some implementations of the short circuit protection circuitry 114 may include an N channel MOSFET as a pull-down and/or include a P channel MOSFET as a pull-up.

[0020] If on detection of a short circuit at the voltage output terminal 128, the N channel MOSFET 116 is abruptly turned off (i.e., current flow from the inductor 112 to the voltage output terminal 128 is abruptly decreased), then in accordance with the inductor voltage equation $\left(v = L\frac{di}{dt}\right)$ the voltage at the inductor connection terminal 108 may rise to a voltage that can damage the boost converter 100 as the inductor 112 discharges. To prevent a high-voltage transient at the inductor connection terminal 108, the P channel MOSFET 122 keeps the N channel MOSFET 116 on while the inductor 112 is discharging (e.g., while the voltage at the inductor connection terminal 108 exceeds the voltage at the voltage input terminal 106). A control terminal (e.g., gate terminal) 150 of the P channel MOSFET 122 is coupled to the voltage input terminal 106. An input terminal (e.g., a source terminal) 146 of the P channel MOSFET 122 is coupled to the inductor connection terminal 108. An output terminal (e.g., drain terminal) of the P channel MOSFET 122 is coupled to the control terminal of the N channel MOSFET 116 via a diode 124.

[0021] When the controller 102 detects a short at the voltage output terminal 128, the controller 102 turns off the power transistor 104 and the N channel MOSFET 120, and turns on the P channel MOSFET 118, which starts to turn off the N channel MOSFET 116. The change in current flow in the inductor 112 caused by turning off the power transistor 104 and partially turning off the N channel MOSFET 116 causes the voltage at the inductor connection terminal 108 (and the input terminal 146 of the P channel MOSFET 122) to increase as the inductor 112 discharges. When the voltage at the inductor connection terminal 108 exceeds the voltage at the voltage input terminal 106 by the threshold voltage of the P channel MOSFET 122, the P channel MOSFET 122 turns on and allows transient current to flow (i.e., routes current) from the inductor connection terminal 108 to the control terminal 144 of the N channel MOSFET 116, thereby turning on the N channel MOSFET 116 (e.g., preventing the N channel MOSFET 116 from being fully turned off by the P channel MOSFET 118). As the inductor 112 discharges, and the inductor current decreases to zero (see Fig. 2), the voltage at the inductor connection terminal 108 falls to about the voltage at the voltage input terminal 106 (e.g.,. the voltage across the inductor 112 falls below the threshold voltage of the P channel MOSFET 122), and the P channel MOSFET 122 turns off. When the P channel MOSFET 122 turns off, the N channel MOSFET 116 is turned off via the pull-down provided by the P channel MOSFET 118. Thus, the P channel MOSFET 122 controls the N channel MOSFET 116 during a short event to allow the inductor 112 to discharge while protecting the boost converter 100 from overcurrent damage.

[0022] In some implementations, the controller 102, the power transistor 104, the voltage input terminal 106, the inductor connection terminal 108, the diode 110, the short circuit protection circuitry 114, and the output terminal output terminal may be components of a same integrated circuit.

[0023] Figure 2 shows a timing diagram for operation of examples of the boost converter boost converter 100 in accordance with the present disclosure. In Figure 2, prior to time t_0, the boost converter 100 is operating with no short circuit present at the voltage output terminal 128. The pulses on the pulse signal 130 cause the power transistor 104 to switch, the voltage at the inductor connection terminal 108 exceeds the voltage at the voltage input terminal 106 while the power transistor 104 is turned off, and the voltage at the voltage output terminal 128 exceeds the voltage at the voltage input terminal 106. At time t_0, the voltage output terminal 128 is shorted to ground and the voltage at the voltage output terminal 128 begins to drop towards ground. At time t_1, the voltage at the voltage output terminal 128 has dropped to equal the voltage at the voltage input terminal 106, and at time t_2 the short circuit detection circuitry 168 of the controller 102 detects the short circuit. Responsive to detection of the short circuit by the short circuit detection circuitry 168, the pulse generation circuitry 166 discontinues generation pulses on the pulse signal 130 to turn off the power transistor 104, and the short circuit detection circuitry 168 sets the signal 134 to turn on the P channel MOSFET 118 and turn off the N channel MOSFET 120. Because the falling time of the control signal 132 is longer than the falling time of the pulse signal 130, current flowing in the inductor 112 flows through the diode 110 and the N channel MOSFET 116 between time t_2 and time t_3. The voltage at the inductor connection terminal 108 is equal to the voltage at the voltage output terminal 128 between time t_2 and time t_3.

[0024] After time t_3, the voltage of the control signal 132 decreases to the Miller plateau voltage of the N channel MOSFET 116, and the voltage at the inductor connection terminal 108 increases. When the voltage at the inductor connection terminal 108 exceeds the voltage at the voltage input terminal 106 by at least the threshold voltage of the P channel MOSFET 122, the P channel MOSFET 122 turns on. Because the drain-source resistance of the P channel MOSFET 122 is substantially smaller than the drain-source resistance of the P channel MOSFET 118, the voltage of the control signal 132 stays at about the Miller plateau voltage of the P channel MOSFET 122 until no current is flowing in the inductor 112 (i.e., the voltage across the inductor 112 is substantially zero (e.g., within a threshold voltage of the P channel MOSFET 122 of zero volts)) at time t_4. Thereafter, the P channel MOSFET 122 and the N channel MOSFET 116 turn off.

[0025] Figure 3 shows a flow diagram for a method 300 for using an N channel MOSFET for output voltage short circuit protection in a boost converter in accordance with the present disclosure. Though depicted sequentially as a matter of convenience, at least some of the actions shown can be performed in a different order and/or performed in parallel. Additionally, some implementations may perform only some of the actions shown. Operations of the method 300 may be performed by implementations of the boost converter 100.

[0026] In block 302, the boost converter 100 is operating. The voltage at the voltage output terminal 128 exceeds the voltage at the voltage input terminal 106, and the short circuit detection circuitry 168 is monitoring the voltage at the voltage output terminal 128 to detect a short circuit. For example, the short circuit detection circuitry 168 may compare the voltage at the voltage output terminal 128 to the voltage at the voltage input terminal 106, and identify a short circuit at the voltage output terminal 128 as being present if the voltage at the voltage input terminal 106 exceeds the voltage at the voltage output terminal 128.

[0027] In block 304, if a short circuit has not been detected at the voltage output terminal 128 (e.g., the voltage at the voltage output terminal 128 exceeds the voltage at the voltage input terminal 106), then monitoring for a short circuit continues in block 302.

[0028] If, in block 304, a short circuit has been detected (e.g., the voltage at the voltage input terminal 106 exceeds the voltage at the voltage output terminal 128), then, in block 306, the power transistor 104 is turned off. For example, the pulse generation circuitry 166 discontinues pulse generation and sets the pulse signal 130 to deactivate the power transistor 104.

[0029] In block 308, the N channel MOSFET 120 is turned off. For example, the signal 134 is set to deactivate the N channel MOSFET 120.

[0030] In block 310, the P channel MOSFET 118 is turned on. For example, setting the signal 134 to deactivate the N channel MOSFET 120 sets the signal 134 to activate the P channel MOSFET 118. Turning on the P channel MOSFET 118 pulls the control terminal 144 of the N channel MOSFET 116 towards the voltage at the voltage output terminal 128 to turn off the N channel MOSFET 116.

[0031] In block 312, after the power transistor 104 is turned off, the voltage at the inductor connection terminal 108 increases, and when the voltage at the inductor connection terminal 108 exceeds the voltage at the voltage input terminal 106 by at least the threshold voltage of the P channel MOSFET 122, the P channel MOSFET 122 is turned on and current flows from the inductor connection terminal 108 to the control terminal 144 of the N channel MOSFET 116 turning on the N channel MOSFET 116.

[0032] In block 314, if the voltage across the inductor 112 is not zero, then the P channel MOSFET 122 and the N channel MOSFET 116 remain on in block 312 to discharge the inductor 112 through the N channel MOSFET 116.

[0033] If in block 314, the voltage across the inductor 112 is zero, then the P channel MOSFET 122 and the N channel MOSFET 116 are turned off.

[0034] The above discussion is meant to be illustrative of the principles and various embodiments of the present invention. Numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

CLAIMS

What is claimed is:

1. A boost converter, comprising:
an inductor connection terminal;
a voltage output terminal;
a power transistor, comprising:
an input terminal coupled to the inductor connection terminal; and
an output terminal coupled a ground reference;
a negative (N) channel metal oxide semiconductor field effect transistor (MOSFET) comprising:
a drain terminal coupled to the inductor connection terminal; and
a source terminal coupled to the voltage output terminal.

2. The boost converter of claim 1, further comprising: a positive (P) channel MOSFET comprising:
a source terminal coupled to the inductor connection terminal; and
a drain terminal coupled to a gate terminal of the N channel MOSFET.

3. The boost converter of claim 2, further comprising a diode that couples the drain terminal of the P channel MOSFET to the gate terminal of the N channel MOSFET.

4. The boost converter of claim 3, further comprising a voltage input terminal, wherein a gate terminal of the first P channel MOSFET is coupled to the voltage input terminal.

5. The boost converter of claim 4, further comprising an inductor comprising:
a first terminal coupled to the inductor connection terminal; and
a second terminal coupled to the voltage input terminal.

6. The boost converter of claim 1, wherein the N channel MOSFET is a first N channel MOSFET, and the boost converter further comprises a second N channel MOSFET, comprising:

a drain terminal coupled to a charge pump; and

a source terminal coupled to a gate terminal of the first N channel MOSFET.

7. The boost converter of claim 6, further comprising a P channel MOSFET, comprising:

a source terminal coupled to the gate terminal of the first N channel MOSFET; and

a drain terminal coupled to the voltage output terminal.

8. The boost converter of claim 7, further comprising a controller, the controller comprising:

pulse generation circuitry coupled to a control terminal of the power transistor;

short circuit detection circuit coupled to:

the pulse generation circuitry;

the voltage output terminal;

a gate terminal of the second N channel MOSFET; and

a gate terminal of the P channel MOSFET.

9. The boost converter of claim 1, further comprising a diode that couples the input terminal of the power transistor to the drain terminal of the N channel MOSFET.

10. A boost converter, comprising:

a voltage output terminal configured to provide a boosted output voltage generated by the boost converter;

a power transistor configured to draw current through an inductor; and

short circuit protection circuitry configured to control current through the inductor responsive to a detection of a short circuit at the voltage output terminal, the short circuit protection circuitry comprising:

an output switch coupled to an input terminal of the power transistor and connected to the voltage output terminal, the output switch configured to switch current from the inductor to the voltage output terminal;

wherein the output switch is a negative (N) channel metal oxide semiconductor field effect transistor (MOSFET).

11. The boost converter of claim 10, further comprising a control transistor coupled to the output switch and to the power transistor, the control transistor configured to route current from the inductor to a control terminal of the output switch.

12. The boost converter of claim 11, wherein the control transistor is configured to activate the output switch, responsive to the detection of the short circuit, until a voltage across the inductor substantially equal to zero.

13. The boost converter of claim 11, further comprising a voltage input terminal coupled to a control terminal of the control transistor; wherein the voltage input terminal is configured to be connected to the inductor.

14. The boost converter of claim 10, further comprising a pull-up/pull-down circuit configured to control the output switch, the pull-up/pull-down circuit comprising an output coupled to a control terminal of the output switch.

15. The boost converter of claim 14, further comprising a controller configured to:
detect the short circuit at the voltage output terminal of the boost converter; and
turn off the power transistor responsive to detection of the short circuit.

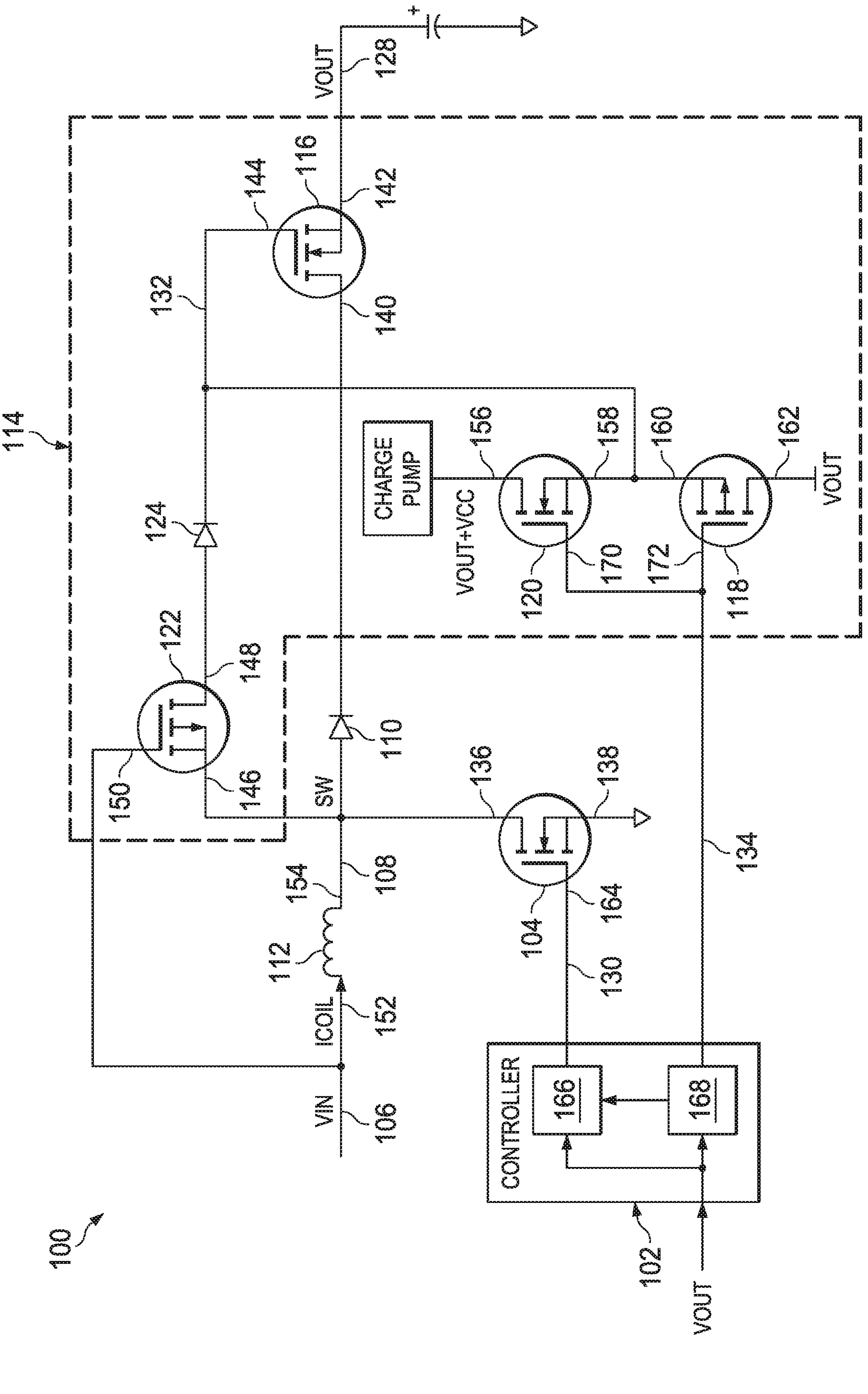
16. The boost converter of claim 15, wherein the pull-up/pull-down circuit comprises:
a high-side transistor; and
a low-side transistor;
wherein the controller is configured to:
turn on the low-side transistor responsive to detection of the short circuit at the voltage output terminal; and
turn on the high-side transistor responsive to detection of no short circuit at the voltage output terminal.

17. A method for boost converter short circuit protection, comprising:
detecting a short circuit at a voltage output terminal of a boost converter; and
responsive to a detected short circuit at the voltage output terminal:
turning off a first negative (N) channel metal oxide semiconductor field effect transistor (MOSFET) that draws current from an inductor; and
turning off a second N channel MOSFET that is connected to the voltage output terminal and couples the inductor to the voltage output terminal.

18 The method of claim 17, further comprising:
responsive to the detected short circuit at the voltage output terminal:
turning off a third N channel MOSFET that pulls up a gate terminal of the second N channel MOSFET; and
turning on a positive (P) channel MOSFET to pull down the gate terminal of the second N channel MOSFET.

19. The method of claim 17, further comprising turning on a P channel MOSFET to route current from the inductor to a gate terminal of the second N channel MOSFET responsive to voltage at a drain terminal of the first N channel MOSFET being greater than a voltage at a voltage input terminal of the boost converter by a threshold voltage of the P channel MOSFET.

20. The method of claim 17, further comprising after turning off the first N channel MOSFET and prior to turning off the second N channel MOSFET, keeping the second N channel MOSFET on until no current is flowing in the inductor.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102
VOUT
134
150
146
122
148
124
114
132
144
116
142
140
VOUT
128
CHARGE PUMP
VOUT+VCC
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158
160
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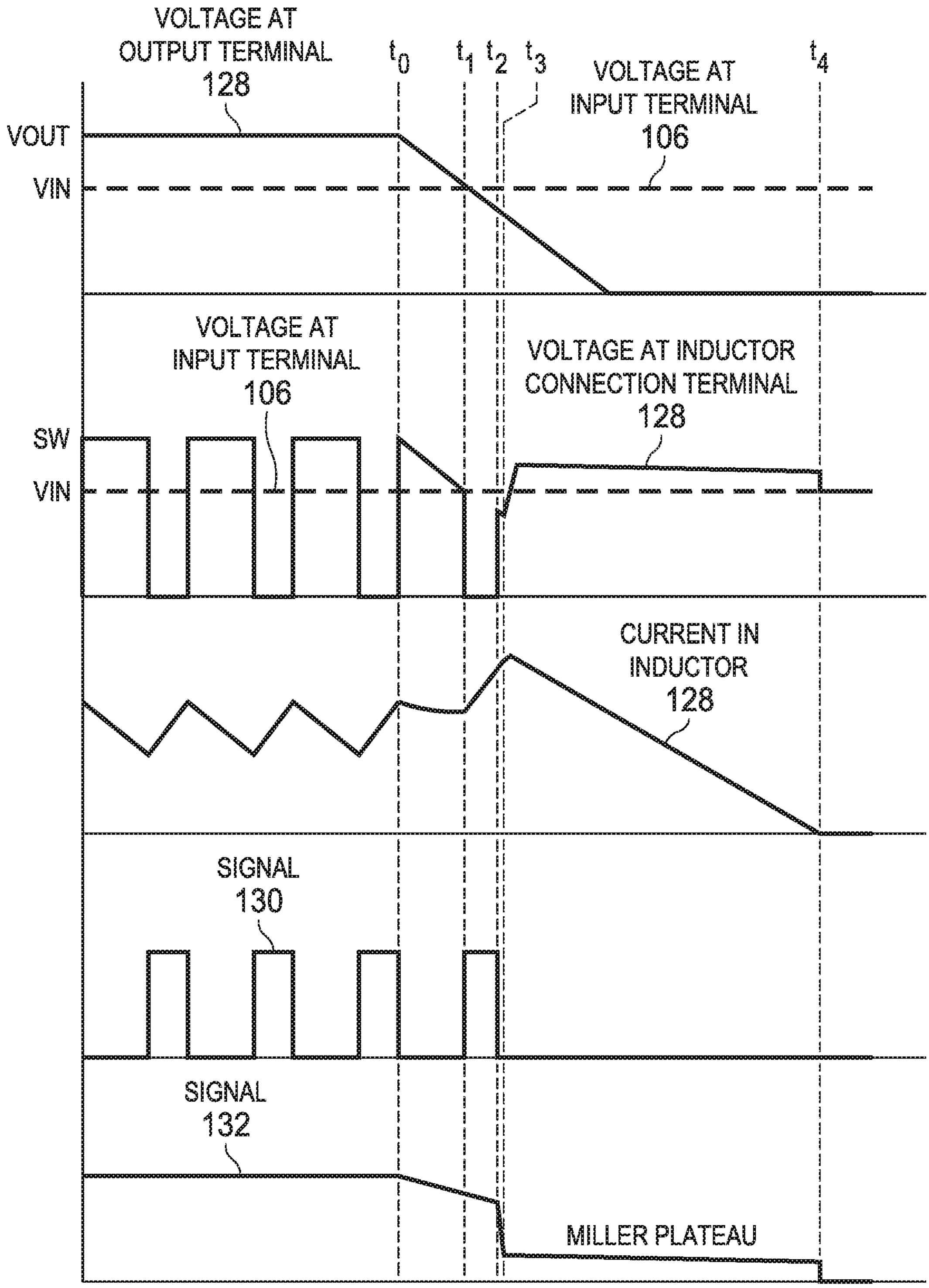
120
170
172
118

FIG. 1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OUTPUT TERMINAL
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t_1
t_2
t_3
VOLTAGE AT
INPUT TERMINAL
106
t_4
VOUT
VIN
VOLTAGE AT
INPUT TERMINAL
106
VOLTAGE AT INDUCTOR
CONNECTION TERMINAL
128
SW
VIN
CURRENT IN
INDUCTOR
128
SIGNAL
130
SIGNAL
132
MILLER PLATEAU

FIG. 2

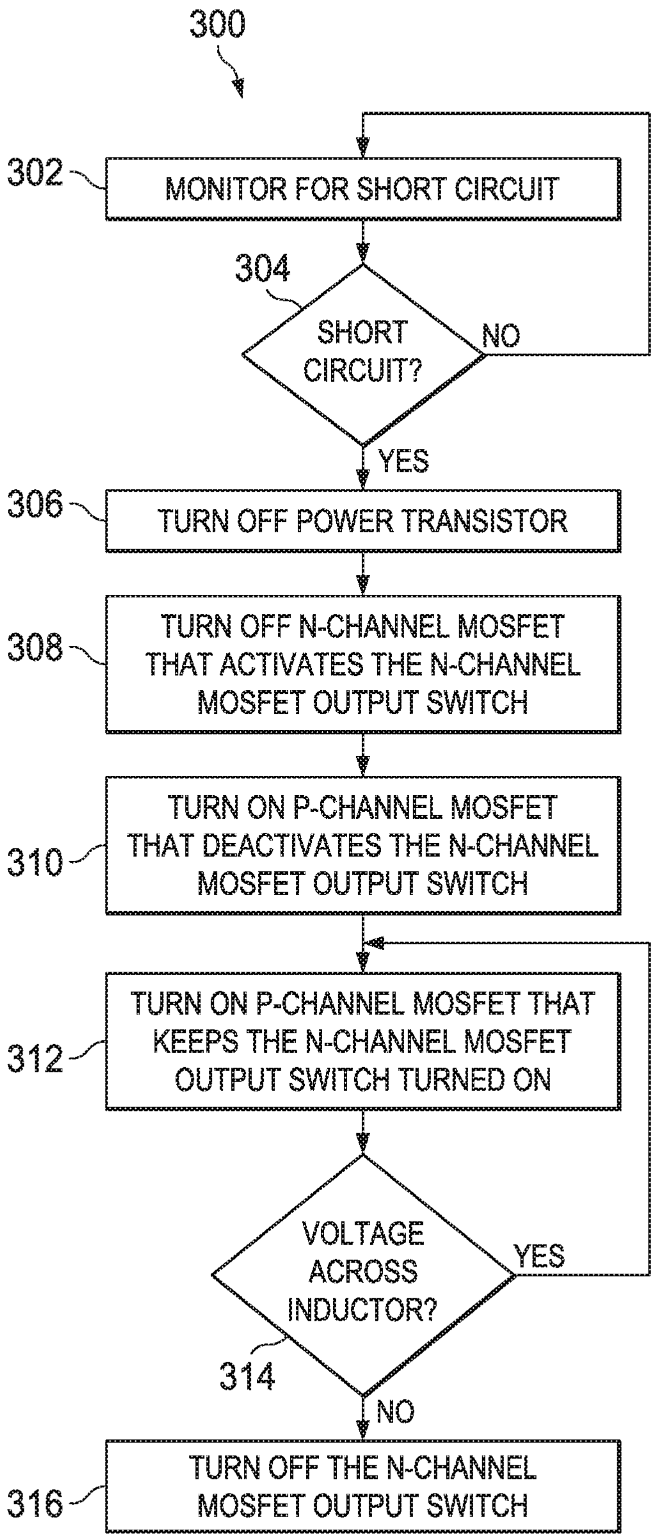
300
302
MONITOR FOR SHORT CIRCUIT
304
SHORT CIRCUIT?
NO
YES
306
TURN OFF POWER TRANSISTOR
308
TURN OFF N-CHANNEL MOSFET THAT ACTIVATES THE N-CHANNEL MOSFET OUTPUT SWITCH
310
TURN ON P-CHANNEL MOSFET THAT DEACTIVATES THE N-CHANNEL MOSFET OUTPUT SWITCH
312
TURN ON P-CHANNEL MOSFET THAT KEEPS THE N-CHANNEL MOSFET OUTPUT SWITCH TURNED ON
VOLTAGE ACROSS INDUCTOR?
YES
314
NO
316
TURN OFF THE N-CHANNEL MOSFET OUTPUT SWITCH

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/082528

A. CLASSIFICATION OF SUBJECT MATTER

H02H 7/122(2006.01)i

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)

HO2H; H02M

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)

WPI, EPODOC, CNKI, CNPAT, IEEE: boost, peak, zcs, soft switch, off, short circuit, mosfet, discharge, over, induct, high, voltage, output transistor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 206506287 U (GUANGDONG BESTEK ELECTRONIC COMMERCE CO., LTD.) 19 September 2017 (2017-09-19) description, paragraphs [0020]-[0027] and figures 1-2	1, 6-10, 14-18
X	JP H07194100 A (MATSUSHITA ELECTRIC IND. CO., LTD.) 28 July 1995 (1995-07-28) description, paragraphs [0002]-[0012] and figures 1-2	1, 6-10, 14-18
A	US 5726845 A (ASTEC INTERNATIONAL LIMITED) 10 March 1998 (1998-03-10) the whole document	1-20
A	US 2007216390 A1 (YUAN ZE UNIVERSITY) 20 September 2007 (2007-09-20) the whole document	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 2018	**04 January 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**DUAN,Wenting**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/082528

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	206506287	U	19 September 2017	None			
JP	H07194100	A	28 July 1995	None			
US	5726845	A	10 March 1998	None			
US	2007216390	A1	20 September 2007	US	7382113	B2	03 June 2008