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(54) **BATTERY CHARGING APPARATUS AND BATTERY CHARGING PROTECTION CONTROL METHOD**

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CPC ***H02J 7/0072*** (2013.01); ***H02J 7/0045*** (2013.01); ***H02J 7/0068*** (2013.01); *H02J 2007/0096* (2013.01)

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CPC H02J 7/0072; H02J 7/0045; H02J 7/0068; H02J 7/0029; H02J 7/00; H02J 2007/0037;
(Continued)

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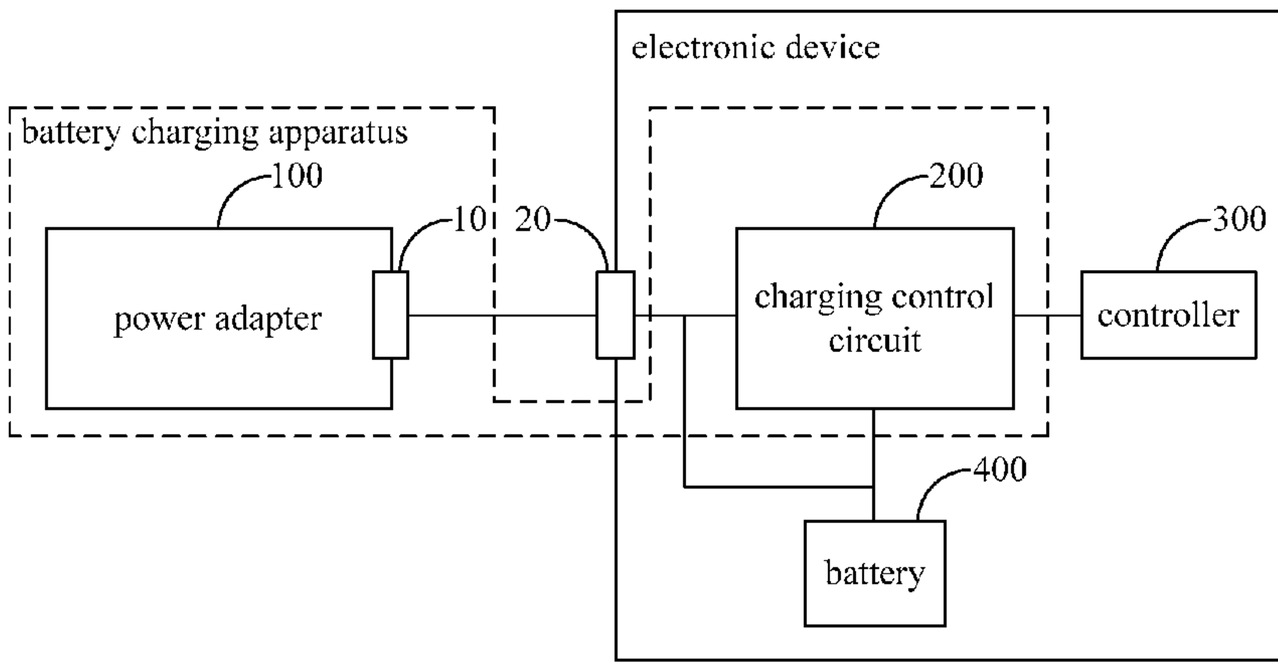
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(57) **ABSTRACT**

The present disclosure provides a battery charging apparatus and a battery charging protection control method. A power adapter in the battery charging apparatus performs data communication with a charging control circuit; when the power adapter determines that overvoltage and/or overcurrent occurs in the direct current output by a communication interface of the power adapter, the power adapter notifies the charging control circuit to drive a controller in the electronic
(Continued)



device to switch off a communication interface of the electronic device and switches off the direct current output automatically; when the charging control circuit; determines that overvoltage and/or overcurrent occurs upon receiving output voltage and output current of the power adapter, the charging control circuit notifies the power adapter to switch off the direct current output and drives the controller in the electronic device to switch off the communication interface of the electronic device.

12 Claims, 4 Drawing Sheets

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CPC H02J 2007/0039; H02J 2007/0096; H02J 2007/0025; H02J 7/02; H02J 7/025; H02J 50/23; H01Q 1/362; H01Q 1/40; H01Q 1/36; H01Q 1/405; H01Q 21/08; H01Q 11/08
USPC 320/107, 108
See application file for complete search history.

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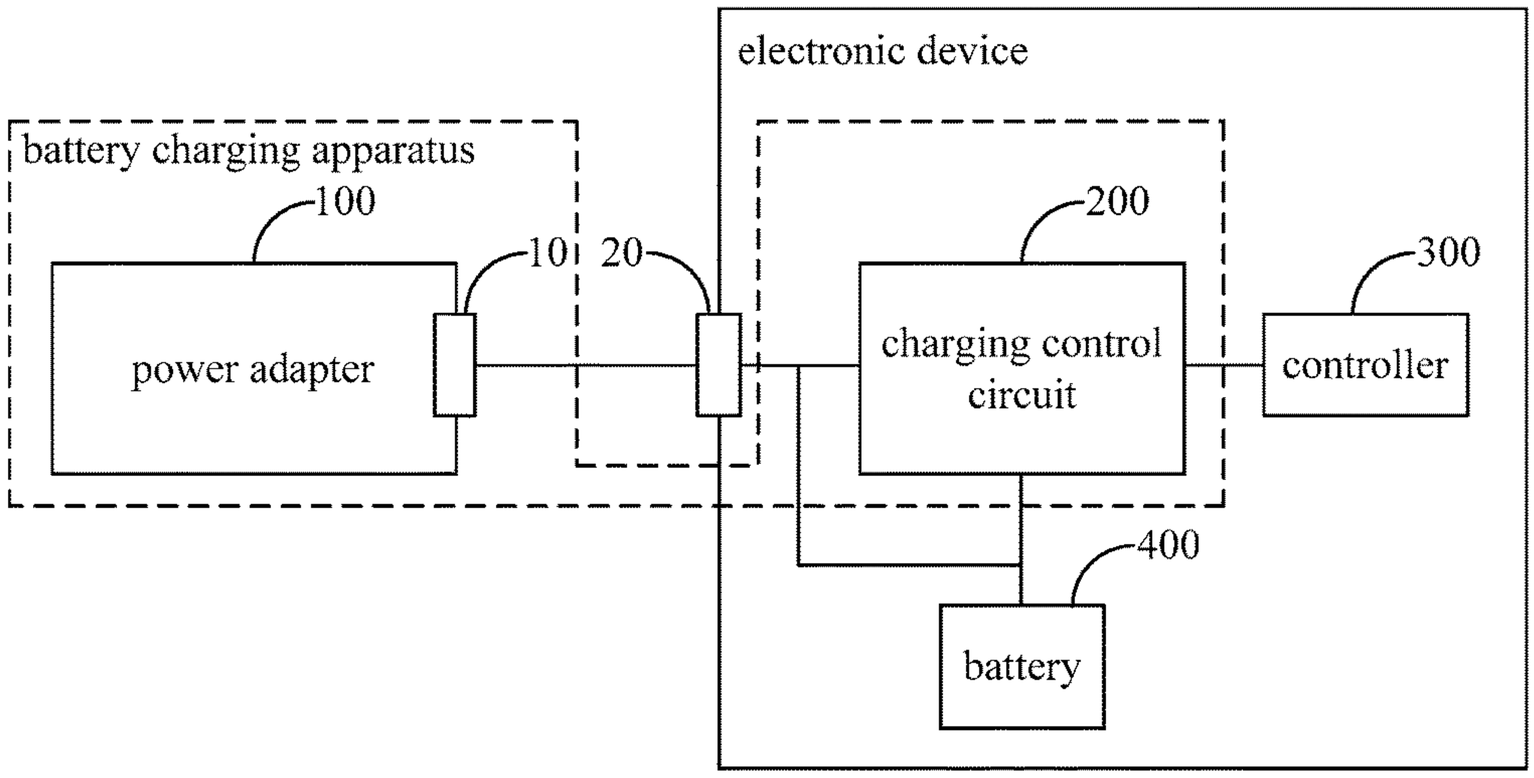

electronic device
battery charging apparatus
100
10
20
200
300
power adapter
charging control circuit
controller
400
battery

Fig. 1

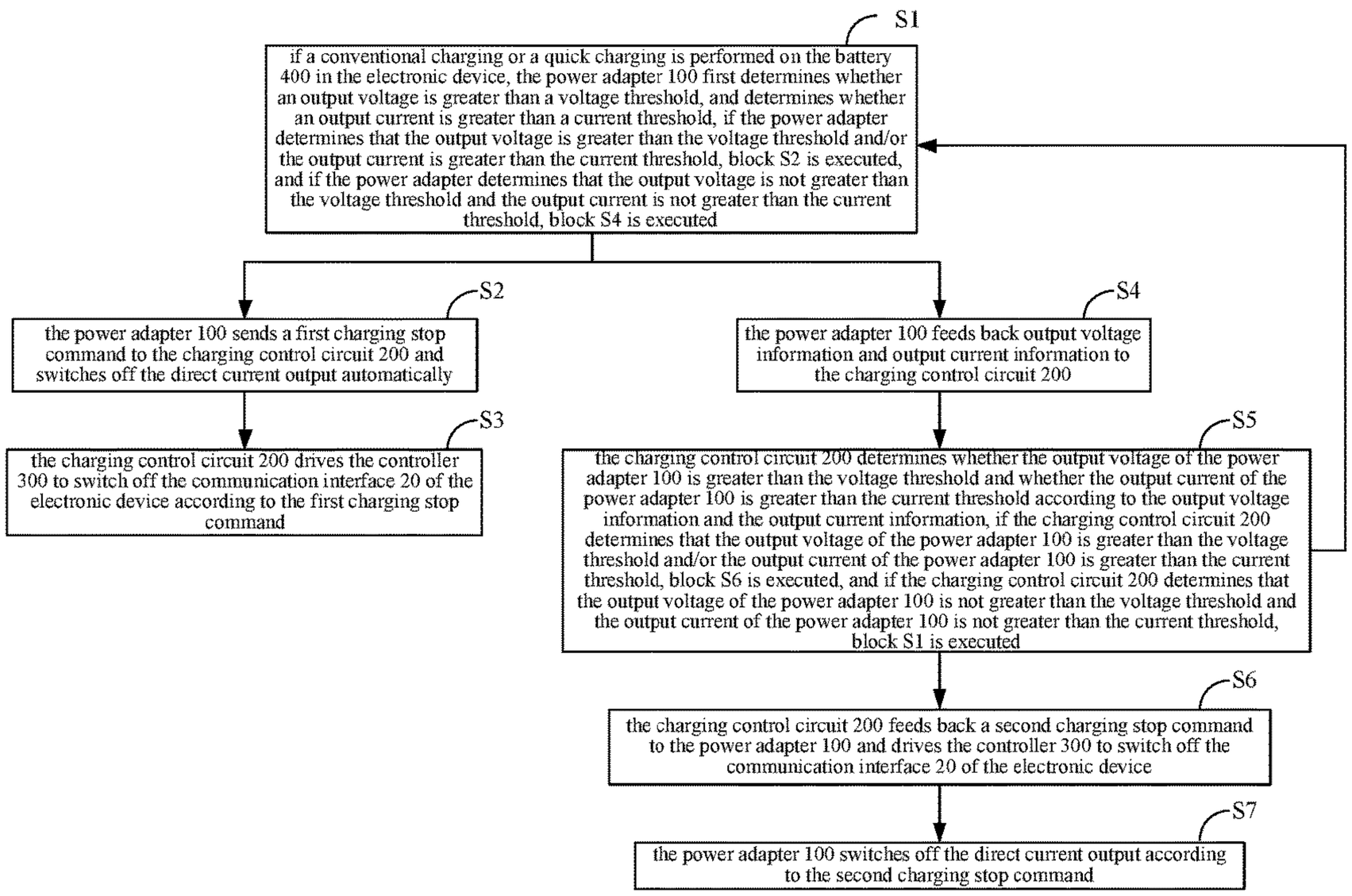

S1
if a conventional charging or a quick charging is performed on the battery 400 in the electronic device, the power adapter 100 first determines whether an output voltage is greater than a voltage threshold, and determines whether an output current is greater than a current threshold, if the power adapter determines that the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, block S2 is executed, and if the power adapter determines that the output voltage is not greater than the voltage threshold and the output current is not greater than the current threshold, block S4 is executed
S2
the power adapter 100 sends a first charging stop command to the charging control circuit 200 and switches off the direct current output automatically
S3
the charging control circuit 200 drives the controller 300 to switch off the communication interface 20 of the electronic device according to the first charging stop command
S4
the power adapter 100 feeds back output voltage information and output current information to the charging control circuit 200
S5
the charging control circuit 200 determines whether the output voltage of the power adapter 100 is greater than the voltage threshold and whether the output current of the power adapter 100 is greater than the current threshold according to the output voltage information and the output current information, if the charging control circuit 200 determines that the output voltage of the power adapter 100 is greater than the voltage threshold and/or the output current of the power adapter 100 is greater than the current threshold, block S6 is executed, and if the charging control circuit 200 determines that the output voltage of the power adapter 100 is not greater than the voltage threshold and the output current of the power adapter 100 is not greater than the current threshold, block S1 is executed
S6
the charging control circuit 200 feeds back a second charging stop command to the power adapter 100 and drives the controller 300 to switch off the communication interface 20 of the electronic device
S7
the power adapter 100 switches off the direct current output according to the second charging stop command

Fig. 2

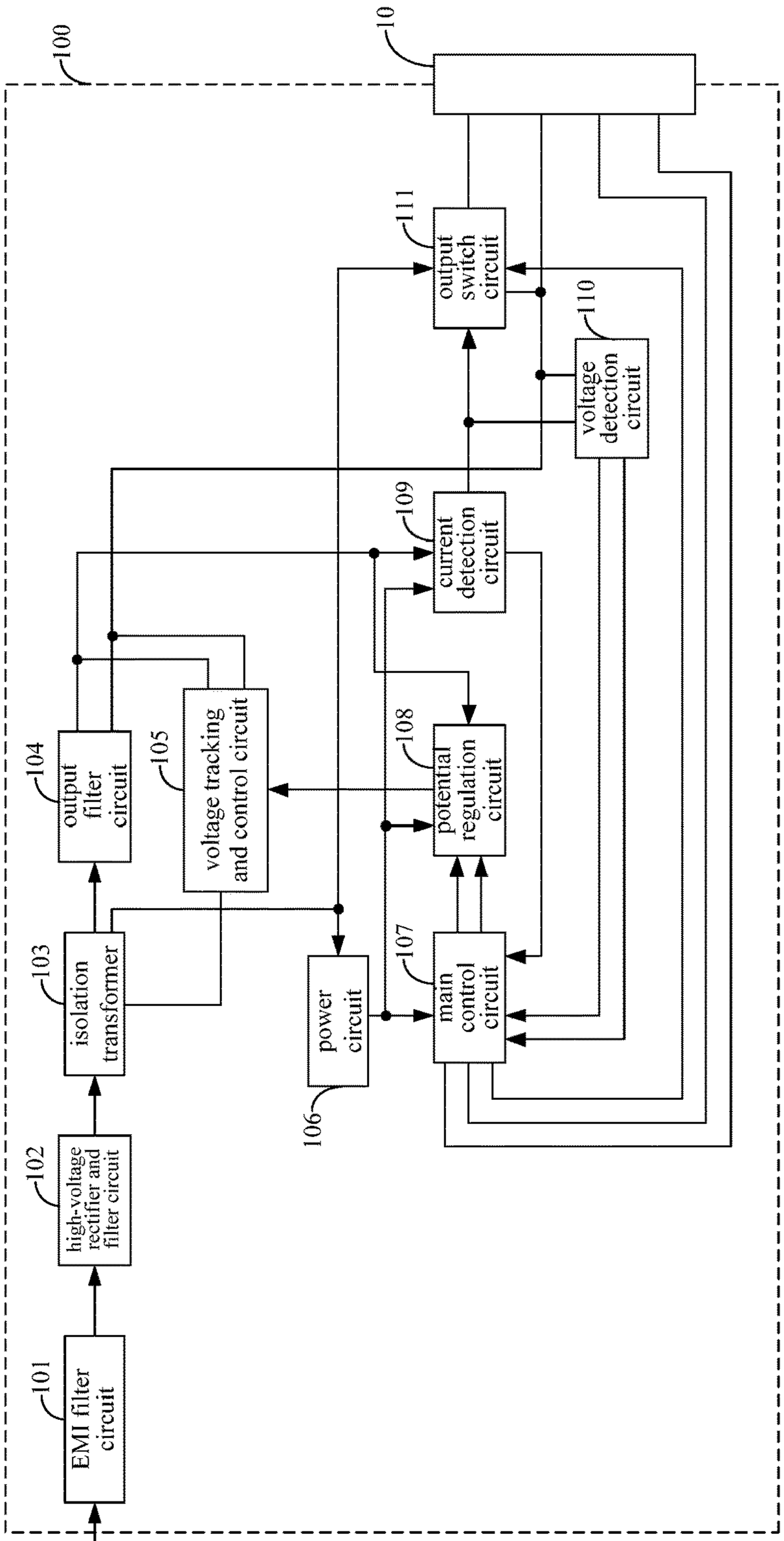

100
10
111
output switch circuit
110
voltage detection circuit
109
current detection circuit
108
potential regulation circuit
107
main control circuit
106
power circuit
105
voltage tracking and control circuit
104
output filter circuit
103
isolation transformer
102
high-voltage rectifier and filter circuit
101
EMI filter circuit
mains supply

Fig. 3

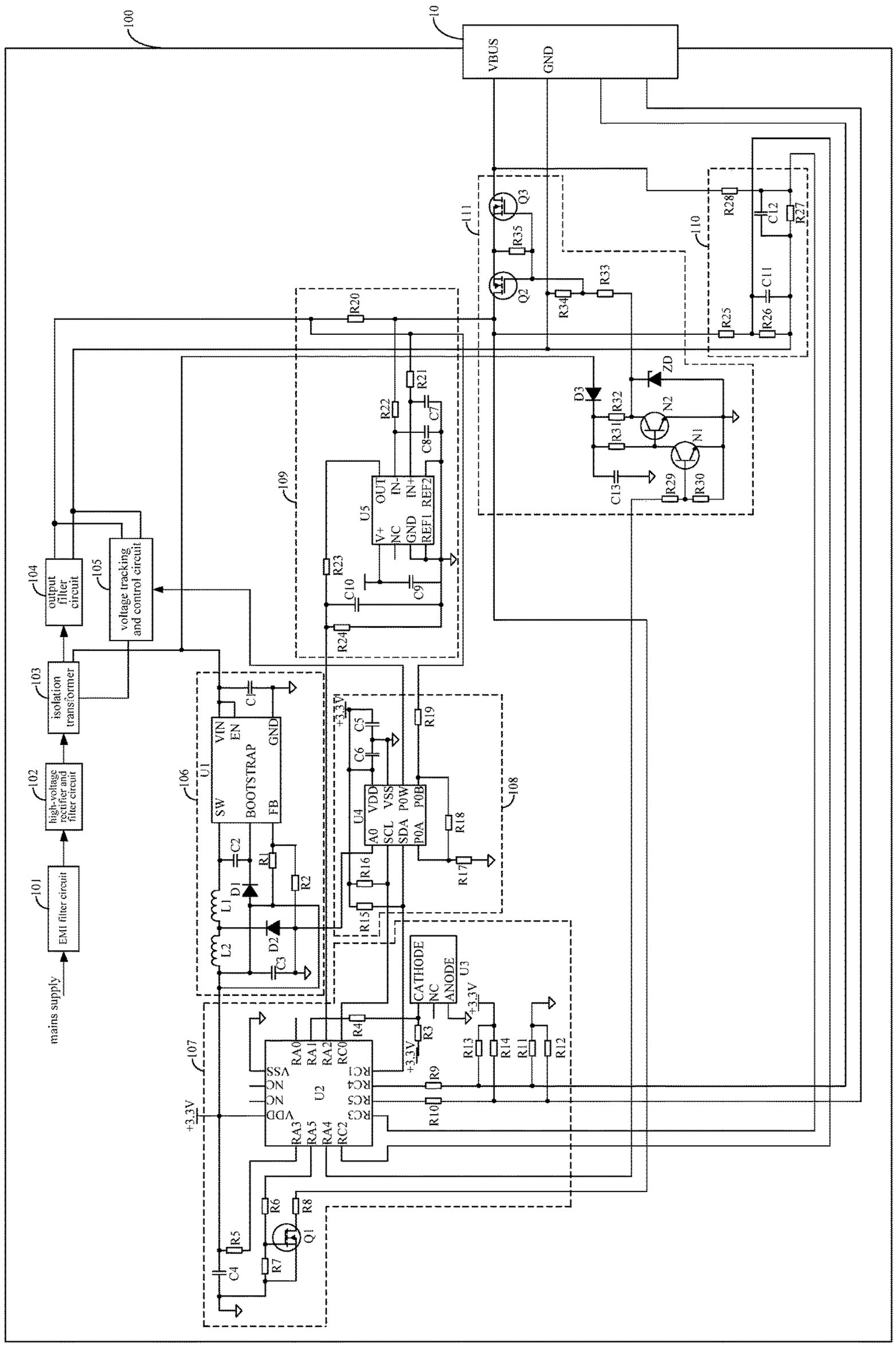

100
10
VBUS
GND
111
Q3
R35
Q2
R34
R33
110
R28
C12
R27
C11
R26
R25
R20
R21
R22
C7
C8
109
U5
OUT
IN-
IN+
REF2
V+
NC
GND
REF1
R23
C10
C9
R24
D3
R32
ZD
N2
N1
R31
R29
R30
C13
104
output filter circuit
105
voltage tracking and control circuit
103
isolation transformer
102
high-voltage rectifier and filter circuit
101
EMI filter circuit
mains supply
106
U1
VIN
EN
GND
SW
BOOTSTRAP
FB
C1
C2
R1
R2
L1
L2
D1
D2
C3
+3.3V
C5
C6
R19
108
U4
VDD
VSS
P0W
P0B
A0
SCL
SDA
P0A
R18
R17
R16
R15
CATHODE
NC
ANODE
U3
R3
R4
107
U2
RA0
RA1
RA2
RC0
RC1
RC4
RC5
RC3
RA3
RA5
RA4
RC2
VDD
NC
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R14
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R6
R8
R5
R7
Q1
C4

Fig. 4

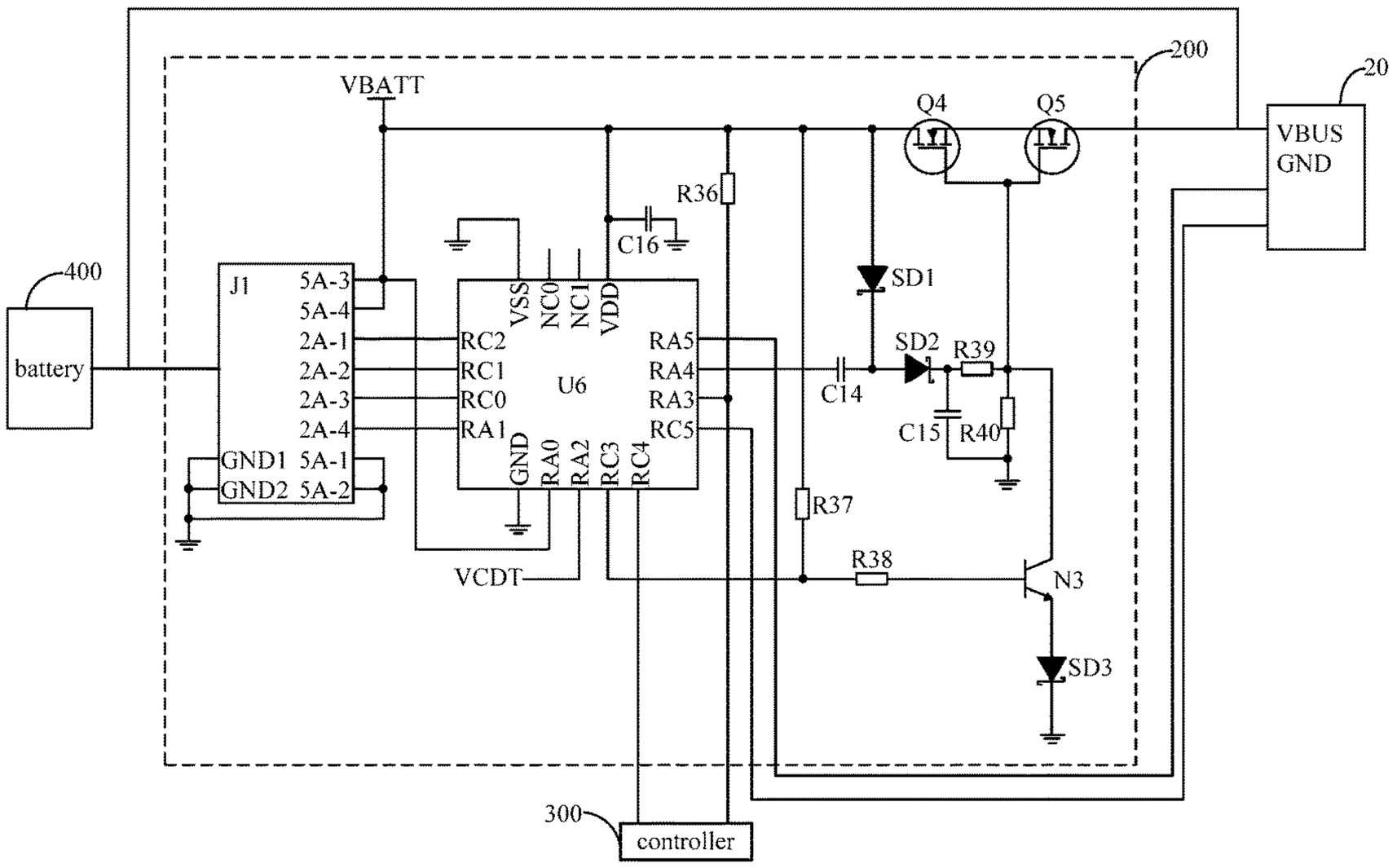

200
20
VBATT
Q4
Q5
VBUS
GND
R36
C16
400
J1
5A-3
5A-4
2A-1
2A-2
2A-3
2A-4
GND1 5A-1
GND2 5A-2
VSS
NC0
NC1
VDD
RC2
RC1
RC0
RA1
U6
RA5
RA4
RA3
RC5
GND
RA0
RA2
RC3
RC4
SD1
SD2
R39
C14
C15
R40
R37
R38
N3
SD3
battery
VCDT
300
controller

Fig. 5

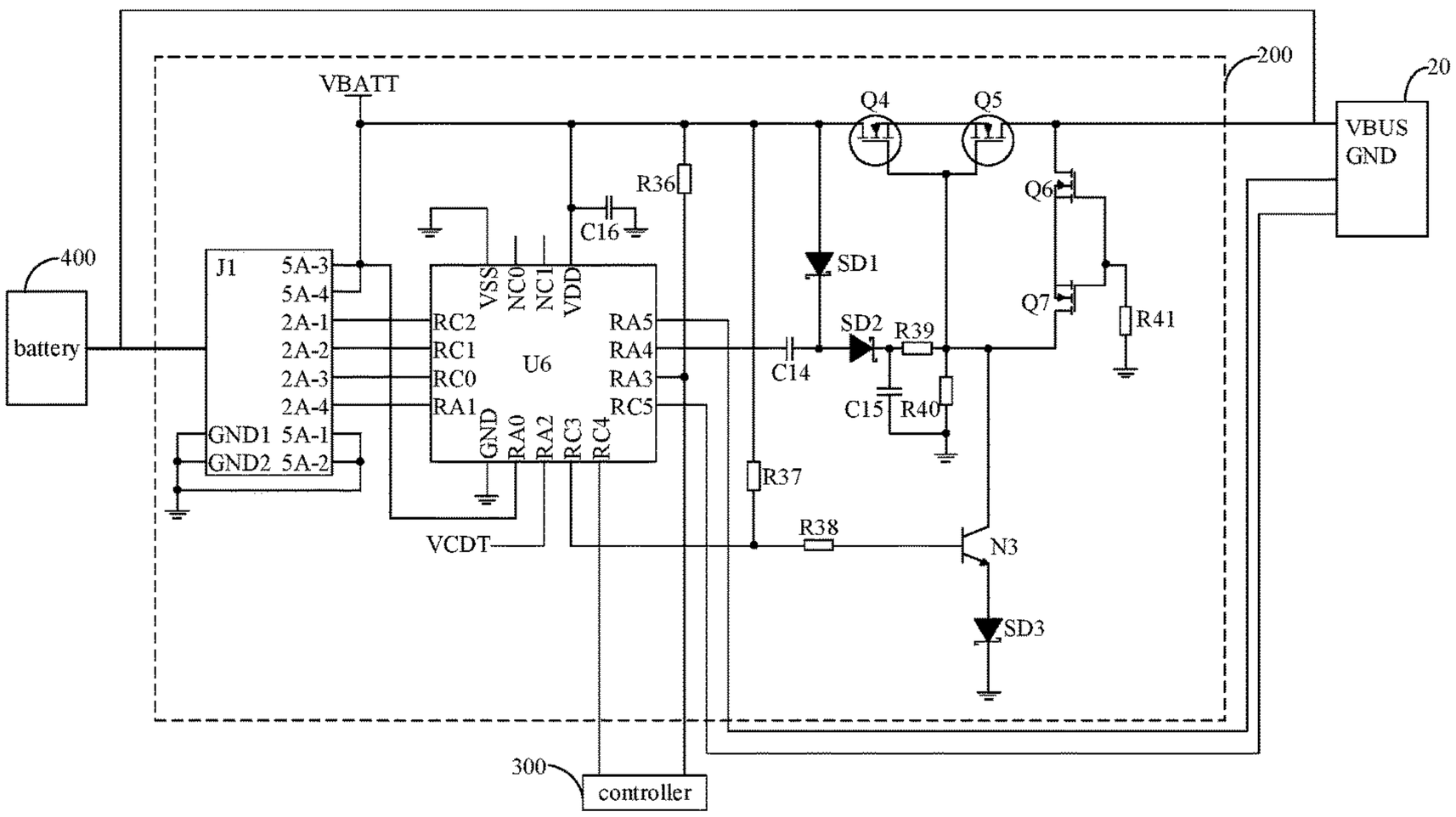

200
20
VBATT
Q4
Q5
VBUS
GND
Q6
R36
C16
400
J1
5A-3
5A-4
2A-1
2A-2
2A-3
2A-4
GND1 5A-1
GND2 5A-2
VSS
NC0
NC1
VDD
RC2
RC1
RC0
RA1
U6
RA5
RA4
RA3
RC5
GND
RA0
RA2
RC3
RC4
SD1
Q7
R41
SD2
R39
C14
C15
R40
R37
R38
N3
SD3
battery
VCDT
300
controller

Fig. 6

BATTERY CHARGING APPARATUS AND BATTERY CHARGING PROTECTION CONTROL METHOD

CROSS REFERENCE

This application is a U.S. national phase application based on International Application No. PCT/CN2014/077474, filed May 9, 2014, which is based on and claims priority to Chinese Patent Application No. 201410043218.5, filed on Jan. 28, 2014, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

This disclosure relates to charging technical field, and particularly relates to a battery charging apparatus and a battery charging protection control method.

BACKGROUND

Currently, a battery in an electronic device is generally charged by coupling a communication interface of the electronic device to an external power adapter. During charging the battery, in order to shorten charging time, a charging current is increased in the related art for quick charging of the battery. However, for charging the battery either with conventional constant voltage or with increased charging current, if the charging voltage and/or the charging current for the battery is too large in the charging process, the battery will be damaged because of an overvoltage charging and/or an overcurrent charging. Therefore, the above mentioned charging methods cannot realize an overvoltage protection and/or an overcurrent protection for the battery in the electronic device during a conventional charging or a quick charging

SUMMARY

An objective of this disclosure is to provide a battery charging apparatus so as to solve the problem in the related art that overvoltage and/or overcurrent protection cannot be realized for a battery when a conventional charging or a quick charging is performed on the battery in an electronic device.

The present disclosure is realized as follows. A battery charging apparatus includes a power adapter and a charging control circuit, in which, the charging control circuit is built in an electronic device and coupled to a controller and a battery in the electronic device, the power adapter is coupled to a communication interface of the electronic device via a communication interface thereof, the battery is charged by the power adapter via the communication interface of the electronic device, and the charging control circuit performs data communication with the power adapter via the communication interface of the electronic device;

if a conventional charging or a quick charging is performed on the battery, the power adapter first determines whether an output voltage is greater than a voltage threshold and whether an output current is greater than a current threshold, if the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, the power adapter sends a first charging stop command to the charging control circuit and automatically switches off direct current output, the charging control circuit drives the controller to switch off the communication interface of the electronic device according to the first charging stop command; if the output voltage is not greater than the voltage threshold, and the output current is not greater than the current threshold, the power adapter feeds back output voltage information and output current information to the charging control circuit, if the charging control circuit determines that the output voltage of the power adapter is greater than the voltage threshold and/or the output current of the power adapter is greater than the current threshold according to the output voltage information and the output current information, the charging control circuit feeds back a second charging stop command to the power adapter and drives the controller to switch off the communication interface of the electronic device, and the power adapter switches off the direct current output according to the second charging stop command; and if the charging control circuit determines that the output voltage of the power adapter is not greater than the voltage threshold and the output current of the power adapter is not greater than the current threshold according to the output voltage information and the output current information, the charging power adapter continues to determine the output voltage and the output current.

Another objective of this disclosure is to provide a battery charging protection control method based on the above-described battery charging apparatus, the battery charging protection control method is executed as follows.

If a conventional charging or a quick charging is performed on the battery in the electronic device, the power adapter first determines whether an output voltage is greater than a voltage threshold, and determines whether an output current is greater than a current threshold.

If the power adapter determines that the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, the power adapter sends a first charging stop command to the charging control circuit and switches off direct current output automatically, and

charging control circuit drives the controller to switch off the communication interface of the electronic device according to the first charging stop command.

If the power adapter determines that the output voltage is not greater than the voltage threshold and the output current is not greater than the current threshold, the power adapter feeds back output voltage information and output current information to the charging control circuit.

The charging control circuit determines whether the output voltage of the power adapter is greater than the voltage threshold and whether the output current of the power adapter is greater than the current threshold according to the output voltage information and the output current information.

If the charging control circuit determines that the output voltage of the power adapter is greater than the voltage threshold and/or the output current of the power adapter is greater than the current threshold, the charging control circuit feeds back a second charging stop command to the power adapter and drives the controller to switch off the communication interface of the electronic device, and

the power adapter switches off the direct current output according to the second charging stop command.

If the charging control circuit determines that the output voltage of the power adapter is not greater than the voltage threshold and the output current of the power adapter is not greater than the current threshold, the power adaptor continues to determine whether the output voltage is greater

than the voltage threshold and whether the output current is greater than the current threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic block diagram of a battery charging apparatus provided by an exemplary embodiment of this disclosure.

FIG. **2** shows a flow chart for realizing a battery charging protection control method based on the battery charging apparatus shown in FIG. **1**.

FIG. **3** shows a schematic block diagram of a power adapter in the battery charging apparatus shown in FIG. **1**.

FIG. **4** shows an exemplary circuit of the power adapter shown in FIG. **3**.

FIG. **5** shows an exemplary circuit of a charging control circuit in the battery charging apparatus shown in FIG. **1**.

FIG. **6** shows another exemplary circuit of a charging control circuit in the battery charging apparatus shown in FIG. **1**.

DETAILED DESCRIPTION

In order to make the objectives, the technical solutions and the advantages of the present disclosure more clear, further explanations on this disclosure are given below in details with reference to figures and exemplary embodiments. It is to be understood that, the exemplary embodiments described herein are merely used to explain the disclosure, rather than to limit this disclosure.

FIG. **1** shows a schematic block diagram of a battery charging apparatus provided by an exemplary embodiment of this disclosure. For description, only parts related to the exemplary embodiment of this disclosure are shown, and detailed description thereof is as follows.

The battery charging apparatus provided by the exemplary embodiment of this disclosure includes a power adapter **100** and a charging control circuit **200**, the charging control circuit **200** is built in an electronic device and coupled to a controller **300** and a battery **400** in the electronic device, the power adapter **200** is coupled to a communication interface **20** of the electronic device via the communication interface **10** thereof, the battery **400** is charged by the power adapter **100** via the communication interface **20** of the electronic device, and the charging control circuit **200** performs data communication with the power adapter **100** via the communication interface **20** of the electronic device.

If a conventional charging or a quick charging is performed on the battery **400**, the power adapter **100** first determines whether an output voltage is greater than a voltage threshold and whether an output current is greater than a current threshold, if the output voltage of the power adapter **100** is greater than the voltage threshold and/or the output current of the power adapter **100** is greater than the current threshold, the power adapter **100** sends a first charging stop command to the charging control circuit **200** and switches off the direct current automatically, the charging control circuit **200** drives the controller **300** to switch off the communication interface **20** of the electronic device according to the first charging stop command; if the output voltage of the power adapter **100** is not greater than the voltage threshold, and the output current of the power adapter **100** is not greater than the current threshold, the power adapter **100** feeds back output voltage information and output current information to the charging control circuit **200**, if the charging control circuit **200** determines that the output voltage of the power adapter **100** is greater than the voltage threshold and/or the output current of the power adapter **100** is greater than the current threshold according to the output voltage information and the output current information, the charging control circuit **200** feeds back a second charging stop command to the power adapter **100** and drives the controller **300** to switch off the communication interface **20** of the electronic device, and the power adapter **100** switches off the direct current output according to the second charging stop command; and if the charging control circuit **200** determines that the output voltage of the power adapter **100** is not greater than the voltage threshold and the output current of the power adapter **100** is not greater than the current threshold according to the output voltage information and the output current information, the power adapter **100** continues to determine the output voltage and the output current.

Based on the battery charging apparatus shown in FIG. **1**, the present disclosure further provides a battery charging protection control method, as shown in FIG. **2**, the battery charging protection control method includes following blocks.

In block S**1**, if a conventional charging or a quick charging is performed on the battery **400** in the electronic device, the power adapter **100** first determines whether an output voltage is greater than a voltage threshold, and determines whether an output current is greater than a current threshold. If the power adapter **100** determines that the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, block S**2** is executed, and if the power adapter **100** determines that the output voltage is not greater than the voltage threshold and the output current is not greater than the current threshold, block S**4** is executed.

In block S**2**, the power adapter **100** sends a first charging stop command to the charging control circuit **200** and switches off the direct current output automatically.

In block S**3**, the charging control circuit **200** drives the controller **300** to switch off the communication interface **20** of the electronic device according to the first charging stop command.

In block S**4**, the power adapter **100** feeds back output voltage information and output current information to the charging control circuit **200**.

In block S**5**, the charging control circuit **200** determines whether the output voltage of the power adapter **100** is greater than the voltage threshold and whether the output current of the power adapter **100** is greater than the current threshold according to the output voltage information and the output current information. If the charging control circuit **200** determines that the output voltage of the power adapter **100** is greater than the voltage threshold and/or the output current of the power adapter **100** is greater than the current threshold, block S**6** is executed, and if the charging control circuit **200** determines that the output voltage of the power adapter **100** is not greater than the voltage threshold and the output current of the power adapter **100** is not greater than the current threshold, block S**1** is executed.

In block S**6**, the charging control circuit **200** feeds back a second charging stop command to the power adapter **100** and drives the controller **300** to switch off the communication interface **20** of the electronic device.

In block S**7**, the power adapter **100** switches off the direct current output according to the second charging stop command.

The voltage threshold and the current threshold are a preset maximum voltage value and a preset maximum current value respectively.

Further, in at least one embodiment, block S4 is executed as follows.

The charging control circuit **200** sends a charging parameter acquiring request to the power adapter **100**.

The power adapter **100** feeds back the output voltage information and the output current information to the charging control circuit **200** according to the charging parameter acquiring request.

When a quick charging is performed on the battery **400**, since the charging control circuit **200** will introduce the direct current from the power adapter **100** to charge the battery **400** so as to increase charging current on the battery for realizing a quick charging on the battery, the charging control circuit **200** also needs to stop introducing the direct current from the power adapter **100** in addition to driving the controller **300** to switch off the communication interface **20** of the electronic device if overvoltage and/or overcurrent occur on the output of the power adapter **100**. Therefore, block S3 is specifically performed as follows.

The charging control circuit **200** stops introducing the direct current from the power adapter **100** to charge the battery **400**, and drives the controller **300** to switch off the communication interface **20** of the electronic device, according to the first charging stop command.

In at least one embodiment, block S4 is executed as follows.

The charging control circuit **200** feeds back the second charging stop command to the power adapter **100**.

The charging control circuit **200** stops introducing the direct current from the power adapter **100** to charge the battery **400**, and drives the controller **300** to switch off the communication interface **20** of the electronic device.

For the battery charging apparatus realizing the battery charging protection control method, FIG. **3** shows a schematic block diagram thereof. For description, it only shows the parts related to the exemplary embodiment of this disclosure, which is detailed as follows.

The power adapter **100** includes an EMI filter circuit **101**, a high-voltage rectifier and filter circuit **102**, an isolation transformer **103**, an output filter circuit **104**, and a voltage tracking and control circuit **105**; after—an electromagnetic interference filter is performed by the EMI filter circuit on mains supply, a rectifying and filtering process is performed by the high-voltage rectifier and filter circuit for outputting a high-voltage direct current, the high-voltage direct current is output to the output filter circuit after an electrical isolation through the isolation transformer so as to charge the battery after a filtering process, the voltage tracking and control circuit regulates an output voltage of the isolation transformer according to an output voltage of the output filter circuit.

The power adapter **100** further includes a power circuit **106**, a main control circuit **107**, a potential regulation circuit **108**, a current detection circuit **109**, a voltage detection circuit **110** and an output switch circuit **111**.

An input terminal of the power circuit **106** is coupled to a secondary terminal of the isolation transformer **103**; a power terminal of the main control circuit **107**, a power terminal of the potential regulation circuit **108**, and a power terminal of the current detection circuit **109** are jointly coupled to an output terminal of the power circuit **108**, a high-potential terminal of the main control circuit **107** and a high-potential terminal of the potential regulation circuit **108** are both coupled to a positive output terminal of the output filter circuit **104**, a potential regulation terminal of the potential regulation circuit **108** is coupled to the voltage tracking and control circuit **105**; a direct current input terminal of the current detection circuit **109** is coupled to a positive output terminal of the output filter circuit **104**; a current detection feedback terminal of the current detection circuit **109** is coupled to a current detection terminal of the main control circuit **107**; a clock output terminal and a data output terminal of the main control circuit **107** are coupled to a clock input terminal and a data input terminal of the potential regulation circuit **108**; a first detection terminal and a second detection terminal of the voltage detection circuit **110** are coupled to a direct current output terminal of the current detection circuit **109** and a negative output terminal of the output filter circuit **104** respectively, a first output terminal and a second output terminal of the voltage detection circuit **110** are coupled to a first voltage detection terminal and a second voltage detection terminal of the main control circuit **107** respectively; an input terminal of the output switch circuit **111** is coupled to the direct current output terminal of the current detection circuit **109**; an output terminal of the output switch circuit **111** is coupled to a third detection terminal of the voltage detection circuit **110**; a ground terminal of the output switch circuit **111** is coupled to a negative output terminal of the output filter circuit **104**; a controlled terminal and a power terminal of the output switch circuit **111** are coupled to a switch control terminal of the main control circuit **107** and the secondary terminal of the isolation transformer **103** respectively; each of a negative output terminal of the output filter circuit **104**, the output terminal of the output switch circuit **111**, and a first communication terminal and a second communication terminal of the main control circuit **107** is coupled to the communication interface **10** of the power adapter **100**.

The power circuit **106** obtains power from the isolation transformer **103** and provides power to the main control circuit **107**, the potential regulation circuit **108**, and the current detection circuit **109**; when a quick charging is performed on the battery **400** in the electronic device, the potential regulation circuit **108** drives the voltage tracking and control circuit **105** to regulate the output voltage of the isolation transformer **103** according to a control signal sent by the main control circuit **107** so as to perform the quick charging on the battery; the current detection circuit **109** and the voltage detection circuit **110** respectively detects the output current and the output voltage of the power adapter **100**, and correspondingly feeds back a current detection signal and a voltage detection signal to the main control circuit **107**; the output switch circuit **111** switches on or off the direct current output of the power adapter **100** according to a switch control signal sent by the main control circuit **107**.

When a conventional charging or a quick charging is performed on the battery **400**, the main control circuit **107** determines whether the output current of the power adapter **100** is greater than the current threshold according to the current detection signal, and determines whether the output voltage of the power adapter **100** is greater than the voltage threshold according to the voltage detection signal, if the output voltage of the power adapter **100** is greater than the voltage threshold and/or the output current of the power adapter **100** is greater than the current threshold, the main control circuit **107** sends the first charging stop command to the charging control circuit **200** and controls the output switch circuit **111** to switch off the direct current output of the power adapter **100**, and the charging control circuit **200** drives the controller **300** to switch off the communication

interface **20** of the electronic device according to the first charging stop command; if the output voltage of the power adapter **100** is not greater than the voltage threshold, and the output current of the power adapter **100** is not greater than the current threshold, the main control circuit **107** feeds back the output voltage information and the output current information to the charging control circuit **200** according to the voltage detection signal and the current detection signal, the charging control circuit **200** determines whether the output voltage of the power adapter **100** is greater than the voltage threshold and whether the output current of the power adapter **100** is greater than the current threshold according to the output voltage information and the output current information, if the output voltage of the power adapter **100** is greater than the voltage threshold and/or the output current of the power adapter **100** is greater than the current threshold, the charging control circuit **200** feeds back the second charging stop command to the main control circuit **107** and drives the controller **300** to switch off the communication interface **20** of the electronic device, and the main control circuit **107** controls the output switch circuit **111** to switch off the direct current output of the power adapter **100** according to the second charging stop command.

In at least one embodiment, the main control circuit **107** feeds back the output voltage information and the output current information to the charging control circuit **200** according to the voltage detection signal and the current detection signal as follows.

The charging control circuit **200** sends a charging parameter acquiring request to the main control circuit **107**, and the main control circuit **107** feeds back the output voltage information and the output current information to the charging control circuit **200** according to the charging parameter acquiring request.

When a quick charging is performed on the battery **400**, since the charging control circuit **200** will introduce the direct current from the power adapter **100** to charge the battery **400** so as to increase charging current on the battery for realizing a quick charging on the battery, the charging control circuit **200** also needs to stop introducing the direct current from the power adapter **100** in addition to driving the controller **300** to switch off the communication interface **20** of the electronic device if overvoltage and/or overcurrent occur on the output of the power adapter **100**. Therefore, the charging control circuit **200** specifically drives the controller **300** to switch off the communication interface **20** of the electronic device according to the first charging stop command as follows.

The charging control circuit **200** stops introducing the direct current from the power adapter **100** to charge the battery **400**, and drives the controller **300** to switch off the communication interface **20** of the electronic device, according to the first charging stop command.

In at least one embodiment, the charging control circuit **200** feeds back the second charging stop command to the main control circuit **107** as follows.

The charging control circuit **200** feeds back the second charging stop command to the main control circuit **107**; the charging control circuit **200** stops introducing the direct current from the power adapter **100** to charge the battery **400**, and drives the controller **300** to switch off the communication interface **20** of the electronic device.

FIG. **4** shows an exemplary circuit of the power adapter **100**. For description, it only shows the parts related to the exemplary embodiment of this disclosure, which is detailed as follows.

The power circuit **106** includes: a first capacitor C**1**, a voltage stabilizing chip U**1**, a second capacitor C**2**, a first inductor L**1**, a second inductor L**2**, a first diode D**1**, a second diode D**2**, a third capacitor C**3**, a first resistor R**1** and a second resistor R**2**.

A junction of a first terminal of the first capacitor C**1**, and an input power pin Vin and an enable pin EN of the voltage stabilizing chip U**1** is configured as the input terminal of the power circuit **106**, a second terminal of the first capacitor C**1** and a ground pin GND of the voltage stabilizing chip U**1** are jointly grounded, a switch pin SW of the voltage stabilizing chip U**1** and a first terminal of the second capacitor C**2** are jointly coupled to a first terminal of first inductor L**1**, an internal switch pin BOOST of the voltage stabilizing chip U**1** and a second terminal of the second capacitor C**2** are jointly coupled to a cathode of the first diode D**1**, an voltage feedback pin FB of the voltage stabilizing chip U**1** is coupled to a first terminal of the first resistor R**1** and a first terminal of the second resistor R**2**, a second terminal of the first inductor L**1** and a cathode of the second diode D**2** are jointly coupled to a first terminal of the second inductor L**2**, a junction of a second terminal of the second inductor L**2**, an anode of the first diode D**1**, the second terminal of the first resistor R**1** and a first terminal of the third capacitor C**3** is configured as the output terminal of the power circuit **106**, an anode of the second diode D**2**, a second terminal of the second resistor R**2** and a second terminal of the third capacitor C**3** are jointly grounded. In at least one embodiment, the power circuit **106** performs the voltage conversion processing on the voltage at the secondary terminal of the isolation transformer **103** by using voltage stabilizing chip U**1** as the core, and outputs +3.3V voltage for supplying power to the main control circuit **107**, the potential regulation circuit **108** and the current detection circuit **109**. In at least one embodiment, the voltage stabilizing chip U**1** may specifically be an CP16301 buck DC/DC converter.

The main control circuit **107** includes: a main control chip U**2**, a third resistor R**3**, a reference voltage chip U**3**, a fourth resistor R**4**, a fifth resistor R**5**, a fourth capacitor C**4**, a sixth resistor R**6**, a seventh resistor R**7**, a first NMOS transistor Q**1**, an eighth resistor R**8**, a ninth resistor R**9**, a tenth resistor R**10**, an eleventh resistor R**11**, a twelfth resistor R**12**, a thirteenth resistor R**13** and a fourteenth resistor R**14**.

A power pin VDD of the main control chip U**3** is configured as the power terminal of the main control circuit **107**, a ground pin VSS of the main control chip U**3** is grounded, a first input/output pin RA**0** of the main control chip U**3** is suspended, a first terminal of the third resistor R**3** is coupled to the power pin VDD of the main control chip U**3**, a second terminal of the third resistor R**3** and a first terminal of the fourth resistor R**4** are jointly coupled to a positive pole CATHODE of the reference voltage chip U**3**, a negative pole ANODE of the reference voltage chip U**3** is grounded, a vacant pin NC of the reference voltage chip U**3** is suspended, a second terminal of the fourth resistor R**4** is coupled to a second input/output pin RA**1** of the main control chip U**2**, a third input/output pin RA**2** of the main control chip U**2** is configured as the current detection terminal of the main control circuit **107**, a fourth input/output pin RA**3** of the main control chip U**2** is coupled to a first terminal of fifth resistor R**5**, a second terminal of the fifth resistor R**5** and a first terminal of the fourth capacitor C**4** are jointly coupled to the power pin VDD of the main control chip U**2**. A second terminal of the fourth capacitor C**4** is grounded. A fifth input/output pin RA**4** of the main control chip U**2** is configured as the switch control terminal of the main control circuit **107**. A sixth input/output pin RA**5**

of the main control chip U2 is coupled to a first terminal of the sixth resistor R6. A second terminal of the sixth resistor R6 and a gate electrode of the first NMOS transistor Q1 are jointly coupled to a first terminal of seventh resistor R7. A second terminal of the seventh resistor R7 and a source electrode of a first NMOS transistor Q1 are jointly grounded. A drain electrode of the first NMOS transistor Q1 is coupled to a first terminal of the eighth resistor R8. A second terminal of the eighth resistor R8 is configured as the high-potential terminal of the main control circuit **107**. A seventh input/output pin RC0 and an eighth input/output pin RC1 of the main control chip U2 are configured as the clock output terminal and the data output terminal of the main control circuit **107** respectively. A tenth input/output pin RC3 and a ninth input/output pin RC2 of the main control chip U2 are configured as the first voltage detection terminal and the second voltage detection terminal of the main control circuit **107** respectively. An eleventh input/output pin RC4 and a twelfth **12** input/output pin RC5 of the main control chip U2 are coupled to a first terminal of the ninth resistor R9 and a first terminal of the tenth resistor R10 respectively. A first terminal of an eleventh resistor R11 and a first terminal of the twelfth resistor R12 are coupled to a second terminal of the ninth resistor R9 and a second terminal of the tenth resistor R10 respectively. A second terminal of the eleventh resistor R11 and a second terminal of the twelfth resistor R12 are jointly grounded. A first terminal of the thirteenth resistor R13 and a first terminal of the fourteenth resistor R14 are coupled to a second terminal of the ninth resistor R9 and the second terminal of tenth resistor R10 respectively. A second terminal of the thirteenth resistor R13 and a second terminal of the fourteenth resistor R14 are jointly coupled to the power pin VDD of the main control chip U2. The second terminal of ninth resistor R9 and the second terminal of the tenth resistor R10 are configured as the first communication terminal and the second communication terminal of the main control circuit **107** respectively. In particular, the main control chip U2 may be a PIC12LF1822, PIC12F1822, PIC16LF1823 or PIC16F1823 single chip microcomputer, and reference voltage chip U3 may be an LM4040 voltage reference device.

The potential regulation circuit **108** includes: a fifteenth resistor R15, a sixteenth resistor R16, a digital potentiometer U4, a seventeenth resistor R17, an eighteenth resistor R18, a fifth capacitor C5, a sixth capacitor C6 and a nineteenth resistor R19.

A junction of a first terminal of fifteenth resistor R15, a first terminal of sixteenth resistor R16, a power pin VDD of the digital potentiometer U4 and a first terminal of the fifth capacitor C5 is configured as the power terminal of the potential regulation circuit **108**. A second terminal of the fifth capacitor C5, a first terminal of the sixth capacitor C6, a ground pin VSS of the digital potentiometer U4 and a first terminal of the seventeenth resistor R17 are jointly grounded. A second terminal of the sixth capacitor C6 is coupled to the power pin VDD of the digital potentiometer U4. A junction of a second terminal of the fifteenth resistor R15 and a serial data pin SDA of the digital potentiometer U4 is configured as the data input terminal of the potential regulation circuit **108**. A junction of a second terminal of the sixteenth resistor R16 and a clock input pin SCL of the digital potentiometer U4 is configured as the clock input terminal of the potential regulation circuit **108**. An address zero pin A0 of the digital potentiometer U4 is grounded. A first potential wiring pin P0A of the digital potentiometer U4 and a first terminal of eighteenth resistor R18 are jointly coupled to a second terminal of the seventeenth resistor R17. A second terminal of the eighteenth resistor R18 and a second potential wiring pin P0B of the digital potentiometer U4 are jointly coupled to a first terminal of nineteenth resistor R19. A second terminal of the nineteenth resistor R19 is configured as the high-potential terminal of the potential regulation circuit **108**. A potential tap pin P0W of digital potentiometer U4 is configured as the potential regulation terminal of the potential regulation circuit **108**. In at least one embodiment, the digital potentiometer U4 adjusts an internal slide rheostat according to the clock signal and the data signal output from the main control chip U2 so as to change the potential at the tap terminal of the internal slide rheostat (i.e., the potential tap pin P0W of the digital potentiometer U4), such that the voltage tracking and control circuit **104** adjusts the output voltage of the isolation transformer **103** by following the potential change. In at least one embodiment, the digital potentiometer U4 may be an MCP45X1 digital potentiometer.

The current detection circuit **109** includes: a twentieth resistor R20, a twenty-first resistor R21, a twenty-second resistor R22, a seventh capacitor C7, an eighth capacitor C8, a current detection chip U5, a twenty-third resistor R23, a ninth capacitor C9, a tenth capacitor C10 and a twenty-fourth resistor R24.

A first terminal and a second terminal of twentieth resistor R20 are configured as the direct current input terminal and the direct current output terminal of current detection circuit **109** respectively, a first terminal of the twenty-first resistor R21 and a first terminal of the twenty-second resistor R22 are coupled to the first terminal and the second terminal of twentieth resistor R20 respectively, a second terminal of the twenty-first resistor R21 and a first terminal of seventh capacitor C7 are jointly coupled to a positive input pin IN+ of the current detection chip U5, a second terminal of the twenty-second resistor R22 and a first terminal of the eighth capacitor C8 are jointly coupled to a negative input pin IN− of the current detection chip U5, a junction of a power pin V+ of the current detection chip U5 and a first terminal of the ninth capacitor C9 is configured as the power terminal of the current detection circuit **109**, a vacant pin NC of the current detection chip U5 is suspended, an output pin OUT of the current detection chip U5 is coupled to a first terminal of the twenty-third resistor R23, a second terminal of the twenty-third resistor R23 is configured as the current detection feedback terminal of the current detection circuit **109**, a first terminal of the tenth capacitor C10 and a first terminal of the twenty-fourth resistor R24 are jointly coupled to the second terminal of the twenty-third resistor R23, a second terminal of the seventh capacitor C7, a second terminal of the eighth capacitor C8, a second terminal of the ninth capacitor C9, a second terminal of the tenth capacitor C10, a second terminal of the twenty-fourth resistor R24, and a ground pin GND, a first reference voltage pin REF1 and a second reference voltage pin REF2 of the current detection chip U5 are jointly grounded. The twentieth resistor R20, as a current detection resistor, samples the output current of the output filter circuit **104** (i.e., the output current of the power adapter **100**). Then, the current detection chip U5 outputs a current detection signal to the main control chip U2 according to the voltage across two terminals of the twentieth resistor R20, in which the current detection chip U5 may specifically be an INA286 current shunt monitor.

The voltage detection circuit **110** includes: a twenty-fifth resistor R25, a twenty-sixth resistor R26, an eleventh capacitor C11, a twelfth capacitor C12, a twenty-seventh resistor R27 and a twenty-eighth resistor R28.

A first terminal of the twenty-fifth resistor R25 is configured as the first detection terminal of the voltage detection circuit **110**, a junction of a second terminal of the twenty-fifth resistor R25, a first terminal of the twenty-sixth resistor R26 and a first terminal of the eleventh capacitor C11 is configured as the second output terminal of the voltage detection circuit **110**, a second terminal of the twenty-sixth resistor R26 is configured as the second detection terminal of the voltage detection circuit **110**, a second terminal of eleventh capacitor C11, a first terminal of the twelfth capacitor C12 and a first terminal of the twenty-seventh resistor R27 are jointly coupled to a second terminal of the twenty-sixth resistor R26, a junction of a second terminal of the twelfth capacitor C12, a second terminal of the twenty-seventh resistor R27 and a first terminal of the twenty-eighth resistor R28 is configured as the first output terminal of the voltage detection circuit **110**, and a second terminal of the twenty-eighth resistor R28 is configured as the third detection terminal of voltage detection circuit **110**.

The output switch circuit **111** includes: a twenty-ninth resistor R29, a thirtieth resistor R30, a thirteenth capacitor C13, a thirty-first resistor R31, a first NPN triode N1, a thirty-second resistor R32, a second NPN triode N2, a third diode D3, a voltage stabilizing diode ZD, a thirty-third resistor R33, a thirty-fourth resistor R34, a thirty-fifth resistor R35, a second NMOS transistor Q2 and a third NMOS transistor Q3.

A first terminal of the twenty-ninth resistor R29 is configured as the controlled terminal of the output switch circuit **111**, a second terminal of the twenty-ninth resistor R29 and a first terminal of the thirtieth resistor R30 are jointly coupled to a base electrode of the first NPN triode N1, a first terminal of the thirteenth capacitor C13, a first terminal of the thirty-first resistor R31 and a first terminal of the thirty-second resistor R32 are jointly coupled to a cathode of the third diode D3, an anode of the third diode D3 is configured as the power terminal of the output switch circuit **111**, a second terminal of the thirty-first resistor R31 and a base electrode of the second NPN triode N2 are jointly coupled to a collector electrode of the first NPN triode N1, a second terminal of the thirty-second resistor R32, a cathode of the voltage stabilizing diode ZD and a first terminal of the thirty-third resistor R33 are jointly coupled to a collector electrode of the second NPN triode N2, a second terminal of the thirtieth resistor R30, a 15 second terminal of the thirteenth capacitor C13, an emitter electrode of the first NPN triode N1, an emitter electrode of the second NPN triode N2 and an anode of the voltage stabilizing diode ZD are jointly grounded, a second terminal of the thirty-third resistor R33 is coupled to a first terminal of the thirty-fourth resistor R34, a first terminal of the thirty-fifth resistor R35, a gate electrode of the second NMOS transistor Q2 and a gate electrode of the third NMOS transistor Q3, a second terminal of thirty-fourth resistor R34 is configured as the ground terminal of output switch circuit **111**, a drain electrode of the second NMOS transistor Q2 is configured as the input terminal of the output switch circuit **111**, and a source electrode of the second NMOS transistor Q2 and a second terminal of the thirty-fifth resistor R35 are jointly coupled to a source electrode of the third NMOS transistor Q3, a drain electrode of third NMOS transistor Q3 is configured as the output terminal of output switch circuit **111**. Specifically, the second NMOS transistor Q2 and the third NMOS transistor Q3 are simultaneously switched on or off so as to switch on or off the direct current output of the power adapter **100**.

FIG. **5** shows an exemplary circuit of the charging control circuit **200**. For illustration, it only shows parts related to the exemplary embodiment of this disclosure, which is detailed as follows.

The charging control circuit **200** includes: a battery connector J1, a main controller U6, a thirteenth sixteenth capacitor C16, a thirty-sixth resistor R36, a thirty-seventh resistor R37, a fourteenth capacitor C14, a first Schottky diode SD1, a second Schottky diode SD2, a fifteenth capacitor C15, a thirty-eighth resistor R38, a thirty-ninth resistor R39, a fortieth resistor R40, a third NPN triode N3, a fourth NMOS transistor Q4 and a fifth NMOS transistor Q5.

The battery connector J1 is coupled to multiple electrodes of the battery **300**, a first pin 5A-1 and a second pin 5A-2 of the battery connector J1 are jointly grounded, a first ground pin GND1 and a second ground pin GND2 of the battery connector J1 are jointly grounded, a first input/output pin RAO of the main controller U6 is coupled to a seventh pin 5A-3 and an eighth pin 5A-4 of the battery connector J1, a second input/output pin RA1, a seventh input/output pin RC0, an eighth input/output pin RC1 and a ninth input/output pin RC2 of the main controller U6 are coupled to a sixth pin 2A-4, a fifth pin 2A-3, a fourth pin 2A-2 and a third pin 2A-1 of the battery connector J1 respectively, an analog ground pin VSS and a ground pin GND of the main controller U6 are both grounded, a first vacant pin NC0 and a second vacant pin NC1 of the main controller U6 are suspended, a power pin VDD of the main controller U6 and a first terminal of sixteenth capacitor C16 are both coupled to the seventh pin 5A-3 and the eighth pin 5A-4 of the battery connector J1, a fourth input/output pin RA3 and an eleventh input/output pin RC4 of the main controller U6 are configured to perform data communication with the controller **300** in the electronic device, the thirty-sixth resistor R36 is coupled between the fourth input/output pin RA3 and the power pin VDD of the main controller U6, a sixth input/output pin RA5 and a twelfth input/output pin RC5 of the main controller U6 are coupled to the first communication terminal and the second communication terminal of the main control circuit **107** in power adapter **100** respectively, a first terminal of the thirty-seventh resistor R37 and a first terminal of the thirty-eighth resistor R38 are jointly coupled to a tenth input/output terminal RC3 of the main controller U6, a second terminal of the thirty-seventh resistor R37 is coupled to the power pin VDD of the main controller U6, a second terminal of the thirty-eighth resistor R38 is coupled to a base electrode of the third NPN triode N3, a fifth input/output terminal RA4 of the main controller U6 is coupled to a first terminal of the fourteenth capacitor C14, a second terminal of the fourteenth capacitor C14 and a cathode of the first Schottky diode SD1 are jointly coupled to an anode of the second Schottky diode SD2, a first terminal of the thirty-ninth resistor R39 and a first terminal of the fifteenth capacitor C15 are jointly coupled to a cathode of the second Schottky diode SD2, each of a second terminal of the thirty-ninth resistor R39, a first terminal of the fortieth resistor R40 and a collector electrode of third NPN triode N3 is coupled to a gate electrode of the fourth NMOS transistor Q4 and a gate electrode of the fifth NMOS transistor Q5, a second terminal of fortieth resistor R40 and a second terminal of the fifteenth capacitor C15 are jointly grounded, a source electrode of the fourth NMOS transistor Q4 is coupled to an anode of first Schottky diode SD1 and is also coupled to the seventh pin 5A-3 and the eighth pin 5A-4 of the battery connector J1, a drain electrode of the fourth NMOS transistor Q4 is coupled to a drain electrode of the fifth NMOS transistor Q5, a source electrode of the

fifth NMOS transistor Q5 is coupled to a power line VBUS of the communication interface **20** of the electronic device **3**, an emitter electrode of the third NPN triode N**3** is coupled to an anode of third Schottky diode SD**3**, and a cathode of the third Schottky diode SD**3** is grounded. The main controller U**6** may specifically be a PIC12LF1501, PIC12F1501, PIC16LF1503, PIC16F1503, PIC16LF1507, PIC16F1507, PIC16LF1508, PIC16F1508, PIC16LF1509 or PIC16F1509 single chip microcomputer.

When a quick charging is performed on the battery **400**, the main controller U**6** outputs a high level via its fifth input/output pin RA**4** for driving the fourth NMOS transistor Q**4** and the fifth NMOS transistor Q**5** to switch on, and controls the third NPN triode N**3** to switch off by outputting a low level via its tenth input/output pin RC**3**. As the battery **400** itself already obtains direct current from the power adapter **100** via the communication interface **20** of the electronic device, the direct current introduced by the fourth NMOS transistor Q**4** and the fifth NMOS transistor Q**5** can further increase the current charging the battery **400**, thus enabling the quick charging to the battery **400**. In contrast, when a conventional charge is needed for battery **400**, or the communication interface **20** of the electronic device needs to be switched off due to the overvoltage and/or overcurrent phenomenon occurring in the output of the power adapter **100**, the main controller U**6** controls the fourth NMOS transistor Q**4** and the fifth NMOS transistor Q**5** to turn off by outputting the low level via its fifth input/output pin RA**4**, and controls the third NPN triode N**3** to turn on by outputting the high level via its tenth input/output pin RC**3**.

In addition, the main controller U**6** performs the data communication with the electronic device via its fourth input/output Pin RA**3** and eleventh input/output Pin RC**4**. The main controller U**6** can transmit the voltage and electric quantity information of the battery **400** to the controller **300** of the electronic device, and can also determine whether the quick charging process for the battery **400** has been completed according to the voltage of battery **400**. If the quick charging process for the battery **400** has been completed, the main controller U**6** may feed back a quick charging stop command to notify the electronic device to switch to the conventional charge mode from the quick charging mode. During the process of charging the battery **400** by the power adapter **100**, if the power adapter **100** is disconnected suddenly from the battery **400**, the main controller U**6** detects the voltage of the battery **400** via the battery connector J**1**, and feeds back a charging termination command to notify the controller **300** to switch off the communication interface **20** of the electronic device, so as to terminate the charge process for the battery **400**. In addition, if the electronic device can detect the temperature of the battery **400**, the controller **300** of the electronic device may, in the case of abnormal temperature, inform the main controller U**6** to switch off the fourth NMOS transistor Q**4** and the fifth NMOS transistor Q**5** for stopping the quick charging to the battery **400**, and meanwhile the electronic device may switch to the conventional charge mode from the quick charging mode.

Further, when the quick charging is performed on the battery **400**, if the power line VBUS and the ground line GND of the communication interface **10** of the power adapter **100** are coupled to the ground line GND and the power line VBUS of the communication interface **20** of the electronic device respectively (i.e., the power line VBUS and the ground line GND of the communication interface **10** of power adapter **100** are coupled to the ground terminal of the charging control circuit **200** and the source electrode of the fifth NMOS transistor Q**5** respectively), which means that the communication interface **10** of the power adapter **100** is reversely coupled to the communication interface **20** of the electronic device, direct current is coupled to the ground terminal of charging control circuit **200**, and the source electrode of fifth NMOS transistor Q**5** is grounded. In order to prevent any damage to the components, as shown in FIG. **6**, the charging control circuit **200** may further include a sixth NMOS transistor Q**6**, a seventh NMOS transistor Q**7** and a forty-first resistor R**41**. A source electrode of the sixth NMOS transistor Q**6** is coupled to a source electrode of the fifth NMOS transistor Q**5**. A drain electrode of the sixth NMOS transistor Q**6** is coupled to a drain electrode of the seventh NMOS transistor Q**7**. A source electrode of the seventh NMOS transistor Q**7** is coupled to the collector electrode of the third NPN triode N**3**. A gate electrode of the sixth NMOS transistor Q**6** and a gate electrode of the seventh NMOS transistor Q**7** are jointly coupled to a first terminal of the forty-first resistor R**41**. A second terminal of the forty-first resistor R**41** is grounded.

In the case of the above reverse connection, direct current is coupled to the second terminal of the forty-first resistor R**41** via the ground for driving the sixth NMOS transistor Q**6** and the seventh NMOS transistor Q**7** to switch off, which prevents the direct current that flows into the charging control circuit **200** from the ground from forming a loop, thereby protecting components in the charging control circuit **200** from any damage.

In summary, embodiments of the present disclosure adopts the battery charging apparatus including the power adapter **100** and the charging control circuit **200** to perform a charging control on the battery **400** in the electronic device. In a process of a conventional charging or a quick charging on the battery **400**, the power adapter **100** performs a data communication with the charging control circuit **200**, and when the power adapter **100** determines that overvoltage and/or overcurrent occurs in the direct current output via the communication interface **10** of the power adapter **100**, the power adapter **100** notifies the charging control circuit **200** to drive the controller **300** in the electronic device to switch off the communication interface **20** of the electronic device and switches off the direct current output automatically; when the charging control circuit **200** determines that overvoltage and/or overcurrent occurs upon receiving output voltage and output current of the power adapter **100**, the charging control circuit **200** notifies the power adapter **100** to switch off the direct current output and drives the controller **300** in the electronic device to switch off the communication interface **20** of the electronic device. In this way, overvoltage and/or overcurrent protection of the battery **400** is achieved when overvoltage and/or overcurrent output occurs at the communication interface **10** of the power adapter **100**.

The above descriptions are merely preferred exemplary embodiments of the disclosure, and not intended to limit the scope of the disclosure. Any modifications, equivalent substitutions and improvements made within the spirit and principles of the disclosure shall fall in the protection scope of the disclosure.

What is claimed is:

1. A battery charging apparatus, comprising a power adapter and a charging control circuit, wherein, the charging control circuit is built in an electronic device and coupled to a controller and a battery in the electronic device, the power adapter is coupled to a communication interface of the electronic device via a communication interface thereof, the battery is charged by the power adapter via the communi-

cation interface of the electronic device, and the charging control circuit performs data communication with the power adapter via the communication interface of the electronic device;

if a conventional charging or a quick charging is performed on the battery, the power adapter first determines whether an output voltage is greater than a voltage threshold and whether an output current is greater than a current threshold, if the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, the power adapter sends a first charging stop command to the charging control circuit and automatically switches off direct current output, the charging control circuit drives the controller to switch off the communication interface of the electronic device according to the first charging stop command; if the output voltage is not greater than the voltage threshold, and the output current is not greater than the current threshold, the power adapter feeds back output voltage information and output current information to the charging control circuit, if the charging control circuit determines that the output voltage of the power adapter is greater than the voltage threshold and/or the output current of the power adapter is greater than the current threshold according to the output voltage information and the output current information, the charging control circuit feeds back a second charging stop command to the power adapter and drives the controller to switch off the communication interface of the electronic device, and the power adapter switches off the direct current output according to the second charging stop command; and if the charging control circuit determines that the output voltage of the power adapter is not greater than the voltage threshold and the output current of the power adapter is not greater than the current threshold according to the output voltage information and the output current information, the power adapter continues to determine the output voltage and the output current,

wherein, the power adapter comprises an EMI filter circuit, a high-voltage rectifier and filter circuit, an isolation transformer, an output filter circuit, and a voltage tracking and control circuit;

the EMI filter circuit is configured to perform an electromagnetic interference filter on mains supply, the high-voltage rectifier and filter circuit is configured to perform a rectifying and filtering process for outputting a high-voltage direct current, the isolation transformer is configured to perform an electrical isolation on the high-voltage direct current, the output filter circuit is configured to perform a filtering process on an output voltage of the isolation transformer so as to charge the battery, the voltage tracking and control circuit is configured to regulate the output voltage of the isolation transformer according to an output voltage of the output filter circuit;

the power adapter further comprises a power circuit, a main control circuit, a potential regulation circuit, a current detection circuit, a voltage detection circuit and an output switch circuit:

an input terminal of the power circuit is coupled to a secondary terminal of the isolation transformer; a power terminal of the main control circuit, a power terminal of the potential regulation circuit, and a power terminal of the current detection circuit are jointly coupled to an output terminal of the power circuit, a high-potential terminal of the main control circuit and a high-potential terminal of the potential regulation circuit are both coupled to a positive output terminal of the output filter circuit, a potential regulation terminal of the potential regulation circuit is coupled to the voltage tracking and control circuit; a direct current input terminal of the current detection circuit is coupled to a positive output terminal of the output filter circuit; a current detection feedback terminal of the current detection circuit is coupled to a current detection terminal of the main control circuit; a clock output terminal and a data output terminal of the main control circuit are coupled to a clock input terminal and a data input terminal of the potential regulation circuit; a first detection terminal and a second detection terminal of the voltage detection circuit are coupled to a direct current output terminal of the current detection circuit and a negative output terminal of the output filter circuit respectively, a first output terminal and a second output terminal of the voltage detection circuit are coupled to a first voltage detection terminal and a second voltage detection terminal of the main control circuit respectively; an input terminal of the output switch circuit is coupled to the direct current output terminal of the current detection circuit; an output terminal of the output switch circuit is coupled to a third detection terminal of the voltage detection circuit; a ground terminal of the output switch circuit is coupled to a negative output terminal of the output filter circuit; a controlled terminal and a power terminal of the output switch circuit are coupled to a switch control terminal of the main control circuit and the secondary terminal of the isolation transformer respectively; each of a negative output terminal of the output filter circuit, the output terminal of the output switch circuit, and a first communication terminal and a second communication terminal of the main control circuit is coupled to the communication interface of the power adapter;

the power circuit comprises: a first capacitor, a voltage stabilizing chip, a second capacitor, a first inductor, a second inductor, a first diode, a second diode, a third capacitor, a first resistor and a second resistor;

a junction of a first terminal of the first capacitor and an input power pin and an enable pin of the voltage stabilizing chip is configured as the input terminal of the power circuit, a second terminal of the first capacitor and a ground pin of the voltage stabilizing chip are jointly grounded; a switch pin of the voltage stabilizing chip and a first terminal of the second capacitor are jointly coupled to a first terminal of the first inductor; an internal switch pin of the voltage stabilizing chip and a second terminal of the second capacitor are jointly coupled to a cathode of the first diode; a voltage feedback pin of the voltage stabilizing chip is coupled to a first terminal of the first resistor and a first terminal of the second resistor, a second terminal of the first inductor and a cathode of the second diode are jointly coupled to a first terminal of the second inductor, a junction of a second terminal of the second inductor, an anode of the first diode, a second terminal of the first resistor and a first terminal of the third capacitor is configured as the output terminal of the power circuit; an anode of the second diode, a second terminal of the second resistor and a second terminal of the third capacitor are jointly grounded.

2. The battery charging apparatus according to claim **1**, wherein,

the power circuit obtains power from the isolation transformer and provides power to the main control circuit, the potential regulation circuit, and the current detection circuit; when a quick charging is performed on the battery in the electronic device, the potential regulation circuit drives the voltage tracking and control circuit to regulate the output voltage of the isolation transformer according to a control signal sent by the main control circuit so as to perform the quick charging on the battery; the current detection circuit and the voltage detection circuit respectively detects the output current and the output voltage of the power adapter, and correspondingly feeds back a current detection signal and a voltage detection signal to the main control circuit; the output switch circuit switches on or off the direct current output of the power adapter according to a switch control signal sent by the main control circuit;

when a conventional charging or a quick charging is performed on the battery, the main control circuit determines whether the output current of the power adapter is greater than the current threshold according to the current detection signal, and determines whether the output voltage of the power adapter is greater than the voltage threshold according to the voltage detection signal, if the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, the main control circuit sends the first charging stop command to the charging control circuit and controls the output switch circuit to switch off the direct current output of the power adapter, and the charging control circuit drives the controller to switch off the communication interface of the electronic device according to the first charging stop command;

if the output voltage is not greater than the voltage threshold, and the output current is not greater than the current threshold, the main control circuit feeds back the output voltage information and the output current information to the charging control circuit according to the voltage detection signal and the current detection signal, the charging control circuit determines whether the output voltage is greater than the voltage threshold and whether the output current is greater than the current threshold according to the output voltage information and the output current information, if the output voltage is greater than the voltage threshold and/or the output current is greater than the current threshold, the charging control circuit feeds back the second charging stop command to the main control circuit and drives the controller to switch off the communication interface of the electronic device, and the main control circuit controls the output switch circuit to switch off the direct current output of the power adapter according to the second charging stop command.

3. The battery charging apparatus according to claim **1**, wherein,

the main control circuit comprises: a main control chip, a third resistor, a reference voltage chip, a fourth resistor, a fifth resistor, a fourth capacitor, a sixth resistor, a seventh resistor, a first NMOS transistor, an eighth resistor, a ninth resistor, a tenth resistor, an eleventh resistor, a twelfth resistor, a thirteenth resistor and a fourteenth resistor;

a power pin of the main control chip is configured as the power terminal of the main control circuit; a ground pin of the main control chip is grounded, a first input/output pin of the main control chip is suspended, a first terminal of the third resistor is coupled to the power pin of the main control chip, a second terminal of the third resistor and a first terminal of the fourth resistor are jointly coupled to a positive pole of the reference voltage chip, a negative pole of the reference voltage chip is grounded, a vacant pin of the reference voltage chip is suspended; a second terminal of the fourth resistor is coupled to a second input/output pin of the main control chip; a third input/output pin of the main control chip is configured as the current detection terminal of the main control circuit; a fourth input/output pin of the main control chip is coupled to a first terminal of the fifth resistor; a second terminal of the fifth resistor and a first terminal of the fourth capacitor are jointly coupled to the power pin of the main control chip, a second terminal of the fourth capacitor is grounded; a fifth input/output pin of the main control chip is configured as the switch control terminal of the main control circuit; a sixth input/output pin of the main control chip is coupled to a first terminal of the sixth resistor; a second terminal of the sixth resistor and a gate electrode of the first NMOS transistor are jointly coupled to a first terminal of the seventh resistor; a second terminal of the seventh resistor and a source electrode of the first NMOS transistor are jointly grounded; a drain electrode of the first NMOS transistor is coupled to a first terminal of the eighth resistor; a second terminal of the eighth resistor is configured as the high-potential terminal of the main control circuit; a seventh input/output pin and an eighth input/output pin of the main control chip are configured as the clock output terminal and the data output terminal of the main control circuit respectively; a tenth input/output pin and a ninth input/output pin of the main control chip are configured as the first voltage detection terminal and the second voltage detection terminal of the main control circuit respectively; an eleventh input/output pin and a twelfth input/output pin of the main control chip are coupled to a first terminal of the ninth resistor and a first terminal of the tenth resistor respectively; a first terminal of the eleventh resistor and a first terminal of the twelfth resistor are coupled to a second terminal of the ninth resistor and a second terminal of the tenth resistor respectively; a second terminal of the eleventh resistor and a second terminal of the twelfth resistor are jointly grounded; a first terminal of the thirteenth resistor and a first terminal of the fourteenth resistor are coupled to the second terminal of the ninth resistor and the second terminal of the tenth resistor respectively; a second terminal of the thirteenth resistor and a second terminal of the fourteenth resistor are jointly coupled to the power pin of the main control chip; and the second terminal of the ninth resistor and the second terminal of the tenth resistor are configured as the first communication terminal and the second communication terminal of the main control circuit respectively.

4. The battery charging apparatus according to claim **1**, wherein,

the potential regulation circuit comprises: a fifteenth resistor, a sixteenth resistor, a digital potentiometer, a seventeenth resistor, an eighteenth resistor, a fifth capacitor, a sixth capacitor and a nineteenth resistor;

a junction of a first terminal of the fifteenth resistor, a first terminal of the sixteenth resistor, a power pin of the digital potentiometer and a first terminal of the fifth capacitor is configured as the power terminal of the potential regulation circuit; a second terminal of the

fifth capacitor, a first terminal of the sixth capacitor, a ground pin of the digital potentiometer and a first terminal of the seventeenth resistor are jointly grounded; a second terminal of the sixth capacitor is coupled to the power pin of the digital potentiometer; a junction of a second terminal of the fifteenth resistor and a serial data pin of the digital potentiometer is configured as the data input terminal of the potential regulation circuit; a junction of a second terminal of the sixteenth resistor and a clock input pin of the digital potentiometer is configured as the clock input terminal of the potential regulation circuit; an address zero pin of the digital potentiometer is grounded; a first potential wiring pin of the digital potentiometer and a first terminal of the eighteenth resistor are jointly coupled to a second terminal of the seventeenth resistor; a second terminal of the eighteenth resistor and a second potential wiring pin of the digital potentiometer are jointly coupled to a first terminal of the nineteenth resistor; a second terminal of the nineteenth resistor is configured as the high-potential terminal of the potential regulation circuit; and a potential tap pin of the digital potentiometer is configured as the potential regulation terminal of the potential regulation circuit.

5. The battery charging apparatus according to claim, wherein, the current detection circuit comprises: a twentieth resistor, a twenty-first resistor, a twenty-second resistor, a seventh capacitor, an eighth capacitor, a current detection chip, a twenty-third resistor, a ninth capacitor, a tenth capacitor and a twenty-fourth resistor;

a first terminal and a second terminal of the twentieth resistor are configured as the direct current input terminal and the direct current output terminal of the current detection circuit respectively; a first terminal of the twenty-first resistor and a first terminal of the twenty-second resistor are coupled to a first terminal and a second terminal of the twentieth resistor respectively; a second terminal of the twenty-first resistor and a first terminal of the seventh capacitor are jointly coupled to a positive input pin of the current detection chip; a second terminal of the twenty-second resistor and a first terminal of the eighth capacitor are jointly coupled to a negative input pin of the current detection chip; a junction of a power pin of the current detection chip and a first terminal of the ninth capacitor is configured as the power terminal of the current detection circuit; a vacant pin of the current detection chip is suspended; an output pin of the current detection chip is coupled to a first terminal of the twenty-third resistor; a second terminal of the twenty-third resistor is configured as the current detection feedback terminal of the current detection circuit; a first terminal of the tenth capacitor and a first terminal of the twenty-fourth resistor are jointly coupled to a second terminal of the twenty-third resistor; a second terminal of the seventh capacitor, a second terminal of the eighth capacitor, a second terminal of the ninth capacitor, a second terminal of the tenth capacitor, a second terminal of the twenty-fourth resistor, and a ground pin, a first reference voltage pin and a second reference voltage pin of the current detection chip are jointly grounded.

6. The battery charging apparatus according to claim **1**, wherein,

the voltage detection circuit comprises: a twenty-fifth resistor, a twenty-sixth resistor, an eleventh capacitor, a twelfth capacitor, a twenty-seventh resistor and a twenty-eighth resistor;

a first terminal of the twenty-fifth resistor is configured as the first detection terminal of the voltage detection circuit; a junction of a second terminal of the twenty-fifth resistor, a first terminal of the twenty-sixth resistor and a first terminal of the eleventh capacitor is configured as the second output terminal of the voltage detection circuit; a second terminal of the twenty-sixth resistor is configured as the second detection terminal of the voltage detection circuit; a second terminal of the eleventh capacitor, a first terminal of the twelfth capacitor and a first terminal of the twenty-seventh resistor are jointly coupled to a second terminal of the twenty-sixth resistor; a junction of a second terminal of the twelfth capacitor, a second terminal of the twenty-seventh resistor and a first terminal of the twenty-eighth resistor is configured as the first output terminal of the voltage detection circuit; and a second terminal of the twenty-eighth resistor is configured as the third detection terminal of the voltage detection circuit.

7. The battery charging apparatus according to claim **1**, wherein,

the output switch circuit comprises: a twenty-ninth resistor, a thirtieth resistor, a thirteenth capacitor, a thirty-first resistor, a first NPN triode, a thirty-second resistor, a second NPN triode, a third diode, a voltage stabilizing diode, a thirty-third resistor, a thirty-fourth resistor, a thirty-fifth resistor, a second NMOS transistor and a third NMOS transistor;

a first terminal of the twenty-ninth resistor is configured as the controlled terminal of the output switch circuit; a second terminal of the twenty-ninth resistor and a first terminal of the thirtieth resistor are jointly coupled to a base electrode of the first NPN triode; a first terminal of the thirteenth capacitor, a first terminal of the thirty-first resistor and a first terminal of the thirty-second resistor are jointly coupled to a cathode of the third diode; an anode of the third diode is configured as the power terminal of the output switch circuit; a second terminal of the thirty-first resistor and a base electrode of the second NPN triode are jointly coupled to a collector electrode of the first NPN triode; a second terminal of the thirty-second resistor, a cathode of the voltage stabilizing diode and a first terminal of the thirty-third resistor are jointly coupled to a collector electrode of the second NPN triode; a second terminal of the thirtieth resistor, a second terminal of the thirteenth capacitor, an emitter electrode of the first NPN triode, an emitter electrode of the second NPN triode and an anode of the voltage stabilizing diode are jointly grounded; a second terminal of the thirty-third resistor is coupled to a first terminal of the thirty-fourth resistor, a first terminal of the thirty-fifth resistor, a gate electrode of the second NMOS transistor and a gate electrode of the third NMOS transistor; a second terminal of the thirty-fourth resistor is configured as the ground terminal of the output switch circuit; a drain electrode of the second NMOS transistor is configured as the input terminal of the output switch circuit; a source electrode of the second NMOS transistor and a second terminal of the thirty-fifth resistor are jointly coupled to a source electrode of the third NMOS transistor; and a drain electrode of the third NMOS transistor is configured as the output terminal of the output switch circuit.

8. The battery charging apparatus according to claim **1**, wherein,

the charging control circuit comprises a battery connector, a main controller, a thirty-sixth resistor, a thirty-seventh

resistor, a fourteenth capacitor, a first Schottky diode, a second Schottky diode, a fifteenth capacitor, a sixteenth capacitor, a thirty-eighth resistor, a thirty-ninth resistor, a fortieth resistor, a third NPN triode, a fourth NMOS transistor and a fifth NMOS transistor;

the battery connector is coupled to an electrode of the battery; a first pin and a second pin of the battery connector are jointly grounded; a first ground pin and a second ground pin of the battery connector are jointly grounded; a first input/output pin of the main controller is coupled to a seventh pin and an eighth pin of the battery connector; a second input/output pin, a seventh input/output pin, an eighth input/output pin and a ninth input/output pin of the main controller are coupled to a sixth pin, a fifth pin, a fourth pin and a third pin of the battery connector respectively; an analog ground pin and a ground pin of the main controller are both grounded; a first vacant pin and a second vacant pin of the main controller are suspended; a power pin of the main controller and a first terminal of the sixteenth capacitor are both coupled to the seventh pin and the eighth pin of the battery connector; a fourth input/output pin and an eleventh input/output pin of the main controller are configured to perform data communication with the controller in the electronic device; the thirty-sixth resistor is coupled between the fourth input/output pin and the power pin of the main controller; the sixth input/output pin and the twelfth input/output pin of the main controller are coupled to the first communication terminal and the second communication terminal of the main control circuit in the power adapter respectively; a first terminal of the thirty-seventh resistor and a first terminal of the thirty-eighth resistor are jointly coupled to a tenth input/output terminal of the main controller; a second terminal of the thirty-seventh resistor is coupled to the power pin of the main controller; a second terminal of the thirty-eighth resistor is coupled to a base electrode of the third NPN triode; a fifth input/output pin of the main controller is coupled to a first terminal of the fourteenth capacitor; a second terminal of the fourteenth capacitor and a cathode of the first Schottky diode are jointly coupled to an anode of the second Schottky diode; a first terminal of the thirty-ninth resistor and a first terminal of the fifteenth capacitor are jointly coupled to a cathode of the second Schottky diode; each of a second terminal of the thirty-ninth resistor, a first terminal of the fortieth resistor and a collector electrode of the third NPN triode is coupled to a gate electrode of the fourth NMOS transistor and a gate electrode of the fifth NMOS transistor; a second terminal of the fortieth resistor and a second terminal of the fifteenth capacitor are jointly grounded; a source electrode of the fourth NMOS transistor is coupled to an anode of the first Schottky diode, and also coupled to the seventh pin and the eighth pin of the battery connector; a drain electrode of the fourth NMOS transistor is coupled to a drain electrode of the fifth NMOS transistor; a source electrode of the fifth NMOS transistor is coupled to a power line of the communication interface of the electronic device; an emitter electrode of the third NPN triode is coupled to an anode of the third Schottky diode, and a cathode of the third Schottky diode is grounded.

9. The battery charging apparatus according to claim **8**, wherein, the charging control circuit further comprises a sixth NMOS transistor, a seventh NMOS transistor and a forty-first resistor; a source electrode of the sixth NMOS transistor is coupled to the source electrode of the fifth NMOS transistor; a drain electrode of the sixth NMOS transistor is coupled to a drain electrode of the seventh NMOS transistor, a source electrode of the seventh NMOS transistor is coupled to the collector electrode of the third NPN triode, a gate electrode of the sixth NMOS transistor and a gate electrode of the seventh NMOS transistor are jointly coupled to a first terminal of the forty-first resistor, and a second terminal of the forty-first resistor is grounded.

10. The battery charging apparatus according to claim **8**, wherein, the main controller is configured to transmit voltage information and electric quantity information of the battery to the controller, to determine whether the quick charging for the battery has been completed according to a voltage of the battery, and if yes, to feed back a quick charging stop command to the electronic device for notifying the electronic device to switch from a quick charging mode to a conventional charging mode.

11. The battery charging apparatus according to claim **8**, wherein the main controller is configured to determine whether the power adapter is disconnected from the battery according to a voltage of the battery during a charging process for the battery, and if yes, to feed back a charging termination command to the controller for notifying the controller to switch off the communication interface of the electronic device.

12. The battery charging apparatus according to claim **8**, wherein the controller in the electronic device is configured to feed back an indication signal to the main controller if a temperature of the battery is abnormal, the main controller is configured to switch off the fourth NMOS transistor and the fifth NMOS transistor according to the indication signal, and the electronic device is configured to switch from the quick charging mode to the conventional charging mode.

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