MOBILE DEVICE CHARGER FOR CHARGING MOBILE DEVICE AND RELATED ADAPTIVE CHARGING VOLTAGE GENERATOR

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ABSTRACT

An adaptive charging voltage generator of a mobile device charger includes: a power receiving interface for receiving a DC voltage and a cable current from a cable; a terminal communication interface for transmitting a charging voltage and a charging current to a connection terminal of the mobile device charger and for receiving a communication signal generated by the mobile device from the connection terminal; a buck converter for receiving the DC voltage and the cable current from the power receiving interface and for generating the charging voltage and the charging current, wherein the charging voltage is lower than the DC voltage while the charging current is greater than the cable current; and a charging voltage control circuit coupled with the buck converter and configured for controlling the buck converter according to the communication signal.
FIG. 3

Battery Charging Circuit Controller

ADC

Vbat

DS2

SW

IB

X1B

X2B

154

156

152

Ibat
FIG. 4

Power Stage Control Circuit

Feedback Circuit

S1

S2

CTRL

VA

FB

IB

VB

220

410

411

413

415

420

430
MOBILE DEVICE CHARGER FOR CHARGING MOBILE DEVICE AND RELATED ADAPTIVE CHARGING VOLTAGE GENERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to U.S. Provisional Application Ser. No. 62/777,737, filed on Jan. 12, 2016; the entirety of which is incorporated herein by reference for all purposes.

BACKGROUND

[0002] The disclosure generally relates to a battery charger and, more particularly, to a mobile device charger and related adaptive charging voltage generator.

[0003] The battery capacity is always the major bottleneck to the usage time of a mobile device. Therefore, many technologies and materials have been developed to increase the battery capacity of the mobile device. When the mobile device runs out of battery power, a charging cable is typically employed by the user to connect to the mobile device to recharge the battery.

[0004] However, the time required to charge the battery is proportional to the capacity of the battery. For many modern mobile devices, it may take several hours to fully recharge the battery inside the mobile device. It is apparent that traditional charging solutions for the mobile device are time-consuming and inefficient.

SUMMARY

[0005] An example embodiment of a mobile device charger for charging a mobile device is disclosed, comprising: an adaptive charging voltage generator; a connection terminal coupled with the adaptive charging voltage generator and utilized for detachably connecting to the mobile device; a cable coupled with the adaptive charging voltage generator; and a power source unit connected to the cable and utilized for supplying a DC voltage and a cable current to the cable. The adaptive charging voltage generator comprises: a power receiving interface arranged to operably receive the DC voltage and the cable current from the cable; a terminal communication interface arranged to operably transmit a charging voltage and a charging current to the connection terminal and to operably receive a communication signal generated by the mobile device from the connection terminal; a buck converter, coupled between the power receiving interface and the terminal communication interface, arranged to operably receive the DC voltage and the cable current from the power receiving interface and to operably generate the charging voltage and the charging current, wherein the charging voltage is lower than the DC voltage while the charging current is greater than the cable current; and a charging voltage control circuit, coupled with the terminal communication interface and the buck converter, arranged to operably control the buck converter according to the communication signal.

[0006] Another example embodiment of an adaptive charging voltage generator of a mobile device charger is disclosed. The mobile device charger is utilized for charging a mobile device and comprises a connection terminal utilized for detachably connecting to the mobile device; a cable; and a power source unit utilized for supplying a DC voltage and a cable current to the cable. The adaptive charging voltage generator comprises: a power receiving interface arranged to operably receive the DC voltage and the cable current from the cable; a terminal communication interface arranged to operably transmit a charging voltage and a charging current to the connection terminal and to operably receive a communication signal generated by the mobile device from the connection terminal; a buck converter, coupled between the power receiving interface and the terminal communication interface, arranged to operably receive the DC voltage and the cable current from the power receiving interface and to operably generate the charging voltage and the charging current, wherein the charging voltage is lower than the DC voltage while the charging current is greater than the cable current; and a charging voltage control circuit, coupled with the terminal communication interface and the buck converter, arranged to operably control the buck converter according to the communication signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 shows a simplified functional block diagram of a mobile device charger utilized for charging a mobile device according to one embodiment of the present disclosure.

[0009] FIG. 2 shows a simplified functional block diagram of an adaptive charging voltage generator of the mobile device charger in FIG. 1 according to one embodiment of the present disclosure.

[0010] FIG. 3 shows a simplified functional block diagram of a battery charging circuit of the mobile device in FIG. 1 according to one embodiment of the present disclosure.

[0011] FIG. 4 shows a simplified functional block diagram of a buck converter of the adaptive charging voltage generator of FIG. 2 according to one embodiment of the present disclosure.

[0012] FIG. 5 shows a simplified functional block diagram of a buck converter of the adaptive charging voltage generator of FIG. 2 according to another embodiment of the present disclosure.

DETAILED DESCRIPTION

[0013] Reference is made in detail to embodiments of the invention, which are illustrated in the accompanying drawings. The same reference numbers may be used throughout the drawings to refer to the same or like parts, components, or operations.

[0014] FIG. 1 shows a simplified functional block diagram of a mobile device charger 100 utilized for charging a mobile device 150 according to one embodiment of the present disclosure. As shown in FIG. 1, the mobile device charger 100 comprises an adaptive charging voltage generator 110, a connection terminal 120, a cable 130, and a power source unit 140. The mobile device 150 comprises a connector 152, a battery 154, and a battery charging circuit 156.

[0015] In the mobile device charger 100, the connection terminal 120 is coupled with the adaptive charging voltage generator 110 and utilized for detachably connecting to the connector 152 of the mobile device 150. The cable 130 is
coupled with the adaptive charging voltage generator 110. The power source unit 140 is connected to the cable 130. The power source unit 140 is utilized for supplying a programmable DC voltage and a programmable current to the cable 130 in response to an instruction data generated by the adaptive charging voltage generator 110. Then, the adaptive charging voltage generator 110 generates and supplies a DC charging voltage and a charging current for charging the mobile device 150 to the connection terminal 120 based on the programmable DC voltage and the programmable current received from the cable 130.

In the mobile device 150, the connector 152 is utilized for detachably connecting with the connection terminal 120 of the mobile device charger 100 to receive the charging voltage and the charging current generated by the adaptive charging voltage generator 110 from the connection terminal 120. The battery charging circuit 156 is coupled with the connector 152 and the battery 154 and utilized for controlling the charging operation of the battery 154. For simplicity of illustration, other components in the mobile device 150 and their connection relationships are not illustrated in FIG. 1.

When the connection terminal 120 is connected with the connector 152, the battery charging circuit 156 may transmit an instruction data to the adaptive charging voltage generator 110 to instruct the adaptive charging voltage generator 110 to supply appropriate charging voltage and charging current to the mobile device 150 through the connection terminal 120 and the connector 152. Upon receipt of the instruction data transmitted from the battery charging circuit 156, the adaptive charging voltage generator 110 generates and transmits another instruction data to the power source unit 140 to instruct the power source unit 140 to supply a high-voltage and low-current signal to the adaptive charging voltage generator 110 through the cable 130. The adaptive charging voltage generator 110 converts the high-voltage and low-current signal supplied from the power source unit 140 into a low-voltage and high-current signal, and then transmit the low-voltage and high-current signal to the battery charging circuit 156 through the connection terminal 120 and the connector 152.

For example, the adaptive charging voltage generator 110 may instruct the power source unit 140 to provide a DC voltage VA and a cable current IA to the adaptive charging voltage generator 110 through the cable 130. The adaptive charging voltage generator 110 converts the DC voltage VA and the cable current IA into a charging voltage VB and a charging current IB, and then transmit the charging voltage VB and the charging current IB to the battery charging circuit 156 through the connection terminal 120 and the connector 152. In above situation, the DC voltage VA generated by the power source unit 140 is higher than the charging voltage VB generated by the adaptive charging voltage generator 110, while the cable current IA generated by the power source unit 140 is lower than the charging current IB generated by the adaptive charging voltage generator 110.

Since the cable 130 only needs to transmit a small cable current IA, the cable 130 can be realized with a thin cable, such as a conventional USB (Universal Serial Bus) cable, instead of a thick and short power cable.

From one aspect, the power loss of the cable 130 can be minimized when the cable 130 is realized with a thin cable. From another aspect, there is no special restriction to the length of the cable 130 since the resistance of the thin cable is low.

For the purpose of explanatory convenience in the following description, it is assumed hereinafter that the adaptive charging voltage generator 110 may utilize communication signals X1A and X2A to transmit instruction data to the power source unit 140, and the battery charging circuit 156 may utilize communication signals X1B and X2B to transmit instruction data to the adaptive charging voltage generator 110.

In some embodiments where the cable 130 is realized with a USB cable, the communication signals X1A and X2A as well as the communication signals X1B and X2B may be realized with the D+ and D− signals defined by USB series specifications.

Alternatively, the communication signals X1A and X2A as well as the communication signals X1B and X2B may be realized with the CC1 and CC2 signals defined by USB-PD (Universal Serial Bus Power Delivery) series specifications.

In practice, the power source unit 140 may be realized with a power adapter, a power bank, a car charger, a display monitor, or any other device capable of supplying programmable DC voltage and programmable current in response to the instruction of the adaptive charging voltage generator 110. In some embodiments where the power source unit 140 is realized with a power adapter, the mobile device charger 100 may be assembled as a single data transmitting and charging cable. In some embodiments where the power source unit 140 is realized with a power bank or a display monitor, the cable 130 may be provided with a connection terminal (not shown in FIG. 1) for detachably connecting to the power source unit 140.

Additionally, the mobile device 150 may be realized with various portable electronic devices, such as a mobile phone, a tablet PC, a notebook computer, a netbook computer, a portable video display, or the like.

Please refer to FIG. 2, which shows a simplified functional block diagram of the adaptive charging voltage generator 110 of the mobile device charger 100 according to one embodiment of the present disclosure.

As shown in FIG. 2, the adaptive charging voltage generator 110 comprises a power receiving interface 210, a terminal communication interface 220, a buck converter 230, a first ADC (analog-to-digital converter) 240, a temperature sensor 250, and a charging voltage control circuit 260.

The power receiving interface 210 is arranged to operably receive the DC voltage VA and the current IA from the cable 130 and to operably communicate with the power source unit 140 through the cable 130. The terminal communication interface 220 is arranged to operably transmit the charging voltage VB and the charging current IB to the connection terminal 120 and to operably receive the communication signals X1B and X2B generated by the mobile device 150 from the connection terminal 120. In practice, each of the power receiving interface 210 and the terminal communication interface 220 may be realized with a signal bus or a set of circuitry pins or signal pads.

The buck converter 230 is coupled between the power receiving interface 210 and the terminal communication interface 220. The buck converter 230 is arranged to operably receive the DC voltage VA and the cable current IA.
from the power receiving interface 210 and to operably generate the charging voltage VB and the charging current IB in response to a control signal CTRL. As described previously, the charging voltage VB is lower than the DC voltage VA while the charging current IB is greater than the cable current IA.

[0030] For example, the charging current IB generated by the buck converter 230 may be configured to be 5 A, 8 A, 10 A, or even larger magnitude to effectively expedite the charging operation of the mobile device 150.

[0031] Please note that there is no switch device positioned on a current path between the power receiving interface 210 and the input terminal of the buck converter 230.

[0032] The first ADC 240 is coupled with the output of the buck converter 230, and arranged to operably generate a first digital signal DS1 corresponding to at least one of the charging voltage VB and the charging current IB.

[0033] The temperature sensor 250 is coupled with the charging voltage control circuit 260, and arranged to operably sense temperature of the connection terminal 120 to generate a temperature indicator signal TS. In some embodiments, the temperature sensor 250 may be positioned close to the connection terminal 120.

[0034] As described previously, the connection terminal 120 is detachably connected with the connector 152 when the mobile device charger 100 is employed to charge the battery 154 of the mobile device 150. During the charging operation of the battery 154, the battery 154 and/or the battery charging circuit 156 inevitably generate heat. Due to the volume and size restriction of the mobile device 150, the heat dissipation device of the mobile device 150 is not possible to immediately dissipate the heat to outside space. As a result, the temperature of the mobile device 150 would inevitably increase during the charging operation. Through the thermal conduction between the connector 152 and the connection terminal 120, the temperature sensor 250 may indirectly detect the temperature of the mobile device 150 by sensing the temperature of the connection terminal 120.

[0035] In some embodiments where the terminal communication interface 220 is positioned close to the connection terminal 120, the temperature sensor 250 may be arranged close to the terminal communication interface 220 and indirectly sense the temperature of the connection terminal 120 through the thermal conduction between the terminal communication interface 220 and the connection terminal 120.

[0036] The charging voltage control circuit 260 is coupled with the power receiving interface 210, the terminal communication interface 220, the buck converter 230, the first ADC 240, and the temperature sensor 250. The charging voltage control circuit 260 is arranged to operably generate the control signal CTRL according to the communication signals X1B and X2B, the first digital signal DS1, and further in view of the temperature indicator signal TS.

[0037] For example, when the communication signals X1B and X2B indicates that the mobile device 150 is requesting for a higher charging voltage and/or a larger charging current, the charging voltage control circuit 260 may adjust the control signal CTRL to instruct the buck converter 230 to increase the charging voltage VB and/or the charging current IB. On the contrary, when the communication signals X1B and X2B indicates that the mobile device 150 is requesting for a lower charging voltage and/or a smaller charging current, the charging voltage control circuit 260 may adjust the control signal CTRL to instruct the buck converter 230 to reduce the charging voltage VB and/or the charging current IB.

[0038] When the charging voltage control circuit 260 determines that the charging voltage VB and/or the charging current IB exceeds a desired level based on the first digital signal DS1, the charging voltage control circuit 260 may adjust the control signal CTRL to instruct the buck converter 230 to reduce the charging voltage VB and/or the charging current IB. On the contrary, when the charging voltage control circuit 260 determines that the charging voltage VB and/or the charging current IB is below a desired level based on the first digital signal DS1, the charging voltage control circuit 260 may adjust the com-
munication signals X1A and X2A to instruct the power source unit 140 to increase the DC voltage VA and/or the cable current IA.

[0044] In addition, the charging voltage control circuit 260 may adjust the communication signals X1A and X2A to instruct the power source unit 140 to reduce the DC voltage VA and/or the cable current IA when the temperature indicator signal TS indicates that the temperature of the connection terminal 120 increases.

[0045] In other embodiments, the charging voltage control circuit 260 may adjust the communication signals X1A and X2A to instruct the power source unit 140 to reduce the DC voltage VA and/or the cable current IA when the temperature indicator signal TS indicates that the temperature of the connection terminal 120 exceeds a predetermined threshold level.

[0046] In practice, the charging voltage control circuit 260 may be realized with various digital circuits, or a combination of digital circuits and analog circuits.

[0047] As can be appreciated from the foregoing elaborations, the charging voltage control circuit 260 may adjust the control signal CTRL and/or the communication signals X1A and X2A based on the temperature indicator signal TS. Accordingly, the charging voltage VB and charging current IB generated by the adaptive charging voltage generator 110 can be adaptively modified based on the thermal condition of the connector 152 or the mobile device 150. From one aspect, the adaptive charging voltage generator 110 offers an additional over temperature protection to the mobile device 150.

[0048] In practice, the charging voltage control circuit 260 may utilize the communication signals X1B and X2B to report the temperature sensing result of the temperature sensor 250 to the battery charging circuit 156, so that the battery charging circuit 156 is enabled to have more information about the thermal condition of the connector 152 or the mobile device 150.

[0049] Please refer to FIG. 3, which shows a simplified functional block diagram of the battery charging circuit 156 of the mobile device 150 according to one embodiment of the present disclosure. The battery charging circuit 156 comprises a switch device 310, a second ADC 320, and a battery charging circuit controller 330.

[0050] The switch device 310 is coupled between the connector 152 and the battery 154. The switch device 310 is arranged to selectively conduct the charging voltage VB and the charging current IB to the battery 154 under control of a switch signal SW.

[0051] The second ADC 320 is arranged to operably generate a second digital signal DS2 corresponding to at least one of a battery input voltage Vbat and a battery input current that of the battery 154.

[0052] The battery charging circuit controller 330 is coupled with the connector 152, the switch device 310, and the second ADC 320. The battery charging circuit controller 330 is arranged to operably generate and transmit the communication signals X1B and X2B to the mobile device charger 100 through the connector 152 to instruct the adaptive charging voltage generator 110 to provide appropriate charging voltage VB and charging current IB. Additionally, the battery charging circuit controller 330 is further arranged to operably generate the switch signal SW according to the second digital signal DS2, so as to control the battery input voltage Vbat and the battery input current that.

[0053] For example, when the battery charging circuit controller 330 determines that the battery input voltage Vbat and/or the battery input current that exceeds (or is lower than) a desired level based on the second digital signal DS2, the battery charging circuit controller 330 may adjust the switch signal SW to turn off the switch device 310.

[0054] When the battery 154 is fully charged or charged to a predetermined level, the battery charging circuit controller 330 may adjust the switch signal SW to turn off the switch device 310 to protect the battery 154 from over charging.

[0055] FIG. 4 shows a simplified functional block diagram of the buck converter 230 of the adaptive charging voltage generator 110 according to one embodiment of the present disclosure.

[0056] In this embodiment of FIG. 4, the buck converter 230 comprises a single power stage 410, an output capacitor 420, a feedback circuit 430, and a power stage control circuit 440.

[0057] The power stage 410 is coupled with the input terminal of the buck converter 230 and arranged to operably receive the DC voltage VA. The output capacitor 420 is coupled with the output of the power stage 410 and arranged to operably provide the charging voltage VB and the charging current IB to the output terminal of the buck converter 230.

[0058] In practice, the power stage 410 may be realized with a synchronous power stage or an asynchronous power stage. For example, as shown in FIG. 4, the power stage 410 is realized with a synchronous power stage and comprises an upper switch 411, a lower switch 413, and an inductor 415. The upper switch 411 comprises a first terminal for receiving the DC voltage VA. A first terminal of the lower switch 413 is coupled with a second terminal of the upper switch 411, while a second terminal of the lower switch 413 is coupled with a fixed-level terminal, such as a ground terminal. A first terminal of the inductor 415 is coupled with the second terminal of the upper switch 411 and the first terminal of the lower switch 413, while a second terminal of the inductor 415 is coupled with the output capacitor 420.

[0059] The feedback circuit 430 is coupled with the output capacitor 420 and arranged to operably generate a feedback signal FB according to at least one of the charging voltage VB and the charging current IB.

[0060] The power stage control circuit 440 is coupled with the power stage 410 and the feedback circuit 430. The power stage control circuit 440 is arranged to operably control the energy conversion operation of the power stage 410 according to the feedback signal FB and the control signal CTRL. For example, the power stage control circuit 440 may generate and utilize switch control signals S1 and S2 to respectively control the switching operations of the upper switch 411 and the lower switch 413, so that the charging voltage VB and the charging current IB provided by the output capacitor 420 meets the instruction of the control signal CTRL.

[0061] In practice, the power stage control circuit 440 may be realized with various PWM (pulse width modulation) signal generators or PFM (pulse frequency modulation) signal generators.

[0062] The buck converter 230 may comprise more than one power stage. For example, FIG. 5 shows a simplified functional block diagram of the buck converter 230 according to another embodiment of the present disclosure.
[0063] In the embodiment of FIG. 5, the buck converter 230 comprises multiple power stages, the output capacitor 420, the feedback circuit 430, and a power stage control circuit 540. For the purpose of explanatory convenience in the following description, only two exemplary power stages (i.e., a first power stage 510 and a second power stage 520) are illustrated in FIG. 5.

[0064] The first power stage 510 is coupled with the input terminal of the buck converter 230 and arranged to operably receive the DC voltage VA.

[0065] The second power stage 520 is coupled with the input terminal of the buck converter 230 and arranged to operably receive the DC voltage VA. In addition, the second power stage 520 is configured in parallel connection with the first power stage 510.

[0066] The output capacitor 420 is coupled with the outputs of both the first power stage 510 and the second power stage 520 and arranged to operably provide the charging voltage VB and the charging current IB.

[0067] The feedback circuit 430 is coupled with the output capacitor 420, and arranged to operably generate a feedback signal FB according to at least one of the charging voltage VB and the charging current IB.

[0068] The power stage control circuit 540 is coupled with the first power stage 510, the second power stage 520, and the feedback circuit 430. The power stage control circuit 540 is arranged to operably control energy conversion operations of the first power stage 510 and the second power stage 520 according to the feedback signal FB and the control signal CTRL.

[0069] In practice, each of the first power stage 510 and the second power stage 520 may be realized with a synchronous power stage or an asynchronous power stage. In the embodiment of FIG. 5, for example, each of the first power stage 510 and the second power stage 520 is realized with a synchronous power stage.

[0070] As shown in FIG. 5, the first power stage 510 comprises an upper switch 511, a lower switch 513, and an inductor 515. The upper switch 511 comprises a first terminal for receiving the DC voltage VA. A first terminal of the lower switch 513 is coupled with a second terminal of the upper switch 511, while a second terminal of the lower switch 513 is coupled with a fixed-level terminal, such as a ground terminal A first terminal of the inductor 515 is coupled with the second terminal of the upper switch 511 and the first terminal of the lower switch 513, while a second terminal of the inductor 515 is coupled with the output capacitor 420.

[0071] Similarly, the second power stage 520 comprises an upper switch 521, a lower switch 523, and an inductor 525. The upper switch 521 comprises a first terminal for receiving the DC voltage VA. A first terminal of the lower switch 523 is coupled with a second terminal of the upper switch 521, while a second terminal of the lower switch 523 is coupled with a fixed-level terminal, such as a ground terminal A first terminal of the inductor 525 is coupled with the second terminal of the upper switch 521 and the first terminal of the lower switch 523, while a second terminal of the inductor 525 is coupled with the output capacitor 420.

[0072] The power stage control circuit 540 may generate and utilize switch control signals S1 and S2 to alternatively turn on the upper switch 511 and the lower switch 513 of the first power stage 510. In addition, the power stage control circuit 540 may further generate and utilize switch control signals S1 and S2 to alternatively turn on the upper switch 521 and the lower switch 523 of the second power stage 520. In practice, the power stage control circuit 540 may be realized with various PWM signal generators or PFM signal generators.

[0073] As is well known in related art, a higher DC voltage VA may cause a higher power loss and heat at the power stage of the buck converter 230, such as the power stage 410 in FIG. 4 or the power stages 510 and 520 in FIG. 5. The development trend of the mobile device 150 is slim and compact, and thus the volume and inner space of the mobile device 150 are very restricted. Therefore, it is very difficult for the mobile device 150 to have sufficient space to install heat dissipation devices for effectively and rapidly dissipating the heat generated by the buck converter 230.

[0074] In addition, the components inside the mobile device 150 must be very small due to the volume restriction of the mobile device 150. Accordingly, if the mobile device manufacturer wants to forcibly integrate a buck converter into the mobile device 150, then the inductors of the buck converter must be very small. As a result, the switching frequency of the power switches of the buck converter must be high, which results in more power loss at the power switches and the inductors of the buck converter.

[0075] The buck converter 230 in this disclosure is arranged in the adaptive charging voltage generator 110 outside the mobile device 150, and thus the buck converter 230 is allowed to use larger inductors. In this situation, the switching frequency of the power switches of the buck converter 230 (e.g., the switches 411, 413, 511, 513, 521, and 523) can be much lower than the case where the buck converter is arranged inside the mobile device 150. As a result, the power loss of the buck converter 230 can be effectively reduced.

[0076] Due to the heat dissipation and power efficiency concerns described above, it is obvious that the disclosed buck converter 230 is not suitable to be integrated into the mobile device 150.

[0077] As can be seen from the foregoing descriptions, the single power stage 410 in the embodiment of FIG. 4 is replaced by multiple power stages in the embodiment of FIG. 5. Hence, the volume and size of each inductor in the embodiment of FIG. 5 can be smaller than the single inductor 415 in the embodiment of FIG. 4. As a result, the volume and size of the entire buck converter 230 of FIG. 5 can be greatly reduced compared to the embodiment of FIG. 4.

[0078] Accordingly, the volume and size of the adaptive charging voltage generator 110 can be effectively reduced by adopting the buck converter 230 of FIG. 5 in comparison with the embodiment adopting the buck converter 230 of FIG. 4.

[0079] According to the foregoing elaborations, it can be appreciated that there is no volume and size restriction to the components of the adaptive charging voltage generator 110 since the adaptive charging voltage generator 110 is outside the mobile device 150. Accordingly, there is no volume and size restriction to the components (e.g., the inductors) of the buck converter 230 inside the adaptive charging voltage generator 110. As a result, the switching frequency of the power switches of the buck converter 230 can be lowered to reduce the power loss at the power stages of the buck converter 230.
[0079] In addition, since the cable 130 only needs to transmit a small cable current IA, the cable 130 can be realized with a thin and long cable, instead of a thick and short power cable.

[0080] Furthermore, since the disclosed adaptive charging voltage generator 110 converts the cable current IA supplied by the power source unit 140 into a much larger charging current IB, the charging speed of the battery 154 can be effectively increased and thus reduce the required time for charging the battery 154.

[0080] In addition, the adaptive charging voltage generator 110 is able to adaptively modify the charging voltage VB and the charging current IB according to the communication signal generated by the mobile device 150. Accordingly, the disclosed adaptive charging voltage generator 110 can be utilized to charge different kinds of mobile devices, and thus can be employed in various applications.

[0082] In some embodiments, the power source unit 140 may be configured to simply supply the DC voltage VA at a fixed voltage level. In this situation, the circuitry of the charging voltage control circuit 260 may be simplified since there is no need to generate the communication signals XIA and X2A described above.

[0083] In some embodiments, the first ADC 240 and/or the temperature sensor 250 may be omitted to simplify the circuitry complexity of the adaptive charging voltage generator 110.

[0084] In the previous descriptions, each of the power stages of the buck converter 230 is realized with a synchronous power stage. This is merely an exemplary embodiment, rather than a restriction to the practice implementations. For example, each of the power stages 410, 510, and 520 shown in FIG. 4 and FIG. 5 may be instead realized to be an asynchronous power stage.

[0085] Certain terms are used throughout the description and the claims to refer to particular components. One skilled in the art appreciates that a component may be referred to as different names. This disclosure does not intend to distinguish between components that differ in name but not in function. In the description and in the claims, the term “comprise” is used in an open-ended fashion, and thus should be interpreted to mean “include, but not limited to.” The phrases “be coupled with,” “couples with,” “and coupling with” and are intended to encompass any indirect or direct connection. Accordingly, if this disclosure mentioned that a first device is coupled with a second device, it means that the first device may be directly or indirectly connected to the second device through electrical connections, wireless communications, optical communications, or other signal connections with/without other intermediate devices or connection means.

[0086] The term “and/or” may comprise any and all combinations of one or more of the associated listed items. In addition, the singular forms “a,” “an,” and “the” herein are intended to comprise the plural forms as well, unless the context clearly indicates otherwise.

[0087] The term “voltage signal” used throughout the description and the claims may be expressed in the format of a current in implementations, and the term “current signal” used throughout the description and the claims may be expressed in the format of a voltage in implementations.

[0088] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention indicated by the following claims.

What is claimed is:

1. A mobile device charger (100) for charging a mobile device (150), comprising:
   a power receiving interface (210) arranged to operably receive the DC voltage (VA) and the cable current (IA) from the cable (130);
   a terminal communication interface (220) arranged to operably transmit a charging voltage (VB) and a charging current (IB) to the connection terminal (120) and to operably receive a communication signal (X1B; X2B) generated by the mobile device (150) from the connection terminal (120);
   a buck converter (230), coupled between the power receiving interface (210) and the terminal communication interface (220), arranged to operably receive the DC voltage (VA) and the cable current (IA) from the power receiving interface (210) and to operably generate the charging voltage (VB) and the charging current (IB), wherein the charging voltage (VB) is lower than the DC voltage (VA) while the charging current (IB) is greater than the cable current (IA); and
   a charging voltage control circuit (260), coupled with the terminal communication interface (220) and the buck converter (230), arranged to operably control the buck converter (230) according to the communication signal (X1B; X2B).

2. The mobile device charger (100) of claim 1, wherein the adaptive charging voltage generator (110) further comprises:
   a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);
   wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B) and further in view of the first digital signal (DS1).

3. The mobile device charger (100) of claim 1, wherein the adaptive charging voltage generator (110) further comprises:
   a temperature sensor (250), coupled with the charging voltage control circuit (260), arranged to operably sense temperature of the connection terminal (120); wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B) and further in view of a sensing result of the temperature sensor (250).
4. The mobile device charger (100) of claim 3, wherein the adaptive charging voltage generator (110) further comprises:

- a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB); wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B), the sensing result of the temperature sensor (250), and further in view of the first digital signal (DS1).

5. The mobile device charger (100) of claim 3, wherein the charging voltage control circuit (260) controls the buck converter (230) to reduce at least one of the charging voltage (VB) and the charging current (IB) when the temperature of the connection terminal (120) increases.

6. The mobile device charger (100) of claim 3, wherein the charging voltage control circuit (260) controls the buck converter (230) to reduce at least one of the charging voltage (VB) and the charging current (IB) when the temperature of the connection terminal (120) exceeds a predetermined threshold level.

7. The mobile device charger (100) of claim 1, wherein the charging voltage control circuit (260) is further coupled with the power receiving interface (210), and arranged to operably control the power source unit (140) through the power receiving interface (210) and the cable (130) according to the communication signal (X1B; X2B);

- wherein the power source unit (140) generates the DC voltage (VA) and the cable current (IA) under control of the charging voltage control circuit (260).

8. The mobile device charger (100) of claim 7, wherein the adaptive charging voltage generator (110) further comprises:

- a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB); wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B) and further in view of the first digital signal (DS1).

9. The mobile device charger (100) of claim 7, wherein the adaptive charging voltage generator (110) further comprises:

- a temperature sensor (250), coupled with the charging voltage control circuit (260), arranged to operably sense temperature of the connection terminal (120);

- wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B) and further in view of a sensing result of the temperature sensor (250).

10. The mobile device charger (100) of claim 9, wherein the adaptive charging voltage generator (110) further comprises:

- a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);

- wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B), the sensing result of the temperature sensor (250), and further in view of the first digital signal (DS1).

11. The mobile device charger (100) of claim 9, wherein the charging voltage control circuit (260) instructs the power source unit (140) to reduce at least one of the DC voltage (VA) and the cable current (IA) when the temperature of the connection terminal (120) increases.

12. The mobile device charger (100) of claim 9, wherein the charging voltage control circuit (260) instructs the power source unit (140) to reduce at least one of the DC voltage (VA) and the cable current (IA) when the temperature of the connection terminal (120) exceeds a predetermined threshold level.

13. The mobile device charger (100) of claim 1, wherein the cable (130) is a USB (Universal Serial Bus) cable, while the communication signal (X1B; X2B) is selected from D+ and D- signals defined by USB series specifications.

14. The mobile device charger (100) of claim 1, wherein the cable (130) is a USB cable, while the communication signal (X1B; X2B) is selected from CC1 and CC2 signals defined by USB-PD (Universal Serial Bus Power Delivery) series specifications.

15. The mobile device charger (100) of claim 1, wherein the charging current (IB) is greater than 5 A.

16. The mobile device charger (100) of claim 1, wherein the buck converter (230) comprises:

- a first power stage (510) arranged to operably receive the DC voltage (VA);

- a second power stage (520) arranged to operably receive the DC voltage (VA) and configured in parallel connection with the first power stage (510);

- an output capacitor (420), coupled with outputs of the first power stage (510) and the second power stage (520), arranged to operably provide the charging voltage (VB) and the charging current (IB);

- a feedback circuit (430), coupled with the output capacitor (420), arranged to operably generate a feedback signal (FB) according to at least one of the charging voltage (VB) and the charging current (IB); and

- a power stage control circuit (540), coupled with the first power stage (510), the second power stage (520), and the feedback circuit (430), arranged to operably control energy conversion operations of the first power stage (510) and the second power stage (520) according to the feedback signal (FB) under control of the charging voltage control circuit (260).

17. The mobile device charger (100) of claim 16, wherein each of the first power stage (510) and the second power stage (520) is a synchronous power stage and comprises:

- an upper switch (511; 521), comprising a first terminal for receiving the DC voltage (VA);

- a lower switch (513; 523), wherein a first terminal of the lower switch (513; 523) is coupled with a second terminal of the upper switch (511; 521), while a second terminal of the lower switch (513; 523) is coupled with a fixed-level terminal; and
an inductor (515; 525), wherein a first terminal of the inductor (515; 525) is coupled with the second terminal of the upper switch (511; 521) and the first terminal of the lower switch (513; 523), while a second terminal of the inductor (515; 525) is coupled with the output capacitor (420);

wherein the power stage control circuit (540) alternatively turns on the upper switch (511; 521) and the lower switch (513; 523).

18. The mobile device charger (100) of claim 1, wherein there is no switch device positioned on a current path between the power receiving interface (210) and an input terminal of the buck converter (230).

19. The mobile device charger (100) of claim 1, wherein the power source unit (140) is an adapter, a power bank, a car charger, or a display monitor.

20. The mobile device charger (100) of claim 1, wherein the mobile device (150) comprises:

- a connector (152) for detachably connecting with the connection terminal (120) of the mobile device charger (100) to receive the charging voltage (VB) and the charging current (IB) from the connection terminal (120);
- a battery (154); and
- a battery charging circuit (156), comprising:
  - a switch device (310), coupled between the connector (152) and the battery (154), to selectively conduct the charging voltage (VB) and the charging current (IB) to the battery (154) under control of a switch signal (SW);
  - a second ADC (320), arranged to operably generate a second digital signal (DS2) corresponding to at least one of a battery input voltage (Vbat) and a battery input current (Ibat) of the battery (154); and
  - a battery charging circuit controller (330), coupled with the connector (152), the switch device (310), and the second ADC (320), wherein the battery charging circuit controller (330) is arranged to operably generate and transmit the communication signal (X1B; X2B) to the mobile device charger (100) through the connector (152), and arranged to operably generate the switch signal (SW) according to the second digital signal (DS2).

21. An adaptive charging voltage generator (110) of a mobile device charger (100), wherein the mobile device charger (100) is utilized for charging a mobile device (150) and comprises a connection terminal (120) utilized for detachably connecting to the mobile device (150), a cable (130), and a power source unit (140) utilized for supplying a DC voltage (VA) and a cable current (IA) to the cable (130), the adaptive charging voltage generator (110) comprising:

- a power receiving interface (210) arranged to operably receive the DC voltage (VA) and the cable current (IA) from the cable (130);
- a terminal communication interface (220) arranged to operably transmit a charging voltage (VB) and a charging current (IB) to the connection terminal (120) and to operably receive a communication signal (X1B; X2B) generated by the mobile device (150) from the connection terminal (120);
- a buck converter (230), coupled between the power receiving interface (210) and the terminal communication interface (220), arranged to operably receive the DC voltage (VA) and the cable current (IA) from the power receiving interface (210) and to operably generate the charging voltage (VB) and the charging current (IB), wherein the charging voltage (VB) is lower than the DC voltage (VA) while the charging current (IB) is greater than the cable current (IA); and
- a charging voltage control circuit (260), coupled with the terminal communication interface (220) and the buck converter (230), arranged to operably control the buck converter (230) according to the communication signal (X1B; X2B).

22. The adaptive charging voltage generator (110) of claim 21, further comprising:

- a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);

wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B) and further in view of the first digital signal (DS1).

23. The adaptive charging voltage generator (110) of claim 21, further comprising:

- a temperature sensor (250), coupled with the charging voltage control circuit (260), arranged to operably sense temperature of the connection terminal (120);

wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B) and further in view of a sensing result of the temperature sensor (250).

24. The adaptive charging voltage generator (110) of claim 23, further comprising:

- a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);

wherein the charging voltage control circuit (260) controls the buck converter (230) according to the communication signal (X1B; X2B), the sensing result of the temperature sensor (250), and further in view of the first digital signal (DS1).

25. The adaptive charging voltage generator (110) of claim 23, wherein the charging voltage control circuit (260) controls the buck converter (230) to reduce at least one of the charging voltage (VB) and the charging current (IB) when the temperature of the connection terminal (120) increases.

26. The adaptive charging voltage generator (110) of claim 23, wherein the charging voltage control circuit (260) controls the buck converter (230) to reduce at least one of the charging voltage (VB) and the charging current (IB) when the temperature of the connection terminal (120) exceeds a predetermined threshold level.

27. The adaptive charging voltage generator (110) of claim 21, wherein the charging voltage control circuit (260) is further coupled with the power receiving interface (210), and arranged to operably control the power source unit (140) through the power receiving interface (210) and the cable (130) according to the communication signal (X1B; X2B); wherein the power source unit (140) generates the DC voltage (VA) and the cable current (IA) under control of the charging voltage control circuit (260).
28. The adaptive charging voltage generator (110) of claim 27, further comprising:
a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);
wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B) and further in view of the first digital signal (DS1).

29. The adaptive charging voltage generator (110) of claim 27, further comprising:
a temperature sensor (250), coupled with the charging voltage control circuit (260), arranged to operably sense the temperature of the connection terminal (120);
wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B) and further in view of the sensing result of the temperature sensor (250).

30. The adaptive charging voltage generator (110) of claim 29, further comprising:
a first ADC (240), coupled with the charging voltage control circuit (260), arranged to operably generate a first digital signal (DS1) corresponding to at least one of the charging voltage (VB) and the charging current (IB);
wherein the charging voltage control circuit (260) instructs the power source unit (140) to adjust at least one of the DC voltage (VA) and the cable current (IA) according to the communication signal (X1B; X2B), the sensing result of the temperature sensor (250), and further in view of the first digital signal (DS1).

31. The adaptive charging voltage generator (110) of claim 29, wherein the charging voltage control circuit (260) instructs the power source unit (140) to reduce at least one of the DC voltage (VA) and the cable current (IA) when the temperature of the connection terminal (120) increases.

32. The adaptive charging voltage generator (110) of claim 29, wherein the charging voltage control circuit (260) instructs the power source unit (140) to reduce at least one of the DC voltage (VA) and the cable current (IA) when the temperature of the connection terminal (120) exceeds a predetermined threshold level.

33. The adaptive charging voltage generator (110) of claim 21, wherein the cable (130) is a USB (Universal Serial Bus) cable, while the communication signal (X1B; X2B) is selected from D+ and D- signals defined by USB series specifications.

34. The adaptive charging voltage generator (110) of claim 21, wherein the cable (130) is a USB cable, while the communication signal (X1B; X2B) is selected from CC1 and CC2 signals defined by USB-PD (Universal Serial Bus Power Delivery) series specifications.

35. The adaptive charging voltage generator (110) of claim 21, wherein the charging current (IB) is greater than 5 A.

36. The adaptive charging voltage generator (110) of claim 21, wherein the buck converter (230) comprises:
a first power stage (510) arranged to operably receive the DC voltage (VA);
a second power stage (520) arranged to operably receive the DC voltage (VA) and configured in parallel connection with the first power stage (510);
an output capacitor (420), coupled with outputs of the first power stage (510) and the second power stage (520), arranged to operably provide the charging voltage (VB) and the charging current (IB);
a feedback circuit (430), coupled with the output capacitor (420), arranged to operably generate a feedback signal (FB) according to at least one of the charging voltage (VB) and the charging current (IB); and a power stage control circuit (540), coupled with the first power stage (510), the second power stage (520), and the feedback circuit (430), arranged to operably control energy conversion operations of the first power stage (510) and the second power stage (520) according to the feedback signal (FB) under control of the charging voltage control circuit (260).

37. The adaptive charging voltage generator (110) of claim 36, wherein each of the first power stage (510) and the second power stage (520) is a synchronous power stage and comprises:
an upper switch (511; 521), comprising a first terminal for receiving the DC voltage (VA);
a lower switch (513; 523), wherein a first terminal of the lower switch (513; 523) is coupled with a second terminal of the upper switch (511; 521), while a second terminal of the lower switch (513; 523) is coupled with a fixed-level terminal; and an inductor (515; 525), wherein a first terminal of the inductor (515; 525) is coupled with the second terminal of the upper switch (511; 521) and the first terminal of the lower switch (513; 523), while a second terminal of the inductor (515; 525) is coupled with the output capacitor (420);
wherein the power stage control circuit (540) alternatively turns on the upper switch (511, 521) and the lower switch (513, 523).

38. The adaptive charging voltage generator (110) of claim 21, wherein there is no switch device positioned on a current path between the power receiving interface (210) and an input terminal of the buck converter (230).

39. The adaptive charging voltage generator (110) of claim 21, wherein the power source unit (140) is an adapter, a power bank, a car charger, or a display monitor.

40. The adaptive charging voltage generator (110) of claim 21, wherein the mobile device (150) comprises:
a connector (152) for detachably connecting with the connection terminal (120) of the mobile device charger (100) to receive the charging voltage (VB) and the charging current (IB) from the connection terminal (120);
a battery (154); and
a battery charging circuit (156), comprising:
a switch device (310), coupled between the connector (152) and the battery (154), arranged to selectively conduct the charging voltage (VB) and the charging current (IB) to the battery (154) under control of a switch signal (SW); and a second ADC (320), arranged to operably generate a second digital signal (DS2) corresponding to at least one of a battery input voltage (Vbat) and a battery input current (that) of the battery (154); and
a battery charging circuit controller (330), coupled with the connector (152), the switch device (310), and the second ADC (320), wherein the battery charging circuit controller (330) is arranged to operably generate and transmit the communication signal (X1B; X2B) to the mobile device charger (100) through the connector (152), and arranged to operably generate the switch signal (SW) according to the second digital signal (DS2).

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