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(54) MOBILE DEVICE CHARGER FOR CHARGING MOBILE DEVICE AND RELATED ADAPTIVE CHARGING VOLTAGE GENERATOR

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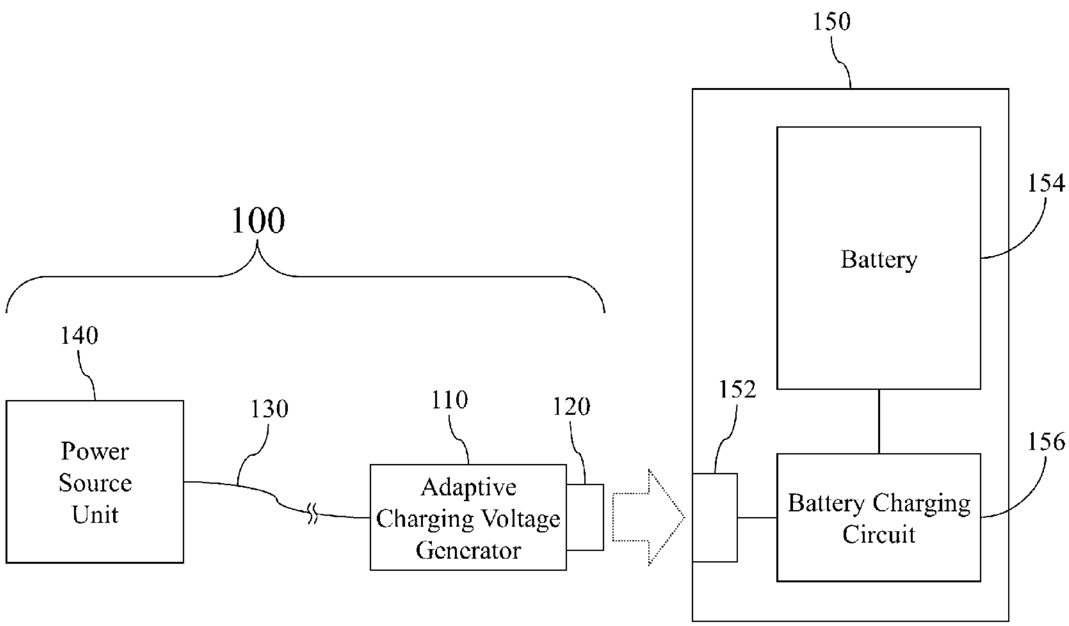
(57) **ABSTRACT**

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.



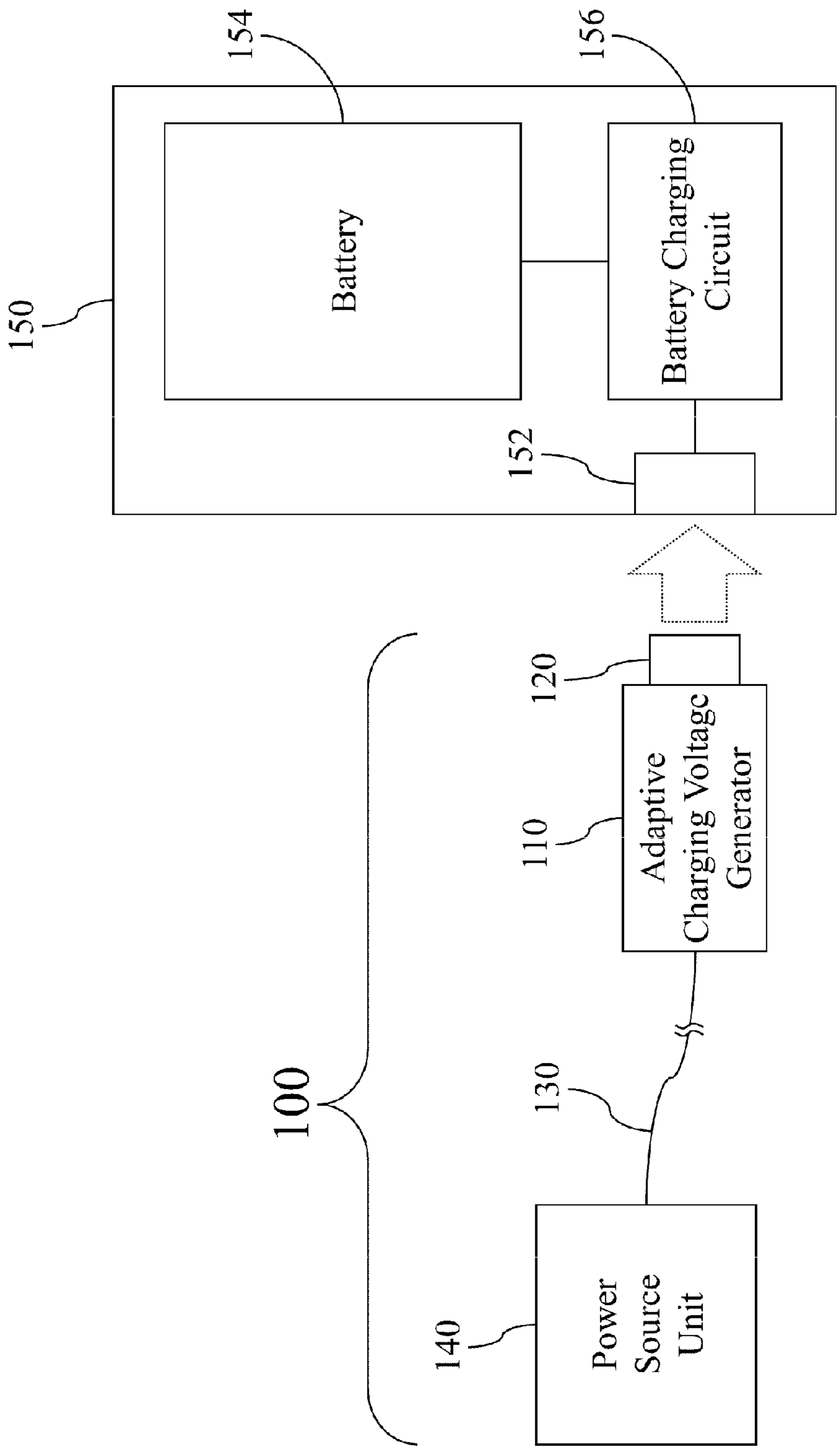

154
156
150
Battery
Battery Charging Circuit
152
100
120
110
Adaptive Charging Voltage Generator
130
140
Power Source Unit

FIG. 1

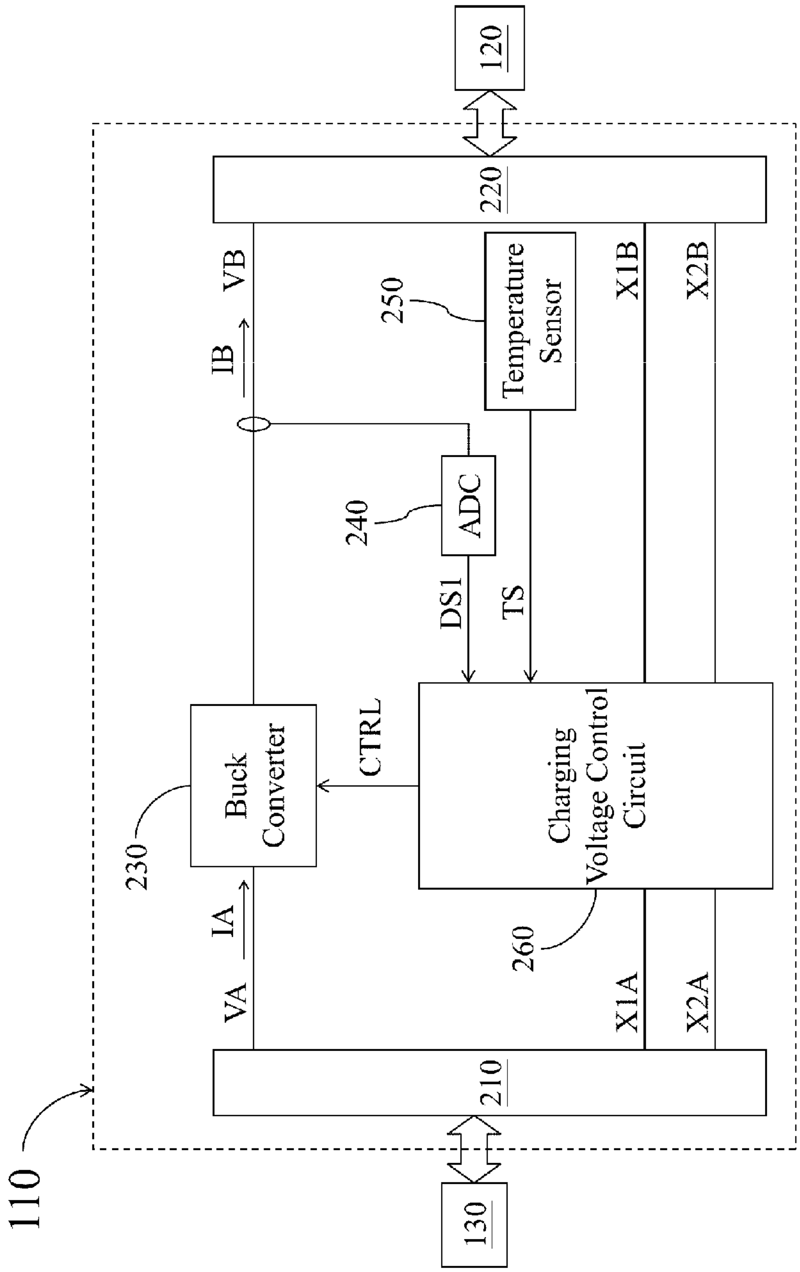

110
120
130
210
220
230
Buck Converter
240
ADC
250
Temperature Sensor
260
Charging Voltage Control Circuit
VA
IA
VB
IB
CTRL
DS1
TS
X1A
X2A
X1B
X2B

FIG. 2

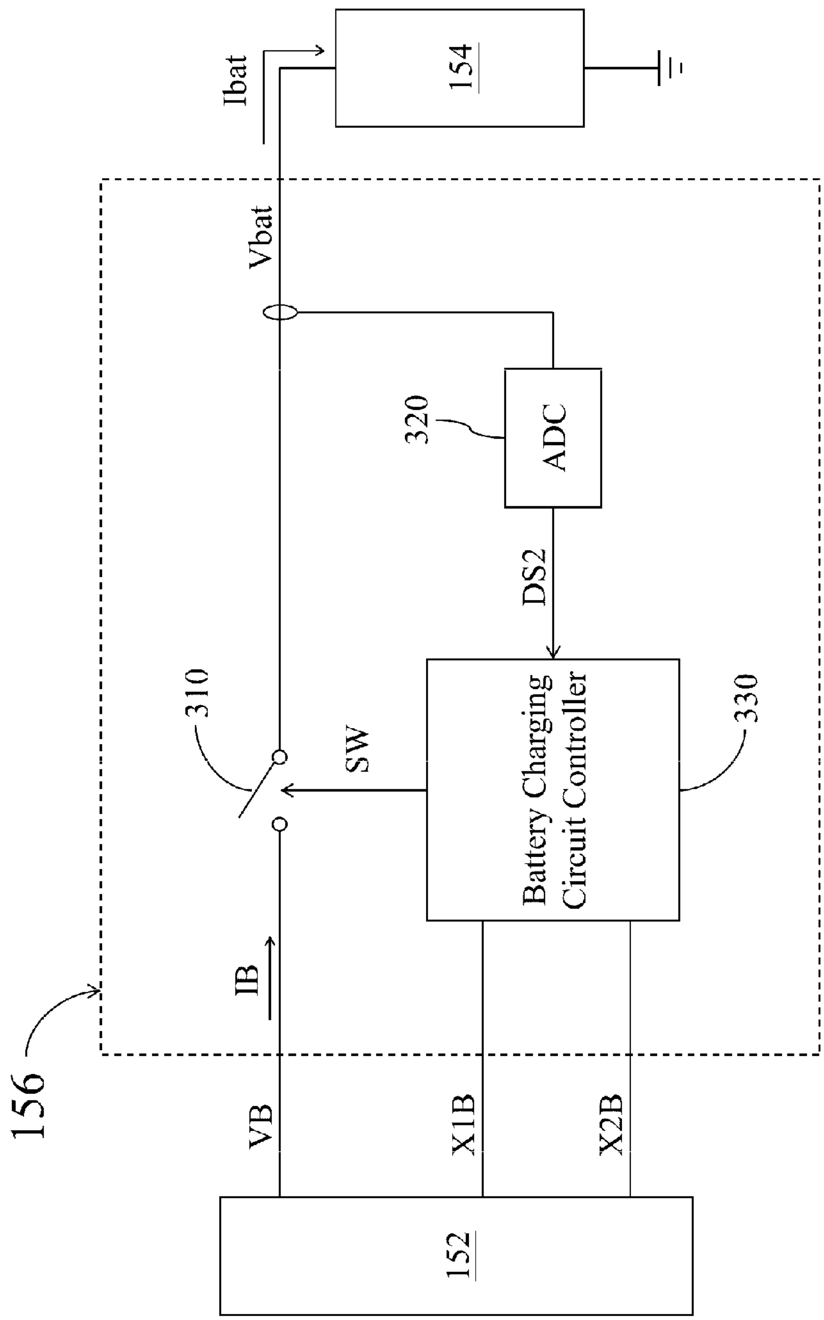

154
Ibat
Vbat
320
ADC
DS2
310
SW
Battery Charging
Circuit Controller
330
IB
156
VB
X1B
X2B
152

FIG. 3

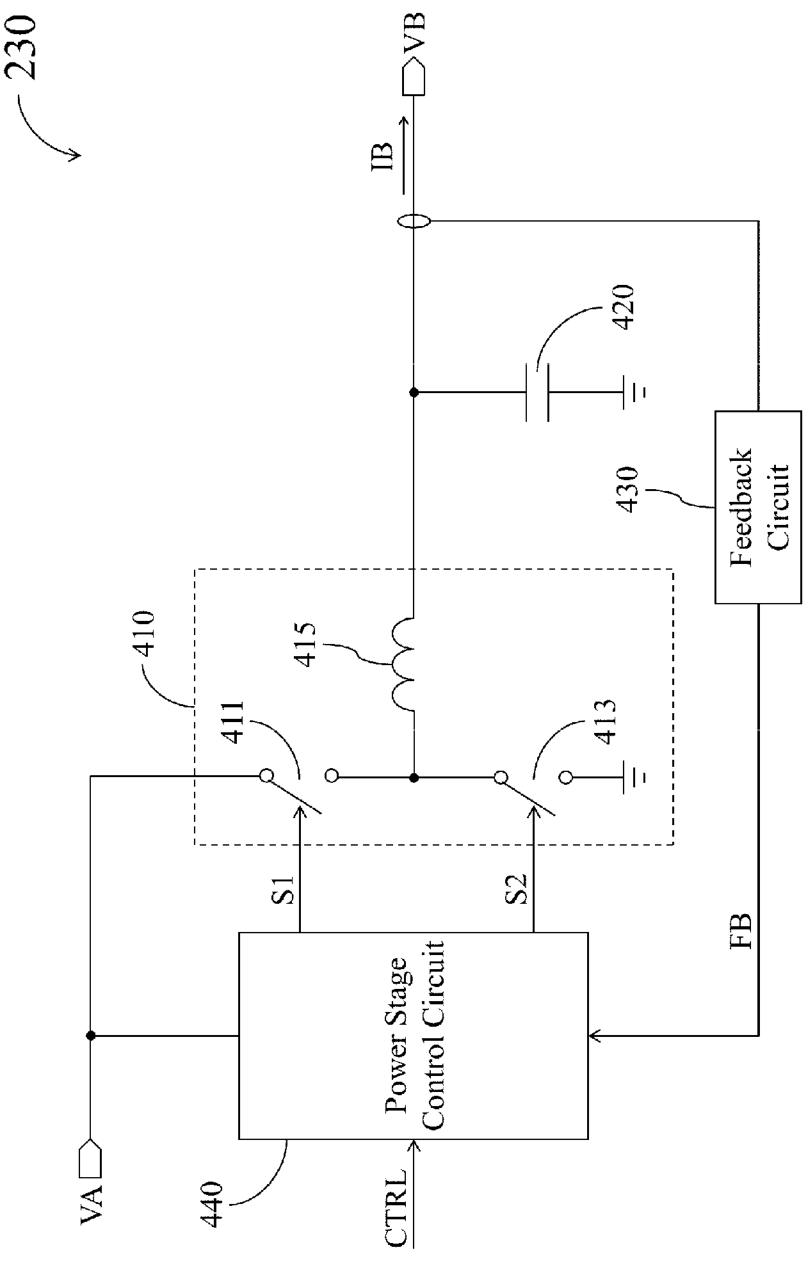

230
VB
IB
420
430
Feedback Circuit
410
415
411
413
S1
S2
FB
Power Stage Control Circuit
VA
440
CTRL

FIG. 4

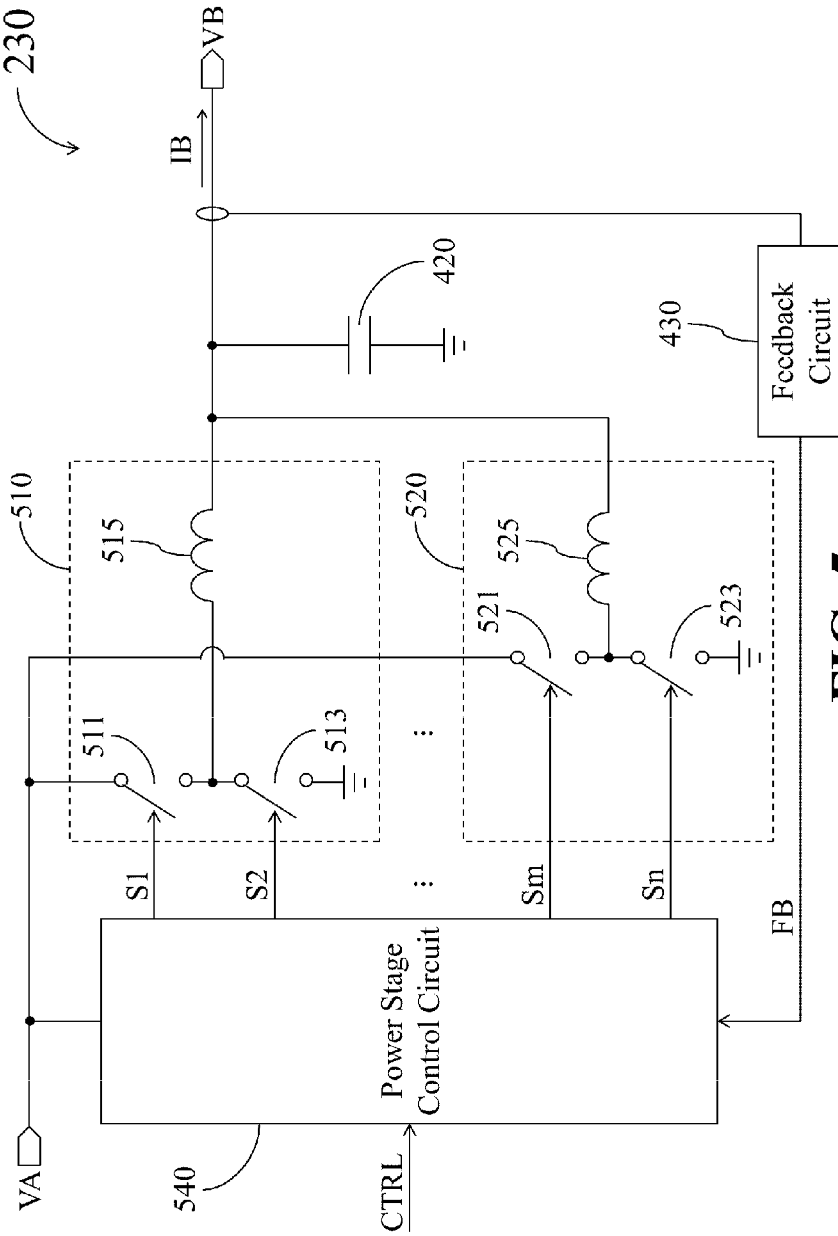

230
VB
IB
420
430
Feedback Circuit
510
515
520
525
521
523
511
513
S1
S2
Sm
Sn
FB
Power Stage Control Circuit
VA
540
CTRL

FIG. 5

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. 62/277,737, 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.

[0007] Both the foregoing general description and the following detailed description are examples and explanatory only, and are not restrictive of the invention as claimed.

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**.

[0016] 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**.

[0017] 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**.

[0018] 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**.

[0019] 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.

[0020] 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.

[0021] 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**.

[0022] 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.

[0023] 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.

[0024] 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**.

[0025] 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.

[0026] 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.

[0027] 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**.

[0028] The power receiving interface **210** is arranged to operably receive the DC voltage VA and the cable 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.

[0029] 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 DS**1** 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 X**1**B and X**2**B, the first digital signal DS**1**, and further in view of the temperature indicator signal TS.

[0037] For example, when the communication signals X**1**B and X**2**B 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 X**1**B and X**2**B 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 DS**1**, 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 DS**1**, 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.

[0039] In addition, 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 when the temperature indicator signal TS indicates that the temperature of the connection terminal **120** increases.

[0040] In other embodiments, 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 when the temperature indicator signal TS indicates that the temperature of the connection terminal **120** exceeds a predetermined threshold level.

[0041] In addition, the charging voltage control circuit **260** is further arranged to operably generate the communication signals X**1**A and X**2**A according to the communication signals X**1**B and X**2**B, the first digital signal DS**1**, and further in view of the temperature indicator signal TS. As described previously, the charging voltage control circuit **260** transmits the communication signals X**1**A and X**2**A to the power source unit **140** through the power receiving interface **210** and the cable **130**.

[0042] For example, when the communication signals X**1**B and X**2**B 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 communication signals X**1**A and X**2**A to instruct the power source unit **140** to increase the DC voltage VA and/or the cable current IA. On the contrary, when the communication signals X**1**B and X**2**B 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 communication signals X**1**A and X**2**A to instruct the power source unit **140** to reduce the DC voltage VA and/or the cable current IA.

[0043] 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 DS**1**, the charging voltage control circuit **260** may adjust the communication signals X**1**A and X**2**A to instruct the power source unit **140** to reduce the DC voltage VA and/or the cable current IA. 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 DS**1**, the charging voltage control circuit **260** may adjust the communication 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 DS**2** 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 DS**2**, 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 DS**2**, 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 recharged 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 S**1** and S**2** 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 **51** 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 Sm and Sn 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 required 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 forcedly 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 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**. 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**.

[0078] 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**.

[0081] 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 X1A 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" are intended to compass 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:

an adaptive charging voltage generator (**110**);

a connection terminal (**120**) coupled with the adaptive charging voltage generator (**110**) and utilized for detachably connecting to the mobile device (**150**);

a cable (**130**) coupled with the adaptive charging voltage generator (**110**); and

a power source unit (**140**) connected to the cable (**130**) and utilized for supplying a DC voltage (VA) and a cable current (IA) to the cable (**130**);

wherein the adaptive charging voltage generator (**110**) comprises:

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 (DS**1**) 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 (DS**1**).

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 (DS**1**) 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 (X**1**B; X**2**B), the sensing result of the temperature sensor (**250**), and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B);

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 (DS**1**) 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 (X**1**B; X**2**B) and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B) 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 (DS**1**) 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 (X**1**B; X**2**B), the sensing result of the temperature sensor (**250**), and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B) 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 (X**1**B; X**2**B) 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**), arranged 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 (DS**2**) 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 (X**1**B; X**2**B) 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 (DS**2**).

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 (X**1**B; X**2**B) 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 (X**1**B; X**2**B).

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 (DS**1**) 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 (X**1**B; X**2**B) and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B) 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 (DS**1**) 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 (X**1**B; X**2**B), the sensing result of the temperature sensor (**250**), and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B);

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 (DS**1**) 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 (X**1**B; X**2**B) and further in view of the first digital signal (DS**1**).

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 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 (X**1**B; X**2**B) and further in view of a 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 (DS**1**) 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 (X**1**B; X**2**B), the sensing result of the temperature sensor (**250**), and further in view of the first digital signal (DS**1**).

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 (X**1**B; X**2**B) 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 (X**1**B; X**2**B) 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);

a second ADC (**320**), arranged to operably generate a second digital signal (DS**2**) 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 (X**1**B; X**2**B) 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 (DS**2**).

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