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Baumohl et al.

(54) SYSTEMS AND METHODS FOR ADVANCED BATTERY CHARGING

(71) Applicants: **Diana W. Baumohl**, Chesterfield, MO (US); **Charles E. Turco**, Des Peres, MO (US)

(72) Inventors: **Diana W. Baumohl**, Chesterfield, MO (US); **Charles E. Turco**, Des Peres, MO (US)

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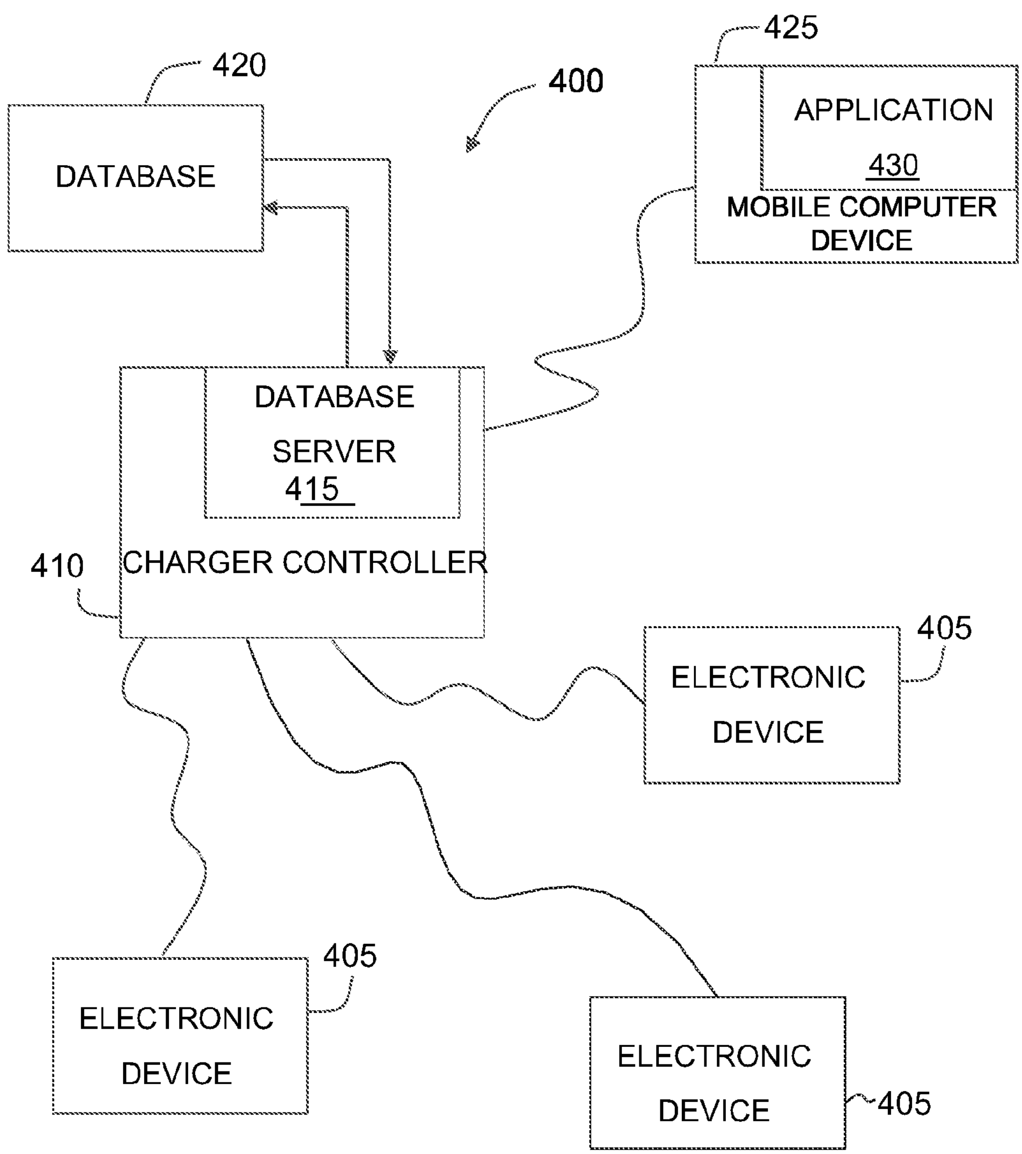
(57) **ABSTRACT**

A charging system is provided. The charging system includes a charging device including an electrical input for receiving electrical energy, at least one output for outputting electrical energy, and a communication interface; and a charger controller programmed to a) determine a current rate of charging for a connected device; b) provide electrical energy to the connected device based upon the current rate of charging; c) determine if the connected device accepts the electrical energy at the current rate of charging; and/or d) if the connected device does not accept the electrical energy at the current rate of charging, increase the current rate of charging until the connected device accepts the electrical energy at the current rate of charging.



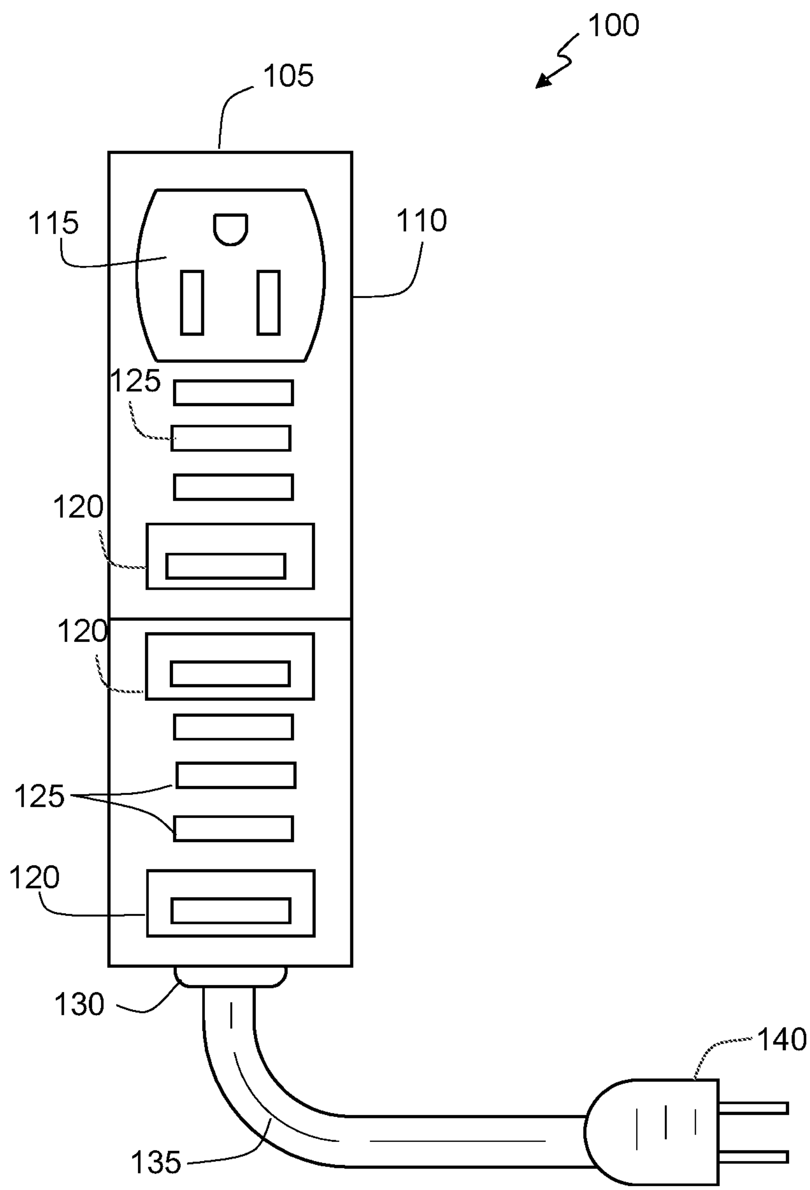


FIGURE 1

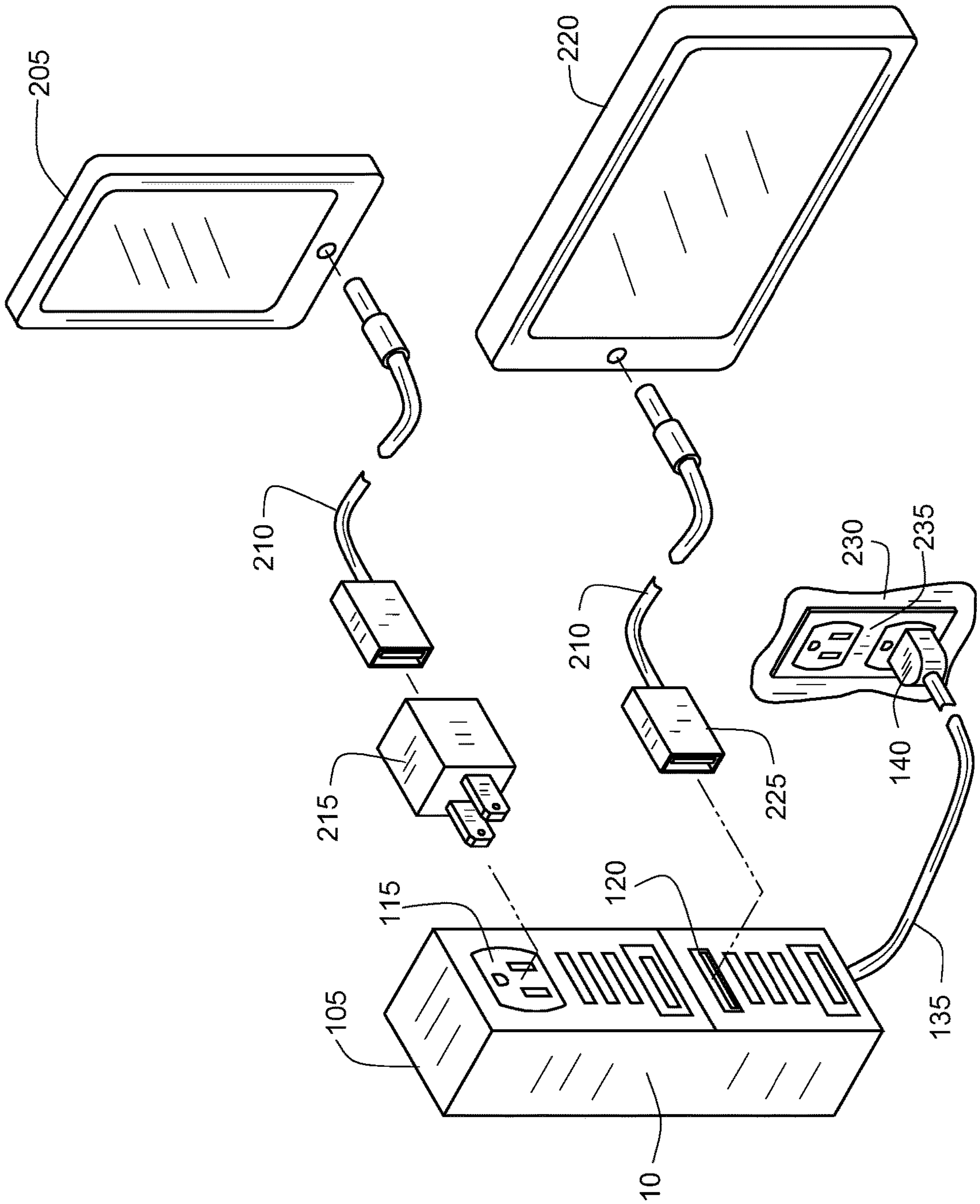


FIGURE 2

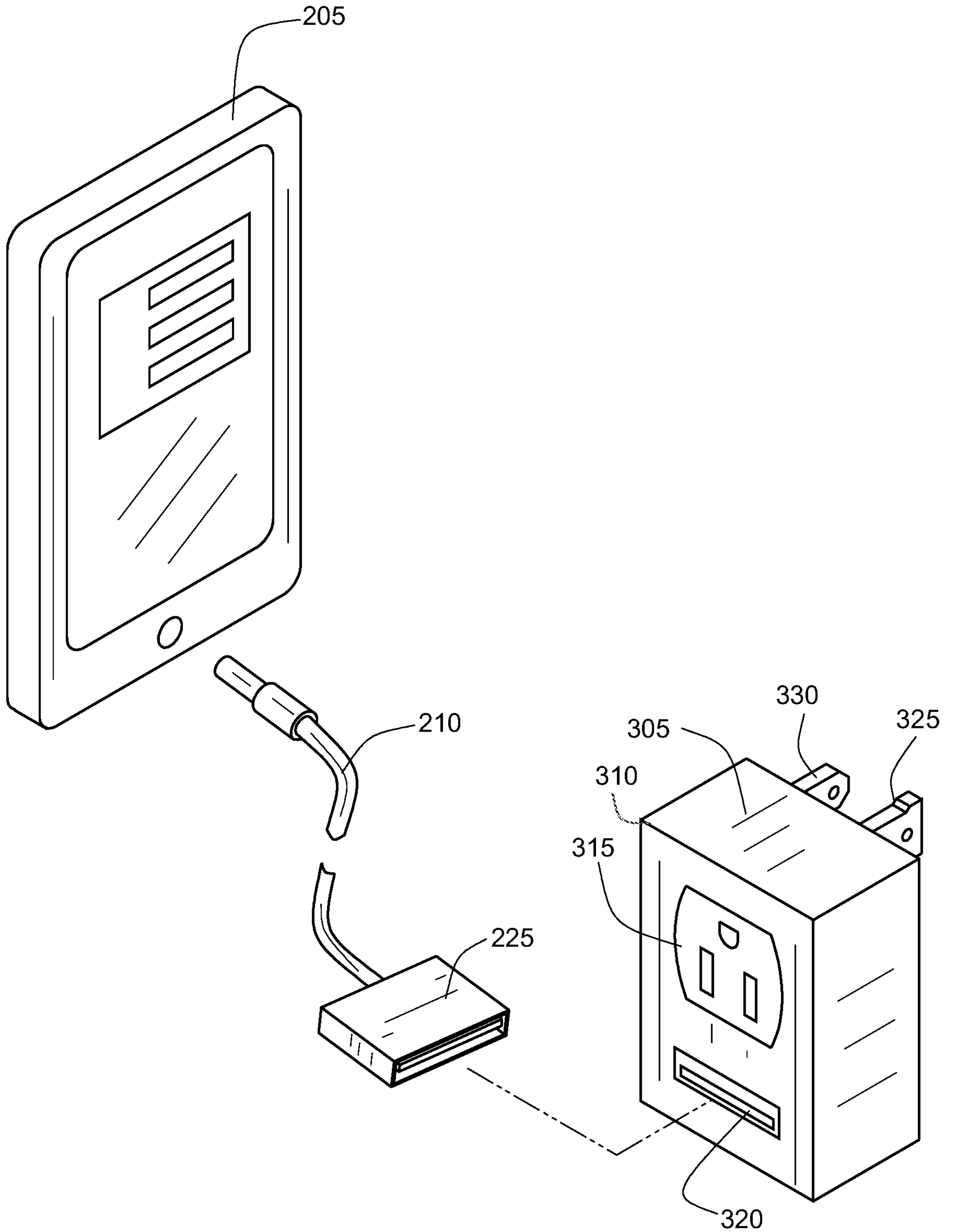


FIGURE 3

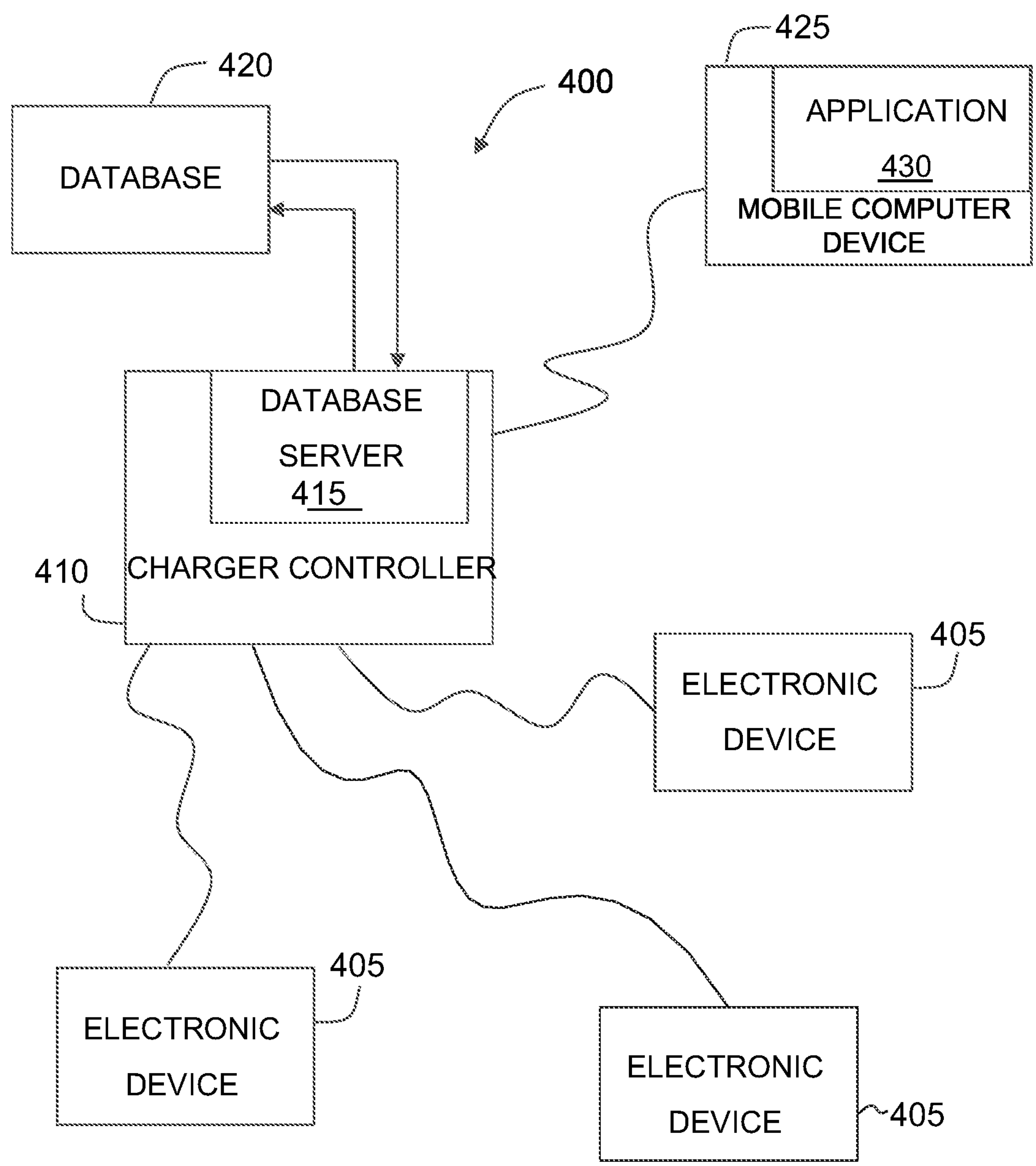

420
DATABASE
400
425
APPLICATION
430
MOBILE COMPUTER DEVICE
DATABASE
SERVER
415
CHARGER CONTROLLER
410
ELECTRONIC DEVICE
405
ELECTRONIC DEVICE
405
ELECTRONIC DEVICE
405

FIGURE 4

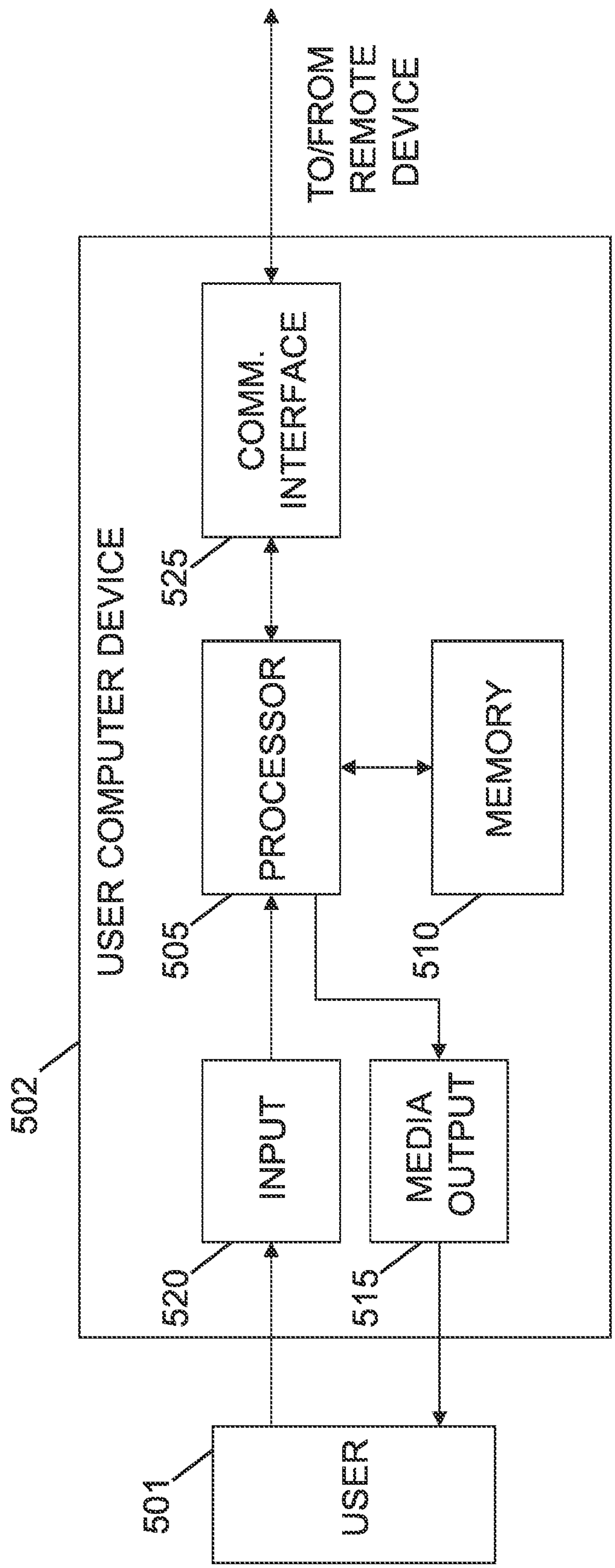

TO/FROM
REMOTE
DEVICE
USER COMPUTER DEVICE
COMM.
INTERFACE
PROCESSOR
MEMORY
INPUT
MEDIA
OUTPUT
USER
502
525
505
510
520
515
501

FIGURE 5

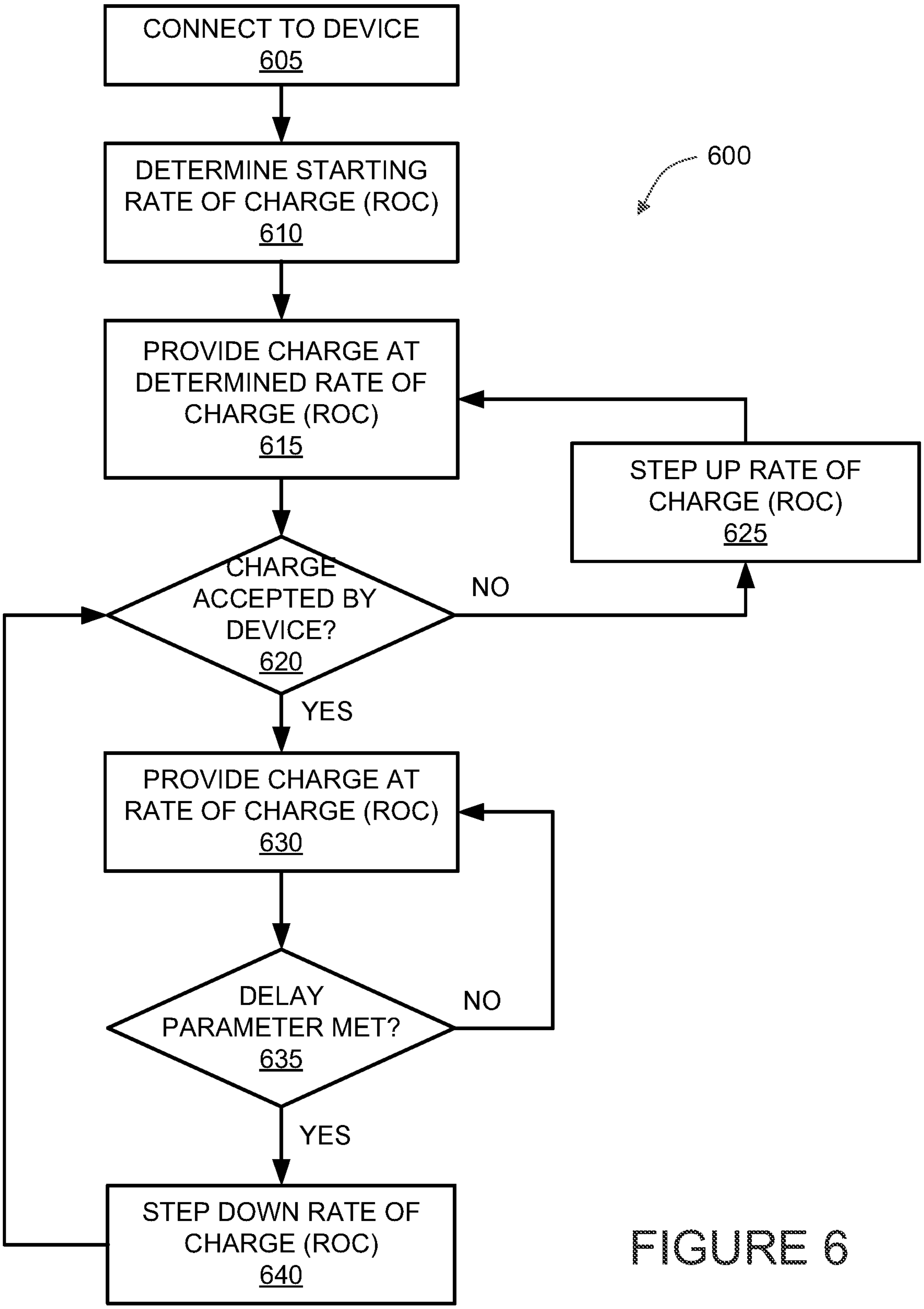

CONNECT TO DEVICE
605
DETERMINE STARTING RATE OF CHARGE (ROC)
610
600
PROVIDE CHARGE AT DETERMINED RATE OF CHARGE (ROC)
615
STEP UP RATE OF CHARGE (ROC)
625
CHARGE ACCEPTED BY DEVICE?
620
NO
YES
PROVIDE CHARGE AT RATE OF CHARGE (ROC)
630
DELAY PARAMETER MET?
635
NO
YES
STEP DOWN RATE OF CHARGE (ROC)
640

FIGURE 6

SYSTEMS AND METHODS FOR ADVANCED BATTERY CHARGING

BACKGROUND

[0001] The field of the disclosure relates generally to advanced battery charging, and more particularly, to systems and methods for controlling the amount of charge and rate of charge delivered into a battery for portable devices.

[0002] The majority of charging devices for small portable electronics, including mobile phones, tablets and the like, support users with the fastest possible charge to a target device prioritizing short-term convenience versus longer term battery and device life. The majority of these electronic devices have embedded lithium-ion batteries (LIBs) that a user either cannot replace or are prohibitively expensive to replace. Furthermore, there are variations in the performance of different charging cables and charging devices.

[0003] A battery has its internal components that store charge. In particular, the battery has an array, or particle lattice, that stores charge and then releases charge upon demand of a device connected thereto. Heat may break down the particle lattice overtime as excessive heat energizes particles and may loosen, stretch, or break the lattice. A broken lattice has less storage potential than a new battery. Furthermore, abrupt or instantaneous demand upon a battery also affects the lattice as a large charge flow partially empties the lattice and increases the polarity of the remaining charge in the lattice. In addition, many available tools do not allow the user to control the attributes of the charging process. Accordingly, there is a need to extend the recharging life of batteries such as those for electronic devices.

BRIEF DESCRIPTION

[0004] In one aspect, a charging system is provided. The charging system includes a charging device including an electrical input for receiving electrical energy, at least one output for outputting electrical energy, and a communication interface; and a charger controller programmed to a) determine a current rate of charging for a connected device; b) provide electrical energy to the connected device based upon the current rate of charging; c) determine if the connected device accepts the electrical energy at the current rate of charging; and/or d) if the connected device does not accept the electrical energy at the current rate of charging, increase the current rate of charging until the connected device accepts the electrical energy at the current rate of charging. The system may direct additional, less, or alternate functionality, including that discussed elsewhere herein.

[0005] Advantages will become more apparent to those skilled in the art from the following description of the preferred embodiments which have been shown and described by way of illustration. As will be realized, the present embodiments may be capable of other and different embodiments, and their details are capable of modification in various respects. Accordingly, the drawings and description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The Figures described below depict various aspects of the systems and methods disclosed therein. It should be understood that each Figure depicts an embodiment of a particular aspect of the disclosed systems and methods, and that each of the Figures is intended to accord with a possible embodiment thereof. Further, wherever possible, the following description refers to the reference numerals included in the following Figures, in which features depicted in multiple Figures are designated with consistent reference numerals.

[0007] There are shown in the drawings arrangements which are presently discussed, it being understood, however, that the present embodiments are not limited to the precise arrangements and are instrumentalities shown, wherein:

[0008] FIG. **1** is a front view of an exemplary charger in accordance with at least one embodiment of the present disclosure.

[0009] FIG. **2** is a perspective view of the exemplary charger shown in FIG. **1**.

[0010] FIG. **3** is a perspective view of an alternate exemplary charger.

[0011] FIG. **4** illustrates a simplified block diagram of an exemplary computer system for monitoring and controlling a charging process in accordance with at least one embodiment of the present disclosure.

[0012] FIG. **5** illustrates an exemplary configuration of a client computer device shown in FIG. **4**, in accordance with one embodiment of the present disclosure.

[0013] FIG. **6** illustrates a flow chart of an exemplary computer implemented process **600** for monitoring and charging electronic devices shown in FIG. **4** at a minimum rate of charge (ROC) using the system shown in FIG. **4**.

[0014] The Figures depict preferred embodiments for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the systems and methods illustrated herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION

[0015] The present disclosure relates generally to advanced battery charging, and more particularly, to systems and methods for controlling the amount of charge and rate of charge delivered into a battery for portable devices.

[0016] Users, particularly those of mobile phones and portable devices, generally lack an understanding of how their devices work. In general, most users of portable electronics only know that something is wrong when their device does not perform the actions that they wish. Furthermore, many existing charging products primarily emphasize reaching maximum charge, i.e., fully charged, as fast as possible so that the device receiving the charge returns to function, fast.

[0017] Presently, lithium-ion batteries, or LIB, have the widest use as technology and materials for mobile device energy storage. Like other batteries, LIB begin to degrade over time due to repeated charging. The rate of degradation of LIB comes from environmental conditions and how users charge and use the devices that the LIB is housed in. Manufacturers of electronic devices do not provide consistent guidance and there currently are no industry standards in charging electronic devices. There can be a difference between what chargers put out in terms of electrical energy and what devices need to charge safely. Devices of different types may have different charging requirements. For example, a laptop has different charging requirements than a tablet or a smartphone, which have different charging requirements from each other. Furthermore, users may be unaware of these different charging requirements.

[0018] Accordingly, there are multiple different strategies for charging LIB and other battery devices. These strategies may include, but are not limited to, expediting to provide the fastest charge for the device, reduced charging rate to limit adverse effects on the battery, and/or charging to less than 100% to extend the life of the battery. The systems and methods described herein may be used to provide reduced charging rate to limit adverse effects on the battery and extend battery useful life.

[0019] The present disclosure allows a user who has an electronic device with an internal battery to deliver power to target device and to regulate the inflow of electricity to the battery so that the battery is charged at the minimum rate of charge (RoC) possible for that battery.

[0020] In the exemplary embodiment, the system determines the minimum rate of charge (ROC) that will allow an attached battery to charge. Furthermore, the system continually monitors the battery charging and updates the minimum ROC of the battery during the charging process. The minimum ROC of a battery is the minimum amount of current that may be provided to the battery and increase the state of charge of the battery receiving said charge.

[0021] In the exemplary embodiment, the charger attempts to start charging at a predetermined rate of charge. In some embodiments, the predetermined rate of charge is provided by the user. In other embodiments, the predetermined rate of charge was previously determined by a computing device using the systems and methods described herein. In further embodiments, the predetermined or starting rate of charge is further based upon variations of other attributes and/or parameters, such as, but not limited to, the current temperature and/or the number of prior recharging cycles.

[0022] Then the charger monitors the battery to determine if the battery is charging at that predetermined ROC. If the battery is not charging at that predetermined rate, then the charger increases its provided ROC and continues to monitor the state of charge of the battery. In some embodiments, the charger determines if the battery is accepting the provided ROC. The charger continues to increase the ROC provided to the battery until the battery accepts the provided energy and begins to charge. In the exemplary embodiment, the charger increases the ROC in a stepped manner, where each step includes a measured increase in the current provided to the battery. The charger notes the provided ROC and continues to monitor the battery to determine if the battery continues to charge. In some embodiments, the attributes of the battery may change based on different attributes of the battery. For example, if a battery heats up and/or has a different state of charge, then one or more attributes of the battery, such as minimum ROC may change over time. If during later monitoring, the battery stops accepting the charge from the charger, the charger increases the ROC in steps until the battery accepts the charge from the charger.

[0023] In some embodiments, after the battery has accepted a ROC for a predetermined period of time, the charger checks to see if a delay condition has been met. The delay parameter may be a period of time and/or a state of charge threshold, for example. While the delay parameter conditions/threshold has not been met, the charger continues to provide charge at the current ROC. For example, the delay parameter may be state of charge of the battery, where the condition is met when the state of charge reaches 20%, for example. The delay parameter may be set by the user and/or historical charging information about the individual battery and/or other batteries similar to the one charging. In some embodiments, the delay parameter may include a plurality of thresholds. For example, the delay parameter may cause the charger to attempt to reduce the ROC at a state of charge of 20%, 40%, 60%, and/or 80%.

[0024] Once the delay parameter conditions/threshold has been met, the charger reduces the ROC by one or more steps and determines if the battery accepts that reduced ROC. If the battery accepts the reduced ROC, then the charger further reduces the ROC until the battery no longer accepts the further reduced ROC. Then the charger returns to a previously accepted minimum ROC to charge the battery. The system continues to ensure that the battery is charged at the minimum ROC allowed by the battery.

[0025] In some embodiments, the step-up amount and the step-down amount are the same. In other embodiments, the step-up amount and the step-down amount are different. The charger then determines if the newly lowered ROC is accepted by the battery. If accepted, then the charger continues to provide charge at that rate. If the charge is not accepted, then the charger steps-up the ROC. In some embodiments, the charger returns the ROC to the previously accepted amount. In this way the charger charges the device at the lowest ROC possible during the entire charging process.

[0026] FIGS. **1**-**3** illustrate two exemplary configurations for the charging device described herein. One having skill in the art would understand that other configurations may also be used with the systems and methods described herein to perform the features and functions described herein.

[0027] FIG. **1** is a front view of an exemplary charger **100** in accordance with at least one embodiment of the present disclosure. Charger **100** as shown in FIG. **1** includes an elongated power strip **105**, which acts as an interface device as described herein. Power strip **105** includes a housing **110** that holds at least one outlet **115** and at least one USB socket **120** for connecting devices to charge. Power strip **105** is configured to provide electrical energy through the at least one outlet **115** and the at least one USB socket **120** to connected devices. The USB socket **120** may include any type of USB or charging port, such as, but not limited to, USB Type A, USB Type B, USB Type C, USB Mini B, USB Micro B, USB 3.0 Type A, USB 3.0 Type B, USB 3.0 Micro B, and/or lightning connector.

[0028] The power strip **105** also includes a one or more visible gauges **125**, where the visible gauges **125** may defines the current state of charge (SoC) for the corresponding connected device that is connected to the corresponding outlet **115** or USB socket **120**. While the visible gauges **125** may be LED (light emitting diode) numerical displays, one having skill in the art would understand that other displays may be used to display information to the user. These may include, but are not limited to, LED indicator lights, OLED (organic light-emitting diode) screen, LCD (liquid crystal display) screen, and/or any other type of display to provide the information to the user. The connected device may be an electronic device, such as a mobile phone, a tablet computer, and the like.

[0029] The strip **105** may also include a surge protector **130** generally centered upon an end of the strip **105** and a cord **135** extending outwardly through the protector **130**. The cord **135** has a desirable length such as between three to eight feet where the length may be limited from power loss. Opposite the protector **130**, the cord **135** ends with a plug **140**. The plug **140** connects the strip **105** to a source of electrical charge, such as a wall outlet with utility service, a generator, a line from solar power, a battery pack, an electric vehicle, and/or any available power source. In some further embodiments, the charger **100** includes a battery for holding charge to provide through the outlets **115** or USB sockets **120**.

[0030] FIG. **2** is a perspective view of the exemplary charger **100** (shown in FIG. **1**). FIG. **2** shows a perspective view of the charger **100** with the strip **105** deployed for usage. The strip **105** has its cord **135** extended and its plug **140** having its prongs (not shown) inserted into an existing outlet **235** in a wall **230**, as in a residential or an office setting. The strip's outlet **115** then receives a charging cube **215**, or USB adapter **225**, that connects with a charging cable **210** usually with a USB end and an opposite fitted end. The fitted end then connects with an electronic device such as a mobile phone **205**. Also, the strip's USB socket **120** connects with a charging cable **210** usually with a USB end **225** and an opposite fitted end. The fitted end here then connects to another electronic device such as a tablet computer **220** or mobile phone **205**. In some embodiments, the fitted end is a specialized connector. In other embodiments, the fitted end **225** is a charging port, such as, but not limited to, USB Type A, USB Type B, USB Type C, USB Mini B, USB Micro B, USB 3.0 Type A, USB 3.0 Type B, USB 3.0 Micro B, lightning connector, and/or any other desired connector.

[0031] FIG. **3** is a perspective view of an alternate exemplary charger **305**. FIG. **3** describes a perspective view of the block charger **305** with the block form deployed for usage towards the right. Block charger **305** has its housing **310** with the prongs **325**, **330** extended to the right towards an existing outlet **235** (shown in FIG. **2**), as in a residential or an office setting. The block's outlet **315** may receive a charging cube or other adapter, not shown, for an existing charging cable. Here in this figure though, the block's USB socket **320** receives a charging cable **210** with its USB end as at **225** inserting into the socket **320** and an opposite fitted end. The fitted end then connects to another electronic device such as a mobile phone **205**. In some embodiments, the fitted end is a specialized connector. In other embodiments, the fitted end is a charging port, such as, but not limited to, USB Type A, USB Type B, USB Type C, USB Mini B, USB Micro B, USB 3.0 Type A, USB 3.0 Type B, USB 3.0 Micro B, and/or lightning connector.

[0032] Charger **100** and Charger **305** may also include a wireless connection (not shown). The wireless connections allow the chargers **100** and **305** to communicate with remote computer devices to provide charging information about the connected devices and to receive parameters for charging those devices. Some examples of the wireless connection include, but are not limited to, Wi-Fi, Bluetooth, NFC (Near Field Communication), and/or any other wireless system that allows the system to work as described herein.

[0033] In some embodiments, the charger **100** or **305** is modular and allows different outlets **115/315** and/or charging ports **120/320** to be added and/or removed from the modular charger. The additional modules are configured to be electrically connected to the rest of the charger **100** or **305** to provide charge to the connected electronic devices **205** and **220**. Furthermore, the additional modules are in communication with the charger controller **410** (shown in FIG. **4**) to control the rate of charge provided by the added outlet **115/315** and/or charging port **120/320**.

[0034] FIG. **4** depicts a simplified block diagram of an exemplary computer system **400** for monitoring and controlling a charging process in accordance with at least one embodiment of the present disclosure. In the exemplary embodiment, system **400** may be used for controlling the charging of electronic devices **405**. In the exemplary embodiment, the charging of the electronic devices **405** is through a charger **100** and **305** (shown in FIGS. **1** and **3**), which provides throttled electrical current to the connected electronic devices **405** to charge the battery(s) of those devices.

[0035] In the exemplary embodiment, the system **400** is configured to provide for charging devices **405** at the minimum charging rate to extend the useful life of a given device **405** over the fastest possible (daily) charge to reach a maximum charge state.

[0036] In the exemplary embodiment, the system **400** provides users of portable electronic devices **405** with the ability to charge those devices **405** at the minimum rate of charge (RoC) in order to lengthen the useful life of the LIB. This system **400** prolongs battery life in electronic devices **405** such as cell phones, tablets, laptops or remotely managed devices or other devices that rely on LIBs. System **400** determines the minimum rate of charge of a device **405** by starting at a predetermined starting ROC.

[0037] In some embodiments, the predetermined rate of charge is provided by the user. In other embodiments, the predetermined rate of charge was previously determined by a computing device using the systems and methods described herein. In further embodiments, the predetermined or starting rate of charge is further based upon variations of other attributes and/or parameters, such as, but not limited to, the current temperature and/or the number of prior recharging cycles.

[0038] Then the system **400** determines if the device **405** accepts the charge at that ROC. In some embodiments, the system **400** determines the acceptance of the charge by the device **405** accepting the charge and completing the circuit. In other embodiments, the system **400** determines the acceptance of the charge by monitoring the current state of charge of the device **405** to determine if it increases. If the device **405** does not accept the starting ROC, then the system **400** increases the ROC in a stepped manner until the device **405** accepts the charge.

[0039] The system **400** notes the provided ROC and continues to monitor the device **405** to determine if the device **405** continues to charge. In some embodiments, the charging attributes of the device **405** may change based on different attributes of the battery. For example, if a battery heats up and/or has a different state of charge, then one or more charging attributes of the battery, such as minimum ROC may change over time. If during later monitoring, the battery stops accepting the charge from the system **400**, the system **400** increases the ROC in steps until the battery accepts the charge from the system **400**.

[0040] In some embodiments, after the battery has accepted a ROC for a predetermined period of time, the system **400** reduces the ROC by one or more steps and determines if the battery accepts that reduced ROC. If the battery accepts the reduced ROC, then the system **400** further reduces the ROC until the battery no longer accepts the further reduced ROC. Then the system **400** returns to a previously accepted minimum ROC to charge the battery. The system **400** continues to ensure that the battery is charged at the minimum ROC allowed by the battery.

[0041] In the exemplary embodiment, electronic devices **405** are powered by rechargeable batteries, such as, but not limited to, including lead-acid, zinc-air, nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion (Li-ion), lithium iron phosphate (LiFePO4), lithium-ion polymer (Li-ion polymer), and any other rechargeable battery. In the exemplary embodiment, electronic devices **405** electrically connect to the charger **100** or **305** via a wired or wireless connection to receive charge from the charger **100** and **305**. In some embodiments, the electronic devices **405** are in communication with the charger controller **410** via a wired connection, such as the wired connection for receiving electrical charge. In other embodiments, the electronic devices **405** are in communication with the charger controller **410** via a wireless connection, such as, but not limited to, Wi-Fi, Bluetooth, NFC, etc. Examples of electronic devices **405** include, but are not limited to, a laptop computer, a personal digital assistant (PDA), a cellular phone, a smartphone, a tablet, a phablet, wearable electronics, smart watch, earbuds, electronic toys, a power bank, power tools, an electric vehicle, and/or other electronic, battery-powered devices.

[0042] In at least one embodiment, the charger controller **410** is a part of charger **100** and **305**. In other embodiments, charger controller **410** is in communication with the charger **100** and **305**. The charger controller **410** throttles typical US electrical utility current delivered at a wall outlet through resistance and impedance. In the exemplary embodiment, charger controller **410** is a computer that allows remote computer devices, such as, but not limited to electronic device **405** and mobile computer device **425** to connect using a web browser or a software application, which enables electronic device **405** and/or mobile computer device **425** to access the charger controller **410** using the Internet or other network. More specifically, charger controller **410** is communicatively coupled to the Internet through many interfaces including, but not limited to, at least one of a network, such as the Internet, a local area network (LAN), a wide area network (WAN), or an integrated services digital network (ISDN), a dial-up-connection, a digital subscriber line (DSL), a cellular phone connection, and a cable modem. Charger controller **410** may be any device capable of accessing the Internet including, but not limited to, a desktop computer, a laptop computer, a personal digital assistant (PDA), a cellular phone, a smartphone, a tablet, a phablet, wearable electronics, smart watch, or other web-based connectable equipment or mobile devices. The charger controller **410** may be remote from the charger **100** and **305** and cloud-based or the charger controller **410** may be located at the charger **100** and **305**.

[0043] A database server **415** may be communicatively coupled to a database **420** that stores data. In one embodiment, database **420** may include battery profiles, charging parameters, and/or user preferences. In the exemplary embodiment, database **420** may be stored remotely from charger controller **410**. In some embodiments, database **420** may be decentralized. In the exemplary embodiment, a user may access database **420** via mobile computer devices **425** by logging onto charger controller **410**, as described herein.

[0044] Mobile computer devices **425** may also execute an application **430**. Mobile computer devices **425** may be configured to execute application **430** to receive data from charger controller **410** and transmit data to charger controller **410**. Mobile computer device **425** may be communicatively coupled to the Internet through many interfaces including, but not limited to, at least one of a network, such as the Internet, a local area network (LAN), a wide area network (WAN), or an integrated services digital network (ISDN), a dial-up-connection, a digital subscriber line (DSL), a cellular phone connection, and a cable modem. Mobile computer device **425** may be any device capable of accessing the Internet including, but not limited to, a desktop computer, a laptop computer, a personal digital assistant (PDA), a cellular phone, a smartphone, a tablet, a phablet, wearable electronics, smart watch, or other web-based connectable equipment or mobile devices. In some embodiments, mobile computer device **425** is configured to execute application **430** to communicate with charger controller **410**. In these embodiments, the application **430** receives charging status information from the charger controller **410**.

[0045] A further embodiment of the disclosure has two primary components: 1) the above-described charger **100** and **305** that delivers and regulates the charge delivered to connected electronic devices **405**, and 2) a charger controller **410** that controls the rate of charge delivered to the connected electronic devices **405**. In some embodiments, the charger controller **410** is a part of the charger **100** and **305**. In other embodiments, the charger controller **410** is remoted from the charger **100** and **305**, such as in the cloud.

[0046] The above system **400** may be used in multiple different manners to provide charging power to these electronic devices **405**. In some embodiments, the system **400** is configured to allow the user to provide the predetermined starting ROC for the connected device **405**, such as via the application **430** or an input on the charger **100**. In still further embodiments, the system **400** is also configured to allow the user to set one or more additional attributes, including, but not limited to, the step size between ROCs, a maximum ROC, the waiting period of time before the system **400** tries to reduce the ROC, and/or the waiting period of time to determine if the device **405** is accepting the charge.

[0047] In another embodiment, the electronic device **405** is wired into the charger **100** and **305** and the electronic device **405** also includes an application. In this embodiment, the electronic device **405** includes all transformer and protection capabilities inside device **405**.

[0048] The Application **430** and/or charger controller **410** are designed to run on either a mobile or PC platform and manages the connection between a user's device and the charger **100** and **305**. The Application **430** and/or charger controller **410** allows a user to control the charging of their electronic device **405** in several different ways. Various statistics of the user's device, including the state-of-charge (SoC) and rate-of-charge (RoC), are communicated from the Application **430** and/or charger controller **410** to the charger **100** and **305**. These statistics allow the charger **100** and **305** to adjust its status to meet the charging parameters set by the user. Furthermore, the Application **430** and/or charger controller **410** are designed to run in the background while the user's electronic device **405** is connected to the charger **100** and **305**, in order to continuously send updates to the charger **100** and **305**. Additionally, the Application **430** and/or charger controller **410** are capable of calculating and providing estimates to users about parameters such as time to charge completion.

[0049] The application **430** provides charging parameters from the user to the charger controller **410** and provides attributes of the electronic device **405** being charged to the user. The attributes include information about the health and status of the battery and/or the electronic device **405**. The information may include, but is not limited to, current battery charge, maximum battery charge, maximum potential battery charge, maximum charging rate for electronic device, minimum charging rate for electronic device, time to maximum battery charge, battery temperature, and/or other information. In some embodiments, some of this information may be provided via indicators, (i.e., visible gauges **125** (shown in FIG. **1**).

[0050] The system **400** is informed by a database **420** of popular target devices with battery capacity (mAh) and recommended min and max RoCs and min and max SoCs. The Application **430** and/or charger controller **410** will use this database **420** to provide estimates of time to complete charging for a given electronic device **405** as well as to set optimal minimum RoC.

[0051] In at least one embodiment, the charger **100** and **305** contains a pre-programmed microcontroller which is capable of adjusting the powered-on status and RoC of the charger **100** and **305**. The microcontroller establishes a wireless connection or can be used via a wired connection with the user's mobile computer device **425** which allows it to receive periodic updates from the device **405**.

[0052] When the charger **100** and **305** receives the signal from the user's mobile computer device **425** to begin the charging process, it first reads the user-set parameters, such as, but not limited to, starting ROC, RCO step value, Max SoC, and desired time to completion, and saves these parameters in non-volatile memory. The microcontroller enables the charger **100** and **305** at a specified predetermined RoC and monitors to determine if the connected device **405** accepts the charge. In some embodiments, the charger **100** and **305** determines that the device **405** accepts the charge. In other embodiments, the user's device's **425** informs the charger **100** and **305** that the charge has been accepted.

[0053] In the exemplary embodiment, the application **430** and charger controller **410** use Bluetooth Low Energy (BLE) technology to establish a connection with the charger **100** and **305** when it is first connected. When using the charger **100** and **305** for the first time, the application **430** and charger controller **410** provide an onboarding process which helps users pair the charger **100** and **305** with their mobile computer device **425**. Once the device **425** is paired, the charger **100** and **305** will automatically connect to the user's mobile computer device **425** once it is plugged in.

[0054] During the charging process, the application **430** and/or the charger controller **410** will periodically send updates to the charger **100** and **305** containing information about the device's current SoC. Additionally, the application **430** and/or the charger controller **410** will determine the ROC used at different points during the charging of the device **405**. The application **430** and/or the charger controller **410** will then store these values. In some embodiments, the application **430** and/or the charger controller **410** use the stored ROC values from past charging sessions to determine the starting ROC value and/or the ROC step value.

[0055] FIG. **5** depicts an exemplary configuration of mobile computer device **425** shown in FIG. **4**, in accordance with one embodiment of the present disclosure. User computer device **502** may be operated by a user **501**. User computer device **502** may include, but is not limited to, mobile computer devices **425**, electronic device **405**, charger controller **410** (all shown in FIG. **4**), charger **100** (shown in FIG. **1**), and charger **305** (shown in FIG. **3**). User computer device **502** may include a processor **505** for executing instructions. In some embodiments, executable instructions are stored in a memory area **510**. Processor **505** may include one or more processing units (e.g., in a multi-core configuration). Memory area **510** may be any device allowing information such as executable instructions and/or transaction data to be stored and retrieved. Memory area **510** may include one or more computer readable media.

[0056] User computer device **502** may also include at least one media output component **515** for presenting information to user **501**. Media output component **515** may be any component capable of conveying information to user **501**. In some embodiments, media output component **515** may include an output adapter (not shown) such as a video adapter and/or an audio adapter. An output adapter may be operatively coupled to processor **505** and operatively couplable to an output device such as a display device (e.g., a cathode ray tube (CRT), liquid crystal display (LCD), light emitting diode (LED) display, or "electronic ink" display) or an audio output device (e.g., a speaker or headphones).

[0057] In some embodiments, media output component **515** may be configured to present a graphical user interface (e.g., a web browser and/or a client application) to user **501**. A graphical user interface may include, for example, an interface for displaying charging status. In some embodiments, user computer device **502** may include an input device **520** for receiving input from user **501**. User **501** may use input device **520** to, without limitation, provide charging parameters.

[0058] Input device **520** may include, for example, a keyboard, a pointing device, a mouse, a stylus, a touch sensitive panel (e.g., a touch pad or a touch screen), a gyroscope, an accelerometer, a position detector, a biometric input device, and/or an audio input device. A single component such as a touch screen may function as both an output device of media output component **515** and input device **520**.

[0059] User computer device **502** may also include a communication interface **525**, communicatively coupled to a remote device such as charger controller **410**. Communication interface **525** may include, for example, a wired or wireless network adapter and/or a wireless data transceiver for use with a mobile telecommunications network.

[0060] Stored in memory area **510** are, for example, computer readable instructions for providing a user interface to user **501** via media output component **515** and, optionally, receiving and processing input from input device **520**. A user interface may include, among other possibilities, a web browser and/or a client application. Web browsers enable users, such as user **501**, to display and interact with media and other information typically embedded on a web page or a website from charger controller **410**. A client application allows user **501** to interact with, for example, charger controller **410**. For example, instructions may be stored by a cloud service, and the output of the execution of the instructions sent to the media output component **515**.

[0061] Processor **505** executes computer-executable instructions for implementing aspects of the disclosure. In some embodiments, the processor **505** is transformed into a special purpose microprocessor by executing computer-executable instructions or by otherwise being programmed. For example, the processor **505** may be programmed with the instruction such as illustrated in FIG. **6**.

[0062] In some embodiments, user computer device **502** may include, or be in communication with, one or more applications, such as application **430** (shown in FIG. **4**). User computer device **502** may be configured to receive data from the one or more sensors and store the received data in memory area **510**. Furthermore, user computer device **502** may be configured to transmit the sensor data to a remote computer device, such as charger controller **410**, through communication interface **525**.

[0063] FIG. **6** illustrates a flow chart of an exemplary computer implemented process **600** for monitoring and charging electronic devices **405** (shown in FIG. **4**) at a minimum rate of charge (ROC) using the system **400** (shown in FIG. **4**). Process **600** may be implemented by a computing device, for example charger controller **410** (shown in FIG. **4**). In the exemplary embodiment, charger controller **410** may be in communication with a mobile computer device **425** (shown in FIG. **4**), one or more electronic devices **405**, charger **100** (shown in FIG. **1**), and/or charger **305** (FIG. **3**).

[0064] In the exemplary embodiment, the charger **100** and/or **305** connects **605** to an electronic device **405** to charge. In the exemplary embodiment, the charger controller **410** determines that the charger **100** and/or **305** has connected **605** to a device **405**.

[0065] In the exemplary embodiment, the charger controller **410** determines **610** a starting rate of charge (ROC) for charging the device **405**. The starting ROC is determined to be a prediction for the minimum ROC that will allow the device **405** to charge. In some embodiments, the starting ROC is set by the user. In other embodiments, the starting ROC is based on the connected device type. For example, a smartphone **205** (shown in FIG. **2**) may have a smaller starting ROC than a tablet **220** (shown in FIG. **2**) or a laptop. In other embodiments, the charger controller **410** determines **610** the starting ROC based on historical charging information and detected minimum ROCs. For example, the charger controller **410** may store the minimum accepted ROC for a battery and/or electronic device **405**. The charger controller **410** may also store other attributes of that battery and/or electronic device **405**, such as temperature, number of prior recharging cycles, starting state of charge, and/or any other attributes desired. In the exemplary embodiment, the starting ROC is for current and is provided in amps.

[0066] In the exemplary embodiment, the charger **100** and/or **305** provides **615** a charge to the device **405** at the determined ROC. In some embodiments, the charger controller **410** instructions the charger **100** and/or **305** to provide **615** the charge to the device **405** at the determined ROC.

[0067] Then the charger controller **410** determines **620** if the charge is being accepted by the device **405**. In some embodiments, the charger **100** and/or **305** determines that the charge is being accepted by the current being accepted by the device. In other embodiments, the charger controller **410** determines that the charge is being accepted by the device **405** by detecting an increase in the state of charge of the device **405**. If the device **405** is not accepting the charge, then the charger controller **410** steps-up **625** the rate of charge and instructs the charger **100** and/or **305** to provide **615** the increased ROC. In the exemplary embodiment, the step-up value is 0.1 amps. In other embodiments, the step-up value is 1 mA. One having skill in the art would understand that the step-up value could be any increase in the amount of current desired. In some embodiments, the step-up value is set by the user. In other embodiments, the step-up value is set by the charger controller **410** based upon the device type and/or the historical charging information. The charger controller **410** continues to step-up **625** the ROC until the charge is accepted **620** by the device **405**.

[0068] Once the determination **620** is that the charge is accepted by the device **405**, the charger **100** and/or **305** and the charger controller **410** continues to provide **630** charge at the current ROC. Next the charger **100** and/or **305** and the charger controller **410** determines **635** if a delay parameter has been met. The delay parameter may be a period of time and/or a state of charge threshold, for example. While the delay parameter conditions/threshold has not been met, the charger **100** and/or **305** and the charger controller **410** continues to provide **620** charge at the current ROC. For example, the delay parameter may be state of charge of the battery, where the condition is met when the state of charge reaches 20%, for example. The delay parameter may be set by the user and/or historical charging information about the individual battery and/or other batteries similar to the one charging. In some embodiments, the delay parameter may include a plurality of thresholds. For example, the delay parameter may cause the charger **100** and/or **305** and the charger controller **410** attempt to reduce the ROC at a state of charge of 20%, 40%, 60%, and/or 80%.

[0069] Once the delay parameter conditions/threshold has been met, the charger controller **410** steps down **640** the ROC. In some embodiments, the step-up amount and the step-down amount are the same. In other embodiments, the step-up amount and the step-down amount are different. The charger controller **410** then determines **620** if the newly lowered ROC is accepted by the device **405**. If accepted, then the charger **100** and/or **305** continues to provide **630** charge at that rate. If the determination **620** is that the charge is not accepted, then the charger controller **410** steps-up **625** the ROC. In some embodiment, the charger controller **410** returns the ROC to the previously accepted amount. In this way the charger controller **410** charges the device **405** at the lowest ROC possible during the entire charging process.

[0070] In some embodiments, the charger controller **410** is configured to recognize the battery being charged. The charger controller **410** may then set the starting ROC based on past charging information about that battery. In other embodiments, the charger controller **410** may adjust the starting ROC based upon one or more parameters of the battery, such as, but not limited to, current temperature and/or number of prior recharging cycles. The starting ROC may also be set based on the nature of the battery and/or the electronic device **405**. For example, an electric vehicle would have a higher starting ROC than a smartphone or a smartwatch.

[0071] At least one of the technical problems addressed by this system may include: (i) lessens battery degradation; (ii) extends battery life; (iii) reduces energy cost; (iv) conserves electrical power; (v) provides optimal battery life; (vi) enables the collection of data to optimize charging over time; (vii) tailors charging speed to device being charged; and/or (viii) charge the device at the minimum ROC possible.

[0072] The methods and systems described herein may be implemented using computer programming or engineering techniques including computer software, firmware, hardware, or any combination or subset thereof, wherein the technical effects may be achieved by performing at least one of the following steps: a) determine a current rate of charging for a connected device; b) provide electrical energy to the connected device based upon the current rate of charging; c) determine if the connected device accepts the electrical energy at the current rate of charging; d) if the connected device does not accept the electrical energy at the current rate of charging, increase the current rate of charging until the connected device accepts the electrical energy at the current rate of charging; e) determine a starting rate of charging for the connected device; f) provide electrical energy to the connected device based upon the starting rate of charging; g) determine if the connected device accepts the electrical energy at the starting rate of charging; h) if the connected device does not accept the electrical energy at the starting rate of charging, increase the current rate of charging from the current rate of charging; i) determine the starting rate of charge based upon a device type of the connected device; j) determine the starting rate of charge based upon a plurality of historical charging information; k) determine the starting rate of charge based upon one or more user preferences; l) increase the current rate of charging by a step amount; m) after increasing the current rage of charging by a step amount determine if the connected device accepts the electrical energy at the increased current rate of charging; n) if the connected device does not accept the electrical energy at the increased current rate of charging, increase the current rate of charging by another step amount; o) reduce the current rate of charging by a step amount; p) determine if the connected device accepts the electrical energy at the decreased current rate of charging; q) increase the rate of charging if the connected device does not accept the electrical energy at the decreased current rate of charging; r) reduce the current rate of charging by a step amount after a predetermined period of time of providing electrical energy at the current rate of charging; s) reduce the current rate of charging by a step amount after a threshold state of charge for the connected device has been reached; t) reduce the current rate of charging by a step amount after a delay parameter condition has been met; u) wherein the charger controller is housed in a housing of the charging device; v) wherein the charger controller is in communication with the charging device via a wireless connection; w) wherein an application on the mobile computer device interfaces between a user and the charger controller; x) wherein an output of the at least one output is an outlet; y) wherein an output of the at least one output is an USB connector; z) wherein an output of the at least one output is a lightning connector; aa) wherein the charging device is configured to be plugged into a wall outlet; and/or bb) wherein the charging device is lightweight and portable.

Additional Considerations

[0073] As will be appreciated based upon the foregoing specification, the above-described embodiments of the disclosure may be implemented using computer programming or engineering techniques including computer software, firmware, hardware or any combination or subset thereof. Any such resulting program, having computer-readable code means, may be embodied or provided within one or more computer-readable media, thereby making a computer program product, i.e., an article of manufacture, according to the discussed embodiments of the disclosure. The computer-readable media may be, for example, but is not limited to, a fixed (hard) drive, diskette, optical disk, magnetic tape, semiconductor memory such as read-only memory (ROM), and/or any transmitting/receiving medium such as the Internet or other communication network or link. The article of manufacture containing the computer code may be made and/or used by executing the code directly from one medium, by copying the code from one medium to another medium, or by transmitting the code over a network.

[0074] These computer programs (also known as programs, software, software applications, "apps," or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms "machine-readable medium" "computer-readable medium" refers to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The "machine-readable medium" and "computer-readable medium," however, do not include transitory signals. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0075] As used herein, the term "database" can refer to either a body of data, a relational database management system (RDBMS), or to both. As used herein, a database can include any collection of data including hierarchical databases, relational databases, flat file databases, object-relational databases, object-oriented databases, and any other structured collection of records or data that is stored in a computer system. The above examples are example only, and thus are not intended to limit in any way the definition and/or meaning of the term database. Examples of RDBMS' include, but are not limited to including, Oracle® Database, MySQL, IBM® DB2, Microsoft® SQL Server, and PostgreSQL. However, any database can be used that enables the systems and methods described herein. (Oracle is a registered trademark of Oracle Corporation, Redwood Shores, California; IBM is a registered trademark of International Business Machines Corporation, Armonk, New York; and Microsoft is a registered trademark of Microsoft Corporation, Redmond, Washington.)

[0076] As used herein, a processor may include any programmable system including systems using micro-controllers, reduced instruction set circuits (RISC), application specific integrated circuits (ASICs), logic circuits, and any other circuit or processor capable of executing the functions described herein. The above examples are example only, and are thus not intended to limit in any way the definition and/or meaning of the term "processor."

[0077] As used herein, the terms "software" and "firmware" are interchangeable, and include any computer program stored in memory for execution by a processor, including RAM memory, ROM memory, EPROM memory, EEPROM memory, and non-volatile RAM (NVRAM) memory. The above memory types are example only, and are thus not limiting as to the types of memory usable for storage of a computer program.

[0078] In another example, a computer program is provided, and the program is embodied on a computer-readable medium. In an example, the system is executed on a single computer system, without requiring a connection to a server computer. In a further example, the system is being run in a Windows® environment (Windows is a registered trademark of Microsoft Corporation, Redmond, Washington). In yet another example, the system is run on a mainframe environment and a UNIX® server environment (UNIX is a registered trademark of X/Open Company Limited located in Reading, Berkshire, United Kingdom). In a further example, the system is run on an iOS® environment (iOS is a registered trademark of Cisco Systems, Inc. located in San Jose, CA). In yet a further example, the system is run on a Mac OS® environment (Mac OS is a registered trademark of Apple Inc. located in Cupertino, CA). In still yet a further example, the system is run on Android® OS (Android is a registered trademark of Google, Inc. of Mountain View, CA). In another example, the system is run on Linux® OS (Linux is a registered trademark of Linus Torvalds of Boston, MA). The application is flexible and designed to run in various different environments without compromising any major functionality.

[0079] In some embodiments, the system includes multiple components distributed among a plurality of computing devices. One or more components may be in the form of computer-executable instructions embodied in a computer-readable medium. The systems and processes are not limited to the specific embodiments described herein. In addition, components of each system and each process can be practiced independent and separate from other components and processes described herein. Each component and process can also be used in combination with other assembly packages and processes.

[0080] As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural elements or steps, unless such exclusion is explicitly recited. Furthermore, references to "example" or "one example" of the present disclosure are not intended to be interpreted as excluding the existence of additional examples that also incorporate the recited features. Further, to the extent that terms "includes," "including," "has," "contains," and variants thereof are used herein, such terms are intended to be inclusive in a manner similar to the term "comprises" as an open transition word without precluding any additional or other elements.

[0081] Furthermore, as used herein, the term "real-time" refers to at least one of the time of occurrence of the associated events, the time of measurement and collection of predetermined data, the time to process the data, and the time of a system response to the events and the environment. In the examples described herein, these activities and events occur substantially instantaneously.

[0082] The patent claims at the end of this document are not intended to be construed under 35 U.S.C. § 112 (f) unless traditional means-plus-function language is expressly recited, such as "means for" or "step for" language being expressly recited in the claim(s).

[0083] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A charging system comprising:

a charging device including an electrical input for receiving electrical energy, at least one output for outputting electrical energy, and a communication interface; and

a charger controller including at least one processor in communication with at least one memory device and in communication with the charging device, wherein the at least one processor is programmed to:

determine a current rate of charging for a connected device;

provide electrical energy to the connected device based upon the current rate of charging;

determine if the connected device accepts the electrical energy at the current rate of charging; and

if the connected device does not accept the electrical energy at the current rate of charging, increase the current rate of charging until the connected device accepts the electrical energy at the current rate of charging.

2. The charging system of claim **1**, wherein the at least one processor is further programmed to:

determine a starting rate of charging for the connected device;

provide electrical energy to the connected device based upon the starting rate of charging;

determine if the connected device accepts the electrical energy at the starting rate of charging; and

if the connected device does not accept the electrical energy at the starting rate of charging, increase the current rate of charging from the current rate of charging.

3. The charging system of claim **2**, wherein the at least one processor is further programmed to determine the starting rate of charging based upon a device type of the connected device.

4. The charging system of claim **2**, wherein the at least one processor is further programmed to determine the starting rate of charging based upon a plurality of historical charging information.

5. The charging system of claim **2**, wherein the at least one processor is further programmed to determine the starting rate of charging based upon one or more user preferences.

6. The charging system of claim **1**, wherein the at least one processor is further programmed to increase the current rate of charging by a step amount.

7. The charging system of claim **6**, wherein the at least one processor is further programmed to after increasing the current rate of charging by a step amount determine if the connected device accepts the electrical energy at the increased current rate of charging.

8. The charging system of claim **7**, wherein the at least one processor is further programmed to if the connected device does not accept the electrical energy at the increased current rate of charging, increase the current rate of charging by another step amount.

9. The charging system of claim **1**, wherein the at least one processor is further programmed to reduce the current rate of charging by a step amount.

10. The charging system of claim **9**, wherein the at least one processor is further programmed to determine if the connected device accepts the electrical energy at the decreased current rate of charging.

11. The charging system of claim **10**, wherein the at least one processor is further programmed to increase the current rate of charging if the connected device does not accept the electrical energy at the decreased current rate of charging.

12. The charging system of claim **9**, wherein the at least one processor is further programmed to reduce the current rate of charging by a step amount after a predetermined period of time of providing electrical energy at the current rate of charging.

13. The charging system of claim **9**, wherein the at least one processor is further programmed to reduce the current rate of charging by a step amount after a threshold state of charge for the connected device has been reached.

14. The charging system of claim **9**, wherein the at least one processor is further programmed to reduce the current rate of charging by a step amount after a delay parameter condition has been met.

15. The charging system of claim **1**, wherein the charger controller is housed in a housing of the charging device.

16. The charging system of claim **1**, wherein the charger controller is in communication with the charging device via a wireless connection.

17. The charging system of claim **1**, wherein an application on a mobile computer device interfaces between a user and the charger controller.

18. The charging system of claim **1**, wherein an output of the at least one output is an outlet.

19. The charging system of claim **1**, wherein an output of the at least one output is an USB connector.

20. The charging system of claim **1**, wherein an output of the at least one output is a lightning connector.

21. The charging system of claim **1**, wherein the charging device is configured to be plugged into a wall outlet.

22. The charging system of claim **1**, wherein the charging device is lightweight and portable.

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