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(54) **INDUCTIVE POWER SUPPLY SYSTEM WITH BATTERY TYPE DETECTION**

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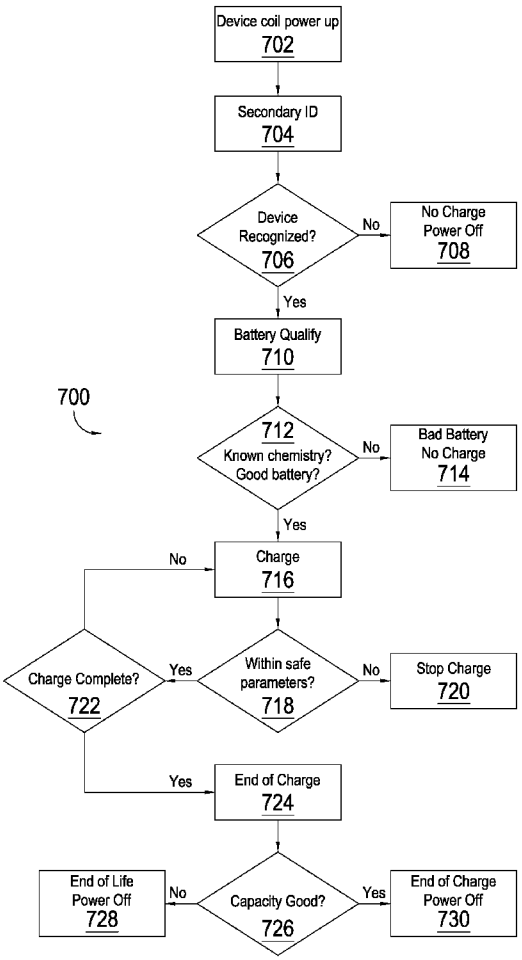
(57) **ABSTRACT**

An inductive power supply system to wirelessly charge a remote device based on detected battery characteristics. The system includes an inductive power supply with a primary coil capable of inductively providing power to a secondary coil in a remote device. The inductive power supply and remote device include communication means for wirelessly communicating. The system further includes a remote device, having a battery with detectable battery characteristics. In operation, the remote device is capable of detecting the battery characteristics by applying a qualification charge to the battery. The inductive power supply system is capable of identifying the battery installed in the remote device by analyzing the detected battery characteristics. The inductive power supply system selects an appropriate charging algorithm based on the analyzed characteristics.



ANKER 1008

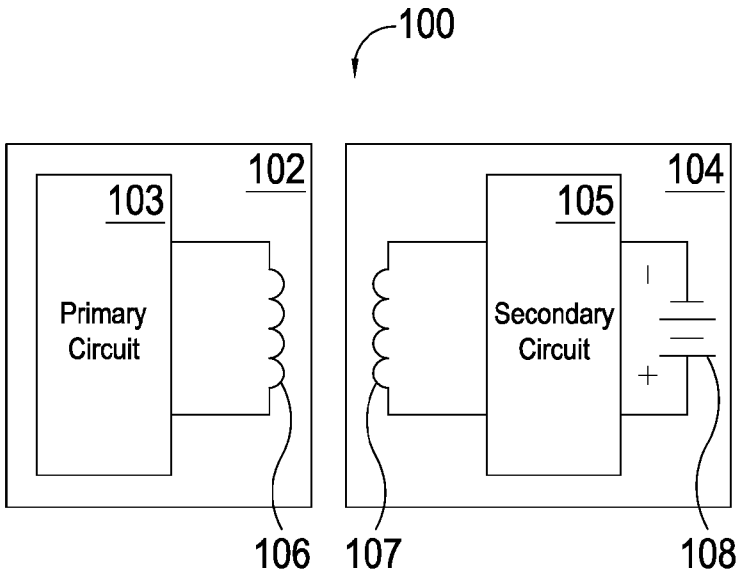

100
102
103
Primary Circuit
104
105
Secondary Circuit
106
107
108

FIG. 1

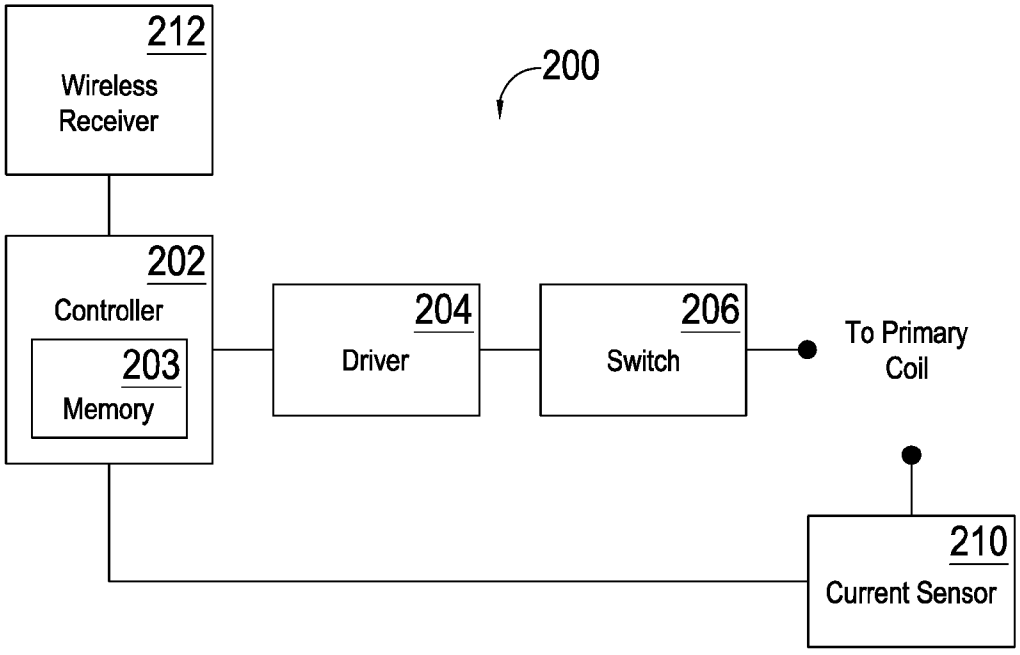

212
Wireless Receiver
200
202
Controller
203
Memory
204
Driver
206
Switch
To Primary Coil
210
Current Sensor

FIG. 2

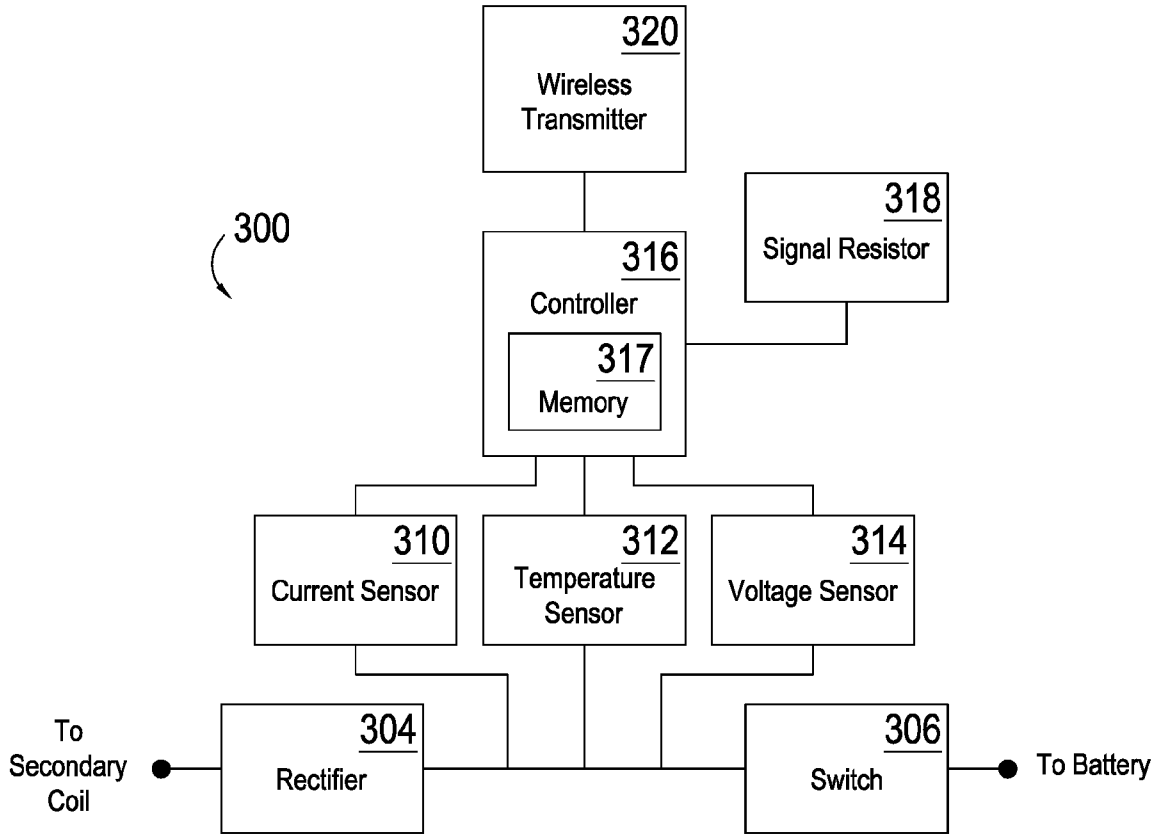

320
Wireless Transmitter
300
318
Signal Resistor
316
Controller
317
Memory
310
Current Sensor
312
Temperature Sensor
314
Voltage Sensor
To Secondary Coil
304
Rectifier
306
Switch
To Battery

FIG. 3

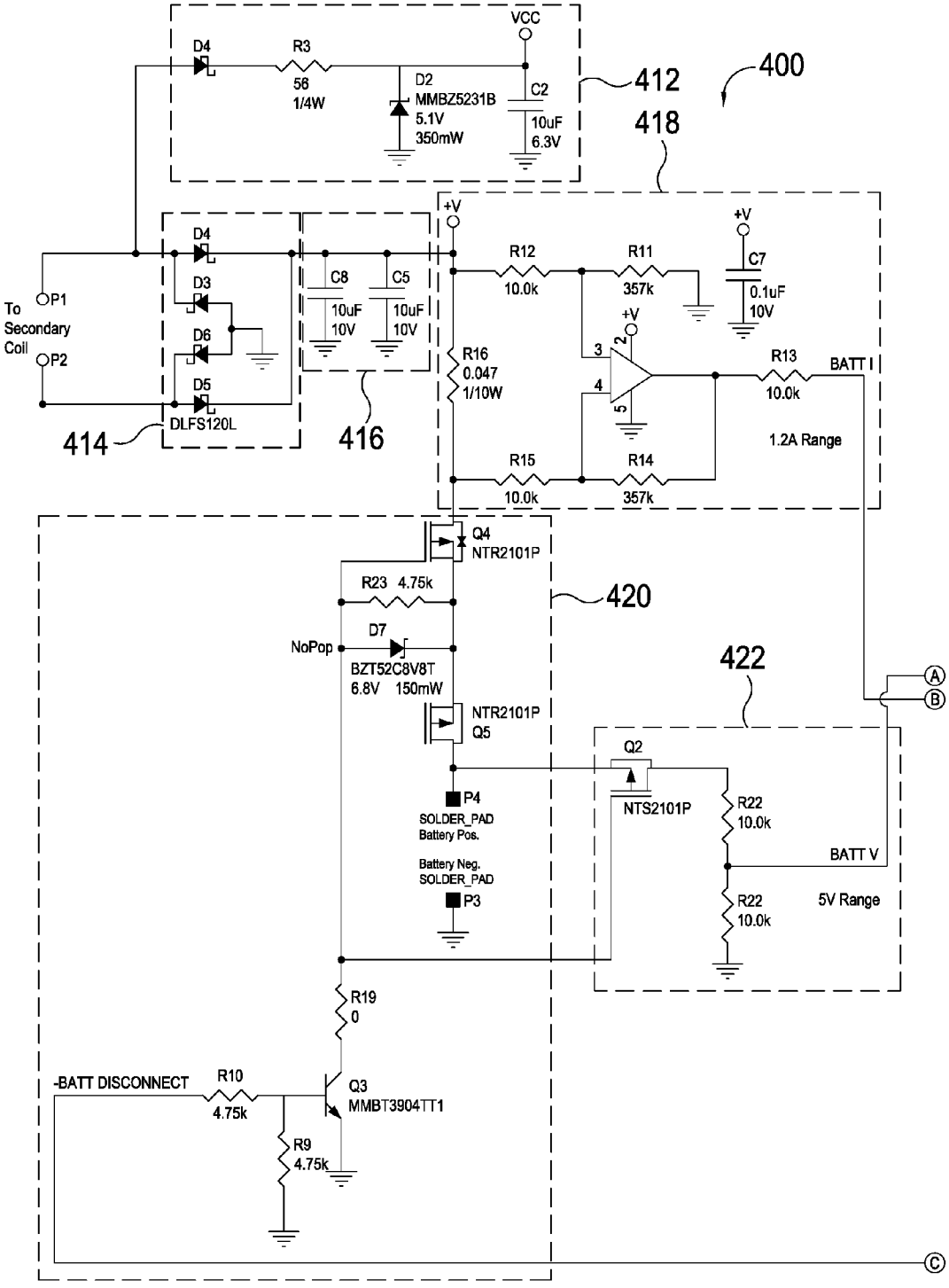

VCC
D4
R3
56
1/4W
D2
MMBZ5231B
5.1V
350mW
C2
10uF
6.3V
412
400
418
+V
D4
D3
D6
D5
To
Secondary
Coil
P1
P2
DLFS120L
414
C8
C5
10uF
10V
10uF
10V
416
R12
10.0k
R11
357k
+V
C7
0.1uF
10V
R16
0.047
1/10W
+V
R13
10.0k
BATT I
1.2A Range
R15
10.0k
R14
357k
Q4
NTR2101P
R23 4.75k
420
D7
NoPop
BZT52C8V8T
6.8V 150mW
NTR2101P
Q5
422
Q2
NTS2101P
R22
10.0k
BATT V
R22
10.0k
5V Range
P4
SOLDER_PAD
Battery Pos.
Battery Neg.
SOLDER_PAD
P3
R19
0
-BATT DISCONNECT
R10
4.75k
Q3
MMBT3904TT1
R9
4.75k
A
B
C

FIG. 4a

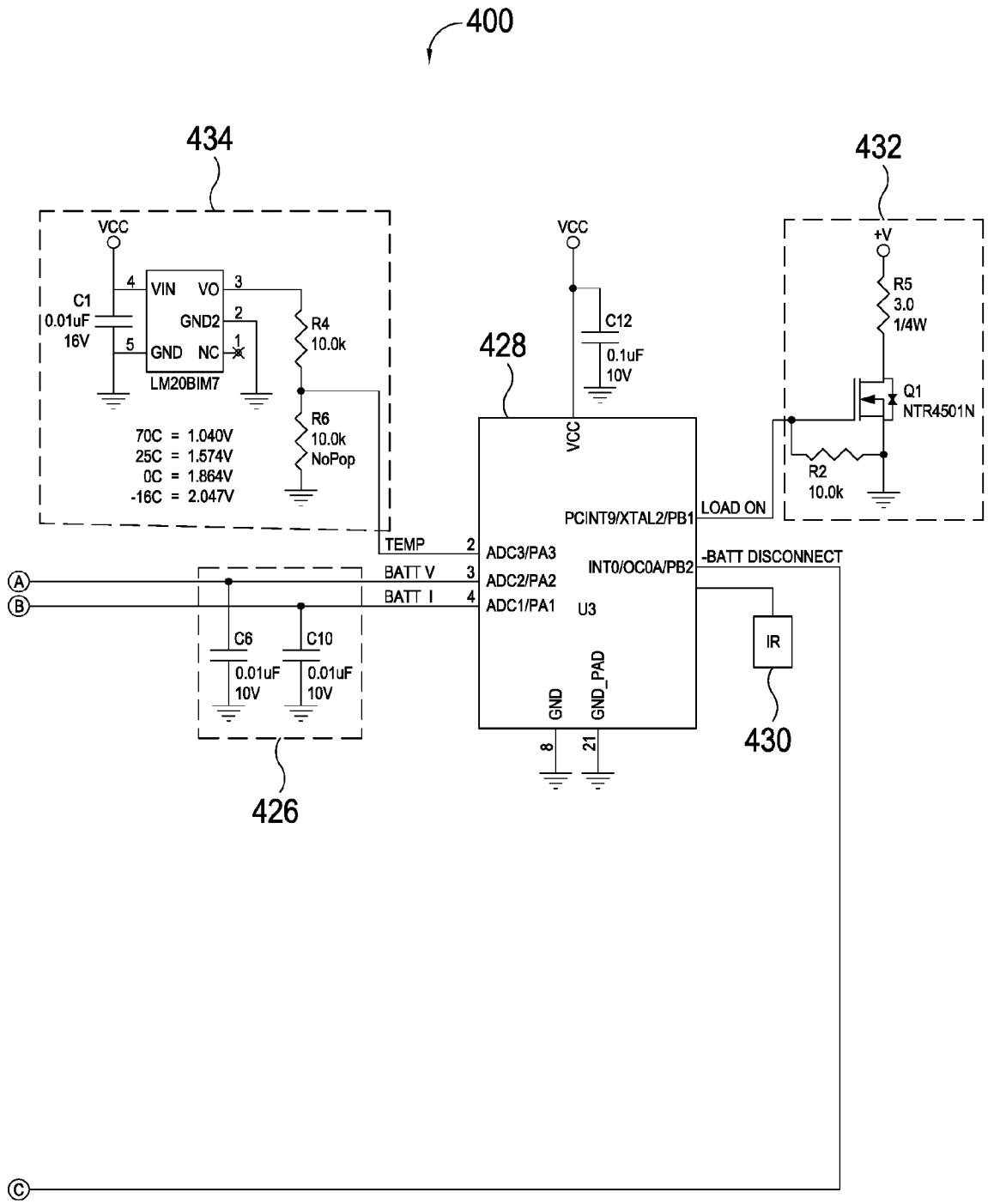

400
434
VCC
C1
0.01uF
16V
VIN
VO
GND2
GND
NC
LM20BIM7
R4
10.0k
R6
10.0k
NoPop
70C = 1.040V
25C = 1.574V
0C = 1.864V
-16C = 2.047V
TEMP
BATT V
BATT I
A
B
C6
0.01uF
10V
C10
0.01uF
10V
426
428
VCC
C12
0.1uF
10V
ADC3/PA3
ADC2/PA2
ADC1/PA1
U3
PCINT9/XTAL2/PB1
INT0/OC0A/PB2
LOAD ON
-BATT DISCONNECT
GND
GND_PAD
8
21
IR
430
432
+V
R5
3.0
1/4W
Q1
NTR4501N
R2
10.0k
C

FIG. 4b

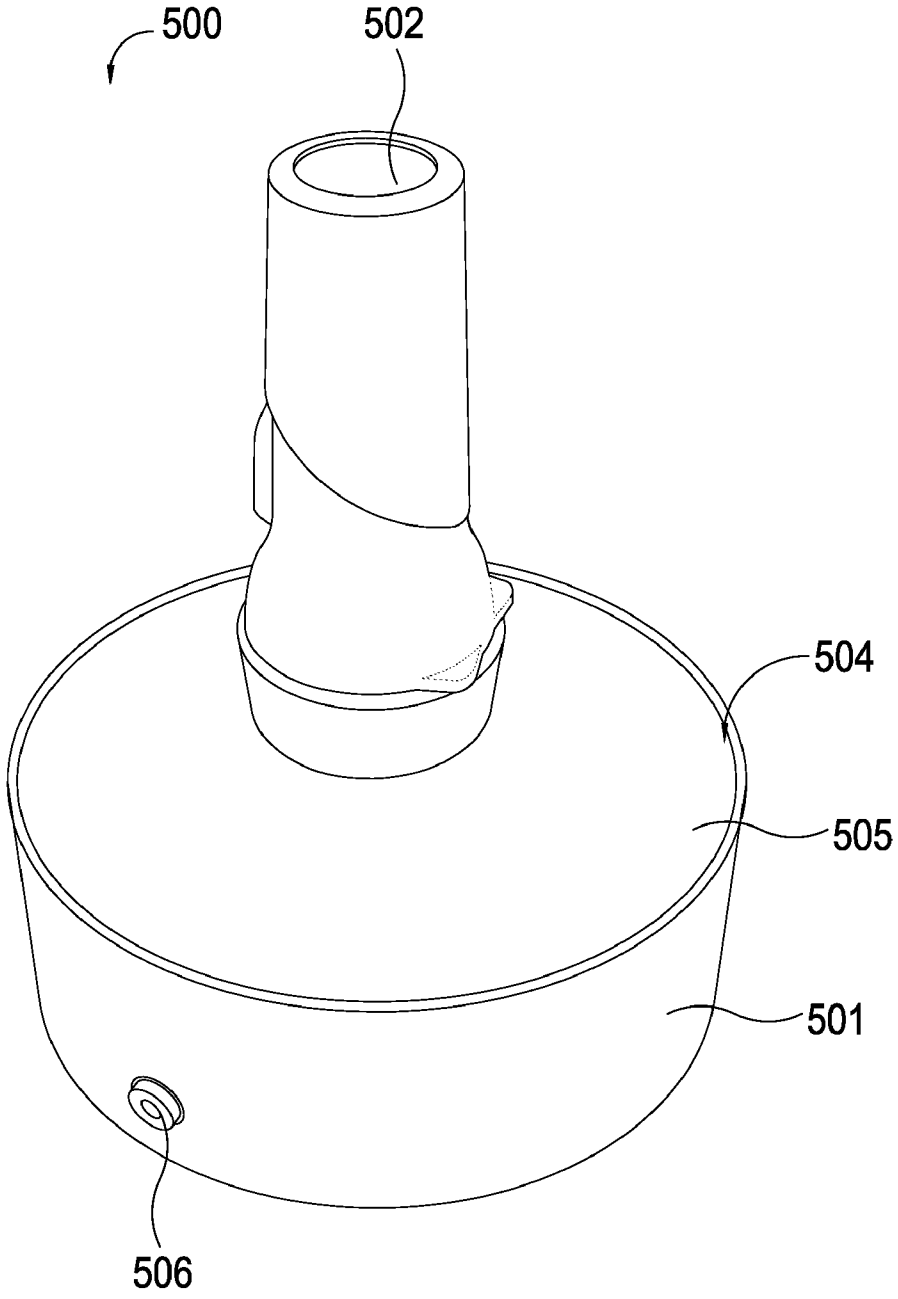


FIG. 5

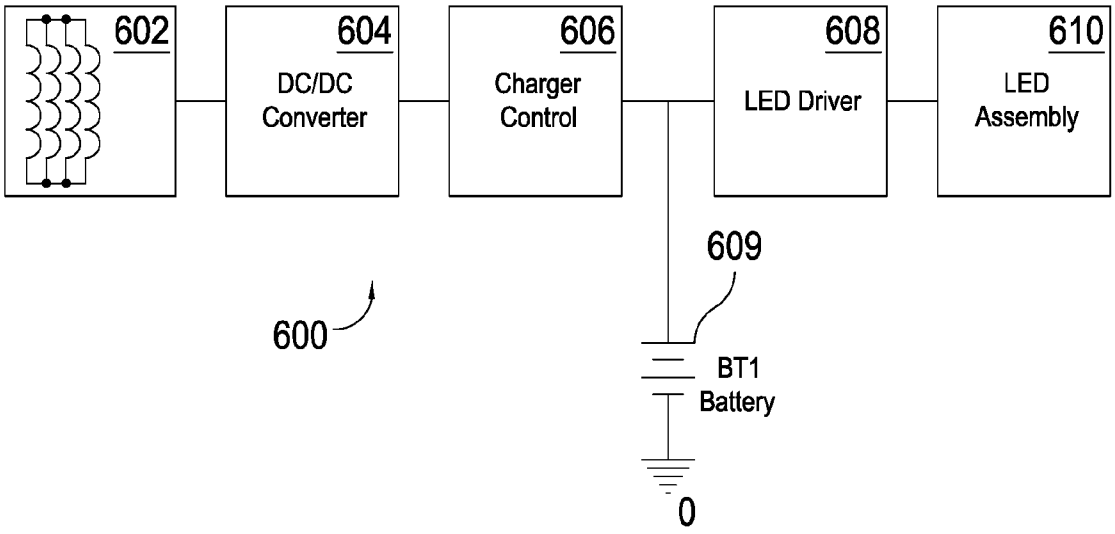

602
604
DC/DC Converter
606
Charger Control
608
LED Driver
610
LED Assembly
609
600
BT1
Battery
0

FIG. 6

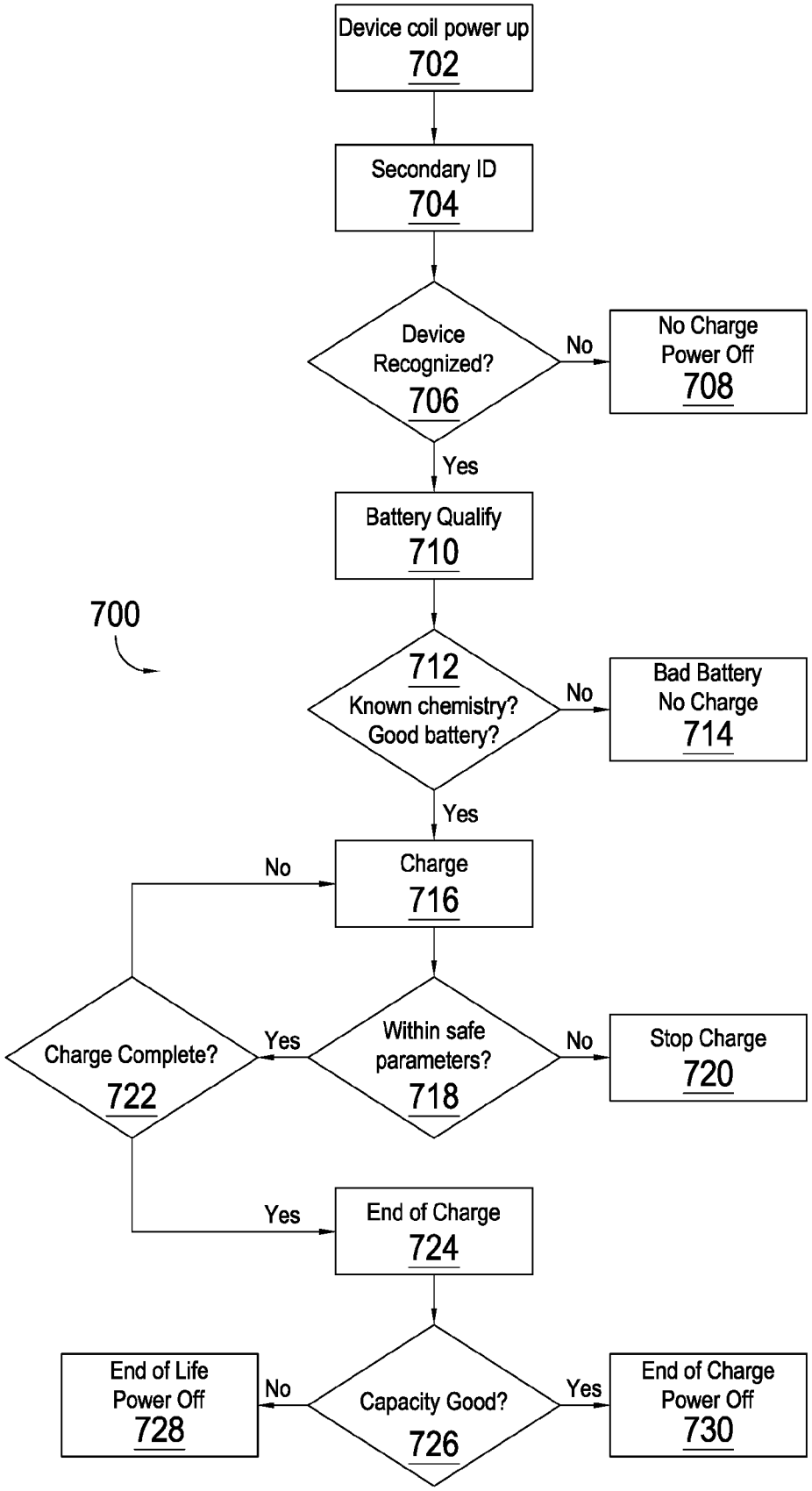

Device coil power up
702
Secondary ID
704
Device Recognized?
706
No
No Charge Power Off
708
Yes
Battery Qualify
710
700
712
Known chemistry? Good battery?
No
Bad Battery No Charge
714
Yes
No
Charge
716
Charge Complete?
722
Yes
Within safe parameters?
718
No
Stop Charge
720
Yes
End of Charge
724
End of Life Power Off
728
No
Capacity Good?
726
Yes
End of Charge Power Off
730

FIG. 7

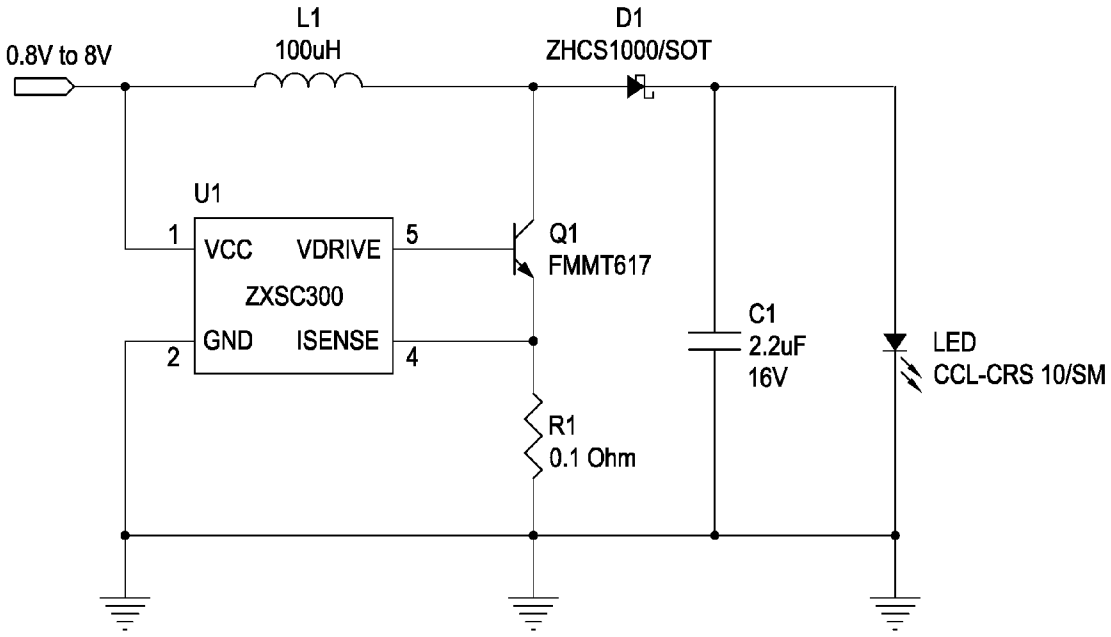

L1
100uH
D1
ZHCS1000/SOT
0.8V to 8V
U1
1
VCC
VDRIVE
5
ZXSC300
GND
ISENSE
2
4
Q1
FMMT617
C1
2.2uF
16V
LED
CCL-CRS 10/SM
R1
0.1 Ohm

FIG. 8

INDUCTIVE POWER SUPPLY SYSTEM WITH BATTERY TYPE DETECTION

[0001] This application claims the benefit of U.S. Provisional Application No. 61/030,749 filed Feb. 22, 2008.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to wireless power and more particularly to a system and method for detecting remote device battery characteristics and wirelessly supplying power to the remote device based on the detected characteristics.

[0003] Charging of batteries with an inductive power supply is well-known. Inductive chargers for electric automobiles or small electric appliances such as toothbrushes have met some amount of success. Because inductive charging does not require a physical connection between the battery and the charger, the charging is considerably more convenient. However, there is room for improvement. One inconvenient aspect of conventional inductive chargers is that they only charge one battery chemistry. That is, conventional inductive chargers use pre-determined hard coded charging algorithms that do not adapt to account for different battery chemistries. Many devices accept batteries of multiple chemistries, but if the user does not employ the correct batteries for the particular inductive charger, the batteries will not charge efficiently, and might not charge at all.

[0004] Some wired battery chargers employ multiple charging algorithms to accommodate devices that use different battery chemistries. For example, some flashlights accept either NiMH batteries or alkaline batteries. Wired battery chargers rely on a direct physical connection to the batteries, which conventional inductive charging systems do not have, in order to determine battery chemistry. For example, conventional wired battery chargers may determine remote device battery chemistry by directly sensing voltage, current or temperature during a qualification charge. These direct measurements may not be taken by a conventional inductive charger, which makes determining the remote device battery chemistry and other remote device battery characteristics difficult.

SUMMARY OF THE INVENTION

[0005] The present invention provides an inductive power supply system and method for detecting remote device battery characteristics and wirelessly supplying power to the remote device based on the detected characteristics. The system and method may accommodate a remote device that accepts batteries with various battery characteristics or multiple remote devices that operate using batteries with different battery characteristics.

[0006] One embodiment of the system includes an inductive power supply with a primary circuit and primary coil as well as a remote device with a secondary coil, secondary circuit and battery. The primary circuit includes a controller, a driver, a switch, and a communication means for communicating with the secondary circuit. The secondary circuit includes a rectifier, one or more sensors, a controller, a communication means for communicating with the primary circuit and a switch. The primary coil and secondary coil inductively couple to wirelessly transfer power from the inductive power supply to the remote device according to a selected wireless power charging algorithm. The wireless power charging algorithm is selected based on at least one characteristic of the battery, which are detected by the secondary circuit. The remote device may also store and communicate data about the secondary device, such as number of batteries, expected cell types, reference voltage or calibration information.

[0007] One embodiment of the method includes the steps of identifying the remote device, qualifying the battery of the remote device, selecting a wireless power charging algorithm based on the battery qualification and wirelessly charging the remote device using the selected wireless power charging algorithm.

[0008] The present invention provides a simple and effective system and method for wirelessly charging qualified batteries of a remote device, regardless of the particular type of rechargeable batteries employed by the device. The ability for the inductive power supply system to effectively detect various battery characteristics and employ an appropriate wireless power charging algorithm results in additional flexibility and transparency for the user.

[0009] These and other objects, advantages, and features of the invention will be readily understood and appreciated by reference to the detailed description of the current embodiment and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a block diagram of an inductive power supply system.

[0011] FIG. **2** is a block diagram of a primary circuit.

[0012] FIG. **3** is a block diagram of a secondary circuit.

[0013] FIG. **4** is a circuit diagram of a secondary circuit.

[0014] FIG. **5** is a picture of an inductive power supply system including an inductive power supply and a flashlight.

[0015] FIG. **6** is a block diagram of a flashlight.

[0016] FIG. **7** is a flowchart illustrating a method for detecting remote device battery characteristics and wirelessly supplying power to the remote device based on the detected characteristics.

[0017] FIG. **8** is a circuit diagram of an LED driver.

DESCRIPTION OF THE CURRENT EMBODIMENT

I. Overview

[0018] An inductive power supply system in accordance with an embodiment of the present invention is shown in FIG. **1**, and generally designated **100**. The inductive power supply **102** includes a primary circuit **103** and a primary coil **106**. The remote device **104** includes a secondary coil **107**, a secondary circuit **105** and a battery **108**. The secondary circuit **105** detects certain remote device battery characteristics and the system **100** uses the detected characteristics to determine whether the battery qualifies for charging. If the battery qualifies, an appropriate wireless power charging algorithm is selected and used to wirelessly charge the battery. Although the present invention is generally described in connection with a single battery, a person of ordinary skill in the art would understand that the present invention may be modified to operate with remote devices that have multiple batteries and batteries that have multiple cells.

[0019] A method for detecting remote device battery characteristics and wirelessly supplying power from the inductive power supply to the remote device based on the detected

characteristics in accordance with an embodiment of the present invention is illustrated in FIG. **7**, and generally designated **700**. The method includes identifying the remote device **702-708**, qualifying the battery of the remote device including selecting a wireless power charging algorithm based on the battery qualification **710-714**, and wirelessly charging the remote device using the selected wireless power charging algorithm **716-724**. Other optional steps may be included, such as testing the capacity of the remote device battery **726-730**.

[0020] The inductive power supply system **100** may include memory **203/317** capable of storing, among other things, wireless power supply charging algorithms and battery types. In one embodiment, each wireless power supply charging algorithm is associated with at least one different battery type. In one embodiment, each wireless power supply charging algorithm is associated with at least one different battery chemistry. Further, the memory **203/317** may also store associations between battery characteristics and battery types. In one embodiment the primary controller **202** includes memory **203** and the secondary controller **316** includes memory **317**. In alternative embodiments, only one of the controllers includes memory or the memory is external to the controllers and may be included in the inductive power supply or the remote device. The information stored in memory may be used to permit the inductive power supply **102** to efficiently power the remote device **104**. In applications where the inductive power supply is capable of identifying the remote device, the memory may includes the unique resonant frequency (or pattern of frequencies) for various remote device **102**, along with the desired collection of associated information, such as maximum and minimum operating frequencies, current usage, number of batteries and size of batteries. The memory may, however, include essentially any information that may be useful to the inductive power supply **102** in operating the remote device **104**. For example, the memory may include information regarding the wireless communication protocol of the remote device.

II. Inductive Power Supply

[0021] The present invention is suitable for use with essentially any inductive power supply. Accordingly, the inductive power supply **102** will not be described in detail. Suffice it to say that the inductive power supply **102** includes a primary circuit **103** and a primary coil **106**. The power supply circuit **103** generates and applies alternating current to the primary coil **106**. As a result of the alternating current applied by the power supply circuit **103**, the primary coil **106** generates an electromagnetic field. The power supply circuit **103** may be essentially any circuitry capable of supplying alternating current to the primary coil **106** at the desired frequency or frequencies. For example, the power supply circuit **103** may be the resonant seeking circuit of the inductive power supply system disclosed in U.S. Pat. No. 6,825,620, which is entitled "Inductively Coupled Ballast Circuit" and issued Nov. 30, 2004, to Kuennen et al; the adaptive inductive power supply of U.S. Pat. No. 7,212,414, which is entitled "Adaptive Inductive Power Supply" and issued May 1, 2007, to Baarman; the inductive power supply with communication of U.S. Ser. No. 10/689,148, which is entitled "Adaptive Inductive Power Supply with Communication" and filed on Oct. 20, 2003 to Baarman; the inductive power supply for wirelessly charging a LI-ION battery of U.S. Ser. No. 11/855,710, which is entitled "System and Method for Charging a Battery" and filed on Sep. 14, 2007 by Baarman; the inductive power supply with device identification of U.S. Ser. No. 11/965,085, which is entitled "Inductive Power Supply with Device Identification" and filed on Dec. 27, 2007 by Baarman et al; or the inductive power supply with duty cycle control of U.S. Ser. No. 61/019,411, which is entitled "Inductive Power Supply with Duty Cycle Control" and filed on Jan. 7, 2008 by Baarman—all of which are incorporated herein by reference in their entirety.

[0022] One embodiment of an inductive power supply system in accordance with the present invention is pictured in FIG. **5**. The inductive power supply system depicts an inductive power supply **504** and remote device flashlight **502**. The inductive power supply **504** is contained within a housing **501** having a surface **505** on which to place the remote device flashlight **502**. The housing includes a power plug adapter **506** for plugging the inductive power supply into a wall outlet. The size, shape and configuration of the housing **501** and surface **505** may vary. For example, the surface **505** may be flat and circular (as shown) or it may be contoured to receive one or more remote devices **502**. In one embodiment, the housing may incorporate the inventive principles of U.S. Ser. No. _____ entitled "Magnetic Positioning for Inductive Coupling" to Baarman, which is being filed contemporaneously with the present application.

[0023] One embodiment of a primary circuit of an inductive power supply **102** is illustrated in FIG. **2**, and generally designated **200**. The primary circuit **200** of the illustrated embodiment generally includes a primary controller **202**, a driver circuit **204** and a switching circuit **206**. The primary circuit **200** also includes a communication means for communicating with the remote device. In the illustrated embodiment, primary circuit **200** includes a wireless IR receiver **212** and a current sensor **210**. The current sensor **210** may be used to sense reflected impedance from the remote device, which effectively allows communication over the inductive coupling. In some embodiments, a peak detector replaces or is used in conjunction with the current sensor **210**. In alternative embodiments, the receiver **212** or current sensor **210** may be deleted. In other alternative embodiments, the wireless communication means may replace one or both of the receiver **212** and current sensor **210**, for example, any of WIFI, infrared, Bluetooth, cellular or RFID devices may be implemented in the primary circuit **200**. In operation, as described above, the primary controller **202**, driver circuit **204** and switching circuit **206** apply alternating current to the primary coil **106** to generate a source of electromagnetic inductive power at a selected frequency.

[0024] The primary coil **106** of the illustrated embodiment is a circular coil of wire suitable for generating an electromagnetic field. In some applications, the primary coil **106** may be a coil of Litz wire. The characteristics of the coil may vary from application to application. For example, the number of turns, size, shape and configuration of the coil may vary. Further, the characteristics of the wire may vary, such as length, gauge and type of wire. Although described in connection with a coil of wire, the primary coil **106** may alternatively be essentially any structure capable of generating a suitable electromagnetic field. In one embodiment, the primary coil **106** (or secondary coil **107**) may be replaced by a printed circuit board coil, such as a printed circuit board coil incorporating the inventive principles of U.S. Ser. No. 60/975,953, which is entitled "Printed Circuit Board Coil"

and filed on Sep. 28, 2007 by Baarman et al, and which is incorporated herein by reference in its entirety.

[0025] In certain embodiments of the present invention, the primary controller **202** includes intelligence or programming for making decisions based on the detected battery characteristics. For example, the secondary circuit **105** may be programmed to communicate any detected battery characteristics or a determined battery type to the primary controller **202**. Once the primary controller **202** has access to the battery characteristics or determined battery type, an appropriate charging algorithm may be selected from memory or otherwise determined. In other embodiments, the primary controller **202** does not receive and does not have any specific intelligence or programming for making decisions based on the detected battery characteristics. That is, the primary circuit **103** merely receives messages that dictate the desired power level that should be provided. For example, the primary controller **202** may be programmed to ramp up power (subject to safety conditions) until it receives a message from the secondary to stop. In another embodiment, the primary receives instructions from the secondary about whether to provide more or less power. Alternatively, the primary controller may receive specific instructions to transmit at a particular operating frequency or to adjust its operating frequency in a particular manner. In another embodiment, the primary controller may receive instructions from the remote device **104** to reconfigure the primary circuit **103** to change the resonant frequency based on determinations made by the secondary circuit **105** using detected battery characteristics. In yet another embodiment, the primary controller may receive instructions to change the input voltage to adjust the inductive power output.

[0026] The primary controller **202** may optionally be programmed with additional features. For example, in one embodiment, the primary controller **202** is programmed to identify remote devices using the inventive principles described in U.S. Ser. No. 11/965,085, which was previously incorporated by reference. The remote device ID may include information about the remote device battery. Alternatively, information about the remote device battery may be accessed using the remote device ID as a key to a look up table on the inductive power supply. For example, the information may indicate whether the remote device is within the power range of the inductive power supply. Or, the information may include the types and sizes of batteries accepted by the remote device. For example, a particular remote device may only be capable of receiving two AA batteries due to geometric constraints. The

[0027] Optionally, the inductive power supply may include an LED scheme to indicate charging status. When the LED is off, no device is present. If the LED is solid, a remote device is detected. A flashing LED indicates that the battery is bad or unqualified. A breathing LED indicates that the remote device is currently being charged. A color or intensity change in the LED indicates that charging is complete. A person of ordinary skill in the art would understand that additional or different schemes may be implemented to indicate charging status to the user.

III. Remote Device

[0028] The present invention is suitable for use with a wide variety of remote devices of varying designs and constructions. The present invention may accommodate remote devices that accept various battery types. Battery type is used generally to distinguish between batteries based on one or more battery characteristics of the batteries. For example, batteries with different battery types may have different battery chemistry, battery cells, battery capacity, battery size, battery shape, battery voltage characteristics, battery current characteristics, battery temperature characteristics, battery terminal layouts, cycles, span of cycles, or any combination thereof. The scope of the term battery type may differ depending on the embodiment. For example, in some embodiments, batteries may be different battery types even if they only differ by a single battery characteristic. In other embodiments, batteries may be the same battery type even if they only share a single battery characteristic. The term battery is used throughout this application in the singular, but a person of ordinary skill in the art would understand that the battery could be a battery pack and that battery characteristics or type of battery may refer to battery pack characteristics or the type of battery pack.

[0029] The present invention may accommodate individually charging multiple remote devices that operate using batteries with different battery characteristics. In alternative embodiments, multiple remote devices with similar battery characteristics may be charged simultaneously. It is anticipated that these various remote devices will require power at varying frequency and will have different power requirements.

[0030] As noted above, the remote device **104** generally includes a secondary coil **107**, a secondary circuit **105** and a battery **108**. The remote device **104** is illustrated representatively in the drawings, but it may be essentially any device or component that operates on batteries. For example, a flashlight (as shown in FIG. **5**), cell phone, personal digital assistant, digital media player or other electronic device that is capable of utilizing a rechargeable battery.

[0031] The secondary coil **107** of the illustrated embodiment is a circular coil of wire suitable for generating electricity when in the presence of a varying electromagnetic field. As shown, the secondary coil **107** may correspond in size and shape to the primary coil **106**. For example, the two coils **106** and **107** may have substantially equal diameters. In some applications, the secondary coil **107** may be a coil of Litz wire. As with the primary coil **106**, the characteristics of the secondary coil **107** may vary from application to application. For example, the number of turns, size, shape and configuration of the secondary coil **107** may vary. Further, the characteristics of the wire may vary, such as length, gauge and type of wire. Although described in connection with a coil of wire, the secondary coil **107** may alternatively be essentially any structure capable of generating sufficient electrical power in response to the intended electromagnetic field.

[0032] A secondary circuit in accordance with an embodiment of the present invention is shown in FIG. **3**, and generally designated **300**. The illustrated secondary circuit **300** includes a secondary controller **316**, a rectifier **304**, a switch **306**, a current sensor **310**, a temperature sensor **312** and a voltage sensor **314**. The secondary circuit **300** also includes a communication means for communicating with the inductive power supply **102**. The illustrated embodiment includes a signal resistor **318** for communicating using reflected impedance over the inductive coupling and a wireless transmitter **320**. In alternative embodiments, the signal resistor **318** or wireless transmitter **320** may be deleted. In alternative embodiments, other wireless communication means may replace one or both of the wireless transmitter **320** and signal

resistor **318**. For example, any of a WIFI, infrared, Bluetooth, cellular or RFID device may be used to wirelessly communicate with the inductive power supply **102**.

[0033] In operation, the illustrated secondary circuit **300** is programmed to detect various battery characteristics, such as battery voltage, battery current, battery temperature or a combination thereof. The secondary circuit uses the detected characteristics to determine whether the battery qualifies for charging and if it does, an appropriate charging algorithm is selected by the secondary controller **316**. In alterative embodiments, the intelligence may be spread across the primary circuit and secondary circuit, as described above. For example, as noted above, in one embodiment, the secondary circuit **300** may communicate the detected battery characteristics to the inductive power supply so that an appropriate charging algorithm may be selected by the primary circuit **103**.

[0034] For purposes of disclosure, one embodiment of a secondary circuit is shown in FIG. **4**, and generally designated **400**. In the embodiment illustrated in FIG. **4**, the secondary circuit **400** generally includes a secondary controller **428**, rectifier **414** (or other components for converting AC power to DC), a low voltage power supply **412** that scales the received power to operate the secondary controller **428**, conditioning circuitry **416**, **426** to remove ripple in the signal, current sensor **418**, voltage sensor **422**, temperature sensor **434**, switch **420**, a signal resistor **432** and an optional wireless transmitter **430**. In operation, the rectifier **414** converts the AC power generated in the secondary coil **107** to DC power, which is typically needed to charge the battery **108**. Alternatively, multiple secondary coils receiving power of different phases can be used to reduce the ripple voltage. This is referenced in Application 60/976,137, entitled "Multiphase Inductive Power Supply System" filed Sep. 9, 2007 to Baarman et al, which is herein incorporated by reference. Multiple primary coils may be desired to transmit power on different phases in such an embodiment. In alternative embodiments the rectifier may be unnecessary and AC power may be conditioned to be used to power the load.

[0035] The secondary circuit includes a battery characteristic detection system for detecting one or more characteristics of a battery that either alone or in combination, directly or indirectly, are indicative of the type of battery installed in the remote device or the wireless power charging algorithms capable of charging that battery. A characteristic is to be considered indicative of the type of battery even if other characteristics must be considered to identify the battery type. Further, a characteristic is to be considered indicative of the type of battery even if the characteristic only allows the battery type to be narrowed to a list of possible battery types. In the current embodiment, the battery characteristic detection system includes a current sensor **418**, a voltage sensor **428**, and a temperature sensor **434**. The current sensor **418** detects the amount of current in the received power and provides that information to the secondary controller **428**. The voltage sensor **422** detects the amount of voltage in the received power and provides that information to the secondary controller **428**. The temperature sensor **434** detects the temperature and provides that information to the secondary controller **428**. Although the illustrated embodiment includes a voltage sensor **422**, a current sensor **418** and a temperature sensor **434**, alternative embodiments need not include all three. One or more sensors, detectors, or other devices or systems that assess, detect, or sense battery characteristics may replace or supplement the illustrated battery characteristic detection system. In the current embodiment, by sensing the voltage, current and temperature of the battery, the inductive power supply system **100** can determine, among other things, the battery type.

[0036] The secondary controller **428** may be essentially any type of microcontroller. In the illustrated embodiment, the secondary controller **428** is an ATTINY2MV-10MU microcontroller. The secondary controller **428** generally includes an analog to digital converter, and is programmed to process the voltage, current and temperature readings in order to determine if the battery qualifies as chargeable. The microprocessor may also include other code unrelated to battery qualification. Furthermore, the ability to have a controller or other intelligence in the remote device allows characterization of various battery characteristics. For example, the secondary may make determinations about battery type and battery life by tracking cycles, span of these cycles and the ability to hold a charge. It also allows coulombs counting, which is a method known in the art for accurate energy use and expenditure calculations. Thresholds may be set for battery end of life tracking on almost any type of battery.

[0037] In one embodiment, signal resistor **432** may be used to send information to the primary controller **310**. The use of a signal resistor **432** to provide communication from the secondary to the primary was discussed in U.S. patent application Ser. No. 11/855,710, which was previously incorporated by reference. The signal resistor **432**, when shunted, sends a communication signal that signifies an over-current or over-voltage state. When the resistor is shunted, the current or peak detector on the primary circuit **103** is able to sense the over-voltage/over-current condition and act accordingly. The signal resistor **432** of the present invention may be shunted systematically to communicate additional data to the primary controller **310**. For example, a stream of data could represent the detected current, detected voltage, detected temperature, detected battery chemistry, or merely provide an instruction to the primary circuit **103** to adjust the inductive power supply. Alternatively, the signal resistor could be removed and a different communication means entirely could be used to wirelessly communicate with the primary circuit **103**.

[0038] Use of a wireless transmitter or transceiver was previously described in U.S. Patent Application Publication US 2004/130915A1 to Baarman, which was previously incorporated by reference. Specifically, the use of WIFI, infrared, Bluetooth, cellular or RFID were previously discussed as ways to wirelessly communicate data between a remote device to an inductive power supply. Further, communication using the induction coils and a power line communication protocol was discussed. Any of these methods of transmitting data could be implemented in the present invention in order to transfer the desired data from the remote device to the inductive power supply.

[0039] In the illustrated embodiment, charging is controlled by the secondary circuit. The primary circuit **103** provides wireless power and responds appropriately to control signals from the secondary circuit **105**. In the current embodiment, communications happens at pre-defined, continuous intervals while power is being transferred. For example, communication may occur in the form of trip points or error signals.

[0040] A remote device in accordance with one embodiment of the present invention is shown in FIG. **6**, and generally designated **600**. The remote device **600** includes Plitz coil

602, a DC/DC converter, a charger controller **606**, a battery **609**, an LED driver **608** and an LED assembly **610**. As noted above with respect to the primary coil, either or both of the primary coil **602** and secondary coil **604** may be replaced by a printed circuit board coil, such as a printed circuit board coil incorporating the inventive principles of U.S. Ser. No. 60/975,953, entitled "Printed Circuit Board Coil" which was previously incorporated by reference. Further, either coil **602**, **604** may be replaced with a standard litz wire coil, which in some circumstances grants additional transfer capabilities.

[0041] Flashlight LEDs typically run at a relatively low voltage range, around 3.6V. The driver takes a voltage in a range and outputs 3.6V for the LED. An exemplary driver is shown in FIG. **8**. For example, two nearly depleted AA batteries might give 0.9V each, or 1.8V total. Four new AA batteries might give 1.5V each, or 6V total. The LED driver converts either of these voltages to the 3.6V required by the LED without significant power loss.

[0042] A DC/DC converter regulates the amount of current and is particularly useful in applications where the inductive power supply is doing less adjustment. An inductive power supply may supply power to multiple remote devices provided the remote devices have a mechanism to regulate the amount of power received, such as by using a DC/DC converter.

[0043] Optionally, the remote device may include an LED and LED scheme to indicate charging status. When the LED is off, no inductive power supply is present. If the LED is solid, the remote device is receiving power. A pre-determined number of LED flashes indicates that the battery is bad. A breathing LED indicates that the remote device is currently being charged. A color or intensity change in the LED indicates that charging is complete. A person of ordinary skill in the art would understand that additional or different schemes may be implemented to indicate charging status to the user. Further, inclusion of an LED and LED scheme on either or both of the inductive power supply and remote device is optional.

IV. Operation

[0044] General operation of the inductive power supply **102** and remote device **104** is described in connection with FIG. **7**. In particular, a method for detecting remote device battery characteristics and wirelessly supplying power from the inductive power supply to the remote device based on the detected characteristics in accordance with an embodiment of the present invention is illustrated in FIG. **7**, and generally designated **700**. The method includes optionally identifying the remote device **702-708**, qualifying the battery of the remote device including selecting a charging algorithm based on the battery qualification **710-714**, and wirelessly charging the remote device using the selected charging algorithm **716-724**. Other optional steps may be included, such as testing the capacity of the remote device battery **726-730**.

[0045] The optional remote device identification may be accomplished using essentially any method. In one embodiment, the inductive power supply periodically transmits an identification charge for a pre-selected amount of time. If a remote device with a secondary coil is present and aligned during the identification charge, the remote device sends a pre-encoded identification string back to the primary. As discussed above, the communication channel could be near field, IR, RF or essentially any other suitable communication channel. In an alternative embodiment, the remote device may include an identification capacitor that creates resonance at a specific frequency. The inductive power supply sweeps a range of identification frequencies seeking resonance. The frequency at which resonance is found may be used to identify the remote device using a look up table on the primary controller. Remote device identification potentially increases safety because metal slugs or other foreign devices will not transmit the proper ID and the inductive power supply will not continue to provide power. Remote device identification is optional though, and embodiments of the present invention need not include remote device identification in order to function.

[0046] Battery qualification or battery wireless power charging algorithm selection **710-714** includes detecting battery characteristics, analyzing the known and detected battery characteristics to determine whether the battery qualifies for charging, and selecting an appropriate charging algorithm either directly based on the known and detected battery characteristics or indirectly based on the known and detected battery characteristics. Indirect qualification may include additional analyzing, such as categorizing the battery type of the battery based on the raw battery characteristics. Direct qualification may forgo this step in favor of selecting a charging algorithm based on the raw battery characteristics. In the current embodiment, qualification is primarily dependent on battery chemistry. Unknown chemistries do not charge **712-714**, while known chemistries are charged based on their battery chemistry **712-716**. In an alternative embodiment, battery qualification includes categorizing the battery into one of a plurality of general power class, each associated with a different charging algorithm. Although the ultimate selection of a wireless power charging algorithm may not be based on raw battery characteristics and instead based on a product of additional analyzing, such as a categorization into battery type or power class, it should be understood that this is ultimately still a selection based on a battery characteristic, either known, detected, or both.

[0047] In operation, the secondary controller **428** is programmed to determine if the battery **108** qualifies for charging. Some battery information may be known based on the physical limitations of the remote device **104**. For example, the type and size of batteries that fit into the remote device is typically set during manufacture by the geometric configuration of the remote device. Additionally, the remote device may include cell information, including the number of cells. The number of cells and number of batteries may be interrelated are in some applications the terms may be used interchangeably. As noted above, this information may be directly or indirectly stored in memory. That is, specific information related to a specific remote device may be stored in the memory, or a look-up table may be stored in memory which may be accessed using a remote device ID. This information may be factored in to the battery qualification decision. For example, most remote devices cannot operate on both 1.5V AAs and 3.7V LiIon batteries.

[0048] Not all remote devices are limited by geometry, some may be capable of accepting batteries of different shapes and sizes. To account for that, the secondary controller **428** may be programmed to narrow down the battery possibilities. For example, the secondary controller **428** may determine the number of battery cells and the starting voltage of each of the cells. If the starting voltage is greater than a pre-defined threshold for that number of cells then the battery may be identified as a LiIon battery. If the starting voltage is

less than a different pre-defined threshold for that number of cells the battery may be identified as non-chargeable because of an internal short or over depletion. If the starting voltage is between the two thresholds, the battery may be identified as a non-LiIon battery, such as NiMH or Alkaline.

[0049] In addition to using known, pre-defined battery characteristics, unknown battery characteristics may be actively measured. For example, by using the inductive power supply to feed a qualification charge to the remote device battery, the change in voltage may be measured and used to characterize the battery. The qualification charge may be any suitable charge that assists in the identification of battery characteristics. In the current embodiment, the qualification charge is a low current, $\frac{1}{400}^{th}$ of the rated battery capacity which is approximately 20 milliamps. Other steps may be taken to help characterize the battery. For example, a change in current, voltage and/or temperature in response to the qualification charge may be monitored.

[0050] In the current embodiment, the secondary circuit **400** monitors the change in voltage in response to the qualification charge. If the change in voltage is above a certain threshold, the internal resistance of the batteries is too high and the batteries are deemed bad or non-rechargeable. If the change in voltage is below a certain threshold the batteries are also deemed bad, likely because they are shorted internally. If the change in voltage is between the two thresholds, the batteries are deemed chargeable and the inductive power supply proceeds to full charge rate.

[0051] The voltage is monitored as the full charge rate is employed. Similar thresholds to those employed during the qualification charge may be monitored while charging at the full rate. Passing one of the thresholds is a substantial indication that the battery is near the end of its life. Further, battery capacity may be determined by monitoring the charge rate and battery voltage. If the battery voltage passes a pre-determined threshold, the batteries may be deemed damaged or near the end of their life.

[0052] Additional information may be provided by the remote device configuration like the number of cells and typical operation with various batteries. For example, points on a curve for each type of battery may be stored in memory on the secondary device. A person of ordinary skill in the art would understand how these curves can be used as patterns to recognize battery types, battery life, diagnostics and other pattern comparison information.

[0053] Once full charging rate is reached, any number of battery chemistry charging profiles may be employed. The most common difference in charging algorithm is between nickel based batteries, which utilize a negative delta V algorithm and Li Ion batteries, which transition from a constant current a constant voltage after a current lower limit is reached. Many other battery chemistry charging profiles are known and may be implemented in the present invention. For example, a particular chemistry charging profile may be included for alkaline rechargeable batteries that is different from the Nickel based and LiIon charging profiles. In the current embodiment, the secondary circuit can distinguish between Alkaline, NiMH, NiCad, CZn and Li Ion batteries. In alternative embodiments, the secondary controller may be able to distinguish between additional, different or fewer battery chemistries.

[0054] Battery capacity may be determined by monitoring the charge rate and battery voltage. If the battery voltage passes a pre-determined threshold, the batteries may be deemed damaged or near the end of their life.

[0055] The above description is that of the current embodiment of the invention. Various alterations and changes can be made without departing from the spirit and broader aspects of the invention.

1. An inductive power supply system comprising:
- an inductive power supply including a primary circuit and a primary for wirelessly transferring power;
- a remote device separable from said inductive power supply, said remote device including a secondary for wirelessly receiving power from said inductive power supply, a battery having a battery type, and a secondary circuit that includes a battery characteristic detection system for detecting a characteristic of said battery indicative of said battery type;
- a memory located in at least one of said inductive power supply and said remote device, said memory including a plurality of wireless power charging algorithms;
- a communication system for wireless communication between said remote device and said inductive power supply;
- a controller adapted to communicate with said memory, said controller located in at least one of said inductive power supply and said remote device, wherein said controller is programmed to select a wireless power charging algorithm from said plurality of wireless power charging algorithms in said memory based at least in part on said detected battery characteristic indicative of said battery type; and
- wherein said primary wirelessly transfers power from said inductive power supply to said remote device according to said selected wireless power charging algorithm.

2. The inductive power supply system of claim **1** wherein said battery is replaceable with a different battery having a different battery type.

3. The inductive power supply system of claim **2** wherein said controller selects a different wireless power charging algorithm for said different battery based at least in part on said battery characteristic detection system detecting a characteristic of said different battery indicative of a different battery type.

4. The inductive power supply system of claim **1** wherein said memory includes a plurality of battery types, wherein each of said battery types is associated with one or more wireless power charging algorithms.

5. The inductive power supply system of claim **1** wherein said inductive power supply selects said wireless power charging algorithm based at least in part on at least one of 1) said detected battery characteristic; and 2) a determined battery type communicated from said remote device to said inductive power supply, said determined battery type determined by said controller based at least in part on said detected battery characteristic.

6. The inductive power supply system of claim **1** wherein said remote device selects said wireless power charging algorithm based at least in part on at least one of 1) said detected battery characteristic; and 2) a determined battery type, said determined battery type determined by said controller based at least in part on said detected battery characteristic.

7. The inductive power supply system of claim **1** wherein said characteristic of said battery includes at least one of battery chemistry, battery cells, battery capacity, battery size, battery shape, battery voltage characteristics, battery current

characteristics, battery temperature characteristics, battery terminal layouts, cycles, and span of cycles.

8. The inductive power supply system of claim **1** wherein said communication system includes:

a remote device communication system for wirelessly communicating with said inductive power supply including at least one of a signal resistor for communicating using said secondary and a wireless transmitter; and

an inductive power supply communication system for wirelessly communicating with said remote device including at least one of a current sensor for communicating using said primary and a wireless receiver.

9. A remote device separable from an inductive power supply, said remote device comprising:

a secondary for wirelessly receiving power from said inductive power supply;

a battery having a battery type;

a battery characteristic detection system for detecting a characteristic of said battery indicative of said battery type of said battery;

a communication system for wirelessly communicating with said inductive power supply;

a controller adapted to communicate with a memory including a plurality of wireless power charging algorithms, said controller programmed to at least one of:

1) select a wireless power charging algorithm from said plurality of wireless power charging algorithms in said memory based at least in part on said detected battery characteristic indicative of said battery type detected by said battery characteristic detection system; and

2) communicate said detected battery characteristic to said inductive power supply for use in selecting a wireless power charging algorithm;

wherein said secondary wirelessly receives power from said inductive power supply according to said selected wireless power charging algorithm.

10. The remote device of claim **9** wherein said battery is replaceable with a different battery having a different battery type.

11. The remote device of claim **10** wherein said controller selects a different wireless power charging algorithm for said different battery based at least in part on said battery characteristic detection system detecting a characteristic of said different battery indicative of a different battery type.

12. The remote device of claim **9** wherein said memory includes a plurality of battery types, wherein each of said battery types is associated with one or more wireless power charging algorithms.

13. The remote device of claim **9** wherein said communication system communicates to said inductive power supply at least one of 1) said detected battery characteristic; and 2) a determined battery type, said determined battery type determined by said controller based at least in part on said detected battery characteristic.

14. The remote device of claim **13** wherein said controller selects said wireless power charging algorithm based at least in part on said determined battery type.

15. The remote device of claim **9** wherein said characteristic of said battery includes at least one of battery chemistry, battery cells, battery capacity, battery size, battery shape, battery voltage characteristics, battery current characteristics, battery temperature characteristics, battery terminal layouts, cycles, and span of cycles.

16. The remote device of claim **9** wherein said communication system for wirelessly communicating with said inductive power supply includes at least one of a signal resistor for communicating using said secondary and a wireless transmitter.

17. An inductive power supply separable from a remote device, said inductive power supply comprising:

a primary for wirelessly transferring power to said remote device;

a communication system for receiving from said remote device a detected battery characteristic indicative of a battery type;

a memory including a plurality of wireless power charging algorithms;

a controller adapted to communicate with said memory, said controller programmed to select a wireless power charging algorithm from said plurality of wireless power charging algorithms in said memory based at least in part on said detected battery characteristic indicative of said battery type;

wherein said primary wirelessly transfers power from said inductive power supply to said remote device according to said selected wireless power charging algorithm.

18. The inductive power supply of claim **17** wherein said memory includes a plurality of battery types, wherein each of said battery types is associated with one or more wireless power charging algorithms.

19. The inductive power supply system of claim **17** wherein said detected characteristic of said battery includes at least one of battery chemistry, battery cells, battery capacity, battery size, battery shape, battery voltage characteristics, battery current characteristics, battery temperature characteristics, battery terminal layouts, cycles, and span of cycles.

20. The inductive power supply system of claim **17** wherein said communication system for wirelessly communicating with said remote device includes at least one of a current sensor for communicating using said primary and a wireless receiver.

21. A method for transferring power from an inductive power supply to a remote device adapted to operate with a plurality of different types of batteries, said method comprising the steps of:

detecting a characteristic of a battery installed in said remote device, wherein said characteristic of said battery is indicative of a battery type;

selecting a wireless power charging algorithm based at least in part on said detected battery characteristic indicative of said battery type;

wirelessly transferring power from said inductive power supply to said remote device according to said selected wireless power charging algorithm.

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