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(54) **COUNTERTOP MOUNTING BRACKET FOR WIRELESS CHARGING**

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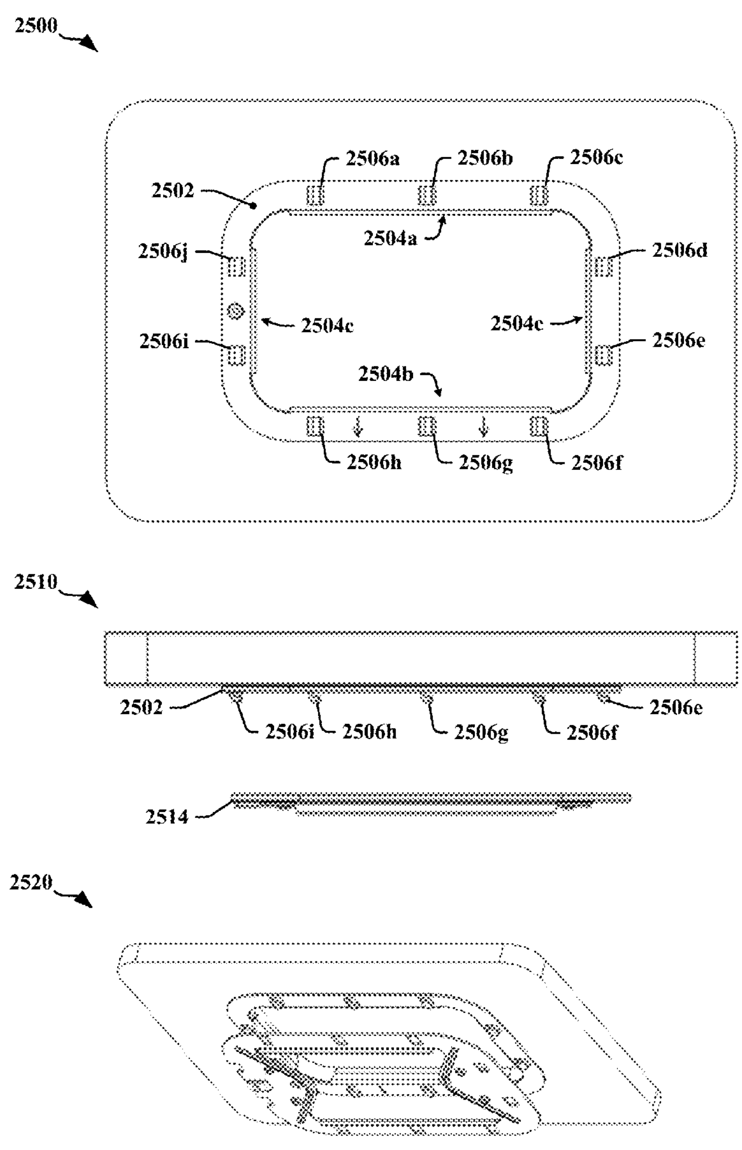
(57) **ABSTRACT**

A mounting bracket has a rim configured to encompass a cavity formed in a countertop. At least one flange of the rim has a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavity. One or more fasteners formed on the rim may be configured to engage with corresponding features of a cover plate. The mounting bracket can be configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop. In one example, the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the mounting bracket



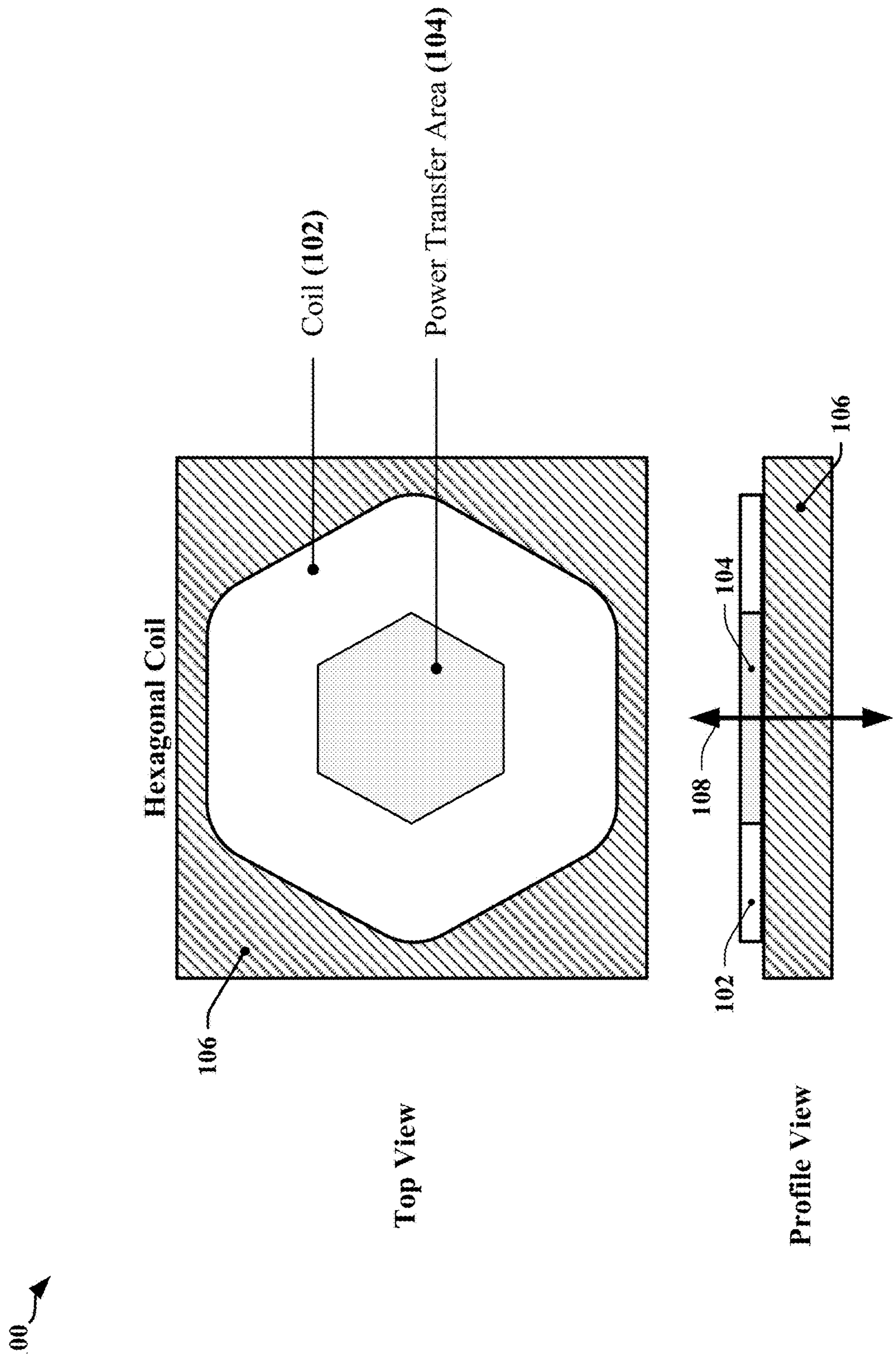

100
Top View
Profile View
Hexagonal Coil
Coil (102)
Power Transfer Area (104)
106
104
108
102
106

FIG. 1

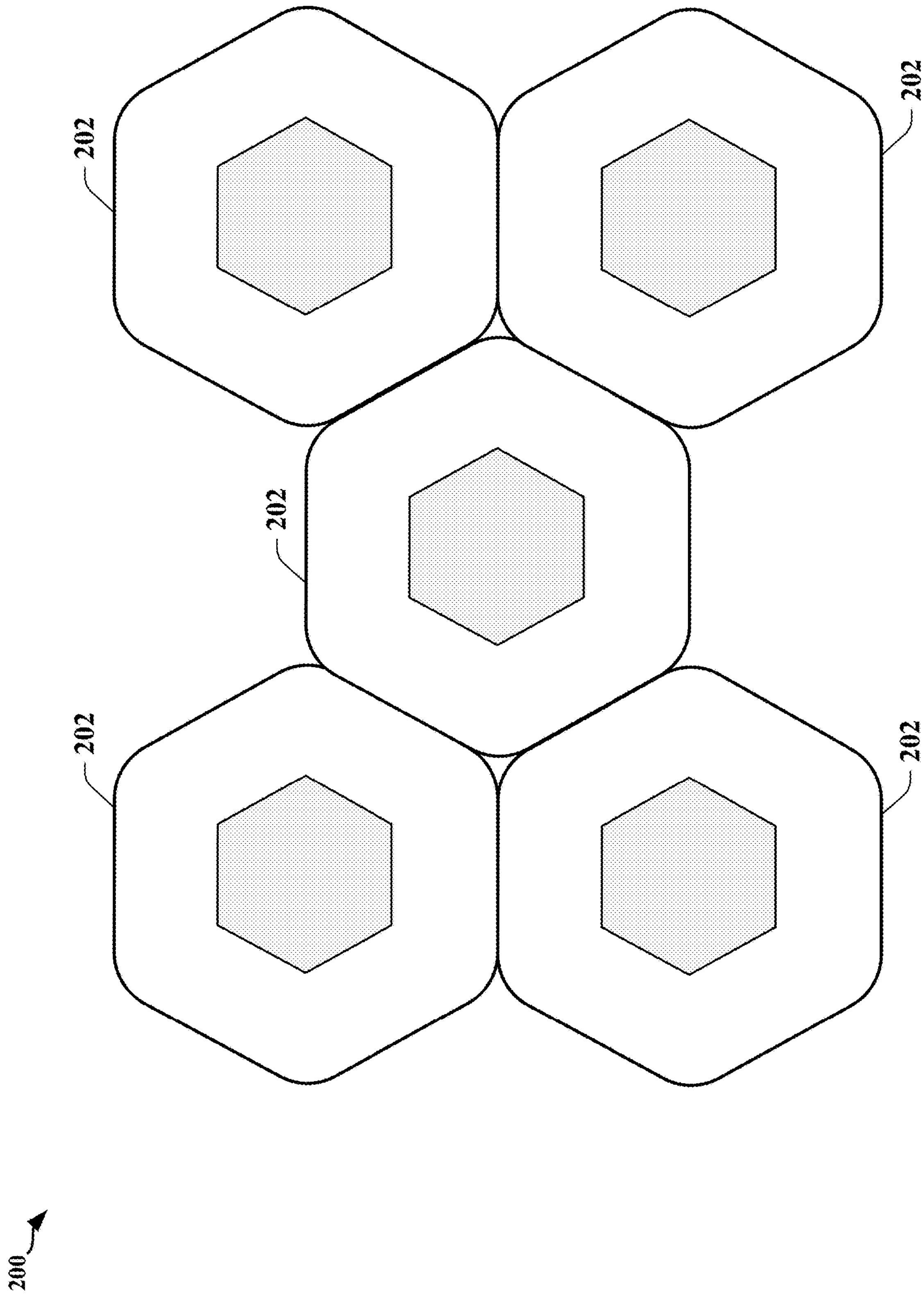


FIG. 2

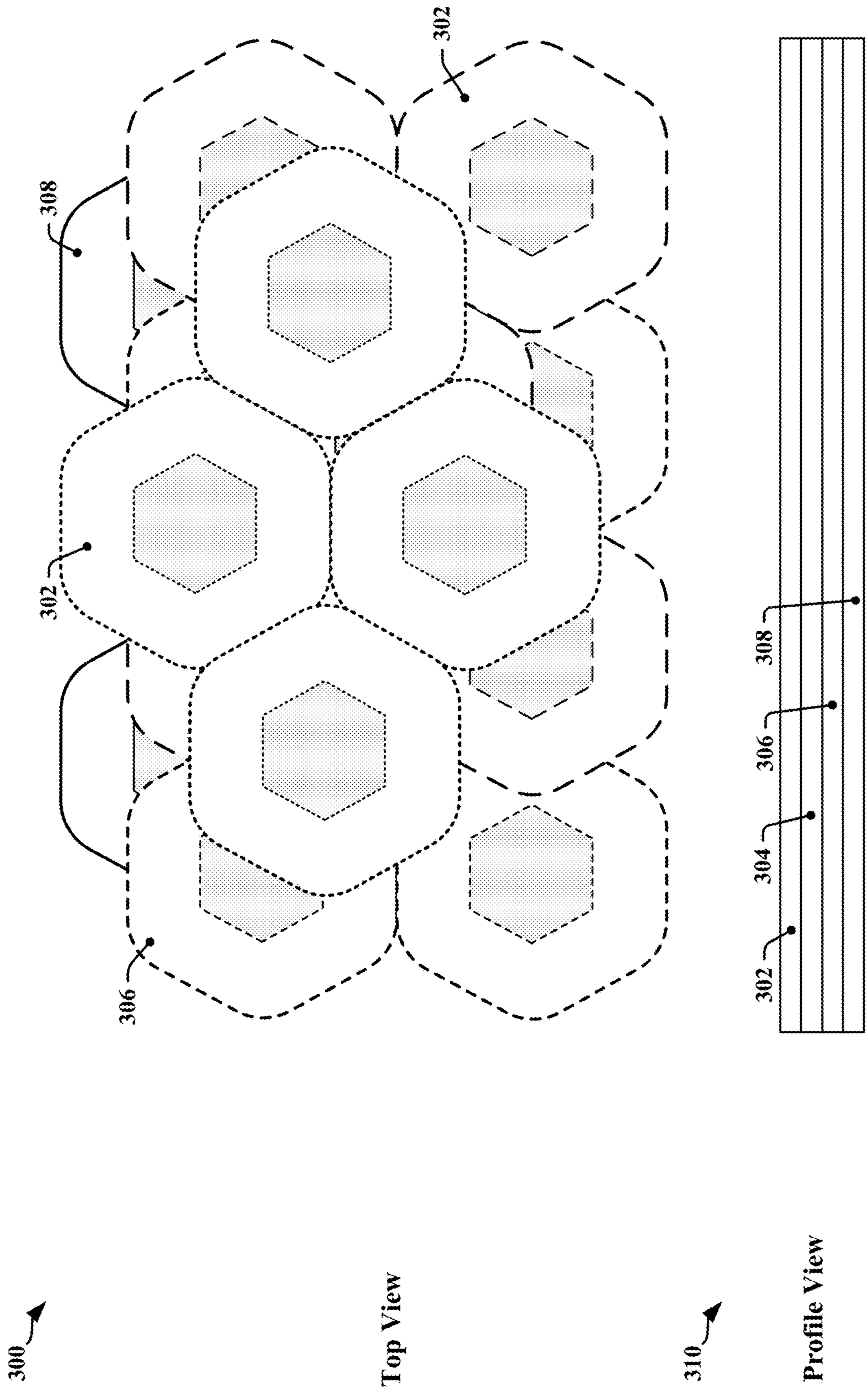


FIG. 3

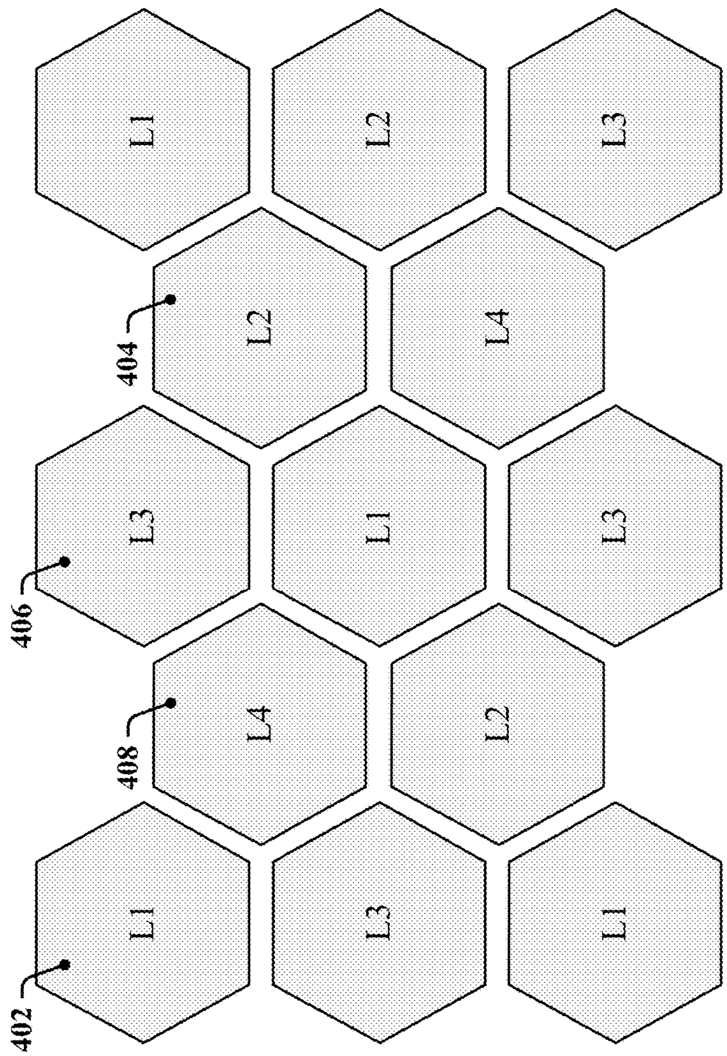


FIG. 4

400

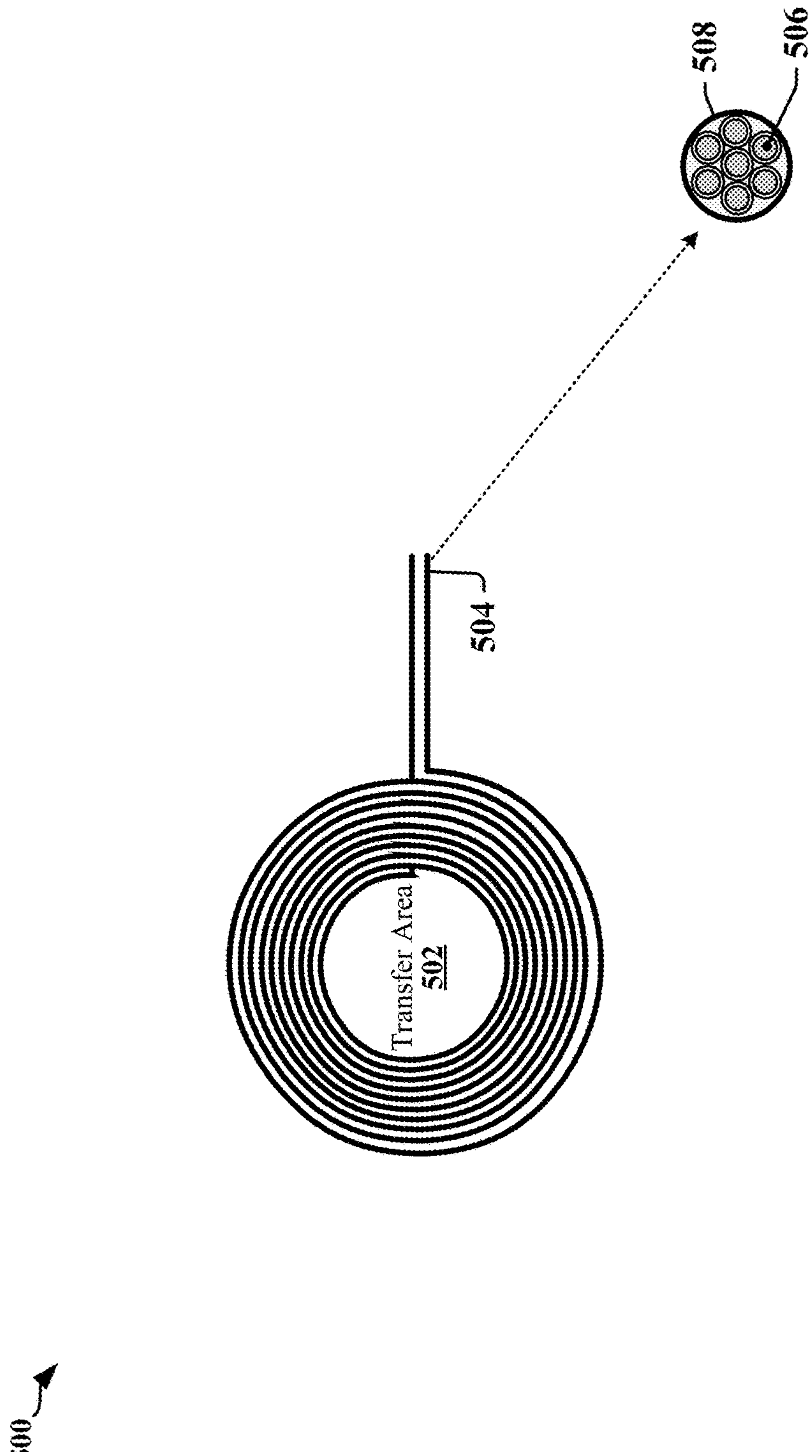
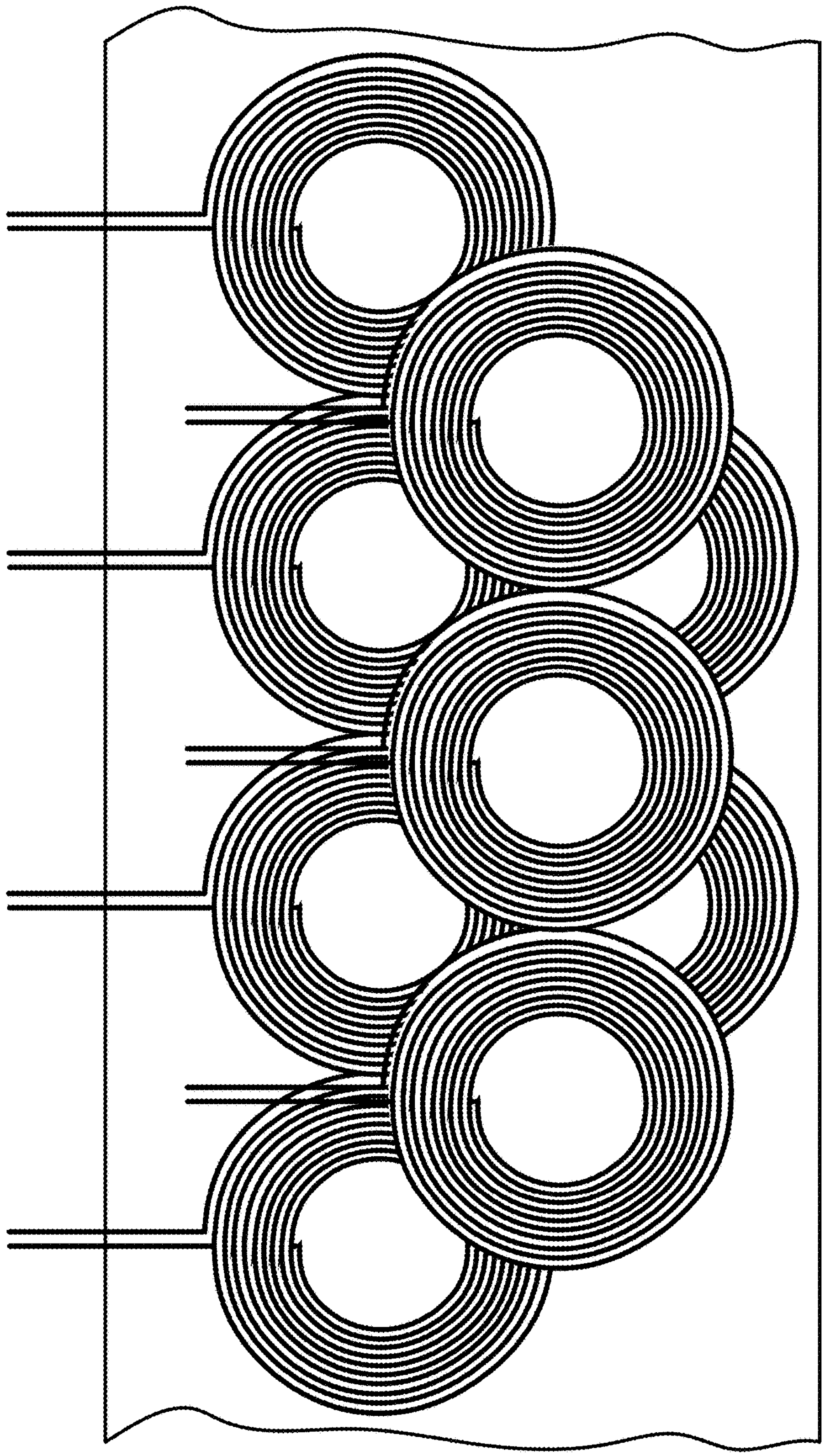


FIG. 5



600

FIG. 6

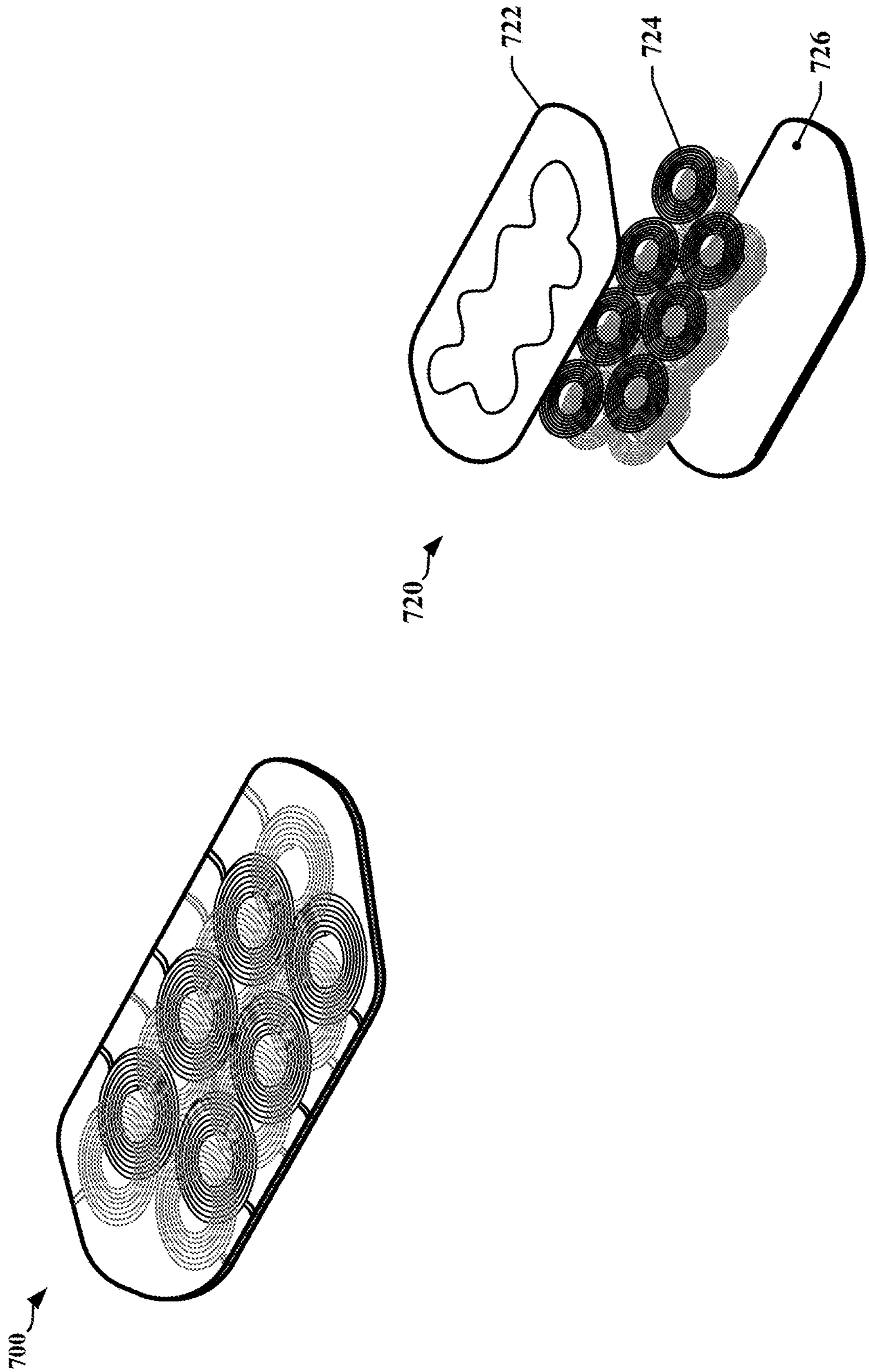


FIG. 7

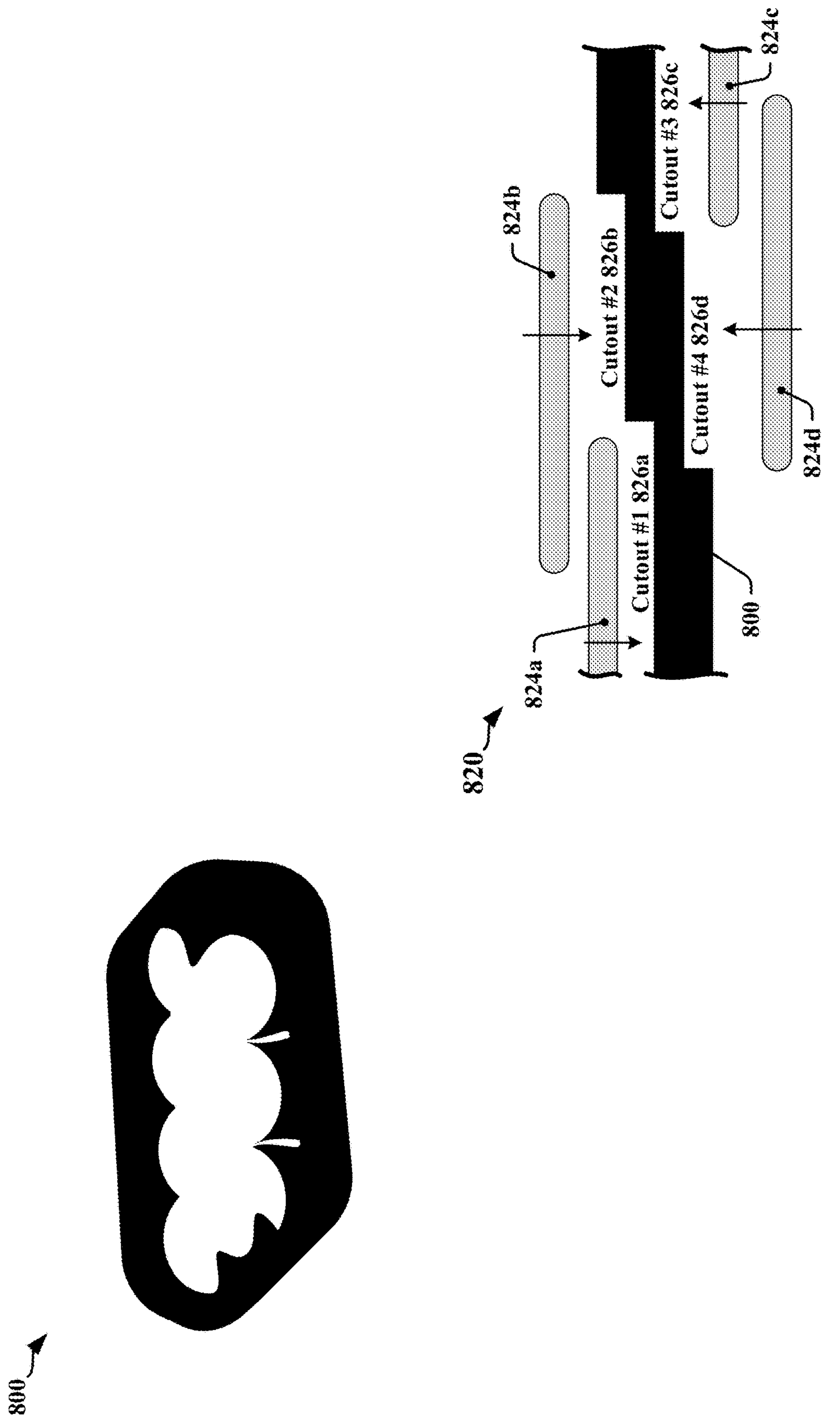

800
820
824a
824b
824c
824d
Cutout #1 826a
Cutout #2 826b
Cutout #3 826c
Cutout #4 826d
800

FIG. 8

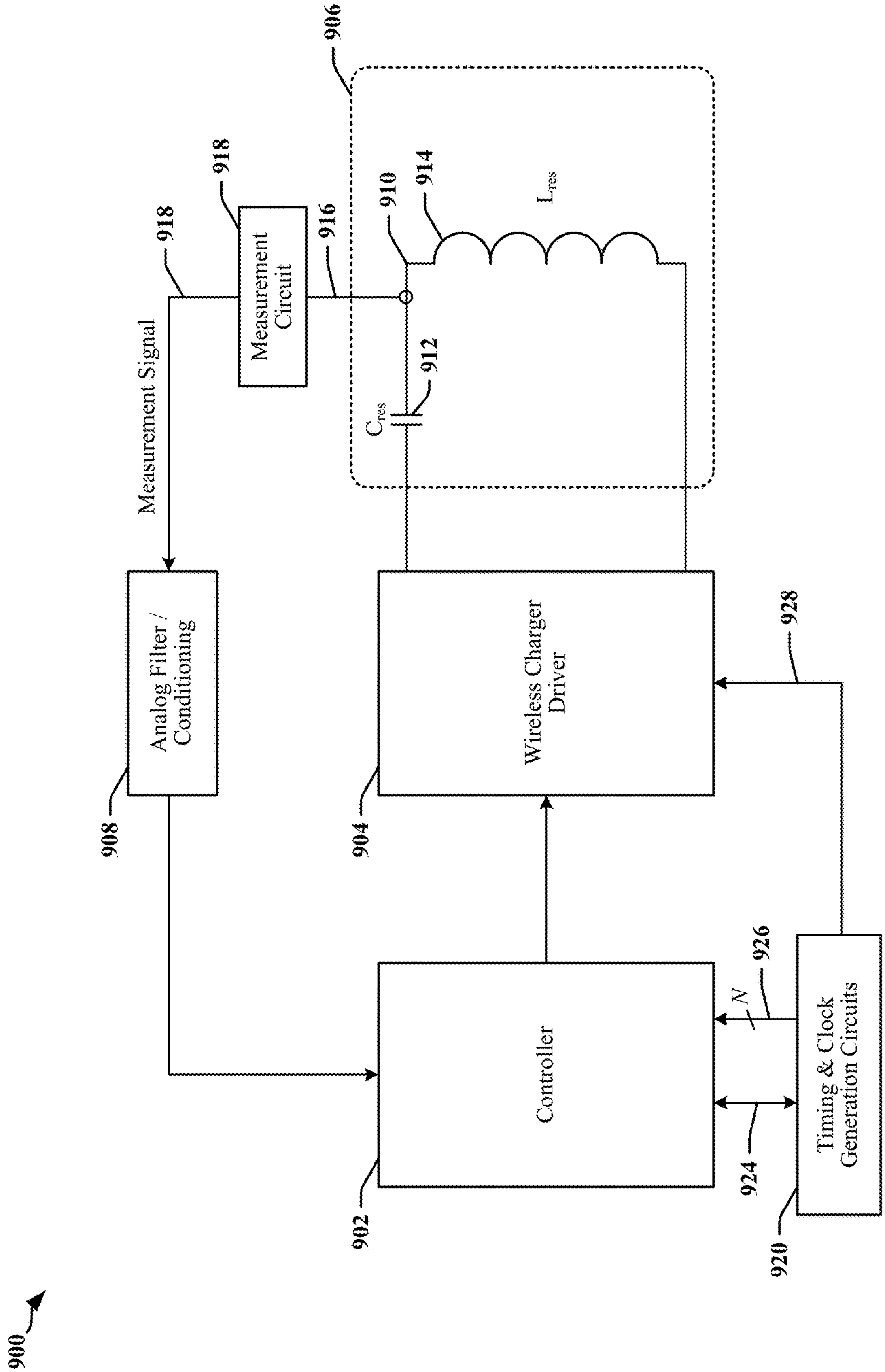

900
906
918
918
916
910
914
L_{res}
Measurement Circuit
Measurement Signal
912
C_{res}
Analog Filter / Conditioning
908
Wireless Charger Driver
904
928
Controller
902
N
926
924
Timing & Clock Generation Circuits
920

FIG. 9

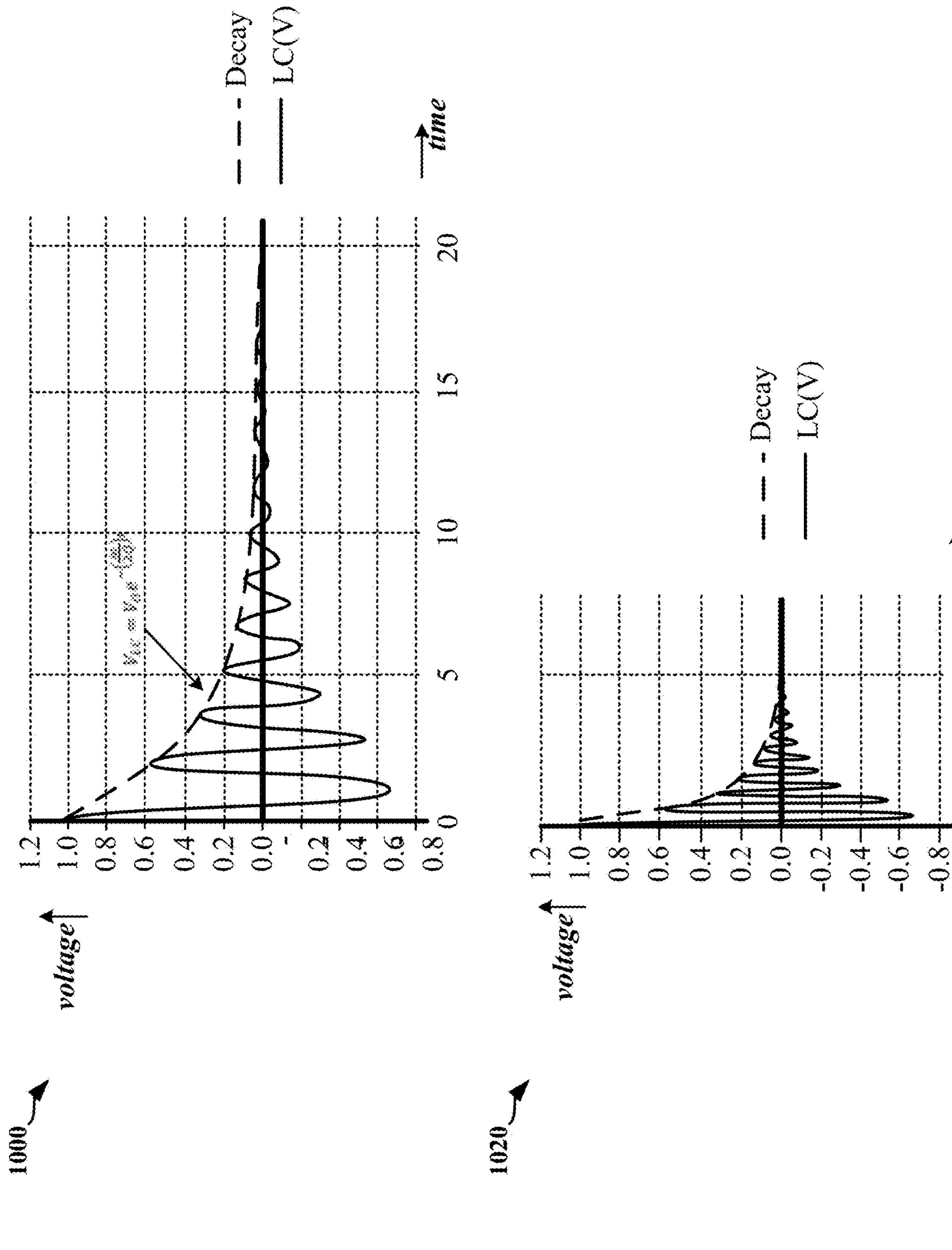
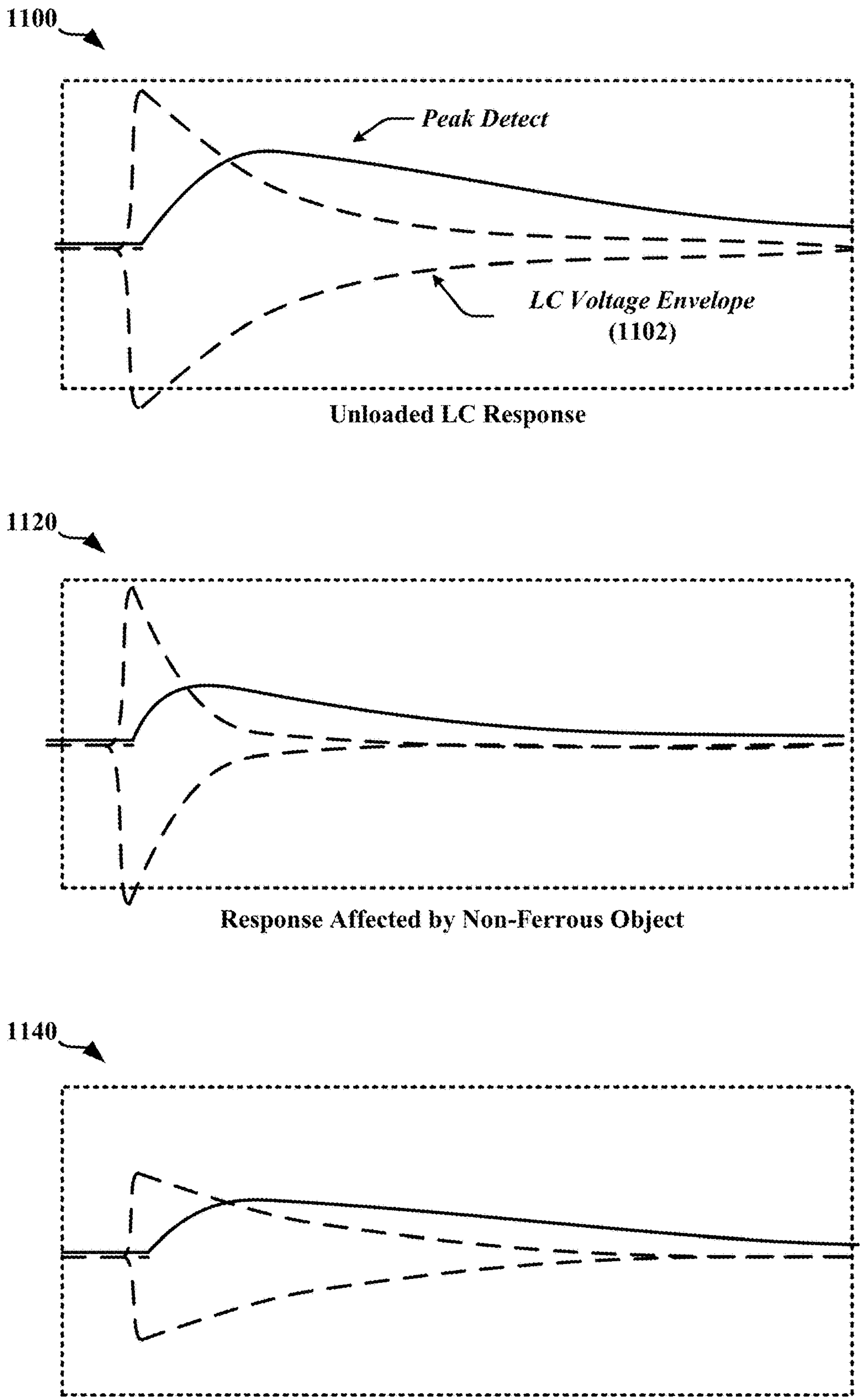


FIG. 10



Unloaded LC Response

Response Affected by Non-Ferrous Object

Response Affected by Proximate Receiver

FIG. 11

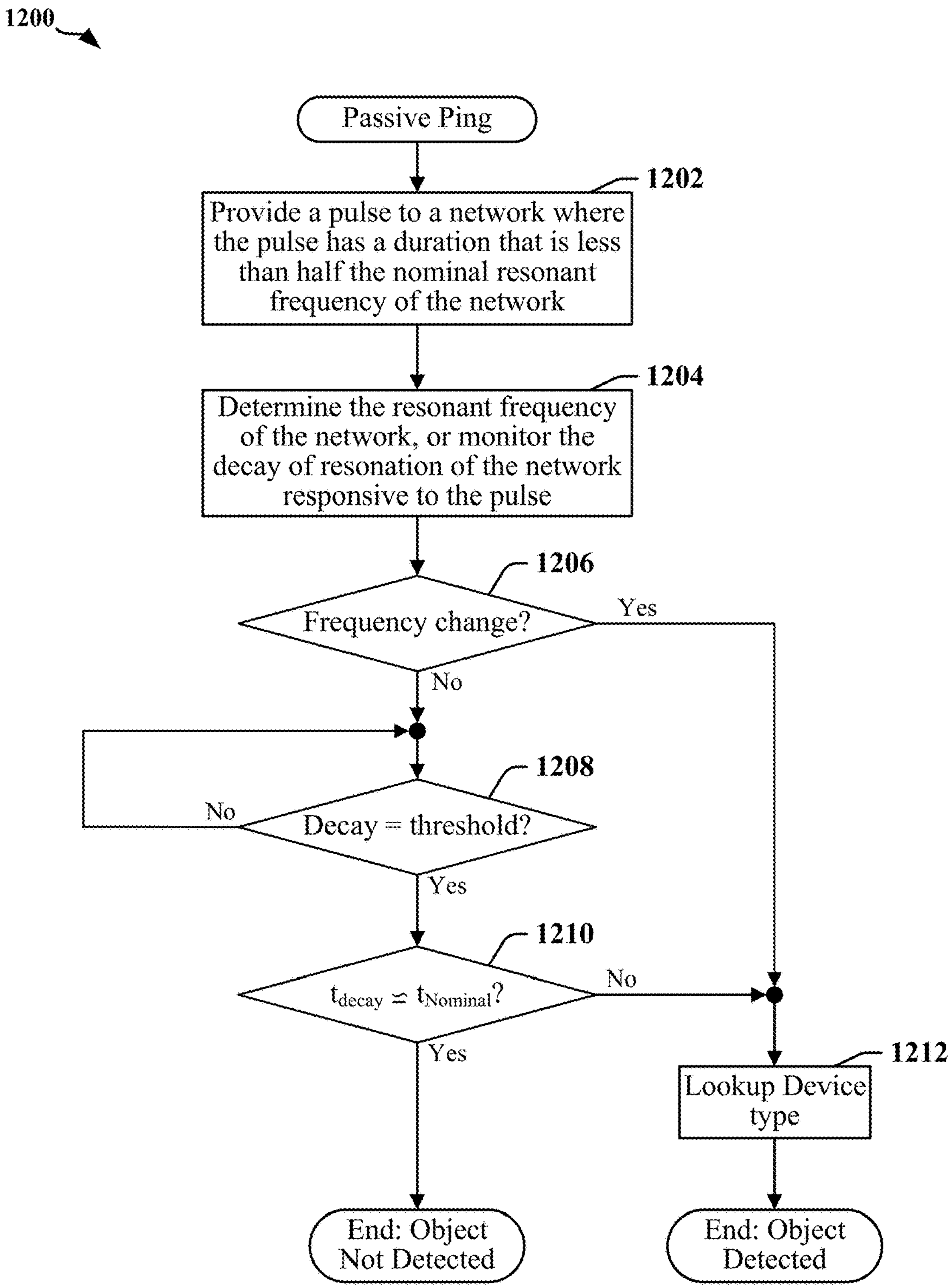

1200
Passive Ping
1202
Provide a pulse to a network where the pulse has a duration that is less than half the nominal resonant frequency of the network
1204
Determine the resonant frequency of the network, or monitor the decay of resonation of the network responsive to the pulse
1206
Frequency change?
Yes
No
1208
No
Decay = threshold?
Yes
1210
$t_{decay} \simeq t_{Nominal}$?
No
Yes
1212
Lookup Device type
End: Object Not Detected
End: Object Detected

FIG. 12

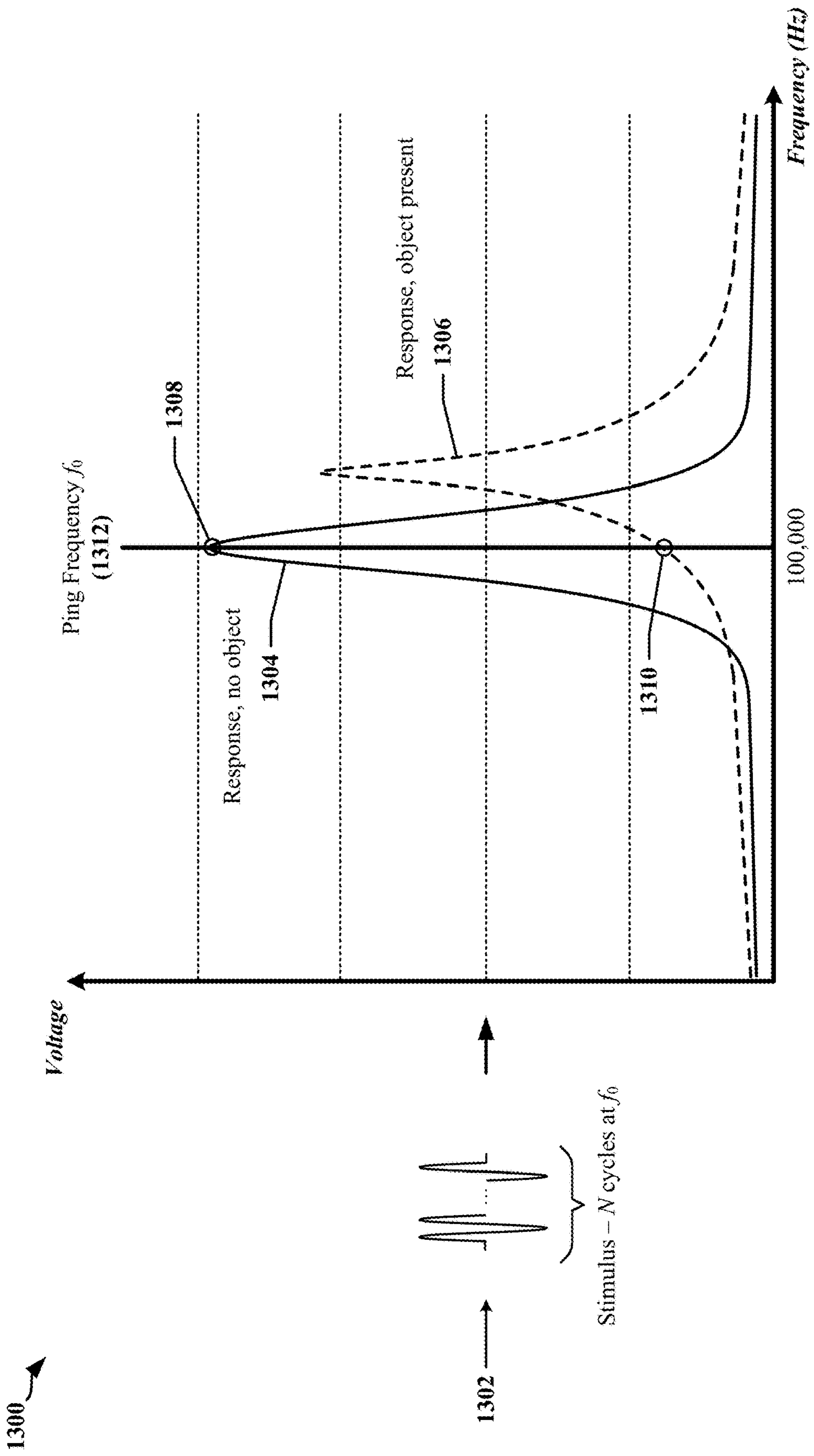

1300
1302
Stimulus – N cycles at f_0
Voltage
Ping Frequency f_0
(1312)
1308
Response, no object
1304
1310
Response, object present
1306
100,000
Frequency (Hz)

FIG. 13

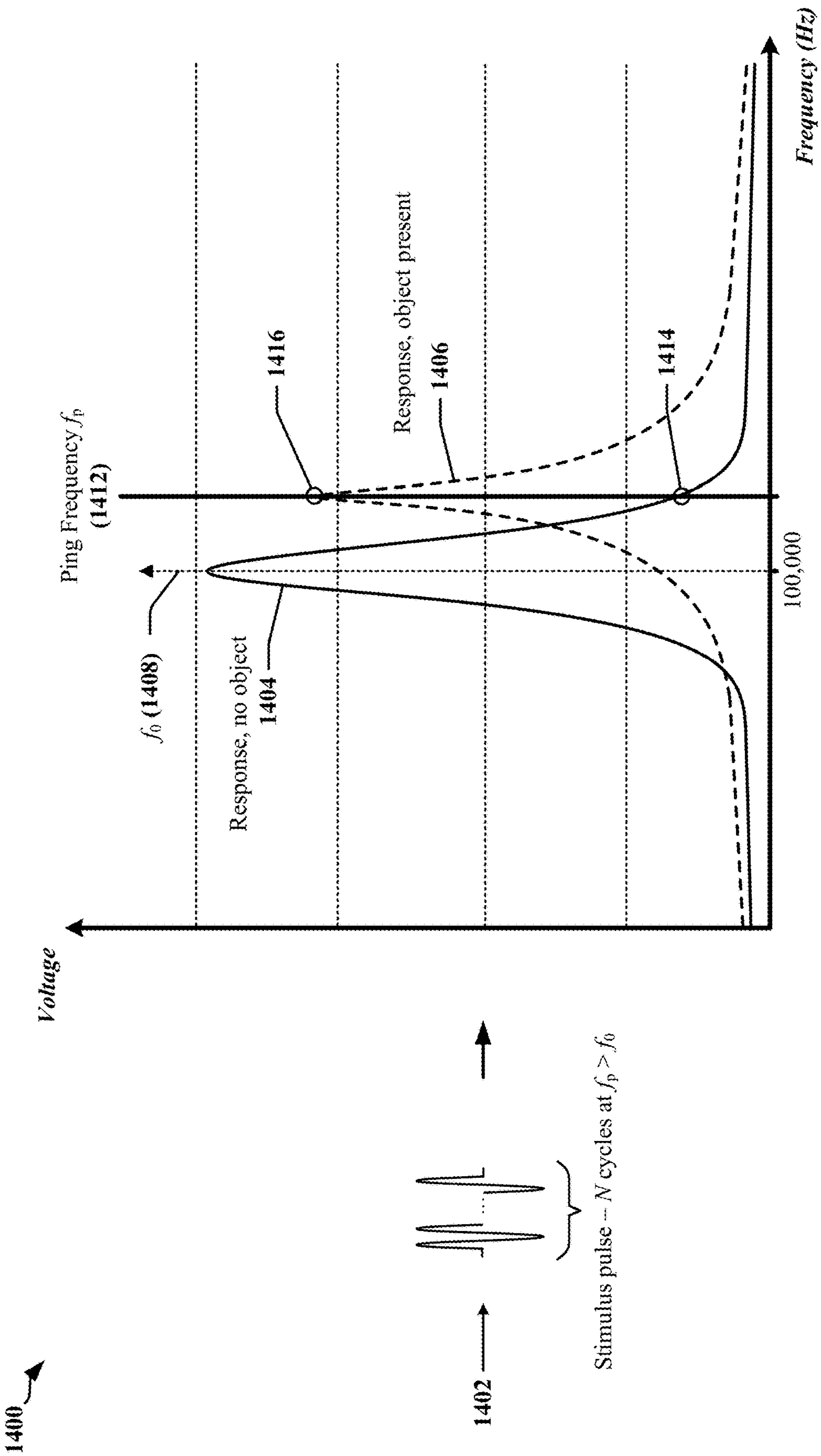

1400
1402
Stimulus pulse – N cycles at $f_p > f_0$
Voltage
Frequency (Hz)
Ping Frequency f_p
(1412)
1416
Response, object present
1406
1414
f_0 (1408)
Response, no object
1404
100,000

FIG. 14

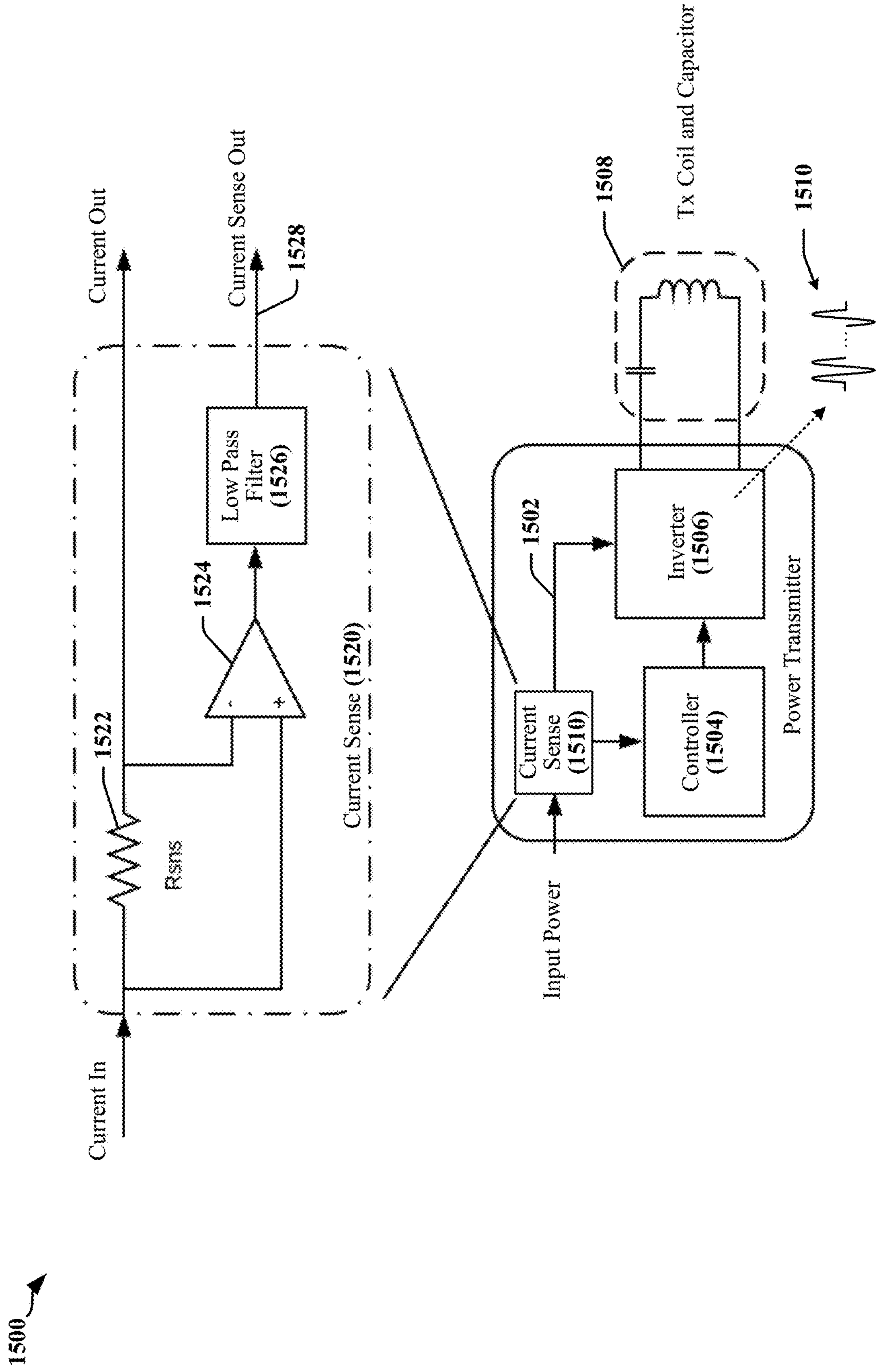

1500
Current In
Current Out
Rsns
1522
1524
Low Pass Filter (1526)
Current Sense Out
1528
Current Sense (1520)
Input Power
Current Sense (1510)
Controller (1504)
1502
Inverter (1506)
Power Transmitter
1508
Tx Coil and Capacitor
1510

FIG. 15

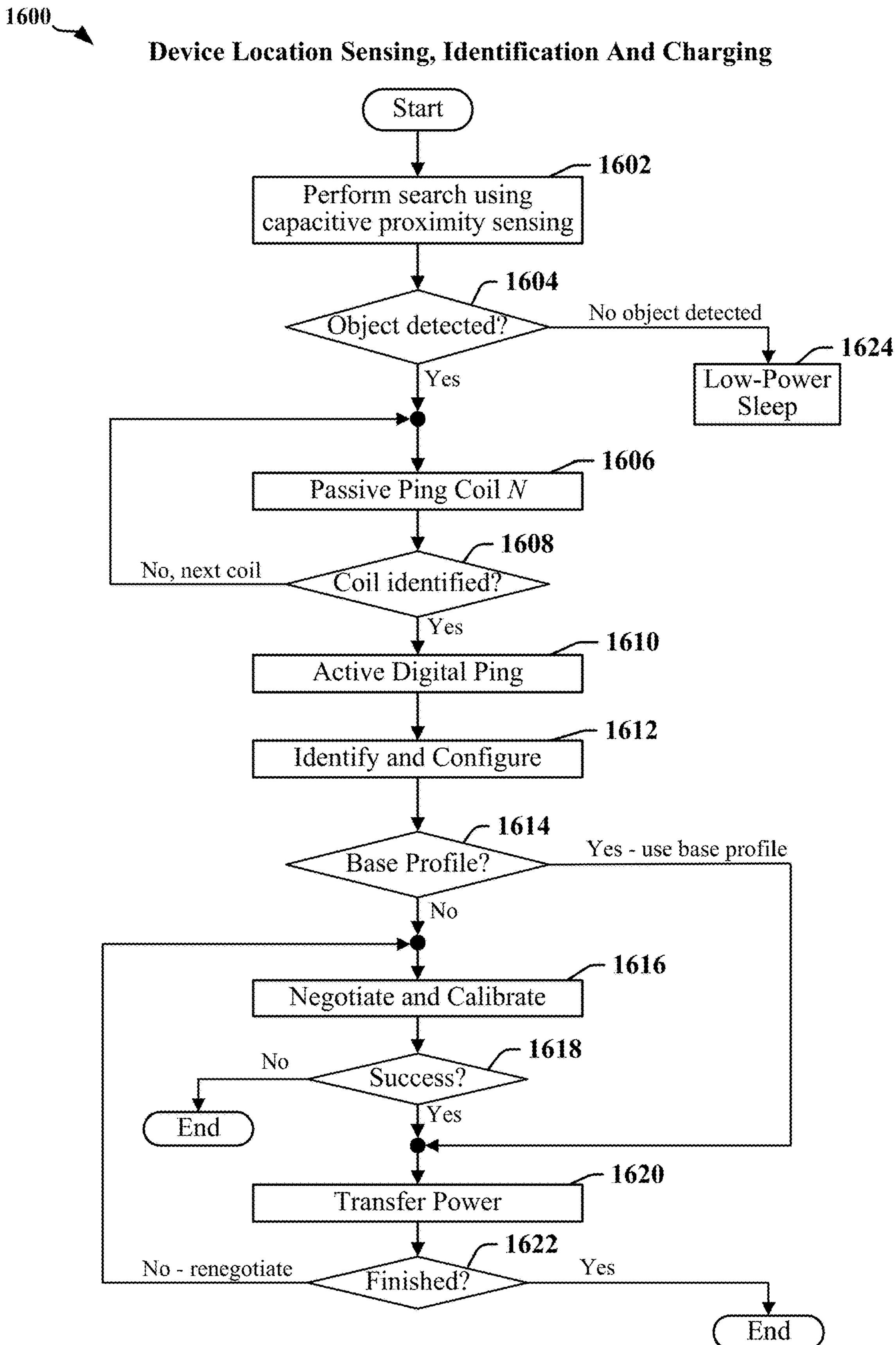

1600
Device Location Sensing, Identification And Charging
Start
Perform search using capacitive proximity sensing
1602
Object detected?
1604
No object detected
Low-Power Sleep
1624
Yes
Passive Ping Coil N
1606
Coil identified?
1608
No, next coil
Yes
Active Digital Ping
1610
Identify and Configure
1612
Base Profile?
1614
Yes - use base profile
No
Negotiate and Calibrate
1616
Success?
1618
No
End
Yes
Transfer Power
1620
Finished?
1622
No - renegotiate
Yes
End

FIG. 16

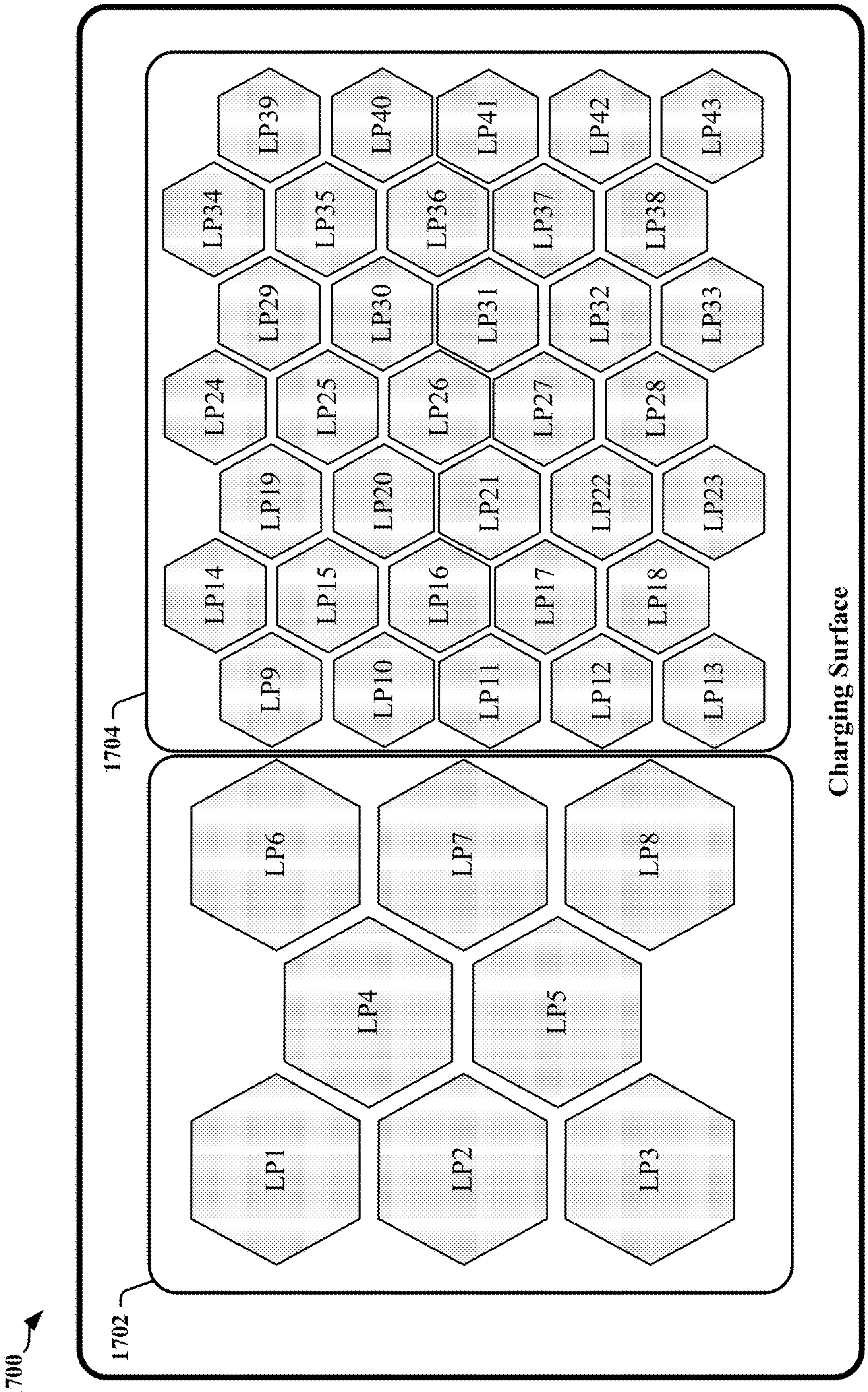

1700
1702
1704
Charging Surface
LP1
LP2
LP3
LP4
LP5
LP6
LP7
LP8
LP9
LP10
LP11
LP12
LP13
LP14
LP15
LP16
LP17
LP18
LP19
LP20
LP21
LP22
LP23
LP24
LP25
LP26
LP27
LP28
LP29
LP30
LP31
LP32
LP33
LP34
LP35
LP36
LP37
LP38
LP39
LP40
LP41
LP42
LP43

FIG. 17

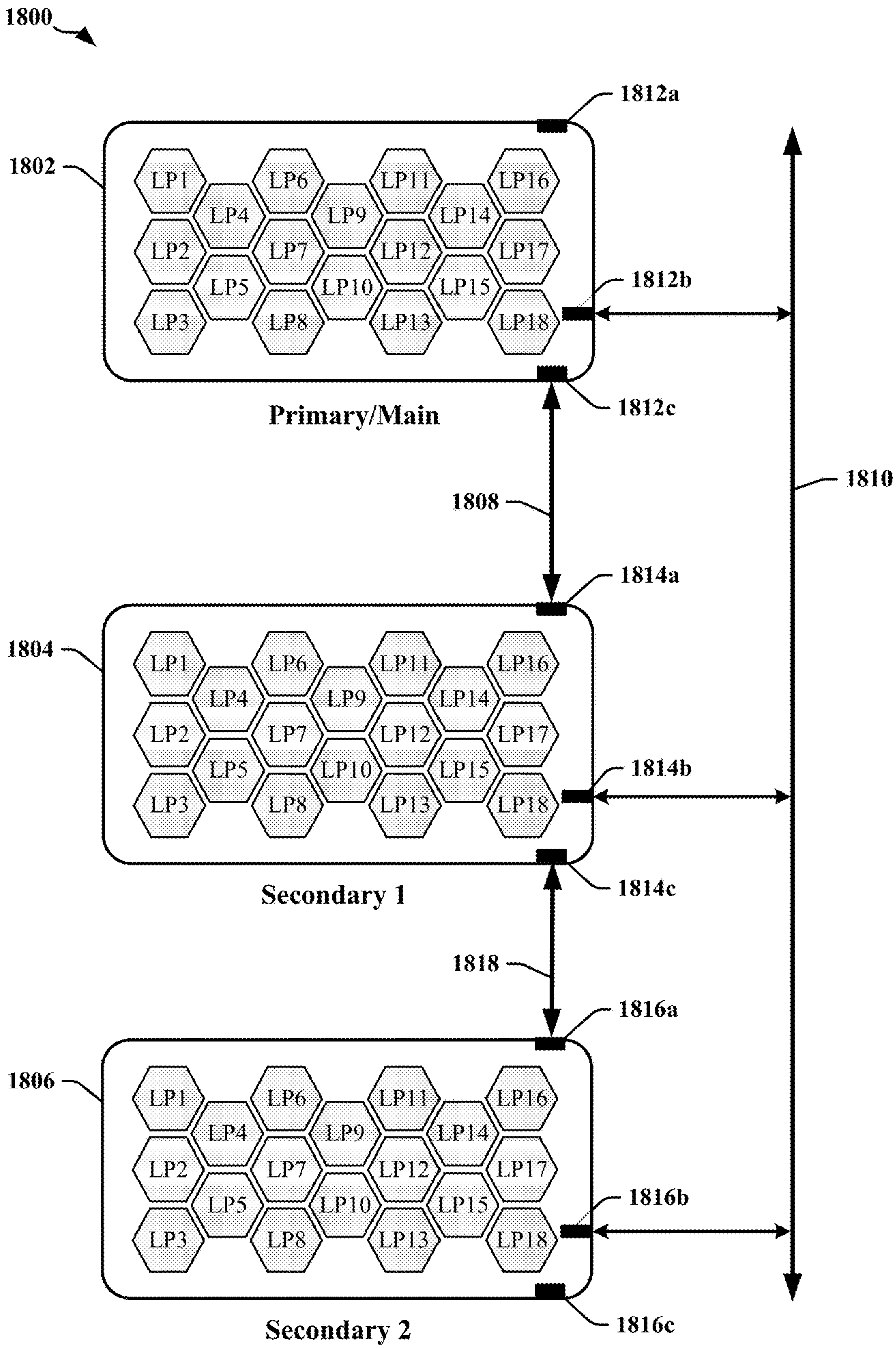
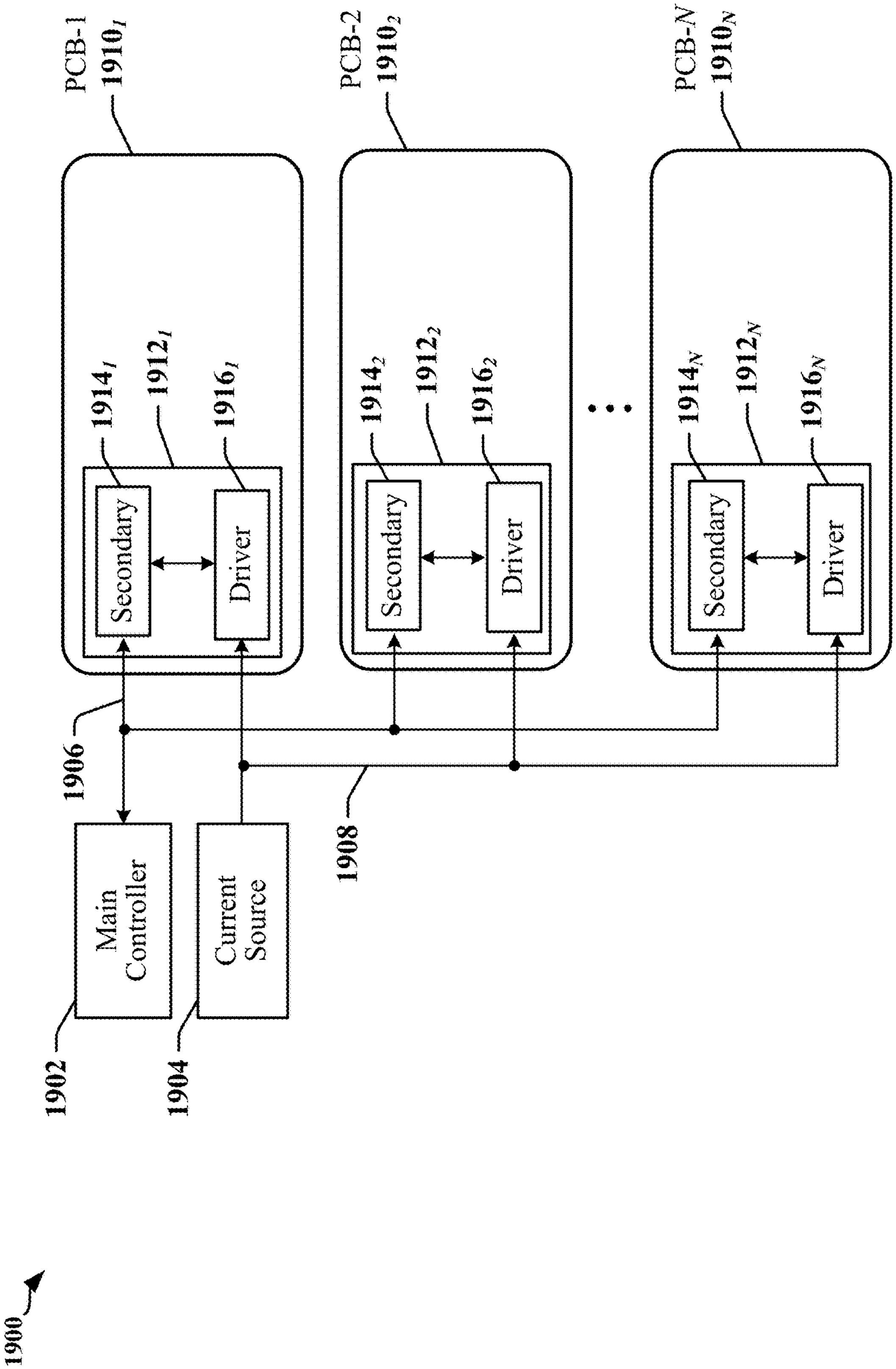

1800
1812a
1802
LP1
LP6
LP11
LP16
LP4
LP9
LP14
LP2
LP7
LP12
LP17
LP5
LP10
LP15
LP3
LP8
LP13
LP18
1812b
1812c
Primary/Main
1808
1810
1814a
1804
LP1
LP6
LP11
LP16
LP4
LP9
LP14
LP2
LP7
LP12
LP17
LP5
LP10
LP15
LP3
LP8
LP13
LP18
1814b
1814c
Secondary 1
1818
1816a
1806
LP1
LP6
LP11
LP16
LP4
LP9
LP14
LP2
LP7
LP12
LP17
LP5
LP10
LP15
LP3
LP8
LP13
LP18
1816b
1816c
Secondary 2

FIG. 18



1900
PCB-1
1910_1
PCB-2
1910_2
PCB-N
1910_N
1914_1
1912_1
1916_1
1914_2
1912_2
1916_2
1914_N
1912_N
1916_N
Secondary
Driver
Secondary
Driver
Secondary
Driver
1906
1908
Main Controller
Current Source
1902
1904

FIG. 19

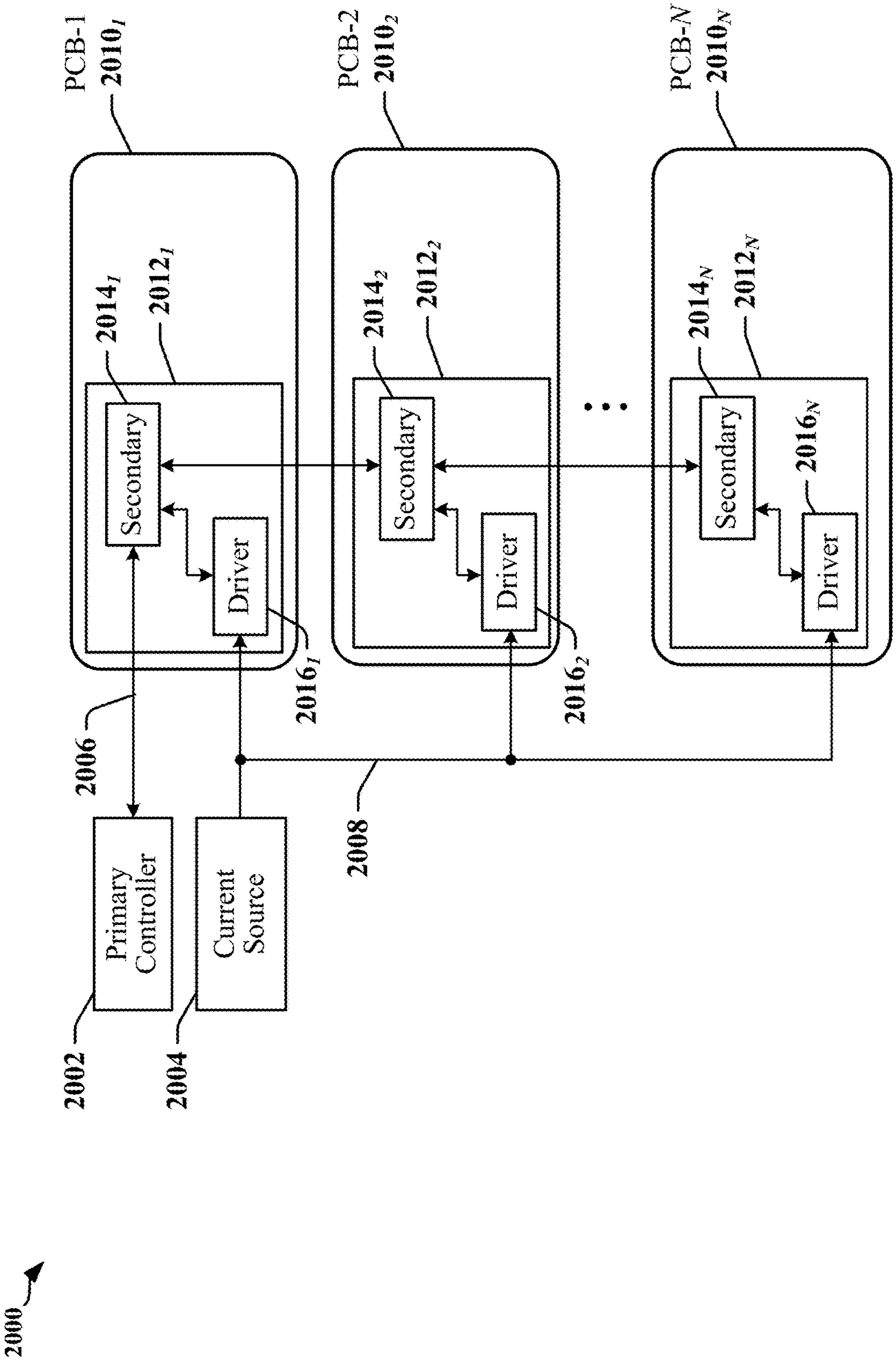
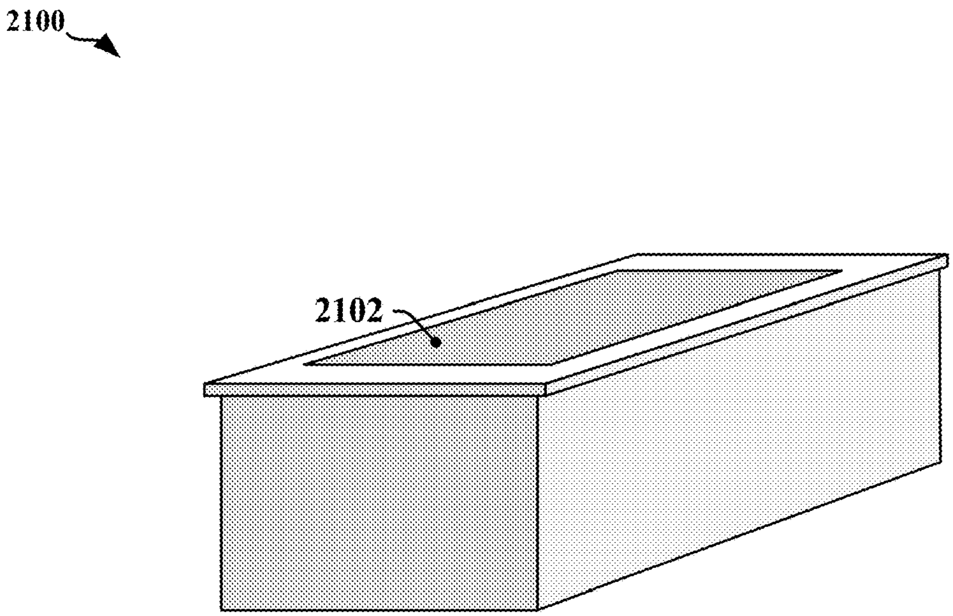

PCB-1
2010_1
PCB-2
2010_2
PCB-N
2010_N
2014_1
2012_1
2014_2
2012_2
2014_N
2012_N
Secondary
Secondary
Secondary
2016_N
Driver
Driver
Driver
2016_1
2016_2
2006
2008
Primary Controller
Current Source
2002
2004
2000

FIG. 20



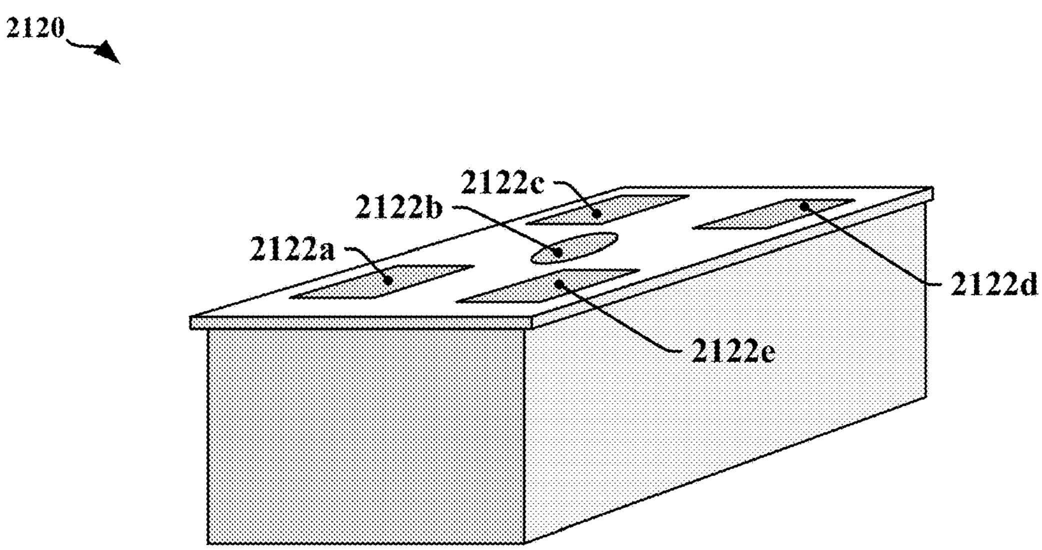


FIG. 21

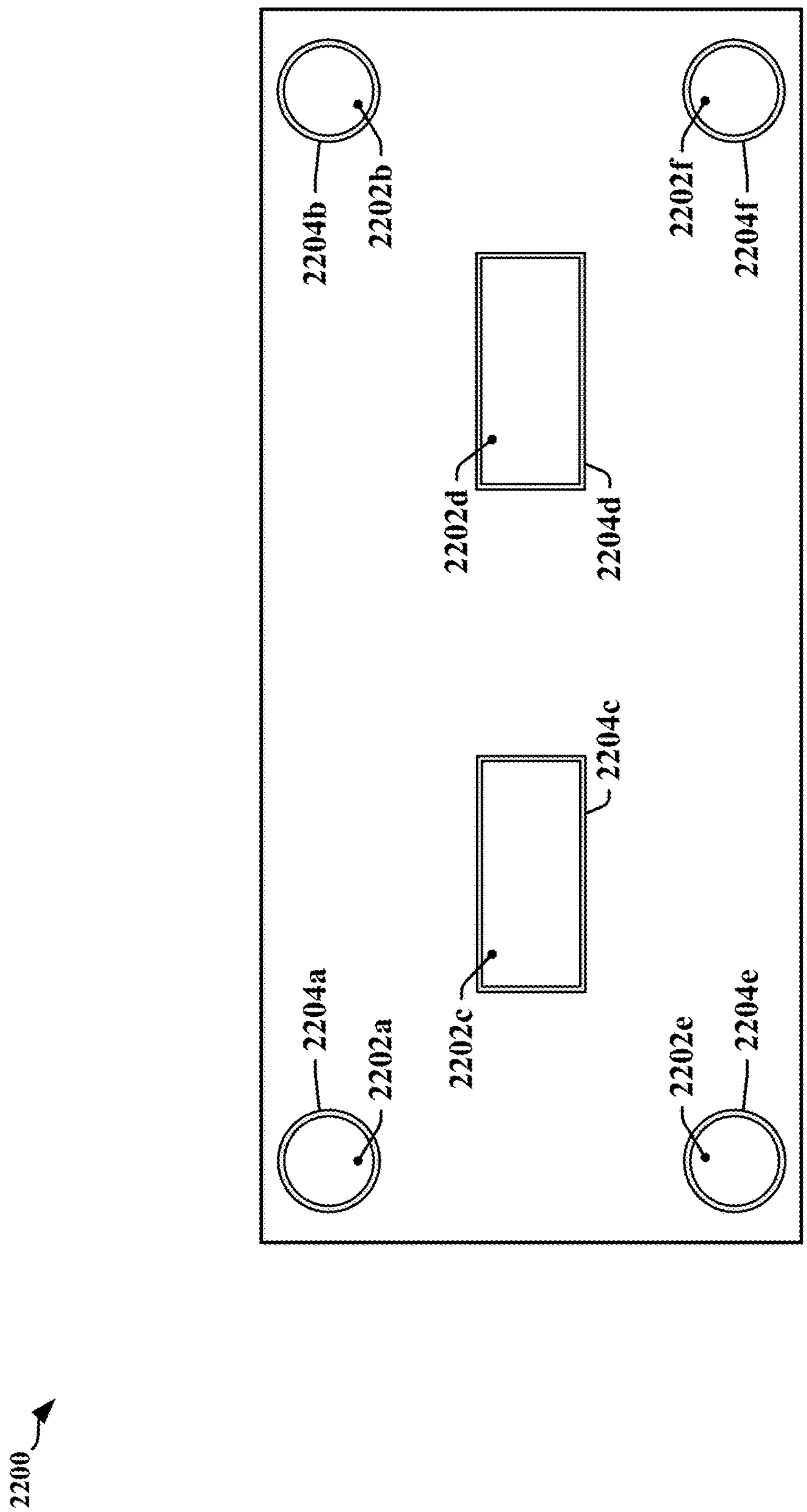

2204b
2202b
2202f
2204f
2202d
2204d
2204c
2204a
2202a
2202c
2202e
2204e
2200

FIG. 22

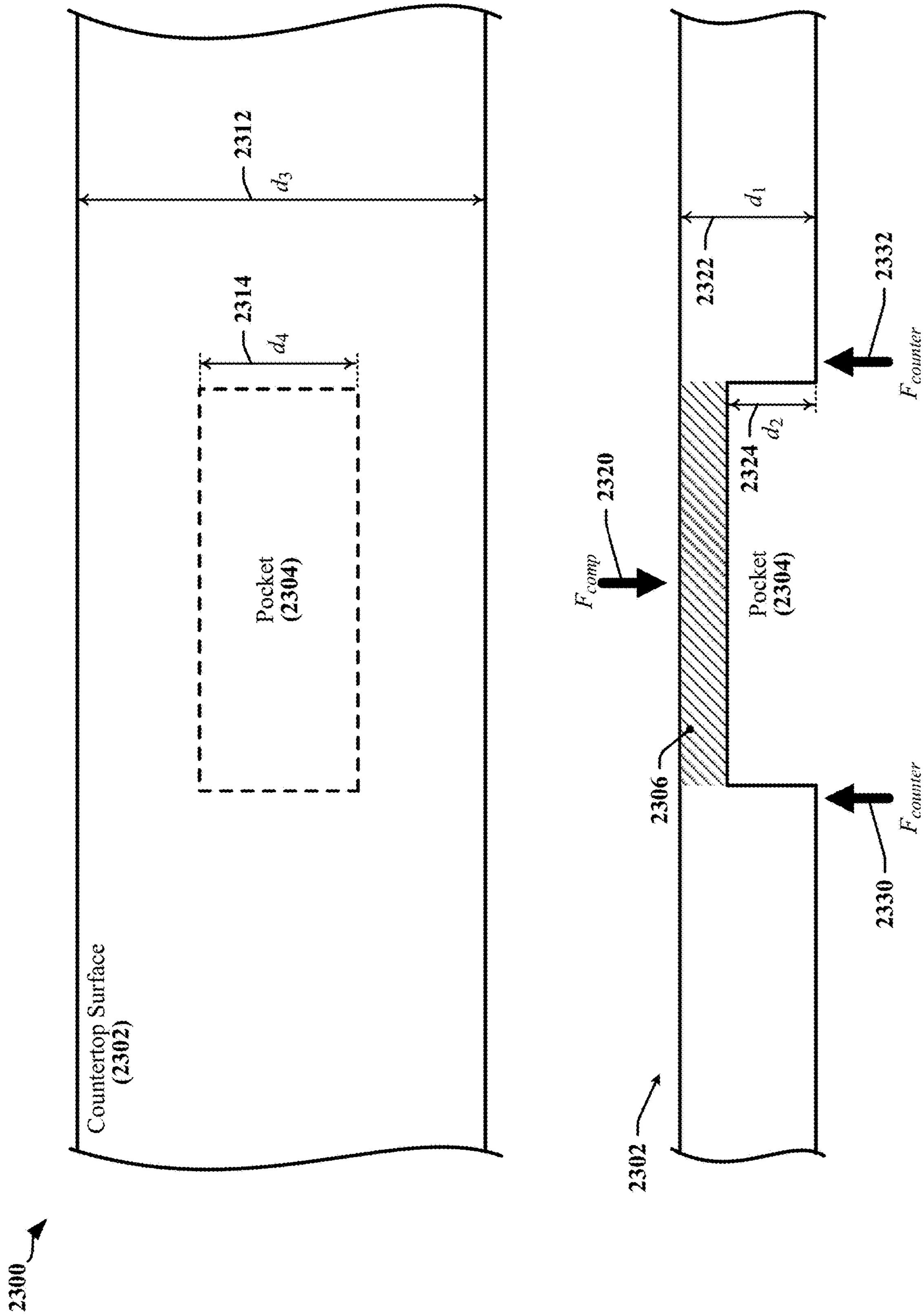

2300
Countertop Surface
(2302)
2312
d_3
2314
d_4
Pocket
(2304)
2302
2306
F_{comp}
2320
2322
d_1
2324
d_2
Pocket
(2304)
$F_{counter}$
2332
$F_{counter}$
2330

FIG. 23

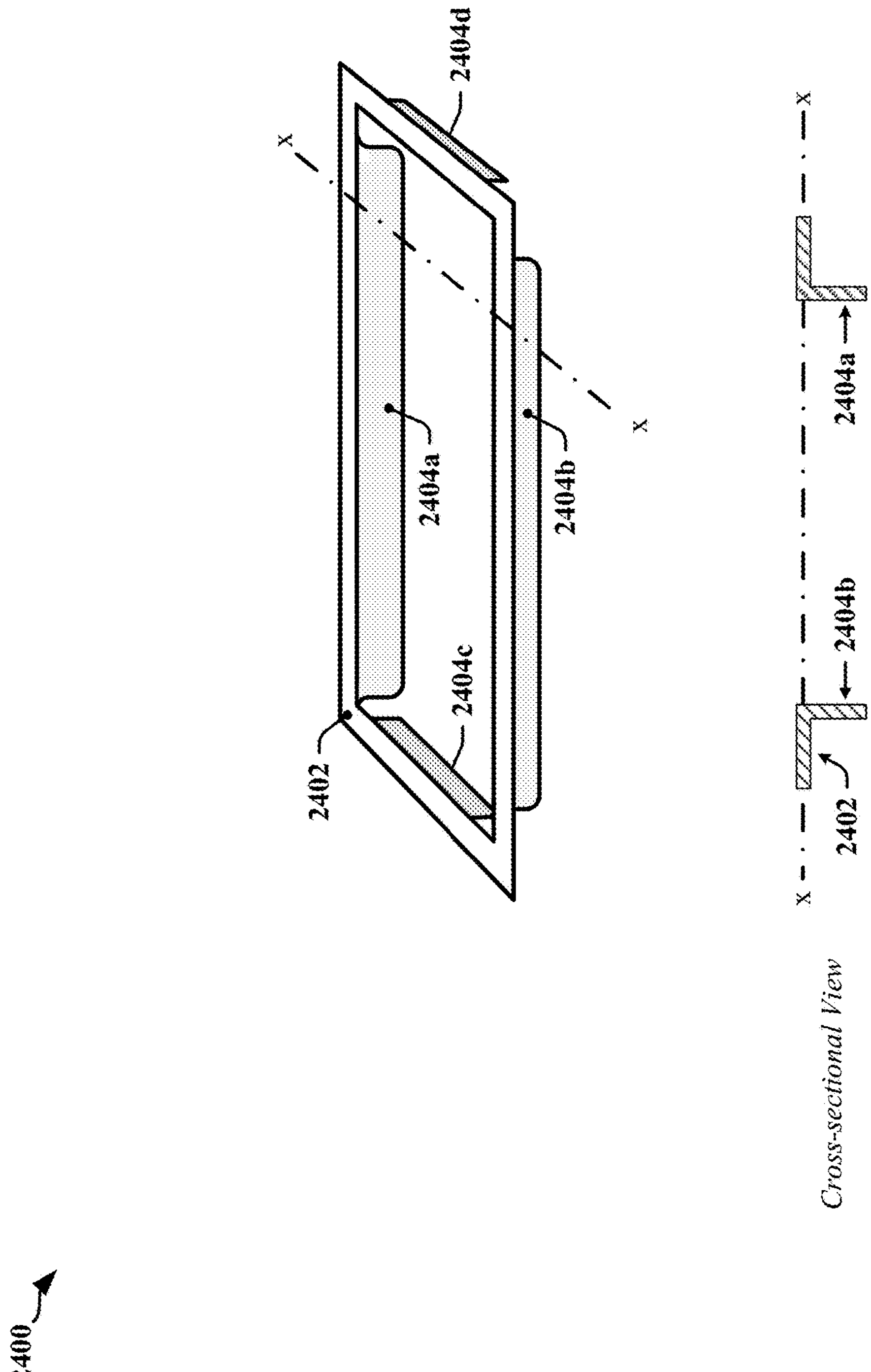
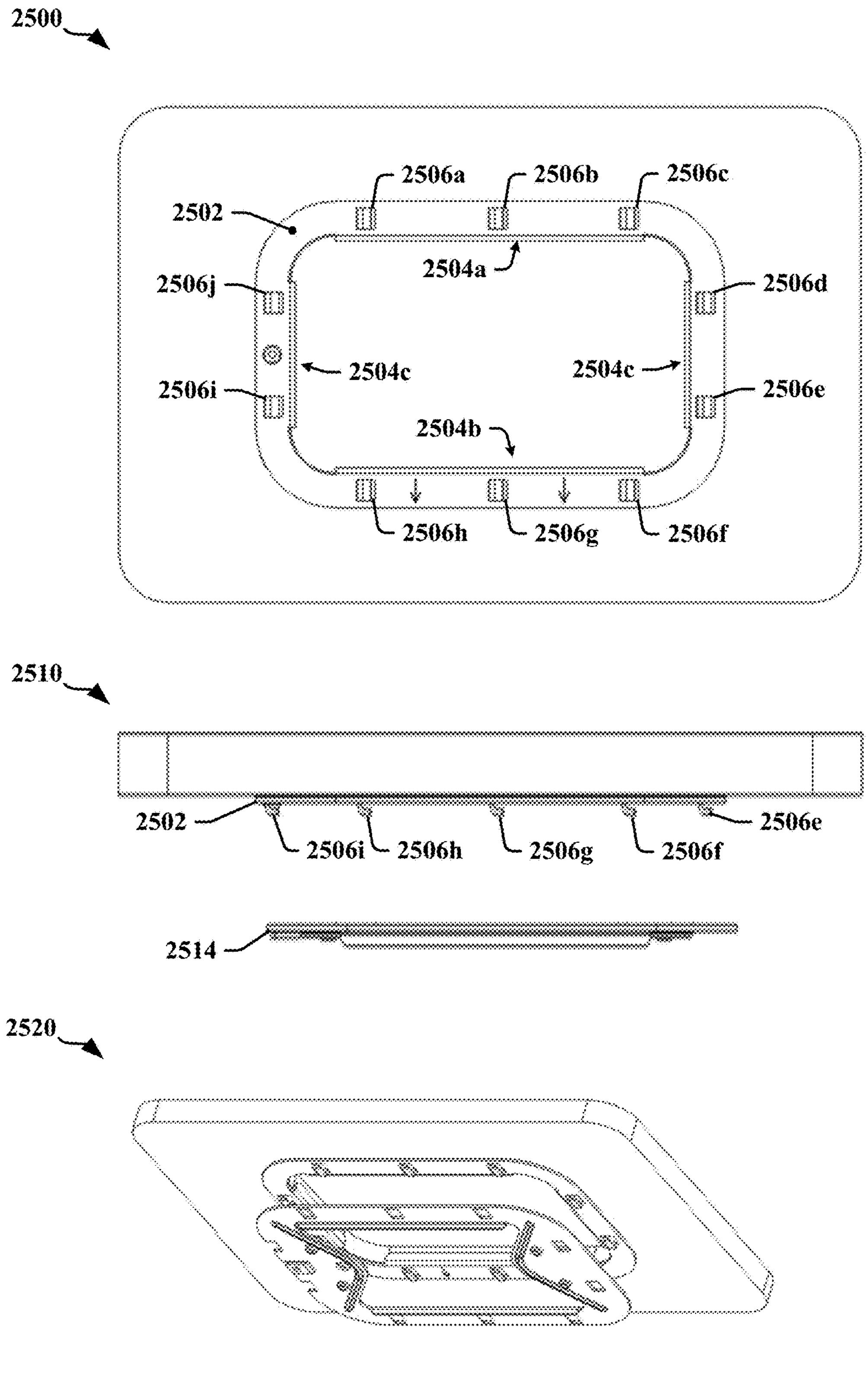

2400
2402
2404a
2404b
2404c
2404d
x
x
2402
2404b
2404a
x
x
Cross-sectional View

FIG. 24



2500
2506a
2506b
2506c
2502
2504a
2506j
2506d
2504c
2504c
2506i
2506e
2504b
2506h
2506g
2506f
2510
2502
2506i
2506h
2506g
2506f
2506e
2514
2520

FIG. 25

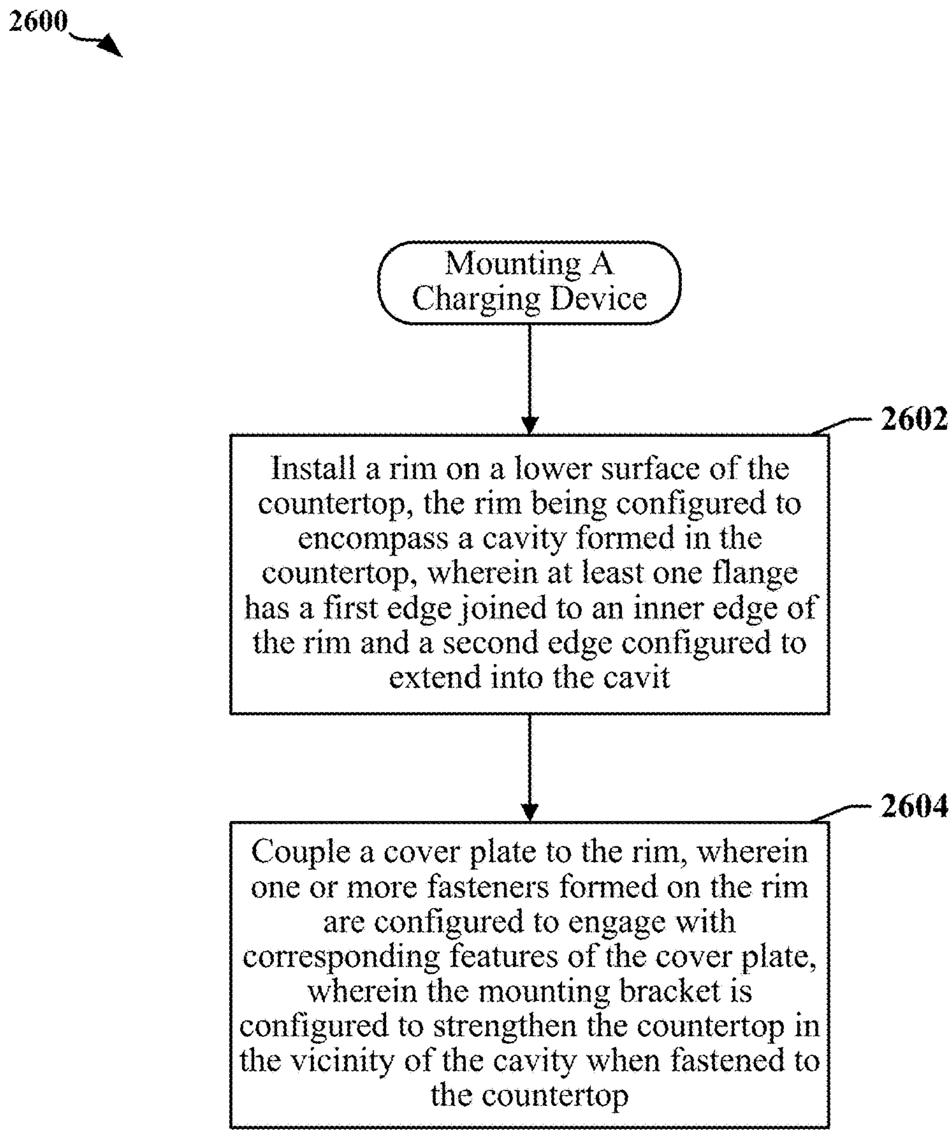

2600
Mounting A Charging Device
2602
Install a rim on a lower surface of the countertop, the rim being configured to encompass a cavity formed in the countertop, wherein at least one flange has a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavit
2604
Couple a cover plate to the rim, wherein one or more fasteners formed on the rim are configured to engage with corresponding features of the cover plate, wherein the mounting bracket is configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop

FIG. 26

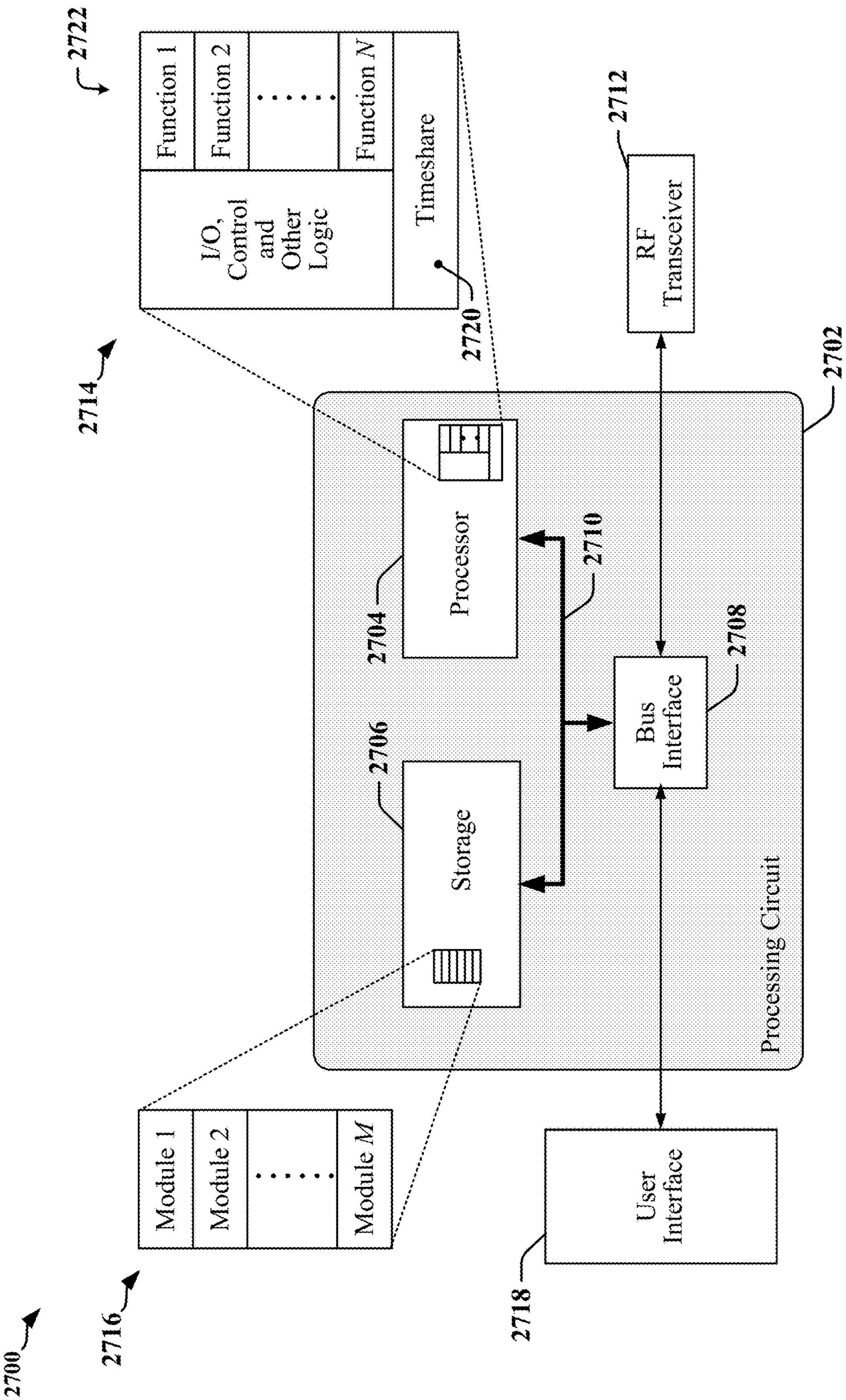

2722
Function 1
Function 2
Function N
I/O, Control and Other Logic
Timeshare
2720
2714
2712
RF Transceiver
2702
Processor
2704
2710
Bus Interface
2708
Storage
2706
Processing Circuit
Module 1
Module 2
Module M
2716
2700
User Interface
2718

FIG. 27

COUNTERTOP MOUNTING BRACKET FOR WIRELESS CHARGING

PRIORITY CLAIM

[0001] This application claims priority to and the benefit of provisional patent application No. 63/553,558 filed in the United States Patent Office on Feb. 14, 2024, the entire content of this application being incorporated herein by reference as if fully set forth below in its entirety and for all applicable purposes.

TECHNICAL FIELD

[0002] The present invention relates generally to charging surfaces for wireless charging of batteries, including batteries in mobile computing devices and more particularly to providing a charging surface in a countertop.

BACKGROUND

[0003] Wireless charging systems have been deployed to enable certain types of devices to charge internal batteries without the use of a physical charging connection. Devices that can take advantage of wireless charging include mobile processing and/or communication devices. Standards, such as the Qi standard defined by the Wireless Power Consortium enable devices manufactured by a first supplier to be wirelessly charged using a charger manufactured by a second supplier. Standards for wireless charging are optimized for relatively simple configurations of devices and tend to provide basic charging capabilities.

[0004] Improvements in wireless charging capabilities are required to provide flexibility in charging configurations and support continually increasing complexity of mobile devices and changing form factors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates an example of a charging cell that may be employed to provide a charging surface in accordance with certain aspects disclosed herein.

[0006] FIG. **2** illustrates an example of an arrangement of charging cells provided on a single layer of a segment of a charging surface that may be adapted in accordance with certain aspects disclosed herein.

[0007] FIG. **3** illustrates an example of an arrangement of charging cells when multiple layers are overlaid within a segment of a charging surface that may be adapted in accordance with certain aspects disclosed herein.

[0008] FIG. **4** illustrates the arrangement of power transfer areas provided by a charging surface that employs multiple layers of charging cells configured in accordance with certain aspects disclosed herein.

[0009] FIG. **5** illustrates an example of a Litz transmitting coil configured in accordance with certain aspects of this disclosure.

[0010] FIG. **6** illustrates an example of a portion of a charging surface provided using multiple overlapping Litz coils in accordance with certain aspects of this disclosure.

[0011] FIG. **7** illustrates a charging assembly in a wireless charging device constructed from Litz coils according to certain aspects of this disclosure.

[0012] FIG. **8** illustrates certain aspects of a Litz coil substrate provided in accordance with certain aspects of this disclosure.

[0013] FIG. **9** illustrates a wireless transmitter in a charger base station.

[0014] FIG. **10** illustrates a response to a passive ping.

[0015] FIG. **11** illustrates differences in responses to a passive ping.

[0016] FIG. **12** illustrates a method involving passive ping implemented in a wireless charging device adapted in accordance with certain aspects disclosed herein.

[0017] FIG. **13** illustrates an example of frequency response obtained when a resonant circuit is stimulated by a ping that includes several cycles of a signal that oscillates at or near the nominal resonant frequency of the resonant circuit.

[0018] FIG. **14** illustrates an example of frequency response obtained when a resonant circuit is stimulated by a ping that includes a burst of a stimulation signal that oscillates at a frequency that is greater than the nominal resonant frequency of the resonant circuit.

[0019] FIG. **15** illustrates a circuit that can measure response of a resonant circuit in a passive ping procedure.

[0020] FIG. **16** is a flowchart that illustrates a power transfer management procedure that may be employed by a wireless charging device implemented in accordance with certain aspects disclosed herein.

[0021] FIG. **17** illustrates an example of a modular or physically distributed charging surface that have charging cell of different sizes in accordance with certain aspects disclosed herein.

[0022] FIG. **18** illustrates an example of a charging system that includes multiple charging devices provided in accordance with certain aspects of this disclosure.

[0023] FIG. **19** illustrates a first example of a combined control circuit in a modular charging surface provided in accordance with certain aspects disclosed herein.

[0024] FIG. **20** illustrates a second example of a combined control circuit that may be provided in a modular charging surface provided according to certain aspects disclosed herein.

[0025] FIG. **21** illustrates the use of modular charging devices to provide one or more charging surfaces on an item of furniture in accordance with certain aspects of this disclosure.

[0026] FIG. **22** illustrates a configuration of charging areas on a surface configured in accordance with certain aspects of this disclosure.

[0027] FIG. **23** illustrates an example of a countertop in which a cavity, hollow or pocket is provided near an upper surface of the countertop.

[0028] FIG. **24** illustrates an example of a structural brace that may be configured in accordance with certain aspects of this disclosure.

[0029] FIG. **25** illustrates an example of a mounting bracket that may be configured in accordance with certain aspects of this disclosure.

[0030] FIG. **26** is flowchart illustrating an example of a method for mounting a charging device to a countertop in accordance with certain aspects disclosed herein.

[0031] FIG. **27** illustrates one example of an apparatus employing a processing circuit that may be adapted according to certain aspects disclosed herein.

DETAILED DESCRIPTION

[0032] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0033] Several aspects of wireless charging systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawing by various blocks, modules, components, circuits, steps, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0034] By way of example, an element, or any portion of an element, or any combination of elements may be implemented with a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software may reside on a processor-readable storage medium. A processor-readable storage medium, which may also be referred to herein as a computer-readable medium may include, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., compact disk (CD), digital versatile disk (DVD)), a smart card, a flash memory device (e.g., card, stick, key drive), Near Field Communications (NFC) token, random access memory (RAM), read only memory (ROM), programmable ROM (PROM), erasable PROM (EPROM), electrically erasable PROM (EEPROM), a register, a removable disk, a carrier wave, a transmission line, and any other suitable medium for storing or transmitting software. The computer-readable medium may be resident in the processing system, external to the processing system, or distributed across multiple entities including the processing system. Computer-readable medium may be embodied in a computer-program product. By way of example, a computer-program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0035] Certain aspects of the present disclosure relate to systems, apparatus and methods associated with wireless charging devices that provide a free-positioning charging surface using multiple transmitting coils or that can concurrently charge multiple receiving devices. In one aspect, a controller in the wireless charging device can locate a device to be charged and can configure one or more transmitting coils optimally positioned to deliver power to the receiving device. Charging cells may be provisioned or configured with one or more inductive transmitting coils and multiple charging cells may be arranged or configured to provide the charging surface. The location of a device to be charged may be detected through sensing techniques that associate location of the device to changes in a physical characteristic centered at a known location on the charging surface. In some examples, sensing of location may be implemented using capacitive, resistive, inductive, touch, pressure, load, strain, and/or another appropriate type of sensing.

[0036] Certain aspects of the present disclosure relate to systems, apparatus and methods that enable fast, low-power detection of objects placed in proximity to a charging surface. In one example, an object may be detected when a pulse provided to a charging circuit stimulates an oscillation in the charging circuit, or in some portion thereof. A frequency of oscillation of the charging circuit responsive to the pulse or a rate of decay of the oscillation of the charging circuit may be indicative or determinative of presence of a chargeable device has been placed in proximity to a coil of the charging circuit. Identification of a type or nature of the object may be made based on changes in a characteristic of the charging circuit. The pulse provided to the charging circuit may have a duration that is less than half the period of a nominal resonant frequency of the charging circuit.

[0037] Certain aspects disclosed herein relate to improved wireless charging systems. Systems, apparatus and methods are disclosed that accommodate free placement of chargeable devices on one or more surfaces provided by a charging system constructed from modular surface elements. In one example, a single surface provided by the charging system is formed from a configuration of multiple modular multi-coil wireless charging elements. In another example, a distributed charging surface may be provided by the charging system using multiple interconnected multi-coil wireless charging elements. Certain aspects can improve the efficiency and capacity of a wireless power transmission to a receiving device. In one example, a wireless charging device has a battery charging power source, a plurality of charging cells configured in a matrix, a first plurality of switches in which each switch is configured to couple a row of coils in the matrix to a first terminal of the battery charging power source, and a second plurality of switches in which each switch is configured to couple a column of coils in the matrix to a second terminal of the battery charging power source. Each charging cell in the plurality of charging cells may include one or more coils surrounding a power transfer area. The plurality of charging cells may be arranged adjacent to a charging surface without overlap of power transfer areas of the charging cells in the plurality of charging cells.

[0038] Certain aspects of the present disclosure relate to systems, apparatus and methods for a wireless charging system that provide multiple power transmitting coils in elements of a modular or distributed surface. The coils may be stacked and can be used to charge target devices presented to the wireless charging systems without a requirement to match a particular geometry or location within a charging surface of the charging device. Each coil may have a shape that is substantially polygonal. In one example, each coil may have a hexagonal shape. Each coil may be implemented using wires, printed circuit board traces and/or other connectors that are provided in a spiral. Each coil may span two or more layers separated by an insulator or substrate such that coils in different layers are centered around a common axis.

[0039] According to certain aspects disclosed herein, devices placed on a charging surface provided by the wireless charging system may receive power that is wirelessly transmitted through one or more of the charging cells that are associated with the charging surface. Power can be wirelessly transferred to a receiving device located anywhere on the charging surface. The receiving device can have an arbitrarily defined size and/or shape and may be placed without regard to any discrete placement locations enabled for charging. Multiple devices can be simultaneously or concurrently charged on a single surface. The apparatus can track motion of one or more devices across the surface. A charging system may provide multiple charging surface portions that are physically separated from one another but managed as a single modular charging surface that can manage and control simultaneously charging of multiple devices. The charging system may be manufactured using printed circuit board technology, at low cost and/or with a compact design.

[0040] Certain aspects of this disclosure relate to systems and methods implemented using low power radio frequency (RF) communication. For example, near-field communication (NFC) standards or protocols can be used to operate low-power wireless tags using a small amount of energy incident in a radio frequency (RF) field. In one example, the wireless tag may operate in accordance with a radio-frequency identification (RFID) protocol. The energy used to operate the wireless tag may be extracted from an interrogation signal transmitted by an interrogating device, RFID reader or other device. In one aspect of this disclosure, the mobile device may be configured to operate as an interrogating device. Certain devices constructed according to certain aspects of the presently described invention can be incorporated in, or controlled by wireless charging devices.

[0041] Another aspect of the present disclosure relates to systems, apparatus and methods related to a charging device has a first plurality of transmitting coils arranged in a pattern on a first printed circuit board, the first plurality of transmitting coils defining a first charging surface, a second plurality of transmitting coils arranged in the pattern on a second printed circuit board, the second plurality of transmitting coils defining a second charging surface, a fastening device configured to fasten the first printed circuit board in alignment with the second printed circuit board such that the pattern is continued from the first charging surface into the second charging surface, an electrical interconnect configured to conduct a charging current from the first charging surface into the second charging surface, and a processor configured to select one or more transmitting coils to receive the charging current. Each of the one or more transmitting coils is provided in the first plurality of transmitting coils or the second plurality of transmitting coils.

[0042] Certain aspects of the present disclosure relate to systems, apparatus and methods applicable to wireless charging devices that provide a free-positioning charging surface that has multiple transmitting coils or that can concurrently charge multiple receiving devices. In one aspect, a processing circuit coupled to the free-positioning charging surface can be configured to locate a device to be charged and can select and configure one or more power transmitting coils that are optimally positioned to deliver power to the receiving device. Charging cells may be configured with one or more inductive transmitting coils and multiple charging cells may be arranged or configured to provide the charging surface. The location of a device to be charged may be detected through sensing techniques that associate location of the device to changes in a physical characteristic centered at a known location on the charging surface. In some examples, sensing of location may be implemented using capacitive, resistive, inductive, touch, pressure, load, strain, and/or another appropriate type of sensing.

[0043] According to certain aspects disclosed herein, a charging surface in a wireless charging device may be provided using charging cells that are deployed adjacent to a surface of the charging device. In one example the charging cells are deployed in accordance with a honeycomb packaging configuration. A charging cell may be implemented using one or more coils that can each induce a magnetic field along an axis that is substantially orthogonal to the charging surface. In this disclosure, a charging cell may refer to an element having one or more coils where each coil is configured to produce an electromagnetic field that is additive with respect to the fields produced by other coils in the charging cell and directed along or proximate to a common axis. In this description, a coil in a charging cell may be referred to as a charging coil or a transmitting coil.

[0044] In some examples, a charging cell includes coils that are stacked along a common axis. One or more coils may overlap such that they contribute to an induced magnetic field substantially orthogonal to the charging surface. In some examples, a charging cell includes coils that are arranged within a defined portion of the charging surface and that contribute to an induced magnetic field within the defined portion of the charging surface, the magnetic field contributing to a magnetic flux flowing substantially orthogonal to the charging surface. In some implementations, charging cells may be configurable by providing an activating current to coils that are included in a dynamically-defined charging cell. For example, a wireless charging device may include multiple stacks of coils deployed across a charging surface, and the wireless charging device may detect the location of a device to be charged and may select some combination of stacks of coils to provide a charging cell adjacent to the device to be charged. In some instances, a charging cell may include, or be characterized as a single coil. However, it should be appreciated that a charging cell may include multiple stacked coils and/or multiple adjacent coils or stacks of coils.

[0045] FIG. **1** illustrates an example of a charging cell **100** that may be deployed and/or configured to provide a charging surface in a wireless charging device. In this example, the charging cell **100** has a substantially hexagonal shape that encloses one or more coils **102** constructed using conductors, wires or circuit board traces that can receive a current sufficient to produce an electromagnetic field in a power transfer area **104**. In various implementations, some coils **102** may have a shape that is substantially polygonal, including the hexagonal charging cell **100** illustrated in FIG. **1**. Other implementations may include or use coils **102** that have other shapes. The shape of the coils **102** may be determined at least in part by the capabilities or limitations of fabrication technology or to optimize layout of the charging cells on a substrate **106** such as a printed circuit board substrate. Each coil **102** may be implemented using wires, printed circuit board traces and/or other connectors in a spiral configuration. Each charging cell **100** may span two or more layers separated by an insulator or substrate **106** such that coils **102** in different layers are centered around a common axis **108**.

[0046] FIG. **2** illustrates an example of an arrangement **200** of charging cells **202** provided on a single layer of a segment or portion of a charging surface that may be adapted in accordance with certain aspects disclosed herein. The charging cells **202** are arranged according to a honeycomb packaging configuration. In this example, the charging cells **202** are arranged end-to-end without overlap. This arrangement can be provided without through-holes or wire interconnects. Other arrangements are possible, including arrangements in which some portion of the charging cells **202** overlap. For example, wires of two or more coils may be interleaved to some extent.

[0047] FIG. **3** illustrates an example of an arrangement of charging cells from two perspectives **300**, **310** when multiple layers are overlaid within a segment or portion of a charging surface that may be adapted in accordance with certain aspects disclosed herein. Layers of charging cells **302**, **304**, **306**, **308** are provided within the charging surface. The charging cells within each layer of charging cells **302**, **304**, **306**, **308** are arranged according to a honeycomb packaging configuration. In one example, the layers of charging cells **302**, **304**, **306**, **308** may be formed on a printed circuit board that has four or more layers. The arrangement of charging cells **100** can be selected to provide complete coverage of a designated charging area that is adjacent to the illustrated segment.

[0048] FIG. **4** illustrates the arrangement of power transfer areas provided across a charging surface **400** of a charging device that employs multiple layers of charging cells configured in accordance with certain aspects disclosed herein. The charging device may be constructed from four layers of charging cells **402**, **404**, **406**, **408**. In FIG. **4**, each power transfer area provided by a charging cell in the first layer of charging cells **402** is marked "L**1**", each power transfer area provided by a charging cell in the second layer of charging cells **404** is marked "L**2**", each power transfer area provided by a charging cell in the third layer of charging cells **406** is marked "L**3**", and each power transfer area provided by a charging cell in the fourth layer of charging cells **408** is marked "L**4**".

[0049] FIG. **5** illustrates an example of a transmitting coil configured in accordance with certain aspects of this disclosure. The transmitting coil may be wound from a multi-stranded Litz wire **504** and may be referred to as a Litz coil **500**. Each strand **506** of the Litz wire **504** is formed as an insulated conductor that is sufficiently thin to mitigate or substantially reduce skin effect loss. Skin effect losses occur in wires carrying high frequency signals where the current tends to flow at outermost reaches (skin) of the wire. The strands **506** are insulated to maintain their individual nature and are twisted such that the relative positioning of the individual strands **506** changes over the length of the Litz wire **504**. In some instances, the strands **506** are bound by an exterior insulating layer **508**. The Litz coil **500** is wound as a substantially planar coil with an open interior that corresponds to the power transfer area **502**.

[0050] FIG. **6** illustrates an example of a portion of a charging surface **600** provided using multiple overlapping Litz coils **500**. In the illustrated example, the charging surface **600** is constructed using three layers of Litz coils **500**, although the number of layers of Litz coils **500** and arrangement of the Litz coils **500** in the charging surface **600** may vary according to application, size of the charging surface **600** and power transfer requirements per Litz coil **500**.

[0051] The configuration of Litz coils **500** in a charging surface **600** may be precisely defined by design requirements. In some instances, it can be difficult to manage and align the number of Litz coils **500** to be assembled during manufacture of a wireless charging device that provides a free positioning charging surface using multiple transmitting coils. Variability in positioning of the Litz coils **500** during manufacture can result in imprecise configurations of coils in some finished devices. In some instances, the Litz coils **500** may be retained in position using an adhesive or epoxy resin. According to certain aspects of this disclosure, a substrate may be configured to receive the Litz coils **500** and maintain the Litz coils **500** in a desired configuration for the lifetime of the wireless charging device.

[0052] FIG. **7** illustrates a charging assembly **700** in a wireless charging device constructed from Litz coils **500** according to certain aspects of this disclosure. The exploded view **720** shows a Litz coil substrate **722** configured to receive Litz coils and maintain the Litz coils in a predefined multi-layer Litz coil structure **724** with 3D displacements between coils that meet tolerances defined by a designer. The Litz coil substrate **722** may also define the spatial relationship between the multi-layer Litz coil structure **724** and a ferrite layer **726** or another type of magnetic half-core.

[0053] FIG. **8** illustrates certain aspects of a Litz coil substrate **800** provided in accordance with certain aspects of this disclosure. The Litz coil substrate **800** may be formed from a polymer, acetate, vinyl, nitrile rubber, latex, extruded polystyrene foam and/or other material. The Litz coil substrate **800** may have multiple cutouts that enable Litz coils **800** to be placed in position in an ordered assembly. In some examples, the cut-outs may be preformed, including when the Litz coil substrate **800** is manufactured by 3D printing, molding, extrusion and/or low-pressure expansion. In some examples, the cut-outs may be formed by milling, grinding, etching, abrading, chemical erosion, chemical dissolution or by another technique suitable for use with the material used to form the Litz coil substrate **800**.

[0054] Certain aspects of the Litz coil substrate **800** are illustrated in a cross-sectional view **820**. The illustrated Litz coil substrate **800** provides a four-layer charging surface and the cross-sectional view **820** illustrates an example of placement and assembly of four Litz coils **824*a*-824*d***. The Litz coil substrate **800** has a deep, first cutout **826*a*** in the Litz coil substrate **800** that receives a first Litz coil **824*a***. This first cutout **826*a*** may be formed as a complete circle in some examples. In other examples, the first cutout **826*a*** may have a portion that overlaps a portion of another cutout in the same plane of the Litz coil substrate **800**.

[0055] When the first Litz coil **824*a*** has been secured within the first cutout **826*a***, a second Litz coil **824*b*** may be placed in a second cutout **826*b*** in the Litz coil substrate **800**. When in position within the Litz coil substrate **800**, the second Litz coil **824***b* lies in a plane above the plane that includes the first Litz coil **824***a*. A portion of the second Litz coil **824***b* overlaps a portion of the first Litz coil **824***a*. The separation of the planes that include the horizontal center lines of the first Litz coil **824***a* and the second Litz coil **824***b* may be configured by the relative difference in depths of the first cutout **826***a* and the second cutout **826***b*.

[0056] The third Litz coil **824***c* is received by a deep, third cutout **826***c* in the Litz coil substrate **800**. This third cutout **826***c* may be formed as a complete circle in some examples. In other examples, the third cutout **826***c* may overlap with another cutout in the same plane. In one example, the third cutout **826***c* may partially overlap the first cutout **826***a* resulting in a through-hole, when the bottom surface of the first Litz coil **824***a* is in the same plane as the top surface or some other portion of the third Litz coil **824***c*.

[0057] When the third Litz coil **824***c* has been secured within the third cutout **826***c*, a fourth Litz coil **824***d* may be placed in a fourth cutout **826***d*. The fourth Litz coil **824***d* lies in a plane below the plane that includes the third Litz coil **824***c*. A portion of the fourth Litz coil **824***d* overlaps a portion of the third Litz coil **824***c* when secured within the Litz coil substrate **800**. The separation of the planes that include the horizontal center lines of the third Litz coil **824***c* and the fourth Litz coil **824***d* may be configured by the relative difference in depths of the third cutout **826***c* and the fourth cutout **826***d*.

[0058] A Litz coil **824***a*-**824***d* may be secured within the Litz coil substrate **800** through a pressure fit, including when the Litz coil substrate **800** is manufactured from a foam material. In some examples, a Litz coil **824***a*-**824***d* may be secured within the Litz coil substrate **800** by adhesive. In some examples, a Litz coil **824***a*-**824***d* may be secured within the Litz coil substrate **800** by mechanical means.

[0059] In some implementations, a completed charging assembly comprising the Litz coil substrate **800** and the Litz coils **824***a*-**824***d* may be attached to, or mounted on a substrate, which may be retained within a housing that can be mounted under a countertop, for example. In some implementations, the completed charging assembly comprising the Litz coil substrate **800** and the Litz coils **824***a*-**824***d* may be attached to, or mounted on a printed circuit board, which may be retained within a housing.

[0060] In accordance with certain aspects disclosed herein, location sensing may rely on changes in some property of the electrical conductors that form coils in a charging cell. Measurable differences in properties of the electrical conductors may include capacitance, resistance, inductance and/or temperature. In some examples, loading of the charging surface can affect the measurable resistance of a coil located near the point of loading. In some implementations, sensors may be provided to enable location sensing through detection of changes in touch, pressure, load and/or strain. Certain aspects disclosed herein provide apparatus and methods that can sense the location of devices that may be freely placed on a charging surface using low-power differential capacitive sense techniques.

[0061] According to certain aspects of this disclosure, a search may be conducted using passive pings to identify objects that may be chargeable devices placed on or near in a multi-coil, free position charging pad. Active pings may then be used to establish whether the object is a chargeable device that is configured to receive charge from the wireless charging device. A valid or compatible chargeable device is expected to respond to the active ping by modulating the flux transmitted by the wireless charging device to encode information that can be detected and decoded at the transmitter. Savings in power consumption can be obtained by refraining from providing active pings until a potential device is detected in a search, thereby limiting the number of active ping transmissions needed to detect presence of a chargeable device and establish an electromagnetic charging connection with the detected chargeable device.

[0062] In accordance with certain aspects disclosed herein, location sensing may rely on changes in some property of the electrical conductors that form coils in a charging cell. Measurable differences in properties of the electrical conductors may include changes in capacitance, resistance, inductance and/or temperature when an object is placed in proximity to one or more coils. In some examples, placement of an object on the charging surface can affect the measurable resistance, capacitance, inductance of a coil located near the point of placement. In some implementations, circuits may be provided to measure changes in resistance, capacitance, and/or inductance of one or more coils located near the point of placement. In some implementations, sensors may be provided to enable location sensing through detection of changes in touch, pressure, load and/or strain in the charging surface. Conventional techniques used in current wireless charging applications for detecting devices employ "ping" methods that drive the transmitting coil and consume substantial power (e.g., 100-200 mW). The field generated by the transmitting coil is used to detect a receiving device.

[0063] Wireless charging devices may be adapted in accordance with certain aspects disclosed herein to support a low-power discovery technique that can replace and/or supplement conventional ping transmissions. A conventional ping is produced by driving a resonant LC circuit that includes a transmitting coil of a base station. The base station then waits for an ASK-modulated response from the receiving device. A low-power discovery technique may include utilizing a passive ping to provide fast and/or low-power discovery. According to certain aspects, a passive ping may be produced by driving a network that includes the resonant LC circuit with a fast pulse that includes a small amount of energy. The fast pulse excites the resonant LC circuit and causes the network to oscillate at its natural resonant frequency until the injected energy decays and is dissipated. In one example, the fast pulse may have a duration corresponding to a half cycle of the resonant frequency of the network and/or the resonant LC circuit. When the base station is configured for wireless transmission of power within the frequency range 100 kHz to 200 kHz, the fast pulse may have a duration that is less than 2.5 μs.

[0064] The passive ping may be characterized and/or configured based on the natural frequency at which the network including the resonant LC circuit rings, and the rate of decay of energy in the network. The ringing frequency of the network and/or resonant LC circuit may be defined as:

$$\omega = \frac{1}{\sqrt{LC}} \tag{Eq. 1}$$

[0065] The rate of decay is controlled by the quality factor (Q factor) of the oscillator network, as defined by:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} \tag{Eq. 2}$$

[0066] Equations 1 and 2 show that resonant frequency is affected by L and C, while the Q factor is affected by L, C and R. In a base station provided in accordance with certain aspects disclosed herein, the wireless driver has a fixed value of C determined by the selection of the resonant capacitor. The values of L and R are determined by the wireless transmitting coil and by an object or device placed adjacent to the wireless transmitting coil.

[0067] The wireless transmitting coil is configured to be magnetically coupled with a receiving coil in a device placed within close proximity of the transmitting coil, and to couple some of its energy into the proximate device to be charged. The L and R values of the transmitter circuit can be affected by the characteristics of the device to be charged, and/or other objects within close proximity of the transmitting coil. As an example, if a piece of ferrous material with a high magnetic permeability placed near the transmitter coils can increase the total inductance (L) of the transmitter coil, resulting in a lower resonant frequency, as shown by Equation 1. Some energy may be lost through heating of materials due to eddy current induction, and these losses may be characterized as an increase the value of R thereby lowering the Q factor, as shown by Equation 2.

[0068] A wireless receiver placed in close proximity to the transmitter coil can also affect the Q factor and resonant frequency. The receiver may include a tuned LC network with a high Q which can result in the transmitter coil having a lower Q factor. The resonant frequency of the transmitter coil may be reduced due to the addition of the magnetic material in the receiver, which is now part of the total magnetic system. Table 1 illustrates certain effects attributable to different types of objects placed within close proximity to the transmitter coil.

TABLE 1

Object	L	R	Q	Frequency
None present	Base Value	Base value	Base Value (High)	Base Value
Ferrous	Small Increase	Large Increase	Large Decrease	Small Decrease
Non-ferrous	Small Decrease	Large Increase	Large Decrease	Small Increase
Wireless Receiver	Large Increase	Small Decrease	Small Decrease	Large Decrease

[0069] FIG. **9** illustrates a wireless transmitter **900** that may be provided in a charger base station. A controller **902** may receive a feedback signal filtered or otherwise processed by a filter circuit **908**. The controller may control the operation of a driver circuit **904**. The driver circuit **904** provides an alternating current to a resonant circuit **906** that includes a capacitor **912** and inductor **914**. The frequency of the alternating current may be determined by a charging clock signal **928** provided by timing circuits **920**. A measurement circuit may obtain a measurement signal **918** indicative of current flow or voltage **916** measured at an LC node **910** of the resonant circuit **906**. The measurement signal **918** may be used to calculate or estimate Q factor of the resonant circuit **906**.

[0070] The timing circuits **920** may provide the controller with one or more clock signals **924**, including a system clock signal that controls the operation of the controller **902**. The one or more clock signals **924** may further include a clock signal used to modulate or demodulate a data signal carried on a charging current in the resonant circuit **906**. The timing circuits **920** may include configurable clock generators that produce signals at frequencies defined by configuration information, including the charging clock signal **928**. The timing circuits **920** may be coupled to the controller through an interface **926**. The controller **902** may configure the frequency of the charging clock signal **928**. In some implementations, the controller **902** may configure the duration and frequency of a pulsed signal used for passive ping in accordance with certain aspects disclosed herein. In one example, the pulsed signal includes a number of cycles of the pulsed signal.

[0071] Passive ping techniques may use the voltage and/or current measured or observed at the LC node **910** to identify the presence of a receiving coil in proximity to the charging pad of a device adapted in accordance with certain aspects disclosed herein. Many conventional wireless charger transmitters include circuits that measure voltage at the LC node **910** or measure the current in the network. These voltages and currents may be monitored for power regulation purposes and/or to support communication between devices. In the example illustrated in FIG. **9**, voltage at the LC node **910** may be measured, although it is contemplated that a circuit may be adapted or provided such that current can additionally or alternatively be monitored to support passive ping. A response of the resonant circuit **906** to a passive ping (initial voltage V_0) may be represented by the voltage (VLC) at the LC node **910**, such that:

$$V_{LC} = V_0 e^{-\left(\frac{\omega}{2Q}\right)t} \tag{Eq. 3}$$

[0072] FIG. **10** illustrates examples of responses **1000**, **1020** to a passive ping. In each of the responses **1000**, **1020**, an initial voltage decays according to Equation 3. After the excitation pulse at time=0, the voltage and/or current is seen to oscillate at the resonant frequency defined by Equation 1, and with a decay rate defined by Equation 3. The first cycle of oscillation begins at voltage level V_0 and VLC continues to decay to zero as controlled by the Q factor and @. The first response **1000** illustrates a typical open or unloaded response when no object is present or proximate to the charging pad. In this first response **1000**, the value of the Q factor may be assumed to be 20. The second response **1020** illustrates a loaded response that may be observed when an object is present or proximate to the charging pad loads the coil. In the illustrated second response **1020**, the Q factor may have a value of 7. VLC oscillates at a higher frequency in the voltage response **1020** with respect to the voltage response **1000**.

[0073] FIG. **11** illustrates a set of examples in which differences in responses **1100**, **1120**, **1140** may be observed. A passive ping is initiated when a driver circuit **904** excites the resonant circuit **906** using a pulse that is shorter than 2.5 μs. Different types of wireless receivers and foreign objects placed on the transmitter result in different responses observable in the voltage at the LC node **910** or current in the resonant circuit **906** of the transmitter. The differences may indicate variations in the Q factor of the resonant circuit **906** frequency of the oscillation of V_0. Table 2 illustrates certain examples of objects placed on the charging pad in relation to an open state.

TABLE 2

Object	Frequency	V_{peak} (mV)	50% Decay Cycles	Q Factor
None present	96.98 kHz	134 mV	4.5	20.385
Type-1 Receiver	64.39 kHz	122 mV	3.5	15.855
Type-2 Receiver	78.14 kHz	78 mV	3.5	15.855
Type-3 Receiver	76.38 kHz	122 mV	3.2	14.496
Misaligned Type-3 Receiver	210.40 kHz	110 mV	2.0	9.060
Ferrous object	93.80 kHz	110 mV	2.0	9.060
Non-ferrous object	100.30 kHz	102 mV	1.5	6.795

[0074] In Table 2, the Q factor may be calculated as follows:

$$Q = \frac{\pi N}{\ln(2)} \cong 4.53N, \tag{Eq. 4}$$

[0075] where N is the number of cycles from excitation until amplitude falls below 0.5 V_0. FIG. **12** is a flowchart **1200** that illustrates a method involving passive ping implemented in a wireless charging device adapted in accordance with certain aspects disclosed herein. At block **1202**, a controller may generate a short excitation pulse and may provide the short excitation pulse to a network that includes a resonant circuit. The network may have a nominal resonant frequency and the short excitation pulse may have a duration that is less than half the nominal resonant frequency of the network. The nominal resonant frequency may be observed when the transmitting coil of the resonant circuit is isolated from external objects, including ferrous objects, non-ferrous objects and/or receiving coils in a device to be charged.

[0076] At block **1204**, the controller may determine the resonant frequency of the network or may monitor the decay of resonation of the network responsive to the pulse. According to certain aspects disclosed herein, the resonant frequency and/or the Q factor associated with the network may be altered when a device or other object is placed in proximity to the transmitting coil. The resonant frequency may be increased or decreased from the nominal resonant frequency observed when the transmitting coil of the resonant circuit is isolated from external objects. The Q factor of the network may be increased or decreased with respect to a nominal Q factor measurable when the transmitting coil of the resonant circuit is isolated from external objects. According to certain aspects disclosed herein, the duration of delay can be indicative of the presence or type of an object placed in proximity to the transmitting coil when differences in Q factor prolong or accelerate decay of amplitude of oscillation in the resonant circuit with respect to delays associated with a nominal Q factor.

[0077] In one example, the controller may determine the resonant frequency of the network using a transition detector circuit configured to detect zero crossings of a signal representative of the voltage at the LC node **910** using a comparator or the like. In some instances, direct current (DC) components may be filtered from the signal to provide a zero crossing. In some instances, the comparator may account for a DC component using an offset to detect crossings of a common voltage level. A counter may be employed to count the detected zero crossings. In another example the controller may determine the resonant frequency of the network using a transition detector circuit configured to detect crossings through a threshold voltage by a signal representative of the voltage at the LC node **910**, where the amplitude of the signal is clamped or limited within a range of voltages that can be detected and monitored by logic circuits. In this example, a counter may be employed to count transitions in the signal. The resonant frequency of the network may be measured, estimated and/or calculated using other methodologies.

[0078] In another example, a timer or counter may be employed to determine the time taken for Vic to decay from voltage level V_0 to a threshold voltage level. The elapsed time may be used to represent a decay characteristic of the network. The threshold voltage level may be selected to provide sufficient granularity to enable a counter or timer to distinguish between various responses **1100**, **1120**, **1140** to the pulse. Vic may be represented by detected or measured peak, peak-to-peak, envelope **1102** and/or rectified voltage level. The decay characteristic of the network may be measured, estimated and/or calculated using other methodologies.

[0079] If at block **1206**, the controller determines that a change in resonant frequency with respect to a nominal resonant frequency indicate presence of an object in proximity to the transmitting coil, the controller may attempt to identify the object at block **1212**. If the controller determines at block **1206** that resonant frequency is substantially the same as the nominal resonant frequency, the controller may consider the decay characteristic of the amplitude of oscillation in the resonant circuit at block **1208**. The controller may determine that the resonant frequency of the network is substantially the same as the nominal resonant frequency when the frequency remains within a defined frequency range centered on, or including the nominal resonant frequency. In some implementations, the controller may identify objects using changes in resonant frequency and decay characteristics. In these latter implementations, the controller may continue at block **1208** regardless of resonant frequency, and may use changes in change in resonant frequency as an additional parameter when identifying an object positioned proximately the transmission coil.

[0080] At block **1208**, the controller may use a timer and/or may count the cycles of the oscillation in the resonant circuit that have elapsed between the initial V_0 amplitude and a threshold amplitude used to assess the decay characteristic. In one example, $V_0/2$ may be selected as the threshold amplitude. At block **1210**, the number of cycles or the elapsed time between the initial V_0 amplitude and the threshold amplitude may be used to characterize decay in the amplitude of oscillation in the resonant circuit, and to compare the characterize decay with a corresponding nominal decay characteristic. If at block **1210**, no change in frequency and delay characteristic is detected, the controller may terminate the procedure with a determination that no object is proximately located to the transmission coil. If at block **1210**, a change in frequency and/or delay characteristic has been detected, the controller may identify the object at block **1212**. At block **1212**, the controller may be configured to identify receiving devices placed on a charging pad. The controller may be configured to ignore other types of objects, or receiving devices that are not optimally placed on the charging pad including, for example, receiving devices that are misaligned with the transmission coil that provides the passive ping. In some implementations, the controller may use a lookup table indexed by resonant frequency, decay time, change in resonant frequency, change in decay time and/or Q factor estimates. The lookup table may provide information identifying specific device types, and/or charging parameters to be used when charging the identified device or type of device.

[0081] Passive ping uses a very short excitation pulse that can be less than a half-cycle of the nominal resonant frequency observed at the LC node **910** in the resonant circuit **906**. A conventional ping may actively drive a transmission coil for more than 16,000 cycles. The power and time consumed by a conventional ping can exceed the power and time use of a passive ping by several orders of magnitude. In one example, a passive ping consumes approximately 0.25 μJ per ping with a max ping time of around ~100 μs, while a conventional active ping consumes approximately 80 mJ per ping with a max ping time of around 90 ms. In this example, energy dissipation may be reduced by a factor of 320,000 and the time per ping may be reduced by a factor of 900.

[0082] Detection and characterization of the decay of the voltage at the LC node **910** may require fast, sensitive and/or low-voltage circuits to accommodate the low-power nature of resonant signals at the LC node **910** when a short excitation pulse is used to produce resonant signals in the resonant circuit **906**. In some instances, passive ping may be implemented using a burst of energy at the nominal resonant frequency of the resonant circuit **906**. The burst of energy may have a duration of several periods of the nominal resonant frequency. This burst-mode passive ping necessarily consumes more energy per ping that passive ping that is initiated by short excitation pulses. The additional energy provides additional time to characterize resonant response.

[0083] FIG. **13** illustrates an example of frequency response **1300** of the resonant circuit **906** when the resonant circuit **906** is stimulated by a ping (here, a passive ping **1302**) that includes several cycles of a signal that oscillates at or near the nominal resonant frequency (f_0 **1312**) of the resonant circuit **906**. A first frequency response **1304** illustrates the response of the resonant circuit **906** when no device is present, while a second frequency response **1306** illustrates the response of the resonant circuit **906** when a chargeable object is present. The chargeable object reduces the Q-factor of the resonant circuit **906**. The higher Q-factor of the resonant circuit **906** when no device is present causes the resonant circuit **906** to produce a significantly higher voltage response **1308** and draw the maximum current with the longest decay time in response to a passive ping **1302** at f_0 **1312** than the voltage response **1310** produced when a chargeable device lowers the Q-factor of the resonant circuit **906**, causing the resonant circuit **906** to produce lower voltage, draw less current and have a shorter decay time in response to a passive ping at f_0 **1312**. In typical applications, no object is present for a majority of the time a charging device is in operation, and the resonant circuit **906** in the charging device has a high Q-factor for a majority of the time. The high Q-factor results in a high power draw. The resonant circuit **906** has a slower response time when it has a high Q-factor, since more time is needed for the energy in the passive ping **1302** to decay thereby delaying initiation of another ping.

[0084] An improved passive ping technique implemented in accordance with certain aspects disclosed herein can reduce power consumption associated with passive pings **1302** and can increase the ping rate. The improved passive ping technique may use a frequency that is significantly different from the resonant frequency of the resonant circuit **906**. FIG. **14** illustrates an example of frequency responses **1400** of the resonant circuit **906** illustrating the effect of a ping (here, a pulse **1402**) provided as burst of a stimulation signal that oscillates at a frequency (f_p **1412**) that is greater than the nominal resonant frequency (f_0 **1408**) of the resonant circuit **906**. The burst spans two or more cycles of the stimulation signal. In one example, the duration of the burst may be controlled by a timer. In another example, the stimulation may be modulated using a gating signal that causes the stimulation signal to be provided to the resonant circuit at a desired repetition rate and with an active duration that defines the number of cycles of the stimulation signal in the burst. In some implementations, the ping is provided as a multi-cycle burst of a stimulation signal that has a frequency that is lower than f_0 **1408**.

[0085] The use of a stimulation signal that has a frequency different from the resonant frequency of the resonant circuit **906** can result in the dominant state of the charging device, where no chargeable object is present, to have a lower power draw and faster decay rate than would be expected for a stimulation signal that has a frequency at or near the resonant frequency of the resonant circuit **906**. The use of a non-resonant stimulation signal can provide improved performance with respect to the example illustrated in FIG. **13**. The disclosed ping technique can result in increased decay rates and can limit the occurrence of higher-power draws to pulses **1402** that lead to detection of a chargeable object. Additional pulses **1402** are typically superfluous after detection. The resonant circuit **906** may be stimulated during a passive ping procedure by a pulsed signal that includes pulses of a duration that can include several cycles at f_p **1412**. A first frequency response **1404** illustrates the response of the resonant circuit **906** to a pulse **1402** when no device is present, while a second frequency response **1406** illustrates the response of the resonant circuit **906** to a pulse **1402** when a chargeable object is present. The effect of the chargeable object on the resonant circuit **906** may be exhibited in a reduction in the Q-factor of the resonant circuit **906**. The resonant circuit **906** produces a significantly lower voltage level **1414** and draws a lower current with a shorter decay time in response to a ping at f_p **1412** when no device is present than the voltage level **1416** produced when a chargeable device is present. In typical applications, no object is present for a majority of the time a charging device is in operation, and the resonant circuit **906** exhibits a lower power consumption and a faster decay time per ping with respect to the example illustrated in FIG. **13**.

[0086] The frequency spread (f_p-f_0 or f_0-f_p) between the resonant frequency (f_0 **1408**) and the ping frequency (f_p **1412**) may be proportionate to the value of f_0 **1408**. For example, the frequency spread may increase as f_0 **1408** increases. In some implementations, the frequency spread and f_0 **1408***a* have a logarithmic (log base **10**) relationship. In an example that is compliant or compatible with Qi standards, where 80 Khz<f_0<110 Khz, a passive ping frequency may be defined such that 175 KHz<f_p<210 KHz.

[0087] According to certain aspects disclosed herein, frequency spread may be selected as a trade-off between signal-to-noise ratio (SNR) and power consumption or response time. In the example illustrated in FIG. **14**, an overly high value for frequency spread may result in lower SNR, while an overly high value for frequency spread may result in high power draw and/or slow response. The optimal balance between SNR and power draw may vary by application. In some implementations, the lowest power and fast scan rate is obtained by setting f_p **1412** as high as possible while permitting reliable detection of objects given SNR for the system.

[0088] The duration of a pulse **1402** can be defined as a number of fractions of a cycle of f_p **1412**. In one example, the duration of the passive ping pulse may be set to a half-cycle of f_p **1412**. In another example, the duration of the passive ping pulse may be set to multiple cycles of f_p **1412**. In some implementations, the duration of the passive ping pulse includes enough half-cycles of f_p **1412** to obtain a current draw in the detectable range of an analog-to-digital converter (ADC) in microprocessor of a charging device. The passive ping pulse may include additional cycles to accommodate the SNR margin. The number of additional cycles may be the subject of a trade-off to increase the SNR, while limiting power and ping time. In one example, where f_p=190 KHz and f_0=100 KHz, the duration of the passive ping pulse is less than 100 μS.

[0089] The repetition rate for pulses **1402** in a pulsed stimulus signal can be determined dynamically when speed of detection is prioritized. In one example, the ADC can be checked to determine when current has fallen back to zero before launching the next pulse **1402**. In this manner, a detection circuit can determine that no energy remains in the resonant circuit **906** from the pulse **1402** before initiating the next pulse **1402**. In some implementations, a fixed delay between pulses **1202** may be implemented. In one example, the fixed delay may be configured to be 6 times the longest decay time constant expected or observed in the resonant circuit **906**. In one example, the fixed delay may be configured to provide a one millisecond interval between pulses. The one millisecond ping interval may enable an 18-coil charging pad to be scanned in 18 mS, permitting sub-second device detection. The fixed time approach can be used if further optimization for speed is not necessary. For example, a dynamic ping interval may be used when larger numbers of charging coils are provided in a charging pad.

[0090] FIG. **15** illustrates a circuit **1500** that may be used to measure response of a resonant circuit in a passive ping procedure. In the illustrated example, the circuit **1500** monitors the power **1502** supplied to an inverter **1506** that produces the pulse **1510**. The power **1502** may be measured as current flow to the resonant circuit **1508**. In some implementations, power **1502** may be measured as a voltage across the resonant circuit **1508**. In the illustrated example, a current sensing circuit **1520** provides measurements to a controller **1504** that configures, initiates and/or triggers pulses **1510** provided to the resonant circuit **1508**. In one example, the current sensing circuit **1520** uses a comparator **1524** to measure the voltage across a low-value resistor **1522** in the power supply coupling to the inverter **1506**. A low-pass filter **1526** may be used to provide an average or root-mean square value as the output **1528** of the current sensing circuit **1520**.

[0091] Passive ping procedures may also be coupled with another, reduced-power sensing methodology, such as capacitive sensing. Capacitive sensing or the like can provide an ultra-low power detection method that determines presence or non-presence of an object is in proximity to the charging surface. After capacitive sense detection, a passive ping can be transmitted sequentially or concurrently on each coil to produce a more accurate map of where a potential receiving device and/or object is located. After a passive ping procedure has been conducted, an active ping may be provided in the most likely device locations. An example algorithm for device location sensing, identification and charging is illustrated in FIG. **16**.

[0092] FIG. **16** is a flowchart **1600** that illustrates a power transfer management procedure involving multiple sensing and/or interrogation techniques that may be employed by a wireless charging device implemented in accordance with certain aspects disclosed herein. The procedure may be initiated periodically and, in some instances, may be initiated after the wireless charging device exits a low-power or sleep state. In one example, the procedure may be repeated at a frequency calculated to provide sub-second response to placement of a device on a charging pad. The procedure may be re-entered when an error condition has been detected during a first execution of the procedure, and/or after charging of a device placed on the charging pad has been completed.

[0093] At block **1602**, a controller may perform an initial search using capacitive proximity sensing. Capacitive proximity sensing may be performed quickly and with low power dissipation. In one example, capacitive proximity sensing may be performed iteratively, where one or more transmission coils is tested in each iteration. The number of transmission coils tested in each iteration may be determined by the number of sensing circuits available to the controller. At block **1604**, the controller may determine whether capacitive proximity sensing has detected the presence or potential presence of an object proximate to one of the transmission coils. If no object is detected by capacitive proximity sensing, the controller may cause the charging device to enter a low-power, idle and/or sleep state at block **1624**. If an object has been detected, the controller may initiate passive ping sensing at block **1606**.

[0094] At block **1606**, the controller may initiate passive ping sensing to confirm presence of an object near one or more transmission coils, and/or to evaluate the nature of the proximately located object. Passive ping sensing may consume a similar quantity of power but span a greater of time than capacitive proximity sensing. In one example, each passive ping can be completed in approximately 100 μs and may expend 0.25 μJ. A passive ping may be provided to each transmission coil identified as being of-interest by capacitive proximity sensing. In some implementations, a passive ping may be provided to transmission coils near each transmission coil identified as being of-interest by capacitive proximity sensing, including overlaid transmission coils. At block **1608**, the controller may determine whether passive ping sensing has detected the presence of a potentially chargeable device proximate to one of the transmission coils that may be a receiving device. If a potentially chargeable device has been detected, the controller may initiate active digital ping sensing at block **1610**. If no potential chargeable device has been detected, passive ping sensing may continue at block **1606** until all of the coils have been tested and/or the controller terminates passive ping sensing. In one example, the controller terminates passive ping sensing after all transmitting coils have been tested. When passive ping sensing fails to find a potentially chargeable device, the controller the controller may cause the charging device to enter a low-power, idle and/or sleep state. In some implementations, passive ping sensing may be paused when a potentially chargeable device is detected so that an active ping can be used to interrogate the potentially chargeable device. Passive ping sensing may be resumed after the results of an active ping have been obtained.

[0095] At block **1610**, the controller may use an active ping to interrogate a potentially chargeable device. The active ping may be provided to a transmitting coil identified by passive ping sensing. In one example, a standards-defined active ping exchange can be completed in approximately 90 ms and may expend 80 mJ. An active ping may be provided to each transmission coil associated with a potentially chargeable device.

[0096] At block **1612**, the controller may identify and configure a chargeable device. The active ping provided at block **1610** may be configured to stimulate a chargeable device such that it transmits a response that includes information identifying the chargeable device. In some instances, the controller may fail to identify or configure a potentially chargeable device detected by passive ping, and the controller may resume a search based on passive ping at block **1606**. At block **1614**, the controller may determine whether a baseline charging profile or negotiated charging profile should be used to charge an identified chargeable device. The baseline, or default charging profile may be defined by standards. In one example, the baseline profile limits charging power to 5 W. In another example, a negotiated charging profile may enable charging to proceed at up to 17 W. When a baseline charging profile is selected, the controller may begin transferring power (charging) at block **1620**.

[0097] At block **1616**, the controller may initiate a standards-defined negotiation and calibration process that can optimize power transfer. The controller may negotiate with the chargeable device to determine an extended power profile that is different from a power profile defined for the baseline charging profile. The controller may determine at block **1618** that the negotiation and calibration process has failed and may terminate the power transfer management procedure. When the controller determines at block **1618** that the negotiation and calibration process has succeeded, charging in accordance with the negotiate profile may commence at block **1620**.

[0098] At block **1622**, the controller may determine whether charging has been successfully completed. In some instances, an error may be detected when a negotiated profile is used to control power transfer. In the latter instance, the controller may attempt to renegotiate and/or reconfigure the profile at block **1616**. The controller may terminate the power transfer management procedure when charging has been successfully completed.

[0099] The use of passive ping techniques disclosed herein can enable rapid, low-power detection or discovery of devices or objects that have been placed or positioned proximate to a charging surface. A charging device that employs passive ping can benefit from reduced quiescent power draw, increased detection speed, and reduced radiated EMI. A conventional system that uses passive ping detection operates by providing a stimulating pulse that is used to measure a current or voltage value or rate of decay in order to determine a characteristic of the stimulated the network. Conventional systems, for example, strive to detect changes in Q factor of a resonant circuit stimulated by the stimulating pulse. The value of the Q factor may be calculated or estimated base do a comparison of an electrical or electromagnetic signal to a threshold value.

[0100] According to certain aspects of this disclosure, a charging surface provided in wireless charging system may be implemented using a modular PCB system in which each modular PCB carries one or more charging coils arranged in substantially parallel alignment with the charging surface. According to one aspect, the charging system may include multiple modular PCBs configured to provide a large surface area on which a chargeable device can be placed for charging and which can be controlled, managed or drive by a single controlling system. In one example, the modular PCBs may be physically coupled, joined or otherwise provided in a side-by-side or end-on-end configuration to provide a combined charging surface with a desired length, breadth or surface area. In another example, two or more of the modular PCBs may be physically separated and may provide multiple charging surfaces within a room or cabin of a vehicle or in different locations of an item of furniture, such as a desk. The charging system may include modular PCBs that have the same charging coil configuration, including same size and layout of charging coils. In some examples, the charging system includes different types of modular PCBs, including modular PCBs with different layouts, differently-sized charging coils and/or different PCB size. In some examples, a modular PCB may include charging coils of different sizes. In some examples, a modular PCB may include charging coils of different shapes. In some examples, some modular PCBs may be made from a flexible PCB while other modular PCBs may be made from inflexible materials.

[0101] In some examples, a modular PCB may be manufactured on printed circuit boards that have 4 or more layers and the charging coils may include coil portions on one or more surfaces of each layer. In conventional systems, it can be advantageous to have an interconnect that passes through some layers but not all layers of the board in printed circuit board designs employing more than 2 layers. Blind vias penetrate a surface on only one side of the PCB, while buried vias connect internal layers without penetrating either surface of the PCB. The use of blind and buried vias can allow higher density packing of circuits onto a PCB. However, the use of blind and buried vias requires additional process steps in PCB production, that can increase cost and time of manufacturing substantially. According to certain aspects disclosed herein, blind and buried vias can be implemented using standard low-cost PCB manufacturing techniques using through holes/vias without increased time and/or cost associated with PCB manufacture and assembly. In some instances, multiple standard-technology, low-cost PCBs may be joined to form a laminate using an adhesive or other mechanical means to bond boards together to form a single larger multilayer board. Interconnections can be made by pressing in pins or soldering a bus connection between the boards.

[0102] Certain aspects of this disclosure apply to systems that provide a distributed charging surface that may be implemented using two or more modular charging devices to provide physically distributed charging surface portions that can be operated as a single modular charging surface. From an electrical circuit perspective, the components of the distributed charging surface may be electrically coupled or interconnected in the same manner as that the components of a single charging surface implemented using multiple modular charging devices. From a data communication perspective, the components of the distributed charging surface may be logically coupled or interconnected in the same manner as that the components of a single charging surface implemented using multiple modular charging devices. The physical and electrical characteristics of interconnects may differ between a distributed charging surface and a single charging surface implemented using multiple modular charging devices based on length and impedance of interconnects and other physical characteristics of the interconnects. For the purposes of this description the communication and power distribution architectures may be considered to be identical for a distributed charging surface and for a single charging surface implemented using multiple modular charging devices.

[0103] In one example, a primary or main controller may be provided to manage and control charging and/or device discovery procedures in a wireless charging system that includes multiple modular charging devices. In some examples, a controller provided in one of the modular charging devices may be configured to serve as the main controller. In some examples, the main controller may be attached to an edge of a charging surface or provided separately from the modular charging devices. In the latter examples, the separated main controller may enable thin charging surfaces to be attached to or embed in an object of furniture or a surface in a vehicle.

[0104] The modular charging devices may include control circuits that can be used to monitor, configure and manage charging operations through the respective charging surfaces provided by the modular charging devices. In some instances, the control circuits may include processing devices or switches that enable the control circuits in a first modular charging device to manage and control charging and/or device discovery in a second modular charging device, including where the second modular charging device is spaced apart or otherwise physically separated from the first modular charging device. The control circuits may control flow of charging currents through access to a power source or by directing the charging current to independent groupings of coils provided on multiple PCBs in interconnected charging devices. The control circuits may be configured to define physically independent charging zones that can be managed and operated as a single system. In one example, the independent charging zones may be provided on a tabletop, shelf, appliance, or other suitable carrier. In another example, the independent charging zones may be deployed in multiple locations within a confined space, such as within a cabin of a car or other vehicle or form of transportation.

[0105] A modular or physically-distributed charging surface may be configured to optimize concurrent wireless charging of devices that have a variety of sizes and shapes or that have different sized receiving coils. Concurrent wireless charging of devices may be optimized when a maximum number of devices can be charged simultaneously without compromising speed of charging devices associated with high power consumption. In one example, a wireless charging system may be expected to charge a tablet computer and multiple smaller devices such as a smartwatch or mobile telephone. Optimal charging of the tablet computer may necessitate the use of a large transmitting coil, while smaller transmitting coils may facilitate stacking of physically smaller devices or devices associated with low power consumption by providing a larger number of charging cells within an area of the charging surface.

[0106] In one aspect of the disclosure, a mixture of modular or physically-distributed charging surfaces can be connected or coupled to provide different charging zones with different charging cell sizes. In another aspect of the disclosure, certain modular or physically-distributed charging surfaces can include different charging zones with different charging cell sizes. In another aspect of the disclosure, a standalone charging surface can include different charging zones with different charging cell sizes.

[0107] FIG. **17** illustrates an example of a modular or physically distributed charging surface **1700** that includes two charging zones **1702**, **1704** that have charging cells of different sizes. The first charging zone **1702** includes larger charging cells that may be suited for high-power wireless transfers. In one example, multi-coil transmitting cells in the first charging zone **1702** may be configured to transfer power up to 30 W. The second charging zone **1704** includes smaller charging cells that may be suited for lower-power wireless transfers. In one example, transmitting cells in the second charging zone **1704** may be configured to wirelessly transfer power at 5-10 W.

[0108] FIG. **18** illustrates an example of a charging system **1800** that includes multiple charging devices **1802**, **1804**, **1806** provided in accordance with certain aspects of this disclosure. In one example, the charging devices **1802**, **1804**, **1806** may be physically joined or interconnected to provide a single scalable, modular charging surface such as the modular charging surfaces illustrated in FIGS. **14-16**. In some examples, one or more of the charging devices **1802**, **1804**, **1806** may be remotely located from at least one other charging device **1802**, **1804**, **1806** to provide a distributed charging surface. The charging system **1800** may include one or more controllers that can communicate with the charging devices **1802**, **1804**, **1806**. In one example, a primary controller may communicate control messages to a secondary controller over a data communication link. In some examples, a primary controller may provide control signals that are used to control charging or detection operations at the charging devices **1802**, **1804**, **1806**. In some examples, the primary controller may control power flow in the charging devices **1802**, **1804**, **1806**. In some examples, the primary controller may provide charging currents to one or more groups of charging coils on the charging devices **1802**, **1804**, **1806**.

[0109] Each charging device **1802**, **1804**, **1806** may include one or more charging cells that encompass one or more power transfer areas. Each power transfer area is substantially planar and centered around an axis that is substantially perpendicular to its a charging surface of its associated charging device **1802**, **1804**, **1806**. In some examples, each of the charging devices **1802**, **1804**, **1806** can operate as a standalone wireless charger that includes controllers and power management circuits. The standalone wireless charger may be configured to detect chargeable devices, generate charging configurations and provide a charging current to one or more charging cells identified by the charging configurations.

[0110] In some examples, certain charging devices **1804**, **1806** operate as secondary devices that have limited capability. In one example, the limited-capability charging devices **1804**, **1806** receive charging currents through dedicated connectors and the charging currents are directed to one or more charging cells through fixed electrical paths or through a switch that may be controlled by a primary charging device **1804** or other centralized or distributed controller. In another example, the limited-capability charging devices **1804**, **1806** may have a controller capable of selecting charging cells to receive a charging current and to provide the charging current to the selected charging cells. In the latter example, some limited-capability charging devices **1804**, **1806** may be configured to exchange messages with one or more other charging devices **1802**, **1804**, **1806** in the system, or exchange messages with a chargeable device. In some instances, the limited-capability charging devices **1804**, **1806** may be capable of conducting searches for chargeable devices or may be configured to participate in a search for chargeable devices controlled by a primary charging device **1804** or other centralized or distributed controller.

[0111] The charging system **1800** is constructed from interconnected charging devices **1802**, **1804**, **1806**. The charging devices **1802**, **1804**, **1806** may have a same or different size or shape. The charging devices **1802**, **1804**, **1806** may have a same or different number or configuration of power transmitting coils. In the illustrated example, the charging devices **1802**, **1804**, **1806** have similar size, shape and transmitting coil configuration, although the charging devices **1802**, **1804**, **1806** have a same or different configuration in other implementations. The charging devices **1802**, **1804**, **1806** may correspond to the charging devices illustrated in FIGS. **13-19** or may provide similar configurations of charging surfaces illustrated in the charging devices of FIGS. **13-19**.

[0112] In certain examples, each of the charging devices **1802**, **1804**, **1806** includes one or more connectors **1812***a*, **1812***b*, **1812***c*, **1814***a* **1814***b*, **1814***c*, **1816***a* **1816***b*, **1816***c*, which may couple the charging devices **1802**, **1804**, **1806** to a multi-drop serial bus **1810** or support a daisy chain connection **1808**, **1818**. In one example, the multi-drop serial bus **1810** is configured as a serial bus that enables the charging devices **1802**, **1804**, **1806** to exchange command and control messages. In one example, the serial bus is operated in accordance with Improved Inter-Integrated Circuit (13C) protocols, Controller Area Network (CAN) bus protocols, Local Interconnected Network (LIN) bus protocols, or the like. In some instances, the charging devices **1802**, **1804**, **1806** may communicate wirelessly. In some implementations, the daisy chain connection **1808**, **1818** is used to distribute charging current among the charging devices **1802**, **1804**, **1806**. The daisy chain connection **1808**, **1818** may also be used for exchanging command and control messages.

[0113] In one example, one or more of the charging devices **1802**, **1804**, **1806** can serve as a primary device and may include a processing circuit configured to manage operation of one or more charging devices **1802**, **1804**, **1806** that is operated as a secondary device. In the illustrated example, two charging devices **1804**, **1806** operate as secondary devices and may include processing circuits configured to communicate over the multi-drop serial bus **1810** in order to receive commands from the primary charging device **1802** and to report feedback information to the primary charging device **1802**. Secondary charging devices **1802**, **1804**, **1806** may include or control a driver circuit that provides a flow of a charging current provided through the daisy chain connection **1808**, **1818**, when the charging current is provided by a current source through the operation of the primary charging device **1802**.

[0114] The secondary charging devices **1804**, **1806** may cooperate with the primary charging device **1802** to discover, enumerate and configure the combination of charging devices **1802**, **1804**, **1806** provided in the charging system **1800**. In one example, the secondary charging devices **1804**, **1806** participate in a serial bus arbitration process to identify themselves to the primary charging device **1802** and/or to obtain unique addresses. In another example, the secondary charging devices **1804**, **1806** may be preconfigured with at least a secondary address that the primary charging device **1802** can use to address each secondary charging device **1804**, **1806** through the multi-drop serial bus **1810**. The primary charging device **1802** may use the multi-drop serial bus **1810** to configure the secondary charging devices **1804**, **1806**, interrogate the secondary charging devices **1804**, **1806** for capability, charging cell size, number and configuration as well as status information. The primary charging device **1802** may use the multi-drop serial bus **1810** to configure the secondary charging devices **1804**, **1806** for one or more charging operations.

[0115] In some implementations, each of the charging devices **1802**, **1804**, **1806** can be independently connected to a power supply that can be used to provide and configure a charging current. In one example, the charging devices **1802**, **1804**, **1806** may include an inverter or switching power supply configurable to produce an alternating current (AC) that has frequency suitable for wireless charging. In some implementations, each of the charging devices **1802**, **1804**, **1806** may be coupled to a multi-purpose communication bus that is used by other devices or systems (in an automobile for example). In the latter implementations, the primary charging device **1802** may also be a controlling entity on the bus.

[0116] FIG. **19** illustrates a first example of a combined control circuit **1900** in a charging system provided in accordance with certain aspects disclosed herein. Each PCB **1910**$_1$-**1912**$_N$ includes a processing circuit **1912**$_1$-**1912**$_N$ that is configured and controlled by a main controller **1902** to manage operation of its respective PCB **1910**$_1$-**1912**$_N$. In one example, each processing circuit **1912**$_1$-**1912**$_N$ includes a secondary circuit **1914**$_1$-**1914**$_N$ configured to communicate over a serial bus **1906** in order to receive commands and report feedback information to the main controller **1902**. The secondary circuit **1914**$_1$-**1914**$_N$ may control a driver circuit **1916**$_1$-**1916**$_N$ that controls flow of a charging current provided through an interlink **1908** by a current source.

[0117] The secondary circuits **1914**$_1$-**1914**$_N$ may cooperate with the main controller **1902** to discover, enumerate and configure the combination of PCBs **1910**$_{1}$-**1912**$_{N}$ provided in the modular charging surface. In one example, the secondary circuits **1914**$_{1}$-**1914**$_{N}$ participate in an arbitration process to identify themselves to the main controller **1902** and/or to obtain unique addresses. In another example, the secondary circuits **1914**$_{1}$-**1914**$_{N}$ may be preconfigured with at least a secondary address that the main controller **1902** can use to address each secondary circuit **1914**$_{1}$-**1914**$_{N}$ through the serial bus **1906**. The main controller **1902** may use the serial bus **1906** to configure the secondary circuits **1914**$_{1}$-**1914**$_{N}$, interrogate the secondary circuits **1914**$_{1}$-**1914**$_{N}$ for capability and status information, and configure the secondary circuits **1914**$_{1}$-**1914**$_{N}$ for one or more charging operations.

[0118] FIG. **20** illustrates a second example of a combined control circuit **2000** that may be provided in a charging system provided in accordance with certain aspects disclosed herein. Each PCB **2010**$_{1}$-**2012**$_{N}$ includes a processing circuit **2012**$_{1}$-**2012**$_{N}$ that is configured and controlled by a main controller **2002** to manage operation of its respective PCB **2010**$_{1}$-**2012**$_{N}$. In one example, each processing circuit **2012**$_{1}$-**2012**$_{N}$ includes a secondary circuit **2014**$_{1}$-**2014**$_{N}$ configured to communicate over a serial bus **2006** in order to receive commands and report feedback information to the main controller **2002**. The secondary circuit **2014**$_{1}$-**2014**$_{N}$ may control a driver circuit **2016**$_{1}$-**2016**$_{N}$ that controls flow of a charging current provided through an interlink **2008** by a current source.

[0119] The secondary circuits **2014**$_{1}$-**2014**$_{N}$ may cooperate with the main controller **2002** to discover, enumerate and configure the combination of PCBs **2010**$_{1}$-**2012**$_{N}$ provided in the modular charging surface. In the illustrated example, the secondary circuits **2014**$_{1}$-**2014**$_{N}$ are connected in a daisy chain fashion, whereby the main controller **2002** connects with and configures a first secondary circuit **2014**$_{1}$, which then couples the second secondary circuit **20142** to the main controller **2002** through the serial bus **2006**. The main controller **2002** configures the second secondary circuit **20142** and the process continues until the last secondary circuit **2014***w* has been configured. In another example, the secondary circuits **2014**$_{1}$-**2014**$_{N}$ may be preconfigured with at least a secondary address that the main controller **2002** can use to address each secondary circuit **2014**$_{1}$-**2014**$_{N}$ through the serial bus **2006**.

[0120] FIG. **21** illustrates the use of modular charging devices to provide one or more charging surfaces on an item of furniture in accordance with certain aspects of this disclosure. The item of furniture is selected for clarity and case of illustration. Modular charging devices may be provided in other items including armrests of an armchair, armrests in an automobile, windowsills in a room, consoles in a vehicle, tray tables in an airplane and other examples. A first table **2100** is equipped with a large charging surface **2102** that may be assembled from numerous charging modules that are arranged and configured to provide the large charging surface **2102**. A second table **2120** is equipped with a multiple charging surfaces **2122***a*-**2122***e* that can have different sizes or shapes. Each of the charging surfaces **2122***a*-**2122***e* may be implemented using one or more charging modules constructed in accordance with the examples illustrated in FIGS. **13**-**22**. In some examples, at least one of the charging modules may differ from other charging modules by overall size or shape or by the number, size or configuration of included charging coils.

[0121] FIG. **22** illustrates an example of modular charging devices deployed on a surface **2200** of a table, desk, workbench, bar top, kitchen worksurface, or other item of furniture in accordance with certain aspects of this disclosure. The modular charging devices are deployed to provide multiple charging areas **2202***a*-**2202***f* across the surface **2200** of the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture, including armrests of an armchair, armrests in an automobile, windowsills in a room, consoles in a vehicle, tray tables in an airplane and other examples. Each of the charging areas **2202***a*-**2202***f* may be implemented using one or more charging modules constructed in accordance with the examples illustrated in FIGS. **13**-**22**. In some examples, at least one of the charging modules may differ from other charging modules by overall size or shape or by the number, size or configuration of included charging coils.

[0122] In the illustrated example, each of the charging areas **2202***a*-**2202***f* is circumscribed by an indicator line **2204***a*-**2204***f* that follows the shape of the corresponding charging area **2202***a*-**2202***f*. In this example, visual indicators such as LED lamps or strips of LED lamps are used to illuminate the indicator lines **2204***a*-**2204***f*. The LED lamps may be configured to emit colored light that is visible to a user during placement and/or charging of a device through the charging surface. In some examples, light from the LED lamps is carried through light pipes, light guides and/or light diffusers to an upper surface of the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture. In some implementations, the light pipes, light guides or light diffusers may be used alone or in combination to provide the visible indicator line **2204***a*-**2204***f* on the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture. In these latter implementations, the visible indicator line **2204***a*-**2204***f* may be illuminated when a chargeable device is detected nearby, or may be in an always on state. The visible indicator line **2204***a*-**2204***f* may present a first color to indicate availability of charging circuits and may present a second color to indicate that the charging surface is in use. In some instances, the color of the visible indicator line **2204***a*-**2204***f* may indicate whether charging is in progress or completed, or whether an error has occurred. The error may relate to misalignment of the chargeable device, presence of a foreign object, an overheating condition or the like.

[0123] The visible indicator line **2204***a*-**2204***f* may be illuminated when a chargeable device is detected using capacitive sensing, passive ping, active or digital ping, detection of NFC transmissions, detection of responses to NFC transmissions, wireless identification transmissions using Bluetooth, Wi-Fi based on the IEEE 802.11 standard, Zigbee, WiMax based on the IEEE 802.16 standard, Ultra-Wide Band, wireless USB and other known technologies, or some combination of these transmissions, technologies and detections.

[0124] In some implementations, a controller in a processing circuit of a wireless charging device may implement device detection steps of the power transfer management procedure illustrated in FIG. **16**. The power transfer management procedure uses multiple sensing and/or interrogation techniques and may be initiated periodically to determine whether a chargeable device is located near a charging surface controlled by the processing circuit of the wireless charging device. In some implementations, the procedure may be repeated at a frequency calculated to provide sub-second response to placement of a device on a charging pad.

[0125] In some instances, the controller in the processing circuit of the wireless charging device may perform an initial search using capacitive proximity sensing. Capacitive proximity sensing may be performed to determine whether changes in capacitance measured in one or more power transmitting coils has changed, indicating the presence or potential presence of an object proximate to one of the power transmitting coils.

[0126] In some instances, the controller in the processing circuit of the wireless charging device may employ passive ping sensing to confirm presence of an object near one or more power transmitting coils, and/or to evaluate the nature of the proximately located object. A passive ping may be provided to one or more power transmitting coils and the controller may determine that a potentially chargeable device is proximate to one of the power transmitting coils based on a change in resonance frequency that may be attributable to such potentially chargeable device.

[0127] In some instances, the controller in the processing circuit of the wireless charging device may employ active digital ping sensing. The controller may transmit the active digital ping using a burst of power transmitted through one or more power transmitting coils. A receiving device may respond by modulating the magnetic flux generated by the transmission of power.

[0128] The use of capacitive sensing, passive ping and active ping techniques can be used to detect chargeable devices that are passed close to a charging area **2202***a*-**2202***f* provided in the surface **2200** of a table, desk, workbench, bar top, kitchen worksurface, or other item of furniture. In one aspect of this disclosure, the chargeable device may be waved the across the surface **2200** in order to activate one or more charging areas **2202***a*-**2202***f* that detect presence of the chargeable device. A controller may illuminate the indicator line **2204***a*-**2204***f* of any charging area **2202***a*-**2202***f* near to which the chargeable device has been detected. A charging area **2202***a*-**2202***f* associated with an illuminated indicator line **2204***a*-**2204***f* may be defined as an activated charging area.

[0129] The controller in the processing circuit of the wireless charging device may increase the frequency at which the power transfer management procedure is performed (scc FIG. **16** for example) and for a period of time calculated to permit a user to place the chargeable device within the boundary of one of the illuminated indicator lines **2204***a*-**2204***f*. The controller in the processing circuit of the wireless charging device may generate a charging configuration for the chargeable device and begin transmitting a charging electromagnetic flux. The LED lamps in an indicator line **2204***a*-**2204***f* may be configured to emit different colored lights during detection of an approaching chargeable device or placement and/or charging of the device. The colored lights in the indicator line **2204***a*-**2204***f* may be visible to a user through the charging surface and may indicate a physical location of a charging area **2202***a*-**2202***f*, and/or may indicate whether the chargeable device has been detected, is optimally placed, is being charged or is fully charged.

[0130] According to certain aspects of this disclosure, other wireless technologies may be used to detect presence or proximity of a chargeable device, including when the chargeable device is being waved over the surface **2200** of a table, desk, workbench, bar top, kitchen worksurface, or other item of furniture. The approach of a chargeable device toward a charging area **2202***a*-**2202***f* or movement across or near a chargeable device may generate small changes in capacitance or resonant frequency of resonant circuits and/or transmitting coils. These small changes in capacitance or resonant frequency may be ignored in conventional systems that are configured to detect chargeable devices and other objects that are placed proximate to a charging area **2202***a*-**2202***f* and directly on the surface **2200** of a table, desk, workbench, bar top, kitchen worksurface, or other item of furniture. For example, a conventional system may be configured to respond to changes in capacitance or resonant frequency that exceed a threshold level. In some instances, the small changes in capacitance or resonant frequency resulting from a chargeable device that is being waved over the surface **2200** may resemble variations due to changes in temperature, voltage or changes induced by noise.

[0131] According to certain aspects of this disclosure, a waved chargeable device can be detected based on small changes or perturbations in capacitance or resonant frequency involving multiple power transmitting coils, when a geometric pattern of changes can be discerned. In one example, small changes or perturbations in capacitance or resonant frequency may be detected in a set of power transmitting coils that are centered along a line, along an arc of an ellipse, or along an arc of a curve. In some instances, a controller in the processing circuit of the wireless charging device may be able to time stamp each of a sequence of small changes or perturbations in capacitance or resonant frequency affecting the set of power transmitting coils. The time stamp may reveal an order in which the small changes or perturbations occurred.

[0132] In one aspect, the controller in the processing circuit of the wireless charging device may be configured to correlate a sequence of small changes or perturbations in capacitance or resonant frequency with an event involving a chargeable device being moved above the surface **2200** in a wiping motion. The wiping motion may cause the chargeable device to pass over or affect one or more power transmitting coils in at least one charging area **2202***a*-**2202***f*. The detection of a correlated sequence of small changes or perturbations may trigger the illumination of any of the indicator lines **2204***a*-**2204***f* associated with a charging area **2202***a*-**2202***f* that includes transmitting coils affected by the wiping motion.

[0133] In some implementations, the surface **2200** of the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture may be equipped with one or more wireless transmitters and receivers that can be used to detect doppler shifts in reflected signals transmitted by one of the wireless transmitters. In one example, the controller in the processing circuit of the wireless charging device may be coupled to a receiver may be configured to detect doppler shift in an acoustic ultrasound signal, a microwave signal or an infrared signal that indicates approach of an object toward a charging area **2202***a*-**2202***f* embedded in or attached to the surface **2200**. The timing and strength of the reflected signal and the frequency or phase of a signal representative of the doppler shift may indicate proximity, direction and other information related to the positioning of the object with respect to one or more of the charging areas **2202***a*-**2202***f*. In some instances, information received from multiple wireless receivers may be used to triangulate the position of an object. In some examples, each of the wireless receivers is tuned to a single frequency or wireless transmitter. In some examples, triangulation can be accomplished using signals received by wireless receivers that are reflections of a signal transmitted by a single wireless transmitter. In these latter examples, information received from the wireless receivers may relate to reflected signals corresponding to a time-sequence of signals transmitted by multiple wireless transmitters.

[0134] In some implementations, the surface **2200** of the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture may be equipped with one or more wireless transmitters and/or wireless receivers that can be used to detect transmissions involving an object located near a charging area **2202***a*-**2202***f* that has been embedded or attached to the surface **2200**. In one example, short range NFC transmissions by a chargeable device may be detected. In another example, responses to NFC interrogating signals by a chargeable device may be detected. NFC typically has a range of 4 centimeters or less, and can indicate proximity to a specific charging area **2202***a*-**2202***f* embedded in or attached to the surface **2200**. In some instances, the detection of an NFC transmission is sufficient to cause a controller to activate a charging area **2202***a*-**2202***f* near the receiver that detects the NFC transmission without a need to decode the content of the NFC transmission. In some instances, a processing circuit may be configured to activate or refrain from activating a charging area **2202***a*-**2202***f* near the receiver that detects the NFC transmission based on an identity of a specific device or types of devices that is determined based on the content of a detected NFC transmission or sequence of NFC transmissions.

[0135] In some implementations, the surface **2200** of the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture may be equipped with one or more wireless transmitters and/or wireless receivers that can be used to communicate with chargeable devices or detect transmissions involving an object located near a charging area **2202***a*-**2202***f* that has been embedded or attached to the surface **2200**. In some implementations, a processing circuit of the wireless charging device may be coupled to one or more wireless communication receivers and may be configured to determine identity of a device or a type of device that is communicating using NFC, Bluetooth, Wi-Fi, Zigbee, WiMax, Ultra-Wide Band, wireless USB, or other protocols. Certain types of wireless communication have ranges of 100 meters or more and decoding or detection of identifying information in a wireless transmission may not indicate that a device is sufficiently close to a charging area **2202***a*-**2202***f* to be a candidate for charging. In some instances, the processing circuit of the wireless charging device may be configured to determine strength of transmission or to triangulate the source of a transmission based on received wireless signals.

[0136] FIGS. **23**-**25** relate to apparatus, structures, systems, techniques and methods for embedding a charging device within a cavity, hollow or pocket formed within the body of a table, desk, workbench, bar top, kitchen worksurface, or other item of furniture in accordance with certain aspects of this disclosure. In certain embodiments, a mounting bracket installed within the hollow or pocket may be configured and/or structured to strengthen and/or stiffen the table, desk, workbench, bar top, kitchen worksurface, or other item of furniture around the location of the hollow or pocket. The creation of the hollow or pocket can be expected to weaken the structure in which the charging device is to be installed.

[0137] FIG. **23** illustrates an example of a countertop **2300** in which a cavity, hollow or pocket **2304** is provided near an upper surface **2302** of the countertop **2300**. In the illustrated example, the cavity, hollow or pocket **2304** has a depth **2324** that is a significant proportion of the height **2322** of the countertop **2300**. The depth **2324** of the cavity, hollow or pocket **2304** may be selected, calculated and/or configured to position power transmitting coils of an embedded charging device close as possible to the upper surface **2302** of the countertop **2300**. The distance between the power transmitting coils and a receiving coil in a chargeable device placed on the surface can limit the rate at which power can be transferred between the charging device and the chargeable device due to imperfect coupling between the power transmitting coils and the receiving coil.

[0138] The depth **2324** of the cavity, hollow or pocket **2304** can significantly reduce the ability of the countertop **2300** to withstand forces applied in the vicinity of the cavity, hollow or pocket **2304**. In one example, a compressive force **2320** acting on the upper surface **2302** of the countertop **2300** is met by counteracting forces **2330**, **2332** attributable to the structure on which the countertop **2300** is mounted. In one example the countertop **2300** is mounted on a closed cabinet. In a countertop that has no pocket or hollow section, the counteracting force may be applied evenly across a portion of the lower surface of the countertop **2300**. In the illustrated example, the counteracting forces **2330**, **2332** applied at the edges of the cavity, hollow or pocket **2304** resist a compressive force **2320** applied to the upper surface **2302** of the countertop **2300** at a point or area located above the center of the cavity, hollow or pocket **2304**. The compressive force **2320** is resisted by a suspended section **2306** of the countertop **2300** that is located over the cavity, hollow or pocket **2304**. In some examples, the countertop **2300** is constructed from a material that has sufficient elasticity to cause the suspended section **2306** of the countertop **2300** to bow. In some examples, the countertop **2300** is constructed from an inelastic material that substantially maintains its shape until a maximum shear force is reached where the structure of the countertop **2300** fails. The maximum force that the countertop **2300** can withstand decreases with the thickness of the suspended section **2306** of the countertop **2300**.

[0139] The need to limit distance between the power transmitting coils of a charging device and a receiving coil in a chargeable device conflicts with the preference to maintain the thickness of the suspended section **2306** of the countertop **2300**. Certain aspects of this disclosure relate to a structural brace that can be used to strengthen the countertop **2300** in the vicinity of the cavity, hollow or pocket **2304**. In certain implementations, the structural brace can be included in a mounting bracket used to locate and hold a charging device within the cavity, hollow or pocket **2304**.

[0140] FIG. **24** illustrates an example of a structural brace **2400** that may be configured in accordance with certain aspects of this disclosure. With continued reference to FIG. **23**, the structural brace **2400** can be fixed within the cavity, hollow or pocket **2304** formed in the countertop **2300**. The illustrated structural brace **2400** is rectangular in shape and comprises a rim **2402** and flanges **2404***a*, **2404***b*, **2404***c* and **2404***d*. Each flange **2404***a*-**2404***d* is joined to one side of the rim **2402** and extends perpendicularly from a line along the side of the rim **2402** to which the flange **2404**_a_-**2404**_d_ is joined.

[0141] In some implementations, the flanges **2404**_a_-**2404**_d_ are formed as an integral part of the structural brace **2400**. In one example, the structural brace **2400** may be manufactured from a single sheet of metal, whereby the structural brace **2400** is formed by stamping or cutting and the flanges **2404**_a_-**2404**_d_ are bent to obtain a perpendicular or other desired orientation with respect to the rim **2402**. In some implementations, the flanges **2404**_a_-**2404**_d_ are manufactured separately from the rim **2402** and subsequently welded, bonded or otherwise fastened to the rim **2402**.

[0142] In the illustrated example, the flanges **2404**_a_-**2404**_d_ are straight and extend perpendicularly from the rim **2402**. In some examples, the orientation of the flanges **2404**_a_-**2404**_d_ may be offset from the perpendicular. In some examples, the flanges **2404**_a_-**2404**_d_ may be curved.

[0143] In some implementations, the flanges **2404**_a_-**2404**_d_ are not interconnected. In some examples, the flanges **2404**_a_-**2404**_d_ may be joined by interconnecting elements. In some examples, the flanges **2404**_a_-**2404**_d_ may be joined at their vertical edges.

[0144] In some implementations, the flanges **2404**_a_-**2404**_d_ are dimensioned to provide a tight or precise fit within the cavity, hollow or pocket **2304**. A tight or precise fit may be provided when the flanges **2404**_a_-**2404**_d_ align with the outer edges of the cavity, hollow or pocket **2304** and are dimensioned such that portions of the structural brace **2400** are compressed during insertion exert pressure on the walls of the cavity, hollow or pocket **2304** sufficient to hold the structural brace **2400** in place after insertion. In some implementations, the flanges **2404**_a_-**2404**_d_ are dimensioned to provide a close fit whereby any gaps between the flanges **2404**_a_-**2404**_d_ and the walls of the cavity, hollow or pocket **2304** are filled by glue or bonding compounds used to fix the structural brace **2400** in place.

[0145] The thickness of the rim **2402** and thickness of the flanges **2404**_a_-**2404**_d_ may be selected to provide a desired tensile or compressive strength. The thickness of the rim **2402** and thickness of the flanges **2404**_a_-**2404**_d_ may be selected to provide a desired stiffness, which may be defined as the ability of the structural brace **2400** to resist deformation in response to the compressive force **2320**.

[0146] The cross-sectional shape of the illustrated structural brace **2400** is configured to enable each flange **2404**_a_-**2404**_d_ in combination with a portion of the rim **2402** can resist deformation along multiple axes. The flanges **2404**_a_-**2404**_d_ may be configured to prevent deformation of the rim **2402** in the presence of the compressive force **2320**.

[0147] FIG. **25** illustrates an example of a mounting bracket **2500** that may be configured in accordance with certain aspects of this disclosure. The mounting bracket **2500** incorporates many of the concepts and features of the structural brace **2400** illustrated in FIG. **24** and is shown as mounted and/or fixed within the cavity, hollow or pocket **2304** formed in the countertop **2300** illustrated in FIG. **23**. The illustrated mounting bracket **2500** is generally rectangular in shape and has rounded corners. The mounting bracket **2500** comprises a rim **2502** and flanges **2504**_a_, **2504**_b_, **2504**_c_ and **2504**_d_. Each flange **2504**_a_-**2504**_d_ is joined to one side of the rim **2502** and extends perpendicularly from a line along the side of the rim **2502** to which the flange **2504**_a_-**2504**_d_ is joined. In some implementations, the flanges **2504**_a_-**2504**_d_ are formed as an integral part of the mounting bracket **2500**. In one example, the mounting bracket **2500** may be manufactured from a single sheet of metal, whereby the mounting bracket **2500** is formed by stamping or cutting and the flanges **2504**_a_-**2504**_d_ are bent to obtain a perpendicular or other desired orientation with respect to the rim **2502**. In some implementations, the flanges **2504**_a_-**2504**_d_ are manufactured separately from the rim **2502** and subsequently welded, bonded or otherwise fastened to the rim **2502**.

[0148] In the illustrated example, the flanges **2504**_a_-**2504**_d_ are straight and extend perpendicularly from the rim **2502**. In some examples, the orientation of the flanges **2504**_a_-**2504**_d_ may be offset from the perpendicular. In some examples, the flanges **2504**_a_-**2504**_d_ may be curved.

[0149] In some implementations, the flanges **2504**_a_-**2504**_d_ are not interconnected. In some examples, the flanges **2504**_a_-**2504**_d_ may be joined by interconnecting elements. In some examples, the flanges **2504**_a_-**2504**_d_ may be joined at their vertical edges.

[0150] In some implementations, the flanges **2504**_a_-**2504**_d_ are not interconnected. In some examples, the flanges **2504**_a_-**2504**_d_ may be joined by interconnecting elements. In some examples, the flanges **2504**_a_-**2504**_d_ may be joined at their vertical edges.

[0151] In some implementations, the flanges **2504**_a_-**2504**_d_ are dimensioned to provide a tight or precise fit within the cavity, hollow or pocket **2304**. A tight or precise fit may be provided when the flanges **2504**_a_-**2504**_d_ align with the outer edges of the cavity, hollow or pocket **2304** and are dimensioned such that portions of the mounting bracket **2500** are compressed during insertion exert pressure on the walls of the cavity, hollow or pocket **2304** sufficient to hold the mounting bracket **2500** in place after insertion. In some implementations, the flanges **2504**_a_-**2504**_d_ are dimensioned to provide a close fit whereby any gaps between the flanges **2504**_a_-**2504**_d_ and the walls of the cavity, hollow or pocket **2304** are filled by glue or bonding compounds used to fix the mounting bracket **2500** in place.

[0152] The thickness of the rim **2502** and thickness of the flanges **2504**_a_-**2504**_d_ may be selected to provide a desired tensile or compressive strength. The thickness of the rim **2502** and thickness of the flanges **2504**_a_-**2504**_d_ may be selected to provide a desired stiffness, which may be defined as the ability of the mounting bracket **2500** to resist deformation in response to the compressive force **2320**.

[0153] The mounting bracket **2500** includes a number of fasteners **2506**_a_-**2506**_j_ configured to align with openings in a cover plate **2514**, which is shown in the cross-sectional view **2510**. In a fully assembled system, the cover plate may be attached to the bottom of a muti-coil charging device that is located within the cavity, hollow or pocket **2304** of the countertop **2300** when the cover plate **2514** is mated with the mounting bracket **2500**. Certain aspects of the cover plate **2514** and mounting bracket **2500** are illustrated in the three-dimensional view **2520**. The cover plate **2514** may be alternatively or additionally fastened to the mounting bracket **2500**. In the illustrated example, the fasteners **2506**_a_-**2506**_j_ are formed as hook-like structures that are configured to engage with corresponding holes in the cover plate **2514**. Any suitable fastener may be used to secure the coupling of the cover plate **2514** and mounting bracket **2500**.

[0154] In certain implementations, a surface of the cover plate **2514** has a ribbed profile. In one aspect peaks of the ribs contact the lower surface of the countertop **2300** (see FIG. **23**) within the cavity, hollow or pocket **2304**, and can provide structural reinforcement to the stone or material of the countertop **2300**. A ribbed cover plate **2514** can provide additional resistance to a compressive force **2320** exerted on the countertop **2300**. In another aspect, the ribbing may be configured to conduct an airflow across the cover plate **2514**. The airflow may be provided by a fan, vent, blower or other active cooling component. In one example, ribs may be provided in a substantially parallel orientation across the cover plate **2514**. In another example, ribs may be curved across the cover plate **2514**. In another example, ribs may be configured to provide a tortuous path across the surface of the cover plate **2514**, where the tortuous path can optimize heat transfer through the cover plate **2514**. Optimized heat transfer may be obtained by ensuring that airflows across known or expected hotspots on the cover plate **2514**.

[0155] In one example, a mounting bracket has a rim, at least one flange and one or more fasteners. The rim may be configured to encompass a cavity formed in a countertop. The at least one flange may have a first edge joined to an inner edge of the rim. The at least one flange may have a second configured to extend into the cavity. The one or more fasteners may be formed on the rim. The one or more fasteners may be configured to engage with corresponding features of a cover plate. The mounting bracket may be configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop.

[0156] In some implementations, the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the mounting bracket. In some implementations, a plurality of ribs is provided on a surface of the cover plate. Peaks of the plurality of ribs may be configured to contact a lower surface of the countertop within the cavity when the mounting bracket is fastened to the countertop and the cover plate is engaged with the one or more fasteners. The mounting bracket may be configured to receive an airflow and to conduct the airflow across the cover plate and/or a surface of the countertop. The source of the airflow may be fluidically coupled to the cover plate. For example, the airflow may follow a path defined by channels formed between the plurality of ribs. The source of an airflow may be a fan. The source of an airflow may be vent. The source of an airflow may be a blower. The source of an airflow may be an active cooling device.

[0157] FIG. **26** is flowchart **2600** illustrating one example of a method for mounting a charging device to a countertop. At block **2602**, a rim is installed on a lower surface of the countertop. The rim may be configured to encompass a cavity formed in the countertop. At least one flange of the rim may have a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavity. At block **2604**, a cover plate is coupled to the rim. One or more fasteners formed on the rim may be configured to engage with corresponding features of the cover plate. The mounting bracket can be configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop. In one example, the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the mounting bracket.

[0158] In certain implementations, a plurality of ribs may be provided on a surface of the cover plate. Peaks of the plurality of ribs may be configured to contact a lower surface of the countertop within the cavity when the mounting bracket is fastened to the countertop and the cover plate is engaged with the one or more fasteners. A source of airflow may be fluidically coupled to the cover plate. The airflow may follow a path defined by channels formed between the plurality of ribs. In one example, the source of the airflow comprises a fan. In one example, the source of the airflow comprises a vent. In one example, the source of the airflow comprises a blower. In one example, the source of the airflow comprises an active cooling device.

[0159] A mounting bracket provided in accordance with certain aspects of this disclosure has a rim configured to encompass a cavity formed in a countertop. At least one flange of the rim has a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavity. One or more fasteners formed on the rim may be configured to engage with corresponding features of a cover plate. The mounting bracket can be configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop. In one example, the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the mounting bracket.

[0160] In certain implementations, a plurality of ribs is provided on a surface of the cover plate. Certain peaks of the plurality of ribs may be configured to contact a lower surface of the countertop within the cavity when the mounting bracket is fastened to the countertop and the cover plate is engaged with the one or more fasteners. A source of an airflow may be fluidically coupled to the cover plate. The airflow may follow a path defined by channels formed between the plurality of ribs. In one example, the source of the airflow comprises a fan. In one example, the source of the airflow comprises a vent. In one example, the source of the airflow comprises a blower. In one example, the source of the airflow comprises an active cooling device

Example of a Processing Circuit

[0161] FIG. **27** is a diagram illustrating an example of a hardware implementation for an apparatus **2700** that may be incorporated in a charging device or in a receiving device that enables a battery to be wirelessly charged. In some examples, the apparatus **2700** may perform one or more functions disclosed herein. In accordance with various aspects of the disclosure, an element, or any portion of an element, or any combination of elements as disclosed herein may be implemented using a processing circuit **2702**. The processing circuit **2702** may include one or more processors **2704** that are controlled by some combination of hardware and software modules. Examples of processors **2704** include microprocessors, microcontrollers, digital signal processors (DSPs), SoCs, ASICs, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, sequencers, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. The one or more processors **2704** may include specialized processors that perform specific functions, and that may be configured, augmented or controlled by one of the software modules **2716**. The one or more processors **2704** may be configured through a combination of software modules **2716** loaded during initialization, and further configured by loading or unloading one or more software modules **2716** during operation.

[0162] In the illustrated example, the processing circuit **2702** may be implemented with a bus architecture, represented generally by the bus **2710**. The bus **2710** may include any number of interconnecting buses and bridges depending on the specific application of the processing circuit **2702** and the overall design constraints. The bus **2710** links together various circuits including the one or more processors **2704**, and storage **2706**. Storage **2706** may include memory devices and mass storage devices, and may be referred to herein as computer-readable media and/or processor-readable media. The storage **2706** may include transitory storage media and/or non-transitory storage media.

[0163] The bus **2710** may also link various other circuits such as timing sources, timers, peripherals, voltage regulators, and power management circuits. A bus interface **2708** may provide an interface between the bus **2710** and one or more transceivers **2712**. In one example, a transceiver **2712** may be provided to enable the apparatus **2700** to communicate with a charging or receiving device in accordance with a standards-defined protocol. Depending upon the nature of the apparatus **2700**, a user interface **2718** (e.g., keypad, display, speaker, microphone, joystick) may also be provided, and may be communicatively coupled to the bus **2710** directly or through the bus interface **2708**.

[0164] A processor **2704** may be responsible for managing the bus **2710** and for general processing that may include the execution of software stored in a computer-readable medium that may include the storage **2706**. In this respect, the processing circuit **2702**, including the processor **2704**, may be used to implement any of the methods, functions and techniques disclosed herein. The storage **2706** may be used for storing data that is manipulated by the processor **2704** when executing software, and the software may be configured to implement any one of the methods disclosed herein.

[0165] One or more processors **2704** in the processing circuit **2702** may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, algorithms, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software may reside in computer-readable form in the storage **2706** or in an external computer-readable medium. The external computer-readable medium and/or storage **2706** may include a non-transitory computer-readable medium. A non-transitory computer-readable medium includes, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., a compact disc (CD) or a digital versatile disc (DVD)), a smart card, a flash memory device (e.g., a "flash drive," a card, a stick, or a key drive), RAM, ROM, a programmable read-only memory (PROM), an erasable PROM (EPROM) including EEPROM, a register, a removable disk, and any other suitable medium for storing software and/or instructions that may be accessed and read by a computer. The computer-readable medium and/or storage **2706** may also include, by way of example, a carrier wave, a transmission line, and any other suitable medium for transmitting software and/or instructions that may be accessed and read by a computer. Computer-readable medium and/or the storage **2706** may reside in the processing circuit **2702**, in the processor **2704**, external to the processing circuit **2702**, or be distributed across multiple entities including the processing circuit **2702**. The computer-readable medium and/or storage **2706** may be embodied in a computer program product. By way of example, a computer program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0166] The storage **2706** may maintain software maintained and/or organized in loadable code segments, modules, applications, programs, etc., which may be referred to herein as software modules **2716**. Each of the software modules **2716** may include instructions and data that, when installed or loaded on the processing circuit **2702** and executed by the one or more processors **2704**, contribute to a run-time image **2714** that controls the operation of the one or more processors **2704**. When executed, certain instructions may cause the processing circuit **2702** to perform functions in accordance with certain methods, algorithms and processes described herein.

[0167] Some of the software modules **2716** may be loaded during initialization of the processing circuit **2702**, and these software modules **2716** may configure the processing circuit **2702** to enable performance of the various functions disclosed herein. For example, some software modules **2716** may configure internal devices and/or logic circuits **2724** of the processor **2704**, and may manage access to external devices such as a transceiver **2712**, the bus interface **2708**, the user interface **2718**, timers, mathematical coprocessors, and so on. The software modules **2716** may include a control program and/or an operating system that interacts with interrupt handlers and device drivers, and that controls access to various resources provided by the processing circuit **2702**. The resources may include memory, processing time, access to a transceiver **2712**, the user interface **2718**, and so on.

[0168] One or more processors **2704** of the processing circuit **2702** may be multifunctional, whereby some of the software modules **2716** are loaded and configured to perform different functions or different instances of the same function. The one or more processors **2704** may additionally be adapted to manage background tasks initiated in response to inputs from the user interface **2718**, the transceiver **2712**, and device drivers, for example. To support the performance of multiple functions **2722**, the one or more processors **2704** may be configured to provide a multitasking environment, whereby each of a plurality of functions is implemented as a set of tasks serviced by the one or more processors **2704** as needed or desired. In one example, the multitasking environment may be implemented using a timesharing program **2720** that passes control of a processor **2704** between different tasks, whereby each task returns control of the one or more processors **2704** to the timesharing program **2720** upon completion of any outstanding operations and/or in response to an input such as an interrupt. When a task has control of the one or more processors **2704**, the processing circuit is effectively specialized for the purposes addressed by the function associated with the controlling task. The timesharing program **2720** may include an operating system, a main loop that transfers control on a round-robin basis, a function that allocates control of the one or more processors **2704** in accordance with a prioritization of the functions, and/or an interrupt driven main loop that responds to external events by providing control of the one or more processors **2704** to a handling function.

[0169] In some examples, the apparatus **2700** is included in, or operates as a wireless charging system that has a battery charging power source coupled to a charging circuit, a plurality of charging cells and one or more processors **2704**. The plurality of charging cells may be configured to provide one or more charging surfaces that may be physically separated. At least one coil may be configured to direct an electromagnetic field through a charge transfer area of each charging cell.

[0170] In one example, a charging system associated with a planar surface includes one or more charging areas associated with a wireless charging device, one or more wireless transmitters, one or more wireless receivers configured to receive reflections of a signal transmitted by at least one wireless transmitter, and a controller. The controller may be configured to determine that the reflections are received from an object moving across and displaced from the surface and illuminate one or more indicator lines to identify a physical location of one of the charging areas available to wirelessly charge a chargeable device.

[0171] In one example, the controller is further configured to detect a doppler shift in the reflections with respect to the signal transmitted by the at least one wireless transmitter, and determine presence of the object based on the doppler shift.

[0172] In one example, the controller is further configured to triangulate reflections of signals transmitted by multiple wireless transmitters, and determine presence of the object based on triangulation.

[0173] In one example, the signal transmitted by the at least one wireless transmitter comprises an infrared signal. In another example, the signal transmitted by the at least one wireless transmitter comprises a radio frequency signal. In another example, the signal transmitted by the at least one wireless transmitter comprises a near field communications signal. In another example, the signal transmitted by the at least one wireless transmitter comprises an acoustic signal.

[0174] In certain examples, the changes in the electrical or magnetic characteristic associated with the two or more power transmitting coils occur when the chargeable device is moved across and displaced from the planar surface. The one or more charging areas may be embedded in the planar surface. The one or more charging areas may be located behind the planar surface.

[0175] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. § 112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."

What is claimed is:

1. A mounting bracket, comprising:

a rim configured to encompass a cavity formed in a countertop, wherein at least one flange of the rim has a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavity; and

one or more fasteners formed on the rim and configured to engage with corresponding features of a cover plate,

wherein the mounting bracket is configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop.

2. The mounting bracket of claim **1**, wherein the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the mounting bracket.

3. The mounting bracket of claim **1**, wherein a plurality of ribs is provided on a surface of the cover plate.

4. The mounting bracket of claim **3**, wherein peaks of the plurality of ribs are configured to contact a lower surface of the countertop within the cavity when the mounting bracket is fastened to the countertop and the cover plate is engaged with the one or more fasteners.

5. The mounting bracket of claim **3**, further comprising:

a source of an airflow fluidically coupled to the cover plate, wherein the airflow follows a path defined by channels formed between the plurality of ribs.

6. The mounting bracket of claim **5**, wherein the source of the airflow comprises a fan.

7. The mounting bracket of claim **5**, wherein the source of the airflow comprises a vent.

8. The mounting bracket of claim **5**, wherein the source of the airflow comprises a blower.

9. The mounting bracket of claim **5**, wherein the source of the airflow comprises an active cooling device.

10. A method for mounting a charging device to a countertop, comprising:

installing a rim on a lower surface of the countertop, the rim being configured to encompass a cavity formed in the countertop, wherein at least one flange of the rim has a first edge joined to an inner edge of the rim and a second edge configured to extend into the cavity; and

coupling a cover plate to the rim, wherein one or more fasteners formed on the rim are configured to engage with corresponding features of the cover plate, wherein the rim is configured to strengthen the countertop in the vicinity of the cavity when fastened to the countertop.

11. The method of claim **10**, wherein the cover plate is mounted on a charging device that is located within the cavity when the cover plate is coupled to the rim.

12. The method of claim **10**, wherein a plurality of ribs is provided on a surface of the cover plate.

13. The method of claim **12**, wherein peaks of the plurality of ribs are configured to contact a lower surface of the countertop within the cavity when the rim is fastened to the countertop and the cover plate is engaged with the one or more fasteners.

14. The method of claim **12**, further comprising:
fluidically coupling a source of an airflow to the cover plate, wherein the airflow follows a path defined by channels formed between the plurality of ribs.

15. The method of claim **14**, wherein the source of the airflow comprises a fan.

16. The method of claim **14**, wherein the source of the airflow comprises a vent.

17. The method of claim **14**, wherein the source of the airflow comprises a blower.

18. The method of claim **14**, wherein the source of the airflow comprises an active cooling device.

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