US009800172B1

(12) **United States Patent**
Leabman

(10) **Patent No.: US 9,800,172 B1**
(45) **Date of Patent: Oct. 24, 2017**

(54) **INTEGRATED RECTIFIER AND BOOST CONVERTER FOR BOOSTING VOLTAGE RECEIVED FROM WIRELESS POWER TRANSMISSION WAVES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 406 days.

(21) Appl. No.: **14/584,939**

(22) Filed: **Dec. 29, 2014**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/272,287, filed on May 7, 2014.

(51) **Int. Cl.**
H02M 7/217 (2006.01)
H02J 5/00 (2016.01)

(52) **U.S. Cl.**
CPC ***H02M 7/217*** (2013.01); ***H02J 5/005*** (2013.01)

(58) **Field of Classification Search**
CPC H02M 7/217
See application file for complete search history.

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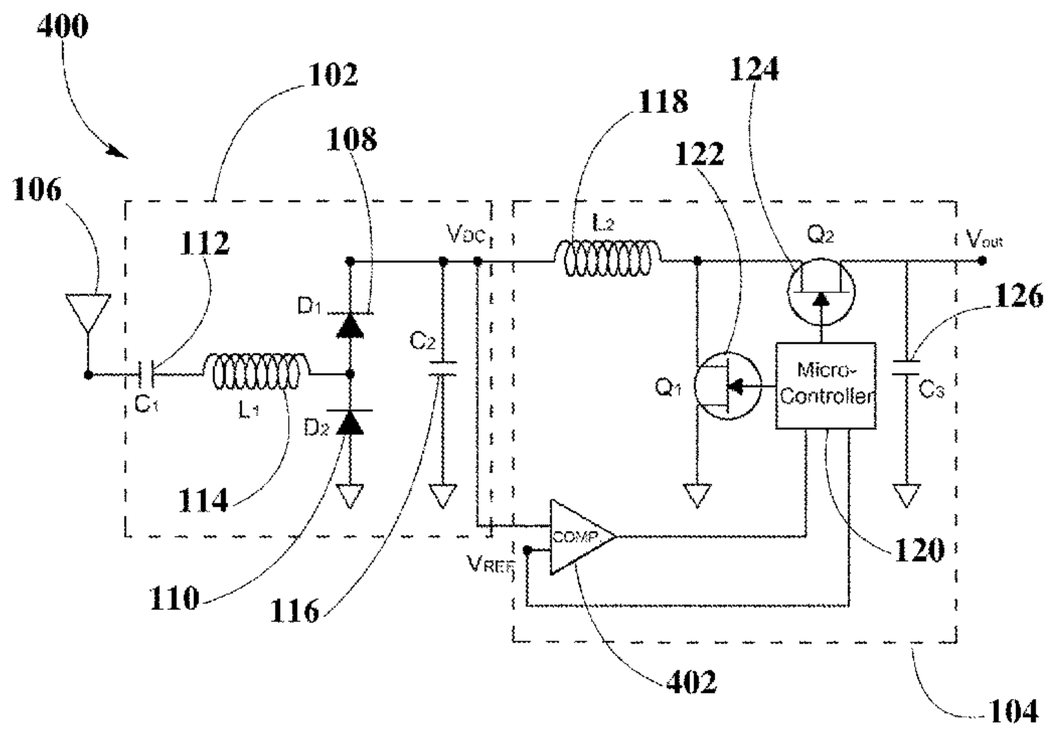
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(57) **ABSTRACT**

A novel integrated rectifier and boost converter circuit architecture is disclosed. The rectifier architecture includes a plurality of identical half-bridge rectifiers connected to receiving antennas to convert wireless AC power into DC power. The integrated rectifier may be coupled in series with a charging inductor in a boost converter. The inductor may discharge upon operation of two micro-controller-driven switching transistors using predetermined threshold and timing scheme to turn on/off. The rectifier architecture may provide high power densities, improve efficiency at larger load currents, and may be enabled in an integrated circuit with eight RF signal inputs, eight half-bridge rectifiers, and eight DC outputs ganged together as single feed into the boost converter. The rectifier circuit topology may include a comparator driven by the boost controller with a proprietary algorithm which suits control for a maximum power point tracking functionality, and an external micro-controller for additional control of the boost converter.

20 Claims, 5 Drawing Sheets



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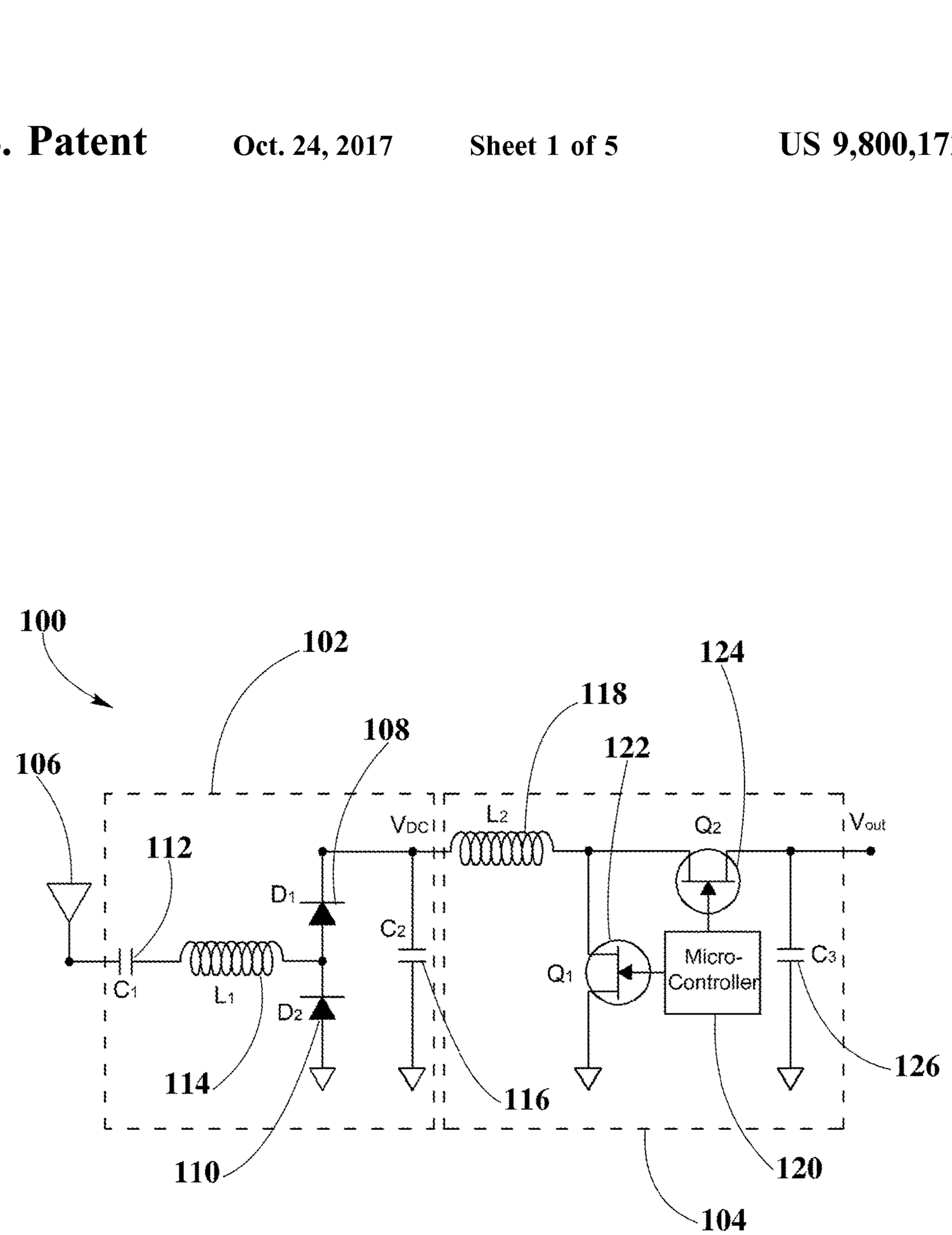

100
102
124
118
108
122
106
112
VDC
L2
Q2
Vout
D1
C2
Micro-
Controller
C3
Q1
C1
L1
D2
114
116
126
110
120
104

FIG. 1

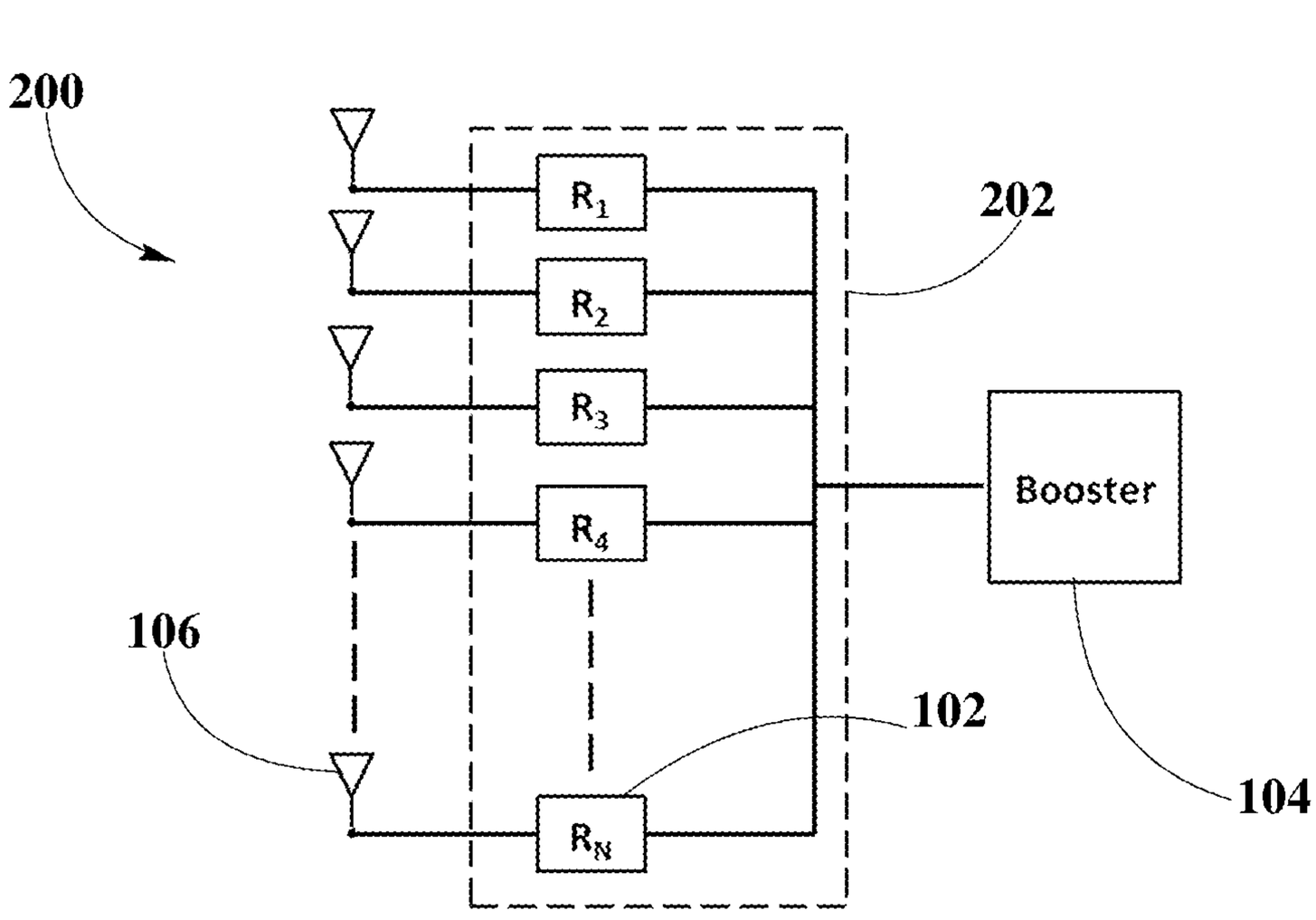


FIG. 2

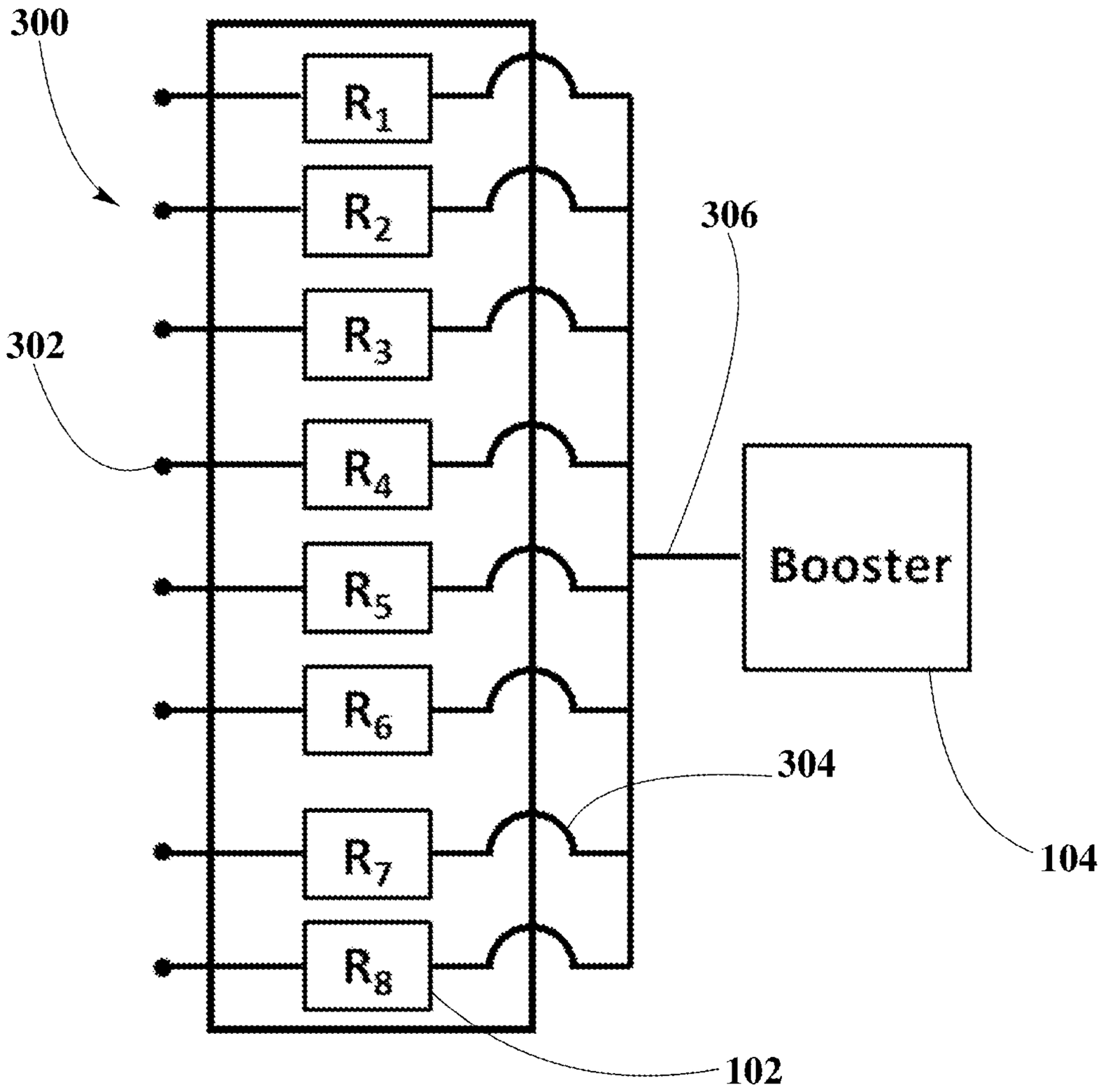


FIG. 3

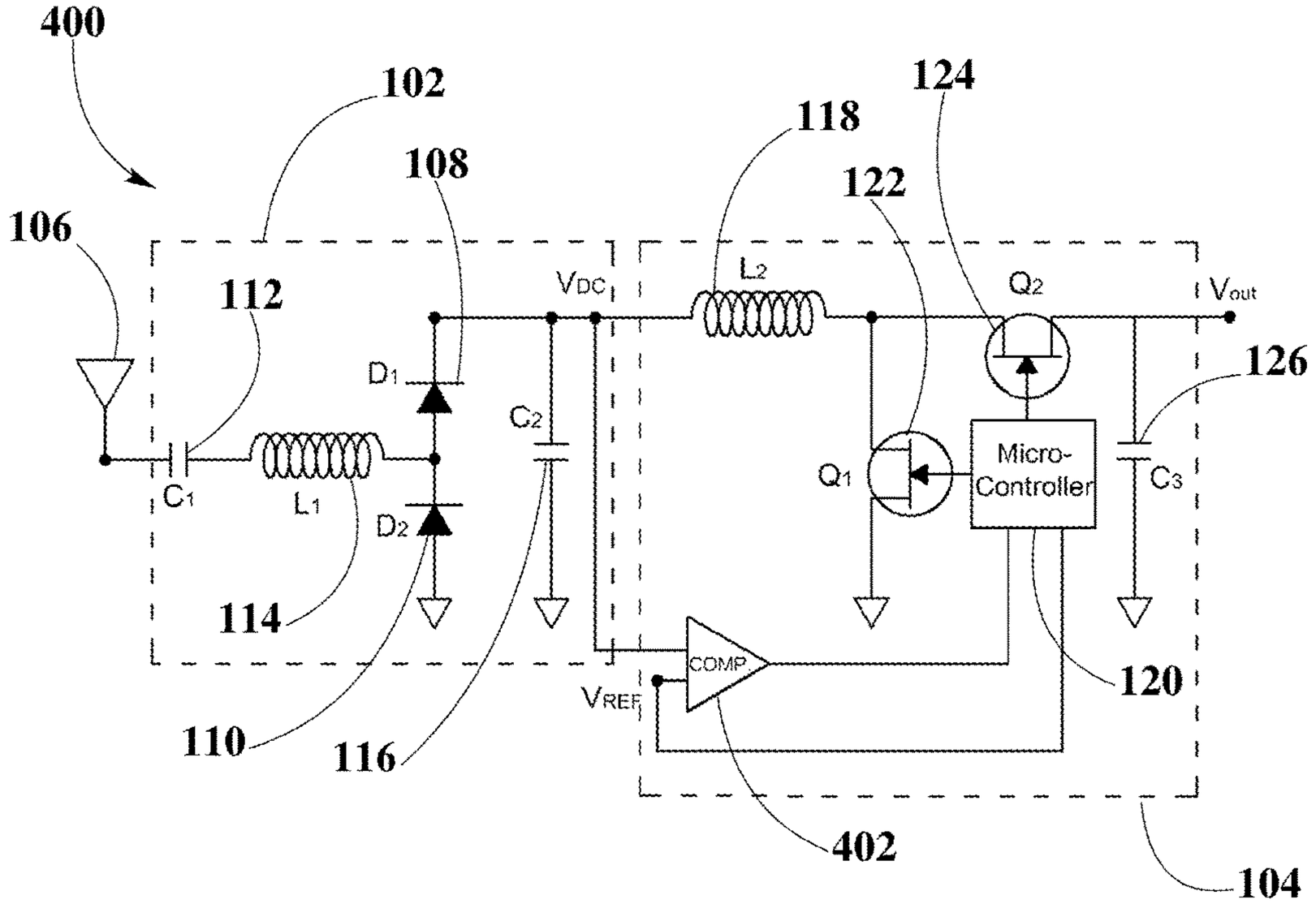

400
102
108
118
124
122
106
112
VDC
L2
Q2
Vout
126
D1
C2
Q1
Micro-
Controller
C3
C1
L1
D2
114
COMP.
120
VREF
110
116
402
104

FIG. 4

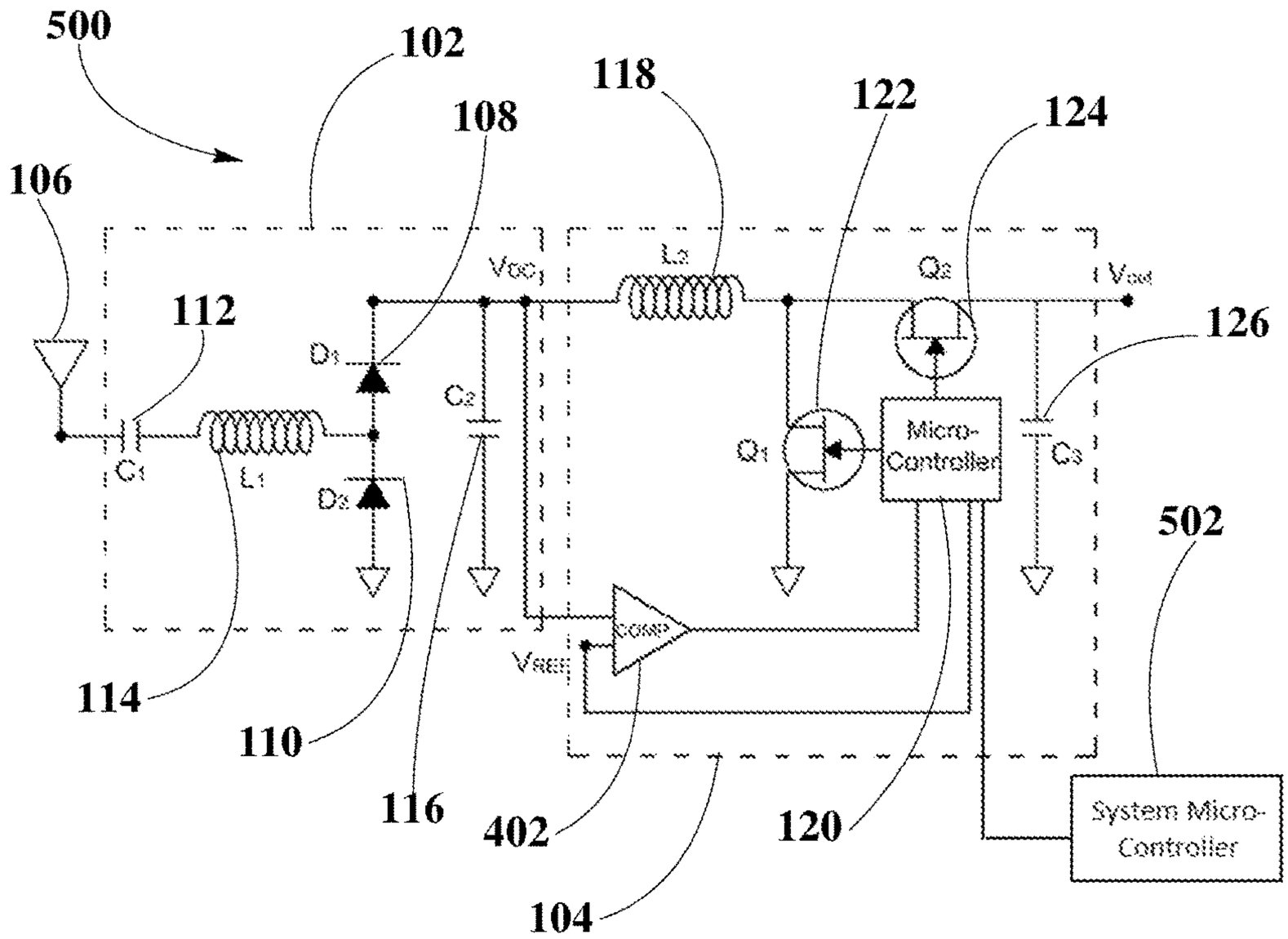

500
102
118
108
122
124
106
112
126
Micro-Controller
502
114
110
116
402
120
104
System Micro-Controller

FIG. 5

INTEGRATED RECTIFIER AND BOOST CONVERTER FOR BOOSTING VOLTAGE RECEIVED FROM WIRELESS POWER TRANSMISSION WAVES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 14/272,287, filed May 7, 2014, which is herein fully incorporated by reference in its entirety.

This application is related to U.S. patent application Ser. No. 13/891,430, filed May 10, 2013; U.S. patent application Ser. No. 13/946,082, filed Jul. 19, 2013; U.S. patent application Ser. No. 13/891,399, filed May 10, 2013; U.S. patent application Ser. No. 13/891,445, filed May 10, 2013; U.S. patent application Ser. No. 14/272,179, filed May 7, 2014; U.S. patent application Ser. No. 14/272,247, filed May 7, 2014; U.S. Non-Provisional patent application Ser. No. 14/583,625, filed Dec. 27, 2014, entitled "Receivers for Wireless Power Transmission," U.S. Non-Provisional patent application Ser. No. 14/583,630, filed Dec. 27, 2014, entitled "Methodology for Pocket-Forming," U.S. Non-Provisional patent application Ser. No. 14/583,634, filed Dec. 27, 2014, entitled "Transmitters for Wireless Power Transmission," U.S. Non-Provisional patent application Ser. No. 14/583,640, filed Dec. 27, 2014, entitled "Methodology for Multiple Pocket-Forming," U.S. Non-Provisional patent application Ser. No. 14/583,641, filed Dec. 27, 2014, entitled "Wireless Power Transmission with Selective Range," U.S. Non-Provisional patent application Ser. No. 14/583,643, filed Dec. 27, 2014, entitled "Method for 3 Dimensional Pocket-Forming," all of which are fully incorporated herein by reference in their entirety for all purposes.

FIELD OF THE DISCLOSURE

This disclosure relates generally to wireless power transmission, and, more particularly, to integrated half-bridge rectifiers of novel design architecture, using a circuit topology of high efficiency power conversion characteristics and connected to a boost converter in a wireless power receiver.

BACKGROUND

For low-volume electronic devices capable of supplying a large amount of power, power converters must be of very high efficiency since losses in the power converter must be dissipated from the low volume and surface of the power converter, which is required to exhibit a high performance to accommodate large changes in load current between idle and active power states with acceptable transient response. Currently, on-board distributed power system applications include development of power converters capable of providing high power densities using topologies for high frequency ranges and efficiencies of about 90%.

Because of alternating current is preferred for efficient power transmission, power sources generally provide power at alternating current, but the operation of the electronic devices demands direct current (DC), which is provided by converting the current supplied from alternating to direct using rectifiers. For this, a wireless power receiver includes a rectifying circuit for converting received radio frequency (RF) signals in the form of AC waveforms to DC waveforms that are adjusted to have a determined voltage level at the output terminals.

Half-bridge rectifiers are commonly used in power converters to provide half-wave rectification of alternating current. A typical half-bridge rectifier include two diodes which are inherently inefficient conductors producing a number of well-known problems. One problem resulting from the inefficiency of diodes is that they produce a forward voltage drop. This is most noticeable in low-voltage power converters where the voltage drop may be a significant proportion of the desired voltage output. Apart from reducing overall efficiency of the power converter, resulting high temperatures also reduce the reliability of components. Thus, additional design effort may be required to overcome the problems, and other factors such as the dimensions of the system, which may be affected as a result.

As most electronic devices require smooth DC current to operate properly, adding a capacitor to the output of a half-wave rectifier filters pulsating DC into smooth DC, but filter capacitors are a major concern in determining cost, size and weight in design of a rectifying circuit. Moreover, difficulties arise in the implementation of the rectifying circuit due to constraints from the available mounting area and requirements for high output and efficiency, since the rectifying circuit typically uses passive devices having large external parameters. Additionally, the rectifying circuit does not operate over a large range of frequencies since it is an external packaged active device. Therefore, it is possible to manufacture a rectifying circuit that may be smaller and lighter than a conventional rectifying circuit, including a reduced number of passive devices, such that a stable DC output power may be obtained at the output terminals of the wireless power receiver in which the rectifying circuit is to operate. Benefits of half-wave rectification may reduce increased expenses and circuit complexity to achieve high power densities and power transmission efficiency.

Based on the foregoing, there is a need for a rectifier, which may be integrated with a boost converter and designed based on an architecture and circuit topology capable of providing high power densities.

SUMMARY

According to embodiments, it is an object of the present disclosure to provide an integrated rectifier designed to include a novel rectifying circuit architecture connected to a boost converter in a wireless receiver. The architecture of the integrated rectifier may be characterized by a circuit topology of low power loss characteristics and low associated heat loss for wireless power transfer systems that may handle varying power levels to increase wireless power transmission efficiency to electronic devices, at the same time that problems encountered when using discrete circuit elements may be solved integrating the rectifier in a single package in which the novel architecture may be applied.

In accordance with one aspect of the present disclosure, the design of the integrated rectifier circuit architecture of present disclosure may include a plurality of identical topology-half-bridge rectifying circuits for power conversion, where the voltage output, alternating current (AC) waveforms, from a wireless transmitter may be received by same number of wireless receiver antennas as rectifying circuits may there be in the integrated rectifier architecture. The half-bridge rectifying circuits converting AC to direct current (DC) may be synchronous rectifiers. The integrated rectifier may include as many half-bridge rectifying circuits of identical topology as needed to supply the power levels required by the wireless receiver or the electronic device housing the wireless receiver.

In an embodiment, the integrated rectifier may be connected to a boost converter in which an integrated controller circuit may drive two control switches for power transfer to other modules of the wireless receiver. The integrated controller may be a programmable or non-programmable type controller. When one of the power switches is on for a particular amount of time, the output voltage from the integrated rectifier may charge an inductor increasing the current flowing through it. As the inductor may store energy, the voltage may increase to a predetermined level which may turn the other control switch on for a particular amount of time, providing the conduction path between the inductor and the output to discharge the inductor.

The charging inductor may be an external component of the integrated rectifier or may be included internally in the integrated rectifier. In one embodiment the charging inductor may be included in the boost converter circuit.

In another aspect, present disclosure may include an integrated rectifier with eight radio frequency (RF) voltage inputs connected to eight half-bridge rectifying circuits respectively, and eight DC outputs ganged together as a single feed into the boost converter.

The architecture of the integrated rectifier may be designed to be low cost, complexity, and size.

The architecture of the integrated rectifier may have the boost converter to control the current flowing out of the integrated rectifier with the plurality of half-bridge rectifying circuits to provide energy and capable of operating over a large range of frequencies.

The integrated rectifier may be enabled as an integrated circuit (IC), which may be much smaller than any discrete circuit made from independent components with known operational problems, such as operation over a large range of frequencies, and physical size design constraints. Half-bridge rectifiers in the IC may be synchronous rectifiers. In this embodiment, the charging inductor may be packaged with the integrated rectifier.

In yet another aspect of present disclosure, the boost converter controller may control the RF power that may be extracted and converted through the integrated rectifier architecture in the present disclosure by adding a comparator in the boost converter controller. The comparator may directly sense the extracted DC waveforms and compare their output voltage levels with a reference signal from the boost converter controller. For this, a proprietary algorithm may be employed to adjust the behavior of the boost converter controller in order to suit maximum power point tracking functionality.

In still another aspect of present disclosure, an external input may be added to the boost converter to connect an external micro-controller to provide additional feedback to the boost converter.

Numerous other aspects, features and benefits of the present disclosure may be made apparent from the following detailed description taken together with the drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure can be better understood by referring to the following figures. The components in the figures are not necessarily to scale, emphasis instead being place upon illustrating the principles of the disclosure. In the figures, reference numerals designate corresponding parts throughout the different views.

FIG. **1** illustrates a schematic diagram of a circuit topology for an integrated rectifier and boost converter, according to an embodiment;

FIG. **2** depicts a block diagram of circuit architecture including antenna elements connected to integrated rectifier and boost converter, according to an embodiment;

FIG. **3** shows a block diagram of an integrated circuit of arrangement of rectifiers, according to an embodiment;

FIG. **4** represents a schematic diagram for a circuit topology of half-bridge rectifier power conversion controlled via a comparator, according to an embodiment; and

FIG. **5** depicts a schematic diagram for a circuit topology of half-bridge rectifier power conversion including an additional external micro-controller.

DETAILED DESCRIPTION

The present disclosure is here described in detail with reference to embodiments illustrated in the drawings, which form a part here. Other embodiments may be used and/or other changes may be made without departing from the spirit or scope of the present disclosure. The illustrative embodiments described in the detailed description are not meant to be limiting of the subject matter presented here.

As used here, the following terms may have the following definitions:

"Electronic device" refers to a device depending on the principles of electronics and using the manipulation of electron flow for its operation. In present disclosure, refers to a device able to communicate using one or more suitable wireless technologies.

"Wireless receiver" refers to a device including at least one antenna element, at least one rectifying circuit and at least one power converter, which may utilize pockets of energy for powering, or charging a wireless device.

"Rectifier" refers to an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.

"Synchronous rectifier" refers to a power transmission circuit including active rectifiers controlled by switches such as transistors for improving the efficiency of rectification. The control circuitry for active rectification usually uses sensors for the voltage of the input AC to open the transistors at the correct times to allow current to flow in the correct direction.

"Switching transistor" refers to a semiconductor device used to switch electronic signals and electrical power in analog or digital circuits.

"Comparator" refers to a specialized high-gain differential amplifier used to measure and digitize analog signals, or to compare two voltages and determine whether a given input voltage is under voltage or over voltage.

The present disclosure may provide rectifier architecture designed to include a circuit topology integrated with a boost converter for wireless receivers of a plurality of system configurations with maximum power transfer control. The design of the integrated rectifier circuit topology of present disclosure may include a plurality of half-bridge rectifiers whose power conversion and transmission may be controlled by switching devices in the boost converter. For power conversion in the integrated rectifier, the voltage output from a wireless transmitter is received by wireless receiver antenna elements and may be transferred as output voltage to other modules in the wireless receiver.

Simplified Circuit Topology of an Integrated Rectifier and Boost Converter

FIG. **1** illustrates a schematic diagram of a simplified circuit topology **100** for an integrated rectifier **102** and boost converter **104**.

Present embodiment may include at least one antenna element **106** which may convert RF waves or pockets of energy into electrical power. Antenna element **106** may be operatively coupled with one or more rectifiers **102**. RF waves may exhibit a sinusoidal shape within a voltage amplitude and power range that may depend on characteristics of a wireless power transmitter (not shown). Because of this sinusoidal nature of RF waves, the voltage or power generated by rectifier **102** may be variable. As an illustrative embodiment, and not by way of limitation, the alternating current (AC) voltage or power generated by antenna element **106** from transmitted RF waves or pocket of energy may vary from about 0 volts or 0 watt to about 5 volts at 3 watts.

Antenna element **106** may include suitable antenna types for operating in frequency bands similar to frequency bands, such as 900 MHz, 2.4 GHz, and 5.7 GHz, amongst others, from the wireless transmitter. These frequency bands comply with Federal Communications Commission (FCC) regulations part **18** (Industrial, Scientific and Medical equipment). Antenna element **106** may include vertical or horizontal polarization, right hand or left hand polarization, elliptical polarization, or other suitable polarizations as well as suitable polarization combinations. Using multiple polarizations may be beneficial in devices where there may not be a preferred orientation during usage or whose orientation may vary continuously through time. For devices with well-defined orientations, there might be a preferred polarization for antennas which may dictate a ratio for the number of antennas of a given polarization. Suitable antenna types may include patch antennas with heights from about ⅛ inches to about 6 inches and widths from about ⅛ inches to about 6 inches. Patch antennas may have the advantage that polarization may depend on connectivity, i.e. depending on which side the patch is fed, the polarization may change.

Rectifier **102** may include diodes, resistors, inductors, transistors and/or capacitors to rectify the AC voltage generated by antenna element **106** to direct current (DC) voltage. Rectifier **102** may be placed as close as technically possible to antenna element **106** to minimize losses. In one embodiment, rectifier **102** may operate in synchronous mode, in which case rectifier **102** may include switching elements, transistors, which may improve the efficiency of rectification. Half-bridge rectifier **102** may be used to produce an output with a fixed polarity that is independent of the polarity of the input.

Transmission of power converted by rectifier **102** may be controlled using either an active-drive approach to provide control signals with electronic circuitry which may have timing information from voltage or current waveforms within the power circuit, or a passive-drive approach in which control signals may be directly provided or through passive circuit elements from a waveform in the power circuit.

When an alternating RF signal is received by antenna element **106** from the wireless transmitter, a direct voltage output, V_{DC}, may be drawn from the output terminals of half-bridge rectifier **102**, including two diodes, D_1 and D_2, respectively identified as diode **108** and diode **110**, which may be wired in series upstream and connected to the output terminal. Antenna element **106** is connected in series to capacitor **112**, which is connected in series to inductor **114**, both acting as the resonant filter for the power signal being transferred from wireless transmitter and received by antenna element **106**. Additionally, rectifier **102** may be connected in parallel to a second filter capacitor **116** and in series with charging inductor **118**.

When the polarity of the alternating RF signal received may be positive, current flows through the first upstream diode **108** and when the polarity of the alternating RF signal received is negative, current flows through second upstream diode **110**.

Boost converter **104** may include charging inductor **118**, but it may be laid out internally of rectifier **102**. In the present embodiment inductor **118** may be preferably laid out as an internal component of boost converter **104** and may be designed with an appropriate, smaller form factor and scaled to a plurality of values, such that maximum power that may be converted may not saturate inductor **118**. Boost converter **104** may convert the variable DC output voltage of rectifier **102** into a more stable DC voltage that can be used by components of a wireless receiver and/or electronic device housing the wireless receiver. Boost converter **104** may operate as a step-up DC-to-DC converter to increase the voltage from rectifier **102** to a voltage level suitable for proper operation of other modules in the wireless receiver. In addition, boost converter **104** may reduce or eliminate rail-to-rail deviations. Additional filtering capabilities, capacitor **126**, may be added at the output of boost converter **104** as shown in FIG. **1**. In one embodiment, boost converter **104** may exhibit a synchronous topology to increase power conversion efficiency.

As the voltage or power generated from RF waves may be zero at some instants of wireless power transmission, circuit topology **100** may include circuit elements to store energy or electric charge from the output voltage produced by rectifier **102**. In this way, inductor **118**, may deliver continuous voltage or power to the output terminal of boost converter **104**, where a load (not shown) may represent a battery or internal circuitry of electronic device requiring continuous powering or charging.

When the required level of voltage may be present at the output terminal of rectifier **102**, micro-controller **120** may turn switching transistor **122**, Q_1, on for current to flow through inductor **118**, which may start storing energy. Then, according to a predetermined control switching scheme in micro-controller **120**, switching transistor **122** may be turned off Subsequently, inductor **118** may discharge its stored energy by sending current to switching transistor **124**, Q_2, which may be presently in off state. Due to this current and the state of switching transistor **124**, the voltage may rise at the input of switching transistor **124**. At some level of voltage in accordance with the switching control scheme, micro-controller **120** may turn switching transistor **124** on for a particular amount of time allowing energy transmission at a level of voltage that is higher than the original voltage at capacitor **116**, C_2. Switching transistors **122**, **124** may be identical field-effect transistors, bipolar junction transistors, insulated-gate bipolar transistors, or gallium nitride transistors, amongst others.

Micro-controller **120** may be an integrated controller circuit driving switching transistor **122**, **124** for power transfer to other modules of the wireless receiver and it may be a programmable or non-programmable type controller.

Circuit Architecture of an Integrated Rectifier and Boost Converter

FIG. **2** depicts a block diagram of circuit architecture **200** including antenna elements **106** connected to integrated rectifier **202** and boost converter **104**, according to an embodiment.

Better efficiency and power density may not be achieved using one sole rectifier **102** as shown in FIG. **1**. The well-known problem of power availability at the output of a wireless receiver may be solved using circuit architecture

200 including a plurality of identical rectifiers 102, as described in circuit topology 100, including same passive and active circuit components and switching control schemes, and integrated as rectifier 202, connected to boost converter 104. Accordingly, multiple configurations may be used to transfer wireless power from antenna elements 106. This way, integrated rectifier 202 may include as many identical rectifiers 102 as required by the power level that may be needed for a wireless receiver to operate efficiently, as well as the electronic device housing the wireless receiver. Integrated rectifier 202 may include from one to N identical rectifiers 102, R_1, R_2, R_3 . . . R_N, feeding one boost converter 104.

In one embodiment, inductor 118 may be included in the circuit topology of integrated rectifier 202. In another embodiment inductor 118 may be externally placed next to boost converter 104. The size and shape of the external inductor 118 may depend on the electrical constraints and parameters of the circuit.

As may be seen in FIG. 2, circuit architecture 200 may allow to have two rectifiers 102, or four rectifiers 102, or eight rectifiers 102, as integrated rectifier 202, each connected to a dedicated antenna element 106 and the total power output feeding one boost converter 104.

Integrated Circuit of Rectifiers and Boost Converter

FIG. 3 shows a block diagram of integrated circuit 300 of arrangement of rectifiers 102, according to an embodiment.

Given that circuit architecture 200, including rectifiers 102 of circuit topology 100, may be an expensive implementation using discrete components for rectifier 102, a configuration of eight rectifiers 102 may be enabled in integrated circuit 300.

Integrated circuit 300 may include eight RF input terminals 302, eight rectifiers 102, and eight DC output lines 304 connected together to provide the total power extracted from RF signals received by antenna elements 106 through a single feed line 306 into boost converter 104. Integrated circuit 300 may also include synchronous half-bridge rectifiers 102.

Additionally, integrated circuit 300 may enable an implementation of circuit architecture 200 that may be capable of operating over a large range of frequencies. This capability may not be possible using discrete components. Moreover, inductor 118, shown in FIG. 1, may be included in integrated circuit 300 and physically sized to smaller form factor and value such that maximum power extracted and converted may not saturate inductor 118.

Capacitor 116 in each rectifier 102 may be substituted in the package by the layout of bonded wires used for output lines 304, thus significantly reducing the size of integrated circuit 300 and increasing power transmission efficiency.

Control-Driven Integrated Rectifier and Boost Converter Circuit Topology

FIG. 4 represents a schematic diagram for a circuit topology 400 of half-bridge rectifier 102 power conversion controlled via a comparator 402, according to an embodiment.

Circuit architecture 200 may include micro-controller 120, in boost converter 104, to control the RF power that may be extracted. Micro-controller 120 may drive comparator 402 to which a reference signal, V_{REF}, may be fed to compare it with the extracted DC waveforms and enabling a proprietary algorithm to turn switch transistors 122, 124 on at the appropriate voltage point and particular amount of time to suit maximum power point tracking (MPPT) functionality, charging and discharging inductor 118 as described in FIG. 1. All other circuit elements in circuit topology 400 are the same as in circuit topology 100 in FIG. 1. Directly sensing of the output voltage, V_{DC}, may be performed by comparator 402 to see if it is below of a predetermined design voltage threshold.

Micro-controller 120, based on voltage measurements, may control the power or voltage delivered at the output terminals of boost converter 104, and therefore, adjust the current limits supplied to other modules in the wireless receiver.

An MPPT algorithm may be executed by micro-controller 120 to control and optimize the amount of power that boost converter 104 may pull from antenna elements 106. Accordingly, MPPT functionality may be enabled having micro-controller 120 to monitor the power levels converted. Subsequently, the comparison of DC voltage at the output terminal of rectifier 102, V_{DC}, with the voltage reference, V_{REF}, may be used by micro-controller 120 to detect the maximum power point in the RF signals received by antenna elements 106 and for the proprietary algorithm to adjust the level of power extracted in conformity with the MPPT data in micro-controller 120.

This active-drive approach of control may be also implemented including comparator 402 in integrated circuit 300.

FIG. 5 represents a schematic diagram for a circuit topology 500 of half-bridge rectifier 102 power conversion including an additional external system micro-controller 502, according to an embodiment.

Circuit topology 500 may include all components in circuit topology 400, to which the external system micro-controller 502 may be added to provide additional control of boost converter 104 in a wireless receiver (not shown).

Micro-controller 120 in circuit topology 400, may drive comparator 402 to which a reference signal, V_{REF}, may be fed to compare it with the extracted DC waveforms and enabling a proprietary algorithm to turn switch transistors 122, 124 on at the appropriate voltage point and particular amount of time to suit maximum power point tracking (MPPT) functionality, charging and discharging inductor 118. This active-drive approach of control may be also implemented including comparator 402 in integrated circuit 300.

System micro-controller 502 may process information sent by the wireless receiver through its communications component for determining optimum times and locations for pocket-forming and may also operate in conjunction with an EEPROM module to run an algorithm for controlling the operation of boost converter 104 according to load requirements. System micro-controller 502 may actively monitor the overall operation of the wireless receiver by taking one or more power measurements at different nodes or sections of the wireless receiver. For example, system micro-controller 502 may measure how much voltage or power is being delivered at rectifier 102, boost converter 104, and other components in the wireless receiver, including the connected load and may communicate these power measurements to the connected load so that electronic device may know how much power it can pull from the wireless receiver. System micro-controller 502 may provide additional feedback to the boost converter 104.

While various aspects and embodiments have been disclosed, other aspects and embodiments may be contemplated. The various aspects and embodiments disclosed here are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A wireless power receiver comprising:

a controller coupled with a comparator;

a rectifier coupled to an antenna of the wireless power receiver, the rectifier being configured to rectify energy from wireless power transmission waves received by the antenna into a first voltage;

a boost converter coupled to the rectifier, the boost converter being configured to increase the first voltage to a second voltage based on instructions from the controller; and

the controller configured to control an amount of increase in voltage from the first voltage to the second voltage based on a comparison, performed by the comparator, of the first voltage with a reference voltage generated by the controller.

2. The wireless power receiver of claim **1**, wherein:

the wireless power receiver is coupled with an electronic device; and

the amount of increase in voltage from the first voltage to the second voltage is controlled by the controller based also at least in part on a power level required by the electronic device.

3. The wireless power receiver of claim **2**, wherein the electronic device houses the wireless power receiver.

4. The wireless power receiver of claim **1**, wherein the antenna receives the wireless power transmission waves from a remote wireless power transmitter.

5. The wireless power receiver of claim **1**, wherein the wireless power transmission waves are radio frequency power transmission waves.

6. The wireless power receiver of claim **1**, wherein the controller is a microcontroller.

7. The wireless power receiver of claim **1**, wherein:

the antenna is one of a plurality of antennas; and

the rectifier is one a plurality of rectifiers, and each of the plurality of rectifiers, including the rectifier, is configured to rectify energy from wireless power transmission waves received by the plurality of antennas into the first voltage.

8. The wireless power receiver of claim **7**, wherein:

the wireless power receiver is coupled with an electronic device; and

a number of rectifiers is included in the plurality of rectifiers so as to supply a power level power required by the electronic device.

9. The wireless power receiver of claim **1**, further comprising an inductor coupled to the rectifier, the inductor being configured to:

receive the first voltage from the rectifier, and

provide the second voltage to an output terminal of the boost converter.

10. The wireless power receiver of claim **9**, wherein:

the wireless power receiver further comprises a plurality of transistors coupled to the inductor and the controller; and

the controller is configured to control the amount of increase in voltage by controlling the plurality of transistors.

11. The wireless power receiver of claim **1**, wherein:

the energy rectified by the rectifier is an alternating current; and

the antenna is configured to convert energy from the wireless power transmission waves into the alternating current.

12. An electronic device comprising:

a wireless power receiver, comprising:

a controller coupled with a comparator;

a rectifier coupled to an antenna of the wireless power receiver, the rectifier being configured to rectify energy from wireless power transmission waves received by the antenna into a first voltage;

a boost converter coupled to the rectifier, the boost converter being configured to increase the first voltage to a second voltage based on instructions from the controller; and

the controller configured to control an amount of increase in voltage from the first voltage to the second voltage based on a comparison, performed by the comparator, of the first voltage with a reference voltage generated by the controller.

13. The electronic device of claim **12**, wherein:

the amount of increase in voltage from the first voltage to the second voltage is controlled by the controller based also at least in part on a power level required by the electronic device.

14. The electronic device of claim **12**, wherein the electronic device houses the wireless power receiver.

15. The electronic device of claim **12**, wherein the antenna receives the wireless power transmission waves from a remote wireless power transmitter.

16. The electronic device of claim **12**, wherein the wireless power transmission waves are radio frequency power transmission waves.

17. The electronic device of claim **12**, wherein the controller is a microcontroller.

18. The electronic device of claim **12**, wherein the wireless power receiver further comprises an inductor coupled to the rectifier, the inductor being configured to:

receive the first voltage from the rectifier, and

provide the second voltage to an output terminal of the boost converter.

19. The electronic device of claim **18**, wherein:

the wireless power receiver further comprises a plurality of transistors coupled to the inductor and the controller; and

the controller is configured to control the amount of increase in voltage by controlling the plurality of transistors.

20. A method of receiving wireless power from a remote wireless power transmitter, the method comprising:

at a wireless power receiver having a controller coupled with a comparator, an antenna, a rectifier coupled with the antenna, and a boost converter coupled with the rectifier:

rectifying, by the rectifier, energy from wireless power transmission waves received by the antenna into a first voltage;

increasing, by the boost converter, the first voltage to a second voltage based on instructions from the controller; and

controlling, by the controller, an amount of increase in voltage from the first voltage to the second voltage based on a comparison, performed by the comparator, of the first voltage with a reference voltage generated by the controller.

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