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(54) DUAL-MODE POWER STEALING FOR A CLIMATE CONTROL SYSTEM CONTROLLER

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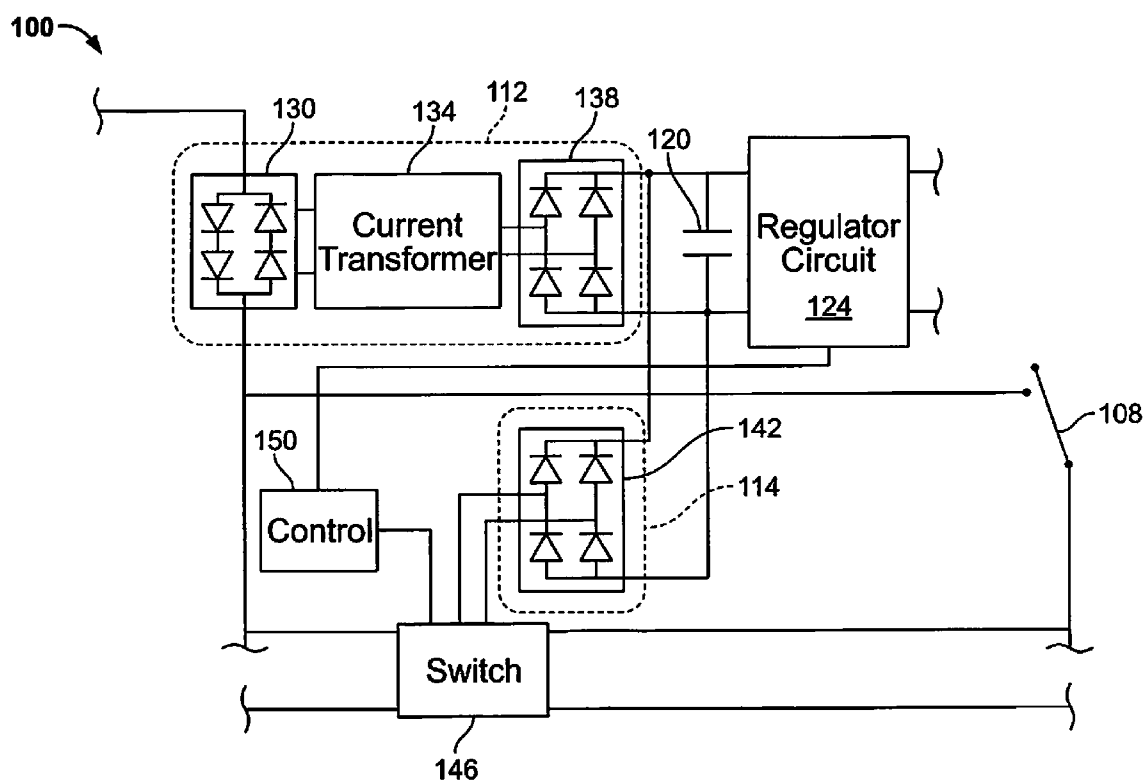
USPC **307/39**

(57) **ABSTRACT**

A controller for use in a climate control system. The controller, which may be a wireless-enabled thermostat, includes a power stealing circuit configured to steal power from a first load that is in an "on" mode and from a second load that is in an "off" mode. The stealing is performed from the first and second loads at the same time. Sufficient power can be stolen to support substantially constant operation of a transceiver of the controller.



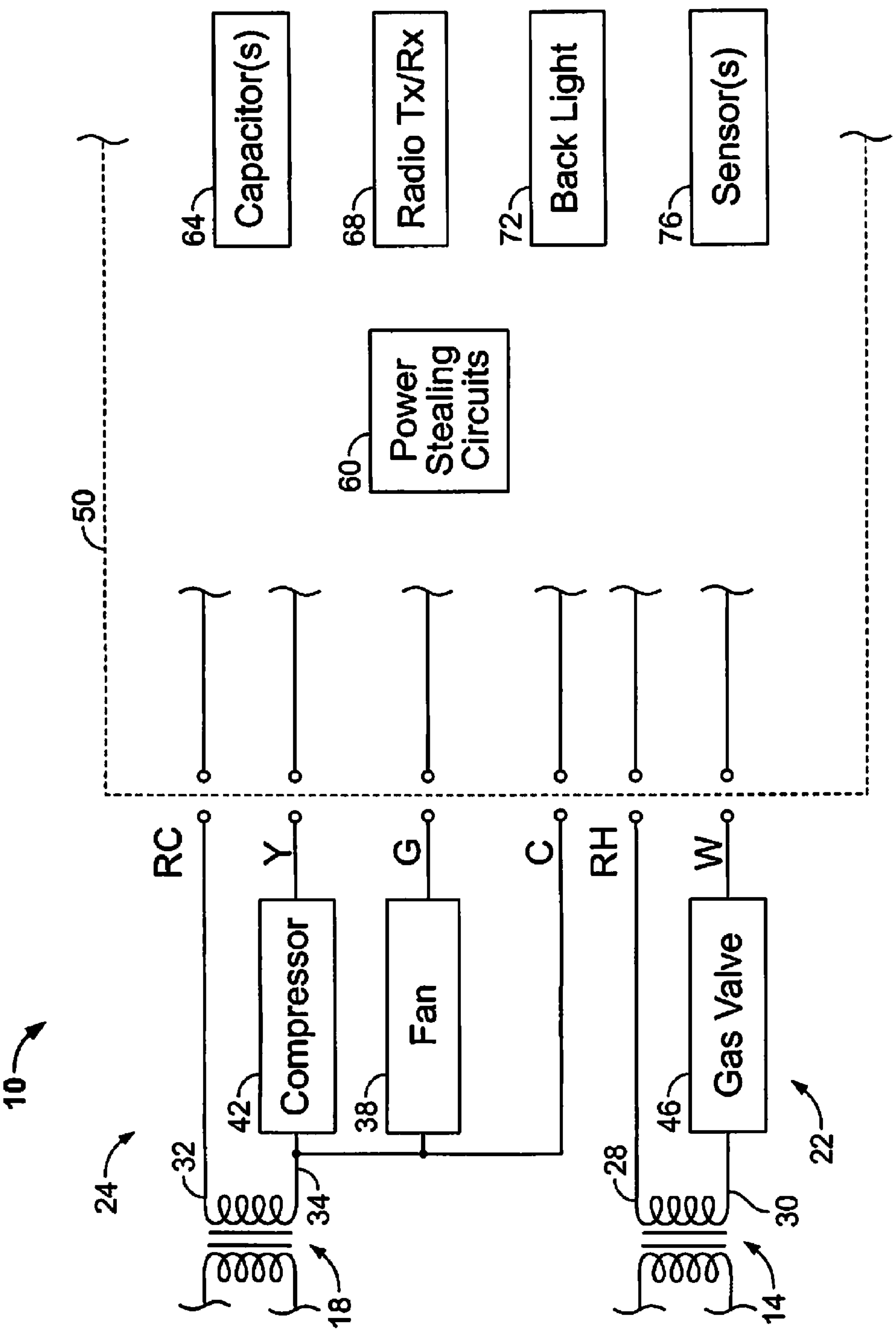

10
24
18
32
34
42
Compressor
38
Fan
RC
Y
G
C
RH
W
28
30
46
Gas Valve
14
22
50
60
Power Stealing Circuits
64
Capacitor(s)
68
Radio Tx/Rx
72
Back Light
76
Sensor(s)

FIG. 1

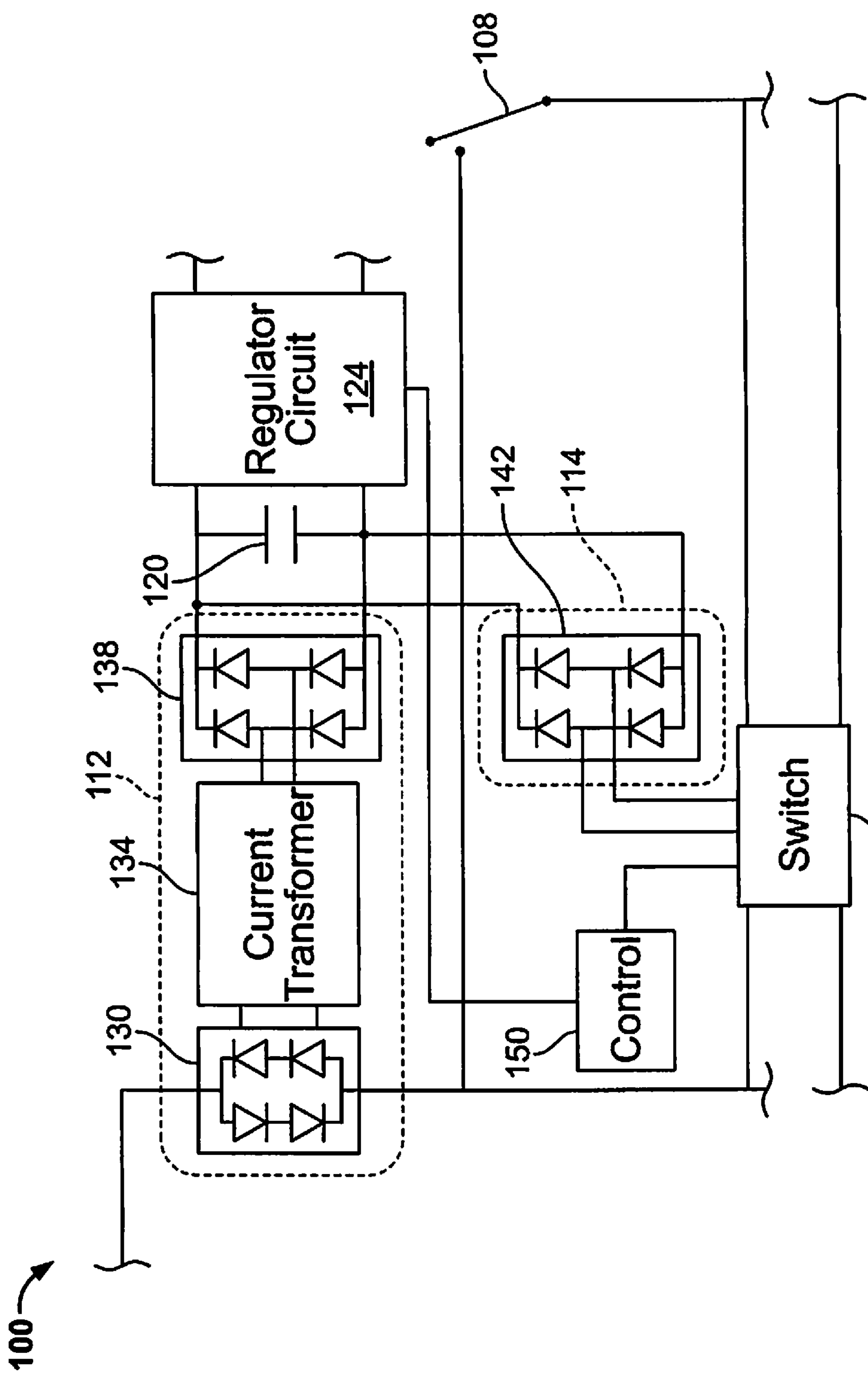

100
108
Regulator Circuit
124
120
142
114
138
112
134
Current Transformer
130
150
Control
Switch
146

FIG. 2

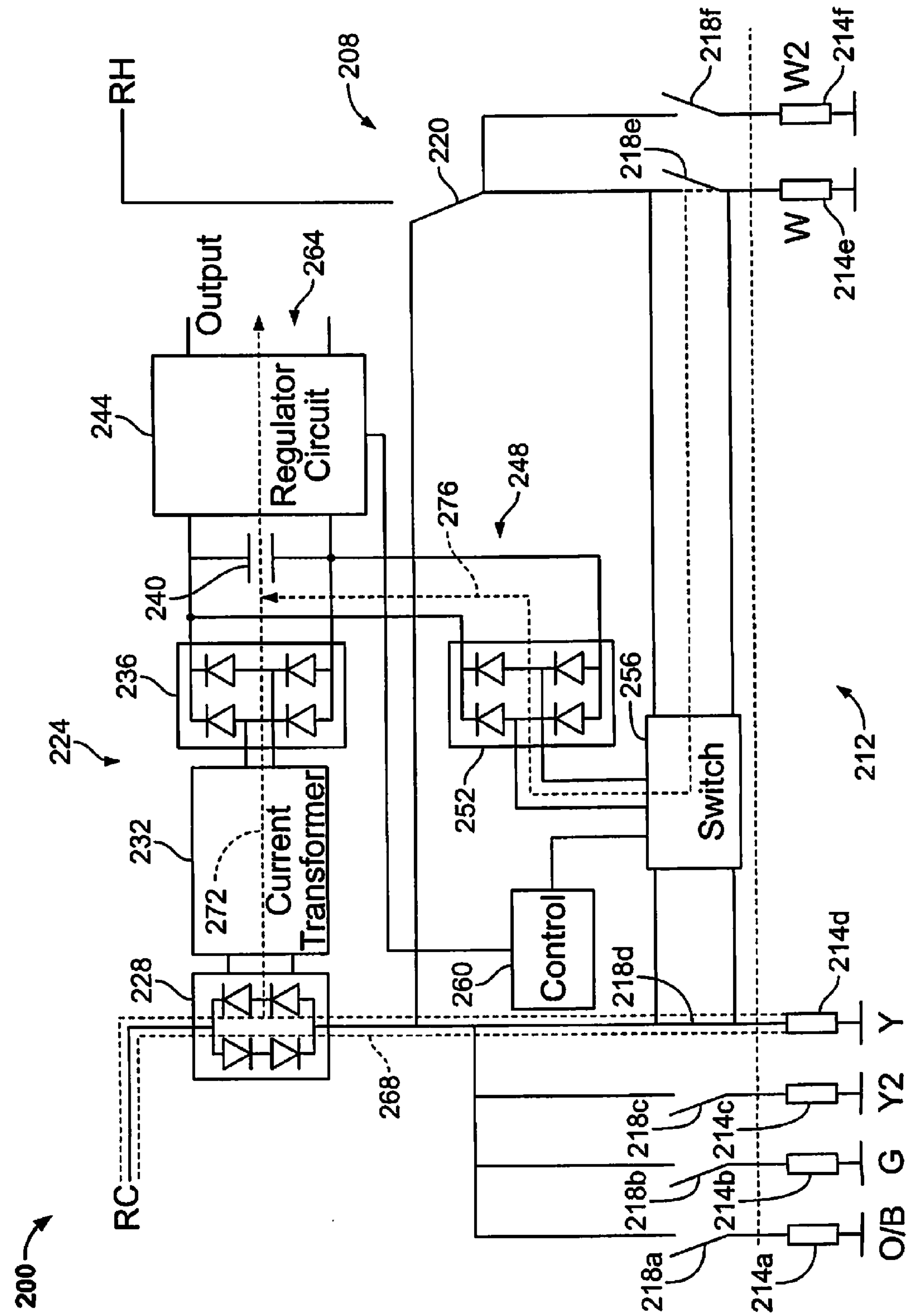
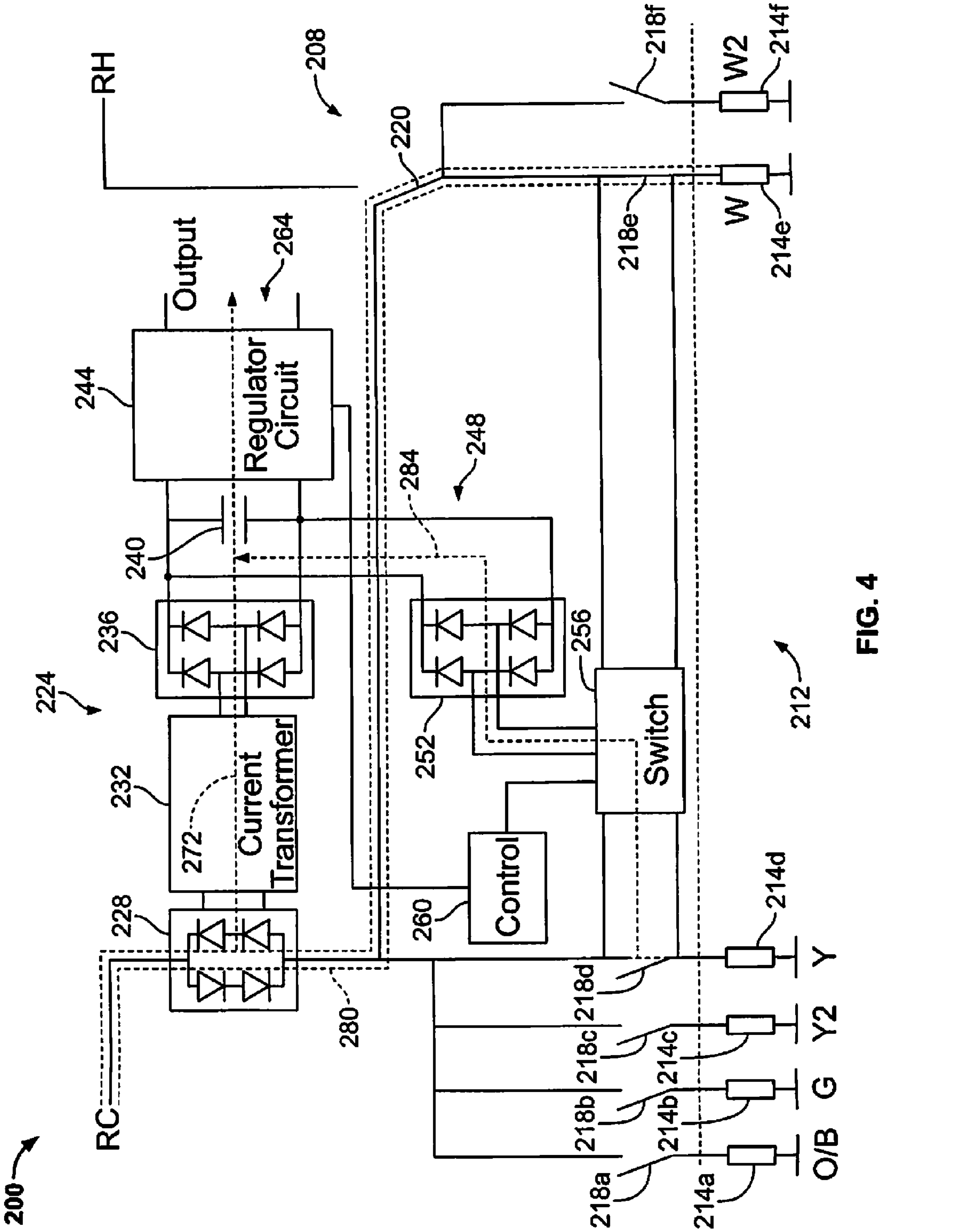

200
RC
RH
208
212
218f
W2
214f
220
218e
W
214e
Output
264
244
Regulator Circuit
248
276
240
236
256
224
252
Switch
232
272
Current Transformer
228
260
Control
218d
214d
Y
268
218c
214c
Y2
218b
214b
G
218a
214a
O/B

FIG. 3



200
RC
RH
208
220
218f
W2
214f
W
214e
218e
Output
264
244
Regulator Circuit
248
284
240
236
224
232
Current Transformer
272
228
256
252
Switch
Control
260
280
212
214d
Y
218d
Y2
218c
214c
G
218b
214b
O/B
218a
214a

FIG. 4

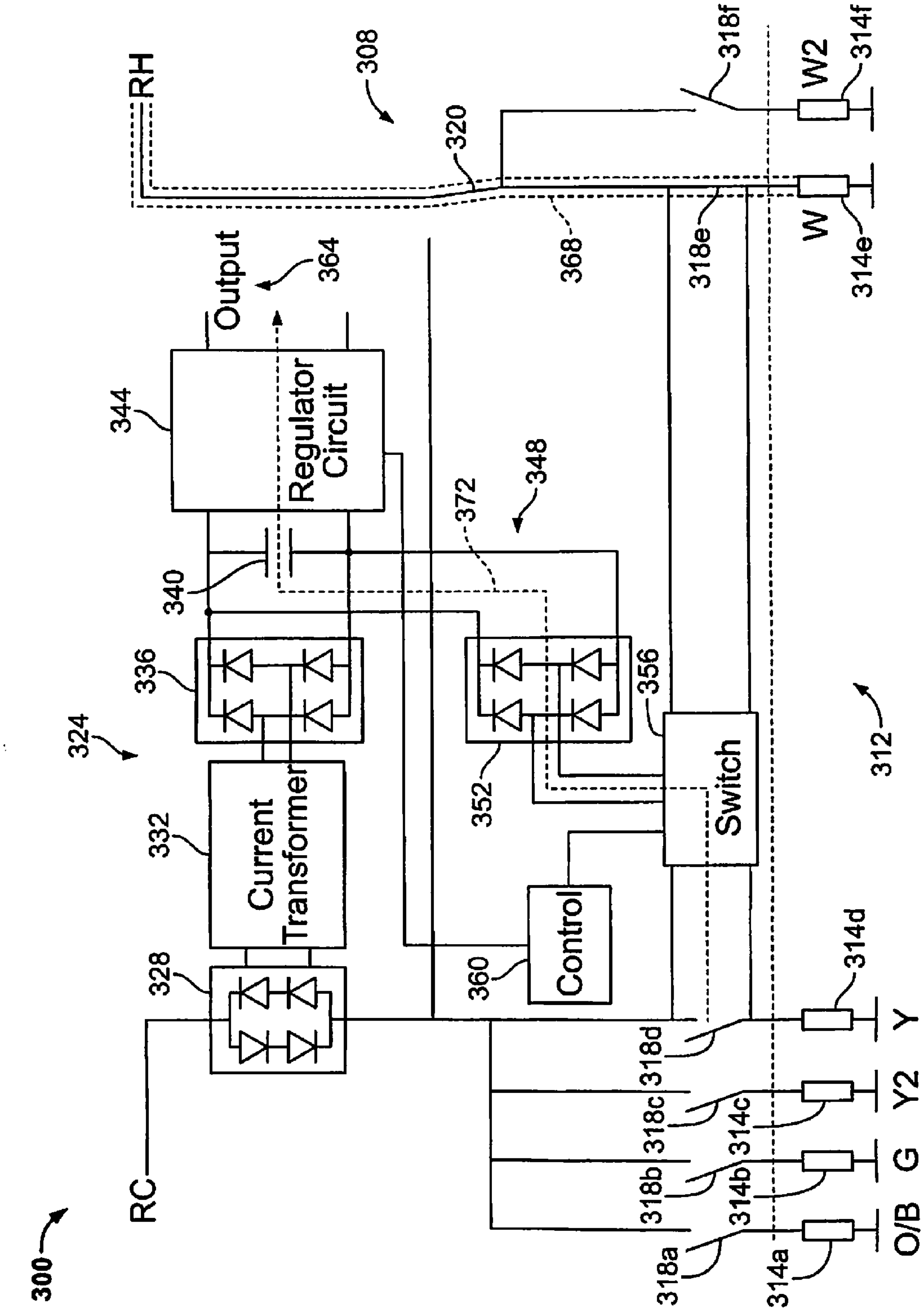

300
RC
RH
308
320
368
Output
364
344
Regulator Circuit
348
372
340
336
324
332
Current Transformer
328
356
352
Switch
360
Control
312
318a
318b
318c
318d
318e
318f
314a
314b
314c
314d
314e
314f
O/B
G
Y2
Y
W
W2

FIG. 5

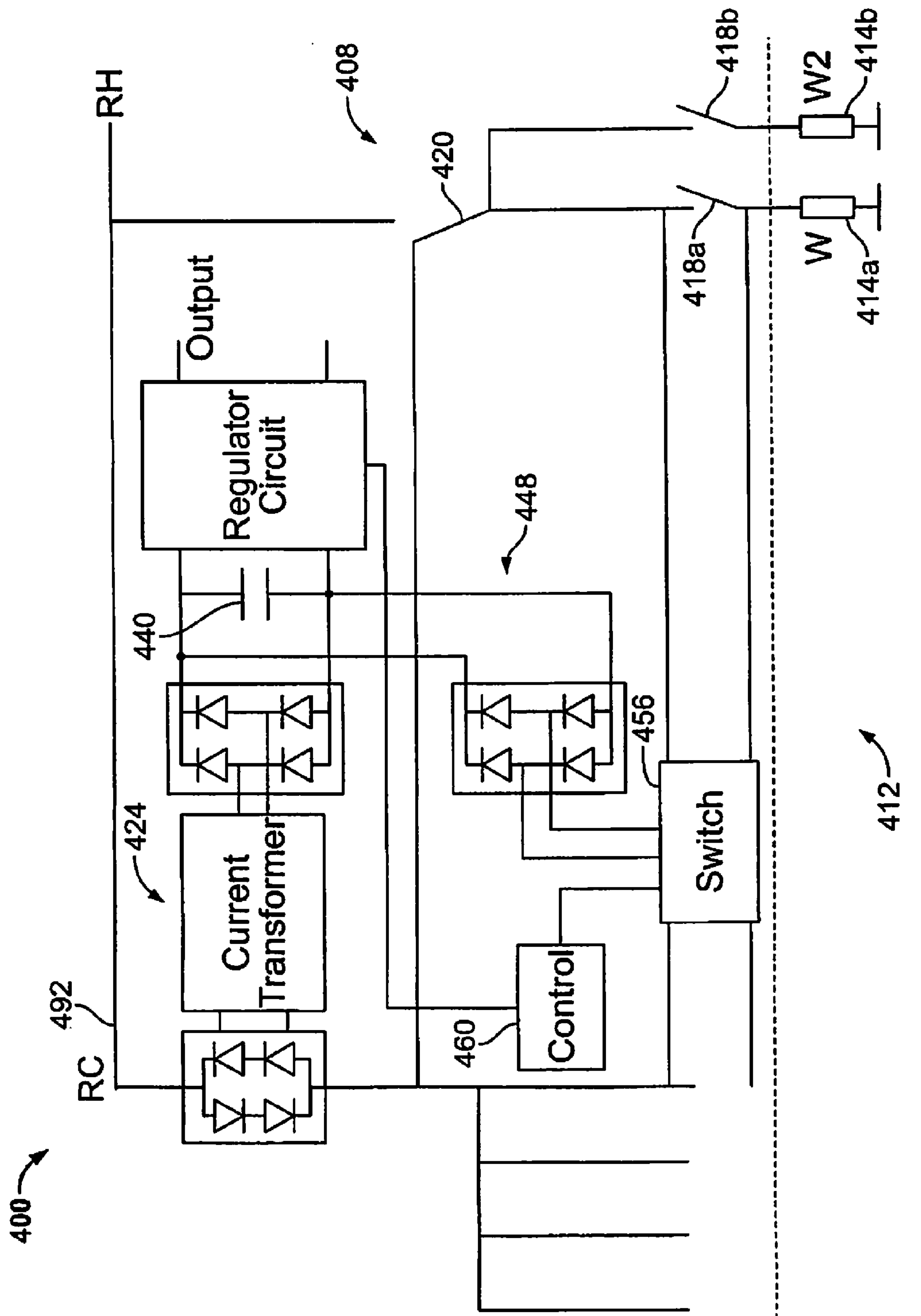

400
RC
492
RH
408
Output
Regulator Circuit
440
Current Transformer
424
448
456
Switch
Control
460
420
418a
418b
W
W2
414a
414b
412

FIG. 6

DUAL-MODE POWER STEALING FOR A CLIMATE CONTROL SYSTEM CONTROLLER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit and priority of Chinese Patent of Invention Application No. 201310142164.3 filed Apr. 22, 2013 and Chinese Patent of Invention Application No. 201310168169.3, filed May 9, 2013. The entire disclosures of each of the above applications are incorporated herein by reference.

FIELD

[0002] The present disclosure relates to apparatus, systems and methods for dual-mode power stealing for a climate control system controller.

BACKGROUND

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] Digital thermostats and other climate control system controllers typically have microcomputers and other components that continuously use electrical power. Various thermostats may utilize "off-mode" power stealing to obtain operating power. That is, when a load (e.g., a compressor, fan, or gas valve) in a climate control system has been switched off, power may be stolen from that "off-mode" load's circuit to power the thermostat.

SUMMARY

[0005] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0006] Exemplary embodiments or implementations are disclosed of methods, apparatus, and systems for dual-mode power stealing for a controller. An exemplary implementation is directed to a controller for use in a climate control system. In this example, the controller includes a power stealing circuit configured to steal power from a first load that is in an "on" mode and from a second load that is in an "off" mode. The stealing is performed from the first and second loads at the same time.

[0007] Another exemplary embodiment is directed to a controller for use in a climate control system. The controller includes a power stealing circuit and a processor. The processor detects "on-mode" operation of a first load of the climate control system. In response to the detecting, the processor selectively connects the power stealing circuit with a second load in an "off" mode. The power stealing circuit thus is configured to steal power from the first and second loads at the same time.

[0008] Another exemplary implementation is directed to a control-performed method of stealing power in a climate control system to operate a controller of the climate control system. In this example, the method includes monitoring a plurality of loads of the climate control system, and detecting that one of the loads is in an "on" mode. In response to the detecting, power stealing is actuated from one of the loads that is in an "off" mode. The method may be performed while power is being stolen from the one of the loads that is in the "on" mode.

[0009] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0010] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0011] FIG. **1** is a diagram of an exemplary climate control system including a thermostat in accordance with an exemplary embodiment of the present disclosure; and

[0012] FIGS. **2** through **6** are diagrams of exemplary power stealing circuits in accordance with exemplary embodiments of the present disclosure.

[0013] Corresponding reference numerals and/or reference characters indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0014] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0015] The inventors have observed that although various thermostats may be configured to steal power from an "off-mode" load, some thermostats may be configured to steal power from an "on-mode" load, i.e., from a load while the load is in operation. The inventors have also observed that thermostats typically perform power stealing in only one mode or the other. The inventors have provided and disclose herein various embodiments and implementations of apparatus, systems and methods for power stealing from "off-mode" and "on-mode" loads at the same time. In various example embodiments, sufficient power may be stolen, e.g., to provide substantially continuous power to a radio transceiver of a wireless-enabled thermostat.

[0016] One example embodiment of a climate control system is indicated generally in FIG. **1** by reference number **10**. The climate control system **10** includes two power sources, e.g., two transformers **14** and **18** for providing power respectively to a heating subsystem **22** and a cooling subsystem **24**. The heating subsystem transformer **14** has a hot (typically 24-volt) side **28** and a common, i.e., neutral, side **30**. The cooling subsystem transformer **18** has a hot (typically 24-volt) side **32** and a common, i.e., neutral, side **34**. The cooling subsystem **24** includes a fan **38** and a compressor **42** connected on the common side **34** of the transformer **18**. The heating subsystem **22** includes a furnace gas valve **46** connected on the common side **30** of the heating subsystem transformer **14**. In the present example, a C terminal is provided from a common C wire connected, e.g., with the common side **34** of the transformer **18**. In various alternative embodiments of the disclosure, no C wire is provided.

[0017] In one example embodiment, a thermostat **50** is provided for controlling operation of the climate control system **10**. The thermostat **50** may activate one or more relays and/or other switching devices(s) (not shown in FIG. **1**) to activate the heating subsystem **22** or cooling subsystem **24**. When, e.g., a user operates the thermostat **50** to cause the climate control system **10** to provide heating, the thermostat **50** turns on the heating subsystem **22** and gas valve **46** by using a relay or other switching device to connect a "hot" terminal RH to a load terminal W. To provide cooling, the thermostat **50** may turn on the compressor **42** and/or fan **38** by using one or more relays or other switching device(s) to connect a "hot" terminal RC to load terminals Y and/or G.

[0018] An example power stealing circuit **60** may obtain power from the transformers **14** and/or **18** for the thermostat **50**. In various embodiments of the disclosure, and as further described below, the power stealing circuit **60** may utilize "off-mode" and "on-mode" power stealing at the same time. Stolen power may be used for powering one or more components of the thermostat **50**. Stolen power also may be stored in one or more optional capacitors **64** and/or may be used, e.g., to power one or more circuits ancillary to the thermostat **50**, including but not limited to a radio transceiver **68**, a back light **72**, and/or one or more sensors **76**. In various embodiments, power from a battery (not shown) may be provided in the event, e.g., that power stealing is inoperable.

[0019] It should be noted generally that thermostat embodiments and/or power stealing circuit embodiments in accordance with various aspects of the disclosure could be installed in other types of climate control systems, including but not limited to systems having a single transformer, heat-only systems, cool-only systems, heat pump systems, etc. In some embodiments a C terminal may be provided, e.g., from the common side **30** of the transformer **14**. In some other embodiments, a thermostat may not be provided with a connection to a common C wire. Further, although the climate control system **10** shown in FIG. **1** provides single-stage heat and single-stage cooling, in various embodiments a thermostat having a power stealing circuit as described herein may be provided in a climate control system having multiple stages of heating and/or cooling.

[0020] An example embodiment of a power stealing circuit is indicated in FIG. **2** by reference number **100**. The power stealing circuit **100** may be adapted for use in a thermostat for any one of a plurality of climate control system types, e.g., systems having a single transformer, two-transformer systems, heat-only systems, cool-only systems, heat pump systems, etc. The power stealing circuit **100** may be configured to steal power through one or more climate control system loads. In various embodiments, and as further described below, the power stealing circuit **100** is configured to steal power from a load that is in an "on" mode and from another load that is in an "off" mode. In some example embodiments, power can be stolen, e.g., from both "on-mode" and "off-mode" loads at the same time. A switch **108**, which may be e.g., a jumper, a relay, transistor-based, etc., is provided to connect the power stealing circuit **100** selectively to one transformer, to two transformers, or to one of two transformer (s) (not shown) of a climate control system. In some example embodiments, the switch **108** is configurable, e.g., manually when a thermostat that includes the power stealing circuit **100** is installed in a climate control system.

[0021] The power stealing circuit **100** includes an "on-mode" stealing circuit **112** and an "off-mode" stealing circuit **114**. The "on-mode" stealing circuit **112** and "off-mode" stealing circuit **114** are connected across a capacitor **120** and regulator circuit **124**, e.g., a buck circuit. The "on-mode" stealing circuit **112** includes a current sensor **130**, a step-down current transformer **134**, and a rectifier **138**. The "off-mode" stealing circuit **114** includes a rectifier **142**.

[0022] The power stealing circuit **100** also includes a switch **146** controlled by a control **150**, e.g., a microprocessor. In various embodiments, the control **150** is a processor control unit (MCU) of a thermostat in which the power stealing circuit **100** is included. The control **150** may be made by, e.g., Texas Instruments Inc., Freescale Semiconductor, Inc., etc. Thus the control **150** may include a processor and memory configured to control thermostat functions, including, e.g., calling for heat or cooling in response to user input to the thermostat. As further described below, the control **150** is configured to detect operation of a load that is in the "on" mode. In response to the detecting, the control **150** may determine which load is in the "off" mode and connect the "off-mode" stealing circuit **114** with the "off-mode" load, so that power may be stolen from the "off-mode" load. For example, if a user has selected heating, then the control **150** can select a cooling circuit, e.g., through a Y circuit as shown in FIG. **1**, from which to steal power. In such event, the control **150** can control the switch **146** to select the Y circuit. Conversely, if the user has selected cooling, then the control **150** can select a heating circuit, e.g., through a W circuit as shown in FIG. **1**, from which to steal power. In such event, the control **150** can control the switch **146** to select the W circuit. If the user has selected an "auto" thermostat setting, then the control **150** can dynamically select an "off-mode" load as the loads are switched, e.g., from heat to cooling and vice versa.

[0023] In various embodiments and as further described below, stolen power may be transferred from one or more climate control system "hot" wires along one or more paths to produce a DC output voltage, e.g., for operating a radio transceiver and/or other thermostat components. Component values for power stealing circuits may vary dependent on the climate control systems in which the power stealing circuits are used. In one example embodiment the current sensor **130** may include four 1N4004 diodes, and the capacitor **120** may be a 4000 uF capacitor.

[0024] Another example embodiment of a thermostat power stealing circuit is indicated generally in FIGS. **3** and **4** by reference number **200**. The power stealing circuit **200** is configured in a thermostat **208** of an example climate control system **212**. Possible loads **214*a*-214*f*** of the climate control system **212** include two furnace heating stages **214*e*** and **214*f*** that may be powered through wires W and W2, two cooling stages **214*c*** and **214*d*** that may be powered through wires Y2 and Y, a fan **214*b*** powered through a wire G and a heat pump reversing valve **214*a*** powered through a wire O/B. Thermostat relays **218*a*-218*f*** are selectively operable to switch each load **214*a*-214*f*** into or out of operation in the climate control system **212**. The climate control system **212** is configured to use one transformer (not shown). A switch **220** (e.g., a jumper, relay, etc.) is configured to connect all of the loads **214*a*-214*f*** with a single "hot" wire RC.

[0025] An "on-mode" stealing circuit **224** of the power stealing circuit **200** includes a current sensor **228**, e.g., a clipping circuit connected between the "hot" wire RC and a current transformer **232**. A rectifier **236**, e.g., a full-wave bridge rectifier, is connected between the current transformer **232** and a capacitor **240**. The capacitor **240** is provided between and in parallel with the rectifier **236** and a regulator circuit **244**, e.g., a buck circuit. An "off-mode" stealing circuit **248** of the power stealing circuit **200** includes a rectifier **252**, e.g., a full-wave bridge rectifier. The rectifier **252** is connected with a switch **256** and also is connected across the capacitor **240**. The switch **256** is controlled by a control **260**. The control **260** detects the voltage of the capacitor **240**. If the voltage is high enough (e.g., over fifteen volts), the control **260** may control the regulator circuit **244** to output the voltage

264 to the load. Otherwise, the control **260** doesn't start the regulator circuit **244**. The regulator circuit **244** may include, e.g., an inductor and capacitor for alternately storing and outputting energy.

[0026] It should be understood generally that other or additional components could be used in place of and/or in addition to various components described herein. For example, in some embodiments, one or more half-wave rectifiers could be used in place of one or more full-wave rectifiers. Additionally or alternatively, other or additional types of regulator circuits could be used, e.g., other or additional converter circuits, boost circuits, integrated circuits, etc.

[0027] In the present example embodiment, the control **260** manages power stealing and manages the provision of stolen power through the regulator circuit **244** to components of the thermostat **208**. Thus, for example, the control **260** monitors voltage across the capacitor **240** and starts or shuts off operation of the regulator circuit **244**. If the voltage across the capacitor **240** is too low, the output of the regulator circuit **244** can't support the load. The control **260** also is configured to control the switch **256** for selectively connecting an "off-mode" load with the "off-mode" stealing circuit **248**.

[0028] The power stealing circuit **200** may be operable, e.g., as follows. Where, e.g., a user of the climate control system **212** operates the thermostat **208** to request cooling, the climate control system **212** may perform cooling, e.g., as shown in FIG. **3**. The relay **218*d*** is closed and thus the first cooling stage load **214*d*** is in an "on" mode. The first cooling stage load **214*d*** receives power through the "hot" wire RC, as indicated in FIG. **3** by double dashed lines **268**. Additionally, the "on-mode" stealing circuit **224** is activated to steal power through the first cooling stage load **214*d*,** along a path indicated by dashed line **272**. Specifically and for example, current through the load **214*d*** is sensed and clipped by the current sensor **228**. The sensed signal is reduced by the current transformer **232** and rectified by the rectifier **236**. The rectified signal may be filtered and stored by the capacitor **240**.

[0029] The control **260** detects that the first cooling stage load **214*d*** is in the "on" mode. In response the control **260** may operate the switch **256** to connect the "off-mode" stealing circuit **248** with an "off-mode" load, e.g., the first heating stage load **214*e***. "Off-mode" power stealing then may be performed along a path indicated by dashed line **276**. Specifically and for example, power may be stolen from the "off-mode" first heating stage load **214*e*** through the open relay **218*e*** and rectified by the rectifier **252**. The rectified signal may be filtered and stored by the capacitor **240**.

[0030] The control **260** manages provision of power to the thermostat **208** through the capacitor **240** and regulator circuit **244**. For example, the control **260** may control operation of the regulator circuit **244** based on a voltage level available from the capacitor **240**, e.g., so that the regulator circuit **244** may provide a substantially continuous output voltage **264**. In various embodiments, an output voltage of between about 3.3 and 3.6 volts may be provided.

[0031] Where, e.g., a user of the climate control system **212** operates the thermostat **208** to request heating, the climate control system **212** may perform heating, e.g., as shown in FIG. **4**. The relay **218*e*** is closed, and thus the first heating stage load **214*e*** is in an "on" mode. The first heating stage load **214*e*** receives power through the "hot" wire RC, as indicated by double dashed lines **280**. Additionally, the "on-mode" stealing circuit **224** is activated to steal power through the first heating stage load **214*e*,** along the path **272**. Specifically and for example, current through the load **214*e*** is sensed by the current sensor **228**. The sensed signal is reduced by the current transformer **232** and rectified by the rectifier **236**. The rectified signal may be filtered and stored by the capacitor **240**.

[0032] The control **260** detects that the first heating stage load **214*e*** is in the "on" mode. In response the control **260** may operate the switch **256** to connect the "off-mode" stealing circuit **248** with an "off-mode" load, e.g., the first cooling stage load **214*d*.** "Off-mode" power stealing then may be performed along a path **284**. Specifically and for example, power may be stolen from the "off-mode" first cooling stage load **214*d*** through the open relay **218*d*** and rectified by the rectifier **252**. The rectified signal may be filtered and stored by the capacitor **240**.

[0033] Another example embodiment of a power stealing circuit is indicated generally in FIG. **5** by reference number **300**. The power stealing circuit **300** is configured in a thermostat **308** of an example climate control system **312**. Possible loads **314*a*-314*f*** of the climate control system **312** include two furnace heating stages **314*e*** and **314*f*** that may be powered through wires W and W2, two cooling stages **314*c*** and **314*d*** that may be powered through wires Y2 and Y, a fan **314*b*** powered through a wire G and a heat pump reversing valve **314*a*** powered through a wire O/B. Thermostat relays **318*a*-318*f*** are selectively operable to switch each load **314*a*-314*f*** into or out of operation in the climate control system **312**. The climate control system **312** is configured to use two transformers (not shown). A switch **320** (e.g., a jumper, relay, etc.) is configured to connect the loads **314*e*** and **314*f*** with a "hot" wire RH. The loads **314*a*-314*d*** are connected with a "hot" wire RC.

[0034] An "on-mode" stealing circuit **324** of the power stealing circuit **300** includes a current sensor **328**, e.g., a clipping circuit connected between the "hot" wire RC and a current transformer **332**. A rectifier **336**, e.g., a full-wave bridge rectifier, is connected between the current transformer **332** and a capacitor **340**. The capacitor **340** is provided between and in parallel with the rectifier **336** and a regulator circuit **344**, e.g., a buck circuit. An "off-mode" stealing circuit **348** of the power stealing circuit **300** includes a rectifier **352**, e.g., a full-wave bridge rectifier. The rectifier **352** is connected with a switch **356** and also is connected across the capacitor **340**. The control **360** detects the voltage of the capacitor **340**. If the voltage is high enough (e.g., over fifteen volts), the control **360** may control the regulator circuit **344** to output the voltage **364** to the load. Otherwise, the control **360** doesn't start the regulator circuit **344**.

[0035] In the present example embodiment, the control **360** manages power stealing and manages the provision of stolen power through the regulator circuit **344** to components of the thermostat **308**. Thus, for example, the control **360** monitors voltage across the capacitor **340** and starts or shuts off operation of the regulator circuit **344**. If the voltage across the capacitor **340** is too low, the output of the regulator circuit **344** can't support the load. The control **360** also is configured to control the switch **356** for selectively connecting an "off-mode" load with the "off-mode" stealing circuit **348**.

[0036] The power stealing circuit **300** may be operable, e.g., as follows. Where, e.g., a user of the climate control system **312** operates the thermostat **308** to request heating, the climate control system **312** may perform heating, e.g., as shown in FIG. **5**. The relay **318*e*** is closed, and thus the first heating stage load **314***e* is in an "on" mode. The first heating stage load **314** receives power through the "hot" wire RH, as indicated by double dashed lines **368**.

[0037] The control **360** detects that the first heating stage load **314***e* is in the "on" mode. In response the control **360** may operate the switch **356** to connect the "off-mode" stealing circuit **348** with an "off-mode" load, e.g., the first cooling stage load **314***d*. "Off-mode" power stealing then may be performed along a path **372**. Specifically and for example, power may be stolen from the "off-mode" first cooling stage load **314***d* and rectified by the rectifier **352**. The rectified signal may be filtered and stored by the capacitor **340**.

[0038] Where, e.g., a user of the climate control system **312** operates the thermostat **308** to request cooling, the climate control system **312** may perform cooling, e.g., in the same or similar manner as discussed with reference to FIG. **3**. The relay **318***d* is closed and thus the first cooling stage load **314***d* is in an "on" mode. The first cooling stage load **314***d* receives power through the "hot" wire RC. Additionally, the "on-mode" stealing circuit **324** is activated to steal power through the first cooling stage load **314***d*. Specifically and for example, current through the load **314***d* is sensed by the current sensor **328**. The sensed signal is reduced by the current transformer **332** and rectified by the rectifier **336**. The rectified signal may be filtered and stored by the capacitor **340**.

[0039] The control **360** detects that the first cooling stage load **314***d* is in the "on" mode. In response the control **360** may operate the switch **356** to connect the "off-mode" stealing circuit **348** with an "off-mode" load, e.g., the first heating stage load **314***e*. "Off-mode" power stealing then may be performed. Specifically and for example, power may be stolen from the "off-mode" first heating stage load **314***e* and rectified by the rectifier **352**. The rectified signal may be filtered and stored by the capacitor **340**.

[0040] In some two-transformer climate control systems, embodiments are possible in which an "on-mode" stealing circuit is provided for each "hot" wire, to provide for "on-mode" power stealing from both transformers. In such an embodiment, both "on-mode" stealing circuits could be connected, e.g., across a single capacitor to provide input into a buck circuit to provide DC power.

[0041] Another example embodiment of a power stealing circuit is indicated generally in FIG. **6** by reference number **400**. The power stealing circuit **400** is configured in a thermostat **408** of an example climate control system **412**, which is a heat-only system having one transformer. Possible loads of the climate control system **412** include two furnace heating stages **414***a* and **414***b* that may be powered through wires W and W2. Thermostat relays **418***a* and **418***b* are selectively operable to switch each load **414***a* and **414***b* into or out of operation in the climate control system **412**. A switch **420** (e.g., a jumper, relay, etc.) is configured with a switch **492** (e.g., a jumper, relay, etc.) to connect the loads **414***a* and **414***b* with a single "hot" wire RH.

[0042] The power stealing circuit **400** may be operable, e.g., as follows. Where, e.g., a user of the climate control system **412** operates the thermostat **408** to request heating, the climate control system **412** may perform heating, e.g., as follows. The relay **418***a* is closed, and thus the first heating stage load **414***a* is in an "on" mode. The first heating stage load **414***a* receives power through the "hot" wire RH. Additionally, an "on-mode" stealing circuit **424** is activated to steal power through the first heating stage load **414***a* for storage by a capacitor **440** in the same or a similar manner as previously described. Because the example climate control system **412** does not provide cooling, there are no "off-mode" cooling loads available through which to perform "off-mode" power stealing while heating is being performed. But, e.g., when the load **414***a* is switched off, a control **460** uses a switch **456** to connect the load **414***a* with an "off-mode" stealing circuit **448** so that off-mode power stealing may be performed.

[0043] In many conventional thermostats, a jumper needs to be installed between heating and cooling terminals (RH and RC) so that the thermostat may be used in a single-transformer climate control system that provides both heating and cooling. It should be noted that for a given single-transformer system, an embodiment of a thermostat power stealing circuit in which RH and RC terminals of the thermostat are connected through a switch (such as the switch **220** of FIGS. **3** and **4**) makes it unnecessary to install a jumper between RH and RC terminals of the thermostat.

[0044] Various combinations of on-mode and/or off-mode power stealing could be performed in climate control systems in accordance with various implementations of the disclosure. In various two-transformer embodiments, an "on-mode" stealing circuit could be provided in connection with either transformer or connection with both transformers. Although first stage heating and cooling loads were referred to as being subject to various ways of on-mode and/or off-mode power stealing, other or additional types of loads, including but not limited to second stage loads, heat pump reversing valves, etc. could be subject to various ways of on-mode and/or off-mode power stealing.

[0045] Various climate control system types may lend themselves to various types of power stealing. For example, in a single-transformer system that includes a fan, a compressor, and a furnace, on-mode power may be stolen, e.g., from the compressor. In such case, a switch may be control-activated so as to provide a connection for stealing off-mode power, e.g., from the furnace. Conversely, on-mode power may be stolen, e.g., from the furnace. In such case, a switch may be control-activated so as to provide a connection for stealing off-mode power, e.g., from the compressor.

[0046] In a single-transformer, cooling-only system that includes a fan and a compressor, on-mode power may be stolen, e.g., from the compressor. When the compressor is switched off, off-mode power may be stolen from the compressor. Thus, power stealing may be performed substantially continuously in such a system. In a single-transformer system that has a heat pump, on-mode power may be stolen, e.g., from a compressor and/or heater. Off-mode power may be stolen, e.g., from the heater. In various embodiments, power stealing may be provided so as to take into account the various impedances of climate control system loads. For example, a typical fan load may be about 2 kΩ, a typical first-stage cooling load may be about 1 kΩ, and a typical first-stage heating load may be about 667Ω.

[0047] The foregoing power stealing circuit examples can be seen to embody various example methods of performing power stealing for a climate control system controller. For example, one implementation of a control-performed method includes monitoring a plurality of climate control system loads. Based on the monitoring, the control may detect whether one of the loads is in an "on" mode. In response to the detecting, the control may actuate power stealing from an "off-mode" load. Additionally or alternatively, a control in a climate control system may actuate power stealing from an "off-mode" load of the climate control system regardless of whether or not another load of the climate control system is in an "on" mode.

[0048] The foregoing apparatus, systems and methods make it possible to provide a thermostat with power sufficient to operate a wireless transceiver or other wireless module. Power stealing can be particularly effective in embodiments in which power can be stolen from both "on-mode" (e.g., a regular load situation) and "off-mode" loads at the same time. Using a capacitor as an energy storage medium makes it possible to provide substantially continuous power to a transceiver. Embodiments of the regulator circuit can provide highly efficient power transfer. Further, in various embodiments, power can be stolen from a number of different loads, which can be changed in response to different operating conditions in a climate control system.

[0049] Although various embodiments of the disclosure are described with reference to thermostats, other or additional configurations are possible in relation to devices, controllers, controls, and control systems other than thermostats. Power stealing could be implemented, e.g., in relation to a device that has access to two or more load circuits, such that at a given time one of the circuits would be available from which to steal power in accordance with aspects of the present disclosure.

[0050] Thus, exemplary embodiments or implementations are disclosed of a controller for use in a climate control system, the controller comprising a power stealing circuit configured to steal power from a first load that is in an "on" mode and from a second load that is in an "off" mode, the stealing performed from the first and second loads at the same time.

[0051] The controller may further comprise a processor configured to: detect operation of the first load in the "on" mode; and selectively connect the power stealing circuit with the second load in the "off" mode in response to detection of the first load in the "on" mode. The power stealing circuit of the controller may comprise a regulator circuit and a capacitor configured to provide input to the regulator circuit; and the processor is configured to control operation of the regulator circuit based on a voltage across the capacitor.

[0052] The power stealing circuit may comprise: an "off-mode" stealing circuit; and a processor-controlled switch for connecting the "off-mode" stealing circuit with the second load based on operation of the first load in the "on" mode.

[0053] The power stealing circuit may include a current transformer through which power is stolen from the first load in the "on" mode. The power stealing circuit may include a capacitor and regulator circuit through which power is provided to the controller and/or one or more circuits ancillary to the controller.

[0054] The controller may be a thermostat.

[0055] Additionally or alternatively, exemplary embodiments or implementations are disclosed of a controller for use in a climate control system, the controller comprising a power stealing circuit; and a processor configured to: detect "on-mode" operation of a first load of the climate control system; and selectively connect the power stealing circuit with a second load in an "off" mode in response to detection of the "on-mode" operation of the first load; whereby the power stealing circuit is configured to steal power from the first and second loads at the same time.

[0056] In the foregoing controller, the power stealing circuit may comprise a capacitor and a regulator circuit configured to provide an output voltage, and the processor may be further configured to monitor the capacitor, and control the regulator circuit based on the monitoring. The power stealing circuit may further comprise a switch controllable by the processor to selectively connect the power stealing circuit with the second load. The power stealing circuit may further comprise an "on-mode" stealing circuit and an "off-mode" stealing circuit each selectively switchable between loads of the climate control system.

[0057] Additionally or alternatively, exemplary embodiments or implementations are disclosed of a control-performed method of stealing power in a climate control system to operate a controller of the climate control system.

[0058] The method comprises: monitoring a plurality of loads of the climate control system; detecting that one of the loads is in an "on" mode; and in response to the detecting, actuating power stealing from one of the loads that is in an "off" mode; the method being performed while power is being stolen from the one of the loads that is in the "on" mode. The plurality of loads may be powered from a single transformer. The method may further comprise combining power stolen from the load in the "off" mode with power stolen from the load in the "on mode" to provide a voltage output for use by the controller.

[0059] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms, and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail. In addition, advantages and improvements that may be achieved with one or more exemplary embodiments of the present disclosure are provided for purpose of illustration only and do not limit the scope of the present disclosure, as exemplary embodiments disclosed herein may provide all or none of the above mentioned advantages and improvements and still fall within the scope of the present disclosure.

[0060] Specific dimensions, specific materials, and/or specific shapes disclosed herein are example in nature and do not limit the scope of the present disclosure. The disclosure herein of particular values and particular ranges of values for given parameters are not exclusive of other values and ranges of values that may be useful in one or more of the examples disclosed herein. Moreover, it is envisioned that any two particular values for a specific parameter stated herein may define the endpoints of a range of values that may be suitable for the given parameter (i.e., the disclosure of a first value and a second value for a given parameter can be interpreted as disclosing that any value between the first and second values could also be employed for the given parameter). For example, if Parameter X is exemplified herein to have value A and also exemplified to have value Z, it is envisioned that parameter X may have a range of values from about A to about Z. Similarly, it is envisioned that disclosure of two or more ranges of values for a parameter (whether such ranges are nested, overlapping or distinct) subsume all possible combination of ranges for the value that might be claimed using endpoints of the disclosed ranges. For example, if parameter

X is exemplified herein to have values in the range of 1-10, or 2-9, or 3-8, it is also envisioned that Parameter X may have other ranges of values including 1-9, 1-8, 1-3, 1-2, 2-10, 2-8, 2-3, 3-10, and 3-9.

[0061] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0062] When an element or layer is referred to as being "on," "engaged to," "connected to," or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0063] The term "about" when applied to values indicates that the calculation or the measurement allows some slight imprecision in the value (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If, for some reason, the imprecision provided by "about" is not otherwise understood in the art with this ordinary meaning, then "about" as used herein indicates at least variations that may arise from ordinary methods of measuring or using such parameters. For example, the terms "generally," "about," and "substantially," may be used herein to mean within manufacturing tolerances. Or, for example, the term "about" as used herein when modifying a quantity of an ingredient or reactant of the invention or employed refers to variation in the numerical quantity that can happen through typical measuring and handling procedures used, for example, when making concentrates or solutions in the real world through inadvertent error in these procedures; through differences in the manufacture, source, or purity of the ingredients employed to make the compositions or carry out the methods; and the like. The term "about" also encompasses amounts that differ due to different equilibrium conditions for a composition resulting from a particular initial mixture. Whether or not modified by the term "about," the claims include equivalents to the quantities.

[0064] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0065] Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0066] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements, intended or stated uses, or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

What is claimed is:

1. A controller for use in a climate control system, the controller comprising:

a power stealing circuit configured to steal power from a first load that is in an "on" mode and from a second load that is in an "off" mode, the stealing performed from the first and second loads at the same time.

2. The controller of claim **1**, further comprising a processor configured to:

detect operation of the first load in the "on" mode; and

selectively connect the power stealing circuit with the second load in the "off" mode in response to detection of the first load in the "on" mode.

3. The controller of claim **2**, wherein:

the power stealing circuit comprises a regulator circuit and a capacitor configured to provide input to the regulator circuit; and

the processor is configured to control operation of the regulator circuit based on a voltage across the capacitor.

4. The controller of claim **1**, wherein the power stealing circuit comprises:

an "off-mode" stealing circuit; and

a processor-controlled switch for connecting the "off-mode" stealing circuit with the second load based on operation of the first load in the "on" mode.

5. The controller of claim **1**, wherein the power stealing circuit comprises a current transformer through which power is stolen from the first load in the "on" mode.

6. The controller of claim **1**, wherein the power stealing circuit comprises a capacitor and regulator circuit through which power is provided to the controller and/or one or more circuits ancillary to the controller.

7. The controller of claim **1**, comprising a thermostat.

8. The controller of claim **1**, wherein the power stealing circuit further comprises an "on-mode" stealing circuit and an "off-mode" stealing circuit each selectively switchable between loads of the climate control system.

9. A controller for use in a climate control system, the controller comprising:

a power stealing circuit; and

a processor configured to:

detect "on-mode" operation of a first load of the climate control system; and

selectively connect the power stealing circuit with a second load in an "off" mode in response to detection of the "on-mode" operation of the first load;

whereby the power stealing circuit is configured to steal power from the first and second loads at the same time.

10. The controller of claim **9**, wherein:

the power stealing circuit comprises a capacitor and a regulator circuit configured to provide an output voltage; and

the processor is further configured to:

monitor the capacitor; and

control the regulator circuit based on the monitoring.

11. The controller of claim **9**, wherein the power stealing circuit comprises a switch controllable by the processor to selectively connect the power stealing circuit with the second load.

12. The controller of claim **8**, wherein the power stealing circuit further comprises an "on-mode" stealing circuit and an "off-mode" stealing circuit each selectively switchable between loads of the climate control system.

13. The controller of claim **9**, comprising a thermostat.

14. A control-performed method of stealing power in a climate control system to operate a controller of the climate control system, the method comprising:

monitoring a plurality of loads of the climate control system;

detecting that one of the loads is in an "on" mode; and

in response to the detecting, actuating power stealing from one of the loads that is in an "off" mode;

the method performed while power is being stolen from the one of the loads that is in the "on" mode.

15. The method of claim **14**, wherein the plurality of loads are powered from a single transformer.

16. The method of claim **14**, further comprising combining power stolen from the load in the "off" mode with power stolen from the load in the "on mode" to provide a voltage output for use by the controller.

17. The method of claim **14**, wherein the controller is a thermostat installed in the climate control system without installing a jumper between heating and cooling terminals of the thermostat.

18. The method of claim **14**, further comprising controlling a switch to select between the loads.

19. The method of claim **14**, further comprising:

monitoring a capacitor configured to provide input to a regulator circuit of the power stealing circuit where the regulator circuit provides an output voltage for use by the controller; and

controlling operation of the regulator circuit based on the monitoring.

20. The method of claim **19**, wherein the operation of the regulator circuit is controlled based on a voltage across the capacitor.

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