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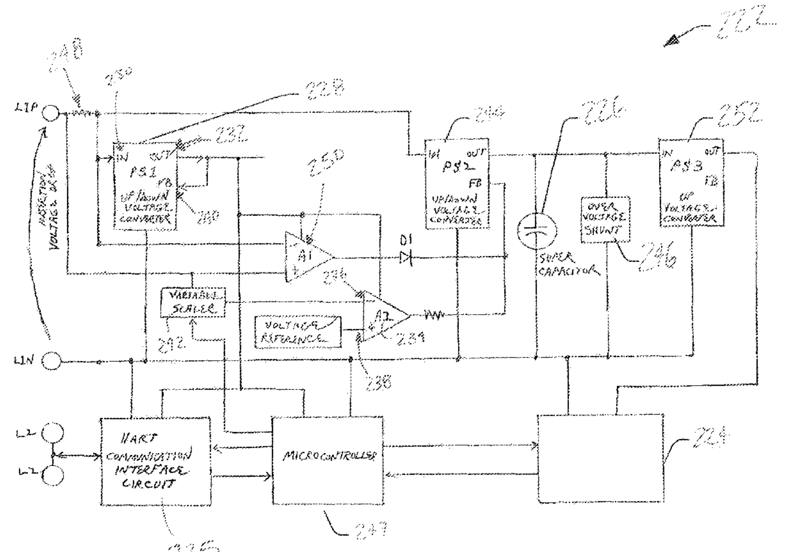

FIG. 3

(57) Abstract: A power management circuit includes a power regulator and a wireless communication device. The power regulator is configured to maintain a voltage level at an input and includes an input and an output. The input is configured to receive a current signal communicated between a power supply and a field device. The output is configured to deliver charging power. The wireless communication device is in electrical communication with the power regulator and is configured to receive the charging power from the power regulator to power the wireless communication device. The charging power is generated from the voltage level at the input and the current signal. The charging power also changes in response to a change in the current signal. Process control systems and methods are also provided.

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POWER MANAGEMENT CIRCUIT FOR A WIRELESS COMMUNICATION DEVICE AND PROCESS CONTROL SYSTEM USING SAME

Mark Sinreich

REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority of U.S. Provisional Application Serial No. 60/937,396, filed June 26, 2007, U.S. Provisional Application Serial No. 60/937,397, filed June 26, 2007, U.S. Provisional Application Serial No. 61/012,262 filed December, 07, 2007, the entire disclosures of which are hereby incorporated herein by reference.

TECHNICAL FIELD

[0002] The systems and methods relate generally to the field of process control systems. More specifically, the disclosed systems and methods relate to field devices powered at least partly by process control loops.

BACKGROUND

[0003] Conventional process control systems generally include basic components for sensing, measuring, evaluating, and adjusting or otherwise controlling a variety of process variables. Additionally, common systems include components that provide means for communicating information about process control variables between sensing, measuring, or adjusting components and evaluation components. One such system for communicating information is a two-wire system that creates a loop that physically connects a sensing, measuring, evaluating, or adjusting device to a controller.

[0004] Sensing, measuring, evaluating, and/or adjusting devices in industrial production environments are generally referred to as field devices. Field devices commonly sense or monitor one or more process control variables such as temperature, pressure, or rate of fluid flow, among others. Many of these field devices can communicate information about the sensed or monitored variable to a process controller by regulating electrical current on the two-wire system. The controller in this type of environment can sense the electrical current, such as by using a current sense resistor, and translate the sensed magnitude of the current, as well as any sensed change of the current, into information about the sensed or monitored control variable. Many common field devices can receive information from the controller and effect changes or adjustments to the sensed or monitored control.

[0005] Two methods of communicating information using a multi-wire loop system include analog signaling methods, such as communicating information via an analog current signal, and digital signaling methods that can communicate information as a frequency shift keyed carrier signal which can be superimposed on, and coexist with, an analog signaling method on the multi-wire loop. One digital signaling method is the Highway Addressable Remote Transducer ("HART") communications protocol from the HART® Communication Foundation. As referred to herein, HART refers to any past or present version of the HART protocol, including Wireless HART, variants of such versions, as well as any future version that may be created so long as those future versions are compatible or can be modified to be compatible with the systems and methods disclosed herein.

SUMMARY

[0006] According to one embodiment, a power management circuit can comprise a power regulator and a wireless communication device. The power regulator is configured to maintain a voltage level at an input and includes an input and an output. The input is configured to receive a current signal communicated between a power supply and a field device. The output is configured to deliver charging power. The wireless communication device is in electrical communication with the power regulator and is configured to receive the charging power to power the wireless communication device. The charging power is generated from the voltage level at the input and the current signal. The charging power also changes in response to a change in the current signal.

[0007] A process control system comprises a field device, a power supply, and a power management circuit. The power supply is in electrical communication with the field device. The power supply is configured to transmit a current signal to the field device. The field device is configured to regulate the current signal. The power management circuit is in electrical communication with each of the field device and the power supply. The power management circuit comprises a power regulator and a wireless communication device. The power regulator is configured to maintain a voltage level at an input. The power regulator includes an input and an output. The input is configured to receive the current signal. The output is configured to deliver charging power. The wireless communication device is in electrical communication with the power regulator and is configured to receive the charging power to power the wireless communication device. The charging power is generated from the voltage level at the input and the current signal. The charging power changes in response to a change in the current signal.

[0008] A method for managing power for a wireless communication device comprises receiving a current signal at an input, the current signal being transmitted between a power supply and a field device. The method further comprises regulating a voltage level at the input and generating charging power from the voltage level at the input and the current signal, wherein the charging power changes in response to a change in the current signal. The method yet further comprises delivering the charging power to an electrical storage device and delivering the charging power from the electrical storage device to a wireless communication device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] While the specification concludes with claims particularly pointing out and distinctly claiming the present invention, it is believed that the same will be better understood from the following description taken in conjunction with the accompanying drawings in which:

[0010] FIG. 1 is a system block diagram of a process control loop;

[0011] FIG. 2 is a system block diagram of a process control loop; and

[0012] FIG. 3 is a system block diagram of a power management circuit.

DETAILED DESCRIPTION

[0013] Most components and methods disclosed are described with reference to the drawings. In drawings, like reference numbers are used to refer to like elements throughout the drawings. In the following description, to aid in explanation, a number of specific details are provided to promote understanding of the disclosed subject matter. It may be evident, however, that certain of these specific details can be omitted or combined with others in a specific implementation. In other instances, certain structures and devices are shown in block diagram form in order to facilitate description. Further, it should be noted that although specific examples presented can include or reference specific components, a specific implementation of the components and methods disclosed and described is not necessarily limited to those specific examples and can be employed in other contexts as well. Those of ordinary skill in the art will readily recognize that the disclosed and described components and methods can be used to create other components and execute other methods in a wide variety of ways.

[0014] FIG. 1 is a system block diagram of a process control system 100. As illustrated, a field device 102 can include connection terminals 104, 106 to which control loop wires 108, 110 can be connected. A controller 112 can include a power supply 114 that is operable to supply electrical current (e.g., loop current) and voltage to the control loop wires 108, 110. In particular, a positive terminal of the power supply 114 can be in electrical communication with the control loop wire 108 and a negative terminal of the power supply 114 can be in electrical communication with the control loop wire 110. In one embodiment, the power supply 114 can produce loop current magnitudes levels from approximately 3.5mA to approximately 20mA during normal operation, with maximum current values as high as approximately 130mA during maximum fault conditions. However, any of a variety of other current or voltage ranges may be provided by the power supply, such as may correspond with voltage and current parameters for a particular field device, for example.

[0015] In one embodiment, as illustrated in FIG. 1, the field device 102 can include a current regulator 116 that is operable to change amounts of loop current provided through the control loop wires 108, 110. Using the current regulator 116, the field device 102 can regulate the amounts of electrical current to communicate a control process variable to the controller 112. For example, if the field device 102 is configured to sense temperature, the current regulator 116 can regulate the amounts of current provided through the control loop wires 108, 110 to indicate the monitored temperature. It will be appreciated that any of a variety of suitable alternative embodiments can indicate a control process variable in the field device such as, for example, a current shunt, a voltage shunt, or the like.

[0016] In order to communicate the amount of current to the controller 112, in one embodiment, the controller 112 can include a current sense resistor 118 which can operate to sense the loop current provided through the control loop wires 108, 110. However, it will be appreciated that the controller 112 can sense loop current or other variable in any of a variety of suitable alternative configurations. Additionally or alternatively, the process control system 100 can include digital signaling components (not shown) to facilitate the communication of information as a carrier signal on the control loop wires 108, 110. In one embodiment, the field device 102 can include HART communication components, such as wireless HART communication components. However, the process control system can include components for any of a variety of suitable alternative communication protocols such as, for example, ISA SP100 and Fieldbus among others.

[0017] It will be appreciated however, that in some embodiments, the controller 112 may not support digital signaling methods such as, for example, when digital signaling equipment is not present on the controller 112 or during failure of digital signaling equipment. Therefore, in one embodiment, as illustrated in FIG. 2, a wireless adapter device 220 can be provided. As will be described in more detail below, the wireless adapter device 220 can include components and circuitry that are configured to provide wireless radio frequency ("RF") communications with an RF-based network in a facility that can communicate with a controller 212 or other suitable host controller. The wireless adapter device 220 can function as a gateway between components that can provide digital signaling for a field device 202 and a wireless communication network in a facility. The controller 212 can be implemented as the controller 112 of FIG. 1 or as another suitable controller. The field device 202 can be the field device 102 depicted and described in FIG. 1 or can be another suitable field device.

[0018] Conventionally, the wireless adapter device 220 can be powered by dedicated power sources such as, for example, a separate wired power circuit, a battery, or a solar power cell, among others. However, installation and maintenance of a wireless adapter device powered by these dedicated power sources can be costly and time consuming. Therefore, as illustrated in FIG. 3, the wireless adapter device 220 can provided in electrical communication with the control loop wires 208a, 208b, 210a, 210b such that the wireless adapter device 220 can be powered from loop current through the control loop wires 208a, 208b, 210a, 210b. In such an embodiment, the wireless adapter device 220 can include a power management circuit 222 provided between nodes L1P and L1N which can be connected in series with the control loop wires 208a and 208b. As described in more detail below, the insertion power can be provided to the power management circuit 222 to power the wireless adapter device 220 without substantially interfering with the loop current. Accordingly, the wireless adapter device 220 can be powered by the process control system 200 without hindering the field device 202 from communicating a control process variable to the controller 212 (e.g., via current on process control wires 208a, 208b, 210a, 210b).

[0019] FIG. 3 is a system block diagram of one embodiment of the power management circuit 222. It will be appreciated that, the power management circuit 222 can be used in any of a variety of process control systems such as illustrated in FIGS. 1 and 2, among other systems. The power management circuit 222 can be electrically connected between nodes L1P and L1N to facilitate the flow of loop current through the power management circuit 222 when the nodes L1P and L1N are connected in series with the process control wires 208a and 208b. The power management circuit 224 can include a wireless communication device 224. The wireless communication device 224 can be configured to provide wireless RF communications to transmit information (e.g., process variable information) between the wireless adapter device 220 and an RF based network in a facility. In certain embodiments, the wireless communication device 224 can include a transceiver that is supportive of any of a variety of wireless platforms such as IEEE 802.11b, IEEE 802.11g, Bluetooth, microwave, infrared, or the like. In addition, the power management circuit can further include HART interface logic 225 associated with the wireless communication device 224 to facilitate communication according to a HART protocol.

[0020] It will be appreciated that the wireless communication device 224 can consume more power than is instantaneously provided by the insertion power. Accordingly, the power management circuit 222 can store electrical power in order to power the wireless communication device 224. In one embodiment, the power management circuit 222 can include an electrical storage element configured to store insertion power and deliver the stored insertion power to the wireless communication device 224 as needed. Although the electrical storage device is illustrated in FIG. 3 to comprise a supercapacitor 226, it will be appreciated that, any of a variety of alternative suitable electrical storage devices can be provided such as capacitor or a battery, for example.

[0021] The power management circuit 222 can power the wireless communication device 224 and charge the electrical storage device from loop current. In particular, loop current can be provided through the power management circuit 222 and can induce an insertion voltage drop across nodes L1P and L1N. It will be appreciated that the power available from the loop current to power the wireless communication device 224 and charge the electrical storage device (e.g., insertion power) is generally the multiplicative product of a magnitude of the loop current provided through the power management circuit 222 and the insertion voltage drop.

[0022] It will be appreciated that the insertion voltage drop induced by the flow of current through the power management circuit can provide an additional voltage drop to the process control system 200. When the wireless adapter device 220 is connected between nodes L1P and L1N, the magnitude of the insertion drop voltage should be such, that when the insertion drop voltage is combined with the other voltage losses in the process control system 200, the power supply voltage is not exceeded. For example, the combined voltage losses across the process control wires 208a, 208b, 210a, 210b, the wireless adapter device 220, the field device 202, and the current sense resistor 218 should be maintained at or below the power supply voltage.

[0023] It will be appreciated that the power supply voltage and corresponding voltage losses can vary for different process control system configurations. Conventionally, the insertion voltage drop on a power management circuit is permanently set at a low level (e.g., about 1 Volt DC ("VDC")) in order to ensure compatibility with various process control system configurations. However, if these conventional power management circuits are provided on a process control system with low cumulative voltage losses, insertion power can be lost. For example, if the power supply 214 can supply about a 5 VDC voltage, and the combined voltage losses of a process control system (ignoring the insertion voltage drop) total about 2 VDC, the process control system can accept an insertion voltage drop of up to about 3 VDC. However, if the insertion voltage drop of the conventional power management circuit has been set at about 1 VDC, the insertion power will be comparatively less than a conventional management circuit having an insertion voltage drop of about 3 VDC. Therefore, the power management circuit 222 can be configured to control the insertion voltage drop (e.g., stabilize, regulate) to maximize the insertion power for any of a variety of process control system configurations.

[0024] It will be appreciated that the insertion voltage drop of a conventional power management circuit can be controlled with a current shunt provided in parallel with the power management circuit. The current shunt can control the insertion voltage drop by balancing the loop current with a combination of current consumption in the power management circuit plus the current consumption in the current shunt (e.g., a current divider circuit). As the loop current changes with a process variable, the current shunt can regulate the current flow through each of the shunt and the power management circuit, to maintain a constant insertion voltage drop. It will be appreciated however, that any current that flows through the current shunt may not be available to the power management circuit to power the wireless adapter device, and thus can be wasted power.

[0025] The power management circuit 222, however, can be configured to control the insertion voltage drop while allowing full loop current (less the miniscule current consumed by the other circuits) to flow to the power management circuit 222 (e.g., to power the wireless adapter device 220). In one embodiment, the power management circuit 222 can include a voltage converter 228 having an input 230 and an output 232. The input 230 is configured to receive loop current from node L1P and the output 232 is configured to deliver insertion power derived from the loop current.

[0026] In some conventional configurations, voltage converters, such as voltage converter 228, can maintain a consistent voltage level at the output 232 by varying the power transferred from the input 230. Generally, this conventional voltage regulator configuration is suitable where there is ample power provided at the input 230 (e.g., to satisfy the power demands of a circuit electrically connected to the output 232 of the voltage regulator). However, when the current and power provided at the input 230 is limited, as is the case with the loop current, and the demand on the output is significant, as is the case with the electrical storage device, this common voltage converter configuration may quickly transfer too much power to the output 232 thereby reducing the insertion voltage drop at input 230.

[0027] The voltage converter 228, therefore, can be configured as a power converter whereby the insertion power can be balanced with the power transferred into the electrical storage device to maintain the insertion voltage drop at the input 230 at a controlled value. In one embodiment, to facilitate the configuration of the voltage converter 228 as a power converter, the insertion voltage drop can be compared with a fixed reference voltage to regulate the insertion voltage drop to a fixed value. For example, as illustrated in FIG. 3, the power management circuit 222 can include a feedback circuit configured to maintain the insertion voltage drop at the input according to a reference voltage. The feedback circuit can include an amplifier 234. A negative input 236 of the amplifier 234 can be connected to a reference voltage 241 while the insertion voltage drop can be provided to a positive input 238 of the amplifier 234. The amplifier 234 can compare the insertion voltage drop to the reference voltage and then provide a control signal to a feedback input 240 of the voltage converter 228. It will be appreciated, however, that a power converter can be provided in any of a variety of suitable alternative arrangements to maintain an insertion voltage drop at a particular level.

[0028] In such a configuration, the voltage converter 228 can overcome some of the shortcomings of using a current shunt in a power management circuit. For example, the insertion power (less the miniscule power consumed by the other circuits) generated from the insertion voltage drop and the loop current can be delivered to the output 232 of the voltage converter 228 (e.g., charging power). In addition, the delivery power can response to a change in the loop current for a greater range of loop current magnitudes. For example, when the loop current changes (e.g., when a control process variable changes) the power management circuit 222 can dynamically adjust to allow for the additional loop current. This additional loop current, when multiplied by the insertion voltage drop, can provide more insertion power than can be provided with a conventional power management circuit. For example, if a 20mA loop current is generated by the power supply 214 and provided to a conventional power management circuit, the current shunt would only allow a portion of the loop current to flow through the conventional power management circuit. If the insertion voltage drop is controlled to about 1 VDC and the current shunt is configured to allow 50% loop current through the conventional power management circuit, the insertion power will be about 10mW. However, if a 20mA loop current is generated by the power supply 214 and provided to the power management circuit 222, the entire loop current would flow through the power management circuit 222. If the insertion voltage drop is controlled to about 1 VDC, the insertion power would be about 20mW.

[0029] As illustrated in FIG. 3, the supercapacitor 226 can be in electrical communication with the output 232 of the voltage converter 228. The voltage converter 228 can utilize the available insertion power to charge the supercapacitor 226 to a desired level. It will be appreciated however, that a capacity of an electrical storage device can be many times greater than the insertion power such that charging of the electrical storage device can take a relatively long period of time (potentially ranging from approximately one minute to hours). To attempt to optimize use of power stored in the electrical storage device (e.g., to fully exhaust the power stored), power can be delivered from the electrical storage device for a range of capacities. For example, power can be delivered to the electrical storage device when the electrical storage device is at maximum capacity, as well as when the electrical storage device is close to zero capacity. To facilitate the delivery of power from the electrical storage device to the wireless communication device 224, as illustrated in FIG. 3, a voltage converter 244 can be provided in electrical communication with each of the supercapacitor 226 and the wireless communication device 224. The voltage converter 244 can be configured to regulate the power delivered from the supercapacitor 226 to the wireless communication device. In one embodiment, the voltage converter 244 can generate a constant regulated output voltage regardless of whether the supercapacitor 226 is charged to maximum capacity, or is nearly depleted.

[0030] The power management circuit 222 can be configured to define a variable setpoint to vary the insertion voltage drop. By varying the insertion voltage drop, the insertion power made available to the power management circuit 222 can be changed. In certain embodiments, where a range of insertion voltage drop values may be appropriate, the insertion voltage drop can be increased to a maximum value (in light of the other cumulative voltage losses of the process control system 200) to provide increased insertion power to the power management circuit 222. Increasing this insertion power may improve the rate at which the electrical storage component stores power and how much total average power can be available to operate the wireless communication device 224.

[0031] It will be appreciated that the variable setpoint can defined in any of a variety of configurations. In one embodiment, a variable scalar circuit can be provided in communication with the feedback circuit. In such an embodiment, the variable scalar circuit can be configured to facilitate selective control of the insertion voltage drop. For example, as illustrated in FIG. 3, a variable scaler 242 can be provided between the positive input 238 of the amplifier 234. The variable scaler 242 can provide a programmable variable setpoint for the insertion voltage drop. A microcontroller 247 can be provided to facilitate control of the variable scaler 242. However, any of a variety of additional or alternative components can facilitate control of the variable scaler 242. It will be appreciated that the variable setpoint can be configured at time of installation, or can be dynamically configured such as with the microcontroller 248 or across a wireless communication network by a host system as required or desired.

[0032] It will be appreciated that during charging of the electrical storage device and prior to the electrical storage device reaching capacity, the power delivered from the output 232 of the voltage converter 228 (less the miniscule power consumed by the other circuits) can be provided to charge the supercapacitor 226. However, as the supercapacitor 226 reaches maximum capacity, the voltage across the supercapacitor 226 can continue to rise beyond proper operating limits of the power management circuit 222. Rather than shunting current and power away from the power management circuit 222 with a current shunt, a voltage shunting circuit can be provided in communication with the supercapacitor 226. The voltage shunting circuit can be configured to prevent an over-voltage condition within the supercapacitor 226. In one embodiment, as illustrated in FIG. 3, a voltage shunt 246 can be provided in parallel with the supercapacitor 226, such that as the supercapacitor 226 reaches capacity, the voltage shunt 246 can bypass current and power to prevent the voltage across the supercapacitor 226 from further increasing. In such an embodiment, the power delivered from the output 232 of the voltage converter 228 (less the miniscule power consumed by the other circuits) can be shunted by the voltage shunt 246 to balance the power and regulate the voltage across the supercapacitor 226. As power is delivered from the supercapacitor 226 to the the wireless communication device 224, the voltage shunt 335 can cease shunting until the supercapacitor 226 is at capacity again.

[0033] It will be appreciated to power various components of the power management circuit 222, a stable voltage can be provided from the insertion voltage drop. In one embodiment, as illustrated in FIG. 3, a voltage converter 252 can be provided to create a constant regulated control voltage to power certain electronic components of FIG. 3.

[0034] The power management circuit 222 can provide fast deployment that allows the application of loop currents in excess of the loop current normal operating ranges (e.g., about 3.5-20mA, up to about 130mA). This fast deployment can allow a user installing wireless adapter device 220 to rapidly charge the electrical storage device to provide minimal delay after installation to power the wireless communication device 224. To facilitate this fast deployment, the power management circuit 222 includes a fast deployment circuit configured to sense a magnitude of the loop current, and when the magnitude of the loop current reaches a threshold value, maintain the voltage level at the input at an elevated level to facilitate a substantial increase in the charging power delivered to the electrical storage element. In one embodiment, the power management circuit 222 can include a sense resistor 248 and a loop current amplifier 250. The microcontroller 247 can monitor the loop current across the sense resistor 248 and compare it with a threshold value. When the magnitude of the loop current exceeds the threshold value, the microcontroller 247 can define a setpoint for maximum insertion voltage with using the variable scaler 242, and the power management circuit can then receive maximum insertion power. In one embodiment, the microcontroller can compare the loop current against a threshold value of 25mA. When the loop current exceeds 25mA for a period of time the variable scaler 242 can be set to provide a maximum insertion voltage drop.

[0035] The power management circuit 222 can include over-current protection. This over current protection can limit the amount of insertion power when an excessive amount of loop current is being provided to the power management circuit. To facilitate over-current protection the power management circuit 222 can include an over current protection circuit configured to sense the magnitude of the loop current and, when the magnitude of the loop current reaches an over-current threshold value, disable the power regulator. In one embodiment, over current protection circuit can include the sense resistor 248 and the loop current amplifier 250. The positive input and negative input of the loop current amplifier 250 can be electrically connected on opposite sides of the sense resistor 248 to monitor the magnitude of the loop current. If the loop current exceeds a maximum threshold, the output of the loop current amplifier can provide a signal to shut down the power regulator thereby limiting the insertion power provided to the power management circuit 222. In one embodiment, the loop current amplifier 250 can compare the loop current against about a 130mA threshold. When the loop current exceeds 130mA, the loop current amplifier 250 can provide a signal to shut down the power regulator.

[0036] The power management circuit 222 can include a power save capability. The power management circuit can monitor the loop current (e.g., through sense resistor 248). If the magnitude of the loop current is reduced to a negligible amount, the power management circuit 222 can power down all significant power consuming circuits to preserve the power stored in the electrical storage device. When the loop current regains a particular magnitude (e.g., greater than a negligible amount), the power management circuit 222 can return power to the circuits that were previously shut down. If a process control system has a power outage, this function can help ensure that the wireless adapter device 220 will be immediately available with the electrical storage device at capacity when power returns. If a user has pre-charged the wireless adapter device 220 (e.g., in a lab), this feature can ensure that the wireless adapter device 220 will be fully powered and immediately available to begin radio communications when it is installed on a process control system.

[0037] The power management circuit 222 can include an instant-on function, whereby an auxiliary power is established to power the internal control circuitry before the electrical storage element charges up.

[0038] The power management circuit 222 can include dynamic radio duty cycle management. In particular, the power management circuit 222 can inform a wireless communication network of the insertion power available to power the wireless communication device 224. Accordingly, the wireless communication network can dynamically configure a maximum radio duty cycle to match the insertion power available to power the wireless communication device 224. When the insertion power is elevated, a duty cycle can be increased to achieve faster update rates for changing process variables. However, when the insertion power is depleted, the duty cycle can be reduced to ensure that the power demand by the wireless communication network does not exhaust the storage capacity of the electrical storage device thereby causing an ultimately loss of radio communication until the electrical storage device can be recharged.

[0039] What has been described above includes illustrative examples of certain components and methods. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations are possible.

[0040] In particular and in regard to the various functions performed by the above described components, devices, circuits, systems and the like, the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (for example, a functional equivalent), even though not structurally equivalent to the disclosed structure, which performs the function in the examples provided. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired or advantageous for any given or particular application.

[0041] The foregoing description of embodiments and examples has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the forms described. Numerous modifications are possible in light of the above teachings. Some of those modifications have been discussed and others will be understood by those skilled in the art. The embodiments were chosen and described for illustration of various embodiments. The scope is, of course, not limited to the examples or embodiments set forth herein, but can be employed in any number of applications and equivalent devices by those of ordinary skill in the art. Rather it is hereby intended the scope be defined by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A power management circuit comprising:

a power regulator configured to maintain a voltage level at an input and including:

an input configured to receive a current signal communicated between a power supply and a field device; and

an output configured to deliver charging power; and

a wireless communication device in electrical communication with the power regulator and configured to receive the charging power to power the wireless communication device;

wherein the charging power is generated from the voltage level at the input and the current signal and wherein the charging power changes in response to a change in the current signal.

2. The power management circuit of claim 1 further comprising an electrical storage element in electrical communication with the output of the power regulator and configured to store the charging power and deliver the charging power to the wireless communication device.

3. The power management circuit of claim 2 further comprising a voltage regulator in electrical communication with each of the electrical storage element and the wireless communication device and configured to regulate the stored charging power delivered from the storage element to the wireless communication device.

4. The power management circuit of claim 2 further comprising a voltage shunting circuit in communication with the electrical storage device, the voltage shunting circuit being configured to prevent an over-voltage condition within the electrical storage device.

5. The power management circuit of claim 1 further comprising a feedback circuit configured to maintain the voltage level at the input in response to a reference voltage.

6. The power management circuit of claim 5 further comprising a variable scaler circuit in communication with the feedback circuit, the variable scaler circuit being configured to facilitate selective control of the voltage level at the input.

7. The power management circuit of claim 2 further comprising a fast-deployment circuit configured to sense a magnitude of the current signal and, when the magnitude of the current signal reaches a threshold value, maintain the voltage level at the input at an elevated level to facilitate a substantial increase in the charging power delivered to the electrical storage element.

8. The power management circuit of claim 1 further comprising an over-current protection circuit configured to sense a magnitude of the current signal and, when the magnitude of the current signal reaches an over-current threshold value, disable the power regulator.

9. The power management circuit of claim 1 wherein the power regulator is configured to regulate the voltage level at the input to a substantially constant value.

10. The power management circuit of claim 2 wherein the electrical storage element comprises at least one of a capacitor and a battery.

11. The power management circuit of claim 1 further comprising HART interface logic associated with the wireless communication device to facilitate communication according to a HART protocol.

12. The power management circuit of claim 1, wherein the power regulator is configured to maintain a voltage level of at least about 0.5 VDC at the input.

13. The power management circuit of claim 1, wherein the current signal includes a magnitude and the charging power is generated from the voltage level at the input and substantially the entire magnitude of the current signal.

14. A process control system comprising:

a field device;

a power supply in electrical communication with the field device, the power supply being configured to transmit a current signal to the field device and the field device being configured to regulate the current signal; and

a power management circuit in electrical communication with each of the field device and the power supply; the power management circuit comprising:

a power regulator configured to maintain a voltage level at an input and including:

an input configured to receive the current signal; and

an output configured to deliver charging power; and a wireless communication device in electrical communication with the power regulator and configured to receive the charging power to power the wireless communication device;

wherein the charging power is generated from the voltage level at the input and the current signal and wherein the charging power changes in response to a change in the current signal.

15. The process control system of claim 14 wherein the field device comprises a voltage transducer.

16. The process control system of claim 14 wherein the power management circuit is in serial electrical communication between the field device and the power supply.

17. The process control system of claim 14 further comprising an electrical storage element in electrical communication with the output of the power regulator and configured to store charging power and deliver the charging power to the wireless communication device.

18. The process control system of claim 17 further comprising a voltage regulator in electrical communication with each of the electrical storage element and the wireless communication device, the voltage regulator being configured to regulate the stored charging power delivered from the storage element to the wireless communication device.

19. The process control system of claim 17 further comprising a voltage shunting circuit in communication with the electrical storage device, the voltage shunting circuit being configured to prevent an overvoltage condition within the electrical storage device.

20. The process control system of claim 14 further comprising a feedback circuit configured to maintain the voltage level at the input in response to a reference voltage.

21. The process control system of claim 20 further comprising a variable scaler circuit in communication with the feedback circuit, the variable scaler circuit being configured to facilitate selective control of the voltage level at the input.

22. The process control system of claim 17 further comprising a fast-deployment circuit configured to sense a magnitude of the current signal and, when the magnitude of the current signal reaches a threshold value, maintain the voltage level at the input at an elevated level to facilitate a substantial increase in the charging power delivered to the electrical storage element.

23. The process control system of claim 14 further comprising an over-current protection circuit configured to sense a magnitude of the current signal and, when the magnitude of the current signal reaches an over-current threshold value, disable the power regulator

24. The process control system of claim 14 wherein the power regulator is configured to regulate the voltage level at the input to a constant value.

25. The process control system of claim 17 wherein the electrical storage element comprises at least one of a capacitor and a battery.

26. The process control system of claim 14 further comprising HART interface logic associated with the wireless communication device to facilitate communication according to a HART protocol.

27. The process control system of claim 14, wherein the power regulator is configured to maintain a voltage level of at least about 0.5 VDC at the input.

28. The process control system of claim 14, wherein the current signal includes a magnitude and the charging power is generated from the voltage level at the input and substantially the entire magnitude of the current signal.

29. A method for managing power for a wireless communication device, the method comprising:

receiving a current signal at an input, the current signal being transmitted between a power supply and a field device;

regulating a voltage level at the input;

generating charging power from the voltage level at the input and the current signal, wherein the charging power changes in response to a change in the current signal;

delivering the charging power to an electrical storage device; and

delivering the charging power from the electrical storage device to a wireless communication device.

30. The method of claim 29 further comprising storing the charging power within the electrical storage device.

31. The method of claim 30 wherein the electrical storage device comprises at least one of a capacitor and a battery.

32. The method of claim 30 further comprising regulating the stored charging power delivered from the storage element to the wireless communication device.

33. The method of claim 29 further comprising shunting the electrical storage device to prevent an overvoltage condition.

34. The method of claim 29 further comprising regulating the voltage level at the input in response to a reference voltage.

35. The method of claim 29 further comprising selectively controlling the voltage level at the input.

36. The method of claim 29 further comprising:

sensing a magnitude of the current signal; and

when the magnitude of the current signal reaches a threshold value, elevating the voltage level at the input to facilitate a substantial increase in the charging power delivered to the electrical storage element.

37. The method of claim 29 further comprising:

sensing a magnitude of the current signal; and

when the magnitude of the current signal reaches an over-current threshold value, disabling the power regulator.

38. The method of claim 29 further comprising regulating the voltage level at the input to a substantially constant value.

39. The method of claim 29 wherein the electrical storage element comprises at least one of a capacitor and a battery.

40. The method of claim 29 further comprising communicating process control variable information from the wireless communication device to a gateway.

41. The method of claim 40 further comprising communicating process control variable information via a HART protocol.

42. The method of claim 29 further comprising regulating the voltage level to at least about 0.5 VDC at the input.

43. The method of claim 29 wherein the current signal includes a magnitude, and generating charging power comprises generating charging power from and the voltage level at the input and substantially the entire magnitude of the current signal.

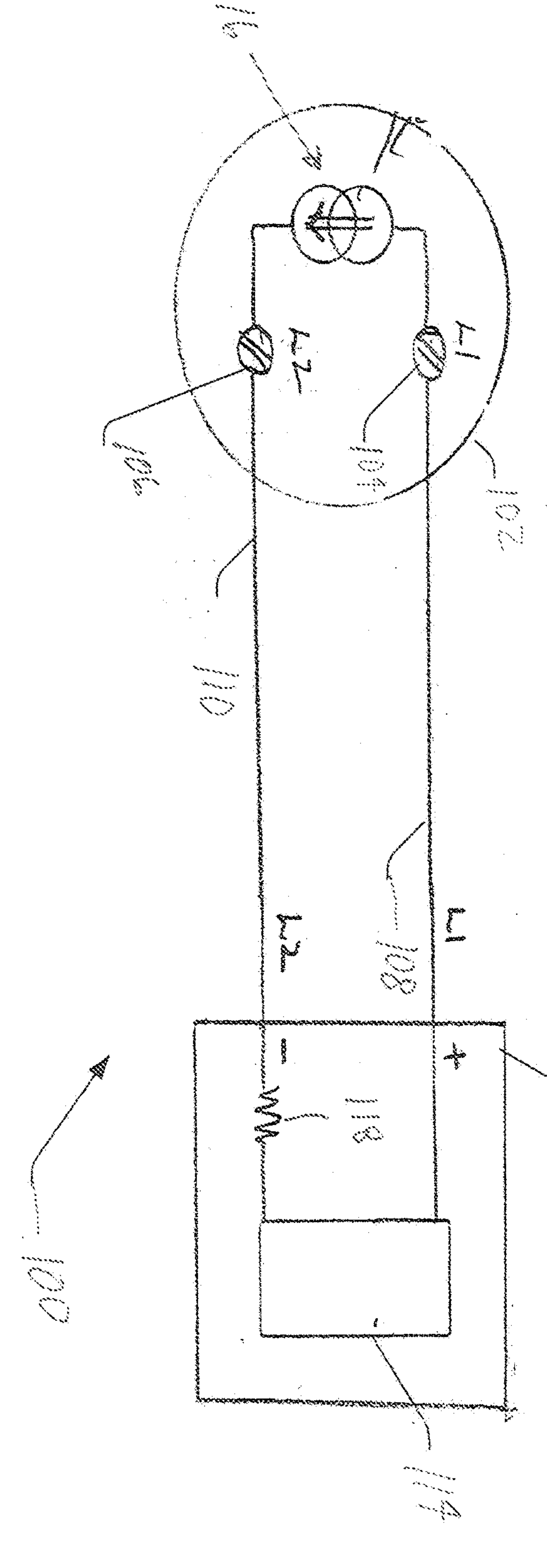

FIG-1

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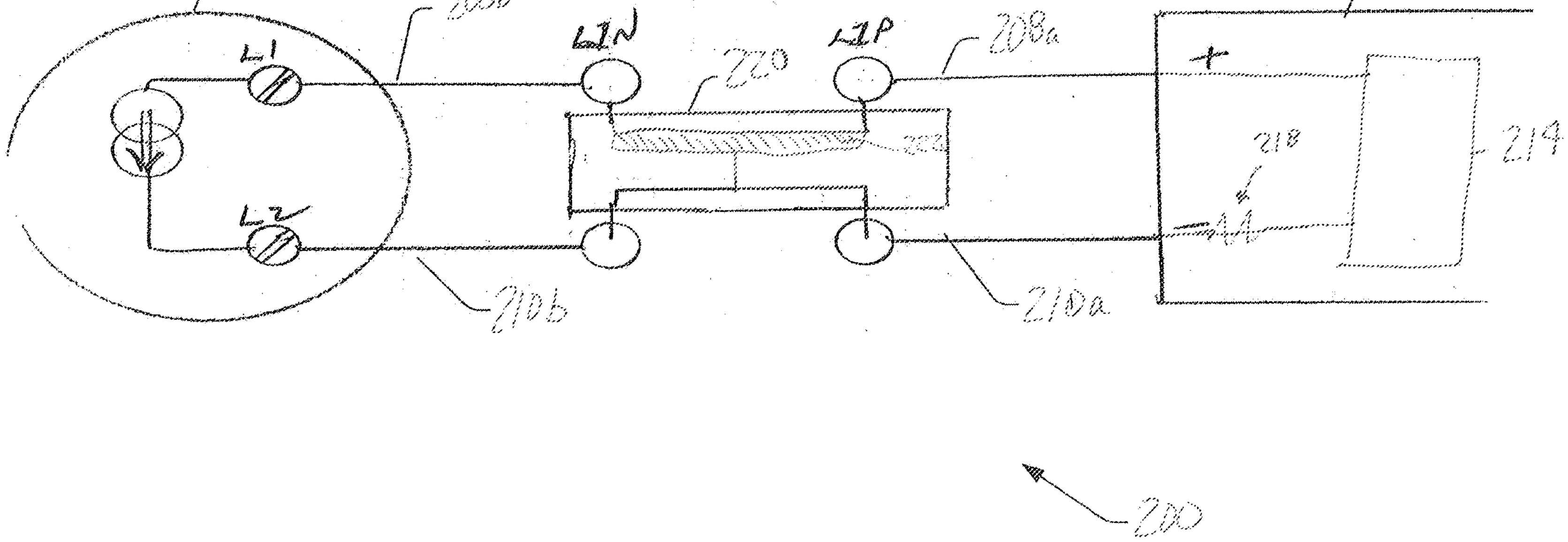
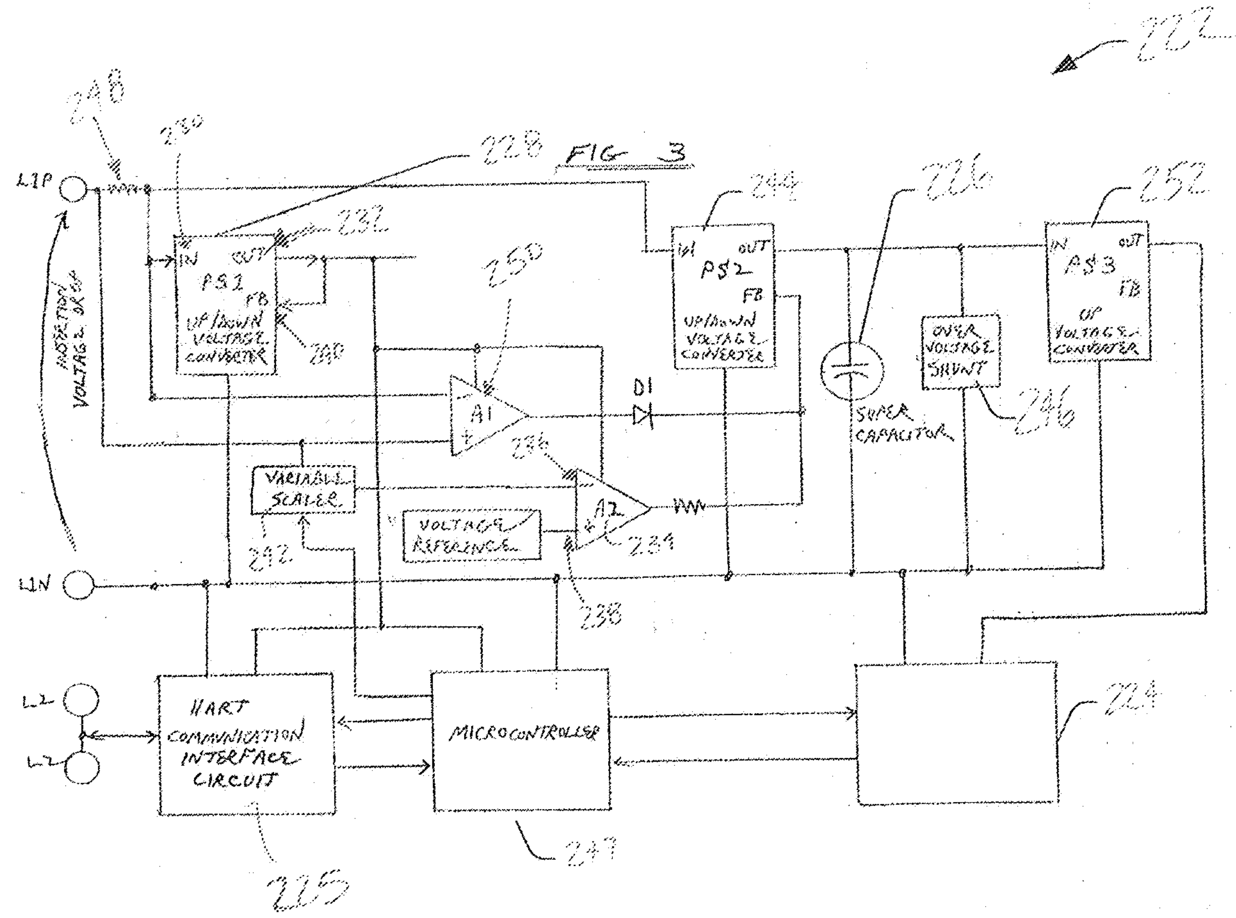
FIG 2

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232
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L1N
L2
L2
IN
OUT
PS1
FB
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250
A1
A2
D1
236
234
238
VARIABLE SCALER
242
VOLTAGE REFERENCE
244
PS2
UP/DOWN VOLTAGE CONVERTER
226
SUPER CAPACITOR
OVER VOLTAGE SHUNT
246
252
PS3
UP VOLTAGE CONVERTER
HART COMMUNICATION INTERFACE CIRCUIT
225
MICROCONTROLLER
247
224

FIG 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/068444

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04B 1/16 (2008.04)
USPC - 455/343.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H04B 1/16 (2008.04)
USPC - 455/343.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
MicroPatent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0245291 A1 (BROWN et al) 03 November 2005 (03.11.2005) entire document	1-43
Y	US 6,304,978 B1 (HORIGAN et al) 16 October 2001 (16.10.2001) entire document	1-43
Y	US 2001/0017572 A1 (HARPHAM) 30 August 2001 (30.08.2001) entire document	4-6, 19-21, 33-35

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 August 2008	03 SEP 2008

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774