US012393248B2

(12) **United States Patent**
Hird et al.

(10) **Patent No.: US 12,393,248 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **DEVICES, SYSTEMS, AND METHODS FOR COLLECTING DOWNHOLE MEASUREMENTS**

(71) Applicant: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

(72) Inventors: **Jonathan Robert Hird**, Cambridge (GB); **Andrew David Robinson**, Cambridge (GB)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, AS (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 114 days.

(21) Appl. No.: **18/479,412**

(22) Filed: **Oct. 2, 2023**

(65) **Prior Publication Data**

US 2024/0152195 A1 May 9, 2024

Related U.S. Application Data

(60) Provisional application No. 63/382,226, filed on Nov. 3, 2022.

(51) **Int. Cl.**

G06F 1/00 (2006.01)
G06F 1/3209 (2019.01)
H01H 19/58 (2006.01)
G06F 1/3203 (2019.01)

(52) **U.S. Cl.**

CPC ***G06F 1/3209*** (2013.01); ***H01H 19/585*** (2013.01); *G06F 1/3203* (2013.01)

(58) **Field of Classification Search**

CPC G06F 1/3209; H01H 19/585; E21B 47/00
USPC 713/310
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,713,334	A *	1/1973	Vann	E21B 47/26 166/241.6
5,812,068	A *	9/1998	Wisler	E21B 47/26 175/45
10,968,731	B2 *	4/2021	Gupta	E21B 33/064
2001/0039626	A1 *	11/2001	Jauert	G07B 17/00314 713/300
2005/0284659	A1 *	12/2005	Hall	H04L 67/025 175/27
2016/0290118	A1 *	10/2016	Xue	E21B 47/00
2017/0002640	A1 *	1/2017	Hoefel	G05B 23/0291
2017/0269260	A1 *	9/2017	Chen	E21B 49/08
2018/0106927	A1 *	4/2018	Larimore	E21B 43/04
2020/0370375	A1 *	11/2020	Gleitman	E21B 44/00
2021/0372261	A1 *	12/2021	Miller	G05B 13/0265

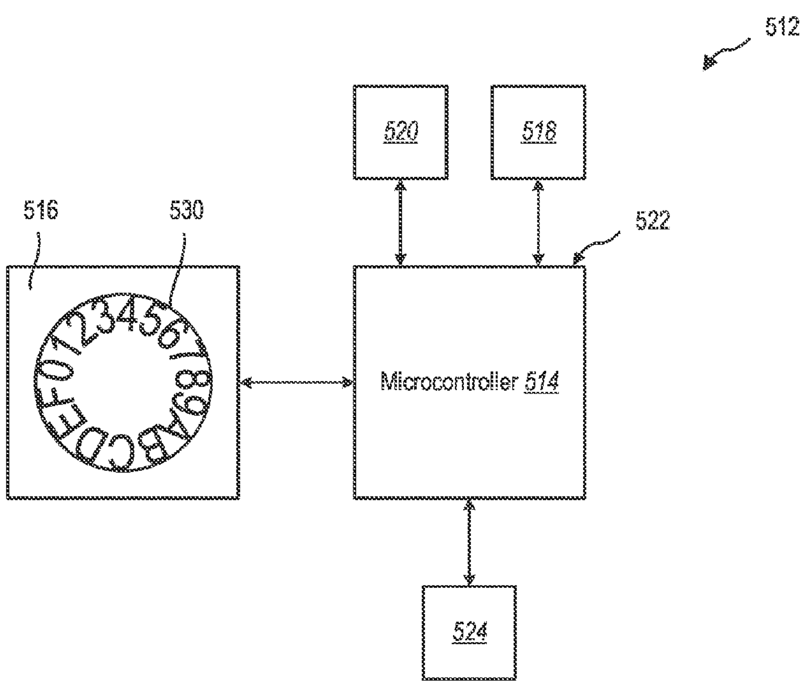
* cited by examiner

Primary Examiner — Volvick Derose
(74) *Attorney, Agent, or Firm* — Jeffrey D. Frantz

(57) **ABSTRACT**

A downhole measurement module includes a microcontroller having a plurality of inputs and a sensor connected to a first input of the plurality of inputs. A switch is connected to a second input of the plurality of inputs. The microcontroller implements a measurement program to receive measurements from the sensor, the measurement program being based on a setting of the switch.

12 Claims, 5 Drawing Sheets



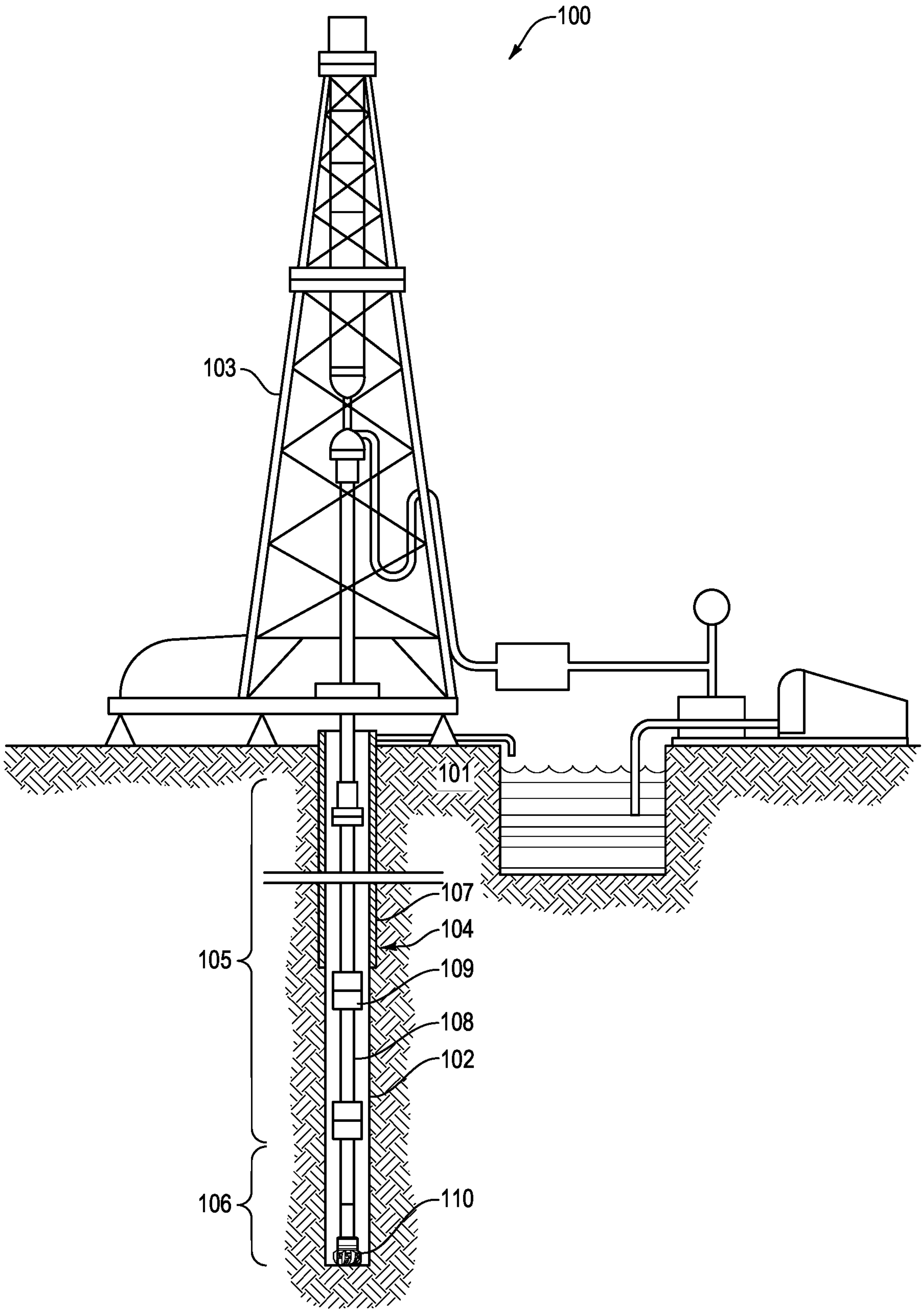


FIG. 1

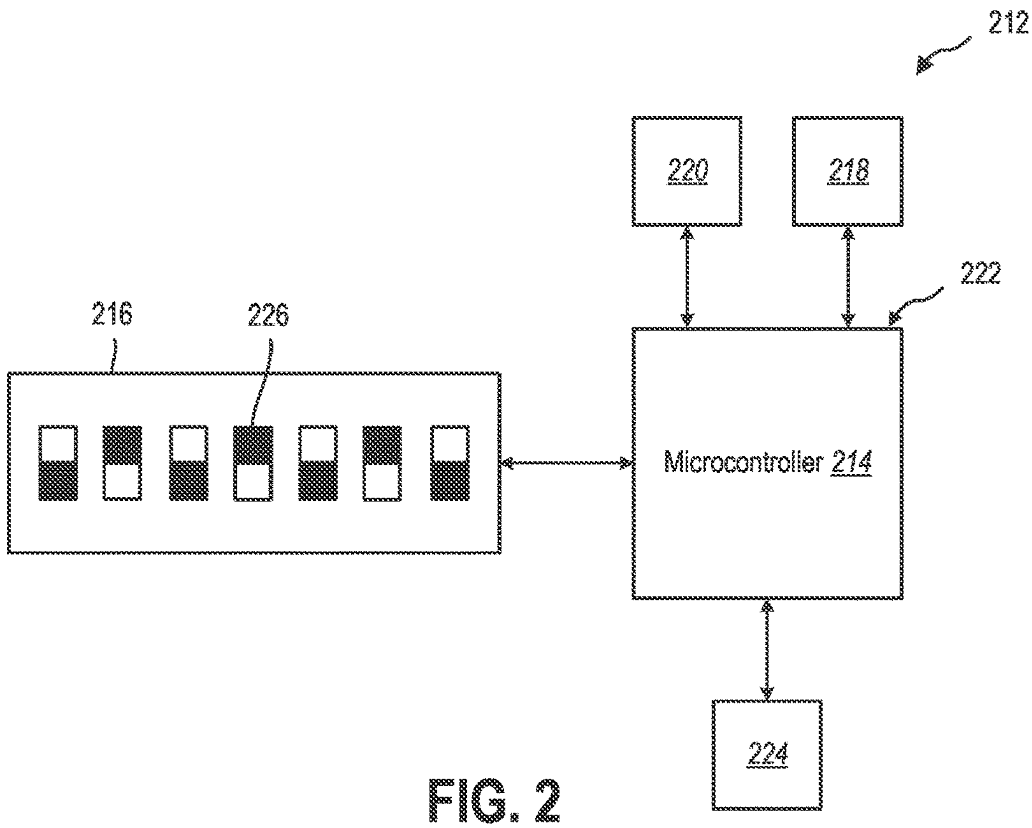

212
220
218
222
216
226
Microcontroller 214
224

FIG. 2

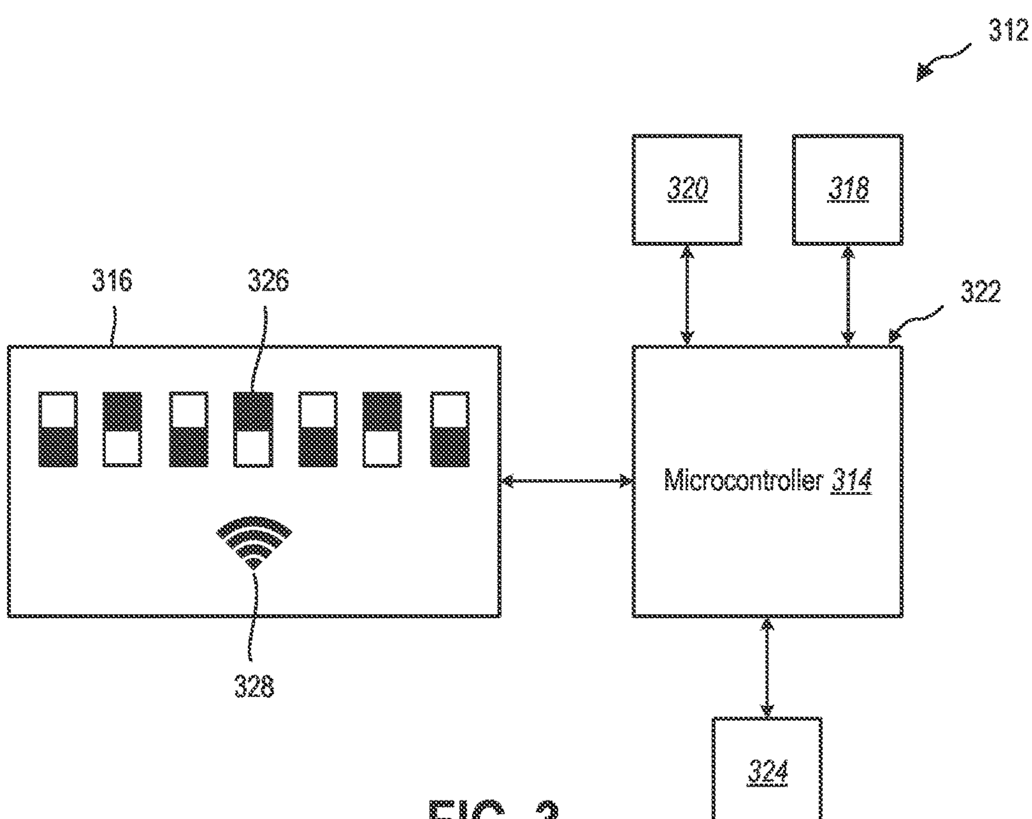

312
320
318
322
316
326
Microcontroller 314
328
324

FIG. 3

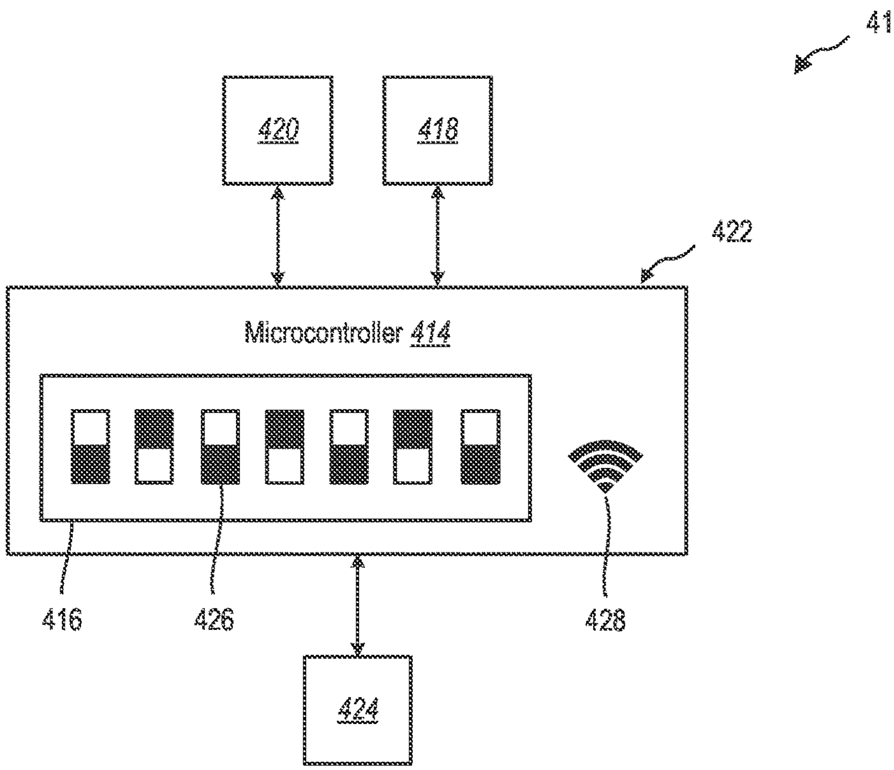

412
420
418
422
Microcontroller 414
416
426
428
424

FIG. 4

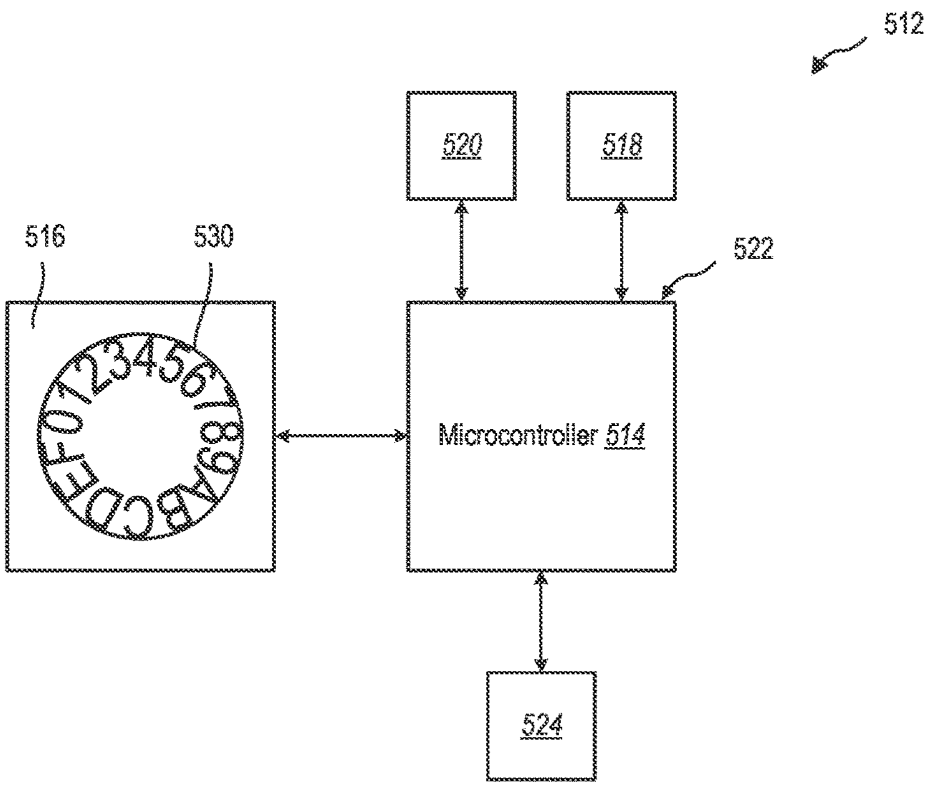

512
520
518
516
530
522
0123456789ABCDEF
Microcontroller 514
524

FIG. 5

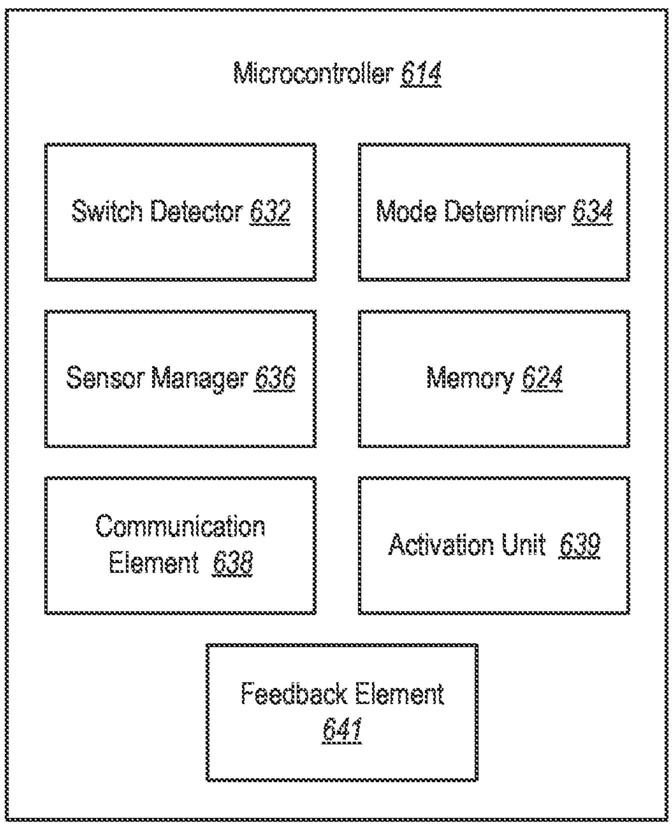

Microcontroller 614
Switch Detector 632
Mode Determiner 634
Sensor Manager 636
Memory 624
Communication Element 638
Activation Unit 639
Feedback Element 641

FIG. 6

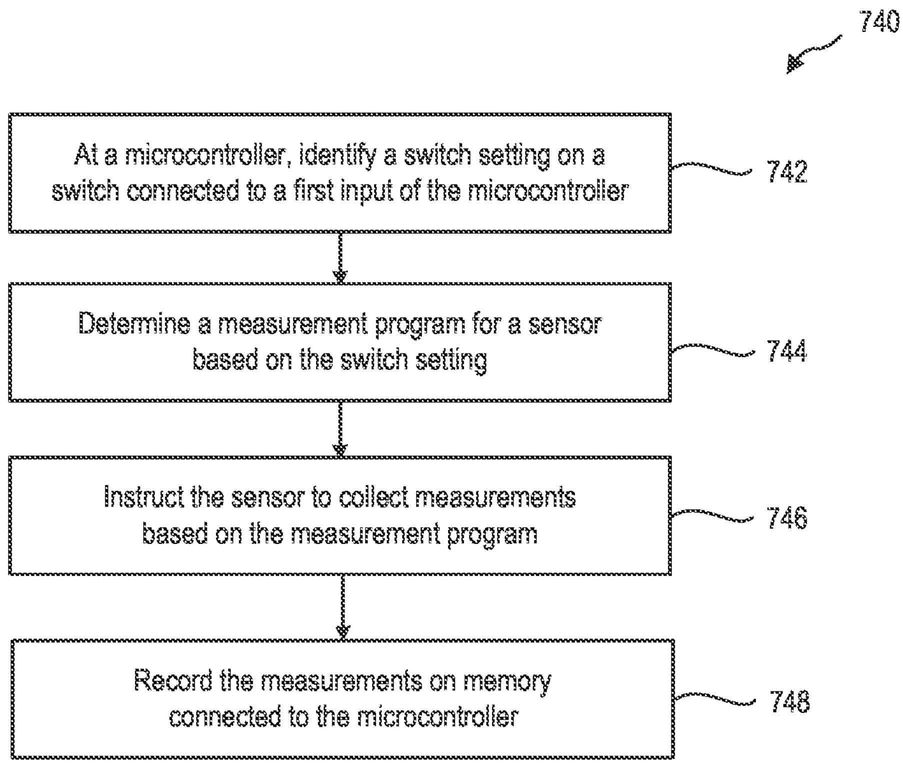

740
At a microcontroller, identify a switch setting on a switch connected to a first input of the microcontroller
742
Determine a measurement program for a sensor based on the switch setting
744
Instruct the sensor to collect measurements based on the measurement program
746
Record the measurements on memory connected to the microcontroller
748

FIG. 7

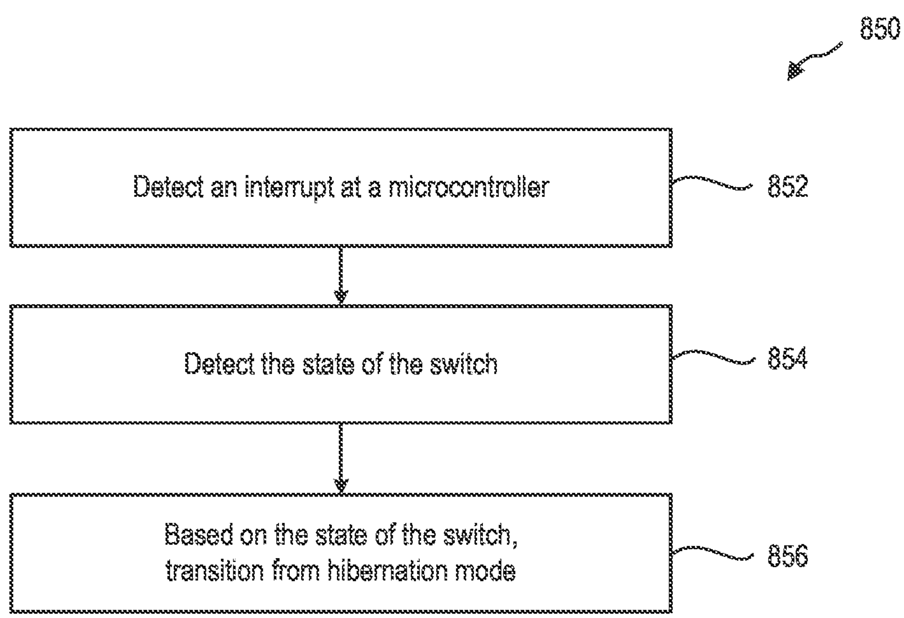

850
Detect an interrupt at a microcontroller
852
Detect the state of the switch
854
Based on the state of the switch, transition from hibernation mode
856

FIG. 8

DEVICES, SYSTEMS, AND METHODS FOR COLLECTING DOWNHOLE MEASUREMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

The subject disclosure claims priority from U. S. Provisional Appl. No. 63/382,226, filed on Nov. 3, 2022, herein incorporated by reference in its entirety.

BACKGROUND

Natural resources such as oil, natural gas, and geothermal reservoirs are often found in reservoirs located hundreds to thousands of feet underground. Such natural resources are often accessed by drilling a wellbore from a surface location to the reservoir. The wellbore may be vertical and/or may include one or more curves, dog legs, or horizontal sections. The drilling operation may include one or more sensors to determine features of the wellbore, including survey information, directional information, and so forth.

SUMMARY

In some aspects, the techniques described herein relate to a downhole measurement module. The downhole measurement module includes a microcontroller having a plurality of inputs and a sensor connected to a first input of the plurality of inputs. A switch is connected to a second input of the plurality of inputs. The microcontroller implements a measurement program to receive measurements from the sensor, the measurement program being based on a setting of the switch.

In some aspects, the techniques described herein relate to a downhole measurement module, including a sensor and a switch movable between a plurality of switch settings. A microcontroller includes a plurality of inputs, the sensor being connected to a first input of the plurality of inputs, the switch being connected to a second input of the plurality of inputs. The microcontroller includes a processor in communication with the sensor and the switch, the processor causing the microcontroller to operate in one of a plurality of modes based upon the plurality of switch settings.

In some aspects, the techniques described herein relate to a method for performing downhole measurements. At a microcontroller of a downhole measurement module, the method includes identifying a switch setting on a switch connected to a first input of the microcontroller. The microcontroller determines a measurement program for a sensor connected to a second input of the microcontroller, the measurement program being based on the switch setting and instructs the sensor to collect measurements based on the measurement program. The microcontroller records the measurements on memory connected to the microcontroller.

This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter. Additional features and aspects of embodiments of the disclosure will be set forth herein, and in part will be obvious from the description, or may be learned by the practice of such embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to describe the manner in which the above-recited and other features of the disclosure can be obtained, a more

particular description will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. For better understanding, the like elements have been designated by like reference numbers throughout the various accompanying figures. While some of the drawings may be schematic or exaggerated representations of concepts, at least some of the drawings may be drawn to scale. Understanding that the drawings depict some example embodiments, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** shows one example of a drilling system for drilling an earth formation to form a wellbore, according to at least one embodiment of the present disclosure;

FIG. **2** is a schematic representation of a downhole measurement module including a microcontroller and a switch, according to at least one embodiment of the present disclosure;

FIG. **3** is a schematic representation of a downhole measurement module including a microcontroller and a switch, according to at least one embodiment of the present disclosure;

FIG. **4** is a schematic representation of a downhole measurement module including a microcontroller and a switch, according to at least one embodiment of the present disclosure;

FIG. **5** is a schematic representation of a downhole measurement module including a microcontroller and a switch, according to at least one embodiment of the present disclosure;

FIG. **6** is a representation of a microcontroller, according to at least one embodiment of the present disclosure;

FIG. **7** is a flowchart of a method for collecting downhole measurements, according to at least one embodiment of the present disclosure; and

FIG. **8** is a flowchart of a method for collecting downhole measurements, according to at least one embodiment of the present disclosure.

DETAILED DESCRIPTION

This disclosure generally relates to devices, systems, and methods for control of a downhole measurement module that collects downhole measurements. A microcontroller may control collection of the downhole measurements by the downhole measurement module, including control of any connected sensors and the recording in memory measurements from the connected sensors. The microcontroller may be connected to a switch. A setting of the switch may determine a measurement program for the microcontroller. The measurement program may include multiple instructions for the microcontroller, such as a hibernation period, a sensor to collect measurements, a measurement frequency, any other instructions for the microcontroller, and combinations thereof. The microcontroller may identify the switch setting (e.g., the logic setting) of the switch, and enter or establish a particular measurement program, based on the identified switch setting. In this manner, the microcontroller may enter a particular measurement program using a setting on the switch.

Conventionally, a measurement program for the microcontroller may be uploaded to the microcontroller by a specialized technician or engineer. In some situations, the engineer may travel to the wellsite to upload the measurement program. This may be expensive in time and/or materials. In some situations, the engineer may program the microcontroller at a shop, including delays for transportation for the downhole measurement module to the wellsite. But adjustments to a drilling schedule, including delays and/or faster-than-expected use, may result in the microcontroller not capturing the intended data at the intended depth below the surface.

In accordance with at least one embodiment of the present disclosure, the switch is a manual or mechanical switch. The setting of the switch may be manually changed at a wellsite. For example, a drilling operator may have a look-up table of measurement programs, with each measurement program associated with a particular switch setting. The drilling operator may identify a desired measurement program, and adjust the switch setting of the switch to the switch setting associated with the desired measurement program. The drilling operator may not be a specially trained engineer or technician. In this manner, the measurement program of the microcontroller may be set based on the switch setting of the switch. This may reduce the cost of the wellbore by reducing or preventing an engineer from traveling to the wellsite. In some embodiments, setting the measurement program with a switch on-site allows the measurement program to be set on the microcontroller when the microcontroller is ready to be installed on the drill string. This may help to reduce or prevent the microcontroller from not capturing the intended data at the intended depth below the surface.

FIG. **1** shows one example of a drilling system **100** for drilling an earth formation **101** to form a wellbore **102**. The drilling system **100** includes a drill rig **103** used to turn a drilling tool assembly **104** which extends downward into the wellbore **102**. The drilling tool assembly **104** may include a drill string **105**, a bottomhole assembly ("BHA") **106**, and a bit **110**, attached to the downhole end of drill string **105**.

The drill string **105** may include several joints of drill pipe **108** connected end-to-end through tool joints **109**. The drill string **105** transmits drilling fluid through a central bore and transmits rotational power from the drill rig **103** to the BHA **106**. In some embodiments, the drill string **105** further includes additional components such as subs, pup joints, etc. The drill pipe **108** provides a hydraulic passage through which drilling fluid is pumped from the surface. The drilling fluid discharges through selected-size nozzles, jets, or other orifices in the bit **110** for the purposes of cooling the bit **110** and cutting structures thereon, and for lifting cuttings out of the wellbore **102** as it is being drilled.

The BHA **106** may include the bit **110** or other components. An example BHA **106** may include additional or other components (e.g., coupled between to the drill string **105** and the bit **110**). Examples of additional BHA components include drill collars, stabilizers, measurement-while-drilling ("MWD") tools, logging-while-drilling ("LWD") tools, downhole measurement modules, downhole motors, underreamers, section mills, hydraulic disconnects, jars, vibration or dampening tools, other components, or combinations of the foregoing. The BHA **106** may further include a rotary steerable system (RSS). The RSS may include directional drilling tools that change a direction of the bit **110**, and thereby the trajectory of the wellbore **102**. At least a portion of the RSS may maintain a geostationary position relative to an absolute reference frame, such as gravity, magnetic north, and/or true north. Using measurements obtained with the geostationary position, the RSS may locate the bit **110**, change the course of the bit **110**, and direct the directional drilling tools on a projected trajectory.

The illustrated BHA **106** includes a microcontroller on a downhole measurement module. While embodiments of the present disclosure discuss the microcontroller as being located on a downhole measurement module, it should be understood that the microcontroller may be located on any downhole tool or element. For example, the microcontroller may be located on an MWD, an LWD, an RSS, a downhole tool, a downhole sensor, a sub, any other downhole element, and combinations thereof. The downhole measurement module may be configured to collect downhole measurements. The downhole measurements may include any type of downhole measurements. For example, the downhole measurements may include survey measurements, such as accelerometer, visual, infrared, gravimetric, nuclear magnetic resonance, any other type of survey measurement, and combinations thereof. In some examples, the downhole measurements may include directional or positional measurements, such as azimuth, inclination, dead-reckoning, any other type of directional or positional measurements, and combinations thereof. In some embodiments, the downhole measurements includes status measurements of a downhole tool.

The BHA **106** may include a switch connected to the microcontroller. The switch may include a plurality of switch settings (e.g., logic settings). Each switch setting may be associated with a measurement program for the microcontroller. The switch setting on the switch may be set at any time before the downhole measurement module is connected to the BHA **106** and installed downhole. For example, the switch setting on the switch may be set while the downhole measurement module is being stored in a lay-down yard at the well site, while the downhole measurement module is being staged for connection to the BHA **106** (such as at the drill rig **103**), while the downhole measurement module is connected to the drill string **105** above the collar of the wellbore, at any other location at the wellsite, and combinations thereof. As discussed herein, setting the switch settings at the wellsite may help to reduce costs by reducing a number of engineers that travel to the wellbore and/or may help to ensure that the measurements collected by the downhole measurement modules are collected at the desired time and/or downhole location.

In general, the drilling system **100** may include other drilling components and accessories, such as special valves (e.g., kelly cocks, blowout preventers, and safety valves). Additional components included in the drilling system **100** may be considered a part of the drilling tool assembly **104**, the drill string **105**, or a part of the BHA **106** depending on their locations in the drilling system **100**.

The bit **110** in the BHA **106** may be any type of bit suitable for degrading downhole materials. For instance, the bit **110** may be a drill bit suitable for drilling the earth formation **101**. Example types of drill bits used for drilling earth formations are fixed-cutter or drag bits. In other embodiments, the bit **110** is a mill used for removing metal, composite, elastomer, other materials downhole, or combinations thereof. For instance, the bit **110** may be used with a whipstock to mill into casing **107** lining the wellbore **102**. The bit **110** may also be a junk mill used to mill away tools, plugs, cement, other materials within the wellbore **102**, or combinations thereof. Swarf or other cuttings formed by use of a mill may be lifted to surface, or may be allowed to fall downhole.

FIG. **2** is a schematic representation of a downhole measurement module **212** including a microcontroller **214** and a switch **216**, according to at least one embodiment of the present disclosure. The microcontroller **214** may be any type of microcontroller. For example, the microcontroller **214** may be a processor configured to control or manage the downhole measurement module **212**. In some embodiments, the microcontroller **214** is a low-power controller. For example, the microcontroller **214** may utilize small amounts of power, thereby allowing the microcontroller **214** to utilize an independent power source **218**, such as a battery or supercapacitor. This independent power source **218** may provide the downhole measurement module **212** with power to perform its operations, such as data collection from one or more sensors **220**. In some embodiments, the downhole measurement module **212** and/or the microcontroller **214** are not connected to a central power source of a BHA. For example, the downhole measurement module **212** and/or the microcontroller **214** may not be connected to a power generator, such as a mud-motor or turbine connected to the BHA.

The microcontroller **214** may include a plurality of inputs **222**. The inputs **222** may be connected to one or more elements of the downhole measurement module **212**. For example, the switch **216**, the sensors **220**, the independent power source **218**, memory **224**, any other elements, and combinations thereof may be connected to an input of the plurality of inputs **222**. The inputs **222** may be input/output (I/O) connections. For example, the I/O connections may be able to send and receive information from the connected element. This may allow the microcontroller **214** to control operation of the sensors **220**, to detect the switch setting (e.g., the logic setting) of the switch **216**, to receive power from the independent power source **218**, and to read and write information to the memory **224**.

As discussed herein, the switch **216** may be adjustable to a plurality of switch settings. The switch **216** includes a plurality of levers **226**. The levers **226** may be movable between two positions, or between an on position and an off position. The combination of levers **226** positions may be the switch setting of the switch **216**. The microcontroller **214** may identify the switch position of the switch **216** by determining which of the levers **226** are in the on position. As discussed herein, the microcontroller **214** may associate the switch position with a particular measurement program. After detecting the switch position, the microcontroller **214** may implement the associated measurement program.

In accordance with at least one embodiment of the present disclosure, the switch **216** is a mechanical switch or a manual switch. The position of each of the levers **226** may be manually changed between the on position and the off position. For example, to move a lever **226** between the on position and the off position, an operator may physically change the position of the lever **226**. The operator may consult a look-up table that associates measurement programs with switch positions. The operator may have an instruction to implement a particular measurement program, and may adjust the position of the levers **226** to the associated switch position.

In the embodiment shown, the switch **216** has eight levers **226**. As will be understood, this may provide the switch **216** with **256** switch positions. But it should be understood that the switch **216** may have any number of levers **226** with an accompanying number of switch positions. In some embodiments, the switch **216** is a dual in-line package (DIP) switch. In some embodiments, the switch **216** is a surface mount device (SMD) switch.

The switch **216** may be locally or remotely actuated. For example, the downhole measurement module **212** may include an actuation mechanism (e.g., servo motors; memory materials, etc.). The actuation mechanism may be configured to mechanically change the position of the levers **226** based on an instruction from a remote operator and/or remote computing device. In this manner, the housing for the switch **216** may not be accessed prior to adjusting the switch position. This may help to reduce the amount of time taken to change the switch setting of the switch **216**.

The switch **216** can be powered or unpowered. For example, an unpowered switch **216** may not include any processor or other powered element. The unpowered switch **216** may not be connected to any power element, including the independent power source **218** or other power element. In this manner, the unpowered switch **216** may not draw on the limited power provided by the independent power source **218**. This may extend the life of the independent power source **218**, thereby allowing the downhole measurement module **212** to collect more measurements and/or collect measurements for longer.

The microcontroller **214** can be used to detect or identify the switch setting of the switch **216**. For example, the output of the switch **216** may be connected to an input **222** of the microcontroller **214**. The microcontroller **214** may identify the switch setting of the switch **216** by determining which of the levers **226** are in the on position and the off position. For example, the microcontroller **214** may send a signal to the switch **216**, and the response of the signal may determine the switch setting of the switch **216**.

The microcontroller **214** may include firmware that controls the operation of the microcontroller **214**. The firmware may include instructions for the sensors **220** to record information on the memory **224**. In some embodiments, instructions are stored as one or more measurement programs. A measurement program may include a series of actions taken by the microcontroller **214** and the connected elements of the downhole measurement module **212**. The actions may include any type of action, for example, the actions of a measurement program may include a hibernation period, an instruction for a particular sensor **220** to collect measurements, a measurement schedule or frequency, trigger conditions for the sensor **220** to transition to and/or enter the sensing mode and begin collecting measurements, instructions for recording measurements in the memory **224**, any other action, and combinations thereof.

In accordance with at least one embodiment of the present disclosure, in the hibernation period, the downhole measurement module **212** operates in a low-power mode. The hibernation period may be time-based. A timer or clock on the microcontroller **214** may identify the end of the hibernation period. In some embodiments, the hibernation period is condition-based. For example, the microcontroller **214** may monitor for a trigger condition, such as the detection of certain downhole conditions. The microcontroller **214** may monitor with a low frequency, such as taking a measurement every day, every several hours, every hour, or other measurement frequency. When the microcontroller **214** detects the trigger condition, the microcontroller **214** may come out of the hibernation mode and transition to and/or enter a different mode, such as the sensing mode. This may allow the microcontroller **214** to conserve power, thereby preventing or reducing premature depletion of the independent power source **218** based on usage by the switch **216**.

After the hibernation period is over, has ended, or expired, the microcontroller **214** may transition from the hibernation mode to a different mode. For example, the microcontroller **214** may transition to a sensing mode. In the sensing mode, the microcontroller **214** may instruct one of the sensors **220** to collect measurements. In some embodiments, the microcontroller **214** instructs the sensor **220** to collect measurements with a collection frequency. The sensing mode may be a full-power mode, or a power mode that draws more power than both the hibernation mode and the trigger detection mode. In some embodiments, the sensing mode has different power settings based on the particular sensor **220** being used. For example, different sensors may have different power requirements, and the sensing mode may utilize the minimum power for each particular sensor **220**.

After the hibernation period is over, has ended, or expired, the microcontroller **214** can in some embodiments transition from the hibernation mode to a trigger detection mode, or enter the trigger detection mode from the hibernation mode. The hibernation mode may be a low-power mode, where the microcontroller **214** only includes a timer or clock, thereby drawing minimal power from the independent power source **218**.

Optionally, the trigger detection mode is a mid-power mode (e.g., a third, half, two-thirds, or another percentage of the difference in power between the sensing mode and the low-power mode or a power mode between the sensing mode and the low-power mode). In the trigger detection mode, the microcontroller **214** may cause a trigger detection sensor to detect whether a trigger condition has been met. The trigger condition may include any trigger condition, such as a particular temperature, a particular formation type, a particular RPM, a particular fluid flow rate, a particular azimuth, a particular inclination, any other trigger condition, and combinations thereof. In some embodiments, after the trigger condition has been met, the microcontroller **214** transitions from the trigger detection mode to the sensing mode. In the same or other embodiments, in the trigger detection mode, the microcontroller **214** causes the trigger detection sensor to take a trigger detection measurement with a trigger detection frequency. Optionally, the trigger detection frequency is less than the collection frequency. For example, the trigger detection frequency may be periodic. As discussed herein, the microcontroller **214** may transition from the trigger detection mode to the sensing mode based on the detection of the trigger and/or the microcontroller **214** may enter the sensing mode from the trigger detection mode based on the detection of the trigger.

In some embodiments, the measurement program includes a stop-measurement condition, or conditions under which the microcontroller **214** causes the sensor **220** to stop collecting measurements. For example, the stop-measurement condition may include any type of stop-measurement condition, such as a duration, a number of measurements, a particular measurement threshold (e.g., a high measurement value or a low measurement value), any other stop-measurement condition, and combinations thereof.

As discussed herein, the firmware of the microcontroller **214** may include a plurality of measurement programs. Each of the measurement programs may be associated with a switch setting (e.g., one switch setting or a plurality of switch settings) of the switch **216**. When the microcontroller **214** detects a particular switch setting, the microcontroller **214** may compare the switch setting to the list of switch settings, and implement the associated measurement program. The measurement programs may include any combination of actions implemented by the downhole measurement module **212**. For example, the measurement program may include any combination of hibernation modes, trigger detection modes, and collection modes from a particular sensor **220**.

In some embodiments, the measurement program includes two or more hibernation modes. In some embodiments, some or all of the two or more hibernation modes can have the same hibernation frequency. In some embodiments, some or all of the two or more hibernation modes have two different hibernation periods. The measurement program optionally includes two or more trigger detection modes, which can have the same and/or different trigger conditions. In some embodiments, the measurement program includes two or more collection modes. The two or more collection modes can use the same sensor and/or have the same collection frequency. In some embodiments, the two or more collection modes use different sensors and/or have different collection frequencies. In some embodiments, the sensors **220** use the same stop-measurement condition, while in the same or other embodiments, the sensors **220** use a different stop-measurement condition.

One or more of the switch settings are, in some embodiments, associated with management of the downhole measurement module **212**. For example, a switch setting may be associated with an update condition of the microcontroller **214**. When the microcontroller **214** identifies that the switch **216** has a switch setting associated with the update condition, the microcontroller **214** may be prepared to receive software and/or firmware updates. For example, an engineer, technician, or operator may apply the switch setting associated with the update condition to place the microcontroller **214** in the update condition. While the microcontroller **214** is in the update condition, one or more of the engineer, technician, or operator may connect to a communication element of the microcontroller **214** and upload a software and/or firmware update to the microcontroller **214**. This may help to improve the ease of update installation.

The switch **216** optionally has a switch setting that is associated with a download condition of the microcontroller **214**. The microcontroller **214** may have a communication element connected to the memory **224**. The communication element may transmit the measurements and/or other data stored on the memory **224** to a remote computing device. The microcontroller **214** can transmit the measurements and/or other information stored on the memory **224** to the remote computing device in any manner. For example, the microcontroller **214** may transmit the measurements and/or other information stored on the memory **224** wirelessly, such as over a Wi-Fi connection, over the Internet, over a Bluetooth connection, any other wireless connection, and combinations thereof. In some examples, the microcontroller **214** may transmit the measurements and other information stored on the memory **224** over a wired connection, such as through a physical plug, a local area network (LAN), a USB connection, any other wired connection, and combinations thereof.

In some embodiments, the microcontroller **214** is not transmitting the stored measurements and/or other information to the remote computing device, or is not doing so unless the switch **216** is in the switch setting associated with the download condition. For example, the microcontroller **214** may include firmware that controls transmittal of the measurements and/or other information stored in the memory **224**. The firmware may not allow transmittal of the memory **224** until the switch **216** is identified as having the switch setting associated with the download condition. This may help to prevent or reduce unauthorized downloading of the memory **224**, thereby increasing the data security of the microcontroller **214**.

FIG. **3** is a schematic representation of a downhole measurement module **312** including a microcontroller **314** and a switch **316**, according to at least one embodiment of the present disclosure. In some embodiments, the microcontroller **314** is a low-power controller. For example, the microcontroller **314** may utilize small amounts of power, thereby allowing the microcontroller **314** to utilize an independent power source **318**, such as a battery or supercapacitor. This independent power source **318** may provide the downhole measurement module **312** with power to perform its operations, such as data collection from one or more sensors **320**.

The microcontroller **314** may include a plurality of inputs **322**. The inputs **322** may be connected to one or more elements of the downhole measurement module **312**. For example, the switch **316**, the sensors **320**, the independent power source **318**, memory **324**, any other elements, and combinations thereof may be connected to an input of the plurality of inputs **322**.

The switch **316** may include a plurality of latches **326**. The switch position of the switch **316** may be determined by the position of each of the latches **326**. As discussed herein, in some embodiments, the switch **316** is an unpowered switch and/or a mechanical switch. In some embodiments, the position of the latches **326** is remotely controlled. For example, the switch **316** may include a communication element **328**. The communication element **328** may receive instructions from a remote computing device to change the position of the latches **326**. In this manner, an operator may not need to open the housing of the downhole measurement module **312** to adjust the switch position of the switch **316**. In other words, the position of the latches **326** may be changed without manual operator directly (e.g., manually) changing the position.

The communication element **328** can be any type of suitable communication element **328**. For example, the communication element **328** may be a wireless connection, such as a WiFi connection, a Bluetooth connection, a Zigbee connection, an IR receiver, a mesh network connection, any other wireless connection, and combinations thereof. In some examples, communication element **328** may be connected to the Internet. In some embodiments, the communication element **328** is connected to a local network, such as a wireless area network (WAN), LAN, intranet, a mesh network, any other local network, and combinations thereof.

The position of the latches **326** can be changed manually, or by using one or more actuators. For example, each of the latches **326** can include an actuator. The actuator may change the position of the latches **326** to adjust the switch setting. When the communication element **328** receives an instruction to adjust the switch setting, the actuators of the switch **316** may cause the appropriate latches **326** to change position (e.g., between the on position and the off position). In some embodiments, the communication element **328** is directly connected to the actuators of the latches **326**. A remote computing device may provide the communication element **328** with instructions to adjust the position of the latches **326**. The switch **316** can include or communicate with a processor connected to the actuators. The processor may receive the revised switch setting and cause the actuators to move the latches **326** into the appropriate position for the switch setting.

In some embodiments, the switch **316** is a digital switch. For example, the switch **316** may include a plurality of switch settings. The microcontroller **314** may use a look-up table or query the digital switch **316** for the switch setting, and the digital switch **316** optionally provides the microcontroller **314** with the appropriate switch setting. In some embodiments, the digital switch **316** receives instructions from the communication element **328**. This may cause the switch **316** to adjust the digital switch setting. In some embodiments, the digital switch **316** actively transmits the switch setting to the microcontroller **314**.

In some embodiments, the switch may be an analog switch. Optionally, a potentiometer may be connected to an analog input on the microcontroller. An analog input or an analog switch may allow for additional permutations and/or settings based on the voltage levels set in the firmware of the analog switch.

FIG. **4** is a schematic representation of a downhole measurement module **412** including a microcontroller **414** and a switch **416**, according to at least one embodiment of the present disclosure. The microcontroller **414** can operate as a low-power controller. For example, the microcontroller **414** may utilize small amounts of power, thereby allowing the microcontroller **414** to utilize an independent power source **418**, such as a battery or supercapacitor. This independent power source **418** may provide the downhole measurement module **412** with power to perform its operations, such as data collection from one or more sensors **420**.

The microcontroller **414** may include a plurality of inputs **422**. The inputs **422** may be connected to one or more elements of the downhole measurement module **412**. For example, the sensors **420**, the independent power source **418**, memory **424**, any other elements, and combinations thereof may be connected to an input of the plurality of inputs **422**.

The microcontroller **414** may include a switch **416**. The switch **416** may be formed as a part of the microcontroller **414**. For example, the switch **416** may be integrally formed as part of the microcontroller **414**. In some embodiments, the switch **416** is formed as part of a printed circuit board of the microcontroller **414**. This may help to simplify the manufacture and the installation of the downhole measurement module **412**.

As discussed herein, the switch **416** may include a plurality of latches **426**. The switch position of the switch **416** may be determined by the position of each of the latches **426**. As discussed herein, in some embodiments, the switch **416** is an unpowered switch and a mechanical switch. In some embodiments, the position of the latches **426** is remotely controlled. For example, the switch **416** and/or the microcontroller **414** may include a communication element **428**. The communication element **428** may receive instructions from a remote computing device to change the position of the latches **426**. In this manner, an operator may not need to open the housing of the downhole measurement module **412** to adjust the switch position of the switch **416**.

FIG. **5** is a schematic representation of a downhole measurement module **512** including a microcontroller **514** and a switch **516**, according to at least one embodiment of the present disclosure. In some embodiments, the microcontroller **514** is a low-power controller. For example, the microcontroller **514** may utilize small amounts of power, thereby allowing the microcontroller **514** to utilize an independent power source **518**, such as a battery or supercapacitor. This independent power source **518** may provide the downhole measurement module **512** with power to perform its operations, such as data collection from one or more sensors **520**.

The microcontroller **514** may include a plurality of inputs **522**. The inputs **522** may be connected to one or more elements of the downhole measurement module **512**. For example, the switch **516**, the sensors **520**, the independent power source **518**, memory **524**, any other elements, and combinations thereof may be connected to an input of the plurality of inputs **522**.

In some embodiments, the switch **516** is a rotary switch. For example, the switch **516** may include a rotary dial **530**. The switch **516** may be moved between switch settings based on a movement of the rotary dial **530**. As discussed herein, the microcontroller **514** may identify the switch setting from the switch **516**, which may be associated with a measurement program of the microcontroller **514**.

FIG. **6** is a representation of a microcontroller **614**, according to at least one embodiment of the present disclosure. Each of the components of the microcontroller **614** can include software, hardware, or both. For example, the components can include one or more instructions stored on computer-readable storage media and executable by one or more processors of one or more computing devices, such as a client device or server device. When executed by the one or more processors, the computer-executable instructions of the microcontroller **614** can cause the computing device(s) to perform the methods described herein. Alternatively, the components can include hardware, such as a special-purpose processing device to perform a certain function or group of functions. Alternatively, the components of the microcontroller **614** can include a combination of computer-executable instructions and hardware. In some embodiments, the computer-readable storage media (e.g., RAM, ROM, EEPROM, flash memory, etc.) may be separate from, but accessible to, the microcontroller **614**.

The microcontroller **614** of this embodiment includes a switch detector **632**. The switch detector **632** may detect the presence of a switch. In some embodiments, the switch detector **632** identifies a switch setting of the switch. The switch detector **632** may identify the switch setting of the switch in any manner, including by identifying which latches on the switch are in the on and off position.

The microcontroller **614** of the illustrative embodiment includes a mode determiner **634**. The mode determiner **634** may determine an operating mode of the microcontroller **614**. For example, the mode determiner **634** may determine a measurement program for the microcontroller **614** based on the switch setting. In some embodiments, the mode determiner **634** consults or refers to a look-up table or other mechanism to determine the measurement program. The look-up table may include a series of switch settings and associated measurement programs. For example, the mode determiner **634** may receive the switch setting from the switch detector **632**. The mode determiner **634** may compare the switch setting to the look-up table to determine the associated measurement program.

In some embodiments, the mode determiner **634** provides the measurement program to the microcontroller **614**. For example, after the mode determiner **634** has determined the measurement program associated with the switch setting, the mode determiner **634** may provide the measurement program to the microcontroller **614**. The microcontroller **614** may implement the measurement program.

The microcontroller **614** may include a sensor manager **636**. The sensor manager **636** may provide instructions to one or more sensors to collect sensor measurements. In some embodiments, the sensor manager **636** sends the instructions to the one or more sensors based on the measurement program. For example, the measurement program may include a particular set of measurements to be collected from a particular sensor with a particular measurement frequency. The sensor manager **636** may instruct the identified sensor to collect the measurements at the identified measurement frequency. In this manner, the microcontroller **614** may collect measurements based on the switch position of the switch.

The microcontroller **614** can be used to record the measurements to memory **624**. In some embodiments, when the microcontroller **614** is powered up, the microcontroller **614** causes a new file in memory **624** to be opened. The microcontroller **614** may write any measurements or other information collected while the microcontroller **614** is powered up to the memory **624**. When the microcontroller **614** is powered down, the microcontroller **614** may save the file in the memory **624**. In some embodiments, the microcontroller **614** prepares new files and/or saves to different files based on the data type, the time of collection, the sensor type, any other distinction, and combinations thereof.

The microcontroller **614** can include a communication element **638**. As discussed herein, the communication element **638** may receive information from a remote computing device. For example, the communication element **638** may receive software and/or firmware updates, measurement programs, instructions for the switch, any other information, and combinations thereof. In some embodiments, the microcontroller **614** transmits the measurements recorded on the memory **624** to the remote computing device.

An activation unit **639** can be included in or accessible to the microcontroller **614** in some embodiments. The activation unit **639** may be used to activate the microcontroller **614**. For example, the activation unit **639** may include a sensor that may receive an input to activate the microcontroller **614**. Activating the microcontroller **614** may include transitioning the microcontroller **614** from a hibernation mode (e.g., an unpowered mode, an ultra-low power mode, a lower power mode) to an identification mode. In the identification mode, the switch detector **632** of the microcontroller **614** may identify the state of the switch. Based on the state of the switch, the microcontroller **614** may transition to any of the modes discussed herein. For example, the microcontroller **614** may transition back into a hibernation mode, a detect mode, a sensing mode, any other mode, and combinations thereof.

The activation unit **639** may include any type of sensor. For example, the activation unit **639** may include a magnetic field sensor, such as a Hall effect sensor. When the magnetic field sensor is triggered, the microcontroller **614** may enter the identification mode and identify the state of the switch. To trigger the magnetic field sensor, an operator may place a magnet in proximity to the activation unit **639**. This may cause the magnetic field sensor in the activation unit **639** to trip, thereby placing the microcontroller **614** in the identification mode.

The activation unit **639** can be activated in any suitable manner, including using an activation tool. In the example of a magnetic field sensor, the activation tool may include a magnet that is sufficiently strong to trigger the activation unit **639**. For example, the activation unit **639** may be located in a housing. The activation tool may include a magnet with a magnetic field that is strong enough to pass through the housing (e.g., a face plate) and trigger the magnetic field sensor. In some embodiments, the housing includes a magnetically permeable material. For example, the portion of the housing located directly opposite the activation unit **639** may be formed from a magnetically permeable plate. This may allow the magnetic field from the activation tool to pass through the housing and to the activation unit **639**.

In some embodiments, the activation unit **639** places the microcontroller **614** into the identification mode when the activation unit **639** is tripped in a pattern. For example, the activation tool may move into and out of the detection range of the activation unit **639** to trip the sensor in a pattern. This may help to prevent inadvertent tripping of the magnetic field sensor by stray or environmental magnetic fields.

The activation tool of some embodiments can be or include a permanent magnet and/or an electromagnet. In some embodiments, the electromagnet may be external to the activation unit. The electromagnet may alter the local magnetic field in the proximity of the sensor in the activation unit **639**, including turning the magnetic field on and off, adjusting the strength of the magnetic field, adjusting the polarity of the magnetic field, any other adjustment to the magnetic field, and combinations thereof. In some embodiments, the activation tool adjusts the magnetic field to trigger the sensor in the activation unit **639**.

In some embodiments, the activation unit **639** is or includes a strain sensor such as a strain gauge. The strain sensor in the activation unit **639** may sense strain in an area of the housing and/or sub in which the microcontroller **614** is located. For example, the strain sensor may sense the torsional strain in the housing when the tool is made up to the make-up torque. In some embodiments, the strain sensor senses the presence of a clamp or other intentional force applied to a specific area of the housing containing the gauge. For example, an operator may torque a bolt in a hole on the housing or a pocket cover to a specific torque. This may activate the microcontroller **614**. In some embodiments, the microcontroller **614** remains activated while the strain sensor senses a threshold strain.

The activation unit **639** optionally is or includes an electromagnetic (EM) receiver. When the EM receiver receives an EM signal, the activation unit **639** may place the microcontroller **614** in the identification mode. The EM receiver may receive any type of EM signal, such as infrared, radio frequency, microwaves, x-rays, any other type of EM signal, and combinations thereof. In some embodiments, the portion of the housing outside of the EM receiver is transparent to the EM signals, allowing the signals to reach the EM receiver. In some embodiments, any activation tool that emits EM signals is used to transmit to the EM receiver. For example, the activation tool may include a television remote using an infrared transmitter in the remote paired to an infrared receiver in the tool. In some embodiments, the EM receiver includes a Bluetooth transceiver, and the activation tool may include a computing device, such as a smartphone, tablet, or laptop computer. An EM receiver may allow for remote instructions and/or complicated instructions to be passed to the EM receiver.

The activation unit **639** of some embodiments is or includes an acoustic sensor. For example, the microcontroller **614** may include an onboard microphone, a sound-sensitive accelerometer, or other acoustic sensor. The acoustic sensor may sense vibrations in the environment of the microcontroller **614**. For example, the acoustic sensor may sense acoustic vibrations in the body of the housing supporting the microcontroller **614**.

In some embodiments, the activation unit **639** is or includes a motion or position detection sensor. For example, the activation unit **639** may include an accelerometer that is configured to detect one or more specific motions or positions of the housing. The activation unit **639** may be configured to detect motions that would not normally be experienced by the housing of the microcontroller **614** during transportation or storage. In some embodiments, the location sensors include one or more magnetometers to detect positions relative to the Earth's magnetic field. This may allow the activation unit **639** to activate the microcontroller **614** without active input from the user.

The microcontroller **614** can include a feedback element **641**. The feedback element **641** may provide feedback of the status of the microcontroller **614** to the operator. This may allow the operator to determine in which mode the microcontroller **614** is operating.

The feedback element **641** may provide any type of feedback to the operator. For example, the feedback element **641** may include a series of LED lights. The number, type, color, repeating pattern, or any quality of the LED lights may be used to communicate the status of the microcontroller **614** to the operator.

In some embodiments, the feedback element **641** includes any type of feedback. For example, the feedback element **641** may include haptic feedback. The feedback element **641** may include a piezo transducer, a solenoid, a vibrating element, any other haptic feedback element, and combinations thereof. In some embodiments, the feedback element **641** sends a physical impulse to the housing. The impulse may be detected (e.g., felt or heard). The impulse may include encoded data that, when decoded, may provide the operator with the status of the microcontroller **614**. In some embodiments, this impulse is tuned to the resonant frequency of the housing or sub to reduce the power used to generate the impulse.

In some embodiments, the feedback element **641** includes an EM transmitter. For example, the feedback element **641** may include an antenna or other EM transmitter to transmit any type of EM signal, such as visible light, infrared light, short-range radio frequencies (e.g., Bluetooth or LoRa technology). In some embodiments, a local computing device, such as a smartphone, tablet, or laptop computer, receives the EM signal from the feedback element **641** to determine the status of the microcontroller **614**.

FIGS. **7** and **8**, the corresponding text, and the examples provide a number of different methods, systems, devices, and computer-readable media of the downhole measurement modules discussed herein. In addition to the foregoing, one or more embodiments can also be described in terms of flowcharts comprising acts for accomplishing a particular result, as shown in FIGS. **7** and **8**. FIGS. **7** and **8** may be performed with more or fewer acts. Further, the acts may be performed in differing orders. Additionally, the acts described herein may be repeated or performed in parallel with one another or parallel with different instances of the same or similar acts.

As mentioned, FIG. **7** illustrates a flowchart of a method **740** of a series of acts for performing downhole measurements, in accordance with one or more embodiments. While FIG. **7** illustrates acts according to one embodiment, alternative embodiments may omit, add to, reorder, and/or modify any of the acts shown in FIG. **7**. The acts of FIG. **7** can be performed as part of a method. Alternatively, a non-transitory computer-readable medium can comprise instructions that, when executed by one or more processors, cause a computing device to perform the acts of FIG. **7**. In some embodiments, a system can perform the acts of FIG. **7**.

A microcontroller may identify a switch setting on a switch connected to a first input of the microcontroller at **742**. As discussed herein, the switch may be a mechanical switch and/or an unpowered switch. In some embodiments, the microcontroller determines a measurement program for a sensor connected to a second input of the microcontroller, the measurement program being based on the switch setting at **744**. For example, the microcontroller may include a plurality of measurement programs associated with a switch setting of the switch. The microcontroller may compare the switch setting to the list of switch settings and measurement programs to determine the measurement program. The measurement program may include a plurality of modes. A first mode may include a low-power mode.

The microcontroller may instruct the sensor to collect measurements based on the measurement program at **746**. In some embodiments, instructing the sensor to collect the measurements includes transitioning the microcontroller to a second mode of the plurality of modes. The second mode of the plurality of modes may be a sensing mode. In some embodiments, the microcontroller records the measurements on memory connected to the microcontroller at **748**.

In some embodiments, the switch setting is a first switch setting. The microcontroller may identify a second switch setting on the switch. The second switch setting may be associated with a transmission mode and the microcontroller may transmit the measurements on the memory to a remote computing device. In some embodiments, the microcontroller is not transmitting the measurements to the remote computing device unless the second switch setting is identified.

As mentioned, FIG. **8** illustrates a flowchart of a method **850** of a series of acts for performing downhole measurements, in accordance with one or more embodiments. While FIG. **8** illustrates acts according to one embodiment, alternative embodiments may omit, add to, reorder, and/or modify any of the acts shown in FIG. **8**. The acts of FIG. **8** can be performed as part of a method. Alternatively, a non-transitory computer-readable medium can comprise instructions that, when executed by one or more processors, cause a computing device to perform the acts of FIG. **8**. In some embodiments, a system can perform the acts of FIG. **8**.

In some embodiments, an activation unit detects an interrupt event at a microcontroller at **852**. For example, as discussed herein, the activation unit may include a sensor configured to detect a particular signal. When the activation unit detects the signal, the activation unit may instruct the microcontroller to enter an identification mode. In some embodiments, detecting the interrupt includes detecting a pattern in the input signal. If the activation unit detects a predetermined pattern in the input signal, then the microcontroller may enter the identification mode. In some embodiments, when the activation unit first detects the input signal, the microcontroller enters the identification mode while the activation unit searches for the predetermined pattern. If the predetermined pattern is not identified, then the microcontroller may return to hibernation.

In the identification mode, the microcontroller optionally detects a state of the switch at **854**. For example, the microcontroller may send a signal to the switch and may determine the position of each of the levers of the switch. As discussed herein, based on the switch position of the switch, the microcontroller may transition from the hibernation mode at **856**.

The embodiments of the downhole measurement module have been primarily described with reference to wellbore drilling operations; the downhole measurement modules described herein may be used in applications other than the drilling of a wellbore. In other embodiments, downhole measurement modules according to the present disclosure may be used outside a wellbore or other downhole environment used for the exploration or production of natural resources. For instance, downhole measurement modules of the present disclosure may be used in a borehole used for placement of utility lines. Accordingly, the terms "wellbore," "borehole" and the like should not be interpreted to limit tools, systems, assemblies, or methods of the present disclosure to any particular industry, field, or environment.

One or more specific embodiments of the present disclosure are described herein. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, not all features of an actual embodiment may be described in the specification. It should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. For example, any element described in relation to an embodiment herein may be combinable with any element of any other embodiment described herein. The terms "may" and "can", when used in reference to an illustrated or described embodiment, should be interpreted to mean that a particular embodiment includes such feature or component, but that such feature or component is optional and is excluded in other embodiments within the present disclosure.

Numbers, percentages, ratios, or other values stated herein are intended to include that value, and also other values that are "about" or "approximately" the stated value, as would be appreciated by one of ordinary skill in the art encompassed by embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least the variation to be expected in a suitable manufacturing or production process, and may include values that are within 5%, within 1%, within 0.1%, or within 0.01% of a stated value.

A person having ordinary skill in the art should realize in view of the present disclosure that equivalent constructions are embraced by the present disclosure, and that various changes, substitutions, and alterations may be made to embodiments disclosed herein without departing from the scope of the disclosure and claims. Equivalent constructions, including functional "means-plus-function" clauses are intended to cover the structures described herein as performing the recited function, including both structural equivalents that operate in the same manner, and equivalent structures that provide the same function. It is the express intention of the applicant not to invoke means-plus-function or other functional claiming for any claim except for those in which the words 'means for' appear together with an associated function. Each addition, deletion, and modification to the embodiments that falls within the meaning and scope of the claims is to be embraced by the claims.

The terms "approximately," "about," and "substantially" as used herein represent an amount close to the stated amount that is within standard manufacturing or process tolerances, or which still performs a desired function or achieves a desired result. For example, the terms "approximately," "about," and "substantially" may refer to an amount that is within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of a stated amount. Further, it should be understood that any directions or reference frames in the preceding description are merely relative directions or movements. For example, any references to "up" and "down" or "above" or "below" are merely descriptive of the relative position or movement of the related elements.

The present disclosure may be embodied in other specific forms without departing from its spirit or characteristics. The described embodiments are to be considered as illustrative and not restrictive. The scope of the disclosure is, therefore, indicated by the appended claims rather than by the foregoing description. Changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A downhole measurement module, comprising:
a microcontroller having a plurality of inputs;
a sensor connected to a first input of the plurality of inputs; and
a switch connected to a second input of the plurality of inputs, the microcontroller implementing a measurement program to receive measurements from the sensor, the measurement program being based on a switch setting of the switch,
wherein the switch includes a plurality of switch settings, and the switch setting is a first switch setting of the plurality of switch settings, and
wherein the switch includes a second switch setting of the plurality of switch settings, the second switch setting instructing the microcontroller to transmit measurements recorded on a memory to a remote computing device.

2. The downhole measurement module of claim **1**, wherein the switch is a mechanical switch.

3. The downhole measurement module of claim **2**, wherein the mechanical switch includes a plurality of levers, the switch setting being based on a position of each lever of the plurality of levers.

4. The downhole measurement module of claim **1**, wherein the switch is unpowered.

5. The downhole measurement module of claim **1**, wherein the measurement program includes at least one of a hibernation period, a trigger detection mode, or a sensing mode.

6. The downhole measurement module of claim **1**, wherein the microcontroller will not transmit the measurements unless the switch is in the second switch setting.

7. The downhole measurement module of claim **1**, wherein the measurement program is stored in firmware on the microcontroller.

8. The downhole measurement module of claim **1**, wherein the switch includes a communication element, and wherein a position of the switch is adjustable from a remote computing device.

9. A method for performing downhole measurements, comprising:
at a microcontroller of a downhole measurement module, identifying a switch setting on a switch connected to a first input of the microcontroller, wherein the switch setting is a first switch setting;
at the microcontroller, identifying a second switch setting on the switch;
determining a measurement program implemented by the microcontroller for a sensor connected to a second input of the microcontroller, the measurement program being based on the switch setting;
instructing the sensor to collect measurements based on the measurement program;
recording the measurements on memory connected to the microcontroller; and
instructing the microcontroller, via the second switch setting, to transmit the measurements recorded on the memory to a remote computing device.

10. The method of claim **9**, wherein the microcontroller will not transmit the measurements to the remote computing device unless the second switch setting is identified.

11. The method of claim **9**, wherein the measurement program includes a plurality of modes, and wherein, in a first mode of the plurality of modes, the microcontroller is in a low-power mode, and wherein instructing the sensor to collect the measurements includes transitioning the microcontroller to a second mode of the plurality of modes, the second mode of the plurality of modes being a sensing mode.

12. The method of claim **9**, further comprising:
adjusting the switch setting on the switch.

* * * * *