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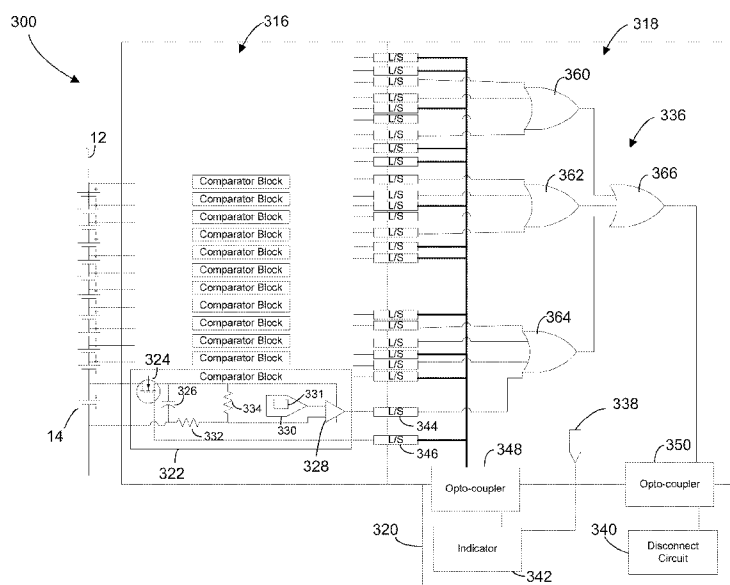
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- (71) Applicant (for all designated States except US): **JOHN-SON CONTROLS TECHNOLOGY COMPANY** [US/US]; 915 East 32nd Street, Holland, Michigan 49423 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **CHEN, Deeyu, C.** [US/US]; 9745 S. Shepard Hills Drive, Oak Creek, Wisconsin 53154 (US). **THOMPSON, Michael, L.** [US/US]; W1317 Beach Road, East Troy, Wisconsin 53120 (US).
- (74) Agent: **SHIPLEY, Howard, N.; FOLEY & LARDNER LLP**, 777 E. Wisconsin Avenue, Milwaukee, Wisconsin 53202 (US).
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(57) Abstract: A battery management system includes a plurality of comparator circuits and each of the comparator circuits is associated with a single cell of a battery system. Each comparator circuit includes a source for providing a reference voltage and a comparator coupled to the source and to a cell of the battery system. The comparator is configured to provide a signal representative of an over-voltage condition if a voltage of the cell to which it is coupled exceeds the reference voltage. A device is coupled to the plurality of comparator circuits and is configured to disconnect the battery system from an electrical load if at least one of the comparator circuits provides a signal representative of an over-voltage condition.

OVER-VOLTAGE PROTECTION CIRCUIT AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Patent Application No. 60/800,973 filed May 17, 2007, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

[0002] The present invention relates generally to the field batteries and battery systems. More specifically, the present system relates to over-voltage protection and over-voltage protection systems and methods for use with battery systems in vehicles such as automobiles.

[0003] It is known to provide batteries for use in vehicles such as automobiles. For example, lead-acid batteries have been used in starting, lighting, and ignition applications. More recently, hybrid vehicles have been produced which utilize a battery (e.g., a nickel-metal-hydride (“NiMH”) battery) in combination with other systems (e.g., an internal combustion engine) to provide power for the vehicle.

[0004] Lithium batteries perform differently than nickel-metal-hydride batteries. In some applications, it may be desirable to obtain the enhanced power and/or performance of a lithium battery. For example, lithium batteries may provide greater specific power than nickel-metal-hydride batteries. However, the application of lithium battery technology may present design and engineering challenges beyond those typically presented in the application of conventional nickel-metal-hydride battery technology.

[0005] The design and management of a lithium battery system that can be advantageously utilized in a hybrid vehicle may involve considerations such as electrical monitoring, thermal management, and containment of effluent.

[0006] Certain battery systems may include circuitry intended to prevent undesirable consequences that may result in the event that one or more batteries or cells in the battery system exceed a predetermined voltage threshold (referred to herein as “overvoltage protection”). One such consequence is that one or more batteries or cells in the battery system may reach an undesirable temperature such that all or a portion of the batteries melt

or experience more catastrophic damage, which may result in damage to the battery system or adjacent systems. It is therefore known that temperature increases in a battery system are related to the amount of charge in the system, and thus overheating generally occurs when too much charge is stored in the system.

[0007] Overcharge protection circuitry generally includes a single comparator and a set of analog switches. Such a configuration is relatively expensive and does not provide monitoring of individual batteries or cells for overcharge conditions. Such configuration also does not provide the ability to turn off or disconnect individual batteries or cells when they are not in use in order to save power.

[0008] Other known overcharge protection circuitry may individually monitor each cell with a measuring unit containing an opto-coupler. These systems generally do not allow for the power to be cut-off from the measuring units when not in use and thus may consume an undesirable amount power within the battery system. Additionally, the inclusion of an opto-coupler in every measuring unit may result in a relatively expensive construction.

[0009] Thus, there is a need for overcharge protection circuitry that allows for individual battery cells to be monitored for increased safety and a reduction in damage. There is also a need for overcharge protection circuitry that includes elements that can be turned off when not in use to save power. There is also a need for overcharge protection circuitry that has a relatively low-cost design.

[0010] What is needed is a system and/or method that satisfies one or more of these needs or provides other advantageous features. Other features and advantages will be made apparent from the present specification. The teachings disclosed extend to those embodiments that fall within the scope of the claims, regardless of whether they accomplish one or more of the aforementioned needs.

SUMMARY

[0011] An exemplary embodiment relates to a battery management system including a plurality of comparator circuits. Each of the comparator circuits is associated with a single cell of a battery system and includes a source for providing a reference voltage and a comparator coupled to the source and to a cell of the battery system, the comparator configured to provide a signal representative of an over-voltage condition if a voltage of the cell to which it is coupled exceeds the reference voltage. A device is coupled to the

plurality of comparator circuits and is configured to disconnect the battery system from an electrical load if at least one of the comparator circuits provides a signal representative of an over-voltage condition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The application will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0013] FIGURE 1 is a perspective view of a vehicle having a battery system according to one exemplary embodiment;

[0014] FIGURE 2 is a perspective view of a battery system according to an exemplary embodiment;

[0015] FIGURE 3 is a block diagram of an over-voltage protection circuit and battery system according to an exemplary embodiment;

[0016] FIGURE 4 is a block diagram of an over-voltage protection circuit and battery system according to another exemplary embodiment;

[0017] FIGURE 5 is a block diagram showing over-voltage protection circuits being used as redundant over-voltage protection measures according to various exemplary embodiments;

[0018] FIGURE 6 is a flow chart of a method of providing over-voltage protection to a battery system according to an exemplary embodiment; and

[0019] FIGURE 7 is a flow chart of a method of providing over-voltage protection to a battery system according to another exemplary embodiment.

DETAILED DESCRIPTION

[0020] Before turning to the figures which illustrate the exemplary embodiments in detail, it should be understood that the application is not limited to the details or methodology set forth in the following description or illustrated in the figures. It should also be understood that the phraseology and terminology employed herein is for the purpose of description only and should not be regarded as limiting.

[0021] Referring generally to the FIGURES, a vehicle battery system is shown. The vehicle battery system includes an over-voltage protection circuit that includes a comparator. Each comparator receives voltage indication from an interface with a cell and voltage indication from a reference source. The comparator block compares the voltage indication from the cell to the voltage indication from the reference source. Output from each comparator block is converted to a digital signal for further recognition by a battery management system. A level shifter may conduct the analog to digital conversion. If a comparator block detects a voltage greater than a threshold, the output from the comparator block is converted to a digital / logical "1" and sent to a digital circuit. The digital circuit is configured to pass a logical "1" to a device of the battery management system if any of the comparator blocks detect a voltage greater than the threshold. The digital circuit may include a series of OR gates configured to provide output to an opto-coupler between the digital circuit and the device. According to an exemplary embodiment, the system uses a reduced number of opto-couplers compared to conventional designs by combining digital outputs from the level shifters into a single opto-coupler via the OR array.

[0022] Referring to FIGURE 1, a vehicle 10 is shown according to an exemplary embodiment. Vehicle 10 includes a battery system 12. While vehicle 10 is shown as an automobile, according to various alternative embodiments, vehicle 10 may comprise a wide variety of vehicles, including, among others, motorcycles, buses, recreational vehicles, boats, and the like. Battery system 12 is configured to provide at least a portion of the power required to operate vehicle 10. Further, it should be understood that according to various alternative embodiments, battery system 12 may be utilized in a variety of applications not involving a vehicle such as vehicle 10 (e.g., vehicle auxiliary power applications, computing applications, laptop application, cellular phone applications, audio/video applications, home electronics, business electronics, etc.), and all such applications are intended to be within the scope of the present disclosure.

[0023] Referring to FIGURE 2, a perspective view of battery system 12 is shown according to an exemplary embodiment. Battery system 12 includes a plurality of battery cells 14, a housing or frame 18, a cooling device (e.g., fan) 22, and a battery management system 16. Battery system 12 may be installed in or include exterior housing 20. It is important to note that battery system 12 may include any number of cells, housing or frame structures, cooling devices, and/or any other combination of design features and may still be used with the over-voltage protection circuits and methods of the present application.

Frame 18 may serve to package cells 14 in a cell assembly. Battery system 12 may typically be installed into a rear portion of a vehicle, perhaps residing in a trunk portion. Exterior housing 20 may be integral with structures of the vehicle, or may be installed into the vehicle. Housing 20 may fit the contours of the vehicle and provide stability to the various components of the battery system including frame 18. Battery management system 16 may include or house any number of battery control components or circuitry including, for example, the circuitry shown herein.

[0024] Cells 14 may be electrochemical cells (e.g., lithium-ion cells, NiMH cells, nickel cadmium, lead-acid cells) or suitable electrochemical cells of any other type or configuration. Cells 14 are generally configured to store and deliver an electrical charge. According to various exemplary embodiments, cells 14 may take any shape or form (e.g., oval, round, prismatic, rectangular, etc.). While the FIGURES illustrate particular exemplary embodiments of lithium batteries and battery systems, any of a variety of lithium batteries or battery systems may be used according to various other exemplary embodiments. Various nonexclusive exemplary embodiments of lithium batteries are shown and described in U.S. Patent Application No. 10/976,169, filed October 28 2004, the entire disclosure of which is incorporated by reference. The batteries, modules, circuits, and other features described herein may be used in conjunction with features disclosed in U.S. Patent Application No. 10/976,169, as will be appreciated by those of skill in the art reviewing this disclosure. Further, according to an exemplary embodiment in which a module or system including a plurality of lithium batteries is provided, the module may be included in a system that includes a plurality of lithium battery modules of any presently known configuration or any other configuration that may be developed in the future.

[0025] Referring to FIGURE 3, a block diagram of an over-voltage protection circuit 300 is shown according to an exemplary embodiment. Over-voltage protection circuit 300 is generally configured to protect battery system 12 from an over-voltage condition and resulting consequences thereof. Battery system 12 is shown including one or more cells 14 (e.g., shown schematically as ten or more cells) that may store and deliver an electrical charge. While the exemplary embodiment shown in FIGURE 1 includes twelve cells 14, according to other exemplary embodiments, a greater or lesser number of cells may be used (e.g., according to an exemplary embodiment, six cells may be provided in the battery system).

[0026] According to an exemplary embodiment, cells 14 are generally connected together in series such that the positive terminal of one cell is connected to the negative terminal of the next cell, and so on. This connection may be made using a bus bar and/or any other connector configured to interconnect the cells so that electricity may be delivered to the vehicle's electrical system.

[0027] According to an exemplary embodiment, protection circuit 300 includes a first circuit or section 316, a second circuit or section 318, and a device 320. First circuit 316 includes a comparator block 322 for each cell 14. Comparator block or circuit 322, in addition to having other features, compares the voltage across a connected cell 14 against a threshold voltage. Comparator blocks 322 may be coupled to cells 14 in a number of ways to compare the voltage across the cell. For example, each comparator block 322 may include an interface that includes sense lines (shown schematically in FIGURE 3) connecting the terminals of cell 14 to comparator block 322. While the elements or components included in comparator blocks 322 are shown for only one of the comparator blocks 322 in FIGURE 3, it should be understood by those reviewing this disclosure that each of the comparator blocks 322 includes identical or equivalent elements or components.

[0028] While the illustrated exemplary embodiment includes a comparator block 322 for each battery cell 14 provided in battery system 312, according to other exemplary embodiments, more than one comparator block may be used for each cell so that over-voltage protection is still possible if one comparator block 322 malfunctions. According to other exemplary embodiments, only a some or a portion of the cells may have an associated comparator block such that a random sampling of cells may be obtained. According to still other exemplary embodiments, a group of cells may be associated with a single comparator block.

[0029] Each of the comparator blocks 322 generally includes a switch 324, a capacitor 326, a comparator 328, a reference source 330 for providing a reference or threshold voltage, a resistor 332, and a resistor 334.

[0030] Capacitor 326 is intended to hold the charge of cell 14 relatively steady or constant across switch 324 for more accurate switching. According to various other exemplary embodiments, other electrical components may be used to hold, hold steady, and/or smooth or filter the charge of cell 14.

[0031] Comparator 328 is configured to compare the voltage of cell 14 with a reference voltage provided by source 330. If the voltage of cell 14 is higher than the reference voltage, a high voltage (e.g., a binary “1”) is output to second circuit 318. On the other hand, if the voltage of cell 14 is lower than the reference voltage, a low voltage (e.g., a binary “0”) is output to second circuit 318. According to various other exemplary embodiments, comparator 328 may be of any past, present, or future design capable of comparing two voltages (e.g., a comparing logic chip, a signal comparing op-amp, a comparing circuit, one or more relays, a schmitt trigger, a comparing trigger, etc.).

[0032] According to an exemplary embodiment, source 330 obtains its input from cell 14. The voltage provided by source 330 is stepped down by source 330 to a predetermined lower voltage utilizing suitable circuitry (e.g., a zener diode 331) prior to being provided to comparator 328. According to one exemplary embodiment, source 330, utilizing zener diode 331, provides an output voltage to comparator 328 only in the event that the voltage across cell 14 is above a predetermined activation or threshold voltage. For example, source 330 may be configured to provide an output voltage of 2.2 volts whenever cell 14 has a voltage of greater than 3.6 volts. In this manner, the reference voltage provided by source 330 will always be either zero volts or 2.2 volts, depending on whether the voltage of cell 14 is above the 3.6 volt threshold. While zener diode 331 is shown as a component of reference source 330, it should be noted that any other suitable component or combination of components may also be used to regulate, lower, step-down, and/or otherwise hold voltage input from cell 14 (or some other source that may be used as a reference for comparison).

[0033] Comparator 328 compares the reference voltage (e.g., 2.2 volts) received from source 330 with a voltage received from cell 14 by way of a voltage divider (shown as resistors 332 and 334 in FIGURE 1). That is, resistors 332 and 334 are provided to lower the voltage of cell 14 that is provided to comparator 328. It should be appreciated that components other than resistors 332 and 334 may be used to divide or controllably step down voltage received from cell 14. It should also be appreciated that source 330 may be configured to provide an output voltage of a higher reference level (e.g., 4.8 volts) whenever comparator block 322 is activated. That is, voltage received from cell 14 may not be lowered and may be directly compared to a relatively high reference voltage of source 330, according to various exemplary embodiments. The voltage receiving components configured to receive the voltage from cell 14 to be compared against the reference voltage

may generally define a cell interface (including, for example, sense lines or other electrical input lines coming from cell 14, capacitor 326, resistors 332 and 334, etc.).

[0034] According to yet other exemplary embodiments, comparator block 322 may include an additional capacitor and/or resistor to filter the input voltage from cell 14 to prevent spurious operation. According to yet other exemplary embodiments, less filtering and/or different filtering mechanisms may be used to prevent spurious operation.

[0035] According to a particular exemplary embodiment, source 330 is provided to comparator 328 as a 2.2 volt reference voltage when cell 14 is above 3.6 volts. The input voltage received from cell 14 is provided to comparator 328 at a value that is half that of the voltage for cell 14 (e.g., if the cell voltage is 4 volts, the voltage provided to the comparator 328 will be 2 volts due to the presence of the voltage divider; it should be noted that depending on the value of the resistors used in the voltage divider, the value of the input voltage may differ according to other exemplary embodiments). In such an embodiment, if the voltage of cell 14 is higher than 4.4 volts, comparator outputs a high voltage (e.g., a binary “1”) and if voltage of cell 14 is below 4.4 volts, comparator 328 outputs a low voltage (e.g., a binary “0”).

[0036] It should be understood by those reviewing this disclosure that the particular values for voltages and other characteristics of the components described herein with respect to the various exemplary embodiments are provided as examples only, and are not intended to be limiting in any way to the scope of the inventions described herein. It should also be noted that according to other exemplary embodiments, any threshold voltage or activation voltage may be used as may be appropriate for battery system 12. In still another exemplary embodiments, source 330 may be independent of the voltage of cell 14.

[0037] A level shifter 344 (e.g., voltage shifter, analog to digital converter, etc.) is associated with each comparator block 322 and serves to shift the voltage range output by first circuit 316 to a form suitable for use by second circuit 318. A level shifter 346 is also associated with each comparator block 322 and serves to shift the voltage output by device 320 to a form suitable for use by first circuit 316. A single opto-coupler 348 serves as an interface between the output of indicator 342 and the input of all level-shifters 346. A single opto-coupler 350 serves as an interface between the output of OR array 336 and the input of disconnect circuit 340. Opto-coupler 350 may be any device that isolates one set of circuitry from the other while allowing a signal to be communicated from one circuit to the

next. Opto-coupler 350 (i.e., optical-coupler, optical-isolator, photocoupler, etc.) may be any suitable device or combination of devices capable of communicating state while maintaining coupled circuits as electrically isolated. According to various exemplary embodiments, opto-coupler 350 is not included between second circuit 318 and device 320. According to yet other exemplary embodiments, opto-coupler 350 is provided entirely in or on second circuit 318 and/or device 320. The same variety of possibilities exist for opto-coupler 348, according to various exemplary embodiments.

[0038] Second circuit 318 (i.e., digital circuit 318) generally includes a hierarchical array 336 of OR gates (shown in FIGURE 3 as OR gates 360, 362, 364, and 366) that are powered by a reference voltage provided by a source 338. Second circuit 318 combines the outputs of comparator blocks 322 into one signal that is provided to device 320. If the output of any comparator block 322 included in first circuit 316 is high signal (e.g., a binary “1”), indicating an over-voltage condition, then the output of OR array 336 will also be high (e.g., a binary “1”). In various exemplary embodiments, different numbers of OR gates than illustrated in FIGURE 3 may be used as long as the output of OR array 336 (e.g., provided by OR gate 366 as shown in FIGURE 3) remains representative of a condition in which any of the cells in battery system 12 are showing an over-voltage characteristic. For example, instead of being associated with four cells each (as shown in FIGURE 1 for OR gates 360, 362, and 364), each of the OR gates in the “first level” may be associated with a different number of cells (e.g., two cells, three cells, six cells, etc.).

[0039] Device 320 is configured to use the output of second circuit 318 to control battery system 312 and to send control signals to comparator block 322. Device 320 includes an indicator 342 and a disconnect circuit 340. Disconnect circuit 342 is configured to disconnect battery system 312 from the coupled load (e.g., the vehicle’s electrical system) if second circuit 318 indicates that at least one of cells 14 is in an over-voltage condition.

[0040] According to other exemplary embodiments, device 320 may contain a time based digital circuit (e.g., clock and shift register or accumulator) to filter the output of second circuit 318. This would require that a high (e.g., a binary “1”) be present for a predetermined length or duration of time (e.g., some number of clock pulses) to pass a signal on to the disconnect circuit 342. Such a time based digital circuit may be used to prevent spurious operation.

[0041] According to an exemplary embodiment, indicator 342 outputs signals to switch 324 in order to control whether or not comparator block 322 is active. Switch 324 is a MOSFET transistor that may disconnect comparator block 322 from cell 14 based on a signal received from device 320. According to other exemplary embodiments, switch 324 may be any past, present, or future type of switch that may function to disconnect or terminate an electrical circuit (e.g., another type of transistor, an analog switch, one or more relays, etc.). Switch 324 is intended to allow each comparator block 322 to shut down and save power when not in use. Switch 324 may be configured to activate comparator block 322 using only sensed voltage levels of a cell 14. For example, switch 324 may be configured to switch the components of comparator block 322 on if it detects a certain voltage or current indicating that the vehicle is in use or in use and providing an amount of charge so that over-voltage might be a concern. For example, a “reed switch” may be used that senses magnetic fields. This switch is very low cost and will turn on when current is detected and off when current is not detected.

[0042] According to various other exemplary embodiments, indicator 342 is coupled to battery system reference source 338. Indicator 342 may include a voltage divider, comparator and other appropriate circuitry to detect when a battery system voltage level has been reached. When a battery system voltage level has been reached, indicator 342 may signal comparator blocks 322 to activated via switches 324. Indicator 342 is coupled to level shifters 346 by opto-coupler 348. Level shifters 346 may shift, transform, or otherwise convert or change a signal from opto-coupler 348 into a signal sufficient to trigger or activate switch 324. In this manner, device 320 may activate the comparator blocks 322 only when necessary and may turn comparator blocks 322 off when not necessary to save battery power.

[0043] Indicator 342 may use a variety of components and/or inputs to determine whether or not comparator blocks 322 should be activated. For example, indicator 342 may measure or otherwise read voltage across the entire battery system 12 or a group of cells. Indicator 342 may use a divider (e.g., similar to resistors shown in comparator block 322) to divide voltage appropriately for the number of battery cells in the battery system. Indicator 342 may then use a comparator (e.g., similar to comparator 328 shown in comparator block 322) to compare the divided voltage to a reference source 338. When used in this manner, indicator 342 may determine whether or not the average cell voltage has exceeded a certain value. If the average cell voltage has exceeded a certain value, indicator 342 may send an

appropriate electrical signal to switch 324 to activate the comparator block(s) of battery system 12.

[0044] According to other exemplary embodiments, indicator 342 may use any number of additional or alternative methods to determine whether or not the comparator blocks should be activated. For example, according to one exemplary embodiment, indicator 342 will send a comparator block activating signal based on ignition signals received from the vehicle's ignition system. According to other exemplary embodiments, indicator 342 sends comparator block activating signals when the total voltage across battery system 12 exceeds the voltage of reference source 338.

[0045] According to one exemplary embodiment, device 320 may be a vehicle with battery system 312 used by the vehicle for various purposes such as drive-train power, for starting purposes, or to power accessories. According to other exemplary embodiments, device 320 may be any other device that manipulates battery power in consumer, industrial, or commercial sectors.

[0046] Referring to FIGURE 4, an over-voltage protection circuit is shown, according to another exemplary embodiment. In FIGURE 4, second circuit 418 differs from that shown in FIGURE 3 in that OR array 436 is configured such that OR gates 460, 462, and 464 are cascading so that the output of one OR gate is provided to an input of a next OR gate. The last OR gate 464 provides an input to device 320, and more particularly to opto-coupler 350. The configuration shown in FIGURE 4 may provide an increased amount of modularity in that more cells, comparator blocks, level shifters and OR gates may be provided by linking one module to the next via the cascading OR gates. Any additional set of components may be linked to before, between, or after OR gates for integration into the system. According to various other exemplary embodiments, a number of logical gates and/or other components may be used to simulate the OR array shown in the FIGURES. For example, various combinations of NAND gates, AND gates, NOR gates, relays, and other components may be used to receive input from a plurality of comparator blocks and provide output to opto-coupler 350 if any of the comparator blocks indicate an over-voltage situation.

[0047] Referring to FIGURE 5, a block diagram of over-voltage circuits 500 serving as redundant over-voltage protection is shown, according to an exemplary embodiment. In the embodiment shown in FIGURE 5, cells 502 are shown as being coupled by electrical connectors 504 in series. Cells 502 are coupled to ground 506 and to load 508. Load 508

may be the electrical load of the electrical system of a vehicle and/or drive system of a hybrid vehicle. Sense lines 510, 512 are connected to the terminals of cells 502 to provide an input of voltage between terminals of any given cell to a circuit or device of the battery management system. For example, sense lines 510, 512 may provide input to digital measurement units 514. Digital measurement units 514 may serve as the primary battery regulation and over-voltage protection devices for the battery system. Digital measurement units 514 may obtain a variety of readings from sensing lines 510, 512 and provide these readings to coupled processor 516. Processor 516 may serve to disconnect the battery system from the load and/or to otherwise regulate cells 502. Over-voltage protection circuits 500 may also receive inputs from sensing lines 510, 512 to obtain a reading of the voltage across the terminals (shown as connection circles) of battery cells 502. Over-voltage protection circuits 500 may thus serve as redundant over-voltage protection circuits for the battery system.

[0048] According to some exemplary embodiments, the threshold levels used to detect over-voltage in over-voltage protection circuits 500 is higher than that used with digital measurement unit 514 and processor 516. According to yet other exemplary embodiments, the threshold voltage levels used to activate over-voltage protection circuits 500 are higher than or on the high end of voltage levels allowed by digital measurement unit 514 and processor 516. When used in these manners, for example, over-voltage protection unit provides redundant protection without being activated and/or wasting resources if the digital measurement and processor are working properly. According to yet other exemplary embodiments, over-voltage protection circuits 500 are the primary over-voltage protection devices in a redundant system.

[0049] It should be noted that the over-voltage protection circuits shown the FIGURES and otherwise may be implemented in a variety of ways. For example, according to some exemplary embodiments, the comparator blocks and/or other components of the over-voltage protection circuits are provided on a single integrated circuit chip. According to yet other exemplary embodiments, the over-voltage protection circuits are provided on single printed circuit boards and/or are implemented partially with suitable processing units such as field programmable gate arrays.

[0050] Referring to FIGURE 6, a method of monitoring a battery system is shown, according to an exemplary embodiment. In its default state, a comparator block, and the complete array of comparator blocks, will be “off” and not comparing any voltages or

conducting any comparing activity. This “off” state will remain until the comparator block receives an activation signal (step 602). The activation signal may be sent from any number of components or systems (e.g., ignition system, lights, another circuit of the battery management system, etc.). According to various exemplary embodiments, the indicator will compare a sensed battery system voltage to a reference voltage (step 601). If the sensed voltage is above a certain level, the battery system will self-activate the comparator blocks (e.g., send an activation signal to a switch of the comparator blocks). Once the activation signal is received, the comparator blocks will be activated (step 604) and the comparator block may begin receiving voltage input (step 606) from an attached cell. A comparator of the comparator block may then compare the received voltage input to a threshold voltage (step 608). During comparison the comparator will determine whether the received voltage input is greater than the threshold (step 610). If the received input voltage is not greater than the threshold, the comparator block will continue receiving input (step 606) until the comparator block (or the battery system) is deactivated. If the received input voltage is greater than the threshold, the comparator block will provide an output signal a digital circuit (step 612). The digital circuit is coupled to a device that will disconnect the battery system (step 614) if any of the comparator circuits indicates an overvoltage condition occurring with its connected cell.

[0051] Referring to FIGURE 7, a method of monitoring a battery system is shown, according to another exemplary embodiment. The over-voltage protection circuit may start or activate via one of the previously mentioned activation activities (e.g., started via a connection to the vehicle ignition system, self-activated when certain voltage levels are reached, etc.) or otherwise to start the process (step 700). The system will receive voltage input from the cell attached to a comparator (step 702). Smoothing circuitry (e.g., a capacitor) will smooth the voltage input from the cell (step 704). The comparator block may then divide the voltage input (step 706) to obtain a voltage that may be easier to compare to a reference source voltage. A reference source of a comparator block may also receive input voltage from the cell (step 708). If the voltage in step 708 exceeds some minimum level, the reference source (or a component thereof) may hold the voltage at a regulated and stepped-down level (step 710). If the voltage in step 708 does not exceed some minimum level, the comparator block may be deactivated and/or the comparison between the voltage and reference source may not occur. When used in this manner, each comparator block is able to sense over-voltage conditions independent of battery system

wide conditions or the conditions of any other cell. The comparator block may then check to determine whether the instant voltage from step 706 is greater than the regulated and stepped down voltage from step 710. If the instant voltage is not greater than that from the reference source, the process may restart (i.e., the comparator block will continue the receiving, smoothing, dividing, and holding and regulating steps). If the instant voltage is greater than that from the reference source, the comparator block may provide an output signal to an analog to digital converter (step 712). The analog to digital converter may convert any received signal to a '1' or '0' (step 714) or otherwise digitally indicate whether an over-voltage condition has been detected. Digital logic may then be passed through to a battery system device (step 716). This step may include logically combining the signals from a plurality of comparator blocks (e.g., via the OR arrays shown previously) so that if any comparator block detects an over-voltage condition an opto-coupler between the digital logic and the device may be fed a logical '1'. The device may be configured to wait a period of time (step 720) after any initial over-voltage condition is received (e.g., to determine whether or not the over-voltage condition was merely spurious or temporary). If the over-voltage condition is still detected after the period of time has been waited, the device may disconnect the battery system (or a group of cells)(step 722).

[0052] According to any preferred embodiment, the battery management system and over-voltage protection circuits provides a number of advantages. A relatively inexpensive analog comparator block is advantageously provided for each battery cell. This design ensures cell-level monitoring for over-voltage conditions where many battery systems only monitor for over-charge or over-voltage at a battery system level. Additionally, the over-voltage circuit design and methods herein described avoid the need for expensive switching mechanisms configured to switch protection circuitry between battery system cells. Furthermore, the system may be provided as a redundant over-voltage protection mechanism. Yet further, the configuration of the indicator, comparator blocks, and switch advantageously allow the system to power down comparator blocks when they are not needed, saving system power resources. Also, because of the first and second circuit configuration and the use of individual comparators, the level-shifters, and the OR gate array, no component of the over-voltage protection system (or a reduced number of components) experiences high voltages. Rather, the components experience only cell-level voltages, even in over-voltage conditions. A reduced number of expensive opto-coupler are needed as the outputs from the comparator blocks are digitally combined. Further, in some

exemplary embodiments, the system may be modular in that additional comparator blocks, cells, level-shifters and OR gates may be added to the system easily.

[0053] An exemplary embodiment relates to an over-voltage protection circuit for a battery system. The protection circuit includes a plurality of comparator circuits, each of the comparator circuits associated with a single cell of the battery system and including a switch for disconnecting the cell from the battery system and a comparator for comparing a voltage of the associated cell to a reference voltage. The protection circuit further includes a plurality of level shifters, each of the level shifters electrically coupled to the output of a single one of the comparators; at least one OR gate electrically coupled to a plurality of level shifters; and an opto-coupler electrically coupled to the at least one OR gate. The OR gate is configured to provide a signal to the opto-coupler when any one of the cells of the battery system exhibits an over-voltage condition.

[0054] According to yet other exemplary embodiments, a method of monitoring a battery system includes receiving inputs representative of the voltage of a battery included in the battery system and comparing such inputs to a threshold value (e.g., a reference voltage) provided by a source. The threshold value may be provided as a stepped-down value of the voltage of the cell from which an input signal is received (e.g., using a zener diode or other device for stepping down the voltage). The inputs representative of the voltage of a battery may be equivalent to the voltage of a battery or may have a value that is less than the voltage of the battery (e.g., using a voltage divider). The method further includes providing an output signal in the event that the input representative of the voltage of the battery exceeds a predetermined threshold value (e.g., a comparator is provided to compare the stepped-down voltage value provided by the source with the voltage value obtained from the voltage divider or directly from the cell and to provide an output signal if the battery voltage exceeds a predetermined threshold value). The method further includes providing a signal to a device configured to disconnect one or more of the batteries included in the battery system in the event that any one or more of the batteries exceeds a predetermined threshold value and providing a signal from the device to one or more of the batteries to disconnect the batteries from the battery system or from the vehicle electrical system.

[0055] The present disclosure has been described with reference to example embodiments, although workers skilled in the art will recognize that changes may be made in form and detail without departing from the scope of the subject matter disclosed herein. For example, although different example embodiments may have been described as including one or more

features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

[0056] It is important to note that the construction and arrangement of the battery system and/or over-protection circuitry as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. For example, elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present application. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present application. As noted above, embodiments within the scope of the present application include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon.

[0057] It should be noted that although the figures herein may show a specific order of method steps, it is understood that the order of these steps may differ from what is depicted. Also, two or more steps may be performed concurrently or with partial concurrence. Such variation will depend on the software and hardware systems chosen and on designer choice. It is understood that all such variations are within the scope of the application. Likewise, software implementations could be accomplished with standard programming techniques

with rule based logic and other logic to accomplish the various connection steps, processing steps, comparison steps and decision steps.

WHAT IS CLAIMED IS:

1. A battery management system comprising:
a plurality of comparator circuits, each of the comparator circuits associated with a single cell of a battery system and comprising:
a source for providing a reference voltage; and
a comparator coupled to the source and to a cell of the battery system, the comparator configured to provide a signal representative of an over-voltage condition if a voltage of the cell to which it is coupled exceeds the reference voltage; and
a device coupled to the plurality of comparator circuits and configured to disconnect the battery system from an electrical load if at least one of the comparator circuits provides a signal representative of an over-voltage condition.
2. The battery management system of Claim 1, further comprising a plurality of analog to digital converters coupled to the plurality of comparator circuits and a digital circuit coupled to the plurality of analog to digital converters, the digital circuit configured to provide a single output from the digital circuit to the device.
3. The battery management system of Claim 1 further comprising a plurality of level shifters, each of the level shifters electrically coupled to one of the comparator circuits.
4. The battery management system of Claim 3 further comprising at least one OR gate electrically coupled to at least two of the plurality of level shifters.
5. The battery management system of Claim 4 further comprising an opto-coupler electrically coupled to the at least one OR gate.
6. The battery management system of Claim 5 wherein the at least one OR gate is configured to provide a signal to the opto-coupler when a cell of the battery system exhibits an over-voltage condition.
7. The battery management system of Claim 1 wherein the source for providing a reference voltage is a cell-level reference voltage source so that each comparator receives a separate reference voltage.

8. The battery management system of Claim 7 wherein the source for providing a reference voltage includes a zener diode and regulates the separate reference voltage provided to the comparator when the voltage of the cell has exceeded a threshold voltage.

9. The battery management system of Claim 1 wherein each of the comparator circuits further comprise a switch coupled to an indicator, the switch enabling the comparator circuit only if a signal is received from the indicator.

10. The battery management system of Claim 9 wherein the indicator sends a signal to the switch when a vehicle ignition is turned on.

11. The battery management system of Claim 9 wherein the indicator determines a voltage across the plurality of cells of the battery system and sends a signal to the switch if a determined voltage per cell exceeds a predetermined level.

12. The battery management system of Claim 9 wherein the indicator determines a voltage across a plurality of cells and sends a signal to the switch if a determined total voltage level across the plurality of cells exceeds a predetermined level.

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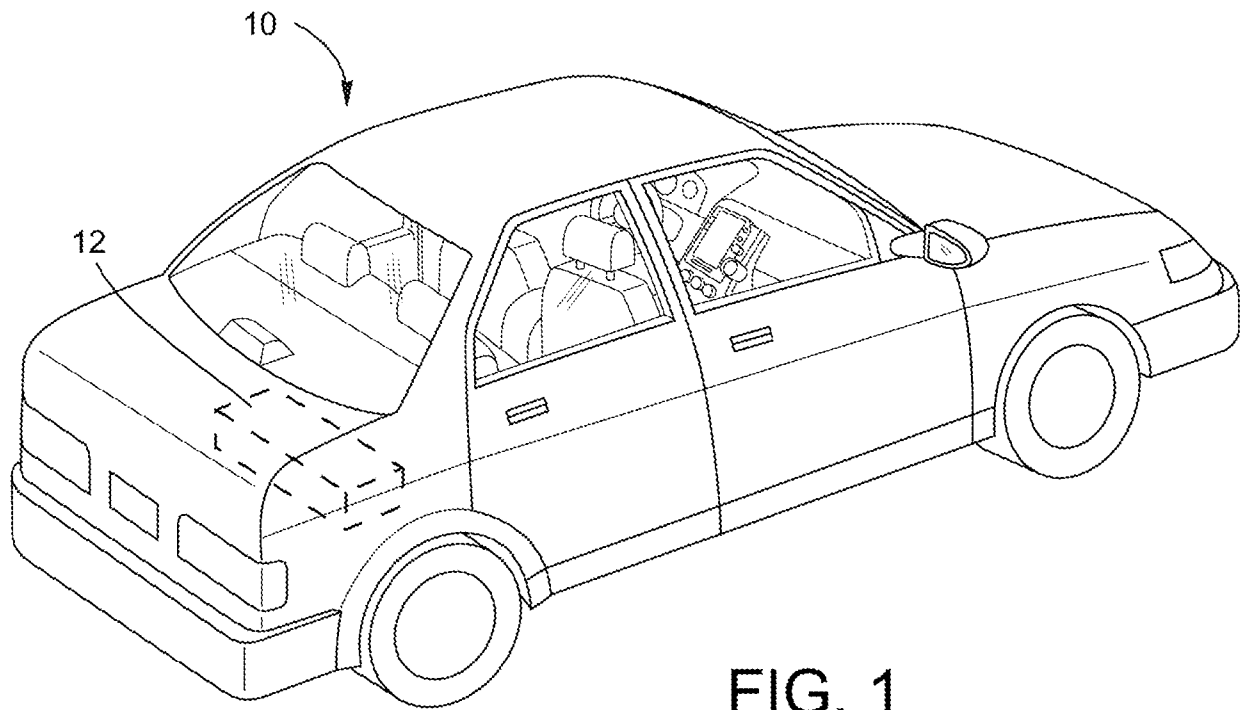


FIG. 1

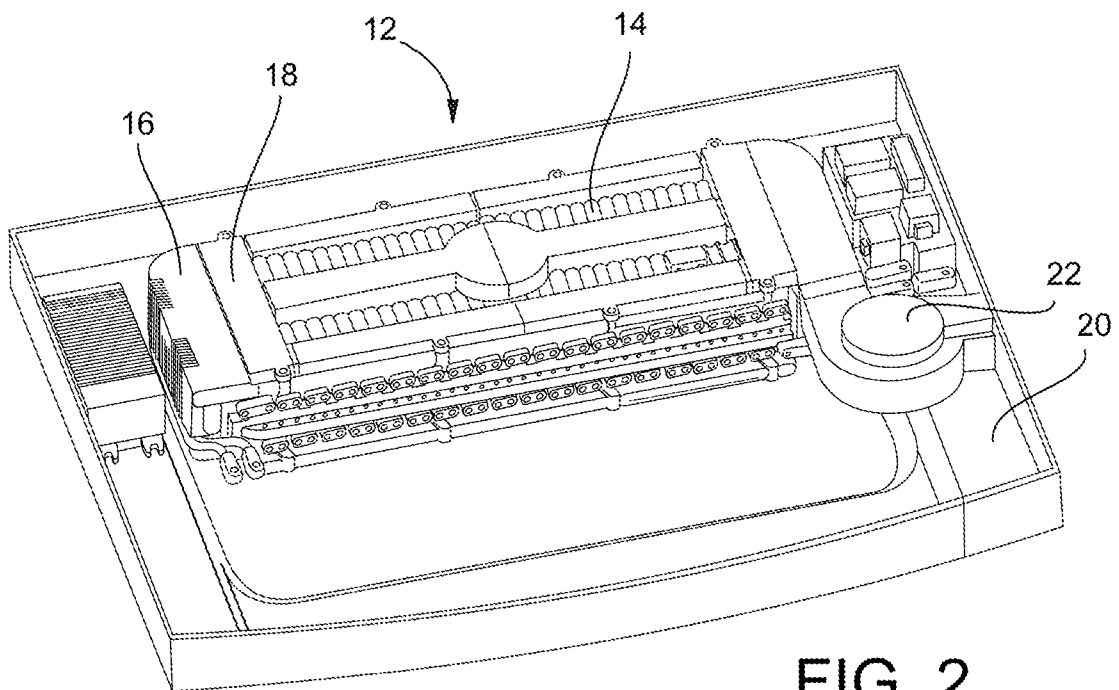
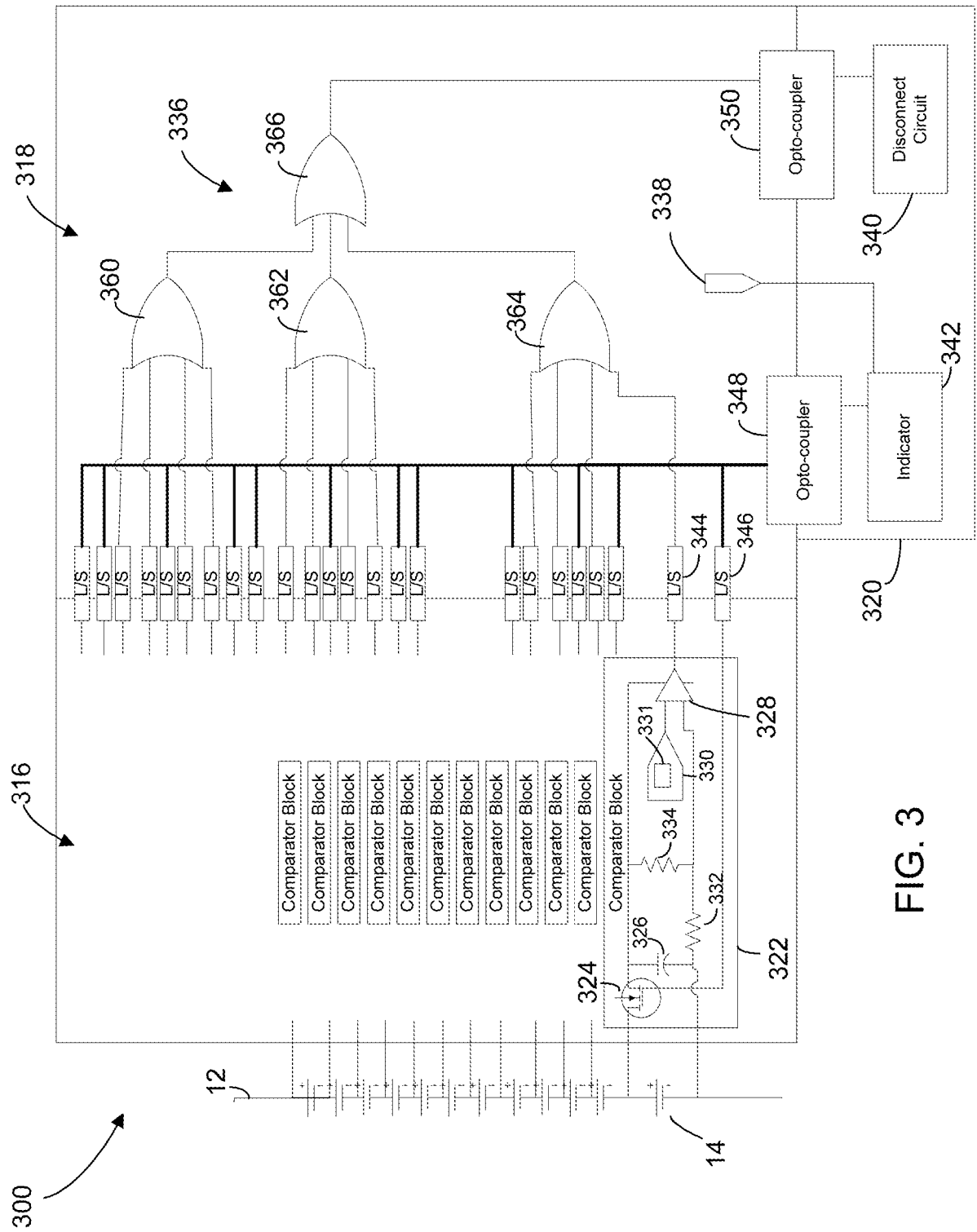


FIG. 2



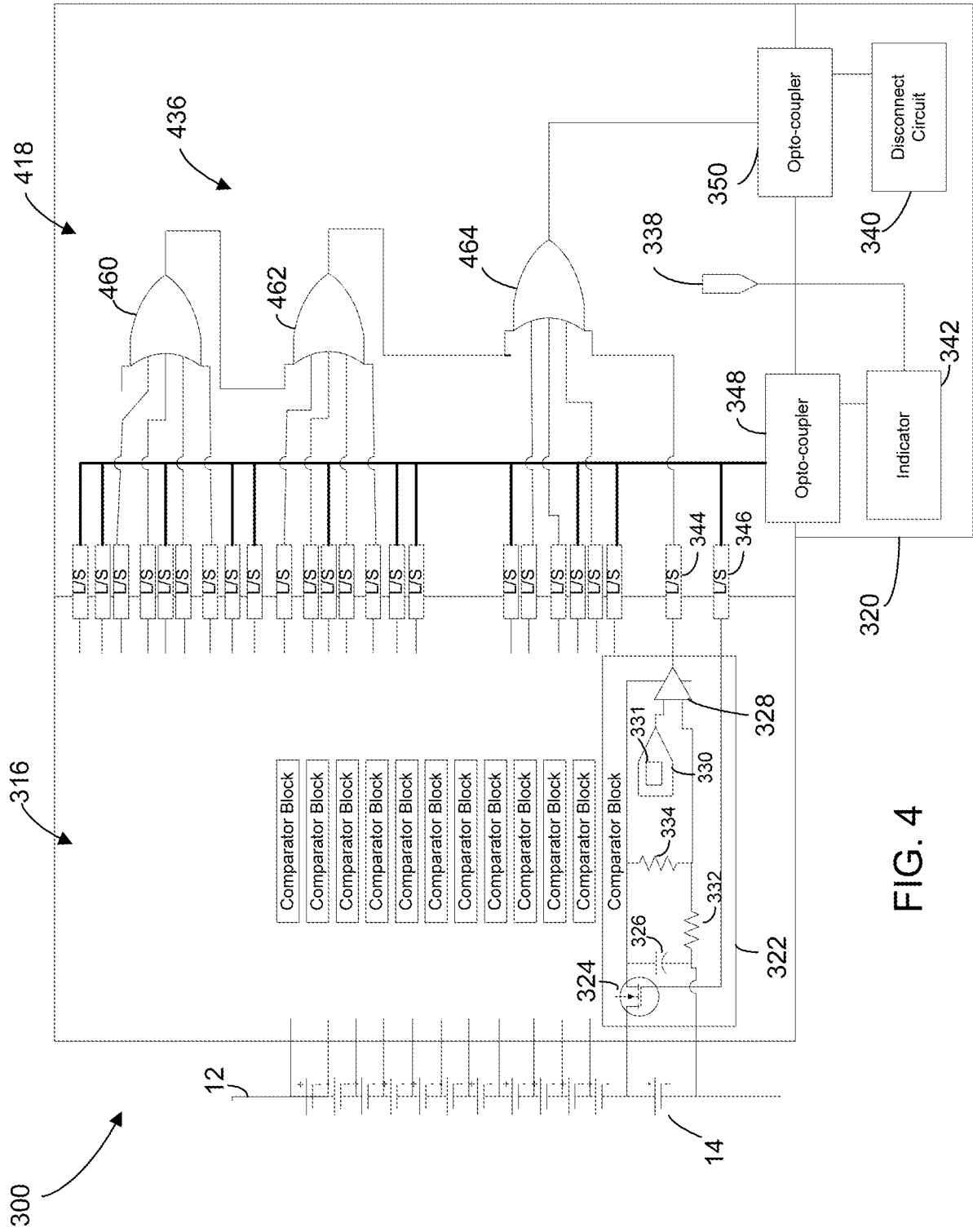


FIG. 4

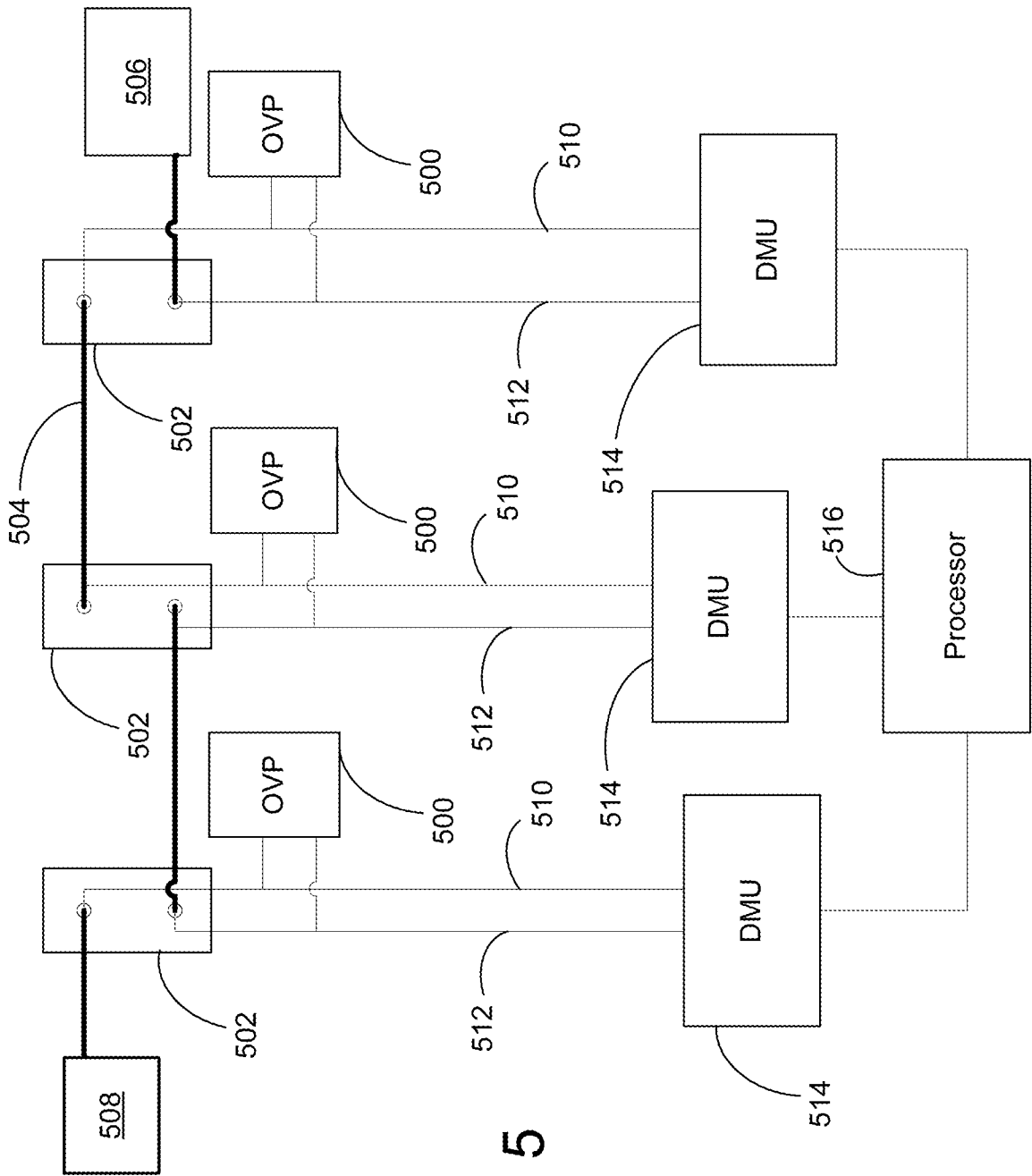


FIG. 5

FIG. 6

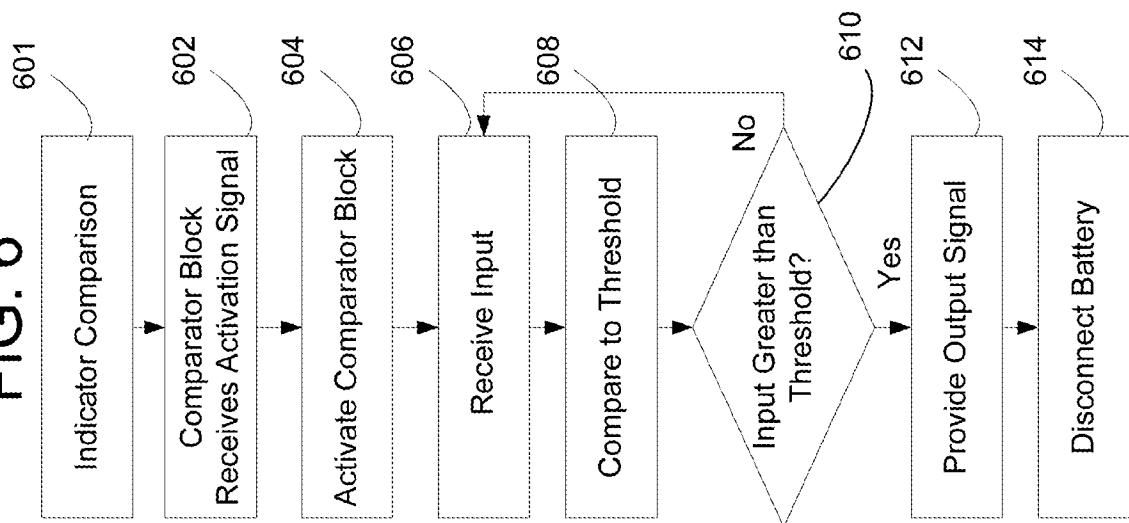


FIG. 7

