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(54) **MODULAR APPROACH FOR ADVANCED BATTERY MODULES HAVING DIFFERENT ELECTRICAL CHARACTERISTICS**

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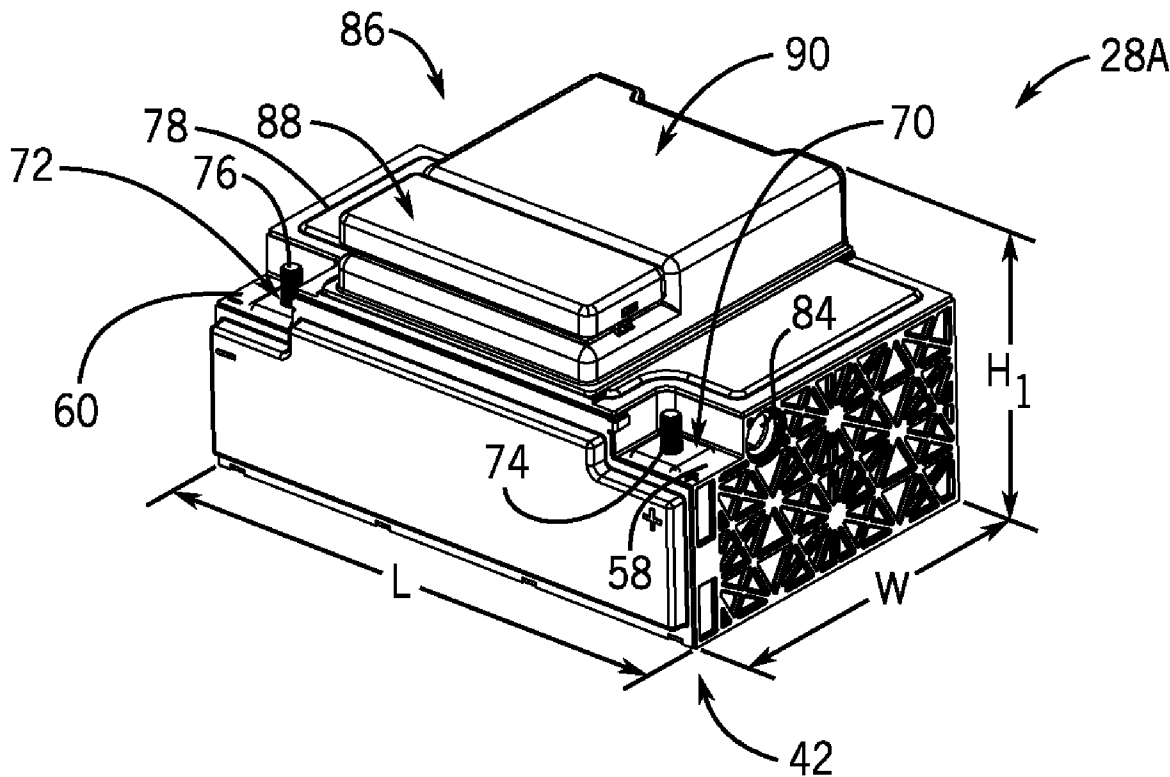
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ABSTRACT

Present embodiments include a series of lithium battery modules having a plurality of electrochemical cells having different electrical characteristics such as voltages and/or capacities. The battery modules are each constructed using components, architectures, production methods, among other things, in common with each other. The lithium ion battery modules may include a first battery module type having a first capacity and a first voltage, a second battery module type having a second capacity and a second voltage, and, in some embodiments, additional battery module types (e.g., a third battery module type having a third capacity and a third voltage) having different voltages and/or capacities. The lithium ion battery modules may all have the same footprint.



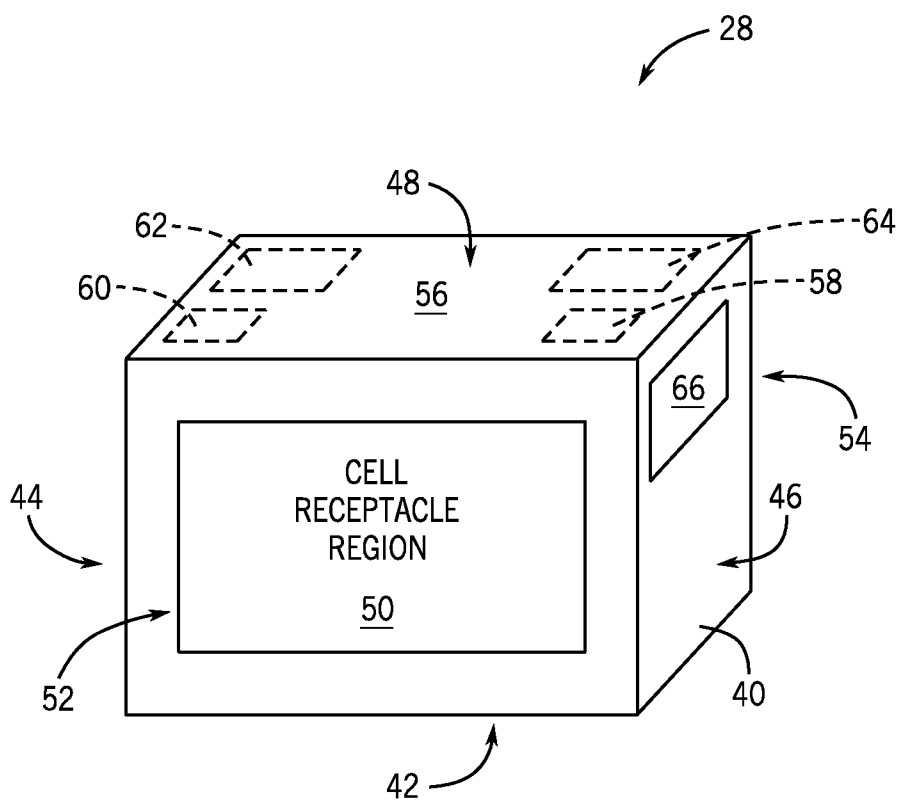
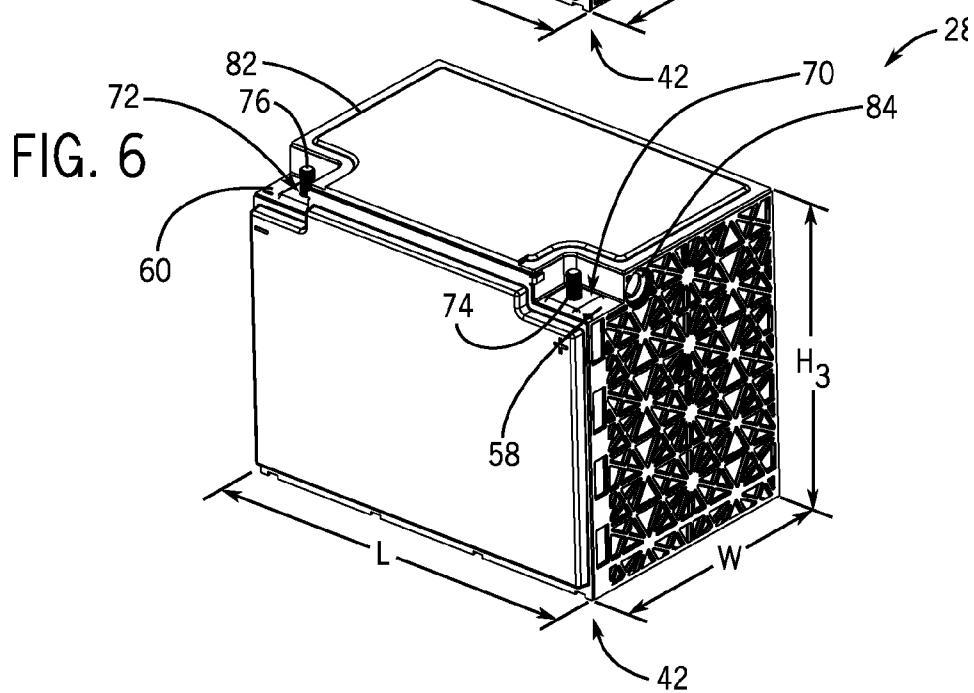
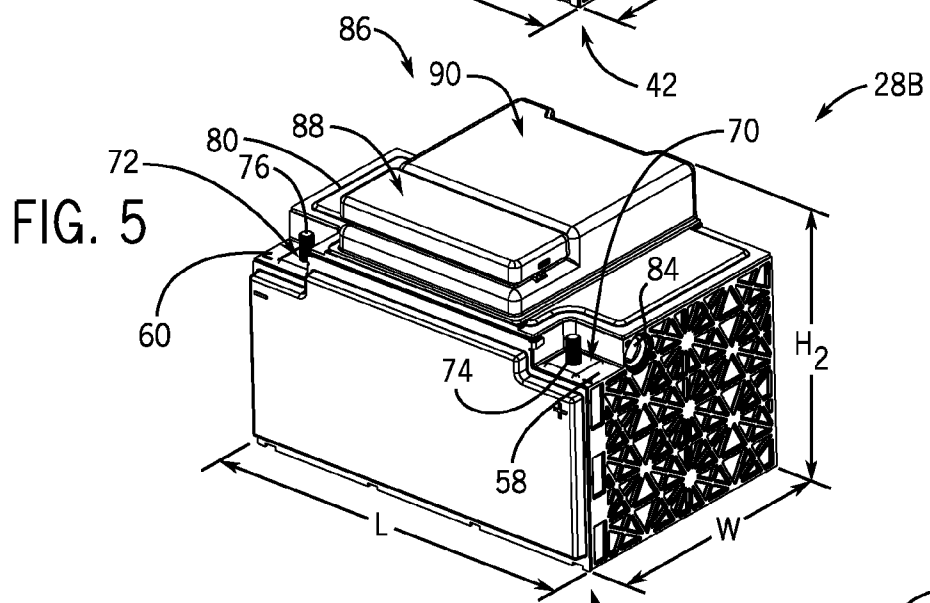
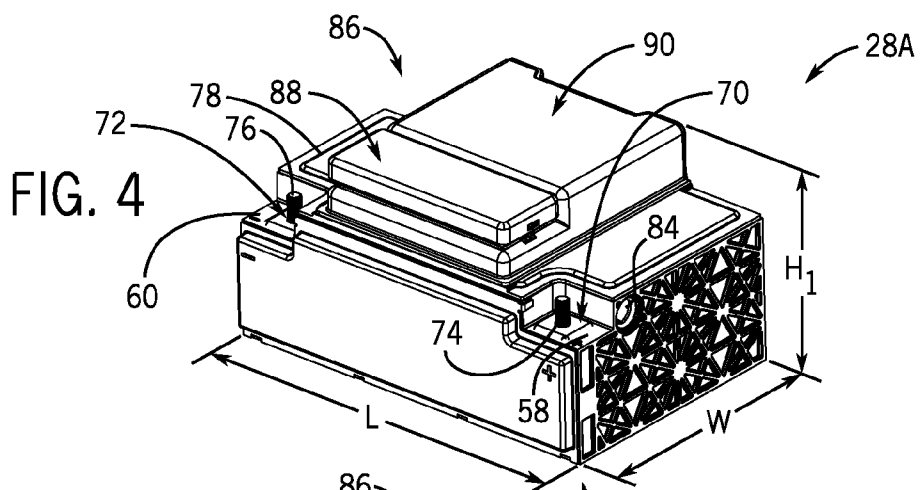


FIG. 3



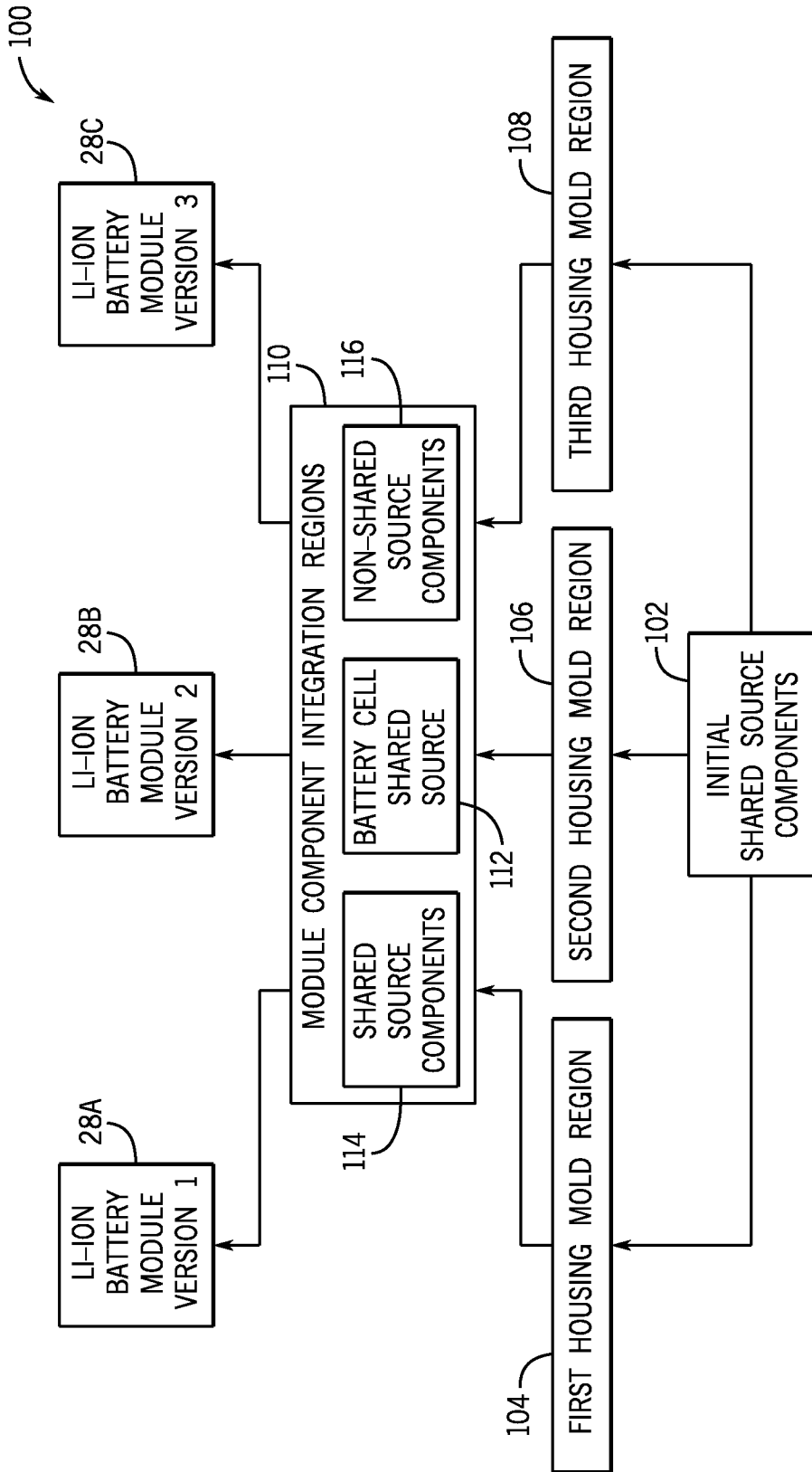


FIG. 7

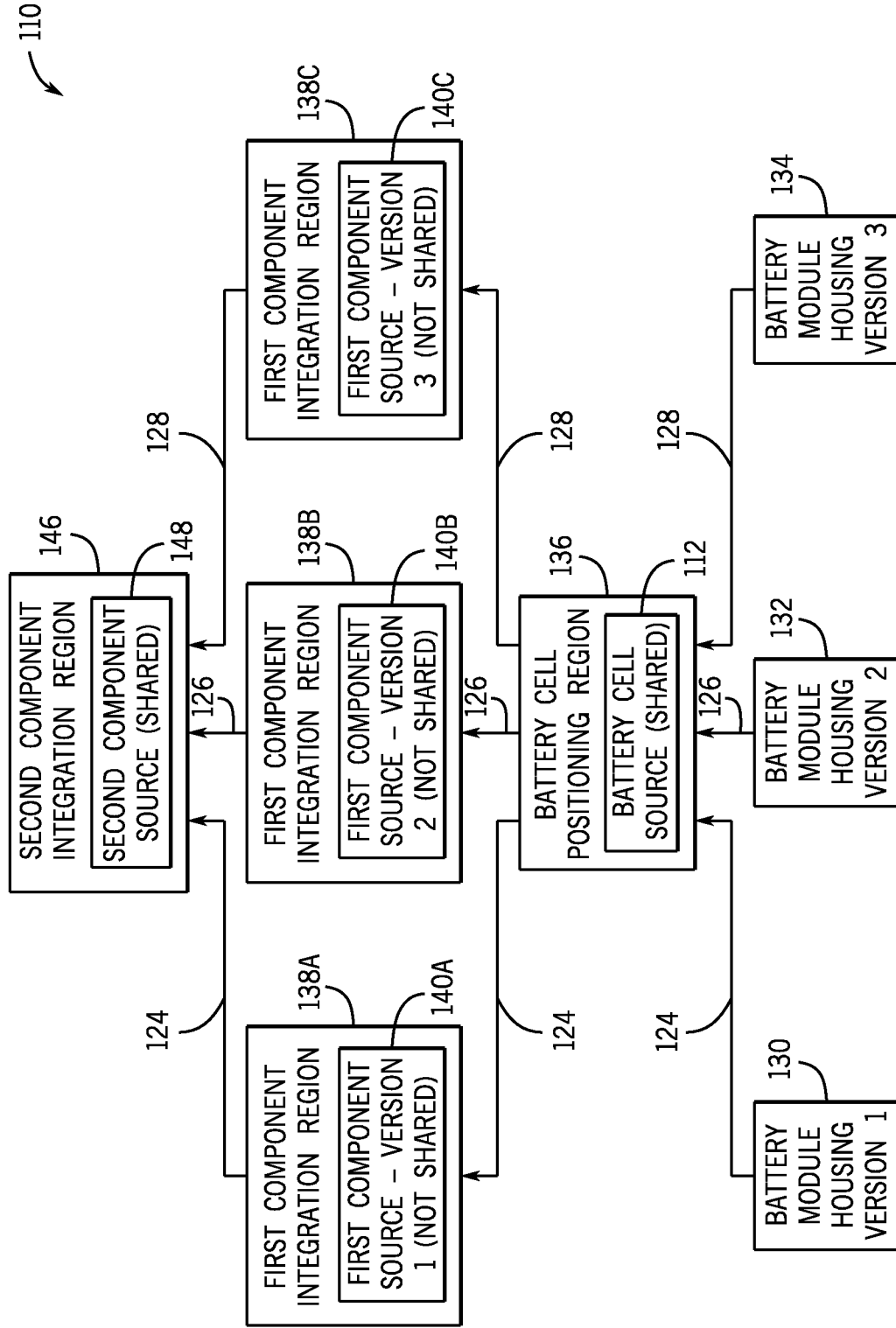


FIG. 8

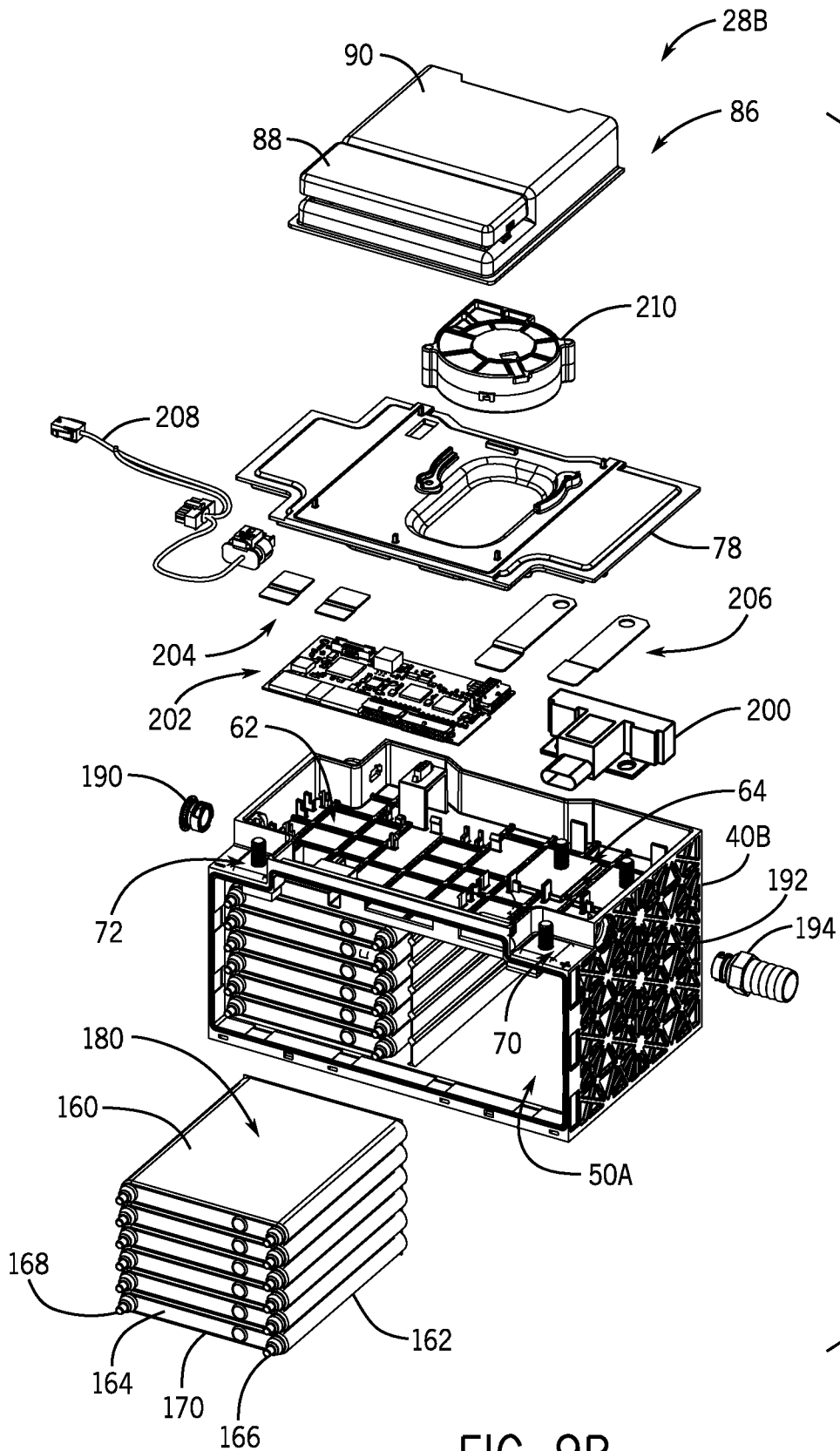


FIG. 9B

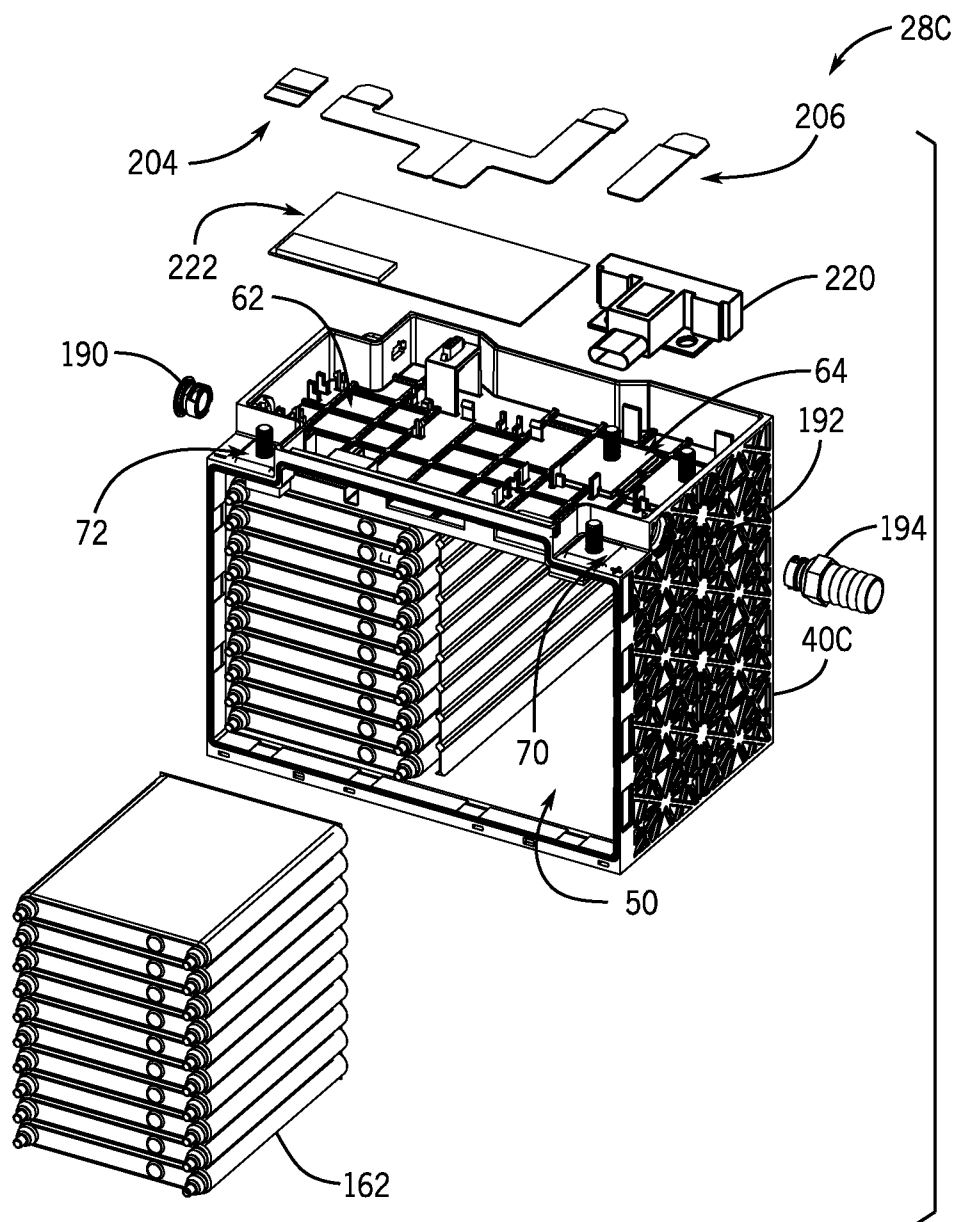


FIG. 10B

MODULAR APPROACH FOR ADVANCED BATTERY MODULES HAVING DIFFERENT ELECTRICAL CHARACTERISTICS

BACKGROUND

[0001] The present disclosure relates generally to the field of batteries and battery modules. More specifically, the present disclosure relates to water management features for Lithium-ion (Li-ion) battery modules.

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] A vehicle that uses one or more battery systems for providing all or a portion of the motive power for the vehicle can be referred to as an xEV, where the term “xEV” is defined herein to include all of the following vehicles, or any variations or combinations thereof, that use electric power for all or a portion of their vehicular motive force. For example, xEVs include electric vehicles (EVs) that utilize electric power for all motive force. As will be appreciated by those skilled in the art, hybrid electric vehicles (HEVs), also considered xEVs, combine an internal combustion engine propulsion system and a battery-powered electric propulsion system, such as 48 Volt (V) or 130V systems. The term HEV may include any variation of a hybrid electric vehicle. For example, full hybrid systems (FHEVs) may provide motive and other electrical power to the vehicle using one or more electric motors, using only an internal combustion engine, or using both. In contrast, mild hybrid systems (MHEVs) disable the internal combustion engine when the vehicle is idling and utilize a battery system to continue powering the air conditioning unit, radio, or other electronics, as well as to restart the engine when propulsion is desired. The mild hybrid system may also apply some level of power assist, during acceleration for example, to supplement the internal combustion engine. Mild hybrids are typically 96V to 130V and recover braking energy through a belt or crank integrated starter generator. Further, a micro-hybrid electric vehicle (mHEV) also uses a “Stop-Start” system similar to the mild hybrids, but the micro-hybrid systems of a mHEV may or may not supply power assist to the internal combustion engine and operates at a voltage below 60V. For the purposes of the present discussion, it should be noted that mHEVs typically do not technically use electric power provided directly to the crankshaft or transmission for any portion of the motive force of the vehicle, but an mHEV may still be considered as an xEV since it does use electric power to supplement a vehicle’s power needs when the vehicle is idling with internal combustion engine disabled and recovers braking energy through an integrated starter generator. In addition, a plug-in electric vehicle (PEV) is any vehicle that can be charged from an external source of electricity, such as wall sockets, and the energy stored in the rechargeable battery packs drives or contributes to drive the wheels. PEVs are a subcategory of EVs that include all-electric or battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles.

[0004] xEVs as described above may provide a number of advantages as compared to more traditional gas-powered vehicles using only internal combustion engines and traditional electrical systems, which are typically 12V systems powered by a lead acid battery. For example, xEVs may produce fewer undesirable emission products and may exhibit greater fuel efficiency as compared to traditional internal combustion vehicles and, in some cases, such xEVs may eliminate the use of gasoline entirely, as is the case of certain types of EVs or PEVs.

[0005] As technology continues to evolve, there is a need to provide improved power sources, particularly battery modules, for such vehicles and other implementations. For example, traditional battery modules may be constructed on an individually-designed basis, meaning that each traditional battery module may be designed for a specific implementation (e.g., voltage and capacity). Accordingly, each type of traditional battery module may use components specifically selected for that module. It is now recognized that in traditional approaches, it may be difficult to construct battery modules for different applications, but using a shared approach and source of components for the modules. Indeed, it is now recognized that it may be desirable to provide battery modules that utilize a set of common (shared) components, and other shared features.

SUMMARY

[0006] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0007] Present embodiments are directed toward a series of battery modules having a plurality of electrochemical cells (which may also be referred to as battery cells herein) having different voltages and/or capacities, where the battery modules are each constructed using components, architectures, production methods, among other things, in common with each other. For example, in certain implementations of the present approach, the battery modules may include a first battery module type having a first capacity and a first voltage, a second battery module type having a second capacity and a second voltage, and, in some embodiments, additional battery module types (e.g., a third battery module type having a third capacity and a third voltage) having different voltages and/or capacities.

[0008] For example, in one aspect, the present disclosure relates to a lithium ion battery module product portfolio, including a first lithium ion battery module product having a first housing configured to receive a first set of prismatic electrochemical cells, the housing including a base having a first footprint; a second lithium ion battery module product having a second housing configured to receive a second set of prismatic electrochemical cells, the second housing including a base having a second footprint that is substantially the same as the first footprint. A vertical profile opposing the base of the first and second housings is different for each of the first and second lithium ion battery module products, and each prismatic electrochemical cell of the first and second sets of prismatic electrochemical cells conforming to the same manufacturing specifications. The first housing of the first lithium ion battery module product is sized to fit a first num-

ber of the prismatic electrochemical cells, the second housing of the second lithium ion battery module product is sized to fit a second number of the prismatic electrochemical cells, and the first and second numbers of the prismatic lithium ion electrochemical cells are different. The lithium ion battery module product portfolio also includes a component configured to interchangeably couple with a first region of the first housing of the first lithium ion battery module product and a second region of the second housing of the second lithium ion battery module product, the first and second regions having corresponding locations on the first and second housings.

[0009] In another aspect, the present disclosure also relates to a method of manufacturing lithium ion battery modules. The method includes producing a first lithium ion battery module by a first process that includes disposing a first number of prismatic electrochemical cells having a set of standardized dimensions in a first housing, the first housing having a first base with a length and a width, and electrically connecting the first number of prismatic electrochemical cells such that the first lithium ion battery module has a first voltage and a first capacity. The method also includes producing a second battery module by a second process, the second process including disposing a second number of prismatic electrochemical cells having the set of standardized dimensions in a second housing different from the first housing, the second housing having a second base with the length and the width, and electrically connecting the second number of prismatic electrochemical cells such that the second lithium ion battery module has a second voltage and a second capacity. The first process and the second process collectively comprise using a type of component configured to interchangeably couple with a first region of the first housing of the first lithium ion battery module and a second region of the housing of the second lithium ion battery module, the first and second regions having the same location on their first and second housings, respectively.

[0010] In yet another aspect, the present disclosure also relates to a lithium ion battery module product portfolio, including a first lithium ion battery module product having a first layout. The first layout includes a first module housing configured to house a first set of electrochemical cells. The first module housing includes a first top portion having terminals configured to provide a voltage output of the first lithium ion battery module product, a first base disposed opposite the top portion and having a set of dimensions; and a first cell receptacle region disposed between the first top portion and the first base, the first cell receptacle region being configured to receive the first set of electrochemical cells in an orientation. The system also includes a second lithium ion battery module product having a second layout, the layout including a second module housing configured to house a second set of electrochemical cells, the second set of electrochemical cells having a greater number of electrochemical cells compared to the first set of electrochemical cells. The second module housing includes a second top portion having terminals configured to provide a voltage output of the second lithium ion battery module, a second base disposed opposite the second top portion and having the same set of dimensions as the first base, and a second cell receptacle region disposed between the second top portion and the second base, the second cell receptacle region being configured to receive the second set of electrochemical cells in the orientation. The system further includes a plurality of components configured to interchangeably couple with a plurality of corresponding

first regions of the first battery module housing and a plurality of corresponding second regions of the second module housing, and the first and second layouts are such that the corresponding first and second regions have the same location on their respective housings.

DRAWINGS

[0011] FIG. 1 is a perspective view of an xEV having a battery system configured in accordance with present embodiments to provide power for various components of the xEV, in accordance with an aspect of the present disclosure;

[0012] FIG. 2 is a cutaway schematic view of an embodiment of the xEV having a start-stop system that utilizes the battery system of FIG. 1, the battery system having a lithium ion battery module, in accordance with an aspect of the present disclosure;

[0013] FIG. 3 is a schematic representation of a layout of an embodiment of the lithium ion battery module of FIG. 2, in accordance with an aspect of the present disclosure;

[0014] FIG. 4 is a perspective view of an embodiment of the lithium ion battery module of FIG. 2 having various components that may be used in other versions of a lithium ion battery module, in accordance with an aspect of the present disclosure;

[0015] FIG. 5 is a perspective view of an embodiment of the lithium ion battery module of FIG. 2 having various components that may be used in other versions of a lithium ion battery module, in accordance with an aspect of the present disclosure;

[0016] FIG. 6 is a perspective view of an embodiment of the lithium ion battery module of FIG. 2 having various components that may be used in other versions of a lithium ion battery module, in accordance with an aspect of the present disclosure;

[0017] FIG. 7 is a block diagram representing an embodiment of a manufacturing system configured to produce a set of lithium ion battery modules having a plurality of common components, in accordance with an aspect of the present disclosure;

[0018] FIG. 8 is a block diagram representing an embodiment of a region of the manufacturing system of FIG. 7 in which various shared components may be incorporated into a variety of different lithium ion battery modules, in accordance with an aspect of the present disclosure;

[0019] FIG. 9 (FIGS. 9A and 9B) is a combined exploded perspective view of the embodiments of the lithium ion battery modules of FIGS. 4 and 5 and highlighting various shared components between the modules, in accordance with an aspect of the present disclosure;

[0020] FIG. 10 (FIGS. 10A and 10B) is a combined exploded perspective view of the embodiments of the lithium ion battery modules of FIGS. 4 and 6 and highlighting various shared components between the modules, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

[0021] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve

the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, 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.

[0022] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. 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.

[0023] The battery systems described herein may be used to provide power to various types of electric vehicles (xEVs) and other high voltage energy storage/expending applications (e.g., electrical grid power storage systems). Such battery systems may include one or more battery modules, each battery module having a housing and a number of battery cells (e.g., Lithium-ion (Li-ion) electrochemical cells) arranged within the housing to provide particular voltages and/or currents useful to power, for example, one or more components of an xEV. As another example, battery modules in accordance with present embodiments may be incorporated with or provide power to stationary power systems (e.g., non-automotive systems).

[0024] Present embodiments are directed toward a lithium ion battery module product portfolio including a series of battery module products having a plurality of electrochemical cells (which may also be referred to as battery cells) having different electrical characteristics such as voltages and/or capacities, where the battery module products are each constructed using components, architectures, production methods, among other things, in common with each other. For example, in certain implementations of the present approach, the battery module products (also referred to herein individually as a "battery module" and collectively as "battery modules") may include a first battery module type (e.g., a first battery module product) having a first capacity and a first voltage, a second battery module type (e.g., a second battery module product) having a second capacity and a second voltage, and, in some embodiments, additional battery module types (e.g., a third battery module type or product having a third capacity and a third voltage) having different voltages and/or capacities.

[0025] Again, the battery module types (e.g., a battery module products) may differ in voltage and/or capacity, but may have a number of similar components that may be utilized in any of the different designs in a modular fashion. For instance, these modular components may include, but are not limited to, battery cells, terminals, bus bar connections, shunt bridges, side plugs, fans, low voltage connectors, relays, printed circuit boards (PCBs), and fan filters.

[0026] Not only are the same types of components used across the different battery module types or products, but the battery module types also include housings that, while different in terms of the number of battery cells they may hold, ultimately include features that perform the same functions in substantially the same way. That is, the different battery module types include similar design concepts for their respective

housings, including similar receptacles for the similar components and, in some embodiments, a similar layout.

[0027] Though there may be two, three, or more different battery module types depending, for example, on the number of battery cells utilized in the battery module and the manner in which they are connected, the present embodiments are described in the context of two or three battery modules (which are also battery module products as described herein). For example, two battery modules may have a similar voltage rating but different capacities, and a third battery module may have a different voltage but the same capacity as one of the other two battery modules. However, any combination of overlapping voltages and/or capacities is encompassed by the present disclosure.

[0028] As set forth above, in certain xEV contexts (among others, such as non-automotive or stationary energy expending applications), a 12 V output from a lithium ion battery module may be desirable to power certain types of components (e.g., similar types of components traditionally powered by a traditional lead acid battery in traditional vehicles), while a 48 V output may be more suitable to power other types of components that may require a higher voltage, such as an air conditioning system. With this in mind, it is now recognized that the present battery module embodiments may be particularly applicable to such types of battery modules.

[0029] By way of non-limiting example, the different battery modules constructed in accordance with the modular approaches described herein may include a first battery module type having a voltage of 12V and a capacity of 10 Amp hours (Ah), a second battery module type having a voltage of 12V and a capacity of 20 Ah, and a third battery module type having a voltage of 48V and a capacity of 10 Ah.

[0030] To help illustrate, FIG. 1 is a perspective view of an embodiment of a vehicle 10, which may utilize a regenerative braking system. Although the following discussion is presented in relation to vehicles with regenerative braking systems, the techniques described herein are adaptable to other vehicles that capture/store electrical energy with a battery, which may include electric-powered and gas-powered vehicles.

[0031] It is now recognized that it is desirable for a non-traditional battery system 12 (e.g., a lithium ion car battery) to be largely compatible with traditional vehicle designs. In this respect, present embodiments include various types of battery modules for xEVs and systems that include xEVs. Accordingly, the battery system 12 may be placed in a location in the vehicle 10 that would have housed a traditional battery system. For example, as illustrated, the vehicle 10 may include the battery system 12 positioned similarly to a lead-acid battery of a typical combustion-engine vehicle (e.g., under the hood of the vehicle 10). Furthermore, as will be described in more detail below, the battery system 12 may be positioned to facilitate managing temperature of the battery system 12. For example, in some embodiments, positioning a battery system 12 under the hood of the vehicle 10 may enable an air duct to channel airflow over the battery system 12 and cool the battery system 12.

[0032] A more detailed view of the battery system 12 is described in FIG. 2. As depicted, the battery system 12 includes an energy storage component 14 coupled to an ignition system 16, an alternator 18, a vehicle console 20, and optionally to an electric motor 22. Generally, the energy storage component 14 may capture/store electrical energy

generated in the vehicle 10 and output electrical energy to power electrical devices in the vehicle 10.

[0033] In other words, the battery system 12 may supply power to components of the vehicle's electrical system, which may include radiator cooling fans, climate control systems, electric power steering systems, active suspension systems, auto park systems, electric oil pumps, electric super/turbochargers, electric water pumps, heated windscreen/defrosters, window lift motors, vanity lights, tire pressure monitoring systems, sunroof motor controls, power seats, alarm systems, infotainment systems, navigation features, lane departure warning systems, electric parking brakes, external lights, or any combination thereof. Illustratively, in the depicted embodiment, the energy storage component 14 supplies power to the vehicle console 20 and the ignition system 16, which may be used to start (e.g., crank) the internal combustion engine 24.

[0034] Additionally, the energy storage component 14 may capture electrical energy generated by the alternator 18 and/or the electric motor 22. In some embodiments, the alternator 18 may generate electrical energy while the internal combustion engine 24 is running. More specifically, the alternator 18 may convert the mechanical energy produced by the rotation of the internal combustion engine 24 into electrical energy. Additionally or alternatively, when the vehicle 10 includes an electric motor 22, the electric motor 22 may generate electrical energy by converting mechanical energy produced by the movement of the vehicle 10 (e.g., rotation of the wheels) into electrical energy. Thus, in some embodiments, the energy storage component 14 may capture electrical energy generated by the alternator 18 and/or the electric motor 22 during regenerative braking. As such, the alternator and/or the electric motor 22 are generally referred to herein as a regenerative braking system.

[0035] To facilitate capturing and supplying electric energy, the energy storage component 14 may be electrically coupled to the vehicle's electric system via a bus 26. For example, the bus 26 may enable the energy storage component 14 to receive electrical energy generated by the alternator 18 and/or the electric motor 22. Additionally, the bus may enable the energy storage component 14 to output electrical energy to the ignition system 16 and/or the vehicle console 20. Accordingly, when a 12 volt battery system 12 is used, the bus 26 may carry electrical power typically between 8-18 volts.

[0036] Additionally, as depicted, the energy storage component 14 may include multiple battery modules. For example, in the depicted embodiment, the energy storage component 14 includes a lithium ion (e.g., a first) battery module 28 and a lead-acid (e.g., a second) battery module 30, which each includes one or more battery cells. In other embodiments, the energy storage component 14 may include any number of battery modules. Additionally, although the lithium ion battery module 28 and lead-acid battery module 30 are depicted adjacent to one another, they may be positioned in different areas around the vehicle. For example, the lead-acid battery module may be positioned in or about the interior of the vehicle 10 while the lithium ion battery module 28 may be positioned under the hood of the vehicle 10.

[0037] In some embodiments, the energy storage component 14 may include multiple battery modules to utilize multiple different battery chemistries. For example, when the lithium ion battery module 28 is used, performance of the battery system 12 may be improved since the lithium ion

battery chemistry generally has a higher coulombic efficiency and/or a higher power charge acceptance rate (e.g., higher maximum charge current or charge voltage) than the lead-acid battery chemistry. As such, the capture, storage, and/or distribution efficiency of the battery system 12 may be improved.

[0038] To facilitate controlling the capturing and storing of electrical energy, the battery system 12 may additionally include a control module 32. More specifically, the control module 32 may control operations of components in the battery system 12, such as relays (e.g., switches) within energy storage component 14, the alternator 18, and/or the electric motor 22. For example, the control module 32 may regulate amount of electrical energy captured/supplied by each battery module 28 or 30 (e.g., to de-rate and re-rate the battery system 12), perform load balancing between the battery modules 28 and 30, determine a state of charge of each battery module 28 or 30, determine temperature of each battery module 28 or 30, control voltage output by the alternator 18 and/or the electric motor 22, and the like.

[0039] Accordingly, the control unit 32 may include one or processor 34 and one or more memory 36. More specifically, the one or more processor 34 may include one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), one or more general purpose processors, or any combination thereof. Additionally, the one or more memory 36 may include volatile memory, such as random access memory (RAM), and/or non-volatile memory, such as read-only memory (ROM), optical drives, hard disc drives, or solid-state drives. In some embodiments, the control unit 32 may include portions of a vehicle control unit (VCU) and/or a separate battery control module. Furthermore, as depicted, the lithium ion battery module 28 and the lead-acid battery module 30 are connected in parallel across their terminals. In other words, the lithium ion battery module 28 and the lead-acid module 30 may be coupled in parallel to the vehicle's electrical system via the bus 26.

[0040] It should be noted that presently disclosed embodiments may be applicable to any battery module having the same or different configurations and/or orientations described above and in detail below. One of ordinary skill in the art would recognize that the components and examples used to describe battery modules in accordance with the present disclosure should not be construed to limit the present disclosure to those components and examples alone. Rather, the disclosed examples are merely intended to serve as non-limiting examples to facilitate discussion of the present disclosure.

[0041] As set forth above, in accordance with the present disclosure, different types of the lithium ion battery module 28 (e.g., a lithium ion battery module product portfolio including different lithium ion battery module products) may utilize components of the same type and may have similar geometrical features (e.g., layout, overall architecture). An example embodiment of the layout of the lithium ion battery module 28 is illustrated in FIG. 3. Specifically, the illustrated embodiment of the lithium ion battery module 28 includes a housing 40, which is intended to represent a one-piece housing or a multi-piece housing (e.g., two-piece, three-piece, or more). To facilitate discussion, different sections of the housing 40 (which may or may not correspond to sections of the overall lithium ion battery module 28) may be defined as follows: a base 42, which may also be referred to as a bottom

portion and generally defines the footprint of the lithium ion battery module 28 when placed in operation (e.g., in the xEV 10), sides including a left side 44 and a right side 46, and a top region or top portion 48. The top portion 48 is generally opposite the base 42, with the sides generally extending between the two. The left side 44 and right side 46 are determined, in the illustrated embodiment, with reference to a cell receptacle region 50, which may be considered to correspond to a front end 52 of the lithium ion battery module 28. As described in further detail below, the cell receptacle region 50 is configured to receive a plurality of battery cells (e.g., prismatic electrochemical cells) in a particular orientation. A back end 54 of the lithium ion battery module 28 may be considered to correspond to an end opposite the cell receptacle region 50 (and, accordingly, opposite the front end 52). In accordance with present embodiments, these different sections of the lithium ion battery module 28 may have substantially the same layout and/or configuration across multiple versions, meaning that similar components (e.g., components from the same source), referred to as components of the same type, may be located in these regions. It should be noted that the battery module 28 of FIG. 3 is intended to represent multiple versions (e.g., individual products of a product portfolio), also referred to as embodiments or types, of lithium ion battery modules having the same regions located in the same (e.g., corresponding from a location standpoint) portion of the battery module relative to all other features of the battery module. For example, a region of the lithium ion battery module 28 of FIG. 3 is intended to represent first, second, third, fourth, and so on, regions of the housing 40 corresponding to first, second, third, fourth, and so on, respective embodiments of the battery module 28.

[0042] In accordance with the present disclosure, the phrase “common component” or “shared component” is intended to denote a component that can be interchangeably coupled for use in a set of different types of the lithium ion battery module 28, where the component is provided from a common source. For instance, a source of a particular one component such as a particular relay, a particular bus bar, a particular battery cell, and so forth, may be interchangeably used in the different types of lithium ion battery modules 28 set forth herein. That is, common or shared components are interchangeable, and have dimensions to within manufacturing tolerances of their common source.

[0043] In accordance with an aspect of the present disclosure, one common layout for the different versions of the lithium ion battery module 28 may include an electrical layout 56 of the top region 48. For example, the electrical layout 56, as illustrated, may include first and second terminal regions 58, 60, corresponding to respective locations of a first terminal and second terminal (e.g., pairs of terminals, which are shown in FIG. 4) of the lithium ion battery module 28, the terminals being configured to provide an electrical output of the respective lithium ion battery modules 28. The illustrated electrical layout 56 also includes a control board region 62 corresponding to a location of a control board (where examples of the control board are shown in FIGS. 9 and 10), and a relay region 64 corresponding to a location of a relay. Examples of the relay are shown in FIGS. 9 and 10. It should be noted that the regions 58, 60, 62, 64 are not only locations corresponding to these components, but also may include certain features (e.g., receptacle areas, connectors, pegs, electrical traces) that enable that particular region to interface

with these components, and, in certain embodiments enable them to interface and house the components in a particular way.

[0044] The sides of the lithium ion battery module 28 (e.g., the housing 40) may also be configured in this manner. For example, the left and/or right sides 44, 46 (located laterally with respect to the cell receptacle region 50) may include a vent region 66, corresponding to a location where gases may be vented out of the module 14. The vent region 66 may include one or more features configured to interface with, for example, vent plugs, vent adapters for hose connections of a vehicle, and the like. It should be noted that the disclosed embodiments are not limited to these regions and the particular components set forth above. Rather, there may be other features, including but not limited to those described in further detail below. For example, the lithium ion battery modules 28 configured in accordance with present embodiments may also include regions specifically configured to couple with other components, such as fans, fan filters, fan covers, thermal management features, and the like.

[0045] As set forth above, the base 42 of the lithium ion battery module 28 generally defines its footprint. With regard to vehicle integration, this can be an important design concern in that certain sizes for the base 42 may be desired for integration into a particular vehicle due to, for example, spatial constraints. Indeed, in embodiments where the xEV 10 of FIGS. 1 and 2 is a micro-hybrid, it may be desirable for the base 42 to be a size that enables the lithium ion battery module 28 to be located relatively close to a lead acid battery, close to an alternator, etc. Thus, the lithium ion battery module 28 may be a size that enables vehicle integration, as an example, under a hood of the xEV 10, or within a cage located toward a front of the xEV 10.

[0046] With this in mind, one aspect of the present disclosure provides embodiments in which first, second, and third types of the lithium ion battery module 28 may have substantially the same base configuration (e.g., substantially the same footprint). This aspect may be further appreciated with reference to FIGS. 4, 5, and 6, which respectively depict a first embodiment of the lithium ion battery module 28A, a second embodiment of the lithium ion battery module 28B, and a third embodiment of the lithium ion battery module 28C. Again, the base 42 may be represented by the dimensions of the portion of the battery module housing 40 that is ultimately mounted to or rests on a surface of the xEV 10 (e.g., closest to the ground/floor). In accordance with an embodiment, the respective housings 40 have bases 42 each having the same dimensions.

[0047] The base 42 may generally correspond to a length (L) and a width (W) of the lithium ion battery module 28, and the length and width of the respective bases of the first, second, and third embodiments of the lithium ion battery modules 28 may be the same, which is intended to account for manufacturing tolerances. Further, although the lithium ion battery modules 28 are intended to represent advanced battery modules having lithium ion electrochemical cells, the base 42 may correspond to any one of the many group representations (e.g., Battery Council International (BCI) group numbers, Deutsche Industrie Normen (DIN codes), European Norm (EN) codes) established for traditional lead acid batteries (e.g., lead acid battery module 30). Each group (e.g., group number) from these established set of standards has a standard length and width for the base of the particular battery corresponding to the particular group designation. The sec-

ondary lithium ion battery modules described herein may or may not have dimensions that substantially match or comply with the standard dimension requirements of at least a base of a known lead acid battery standard (e.g., a BCI group, DIN code, or EN code).

[0048] As one example, the first, second, and third embodiments of the lithium ion battery modules **28** of FIGS. **4-6** may be sized to have an H5 (DIN code) base, which is 242 mm in length by 175 mm in width. The H5 base is also commonly referred to as an LN2 base. However, the base **42** of the lithium ion battery modules **28** may have any length and width suitable to substantially match a particular base of a lead acid battery. Although standardized for lead acid batteries, it can be difficult to conform to such standards using lithium ion electrochemical cell technologies, especially when considering that lithium ion battery modules, such as those described herein, may be associated with equipment not found in traditional lead acid batteries such as intelligent control features, thermal management features, advanced venting features, and so forth. However, the present disclosure is not limited to the bases **42** of the lithium ion battery modules **28** being the same size as a lead acid standard. Rather, the lithium ion battery modules **28** may have any size for their respective bases **42**, which in certain embodiments may be the same for the different lithium ion battery modules **28**. As a non-limiting example, the length L may be a value between 150 mm and 450 mm, and the width W may be a value between 100 mm and 200 mm, where the values match for all the modular lithium ion battery modules **28**.

[0049] While the lithium ion battery modules **28** of FIGS. **4-6** have aspects or features with the same configuration or layout (e.g., substantially the same base **42** or the same lateral arrangement of terminals), it should be noted that their respective heights (e.g., vertical profiles opposing respective bases of the housings) may differ, depending, for example, on their power components. For example, in FIG. **4**, the lithium ion battery module **28** may have a first output voltage (e.g., 12 V) and a first capacity (e.g., 10 amp hours (Ah)). In FIG. **5**, the lithium ion battery module **28** may have a second output voltage that is the same as the first output voltage while having a second capacity greater than the first capacity (e.g., 20 Ah). From a power component standpoint, the lithium ion battery module **28** of FIG. **5** differs from the first lithium ion battery module **28** of FIG. **4** by the number of total electrochemical cells in their respective housings **40**. In one embodiment, the first embodiment of the lithium ion battery module **28A** of FIG. **4** may include a first number (e.g., 6) of electrochemical cells electrically coupled in a serial arrangement, while the second embodiment of the lithium ion battery module **28B** of FIG. **5**, which has a larger capacity (e.g., twice the capacity), has a second number (e.g., 12) of the same type of electrochemical cells coupled using a combination of serial and parallel electrical connections. The arrangement of the electrochemical cells within the housings **40**, which is described in further detail below, is the primary factor that causes a respective vertical profile, or height H1 of the lithium ion battery module **28** of FIG. **4** and a vertical profile, or respective height H2 of the lithium ion battery module **28** of FIG. **5** to differ. For the lithium ion battery module **28** in FIG. **4**, its cell receptacle region **50** and, therefore, its housing **40**, is configured to (e.g., sized to) receive (e.g., fit) a first number of prismatic electrochemical cells conforming to a set of manufacturing specifications, while the lithium ion battery module **28** of FIG. **5** has an embodiment of the housing **40**

configured to (e.g., sized to) receive (e.g., fit) a second number of the prismatic electrochemical cells, the second number being greater than the first.

[0050] The third embodiment of the lithium ion battery module **28C** of FIG. **6** has a significantly larger vertical profile or height H3, compared to the lithium ion battery modules **28** of FIGS. **4** and **5**. This is due, at least in part, to the additional number of electrochemical cells required for the lithium ion battery module **28** to reach a higher voltage (e.g., 48 V using a third number, such as 20, of the same type of electrochemical cells connected in series). That is, the housing **40** of the third embodiment of the lithium ion battery module **28C** may be configured to (e.g., sized to) receive (e.g., fit) the third number of prismatic electrochemical cells. It should be noted that the different lithium ion battery modules **28** of FIGS. **4-6** all utilize lithium ion electrochemical cells having standardized dimensions, which are dimensions that are intended to be produced for a particular electrochemical cell type, and is intended to allow for manufacturing tolerances. For instance, the electrochemical cells in some embodiments may be prismatic electrochemical cells that have standardized dimensions associated with a particular tolerance.

[0051] As will be appreciated from the present disclosure, the lithium ion battery modules **28** described herein may be modular not only from the standpoint of their electrochemical cells and their footprint (e.g., base **42**), but also from the standpoint of their architecture and common components. For instance, the base **42** of each lithium ion battery module **28** is located at an end that is substantially opposite a location of a set of terminals of the lithium ion battery module **28**, illustrated as a first terminal **70** (e.g., a positive terminal) and a second terminal **72** (e.g., a negative terminal), which are positioned in the first and second terminal regions **58**, **60**, respectively. The terminals **70**, **72** may include a single component or a set of components that are common to (e.g., of the same type and configured to be interchangeably coupled to) the different lithium ion battery modules **28**. Further, in accordance with certain embodiments, the first and second terminal regions **58**, **60** are specifically configured to position terminal posts **74**, **76** (e.g., an end of the terminal posts) of the first and second terminals **70**, **72** at substantially the same level as a top cover **78** of the first lithium ion battery module **28** of FIG. **4**, a top cover **80** of the second embodiment of the lithium ion battery module **28B** of FIG. **5** (which may be the same as the top cover **78**), and a top cover **82** of the third embodiment of the lithium ion battery module **28C** of FIG. **6**. In this regard, the terminal posts **74**, **76** may not protrude beyond an outer surface of the lithium ion battery modules **28**, which may reduce the likelihood that the terminals **74**, **76** will be subjected to tangential forces, short circuits, and so forth, that could potentially damage the lithium ion battery modules **28**. The terminal regions **58**, **60** may, in some embodiments, be the same size for the different lithium ion battery modules **28**, in terms of volume or any one of a length, width, height, or any combination thereof, to within manufacturing tolerances. In certain embodiments, a top cover (e.g., top cover **78**) may be configured to interchangeably cover the top portions of the lithium ion battery modules **28A** and **28B** of FIGS. **4** and **5**.

[0052] In the illustrated embodiments of FIGS. **4-6**, immediately adjacent to the first terminal region **58** is the venting region **66** including a vent plug **84**, which is a common component for the different lithium ion battery modules **28**. The vent plug **84** may be configured to open a vent of the

lithium ion battery module **28** after an internal portion of the housing **40** reaches a pressure threshold (e.g., as a result of a battery cell rupture).

[0053] The first and second embodiments of the lithium ion battery modules **28** in FIGS. **4** and **5**, respectively, may include additional shared components. For example, the first and second embodiments of the lithium ion battery modules **28** of FIGS. **4** and **5**, respectively, may include a common fan assembly **86**, which may include a filter portion **88** including a fan filter, and a fan portion **90** including a fan. The common fan assembly **86** of the first and second embodiment of the lithium ion battery modules **28** of FIGS. **4** and **5** may also include a cover that is specifically configured (e.g., shaped and sized and having specific connection features) to couple with the respective top portions **48** of the first and second lithium ion battery modules **28** of FIGS. **4** and **5**.

[0054] It is now recognized that the ability to utilize interchangeable and modular components across the different embodiments (i.e., types, versions) of the lithium ion battery modules **28** may result in the ability to manufacture the lithium ion battery modules **28** according to more efficient processes, such as performed by the embodiment of a manufacturing system **100** shown in FIG. **7**. Such a process may be more efficient than a traditional manufacturing process in that different types of lithium ion battery modules may be formed using shared assembly regions, shared component sources, and so forth, which may reduce capital costs and increase the speed of manufacturing. The shared assembly regions and shared component sources may include common components of the same type, size, and overall configuration, to within manufacturing tolerances, that can be used in any one or a combination of different types of the lithium ion battery modules (e.g., lithium ion battery modules **28** having different output voltages, different capacities, and so forth).

[0055] As depicted, the manufacturing system **100** may include the use of an initial set of shared source components **102**, which may include, for example, components that can be integrated into the respective housings **40** of the different lithium ion battery modules **28**. For example, overmolded components such as terminals, structural support components, and the like, shared by the different lithium ion battery modules **28** may be incorporated into this particular portion of the system **100**.

[0056] The initial shared source components **102** may be distributed among different areas of the manufacturing system **100** where the housings **40** may be produced. For example, the initial shared source components **102** (e.g., common heat sinks for in-molding with housings) may be distributed to a first housing mold region **104** where the housing **40** of the first embodiment of the lithium ion battery module **28A** may be molded, to a second housing mold region **106** where the housing **40** of the second embodiment of the lithium ion battery module **28B** may be molded, and/or to a third housing mold region **108** where the housing **40** of the third embodiment of the lithium ion battery module **28C** may be molded. From these regions, the different module housings **40** may be provided to various module component integration regions **110**, where different portions of the modules are provided to the housings **40** for module completion.

[0057] The module component integration regions **110** may include, as shown, a battery cell (electrochemical cell) shared source **112**, which provides the same type of battery cell (e.g., prismatic lithium ion electrochemical cells having the same manufacturing specifications) to the different mod-

ule housings **40** in their respective cell receptacle regions **50**. Other shared source components **114** may be similarly provided, including fans, fan covers, fan filters, printed control boards, bus bars, vent plugs, and the like. Non-shared source components **116** provided at the regions **114** may include size-specific components, such as integrated bus bar and voltage sense carrier assemblies, certain types of relays, front covers, thermal gap pads, and the like. As a result of the integration of these various components into the three different housings **40**, the first, second, and third embodiments of the lithium ion battery module **28**, for example corresponding to the modules **28A-28C**, respectively, are produced.

[0058] An example embodiment of the component integration region **110** is depicted in FIG. **8**. As shown, the region **110** includes a first path **124** that conveys intermediates for the first embodiment of the battery module **28A**, a second path **126** that conveys intermediates for the second embodiment of the battery module **28B**, and a third path **128** that conveys intermediates for the third embodiment of the battery module **28C**, wherein the term “intermediates” refers to incomplete versions of the battery modules (e.g., the battery module housings **40** will some, but not all, of their respective components). As an example, the paths **124**, **126**, **128** may correspond to one or more conveyance paths, such as conveyor belts or the like, that traverse all or a portion of the region **110**.

[0059] The illustrated embodiment includes a first version of the battery module housing **130** introduced along the first path **124**, a second version of the battery module housing **132** introduced along the second path **126**, and a third version of the battery module housing **134** introduced along the third path **128**. The first, second, and third versions of the battery module housing **130**, **132**, **134** may correspond, for example, to as-formed versions of the battery module housing **40** shown in FIGS. **4**, **5**, and **6**, respectively. The as-formed versions may be provided, for example, after molding the housings in the first, second, and third housing molding regions **104**, **106**, **108** of FIG. **7**.

[0060] In the component integration region **110** of the system **100**, the paths **124**, **126**, **128** may converge in regions where a common component is introduced to the different modules, while they diverge in regions where size-specific or other non-shared components are introduced to the modules **28**. For example, as shown, the paths **124**, **126**, **128** convey the housings **40** to a battery cell positioning region **136** that uses the battery cell source **112**. The battery cell positioning region **136**, in certain embodiments, includes an automated system that positions battery cells in the housings **130**, **132**, **134** in a particular manner, for example in a specific orientation and in a specific number for the different embodiments of the battery module **28**.

[0061] The paths **124**, **126**, **128** may then diverge from one another to separate respective sections of a first component integration region, depicted as region **138A** for path **124**, region **138B** for path **126**, and region **138C** for path **128**. The regions **138A-138C** utilize different sources of a component not shared by the different lithium ion battery modules **28**, including a first version of a first non-shared component **140A** for region **138A**, a second version of the first non-shared component **140B** for region **138B**, and a third version of the first non-shared component **140C**. As an example, the different versions of the first non-shared component may include size-specific components, such as structural supports (carriers) for integrated bus bar and voltage sense assemblies for each lithium ion battery module **28**, a front cover for each

lithium ion battery module **28**, and the like. It should be noted that conveyance of different partial battery module assemblies on an area for shared components may be avoided in accordance with present embodiments by distributing the shared components from a common source (i.e., a source of a set of the same type of component having the same dimensions and configuration, to within manufacturing tolerances).

[0062] The illustrated component integration region **110** may also include additional regions where common (i.e., interchangeably couplable) components are provided to the different types of the lithium ion battery module **28**. Such embodiments are intended to be represented by a second component integration region **146** that utilizes a second shared component **148** (and/or source thereof), where the different types of the lithium ion battery module **28** may be fitted with common components, such as the same fan assemblies, the same bus bars, the same electrical connectors, and so forth. It should be noted that such modularity of the different versions of the lithium ion battery module **28** may be a result of all the lithium ion battery modules **28** having a corresponding region (e.g., a recess having a particular shape) for these different common components, including connectors, receptacles, spaces, or the like, that are specifically configured to receive the shared components. Further, the component integration region **110** may include more regions where additional components, from shared or non-shared sources of these components, may be used to integrate the components with the lithium ion battery modules **28**.

[0063] The modular aspect of the lithium ion battery modules **28** described herein may be further appreciated with respect to FIGS. **9** and **10**, which depict exploded perspective views of the first, second, and third embodiments of the lithium ion battery module **28A**, **28B**, and **28C**, respectively. Specifically, as shown in FIG. **9**, a comparison between the first and second lithium ion battery modules **28A**, **28B** demonstrates that the two modules **28** have a similar architecture, and have a number of shared components.

[0064] Starting from their respective housings **40A** and **40B**, it can be seen that while the respective heights **H1**, **H2** (FIGS. **4** and **5**) of the two are different, they actually have a very similar configuration. For example, the housing **40A** of the first embodiment of the lithium ion battery module **28A** and the housing **40B** of the second embodiment of the lithium ion battery module **28B** each have a layout including a plurality of regions (e.g., the terminal regions, the relay regions, and so forth). Each region of the plurality of regions has a particular location on the respective housings **40A**, **40B**, and is configured to mechanically couple to a particular component, such as control boards, relays, plugs, and so on. The particular locations and particular components of the plurality of regions of the first and second embodiments of the lithium ion battery modules **28A**, **28B** match (e.g., have the same corresponding location and the same type of component).

[0065] For instance, the illustrated lithium ion battery modules **28A**, **28B** include a common electrochemical cell **160**, meaning that the electrochemical cells **160** used in the different embodiments of the lithium ion battery modules **28** have the same manufacturing specifications, including the same chemistry (e.g., cathode and anode electrode active materials, electrolyte, additives) and the same size manufacturing specifications, to within a specified tolerance. In accordance with an aspect of the present disclosure, it is now recognized that certain types of electrochemical cells may benefit such

approaches more than others. For example, in one embodiment, the electrochemical cells **160** may have a particular combination of anode active materials (e.g., including $\text{Li}_4\text{Ti}_5\text{O}_{12}$, which is lithium titanate (LTO)) and cathode active materials (e.g., including $\text{LiNi}_{1/3}\text{Co}_{1/3}\text{Mn}_{1/3}\text{O}_2$, which is nickel cobalt manganese oxide (NMC)) that prevent them from swelling beyond a predetermined threshold. For example, in the illustrated embodiments, the electrochemical cells **160** have a prismatic casing **162**. The prismatic casings **162** are subject to, and may conform to, a set of manufacturing specifications, including their size in all dimensions.

[0066] The prismatic casings **162** include a top casing portion **164** where a set of cell terminals **166**, **168** (e.g., positive and negative cell terminals) are located. One or more cell vents **170** may also be located on the top casing portion **164**. The set of cell terminals **166**, **168** for each of the electrochemical cells **160** enables the cells to be electrically connected to various electrical components, including each other, to the terminals **70**, **72** of the lithium ion battery module **28**, and a load to which the lithium ion battery module **28** may be coupled. The cell vents **170** are configured to enable venting of gases under certain conditions.

[0067] The prismatic cell casings **162** also include a bottom casing portion **172** positioned opposite the top casing portion **164**, first and second rounded sides **174**, **176** that extend between the bottom and top casing portions **172**, **164** proximate the cell terminals **166**, **168**, and first and second faces **178**, **180** that couple the first and second rounded sides **174**, **176** at opposing ends of each cell **160**. The presently disclosed configurations may be, in some embodiments, facilitated by the presently illustrated orientation of the electrochemical cells **160** within the housings **40**. Specifically, the electrochemical cells **160**, which are prismatic in FIGS. **9** and **10**, are situated in the housings **40** with their respective sets of terminals **166**, **168** pointed outward from the cell receptacle regions **50**. Further, the electrochemical cells **160** rest on one of their two faces **178**, **180** within the lithium ion battery modules **28**, and the electrochemical cells are in a stacked arrangement in which the faces **178**, **180** are oriented substantially parallel with respect to one another in a particular column **182** having a plurality (i.e., more than one) electrochemical cells **160**. In the embodiments illustrated in FIGS. **9** and **10**, the electrochemical cells **160** are arranged in two such columns **182**, with the number of rows depending on the number of total electrochemical cells **160**.

[0068] Such an arrangement may be desirable, for example, to maintain standard dimensions for the base **42** across the different embodiments of the lithium ion battery modules **28**. Indeed, it is now recognized that a combination of the cell chemistry (e.g., NMC/LTO electrochemical cells), cell shape (e.g., prismatic), and cell size may provide advantages that have not traditionally been used to achieve the technical effects set forth herein. For example, it is now recognized that NMC/LTO electrochemical cells may enable a total cell volume to be defined for the housing, and the remaining layout of the battery modules **28** to be defined relative to this volume.

[0069] As noted above, the terminals **70**, **72** of the lithium ion battery modules **28** are all the same across the different embodiments described above with respect to FIGS. **4-6**. In addition, their illustrated vent configurations are also the same—where the battery modules **28** may use the same type of closure, securement, and venting features, such as a common set of threads and screws, a common side plug **190**, and a common vent opening **192** into which a common barbed

fitting **194** of a corresponding size may be used to enable the vent opening **192** to be coupled to a vent hose of the xEV **10** (where the xEV is shown in FIG. 2). As an example, the first and second embodiments of the lithium ion battery module **28A**, **28B**, may each include a respective set of common components, and the common components may represent between 60% and 95% of a total part count of the first and second embodiments of the lithium ion battery modules **28A**, **28B**. For example, the common components may represent between 60% and 90% of the total part count, between 65% and 85% of the total part count, or between 70% and 80% of the total part count of the lithium ion battery modules **28A**, **28B**.

[0070] Further, it should be noted that the respective layouts of the different lithium ion battery modules **28** described herein are substantially the same. For example, the relative location of the components of the different embodiments of the lithium ion battery modules **28** is the same (i.e., matching) for each module **28**. This includes, for example, the regions described above with respect to FIG. 3.

[0071] With respect to their electrical components, the first and second embodiments of the lithium ion battery modules **28** include a common relay **200** configured to electrically couple and de-couple one of the terminals (e.g., the first terminal **70**) to an electrical load, and a common set of electronics **202**. The electronics **202** may include the same shape and size of circuit board, as well as the same electrical architecture (e.g., components, location, and connections) and layout. For instance, a single source of the electronics **202** is intended to be appropriately used in either the first embodiment or the second embodiment of the lithium ion battery module **28**. The electronics **202** may include a control board, as shown, as well as various short circuit protection circuitry, a battery control module including control circuitry configured to control operational parameters of the battery modules **28**, and so forth.

[0072] The modularity of the present approaches is reflected in the different regions of the housings **40**, as well. For instance, the top portions **48** of the housings **40** also include the control board region **62** and the relay region **64**, which are all the same layout and configuration for the first and second embodiments of the lithium ion battery module **28**. That is, the control board region **62** for both the first and second embodiments of the lithium ion battery module **28** includes the same arrangement of prongs, connectors, and so forth, that enable the top portion **48** to mechanically couple to and secure the set of electronics **202**. In addition, the relay region **64** for both the first and second embodiments of the lithium ion battery module **28** includes the same arrangement of prongs, connectors, and so forth, that enable the top portion **48** to mechanically couple to and secure the relay **200** (i.e., the same type and configuration of relay). It should be noted that such common configurations may enhance manufacturing capability, even for different housing molds. For example, the top portion **48** of the different lithium ion battery modules **28** may be the same, meaning that if the housing **40**, or the portion of the housings illustrated, are formed from different pieces, the top portion **48** may be produced at a common source. Further, in embodiments where the housings **40** are one-piece molded units, then the mold tools used to mold the housings **40** may utilize the same types of equipment, for example the same portion of the mold tool used to form the top portion **48**.

[0073] Other illustrated and common electrical components include shunt bridges **204** and relay bus bars **206**. Indeed, various other connectors and features may also be common to two or more of the lithium ion battery modules **28**. For example, the first and second embodiments of the lithium ion battery modules **28** may include a common low voltage connector **208** that may be used to electrically couple the relay **200** to certain components, for example to couple the lithium ion battery module **28** to the xEV **10**, and/or to electrically couple a common fan **210** to the lithium ion battery module **28** to power the fan **210**.

[0074] The top cover **78**, over which the fan **210** is disposed, is also common for the first and second embodiments of the lithium ion battery modules **28**. Further, as noted above, the fan assembly **86** is also common between the two, including a fan filter **212**. The manner in which a back cover **214** of the fan assembly **86** interfaces with the first and second embodiments of the lithium ion battery modules **28** may also be the same.

[0075] The third embodiment of the lithium ion battery module **28C**, as shown in FIG. 10, also includes common components as set forth above. Indeed, in addition to having the same general layout as set forth above for the first and second embodiments of the lithium ion battery module **28A**, **28B**, the third embodiment of the lithium ion battery module **28C** also uses the same shunt bridge **204**, relay bus bar **206**, terminals **70**, **72**, side plugs **190**, and barbed fittings **194**, among others. As noted above, the modular aspect of the lithium ion battery modules **28** also includes the use of the common electrochemical cell **160**.

[0076] Furthermore, while a respective relay **220** and a respective set of electronics **222** may be different for the third embodiment of the lithium ion battery module **28C** compared to others, the relative layout and placement of these features on its respective top portion **48** of the housing **40** is substantially the same (i.e., matches the first and second embodiments of the lithium ion battery modules **28A-28C**). Furthermore, because these components are different, the electronics region **62** and the relay region **64** of the third embodiment of the lithium ion battery module **28C** may be different compared to the others illustrated. For example, its layout of connectors, prongs, and so forth, may be different but generally located in a matching position as set forth for modules **28A** and **28B**.

[0077] One or more of the disclosed embodiments, alone or on combination, may provide one or more technical effects including the use of a number of shared components across different battery modules having different electrical characteristics. For example, two or more battery modules, each having a different number of electrochemical cells, may include a number of components that are provided by a common source. The use of such common components facilitates manufacturing and reduces associated costs by enabling faster manufacture and greater compatibility between battery modules. The technical effects and technical problems in the specification are exemplary and are not limiting. It should be noted that the embodiments described in the specification may have other technical effects and can solve other technical problems.

[0078] While only certain features and embodiments have been illustrated and described, many modifications and changes may occur to those skilled in the art (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters (e.g., temperatures,

pressures, etc.), mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the disclosed subject matter. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention. Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. 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, without undue experimentation.

1. A lithium ion battery module product portfolio, comprising:

a first lithium ion battery module product comprising a first housing configured to receive a first set of prismatic electrochemical cells, the housing including a base having a first footprint;

a second lithium ion battery module product comprising a second housing configured to receive a second set of prismatic electrochemical cells, the second housing including a base having a second footprint that is substantially the same as the first footprint, wherein a vertical profile opposing the base of the first and second housings is different for each of the first and second lithium ion battery module products;

each prismatic electrochemical cell of the first and second sets of prismatic electrochemical cells conforming to the same manufacturing specifications, wherein the first housing of the first lithium ion battery module product is sized to fit a first number of the prismatic electrochemical cells, the second housing of the second lithium ion battery module product is sized to fit a second number of the prismatic electrochemical cells, and the first and second numbers of the prismatic lithium ion electrochemical cells are different; and

a component configured to interchangeably couple with a first region of the first housing of the first lithium ion battery module product and a second region of the second housing of the second lithium ion battery module product, the first and second regions having corresponding locations on the first and second housings.

2. The lithium ion battery module product portfolio of claim 1, wherein the first and second housings each comprise a pair of terminal regions and a pair of terminals located in the pair of terminal regions, the respective pairs of terminal regions of the first lithium ion battery module product and the second lithium ion battery module product have the same size and are located in corresponding locations on the respective first and second housings.

3. The lithium ion battery module product portfolio of claim 1, wherein the component is a relay configured to interchangeably couple with both of the first and second lithium ion battery module products, wherein the first region comprises a first relay region and the second region comprises

a second relay region, and the first and second relay regions each comprises a set of connectors configured to mechanically couple to the relay.

4. The lithium ion battery module product portfolio of claim 1, wherein the component is a control board having control circuitry configured to control operational parameters of the first and second lithium ion battery module products, wherein the first region comprises a first control board region and the second region comprises a second control board region, and the first and second control board regions each comprises a set of connectors configured to mechanically couple to the control board, and wherein the first and second control board regions are positioned on corresponding top portions of the first and second housings, the corresponding top portions being located opposite the respective bases of the first and second lithium ion battery module products.

5. The lithium ion battery module product portfolio of claim 1, wherein the component is a barbed fitting configured to interface with a vent hose of an xEV, wherein the first region comprises a first vent region located on a side of the first housing of the first lithium ion battery module product and the second region comprises a second vent region located on a side of the housing of the second lithium ion battery module product, the first and second vent regions are configured to mechanically couple to the barbed fitting, and are each positioned on a corresponding side portion of the respective housing, the corresponding side portion being located between the respective base and a respective top portion opposite the respective base.

6. The lithium ion battery module product portfolio of claim 1, wherein the component is a fan assembly having a fan, a fan cover, a fan filter, and a fan filter cover, wherein the first and second housings of the first and second lithium ion battery module products each comprise a top portion configured to mechanically couple to the fan assembly, and the fan cover is shaped to conform around a section of the respective top portions.

7. The lithium ion battery module product portfolio of claim 1, wherein the first and second housings comprise respective top portions opposite the bases, the top portions having electrical layouts comprising regions configured to mechanically couple with a control board and a relay, and the component comprises a top cover configured to interchangeably cover the top portion of the first and second lithium ion battery module products.

8. The lithium ion battery module product portfolio of claim 1, wherein the first housing and the second housing each have a layout comprising a plurality of regions, each region of the plurality of regions having a particular location on the respective housing and being configured to mechanically couple to a particular component, and the particular locations and particular components of the plurality of regions of the first and second lithium ion battery module products are matching.

9. The lithium ion battery module product portfolio of claim 8, wherein the first and second lithium ion battery module products each comprise a respective set of the particular components, the particular components representing between 60% and 95% of a total part count of the first and second lithium ion battery module products.

10. The lithium ion battery module product portfolio of claim 9, wherein the particular components of each of the first and second lithium ion battery module products comprise a relay configured to couple a voltage output of the respective

number of prismatic electrochemical cells with a terminal of the respective battery module product, a top cover for a corresponding top portion of the first and second housings positioned opposite their respective bases, a control board comprising circuitry configured to control operational parameters of the first and second lithium ion battery module products, a low voltage connector configured to couple the relay with an xEV, and terminals configured to provide a voltage output of the first and second lithium ion battery module products.

11. The lithium ion battery module product portfolio of claim **10**, wherein the first housing comprises a first cell receptacle region, and wherein the second housing comprises a second cell receptacle region that is larger than the first cell receptacle region, and the first and second cell receptacle regions are configured to hold the first and second numbers of prismatic electrochemical cells in the first and second lithium ion battery module products, respectively.

12. The lithium ion battery module product portfolio of claim **11**, wherein the first number of the prismatic electrochemical cells of the first lithium ion battery module product are electrically coupled as a group such that the first lithium ion battery module product has a first voltage output and a first capacity, and wherein the second number of the prismatic electrochemical cells of the second lithium ion battery module product are electrically coupled as a group such that the second lithium ion battery module product has a second voltage output and a second capacity, wherein the second voltage output is the same as the first voltage output, and the second capacity is larger than the first capacity.

13. The lithium ion battery module product portfolio of claim **12**, wherein the first and second voltage outputs are 12 volts (V), the first capacity is 10 amp-hours (Ah), and the second capacity is 20 Ah.

14. The lithium ion battery module product portfolio of claim **1**, comprising a third lithium ion battery module product comprising a third housing configured to receive a third set of prismatic electrochemical cells, the third housing having a respective base with a third footprint as the first and second lithium ion battery module products, and a respective vertical profile of the third housing is different than the respective vertical profiles of the first and second lithium ion battery module products;

wherein the third housing is sized to fit a third number of the prismatic electrochemical cells, and the third number of the prismatic electrochemical cells is greater than the first and second numbers; and

wherein the third housing comprises a third region, and the component is configured to interchangeably couple with the first, second, and third regions.

15. The lithium ion battery module product portfolio of claim **1**, wherein the prismatic electrochemical cells each have a cathode including lithium nickel cobalt manganese oxide (NMC) (e.g., $\text{LiNi}_{1/3}\text{Co}_{1/3}\text{Mn}_{1/3}\text{O}_2$) as a cathode active material, and an anode including LTO ($\text{Li}_4\text{Ti}_5\text{O}_{12}$) as an anode active material.

16. A method of manufacturing lithium ion battery modules, comprising:

producing a first lithium ion battery module by a first process comprising:

disposing a first number of prismatic electrochemical cells having a set of standardized dimensions in a first housing, the first housing having a first base with a length and a width; and

electrically connecting the first number of prismatic electrochemical cells such that the first lithium ion battery module has a first voltage and a first capacity; producing a second battery module by a second process comprising:

disposing a second number of prismatic electrochemical cells having the set of standardized dimensions in a second housing different from the first housing, the second housing having a second base with the length and the width; and

electrically connecting the second number of prismatic electrochemical cells such that the second lithium ion battery module has a second voltage and a second capacity;

wherein the first process and the second process collectively comprise using a type of component configured to interchangeably couple with a first region of the first housing of the first lithium ion battery module and a second region of the housing of the second lithium ion battery module, the first and second regions having the same location on their first and second housings, respectively.

17. The method of manufacturing lithium ion battery modules of claim **16**, wherein electrically connecting the first number of prismatic electrochemical cells such that the first lithium ion battery module has the first voltage and the first capacity comprises connecting the first number of prismatic electrochemical cells serially to provide a 12 volt (V) output, and a 10 amp-hour (Ah) capacity, and wherein electrically connecting the second number of prismatic electrochemical cells such that the second lithium ion battery module has the second voltage and the second capacity comprises connecting the second number of prismatic electrochemical cells in a combination of serial and parallel connections to provide a 12 V output, and a 20 Ah capacity.

18. The method of manufacturing lithium ion battery modules of claim **16**, comprising:

producing a third lithium battery module by a third process comprising:

disposing a third number of prismatic electrochemical cells having the standardized dimensions in a third housing different from the first and second housings, the third housing having a third base with the length and the width; and

electrically connecting the third number of prismatic electrochemical cells such that the third lithium ion battery module has a third voltage and a third capacity; and

wherein the first, second, and third number of prismatic electrochemical cells are different, and the first base, the second base, and the third base all have the same length and width.

19. The method of manufacturing lithium ion battery modules of claim **18**, comprising performing the first and second processes using a plurality of components that are each configured to interchangeably couple with the first and second lithium ion battery modules and third lithium ion battery modules, but not the third lithium ion battery module.

20. The method of manufacturing lithium ion battery modules of claim **19**, wherein the components comprise a relay configured to couple a voltage output of the respective number of prismatic electrochemical cells with a terminal of the respective battery module, a top cover for a top portion of the respective housings positioned opposite the respective bases,

a control board comprising circuitry configured to control operational parameters of the first and second lithium ion battery modules, a low voltage connector configured to couple the relay with an xEV, and terminals configured to provide a voltage output of the first and second lithium ion battery modules.

21. The method of manufacturing lithium ion battery modules of claim 19, comprising performing the first, second, and third processes using a plurality of components that are each configured to interchangeably couple with the first, second, and third lithium ion battery modules.

22. The method of manufacturing lithium ion battery modules of claim 18, wherein the prismatic electrochemical cells each have a cathode including lithium nickel cobalt manganese oxide (NMC) (e.g., $\text{LiNi}_{1/3}\text{Co}_{1/3}\text{Mn}_{1/3}\text{O}_2$) as a cathode active material, and an anode including LTO ($\text{Li}_4\text{Ti}_5\text{O}_{12}$) as an anode active material.

23. The method of manufacturing lithium ion battery modules of claim 16, wherein the first and second processes collectively comprise:

conveying the first and second housings along a first path and a second path, respectively, in a manufacturing system;

converging the first and second paths in a first module integration region of the manufacturing system where a source of the component configured to interchangeably couple with the first and second lithium ion battery modules is located;

integrating a first one of the component with the first housing and a second one of the component with the second housing;

converging the first and second paths in an additional module integration region of the manufacturing system where a source of an additional component configured to interchangeably couple with the first and second lithium ion battery modules is located; and

integrating a first one of the additional component with the first housing and a second one of the additional component with the second housing.

24. A lithium ion battery module product portfolio, comprising:

a first lithium ion battery module product having a first layout, comprising:

a first module housing configured to house a first set of electrochemical cells, wherein the first module housing comprises:

a first top portion having terminals configured to provide a voltage output of the first lithium ion battery module product;

a first base disposed opposite the top portion and having a set of dimensions; and

a first cell receptacle region disposed between the first top portion and the first base, the first cell receptacle region being configured to receive the first set of electrochemical cells in an orientation; and

a second lithium ion battery module product having a second layout, comprising:

a second module housing configured to house a second set of electrochemical cells, the second set of electrochemical cells having a greater number of electrochemical cells compared to the first set of electrochemical cells, wherein the second module housing comprises:

a second top portion having terminals configured to provide a voltage output of the second lithium ion battery module product;

a second base disposed opposite the second top portion and having the same set of dimensions as the first base; and

a second cell receptacle region disposed between the second top portion and the second base, the second cell receptacle region being configured to receive the second set of electrochemical cells in the orientation; and

a plurality of components configured to interchangeably couple with a plurality of corresponding first regions of the first battery module housing and a plurality of corresponding second regions of the second module housing, and the first and second layouts are such that the corresponding first and second regions have the same location on their respective housings.

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