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(54) **REDUNDANT BATTERY PROTECTION SYSTEM AND METHOD**

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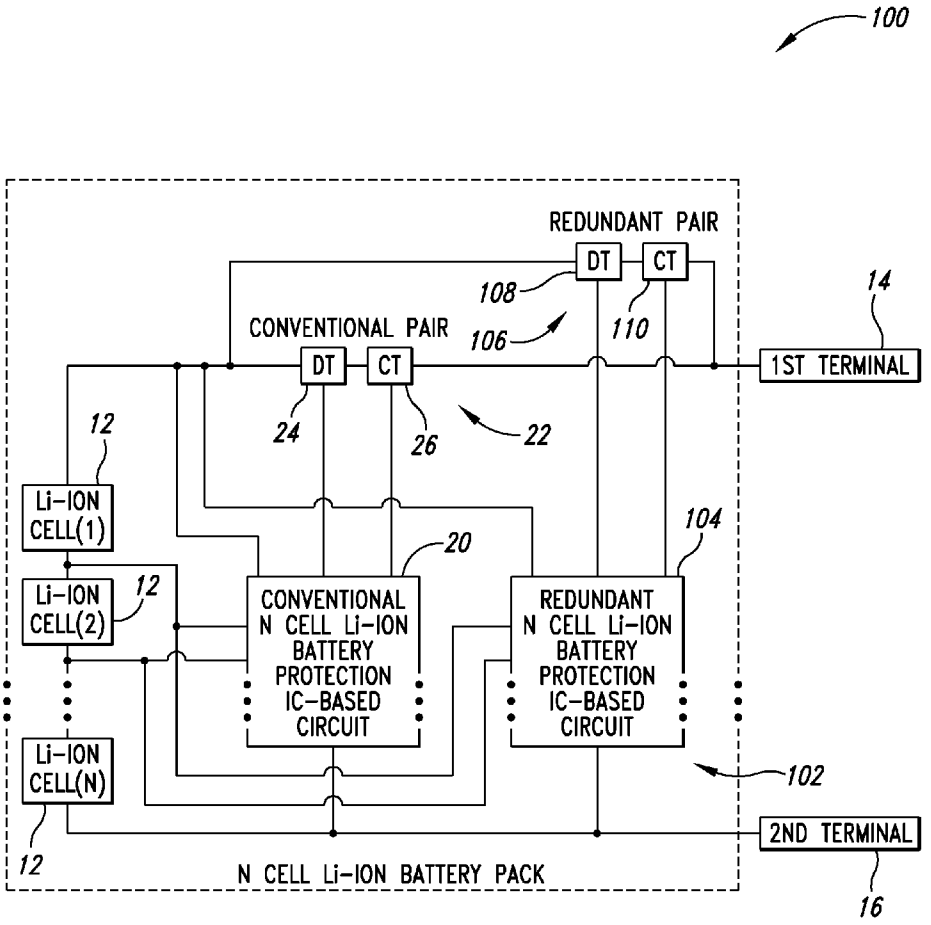
(57) **ABSTRACT**

An enhanced battery pack having an enhanced protection system addresses a potential weakness of the conventional protection system of a conventional battery pack. The enhanced protection system includes both the convention protection circuit and a redundant protection circuit. The redundant protection circuit is either a duplicate copy of the conventional protection circuit or is at least a functional equivalent of the conventional protection circuit. The components of the redundant protection circuit are electrically coupled into the enhanced battery pack in a parallel fashion with the corresponding components of the conventional protection circuit. Consequently, if one or more components of the conventional protection circuit fail due to defective conditions of the one or more components of the conventional protection circuit, the redundant protection circuit will still be operable to allow the enhanced battery pack to function while the enhanced protection system continues to protect the enhanced battery pack.



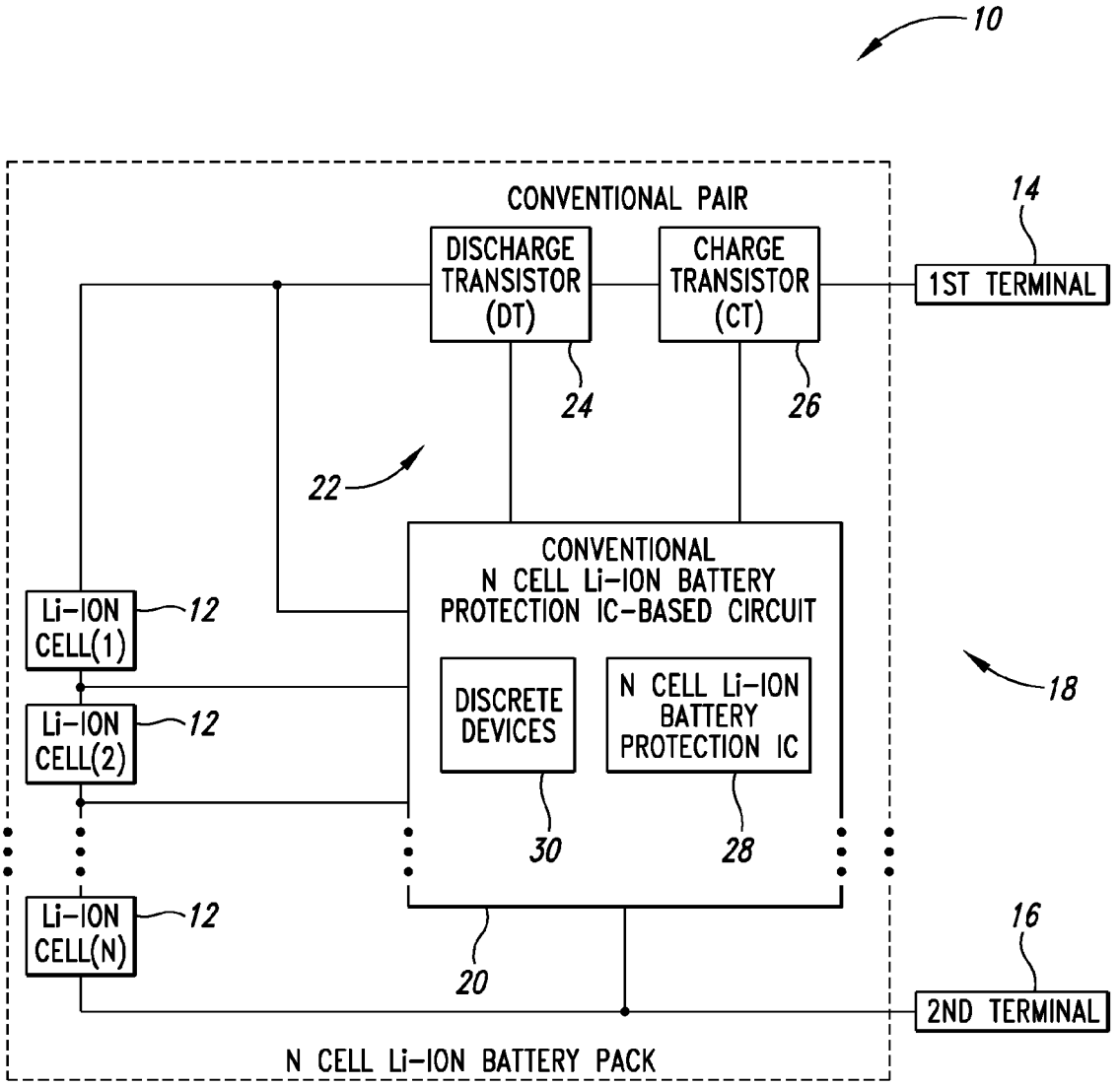


Fig. 1
(Prior Art)

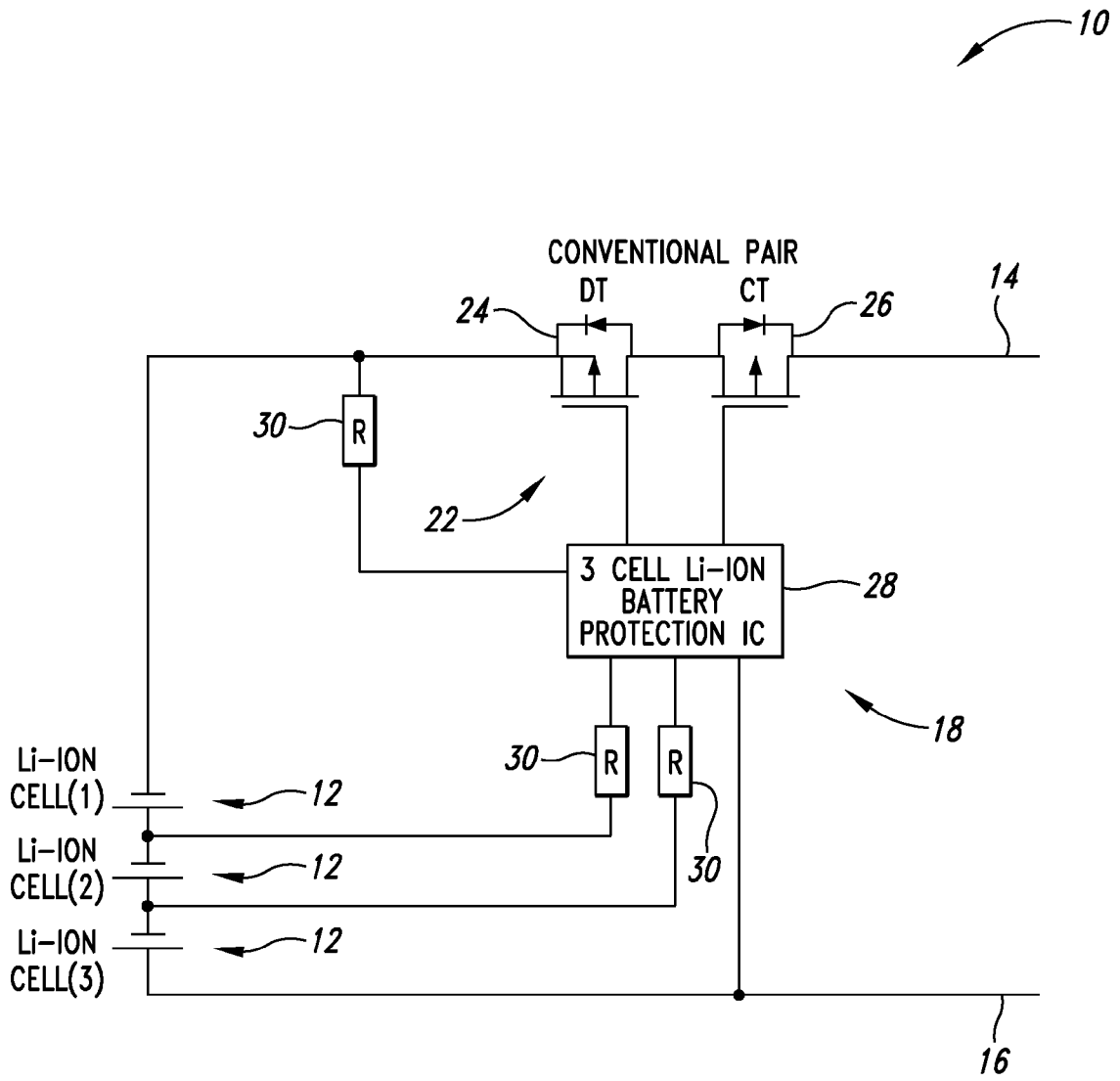


Fig. 2
(Prior Art)

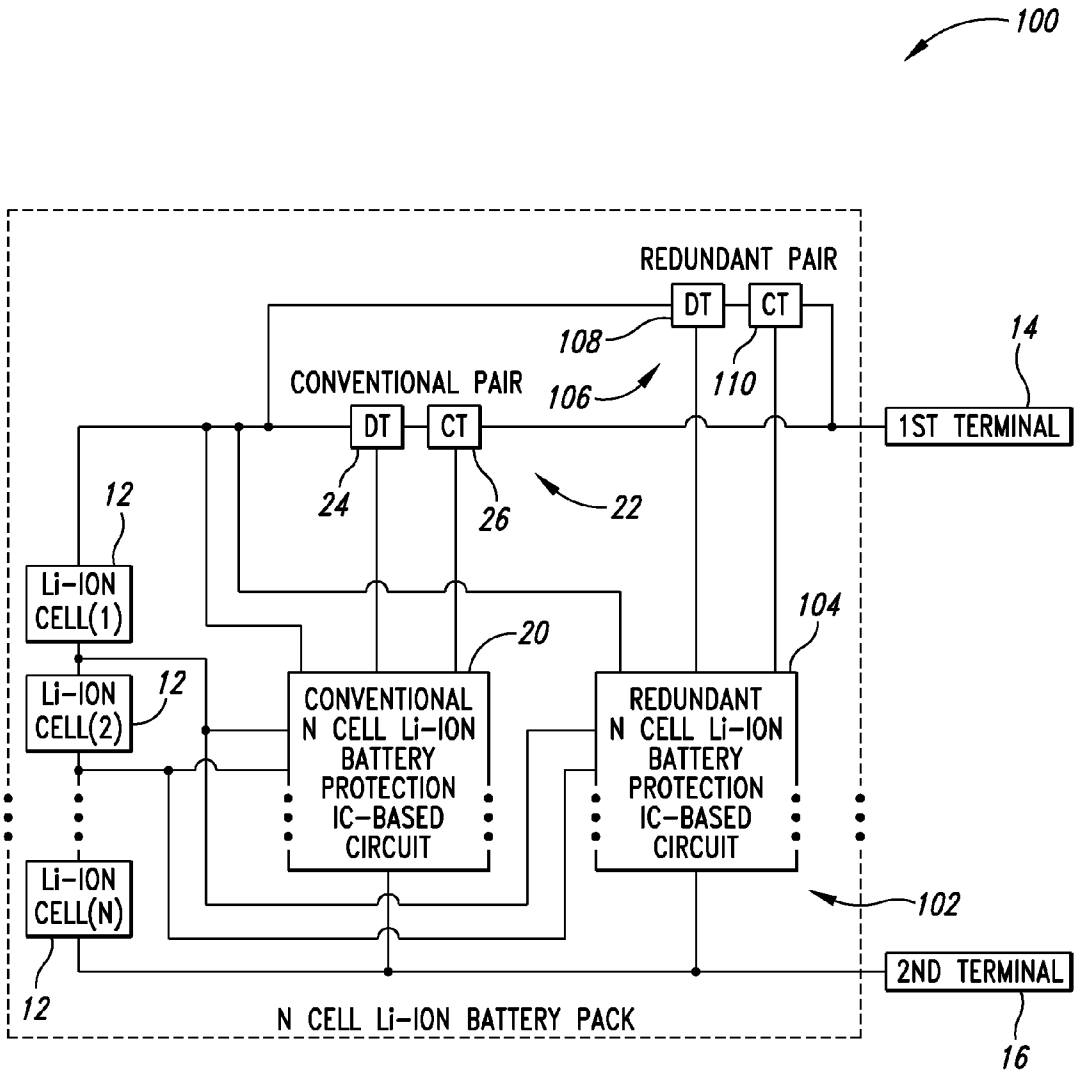

100
REDUNDANT PAIR
DT
CT
108
110
14
CONVENTIONAL PAIR
106
DT
CT
1ST TERMINAL
24
26
22
12
Li-ION CELL(1)
Li-ION CELL(2)
Li-ION CELL(N)
12
12
20
104
CONVENTIONAL N CELL Li-ION BATTERY PROTECTION IC-BASED CIRCUIT
REDUNDANT N CELL Li-ION BATTERY PROTECTION IC-BASED CIRCUIT
102
2ND TERMINAL
16
N CELL Li-ION BATTERY PACK

Fig. 3

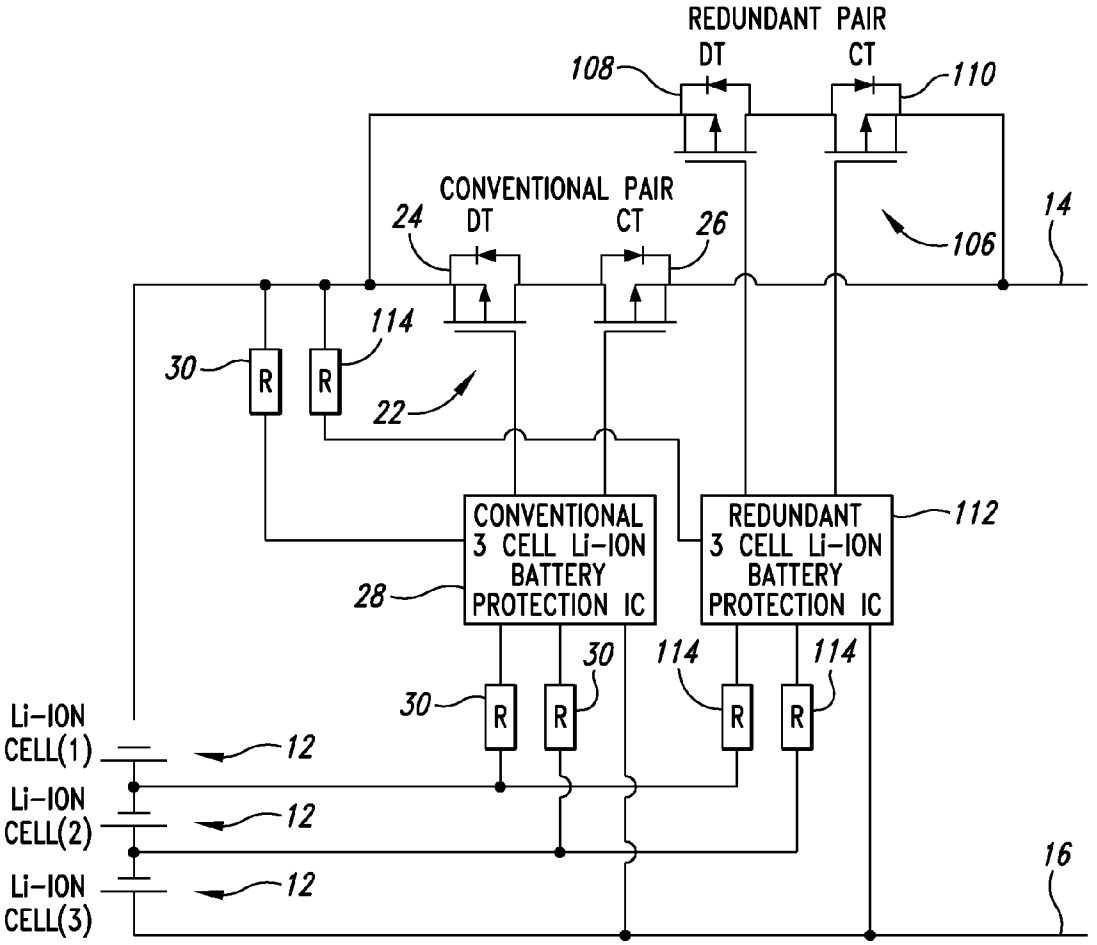

REDUNDANT PAIR
DT
CT
108
110
CONVENTIONAL PAIR
DT
CT
24
26
14
106
114
30
R
R
22
CONVENTIONAL
3 CELL Li-ION
BATTERY
PROTECTION IC
28
REDUNDANT
3 CELL Li-ION
BATTERY
PROTECTION IC
112
30
114
114
30
R
R
R
R
Li-ION
CELL(1)
12
Li-ION
CELL(2)
12
Li-ION
CELL(3)
12
16

Fig. 4

REDUNDANT BATTERY PROTECTION SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention is directed generally to protection systems for battery packs.

[0003] 2. Description of the Related Art

[0004] Battery packs generally have more than one battery cell internally housed in the battery pack such as generally depicted in FIG. **1** for a conventional battery pack **10** using an indefinite number, N, of lithium (Li) ion cells **12** electrically coupled between a first external terminal **14** and a second external terminal **16**. As shown, the Li ion cells **12** are arranged in a series configuration, but in other battery packs the Li ion cells could be arranged in a parallel configuration or in a combination of a series configuration and a parallel configuration.

[0005] Battery cells, such as the Li ion cells **12** depicted are typically dependable, but on occasion an individual one of the Li ion cells may enter into a state causing such an undesirable internal condition as an overvoltage condition, which could potentially damage one or more other of the Li ion cells in the conventional battery pack or may potentially damage equipment (not shown) electrically coupled to the conventional battery pack **10**. At other times, a charger or other external device (not shown) electrically coupled to the conventional battery pack may enter into a state that may result in an undesirable condition that may potentially damage one or more of the Li ion cells **12** of the conventional battery pack if the external device is allowed to remain electrically coupled to the conventional battery pack.

[0006] Conventional battery protection systems exist to help protect battery cells from undesirable internal and/or external conditions. For instance, a conventional protection system **18** is shown in FIG. **1** as having a conventional integrated circuit (IC) based battery protection circuit **20**, and a conventional transistor pair **22** of a discharge transistor **24**, and a charge transistor **26**. The conventional protection circuit **20** includes an N cell Li ion battery conventional protection IC **28** and can also include one of more discrete devices **30** such as electrical resistors and/or capacitors and/or other discrete electrical components.

[0007] The conventional protection IC **28** is electrically coupled to circuit locations positioned between each of the series connected N number of the Li ion cells **12** for a total of N-1 number of electrical couplings from between a pair of the Li ion cells to the conventional protection IC. The conventional protection IC **28** also is electrically coupled to a circuit location positioned between the number 1 of the Li ion cells and the discharge transistor **24** of the conventional transistor pair **22** as depicted. The conventional protection IC **28** is electrically coupled to a circuit location positioned between the number N of the Li ion cells and the second external terminal **16**. Consequently, the conventional protection IC is electrically coupled to either terminal of each of the Li ion cells **12** to allow, among other things, measurements of voltages conditions of each of the Li ion cells by the convention protection IC.

[0008] The conventional protection IC **28** is also coupled to the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26**, which allows, among other things, control of the open and closed circuit states of the conventional transistor pair acting as a switch dependent upon the presence or absence of a first state of the conventional protection IC.

[0009] In practice when an undesirable condition occurs, such as an overcharge condition in one of the Li ion cells **12**, the conventional protection circuit **20** is in the first state to cause the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26** to have an open circuit condition between the number 1 of the Li ion cells and the first external terminal **14** so that electrical current is no longer allowed to flow thereby protecting the Li ion cells and any external devices (not shown) electrically coupled to the conventional battery pack **10**.

[0010] An implementation of the conventional battery pack **10** is shown in FIG. **2** as having three of the Li ion cells **12**. The implementation has a version of the conventional protection system **18** with a version of the conventional protection circuit **20** that has a three-cell version of the conventional protection IC **28** and MOSFET versions of the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26**. Electrical resistors are used with the version of the conventional protection circuit **20** as the discrete devices **30** to couple the conventional protection IC **28** to circuit locations positioned between pairs of the Li-ion cells and a location between the number 1 of the Li ion cells **12** and the discharge transistor **24** of the conventional transistor pair **22**.

[0011] Although the conventional protection system **18** gives a level of safety to the conventional battery pack **10**, in certain circumstances, the conventional protection system can unfortunately, detract from the overall effectiveness of the conventional battery pack. In particular, if one of the components of the conventional protection system **18** inadvertently fails due to faulty conditions of the component rather than an undesirable internal or external condition described above, the conventional battery pack **10** will be rendered in this situation inoperable even though all of the internal Li ion cells **12** and externally coupled one or more external devices (not shown) are functioning properly. Consequently, the conventional battery pack **10** is disabled by the conventional protection system **18** even though no undesirable condition exists for which that the conventional protection system was designed to disable the conventional battery pack.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0012] FIG. **1** is a schematic of a generally depicted conventional battery pack having a conventional protection system with a conventional protection circuit.

[0013] FIG. **2** is a schematic of a three Li ion cell implementation of the generally depicted conventional battery pack of FIG. **1** having a three cell version of the conventional protection circuit.

[0014] FIG. **3** is a schematic of a generally depicted enhanced battery pack according to the present invention with an enhanced protection system having the conventional protection circuit and a redundant protection circuit electrically coupled in parallel.

[0015] FIG. **4** is a schematic of a three Li ion cell version of the generally depicted enhanced battery pack of FIG. **3** with a three Li ion cell version of the enhanced protection system.

DETAILED DESCRIPTION OF THE INVENTION

[0016] As disclosed herein, an enhanced battery pack having an enhanced protection system addresses a potential weakness of the conventional protection system **18** of the conventional battery pack **10** that solely relies on the conventional protection circuit **20**. The conventional protection system **18** can become inoperable due to a faulty condition of one or more components of the conventional protection circuit **20** itself. The enhanced protection system includes both the convention protection circuit **20** and a redundant protection circuit. The redundant protection circuit is either a duplicate copy of the conventional protection circuit **20** or is at least a functional equivalent of the conventional protection circuit. The components of the redundant protection circuit are electrically coupled into the enhanced battery pack in a parallel fashion with the corresponding components of the conventional protection circuit **20**.

[0017] Consequently, if one or more components of the conventional protection circuit **20** fail due to defective conditions of the one or more components of the conventional protection circuit, the redundant protection circuit will still be operable to allow the enhanced battery pack to function while the enhanced protection system continues to protect the enhanced battery pack. Likewise, if the redundant protection circuit becomes inoperable due to one or more of the components of the redundant protection circuit being faulty, the conventional protection circuit **20** can be used as a backup so that the enhanced battery pack will continue to function while the enhanced protection system continues to protect the enhanced battery pack. Only in the case where both the conventional protection circuit **20** and the redundant protection circuit are inoperable due to one or more faulty components of each of the conventional protection circuit and the redundant protection circuit, will the enhanced battery pack cease to function due to faulty conditions of the conventional protection circuit and the enhanced protection circuit.

[0018] On the other hand, when both the conventional protection circuit **20** and the redundant protection circuit are properly functioning, if an undesirable condition should occur either internally to the enhanced battery pack such as an overvoltage condition with one or more of the Li ion cells **12** or externally to the enhanced battery pack such as due to improper charging of the enhanced battery pack by an external charger, both the conventional protection circuit **20** and the redundant protection circuit will cause an open circuit condition within the enhanced battery pack so that current is not allowed to flow from the enhanced battery pack thereby protecting the enhanced battery pack and also external devices electrically coupled to the enhanced battery pack.

[0019] Generally depicted, an enhanced battery pack **100** having an enhanced protection system **102** is shown in FIG. **3** having the conventional protection circuit **20** coupled to N number of the Li ion cells **12** and the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26** as described above. Furthermore, the enhanced protection system **102** has a redundant protection circuit **104** and a redundant transistor pair **106** of a discharge transistor **108** and a charge transistor **110**. The redundant protection circuit **104** is electrically coupled into the enhanced battery pack **100** in parallel with the conventional protection circuit.

[0020] The components of the redundant protection circuit **104** (such as the examples of a redundant protection IC **112** and discrete devices **114** shown in FIG. **4**) are either substantially identical to the components of conventional protection circuit **20** regarding component type and circuit location or the components of the redundant protection circuit **104** are at least substantially functionally equivalent to the components of the conventional protection circuit. Further shown in FIG. **2** the redundant transistor pair **106** of the discharge transistor **108** and the charge transistor **110** is electrically coupled into the enhanced battery pack **100** in parallel with the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26**. The redundant protection circuit **104** is electrically coupled to the redundant transistor pair **106** of the discharge transistor **108** and the charge transistor **110**. Given the parallel configuration between the conventional transistor pair **22** and the redundant transistor pair **106**, if the conventional transistor pair should inadvertently be put in an open circuit condition due to a faulty component of either the conventional transistor pair or the conventional protection circuit **22** without an undesired internal or external condition occurring with the Li ion cells **12** or an externally coupled device (not shown), the redundant transistor pair will still provide a closed circuit condition so that electrical current can flow through the redundant transistor pair.

[0021] Likewise, if a reverse situation occurs that the redundant transistor pair **106** is in an open circuit condition due to one or more faulty components of the redundant transistor pair and/or the redundant protection circuit **104** without an undesired internal or external condition occurring with the Li ion cells **12** or an externally coupled device (not shown), the conventional transistor pair **22** will still provide a closed circuit condition so that electrical current can flow through the conventional transistor pair.

[0022] An implementation of the enhanced battery pack **100** is shown in FIG. **4** as having three of the Li ion cells **12**. The implementation has a version of the conventional protection system **18** with a version of the conventional protection circuit **18** that has a three-cell version of the conventional protection IC **28** and MOSFET versions of the conventional transistor pair **22** of the discharge transistor **24** and the charge transistor **26**. Electrical resistors are used with the version of the conventional protection circuit **18** as the discrete devices **30** to couple the conventional protection IC **28** to circuit locations positioned between pairs of the serially connected Li-ion cells and a circuit location positioned between the number 1 of the Li ion cells **12** and the discharge transistor **24** of the conventional transistor pair **22**.

[0023] The implementation has a version of the enhanced protection system **102** with a version of the redundant protection circuit **104** that has a three-cell version of the redundant protection IC **112** and MOSFET versions of the redundant transistor pair **106** of the discharge transistor **108** and the charge transistor **110**. Electrical resistors are used with the version of the redundant protection circuit **104** as

the discrete devices **114** to couple the redundant protection IC **112** to circuit locations between pairs of the Li-ion cells and a location between the number 1 of the Li ion cells **12** and the discharge transistor **24** of the conventional transistor pair **22**.

[**0024**] From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

The invention claimed is:

1. A battery pack comprising:

a first external terminal;

a second external terminal;

a first battery cell electrically coupled with the first external terminal and the second external terminal;

a first electrical switch electrically coupled in series with the first battery cell and the first external terminal;

a first protection circuit electrically coupled to the first battery cell and electrically coupled to the first electrical switch, the first protection circuit having a first state when a first electrical condition of the first battery cell exists and having an absence of the first state when the first condition does not exist, the first electrical switch configured to be in an electrically open circuit state to prevent electrical current from flowing through the first electrical switch when the first state of the first protection circuit exists and to be in an electrically closed circuit state to allow electrical current to flow through the first electrical switch when the first state of the first protection circuit is absent;

a second electrical switch electrically coupled in series with the first battery cell and the first external terminal, the second electrical switch electrically coupled in parallel with the first electrical switch; and

a second protection circuit electrically coupled to the second battery cell and electrically coupled to the second electrical switch, the second protection circuit having a first state when the first electrical condition of the first battery cell exists and having an absence of the first state when the first condition does not exist, the second electrical switch configured to be in an electrically open circuit state to prevent electrical current from flowing through the second electrical switch when the first state of the second protection circuit exists and to be in an electrically closed circuit state to allow electrical current to flow through the second electrical switch when the first state of the second protection circuit is absent.

2. The battery pack of claim 1 wherein the first electrical switch is a first pair of transistors.

3. The battery pack of claim 2 wherein the first pair of transistors are MOSFET transistors.

4. The battery pack of claim 1 wherein the first protection circuit has the first state when an overvoltage condition exists with the battery cell.

5. The battery pack of claim 1 further including a plurality of battery cells and wherein the first protection circuit is electrically coupled to the plurality of battery cells, the first protection circuit configured to be in the first state if at least one of the plurality of battery cells is in the firsts condition.

6. The battery pack of claim 1 wherein the battery cell is a Li ion battery cell.

7. The battery pack of claim 1 further comprising a discrete device electrically coupled between the first protection circuit and the battery cell.

8. The battery pack of claim 1 wherein the discrete device is an electrical resistor.

9. The battery pack of claim 1 wherein the battery cell includes a first terminal and a second terminal and the first protection circuit is coupled to the first terminal and the second terminal of the battery cell.

10. A battery pack comprising:

a first external terminal;

a second external terminal;

a plurality of battery cells electrically coupled to one another and the first external terminal and the second external terminal in series;

a first transistor pair of a charge transistor and a discharge transistor electrically coupled in series with the plurality of battery cells and the first external terminal;

a first integrated circuit electrically coupled to each of the plurality of battery cells, and electrically coupled to the first transistor pair, the first integrated circuit having a first state when a first electrical condition of at least one of the plurality of battery cells exists and having an absence of the first state when the first condition does not exist, the first transistor pair configured to be in an electrically open circuit state to have an absence of electrical continuity between the first external terminal and the plurality of battery cells when the first state of the first integrated circuit exists and to be in an electrically closed circuit state to have electrical continuity between the first external terminal and the plurality of battery cells when the first state of the first integrated circuit is absent;

a second transistor pair of a charge transistor and a discharge transistor electrically coupled in series with the plurality of battery cells and the first external terminal, the second transistor pair electrically coupled in parallel with the first transistor pair;

a second integrated circuit electrically coupled to each of the plurality of battery cells, and electrically coupled to the second transistor pair, the second integrated circuit having a first state when the first electrical condition of at least one of the plurality of battery cells exists and having an absence of the first state when the first condition does not exist, the second transistor pair configured to be in an electrically open circuit state to have an absence of electrical continuity between the first external terminal and the plurality of battery cells when the first state of the second integrated circuit exists and to be in an electrically closed circuit state to have electrical continuity between the first external terminal and the plurality of battery cells when the first state of the second integrated circuit is absent;

11. The battery pack of claim 10 wherein the first transistor pair are MOSFET transistors.

12. The battery pack of claim 10 wherein the first integrated circuit has the first state when an overvoltage condition exists with at least one of the plurality of the battery cells.

13. The battery pack of claim 10 wherein the plurality of the battery cells are Li ion battery cells.

14. The battery pack of claim 10 further comprising a discrete device electrically coupled between the first integrated circuit and one of the plurality of the battery cells.

15. The battery pack of claim 14 wherein the discrete device is an electrical resistor.

16. The battery pack of claim 1 wherein each of the plurality of the battery cells includes a first terminal and a second terminal and the first integrated circuit is coupled to the first terminal and the second terminal of each of the plurality of the battery cells.

* * * * *