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(54) BATTERY TEST MODULE

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(60) Provisional application No. 60/341,902, filed on Dec. 19, 2001. Provisional application No. 60/181,854, filed on Feb. 11, 2000. Provisional application No. 60/204,345, filed on May 15, 2000. Provisional application No. 60/218,878, filed on Jul. 18, 2000. Provisional application No. 60/224,092, filed on Aug. 9, 2000. Provisional application No. 60/128,366, filed on Apr. 8, 1999.

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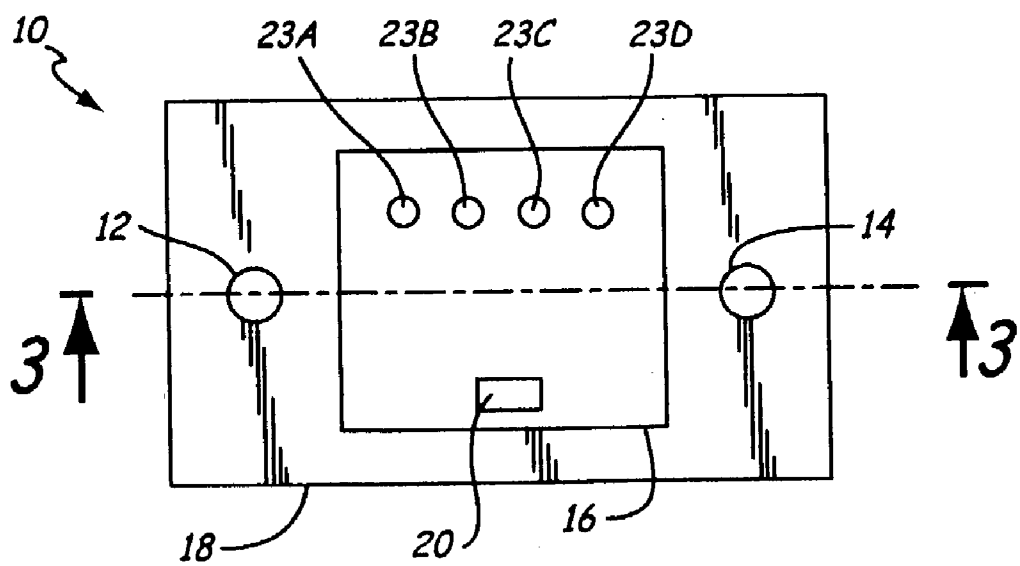
(52) U.S. Cl. ............................ **429/90**; 429/121; 429/180; 324/426

(57) **ABSTRACT**

A storage battery includes a battery housing and a plurality of electrochemical cells in the battery housing electrically connected to terminals of the battery. A battery test module is mounted to the battery housing and electrically coupled to the terminals through Kelvin connections. A display or other output is configured to output battery condition information from the battery test module. Battery post extensions couple the battery test module to terminals of the battery.



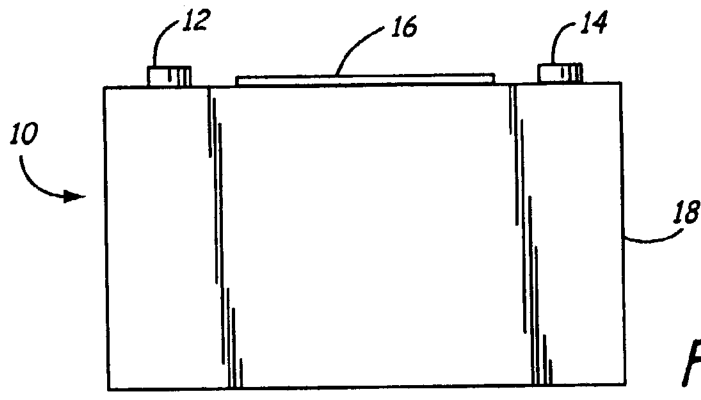



Fig. 1

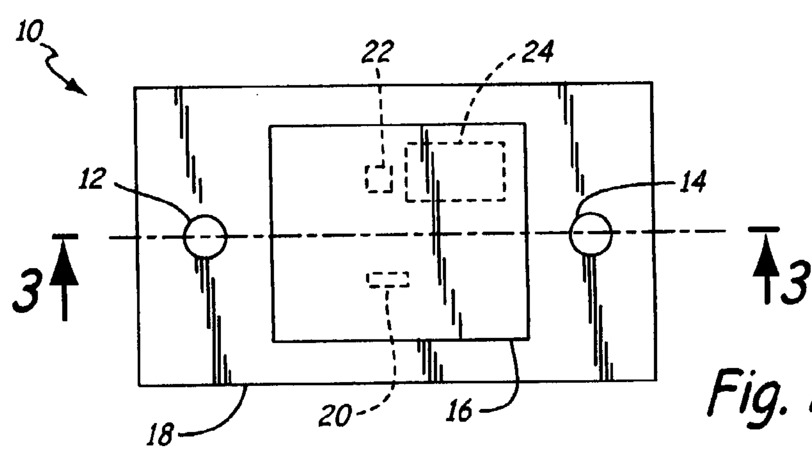



Fig. 2A

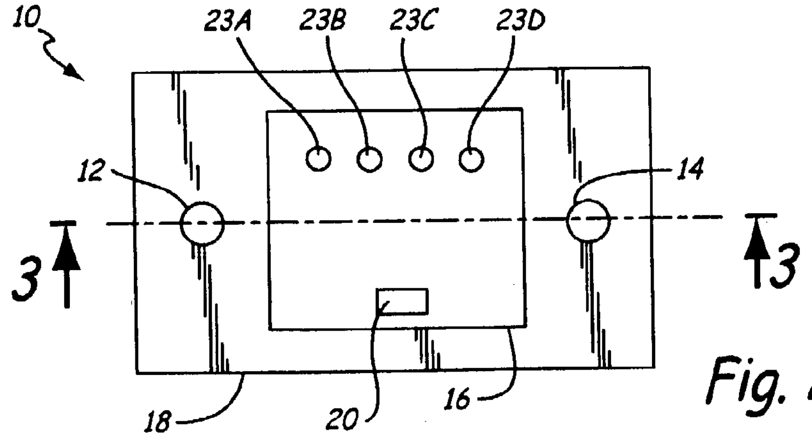
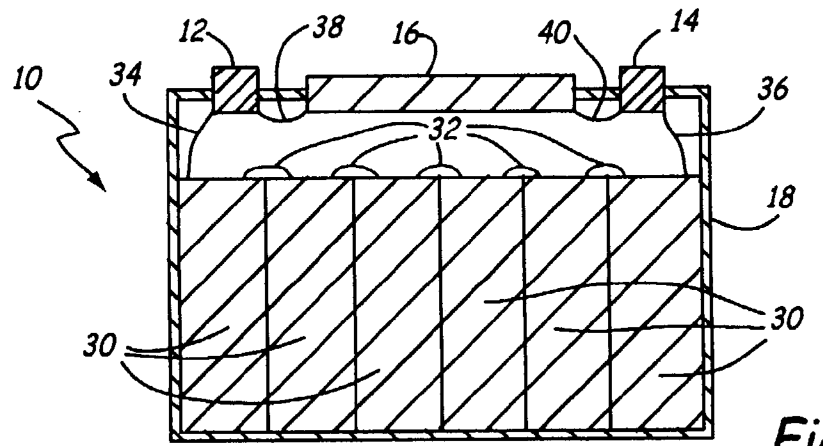



Fig. 2B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12
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16
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14
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Fig. 3

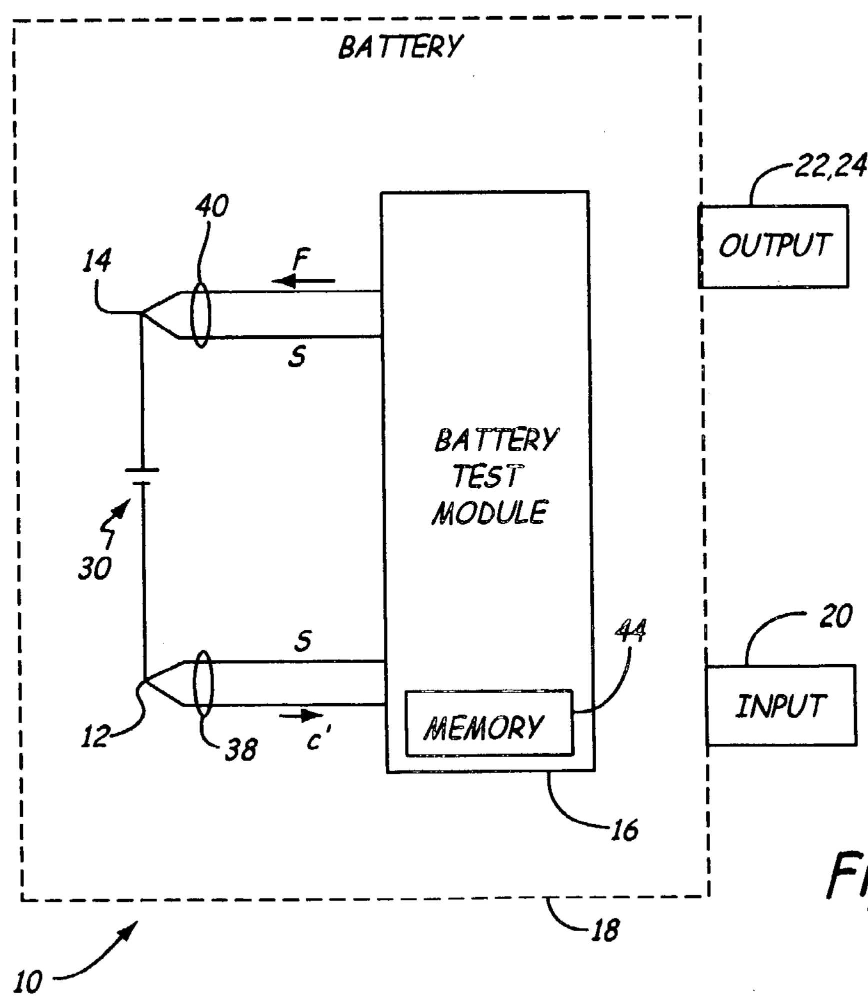
BATTERY
22,24
OUTPUT
40
14
F
S
BATTERY
TEST
MODULE
30
S
20
44
INPUT
12
38
C'
MEMORY
16
18
10

Fig. 4

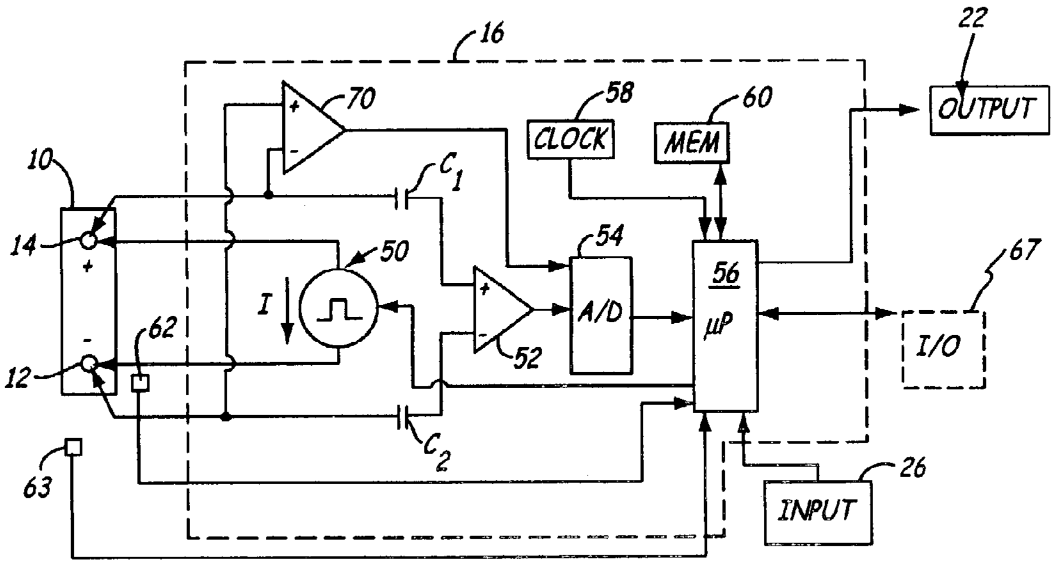
16
22
OUTPUT
70
58
CLOCK
60
MEM
10
C1
14
50
54
56
μP
67
I
A/D
I/O
52
62
12
C2
26
63
INPUT

Fig. 5

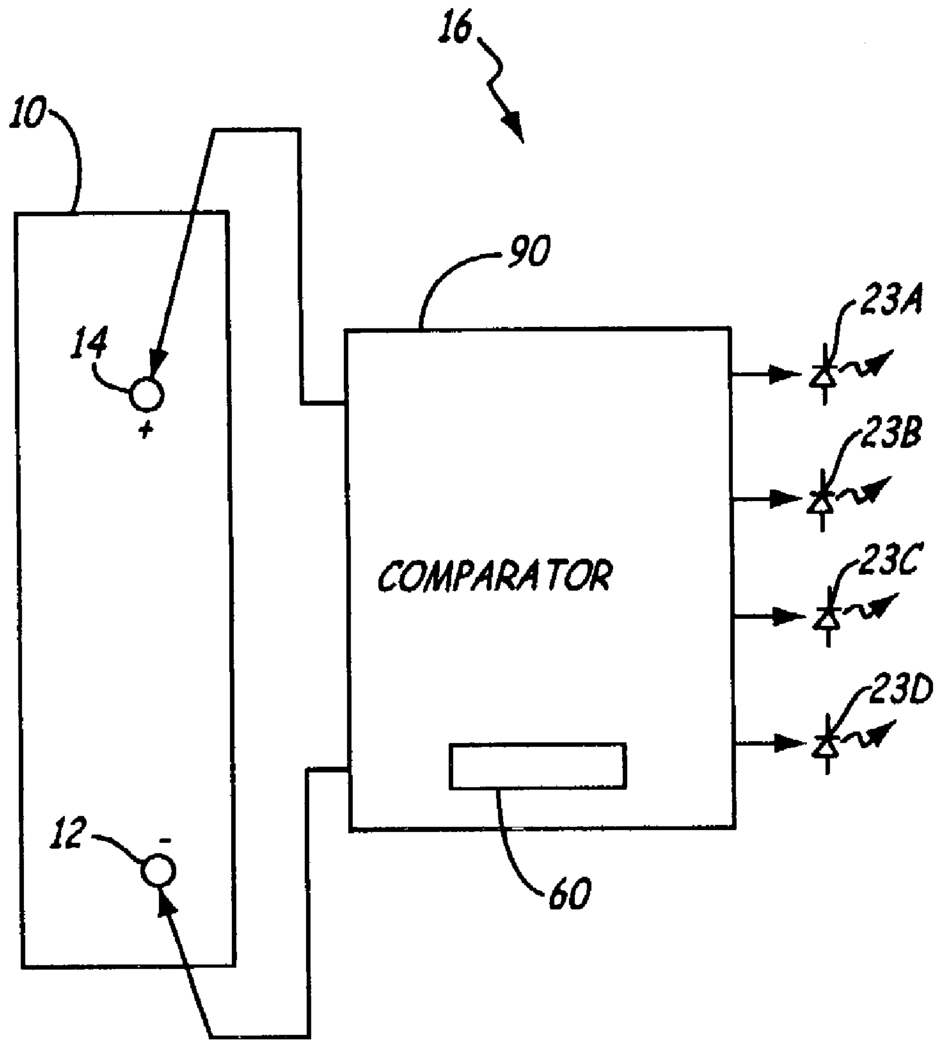


Fig. 6

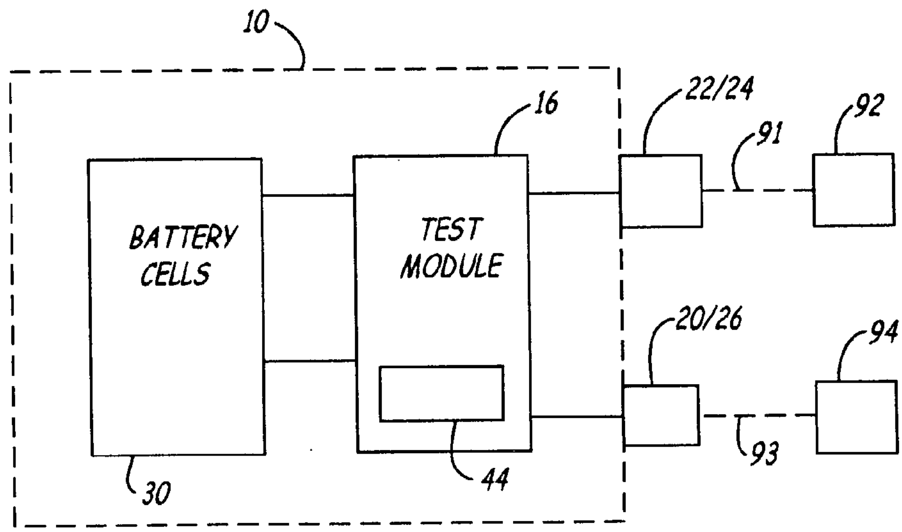
10
16
22/24
91
92
BATTERY CELLS
TEST MODULE
20/26
94
30
44
93

Fig. 7

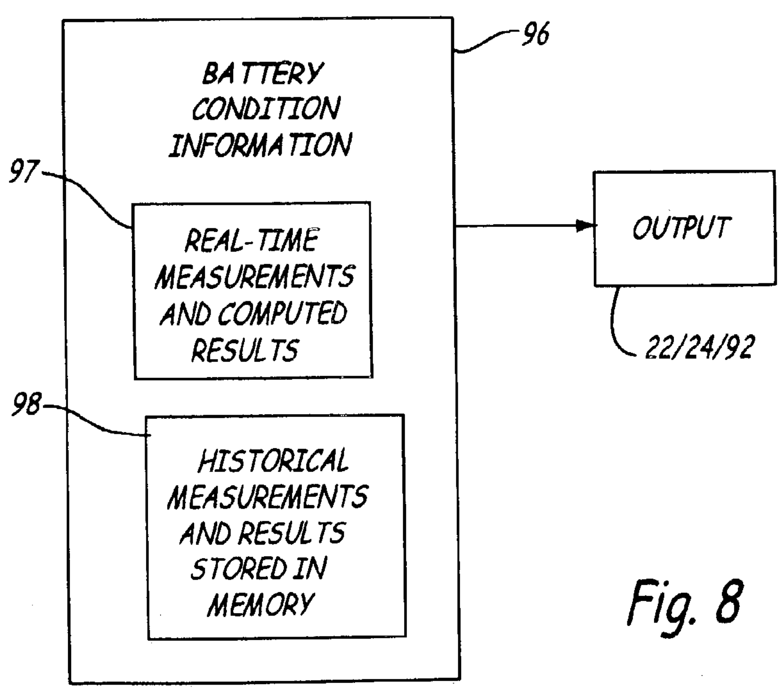
96
BATTERY CONDITION INFORMATION
97
REAL-TIME MEASUREMENTS AND COMPUTED RESULTS
OUTPUT
22/24/92
98
HISTORICAL MEASUREMENTS AND RESULTS STORED IN MEMORY

Fig. 8

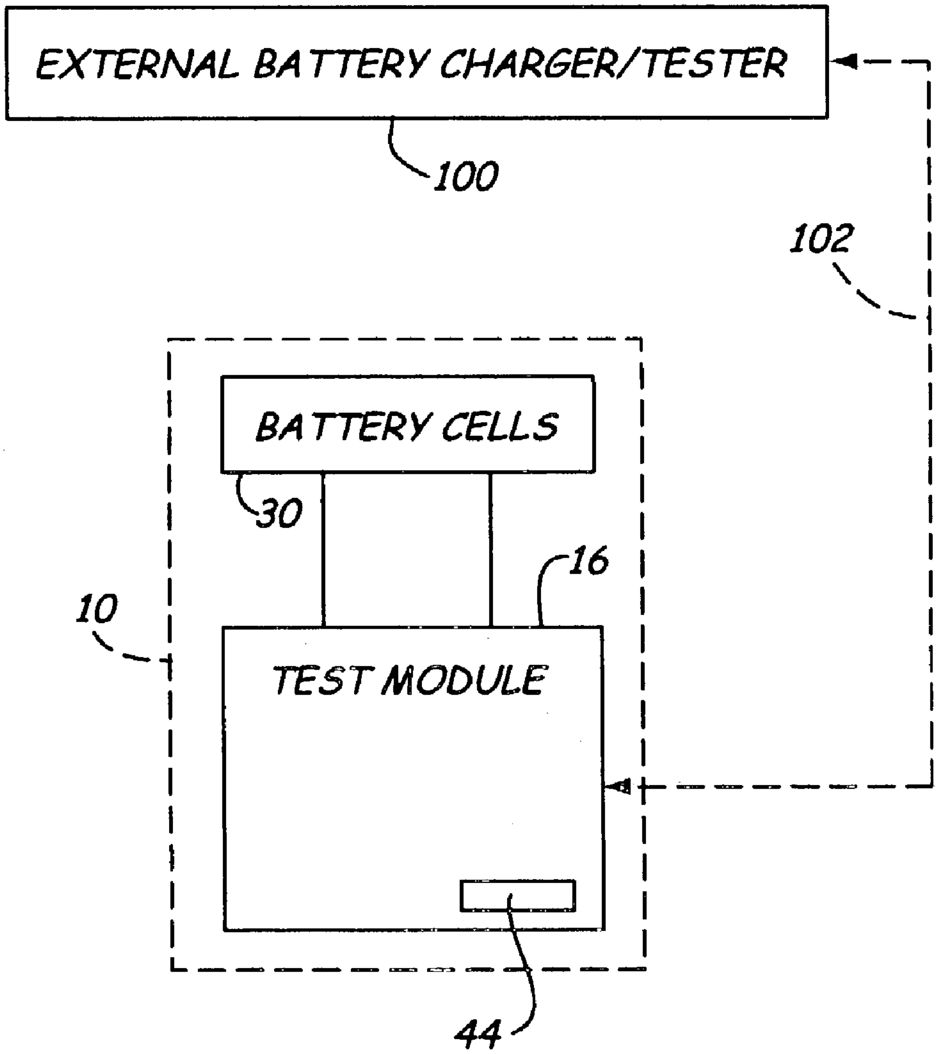
EXTERNAL BATTERY CHARGER/TESTER
100
102
BATTERY CELLS
30
16
10
TEST MODULE
44

FIG. 9

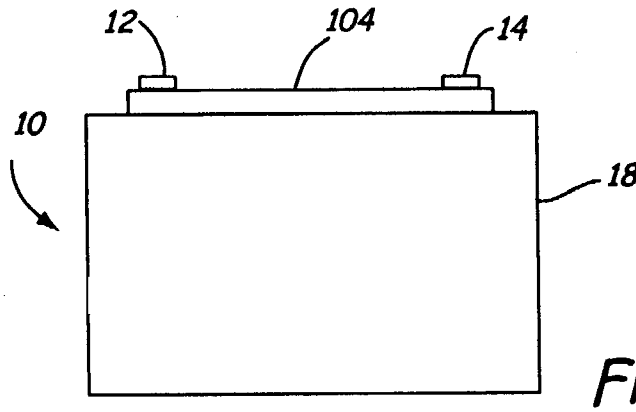


Fig. 10

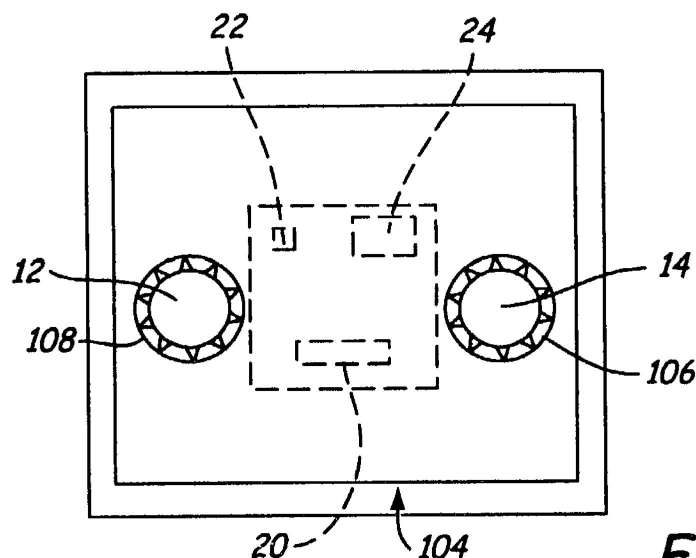


Fig. 11

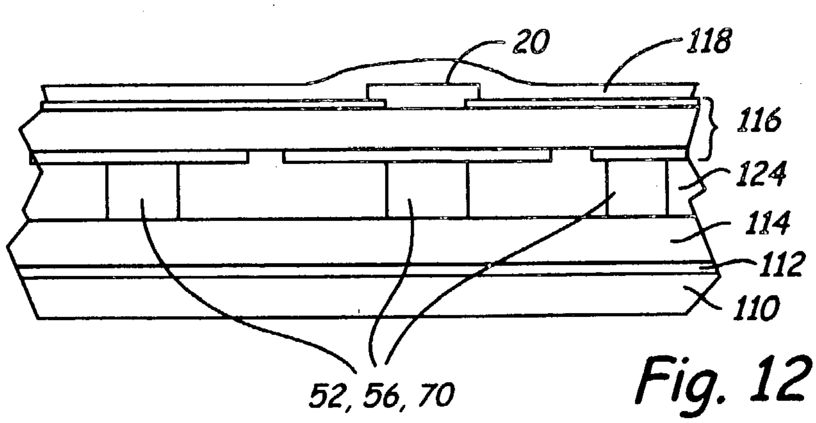


Fig. 12

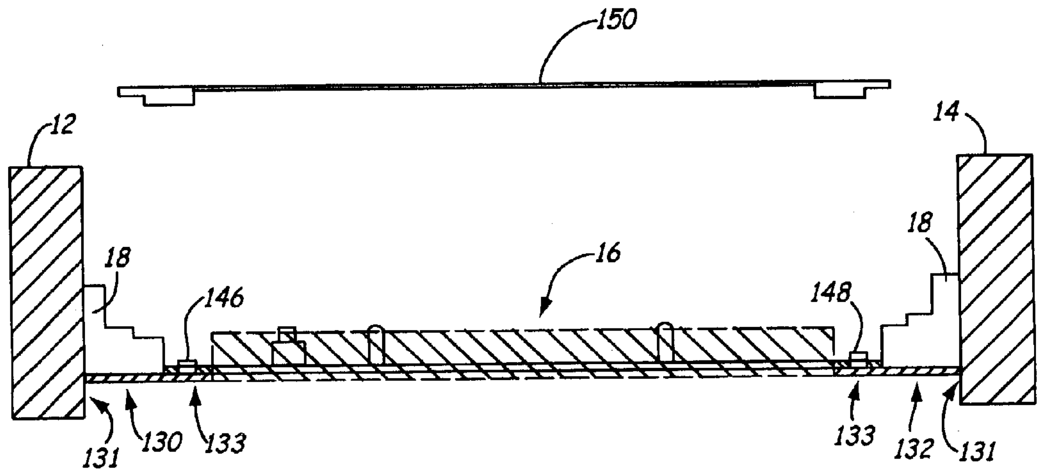


Fig. 13A

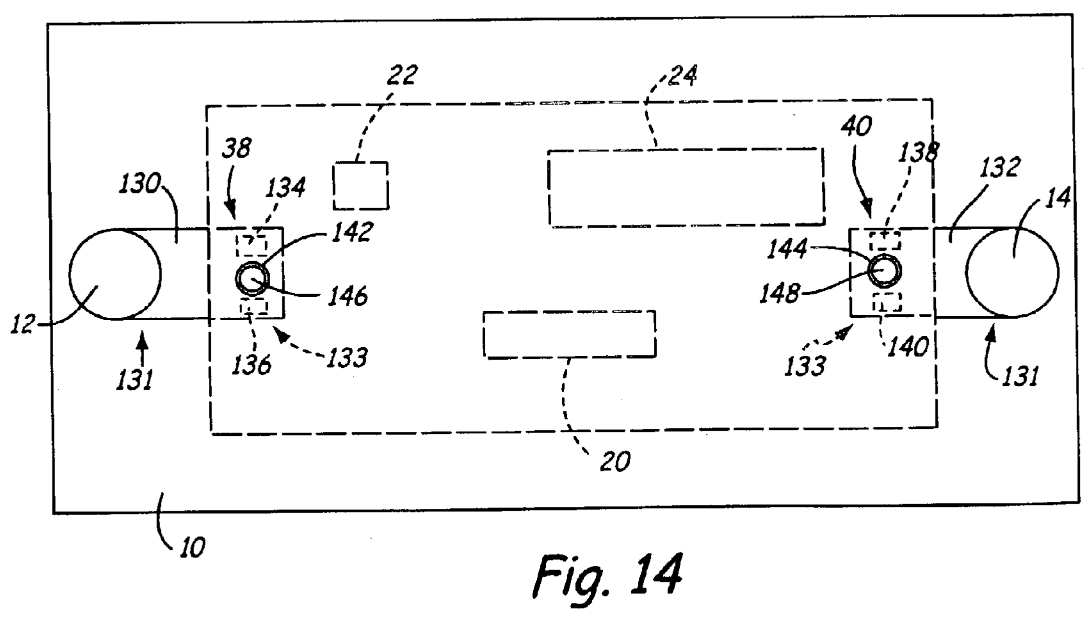


Fig. 14

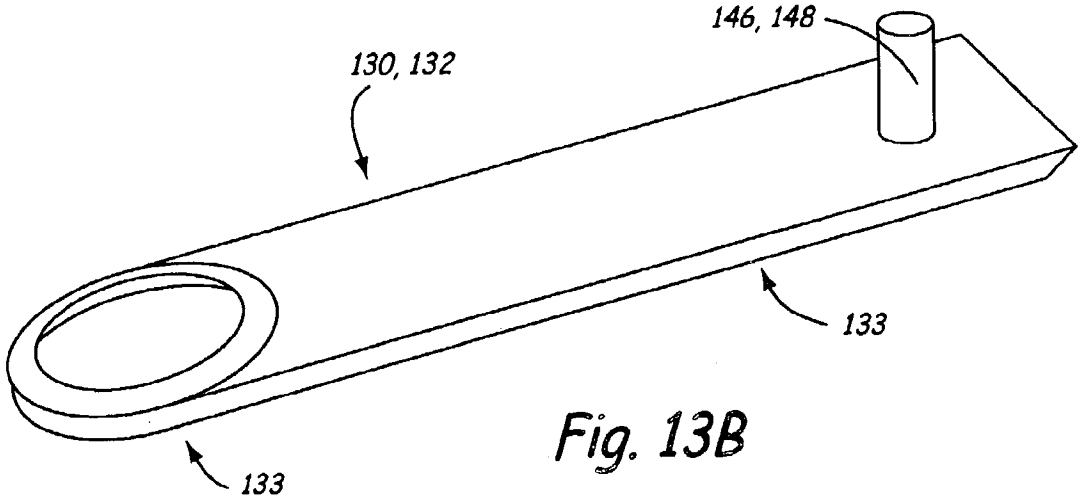


Fig. 13B

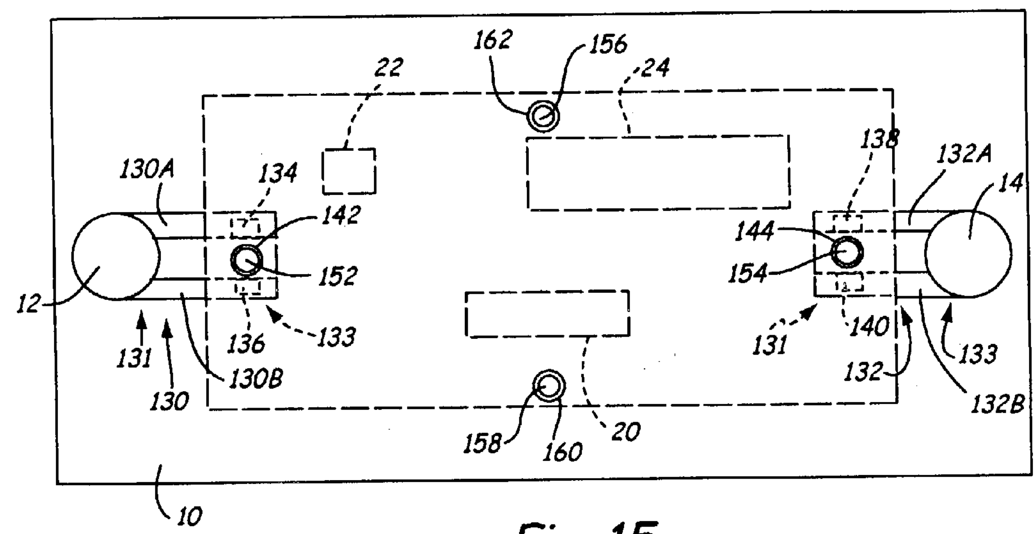


Fig. 15

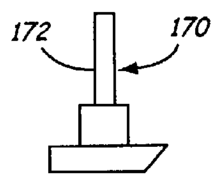


Fig. 16-1

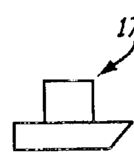


Fig. 16-2

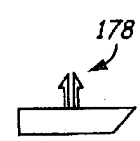


Fig. 16-3

# BATTERY TEST MODULE

## CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. provisional patent application Serial No. 60/341,902, filed Dec. 19, 2001 and is a Continuation-In-Part of U.S. patent application Ser. No. 10/217,913, filed Aug. 13, 2002 which is a Continuation-In-Part of U.S. patent application Ser. No. 09/880,473, filed Jun. 13, 2001 which is a Continuation-In-Part of and claims priority of U.S. patent application Ser. No. 09/780,146, filed Feb. 9, 2001 which is based on and claims the benefit of U.S. provisional patent application Serial No. 60/181,854, filed Feb. 11, 2000; U.S. Provisional patent application Serial No. 60/204,345, filed May 15, 2000; U.S. provisional patent application Serial No. 60/218,878, filed Jul. 18, 2000; and U.S. provisional patent application Serial No. 60/224,092, filed Aug. 9, 2000, and is a Continuation-In-Part of and claims priority of U.S. patent application Ser. No. 09/544,696, filed Apr. 7, 2000, which claims the benefit of priority of U.S. provisional patent application Serial No. 60/128,366, filed Apr. 8, 1999, the contents of which are hereby incorporated by reference in their entirety.

## BACKGROUND OF THE INVENTION

[0002] The present invention relates to storage batteries. More specifically, the present invention relates to storage batteries with integral battery testers.

[0003] Storage batteries, such as lead acid storage batteries, are used in a variety of applications such as automotive vehicles and standby power sources. Typical storage batteries consist of a plurality of individual storage cells which are electrically connected in series. Each cell can have a voltage potential of about 2.1 volts, for example. By connecting the cells in the series, the voltages of the individual cells are added in a cumulative manner. For example, in a typical automotive storage battery, six storage cells are used to provide a total voltage of about 12.6 volts. The individual cells are held in a housing and the entire assembly is commonly referred to as the "battery."

[0004] It is frequently desirable to ascertain the condition of a storage battery. Various testing techniques have been developed over the long history of storage batteries. For example, one technique involves the use of a hygrometer in which the specific gravity of the acid mixture in the battery is measured. Electrical testing has also been used to provide less invasive battery testing techniques. A very simple electrical test is to simply measure the voltage across the battery. If the voltage is below a certain threshold, the battery is determined to be bad. Another technique for testing a battery is referred to as a load test. In a load test, the battery is discharged using a known load. As the battery is discharged, the voltage across the battery is monitored and used to determine the condition of the battery. More recently, a technique has been pioneered by Dr. Keith S. Champlin and Midtronics, Inc. of Willowbrook, Ill. for testing storage battery by measuring a dynamic parameter of the battery such as the dynamic conductance of the battery. This technique is described in a number of United States Patents and United States Patent Applications, for example, U.S. Pat. No. 3,873,911, issued Mar. 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 3,909,708, issued Sep. 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,816,768, issued Mar. 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,825,170, issued Apr. 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Pat. No. 4,881, 038, issued Nov. 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Pat. No. 4,912,416, issued Mar. 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Pat. No. 5,140,269, issued Aug. 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Pat. No. 5,343,380, issued Aug. 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Pat. No. 5,572, 136, issued Nov. 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,574,355, issued Nov. 12, 1996, entitled METHOD AND APPARATUS FOR DETECTION AND CONTROL OF THERMAL RUNAWAY IN A BATTERY UNDER CHARGE; U.S. Pat. No. 5,585,416, issued Dec. 10, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Pat. No. 5,585, 728, issued Dec. 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,589,757, issued Dec. 31, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Pat. No. 5,592, 093, issued Jan. 7, 1997, entitled ELECTRONIC BATTERY TESTING DEVICE LOOSE TERMINAL CONNECTION DETECTION VIA A COMPARISON CIRCUIT; U.S. Pat. No. 5,598,098, issued Jan. 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Pat. No. 5,656,920, issued Aug. 12, 1997, entitled METHOD FOR OPTIMIZING THE CHARGING LEAD-ACID BATTERIES AND AN INTERACTIVE CHARGER; U.S. Pat. No. 5,757,192, issued May 26, 1998, entitled METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY; U.S. Pat. No. 5,821,756, issued Oct. 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,831,435, issued Nov. 3, 1998, entitled BATTERY TESTER FOR JIS STANDARD; U.S. Pat. No. 5,914,605, issued Jun. 22, 1999, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 5,945,829, issued Aug. 31, 1999, entitled MIDPOINT BATTERY MONITORING; U.S. Pat. No. 6,002,238, issued Dec. 14, 1999, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,037,751, issued Mar. 14, 2000, entitled APPARATUS FOR CHARGING BATTERIES; U.S. Pat. No. 6,037,777, issued Mar. 14, 2000, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Pat. No. 6,051,976,; issued Apr. 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BAT-

TERY TEST; U.S. Pat. No. 6,081,098, issued Jun. 27, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,091,245, issued Jul. 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Pat. No. 6,104,167, issued Aug. 15, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,137,269, issued Oct. 24, 2000, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,163,156, issued Dec. 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,172,483, issued Jan. 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELL AND BATTERIES; U.S. Pat. No. 6,172,505, issued Jan. 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,222,369, issued Apr. 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Pat. No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,249,124, issued Jun. 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Pat. No. 6,259,254, issued Jul. 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Pat. No. 6,262,563, issued Jul. 17, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX ADMITTANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,294,896, issued Sep. 25, 2001; entitled METHOD AND APPARATUS FOR MEASURING COMPLEX SELF-IMMITANCE OF A GENERAL ELECTRICAL ELEMENT; U.S. Pat. No. 6,294,897, issued Sep. 25, 2001, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,304,087, issued Oct. 16, 2001, entitled APPARATUS FOR CALIBRATING ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,310,481, issued Oct. 30, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,313,607, issued Nov. 6, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,313,608, issued Nov. 6, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,316,914, issued Nov. 13, 2001, entitled TESTING PARALLEL STRINGS OF STORAGE BATTERIES; U.S. Pat. No. 6,323,650, issued Nov. 27, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,329,793, issued Dec. 11, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,331,762, issued Dec. 18, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Pat. No. 6,332,113, issued Dec. 18, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,351,102, issued Feb. 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Pat. No. 6,359,441, issued Mar. 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,363,303, issued Mar. 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM, U.S. Ser. No. 09/595,102, filed Jun. 15, 2000, entitled APPARATUS AND METHOD FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Ser. No. 09/703,270, filed Oct. 31, 2000, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/575,629, filed May 22, 2000, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Ser. No. 09/780,146, filed Feb. 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Ser. No. 09/816,768, filed Mar. 23, 2001, entitled MODULAR BATTERY TESTER; U.S. Ser. No. 09/756,638, filed Jan. 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Ser. No. 09/862,783, filed May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Ser. No. 09/483,623, filed Jan. 13, 2000, entitled ALTERNATOR TESTER; U.S. Ser. No. 09/870,410, filed May 30, 2001, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/960,117, filed Sep. 20, 2001, entitled IN-VEHICLE BATTERY MONITOR; U.S. Ser. No. 09/908,389, filed Jul. 18, 2001, entitled BATTERY CLAMP WITH INTEGRATED CIRCUIT SENSOR; U.S. Ser. No. 09/908,278, filed Jul. 18, 2001, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S. Ser. No. 09/880,473, filed Jun. 13, 2001; entitled BATTERY TEST MODULE; U.S. Ser. No. 09/876,564, filed Jun. 7, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/878,625, filed Jun. 11, 2001, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Ser. No. 09/902,492, filed Jul. 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; and U.S. Ser. No. 09/940,684, filed Aug. 27, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Ser. No. 09/977,049, filed Oct. 12, 2001, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Ser. No. 10/047,923, filed Oct. 23, 2001, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER, U.S. Ser. No. 10/046,659, filed Oct. 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Ser. No. 09/993,468, filed Nov. 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Ser. No. 09/992,350, filed Nov. 26, 2001, entitled ELECTRONIC BATTERY TESTER, U.S. Ser. No. 10/042,451, filed Jan. 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE; U.S. Ser. No. 10/042,451, filed Jan. 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE, U.S. Ser. No. 10/073,378, filed Feb. 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Ser. No. 10/093,853, filed Mar. 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Ser. No. 60/364,656, filed Mar. 14, 2002, entitled ELECTRONIC BATTERY TESTER WITH LOW TEMPERATURE RATING DETERMINATION; U.S. Ser. No. 10/101,543, filed Mar. 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/112,114, filed Mar. 28, 2002; U.S. Ser. No. 10/109,734, filed Mar. 28, 2002; U.S. Ser. No.

10/112,105, filed Mar. 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Ser. No. 10/112,998, filed Mar. 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; which are incorporated herein in their entirety.

[0005] In general, battery testers have been separate pieces of equipment which can be moved between storage batteries and electrically coupled to a storage battery. The prior art has lacked a simple technique for the testing of a storage battery without relying on separate testing equipment.

## SUMMARY OF THE INVENTION

[0006] A storage battery includes a battery housing and a plurality of electrochemical cells in the battery housing electrically connected to terminals of the battery. A battery test module is mounted to the battery housing and electrically coupled to the terminals through Kelvin connections. A display or other output is configured to output battery condition information from the battery test module. Another aspect of the invention includes battery post extensions that couple the battery test module to terminals of the battery.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0007] **FIG. 1** is a side plan view of a storage battery including a battery test module in accordance with the present invention.

[0008] **FIGS. 2A and 2B** are top plan views of the storage battery of **FIG. 1**.

[0009] **FIG. 3** is a side cross-sectional view of the storage battery of **FIGS. 1 and 2** taken along the line labeled **3-3** in **FIG. 2**.

[0010] **FIG. 4** is a block diagram of a storage battery in accordance with the present invention.

[0011] **FIG. 5** is an electrical diagram of one example embodiment.

[0012] **FIG. 6** is an electrical diagram of another example embodiment.

[0013] **FIG. 7** is a block diagram of a storage battery in accordance with another example embodiment of the present invention.

[0014] **FIG. 8** is a block diagram illustrating various types of battery test condition information provided by the battery test module.

[0015] **FIG. 9** is a simplified block diagram of a storage battery with a battery test module that can communicate with an external charger/tester in accordance with an embodiment of the present invention.

[0016] **FIG. 10** is a side plan view of the storage battery upon which the battery test module is affixed.

[0017] **FIG. 11** is a top plan view of the storage battery of **FIG. 10**.

[0018] **FIG. 12** illustrates a cross section of a portion of the test module.

[0019] **FIG. 13A** illustrates a cross section of a portion of the battery.

[0020] **FIG. 13B** illustrates a battery post extension in accordance with an embodiment of the present invention.

[0021] **FIGS. 14 and 15** are top plan views of storage battery showing different embodiments of battery post extensions.

[0022] FIGS. **16-1** through **16-3** illustrate different embodiments of fasteners used to couple the battery test module to the battery.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] In one aspect of the present invention a storage battery is provided having an integrated battery test module for performing a battery test on electrical cells of the storage battery. As used herein "integrated" can include a separate module which is attached to the battery housing. In one embodiment, the battery test module is electrically coupled to the electrical cells of the storage battery through Kelvin connections. In certain aspects, Kelvin connections are not used. As the battery test module is integral with the battery, an operator can test the battery without relying on external battery test equipment. In one embodiment, the battery test is one that can be easily performed by an unskilled operator. The battery test module is preferably manufactured using low cost techniques which may be integrated with a storage battery without an excessive increase in the cost to produce the battery. Further, the battery test module is capable of outputting battery condition information to an output device that is attached to the battery housing and/or to a separate output that may be at a location that is remote from the storage battery. As used herein, battery condition information can be any information generated by the battery test module or any battery test result obtained by the battery test module. Examples of battery condition information include real-time measurements (such as, battery voltage, current, temperature, etc.) conducted by the test module, intermediate test results and final test results obtained by the battery test module.

[0024] **FIG. 1** is a side plan view of a storage battery **10** in accordance with the present invention. Storage battery **10** includes a positive terminal **12** and a negative terminal **14**. A battery test module **16** is mounted to a housing **18** of the storage battery.

[0025] **FIGS. 2A and 2B** are top plan views of the storage battery **10** of **FIG. 1**. As illustrated in **FIG.** 2A, battery test module **16** includes an optional input **20** and optional outputs **22** and **24**. Input **20** can be, for example, a push button or other input which can be actuated by an operator or automated by a system. Output **22** can be, for example, an LED or other type of visual indicator which provides a pass/fail indication of a battery test. However, in other aspects, output **24** can be used to send data, using any appropriate technique, to a remote computer or monitoring system. Output **24** can be used to provide a quantitative output of a battery test. In **FIG.** 2B, the output **22** is in the form of a series of outputs **23**A, **23**B, **23**C and **23**D which can comprise LEDs.

[0026] **FIG. 3** is a side cross-sectional view of battery **10** taken along the line labeled **3-3** in **FIG. 2**. As illustrated in **FIG. 3**, battery **10** is a storage battery such as a lead-acid battery and includes a number of electrochemical cells which are electrically connected in series by conductors **32**. This forms a string of cells **30** having one end electrically coupled to positive terminal **12** through conductor **34** and having the other end electrically coupled to negative terminal **14** through conductor **36**. As illustrated in **FIG. 3**, battery test module **16** is coupled to terminals **12** and **14** through two pairs of electrical connections which provide Kelvin connections **38** and **40**. The connections to terminals **12** and **14** can be achieved through direct contact with the external battery posts **12** or **14**, through battery post extensions tooled, molded or configured to the battery posts **12** or **14**, through direct internal or external wiring connections to battery posts **12** or **14**, or through a reconfiguration of the battery casing and battery posts **12** or **14**.

[**0027**] In operation, a user can test the condition of battery **10** using battery test module **16**. For example, through actuation of button **20** or another input device, a test can be performed on the battery. The results of the battery test are displayed on outputs **22** or **24**. In one embodiment, battery test module **16** monitors the battery and waits for a period when the battery is not in use or there is not excessive noise on the electrical system to which the battery is connected and then performs a test on the battery. The results of the battery test can be stored in memory and displayed on output **22** or **24**. In such an embodiment, an input such as input **20** is not required to activate the test. However, in such an embodiment, the circuitry within test module **16** could cause the battery to discharge over an extended period.

[**0028**] In the embodiment shown in **FIG. 2**B, battery test module **16** compares the voltage between terminals **12** and **14** to a number of different threshold voltages. Depending upon the voltage of battery **10**, an appropriate number of LEDs **23**A-D are illuminated on test module **16**. For example, each LED can correspond to a different threshold. These thresholds can be spaced as desired. The LEDs **23**A-D can also be of different colors. For example, **23**A can be a read LED while **23**D can be a green LED. In a slightly more complex embodiment, a load, such as a load resistance, in module **16** can be applied to battery **10** during or prior to a voltage measurement. The output of module **16** can be a function of the applied load.

[**0029**] In one embodiment, test module **16** illuminates outputs **23**A-D consecutively until the appropriate threshold is reached. To provide a more desirable user-interface, a small delay can be introduced between the illumination of the each LED. The timing can be as appropriate. The results of the battery test can be maintained on outputs **23**A-D for a desired length of time, preferably sufficiently long for a user to observe the test result. In one embodiment, the appropriate number of LEDs remain lit until the test is complete. In another embodiment, only a single LED is lit at a time. Of course, any number of LEDs and thresholds may be used. In other embodiments, additional information can be communicated to an operator by flashing LEDs providing a code or a warning.

[**0030**] The circuitry of the battery tester in the embodiment of **FIG. 2B** can be implemented using simple comparators and timing circuits as will be apparent to those skilled in the art. A more complex embodiment can include a small microprocessor. Typically, the circuitry of battery test module **16** is powered by storage battery **10**.

[**0031**] **FIG. 4** shows a more detailed view of the electrical connections between battery test module **16** and the cells **30** of the battery **10**. Cells **30** are illustrated using the electrical symbol for a battery. Battery test module **16** is coupled to electrochemical cells **30** through Kelvin connections **38** and **40**.

[**0032**] A microprocessor in battery test module **16** can store information in memory **44** for later retrieval. For example, information regarding the history of battery usage and battery charging can be maintained in memory for later output. A special access code can be entered through user input **20** to cause the data to be output through output **22** or **24** or other output. In one embodiment, the output can be an audio output such as a series of tones or pre-recorded words. The input can comprise a special series of buttons or timing of pressing of buttons. Alternative inputs can also be provided such as an IR sensor, a vibration sensor, a magnetic switch, a proximity receiver which inductively couples to an external device or others. The output can be provided by energizing an LED in accordance with a digital code which could be read by an external device. Other types of outputs can be provided through an IR link, a proximity communication technique such as inductive coupling, etc. Other techniques include a serial or other hard wired output, RF and optical. Further, a battery test can be initiated based upon an input received through input **20** or **26**, using any of the above communication techniques, from a remote computer or other circuitry. This can also be used to initiate a data dump of information stored in memory. Inputs and outputs can also be provided to test module **16** by modulating data onto positive and negative terminals **12** and **14**. The data can be received or transmitted using transmit and receive circuitry in battery module **16**. Various modulation techniques are known in the art. In one embodiment, the modulation technique is selected such that it does not interfere with external circuitry to which battery **10** may be coupled.

[**0033**] The data recording and reporting technique allows a manufacturer to monitor usage of a battery. For example, the manufacturer could determine that the battery was left in an uncharged condition for an extended period, prior to sale, which caused damage to the battery. The data stored in memory can be keyed to date information if such information is maintained by a microprocessor in battery test module **16** such that various events in the life of the battery **18** can be linked to specific dates. Examples of other information which can be stored in memory **44** include the date of manufacture, battery ratings, battery serial number of other identification, distribution chain, etc.

[**0034**] **FIG. 4** also illustrates another aspect of the present invention. In **FIG. 4**, element **10** can also illustrate a standby jumper or auxiliary system **10** which contains an internal battery **30**. Jumper cables or other output such as a cigarette lighter adapter, can couple to battery **30** and can be used to provide auxiliary power to an automotive vehicle. For example, such a system can be used to provide a brief charge to a vehicle or to start a vehicle having a dead battery. This can be used to "jump start" the vehicle. Such devices are known in the art and are typically small, portable devices which contain an internal battery. The internal battery can be, for example, a gel cell, a NICAD battery, a nickel metal hydride battery or other type of battery. One problem with such auxiliary power systems is that the internal battery can fail without the knowledge of the user. When use of the of auxiliary power system is required, the battery may have failed. Further, the type of a failure may be one which is not easily detected in that the battery may provide a normal voltage output but is not capable of supplying a great deal of current for any period of time. With the present invention, system **10** can also include a test module **16** for testing battery **30**. In such an embodiment, a user could periodically test battery **30** to ensure it has not failed. Further, test module **16** can periodically test battery **30** and provide a warning indication such as a flashing light or a warning sound if battery **30** fails. In one aspect of the invention, any type of battery tester can be used to test such an auxiliary battery system.

[**0035**] The present invention can be implemented using any appropriate technique. One example is set forth in U.S. Pat. No. 6,172,505, issued Jan. 9, 2001, and entitled ELECTRONIC BATTERY TESTER which is incorporated herein by reference.

[**0036**] In one aspect, the battery test module determines battery condition based upon a dynamic parameter of the battery, that is a measurement of the battery which is made using a time varying forcing function F as shown in **FIG. 4**. The resultant signals in **FIG. 4** can be used to determine the dynamic parameter. Example dynamic parameters include dynamic conductance, resistance, impedance and admittance. In another example, single contacts are used to obtain a measurement across the battery.

[**0037**] Memory such as memory **44** within test module **16** can be used to store battery specific information such as the rating of battery **10**. The information can be loaded into permanent memory during manufacture. Thus, the user is not required to enter any information regarding the battery. This information can be used in performing the battery test and to provide a qualitative output to a user.

[**0038**] Output **22** can be any type of output including a visual output. Examples include bi or tri-color LEDs. The color along with a flashing condition of an LED can indicate test results such as good, bad, low charge, too low to test, or other conditions and determinations. A flashing LED can be used to indicate system noise, bad cell, or other conditions and determinations. When the user input **20** is used, the circuitry does not provide any drain on the battery except when activated. However, an input such a switch can increase cost and could allow a user to attempt a test at an inopportune time, such as during periods of high system noise.

[**0039**] In embodiments without input **20**, test module **16** can wait for a quiet time or other appropriate time to perform a test. The result can be stored in internal memory and periodically displayed on output **22**/**24** for a brief period. However, extended operation of the test module can drain the battery. In one embodiment, a start-up circuit can be triggered to 'wake up' the test module when the battery experiences a voltage increase such as that due to charging of the battery. The circuitry can then enter a 'sleep' mode based during period of non-charging in order to save power, for example, shortly after charging stops.

[**0040**] The battery test module of the present invention is preferably integral with the battery. For example, the module can be mounted to the housing such as to a top cover of the housing. In various embodiments, the module can be carried within the housing or within an isolated compartment in the housing. The Kelvin connections can couple to the battery terminals either through external or internal conductors.

[**0041**] Of course, the test circuitry and test module can be attached to the battery through any technique including for example, techniques that do not require any modifications to the battery container. For example, it can attach under bolts used on the battery post or can use a press fit or "trap" configuration to fit over the battery posts. This allows the circuitry to be optionally added to existing batteries.

[**0042**] Further, one aspect of the invention includes any tester that is integral with the battery or substantially permanently attached to the battery that provides an output related to a battery condition such as cold cranking amps (CCA) and/or uses Kelvin connections to couple to the battery.

[**0043**] **FIG. 5** is a simplified circuit diagram of test module **16**. Module **16** is shown coupled to battery **10**. Module **16** operates in accordance with one embodiment of the present invention and determines the conductance ($G_{BAT}$) of battery **10** and the voltage potential ($V_{BAT}$) between terminals **12** and **14**. Module **16** includes current source **50**, differential amplifier **52**, analog-to-digital converter **54** and microprocessor **56**. Amplifier **52** is capacitively coupled to battery **10** through capacitors $C_1$ and $C_2$. Amplifier **52** has an output connected to an input of analog-to-digital converter **54**. Microprocessor **56** is connected to system clock **58**, memory **60**, visual output **62** and analog-to-digital converter **54**. Microprocessor **56** is also capable of receiving an input from input device **26**. Further, an input/output (I/O) port **67** is provided.

[**0044**] In operation, current source **50** is controlled by microprocessor **56** and provides a current in the direction shown by the arrow in **FIG. 5**. In one embodiment, this is a square wave or a pulse. Differential amplifier **52** is connected to terminals **22** and **24** of battery **10** through capacitors $C_1$ and $C_2$, respectively, and provides an output related to the voltage potential difference between terminals **12** and **14**. In a preferred embodiment, amplifier **52** has a high input impedance. Circuitry **16** includes differential amplifier **70** having inverting and noninverting inputs connected to terminals **24** and **22**, respectively. Amplifier **70** is connected to measure the open circuit potential voltage ($V_{BAT}$) of battery **10** between terminals **12** and **14**. The output of amplifier **70** is provided to analog-to-digital converter **54** such that the voltage across terminals **12** and **14** can be measured by microprocessor **56**.

[**0045**] Module **16** is connected to battery **10** through a four-point connection technique known as a Kelvin connection. This Kelvin connection allows current I to be injected into battery **10** through a first pair of terminals while the voltage V across the terminals **12** and **14** is measured by a second pair of connections. Because very little current flows through amplifier **52**, the voltage drop across the inputs to amplifier **52** is substantially identical to the voltage drop across terminals **12** and **14** of battery **12**. The output of differential amplifier **52** is converted to a digital format and is provided to microprocessor **56**. Microprocessor **56** operates at a frequency determined by system clock **58** and in accordance with programming instructions stored in memory **60**.

[**0046**] Microprocessor **56** determines the conductance of battery **10** by applying a current pulse I using current source

**50**. The microprocessor determines the change in battery voltage due to the current pulse I using amplifier **52** and analog-to-digital converter **54**. The value of current I generated by current source **50** is known and is stored in memory **60**. In one embodiment, current I is obtained by applying a load to battery **10**. Microprocessor **56** calculates the conductance of battery **10** using the following equation:

$$\text{Conductance} = G_{BAT} = \frac{\Delta I}{\Delta V} \qquad \text{Equation 1}$$

**[0047]** where ΔI is the change in current flowing through battery **10** due to current source **50** and ΔV is the change in battery voltage due to applied current ΔI. A temperature sensor **62** can be thermally coupled to battery **10** and used to compensate battery measurements. Temperature readings can be stored in memory **60** for later retrieval.

**[0048]** In one embodiment of the present invention, test module **16** includes a current sensor **63** which measures charge/discharge current of the battery. The battery current measurements are utilized by microprocessor **56** to relatively accurately determine state of charge and state of health of battery **10**.

**[0049]** **FIG. 6** is a simple diagram for the embodiment of module **16** shown in **FIG. 2B**. A comparator **90** can periodically compare a voltage measurement to a plurality of reference levels and responsively energize LEDs **23**A-D to provide an indication of the condition of battery **10**. This display can be provided or be activated by a switch or other condition. Any of the various features set forth in the Figures and discussion can be used in any appropriate combination and should not be limited to the specific examples shown.

**[0050]** In one aspect of the invention, battery test module **16** is advantageously used while manufacturing and/or during delivery of a vehicle. Module **16** can be installed in battery **10** during the vehicle manufacturing process. As the vehicle moves through the assembly line, various loads are placed on the electrical system. For example, the radio may be run, starter actuated, head lights turned on, etc. Module **16** provides an indication if the battery has been discharged, and should be recharged (or should be replaced due to failure or impending failure) prior to delivery to a dealer or sale to a customer. Module **16** provides an output, such as a visual output to indicate that the battery **10** is discharged and should be recharged.

**[0051]** The module **16** can be configured to store information based on the particular type of rating of battery **10**. This can be used in the battery test to determine if the battery should be recharged. Module **16** can be removed from the battery **10** once the vehicle has been assembled or delivered. The module **16** can be reconnected and reused on another vehicle in the assembly line.

**[0052]** With various aspects of the invention, including a module used during manufacture or delivery of a vehicle, module **16** can provide a simple pass/fail visual output, for example through colored LED(s). Additional data can be output to other equipment, for example, by coupling to a data bus of the vehicle, through IR, RF, an external data bus or connection, etc. Additional information can be stored for later retrieval such as information related to battery temperature, usage or cycle history, etc. This data can be time or date stamped and used to diagnose common failures which occur during vehicle manufacturing. Additional information can be stored in the memory such as serial numbers, multiple battery characteristics, self learning, etc.

**[0053]** In general, measurements and computations carried out by module **16** can be time or date stamped. Based on this time and date stamped information, module **16** can provide an output related to how long the battery was in an unused condition when installed in a vehicle, how long the battery was on the shelf, how long the battery was in a completely discharged condition, etc.

**[0054]** **FIG. 7** illustrates another embodiment of a storage battery in accordance with the present invention. A number of items illustrated in **FIG. 7** are similar to those shown in FIGS. **1-6** and are similarly numbered. In addition, **FIG. 7** illustrates a remote output **92** and a remote input **94** with which test module **16** can communicate via communication links **91** and **93**, respectively. Test module **16** can output battery condition information to output **22/24** and/or to remote output device **92**. Remote output device **92** can be any output device such as a gauge, meter, speaker, etc. Remote output device **92** may be located, for example, in a driver cabin or on a dashboard of the vehicle in which storage battery **10** is installed. Remote output device **92** may be an analog output device or a digital output device. Communication link **91** may be any type of communication link, such as a wireless communication link, hard wired communication link, optical communication link, etc. Communication link **91** can also be a vehicle bus such as a Controller Area Network (CAN) bus or a Local Interconnect Network (LIN) bus. Depending upon the type of communication link **91** and type of remote output device **92**, test module **16** can provide test condition information in an appropriate form for remote output **92** to receive. Thus, test condition information can be provided in analog form, digital form, in the form of RF signals, IR signals, audio signals, etc. Test module **16** can also receive an activation signal from a remote input device **94** via communication link **93**. Communication link **93**, like above-discussed communication link **91**, can be any type of communication link which can communicate an activation signal sent from remote input **94** to test module **16**. Input **94** can be, for example, a remotely located push-button activation device that can provide the activation signal, via communication link **93**, to test module **16**. In some aspects, remote input **94** may provide the activation signal automatically when a vehicle that contains storage battery **10** is started or stopped. The activation signal may be in the form of an RF signal, an IR signal, an audio signal, digital signal, CAN bus signal, LIN bus signal, etc. Remote input **94** may be located in a driver cabin of a vehicle in which battery **10** is installed, on a dashboard of a vehicle in which the battery is installed, etc. Input **20/26** may include a timing controller configured to apply the activation signal after a predetermined time period. Also, remote input **94** may include such a timing controller that can apply the activation signal after a predetermined time period. Test module **16** can also provide historical battery condition information to remote output device **92** via communication link **91**. In some embodiments of the present invention, test module **16**, communication links **91** and **93**, remote output device **92** and remote input **93** are part of an apparatus for testing a storage battery.

[0055] **FIG. 8** is a block diagram illustrating contents of battery condition information provided to different outputs. As illustrated in **FIG. 8**, battery condition information **96** includes real-time measurements (battery current, voltage measurement, etc.) and computed results represented by block **97**, and measurements and results stored in memory **44**, represented by block **98**. Battery test module **16** can provide battery condition information **96** to different outputs, such as **22**, **24** and **92**.

[0056] **FIG. 9** illustrates a storage battery with an integrated battery test module in accordance with an embodiment of the present invention. A number of items illustrated in **FIG. 9** are similar to those shown in FIGS. **1-7** and are similarly numbered. In addition, **FIG. 9** shows an external battery charger/tester **100** with which test module **16** can communicate via communication link **102**. One example battery charger/tester, similar to charger/tester **100**, is set forth in U.S. Pat. No. 6,104,167, issued Aug. 15, 2000, and entitled "METHOD AND APPARATUS FOR CHARGING A BATTERY" which is incorporated herein by reference. Communication link **102** may be any hard wired or wireless link, such as those described in connection with communication links **91** and **93** (**FIG. 7**) and can transfer battery condition information from test module **16** to external battery charger/tester **100**. Additionally, data from external battery charger/tester **100** can be received by test module **16** via communication link **102**. In some aspects, battery condition information includes a warranty code for storage battery **10**. The warranty code can be determined by either test module **16** or external battery charger/tester **100**. In addition, battery test module **16** can send historical battery condition information from memory **44** to external battery charger/tester **100**. As mentioned above, this historical information can be utilized to monitor usage of the battery and to maintain a record of various events in the life of the battery. In embodiments of the present invention, battery test module **16** can implement one or more computational algorithms which are substantially similar to, and compatible with computational algorithms included in external battery charger/tester **100**. In some aspects, the compatible computational algorithms are capable of determining the state of charge and state of health of storage battery **100**. Such compatibility of computational algorithms allows for an exchange of intermediate computations or results between the test module **16** and external battery charger/tester **100**. These exchanged intermediate computations or results can be utilized by test module **16** and external battery charger/tester **100** to carry out additional computations.

[0057] In the embodiments of the present invention described above, the test module has been described as a device that can releasably attach to the battery under bolts on the battery posts, for example, or be substantially permanently attached to the battery. In such embodiments, the battery test module typically includes a rigid printed circuit board (PCB) with electronic components mounted on the PCB and is therefore relatively large. Retooling of the battery case or housing is typically required to integrate such a battery test module with the battery housing. Further, since batteries are classified into group sizes based on external dimensions, the addition of the relatively large battery test module could affect the group size dimensions of the battery. Thus, although such a battery test module has several advantages over prior art battery testers, which are pieces of equipment separate from the battery, it can be relatively costly to manufacture and install. An embodiment of the present invention that can be affixed to a battery of any group size without retooling the battery case or affecting the group size dimensions of the battery is described below in connection with **FIG. 10**.

[0058] **FIG. 10** is a side plan view of storage battery **10** upon which battery test module **104** is affixed. In this embodiment of the present invention, the components included in battery test module **104** function in a manner substantially similar to the components of battery test module **16**. However, battery test module **104** is formed using flexible circuit and/or flipped chip technology and therefore test module **104** is a flexible "battery label" with embedded electronic components. Thus, test module **104** can be manufactured in one size and can be affixed to a top surface an sides of a housing of a battery of any group size. Further, since test module **104** is a relatively thin label, the dimensions and therefore the group size of the battery to which it is affixed are not altered. Due to the above-mentioned advantages, battery test module **104** can be produced at a relatively low cost and in very high volume. A technique for mechanically and electrically coupling test module **104** to battery **10** is described below in connection with **FIG. 11**.

[0059] **FIG. 11** is a top plan view of storage battery **10** of **FIG. 10**. As can be seen in **FIG. 11**, battery test module **104** includes components similar to those included in test module **16** (**FIG. 2A**). However, as mentioned above, test module **104** is formed of multiple flexible layers. Battery test module **104** is coupled to battery posts **12** and **14** with the help of a "trap" configuration, pointed to by numerals **106** and **108**, to fit over the battery posts **12** and **14**. Post or terminal grasping portions **106** and **108** comprise grooves in battery test module **104**, with electrically conductive teeth protruding into the grooves to make electrical contact with posts **12** and **14**. Portions of battery test module **104** may be substantially elastic to enable coupling of test module **104** to posts of batteries of different dimensions. A bottom surface of test module **104** may be affixed to the top surface of battery **10** with the help of any suitable adhesive. In some embodiments, a first portion of battery test module **104** may be affixed to the top surface of the battery housing and the remaining portion(s) of test module **104** may be bent and affixed to sides of the housing. In some embodiments of the present invention, battery test module **104** is sufficiently thin and flexible such that it is capable of conforming to irregularities on an outer surface (top and sides) of the battery housing. In one embodiment of the present invention, battery test module **104** is substantially permanently affixed to the housing of battery **10**. In some embodiments, battery test module **104** may be temporarily affixed or selectively removable from the housing of battery **10**. **FIG. 12** illustrates a cross-section of a portion of an example embodiment of test module **104**. As can be seen in **FIG. 12**, test module **104** is a multi-layered structure that includes a heat spreader layer **110**, an adhesive layer **112**, a flexible substrate **114**, a flex circuit **116** and a protective layer **118**. Components such as push button **20**, which is used to activate test module **104** to conduct a battery test, are included on a top surface of flex circuit **116**, and components such as operational amplifiers **52** and **70** and microprocessor **56** are included on a bottom surface of flex circuit **116** and are supported by flexible substrate **114** and encapsulant **124**. Encapsulation of components such as amplifiers **52** and **70** and microprocessor **56** improves the robustness of test module **104** and reduces stress on the components. Components such as amplifiers **52** and **70** and microprocessor **56** may be mounted on flex circuit **116** using flip chip technology, surface mount technology, or other techniques as are known in the industry or are developed in the future. The use of flip chip technology for mounting such components is described in U.S. Pat. No. 6,410,415 entitled "FLIP CHIP MOUNTING TECHNIQUE," which is herein incorporated by reference. Flex circuit **116** is a multi-layered structure upon which some components such as resistors and push buttons (such as **20**) are formed by additive or subtractive fabrication processes and, as mentioned above, other components (such as amplifiers **52** and **70** and microprocessor **56**) are mounted. An example process for fabricating a flex circuit is described in U.S. Pat. No. 6,150,071 entitled "FABRICATION PROCESS FOR FLEX CIRCUIT APPLICATIONS," which is herein incorporated by reference.

[**0060**] The embodiment of test module **104** described in connection with **FIG. 12** is only an example embodiment of the present invention. It should be noted that a different number of layers and different types of layers may be employed, components (such as **20**, **52**, **56** and **70**) may be positioned on different layers and any suitable material or combination of materials may be employed for each layer without departing from the spirit and scope of the invention.

[**0061**] **FIG. 13A** illustrates a cross-section of a portion of battery **10** on which battery test module **16**, **104** is mounted. As illustrated in **FIG. 13**A, test module **16**, **104** couples to battery posts **12** and **14** via post extensions **130** and **132**. Each post extension **130**, **132** is an electrically conductive plate member having a proximal end **131** coupled to battery post **12**, **14** and a distal portion **133** that includes a raised member **146**, **148** that is configured to fit into grooves such as **142** and **144** (**FIG. 14**) in battery test module **16**, **104**. Proximal end **131** of post extension **130**, **132** may be formed integral with post **12**, **14**, during manufacture of battery **10**, or may be annular in configuration to slidably engage with post **12**, **14** (**FIG. 13B**). The embodiment of post extension **130**, **132** shown in **FIG. 13B** is formed separate from post **12**, **14** and can be installed on post **12**, **14** subsequent to battery manufacture. In the embodiment shown in **FIG. 13**A, post extension **130**, **132** is shown as being recesssed in battery housing **18**. However, in some embodiments, post **130**, **132** may be positioned external to battery housing **18**. In some embodiments of the present invention, although proximal end **131** is formed integral with distal portion **133**, each of these portions may be formed from a different conductive material. For example, proximal end **131** may be formed of a conductive metal such as copper or brass to ensure good mechanical and electrical coupling between post **12**, **14** and post extension **130**, **132**, and distal portion **133** may be made of lead. Raised member **146**, **148** may be formed of a metal, such as lead, which can be melted after raised member **146**, **148** is fit into groove **142**, **144** to provide, upon cooling, secure mechanical coupling between test module **16**, **104** and post extension **130**, **132**. A cover **150** may be employed to protect battery test module **16**, **104** and exposed portions of post extensions **130** and **132**.

[**0062**] **FIG. 14** is a top plan view of storage battery **10** showing Kelvin electrical connections **38** and **40** between test module **16**, **104** and post extensions **130** and **132**. As a result of coupling test module **16**, **104** to battery post extension **130**, **132** as described above, conductive pads **134** and **136**, **138** and **140**, which are included on a bottom surface of test module **16**, **104**, are urged against post extension **130**, **132** to form Kelvin connection **38**, **40**.

[**0063**] In the embodiment of the present invention shown in **FIG. 15**, instead of distal portion **131** of post extension **130**, **132** being a flat plate member, arms **130**A and **130**B, **132**A and **132**B that connect to pads **134** and **136**, **138** and **140** to form Kelvin connections **38**, **40** are employed. In some embodiments, arms **130**A and **130**B, **132**A and **132**B may be soldered to conductive pads **134** and **136**, **138** and **140**. In some embodiments, post extension **130**, **132** may be formed integral with test module **16**, **104** and subsequently coupled to post **12**, **14**. Raised members **146** and **148** are not included in this embodiment. Therefore, mechanical coupling between battery test module **16**, **104** and battery **10** is carried out using fasteners (such as **152**, **154**, **156** and **158**), attached to the top surface of battery housing **18**, which are fit into grooves such as **142**, **144**, **160** and **162** in battery test module **16**, **104**. Fasteners (such as **152**, **154**, **156** and **158**) may be melt caps **170** (**FIG. 16-1**), screw standoffs **174** (**FIG. 16-2**) that receive screws or snap tabs **176**. Melt cap **170** includes an extended portion **172** that can be melted and cooled after melt cap **170** is fit into a groove (such as **142**, **144**, **160** and **162**) to provide secure mechanical coupling between test module **16**, **104** and battery **10**.

[**0064**] The embodiments of test module **16**, **104** coupled to battery **10** through post extensions **130** and **132** described in connection with FIGS. **113A-16** are only example embodiments of the present invention. It should be noted that any suitable material or combination of materials may be employed for proximal end **131** and distal portion **133** of post extensions **130**, **132**. Further, proximal end **131** and distal portion **133** may be of any suitable shape without departing from the spirit and scope of the invention. Also, any suitable fastener may be employed to attach battery test module **16**, **104** to the housing of battery **10**.

[**0065**] Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. Although battery **10** is described as including a plurality of electrochemical cells, in some embodiments of the present invention, battery **10** can consist of only a single electrochemical cell.

What is claimed is:

**1**. A storage battery comprising:

a battery housing supporting a positive post of the battery and a negative post of the battery;

at least one electrochemical cell in the battery housing electrically connected between to the positive post of the battery and the negative post of the battery;

a first post extension coupled to the positive post of the battery;

a second post extension coupled to the negative post of the battery;

a battery test module coupled to the first and second post extensions to form a first Kelvin connection between the battery test module and the first post extension and a second Kelvin connection between the battery test module and the second post extension; and

an output from the battery test module configured to output battery condition information.

2. The storage battery of claim 1 wherein the first post extension is formed integral with the positive post and the second post extension is formed integral with the negative post.

3. The storage battery of claim 1 wherein the first post extension and the second post extension are formed separate from the positive and negative battery posts, and wherein a proximal end of the first post extension is configured to fit onto the positive post and a proximal end of the second post extension is configured to fit onto the negative post.

4. The storage battery of claim 3 wherein the proximal end of the first post extension including a first ring configured to fit onto the positive post, and wherein the proximal end of the second post extension including a second ring configured to fit onto the negative post.

5. The storage battery of claim 1 wherein a distal portion of the first post extension including a first raised member and a distal portion of the second post extension including a second raised member, and wherein each the first raised member and the second raised member are configured to fit into a corresponding grooves in the battery test module.

6. The storage battery of claim 5 wherein the first raised member and the second raised member are configured to be melted and cooled to provide secure coupling between the battery test module and the first and second post extensions after the first raised member and the second raised member are fit into the corresponding grooves.

7. The storage battery of claim 1 wherein the first post extension and the second post extension are recessed in the battery housing.

8. The storage battery of claim 1 wherein the first post extension and the second post extension are external to the battery housing.

9. The storage battery of claim 1 wherein a proximal end of each of the first post extension and the second post extension comprises copper, and wherein a distal portion of each of the first post extension and the second post extension comprises lead.

10. The storage battery of claim 1 wherein a proximal end of each of the first post extension and the second post extension comprises brass, and wherein a distal portion of each of the first post extension and the second post extension comprises lead.

11. The storage battery of claim 1 wherein a distal portion of each of the first post extension and the second post extension comprises a single plate member.

12. The storage battery of claim 1 wherein a distal portion of each of the first post extension and the second post extension comprises a pair of arms.

13. The storage battery of claim 1 wherein the battery test module comprises a first pair of contact pads that electrically couple to a distal portion of the first post extension and a second pair of contact pads that electrically couple to a distal portion of the second post extension.

14. The storage battery of claim 1 further comprising a plurality of fasteners attached to the battery housing and extending in an upward direction from the battery housing, wherein each fastener of the plurality of fasteners is configured to fit into corresponding grooves in the battery test module.

15. The storage battery of claim 14 wherein each fastener of the plurality of fasteners includes a screw standoff configured to receive a screw.

16. The storage battery of claim 14 wherein each fastener of the plurality of fasteners is a snap tab.

17. The storage battery of claim 14 wherein each fastener of the plurality of fasteners is a melt cap.

18. The storage battery of claim 17 wherein an extended portion of the melt cap is configured to be melted and cooled to provide secure coupling between the battery housing and the battery test module when the melt cap is fit into a groove of the corresponding grooves.

19. The storage battery of claim 1 wherein the first post extension and the second post extension are formed integral with the battery test module and configured to couple to the positive post and the negative post.

20. A apparatus for testing a storage battery, comprising:

a first Kelvin connection coupled to a first post extension that couples to a positive post of the battery;

a second Kelvin connection coupled to a second post extension that couples at a negative post of the battery;

a battery test module affixed to a battery housing of the storage battery and electrically coupled to the first and second post extensions through the respective first and second Kelvin connections; and

an output from the battery test module configured to output battery condition information.

21. The storage battery of claim 20 wherein the first post extension and the second post extension are recessed in the battery housing.

22. The storage battery of claim 20 wherein the first post extension and the second post extension are formed separate from the positive and negative battery posts, and wherein a proximal end of the first post extension is configured to fit onto the positive post and a proximal end of the second post extension is configured to fit onto the negative post.

23. An auxiliary power system, comprising:

an auxiliary battery having a positive post and a negative post;

a first post extension coupled to the positive post of the auxiliary battery;

a second post extension coupled to the negative post of the auxiliary battery;

a battery test module electrically coupled to the auxiliary battery through the positive post extension and the negative post extension and configured to perform a battery test on the auxiliary battery and responsively provide a battery test output; and

an output configured to output results of the battery test output.

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