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U.S. DISTRICT COURT

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

DOCKETED
APR 0 5 2004

MIDTRONICS, INC.	)	
Plaintiff,	)	04C 2423
	)	Civil Action No.
vs.	)	
	)	JUDGE AMY ST. EVE
DHC SPECIALITY CORPORATION	)	**JURY DEMANDED**
	)	
	)	
Defendant.	)	MAGISTRATE JUDGE BOBRICK

COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff alleges as follows:

The Parties

1. Plaintiff Midtronics, Inc. ("Midtronics") is a corporation of the State of Illinois and has its principal place of business in Willowbrook, Illinois.

2. Upon information and belief, Defendant DHC Specialty Corporation ("DHC") is a Taiwanese corporation having its principal offices at 7R, NO. 83, Chou Tzu Street, Taipei 114 Taiwan. DHC does business in this judicial district directly or through established distribution channels.

Jurisdiction and Venue

3. This is an action for patent infringement that arises under the patent laws of the United States, Title 35 U.S.C. § 1 et seq. This Court has subject matter jurisdiction under 28 USC Sections 1331 and 1338(a).

4. Venue is proper in this district under 28 U.S.C. §§ 1391(c) and (d) and 1400(b).

1-1

The Patents in Suit

5. On October 13, 1998, United States Patent No. 5,821,756 ("the '756 Patent") duly and legally issued to Stephen J. McShane, Kevin I. Bertness and Keith S. Champlin. The '756 Patent is entitled "ELECRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF CHARGE." A copy of the '756 Patent is attached hereto as Exhibit A.

6. The '756 Patent is assigned to Midtronics.

7. On May 26, 1998, United States Patent No. 5,757,192 ("the '192 Patent") was duly and legally issued to Stephen J. McShane and Kevin I. Bertness. The '192 Patent is entitled "METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY." A copy of the '192 Patent is attached hereto as Exhibit B.

8. The '192 Patent is assigned to plaintiff Midtronics.

COUNT I – PATENT INFRINGEMENT OF UNITED STATES PATENT NO. 5,821,756

9. Midtronics restates and realleges the allegations in paragraphs 1-8 and incorporates them by reference.

10. DHC has manufactured, used, imported, offered for sale or sold, or has actively induced others to use, import, offer for sale or sell, in this judicial district and elsewhere in the United States, electronic battery testing devices that infringe the claims of the '756 Patent, including DHC's BT501 product or DHC's BTY01 product. On information and belief, DHC also offers other products utilizing similar technology.

11. DHC has had actual notice of the '756 Patent prior to the filing of this Complaint.

12. The infringement of the '756 Patent by DHC has injured and damages Midtronics. The injury to Midtronics is irreparable and will continue unless and until DHC is enjoined from further infringement.

COUNT II – PATENT INFRINGEMENT OF UNITED STATES PATENT NO. 5,757,192

13. Midtronics restates and realleges the allegations in paragraphs 1-8 and incorporates them by reference.

14. DHC has manufactured, used, imported, offered for sale or sold, or has actively induced others to use, import, offer for sale or sell, in this judicial district and elsewhere in the United States, electronic battery testing devices that infringe the claims of the '192 Patent, including DHC's BT501 product or DHC's BTY01 product. On information and belief, DHC also offers other products utilizing similar technology.

15. DHC has had actual notice of the '192 Patent prior to the filing of this Complaint.

16. The infringement of the '192 Patent by DHC has injured and damages Midtronics. The injury to Midtronics is irreparable and will continue unless and until DHC is enjoined from further infringement.

JURY DEMAND

17. Midtronics demands a trial by jury on all issues so triable in this Complaint.

PRAYER FOR RELIEF

WHEREFORE, Midtronics prays for judgment as follows:

A. That United States Patent Nos. 5,821,756 and 5,757,192 be judged valid, enforceable, and infringed by DHC and that defendant's infringement is judged to be willful;

B. That DHC be ordered to account and pay to Midtronics the damages to which Midtronics is entitled as a consequence of the infringement;

C. That such damages be trebled for the willful, deliberate and intentional infringement of the '756 and '192 Patents, as alleged herein;

D. That plaintiff Midtronics be awarded prejudgment interest and its costs, disbursements, and attorneys' fees here in accordance with Title 35 United States Code Section 285;

E. That the Court permanently enjoin DHC, its subsidiaries, parent, divisions, agents, servants, and employees, and all other persons or entities acting in concert with DHC, from making, using, selling, importing, offering for sale, or distributing the BT501 and BTY01 and any other devices that are found to infringe and from contributing to the infringement of, and inducing infringement of the '756 and '192 Patents and for such further injunctive relief as may be proper; and

G. That Midtronics be awarded other and further relief as this Court may deem just and proper under the circumstances.

Respectfully submitted,

Dated: April 2, 2004

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US005821756A

United States Patent [19]

McShane et al.

[11] **Patent Number:** 5,821,756

[45] **Date of Patent:** Oct. 13, 1998

[54] **ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF CHARGE**

[75] Inventors: **Stephen J. McShane**, Oak Brook; **Kevin I. Bertness**, Batavia, both of Ill.; **Keith S. Champlin**, Minneapolis, Minn.

[73] Assignee: **Midtronics, Inc.**, Burr Ridge, Ill.

[21] Appl. No.: **721,618**

[22] Filed: **Sep. 26, 1996**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 496,467, Jun. 29, 1995, Pat. No. 5,585,728, which is a continuation of Ser. No. 292,925, Aug. 18, 1994, abandoned, which is a continuation of Ser. No. 877,646, May 1, 1992, abandoned.

[51] **Int. Cl.**[6] **G01N 27/416; G01R 31/36**

[52] **U.S. Cl.** **324/430**; 324/427; 324/429

[58] **Field of Search** 324/426, 427, 324/429, 430; 320/106, 162; 340/636

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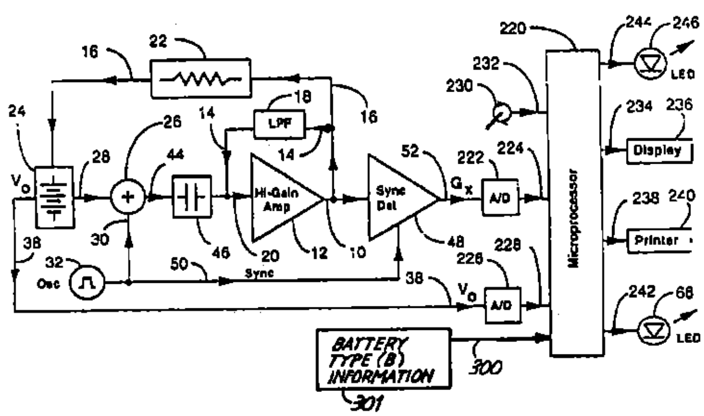
IEEE Recommended Practice for Maintenance, Testings and Replacement of Large Lead Storage Batteries for Generating Stations and Substations, The Institute of Electrical and Electronics Engineers, Inc., ANSI/IEEE Std. 450–1987, Mar. 9, 1987, pp. 7–15.

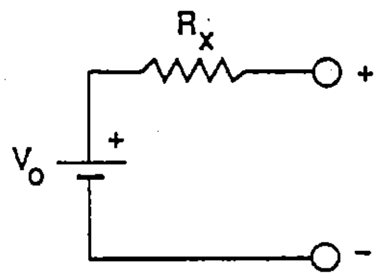
Primary Examiner—Glenn W. Brown
Attorney, Agent, or Firm—Westman, Champlin & Kelly, P.A.

[57] **ABSTRACT**

Various embodiments of an improved electronic device for testing or monitoring storage batteries that may be only partially charged are disclosed. The device determines the battery's small-signal dynamic conductance in order to provide either a proportional numerical readout, displayed in appropriate battery measuring units, or a corresponding qualitative assessment of the battery's relative condition based upon its dynamic conductance and electrical rating. The device also determines the battery's terminal voltage in an essentially unloaded condition and utilizes this information to automatically correct the measured dynamic conductance. The automatic correction is performed by the electronic device using information or functions which are tailored for the particular type of battery being tested. By virtue of this automatic correction, the quantitative or qualitative information displayed to the user conforms with that of a fully-charged battery even though the battery may, in actual fact, be only partially charged. If the battery's state-of-charge is too low for an accurate assessment to be made, no information is displayed. Instead, an indication is made to the user that the battery must be recharged before testing.

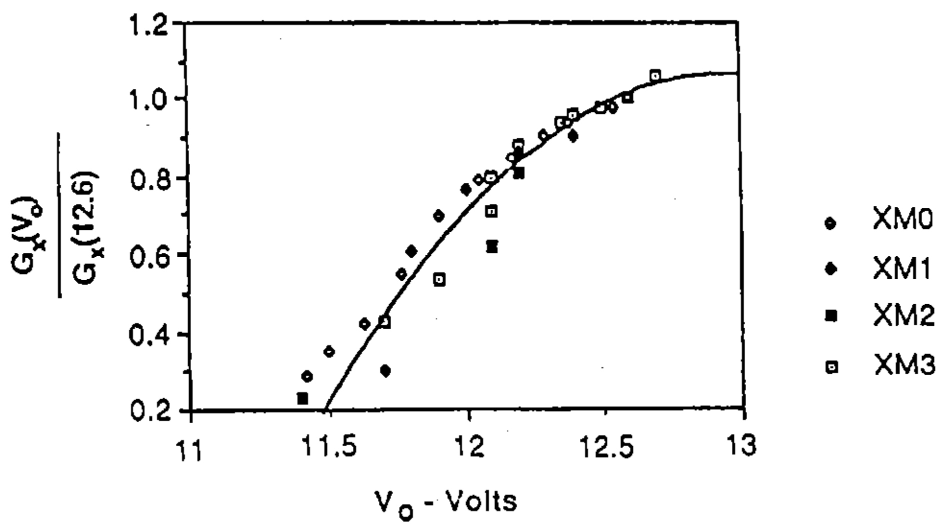
12 Claims, 7 Drawing Sheets





R_x
+
V_o
+
−

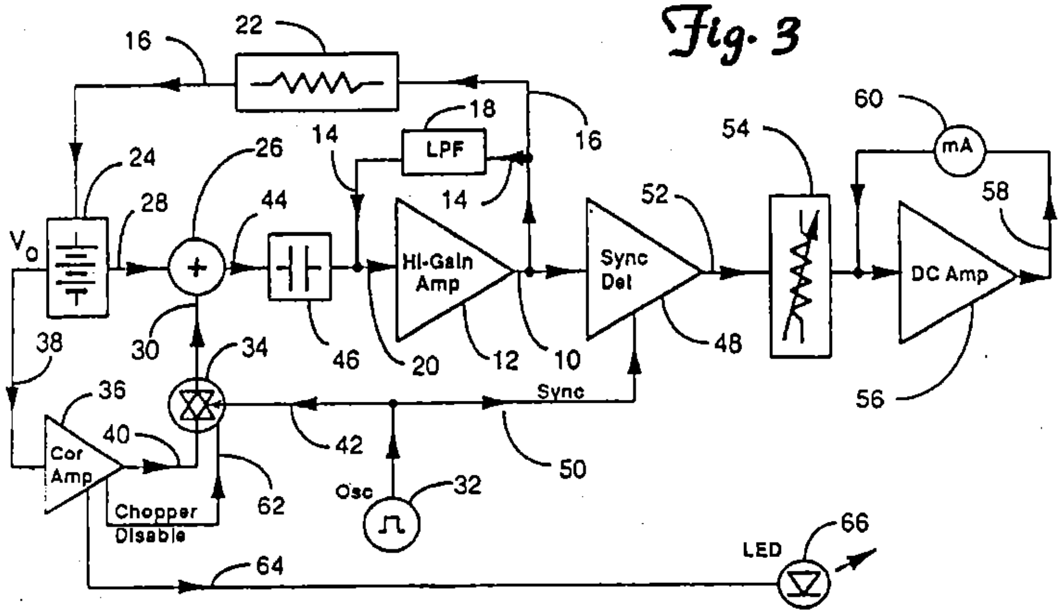
Fig. 1



1.2
1.0
0.8
0.6
0.4
0.2
11
11.5
12
12.5
13
$\frac{G_x(V_o)}{G_x(12.6)}$
V_o - Volts
XM0
XM1
XM2
XM3

Fig. 2

Fig. 3


LPF
Hi-Gain Amp
Sync Det
DC Amp
mA
Cor Amp
Chopper Disable
Sync
Osc
LED
Vo
16
22
18
14
26
24
28
44
52
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56
32
62
64
66

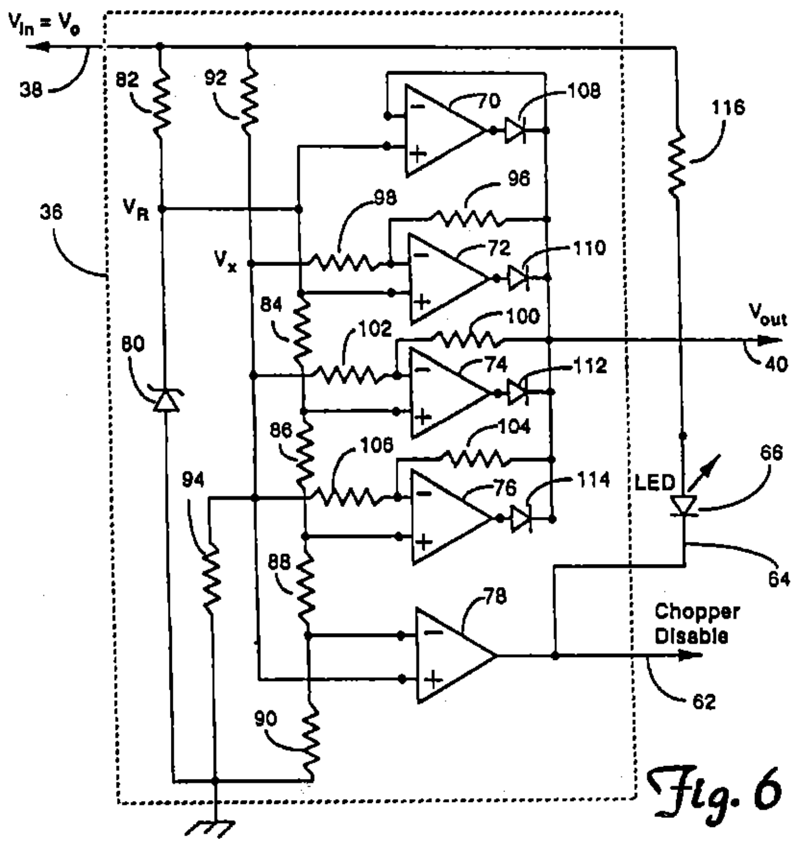
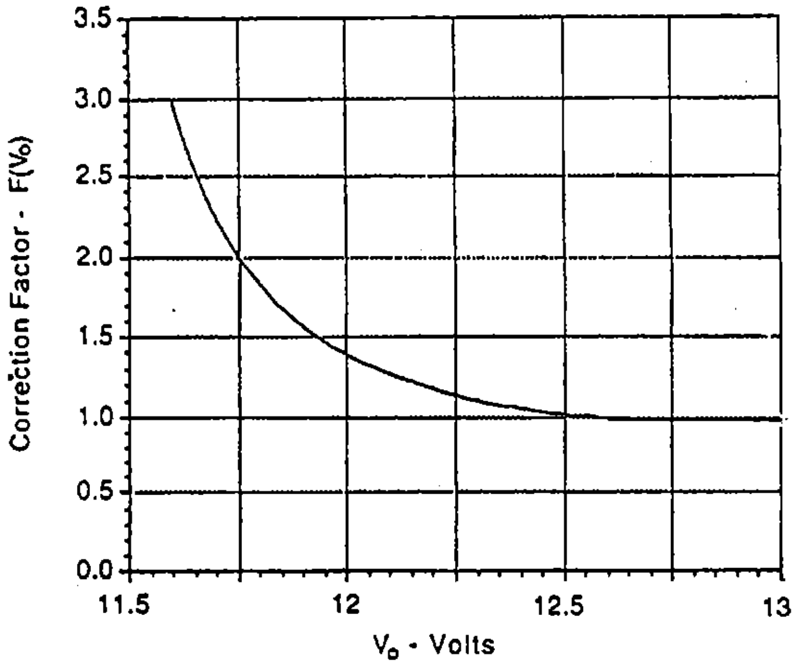
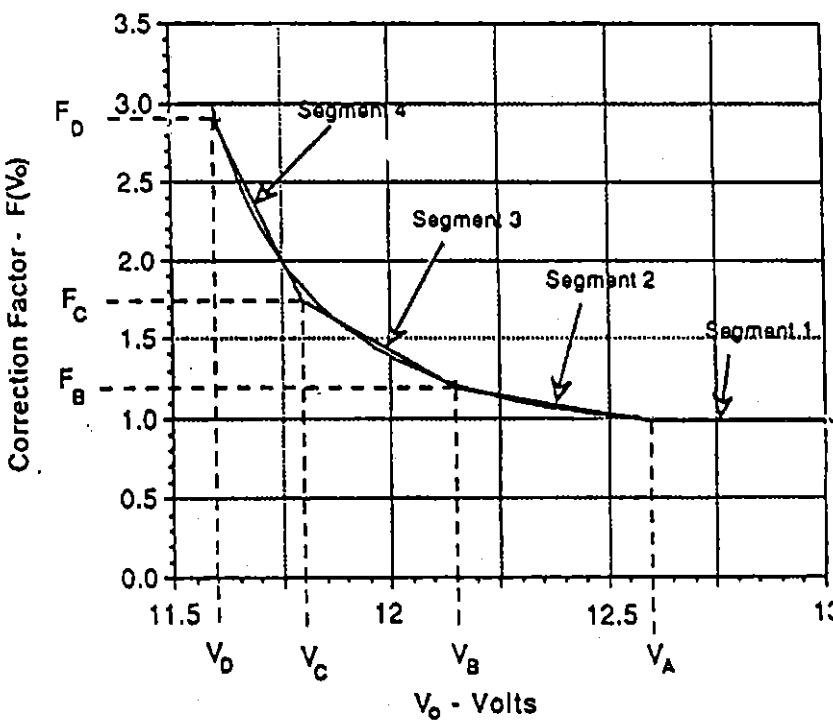

Vin = Vo
38
82
92
70
108
116
36
VR
98
96
Vx
72
110
84
102
100
Vout
40
80
74
112
86
106
104
66
94
76
114
LED
88
64
78
Chopper Disable
62
90

Fig. 6



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Correction Factor - F(Vo)
11.5
12
12.5
13
Vo - Volts

Fig 4



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FD
FC
FB
Segment 4
Segment 3
Segment 2
Segment 1
Correction Factor - F(Vo)
11.5
12
12.5
13
VD
VC
VB
VA
Vo - Volts

Fig 5

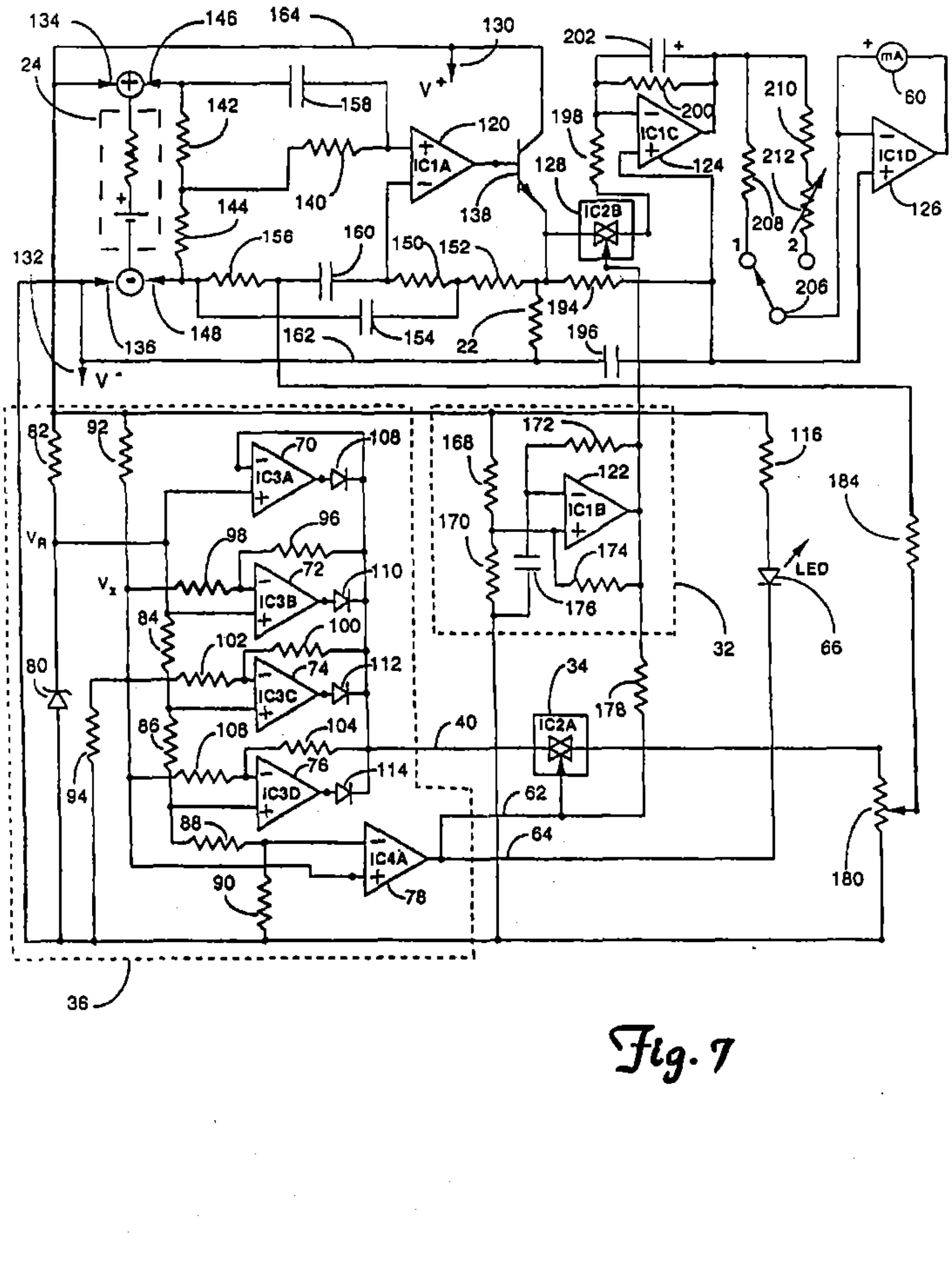

IC1A
IC1B
IC1C
IC1D
IC2A
IC2B
IC3A
IC3B
IC3C
IC3D
IC4A
mA
LED
V+
V-
VR
Vx
1
2

Fig. 7

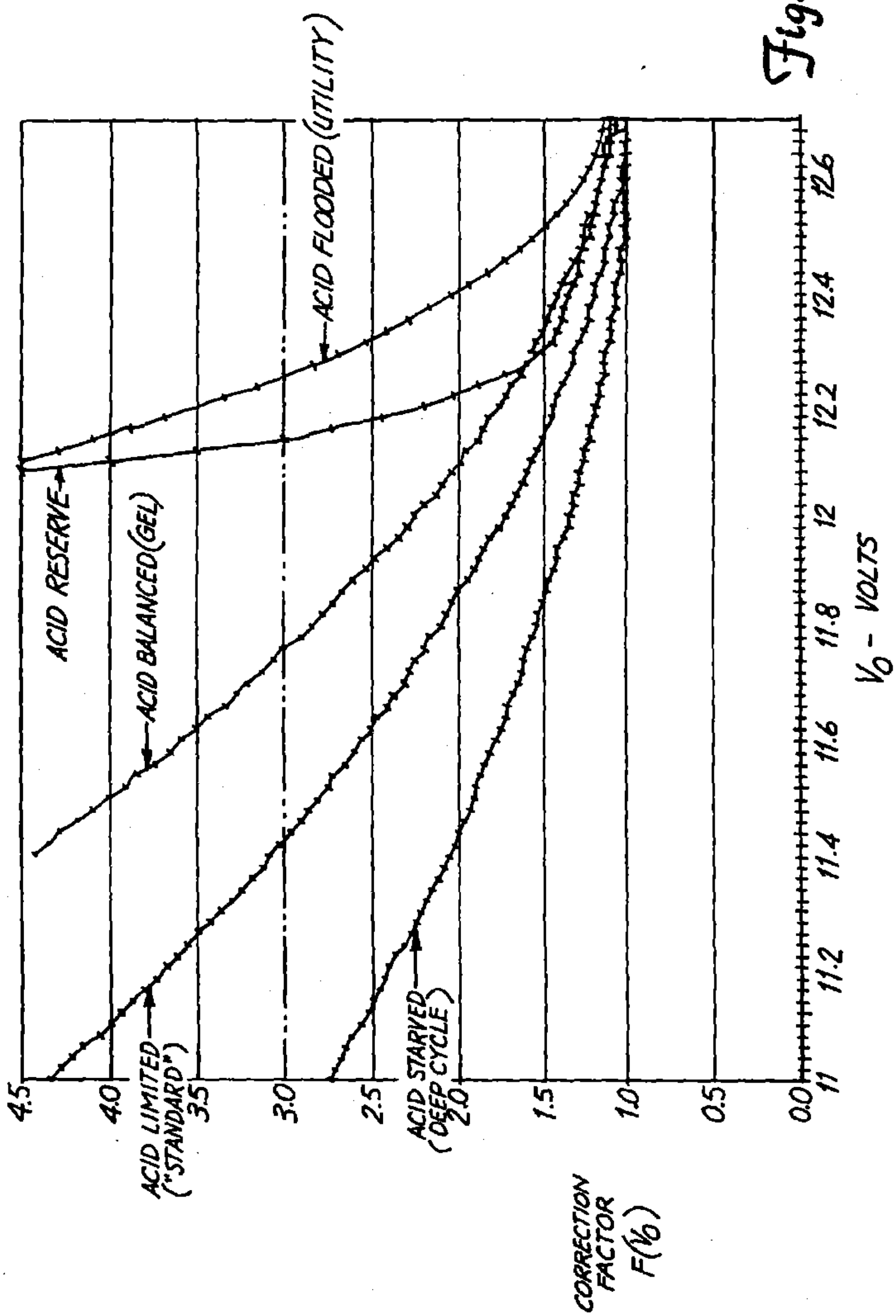

ACID FLOODED (UTILITY)
ACID RESERVE
ACID BALANCED (GEL)
ACID LIMITED ("STANDARD")
ACID STARVED (DEEP CYCLE)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CORRECTION FACTOR F(V0)
11
11.2
11.4
11.6
11.8
12
12.2
12.4
12.6
V0 - VOLTS

Fig. 8

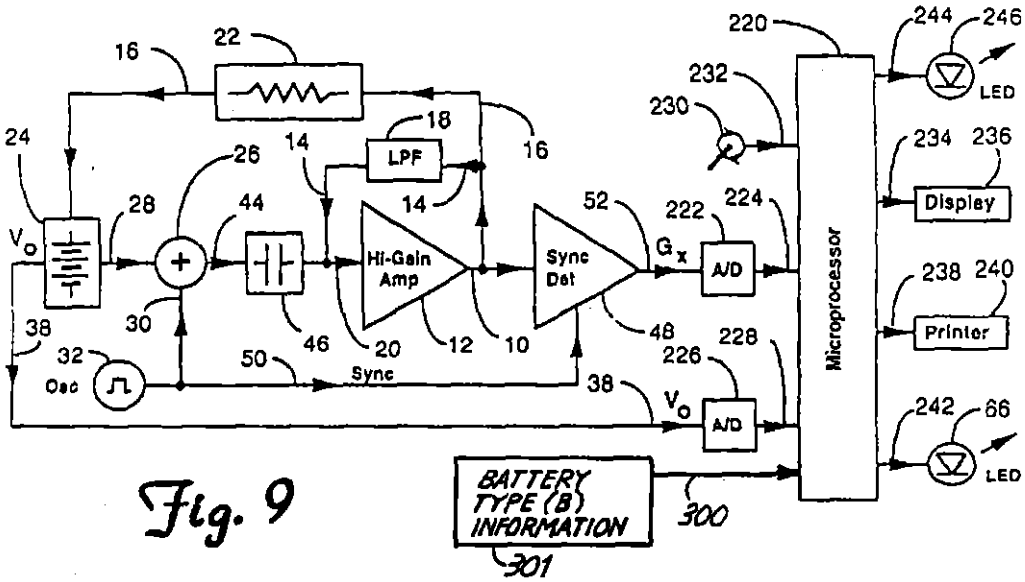

LPF
Hi-Gain Amp
Sync Det
Osc
Sync
A/D
A/D
Microprocessor
LED
Display
Printer
LED
BATTERY TYPE (B) INFORMATION

Fig. 9

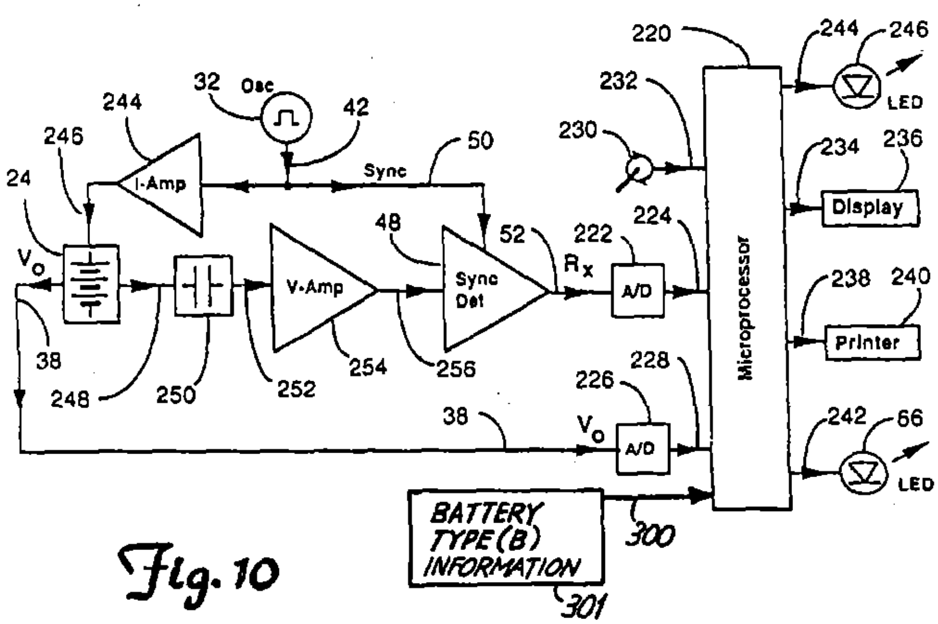

Osc
I-Amp
Sync
V-Amp
Sync Det
A/D
A/D
Microprocessor
LED
Display
Printer
LED
BATTERY TYPE (B) INFORMATION

Fig. 10

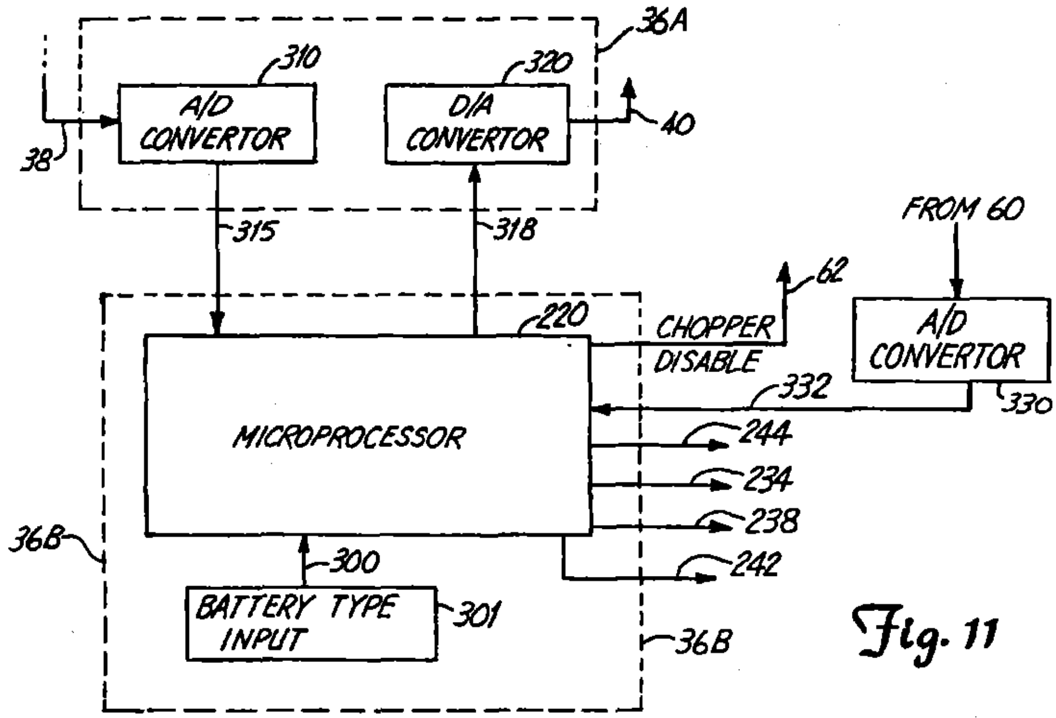

36A
310
A/D CONVERTOR
320
D/A CONVERTOR
40
38
315
318
FROM 60
62
220
CHOPPER DISABLE
A/D CONVERTOR
332
330
MICROPROCESSOR
244
234
238
242
36B
300
BATTERY TYPE INPUT
301
36B

Fig. 11

ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF CHARGE

BACKGROUND OF THE INVENTION

This application is a Continuation-In-Part of patent application entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE, United States patent application Ser. No. 08/496,467, filed Jun. 29, 1995, now U.S. Pat. No. 5,585,728, which is a file wrapper continuation of Ser. No. 08/292,925, filed on Aug. 18, 1994, now abandoned, which is a file wrapper continuation of Ser. No. 07/877,646, filed May 1, 1992, now abandoned.

This invention relates to an electronic measuring or monitoring device for assessing the ability of a storage battery to deliver power to a Load. More specifically, it relates to improved apparatus of the type disclosed previously in U.S. Pat. Nos. 3,873,911, 3,909,708, 4,816,768, 4,825,170, 4,881,038, and 4,912,416 issued to Keith S. Champlin.

Storage batteries are employed in many applications requiring electrical energy to be retained for later use. Most commonly, they are employed in motor vehicles utilizing internal combustion engines. In such applications, energy stored by "charging" the battery during engine operation is later used to power lights, radio, and other electrical apparatus when the engine is stopped. The most severe demand upon the battery of a motor vehicle is usually made by the starter motor. Failure to supply the starter motor with sufficient power to crank the engine, particularly in cold weather, is often the first indication of battery deterioration. Clearly, a simple measurement that accurately assesses a battery's ability to supply cranking power is of considerable value.

Prior to the introduction of the dynamic conductance testing method disclosed in the six U.S. patents enumerated above, the method most generally available for assessing a battery's ability to supply cranking power was the standard load test. This test subjects a battery to a heavy dc current having a predetermined value dictated by the battery's rating. After a prescribed time interval, the battery's voltage under load is observed. The battery is then considered to have "passed" or "failed" the load test according to whether its voltage under load is greater, or less, than a particular value.

Although the standard load test has been widely used for many years, it has several serious disadvantages. These include:

1. The test draws a large current and therefore requires apparatus that is heavy and cumbersome.

2. Considerable "sparking" can occur if the test apparatus is connected or disconnected under load conditions. Such "sparking" in the presence of battery gasses can cause an explosion with the potential for serious injury to the user.

3. A standard load test leaves the battery in a significantly reduced state-of-charge and therefore less capable of cranking the engine than before the test was performed.

4. The battery's terminal voltage decreases with time during performance of the load test. Accordingly, test results are generally imprecise and often dependent upon the skill of the operator.

5. Load test results are not repeatable since the test itself temporarily polarizes the battery. Such test-induced polarization significantly alters the initial conditions of any subsequently-performed tests.

A practical alternative to the standard load test is taught in the six U.S. Patents enumerated above. These documents disclose electronic apparatus for accurately assessing a battery's condition by means of small-signal ac measurements of its dynamic conductance. They teach that a battery's dynamic conductance is directly proportional to its dynamic power—the maximum power that the battery can deliver to a load. Dynamic conductance is therefore a direct measure of a battery's ability to supply cranking power.

In comparison with the load test method of battery appraisal, the dynamic conductance testing method has many advantages. For example, dynamic conductance testing utilizes electronic apparatus that is small and lightweight, draws very little current, produces virtually no sparking when connected or disconnected, does not significantly discharge or polarize the battery, and yields accurate, highly reproducible, test results. Virtually millions of battery measurements performed over the years have fully corroborated these teachings and have proven the validity of this alternative testing method.

One disadvantage, however, of the dynamic conductance testing method has been the fact that test results are somewhat dependent upon the battery's state-of-charge. Accordingly, the methods and apparatus disclosed in the first five of the six U.S. patents cited above have generally required that the battery be essentially fully charged to be tested. Since many batteries are, in fact, fairly discharged when they are returned for replacement under warranty, or when they are otherwise suspected of being faulty, it has been frequently necessary to recharge a battery before testing it. Such recharging is costly and time-consuming. Clearly, a simple method for performing accurate dynamic conductance tests on batteries "as is"—batteries that may be only partially charged—would be of considerable benefit.

Great progress toward solving this problem has been engendered by the methods and apparatus disclosed in the sixth U.S. patent cited above; U.S. Pat. No. 4,912,416. As is well known to those skilled in the art, a battery's state-of-charge is directly related to its open-circuit (unloaded) terminal voltage. By utilizing this fact, along with extensive experimental data, an empirical relationship was established between a battery's state-of charge, as reflected by its open-circuit voltage, and its relative dynamic conductance, normalized with respect to its fully-charged value. This empirical relationship was first disclosed in U.S. Pat. No. 4,912,416. Further, apparatus disclosed therein utilized this empirical relationship, along with measurements of open-circuit voltage, to appropriately correct dynamic conductance readings—thus yielding battery assessments that were essentially independent of the battery's state-of-charge.

However, the measuring apparatus disclosed in U.S. Pat. No. 4,912,416 utilized an inconvenient two-step testing procedure requiring intermediate interaction by the user. The battery's open-circuit voltage was first measured. Next, using the results of the voltage measurement, the user adjusted a variable attenuator to an appropriate setting. Finally, the dynamic conductance was measured. By virtue of the previously adjusted variable attenuator, the quantitative or qualitative dynamic conductance information ultimately displayed to the user conformed with that of a fully-charged battery even though the battery may, in actual fact, have been only partially charged when tested. The state-of-charge problem was thus solved in principle by the methods and apparatus taught in U.S. Pat. No. 4,912,416.

Measuring apparatuses and methods which compensate a battery's relative conductance based upon the teaching of

U.S. Pat. No. 4,912,416 work extremely well for "standard" (i.e., "acid-limited") battery types—batteries for which the relationship between the state-of-charge and the relative dynamic conductance closely follows the empirical relationship disclosed in U.S. Pat. No. 4,912,416. However, this "standard" empirical relationship does not work as well for compensating the relative dynamic conductance of batteries constructed differently, for which the "standard" empirical relationship may not be as accurate. For example, a battery designed for use in warmer climates may have a lower plate count for its size as compared to a more expensive battery which has more plates per acid volume. The higher plate count battery ("acid-starved") will typically provide power down to a much lower voltage than will the lower plate count ("acid-flooded") battery. Thus, a "standard" charge compensation curve will tend to overcompensate the battery with the high plate count and undercompensate the battery with the low plate count.

It is therefore quite apparent that an improved apparatus which provides automatic state-of-charge correction for a wide variety of battery types would be highly advantageous. Just such an improved electronic battery testing apparatus, providing for automatic correction for low state-of-charge for a wide variety of battery types, is disclosed herein below.

SUMMARY OF THE INVENTION

Various embodiments of an improved electronic device for testing or monitoring storage batteries that may be only partially charged are disclosed. The device determines the battery's small-signal dynamic conductance in order to provide either a proportional numerical readout, displayed in appropriate battery measuring units, or a corresponding qualitative assessment of the battery's relative condition based upon its dynamic conductance and electrical rating. The device also determines the battery's terminal voltage in an essentially unloaded condition and utilizes this information to automatically correct the measured dynamic conductance. The automatic correction is performed by the electronic device using information or functions which are tailored for the particular type of battery being tested. By virtue of this automatic correction, the quantitative or qualitative information displayed to the user conforms with that of a fully-charged battery even though the battery may, in actual fact, be only partially charged. If the battery's state-of-charge is too low for an accurate assessment to be made, no information is displayed. Instead, an indication is made to the user that the battery must be recharged before testing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts the Thevenin's equivalent circuit of a lead-acid storage battery comprising its open-circuit voltage, V_o, and its internal resistance, R_x, connected in series.

FIG. 2 is an empirical plot of normalized dynamic conductance, G_x, versus open-circuit voltage, V_o, showing the correlation with measurements performed upon four different "standard" (acid-limited) lead-acid storage batteries having differing electrical ratings and fabricated by different manufacturers.

FIG. 3 is a simplified block diagram of an improved electronic battery testing/monitoring device employing automatic compensation for low state-of-charge in accordance with a first embodiment of the present invention.

FIG. 4 is a graphical plot of the state-of-charge correction factor obtained by taking the reciprocal of the "standard" empirical normalized dynamic conductance curve of FIG. 2.

FIG. 5 is a plot of a four-segment piecewise-linear approximation to the correction factor curve of FIG. 4 implemented by the correction amplifier circuit disclosed in FIG. 6.

FIG. 6 is a schematic diagram of a dc correction amplifier embodiment which implements the four-segment piecewise-linear transfer function disclosed in FIG. 5.

FIG. 7 is a complete schematic diagram of an improved electronic battery testing/monitoring device with automatic compensation for low state-of-charge configured for testing/monitoring "standard" 12-volt automotive batteries.

FIG. 8 is a graphical plot similar to FIG. 4 but illustrating state-of-charge correction factors for five different types of batteries.

FIG. 9 is a simplified block diagram of an embodiment of an improved electronic battery testing/monitoring device which provides battery type specific automatic compensation for low state-of-charge.

FIG. 10 is a simplified block diagram of another embodiment of an improved electronic battery testing/monitoring device which provides battery type specific automatic compensation for low state-of-charge.

FIG. 11 is a simplified block diagram illustrating one embodiment of the correction amplifier of the device shown in FIG. 3 which can be used to implement the multiple charge compensation curve approach of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, the Thevenin's equivalent circuit of a lead-acid storage battery is shown. In this equivalent representation, the battery is described by its open-circuit voltage, V_o, and its internal resistance, R_x, connected in series.

As has been fully disclosed in the first five of the six U. S. Patents cited above, a conventional dynamic conductance battery test of a fully-charged battery traditionally ignores the open-circuit voltage, V_o. Instead, the electronic test apparatus directly measures the battery's dynamic conductance $G_x=1/R_x$. The testing/monitoring device then provides the operator with either a numerical readout displayed in proportional battery measuring units (such as "Cold Cranking Amps", "Ampere-Hours", or "Watts") or else with a qualitative display ("Pass/Fail") based upon comparing the measured value of G_x with a corresponding reference value determined from the battery's electrical rating and temperature.

Although the open-circuit voltage, V_o, has not been normally used in dynamic conductance testing of fully-charged batteries, it has been previously used to determine state-of-charge. As is well known to those skilled in the art, a battery's state-of-charge is directly related to its open-circuit (unloaded) terminal voltage. For example, with "standard" (acid-limited) automotive-type lead-acid batteries having nominal voltage of 12 volts, the open-circuit voltage is known to vary from about 11.4 volts, for batteries that are virtually totally discharged, to about 12.6 volts, for batteries that are nearly fully charged.

FIG. 2 shows the observed relationship between normalized dynamic conductance and open-circuit voltage appropriate to "standard" (acid-limited) automotive-type lead-acid storage batteries. This information was disclosed previously in U. S. Pat. No. 4,912,416. FIG. 2 displays an empirical graph of relative dynamic conductance, normalized with respect to the fully-charged value, $G_x(V_o)/G_x(12.6)$, plotted as a function of open-circuit voltage, V_o. The solid curve plotted in FIG. 2 is described by a second-order polynomial equation having coefficients adjusted to best fit the experimental data. The appropriately adjusted polynomial equation is:

$$\frac{G_x(V_o)}{G_x(12.6)} = -\{78.1963\} + \{12.3939\}V_o - \{0.4848\}V_o^2 \qquad \text{Eq. 1}$$

FIG. 2 also discloses normalized experimental points which represent actual measurements obtained from four different "standard"-type (acid-limited) batteries possessing different electrical ratings and fabricated by different manufacturers. Batteries XM0, XM1, and XM3 are six-cell batteries having nominal voltages of 12 volts. Battery XM2 is actually a three-cell, 6-volt battery. Open-circuit voltage measurements of battery XM2 were multiplied by a factor of two in order to plot XM2 data points on the same graph as the other three batteries. One sees that the normalized measurements obtained from all four batteries agree quite closely with the empirical relation described by Equation (1). The fact that the same empirical relation shows strong correlation with experimental data obtained from both 6-volt and 12-volt batteries indicates that the empirical state-of-charge correction disclosed in FIG. 2 is quite universal and is actually a fundamental property of a single cell.

Referring now to FIG. 3, a simplified block diagram of a first embodiment of an improved electronic battery testing/monitoring device with automatic compensation for low state-of-charge is disclosed. Except for specific details having to do with the circuitry for automatic compensation for low state-of-charge, the explanation of the operation of the block diagram of FIG. 3 is identical with that of the corresponding block diagram referred to as FIG. 1 in U.S. Pat. No. 4,816,768.

Accordingly, signals representative of the signal at output 10 of high-gain amplifier cascade 12 are fed back to input 20 of high-gain amplifier cascade 12 by means of two feedback paths; internal feedback path 14 and external feedback path 16. Internal feedback path 14 includes low pass filter (LPF) 18 and feeds a signal directly back to input 20 of high-gain amplifier cascade 12. The purpose of internal feedback path 14 and low pass filter 18 is to provide large dc feedback but relatively little ac feedback in order to define the operating point of high-gain amplifier cascade 12 and ensure its dc stability without appreciably reducing its ac voltage gain. External feedback path 16 contains resistive network 22 and feeds a signal current back to the battery undergoing test 24. Summation circuitry 26 combines the resulting signal voltage 28 developed thereby across battery 24 with a 100 Hz periodic square-wave signal voltage 30.

In the embodiment disclosed in FIG. 3, the periodic square-wave signal voltage 30 is formed by the action oscillator 32, chopper switch 34, and dc correction amplifier (Cor Amp) 36. The oscillation frequency of oscillator 32 may, for example, be 100 Hz. The voltage applied to input 38 of dc correction amplifier 36 is the dc terminal voltage of battery 24. By virtue of the fact that the electronic apparatus disclosed in FIG. 3 draws very little load current from the battery, this terminal voltage is essentially the battery's open-circuit (unloaded) terminal voltage V_o. Signal output 40 of dc correction amplifier 36 is a dc voltage derived from V_o —having a voltage level that is inversely related to V_o—and hence inversely related to the state-of-charge of battery 24. This derived dc voltage 40 is repetitively interrupted by chopping switch 34 whose control input 42 is activated by the output of oscillator 32. The chopped dc voltage thus comprises a periodic square-wave signal voltage 30 having a voltage amplitude chat is inversely related to V_o, and hence inversely related to the state-of-charge of battery 24. This signal voltage 30 is presented to summation circuitry 26 along with the signal voltage 28 developed across battery 24. The resulting composite signal voltage 44 at the output of summation circuitry 26 is then capacitively coupled to input 20 of high-gain amplifier cascade 12 by means of capacitive coupling network 46.

As has been fully explained in U.S. Pat. No. 4,816,768, the voltage at out-put 10 of high-gain amplifier cascade 12 comprises a constant dc bias component along with an ac signal component that is proportional to the dynamic conductance G_x of the battery undergoing test 24 as well as to the level of the square-wave signal voltage 30. The constant dc bias component is ignored while the variable ac signal component is detected and accurately converted to a dc signal voltage by synchronous detector 48, synchronized to oscillator 32 by means of synchronizing path 50.

The dc signal voltage at output 52 of synchronous detector 48 passes through adjustable resistive network 54 to the input of dc-coupled operational amplifier 56. Feedback path 58 of operational amplifier 56 contains dc milliammeter 60. Accordingly, the reading of dc milliammeter 60 is proportional to the dc signal voltage level at the output 52 of synchronous detector 48, and hence to the dynamic conductance G_x of battery 24. In addition, the constant of proportionality relating the milliammeter reading to G_x is determined by the value assumed by adjustable resistive network 54 as well as by the level of the signal voltage at 30—and hence by the battery's state-of-charge as exemplified by its unloaded dc terminal voltage V_o.

By utilizing an appropriate fixed resistance value in resistive network 54 and then calibrating milliammeter 60 in battery measuring unit numbers that are proportional to the battery's dynamic conductance, the embodiment disclosed in FIG. 3 will emulate the direct reading battery tester disclosed in U.S. Pat. 3,873,911. In addition, as is fully taught in U.S. Pat. No. 4,816,768, the resistance value of resistive network 54 which brings the reading of dc milliammeter 60 to a particular fixed value is directly proportional to the dynamic conductance of battery 24. Hence, by calibrating resistive network 54 in traditional battery rating units, and then designating "pass" and "fail" regions on the face of milliammeter 60, the embodiment disclosed in FIG. 3 will also emulate the "pass-fail" battery testing device disclosed in U.S. Pat. No. 3,909,708. Furthermore, one can employ a switch to select either a fixed-valued resistive network 54 or an adjustable-valued network 54 and can arrange both a number scale and "pass-fail" regions on the face of milliammeter 60. One can therefore realize both a direct-reading battery tester and a "pass-fail" battery tester with a single device.

For either emulation, the amplitude of the detected signal at the output 52 of synchronous detector 48 is directly proportional to the amplitude of the square-wave signal 30 at the output of chopper switch 34. Hence, both the level of the numerical quantity displayed during direct-reading operation as well as the relative qualitative assessment provided in "pass-fail" operation are influenced by the battery's "state-of-charge", as exemplified by its unloaded terminal voltage V_o. In order for this displayed information to be independent of the battery's state-of-charge, one must require V_{out}, the dc output voltage at 40 of dc correction amplifier 36, to be proportional to the reciprocal of $G_x(V_o)$. Under these conditions, V_{out} can be written as:

$$V_{out}(V_o) = V_{out}(12.6) \times F(V_o) \qquad \text{Eq. 2}$$

where:

$$F(V_o)=\frac{G_x(12.6)}{G_x(V_o)} \qquad \text{Eq. 3}$$

is an appropriate state-of-charge "correction factor" imposed by correction amplifier **36**. Rearranging Equation 2 leads to:

$$F(V_o)=\frac{V_{out}(V_o)}{V_{out}(12.6)} \qquad \text{Eq. 4}$$

which shows that $F(V_o)$ may be simply regarded as the dc output voltage of amplifier **36** normalized with respect to the corresponding dc output voltage obtained with a fully-charged battery; i.e., a battery for which V_o=12.6 volts.

In addition to providing a dc signal output **40**, the dc correction amplifier **36** also provides a "Chopper Disable" output **62** and an LED output **64**. These two additional outputs become activated whenever the battery's terminal voltage V_o, and hence its state-of-charge, is too small for an accurate dynamic conductance test to be made. Under these special conditions, chopper switch **34** becomes disabled so that no qualitative or quantitative information is displayed to the user. Instead, LED **66** lights to indicate to the user that the battery must be recharged before it can be tested.

FIG. **4** displays a graphical plot of the state-of-charge correction factor $F(V_o)$ obtained by taking the reciprocal of the empirical $\{G_x(V_o)/G_x(12.6)\}$ curve disclosed in FIG. **2**. A four-segment piecewise-linear approximation to this empirical curve is disclosed in FIG. **5**. The parameters which specify the four breakpoints of this piecewise-linear approximation are listed in Table I.

TABLE I

Piecewise-Linear Approximation Parameters

Breakpoint	V_o(Volts)	Correction Factor - F
A	12.60	1.00
B	12.15	1.21
C	11.80	1.78
D	11.60	2.91

The piecewise-linear input-output relationship of FIG. **5** is implemented by the transfer function of the dc correction amplifier circuit embodiment disclosed in FIG. **6**. Referring now to FIG. **6**, the dc correction amplifier contained generally in block **36** comprises the interconnection of four operational amplifiers, **70**, **72**, **74**, and **76** along with comparator **78**. Circuit input lead **38** connects to the positive terminal of the battery **24** under test, while the negative battery terminal is grounded. By virtue of the fact that very little current is drawn from battery **24**, the circuit's input voltage at **38**, V_{in}, measured with respect to ground, is essentially equal to the battery's open-circuit terminal voltage V_o.

Within the dc correction amplifier circuit disclosed in FIG. **6**, a constant reference voltage V_R is established by means of voltage reference diode **80** receiving operating current through series resistor **82**. Reference voltage V_R may, for example, be 2.5 volts. V_R is further operated on by a voltage divider chain comprising resistors **84**, **86**, **88**, and **90**. Accordingly, the voltage level applied to the noninverting inputs of operational amplifiers **70** and **72** is V_R, while increasingly smaller fractions of reference voltage V_R are applied to the noninverting inputs of operational amplifiers **74** and **76** and to the inverting input of comparator **78**, respectively. In addition to these fixed voltage levels, a variable voltage V_x, that is proportional to battery voltage V_o, is derived from V_{in} by means of voltage divider resistors **92** and **94**. This variable voltage is applied directly to the noninverting input of comparator **78** and to the inverting inputs of operational amplifiers **72**, **74**, and **76** through resistors **98**, **102**, and **106**, respectively.

The outputs of the four operational amplifiers, **70**, **72**, **74**, and **76**, are connected to a common output bus, V_{out}, through the four diodes, **108**, **110**, **112**, and **114**, respectively. Because of the operation of these four diodes, only one of the operational amplifiers will be active at any one given time—the amplifier having the largest (most positive) output voltage. That operational amplifier alone will be connected to the output bus and will thus be controlling the output voltage V_{out}. The other three operational amplifiers, those having smaller output voltages, will be disconnected from the output bus by virtue of their having reverse-biased diodes in their output circuits.

Operational amplifier **70** has its inverting input connected directly to the output bus and is therefore configured as a unity-gain voltage-follower amplifying the reference voltage V_R. Operational amplifiers **72**, **74**, and **76** utilize feedback resistors and are configured as inverting amplifiers; each amplifying the variable voltage V_x; and each providing a negative incremental voltage gain given, respectively, by the appropriate resistance ratio {R(96)/R(98)}, {R(100)/R(102)}, or {R(104)/R(106)}.

The circuit of FIG. **6** functions as follows: For $V_{in}>V_A$=12.6 volts, the output voltage of operational amplifier **70** will be larger than the output voltages of the other three operational amplifiers. Accordingly, the output bus will be controlled by the unity-gain voltage-follower amplifier **70** so that $V_{out}=V_R$. This region of constant output-voltage is represented by segment **1** in the piecewise-linear transfer function displayed in FIG. **5**.

When V_{in} has decreased to V_A=12.6 volts, V_x will have become sufficiently less than V_R that the output of inverting amplifier **72** will equal that of amplifier **70**. Thus, for $V_{in}<V_A$, diode **108** will be reverse biased while diode **110** will be forward biased, and amplifier **72** will control the output bus. Due to the amplification of inverting amplifier **72**, further decreases in V_{in} will cause V_{out} to increase with incremental gain or "slope" of −{(R96)/R(98)}. This region of amplification, which continues unitil $V_{in}=V_B$, is represented by segment **2** in FIG. **5**.

When V_{in} has decreased to V_B, V_X will have decreased sufficiently that the output of inverting amplifier **74** will exceed that of amplifier **72**. Diode **110** will therefore be reverse biased while diode **112** will be forward biased, and amplifier **74** will now control the output bus. Due to the amplification of inverting amplifier **74**, further decreases in V_{in} will cause V_{out} to increase with the larger incremental gain or "slope" of −{R(100)/R(102)}. This region of amplification continues until $V_{in}=V_c$ and is represented by segment **3** in FIG. **5**.

When V_{in} has decreased to V_c, V_x will have decreased sufficiently that the output of inverting amplifier **76** will exceed that of amplifier **74**. Diode **112** will therefore be reverse biased while diode **114** will be forward biased. Thus, amplifier **76** will now control the output bus. Due to the amplifying action of inverting amplifier **76**, any further decreases in V_{in} will cause V_{out} to increase with the still larger incremental gain or "slope" −{R(104)/R(106)}. This region of largest amplification is represented by segment **4** in FIG. **5**.

Finally, for $V_{in}<V_D$, the derived voltage V_x will be less than the tapped-down reference voltage existing at the point of interconnection of resistors **88** and **90**. Under these special conditions, the noninverting input of comparator **78**

will be at a lower potential than the inverting input thus causing comparator 78's output to be in a "low" state. As a consequence, LED 66 will be lit to provide an indication to the user that the battery must be recharged before it can be tested. In addition, output line 62 will be in a "low" state, thus disabling chopper switch 34 and preventing any qualitative or quantitative dynamic conductance information from being conveyed to the user.

FIG. 7 discloses a complete schematic diagram of a first embodiment of an improved electronic battery testing/monitoring device with automatic state-of-charge compensation configured or testing/monitoring 12-volt batteries in accordance with the present invention. Operational amplifiers 120, 122, 124, and 126 comprise four elements of a quad operational amplifier integrated circuit, IC1. Bilateral analog switches 34 and 128 comprise two elements of a quad CMOS bilateral switch integrated circuit, IC2. Operational amplifiers 70, 72, 74, and 76 comprise four elements of a quad operational amplifier integrated circuit, IC3. Comparator 78 comprises one element of a quad comparator integrated circuit IC4. All four integrated circuits, IC1, IC2, IC3, and IC4 are powered by means of common power connections, V^+ 130 and V^- 132, connected to the battery undergoing test 24 through battery contacts 134 and 136, respectively.

High-gain amplifier cascade 12 of FIG. 3 comprises operational amplifier 120 and npn transistor 138 connected as an emitter follower. Resistor 140 conducts a dc bias voltage to the noninverting (+) input of operational amplifier 120 from voltage divider resistors 142 and 144 which are connected to battery 24 through battery contacts 146 and 148. The output voltage of high-gain amplifier cascade 12 is established across external-path feedback resistor 22. An internal feedback path comprising resistors 150 and 152 conducts the dc voltage at the common connection between the emitter of npn transistor 138 and resistor 22 to the inverting (−) input of operational amplifier 120. Resistors 150 and 152 along with capacitor 154 comprise low-pass filter 18 of FIG. 3.

The ac signal voltage developed across battery 24 is sensed at battery contacts 146 and 148 and added in series to an input signal voltage component established across viewing resistor 156. The resultant composite ac signal voltage is coupled to the differential input of operational amplifier 120 by means of a capacitive coupling network comprising capacitors 158 and 160. A feedback current that is proportional to the voltage established across resistor 22 passes through battery 24 by means of external feedback path conductors 162 and 164 along with battery contacts 134 and 136.

An ac square-wave input signal voltage is established across viewing resistor 156 and is formed by the action of oscillator 32, chopper switch 34, and correction amplifier 36. Oscillator 32, which generates a 100 Hz square-wave synchronizing signal, is a conventional a stable multivibrator comprising operational amplifier 122 along with resistors 168, 170, 172, 174, and capacitor 176. The synchronizing output signal of oscillator 32 is conducted to the control input of chopper switch 34 through resistor 178. Accordingly, chopper switch 34 turns on and off periodically at a 100 Hz rate. The signal terminals of chopper switch 118 interconnect the dc signal output 40 of correction amplifier 36 with the input lead of trimmer potentiometer 180 used for initial calibration adjustment. The signal voltage across trimmer potentiometer 180 therefore comprises a 100 Hz square wave having amplitude proportional to the dc output voltage of correction amplifier 36. A signal current proportional to the signal output voltage of trimmer potentiometer 180 passes through injection resistor 184 and is injected into viewing resistor 156 thereby developing a 100 Hz signal voltage across viewing resistor 156.

By virtue of the action of correction amplifier 36 described with reference to FIG. 6, the signal voltage across viewing resistor 156 will contain an automatic correction for the state-of-charge of the battery undergoing test. If, however, the battery's state-of-charge is too low for an accurate battery assessment to be made, the correction amplifier's output lines 62 and 64 will be in logic low states. These output lines will, in turn, pull the control input of chopper switch 34 low and pull the cathode of LED 66 low. As a result, chopper switch 34 will be disabled so that no ac signal will be injected into viewing resistor 156, and LED 66 will light to indicate to the user that the battery must be recharged before a dynamic conductance test can be performed.

Analog switch 128 along with operational amplifier 124, which is connected as an integrator, comprise synchronous detector 48 of FIG. 3. Resistor 194 and bypass capacitor 196 comprise a low-pass filter which biases the noninverting input of operational amplifier 124 to the voltage level of the dc bias component developed across feedback resistor 22. A signal current derived from the total voltage at the common connection between resistor 22 and transistor 138 passes through resistor 198 and analog switch 128 to the inverting input of operational amplifier 124. This signal current is periodically interrupted at the oscillator frequency by virtue of the control input of analog switch 128 being connected to the synchronizing output of oscillator 32. Resistor 200 provides negative dc feedback to operational amplifier 124. Integration capacitor 202 serves to smooth the detected voltage signal outputted by operational amplifier 124.

The noninverting input of operational amplifier 126 is biased to the dc level of the noninverting input of operational amplifier 124 while the inverting input of operational amplifier 126 is connected to SPDT selector switch 206. Accordingly, a dc current proportional to the detected signal voltage at the output of operational amplifier 124 passes through milliammeter 60 to the output of operational amplifier 116 by way of one of the two paths selected by selector switch 206. With switch 206 in position 1, the meter current passes through fixed resistor 208. Under these conditions, the disclosed invention emulates a direct reading battery testing device providing a quantitative output displayed in battery measuring units that are proportional to the dynamic conductance of battery 24. With switch 206 in position 2, the meter current passes through fixed resistor 210 and variable resistor 212. Under these conditions the disclosed invention emulates a qualitative, "pass-fail", battery testing device having a manually adjusted battery rating scale that is linearly related to the setting of variable resistance 212, and a rating offset that is determined by the value of fixed resistor 210.

The improved battery testing/monitoring device embodiment having automatic compensation for low state-of-charge disclosed in FIG. 7 is operated as follows: The operator simply connects the device to the battery undergoing test and selects one of the two positions of selector switch 206. If position 1 is selected, meter 60 will display the battery's quantitative condition in appropriate battery measuring units—with the displayed quantitative results having been automatically adjusted to conform with those of a fully-charged battery. If switch 206 is in position 2, and variable resistance 212 has been set in accordance with the battery's rating, meter 60 will display the battery's qualitative ("pass/fail") condition. Again, the displayed results will have been automatically adjusted to conform with those of a fully-charged battery. With either selection, if the battery's state-of-charge is too low for an accurate assessment to be made, no information will be displayed to the user. Instead, an LED will light to indicate to the user that the battery must be recharged before testing.

Table II contains a listing of component types and values for the first embodiment of an improved electronic battery testing/monitoring device with automatic compensation for low state-of-charge disclosed in FIG. 7.

TABLE II

Component Types and Values for Circuit of FIG. 7

REFERENCE NUMBER	COMPONENT
Semiconductor Devices	
120, 122, 124, 126	IC1 - LM324N
34, 128	IC2 - CD4066B
70, 72, 74, 76	IC3 - LM324N
78	IC4 - LM339
80	IC5 - LM336-2.5
138	TIP31C Power Transistor
108, 110, 112, 114	1N4148 Diodes
66	T-1 ¾ LED
Resistors - Ohms (¼-W unless specified)	
22	22Ω - 5 Watts
82	4.7K
84	5.36K
86	6.19K
88	6.04K
90	200K
92	2.25K
94	576
96, 100, 104	1.00M
98	174K
102	49.9K
106	13.7K
116, 142, 144	1.0K
156, 210	100
208	470
212	500 Variable
180	10K Trimpot
184	470K
140, 200	47K
178, 194, 198	100K
172	150K
174	270K
150, 152, 168, 170	1 Meg
Capacitors - Mfd	
176	0.022
154, 158, 160, 196	0.47
202	1.0
Meter	
204	1 mA dc milliammeter
Switch	
206	SPDT

Frequently, modern batteries are designed for specific cost targets and specific applications. For example, a low cost battery which may be used in warmer climates may have a lower plate count (less active material surface area) for its size as compared to a colder climate battery which costs more and has a higher plate count (more plates per acid volume). The low plate count battery may consume all plate surface area by the time the battery discharges to a voltage of only about 12.4 volts, while the battery with a relatively higher plate count will be able to provide power at much lower voltages. A wide variety of different battery types are available, using different technologies and construction techniques. The various battery types have different relationships between the battery's open circuit voltage and its relative dynamic conductance. Therefore, using a single "standard" state-of-charge correction factor curve for all battery types can tend to overcompensate some batteries, while undercompensating other batteries.

In order to improve the accuracy of the state-of-charge correction of the present invention, a potentially infinite number of different state-of-charge correction factor curves, corresponding to different battery types, can be used. Like the single correction factor curve approach, the multiple correction factor curve approach of the present invention uses empirical data to establish the correction factor curves in the manner described above. From a practical standpoint, it has been observed that a relatively limited number of correction factor curves can be used by establishing categories of battery types which tend to respond in the same manner. The exact number of curves can be varied to increase the accuracy of the correction.

FIG. 8 is a graphical plot, similar to FIG. 4, illustrating state-of-charge correction factor curves for five different types of batteries. These five battery types, ordered from the largest to the smallest ratio of plate area to acid volume, are designated:

Acid Starved ("Deep Cycle")

Acid Limited ("Standard")

Acid Balanced

Acid Reserve

Acid Flooded ("Utility")

The five curves of FIG. 8 were each determined empirically from experimental data in the same manner as is described above with reference to the single "standard" curve of FIG. 4. Similar to the approximation discussed above with reference to FIG. 5, each of the correction factor curves illustrated in FIG. 8 can be described using segmented piecewise-linear approximations for implementation by the electronic testing devices of the present invention.

The invention provides for the use of one of the standard curves illustrated in FIG. 8, or for the use of one of an infinite variety of curves, as is required to best represent the battery being tested. Theoretically, every battery type or style in existence can be accurately correlated to a specific correction factor curve, so long as the specific battery type can be identified by a stock number or by other identifying codes or designations.

In some embodiments of the present invention, in addition to a compensation factor curve being chosen which most closely represents the characteristic performance of the battery being tested, a threshold voltage for the battery being tested is also selected. Recall that the threshold voltage is the open circuit voltage, for a particular battery type, below which an indication should be given that the battery must be charged before testing can be continued. A wide variety of correction factor functions or look-up tables and threshold voltages can be programmed into a microprocessor in the testing equipment. The particular battery type (B) is identified to the battery tester. By utilizing the particular correction factor function and threshold voltage most closely correlated to the specific battery type being tested, the "fully-charged" dynamic conductance can be more accurately determined and a more accurate indication of the condition of the battery can be given.

FIG. 9 discloses a simplified block diagram of another embodiment of an improved electronic battery testing/monitoring device with automatic compensation for low state-of-charge. This embodiment eliminates the correction amplifier **36** and chopper switch **34** of the first embodiment disclosed in block diagram form in FIG. **3**. Instead, it contains a microprocessor represented generally by block **220** of FIG. **9**. Further, this embodiment allows the automatic state-of-charge compensation to be tailored for the specific battery type. Microprocessor block **220** includes all of the usual elements which comprise a microprocessor system such as the requisite logic elements, a clock oscillator, a random access memory, a firmware program contained in read-only memory, and, of course, the processor itself. The memory and other components can be integrated with the microprocessor, or they can be distinct external components coupled the microprocessor for operation therewith. With the embodiment of FIG. **9**, the appropriate correction for low state-of-charge is performed by microprocessor block **220** under the control of the firmware program contained therein.

Microprocessor block **220** is programmed with functional representations of multiple state-of-charge correction factor curves, such as those illustrated in FIG. **8**, for a number of different battery types (B). Alternatively, microprocessor block **220** can be programmed with look-up table data representative of multiple state-of-charge correction factor curves. Further, voltage threshold values, below which the battery must be recharged prior to testing, are programmed into microprocessor block **220**. The voltage threshold values and the state-of-charge correction factor functions, curves, or look-up tables can be stored for example, in the ROM or RAM associated with microprocessor block **220**. Alternatively, this data can be programmed into EEPROM type memory devices. Further, this data can be updated or altered using a keyboard, a modem communication link with another system, and/or with any other type of suitable input device.

Battery type information is provided to microprocessor block **220** at input **300** using input device **301**. Input device **301** can be a keypad entry device, a barcode reader, a menu driven terminal or any other type of input device adapted for supplying battery type information about the battery being tested to microprocessor block **220**. Battery type related information B can include battery manufacturer serial numbers, model information, manufacturer data, battery ratings in cold cranking amps (CCA), vehicle identification numbers or any other information or format which can be used to inform microprocessor block **220** of the particular type, class, group or characteristics of the battery being tested. With battery type information provided to microprocessor block **220** at input **300**, microprocessor block **220** can tailor the state-of-charge correction by selecting an appropriate correction factor function and threshold voltage which most closely correlate to the battery type of the particular battery being tested.

A description of operation of most of the elements of FIG. **9** parallels the description of operation of the embodiment disclosed in FIG. **3**. Signals representative of the signal at output **10** of high-gain amplifier cascade **12** are fed back to input **20** of high-gain amplifier cascade **12** by means of two feedback paths; internal feedback path **14** and external feedback path **16**. Internal feedback path **14** includes low pass filter (LPF) **18** and feeds a signal voltage directly back to input **20** of high-gain amplifier cascade **12**. External feedback path **16** contains resistive network **22** and feeds a signal current back to the battery undergoing test **24**. Summation circuitry **26** combines the resulting signal voltage **28** developed thereby across battery **24** with a periodic square-wave signal voltage **30**.

In the embodiment of FIG. **9**, signal voltage **30** simply comprises the constant output signal of oscillator **32**. The oscillation frequency of oscillator **32** may, for example, be 100 Hz. This periodic signal voltage is presented to summation circuitry **26** along with the signal voltage **28** developed across battery **24**, the resulting composite signal voltage **44** at the output of summation circuitry **26** is then capacitively coupled to input **20** of high-gain amplifier cascade **12** by means of capacitive coupling network **46**. Accordingly, the voltage at output **10** of high-gain amplifier cascade **12** comprises a constant dc bias component along with an ac signal component that is proportional to the dynamic conductance G_x of the battery undergoing test **24**. The constant dc bias component is ignored while the variable ac signal component is detected and accurately converted to a dc signal voltage by synchronous detector **48**, synchronized to the oscillator by means of synchronizing path **50**.

The dc signal level at output **52** of synchronous detector **50** is proportional to the battery's dynamic conductance G_x. This analog voltage is converted to a corresponding digital representation of G_x by analog to digital (A/D) converter **222** and then inputted to microprocessor block **220** through input port **224**. In addition, the battery's unloaded voltage V_o is connected via dc path **38** to the input of analog to digital converter **226**. A corresponding digital representation of V_o at the output of A/D converter **226** is thereby inputted to microprocessor block **220** through input port **228**.

By programmed algorithmic techniques that are well-known to those skilled in the art, the microprocessor's firmware program utilizes the digital representation of V_o to correct the digital representation of G_x for the battery's state-of-charge. This can be done, for example, by inputting V_o to a "look-up table" whose output is the corresponding correction factor F, and then multiplying G_x by the resulting factor F to obtain the corrected conductance value, G_x (12.6). Alternatively, the appropriate value of G_x (12.6) could be calculated directly by numerically evaluating the reciprocal of the empirical relationship disclosed in Equation 1. In either case, in preferred embodiments, the microprocessor uses the battery type information from input device **301** provided at input **300** to tailor the state-of-charge correction by selecting the appropriate correction factor function and threshold voltage which most closely correlate to the battery type.

In order to emulate a quantitative-type electronic battery tester, a numerical value proportional to G_x (12.6) is outputted and displayed on a digital display such as **236** interfaced through output port **234**, or printed by a printer such as **240** interfaced to microprocessor **220** through output port **238**. In addition, whenever V_o is less than a predetermined minimum value determined as a function of the particular type of battery being tested, the firmware program suppresses the numerical display and instead provides an indication to the user that the battery must be recharged before testing. This special information can, for example, be displayed by digital display **236**, printed by printer **240**, or conveyed to the user by an LED **66** interfaced to microprocessor **220** through output port **242**.

For emulation of a qualitative ("pass/fail") electronic battery tester, the battery's rating is first inputted to microprocessor **220** through an input device such as a shaft encoder **230** interfaced to microprocessor **220** through input port **232**. A dial associated with shaft encoder **230** is calibrated in battery rating units such as cold cranking amperes or ampere-hours. By programmed algorithmic techniques that are well-known to those skilled in the art, the

Microprocessor block **220** of correction amplifier section **36B** uses battery type information obtained at input **300** from input device **301** to select which of a variety of state-of-charge correction factor curves, functions or look-up tables best correlates to the particular type of battery being tested. Microprocessor block **220** then provides a digital signal at output **318** which is representative of a DC voltage, derived from open circuit voltage V_o having a voltage level that is inversely related to V_o—and hence is inversely related to the state-of-charge of the battery being tested or monitored. Digital-to-analog converter **320** then converts the derived voltage into analog signal **40**. Portions **36A** and **36B** of the correction amplifier illustrated in FIG. **11** can be used as correction amplifier **36** in the device shown in FIG. **3** to provide battery-type specific compensation.

Additionally, microprocessor block **220** shown in FIG. **11** can be used to form a variety of other functions. For example, chopper disable signal **62** from correction amplifier **36** can also be provided as an output of microprocessor block **220**. Further, from FIG. **3**, the output of DC milliammeter **60** can be provided to analog-to digital converter **330** for conversion to a digital signal which is supplied at input **332** to microprocessor block **220**. Thus, the output reading of DC milliammeter **60**, which is proportional to the corrected dynamic conductance of the battery, can be provided to microprocessor **220**. Hence, microprocessor **220** can use this information to provide outputs **244, 234, 238** and or **242** of the type shown in FIGS. **9** and **10**. Thus, LEDs, displays and or printers can be controlled by microprocessor block **220** to display the results of the battery test.

Additionally, it is possible to implement the multiple state-of-charge correction factor curve approach of the present invention with limited or no use of a microprocessor. For example, each of multiple correction amplifiers **36** of the type illustrated in FIG. **6** can be separately tailored for use with different battery types to implement a corresponding state-of-charge correction factor curve. Then, a microprocessor, a manually controlled switch, or other control devices can be used to switch the appropriate correction amplifier into the circuit. In the alternative, a single correction amplifier of the type illustrated in FIG. **6** can be used with selectable components to achieve various piece-wise-linear curves, depending on the battery type being tested.

Although three specific modes for carrying out the invention hereof have been described, it should be understood that many modifications and variations can be made without departing from what is regarded to be the scope and subject matter of the invention. For example, the invention may comprise a single, self-contained, instrument that is temporarily connected to the battery to test the battery on-site. Alternatively, the device may comprise a monitoring device that is semi-permanently connected to the battery to provide continuous monitoring of the battery's condition at a remote location. In this latter case, the device will probably be separated into two parts—one part connected to the battery and located at the battery's site; the other part containing the remote display and located at the remote location. The division between the two parts can be made somewhat arbitrarily. Further, the device can measure either the dynamic conductance of a battery, or the dynamic resistance of the battery. Therefore, as used herein, the term "dynamic battery parameter" is intended to refer to either the dynamic conductance or the dynamic resistance of a battery. We contend that all such divisions, modifications, and variations fall within the scope of the invention disclosed herein and are therefore intended to be covered by the appended claims.

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.

What is claimed is:

1. An electronic device for monitoring or testing a battery having one of a plurality of battery types associated therewith, comprising:

input circuitry for receiving information related to the type of the battery;

dynamic battery parameter determining circuitry for determining an intermediate dynamic parameter of the battery;

open circuit voltage sense circuitry coupled to the battery for sensing an open circuit voltage of the battery;

correction circuitry coupled to the dynamic battery parameter determining circuitry, to the open circuit voltage sense circuitry and to the input circuitry which adjusts the determined intermediate dynamic parameter based upon the battery type information and upon a value of the open circuit voltage of the battery;

output circuitry coupled to the correction circuitry for providing test results indicative of the condition of the battery, wherein the test results are provided as a function of the adjusted intermediate parameter.

2. The electronic device of claim 1 wherein the test results comprise qualitative results in conformance with the adjusted intermediate dynamic parameter relative to a reference dynamic parameter value.

3. The electronic device of claim 1 wherein the correction circuitry comprises a microprocessor and wherein digital representations of the open circuit voltage and the intermediate dynamic parameter are both inputted to the microprocessor and combined algorithmically to adjust the intermediate dynamic parameter.

4. The electronic device of claim 1 wherein the output circuitry provides a special indication when the open circuit voltage is less than a predetermined value and suppresses the test results when the open-circuit voltage is less than the predetermined value.

5. The electronic device of claim 1 wherein the dynamic battery parameter determining circuitry comprises:

a time varying current source coupled to the battery for providing a current therethrough;

voltage response sense circuitry for sensing a response voltage between two terminals of the battery developed in response to the current flowing therethrough; and

detection circuitry coupled to the sense circuitry for determining the intermediate dynamic parameter of the battery based upon the current and the sensed response voltage.

6. The electronic device of claim 5 wherein the time varying current source comprises a load.

7. The electronic device of claim 1 wherein the dynamic battery parameter determining circuitry comprises:

a time varying voltage source for applying a time varying voltage between two terminals of the battery;

current response sense circuitry for sensing a current flowing through the battery developed in response to the time varying voltage applied thereto;

detection circuitry coupled to the sense circuitry for determining the intermediate dynamic parameter of the battery based upon the time varying voltage and the sensed response current.

8. The electronic device of claim 7 wherein the current response sense circuitry senses current flowing through a load.

9. The electronic device of claim 1 wherein the intermediate parameter of the battery is a dynamic couductance of the battery, and wherein the correction circuitry adjusts the dynamic conductance in inverse correspondence with the value of the open circuit voltage of the battery.

10. The electronic device of claim 9 wherein the test results comprise numbers proportional to the adjusted intermediate dynamic conductance.

11. The electronic device of claim 1 wherein the intermediate dynamic parameter of the battery is a dynamic resistance of the battery, and wherein the correction circuitry adjusts the dynamic resistance in direct correspondence with the value of the open circuit voltage of the battery.

12. The electronic device of claim 11 wherein the test results comprise numbers inversely proportional to the adjusted intermediate dynamic resistance.

* * * * *

US005757192A

United States Patent [19]

McShane et al.

[11] Patent Number: 5,757,192
[45] Date of Patent: May 26, 1998

[54] **METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY**

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[73] Assignee: Midtronics, Inc., Burr Ridge, Ill.

[21] Appl. No.: 650,431

[22] Filed: May 20, 1996

[51] Int. Cl.[6] G01N 27/416
[52] U.S. Cl. 324/427; 340/636
[58] Field of Search 320/48; 340/636; 364/483; 324/433, 434, 426, 427

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,873,911 3/1975 Champlin .
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4,322,685 3/1982 Frailing et al. .
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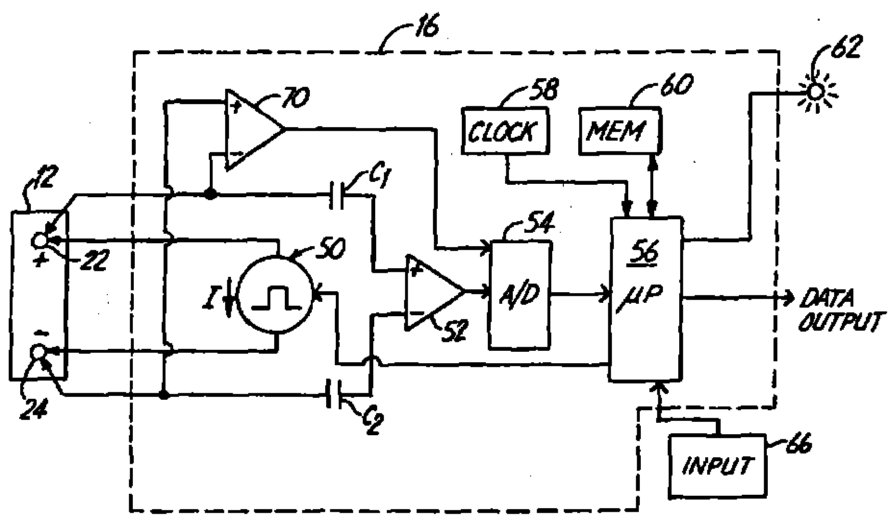
4,825,170 4/1989 Champlin .
4,881,038 11/1989 Champlin .
4,912,416 3/1990 Champlin .
5,140,269 8/1992 Champlin .
5,585,728 12/1996 Champlin 324/430

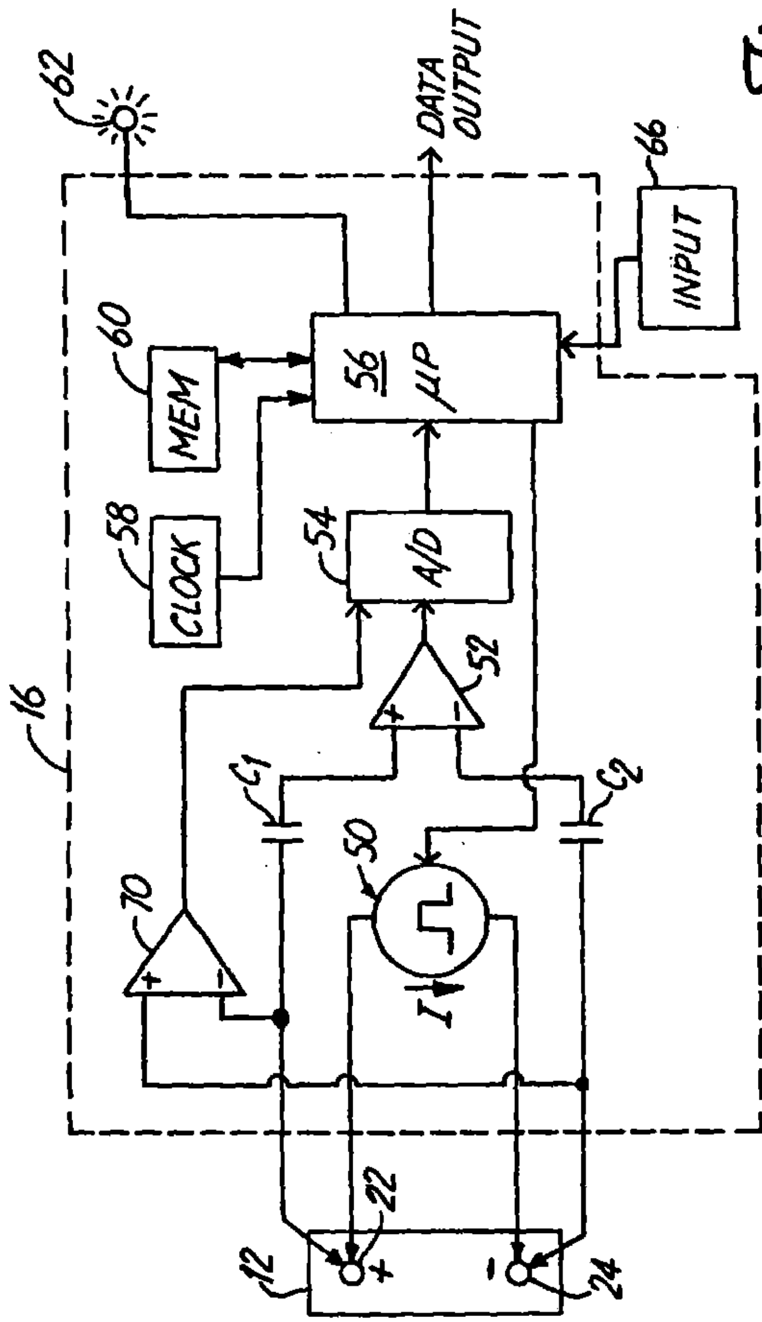
Primary Examiner—Christine K. Oda
Attorney, Agent, or Firm—Westman, Champlin & Kelly, P.A.

[57] **ABSTRACT**

A method and apparatus for detecting a bad cell in a storage battery having a plurality of cells as provided. Input circuitry electrically couples to first and second terminals of the storage battery. Voltage measuring circuitry coupled to the input circuitry provides a voltage output related to a voltage potential between the first and second terminals of the storage battery. Conductance measuring circuitry coupled to the input circuitry provides a conductance output related to conductance of the storage battery. Voltage and conductance comparison circuitry compares the measured voltage and conductance to references and provide outputs. Output circuitry provides a bad cell output based upon the results of the comparisons.

12 Claims, 2 Drawing Sheets

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INPUT
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CLOCK
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A/D
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C2
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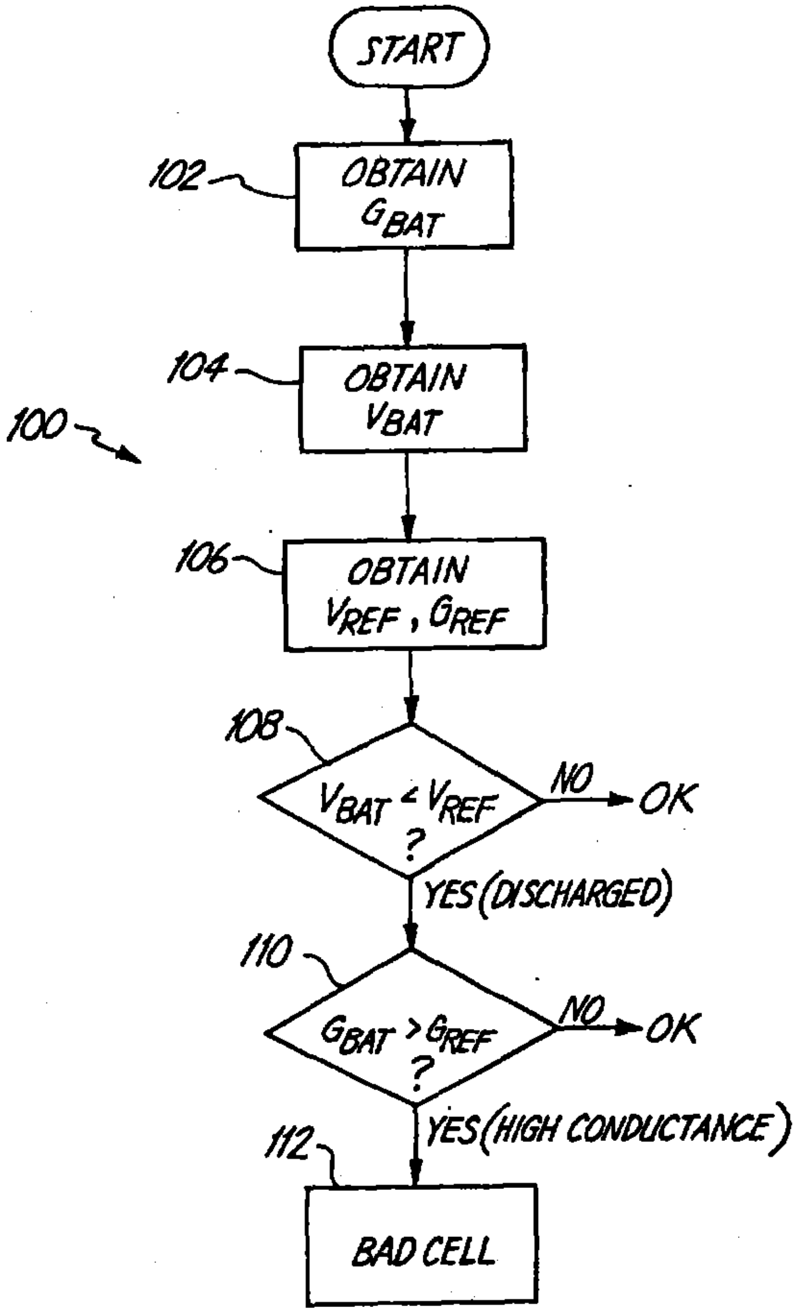
I
22
12
24

Fig. 1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OBTAIN G_BAT
104
OBTAIN V_BAT
100
106
OBTAIN V_REF, G_REF
108
V_BAT < V_REF ?
NO
OK
YES (DISCHARGED)
110
G_BAT > G_REF ?
NO
OK
YES (HIGH CONDUCTANCE)
112
BAD CELL

Fig. 2

METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY

BACKGROUND OF THE INVENTION

The present invention relates to testing of storage batteries. More specifically, the present invention relates to identifying a bad or defective cell in a storage battery.

Storage batteries, such as lead acid storage batteries of the type used in the automotive industry, have existed for many years. However, understanding the nature of such storage batteries, how such storage batteries operate and how to accurately test such batteries has been an ongoing endeavor and has proved quite difficult. Storage batteries consist of a plurality of individual storage cells electrically connected in series. Typically each cell has a voltage potential of about 2.1 volts. By connecting the cells in 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 when the battery is fully charged of 12.6 volts.

There has been a long history of attempts to accurately test the condition of storage batteries. A simple test is to measure the voltage of the battery. If the voltage is below a certain threshold, the battery is determined to be bad. However, this test is inconvenient because it requires the battery to be charged prior to performing the test. If the battery is discharged, the voltage will be low and a good battery may be incorrectly tested as bad. Furthermore, such a test does not give any indication of how much energy is stored in the battery. Another technique for testing a battery is referred 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. This technique requires that the battery be sufficiently charged in order that it can supply current to the load.

More recently, a technique has been pioneered by Dr. Keith S. Champlin for testing storage batteries by measuring the conductance of the batteries. This technique is described in a number of United States patents obtained by Dr. Champlin, 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; and U.S. Pat. No. 5,140,269, issued Aug. 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY.

The prior art has largely failed to provide a useful and convenient technique for locating a bad cell in a battery. One technique for determining the presence of a bad cell among the plurality of cells in the storage battery is to measure the specific gravity of the acid in each cell. This is a time consuming technique in which acid must be removed from each of the individual cells. Furthermore, many new batteries are "maintenance free" batteries in which the battery is sealed and access to individual cells is prevented. In such batteries, it is impossible to test the specific gravity of the individual cells.

Another technique for identifying a bad cell is described in U.S. Pat. No. 4,322,685 which was issued on Mar. 30, 1982 to Frailing et al., entitled AUTOMATIC BATTERY ANALYZER INCLUDING APPARATUS FOR DETERMINING PRESENCE OF A SINGLE BAD CELL. The Frailing patent identifies bad cells in a storage battery using a load test technique. As described in column 2, lines 58–64, of the reference batteries having a voltage of less than 10.80 volts are always rejected as unacceptable.

The prior art lacks a simple and convenient technique for identifying a bad cell in a storage battery. More specifically, the art lacks a technique for quickly and accurately identifying a bad cell without requiring the battery be charged.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for accurately identifying a bad cell in a storage battery having a plurality of cells. The apparatus includes input circuitry for electrically coupling to first and second terminals of the storage battery. Voltage measuring circuitry couples to the input circuitry and provides a voltage output related to a voltage potential measured between the first and second terminals of the storage battery. Conductance measuring circuitry coupled to the input circuitry provides a conductance output which is related to the conductance of the storage battery as measured between the first and second terminals of the storage battery. Voltage comparison circuitry compares the voltage output to a voltage reference and provides a discharged output if the voltage output is less than the voltage reference. Conductance comparison circuitry compares the conductance output to a conductance reference and provides a high conductance output if the conductance output is greater than the conductance reference. Output circuitry provides a bad cell output and response to the detection of the discharged output and a high conductance output. The bad cell output is indicative of a bad cell detected among the plurality of cells in the storage battery.

In a method for detecting a bad cell in a storage battery having a plurality of cells, the voltage of the storage battery is measured between the two terminals of the storage battery. The conductance of the storage battery is measured. The voltage of the storage battery is compared with a reference voltage and the conductance of the storage battery is compared with a reference conductance. A bad cell is detected if the voltage of the storage battery is less than the reference voltage and if the conductance of the battery is greater than the reference conductance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic diagram showing bad cell detection circuitry in accordance with the present invention.

FIG. 2 is a flow chart showing steps performed by a microprocessor and FIG. 1 operating in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a new and useful technique for detecting a bad cell among of a plurality of cells in a storage battery, such as a lead acid storage battery. The present invention makes use of the aforementioned techniques of Dr. Keith S. Champlin to measure the electrical conductance of the storage battery in determining if a bad cell exists, in accordance with the present invention. By making use of the techniques provided by Dr. Champlin, the present invention provides a quick and convenient method and apparatus for detecting a bad cell which does not require the battery to be charged in order to make an accurate determination.

FIG. 1 is a simplified block diagram of bad cell detection circuitry 16 in accordance with the present invention. Apparatus 16 is shown coupled to battery 12 which includes a positive battery terminal 22 and a negative battery terminal 24. Battery 12 is a storage battery having a plurality of individual cells, typically six, and a voltage of 12.6 volts.

Circuitry 16 operates in accordance with one embodiment of the present invention and determines the conductance (G_{BAT}) of battery 12 and the voltage potential (V_{BAT}) between terminals 22 and 24 of battery 12. Circuitry 16 includes current source 50, differential amplifier 52, analog-to-digital converter 54 and microprocessor 56. Amplifier 52 is capacitively coupled to battery 12 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, bad cell indicator 62 and analog-to-digital converter 54. Microprocessor 56 is also capable of receiving an input from input device 66.

In operation, current source 50 is controlled by microprocessor 56 and provides a current in the direction shown by the arrow in FIG. 1. In one embodiment, this is a square wave or a pulse. Differential amplifier 52 is connected to terminals 22 and 24 of battery 12 through capacitors C_1 and C_2, respectively, and provides an output related to the voltage potential difference between terminals 22 and 24. 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 12 between terminals 22 and 24. The output of amplifier 70 is provided to analog-to-digital converter 54 such that the voltage across terminals 22 and 24 can be measured by microprocessor 56.

Circuitry 16 is connected to battery 12 through a four-point connection technique known as a Kelvin connection. This Kelvin connection allows current I to be injected into battery 12 through a first pair of terminals while the voltage V across the terminals 22 and 24 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 22 and 24 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.

Microprocessor 56 determines the conductance of battery 12 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 12. Microprocessor 56 calculates the conductance of battery 12 using the following equation:

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

where ΔI is the change in current flowing through battery 12 due to current source 50 and ΔV is the change in battery voltage due to applied current ΔI.

Microprocessor 56 operates in accordance with the present invention and determines the presence of a bad cell in battery 12. FIG. 2 is a flow chart 100 showing operation of microprocessor 56 based upon programming instructions stored in memory 60. At block 102, microprocessor 56 calculates battery conductance G_{BAT} in accordance with equation 1. At block 104, microprocessor 56 determines the open circuit voltage V_{BAT} across terminals 22 and 24 using, for example, analog-to-digital converter 54 and amplifier 70. Note that in measuring the voltage V_{BAT}, capacitors C_1 and C_2 should be removed from the circuit such that the DC voltage of the battery may be measured.

Next, at block 106, microprocessor 56 obtains a reference voltage V_{REF} and a reference conductance G_{REF} stored in memory 60. At block 108, if V_{BAT} is less than V_{REF}, a discharge condition is detected and control is passed to block 110. If, on the other hand, V_{BAT} is not less than V_{REF}, then the battery is determined to be in a charge condition and may be tested in accordance with known battery testing techniques, such as those described by Dr. Champlin.

At block 110, if G_{BAT} is less than G_{REF}, the discharged condition is determined to be not due to a bad cell. If, on the other hand, G_{BAT} is greater than G_{REF}, a bad cell output is provided at block 112. For example, warning light 62 can be illuminated to indicate that a bad cell condition exists or data can be provided on a data output line from microprocessor 56 for storage or display in some other fashion.

In one preferred embodiment, the voltage reference V_{REF} is about 11.0 volts and the conductance reference G_{REF} is about 30 Mhos.

In one embodiment, values for V_{REF} and G_{REF} are stored in memory 60 for various types of storage batteries. An operator selects the particular storage battery being tested using input device 66 whereby microprocessor 56 retrieves the appropriate reference values from memory 60.

Table 1 is a table which shows a number of tests performed in accordance with the present invention. Table 1 shows the open circuit voltage V_{BAT} of a battery and the battery conductance G_{BAT}. The bad cell in a battery is determined by measuring the specific gravity of each cell in the battery and number of that cell (1–6) is indicated. The result of a test performed in accordance with the present invention is also shown.

Voltage (V_{BAT})	Conductance (Mhos) (G_{BAT})	Bad cell Number	Test Result
10.6	61	3	Bad cell
10.6	84	2	Bad cell
10.5	54	1	Bad cell
10.2	44	1	Bad cell
10.1	33	5	Bad cell
9.9	38	3	Bad cell
9.9	0	None	No bad cell
9.8	0	None	No bad cell
9.8	38	5	Bad cell
9.7	0	None	No bad cell
9.7	29	3	Bad cell
8.8	40	4	Bad cell
8.1	63	2 and 3	Bad cell
7.7	40	3 and 5	Bad cell

-continued

Voltage (V_{BAT})	Conductance (Mhos) (G_{BAT})	Bad cell Number	Test Result
6.6	0	None	No bad cell
6.2	0	None	No bad cell
6.0	0	None	No bad cell

The present invention may be implemented using any appropriate technique. For simplicity, a single technique has been illustrate herein. However, other techniques may be used including implementation in all analog circuitry. Additionally, by using appropriate techniques, the battery resistance and a reference resistance (the reciprocal of conductance) may be employed in the invention. It should be noted that the various reference values may be stored in memory or may be generated using appropriate circuits and the various comparisons described in the flow chart of FIG. 2 may be implemented using analog comparison circuitry.

The present invention provides a quick and convenient technique for determining if a battery has a bad cell. The invention does not require that the battery be recharged before testing. This saves time which is of particular importance in an automotive service environment. Furthermore, the present invention will indicate that the battery has a bad cell so that an operator knows that the battery does not need to be recharged which could lead to potential damage. The techniques described herein may be incorporated as one step of an overall battery test procedure.

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.

What is claimed is:

1. An apparatus for detecting a bad cell in a storage battery having a plurality of cells, comprising:

input circuitry for electrically coupling to first and second terminals of the storage battery;

voltage measuring circuitry coupled to the input circuitry providing voltage output related to a voltage potential between the first and second terminals of the storage battery;

conductance measuring circuitry coupled to the input circuitry providing a conductance output related to conductance of the storage battery measured between the first and second terminals

voltage comparison circuitry comparing the voltage output to a voltage reference and providing a discharged output if the voltage output is less than the voltage reference;

conductance comparison circuitry comparing the conductance output to a conductance reference and providing a high conductance output if the conductance output is greater than the conductance reference; and

output circuitry providing a bad cell output in response to detection of a discharged output and a high conductance output, the bad cell output indicative of a bad cell among the plurality of cells in the storage battery.

2. The apparatus of claim 1 including a memory containing the voltage reference and the conductance reference.

3. The apparatus of claim 2 including an input device for receiving an input from an operator used to select the voltage reference and conductance reference from a plurality of references stored in the memory.

4. The apparatus of claim 1 wherein the conductance measurement circuitry determines conductance by measuring resistance.

5. The apparatus of claim 1 wherein the voltage measuring circuitry, conductance measuring circuitry, voltage comparison circuitry, conductance comparison circuitry and the output circuitry are implemented using a microprocessor.

6. The apparatus of claim 1 including a known current source for injecting a known current into the storage battery and the conductance measuring circuitry measure conductance based upon the known current and a resultant change in voltage of the storage battery.

7. The apparatus of claim 1 wherein the conductance measuring circuitry uses a Kelvin connection to connect to the storage battery.

8. A method of detecting a bad cell in a storage battery having a plurality of cells, comprising the steps of:

measuring a voltage (V_{BAT}) across terminals of the storage battery;

measuring a conductance (G_{BAT}) of the storage battery;

comparing the voltage (V_{BAT}) to a reference voltage (V_{REF});

comparing the conductance (G_{BAT}) to a reference conductance (G_{REF}); and

indicating a bad cell exists in the battery based upon the comparisons.

9. The method of claim 8 including:

detecting a discharged condition if the voltage V_{BAT} is less than the reference voltage (V_{REF});

detecting a high conductance condition if the conductance (G_{BAT}) is greater than the reference conductance (G_{REF}); and

indicating the bad cells exists in response to the discharged condition and the high conductance condition.

10. The method of claim 8 wherein determining the conductance comprises injecting a current and measuring change in voltage.

11. The method of claim 8 including retrieving the reference voltage V_{REF} and the reference conductance G_{REF} from a memory.

12. The method of claim 8 wherein the reference voltage V_{REF} and the reference conductance G_{REF} are selected based upon the type of the storage battery.

* * * * *

Civil Cover Sheet

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NORTHERN DISTRICT OF ILLINOIS

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U.S. DISTRICT COURT

#1

Civil Cover Sheet

This automated JS-44 conforms generally to the manual JS-44 approved by the Judicial Conference of the United States in September 1974. The data is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. The information contained herein neither replaces nor supplements the filing and service of pleadings or other papers as required by law. This form is authorized for use only in the Northern District of Illinois.

Plaintiff(s): MIDTRONICS, INC.

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Plaintiff's Atty: Donald Flayton
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Defendant(s):DHC SPECIALITY CORPORATION

County of Residence: Du Page

Defendant's Atty:

DOCKETED
APR 0? 2004

04C 2423

II. Basis of Jurisdiction: **3. Federal Question (U.S. not a party)**

III. Citizenship of Principal Parties **(Diversity Cases Only)**

Plaintiff:- **N/A**
Defendant:- **N/A**

JUDGE AMY ST. EVE

MAGISTRATE JUDGE BOBRICK

IV. Origin : **1. Original Proceeding**

V. Nature of Suit: **830 Patent**

VI.Cause of Action: **Patent Infringement Under 35 USC Section 271**

VII. Requested in Complaint
Class Action: **No**
Dollar Demand:
Jury Demand: **Yes**

VIII. This case IS NOT a refiling of a previously dismissed case.

Signature: [signature]

Date: Apr 2, 2004

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Revised: 06/28/00

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4/2

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

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04 APR -2 PM 4:12
CLERK
U.S. DISTRICT COURT

In the Matter of

Midtronics, Inc., Plaintiff
vs.
DHC Speciality Corporation, Defendants

Case Number: **04C 2423**

JUDGE AMY ST. EVE

APPEARANCES ARE HEREBY FILED BY THE UNDERSIGNED AS ATTORNEY(S) FOR:

MIDTRONICS, INC.

~~MAGISTRATE JUDGE BOBRICK~~

DOCKETED
APR 0 5 2004

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IDENTIFICATION NUMBER (SEE ITEM 4 ON REVERSE) 830518		IDENTIFICATION NUMBER (SEE ITEM 4 ON REVERSE) 6205751	
MEMBER OF TRIAL BAR?	YES ☒ NO ☐	MEMBER OF TRIAL BAR?	YES ☒ NO ☐
TRIAL ATTORNEY?	YES ☒ NO ☐	TRIAL ATTORNEY?	YES ☒ NO ☐
		DESIGNATED AS LOCAL COUNSEL?	YES ☐ NO ☒

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MEMBER OF TRIAL BAR?	YES ☐ NO ☒	MEMBER OF TRIAL BAR?	YES ☐ NO ☐
TRIAL ATTORNEY?	YES ☐ NO ☒	TRIAL ATTORNEY?	YES ☐ NO ☐
DESIGNATED AS LOCAL COUNSEL?	YES ☐ NO ☒	DESIGNATED AS LOCAL COUNSEL?	YES ☐ NO ☐

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