US007012433B2

(12) **United States Patent**
Smith et al.

(10) **Patent No.: US 7,012,433 B2**
(45) **Date of Patent: Mar. 14, 2006**

(54) **BATTERY TESTER UPGRADE USING SOFTWARE KEY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 424 days.

(21) Appl. No.: **10/246,439**

(22) Filed: **Sep. 18, 2002**

(65) **Prior Publication Data**

US 2004/0051532 A1 Mar. 18, 2004

(51) **Int. Cl.**
G01N 27/416 (2006.01)

(52) **U.S. Cl.** **324/426**; 324/427

(58) **Field of Classification Search** 324/426, 324/427, 429, 428, 431; 320/132, 134, 136, 320/137

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,514,745	A	7/1950	Dalzell	171/95
3,356,936	A	12/1967	Smith	324/29.5
3,562,634	A	2/1971	Latner	31/4
3,593,099	A	7/1971	Scholl	320/13
3,607,673	A	9/1971	Seyl	204/1
3,676,770	A	7/1972	Sharaf et al.	324/29.5
3,729,989	A	5/1973	Little	73/133
3,753,094	A	8/1973	Furuishi et al.	324/29.5
3,808,522	A	4/1974	Sharaf	324/29.5
3,811,089	A	5/1974	Strezelewicz	324/170
3,873,911	A	3/1975	Champlin	324/29.5
3,876,931	A	4/1975	Godshalk	324/29.5
3,886,443	A	5/1975	Miyakawa et al.	324/29.5
3,889,248	A	6/1975	Ritter	340/249
3,906,329	A	9/1975	Bader	320/44
3,909,708	A	9/1975	Champlin	324/29.5
3,936,744	A	2/1976	Perlmutter	324/158
3,946,299	A	3/1976	Christianson et al.	320/43
3,947,757	A	3/1976	Grube et al.	324/28
3,969,667	A	7/1976	McWilliams	324/29.5

(Continued)

FOREIGN PATENT DOCUMENTS

DE	29 26 716 B1	1/1981
EP	0 022 450 A1	1/1981
EP	0 637 754 A1	2/1995
EP	0 772 056 A1	5/1997
FR	2 749 397	12/1997

(Continued)

OTHER PUBLICATIONS

"Electrochemical Impedance Spectroscopy in Battery Development and Testing", *Batteries International*, Apr. 1997, pp. 59 and 62–63.

(Continued)

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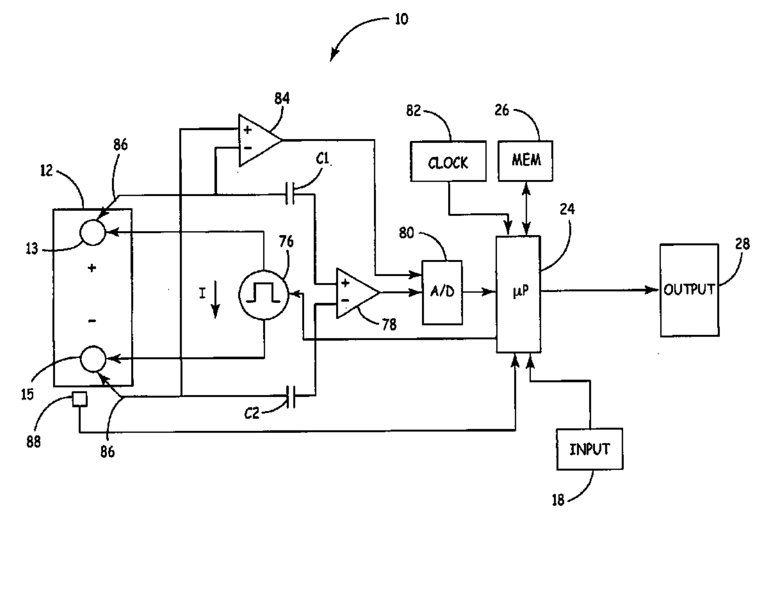
(57) **ABSTRACT**

An electronic battery tester, comprising first and second connectors configured to electrically couple to terminals of the battery, a microprocessor configured to test the battery using the first and second connectors, a memory containing a set of locked instructions for the microprocessor, an input configured to receive a software unlocking key, and the microprocessor configured to execute the set of locked instructions in response to the software unlocking key corresponding a predetermined software unlocking key.

37 Claims, 4 Drawing Sheets



U.S. PATENT DOCUMENTS

3,979,664	A		9/1976	Harris	324/17
3,984,762	A		10/1976	Dowgiallo, Jr.	324/29.5
3,984,768	A		10/1976	Staples	324/62
3,989,544	A		11/1976	Santo	429/65
4,008,619	A		2/1977	Alcaide et al.	73/398
4,024,953	A		5/1977	Nailor, III	206/344
4,047,091	A		9/1977	Hutchines et al.	363/59
4,053,824	A		10/1977	Dupuis et al.	324/29.5
4,070,624	A		1/1978	Taylor	327/158
4,086,531	A		4/1978	Bernier	324/158
4,112,351	A		9/1978	Back et al.	324/16
4,114,083	A		9/1978	Benham et al.	320/39
4,126,874	A		11/1978	Suzuki et al.	354/60
4,178,546	A		12/1979	Hulls et al.	324/158
4,193,025	A		3/1980	Frailing et al.	324/427
4,207,611	A		6/1980	Gordon	364/580
4,217,645	A		8/1980	Barry et al.	364/483
4,297,639	A		10/1981	Branham	324/429
4,315,204	A		2/1982	Sievers et al.	322/28
4,316,185	A		2/1982	Watrous et al.	340/636
4,322,685	A		3/1982	Frailing et al.	324/429
4,351,405	A		9/1982	Fields et al.	180/65
4,361,809	A		11/1982	Bil et al.	324/426
4,363,407	A		12/1982	Buckler et al.	209/3.3
4,369,407	A		1/1983	Korbell	324/416
4,379,989	A		4/1983	Kurz et al.	320/26
4,379,990	A		4/1983	Sievers et al.	322/99
4,390,828	A		6/1983	Converse et al.	320/32
4,392,101	A		7/1983	Saar et al.	320/20
4,396,880	A		8/1983	Windebank	320/21
4,408,157	A		10/1983	Beaubien	324/62
4,412,169	A		10/1983	Dell'Orto	320/64
4,423,378	A		12/1983	Marino et al.	324/427
4,423,379	A		12/1983	Jacobs et al.	324/429
4,424,491	A		1/1984	Bobbett et al.	324/433
4,459,548	A		7/1984	Lentz et al.	324/158
4,514,694	A		4/1985	Finger	324/429
4,520,353	A		5/1985	McAuliffe	340/636
4,564,798	A		1/1986	Young	320/6
4,633,418	A		12/1986	Bishop	364/554
4,659,977	A		4/1987	Kissel et al.	320/64
4,663,580	A		5/1987	Wortman	320/35
4,665,370	A		5/1987	Holland	324/429
4,667,143	A		5/1987	Cooper et al.	320/22
4,667,279	A		5/1987	Maier	363/46
4,678,998	A		7/1987	Muramatsu	324/427
4,679,000	A		7/1987	Clark	324/428
4,680,528	A		7/1987	Mikami et al.	320/32
4,697,134	A		9/1987	Burkum et al.	320/48
4,707,795	A		11/1987	Alber et al.	364/550
4,709,202	A		11/1987	Koenck et al.	320/43
4,710,861	A		12/1987	Kanner	363/46
4,719,428	A		1/1988	Liebermann	324/436
4,743,855	A		5/1988	Randin et al.	324/430
4,745,349	A		5/1988	Palanisamy et al.	320/22
4,816,768	A		3/1989	Champlin	324/428
4,820,966	A		4/1989	Fridman	320/32
4,825,170	A		4/1989	Champlin	324/436
4,847,547	A		7/1989	Eng, Jr. et al.	320/35
4,849,700	A		7/1989	Morioka et al.	324/427
4,876,495	A		10/1989	Palanisamy et al.	320/18
4,881,038	A		11/1989	Champlin	324/426
4,912,416	A		3/1990	Champlin	324/430
4,913,116	A		4/1990	Katogi et al.	123/425
4,929,931	A		5/1990	McCuen	340/636
4,931,738	A		6/1990	MacIntyre et al.	324/435
4,933,845	A	*	6/1990	Hayes	710/104
4,937,528	A		6/1990	Palanisamy	324/430
4,947,124	A		8/1990	Hauser	324/430
4,956,597	A		9/1990	Heavey et al.	320/14
4,968,941	A		11/1990	Rogers	324/428
4,968,942	A		11/1990	Palanisamy	324/430
5,004,979	A		4/1991	Marino et al.	324/160
5,032,825	A		7/1991	Kuznicki	340/636
5,037,778	A		8/1991	Stark et al.	437/216
5,047,722	A		9/1991	Wurst et al.	324/430
5,087,881	A		2/1992	Peacock	324/378
5,095,223	A		3/1992	Thomas	307/110
5,126,675	A		6/1992	Yang	324/435
5,140,269	A		8/1992	Champlin	324/433
5,144,218	A		9/1992	Bosscha	320/44
5,144,248	A		9/1992	Alexandres et al.	324/428
5,160,881	A		11/1992	Schramm et al.	322/7
5,170,124	A		12/1992	Blair et al.	324/434
5,179,335	A		1/1993	Nor	320/21
5,194,799	A		3/1993	Tomantschger	320/2
5,204,611	A		4/1993	Nor et al.	320/21
5,214,370	A		5/1993	Harm et al.	320/35
5,214,385	A		5/1993	Gabriel et al.	324/434
5,241,275	A		8/1993	Fang	324/430
5,254,952	A		10/1993	Salley et al.	324/439
5,266,880	A		11/1993	Newland	320/14
5,281,919	A		1/1994	Palanisamy	324/427
5,281,920	A		1/1994	Wurst	324/430
5,295,078	A		3/1994	Stich et al.	364/483
5,298,797	A		3/1994	Redl	307/246
5,300,874	A		4/1994	Shimamoto et al.	320/15
5,302,902	A		4/1994	Groehl	324/434
5,315,287	A		5/1994	Sol	340/455
5,321,626	A		6/1994	Palladino	364/483
5,331,268	A		7/1994	Patino et al.	320/20
5,336,993	A		8/1994	Thomas et al.	324/158.1
5,338,515	A		8/1994	Dalla Betta et al.	422/95
5,339,018	A		8/1994	Brokaw	320/35
5,343,380	A		8/1994	Champlin	363/46
5,347,163	A		9/1994	Yoshimura	307/66
5,352,968	A		10/1994	Reni et al.	320/35
5,365,160	A		11/1994	Leppo et al.	320/22
5,365,453	A		11/1994	Startup et al.	364/481
5,381,096	A		1/1995	Hirzel	324/427
5,412,323	A		5/1995	Kato et al.	324/429
5,426,371	A		6/1995	Salley et al.	324/429
5,426,416	A		6/1995	Jefferies et al.	340/664
5,432,426	A		7/1995	Yoshida	320/20
5,434,495	A		7/1995	Toko	320/44
5,435,185	A		7/1995	Eagan	73/587
5,442,274	A		8/1995	Tamai	320/23
5,445,026	A		8/1995	Eagan	73/591
5,449,996	A		9/1995	Matsumoto et al.	320/20
5,449,997	A		9/1995	Gilmore et al.	320/39
5,451,881	A		9/1995	Finger	324/433
5,457,377	A		10/1995	Jonsson	320/5
5,469,043	A		11/1995	Cherng et al.	320/31
5,485,090	A		1/1996	Stephens	324/433
5,488,300	A		1/1996	Jamieson	324/432
5,519,383	A		5/1996	De La Rosa	340/636
5,528,148	A		6/1996	Rogers	324/426
5,537,967	A		7/1996	Tashiro et al.	123/792.1
5,546,317	A		8/1996	Andrieu	364/481
5,548,273	A		8/1996	Nicol et al.	340/439
5,550,485	A		8/1996	Falk	324/772
5,561,380	A		10/1996	Sway-Tin et al.	324/509
5,562,501	A		10/1996	Kinoshita et al.	439/852
5,563,496	A		10/1996	McClure	320/48
5,572,136	A		11/1996	Champlin	324/426
5,574,355	A		11/1996	McShane et al.	320/39
5,583,416	A		12/1996	Klang	320/22
5,585,728	A		12/1996	Champlin	324/427
5,589,757	A		12/1996	Klang	320/22
5,592,093	A		1/1997	Klingbiel	324/426
5,596,260	A		1/1997	Moravec et al.	320/30

5,598,098	A		1/1997	Champlin	324/430
5,602,462	A		2/1997	Stich et al.	323/258
5,606,242	A		2/1997	Hull et al.	320/48
5,621,298	A		4/1997	Harvey	320/5
5,633,985	A		5/1997	Severson et al.	395/2.76
5,637,978	A		6/1997	Kellett et al.	320/2
5,642,031	A		6/1997	Brotto	320/21
5,650,937	A		7/1997	Bounaga	364/483
5,652,501	A		7/1997	McClure et al.	320/17
5,653,659	A		8/1997	Kunibe et al.	477/111
5,656,920	A		8/1997	Cherng et al.	320/31
5,675,234	A		10/1997	Greene	320/15
5,677,077	A		10/1997	Faulk	429/90
5,699,050	A		12/1997	Kanazawa	340/636
5,701,089	A		12/1997	Perkins	327/772
5,705,929	A		1/1998	Caravello et al.	324/430
5,710,503	A		1/1998	Sideris et al.	320/6
5,711,648	A		1/1998	Hammerslag	414/786
5,717,336	A		2/1998	Basell et al.	324/430
5,717,937	A		2/1998	Fritz	395/750.01
5,739,667	A		4/1998	Matsuda et al.	320/5
5,745,044	A	*	4/1998	Hyatt et al.	340/5.23
5,747,909	A		5/1998	Syverson et al.	310/156
5,754,417	A		5/1998	Nicollini	363/60
5,757,192	A		5/1998	McShane et al.	324/427
5,760,587	A		6/1998	Harvey	324/434
5,773,978	A		6/1998	Becker	324/430
5,789,899	A		8/1998	van Phuoc et al.	320/30
5,793,359	A		8/1998	Ushikubo	345/169
5,796,239	A		8/1998	van Phuoc et al.	320/107
5,808,469	A		9/1998	Kopera	324/43.4
5,818,234	A		10/1998	McKinnon	324/433
5,821,756	A		10/1998	McShane et al.	324/430
5,821,757	A		10/1998	Alvarez et al.	324/434
5,825,174	A		10/1998	Parker	324/106
5,831,435	A		11/1998	Troy	324/426
5,862,515	A		1/1999	Kobayashi et al.	702/63
5,872,443	A		2/1999	Williamson	320/21
5,895,440	A		4/1999	Proctor et al.	702/63
5,914,605	A		6/1999	Bertness	324/430
5,927,938	A		7/1999	Hammerslag	414/809
5,929,609	A		7/1999	Joy et al.	322/25
5,939,855	A		8/1999	Proctor et al.	320/104
5,939,861	A		8/1999	Joko et al.	320/122
5,945,829	A		8/1999	Bertness	324/430
5,951,229	A		9/1999	Hammerslag	414/398
5,961,561	A		10/1999	Wakefield, II	701/29
5,961,604	A		10/1999	Anderson et al.	709/229
5,969,625	A		10/1999	Russo	340/636
5,978,805	A	*	11/1999	Carson	707/10
6,002,238	A		12/1999	Champlin	320/134
6,005,759	A	*	12/1999	Hart et al.	361/66
6,008,652	A		12/1999	Theofanopoulos et al.	324/434
6,009,369	A		12/1999	Boisvert et al.	701/99
6,031,354	A		2/2000	Wiley et al.	320/116
6,037,751	A		3/2000	Klang	320/160
6,037,777	A		3/2000	Champlin	324/430
6,051,976	A		4/2000	Bertness	324/426
6,064,372	A	*	5/2000	Kahkoska	345/173
6,072,299	A		6/2000	Kurie et al.	320/112
6,072,300	A		6/2000	Tsuji	320/116
6,081,098	A		6/2000	Bertness et al.	320/134
6,091,245	A		7/2000	Bertness	324/426
6,094,033	A		7/2000	Ding et al.	320/132
6,104,167	A		8/2000	Bertness et al.	320/132
6,114,834	A		9/2000	Parise	320/109
6,137,269	A		10/2000	Champlin	320/150
6,140,797	A		10/2000	Dunn	320/105
6,144,185	A		11/2000	Dougherty et al.	320/132
6,150,793	A		11/2000	Lesesky et al.	320/104
6,158,000	A	*	12/2000	Collins	713/1
6,161,640	A		12/2000	Yamaguchi	180/65.8
6,163,156	A		12/2000	Bertness	324/426
6,167,349	A		12/2000	Alvarez	702/63
6,172,483	B1		1/2001	Champlin	320/134
6,172,505	B1		1/2001	Bertness	324/430
6,181,545	B1		1/2001	Amatucci et al.	361/502
6,222,369	B1		4/2001	Champlin	324/430
6,225,808	B1		5/2001	Varghese et al.	324/426
6,236,332	B1		5/2001	Conkright et al.	340/825.06
6,249,124	B1		6/2001	Bertness	324/426
6,250,973	B1		6/2001	Lowery et al.	439/763
6,254,438	B1		7/2001	Gaunt	439/755
6,259,254	B1		7/2001	Klang	324/427
6,262,563	B1		7/2001	Champlin	320/134
6,294,896	B1		9/2001	Champlin	320/134
6,294,897	B1		9/2001	Champlin	320/153
6,304,087	B1		10/2001	Bertness	324/426
6,307,349	B1		10/2001	Koenck et al.	320/112
6,310,481	B1		10/2001	Bertness	324/430
6,313,607	B1		11/2001	Champlin	320/132
6,313,608	B1	*	11/2001	Varghese et al.	320/132
6,316,914	B1		11/2001	Bertness	320/134
6,323,650	B1		11/2001	Bertness et al.	324/426
6,329,793	B1		12/2001	Bertness et al.	320/132
6,331,762	B1		12/2001	Bertness	320/134
6,332,113	B1		12/2001	Bertness	702/63
6,346,795	B1		2/2002	Haraguchi et al.	320/136
6,347,958	B1		2/2002	Tsai	439/488
6,351,102	B1		2/2002	Troy	320/139
6,359,441	B1		3/2002	Bertness	324/426
6,363,303	B1		3/2002	Bertness	701/29
6,384,608	B1		5/2002	Namaky	324/425
6,388,448	B1		5/2002	Cervas	324/426
6,392,414	B1		5/2002	Bertness	324/429
6,411,098	B1		6/2002	Laletin	324/436
6,417,669	B1		7/2002	Champlin	324/426
6,424,158	B1		7/2002	Klang	324/433
6,441,585	B1		8/2002	Bertness	320/132
6,445,158	B1		9/2002	Bertness et al.	320/104
6,456,045	B1		9/2002	Troy et al.	320/139
6,466,025	B1		10/2002	Klang	324/429
6,466,026	B1		10/2002	Champlin	324/430
6,600,815	B1	*	7/2003	Walding	379/93.07
6,618,644	B1	*	9/2003	Bean	700/231
2002/0176010	A1	*	11/2002	Wallach et al.	348/229.1

FOREIGN PATENT DOCUMENTS

GB	2 088 159	A	6/1982
JP	59-17892		1/1984
JP	59-17893		1/1984
JP	59-17894		1/1984
JP	59017894		1/1984
JP	59215674		12/1984
JP	60225078		11/1985
JP	62-180284		8/1987
JP	63027776		2/1988
JP	03274479		12/1991
JP	03282276		12/1991
JP	4-8636		1/1992
JP	04131779		5/1992
JP	04372536		12/1992
JP	5216550		8/1993
JP	7-128414		5/1995
JP	09061505		3/1997
JP	10056744		2/1998
RU	2089015	C1	8/1997
WO	WO 93/22666		11/1993
WO	WO 94/05069		3/1994
WO	WO 98/58270		12/1998
WO	WO 99/23738		5/1999

OTHER PUBLICATIONS

"Battery Impedance", by E. Willihnganz et al., *Electrical Engineering*, Sep. 1959, pp. 922–925.
"Determining The End of Battery Life", by S. DeBardelaben, *IEEE*, 1986, pp. 365–368.
"A Look at the Impedance of a Cell", by S. Debardelaben, *IEEE*, 1988, pp. 394–397.
"The Impedance of Electrical Storage Cells", by N.A. Hampson et al., *Journal of Applied Electrochemistry*, 1980, pp. 3–11.
"A Package for Impedance/Admittance Data Analysis", by B. Boukamp, *Solid State Ionics*, 1986, pp. 136–140.
"Precision of Impedance Spectroscopy Estimates of Bulk, Reaction Rate, and Diffusion Parameters", by J. McDonald et al., *J. Electroanal, Chem.*, 1991, pp. 1–11.
Internal Resistance: Harbinger of Capacity Loss in Starved Electrolyte Sealed Lead Acid Batteries, by Vaccaro, F.J. et al., *AT&T Bell Laboratories*, 1987 IEEE, Ch. 2477, pp. 128,131.
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.
"Field and Laboratory Studies to Assess the State of Health of Valve–Regulated Lead Acid Batteries: Part I Conductance/Capacity Correlation Studies", by D. Feder et al., *IEEE*, Aug. 1992, pp. 218–233.
"JIS Japanese Industrial Standard–Lead Acid Batteries for Automobiles", *Japanese Standards Association UDC*, 621.355.2:629.113.006, Nov. 1995.
"Performance of Dry Cells", by C. Hambuechen, Preprint of *Am. Electrochem. Soc.*, Apr. 18–20, 1912, paper No. 19, pp. 1–5.
"A Bridge for Measuring Storage Battery Resistance", by E. Willihncanz, *The Electrochemical Society*, preprint 79–20, Apr. 1941, pp. 253–258.
National Semiconductor Corporation, "High Q Notch Filter", 3/69, Linear Brief 5, Mar. 1969.
Burr–Brown Corporation, "Design A 60 Hz Notch Filter with the UAF42", 1/94, AB–071, 1994.
National Semiconductor Corporation, "LMF90–4th–Order Elliptic Notch Filter", 12/94, RRD–B30M115, Dec. 1994.
"Alligator Clips with Wire Penetrators" *J.S. Popper, Inc.* product information, downloaded from http://www.jspopper.com/, undated.
"#12: LM78S40 Simple Switcher DC to DC Converter", *ITM e–Catalog*, downloaded from http://www.pcbcafe.com, undated.
"Simple DC–DC Converts Allows Use of Single Battery", *Electronix Express*, downloaded from http://www.elexp.com/t_dc–dc.htm, undated.
"DC–DC Converter Basics", *Power Designers*, downloaded from http://www.powederdesigners.com/InforWeb.design_center/articles/DC–DC/converter.shtm, undated.

* cited by examiner

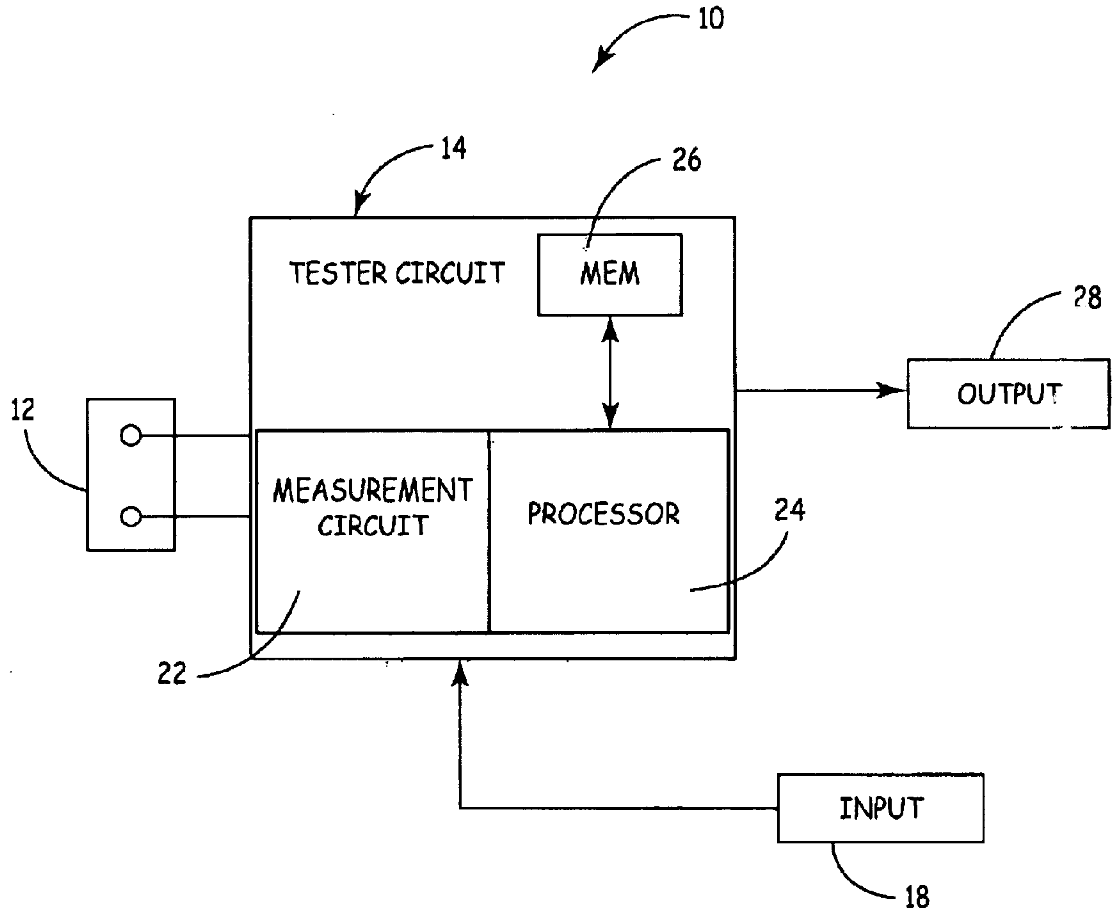

10
14
26
TESTER CIRCUIT
MEM
28
OUTPUT
12
MEASUREMENT CIRCUIT
PROCESSOR
24
22
INPUT
18

FIG. 1

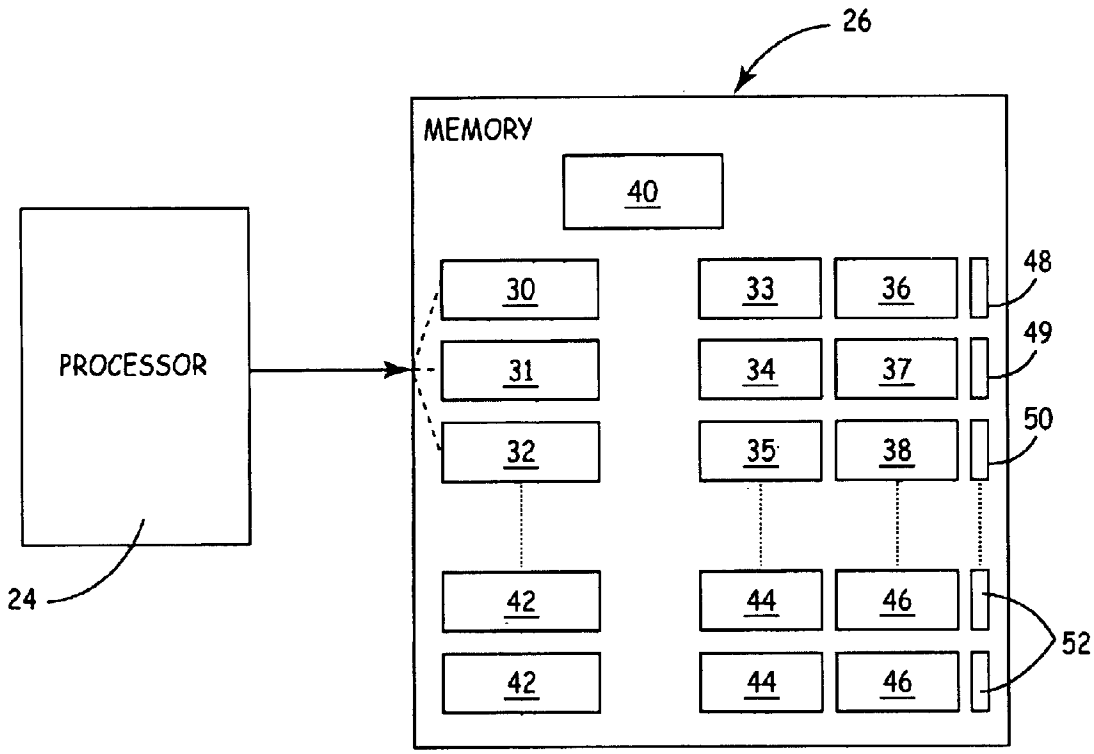

26
MEMORY
40
30
31
32
33
34
35
36
37
38
42
42
44
44
46
46
48
49
50
52
PROCESSOR
24

FIG. 2

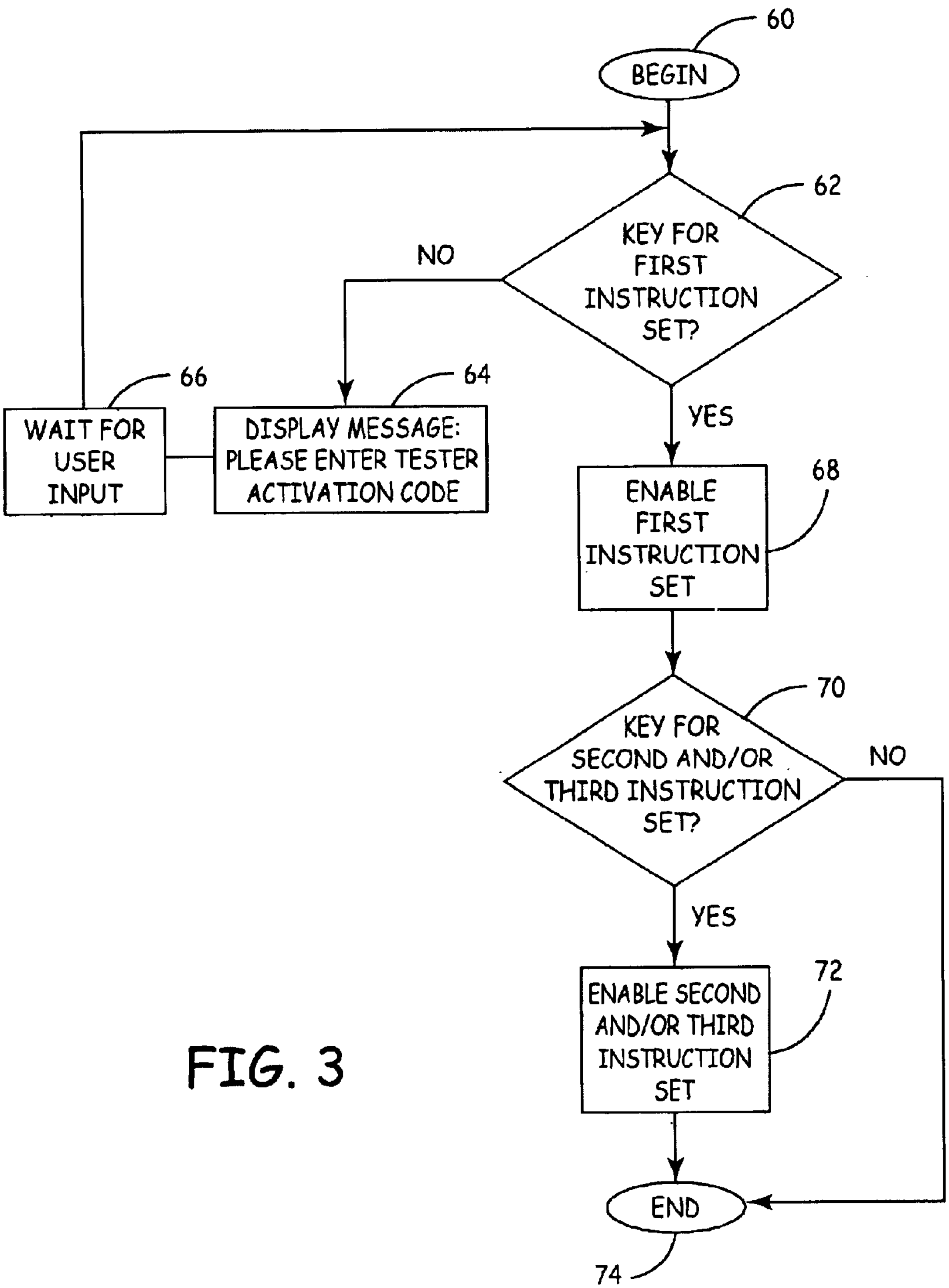
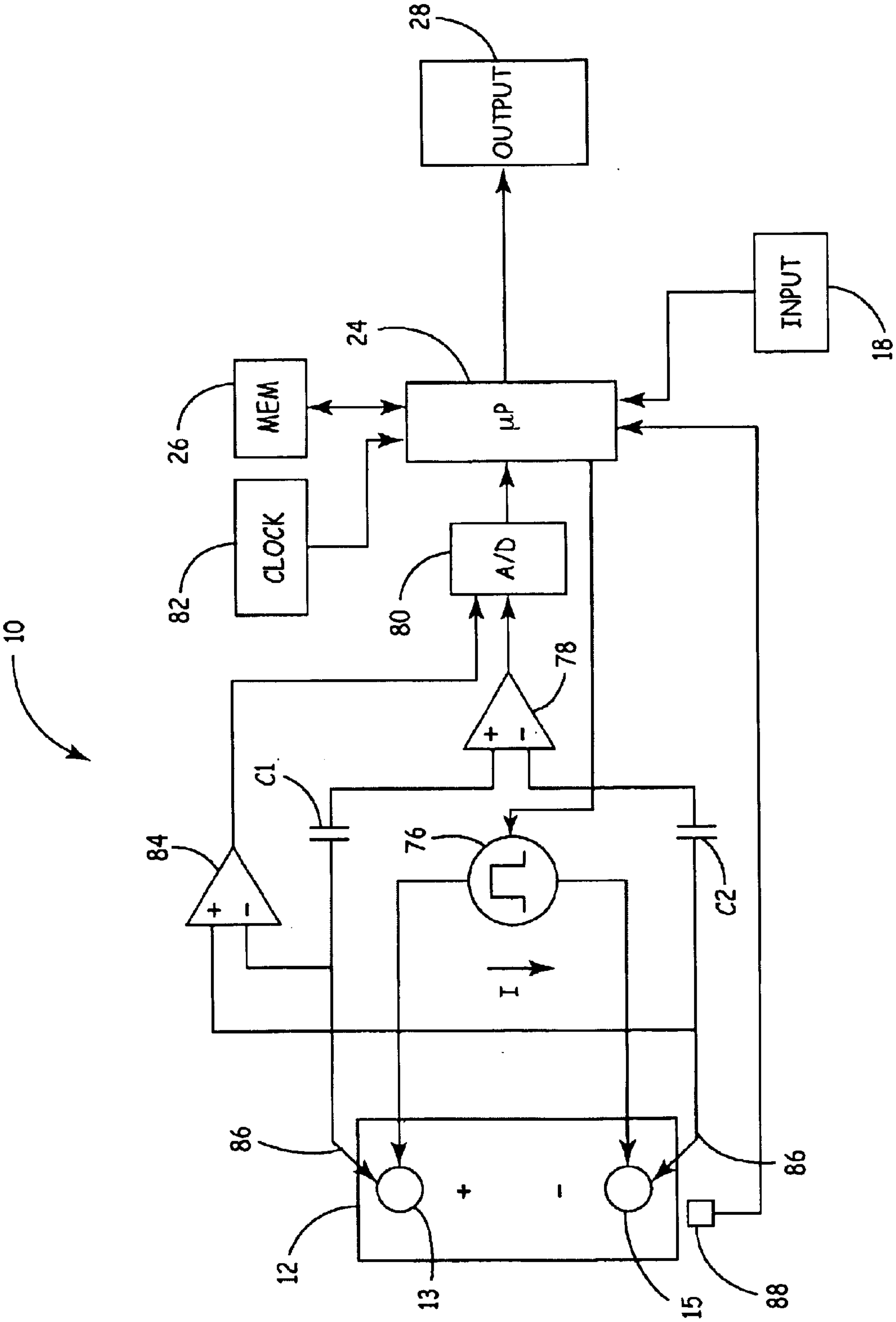

60
BEGIN
62
KEY FOR FIRST INSTRUCTION SET?
NO
YES
66
WAIT FOR USER INPUT
64
DISPLAY MESSAGE: PLEASE ENTER TESTER ACTIVATION CODE
68
ENABLE FIRST INSTRUCTION SET
70
KEY FOR SECOND AND/OR THIRD INSTRUCTION SET?
NO
YES
72
ENABLE SECOND AND/OR THIRD INSTRUCTION SET
END
74

FIG. 3



OUTPUT
28
INPUT
18
24
µP
MEM
26
CLOCK
82
A/D
80
78
10
84
C1
76
C2
I
86
86
12
13
15
88

FIG. 4

BATTERY TESTER UPGRADE USING SOFTWARE KEY

BACKGROUND OF THE INVENTION

The present invention relates to storage batteries. More specifically, the present invention relates to a battery system tester for testing storage batteries.

Storage batteries, such as lead acid storage batteries of the type used in the automotive industry, have existed for many years. These storage batteries usually 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 voltage 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 up to 12.6 volts.

Several techniques have been used to test the condition of storage batteries. These techniques include a voltage test to determine if the battery voltage is below a certain threshold, and a load test that involves discharging a battery using a known load. A more recent technique involves measuring the conductance of the storage batteries. This technique, which has been pioneered by Dr. Keith S. Champlin and Midtronics, Inc. of Burr Ridge, Ill., is described in a number of U.S. patents, for example, U.S. Pat. No. 3,873,911, issued Mar. 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 3,909,708, issued Sep. 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,816,768, issued Mar. 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,825,170, issued Apr. 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Pat. No. 4,881,038, issued Nov. 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Pat. No. 4,912,416, issued Mar. 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Pat. No. 5,140,269, issued Aug. 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Pat. No. 5,343,380, issued Aug. 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Pat. No. 5,572,136, issued Nov. 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,574,355, issued Nov. 12, 1996, entitled METHOD AND APPARATUS FOR DETECTION AND CONTROL OF THERMAL RUNAWAY IN A BATTERY UNDER CHARGE; U.S. Pat. No. 5,585,416, issued Dec. 10, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Pat. No. 5,585,728, issued Dec. 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,589,757, issued Dec. 31, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Pat. No. 5,592,093, issued Jan. 7, 1997, entitled ELECTRONIC BATTERY TESTING DEVICE LOOSE TERMINAL CONNECTION DETECTION VIA A COMPARISON CIRCUIT; U.S. Pat. No. 5,598,098, issued Jan. 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Pat. No. 5,656,920, issued Aug. 12, 1997, entitled METHOD FOR OPTIMIZING THE CHARGING LEAD-ACID BATTERIES AND AN INTERACTIVE CHARGER; U.S. Pat. No. 5,757,192, issued May 26, 1998, entitled METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY; U.S. Pat. No. 5,821,756, issued Oct. 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,831,435, issued Nov. 3, 1998, entitled BATTERY TESTER FOR JIS STANDARD; U.S. Pat. No. 5,914,605, issued Jun. 22, 1999, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 5,945,829, issued Aug. 31, 1999, entitled MIDPOINT BATTERY MONITORING; U.S. Pat. No. 6,002,238, issued Dec. 14, 1999, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,037,751, issued Mar. 14, 2000, entitled APPARATUS FOR CHARGING BATTERIES; U.S. Pat. No. 6,037,777, issued Mar. 14, 2000, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Pat. No. 6,051,976, issued Apr. 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Pat. No. 6,081,098, issued Jun. 27, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,091,245, issued Jul. 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Pat. No. 6,104,167, issued Aug. 15, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,137,269, issued Oct. 24, 2000, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,163,156, issued Dec. 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,172,483, issued Jan. 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELL AND BATTERIES; U.S. Pat. No. 6,172,505, issued Jan. 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,222,369, issued Apr. 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Pat. No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,249,124, issued Jun. 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Pat. No. 6,259,254, issued Jul. 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Pat. No. 6,262,563, issued Jul. 17, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX ADMITTANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,294,896, issued Sep. 25, 2001; entitled METHOD AND APPARATUS FOR MEASURING COMPLEX SELF-IMMITANCE OF A GENERAL ELECTRICAL ELEMENT; U.S. Pat. No. 6,294,897, issued Sep. 25, 2001, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,304,087, issued Oct. 16, 2001, entitled APPARATUS FOR CALIBRATING ELEC-

TRONIC BATTERY TESTER; U.S. Pat. No. 6,310,481, issued Oct. 30, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,313,607, issued Nov. 6, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,313,608, issued Nov. 6, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,316,914, issued Nov. 13, 2001, entitled TESTING PARALLEL STRINGS OF STORAGE BATTERIES; U.S. Pat. No. 6,323,650, issued Nov. 27, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,329,793, issued Dec. 11, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Pat. No. 6,331,762, issued Dec. 18, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Pat. No. 6,332,113, issued Dec. 18, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,351,102, issued Feb. 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Pat. No. 6,359,441, issued Mar. 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,363,303, issued Mar. 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM, U.S. Ser. No. 09/595,102, filed Jun. 15, 2000, entitled APPARATUS AND METHOD FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Ser. No. 09/703,270, filed Oct. 31, 2000, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/575,629, filed May 22, 2000, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Ser. No. 09/780,146, filed Feb. 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Ser. No. 09/816,768, filed Mar. 23, 2001, entitled MODULAR BATTERY TESTER; U.S. Ser. No. 09/756,638, filed Jan. 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Ser. No. 09/862,783, filed May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Ser. No. 09/483,623, filed Jan. 13, 2000, entitled ALTERNATOR TESTER; U.S. Ser. No. 09/870,410, filed May 30, 2001, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/960,117, filed Sep. 20, 2001, entitled IN-VEHICLE BATTERY MONITOR; U.S. Ser. No. 09/908,389, filed Jul. 18, 2001, entitled BATTERY CLAMP WITH INTEGRATED CIRCUIT SENSOR; U.S. Ser. No. 09/908,278, filed Jul. 18, 2001, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S. Ser. No. 09/880,473, filed Jun. 13, 2001; entitled BATTERY TEST MODULE; U.S. Ser. No. 09/876,564, filed Jun. 7, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/878,625, filed Jun. 11, 2001, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Ser. No. 09/902,492, filed Jul. 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; and U.S. Ser. No. 09/940,684, filed Aug. 27, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Ser. No. 09/977,049, filed Oct. 12, 2001, untitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Ser. No. 10/047,923, filed Oct. 23, 2001, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER, U.S. Ser. No. 10/046,659, filed Oct. 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Ser. No. 09/993,468, filed Nov. 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Ser. No. 09/992,350, filed Nov. 26, 2001, entitled ELECTRONIC BATTERY TESTER, U.S. Ser. No. 10/042,451, filed Jan. 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE; U.S. Ser. No. 10/042,451, filed Jan. 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE, U.S. Ser. No. 10/073,378, filed Feb. 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Ser. No. 10/093,853, filed Mar. 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Ser. No. 60/364,656, filed Mar. 14, 2002, entitled ELECTRONIC BATTERY TESTER WITH LOW TEMPERATURE RATING DETERMINATION; U.S. Ser. No. 10/101,543, filed Mar. 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/112,114, filed Mar. 28, 2002; U.S. Ser. No. 10/109,734, filed Mar. 28, 2002; U.S. Ser. No. 10/112,105, filed Mar. 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Ser. No. 10/112,998, filed Mar. 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; U.S. Ser. No. 10/119,297, filed Apr. 9, 2002, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Ser. No. 10/128,790, filed Apr. 22, 2002, entitled METHOD OF DISTRIBUTING JUMP-START BOOSTER PACKS; U.S. Ser. No. 10/143,307, filed May 10, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/207,495, filed Jul. 29, 2002, entitled KELVIN CLAMP FOR ELECTRICALLY COUPLING TO A BATTERY CONTACT, which are incorporated herein in their entirety.

Battery testers are available in different models, with the most basic models just indicating whether the battery is "good" or "bad", and the more developed models providing information such as the state of charge of the battery, the state of health of the battery, etc. Currently, when a user needs to upgrade to a more advanced model, the user may, for example, have to place an order with the vendor, and the battery tester must be shipped to the user from inventory. This series of transactions creates delays that may frustrate the user, while adding significant overhead to the vendor's operations. Further, the vendor may be obligated to inventory and support nonrevenue producing models of battery testers.

SUMMARY OF THE INVENTION

An electronic battery tester, comprising first and second connectors configured to electrically couple to terminals of the battery, a microprocessor configured to test the battery using the first and second connectors, a memory containing a set of locked instructions for the microprocessor, an input configured to receive a software unlocking key, and the microprocessor configured to execute the set of locked instructions in response to the software unlocking key corresponding a predetermined software unlocking key.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a very simplified block diagram showing a battery tester in accordance with an embodiment of the present invention.

FIG. **2** is a block diagram illustrating different software modules stored in battery tester memory in accordance with an embodiment of the present invention.

FIG. **3** is a flow chart illustrating the operation of battery tester key recognition routine in accordance with an embodiment of the present invention.

FIG. **4** is a simplified block diagram showing details of battery tester measurement circuit in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention, described below, all relate to a battery testing system which includes locked battery testing instructions that can be executed upon receipt of a software unlocking key that corresponds to a predetermined software unlocking key.

FIG. **1** is a very simplified block diagram of a battery tester **10** in accordance with an illustrative embodiment of the present invention. The same reference numerals are used in the various figures to represent the same or similar elements. Note that FIG. **1** is a simplified block diagram of a specific type of battery tester. However, the present invention is applicable to any type of battery tester including those which do not use dynamic parameters. Other types of example testers include testers that conduct load tests, current based tests, voltage based tests, tests which apply various conditions or observe various performance parameters of a battery, etc. Battery tester **10** includes a test circuit **14** that directly couples to vehicle battery **12**, an input **18** and an output **28**. Test circuit **14** includes measurement circuit **22**, processor **24** and memory **26**. Measurement circuit **22** can be any circuit configuration which measures a dynamic parameter of battery **12**. As used herein, a dynamic parameter is one which is related to a signal having an alternating current (AC) component. The signal can be either applied directly or drawn from battery **12**. Example dynamic parameters include dynamic resistance, conductance, impedance, admittance, etc. This list is not exhaustive, for example, a dynamic parameter can include a component value of an equivalent circuit of battery **12**. Operation of measurement circuit **22** is controlled by processor **24** which, in turn, carries out different battery testing functions based upon battery testing instructions stored in memory **26**. In accordance with the present invention, the battery testing instructions are locked in memory **26** when tester **10** is delivered to a customer. Tester **10** can be utilized to test battery **12** only when it is enabled by unlocking the battery testing instructions by entering a software unlocking key that corresponds to a predetermined software unlocking key that is stored in memory **26**. The software unlocking key can be entered by the user through input **18**. Input **18** may be a keyboard, a reader through which a card including the software unlocking key can be swiped, etc. Input **18** can also include a keyboard that is a touchscreen or integrated with a touchscreen, a unit capable of radio frequency (RF) communication with a personal computer (PC) or a personal digital assistant (PDA), a RF identification (ID) tag, a unit capable of infrared (IR) communication with a PC or a PDA, a serial interface cable, a parallel interface cable, a universal serial bus (USB) interface cable, a bus using the Institute of Electrical and Electronics Engineers (IEEE) 1394 standard, an Ethernet interface cable, a Transmission Control Protocol/Internet Protocol (TCP/IP) internet connection, a plug-in device (such as a memory card, a memory chip, an ID button, etc.), etc. Upon receiving the software unlocking key from input **18**, microprocessor **24** utilizes a key recognition module stored in memory **26** to validate the entered software unlocking key. If the software unlocking key is recognized (or found to be valid) by the key recognition routine, the key is stored in memory and the battery testing instructions are unlocked to thereby enable tester **10** for use in testing battery **12**.

In preferred embodiments of the present invention, multiple locked battery testing instruction sets are stored in memory **26** and a different unique software unlocking key is required to unlock each different instruction set of the multiple battery testing instruction sets. The use of such multiple locked battery testing instruction sets to upgrade battery tester **10** is described below in connection with FIGS. **2** and **3**.

FIG. **2** is a block diagram illustrating different software modules stored in battery tester memory **26** in accordance with an embodiment of the present invention. As can be seen in FIG. **2**, memory **26** includes multiple battery testing instruction sets, such as, first instruction set **30**, second instruction set **31** and third instruction set **32**. Encrypted codes or predetermined software unlocking keys **33–35**, each corresponding to a respective battery testing instruction set of instruction sets **30–32**, are also stored in memory **26**. Memory registers **36–38** can each store a software unlocking key that matches a respective one of encryption codes **33–35**. As mentioned above, the software unlocking keys are entered by the battery tester user. Key recognition routine **40** can compare the user entered software unlocking keys, which can be stored in registers **36–38**, with respective encrypted codes **33–35** and can enable one or more of corresponding instruction sets **30–32** if matches are detected between one or more unlocking keys and one or more encrypted codes **33–35**. The operation of an example key recognition routine is described further below in connection with FIG. **3**.

In an example embodiment of the present invention, first instruction set **30** contains basic functions which, when executed, only provide an output indicating whether battery **12** is "good" or "bad". Second instruction set **31** contains more advanced functions which, when executed, provide an output indicating the state of charge, state of health, etc., of battery **12**. Third instruction set **32** contains functions which, when executed, provide an output related to a replacement battery or replacement options for battery **12**. Each instruction set is in a locked condition when battery tester **10** is delivered to the user. The price of tester **10** is tied to the number of software unlocking keys that the user purchases. For example, the user may purchase battery tester **10** and only one software unlocking key to enable first instruction set **30** at a relatively low price. Subsequently, if the user desires an upgrade of the functions, the user may, for example, call a 1-800 number and, upon providing a credit card number, obtain an unlocking key for second instruction set **31** and/or third instruction set **32**. Thus, the upgrade of battery tester **10** takes place locally after the appropriate software unlocking key is input into tester **10**.

In some embodiments of the present invention, additional instruction sets may be provided to battery tester **10** by coupling input **18** to a separate device or remote system via a telephone line, for example, and downloading the additional instruction sets into memory locations **42** and corresponding encrypted codes or predetermined software unlocking keys into memory locations **44** form the remote system. Additional unlocking keys entered by the battery tester user for unlocking the additional instruction sets can be stored in memory registers **46**.

In embodiments of the present invention, key recognition routine **40** can be executed by microprocessor **24** each time it receives a start test command, which may be provided by the tester user through input **18**. FIG. **3** is a flow chart illustrating the operation of key recognition routine **40** in accordance with an embodiment of the present invention. The routine begins at step **60** and proceeds to step **62** at which a determination is made as to whether the software unlocking key for first instruction set **30** is valid. This step may involve comparing the contents of register **36** with encrypted code **33**. If the comparison indicates that the software unlocking key is invalid, a message is displayed to the user requesting the user to enter an activation code (or unlocking key) at step **64** and the routine waits for the user input at step **66**. Upon receipt of the user input, control returns to step **62**. If the comparison indicates that the software unlocking key is valid, first instruction set **30** is enabled at step **68** by setting a status flag in register **48** to a predetermined value. At step **70**, a determination is made as to whether the software unlocking key for second instruction set **31** and/or the unlocking key for third instruction set **32** is valid. This step involves a comparison of encrypted codes **34** and **35** and unlocking keys in registers **37** and **38**. If no matches are detected between the unlocking keys and the encrypted codes, the routine ends at step **74**. If one or more matches are detected, second instruction set **31** and/or third instruction set **32** are enabled by appropriately setting status flags in registers **49** and **50** to predetermined values at step **72** before the routine ends at step **74**.

In some embodiments of the present invention, key recognition routine **40** first checks if the status flags in registers **48–50** are set to an appropriate predetermined value that indicates that the instruction sets are enabled and only carries out a comparison of software unlocking keys and encryption codes for instruction sets that are not in an enabled status. Status flags for instruction sets that are subsequently downloaded into memory locations **42** are stored in registers **52**.

In some embodiments of the present invention, all instruction sets are enabled for trial use (for example, one-time use) when tester **10** is delivered to the user. This may be carried out by setting status flags in registers **48–50** to appropriate predetermined values that indicate one-time activation of instruction sets **30–32**.

In some embodiments of the present invention, encrypted codes **33–35** for a particular battery include the encrypted serial number of the particular battery tester unit. Thus, each predetermined software unlocking key or encrypted code of encrypted codes **33–35** for a particular battery tester unit can consist of a combination of the encrypted serial number for the battery tester unit and one or more characters and/or digits that render each encrypted code of encrypted codes **33–35** unique.

As used herein, "the microprocessor executing the set of locked instructions in response to a software unlocking key corresponding to a predetermined software unlocking key" includes the microprocessor being configured to execute the set of locked instructions if the software unlocking key corresponding to the predetermined software unlocking key is stored in the memory, the microprocessor being configured to execute the set of locked instructions if a status flag is set to a predetermined value in the memory, the microprocessor being configured to execute the first set of locked instructions upon receipt of a start test command, etc.

FIG. **4** is a simplified block diagram of electronic battery tester circuitry **10** in accordance with a specific embodiment of the present invention. Apparatus **10** is shown coupled to battery **12** which includes a positive battery terminal **13** and a negative battery terminal **15**. Circuitry **10** includes current source **76**, differential amplifier **78**, analog-to-digital converter **80** and microprocessor **24**. Amplifier **78** is capacitively coupled to battery **12** through capacitors C_1 and C_2. Amplifier **78** has an output connected to an input of analog-to-digital converter **80**. Microprocessor **24** is connected to system clock **82**, memory **26** and analog-to-digital converter **80**. Microprocessor **24** is also capable of receiving an input from input device **18**. Microprocessor **24** also connects to output device **28**.

In operation, current source **76** is controlled by microprocessor **24** and provides current I in the direction shown by the arrow in FIG. **4**. In one embodiment, this is a square wave or a pulse. Differential amplifier **78** is connected to terminals **13** and **15** of battery **12** through capacitors C_1 and C_2, respectively, and provides an output related to the voltage potential difference between terminals **13** and **15**. In a preferred embodiment, amplifier **78** has a high input impedance. Circuitry **10** includes differential amplifier **84** having inverting and noninverting inputs connected to terminals **13** and **15**, respectively. Amplifier **84** is connected to measure the open circuit potential voltage (V_{BAT}) of battery **12** between terminals **13** and **15**. The output of amplifier **84** is provided to analog-to-digital converter **80** such that the voltage across terminals **13** and **15** can be measured by microprocessor **24**.

Circuitry **10** is connected to battery **12** through a four-point connection technique known as a Kelvin connection. This Kelvin connection **86** allows current I to be injected into battery **10** through a first pair of terminals while the voltage V across the terminals **13** and **15** is measured by a second pair of connections. Because very little current flows through amplifier **78**, the voltage drop across the inputs to amplifier **78** is substantially identical to the voltage drop across terminals **13** and **15** of battery **12**. The output of differential amplifier **78** is converted to a digital format and is provided to microprocessor **24**. Microprocessor **24** operates at a frequency determined by system clock **82** and in accordance with programming instructions stored in memory **26**.

Microprocessor **26** determines the conductance of battery **12** by applying a current pulse I using current source **76**. The microprocessor determines the change in battery voltage due to the current pulse I using amplifier **78** and analog-to-digital converter **80**. The value of current I generated by current source **76** is known and is stored in memory **26**. In one embodiment, current I is obtained by applying a load to battery **12**. Microprocessor **24** 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 **76** and ΔV is the change in battery voltage due to applied current ΔI.

Based upon the battery conductance G_{BAT} and the battery voltage, the battery tester **10** determines the condition of battery **12**. A temperature sensor **88** can be thermally coupled to battery **12** and used to compensate battery measurements. Temperature readings can be stored in memory **26** for later retrieval.

As mentioned above, microprocessor **24** operates at a frequency determined by system clock **82** and in accordance with programming instructions stored in memory **26**. In accordance with the present invention, the programming instructions stored in memory **26** are locked and can be executed by microprocessor **24** upon receipt of a software unlocking key that corresponds to a predetermined software unlocking key.

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 battery tester, comprising:

first and second connectors configured to electrically couple to terminals of a battery;

a microprocessor configured to test the battery using the first and second connectors;

a memory containing a first set of locked instructions for the microprocessor;

an input configured to receive a first software unlocking key; and

the microprocessor configured to execute the first set of locked instructions in response to the first software unlocking key corresponding to a first predetermined software unlocking key, wherein the first set of locked instructions are a first set of battery testing instructions.

2. The electronic battery tester of claim **1** wherein the first predetermined software unlocking key including an encrypted serial number of the electronic battery tester, and wherein the encrypted serial number is stored in the memory.

3. The electronic battery tester of claim **1** wherein the microprocessor being configured to execute the first set of locked instructions in response to the first software unlocking key corresponding to the first predetermined software unlocking key further comprises the microprocessor being configured to execute the first set of locked instructions if the first software unlocking key corresponding to the first predetermined software unlocking key is stored in the memory.

4. The electronic battery tester of claim **1** wherein the microprocessor being configured to execute the first set of locked instructions in response to the first software unlocking key corresponding to the first predetermined software unlocking key further comprises the microprocessor being configured to execute the first set of locked instructions if a first status flag is set to a predetermined value in the memory.

5. The electronic battery tester of claim **1** wherein the microprocessor being configured to execute the first set of locked instructions in response to the first software unlocking key corresponding to the first predetermined software unlocking key further comprises the microprocessor being configured to execute the first set of locked instructions upon receipt of a start test command.

6. The electronic battery tester of claim **1** wherein the first set of locked instructions is one of a plurality of sets of locked instructions; the first software unlocking key is one of a plurality of software unlocking keys, and the first predetermined software unlocking key is one of a plurality of software unlocking keys, and wherein the microprocessor is configured to execute at least one of the plurality of sets of locked instructions in response to at least one of the plurality of software unlocking keys corresponding to at least one of the plurality of predetermined software unlocking keys.

7. The electronic battery tester of claim **6** wherein the plurality of locked instructions are enabled for one-time execution by setting a corresponding plurality of status flags to a predetermined value in the memory.

8. The electronic battery tester of claim **1** wherein the input comprises a keyboard.

9. The electronic battery tester of claim **1** wherein the input comprises a touchscreen keyboard.

10. The electronic battery tester of claim **1** wherein the input comprises a reader through which a card including the first software unlocking key can be swiped.

11. The electronic battery tester of claim **1** wherein the input is further configured to communicate with a remote system.

12. The electronic battery tester of claim **11** wherein the input is further configured to communicate with the remote system via a telephone line.

13. The electronic battery tester of claim **11** wherein the remote system is a personal computer.

14. The electronic battery tester of claim **11** wherein the remote system is a personal digital assistant.

15. The electronic battery tester of claim **1** wherein the input is further configured for radio frequency communication.

16. The electronic battery tester of claim **1** wherein the input is further configured for infrared communication.

17. The electronic battery tester of claim **1** wherein the input further comprises a radio frequency identification tag.

18. The electronic battery tester of claim **1** wherein the input further comprises a serial interface cable.

19. The electronic battery tester of claim **1** wherein the input further comprises a parallel interface cable.

20. The electronic battery tester of claim **1** wherein the input further comprises a universal serial bus interface cable.

21. The electronic battery tester of claim **1** wherein the input further comprises an IEEE 1394 interface cable.

22. The electronic battery tester of claim **1** wherein the input further comprises an Ethernet interface cable.

23. The electronic battery tester of claim **1** wherein the input further comprises a TCP/IP internet connection.

24. The electronic battery tester of claim **1** wherein the input further comprises a plug-in device.

25. The electronic battery tester of claim **24** wherein the plug-in device is a memory card.

26. The electronic battery tester of claim **24** wherein the plug-in device is a memory chip.

27. The electronic battery tester of claim **24** wherein the plug-in device is an identification button.

28. The electronic battery tester of claim **1** wherein the memory is configured to store additional instruction sets received from a remote system.

29. The electronic battery tester of claim **1** wherein the microprocessor determines a dynamic parameter of the battery upon execution of the first set of locked instructions.

30. The electronic battery tester of claim **29** wherein the dynamic parameter is battery conductance.

31. The electronic battery tester of claim **1** wherein the first and second connectors are Kelvin electrical connectors.

32. A method of testing a battery, comprising:

(a) providing a first and second connector configured to electrically couple to terminals of the battery;

(b) providing a microprocessor configured to test the battery using the first and second connectors;

(c) providing a memory containing a first set of locked instructions for the microprocessor;

(d) receiving a first software unlocking key; and

(e) executing, with the microprocessor, the first set of locked instructions upon receipt of the first software unlocking key and upon the first software unlocking key corresponding to a first predetermined software unlocking key, wherein the first set of locked instructions are a first set of battery testing instructions.

33. The method of claim **32** wherein the first predetermined software unlocking key including an encrypted serial number of the electronic battery tester, and wherein the encrypted serial number is stored in the memory.

34. The method of claim **32** wherein the executing step (e) comprises executing the first set of locked instructions if the first software unlocking key corresponding to the first predetermined software unlocking key is stored in the memory.

35. The method of claim **32** wherein the executing step (e) comprises executing the first set of locked instructions if a first status flag is set to a predetermined value in the memory.

36. The method of claim **32** wherein the executing step (e) comprises executing the first set of locked instructions upon receipt of a start test command.

37. The method of claim **32** wherein the first set of locked instructions is one of a plurality of sets of locked instructions, the first software unlocking key is one of a plurality of software unlocking keys, and the first predetermined software unlocking key is one of a plurality of software unlocking keys, and wherein the executing step (e) comprises executing at least one of the plurality of sets of locked instructions in response to at least one of the plurality of software unlocking keys corresponding to at least one of the plurality of predetermined software unlocking keys.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,012,433 B2
APPLICATION NO. : 10/246439
DATED : March 14, 2006
INVENTOR(S) : Clark E. Smith et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

<u>Title Page 2</u>
Item (56) References Cited:

delete “Buckler et al.” and insert --Barkler et al.--

<u>Column 9</u>
Line 55 delete “;” and insert --,--

Signed and Sealed this

Fourteenth Day of July, 2009

JOHN DOLL
Acting Director of the United States Patent and Trademark Office