SBS Implementers Forum

Smart Battery Data Accuracy Testing Guidelines

Revision 2.0

March 20, 2001

Smart Battery Data Accuracy Testing Guidelines

Questions and comments regarding this guidelines may be forwarded to:
Email:

questions@sbs-forum.org

For additional information on Smart Battery System Specifications, visit the SBS Implementers Forum (SBS-IF) at:

www.sbs-forum.org
and
www.smbus.org

Table of Contents

1. Introduction to Smart Battery Data Accuracy Measurements 1

1.1 Scope 2

1.2 Audience 2

2. References 2

3. Definitions and Procedures 2

3.1 Definitions 2
3.1.1 Load-1 2
3.1.2 Load-2 3
3.1.3 Full 3
3.1.4 Empty 4
3.1.5 Charge-A 4
3.1.6 Charge-B 4
3.1.7 Measured Values 4
3.1.8 Reported Values 5
3.1.9 Test Environment 5

3.2 Procedures 5
3.2.1 Charge Battery 5
3.2.2 Discharge Battery 6
3.2.3 Rest Battery 6
3.2.4 Re-Learn Capacity 7

4. Accuracy Tests 8

4.1 Capacity Estimation Tests 8
4.1.1 TEST 1A: 3 complete cycles at 35°C using Charge-A and Load-1 8
4.1.2 TEST 1B: 3 complete cycles at 35°C using Charge-A and Load-2 9
4.1.3 TEST 1C: 3 complete cycles at 35°C using Charge-A, Load-1, and Load-2 10
4.1.4 TEST 2A: 5 cycles to 35% at 35°C using Charge-B and Load-1 11
4.1.5 TEST 2B: 5 cycles to 35% at 35°C using Charge-B and Load-2 12
4.1.6 TEST 3A: 5 cycles 80% to 30% at 35°C using Charge-A and Load-1 13
4.1.7 TEST 3B: 5 cycles 80% to 30% at 35°C using Charge-A and Load-2 14
4.1.8 TEST 4: Storage Test at 40°C 15
4.1.9 TEST 5: Prolonged Suspend Current 16

4.2 Measurement Accuracy Tests 17
4.2.1 TEST 6: Temperature(), Voltage(), Current() and AverageCurrent() Accuracy 17

5. Data Reporting 18

5.1 Test Results Reporting Formats 18
5.1.1 Report Format for Tests 1 to 5 18
5.1.2 Report Format for Test 6 19

Revision History

Revision Number	Date	Author	Notes
1.0	12/15/1998	P. Mummah	Public release
2.0	3/20/2001	SBS IF Accuracy WG (Friel, Rush, Konaka, Dunstan, Stolitzka, et. al.)	Public release

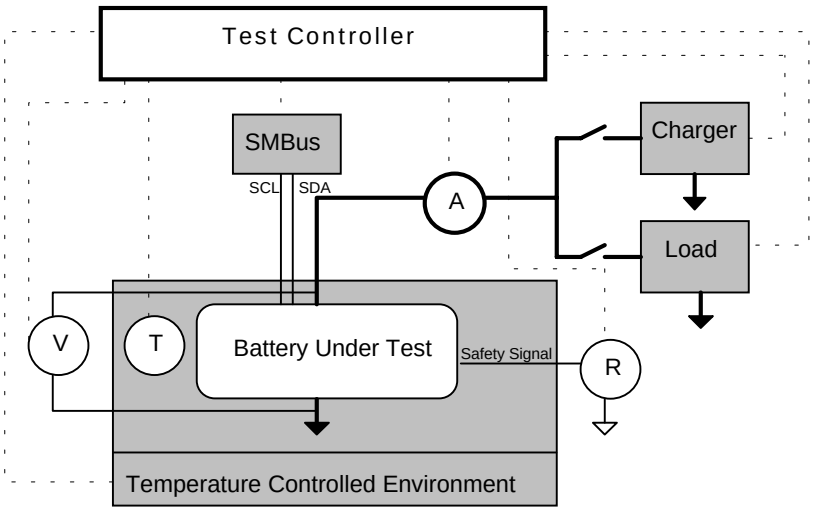
1. Introduction to Smart Battery Data Accuracy Measurements

The smart battery data accuracy measurements are intended to test the accuracy of the data that a smart battery reports. This information must be accurate if a smart battery powered system is to obtain maximum battery run time and maximum battery life. These data accuracy measurements consist of six basic tests (some with multiple parts) that reflect how a battery is used in a typical computer laptop environment with a compliant SBS Smart Battery design. The tests are best done in numerical order, however each test procedure is self-contained and may be performed independently.

The equipment necessary to complete the tests are:

1) A test controller which orchestrates the tests according to the test procedures; initiates and records the results of measurements of the battery voltage and current; measures, controls and records the test environment temperature; and initiates, responds and records communication with the battery's SMBus interface and Safety Signal.
2) A variable/programmable load that is capable of producing constant current, constant power, pulsed current and pulse power loads. The pulsed loading modes require pulse width resolution of better than 25ms.
3) A programmable charge source capable of constant current, constant power, pulsed current and pulsed power. The pulsed charging modes require pulse width resolution of 25ms.
4) Voltage, current, resistance and temperature measurement instrumentation capable of sampling each value at a 5ms rate by command of the test controller.
5) A temperature controlled test environment capable of providing 0°C to 60°C temperatures on command of the test controller, with +/-5°C accuracy and stability. Relative humidity can be reported if measured.
6) An SMBus host port capable of sending and receiving all SMBus protocols required in the Smart Battery Data Specification v1.1. The SMBus port should be fully compliant with the SMBus Specification v1.1.

Block Diagram of Test Setup



1.1 Scope

This document specifies a set of guidelines for tests designed to evaluate the integrity and accuracy of the data returned from a SBS Smart Battery. The scope of the tests is limited to basic data accuracy and do not constitute a complete set of tests that may be required to evaluate battery performance and safety. These tests are designed for notebook computer applications. Manufacturers of Smart Batteries used in other types of electrically powered devices may modify these tests to meet their specific needs.

1.2 Audience

The audience for this document includes:

- Smart Battery System component manufacturers
- Smart Battery System designers
- Designers of power management systems for Smart Battery powered notebook computers
- Designers of BIOS, driver and operating system software

2. References

- *Smart Battery Data Specification*, Revision 1.1a, SBS-Implementers Forum, December 1998. Available from http://www.sbs-forum.org.
- *Smart Battery Charger Specification*, Revision 1.1, SBS-Implementers Forum, December 1998. Available from http://www.sbs-forum.org.
- *Smart Battery System Manager Specification*, Revision 1.1, SBS-Implementers Forum, December 1998. Available from http://www.sbs-forum.org.
- *System Management Bus Specification*, Revision 1.1, SBS-Implementers Forum, December 1998. Available from http://www.smbus.org.

- *ACPI Specifications*, Version 1.0b, Intel Corporation, Microsoft Corporation, Toshiba Corp., July 1998 (Available at: www.teleport.com/~acpi)

3. Definitions and Procedures

3.1 Definitions

3.1.1 LOAD-1

Constant power P/2 load, where P = DesignCapacity() [mWh]. Load current must not exceed manufacturer's recommended maximum discharge rate.

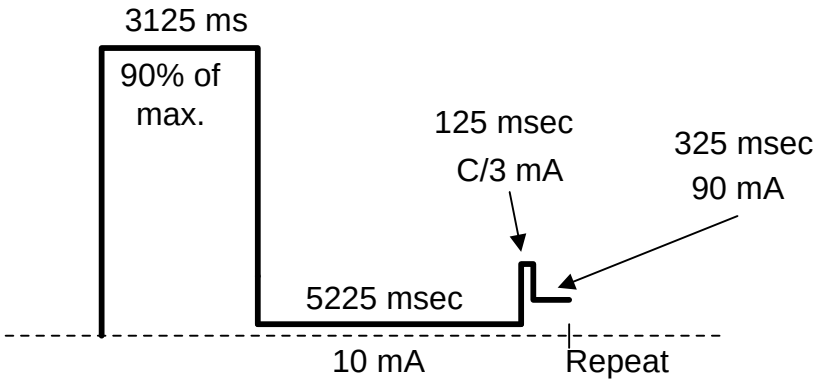
NOTE: The Smart Battery Data Specification defines various capacity functions, such as RemainingCapacity(), FullChargeCapacity(), etc. at a **P/5 mWh** or **C/5 mAh** rate which is different than the **P/2 mWh** rate defined by this LOAD-1. This difference must be considered when comparing test equipment reported data with Smart Battery reported data.

3.1.2 LOAD-2

Load profile to approximate a running notebook load's frequency and power characteristics. Maximum discharge rate not to exceed manufacturer's recommended limit.

Repetitive load definition:

Discharge Current	Duration
90% of maximum	3125 msec
10 mA	5225 msec
C/3	125 msec
90 mA	325 msec



If the C rate is not supplied in mAh by the pack manufacturer, then the C rate will be calculated by:

DesignCapacity()[mWh] / DesignVoltage()[mV]

3.1.3 END OF CHARGE CYCLE

The battery is considered at an **END OF CHARGE CYCLE** when it has been charged until a combination of the following bits in the AlarmWarning() or BatteryStatus() values are set:

	FULLY_CHARGED
and/or	TERMINATE_CHARGE_ALARM
and/or	OVERCHARGED_ALARM
and/or	ChargingCurrent() value is zero.

Any combination of the above bits may indicate that charging is complete. Note that the combination of bits used in the test may simply indicate that charging is to be stopped but that the Smart Battery is not yet "full." Refer to the *Smart Battery Data Specification* for the correct way to set or clear BatteryStatus() values to specify a "full" battery.

<u>The specific combination used for the particular Smart Battery being tested must be documented in the test report.</u>

3.1.4 END OF DISCHARGE CYCLE

The battery is considered at an **END OF DISCHARGE CYCLE** when it has been discharged until a combination of the following bits in AlarmWarning() or BatteryStatus() values are set:

FULLY_DISCHARGED
and/or TERMINATE_DISCHARGE_ALARM

Any combination of the above bits used in the test may indicate that discharging cycle is complete at the present discharge rate. Note that the combination of bits used in the test may simply indicate that discharging is to be stopped but that the Smart Battery is not yet "empty." Refer to the *Smart Battery Data Specification* for the correct way to set or clear BatteryStatus() values to specify an "empty" battery.

The specific combination used for the particular Smart Battery being tested must be documented in the test report.

3.1.5 CHARGE-A

Charge at the rate specified by ChargingCurrent() and ChargingVoltage() values read from the battery or broadcast by the battery. **CHARGE-A** is complete when the battery indicates that it has reached an **END OF CHARGE CYCLE** or it has reached the value of RelativeStateOfCharge() specified in the test definition. The charge current and voltage may not exceed the manufacturer's maximum charge limits.

3.1.6 CHARGE-B

Charge at 0.5C rate. If the 0.5C rate is not supplied in mAh by the pack manufacturer, then the 0.5C rate will be calculated by the equation:

0.5 * DesignCapacity()[mWh] / DesignVoltage()[mV]

The charge current and voltage may not exceed the manufacturer's maximum charge limits or exceed the values of ChargingCurrent() and ChargingVoltage() values read from the battery or broadcast by the battery. **CHARGE-B** is complete when the battery indicates that it has reached an **END OF CHARGE CYCLE** or it has reached the value of RelativeStateOfCharge() as specified in the test definition.

3.1.7 MEASURED VALUES

Pack voltage, current and test environment temperature as measured by the test system. Pack voltage must be measured at the pack terminals. The test system must be able to supply and deliver the specified energy values. This value may be supplied by the test system itself or by a connected device such as a PC.

Accuracy requirements of the test equipment measured values:
Voltage: +/- 0.1 % of full scale
Current: +/- 0.2 % of full scale
Temperature: +/- 0.5 °C
Capacity Integration: +/- 0.5 % of full scale (requires accurate measurement and calculation)

3.1.8 REPORTED VALUES

The following Smart Battery Data Specification data functions must be reported for the tests, unless otherwise directed by each test: Temperature(), Voltage(), Current(), AverageCurrent(), RemainingCapacity() [mWh], FullChargeCapacity() [mWh], BatteryStatus(), RunTimeToEmpty(), AverageTimeToEmpty(), AverageTimeToFull(), CycleCount(), RelativeStateOfCharge(), and MaxError(). These values will be plotted as part of the test report.

NOTE: Although not all Smart Battery Data Specification data value functions are required for these tests, they are still required for Smart Battery Data compliance. Data functions such as AtRate(), AtRateTimeToEmpty(), etc. are important for predictive power management in Smart Battery Systems. Future versions of these guidelines may include tests for these functions.

The Smart Battery must be set to 10mWh mode for all tests by setting the CAPACITY_MODE bit in the BatteryMode() function. If the 10mWh CAPACITY_MODE operation is not possible, it must be noted in the test log as differing from the procedures.

3.1.9 TEST ENVIRONMENT

Testing must be performed at the environmental temperature specified in the test definition with a tolerance of +/-5°C. The MEASURED temperature value should be measured with the temperature sensing device within 10mm of the battery pack. When setting the temperature during a test, the test environment must be allowed to stabilize before continuing with the next test step. Pressure and humidity are assumed to be 1 atmosphere at sea level non-condensing. Abnormal altitude or humidity conditions should be noted on the test log.

The maximum allowable skew between data collected from the test equipment and data read from the Smart Battery must be less than +/-5 seconds. Retries within the maximum skew period are allowed.

3.2 Procedures

3.2.1 CHARGE BATTERY

Charge the battery using CHARGE-A or CHARGE-B. While charging the battery, the test system must record and timestamp MEASURED and REPORTED values at a minimum rate of once per minute while RelativeStateOfCharge() < 90% and once every 10 seconds while RelativeStateOfCharge() => 90%.
The CHARGE BATTERY procedure is complete when the battery has reached an END OF CHARGE CYCLE unless one of the following conditions is specified in the test definition:

- RelativeStateOfCharge() reaches the specified value
- A specified time period expires
- The battery terminal voltage reaches the maximum value specified by the manufacturer. (A test stopped due to manufacturer limits must be noted in the test log since this is a non-expected operation.)

If one of the above conditions is specified, the charge must be stopped when the specified condition is reached.

The data collection rate may be changed in any procedure by specifying a new collection rate. The new rate will apply regardless of the RelativeStateOfCharge() value, as long as the new rate is higher than the original rate. The SMBus clock and data lines must be held high in the idle periods between communication transactions.

Smart Batteries with internal chargers may not be able to use the Charge-A or -B rates. Alternate test criteria must be specifically noted in the test log when these systems are tested.

3.2.2 DISCHARGE BATTERY

Discharge the battery using LOAD-1, LOAD-2, or a specified power or current. While discharging the battery, the test system must record and timestamp MEASURED and REPORTED values at a minimum rate of once per minute while RelativeStateOfCharge() >= 10% and once every 10 seconds while RelativeStateOfCharge() < 10%.
The DISCHARGE BATTERY procedure is complete when the battery indicates that it has reached an END OF DISCHARGE CYCLE unless one of the following conditions is specified in the test definition:

- RelativeStateOfCharge() reaches a specified value
- A specified time period expires
- The battery terminal voltage reaches a minimum value specified by the manufacturer. (A test stopped due to manufacturer limits must be noted in the test log since this is a non-expected operation.)

If one of the above conditions is specified, the discharge must be stopped when the specified condition is reached.

The data collection rate may be increased in any procedure by specifying a new collection rate. The new rate will apply regardless of the RelativeStateOfCharge() value, as long as the new rate is higher than the original rate. The SMBus clock and data lines must be held high in the idle periods between communication transactions.

3.2.3 REST BATTERY

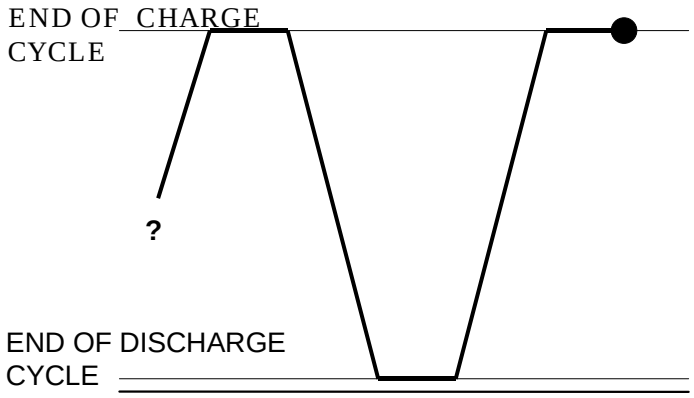
Disconnect only loads and sources between the battery and test system for specified time period and record and timestamp MEASURED and REPORTED values at a minimum rate of once per minute. The SMBus clock and data lines must be held high in the idle periods between communication transactions.

3.2.4 RE-LEARN CAPACITY

Capacity self re-learn by battery electronics

1. Set TEST ENVIRONMENT to 25°C (allow temperature to stabilize)
2. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE *
3. REST BATTERY for 60 minutes
4. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE *
5. REST BATTERY for 60 minutes
6. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE *
7. REST BATTERY for 60 minutes

* Note: If, in order to cause a capacity re-learn, the above conditions are different, then they should be noted on the test log.



Estimated time: __>7__ hours

4. Test Procedures

4.1 Capacity Estimation Tests

Capacity Test Matrix

Test Name & Description	Charge Procedure	Discharge Cycling Load	Final Discharge Load
TEST 1A (Full to Empty)	Charge-A	Load-1	Load-1
TEST 1B	Charge-A	Load-2	Load-2
TEST 1C	Charge-A	Load-2	Load-1
TEST 2A (Full to 35%)	Charge-B	Load-1	Load-1
TEST 2B	Charge-B	Load-2	Load-2
TEST 3A (80% to 30%)	Charge-A	Load-1	Load-1
TEST 3B	Charge-A	Load-2	Load-2

4.1.1 TEST 1A: 3 complete cycles at 35°C using Charge-A and Load-1

Full cycle capacity measurement accuracy test 1A

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
14. REST BATTERY for 60 minutes
15. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
16. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
17. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 16) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

4.1.2 TEST 1B: 3 complete cycles at 35°C using Charge-A and Load-2

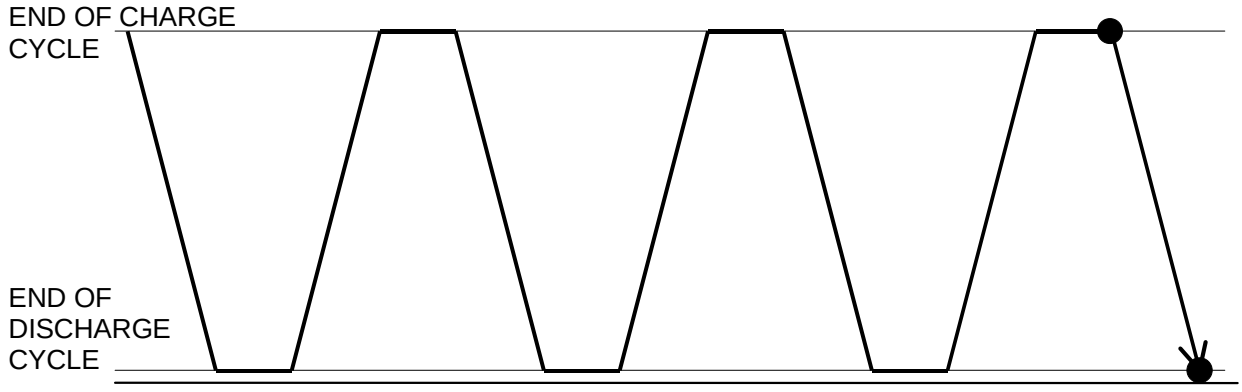
Full cycle capacity measurement accuracy test 1B

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
14. REST BATTERY for 60 minutes
15. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
16. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
17. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 16) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

Example Waveform: Tests 1A, 1B, 1C



4.1.3 Test 1C: 3 complete cycles at 35°C using Charge-A, Load-2, and Load-1

Full cycle capacity measurement accuracy test 1C

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-A until END OF CHARGE CYCLE
14. REST BATTERY for 60 minutes
15. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
16. DISCHARGE BATTERY using **LOAD-1** until END OF DISCHARGE CYCLE
17. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 16) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

4.1.4 TEST 2A: 5 cycles to 35% at 35°C using Charge-B and Load-1

Partial discharge, full charge capacity measurement accuracy test 2A

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=35%
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=35%
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=35%
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
14. REST BATTERY for 60 minutes
15. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=35%
16. REST BATTERY for 60 minutes
17. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
18. REST BATTERY for 60 minutes
19. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=35%
20. REST BATTERY for 60 minutes
21. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
22. REST BATTERY for 60 minutes
23. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
24. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
25. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 24) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

4.1.5 TEST 2B: 5 cycles to 35% at 35°C using Charge-B and Load-2

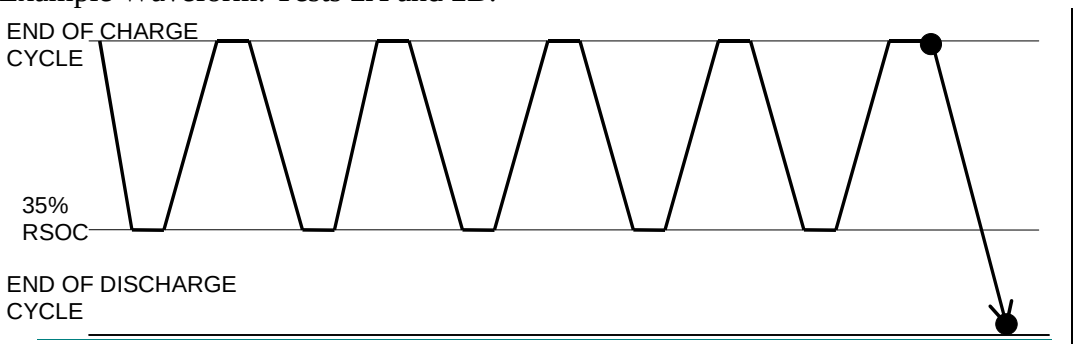
Partial discharge, full charge capacity measurement accuracy test 2B

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=35%
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=35%
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=35%
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
14. REST BATTERY for 60 minutes
15. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=35%
16. REST BATTERY for 60 minutes
17. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
18. REST BATTERY for 60 minutes
19. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=35%
20. REST BATTERY for 60 minutes
21. CHARGE BATTERY using CHARGE-B until END OF CHARGE CYCLE
22. REST BATTERY for 60 minutes
23. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
24. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
25. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 24) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

Example Waveform: Tests 2A and 2B:



4.1.6 TEST 3A: 5 cycles from 80% to 30% at 35°C using Charge-A and Load-1 Partial charge, partial discharge capacity measurement accuracy test 3A

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=30%
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=30%
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=30%
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
14. REST BATTERY for 60 minutes
15. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=30%
16. REST BATTERY for 60 minutes
17. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
18. REST BATTERY for 60 minutes
19. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge()=30%
20. REST BATTERY for 60 minutes
21. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
22. REST BATTERY for 60 minutes
23. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
24. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
25. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 24) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

4.1.7 TEST 3B: 5 cycles from 80% to 30% at 35°C using Charge-A and Load-2

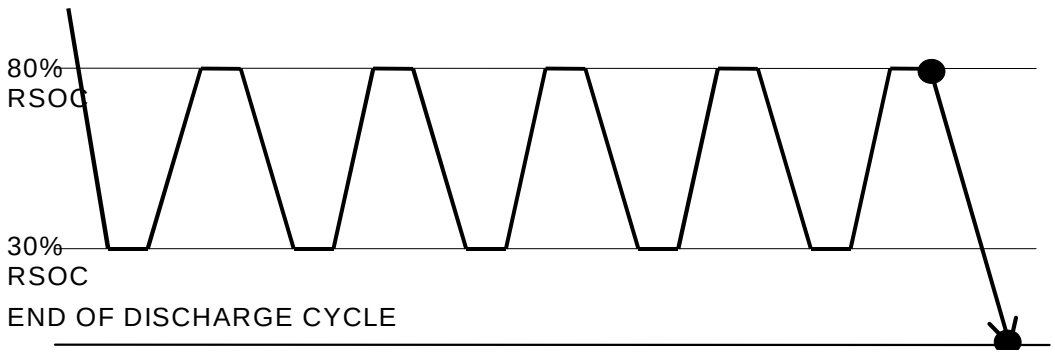
Partial charge, partial discharge capacity measurement accuracy test 3B

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 35°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=30%
4. REST BATTERY for 60 minutes
5. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
6. REST BATTERY for 60 minutes
7. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=30%
8. REST BATTERY for 60 minutes
9. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
10. REST BATTERY for 60 minutes
11. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=30%
12. REST BATTERY for 60 minutes
13. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
14. REST BATTERY for 60 minutes
15. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=30%
16. REST BATTERY for 60 minutes
17. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
18. REST BATTERY for 60 minutes
19. DISCHARGE BATTERY using LOAD-2 until RelativeStateOfCharge()=30%
20. REST BATTERY for 60 minutes
21. CHARGE BATTERY using CHARGE-A until RelativeStateOfCharge()=80%
22. REST BATTERY for 60 minutes
23. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
24. DISCHARGE BATTERY using LOAD-2 until END OF DISCHARGE CYCLE
25. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 24) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

Example Waveform: Tests 3A and 3B:



4.1.8 TEST 4: Storage Test at 40°C

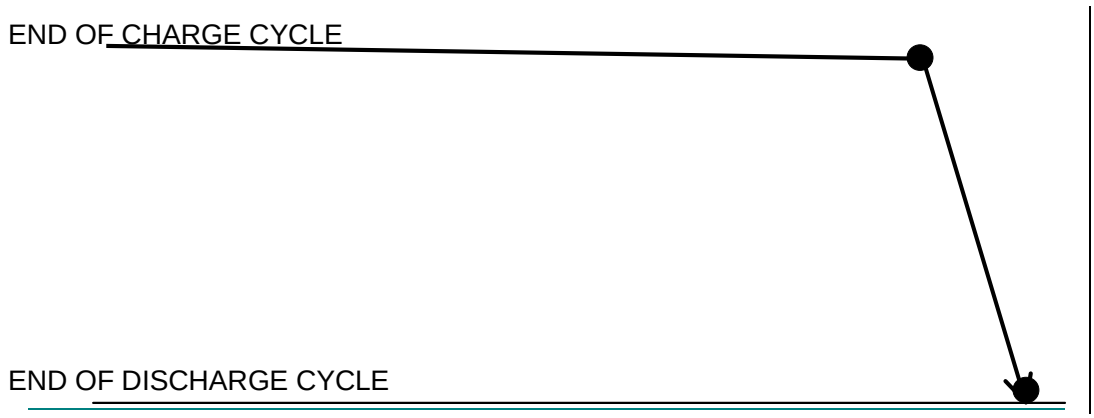
Week long storage at 40°C capacity estimation test

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 40°C
3. REST BATTERY for 168 hours (1 week); (Disconnect battery during the rest.)
4. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
5. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
6. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 5) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

Example Waveform: Test 4:



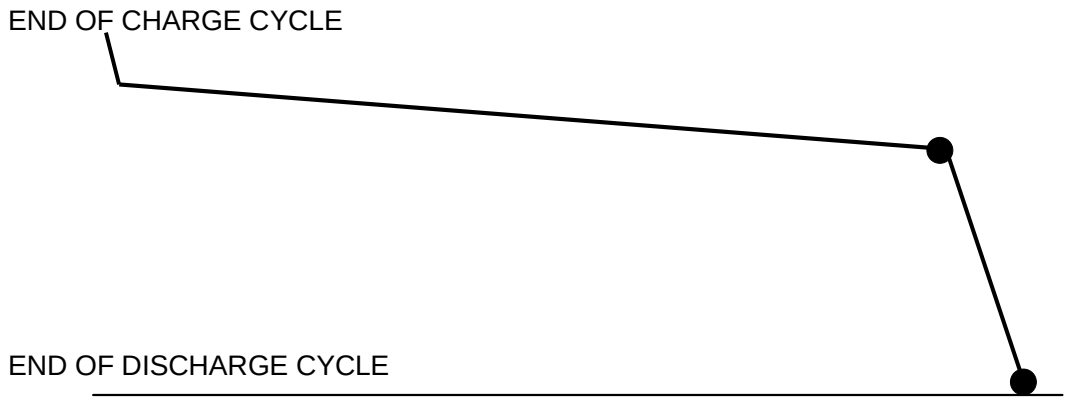
4.1.9 TEST 5: Prolonged Suspend Current

Procedure

1. RE-LEARN CAPACITY
2. Set TEST ENVIRONMENT to 25°C (allow temperature to stabilize)
3. DISCHARGE BATTERY using LOAD-1 until RelativeStateOfCharge() is 60%
4. DISCHARGE BATTERY at 20 mA for 48 hours or until RelativeStateOfCharge() is 15%, whichever occurs first
5. Separately record capacity readings for both Smart Battery (X_0) and test equipment (Y_0) before the beginning of the final discharge.
6. DISCHARGE BATTERY using LOAD-1 until END OF DISCHARGE CYCLE
7. Separately record the final capacity readings for both Smart Battery (X_1) and test equipment (Y_1). Report "single number" result for this test as $|X_1-X_0| - |Y_1-Y_0|$ to represent the error in the final discharge (Step 6) only. (Depending on the test equipment capacity reporting method, the equation may be different.)

Estimated time: _____ hours + RE-LEARN time of __>7__ hours

Example Waveform: Test 5:



4.2 Measurement Accuracy Tests

4.2.1 TEST 6: Temperature(), Voltage(), Current() and AverageCurrent() Accuracy

Since the pack voltage is measured at the pack terminals and the reported Voltage() is measured internally by the battery electronics, a difference is expected in these values. This difference should be proportional to the magnitude of the charge or load current.

Procedure

1. DISCHARGE BATTERY until END OF DISCHARGE CYCLE
2. CHARGE BATTERY until RelativeStateOfCharge()=33%
3. Set TEST ENVIRONMENT to 5°C *
4. DISCHARGE BATTERY using LOAD-1 for 5 minutes while recording data every second
5. DISCHARGE BATTERY at 70 mA for 5 minutes while recording data every second
6. REST BATTERY for 5 minutes while recording data every second
7. CHARGE BATTERY at 70 mA for 5 minutes while recording data every second
8. CHARGE BATTERY using CHARGE-B for 5 minutes while recording data every second
9. Set TEST ENVIRONMENT to 25°C *
10. DISCHARGE BATTERY using LOAD-1 for 5 minutes while recording data every second
11. DISCHARGE BATTERY at 70 mA for 5 minutes while recording data every second
12. REST BATTERY for 5 minutes while recording data every second
13. CHARGE BATTERY at 70 mA for 5 minutes while recording data every second
14. CHARGE BATTERY using CHARGE-B for 5 minutes while recording data every second
15. Set TEST ENVIRONMENT to 40°C *
16. DISCHARGE BATTERY using LOAD-1 for 5 minutes while recording data every second
17. DISCHARGE BATTERY at 70 mA for 5 minutes while recording data every second
18. REST BATTERY for 5 minutes while recording data every second
19. CHARGE BATTERY at 70 mA for 5 minutes while recording data every second
20. CHARGE BATTERY using CHARGE-B for 5 minutes while recording data every second

Estimated time: _____ hours

* Note: After setting the temperature, wait until the Temperature() becomes stable.

5. Data Reporting

Test system must provide data in the CSV (human readable comma delimited text) format. Briefly, a CSV file is a comma delimited text file used to import human readable information into an Excel (or other) spreadsheet. Each line is formed as follows: a series of numbers (integer or floating point) each followed by a comma unless the number is last one in the line. In that case, the number is followed by a carriage return (0x0d) and a linefeed (0x0a). For invalid and missing data, there are two cases: first if the data is not the last number on the line then just the following comma is used (e.g. no number or special characters), in the second when the last number in a line is missing or invalid then no comma is needed and the line is terminated normally (e.g. by a carriage return followed by a linefeed). When there is no data on the line at all, a carriage return followed by a line feed is used.

5.1 Test Results Reporting Formats

5.1.1 Report Format for Tests 1 to 5

General Test Information:

Standard Accuracy Reporting						(Excel Format)									June 15, 2000	
Battery Identification						(General)				New:						
	Cell Arrangement		9S			**Serial Number**	0500			**FULL Definition:**			Bits:			
	Manufacturer		Name			**Device Name**	DEVNAME									
	Nominal Voltage		10.8V			**Chemistry**	NIMH			**EMPTY Definition:**			Bits:			
	Design Capacity		3500 mAH, 37.8 WH			**ManufDate**	January, 2000									
	Test Version		V0.95			**SBData Version**	V1.0									
										New:						
Test Number		2A				(Specific to Test)				**Results Summary**					**SBData**	**Test Equip.**
	Date/Time of Test			Feb., 2000							Last Discharge:		Start		X0	Y0
	Measurement Equipment			Maccor: Ch. 5, Script File: S-3A-									End		X1	Y1
	SBData Equipment			Full Data File: Test3A-Core-NiMH-									Result			
New:	**Test Equipment Accuracy**															

Measured Values Data:

Capacity Tests 1 to 5							
Test Equipment					**Elapsed**		
Measured Values			**Optional**	**Calc.**	**Test**	**Test**	
V	**I**	**T**	**Capacity**	**Energy**	**Step**	**Time**	
(mV)	**(mA)**	**('C)**	**(mAH)**	**(WH)**		**(sec)**	

Smart Battery Data:

Capacity Tests 1 to 5													
Optional	**Smart Battery**	(Data read within +/- 5 sec of test equipment readings.											
Alt.	**Reported Values**	Failed readings can be re-tried and/or reported as blanks.)											
Test Time	**V**	**I**	**T**	**Avg_I**	**RemCap**	**RSOC**	**RTTE**	**AvTTE**	**AvTTF**	**FCC**	**Cycle**	**BattStat**	**MaxErr**
(seconds)	**(mV)**	**(mA)**	**('C)**	**(mA)**	**(10mWH)**	**(%)**	**(min)**	**(min)**	**(min)**	**(10mWH)**	**(integer)**	**(hex)**	**(%)**

5.1.2 Report Format for Test 6

Measurement Test 6												
Test Equipment					Elapsed		Optional	Smart Battery			
Measured Values			Optional	Calc.	Test	Test	Alt.	Reported Values			
V	I	T	Capacity	Energy	Step	Time	Test Time	V	I	T	Avg_I
(mV)	(mA)	('C)	(mAH)	(WH)		(sec)	(seconds)	(mV)	(mA)	('C)	(mA)