Keywords: Fuelgauge, ModelGauge, battery, fuel gauge, stepped discharge, charge to full, constant current discharge, Coulomb

APPLICATION NOTE 5037

Characterizing a Battery for Use with a Fuel Gauge

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Abstract: To maximize a battery fuel gauge's performance, the battery pack must be characterized so that the cell's behavior can be fully understood. This application note outlines the setup and procedure for characterizing a battery, including an explanation of charge-to-full, constant-current-discharge, and stepped-discharge routines. The article also outlines a procedure to perform a stepped discharge.

A similar version of this article appeared in the July 1, 2011 issue of *Power Electronics Technology* magazine.

Introduction

To obtain the best performance from a battery fuel gauge, the battery pack must be characterized so that the cell's behavior in an application can be fully understood. To perform the characterization, Maxim and other fuel-gauge vendors recommend charging the pack at room temperature. Then, discharge the pack at heavy, medium, and light loads at room temperature. At cold and hot temperatures, discharge the pack at medium loads. Additionally, a stepped discharge is recommended to observe how the pack relaxes during discharging. This article outlines the setup and procedure for properly collecting this data for Maxim's ModelGauge™ series (the MAX17040/MAX17041 and MAX17043/MAX17044). The collected data can then be used to create a custom model for use with the fuel-gauge chip.

Setup

The cell being tested should connect to the test system, using good Kelvin sense connections, and be placed in an environmental chamber that can be set to 40°C, 20°C, and 0°C. Additionally, the test-system temperature probe should be placed in close contact with the skin of the cell under test.

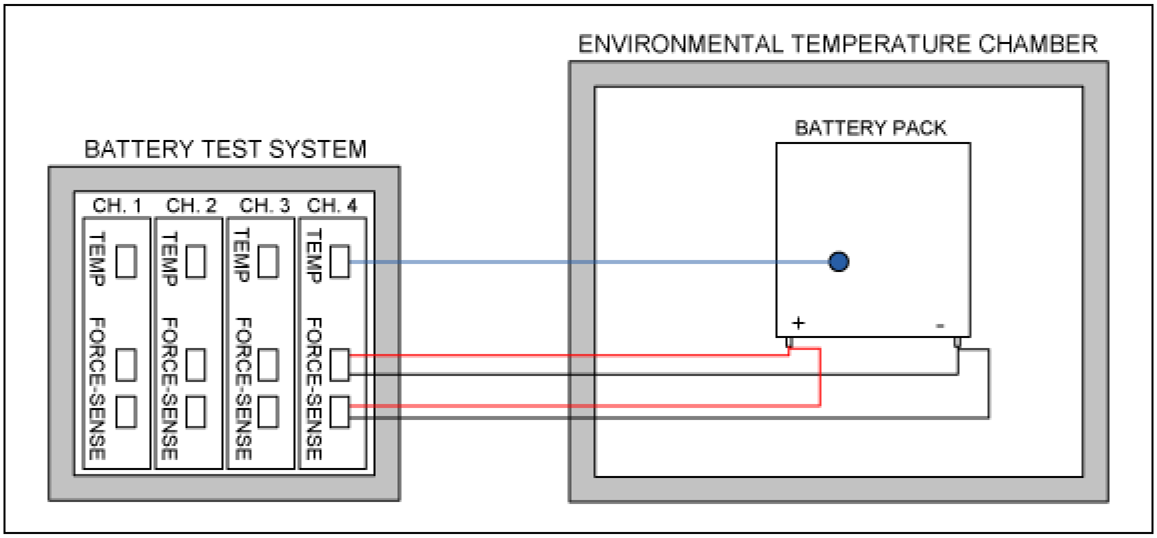

Figure 1. Setup of a cell characterization system.

Next, create a Cell Characterization Request (CCR) form and enter the charge/discharge parameters for this application. Submit it to the fuel-gauge chip supplier to create a profile that will be used to customize the fuel gauge for that specific battery pack. For example, when Maxim's CCR form is filled out and returned, a custom project number is assigned to ensure the fuel-gauge chips are properly configured.

Cell Characterization Parameters

Cycle the battery pack with the charging and discharging levels that will be used in the application. The following are example values for a single-cell battery pack.

Charge Current: C Rate/2
Charge Voltage: 4.2V
Terminating Current: 50mA

Heavy Load: 1.5 × Typical Active Current
Medium Load: 1 × Typical Active Current
Light Load: Typical Active Current/4 or C Rate/10
Empty Voltage: 3.0V
(Note: Measure the empty voltage at the cell, not outside the pack.)

Hot: +40°C
Room: +20°C
Cold: 0°C

Definitions

There are three basic routines that must be implemented to properly characterize a cell for use with a ModelGauge device. These routines are charge to full, constant current discharge, and stepped discharge.

Charge to full is charging the battery pack at the charge current until the pack voltage reaches the charge voltage. At that time, the voltage is held at the charge voltage until the current tapers below the terminating current. It is recommended that during characterization, all charges occur at room temperature, and the cell is allowed to "relax" for at least 60 minutes after each charge. See **Figure 2** for a sample charge cycle.

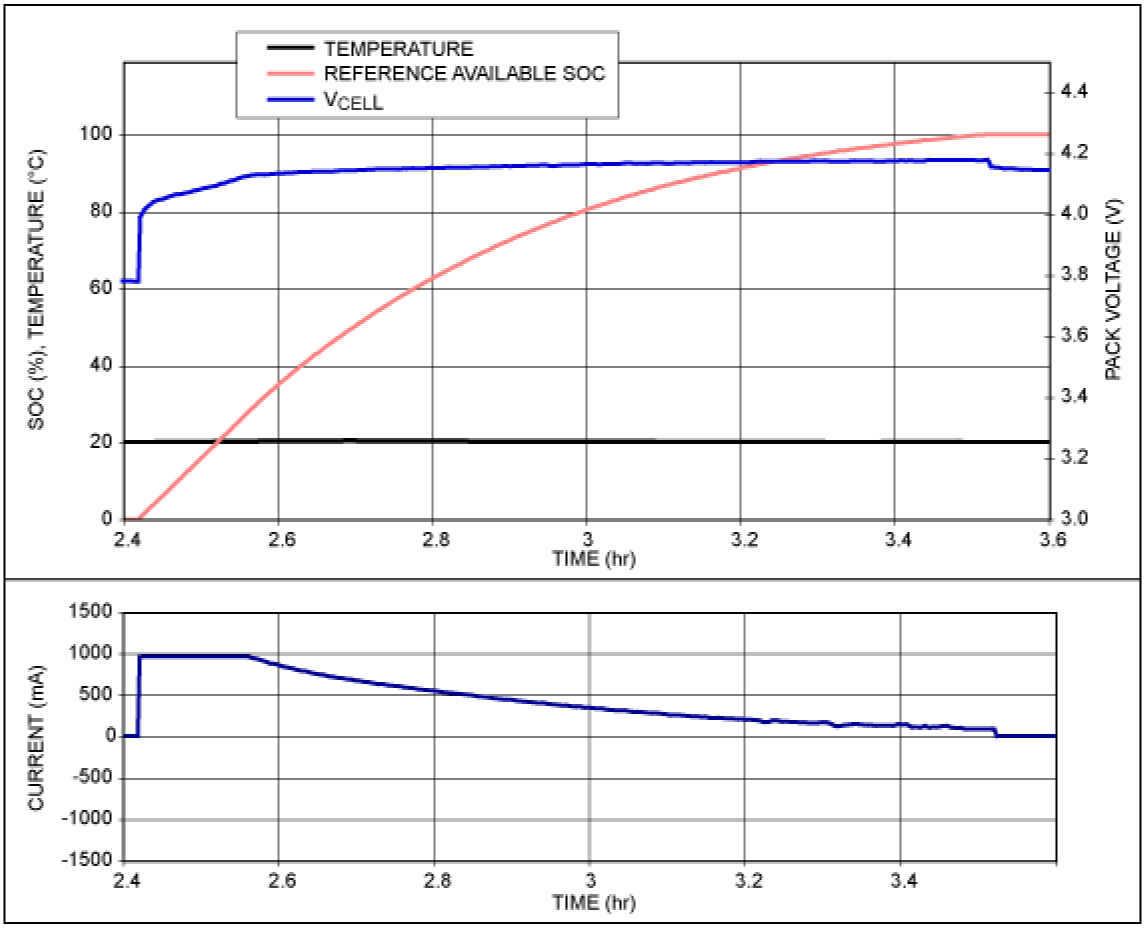

Figure 2. Typical battery-pack characteristics during a charge-to-full cycle.

Discharge is a constant-current loss of charge at the specified rate, until the battery pack's voltage drops to the empty-voltage level. It is recommended that the cell relax for at least 60 minutes after each discharge. At room temperature, perform constant-current discharges with heavy, medium, and light loads. Repeat the constant-current discharge at hot and cold temperatures as well. See **Figure 3** for an example discharge from full to empty with a constant current. Note that after the cell reaches the empty voltage, the cell voltage will recover to a higher voltage, as the cell is allowed to "relax."

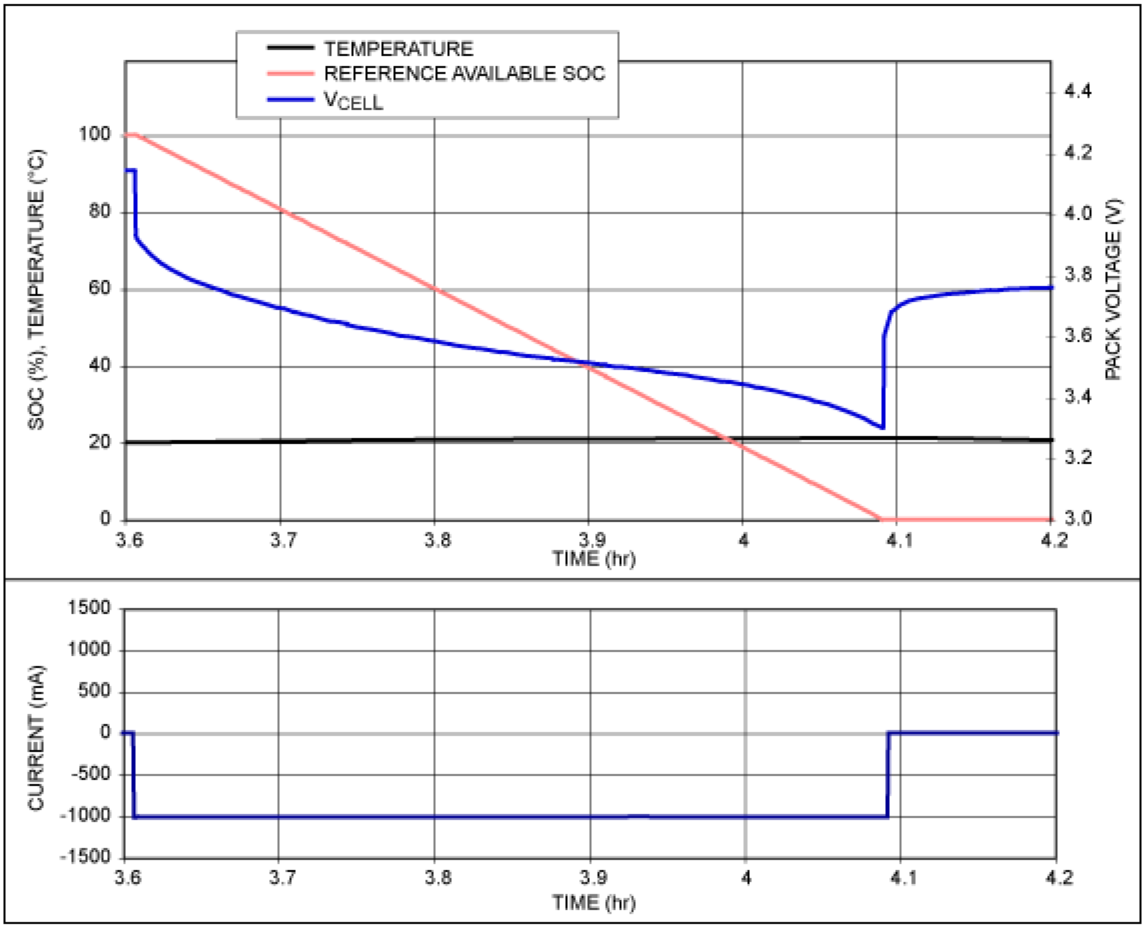

Figure 3. Constant-current discharge from full to empty. After the cell reaches the empty voltage, the cell voltage will recover to a higher voltage as the cell is allowed to "relax."

Stepped discharge is discharging the cell at the heavy load for approximately 20% of the capacity of the battery, and then allowing the cell to relax for 60 minutes (**Figure 4**). For a C/2 discharge rate, a stepped discharge of 24 minutes is recommended. Continue these 20% discharge steps until the voltage reaches the empty voltage level.

To allow the battery to relax between the relaxed states of the first stepped discharge, run three additional stepped discharge cycles with a first step of 5%, 10%, and 15% of the battery's capacity. This creates an offset of the relaxed states. For a C/2 discharge rate, a 6-minute discharge will provide the 5% offset, a 12-minute discharge will provide the 10% offset, and an 18-minute discharge will provide the 15% offset. Continue with the original 20% discharge steps until the voltage reaches the empty-voltage level. The stepped discharges are described in Steps 16-27 of the following procedure.

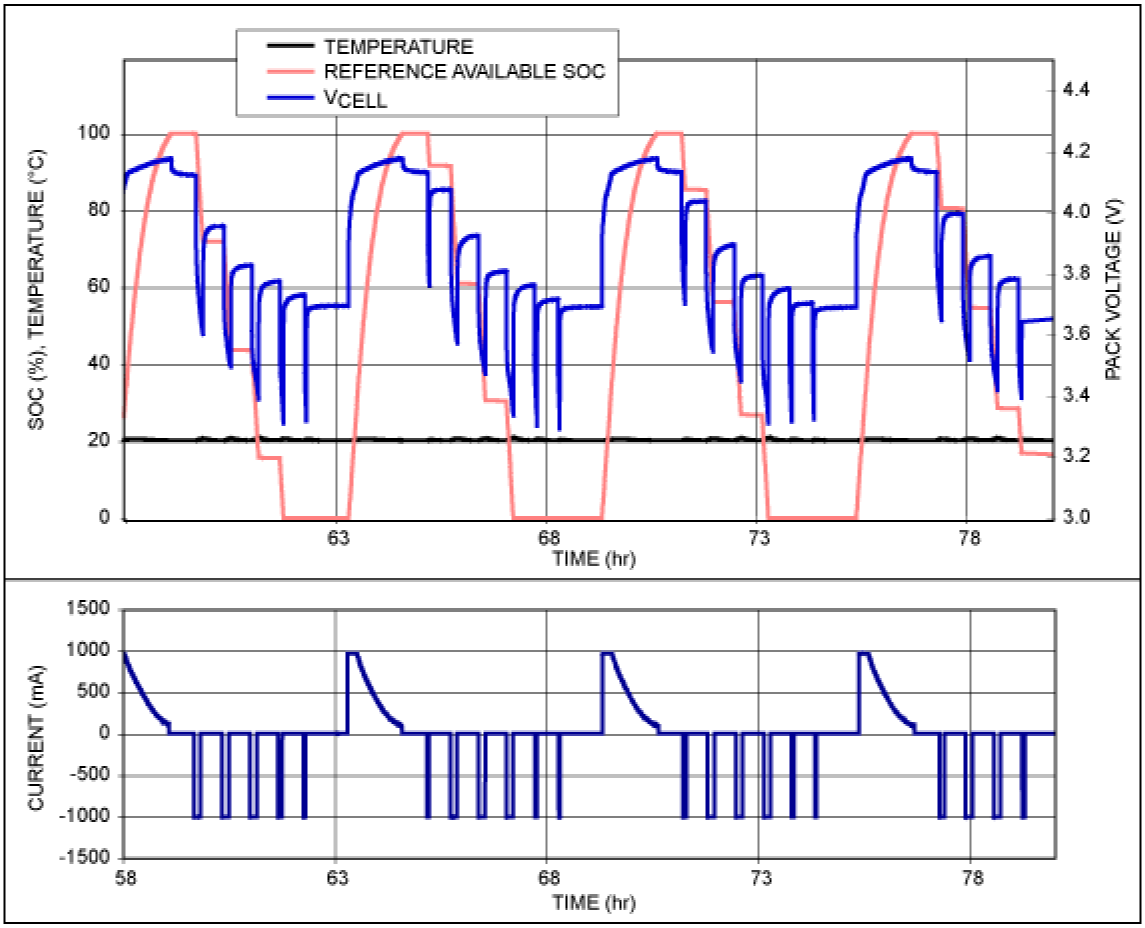

Figure 4. Stepped discharge is done by discharging the cell at the heavy load for approximately 20% of the capacity of the battery, and then allowing the cell to relax for 60 minutes.

Procedure to Perform the Stepped Discharge

1. Set the environmental chamber to 20°C. *(Allow the cell to dwell for 30 minutes at each temperature change.)*
2. Charge the cell to Full and allow the cell to relax. *(Each relax should be approximately 1 hour.)*
3. Set the environmental chamber to 40°C.
4. Discharge to the Empty Voltage with a medium discharge rate and allow the cell to relax. *(The medium rate is the typical active discharge current.)*
5. Set the environmental chamber to 20°C.
6. Charge to Full and allow the cell to relax.
7. Discharge to the Empty Voltage with a medium discharge rate and allow the cell to relax.
8. Charge to Full and allow the cell to relax.
9. Set the environmental chamber to 0°C.
10. Discharge to the Empty Voltage with a medium discharge rate and allow the cell to relax.
11. Set the environmental chamber to 20°C.
12. Charge to Full and allow the cell to relax.
13. Discharge to the Empty Voltage with a heavy discharge rate and allow the cell to relax. *(The heavy rate is 1.5 × typical active discharge current.)*

14. Charge to Full and allow the cell to relax.
15. Discharge to the Empty Voltage with a light discharge rate and allow the cell to relax. (The light rate is typically the typical active discharge current/4 or C rate/10.)
16. Charge to Full and allow the cell to relax.
17. Discharge the cell 20% under a C rate/2 and allow the cell to relax for 1 hour.
18. Repeat Step 17 discharging 20% at a time until the Empty Voltage is reached. This allows the observation of open-circuit voltage (OCV) at 100%, 80%, 60%, 40%, 20%, and 0%.
19. Charge to Full and allow the cell to relax.
20. Discharge the cell 5% under a C rate/2 and allow the cell to relax for 1 hour.
21. Repeat Step 17 discharging 20% at a time until the Empty Voltage is reached. This allows the observation of OCV at 100%, 95%, 75%, 55%, 35%, 15%, and 0%.
22. Charge to Full and allow the cell to relax.
23. Discharge the cell 10% under a C rate/2 and allow the cell to relax for 1 hour.
24. Repeat Step 17 discharging 20% at a time until the Empty Voltage is reached. This allows the observation of OCV at 100%, 90%, 70%, 50%, 30%, 10%, and 0%.
25. Charge to Full and allow the cell to relax.
26. Discharge the cell 15% under a C rate/2 and allow the cell to relax for 1 hour.
27. Repeat step 17 discharging 20% at a time until the Empty Voltage is reached. This allows the observation of OCV at 100%, 85%, 65%, 45%, 25%, 5%, and 0%.
28. Charge to Full and allow the cell to relax.

A complete cycle showing the charging and discharging of the cell is shown in **Figure 5**. The waveforms illustrate what happens during each step in the procedure.

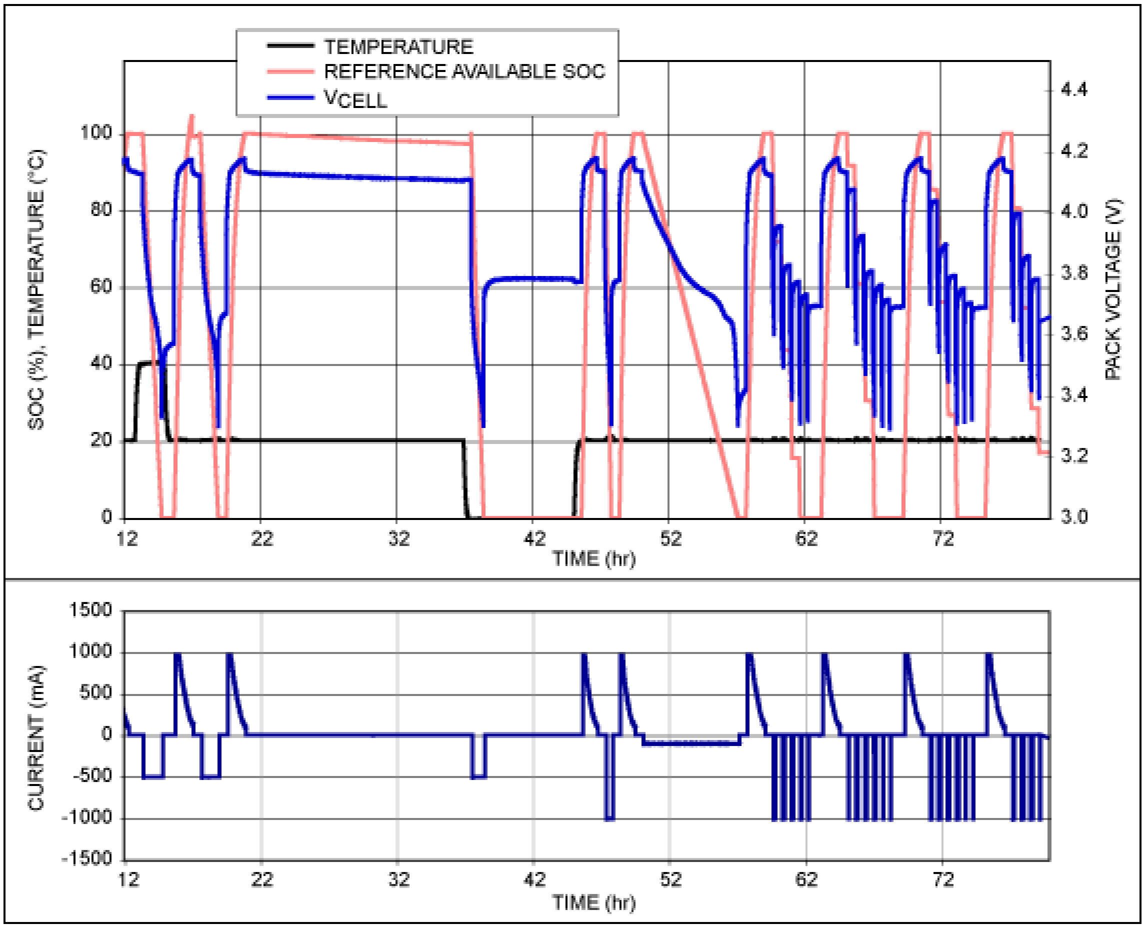

Figure 5. Complete cell-characterization cycle.

Note: Any of the rest periods can be extended indefinitely to accommodate changing temperature of the chamber.

Reference Data

In order to generate a strong reference state-of-charge (for determining error), a minimum of the following data must be collected:

- **Charge and Discharge Coulomb Counters**: These can be two registers or can be combined into one. Capacity should be measured with < 1mA coulomb-counter drift for accurate characterization and performance verification.
- **Battery Voltage**
- **Charge/Discharge Current**
- **Temperature**
- **Time**: If reference and silicon data are collected on different systems, then they should both have synchronized system clocks for accurate comparison.

To prevent the data file from becoming too large, record the data once every 15 seconds. Collect all data in one continuous file, including any extended time delays.

Data Processing

Once the procedure has been completed, send the data to the fuel-gauge vendor, clearly identifying the project number for this data. The vendor will then process the data and provide a recommended model for the cell under test, based on the charge/discharge parameters defined by the application. The model is then embedded in the fuel-gauge chip.

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Related Parts		
MAX17040	Compact, Low-Cost 1S/2S Fuel Gauges	Free Samples
MAX17041	Compact, Low-Cost 1S/2S Fuel Gauges	
MAX17043	Compact, Low-Cost 1S/2S Fuel Gauges with Low-Battery Alert	Free Samples
MAX17044	Compact, Low-Cost 1S/2S Fuel Gauges with Low-Battery Alert	Free Samples
MAX17048	Micropower 1-Cell/2-Cell Li+ ModelGauge ICs	Free Samples
MAX17049	Micropower 1-Cell/2-Cell Li+ ModelGauge ICs	Free Samples

More Information
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APPLICATION NOTE 5037, AN5037, AN 5037, APP5037, Appnote5037, Appnote 5037