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APPLICATION NOTE 4189

Characterizing a Lithium-Ion (Li+) Cell for Use with an Open-Circuit-Voltage (OCV) Based Fuel Gauge

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Abstract: The DS2786 is an open-circuit-voltage (OCV) based fuel gauge that reports the total energy that is stored in a lithium-ion (Li+) cell. The device leaves the factory with a best-fit OCV profile that can be used to accurately predict the remaining capacity of a Li+ cell. The accuracy of the DS2786 OCV fuel gauge can be improved by characterizing the Li+ cell under the conditions of the application in which it will be used.

Introduction

The DS2786 stand-alone, open-circuit-voltage (OCV) based fuel gauge estimates the available capacity of rechargeable lithium-ion (Li+) batteries based on the cell voltage in an open-circuit state following a relaxation period. The open-circuit voltage is used to determine relative cell capacity based on a lookup table stored in the IC. The DS2786 leaves the factory with a best-fit OCV profile loaded into the EEPROM of the device. The accuracy of the DS2786 can be improved by customizing the OCV profile of the Li+ cell with the charge and discharge parameters that are used in the application.

This application note outlines a method for characterizing a Li+ cell for use with an OCV-based fuel gauge, collecting and interpreting the data, and then loading the data into the DS2786K evaluation software.

Procedure for Characterizing a Li+ Cell

1. **Determine the full and empty point**
   The best way to characterize a Li+ cell is to create an environment as close as possible to the actual application in which it will be used. This includes the protection circuitry, a discharge profile consisting of the typical active and standby currents of the application, and a charging profile. This requires a method to simulate the charging and discharging of the cell and a method to monitor and record the current and voltage.

   The full point (100% capacity) is defined as the capacity where the Li+ cell is considered fully charged by the charging circuitry. The empty point (0% capacity) can be defined to be the active empty point, the standby empty point, or the absolute energy remaining in the cell.

2. **Characterize the cell**
   The procedure to characterize a Li+ cell for use with an OCV-based fuel gauge can be performed at room temperature. It is best to perform the following steps on at least three cells to obtain an average OCV profile.

   1. Charge the cell to the full point.
   2. Discharge the cell to the 0% point to learn the capacity of the cell, which should be recorded in mAh.

3. Charge the cell to the full point.
4. Allow the cell to relax for 60 minutes.
5. Record the open-circuit voltage for the 100% point.
6. Discharge the cell 5% (based on the capacity of the cell from Step 2) at a rate of approximately 0.2C.
7. Allow the cell to relax for 60 minutes.
8. Record the open-circuit voltage for the 95% point.
9. Repeat Steps 6–8 19 times until the capacity reaches 0%.

3. **Analyze the data**
   Table 1 contains sample data of a typical cell that was characterized by Maxim Integrated Products. The twenty Capacity/OCV pairs must be summarized into nine pairs that are stored in the EEPROM of the DS2786. The 100% and 0% pairs must be stored in the device. The other seven points should be selected to approximate the full set of data. **Table 2** shows the nine data pairs that were chosen to approximate the data in Table 1. **Figure 1** compares the data in Table 1 and Table 2.

Table 1. OCV Characterization Data for a Typical Li+ Cell

Capacity (%)	OCV (V)
100	4.177454
95	4.129486
90	4.085934
85	4.045427
80	4.008118
75	3.974769
70	3.945074
65	3.917968
60	3.884009
55	3.841219
50	3.820965
45	3.805737
40	3.79325
35	3.783504
30	3.775129
25	3.762185
20	3.741018
15	3.7098
10	3.686654
5	3.674776
0	3.305545

Table 2. OCV Characterization Data Stored in the DS2786

Breakpoint	Capacity (%)	OCV (V)
8	100.0	4.177454
7	82.5	4.026773
6	60.0	3.884009
5	55.0	3.841219
4	40.0	3.79325
3	25.0	3.762185
2	10.0	3.686654
1	5.0	3.674776
0	0.0	3.305545

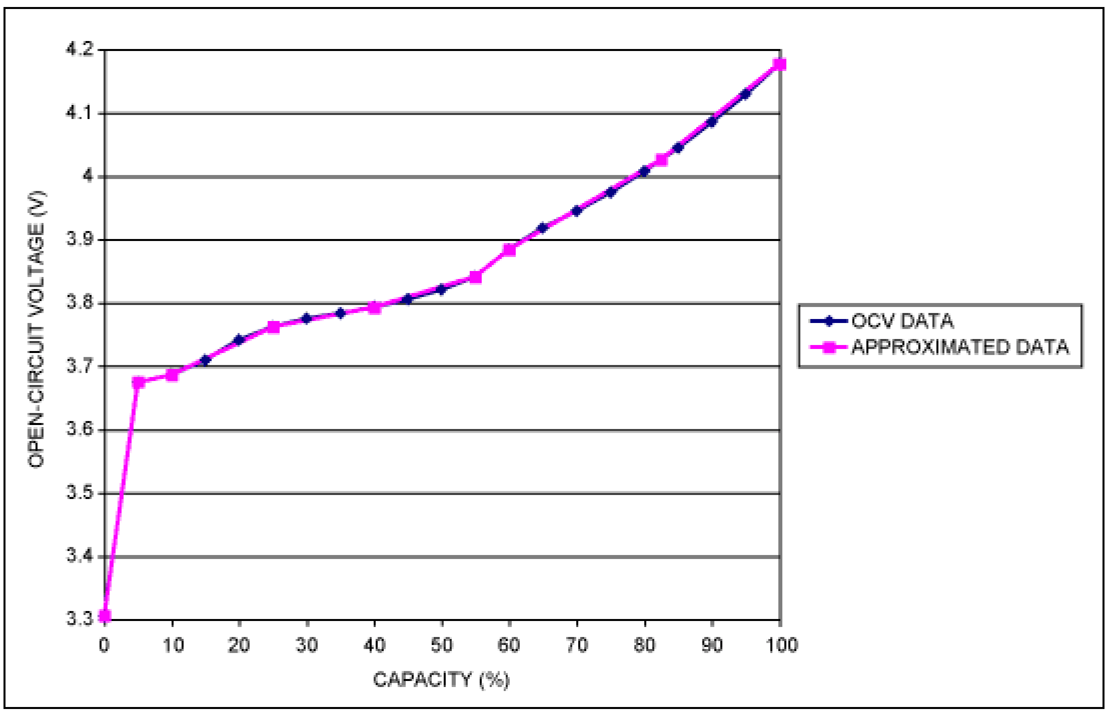

Figure 1. OCV characterization data and the nine approximated breakpoints.

4. **Store the data**
   The last step is to program the data into the EEPROM of the DS2786. The DS2786K evaluation software can be used to easily convert the data into the appropriate format that will be stored in EEPROM. Simply load the values from Table 2 into the Parameters tab of the DS2786K as shown in **Figure 2**. Additionally, the capacity of the cell (learned in Step 2) should be entered into the Initial Cell Capacity text box. Then click the Write & Copy button. Make sure a programming voltage is applied to the V_{PROG} pin of the DS2786 in order for the EEPROM to be properly programmed.

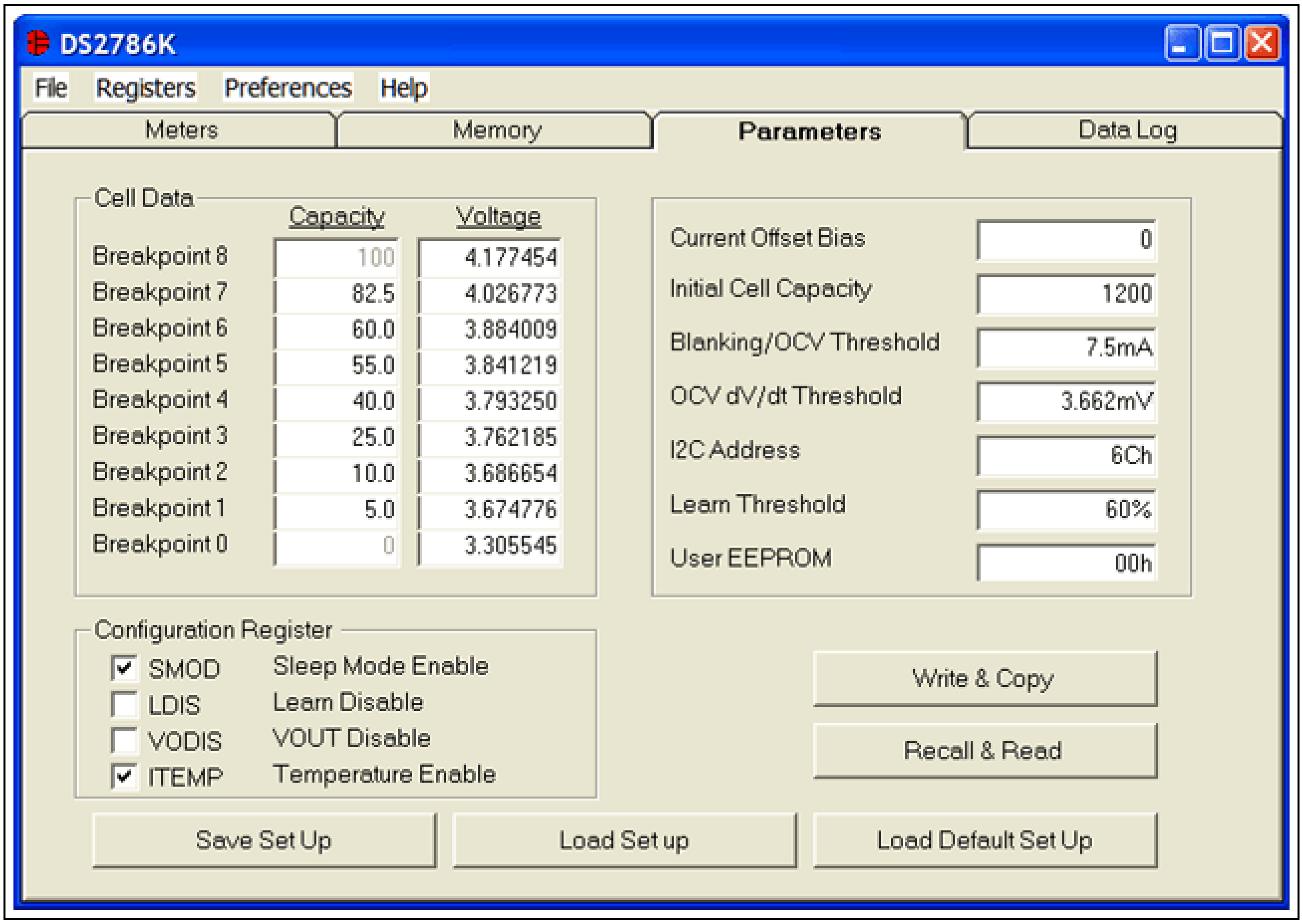

Figure 2. The Parameters tab of the DS2786K evaluation software.

Conclusion

Maxim's OCV-based fuel-gauging algorithm provides an accurate means of tracking the capacity of a Li+ cell as the cell is charged and discharged by the application. Once the characterization data is collected and stored using the evaluation software provided by Maxim, the fuel gauge will accurately estimate the remaining capacity of the cell.

Related Parts		
DS2786	Stand-Alone OCV-Based Fuel Gauge	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
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