![TEXAS INSTRUMENTS]

Support of Multiple Li-Ion Chemistries With Impedance Track™ Gas Gauges

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ABSTRACT

This application report describes the process of selecting the correct chemistry open-circuit voltage table for a particular cell and the method of correctly programming this information during production.

1   Introduction

Impedance Track™ devices rely on a fixed open-circuit voltage (OCV) table to determine the state of charge (SOC), where OCV(SOC) dependence is defined by cell chemistry. Impedance Track™ devices come preprogrammed to support the most common Li-ion cells with $LiCoO_2$ cathode and graphitized carbon anode. However, multiple other chemistries are grouped under *Li-ion*, two examples of which are Co/Mn oxide cathode cells and Ni/Co/Mn cathode cells. Therefore, Impedance Track™ devices have been designed with the ability to be programmed with any Li-ion chemistry OCV table. This application report describes the process of selecting the correct chemistry OCV table for a particular cell and the specifics of correctly programming this information during production.

2   Selection of Correct Chemistry

2.1   Chemistry Selection Table

Chemistries that are currently supported are listed in the table *Chemistry Selection* which can be found on the TI Web site, in the Tools and Software folder of the corresponding Impedance Track™-based device. The following is an example of the table format, which contains a sample of the data currently available. In the future, more entries will be added to this Web-based table as additional chemistries are identified.

Description	Chemical ID	Known Compatible Cells (Not Exclusive)
$LiCoO_2$/graphitized carbon (default)	0100	Sony US18650S, Sony 18650GR, Moly ICR-18650G, Panasonic CGR-18650C, LG Chem ICR18650A2, LG Chem ICR18650S2, A&TB LGR18650OU, Samsung SDI ICR18650-20
Co/Ni/Mn cathode	0101	Sony SF US18650GR
Hybrid Co/Mn oxide cathode	0102	Sanyo-laminate
$LiCoO_2$ ATL	0103	ATL-laminate 554490

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2.2 Firmware Support for Different Chemistries

The firmware required to support the various chemistries is identical, and therefore, no firmware upgrades are required when programming new chemistries into the data-flash (DF) memory of the corresponding Impedance Track™-based device. As an added feature, the Chemical ID of currently programmed OCV data can be checked using TI's EV Software. This is accomplished by entering 0008 into the Manufacturer Access field in the SBS screen and pressing <enter>. The Chemical ID then is reported in the Manufacturer Access field. Note that scanning should be enabled.

2.2.1 Methods to Identify Chemistry of a Particular Cell

1. Ask the manufacturer. If the use of standard LiCoO2 can be ensured, then the default database with ID 0100 can be used without change.

2. Search for the cell part number, in the *Known Compatible Cells* column of the Chemistry Selection table provided by TI. If found, then the corresponding chemistry ID can be used.

3. In manufacturer information, search for a *Description* entry similar to that found in the Chemistry Selection table provided by TI. If a similar description is found, then the corresponding chemistry ID can be used.

4. If none of these methods are successful, then a chemistry selection test can be run to help select the best possible fit. Note that this is the most time-consuming option, which requires common charge/discharge test equipment such as a Maccor or Arbin tester. However, it provides the highest confidence in a chemical database selection process. The chemistry selection test procedure is described in the Addendum *Chemistry Compatibility Check.*

2.3 Preproduction Testing With Nondefault Chemistry

Preproduction testing, using a nondefault chemistry, is the same as when using the default chemistry, with one exception — a new firmware file (*.senc) containing the OCV table specific for a particular chemistry has to be programmed into the pack first. Firmware files for selected chemistry IDs can be download from the *Tools and Software* folder of a corresponding Impedance Track™-based device. Programming of the firmware file using TI's EV Software is described in the application note *Updating Firmware With The bq20z80 and EVM* (SLUA336).

After the correct firmware file is programmed, the normal production process can proceed using the steps described in the application report *Pack Assembly and the bq20z80* (SLUA335). Note that prior to production, a relaxation/discharge/relaxation test should be done to acquire optimized parameters for use. This process is described in the application report *Preparing Optimized Default Flash Constants For Specific Battery Types* (SLUA334).

2.4 Production Process With Nondefault Chemistry

With the exception of preparing the data-flash image file, the general production process with nondefault chemistries is the same as with default chemistries, as described in the applications report *Data Flash Programming and Calibrating the bq20z80 Family of Gas Gauges* (SLUA355).

The additional steps required to prepare the data-flash image file follow.

1. Using an Impedance Track™-based device programmed with the corresponding chemistry specific firmware file (*.senc), complete the Battery Pack assembly steps, as outlined in the application report *Pack Assembly and the bq20z80* (SLUA335). Key steps include: setting basic flash constants for a given pack configuration; calibrating the pack; connecting System Present to ground; and enabling IT. It is also important to correctly set the parameters specific to the number of serial cells used. This is described in the application report *bq20z80 EVM Data Flash Settings for Number of Serial Cells and Pack Capacity* (SLVA208).

2. Input an initial estimate for QmaxCell 0, Qmax Cell 1, Qmax Cell 2, Qmax Cell 3, and Qmax Pack using the value specified in the battery manufacturer data sheet. For example, if single-cell data-sheet capacity is 2400 mAh and three parallel cells are used, set each value to $2400 \times 3 = 7200$ mAh.

3. Charge the pack to full.

4. Let the pack relax for 2 hours.

5. Discharge the pack to the minimum system-acceptable voltage (this should be the same as DF:Term Voltage) at the typical application rate. Note that the exact rate is not critical.

6. Let the pack relax for 5 hours.

7. Repeat steps 3 through 6 two times to achieve the maximum accuracy. Using the Data Flash screen in the EVSW, verify that *Update Status*, under the Gas Gauging tab, reads 06. If not, then repeat the cycle.

8. Use the EVSW to export the .gg file.

9. Open the .gg file with an application like Notepad and manually change the [IT Cfg(Gas Gauging)] *Update Status* to 02 and the [Data(SBS Configuration)] *Cycle Count* to 0. Save and close the .gg file

10. Reprogram the pack with a fresh firmware (*.senc) file with selected chemistry ID, to clear all hidden constants and set the correct chemistry specific table.

11. Use the Data Flash screen in the EVSW to import the modified .gg file, saved in step 9.

12. In the Data Flash screen of the EVSW click *Write All*

13. In the Pro screen of the EVSW, send the reset command (0x0041).

The golden pack is now ready to have its data flash read into a binary file, as described in Section 3 of the application report titled *Data Flash Programming and Calibrating the bq20z80 Family of Gas Gauges* (SLUA355).

Note that as an alternative option, small volume production facilities can use TI's single-channel prototype data-flash writing and calibration software called *bqTester*. The single site bqTester software can be downloaded directly form the TI Web site (see SLUA352). Ensure that the correct firmware version is input into the bqTester.ini file. For example for bq20z80-v102 set: DEV_VER_REV=800.1.02.

3 Addendum: Chemistry Compatibility Check

3.1 Setup

- Use a single cell, or an assembled battery pack without any electronics connected. This avoids any current draw and is important because this test takes an extended time and has long inactivity periods.
- Measure the voltage at a single cell (even if a battery pack is used)
- Current measurement accuracy is important. Especially, the current offset should be calibrated to better than a 1-mA accuracy.
- Voltage measurement accuracy is equally important and should be accurate to 1 mV (should be checked with a 0.1-mV accurate digital voltmeter).
- Configure a thermal chamber to 25°C. Note that testing at 0°C and 50°C is also required in order to create a database, but not for a compatibility check.
- Voltage, current, and temperature data should be collected with 10-s to 100-s intervals continuously during the test. The resulting file is used in the chemistry selection tool. Plain text files or Microsoft™ Excel spreadsheets are acceptable formats.

3.2 Automated Test (Can be Set Up Using Maccor or Arbin Battery Testers)

1. Charge the cell to full using the CC/CV method, and terminate the charge when taper current reaches C/100. This state of charge corresponds to full chemical capacity. Note that using the C/100 taper current is critical to ensuring an absolutely fully charged cell.

2. Turn off the current (ensure the actual current is below 1 mA) and wait 5 hours for full cell relaxation. If dV/dt smoothed over 100 s is available, wait can be terminated before 5 hours if dV/dt < 1 µV/s. This method helps speed up testing.

3. Discharge at C/20 rate for 1 hour, then go to step 2. If the voltage goes below 3 V, go to step 4.

4. Turn off the current (ensure actual current is below 1 mA) and wait 5 hours for full relaxation. If dV/dt smoothed over 100 s is available, wait can be terminated before 5 hours if dV/dt < 1 µV/s. This method helps speed up testing. Check the voltage after relaxation is terminated. If V < 3V, exit test; otherwise, proceed to step 5).

5. Discharge at C/60 rate for 30 min, or until V < 2.7 V; go to step 4.

Data obtained in this test is used in a Mathcad™ tool provided by TI. For database purposes, additional data at 0°C and 50°C is needed.

3.3 Using Mathcad™ Tool to Select Battery Chemistry

To use the chemistry selection tool, Mathcad™ 2001i or higher is needed.

Download the chemistry selection worksheet *chemselect.mcd* from *Tools and Software* folder of the corresponding Impedance Track™-based device, and then follow these steps to verify battery chemistry:

1. Remove the charge portion of the data-file acquired in the preceding testing.
2. Place the file in the same directory containing the *chemselect.mcd* file.
3. Open the chemistry selection file *chemselect.mcd.*
4. Assign columns to reflect your file format:

Columns assignment time $tn := 0$ voltage $vn := 2$ temper $ttn := 100$ curr $in := 1$
in data-file:

Change column numbers for time (tn), voltage (vn), temperature (ttn) and current (in). If temperature column is not available, set ttn:=100, and set correct chamber temperature in C in the following section:

temperature used in simulation of voltage $T := 25$
if no temperature is present in file. set
ttn=100 if not temperature info present $Tpres := T \cdot 10$

5. Enter your file name into data-loading section. You can try running the program with included example data-file *tIV_example.dat*.

Data import: load tVIT file Plain text $A := READPRN("tIV\_example.dat")$

Excel $A :=$ some_excel_file.xls

If the file is in Excel format, then right-click on the section to the right labeled *Excel* line, and click *enable evaluation*. If the file is in plain-text format, leave this section disabled. Note that, regardless, the file should not include any text headers, only data.

6. Scroll to the bottom of document, and click anywhere to place the cursor below all lines. Press F9 to execute all calculations
7. Read out the chemical ID best-suited for your battery:

Best chemistry ID

$bestchem = 103$

8. Analyze the reported error for best chemistry. If it is below 3%, this chemical ID firmware can be used with your chemistry:

$$\text{maxerr} = \begin{pmatrix} \overset{\text{error \%}}{1.96682} & \overset{\text{ID}}{103} \\ 3.937942 & 100 \\ 9.521751 & 101 \\ 17.384558 & 102 \end{pmatrix}$$

In this example, the maximum error is 1.96% for chemical ID 103 where anything below 3% is acceptable. Therefore, the firmware file (*.senc) for chemical ID 103, should be downloaded and used.

If *maxerr* for all chemical IDs exceeds 3%, a new chemical table needs to be created. To facilitate this, repeat the *Automated test* for the additional required temperatures of 0°C and 50°C. Then contact Texas Instrument support at http://www-k.ext.ti.com/sc/technical-support/product-information-centers.htm or the local sales representative. Using this data, TI will create a new chemical database. Alternatively, the cells can be sent directly to TI for evaluation/characterization but this process takes longer.

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