Application Report
SLUA771–May 2016

bq27220 Calibration Guide

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ABSTRACT

The bq27220 includes one-time programmable (OTP) profiles that allow users to program the settings that would otherwise be required to be initialized in RAM after powering up. Calibration data is one of the included subsets of data that can be programmed in to OTP. This guide goes over the process on how to calibrate the bq27220 using the provided TI tools and how to transfer that to OTP.

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1 Tools Required for Calibration

The following tools are required for calibration:

- bq27220EVM with EV2400
- 2x power supplies, one for powering the gauge; another, for the OTP programming voltage.
- DC load capable of at least 1 A.
- bqStudio (minimum v1.3.51)
- SmartFlash

2 Operation

This section details the operation of the bq27220 bqStudio software.

2.1 Starting the Program

With the EV2300 or EV2400 and the bq27220EVM connected to the computer, run bqStudio from the desktop or installation directory. The window consists of a tools panel at the top, and other child windows that can be hidden, docked in various positions, or allowed to float as separate windows. When bqStudio first starts up, the *DashBoard*, the *Registers*, and the *Commands* windows should be open. Additional windows can be added by clicking the corresponding icons in the tools panel at the top of the main window.

The **Scan** (continuous scan) or **Refresh** (single time scan) buttons can be clicked in order to update the data in the *Registers* and *Data Memory* windows.

bqStudio provides a logging function which logs selected *Data Registers* last received from the bq27220. To enable this function, click the **Start Log** button. The default elapsed interval is 4000 milliseconds, to change this interval, go to *Windows*, select *Preferences*, choose *Registers*, and change *Scan/Log* Interval from 4000 to 1000 milliseconds. There is no need to log faster than 1 second as the gauge will not update the registers faster than 1 second.

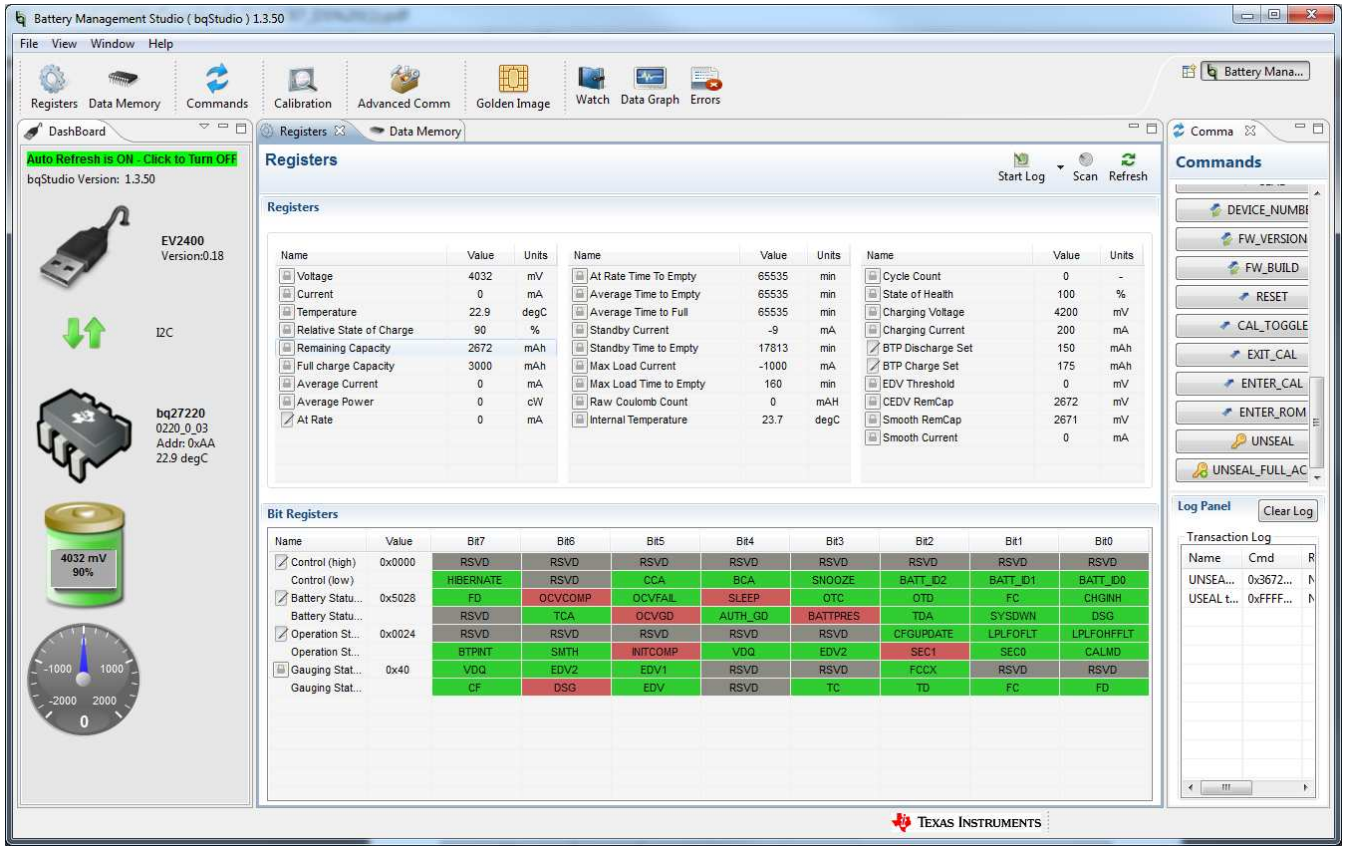

Figure 1. Registers Screen

2.2 Setting Programmable bq27220 Options

The bq27220 comes configured per the default settings detailed in the *bq27220 Technical Reference Manual* (TRM – SLUUBD4) . Ensure that the settings are correctly changed to match pack and application for the bq27220 solution being evaluated.

NOTE: The correct setting of these options is essential to get the best performance. The settings can be configured using the *Data Memory* window (Figure 2).

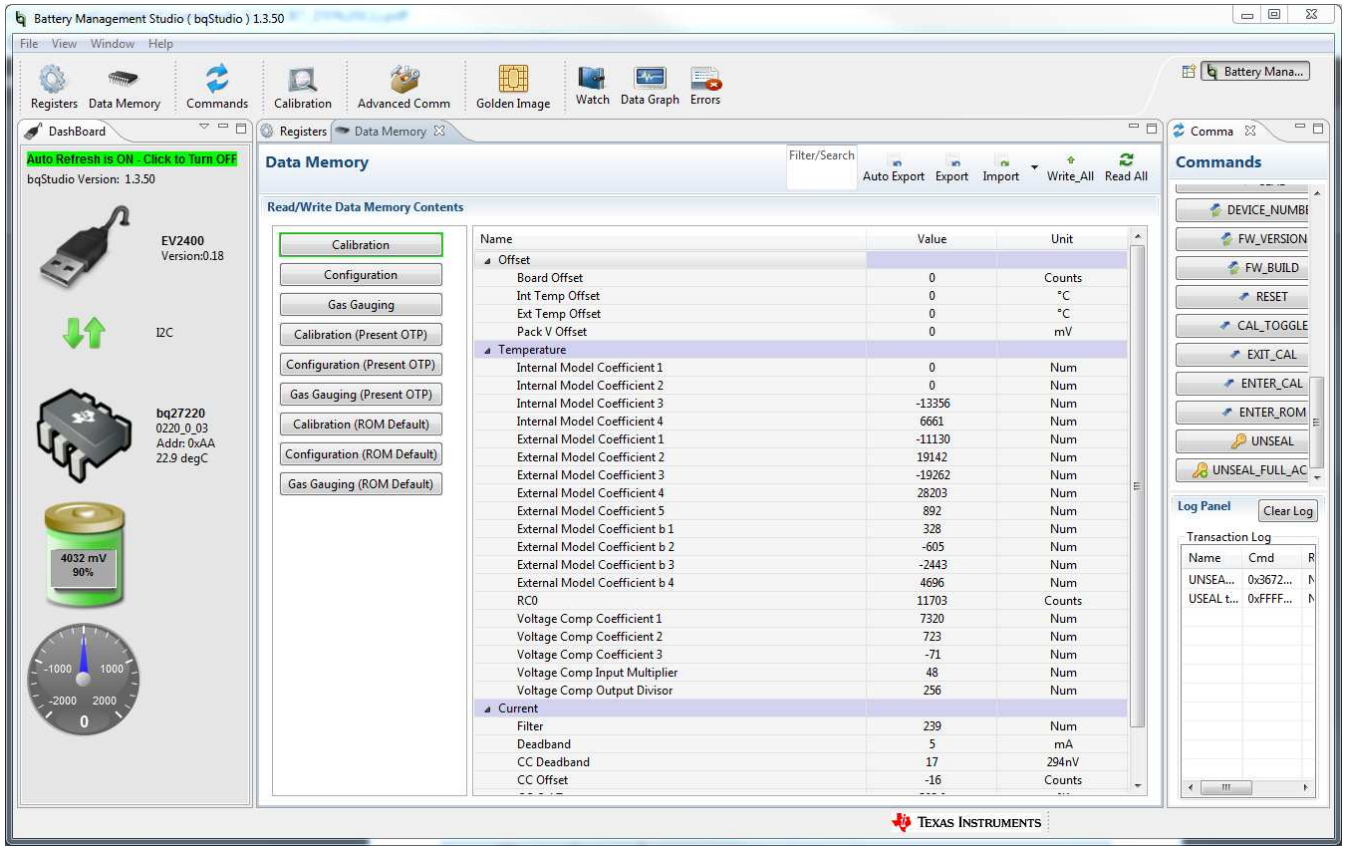

Figure 2. Data Memory Screen

To read all the data from the bq27220 RAM, OTP, and non-volatile memory, click on the **Read All** button on the *Data Memory* window. Make sure the device is not sealed and in full access to read/write to the data memory. To update a parameter in RAM, click on the desired parameter and a window will pop-up that provides details on the selected parameter. Next, enter the value in the value textbox and press **Enter**. After **Enter** has been pressed, bqStudio will update the selected parameter.

See the TRM (SLUUBD4) for details on how to program the OTP values on the bq27220.

The **Import** button in the *Data Memory* window can be clicked in order to import an entire configuration from a specified *.gg.csv file.

The configuration can be saved to a file by clicking the **Export** button in the *Data Memory* window and entering a file name. The configuration will be saved to a *.gg.csv file. The module calibration data is also held in the bq27220 data memory. If the *Gauge Dashboard* is not displaying any information, then the bq27220 may not be supported by the bqStudio version that is being used, a bqStudio upgrade may be required.

3 Calibration Process

The process to calibrate and program the OTP on the bq27220 is as follows:

1. Connect the bq27220 to bqStudio using the EV2400.
2. Perform the calibration storing the calibration data in RAM.
3. Use bqStudio to generate the ot.fs file required for OTP programming.
4. Use SmartFlash to program the OTP profile on the gauge.

See the following sections detailing the steps.

3.1 Calibration

The bq27220 must be calibrated to ensure accurate value reporting. This can be done by going to the *Calibration* window in bqStudio.

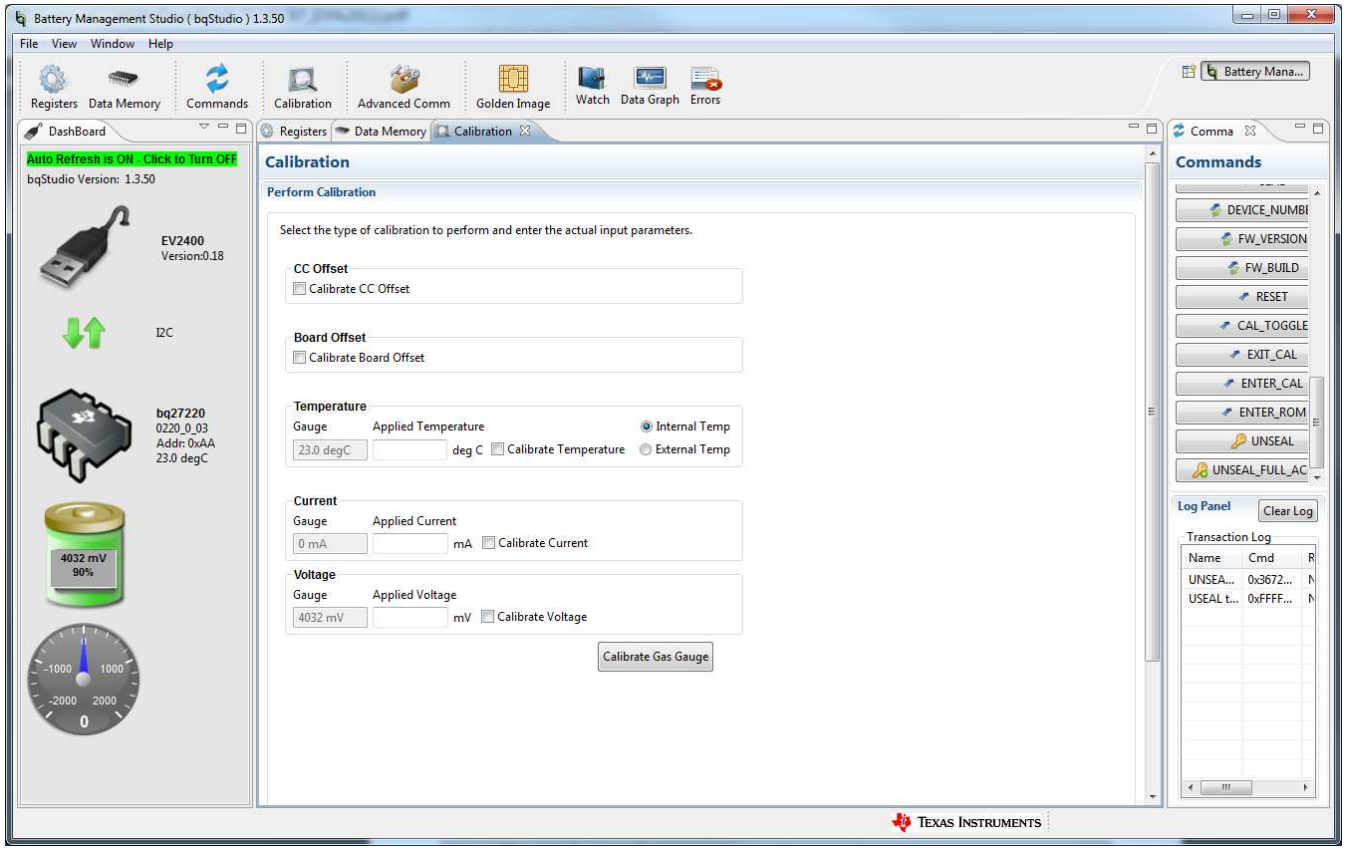

Figure 3. Calibration Screen

NOTE: Please ensure the gauge is unsealed and in full access before proceeding with the calibration procedure. See the TRM for details on how to unseal and place the gauge in full access.

Calibration consists of the following:

- CC Offset/Board Offset: Simply check **Calibrate CC Offset** and **Calibrate Board Offset** and click **Calibrate Gas Gauge** to calibrate the Coulomb counter and board offsets. Ensure no current is flowing through the sense resistor during these steps. After a successful calibration, a green check mark shows next to the **Calibrate Gas Gauge** button.
- Current: Connect a 2-A load to LOAD+/LOAD– or a current source to LOAD–/PACK–. Ensure the measured current reported is negative, or else reverse the connections. Check **Calibrate Current** and enter the current into the textbox followed by **Calibrate Gas Gauge**.
- Voltage: Apply a known DC voltage to PACK+/PACK– with no current flowing through the sense resistor. Check **Calibrate Voltage** and enter the voltage into the textbox followed by **Calibrate Gas Gauge**.

Once these steps are completed, program the design parameters for the application in RAM. Once both the design and calibration parameters are verified, the ot.fs file can be generated. This file is used to program the OTP profile by using SmartFlash.

The OTP profile must be programmed in its entirety using the ot.fs. In order to avoid programming incorrect values, validate the configuration files before programming the OTP, for example, test out the values in RAM and ensure performance is acceptable before proceeding with writing to OTP.

4 OTP Mode FlashStream (ot.fs) Files

The Battery Management Studio (bqStudio) software allows generation of specific instruction files (ot.fs files), containing the necessary I²C commands a host can send to the bq27220 device to program the RAM-based data memory parameters. The commands in these files are largely ROM commands only used when the gauge is in CONFIG_UPDATE mode.

The ot.fs file is an ASCII text file containing commands and data. Each line of the file represents one command and potentially 96 bytes of data, as described in the following text. No row contains more than 96 data bytes. The first two characters of each row represent the command, followed by a ":

"W:" — Indicates that the row is a command to write one or more bytes of data.

"C:" — Indicates that the row is a command to read and compare one or more bytes of data.

"X:" — Indicates that the row is a command to wait a given number of milliseconds before proceeding.

White space is used to separate fields within the ot.fs files. Each row contains only one of the four commands. The commands discussed in this section can be implemented by a system that can perform multi-byte or single-byte operations for I²C.

Figure 4 shows a typical ot.fs file snippet generated from the bqStudio software.

```
;-----------------------------------------------------------
;Verify Existing Firmware Version
;-----------------------------------------------------------
W: AA 00 01 00
C: AA 00 21 06
W: AA 00 02 00
C: AA 00 05 01
;-----------------------------------------------------------
;SET_CFGUPDATE
;-----------------------------------------------------------
W: AA 00 13 00
X: 1500
W: AA 3E 02 00
W: AA 40 02 26 00 00 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
W: AA 60 A5
X: 200
W: AA 3E 02 00
C: AA 60 A5
W: AA 3E 24 00
W: AA 40 00 19 28 63 5F FF 62 00 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
W: AA 60 69
X: 200
W: AA 3E 24 00
C: AA 60 69
W: AA 3E 30 00
W: AA 40 0E 10 FD FF 38 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
W: AA 60 AD
X: 200
W: AA 3E 30 00
C: AA 60 AD
W: AA 3E 31 00
W: AA 40 0A 0F 02 05 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
W: AA 60 AD
```

Normal text file | length : 5015 | lines : 181 | Ln : 112 | Col : 6 | Sel : 0 | 0 | UNIX | ANSI as UTF-8 | INS

Figure 4. Typical ot.fs File Snippet

4.1 Write Command

The write command "W:" instructs the I²C master to write one or more bytes to a given I²C address and given register address. The I²C address format used throughout this document is based on an 8-bit representation of the address. The format of this sequence is:

`"W: I2CAddr RegAddr Byte0 Byte1 Byte2…"`

For example, the following:

```
W: AA 55 AB CD EF 00
```

indicates that the I²C master writes the byte sequence 0xAB 0xCD 0xEF 0x00 to register 0x55 of the device addressed at 0xAA.

More precisely, it indicates to write the following data to the device address 0xAA:

0xAB to register 0x55

0xCD to register 0x56

0xEF to register 0x57

0x00 to register 0x58

4.2 Read and Compare Command

The read and compare command is formatted identically to the write command. The data presented with this command matches the data read exactly, or the operation should cease with an error indication. The ot.fs file contains no information about program flow or decision making. If a read and compare command results in data which does not match the expected values, the interpreting program needs to handle the next step itself. It should not continue with further commands but would typically go back to the beginning of the ot.fs file and try again several times before giving up.

The format of this sequence is:

```
"C: i2cAddr RegAddr Byte0 Byte1 Byte2"
```

An example of this command is as follows:

```
C: AA 55 AB CD EF 00
```

This example expects the master to read back 4 bytes from the register address 0x55 of the device addressed at 0xAA and then compare the data to the values given on the line command in this same order as 0xAB, 0xCD, 0xEF, and 0x00.

4.3 Wait Command

The wait command indicates the host waits a minimum of the given number of milliseconds before continuing to the next row of the FlashStream file. A wait command is typically used to allow the fuel gauge processor to complete a process before proceeding to the next command in the file.

For example, the following:

```
X: 200
```

indicates that the I²C master must wait at least 200 ms before continuing.

4.4 CONFIG UPDATE Mode

If the application requires different configuration data for the fuel gauge, the system processor can update RAM-based data memory parameters using the *Control()SET_CFGUPDATE* subcommand to enter the CONFIG UPDATE mode.

NOTE: To ensure that the fuel gauge has entered CONFIG UPDATE mode correctly, there must be at least an 1100-ms delay after sending the *SET_CFGUPDATE*. Operation in this mode is indicated by the *Flags()[CFGUPMODE]* status bit.

In this mode, fuel gauging is suspended while the host uses the extended data commands to modify the configuration data blocks. To resume fuel gauging, the host must send a *Control()SOFT_RESET* subcommand to exit the CONFIG UPDATE mode, which clears both *Flags()[ITPOR]* and *[CFGUPMODE]* bits. After a timeout of approximately 240 seconds (4 minutes), the gauge automatically exits the CONFIG UPDATE mode if it has not received a *SOFT_RESET* subcommand from the host.

The memory of the bq27220 device is separated into memory subclasses defined in this document. The memory cannot be directly addressed, but is updated through a sequence of extended commands that can access each block of memory indirectly. The ot.fs file updates these blocks to write the proper configuration so the bq27220 device can have proper gauging performance and match the system characteristics. These updates are stored in RAM and need to be reprogrammed any time the device loses power. (The *[ITPOR]* bit in the *Flags()* register indicates that the RAM configuration has been reset to the defaults and is in need of updating using the ot.fs file.)

4.5 Programming Instructions

4.5.1 Using ot.fs Files

The following list shows how to use ot.fs files to configure the bq27220 device on power up:

1. Use the GPCCEDV tool (on ti.com) to generate the 7-point CEDV parameter and the 11-point loaded voltage points, see the *bq27220EVM-744 User's Guide* (SLUUBF5).
2. Use the Battery Management Studio (bqStudio) software to finalize all the values for Calibration, Configuration, or Gas Gauging in RAM based on the application.
3. Complete the following OTP profiles:
   (a) Programming the OTP Profile 1
      (i) Fill out the CEDV Profile 1 section in RAM with required values.
      (ii) Write CEDV Profile Select → Battery ID to 4.
   (b) Programming the OTP Profile 2
      (i) Fill out the CEDV Profile 1 section in RAM with required values.
      (ii) Write CEDV Profile Select → Battery ID to 8.
   (c) Programming the OTP Profile 3
      (i) Fill out the CEDV Profile 1 section in RAM with required values.
      (ii) Write CEDV Profile Select → Battery ID to 16.
4. Use bqStudio to generate the ot.fs file, which contains I^2C instructions (with data) on how to program the OTP with the values that were just set up in RAM.
5. Use the ot.fs file with the SmartFlash programming tool; the OTP on the bq27220 device can be programmed.

4.6 General Setup and Software Installation to Program OTP

1. Equipment needed:
   (a) Lab power supply configured for 7.4-V output (expect approximately 5-mA maximum current)
   (b) Battery or second power supply with ≥ 3.0-V output (expect approximately 1-mA maximum current)
   (c) EV2300 (v3.1r or later) or EV2400 USB with I^2C interface adapter
   (d) Unprogrammed bq27220 device assembled in the battery pack or on the EVM
   (e) Example .gg file provided by factory
   (f) Battery Management Studio (bqStudio) software installer
   (g) SmartFlash software executable
2. Install bqStudio software.
3. Connect the EV2300 or EV2400 to the unprogrammed device or EVM.
4. Connect the battery to BAT(+) and VSS(–) pins.
5. With output disabled, connect the lab power supply to GPOUT and VSS(–) pins.

NOTE: Do not apply 7.4 V to the device until prompted by software.

4.7 Launch bqStudio Software

1. Launch bqStudio software.
2. Confirm *Gauge Dashboard* panel detects the EV2x00 adapter and the bq27220 device.
3. If the device has been previously SEALED, UNSEAL it by sending the appropriate keys to *Control()* (0x00 and 0x01). The bq27220 boots up in UNSEAL mode, but not in FULL ACCESS mode. Enter FULL ACCESS mode to gain access to the *Data Memory*.
4. Click **Data Memory** to show the OTP factory defaults that are in data memory (RAM).
5. Click **Import** to load **Data Memory** contents from the provided sample .gg file.

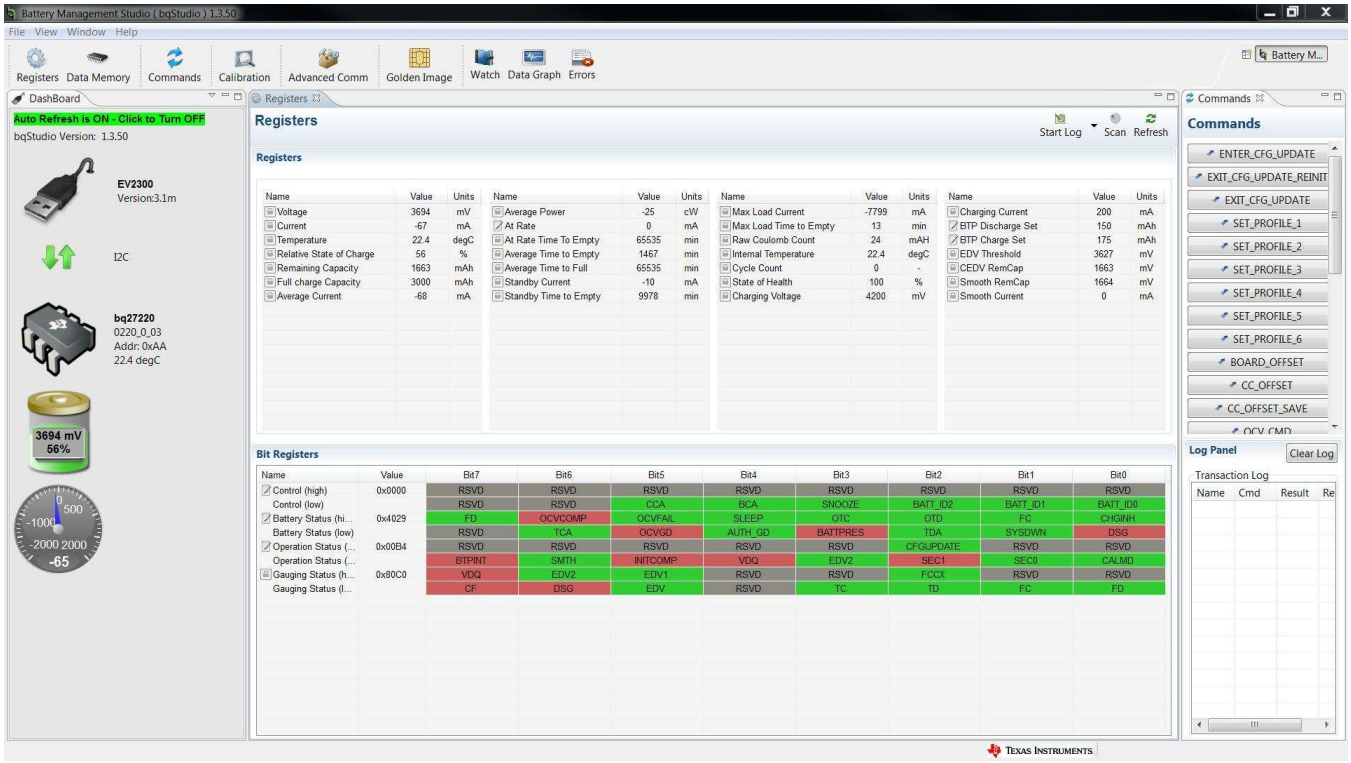

Figure 5. Launch bqStudio Software

4.8 Load .GG File

This procedure imports the fuel gauge data or the data memory image to the device.

1. Browse to a desired template or sample *.GG parameter file. (example: bq27220.gg.csv in Figure 6.)
2. Click the **Open** button.

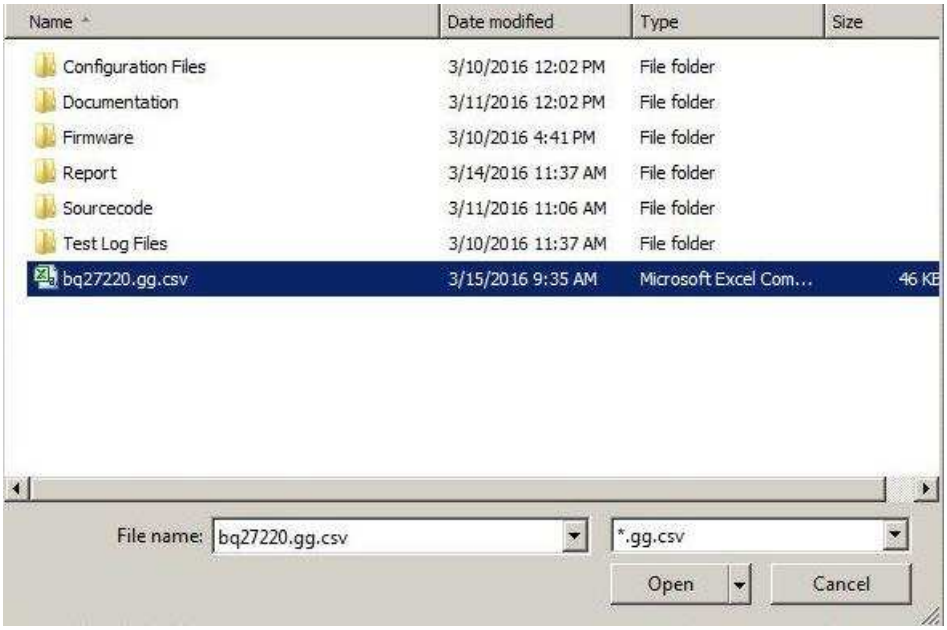

Figure 6. Load .GG File

4.9 Confirm or Update Data Memory Parameters

Use the following list to confirm or update data memory parameters:

1. Imported *Data Memory* (RAM) parameters that differ from the factory defaults appear in orange font.
2. Confirm or update *Data Memory* (RAM) parameters as required.
3. Save .gg file for future reference by clicking **Export**.

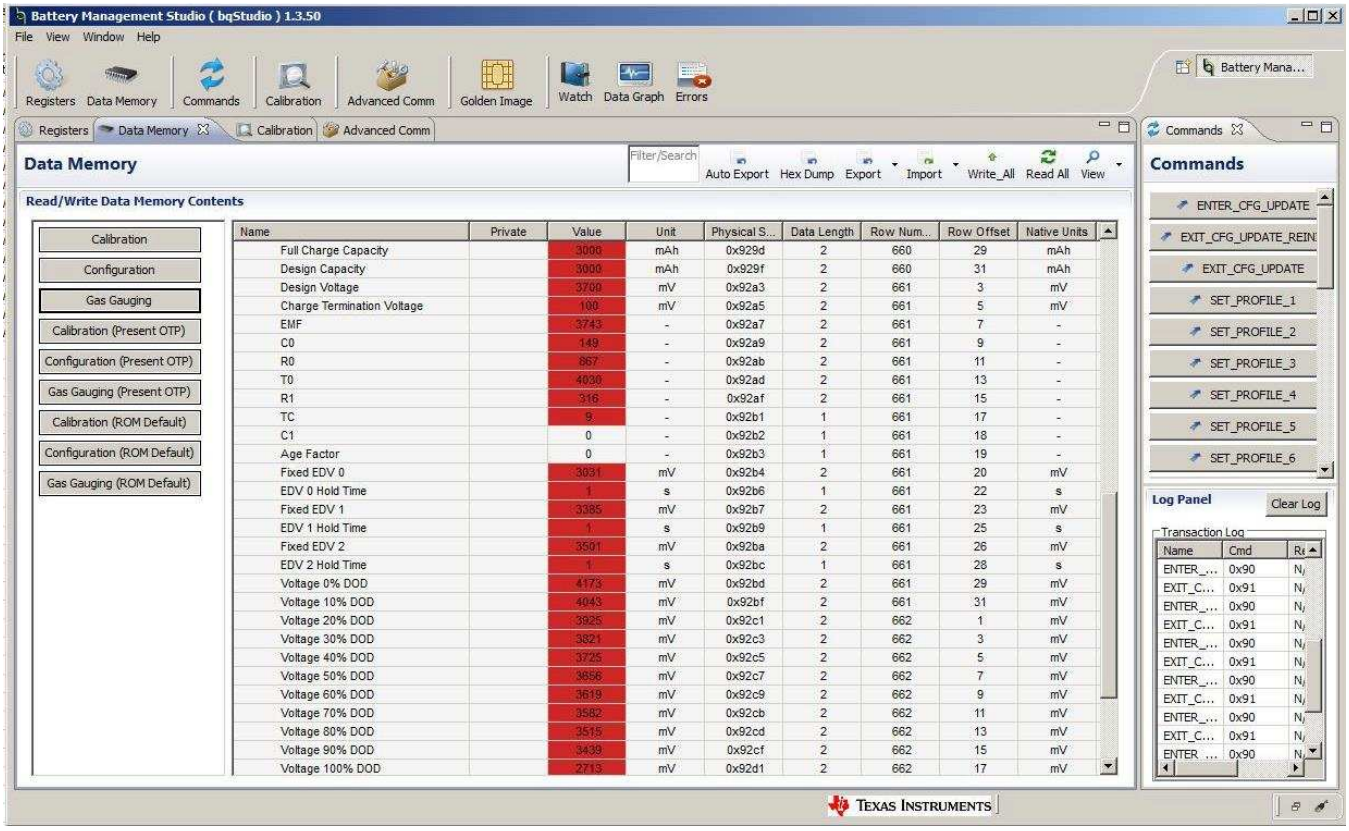

Figure 7. Confirm or Update Data Memory Parameters

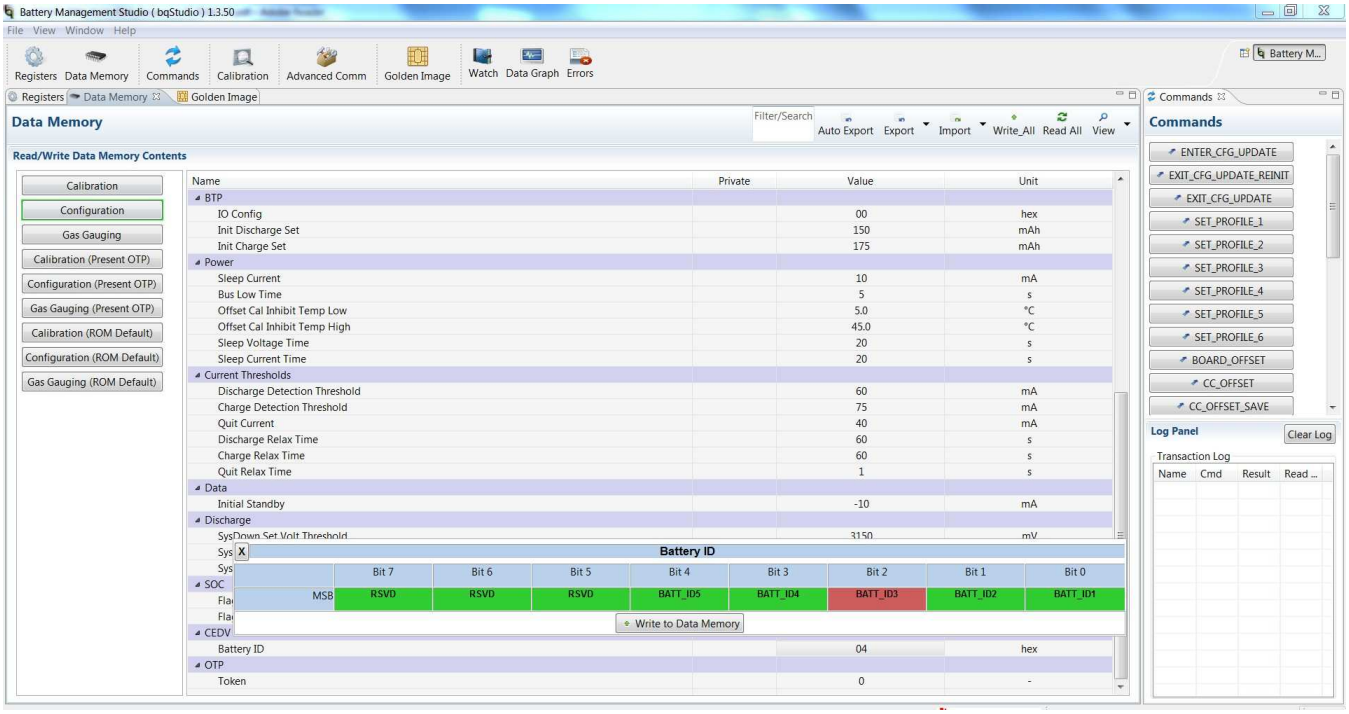

Figure 8. Update Battery ID

4. Set BATT_ID2 to 1.

4.10 Save .OTFS File

The following steps show how to save an .OTFS file

1. Click the **GoldenImage** icon.
2. From the **GoldenImage** panel, enter desired .OTFS base file name (example, bq27220.ot.fs).

NOTE: No **Options** changes are required.

3. Click **Create Image File**.
4. Exit bqStudio software.

NOTE: It is important to exit the bqStudio software because the EV2x00 adapter must be freed for SmartFlash.

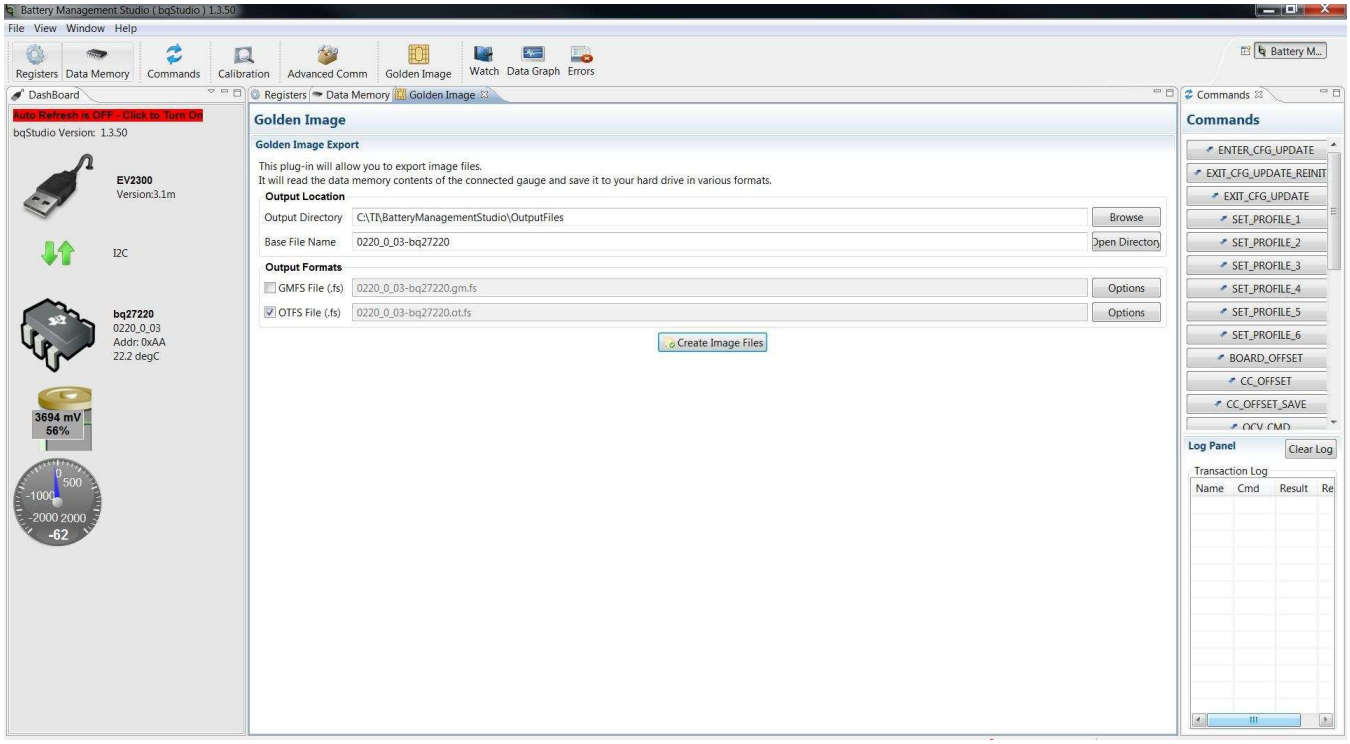

Figure 9. Save .OTFS File

4.11 Launch SmartFlash Software

Use the following steps when launching the SmartFlash software:

1. Launch SmartFlash software.
2. Confirm auto-detection of the EV2x00 adapter, gauge = 220 and version ≥ 1.09.
3. Click **File → Open.**

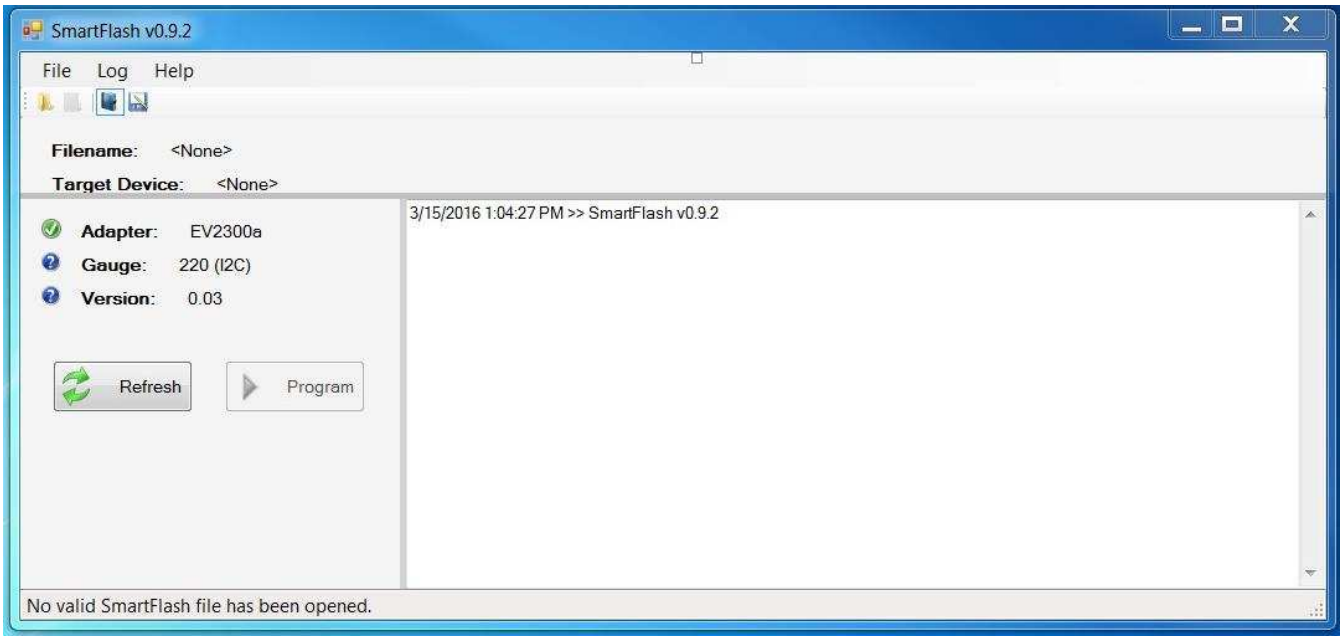

Figure 10. Launch SmartFlash Software

4.12 Open ot.fs File

1. From the pop-up dialog box, click the needed ot.fs file and click **Open**.
2. Confirm successful file load from log window.

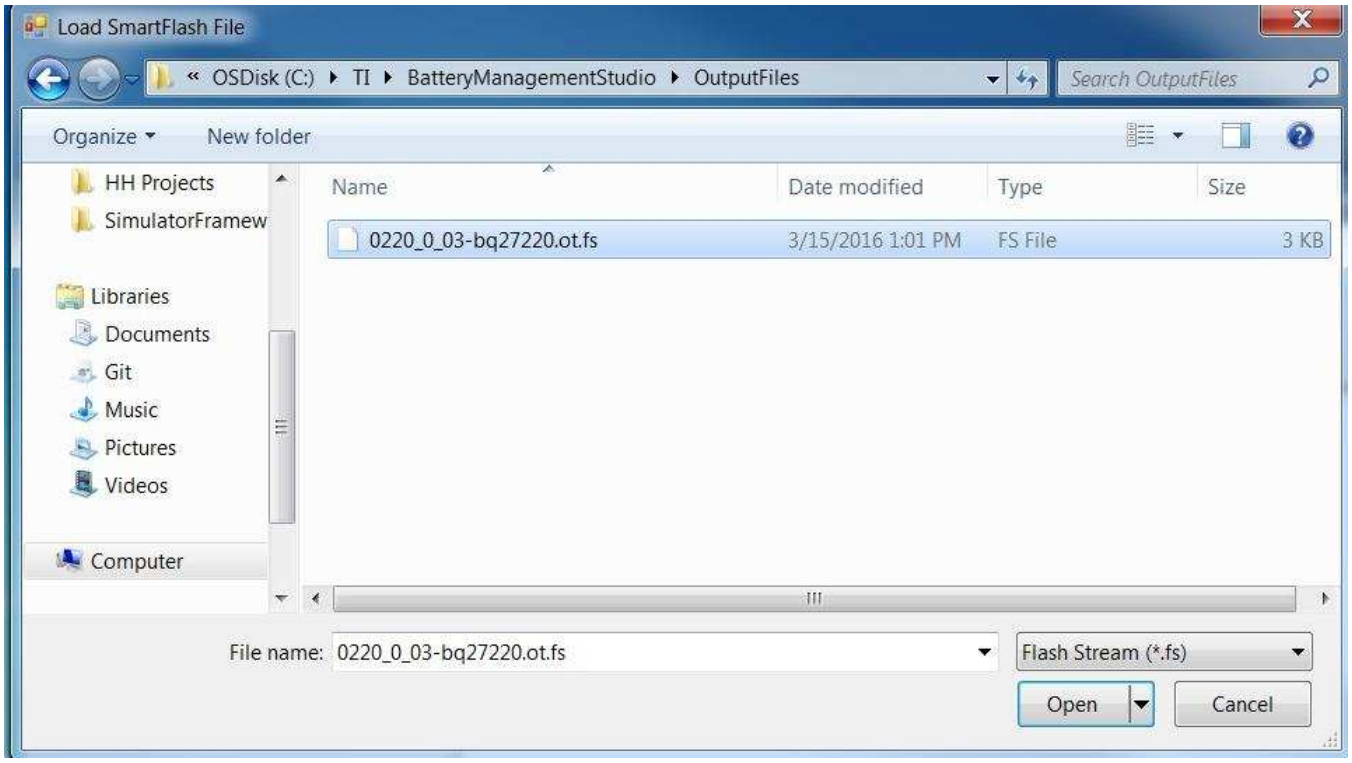

Figure 11. Open .OTFS File

4.13 Program OTP

1. Click the **Program** button.
2. When the *Apply Programming Voltage* pop-up dialog box appears, enable 7.4-V power supply and click **OK**.
3. After a brief delay (approximately 1-second) for OTP programming and when the *Remove Programming Voltage* pop-up dialog box appears, disable the power supply and click **OK**.

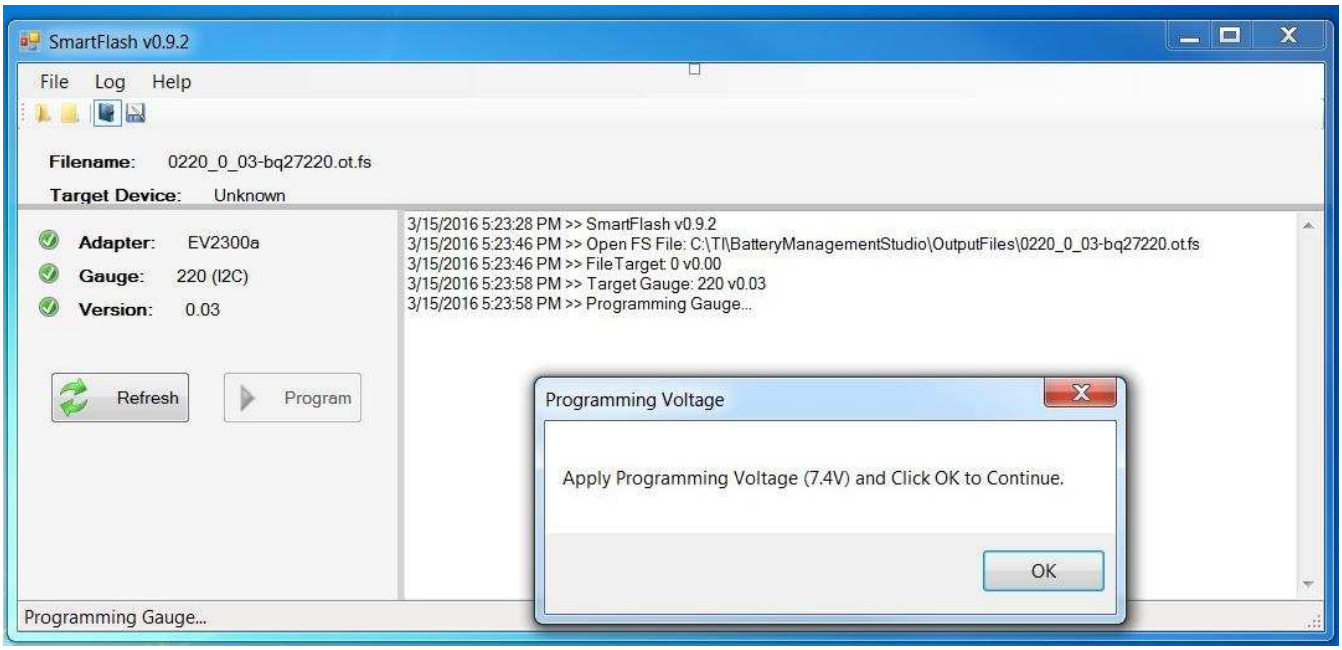

Figure 12. Apply 7.4 V

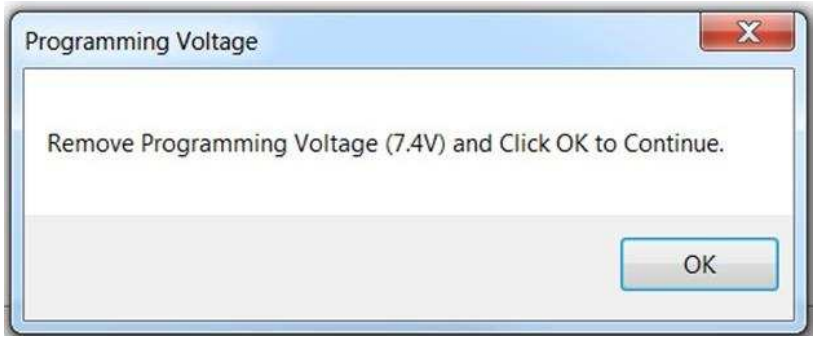

Figure 13. Program OTP

4.14 Confirm Success

1. Confirm the message *Programming completed successfully!* from the log window.
2. The device is now fully programmed.

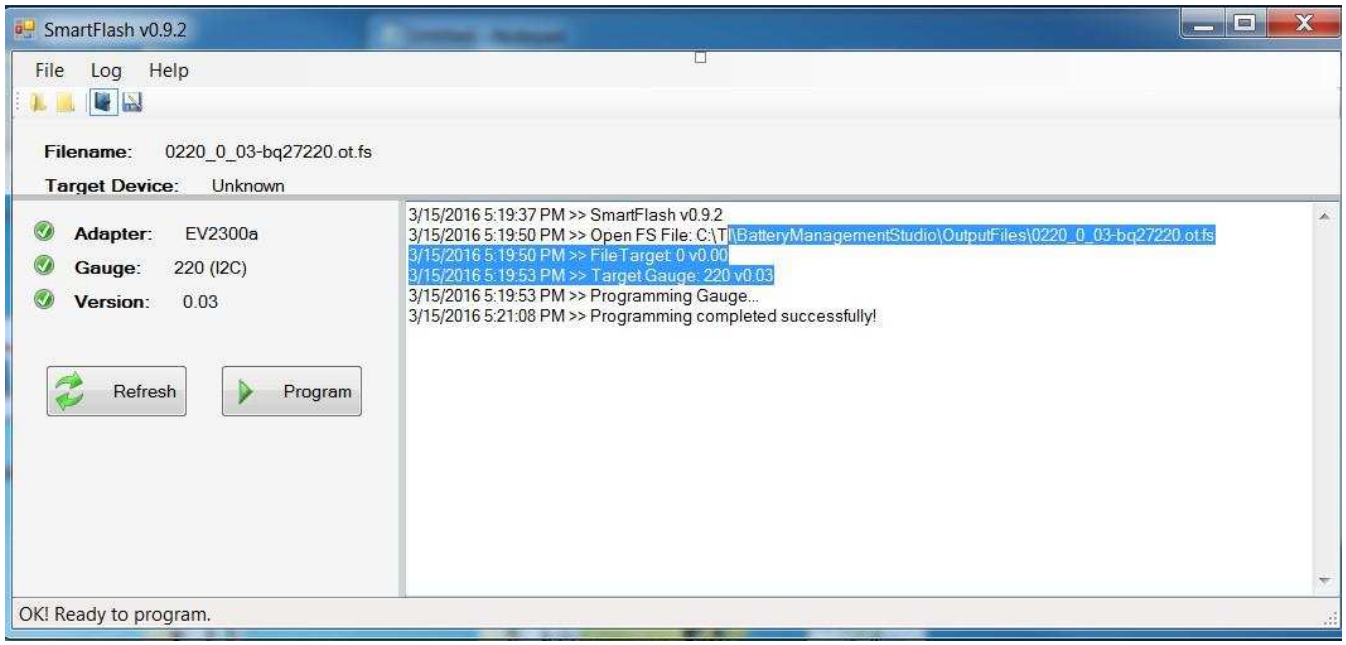

Figure 14. Confirm Success

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