Application Report

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What is a .tmap File?

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ABSTRACT

The PowerLAN™ Master Gateway Battery Management Controller uses a file, identified by the .tmap file extension, to load configuration parameters. This file serves to configure the operation of the controller to the specific application. Examples of configurable parameters are number of parallel and series cells in the pack, number of temperature sensors, and state-of-charge indication (SOCi) display settings.

1 Introduction

The .tmap file is used to configure the PowerLAN™ Master Gateway Battery Management Controller. The .tmap name is derived from the fact that the temperature sensor mapping is configured using this file. The file is part of a series of configuration files that are specified by the user during the development stage. See Figure 1 for PowerLAN™ BMS Development cycle information. This application report explains Phase 3 in the process.

PowerLAN BMS Development				
	Development Phase	Component	Configuration File(s) Associated with Phase	Activities
1	Explore	Cell Type, technology	(.chem)	Selection of Cell type for application, select/create (.chem) file
2	Design	Cell Pack & Electronics	None	Design of Cell Pack, Electronics and Packaging
3	Build Prototype	PCB, Wiring, Pack	(.tmap), (.enc)	Assemble PCB, wiring, Cell Pack, packaging, load firmware, create & load (.tmap)
4	Test & Debug	Prototype Battery Management System	(.aux), (.ppcsv), (.dlog), (.slog)	Perform prescribed BMS test to create .aux file, load safety registers, configure SBData, use bqWizard to log data, circuit test, debug
5	Test	Design Validation	(.dlog), (.slog)	Performance testing, data logging with bqWizard
6	Production Readiness	Production Unit	(.dat), (.cal)	clone packs in production by loading .dat file, save system calibration

Figure 1. PowerLAN™ BMS Development Cycle

The configuration files customize the PowerLAN™ controller to suit the application needs. This .tmap file along with other configuration files then are combined into a single production configuration file called a .dat file during the Production Readiness phase. The bqWizard™ software is used to extract the .dat file from the PowerLAN™ Master Gateway Controller. The .dat file is then used to clone each production pack. This file is often referred to as the *Golden Flash File*. The file is encoded and ensures a level of protection against unwanted tampering.

1.1 bq78PL114 and Firmware 4452

The .tmap file for the bq78PL114 with base firmware 4452 only allows the user to change the number of series and parallel cell count that describe the battery construction. This information is provided in the application report *Configuring the bq78PL114 Cell Count* (SLUA495).

CAUTION

The bq78PL114, shipped with firmware 4452, is not recommended for new designs. The (.tmap) file details that follow pertain exclusively to the firmware 5000 associated with part number bq78PL114S12.

1.2 bq78PL114(S12) and Firmware 5000

A firmware update is now available for the bq78PL114, called FW5000. It is available by downloading the current version of the bqWizard™ software (2.5.7 and later) and following the update instructions. Two fundamentally distinguishing features of this firmware are that it increases the series cell range from 3-8 to 3-12 cells and it has an expanded (.tmap) file.

1.3 bq78PL116

The bq78PL116 is a firmware revision of bq78PL114 that supports up to 16 cells. This device also uses the .tmap file for configuration. Consult the Technical Reference Manual for this part for additional details (SLUU481).

2 File Creation

The intended implementation of the (.tmap) file feature is that the user does not directly edit it. Most of the entries in the file are coded as bit-packed values. The coding was used to satisfy certain firmware requirements for optimal memory usage. See the example .tmap file located in the Appendix. The file entries are purposefully not commented so as to avoid manual data entry.

A software utility, called PackConfigurationUitlity, has been developed as part of the bqWizard™ software to facilitate the creation of the (.tmap) files. Read this application report to discover the information required to customize the .tmap file.

3 File Features

The following are details of the (.tmap) file. All of the parameters must be reviewed and changed as necessary to suit the application. A default .tmap file is loaded with the device. These default values are listed in each of the following sections. The default values for firmware 5000 and firmware 6000 are the same except for the temperature sensor count. Firmware 6000 default temperature sensor count is 3 and only supports up to four external temperature sensors connected to the bq78PL116.

3.1 Battery Configuration

The series and parallel cell count of the battery pack must be specified. The default values are three series cells, one parallel cell (3S1P).

3.2 Current Measurement

Configuration of the current measurement involves setting the value of the external sense resistor, the SBData Current Scale Factor and the Current Gain. The firmware allows for the specification of three different current measurement settings. This allows one .tmap file to be used in three different applications if the sense resistor is the only change to the configuration. Most users only need to be concerned with changing one of the three settings and leaving the other two at the default.

The current measurement setting is selected, from the three available, by programming bits 10 and 11 of the Hardware Configuration register with 01, 10, or 11.

Table 1. Current Measurement Selection via Hardware Configuration Register

Current Measurement	Hardware Configuration		Default Sense Resistor (μΩ)	Default Gain	Default Scale	Discharge Current Range (A)	Charge Current Range (A)
	Bit 10	Bit 11					
Sense 1	0	1	10000	9	0	–11.2	10
Sense 2	1	0	3000	13	0	–26	26
Sense 3	1	1	1000	9	1	–111	100

3.2.1 Sense Resistor

The value of the external resistance used to measure current must be specified. Table 1 identifies three default values. The primary reason to change the resistor value from one of these three values is to expand the range to higher currents or decrease the range for higher resolution and accuracy. Changing the resistor value to suit the application is preferred over changing the Current Gain setting.

3.2.2 Current Scale

The current scale setting refers to the IPScale factor from the SBData Specification. The IPScale factor specifies bits 12 to 15 in the SBData parameter SpecificationInfo() [0×1A]. The allowable binary-coded values are 0000 and 0001 and serve to multiply the reported currents and capacities by $10^{IPScale}$. This IPScale factor is typically needed when the current measurement range exceeds ±32.768 A. This ±32.768-A value is the default range of the SBData specification. Consult the SBS Specification for further details.

Table 2. IPScale Operation

Actual Current (mA)	Current (mA) (Register 0x0A)	IPScale Bits	Resulting Scale Factor for Current and Capacity	Current With IPScale Factor (mA)
–5000.0	–5000.0	0000	1	–5000.0 × 1
–50000	–5000	0001	10	–5000 × 10

Table 1 identifies two default values. When the desired current range is less than ±32.768 A, choose an IPScale of 0000. If the desired current range is ±327 A, then choose IPScale = 0001.

For example, the default Sense 3 range uses a 0.001-Ω resistor, gain of 9, and an IPScale value of 0001. When –50 A of discharge current flows, it is reported over SBData Current (register 0x0A) as –5000 mA. This current reading must be multiplied by the IPScale as 10^1 × Current = 10 × –5000 mA = –50 A to get the actual current.

3.2.3 Current Gain

Current gain refers to the gain of the device hardware used to measure current. Table 1 identifies three default values.

Gain values 9 and 13 cover all expected current measurement ranges. These values therefore are recommended for all designs. Changing the resistor value to suit the application is preferred over changing the Current Gain setting. Note that all resistor values in the following equations are in Ohms (Ω).

Discharge Current Range Calculator:
The equation used to determine the current measurement range in the discharge direction is as follows:

$$Range_{DSG}\ (A) = (\ 1.26\ V/Gain \times 80\%)/Resistor\ Value \qquad (1)$$

Charge Current Range Calculator:
Because the measurement in the direction of charge current is always limited to less than 100 mV, the charge current range is calculated as the lesser of two values

$$Range_{CHG}\ (A) = minimum\ [\ (1.26\ V/Gain\ x\ 80\%\ )/Resistor,\ 0.100\ V/Resistor] \qquad (2)$$

Examples of alternate current measurement configurations are listed in Table 3.

Table 3. Example Alternate Current Measurement Settings

Application	Current Measurement	Sense Resistor (μΩ)	Gain	Scale	Discharge Current Range (A)	Charge Current Range (A)
Remote Telemetry, Very Low Current	Sense 1	22000	9	0	–5.05	4.54
General Purpose, Midscale	Sense 2	5000	9	0	–22	20
Motor Drive, Very High Current	Sense 3	500	9	1	–222	200

3.2.4 Hardware Safety Trips

Operation of the Hardware Safety current trips called Hardware Overcurrent Charge, Hardware Overcurrent Discharge, and Hardware Short Circuit are affected by the value of the sense resistor. It is not influenced by the gain or the current scale. The effect is that it changes the range of settable safety thresholds.

The Default hardware overcurrent and short-circuit range of settings are shown in Table 4 and Table 5. See the *bq78PL114 and bq78PL114S12 Technical Reference Manual* (SLUU330) and the *bq78PL116 Technical Reference Manual* (SLUU481) for more details.

Table 4. Default Hardware Overcurrent Range of Settings

Sense Resistor (μΩ)	HW OC Threshold	HW OC Register Value, Decimal	Typical (A)	Tolerance (±A)	Step Size (A)
10000	Lowest	35	4.28	0.244	0.122
	Highest	255	31.19		
3000	Lowest	35	14.27	0.816	0.408
	Highest	255	103.96		
1000	Lowest	35	42.81	2.446	1.223
	Highest	255	311.89		

The Lowest and Highest Register Values listed in Table 4 are constant. Equations to calculate the typical Overcurrent (OC) thresholds, tolerance, and step size are as follows.

$$\text{OC Step Size} = OC_{STEP} = 0.3125/\text{Resistor}/255.5 = 1.223 \times 10^{-3}/\text{Resistor} \quad (3)$$

$$\text{Minimum OC Setting} = 35 \times OC_{STEP} \quad (4)$$

$$\text{Maximum OC Setting} = 255 \times OC_{STEP} \quad (5)$$

$$\text{Tolerance} = \pm 2 \times OC_{STEP} \quad (6)$$

Table 5. Default Hardware Short-Circuit Range of Settings

Sense Resistor (μΩ)	HW OC Threshold	HW SC Register Value, Decimal	Typical (A)	Tolerance (±A)	Step Size (A)
10000	Lowest	37	4.86	1.984	0.992
	Highest	63	30.75		
3000	Lowest	37	16.53	6.614	3.307
	Highest	63	102.51		
1000	Lowest	37	49.60	19.842	9.921
	Highest	63	307.54		

The Lowest and Highest Register Values listed in Table 5 are constant. Equations to calculate the typical Short Circuit (SC) thresholds, tolerance and step size are as follows.

$$\text{OC Step Size} = SC_{STEP} = 0.3125/R/31.5 = 9.921 \times 10^{-3}/R \quad (7)$$

$$\text{Minimum SC Setting} = 37 \times SC_{STEP} \quad (8)$$

$$\text{Maximum SC Setting} = 63 \times SC_{STEP} \quad (9)$$

$$\text{Tolerance} = \pm 2 \times SC_{STEP} \quad (10)$$

The PackConfigurationUtility calculates the range, tolerance, and step size needed to set the hardware current safety settings. This is done as a convenience for the user. The values for the three Hardware Current trip settings are not contained in the (.tmap) file. These are entered by the user directly or by editing a (.ppcsv) file and loading into the PowerLAN™ Gateway Controller.

3.3 State-of-Charge Indication (SOCi) Display

The SOCi display is configurable by the user. The PowerLAN™ Gateway Controller supports five LEDs, a 5-segment LCD or a 5-segment EPD via the LED1, -2, -3, -4, and -5 pins.

3.3.1 EPD Refresh

When using an Electronic Paper Display (EPD), the refresh rate can be specified by the user. The value is in units of minutes. The default value is set to 10 (minutes). This value depends on the type of EPD used. If an EPD is not being used, this value can remain at the default.

3.3.2 RSOC Thresholds and Pattern

Each segment of the SOCi display corresponds to a relative state-of-charge (RSOC) level as computed by the gas gauge. The user can specify the RSOC level that each LED output provides and the associated pattern. The default configuration is listed in Table 6.

Table 6. Default SOCI RSOC Thresholds and Pattern

bq78PL114S12 Pin	Default RSOC Threshold Value %	LED5	LED4	LED3	LED2	LED1
LED5	> 80	ON	ON	ON	ON	ON
LED4	> 60	OFF	ON	ON	ON	ON
LED3	> 40	OFF	OFF	ON	ON	ON
LED2	> 20	OFF	OFF	OFF	ON	ON
LED1	≤ 20	OFF	OFF	OFF	OFF	ON

The user can elect to change the values in the Default RSOC Threshold Value % column as well as the values in the LED1, 2, 3, 4, and 5 columns to achieve desired results.

3.4 Temperature Sensor Mapping

The bq78PL114S12 provides one temperature sensor per cell, for the first four cells, plus one internal device temperature sensor. The cell sensors are obtained externally by a dual-diode/capacitor sensor. For every PowerLAN™ Dual Cell Monitor (bq76PL102) added, the number of temperature sensors increases by two. These temperature sensors can be assigned in several ways. The default configuration is shown in Table 7. The bq78PL116 is limited to up to four external temperature sensors. The additional bq76PL102, when used for series cell counts above 4, cannot have temperature sensors connected to them.

Table 7. Default Temperature Sensor Mapping for bq78PL114S12 Only

Temperature Measurement	Series Cell Count	PowerLAN™ Gateway Controller	bq76PL102 (1)	bq76PL102 (2)	bq76PL102 (3)	bq76PL102 (4)
Device Compensation and Board Temperature		Device				
Cell 1 Temperature	1	XT1				
Cell 2 Temperature	2	XT2				
Cell 3 Temperature	3	XT3				
Cell 4 Temperature	4	XT4				
Cell 5 Temperature	5		XT1			
Cell 6 Temperature	6		XT2			
Cell 7 Temperature	7			XT1		
Cell 8 Temperature	8			XT2		
Cell 9 Temperature	9				XT1	

Table 7. Default Temperature Sensor Mapping for bq78PL114S12 Only (continued)

Temperature Measurement	Series Cell Count	PowerLAN™ Gateway Controller	bq76PL102 (1)	bq76PL102 (2)	bq76PL102 (3)	bq76PL102 (4)
Cell 10 Temperature	10				XT2	
Cell 11 Temperature	11					XT1
Cell 12 Temperature	12					XT2

Each bq76PL102 has a number following it in Table 7. The number represents the position of the device in the PowerLAN™ network. The lower number indicates a lower position in the network and closer to the bq78PL114S12.

The .tmap file allows the user to reconfigure the matrix in Table 7 to suit application-specific needs. One important design restriction is that each series cell temperature must be mapped in firmware to a physical temperature sensor. This implies that each system must have at least one temperature sensor. The minimum cost system has all temperatures mapped to the sensor inside the PowerLAN™ gateway controller. This configuration is shown in Table 8. The unused temperature sensor inputs can be left as open circuit.

Table 8. Minimum Cost Temperature Sensor Configuration

Temperature Measurement	Series Cell Count	PowerLAN™ Gateway Controller	bq76PL102 (1)	bq76PL102 (2)	bq76PL102 (3)	bq76PL102 (4)
Device Compensation and Board Temperature		Device				
Cell 1 Temperature	1	Device				
Cell 2 Temperature	2	Device				
Cell 3 Temperature	3	Device				
Cell 4 Temperature	4	Device				
Cell 5 Temperature	5	Device				
Cell 6 Temperature	6	Device				
Cell 7 Temperature	7	Device				
Cell 8 Temperature	8	Device				
Cell 9 Temperature	9	Device				
Cell 10 Temperature	10	Device				
Cell 11 Temperature	11	Device				
Cell 12 Temperature	12	Device				

Temperature sensing in large cell count packs must not generally be minimized, particularly those with highly paralleled cells. The PowerLAN™ Battery Management system provides for distributed temperature sensing because battery packs can have a considerable temperature gradient across them. This typically depends on physical configuration and proximity to point sources of heat like power converters and/or power switches. Distributed temperature sensors, one per series cell, can detect temperature fluctuations faster than a single sensor system. This can produce more accurate gas gauging and can possibly stop a thermal runaway situation if one cell in a large cell array exhibits a rapid rate of rise.

3.5 Device SMBus Address

The default SMBus address for the PowerLAN™ Gateway Controller is 0x16. The address value is coded into one of the .tmap file registers. This value can be changed, if needed, to meet special applications. The standard address can be used in most applications except those with multiple PowerLAN™ Gateway Controllers.

4 Creating a Pack Configuration File (.tmap)

Use bqWizard 3.0.19 or later. Under the Utilities Menu is a submenu called AddOns. The PackConfiguration Utility can be found there. Follow the on-screen instructions to create a .tmap file.

5 Implementing the Pack Configuration File

This section describes loading the .tmap file, setting the current measurement range in the bqWizard™ software, and lists parameters that may be affected by choice of current measurement range.

A few steps must be performed to complete the product configuration process . Product configuration refers only to the features that can be set with the .tmap file. A full product configuration, not described here, includes the parameter data set and chemistry files but are available on the TI Web site in other publications.

5.1 Requirements

The bqWizard™ version 3.0.19 or later must be installed on a personal computer (PC). An appropriately powered bq78PL114S12 or bq78PL116 battery management circuit must be connected to the PC using the USB-TO-GPIO adapter.

The following procedure is also applicable to the bq78PL116 and firmware 6000. Only one part number is referenced in the following text for simplicity.

5.2 Loading .tmap File

Loading of a .tmap file is only required if one was made to change the product configuration to something other than the default.

The procedure to load the .tmap file is as follows:

1. Connect bq78PL114S12 to a PC using a USB-TO-GPIO adapter.
2. Open the bqWizard™ software.
3. Firmware 5000 or 6000 must be already loaded on the device. See the technical reference manual for details on reprogramming a bq78PL114 into a bq78PL114S12.
4. Under the File Menu, select Pack Configuration (.dat, .tmap, .aux).
5. Select Load Configuration File and Relearn.
6. Choose your .tmap file, and click Open.
7. A series of status messages appears, one of which is Connecting to Pack.
8. The bqWizard™ software then displays the number of cells specified by the .tmap file.
9. Look in the Pack Configuration Tab to see some of the pertinent parameters like Expected Number of Cells, Parallel Count, Sense Resistor, and Temperature Sensor Count. These all match the values from the .tmap file.

5.3 Setting Current Measurement Range

The default current measurement range selection is Sense 1: 10 mΩ and a range of +10/–11.2 A. If this is appropriate for your application, the only further action is to calibrate the current measurement system. Follow the directions listed in the Technical Reference Manual for the bq78PL114S12. If one of the other two default ranges are appropriate or a custom range was made through the .tmap file described previously, the following procedure applies.

1. Connect the bq78PL114S12 to the PC using the USB-TO-GPIO adapter.
2. Open the bqWizard™ software.
3. Firmware 5000 must be already loaded on the device. See the technical reference manual for details on reprogramming a bq78PL14 into a bq78PL114S12.
4. If a .tmap file was created with new current range selections, first follow the procedure previously described.
5. Read all Parameters (ctrl-r).
6. Select the Pack Configuration Tab. This brings the Hardware Configuration and the Sense Resistor registers into view. Note that the Bit Encoded Data shown in Figure 2 is for viewing only.

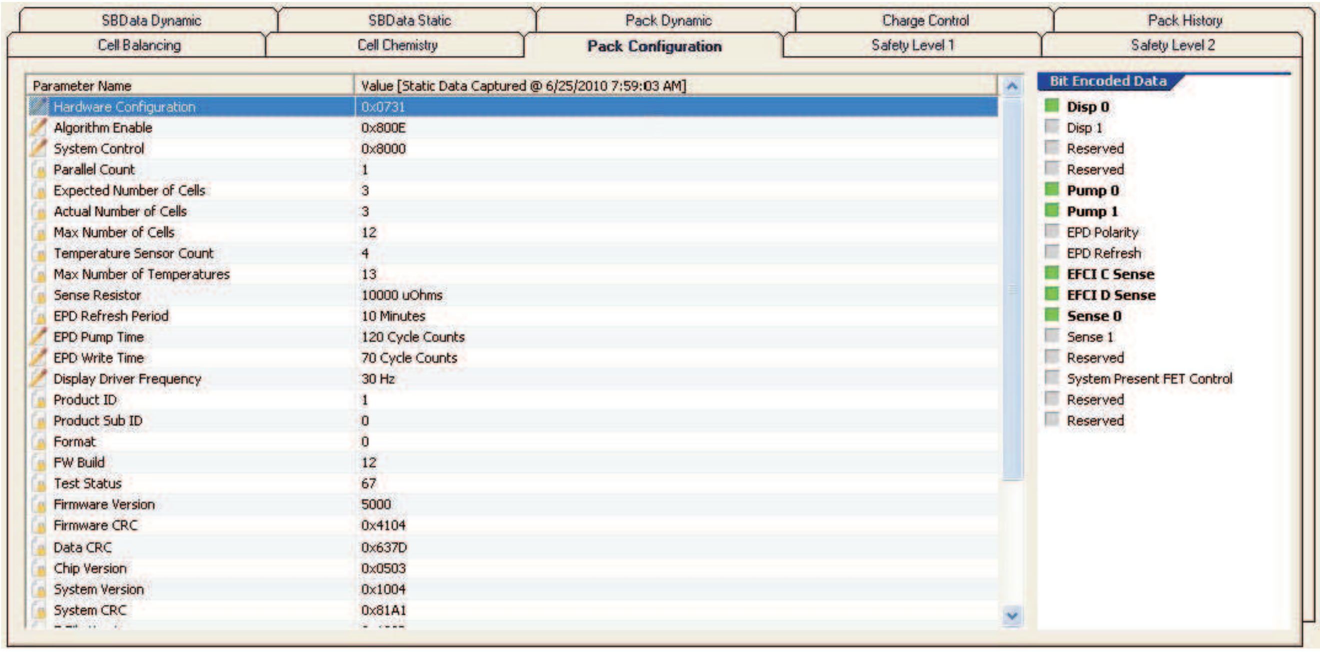

Figure 2. Pack Configuration Tab in the bqWizard™ Software

7. Double-click on the Hardware Configuration Register Row.

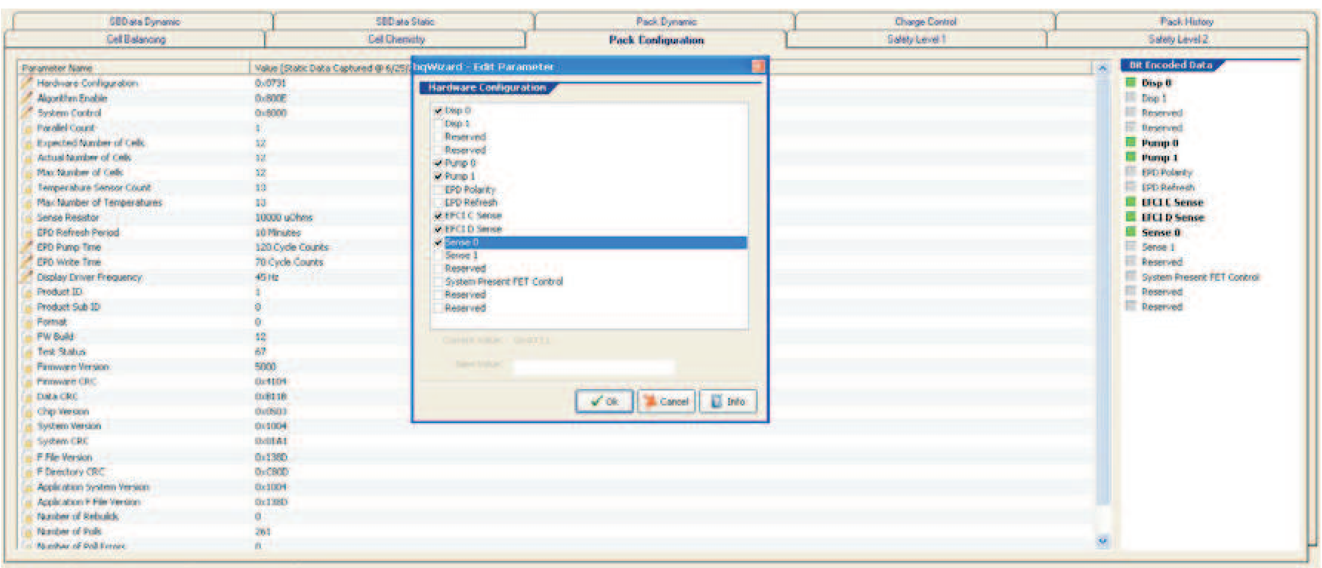

Figure 3. Hardware Configuration Register Dialog Box in the bqWizard™ Software

8. Set Sense 0 and Sense 1 bits in the Hardware Configuration Register according to the values currently programmed into the three choices. The default choices are listed in Table 9. These may or may not match those in the .tmap file that may have been created.

Table 9. Hardware Configuration Register Settings

SETTING	SENSE 0 BIT	SENSE 1 BIT	RESISTOR VALUE (Ω)	RANGE (A)
Sense 1	1	0	0.010	–11.2 to +10
Sense 2	0	1	0.003	–26 to +26
Sense 3	1	1	0.001	–111 to +100

9. Click OK when changes are complete.
10. Write parameter changes to memory (ctrl-w).
11. Perform an initialize command (F3).
12. The Sense Resistor parameter in the Pack Configuration Tab changes to the value selected.
13. Proceed to calibrate current offset and gain with the new current range setting.

5.3.1 Parameters Related to Current Measurement

The scaling of current described in the document is reflected in the parameter set. This means that if current scaling is used to achieve a current range beyond ±32768 mA, then parameters that are based on current also must be scaled in the same manner.

The following is a list of parameters that are affected by the choice of current sense range. This primarily refers to the need to divide the register value by the current scaling.

PARAMETER	UNITS
Pre-Charge Current	mA
Charge Completion Taper Current Qualifier	mA
Transition to Idle Current	mA
Transition to Discharge Current	mA
Transition to Charge Current	mAHr
Design Capacity	10mWh
Design Capacity 10 mWh	mA
Default Charging Current	mA
User Ratevision	mA
Current Delta	mA
OC Charge Tier 1 Threshold	mA
OC Discharge Tier 1 Threshold	mA
OC Charge Tier 2 Threshold	mA
OC Discharge Tier 2 Threshold	mA
Cell Imbalance Current	mA
SOC Charge Threshold	mA
SOC Discharge Threshold	mA
Fuse Fail Limits	mA

6 References

1. *bq78PL114, PowerLAN™ Master Gateway Battery Management Controller With PowerPump™ Cell Balancing Technology* data sheet (SLUS850)
2. *bq78PL114 and bq78PL114S12 Technical Reference Manual* (SLUU330)
3. *Configuring the bq78PL114 Cell Count* application report (SLUA495)
4. *bqWizard™ User's Guide* (SLUU336)
5. *bq78PL114 System Design Guidelines* application report (SLUA537)
6. *bq78PL116 Technical Reference Manual* (SLUU481).

Appendix A Example .tmap File

Table 10. Example .tmap File

pack configuration file
Filename: bq78PL114S12_8S.tmap
Nominal Pack with 8 cells
Pack Configuration version 1.0
Generated : 03/04/09 09:38:36
bqWizard
2.5
1
11
Pack Config
2
136
#############################
1
0
0
67
1
8
2
1000
8192
3000
12288
1000
8193
10
63568
30780
14376
6164
2048
0
0
0
0
0
0
0
0
0
0
0
0
0

Table 10. Example .tmap File (continued)

0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
40704
135
0
65280
255
257
517
774
1031
8
0
0
0
0
0
5632
80
0

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Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com	Wireless	www.ti.com/wireless-apps
RF/IF and ZigBee® Solutions	www.ti.com/lprf		
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