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LTC4015EUHF
Multichemistry Buck Battery Charger with Digital Telemetry System

DESCRIPTION

Demonstration Circuit 2039A features the LTC®4015EUHF, a Multichemistry Buck Battery Charger with Digital Telemetry System, operating as a 2-cell Li-Ion, 8A battery charger. The DC2039A allows configuring the LTC4015 to support up to 9 cells for Li-Ion and LiFePO$_4$, and 3, 6, or 12 cells for Lead-Acid batteries. Programmable and fully automatic charge algorithms can be chosen for each of the chemistries.

Configuration of the DC2039A demo board is achieved by changing 0Ω jumpers to indicate chemistry and cell count. The V_{IN} voltage must then be appropriate for the cell count and chemistry selected.

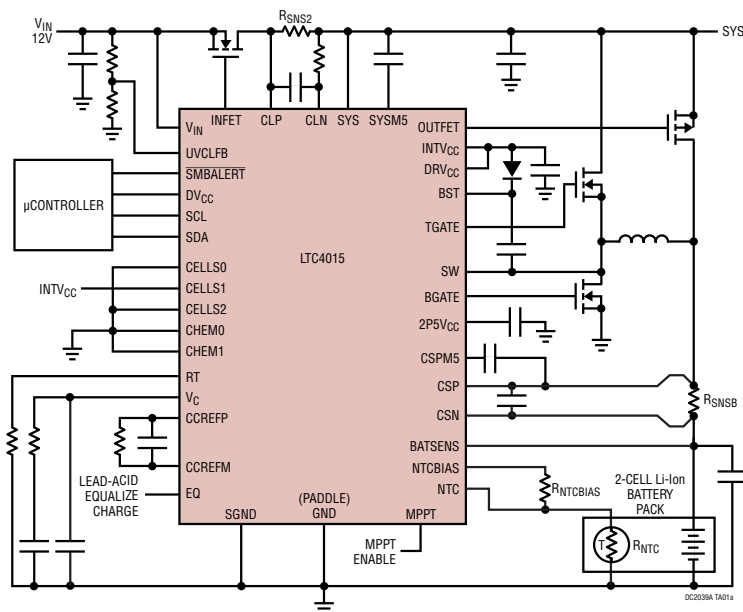**Design files for this circuit board are available.**

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PERFORMANCE SUMMARY Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	DC2039A Input Voltage Range		5		35	V
V(BAT)	DC2039A BAT Turret Pin Voltage (Battery Stack Voltage)	Chemistry = Li, Cell Count = 1 ~ 9 Cells	5		35	V
		Chemistry = Lead-Acid, Cell Count = 12 Cells	5		31.2	V
I(BAT)	DC2039A Charge Current	R_{SNSB} = 4mΩ	7.9	8	8.1	A
V(SYS)	System Voltage	I(SYS) ≤ 8A	$V_{IN} - 0.2V$		V_{IN}	V
I(SYS)	Load Current on System Voltage	I(BAT) = 0A			10.7	A

DEMO BOARD PROCEDURE: TYPICAL APPLICATION

12V$_{IN}$ 2-Cell Li-Ion 8A Step-Down Battery Charger Controller

DC2039A TA01a

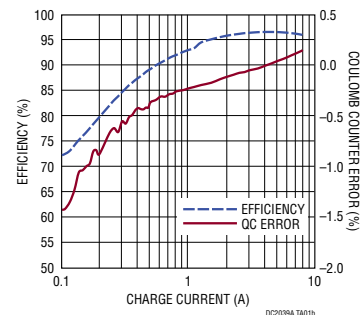**Step-Down Charger Efficiency and Coulomb Counter Error vs Battery Charge Current**

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QUICK START PROCEDURE

Refer to Figure 1 for the proper measurement equipment setup and jumper settings. Please follow the procedure below to familiarize yourself with the DC2039A.

NOTE: When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the V(SYS) or V_{IN} and GND turrets. See Figure 2 for proper scope probe technique.

1. Update to the latest version of QuikEval™ and start QuikEval on the PC. Plug the Micro-B connector on DC2039A board directly into the PC, with the appropriate USB cable, as shown in Figure 1.

2. Set PS1 = 25V, PS2 = 7.4V, and LD1 = 8A. Enable the output on PS1, PS2, and the input on LD1. If this is the first time a DC2039A has been run on this PC, QuikEval will download the GUI from ADI, install it, and start it. Otherwise, it will just start the GUI. Observe V_{IN} voltage and $I(V_{IN})$ current, V(SYS) voltage, V(BAT) voltage and charge current (I(BAT)). The default cell and chemistry configuration for the demo board is 2-cell Li-Ion programmable, and the NTC value was set to

25°C at the factory (when JP2 is on "INT"). The factory default battery charge current sense resistor is 4mΩ, and input current sense resistor is 3mΩ. The default charge current is thus 8A, and the default input current limit 10.667A. PS2 and LD1 form a battery emulator that sets the battery stack voltage, V(BAT), to 7.4V. Since the input voltage (V_{IN}) is 25V, and V(BAT) is 7.4V, the LTC4015 should attempt to charge the battery at 8A. V(SYS) ≈ V_{IN}, because the input ideal diode is on. The input current ($I(V_{IN})$) is the reflected charger current ≈ ((V(BAT) × I(BAT))/(V_{IN} × η)), η ≈ 0.925, $I(V_{IN})$ ≈ 2.6A.

3. Set LD2 = 4A, enable the input, and observe input current and estimated I(SYS) current in the GUI. The input current is now the reflected charger current + I(SYS) = 2.6A + 4A = 6.6A.

4. Disable the output on PS1, and input on LD1, and observe V(BAT) voltage and I_{CHARGE} current, V(SYS) voltage and estimated I(SYS) current in the GUI. The charger is not running so the SYS node is being supplied from the battery, PS2, via the battery ideal diode. So the charge current is now –4A, V(SYS) ≈ V(BAT) = 7.4V, and estimated I(SYS) = 4A.
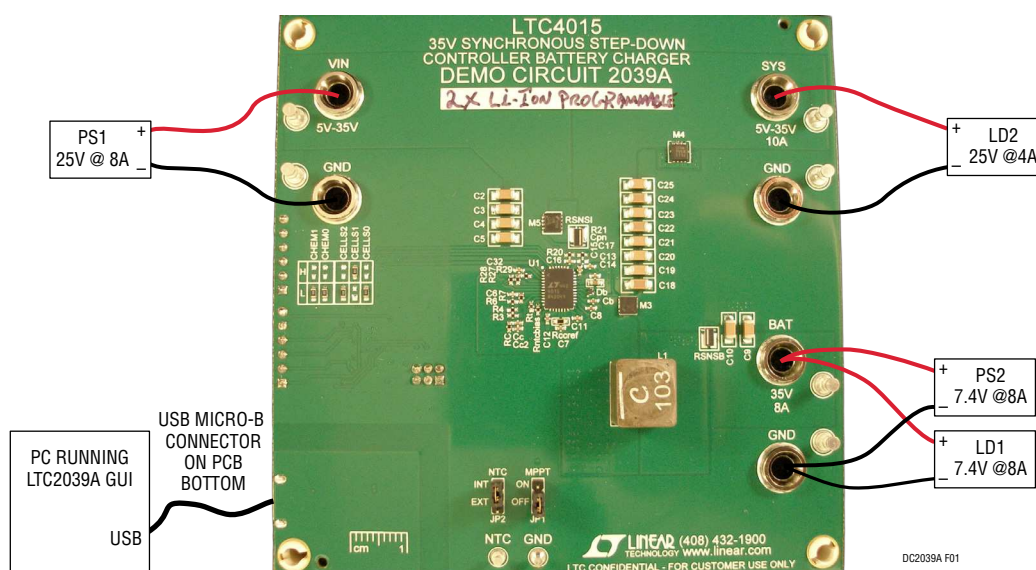

Figure 1. Test Setup for the DC2039 Demo Board
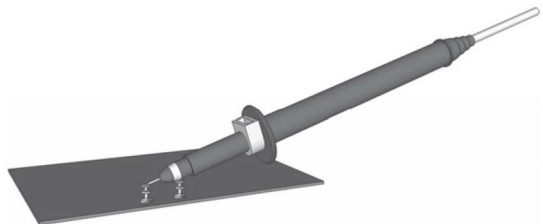
QUICK START PROCEDURE

Figure 2. Measuring Input or Output Ripple

NOTE: All connections from equipment to board pins should be twisted pairs. Any voltage measurements should be Kelvin connections directly to the board pins.

CONFIGURING CHEMISTRY AND CELL COUNT

The chemistry and cell count operation are configured by changing the CHEM[1..0] and CELL[2..0] 0Ω jumpers shown in Figure 3 on the DC2039A demo board. 0Ω 0603 resistors were used instead of jumpers, because the settings must not change after the LTC4015 is powered up by either V_{IN} or V(BAT).
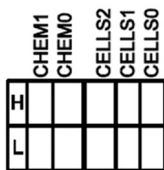
Figure 3. Chemistry and Cell Count Configuration 0Ω Jumpers

The CHEM[1..0] and CELL[2..0] inputs on the LTC4015 are three-level pins. The L means that the low side 0Ω jumper is installed, the H means that the high side 0Ω jumper is installed, and the Z means neither the low side nor the high side 0Ω jumpers are installed. Installing both the low side and high side 0Ω jumpers will short INT_VCC to ground and the LTC4015 may be damaged.

The DC2039A demo board is shipped pre configured for two cells of Li-Ion Programmable charging. If the application of interest requires a different combination of chemistry and/or cell count, modify the jumpers in Figure 3 to suit. Analog Devices recommends that the default configuration be used for initial testing, and changed as needed once the user has gained some experience with the demo board and GUI. In any event, changes to CHEM[1..0] and CELL[2..0] should be made with no voltage applied to V_{IN} or V(BAT).

The data sheet provides tables showing how to set CHEM[1..0] and CELL[2..0], for a given chemistry and cell count, and are reproduced below for convenience.

CHEMISTRY	CHEM1	CHEM0
Li-Ion Programmable	L	L
Li-Ion 4.2V/Cell Fixed	H	H
Li-Ion 4.1V/Cell Fixed	L	Z
Li-Ion 4V/Cell Fixed	Z	L
LiFePO$_4$ Programmable	L	H
LiFePO$_4$ Fixed Fast Charge	H	Z
LiFePO$_4$ Fixed Standard Charge	Z	H
Lead-Acid Fixed	Z	Z
Lead-Acid Programmable	H	L

NUMBER OF CELLS	CELLS2	CELLS1	CELLS0
Invalid	L	L	L
1	L	L	H
2	L	H	L
3**	L	H	H
4	L	L	Z
5	L	Z	L
6**	L	H	Z
7	L	Z	H
8	L	Z	Z
9	H	L	L
Invalid	H	L	H
Invalid	H	H	L
12*	H	H	H

* Lead-Acid Only
**All Chemistries

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DC2039A THEORY OF OPERATION

Introduction to the DC2039A

The DC2039A demonstration circuit features the LTC4015EUHF Multichemistry Buck Battery Charger with Digital Telemetry System. The LTC4015EUHF is a Buck topology switching battery charger controller that includes a comprehensive telemetry system. In addition, the LTC4015 has two ideal diode controllers, and an MPPT function. The LTC4015 also features a Coulomb counter with a 16-bit prescaler. The LTC4015EUHF is packaged in a 5mm × 7mm, 38-lead exposed pad QFN that is rated at 34°C/W.

The LTC4015EUHF implements the switching charger with external switch MOSFETs. The DC2039A demo board implements the switch as a dual N-channel MOSFET in a single package.

The telemetry system features a 14-bit ADC for monitoring all the operating parameters of the charger. The behavior of the charger is controlled by on-die DACs, with only the power MOSFETs and current sense resistors external to the LTC4015.

The LTC4015EUHF has two Ideal Diode controllers with external power MOSFETs. One Ideal diode is between the input voltage, V_{IN}, and the system output node, SYS. The other Ideal Diode is between battery stack at BAT, and the system output node, SYS. This allows the routing of power from either the input or the battery stack to the system output, without backfeeding either.

The dynamic MPPT algorithm ensures that the LTC4015 is operating at the maximum power point condition, even when the MPPT operating point is changing. Thus,

if a photovoltaic cell becomes shaded due to clouds, the LTC4015 will adjust operation to the shaded MPPT.

See the DC2039A schematic and the LTC4015EUHF data sheet for details of the functional descriptions below.

Current Mode Buck Regulator

The battery charger is implemented as a switching regulator with a Current Mode Buck topology. Thus, the battery charge voltage can be less than or nearly equal to the input voltage, V_{IN}.

The buck regulator switch is composed of N-channel MOSFETs in a single package, M3A & M3B. Because two N-channel MOSFETs are used, the gate drive of the top switch MOSFET, M3B, has to be bootstrapped from INT_VCC via D_B and C_B. This bootstrapping provides up to INT_VCC ($\approx$ 4.3V) of gate drive to M3B. The DRVCC pin, also provides the bottom switch MOSFET, M3A, with up to INT_VCC of gate drive. When the top switch is on, the SW pin rises to very nearly V(SYS), and the BOOST and TG pins rise to V(SYS) + INT_VCC, please see Figures 4 and 5.

The buck regulator switching frequency is set by R_t, and on the DC2039A R_t = 95.3kΩ, so the switching frequency is set to 500kHz. The buck inductor, L_1, is a 10mm × 10mm × 10mm 10µH inductor with DCR = 13.4mΩ, and I_{SAT} = 17.5A.

The topology of the DC2039A now diverges from that of a buck regulator to implement a battery charger. After L_1, the switching inductor, the current goes through R_{SNSB} to the battery and $\approx$ 20µF of MLCC capacitance. The instantaneous current measured by R_{SNSB} is used by the Current Mode Buck regulator.

DC2039A THEORY OF OPERATION

VBAT = 7.4V
I_CHARGE = 8A
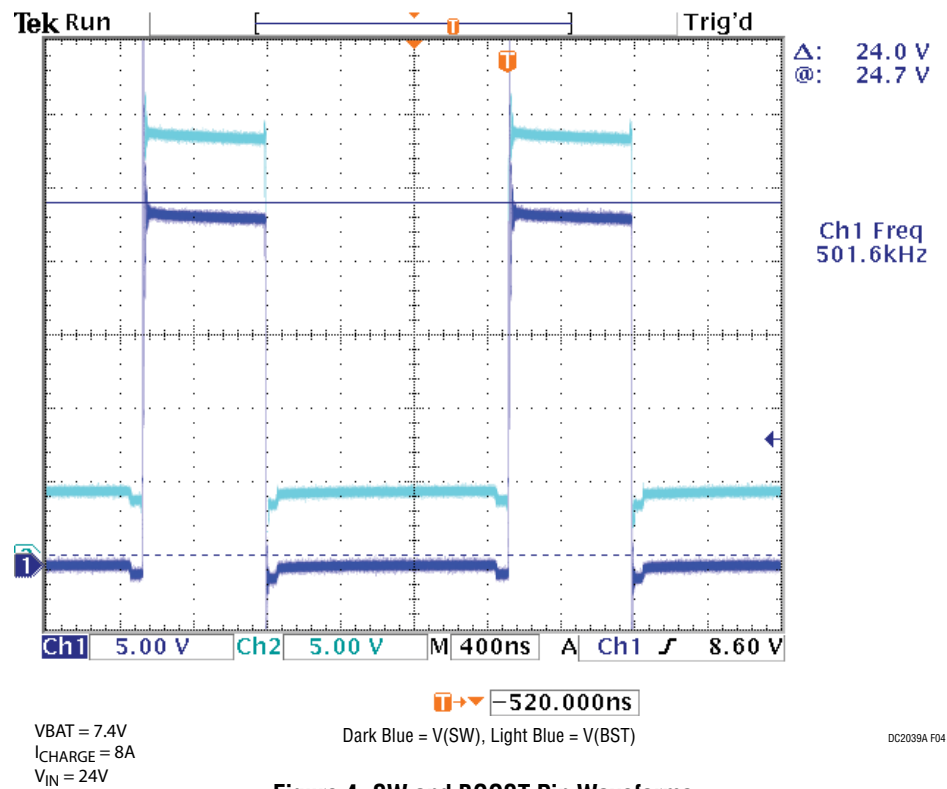V_IN = 24V

Dark Blue = V(SW), Light Blue = V(BST)

DC2039A F04

Figure 4. SW and BOOST Pin Waveforms

VBAT = 7.4V
I_CHARGE = 8A
V_IN = 24V

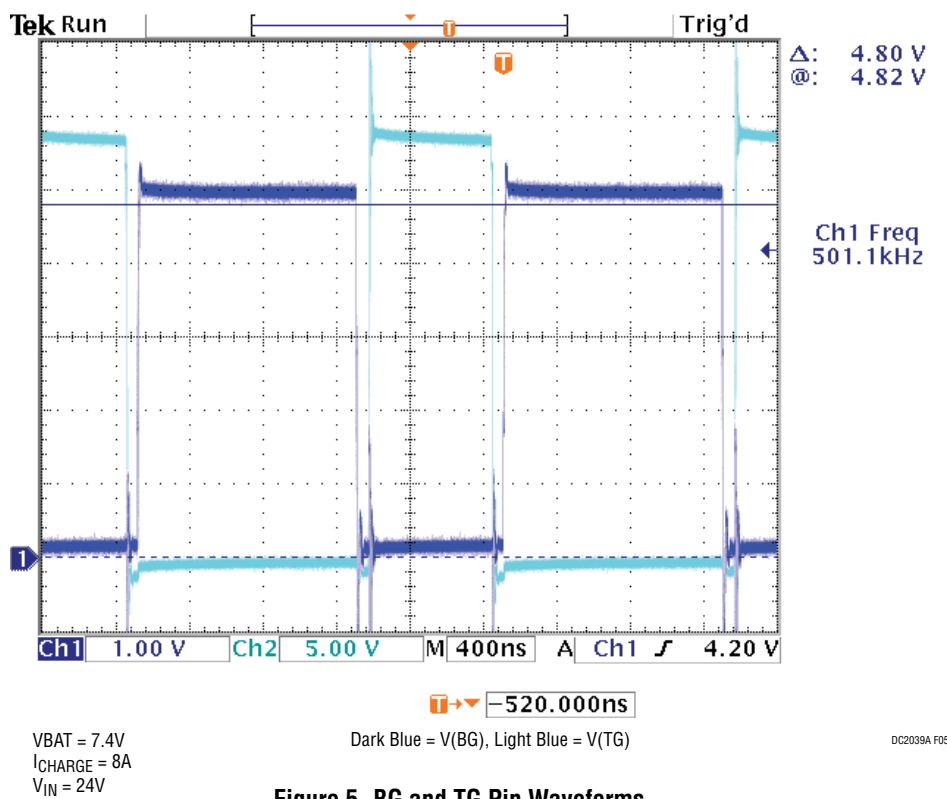Dark Blue = V(BG), Light Blue = V(TG)

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Figure 5. BG and TG Pin Waveforms

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DC2039A THEORY OF OPERATION

The Current Mode Buck regulator also has input Undervoltage Current Limit (UVCL). The LTC4015 tries to keep the UVCLFB pin above 1.2V. When the voltage at the UVCLFB pin falls to 1.2V, the Current Mode Buck regulator begins to dial back the charge current, I(SYS) current is unaffected. If the UVCLFB pins falls to 1.15V, charge current is dialed back to 0A, I(SYS) current continues to be unaffected, and may be large enough to keep the LTC4015 in UVCL.

On the DC2039A, the UVCLFB pin divider, when not in MPPT, is 10/75 = 0.133, so the DC2039A maximum V_{IN} UVCL voltage is 1.2V/0.133V = 9V. This voltage may be reduced, only, by changing the value of the VIN_UVCL_SETTING (0x16) register.

Battery Charger

The battery charger is a full function charger. In CC mode, the average current through R_{SNSB} is used to control the output voltage of the buck regulator such that the battery is charged with a constant current.

In CV mode, the Current Mode Buck regulator behaves like a voltage regulator maintaining the desired voltage at the BAT turret, with an internal feedback divider.

The battery charger supports multiple chemistries, specifically Li-Ion, LiFePO$_4$, and Lead-Acid (PbH+). The battery charger can support whatever battery stack voltage it can make as a buck regulator with a maximum 35V input. The battery charge voltage for Li-Ion has a maximum of 4.2V, so the LT4015 charger can support a stack of up to 8 batteries. However, 9 batteries is a valid cell count for the Li-Ion, as some applications may only charge Li-Ion cells to 3.8V. The maximum battery charge voltage for LiFePO$_4$ is 3.8V, including absorb, so the LTC4015 can support a stack of up to 9 batteries. Finally, PbH+ cells have a maximum voltage of 2.6V, including absorb and equalize, but almost all applications use multiples of 3 cells. So the LTC4015 can charge 3, 6, or 12 PbH+ cells.

Besides the standard CC-CV charging profile, the charger has many other features. The LTC4015 supports programmable charge voltage and charge current, C/x and/or timer termination, trickle charge (Li-Ion chemistries only), maximum total charge time, JEITA temperature based charge control

(Li-Ion and LiFePO$_4$ chemistries only), charge absorption (LiFePO$_4$ and PbH+ chemistries only) and cell equalization (PbH+ chemistries only).

The chemistry and cell count are set using pins, and must not change after power on. The range of charge current is determined by the switch MOSFETs, M3A and B, and the charge current sense resistor R_{SNSB}. On the DC2039A, R_{SNSB} = 4mΩ, and the maximum charge current sense voltage is 32mV, so the maximum charge current is 8A.

The battery charger can also monitor the battery temperature using the NTC resistor. The temperature measured supports the JEITA charge current vs battery temperature without processor intervention. The charger can assert an SMBAlert for battery too hot and too cold. When the NTC jumper (JP2) is on "INT", the DC2039A emulates the NTC resistor with an electronic potentiometer. This allows the demo board user to set the NTC temperature directly and see the resultant operation.

Battery I$_Q$ Measurement

The LT4015 has very low BAT pin I$_Q$ current, 112μA (Typ). This current is measured with voltage applied to the BAT pin only, with the telemetry system off. The GUI and other user interface functions, on the demo board, require that USB power be applied. If USB power is not applied, sneak (leakage) paths in the embedded microcontroller will increase BAT pin I$_Q$ current to over 1mA.

Input Current Limit

The DC2039A contains an input current sense resistor, R_{SNSI}, that allows the input current to be sensed by the LTC4015. R_{SNSI} = 3mΩ and the maximum input current limit sense voltage is 32mV, so the maximum input current limit on the DC2039A is 10.7A. The input current sensed by the LTC4015 is the sum of the I(SYS) current and battery charge current via M3B. The LTC4015 will reduce the battery charge current to keep the input current below the limit. However, once the battery charge current reaches 0A, the LTC4015 cannot further reduce the input current, as it cannot reduce the load current on the SYS node.

DC2039A THEORY OF OPERATION

Ideal Diodes

There are two Ideal Diode controllers, one performs the PowerPath™ function from the BAT to SYS (battery PowerPath function). The other performs the PowerPath function from V_{IN} to SYS (V_{IN} PowerPath function). The battery PowerPath Ideal Diode is M4, a P-channel MOSFET, and the V_{IN} PowerPath Ideal Diode is M5, an N-channel MOSFET.

In each case, the body diode already has the correct polarity, but when forward drop exceeds 15mV, the MOSFET is enhanced, to try and keep the forward drop to 15mV. The forward drop will still exceed 15mV if $(I_D \times R_{DS}(on)) > 15mV$.

Maximum Power Point Tracking (MPPT)

The LTC4015 contains a dynamic power point tracking function that continuously checks for a local maximum, and periodically checks for a global maximum. Thus, as shade obscures a solar cell, the LTC4015 would also track the MPPT down maintaining the optimum operating point at all times.

The LTC4015 can only alter battery charge current to try and stay at the MPPT, but once battery charge current reaches zero, the LTC4015 will not be able to track the MPPT further, as it cannot alter the SYS node load current.

MPPT reuses the UVCLFB pin, and the UVCL threshold must be set to 35V, or higher, to use MPPT. The DC2039A automatically moves the UVCL threshold to 36V using U2, M1, and M2, whenever MPPT is selected with JP1.

Coulomb Counter

The RSNSB current sense resistor provides both peak current information for the Current Mode Buck regulator, and average current information for the battery charger. It also provides 2 quadrant current information to the built in coulomb counter. This counter can be used to track the charge stored in the battery, by integrating the current information from R_{SNSB}. The count increases when battery current is positive—going into and charging the battery. And the count decreases with the battery current is negative—going out of and discharging the battery. Current can be drawn from the battery via the battery PowerPath function.

The coulomb counter has a 16-bit prescaler, and so can be used to track the SoC of very large batteries, up to 15,000Ahr batteries are supported.

Telemetry System

The LTC4015 has a comprehensive telemetry system on board. This telemetry system can read most system parameters, through appropriate dividers or amplifiers, using a 14-bit Analog-to-Digital converter (ADC). Please refer to the LTC4015 data sheet for details.

I²C

The LTC4015 has an I²C port, with SMBus word readback, SMBAlert, and over 70 registers for configuration and status information. All the registers are words (16-bit), some are signed, all registers can be read by (s = start, R_s = restart, p = stop):

> s-device write address-subaddress-R_s-device read address-byte 1/ACK-byte2/NACK-p

Or written by:

> s-device write address-subaddress-byte-byte1/ACK-byte2/NACK-p

An SMBAlert is cleared by reading a byte from the ARA device address (0x19), the returned byte is the address of the a device that posted the SMBAlert:

> s-ARA read address-byte/NACK-p

Please refer to the LTC4015 data sheet for more details about communicating with the LTC4015.

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DC2039A GRAPHICAL USER INTERFACE (GUI)

Introduction to the GUI

The LTC4015 GUI, in conjunction with the DC2039A demo board, provides a way to explore the many features of the LTC4015EUHF. It is also a sophisticated system development platform that helps reduce the number of end product prototype cycles.

The LTC4015 GUI runs within an environment called "LTC4015 Main Page" that can host one or many instances of the LTC4015 GUI simultaneously. The banner of the GUI contains information identifying which demo board corresponds with which GUI, if more than one board is present.

There is no intermediate board for the DC2039A, it plugs directly into a PC USB port via the Micro-B connector (J1), in the lower left hand corner of the demo board. If QuikEval is running when the DC2039A is plugged in, or started after the DC2039A is plugged in, QuikEval will automatically identify the board and check to see if the GUI is installed. If not, the GUI is downloaded and installed, once installed QuikEval will start the GUI. The GUI can be downloaded and installed before starting QuikEval, and QuikEval will still start the GUI when a DC2039A board is plugged in. One copy of the GUI will be started for each DC2039A board plugged into the PC, all running within the LTC4015 Main Page environment.

The GUI can be updated manually, or it can update automatically. If it has been more than 30 days since the GUI last updated, the QuikEval will automatically check for an update on ADI's servers at startup. If it finds a newer version, the newer version will be automatically downloaded and installed. The user can force an update at any time by selecting the "Update LTC4015 GUI" shortcut in the start menu.

The first time that the DC2039A GUI is started, it will create an Excel file (*.xls, Excel 1997~ 2004 format) named "LTC4015, *serial number*"in the directory"~\My Documents\Linear Technology\DC2039A". The Worksheet "serialnumber, createdate" contains information used by the GUI, it is highly recommended that this worksheet only

be altered at ADI's request. Any information gathered by customers can also be saved to this Excel Workbook, as separate time and date stamped Excel worksheets. This Excel file can be deleted, and it will be recreated the next time the GUI is started. However, if the Excel file is deleted, any data and configurations saved by the user will be lost, and all resistor values will be reset to the factory defaults.

Users can save up to 10 named custom configurations, and have the GUI load the custom configuration at startup. Thus, if a current sense resistor value is changed, it isn't necessary to remember to change it each time the GUI is used. Instead it could be save in a configuration named "ADI is #1" (up to 16 arbitrary characters) and the GUI could be set to load "ADI is #1" at startup.

In the same directory as the Excel file, there may also be log files which are named similarly to the Excel file except that the create date and an index are included in the name. The index can be 1 ~ 99, allowing up to 99 different sessions per day to be documented. The log file is a text file, and unlocked, but is intended primarily as a troubleshooting aid should a problem with the DC2039A demo board or GUI be encountered at a customer site. Unneeded log files can be deleted without consequence. ADI will inform the user how to enable logging. No user proprietary information is logged in the log file, only startup and execution information for the GUI, to aid Analog Devices in troubleshooting GUI usage problems.

Each element of the GUI has a tooltip that will pop up when the mouse hovers over the element for a few seconds. Tooltips contain a description of the functionality, editability and short cut keys, if applicable.

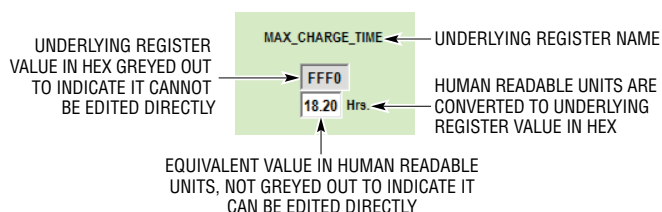This is how to interpret register information presented in the GUI:

Figure 6. Interpreting Register Information in the GUI

LTC4015 GRAPHICAL USER INTERFACE (GUI)

The LTC4015 Main Page Environment

The LTC4015 GUI runs within an environment called the "LTC4015 Main Page". The banner, of the LTC4015 Main Page, indicates how many DC2039A demo boards are currently attached to the PC hosting the LTC4015 GUI.

The LTC4015 Main Page environment contains one or many instances of the LTC4015 GUI. It also contains any child forms an LTC4015 GUI may spawn. The DC2039A demo board serial number is contained in the corresponding LTC4015 GUI's banner, and any corresponding child form's banner.

The LTC4015 Main Page environment dynamically catalogs the DC2039A demo boards attached to the host PC, and will open a new instance of the LTC4015 GUI when a DC2039A demo board is attached to the host PC. It will also close the corresponding LTC4015 GUI when a DC2039A demo board is detached from the host PC.

One or all of the LTC4015 GUI instances may be closed and the LTC4015 Main Page will remain open, but the LTC4015 Main Page will not attempt to reopen any LTC4015 GUIs that are closed by the user. To reopen an LTC4015 GUI closed by the user physically detach and reattach the corresponding DC2039A demo board.

If the LTC4015 Main Page window is closed, all open LTC4015 GUIs are also closed.
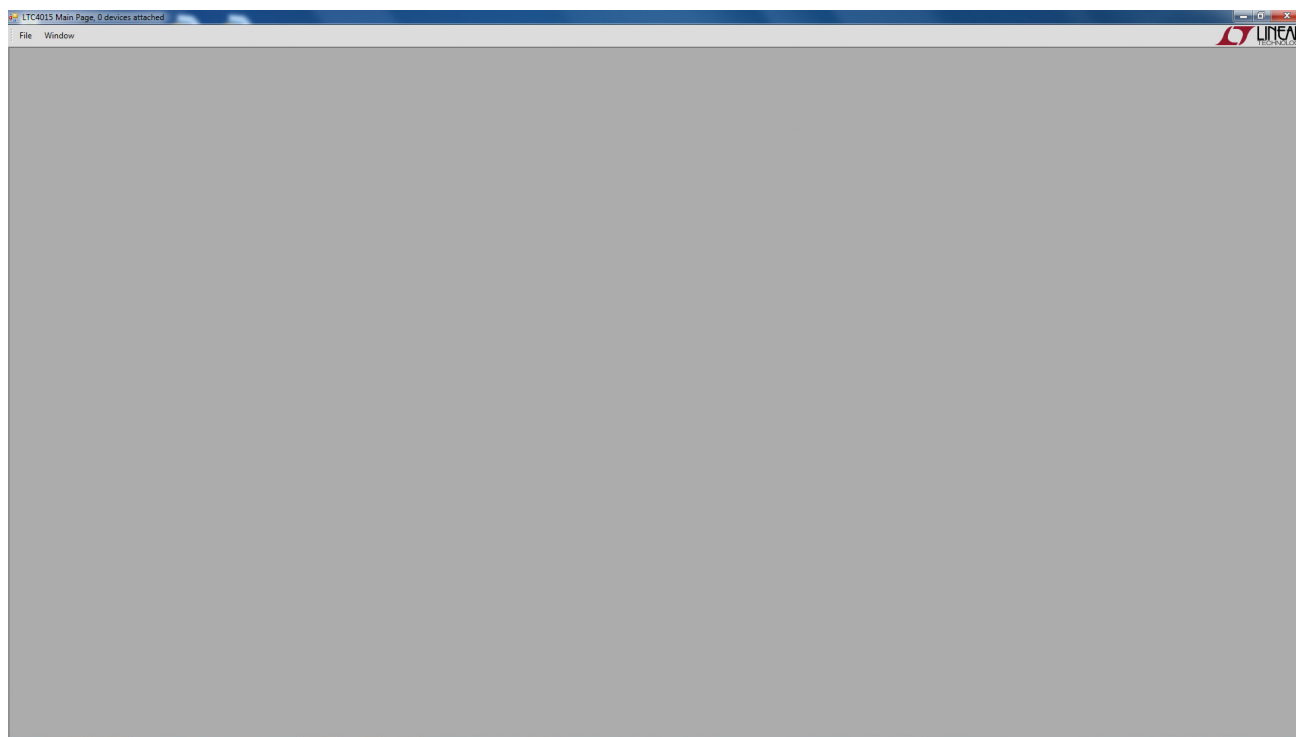
Figure 7. LTC4015 Main Page Environment

LTC4015 GRAPHICAL USER INTERFACE (GUI)

LTC4015 GUI

The LTC4015 Main Page environment hosts the LTC4015 GUIs and any child forms they may spawn. Ownership or parentage is managed via the DC2039A demo board number serial number in the banner of the GUIs and child forms. The serial number of the DC2039A demo board is labeled on the bottom of the board. This also allows users to know which demo board is controlled by which GUI, if more than one GUI and demo board are present.

If more than one GUI is present, the GUIs are arranged in a cascade by default, but the user can use the Window menu on the LTC4015 Main Page to arrange the LTC4015 GUIs as desired. The LTC4015 Main Page Window menu can also be used to bring the desired LTC4015 GUI to the front.
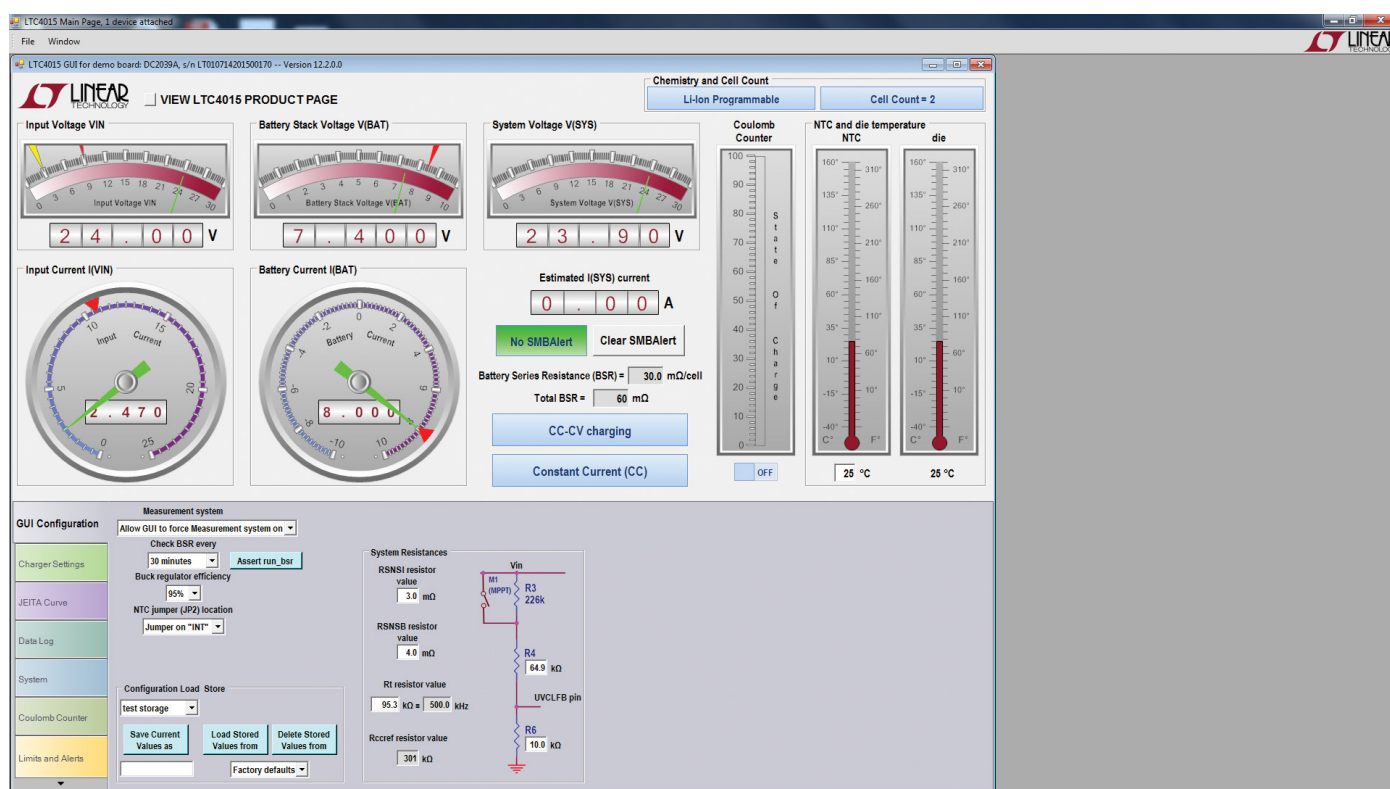
Figure 8. LTC4015 GUI Running Within the LTC4015 Main Page Environment

LTC4015 GRAPHICAL USER INTERFACE (GUI)

LTC4015 GUI Areas

The LTC4015 GUI has two distinct areas, the Dashboard and the Tab areas. Elements in the Dashboard area are always visible if the LTC4015 GUI is not minimized. Elements of the Tab area change depending on which Tab is chosen.

The seven tabs in the Tab area are selected by clicking the mouse on the tabs at the left of the Tab area.

The LTC4015 GUI defaults to the GUI Configuration tab, unless the Coulomb counter is turned on. If the Coulomb counter is turned on, the LTC4015 GUI defaults to the Coulomb counter tab.
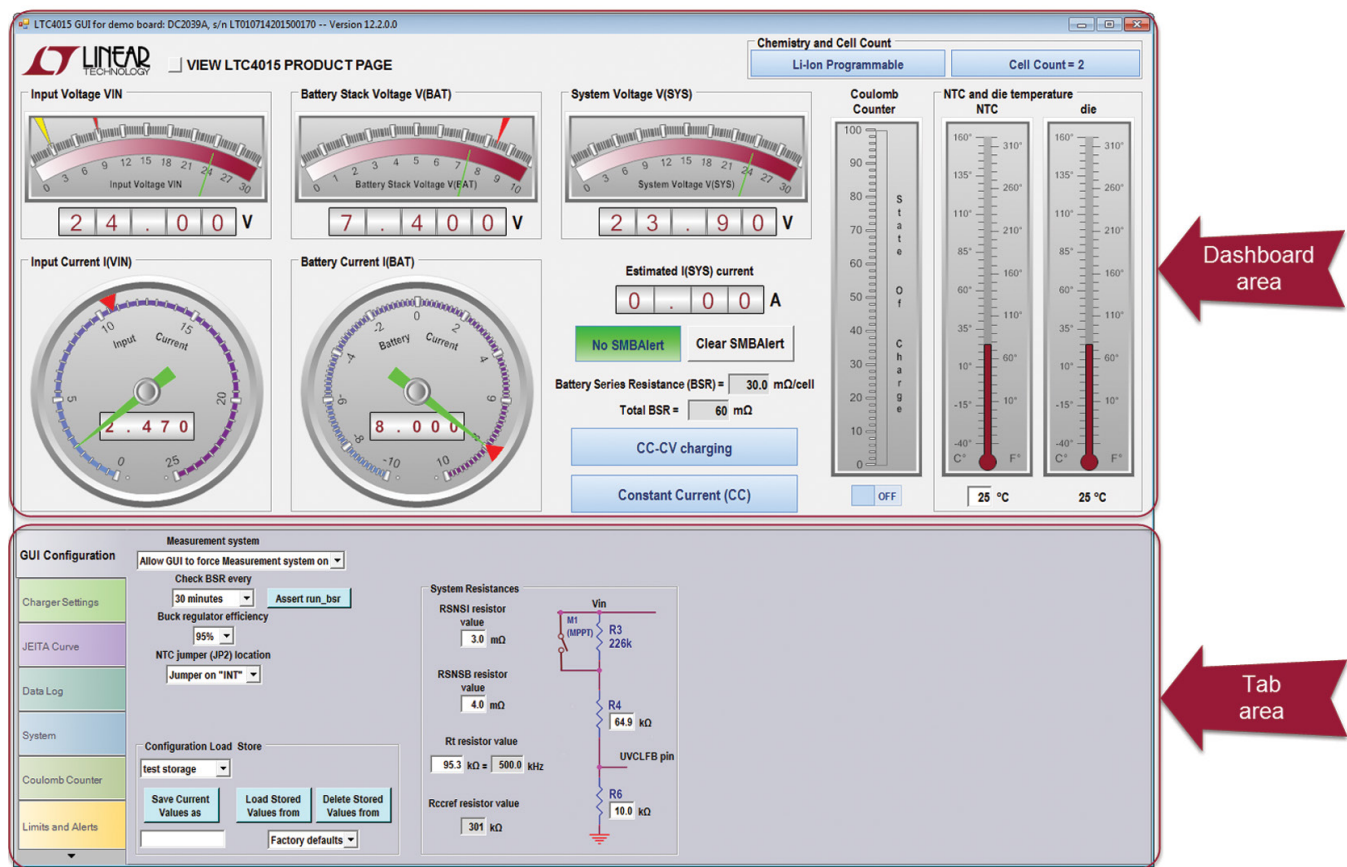
Figure 9. The LTC4015 GUI is Composed of Two Distinct Regions

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LTC4015 GRAPHICAL USER INTERFACE (GUI)

LTC4015 GUI Popups

GUI popup tooltips indicate what the element does, details about what sub-elements may do, such as what the red pointer indicates on an analog meter. The tooltip also indicates whether or not the element contains any user editable fields, and, if so, what keyboard shortcuts are available.

To activate the tooltip, it is necessary to hover the mouse pointer over the GUI element of interest for 2 or 3 seconds. The tooltip will stay open up to 10 seconds, as long as the mouse pointer continues to hover over the element.
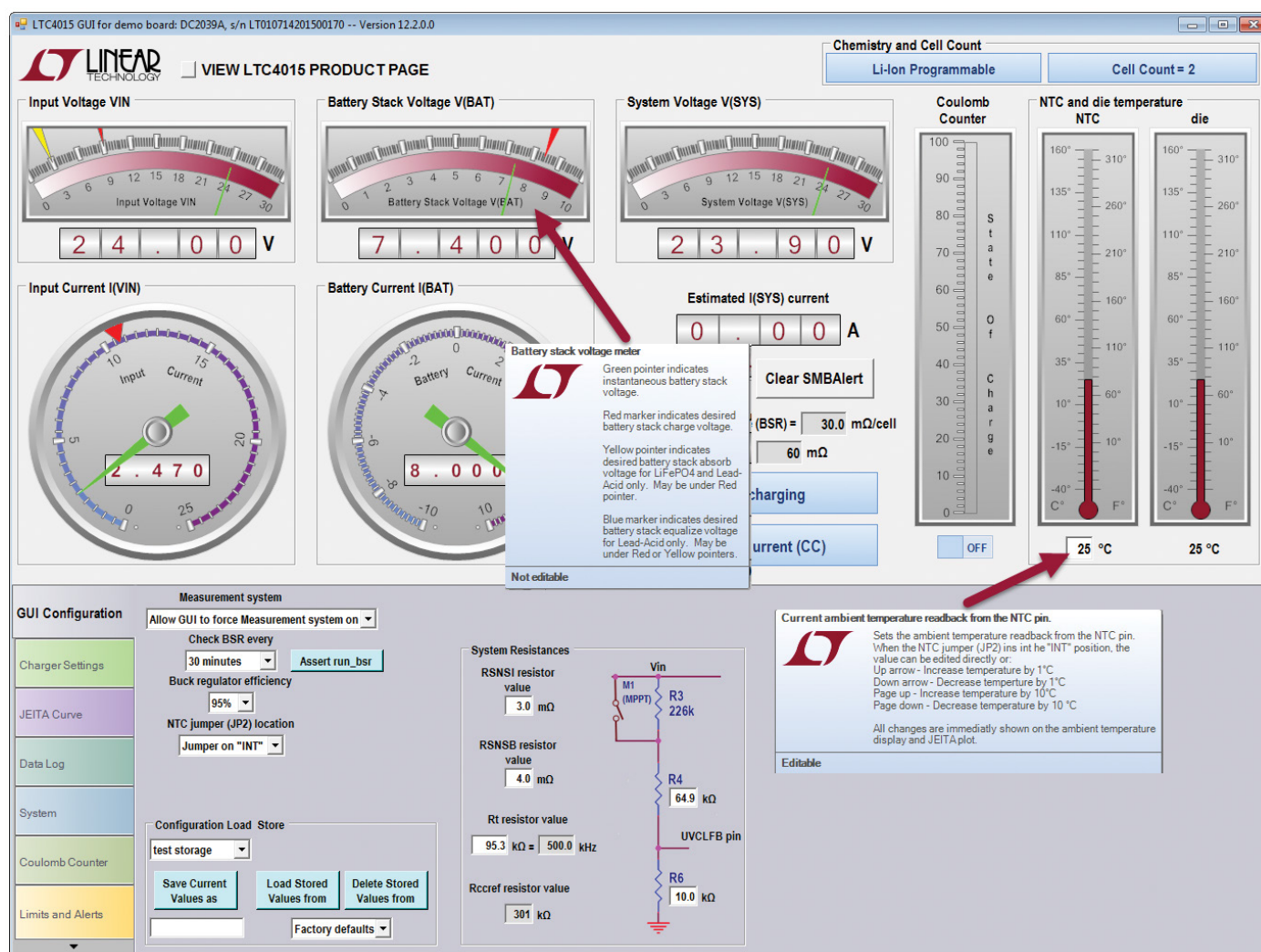
Figure 10. All Elements in the GUI Popup Tooltips

LTC4015 GRAPHICAL USER INTERFACE (GUI)

LTC4015 GUI Tabs

The Tab area is composed of seven different tabs each selectable by clicking on the tabs at the left. The GUI Configuration tab is selected by default, unless the Coulomb counter On/Off switch is toggled to On, in which case the Coulomb counter tab is selected.

Each of the seven tabs is shown below, in the same order as corresponding tabs used to select a tab, on the left of the Tab area. Selecting the arrow at the bottom of the tabs will show a list of all the tabs. The desired tab can also be selected from this list.

The dashboard and individual tabs will be discussed in detail in the next section of the demo manual.
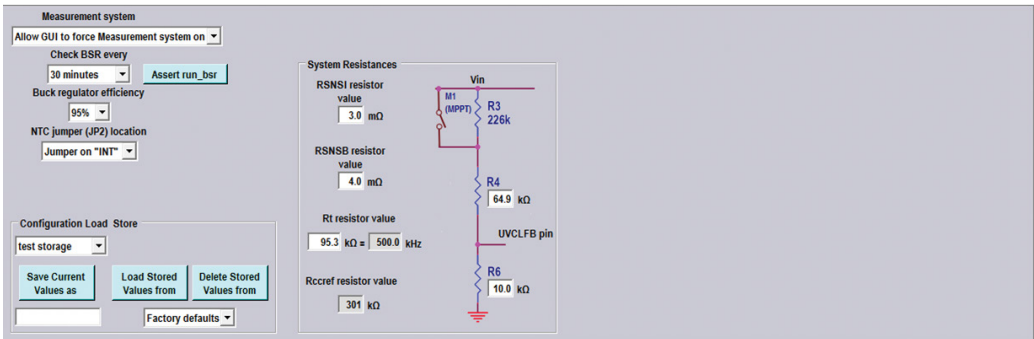
Figure 11. The GUI Configuration Tab
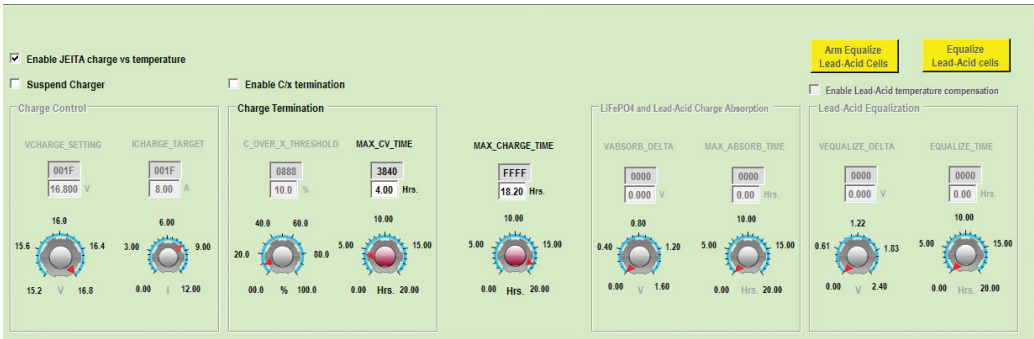
Figure 12. The Charger Settings Tab
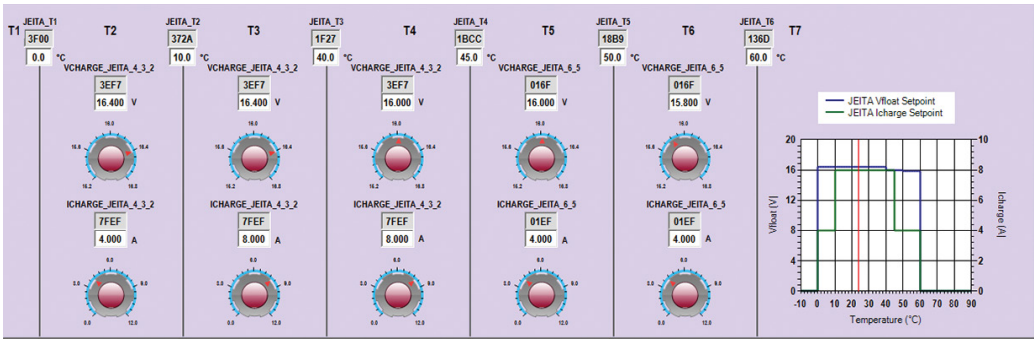
Figure 13. The JEITA Curve Tab

LTC4015 GRAPHICAL USER INTERFACE (GUI)
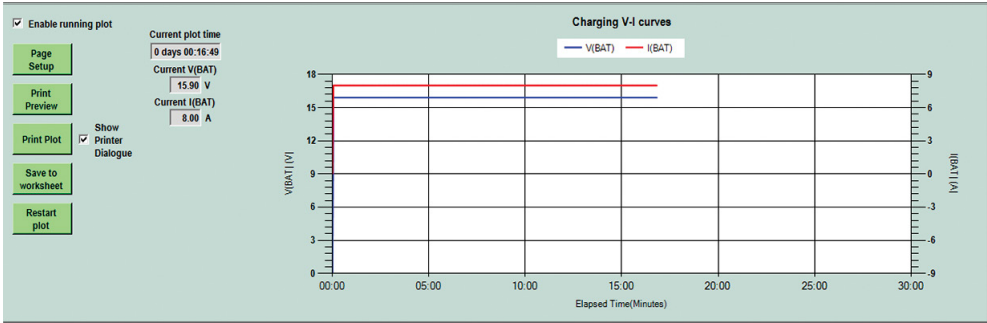
Figure 14. The Charge Status Tab
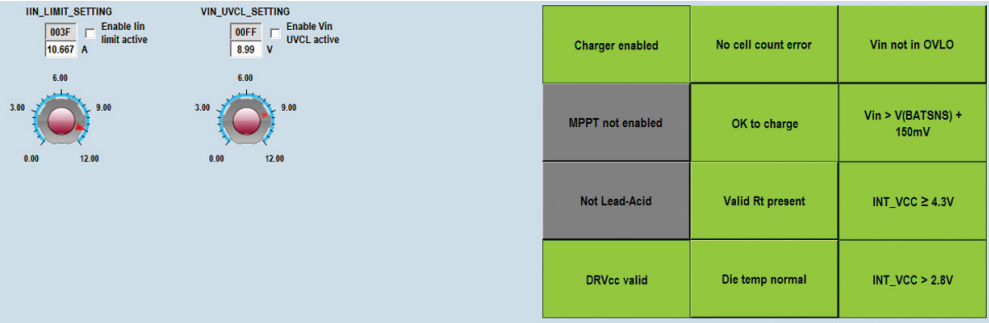
Figure 15. The System Tab

LTC4015 GRAPHICAL USER INTERFACE (GUI)
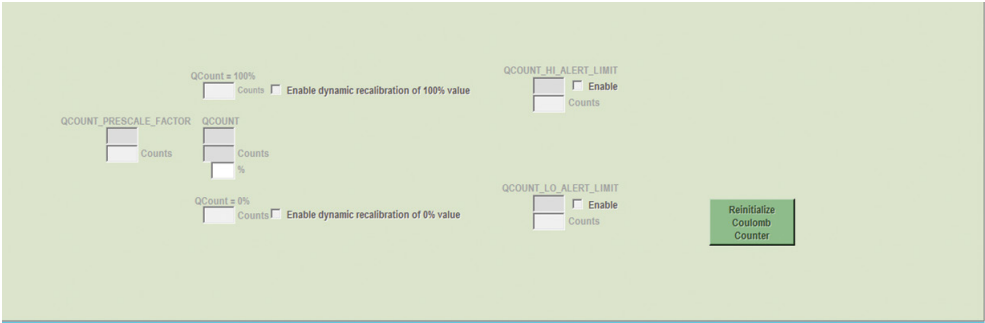
Figure 16. The Uninitialized Coulomb Counter Tab
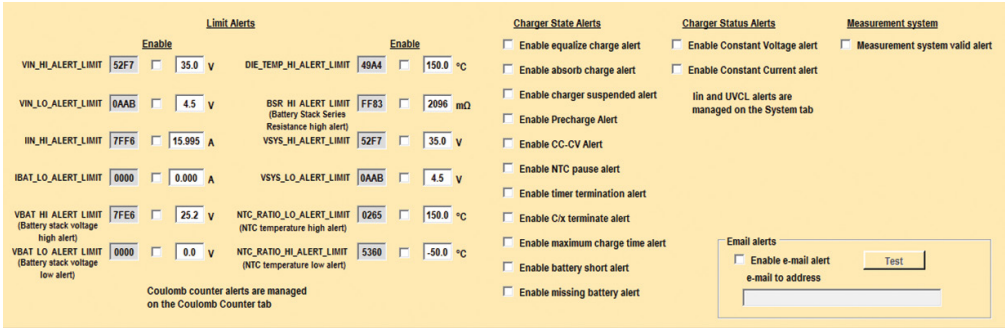
Figure 17. The Limits and Alerts Tab

THE DASHBOARD IN DETAIL

GUI BANNER WITH "LTC4015," "DEMO DC2039A" AND SERIAL #

V_{IN} VOLTAGE VOLTMETER, ANALOG/DIGITAL

BROWSE LTC4015 PAGE AT WWW.LINEAR.COM

V(BAT) BATTERY STACK VOLTAGE VOLTMETER, ANALOG/DIGITAL

SMBALERT STATUS AND IF ASSERTED, CAUSE

ESTIMATED I(SYS) CURRENT

V(SYS) VOLTAGE VOLTMETER, ANALOG/DIGITAL

CHEMISTRY AND CELL COUNT PROGRAMMED BY CHEM[1..0] AND CELLS[2..0] JUMPERS ON THE DC2039A

I(V_{IN}) CURRENT AMMETER, ANALOG/DIGITAL

BATTERY CURRENT AMMETER, ANALOG/DIGITAL – POSITIVE IS CURRENT INTO THE BATTERY

CURRENT CHARGER STATE

CURRENT CHARGE CYCLE STATUS

MEASURED BATTERY STACK RESISTANCE – DEFAULTS TO MAXIMUM MEASURABLE VALUE AT POWER UP

CURRENT VALUE OF THE COULOMB COUNTER

ENABLE/DISABLE COULOMB COUNTER – FIRST TIME IT IS ENABLED, A CONFIGURATION WIZARD IS INVOKED

NTC TEMPERATURE THERMOMETER, ANALOG/DIGITAL – WHEN NTC JUMPER (JP2) IS ON "INT", CAN BE SET DIRECTLY

DIE TEMPERATURE THERMOMETER, ANALOG/DIGITAL

Figure 18. LTC4015 GUI Dashboard Detail

THE DASHBOARD IN DETAIL

The dashboard is always visible, and shows all the instantaneous state variables needed to monitor a charge cycle. The dashboard updates approximately twice a second. The only value directly modifiable by the user is the current NTC temperature (when the NTC jumper (JP2) is on "INT"). However, the Coulomb counter is modifiable indirectly by both the Coulomb counter ON/OFF switch and the Coulomb counter tab. The Battery Stack Resistance update rate is also modifiable in the GUI Configuration tab.

The function of the voltmeters and ammeters is to show the corresponding instantaneous voltages and currents.

The Chemistry and Cell Count box contains two tiles that show the currently selected chemistry and cell count. These items are selected by the CHEM[1..0] and CELL[2..0] jumpers, on the DC2039A demo board, and must not be changed after Power On Reset (POR). Changing these values after POR will produce unexpected results, and is strongly discouraged. The "xxx Programmable" chemistries allow configuration of various charge parameters in the Charger Settings tab and for Li chemistries the JEITA Curve tabs. Most of the Charger Settings and JEITA Curve tab are disabled for Non-Programmable chemistries. Cell count is range checked at power up. If the selected chemistr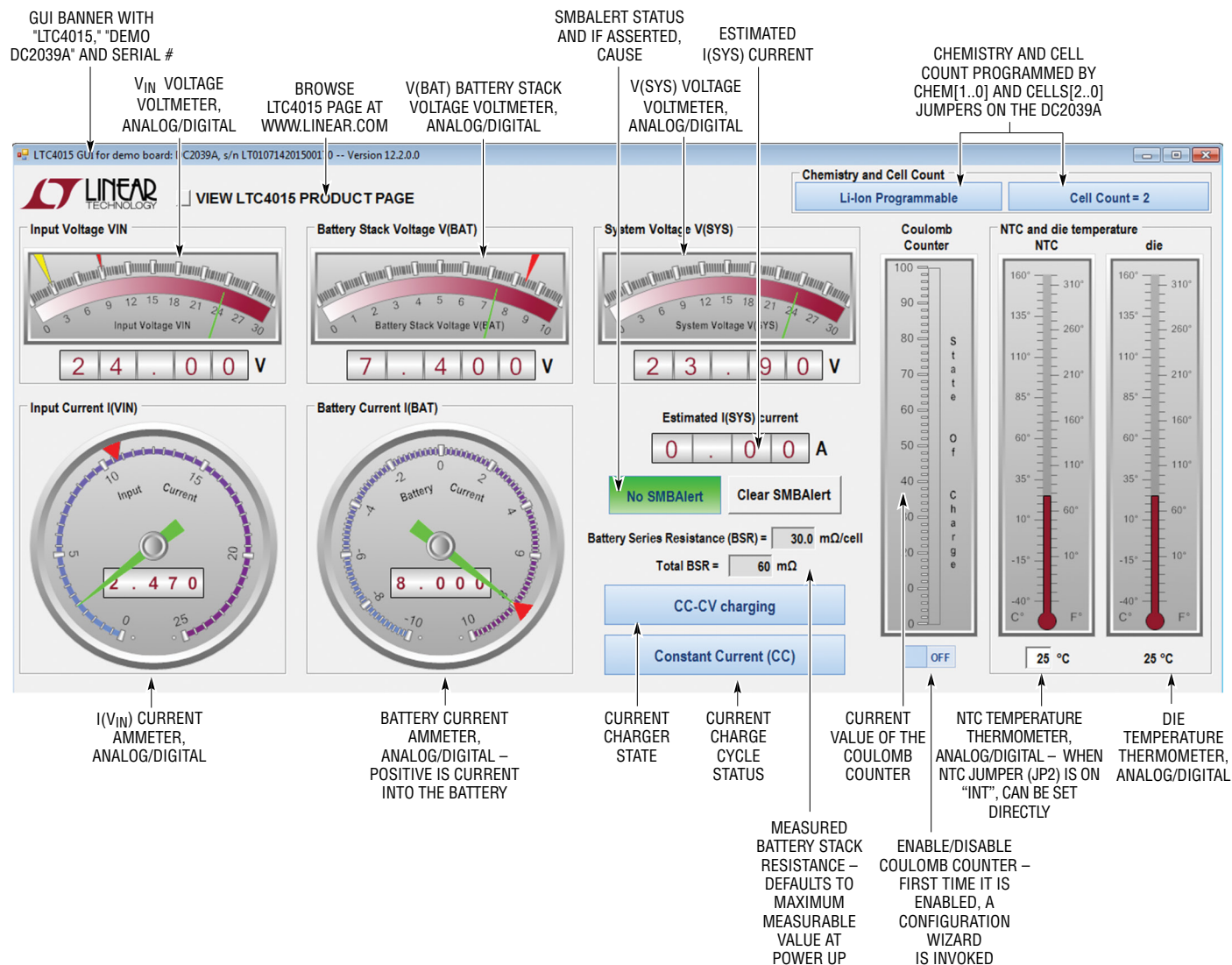y and cell count are not compatible, the GUI will open in a zombie state. None of the GUI will be functional, but the chemistry and cell count will reflect the selection made by the CHEM[1..0] and CELL[2..0], for troubleshooting purposes.

The estimated system current, I(SYS) is calculated by:

$$I(SYS) = I(V_{IN}) - \frac{V(BAT) \cdot I(BAT)}{\eta \cdot V(SYS)}$$

If $V_{IN} \le V(BAT)$, Then :

$$I(SYS) = I(V_{IN}) - I(BAT)$$

The input current measurement of the LTC4015 cannot differentiate between current going to the battery via the charger and current going to the load on SYS. Using the efficiency selected in the pull-down on the GUI Configuration tab, I(SYS) can be estimated with reasonable accuracy.

The SMBAlert tile and Clear SMBAlert button allow managing of the SMBAlert function of the LTC4015. When one or more SMBAlerts are asserted, the SMBAlert tile will change to:
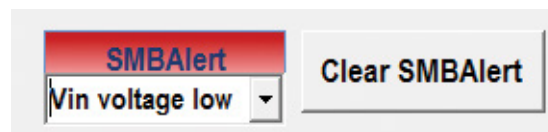
The pulldown box will list all pending SMBAlert causes, pressing Clear SMBAlert clears all the pending alerts using an ARA and checking that the responding device is the LTC4015. It is possible that an SMBAlert will post due to one reason, but one or more other reasons may assert before the Clear SMBAlert button is pushed. The pulldown box is continuously updated with new SMBAlert reasons until the Clear SMBAlert button is pushed. It is also possible that an SMBAlert reason will assert and de-assert before the Clear SMBAlert button is pushed. All reasons for the SMBAlert are kept in the pulldown box, until the Clear SMBAlert button is pushed, even if they've since de-asserted.

The Battery Stack Resistance value is calculated by recording the charge current and battery voltage, momentarily shutting off the charger, and re-measuring the battery voltage. BSR is then the change in battery voltage divided by charge current. As such it can only be measured while charging the battery. The default value at power up, is the maximum measurable BSR for the currently selected cell count. The BSR may be updated on a fixed interval or on demand, using the pulldown box or button on the GUI Configuration tab:
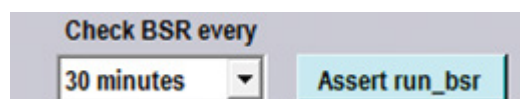
All BSR measurement requests are ignored if the charger is not in a state that allows measurement, such as, for example, NTC pause. Also, if the battery charge current is small, for example at the end of a charge cycle in CV mode, the resultant voltage change from momentarily shutting the charger off will also be small. Thus, one small number may be divided by another small number, and the numerical resolution of the BSR measurement may result in reduced accuracy of the result.

THE DASHBOARD IN DETAIL

The current Charger State and current Charge Status tiles reflect the integer values of the CHARGER_STATE (0x34) and CHARGE_STATUS (0x35) registers, respectively. The integer values have been converted to descriptive text for convenience.

The Coulomb counter graph is an analog representation of the current coulomb counter count as a percentage of the (maximum count – minimum count). This graph is greyed out whenever the coulomb counter ON/OFF switch is turned OFF. The first time the ON/OFF switch is switched ON, a coulomb counter configuration wizard is started:
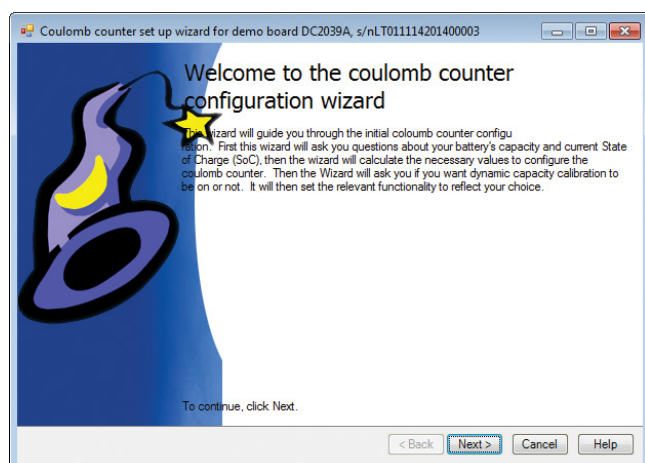

Figure 19. Coulomb Counter Configuration Wizard, Page 1
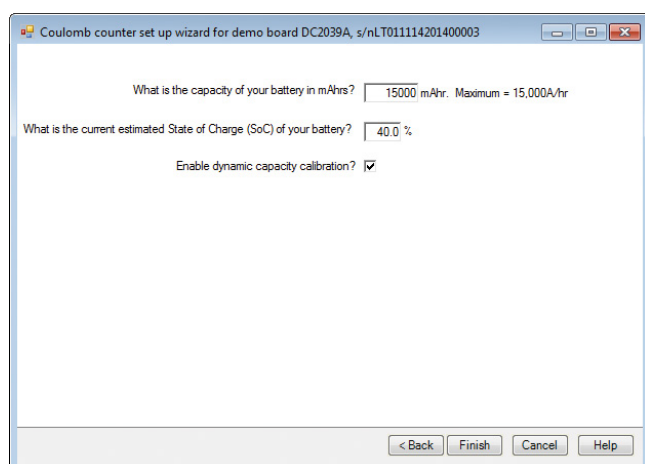
Figure 20. Coulomb Counter Configuration Wizard, Page 2

When page two of the configuration wizard is dismissed by pressing Finish, the Coulomb counter tab is configured and made visible. Note that to allow for dynamic recalibration, the default 0% = 16,384 counts, and 100% = 49,152 counts. If the coulomb counter is subsequently turned off and on, the configuration wizard is not invoked.

The NTC die and temperature measurement thermometers are analog meters representing the reported NTC and die temperatures. The Die temperature is also displayed as an uneditable digital value below the thermometer.

When the NTC jumper (JP2) is set to "INT", the returned temperature result is created by an electronic potentiometer. The desired reported NTC temperature is set in the text box below the NTC temperature thermometer. The desired reported temperature is editable as described by the tooltip for this text box. The electronic potentiometer produces voltage at the NTC pin that is measured by the LTC4015 and reported as the desired temperature. As such, this temperature is live in both the JEITA Curve tab and the Limits and Alerts tab. It is also reported as part of the data, when a charge/discharge curve is saved on the Charge Status tab. The electronic potentiometer emulates the resistance of the NTC resistor accurately between –10°C and 100°C, outside this range, the accuracy of the reported temperature will degrade. For example, attempting to set 140°C, may result in a reported temperature, on the NTC thermometer, of ≈ 130°C.

The NTC temperature is durable, and thus is remembered from session to session. The value is remembered in the electronic potentiometer, and not the Excel file. The DC2039A demo should arrive with the NTC temperature set to ≈ 25°C.

If the NTC jumper (JP2) is set on "EXT", in the pulldown on the "GUI Configuration" tab, the ambient temperature text box is greyed out. The displayed temperature will be determined by the external NTC value.

DEMO MANUAL DC2039A

THE GUI CONFIGURATION TAB DETAIL

ESTIMATED BUCK CHARGER EFFICIENCY

IF THE MEASUREMENT SYSTEM IS OFF, CAN THE GUI FORCE IT ON TO MEASURE DASHBOARD ITEMS

BSR UPDATE FUNCTION DISCUSSED IN THE DASHBOARD SECTION

CHOOSE WHETHER NTC JUMPER (JP2) IS ON "INT" OR "EXT"

CONFIGURATION TO LOAD AT STARTUP

CONFIGURATION NAMING BOX

SAVE AND LOAD CUSTOM CONFIGURATIONS

CONFIGURATION TO SAVE/DELETE AT SHUTDOWN

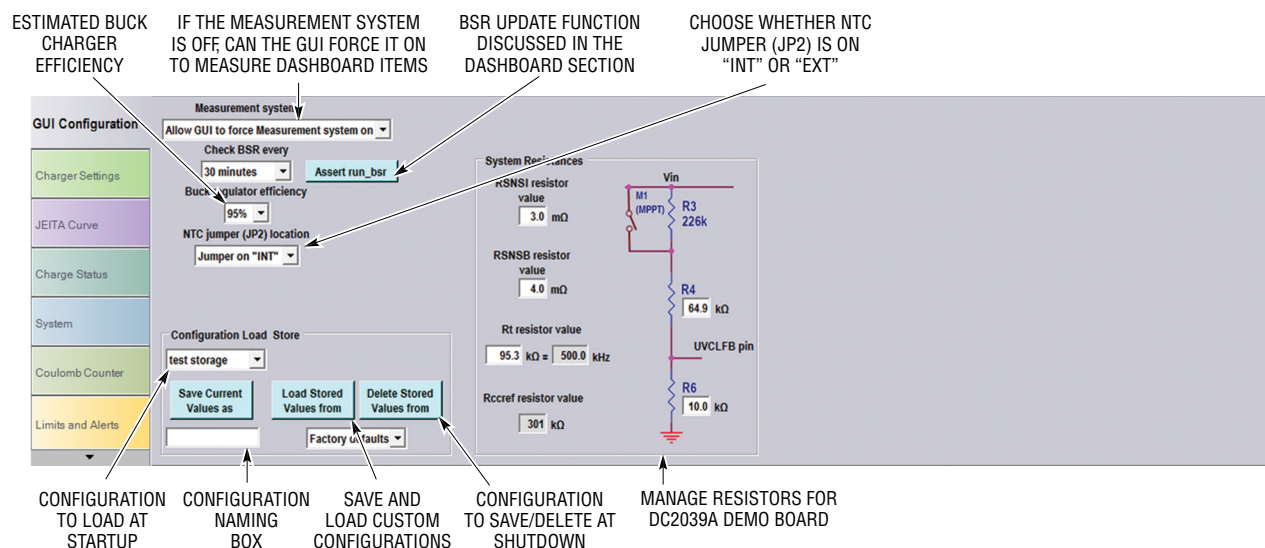MANAGE RESISTORS FOR DC2039A DEMO BOARD

Figure 21. The GUI Configuration Tab in Detail

The measurement system on the LTC4015 can be turned off for a variety of reasons, including operating on V(BAT) only, with V_{IN} = 0V. The GUI needs the measurement system to update the dashboard, and some other values. If this is allowed, it produces periodic load currents, making it very difficult to measure battery I_Q. In this, or similar circumstances choose "Do not allow GUI to force measurement system on" from the pulldown box. This will facilitate measuring battery I_Q, but will freeze the dashboard values.

The buck charger efficiency is used to estimate the SYS current.

The BSR update functions are discussed in the dashboard section.

The Configuration Load and Store box allows managing up to 10 different named configurations. This allows saving the setup from session to session. Although up to 10 different named configurations can be saved, these configurations are only valid once they are given a name. The name is composed of up to 16 arbitrary text characters such as "01/08/2015" or "ADI is #1", or even "√∫∫Φ".

First configure items such as the System resistances and Coulomb counter as desired. Then select an empty storage location using the pulldown box above the "Save Current Values as" button, then enter a name in the text box below

the "Save Current Values as" button, then press the "Save Current Values as" button. The configuration is now saved in the named location. The values of the named location can be updated, for configuring as desired. Selecting the desired named location from the pulldown box over the "Save Current Values as", and pressing the Save Current Values as button. If an empty location is chosen, nothing will be saved until it is named. If a named location is selected, in the pulldown under the "Save Current Values as" button at power down, the current configuration will be saved to the named location.

To load from the saved location, chose the desired named location from the pulldown box under the "Load Stored Values from" box, and press the "Load Stored Values from" button. If a named location is selected, in the pulldown box under the "Delete Stored Values from" button, and the "Delete Stored Values from" button is pushed, all saved values, including the name, are deleted. This location is now once again empty.

The Save and Load/Delete pulldowns are durable, in that they are saved in the associated Excel file from GUI session to GUI session. If Load/Delete pulldown is not on factory defaults at the end of the session, not only is the pulldown value saved, but it is used as the configuration load location on the next GUI power up. This allows a user configuration to become the default at startup.

THE GUI CONFIGURATION TAB DETAIL

There are a variety of resistors that can be managed from the GUI Configuration tab, and one resistor that is not changeable but is presented to keep the user aware of its presence. The DC2039A demo board cannot verify the values of any of the resistors. It is incumbent on the user to maintain correspondence between the actual resistors mounted on the PCB and the resistances shown in the GUI.

The CCREF resistor cannot be changed, Analog Devices has selected its value at $301k\Omega \pm 0.1\%$, to ensure optimal measurement accuracy. Care should be used, not only in component placement and routing, but in manufacturing PCB cleaning and handling. Errors in this resistance directly affect errors in the Coulomb counter.

The Input current sense resistor, R_{SNSI}, and the Charge current sense, R_{SNSB}, resistor are used to sense and control the input current and battery charge current, respectively. The maximum controllable value is 32mV, but the maximum measurable value is 50mV, albeit with some increase in measurement noisiness. For example, if

an 8A maximum charge current is desired, select $4.0m\Omega$ for the R_{SNSB} sense resistor. The values of these resistors are stored as part of the custom configuration, as they are the most likely component to be changed on the DC2039A demo board.

The $R_{uvcltop}$ and $R_{uvclbottom}$ resistors are used to determine the Undervoltage Current Limit threshold, if the LTC4015 is not in MPPT mode. When not in MPPT mode V_{IN} is divided down by $R_{uvcltop}$ and $R_{uvclbottom}$ (R4 and R6, respectively, on the DC2039A schematic) and applied to the UVCLFB pin. The voltage at UVCLFB is compared to a 1.2V reference developed by an 8-bit DAC. The value of this DAC is set by the VIN_UVCL_SETTING register (0x16), which is controlled by the UVCL knob on the System tab. These resistors are saved in the custom configuration, but the default values are $R_{uvcltop} = 64.9k\Omega$ and $R_{uvclbottom} = 10k\Omega$, resulting in a maximum UVCL threshold of $V_{IN} = 9V$.

If the LTC4015 is in MPPT mode, the UVCL threshold is forced to $\approx 36V$, and the UVCL knob, on the System tab is disabled.

THE CHARGER SETTINGS TAB DETAIL

The LTC4015 charge characteristics, for Li chemistries only, can be the same over temperature or vary depending on the reported NTC temperature. The latter control is referred to as JEITA curve control, the actual details of which are discussed in the next section. The Enable JEITA charge vs temperature check box determines if the charge is controlled by the Charge Control box on this tab, or the JEITA curve on the next tab. JEITA curve control is only for the Li chemistries, so this check box and the entire JEITA tab will not be present if Lead-Acid chemistries are selected.

If the operating conditions are such that charging is possible, the charger will start. The Suspend Charger check box turns the charger on and off. This stops the charger, but since the operating conditions are such that the charger would be operating, the charger is suspended rather than off.

The LTC4015 can terminate charging of Li chemistries when the actual charge current drops below a certain percentage of the programmed charge current. This type of termination is called Coverx (or C/x, in brief), and the Enable C/x termination check box enables this functionality. The actual

percent of programmed charge current that constitutes the end of charge is set in the Charge Termination box. Coverx termination is not applicable to the Lead-Acid (PbH+) chemistries. But for Lead-Acid Chemistries, C/x is used to change from absorb phase to CC-CV phase.

The PbH+ chemistries charge voltage can be temperature compensated at $-3.65mV/cell/°C$, and is controlled by the NTC reported temperature. The Enable Lead-Acid temperature compensation check box determines if the temperature compensation is applied or not. This check box only applies for the PbH+ chemistries, and will not be available for the Li chemistries.

There is a procedure to cause Lead-Acid cell capacities to align capacity with one another called Cell Equalization. This procedure involves applying up to 2.6V/cell for a specified amount of time. This procedure can have the positive effect of leveling out the capacities of the cells within a battery. It can also damage the battery irreparably, and so, should be used sparingly and judiciously. The Arm equalize and Equalize Lead-Acid are designed to allow equalization, but prevent it from happening by accident or mispick.
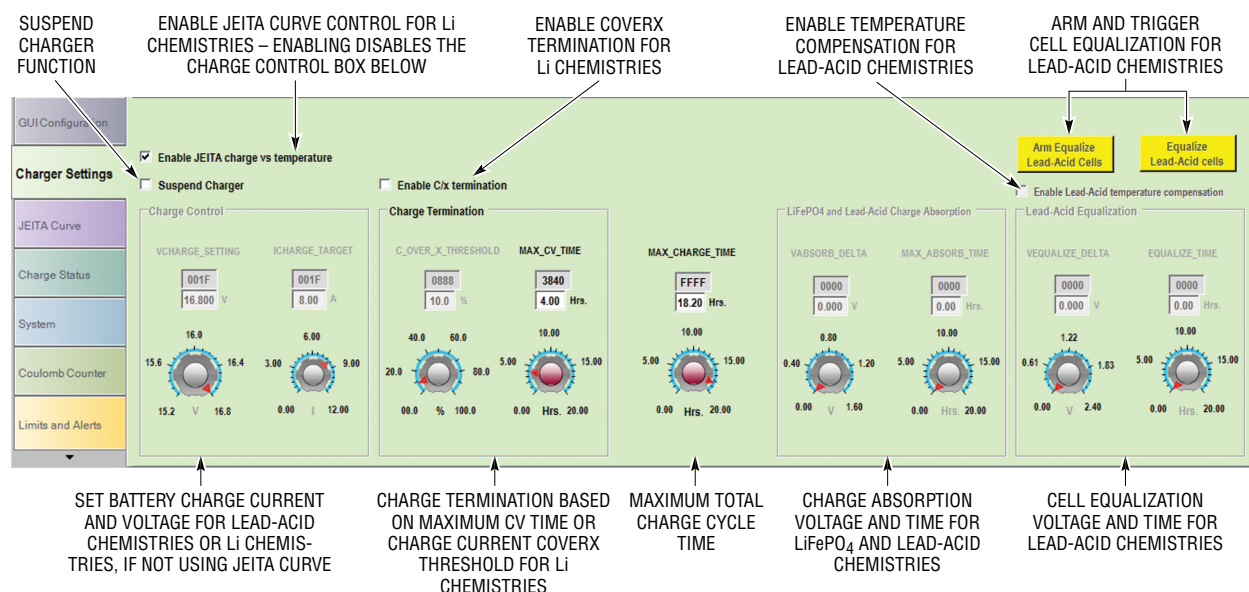
THE CHARGER SETTINGS TAB DETAIL

Figure 22. The Charger Settings Tab in Detail

The Arm Equalize and Equalize Lead-Acid buttons are not available for Li chemistries. If a Lead-Acid chemistry is selected, the Arm Equalize button is enabled, and both buttons are yellow. If the Arm Equalize button is pressed, the Equalize Lead-Acid button is enabled, and the Arm Equalized button turns red. If the Equalize Lead-Acid button is subsequently pressed, the button turns red, and an equalization cycle is started. The amount of equalization voltage applied per cell and the time the equalization voltage is applied is set in the Lead-Acid Equalization box.

The Charge control box contains knobs to set the desired stack charge voltage and charge current. The tooltips contain shortcut keys for changing these parameters. This box is always enabled for the Lead-Acid (PbH+) chemistries, and is enabled for the Li chemistries if the Enable JEITA charge vs temperature is not checked.

The Charge termination provides values for charge termination of Li chemistries. The MAX_CV_TIME knob terminates charging after the charger has been in CV mode for the selected number of hours. If the Enable C/x termination check box is checked the C_OVER_X_THRESHOLD knob is enabled. This knob allows the Coverx threshold to be set as a percentage of programmed charge current. If both are enabled, charging is terminated by the first to occur, Coverx or timeout. Neither of these is used to terminate PbH+ charging, and if the selected chemistry is PbH+, this box is greyed out and disabled.

The MAX_CHARGE_TIME sets the total allowable time for all phases of charging for Lithium chemistries. The charger is shut off after this time, MAX_CHARGE_TIME defaults to the maximum of 65,535 seconds or 18.2 hours. The MAX_CHARGE_TIME is unavailable for PbH+ chemistries.

The LiFePO$_4$ and Lead-Acid Charge Absorption box allows compensation for charge absorption by LiFePO$_4$ and Lead-Acid cells. The selected absorption voltage is applied on top of the desired stack charge voltage for the selected amount of time. This increases the cell charge voltage, for the cell to compensate for charge absorption. When the charger terminates, the battery stack voltage will relax to nearly the desired stack charge voltage. Charge absorption only applies to the LiFePO$_4$ and PbH+ chemistries, and this box will be unavailable for the Li-Ion chemistries.

THE JEITA CURVE TAB DETAIL
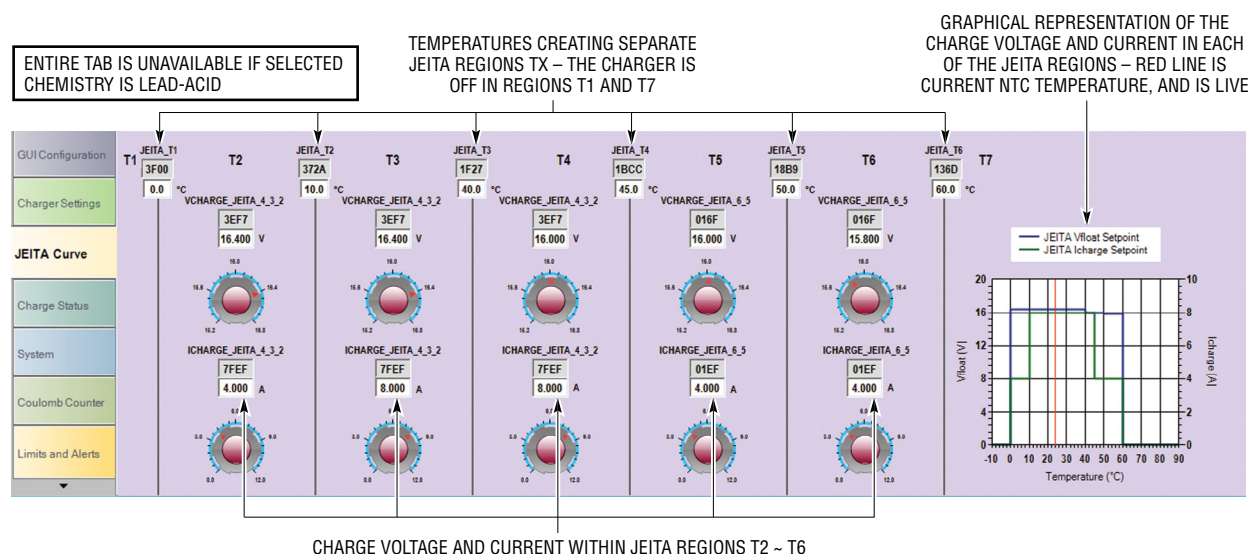
Figure 23. The JEITA Curve Tab in Detail

The JEITA Curve tab appears to be very complicated but it is not. The JEITA curve is divided into temperature regions. The temperatures where the regions begin and end are set in the JEITA_TX registers. Region T1 is anything below JEITA_T1 and the charger is off in this region. Region T7 is anything above JEITA_T6, and the charger is also off in this region.

The graphical representation of the JEITA curve shows the selected charge voltage and current versus temperature. The red line shows the current temperature reported by the NTC resistor. If the NTC jumper (JP2) is set on "INT" the reported NTC temperature is under user control, in the text box under the NTC thermometer. The entire JEITA curve plot is live, including NTC temperature, charge voltage and current. The behavior of the curve can thus be evaluated by simply changing the NTC set temperature.

THE CHARGE STATUS TAB DETAIL

The Charge Status tab plots the current charge/discharge cycle in real time. If the charger is running when the GUI starts, the plot is automatically running. When the charger stops, the plot is automatically stopped. The user can also check or uncheck the running plot box, but if the user checks the box when the charger is stopped, the box will be immediately unchecked.

The "Page Setup," "Print Preview," "Print Plot" and the "Show Printer Dialogue" check box manage the printing of the current plot view. Normally the entire plot will be printed, but if the plot is zoomed, the zoomed view of the plot will be printed.

The running plot axes are automatically scaled based on the cell count, chemistry, and current sense resistor. The running plot updates every 3s, and x axes can be zoomed to an interval by selecting the interval with the mouse in the graphics area. The plot can be unzoomed by clicking on the circle in the lower left hand corner of the plot. The value of battery stack voltage or charge current at any instance can be read by hovering the mouse over the point of interest for a couple of seconds.

The plot can be cleared and restarted by pressing the Restart Plot button. Please note that all saved data, as described in Save to Worksheet button is cleared, not just the battery stack voltage and charge current.

The "Save to Worksheet" button saves the entire current data table to a new worksheet in the associated Excel workbook. The associated Excel workbook is in: ~\My documents\LinearTechnology\DC2039A, and is called LTC4015, serialnumber. The new worksheet is named the current time and date.

The saved datatable consists of not only time, battery stack voltage (V) and charge current (A), but also:

V_{IN} (V)

I_{IN} (A) = IV_{IN}

V(SYS) (V)

BSR (MΩ)

Charge Status (16-bit Integer)

Charger State (16-bit Integer)

$Q_{COUNT0\%}$ (16-bit Integer)

Q_{COUNT} (16-bit Integer)

$Q_{COUNT100\%}$ (16-bit Integer)

NTC Temperature (°C)

Die Temperature (°C)

The Save to Worksheet button does not create a plot on the Excel worksheet, but this could be done by the user within Excel, if desired.

PRINT CURRENT PLOT VIEW - ONLY BATTERY STACK VOLTAGE AND CHARGE CURRENT ARE PRINTED

CLEAR ALL DATA, SET TIME TO 0, AND START PLOTTING AGAIN

SAVE ALL DATA TO A NEW WORKSHEET WITHIN THE ASSOCIATED EXCEL WORKBOOK – THE WORKSHEET NAME IS SET TO THE CURRENT TIMESTAMP – MANY VARIABLES, BESIDES BATTERY STACK VOLTAGE AND CHARGE CURRENT ARE SAVED.
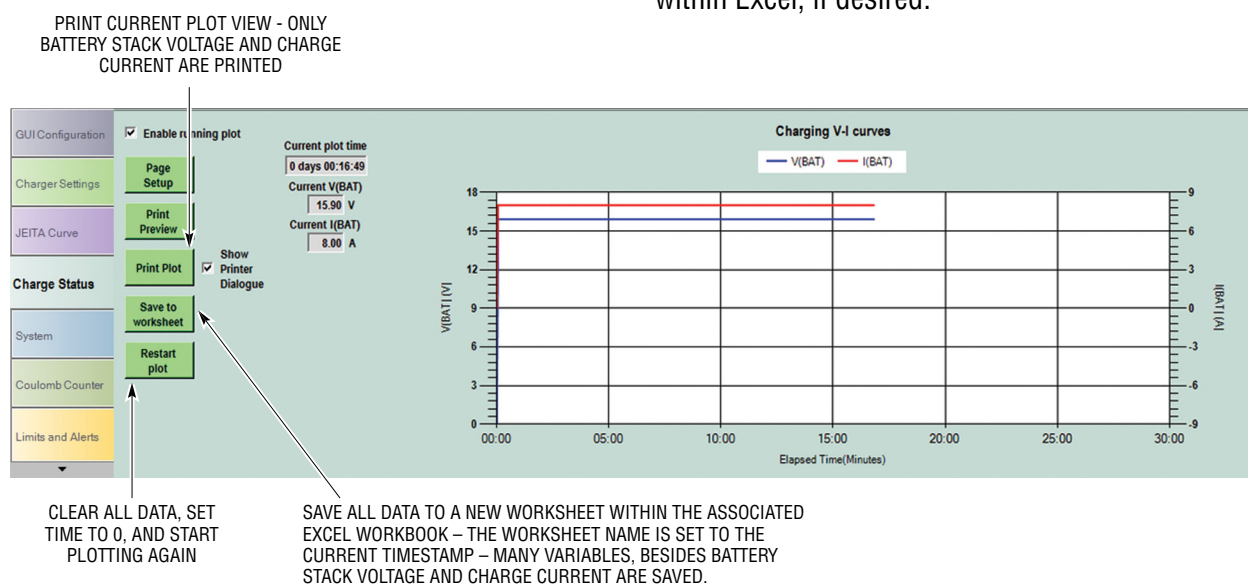
Figure 24. The Charge Status Tab in Detail

THE SYSTEM TAB DETAIL
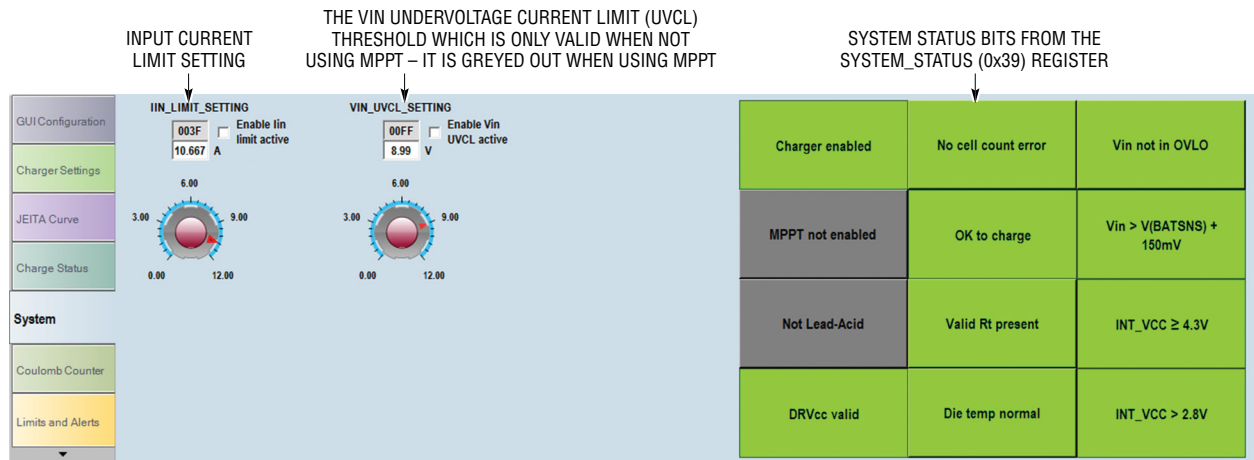
Figure 25. The System Tab in Detail

The input current limit setting is used to limit the current drawn by the LTC4015 system. The sensed input current is the combination of I(SYS) and the I_{CHARGE} (I(BAT)), the LTC4015 cannot distinguish between these two loads. However, the LTC4015 can only change the current drawn by the charger. So, as when the input current reaches the limit value, the LTC4015 begins to reduce charge current, to keep the input current below the threshold set by R_{SNSI} and this knob. If the current drawn by the charger reaches 0A, the LTC4015 can no longer reduce the load and, if the input current continues to increase, the input current will exceed the limit set here. The input current is now set entirely by the load on the SYS node and cannot be controlled by the LTC4015.

These 12 tiles reflect the status of the individual bits in the SYSTEM_STATUS (0x39) register. Some values are also checked by the A/D in the demo board PIC processor (notably INT_VCC > 2.8V). These tiles are updated at the same rate as the dashboard, approximately twice a second.

If the INT_VCC > 2.8V turns red, all other data reported by the GUI may be invalid.

THE COULOMB COUNTER TAB DETAIL

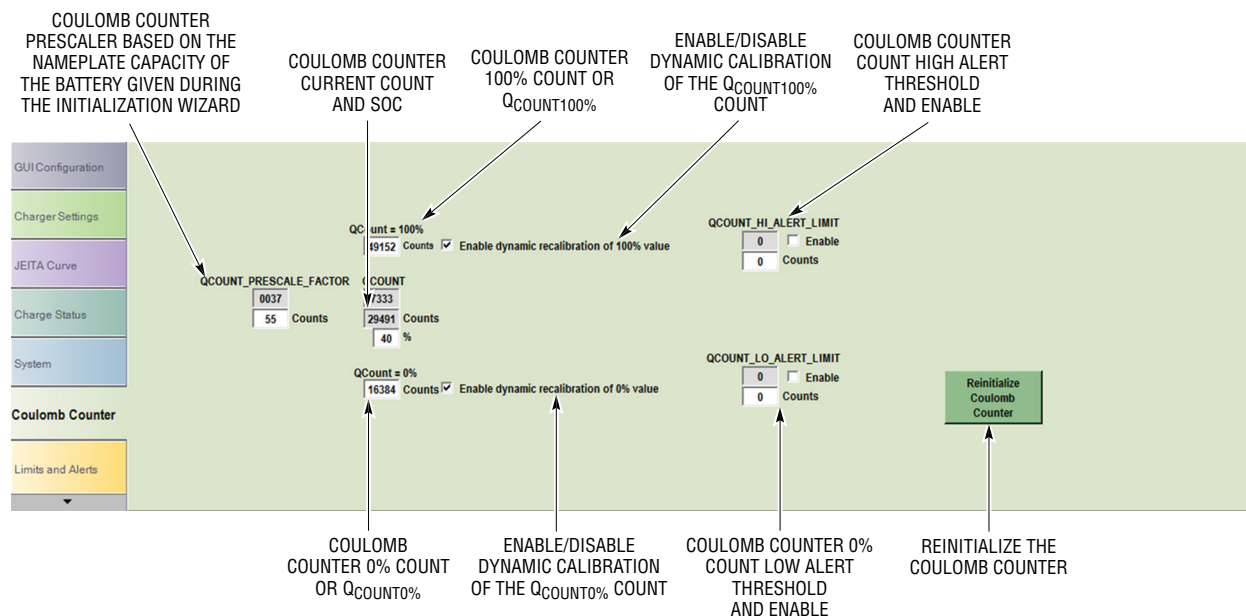**Figure 26. The Coulomb Counter Tab in Detail**

When the coulomb counter is turned on for the first time a configuration wizard is popped up that solicits the battery nameplate capacity, current State of Charge (SoC), and whether or not dynamic recalibration should be enabled. Based on this input, the coulomb counter prescaler value is set. The prescaler value is chosen such that SoC = 100% is a count of 49152 (3/4 of full scale count) and the SoC = 0% is a count of 16384 (1/4 of full scale count).

The configuration wizard also sets the SoC percentage and the current value of the coulomb counter count to the estimated SoC. The coulomb counter is then enabled, and will keep track of the charge in the battery.

The SoC = 100% count of 49152, 3/4 of full scale count, was chosen to provide headroom for dynamic recalibration, as was the SoC = 0% count of 1/4 full scale. If Dynamic recalibration is turned on, the SoC = 100% and SoC = 0% counts will move with the counter. So, if the coulomb counter count exceeds the SoC = 100% count, and dynamic recalibration of the 100% value is enabled, the 100% count will increment to be equal to the count. If dynamic recalibration of the 0% value is enabled, then the 0% count will decrement to be equal to the count during discharge of the battery.

The Alert limits set the threshold, in counts, that triggers an alert. If the coulomb counter count exceeds the QCOUNT_HI_ALERT_LIMIT, and the alert is enabled, then an SMBAlert will be posted. Likewise if the coulomb counter count falls below the QCOUNT_LO_ALERT_LIMIT, and the alert is enabled, then an SMBAlert will be posted.

After the first time the coulomb counter is turned on, the configuration wizard no longer appears. If the coulomb counter is turned off, it stops counting and its value is hidden. If the coulomb counter is then turned on, it starts counting again, and the value is displayed in the dashboard. If it is desired to reinitialize the coulomb counter, then press the Reinitialize Coulomb counter button. This will bring up the wizard, with the previous values still present, for editing.

THE LIMITS AND ALERTS TAB DETAIL

THIS ALLOWS CONFIGURATION TO SEND AN E-MAIL WHEN AN SMBALERT OCCURS – THE E-MAIL WILL CONTAIN ALL THE REASONS FOR THE SMBALERT ACTIVE WHEN THE ALERT IS POSTED

Figure 27. The Limits and Alerts Tab in Detail

The Limit and Alerts tab allows management of most causes of an SMBAlert. It also provides for e-mail notification of pending alerts and clearing of alerts.

The threshold alerts require a threshold to indicate when an alert should occur. Setting the threshold and enabling the alert will cause an alert to post whenever the monitored parameter exceeds or falls below the threshold, as appropriate. For example the VIN_HI_ALERT_LIMIT will post an alert when V_{IN} exceeds the threshold, whereas the VIN_LO_ALERT_LIMIT will post an alert whenever V_{IN} is less than the threshold.

The Coulomb counter tab contains the thresholds and enables for the coulomb counter count high and low alerts.

The I_{IN} limit and UVCL alerts are implicitly threshold alerts in that they assert whenever the input current or UVCL circuits are active. But there is no separate threshold limit from the normal operating value. These alerts are managed on the System tab.

The event based alerts post an SMBAlert whenever the event happens. For example, if the Enable charger suspended alert box is checked, an SMBAlert will be posted whenever the charger is suspended.

The GUI may be configured to send an e-mail whenever an SMBAlert occurs and when it is cleared. The e-mail sent when an SMBAlert is posted will contain all the reasons for the SMBAlert that were asserted at the time the SMBAlert was posted. Subsequent reasons, before an SMBAlert clear will not generate a new e-mail.

Using e-mail requires testing the e-mail. To use the e-mail, enable e-mail alerts, put a valid e-mail address in the text box and then press the Test button. If the message is successfully send, e-mails will be enabled until the Enable e-mail alert is unchecked.

There are several reasons that e-mail may not work. First, e-mail may not be installed on the computer running the LTC4015 GUI, the LTC4015 GUI requires MAPI.dll to operate. Second, the e-mail may be locked down with a password, so that third parties cannot send e-mail through the e-mail server. In this case, the host computer may post a dialogue asking the user to allow third parties to send mail. Please answer yes if you wish to use e-mail notifications. If the host computer e-mail is locked down with a password, and no option is given to allow third parties to send e-mails, the LTC4015 GUI cannot send e-mail notifications.

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	14	C2, C3, C4, C5, C9, C10, C18, C19, C20, C21, C22, C23, C24, C25	CAP, CHIP, X5R, 10µF, ±10%, 50V, 1206	MURATA, GRM31CR61H106KA12L
2	1	C6	CAP, CHIP, C0G, 100pF, ±5%, 50V, 0402	AVX, 04025A101JAT2A
3	3	C7, C13, C17	CAP, CHIP, X7R, 0.1µF, ±10%, 50V, 0402	TDK, C1005X7R1H104K
4	1	C8	CAP, CHIP, X5R, 2.2µF, ±10%, 6.3V, 0402	TDK, C1005X5R0J225K
5	2	C11, C16	CAP, CHIP, X5R, 1000pF, ±10%, 50V, 0402	TDK, C1005X5R1H102K
6	2	C12, C15	CAP, CHIP, X5R, 0.33µF, ±10%, 10V, 0402	MURATA, GRM155R61A334KE15D
7	1	C14	CAP, CHIP, X5R, 10µF, ±10%, 6.3V, 0603	MURATA, GRM188R60J106ME47D
8	1	C26	CAP, ELECTROLYTIC, 120µF, ±20%, 40V, 50V SURGE, 10mm × 12.5mm	SUNCON, 40HVH120M
9	1	CB	CAP, CHIP, X5R, 0.47µF, ±10%, 16V, 0402	TDK, C1005X5R1C474K
10	1	CC	CAP, CHIP, X7R, 0.22µF, ±10%, 10V, 0402	MURATA, GRM155R61A224KE19D
11	1	CC2	CAP, CHIP, X7R, 0.01µF, ±10%, 50V, 0402	TDK, C1005X7R1H103K
12	1	DB	SILICON SWITCHING DIODE, 1mm × 0.6mm DFN2	DIODES INC., 1N4448HLP
13	1	L1	IND, SMT, 10µH, 10A, 10mm × 10mm	COILCRAFT, XAL1010-103ME
14	1	M3	DUAL 40V, 12A, N-CHANNEL MOSFET, 3mm × 3mm MLP	FAIRCHILD, FDMC8030
15	1	M4	−40V, −18A, 25mΩ, P-CHANNEL MOSFET, POWERPAK1212-8	VISHAY, SI7611DN
16	1	M5	40V, 14A, 9.7mΩ, N-CHANNEL MOSFET, 3mm × 3mm MLP	FAIRCHILD, FDMC8327L
17	1	R3	RES, CHIP, 226kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW0402226KFKED
18	1	R4	RES, CHIP, 64.9kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW040264K9FKED
19	2	R6, RNTCBIAS	RES, CHIP, 10kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW040210K0FKED
20	1	R7	RES, CHIP, 10kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW040210K0JNED
21	1	RC	RES, CHIP, 200Ω, ±1%, 1/16W, 0402	VISHAY, CRCW0402200RFKED
22	1	RCCREF	RES, CHIP, 301kΩ, ±0.1%, 25ppm, 1/10W, 0603	SUSUMU, RG1608P-3013-B-T5
23	1	RSNSI	RES, CHIP, 4 TERMINAL, 0.003Ω, ±1%, 1W, KRL3216T4	SUSUMU, KRL3216T4-M-R003-F
24	1	RSNSB	RES, CHIP, 4 TERMINAL, 0.004Ω, ±1%, 1W, KRL3216T4	SUSUMU, KRL3216T4-M-R004-F
25	1	RT	RES, CHIP, 95.3kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW040295K3FKED
26	1	U1	IC, SMT, 35V SYNCHRONOUS STEP-DOWN CONTROLLER BATTERY CHARGER, 5mm × 7mm QFN38	ANALOG DEVICES, LTC4015EUHF
Additional Demo Board Circuit Components				
1	0	C1-OPT	CAP, CHIP, C0G, 2200pF, ±10%, 50V, 0805	AVX, 08055A222KAT9A
2	2	C27, C28	CAP, CHIP, X5R, 10µF, ±10%, 6.3V, 0603	MURATA, GRM188R60J106ME47D
3	0	C29-OPT	CAP, CHIP, X5R, 10µF, ±10%, 6.3V, 0603	MURATA, GRM188R60J106ME47D
4	1	C30	CAP, CHIP, X5R, 0.47µF, ±10%, 16V, 0402	TDK, C1005X5R1C474K
5	1	C31	CAP, CHIP, X7R, 0.1µF, ±10%, 50V, 0402	TDK, C1005X7R1H104K
6	1	C32	CAP, CHIP, X5R, 1000pF, ±10%, 50V, 0402	TDK, C1005X5R1H102K
7	0	CPN-OPT	CAP, CHIP, X5R, 1µF, ±10%, 16V, 0402	TDK, C1005X5R1C105K
8	1	D1	DIODE, ZENER, 15V, ±6.5%, 0.25W, 1mm × 0.6mm DFN2	DIODES INC., BZT52C15LP

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PARTS LIST

| ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
9	1	D2	40V, 200mA, SCHOTTKY DIODE, 1mm × 0.6mm DFN2	DIODES INC., BAS40LP
10	1	M1	–50V, 8Ω, P-CHANNEL MOSFET, 1mm × 0.6mm DFN3	DIODES, INC., DMP58D0LFB
11	1	M2	60V, 1.4Ω, N-CHANNEL MOSFET, 1mm × 0.6mm DFN3	DIODES, INC., DMN62D1SFB
12	1	J1	USB2.0 MICRO-B RECEPTACLE, RT, REVERSE MOUNT, 1932788-1	TE, 1932788-1
13	1	J2	2mm, 2 × 3 TH HEADER	SAMTEC, TMM-103-02-L-D
14	2	J3, J4	0.1, 1 × 6, TH, HEADER	SAMTEC, TSW-106-07-S
15	1	R1	RES, CHIP, 47kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW040247K0JNED
16	2	R2, R23	RES, CHIP, 10kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW040210K0JNED
17	0	R5-OPT, R31-OPT	RES, CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
18	0	R9-OPT, R10-OPT, R11-OPT, R13-OPT, R17-OPT	RES, CHIP, 0Ω JUMPER, 1/16W, 0603	VISHAY, CRCW06030000Z0ED
19	5	R12, R14, R15, R16, R18	RES, CHIP, 0Ω JUMPER, 1/16W, 0603	VISHAY, CRCW06030000Z0ED
20	1	R19	RES, CHIP, 1MEG, ±5%, 1/16W, 0402	VISHAY, CRCW04021M00JNED
21	2	R20, R21	RES, CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
22	1	R22	RES. CHIP, 1Ω, ±5%, 1/16W, 0402	VISHAY, CRCW04021R00JNED
23	1	R24	RES, CHIP, 10kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW040210K0FKED
24	5	R25, R26, R27, R28, R29	RES, CHIP, 4.7kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW04024K70JNED
25	1	R32	RES, CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
26	1	R30	RES, CHIP, 100kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW0402100KJNED
27	2	U2, U6	IC, SMT, SINGLE INVERTER, 1mm MICROPAK6	FAIRCHILD, NC7SZ04L6X
28	1	U3	MODULE, USB ISOLATION WITH POWER TRANSFER, 10mm × 10mm BGA44	ANALOG DEVICES, LTM2884CY
29	1	U4	8-BIT PROCESSOR WITH USB, 4mm × 4mm QFN20	MICROCHIP, PIC16F1459-I/ML
30	1	U5	100kΩ, 8-BIT, ELECTRONIC POTENTIOMETER, MSOP8	ON SEMI, CAT5140ZI-100-GT3
Hardware for Demo Board Only				
1	6	E1, E2, E7, E10, E11, E14	TURRET, 0.09" DIA	MILL-MAX, 2501-2-00-80-00-00-07-0
2	2	E5, E6	TURRET, 0.061" DIA	MILL-MAX, 2308-2-00-80-00-00-07-0
3	6	E3, E4, E8, E9, E12, E13	VERTICAL NANA JACK, 575-4	KEYSTONE, 575-4
4	2	JP1, JP2	3-PIN JUMPER, 2mm	SAMTEC, TMM-103-02-L-S
5	2	JP1, JP2	SHUNT, 2mm	SAMTEC, 2SN-KB-G
6	4	MH1-MH4	STAND-OFF, NYLON, 0.500"	KEYSTONE, 8833

SCHEMATIC DIAGRAM

SCHEMATIC DIAGRAM
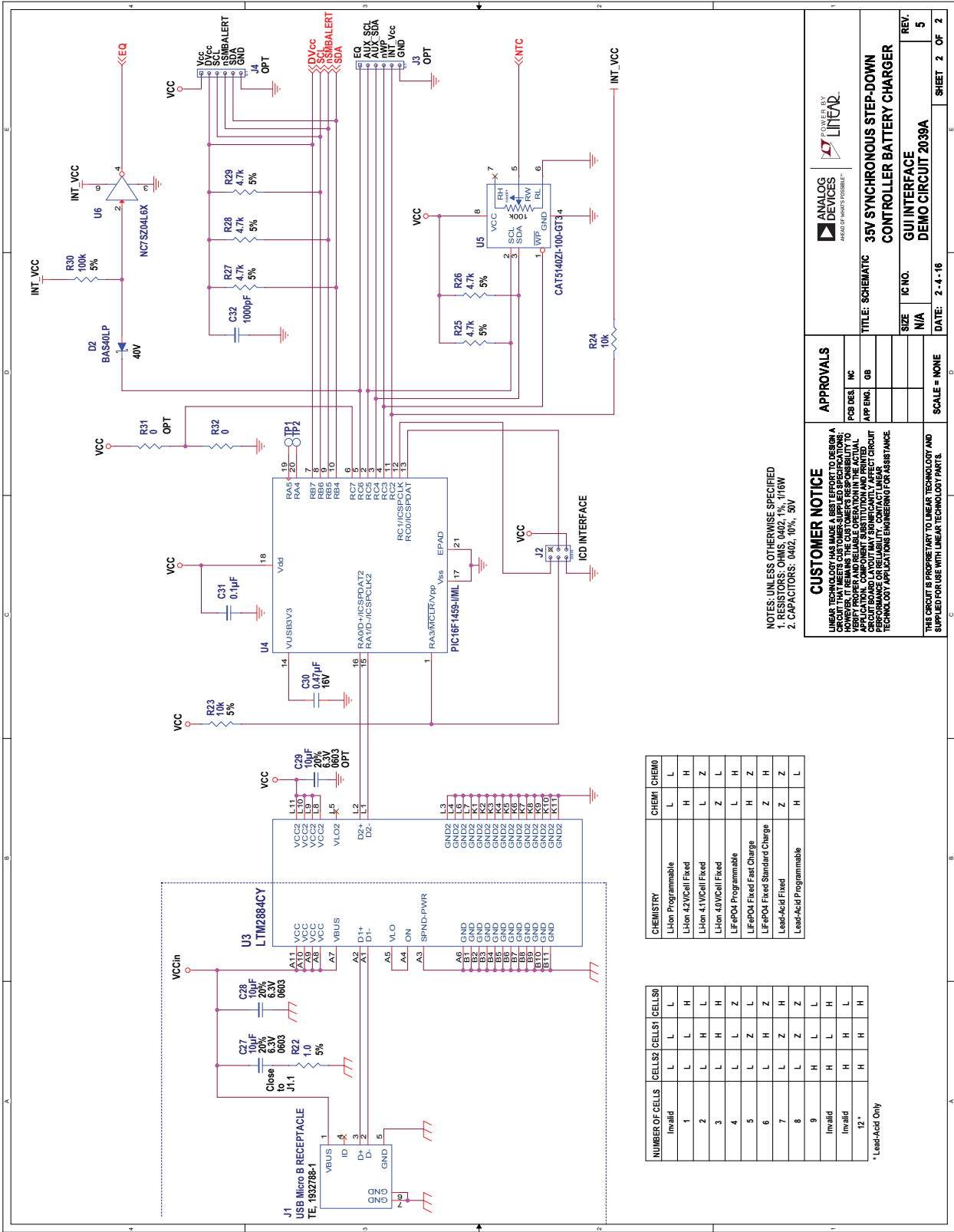
ESD Caution

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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