

## LTC6802-1 Battery Monitor

### HARDWARE/SOFTWARE USERS GUIDE

## DESCRIPTION

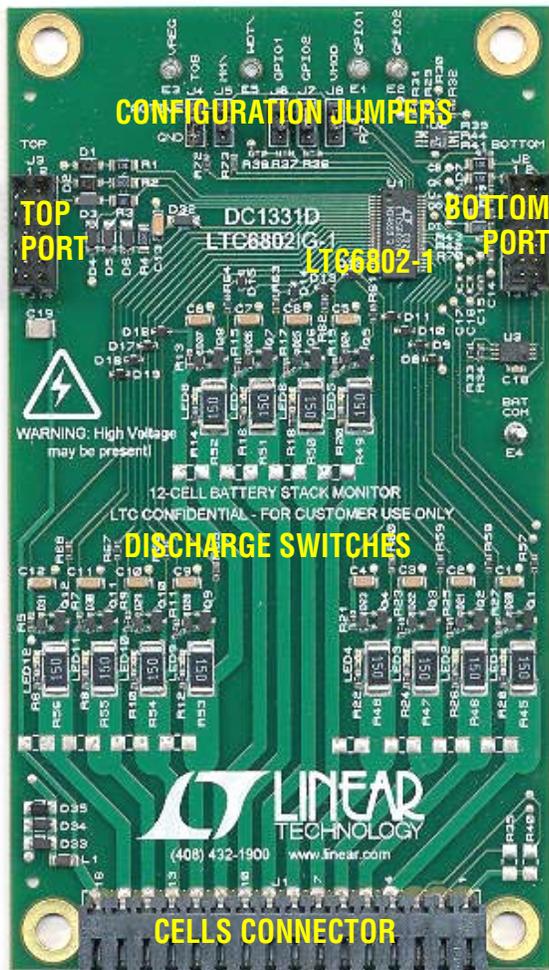
Evaluation circuit DC1331D is a Battery Monitoring System to demonstrate the functional operation of the pre-release Revision C and later versions of the **LTC6802-1** integrated circuit. The basic operation and features of this demo board is the same as previous versions. **This guide will highlight the unique added features of the latest silicon.**

## LATEST LTC6802-1 FEATURES

- Programmable ability to measure 12 cells (in 13msec), 10 cells (in 11msec) or any one specified cell (in 2msec).
- Option to measure cell voltages and perform an open wire detection with or without the cell discharge transistor activated.
- Thermal shutdown built in and flagged.
- Functionality self test commands for cell voltage and temperature data registers.
- Increased daisy chain SPI interface current.
- Silicon revision code provided.
- Permanently activated watchdog feature.

## NEW DC1331D FEATURES

- Added protection circuitry to handle energetic Electro-Static-Discharge (ESD).
- Cell input protection Zener diodes relocated for enhance robustness to hot-insert stresses.



## GETTING STARTED WITH ONE BOARD CONNECTED

### SINGLE BOARD CONNECTION TO PC AND GUI

Step 1. Set jumpers on DC1331D to the default positions indicated in Table 1.

**TABLE 1. JUMPER FUNCTIONS**

JUMPER	FUNCTION	DEFAULT POSITION	ACTIVE POSITION	GROUND POSITION
J4	Top of Stack (TOS)	Active	Indicates that the cells monitored by the board are at the top of the battery stack. Data is not transferred in or out of the Top Port of this board.	Allows data to be passed to and from both the Top and Bottom Ports of the board.
J5	Monitor Mode (MM)	Active (Measure Mode)	Enables measuring of all cell voltages and also provides an over/under voltage monitoring function.	Monitor Mode. Simple monitoring of all cells for over/under voltage conditions.
J6	General Purpose I/O (GPIO1)	Active	Output connected to pull-up resistor to Vreg. Can be programmed as an input or an output.	GPIO1 forced to a logic low level.
J7	General Purpose I/O (GPIO2)	Active	Output connected to pull-up resistor to Vreg. Can be programmed as an input or an output.	GPIO2 forced to a logic low level.
J8	Voltage Mode (VMOD)	Active	Bottom SPI port is configured as normal TTL voltage level inputs and outputs. Required setting for the board on the bottom of the battery cell stack. <b>A 5KΩ PULL-UP RESISTOR MUST BE CONNECTED FROM THE SDO OUTPUT LINE (CONNECTOR J2, PIN 5) TO THE LOGIC POWER RAIL OF THE CIRCUIT DRIVING THE BOTTOM SPI PORT.</b>	Bottom Port is configured as a current inputs and outputs. Required setting for all boards on a cell stack above the bottom board.

Step 2. Connect DC590B Quick Eval USB cable to PC/Laptop USB port. Connect ribbon cable from DC590B to the Bottom Port of DC1331D (J2). Make sure that the driver for DC590B has been downloaded from [www.linear.com](http://www.linear.com) and installed on the computer. Launch the control program:

DC1331\_LTC6802-1\_GUI\_V\_29\_09252008.exe

When the DC590B Quick Eval board recognizes the String ID code from the DC1331D board, the program will open and present the control screen.

A DC590B board has the required pull-up resistor to the SDO line already connected. **If a system other than DC590 is driving the bottom port (which must be set to Voltage Mode) must have a 5KΩ pull-up resistor added between the SDO line (J2, PIN 5) and the 3V/5V logic supply rail of the driving system.** This pull-up resistor was not added to the DC1331 because

it cannot be present when the port is configured for current mode operation on a multiple board monitor of a stack of cells.

Step 3. Connect the cells to be monitored to the cells connector J1. This connector is in two pieces. The setscrew piece can be unplugged to make it easier to attach a wiring harness from a four to twelve cell battery stack. The LTC6802-1 is intended to measure from four to twelve individual cells with a total stack voltage of 10V to 50V.

With fewer than 12 cells to be monitored, the bottom cell of the stack should always be connected as Cell 1 between terminals J1-5(+cell contact) and J1-4(-cell contact). Terminals J1-4, and J1-1 are the ground reference point for the battery cell stack and for the DC1331D board. The second cell on the stack connects between terminals J1-6(+cell contact) and J1-5(-cell contact). All higher numbered

terminals on J1 not used for cell connections may be shorted together. The V+ positive supply for the DC1331D is the potential at terminal J1-16 and therefore must connect to the top of the battery stack. Figure 1 illustrates a connection for fewer than 12 cells.

### SPECIAL NOTE FOR DEMONSTRATION PURPOSES

DC1331D and the GUI program are useful to serve as a demonstration tool to highlight the features of the LTC6802-1. If actual battery cells are not available, a series string of  $150\Omega$  resistors connected between each of the J1 connector terminals can be used instead. Each resistor will serve as a cell voltage. A lab power supply voltage of 10V to 50V can be connected across the resistor string between terminals J1-16(+) and J1-4(-).

When using resistors instead of cells, the discharge indicating LEDs on the DC1331C board will not light due to limited available current.

Step 4. Apply power.

Inserting the setscrew piece into connector J1 will apply power to the board from the battery cell stack. For the demo set up simply turn on the lab power supply preset to a voltage between 10V and 50V.

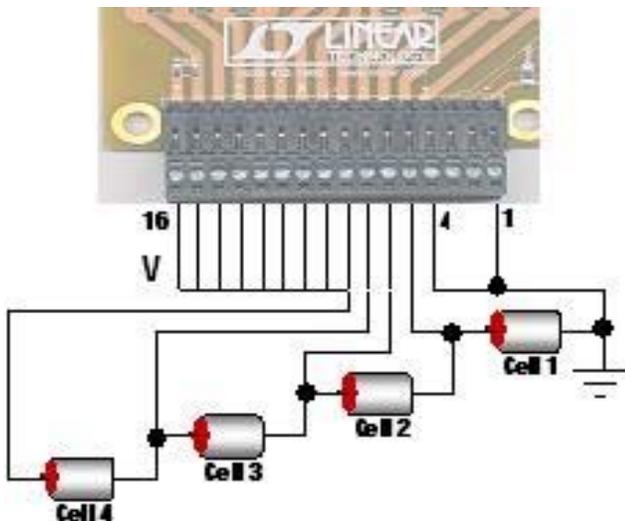


Figure 1. Connection of four cells (cell voltages at least 2.5V)

# THE CONTROL PROGRAM

## THE GRAPHICAL USER INTERFACE (GUI) SCREEN

Figure 2 shows the control panel that appears on the computer screen. The DC1331D board must be connected to the DC590 interface card for the program to open. The control screen will close if any of the boards are disconnected. Controls on this panel are used to communicate with the LTC6802-1. Commands are issued and information is retrieved and displayed on this screen. This panel is useful not only for demonstrating

the operation of the LTC6802-1, but also for software developers to observe the Hex codes exchanged with the device.

The control screen makes good use of color to provide cell status and operating conditions at a glance. White indicates non-existent or stale data. A step by step procedure for one board connected to a stack of cells follows to explain the operation of the control panel. Sections are highlighted for each procedure.

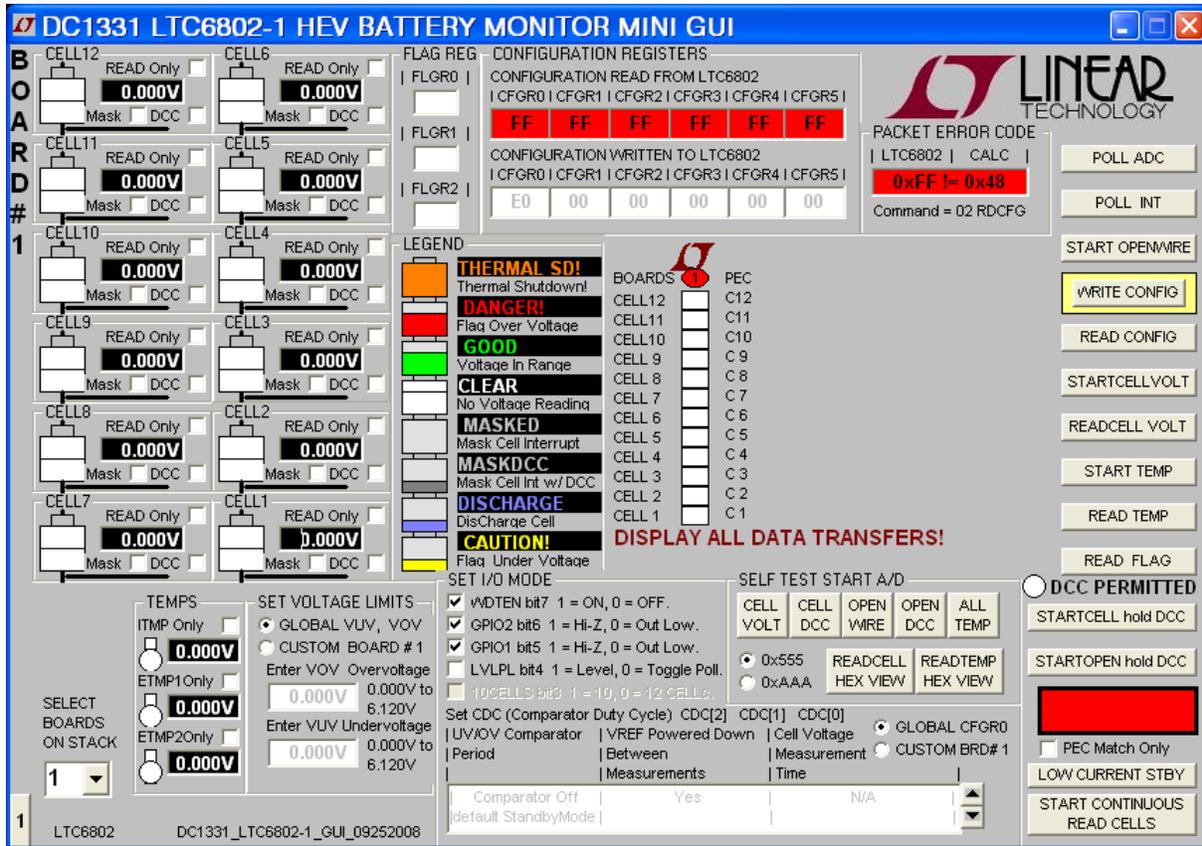


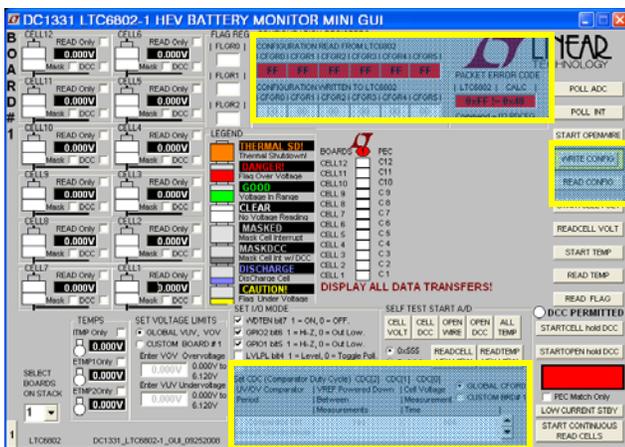
Figure 2. GUI Control Panel Start-up Screen

# OPERATING THE CONTROL SCREEN

## FIRST THINGS FIRST

Figure 2 is the initial start-up screen that appears when the program is launched and the Quick Eval interface card recognizes that the DC1331D board is connected. Once power is supplied to the board from a stack of cells or a power supply, the communication between the PC and the board can be checked.

### 1: READ CONFIGURATION



Click the command button labeled **READ CONFIG**. If all is properly connected and operating the start-up default configuration of the LTC6802-1 will be read from the board. The Hex codes for the six bytes of configuration setting will appear in the **CONFIGURATION REGISTERS** section in the boxes labeled **CONFIGURATION READ FROM LTC6802-1**. The initial configuration bytes should be 0xE0 for register 0 and 0x00 for the other five bytes. **This default configuration is the standby mode for the LTC6802-1. To enable the device and begin taking cell voltage measurements, a CDC (Comparator Duty Cycle) setting other than Standby or Monitor must be selected from the Configure I/O and Operating Modes selection box at the bottom of the GUI screen (CDC=1 is most common). Once chosen, a WRITE CONFIG command must be executed.**

In addition the LTC6802-1 calculates a Packet Error Code, PEC, and appends it to the data stream each

time it sends out data. For the six bytes sent by this command and received by the GUI, the control program calculates a PEC in the same manner. This byte is compared with the appended byte to check that the data transmission was properly executed. Both PEC bytes are displayed in the top section labeled **PACKET ERROR CODE CHECK** and both bytes should match. The oval located at the top of the color-coded status panel for the one board will turn green if the PEC bytes match. Data transmission errors will produce red warning indications if the PEC bytes do not match.

### 2: WRITE CONFIGURATION

Nothing is changed in the LTC6802-1 until the Write Configuration command is executed. Clicking the **WRITE CONFIG** command button does this. When the command is sent, the six Hex bytes shown in the **CONFIGURATION REGISTERS** section in the boxes labeled **CONFIGURATION WRITTEN TO LTC6802-1** will become **bold type**. Software developers can note the exact hex values required by the LTC6802-1 for specific conditions in these boxes to facilitate their control program development.

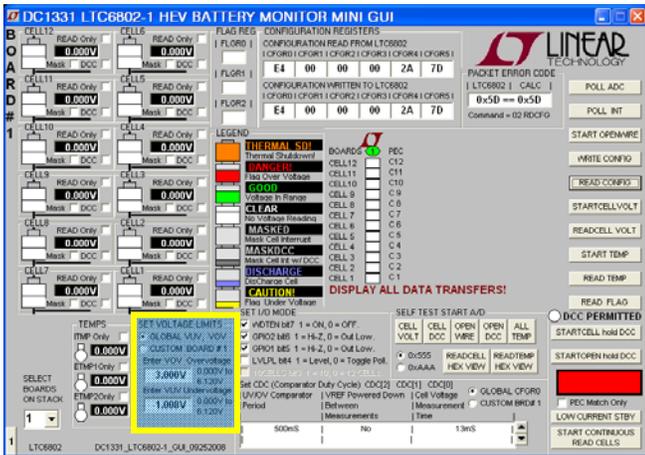
Clicking the **READ CONFIG** button can see confirmation that the configuration change was actually made. The six bytes read back should match the six bytes sent and the PEC/CRC check bytes should be a match (green PEC oval on stack display).

When any configuration information is changed on the screen the **WRITE CONFIG** command button will be back-lit illuminated. This serves as a reminder that this command still needs to be executed.

### IMPORTANT NOTE

**No configuration changes take effect until the WRITE CONFIG button is clicked.**

## 3: PROGRAM THE CELL MONITORING VOLTAGE THRESHOLDS



In the section labeled **SET VOLTAGE LIMITS** click on the boxes and enter voltage values for the over-voltage and under-voltage thresholds required for the cells being monitored. The voltage value entered will be rounded to the actual value used by the LTC6802-1 and displayed in the box. The voltage ranges for these thresholds is 0V to 5.12V and the program will not allow the under to be greater than the over voltage threshold.

These monitor thresholds can be applied globally to each and every cell in the system or customized for the cells connected to an individual board by clicking the desired option button. Individual boards are selected for programming by the left hand tabs in multiple board systems.

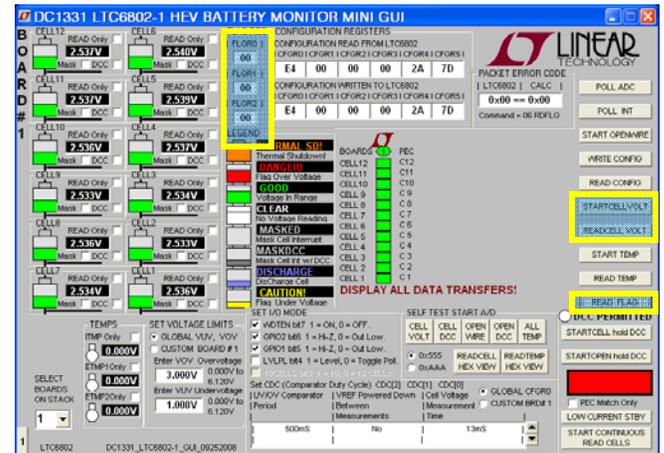
## 4: READ CELL VOLTAGES

The essential function of the LTC6802-1 is to measure and report the voltage on each battery cell when commanded. Once again this is accomplished from the control screen with two command button clicks. First click on the **START CELL VOLTAGE** button. This commands an A/D conversion of all 12-cell voltages in the time configured from the selected Set CDC option in the **SET I/O MODE** box. The actual cell voltage measurements are not displayed until the **READ CELL VOLTAGE** command button is clicked.

## 5: READ FLAGS

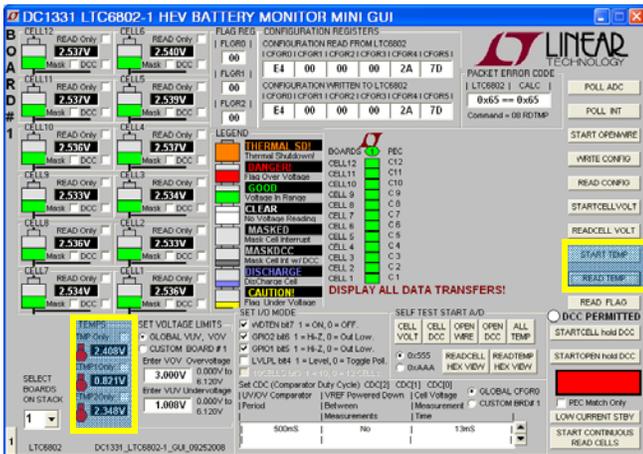
When any cell in a stack exceeds the programmed over or under voltage threshold limit, one of two flag bits is set in an internal register for that cell to serve as a warning. This is important feedback for battery charging algorithms to know when to start or stop charging. To read the state of these warning flags at any time is a simple click of the **READ FLAG** command button. The Hex code for the three flag bytes appears in the **FLAG REGISTERS** section of the control panel.

One of the configuration options is to mask these flags from appearing in the register bytes that are read from the LTC6802-1. This feature can be used to prevent or allow these flags to interrupt the flow of the control algorithm. A check box is provided for each cell in a stack to select the mask interrupt option for that cell. To implement the masking requires checking the box and then writing the new configuration with a **WRITE CONFIG** button push.



If the measured voltage of a cell is within the monitoring thresholds all indications for the cell appear green.

## 5: READ TEMPERATURE



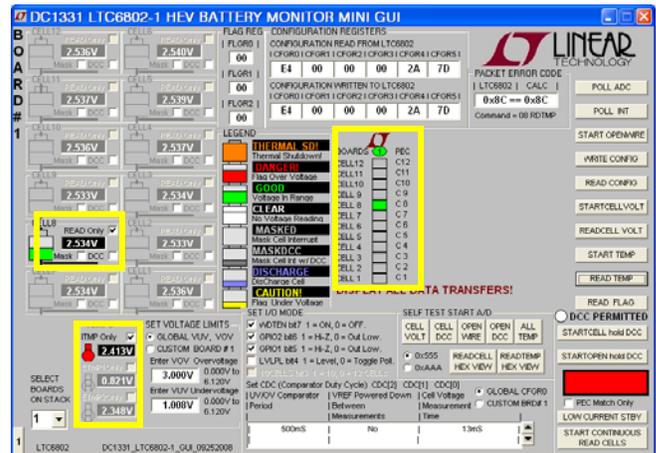
The LTC6802-1 has three ADC channels dedicated to measuring temperature. The temperature indications are for the internal die temperature of the LTC6902-1 and two externally connected thermistors. The display returns a voltage measurement.

The internal die temperature sensor produces a voltage that changes at a rate of 8mV/°C relative to absolute zero. To convert the voltage reading to degrees Centigrade divide the voltage by 8mV then subtract 273°C. For example, 25°C is a reading of 2.384V.

For external temperature measurements connect thermistors across cells connector terminals J1-3 to J1-1 and J1-2 to J1-1. A thermistor with a 25°C value of 10KΩ will produce a half scale voltage reading at 25°C. Any thermistor value may be used but scaling the voltage measurement may require changing the values of resistors R29 and R30 on the DC1331D circuit board.

To take a temperature reading simply click the **START TEMP** command button to make the LTC6802-1 ADC conversion followed by clicking the **READ TEMP** command button to download the data from the board and display the voltage readings.

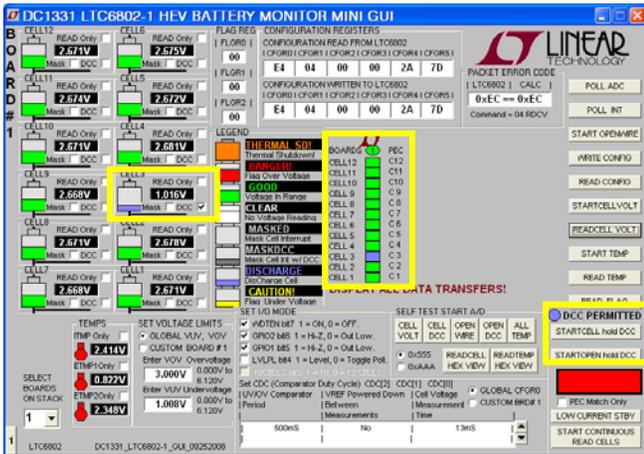
## 6: READ AN INDIVIDUAL CELL OR TEMPERATURE



Each cell and each temperature channel has a check box to allow individual measurements. Checking these “Only” boxes sends the command (**STARTCELL VOLT** then **READCELL VOLT**, **START TEMP** then **READ TEMP**) to read only that channel and display its status. Cell 8 and Internal Temp are shown in the example screen above. Older or stale readings for all other cells and temperatures are faded out.

## 8: DISCHARGE CELLS

Another major feature of the LTC6802-1 is the ability to remove charge from individual cells. This can help to distribute the cell charge evenly over a stack of batteries. DC1331D contains a P channel Mosfet in series with a 15Ω resistor across each cell connection. When enabled, a cell is shorted and charge is pulled from the cell with energy dissipated in the switch and resistor.



A check box is provided for each cell to be discharged. Checking this box (Cell 3 in the above example screen shot) and then writing the new configuration with a **WRITE CONFIG** button push will burden the cell.

**IMPORTANT NOTE:** The discharge transistors are automatically turned off momentarily while the A/D converter is measuring the cell voltage using the normal **STARTCELL VOLT** command. This prevents any voltage drop errors caused by the discharge current flowing through the cell inter-connection wiring. An accurate indication of the true state of charge of the cells is then obtained.

The Revision C and later versions of the LTC6802-1 offer the option of keeping the discharge transistors on while measuring the cell voltages. This is done using the **STARTCELL hold DCC** command button. A blue indicator is illuminated when this command has been executed. This lower voltage reading due to the discharging condition is due to battery impedance and wiring-resistance voltage-drops.

## OTHER CONTROL FEATURES

Three additional command buttons are provided on the control screen. The **POLL ADC** and **POLL INTERRUPT** command buttons are used to test if the ADC is busy making conversion and to test if any of the LTC6802-1 devices in a system have an interrupt condition respectively. The result of these commands can be observed by monitoring the serial data output line of the SPI interface to the Bottom Port, J2. There is no indication provided on the control screen.

The **START OPENWIRE** command button connects the built in open wire detection circuitry to all cells. This command must be followed by **STARTCELL VOLT** and **READCELL VOLT** command button clicks to see the result. An open wire connection to any cell will be indicated by an abnormally high voltage measurement for the cell above the open wire and a near 0V measurement for the cell with the open wire.

## CONTINUOUS OPERATION

For convenience, the control panel allows for continuous operation of the DC1331D board. The command button labeled **START CONTINUOUS READ CELLS** can be clicked and the board control is placed in a continuous loop executing the following commands automatically in the following sequence:

- Start cell voltage
- Read cell voltage
- Start temp
- Read temp
- Read flags

All values are updated continually. While running, the configuration can be changed on the fly. Simply changing a configuration item (Discharge cells for example) and clicking the **WRITE CONFIG** button will implement the new configuration and return to continuous operation.

A green box in the lower right hand corner indicates that the system is running continuously. A red box means that the system is stopped and waiting for a new command to be sent.

## DISPLAYING VALID DATA TRANSFERS ONLY

Each time data is transferred from the LTC6801-1 by the four READ commands (Cell Voltage, Configuration, Flag Status and Temperature), a Packet Error Code, PEC, is calculated based on the data stream sent. The control program also calculates a PEC value based on the data it receives. If the calculated PEC matches the transmitted value the data transfer is assumed to be error free and therefore the data is valid.

If the two PEC values do not match, the transmitted data stream has been somehow corrupted. This type of data error becomes more of a concern when boards are stacked and the transmit data stream is lengthened. The transmitted and calculated PEC values are displayed on the GUI and turn red when a mismatch occurs.

A small checkbox located in the lower right corner of the GUI, called **PEC Match Only**, is provided as a system control option. When left unchecked the control of the system is normal and all information read from the LTC6802-1 is displayed, even if the transmitted data was corrupted and a PEC mismatch occurred.

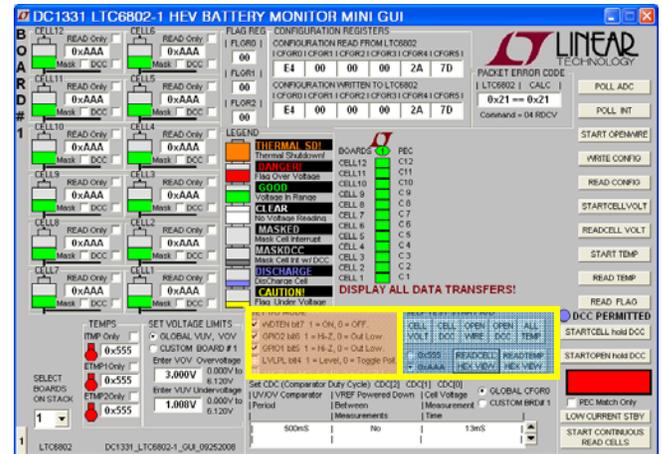
Checking this box instructs the control program to automatically retry the READ commands. The only data displayed is that which was transmitted without error. This setting masks all transmission errors and makes for a smooth running, error free demonstration.

The state of the PEC Match Only option is indicated below the color-coded status panel.

## LOW CURRENT STANDBY

An important system consideration is the ability to put the monitoring circuitry into a low current drain condition. This is done by setting the LTC6802-1 into its standby configuration. A command button in the lower right corner of the screen is provided to facilitate this function. Once pushed all data and configuration settings are reset and the screen goes white on all indicators.

## SELF TEST FUNCTIONS



Revision C and later LTC6802-1 ICs have built in self test functions. These commands apply a test signal to the ADC to check that the internal cell voltage and temperature connections are functioning. The cell voltage and open wire test signals are applied with or without the discharge transistors active. Checking the functionality of each bit in the internal data registers for cell voltages and temperatures can also be seen by choosing which test code (0x555 or 0xAAA) to expect to be returned from the device when a self test command is issued.

## OTHER CONFIGURATION OPTIONS

The SET I/O MODE group of checkboxes can be used to adjust other features of the LTC6802-1. Enabling the Watchdog timer (only Rev C parts), configuring the general purpose I/O pins and setting the type of activity polling scheme can be selected and commanded with a WRITE CONFIG button push.

## STACKING BOARDS TO ADD MORE BATTERY CELLS

A unique characteristic of the LTC6802-1 is the ability to communicate serial data up and down a stack of devices connected to any number of battery cell stacks. Likewise any number of DC1331D boards, monitoring up to 12 cells each, can be stacked in daisy chain fashion. The control GUI however is limited to only 10 boards (120 cells maximum). To stack and control more than one board requires the following hardware and software modifications:

## HARDWARE ADJUSTMENTS

1. The bottom board on the stack, which connects to a system controller or to a DC590 Quick Eval link to a PC, must have its Bottom Port set to voltage mode. Jumper J9 (VMOD) must be connected to the ACTIVE position. **A 5K $\Omega$  pull-up resistor must be connected from the SDO output line (connector J2, pin 5) to the 3V/5V logic power rail of the circuit driving the bottom SPI port, as is provided by the DC590 interface.**
2. The bottom board is no longer at the top of the stack and therefore must have jumper J4 (TOS) set to the GND position.
3. Every board connected above the bottom board must have its serial ports set to Current Mode. Connect Jumper J9 to the GND position on each board to set this. In addition, connect J4 (TOS) on every board below the top one to the GND position.
4. The final board on the top of the stack must have J4 (TOS) set to ACTIVE.
5. A ribbon cable must connect the Top Port (J3) of a lower board to the Bottom Port (J2) of the next board up on the stack. The daisy chain linking with ribbon cables from the Top port of a lower board on the stack to the Bottom port of the next board above it establishes the serial data link for the entire stack.

## CAUTION! CAUTION! CAUTION!

As battery cells are stacked on top of each other, great care must be taken to prevent damage and personal injury from the very high voltage potentials that may be present. Do not allow short circuit connections, whether electrical or human, between a high voltage point and the system or chassis ground at the bottom of the stack. Be very careful and respect the potential danger of high voltage!

## IMPORTANT NOTE FOR DEMONSTRATION OR EVALUATION WHEN NOT USING BATTERY CELLS IN A STACK

When using DC1331D boards in a stacked application where a resistor string is used to simulate cell voltages an extra wire must be added to connect the V+ potential of a lower board to the V- potential of the next board up on the stack. Connector J1, pin 16 of a the lower board must be connected to the connector J1, pin 1 or pin 4 of the next board above it on the stack. The wire making this connection should be kept as short as possible (less than 2 inches or 5 cm). **This supply connection is not provided by the ribbon connector and is required to enable data communication up and down the stack.**

## SOFTWARE ADJUSTMENTS

The GUI program can control up to ten boards on a stack.

1. Select the number of boards on the stack from the pop up window located near the command buttons at the bottom of the screen.
2. Select whether the Operating Configuration (CDC Comparator) and Over/Under voltage thresholds for each board are to be the same (GLOBAL) or different for each board (CUSTOM) and set the duty cycle and voltages accordingly.
3. A tab will appear on the left edge of the control panel for each board on the stack. Clicking on any of these tabs will transfer control commands and data to and from the display screen to that selected board.

## COLOR CODED STATUS PANEL

The color-coded status panel will expand to include all boards connected in a stack. Each small square in this array represents an individual battery in the stack of boards. The intent of this display is to provide a way to see the status of all cells at a glance. The significance of the colors used is explained in the legend on the screen.

Any grayed box indicates that the cell's interrupt flag has been masked so the LTC6802-1 is no longer reporting this status. The cell voltage value measured for this cell however is still accurate.

The next page is the schematic for DC1331D. Consult the data sheet for detailed information concerning the operation of the LTC6802-1.

**DC1331 LTC6802-1 HEV BATTERY MONITOR MINI GUI**

**BOARD # 4**

CELL	Voltage	Status
CELL12	2.723V	Good
CELL11	2.576V	Good
CELL10	2.576V	Good
CELL9	2.582V	Good
CELL8	2.717V	Good
CELL7	2.722V	Good
CELL6	2.723V	Good
CELL5	2.717V	Good
CELL4	2.582V	Good
CELL3	2.579V	Good
CELL2	2.581V	Good
CELL1	2.720V	Good

**LEGEND**

- Thermal SD!** Thermal Shutdown!
- DANGER!** Flag Over Voltage
- GOOD** Voltage In Range
- CLEAR** No Voltage Reading
- MASKED** Mask Cell Interrupt
- MASKDCC** Mask Cell Int w/ DCC
- DISCHARGE** Discharge Cell
- CAUTION!** Flag Under Voltage

**CONFIGURATION REGISTERS**

CONFIGURATION READ FROM LTC6802  
| CFGR0 | CFGR1 | CFGR2 | CFGR3 | CFGR4 | CFGR5 |

E1	04	02	20	6C	6C
----	----	----	----	----	----

CONFIGURATION WRITTEN TO LTC6802  
| CFGR0 | CFGR1 | CFGR2 | CFGR3 | CFGR4 | CFGR5 |

E1	04	02	20	6C	6C
----	----	----	----	----	----

PACKET ERROR CODE  
| LTC6802 | CALC |

0x62 == 0x62  
Command = 02 RDCFG

**SELECT BOARDS ON STACK**: 4

**TEMPS**

- ITMP Only: 2.413V
- ETMP1 Only: 0.822V
- ETMP2 Only: 2.336V

**SET VOLTAGE LIMITS**

- GLOBAL VUV, VOV
- CUSTOM BOARD # 4
- Enter VOV Overvoltage: 2.592V (0.000V to 6.120V)
- Enter VUV Undervoltage: 2.592V (0.000V to 6.120V)

**SET I/O MODE**

- WDTEN bit7: 1 = ON, 0 = OFF.
- GPIO1 bit6: 1 = Hi-Z, 0 = Out Low.
- GPIO1 bit5: 1 = Hi-Z, 0 = Out Low.
- LVLPL bit4: 1 = Level, 0 = Toggle Poll.
- 10CELLS bit3: 1 = 10, 0 = 12 CELLS.

**SELF TEST START A/D**

CELL VOLT	CELL DCC	OPEN WIRE	OPEN DCC	ALL TEMP
0x555	READCELL	READTEMP	HEX VIEW	HEX VIEW
0xAAA				

Set CDC (Comparator Duty Cycle) CDC[2] CDC[1] CDC[0]

UV/OV Comparator	VREF Powered Down	Cell Voltage	Measurement	GLOBAL CFGR0
Period	Between	Measurements	Time	CUSTOM BRD# 4
Comparator Off	Monitor Mode	No	13mS (Cell Voltage)	

**DCC PERMITTED**

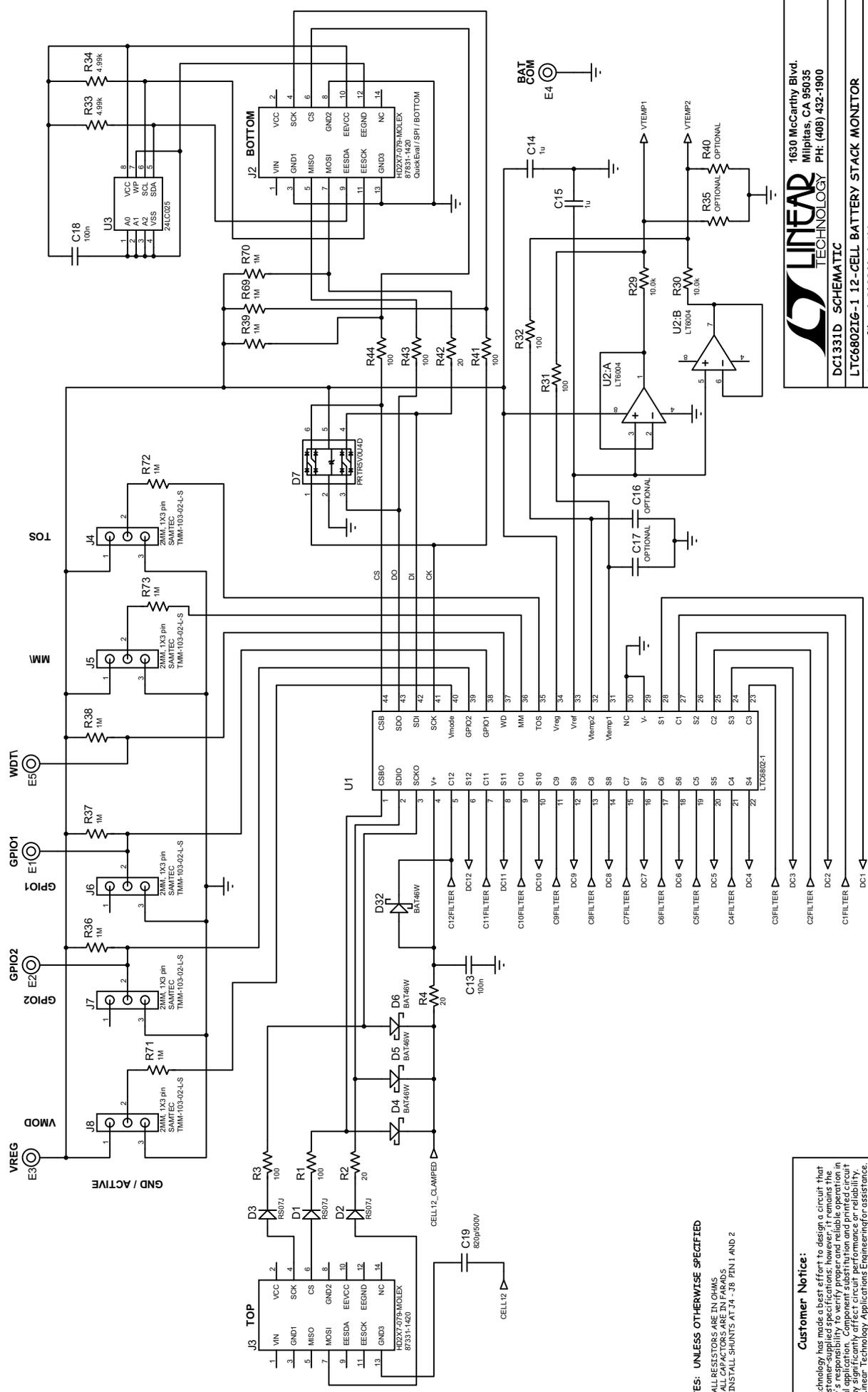
STARTCELL hold DCC

STARTOPEN hold DCC

PEC Match Only

LOW CURRENT STBY

START CONTINUOUS READ CELLS



**NOTES: UNLESS OTHERWISE SPECIFIED**

1. ALL RESISTORS ARE IN OHMS
2. ALL CAPACITORS ARE IN FARADS
3. INSTALL SHUNTS AT J4 - J8 PIN 1 AND 2

**Customer Notice:**

Linear Technology has made a best effort to design a circuit that meets customer-supplied specifications; however, it remains the customer's responsibility to verify proper and reliable operation in the actual application. Component substitution and printed circuit board assembly may affect circuit performance or reliability. Contact Linear Technology Applications Engineering for assistance. This circuit is proprietary to Linear Technology and supplied for use with Linear Technology parts.



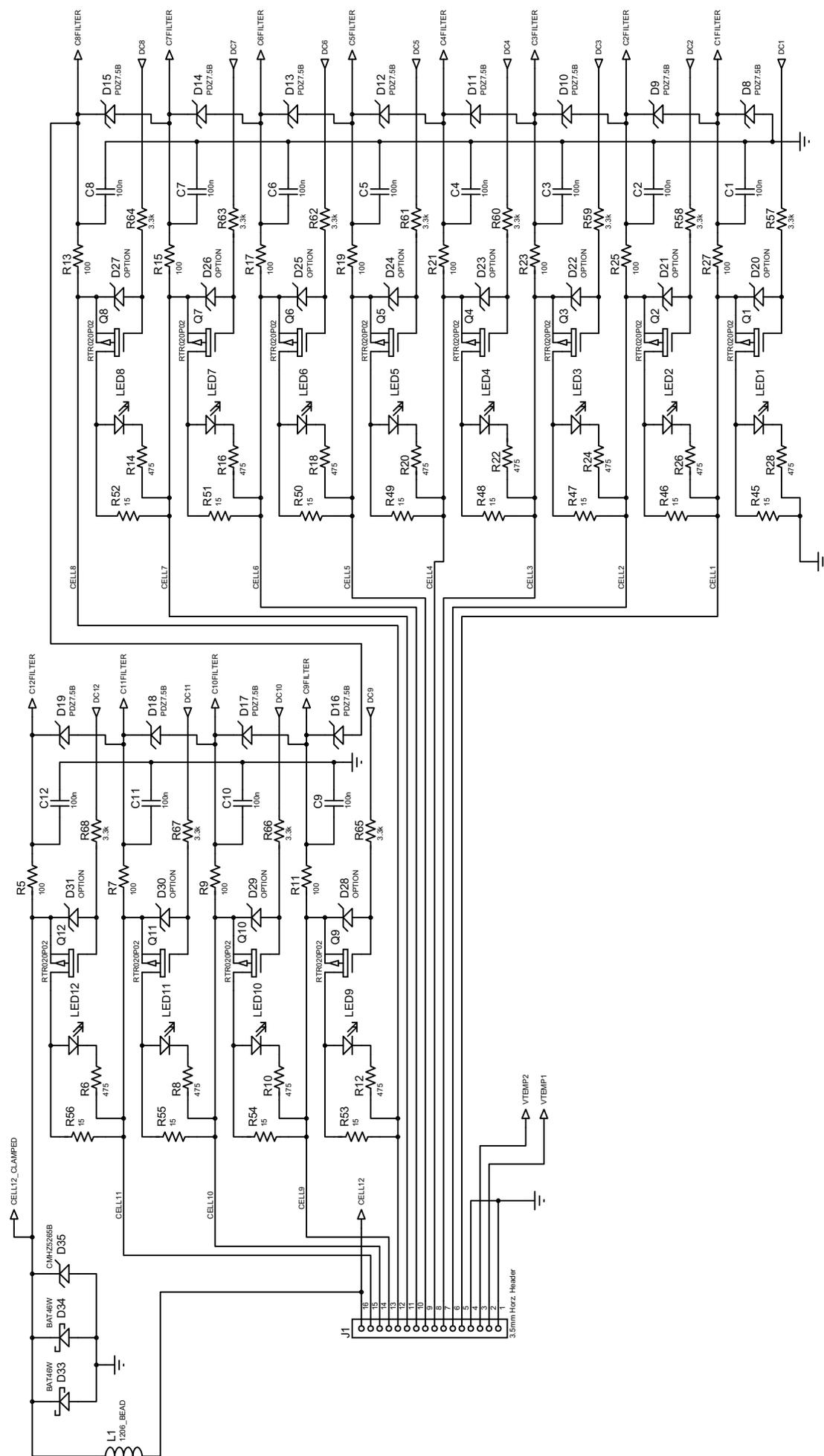
1630 McCarthy Blvd.  
Milpitas, CA 95035  
PH: (408) 432-1900

**DC1331D SCHEMATIC**

LT680216-1 12-CELL BATTERY STACK MONITOR

Sourcefile: DC1331D.DSN

J. Munson 6/4/2009




  
 1630 McCarthy Blvd.  
 Milpitas, CA 95035  
 PH: (408) 432-1900  
**DC1331D SCHEMATIC**  
 LTC6802lg-1 12-CELL BATTERY STACK MONITOR  
 Sourcefile: DC1331D.DSN  
 J. Munson 6/4/2009