# LTC3300-1/LTC6803-2
# Bidirectional Cell Balancer

## DESCRIPTION

Demonstration Circuit DC2064A is a bidirectional cell balancer using two LTC®3300-1 ICs to achieve active cell balancing of up to 12 Li-Ion batteries. The board uses the LTC6803-2 multi-cell addressable battery stack monitor to measure cell voltages and two LTC3300-1 ICs to provide active cell balancing. The demonstration circuit uses a two window GUI developed for the DC2064A. One window is a modified version of the GUI for the LTC6803-2 and also contains a tab to control the LTC3300-1 ICs through the DC590B USB Serial controller and the second window reports the status of the LTC3300-1 devices. All the functions of the LTC6803-2 GUI are supported except that cell balancing is achieved through the LTC3300-1 ICs by transferring charge from one to six batteries per LTC3300-1 to the stack or from the stack to one to six batteries per LTC3300-1.

**Design files for this circuit board are available at http://www.linear.com/demo**



## PERFORMANCE SUMMARY

**Specifications are at $T_A$ = 25°C**

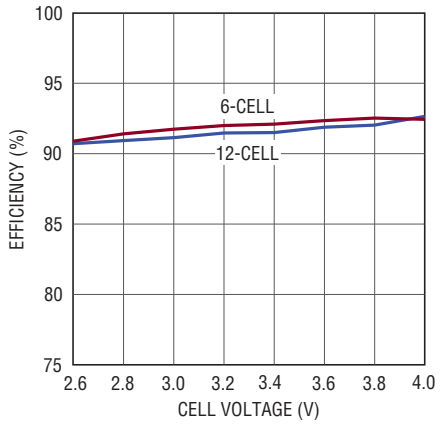
| | |
|---|---|
| Battery Voltage Range | 3.2V to 4.5V (2.5V to 4.5V)* |
| Stack Voltage | 60V Max |
| Average Battery Balancing Charge Current (12 Cell) | 2.6A (Typ) (4A)* |
| Average Battery Balancing Discharge Current (12 Cell) | 2.4A (Typ) (3.6A)* |
| Average Battery Balancing Charge Current (6 Cell) | 2.2A (Typ) (3.3A)* |
| Average Battery Balancing Discharge Current (6 Cell) | 2.4A (Typ) (3.6A)* |
| Balancing Efficiency | 92% (Typ) |

*The battery voltage range may be expanded to 2.5V-4.5V by changing resistor $R_{TONS}$ to 19.1k and resistor $R_{TONP}$ to 29.4k.
The demo board's average balancing current is adjustable up to 4A by scaling and installing new values of RS1A and RS1B through RS12A and RS12B.

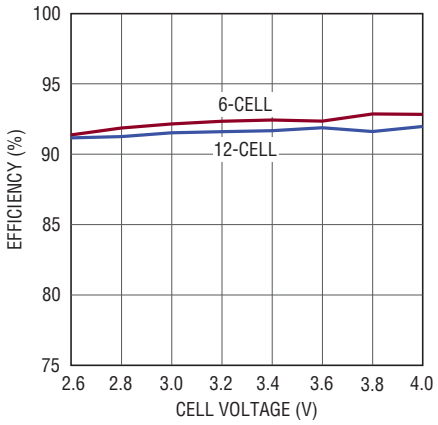
## BOARD PHOTO

## DESCRIPTION

**Power Stage Discharge Efficiency**




**Power Stage Charge Efficiency**



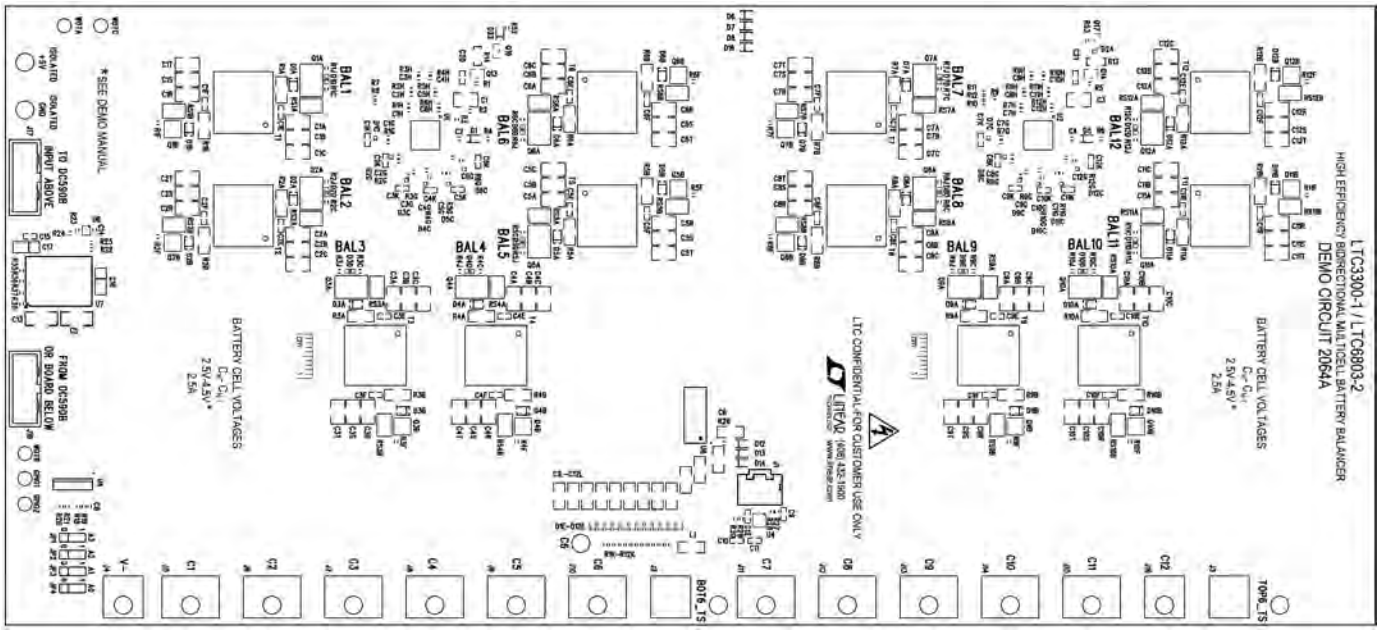




**Figure 1. DC2064A Size 5.5" × 12.2"**

## OPERATING PRINCIPLE

Operation of the LTC6803-2 is detailed in the LTC6803-2 data sheet and the operation of the DC2064A GUI is similar to the DC1652A GUI except additional functionality was added to control the LTC3300-1 balancing devices. Refer to the Quick Start Guide for the DC1652B for operation of the LTC6803-2 GUI. The DC2064A has a two window GUI, one window based on the DC1652A GUI to control the LTC6803-2 with a tab to control the LTC3300-1 for battery balancing and the second window to display the status of the LTC3300-1 based on the command and status registers read from the LTC3300-1.

The LTC3300-1 active balancer is a power stage control IC. The LTC3300-1 does not have a balancer algorithm built into it. The determination of the balancing times and directions are performed at a system level and conveyed to the LTC3300-1 through its SPI interface. The LTC3300-1 only accepts battery charge or discharge commands.

Charge is transferred to/from a cell (battery) from/to the stack, a series connection of adjacent cells, through a flyback converter that is operating in boundary mode.

During discharge of a cell, the current in the primary of a coupled inductor transformer with a turns ratio of 1:2, ramps up to 6.25A at which point the primary switch turns off. The charge in the primary inductor is transferred to the secondary inductor which is connected across the 12-cell pack. This pack current then passes through the series connected cells thus distributing the charge equally across each cell. When charging a cell, the current, in the secondary of the coupled inductor transformer, ramps up to 3.125A at which point the secondary switch turns off. The charge in the secondary inductor is transferred to the primary inductor which is connected across the cell. The secondary current is drawn from the series connected cells thus removing charge equally across each cell. The efficiency through the flyback converter is ≈92%.

## QUICK START PROCEDURE

The demonstration circuit is set up per Figure 27 to evaluate the performance of the DC2064A bidirectional cell balancer using the LTC3300-1.

**Caution: BOT6_TS and TOP6_TS turrets must not be allowed to float and must be connected to their respective top of stack-battery terminal.**

Using short twisted-pair leads for any power connections, refer to Figure 27 for the proper measurement and equipment setup. When installing the batteries start with Cell 1 and progress to Cell 12. Remove batteries in the reverse order. The DC2064A will support a system of 4 to 12 batteries.

Follow the procedure outlined in the DC1835A Quick Start Guide for general use of the modified LTC6803-2 GUI window. The 4-bit board ID code that is set by the A0 through A3 jumpers on the DC2064A must match the board Address box in the LTC6803-2 GUI window shown in Figure 2 for each board in the system.


**Figure 2. Board Address Box**

## QUICK START PROCEDURE

The Voltage Comparator box must be turned off and the VREF must remain on during balancing. Set window by using the Up/Down arrows to the right of the box. See Figure 3.

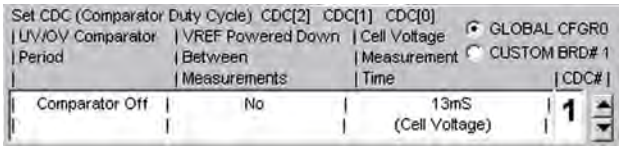



**Figure 3. Voltage Comparator Box**

The DC2064A GUI periodically checks for OV and UV measured on the cells when balancing. To avoid the program from suspending balancing from an OV or UV measurement during normal operation, the OV and UV values must be entered in the VOV and VUV text boxes on the LTC6803-2 tab shown in Figure 4.

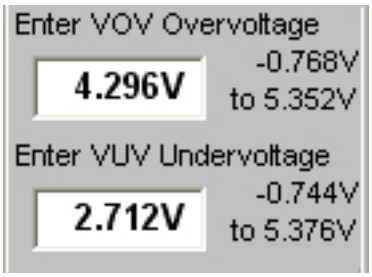



**Figure 4. VOV and VUV text boxes**

Once this is done, Click the WRITE CONFIG button and verify that the configuration was set correctly by clicking the READ CONFIG.


**Figure 5. Write Configuration Box**

Click the START CELL VOLT button followed by the READ CELL VOLT to verify that the batteries are connected and that the LTC6803-2 can read the battery voltages.

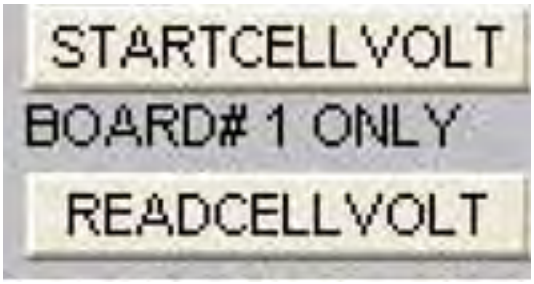



**Figure 6. Start Cell Voltage Read Box**

To access the LTC3300-1 screen, click on the LTC3300-1 tab in the upper left of the LTC6803-2 GUI window.

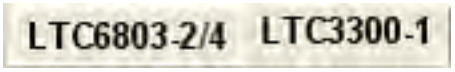



**Figure 7. LTC3300-1 Screen Select Box**

Within this window you can manually select which cells are to be discharged by clicking the cell's DISCHARGE button and which cells are to be charged by clicking the cell's CHARGE button.

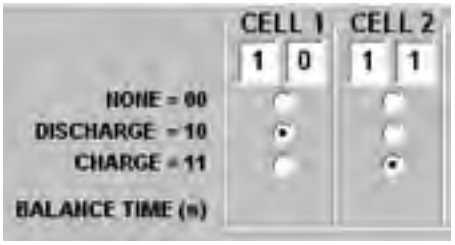



**Figure 8. Balance Mode Select Boxs**

To write this configuration, the WRITE button followed by the SEND button must be clicked. To enable the balancers, the EXECUTE button followed by the SEND button must be clicked. To pause the cell balancers, the SUSPEND button is clicked followed by clicking the SEND button. This will turn off all balancers until the EXECUTE button is clicked followed by clicking the SEND button. This will resume the previous settings of the cell charge/discharge settings.

## QUICK START PROCEDURE

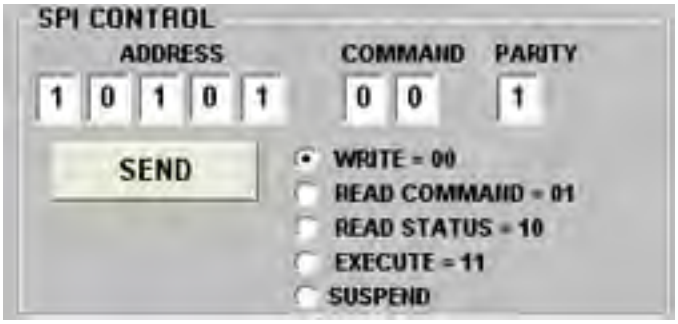



**Figure 9. Write/Execute Command Box**

To change any of the settings "on the fly", a new charge/discharge setting is entered using the respective CHARGE and DISCHARGE buttons followed by clicking the WRITE button followed by the SEND button and then the EXECUTE button followed by the SEND button. To disable any cell from operating, the cell's NONE button must be clicked in the balance mode box followed by clicking the WRITE button followed by the SEND button and then the EXECUTE button followed by the SEND button.

The LTC3300-1 GUI allows the user to program the balancer to charge or discharge each cell for a specific amount of time. The LTC3300-1 is a power stage control IC. The determination of the balancing times and directions are done at the System level and conveyed to the LTC3300-1 through its SPI communications port. In order to perform a timed balance, the TIMED BALANCE check shown in Figure 10 must be selected to have access to the timed balance controls as shown in Figure 25.

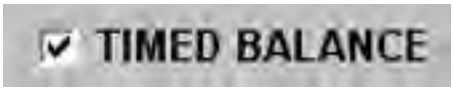



**Figure 10. TIMED BALANCE Check Box**

To do this, select the DISCHARGE or CHARGE button for the desired cell, then enter the time in seconds into the cells "BALANCE TIME" text box. Press the enter key on the key board or select another button in the GUI to load the time. When all the desired balance actions and times have been entered, select the "Balance Cells" START button to start the balancing sequence.


**Figure 11. Balance Cells Start Box**

The START button will display PAUSE. The balancing algorithm will first turn off all cells, then set all cells to be balanced. The cells will run until the first cell(s) have elapsed their balance time. At this time all cell balancing is suspended, the completed cell's balancing action is set to "None", the remaining times to balance are recalculated, then the remaining cells continue to balance until the next cell(s) have completed. This sequence continues until all of the balance times have elapsed.

Selecting the PAUSE button while the balancer is running, will shut off the active cell and pause the timer. The START button now displays CONTINUE. Selecting the CONTINUE button again will start the active cell balancing and continue the timer. After the last cell has completed balancing, all the cells are turned off. The START button will again display START. Selecting the RESET button will reset all the cell actions and times to the previous entered settings.

The LTC3300 STATUS window displays the status of all LTC3300-1 ICs in the system. This GUI is updated every time the LTC3300-1 status or command registers are read. When the balancer timer is running, the command register is read after each execute command is sent.

## QUICK START PROCEDURE

### Cell Balancer Efficiency Measurements:

Figure 28 shows the proper connections for measuring the efficiency of a cell balancer. The secondary of the cell balancer connects to the top of stack. This connection needs to be to an isolated power source through a current sensing resistor (0.10Ω). Cells 1 through 6 are connected to the BOT6_TS turret with its return path the V– turret while Cells 7 through 12 are connected to the TOP6_TS turret with its return path the C6 turret. The primary side connections of the cell balancers are connected to a string of batteries that simulate the battery stack. Cell 1 is a 2-wire connection that connects the positive node, through a current sensing resistor (0.01Ω), to the C1 turret, and the negative node to the V– turret. Remote sense connections for power sources with remote sensing capabilities should be connected to the C1 and V– respectively. All other connections of the simulated string of batteries connect their positive node, through a current sensing resistor (0.01Ω), to respective turrets. Cell voltage measurements should be made across the C(x) and C(x – 1) turrets of the respective cells. Stack voltage measurements should be made at the BOT6_TS and TOP6_TS turrets and their return path turret.

To calculate cell balancer efficiency use the expressions below:

### Cells 1-6

Charge Mode

$$Efficiency_1 = \frac{Vm_1 \bullet Vm_2 \bullet 10}{Vm_3 \bullet Vm_4} \bullet 100\%$$

Discharge Mode

$$Efficiency_1 = \frac{Vm_3 \bullet Vm_4}{Vm_1 \bullet Vm_2 \bullet 10} \bullet 100\%$$

### Cells 7-12

Charge Mode

$$Efficiency_{11} = \frac{Vm_5 \bullet Vm_6 \bullet 10}{Vm_7 \bullet Vm_8} \bullet 100\%$$

Discharge Mode

$$Efficiency_{11} = \frac{Vm_7 \bullet Vm_8}{Vm_5 \bullet Vm_6 \bullet 10} \bullet 100\%$$

### Cell Balancer Performance Measurements:

Table 2 through Table 5 present the typical operational data for a 12-cell and 6-cell balancer in both Discharge and Charge modes. The cell voltages were 3.6V and measurements of Cell Current, Stack Current, Operating Frequency were taken and transfer Efficiency was calculated from the data. Figure 12 through Figure 15 are actual in circuit waveforms taken on Cell 1 and Cell 7 while operating in both modes. The waveforms present voltage on the primary side and secondary side MOSFET's drain to source voltage and the primary side and secondary side current sense inputs to the LTC3300-1.

Figures 16 through 19 are cell and stack currents taken over a range of cell voltages from 2.6V to 4.0V. The RTONP and RTONS resistors for these graphs were set for 2.6V cell voltage operation. All cells were set to the cell voltage under test. The slight negative slope in current at higher voltages is due to the increased operating frequency and the circuit delays and dead time becoming a higher percent-age of the operating period.

# QUICK START PROCEDURE

## 12 Cell Discharge

**Table 2. Typical 12 Cell Discharge Data**

| Cell I (A) | Stack I (A) | Frequency (kHz) | Efficiency |
|---|---|---|---|
| 2.444 | 0.188 | 127.7 | 92.21% |

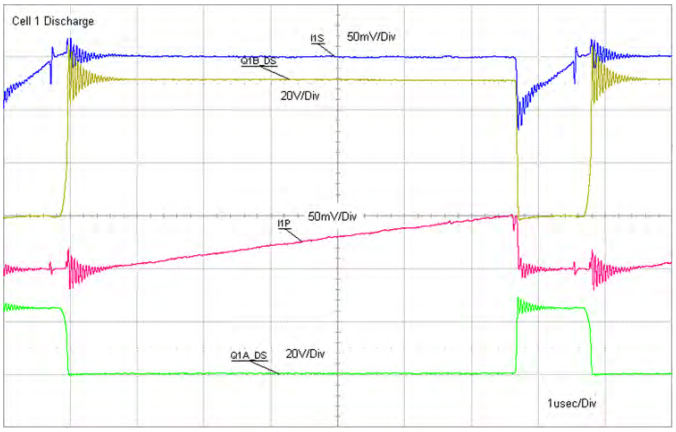



**Figure 12. 12 Cell Discharge Waveforms**

## 12 Cell Charge

**Table 3. Typical 12 Cell Charge Data**

| Cell I (A) | Stack I (A) | Frequency (kHz) | Efficiency |
|---|---|---|---|
| 2.601 | 0.237 | 149.1 | 91.71% |

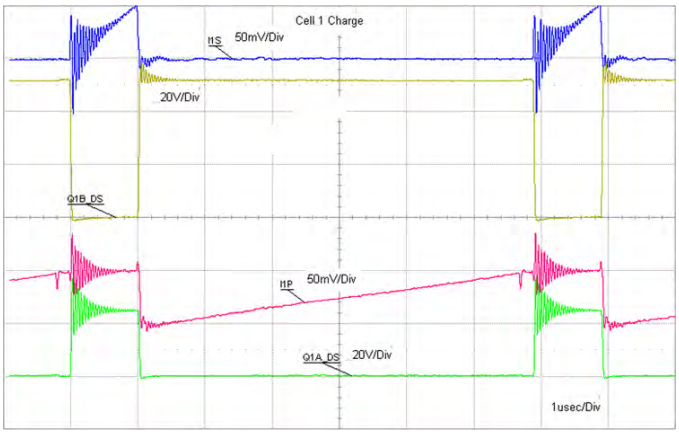



**Figure 13. 12 Cell Charge Waveforms**

## 6 Cell Discharge

**Table 4. Typical 6 Cell Discharge Data**

| Cell I (A) | Stack I (A) | Frequency (kHz) | Efficiency |
|---|---|---|---|
| 2.448 | 0.277 | 126.1 | 92.33% |

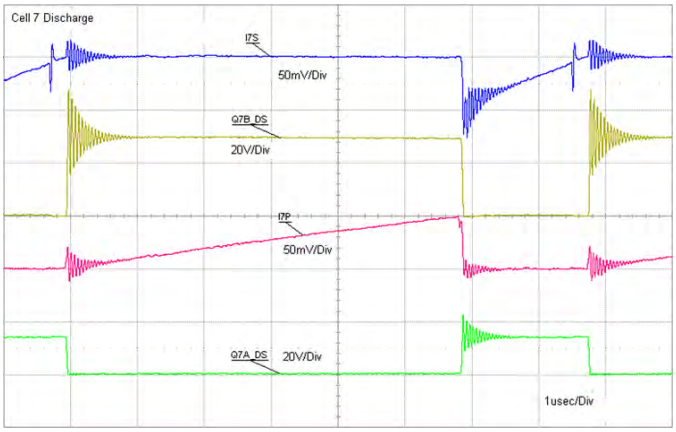



**Figure 14. 6 Cell Discharge Waveforms**

## 6 Cell Charge

**Table 5. Typical 6 Cell Charge Data**

| Cell I (A) | Stack I (A) | Frequency (KHz) | Efficiency |
|---|---|---|---|
| 2.219 | 0.399 | 133.1 | 92.72% |

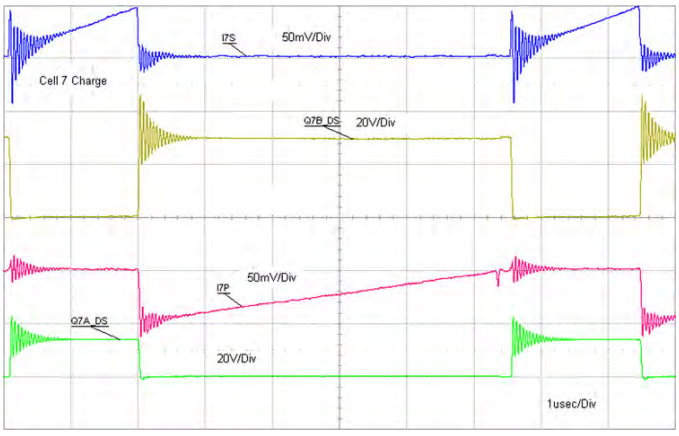



**Figure 15. 6 Cell Charge Waveforms**

## QUICK START PROCEDURE

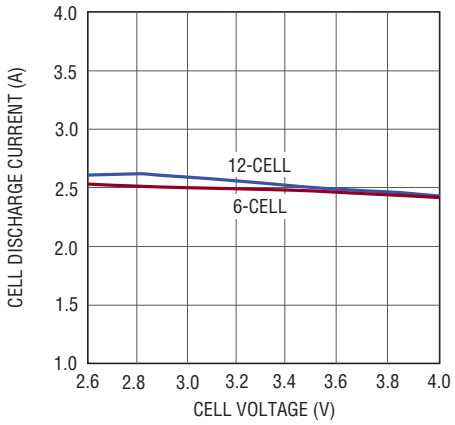



**Figure 16. Cell Discharge Current**

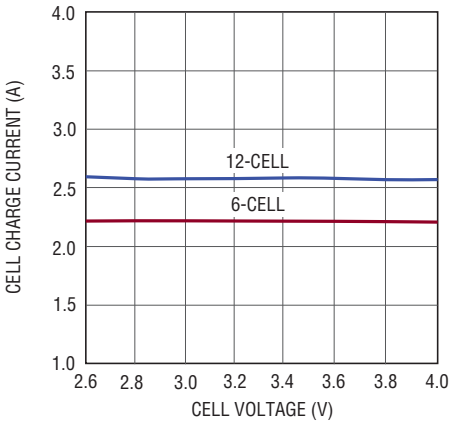



**Figure 18. Cell Charge Current**

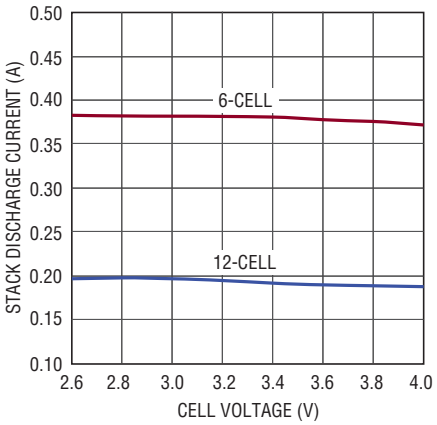



**Figure 17. Stack Discharge Current**

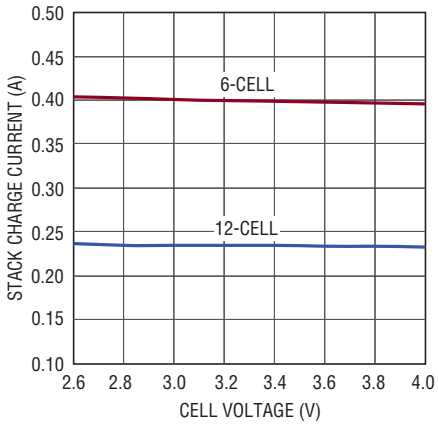



**Figure 19. Stack Charge Current**

## QUICK START PROCEDURE

**Two Board Setup and Operation:**

As a result of communication latency to the PC, the system only supports two series DC2064A boards

When connecting two DC2064A boards together, the interface cables must be connected in sequence as shown in Figure 20 to avoid large inrush currents. The DC590B must be connected to the PC USB port and the bottom DC2064A board first and then the top DC2064A board may be connected.

The 24 cells should be interconnected to allow balancing between the two 12-cell stacks, as shown in Figure 21.

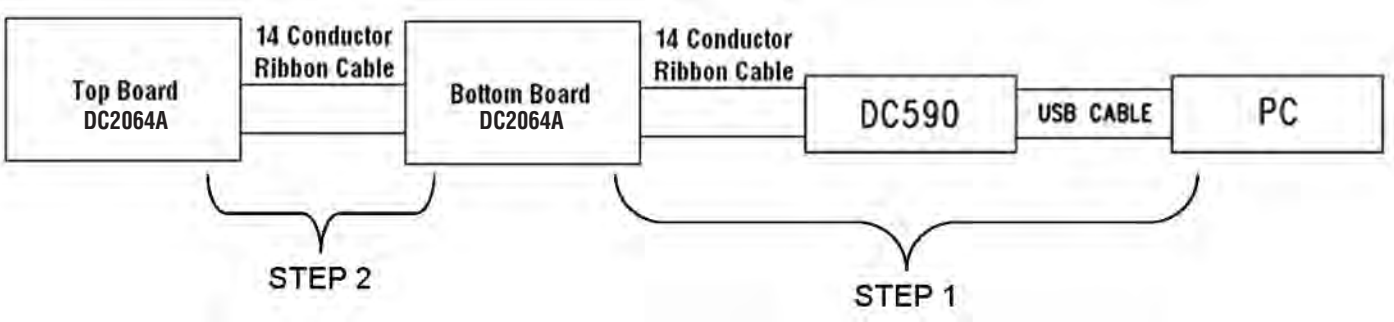



**Figure 20. Two DC2064A SPI Connection Sequence**

## QUICK START PROCEDURE

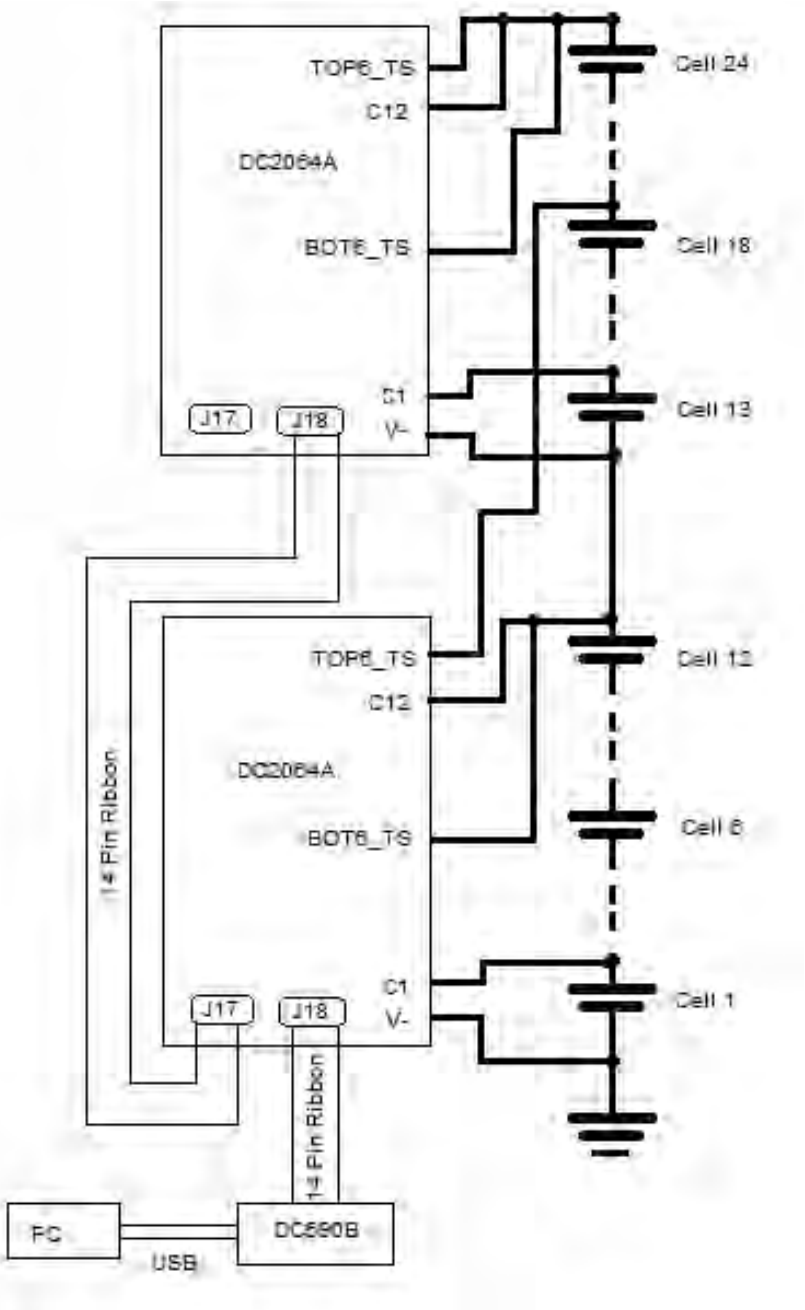



**Figure 21. 24 Cell Interconnected Stacks**

## QUICK START PROCEDURE

On the LTC6803-2 tab on the DC2064A GUI, the Number of Boards in the System drop down box will need to be changed to 2. Make sure the address for each board in the Hex Address box matches the address set by the A0 to A3 jumpers on the respective DC2064A board. The board selection buttons on the bottom left side of the GUI highlight which board is selected in maroon, as shown and the set hexadecimal address is displayed under each board. To change the hexadecimal address on the GUI, select the board to change by clicking on the appropriate board selection number and then select the correct address in the Hex Address Box.

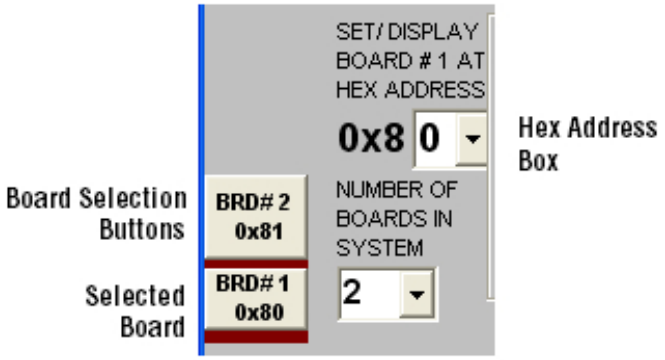



**Figure 22. DC2064A GUI Board Selection Controls**

To set up the charge and discharge actions for each LTC3300, the appropriate board must be selected first and then the commands for each LTC3300-1 can be selected and written to the LTC3300-1 tab. When all the desired actions are selected and written to the four LTC3300-1 ICs, then a single execute command will send an execute command to both boards simultaneously provided the Broadcast Execute/Suspend button is selected as shown in Figure 23.


**Figure 23. Broadcast Execute/Suspend Tab**

### Additional Circuitry

Additional circuitry has been added to increase the robustness of the design for fault insertions.

### Cell 6 Wire Disconnection

A 10A 200V Schottky diode has been added for a high current path when the connection between battery cells is broken when a battery stack load is present. The 200V reverse voltage rating of the diode was selected to mini-mize the reverse leakage current at a battery voltage of 4.2V. The 10A current rating was selected for its low forward voltage drop which will minimize the current in the parallel diode within the LTC3300-1 as well as surviving the fusing current of the 7A fuses on the DC2064A.

Two overvoltage detection circuits have been added to the design that will sense an overvoltage condition on Cell 6 and Cell 7 when a disconnection of the Cell 6 wire connection between battery Cell 6+ and battery Cell 7– of the battery stack occurs. When Cell 6 is being discharged and other cells controlled by the U1, the lower LTC3300-1, and U2, the upper LTC3300-1 are operational, an overvoltage can occur on Cell 7. The overvoltage on Cell 7 will shut down the operation of Cell 7-Cell 12 but Cell 1-Cell 6 will continue to operate. The overvoltage sensing circuit Q15, D21, D23 and R51 will turn off the operations of Cell 1-Cell 6 through the internal overvoltage protection circuit within the LTC3300-1 of U1.

A similar event occurs when Cell 6 is operating in the Charge Mode and the Cell 6 connection from the board to the battery is lost. The overvoltage on Cell 6 will shut down the operation of Cell 1-Cell 6 but Cell 7- Cell 12 will continue to operate. The overvoltage sensing circuit Q16, D22, D24 and R52 will turn off the operations of Cell 7-Cell 12 through the internal overvoltage protection circuit within the LTC3300-1 of U2.

## QUICK START PROCEDURE

### Cell Bypass Capacitors

The DC2064 contains bypass capacitors between the cell connections and the stack connections. These capacitors are intended to smooth the high current triangular wave before they travel down the interconnection wires to the cells within the stack and the secondary stack connections. The RMS current rating of these capacitors is a critical parameter as well as their capacitance with applied voltage and their physical size. The capacitance of MLCC capacitors decreases with applied voltage and this must be taken into account when selecting the capacitance value. The value of the cell bypass capacitor is outline on page 31 of the LTC3300-1 data sheet. Larger size, 1812 and above, MLCC capacitors have a tendency to crack and short due to thermal expansion and physical stress.

Each cell must have an equal capacitance between them to prevent an overvoltage condition across the cell when randomly connecting batteries to the LTC3300-1 battery balancer circuit. There are also capacitors across adjacent cells that act a reservoir of charge for the cell's FET Gate turn on circuit. These capacitors must also be of equal value to maintain the balancing of voltage and a capacitor of ½ the value need to be connected between Cell 1 and V– of the lowest LTC3300-1 and from the top cell to the cell below it to ensure balancing of voltage across all cells when the battery stack is initially connected.

Figure 29 through 35 show the proper way to configure the board for between 4 and 11 batteries.

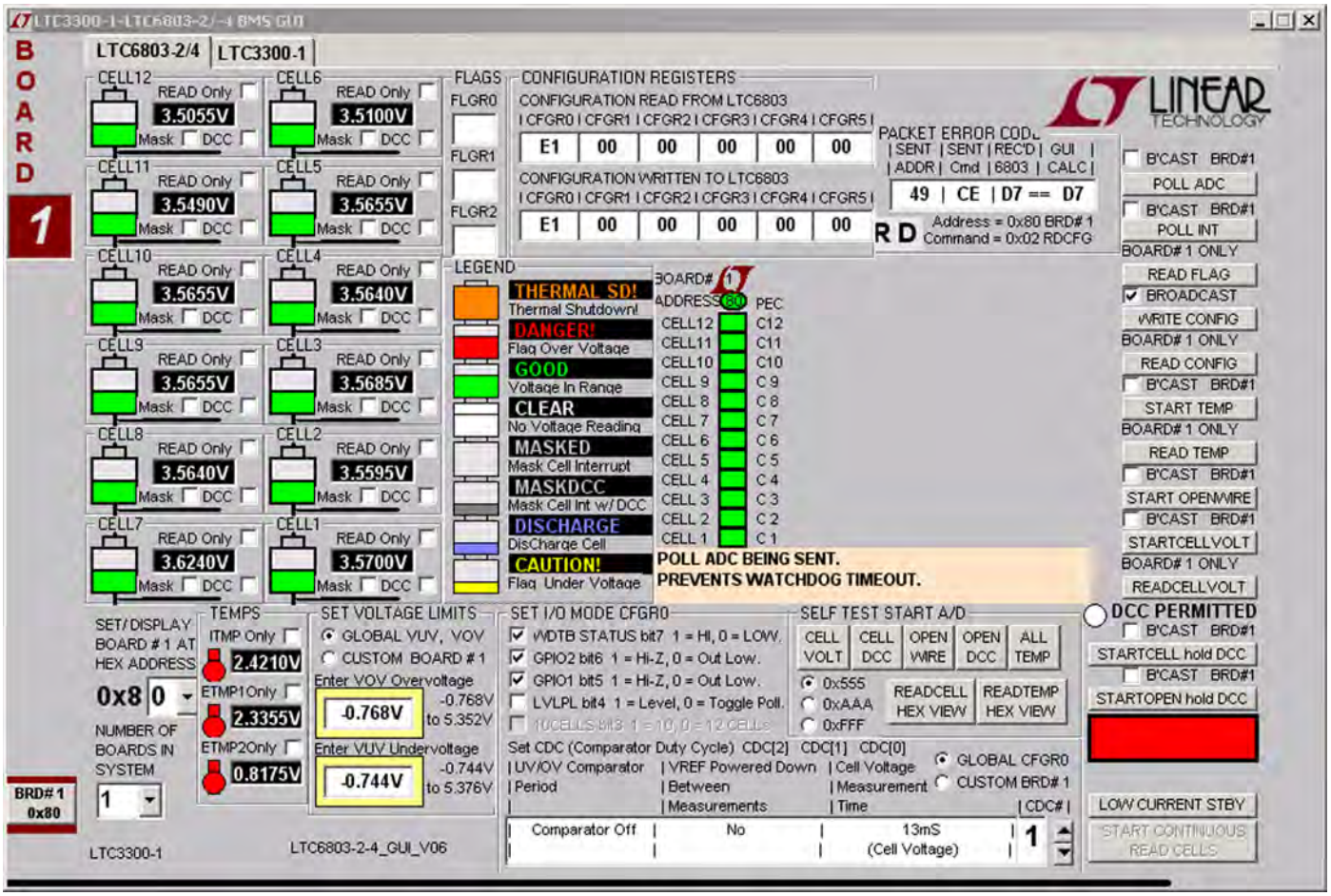



**Figure 24. DC2064A LTC6803-2 Setup Screen**

## QUICK START PROCEDURE

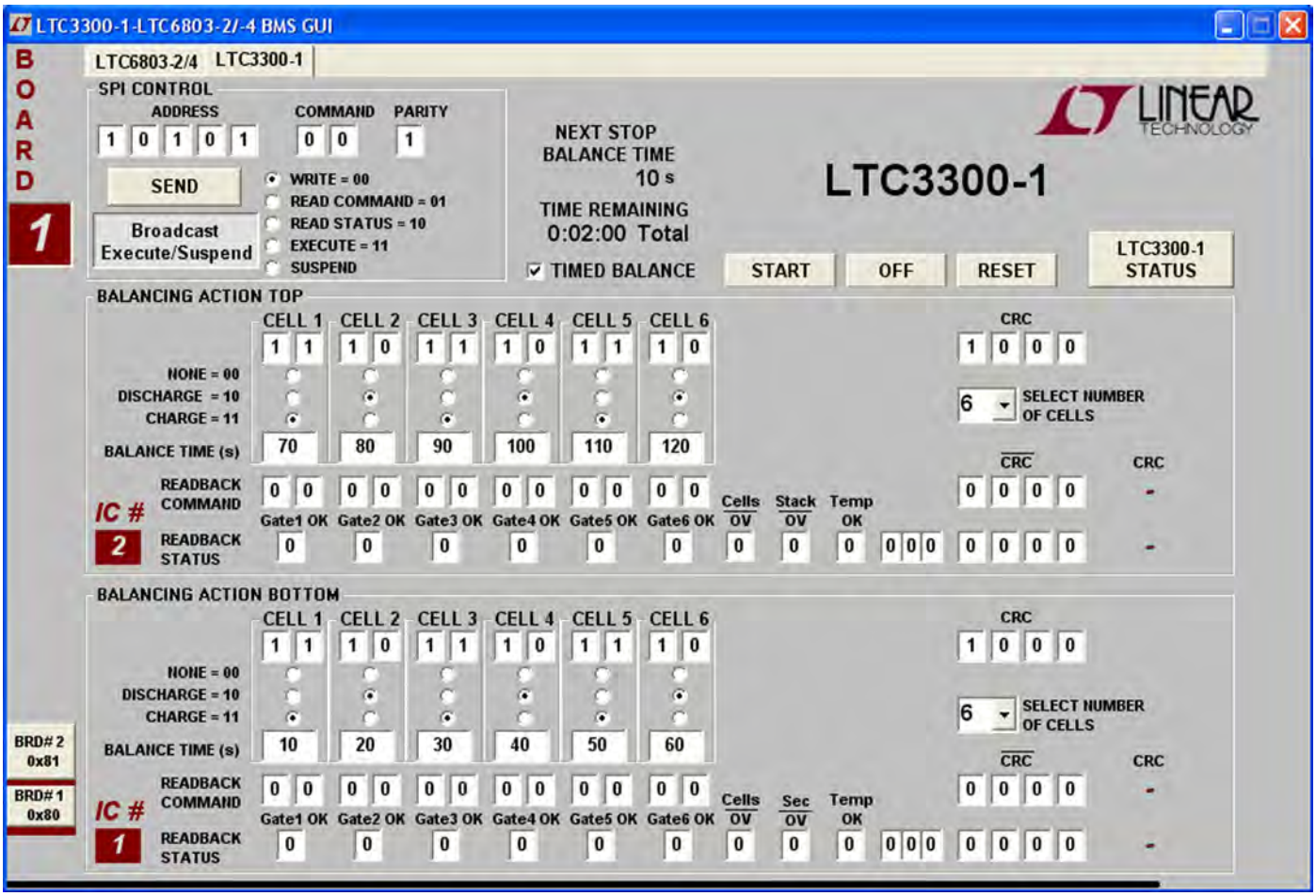



Figure 25. DC2064A LTC3300-1 Setup Screen with Timed Balance Controls

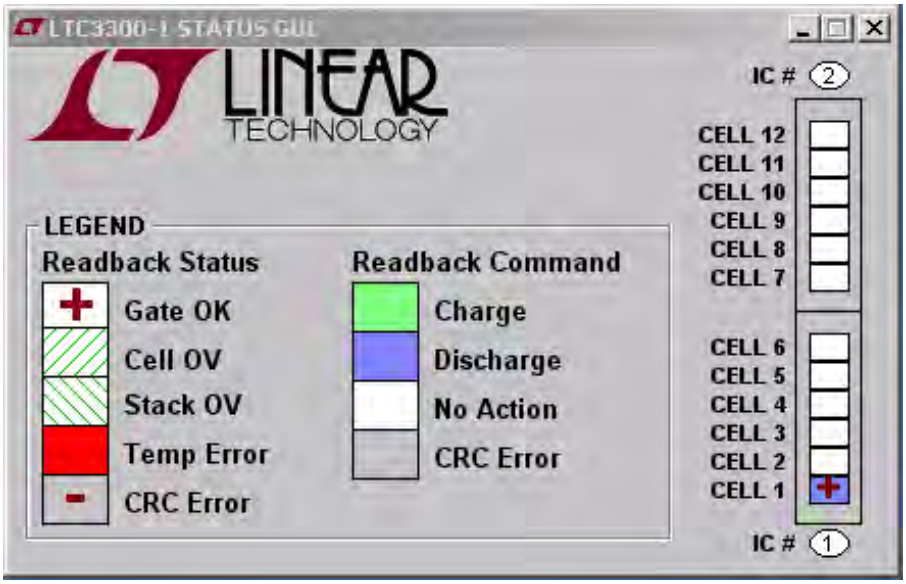



Figure 26. DC2064A LTC3300-1 Status GUI Screen

## QUICK START PROCEDURE

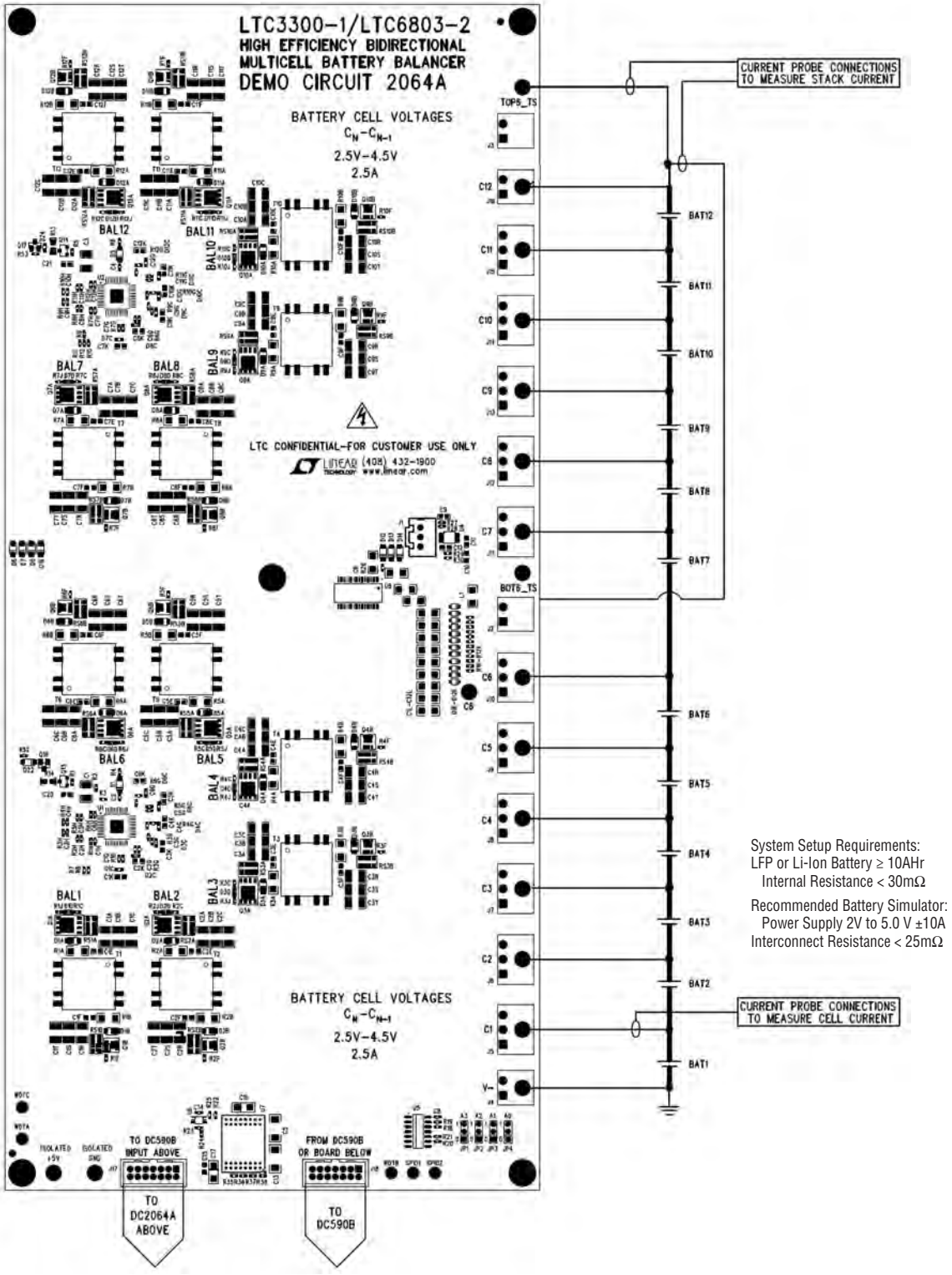
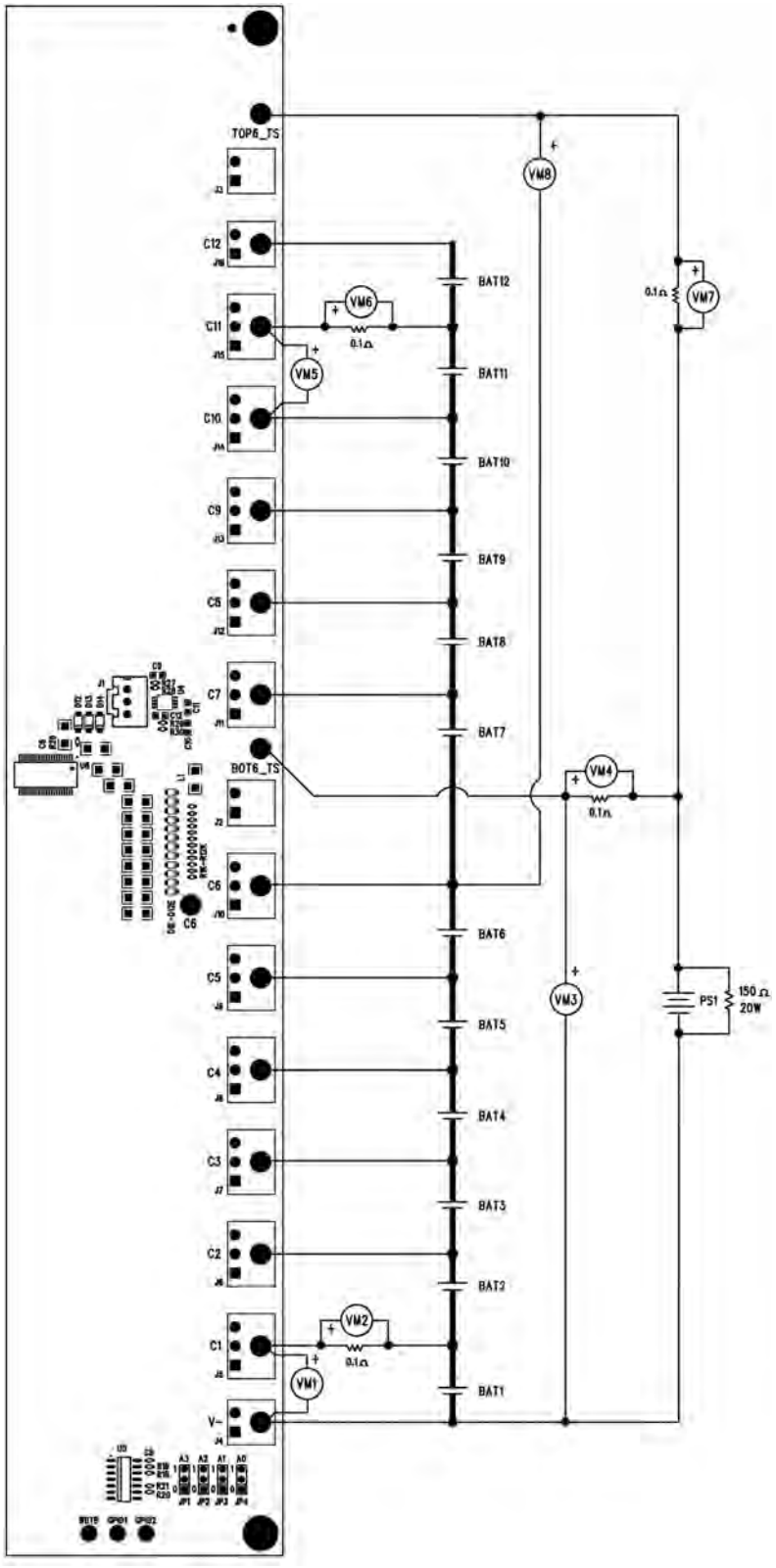



**Figure 27. Proper Measurement Equipment Setup for Bidirectional Cell Balancer**

Note: All connections from equipment should be Kelvin connected directly to the Board Pins which they are connected to on this diagram and any input, or output, leads should be twisted pair, where possible.

## QUICK START PROCEDURE




System Setup Requirements:
LFP or Li-Ion Battery ≥ 10AHr
Internal Resistance < 30mΩ

Recommended Battery Simulator:
Power Supply 2V to 5.0 V ±10A
Interconnect Resistance < 25mΩ

**Figure 28. Proper Equipment Setup for Cell Balancer Efficiency Measurements**

## QUICK START PROCEDURE

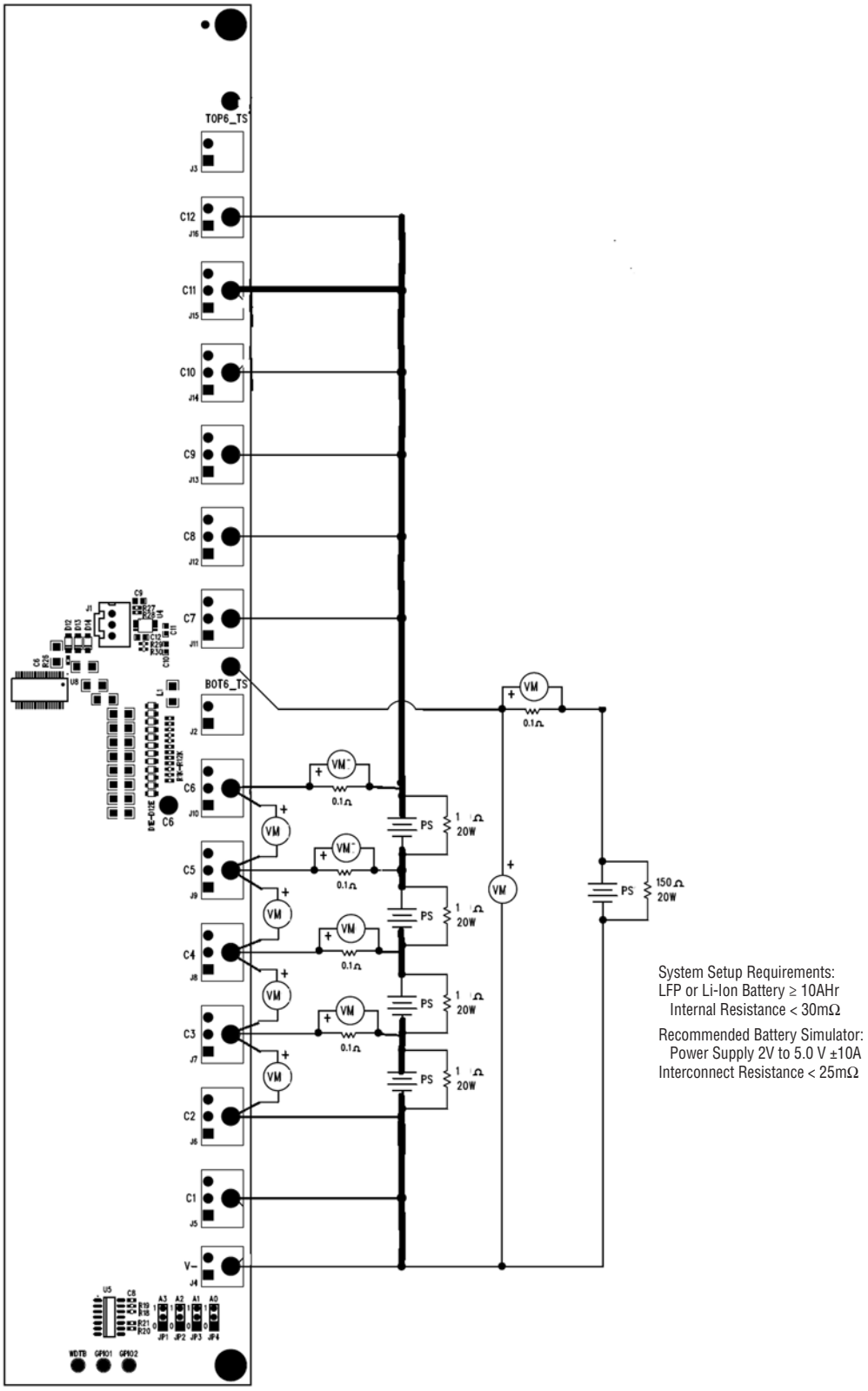



**Figure 29. Proper Equipment Setup for Minimum Number of Cell Efficiency Measurements**

## QUICK START PROCEDURE

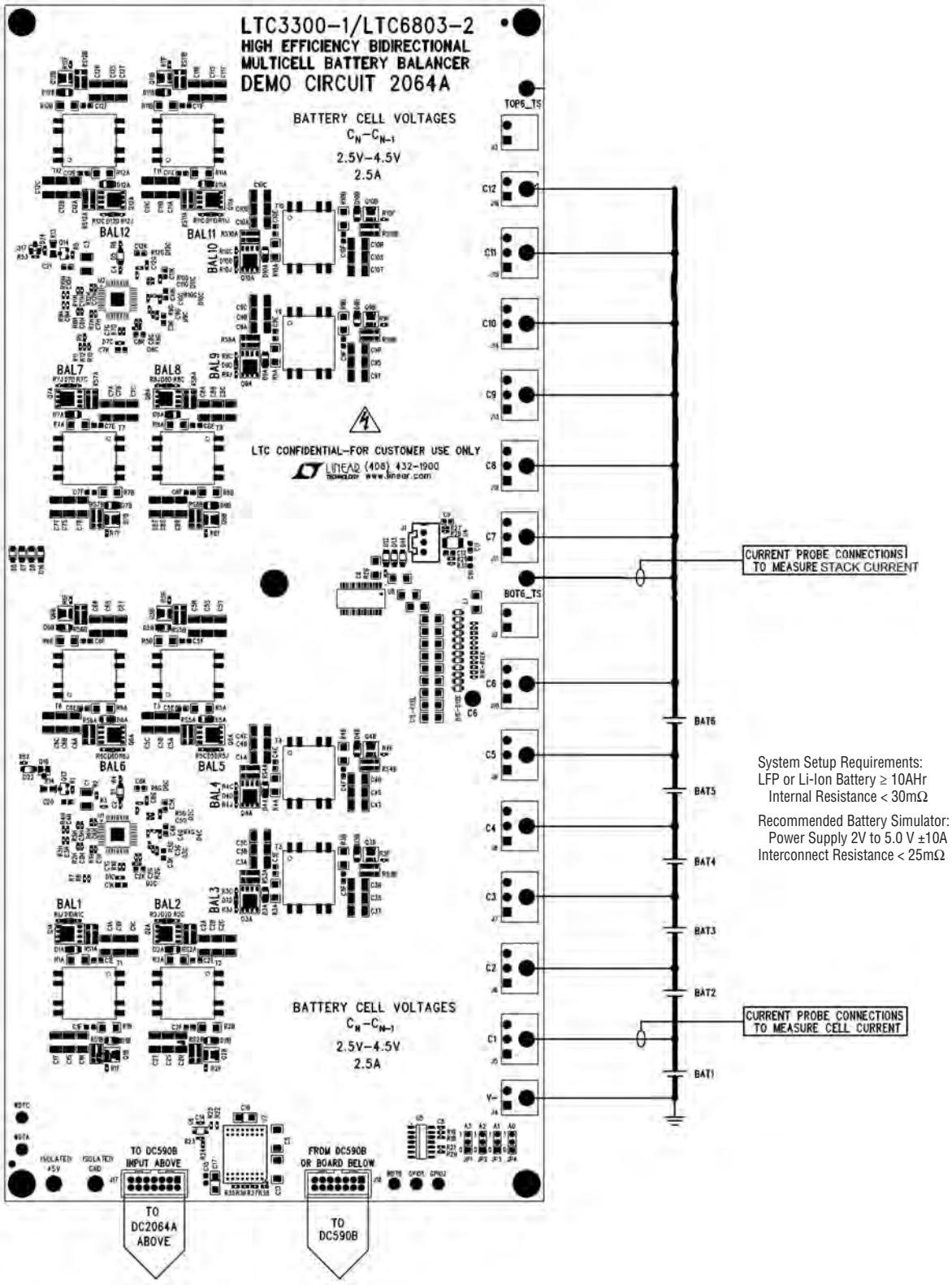



**Figure 30. Configuring the Board for Six Batteries**

## QUICK START PROCEDURE

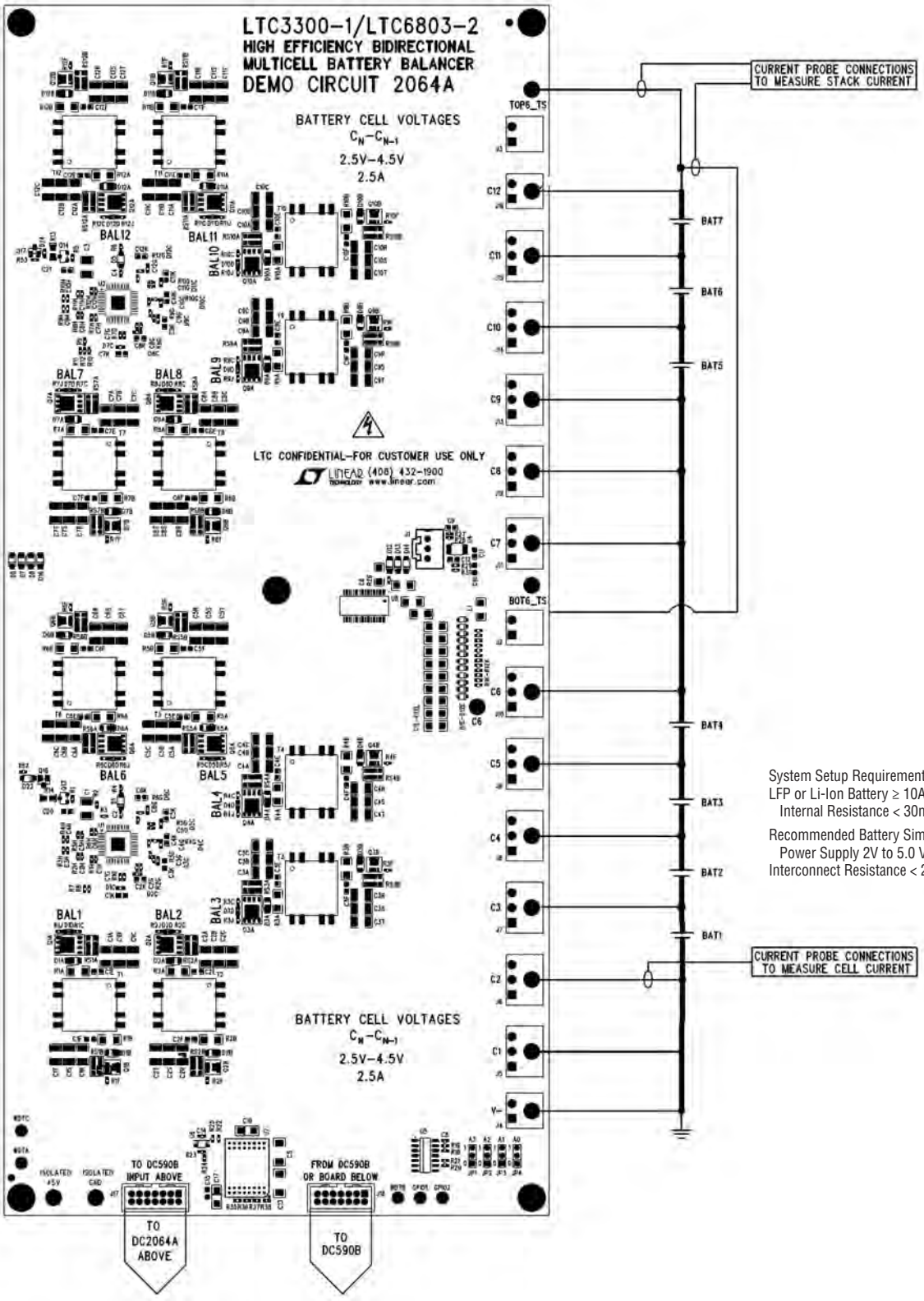



**Figure 31. Configuring the Board for Seven Batteries**

## QUICK START PROCEDURE

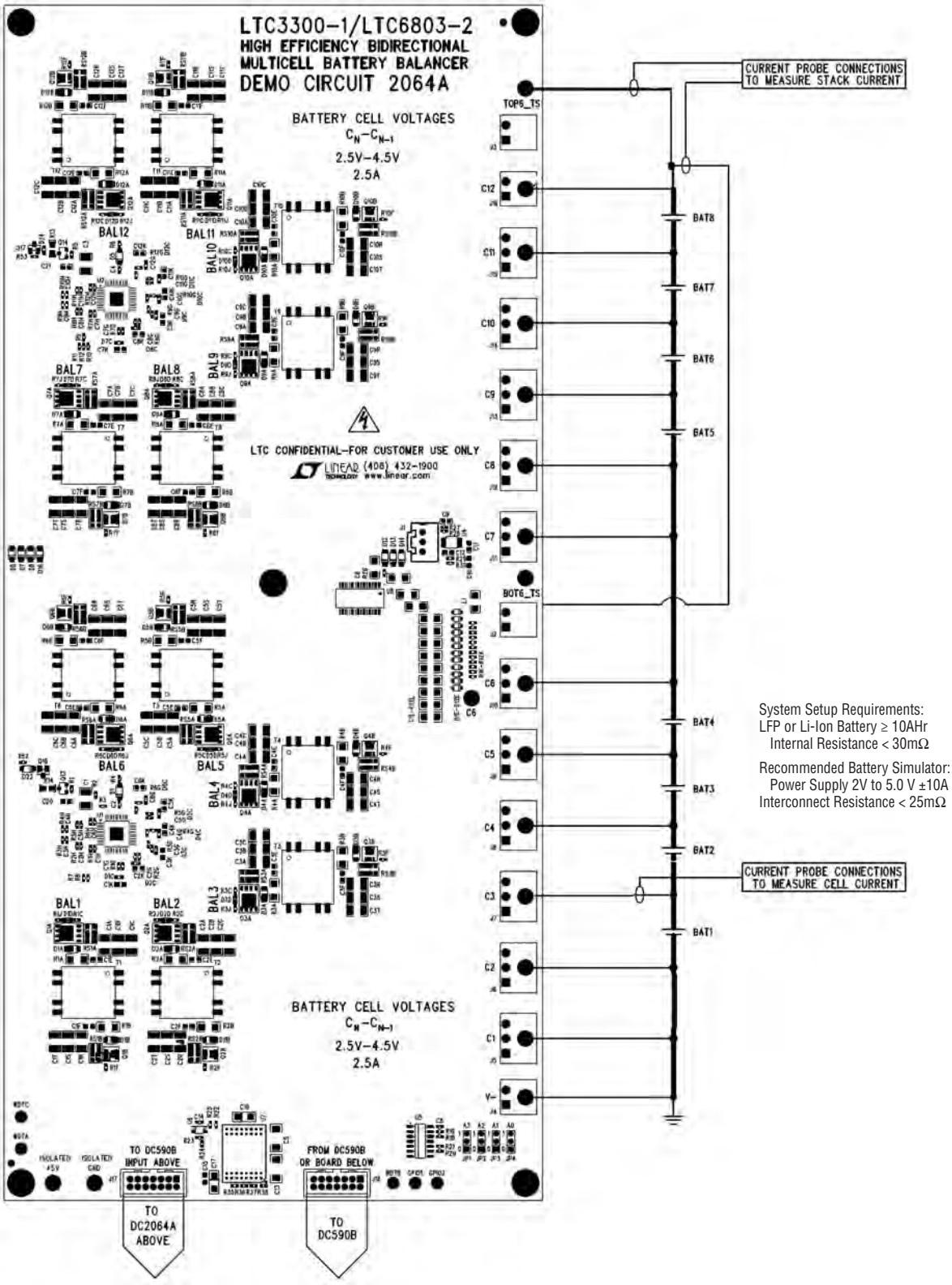



**Figure 32. Configuring the Board for Eight Batteries**

## QUICK START PROCEDURE

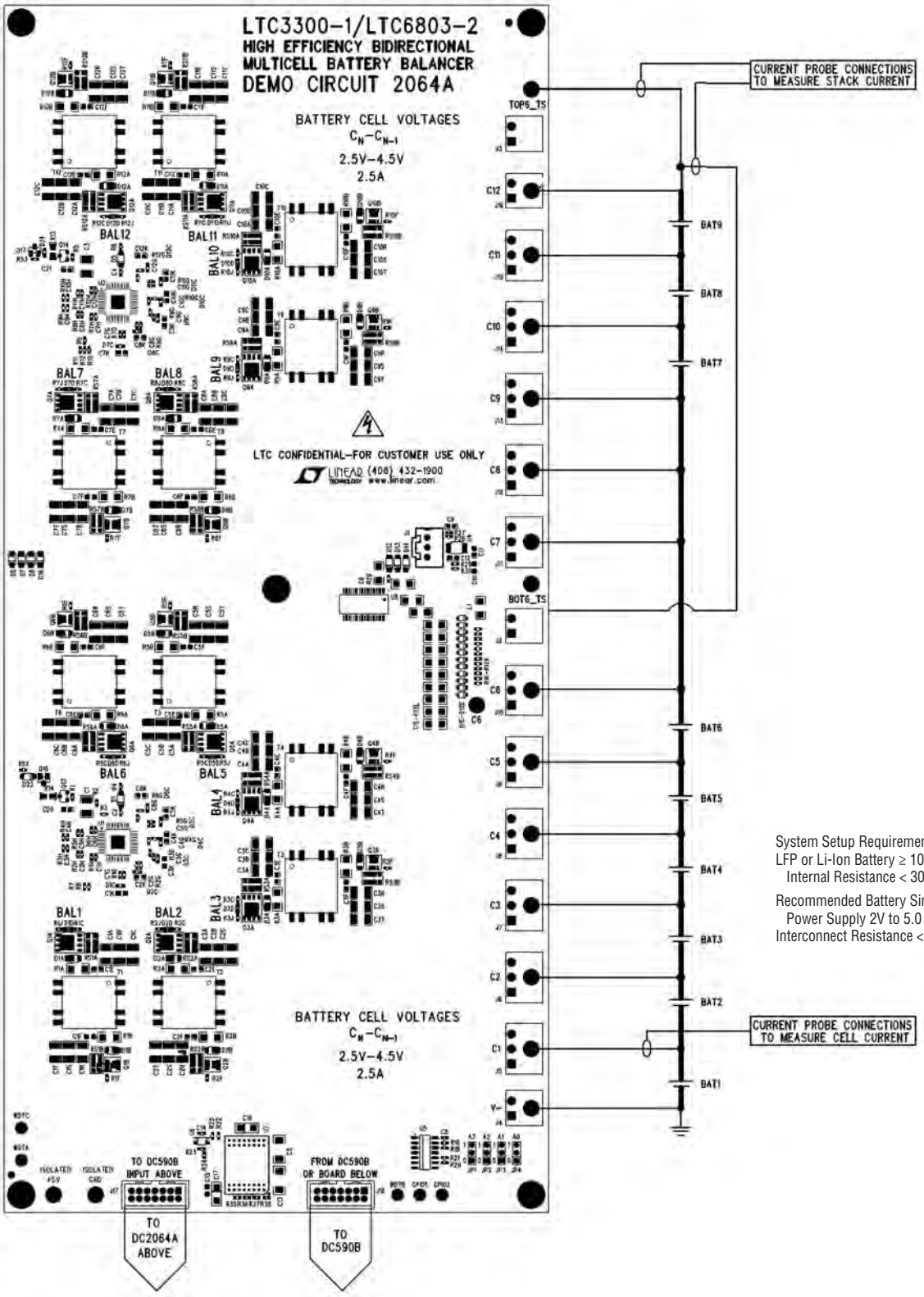



**Figure 33. Configuring the Board for Nine Batteries**

## QUICK START PROCEDURE

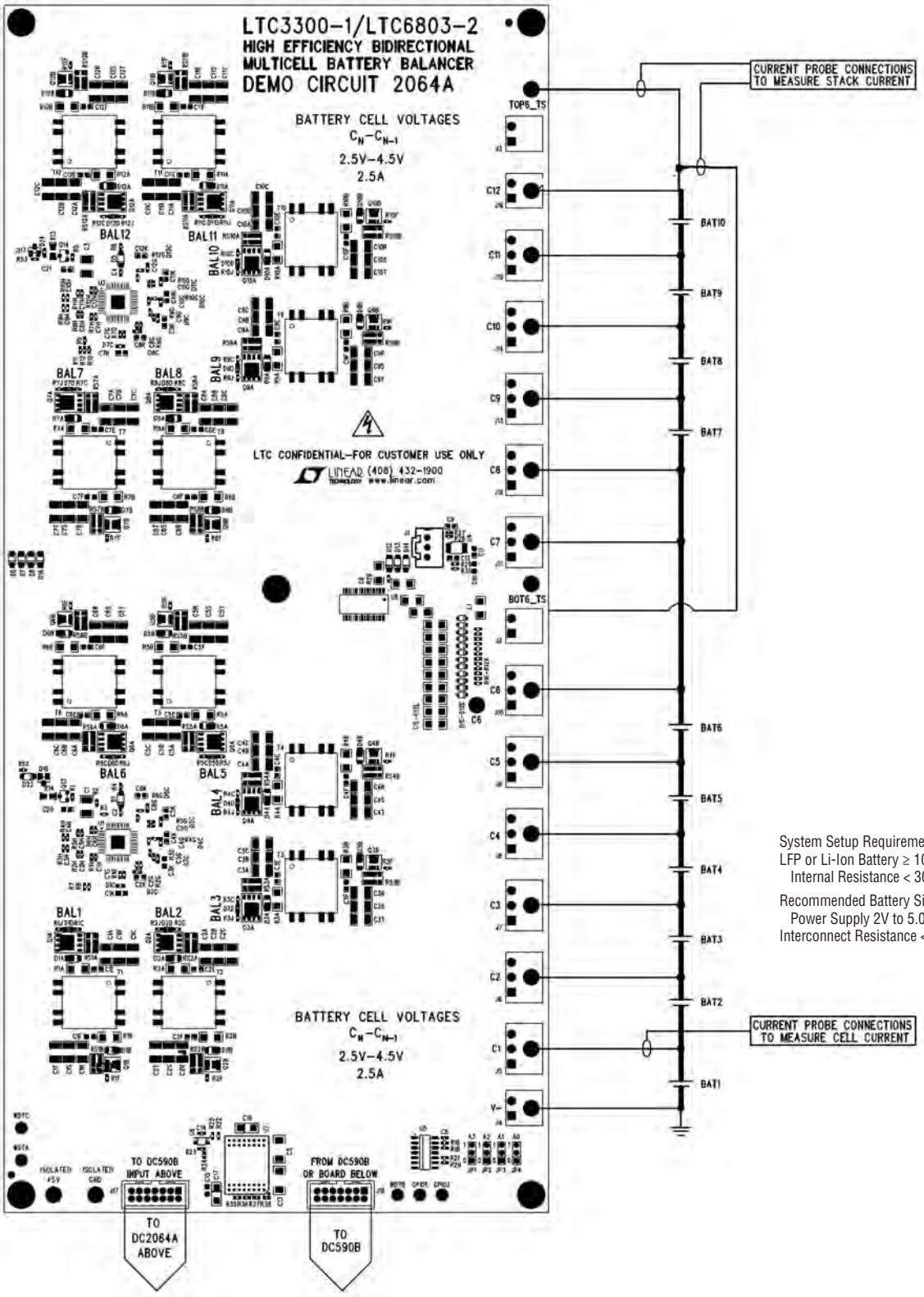



**Figure 34. Configuring the Board for Ten Batteries**

## QUICK START PROCEDURE

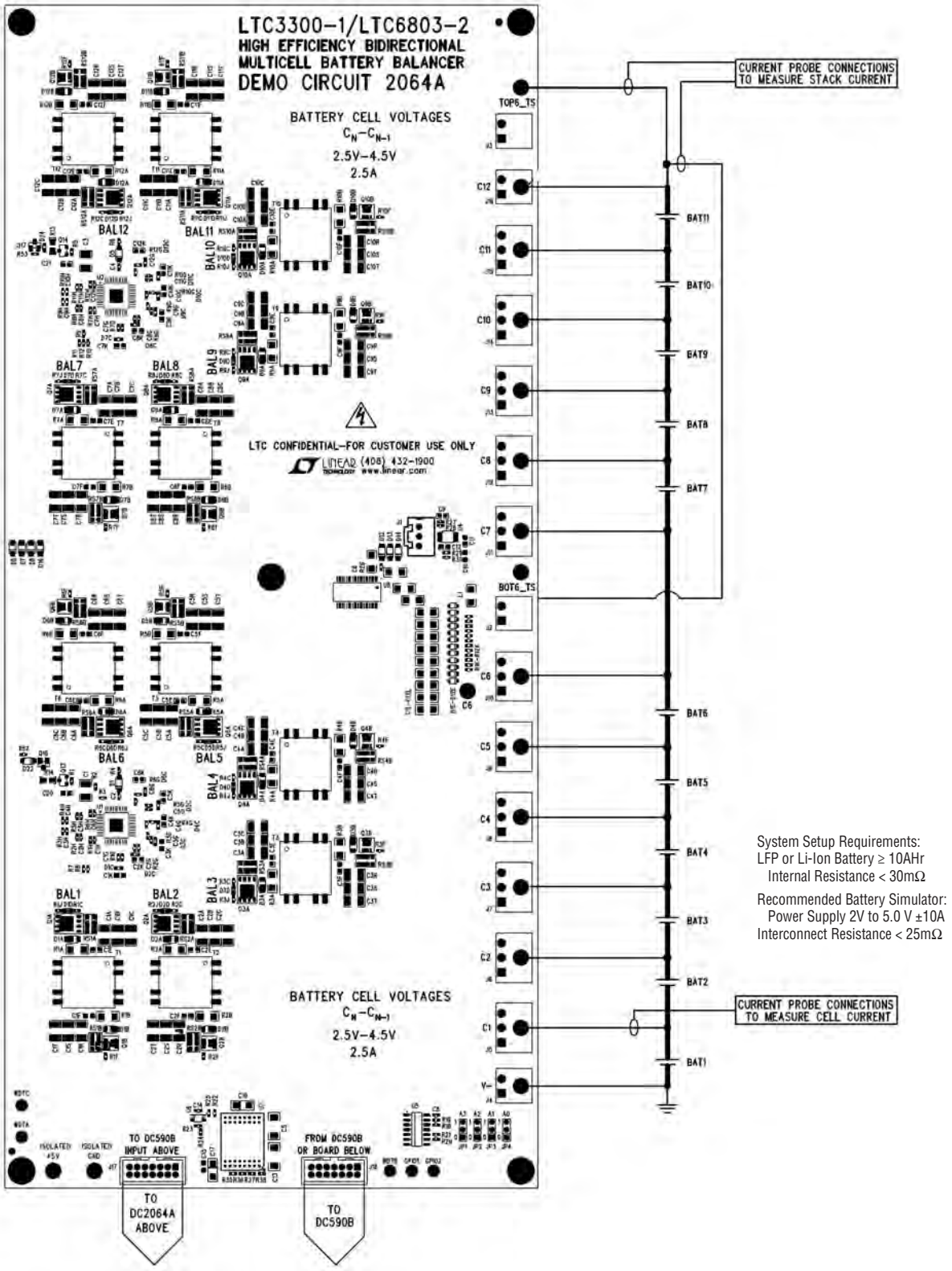



**Figure 35. Configuring the Board for Eleven Batteries**

# SCHEMATIC DIAGRAMS

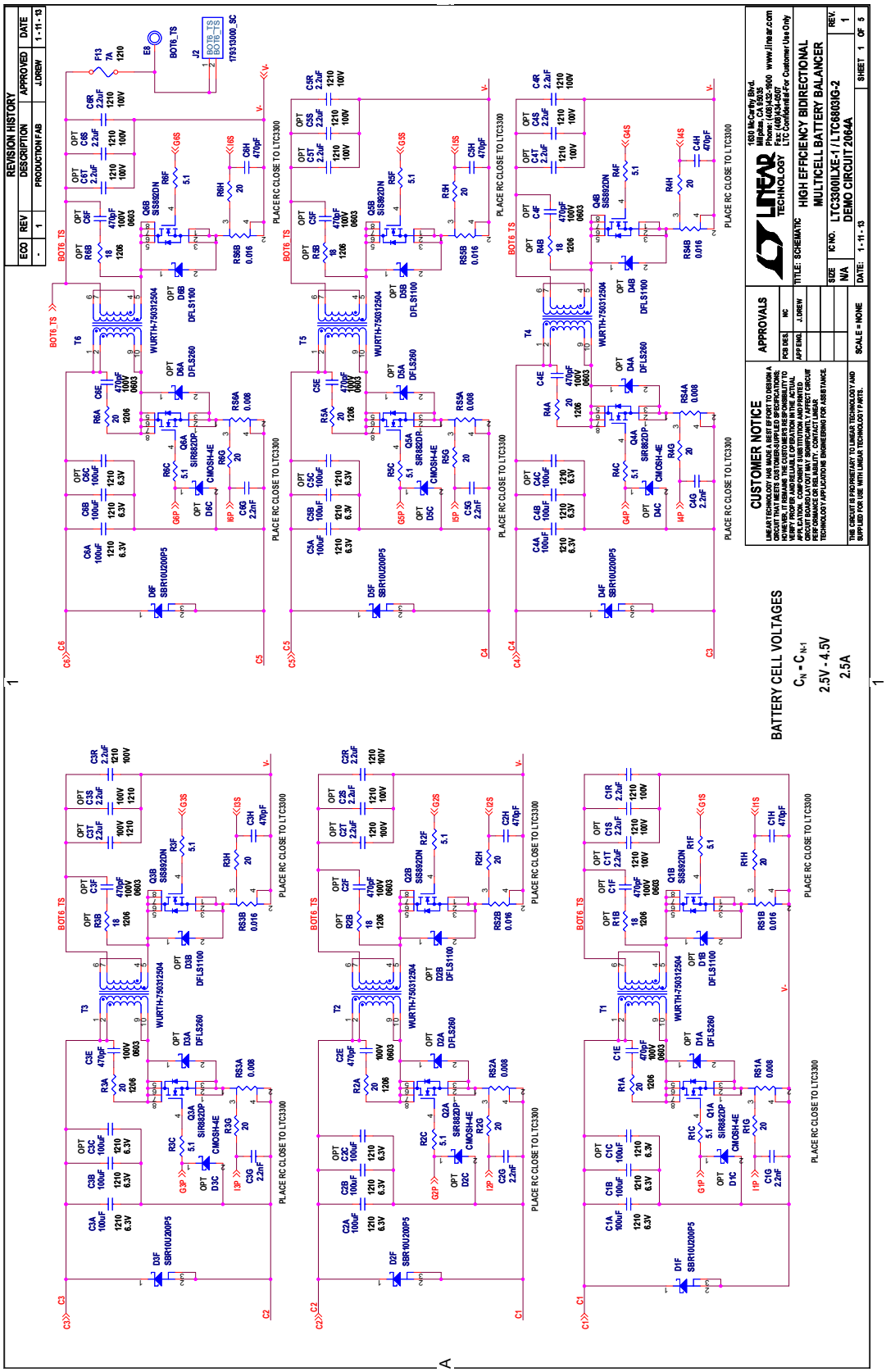



Figure 36. Schematic Diagram Page 1

## SCHEMATIC DIAGRAMS

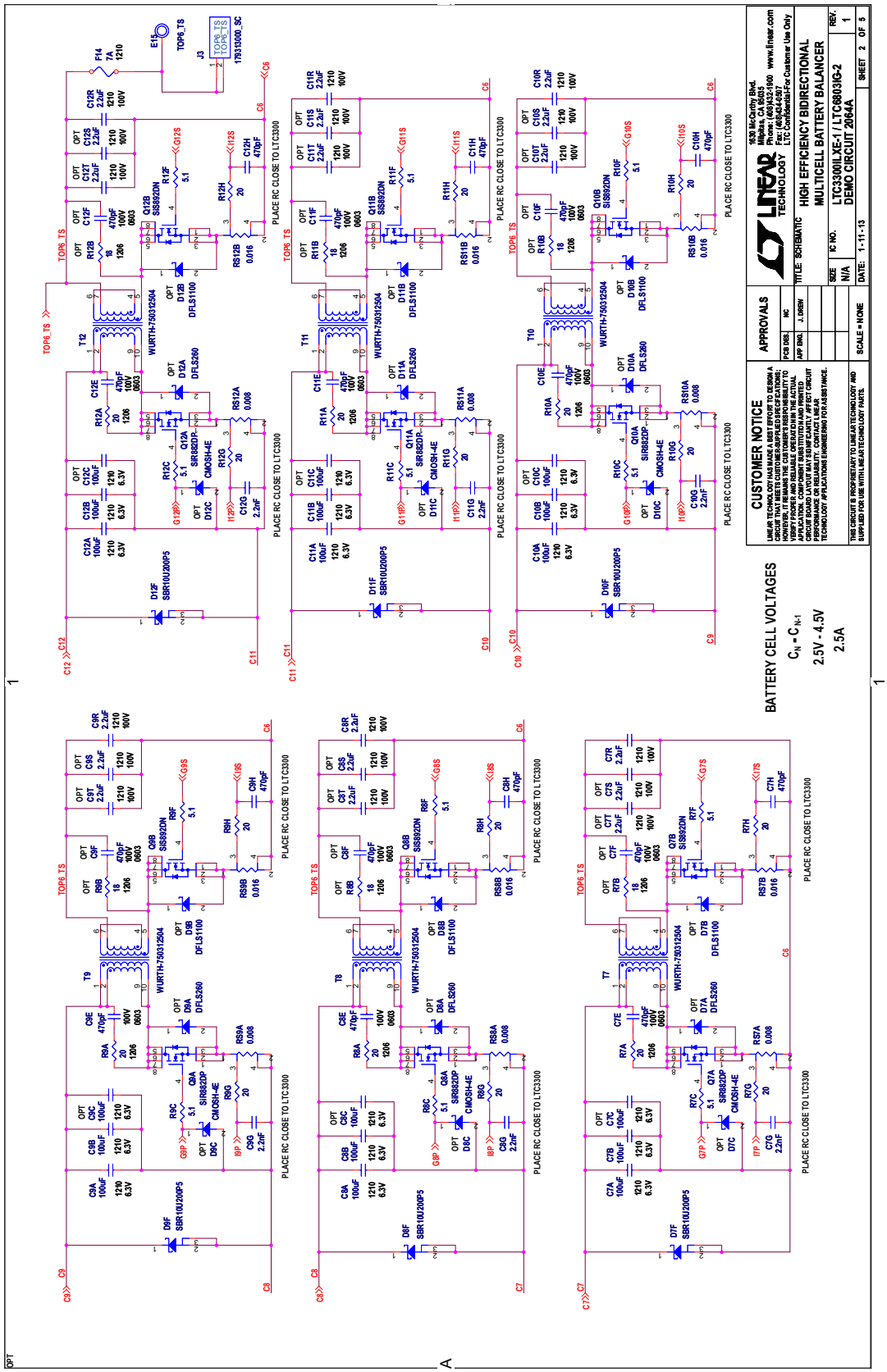



Figure 37. Schematic Diagram Page 2

## SCHEMATIC DIAGRAMS

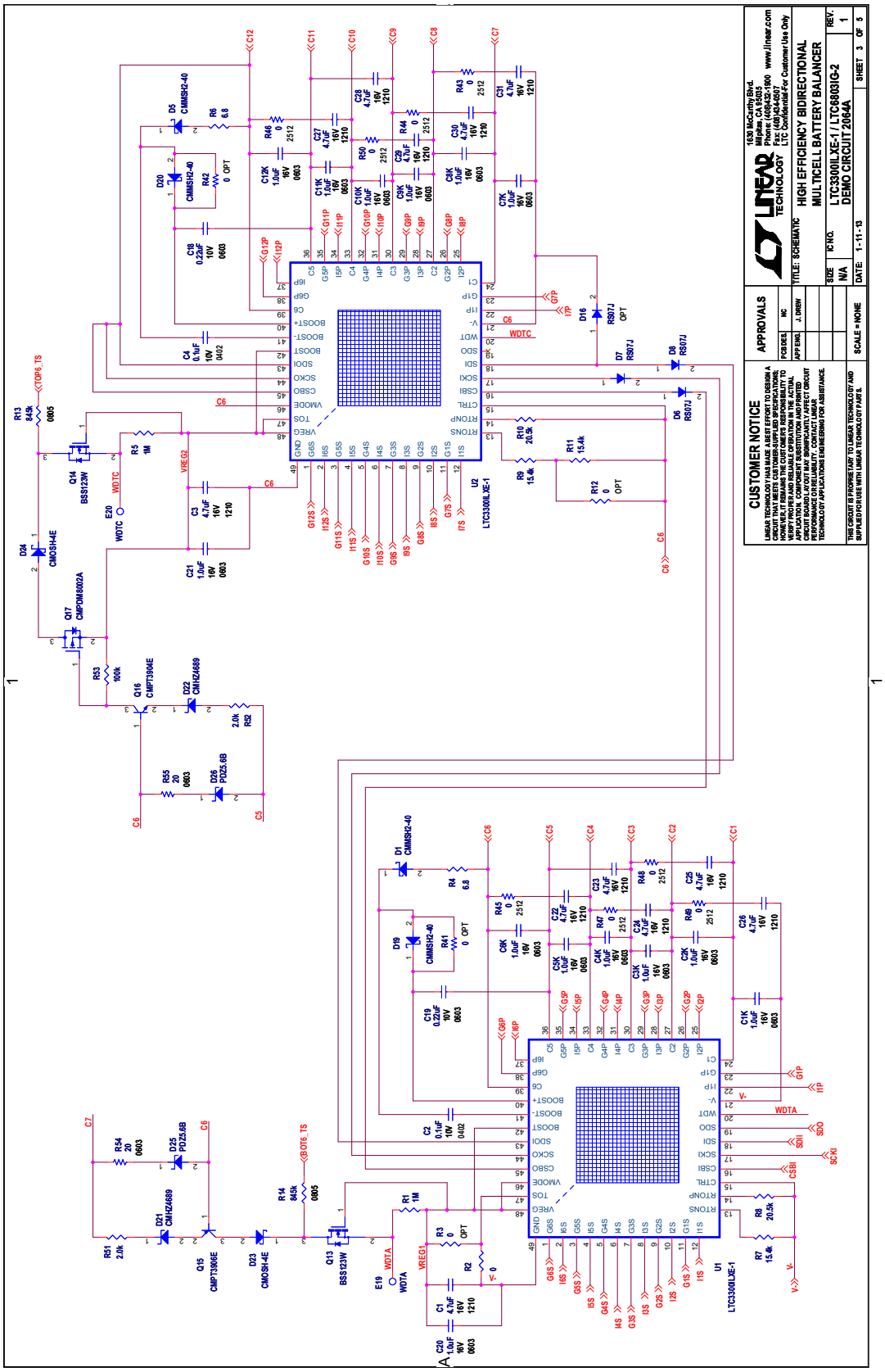



Figure 38. Schematic Diagram Page 3

## SCHEMATIC DIAGRAMS

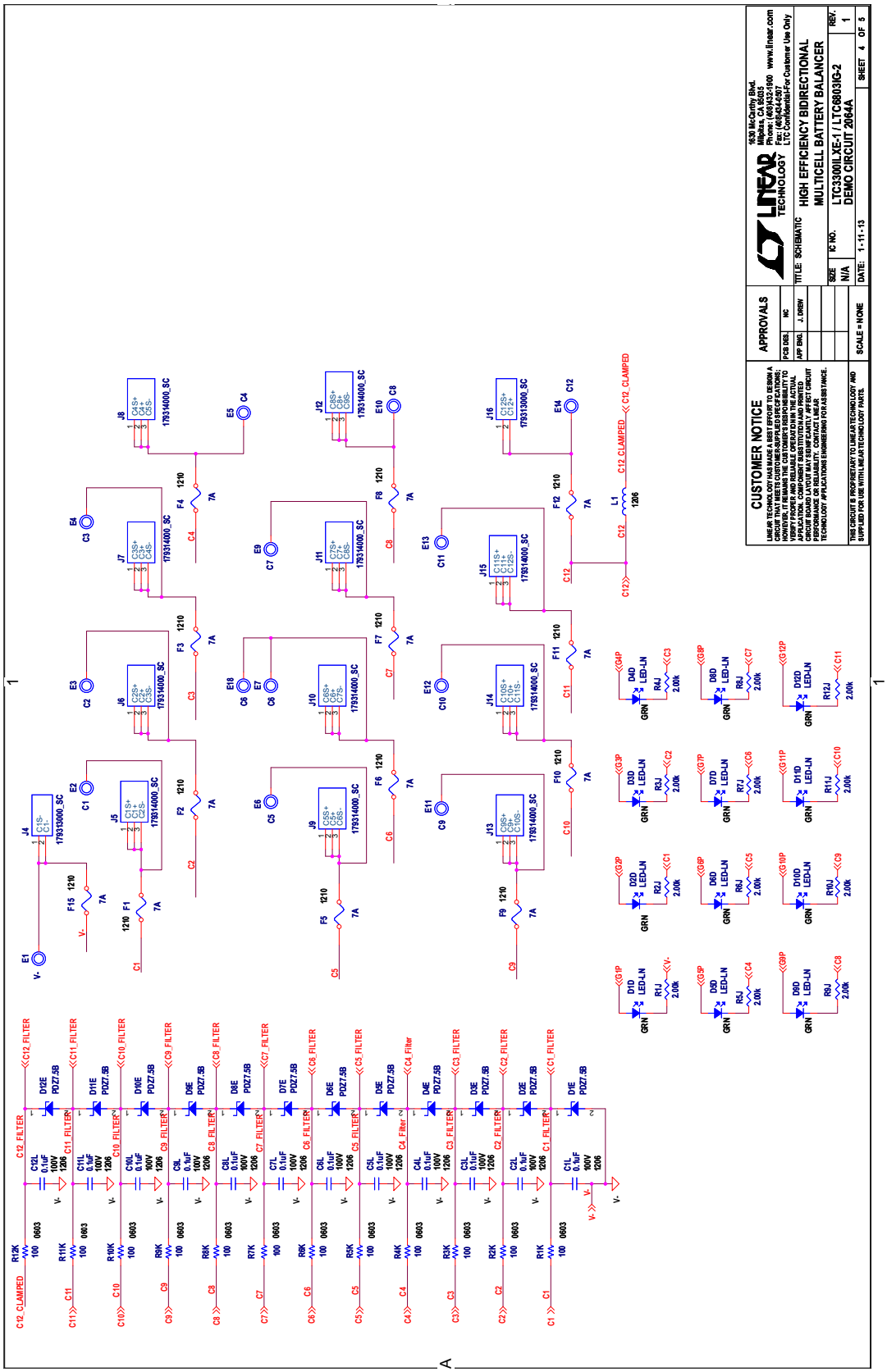



Figure 39. Schematic Diagram Page 4

## SCHEMATIC DIAGRAMS

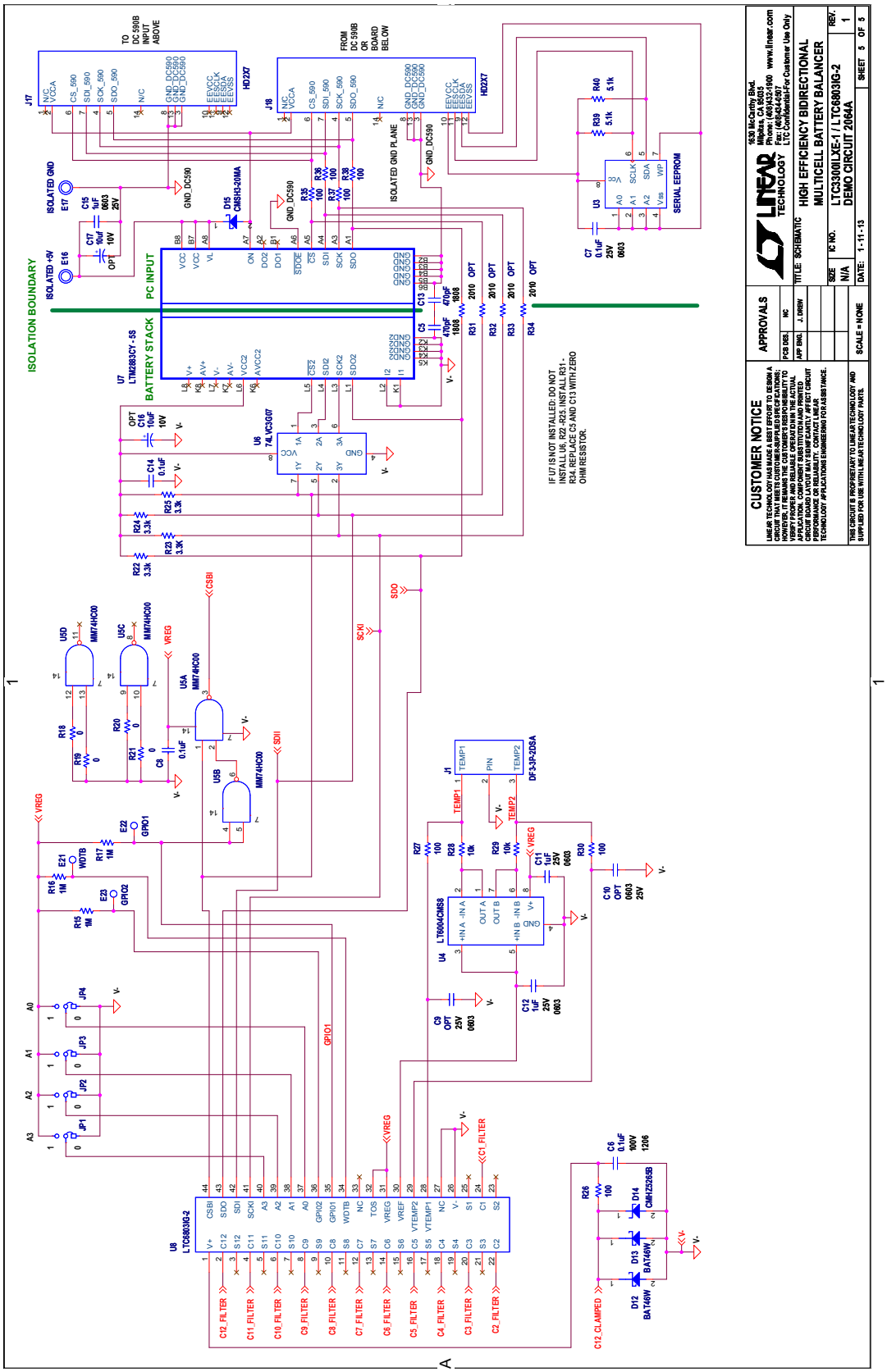



**Figure 40. Schematic Diagram Page 5**

## PCB LAYOUT

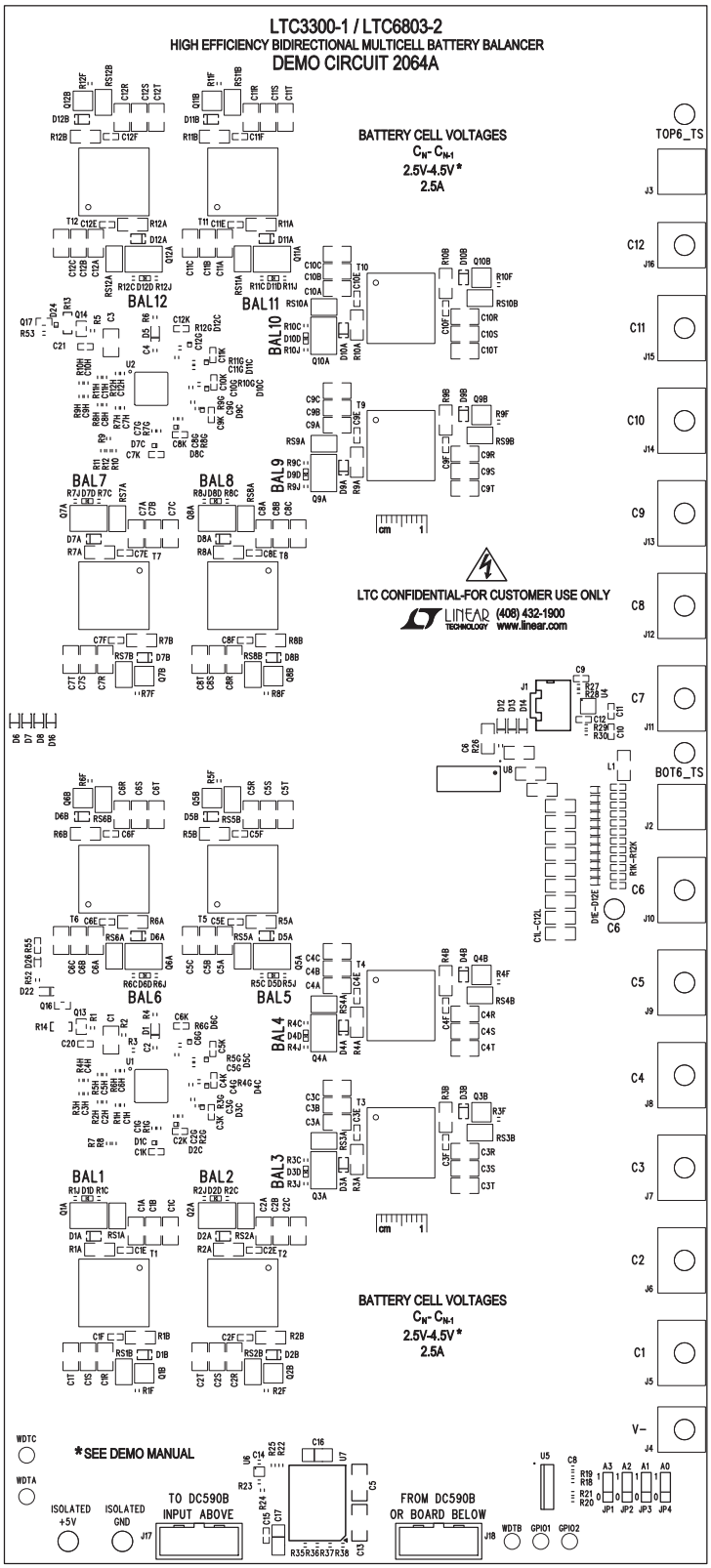



**Figure 41. Top Silk Screen**

## PCB LAYOUT

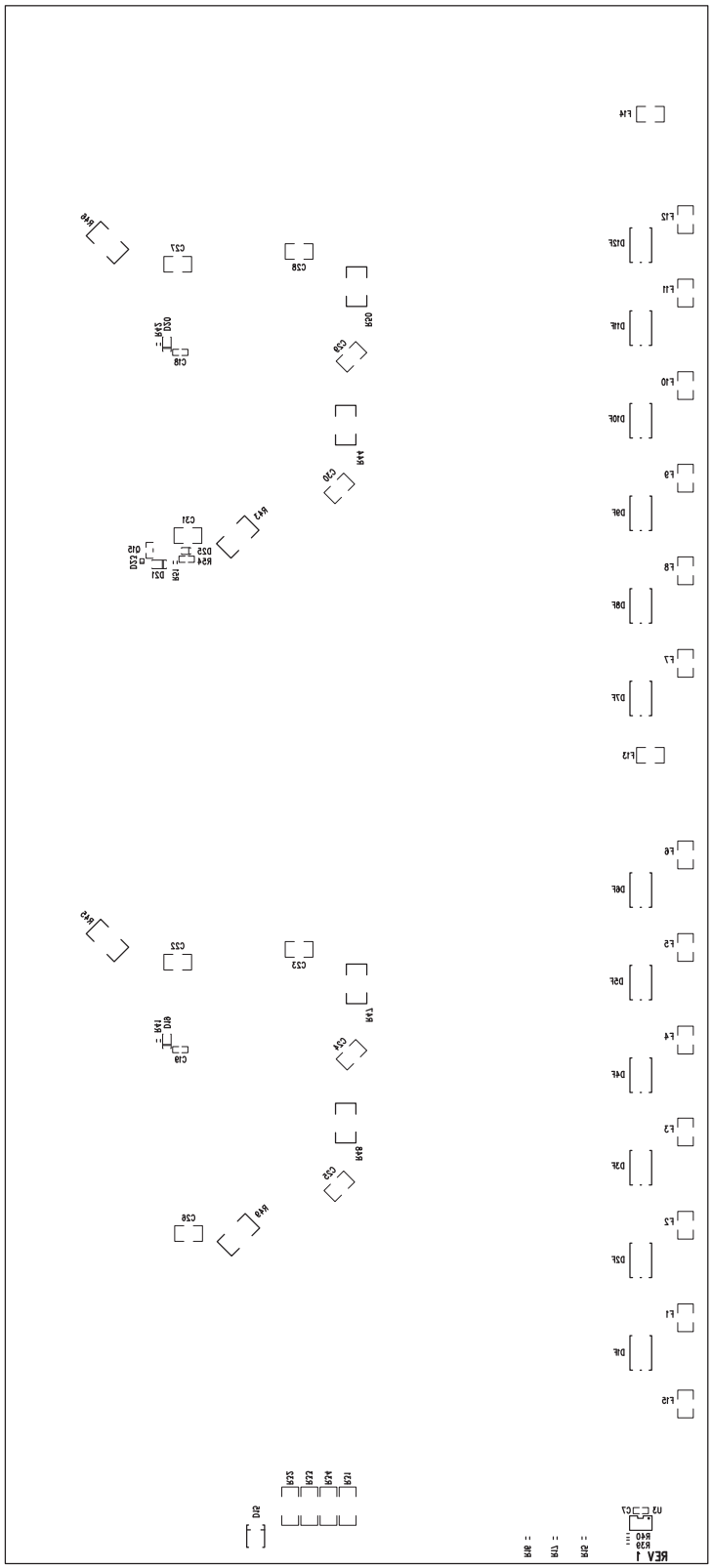


**Figure 42. Bottom Silk Screen**

## PCB LAYOUT

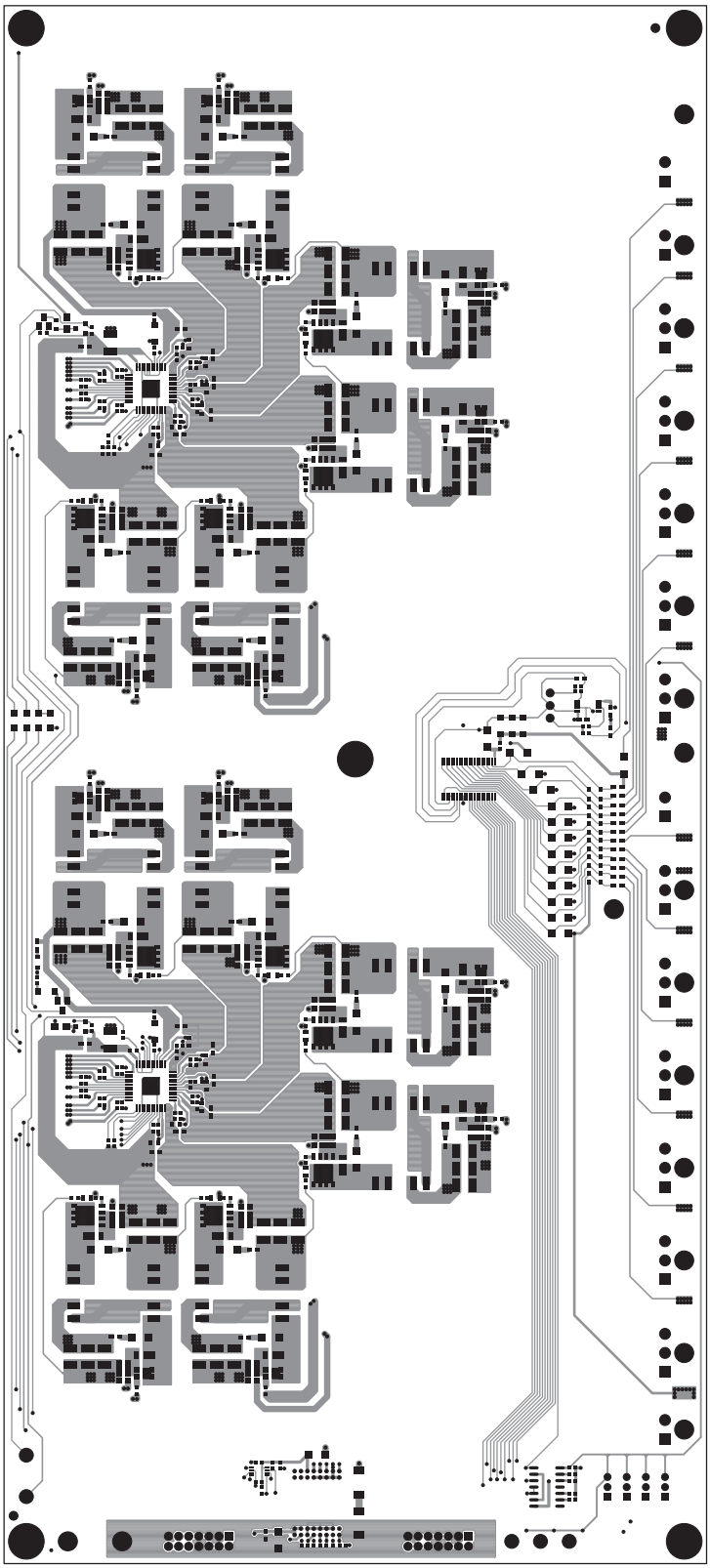


Figure 43. Layer 1

## PCB LAYOUT

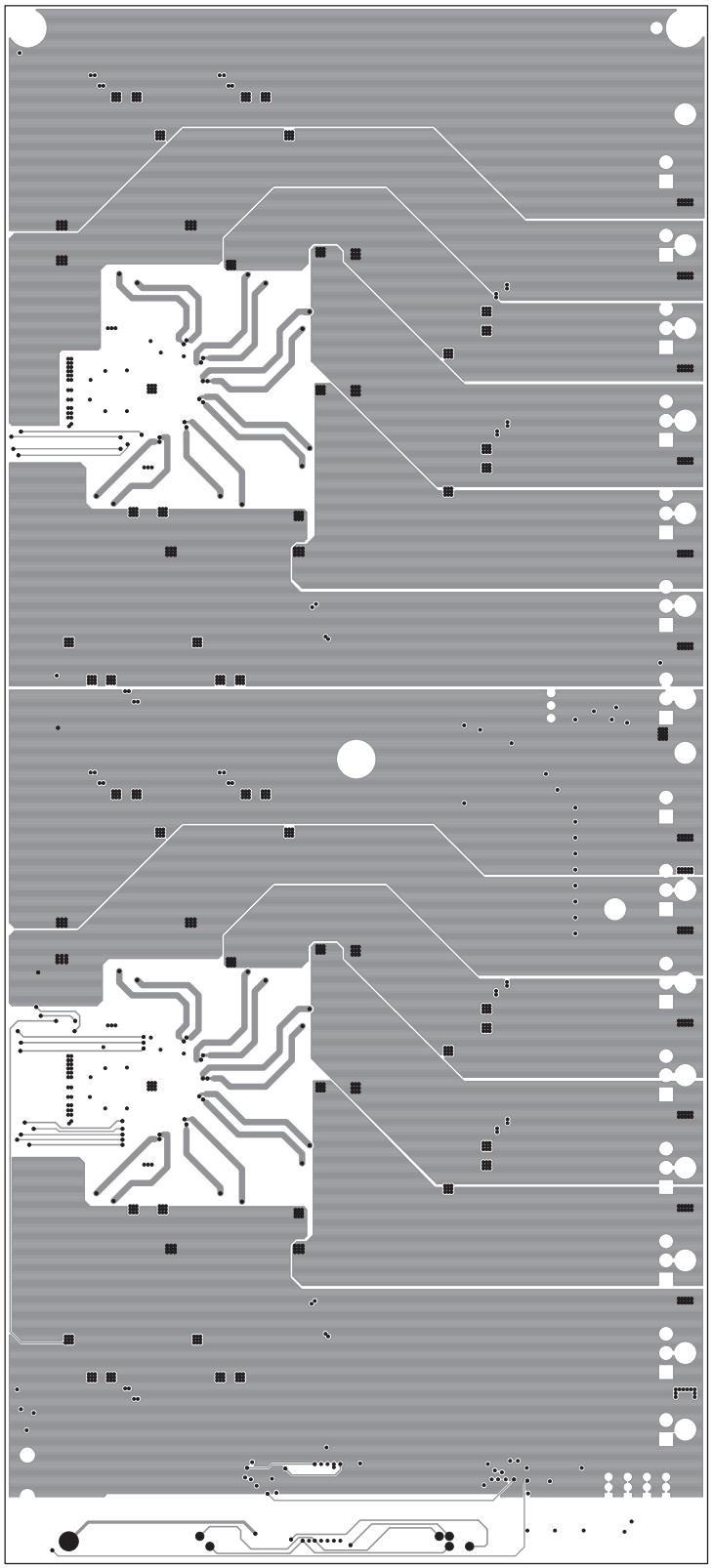


**Figure 44. Layer 2**

## PCB LAYOUT

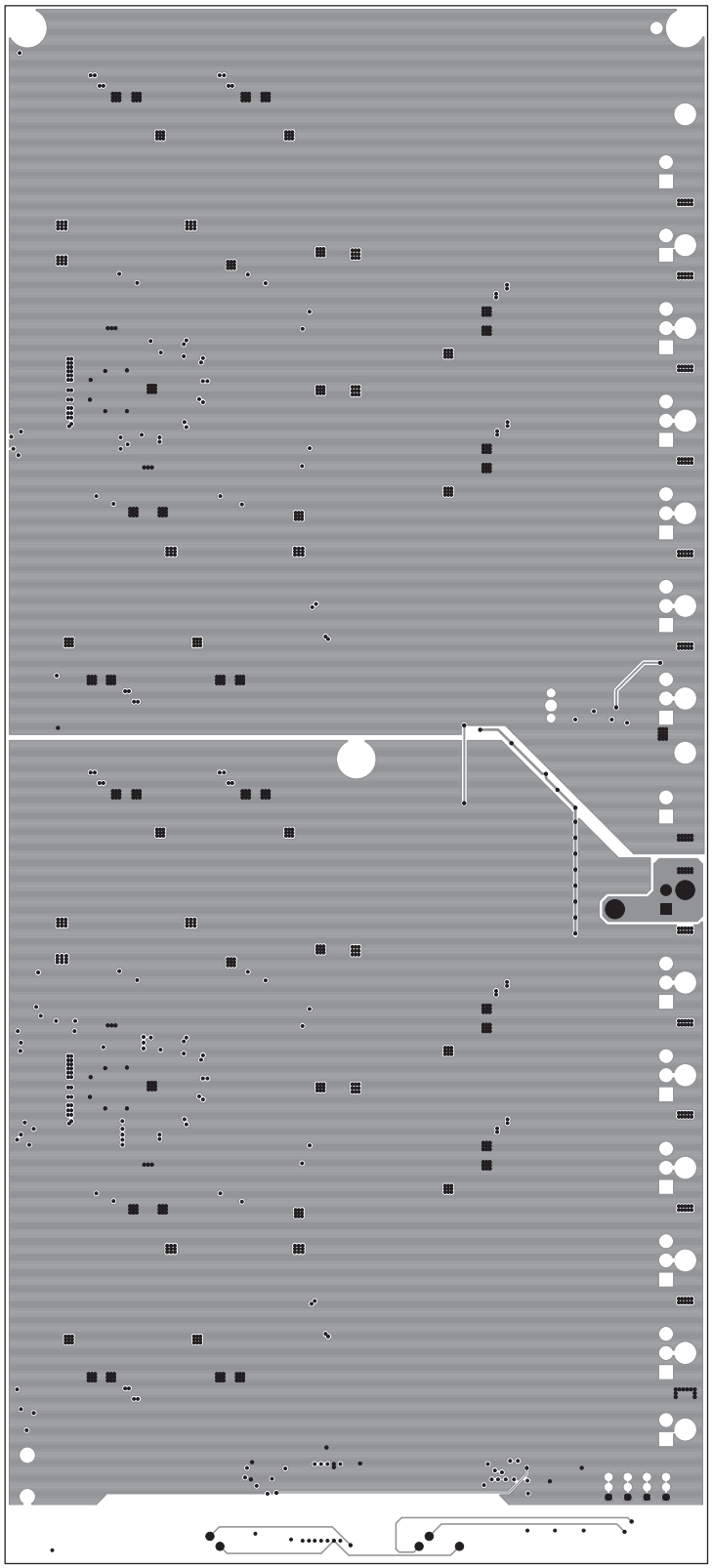


**Figure 45. Layer 3**

## PCB LAYOUT

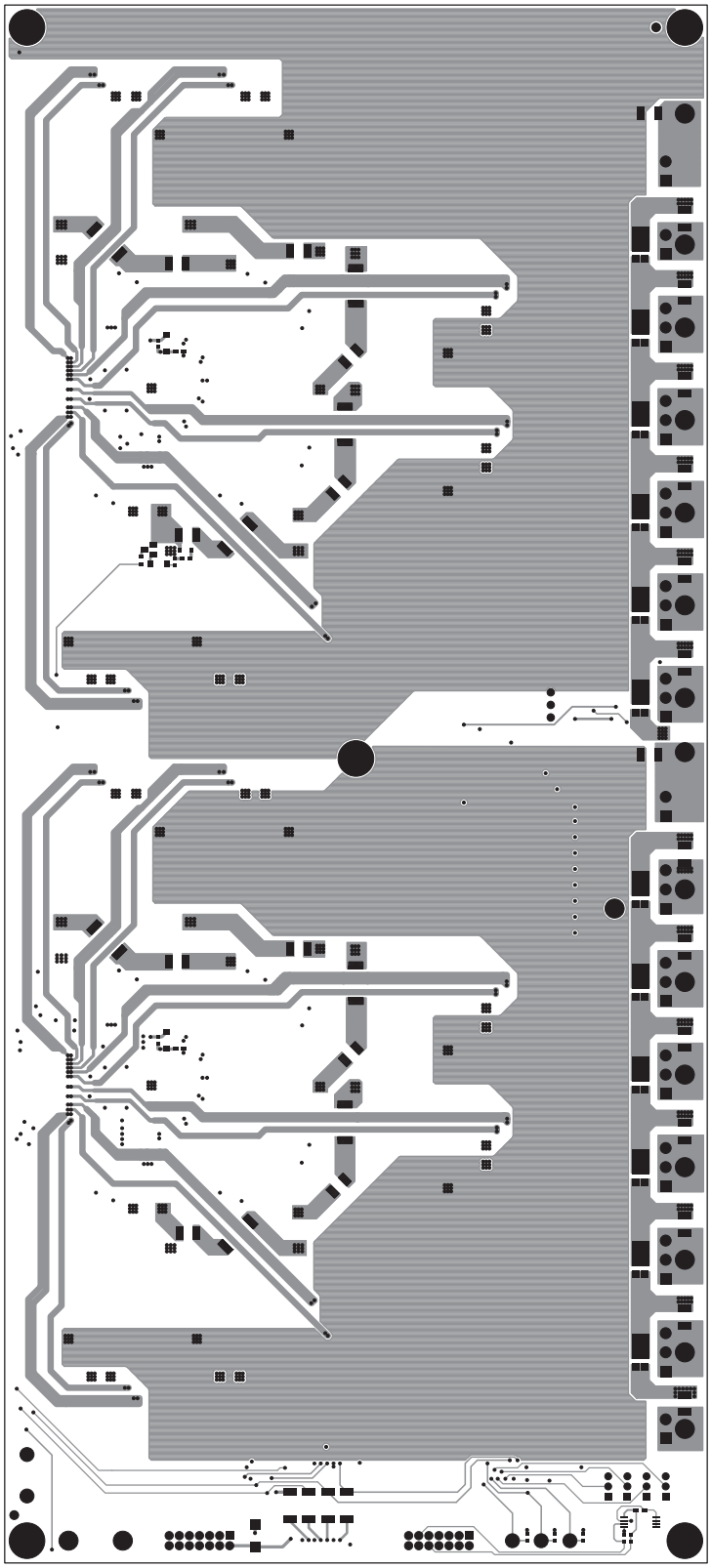


Figure 46. Layer 4

## PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|---|---|---|---|
| **Required Circuit Components** | | | | |
| 1 | 24 | C1A-C12A, C1B-C12B | CAP.,X5R, 100µF, 6.3V,10%, 1210 | MURATA, GRM32ER60J107ME20L |
| 2 | 12 | C1G-C12G | CAP.,X7R, 2200pF, 50V, 10% 0402 | MURATA, GRM155R71H222KA01D |
| 3 | 12 | C1H-C12H | CAP.,X7R, 470pF, 50V, 10% 0402 | MURATA, GRM155R71H471KA01D |
| 4 | 12 | C1R-C12R | CAP.,X7R, 2.2µF, 100V,10%, 1210 | TDK, C3225X7R2A225K |
| 5 | 14 | C1K-C12K, C20,C21 | CAP.,X7R, 1.0µF, 16V,10%, 0603 | MURATA, GRM188R71C105KA12D |
| 6 | 4 | C2, C4, C8, C14 | CAP, X7R, 0.1µF, 16V, 10% 0402 | MURATA, GRM155R71C104KA88D |
| 7 | 1 | C7 | CAP.,X7R, 0.1µF, 25V,10%, 0603 | AVX, 06033C104KAT2A |
| 8 | 3 | C11, C12, C15 | CAP.,X5R, 1µF, 25V,10%, 0603 | TDK, C1608X5R1E105K |
| 9 | 2 | C18, C19 | CAP.,X7R, 0.22µF, 10V,10%, 0603 | MURATA, GRM188R71A224KA01 |
| 10 | 2 | D23, D24 | SMD, SCHOTTKY, SOD523 | CENTRAL SEMI, CMOSH-4E |
| 11 | 4 | D1, D5, D19.D20 | SMD, SCHOTTKY, SOD-123F | CENTRAL SEMI, CMMSH2-40 |
| 12 | 3 | D6, D7, D8 | SMD, SILICON SWITCHING DIODE | VISHAY, RS07J |
| 13 | 12 | D1E-D12E | DIODE, ZENER, 7.5V, 400MW, SOD323 | NXP, PDZ7.5B.115 |
| 14 | 2 | D12, D13 | SMD, SCHOTTKY, 200MW, 100V, SOD-12 | DIODES INC, BAT46W |
| 15 | 1 | D14 | SMD, SILICON ZENER, 62V | CENTRAL SEMI, CMHZ5265B |
| 16 | 1 | D15 | SMD, SCHOTTKY | CENTRAL SEMI, CMSH3-20MA |
| 17 | 2 | D21, D22 | DIODE, ZENER, 5.1V,SOD-123 | CENTRAL SEMI, CMHZ4689 |
| 18 | 2 | D25, D26 | DIODE, ZENER, 5.6V, 400MW, SOD323 | NXP, PDZ5.6B.115 |
| 19 | 12 | D1F-D12F | DIODE, SUPER BARRIER RECTIFIER, 10A, POWERDI5 | DIODES INC, SBR10U200P5 |
| 20 | 24 | R1C-R12C, R1F-R12F | RES,CHIP, 5.1Ω, 1/16W, 5%, 0402 | VISHAY, CRCW04025R10JNED |
| 21 | 2 | R4, R6 | RES,CHIP, 6.8Ω, 1/16W, 5%, 0402 | VISHAY, CRCW04026R80JNED |
| 22 | 24 | R1G-R12G, R1H-R12H | RES,CHIP,20Ω,1/16W,5%,0402 | VISHAY, CRCW040220R0JNED |
| 23 | 7 | R26, R27, R30, R35-R38 | RES,CHIP,100Ω,1/16W,5%,0402 | VISHAY, CRCW0402100RJNED |
| 24 | 5 | R1, R5, R15-R17 | RES,CHIP, 1.00M, 1/16W, 5%, 0402 | VISHAY, CRCW04021M00JNED |
| 25 | 2 | R13, R14 | RES, CHIP, 845k, 1/8W, 1%, 0805 | VISHAY, CRCW0805845KFKEA |
| 26 | 3 | R7, R9, R11 | RES, CHIP, 15.4k, 1/16W, 1%, 0402 | VISHAY, CRCW040215K4FKED |
| 27 | 2 | R8, R10 | RES, CHIP, 20.5k, 1/16W, 1%, 0402 | VISHAY, CRCW040220K5FKED |
| 28 | 2 | R51, R52 | RES,CHIP,2.0k,1/16W,5%,0402 | VISHAY, CRCW04022K00JNED |
| 29 | 2 | R39, R40 | RES, CHIP, 5.1k, 1/16W, 5%, 0402 | VISHAY, CRCW04025K10JNED |
| 30 | 2 | R28, R29 | RES, CHIP, 10.0k, 1/16W, 5%, 0402 | VISHAY, CRCW040210K0JNED |
| 31 | 1 | R53 | RES, CHIP, 100k, 1/16W, 5%, 0402 | VISHAY, CRCW0402100KJNED |
| 32 | 2 | R54, R55 | RES, CHIP, 20Ω, 1/16W, 5%, 0603 | VISHAY, CRCW060320R0JNED |
| 33 | 12 | RS1A-RS12A | RES, CHIP, 8mΩ, 1W, 1%, 1206 | SUSUMU, PRL1632-R008-F-T1 |
| 34 | 12 | RS1B-RS12B | RES, CHIP, 16mΩ, 1W, 1%, 1206 | SUSUMU, PRL1632-R016-F-T1 |
| 35 | 12 | Q1A-Q12A | MOSFET, 100V, 0.0087Ω, 60A, POWERPAK-SO8 | VISHAY, SiR882DP-T1-GE3 |
| 36 | 12 | Q1B-Q12B | MOSFET, 100V, 0.058Ω, 25A, POWERPAK-1212-8 | VISHAY, SiS892DN-T1-GE3 |
| 37 | 2 | Q13,Q14 | MOSFET, 100V, 10Ω, SOT-323 | DIODES INC, BSS123W-7-F |
| 38 | 1 | Q15 | TRANSISTOR,PNP, 60V SOT-23 | CENTRAL SEMI, CMPT3906E |
| 39 | 1 | Q16 | TRANSISTOR, NPN, 60V SOT-23 | CENTRAL SEMI, CMPT3904E |
| 40 | 1 | Q17 | MOSFET, P-CHAN, 50V, 4Ω,SOT-23 | CENTRAL SEMI, CMPDM8002A |
| 41 | 12 | T1-T12 | TRANSFORMER, 1:1, 3.0µH, 10.8A | WURTH, 750312504 |
| 42 | 2 | U1,U2 | IC, SMT, BIDIRECTIONAL BATTERY BALANCER | LINEAR, LTC3300ILXE-1#PBF |
| 43 | 1 | U3 | IC, EEPROM 2KBIT, 400KHZ, 8TSSOP | MICROCHIP TECH. 24LC025-I/ST |
| 44 | 1 | U4 | IC, SMT, OP AMP | LINEAR, LT6004IMS8#PBT |
| 45 | 1 | U5 | IC, GATE NAND QUAD 2-PIN 14-SO | FAIRCHILD, MM74HC00M |
| 46 | 1 | U8 | IC, SMT, BATTERY MONITOR | LINEAR, LTC6803IG-2#PBF |

## PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|---|---|---|---|
| **Components and Hardware for Demo Board Only** | | | | |
| 1 | 12 | C1E-C12E | CAP.,X7R, 470pF, 100V,10%, 0603 | AVX, 06031C471KAT2A |
| 2 | 12 | C1, C3, C22-C31 | CAP.,X7R, 4.7µF, 16V,20%, 1210 | TDK, C3225X7R1C475M |
| 3 | 13 | C1L-C12L, C6 | CAP., X7R, 0.1µF, 100V, 10%, 1206 | AVX, 12061C104KAT2A |
| 4 | 2 | C5, C13 | CAP., X7R, 470pF, 250VAC, 10%, 1808 | MURATA, GA342QR7GF471KW01L |
| 5 | 12 | D1D-D12D | LED,GREEN CLEAR 0603 SMD | LITE-ON, LTST-C190KGKT |
| 6 | 15 | F1-F15 | FUSE, 7A, FAST, SMD, 1206 | COOPER BUSSMANN, 3216FF7-R |
| 7 | 1 | L1 | IND, FERRITE CHIP 33Ω, 6A, 1206 | MURATA, BLM31PG330SN1L |
| 8 | 12 | R1A-R12A | RES, CHIP, 20Ω, 1/4W, 5%, 1206 | VISHAY, CRCW120620R0JNEA |
| 9 | 12 | R1K-R12K | RES, CHIP, 100Ω, 1/16W, 5%, 0603 | VISHAY, CRCW0603100RJNED |
| 10 | 4 | R22-R25 | RES, CHIP, 3.3k, 1/16W, 5%, 0402 | VISHAY, CRCW04023K30JNED |
| 11 | 8 | R43-R50 | RES, CHIP, 0Ω, 2512 | VISHAY, CRCW25120000Z0EG |
| 12 | 12 | R1J-R12J | RES, CHIP, 2.0k, 1/16W, 5%, 0402 | VISHAY, CRCW04022K00JNED |
| 13 | 18 | E1-E18 | TP, TURRET, 0.094", PBF | MILL-MAX, 2501-2-00-80-00-00-07-0 |
| 14 | 5 | E19-E23 | TURRET, 0.061 DIA | MILL-MAX, 2308-2-00-80-00-00-07-0 |
| 15 | 2 | J17,J18 | CONN, HEADER, 14POS 2mm VERT GOLD | MOLEX 87831-1420 |
| 16 | 1 | J1 | CONN, HEADER, 3POS, 2.5mm STR TIN | HIROSE, DF1EC-3P-2.5DSA(05) |
| 17 | 1 | J1 (MATE) | CONN, RECEPT HOUSING, 3POS 2.5mm | HIROSE, DF1E-3S-2.5C |
| 18 | 3 | J1 (MATE CONTACT) | CONTACT, SOCKET, CRIMP 20-22AWG, TIN | HIROSE, DF1E-2022SCF |
| 19 | 4 | JP1-JP4 | HEADER, 3PINS, 2mm | SAMTEC, TMM-103-02-L-S |
| 20 | 4 | JP1-JP4 | SHUNT 2mm | SAMTEC, 2SN-BK-G |
| 21 | 1 | U6 | IC,SMT, TRIPLE BUFFER | TI, SN74LVC3G07DCTR |
| 22 | 1 | U7 | IC,SMT,5V, SPI ISOLATER _ODULE | LINEAR, LTM2883CY-5S#PBF |
| 23 | 5 | MH1-MH5 | STAND-OFF, NYLON, 0.500" TALL (SNAP ON) | KEYSTONE, 8833 (SNAP ON) |
| **Optional Components** | | | | |
| 1 | 0 | C1C-C12C | CAP., X5R, 100µF, 6.3V,10%, 1210 | MURATA, GRM32ER60J107ME20 |
| 2 | 0 | C1F(OPT)-C12F(OPT) | CAP., X7R, 470pF, 100V,10%, 0603 | AVX, 06031C471KAT2A |
| 3 | 0 | C1S-C12S, C1T-C12T | CAP., X7R, 2.2µF, 100V,10%, 1210 | TDK, C3225X7R2A225K |
| 4 | 0 | C5, C13 | RES, CHIP, 0Ω, 2010 | VISHAY, CRCW20100000Z0EF |
| 5 | 0 | C9(OPT), C10(OPT) | CAP, OPT, 25V, 0603 | |
| 6 | 0 | C16, C17 | CAP., TANT, 10µF, 10V, 20%. 1206 | AVX, TAJA106M010RNJ |
| 7 | 0 | D1A-D12A | SMD, SCHOTTKY BARRIER RECTIFIER 2A, 60V, PWRD123 | DIODES INC, DFLS260 |
| 8 | 0 | D1B-D12B (OPT) | SMD, SCHOTTKY BARRIER RECTIFIER, 1A, 100V, PWRD123 | DIODES INC, DFLS1100-7 |
| 9 | 0 | D1C-D12C (OPT) | SMD, SCHOTTKY, SOD-523 | CENTRAL SEMI, CMOSH-4E |
| 10 | 0 | D16(OPT) | SMD, SILICON SWITCHING DIODE | VISHAY, RS07J |
| 11 | 0 | R1B-R12B (OPT) | RES, CHIP, 18Ω, 1/4W, 5%, 1206 | VISHAY, CRCW120618R0JNEA |
| 12 | 0 | R3, R12, R41, R42 (OPT) | RES, CHIP, 0Ω, 0402 | VISHAY, CRCW04020000Z0ED |
| 13 | 0 | R31-R34 (OPT) | RES, CHIP, 0Ω, 2010 | VISHAY, CRCW20100000Z0EF |
| 14 | 0 | J2-J4,J16 (OPT) | HEADER, 1x2, 2-PIN, 3.81mm, 90 DEG | WEIDMULLER, 1793130000 |
| 15 | 0 | J2(OPT) (MATE) | SOCKET, 1x2, 2-PIN, 3.81mm, 180 DEG | WEIDMULLER, 1792770000 |
| 16 | 0 | J5-J15 (OPT) | HEADER, 1x3, 3-PIN, 3.81mm, 90 DEG | WEIDMULLER, 1793140000 |
| 17 | 0 | J5-J15 (OPT) | SOCKET, 1x3, 3-PIN, 3.81mm, 180 DEG | WEIDMULLER, 1792780000 |

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Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

This demonstration board (DEMO BOARD) kit being sold or provided by Linear Technology is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not provided by LTC for commercial use. As such, the DEMO BOARD herein may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including but not limited to product safety measures typically found in finished commercial goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may or may not meet the technical requirements of the directive, or other regulations.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

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**Please read the DEMO BOARD manual prior to handling the product**. Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged**.

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

Mailing Address:

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