

# LT3651EUHE-4.2/-4.1 4A High Voltage Li-Ion Battery Charger

## DESCRIPTION

Demonstration circuit 1362A-A/1362A-B is a 4A high voltage Li-Ion battery charger featuring the [LT<sup>®</sup>3651EUHE-4.2/](#)LT3651EUHE-4.1. The LT3651 is a complete, high power Li-Ion battery charger that can operate over a wide input voltage range. The charger is a constant-current, constant-voltage type with a maximum charge current of 4A that can be externally set. A precondition feature trickle charges a low voltage battery and bad battery detection provides a

signal if the battery doesn't respond to preconditioning. The LT3651EUHE is available in a 36-lead (5mm × 6mm) QFN surface mount package with two exposed thermal pads.

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

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## PERFORMANCE SUMMARY

Specifications are at  $T_A = 25^\circ\text{C}$

|  |                                       |
|--|---------------------------------------|
| Input Voltage Range                          | 6.5V to 32V                           |
| V <sub>OUT</sub>                             | 2.9V to 4.24V (-A)/2.7V to 4.14V (-B) |
| Output Float Voltage (Constant Voltage Mode) | 4.2V (-A)/4.1V (-B)                   |
| Output Current Limit I <sub>LIM</sub>        | 4A                                    |

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## OPERATING PRINCIPLE

LT3651 is a complete Li-Ion battery charger, addressing wide input voltage (6.5V to 32V) and high charge current (up to 4A). High charging efficiency, as shown in Figure 1, is produced with a constant frequency, average current mode synchronous step-down switcher architecture.

The charger includes the necessary circuitry to allow for programming and control of constant-current, constant-voltage (CC/CV) charging with both current only and timer termination. High charging efficiency is achieved by using a bootstrapped supply for low switch drop on the high side driver and a MOSFET for the low side (synchronous) switch.

Maximum charge current is set with an external sense resistor in series with the inductor and is adjusted through the RNG/SS pin. The total system input current is monitored with an input sense resistor and is used to maintain constant input current by regulating battery charge current. It is adjusted through the I<sub>LIM</sub> pin.

If the battery voltage is low, charge current automatically reduces to 15% of the programmed current to provide safe battery preconditioning. Once the battery voltage climbs above the battery precondition threshold, the IC automatically increases the maximum charging current to the full programmed value.

## OPERATING PRINCIPLE

Charge termination can occur when charge current decreases to one-tenth of the programmed maximum charge current (C/10 termination). Alternately, termination can be timer based through the use of an internal programmable charge cycle control timer. When using the timer termination, charging continues beyond the C/10 level to top off a battery. Charging typically terminates three hours after initiation. When the timer-based scheme is used, bad battery detection is also supported. A system fault is triggered if a battery stays in precondition mode for more than one-eighth of the total charge cycle time.

Once charging is terminated and the LT3651 is not actively charging, the IC automatically enters a low current standby mode in which supply bias currents are reduced to  $<85\mu\text{A}$ . If the battery voltage drops below 2.5% from the full charge float voltage, the LT3651 engages an automatic charge cycle restart. The IC also automatically restarts a new charge cycle after a bad battery fault once the failed battery is removed and replaced with another battery.

After charging is complete, the input bias current lines connected to the battery are reduced to minimize battery discharge.

The LT3651 contains provisions for a battery temperature monitoring circuit. Battery temperature is monitored by using an NTC thermistor located with the battery. If the

battery temperature moves outside the safe charging range of  $0^\circ\text{C}$  to  $40^\circ\text{C}$  the charging cycle suspends and signals a fault condition.

The LT3651 contains two digital open-collector outputs, which provide charger status and signal fault conditions. These binary coded pins signal battery charging, standby or shutdown modes, battery temperature faults and bad battery faults.

A precision undervoltage lockout is possible by using a resistor divider on the shutdown pin (SHDN). The input supply current is  $17\mu\text{A}$  when the IC is in shutdown.

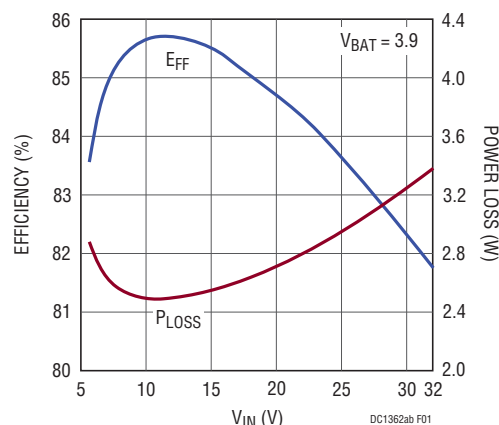


Figure 1. Efficiency and Power Loss vs V<sub>IN</sub>

## QUICK START PROCEDURE

Demonstration circuit 1362A-A/1362A-B is easy to set up to evaluate the performance of the LT3651EUHE-4.2/LT3651EUHE-4.1.

Using short twisted pair leads for any power connections, with all loads and power supplies off, refer to Figure 2 for the proper measurement and equipment setup.

Follow the procedure below:

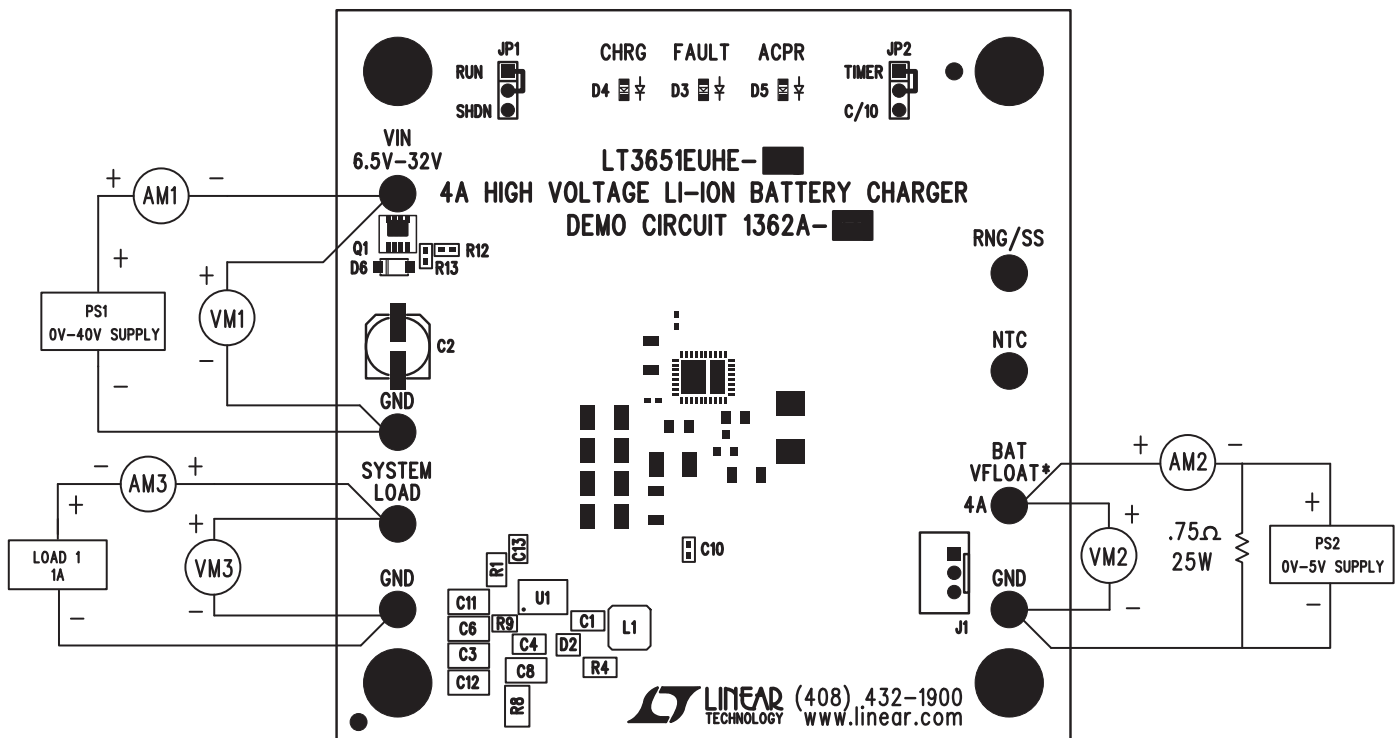
1. Jumper and power supply setting:
 

|            |           |
|------------|-----------|
| JP1 = RUN  | PS1 = OFF |
| JP2 = C/10 | PS2 = OFF |

2. Turn on PS2 and slowly increase the voltage to 2.7V while monitoring the current into the BAT pin. If the current is less than 5mA, turn on PS1. Increase the voltage on PS1 to 4V while monitoring the input current. If the current is less than 5mA, increase PS1 to 12V.
3. Verify that the battery charging current, I<sub>BAT</sub> is between 400mA and 600mA. The CHR<sub>G</sub> LED and ACPR LED should be on and the FAULT LED should be off.

## QUICK START PROCEDURE

- Increase PS2 until VBAT is 3.6V. Verify the input current IIN is between 1.4A and 1.7A, the battery current IBAT is between 3.75A and 4.45A and that the CHRГ LED and ACPR LED are on.
- Increase PS2 until VBAT is 4.25V. Verify the battery charging current IBAT is less than 5mA and that the CHRГ LED and ACPR LED are off.
- Decrease PS2 until VBAT is 3.9V. Verify the battery current IBAT is between 3.75A and 4.45A that the CHRГ LED and ACPR LED are on.
- Decrease PS2 until VBAT is 3.6V. Connect a 10k resistor from the RNG/SS pin to ground. Verify the charging current IBAT is between 1.7A and 2.0A. Verify the voltage VNTC on the NTC turret is between 1.6V and 1.9V and the voltage VRNG on the RNG/SS turret is between 450mV and 700mV. Remove the 10k resistor from the RNG/SS pin to ground
- Set JP1 to SHDN. Verify the charging current IBAT is less than 5mA and that the FAULT LED, CHRГ LED and ACPR LED are off.
- Set JP1 to RUN. Connect a jumper from the NTC pin to ground. Verify the charging current IBAT is less than 5mA and that the FAULT LED, CHRГ LED and ACPR LED are on.
- Remove the jumper from NTC to ground. Verify the charging current IBAT is between 3.75A and 4.45A and that the FAULT LED is off and the CHRГ LED and ACPR LED are on.
- Turn on LOAD1 and set to 1A. Verify the voltage VSYSTEM on the system voltage turret is approximately equal to VIN.
- Turn off PS1, PS2 and LOAD1.



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.

DC1362ab F02

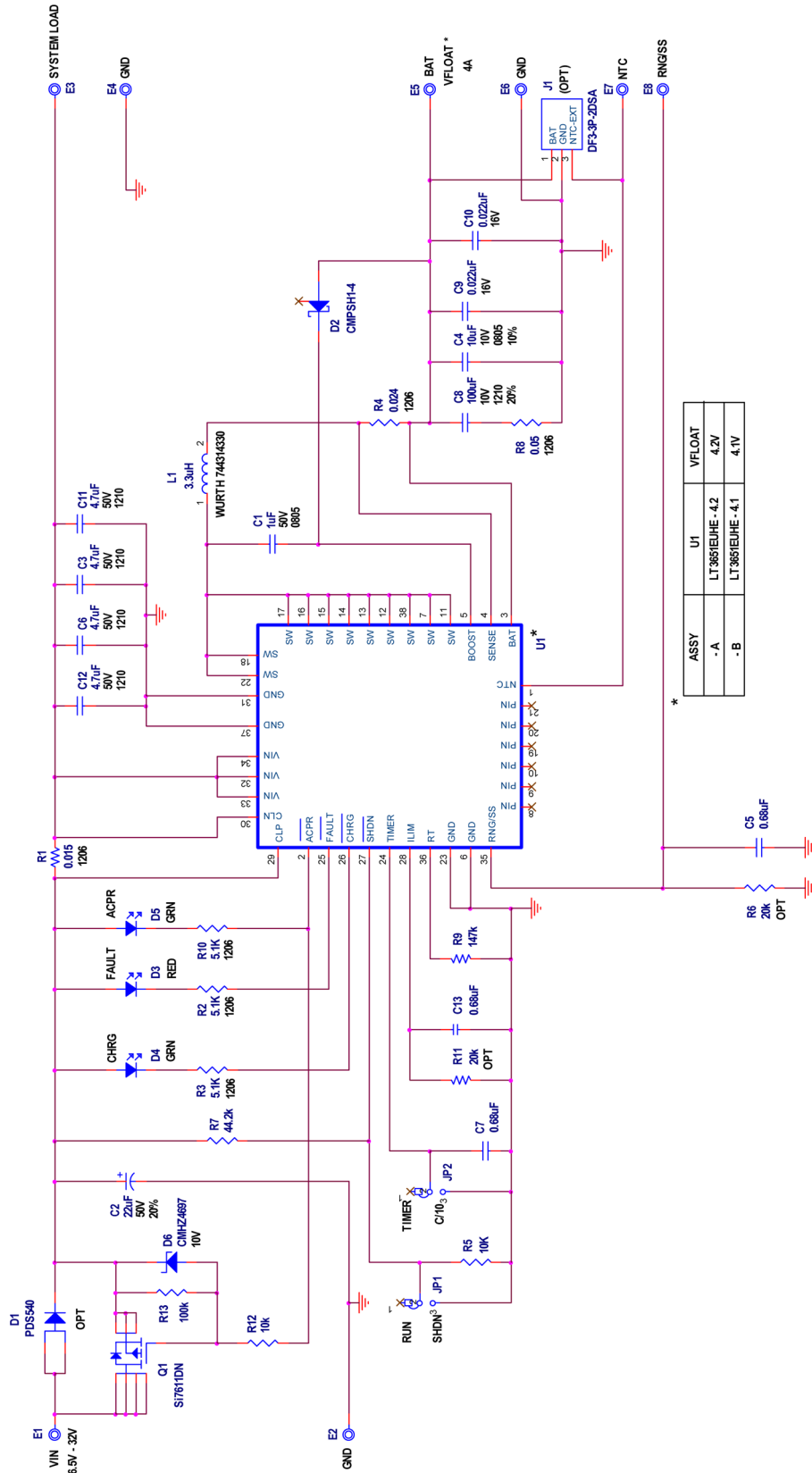
Figure 2. Proper Measurement Equipment Setup

# DEMO MANUAL DC1362A-A/-B

## PARTS LIST

| ITEM                                  | QTY | REFERENCE                          | PART DESCRIPTION   | MANUFACTURER/PART NUMBER   |
|---------------------------------------|-----|------------------------------------|--|--|
| <b>Required Circuit Components</b>    |     |                                    |  |  |
| 1                                     | 1   | C1                                 | CAP, X7R, 1 $\mu$ F, 50V, 10%, 0805                        | MURATA, GRM21BR71H105KA12L   |
| 2                                     | 4   | C3, C6, C11, C12                   | CAP, X7S, 10 $\mu$ F, 50V, 20%, 1210                       | TDK, C3225X7S1H106M  |
| 3                                     | 1   | C4                                 | CAP, X7R, 10 $\mu$ F, 10V, 10%, 0805                       | MURATA, GRM21BR71A106KE51L   |
| 4                                     | 3   | C5, C7, C13                        | CAP, X5R, 0.68 $\mu$ F, 10V, 10%, 0402                     | MURATA, GRM155R61A684KE15D   |
| 5                                     | 1   | C8                                 | CAP, X5R, 100 $\mu$ F, 6.3V, 20%, 1210                     | TAIYO YUDEN, LMK325BJ107MM-T   |
| 6                                     | 1   | D2                                 | SMD, SCHOTTKY DIODE, SOT-23                                | CENTRAL SEMI, CMPSH1-4 TR  |
| 7                                     | 1   | D6                                 | DIODE, ZENER, 10V SOD-123                                  | CENTRAL SEMI, CMHZ4697   |
| 8                                     | 1   | L1                                 | POWER INDUCTOR 3.3 $\mu$ H 20% 8.0A, 9m $\Omega$ 7mm x 7mm | WURTH, 744314330   |
| 9                                     | 1   | Q1                                 | MOSFET, PCHANNEL, 40V, 25m $\Omega$ 1212-8                 | VISHAY, Si7611DN   |
| 10                                    | 1   | R1                                 | RES, CHIP, 0.015 $\Omega$ , 1/2W, 1%, 1206                 | IRC, LRC-LR1206LF-01-R015-F  |
| 11                                    | 1   | R4                                 | RES, CHIP, 0.024 $\Omega$ , 1/2W, 1%, 1206                 | IRC, LRC-LR1206LF-01-R024-F  |
| 12                                    | 2   | R5, R12                            | RES, CHIP, 10k, 1/16W, 1%, 0402                            | VISHAY, CRCW040210K0FKED   |
| 13                                    | 1   | R7                                 | RES, CHIP, 44.2k, 1/16W, 1%, 0402                          | VISHAY, CRCW040244K2FKED   |
| 14                                    | 1   | R8                                 | RES, CHIP, 0.05 $\Omega$ , 1/2W, 1%, 1206                  | IRC, LRC-LR1206LF-01-R050-F  |
| 15                                    | 1   | R9                                 | RES, CHIP, 147k, 1/16W, 1%, 0402                           | VISHAY, CRCW0402147KFKED   |
| 16                                    | 1   | R13                                | RES, CHIP, 100k, 1/16W, 1%, 0402                           | VISHAY, CRCW0402100KFKED   |
| 17                                    | 1   | U1 (-A VERSION)<br>U1 (-B VERSION) | 4A HIGH VOLTAGE LI-ION BATTERY CHARGER                     | LINEAR TECHNOLOGY, LT3651EUHE-4.2<br>LINEAR TECHNOLOGY, LT3651EUHE-4.1 |
| <b>Optional Electrical Components</b> |     |                                    |  |  |
| 1                                     | 1   | C2                                 | CAP, SMT, 22 $\mu$ F, 50V 20%                              | SUNCON, 50CE22BS   |
| 2                                     | 2   | C9, C10                            | CAP, CHIP, X7R, 0.022 $\mu$ F, $\pm$ 10%, 16V, 0402        | AVX, 0402YC223KAT2A  |
| 3                                     | 0   | D1                                 | SMD, SCHOTTKY, 5A, 40V                                     | DIODES INC, PDS540-13  |
| 4                                     | 1   | D3                                 | LED, RED   | PANASONIC, LNJ208R8ARA   |
| 5                                     | 2   | D4, D5                             | LED, GREEN   | LITE-ON, LTST-C190KGKT   |
| 6                                     | 0   | J1                                 | HEADER, 3 PINS   | HIROSE ELECTRIC, DF3A-3P-2DSA  |
| 7                                     | 3   | R2, R3, R10                        | RES, CHIP, 5.1k, 1/4W, 5%, 1206                            | VISHAY, CRCW12065K10JNED   |
| 8                                     | 0   | R6, R11                            | RES, CHIP, 20k, 1/16W, 1%, 0402                            | VISHAY, CRCW040220K0FKED   |
| <b>Hardware for Demo Circuit</b>      |     |                                    |  |  |
| 1                                     | 8   | E1 TO E8                           | TESTPOINT, TURRET 0.095"                                   | MILL-MAX, 2501-2-00-80-00-00-07-0                                      |
| 2                                     | 2   | JP1, JP2                           | 2MM SINGLE ROW HEADER 3 PIN                                | SAMTEC, TMM-103-02-L-S   |
| 3                                     | 2   | JP1, JP2                           | SHUNT  | SAMTEC, 2SN-BK-G   |
| 4                                     | 4   | MH1 TO MH4                         | STAND-OFF, NYLON 0.375" TALL (SNAP ON)                     | KEYSTONE, 8832 (SNAP ON)   |

**SCHEMATIC DIAGRAM**



| ASSY | U1             | VFLOAT |
|------|----------------|--------|
| -A   | LT3651EUHE-4.2 | 4.2V   |
| -B   | LT3651EUHE-4.1 | 4.1V   |

# DEMO MANUAL DC1362A-A/-B

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