LT1769 Constant-Voltage/ Constant-Current Lithium-Ion Battery Charger with Input Current Limiting

DESCRIPTION

Demonstration board DC243 is a complete lithium-ion battery charger designed for 1-, 2- or 3-cell applications. The LT®1769 is used in a high efficiency, current mode step-down topology, capable of providing up to 2A of charging current. The 200kHz switching frequency allows small surface mount components to be used, minimizing board space and height. The precision voltage required by Li-Ion batteries is programmed by a resistor divider and the maximum battery charging current is programmed with a single resistor (or a programming current from a DAC).

A unique feature of the LT1769 is its ability to monitor the input current from the power source, provide current to a load and adjust the battery charging current so as not to exceed a predetermined current level from the input power source. This allows the input power supply or AC adapter to provide current to power system circuitry such as a laptop computer and simultaneously charge a battery, without overloading the input power supply. As the system current requirements increase, the LT1769 begins adjusting the battery charging current downward to keep the input power supply current below a predetermined limit.

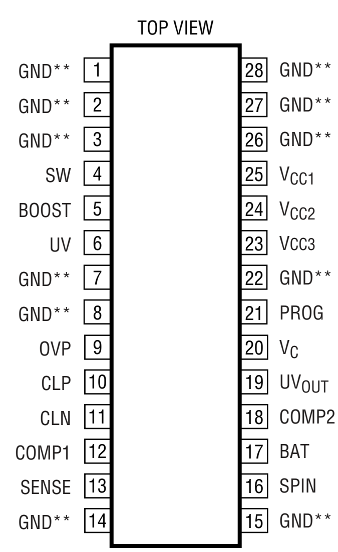
Jumpers JP1 and JP2, located on the demo board, are used to select the correct charging voltage for the number of cells being charged (4.2V, 8.4V or 12.6 V). Maximum battery charge current is programmed for 2A by resistor R14 and the current sense resistors R7, R5 and R6. Maximum input current (or AC adapter current) is set for 2A by current sense resistor R4.

Also included on this demo board is a soft-start function, undervoltage lockout (with an undervoltage lockout signal output) and provisions for driving the boost capacitor from an external low DC voltage rather than the battery voltage, to increase efficiency and thus reduce heat dissipation.

BOARD PHOTO AND PACKAGE INFORMATION

Demo Board

LT1769



GN PACKAGE
28-LEAD PLASTIC SSOP

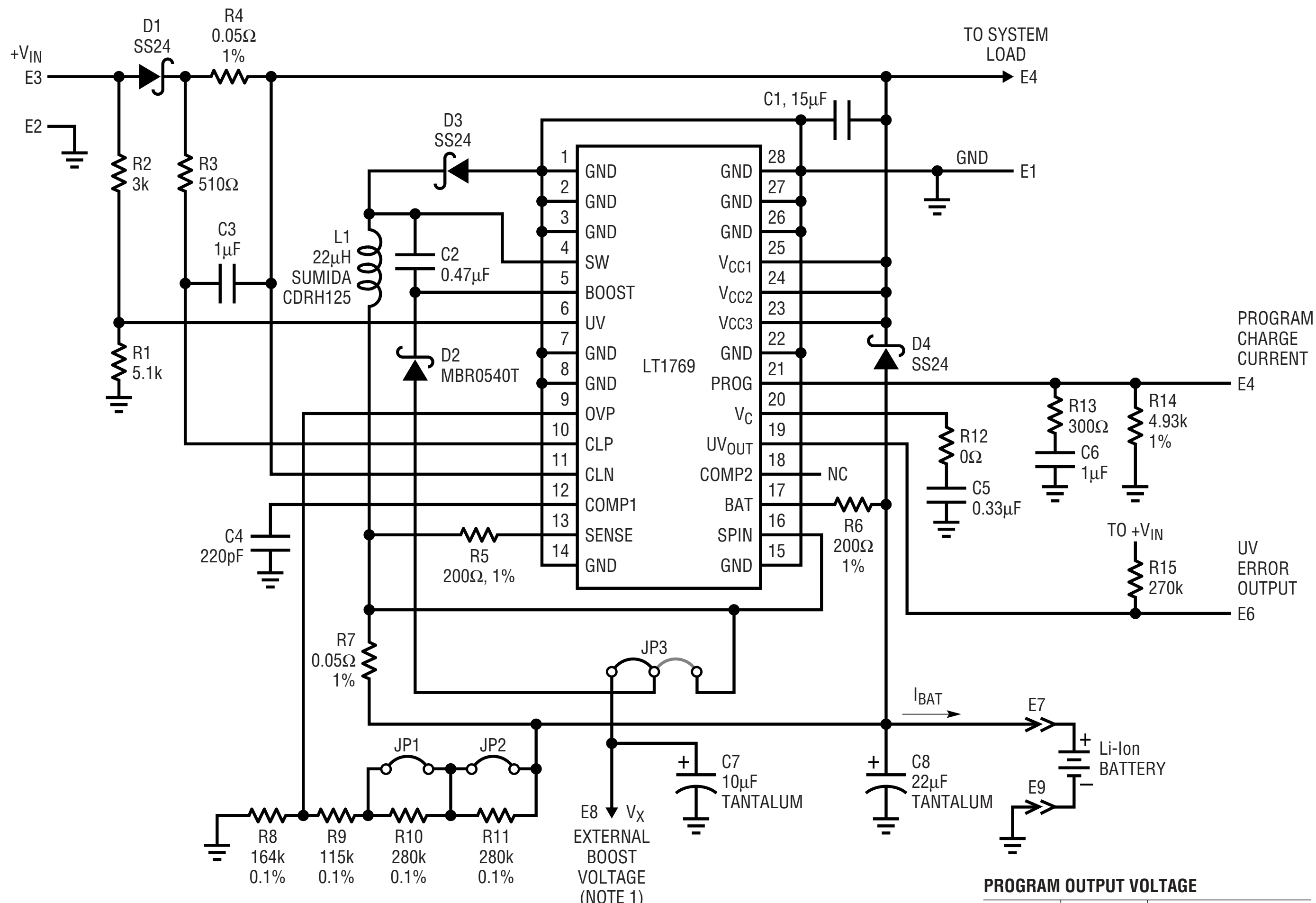
** ALL GND PINS ARE FUSED TO THE INTERNAL DIE ATTACH PADDLE FOR HEAT SINKING TO PC BOARD

PERFORMANCE SUMMARY

PARAMETER	CONDITIONS	LIMITS
V_{IN}		$11V \le V_{IN} \le 25V$*
Battery Voltage (V_{BAT})	$V_{IN} = 12V$, $I_{BAT} = 1.5A$ $V_{IN} = 12V$, $I_{BAT} = 1.5A$ $V_{IN} = 16V$, $I_{BAT} = 1.5A$	4.200V ± 0.75% 8.400V ± 0.75% 12.600V ± 0.75%
Maximum Battery Charging Current		2.0A, −7.5% + 5%
Maximum Adaptor Input Current		2.0A, −7.5% + 5%

* For $V_{IN} \ge 25V$, C1 should be replaced with higher voltage rating.

SCHEMATIC DIAGRAM



PROGRAM OUTPUT VOLTAGE

JP1	JP2	BATTERY VOLTAGE
CLOSED	CLOSED	4.2V
CLOSED	OPEN	8.4V
OPEN	OPEN	12.6V

NOTE 1: FOR LOWER IC POWER DISSIPATION AND PACKAGE TEMPERATURE, USE EXTERNAL BOOST VOLTAGE OF 3V TO 5V.

243 Schem

Figure 1. Constant-Voltage/Constant-Current Lithium-Ion Battery Charger with Input Current Limiting

PARTS LIST

REFERENCE	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1	1	C55Y5U1E156Z	15µF 25V 20% Y5U Ceramic Capacitor	Tokin	(408) 432-8020
C2	1	12063G474ZAT2	0.47µF 25V Y5V Ceramic Capacitor	AVX	(843) 946-0362
C3, C6	2	0603ZG105ZKAT1A	1µF 10V Y5V Ceramic Capacitor	AVX	(843) 946-0362
C4	1	06035C221KAT2A	220pF 50V X7R Ceramic Capacitor	AVX	(843) 946-0362
C5	1	12063C334KAT2A	0.33µF 25V X7R Ceramic Capacitor	AVX	(843) 946-0362
C7	1	TPSD106K035R0200	10µF 35V Tantalum Capacitor	AVX	(207) 282-5111
C8	1	TPSD226K025R0200	22µF 25V Tantalum Capacitor	AVX	(207) 282-5111
D1, D3, D4	3	SS24	2A 30V Schottky Diode	General Semiconductor	(516) 847-3000
D2	1	MMSD4148T1	0.1A, 50V Silicon Diode	ON Semiconductor	(602) 244-6600
E1–E9	9	2501-2	0.090 Turret Test Point	Mill Max	(516) 922-6000
JP1, JP2	2	3801S-02G2	2-Pin Jumper	Comm Con	(626) 301-4200
JP3	1	3801S-03G2	3-Pin Jumper	Comm Con	(626) 301-4200
L1	1	CDRH125-220	22µH SMT Inductor	Sumida	(847) 956-0667
R1	1	CR16-512JM	5.1k 1/8W 5% Chip Resistor	TAD	(800) 508-1521
R2	1	CR16-302JM	3k 1/8W 5% Chip Resistor	TAD	(800) 508-1521
R3	1	CR16-511JM	510Ω 1/8W 5% Chip Resistor	TAD	(800) 508-1521
R4, R7	2	LR2010-01-R050F	0.05Ω 1/2W 1% Chip Resistor	IRC	(361) 992-7900
R5, R6	2	CR16-2000FMJM	200Ω 1/10W 1% Chip Resistor	TAD	(800) 508-1521
R8	1	PFC-W1206R-03-1643-B	164k 1/10W 0.1% Chip Resistor	IRC	(361) 992-7900
R9	1	PFC-W1206R-03-1153-B	115k 1/10W 0.1% Chip Resistor	IRC	(361) 992-7900
R10, R11	2	PFC-W1206R-03-2803-B	280k 1/10W 0.1% Chip Resistor	IRC	(361) 992-7900
R12	1	CJ06-0R0JM	0Ω Chip Resistor	TAD	(800) 508-1521
R13	1	CR16-301JM	300Ω 1/10W 1% Chip Resistor	TAD	(800) 508-1521
R14	1	PFC-W1206R-03-4931-B	4.93k 1/10W 0.1% Chip Resistor	IRC	(361) 992-7900
R15	1	CR16-274JM	270k 1/8W 5% Chip Resistor	TAD	(800) 508-1521
U1	1	LT1769GN	IC SSOP-28 Battery Charger	LTC	(408) 432-1900
	3	CCIJ230-G	2-Pin Shunt for JP1-JP3	Comm Con	(626) 301-4200

OPERATION

The DC243 demonstration board is intended for evaluating the LT1769 switch mode battery charger IC. This board contains all the components necessary for a two amp lithium-ion battery charger with input and charge current management control; it features soft-start, undervoltage lockout, undervoltage error flag output and charge current shutdown.

The input current from the power source (AC adapter) and the battery charging current are monitored using low value current sensing resistors located on the board. This information is used by the LT1769 to control the battery charge current. Both the maximum input and the maximum charge current levels are programmable. The recommended charge current (typically 1**C**) is specified by the battery manufacturer and appropriate resistors are selected to program this current. Likewise, the maximum current available from the input power source or AC adapter is determined by the manufacturer of the power source and an appropriate resistor is selected to program this current input level.

By monitoring these currents, the input power source (AC adapter) can simultaneously power a system load (such as a laptop computer) and charge a battery, without overloading the input power source.

The LT1769 can operate in a constant-voltage and/or constant-current mode. With a discharged battery connected, charging will begin in a constant-current mode with the maximum charge current determined by resistor R14. The battery will continue charging at the maximum rate until the battery voltage approaches the programmed voltage limit, at which time the constant-voltage portion of the charge cycle begins. In constant-voltage mode, the battery will continue to accept charge, with the charge current decreasing exponentially, eventually approaching zero mA.

The input current limit feature allows simultaneous battery charging and system operation without overloading the input power source (AC adapter). If the system load current increases, resulting in the adapter current reaching the limit set by the input current sense resistor, the charge current will begin decreasing. If the system load current continues to rise, the charging current will continue to decrease, eventually reaching zero (see the curve in Figure 4).

A simplified block diagram in Figure 2 shows the various current paths of the demo board. The input current flows through an antireversal diode (D1) and an input current sensing resistor (R_{S1}), to the system load. An additional current path is through the charger and the charge current sensing resistor (R_{S2}), to the battery being charged. D2 provides power to the system load from the battery when the input power is removed.

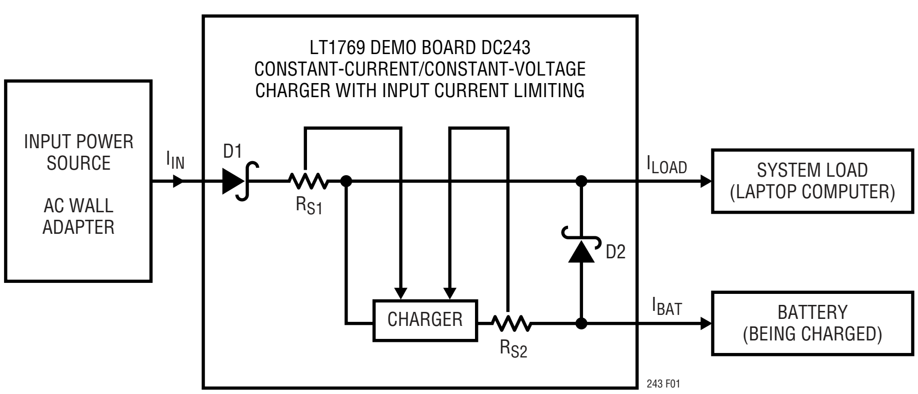


Figure 2. Simplified Block Diagram of Demo Board

OPERATION

External Boost Voltage

The LT1769 uses an NPN transistor as a power switch in a step-down topology. To achieve low switch saturation voltage, the circuit utilizes a bootstrap capacitor (C2) and diode (D2) to generate a voltage that is higher than the input voltage. This voltage provides base drive for the NPN switch to lower the saturation voltage and increase efficiency. The boost voltage can come from either the battery voltage or an external voltage source between 3V and 6V, selected by a 3-pin jumper, JP3.

With jumper JP3 in the VBAT position (jumper between center pin and lower pin), the battery voltage is used to drive the bootstrap components. Moving jumper JP3 to the center pin and upper pin allows an external boost voltage to be used.

When charging higher voltage batteries (greater than 8V, for example) the boost diode D2 (Pin E8 on the demo board) should be connected to a lower voltage (preferably between 3V and 6V). This will reduce power dissipation in the IC, thus lowering the package temperature. It will also reduce the dropout voltage by increasing the maximum switch duty cycle from 90% to 93%. The current needed from this supply is less than 30mA. See the LT1769 data sheet for additional information.

Powering Up the Demo Board

Demo board DC243's input voltage can range from 10.5V (undervoltage lockout) up to 25V. The minimum input voltage can be reduced to approximately 7V by replacing R2 with 0Ω and keeping R1 at 5.1k. A resistor divider selects the correct output voltage for charging either 1, 2 or 3 (4.2V) cells. Charge current is programmed for two amps (R14) and the maximum input current is also programmed for two amps (R4).

Equipment required includes an adjustable power supply (25V and 2.5A), digital voltmeter, ammeter, an electronic load or adjustable 50 watt load resistor to simulate system load (approximately 8Ω to 50Ω) and a lithium-ion rechargeable battery or a battery simulator.

Select the correct charge voltage for the number of cells being charged (4.2V, 8.4V or 12.6 V). This is done by a combination of jumpers (JP1 and JP2) on the board. See the schematic diagram (Figure 1) for jumper information on programing output voltage. Be sure that jumper JP3 is placed between the bottom and center pins.

With the input power supply turned down, connect the input power supply to the demo board solder terminals $+V_{IN}$ and GND. Next, connect a discharged lithium-ion battery to the VBAT and GND terminals. An ammeter in series with the battery is useful for evaluating the the charge current into the battery. See Figure 3 for the connection diagram.

Begin increasing the input supply voltage. The undervoltage lockout will keep the charger off until the input voltage reaches approximately 10.5V, as determined by resistors R1 and R2. As the input voltage exceeds the undervoltage threshold level, the battery begins charging. (Note: the minimum input voltage required for full charge current is approximately 2V greater than the battery voltage.) With a sufficiently discharged battery connected, the charger will begin charging at the programmed 2A current level.

As the battery accepts charge, the battery voltage rises and approaches the programmed voltage of either 4.2V, 8.4V, or 12.6V. The charger will then maintain a constant voltage across the battery, with the charge current decreasing exponentially to near zero over time as the battery reaches a fully charged condition. Charging at a 1**C** rate, a battery will be approximately 95% charged when the charge current drops to **C**/10 (10% of the maximum charge current); this should occur in approximately 90 minutes or less.

Some lithium-ion battery manufacturers recommend terminating the constant-voltage float mode after the charge current has dropped below a specific level (typically 10% of full charge current) and a specific amount of time has elapsed (typically from 30 to 90 minutes). This may extend the life of the battery, but check with the battery manufacturer for details. See the the LT1769 data sheet for additional applications information.

OPERATION

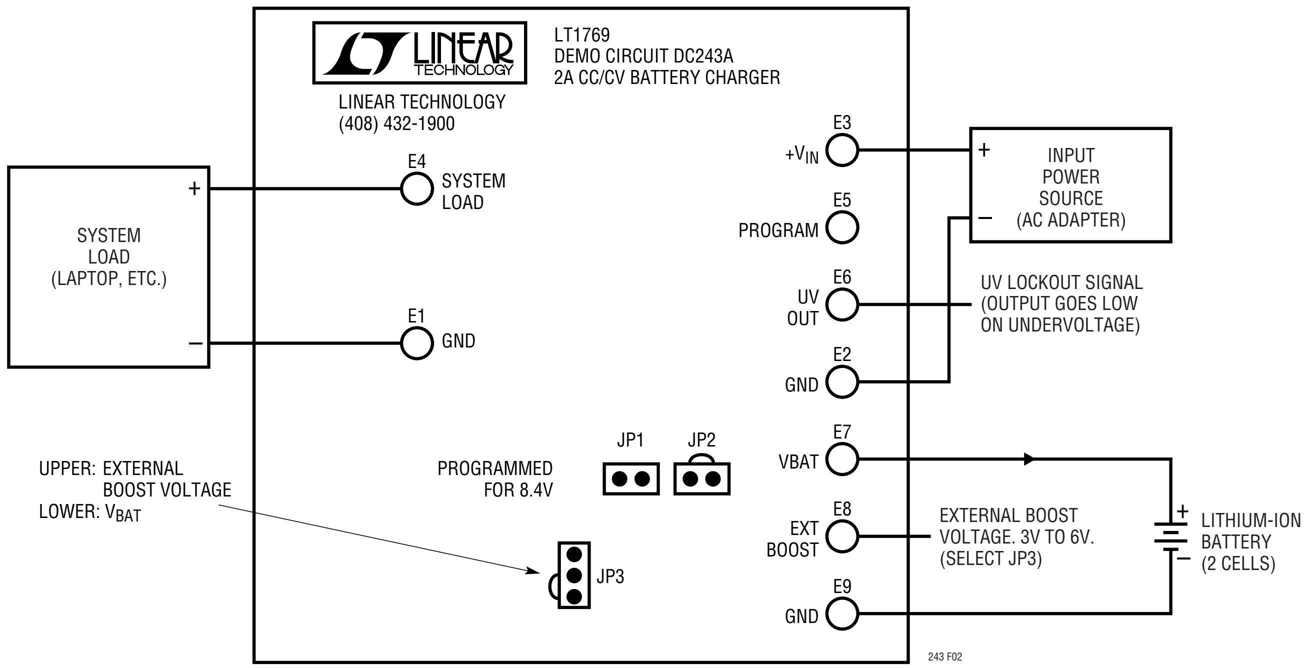


Figure 3. Demo Board Wiring Diagram

Battery Simulator

When evaluating battery chargers, the best type of load to use is the actual battery. Unfortunately, charging and discharging a battery is time consuming. A simple battery simulator consisting of a standard lab power supply and a power resistor can be used in place of a battery to evaluate a charger. Connect a power resistor that will draw approximately twice the maximum charge current across the output of a power supply that has coarse and fine voltage adjust controls. The power supply (with the resistor across the output) can now source or sink current, just like a battery, and can be used in place of the battery. Adjusting the power supply voltage can now simulate a battery from a discharged to a fully charged condition. When the simulator voltage is near the programmed charge voltage, the charge current will drop quickly.

Selecting an Input Current Limit Resistor

The input current from the input power source is sensed by a low value resistor, R4. This sense voltage is fed into the CLN (current limit negative) and CLP (current limit positive) pins of the LT1769. When this voltage exceeds 100mV, the circuit will begin to override (decrease) the maximum programmed charge current. To program the maximum input current for 2A use the following formula:

$$R4 = \frac{100mV}{2A} = 0.05\Omega$$

To evaluate the input current limit feature, connect a discharged battery to the charger and begin increasing the input voltage to the demo board. With V_{IN} =18V, the charge current will be approximately 2A and the input current will be approximately 1.15A (see Figure 4). Now connect an electronic load or adjustable 50Ω load resistor (set for maximum resistance) between the SYSTEM LOAD and GND solder terminals. Begin increasing the system load current. At 1A system load and 2A charge current, the input current is nearly 2A, which is the programmed input current limit of the demoboard. A further increase in system load current will result in a decrease in charge current so as not to exceed the 2A input current limit. As shown in Figure 4, increasing the system load to 2A drops the charge current to 0.

OPERATION

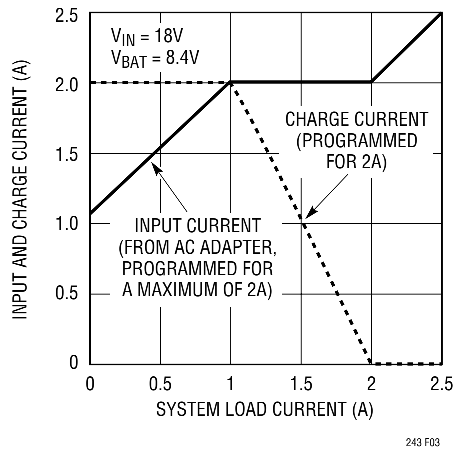


Figure 4. System Load Current vs Input and Charge Current

Selecting Charge Current Resistors

The basic formula for charge current, I_{BAT} (refer to schematic diagram), is:

$$I_{BAT} = I_{PROG}\left(\frac{R6}{R7}\right) = \left(\frac{2.465}{R14}\right)\left(\frac{R6}{R7}\right)$$

Select the current flowing out of the PROG pin (I_{PROG}) to be approximately 500µA. The voltage present at the PROG pin is 2.465V.

$$\text{For } I_{PROG} = 500\mu A\text{, make R14} = \frac{2.465}{500\mu A} = 4.93k$$

To program 2A of charge current, select the current sensing resistor R7 to have approximately 100mV across it when 2A is flowing.

$$R7 = \frac{100mV}{2A} = 0.05\Omega$$

For biasing purposes, R5 should be equal to R6.

$$R6 = R5 = \frac{(I_{CHARGE})(R14)(R7)}{2.465V} = \frac{(2A)(4.93k)(0.05)}{2.465V} = 200\Omega$$

Once the charge current resistors (R5, R6, R7 and R14) have been selected, the maximum charge current is determined by the current out of the program pin. Charge current is proportional to the program pin current with 500µA corresponding to maximum (2A) charge current. In normal operation, the voltage on the program pin is 2.465V.

Undervoltage Lockout

Undervoltage lockout keeps the charger off until the input voltage reaches a minimum threshold level. When the input voltage is rising, the threshold voltage on the undervoltage lockout pin (Pin 6) is approximately 6.7V, with hysteresis of 0.5V. This voltage can be adjusted upward by adding a resistive divider (R1 and R2). With the resistors shown, the undervoltage lockout voltage with the input voltage rising is approximately 10.6V. The following formula is used to determine the undervoltage lockout threshold level.

$$\text{Undervoltage Lockout} = 6.7V\left(1 + \frac{R2}{R1}\right)$$

This feature is useful in situations where the input power source is current limited and cannot deliver full power upon start-up or at reduced input voltages. The undervoltage lockout prevents the input power source from going into a quasi-latch condition. One additional note: this UV feature affects only the charge current (I_{BAT}) and does not interrupt the current flow to the system load.

OPERATION

An open collector undervoltage lockout error output (E6) can be used to provide an indication of insufficient input voltage. A pull-up resistor to V_{IN} is included on the board. The pull-up resistor value must be large because of the limited current sinking capability (100µA) of this transistor. At turn-on, this output remains low until the UV threshold is exceeded.

Soft-Start and Shutdown

The V_C pin (Pin 20) on the LT1769 can be used for soft-start or I_{BAT} shutdown. The soft-start feature ensures that the charge current will rise in an orderly and controlled fashion. A capacitor on this pin is charged from an internal 45µA current source, creating a ramp voltage that controls the I_{BAT} rise time. A 0.33µF capacitor will provide a rise time of approximately 10ms. This capacitor is also used to filter out noise that appears on this pin.

The V_C pin can also be used to shut down the charger. Pulling this pin low stops the charge current but does not put the IC into the 3µA sleep mode.

Reverse Battery Drain Current

The IC goes into a sleep mode when the input voltage is removed. In the sleep mode, the drain from the battery due to the LT1769 is approximately 3µA. If the battery will remain connected to the charger for an extended period of time, all battery draining current paths should be identified. With the values shown, the voltage divider resistors account for 15µA of battery drain current. To eliminate this current, a MOSFET disconnect for the divider can be added, as shown on the LT1769 data sheet .

Another source of battery drain is the leakage current of the Schottky diodes, D1 and D3. Leakage currents could be greater than 50µA at room temperature and could go much higher at higher temperatures. Selecting a low leakage Schottky diode can lower that number considerably. Also, the antireversal diode D3 could be replaced with a low leakage silicon diode if the higher diode ON voltage and slightly increased power dissipation can be tolerated.

If the input voltage is removed and the system load remains connected, the system will remain powered by the battery through diode D4.

One additional item to keep in mind is that when V_{IN} is present, there is about 200µA of current flowing out of the BAT and Sense pins. If the battery is removed, this 200µA will cause the VBAT terminal to rise above the programmed voltage and approach V_{IN}. If this is a problem, the current through the resistor voltage divider could be increased to approximately 500µA to provide a minimum load at the VBAT terminal. A MOSFET would then be needed to disconnect the resistor divider from the battery when V_{IN} is removed. See the LT1769 data sheet for information on disconnecting the voltage divider and for equations for programming other output voltages.

OPERATION

Thermal Considerations

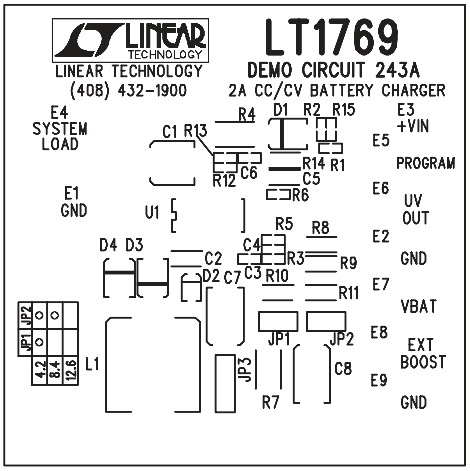
When operating the charger near maximum power levels or at elevated ambient temperatures, some precautions with regard to maximum junction temperature must be taken. The LT1769 is packaged in a specially constructed 28-pin surface mount plastic package. The package uses a total of eleven ground pins that are directly attached (fused) to the die-attach paddle for maximum heat transfer. The majority of the heat generated by the chip is conducted to the PC board through the copper leads of the IC, especially the ground leads. The PC board used in this demo is a four layer board with two inner copper ground layers interconnected with numerous feed-through vias for maximum heat transfers.

The PC board is the heat sink for the LT1769 and the other heat producing components on the board. Many items contribute to the effectiveness of the PC board as an efficient heat sink. Most important is the amount of PC board copper around the leads (especially the ground leads). Use as much as is practical. Total board size, number of layers, copper area, copper thickness, board thickness, quantity and type of components on the board, board orientation, still or moving air and even board temperature are all factors in how effective a heat sink the PC board is. Calculations of maximum IC junction temperature using IC thermal resistance and IC power dissipation numbers can often result in erroneous junction temperatures. This is because of the many PC board variables mentioned above and the fact that there are other heat producing components on the board such as two diodes, two current sense resistors and an inductor.

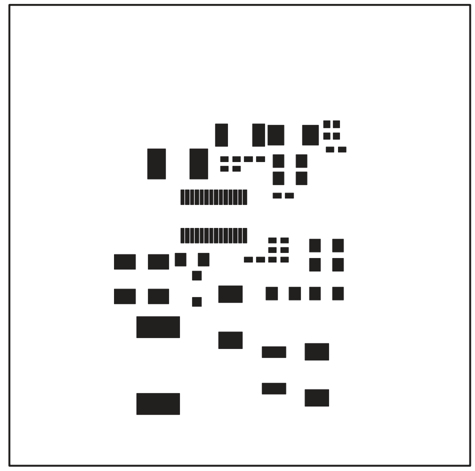
To ensure that maximum IC junction temperatures are within the device ratings of 125°C, it is recommended that a temperature measurement be taken. The suggested method is to solder a small (26 to 30 gauge) thermocouple to the top of one of the IC ground leads, preferably a ground lead near the center of the package (because it is closer to the die). At maximum output power, the peak junction temperature is approximately 10°C hotter than the ground lead. Keep the maximum junction temperature below 125°C; for a more conservative design, a 115°C maximum temperature could be used.

See the LT1769 data sheet for additional information on thermal characteristics.

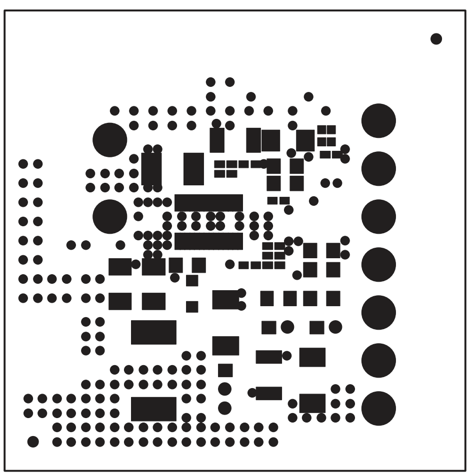
PCB LAYOUT AND FILM



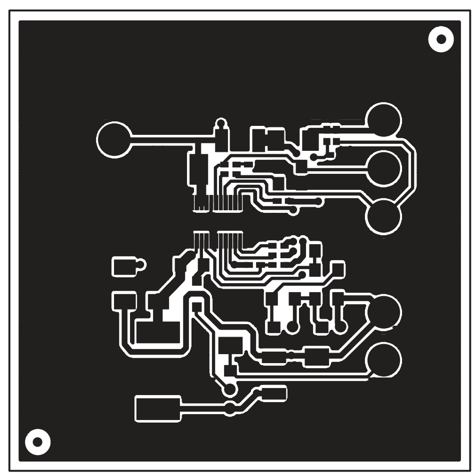
Silkscreen Top



Top Solder Paste



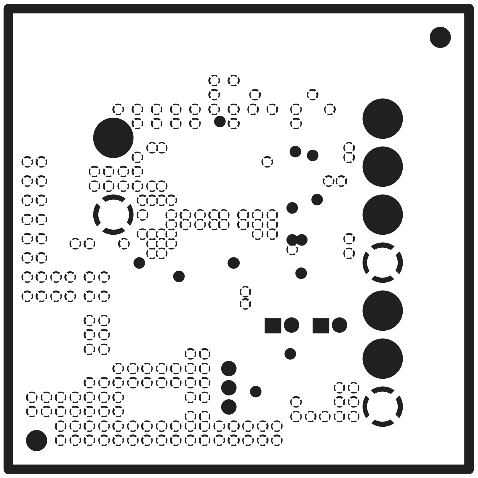
Top Solder Mask



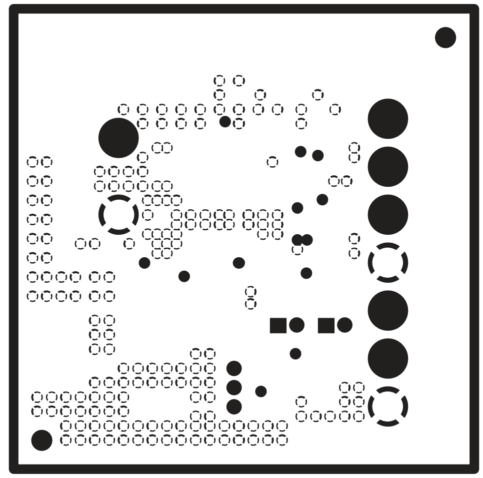
Layer 1—Top Layer

LINEAR TECHNOLOGY

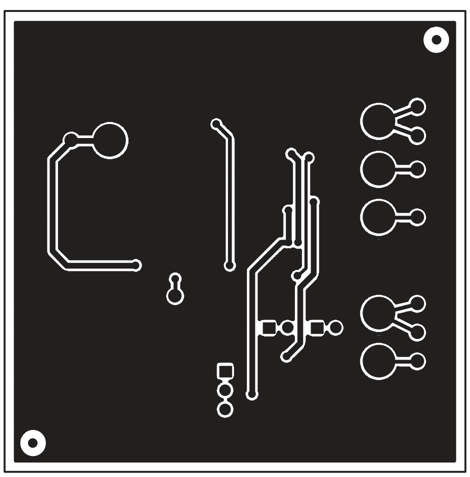
PCB LAYOUT AND FILM



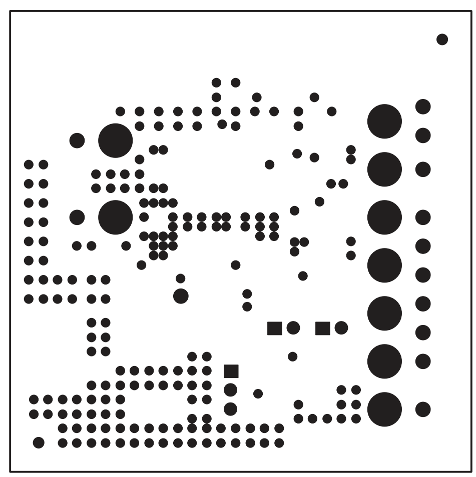
Layer 2—Ground Plane



Layer 3—Ground Plane

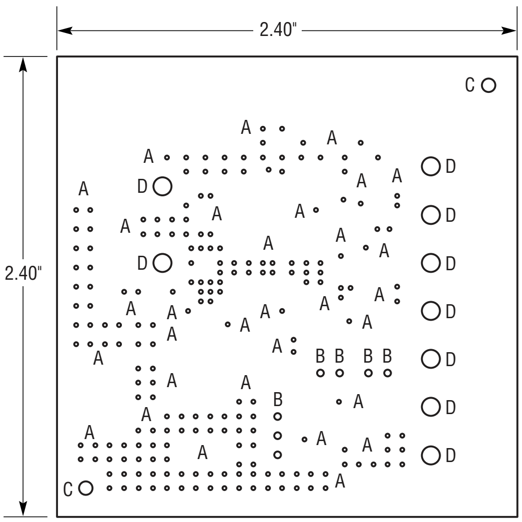


Layer 4—Bottom Layer



Bottom Solder Mask

PC FAB DRAWING

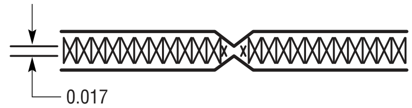


SHOWN FROM COMPONENT SIDE

SYMBOL	DIAMETER	NUMBER OF HOLES	PLATED
A	0.020	201	YES
B	0.035	7	YES
C	0.070	2	NO
D	0.094	9	YES

NOTES: UNLESS OTHERWISE SPECIFIED

1. MATERIAL: FR4 OR EQUIVALENT EPOXY, 2 OZ. COPPER CLAD THICKNESS 0.062 ±0.006 TOTAL OF 4 LAYERS.
2. ALL PLATED HOLES 0.001 MIN/0.0015 MAX COPPER PLATE ELECTRODEPOSITED TIN-LEAD COMPOSITION BEFORE REFLOW, SOLDER MASK OVER BARE COPPER (SMOBC).
3. SOLDER MASK: BOTH SIDES USING LPI OR EQUIVALENT.
4. SILKSCREEN: USING WHITE NONCONDUCTIVE EPOXY INK.
5. UNUSED SMD COMPONENTS SHOULD BE FREE OF SOLDER.
6. FILL UP ALL VIAS WITH SOLDER.
7. SCORING:



243 Fab Dwg

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