

High Efficiency Battery Charger/USB Power Manager with Regulated Output Voltage

DESCRIPTION

Demonstration circuit 1377A is a High Efficiency Battery Charger/USB Power Manager with Regulated Output Voltage featuring the LTC4088-2. The LTC4088-2 includes a synchronous switching input regulator, a full-featured battery charger and an ideal diode. Designed specifically for USB applications, the LTC4088-2's switching regulator automatically limits the input current to a maximum of 100mA or 500mA for USB applications, or 1A for wall-powered applications via logic control.

The switching input stage provides power to VOUT where power sharing between the application circuit and the battery charger is managed. Charge current is automatically reduced to maintain a regulated 3.6V VOUT during low battery conditions. As the battery is charged, VOUT tracks BAT for high efficiency charging. This feature allows the LTC4088-2 to provide more power to the application and eases thermal issues in constrained applications.

An ideal diode ensures that system power is available from the battery when the input current limit is reached or if the USB or wall supply is removed. The external P-channel MOSFET supplements the internal ideal diode by reducing R_{ON} and increasing efficiency.

A CHRГ LED indicates four possible states of the battery charger. Charging is indicated when the LED is steady-ON. Not charging is indicated by a steady-OFF. an NTC fault is indicated by a slow blinking rate (1.5Hz) and a bad battery is indicated by a fast blinking rate (6.1Hz).

The LTC4088-2 is available in a low profile 14-Lead 4mm × 3mm × 0.75mm DFN surface mount package.

Design files for this circuit board are available. Call the LTC factory.

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

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{BUS}	Input Supply Range		4.35		5.5	V
V_{OUT}	Output Voltage Range	$V_{BUS} = 5V$, 1x, 5x, 10x Modes, $0V < BAT \leq 4.2V$	3.5	BAT+0.3	4.7	V
		$V_{BUS} = 5V$, USB Suspend Modes, $I_{OUT} = 250\mu A$	4.5	4.6	4.7	V
V_{FLOAT}	BAT Regulated Output Voltage		4.179	4.2	4.221	V
I_{CHRG}	Constant-Current Mode Charge Current	$V_{BUS} = 5V$, $R_{PROG} = 2K$, $BAT = 3.8V$	490	515	540	mA
$I_{C/X}$	Battery Charge Current at Programmed End of Charge Indication	$V_{BUS} = 5V$, $R_{C/X} = 2K$	42.5	50	57.5	mV

OPERATING PRINCIPLES

This demo circuit is designed to demonstrate the full capability of the LTC4088-2 High Efficiency Battery Charger. Not all components are required in all applications. The critical circuit components are on the top of

the demo board near the IC and listed in the Required Circuit Components section of the Bill-of-Materials.

The input RC network of C6 and R13 is used to dampen source lead inductances that commonly are present in

LTC4088-2

laboratory setups with twisted leads and a bench power supply. When using a USB cable or adaptor cable this input damping network will likely not be required. Please note that the in-circuit capacitance of the 10uF, 0805 ceramic capacitor specified for C2 and C6 is approximately 5uF each at a VBUS greater than 4.25 Volts.

The LTC4088-2 requires a minimum of 10uF on the VOUT pin in 10X mode for voltage loop stability. As an alternative to using two smaller X5R capacitors, one larger X5R ceramic capacitor would be acceptable, provided that the actual in-circuit capacitance with 4.6 Volts applied is greater than 10uF.

The RC network of C4 and R8, R9, and R12 is included to simulate a low impedance battery. It is especially helpful when testing the demo circuit with a battery simulator comprised of a standard power supply with a 3.6 Ohm power resistor across it. The leads connecting the power supply to the demo circuit should be a twisted pair to minimize lead inductance; although, even twisted pairs can introduce enough inductance into the circuit to cause instability in the battery charger section without the presence of C4. If desired, it is possible to use a ceramic capacitor in series with a low valued resistor to stabilize the battery charger when no battery is present. Please refer to the datasheet for the suggested capacitor and resistance range.

QUICK START PROCEDURE

Demonstration circuit 1377A is easy to set up to evaluate the performance of the LTC4088-2. Refer to the Performance Summary for a listing of the inputs and outputs of the 1377A Demo Circuit. Demo Circuit 1377A is best evaluated using a Li-Ion/Polymer battery. When using a battery simulator for evaluation, oscillations must be verified with a real battery at the same conditions because it is difficult to match the impedance of a real battery. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below:

NOTE. When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the VBUS or VOUT and GND terminals. See Figure 2 for proper scope probe technique.

1. If using an external supply, connect a 0 to 6V, 1.5A supply with voltage adjusted to 0V between the VBUS and GND terminals. Connect a Voltmeter across the VBUS and GND terminals. If using the USB input option, have the cable ready to plug in when all loads and jumpers are set. **Do not use the USB input and an external supply at the same time.**
2. Set JP1, NTC jumper, to INT to use the demo board resistor. To use an external 100kOhm NTC resistor, connect the NTC resistor between J2-3 and the GND terminal. Then set the NTC jumper to EXT.

3. Use Table 1 to set JP2, JP3, and JP4 (D0, D1, and D2 respectively) to select the desired input current limit and charger status.

TABLE 1. Controlled Input Current Limit

D0	D1	D2	CHARGER	I _{BUS(LIM)}
0	0	0	ON	100mA(1x)
0	0	1	OFF	100mA(1x)
0	1	0	ON	500mA(5x)
0	1	1	OFF	500mA(5x)
1	0	0	ON	1A(10x)
1	0	1	OFF	1A(10x)
1	1	0	OFF	500uA(Susp Low)
1	1	1	OFF	2.5mA(Susp high)

4. Connect a 0 to 2A adjustable load in series with an ammeter between the VOUT terminal and the GND terminal. Connect a Voltmeter between the VOUT and GND terminals.
5. Connect a partially charged (~3.6V) Lithium ion battery with the positive lead to the BAT terminal and the negative lead to a GND terminal. Connect the positive lead of a Voltmeter to the BAT terminal and the negative lead to the GND terminal. Connect

the positive terminal of a Voltmeter to PROG and the negative terminal to GND to measure the current flowing into the battery. The voltage on PROG will read 1 Volt when the maximum charge current is reached. Observe VOUT.

NOTE. Make sure that the BAT voltage does not exceed 7V.

$$I_{BAT} = \frac{V_{PROG}}{R_{PROG}} \bullet 1031$$

6. If using the USB input, plug in the USB cable and observe the battery charge current and VOUT. If using an external power supply, slowly increase the supply and observe that the LTC4088-2 starts to use the VBUS input power as VBUS reaches 4.35V. Connect a Voltmeter between the CLPROG terminal and the GND terminal. The voltage on CLPROG will read 1.188 Volts when the input current limit is reached.

NOTE. Make sure that the VBUS voltage does not exceed 7V.

$$I_{VBUS} = I_{BUSQ} + \frac{V_{C_{PROG}}}{R_{CLPROG}} \bullet (h_{CLPROG} + 1)$$

See the datasheet for the proper values of I_{BUSQ} and h_{CLPROG} in 1X, 5X and 10X modes.

7. Discharge the battery to 2.5 volts. If Charger mode is on, observe it is charging in trickle charge mode and the charge current is 50mA. As the battery voltage increases above 2.85V observe that the

charger goes into full constant current mode. Observe that VOUT stays above 3.6V when the input current limit is not exceeded. Remove the NTC jumper on JP1. Observe the CHRГ LED slow blinking rate. Also observe the 35KHz pulse width varying duty cycle between 4.7% and 95.3% on the CHRГ terminal with an oscilloscope. Reinstall the NTC jumper.

8. Increase the VOUT load and observe when the input current starts to limit ($V_{CLPROG}=1.188$ V). As the input current limit is reached, VOUT gradually drops from 300mV above the BAT voltage to 15mV below the BAT voltage and the additional load transitions to the battery through the ideal diode. Due to the high efficiency of the switching regulator, the sum of the charge and load current may be significantly above the input current depending on the voltage on the BAT pin.
9. Repeat step 8 with different current limit modes.
10. Set the VBUS input supply to 5V. Observe the battery current as the battery voltage increases above 4.1V. The charge current starts to decrease as the battery voltage increases towards 4.2V.

See the latest LTC4088-1/LTC4088-2 datasheet for more information on how this part performs.

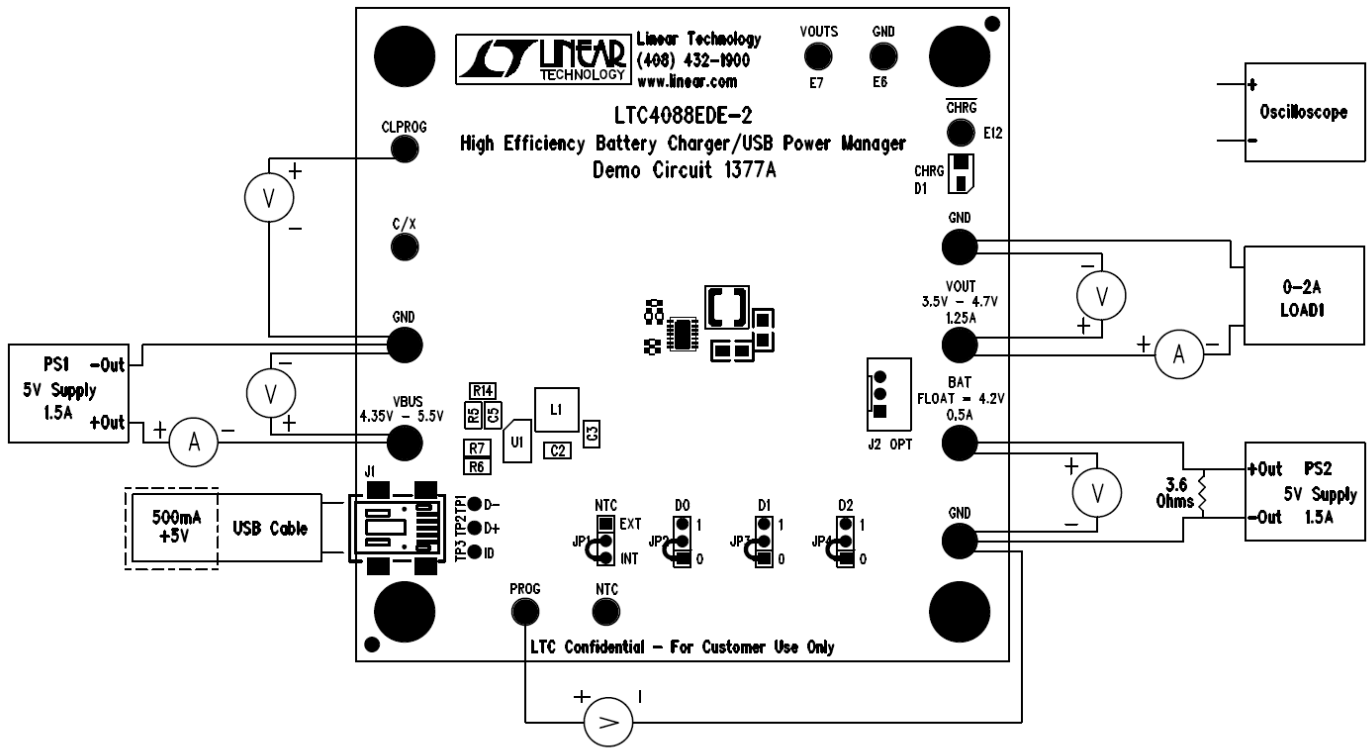


Figure 1. Proper Measurement Equipment Setup

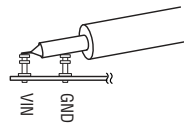
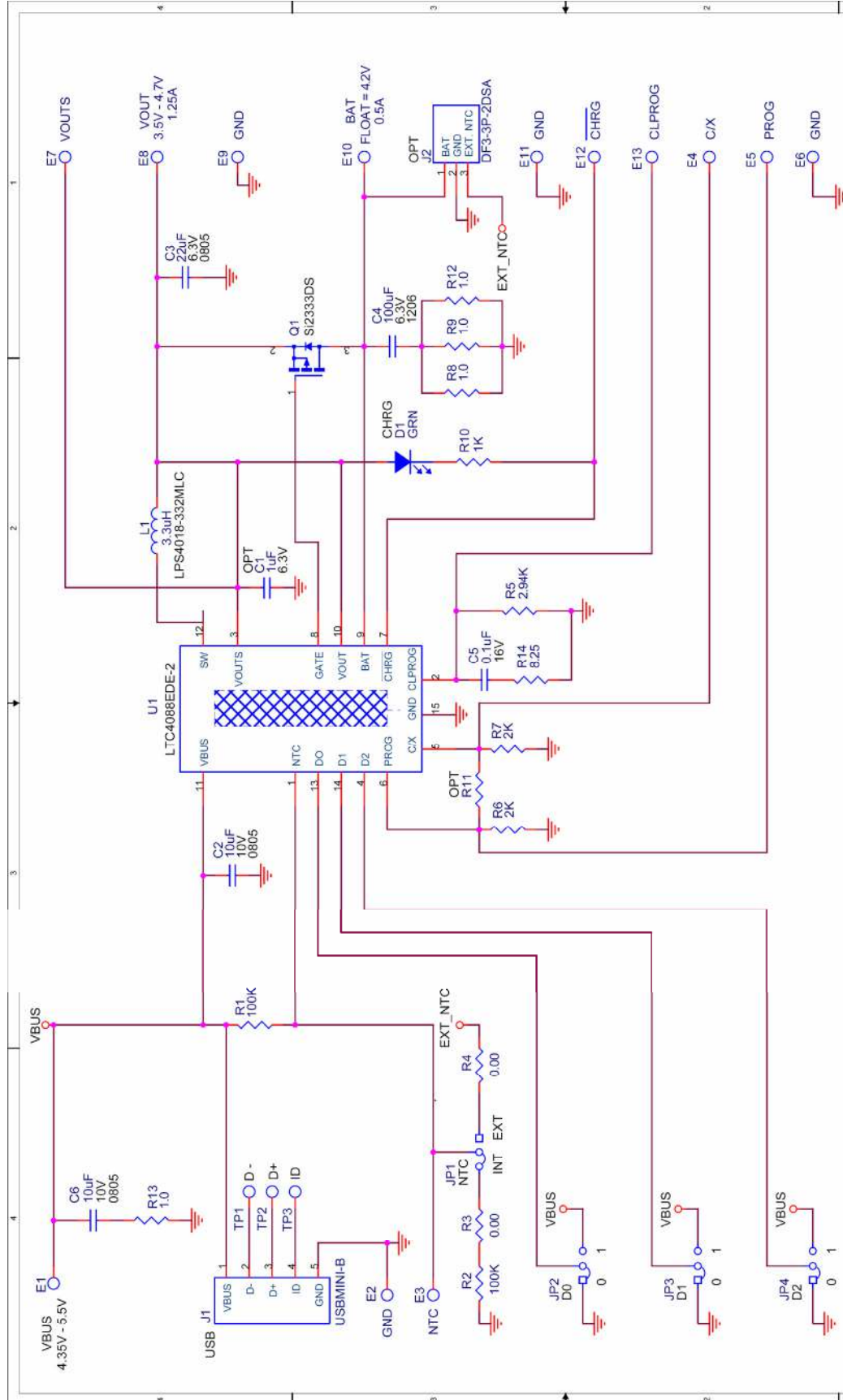


Figure 2. Measuring Input or Output Ripple



NOTE: UNLESS OTHERWISE NOTED,
ALL CAPACITORS AND RESISTORS ARE 0402,
ALL RESISTORS ARE 1%

INPUT CURRENT LIMIT SETTINGS

D0	D1	D2	CURRENT LIMIT	CHARGER STATUS
0	0	0	100mA (1X)	ON
0	0	1	100mA (1X)	OFF
0	1	0	500mA (5X)	ON
0	1	1	500mA (5X)	OFF
1	0	0	1A (10X)	ON
1	0	1	1A (10X)	OFF
1	1	0	500uA (SUSP)	OFF
1	1	1	2.5mA (SUSP)	OFF

CONTRACT NO.

APPROVALS

DRAWN: M. Marchant

CHECKED: M. Marchant

APPROVED:

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TITLE: SCHEMATIC LTC4088EDE-2

High Efficiency Battery Charger/USB Power Manager

SIZE: A

DWG NO.: DC1377A

DATE: Monday, May 05, 2008

SHEET 1 OF 1

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 LAYOUT MAY SIGNIFICANTLY 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.

Item	Qty	Reference - Des	Part Description	Manufacturer, Part #
REQUIRED CIRCUIT COMPONENTS:				
1	1	C2	CAP, CHIP, X5R, 10uF, 10V, 0805	MUR, GRM21BR61A106KE19
2	1	C3	CAP, CHIP, X5R, 22uF, 6.3V, 0805	TAIYO YUDEN, JMK212BJ226MG
3	1	C5	CAP, CHIP, X7R, 0.1uF, 16V, 0402	MUR, GRM155R71C104KA88
4	1	L1	IND, 3.3uH, 0.08Ohms, 2.2A	COILCRAFT, LPS4018-332MLC
5	1	R5	RES, 0402 2.94K OHMS 1% 1/10W	VISHAY, CRCW04022K94FKED
6	2	R6,R7	RES, 0402 2K OHM 1% 1/10W	VISHAY, CRCW04022K00FKED
7	1	R14	RES, 0402 8.25 OHMS 1% 1/16W	VISHAY, CRCW04028R25FNED
8	1	U1	USB BAT CHARGER/POWER MANAGER	LTC4088EDE-2
ADDITIONAL DEMO BOARD CIRCUIT COMPONENTS:				
1	0	C1 (OPT)	CAP, CHIP, X5R, 1.0uF, 6.3V, 0402	TDK, C1005X5R0J105M
2	1	C4	CAP, CHIP, X5R, 100uF, ±20%, 6.3V, 1206	MURATA, GRM31CR60J107ME39L
3	1	C6	CAP, CHIP, X5R, 10uF, 10V, 0805	MUR, GRM21BR61A106KE19
4	1	D1	LED, GREEN	PANASONIC, LN1351C-(TR)
5	1	Q1	XSTR, MOSFET P- CHANNEL	SILICONIX, Si2333DS
6	2	R1,R2	RES, 0402 100K OHMS, 1%, 1/10W	VISHAY, CRCW0402100KFKED
7	2	R3,R4	RES, 0402 0R0 OHMS 1% 1/10W	VISHAY, CRCW04020000Z0ED
8	4	R8,R9,R12,R13	RES, 0402 1 OHMS 1% 1/16W	VISHAY, CRCW04021R00FKED
9	1	R10	RES, 0402 1K OHMS 1% 1/10W	VISHAY, CRCW04021K00FKED
10	0	R11 (OPT)	RES, 0402 0 OHMS 1% 1/10W	VISHAY, CRCW04020000Z0ED
HARDWARE FOR DEMO BOARD ONLY:				
1	1	J1	CONN, USB MINI-B	TYCO, 1734035-2
2	0	J2 (OPT)	CONN, DF3-3P-2DSA	HIROSE, DF3-3P-2DSA
3	6	E1,E2,E8,E9,E10,E11	TURRET, 0.09 DIA	MILLMAX, 2501-2
4	7	E3,E4,E5,E6,E7,E12, E13	TURRET, 0.061 DIA	MILLMAX, 2308-2
5	4	JP1,JP2,JP3,JP4	HEADER,3 PINS 2mm	COMM, 2802S-03G2
6	4	JP1,JP2,JP3,JP4	SHUNT 2mm	SAMTEC, 2SN-BK-G
7	4		STANDOFFS	KEYSTONE, 8831