

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1189A

## HIGH EFFICIENCY BATTERY CHARGER/USB POWER MANAGER WITH REGULATED OUTPUT VOLTAGE

### LTC4088-1

## DESCRIPTION

Demonstration Circuit 1189 is a high efficiency USB power manager with PowerPath™ control and Li-Ion/Polymer battery charger featuring the LTC®4088-1. The LTC4088-1 includes a synchronous switching input regulator, a full-featured battery charger and an ideal diode. Designed specifically for USB applications, the LTC4088-1's switching regulator automatically limits its input current to either 100mA, 500mA 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 VBAT for high efficiency charging. This feature allows the LTC4088-1 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 CHRG 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. A 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 LTC4088-1 is available in the 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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**Table 1. Typical Specifications (25°C)**

|                                                         |                                           |
|---------------------------------------------------------|-------------------------------------------|
| Input Voltage Range, VBUS                               | 4.35V to 5.5V                             |
| VOUT                                                    | 3.5V to 4.7V (Mode and load dependent)    |
| 3.3V                                                    | 3.3V (Load and VOUT dependent)            |
| Output Float Voltage $V_{BAT}$ (constant voltage mode)  | 4.2V                                      |
| Output Charge Current $I_{BAT}$ (constant current mode) | 0.5A ( $R_{PROG}$ equals 2.00K $\Omega$ ) |

## QUICK START PROCEDURE

Refer to Table 1 for a listing of the inputs and outputs of the 1189 Demo Circuit. Demo Circuit 1189 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, which is required for battery charger stability.

Refer to Figure 1 for the proper measurement and equipment setup and follow the procedure below.

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 cable ready to plug in when all loads and jumpers are set.

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Do **not** use the USB input and an external supply at the same time.

- 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.
- Use Table 2 to set JP2, JP3, and JP4 (D0, D1, and D2 respectively) to select the desired input current limit and charger status.

**TABLE 2. Controlled Input Current Limit**

| D0 | D1 | D2 | CHARGER | I <sub>LIM</sub> |
|----|----|----|---------|------------------|
| 0  | 0  | 0  | OFF     | 100mA(1x)        |
| 0  | 0  | 1  | ON      | 100mA(1x)        |
| 0  | 1  | 0  | OFF     | 500mA(5x)        |
| 0  | 1  | 1  | ON      | 500mA(5x)        |
| 1  | 0  | 0  | OFF     | 1A(10x)          |
| 1  | 0  | 1  | ON      | 1A(10x)          |
| 1  | 1  | 0  | OFF     | 2.5mA(Susp High) |
| 1  | 1  | 1  | OFF     | 500uA(Susp Low)  |

- 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.
- 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. The voltage on CLPROG will read 1.188 Volts when the input current limit is reached. Observe VOUT.

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

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

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

- 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 LTC4088-1 starts to use the VBUS input power as VBUS reaches 4.35V.
- 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 JP2. Observe the CHRG LED slow blinking rate. Also observe the 35KHz pulse with varying duty cycle between 4.7% and 95.3% on the CHRG terminal with an oscilloscope. Reinstall the NTC jumper.
- Increase the VOUT load and observe when the input current starts to limit ( $V_{CLPROG}=1.188$  V). When input current limit is reached, VOUT drops from 300 mV 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 charge and load current may be significantly above the input current depending on the voltage on the BAT pin.

9. Repeat step 9 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 data sheet for more information on how this part performs.

## APPLICATION INFORMATION

This demo circuit is designed to demonstrate the full capability of the LTC4088-1 High Efficiency Battery Charger. Not all components are required in all applications. The critical circuit components are on the top of the board near the IC and listed in the Required Circuit Components section of the Bill-of-Materials below.

The input capacitor network of C7 and R13 is used to dampen source lead inductances that commonly occur in laboratory setups with twisted leads and a bench power supply. When using an USB cable or adaptor cable this input damping network will likely not be required. Please note that the in-circuit capacitance of the specified 10uF, 0805 ceramic capacitor for C2 and C7 is approximately 5uF each at a VBUS greater than 4.25 Volts.

Capacitor C4 is only required when using the 10X mode. The LTC4088-1 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.

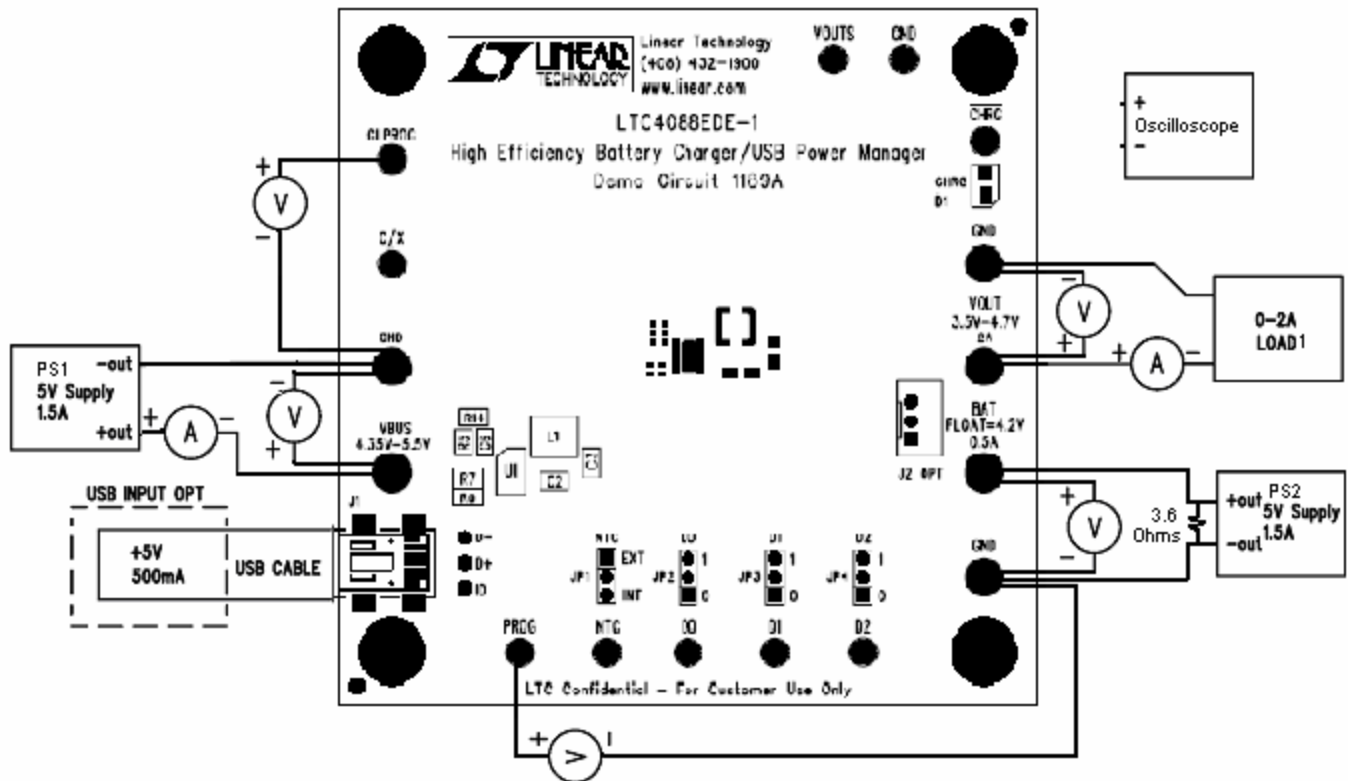
Capacitor C5 is included to simulate a low impedance battery. It is especially helpful when testing the demo circuit with a battery simulator comprised of a standard power supply with a 3.6 Ohm power resistor across it. The leads connecting the power supply to the demo circuit should be a twisted pair 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 C5. Capacitor C5 will also provide proper operation of the circuit without a battery present. Refer to the datasheet for more discussion of operation without a battery. 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.

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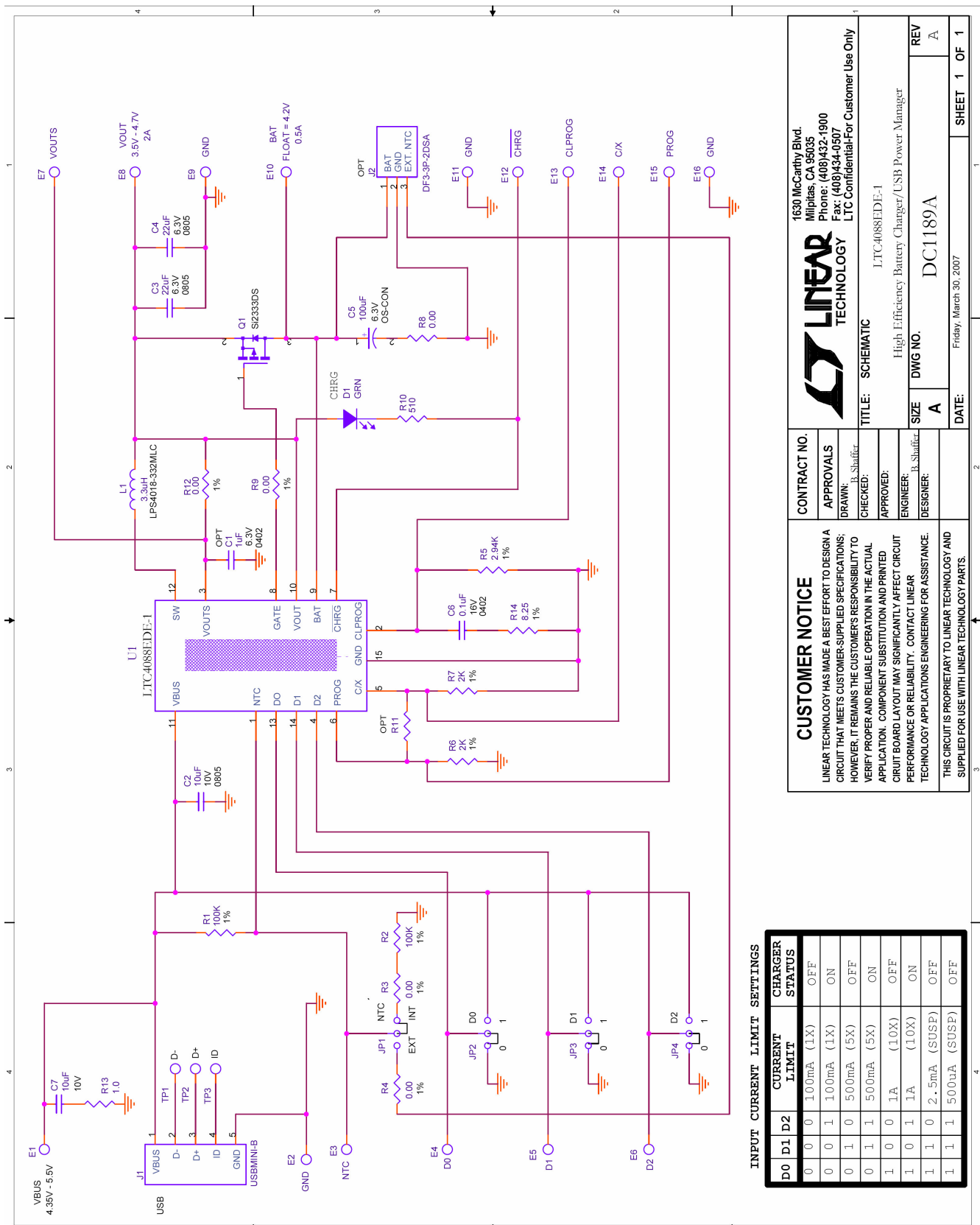
### WITH REGULATED OUTPUT VOLTAGE

**LTC4088-1**



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INPUT CURRENT LIMIT SETTINGS

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

**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.

CONTRACT NO.

APPROVALS

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APPROVED:

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**LINEAR TECHNOLOGY**

TITLE: SCHEMATIC

LTC4088IDE-1

High Efficiency Battery Charger/USB Power Manager

SIZE: A

DWG NO.: DC1189A

REV: A

DATE: Friday, March 30, 2007

SHEET 1 OF 1

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## HIGH EFFICIENCY BATTERY CHARGER/USB POWER MANAGER

### WITH REGULATED OUTPUT VOLTAGE

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| Item                                             | Qty | Reference - Des                    | Part Description                      | Manufacturer, Part #           |
|--------------------------------------------------|-----|------------------------------------|---------------------------------------|--------------------------------|
| <b>REQUIRED CIRCUIT COMPONENTS:</b>              |     |                                    |                                       |                                |
| 1                                                | 1   | C2                                 | CAP, CHIP, X5R, 10uF, 10V, 0805       | MUR, GRM21BR61A106KE19         |
| 2                                                | 1   | C3                                 | CAP, CHIP, X5R, 22uF, 6.3V, 0805      | MUR, GRM21BR60J226ME39         |
| 3                                                | 1   | C6                                 | CAP, CHIP, X7R, 0.1uF, 16V, 0402      | MUR, GRM155R71C104KA88         |
| 4                                                | 1   | L1                                 | IND, 3.3uH, 0.08 OHMS, 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                                 | BAT CHARGER/USB POWER MANAGER         | LINEAR TECHNOLOGY LTC4088EDE-1 |
| <b>ADDITIONAL DEMO BOARD CIRCUIT COMPONENTS:</b> |     |                                    |                                       |                                |
| 1                                                | 0   | C1 (OPT)                           | CAP, CHIP, X5R, 1.0uF, 6.3V, 0402     | TDK, C1005X5R0J105M            |
| 2                                                | 1   | C4                                 | CAP, CHIP, X5R, 22uF, 6.3V, 0805      | MUR, GRM21BR60J226ME39         |
| 3                                                | 1   | C5                                 | CAP, CHIP OS-CON, 100uF, 6.3V, B6     | SANYO, 6SVPC100MY              |
| 4                                                | 1   | C7                                 | CAP, CHIP, X5R, 10uF, 10V, 0805       | MUR, GRM21BR61A106KE19         |
| 5                                                | 1   | D1                                 | LED, GREEN                            | PANASONIC, LN1351C-(TR)        |
| 6                                                | 1   | Q1                                 | XSTR, MOSFET P- CHANNEL               | SILICONIX, Si2333DS            |
| 7                                                | 2   | R1, R2                             | RES, 0402, 100K OHMS, 1%, 1/10W       | VISHAY, CRCW0402100KFKED       |
| 8                                                | 5   | R3, R4, R8, R9, R12                | RES, 0402 0 OHMS 1% 1/10W             | VISHAY, CRCW04020000Z0ED       |
| 9                                                | 1   | R10                                | RES, 0402 510 OHMS 1% 1/10W           | VISHAY, CRCW0402510RFKED       |
| 10                                               | 0   | R11 (OPT)                          | RES, 0402 0 OHMS 1% 1/10W             | VISHAY, CRCW04020000Z0ED       |
| 11                                               | 1   | R13                                | RES, 0402 1 OHMS 1% 1/16W             | VISHAY, CRCW04021R00FKED       |
| <b>HARDWARE FOR DEMO BOARD ONLY:</b>             |     |                                    |                                       |                                |
| 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                                                | 10  | E3,E4,E5,E6,E7,E12,E13,E14,E15,E16 | TURRET, 0.061 DIA                     | MILLMAX 2308-2                 |
| 5                                                | 4   | JP1,JP2,JP3,JP4                    | HEADER, 3 PINS 2mm                    | SAMTEC, TMM-103-02-L-S         |
| 6                                                | 4   | JP1,JP2,JP3,JP4                    | SHUNT 2mm                             | SAMTEC, 2SN-BK-G               |
| 7                                                | 4   |                                    | STAND-OFF, NYLON 0.25" tall (SNAP ON) | KEYSTONE, 8831 (SNAP ON)       |