

# LTC4121EUD/LTC4121EUD-4.2 400mA Synchronous Buck Battery Charger

## DESCRIPTION

|           |                                |
|-----------|--------------------------------|
| DC1977A-A | LTC4120EUD-4.2 (Fixed Output)  |
| DC1977A-B | LTC4121EUD (Adjustable Output) |

Demonstration Board DC1977A showcases the [LTC4121-4.2](#) and [LTC4121](#) 40V, 400mA synchronous-buck battery charger integrated circuit. The DC1977A supports the maximum-power-point tracking (MPPT) feature of the LTC4121EUD to optimize power delivery from photovoltaic cells or highly resistive sources.

The LTC4121 and LTC4121-4.2 feature constant-current-constant-voltage charging capability suitable for lithium-ion or lead-acid cells. The LTC4121-4.2 supports charging a single lithium-ion cell with a cell voltage of 4.2V. The LTC4121 may be programmed to charge battery voltages up to 18V with a resistive divider.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC1977>**

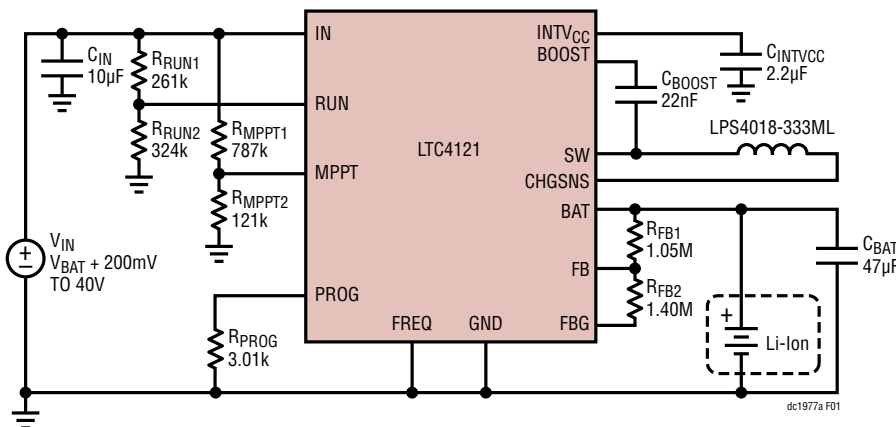
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## PERFORMANCE SUMMARY Specifications are at T<sub>A</sub> = 25°C

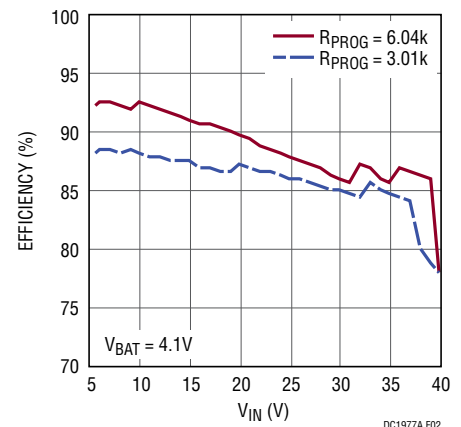
| SYMBOL           | PARAMETER               | CONDITIONS<br><small>Note: Reference designators refer to Schematic on p. 7.</small> | MIN | TYP | MAX  | UNITS |
|------------------|-------------------------|--------------------------------------------------------------------------------------|-----|-----|------|-------|
| IN               | DC1977A Input Voltage   | I(IN) < 800mA                                                                        | 4.4 |     | 40   | V     |
| PV <sub>IN</sub> | DC1977A PV Cell Input   | I(IN) < 800mA                                                                        | 5   |     | 40.5 | V     |
| V(BAT)           | DC1977A BAT Pin Voltage | R11 = 1.40MΩ, R12 = 1.05MΩ                                                           | 2.5 |     | 4.25 | V     |
| I(BAT)           | DC1977A BAT Pin Current | V(BAT) = 3.7V; DC1977A; (R7) = 3.01kΩ; JP1 ("MPPT") = 'OFF'                          | 383 | 402 | 421  | mA    |

## DEMO BOARD APPLICATION

### High Efficiency, Wide Input Voltage Range Charging with LTC4121



### LTC4121 Efficiency vs V<sub>IN</sub>



# DEMO MANUAL

## DC1977A-A/DC1977A-B

### ASSEMBLY TEST PROCEDURE

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

1. Set JP1 ("MPPT") to 'ON', set PS1 to 3.6V and turn on.
2. Connect PS2 to point A, set to 15V and turn on.
3. Verify that VM1 indicates 3.3V to 3.9V, and then verify that AM1 indicates 387mA to 417mA. Verify that VM2 shows 14.5V to 15.1V. There is only a series diode between PV+ and the  $V_{IN}$  pin of the LTC4121. The purpose of this diode is prevent backfeeding a PV cell, if connected. A single diode  $V_f$  is insufficient to activate the MPPT feature, and the LTC4121 delivers full charge current to the battery.
4. Turn PS2 off, move connection to point B, and turn PS2 on.
5. Verify that VM1 indicates 3.3V to 3.9V, and then verify that AM1 indicates 387mA to 417mA. Verify that VM2 shows 12.6V to 13.2. The source impedance of the power supply is now  $\approx 16\Omega$ . But this impedance still allows delivering full charge current without engaging the MPPT feature.
6. Turn PS2 off, move connection to Point C, and turn PS2 on.
7. Verify that VM1 indicates 3.3V to 3.9V, and then Verify that AM1 indicates 105mA to 115mA. Verify that VM2 shows 10.6V to 11.3V. The source impedance of the power supply is now  $98\Omega$ . The MPPT feature has engaged and the charge delivered to the battery has been reduced to allow  $V_{IN}$  to stay at the programmed MPPT point.
8. Set JP1 ("MPPT") to 'OFF', test is finished.

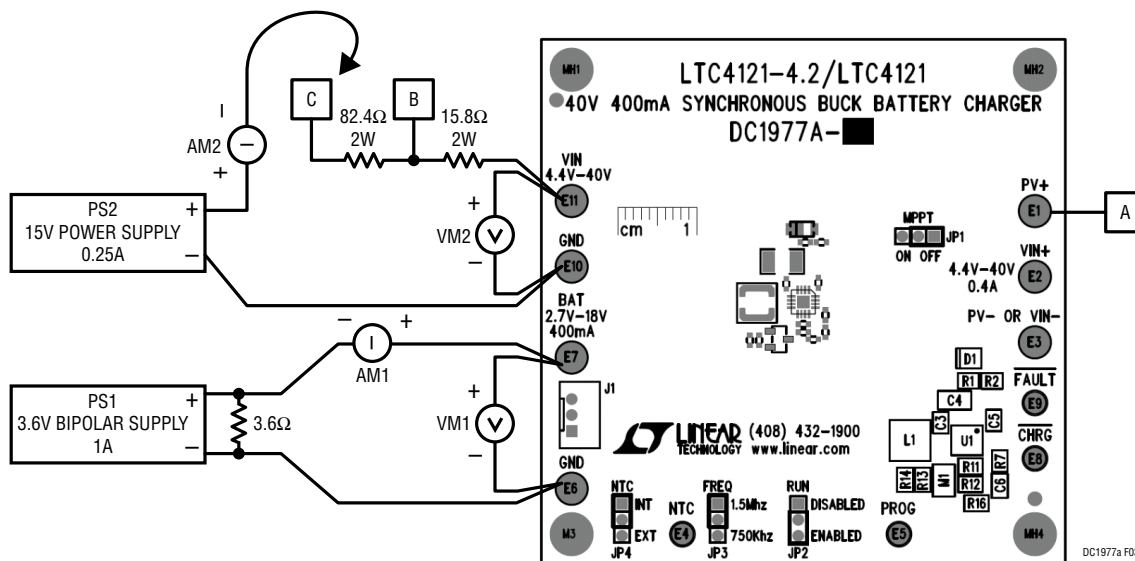


Figure 1. DC1977A Equipment Setup

Note: All connections from equipment should be kelvin-connected directly to the board pins which they are connected on this diagram. All input or output leads should be twisted pair.

## THEORY OF OPERATION

The LTC4121EUD-4.2/LTC4121EUD is a 4.4V ~ 40V input buck topology battery charger with maximum power point tracking (MPPT) for use with PV cells or highly resistive power supplies. The buck-topology charger uses current mode control for stable operation.

### LTC4121EUD ENABLE

The LTC4121 can be enabled or disabled via the RUN pin, and this functionality can be accessed via JP2, the RUN jumper. When JP2 is in the “ENABLE” position, R3 and R4 ensure that the LTC4121 is not enabled until  $V_{in}$  is greater than 4.4V.

**Note: Do not float the LTC4121 RUN pin. Operate the demo board with JP2 in either the DISABLED or ENABLED position.**

### Buck Charger

The heart of the LTC4121EUD is the buck-topology battery charger. The buck-topology charger is a synchronous, current-mode-control regulator with N-channel FETs. The use of N-channel FETs minimizes conduction losses, and requires only a single external 0.022 $\mu$ F capacitor to generate the high-side gate drive.

The LTC4121EUD can charge up to four Li-Ion cells in series, and supports a maximum battery voltage of 18V. The LTC4121EUD-4.2 is optimized for charging a single Li-Ion cell to a fixed cell voltage of 4.2V.

The current in the buck inductor passes through a small on-die resistor for current measurement, and then goes back out to the BAT pin. The battery is connected to the BAT pin; this allows the LTC4121EUD to measure not only the cycle-by-cycle current, but also the average current. The cycle-by-cycle current is used by the current-mode buck regulator, and the average current is the battery charge current as programmed by  $R_{PROG}$ . On DC1977A,  $R_{PROG} = 3.01k\Omega$ , so  $I(BAT) = 402mA$  provided that the MPPT function does not reduce the current.

The buck regulator acts as a current source when the battery is in the constant-current charging region and as a classic voltage output buck regulator when the battery is in the constant-voltage charging region.

The battery charge current is programmed by  $R_{PROG} = 3.01k\Omega$ . The equation for  $R_{PROG}$  is:

$$R_{PROG} = h_{PROG} \cdot \frac{V_{PROG}}{I_{CHG}} = 986 \cdot \frac{1.227V}{0.4} = 3.01k\Omega$$

The LTC4121EUD provides a switching frequency select pin, FREQ, to select between 750kHz and 1.5MHz; this function is accessed by JP4, the “FREQ” jumper.

**Note: Do not float the LTC4121 FREQ pin. Operate the demo board with JP3 in either the 750kHz or 1.5MHz position.**

Figure 2 shows various nodes of interest with  $V_{IN} = 5V$ , and the switching frequency at 750kHz ( $T = 1.333\mu s$ ). The duty cycle is 86% for  $V(BAT) = 3.6V$ , not the 72% duty expected from a buck regulator. When the battery voltage is 3.6V, the charger is in constant-current mode, so the control loop is forcing the output of the buck regulator to the voltage necessary to push 400mA into the battery. This “effective” voltage,  $5 \cdot 0.86 = 4.3V$ , is the voltage necessary to ensure that a 400mA average current is flowing through the on-die sense resistor.

Figure 3 shows the same nodes as Figure 2, but with  $V_{IN} = 40V$ . The switching frequency is still 750kHz. The duty cycle is  $\approx 200ns/1.333\mu s$ , or 15%, but the period is 2.7 $\mu s$ . This is because the LTC4121 minimum on time was greater than that needed to achieve 4.3V, and the LTC4121 starts to pulse skip to get the necessary average duty cycle. The average duty cycle is  $300ns/2.667\mu s = 11\%$ . This produces an output voltage of 4.3V, so the battery still charges at 400mA.

### Maximum Power Point Tracking (MPPT)

The LTC4121EUD provides a maximum-power-point tracking (MPPT) function for use with PV cells or highly

### THEORY OF OPERATION

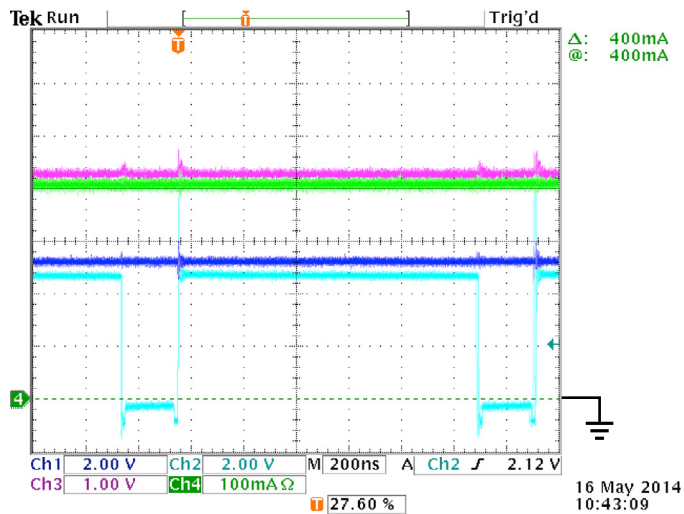


Figure 2. Normal Operation, Zoom,  $V_{IN} = 5.1V$ , DK. Blue =  $V_{IN}$ , Grn =  $I_{CHARGE}$ , LT. Blue =  $V_{SW}$ , Pk. =  $INTV_{CC}$ , 750kHz

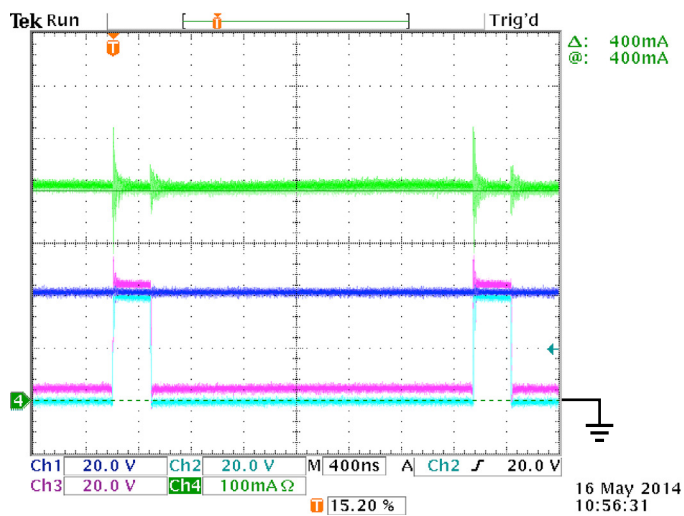


Figure 3. Normal Operation, Zoom,  $V_{IN} = 40V$ , DK. Blue =  $V_{IN}$ , Grn =  $I_{CHARGE}$ , LT. Blue =  $V_{SW}$ , Pk. =  $V_{BOOST}$ , 750kHz

resistive power supplies. The MPPT pin allows programming of the MPPT point as a percentage of the open-circuit  $V_{IN}$  ( $V_{OC}$ ). To access this functionality the demo board provides JP1, the “MPPT” jumper, and R1 and R2.

It is important to note that the disabled position for MPPT is the MPPT pin at  $V_{IN}$ . To enable MPPT, set the MPPT point as a fraction of  $V_{OC}$ . See the discussion in Maximum Power Point Tracking section of the LTC4121 data sheet.

When MPPT is enabled (not equal to  $V_{IN}$ ), the LTC4121EUD periodically disconnects the load from the power source, and measures  $V_{IN}$  with no load =  $V_{OC}$ . It then increases the load on  $V_{IN}$  to meet charger demand until the  $V_{MPPT}$  threshold is reached, after which it no longer increases the load. This allows the MPPT voltage divider to set the desired MPPT point as a percentage of  $V_{IN}$  with no load.

Figure 4 shows the LTC4121EUD operating from a source impedance of  $98\Omega$ . The MPPT pin of the LTC4121EUD sets the MPPT point to 0.75 of the open-circuit voltage. First,  $V_{OC}$  is determined by removing all load and letting  $V_{IN}$  rise to  $V_{OC}$ . The power drawn from  $V_{IN}$  is increased until the voltage at  $V_{IN}$  falls to the MPPT point,  $0.75 \cdot V_{OC} = 0.75 \cdot 15V = 11.25V$ . The resolution of the MPPT DAC is 330mV, thus this example has the MPPT point at 11V. The LTC4121 stops drawing power at this point, and the charge current (green) never exceeds 200mA, even though the Rprog value was chosen for 400mA.

Figure 5 shows the same system, but the source impedance was lowered to  $16\Omega$ . Consequently, the full power needed to meet the requirements of the programmed charge current is available before  $V_{IN}$  falls to the MPPT voltage.

## THEORY OF OPERATION

### Battery capacitors C1 and C2

The maximum battery voltage for the LTC4121EUD is 18V, and for the LTC4121EUD-4.2, it is 4.2V. Analog Devices recommends 47 $\mu$ F of capacitance on the BAT pin, if the battery is not present. For the LTC4121EUD the voltage rating of the capacitor will need to be 25V, so two 22 $\mu$ F, 25V, MLCC capacitors are used. In the case of the LTC4121EUD-4.2, a 6.3V capacitor will suffice, and a single 47 $\mu$ F, 6.3V, MLCC capacitor is used for C1, with C2 not placed.

### Reverse-Blocking Circuit

Components Q1, R16 and C6 comprise a reverse-blocking circuit. The circuit performs two functions. First, the circuit prevents the battery from back-charging the power source when the power source is dormant (e.g., a solar cell in the absence of illumination). Note that this functionality can also be provided through D1. Second, when a charged battery is connected to the circuit in the absence of input voltage, current will flow from the battery into the BAT pin and out the IN pin, charging C4. With battery voltages in excess of ~10V, this current surge can destroy the device. Note that this is not a problem when only one or two series Li-Ion cells are employed. Thus, this reverse-blocking circuit may not be necessary depending on the application. If reverse-blocking is not required, C6 and R16 also become unnecessary. These two components provide a path to the BAT pin from which the LTC4121 derives bias for internal circuits which would be provided by the battery directly in the absence of Q1. See, for example, the application on the first page of this manual.

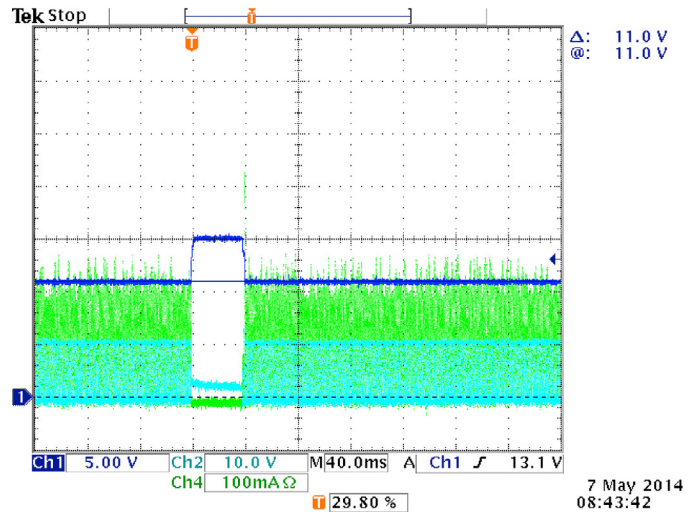


Figure 4. MPPT Test, DK. Blue =  $V_{IN}$  (Through 98 $\Omega$ ), Green =  $I_L$ , LT. Blue =  $V(SW)$ ,  $k = 0.15$ ,  $V_{MPPT}/V_{OC} = 0.75$

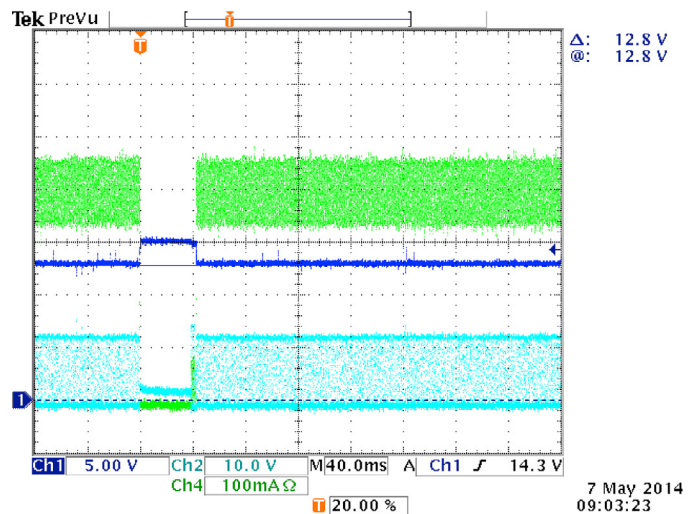


Figure 5. MPPT Test, DK. Blue =  $V_{IN}$  (Through 16 $\Omega$ ), Green =  $I_L$ , LT. Blue =  $V(SW)$ ,  $k = 0.15$ ,  $V_{MPPT}/V_{OC} = 0.75$

# DEMO MANUAL

## DC1977A-A/DC1977A-B

### PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------|-----|-----------|------------------|--------------------------|
|------|-----|-----------|------------------|--------------------------|

#### DC1977A General Bill of Materials

##### Required Circuit Components

|   |   |    |                                                                          |                              |
|---|---|----|--------------------------------------------------------------------------|------------------------------|
| 1 | 1 | C3 | CAP, CHIP, X7R, 0.022 $\mu$ F, $\pm$ 10%, 50V, 0402                      | TDK, C1005X7R1E223K          |
| 2 | 1 | C4 | CAP, CHIP, X5R, 10 $\mu$ F, $\pm$ 10%, 50V, 1210                         | TAIYO-YUDEN, UMK325BJ106KM-T |
| 3 | 1 | C5 | CAP, CHIP, X5R, 2.2 $\mu$ F, $\pm$ 20%, 6.3V, 0402                       | MURATA, GRM155R60J225ME15D   |
| 4 | 1 | L1 | IND, SMT, 33 $\mu$ H, 420m $\Omega$ , $\pm$ 20%, 0.80A, 4mm $\times$ 4mm | COILCRAFT, LPS4018-333ML     |
| 5 | 1 | R1 | RES, CHIP, 787k $\Omega$ , $\pm$ 1%, 1/16W, 0402                         | VISHAY, CRCW0402787KFKED     |
| 6 | 1 | R2 | RES, CHIP, 121k $\Omega$ , $\pm$ 1%, 1/16W, 0402                         | VISHAY, CRCW0402121KFKED     |
| 7 | 1 | R3 | RES, CHIP, 261k $\Omega$ , $\pm$ 1%, 1/16W, 0402                         | VISHAY, CRCW0402261KFKED     |
| 8 | 1 | R4 | RES, CHIP, 324k $\Omega$ , $\pm$ 1%, 1/16W, 0402                         | VISHAY, CRCW0402324KFKED     |
| 9 | 1 | R7 | RES, CHIP, 3.01k $\Omega$ , $\pm$ 1, 1/16W, 0402                         | VISHAY, CRCW04023K01FKED     |

##### Additional Demo Board Circuit Components

|    |   |         |                                                       |                            |
|----|---|---------|-------------------------------------------------------|----------------------------|
| 1  | 1 | C6      | CAP, CHIP, X5R, 4.7 $\mu$ F, $\pm$ 20%, 6.3V, 0603    | MURATA, GRM188R60J475KE19D |
| 2  | 1 | D1      | DIODE, SCHOTTKY, 40V, 2A, PowerDI123                  | DIODES, DFLS240L           |
| 3  | 1 | M1      | MOSFET, P-Channel, -30V, -5.9A, 45m $\Omega$ , SOT-23 | VISHAY, Si2343CDS          |
| 4  | 2 | R5, R9  | RES, CHIP, 10k $\Omega$ , $\pm$ 1%, 1/16W, 0402       | VISHAY, CRCW040210K0FKED   |
| 5  | 1 | R6      | RES, CHIP, 2k $\Omega$ , $\pm$ 5%, 1/16W, 0402        | VISHAY, CRCW04022K00JNED   |
| 6  | 2 | R8, R10 | RES, CHIP, 0 $\Omega$ jumper, 1/16W, 0402             | VISHAY, CRCW04020000Z0ED   |
| 7  | 1 | R13     | RES, CHIP, 47k $\Omega$ , $\pm$ 5%, 1/16W, 0402       | VISHAY, CRCW040247K0JNED   |
| 8  | 1 | R14     | RES, CHIP, 5.1k $\Omega$ , $\pm$ 1%, 1/16W, 0402      | VISHAY, CRCW04025K10JNED   |
| 9  | 1 | R15     | RES, CHIP, 100k $\Omega$ , $\pm$ 5%, 1/16W, 0402      | VISHAY, CRCW0402100KJNED   |
| 10 | 1 | R16     | RES, CHIP, 464k $\Omega$ , $\pm$ 1%, 1/10W, 0603      | YAGEO, RC0603FR-07464KL    |

##### Hardware: For Demo Board Only

|   |   |                              |                         |                                   |
|---|---|------------------------------|-------------------------|-----------------------------------|
| 1 | 7 | E1, E2, E3, E6, E7, E10, E11 | TURRET, 0.09 DIA        | MILL-MAX, 2501-2-00-80-00-00-07-0 |
| 2 | 4 | E4, E5, E8, E9               | TURRET, 0.061"          | MILL-MAX, 2308-2-00-80-00-00-07-0 |
| 3 | 0 | J1-OPT                       | CONN, 3 Pin Polarized   | HIROSE, DF3-3P-2DSA               |
| 4 | 4 | JP1-JP4                      | HEADER, 3 Pin, SMT, 2mm | SULLIN, NRPNO31PAEN-RC            |
| 5 | 4 | JP1-JP4                      | SHUNT, 2mm              | SAMTEC, 2SN-BK-G                  |

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------|-----|-----------|------------------|--------------------------|
|------|-----|-----------|------------------|--------------------------|

#### DC1977A-A Bill of Materials

##### Required Circuit Components

|   |   |     |                                                                        |                                  |
|---|---|-----|------------------------------------------------------------------------|----------------------------------|
| 1 | 0 | R11 | DO NOT INSTALL                                                         |                                  |
| 2 | 1 | R12 | RES, CHIP, 0 $\Omega$ jumper, 1/16W, 0402                              | VISHAY, CRCW04020000Z0E          |
| 3 | 1 | U1  | 40V 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER, 3mm $\times$ 3mmQFN16 | LINEAR TECH., LTC4121EUD-4.2#PBF |
| 1 | 1 | C1  | CAP, CHIP, X5R, 47 $\mu$ F, $\pm$ 10%, 16V, 1210                       | MURATA, GRM32ER61C476KE15L       |
| 2 | 0 | C2  | CAP, CHIP, X5R, 47 $\mu$ F, $\pm$ 10%, 16V, 1210                       | MURATA, GRM32ER61C476KE15L       |

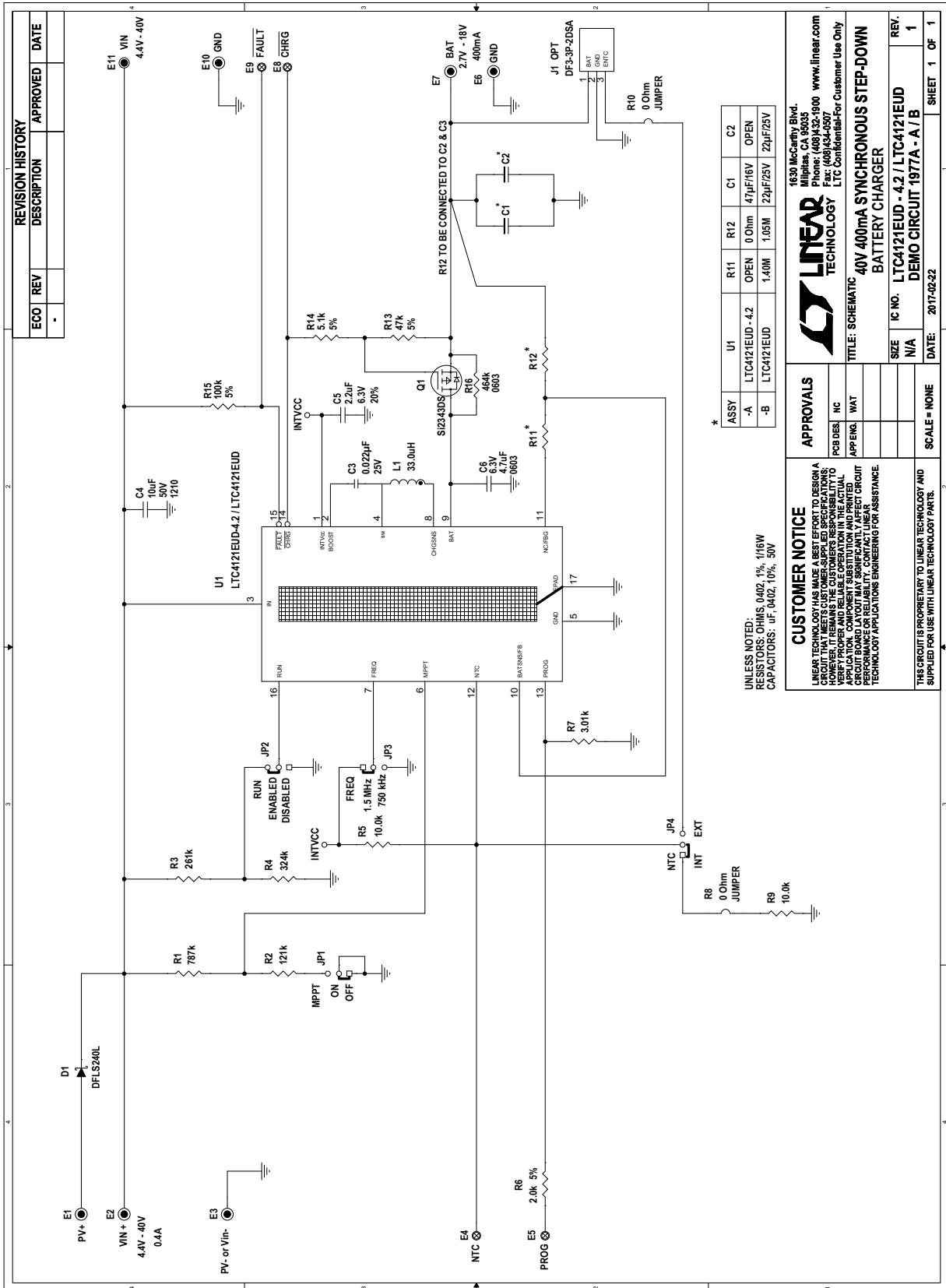
| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------|-----|-----------|------------------|--------------------------|
|------|-----|-----------|------------------|--------------------------|

#### DC1977A-B Bill of Materials

##### Required Circuit Components

|   |   |        |                                                                         |                             |
|---|---|--------|-------------------------------------------------------------------------|-----------------------------|
| 1 | 1 | R11    | RES, CHIP, 1.40M $\Omega$ , $\pm$ 1%, 1/16W, 0402                       | VISHAY, CRCW04021M40FKE     |
| 2 | 1 | R12    | RES, CHIP, 1.05M $\Omega$ , $\pm$ 1%, 1/16W, 0402                       | VISHAY, CRCW04021M05FKED    |
| 3 | 1 | U1     | 40V, 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER, 3mm $\times$ 3mmQFN16 | LINEAR TECH., LTC4121EUD#PB |
| 1 | 2 | C1, C2 | CAP, CHIP, X5R, 47 $\mu$ F, $\pm$ 10%, 16V, 1210                        | MURATA, GRM32ER61C476KE15L  |

## SCHEMATIC DIAGRAM



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**40V 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER**

TITLE: SCHEMATIC

IC NO. LTC4121EUD-4.2 / LTC4121EUD

REV. 1

DEMO CIRCUIT 1977A - A / B

DATE: 2017-02-22

SCALE = NONE

SHEET 1 OF 1

# DEMO MANUAL

## DC1977A-A/DC1977A-B

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### DEMONSTRATION BOARD IMPORTANT NOTICE

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.

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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.

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