LTC4121EUD/LTC4121EUD-4.2 400mA Synchronous Buck Battery Charger

DESCRIPTION

Demonstration circuit 1977A is the demonstration board for LTC®4121EUD-4.2/LTC4121EUD, a 400mA Synchronous Buck Battery Charger. The DC1977A supports the Maximum Power Point Tracking (MPPT) feature on the LTC4121EUD, for use with Photovoltaic (PV) cells or highly resistive sources.

FEATURED PART	
DC1977A-A	LTC4121EUD-4.2 (Fixed Output)
DC1977A-B	LTC4121EUD (Adjustable Output)

The LTC4121EUD is typically used with PV cells to charge

batteries with the maximum power available from the PV cell. It is also used if the power supply is highly resistive, such as applications that are at the end of very long wire runs.

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

PERFORMANCE SUMMARY Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
IN	DC1977A Input Voltage	I(IN) < 800mA	4.4		40	V
PV_{IN}	DC1977A PV Cell Input	I(IN) < 800mA	5		40.5	V
V(BAT)	DC1977A BAT Pin Voltage	R_{FB2} = 1.40MΩ, R_{FB1} = 1.05MΩ	2.4		4.25	V
I(BAT)	DC1977A BAT Pin Current	V(BAT) = 3.7V, DC1977A(R5) = 3.01kΩ, JP1 ("MPPT") = 'OFF'	370	385	400	mA

TYPICAL APPLICATION

High Efficiency, Wide Input Voltage Range Charging with LTC4121

dc1977a F01
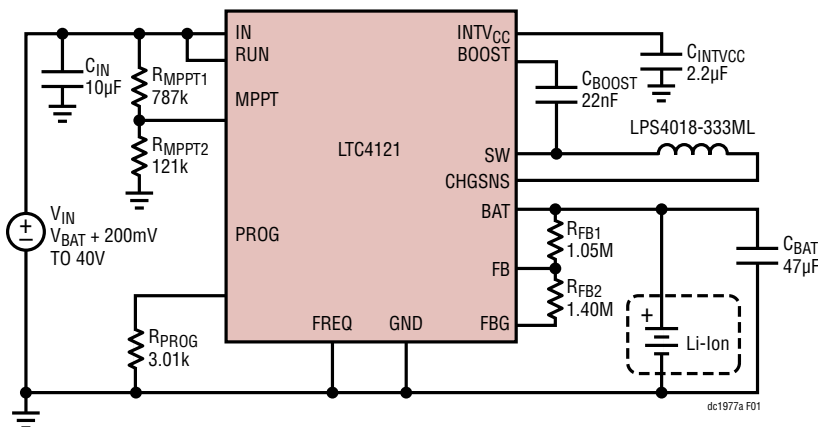
LTC4121 Efficiency vs V_{IN} at V_{FLOAT} = 8.4V

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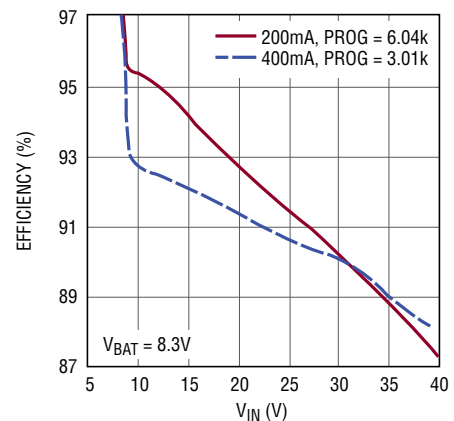
ASSEMBLY TEST PROCEDURE

Refer to Figure 1 for the proper measurement equipment setup and jumper settings 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 V_{CC} or V_{IN} and GND terminals. See Figure 2 for proper scope probe technique.

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 less than 4V, and then verify that AM1 indicates 380mA ~ 400mA. Verify that VM2 shows 14V ~ 14.5 V. 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 Vf 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 less than 4V, and then verify that AM1 indicates between 380mA ~ 400mA. Verify that VM2 shows 2.15V ~ 3.5V. The source impedance of the power supply is now ≈ 16Ω. 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 less than 4V, and then Verify that AM1 indicates 100mA ~150mA. Verify that VM2 shows 10V ~ 11V. The source impedance of the power supply is now 98Ω. 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.
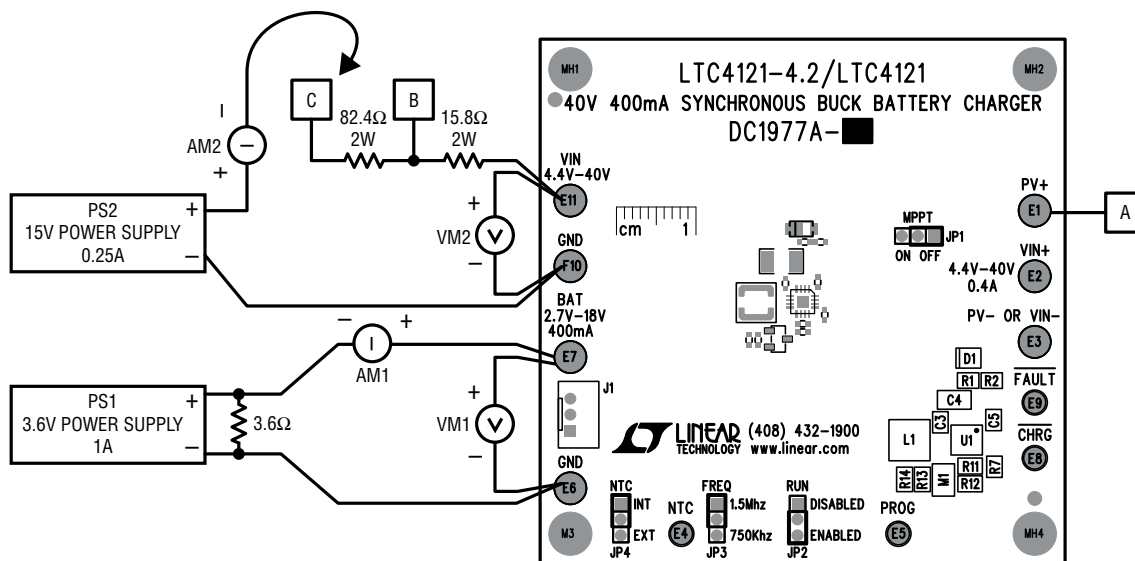
8. Set JP1 ("MPPT") to 'OFF', test is finished.

Figure 1. DC1977A Equipment Setup
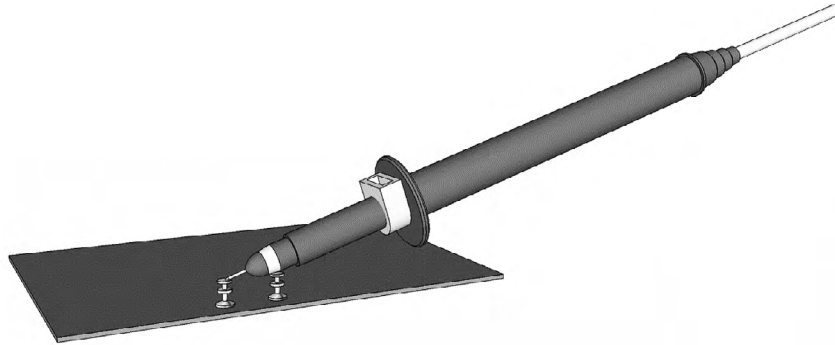
ASSEMBLY TEST PROCEDURE

Figure 2. Measuring Input or Output Ripple

Note: All connections from equipment should be Kelvin connected directly to the board pins which they are connected on this diagram and any 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 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 (see schematic) ensure that the LTC4121 is not enabled until V_{IN} is greater than 4.4V.

Buck Charger

The heart of the LTC4121EUD is the buck topology charger. The buck topology charger is a synchronous current mode regulator with N-channel FETs. The use of N-channel FETs optimizes die area, and only requires a single external 0.022µF capacitor for boostrapping the high side gate drive.

The LTC4121EUD can charge up to 4 Li-Ion batteries in series, and has a maximum float voltage of 18V. The LTC4121EUD-4.2 is optimized for charging a single Li-Ion battery, and has a fixed float voltage of 4.2V.

The buck inductor does not terminate in a capacitor, as in a buck voltage regulator, but rather goes through a small on-die metal 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 Rprog. On the DC1977A, Rprog = 3.01kΩ, so I(BAT) = 400mA, if the MPPT function does not reduce the current.

The buck regulator thus acts as a current source when the battery is in the constant current (CC) charging region and as a classic voltage output buck regulator when the battery is in the constant voltage (CV) charging region. In the constant voltage region, the battery becomes the output capacitor. If no battery is present, please ensure that the capacitors documented in the data sheet are installed on the board, to provide charge storage for the buck regulator.

The battery charge current is programmed by Rprog = 3.01kΩ. The equation for battery charge current is:

$R\_prog = h\_prog \cdot (V\_prog/I\_(chg)) = 988 \cdot 1.227V/0.4 = 3.01k\Omega$

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THEORY OF OPERATION

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.

Figure 3 shows various nodes of interest with V_{IN} = 5V, and the switching frequency at 750kHz (T = 1.333μs), The duty cycle is 86% for V(BAT) = 3.6V, this is 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 making the effective output of the buck regulator the voltage necessary to push 400mA into the battery. This "effective" voltage is 5 X 0.86 = 4.3V, is the voltage necessary to ensure that a 400mA average current is flowing through the on-die metal sense resistor.

Figure 4 shows the same nodes as Figure 3, but with V_{IN} = 40V, and still at 750kHz. The duty cycle is ≈ 200ns/1.333μs, or 15%, but the period is 2.7μs. 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/2.667μs = 11%. This produces an "effective" output voltage of 4.3V, so that the battery 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 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 set the MPPT point as a fraction of V_{OC}, based on the equation:

$$\frac{V_{MPPT}}{V_{OC}} = [\frac{0.1(k+1)}{k}]$$

where R_{MPPT2} = k • R_{MPPT1}. So for the demo board, k = 121/787 = 0.154, and V_{MPPT}/V_{OC} = 0.75 • V_{OC}. When MPPT is enabled (not equal to V_{IN}), the LTC4121EUD periodically disconnects the load, and measures V_{IN} 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
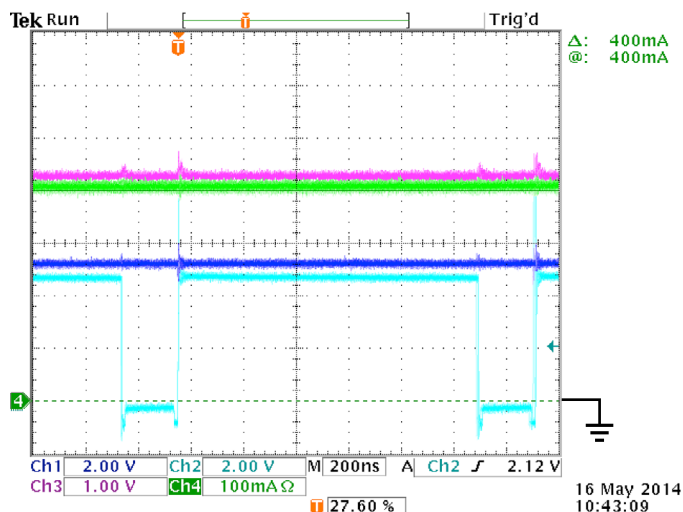

Figure 3. Normal Operation, Zoom, V_{IN} = 5.1V, DK. Blue = V_{IN}, Grn = I_{CHARGE}, LT. Blue = V_{SW}, Pk. = $INTV_{CC}$, 750kHz
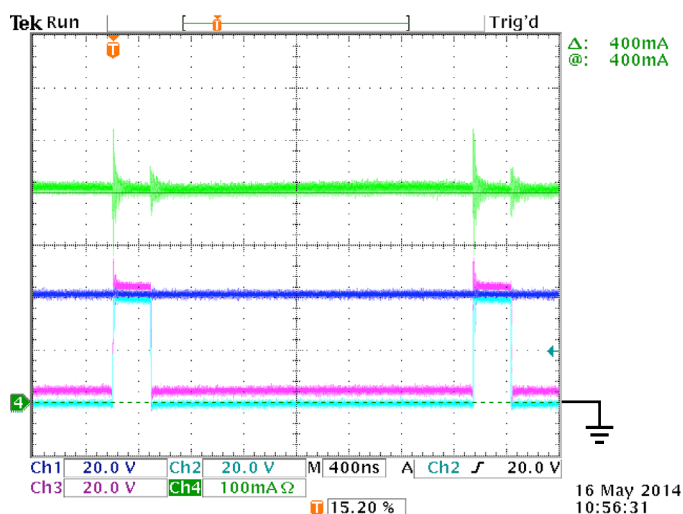

Figure 4. Normal Operation, Zoom, V_{IN} = 40V, DK. Blue = V_{IN}, Grn = I_{CHARGE}, LT. Blue = V_{SW}, Pk. = V_{BOOST}, 750kHz

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THEORY OF OPERATION

longer increases the load. This allows the MPPT voltage divider to set the desired MPPT point as a percentage of the no load V_{IN}:

Figure 5 shows the LTC4121EUD operating into a source impedance of 98Ω so the LTC4121 draws more power from V_{IN} than is available. 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 loads and letting V_{IN} rise to V_{OC}. The power drawn from V_{IN} is increased until the V_{IN} falls to the MPPT point, 0.75 • V_{OC} = 0.75 • 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 6 shows the same system, but the source impedance was lowered to 16Ω, consequently the full power needed to meet the requirements of Rprog is available before V_{IN} falls to the MPPT voltage.

Battery capacitors C1 and C2

The maximum float voltage for the LTC4121EUD is 18V, but for the LTC4121EUD-4.2, it is 4.2V. Linear recommends 47µF of capacitance on the BAT pin, if the battery is missing. For the LTC4121EUD the voltage rating of the capacitor will need to be 25V, so two 22µF, 25V, MLCC capacitors are used. In the case of the LTC4121EUD-4.2, a 6.3V capacitor will suffice and a single 47µF, 6.3V, MLCC capacitor is used for C1, with C2 as a no load.
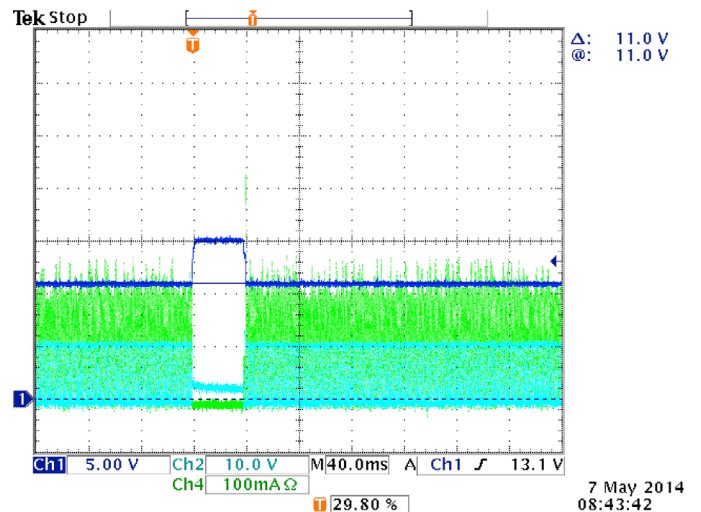

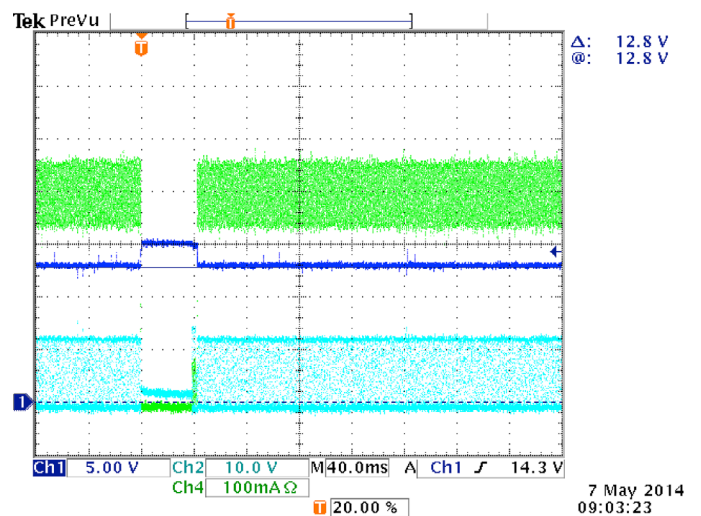Figure 5. MPPT Test, DK. Blue = V_{IN} (Through 98Ω), Green = I_L, LT. Blue = V(SW), k = 0.15, V_{MPPT}/V_{OC} = 0.75

Figure 6. MPPT Test, DK. Blue = V_{IN} (Through 16Ω), Green = I_L, LT. Blue = V(SW), k = 0.15, V_{MPPT}/V_{OC} = 0.75

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PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
DC1977A General Bill of Materials				
Required Circuit Components				
1	1	C3	CAP, CHIP, X7R, 0.022µF, ±10%, 50V, 0402	TDK, C1005X7R1E223K
2	1	C4	CAP, CHIP, X5R, 10µF, ±10%, 50V, 1210	TAIYO-YUDEN, UMK325BJ106KM-T
3	1	C5	CAP, CHIP, X5R, 2.2µF, ±20%, 6.3V, 0402	MURATA, GRM155R60J225ME15D
4	1	L1	IND, SMT, 33µH, 420mΩ, ±20%, 0.80A, 4mm × 4mm	COILCRAFT, LPS4018-333ML
5	1	R1	RES, CHIP, 787kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW0402787KFKED
6	1	R2	RES, CHIP, 121kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW0402121KFKED
7	1	R3	RES, CHIP, 261kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW0402261KFKED
8	1	R4	RES, CHIP, 324kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW0402324KFKED
9	1	R7	RES, CHIP, 3.01kΩ, ±1, 1/16W, 0402	VISHAY, CRCW04023K01FKED
Additional Demo Board Circuit Components				
1	1	D1	DIODE, SCHOTTKY, 40V, 2A, PowerDI123	DIODES, DFLS240L
2	1	M1	MOSFET, P-Channel, −30V, −5.9A, 45mΩ, SOT-23	VISHAY, Si2343CDS
3	2	R5, R9	RES, CHIP, 10kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW040210K0FKED
4	1	R6	RES, CHIP, 2kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW04022K00JNED
5	2	R8, R10	RES, CHIP, 0Ω jumper, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
6	1	R13	RES, CHIP, 47kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW040247K0JNED
7	1	R14	RES, CHIP, 5.1kΩ, ±1%, 1/16W, 0402	VISHAY, CRCW04025K10JNED
8	1	R15	RES, CHIP, 100kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW0402100KJNED
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, NRPN031PAEN-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	No Load	
2	1	R12	RES, CHIP, 0Ω jumper, 1/16W, 0402	VISHAY, CRCW04020000Z0E
3	1	U1	40V 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER, 3mm × 3mmQFN16	LINEAR TECH., LTC4121EUD-4.2#PBF
Additional Demo Board Circuit Components				
1	1	C1	CAP, CHIP, X5R, 47µF, ±10%, 16V, 1210	MURATA, GRM32ER61C476KE15L
2	0	C2	CAP, CHIP, X5R, 47µF, ±10%, 16V, 1210	MURATA, GRM32ER61C476KE15L

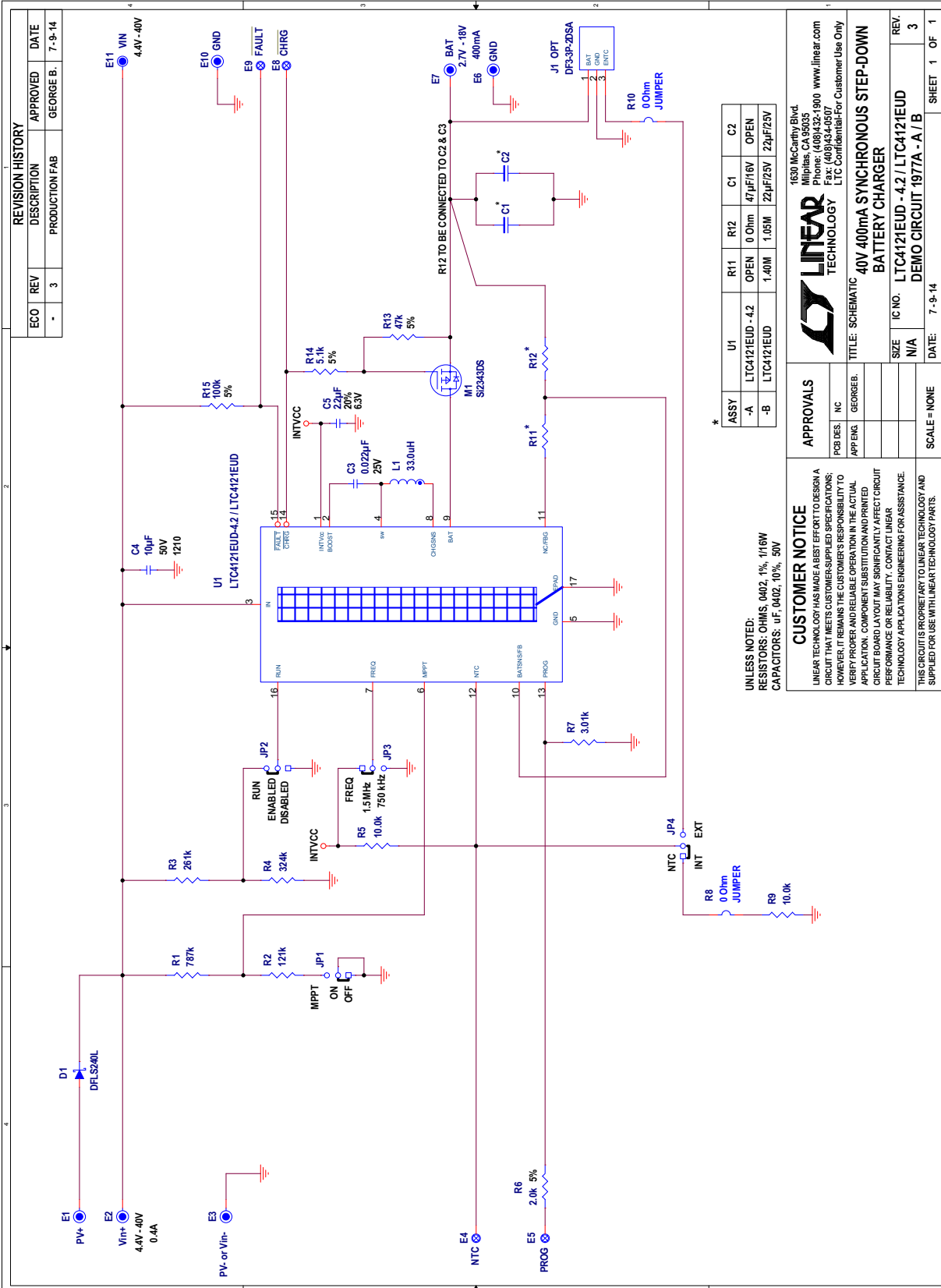| ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
DC1977A-B Bill of Materials				
Required Circuit Components				
1	1	R11	RES, CHIP, 1.40MΩ, ±1%, 1/16W, 0402	VISHAY, CRCW04021M40FKE
2	1	R12	RES, CHIP, 1.05MΩ, ±1%, 1/16W, 0402	VISHAY, CRCW04021M05FKED
3	1	U1	40V, 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER, 3mm × 3mmQFN16	LINEAR TECH., LTC4121EUD#PB
Additional Demo Board Circuit Components				
1	2	C1, C2	CAP, CHIP, X5R, 47µF, ±10%, 16V, 1210	MURATA, GRM32ER61C476KE15L

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6

SCHEMATIC DIAGRAM

REVISION HISTORY

ECO	REV	DESCRIPTION	APPROVED	DATE
-	3	PRODUCTION FAB	GEORGE B.	7-9-14

E11 VIN 4.4V - 40V

E10 GND

E9 FAULT

E8 CHRG

E7 BAT 2.7V - 18V 400mA

E6 GND

J1 OPT DF3-3P-2DSA
BAT / GND / ENTC

R10 0 Ohm JUMPER

R12 TO BE CONNECTED TO C2 & C3

C2 *
C1 *

R13 47k 5%

R14 5.1k 5%

M1 Si2343DS

R12 *

R11 *

INTVCC

C5 22µF 20% 6.3V

C3 0.022µF 25V

L1 33.0µH

R15 100k 5%

C4 10µF 50V 1210

U1 LTC4121EUD-4.2 / LTC4121EUD

IN / RUN / FAULT / CHRG / INTVCC / BOOST / SW / CHGSNS / BAT / NC/FBG / FREQ / MPPT / NTC / BATSNS/FB / PROG / GND / PGND

R3 261k

R4 324k

JP2 RUN ENABLED DISABLED

JP3 FREQ 1.5MHz 750kHz

INTVCC

R5 10.0k

R7 3.01k

R1 787k

R2 121k

JP1 MPPT ON OFF

D1 DFLS240L

JP4 EXT INT NTC

R8 0 Ohm JUMPER

R9 10.0k

E1 PV+

E2 Vin+ 4.4V - 40V 0.4A

E3 PV- or Vin-

E4 NTC

E5 PROG

R6 2.0k 5%

	U1	R11	R12	C1	C2
ASSY					
-A	LTC4121EUD - 4.2	OPEN	0 Ohm	47µF/16V	OPEN
-B	LTC4121EUD	1.40M	1.05M	22µF/25V	22µF/25V

LINEAR TECHNOLOGY

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TITLE: SCHEMATIC 40V 400mA SYNCHRONOUS STEP-DOWN BATTERY CHARGER

IC NO. LTC4121EUD - 4.2 / LTC4121EUD

REV. 3

SIZE N/A DEMO CIRCUIT 1977A - A / B

DATE: 7-9-14 SHEET 1 OF 1

SCALE = NONE

APPROVALS

PCB DES.	NC	
APP ENG.	GEORGE B.	

CUSTOMER NOTICE

UNLESS NOTED:
RESISTORS: OHMS, 0402, 1%, 1/16W
CAPACITORS: uF, 0402, 10%, 50V

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.

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DEMONSTRATION BOARD IMPORTANT NOTICE

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