

# LTC4000EGN/LTC3789EGN 14.6V, 5A Battery Charger with 6V<sub>IN</sub> to 36V<sub>IN</sub> Buck-Boost Converter

## DESCRIPTION

Demonstration circuit 1721A-A is a 14.6V, 5A battery charger and PowerPath™ manager with 6V<sub>IN</sub> to 36V<sub>IN</sub> buck-boost converter featuring the LTC®4000/LTC3789, targeted at 4-cell LiFePO<sub>4</sub> applications. The output of this demo board was specifically tailored for a Tenergy 10A-hour battery, P/N 30207. Other voltages can be set by changing R<sub>OFB2</sub> and R<sub>BFB2</sub>. The desired nominal voltage can be accurately trimmed by using trim resistors R42 and R43. For example, for 14.4V battery float voltage, change R<sub>OFB2</sub> and R<sub>BFB2</sub> to 86.6k, and add 7.5M at R42 and R43 for greater set point accuracy.

This circuit was designed to demonstrate the high levels of performance, efficiency, and small solution size attainable using these parts in a buck-boost converter battery charger,

intelligent PowerPath manager, and power supply. It operates at 400kHz and produces a regulated 5A/14.6V battery charger output as well as a system output of up to 6.25A from an input voltage range of 6V to 36V: suitable for a wide variety of portable applications including instruments, industrial equipment, power tools, and computers. It has a total footprint area of 12.4cm<sup>2</sup> (3.6cm<sup>2</sup> for the LTC4000 circuit only). Synchronous rectification helps to attain efficiency exceeding 96% at full load and nominal input.

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

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## PERFORMANCE SUMMARY (T<sub>A</sub> = 25°C)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V <sub>IN</sub>	Input Supply Range		6		36	V
I <sub>IN</sub>	Input Current Limit			11		A
V <sub>FLOAT</sub>	Battery Float Voltage		14.4	14.6	14.8	V
	Output Regulation	Line and Load (6V to 36V, 0A to 5A)		±0.05		%
I <sub>BAT</sub>	Battery Charge Current			5		A
V <sub>OUT_SYS</sub>	System Output Voltage		12.3	14.6	15.5	V
I <sub>OUT_SYS</sub>	System Output Current Range		0		6.25	A
f <sub>SW</sub>	Switching (Clock) Frequency			400		kHz
V <sub>OUT_SYS_P-P</sub>	System Output Ripple	V <sub>IN</sub> = 24V, I <sub>OUT_SYS</sub> = 5A (20MHz BW)		50		mV <sub>P-P</sub>
P <sub>OUT</sub> /P <sub>IN</sub>	System Output Efficiency (See Figure 3)	V <sub>IN</sub> = 24V, I <sub>OUT_SYS</sub> = 5A		96.5		%
	Approximate Size	Component Area × Top Component Height		12.4cm <sup>2</sup> × 0.40cm		

## QUICK START PROCEDURE

Demonstration circuit 1721 is easy to set up to evaluate the performance of the LTC4000/LTC3789. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below:

**WARNING: BATTERIES ARE POTENTIALLY DANGEROUS HIGH ENERGY SOURCES. IMPROPER CONNECTION, OVERCHARGE, OR RAPID DISCHARGE COULD RESULT IN EXPLOSION AND/OR FIRE.**

**NOTE:** When measuring the output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the output voltage ripple by touching the probe tip and ground ring directly across the last output capacitor as shown in Figure 1.

1. Connect a low ESR electrolytic capacitor to the BAT output ( $\geq 1800\mu\text{F}$  at  $\geq 20\text{V}$ ).

**NOTE:** This capacitor helps simulate the low impedance of a battery and maintain stability of the charge current loop. It is only needed for test purposes with electronic or resistive loads, and not needed in the actual application (where the load is a battery).

2. Set MODE jumper to CCM. Set CHARGE jumper to DISABLE.
3. Set an input power supply that is capable of 6V to 36V and 12A to 24V. Then turn off the supply.
4. With power off, connect the supply to the input terminals  $V_{\text{IN}}$  and GND.

**NOTE:**

- a. Input voltages lower than 6V can keep the converter from turning on due to the undervoltage lockout feature of the LTC4000.
  - b. If efficiency measurements are desired, refer to Figure 1 for test setup.
5. Turn on the power at the input.

**NOTE:** Make sure that the input voltage never exceeds 36V.

6. Check for the proper  $V_{\text{OUT\_SYS}}$  of 15.3V. Turn off the power at the input.
7. Once the proper output voltages are established, connect a variable load capable of sinking 7A at 16V to the output terminals  $V_{\text{OUT\_SYS}}$  and GND. Set the current for 0A.
8. Turn on the power at the input.

**NOTE:** If there is no output, temporarily disconnect the load to make sure that the load is not set too high.

9. Once the proper  $V_{\text{OUT\_SYS}}$  is again established, adjust the load and/or source within the operating range and observe the output voltage regulation, ripple voltage, efficiency, input and output current limit, and other desired parameters.

10. Turn off the power at the input.

11. Connect the output load and meters to the BAT output.

12. Set CHARGE jumper to ENABLE.

13. Turn on the power at the input.

14. Once the proper  $V_{\text{OUT\_SYS}}$  is again established, adjust the load and/or source within the operating range and observe the battery float voltage regulation and other desired parameters.

15. Set the load to constant voltage mode to more easily observe charge current and trickle charge current.

**NOTE:** Operation in the instant-on region ( $V_{\text{OUT}} < 12.5\text{V}$ ) may engage thermal limit circuit to protect Q7 in linear region.

**NOTE:** The optional thermal limit circuit for Q6 (Q9, RNTC3, R55-R59, and U4) is included to protect Q6 in case of an extended short-circuit on  $V_{\text{OUT\_SYS}}$  under adverse thermal conditions ( $T_A > 40^\circ\text{C}$ ). It may not be needed in applications with less severe thermal conditions, lower current available to  $V_{\text{OUT\_SYS}}$ , or where continuous short circuit protection on  $V_{\text{OUT\_SYS}}$  is not required.

**QUICK START PROCEDURE**

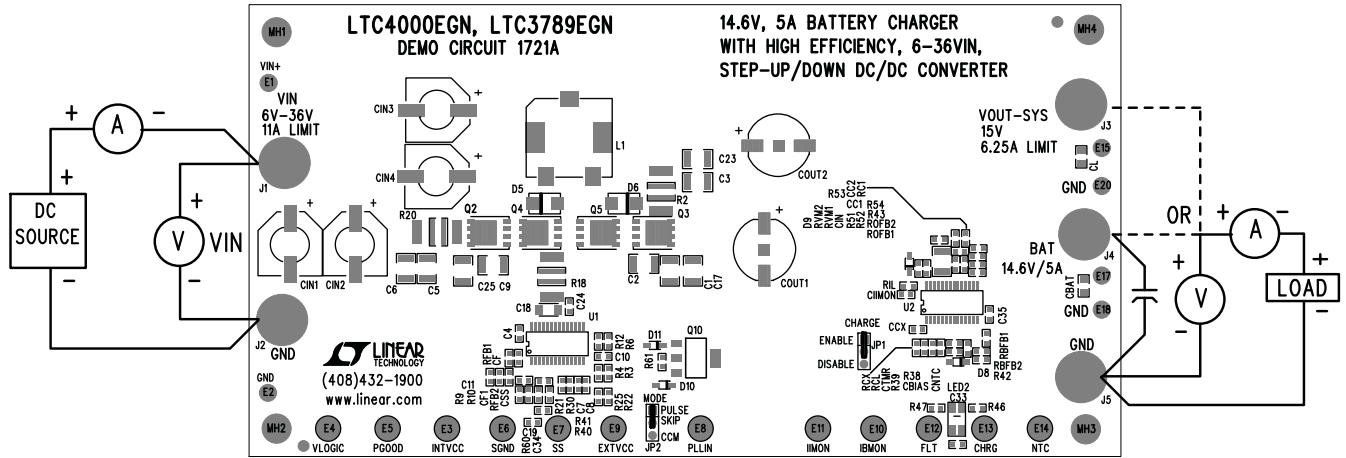


Figure 1. Proper Measurement Equipment Setup

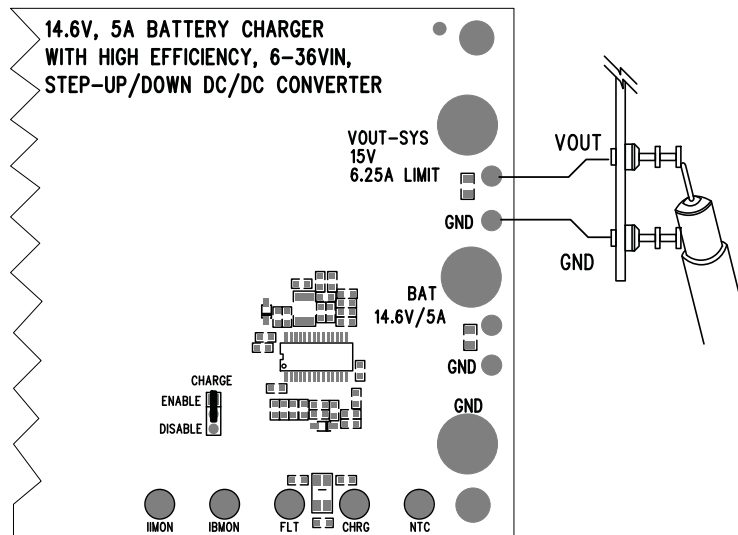


Figure 2. Proper Noise Measurement Setup

## QUICK START PROCEDURE

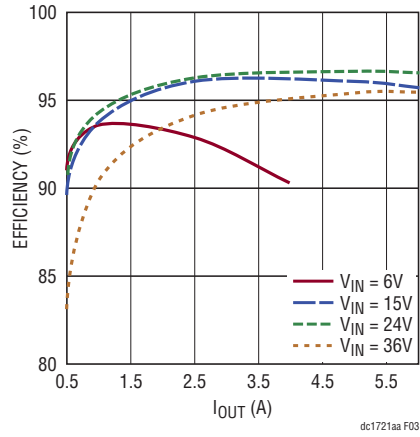


Figure 3. Efficiency from  $V_{IN}$  to  $V_{OUT\_SYS}$

### LTC4000 / LTC3789 SYSTEM BLOCK DIAGRAM

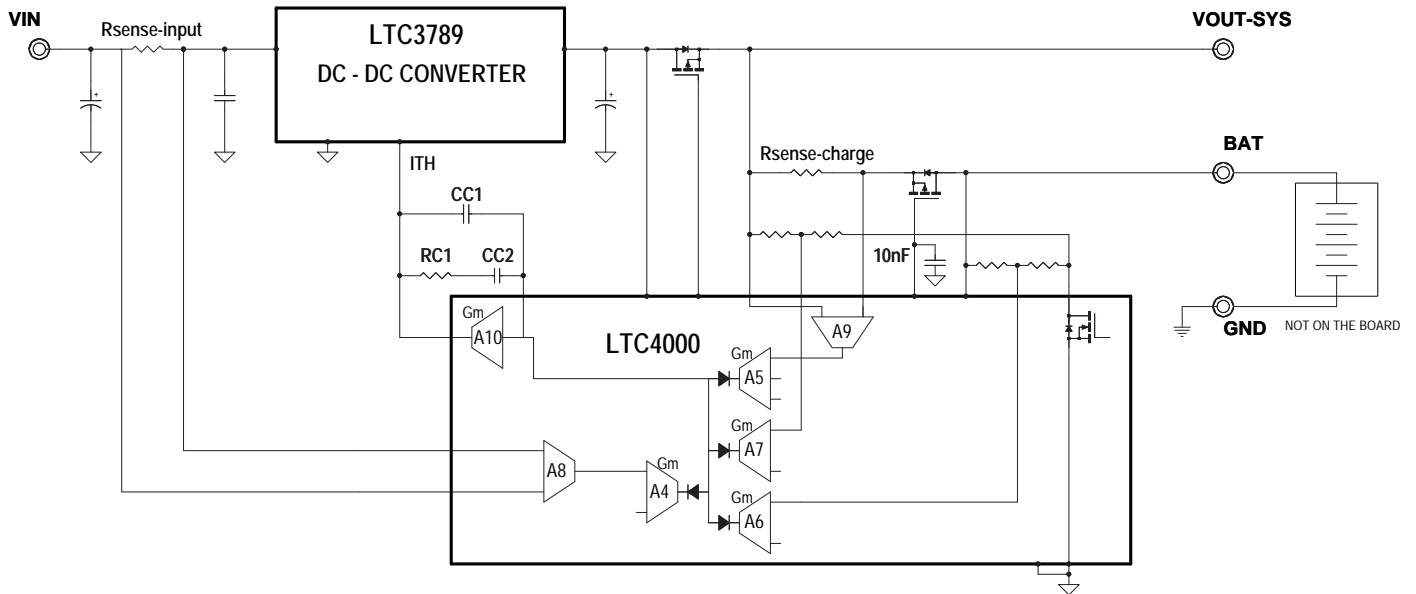


Figure 4. Block Diagram

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	2	CL, CBAT	Capacitor, X5R, 2.2µF, 25V, 20%, 0805	AVX, 08053D225MAT2A
2	2	C24, CBIAS	Capacitor, X7R, 1µF, 16V, 10%, 0603	AVX, 0603YC105KAT2A
3	3	CC2, C14, CTMR	Capacitor, X7R, 0.1µF, 50V, 10%, 0603	AVX, 06035C104KAT2A
4	3	CIIMON, CIBMON, C19	Capacitor, C0G, 1000pF, 25V, 5%, 0603	AVX, 06033A102JAT2A
5	2	C15, CIN	Capacitor, X7R, 1µF, 50V, 10%, 1210	AVX, 12105C105KAT2A
6	2	CIN1, CIN2	Capacitor, Alum, HVH, 56µF, 50V	Sun Electronics, 50HVH56M
7	2	COUT1, COUT2	Capacitor, OS-CON, 150µF, 20V, 20%	Sanyo, 20SVP150M
8	1	CSS	Capacitor, X7R, 0.022µF, 50V, 10%, 0603	AVX, 06035C223KAT2A
9	4	C1, C2, C16, C17	Capacitor, X5R, 22µF, 25V, 10%, 1210	AVX, 12103D226KAT2A
10	2	C4, C22	Capacitor, X7R, 0.22µF, 16V, 10%, 0603	Taiyo Yuden, EMK107BJ224KA
11	4	C5, C6, C9, C25	Capacitor, X7R, 3.3µF, 50V, 10%, 1210	AVX, 12105C335KAT2A
12	1	C10	Capacitor, X5R, 2.2µF, 6.3V, 20%, 0603	AVX, 06036D225MAT2A
13	1	C12	Capacitor, NPO, 390pF, 100V, 5%, 1206	AVX, 12061A391JAT2A
14	1	C13	Capacitor, NPO, 1.8nF, 100V, 5%, 1206	AVX, 12061A182JAT2A
15	1	C18	Capacitor, X7R, 10µF, 10V, 10%, 1206	AVX, 1206ZC106KAT2A
16	1	C33	Capacitor, X5R, 4.7µF, 10V, 20%, 0603	AVX, 0603ZD475MAT2A
17	2	C34, C35	Capacitor, X7R, 10nF, 25V, 5%, 0603	AVX, 06033C103JAT2A
18	1	D2	Diode, Switch, 75V, 350mW, SOT23-3	Diode Inc., BAS16-7-F
19	2	D4, D7	Diode, Schottky, 1A, 60V, POWERD1123	Diode Inc., DFLS160-7
20	2	D5, D6	Diode, Schottky, 40V, 2A, SMA	Diode Inc., B240A-13-F
21	1	D9	Diode, Zener, SM, BZT52C3V0, SOD323	Diodes, BZT52C3V0
22	1	D10	Diode, Zener, 5.6V, 500mW, SOD123	Diode Inc., BZT52C5V6
23	1	F1	FUSE, 6.3A 32V, T-Lag, 1206, SMD	Cooper Bussman, 3216TD6.3-R
24	1	LED2	LED, Dual Red/Green	LiteOn, LTST-C155KGJRK7
25	1	L1	Inductor, 4.7µH	Toko, FDA1254-4R7M
26	2	Q2, Q4	MOSFET N-Channel, 40V, POWERPAK-8	Vishay, SiR422DP-T1-GE3
27	2	Q3, Q5	MOSFET N-Channel, 20V, POWERPAK-8	Vishay, SiR496DP-T1-GE3
28	2	Q6, Q7	MOSFET P-Channel, 30V, 1206-8 ChipFET	Vishay, Si7135DP
29	1	Q8	Small Signal MOSFET	On Semi, 2N7002LT1G
30	3	ROFB1, RBFB1, R45	Resistor, Chip, 1M, 0.1W, 1%, 0603	Vishay, CRCW06031M00FKEA
31	2	ROFB2, RBFB2	Resistor, Chip, 84.5k, 0.1W, 1%, 0603	Vishay, CRCW060384K5FKEA
32	1	RCL	Resistor, Chip, 24k, 0.1W, 5%, 0603	Vishay, CRCW060324KJKEA
33	1	RIL	Resistor, Chip, 18.2k, 0.1W, 1%, 0603	Vishay, CRCW060318K2FKEA
34	1	RCS	Sensor Resistor, 0.01Ω, 1W, 2%, 1508 SMD	Susumu, RL3720WT-R010-G

# DEMO MANUAL DC1721A-A

## PARTS LIST

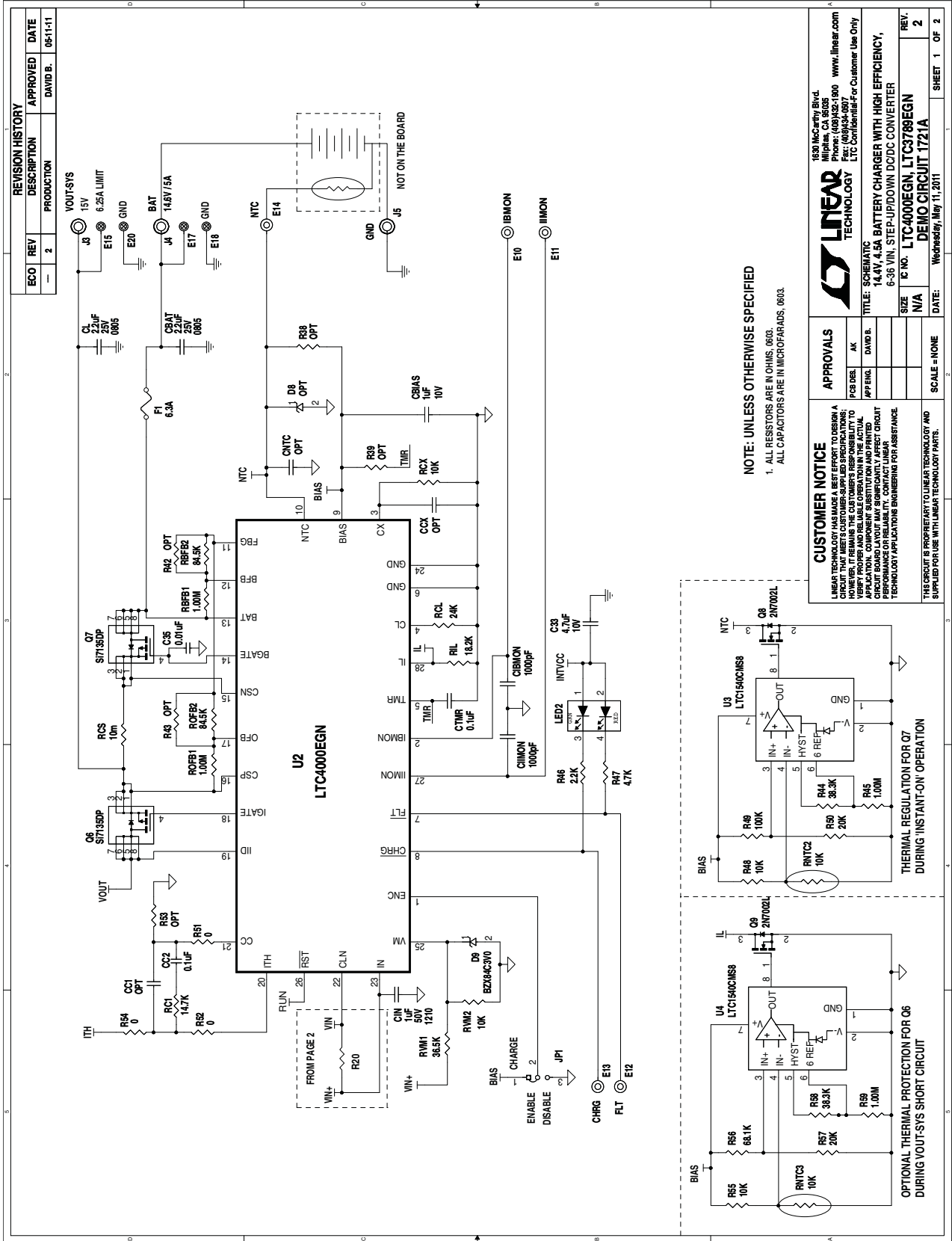
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
35	5	R24, R48, R60, RCX, RVM2	Resistor, Chip, 10k, 0.1W, 1%, 0603	Yageo, RC0603FR-0710KL
36	1	RC1	Resistor, Chip, 14.7k, 0.1W, 1%, 0603	Yageo, RC0603FR-0714K7L
37	1	RFB1	Resistor, Chip, 154k, 0.1W, 1%, 0603	Vishay, CRCW0603154KFKEA
38	1	RFB2	Resistor, Chip, 8.06k, 0.1W, 1%, 0603	Vishay, CRCW06038K06FKEA
39	1	RVM1	Resistor, Chip, 36.5k, 0.1W, 1%, 0603	Vishay, CRCW060336K5FKEA
40	2	R7, R49	Resistor, Chip, 100k, 0.1W, 1%, 0603	Vishay, CRCW0603100KFKEA
41	1	RNTC2	Thermistor, NTC, 10k $\Omega$ , 5%, 0603	Vishay, NTHS0603N02N1002J
42	1	R1	Resistor, Chip, 5.6 $\Omega$ , 0.1W, 5%, 0603	Vishay, CRCW06035R60JNEA
43	4	R3, R4, R13, R14	Resistor, Chip, 100 $\Omega$ , 0.1W, 5%, 0603	Vishay, CRCW0603100RJNEA
44	1	R5	Resistor, Chip, 15 $\Omega$ , 0.125W, 5%, 0805	Vishay, CRCW080515R0JNEA
45	2	R8, R11	Resistor, Chip, 100 $\Omega$ , 0.1W, 5%, 0603	Vishay, CRCW060310R0JNEA
46	2	R9, R10	Resistor, Chip, 1.24k, 0.1W, 1%, 0603	Vishay, CRCW06031K24FKEA
47	2	R2, R18	Sensor Resistor, 0.008 $\Omega$ , 1W, 2%, 1508, SMD	Susumu, RL3720WT-R008-G
48	1	R20	Sensor Resistor, 0.004 $\Omega$ , 1W, 2%, 1508, SMD	Susumu, RL3720WT-R004-G
49	1	R21	Resistor, Chip, 121k, 0.1W, 1%, 0603	Vishay, CRCW0603121KFKEA
50	4	R25, R51, R52, R54	Resistor, 0 $\Omega$ , 1/16W, 1A, 0603	Yageo, RC0603FR-070RL
51	1	R28	Resistor, Chip, 5.6 $\Omega$ , 5%, 1206	Vishay, CRCW12065R60JNEA
52	1	R29	Resistor, Chip, 3.6 $\Omega$ , 5%, 1206	Yageo, RC1206JR-073R6L
53	1	R44	Resistor, Chip, 38.3k, 0.1W, 1%, 0603	Vishay, CRCW060338K3FKEA
54	1	R46	Resistor, Chip, 2.2k, 0.1W, 5%, 0603	Vishay, CRCW06032K2JKEA
55	1	R47	Resistor, Chip, 4.7k, 0.1W, 5%, 0603	Vishay, CRCW06034K7JKEA
56	1	R50	Resistor, Chip, 20k, 0.1W, 1%, 0603	Vishay, CRCW060320K0FKEA
57	1	U1	IC, Voltage Regulator	Linear Technology, LTC3789EGN#PBF
58	1	U2	IC, LTC4000EGN, 28-Pin SSOP	Linear Technology, LTC4000EGN#PBF
59	1	U3	NANOPWR Comparator, MSOP8	Linear Technology, LTC1540CMS8#PBF

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Additional Circuit Components</b>				
1	0	CF1, CC1, R6, C7, C8, C11, R12, R22, R27, R30, R38, R39, R40, R41, R53, R61, CNTC, CF, CCX	OPT, 0603	
2	0	CIN3, CIN4	OPT	
3	0	C3, C23, C26, C27	OPT, 1210	
4	0	D8, D11	OPT	
5	1	Q9	Small Signal MOSFET	On Semi, 2N7002LT1G
6	0	Q10	OPT	
7	1	RNTC3	Thermistor, NTC, 10k $\Omega$ , 5%, 0603	Vishay, NTHS0603N02N1002J
8	0	R42, R43	OPT	
9	1	R55	Resistor, Chip, 10k, 0.1W, 1%, 0603	Yageo, RC0603FR-0710KL
10	1	R56	Resistor, Chip, 68.1k, 0.1W, 1%, 0603	Vishay, CRCW060368K1FKEA
11	1	R57	Resistor, Chip, 20k, 0.1W, 1%, 0603	Vishay, CRCW060320K0FKEA
12	1	R58	Resistor, Chip, 38.3k, 0.1W, 1%, 0603	Vishay, CRCW060338K3FKEA
13	1	R59	Resistor, Chip, 1M, 0.1W, 1%, 0603	Vishay, CRCW06031M00FKEA
14	1	U4	NANOPWR Comparator, MSOP8	Linear Technology, LTC1540CMS8#PBF
<b>Hardware/Components (For Demo Board Only)</b>				
1	6	E1, E2, E15, E17, E18, E20	Testpoint, Turret, 0.061" pbf	Mill-Max, 2308-2-00-80-00-00-07-0
2	12	E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14	Testpoint, Turret, 0.094" pbf	Mill-Max, 2501-2-00-80-00-00-07-0
3	2	JP1, JP2	Header, 3-Pin, 0.079 Single Row	Samtec, TMM-103-02-L-S
4	2	XJP1, XJP2	Shunt, 0.079" Center	Samtec, 2SN-BK-G
5	5	J1, J2, J3, J4, J5	Connector, Banana Jack	Keystone, 575-4
6	4	(STAND-OFF)	Stand-Off, Nylon 0.25"	Keystone, 8831 (Snap On)

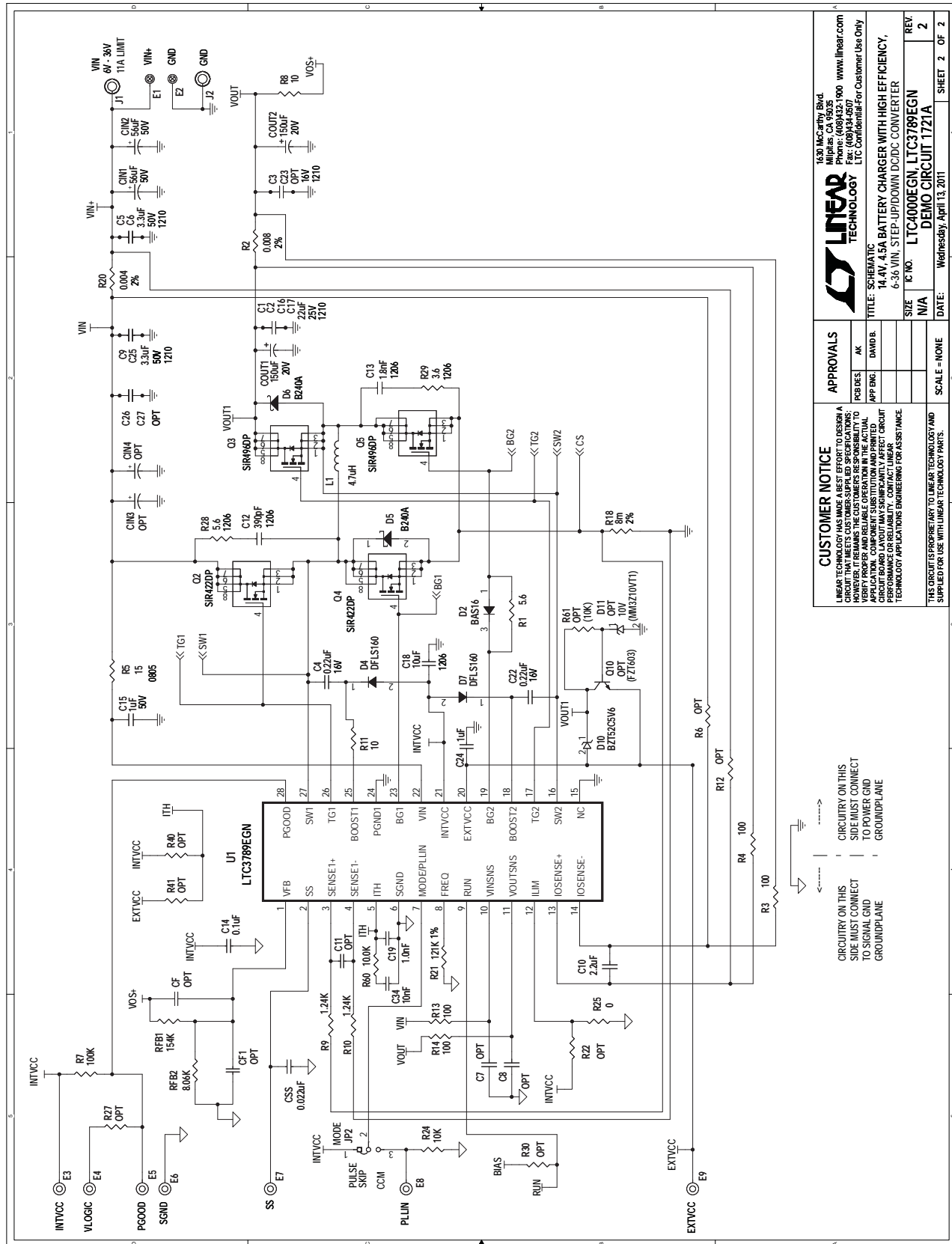
# DEMO MANUAL DC1721A-A

## SCHEMATIC DIAGRAM





## SCHEMATIC DIAGRAM



# DEMO MANUAL DC1721A-A

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