

# High Efficiency PolyPhase® Synchronous Boost Converter

## DESCRIPTION

Demonstration circuit DC2061 is a DC/DC synchronous boost converter featuring the [LTC®3784](#) constant frequency current mode synchronous boost controller. The DC2061A operates over a 6V to 60V input, develops a 48V output and provides 3A to 12A of output current as shown in Figure 3. The 150kHz (2 • 150kHz at the output) constant frequency operation results in a small and efficient circuit. The converter provides high output voltage accuracy (typically  $\pm 3\%$ ) over wide load range with no minimum load requirement. The

demonstration circuit can be easily modified to generate different output voltages.

The DC2061 has a small circuit footprint. It is a high performance and cost effective solution for telecom, automotive and Power over Ethernet applications.

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

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

PARAMETER	CONDITION	VALUE
Minimum Input Voltage	$I_{OUT} = 0\text{A to }3\text{A}$	6V
Maximum Input Voltage	$I_{OUT} = 0\text{A to }12\text{A}$	60V
$V_{OUT}$	$V_{IN} = 6\text{V to }47\text{V}, I_{OUT} = 0\text{A to }3\text{A}$	48V $\pm 3\%$
Typical Output Ripple $V_{OUT}$	$V_{IN} = 6\text{V to }47\text{V}, I_{OUT} = 3\text{A}$	200mV <sub>P-P</sub>
Nominal Switching Frequency		150kHz

## QUICK START PROCEDURE

Demonstration circuit DC2061 is easy to set up to evaluate the performance of the LTC3784. For proper measurement equipment setup refer to Figure 1 and follow the procedure below:

Note: When measuring the input or output voltage ripple, care must be taken to minimize the length of oscilloscope probe ground lead. Measure the input or output voltage ripple by connecting the probe tip directly across the VIN or VOUT and GND terminals as shown in Figure 2.

1. With power off, connect the input power supply to VIN and GND.
2. Keep the load set to 0A or disconnected.
3. Turn the input power source on and slowly increase the input voltage. Be careful not to exceed 60V.

Note: Make sure that the input voltage,  $V_{IN}$ , does not exceed 60V. If higher operating voltage is required, power components with higher voltage ratings should be used. When the input voltage is set higher than 48V the output voltage will follow the input voltage.

4. Set the input voltage to 6V and check for the proper output voltage of 48V. Set the output load to 2A. If there is no output, temporarily disconnect the load to make sure that the load is not set too high.
5. Once the proper output voltage is established, adjust the load and observe the output voltage regulation, ripple voltage, efficiency and other parameters.

## QUICK START PROCEDURE

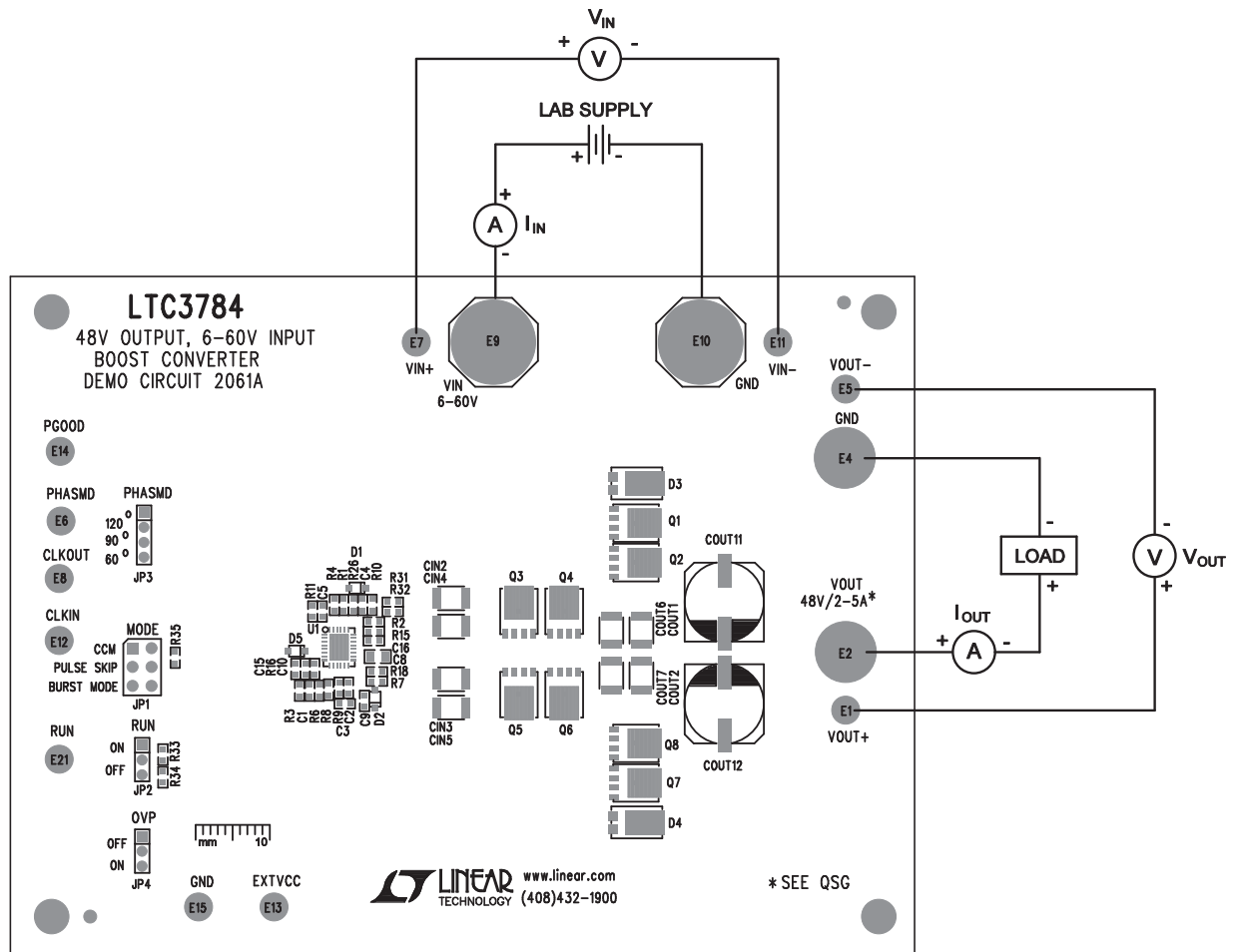


Figure 1. Proper Measurement Equipment Setup

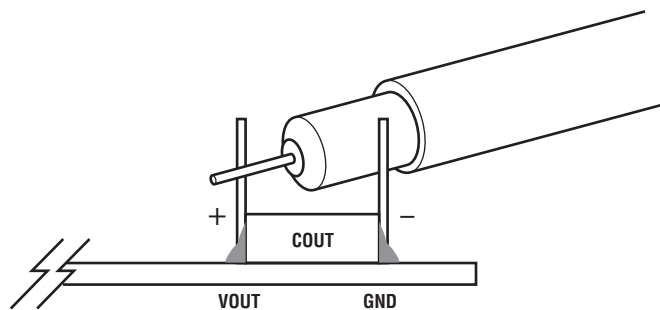


Figure 2. Measuring Input or Output Ripple

## QUICK START PROCEDURE

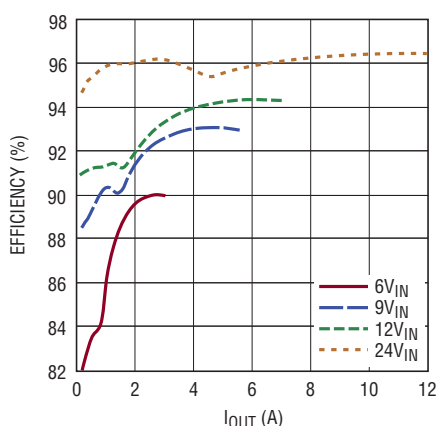
### Changing The Output Voltage

To set the output voltage lower than 48V, change the bottom voltage divider resistors connected to LTC3784 FB pin (see the Schematic Diagram). To get higher than a 48V output voltage, MOSFETs and capacitors with higher voltage ratings may be required.

**Note that the output voltage will start following the input voltage when input voltage is greater than the voltage set by the voltage divider.** In this mode (**wire mode**) the synchronous output rectifier MOSFET is turned continuously ON. The only losses in this mode are due to the current sense resistors, inductors and output MOSFETs DC resistance.

### Converter Efficiency And Output Current

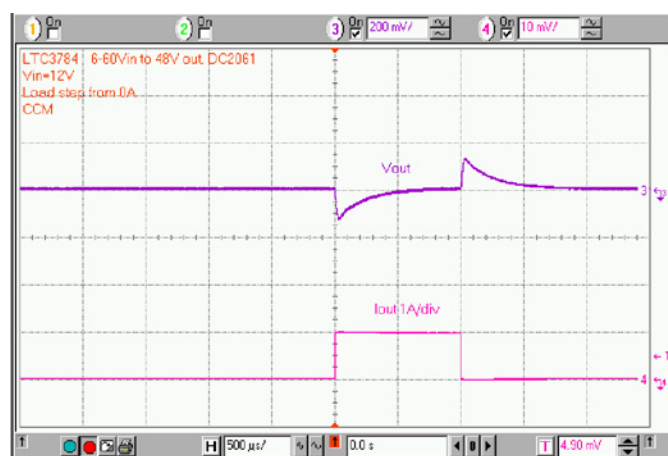
The DC2061 output current capability depends on the input voltage and proper cooling. Typical performance of DC2061A is shown in Figure 3. As can be seen from Figure 3, the output current capability depends on the input voltage. Also, when input voltage is equal to, or higher than the output voltage setting (wire mode) the efficiency is very high (99%) since the converter is not really running and the output MOSFET is shorting VIN to VOUT.



**Figure 3. High Efficiency of DC2061 Allows the Board to Be Used in Thermally Critical Applications with Outputs Over 3A**

### Output Load Step Response

The load step response of DC2061A is very good even though relatively small amount of output capacitance is present at the output. If higher load steps need to be handled more output capacitance can be added in order to keep the voltage transients at the desired level. The load step transients are shown in Figure 4. Also, note that the load step response even from 0% load is excellent thanks to synchronous rectification.



**Figure 4. Fast Transient Response of DC2061 is Achieved with a Small Amount of Output Capacitance**

### Soft-Start Function

The DC2061 features soft-start circuit that controls the inrush current and output voltage ramp at start-up. The capacitor C15 (Figure 6) controls the start-up period. The start-up waveforms are shown in Figure 5. Please note the small output voltage step at about -2ms mark. The step is resulting from synchronous MOSFET being turned on. When the synchronous MOSFET is turned on the voltage drop across the synchronous MOSFET (body diode) is reduced from about 0.7V to  $I_{OUT} \cdot R_{DS(ON)}$ . While the synchronous MOSFET is in off state (prior to -2ms mark) the synchronous MOSFET body diodes are dissipating about  $0.7V \cdot I_{OUT}$  or about 2.1W with 3A load. Please refer to the LTC3784 data sheet for details about proper handling of synchronous MOSFETs in your application.

## QUICK START PROCEDURE

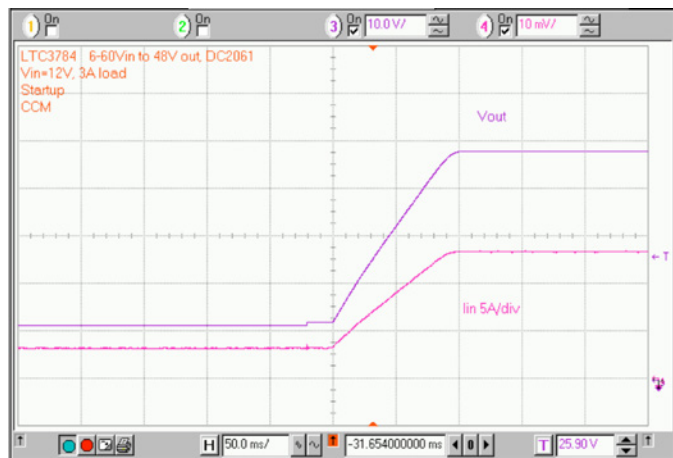


Figure 5. The DC2061 Ramps the Output Slowly at Start-Up without Generating an Input Current Surge

### Bias Circuit

The LTC3784 can operate with input voltages up to 65V. However, depending on input voltage, operating frequency and MOSFETs that are used the power dissipation in the part may become too high. In order to provide bias power at high input voltage the DC2061 circuit is equipped with high efficiency bias circuit LTC3630A.

If the circuit is to be used with limited input voltage the bias power can be derived directly from input power source.

Options to power the LTC3784 from VIN or VOUT are provided on DC2061. Please remove the LTC3630A circuit in order to use these options. Also, refer to the data sheet for more information about bias power.

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	5	CIN1, COUT5, COUT10, COUT11, COUT12	CAP., 33 $\mu$ F, 63V, EP-CAP	SUN ELECTRONICS, 63HVH33M
2	12	COUT1, COUT2, CIN2, COUT3, CIN3, COUT4, CIN4, CIN5, COUT6, COUT7, COUT8, COUT9	CAP., X7S, 4.7 $\mu$ F 100V,20% 3225/1210	TDK, C3225X7S2A475M
3	1	C2	CAP., NPO, 100pF, 25V,10%, 0603	AVX, 06033A101KAT
4	1	C3	CAP., X7R, 15nF, 25V, 10%, 0603	AVX, 06033C153KAT
5	5	C4, C9, C16, C17	CAP., X5R, 0.1 $\mu$ F, 25V, 10%, 0603	AVX, 06033D104KAT2A
6	2	C5, C10	CAP., NPO, 1000pF, 25V,10%, 0603	AVX, 06033A102KAT
7	1	C8	CAP., X5R, 4.7 $\mu$ F, 25V, 10%, 0805	TAIYO YUDEN, TMK212BJ475KG-T
8	1	C12	CAP., X7R, 0.1 $\mu$ F, 100V, 10%, 1206	AVX, 12061C104KAT
9	1	C13	CAP., X7R, 47nF, 25V, 10%, 0603	AVX, 06033C473KAT
10	1	C14	CAP., X5R, 22 $\mu$ F, 16V, 10%, 1206	AVX, 1206YD226KAT2A
11	1	C15	CAP., X5R, 1 $\mu$ F, 10V, 10%, 0603	AVX, 06033D104KAT2A
12	3	D1, D2	DIODE, BAS170W SOD323	INFINEON, BAS170W
13	1	D5	DIODE, PDZ6.8B SOD323	NXP, PDZ6.8B
14	2	L1, L2	IND, 10 $\mu$ H	COILCRAFT, SER2918H-103KL
15	1	L3	IND, 220 $\mu$ H IND-744775222	WURTH ELEC., 744775222
16	4	Q2, Q4, Q6, Q8	MOSFET, N-Channel, LPAK	INFINEON, BSC028N06LS3
17	4	RSNS1, RSNS2, RSNS3, RSNS4	RES., Chip, 0.006 $\Omega$ , 1%, 2010	VISHAY, WSL20106L000FEA
18	7	R2, R3, R7, R13, R15, R18, R21	RES., Chip, 0 $\Omega$ , 1%, 0603	VISHAY, CRCW06030000Z0EA
19	1	R5	RES., Chip, 30.1k, 1%, 0603	VISHAY, CRCW060330K1FKEA
20	1	R6	RES., Chip, 475k, 1%, 0603	VISHAY, CRCW0603475KFEA
21	2	R8	RES., Chip, 12.1k, 1%, 0603	VISHAY, CRCW060312K1FKEA
22	1	R9	RES., Chip, 15k, 1%, 0603	VISHAY, CRCW060315K0FKEA

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
23	2	R17, R23	RES., Chip, 10Ω, 1%, 0603	VISHAY, CRCW060310R0FKEA
24	2	R26, R35	RES., Chip, 100k, 1%, 0603	VISHAY, CRCW0603100KFKEA
25	1	R29	RES., Chip, 47k, 1%, 0603	VISHAY, CRCW060347K0FKEA
26	1	R30	RES., Chip, 523k, 1%, 0603	VISHAY, CRCW0603523KFKEA
27	1	R33	RES., Chip, 150k, 1%, 0603	VISHAY, CRCW0603150KFKEA
28	1	R34	RES., Chip, 38.3k, 1%, 0603	VISHAY, CRCW060338K3FKEA
29	1	R36	RES., Chip, 80.6k, 1%, 0603	VISHAY, CRCW060380K6FKEA
30	1	U1	I.C. LTC3784IUFD QFN28-4 x 5	LINEAR TECH., LTC3784IUFD#PBF
31	1	U2	I.C. LTC3630AEMSE	LINEAR TECH., LTC3630AEMSE

### Additional Demo Board Circuit Components

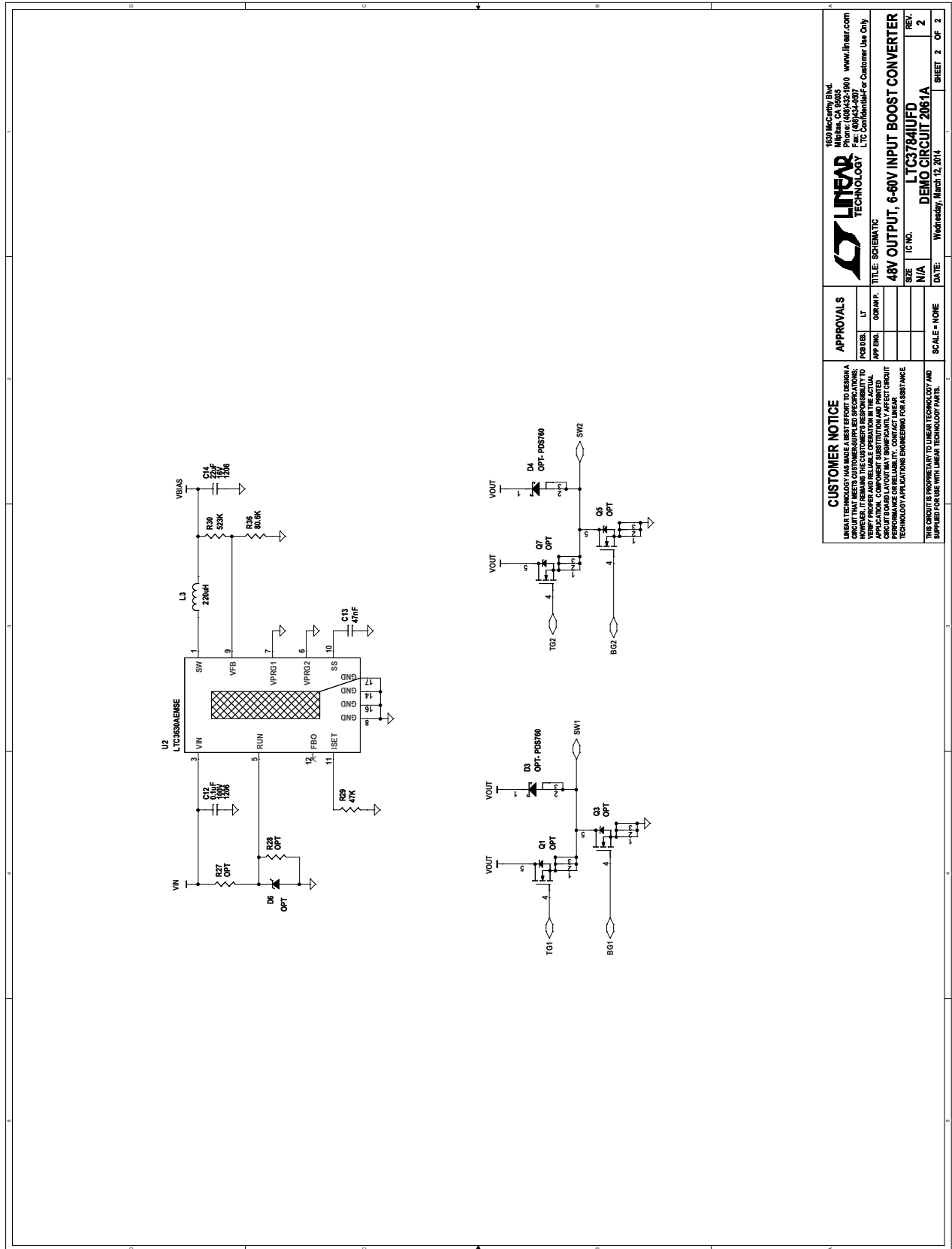
1	0	C1, C19, C20	OPT, 0603	OPT
2	0	D3, D4	DIODE, OPT PDS760 POWERID5-2P	OPT
3	0	D6	DIODE, OPT SOD123	OPT
4	0	Q1, Q3, Q5, Q7	OPT, LPAK	OPT
5	0	R1, R4, R10, R11, R12, R14, R16, R27, R28, R31, R32, R37, R38	OPT, 0603	OPT

### Hardware-For Demo Board Only

1	11	E1, E5-E8, E11-E15, E21	TURRET, TESTPOINT , 091"	MILL-MAX, 2501-2-00-80-00-00-07-0
2	2	E2, E4	JACK BANANA	KEYSTONE, 575-4
3	2	E9, E10	STUD, TEST PIN	PEM, KFH-032-10
4	4	(E9, E10) x 2	NUT, BRASS NUTS # 10-32	ANY, #10-32
5	2	E9, E10	RING, LUG RING # 10	KEYSTONE, 8205
6	2	E9, E10	WASHER, #10, TIN PLATED BRASS	ANY, #10 EXT BZ TN
7	1	JP1	HEADER, 6 PINS 2 x 3 100 Ctrs.	SAMTEC, TSW-106-07-L-D
8	2	JP2, JP4	HEADER, 3 Pins 2mm CTRS.	SULLINS, NRPN031PAEN-RC
9	1	JP3	HEADER, 4 Pins 2mm CTRS.	SULLINS, NRPN041PAEN-RC
10	3	XJP2, XJP3, XJP4	SHUNT, 2mm CTRS.	SAMTEC, 2SN-BK-G
11	1	XJP1	SHUNT, 100 CTRS.	SAMTEC SNT-100-BK-G
12	4	MTGS	HEX STANDOFF 6-32 NYLON 3/4"	KEYSTONE, 1903D
13	4	MTGS	SCREW, PAN PHILLIPS 6-32	B & F, PMSSS 632 0038 PH
14	1		FAB, PRINTED CIRCUIT BOARD	DEMO CIRCUIT 2061A
15	2		STENCILS TOP AND BOTTOM	STENCIL DC2061A



**SCHEMATIC DIAGRAM**



<b>CUSTOMER NOTICE</b>		<b>APPROVALS</b>		<b>LINEAR TECHNOLOGY</b>		<b>48V OUTPUT, 6-60V INPUT BOOST CONVERTER</b>	
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		SCALE	NONE	SCALE	NONE	SCALE	NONE
		SIZE	N/A	SIZE	N/A	SIZE	N/A
		IC NO.	LTC3784UIFD	IC NO.	LTC3784UIFD	IC NO.	LTC3784UIFD
		TITLE	SCHEMATIC	TITLE	SCHEMATIC	TITLE	SCHEMATIC
		DATE	Wednesday, March 12, 2014	DATE	Wednesday, March 12, 2014	DATE	Wednesday, March 12, 2014
		REV.	2	REV.	2	REV.	2
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# DEMO MANUAL DC2061A

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