

## 2-String × 60mA, 2MHz Step-Up LED Driver with ±2% Current Matching

### DESCRIPTION

Demonstration circuit 2176A features the LT<sup>®</sup>3909, a 2-string × 60mA, 2MHz step-up LED driver with ±2% current matching.

The LT3909 precisely regulates two LED strings for equal current, supports LED dimming that reduces brightness down to a 1/40,000 ratio, protects against faults and also reports faults. The LT3909 consists of a step-up converter with a fixed 2MHz switching frequency and current sources for the LED strings.

The operating voltage range for DC2176A is from 7V to 36V. The maximum current in each LED string is 40mA and is programmed by 24.9k I<sub>SET</sub> resistor R1. The I<sub>SET</sub> resistor can be changed to 20k or 16.7k to program the string current to 50mA or 60mA respectively. 16.7k is a 0.1% resistor—a 1% 16.9k resistor will result in slightly less than 60mA string current. See the data sheet for application examples with 50mA and 60mA string currents.

The LT3909 utilizes voltage feedback during PWM dimming and when there are faults on both LED strings. Voltage feedback resistors R2 and R3 on DC2176A optimize operation for LEDs that are 35V maximum. Efficiency is 86% at 12V input, 35V for the LED string forward voltages and 40mA per string.

LED current can be reduced by an external voltage applied to the CTRL terminal. Resistor R8 pulls up CTRL to the INTV<sub>CC</sub> voltage of the LT3909 so the LED current is at the 40mA maximum when there is no external CTRL voltage applied. There are placeholders to add voltage dividers either from V<sub>IN</sub> or INTV<sub>CC</sub> to the CTRL pin. A voltage divider from V<sub>IN</sub> to the CTRL pin can be used to reduce LED current at low input voltages. A resistor divider from INTV<sub>CC</sub> to CTRL allows an NTC to reduce LED current at high temperatures. There are placeholders for an RC filter between the CTRL terminal and the CTRL pin. The RC filter limits the ramp time of the CTRL pin and prevent false faults when CTRL ramps too quickly. The FAULT terminal

is pulled up by 100k R6 to V<sub>IN</sub>, but there is a placeholder to pull up FAULT to INTV<sub>CC</sub> instead.

Resistor divider R4 and R5 from the input to the EN/UVLO pin programs the circuit to turn off when V<sub>IN</sub> decreases below 5V with 0.9V of hysteresis. The circuit can also be turned off by connecting the EN/UVLO terminal to ground.

An external voltage must be applied to the PWM terminal in order for DC2176A to operate. The external voltage can be a DC level or an appropriate PWM dimming signal. A common frequency for PWM dimming is 100Hz. There is a placeholder for a resistor to pull up PWM to INTV<sub>CC</sub> so an external voltage on PWM for operation is unnecessary.

There is a placeholder that allows an external diode to be placed in parallel with the internal LT3909 rectifier for higher current capability. DC2176A uses an inductor that is optimized for high efficiency, and the input supply for power to the inductor can be separated from the LT3909 V<sub>IN</sub> pin to allow operation from two input sources. Ceramic capacitors are used at the input, output and for INTV<sub>CC</sub>. A 50V tantalum polymer capacitor protects the input from ringing that may occur when the input is hot-plugged using long leads. There are placeholders occupied by 0805 size 0Ω jumpers on the back of the PCB for two LED strings and also placeholders for SOD323 diodes to clamp the LED1 and LED2 voltages from ringing below ground.

2-string operation, close current matching, an extremely wide dimming range and fault protection make the LT3909 ideal for functionally advanced back lighting and illumination circuits. DC2176A features the LT3909EDD in a thermally enhanced 12-lead 3mm × 3mm DFN package. The LT3909 data sheet must be read in conjunction with this demo manual to properly use or modify DC2176A.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC2176A>**

LT, LT, LTC, LTM, Linear Technology and the Linear Logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

# DEMO MANUAL DC2176A

## PERFORMANCE SUMMARY

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

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Minimum Input Voltage, $V_{IN}$	$V_{LED1} = V_{LED2} = 35\text{V}$ , $I_{LED1} = I_{LED2} \leq 40\text{mA}$			7	V
Maximum Input Voltage, $V_{IN}$	$V_{LED1} = V_{LED2} = 35\text{V}$ , $I_{LED1} = I_{LED2} \leq 40\text{mA}$	36			V
Maximum LED Voltage, $V_{LED1}$ , $V_{LED2}$	$R2 = 976\text{k } 1\%$ , $R3 = 31.6\text{k } 1\%$	35			V
LED Current, $I_{LED1}$ , $I_{LED2}$	$R1 = 24.9\text{k}$ , $V_{CTRL} = \text{INTV}_{CC}$		40		mA
Input EN/UVLO Turn-On Voltage, $V_{IN}$	$R4 = 402\text{k}$ , $R5 = 130\text{k}$ , $V_{IN}$ Rising		5.9		V
Input EN/UVLO Turn-Off Voltage, $V_{IN}$	$R4 = 402\text{k}$ , $R5 = 130\text{k}$ , $V_{IN}$ Falling		5		V
Efficiency	$V_{IN} = 12\text{V}$ , $V_{LED1} = V_{LED2} = 35\text{V}$ , $I_{LED1} = I_{LED2} = 40\text{mA}$		86		%
Switching Frequency			2		MHz

## QUICK START PROCEDURE

To evaluate the performance of the LT3909 using DC2176A, refer to Figure 1 for the proper measurement equipment setup and then follow the procedure below:

**NOTE:** An external voltage must be applied to the PWM terminal in order for DC2176A to operate. See Step 4 for details.

1. Connect two strings of LEDs with a forward voltage of 35V or less and corresponding meters.
2. Connect the EN/UVLO terminal to GND with a clip-on lead.
3. With the power off, connect the input power supply and corresponding meters.
4. Apply an external voltage to the PWM terminal. The external voltage can be a 2V to 5V DC source or a 100Hz or higher PWM dimming signal. Install resistor R10 to pull up PWM to  $\text{INTV}_{CC}$  if an external voltage on PWM is not desired.
5. Turn the  $V_{IN}$  power supply on and verify that the input voltage is between 7V and 36V. The  $V_{IN}$  voltage is allowed to exceed the LED voltage by a few volts, but a  $V_{IN}$  that is much higher than the LED voltages may activate overtemperature protection or dissipate too much power in the LT3909.
6. Release the EN/UVLO to GND connection.
7. Once the LED strings are running at the programmed LED current; adjust the input voltage within the operating range and observe the LED current regulation or reduction in brightness with LED dimming.

**QUICK START PROCEDURE**

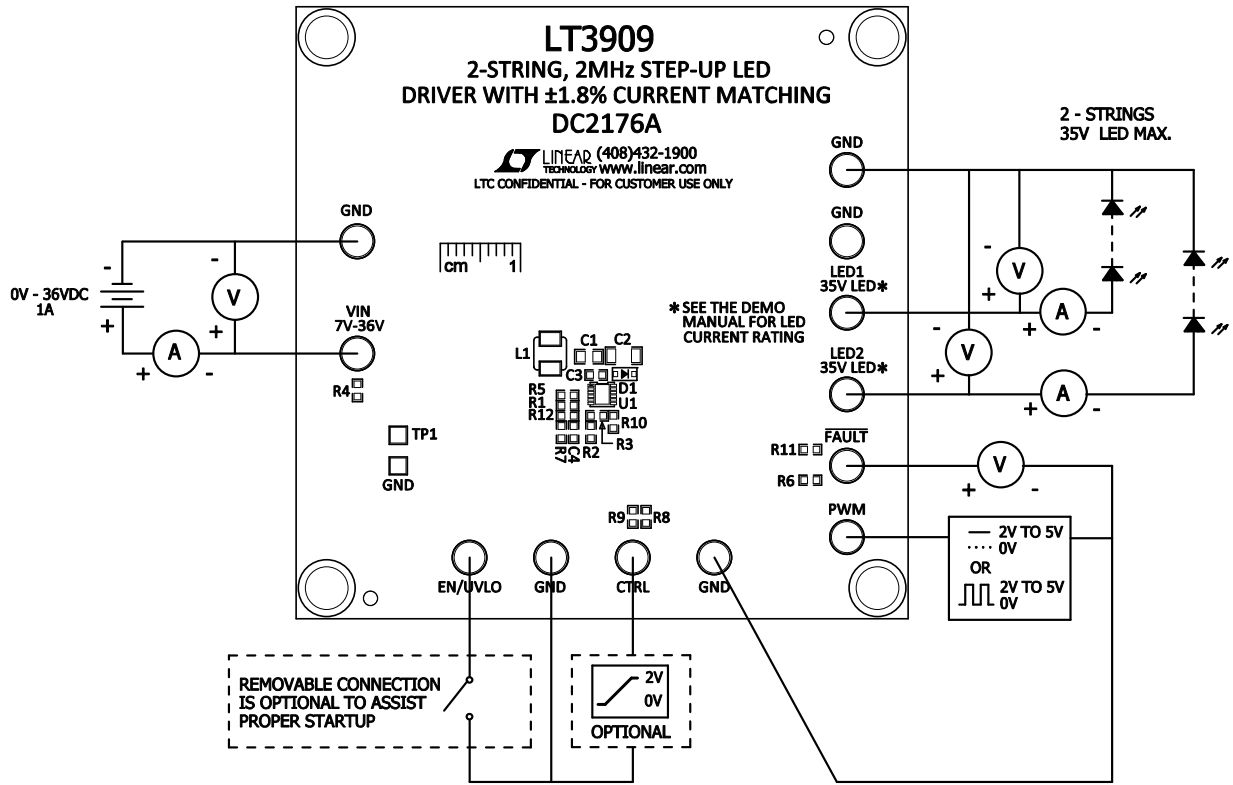


Figure 1. Proper Measurement Equipment Setup for DC2176A

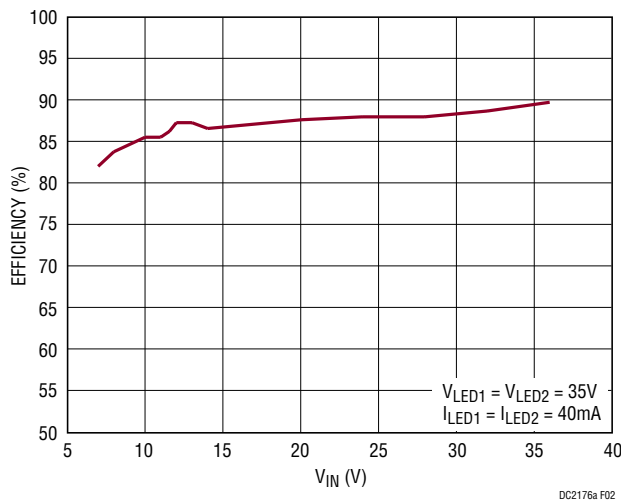


Figure 2. Efficiency vs Input Voltage  $V_{IN}$  with  $V_{LED1} = V_{LED2} = 35V$  and  $I_{LED1} = I_{LED2} = 40mA$

## QUICK START PROCEDURE

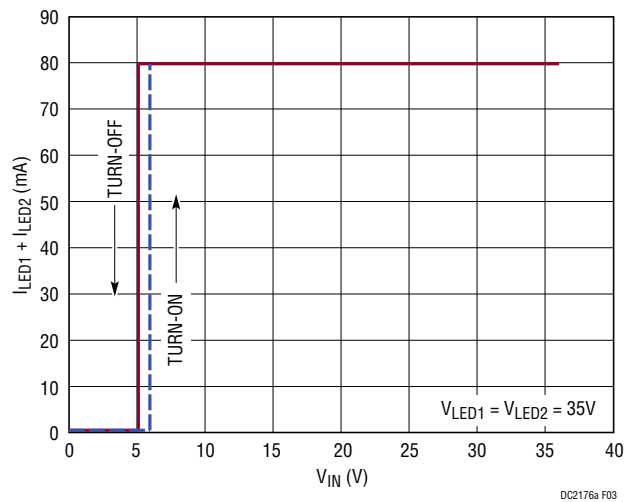


Figure 3. Total Output Current  $I_{LED1} + I_{LED2}$  vs Input Voltage  $V_{IN}$  with  $V_{LED1} = V_{LED2} = 35V$ . UVLO Occurs at  $V_{IN} = 5V$  Input Falling with 0.9V of Hysteresis

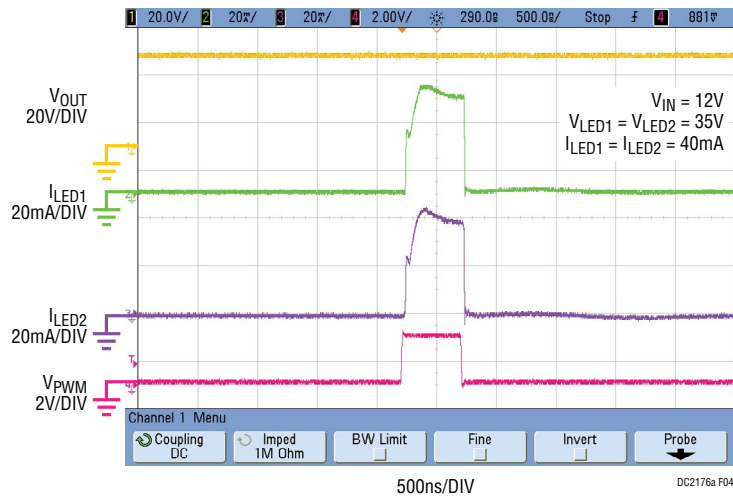
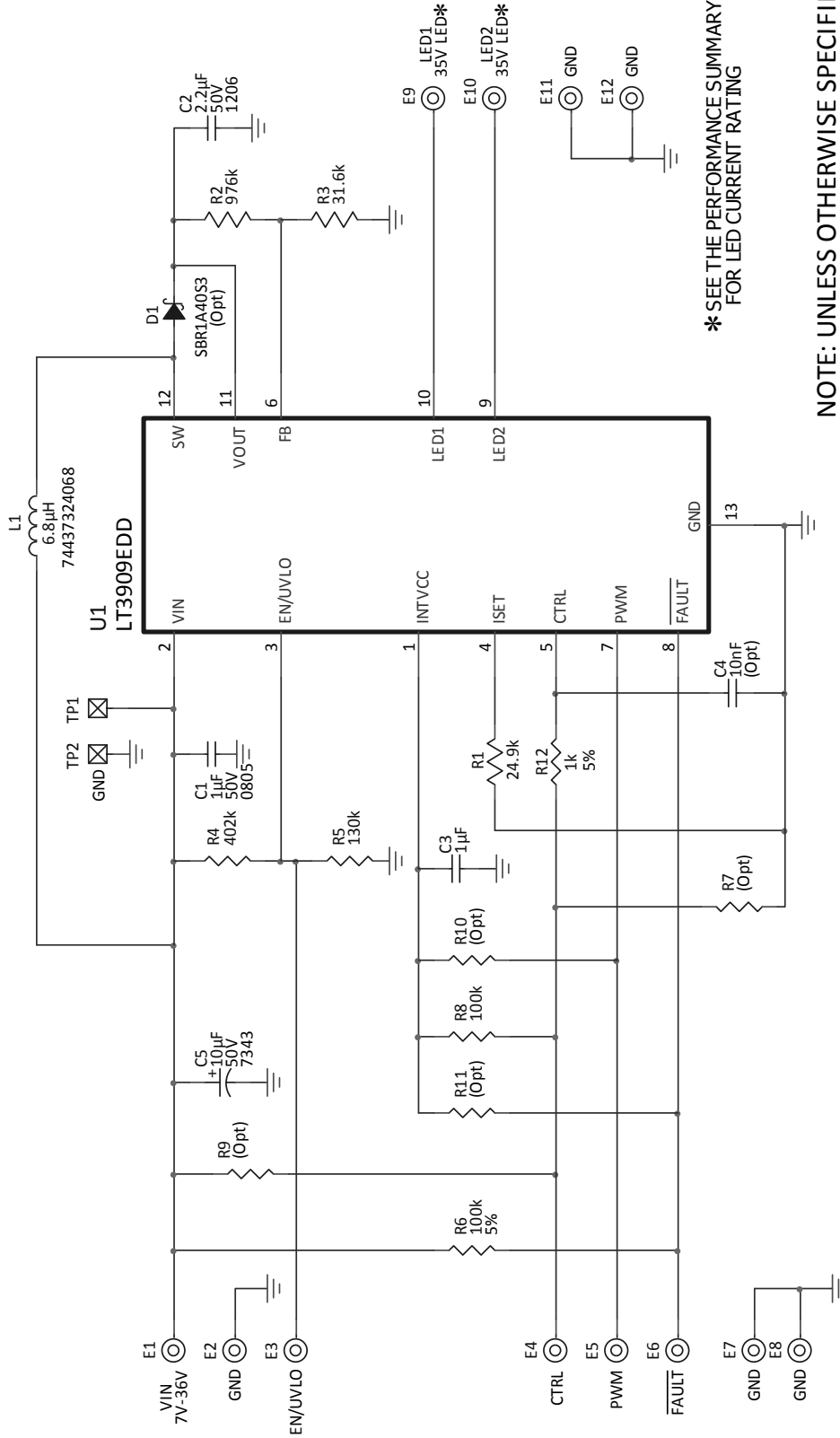


Figure 4. LED Current When Brightness is Reduced to a 1/20,000 Ratio by PWM Dimming at 100Hz

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	1	C1	Cap, 1 $\mu$ F X7R 50V 10% 0805	Murata GRM21BR71H105KA12L
2	1	C2	Cap, 2.2 $\mu$ F X7R 50V 20% 1206	TDK C3216X7R1H225M
3	1	C3	Cap, 1 $\mu$ F X5R 6.3V 20% 0603	TDK C1608X5R0J105M
4	1	L1	Inductor, 6.8 $\mu$ H 4020	Würth Elektronik 74437324068
5	1	R1	Res, Chip 24.9k 0.06W 1% 0603	Vishay CRCW060324K9FKEA
6	1	R2	Res, Chip 976k 0.01W 1% 0603	Vishay CRCW0603976KFKEA
7	1	R3	Res, Chip 31.6k 0.10W 1% 0603	Vishay CRCW060331K6FKEA
8	1	R4	Res, Chip 402k 0.06W 1% 0603	Vishay CRCW0603402KFKEA
9	1	R5	Res, Chip 130k 0.06W 1% 0603	Vishay CRCW0603130KFKEA
10	1	U1	IC, LED Driver DFN(12) (DD) 3mm $\times$ 3mm	Linear Technology Corporation LT3909EDD#PBF
<b>Additional Demo Board Circuit Components</b>				
1	0	C4 (Opt)	Cap, 10nF X7R 100V 10% 0603	AVX 06031C103KAT2A
2	1	C5	Cap, Tant Polymer 10 $\mu$ F 50V 20% 7343	AVX TCJD106M050R0120
3	0	D1 (Opt)	Schottky Diode, 1A SOD-323	Diodes Inc SBR1A40S3
4	1	R6	Res, Chip 100k 0.06W 5% 0603	Vishay CRCW0603100KJEA
5	0	R7, R9, R10, R11 (Opt)	Res, 0603	
6	1	R8	Res, Chip 100k 0.06W 1% 0603	Vishay CRCW0603100KFKEA
7	1	R12	Res, Chip 1k 0.06W 5% 0603	Vishay CRCW06031K00JEA
8	28	R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40	Res/Jumper, Chip 0 0.125W 0805	Vishay CRCW08050000Z0EA
<b>Hardware: For Demo Board Only</b>				
1	12	E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12	Turret, Testpoint	Mill Max 2501-2-00-80-00-00-07-0
2	4	MH1 to MH4	Stand-Off, Nylon 1/4" Tall (Snap On)	Keystone, 8831(Snap On)

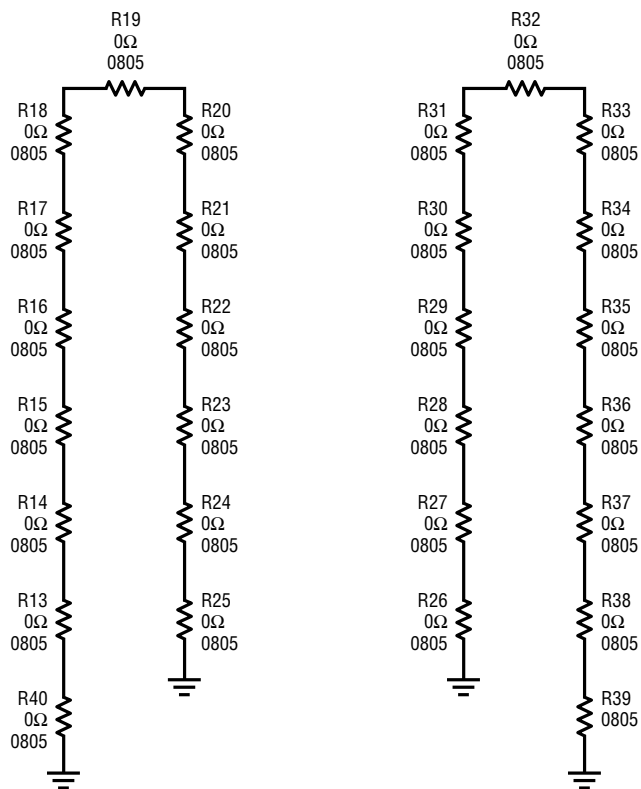
## SCHEMATIC DIAGRAM



**NOTE: UNLESS OTHERWISE SPECIFIED**

1. ALL RESISTORS AND CAPACITORS 0603.
2. ALL RESISTORS ARE 1%.

**SCHEMATIC DIAGRAM**



# DEMO MANUAL DC2176A

---

## 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.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

No License is granted under any patent right or other intellectual property whatsoever. **LTC assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or any other intellectual property rights of any kind.**

LTC currently services a variety of customers for products around the world, and therefore this transaction **is not exclusive**.

**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.

Mailing Address:

Linear Technology  
1630 McCarthy Blvd.  
Milpitas, CA 95035

Copyright © 2004, Linear Technology Corporation