

# LT4276, LT4321, LT4320

## High Efficiency PoE PD Interface with Integrated Switching Regulator and 9-57VDC/24VAC AUX Support

### DESCRIPTION

Demonstration circuit 2047A-A is an IEEE802.3at compliant Power over Ethernet (PoE) Powered Device (PD) with support for 9-57VDC and 24VAC auxiliary supply input. It features the [LT®4276](#) PD interface and switching regulator controller, the LT4321 PoE ideal diode bridge controller, and the LT4320 ideal diode bridge controller.

The LT4276 provides IEEE802.3af (PoE, Type 1) and IEEE802.3at (PoE+, Type 2) compliant interfacing and power supply control. It utilizes an external, low  $R_{DS(ON)}$  (57m $\Omega$  typical) N-channel FET for the hot swap function to improve efficiency. The LT4276 also provides a DC-DC converter configured as a highly efficient flyback topology with synchronous rectification.

The LT4321 controls eight low  $R_{DS(ON)}$  (57m $\Omega$  typical) N-channel FETs to further improve end-to-end power delivery efficiency and ease thermal design. This solution replaces the eight diodes typically found in a passive PoE rectifier bridge.

The LT4320 controls four N-channel FETs (9.6m $\Omega$  typical) to replace a diode bridge typically found at the auxiliary supply input. AC rectification and DC polarity correction are provided. This solution reduces voltage drop associated with the diode bridge and enables the power supply operation as low as 9VDC at the auxiliary supply input. This improves end-to-end efficiency and reduces heat.

The DC2047A-A accepts up to 25.5W of delivered power from a Power Sourcing Equipment (PSE) via the RJ45 connector (J1) or a local AC/DC power supply using the auxiliary supply input. When both supplies are connected, the auxiliary supply input has priority over the PoE input. The DC2047A-A supplies a 12V output at up to 1.9A.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC2047A-A>**

LT, LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks of Analog Devices, Inc. All other trademarks are the property of their respective owners.

### PERFORMANCE SUMMARY

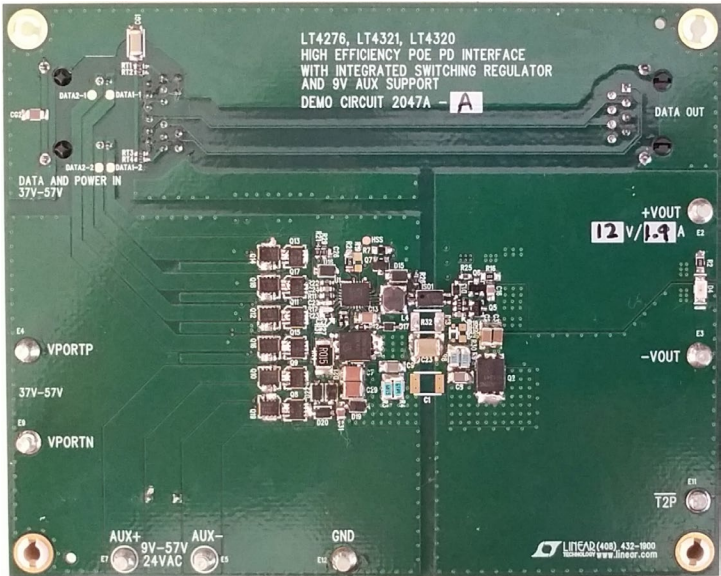
Specifications are at  $T_A = 25^\circ\text{C}$

| PARAMETER                       | CONDITIONS                                         | VALUE                         |
|---------------------------------|----------------------------------------------------|-------------------------------|
| Port Voltage ( $V_{PORT}$ )     | At RJ45                                            | 37V to 57V                    |
| Auxiliary Voltage ( $V_{AUX}$ ) | From AUX+ to AUX- Terminals                        | 9V to 57VDC/24VAC             |
| Output Voltage ( $V_{OUT}$ )    |                                                    | 12V (Typical)                 |
| Output Current ( $I_{OUT}$ )    |                                                    | 1.9A (Max)                    |
| Output Voltage Ripple           | $V_{PORT} = 42.5V$ , $I_{OUT} = 1.9A$              | 90mV <sub>p-p</sub> (Typical) |
| Load Regulation                 |                                                    | $\pm 0.6\%$ (Typical)         |
| Efficiency                      | $V_{PORT} = 42.5V$ , $I_{OUT} = 1.9A$ , End-to-End | 88% (Typical)                 |
| Switching Frequency             |                                                    | 250kHz (Typical)              |

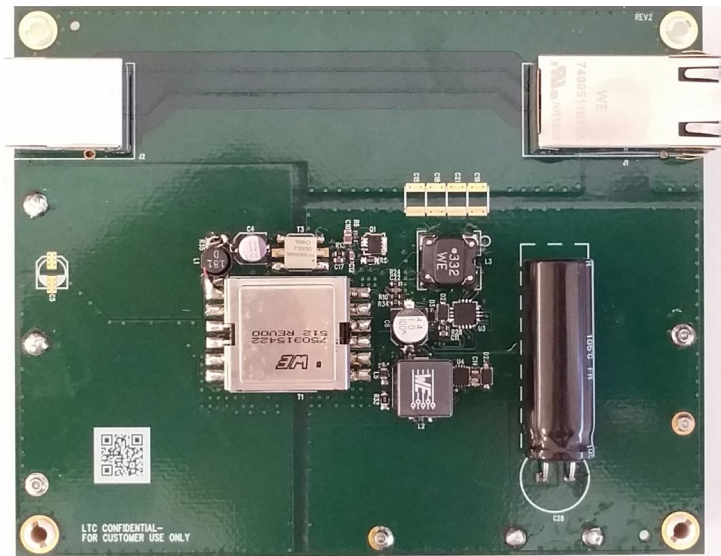
# DEMO MANUAL

## DC2047A-A

### BOARD PHOTO



Top Side



Bottom Side

## TYPICAL PERFORMANCE CHARACTERISTICS

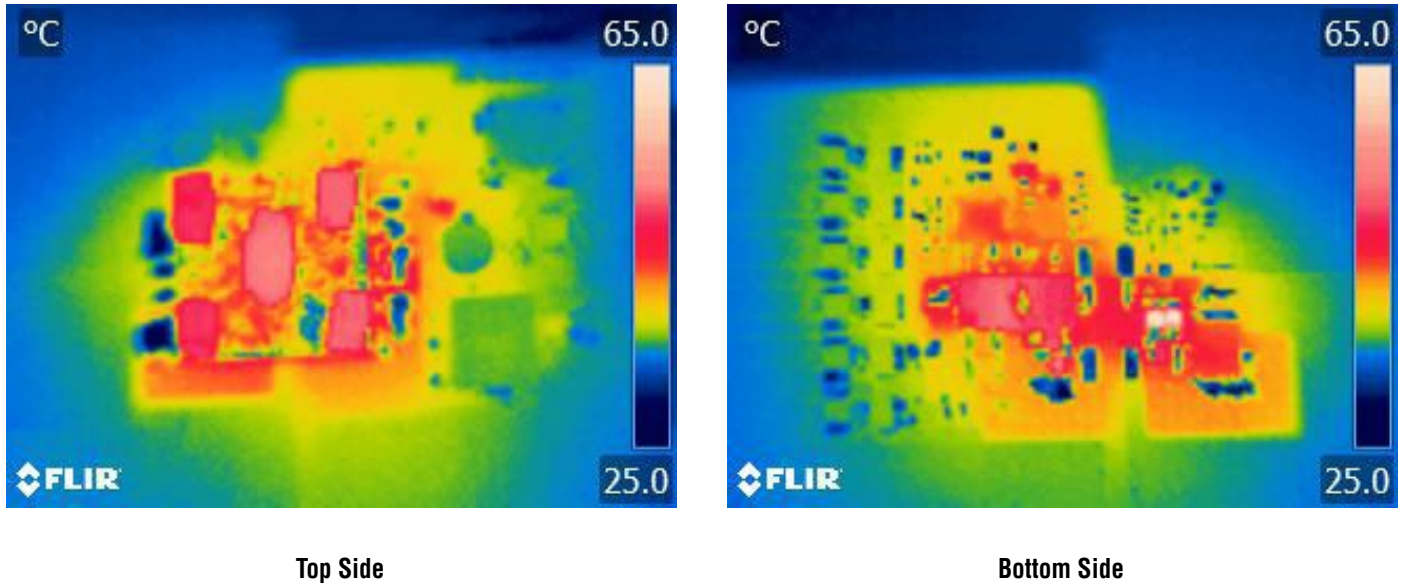


Figure 1. Thermal Pictures (Conditions:  $V_{AUX} = 57V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 1.9A$ )

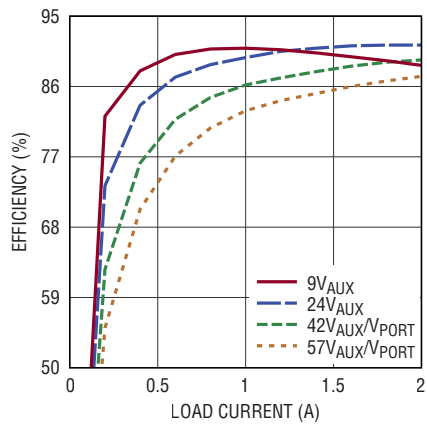


Figure 2. Efficiency (End-to-End)

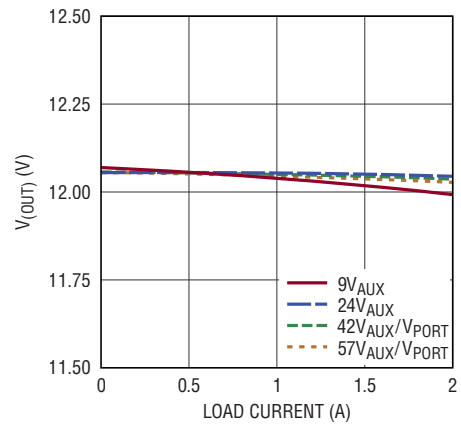


Figure 3. Load Regulation

TYPICAL PERFORMANCE CHARACTERISTICS

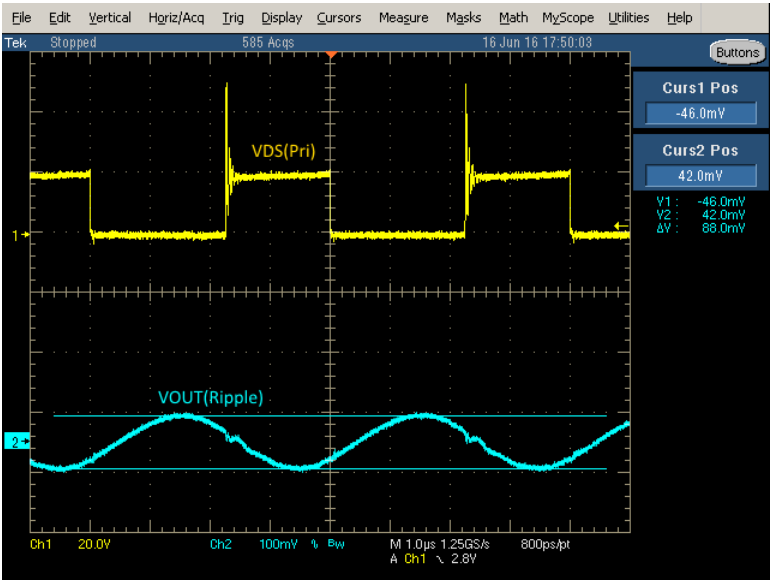


Figure 4. Output Voltage Ripple (Conditions:  $V_{AUX} = 9V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 1.9A$ )

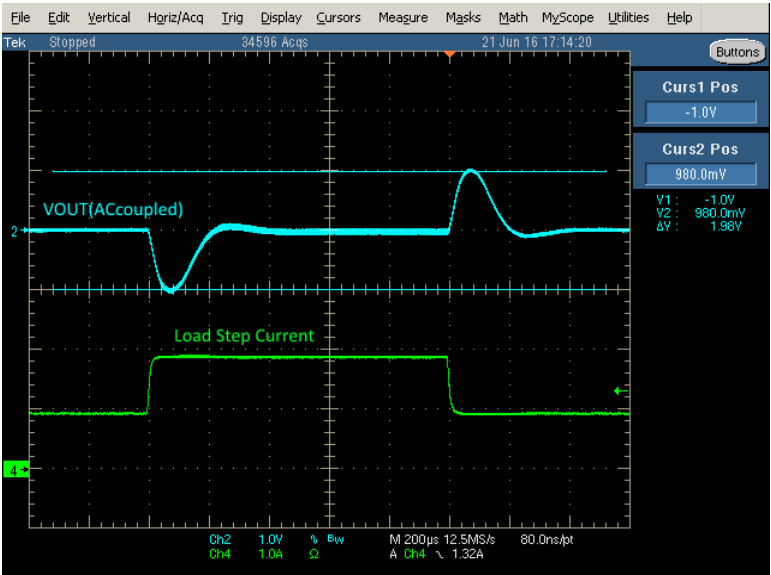


Figure 5. Load Transient Response (Conditions:  $V_{AUX} = 9V$ , Load Step: 0.95A to 1.9A to 0.95A)

## TYPICAL PERFORMANCE CHARACTERISTICS

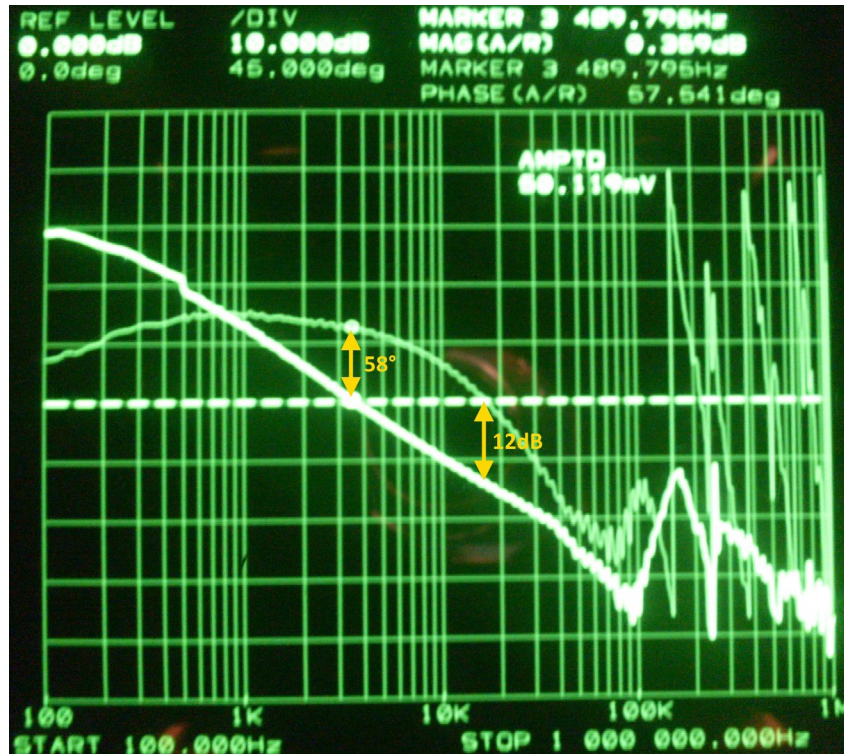


Figure 6. Gain and Phase Margin of the Flyback DC/DC Converter (Conditions:  $V_{AUX} = 9V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 1.9A$ )

| CROSSOVER FREQUENCY | GAIN MARGIN | PHASE MARGIN |
|---------------------|-------------|--------------|
| 3.5kHz              | 12dB        | 58°          |

QUICK START PROCEDURE

Power over Ethernet (PoE) Input

1. Disconnect auxiliary supply if it is connected to AUX+ and AUX- inputs of the DC2047A-A.

2. Place and connect test equipment (voltmeter, ammeter, oscilloscope, and electronic load) as shown in Figure 7.

3. Turn down the electronic load to a minimum value and turn off the electronic load.

4. Connect the DC power supply to the DC1567A. Turn on the DC power supply and set its current limit to 1A. Then increase its output voltage to 57V.

5. Connect the output of the DC1567A to the RJ45 connector (J1) of the DC2047A using a CAT5e or CAT6 Ethernet cable.
6. After the LED (D4) on the DC2047A is lit, check the output voltage using a voltmeter. Output voltage should be within 12.0V  $\pm$ 0.2V.

7. Turn on the electronic load and increase its load current up to 1.9A. Observe the output voltage regulation, efficiency, and other parameters.

8. Verify  $\overline{T2P}$  response with a voltmeter as shown in Figure 7. The  $\overline{T2P}$  response to the type of PSE connected to the DC2047A-A is provided in Table 1.

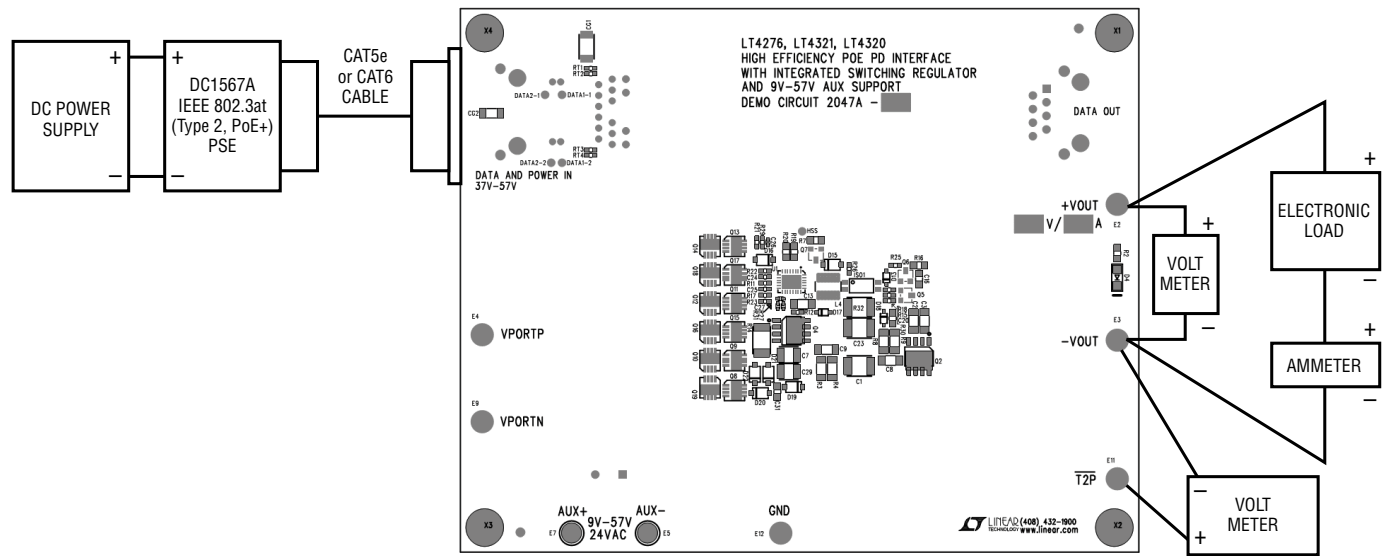


Figure 7. Setup Diagram for PoE Input

Table 1.  $\overline{T2P}$  Response vs PSE Type

| PSE  | $\overline{T2P}$ RESPONSE | NEGOTIATED PD INPUT POWER |
|------|---------------------------|---------------------------|
| IEEE | Logic High                | 13W                       |
|      | Logic Low                 | 25.5W                     |

### QUICK START PROCEDURE

#### Auxiliary Supply Input

1. Place and connect test equipment (voltmeter, ammeter, oscilloscope, and electronic load) as shown in Figure 8.
2. Turn down the electronic load to a minimum value and turn off the electronic load.
3. Connect the output of the auxiliary supply to the DC2047A as shown in Figure 8. Turn on the auxiliary supply and set its current limit to 1A. Then increase its output voltage to 48V.
4. Once the LED (D4) on the DC2047A is lit, check the output voltage using a voltmeter. Output voltage should be within  $12.0V \pm 0.2V$ .
5. Turn on the electronic load and increase its load current up to 1.9A. Observe the output voltage regulation, efficiency, and other parameters.
6. Verify  $\overline{T2P}$  response with a voltmeter as shown in Figure 8. The  $\overline{T2P}$  response during auxiliary power operation is: Logic Low.

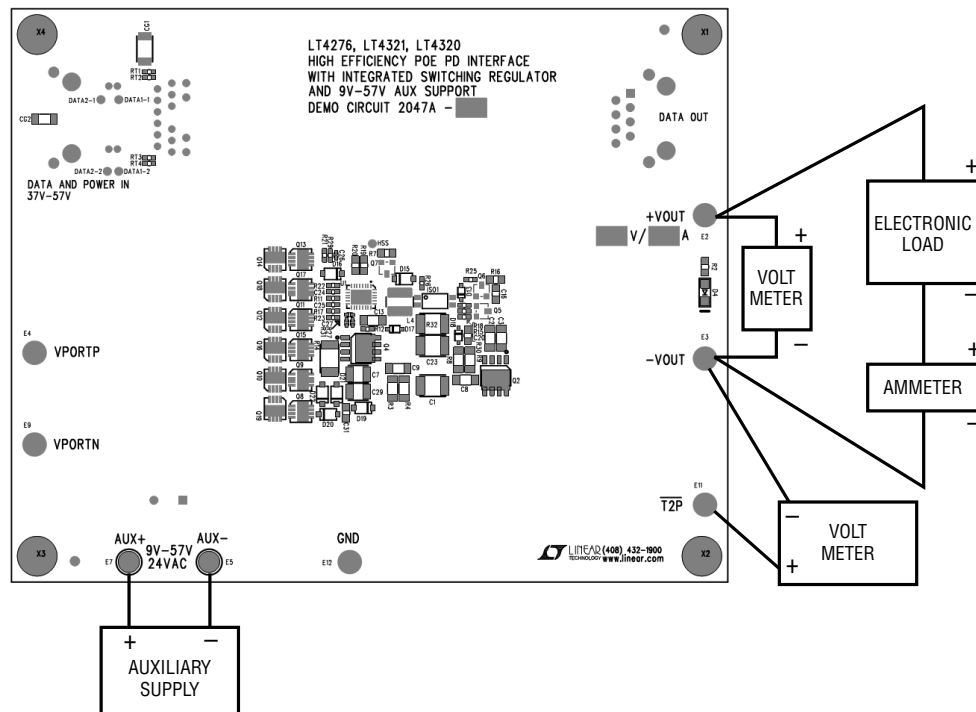


Figure 8. Setup Diagram for Auxiliary Supply Input

# DEMO MANUAL

## DC2047A-A

### PARTS LIST

| ITEM                       | QTY | REFERENCE                                  | PART DESCRIPTION                           | MANUFACTURER/PART NUMBER         |
|----------------------------|-----|--------------------------------------------|--------------------------------------------|----------------------------------|
| <b>DC2047A General BOM</b> |     |                                            |                                            |                                  |
| 1                          | 1   | CG1                                        | CAP, CER, X7R 1000pF 2KV 10% 1808          | MURATA GR442QR73D102KW01L        |
| 2                          | 1   | CG2                                        | CAP, CER, X7R 0.01μF 100V 20% 1206         | AVX 12061C103MAT2A               |
| 3                          | 0   | C1                                         | CAP, CER, OPT 2kV 1812                     | OPT                              |
| 4                          | 0   | C5                                         | CAP, ELEC, OPT 5.0×5.9                     | OPT                              |
| 5                          | 1   | C6                                         | CAP, ELEC, 10μF 100V 10% 6.3×7.7           | SUNCON 100CE10BS                 |
| 6                          | 2   | C7, C29                                    | CAP, CER, X7S 4.7μF 100V 10% 1210          | TDK C3225X7S2A475K200AB          |
| 7                          | 1   | C10                                        | CAP, CER, X7R 100nF 100V 10% 0805          | TDK C2012X7R2A104K125AE          |
| 8                          | 2   | C11, C12                                   | CAP, CER, X7R 0.047μF 100V 10% 0603        | KEMET C0603C473K1RACTU           |
| 9                          | 1   | C13                                        | CAP, CER, X7R 22μF 10V 20% 1206            | MURATA GRM31CR71A226ME15         |
| 10                         | 1   | C14                                        | CAP, CER, X7R 1μF 100V 10% 0805            | MURATA GRJ21BC72A105KE1L         |
| 11                         | 0   | C15, C18, C19, C21                         | CAP, CER, X5R OPT 2KV 20% 1812             | OPT                              |
| 12                         | 1   | C17                                        | CAP, CER, X7R 1μF 25V 10% 0603             | MURATA GRM188R71E105KA12         |
| 13                         | 1   | C20                                        | CAP, CER, X7R 2.2nF 25V 10% 0603           | MURATA GRM188R71E222KA01         |
| 14                         | 1   | C23                                        | CAP, CER, X7R 4.7nF 2kV 1812               | MURATA GR443DR73D472KW01L        |
| 15                         | 1   | C26                                        | CAP, CER, X7R 100pF 16V 10% 0402           | AVX 0402YC101KAT2A               |
| 16                         | 1   | C27                                        | CAP, CER, X7R 4.7nF 6.3V 10% 0402          | MURATA GRM155R70J472KA01D        |
| 17                         | 1   | C28                                        | CAP, ELEC, 680μF 63V 20% 12.5×25           | PANASONIC EEU-FR1J681L           |
| 18                         | 1   | C31                                        | CAP, CER, X7R 0.1μF 100V 10% 0805          | MURATA GRM188R72A104KA35         |
| 19                         | 4   | D2, D16, D19, D23                          | DIODE, TVS, PTVS58VS1UR 58V SOD123         | NXP PTVS58VS1UR                  |
| 20                         | 1   | D3                                         | DIODE, ZENER, MMSZ5252BS 24V SOD323        | DIODES INC MMSZ5256BS-7-F        |
| 21                         | 1   | D4                                         | DIODE, LED                                 | ROHM SML-010FTT86L               |
| 22                         | 1   | D13                                        | DIODE, SCHOTTKY, BAT46WJ,115 100V SOD323   | NXP BAT46WJ,115                  |
| 23                         | 1   | D15                                        | DIODE, SCHOTTKY, PMEG10010ELRX 100V SOD123 | NXP PMEG10010ELRX                |
| 24                         | 1   | D17                                        | DIODE, SCHOTTKY, BAT54WS 30V SOD323        | DIODE INC BAT54WS-7-F            |
| 25                         | 3   | D20, D21, D22                              | DIODE, SILICON, MM5D4148 100V SOD123       | FAIRCHILD SEMI MM5D4148          |
| 26                         | 8   | E2, E3, E4, E5, E7, E9, E11, E12           | TP, TURRET, MILL-MAX-2501 0.094"           | MILL-MAX 2501-2-00-80-00-00-07-0 |
| 27                         | 1   | J1                                         | CONN, INTEGRATED JACK, 7499511611A         | WURTH 7499511611A                |
| 28                         | 1   | J2                                         | CONN, RJ45 JACK, SS-6488S-A-NF             | STEWART CONNECTOR SS-6488S-A-NF  |
| 29                         | 1   | L2                                         | IND, 8.2μH                                 | WURTH 7443330820                 |
| 30                         | 1   | L3                                         | IND, CMC, 3.3mH                            | WURTH 744272332                  |
| 31                         | 1   | L3 (ALTERNATE)                             | IND, CMC, 3.3mH                            | PCA ELECTRONICS EPA4411-LF       |
| 32                         | 1   | L4                                         | IND, 22μH                                  | BOURNS PM43-220M-RC              |
| 33                         | 1   | L5                                         | IND, 2.2μH 0805                            | MURATA LQM21PN2R2NGCD            |
| 34                         | 9   | Q1, Q11, Q12, Q13, Q14, Q15, Q16, Q17, Q18 | MOSFET, N-CH, PSMN075-100MSE 100V LFPK33   | NXP PSMN075-100MSE               |
| 35                         | 1   | Q4                                         | MOSFET, N-CH, BSC109N10NS3 G 100V SUPERSO8 | INFINEON BSC109N10NS3 G          |
| 36                         | 1   | Q5                                         | TRANSISTOR, PNP, PBSS5140T 40V SOT23       | NXP PBSS5140T                    |
| 37                         | 1   | Q6                                         | TRANSISTOR, NPN, PBSS4140T 40V SOT23       | NXP PBSS4140T                    |
| 38                         | 1   | Q7                                         | TRANSISTOR, PNP, FM7T23 100V SOT23         | DIODES INC FM7T23TA              |
| 39                         | 4   | Q8, Q9, Q10, Q19                           | MOSFET, N-CH, PSMN011-60MS 60V LFPK33      | NXP PSMN011-60MS                 |

### PARTS LIST

| ITEM | QTY | REFERENCE          | PART DESCRIPTION                                       | MANUFACTURER/PART NUMBER |
|------|-----|--------------------|--------------------------------------------------------|--------------------------|
| 40   | 4   | RT1, RT2, RT3, RT4 | RES, CHIP, 75Ω 5% 0603                                 | NIC NRC06J750TRF         |
| 41   | 1   | R5                 | RES, CHIP, 8.2Ω 5% 0805                                | NIC NRC10J8R2TRF         |
| 42   | 1   | R6                 | RES, CHIP, 3.3k 5% 0603                                | NIC NRC06J332TRF         |
| 43   | 1   | R7                 | RES, CHIP, 1Ω 5% 0805                                  | NIC NRC10I1R0TRF         |
| 44   | 3   | R12, R28, R34      | RES, CHIP, 0Ω SHUNT 0603                               | NIC NRC06Z0TRF           |
| 45   | 1   | R13                | RES, CHIP, 100Ω 5% 0603                                | VISHAY CRCW0603100RJNEA  |
| 46   | 1   | R14                | RES, CHIP, 15mΩ 1% 2010                                | VISHAY WSL2010R0150FEA   |
| 47   | 1   | R15                | RES, CHIP, 15Ω 5% 0603                                 | NIC NRC06J150TRF         |
| 48   | 1   | R33                | RES, CHIP, 0Ω SHUNT 0805                               | NIC NRC06Z0TRF           |
| 49   | 1   | R17                | RES, CHIP, 2.00k 1% 0603                               | NIC NRC06F2001TRF        |
| 50   | 2   | R18, R26           | RES, CHIP, 10k 5% 0603                                 | NIC NRC06J103TRF         |
| 51   | 1   | R21                | RES, CHIP, 158k 1% 0603                                | NIC NRC06F1583TRF        |
| 52   | 1   | R22                | RES, CHIP, 107k 1% 0603                                | NIC NRC06F1071TRF        |
| 53   | 2   | R27, R31           | RES, CHIP, 10Ω 5% 0402                                 | NIC NRC04J100TRF         |
| 54   | 1   | R29                | RES, CHIP, 931k 1% 0603                                | NIC NRC06F9313TRF        |
| 55   | 0   | R32                | RES, CHIP, OPT 1% 1812                                 | OPT                      |
| 56   | 1   | ISO1               | OPTO, TRANSISTOR OUTPUT OPTOCOUPLER, S04               | TOSHIBA TLP291(GR-TPSE)  |
| 57   | 1   | T3                 | XFMR, SMD GATE DRIVE, EPA4271GE                        | PCA EPA4271GE            |
| 58   | 0   | T3 (ALTERNATE)     | XFMR, SMD GATE DRIVE, PE-68386NL                       | PULSE PE-68386NL         |
| 59   | 0   | T4                 | XFMR, SMD GATE DRIVE, OPT                              | OPT                      |
| 60   | 1   | U1                 | IC, PD AND SWITCHER CONTROLLER, LT4276BIUFD QFN28      | LINEAR TECH LT4276BIUFD  |
| 61   | 1   | U3                 | IC, PoE IDEAL DIODE BRIDGE CONTROLLER, LT4321IUF QFN16 | LINEAR TECH LT4321IUF    |
| 62   | 1   | U4                 | IC, IDEAL DIODE BRIDGE CONTROLLER, LT4320IDD DFN8      | LINEAR TECH LT4320IDD    |
| 63   | 4   | MH1-MH4            | STAND-OFF, NYLON 0.50" TALL (SNAP ON)                  | KEystone 8833            |
| 64   | 1   |                    | STENCIL                                                | STENCIL DC2047A          |

#### DC2047A-A

|    |   |       |                                           |                           |
|----|---|-------|-------------------------------------------|---------------------------|
| 1  | 2 | C2,C3 | CAP, CER, X5R 10μF 16V 10% 1206           | MURATA GRM31CR61C106KA88  |
| 2  | 1 | C4    | CAP, ELEC, 22μF 16V 20% 5.0×5.9           | PANASONIC 16SVP22M        |
| 3  | 1 | C8    | CAP, CER, U2J 220pF 630V 5% 1206          | MURATA GRM31A7U2J221JW31D |
| 4  | 1 | C9    | CAP, CER, U2J 220pF 630V 5% 1206          | MURATA GRM31A7U2J221JW31D |
| 5  | 1 | C16   | CAP, CER, X7R 1μF 25V 10% 0805            | MURATA GRM21BR71E105KA99L |
| 6  | 1 | C22   | CAP, CER, X7R 3.3nF 25V 10% 0603          | AVX 06033C332KAT2A        |
| 7  | 1 | C24   | CAP, CER, X7R 0.1μF 25V 10% 0603          | MURATA GRM188R71E104KA01D |
| 8  | 1 | C25   | CAP, CER, X7R 100pF 25V 10% 0603          | AVX 06033C101KAT2A        |
| 9  | 0 | D18   | DIODE, SCHOTTKY, OPT SOD323               | OPT                       |
| 10 | 1 | L1    | IND, 180nH                                | COILCRAFT DO1813P-181HC   |
| 11 | 1 | Q2    | MOSFET, N-CH, TPH5200FNH 250V SOP ADVANCE | TOSHIBA TPH5200FNH        |
| 12 | 1 | R2    | RES, CHIP, 1.5k 5% 0805                   | NIC NRC06J152TRF          |
| 13 | 1 | R3    | RES, CHIP, 62Ω 5% 1206                    | PANASONIC ERJ-8GEYJ620V   |

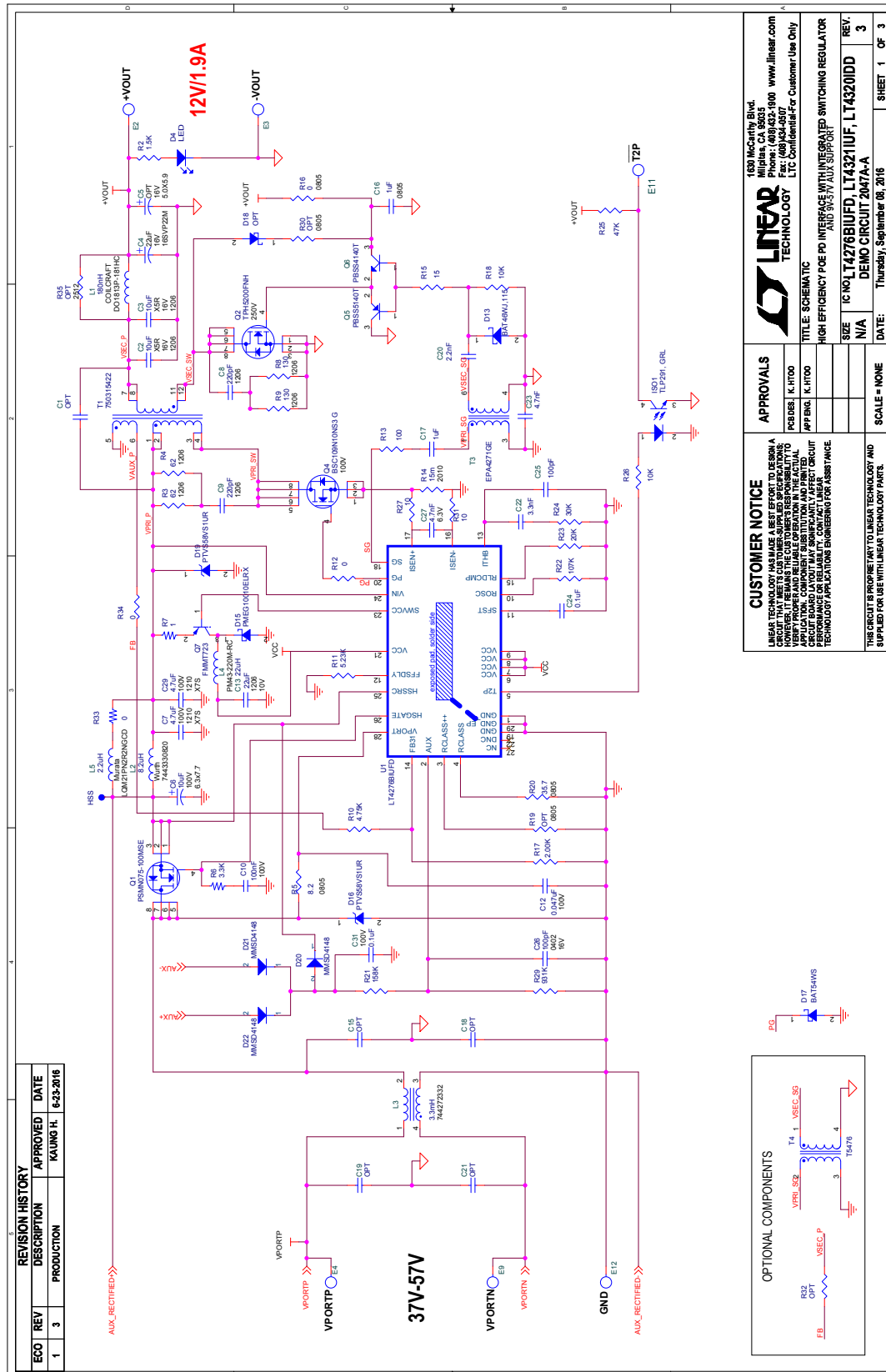
# DEMO MANUAL

## DC2047A-A

### PARTS LIST

| ITEM | QTY | REFERENCE      | PART DESCRIPTION                 | MANUFACTURER/PART NUMBER    |
|------|-----|----------------|----------------------------------|-----------------------------|
| 14   | 1   | R4             | RES, CHIP, 62 $\Omega$ 5% 1206   | PANASONIC ERJ-8GEYJ620V     |
| 15   | 1   | R8             | RES, CHIP, 130 $\Omega$ 5% 1206  | NIC NRC12J131TRF            |
| 16   | 1   | R9             | RES, CHIP, 130 $\Omega$ 5% 1206  | NIC NRC12J131TRF            |
| 17   | 1   | R10            | RES, CHIP, 4.75k 1% 0603         | NIC NRC06F4751TRF           |
| 18   | 1   | R11            | RES, CHIP, 5.23k 1% 0603         | VISHAY, CRCW06035K23FKEA    |
| 19   | 1   | R16            | RES, CHIP, 0 $\Omega$ SHUNT 0805 | VISHAY CRCW08050000Z0EA     |
| 20   | 0   | R19            | RES, CHIP, OPT 1% 0805           | OPT                         |
| 21   | 1   | R20            | RES, CHIP, 35.7 $\Omega$ 1% 0805 | VISHAY CRCW080535R7FKEA     |
| 22   | 1   | R23            | RES, CHIP, 20k 5% 0603           | VISHAY CRCW060320K0JNEA     |
| 23   | 1   | R24            | RES, CHIP, 30k 5% 0603           | VISHAY CRCW060330K0JNEA     |
| 24   | 1   | R25            | RES, CHIP, 47k 5% 0603           | NIC NRC06J473TRF            |
| 25   | 0   | R30            | RES, CHIP, OPT 5% 0805           | OPT                         |
| 26   | 0   | R35            | RES, CHIP, OPT 5% 2512           | OPT                         |
| 27   | 1   | T1             | XFMR, PWR TRAN, 750315422        | WURTH 750315422             |
| 28   | 0   | T1 (ALTERNATE) | XFMR, PWR TRAN, EPC3601          | PCA ELECTRONICS EPC3601G-LF |
| 29   | 1   |                | FAB, PRINTED CIRCUIT BOARD       | DEMO CIRCUIT 2047A          |

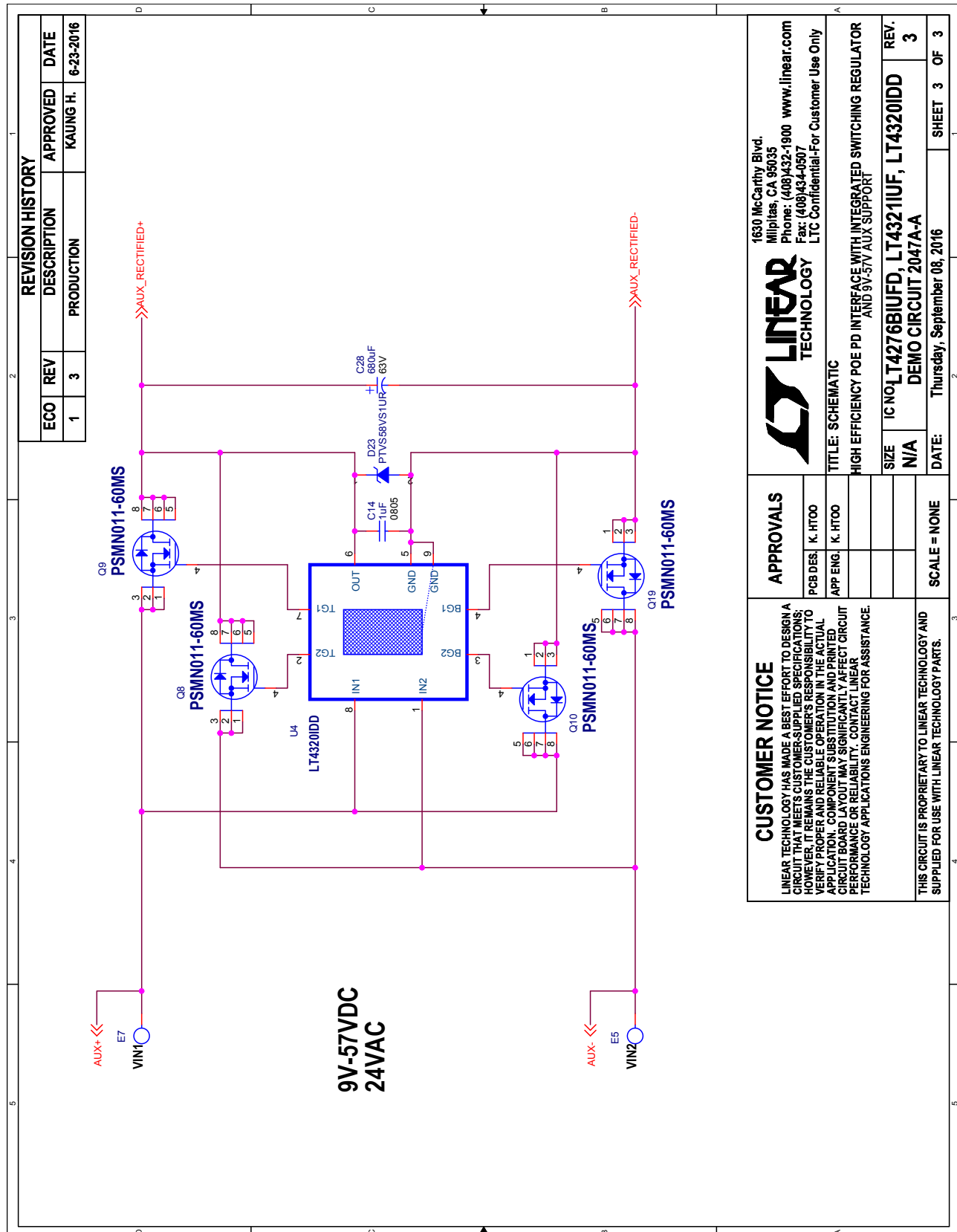
## SCHEMATIC DIAGRAM



## SCHEMATIC DIAGRAM



### SCHEMATIC DIAGRAM



dc2047aafa

# DEMO MANUAL

## DC2047A-A

---

### 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