# DEMO MANUAL DC2199A-A

## LTC3765/LTC3766
## 360W Isolated Forward Converter with Synchronous Rectification

## DESCRIPTION

Demonstration circuit 2199A-A is a 360W isolated forward converter with synchronous rectification featuring the LTC3765/LTC3766. It produces a regulated 12V, 30A output from an input voltage range of 36V to 60V.

This circuit was designed to demonstrate the high levels of performance, efficiency, and small solution size attainable using these parts in an active-clamp-reset forward converter power supply, suitable for telecom, industrial, and other applications. It has a 4.7in$^2$ solution footprint area. Synchronous rectification helps to attain an efficiency exceeding 96%. Secondary-side control eliminates complex opto-coupler feedback, providing fast transient response with minimum output capacitance. For other output requirements, see the LTC3766 data sheet or contact the LTC sales.

**Design files for this circuit board are available at http://www.linear.com/demo/DC2199A-A**



## PERFORMANCE SUMMARY

**Specifications are at $T_A$ = 25°C**

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Input Supply Range | | 36 | | 60 | V |
| $V_{OUT}$ | Output Voltage | | 11.76 | 12.0 | 12.24 | V |
| $I_{OUT}$ | Output Current Range, Continuous | 200LFM | 0 | | 30 | A |
| $f_{SW}$ | Switching (Clock) Frequency | | | 200 | | kHz |
| $V_{OUT(P-P)}$ | Output Ripple | $V_{IN}$ = 24V, $I_{OUT}$ = 30A (20MHz BW) | | 60 | | $mV_{P-P}$ |
| $I_{REG}$ | Output Regulation | Line and Load (36$V_{IN}$ to 60$V_{IN}$, 0$A_{OUT}$ to 30$A_{OUT}$) | | ±0.02 | | % |
| $P_{OUT}/P_{IN}$ | Efficiency (See Figure 3) | $V_{IN}$ =48V, $I_{OUT}$ = 30A | | 96 | | % |
| | Isolation | Basic | | 1500 | | VDC |
| | Approximate Solution Size | Component Area × Top Component Height | | 4.7in$^2$ × 0.6 | | Inches |

## OPERATING PRINCIPLES

The LTC3765 active clamp forward controller and gate driver is used on the primary and provides start-up, gate drive, and protection functions. Once start-up is accomplished, the LTC3766 high efficiency, secondary-side synchronous forward controller takes over, and provides the LTC3765 with timing information and bias power through a small pulse transformer.

When input voltage is applied, the LTC3765 commences soft-start of the output voltage. When the output reaches the RUN threshold, the LTC3766 comes alive and takes control by sending encoded PWM gate pulses to the LTC3765 through T2. These pulses also provide primary bias power efficiently over a wide input voltage range.

The transition from primary to secondary control occurs at some fraction of the nominal output voltage. From then on, operation and design is reduced to that of a simple buck converter. Secondary control eliminates delays, tames large-signal overshoot, and reduces output capacitance needed to meet transient response requirements.

An optional LC filter stage on the input lowers RMS input current. The filter must have output impedance that is less than the converter input impedance to assure stability. This may require a damping impedance, which is provided by R1. (See Linear Technology Application Note 19 for a discussion of input filter stability.) R1 is coupled through a tiny 2mm × 2mm inductor L1, and provides damping with arbitrarily low source impedance. For bench testing, an electrolytic capacitor has been added at the input terminals to provide suitable ripple current capability. The values selected have a filter resonant frequency that is below the converter switching frequency, thus avoiding high circulating currents in the filter.

## QUICK START PROCEDURE

Demonstration circuit 2199A-A is easy to set up to evaluate the performance of the LTC3765/LTC3766. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below:

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. Set an input power supply that is capable of 36V to 60V to 36V. Then turn off the supply.
2. Direct an airflow of 200LFM across the unit for sustained operation at full load.
3. With power off, connect the supply to the input terminals $+V_{IN}$ and $-V_{IN}$.
   a. Input voltages lower than 36V can keep the converter from turning on due to the undervoltage lockout feature of the LTC3765/LTC3766.
   b. If efficiency measurements are desired, an ammeter capable of measuring 15ADC or a resistor shunt can be put in series with the input supply in order to measure the DC2199A-A's input current.
   c. A voltmeter with a capability of measuring at least 60V can be placed across the input terminals in order to get an accurate input voltage measurement.
4. Turn on the power at the input.

   NOTE: Make sure that the input voltage never exceeds 60V.
5. Check for the proper output voltage of 12V. Turn off the power at the input.
6. Once the proper output voltages are established, connect a variable load capable of sinking 30A at 12V to the output terminals $+V_{OUT}$ and $-V_{OUT}$. Set the current for 0A.
   a. If efficiency measurements are desired, an ammeter or a resistor shunt that is capable of handling 30ADC can be put in series with the output load in order to measure the DC2199A-A's output current.

## QUICK START PROCEDURE

b. A voltmeter with a capability of measuring at least 12V can be placed across the output terminals in order to get an accurate output voltage measurement.

7. 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.

8. Once the proper output voltage is again established, adjust the load within the operating range and observe the output voltage regulation, ripple voltage, efficiency and other desired parameters.

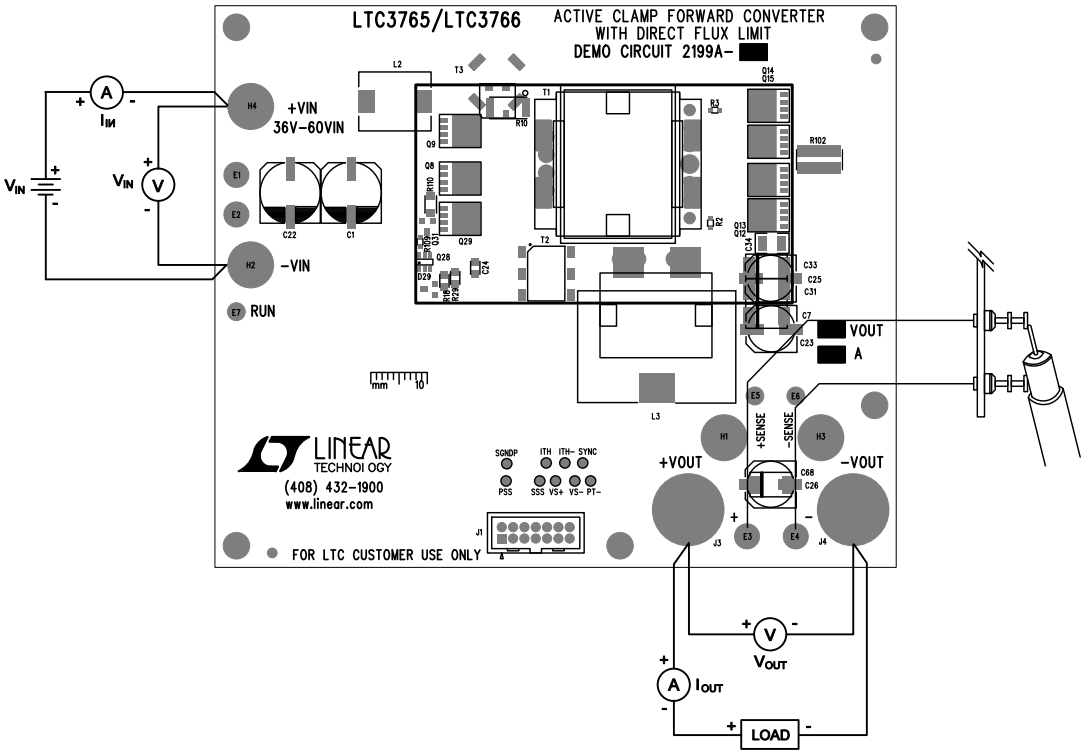



**Figure 1. Proper Measurement Equipment Setup**

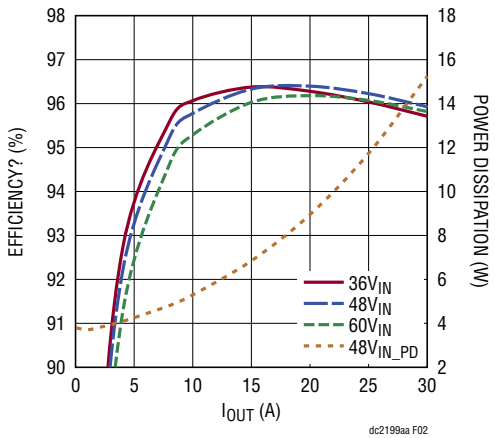



**Figure 2. Efficiency and Power Dissipation**

## QUICK START PROCEDURE

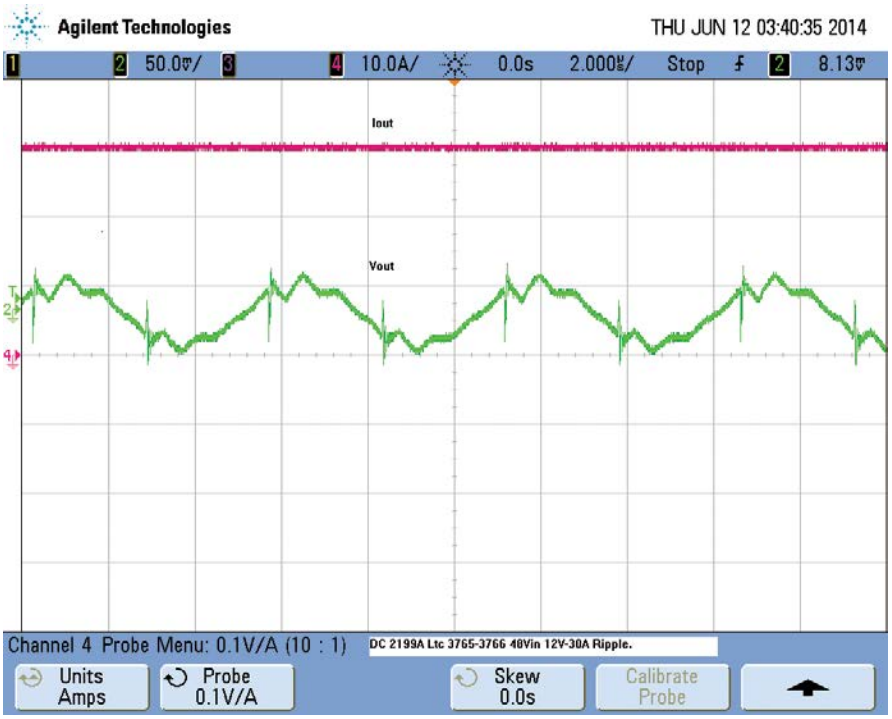



**Figure 3. Output Ripple at $48V_{IN}$ and $30A_{OUT}$ (50mV, 10A, 2µs/DIV, 20MHz)**


**Figure 4. Transient Response Waveform at $48V_{IN}$ and 15A to 30A to $15A_{OUT}$ (10A, 500mV, 200µs/DIV)**

## QUICK START PROCEDURE

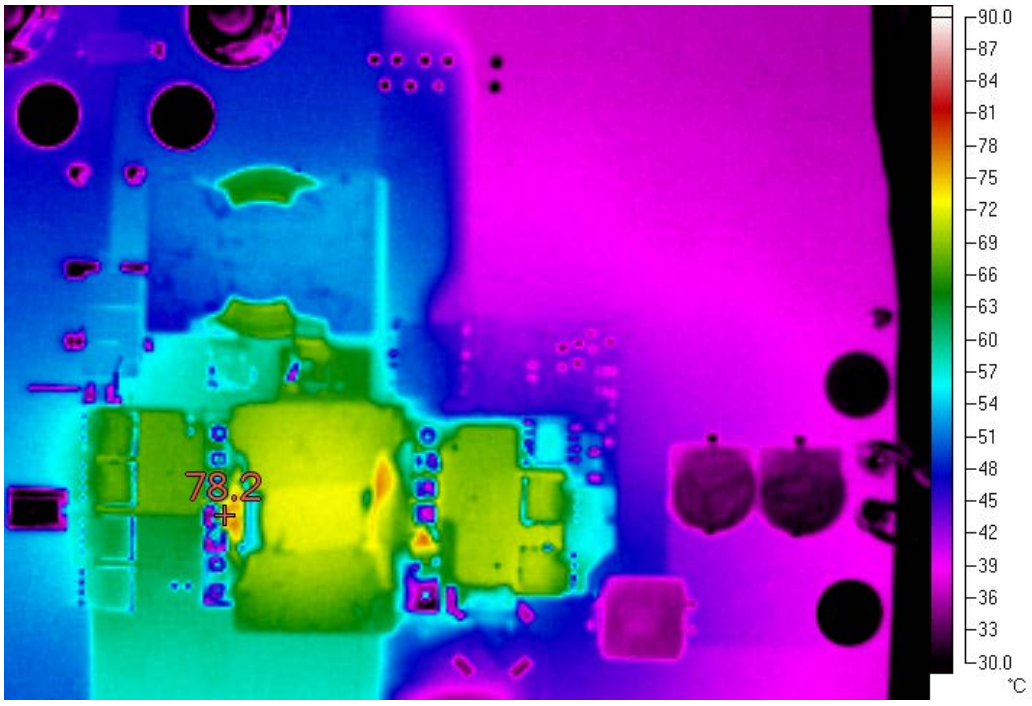



Figure 5. Thermal Map, Front Side at $48V_{IN}$ and $30A_{OUT}$ ($T_A$ = 25°C, 200LFM)

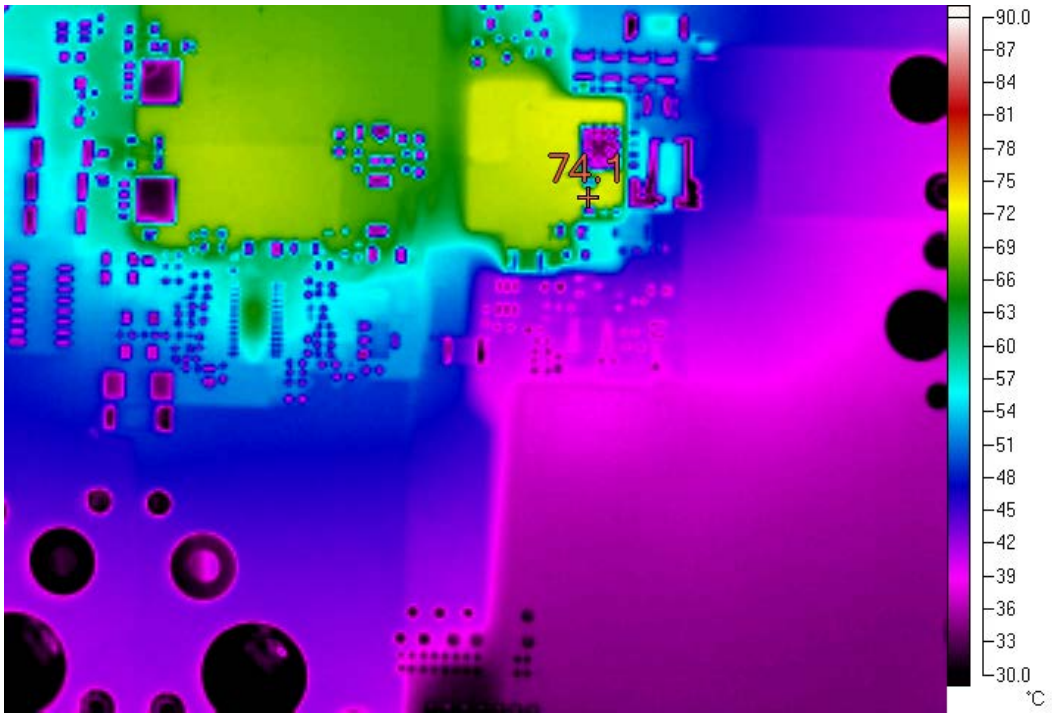



Figure 6. Thermal Map, Back Side at $48V_{IN}$ and $30A_{OUT}$ ($T_A$ = 25°C, 200LFM)

## PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|---|---|---|---|
| **Required Circuit Components** | | | | |
| 1 | 2 | C1, C22 | Cap., Alum., Elect., 33µF, 80V, CAP-10X12.5 | PANASONIC, EEHZA1K330P |
| 2 | 5 | C2, C3, C4, C5, C6 | CAP., X7R, 4.7µF, 100V, 10%, 1210 | MURATA, GRM32ER72A475KE14 |
| 3 | 4 | C7, C31, C33, C68 | CAP., POSCAP, 150µF, 16V, 20%, 7343 | PANASONIC, 16TQC150MYF |
| 4 | 1 | C10 | CAP., X7R, 2.2nF, 630V, 5%, 1206 | MURATA, GRM31A7U2J222JW31 |
| 5 | 1 | C11 | CAP., X7R, 0.015µF, 25V, 10%, 0603 | AVX, 06033C153KAT2A |
| 6 | 2 | C24, C71 | CAP., X7R, 1.0µF, 16V, 10%, 0805 | MURATA, GRM21BR71C105KA01 |
| 7 | 1 | C30 | CAP., X7R, 2200pF, 250V, 10%, 1812 | MURATA, GA343QR7GD222KW01L |
| 8 | 1 | C34 | CAP., X5R, 22µF, 16V, 20%, 1206/1210 | MURATA, GRM32ER71C226MEA8L |
| 9 | 1 | C51 | CAP., C0G, 470pF, 630V, 5%, 1206 | MURATA, GRM31A5C2J471JW01 |
| 10 | 1 | C66 | CAP., X7R, 0.047µF, 200V, X7R, 10% 1206 | MURATA, GRM31CR72D473KW03 |
| 11 | 1 | C69 | CAP., X7R, 1.5nF, 630V, 5%, 1206 | MURATA, GRM31A7U2J152JW31 |
| 12 | 2 | C70, C76 | CAP., X7R, 3.3nF, 25V, 10%, 0603 | AVX, 06033C332KAT2A |
| 13 | 2 | C72, C102 | CAP., X7R, 0.1µF, 25V, 10%, 0805 | AVX, 08053C104KAT2A |
| 14 | 4 | C55, C73, C80, C119 | CAP., X7R, 1nF, 25V, 10%, 0603 | MURATA, GRM188R71E102KA01 |
| 15 | 1 | C75 | CAP., NPO, 100pF, 25V, 5%, 0603 | AVX, 06033A101JAT2A |
| 16 | 1 | C77 | CAP., X7R, 4.7µF, 25V, 10%, 1206 | AVX, 12063C475KAT2A |
| 17 | 1 | C78 | CAP., NPO, 0.033µF, 25V, 5%, 0805 | TDK, C2012C0G1E333J |
| 18 | 1 | C79 | CAP., X7R, 4.7nF, 25V, 10%, 0603 | MURATA, GRM188R71E472KA01 |
| 19 | 1 | C101 | CAP., NPO, 220pF, 25V, 5%, 0603 | AVX, 06033A221JAT2A |
| 20 | 1 | C106 | CAP., COG, 150pF, 250V, 5%, 0603 | TDK, C1608C0G2E151J080AA |
| 21 | 1 | C112 | CAP., X7R, 0.22µF, 250V, 10%, 1206/1210 | TDK C3225X7R2E224K |
| 22 | 1 | C113 | CAP., X7R, 0.033µF, 25V, 10%, 0603 | AVX, 06033C333KAT2A |
| 23 | 1 | C118 | CAP., NPO, 1500pF, 5%, 0603 | AVX, 06033A152JAT2A |
| 24 | 2 | D1, D34 | DIODE ULTRA FAST 1A, 200V, SMP | VISHAY, ES1PD-M3 / 84A |
| 25 | 3 | D27, D29, D30 | DIODE SCHOTTKY 60V, 0.5A, SOT23 | DIODES INC, ZHCS506TA |
| 26 | 1 | D40 | DIODE, 1N4148WS, SOD323 | VISHAY, 1N4148WS-E3-08 |
| 27 | 1 | L1 | INDUCTOR, 1.0µH, 20% | COILCRAFT, XPL2010-102ML |
| 28 | 1 | L2 | INDUCTOR, 2.0µH, 20% | VISHAY, IHLP4040DZER2R0M11 |
| 29 | 1 | L3 | INDUCTOR, 3.3µH, 10% | COILCRAFT, SER2915L-332KL |
| 30 | 2 | Q8, Q9 | MOSFET N-CH 150V, POWERPAK-SO-8 | INFINEON, BSC190N15NS3 G |
| 31 | 4 | Q12, Q13, Q14, Q15 | MOSFET N-CH 80V, POWERPAK-SO-8 | INFINEON, BSC028N06NS3 |
| 32 | 1 | Q27 | TRANS., NPN 40V, 1A, SOT-89 | DIODE INC., FCX491ATA |
| 33 | 1 | Q28 | MOSFET, N-CH, SUPER, SOT-6 | FAIRCHILD, FDC2512-NL |
| 34 | 1 | Q29 | MOSFET, P-CH, IRF6217, POWERPAK-SO-8 | IR, IRF6217TRPBF |
| 35 | 1 | R1 | RES., CHIP, 0.33, 1/4W, 5%, 2512 | PANASONIC, ERJ-1TRQJR33U |
| 36 | 1 | R4 | RES., CHIP, 8.2k, 1W, 5%, 2512 | PANASONIC, ERJ-1TYJ822U |
| 37 | 1 | R18 | RES., CHIP, 102k, 1/8W, 1%, 0805 | VISHAY, CRCW0805102KFKEA |
| 38 | 1 | R22 | RES., CHIP, 3.74k, 1/16W, 1%, 0603 | VISHAY, CRCW06033K74FKEA |
| 39 | 2 | R23, R24 | RES., CHIP, 8.2, 1/4W, 5%, 1206 | VISHAY, CRCW12068R20JKEA |
| 40 | 1 | R29 | RES., CHIP, 100k, 1/8W, 5%, 0805 | VISHAY, CRCW0805100KJNEA |
| 41 | 1 | R41 | RES., CHIP, 11.5k, 1/16W, 1%, 0603 | VISHAY, CRCW060311K5FKEA |

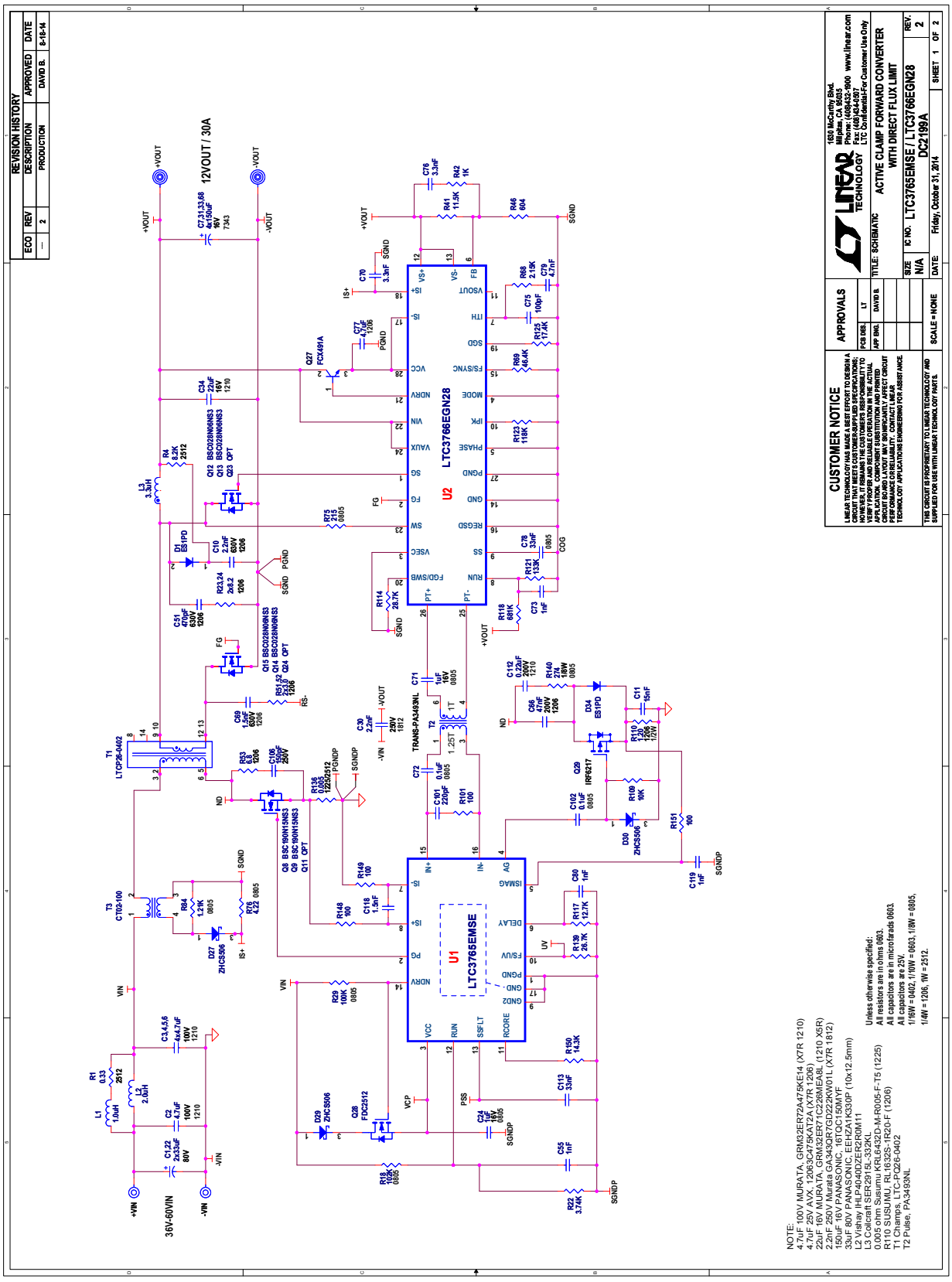
## PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|---|---|---|---|
| 42 | 1 | R42 | RES., CHIP, 1k, 1/16W, 1%, 0603 | VISHAY, CRCW06031K00FKEA |
| 43 | 1 | R46 | RES., CHIP, 604, 1/16W, 1%, 0603 | VISHAY, CRCW0603604RFKEA |
| 44 | 2 | R51, R52 | RES., CHIP, 3.0, 1/4W, 5%, 1206 | PANASONIC, ERJ-8GEYJ3R0V |
| 45 | 1 | R53 | RES., CHIP, 6.8, 1/2W, 1%, 1206 | PANASONIC, ERJ-8RQF6R8V |
| 46 | 1 | R68 | RES., CHIP, 2.15k, 1/16W, 1%, 0603 | VISHAY, CRCW06032K15FKEA |
| 47 | 1 | R69 | RES., CHIP, 46.4k, 1/16W, 1%, 0603 | VISHAY, CRCW060346K4FKEA |
| 48 | 1 | R75 | RES., CHIP, 215, 1/8W, 1%, 0805 | VISHAY, CRCW0805215RFKEA |
| 49 | 1 | R76 | RES., CHIP, 4.22, 1/8W, 1%, 0805 | VISHAY, CRCW08054R22FKEA |
| 50 | 1 | R84 | RES., CHIP, 1.21k, 1/8W, 1%, 0805 | VISHAY, CRCW08051K21FKEA |
| 51 | 4 | R101, R148, R149, R151 | RES., CHIP, 100, 1/16W, 1%, 0603 | VISHAY, CRCW0603100RFKEA |
| 52 | 1 | R109 | RES., CHIP, 10k, 1/16W, 1%, 0603 | VISHAY, CRCW060310K0FKEA |
| 53 | 1 | R110 | RES., CHIP, 1.20, 1/2W, 1%, 1206 | SUSUMU, RL1632S-1R20-F |
| 54 | 1 | R114 | RES., CHIP, 28.7k, 1/16W, 1%, 0603 | VISHAY, CRCW060328K7FKEA |
| 55 | 1 | R117 | RES., CHIP, 12.7k, 1/16W, 1%, 0603 | VISHAY, CRCW060312K7FKEA |
| 56 | 1 | R118 | RES., CHIP, 681k, 1/16W, 1%, 0603 | VISHAY, CRCW0603681KFKEA |
| 57 | 1 | R121 | RES., CHIP, 133k, 1/16W, 1%, 0603 | VISHAY, CRCW0603133KFKEA |
| 58 | 1 | R123 | RES., CHIP, 118k, 1/16W, 1%, 0603 | VISHAY, CRCW0603118KFKEA |
| 59 | 1 | R125 | RES., CHIP, 17.4k, 1/16W, 1%, 0603 | VISHAY, CRCW060317K4FKEA |
| 60 | 1 | R136 | RES., CHIP, 0.005, 1W, 1%, 1225 | SUSUMU, KRL6432D-M-R005-F-T5 |
| 61 | 1 | R139 | RES., CHIP, 26.7k, 1/16W, 1%, 0603 | VISHAY, CRCW060326K7FKEA |
| 62 | 1 | R140 | RES., CHIP, 274, 1/8W, 1%, 0805 | PANASONIC, ERJ-6ENF2740V |
| 63 | 1 | R150 | RES., CHIP, 14.3k, 1/16W, 1%, 0603 | VISHAY, CRCW060314K3FKEA |
| 64 | 1 | T1 | TRANSFORMER | CHAMPS TECH., LTC-PQ26-0402 |
| 65 | 1 | T2 | TRANSFORMER, 1.25:1 | Pulse, PA3493NL |
| 66 | 1 | T3 | TRANSFORMER, 1:100, CT02-100 | ICE COMPONENTS, CT02-100 = 1:100 |
| 67 | 1 | U1 | I.C. LTC3765EMSE, MSOP-16PIN | LINEAR TECH., LTC3765EMSE#PBF |
| 68 | 1 | U2 | I.C. LTC3766EGN, SSOP-GN28 | LINEAR TECH., LTC3766EGN#PBF |
| **Additional Demo Board Circuit Components** | | | | |
| 1 | 0 | C12, C13, C14, C16, C20 | CAP., OPT, 0603 | OPT |
| 2 | 0 | C8, C9, C18, C19, C103, C111 | CAP., OPT, 0603 | OPT |
| 3 | 0 | C15, C21, C114 | CAP., OPT, 0805 | OPT |
| 4 | 0 | C17, C116 | CAP., OPT, 1206 | OPT |
| 5 | 0 | C23, C25, C26 | CAP., OPT, CAP-SVPF-E12 | OPT |
| 6 | 2 | C74, C105 | CAP, 0Ω, JUMPER 0603 | VISHAY, CRCW06030000Z0EA |
| 7 | 0 | D2 | DIODE TBD SOD323 | OPT |
| 8 | 0 | D4, D35 | DIODE OPT, SOD323 | OPT |
| 9 | 0 | D28, D37, D38 | DIODE OPT, SOT23 | OPT |
| 10 | 0 | L4 | INDUCTOR, OPT, DO1606T | OPT |
| 11 | 0 | Q1, Q2 | MOSFET, OPT, SOT23-6 | OPT |
| 12 | 0 | Q4 | MOSFET, OPT, D-PAK | OPT |
| 13 | 0 | Q11, Q23, Q24 | MOSFET, OPT, POWERPAK-SO-8 | OPT |
| 14 | 0 | R5 | RES., OPT, 2512/2010 | OPT |

## PARTS LIST

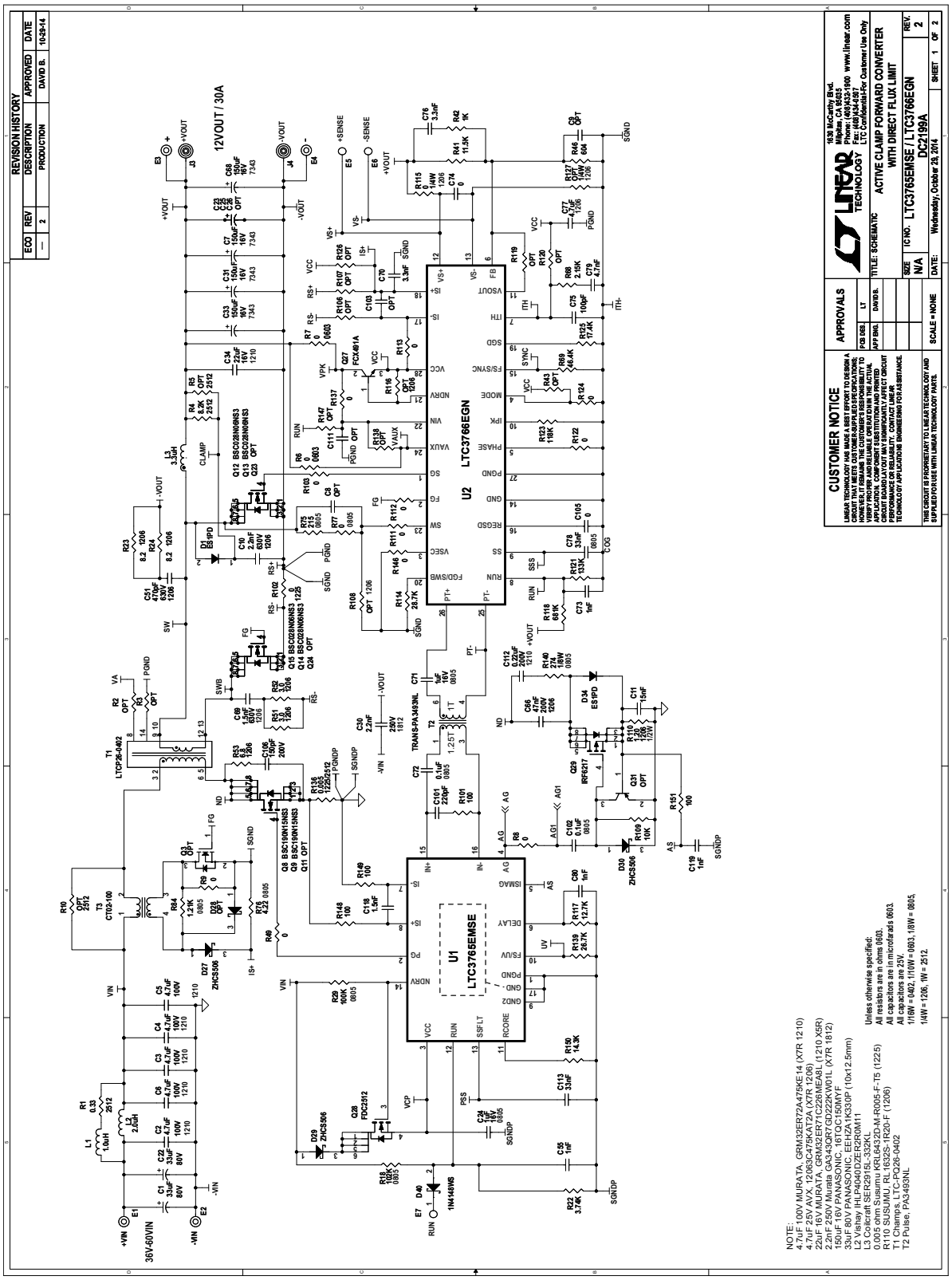
| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|---|---|---|---|
| 15 | 13 | R6, R7, R8, R9, R49, R103, R111, R112, R113, R122, R124, R137, R146 | RES., CHIP, 0Ω, 0603 | VISHAY, CRCW06030000Z0EA |
| 16 | 0 | R10, R13, R14, R15 | RES., OPT, 2512 | OPT |
| 17 | 0 | R17, R108, R116, R127 | RES., OPT, 1206 | OPT |
| 18 | 0 | R25, R26, R27, R28, R30, R31, R32, R33, R34, R35, R43, R106, R107, R119, R120, R126, R138, R147 | RES., OPT, 0603 | OPT |
| 19 | 1 | R77 | RES., CHIP, 0, 1/8W, 0805 | VISHAY, CRCW08050000Z0EA |
| 20 | 1 | R102 | RES., CHIP, 0Ω, 1225 | TEPRO,RN5326 |
| 21 | 1 | R115 | RES., CHIP, 0, 1/4W, 1206 | VISHAY, CRCW12060000Z0EA |
| 22 | 0 | R152 | RES., OPT, 0805 | OPT |
| 23 | 0 | U3 | I.C. OPT, SO16 | OPT |
| **Hardware: For Demo Board Only** | | | | |
| 1 | 4 | E1, E2, E3, E4 | TESTPOINT, TURRET, .094" | MILL-MAX, 2501-2-00-80-00-00-07-0 |
| 2 | 3 | E5, E6, E7 | TESTPOINT, TURRET, .061" | MILL-MAX, 2308-2-00-80-00-00-07-0 |
| 3 | 0 | J1 | HEADER, OPT, 2×7PIN, 0.079CC | OPT, MOLEX, 87331-1420 |
| 4 | 2 | J3, J4 | STUD, TEST PIN | PEM, KFH-032-10 |
| 5 | 4 | J3, J4(2 EACH) | NUT, BRASS, #10-32 | ANY #10-32 |
| 6 | 2 | J3, J4 | WASHER, STAR #10 BRASS NICKEL | ANY, #10EXT BZ TN |
| 7 | 2 | J3, J4 | Ring, Lug Ring # 10 | KEYSTONE, 8205 |
| 8 | 0 | TP1-TP6 | PAD-SMD | PAD-SMD |
| 9 | 4 | (STAND-OFF) | STAND-OFF, NYLON 0.25" | KEYSTONE, 8831 (SNAP ON) |
| 10 | 1 | | FAB, PRINTED CIRCUIT BOARD | DEMO CIRCUIT 2199A |

## SCHEMATIC DIAGRAM



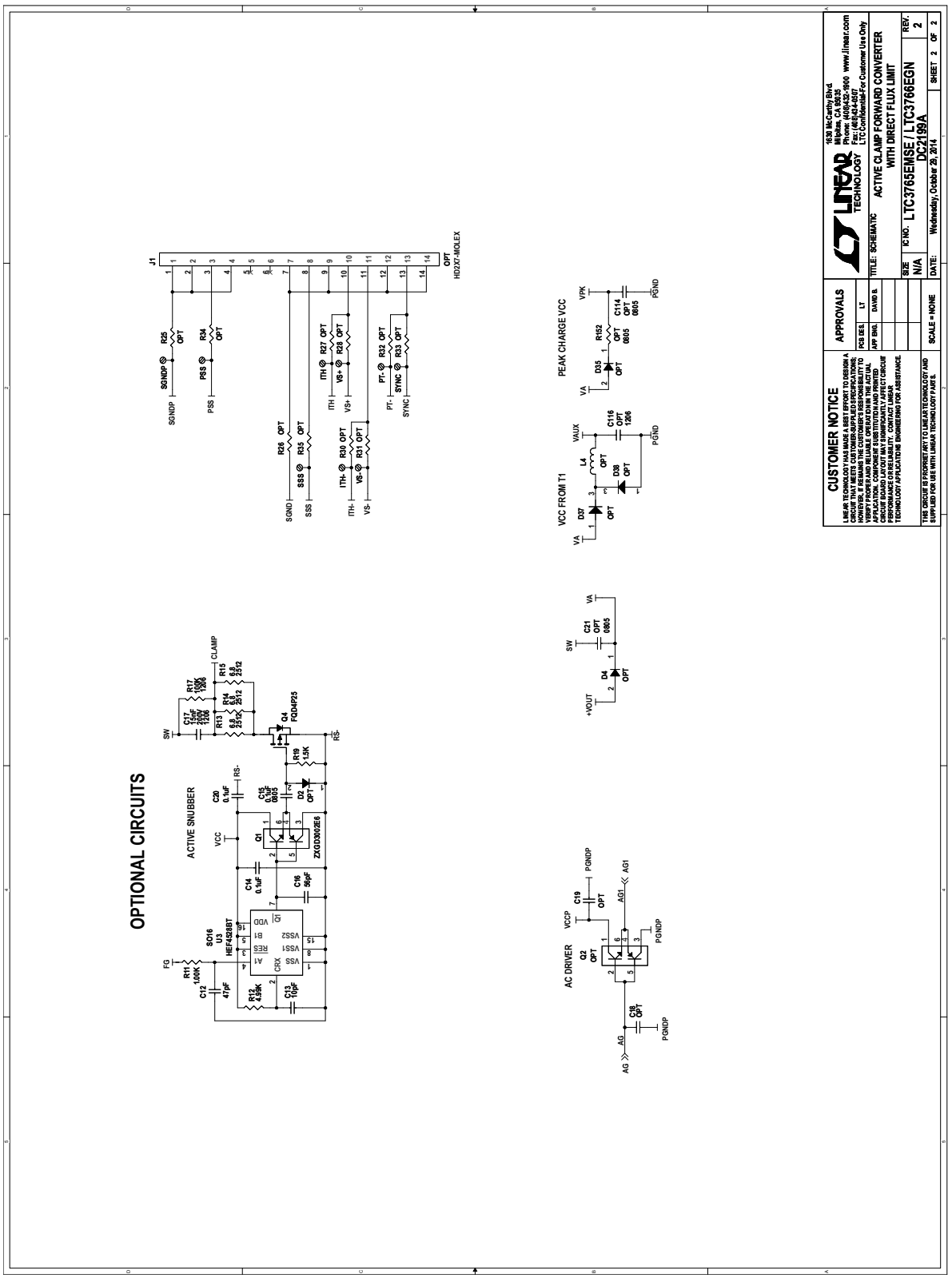

Simplified Schematic (without Unneeded Components)

## SCHEMATIC DIAGRAM




Full Schematic, Page 1

## SCHEMATIC DIAGRAM




Full Schematic, page 2

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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.

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**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.

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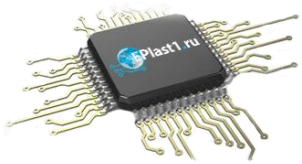
- Поставка специализированных компонентов (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Aeroflex, Peregrine, Syfer, Eurofarad, Texas Instrument, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits,General Dynamics и др.);

Помимо этого, одним из направлений компании «ЭлектроПласт» является направление «Источники питания». Мы предлагаем Вам помощь Конструкторского отдела:

- Подбор оптимального решения, техническое обоснование при выборе компонента;
- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.




**Как с нами связаться**

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