LTC3765/LTC3766
360W Isolated Forward Converter with Synchronous Rectification

DESCRIPTION

Demonstration circuit 2199A-B is a 360W isolated forward converter with synchronous rectification featuring the LTC3765/LTC3766 chip-set. It produces a regulated 24V, 15A 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 approaching 96%. Secondary-side control eliminates complex opto-coupler feedback, providing fast transient response with minimum output capacitance. For other output requirements, see the LTC3765 and LTC3766 data sheets or contact the LTC sales.

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

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			24.0		V
I_{OUT}	Output Current Range, Continuous	300LFM	0		15	A
f_{SW}	Switching (Clock) Frequency			200		kHz
$V_{OUT(P-P)}$	Output Ripple	V_{IN} = 48V, I_{OUT} = 30A (20MHz BW)		60		mV_{P-P}
I_{REG}	Output Regulation	Line and Load (36V_{IN} to 60V_{IN}, 0A_{OUT} to 15A_{OUT})		±0.02		%
P_{OUT}/P_{IN}	Efficiency (See Figure 3)	V_{IN} =48V, I_{OUT} = 15A		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-B 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 300LFM 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-B'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 24V. Turn off the power at the input.
6. Once the proper output voltages are established, connect a variable load capable of sinking 15A 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 15ADC 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 24V 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.

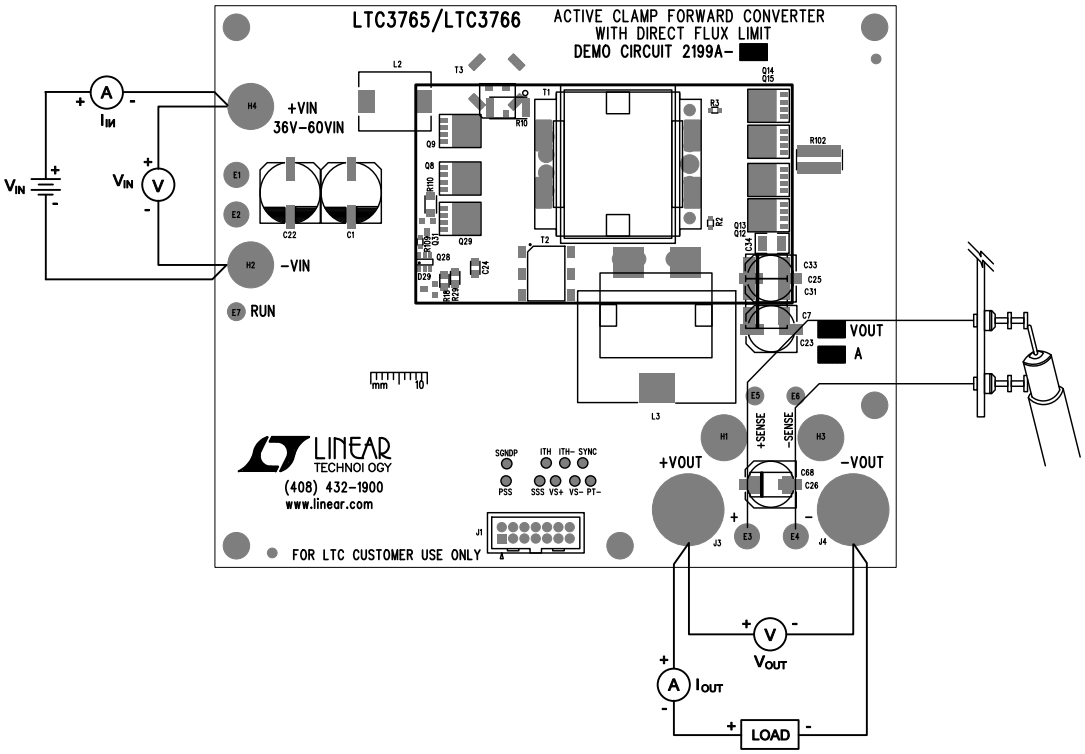


Figure 1. Proper Measurement Equipment Setup

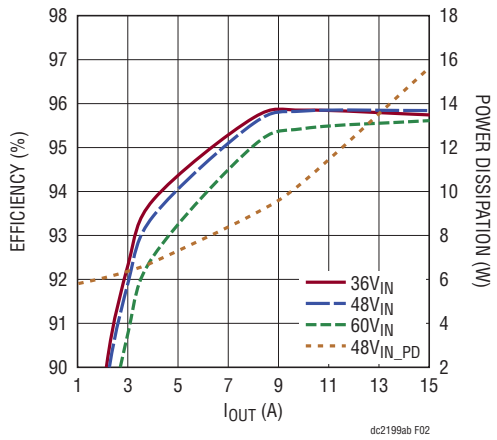


Figure 2. Efficiency and Power Dissipation

QUICK START PROCEDURE

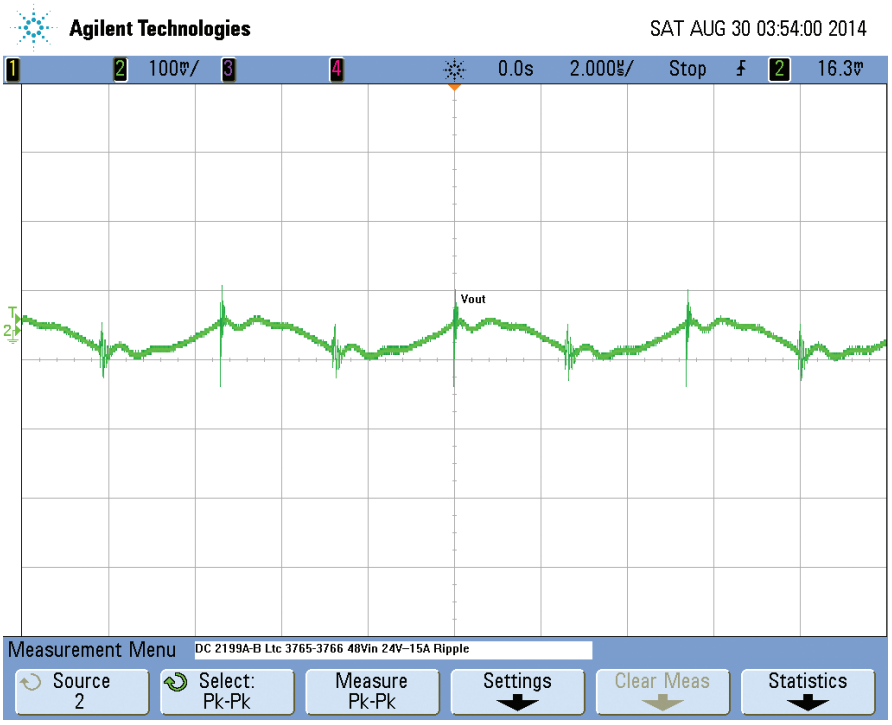


Figure 3. Output Ripple at $48V_{IN}$ and $15A_{OUT}$ (100mV, 2µs/DIV, 20MHz)

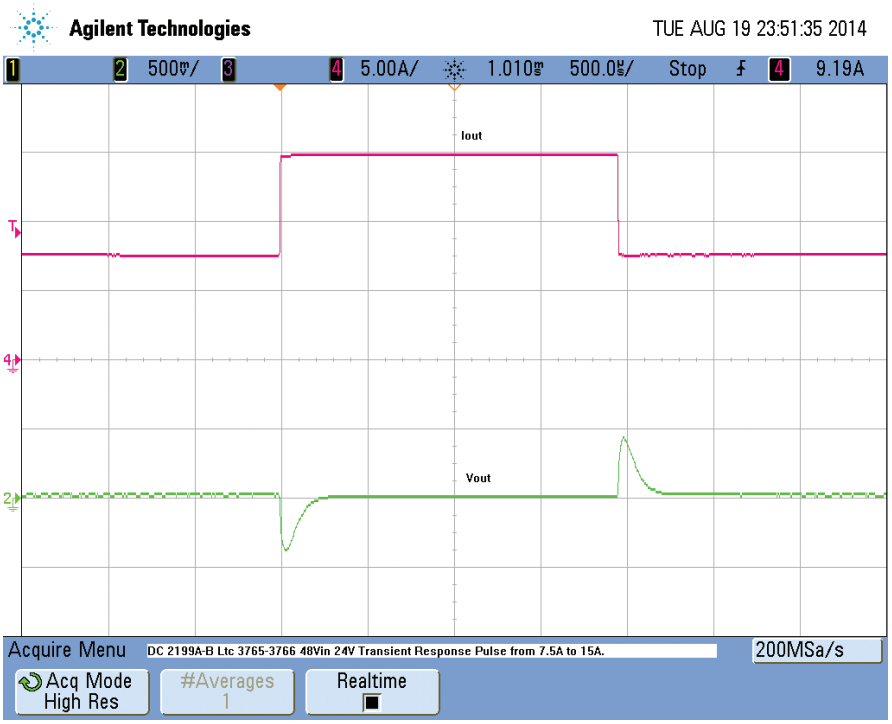


Figure 4. Transient Response Waveform at $48V_{IN}$ and 7.5A to 15A to $7.5A_{OUT}$ (5A, 500mV, 500µs/DIV)

QUICK START PROCEDURE

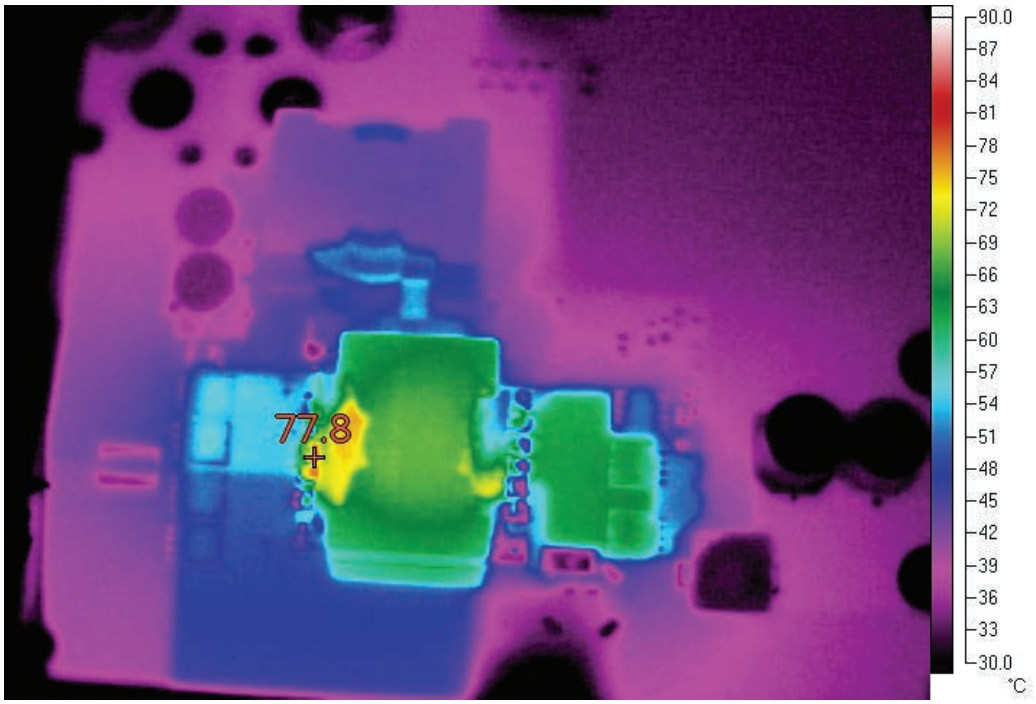


Figure 5. Thermal Map, Front Side at $48V_{IN}$ and $15A_{OUT}$ (T_A = 25°C, 300LFM)

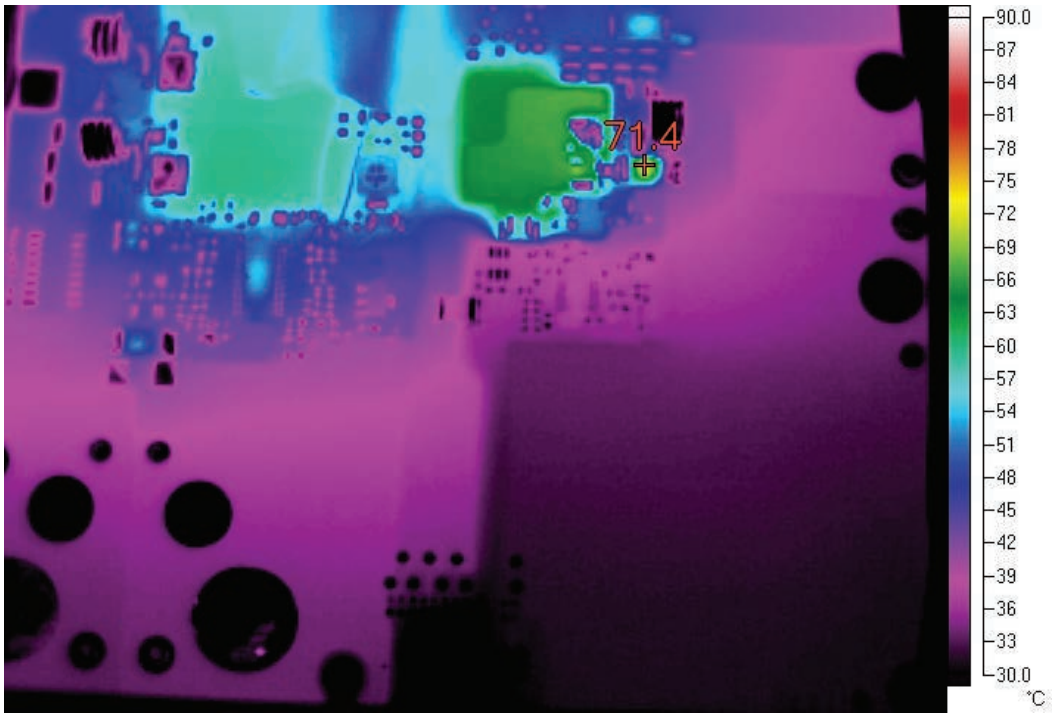


Figure 6. Thermal Map, Back Side at $48V_{IN}$ and $15A_{OUT}$ (T_A = 25°C, 300LFM)

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
4	1	C10	CAP., X7R, 2.2nF, 630V, 5%, 1206	MURATA, GRM31A7U2J222JW31
5	1	C11	CAP., X7R, 0.015µF, 25V, 10%, 0603	AVX, 06033C153KAT2A
7	2	C24, C71	CAP., X7R, 1.0µF, 16V 10%, 0805	MURATA, GRM21BR71C105KA01
4	2	C25, C26	CAP., OSCON, 82µF, 35V, 20%, CAP-SVPF-E12	PANASONIC, 35SVPF82M
8	1	C30	CAP., X7R, 2200pF, 250V, 10%, 1812	MURATA, GA343QR7GD222KW01L
8	1	C34	CAP., X5R, 10µF, 50V, 20%, 1210	MURATA, GRM32ER61H106MA12
9	1	C51	CAP., C0G, 330pF, 630V, 5%, 1206	MURATA, GRM31A5C2J331JW01
12	4	C55, C73, C80, C119	CAP., X7R, 1nF, 25V, 10%, 0603	MURATA, GRM188R71E102KA01
9	1	C66	CAP., X7R, 0.047µF, 200V, X7R, 10%, 1206	MURATA, GRM31CR72D473KW03
11	2	C72, C102	CAP., X7R, 0.1µF, 25V, 10%, 0805	AVX, 08053C104KAT2A
14	1	C75	CAP., NPO, 100pF, 25V, 5%, 0603	AVX, 06033A101JAT2A
10	1	C76	CAP., X7R, 3.3nF, 25V, 10%, 0603	AVX, 06033C332KAT2A
15	1	C77	CAP., X7R, 4.7µF, 25V, 10%, 1206	AVX, 12063C475KAT2A
16	1	C78	CAP., NPO, 0.033µF, 25V, 5%, 0805	TDK, C2012C0G1E333J
17	1	C79	CAP., X7R, 4.7nF, 25V, 10%, 0603	MURATA, GRM188R71E472KA01
18	1	C101	CAP., NPO, 220pF, 25V, 5%, 0603	AVX, 06033A221JAT2A
10	1	C103	CAP., NPO, 470pF, 25V, 5%, 0603	AVX, 06033A471JAT2A
19	1	C106	CAP., COG, 150pF, 250V, 5%, 0603	TDK, C1608C0G2E151J080AA
20	1	C112	CAP., X7R, 0.22µF, 250V, 10%, 1206/1210	TDK C3225X7R2E224K
21	1	C113	CAP., X7R, 0.033µF, 25V, 10%, 0603	AVX, 06033C333KAT2A
11	1	C116	CAP., X7R, 4.7µF, 25V, 10%, 1206	AVX, 12063C475KAT2A
22	1	C118	CAP., NPO, 1500pF, 5%, 0603	AVX, 06033A152JAT2A
23	2	D1, D34	DIODE ULTRA FAST 1A 200V SMP	VISHAY, ES1PD-M3 / 84A
25	3	D29, D30	DIODE SCHOTTKY 60V 0.5A, SOT23	DIODES INC, ZHCS506TA
27	1	D40	DIODE, 1N4148WS, SOD323	VISHAY, 1N4148WS-E3-08
14	2	D37, D38	DIODE, BAS21, SOT23	DIODES INC., BAS21
15	1	L3	INDUCTOR, 6.8µH, 10%	COILCRAFT, SER2915L-682KL
16	1	L4	INDUCTOR, 680µH, DO1606T	COILTRONICS SD25-681
19	4	Q12, Q13, Q14, Q15	MOSFET, N-CH, 120V, POWERPAK-SO-8	FAIRCHILD FDMS86201
35	1	L1	INDUCTOR, 1.0µH, 20%	COILCRAFT, XPL2010-102ML
36	1	L2	INDUCTOR, 2.0µH, 20%	VISHAY, IHLP4040DZER2R0M11
40	2	Q8, Q9	MOSFET, N-CH 150V, POWERPAK-SO-8	INFINEON, BSC190N15NS3 G
42	1	Q27	TRANS., NPN, 40V, 1A, SOT-89	DIODE INC., FCX491ATA
43	1	Q28	MOSFET, N-CH, SUPER, SOT-6	FAIRCHILD, FDC2512-NL
44	1	Q29	MOSFET, P-CH, IRF6217, POWERPAK-SO-8	IR, IRF6217TRPBF
45	1	R1	RES., CHIP, 0.33Ω, 1/4W, 5%, 2512	PANASONIC, ERJ-1TRQJR33U
47	1	R4	RES., CHIP, 8.2k, 1W, 5%, 2512	PANASONIC, ERJ-1TYJ822U
51	1	R18	RES., 102k, 1/8W, 1%, 0805	VISHAY, CRCW0805102KFKEA
52	1	R22	RES., 3.74k, 1/16W, 1%, 0603	VISHAY, CRCW06033K74FKEA

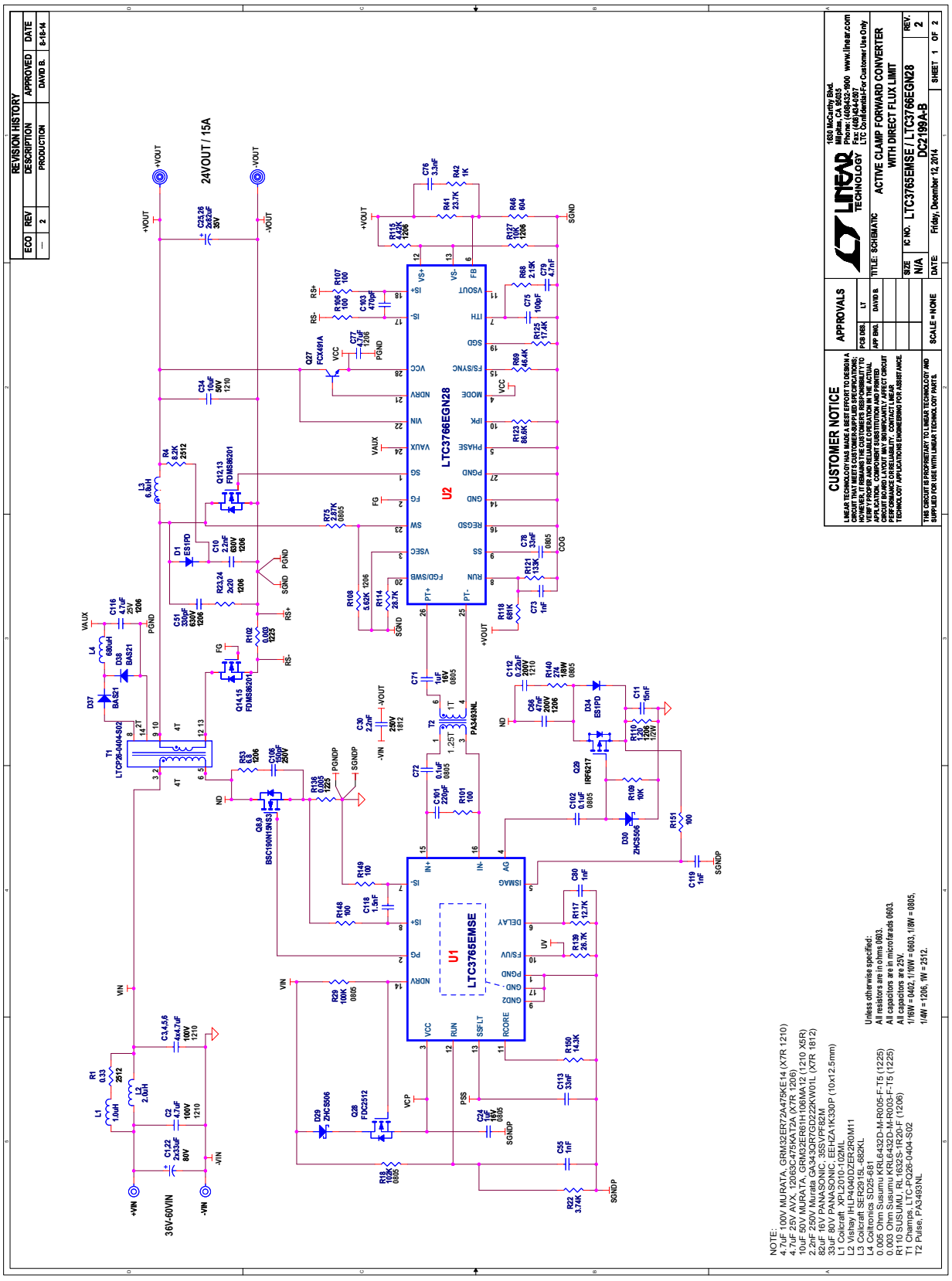
PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
27	2	R23, R24	RES., CHIP, 20Ω, 1/4W, 5%, 1206	VISHAY, CRCW120620R0JKEA
54	1	R29	RES., CHIP, 100k, 1/8W, 5%, 0805	VISHAY, CRCW0805100KJNEA
28	1	R41	RES., CHIP, 23.7k, 1/16W, 1%, 0603	VISHAY, CRCW060323K7FKEA
55	1	R42	RES., CHIP, 1k, 1/16W, 1%, 0603	VISHAY, CRCW06031K00FKEA
56	1	R46	RES., CHIP, 604Ω, 1/16W, 1%, 0603	VISHAY, CRCW0603604RFKEA
57	1	R53	RES., CHIP, 6.8Ω, 1/2W, 1%, 1206	PANASONIC, ERJ-8RQF6R8V
58	1	R68	RES., CHIP, 2.15k, 1/16W, 1%, 0603	VISHAY, CRCW06032K15FKEA
59	1	R69	RES., CHIP, 46.4k, 1/16W, 1%, 0603	VISHAY, CRCW060346K4FKEA
29	1	R75	RES., CHIP, 2.87k, 1/8W, 1%, 0805	VISHAY, CRCW08052K87FKEA
60	4	R101, R148, R149, R151	RES., CHIP, 100Ω, 1/16W, 1%, 0603	VISHAY, CRCW0603100RFKEA
32	1	R102	RES., CHIP, 0.003Ω, 3W, 1%, 1225	SUSUMU, KRL6432D-M-R003-F-T5
33	2	R106, R107	RES., CHIP, 100Ω, 1/16W, 1%, 0603	VISHAY, CRCW0603100RFKEA
34	1	R108	RES., CHIP, 5.62k, 1/4W, 1%, 1206	VISHAY, CRCW12065K62FKEA
61	1	R109	RES., CHIP, 10k, 1/16W, 1%, 0603	VISHAY, CRCW060310K0FKEA
62	1	R110	RES., CHIP, 1.20Ω, 1/2W, 1%, 1206	SUSUMU, RL1632S-1R20-F
63	1	R114	RES., CHIP, 28.7k, 1/16W, 1%, 0603	VISHAY, CRCW060328K7FKEA
35	1	R115	RES., CHIP, 4.42k, 1/4W, 1%, 1206	VISHAY, CRCW12064K42FKEA
64	1	R117	RES., CHIP, 12.7k, 1/16W, 1%, 0603	VISHAY, CRCW060312K7FKEA
65	1	R118	RES., CHIP, 681k, 1/16W, 1%, 0603	VISHAY, CRCW0603681KFKEA
66	1	R121	RES., CHIP, 133k, 1/16W, 1%, 0603	VISHAY, CRCW0603133KFKEA
36	1	R123	RES., CHIP, 86.6k, 1/16W, 1%, 0603	VISHAY, CRCW060386K6FKEA
67	1	R125	RES., CHIP, 17.4k, 1/16W, 1%, 0603	VISHAY, CRCW060317K4FKEA
37	1	R127	RES., CHIP, 10k, 1/4W, 1%, 1206	VISHAY, CRCW120610K0FKEA
68	1	R136	RES., CHIP, 0.005Ω, 1W, 1%, 1225	SUSUMU, KRL6432D-M-R005-F-T5
69	1	R139	RES., CHIP, 26.7k, 1/16W, 1%, 0603	VISHAY, CRCW060326K7FKEA
70	1	R140	RES., CHIP, 274Ω, 1/8W, 1%, 0805	PANASONIC, ERJ-6ENF2740V
71	1	R150	RES., CHIP, 14.3k, 1/16W, 1%, 0603	VISHAY, CRCW060314K3FKEA
38	1	T1	TRANSFORMER, 4T:4T:2T	CHAMPS TECH., LTC-PQ26-0404-S02
73	1	T2	TRANSFORMER, 1.25:1	PULSE, PA3493NL
74	1	U1	I.C. LTC3765EMSE, MSOP-16PIN	LINEAR TECH., LTC3765EMSE#PBF
75	1	U2	I.C. LTC3766EGN, SSOP-GN28	LINEAR TECH., LTC3766EGN#PBF
Additional Demo Board Circuit Components				
2	0	C7, C31, C33, C68	CAP., OPT, 7343	OPT
3	0	C8, C9, C18, C19, C111	CAP., OPT, 0603	OPT
5	0	C12, C13, C14, C16, C20, C70	CAP., OPT, 0603	OPT
6	0	C15	CAP., OPT, 0805	OPT
7	0	C17, C69	CAP., OPT, 1206	OPT
6	0	C21, C114	CAP., OPT, 0805	OPT
3	0	C23	CAP., OPT, CAP-SVPF-E12	OPT
13	2	C74, C105	CAP, 0Ω, JUMPER, 0603	VISHAY, CRCW06030000Z0EA
12	0	D2	DIODE, TBD, SOD323	OPT
24	0	D4, D35	DIODE, OPT, SOD323	OPT

PARTS LIST

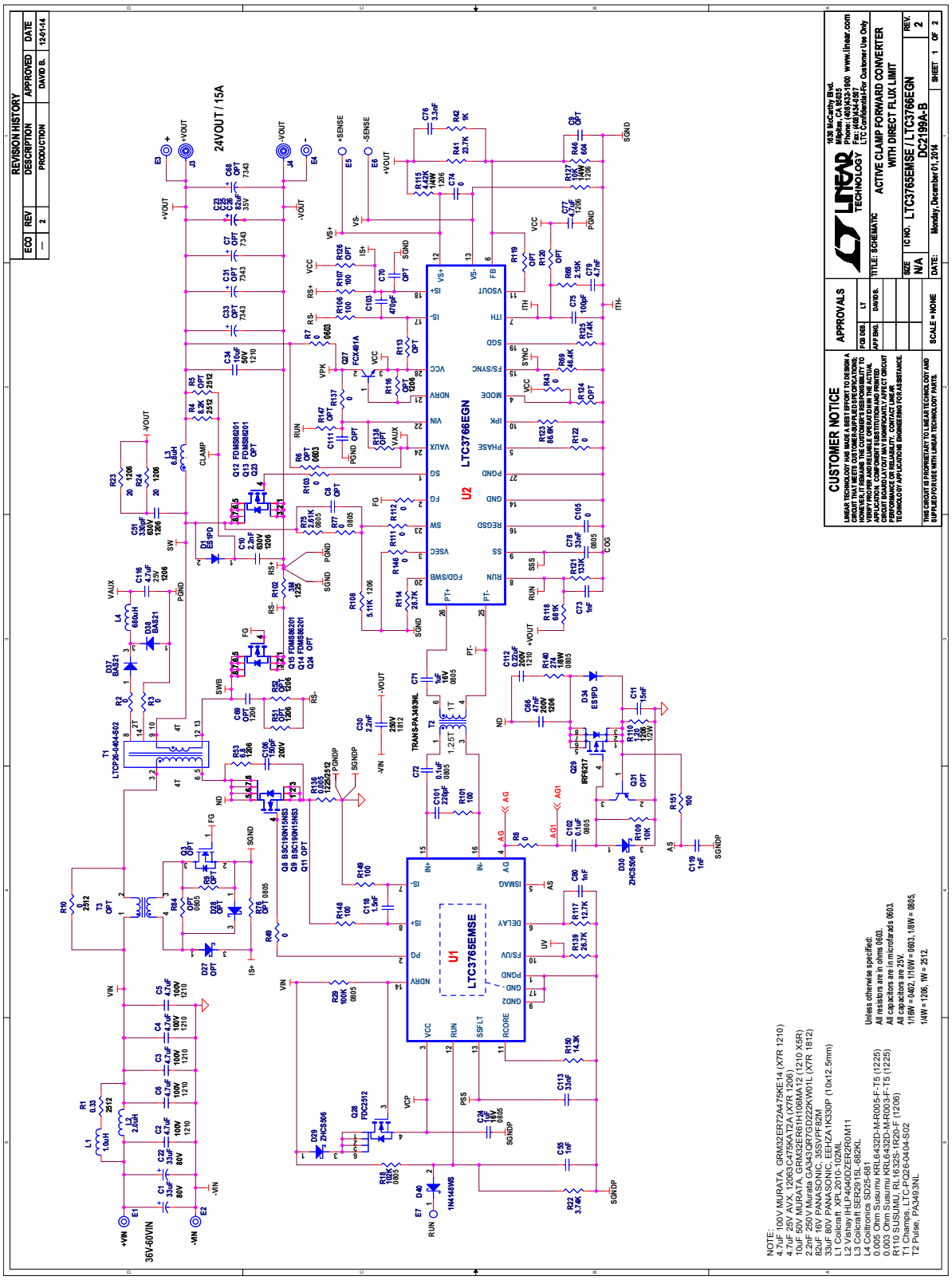
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
13	0	D27	DIODE OPT, SOT23	OPT
26	0	D28	DIODE, OPT, SOT23	OPT
17	0	Q1	MOSFET, OPT, SOT23-6	OPT
18	0	Q4	MOSFET, OPT, D-PAK	OPT
20	0	Q23	MOSFET, OPT, POWERPAK-SO-8	OPT
21	0	Q24	MOSFET, OPT, POWERPAK-SO-8	OPT
37	0	Q2	MOSFET, OPT, SOT23-6	OPT
38	0	Q3	MOSFET, OPT, SOT23	OPT
39	0	Q31	TRANS, OPT, SOT23	OPT
41	0	Q11	MOSFET, OPT, POWERPAK-SO-8	OPT
22	3	R2, R3, R43	RES., CHIP, 0Ω, 0603	VISHAY, CRCW06030000Z0EA
48	0	R5	RES., OPT, 2512/2010	OPT
23	0	R6, R9, R11, R12, R19, R113, R124	RES., OPT, 0603	OPT
49	9	R7, R8, R49, R103, R111, R112	RES., CHIP, 0Ω, 0603	VISHAY, CRCW06030000Z0EA
24	1	R10	RES., CHIP, 0.00Ω, 1225	TEPRO, RN5326
25	0	R13, R14, R15	RES., OPT, 2512	OPT
26	0	R17, R51, R52	RES., OPT, 1206	OPT
46	0	R25, R26, R27, R28, R30, R31, R32, R33, R34, R35, R119, R120, R126, R138, R147	RES., OPT, 0603	OPT
50		R122, R137, R146		
30	0	R76, R84	RES., OPT, 0805	OPT
31	1	R77	RES., CHIP, 0Ω, 1/8W, 0805	VISHAY, CRCW08050000Z0EA
53	0	R116	RES., OPT, 1206	OPT
72	0	R152	RES., OPT, 0805	OPT
39	0	T3	TRANSFORMER, 1:100, CT02-100	OPT
40	0	U3	I.C. OPT, SO16	OPT
Hardware: For Demo Board Only				
1	4	E1, E2, E3, E4	TESTPOINT, TURRET, 0.094"	MILL-MAX, 2501-2-00-80-00-00-07-0
2	3	E5, E6, E7	TESTPOINT, TURRET, 0.061"	MILL-MAX, 2308-2-00-80-00-00-07-0
3	0	J1	HEADER, OPT, 2X7PIN, 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



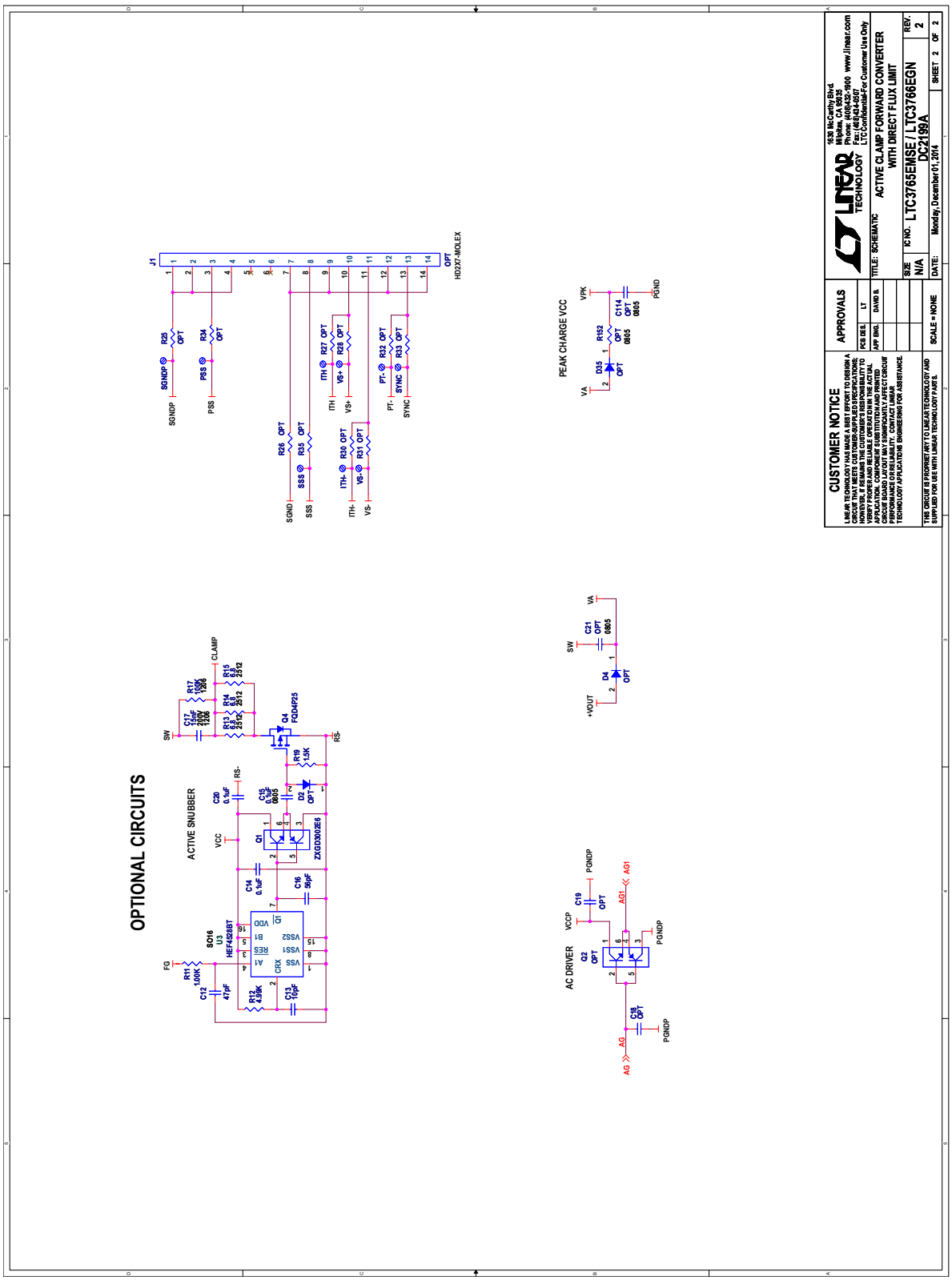
Simplified Schematic (without Unneeded Components)

SCHEMATIC DIAGRAM



Full Schematic, Page 1

SCHEMATIC DIAGRAM



Full Schematic, page 2

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.

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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.

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