AN-2111 LM5045 Evaluation Board

1 Introduction

The LM5045 evaluation board is designed to provide the design engineer with a fully functional power converter based on the full-bridge topology to evaluate the LM5045 PWM controller. The evaluation board is provided in an industry standard quarter brick footprint.

The performance of the evaluation board is as follows:

- Input operating range: 36V to 75V
- Output voltage: 3.3V
- Measured efficiency at 48V: 92% @ 30A
- Frequency of operation: 420kHz
- Board size: 2.28 x 1.45 x 0.5 inches
- Load Regulation: 0.2%
- Line Regulation: 0.1%
- Line UVLO (34V/32V on/off)
- Hiccup Mode Current Limit

The printed circuit board consists of 6 layers; 2 ounce copper outer layers and 3 ounce copper inner layers on FR4 material with a total thickness of 0.062 inches. The unit is designed for continuous operation at rated load at <40°C and a minimum airflow of 200 LFM.

2 Theory of Operation

Power converters based on the full-bridge topology offer high-efficiency and good power handling capability up to 500W. Figure 1 illustrates the circuit arrangement for the full-bridge topology. The switches, in the diagonal, Q1,Q3 and Q2,Q4 are turned alternatively with a pulse width determined by the input and output voltages and the transformer turns ratio. Each diagonal (Q1 and Q3 or Q2 and Q4), when turned ON, applies input voltage across the primary of the transformer. The resulting secondary voltage is then rectified and filtered with an LC filter to provide a smoothened output voltage. In a full-bridge topology, the primary switches are turned on alternatively energizing the windings in such a way that the flux swings back and forth in the first and the third quadrants of the B-H curve. The use of two quadrants allows better utilization of the core resulting in a smaller core volume compared to the single-ended topologies such as a forward converter. Further, in a half-bridge topology, during power transfer when one of the primary switches is active, the voltage across the primary of the power transformer is 1/2 the input voltage (VIN) compared to a full VIN in a full-bridge topology. Therefore, for a given power, the primary current will be half as much for the full-bridge as compared to the half-bridge. The reduced primary current enables higher efficiency as compared to a half-bridge at high load currents.

All trademarks are the property of their respective owners.

Copyright © 2011–2013, Texas Instruments Incorporated

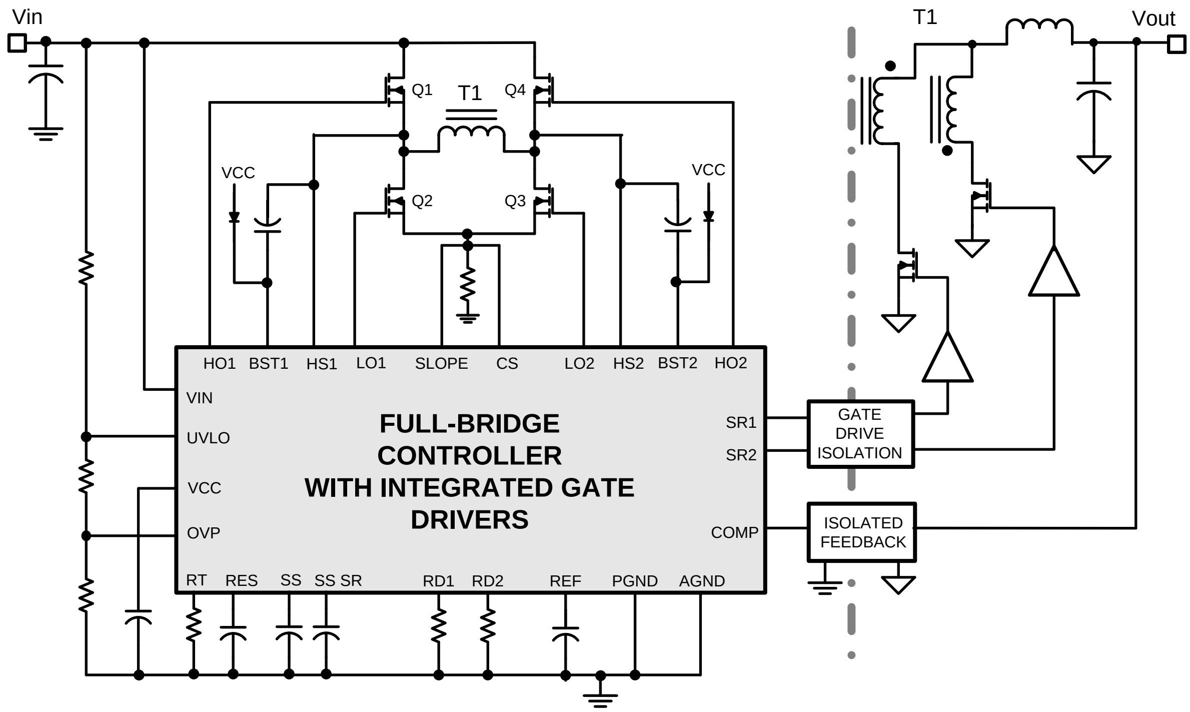


Figure 1. Simplified Full-Bridge Converter

The secondary side employs synchronous rectification scheme, which is controlled by the LM5045. In addition to the basic soft-start already described, the LM5045 contains a second soft-start function that gradually turns on the synchronous rectifiers to their steady-state duty cycle. This function keeps the synchronous rectifiers off until the error amplifier on the secondary side soft-starts, allowing a linear start-up of the output voltage even into pre-biased loads. Then the SR output duty cycle is gradually increased to prevent output voltage disturbances due to the difference in the voltage drop between the body diode and the channel resistance of the synchronous MOSFETs. Once the soft-start is finished, the synchronous rectifiers are engaged with a non-overlap time programmed by the RD1 and RD2 resistors. Feedback from the output is processed by an amplifier and reference, generating an error voltage, which is coupled back to the primary side control through an opto-coupler. The LM5045 evaluation board employs peak current mode control and a standard “type II” network is used for the compensator.

3 Powering and Loading Considerations

When applying power to the LM5045 evaluation board certain precautions need to be followed. A misconnection can damage the assembly.

4 Proper Connections

When operated at low input voltages the evaluation board can draw up to 3.5A of current at full load. The maximum rated output current is 30A. Be sure to choose the correct connector and wire size when attaching the source supply and the load. Monitor the current into and out of the evaluation board. Monitor the voltage directly at the output terminals of the evaluation board. The voltage drop across the load connecting wires will give inaccurate measurements. This is especially true for accurate efficiency measurements.

Copyright © 2011–2013, Texas Instruments Incorporated

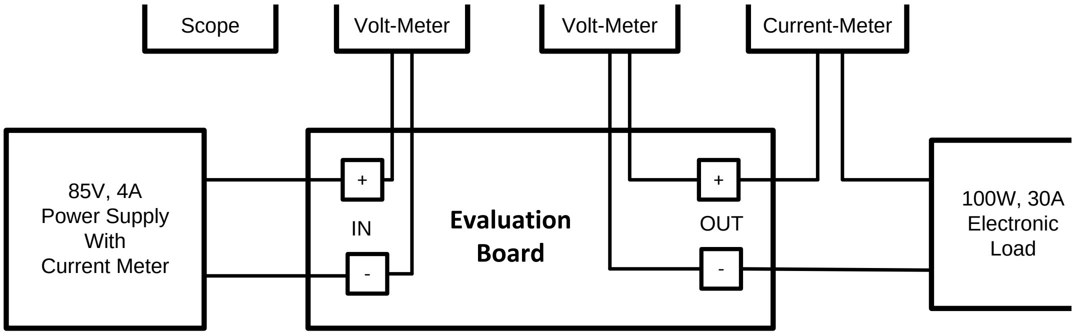


Figure 2.

5 Source Power

The evaluation board can be viewed as a constant power load. At low input line voltage (36V) the input current can reach 3.5A, while at high input line voltage (72V) the input current will be approximately 1.5A. Therefore, to fully test the LM5045 evaluation board a DC power supply capable of at least 85V and 4A is required. The power supply must have adjustments for both voltage and current.

The power supply and cabling must present low impedance to the evaluation board. Insufficient cabling or a high impedance power supply will droop during power supply application with the evaluation board inrush current. If large enough, this droop will cause a chattering condition upon power up. This chattering condition is an interaction with the evaluation board under voltage lockout, the cabling impedance and the inrush current.

6 Loading

An appropriate electronic load, with specified operation down to 3.0V minimum, is desirable. The resistance of a maximum load is 0.11Ω. The high output current requires thick cables! If resistor banks are used there are certain precautions to be taken. The wattage and current ratings must be adequate for a 30A, 100W supply. Monitor both current and voltage at all times. Ensure that there is sufficient cooling provided for the load.

7 Air Flow

Full power loading should never be attempted without providing the specified 200 LFM of air flow over the evaluation board. A stand-alone fan should be provided.

8 Powering Up

It is suggested that the load be kept low during the first power up. Set the current limit of the source supply to provide about 1.5 times the wattage of the load. As soon as the appropriate input voltage is supplied to the board, check for 3.3 volts at the output.

A most common occurrence, that will prove unnerving, is when the current limit set on the source supply is insufficient for the load. The result is similar to having the high source impedance referred to earlier. The interaction of the source supply folding back and the evaluation board going into undervoltage shutdown will start an oscillation, or chatter, that may have undesirable consequences.

A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss you can be reasonably sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

Copyright © 2011–2013, Texas Instruments Incorporated

9 Over Current Protection

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 38A) the unit will discharge the SS capacitor, which disables the power stage. After a delay, programmed by the RES capacitor, the SS capacitor is released. If the overload condition persists, this process is repeated. Thus, the converter will be in a loop of shot bursts followed by a sleep time in continuous overload conditions. The sleep time reduces the average input current drawn by the power converter in such a condition and allows the power converter to cool down.

10 Performance Characteristics

Once the circuit is powered up and running normally, the output voltage is regulated to 3.3V with the accuracy determined by the feedback resistors and the voltage reference. The frequency of operation is selected to be 420 kHz, which is a good comprise between board size and efficiency, see Figure 3. for efficiency curves.

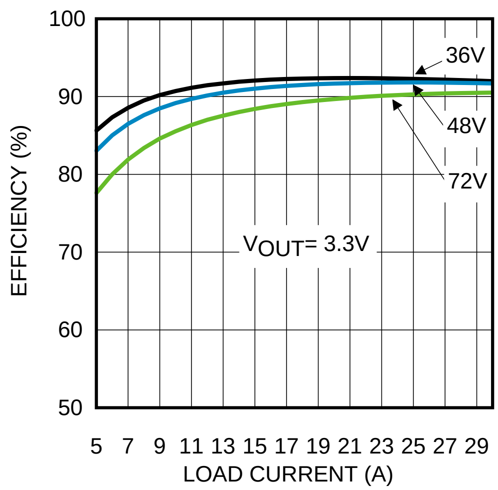
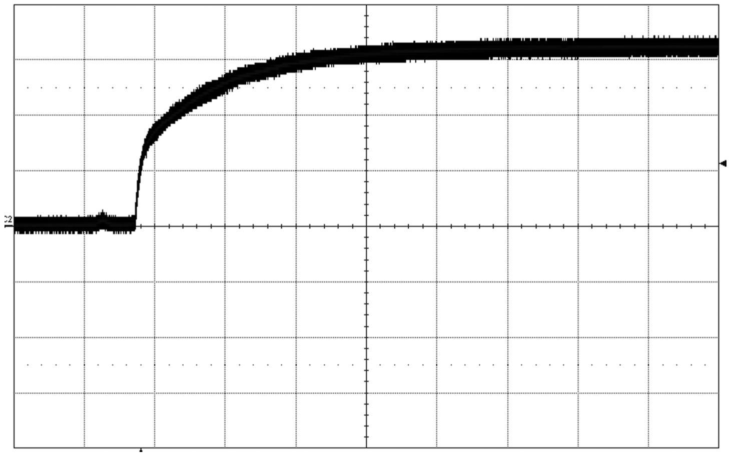


Figure 3. Application Board Efficiency

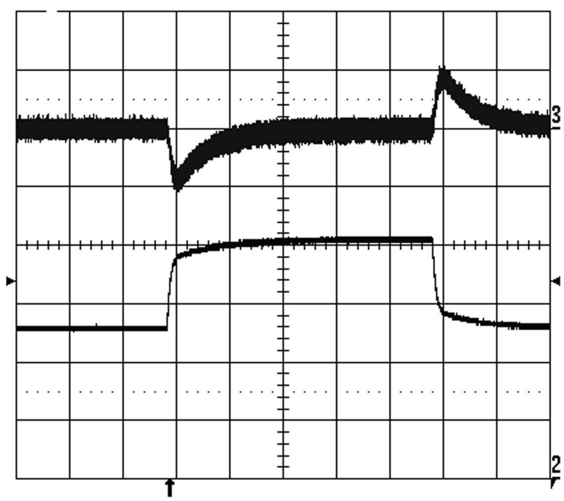
When applying power to the LM5045 evaluation board a certain sequence of events occurs. Soft-start capacitor values and other components allow for a minimal output voltage for a short time until the feedback loop can stabilize without overshoot. Figure 4 shows the output voltage during a typical start-up with a 48V input and a load of 25A. There is no overshoot during start-up.

Copyright © 2011–2013, Texas Instruments Incorporated



Conditions: Input Voltage = 48V
Output Current = 25A
Trace 1: Output Voltage Volts/div = 1V
Horizontal Resolution = 2.0 ms/div

Figure 4. Soft-Start

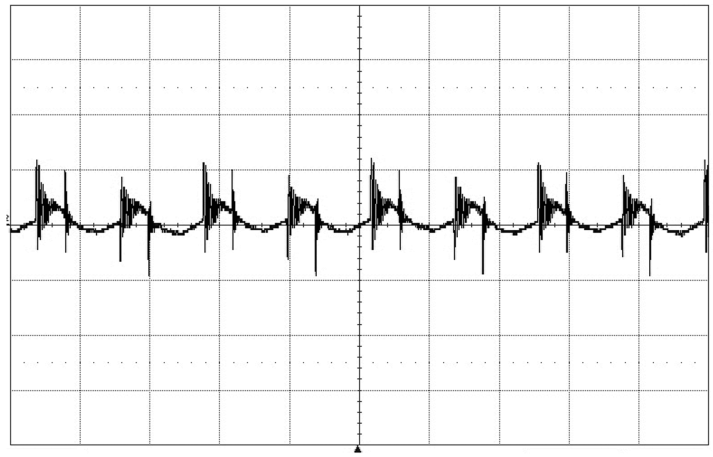


Conditions: Input Voltage = 48V
Output Current = 15A to 22.5A to 15A
Upper Trace: Output Voltage Volts/div = 100mV
Lower Trace: Output Current = 5A/div
Horizontal Resolution = 200 µs/div

Figure 5. Transient Response

Figure 6 shows typical output ripple seen directly across the output capacitor, for an input voltage of 48V and a load of 30A. This waveform is typical of most loads and input voltages.

Copyright © 2011–2013, Texas Instruments Incorporated

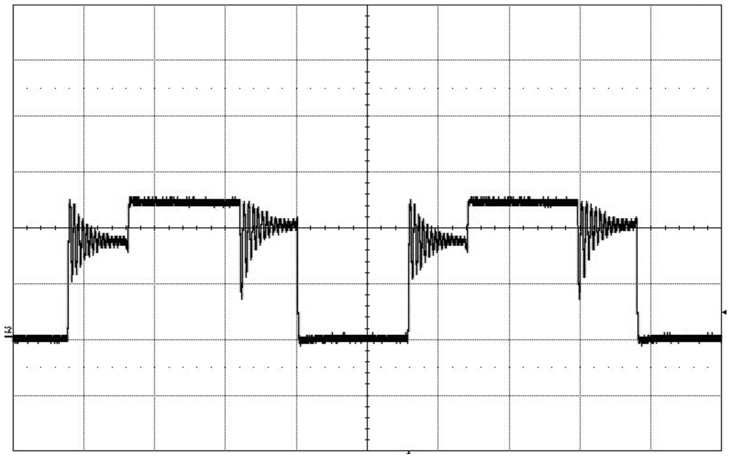


Conditions: Input Voltage = 48V, Output Current = 30A
Trace 1: Output Voltage Volts/div = 50mV
Bandwidth Limit = 20MHz
Horizontal Resolution = 2 µs/div

Figure 6. Output Ripple

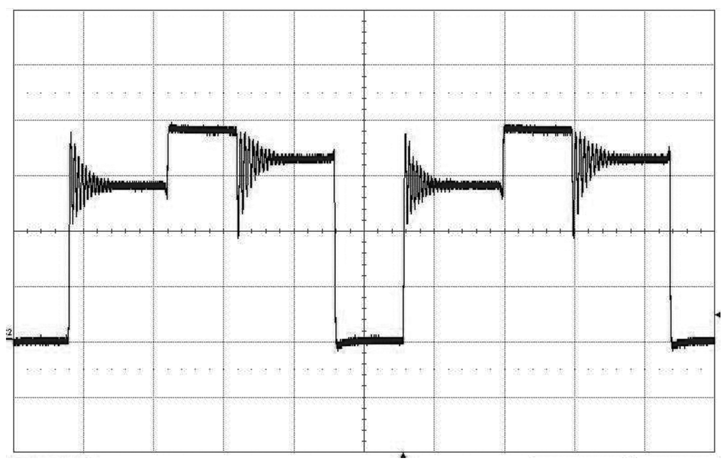
Copyright © 2011–2013, Texas Instruments Incorporated

Figure 7 and Figure 8 show the typical SW node voltage waveforms with a 25A load. Figure 7 shows an input voltage represents an input voltage of 48V and Figure 8 represents an input voltage of 72V.



Conditions: Input Voltage = 48V
Output Current = 30A
Trace 1: SW1 Node (Q2 Drain) Voltage Volts/div = 20V
Horizontal Resolution = 1µs/div

Figure 7. Switch Node Waveforms

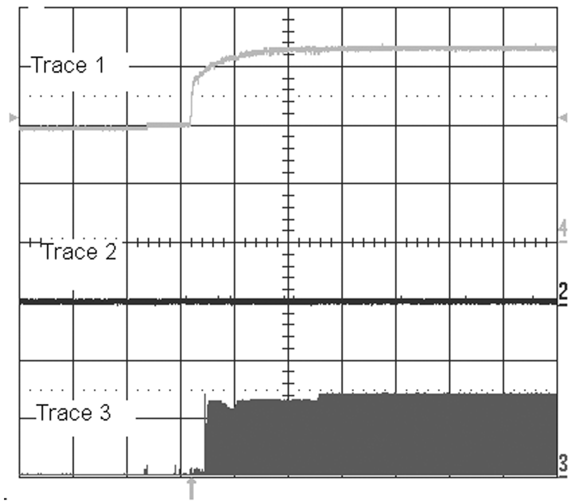


Conditions: Input Voltage = 72V
Output Current = 30A
Trace 1: SW1 Node (Q2 Drain) Voltage Volts/div = 20V
Horizontal Resolution = 1 µs/div

Figure 8. Switch Node Waveforms

Copyright © 2011–2013, Texas Instruments Incorporated

Figure 9 shows a typical startup of the LM5045 into a 2V pre-biased load. Trace 2 represents the output current that is monitored between the output caps of the power converter and the 2V pre-bias voltage supply. It can be inferred from the Trace 2 that the SR MOSFET's do not sink any current during the power-up into pre-biased load.



Conditions: Input Voltage = 48V, Output Pre-Bias = 2V
Trace 1 (Channel 4): Output Voltage Volts/div = 1V
Trace 2 (Channel 2): Output Current Amps/div = 200mA
Trace 3 (Channel 3): SR Gate Voltage Volts/div = 5V

Figure 9. Soft-Start into 2V Pre-Biased Load

11 5V Evaluation Board

The LM5045 evaluation board can be easily modified to achieve a 5V output at 30A load. The 5V board schematic and the Bill of Materials (BOM) change required to achieve it are shown below. A peak efficiency of 93% was observed at 48V input and 5V out at 30A.

Copyright © 2011–2013, Texas Instruments Incorporated

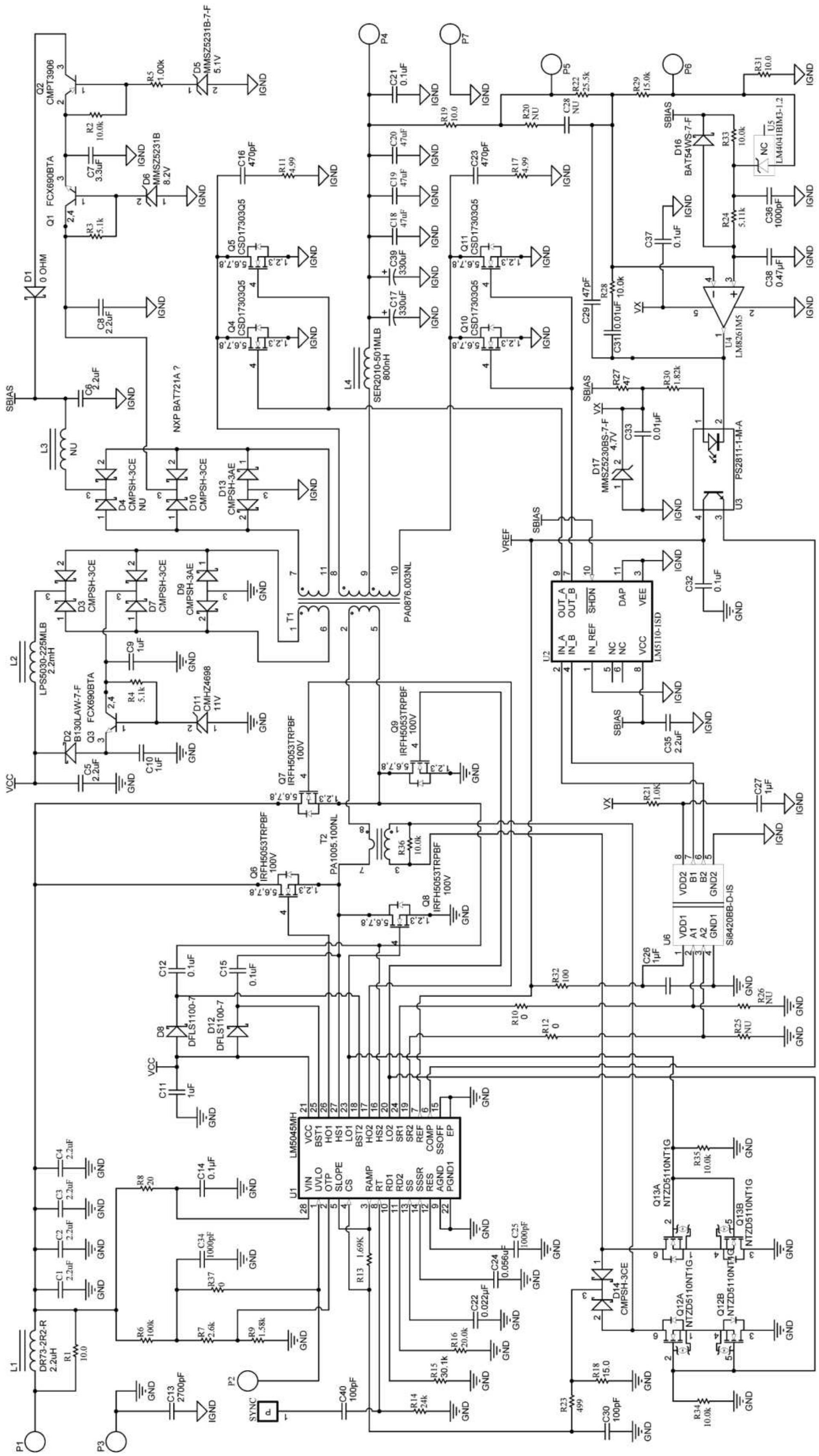


Figure 10. Application Circuit: Input 36V to 75V, Output 3.3V at 30A

Copyright © 2011–2013, Texas Instruments Incorporated

12 Bill of Materials (BOM)

Table 1. Bill of Materials (BOM)

Item	Designator	Description	Part Number
1	AA	Printed Circuit Board	
2	C1, C2, C3, C4	Ceramic 2.2uF, X7R, 100V, 10%, 1210	GRM32ER72A225KA35L
3	C5, C35	Ceramic 2.2uF, X7R, 16V, 10%, 0805	GRM21BR71C225KA12L
4	C7, C8	Ceramic, 2.2uF, X5R, 25V, 10%, 0805	GRM21BR71E225KA73L
5	C9	Ceramic, 1uF, X7R, 50V, 10%, 0805	GRM21BR71H105KA12L
6	C6	Ceramic 2.2uF 10V X7R 0603	GRM188R71A225KE15D
7	C10, C11	Ceramic, 1uF, X7R, 16V, 10%, 0603	C1608X7R1C105K
8	C12, C15, C21, C32	Ceramic,0.1uF, X7R, 25V, 10%, 0603	06033C104KAT2A
9	C13	Ceramic, X7R,2000V, 2700pF,10%	C1808C272KGRACTU
10	C14	Ceramic 0.1uF, 100V, +/-10%, X7R, 0603	GRM188R72A104KA35D
11	C16, C23	Ceramic, C0G/NP0 470pF, 100V, 10%, 1206	12061A471KAT2A
12	C17, C39	Cap 330uF, 4V, AL, 4V, 20%, 0.012 Ω ESR	EEF-UE0G331R
13	C18, C19, C20	Ceramic 47uF, X7R, 6.3V, 10%	GCM32ER70J476KE19L
14	C22	Ceramic 0.022uF, 16V, +/-10%, X7R, 0402	C1005X7R1C223K
15	C34, C36	Ceramic 1000pF, 25V, +/-5%, C0G/NP0, 0402,	C1005C0G1E102J
16	C26, C27	Ceramic 0.47uF, 16V, +/-20%, X7R, 0805	GRM21BR71C474KCO1D
17	C28, R20, D4, L3	NU	NU
18	C29	Ceramic 47pF, 50V, +/-5%, C0G/NP0, 0402	GRM1555C1H470JZ01
19	C30, C40	Ceramic 100pF, C0G/NP0, 50V, 5%, 0603	C1608C0G1H101J
20	C24	CAP, CERM, 0.056uF, 6.3V, +/-10%, X7R, 0402	C0402C563K9RACTU
21	C25, C31, C37, C33	CAP, CERM, 0.01uF, 16V, +/-10%, X7R, 0402	C1005X7R103K
22	C38	CAP, CERM, 0.47uF, 6.3V, +/-10%, X5R, 0402	C1005X5R0J474K
23	D2	Vr = 30V, Io = 1A, Vf = 0.38V	B130LAW-7-F
24	D3, D7, D10, D14	Vr = 40V, Io = 0.2A, Vf = 0.65V, Common Cathode	CMPSH-3CE
25	D5	SMT 5.1V Zener Diode	MMSZ5231B
26	D6	SMT 8.2V Zener Diode	CMHZ4694
27	D8, D12	Vr = 100V, Io = 1A, Vf = 0.77V, Schottky diode	DFLS1100-7
28	D9, D13	Vr = 40V, Io = 0.2A, Vf = 0.65V, Common Anode	CMPSH-3AE
29	D11	SMT 11V Zener Diode	CMHZ4698
30	D16	Vr = 30V, Io = 0.2A, Vf = 0.7V, Schottky	BAT54WS-7-F
31	D17	Diode, Zener, 4.7V, 250mW, SOD-323	CMDZ4L7
32	L1	Shielded Drum Core, 2.2uH 4.15A, 0.0165 Ω	DR73-2R2-R
33	L2	Shielded Drum Core, 0.08A, 11 Ω	LPS5030-225MLB
34	L3	NU	NU
35	L4	Inductor, Shielded E Core, Ferrite, 800nH, 45A, 0.0009 Ω, SMD	SER2010-801MLB
36	P1, P3, P5, P6	PCB Pin	3104-2-00-34-00-00-08-0
37	P2	Test Point, SMT, Miniature	5015
38	P4, P7	PCB Pin	3231-2-00-34-00-00-08-0
39	Q1, Q3	NPN, 2A, 45V	FCX690BTA
40	Q2	PNP, 0.2A, 40V	CMPT3906
41	Q4, Q5, Q10, Q11	32A, 18nC, rDS(on) @ 4.5V = .002 Ω	CSD17303Q5
42	Q6, Q7, Q8, Q9	MOSFET, N-CH, 100V, 9.3A, PQFN 8L 5x6 A	IRFH5053TRPBF
43	Q12, Q13	0.31A, 0.7nC, rDS(on) @ 4.5V =2.5 Ω	NTZD5110NT1G

Copyright © 2011–2013, Texas Instruments Incorporated

Table 1. Bill of Materials (BOM) (continued)

Item	Designator	Description	Part Number
44	R1	RES 10 Ω 1%, 0.125W, 0805	CRCW080510R0FKEA
45	R2, R28, R33, R34, R35, R36	RES 10K Ω 1%, 0.063W, 0402	CRCW040210k0FKED
46	R3, R4	RES 5.1K Ω 5%, 0.125W, 0805	ERJ-6GEYJ512V
47	R5	RES 1K Ω, 5.1, 0.125W, 0805	CRCW08051K00FKEA
48	R6	RES 100K Ω,1%, 0.125W, 0805	CRCW0805100KFKEA
49	R7	RES, 2.61k Ω, 1%, 0.063W, 0402	CRCW04022K61FKED
50	R8	RES 20 Ω 1/8W 5% 0805 SMD	ERJ-6GEYJ200V
51	R9	RES, 1.58k Ω, 1%, 0.063W, 0402	CRCW04021K58FKED
52	R10, R12	RES, 0 Ω, 5%, 0.063W, 0402	RC0402JR-070RL
53	R11, R17	RES 4.99 Ω,1%, 0.25W, 1206	CRCW12064R99FNEA
54	R13	RES, 1.69k Ω, 1%, 0.063W, 0402	CRCW04021K69FKED
55	R14	RES 24K, 5%, 0.063W, 0402	CRCW040224k0JNED
56	R15	RES, 30.1k Ω, 1%, 0.063W, 0402	CRCW040230K1FKED
57	R16	RES 20k Ω,1%, 0.063W, 0402	CRCW040220k0FKED
58	R18	RES, 15.0 Ω, 1%, 0.063W, 0402	CRCW040215R0FKED
59	R19, R31	RES 10.0 Ω, 1%, 0.063W, 0402	CRCW0402750RFKED
60	R21	RES 750 Ω 1/16W 5% 0402 SMD	CRCW04021K00JNED
61	R22	RES 25.5k Ω,1%, 0.063W, 0402	CRCW040225k5FKED
62	R23	RES 499 Ω, 1%, 0.063W, 0402	CRCW0402499RFKED
63	R24	RES 5.11k Ω, 1%, 0.063W, 0402	CRCW04025k11FKED
64	R25, R26	NU	NU
65	R27	RES 47 Ω .25W 5% 0603 SMD	CRCW060347R0JNEAHP
66	R32	RES 100 Ω, 1%, 0.063W, 0402	CRCW0402100RFKED
67	R29	RES 15k Ω,1%, 0.063W, 0402	CRCW040215k0FKED
68	R30	RES 1.82k Ω,1%, 0.063W, 0402	CRCW04021k82FKED
69	R37	RES 0.0 Ω, 5%, 0.063W, 0402	CRCW04020000Z0ED
70	D1	RES 0.0 Ω, 5%, 0.063W, 1206	CRCW12060000Z0EA
71	T1	High Frequency Planar Transformer	PA0876.003NL
72	T2	SMT Current Sense Transformer	PA1005.100NL
73	U1	Full-Bridge PWM Controller	LM5045
74	U2	Dual 5A Compound Gate Driver with Negative Output Voltage Capability	LM5110
75	U3	Low Input Current, High CTR Photo-coupler	PS2811-1-M-A
76	U4	RRIO, High Output Current & Unlimited Cap Load Op Amp in SOT23-5	LM8261
77	U5	Precision Micro-power Shunt Voltage Reference	LM4041
78	U6	Dual-Channel Digital Isolator	ISO742OFED

Copyright © 2011–2013, Texas Instruments Incorporated

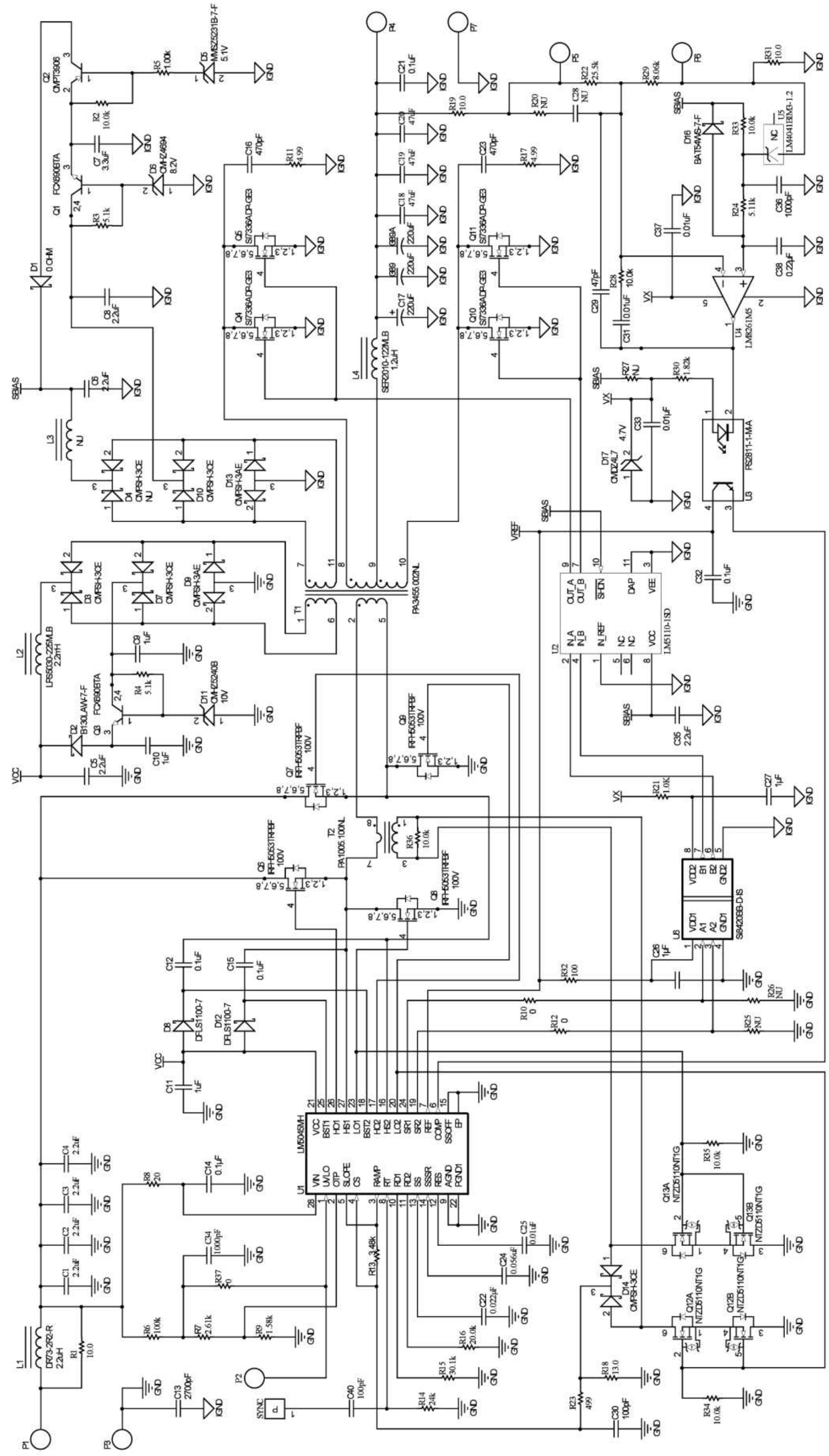


Figure 11. Application Circuit: Input 36V to 75V, Output 5V at 30A

Copyright © 2011–2013, Texas Instruments Incorporated

13 Bill of Materials

Table 2. Bill of Materials (1)

Item	Designator	Description	Manufacturer	Part Number
1	C17, C39,C39A	Cap 220uF, 6.3V, AL, 4V, 20%, 0.012 Ω ESR	Panasonic	EEF-UE0G331R
2	L4	Inductor, Shielded E Core, Ferrite, 1.2uH, 36A, 0.0009 Ω, SMD	Coilcraft	SER2010-122MLB
3	R13	RES, 3.48k Ω, 1%, 0.063W, 0402	Vishay-Dale	CRCW04023K48FKED
4	R18	RES, 13.0 Ω, 1%, 0.063W, 0402	Vishay-Dale	CRCW040213R0FKED
5	R29	RES 8.06k Ω,1%, 0.063W, 0402	Vishay-Dale	CRCW040280k6FKED
6	T1	High Frequency Planar Transformer	Pulse Engineering	PA3455.002NL
7	D11	SMT10V Diode	Central Semiconductor	CMHZ5240B
8	C38	CAP Ceramic 0.22uF 6.3V +/-10% X5R 0402	TDK Corporation	C1005X5R0J224K

(1) All the other parts are the same as 3.3V evaluation board.

14 PCB Layouts

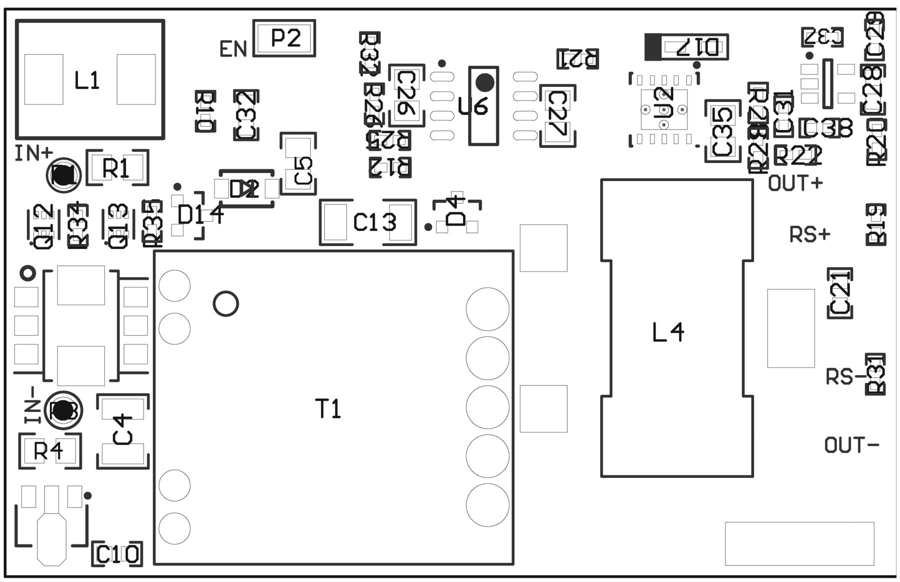


Figure 12. Top Side Assembly

Copyright © 2011–2013, Texas Instruments Incorporated

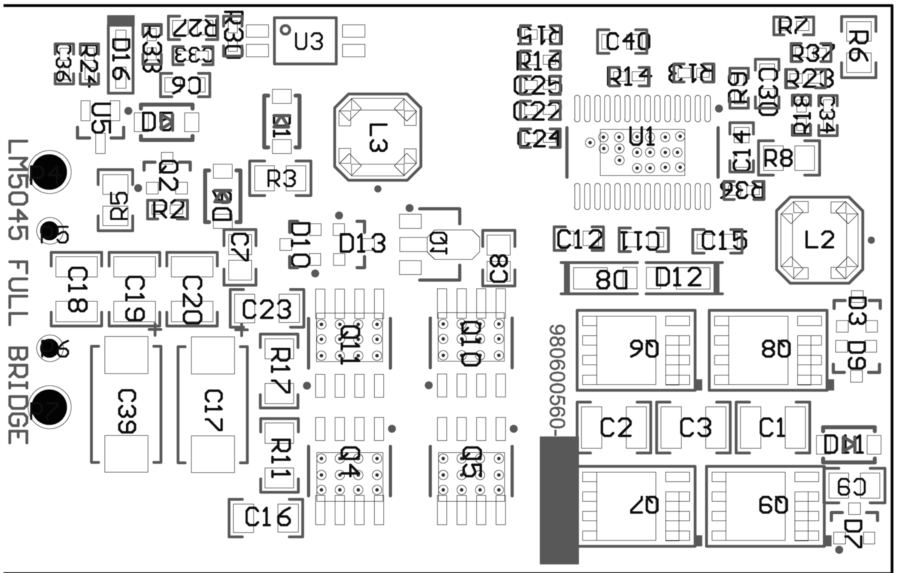


Figure 13. Bottom Side Assembly

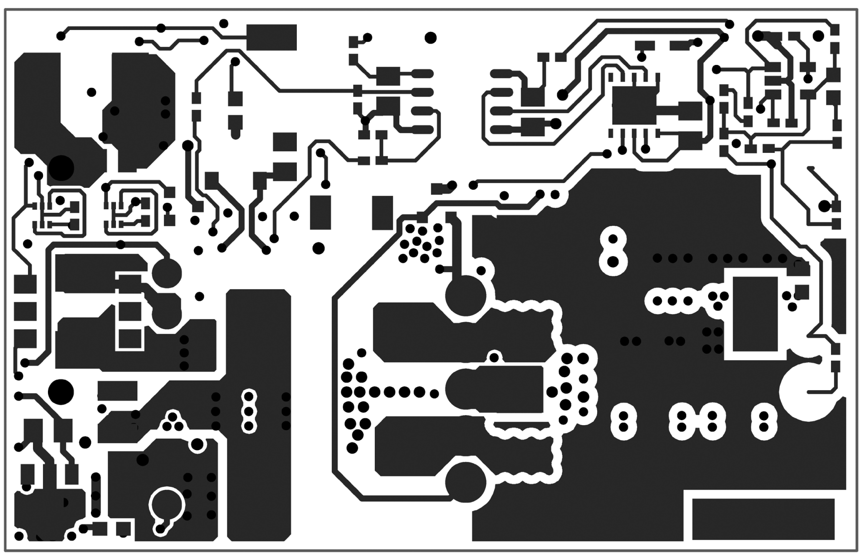


Figure 14. Layer 1 (Top Side)

Copyright © 2011–2013, Texas Instruments Incorporated

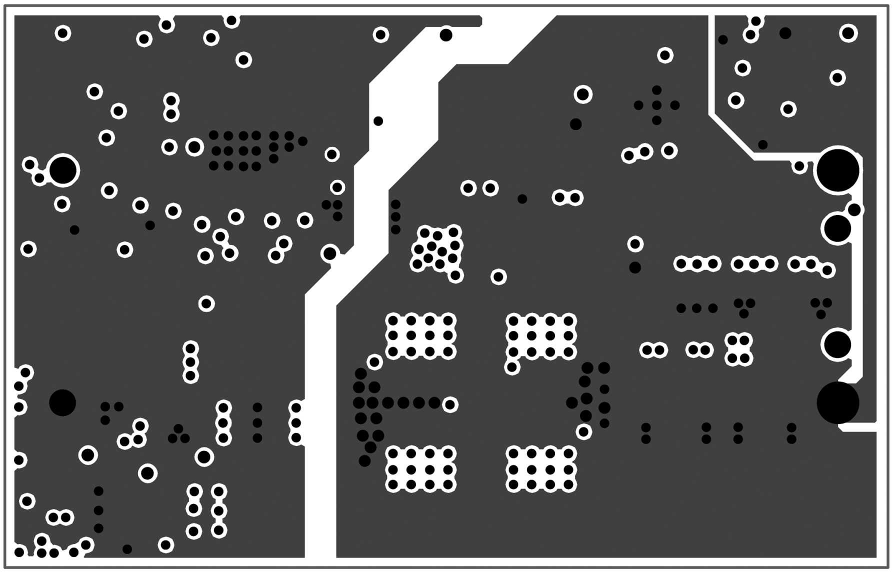


Figure 15. Layer 2

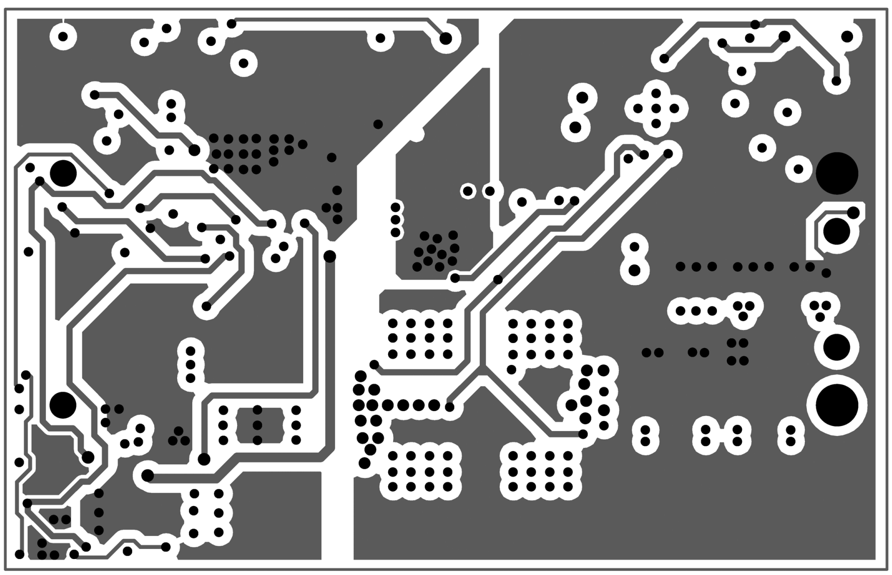


Figure 16. Layer 3

Copyright © 2011–2013, Texas Instruments Incorporated

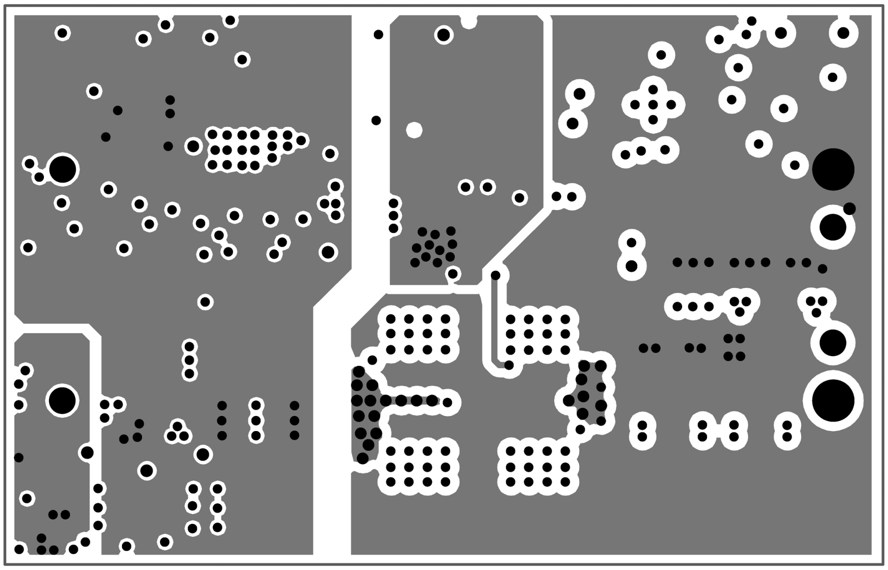


Figure 17. Layer 4

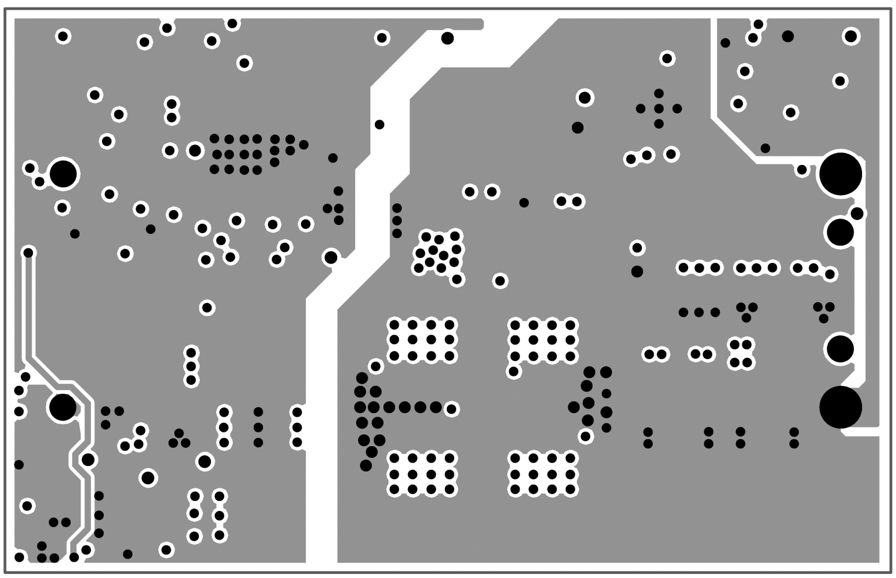


Figure 18. Layer 5

Copyright © 2011–2013, Texas Instruments Incorporated

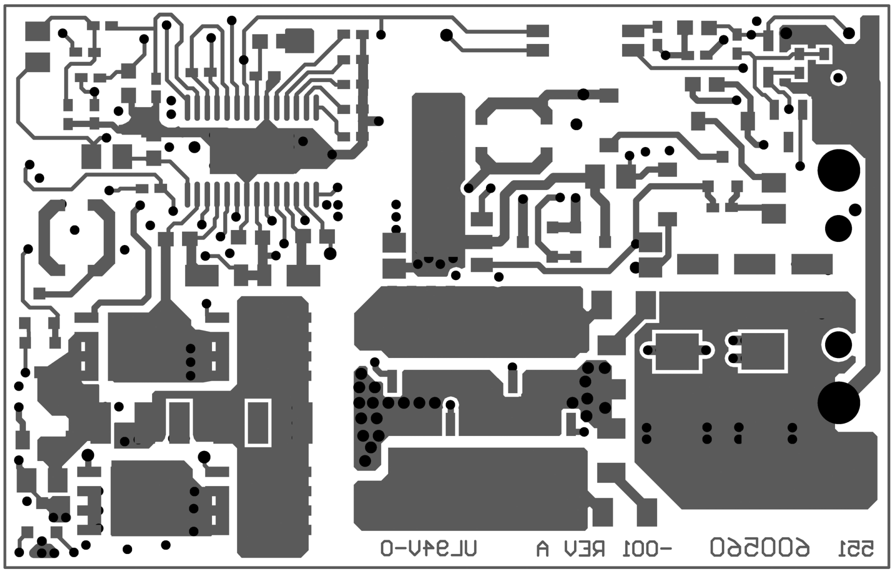


Figure 19. Layer 6 (Bottom Side)

Copyright © 2011–2013, Texas Instruments Incorporated

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Copyright © 2013, Texas Instruments Incorporated