AN-1861 LM25037 Evaluation Board

1 Introduction

The LM25037 evaluation board is designed to provide the design engineer with a fully functional power converter based on push-pull topology to evaluate the LM25037 controller. The performance of the evaluation board is as follows:

Input Operating Range: 16 to 32V

Output Voltage: 5.0V

Output Current: 0 to 10A

Measured Efficiency: 88% @ 10A Load and 24V Input

Frequency of Operation: 250 kHz

Board Size: 3.5x2.25x0.05 inches

Load Regulation: 2%

Line UVLO (14V rising / 11V falling)

The printed circuit board consists of 4 layers of 2 oz copper on FR4 material, with a thickness of 0.050 in. The unit is designed for continuous operation at rated load at <40°C and a minimum airflow of 200 LFM.

2 Theory of Operation

Push-Pull topology consists of two MOSFETs on the primary side driven 180 degrees out of phase. When either MOSFET is turned on, a voltage equal to "Vin-$V_{ds(on)}$", is applied across one half of the power transformer's primary. Where, $V_{ds(on)}$ is the drain to source voltage across the MOSFET when turned ON.

The center-tapped secondary of the transformer has 2 turns in each winding, resulting in a 2:1 step-down of the voltage applied across the primary. The transformer secondary voltage is then rectified and filtered with an LC filter to provide the output voltage.

In a push-pull topology, the primary MOSFETS are turned on alternatively energizing the windings in such a way that the flux swings back and forth in the first and third quadrants of B-H curve. The use of two quadrants allows better utilization of the core resulting in a smaller core volume compared to single-ended topologies such as a forward converter.

The feedback resistors are set so that at the desired output voltage, the voltage at the feedback pin is equal to the internal reference voltage (1.25V). The LM25037 has been configured for current mode control. Current mode control inherently provides line voltage feed-forward, cycle-by-cycle current limiting and ease of loop compensation as it removes the additional pole due to output inductor. Hence, a standard “type II” network is used for the compensation.

In this particular evaluation board, the output inductor not only smoothes the output voltage waveform, but also generates an auxiliary voltage (by means of its secondary winding). This feature reduces power dissipation within the IC, thereby increasing reliability and efficiency. The evaluation board can be synchronized to an external clock with a recommended frequency range of 275 kHz to 500 kHz.

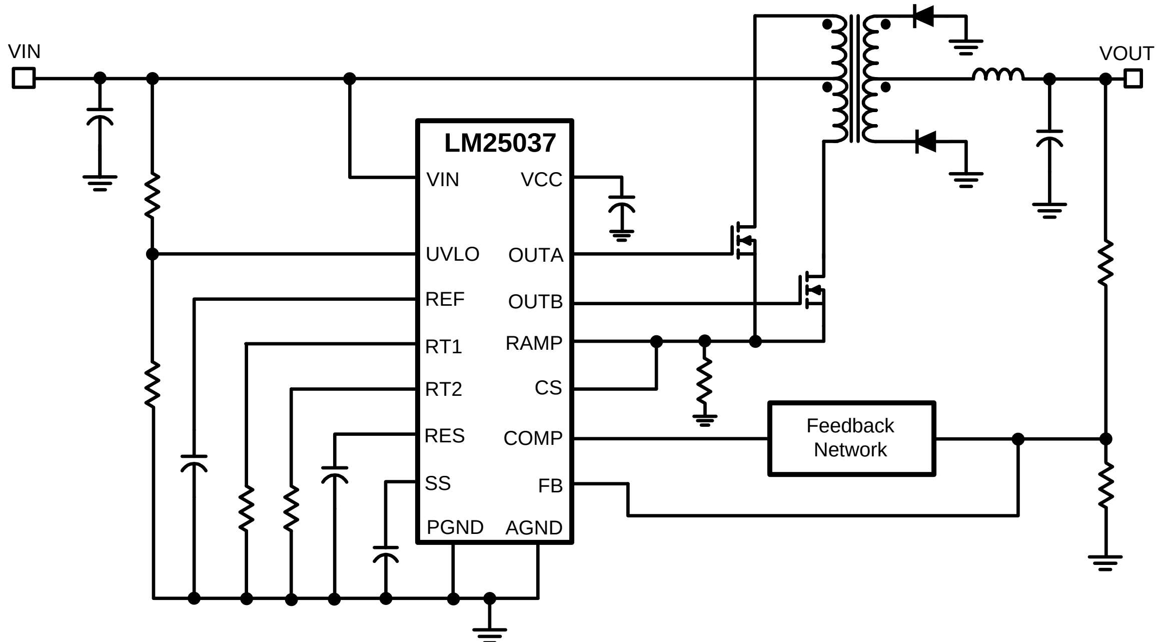


Figure 1. Typical Push-Pull Circuit

3 Powering and Loading Considerations

When applying power to the LM25037 evaluation board certain precautions should be followed. A misconnection can damage the assembly.

3.1 Proper Connections

When operated at low input voltages the evaluation board can draw up to 5A of current at full load. Ensure that the input supply has sufficient current capability. The maximum rated output current is 10A. 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.

3.2 Source Power

The evaluation board can be viewed as a constant power load. At low input line voltage (16V) the input current can reach 3.75A typically in steady state, while at high input line voltage (32V) the input current will be approximately 1.9A. Therefore, to fully test the LM25037 evaluation board a DC power supply capable of at least 50V and 5A 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.

3.3 Loading

When using electronic load, it is strongly recommended to power up the evaluation board at light load and then slowly increase the load. This is necessary as most of the electronic loads do not draw any current till the power supply output voltage reaches an internally set point; this can result in soft-start function to not work as desired and can trip the current sense comparator. Electronic loads, in general, are best suited for monitoring steady state waveforms.

If it is desired to power up the evaluation board at maximum load, resistor banks can be used. This will ensure a soft-start and evaluation board will perform as desired. The high output current requires thick cables! If resistor banks are used there are certain precautions to be taken. The resistance for maximum load is 0.5Ω. The wattage and current ratings must be adequate for a 10A, 60W supply. Monitor both current and voltage at all times. Ensure there is sufficient cooling provided for the load.

3.4 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.

3.5 Powering Up

It is suggested to set the current limit of the source supply to provide about 1.5 times the wattage of the load.

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 under-voltage 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.

3.6 Over Current Protection

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 14A@16V Input) the unit will discharge the soft-start capacitor, which disables the power stage. After a delay the soft-start is released. The shutdown, delay and slow recharge time of the soft-start capacitor protects the unit, especially during a short circuit event where the stress is highest.

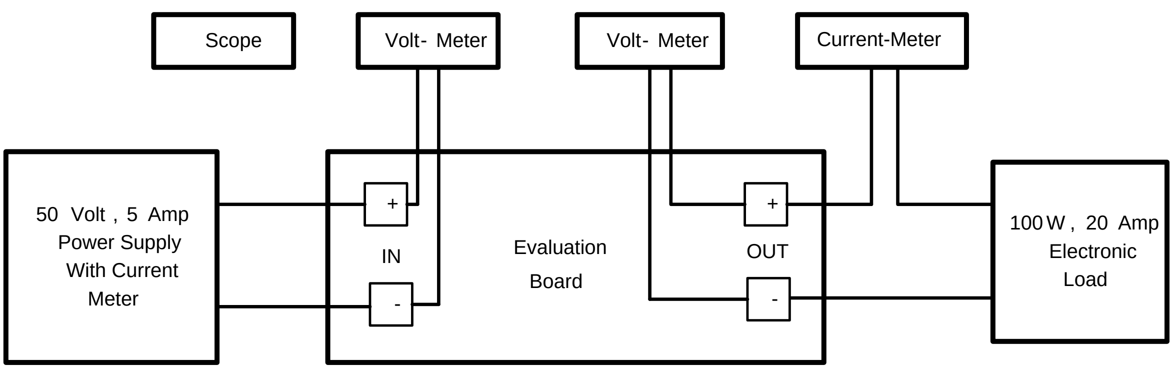


Figure 2. Typical Evaluation Setup

4 Performance Characteristics

Once the circuit is powered up and running normally, the output voltage is regulated to 5.0V, with the accuracy determined by feedback resistors and bandgap reference voltage inside the IC. When the load current is varied from 5A to 10A, the regulator output should vary less than 100 mV. The frequency of operation is selected to be 250 kHz, which is a good compromise between board size and efficiency. The efficiency of the power converter is measured to be 88% at 24V and 10A. Please refer to Figure 3 for efficiency curves.

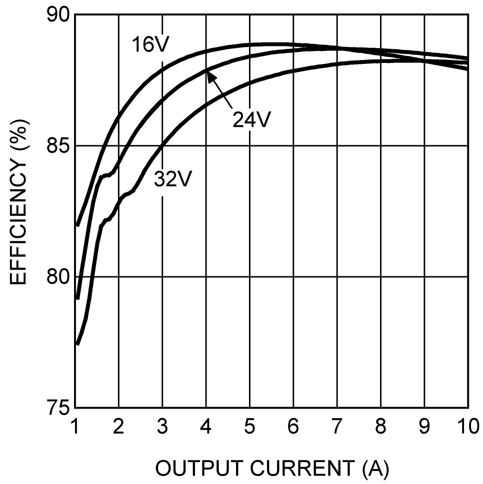
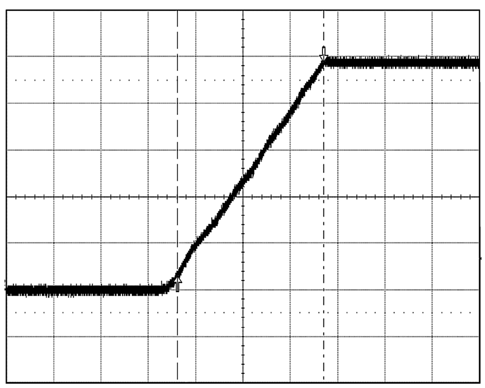


Figure 3. Efficiency vs. Output Current and VIN

5 Waveforms

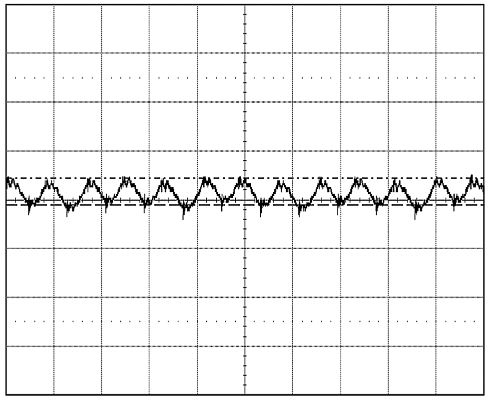
When power is applied to the LM25037 evaluation board a certain sequence of events occurs. Soft-start capacitor values and other components ensure a linear increase in output voltage for a short time until the feedback loop can stabilize without an overshoot. Figure 4 shows the output voltage during a typical start-up with a 24V input and a load of 10A. There is no overshoot during startup. It is strongly recommended to use a resistor load instead of an electronic load, while capturing soft-start data as electronic loads tend to have small idiosyncrasies such as not providing load resistance till the output reaches certain voltage. This occasionally causes a transient during start-up.



Conditions:
Input Voltage = 24VDC
Output Current = 10A
Trace:
Output Voltage, Volts/div = 1V
Horizontal Resolution = 0.5 ms/div

Figure 4. Soft Start

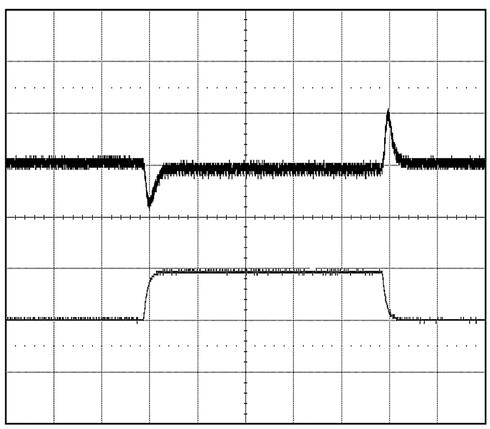
Figure 5 shows typical output ripple seen directly across the output capacitor, for an input voltage of 24V and a load of 10A. This waveform is typical of most loads and input voltages.



Conditions:
Input Voltage = 24VDC
Output Current = 10A
Bandwidth Limit = 20 MHz
Trace:
Output Ripple, Volts/div = 50 mV
Horizontal Resolution = 5.0 µs/div

Figure 5. Output Ripple

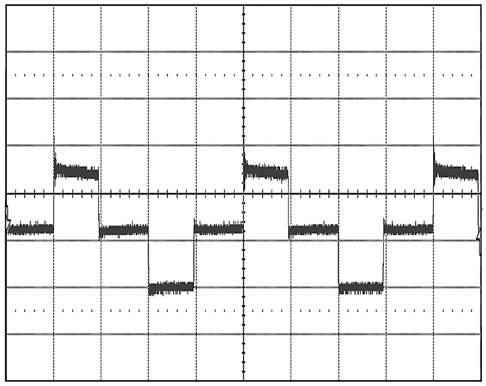
Figure 6 shows the transient response for a load of change from 5A to 10A. The upper trace shows minimal output voltage droop and overshoot during the sudden change in output current shown by the lower trace.



Conditions:
Input Voltage = 24VDC
Output Current = 5A to 10A
Bandwidth Limit = 20 MHz
Traces:
Bottom Trace: Output Current
Amps/div = 5A
Top Trace: Output Voltage response
Volts/div = 100 mV
Horizontal Resolution = 200 µs/div

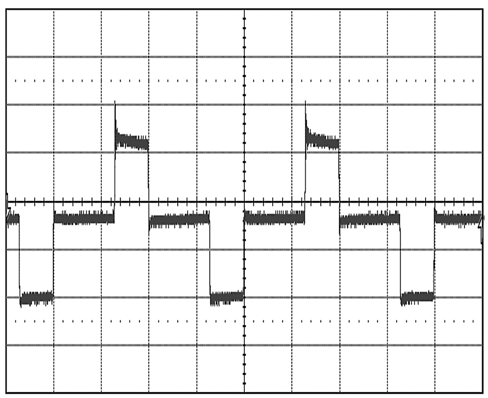
Figure 6. Transient Response

Figure 7 and Figure 8 show the drain voltage of Q1 with a 5A load. Figure 7 represents drain voltage of Q1 at an input voltage of 24V and Figure 8 represents drain voltage at an input voltage of 32V. Drain of Q1 sees twice the input voltage when it is off and during dead-time it exactly sees input voltage.



Conditions:
Input Voltage = 24VDC
Output Current = 5A
Trace:
Q1 drain to source voltage, Volts/div = 20V
Horizontal Resolution = 2 µs/div

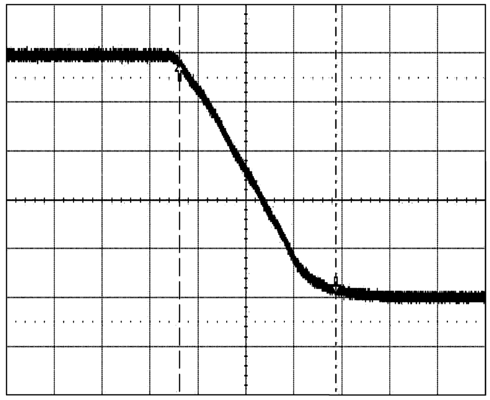
Figure 7. Drain Waveform of Q1 at 24V



Conditions:
Input Voltage = 32VDC
Output Current = 5A
Trace:
Q1 drain to source voltage, Volts/div = 20V
Horizontal Resolution = 2 µs/div

Figure 8. Drain Waveform of Q1 at 32V

[Figure 9](#) shows the soft-stop. This can be achieved by setting the UVLO voltage between 0.4V and 1.25V.



Conditions:
Input Voltage = 24VDC
Trace:
Output Voltage, Volts/div = 1V
Horizontal Resolution = 0.5 ms/div

Figure 9. Soft Stop

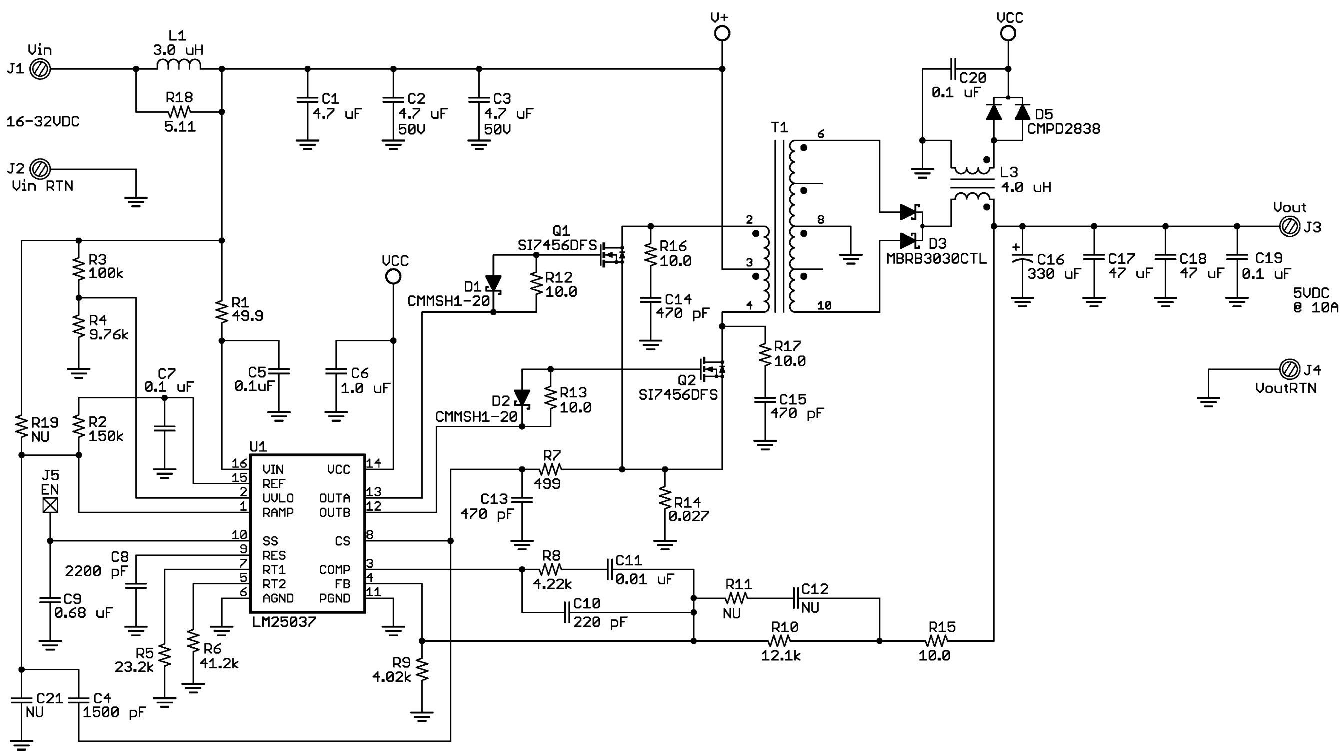


Figure 10. Typical Application Circuit

6 PCB Layout

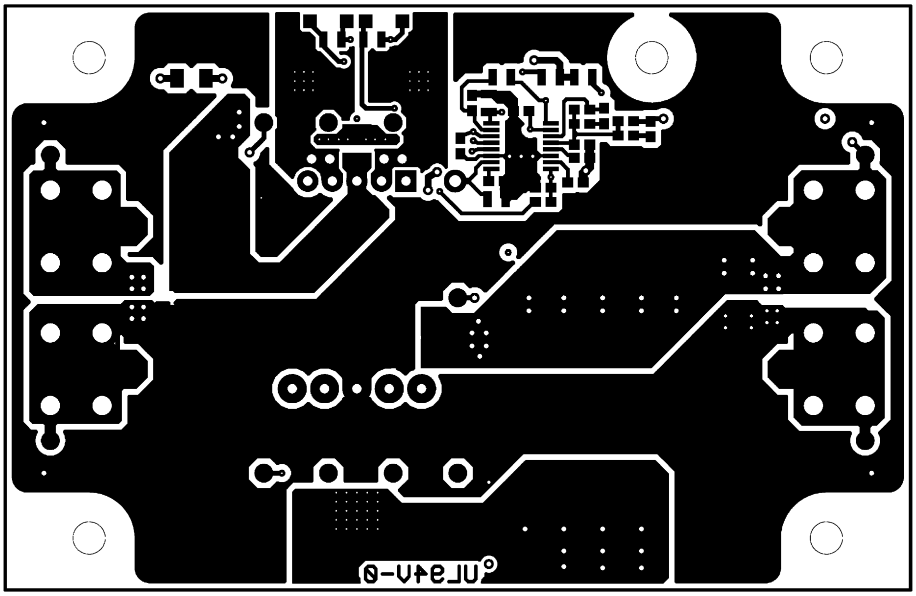


Figure 11. Bottom Layer

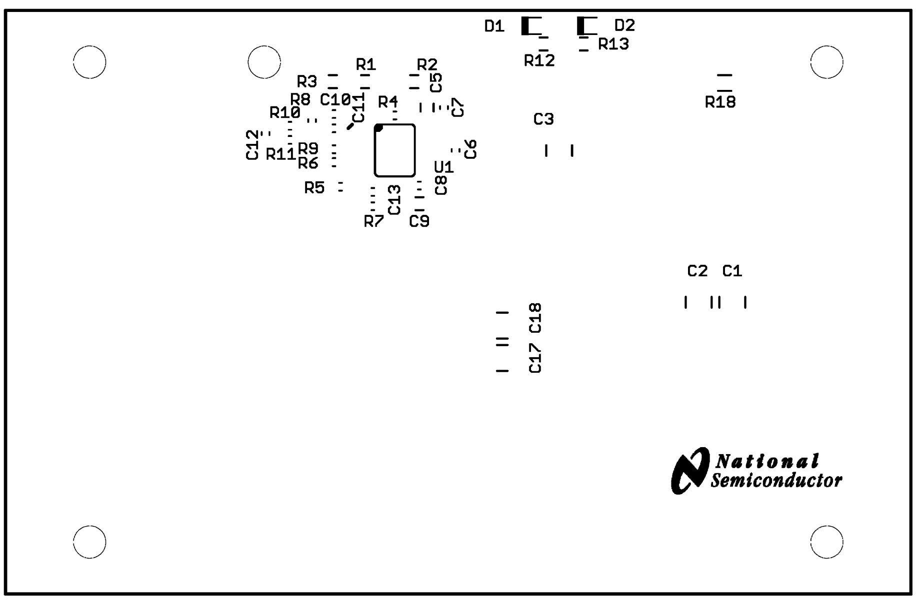


Figure 12. Bottom Layer Silk Screen

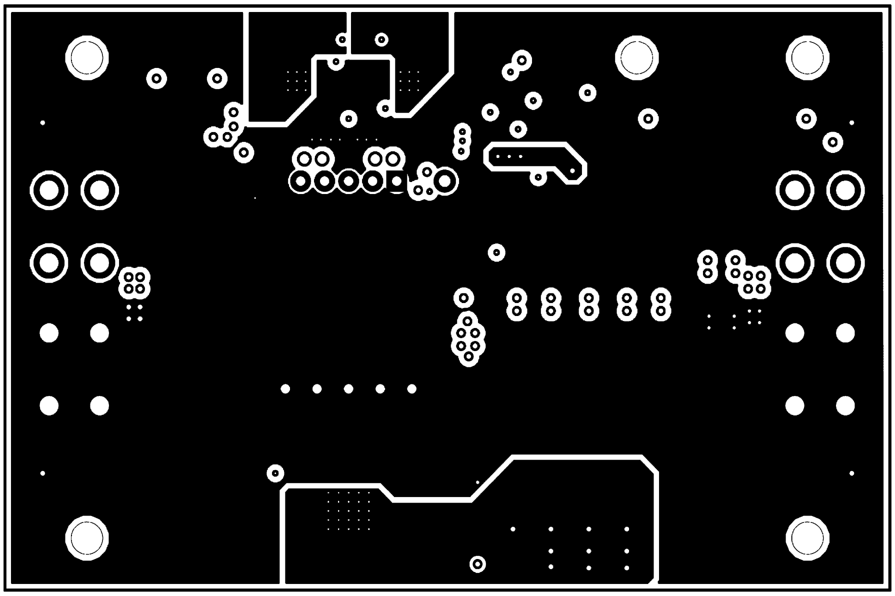


Figure 13. Mid Layer-1

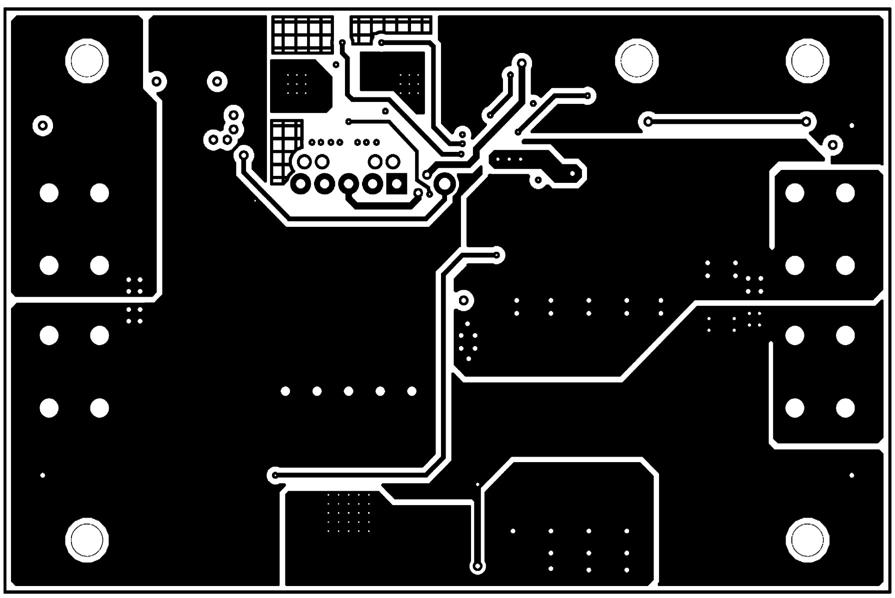


Figure 14. Mid Layer-2

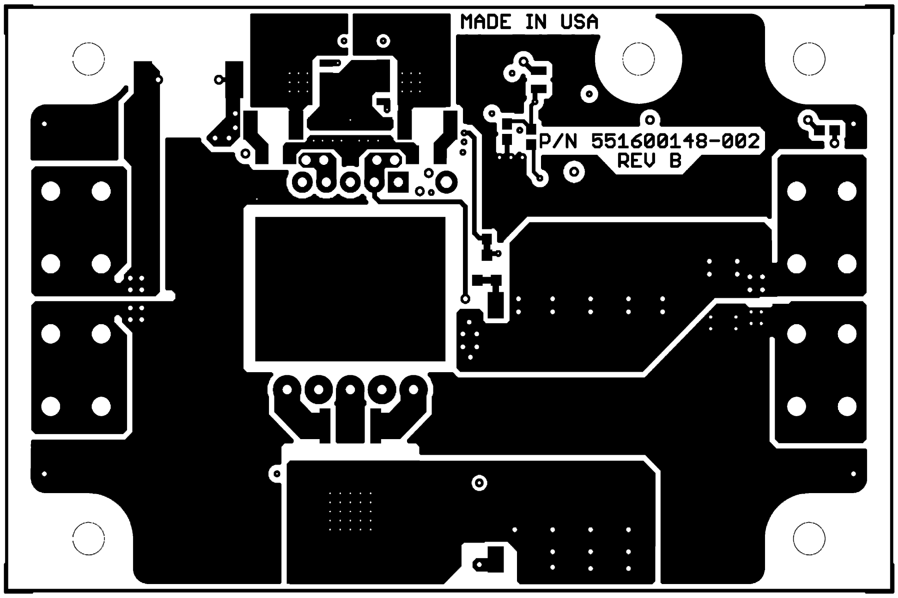


Figure 15. Top Layer

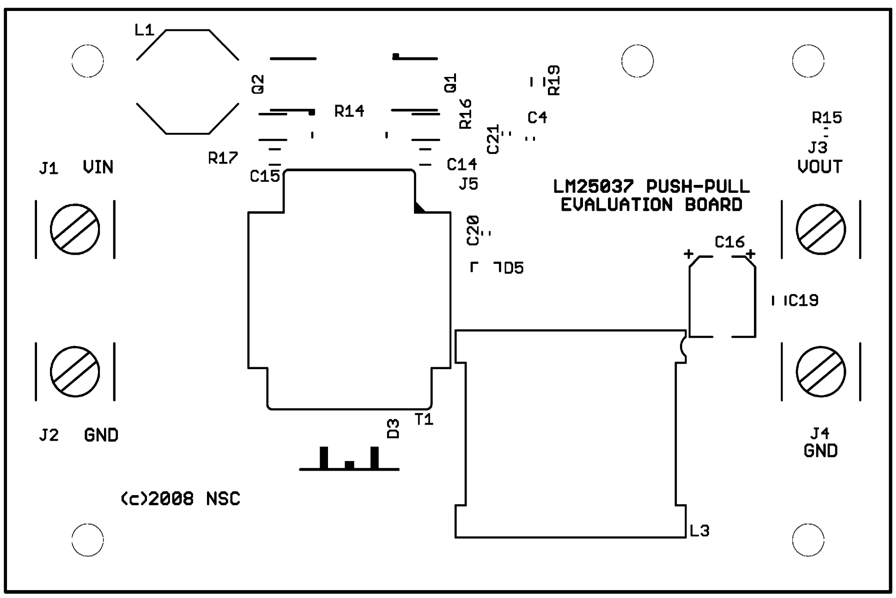


Figure 16. Top Layer Silk Screen

7 Bill of Materials

Table 1. Bill of Materials

Part	Value	Package	Part Number	Manufacturer	Description
C1, C2, C3	4.7 µF	C1210	GCM32ER71475KA55L	Murata	CAP CERAMIC 4.7 µF 50V X7R 1210
C4	1500 pF	C0603	GRM188R71H152KA01D	Murata	CAP CERAMIC 1500 pF 50V 10% X7R 0603
C5	0.1 µF	C0805	GRM21BR71H104KA01L	Murata	CAP CERAMIC .1 µF 50V 10% X7R 0805
C6	1.0 µF	C0603	GRM188R71C105KA12D	Murata	CAP CERAMIC 1 µF 16V X7R 0603
C7, C20	0.1 µF	C0603	GRM188R71H104KA93D	Murata	CAP CERAMIC .1 µF 50V 10% X7R 0603
C8	2200 pF	C0603	GRM188R71H222KA01D	Murata	CAP CERAMIC 2200 pF 50V 10% X7R 0603
C9	0.68 µF	C0805	GRM219R71C684KC01D	Murata	CAP CERAMIC .68 µF 16V 10% X7R 0805
C10	220 pF	C0603	ECT-ZEB1H221K	Murata	CAP CERAMIC 220 pF 50V 10% X7R 0603
C11	10,000 pF	C0603	GRM033R71AQ103KA01D	Murata	CAP CER 3300 pF 50V 10% X7R 0603
C12	NU	C0603	NU	NU	NU
C13	470 pF	C0603	GRM188R71H471KA01D	Murata	CAP CERAMIC 470 pPF 50V 10% X7R 0603
C14, C15	470 pF	C1206	12061A471KAT2A	AVX Corporation	CAP CERAMIC 470 pF 10% 100V NP0 1206
C16	330 µF	CAPSM_AL_ 26x31	APXE6R3ARA331MF80G	NIPPON CHEMI-CON	CAPSM, ALUM ELECT, 0.26X0.31
C17, C18	47 µF	C1210	GCM32ER70J476KE19L	Murata	CAP CERAMIC 47 µF 6.3V X7R 1210
C19	0.1 µF	C0805	GRM219R71C104KA01D	Murata	CAP CERAMIC .1 µF 16V 10% X7R 0805
C21	NU	C0603	NU	NU	NU
D1, D2	1A Schottky	SOD-123F	CMMSH1-20	Central Semiconductor	1A 20V Schottky Diode
D3	30A Schottky	D2PAK	MBRB3030CTL	ON Semiconductor	DIODE SCHOTTKY 30A 30V D2PAK
D5	Common Cathode Diode	SOT 23	CMPD2838	Central Semiconductor	Dual Common Cathode Ultra High Speed Diode
L1	3.0 µH	SMD Inductor	SRU1048-3ROY	Bourns	Inductor, Bourns 3.0 µH
L3	4.0 µH	EFD20-10	GA-3382-BL	Coil Craft	Filter Inductor 4.0 µH, Aux 1:2
T1	MAIN XFMR	SM PLANAR	PL140-100L	Coil Craft	XFMR, PL140-100L, SCHEMATIC A
Q1, Q2	N Channel,100 V MOSFET	PowerPak SO-8	SI7456DP	Vishay/Siliconix	100V, N_channel MOSFET, 25 mΩ, 44 nC
R1	49.9	R0805	MCR10EZHF49R9	Rohm	RES 49.9Ω 1/8W 1% 0805 SMD
R2	150k	R0805	MCR10EZPF1503	Rohm	RES 150 kΩ 1/8W 1% 0805 SMD
R3	100k	R0805	MCR10EZHF1003	Rohm	RES 100 kΩ 1/8W 1% 0805 SMD
R4	9.76k	R0603	MCR03EZPFX9761	Rohm	RES 9.76 kΩ 1/10W 1% 0603 SMD
R5	23.2k	R0603	MCR03EZPFX2322	Rohm	RES 23.2 kΩ 1/10W 1% 0603 SMD
R6	41.2k	R0603	MCR03EZPFX4122	Rohm	RES 41.2 kΩ 1/10W 1% 0603 SMD
R7	499	R0603	MCR03EZPFX4990	Rohm	RES 499Ω 1/10W 1% 0603 SMD

Table 1. Bill of Materials (continued)

Part	Value	Package	Part Number	Manufacturer	Description
R8	4.22k	R0603	MCR03EZPFX4221	Rohm	RES 4.22 kΩ 1/10W 1% 0603 SMD
R9	4.02k	R0603	MCR03EZPFX4021	Rohm	RES 4.02 kΩ 1/10W 1% 0603 SMD
R10	12.1k	R0603	MCR03EZPFX1212	Rohm	RES 12.1 kΩ 1/10W 1% 0603 SMD
R11	NU	R0603	NU	NU	NU
R12, R13	10.0	R0805	MCR10EZHJ100	Rohm	RES 10Ω 1/8W 5% 0805 SMD
R14	0.027	R0830	RL7520WT-R027-F	SUSUMU	RL Series, 2W, 27 mΩ Resistor
R15	10.0	R0603	MCR03EZPFX10R0	Rohm	RES 10.0Ω 1/10W 1% 0603 SMD
R16, R17	10.0	R2010	CRCW201010R0FKEF	Vishay/Dale	RES 10.0Ω 1/2W 1% 2010 SMD
R18	10.0	R1206	MCR18EZHF10R0	Rohm	RES 10.0Ω 1/4W 1% 1206 SMD
R19	NU	R0805	NU	NU	NU
U1	Texas Instruments PWM IC Controller	TSSOP16	LM25037	Texas Instruments	16 Pin Dual Mode PWM IC controller
J1-J4	Terminal Screw, 15A		7693	Keystone Electronics	Terminal Screw, 15A

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