User's Guide
SNVA097B–November 2004–Revised May 2013

AN-1345 LM5025A Evaluation Board

1 Introduction

The LM5025A evaluation board is designed to provide the design engineer with a fully-functional power converter based on the Active Clamp Forward topology to evaluate the LM5025A controller. The evaluation board is provided in an industry standard half-brick footprint.

The performance of the evaluation board is as follows:

- Input range: 36V to 78V (100V peak)
- Output voltage: 3.3V
- Output current: 0 to 30A
- Measured efficiency: 90.5% at 30A, 92.5% at 15A
- Frequency of operation: 230kHz
- Board size: 2.3 x 2.4 x 0.5 inches
- Load Regulation: 1%
- Line Regulation: 0.1%
- Line UVLO, Hiccup Current Limit

The printed circuit board consists of 4 layers of 3 ounce copper on FR4 material with a total thickness of 0.050 inches. Soldermask has been omitted from some areas to facilitate cooling. The unit is designed for continuous operation at rated load at < 40°C and a minimum airflow of 200 CFM.

2 Theory of Operation

Power converters based on the Forward topology offer high efficiency and good power handling capability in applications up to several hundred Watts. The operation of the transformer in a forward topology does not inherently self-reset each power switching cycle, a mechanism to reset the transformer is required. The active clamp reset mechanism is presently finding extensive use in medium level power converters in the 50 to 200W range.

The Forward converter is derived from the Buck topology family, employing a single modulating power switch. The main difference between the topologies are, the Forward topology employs a transformer to provide input / output ground isolation and a step down or step up function.

Each cycle, the main primary switch turns on and applies the input voltage across the primary winding, which has 12 turns. The transformer secondary has 2 turns, leading to a 6:1 step-down of the input voltage. For an output voltage of 3.3V the required duty cycle (D) of the main switch must vary from approximately 60% (low line) to 25% (high line). The clamp capacitor along with the reset switch reverse biases the transformer primary each cycle when the main switch turns off. This reverse voltage resets the transformer. The clamp capacitor voltage is Vin / (1-D).

The secondary rectification employs self-driven synchronous rectification to maintain high efficiency and ease of drive.

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 optocoupler. The LM5025A voltage mode controller pulse width modulates the error signal with a ramp signal derived from the input voltage. Deriving the ramp signal slope from the input voltage provides line feed-forward, which improves line transient rejection. The LM5025A also provides a controlled delay necessary for the reset switch.

The evaluation board can be synchronized to an external clock with a recommended frequency range of 190 to 300KHz.

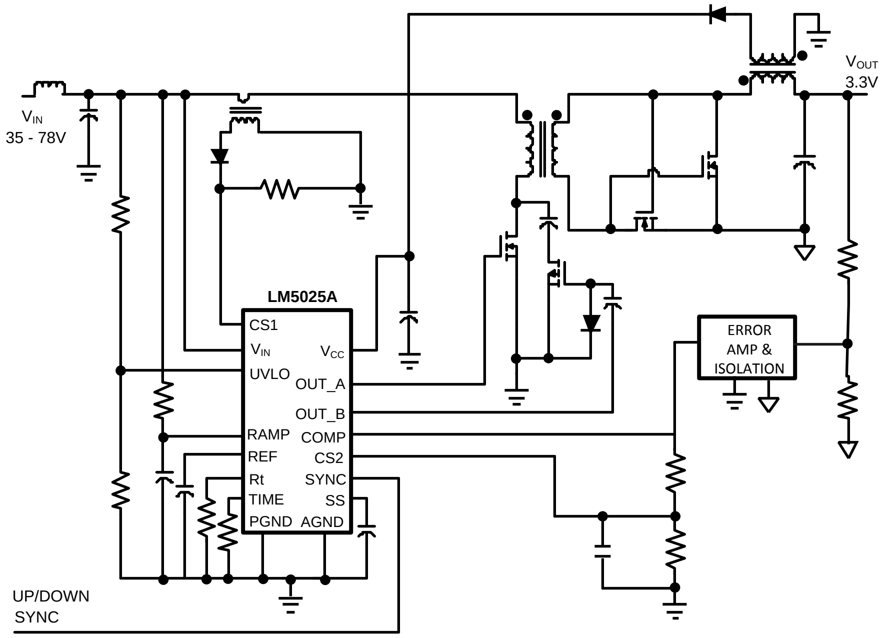


Figure 1. Simplified Active Clamp Forward Converter

3 Powering and Loading Considerations

When applying power to the LM5025A evaluation board certain precautions need to be followed. A failure or mis-connection can present itself in a very alarming manner.

4 Proper Connections

When operated at low input voltages the UUT can draw up to 3.5A of current at full load. The maximum rated output current for the evaluation board 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 UUT (evaluation board or unit under test). Monitor the voltage directly at the output terminals of the UUT. The voltage drop across the load connecting wires will give inaccurate measurements, this is especially true for accurate efficiency measurements.

5 Source Power

The evaluation board can be viewed as a constant power load. At low input line voltage (35V) the input current can reach 3.5A, while at high input line voltage (78V) the input current will be approximately 1.5A. Therefore to fully test the LM5025A evaluation board a DC power supply capable of at least 80V and 4A is required. The power supply must have adjustments for both voltage and current. An accurate readout of output current is desirable since the current is not subject to loss in the cables as voltage is.

The power supply and cabling must present a low impedance to the UUT. Insufficient cabling or a high impedance power supply will droop during power supply application with the UUT inrush current. If large enough, this droop will cause a chattering condition upon power up. This chattering condition is an interaction with the UUT undervoltage 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. You need thick cables! Consult a wire chart if needed. 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. `Be careful!!` The high temperatures reached by even the most adequately rated resistors may burn you or melt your benchtop.

7 Air Flow

Full rated power should never be attempted without providing the specified 200 CFM of air flow over the evaluation board. This can be provided by a stand-alone fan.

8 Powering Up

Using the shutdown pin provided will allow powering up the source supply with the current level set low. 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 you remove the connection from the shutdown pin to ground, immediately 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 UUT going into undervoltage shutdown will start an oscillation, or chatter, that may have highly 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.

9 Over Current Protection

The evaluation board is configured with delayed hiccup over-current protection. In the event of an output overload (approximately 33A) the unit will discharge the softstart capacitor, which disables the power stage. After a delay the softstart is released. The shutdown, delay and slow recharge time of the softstart capacitor protects the unit, especially during short circuit event where the stress is highest.

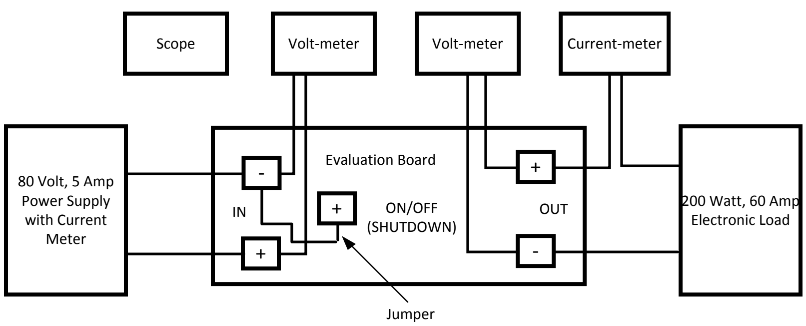


Figure 2. Typical Evaluation Setup

10 Performance Characteristics

10.1 Turn-on Waveforms

When applying power to the LM5025A evaluation board a certain sequence of events must occur. Soft-start capacitor values and other components allow the feedback loop to stabilize without overshoot. Figure 3 shows the output voltage during a typical start-up with a 48V input and a load of 5A. There is no overshoot during startup.

10.2 Output Ripple Waveforms

Figure 4 shows the transient response for a load of change from 5A to 25A. The upper trace shows output voltage droop and overshoot during the sudden change in output current shown by the lower trace.

Conditions: Input Voltage = 48VDC, Output Current = 5A
Trace 1: Output Voltage Volts/div = 0.5V
Horizontal Resolution = 1msec/div

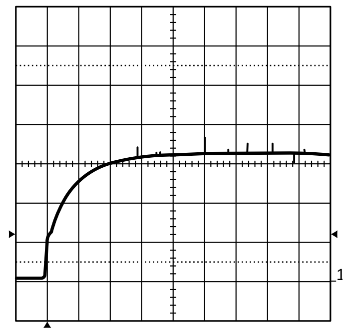


Figure 3. Output Voltage During Typical Startup

Conditions: Input Voltage = 48VDC, Output Current = 5A to 25A
Trace 1: Output Voltage Volts/div = 0.5V
Trace 2: Output Current, Amps/div = 10.0A
Horizontal Resolution = 1µs/div

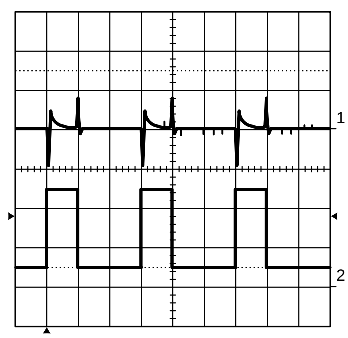


Figure 4. Transient Response

Conditions: Input Voltage = 48VDC, Output Current = 30A
Bandwidth Limit = 25MHz
Trace 1: Output Ripple Voltage Volts/div = 50mV
Horizontal Resolution = 2µs/div

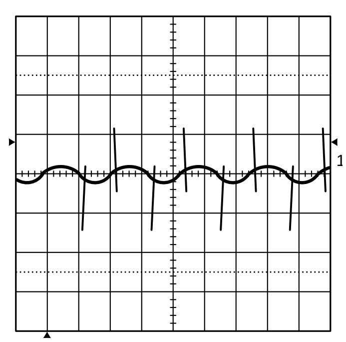


Figure 5. Output Ripple

Figure 5 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.

Figure 6 and Figure 7 show the drain voltage of Q1 with a 25A load. Figure 6 represents an input voltage of 38V and Figure 7 represents an input voltage of 78V.

Figure 8 shows the gate voltages of the synchronous rectifiers. The drive from the main power transformer is delayed slightly at turn-on by a resistor interacting with the gate capacitance. This provides improved switching transitions for optimum efficiency. The difference in drive voltage is inherent in the topology and varies with line voltage.

Conditions: Input Voltage = 38VDC, Output Current = 25A
Trace 1: Q1 drain voltage Volts/div = 20V
Horizontal Resolution = 1µs/div

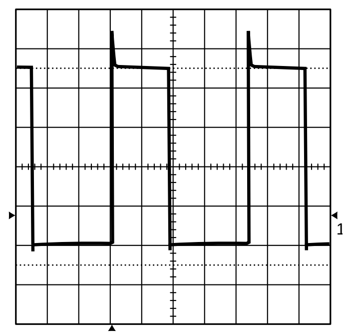


Figure 6. Drain Voltage

Conditions: Input Voltage = 78VDC, Output Current = 25A
Trace 1: Q1 drain voltage Volts/div = 20V
Horizontal Resolution = 1µs/div

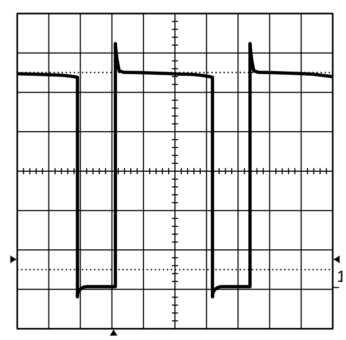


Figure 7. Drain Voltage

Conditions: Input Voltage = 48VDC, Output Current = 5A
Synchronous rectifier, Q3 gate Volts/div = 5V
Trace 1: Synchronous rectifier, Q3 gate Volts/div = 5V
Trace 2: Synchronous rectifier, Q5 gate Volts/div = 5V
Horizontal Resolution = 1µs/div

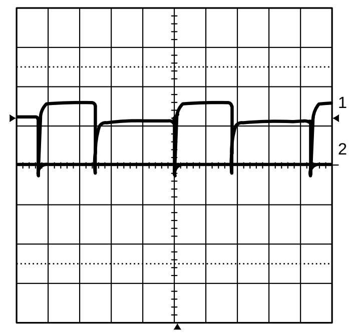


Figure 8. Gate Voltages of the Synchronous Rectifiers

11 Application Circuit

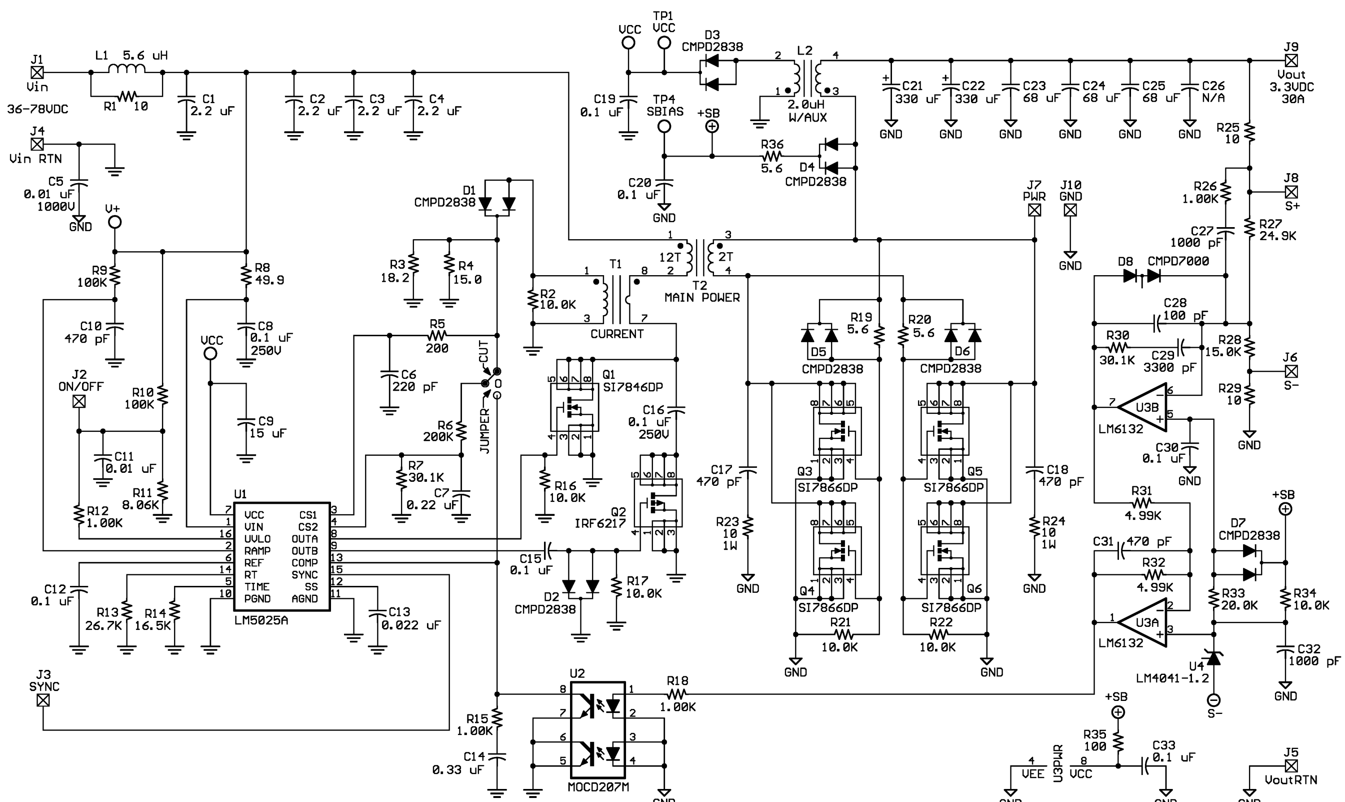


Figure 9. Application Circuit: Input 36 to 78V, Output 3.3V, 30A

12 Layout and Bill of Materials

The Bill of Materials is shown below and includes the manufacturer and part number. The layers of the printed circuit board are shown in top down order. View is from the top down except for the bottom silkscreen which is shown viewed from the bottom. Scale is approximately X1.5. The printed circuit board consists of 4 layers of 3 ounce copper on FR4 material with a total thickness of 0.050 inches.

Table 1. Bill of Materials

DESIGNATOR	QTY	PART NUMBER	DESCRIPTION	VALUE
C1-C4	4	C4532X7R2A225M	CAPACITOR, CER, TDK	2.2u, 100V
C5	1	C4532X7R3A103K	CAPACITOR, CER, TDK	0.01µ, 1000V
C6	1	C0805C221J5GAC	CAPACITOR, CER, KEMET	220p, 50V
C7	1	C2012X7R1E224K	CAPACITOR, CER, TDK	0.22µ, 25V
C8,C16	2	C3216X7R2E104K	CAPACITOR, CER, TDK	0.1µ, 250V
C9	1	C4532X7R1E156M	CAPACITOR, CER, TDK	15µ, 25V
C10,C17,C18, C31	4	C0805C471J5GAC	CAPACITOR, CER, KEMET	470p, 50V
C11	1	C2012X7R2A103K	CAPACITOR, CER, TDK	0.01µ, 100V
C12,C15,C30, C33	4	C2012X7R1H104K	CAPACITOR, CER, TDK	0.1µ, 50V
C13	1	C2012X7R2A223K	CAPACITOR, CER, TDK	0.022µ, 100V
C14	1	C3216X7R1H334K	CAPACITOR, CER, TDK	0.33µ, 50V
C19,C20	2	C1206C104K5RAC	CAPACITOR, CER, KEMET	0.1µ, 50V
C21,C22	2	T520D337M006AS4350	CAPACITOR,TANT, KEMET	330µ, 6.3V
C23,C24,C25	3	C4532X7S0G686M	CAPACITOR, CER, TDK	68µ, 4V
C26		OPEN	NOT USED	
C27,C32	2	C2012X7R2A102K	CAPACITOR, CER, TDK	1000p, 100V
C28	1	C0805C101J5GAC	CAPACITOR, CER, KEMET	100p, 50V
C29	1	C2012X7R2A332K	CAPACITOR, CER, TDK	3300p, 100V
D1- D8	8	CMPD2838-NSA	DIODE, SIGNAL, CENTRAL	
L1	1	SLF10145T-5R6M3R2	INPUT CHOKE, TDK	5.6µH, 3.5A
L2	1	B0358-C	CHOKE with AUX, COILCRAFT	2µH, 33A
Q1	1	SI7846DP	N-FET, SILICONIX	150V, 50m
Q2	1	IRF6217	P-FET, IR	150V, 2.4
Q3 - Q6	4	SI7866DP	FET, SILICONIX	20V, 3m
R1,R25,R29	3	CRCW120610R0F	RESISTOR	10
R2,R16,R17, R21,R22, R34	6	CRCW12061002F	RESISTOR	10K
R19,R20, R36	3	CRCW12065R60F	RESISTOR	5.6
R4	1	CRCW120615R0F	RESISTOR	15
R5	1	CRCW12062000F	RESISTOR	200
R6	1	CRCW12062003F	RESISTOR	200K
R8	1	CRCW120649R9F	RESISTOR	49.9
R9,R10	2	CRCW12061003F	RESISTOR	100K
R3	1	CRCW120618R2F	RESISTOR	18.2
R7	1	CRCW12063012F	RESISTOR	30.1K
R11	1	CRCW12068061F	RESISTOR	8.06K
R12,R15,R18,R26	4	CRCW12061001F	RESISTOR	1K
R13	1	CRCW12062672F	RESISTOR	26.7K

Table 1. Bill of Materials (continued)

DESIGNATOR	QTY	PART NUMBER	DESCRIPTION	VALUE
R14	1	CRCW12061652F	RESISTOR	16.5K
R23,R24	2	CRCW2512100J	RESISTOR	10, 1W
R27	1	CRCW12062492F	RESISTOR	24.9K
R28	1	CRCW12061502F	RESISTOR	15K
R30	1	CRCW12063012F	RESISTOR	30.1K
R31,R32	2	CRCW12064991F	RESISTOR	4.99K
R33	1	CRCW12062002F	RESISTOR	20K
R35	1	CRCW12061000F	RESISTOR	100
T1	1	P8208T	CURRENT XFR, PULSE ENG	100:1
T2	1	B0357-B	POWER XFR, COILCRAFT	12:02
U1	1	LM5025	CONTROLLER, Texas Instruments	
U2	1	MOCD207M	OPTO-COUPLER, QT OPTO	
U3	1	LM6132	OPAMP, Texas Instruments	
U4	1	LM4041	REFERENCE, Texas Instruments	

13 PCB Layouts

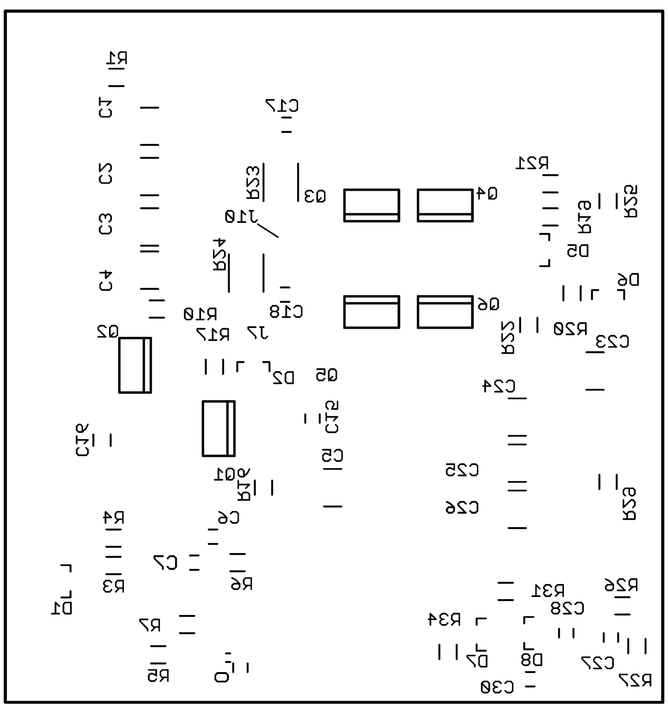


Figure 10.

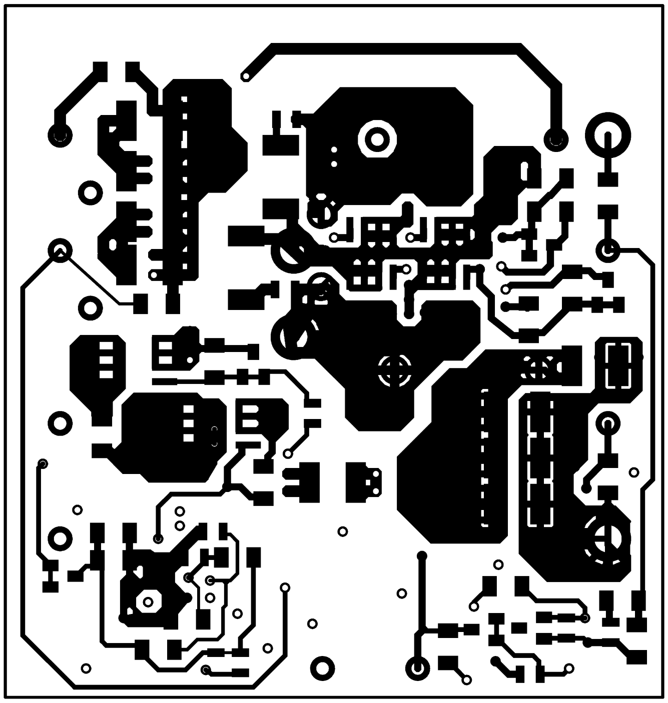


Figure 11.

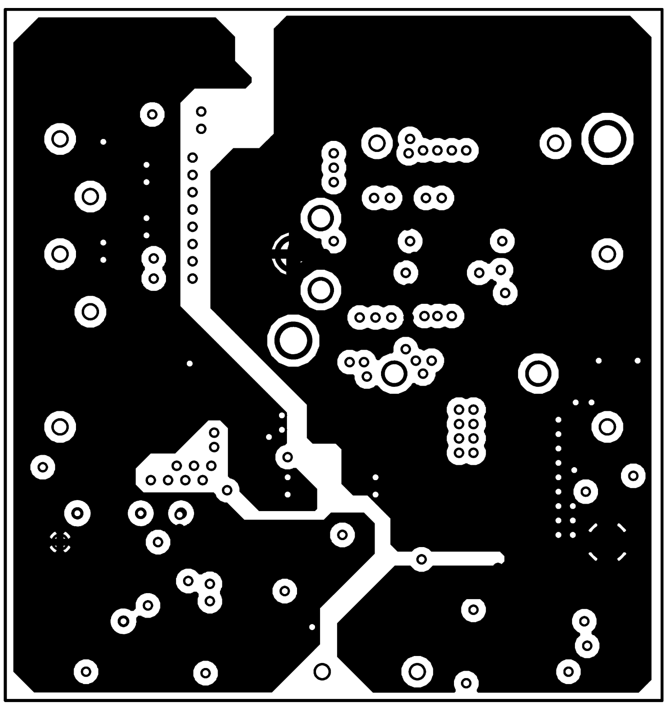


Figure 12.

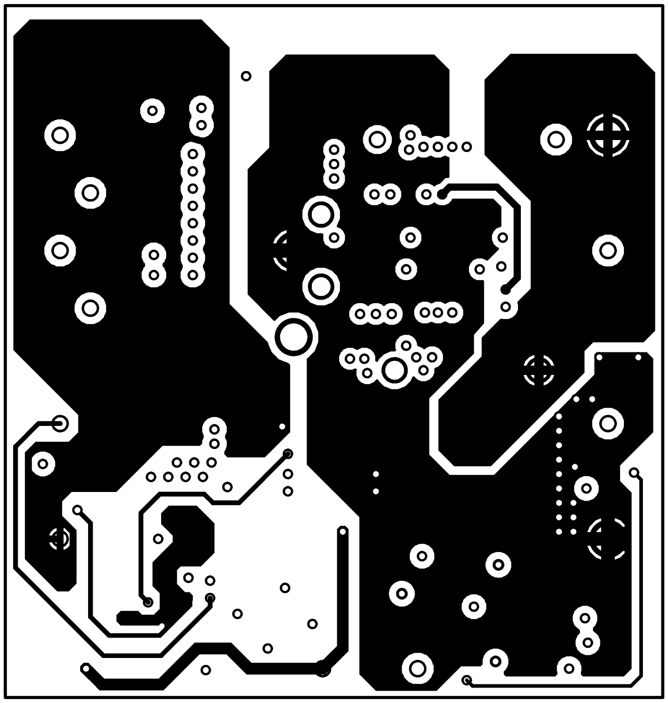


Figure 13.

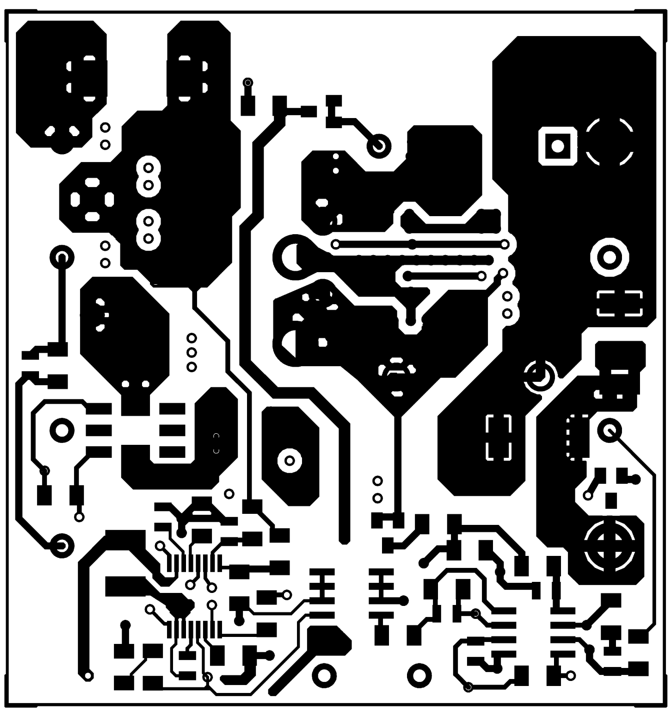
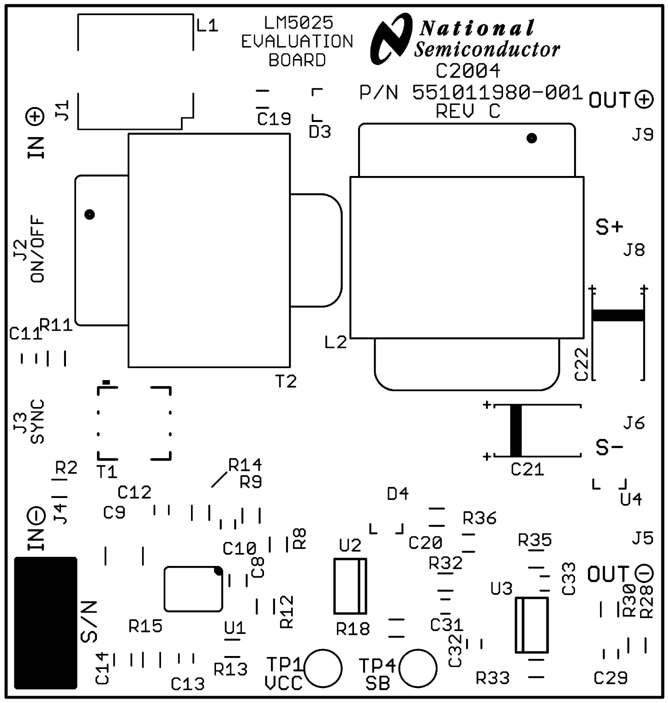


Figure 14.


L1
LM5025
EVALUATION
BOARD
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REV C
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SYNC
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U1
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C31
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R33
C29

Figure 15.

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