LM5039

Application Note 2025 LM5039 Evaluation Board

Literature Number: SNVA423C

LM5039 Evaluation Board

National Semiconductor
Application Note 2025
Ajay Hari
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Introduction

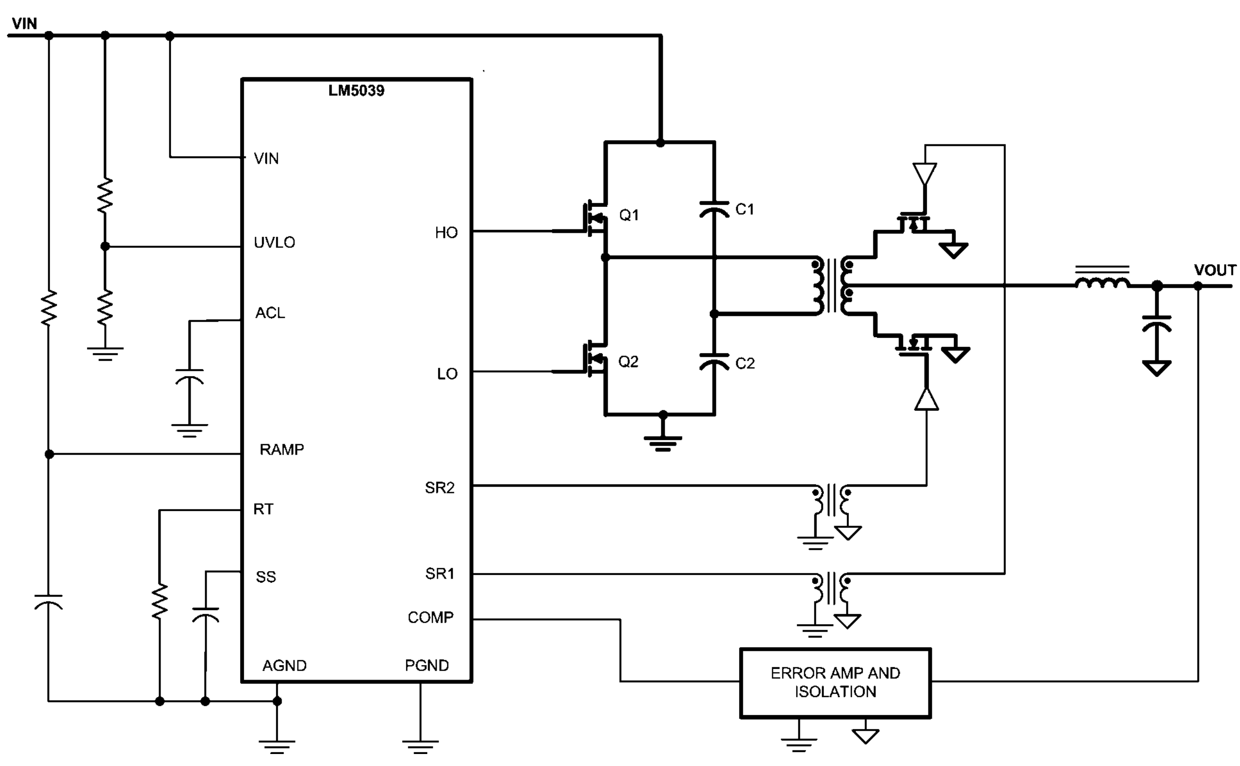
The LM5039 evaluation board is designed to provide the design engineer with a fully functional power converter based on the half-bridge topology to evaluate the LM5039 controller. The evaluation board is provided in an industry standard quarter brick footprint. The performance of the evaluation board is as follows:

- Input Operating Range: 36V to 75V
- Output Voltage: 3.3V
- Measured Efficiency: 89% @ 30A, 92% @ 15A
- Frequency of Operation: 400 kHz
- Board Size: 2.28 x 1.45x 0.5 inches
- Load Regulation: 0.2%
- Line Regulation 0.1%
- Line UVLO (31V/30V on/off)
- Constant 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 CFM.

Theory of Operation

Power converters based on the half-bridge topology offer high-efficiency and good power handling capability up to 500W. A simplified half bridge circuit is illustrated below. The capacitors C1 and C2, which form one-half of the bridge, are arranged in series such that the mid-point is at half the input voltage. The other half of the bridge is formed by the switches Q1 and Q2. Switches Q1 and Q2 are turned on alternatively with a pulse-width determined by the input and output voltages and the transformer turns ratio. Each switch, when turned on, applies one-half the input voltage to 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 half-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.



Simplified Half-Bridge Circuit

The secondary side employs synchronous rectification scheme, which is controlled by the LM5039, during the soft-start, the sync FET body diodes act as the secondary rectifiers. Once, the soft-start is finished, the synchronous rectifiers are engaged with a non-overlap time programmed by the DLY resistor. 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 LM5039 controller pulse width modulates the error signal with a ramp signal derived from the line voltage (feed-forward) to reduce the response time. A standard "type III" network is used for the compensator.

Powering and Loading Considerations

When applying power to the LM5039 evaluation board, certain precautions need to be followed. A misconnection can damage the assembly.

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.

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 LM5039 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.

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.

AIR FLOW

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

POWERING UP

Using the ON/OFF 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 ON/OFF 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 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.

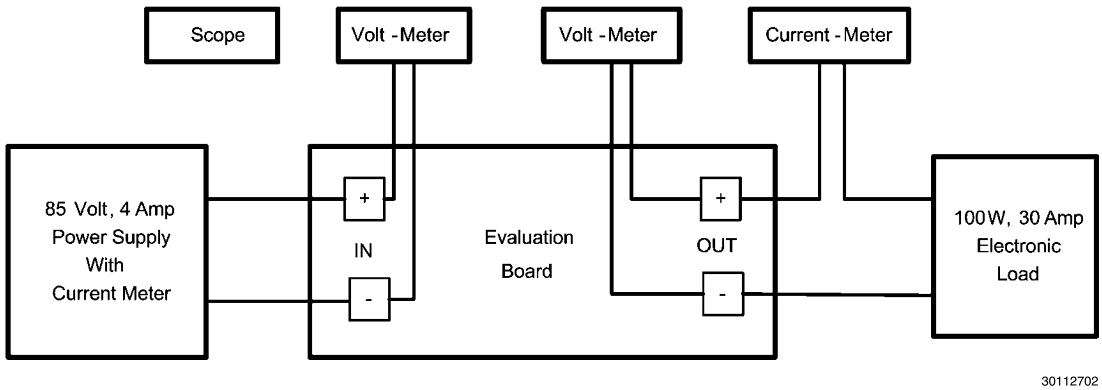


FIGURE 1.

OVER CURRENT PROTECTION

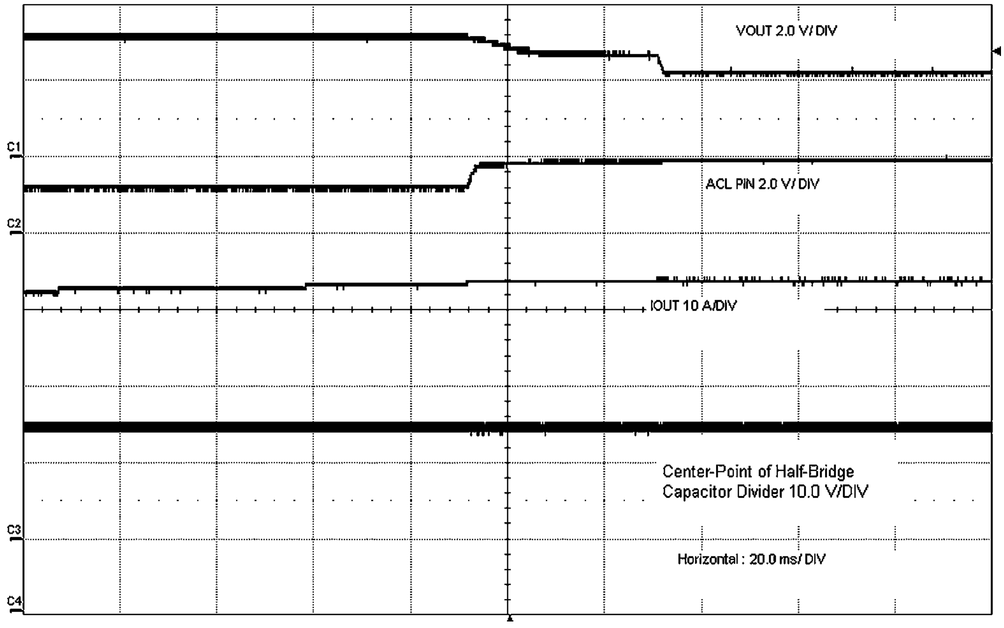
The evaluation board is not configured with over current protection and will be in continuous current limit condition. Therefore, 200 CFM of airflow is a must during the over current condition.

If the customer desires to configure the evaluation board with the hiccup mode enabled, a 4700pF capacitor needs to be connected from RES pin to AGND. In the event of an output overload (approximately 35A) the unit will discharge the soft start capacitor, which disables the power stage. After a delay the softstart is released. The shutdown, delay and slow recharge time of the soft start capacitor reduces the average power consumption of the unit in an overload condition.

Average Current Limit

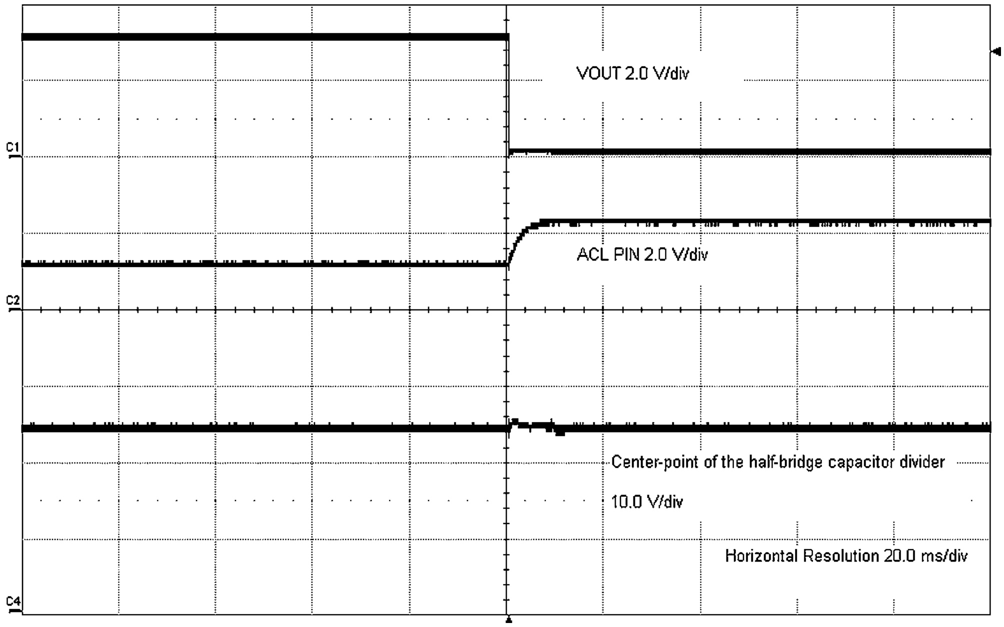
The major drawback of the half-bridge topology is that during current limit condition, the center-point of the capacitor divider tends to runaway either towards the input voltage rail or towards the ground. This phenomenon saturates the transformer and requires the capacitors in the divider to be rated to at least the input voltage. In an overload condition, the PWM cycle is terminated by the current sense comparator instead of the PWM comparator. This is similar to peak current mode control, which inherently results in an on-time between both the phases of the half-bridge topology. Any such imbalance, for an extended period, will cause the voltage at the center-point of the capacitor divider to drift either towards the input voltage or the ground. However, in an average current limit scheme, the PWM cycle is terminated through the PWM comparator, by pulling down the PWM control input. Because of its averaging nature, the PWM control input voltage is slow moving and is essentially held at a constant dc voltage. This results in the on-time between the both the phases to be equal and thus balances the center-point of the capacitor divider. Figure 2 shows the current limit waveforms in a soft-short condition and Figure 3 shows the current limit waveforms in a hard-short condition.

It can be observed from the Figures 2 and 3 that the center-point of the half-bridge capacitor divider is balanced in both soft-short and hard-short conditions. The response of average current limit circuit is same whether the short is soft or hard. During an overload event, the average current limit scheme converts the power supply from a constant voltage source to a constant current source. This scheme is often known as “brickwall current limiting.” A V_{OUT} vs I_{OUT} curve, shown in Figure 4, illustrates the brickwall current limiting.



Trace 1 (C1) Output Voltage
Trace 2(C2): Voltage on the ACL Capacitor
Trace 3 (C3): Output current
Trace 4 (C4): Voltage at the center-point of the half-bridge capacitor divider

FIGURE 2.



Trace 1 (C1) Output Voltage

Trace 2(C2): Voltage on the ACL Capacitor

Trace 3 (C4): Voltage at the center-point of the half-bridge capacitor divider

FIGURE 3.

The LM5039 evaluation board is configured to be in constant current limiting. To configure the board for hiccup mode restart, remove the zero ohm resistor from the RES pin to the AGND and install a 4700pF capacitor from the RES pin to the AGND. The RES capacitor should be selected such that the time taken for the RES capacitor to reach 2.5V is greater than the time taken for the average current mode control circuit to be in control. This will ensure that center-point of the half-bridge capacitor is balanced. Figure 5 illustrates a balanced half-bridge capacitor divider at the inception of a hiccup mode restart. While Figure 6 shows the same over multiple hiccup mode restarts. The RES capacitor should be selected such that the time taken for the RES capacitor to reach 2.5V and hence start the hiccup mode is greater than the time taken for the ACL pin to get into control.

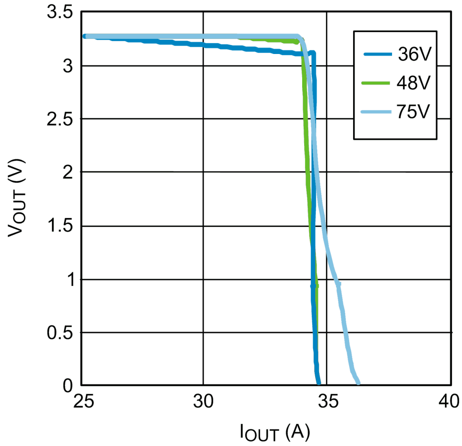
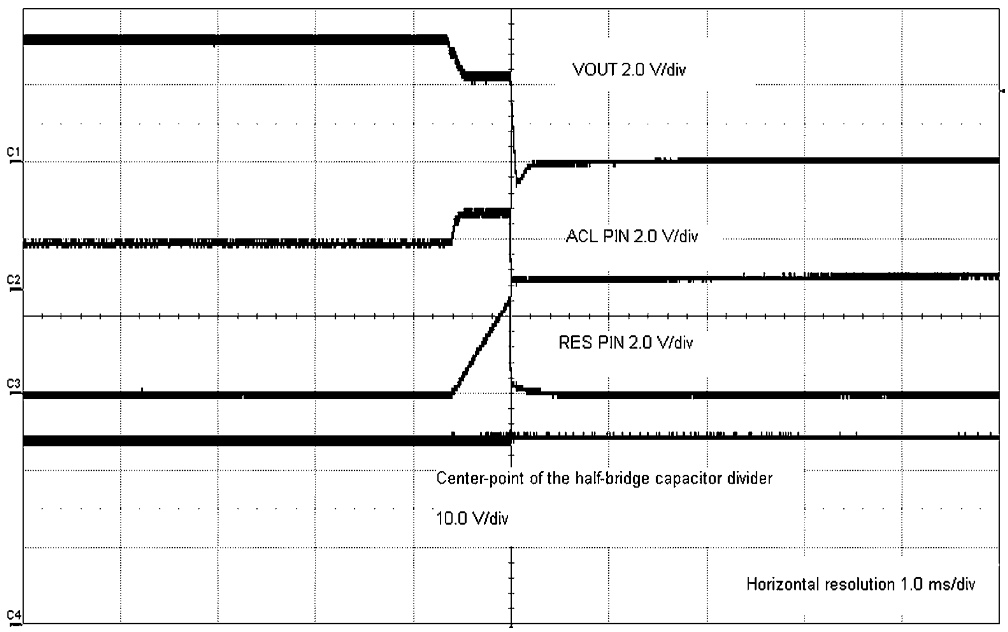


FIGURE 4.



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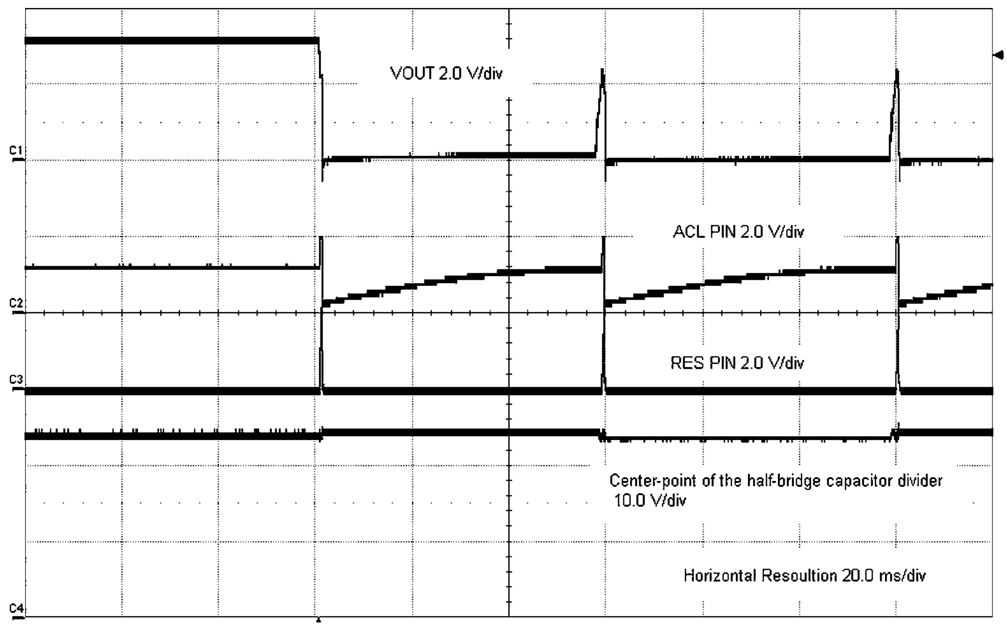
Trace 1 (C1): Output voltage
Trace 2(C2): Voltage on the ACL capacitor
Trace 3(C3): Voltage on the RES capacitor
Trace 4(C4): Voltage at the center-point of the half-bridge capacitor divider

FIGURE 5.



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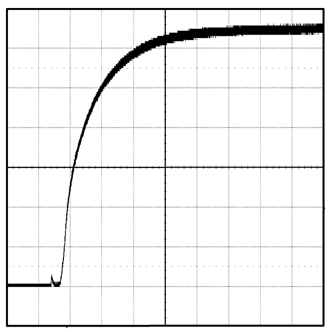
Trace 1 (C1): Output voltage
Trace 2(C2): Voltage on the ACL capacitor
Trace 3(C3): Voltage on the RES capacitor
Trace 4(C4): Voltage at the center-point of the half-bridge capacitor divider

FIGURE 6.

Other Performance Characteristics

When applying power to the LM5039 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 7 shows the output voltage during a typical start-up with a 48V input and a load of 30A. There is no overshoot during start-up.

Figure 8 shows the transient response for a load of change from 5A to 25A. The upper trace shows minimal output voltage droop and overshoot during the sudden change in output current shown by the lower trace.



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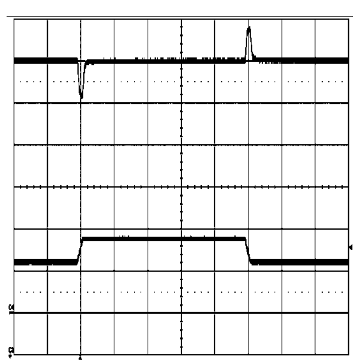
Conditions: Input Voltage=48V
Output Current=5A
Trace 1: Output Voltage Volts/div=500mV
Horizontal Resolution =2.0 ms/div

FIGURE 7.



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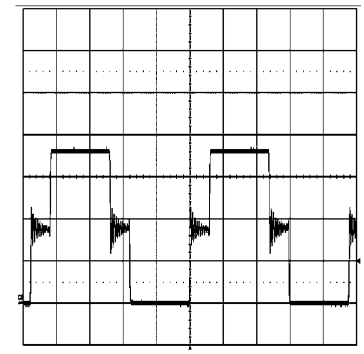
Conditions: Input Voltage=48V
Output Current=15A to 22.5A
Upper Trace: Output Voltage Volts/div=50mV
Lower Trace: Output Current = 15A to 22.5A to 15A
Horizontal Resolution =0.5 ms/div

FIGURE 8.

Figures 9 and 10 show the drain voltage of Q1 with a 25A load. Figure 9 represents an input voltage represents an input voltage of 36V and Figure 10 represents an input voltage of 72V.



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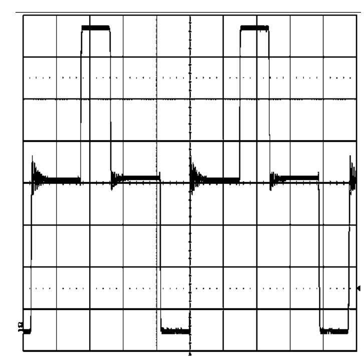
Conditions: Input Voltage =36V
Output Current=5A
Trace 1: Q1 Drain Voltage Volts/div=10V
Horizontal Resolution= 1 us/div

FIGURE 9.



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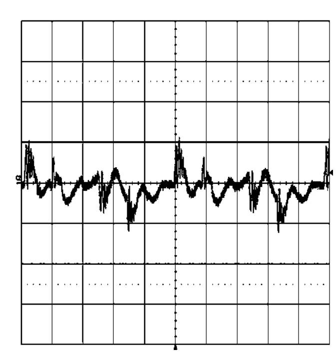
Conditions: Input Voltage =72V
Output Current=5A
Trace 1: Q1 Drain Voltage Volts/div=10V
Horizontal Resolution= 1 us/div

FIGURE 10.

Figure 11 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.



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Conditions: Input Voltage =48V
Output Current=5A
Trace 1: Output Voltage Volts/div=20mV
Horizontal Resolution= 1 us/div

FIGURE 11.

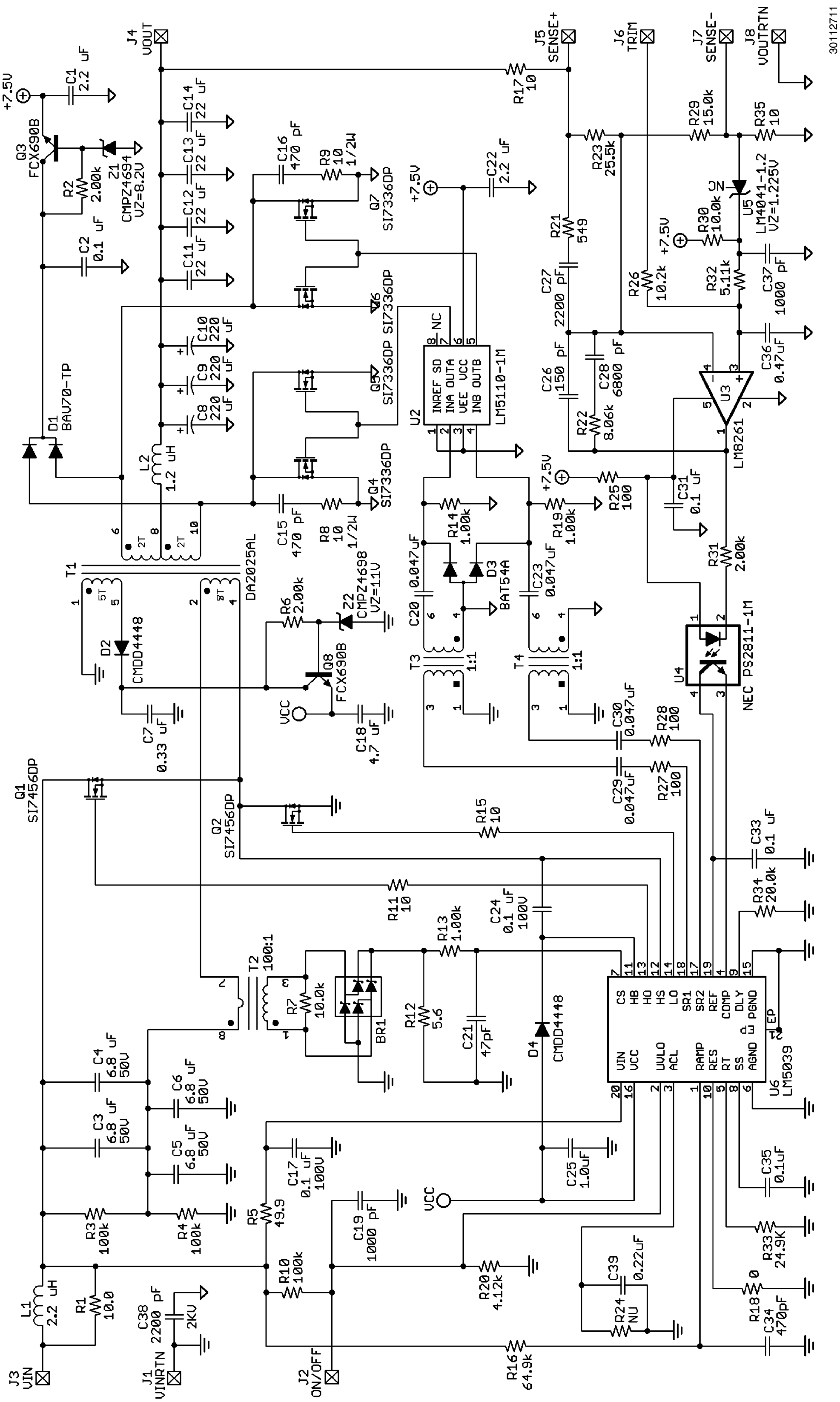

J3 VIN
J1 VINRTN
J2 ON/OFF
J4 VOUT
J5 SENSE+
J6 TRIM
J7 SENSE-
J8 VOUTRTN
L1 2.2 uH
R1 10.0
C38 2200 pF 2KV
R3 100k
R4 100k
C3 6.8 uF 50V
C4 6.8 uF 50V
C5 6.8 uF 50V
C6 6.8 uF 50V
R5 49.9
R10 100k
C17 0.1 uF 100V
C19 1000 pF
R20 4.12k
R16 64.9k
Q1 SI7456DP
Q2 SI7456DP
R11 10
R15 10
T2 100:1
R7 10.0k
BR1
R12 5.6
R13 1.00k
C21 47pF
C24 0.1 uF 100V
D4 CMDD4448
C25 1.0uF
VCC
U6 LM5039
C39 0.22uF
R24 NU
R18 0
C34 470pF
R33 24.9K
C35 0.1uF
R34 20.0k
C33 0.1 uF
T1 DA2025AL
D2 CMDD4448
C7 0.33 uF
R6 2.00k
Z2 CMPZ4698 VZ=11V
Q8 FCX690B
C18 4.7 uF
D1 BAV70-TP
L2 1.2 uH
C15 470 pF
R8 10 1/2W
C16 470 pF
R9 10 1/2W
Q4 SI7336DP
Q5 SI7336DP
Q6 SI7336DP
Q7 SI7336DP
C8 220 uF
C9 220 uF
C10 220 uF
C11 22 uF
C12 22 uF
C13 22 uF
C14 22 uF
Q3 FCX690B
R2 2.00k
Z1 CMPZ4694 VZ=8.2V
C1 2.2 uF
C2 0.1 uF
+7.5V
U2 LM5110-1M
C22 2.2 uF
C20 0.047uF
R14 1.00k
D3 BAT54A
C23 0.047uF
R19 1.00k
T3 1:1
T4 1:1
C30 0.047uF
R28 100
C29 0.047uF
R27 100
R25 100
C31 0.1 uF
R31 2.00k
U4 NEC PS2811-1M
U3 LM8261
R22 8.06k
C26 150 pF
C28 6800 pF
C27 2200 pF
R21 549
R23 25.5k
R26 10.2k
R17 10
R29 15.0k
R30 10.0k
R32 5.11k
U5 LM4041-1.2 VZ=1.225V
R35 10
C36 0.47uF
C37 1000 pF
30112711

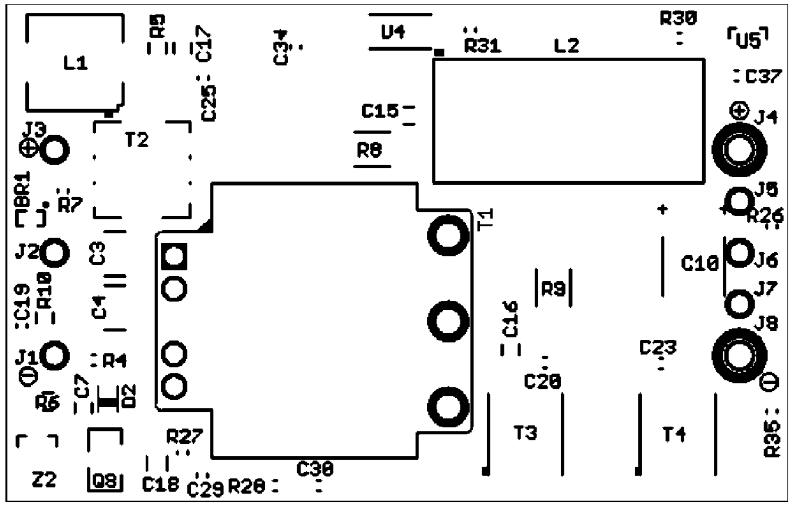
FIGURE 12.

Bill of Materials

#	Designator	Qty	Part #	Description
1	U1	1	NSC LM5039MH	LM5039 Controller
2	U2	1	NSC LM5110-1M	LM5110-1M Dual Driver
3	U3	1	NSC LM8261M5	LM8261M5 Op Amp
4	U5	1	NSC LM4041AIM3-.12	LM4041AIM3-1.2 Ref Amp
5	U4	1	NEC PS2811-1M	Opto-Coupler PS2811-1M
6	C21	1	TDK C1608COG1H470J	Cer Cap 47pF 50V COG
7	C26	1	TDK C1608COG1H151J	Cer Cap 150pF 50V COG
8	C34	1	TDK C1608COG1H471J	Cer Cap 470pF 50V COG
9	C19, C37	2	TDK C1608X7R1H102K	Cer Cap 1000pF 50V X7R
10	C27	2	TDK C1608COG1H222J	Cer Cap 2200pF 50V COG
11	C28	1	TDK C1608COG1H682J	Cer Cap 6800pF 50V COG
12	C20, C23, C29, C30	1	TDK C1608X7R1E473K	Cer Cap 0.047uF 25V COG
13	C2, C33, C31, C35	3	TDK C1608X7R1H104K	Cer Cap 0.1uF 50V X7R
14	C25	2	TDK C1608X7R1C105K	Cer Cap 1.0uF 16V X7R
15	C36	3	TDK C1608X7R1C474K	Cer Cap 0.47uF 50V X7R
16	C32	1	Vishay CRCW06030000Z0TA	Res 0 Ohm 0.1W,5%
17	C39	2	TDK C2012x714224K	Cer Cap 0.22uF 25V COG
18	C15, C16	2	KEMT C0805C471M5RAC	Cer Cap 470pF 50V COG
19	C17, C24	2	TDK C2012X7R2A104K	Cer Cap 0.1uF 100V X7R
20	C7	1	TDK C2012X7R1H334K	Cer Cap 0.33uF 50V X7R
21	C1, C22	2	TDK C2012X7R1C225K	Cer Cap 2.2uF 16V X7R
22	C18	1	TDK C3216X7R1C475K	Cer Cap 4.7uF 16V X7R
23	C11–C14	4	TDK C3216X5R0J226M	Cer Cap 22uF 6.3V X5R
24	C38	1	TDK C4532X7R3D222K	Cer Cap 2200pF 2000V X7R
25	C3–C6	4	TDK C4532X7R1H685M	Cer Cap 6.8uF 50V X7R
26	C8–C10	3	Sanyo 6TPE220MI	POSCAP 220uF 6.3V
27	R12	1	Vishay CRCW06035R60FKTA	Res 5.6 Ohm 0.1W 1%
28	R17, R35	2	Vishay CRCW060310R0F	Res 10 Ohm 0.1W 1%
29	R25, R27, R28	3	Vishay CRCW06031000F	Res 100 Ohm 0.1W 1%
30	R21	1	Vishay CRCW06035490F	Res 549 Ohm 0.1W 1%
31	R13–14, R18–19	4	Vishay CRCW06031001F	Res 1K Ohm 0.1W 1%
32	R24	1	NU	NU
33	R31	1	Vishay CRCW06032001F	Res 2.0K Ohm 0.1W 1%
34	R20	1	Vishay CRCW06034121F	Res 4.12K Ohm 0.1W 1%
35	R32	1	Vishay CRCW06035111F	Res 5.11K Ohm 0.1W 1%
36	R22	1	Vishay CRCW06038061F	Res 8.06K Ohm 0.1W 1%
37	R7, R30	2	Vishay CRCW06031002F	Res 10K Ohm 0.1W 1%
38	R26	1	Vishay CRCW06031022F	Res 10.2K Ohm 0.1W 1%
39	R33	1	Vishay CRCW06032492F	Res 24.9K Ohm 0.1W 1%
40	R29	1	Vishay CRCW06031502F	Res 15K Ohm 0.1W 1%
41	R34	1	Vishay CRCW06032002F	Res 20K Ohm 0.1W 1%
42	R23	1	Vishay CRCW06032552F	Res 25.5K Ohm 0.1W 1%
43	R3, R4	2	Vishay CRCW06031003F	Res 100K Ohm 0.1W 1%
44	R1, R11, R15	3	Vishay CRCW080510R0F	Res 10 OHM 1/10W 1%
45	R5	1	Vishay CRCW080549R9F	Res 49.9 OHM 1/10W 1%
46	R2	1	Vishay CRCW08052001F	Res 2K OHM 1/10W 1%
47	R6	1	Vishay CRCW08051002F	Res 10K OHM 1/10W 1%

48	R16	1	Vishay CRCW08056492F	Res 64.9K OHM 1/10W 1%
49	R10	2	Vishay CRCW08051003F	Res 100K OHM 1/10W 1%
50	R8, R9	2	Vishay CRCW201010R0F	Res 10 OHM 1%
51	D1	1	BAV70-TP	Schottky, Diode, 75V 150mA
52	D2, D4	2	Central CMDD4448	Diode, 75V 250mA
53	D3	1	BAT54A	Schottky Diode, 30V 200mA
54	BR1	1	BAT54BRW	Diodes, Rectifier, Bridge, 30V
55	Z1	1	Central CMPZ4694	Zener 8.2V 5%
56	Z2	1	Central CMPZ4698	Zener 11V 5%
57	Q1, Q2	2	Vishay Si7456DP	N-FET 100V 25m ohm
58	Q4–7	4	Vishay Si7336ADP	N-FET 30V 3m ohm
59	Q3, Q8	2	ZETEX FCX690B	NPN, ZETEX 45V 2A
60	L1	1	TDK RLF7030T-2R2M5R4	Inductor 2.2uH 5.4A
61	L2	1	Coilcraft SER2010-122MX	Inductor 1.2uH 37A
62	T1	1	Coilcraft DA2025-AL	Transformer 8:5:2:2
63	T2	1	Pulse Engr P8208	Current XFR 100:1, 10A
64	T3, T4	2	Coilcraft DA2319-ALB	Gate XFR 1:1
65	J1–3, J5–7	6	Mill-Max 3104-2-00-80-00-00-08-0.	Test Pin, Brick
66	J4, J8	2	Mill-Max 3231-2-00-01-00-00-08-0	Test Pin, Brick

PCB Layouts



TOP SILKSCREEN (.PLC) LAYER AS VIEWED FROM TOP
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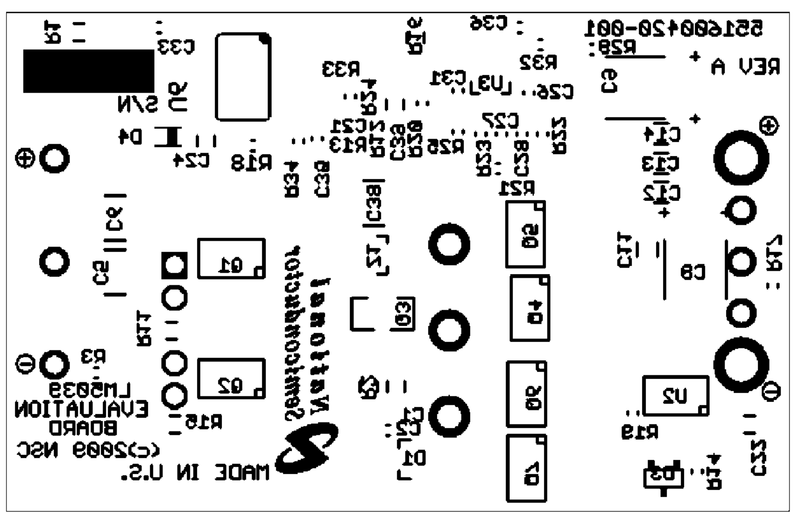
Top Silk



BOTTOM SILKSCREEN (.PLS) AS VIEWED FROM TOP
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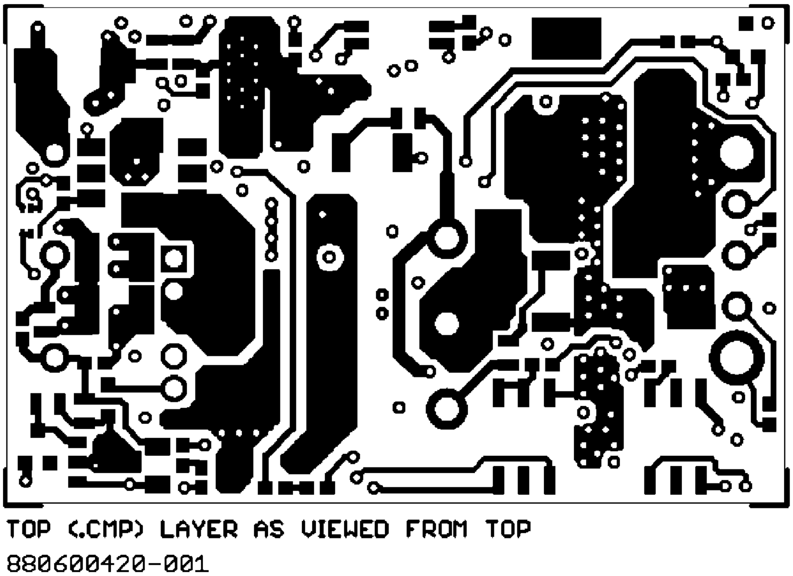
Bottom Silk



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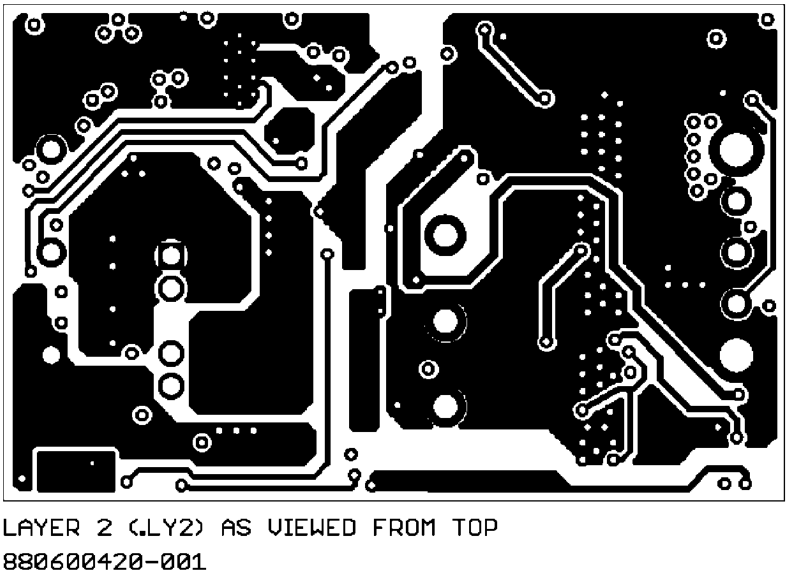
Top Side



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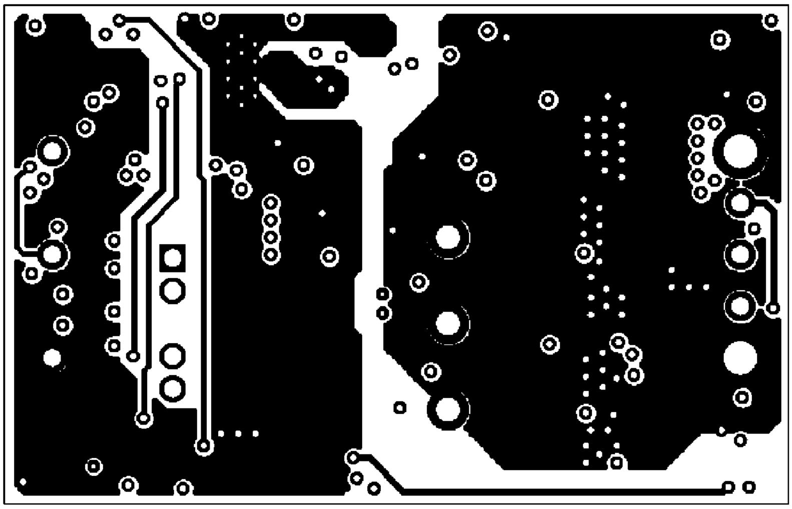
Layer 2



LAYER 3 (.LY3) AS VIEWED FROM TOP
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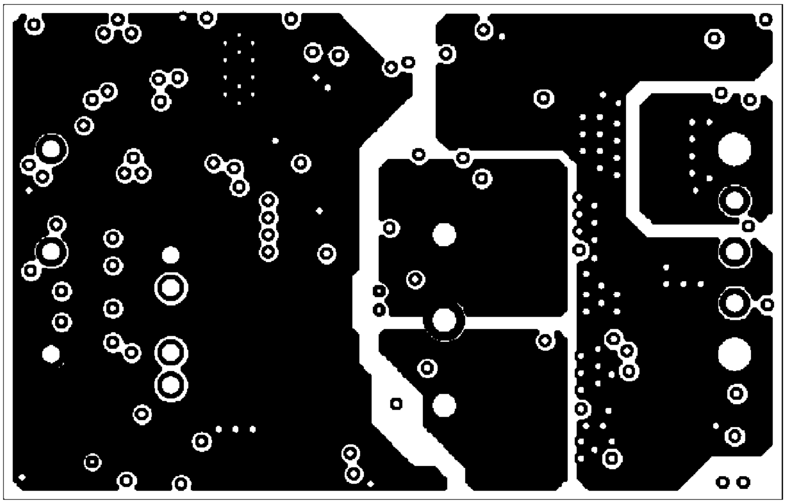
Layer 3



LAYER 4 (.LY4) AS VIEWED FROM TOP
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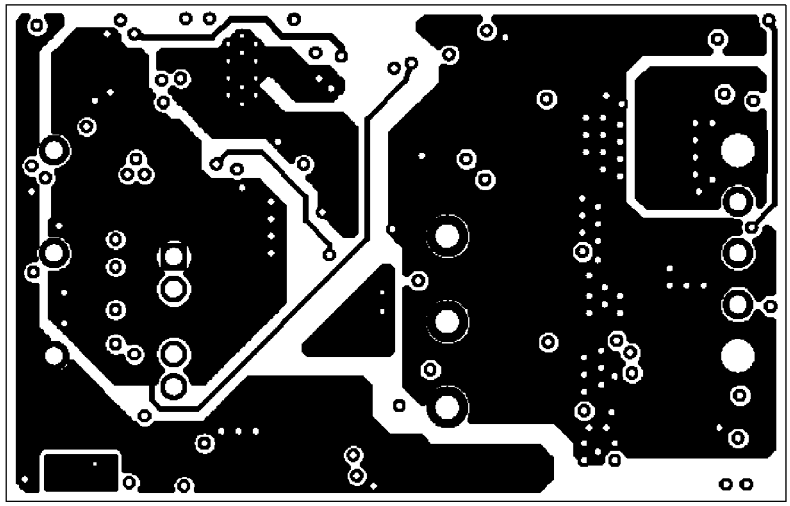
Layer 4



LAYER 5 (.LY5) AS VIEWED FROM TOP
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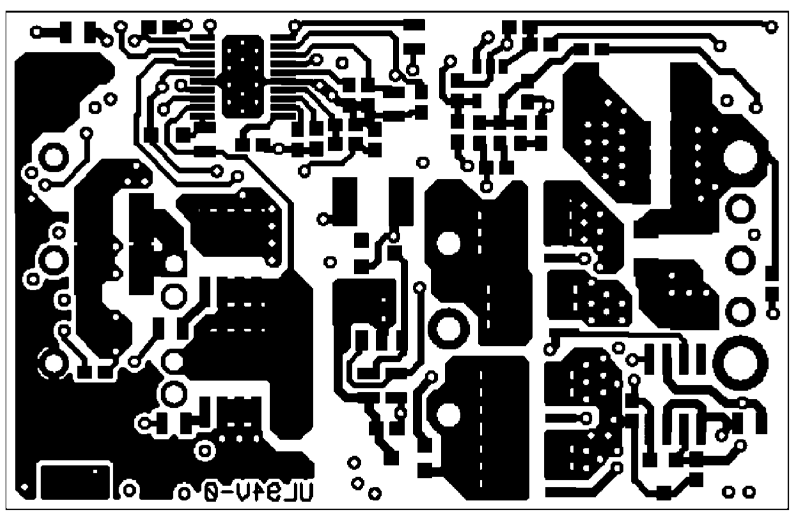
Layer 5



BOTTOM (.SOL) LAYER AS VIEWED FROM TOP
880600420-001

30112720

Bottom

Notes

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