

LM5116 Evaluation Board

National Semiconductor
Application Note 1596
Robert Sheehan
May 2007



Introduction

The LM5116 evaluation board is designed to provide the design engineer with a fully functional power converter based on Emulated Current Mode Control to evaluate the LM5116 controller IC. The evaluation board provides a 5V output with a 7A current capability. The wide input voltage ranges from 7V to 60V. The design operates at 250kHz, a good compromise between conversion efficiency and solution size. The printed circuit board consists of 4 layers, 2 ounce copper top and bottom, 1 ounce copper internal layers on FR4 material with a thickness of 0.06 inches. This application note contains the evaluation board schematic, Bill-of-Materials (BOM) and a quick setup procedure. Refer to the LM5116 datasheet for complete circuit design information.

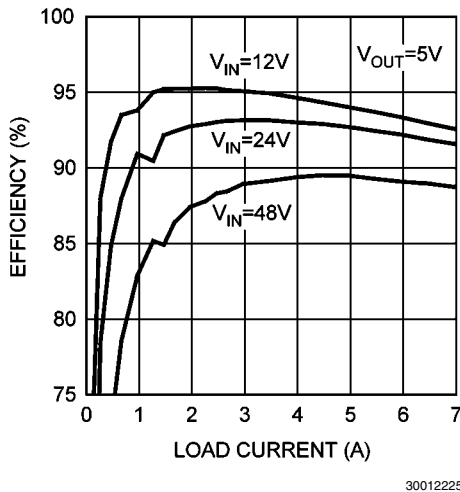


FIGURE 1. Efficiency with 6 μ H Cooper Inductor

The performance of the evaluation board is as follows:

- Input Range: 7V to 60V
- Output Voltage: 5V
- Output Current: 0 to 7A
- Frequency of Operation: 250 kHz
- Board Size: 2.55 X 2.65 X 0.5 inches
- Load Regulation: 1%
- Line Regulation: 0.1%
- Over Current Limiting

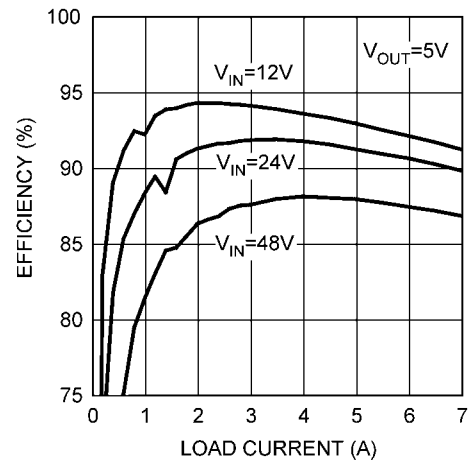


FIGURE 2. Efficiency with 5.6 μ H Pulse Inductor

Powering and Loading Considerations

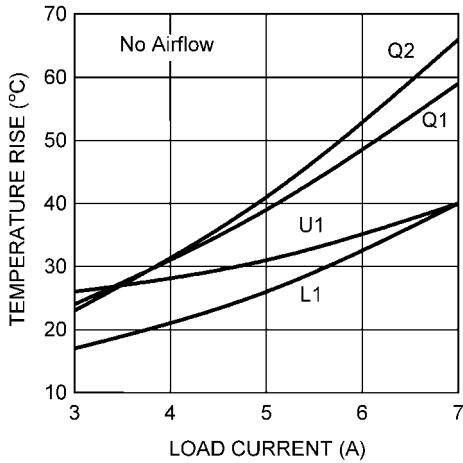
Read this entire page prior to attempting to power the evaluation board.

QUICK SETUP PROCEDURE

- Step 1:** Set the power supply current limit to 15A. Turn off the power supply. Connect the power supply to the V_{IN} terminals.
- Step 2:** Connect the load, with a 7A capability, to the V_{OUT} terminals. Positive connection to P3 and negative connection to P4.
- Step 3:** The EN pin should be left open for normal operation.
- Step 4:** Set V_{IN} to 48V with no load applied. V_{OUT} should be in regulation with a nominal 5V output.
- Step 5:** Slowly increase the load while monitoring the output voltage, V_{OUT} should remain in regulation with a nominal 5V output as the load is increased up to 7 Amps.
- Step 6:** Slowly sweep the input voltage from 7 to 60V, V_{OUT} should remain in regulation with a nominal 5V output.
- Step 7:** Temporally short the EN pin to GND to check the shutdown function.
- Step 8:** Increase the load beyond the normal range to check current limiting. The output current should limit at approximately 11A. Cooling is critical during this step.

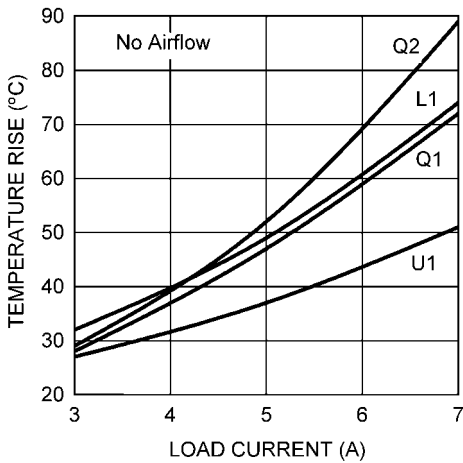
AIR FLOW

Prolonged operation with high input voltage at full power will cause the MOSFETs to overheat. A fan with a minimum of 200 LFM should always be provided.



30012209

FIGURE 3. Temperature Rise at 48V_{IN} with 6 µH Cooper Inductor



30012222

FIGURE 4. Temperature Rise at 48V_{IN} with 5.6 µH Pulse Inductor

POWERING UP

Using the enable 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 anticipated wattage of the load. As you remove the connection from the enable pin to ground, immediately check for 5 volts at the output.

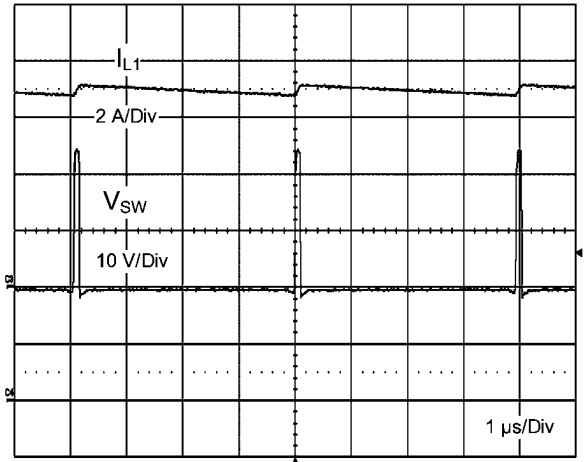
A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss you can be reasonably sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

For operation at 7V_{IN} with full load, a 100 µF aluminum electrolytic capacitor installed across V_{IN} will prevent input filter

oscillation for a typical bench test setup. See the LM5116 data sheet for complete design information.

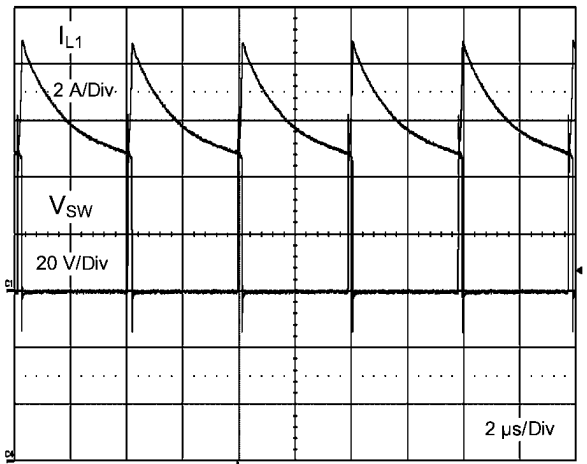
OVER CURRENT PROTECTION

The evaluation board is configured with over-current protection. The output current is limited to approximately 11A. The thermal stress is quite severe while in an overloaded condition. Limit the duration of the overload and provide sufficient cooling (airflow).



30012202

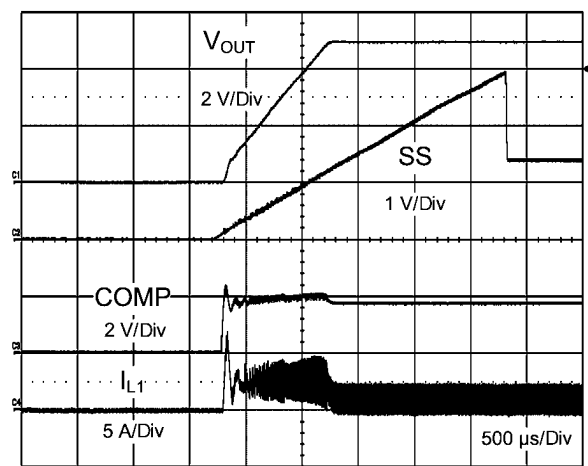
FIGURE 5. Short Circuit at 24V_{IN} Room Temperature



30012203

FIGURE 6. Short Circuit at 48V_{IN} 125°C

For sustained short circuit protection, adding C7 ≥ 1 µF will limit the short circuit power dissipation. D2 should be installed when using C7.



30012204

FIGURE 7. Short Circuit Recovery into Resistive Load with C7 = 1 μ F and D2 Installed

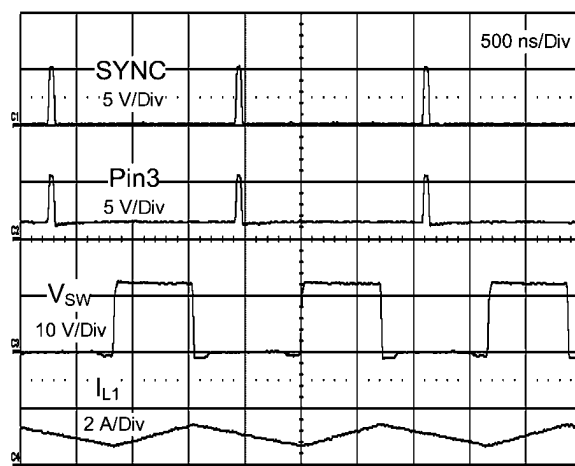
VCCX

This test point supports evaluation of an auxiliary supply voltage derived from V_{OUT} . For output voltages between 7V and 14V, a zero ohm resistor may be installed for R12. The selected MOSFETs need greater than 6V gate drive to fully enhance them for lowest $R_{DS(ON)}$, so R12 is not recommended for the 5V output.

Under no circumstances should an external voltage source be connected to VCCX when $V_{IN} < VCC$. Damage to the controller will result. A series diode from the input voltage source to pin 1 is required to accommodate $V_{IN} < VCC$.

SYNCHRONIZATION

A SYNC pin has been provided on the evaluation board. This pin can be used to synchronize the regulator to an external clock. Refer to the LM5116 datasheet for complete information.



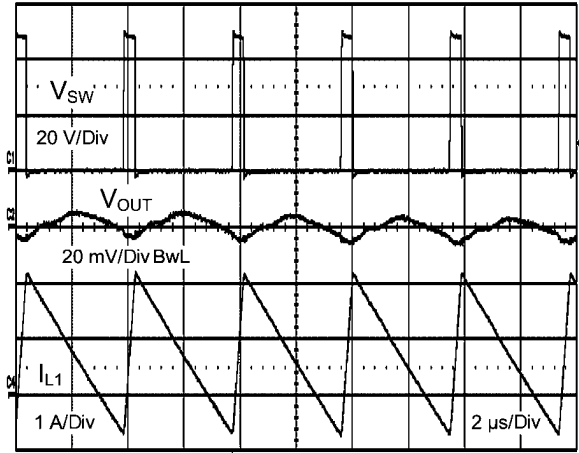
30012207

FIGURE 8. Synchronization at 12V_{IN}

ACTIVE LOADS

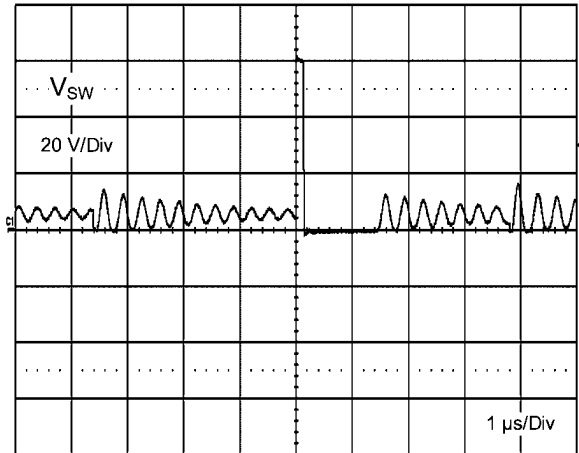
Figure 12 shows a typical start-up characteristic into a constant current active load. This type of load can exhibit an initial short circuit, which is sustained well beyond the normal soft-start cycle. Overshoot of the output voltage is possible with this condition. Increasing the soft-start time to be longer than the initial short circuit period of the active load will minimize any possible overshoot. When using C7, the hiccup off-time may also need adjustment.

Typical Performance Waveforms



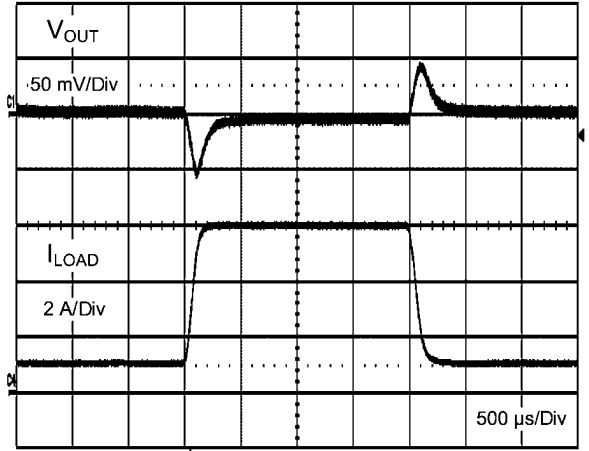
30012206

FIGURE 9. Full Synchronous Operation at 48V_{IN} with JMP1 Removed



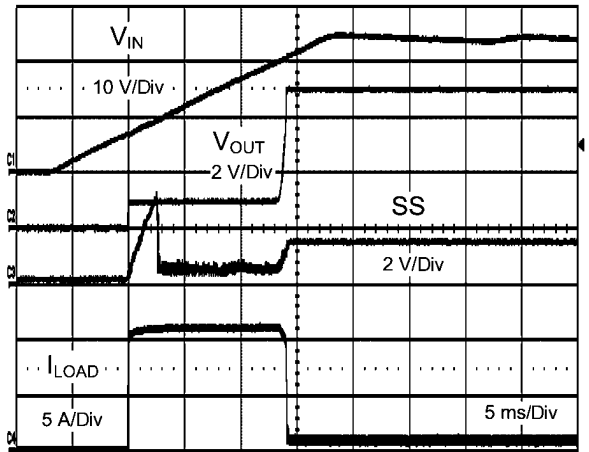
30012201

FIGURE 10. Discontinuous Operation using Diode Emulation Mode at 60V_{IN} with JMP1 Installed



30012208

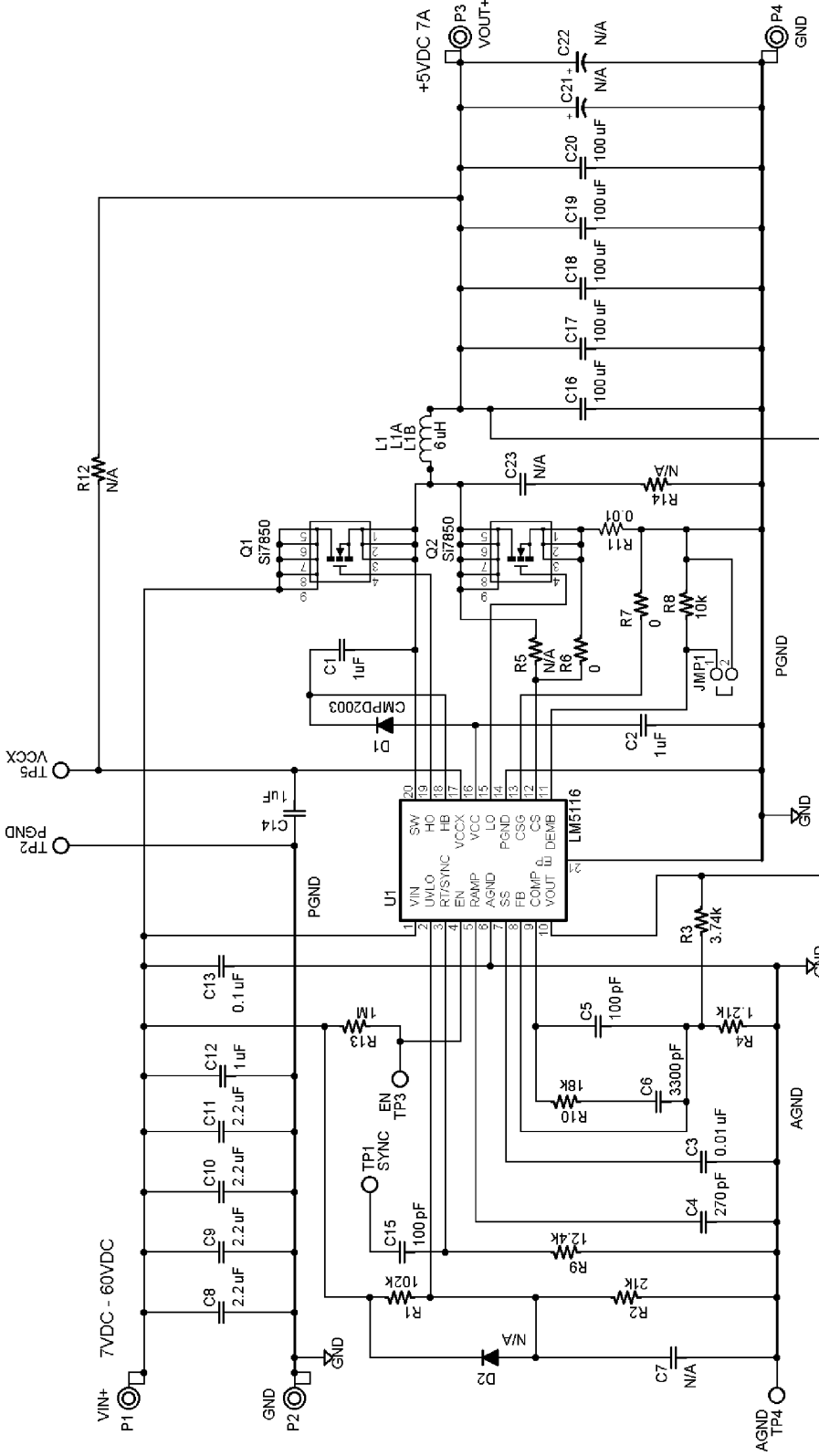
FIGURE 11. Transient Response at 24V_{IN}



30012205

FIGURE 12. Start-up into Active Load at 24V_{IN}

Evaluation Board Schematic



30012224

FIGURE 13.

TABLE 1. Bill of Materials for 7V-60V Input, 5V 7A Output, 250kHz

ID	Part Number	Type	Size	Parameters	Qty	Vendor
C1, C2, C14	C2012X7R1E105K	Capacitor, Ceramic	0805	1 μ F, 25V, X7R	3	TDK
C3	VJ0603Y103KXAAT	Capacitor, Ceramic	0603	0.01 μ F, 50V, X7R	1	Vishay
C4	VJ0603A271JXAAT	Capacitor, Ceramic	0603	270pF, 50V, COG, 5%	1	Vishay
C5, C15	VJ0603Y101KXATW 1BC	Capacitor, Ceramic	0603	100pF, 50V, X7R	1	Vishay
C6	VJ0603Y332KXXAT	Capacitor, Ceramic	0603	3300pF, 25V, X7R	1	Vishay
C7		Capacitor, Ceramic	0603	Not Used	0	
C8, C9, C10, C11	C4532X7R2A225M	Capacitor, Ceramic	1812	2.2 μ F, 100V X7R	4	TDK
C12	C3225X7R2A105M	Capacitor, Ceramic	1210	1 μ F, 100V X7R	1	TDK
C13	C2012X7R2A104M	Capacitor, Ceramic	0805	0.1 μ F, 100V X7R	1	TDK
C16, C17, C18, C19, C20	C4532X6S0J107M	Capacitor, Ceramic	1812	100 μ F, 6.3V, X6S, 105°C	5	TDK
C21, C22		Capacitor, Tantalum	D Case	Not Used	0	
C23		Capacitor, Ceramic	0805	Not Used	0	
D1	CMPD2003	Diode, Switching	SOT-23	200mA, 200V	1	Central Semi
D2	CMPD2003	Diode, Switching	SOT-23	Not Used	0	Central Semi
JMP1		Connector, Jumper		2 pin sq. post	1	
L1	PD0120.532	Inductor		5.6 μ H, 10.4A	1	Pulse
L1A	HC2LP-6R0	Inductor		6 μ H, 16.5A	0	Cooper
L1A	P7611-5R6M	Inductor		5.6 μ H, 17A	0	Profec
P1-P4	1514-2	Turret Terminal	.090" dia.		4	Keystone
TP1-TP5	5012	Test Point	.040" dia.		5	Keystone
Q1, Q2	Si7850DP	N-CH MOSFET	SO-8 Power PAK	10.3A, 60V	2	Vishay Siliconix
R1	CRCW06031023F	Resistor	0603	102k Ω , 1%	1	Vishay
R2	CRCW06032102F	Resistor	0603	21.0k Ω , 1%	1	Vishay
R3	CRCW06033741F	Resistor	0603	3.74k Ω , 1%	1	Vishay
R4	CRCW06031211F	Resistor	0603	1.21k Ω , 1%	1	Vishay
R5		Resistor	0603	Not Used	0	
R6, R7	CRCW06030R0J	Resistor	0603	0 Ω	2	Vishay
R8	CRCW0603103J	Resistor	0603	10k Ω , 5%	1	Vishay
R9	CRCW06031242F	Resistor	0603	12.4k Ω , 1%	1	Vishay
R10	CRCW0603183J	Resistor	0603	18k Ω , 5%	1	Vishay
R11	LRC-LRF2010-01- R010-F	Resistor	2010	0.010 Ω , 1%	0	IRC
R11	WSL2010R0100FEA	Resistor	2010	0.010 Ω , 1%	1	Vishay
R12		Resistor	0603	Not Used	0	
R13	CRCW0603105J	Resistor	0603	1M Ω , 5%	1	Vishay
R14		Resistor	1206	Not Used	0	
U1	LM5116MHX	Synchronous Buck Controller	TSSOP-20EP		1	NSC

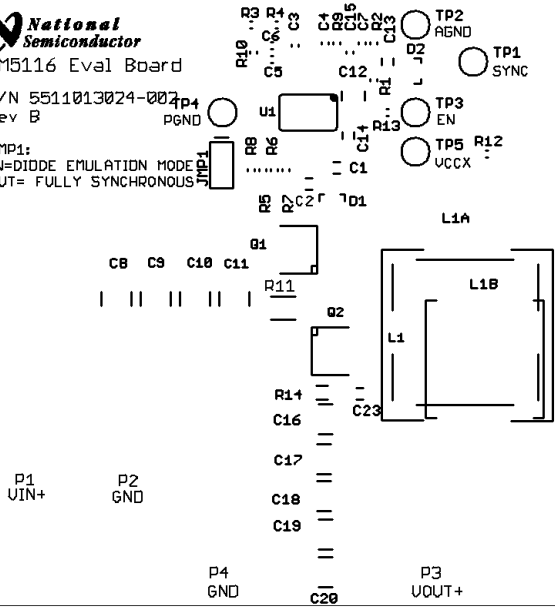
PCB Layout



LM5116 Eval Board

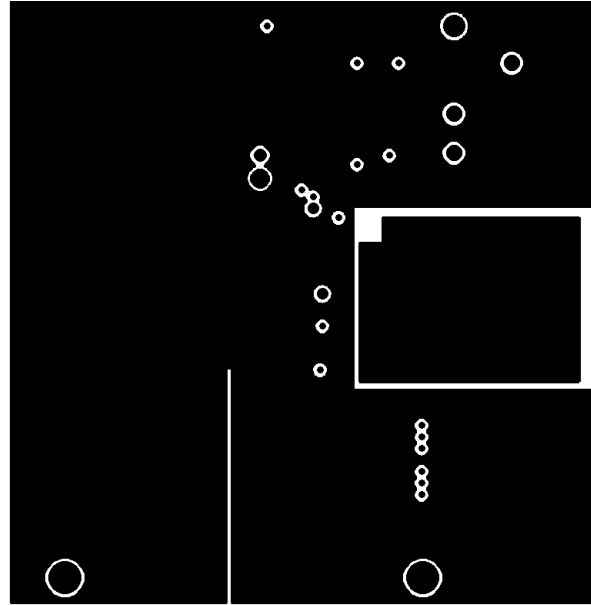
P/N 5511013024-002
Rev B

JMP1:
IN=DIODE EMULATION MODE
OUT= FULLY SYNCHRONOUS



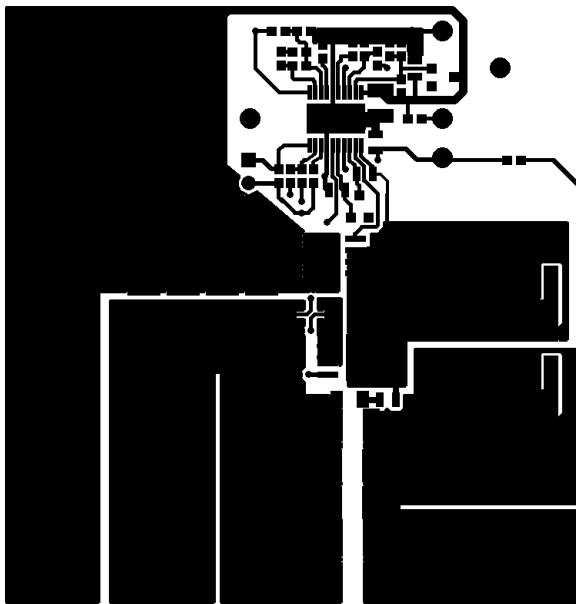
TOP SILKSCREEN (.PLC) AS VIEWED FROM TOP
8801013024-002

30012217



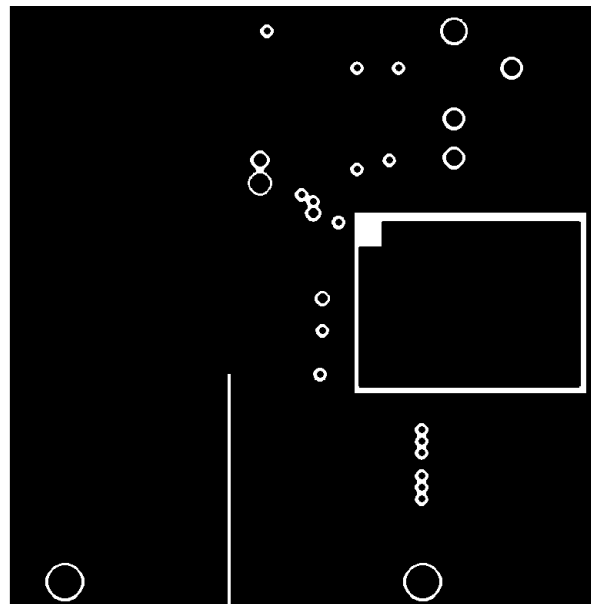
LAYER 2 (.LY2) AS VIEWED FROM TOP
8801013024-002

30012215



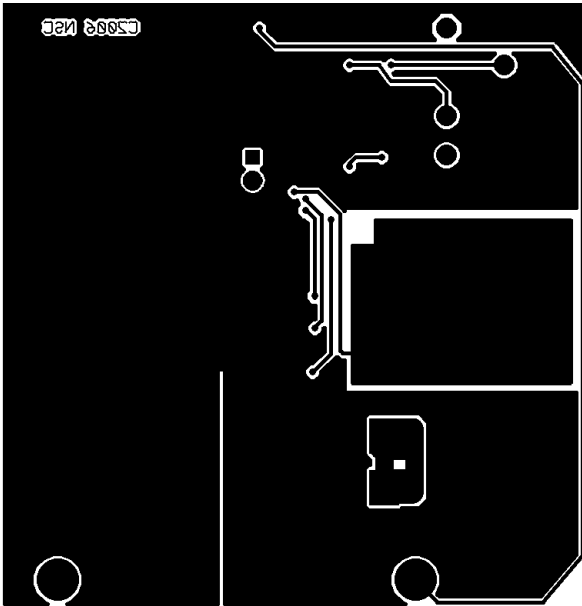
TOP (.CMP) LAYER AS VIEWED FROM TOP
8801013024-002

30012210



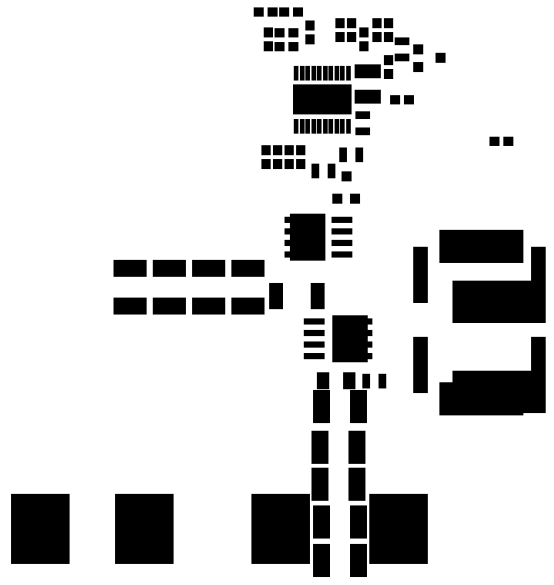
LAYER 3 (.LY3) AS VIEWED FROM TOP
8801013024-002

30012216



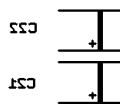
BOTTOM (.SOL) LAYER AS VIEWED FROM TOP
8801013024-002

30012219



TOP SOLDER PASTE MASK (.CRC) AS VIEWED FROM TOP
8811013024-002

30012211



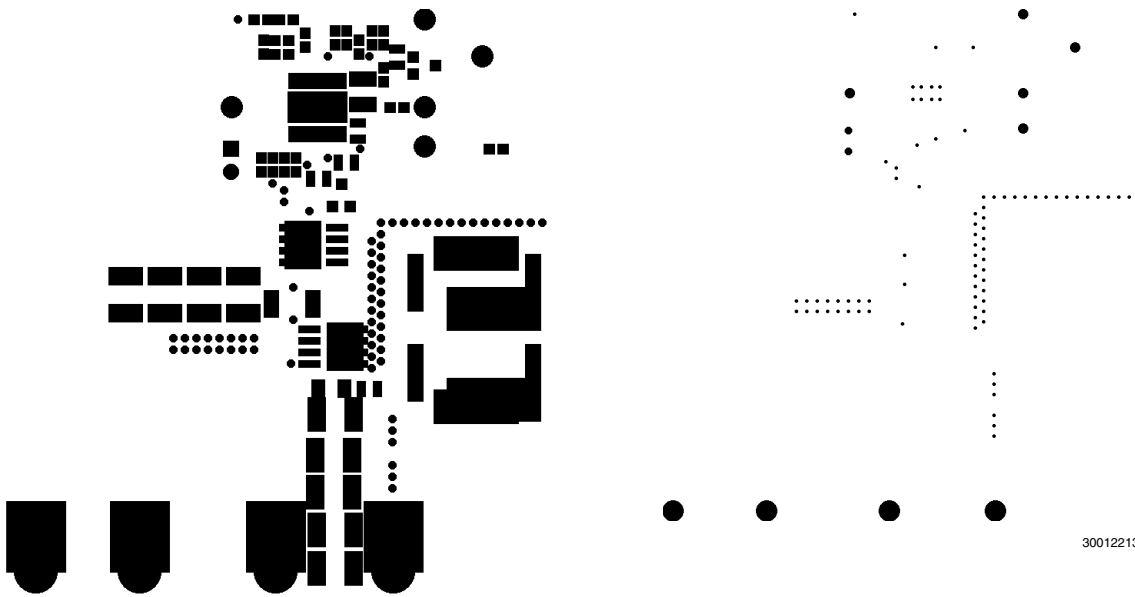
BOTTOM SILK SCREEN (.PLS) LAYER AS VIEWED FROM TOP
8801013024-002

30012218



BOTTOM SOLDER PASTE MASK (.CRS) LAYER AS VIEWED FROM TOP
8811013024-002

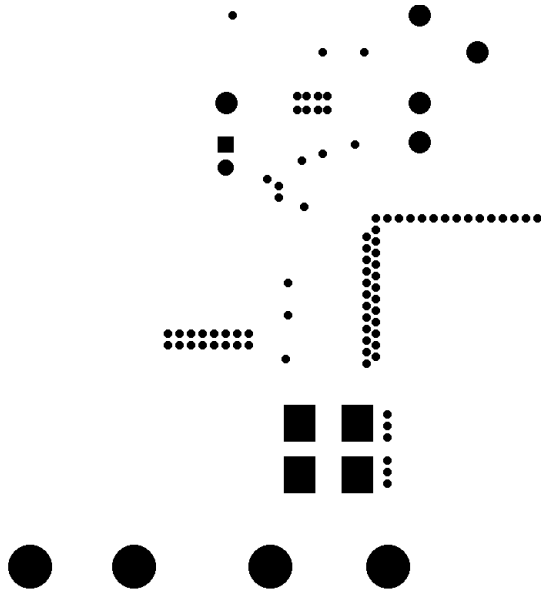
30012212



30012213

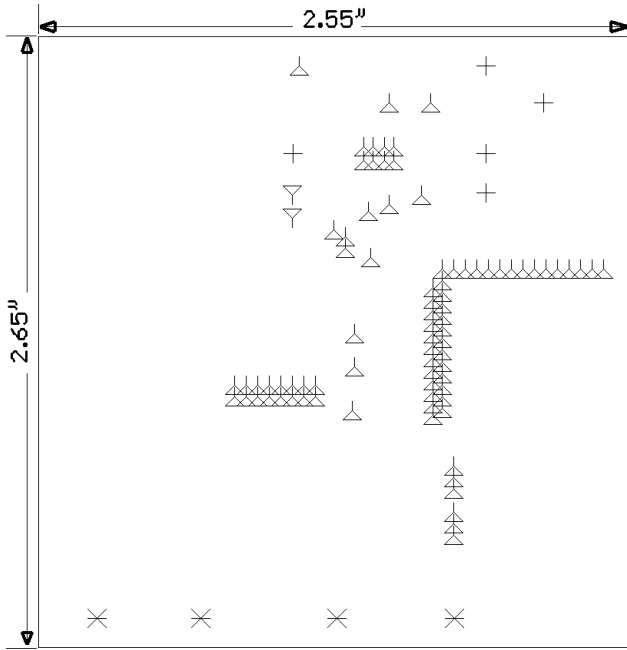
TOP SOLDERMASK (.STC) LAYER AS VIEWED FROM TOP
BB01013024-002

30012220



BOTTOM SOLDER MASK (.STS) LAYER AS VIEWED FROM TOP
BB01013024-002

30012221



DRILL GUIDE	
	0.018, +0.002, -0.002 INCHES
	0.038, +0.003, -0.003 INCHES
	0.047, +0.003, -0.002 INCHES
	0.100, +0.005, -0.005 INCHES

DRILLS AND DIMENSIONS (FAB) LAYER AS VIEWED FROM TOP
8801013024-002

30012214

Notes

AN-1596

Notes

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2007 National Semiconductor Corporation

For the most current product information visit us at www.national.com



National Semiconductor Americas Customer Support Center
 Email: new.feedback@nsc.com
 Tel: 1-800-272-9959

National Semiconductor Europe Customer Support Center
 Fax: +49 (0) 180-530-85-86
 Email: europe.support@nsc.com
 Deutsch Tel: +49 (0) 69 9508 6208
 English Tel: +49 (0) 870 24 0 2171
 Français Tel: +33 (0) 1 41 91 8790

National Semiconductor Asia Pacific Customer Support Center
 Email: ap.support@nsc.com

National Semiconductor Japan Customer Support Center
 Fax: 81-3-5639-7507
 Email: jpn.feedback@nsc.com
 Tel: 81-3-5639-7560