LM5001

Application Note 1956 LM5001 Boost Evaluation Board



Literature Number: SNVA393

LM5001 Boost Evaluation **Board**

National Semiconductor Application Note 1956 Ron Crews March 4, 2009



Introduction

The LM5001 boost evaluation board is designed to provide the design engineer with a fully functional power converter based on the boost topology to evaluate the LM5001 high voltage switch mode regulator.

The performance of the evaluation board is as follows:

Input Operating Range: 16 to 36V

Output Voltage: 48V Output Current: 0 to 150 mA

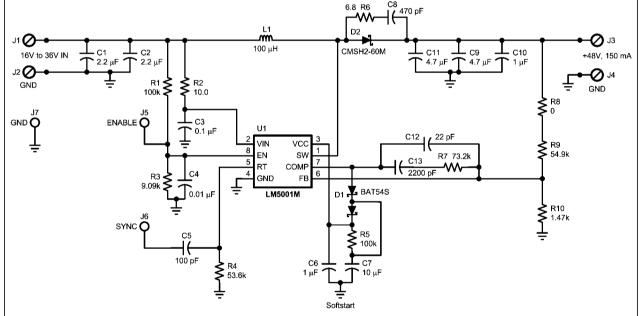
Measured Efficiency: 91% @ 150 mA, 86% @ 75 mA

Frequency of Operation: 240 kHz Board Size: 1.75 X 1.75 inches

Load Regulation: 1% Line Regulation: 0.1% The printed circuit board consists of 2 layers; 1 ounce copper layers FR4 material with a total thickness of 0.062 inches.

When laying out the PCB note the proximity of the ground pin (pin 4) to the output capacitors (see artwork below). Placing the ground pin near the output capacitor will minimize the ripple in the output by forcing a constant current to flow across the board for both the switch on and switch off portions of the cycle. If the board is laid out with the ground pin near the input capacitor then a high di/dt condition will occur due to the small conduction loop area during the switch on time and large loop conduction area during the switch off time. The output ripple and noise will be minimized if the conduction loop area and current both remain constant. Placing the ground pin near the output capacitor accomplishes this goal.

Schematic



30093901

Powering and Loading Considerations

When applying power to the LM5001 Boost evaluation board certain precautions need to be followed. A misconnection can damage the board.

PROPER CONNECTIONS

When operated at low input voltages the evaluation board can draw up to 500mA of current at full load. The maximum rated output current is 150mA. 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. When measuring output ripple with an oscilloscope. Do not use the wire ground lead for the ground connection. The loop formed by the wire lead will pick up noise from the switching circuits and make the ripple voltage look larger then it actually is. Instead use a spring ground clip on the exposed ground ring on the scope probe to minimize the loop area of the ground lead. An alternative is to remove the shroud covering the scope probe. Then touch the exposed scope probe ground connection to the output ground terminal while simultaneously connecting the probe tip to the output terminal.

SOURCE POWER

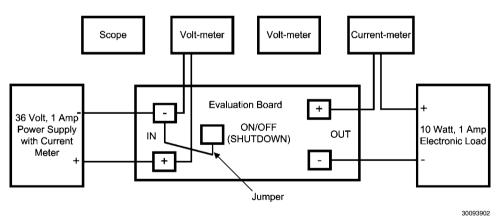
The power supply and cabling must look like a low impedance voltage source to the evaluation board. High inductance power supply leads like the type typically used for bench power supplies, could cause the LM5001 to become unstable or have poor response to load transients. This is due to the inductance of the power supply wiring interacting with the evaluation board input capacitor and causing a series resonant LC oscillation at a frequency defined by the inductance of the input wiring and the value of the input capacitor. In some cases it may be necessary to add an additional capacitor in parallel with input capacitor to move the resonate frequency away from the unity gain crossover frequency of the LM5001. Twisting the input supply lines together will reduce the inductance and potential for problems. Powering up at max rated voltage or close to this voltage can cause damage due to the inductance of the supply lines. Over shoot and ringing can be several volts under a sudden application of power. When operating near maximum input voltage slowly ramp up the voltage to avoid overshoot.

LOADING

An appropriate electronic load, with specified operation up to 48V maximum or more, is desirable. Monitor both current and voltage at all times. Ensure there is sufficient cooling provided for the load.

OVER CURRENT PROTECTION

The LM5001 monitors the peak current through the inductor on a cycle by cycle basis. If the inductor is sized large enough to not saturate when operating at peak current limit. Then the short circuit can be left on indefinitely with out damaging the device or causing it to go into thermal shutdown.



Typical Evaluation Setup

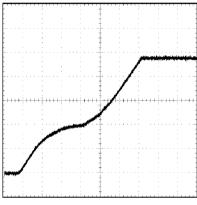
Performance Characteristics

TURN-ON WAVEFORMS

Figure 1 shows the output voltage during a typical start-up with a 20V input and a load of 150 mA. There is no overshoot during startup.

OUTPUT RIPPLE WAVEFORMS

Figure 2 shows the transient response for a load of change from 15 mA to 150 mA. The upper trace shows minimal output voltage droop and overshoot during the sudden change in output current shown by the lower trace.



30093903

Conditions:

Input Voltage = 20VDC

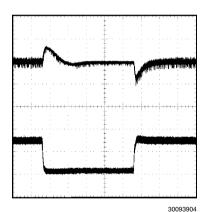
Output Current = 150 mA

Trace 1:

Output Voltage Volts/div = 10V

Horizontal Resolution = 4.0 ms/div

FIGURE 1.



Conditions:

Input Voltage = 20VDC

Output Current = 15 mA to 150 mA

Upper Trace:

Output Voltage

Volts/div = 500 mV

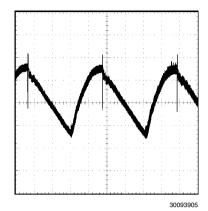
Lower Trace:

Output Current

150 mA to 15 mA to 150 mA

Horizontal Resolution = 0.4 ms/div

FIGURE 2.



Conditions:

Input Voltage = 20VDC
Output Current = 150 mA
Bandwidth Limit = 20 MHz

Trace 1:

Output Voltage Volts/div = 20 mV

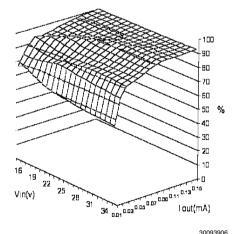
Horizontal Resolution = 1 μs/div

FIGURE 3.

Figure 3 shows typical output ripple seen directly across the output capacitor, for an input voltage of 20V and a load of 150 mA. This waveform is typical of most loads and input voltages.

Figures 4 shows power efficiency over full input voltage and output current range. Peak efficiency is at full rated load and is greater then 90% across the input voltage range.

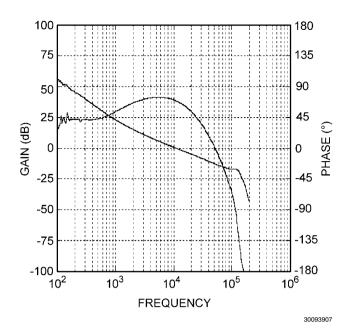
Figure 5 shows the small signal closed loop response with 20V input and 150 mA load current into a resistive load. The gain curve starts at around 60dB the phase curve starts at around 45°. 0dB of crossover frequency is at 11 kHz with a phase margin of 70°.



Conditions:

Input Voltage = 16 - 36VDC Output Current = 10 mA - 150 mA

FIGURE 4.



Conditions:

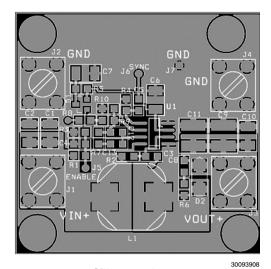
Input Voltage = 20VDC Output Current = 150 mA

FIGURE 5.

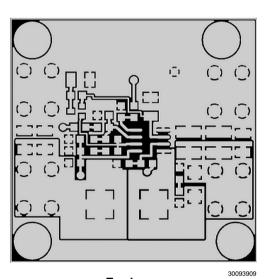
Bill of Materials

Designator	Qty	Part Number	Description	Value
C1, C2	2	GRM31CR71H225KA88L	CAPACITOR, 1206 X7R CER, Murata	2.2µF, 50V
C3	1	C2012X7R1H104M	CAPACITOR, 0805 X7R CER, TDK	0.1μF, 50V
C4	1	C2012X7R1H103M	CAPACITOR, 0805 X7R CER, TDK	0.01μF, 50V
C5	1	C2012COG1H101J	CAPACITOR, 0805 COG CER, TDK	100pF, 50V
C6	1	C3216X7R1C105K	CAPACITOR, 0805 X7R CER, TDK	1µF, 16V
C7	1	GRM21BR61C106KE15L	CAPACITOR, 0805 X7R CER, Murata	10μF, 16V
C8	1	C2012COG1H471J	CAPACITOR, 0805 COG CER, TDK	470pF, 100V
C9, C11	2	C5750X7R2A475M	CAPACITOR, 2220 X7R CER, TDK	4.7μF, 100V
C10	1	C3225X7R2A105K	CAPACITOR, 1210 X7R CER, TDK	1μF, 100V
C12	1	C2012COG1H220J	CAPACITOR, 0805 COG CER, TDK	22pF, 50V
C13	1	C2012COG1H222J	CAPACITOR, 0805 COG CER, TDK	2200pF, 50V
D1	1	BAT54S	DIODE, SOT-23, DUAL, SCHOTTKY, Fairchild Semiconductor	200mA, 30V
D2		CMSH2-60M	DIODE, SMA, SCHOTTKY, Central Semiconductor Corp.	2A, 60V
L1	1	MSS1260	INDUCTOR, COILCRAFT	100μH, 1.8A
R1, R5	2	CRCW08051003F	RESISTOR, 0805, VISHAY	100K
R2	1	CRCW08051002F	RESISTOR, 0805, VISHAY	10.0K
R3	1	CRCW08059091F	RESISTOR, 0805, VISHAY	9.09K
R4	1	CRCW08055362F	RESISTOR, 0805, VISHAY	53.6K
R6	1	CRCW080568R1F	RESISTOR, 0805, VISHAY	6.8
R7	1	CRCW08057322F	RESISTOR, 0805, VISHAY	73.2K
R8	1	CRCW08050000F	RESISTOR, 0805, VISHAY	0
R9	1	CRCW08055492F	RESISTOR, 0805, VISHAY	54.9K
R10		CRCW08051471F	RESISTOR, 0805, VISHAY 1.47K	
J1, J2, J3, J4	4	7693	Keystone Screw Terminal (www.keyelco.com)	
J5, J6, J7	Mar-36	PTC36SAAN	0.025" Sq post, 36 position, Sullins	3 posts used
U1	1	LM5001M	High Voltage Switch Mode Regulator, National Semiconductor	

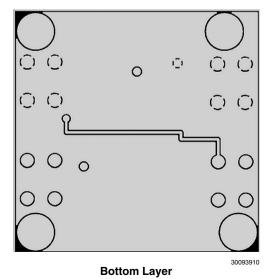
Printed Circuit Layout



Silkscreen Layer



Top Layer



Notes www.national.com

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Pr	oducts	Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
Wireless (PLL/VCO)	www.national.com/wireless	Analog University®	www.national.com/AU

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© 2009 National Semiconductor Corporation

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



National Semiconductor Americas Technical Support Center Email: support@nsc.com Tel: 1-800-272-9959 National Semiconductor Europe Technical Support Center Email: europe.support@nsc.com National Semiconductor Asia Pacific Technical Support Center Email: ap.support@nsc.com

National Semiconductor Japan Technical Support Center Email: jpn.feedback@nsc.com

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products	Applications
----------	--------------

Audio www.ti.com/audio Communications and Telecom www.ti.com/communications **Amplifiers** amplifier.ti.com Computers and Peripherals www.ti.com/computers dataconverter.ti.com Consumer Electronics www.ti.com/consumer-apps **Data Converters DLP® Products** www.dlp.com **Energy and Lighting** www.ti.com/energy DSP dsp.ti.com Industrial www.ti.com/industrial Clocks and Timers www.ti.com/clocks Medical www.ti.com/medical Interface interface.ti.com Security www.ti.com/security

Logic logic.ti.com Space, Avionics and Defense www.ti.com/space-avionics-defense

Power Mgmt power.ti.com Transportation and Automotive www.ti.com/automotive
Microcontrollers microcontroller.ti.com Video and Imaging www.ti.com/video

RFID <u>www.ti-rfid.com</u>
OMAP Mobile Processors www.ti.com/omap

Wireless Connectivity <u>www.ti.com/wirelessconnectivity</u>

TI E2E Community Home Page <u>e2e.ti.com</u>