AN-2206 LM5114 Evaluation Board

1 Introduction

The LM5114 is a single low-side gate driver with 7.6A/1.3A peak sink/source drive current capability. It can be used to drive standard Si MOSFETs or enhancement mode GaN FETs in boost type configurations or to drive secondary synchronous FETs in isolated topologies. The LM5114 evaluation board is designed to provide the design engineer with a fully functional boost dc-dc converter to evaluate the LM5114. A 100V enhancement mode GaN FET (EPC2001) is used as the boost power switch. The control circuitry is implemented with the LM5020, a 100V current mode PWM controller.

The specifications of the evaluation board are as follows:

- Input Operating Voltage: 24V to 66V
- Output Voltage: 75V
- Output Current: 2A
- Measured Efficiency at 48V: 97% @ 2A
- Frequency of Operation: 500 kHz
- Line UVLO: 23.6V (Rising) /21.6V (Falling)
- Board size: 2.99 x 3.26 inches

The printed circuit board consists of 2 layers of 2 ounce copper on FR4 material, with a thickness of 0.050 inches.

2 LM5114 Features

- Independent source and sink outputs for controllable rise and fall times
- +4V to +12.6V single power supply
- 7.6A/1.3A peak sink/source drive current
- 0.23Ω open-drain pull-down sink output
- 2Ω open-drain pull-up source output
- Power-off pull-down clamping
- 12ns (Typ) propagation delay
- Matching delay time between inverting and non-inverting inputs
- Up to +14V logic inputs (Regardless of VDD voltage)
- -40°C to +125°C operating temperature range
- Pin-to-Pin compatible with MAX5048

3 Package

- SOT-23-6
- LLP-6 (3mm x 3mm)

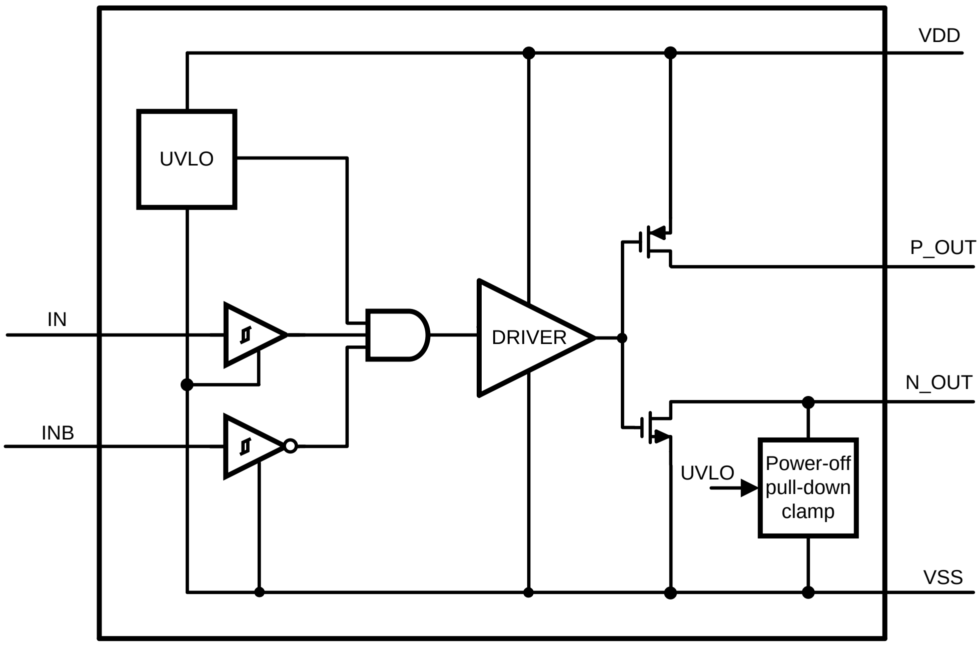


Figure 1. Simplified Block Diagram of LM5114

4 Powering and Loading Considerations

When applying power to the LM5114 evaluation board, certain precautions need to be followed. A misconnection can damage the assembly.

4.1 Proper Board Connection

Figure 2 depicts the typical evaluation setup. The source power is connected to VIN and GND1. The load is connected to VOUT and GND2. Be sure to choose the correct connector and wire size. The input and output voltage must be monitored directly at the terminals of the board. The voltage drop across the connection wires will cause inaccurate measurements.

4.2 Source Power

To fully test the LM5114 evaluation board, a DC power supply capable of 66V and 7A is required. When a boost converter is powered up, a high inrush current may be generated due to the charge of the output capacitors. It is desirable to use a source power with a soft start-up to limit the inrush 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.

4.3 Air Flow

To ensure a proper and reliable operation, sufficient cooling is required. Insufficient airflow can cause a catastrophic failure. A minimum airflow of 200CFM should always be provided.

4.4 Quick Start-up Pfocedure

1. Connect the source supply to VIN and GND1. Connect the load cable between VOUT and GND2.
2. Set the current limit of the source supply to provide about 1.5 times the anticipated output power.
3. Set the load current at 0A.

4. Set the input voltage at 24V and turn on the power supply. Check that the output voltage is 75V.
5. Slowly increase the input voltage and the load current while monitoring the output voltage.
6. A quick efficiency check is the best way to ensure the evaluation board is working properly.

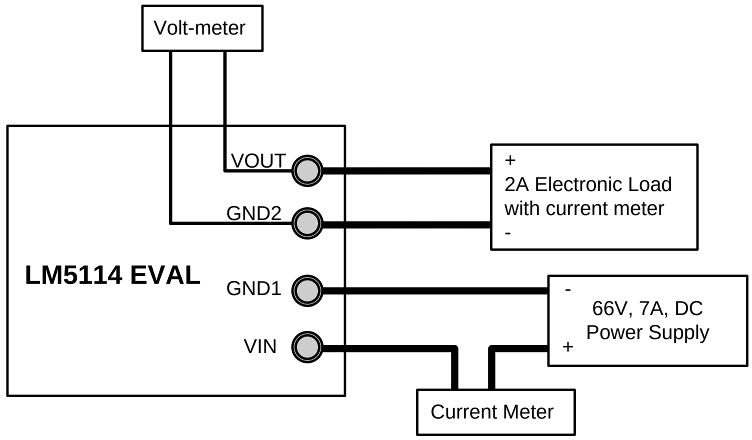


Figure 2. Typical Evaluation Setup

5 Applications Information

5.1 Operating Description

The LM5114 evaluation board operates in both Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). For a given input voltage, the operation mode of the evaluation board is determined by the load current. Figure 3 illustrates the operation mode for different input voltages and load currents. The control loop design of a boost converter is usually more challenging than that of a buck converter due to a right half-plane zero (RHZ) in conjunction with quadratic poles. Thanks to the use of a small inductor in DCM operation, RHZ and the pole associated with the inductor move to the higher frequency, which eases the control loop design.

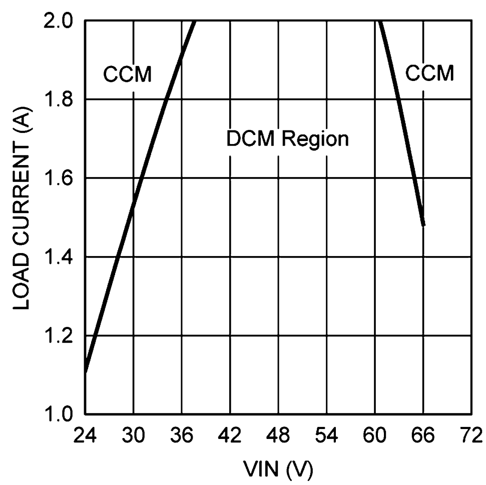


Figure 3. CCM and DCM Operation Boundary

5.2 Gate Drive

The enhancement mode GaN FETs have small gate capacitance and low threshold gate voltage. Therefore GaN FETs are prone to gate oscillations induced by PCB parasitic elements. It is necessary to place the driver as close to the GaN FET as possible to minimize the stray inductance. Gate resistors can be used to damp the oscillations and to adjust the switching speed. The LM5114 has split outputs, providing flexibility to adjust the turn-on and turn-off strength independently. In the evaluation board, 1.5Ω and 2.7 Ω gate resistors are used in the turn-on and turn-off path respectively.

5.3 Bias Supply

The PWM controller LM5020 contains an internal high voltage startup regulator. When power is applied, the regulator generates 7.7 V output voltage with the output current limited to 15 mA. In addition, an auxiliary bias rail is also generated to reduce the power dissipation of the LM5020. As shown in Figure 17, voltages across the boost inductor during respective turn-on and turn-off periods are sensed by an auxiliary winding, and then are stored in two capacitors. The auxiliary bias voltage is the combination of the two capacitor voltages and is proportional to the output voltage in steady state. The calculation of the auxiliary bias voltage is as follows.

$$V_{BIAS} = \frac{1}{N}\left[V_{in} + \left(V_0 - V_{in}\right) \right] = \frac{1}{N} \cdot V_0 \tag{1}$$

Where N is the turns ratio and is equal to 6 in this case. The corresponding bias voltage is around 11 V. Figure 4 compares the efficiency achieved with and without the auxiliary bias winding. As can be seen, with an auxiliary winding, the efficiency is improved by almost 2% at light load.

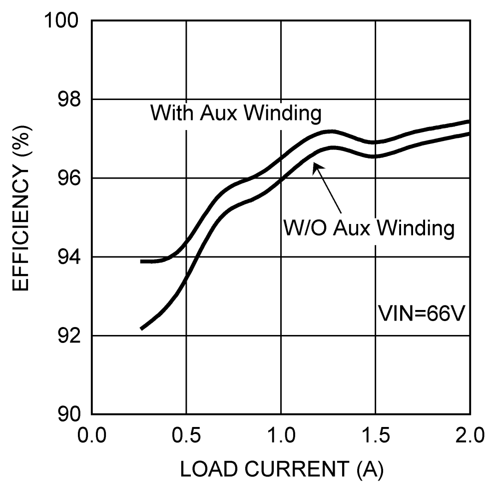


Figure 4. Efficiency Comparison Between With and Without the Auxiliary Bias Winding

6 Performance Characteristics

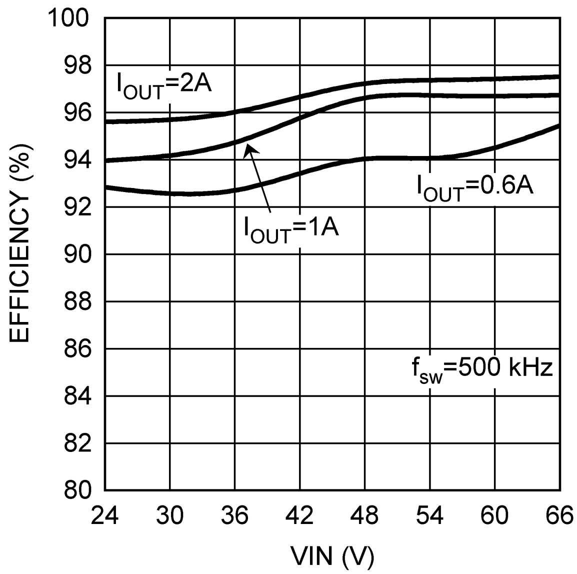
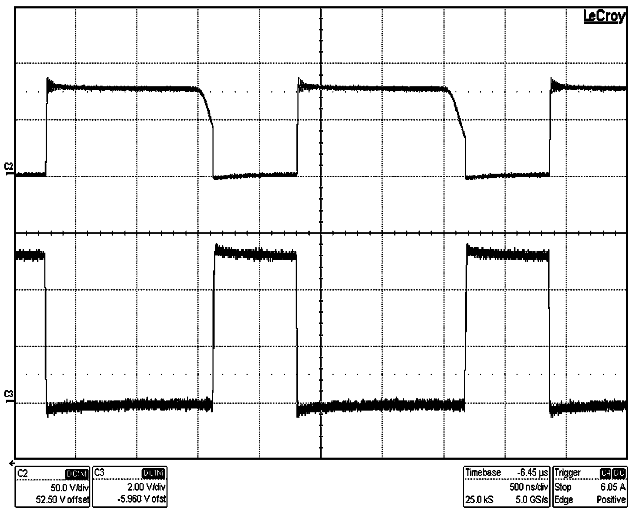


Figure 5. Evaluation Board Efficiency



Conditions: Input Voltage = 48 VDC, Load Current = 2 A
Traces: Top Trace: Switch-node voltage, Volt/div = 50 V
Bottom Trace: Gate-Source Voltage of GaN FET, Volt/div = 2 V Bandwidth Limit = 600 MHz Horizontal Resolution = 500 ns/div

Figure 6. Gate-Source Voltage

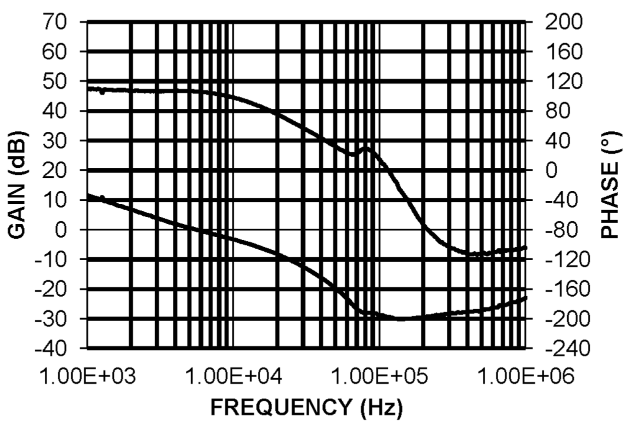
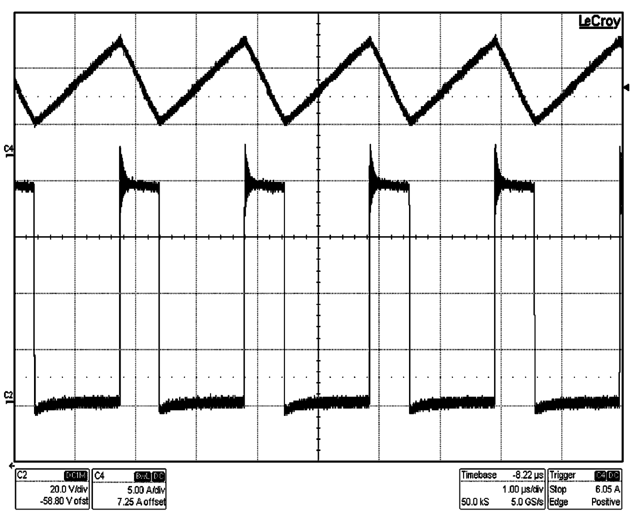
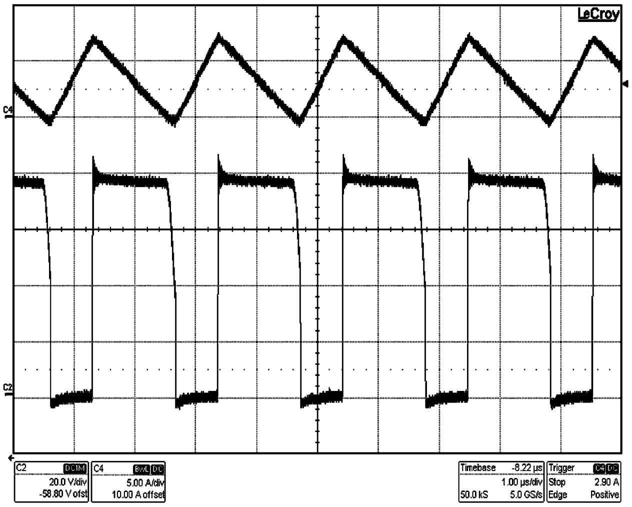


Figure 7. Close Loop Gain Measurement, V_{IN} = 48 V, Load Current = 2 A



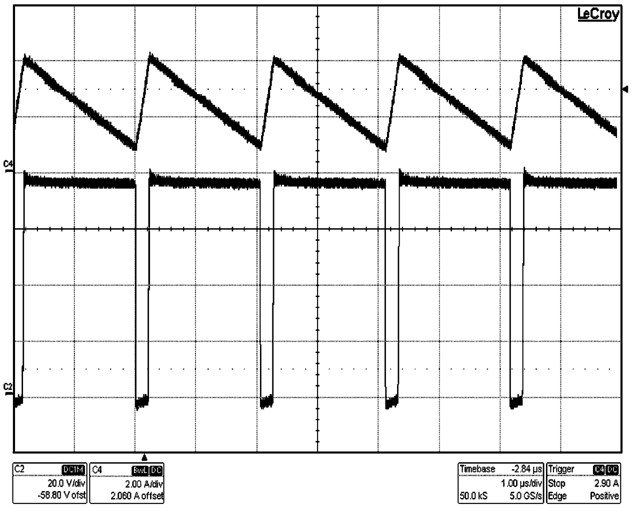
Conditions: Input Voltage = 24 VDC, Load Current = 2 A
Traces: Top Trace: Inductor Current, Amp/div = 5 A Bottom Trace: Switch-Node Voltage, Volt/div = 20 V Bandwidth Limit = 600 MHz Horizontal Resolution = 1 us/div

Figure 8. Switching Node Voltage V_{IN} = 24 V, Load Current = 2 A



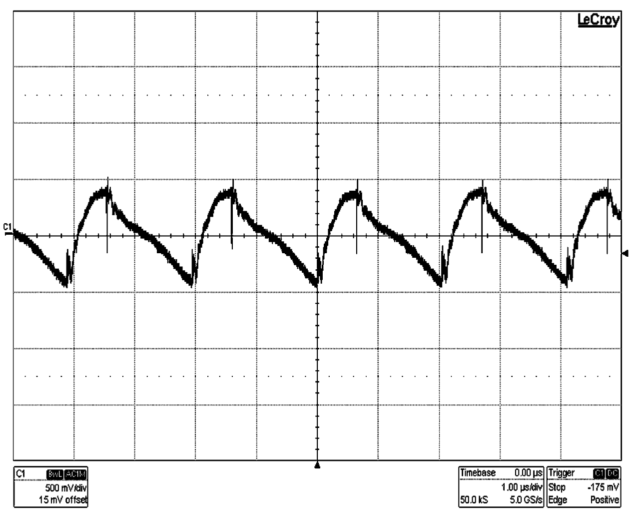
Conditions: Input Voltage = 48 VDC Load Current = 2 A Traces: Top Trace: Inductor Current, Amps/div = 5 A Bottom Trace: Switch-Node Voltage, Volt/div = 20 V Bandwidth Limit = 600 MHz Horizontal Resolution = 1 us/div

Figure 9. Switching Node Voltage V_{IN} = 48 V, Load Current = 2 A



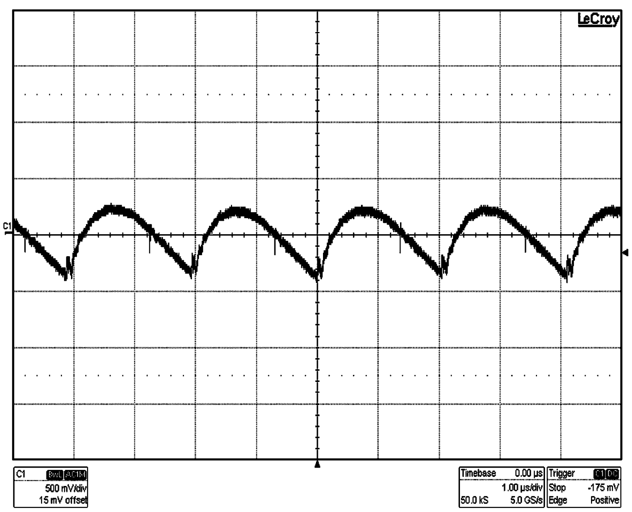
Conditions: Input Voltage = 66 VDC Load Current = 2 A Traces: Top Trace: Inductor Current, Amp/div = 5 A Bottom Trace: Switch-Node Voltage, Volt/div = 20 V Bandwidth Limit = 600 MHz Horizontal Resolution = 1 us/div

Figure 10. Switching Node Voltage V_{IN} = 66 V, Load Current = 2 A



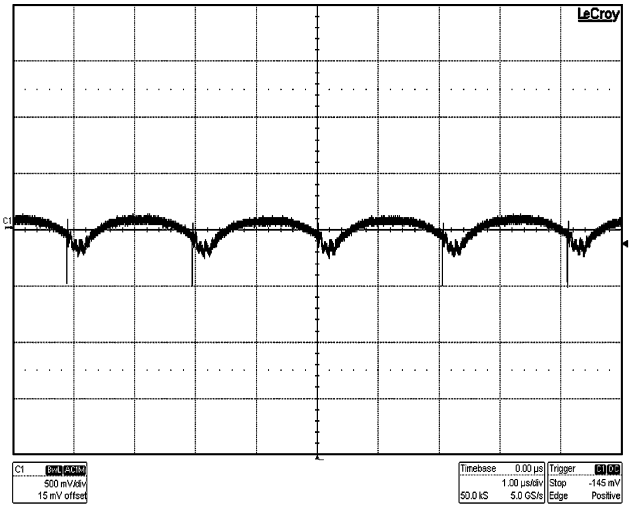
Conditions: Input Voltage = 24 VDC Load Current = 2 A Traces: Trace: Output voltage ripple, Volt/div = 500 mV, AC coupled Bandwidth Limit = 20 MHz Horizontal Resolution = 1 us/div

Figure 11. Output Ripple V_{IN} = 24 V, Load Current = 2 A



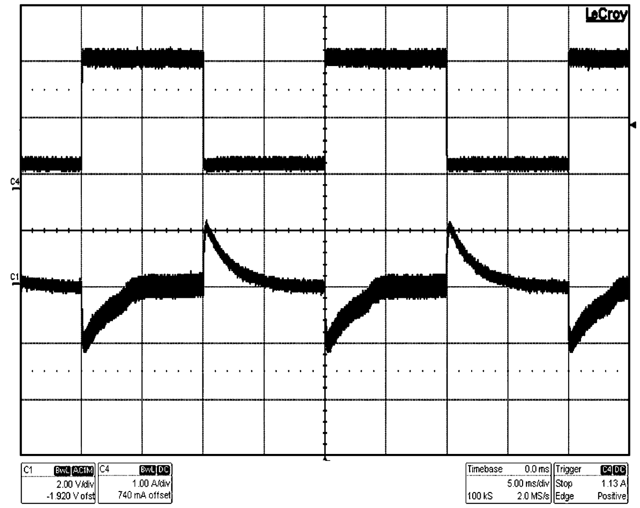
Conditions: Input Voltage = 48 VDC Load Current = 2 A Traces: Trace: Output voltage ripple, Volt/div = 500 mV, AC coupled Bandwidth Limit = 20 MHz Horizontal Resolution = 1 us/div

Figure 12. Output Ripple, V_{IN}= 48 V, Load Current = 2 A



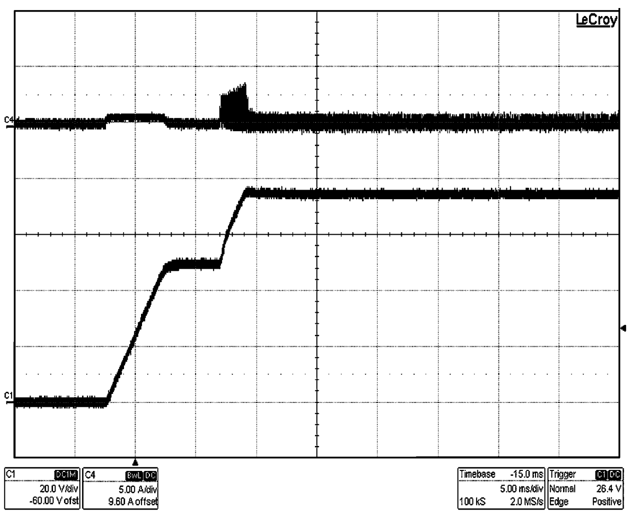
Conditions: Input Voltage = 66 VDC, Load Current = 2 A
Traces: Trace: Output voltage ripple, Volt/div = 500 mV, AC coupled Bandwidth Limit = 20 MHz Horizontal Resolution = 1 us/div

Figure 13. Output Ripple, V_{IN} = 66 V, Load Current = 2 A



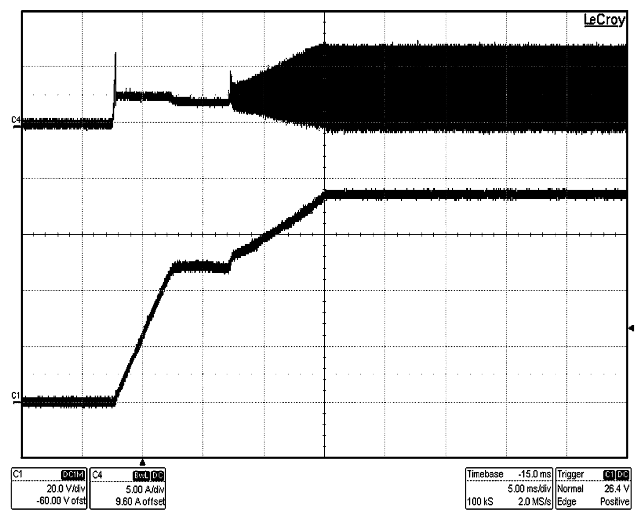
Conditions: Input Voltage = 48 VDC Load Current = 0.1 A to 2 A Traces: Top Trace: Load Current, Amp/div = 1 A Bottom Trace: Output Voltage Volt/div = 2 V, AC coupled Bandwidth Limit = 20 MHz Horizontal Resolution = 5 ms/div

Figure 14. Step Load Response



Conditions: Input Voltage = 48 VDC Load Current = 0A
Traces: Top Trace: Inductor Current, Amp/div = 5 A Bottom Trace: Output Voltage, Volt/div = 20 V Bandwidth Limit = 600 MHz Horizontal Resolution = 5 ms/div

Figure 15. Start-Up at No Load



Conditions: Input Voltage = 48 VDC, Load Current = 2 A
Traces: Top Trace: Inductor Current, Amp/div = 5 A Bottom Trace: Output Voltage, Volt/div = 20 V Bandwidth Limit = 600 MHz Horizontal Resolution = 5 ms/div

Figure 16. Start-Up at Full Load

7 Evaluation Board Schematic

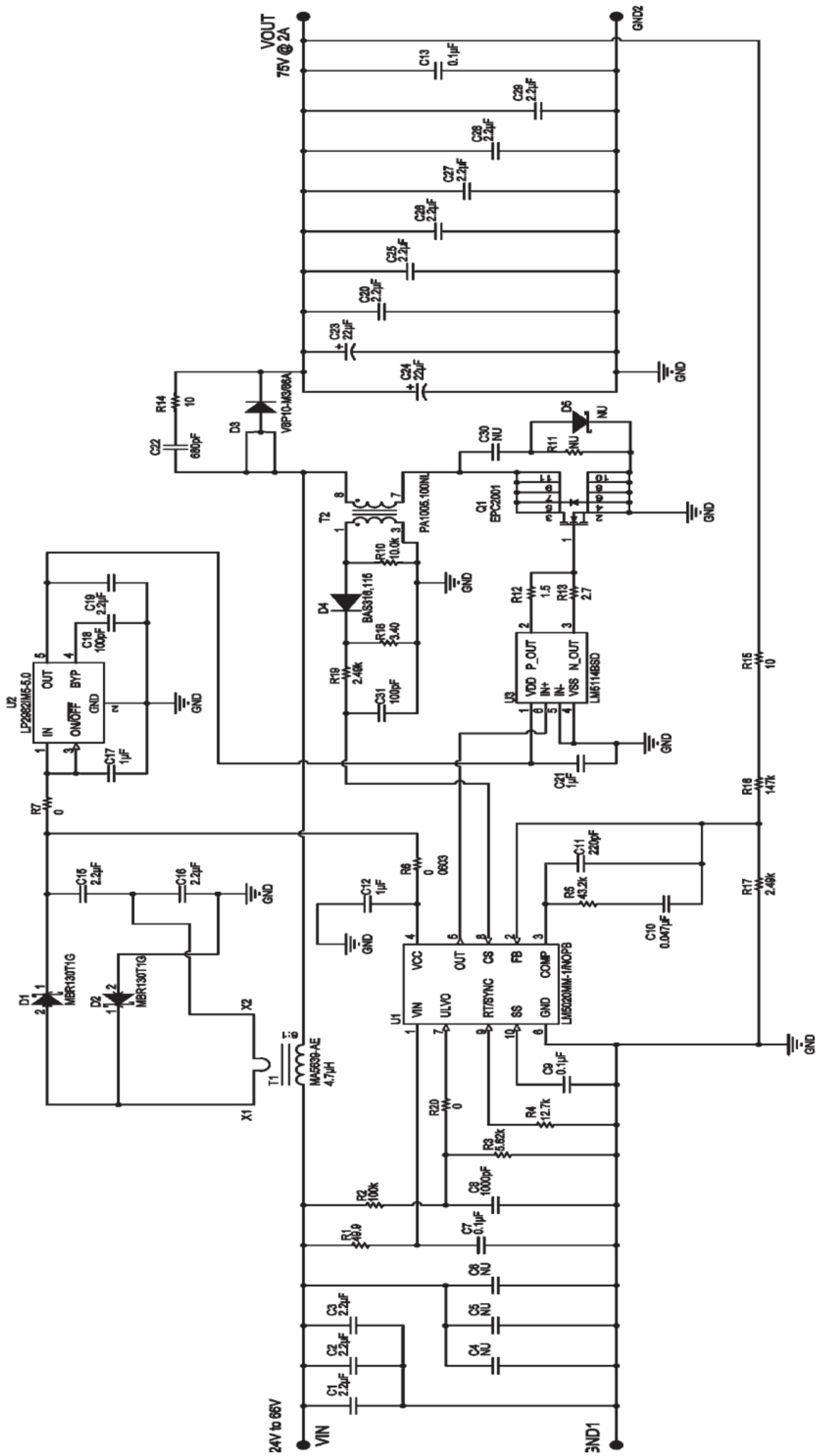


Figure 17. Application Circuit: Input 24 V to 66 V, Output 75 V, 2 A, 500 kHz

8 Bill of Materials

Part	Value	Package	Part Number	Manufacturer
C1, C2, C3, C20, C25, C26, C27, C28, C29	CAP, CERM, 2.2 uF, 100 V, +/-10%, X7R	1210	GRM32ER72A225KA35L	MuRata
C4, C5, C6	NU			
C7, C13	CAP, CERM, 0.1 uF, 100 V, +/-10%, X7R	0805	C0805C104K1RACTU	Kemet
C8	CAP, CERM, 1000 pF, 100 V, +/-5%, C0G/NP0	0603	GRM1885C2A102JA01D	MuRata
C9	CAP, CERM, 0.1 uF, 16 V, +/-10%, X7R	0603	C0603C104K4RACTU	Kemet
C10	CAP, CERM, 0.047 uF, 50 V, +/-10%, X7R	0603	GRM188R71H473KA61D	MuRata
C11	CAP, CERM, 220 pF, 50 V, +/-5%, C0G/NP0	0603	C0603C221K5GACTU	Kemet
C12, C17	CAP, CERM, 1 uF, 16 V, +/-10%, X5R	0603	C0603C105K4PACTU	Kemet
C15, C16	CAP, CERM, 2.2 uF, 25 V, +/-10%, X7R	0805	GRM21BR71E225KA73L	MuRata
C18, C31	CAP, CERM, 100 pF, 50 V, +/-5%, C0G/NP0	0603	C1608C0G1H101J	TDK
C19	CAP, CERM, 2.2 uF, 10 V, +/-10%, X7R	0603	GRM188R71A225KE15D	MuRata
C21	CAP, CERM, 1 uF, 6.3 V, +/-20%, X5R	0402	C1005X5R0J105M	TDK
C22	CAP, CERM, 680 pF, 100 V, +/-10%, X7R	0805	08051C681KAT2A	AVX
C23, C24	CAP, AL, 22 uF, 100 V, +/-20%, 0.55 ohm	SMD	VEJ-220M2ATR-0810	Lelon
C30	NU			
D1, D2	Diode, Schottky, 30 V, 1 A	SOD-123	MBR130T1G	ON Semiconductor
D3	Diode Schottky 8 A 100 V	TO-277	V8P10-M3/86A	Vishay
D4	Diode SW 100 V 250 MA	SOD323	BAS316	NXP Semiconductors
D5	NU			
Q1	eGaN FET, 100 V, 25 A, 7 mΩ	4105um X 1632 um	EPC2001	EPC
R1	RES, 49.9 ohm, 1%, 0.1 W	0603	CRCW060349R9FKEA	Vishay-Dale
R2	RES, 100 k ohm, 1%, 0.1 W	0603	CRCW0603100KFKEA	Vishay-Dale
R3	RES, 5.62 k ohm, 1%, 0.1 W	0603	CRCW06035K62FKEA	Vishay-Dale
R4	RES, 12.7 k ohm, 1%, 0.1 W	0603	RC0603FR-0712K7L	Yageo America
R5	RES, 43.2 k ohm, 1%, 0.1 W	0603	RC0603FR-0743K2L	Yageo America
R6, R7	RES, 0 ohm, 5%, 0.1 W	0603	MCR03EZPJ000	Rohm
R10	RES, 10.0 k ohm, 1%, 0.1 W	0603	RC0603FR-0710KL	Yageo America
R11	NU			
R12	RES, 1.5 ohm, 5%, 0.063 W	0402	CRCW04021R50JNED	Vishay-Dale
R13	RES, 2.7 ohm, 5%, 0.063 W	0402	CRCW04022R70JNED	Vishay-Dale
R14	RES, 10.0 ohm, 1%, 3 W	2512	SCW-SC3LF-10R0-F	TT Electronics
R15	RES, 10 ohm, 5%, 0.1 W	0603	CRCW060310R0JNEA	Vishay-Dale

Part	Value	Package	Part Number	Manufacturer
R16	RES, 147 k ohm, 1%, 0.1 W	0603	CRCW0603147KFKEA	Vishay-Dale
R17, R19	RES, 2.49 k ohm, 1%, 0.1 W	0603	CRCW06032K49FKEA	Vishay-Dale
R18	RES, 3.40 ohm, 1%, 0.1 W	0603	CRCW06033R40FKEA	Vishay-Dale
R20	RES, 0 ohm, 5%, 0.1W	0603	ERJ-3GEY0R00V	Panasonic
T1	Inductor, 4.7 uH, with a single aux winding	SMD 12.6mmX12.7mm	MA5639–AE	Coilcraft
T2	Current Sensing Transformer 100:1	SMT	PA1005.100NL	Pulse Engineering
U1	100 V Current Mode PWM Controller	VSSOP-10	LM5020	Texas Instruments
U2	Micropower 50 mA Ultra Low-Dropout Regulator	5-pin SOT-23	LP2982	Texas Instruments
U3	7.6A Single Low-Side Driver	WQFN-6	LM5114	Texas Instruments

9 PCB Layouts

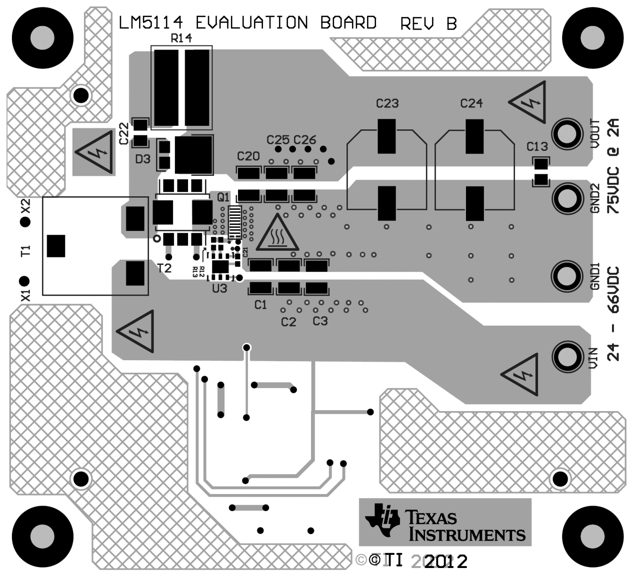


Figure 18. Top Layer Component View

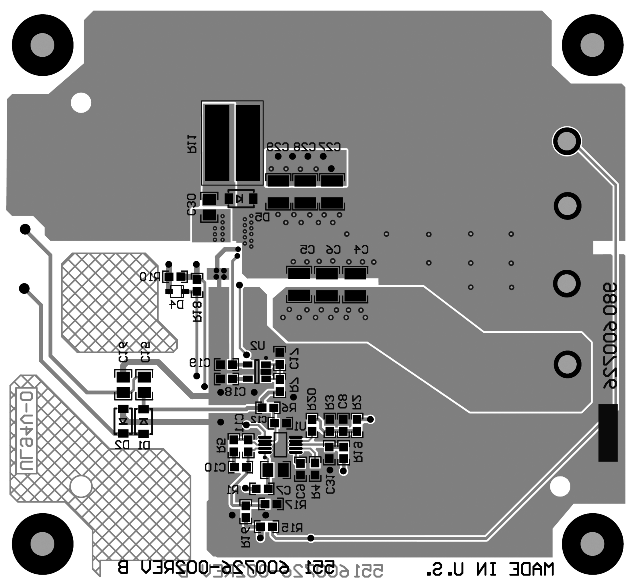


Figure 19. Bottom Layer Component View

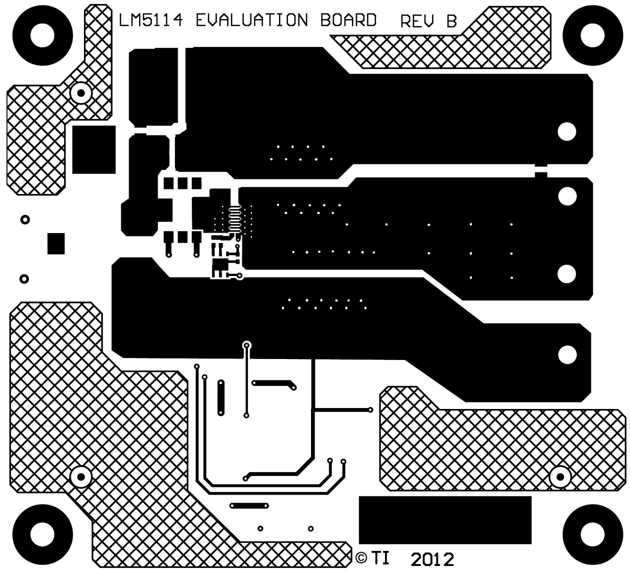


Figure 20. Top Layer

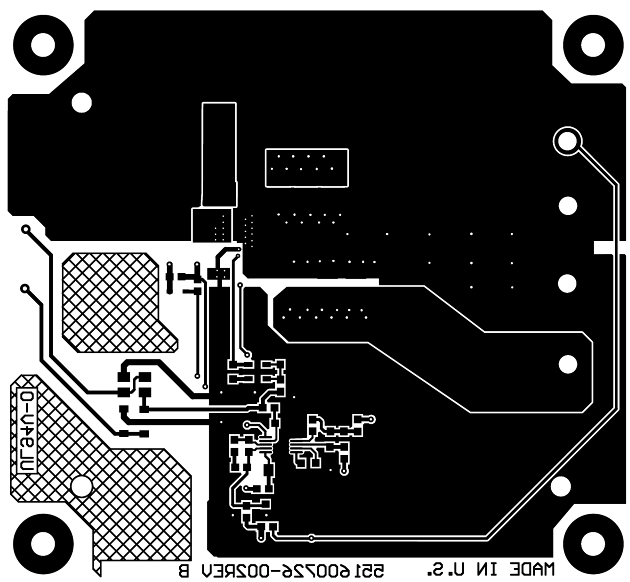


Figure 21. Bottom Layer

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license 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 significant portions 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. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265