AN-1904 LM5037 Evaluation Board

1 Introduction

The LM5037 evaluation board is designed to provide the design engineer with a fully functional power converter based on the half-bridge topology to evaluate the LM5037 controller. The performance of the evaluation board is as follows:

- Input Operating Range: 36V to 72V
- Output Voltage: 5.0V
- Output Current: 0 to 10A
- Measured Efficiency: 88% @ 10A and 48V
- Input Frequency of Operation: 300 kHz
- Board Size: 3.5 × 2.25 × 0.05 inches
- Load Regulation: 2% Line UVLO (34V rising / 31V falling)

The printed circuit board consists of 4 layers of 2 oz copper on FR4 material, with a thickness of 0.050 in. The unit is designed for continuous operation at rated load at <40°C and a minimum airflow of 200 CFM.

2 Theory of Operation

The half-bridge topology belongs to the family of buck converter topologies. The main difference between a buck topology and half-bridge topology is the use of a transformer to isolate the primary and secondary. However, in a half-bridge topology both step-up and step-down of input voltage can be achieved by adjusting the turns ratio of the transformer. Figure 1 illustrates the circuit arrangement for half-bridge topology. 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 switches Q1 and Q2. Switches Q1 and Q2 are turned on alternatively usually with a fixed dead-time. Each cycle, when a switch is turned ON, the primary of the transformer sees one-half the input voltage across it. The LM5037 evaluation board’s transformer primary has 4 turns and the secondary has 2 turns resulting in a 2:1 step down of the voltage applied across the primary. The transformer secondary voltage is then rectified and filtered with an LC filter to provide a smooth output voltage. For an output voltage of 5.0V the composite duty cycle (D) of the primary switches varies from approximately 66% (low line) to 31% (high line).

In the 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 third quadrants of B-H curve. The use of two quadrants allows better utilization of the core resulting in a smaller core volume compared to single-ended topologies such as a forward converter.

The feedback resistors are set such that at the desired output voltage of 5.0V, the voltage at the feedback pin is equal to the internal reference voltage (1.25V). The LM5037 has been configured for voltage mode control. Hence, a standard “type III” network is used for the compensation.

Power dissipation is reduced by raising the VCC voltage using an auxiliary winding of power transformer. The evaluation board can be synchronized to an external clock with a recommended frequency range of 275 kHz to 500 kHz. For more details on synchronization, see *LM5037 Dual-Mode PWM Controller With Alternating Outputs* (SNVS578).

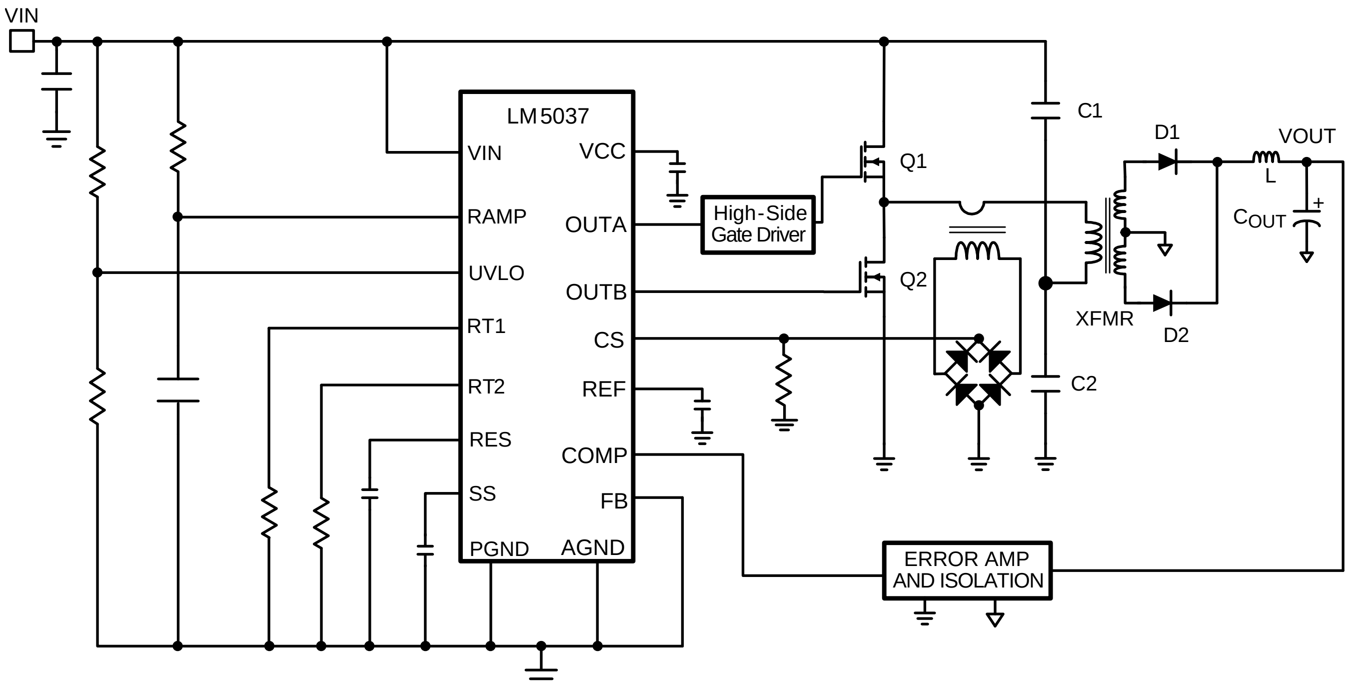


Figure 1. Typical Half-Bridge Circuit

3 Powering and Loading Considerations

When applying power to the LM5037 evaluation board certain precautions need to be followed. A misconnection can damage the assembly.

3.1 Proper Connections

When operated at low input voltages the evaluation board can draw up to 1.5A of current at full load. The maximum rated output current is 10A. 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.

3.2 Source Power

The evaluation board can be viewed as a constant power load. At low input line voltage (36V) the input current can reach 1.5A in steady state, while at high input line voltage (72V) the input current will be approximately 0.75A Therefore, to fully test the LM5037 evaluation board a DC power supply capable of at least 80V and 2A 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.

3.3 Loading

When using electronic load, it is strongly recommended to power up the evaluation board at light load and then slowly increase the load. This is necessary as most of the electronic loads do not draw any current till the output voltage reaches an internally set point; this can result in soft-start function to not work as desired and can trip the current sense comparator. Electronic loads, in general, are best suited for monitoring steady state waveforms. If it is desired to power up the evaluation board at maximum load, resistor banks must be used. This will ensure a soft-start and evaluation board will perform as desired. The high output current requires thick cables! If resistor banks are used there are certain precautions to be taken. The resistance for maximum load is 0.5Ω. The wattage and current ratings must be adequate for a 10A, 50W supply. Monitor both current and voltage at all times. Ensure there is sufficient cooling provided for the load.

3.4 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.

3.5 Powering Up

It is suggested to set the current limit of the source supply to provide about 1.5 times the wattage of the load.

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 under-voltage 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.

3.6 Over Current Protection

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 14A@36V Input) the unit will discharge the soft-start capacitor, which disables the power stage. After a delay the soft-start is released. The shutdown, delay and slow recharge time of the soft-start capacitor protects the unit, especially during a short circuit event where the stress is highest.

4 Typical Application Set-up

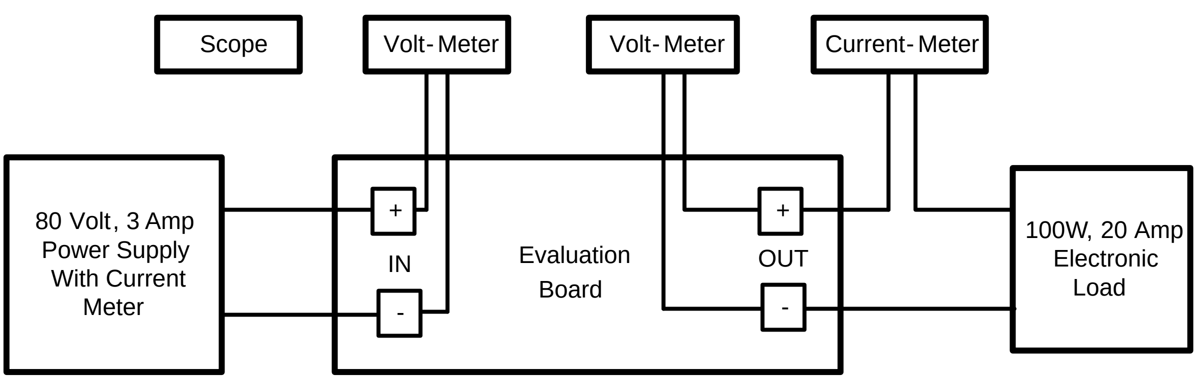


Figure 2. Typical Application Set-up

5 Performance Characteristics

Once the circuit is powered up and running normally, the output voltage is regulated to 5.0V with the accuracy determined by feedback resistors and bandgap reference voltage of the IC. When load current is varied from 5A to 10A, the regulator output is within 100 mV. The frequency of operation is selected to be 250 kHz, which is a good compromise between board size and efficiency. The efficiency of the power converter is measured to be 88% at 48V and 10A. Figure 3 shows the efficiency curve.

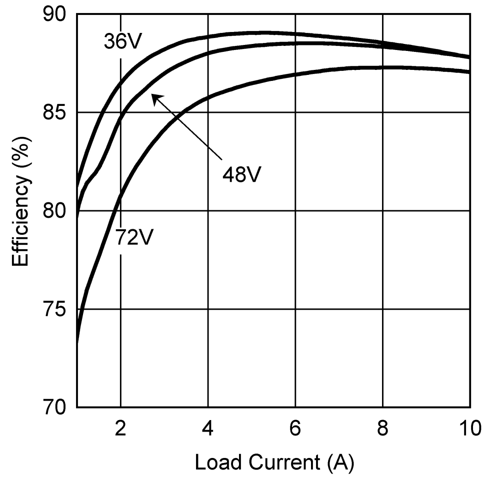
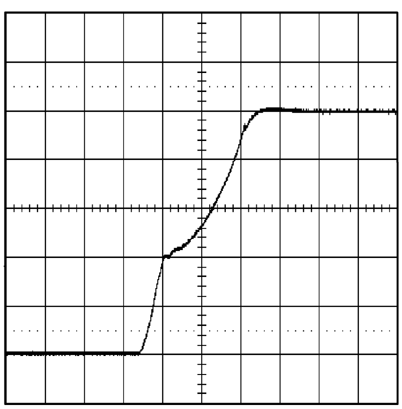


Figure 3. Efficiency vs. Load Current and VIN

6 Waveforms

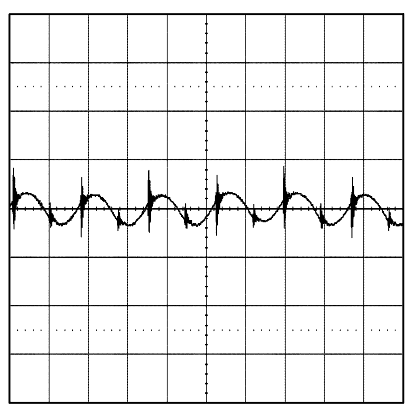
When applying power to the LM5037 evaluation board a certain sequence of events occurs. Soft-start capacitor values and other components allow for a linear increase in output voltage for a short time until the feedback loop can stabilize without an overshoot. Figure 4 shows the output voltage during a typical start-up with a 48V input and a load of 10A. There is no overshoot during startup. It is suggested to use a resistor load instead of an electronic load, while capturing soft-start data as electronic loads tend to (have certain idiosyncrasies of not providing load resistance till the output reaches a preset minimum voltage and thereby occasionally) causing a transient during start-up.

Figure 5 shows typical output ripple seen directly across the output capacitor, for an input voltage of 48V and a load of 10A. This waveform is typical of most loads and input voltages.



Conditions: Input Voltage = 48VDC Output Current = 10A Trace: Output Voltage Volts/div = 1V Horizontal Resolution = 1 msec/div

Figure 4. Soft-Start



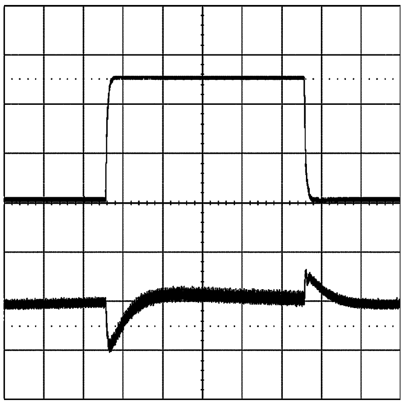
Conditions: Input Voltage = 48VDC Output Current = 10A Bandwidth Limit = 20 MHz Trace: Output Ripple Volts/div = 50 mV Horizontal Resolution = 5.0 µsec/div

Figure 5. Output Ripple

Figure 6 shows the transient response for a load of change from 5A to 10A. The upper trace shows minimal output voltage droop and overshoot during the sudden change in output current shown by the lower trace.

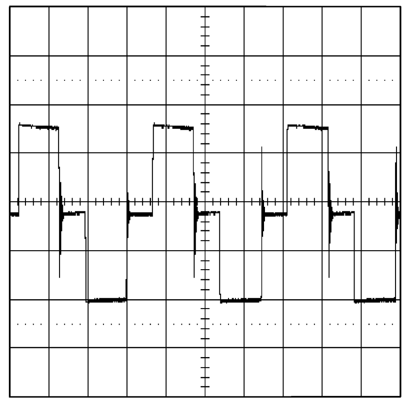
Figure 7 and Figure 8 show the drain voltage waveforms of Q2 with a 10A load and at an input voltage of 36V and 72V, respectively. Drain of Q2 sees the input voltage when it is off and during dead-time it exactly sees input voltage.

Figure 9 shows the soft-stop. This can be achieved by setting the UVLO voltage between 0.4V and 1.25V.



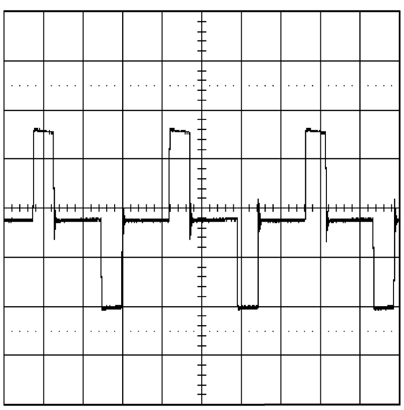
Conditions: Input Voltage = 48VDC Output Current = 5A to 10A Bandwidth Limit = 20 MHz Traces: Top Trace: Output Current Amps/div = 5A Bottom Trace: Output Voltage response Volts/div = 100 mV Horizontal Resolution = 200 µsec/div

Figure 6. Transient Response



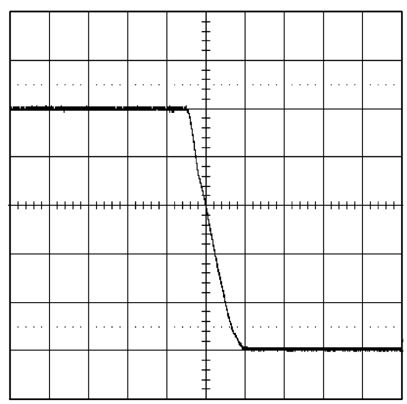
Conditions: Input Voltage = 36VDC Output Current = 10A Trace: Q2 drain to source voltage Volts/div = 10V Horizontal Resolution = 2 µsec/div

Figure 7. Drain Waveform of Q2 at 36V



Conditions: Input Voltage = 72VDC Output Current = 10A Trace: Q2 drain voltage Volts/div = 20V Horizontal Resolution = 2 µsec/div

Figure 8. Drain Waveform of Q2 at 72V



Conditions: Input Voltage = 48VDC Trace: Output Voltage Volts/div = 1V Horizontal Resolution = 1 msec/div

Figure 9. Soft Stop

7 PCB Layout

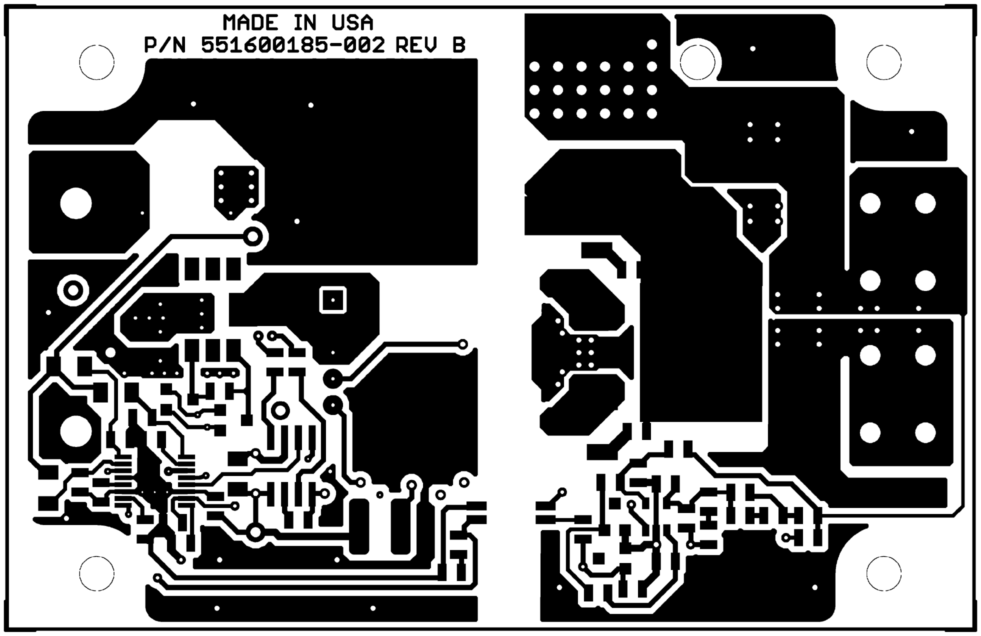


Figure 10. Top Layer

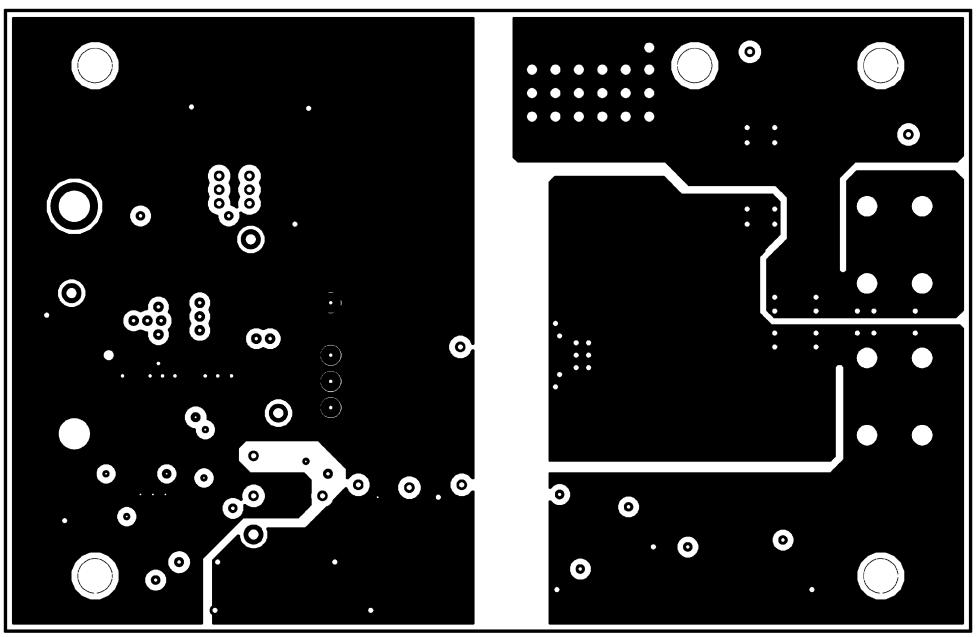


Figure 11. Mid Layer-1

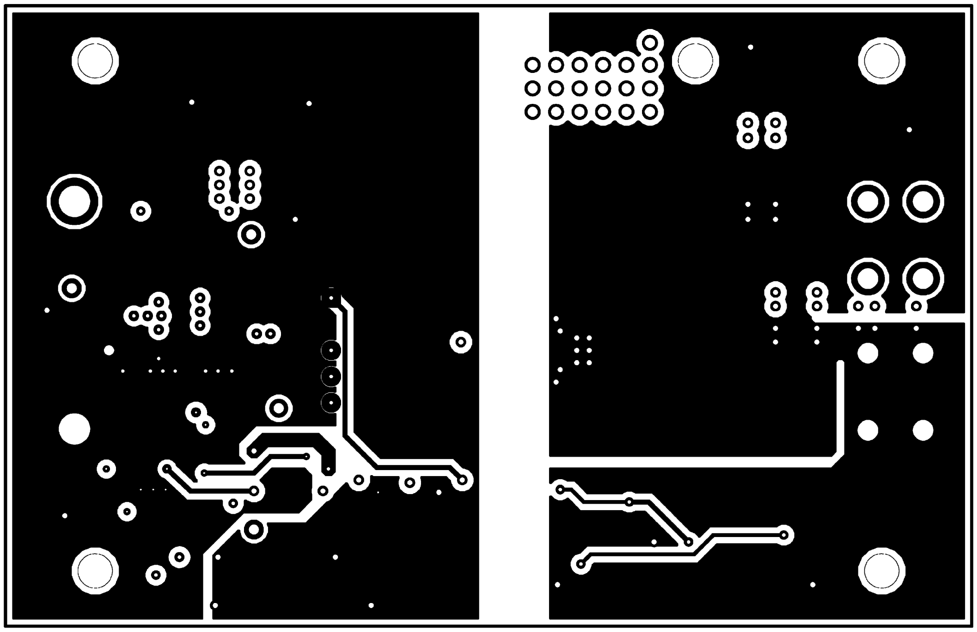


Figure 12. Mid Layer-2

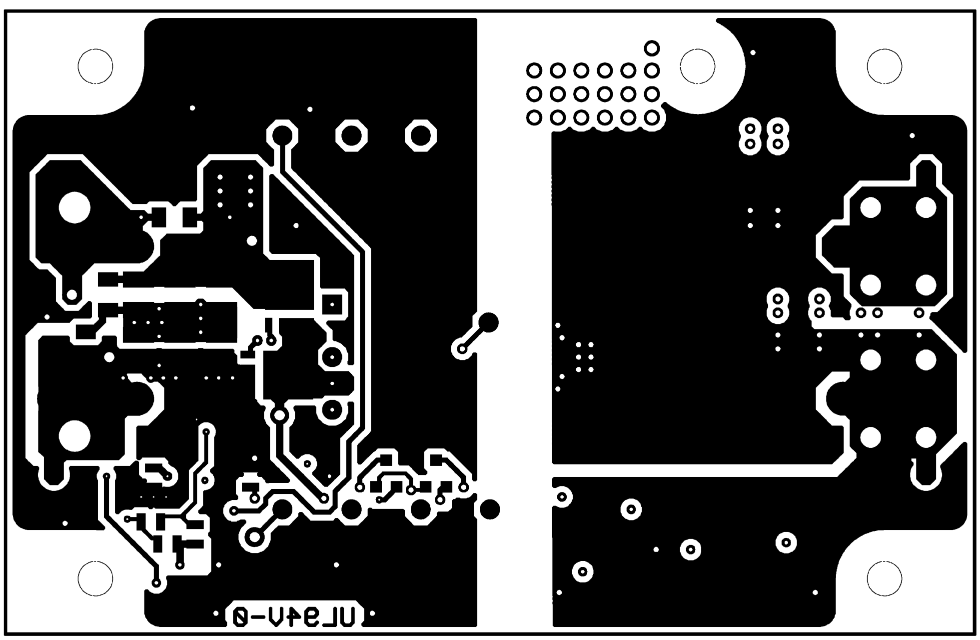


Figure 13. Bottom Layer

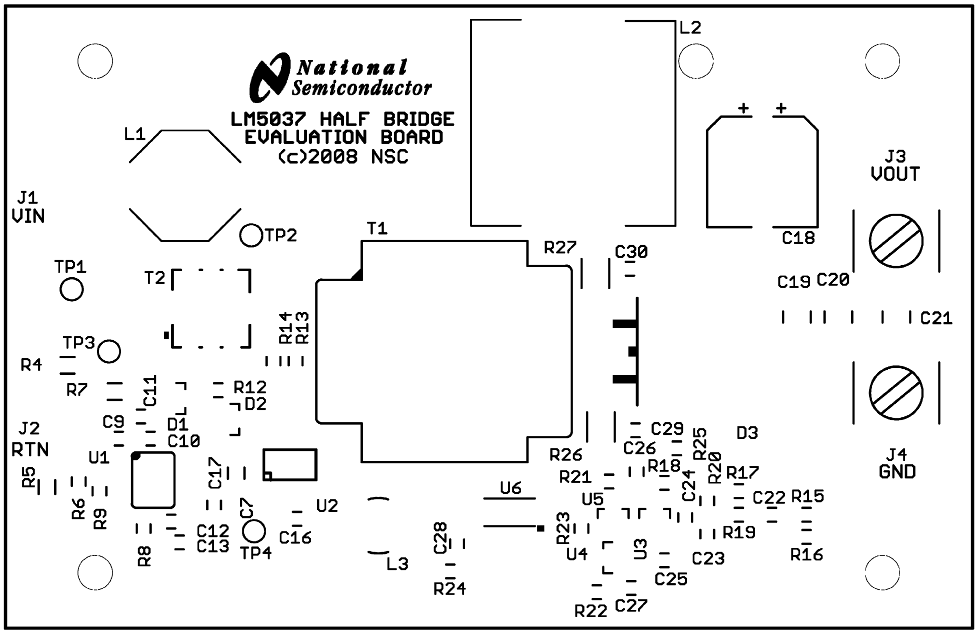


Figure 14. Top Silk Screen

8 Bill of Materials

Table 1. Bill of Materials

Part	Value	Package	Part Number	Manufacturer
C1,C2,C3,C4,C5,C6	4.7 µF	C1210	GCM32ER71H475KA55L	Murata
C7	4.7 µF	C1206	GRM31CR71E475KA88L	Murata
C8,C10,C11,C15,C25,C26	0.1 µF	C0805	GCM21BR72A104KA37L	Murata
C12	0.22 µF	C0805	GRM219R71C224KA01D	Murata
C9,C29,C30	1000 pF	C0805	C0805C102K1RACTU	Kemet
C14,C24	100 pF	C0805	GRM2165C1H101JA01D	Murata
C16	0.047 µF	C0805	GRM21BR72A473KA01L	Murata
C17	0.47 µF	C0805	GRM21BR71E474KC01L	Murata
C18	680 µF	CAPSM_AL_40X45	PCJ1A681MCL1GS	Nippon-Chemicon
C19,C20	47 µF	C1210	GRM32ER61A476KE20L	Murata
C21	1.0 µF	C1210	C1210C105K5RACTU	Kemet
C28	1.0 µF	C0805	GRM21BR71H105KA12L	Murata
C13, C22,C23,C27	10000 pF	C0805	GRM216R71H103KA01D	Murata
D1,D2,D4,D5	Schottky - 1 Pair Series Connection	SOT23	BAS70-04	Diodes Inc
D3	25A,35V Schottky Diode	D2-Pack	MBRB2535	On Semiconductor
L1	2.2 µH	SMD Inductor	SRU1048-2R2Y	Bourns
L2	6.0 µH	SMD Inductor	HC2LP6RO	Coiltronics
L3	3.3 µH	SMD Inductor	SDR0503-332J	Bourns
T1	MAIN XFMR	SM PLANAR	HA3648-BL	Coil Craft
T2	Current XFMR	SMD	P8208	Pulse

Table 1. Bill of Materials (continued)

Part	Value	Package	Part Number	Manufacturer
Q1,Q2	N Channel,100 V MOSFET	SOIC-8	SI4484	Vishay/Siliconix
R1	10.0 Ω	R1206	MCR18EZHF10R0	Rohm
R2,R3	200 kΩ	R1206	MCR18EZHF2003	Rohm
R4	140 kΩ	R1206	MCR18EZHF1403	Rohm
R5	150 kΩ	R1206	MCR18EZHF1503	Rohm
R6	5.76 kΩ	R0805	MCR10EZHF5761	Rohm
R7	49.9 Ω	R1206	MCR18EZHF49R9	Rohm
R8,R17,R18,R20	20.0 kΩ	R0805	MCR10EZHF2002	Rohm
R9	34.8 kΩ	R0805	MCR10EZHF3482	Rohm
R10	499 Ω	R0805	MCR10EZHF4990	Rohm
R11	3.01Ω	R0805	RC0805FR-073R01L	Yageo
R12,R21	10.0 kΩ	R0805	MCR10EZHF1002	Rohm
R13,R14,R15	10.0 Ω	R0805	MCR10EZHJ100	Rohm
R16,R19,R25	100 Ω	R0805	MCR10EZHF1000	Rohm
R22	0 Ω	R0805	MCR10EZHJ000	Rohm
R23	1.50 kΩ	R0805	MCR10EZHF1501	Rohm
R24	249 Ω	R0805	MCR10EZHF2490	Rohm
R26,R27	15.0 Ω	R2010	CRCW201015R0JNEF	Vishay/Dale
U1	PWM IC Controller	TSSOP16	LM5037	Texas Instruments
U2	Dual HV Gate Driver	S08	LM5101	Texas Instruments
U3	OPAMP	SOT23-5	LM8261	Texas Instruments
U4	4.1V Voltage Reference	SOT23	LM4040	Texas Instruments
U5	2.5V Voltage Reference	SOT23	LM4040	Texas Instruments
U6	Opto Coupler	SOP4	PS2811-1M	NEC
J1-J2	Terminal Turret		1509	Keystone Electronics
J3-J4	Terminal Screw, 15A		7693	Keystone Electronics
TP1,TP2,TP3,TP4	Test Point Miniature		1040	Keystone Electronics

9 Application Schematic

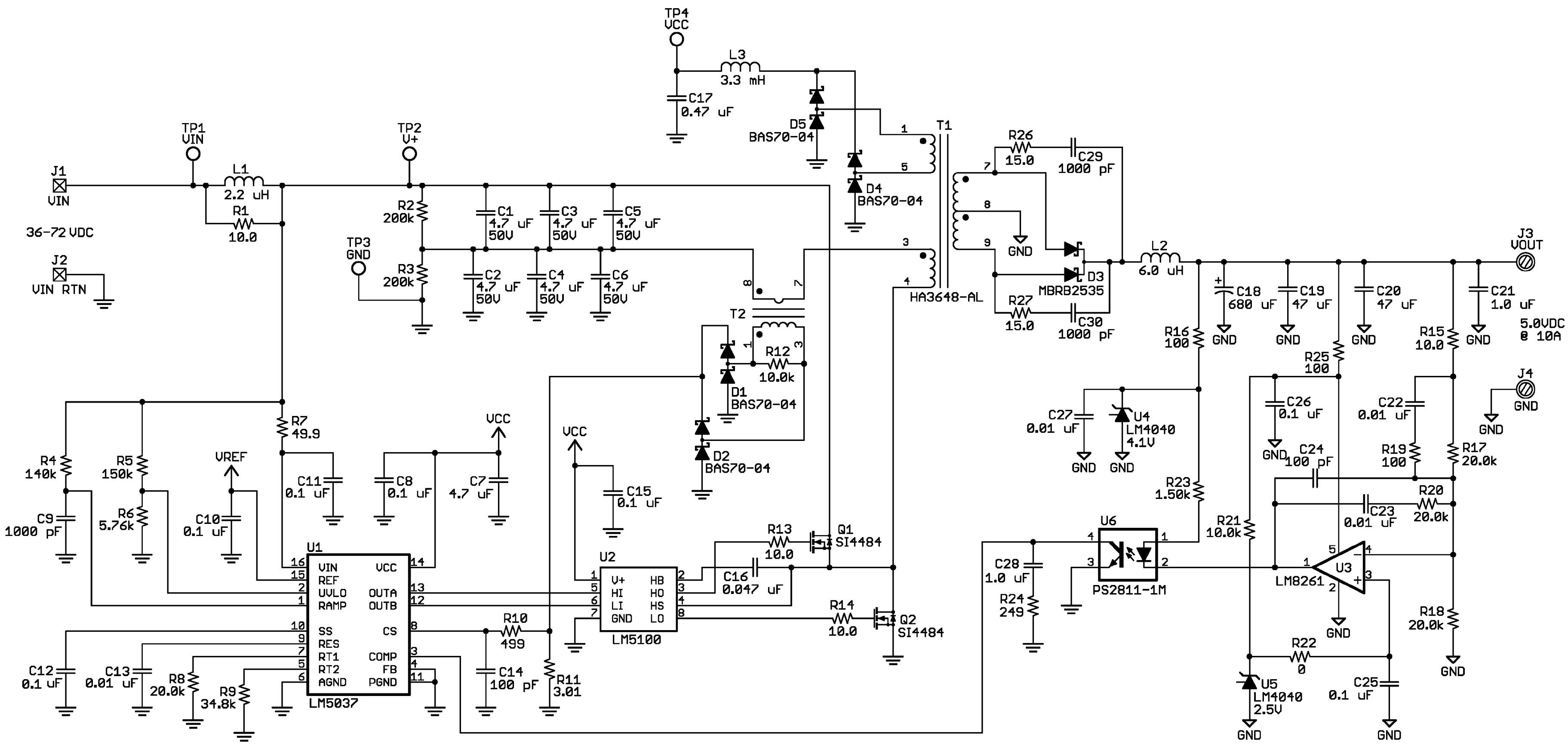


Figure 15. Application Schematic

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