

AN-2111 LM5045 Evaluation Board

The LM5045 evaluation board is designed to provide the design engineer with a fully functional power converter based on the full-bridge topology to evaluate the LM5045 PWM controller. The evaluation board is provided in an industry standard quarter brick footprint.

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1 Introduction

The LM5045 evaluation board is designed to provide the design engineer with a fully functional power converter based on the full-bridge topology to evaluate the LM5045 PWM 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 at 48V: 92% @ 30A
- Frequency of operation: 420kHz
- Board size: 2.28 x 1.45 x 0.5 inches
- Load Regulation: 0.2%
- Line Regulation: 0.1%
- Line UVLO (34V/32V on/off)
- Hiccup Mode 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 LFM.

2 Theory of Operation

Power converters based on the full-bridge topology offer high-efficiency and good power handling capability up to 500W. [Figure 1](#) illustrates the circuit arrangement for the full-bridge topology. The switches, in the diagonal, Q1,Q3 and Q2,Q4 are turned alternatively with a pulse width determined by the input and output voltages and the transformer turns ratio. Each diagonal (Q1 and Q3 or Q2 and Q4), when turned ON, applies input voltage across the primary of the transformer. The resulting secondary voltage is then rectified and filtered with an LC filter to provide a smoothed output voltage. In a full-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. Further, in a half-bridge topology, during power transfer when one of the primary switches is active, the voltage across the primary of the power transformer is 1/2 the input voltage (V_{IN}) compared to a full V_{IN} in a full-bridge topology. Therefore, for a given power, the primary current will be half as much for the full-bridge as compared to the half-bridge. The reduced primary current enables higher efficiency as compared to a half-bridge at high load currents.

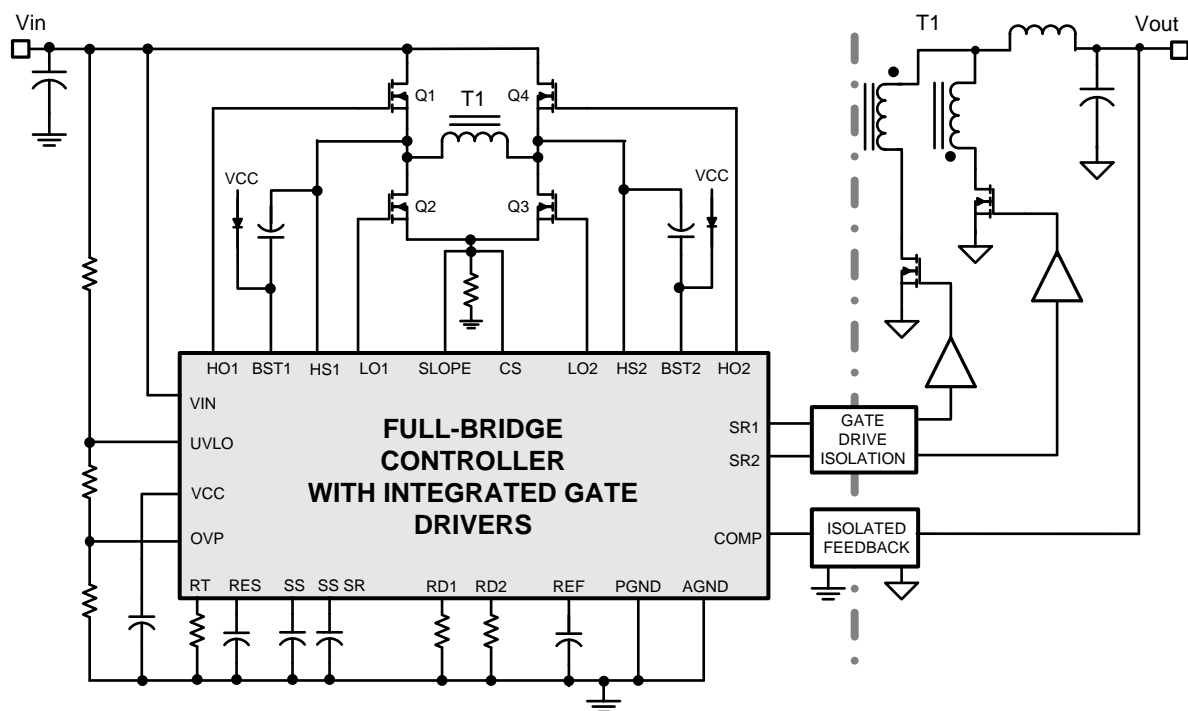


Figure 1. Simplified Full-Bridge Converter

The secondary side employs synchronous rectification scheme, which is controlled by the LM5045. In addition to the basic soft-start already described, the LM5045 contains a second soft-start function that gradually turns on the synchronous rectifiers to their steady-state duty cycle. This function keeps the synchronous rectifiers off until the error amplifier on the secondary side soft-starts, allowing a linear start-up of the output voltage even into pre-biased loads. Then the SR output duty cycle is gradually increased to prevent output voltage disturbances due to the difference in the voltage drop between the body diode and the channel resistance of the synchronous MOSFETs. Once the soft-start is finished, the synchronous rectifiers are engaged with a non-overlap time programmed by the RD1 and RD2 resistors. 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 LM5045 evaluation board employs peak current mode control and a standard "type II" network is used for the compensator.

3 Powering and Loading Considerations

When applying power to the LM5045 evaluation board certain precautions need to be followed. A misconnection can damage the assembly.

4 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.

5 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 LM5045 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.

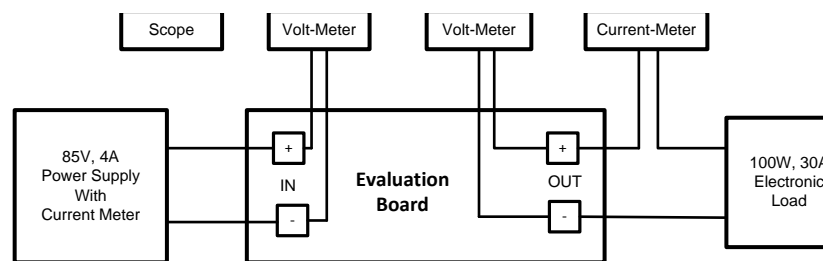
The power supply and cabling must present low impedance to the evaluation board. Insufficient cabling or a high impedance power supply will droop during power supply application with the evaluation board inrush current. If large enough, this droop will cause a chattering condition upon power up. This chattering condition is an interaction with the evaluation board under voltage lockout, the cabling impedance and the inrush current.

6 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.

7 Air Flow

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



8 Powering Up

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 soon as the appropriate input voltage is supplied to the board, 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.

9 Over Current Protection

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 38A) the unit will discharge the SS capacitor, which disables the power stage. After a delay, programmed by the RES capacitor, the SS capacitor is released. If the overload condition persists, this process is repeated. Thus, the converter will be in a loop of shot bursts followed by a sleep time in continuous overload conditions. The sleep time reduces the average input current drawn by the power converter in such a condition and allows the power converter to cool down.

10 Performance Characteristics

Once the circuit is powered up and running normally, the output voltage is regulated to 3.3V with the accuracy determined by the feedback resistors and the voltage reference. The frequency of operation is selected to be 420 kHz, which is a good compromise between board size and efficiency. Please refer to the [Figure 2](#). for efficiency curves.

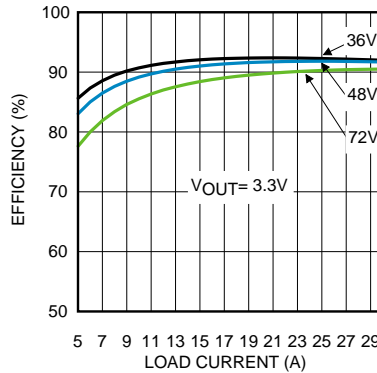
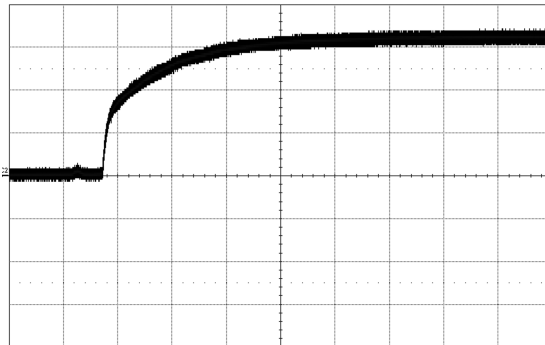


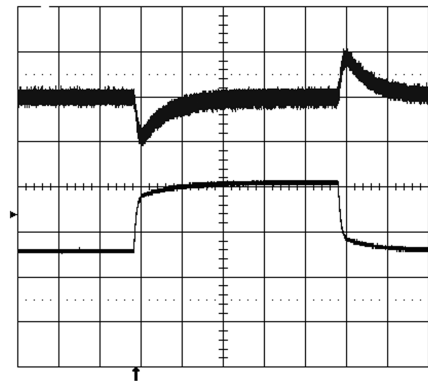
Figure 2. Application Board Efficiency

When applying power to the LM5045 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 3](#) shows the output voltage during a typical start-up with a 48V input and a load of 25A. There is no overshoot during start-up.



Conditions: Input Voltage = 48V
 Output Current = 25A
 Trace 1: Output Voltage Volts/div = 1V
 Horizontal Resolution = 2.0 ms/div

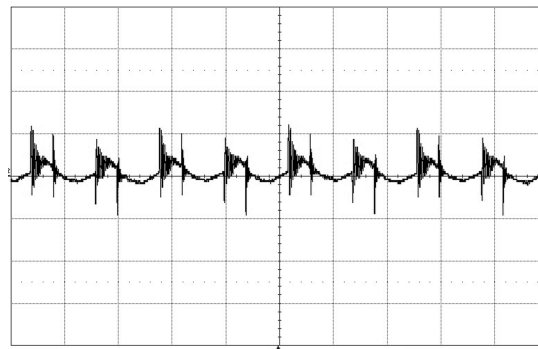
Figure 3. Soft-Start



Conditions: Input Voltage = 48V
 Output Current = 15A to 22.5A to 15A
 Upper Trace: Output Voltage Volts/div = 100mV
 Lower Trace: Output Current = 5A/div
 Horizontal Resolution = 200 μ s/div

Figure 4. Transient Response

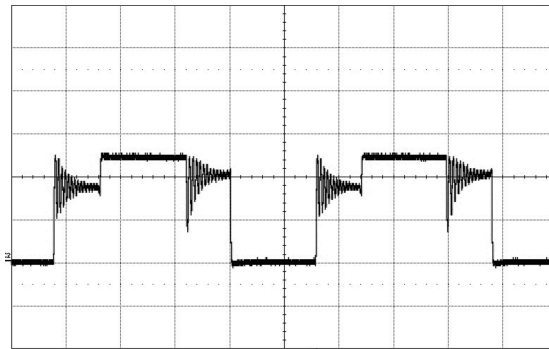
Figure 5 shows typical output ripple seen directly across the output capacitor, for an input voltage of 48V and a load of 30A. This waveform is typical of most loads and input voltages.



Conditions: Input Voltage = 48V, Output Current = 30A
 Trace 1: Output Voltage Volts/div = 50mV
 Bandwidth Limit = 20MHz
 Horizontal Resolution = 2 μ s/div

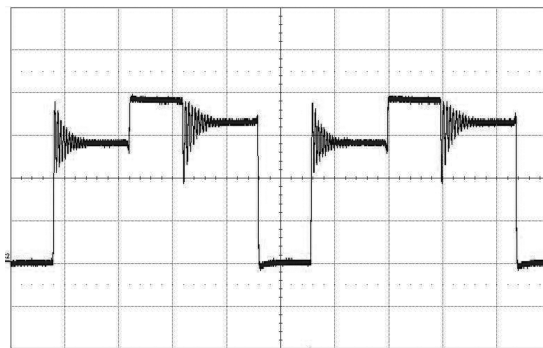
Figure 5. Output Ripple

Figure 6 and Figure 7 show the typical SW node voltage waveforms with a 25A load. Figure 6 shows an input voltage represents an input voltage of 48V and Figure 7 represents an input voltage of 72V.



Conditions: Input Voltage = 48V
 Output Current = 30A
 Trace 1: SW1 Node (Q2 Drain) Voltage Volts/div = 20V
 Horizontal Resolution = 1µs/div

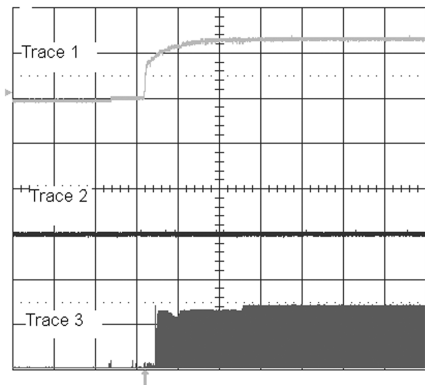
Figure 6. Switch Node Waveforms



Conditions: Input Voltage = 72V
 Output Current = 30A
 Trace 1: SW1 Node (Q2 Drain) Voltage Volts/div = 20V
 Horizontal Resolution = 1 µs/div

Figure 7. Switch Node Waveforms

Figure 8 shows a typical startup of the LM5045 into a 2V pre-biased load. Trace 2 represents the output current that is monitored between the output caps of the power converter and the 2V pre-bias voltage supply. It can be inferred from the Trace 2 that the SR MOSFET's do not sink any current during the power-up into pre-biased load.



Conditions: Input Voltage = 48V, Output Pre-Bias = 2V
 Trace 1 (Channel 4): Output Voltage Volts/div = 1V
 Trace 2 (Channel 2): Output Current Amps/div = 200mA
 Trace 3 (Channel 3): SR Gate Voltage Volts/div = 5V

Figure 8. Soft-Start into 2V Pre-Biased Load

11 5V Evaluation Board

The LM5045 evaluation board can be easily modified to achieve a 5V output at 30A load. The 5V board schematic and the Bill of Materials change required to achieve it are shown below. A peak efficiency of 93% was observed at 48V input and 5V out at 30A.

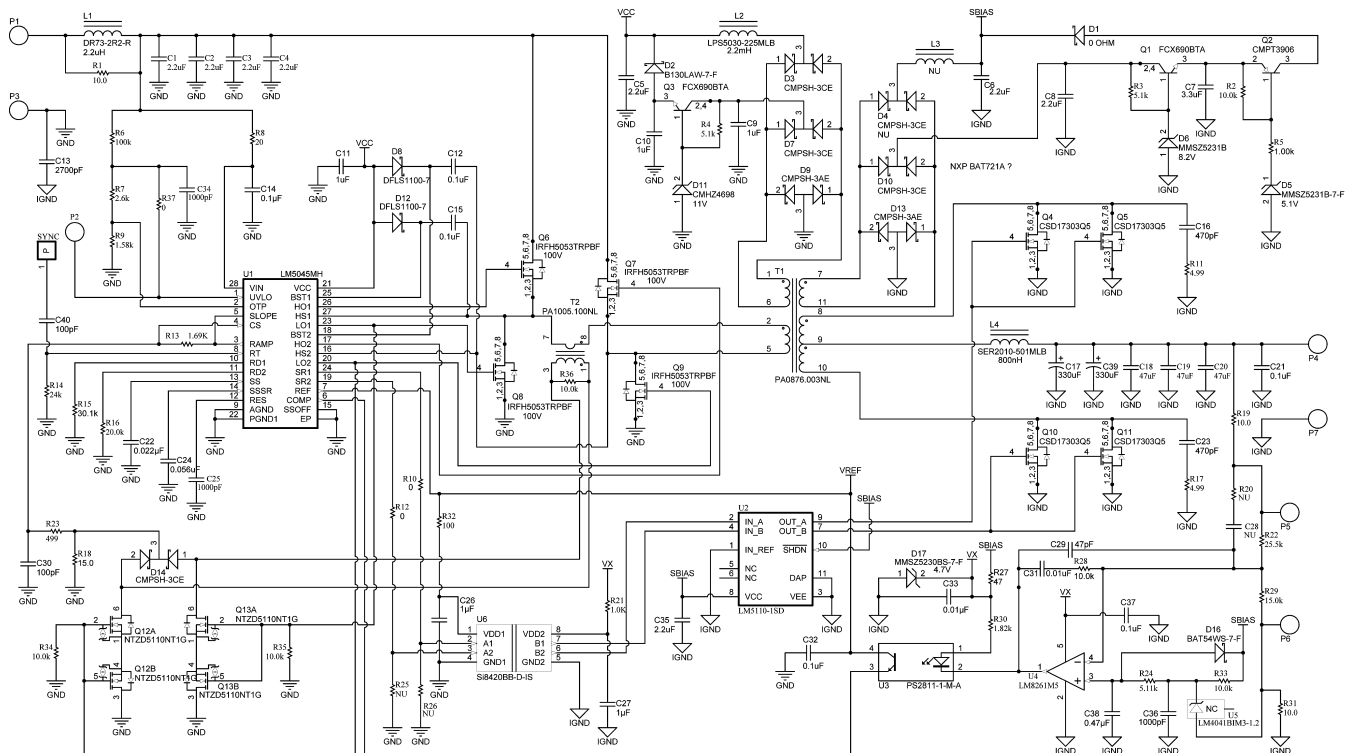


Figure 9. Application Circuit: Input 36V to 75V, Output 3.3V at 30A

12 Bill of Materials

Item	Designator	Description	Part Number
1	AA	Printed Circuit Board	
2	C1, C2, C3, C4	Ceramic 2.2uF, X7R, 100V, 10%, 1210	GRM32ER72A225KA35L
3	C5, C35	Ceramic 2.2uF, X7R, 16V, 10%, 0805	GRM21BR71C225KA12L
4	C7, C8	Ceramic, 2.2uF, X5R, 25V, 10%, 0805	GRM21BR71E225KA73L
5	C9	Ceramic, 1uF, X7R, 50V, 10%, 0805	GRM21BR71H105KA12L
6	C6	Ceramic 2.2uF 10V X7R 0603	GRM188R71A225KE15D
7	C10, C11	Ceramic, 1uF, X7R, 16V, 10%, 0603	C1608X7R1C105K
8	C12, C15, C21, C32	Ceramic, 0.1uF, X7R, 25V, 10%, 0603	06033C104KAT2A
9	C13	Ceramic, X7R, 2000V, 2700pF, 10%	C1808C272KGRACTU
10	C14	Ceramic 0.1uF, 100V, +/-10%, X7R, 0603	GRM188R72A104KA35D
11	C16, C23	Ceramic, C0G/NP0 470pF, 100V, 10%, 1206	12061A471KAT2A
12	C17, C39	Cap 330uF, 4V, AL, 4V, 20%, 0.012 ohm ESR	EEF-UE0G331R
13	C18, C19, C20	Ceramic 47uF, X7R, 6.3V, 10%	GCM32ER70J476KE19L
14	C22	Ceramic 0.022uF, 16V, +/-10%, X7R, 0402	C1005X7R1C223K
15	C34, C36	Ceramic 1000pF, 25V, +/-5%, C0G/NP0, 0402,	C1005C0G1E102J
16	C26, C27	Ceramic 0.47uF, 16V, +/-20%, X7R, 0805	GRM21BR71C474KCO1D
17	C28, R20, D4, L3	NU	NU
18	C29	Ceramic 47pF, 50V, +/-5%, C0G/NP0, 0402	GRM1555C1H470JZ01
19	C30, C40	Ceramic 100pF, C0G/NP0, 50V, 5%, 0603	C1608C0G1H101J
20	C24	CAP, CERM, 0.056uF, 6.3V, +/-10%, X7R, 0402	C0402C563K9RACTU
21	C25, C31, C37, C33	CAP, CERM, 0.01uF, 16V, +/-10%, X7R, 0402	C1005X7R103K
22	C38	CAP, CERM, 0.47uF, 6.3V, +/-10%, X5R, 0402	C1005X5R0J474K
23	D2	Vr = 30V, Io = 1A, Vf = 0.38V	B130LAW-7-F
24	D3, D7, D10, D14	Vr = 40V, Io = 0.2A, Vf = 0.65V, Common Cathode	CMPSH-3CE
25	D5	SMT 5.1V Zener Diode	MMSZ5231B
26	D6	SMT 8.2V Zener Diode	CMHZ4694
27	D8, D12	Vr = 100V, Io = 1A, Vf = 0.77V, Schottky diode	DFLS1100-7
28	D9, D13	Vr = 40V, Io = 0.2A, Vf = 0.65V, Common Anode	CMPSH-3AE
29	D11	SMT 11V Zener Diode	CMHZ4698
30	D16	Vr = 30V, Io = 0.2A, Vf = 0.7V, Schottky	BAT54WS-7-F
31	D17	Diode, Zener, 4.7V, 250mW, SOD-323	CMDZ4L7
32	L1	Shielded Drum Core, 2.2uH 4.15A, 0.0165 ohm	DR73-2R2-R
33	L2	Shielded Drum Core, 0.08A, 11 ohm	LPS5030-225MLB
34	L3	NU	NU
35	L4	Inductor, Shielded E Core, Ferrite, 800nH, 45A, 0.0009 ohm, SMD	SER2010-801MLB
36	P1, P3, P5, P6	PCB Pin	3104-2-00-34-00-00-08-0
37	P2	Test Point, SMT, Miniature	5015
38	P4, P7	PCB Pin	3231-2-00-34-00-00-08-0

Item	Designator	Description	Part Number
39	Q1, Q3	NPN, 2A, 45V	FCX690BTA
40	Q2	PNP, 0.2A, 40V	CMPT3906
41	Q4, Q5, Q10, Q11	32A, 18nC, rDS(on) @ 4.5V = .002 ohm	CSD17303Q5
42	Q6, Q7, Q8, Q9	MOSFET, N-CH, 100V, 9.3A, PQFN 8L 5x6 A	IRFH5053TRPBF
43	Q12, Q13	0.31A, 0.7nC, rDS(on) @ 4.5V =2.5 ohm	NTZD5110NT1G
44	R1	RES 10 ohm 1%, 0.125W, 0805	CRCW080510R0FKEA
45	R2, R28, R33, R34, R35, R36	RES 10K ohm 1%, 0.063W, 0402	CRCW040210k0FKED
46	R3, R4	RES 5.1K ohm 5%, 0.125W, 0805	ERJ-6GEYJ512V
47	R5	RES 1K ohm, 5.1, 0.125W, 0805	CRCW08051K00FKEA
48	R6	RES 100K ohm,1%, 0.125W, 0805	CRCW0805100KFKEA
49	R7	RES, 2.61k ohm, 1%, 0.063W, 0402	CRCW04022K61FKED
50	R8	RES 20 ohm 1/8W 5% 0805 SMD	ERJ-6GEYJ200V
51	R9	RES, 1.58k ohm, 1%, 0.063W, 0402	CRCW04021K58FKED
52	R10, R12	RES, 0 ohm, 5%, 0.063W, 0402	RC0402JR-070RL
53	R11, R17	RES 4.99 ohm,1%, 0.25W, 1206	CRCW12064R99FNEA
54	R13	RES, 1.69k ohm, 1%, 0.063W, 0402	CRCW04021K69FKED
55	R14	RES 24K, 5%, 0.063W, 0402	CRCW040224k0JNED
56	R15	RES, 30.1k ohm, 1%, 0.063W, 0402	CRCW040230K1FKED
57	R16	RES 20k ohm,1%, 0.063W, 0402	CRCW040220k0FKED
58	R18	RES, 15.0 ohm, 1%, 0.063W, 0402	CRCW040215R0FKED
59	R19, R31	RES 10.0 ohm, 1%, 0.063W, 0402	CRCW0402750RFKED
60	R21	RES 750 ohm 1/16W 5% 0402 SMD	CRCW04021K00JNED
61	R22	RES 25.5k ohm,1%, 0.063W, 0402	CRCW040225k5FKED
62	R23	RES 499 ohm, 1%, 0.063W, 0402	CRCW0402499RFKED
63	R24	RES 5.11k ohm, 1%, 0.063W, 0402	CRCW04025k11FKED
64	R25, R26	NU	NU
65	R27	RES 47 ohm .25W 5% 0603 SMD	CRCW060347R0JNEAHP
66	R32	RES 100 ohm, 1%, 0.063W, 0402	CRCW0402100RFKED
67	R29	RES 15k ohm,1%, 0.063W, 0402	CRCW040215k0FKED
68	R30	RES 1.82k ohm,1%, 0.063W, 0402	CRCW04021k82FKED
69	R37	RES 0.0 ohm, 5%, 0.063W, 0402	CRCW04020000Z0ED
70	D1	RES 0.0 ohm, 5%, 0.063W, 1206	CRCW12060000Z0EA
71	T1	High Frequency Planar Transformer	PA0876.003NL
72	T2	SMT Current Sense Transformer	PA1005.100NL
73	U1	Full-Bridge PWM Controller	LM5045MH
74	U2	Dual 5A Compound Gate Driver with Negative Output Voltage Capability	LM5110-1SD
75	U3	Low Input Current, High CTR Photo-coupler	PS2811-1-M-A
76	U4	RRIO, High Output Current & Unlimited Cap Load Op Amp in SOT23-5	LM8261M5
77	U5	Precision Micro-power Shunt Voltage Reference	LM4041BIM3-1.2
78	U6	Dual-Channel Digital Isolator	ISO7420FED

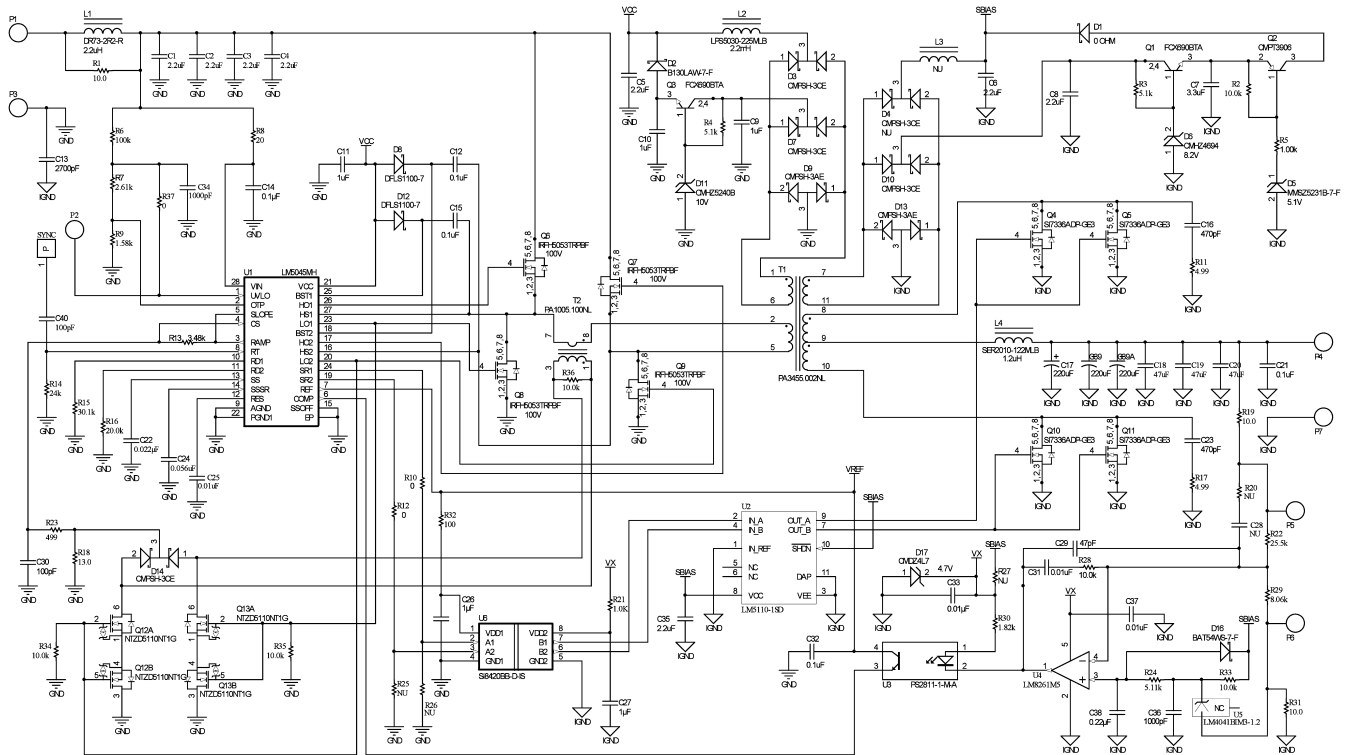


Figure 10. Application Circuit: Input 36V to 75V, Output 5V at 30A

13 Bill of Materials*

Item	Designator	Description	Manufacturer	Part Number
1	C17, C39, C39A	Cap 220uF, 6.3V, AL, 4V, 20%, 0.012 ohm ESR	Panasonic	EEF-UE0G331R
2	L4	Inductor, Shielded E Core, Ferrite, 1.2uH, 36A, 0.0009 ohm, SMD	Coilcraft	SER2010-122MLB
3	R13	RES, 3.48k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04023K48FKED
4	R18	RES, 13.0 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040213R0FKED
5	R29	RES 8.06k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040280k6FKED
6	T1	High Frequency Planar Transformer	Pulse Engineering	PA3455.002NL
7	D11	SMT10V Diode	Central Semiconductor	CMHZ5240B
8	C38	CAP Ceramic 0.22uF 6.3V +/-10% X5R 0402	TDK Corporation	C1005X5R0J224K

***Note:** All the other parts are the same as 3.3V evaluation board.

14 PCB Layouts

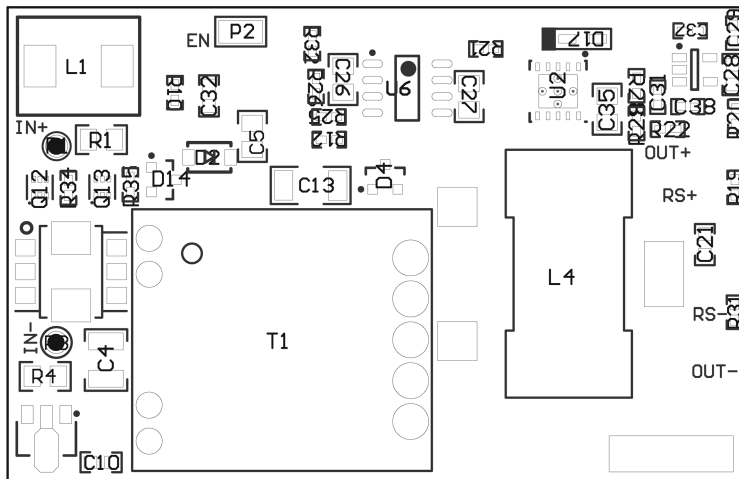


Figure 11. Top Side Assembly

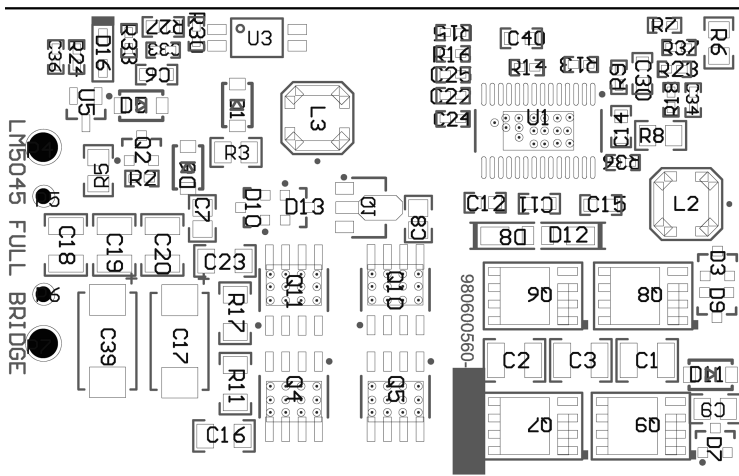


Figure 12. Bottom Side Assembly

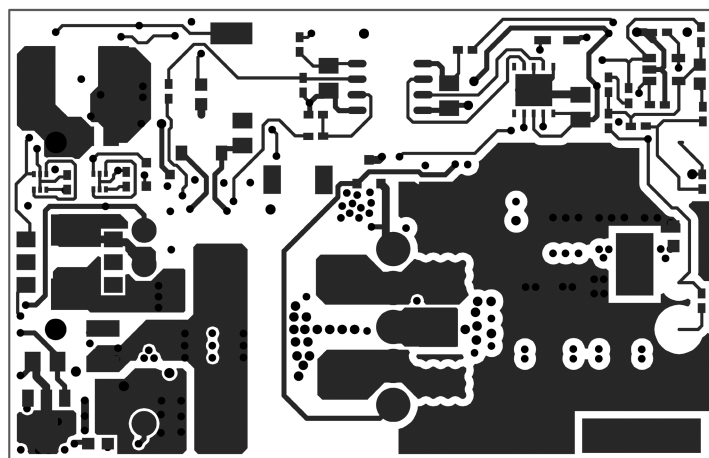


Figure 13. Layer 1 (Top Side)

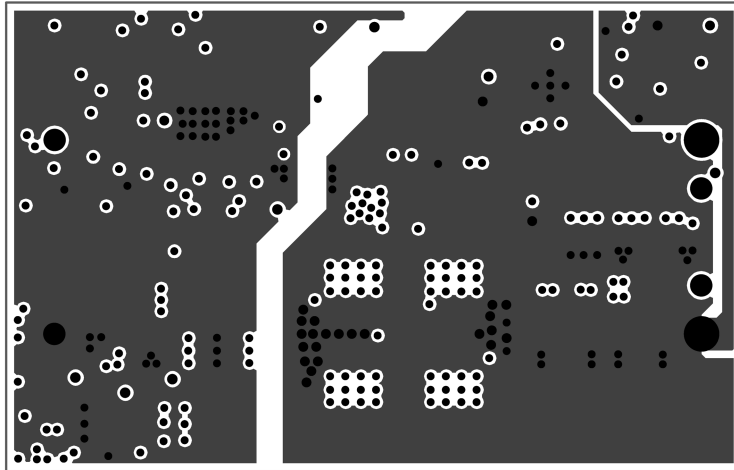


Figure 14. Layer 2

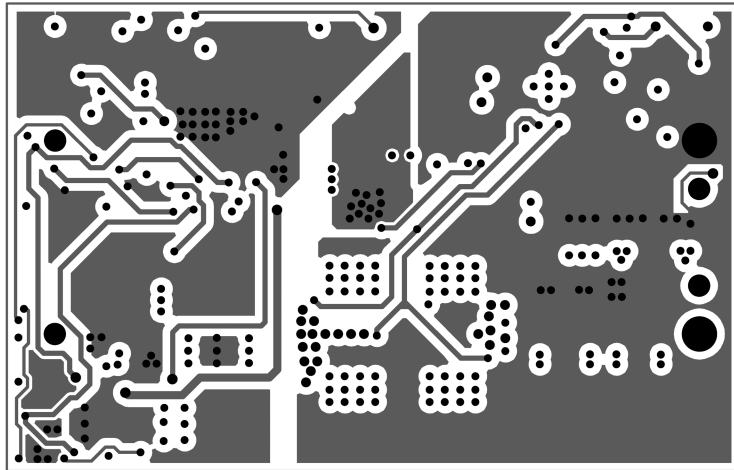


Figure 15. Layer 3

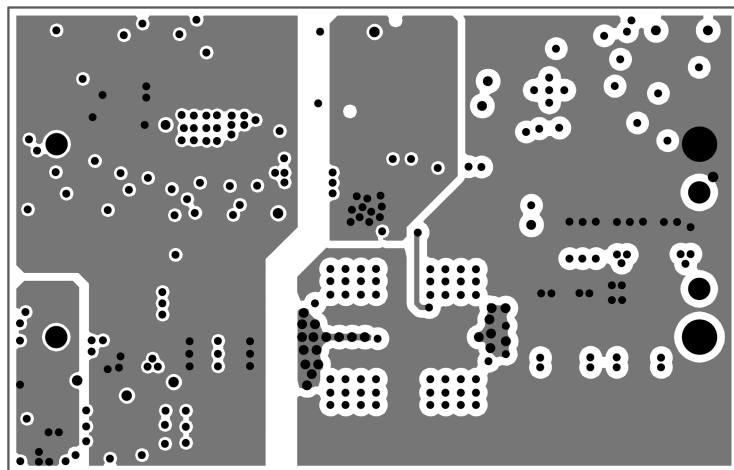


Figure 16. Layer 4

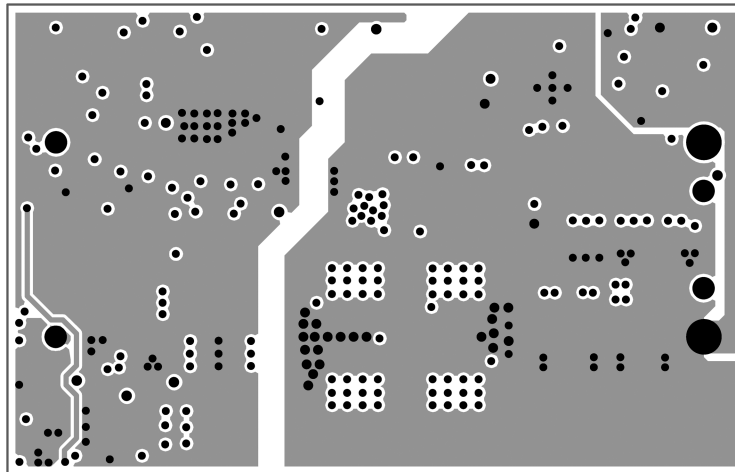


Figure 17. Layer 5

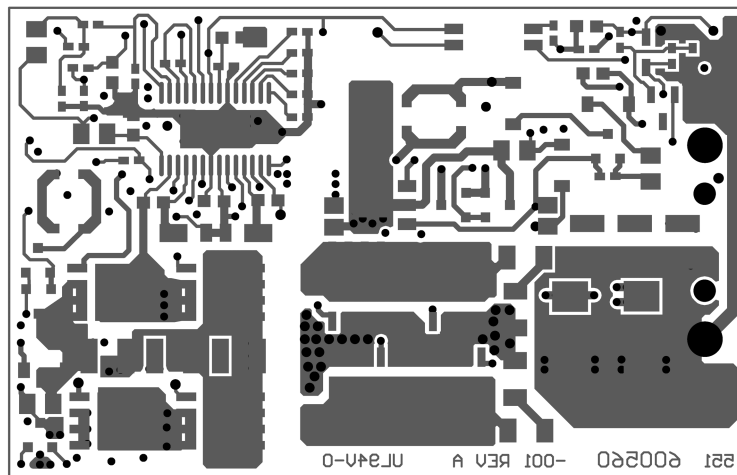


Figure 18. Layer 6 (Bottom Side)

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For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible 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, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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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.

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