EVM User's Guide: LMG2640EVM-090

LMG2640 Half-Bridge Daughter Card Evaluation Module

Description

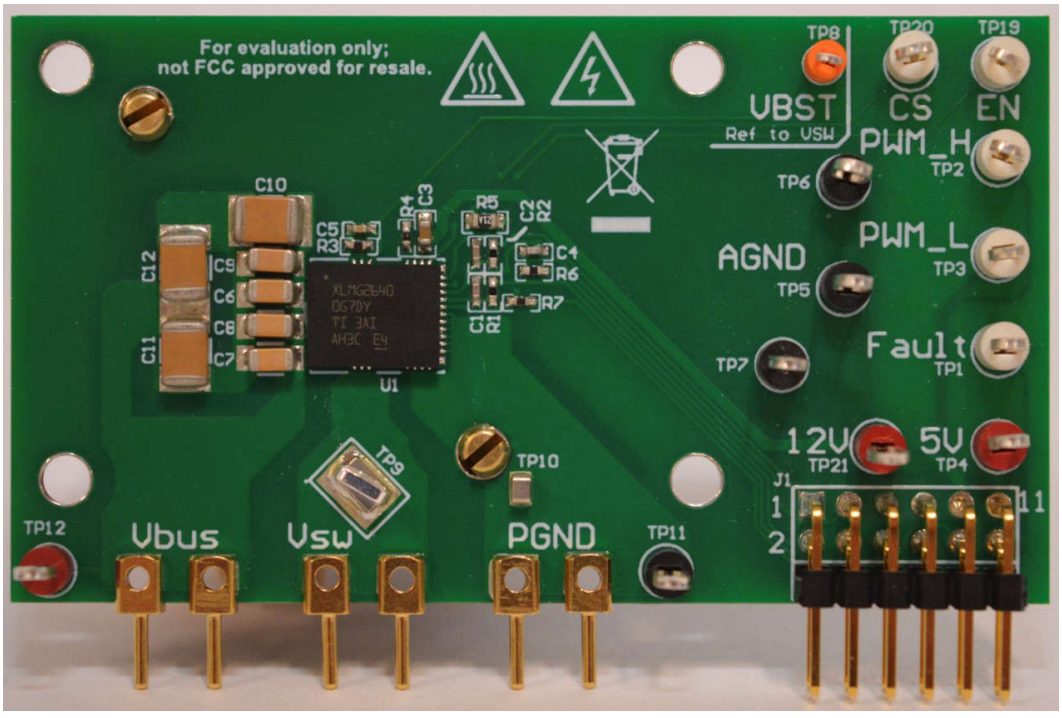
The LMG2640EVM-090 is designed to provide a quick and easy platform to evaluate TI integrated GaN devices in any half-bridge topology. The board is designed to be interfaced with a larger system using the 6 power pins and 10 digital pins on the bottom edge of the board in a socket style external connection. Power pins form the main switching loop consisting of a high voltage DC bus, switch node, and power ground. The digital pins control the LMG2640 device with PWM gate inputs, provide auxiliary power with low voltage supplies, and report faults as a digital output. Essential power stage and gate-driving, high-frequency current loops are fully enclosed on the board to minimize power loop parasitic inductance for reducing voltage overshoots and improving performance. Evaluating the LMG2640EVM performance is most easily demonstrated using a synchronous buck/boost motherboard from TI (LMG342X-BB-EVM). The daughtercard easily plugs into the motherboard and interfaces all power and digital control in an open-loop configuration for full system control. Additionally, a recommended footprint is provided to interface the daughtercard with a custom system for further testing. Refer to the LMG2640 data sheet before using this EVM.

Features

- High-side gate-drive level shifter
- Smart-switched bootstrap diode function: 0 QRR
- Integrated lossless current sensing output measurement
- Low-side and high-side cycle-by-cycle overcurrent protection and overtemperature protection connected to output FAULT signal
- Absolute maximum voltage rating of 650V

Applications

- LLC or TPPFC for gaming, PoE, monitor PSU, PD adapter
- ACF, AHB for PD adapter, server aux
- Motor drive inverter for hair dryer, vacuum, servo motor
- Inverter or micro-inverter for solar, renewable energy
- Buck or boost converters



1 Evaluation Module Overview

1.1 Introduction

The LMG2640EVM-090 operates as a half-bridge daughter card that can be either part of a larger custom designed system or paired with the mother board. TI provides a mother board (LMG342X-BB-EVM) to interface with LMG2640EVM-090. LMG342X-BB-EVM can support up to 4kW. The mother board is designed to operate LMG2640 in an open-loop synchronous buck or boost converters. Probe locations are provided to measure the logic and power stage voltages. This board assembly is not a good choice for Double Pulse Testing (DPT).

The LMG2640EVM-090 is designed for use in AC/DC, DC/DC and DC/AC applications.

1.2 Kit Contents

- One LMG2640EVM-090 board
- EVM disclaimer Read Me

1.3 Specification

The mother boards have the following features and specifications:

- Requires only a single 12V bias supply
- Requires only a single 0V to 5V PWM input to generate a gate drive signal
- PWM disables in the event of a fault from the LMG2640EVM-090
- Maximum recommended operating voltage of 480-V and absolute maximum voltage of 650V

1.4 Device Information

The LMG2640EVM-090 features one LMG2640 650V GaN FET with integrated drivers and protections in a half-bridge configuration with all the required bias circuit and logic/power level shifting. Essential power stage and gate-driving, high-frequency current loops are fully enclosed on the board to minimize power loop parasitic inductance for reducing voltage overshoots and improving performance. The LMG2640EVM-090 is configured for a socket style external connection for easy interface with external power stages to run the LMG2640 in various applications. Refer to the LMG2640 data sheet before using this EVM.

1.5 General TI High Voltage Evaluation User Safety Guidelines

Always follow TI's set-up and application instructions, including the use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center at http://support/ti./com for further information.

Note

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions can result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed PCB (printed circuit board) assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use or application is strictly prohibited by Texas Instruments. If you are not suitably qualified, you must immediately stop from further use of the HV EVM.

- **Work Area Safety:**
  - Maintain a clean and orderly work area.
  - Qualified observers must be present anytime circuits are energized.
  - Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized; indicating operation of accessible high voltages can be present for the purpose of protecting inadvertent access.
  - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50 VRMS/75 VDC must be electrically located within a protected Emergency Power Off (EPO) power strip.
  - Use a stable and non-conductive work surface.
  - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
- **Electrical Safety:**
  - As a precautionary measure, a good engineering practice to assume that the entire EVM can have fully accessible and active high voltages.
  - De-energize the TI HV EVM and all the inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
  - After confirming the EVM is de-energized, proceed with the required electrical circuit configurations, wiring, measurement equipment hook-ups, and other application needs while still assuming the EVM circuit and measuring instruments are electrically live.
  - When EVM readiness is complete, energize the EVM as intended.

WARNING

While the EVM is energized, never touch the EVM or the electrical circuits as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.

- **Personal Safety:**
  - Wear personal protective equipment like latex gloves and safety glasses with side shields, or protect the EVM from accidental touch in an adequate translucent plastic box with interlocks.
- **Limitation for Safe Use:**
  - EVMs are not to be used as all or part of a production unit.

1.5.1 Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training and is designed to operate from an AC power supply or a high-voltage DC supply. Read this user guide and the safety-related documents that come with the EVM package before operating this EVM.

CAUTION

Do not leave the EVM powered when unattended.

WARNING

Hot surface! Contact can cause burns. Do not touch!

WARNING

High Voltage! Electric shock is possible when connecting board to live wire. Board must be handled with care by a professional.
For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

2 Hardware

2.1 LMG2640EVM-090 Daughter Card

The LMG2640EVM-090 has one LMG2640 device with two GaN FETs in a half-bridge configuration. All the bias and level shifting components are included, which allows low-side referenced signals to control both FETs. High-frequency decoupling capacitors are included on the power stage in an optimized layout to minimize parasitic inductance and reduce voltage overshoot.

The layout of the board is critical to the performance and functionality of the device. TI recommends a four-layer or higher layer count board to reduce the parasitic inductance of the layout to the best performance. Layout guidelines are provided in the LMG2640 Integrated 650V GaN Half Bridge data sheet to optimize the solder-joint reliability, power loop inductance, signal to ground connection, switched-node capacitance and thermal heat dissipation.

There is a 12 logic pin header on the LMG2640EVM-090 with 8 pins used for active logic and 4 with no connections

Table 2-1. Logic Pin Function Description

PIN	PIN DESIGNATION	DESCRIPTION
LS PWM	1	Logic gate signal input for low-side LMG2640. Compatible with both 3.3V and 5V logic. Referenced to AGND.
Fault	3,6	FAULT output signal of LMG2640. Referenced to AGND.
HS PWM	8	Logic gate signal input for high-side LMG2640. Compatible with both 3.3V and 5V logic. Referenced to AGND.
12V	9	Auxiliary power input for LMG2640EVM-090.
5V	10	5V auxiliary power for FAULT signal pull-up resistor and circuit debugging.
AGND	11,12	Logic and bias power ground return pin. Functionally isolated from PGND.

There are six power pins on the LMG2640EVM-090.

Table 2-2. Power Pin Function Description

PIN	DESCRIPTION
SW	Switch node of the half-bridge configuration.
HV	Input DC voltage of the half-bridge configuration.
PGND	Power ground of the half-bridge configuration. Functionally isolated from AGND.

CAUTION

High-voltage levels are present on the evaluation module whenever energized. Take proper precautions when working with the EVM.

2.1.1 Test Points

There are multiple test points on the LMG2640EVM-090 daughter card designed for analog and digital measurements with an oscilloscope. For a full list, refer to Table 2-1. Digital test points such as Fault, PWM, EN, and CS test points can be used to debug a system and understand how the device operates. However, note that the high signal ringing is expected. Long traces route these test points for easy measuring, but introduce parasitics that appear as high frequency noise during switching transitions. The test points are designed for observation only, and are useful for functional debugging with this daughter card.

2.1.2 Integrated Current Sensing

The current-sense emulation function creates a scaled replica of the GaN power FET positive drain current at the output of the CS pin. The current-sense emulation gain, GCSE, is 0.616mA output from the CS pin, ICS, for every 1A passing into the drain of the low-side GaN power FET, ID.

A 162 Ohm resistor connected to AGND sets the output conversion ratio which can be monitored on an oscilloscope. In addition to the LMG2640 Integrated 650V GaN Half Bridge data sheet, see the Maximize System Efficiency With Integrated Current Sensing From TI GaN application brief, which describes the function of the CS pin and how to manipulate the output resistor for system-level control.

2.1.3 Enable Pin

The LMG2650 has two modes of operation controlled by the EN pin. The device is in Active mode when the EN is logic high and in Standby mode when the EN pin is logic low. See the LMG2640 Integrated 650V GaN Half Bridge data sheet for more information. The LMG2640EVM-090 by default has the EN pin set high with a 0 Ohm resistor connected to 12V so the device is normally operational. By removing this resistor, the EN test point can be shorted to AGND and the device enters Standby mode.

2.1.4 FAULT

The LMG2640EVM-090 only reports a low-side overtemperature fault. A low-side overtemperature fault is reported on the FLT pin when the low-side overtemperature protection function is asserted. The FLT pin is an active low open-drain output so the pin pulls low when there is a low-side overtemperature fault. Refer to the LMG2640 Integrated 650V GaN Half Bridge data sheet for operation details.

2.1.5 Power Pins

There are some high frequency decoupling capacitors on the LMG2640EVM-090 from VDC to PGND to minimize voltage overshoot during switching, but more bulk capacitance is required to hold up the DC voltage during operation. TI recommends preventing any overlap and parasitic capacitance from VSW to VDC, PGND, and any logic pins. The two ground PGND and AGND pins are functionally isolated from each other on the LMG2640EVM-090.

2.1.6 Heat Sink

The heat sink is installed to help with heat dissipation of the LMG2640. Exposed copper pads are attached to the die attach pad (DAP) on the high-side and low-side devices to provide a low thermal impedance point for the heat sink. The two copper pads have a high-voltage potential difference between them, therefore an electrically isolated thermal interface material (TIM) is required.

For best thermal dissipation and board level reliability, recommendations for thermal via pattern and solder paste example are provided in the LMG2640 Integrated 650V GaN Half Bridge data sheet. Pin numbers 1, 13, 17, 21, 33, 37, and 40 are NC (no connection) which are used to anchor QFN package to PCB. These pins must be soldered to PCB landing pads which have to be non-solder mask defined pads and must not be physically connected to any other metal on the PCB. Internally, pins 1 and 13 are connected to DH and pins 17, 21, 37 are connected to AGND, SL, and PADL. Pin 40 needs to be connected to PADH. All pads must be NSMD for mechanical performance, refer to the device data sheet for trace connection recommendations to the pads. Filling the thermal pad with thermal vias is recommended for thermal performance. Fill and planarize vias.

In this daughter card design, *S05MZZ3S-A* heat sink and *GR80B*, thermal interface material has been used. More details on thermal performance and comparison between different TIM are shown in *Thermal Performance of QFN 12x12 Package for 600V GaN Power Stage* application note.

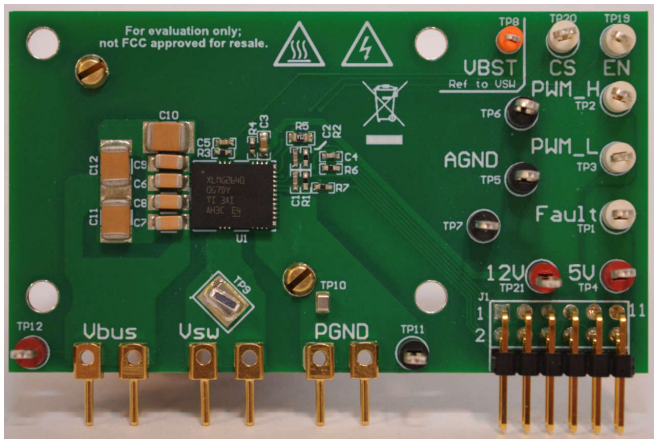


Figure 2-1. EVM (Top View)

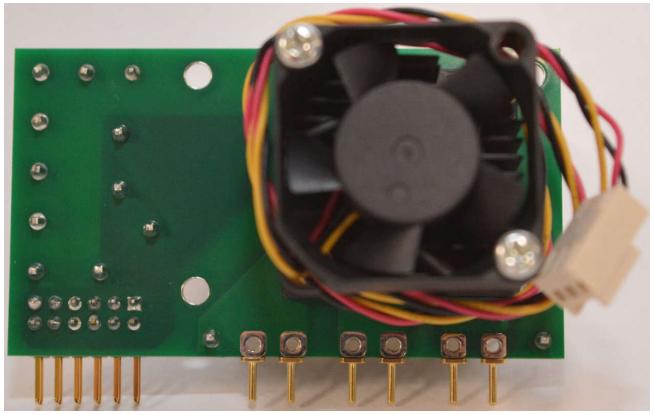


Figure 2-2. EVM (Bottom View)

2.2 Motherboard

A motherboard is available from TI to configure the LMG2640EVM-090 as a full system for evaluation: LMG342X-BB-EVM.

Note

The LMG2640EVM-090 daughter card is not designed to be used by itself, but rather pair with either the LMG342X-BB-EVM or a custom motherboard using the recommended daughter card footprint.

WARNING

External Connections: All external connections to the hardware must stay within the recommended operating conditions and intended usage for all hardware/components connected in the system.

2.2.1 Bias Supply

The motherboard requires one 12V bias supply. A buck regulator (in LMG342X-BB-EVM) steps the voltage down to a tightly regulated 5V for the logic and auxiliary power of the LMG2640 when the LMG2640EVM-090 is configured in isolated power mode.

2.2.2 PWM Input

The LMG342X-BB-EVM mother board has on-board complementary PWM generation circuits that create a pair of complimentary PWM signals out of a single PWM input. A 0V to 5V square wave input is recommended. With LMG342X-BB-EVM, the dead time can be easily adjusted by tuning the trimmer resistance values (R3 and R15).

2.2.3 Fault Protection

There is an option to disable the PWM input to the daughter card in the event of a fault signal from the LMG2640EVM-090. When the FAULT Protect jumper is placed in the EN mode, PWM is disabled when LMG2640 has an active fault. This disable is not latching, so PWM immediately resumes when the fault clears. If the FAULT Protect mode is not desired, then that mode can be disabled by placing the jumper in the DIS position. The FAULT LED still illuminates when either LMG2640 has an active fault, regardless of the position of FAULT Protect jumper.

2.3 Recommended Footprint

When the EVM daughter card is used in a custom design system, the recommended footprint to interface with the LMG2640EVM-090 daughter card is shown below.

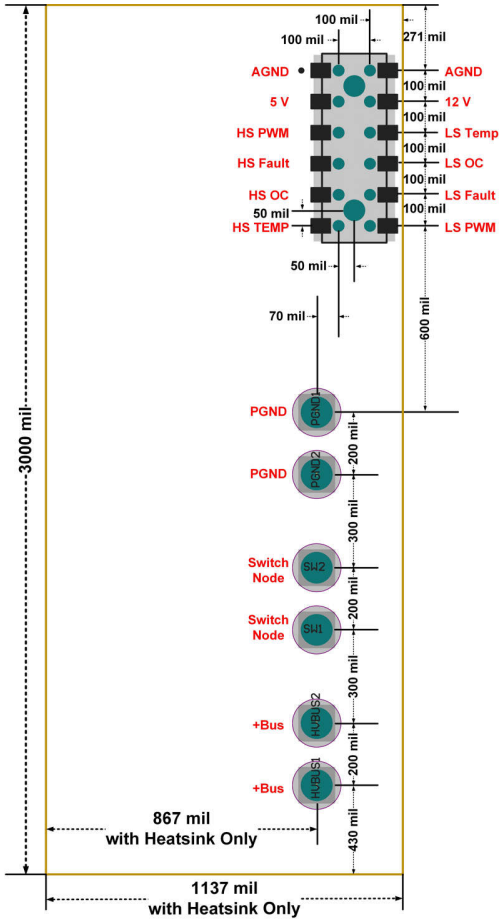


Figure 2-3. Recommended Footprint for LMG2640EVM-090

2.4 Test Equipment

DC Voltage Source: Capable of supplying the input of the EVM up to 480 V.

DC Bias Source: Capable of 12V output up to 1.5A.

Function Generator: Capable of 0V to 5V square wave output with adjustable duty cycle and frequency in the operating range. TI recommends operating the LMG2640EVM-090 and mother boards with a switching frequency between 50kHz to 200kHz in hard-switching converters.

Oscilloscope: Capable of at least 200MHz operation. A 1GHz or greater oscilloscope and probes with short ground springs are required for accurate measurements.

DC Multimeters: Capable of 650V measurement, designed for determining operation and efficiency (if desired).

DC Load: Capable of 650V operation at up to 20A in current-mode operation.

Fan: For the heat-sink-version EVM daughter card, a dedicated cooling fan is attached on the back side of the heat sink. Please make sure the fan is powered by the 12V power supply before test.

2.5 Test Procedure When Paired With LMG342X-BB-EVM

2.5.1 Setup

The inductor on LMG342X-BB-EVM is capable of around 3kW operation. For higher power levels, use an external inductor.

TI recommends the following procedure to set up the LMG342X-BB-EVM with the LMG2640EVM-090:

1. Connect the LMG2640EVM-090 to LMG342X-BB-EVM as shown in 2 Figure 2-4. The area for connection on the mother board is shown in Figure 2-5.
2. Install the LMG342X-BB-EVM inside a ventilated HV safety box.
3. Disconnect jumper J13 to enable the 12V to 5V onboard power conversion.
4. Disconnect jumper J12.
5. If the onboard complementary PWM generation circuits are used to generate the dead time, then connect pin 2 to pin 3 for header J7 and J14 with jumpers. Under this configuration, only one PWM signal is required and can be connected to either J3 or J8.
6. If two complementary PWM signals with dead time are provided to J3 (high-side PWM) and J8 (low-side PWM), then connect pin 1 to pin 2 for header J7 and J14 (pin 1 of J7 and J14 are indicated in Figure 2-5). This action allows the two PWM signals to directly control the high-side and low-side devices.
7. If fault interlock feature is desired, then connect jumper J10 and J11. Otherwise, disconnect them and the PWM signals can always pass through to the devices.
8. Set the signal generator to a desired frequency and duty cycle (that is, 100kHz, and 50% duty cycle). 5V for high input and 0V for low input.
9. Connect the signal generator output to the LMG342X-BB-EVM PWM input as shown in Figure 2-5.
10. Connect 12V, 2A DC power supply to the LMG342X-BB-EVM 12V bias supply as shown in Figure 2-5.
11. Connect the high voltage power supply to the LMG342X-BB-EVM high voltage input for buck mode (high voltage) as shown in Figure 2-5.
12. Provide 12V bias supply to fan by connecting the 3-pin power cord from fan to J15.

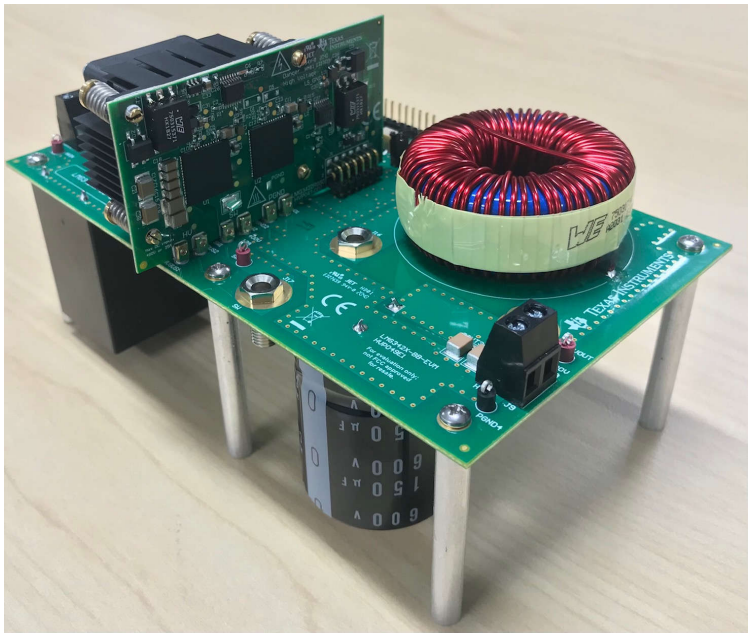


Figure 2-4. LMG342X-BB-EVM Motherboard With LMG2640EVM-090

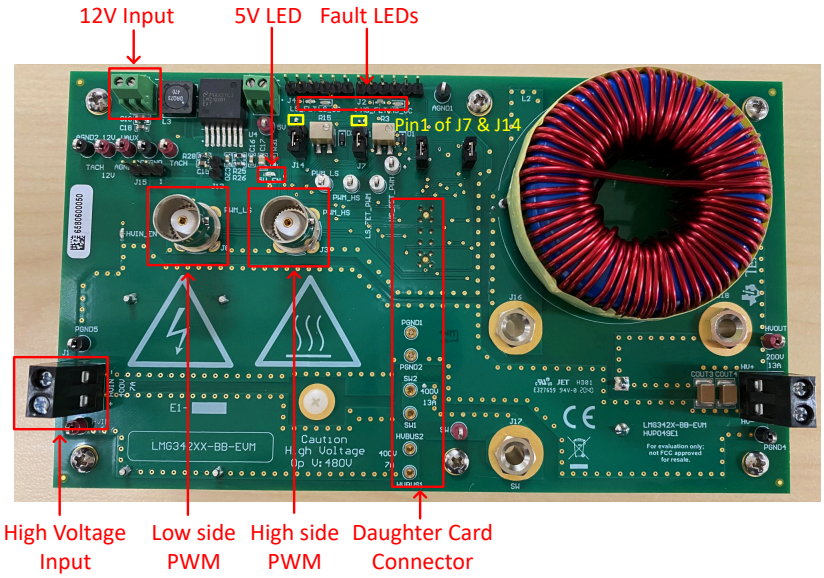


Figure 2-5. Connector and LEDs on the LMG342X-BB-EVM

2.5.2 Start-Up and Operating Procedure

1. Turn on +12VDC to the LMG342X-BB-EVM. Watch the power supply for the DC current to settle down after approximately 3 to 5 seconds.
2. Make sure all the fault LEDs are off and the 5V LED is on.
3. Turn on +12VDC to enable the fan.
4. Turn on the function generator to output the continuous pulse, and check the dead time of the PWM signals.
5. User proper probes for measurement. To measure the fast switching transient in the switch-node, TI recommends to use the high-bandwidth high-voltage passive probes with minimized ground loop connections.
6. TI recommends to add common-mode chokes to the measurement signals and to the power input and output connections.
7. Enable the high voltage power supply and make sure to ramp the voltage up gradually from 0V to the desired bus voltage (up to 480V). As the voltage is ramping up, the HV LED turns on and become brighter.

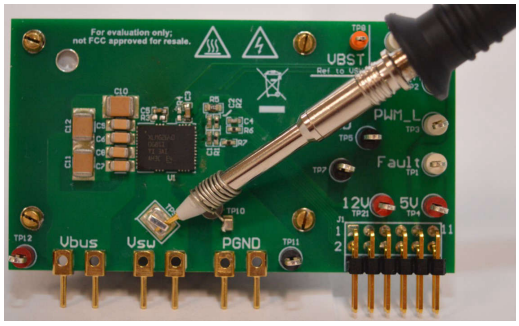


Figure 2-6. Switch-Node Voltage Measurement with High-Bandwidth Probe and Pigtail Ground Connection

WARNING

Do NOT turn on the device at the absolute maximum voltage. TI recommends to start the device at or below 480 V. Slowly increase the input voltage and monitor the VSW to make sure the peak voltage does not exceed the absolute maximum rating of 650 V.

2.5.3 Test Results

In this test example, a synchronous boost converter operation is implemented. The input voltage is 200V, and the output voltage is 400V with 50% duty cycle. With the heat-sink-version EVM, the inductor current is triangular and operating in continuous conduction mode (CCM). The peak inductor current is about 5A in this test, and an output power of 800W is achieved. Higher currents and power levels can be tested, and monitoring the device temperature is recommended to avoid thermal shutdown. The waveform for continuous operation is shown in Figure 2-7.

The slew rate is fixed by connecting a 0Ohm resistor between RDRVL and AGND for the low side FET, and connecting a 0Ohm resistor between RDRVH and SW for the high side FET. A turn-on voltage waveform of 100V/ns is observed with this slew rate, and demonstrated on this EVM at 400V. High slew rate enables the lowest switching losses with minimum overlap during hard-switching events, and integrated gate drivers enable minimum voltage overshoot to aid EMI performance when designing.

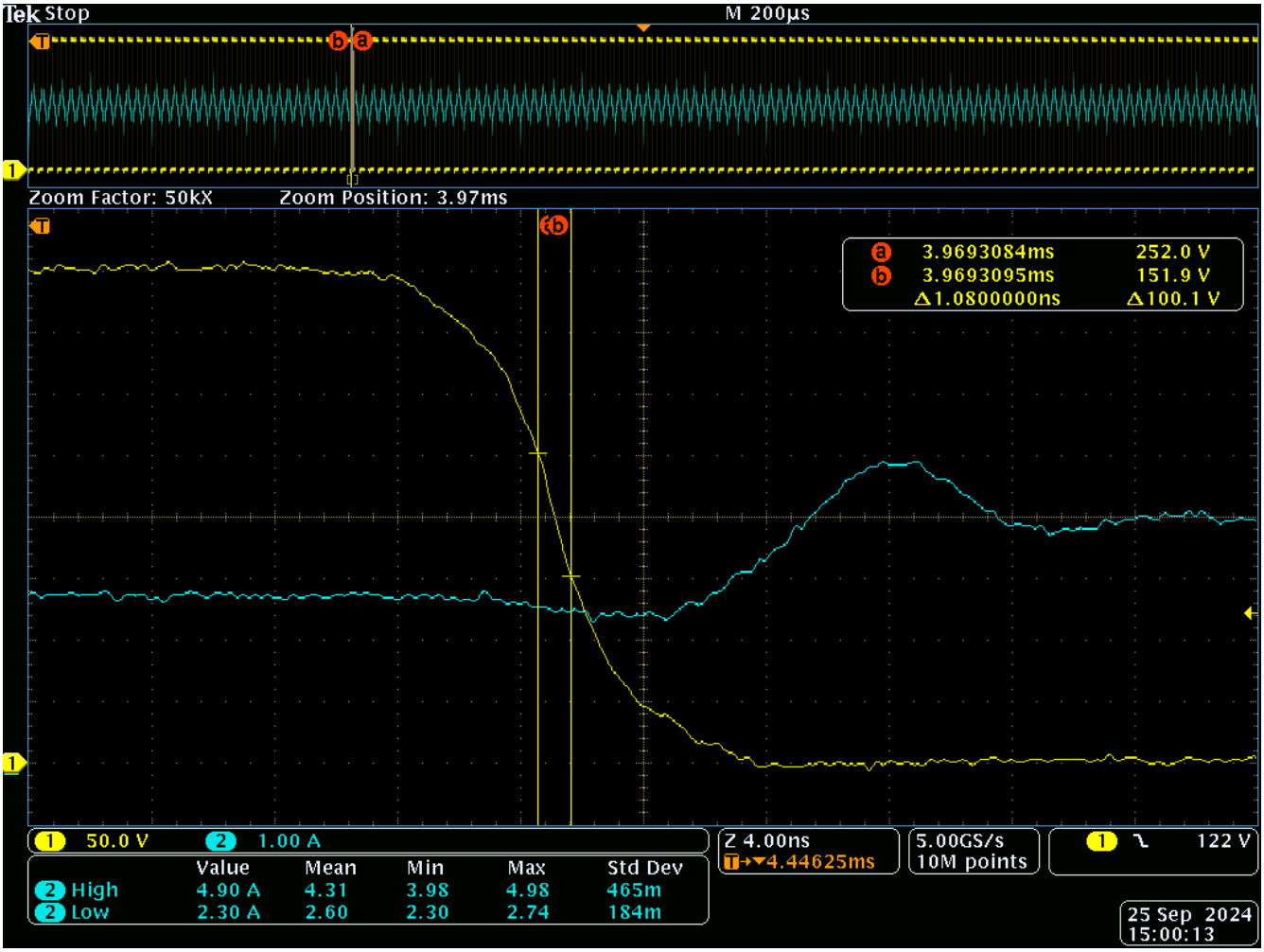


Figure 2-7. 100V/ns at 400V/2A

2.5.4 Shutdown Procedure

1. Turn off the high voltage power supply then PWM. Wait until the red *HV Enable* LED turns off.
2. Disable the 12V bias supply.

2.5.5 Additional Operating Notes

- Fault protection on the LMG342X-BB-EVM is not latching, therefore PWM resumes if a fault clears and the LMG342X-BB- EVM is still operational.

3 Hardware Design Files

3.1 LMG2640EVM-090 Schematic

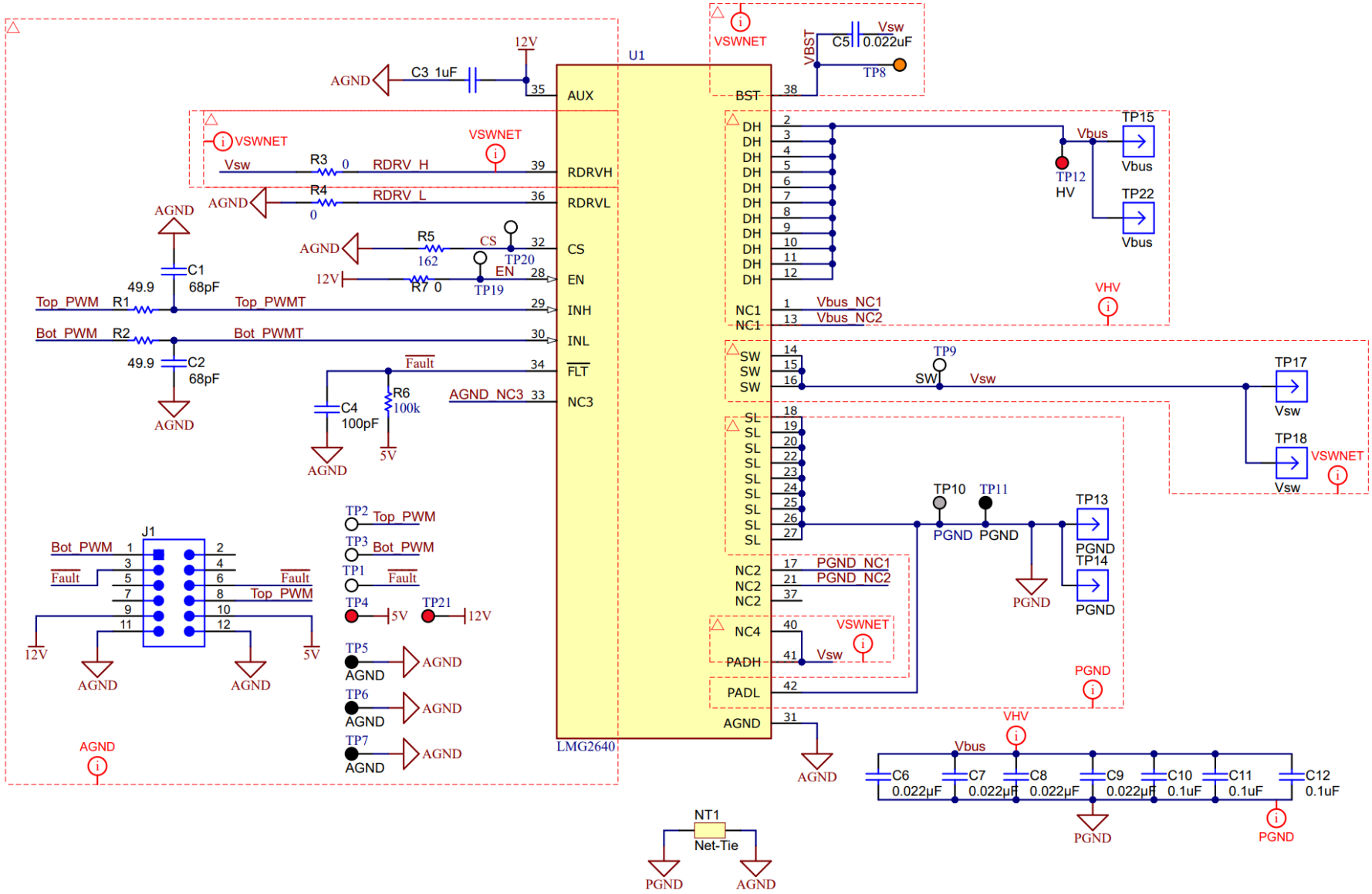


Figure 3-1. LMG2640EVM-090 Schematic

3.2 Motherboard Schematic

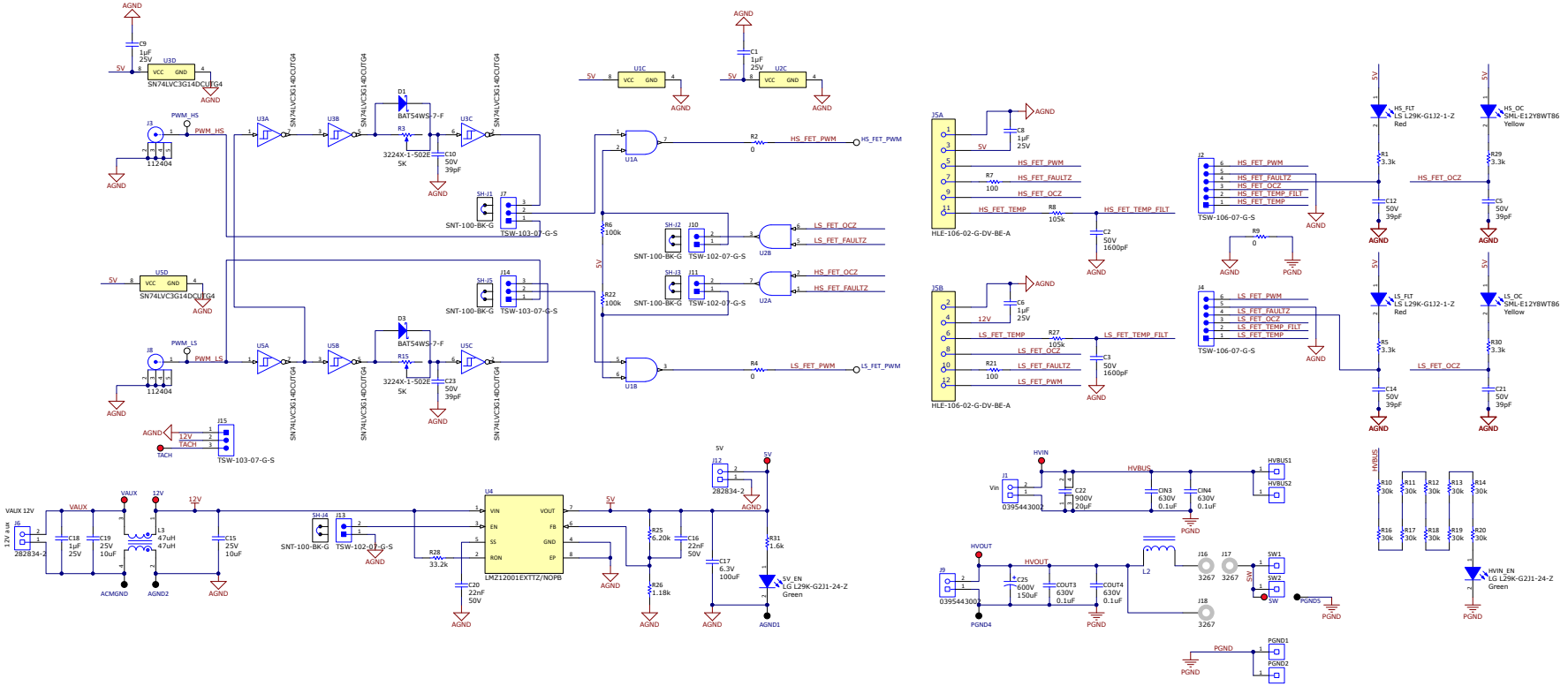


Figure 3-2. LMG342X-BB-EVM Schematic

3.3 PCB Layout

The PCB layers for this EVM are illustrated in Figure 3-3 through Figure 3-6.

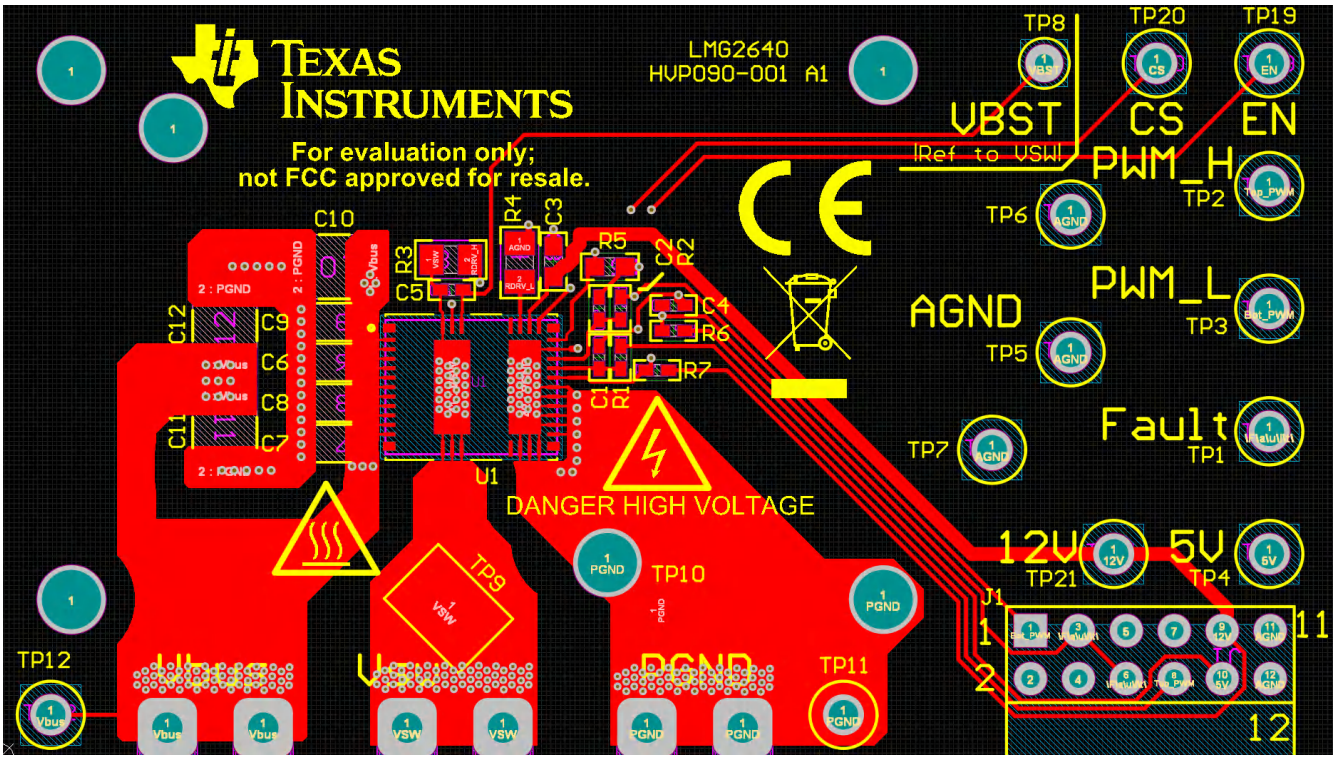


Figure 3-3. Top Layer

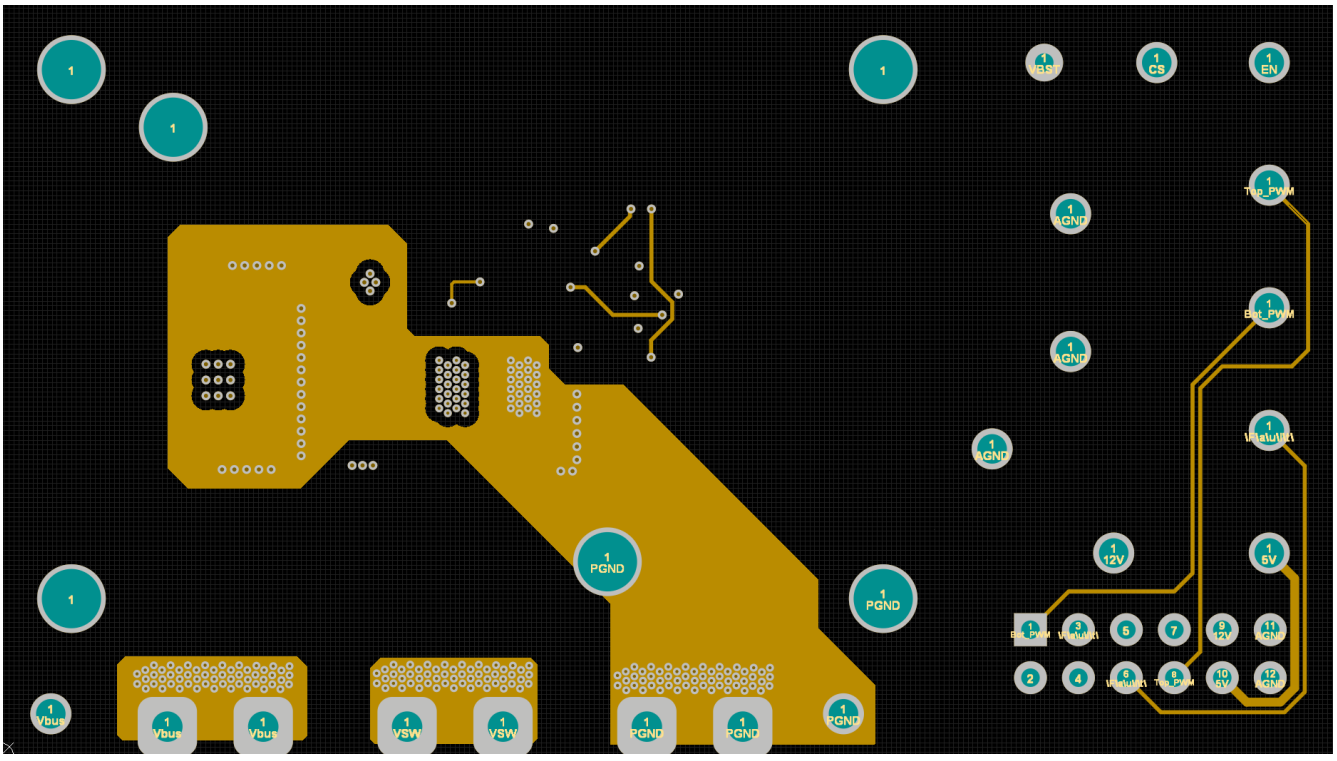


Figure 3-4. Layer 2

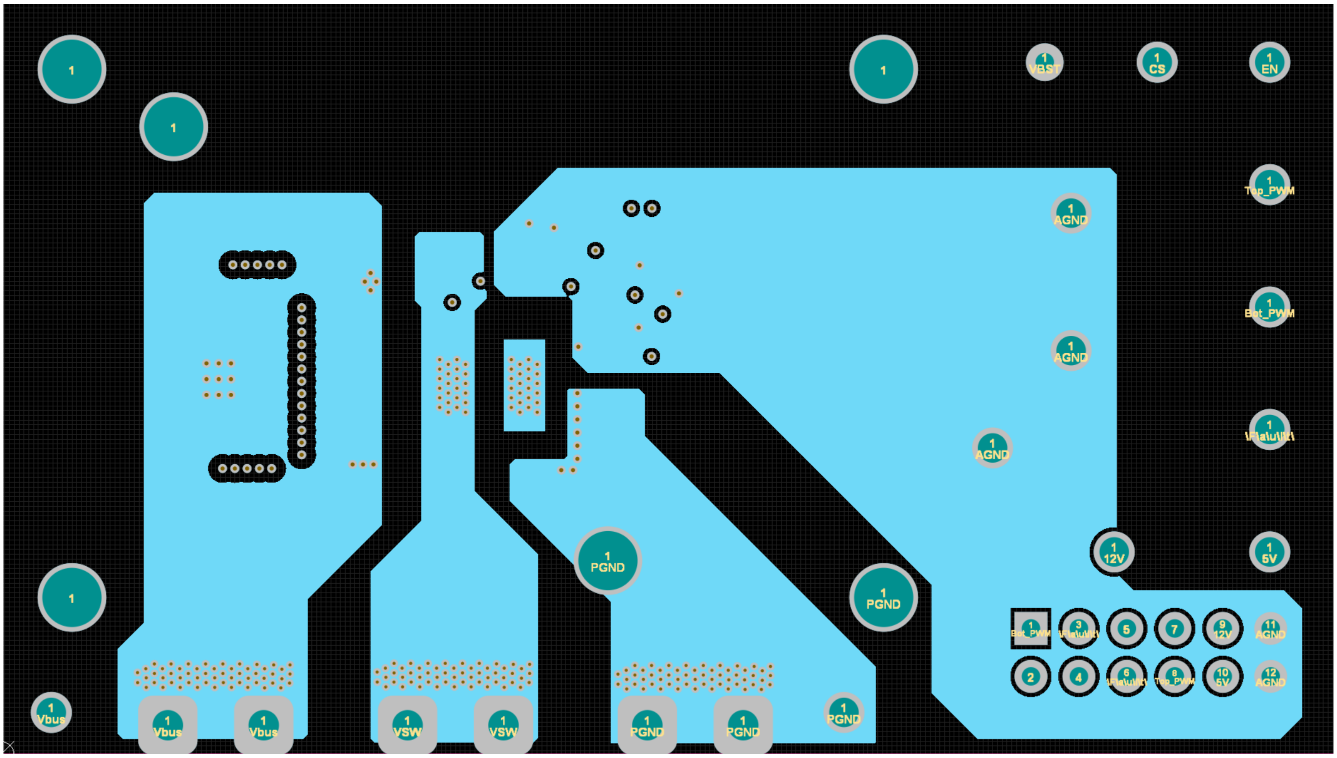


Figure 3-5. Layer 3

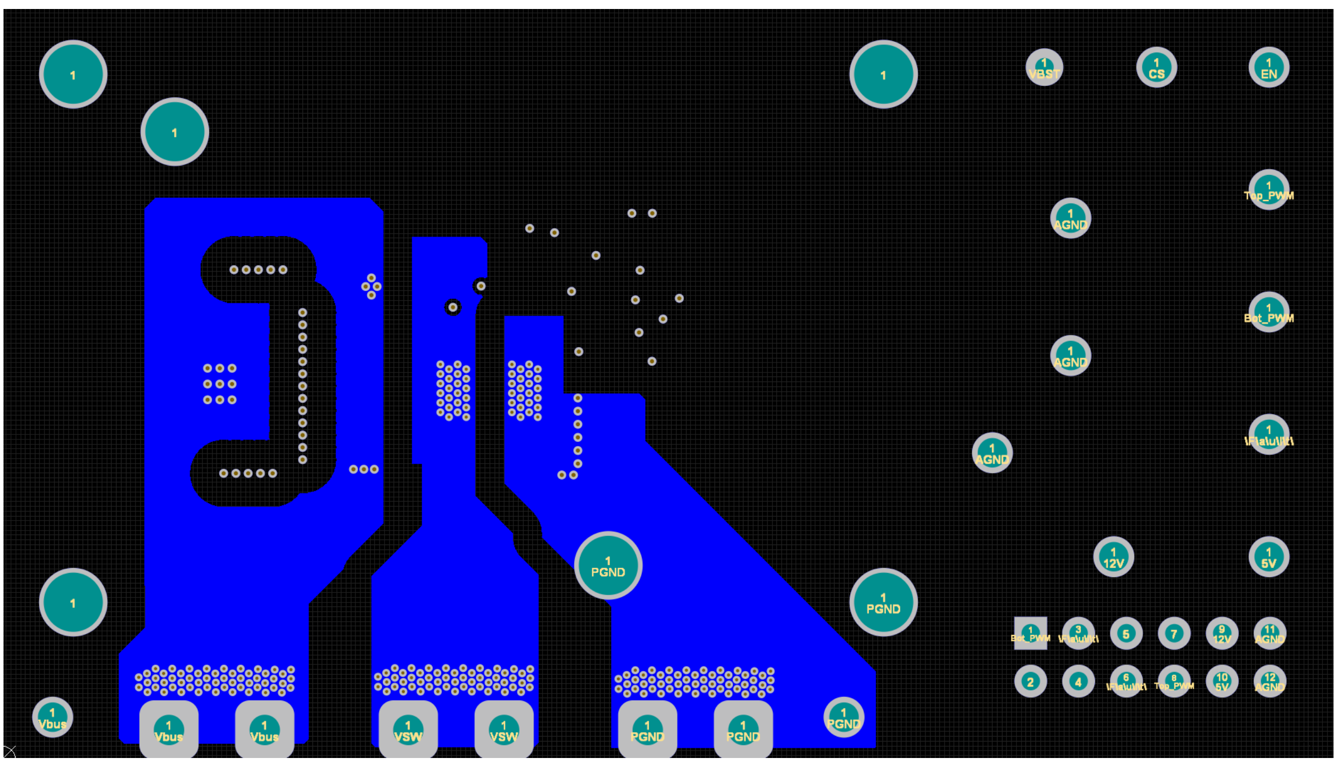


Figure 3-6. Bottom Layer

3.4 Bill of Materials

Table 3-1. Bill of Materials for LMG2640EVM-090

Designator	Quantity	Description	Part Number
!PCB1	1	Printed Circuit Board	HVP090
C1, C2	2	CAP, CERM, 68pF, 50V, +/- 5%, C0G/NP0, 0402	C1005C0G1H680J050BA
C3	1	CAP, CERM, 1µF, 25V, +/- 10%, X7R, 0603	C1608X7R1E105K080AB
C4	1	CAP, CERM, 100pF, 50V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2C0G1H101J050BA
C5	1	CAP, CERM, 0.022uF, 50V, +/- 10%, X7R, 0402	GRM155R71H223KA12D
C6, C7, C8, C9	4	CAP, CERM, 0.022µF, 1000V,+/- 10%, X7R, AEC-Q200 Grade 1, 1206	C1206C223KDRACTU
C10, C11, C12	3	CAP, CERM, 0.1uF, 1000V, +/- 10%, X7R, 1812	C1812W104KDRACTU
H1	1	Thermal Interface Material, 30x30x1mm	GR80B, Fujipoly
J1	1	Header, 100mil, 6x2, Gold, R/A, TH	TSW-106-08-G-D-RA
MP1	1	HTSNK + FAN 30.0x30.0x20.0mm	S05MZZ3S-A
R1, R2	2	RES, 49.9, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040249R9FKED
R3, R4	2	RES, 0, 5%, 0.125 W, 0805	RC0805JR-070RL
R5	1	RES, 162, 1%, 0.1 W, 0603	RC0603FR-07162RL
R6	1	RES, 100 k, 1%, 0.1 W, 0402	ERJ-2RKF1003X
R7	1	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0402	ERJ-2GE0R00X
TP1, TP2, TP3, TP19, TP20	5	Test Point, Compact, White, TH	5007
TP4, TP12, TP21	3	Test Point, Multipurpose, Red, TH	5010
TP5, TP6, TP7, TP11	4	Test Point, Multipurpose, Black, TH	5011
TP8	1	Test Point, Miniature, Orange, TH	5003
TP9	1	Test Point, Compact, SMT	5016
TP10	1	Test Point, SMT	S2751-46R
TP13, TP14, TP15, TP17, TP18, TP22	6	PCB Pin, 0.04" DIA, Edge-Mount	3621-0-32-15-00-00-08-0
U1	1	Integrated 650V GaN Half-Bridge	LMG2640

Table 3-2. Bill of Materials for LMG342X-BB-EVM

DESIGNATOR	QTY	DESCRIPTION	PART NUMBER
5V, 12V, HVIN, HVOUT, SW, TACH, VAUX	7	Test Point, Compact, Red, TH	5005
5V_EN, HVIN_EN	2	LED, Green, SMD	LG L29K-G2J1-24-Z
ACMGND, AGND1, AGND2, PGND4, PGND5	5	Test Point, Compact, Black, TH	5006
C1, C6, C8, C9, C18	5	CAP, CERM, 1µF, 25V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E1X7R1E105K080AD
C2, C3	2	CAP, CERM, 1600pF, 50V, +/- 5%, C0G/NP0, 0603	GRM1885C1H162JA01D
C5, C10, C12, C14, C21, C23	6	CAP, CERM, 39pF, 50V, +/- 5%, C0G/NP0, 0603	GRM1885C1H390JA01D
C15	1	CAP, CERM, 10uF, 25V, +/- 20%, X5R, 0603	GRT188R61E106ME13D
C16, C20	2	CAP, CERM, 0.022uF, 50V, +/- 10%, X7R, 0603	885012206091
C17	1	CAP, CERM, 100uF, 6.3V, +/- 20%, X5R, 0805	GRM21BR60J107M
C19	1	CAP, CERM, 10uF, 25V, +/- 10%, X5R, 0805	CL21A106KAFN3NE
C22	1	CAP, Film, 20µF, 900V,+/- 10%, 0.0055 ohm, TH	FE37M6C0206KB
C25	1	CAP, AL, 150uF, 600V, +/- 20%, TH	LGN2X151MELB50
CIN3, CIN4, COUT3, COUT4	4	CAP, CERM, 0.1uF, 630V, +/- 10%, X7R, 1812	GRM43DR72J104KW01L
D1, D3	2	Diode, Schottky, 30V, 0.2A, SOD-323	BAT54WS-7-F
H1, H8, H9, H10, H11, H12	6		3484
H2, H3, H4, H5, H6, H7	6	MACHINE SCREW PAN PHILLIPS 4-40	PMSSS 440 0025 PH
H13	1	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH
H14	1		1902C
HS_FET_PWM, LS_FET_PWM, PWM_HS, PWM_LS	4	Test Point, Compact, White, TH	5007
HS_FLT, LS_FLT	2	LED, Red, SMD	LS L29K-G1J2-1-Z
HS_OC, LS_OC	2	LED, Yellow, SMD	SML-E12Y8WT86
HVBUS1, HVBUS2, PGND1, PGND2, SW1, SW2	6	Receptacle, 1 Pos, Gold, TH	0435-0-15-15-03-27-10-0
J1, J9	2	Terminal Block, 5.08mm, 2x1, TH	0395443002
J2, J4	2	Header, 100mil, 6x1, Gold, TH	TSW-106-07-G-S
J3, J8	2	Connector, TH, BNC	112404
J5	1	12 Position Receptacle, Bottom Entry Connector Surface Mount	HLE-106-02-G-DV-BE-A
J6, J12	2	Terminal Block, 2x1, 2.54mm, TH	282834-2
J7, J14, J15	3	Header, 100mil, 3x1, Gold, TH	TSW-103-07-G-S
J10, J11, J13	3	Header, 100mil, 2x1, Gold, TH	TSW-102-07-G-S
J16, J17, J18	3	Standard Banana Jack, Uninsulated	3267
L2	1	INDUCTOR 570uH 13A	750317345
L3	1	Coupled inductor, 47uH, 1.14A, 0.4825 ohm, SMD	DRQ73-470-R
LBL1	1	Thermal Transfer Printable Labels, 1.250" W x 0.250" H - 10,000 per roll	THT-13-457-10
R1, R5, R29, R30	4	RES, 3.3 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033K30JNEA
R2, R4, R9	3	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06030000Z0EA
R3, R15	2	Trimmer, 5 K, 0.25 W, SMD	3224X-1-502E
R6, R22	2	RES, 100 k, 5%, 0.1 W, 0603	CRCW0603100KJNEAC

Table 3-2. Bill of Materials for LMG342X-BB-EVM (continued)

DESIGNATOR	QTY	DESCRIPTION	PART NUMBER
R7, R21	2	RES, 100, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603100RJNEA
R8, R27	2	RES, 105 k, 1%, 0.1 W, 0603	RC0603FR-07105KL
R10, R11, R12, R13, R14, R16, R17, R18, R19, R20	10	RES, 30 k, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	CRCW120630K0JNEA
R25	1	RES, 6.20 k, 1%, 0.1 W, 0603	RC0603FR-076K2L
R26	1	RES, 1.18 k, 1%, 0.1 W, 0603	RC0603FR-071K18L
R28	1	RES, 33.2 k, 0.1%, 0.1 W, 0603	RT0603BRD0733K2L
R31	1	RES, 1.6 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06031K60JNEA
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5	5	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G
U1, U2	2	Automotive Catalog Dual 2-Input Positive-AND Gate, DCT0008A, LARGE T&R	
U3, U5	2	Triple Schmitt-Trigger Inverter, DCU0008A (VSSOP-8)	SN74LVC3G14DCUTG4
U4	1	1A SIMPLE SWITCHER® Power Module with 20V Maximum Input Voltage for Military and Rugged Applications, 7 pin TO-PMOD	LMZ12001EXTTZ/NOPB

4 Additional Information

4.1 Trademarks

All trademarks are the property of their respective owners.

5 Related Documentation

- Texas Instruments, LMG2640 Integrated 650V GaN Half Bridge, data sheet
- Texas Instruments, Thermal Performance of QFN 12x12 Package for 600V GaN Power Stage, application note
- Texas Instruments, Maximize System Efficiency With Integrated Current Sensing From TI GaN, application brief

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *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

NOTE: 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

NOTE: 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.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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.

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.

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.

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs 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 EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should 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 also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure 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. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

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9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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