EVM User's Guide: BOOSTXL-LMG2100-MD

BOOSTXL-LMG2100-MD Evaluation Module

Description

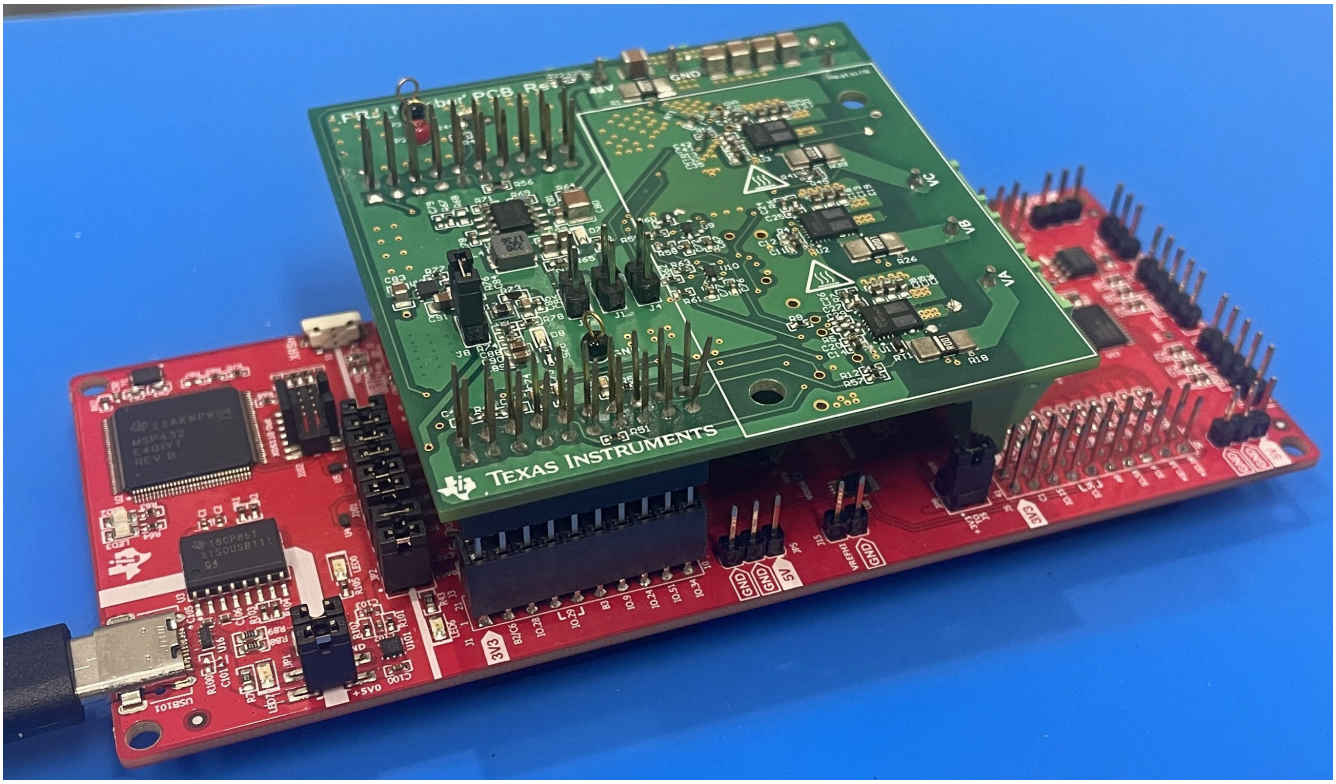
The BOOSTXL-LMG2100-MD Evaluation Module, also referred to as "EVM" throughout this document, implements a GaN inverter with precision in-line shunt-based phase current sensing for accurate control of precision drives such as servo drives. The EVM offers a TI BoosterPack™ compatible interface to connect to a C2000™ MCU LaunchPad™ development kit for easy performance evaluation. For more test results and other technical information please refer to TIDA-010936.

Applications

- Robotics (cobot/AGV/humanoid robot)
- Servo drives and motion control
- Computer numerical control (CNC) drives
- Non-military drone

Features

- Wide input voltage range 12V to 60V
- Compatible for LMG2100R044 and LMG2100R026
- GaN half-bridge power stage simplifies PCB layout and reduces parasitic inductances for optimized switching performance
- Compare with MOS solution, TI GaN reduces >50% size
- Precision in-line phase current sensing with 1mΩ shunt (for theoretical ±33A full-scale range)
- This board can run up to 15.6A_RMS (LMG2100R044) or 24A_RMS (LMG2100R026) without heatsink, and is heatsink compatible
- TI BoosterPack compatible interface with 3.3V I/O for easy performance evaluation with C2000 MCU LaunchPad development kit



BOOSTXL-LMG2100-MD Board (Green) Installed on BOOSTXL Control Board (Red)

1 Evaluation Module Overview

1.1 Introduction

This EVM uses GaN to implement a 3-phase inverter controlled by TMS320F280039C on the C2000 LaunchPad. The GaN inverter demonstrates the ability of GaN to operate at higher switching frequency than traditional MOSFET motor drives. The EVM includes mounting holes for a heatsink and is able to be used with or without a heatsink.

1.2 Kit Contents

The kit includes the BOOSTXL-LMG2100-MD motor drive board. The user will need to order the TMS320F280039C control card and a 48V low-voltage servo motor (example here). There are heatsink mounting holes on the BOOSTXL-LMG2100-MD to provide cooling for the LMG2100 devices in higher power applications. The heatsink is not included in the kit. For more information on dimensions and example heat sinks see Section 2.2.

1.3 Specification

Figure 1-1 shows the system block diagram of the three-phase GaN inverter with the BOOSTXL-LMG2100-MD board indicated in the red-dotted box.

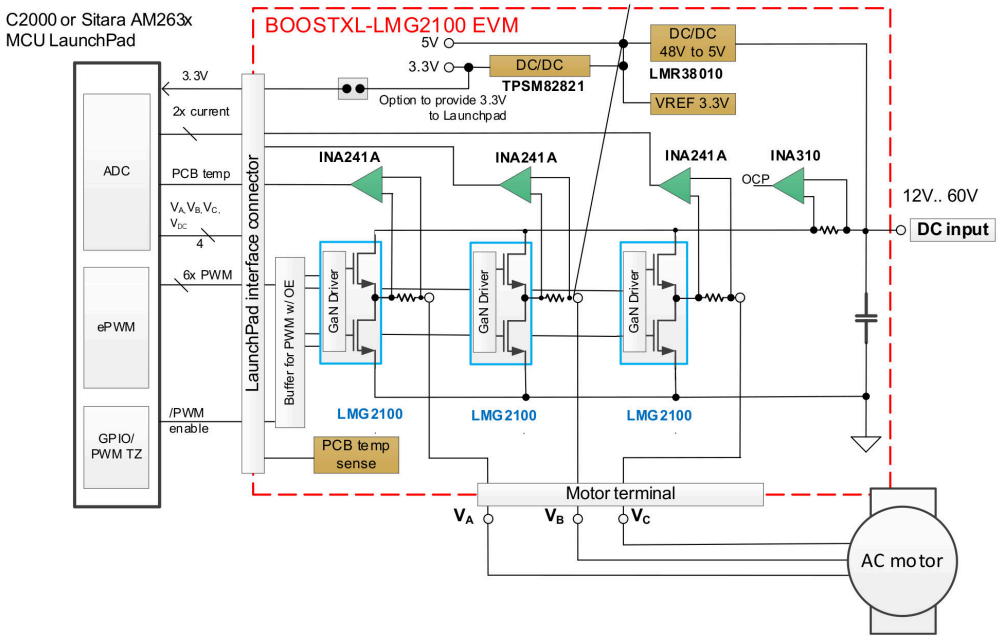


Figure 1-1. BOOSTXL-LMG2100-MD Block Diagram

The three-phase inverter with shunt-based precision phase current sensing accepts input DC voltages from 12V to 60V; the nominal DC input voltage is 48V. A wide input voltage range, DC/DC converter LMR38010 generates the 5V rail to supply the LMG2100 gate driver and the 3.3V current sensor reference, a 3.3V LDO supplies the current sense amplifier, input buffer and other auxiliary circuits.

Each of the three inverter half-bridges employs an integrated GaN half-bridge module (LMG2100), a 1mΩ phase current shunt and a differential current sense amplifier (INA241) with a gain of 50V/V and a midpoint voltage of 1.65V, set by the 3.3V reference (REF3333). A high common mode voltage input amplifier with comparator (INA310) monitors DC bus current and it will disable the PWM buffer when overcurrent occurred (hardware protection). The trip threshold is set to 30A. A linear thermistor (TMP302) monitors the PCB temperature close to the GaN power module.

The EVM interfaces to a host processor, like C2000 MCU. It provides the PWM high- and low-side input signals, the phase current sense amplifier output voltage, and the scaled low-pass filtered phase voltage for each of the three phases. The PWM signals are buffered. A PWM enable signal (active low) allows the host processor or INA310 to enable and disable all three complementary PWM simultaneously through the onboard buffer.

The C2000 MCU LaunchPad with the TMS320F280039C device is connected to the EVM and implements a sensorless, speed-variable, field-oriented control of a synchronous motor using the InstaSPIN-FOC™ software. An example firmware based on the TMS320F280039C LaunchPad has been provided to evaluate the BOOSTXL-LMG2100-MD design with a 48V low-voltage servo motor.

1.4 Device Information

The main ICs used in this design are described below:

- LMG2100R026: 100V 2.6mΩ half-bridge gallium nitride (GaN) power stage
- LMR38010: SIMPLE SWITCHER® 80V, 1.0A, 2.2MHz step-down converter with 40µA I_Q
- INA241A: –5V to 110V bidirectional ultra-precise current sense amplifier with enhanced PWM rejection
- INA310A: –4V to 110V, 1.3MHz, ultra-precise current-sense amplifier with comparator
- TXU0304: Four-channel fixed multidirectional level shifter
- TPS746: 1A, low-I_Q, high-accuracy, adjustable ultra-low-dropout voltage regulator with power good and enable
- TPSM82821: 5.5V input, 1A step-down module with integrated inductor in 2 × 2.5 × 1.1mm µSIP package
- REF3333: 3.3V, 30-ppm/°C drift, 3.9µA, 3-pin SOT-23, 3-pin SC70, 8-pin UQFN voltage reference
- TMP61: 1%, 10kΩ linear thermistor in 0402, 0603/0805 and through hole packages
- SN74LVC1G14: Single 1.65V to 5.5V inverter with Schmitt-Trigger inputs
- SN74LVC1G373: Single D-type latch with 3S output

2 Hardware

2.1 BOOSTXL-LMG2100-MD PCB Overview

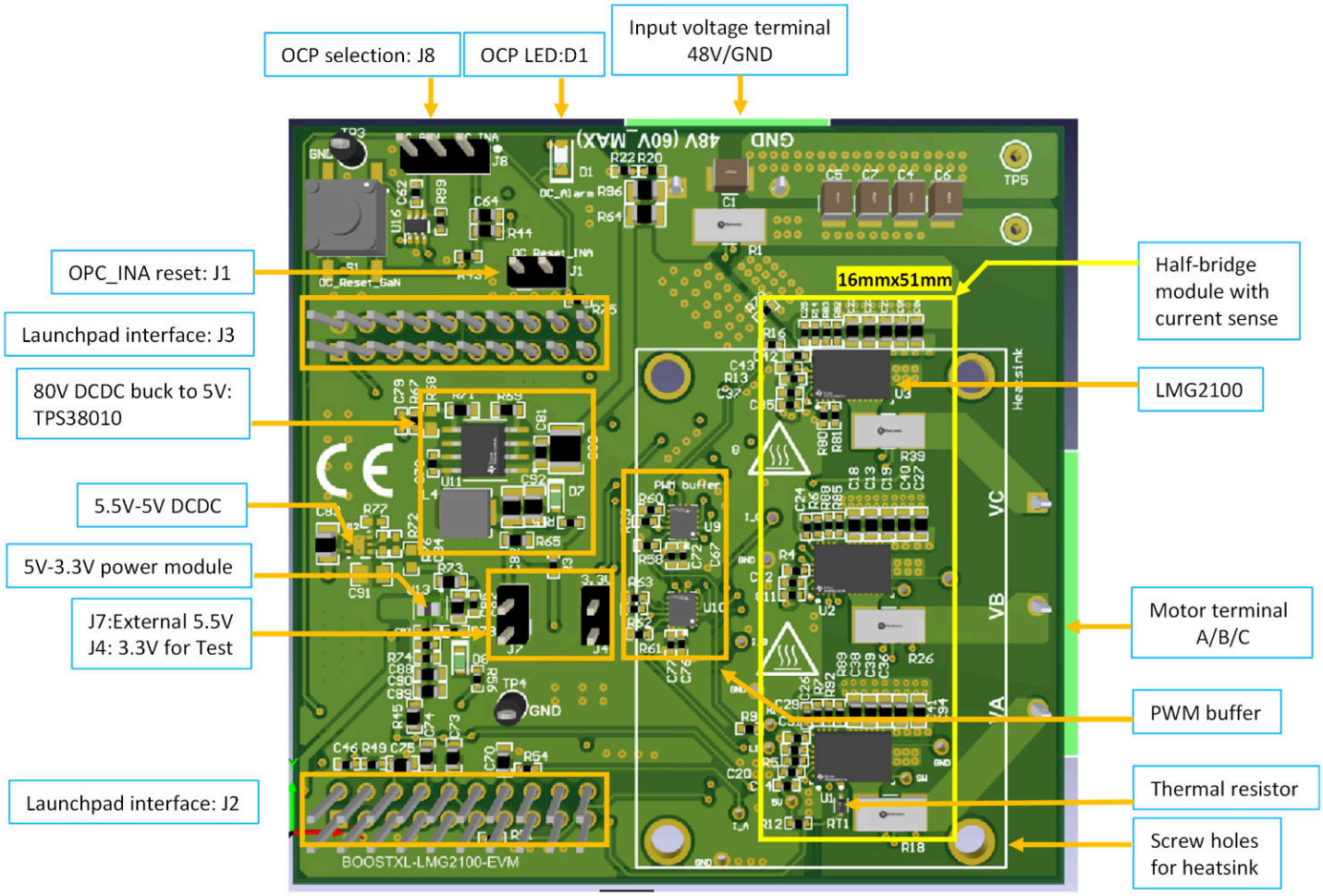


Figure 2-1. BOOSTXL-LMG2100-MD Block Diagram

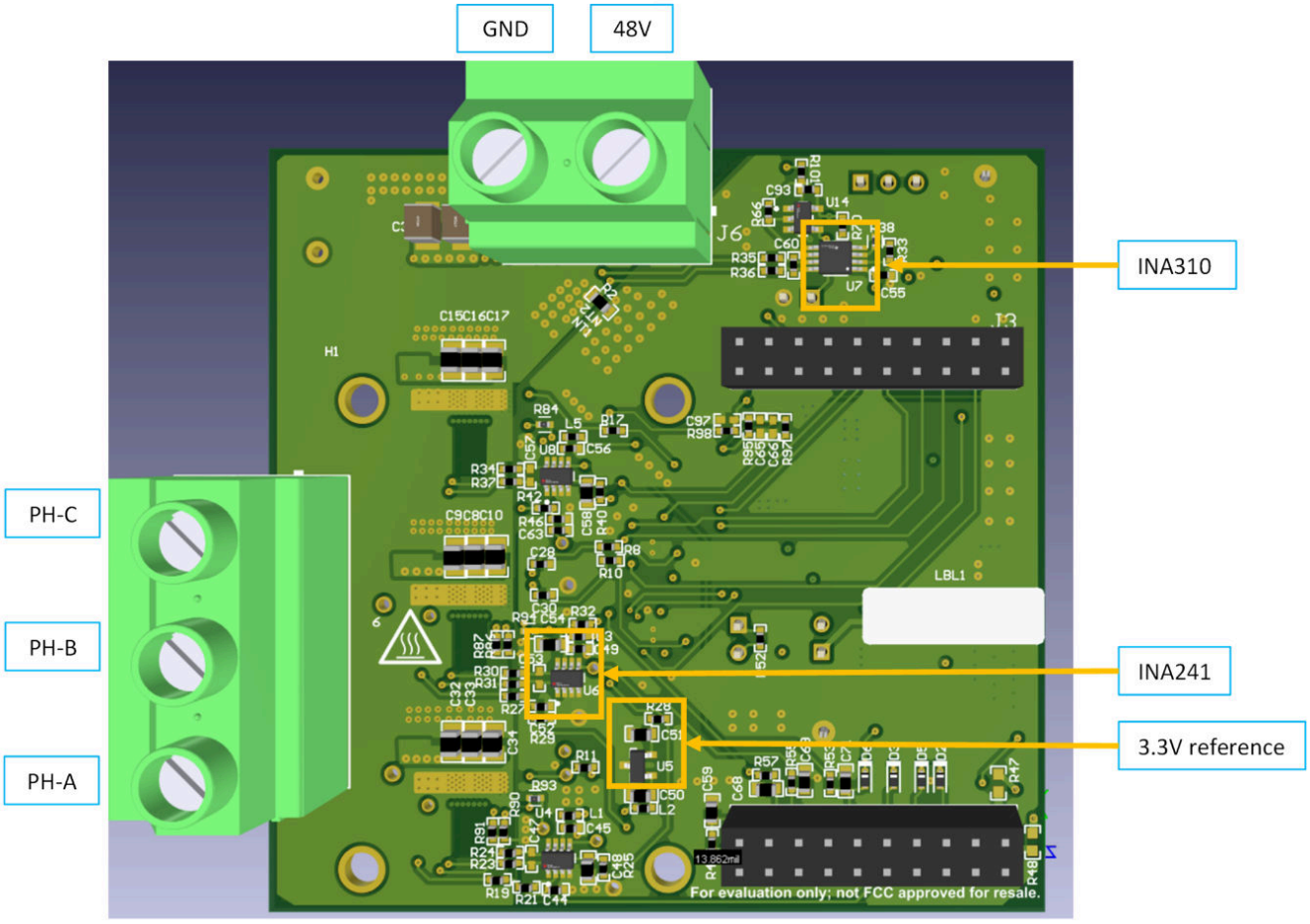


Figure 2-2. BOOSTXL-LMG2100-MD Block Diagram

2.2 Heatsink

The BOOSTXL-LMG2100-MD motor drive includes holes for heat sink mounting (heat sink not included). The measurement for hole placements are shown in Figure 2-4. The holes have a diameter of 3.175mm. The board was tested using the S05MZZ14 from Alphanovatech.

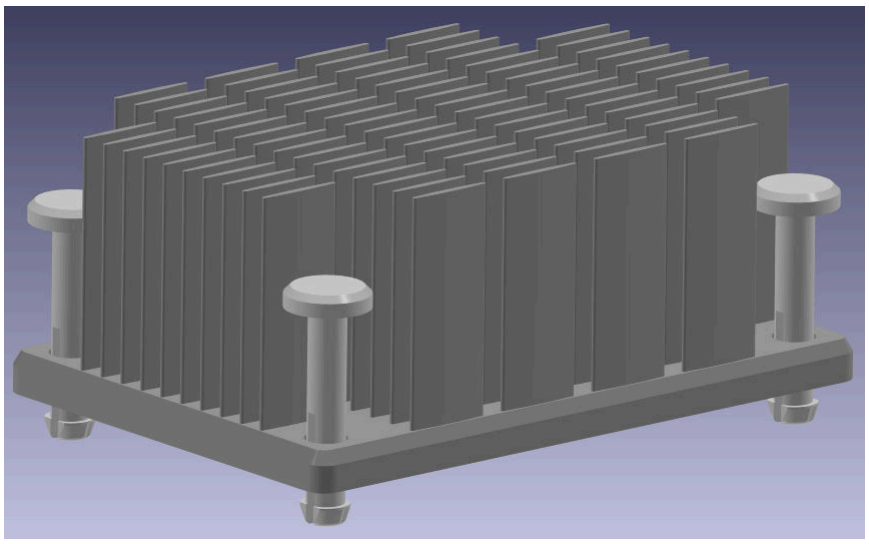


Figure 2-3. S05MZZ14 Heatsink

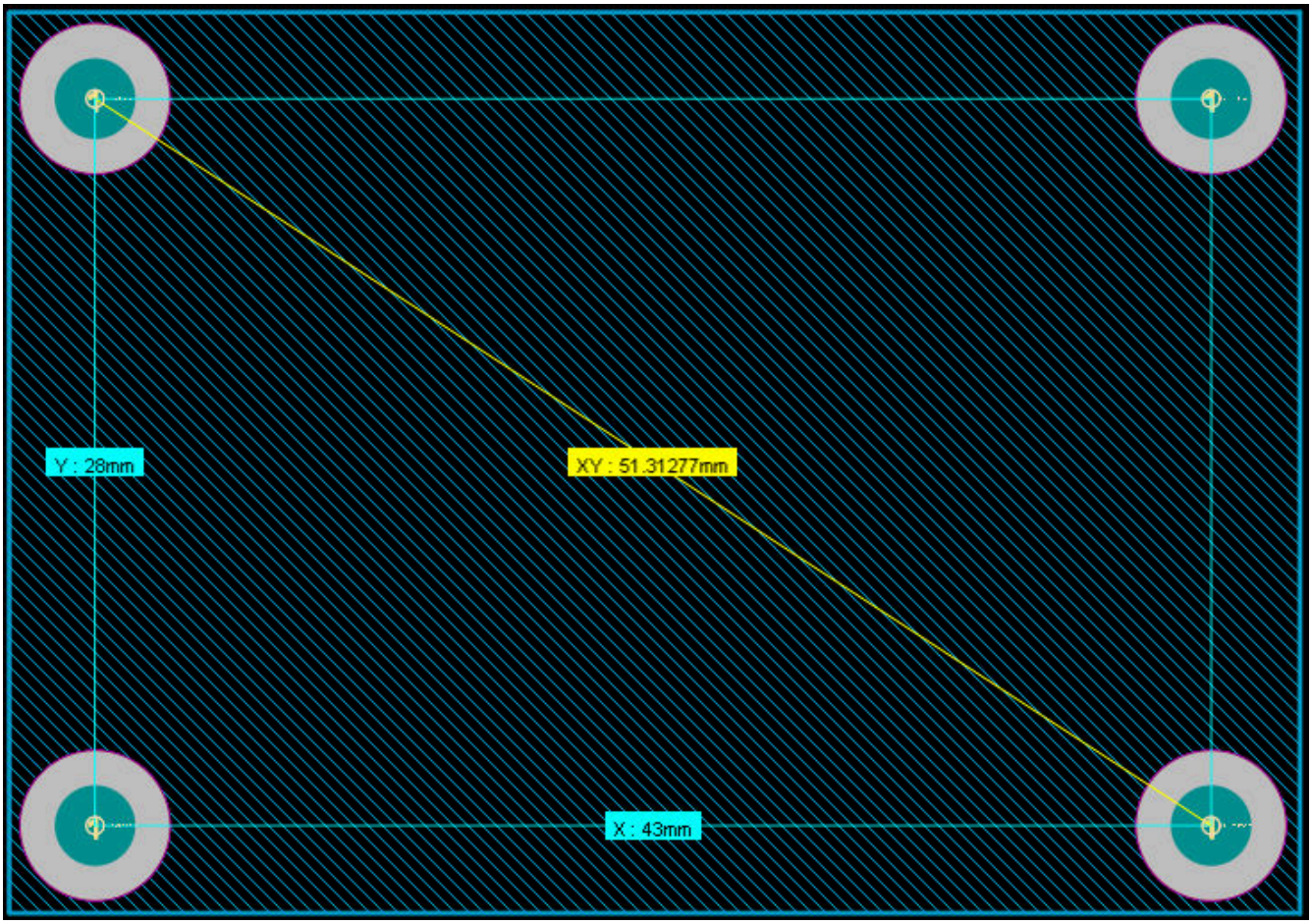


Figure 2-4. Heatsink Hole Measurements

2.3 Jumper Information

Table 2-1. Jumper Configuration

Jumper	Function	Populated / LED_on	Default
S1	INA310 overcurrent protection reset	Reset the OCP signal	
J1	INA310 /Reset pin access	Populated: INA310 latching mode Unpopulated: INA310 Transparent mode	Unpopulated
J4	Test option for voltage input of PWM buffers, R52 populated by default		Unpopulated
J7	Test option for 5.5V to TPS74601PDRVR (not populated)		Unpopulated
J8	Select overcurrent protection mode	1-2 Pin: Enable INA310 2-3 Pin: Enable GaN OCP	Pin 1-2
D1(Red)	Overcurrent fault report	Short circuit	/
D7(Green)	5V power rail	5V on board	/
D8(Green)	3.3V power rail	3.3V on board	/

CAUTION

R47 and R48 should not be populated when the C2000 on Launchpad will be powered by USB.

When the R48 and R47 is populated, the C2000 LaunchPad will be powered through GaN board, should remove both JP2 jumpers in F280039C Launchpad.

2.4 Header Information

The BOOSTXL-LMG2100-MD interface is designed to work with TI BoosterPack standard. The BOOSTXL-LMG2100-MD can connect to the LAUNCHXL-F280039C board on either set of headers:

- J1/J3 (LaunchXL) to J2 (BoostXL) and J4/J2 (LaunchXL) to J3 (BoostXL)

CAUTION

- Need an additional connector to raise the GaN board due to VA,VB, and VC (motor drive output) connector
- The SDK only supports J1-J4 (upper) connection; for J5-J8 (lower) connection need to modify software

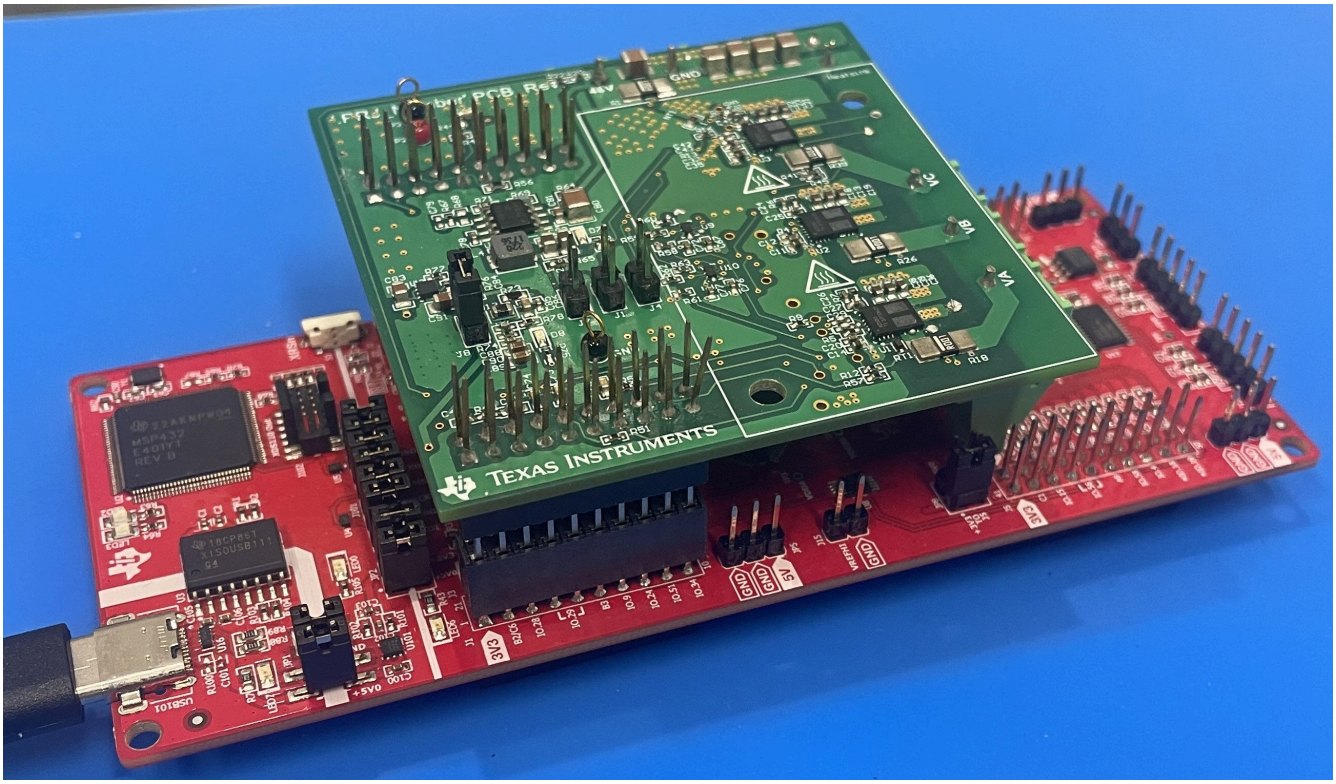


Figure 2-5. BOOSTXL-LMG2100-MD LaunchPad Connection Example

2.5 Setup

Connect the DC power supply (12V to 60V, 48V nominal) to the DC input voltage connector (J6) and the three-phase motor to the three-phase output voltage connector (J5). Validate that the three-phase motor can handle the high slew rates of the phase voltages during PWM switching; otherwise, consider using a low-pass LCR filter to reduce the slew rate of the phase voltage according to the requirements of the motor.

Testing has been done with the LVSERVOMTR.

3 Software

3.1 Software Description

The software example is created for the LAUNCHXL-F280039C using headers J1/J3 and J2/J4. Ensure the EVM board is connected to the LAUNCHXL-F280039C as Figure 2-5 shows.

Be sure to install Texas Instrument's C2000WARE_MotorControl_SDK V5.02.00.00 or newer software package in the default install path, for example *C:\ti\c2000\C2000WARE_Motor*Control_SDK_5_02_00.

Follow the steps in Section 3.2 to create an universal motor control project to evaluate BOOSTXL-LMG2100-MD. Please make sure to make the software changes in Section 3.3 so that the software can be used with BOOSTXL-LMG2100-MD.

3.2 Opening Project Inside CCS

Navigate to “\solution” folder under C2000WARE_MotorControl_SDK, Import the project under “solutions\universal_motorcontrol_lab\f28003x” within CCS. Right click the imported project name, click *Build Configurations* and under *Set Active*, choose *Flash_lib_3phGaN_3SC* as shown in Figure 3-1. Make sure the target configuration *TMS320F280039C_LaunchPad.ccxml* is active, if not, right click *TMS320F280039C_LaunchPad.ccxml* and click *Set as Active Target Configuration*.

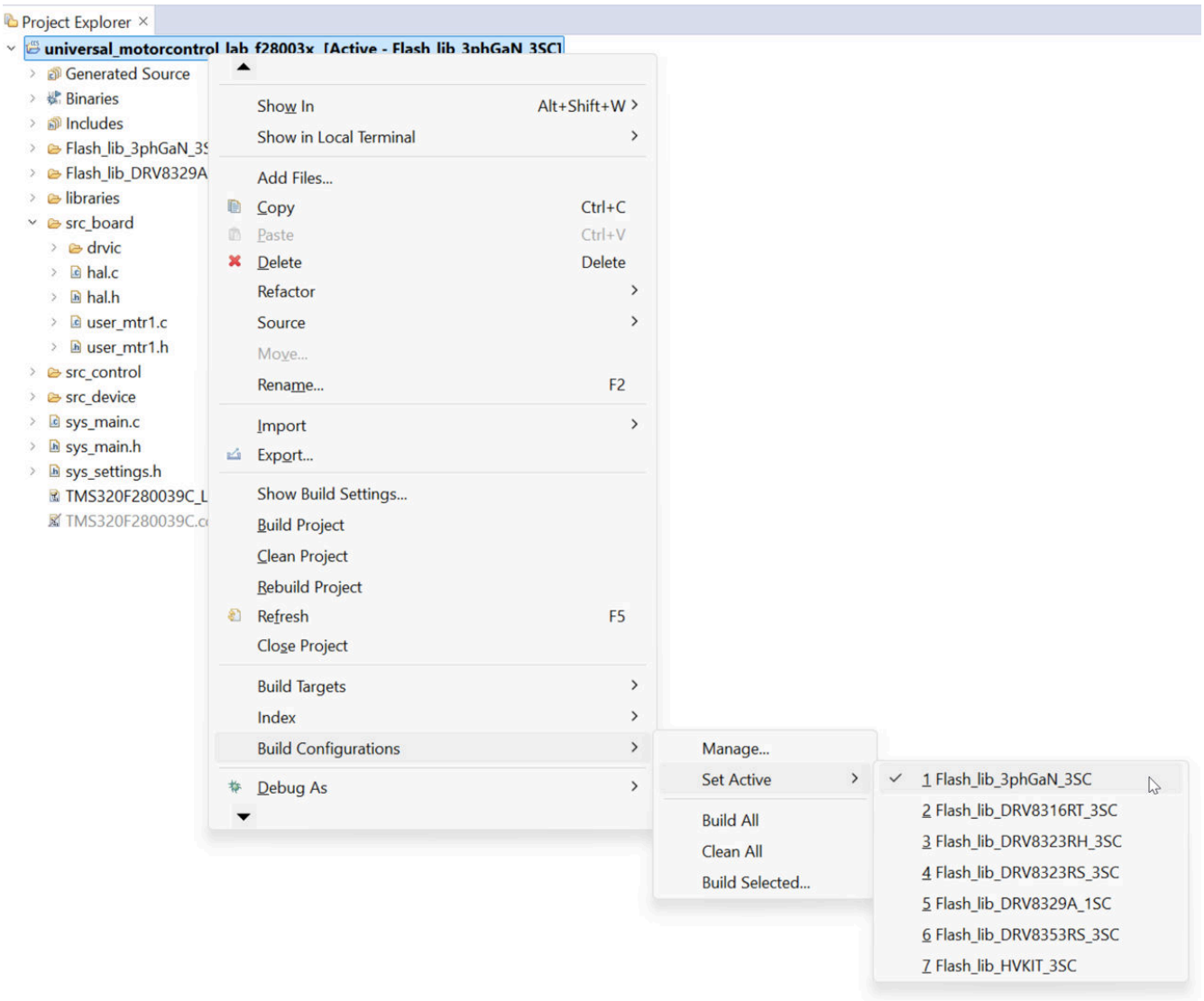


Figure 3-1. Select the Correct Build Configurations

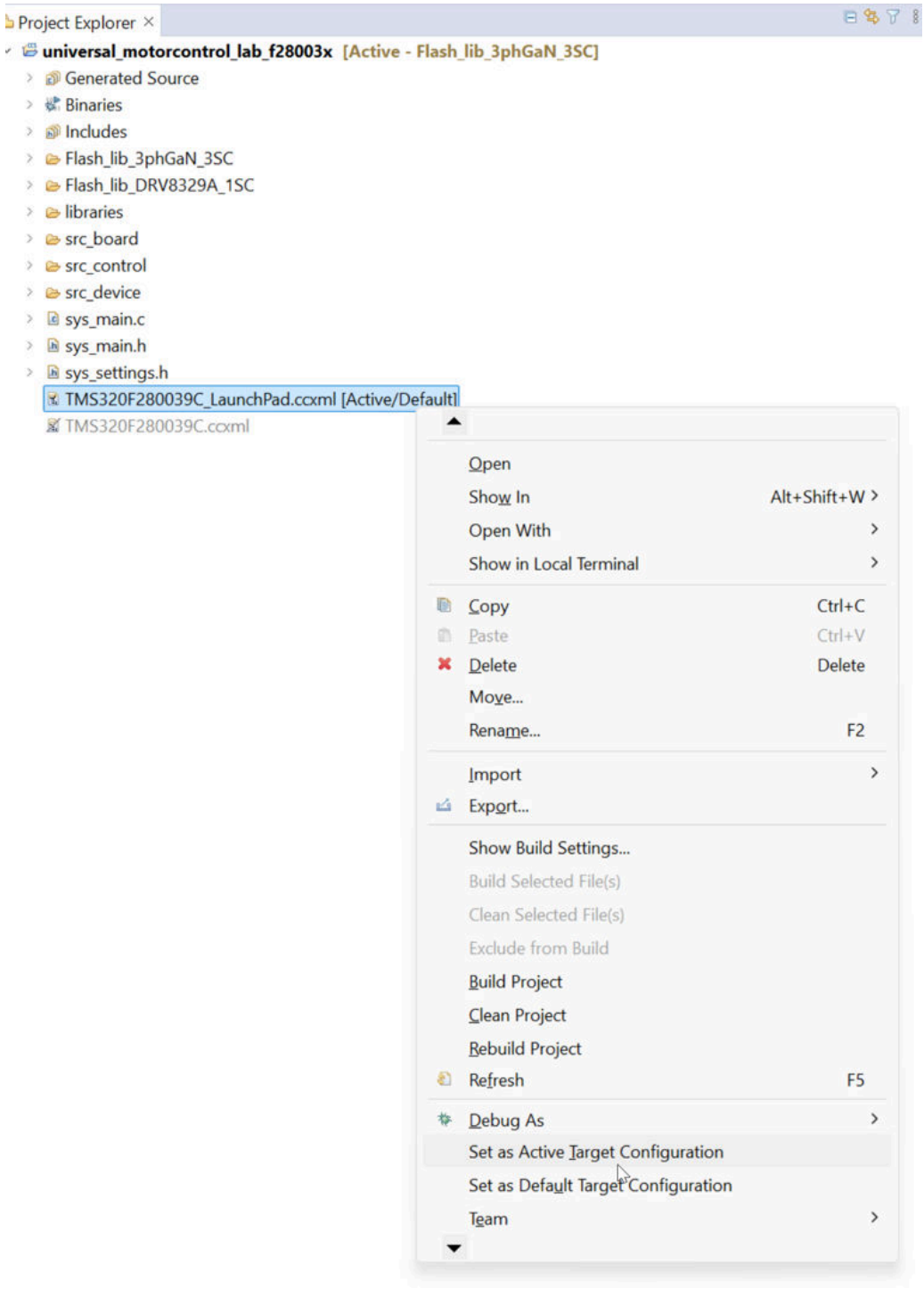


Figure 3-2. Select the Correct Build Configurations

3.3 Modification on Universal Motor Control Lab Example

Some minor software modifications are needed for the Universal Motor Control Lab software example to support LAUNCHXL-F280039C with BOOSTXL-LMG2100-MD. See the following steps to make the modifications.

1. Go to “src_board/hal.c”, **comment out** the definition for GPIO23 (Line 3606–Line 3609).

```
3599    // GPIO22->nEN_uC (only for TEST)
3600    GPIO_setPinConfig(GPIO_22_GPIO22);
3601    GPIO_writePin(20, 0);
3602    GPIO_setDirectionMode(22, GPIO_DIR_MODE_OUT);
3603    GPIO_setPadConfig(22, GPIO_PIN_TYPE_STD);
3604
3605    // GPIO23->M1_DRV_CAL (Low)
3606//    GPIO_setPinConfig(GPIO_23_GPIO23);
3607//    GPIO_writePin(23, 0);
3608//    GPIO_setDirectionMode(23, GPIO_DIR_MODE_OUT);
3609//    GPIO_setPadConfig(23, GPIO_PIN_TYPE_STD);
```

Figure 3-3. Comment Out the Definition for GPIO23

2. Open “src_board/user_mtr1.h”, change MACRO definition **USER_M1_SIGN_CURRENT_SF** to (1.0f) (Line 628).

```
619//!        the "sign" = -1.0f if the current feedback polarity is positive that
620//!        means the same pin of the inline shunt resistor is connected to the
621//!        output of the three-phase power inverter and is also connected to
622//!        the inverting pin of the operational amplifier
623//!
624//!        the "sign" = 1.0f if the current feedback polarity is positive that
625//!        means the same pin of the inline shunt resistor is connected to the
626//!        output of the three-phase power inverter and is also connected to
627//!        the non-inverting pin of the operational amplifier
628#define USER_M1_SIGN_CURRENT_SF         (1.0f)
```

Figure 3-4. Make Sure USER_M1_SIGN_CURRENT_SF is (1.0f)

3. Open “src_board/user_mtr1.h”, change define **USER_M1_OVER_VOLTAGE_FAULT_V** (58.0 f) and define **USER_M1_OVER_VOLTAGE_NORM_V** (55.0f) (Line 644 and Line 647).

```
643//! \brief DC bus over voltage threshold
644#define USER_M1_OVER_VOLTAGE_FAULT_V        (58.0f)
645
646//! \brief DC bus over voltage threshold
647#define USER_M1_OVER_VOLTAGE_NORM_V         (55.0f)
```

Figure 3-5. Change the Overvoltage Protection Threshold

4. Open “src_board/user_mtr1.h”, change define **USER_M1_ADC_FULL_SCALE_CURRENT_A** (66.0f) (Line 614).

```
605#define USER_M1_NOMINAL_DC_BUS_VOLTAGE_V        (48.0f)
606
607//! \brief Defines the maximum voltage at the AD converter
608#define USER_M1_ADC_FULL_SCALE_VOLTAGE_V        (81.49905213f)
609
610//! \brief Defines the analog voltage filter pole location, Hz
611#define USER_M1_VOLTAGE_FILTER_POLE_Hz          (1103.026917f)     // 33nF
612
613//! \brief Defines the maximum current at the AD converter
614#define USER_M1_ADC_FULL_SCALE_CURRENT_A        (66.0f)     // gain=20
```

Figure 3-6. Change Current Sensing Range

3.4 Change PWM Frequency and Deadtime

The default PWM switching frequency is 15kHz. This section describes how to change the PWM frequency and deadtime to further evaluate the GaN device.

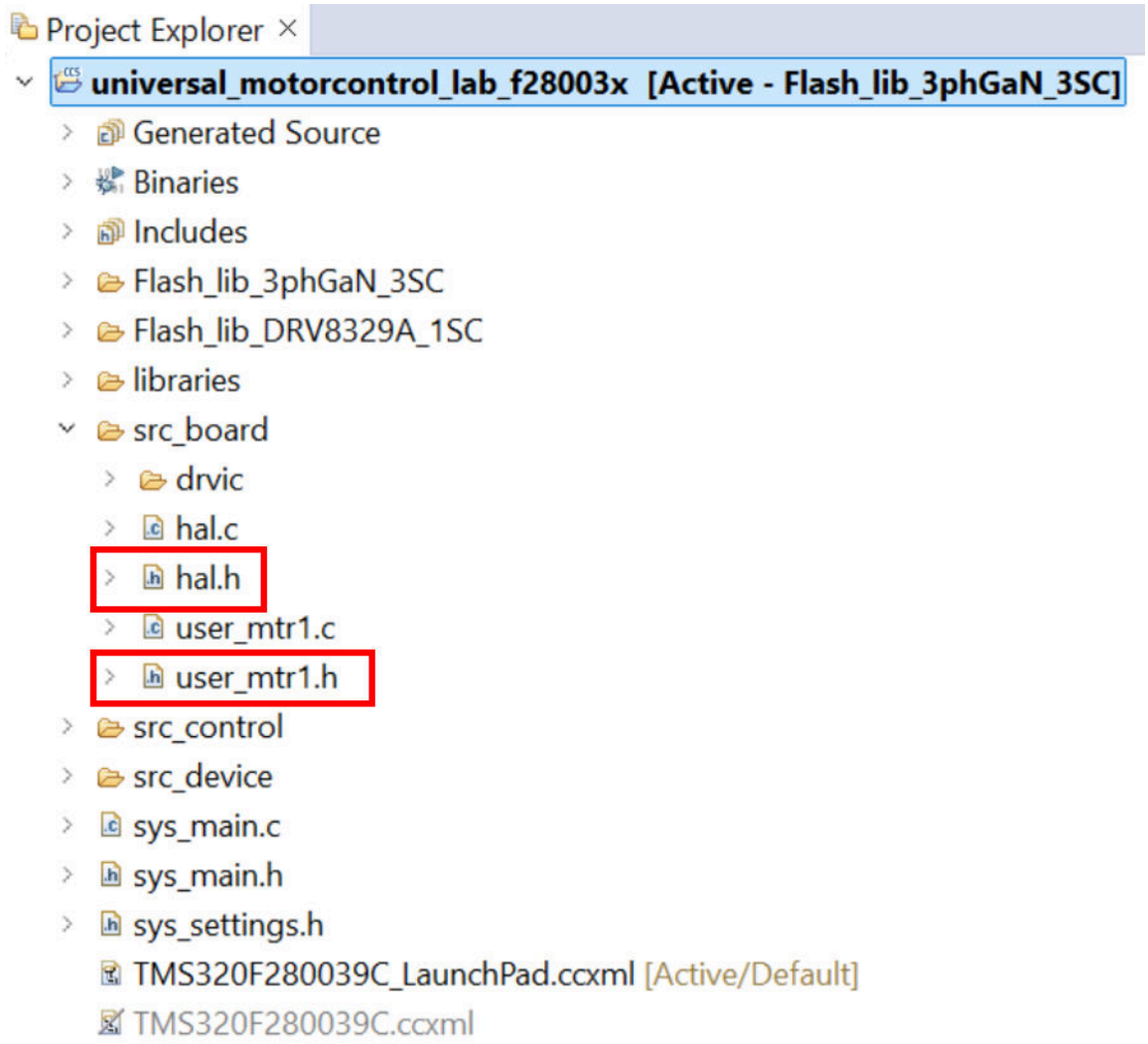


Figure 3-7. Files Containing the Key Variables to Vary PWM Frequency and Deadtime

- To change PWM frequency, open “src_board\user_mtr1.h”, change the MACRO definition “USER_M1_PWM_FREQ_kHz” to desired PWM frequency (Line 834).

> **CAUTION**
>
> Please be aware that with the increase in PWM frequency, control loop frequency might need to vary accordingly, this can be set through MACRO definition **USER_M1_NUM_TICKS_PER_ISK_TICK** (Line 811) the default value is 1, meaning control computation cycle is the same as PWM cycle.

Under sensorless FOC method with FAST as the speed estimator, the below combinations have been verified at TI lab.

PWM Switching Frequency (kHz)	Control Loop Frequency (USER_M1_NUM_TICKS_PER_ISK_TICK value)	Deadtime (ns)
40	40kHz (1)	50
60	30kHz (2)	50
80	40kHz (2)	50
120	40kHz (3)	50

The deadtime can be changed through MACRO MTR1_PWM_DBFED_CNT and MTR1_PWM_DBRED_CNT in “src_board/hal.h” (Line 1479 and Line 1482). The default value is 5, which is equivalent to 50ns by default. Without any changes on ePWM configuration, PWM timebase clock TBCLK = EPWMCLK = 100MHz, and the deadtime is calculated as:

$$\text{Falling edge delay: } \text{MTR1\_PWM\_DBFED\_CNT} \times \text{TTBCLK} = 5 \times (1/100\text{M}) = 50\text{ns} \quad (1)$$

$$\text{Rising edge delay: } \text{MTR1\_PWM\_DBRED\_CNT} \times \text{TTBCLK} = 5 \times (1/100\text{M}) = 50\text{ns} \quad (2)$$

3.5 Software Guide

To explore full options and labs for this board review the software guide for the code. The software guide is located in the folder downloaded for the MotorControl_SDK. To find the software guide, locate the MotorControl_SDK folder then follow: C2000Ware_MotorControl_SDK_x_xx_xx_xx → solutions → boostxl_3phganinv → docs → sluubp1a_BOOSTXL-3PhGaNInv Evaluation Module User Guide (Rev. A).pdf. This guide goes through the software for the BOOSTXL-LMG2100-MD. There is also helpful information in the Motor Control SDK Universal Project and Lab.

4 Hardware Design Files

4.1 Design Files

BOOSTXL-LMG2100-MD design files are available on product page for this EVM on TI.com.

https://www.ti.com/tool/BOOSTXL-LMG2100-MD#design-files

5 Additional Information

5.1 Trademarks

BoosterPack™, C2000™, and LaunchPad™ are trademarks of Texas Instruments.
All trademarks are the property of their respective owners.

6 Related Documentation

- TIDA-010936
- BOOSTXL-3PHGANINV
- C2000WARE-MOTORCONTROL-SDK
- Application Brief: GaN FET in Humanoid Robots
- Application Brief: Motor Control in Humanoid Robots

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.

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   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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL 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 HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

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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