EVM User's Guide: BP-AMC0106-LMG-MD

BP-AMC0106-LMG-MD Evaluation Module

Description

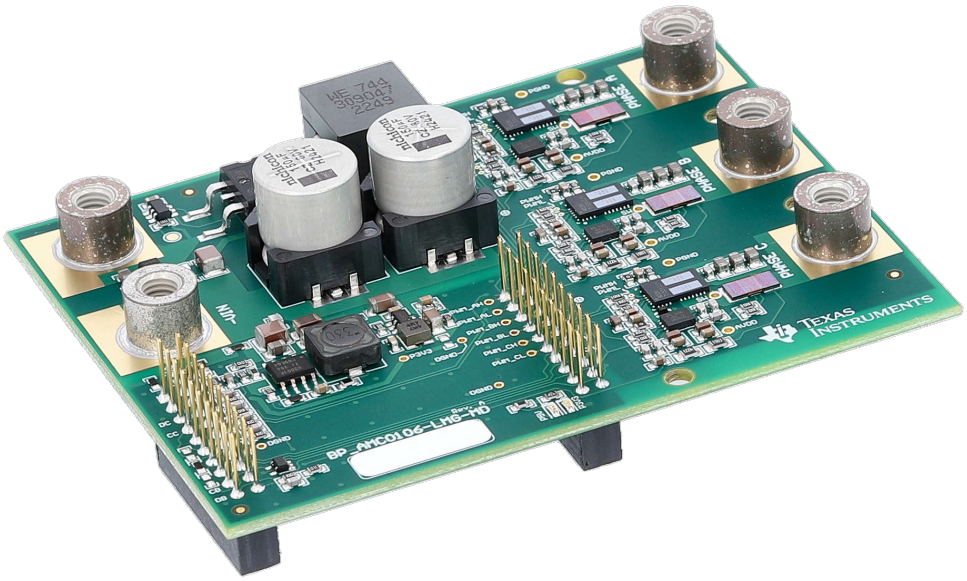
The BP-AMC0106-LMG-MD Evaluation Module (EVM), is an advanced Gallium Nitride (GaN) -based inverter featuring precision shunt-based isolated phase current sensing with AMC0106M05 delta-sigma modulators. This technology enables accurate control of high-precision drives, including servo drives. The EVM features a TI BoosterPack™ compatible interface, which allows seamless connection to a C2000™ microcontroller (MCU) LaunchPad™ development kit for straightforward performance evaluation. This EVM is a successor of TIDA-010936 and BOOSTXL-LMG2100-MD EVM.

Applications

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

Features

- Wide input voltage range from 12V to 60V with reverse polarity protection
- LMG2100R026 100V 2.6mΩ half-bridge GaN power stage
- GaN half-bridge power stage simplifies the PCB layout and reduces parasitic inductances for optimized switching performance
- TI GaN reduces size by >50% compared to metal-oxide-semiconductor (MOS) design
- Precision, functionally isolated, in-line phase current sensing with 1mΩ shunt
- Capable of running up to 24A_RMS (LMG2100R026) without a heat sink
- TI BoosterPack-compatible interface with 3.3V I/O for easy performance evaluation using C2000 MCU LaunchPad development kit



BP-AMC0106-LMG-MD Development Kit

1 Evaluation Module Overview

1.1 Introduction

This EVM uses GaN technology to implement a 3-phase inverter controlled by the TMS320F28P650DK on the C2000 LaunchPad. The GaN inverter demonstrates the ability of GaN to operate at higher switching frequencies than traditional MOSFET motor drives. Phase current sensing leverages the latest precision isolated delta-sigma modulators in a QFN package. This design improves current sensing accuracy and eliminates problems associated with common mode transients. By default, the EVM operates without a heat sink but includes mounting holes for a custom heat sink if needed.

This user's guide describes the characteristics, operation, and recommended use cases of the BP-AMC0106-LMG-MD. This document provides examples and instructions on how to use the BP-AMC0106-LMG-MD board and included software. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the BP-AMC0106-LMG-MD. This document also includes a schematic, reference printed circuit board (PCB) layouts, and a complete bill of materials (BOM).

1.2 Kit Contents

- BP-AMC0106-LMG-MD motor drive board

Users needs to separately order the LAUNCHXL-F28P65X C2000 LaunchPad and a 48V low-voltage servo motor (for example, LVSERVOMTR) separately. The BP-AMC0106-LMG-MD features heat sink mounting holes to provide cooling for the LMG2100 devices in higher power applications. However, the heat sink is not included in the kit.

1.3 Specification

Figure 1-1 shows the system block diagram of BP-AMC0106-LMG-MD three-phase GaN inverter evaluation module.

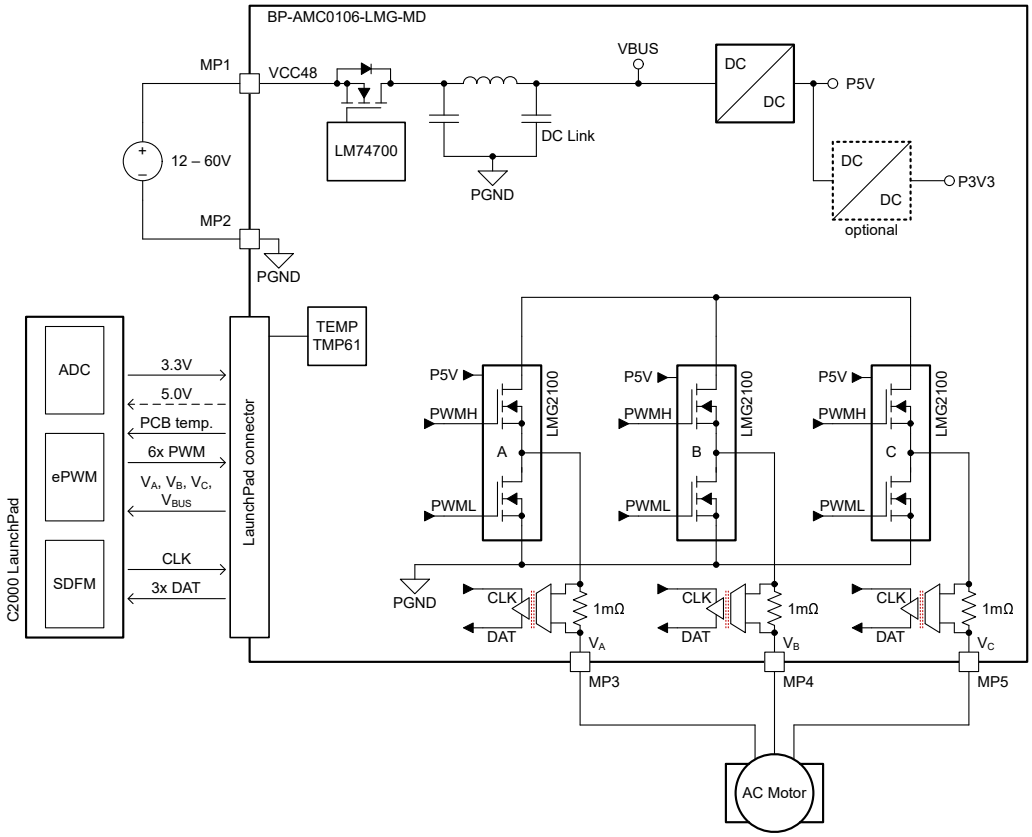


Figure 1-1. BP-AMC0106-LMG-MD Block Diagram

The EVM accepts voltage from an external power supply in the range from 12 to 60V, with a nominal DC input voltage of 48V. The LM7400 diode controller protects the system against reverse polarity. A wide input voltage range DC/DC converter, the LMR38010, generates 5V for the rail that supplies the GaN power stages and optionally the C2000 LaunchPad. There is a second DC/DC converter with the LMR50410 which generates 3.3V. This converter is disabled by default as the LaunchPad supplies the 3.3V rail.

The inverter power stage consists of three GaN half-bridge modules (LMG2100). The LMG2100 device integrates the gate driver and the bootstrap circuit with clamp. Control inputs of the module accept logic levels, allowing direct connection of PWM signals from the microcontroller without an additional level shifter.

Precise torque control and dynamic performance of the inverter require accurate phase current sensing. Three independent delta-sigma modulators (AMC0106M05) with the ±50mV input voltage range sense the voltage drop across 1mΩ current sensing resistor (shunt). The functional isolation completely eliminates common mode transients that are typically visible on the output of the non-isolated current sense amplifiers. The isolated part of the modulator reuses the bootstrap voltage from the GaN half-bridge module. A logic gate (SN74LVC1G17) buffers the clock signal that is shared with all three modulators.

For temperature monitoring, a linear thermistor (TMP61) senses the temperature of the printed circuit board close to the phase C half-bridge module. Additionally, four resistor dividers scale down the VBUS and phase voltages for the analog-to-digital (ADC) converter, enabling voltage monitoring.

The EVM interfaces to a host processor. The connector is compatible with the LaunchPad form-factor. By default, the signal assignment and code example are compatible with LAUNCHXL-F28P65X evaluation module. The code example implements a sensorless, speed-variable, field-oriented control of a synchronous motor using the InstaSPIN™-FOC software. The example firmware is available as a part of the C2000WARE-MOTORCONTROL-SDK and tested 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
- LMR50410: SIMPLE SWITCHER® 4V to 36V, 1A synchronous step-down converter
- LM74700-Q1: 3.2V to 65V, 80uA I_Q automotive diode controller
- AMC0106M05: ±50mV input functionally isolated delta-sigma modulator for current sensing
- SN74LVC1G17: single 1.65V to 5.5V buffer with Schmitt-Trigger inputs
- TMP61: 1%, 10kΩ linear thermistor in 0402, 0603/0805 and through hole packages

2 Hardware

2.1 BP-AMC0106-LMG-MD PCB Overview

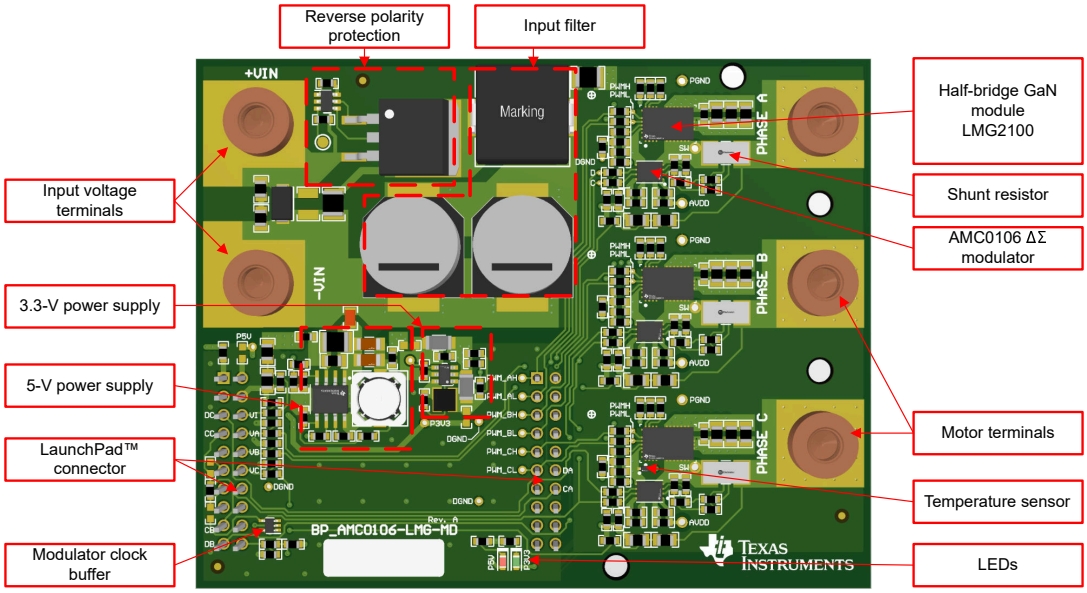


Figure 2-1. BP-AMC0106-LMG-MD Block Diagram

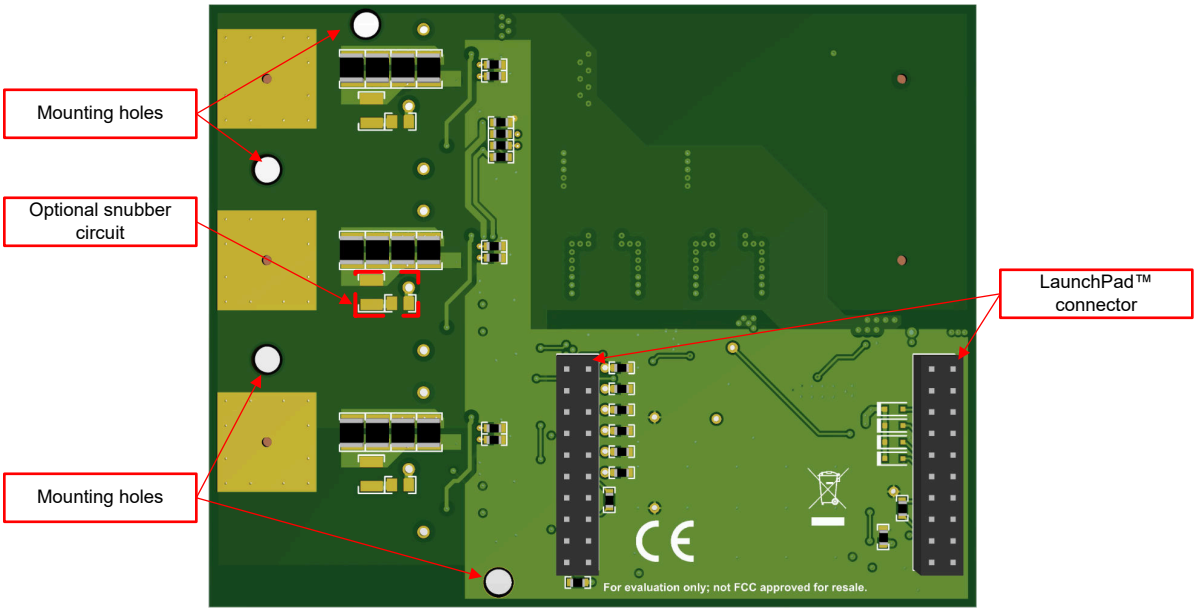


Figure 2-2. BP-AMC0106-LMG-MD Block Diagram

2.2 Board Configuration Information

Table 2-1. Board Configuration

Option	Function	Default
R504	Enables the 5V DC/DC converter by connecting to the VBUS rail (12-60V)	Populated
R505	Connects the output of the 5V DC/DC converter to the P5V rail	Populated
R514	Enables the 3.3V DC/DC converter by connecting to the P5V rail	Unpopulated
R512	Connects the output of the 3.3V DC/DC converter to the P3V3 rail	Unpopulated
C211, R206	Switch node snubber circuit	Unpopulated
R603	Connects the 3.3V rail from the LaunchPad to the P3V3 rail for delta-sigma modulators	Populated
R604	Connects the 5V rail from the LaunchPad to the P5V rail for the GaN half-bridge modules	Unpopulated
R621	Bypass the modulators clock buffer	Unpopulated
R613, R614	Rewires modulator data to additional pins for LAUNCHXL-F280039C compatibility	Populated
R618	Connects modulator clock return for SDFM module	Populated
R617	Allows connecting complementary modulator clock (PWM) to the SDFM module for delay compensation. Refer to the Clock Edge Delay Compensation With Isolated Modulators Digital Interface to MCUs application note.	Unpopulated

CAUTION

The C2000 LaunchPad is powered from the USB by default. Assembling the R604 jumper allows powering the LaunchPad through the EVM. In this case, remove JP1 jumper from the LAUNCHXL-F28P65X. Refer to the C2000™ F28P65x Series LaunchPad™ Development Kit user's guide for further power configurations.

2.3 Header Information

The BP-AMC0106-LMG-MD interface is designed to work with the TI BoosterPack standard. The BP-AMC0106-LMG-MD can connect to the LAUNCHXL-F28P65X board on either set of headers. The provided code example in the C2000WARE-MOTORCONTROL-SDK supports following configuration

- J5, J7 (LAUNCHXL) to J600 (EVM) and J6, J8 (LAUNCHXL) to J601 (EVM)

CAUTION

Using the second set of headers, or a different C2000 LaunchPad can result in very small clearance between the 48V circuitry on the EVM and the additional LaunchPad pin-headers. Use a kapton, or-similar, tape for insulation to avoid accidental damage of the LaunchPad.

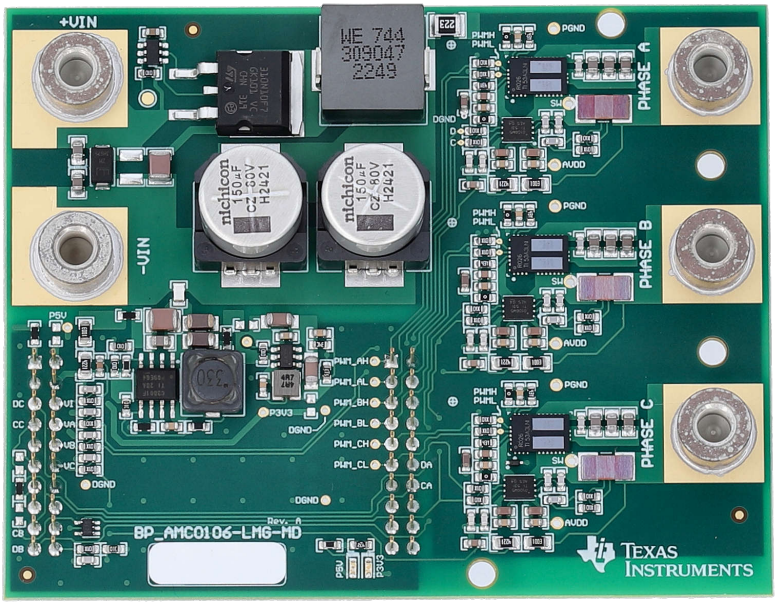


Figure 2-3. BP-AMC0106-LMG-MD EVM (Top View)

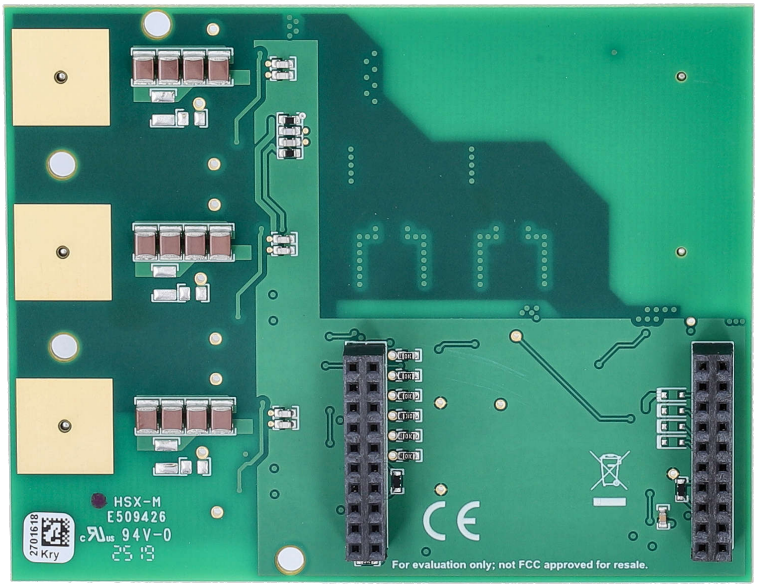


Figure 2-4. BP-AMC0106-LMG-MD EVM (Bottom View)

2.4 EVM Setup

The following sections describe how to prepare the BP-AMC0106-LMG-MD EVM and run the LVSERVOMTR with the LAUNCHXL-F28P65X C2000 LaunchPad.

CAUTION

Turn off the power supply and disconnect the USB cable before handling the EVM, changing the wiring or configuration.

1. Connect the DC power supply (12V to 60V, 48V nominal) to the DC input voltage terminals MP1, MP2
2. Use the wiring harness provided with the LVSERVOMTR to connect the motor to the LAUNCHXL-F28P65X C2000 LaunchPad and BP-AMC0106-LMG-MD EVM
   a. Connect the quadrature-encoder connector (J4) to the J12 header on LAUNCHXL-F28P65X C2000 LaunchPad
   b. Connect motor phases wires (white, red, black) to motor terminals MP3, M4, MP5 on the EVM. Use M3 cable lugs or, alternatively, use screws and washers to secure them in place.
3. Adjust LAUNCHXL-F28P65X C2000 LaunchPad configuration switches:
   a. Set switch S2 SEL1 (LEFT) to 1 (UP towards the USB connector)
   b. Set switch S5 Q1 (LEFT) to 12 (DOWN towards the LAN connectors)
4. Connect the LAUNCHXL-F28P65X C2000 LaunchPad to the PC with the provided USB Type-C® cable
   a. Check the green LED on the EVM lights up
5. Enable the DC power supply output
   a. Check the red LED on the EVM lights up
6. Proceed to the software section

CAUTION

To avoid potential damage or safety hazards, avoid hot-plugging the DC power supply as arcing can occur. Instead, use the output enable function on the power supply to turn on the system. If this option is not possible, then consider lowering the input voltage to less than 24V as an alternative to minimize the risk of arcing or damage.

Refer to Figure 2-5 and Figure 2-6 that shows the proper configuration of the system with the prototype hardware.

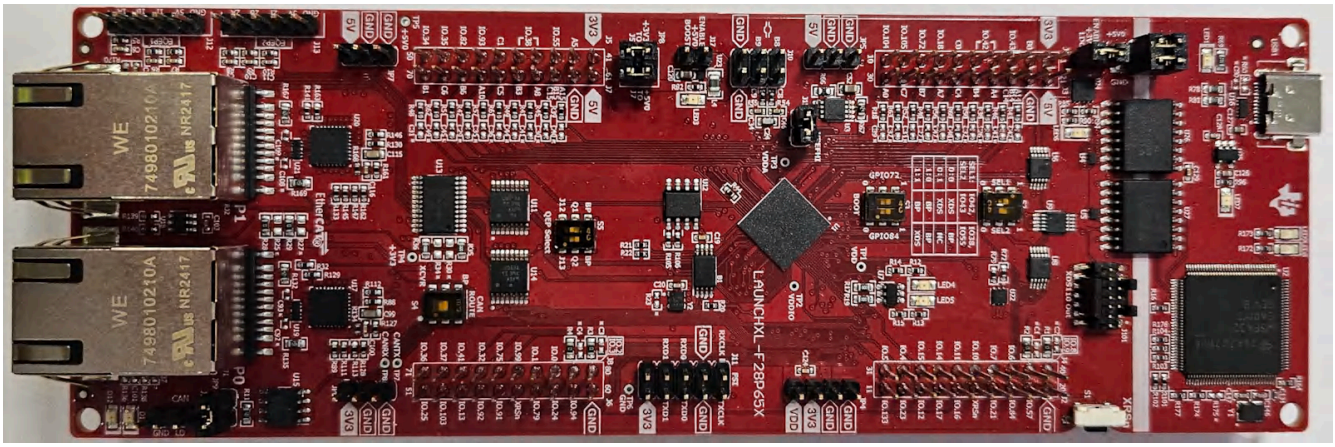


Figure 2-5. LAUNCHXL-F28P65X C2000 LaunchPad Configuration for the EVM

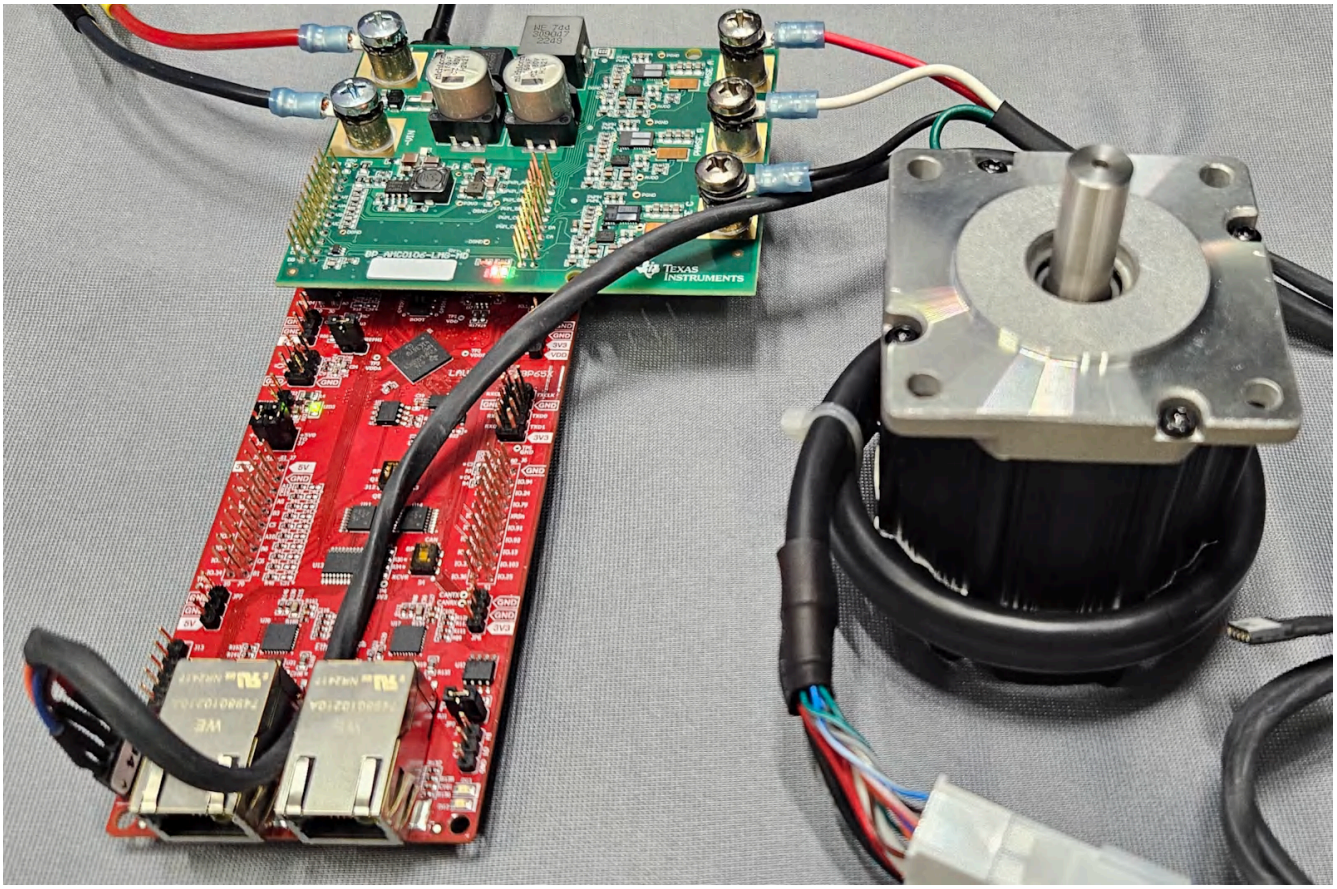


Figure 2-6. LAUNCHXL-F28P65X C2000 LaunchPad with the EVM Ready for Operation

3 Software

3.1 Software Description

The following instructions are compatible with these versions of software packages. To make sure of successful testing of the EVM, install all required software packages before proceeding.

- Code Composer Studio (version 12.8.1) (the last Eclipse-based CCS)
- MotorControl software development kit (SDK) for C2000™ MCUs (version 5.04.00.00)

Note

The provided demo and manual works with future releases of the MotorControl SDK and CCS. However, refer to the change log as minor adjustments can be necessary.

The EVM runs with the *universal_servo_drive* project, which is a part of the MotorControl SDK. This project reuses the *universal_motorcontrol_lab* project but removes the sensorless algorithms and uses the sysconfig system configuration tool. The *universal_servo_drive* project requires motor position sensing and is compatible with the quadrature encoder interface by default. Detailed information on the motor control software can be found in the MotorControl SDK documentation, which is located in the respective project folders.

Follow the steps in Section 3.2 to create a universal servo drive project to evaluate the BP-AMC0106-LMG-MD EVM.

3.2 Importing the Project to Code Composer Studio

Start with importing the project to Code Composer Studio™ (CCS) by following these steps:

1. Open CCS (version 12.8.1), and set up the workspace if prompted
2. Go to *File->Import->Code Composer Studio->CCS Projects* and click next
3. Browse for the search directory with the universal_servo_drive at *C:\ti\c2000\C2000Ware_MotorControl_SDK_5_04_00_00\solutions\universal_servo_drive* on Windows® machines
4. Select the *universal_servo_drive* project in the discovered projects window
5. Click finish to import the project to the workspace

Continue with setting the proper build configuration for the EVM. Right click on the imported project, go to *Build Configurations* and under *Set Active*, choose *BXL_AMC0106_LMG_MD* as shown in Figure 3-1. Now, go to *Project->Build Project.* Make sure the compiler successfully builds the project without any errors or warnings. Make sure the target configuration *TMS320F28P650DK9.ccxml* is active, if not, right click *TMS320F28P650DK9.ccxml* and click *Set as Active Target Configuration*.

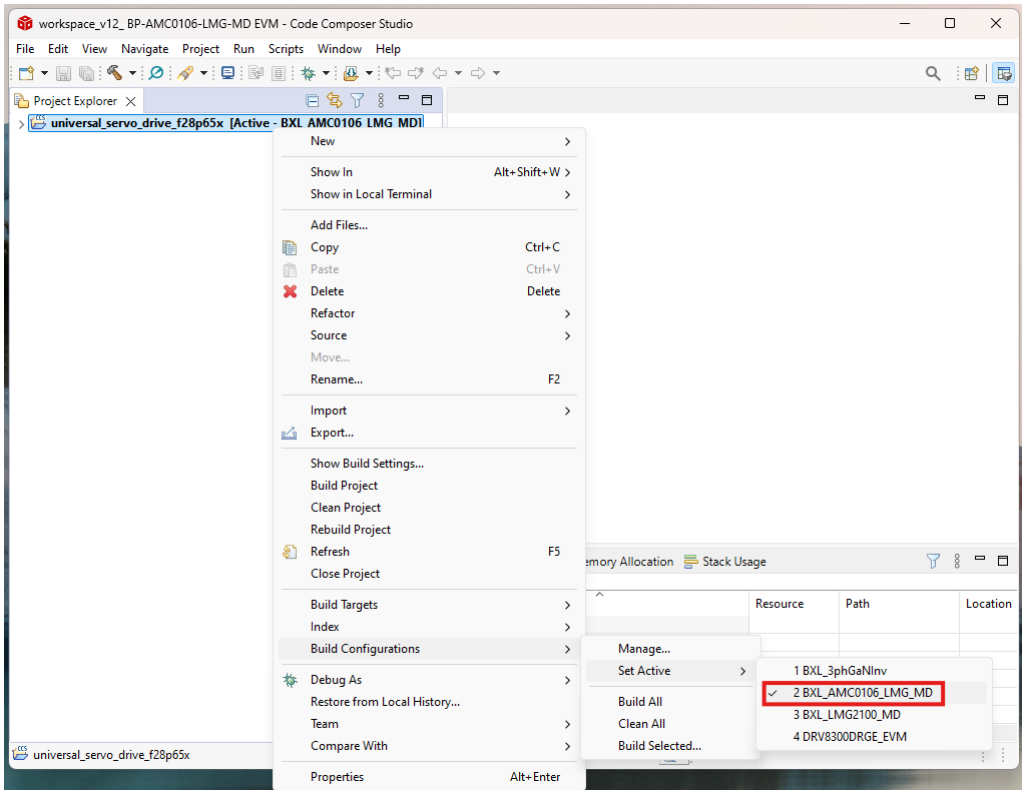


Figure 3-1. Select the Correct Build Configurations

Go to Run->Debug to run the demo software. When running the project for the first time, the CCS asks to select the CPUs to load program on. Disable the CPU2 as shown in Figure 3-2. After confirming, the debugger uploads the binary to the C2000 LaunchPad.

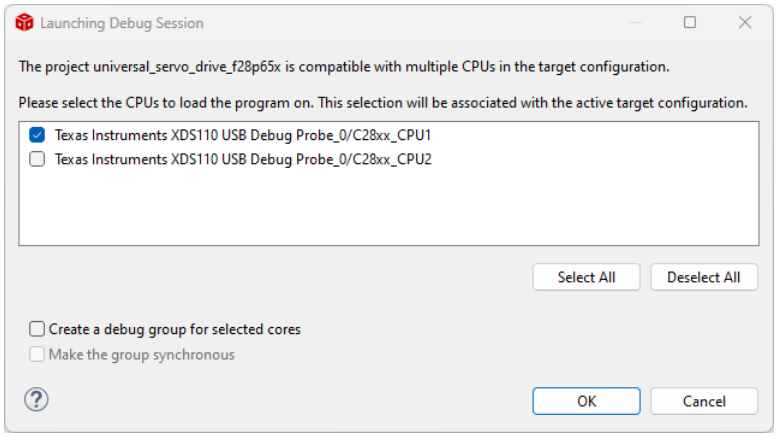


Figure 3-2. Disable CPU2

In the debugger interface, go to *Expressions* window, right-click and select *Import...* In the dialog, search for the *universal_servo_drive_expressions.txt* file that is in *common\debug* folder in the *universal_servo_drive* project folder. Click *Open* to import all important expressions at once. These expressions control and monitor the servo drive system.

3.3 Universal Servo Drive Example Modifications

The universal servo drive project does not require any source code modifications to run the suggested LVSERVOMTR motor for the first tests.

The project supports four incremental build options that are useful when commissioning the servo drive EVM. Open the *sys_settings.h* file and adjust *DMC_BUILDLEVEL* macro to:

- *DMC_LEVEL_1* for all motor phases generating 50% duty cycle
- *DMC_LEVEL_2* for open-loop control to verify the motor current and voltage sensing signals
- *DMC_LEVEL_3* for closed current loop to validate the current sensing on the board and the current control with the PID
- *DMC_LEVEL_4* for closed-loop run with estimator or observers.

Note

The default build configuration is DMC_LEVEL_4

For other configuration options and details, refer to the Motor Control SDK Universal Project and Lab user's guide which part of the MotorControl SDK.

3.4 Change PWM Frequency and Dead Time

The default PWM switching frequency is 20kHz. This section explains how to modify the PWM frequency and dead time, allowing for further evaluation of the EVM.

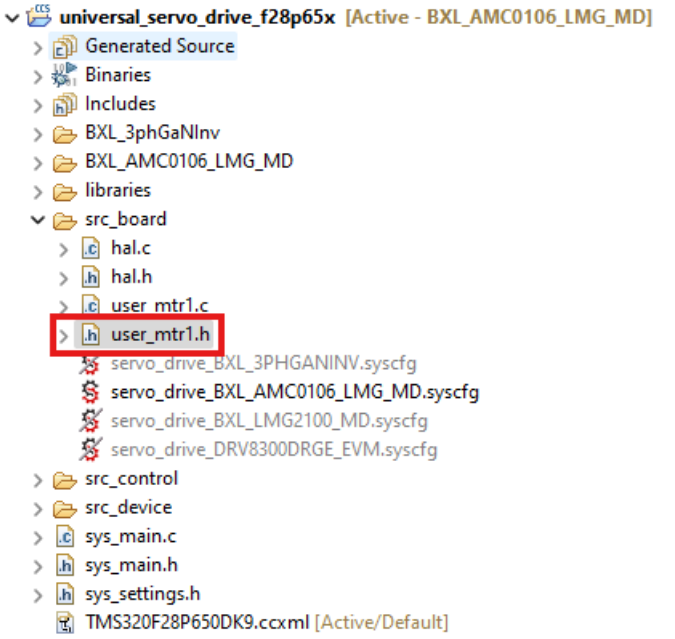


Figure 3-3. File PWM Frequency and dead time

To change the PWM frequency, open *src_board\user_mtr1.h* file and change the macro definition *USER_M1_PWM_FREQ_kHz* to desired PWM frequency (line 579).

CAUTION

Note that as the PWM frequency increases, the control loop frequency also needs to be adjusted accordingly. This can be set using the macro definition *USER_M1_NUM_PWM_TICKS_PER_ISR_TICK* (line 559), which has a default value of 1. This default value means that the control computation cycle is synchronized with the PWM cycle.

Combinations in Table 3-1 have been verified at TI lab.

Table 3-1.

PWM Switching Frequency (kHz)	USER_M1_NUM_PWM_TICKS_PER_ISR_TICK Value	USER_M1_NUM_PWM_TICKS_PER_ISR_TICK Value
15	(15.0f)	(1)
20	(20.0f)	(1)
40	(40.0f)	(1)
60	(60.0f)	(2)
80	(80.0f)	(2)

Dead time configuration is hard-coded in SysConfig tool. The default value is 10 which corresponds to 50ns. The default PWM timebase clock TBCLK = EPWMCLK = 200MHz, and the dead time is calculated as:

$$\text{Falling edge delay} = [\text{value}] \times (1/\text{EPWMCLK}) = 10 \times (1/200\text{MHz}) = 50\text{ns} \quad (1)$$

$$\text{Rising edge delay} = [\text{value}] \times (1/\text{EPWMCLK}) = 10 \times (1/200\text{MHz}) = 50\text{ns} \quad (2)$$

Figure 3-4 shows SysConfig variables that allow dead time adjustment.

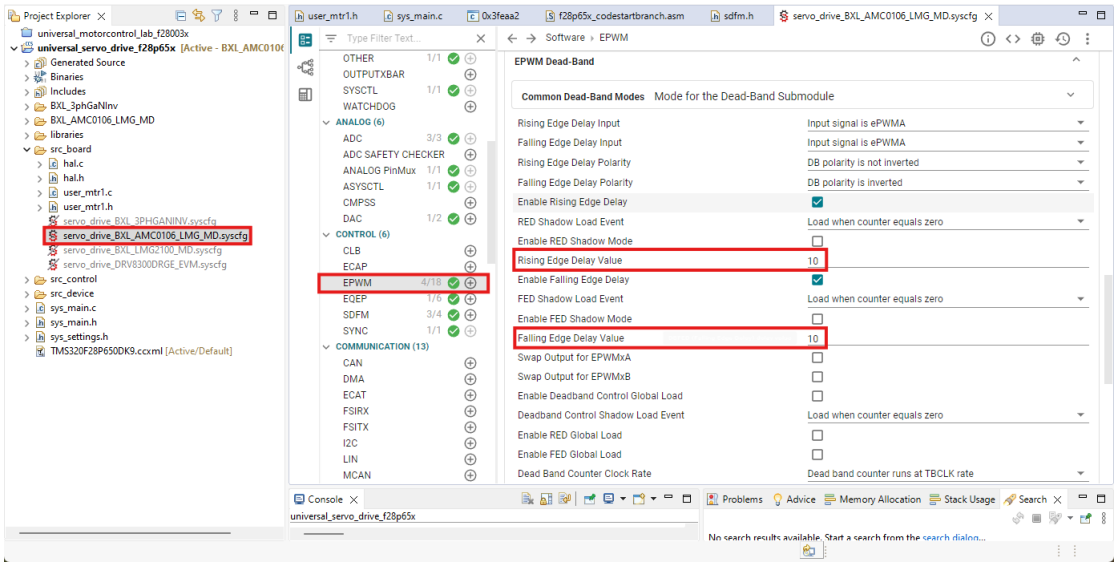


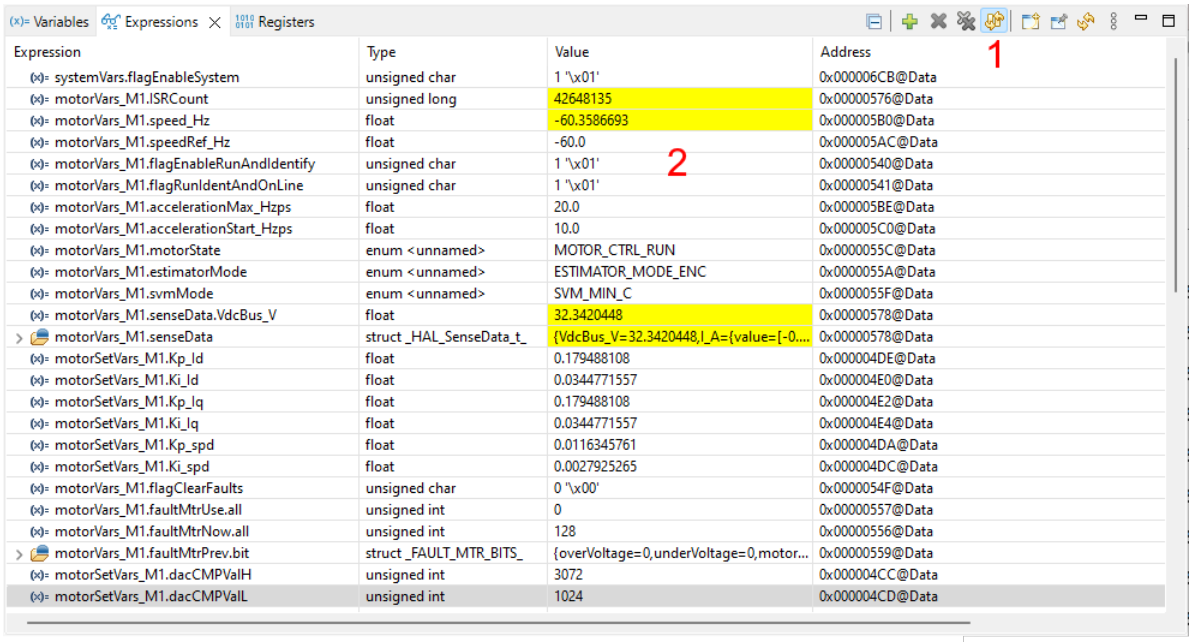
Figure 3-4. PWM Dead Time Adjustment in SysConfig Tool

3.5 Running the Motor

The following steps are true if the source code was not modified and use the recommended LVSERVOMTR motor.

1. Make sure all steps are followed as described in Section 2.4 and Section 3.2
2. Enter debug mode in CCS (*Run-Debug*). The current consumption from the external 48V DC supply cannot exceed 15mA
3. Run the code (*Run-Resume*)
   a. The green LED5 on the LAUNCHXL-F28P65X C2000 LaunchPad starts blinking
4. Enable continuous refresh in the Expressions window (1)
5. Go to expressions window and write *1* to *motorVars_M1.flagEnableRunAndIdentify* variable 2
6. The motor starts slowly spinning
7. Control the speed with *motorVars_M1.speedRef_Hz* float variable
   - Changing the polarity of the variable changes the rotation direction

8. Monitor the speed with *motorVars_M1.speed_Hz* variable



Expression	Type	Value	Address
systemVars.flagEnableSystem	unsigned char	1 '\x01'	0x000006CB@Data
motorVars_M1.ISRCount	unsigned long	42648135	0x00000576@Data
motorVars_M1.speed_Hz	float	-60.3586693	0x000005B0@Data
motorVars_M1.speedRef_Hz	float	-60.0	0x000005AC@Data
motorVars_M1.flagEnableRunAndIdentify	unsigned char	1 '\x01'	0x00000540@Data
motorVars_M1.flagRunIdentAndOnLine	unsigned char	1 '\x01'	0x00000541@Data
motorVars_M1.accelerationMax_Hzps	float	20.0	0x000005BE@Data
motorVars_M1.accelerationStart_Hzps	float	10.0	0x000005C0@Data
motorVars_M1.motorState	enum <unnamed>	MOTOR_CTRL_RUN	0x0000055C@Data
motorVars_M1.estimatorMode	enum <unnamed>	ESTIMATOR_MODE_ENC	0x0000055A@Data
motorVars_M1.svmMode	enum <unnamed>	SVM_MIN_C	0x0000055F@Data
motorVars_M1.senseData.VdcBus_V	float	32.3420448	0x00000578@Data
motorVars_M1.senseData	struct _HAL_SenseData_t_	{VdcBus_V=32.3420448,I_A={value=[-0....	0x00000578@Data
motorSetVars_M1.Kp_Id	float	0.179488108	0x000004DE@Data
motorSetVars_M1.Ki_Id	float	0.0344771557	0x000004E0@Data
motorSetVars_M1.Kp_Iq	float	0.179488108	0x000004E2@Data
motorSetVars_M1.Ki_Iq	float	0.0344771557	0x000004E4@Data
motorSetVars_M1.Kp_spd	float	0.0116345761	0x000004DA@Data
motorSetVars_M1.Ki_spd	float	0.0027925265	0x000004DC@Data
motorVars_M1.flagClearFaults	unsigned char	0 '\x00'	0x0000054F@Data
motorVars_M1.faultMtrUse.all	unsigned int	0	0x00000557@Data
motorVars_M1.faultMtrNow.all	unsigned int	128	0x00000556@Data
motorVars_M1.faultMtrPrev.bit	struct _FAULT_MTR_BITS_	{overVoltage=0,underVoltage=0,motor...	0x00000559@Data
motorSetVars_M1.dacCMPValH	unsigned int	3072	0x000004CC@Data
motorSetVars_M1.dacCMPValL	unsigned int	1024	0x000004CD@Data

Figure 3-5. Expressions Window During Debug Session

CAUTION

If the motor direction does not match the position sensing, then the motor does not run. In this case, try swapping two of the motor phase wires.

To explore full options and labs for this board, review the Motor Control SDK Universal Project and Lab user's guide.

4 Hardware Design Files

The BP-AMC0106-LMG-MD EVM design files are available on BP-AMC0106-LMG-MD product page on TI.com.

5 Additional Information

5.1 Trademarks

BoosterPack™, C2000™, LaunchPad™, InstaSPIN™, and Code Composer Studio™ are trademarks of Texas Instruments.
SIMPLE SWITCHER® is a registered trademark of Texas Instruments.
USB Type-C® is a registered trademark of USB Implementers Forum.
Windows® is a registered trademark of Microsoft Corporation.
All trademarks are the property of their respective owners.

6 Related Documentation

- Texas Instruments, TIDA-010936
- Texas Instruments, C2000WARE-MOTORCONTROL-SDK
- Texas Instruments, High Resolution, Small Form Factor Phase Current Sense for 48V Robotics and Servo Drives, application note
- Texas Instruments, Application of GaN FET in Humanoid Robots, application brief
- Texas Instruments, Motor Control in Humanoid Robots, application brief

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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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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。

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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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