EVM User's Guide: DRV7308EVM
DRV7308EVM Evaluation Module

TEXAS INSTRUMENTS

Description

The DRV7308EVM is a module designed for thorough evaluation of the DRV7308 motor driver. The device is a 250W, 450V integrated triple GaN FET half-bridge gate driver for motor driver applications. The DRV7308EVM provides three 650V E-mode GaN FET half-bridges capable of directly driving a three-phase brushless-DC motor.

The C2000™ LAUNCHXL-F2800137 LaunchPad™ is required for this kit and is used to operate and monitor the DRV7308 driver. PWM, fault response, and further device control are provided by the LAUNCHXL-F2800137 module.
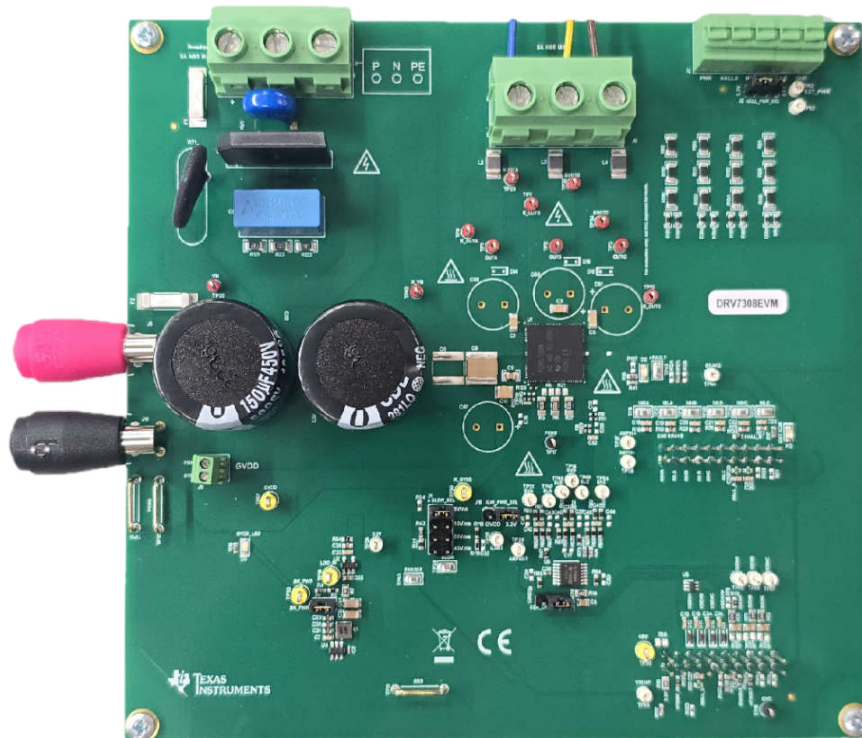
Features

- Up to 450V operating voltage with 5A peak current drive capability
- 250W capability without the need for heat sink

- Ultra low adaptive deadtime (<300ns)
- Ultra low propagation delay (<135ns)
- Low conduction loss with GaN FET's 205mΩ RDS(ON) at TA = 25°C
- Slew rate options from 5V/ns to 40V/ns
- Integrated BRAKE functionality
- Integrated temperature sensor
- Integrated 12MHz, 15V/µs amplifier for single shunt current sensing

Applications

- Residential air conditioners
- Refrigerator and freezer
- Small home appliances
- Appliances, HVAC pumps, and fans
- Dishwasher
- Washer and dryer
- Cooker hood

DRV7308EVM

1 Evaluation Module Overview

1.1 Introduction

The DRV7308EVM is a device designed for quick customer evaluation of the DRV7308 IC. This EVM integrates many useful features such as flexible parameter settings through jumpers for slew rate and ILIMIT control, test points for direct evaluation, isolated power planes, onboard buck regulator, 3.3V LDO, and optional three-shunt current sensing.

This document serves as a startup guide to supplement the DRV7308EVM + LAUNCHXL-F2800137 BLDC motor control demo kit. This user's guide is intended to help engineers begin designing, implementing, and validating reference hardware and software for the LaunchPad MCU and DRV7308.

This document is provided with the DRV7308 evaluation module (EVM) as supplemental material to the DRV7308 data sheet *DRV7308 Three-Phase, 650V Integrated GaN FET Motor Driver* (SLVSGJ9). This user's guide details the hardware, setup, and implementation of the EVM for customer evaluation. A LAUNCHXL-F2800137 BoosterPack™ is used to control the PWM and commutation logic of the driver.

WARNING
Voltages exceeding the standard EVM ratings as specified on the data sheet can cause personal injury, electrical shock hazard, damage the EVM, or a combination of harmful effects to the user or device.
Additionally, do not leave power connections to the EVM connected while not in operation.

WARNING		
⚠	**Hot Surface**	Contact can cause burns. Do not touch.

WARNING		
⚠	**High Voltage**	For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended. Electric shock is possible when connecting board to live wire. The board must be handled with care by a professional. TI recommends to use a safety enclosure when operating the device.

1.2 Kit Contents

Item	Description	Quantity
DRV7308EVM	PCB	1
Box	Cardboard box	1
Label	Standard label	1
Foam	Antistatic foam	2
Literature	EVM disclaimers	1

1.3 Specification

The DRV7308EVM can support voltages up to 450V and peak currents up to 5A. To prevent damage to both the IC and the EVM, confirm that these voltage and current specifications are not exceeded.

1.4 Device Information

The DRV7308 is a three-phase motor driver IPM that consists of 205mΩ, 650V E-mode Gallium Nitride (GaN) for driving three-phase BLDC motors up to 450V DC. These applications include field-oriented control (FOC), sinusoidal current control, and trapezoidal current control of BLDC motors. The device integrates the pre-drivers for all of the GaN FETs with slew rate control of the phase node voltages. The device is in a QFN 12mm x 12mm package and achieves greater than 99% efficiency in FOC-driven 250W motor applications, eliminating the need for a heat sink. Additionally, minimum dead time and propagation delay result in ultra quiet operation. The device provides short circuit and over current protection for each GaN FETin less than 300ns response time, as well as over temperature protection and driver voltage (GVDD & bootstrap power supply) UVLO protection.

2 Hardware

2.1 Hardware Connections Overview - DRV7308 + LAUNCHXL-F2800137

This section describes the hardware interface of the DRV7308EVM to external supplies, motor, hall sensors, and PC through the LAUNCHXL-F2800137 LaunchPad.
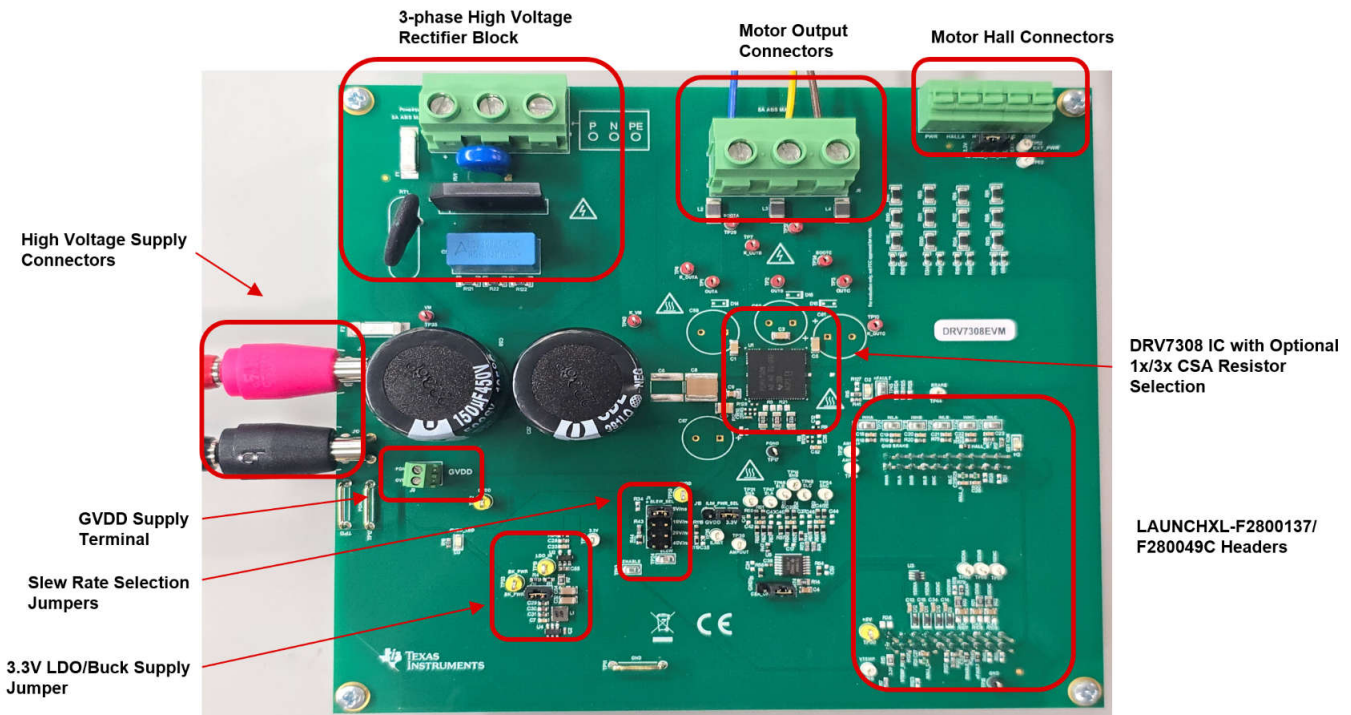

Figure 2-1. DRV7308EVM Block Diagram

Figure 2-2 shows the correct connection between the DRV7308EVM and a LAUNCHXL-F2800137 LaunchPad. The USB port and DRV7308EVM power connectors must be facing the same direction.
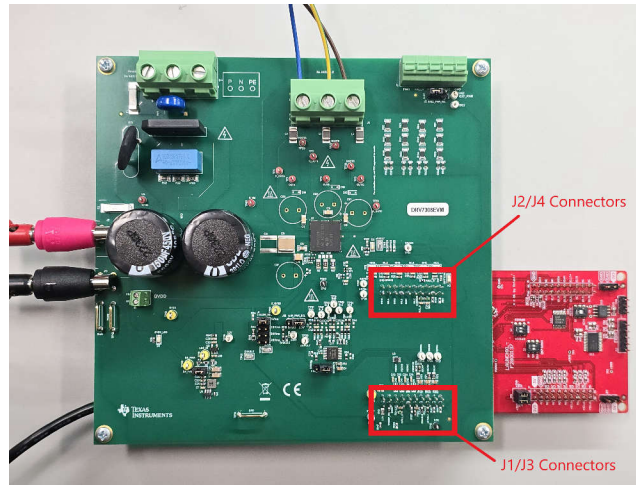
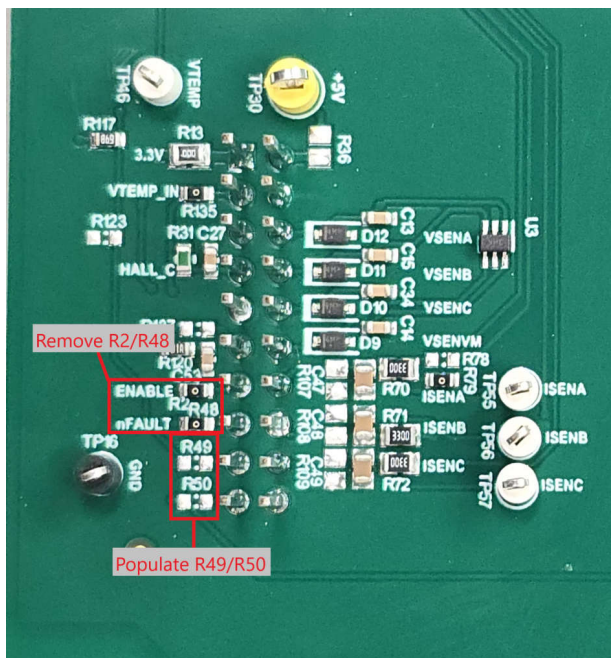**Figure 2-2. DRV7308EVM Mating to C2000 LaunchPad**

Figure 2-3. LAUNCHXL-F280049C Compatibility

Note

If desired to use the LAUNCHXL-F280049C LaunchPad with the DRV7308EVM, then remove resistors R2 and R48 from the EVM and populate R49 and R50 with 0 Ohm resistors.


WARNING

⚠️

High voltage isolation.
LaunchPad USB isolation must be used when operating the EVM with high-voltage supplies. Follow the LAUNCHXL-F2800137 guidelines on isolation configurations to make the necessary changes.

The high-voltage rails of the DRV7308EVM can be powered by AC input up to 225VAC (450V) through use of the onboard AC-DC rectifier (As shown in Figure 2-4). The appropriate AC lines must be connected to the positive, neutral, and earth input screw terminals for proper function.
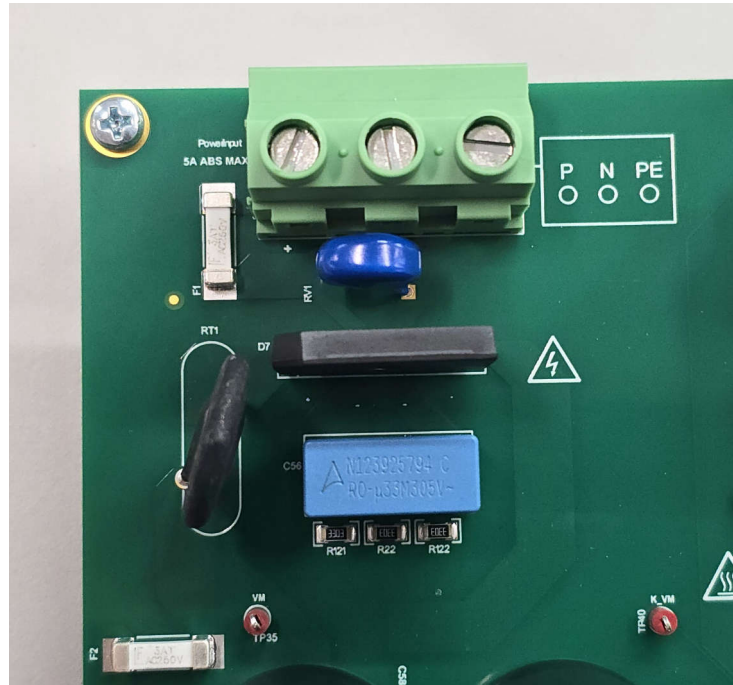
Figure 2-4. AC Voltage Input Rectifier Circuit

The DRV7308EVM is designed for a motor input supply of up to 450 VDC and up to 5A peak drive current. The inputs connect to J5 and J10 with the noted polarity. The VM test point connects to the same node but must not be used for high current input. The GVDD supply of the device is designed for 15V input to the J9 connector, and proper polarity must again be noted.
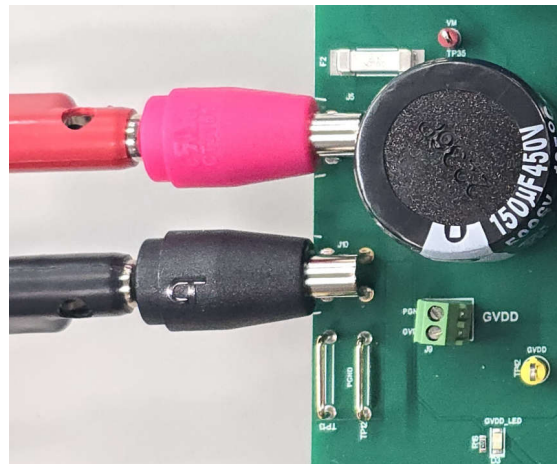

**Figure 2-5. DC Power Supply Input Connectors**

Note

The DRV7308EVM requires two separate power supplies: A 15V supply for GVDD driver power and a high-voltage supply supporting up to 450 VDC.

Hall sensors can be connected to J7, which includes hall power and GND. The 3.3 VDC supply to the hall sensors is supplied from the 3.3V LDO on the EVM. External hall power can be input through the HALL_EXT test point if a different supply or voltage level is desired. To use the included 3.3V LDO to power the halls, connect J2 on the left side to pins 1:2 as shown in Figure 2-6. To use HALL_EXT, connect J2 on the right side to pins 2:3. To insert or remove wires and terminals on J7, use a flat head screwdriver to push down the respective tab on top of the J7 connector.
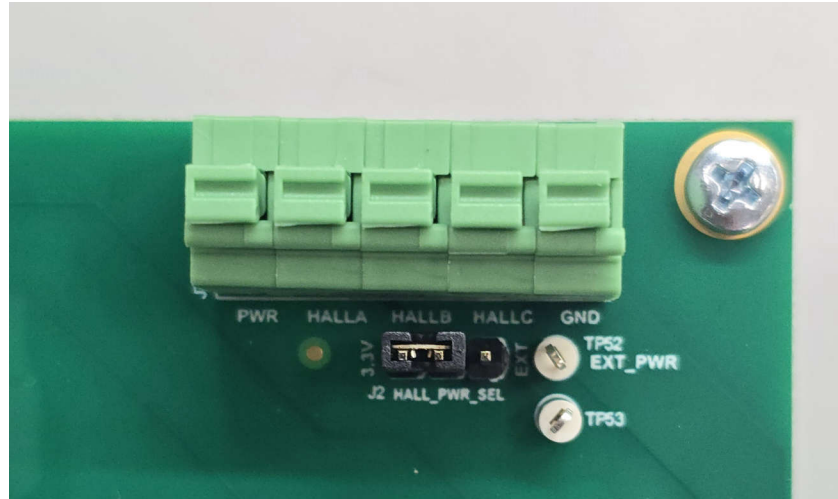
Figure 2-6. Hall Sensor Input and Power Connectors

The DRV7308EVM is designed to drive a 3-phase brushless-DC motor where each phase must be connected to the J6 (OUT_X) screw terminal in the appropriate order.
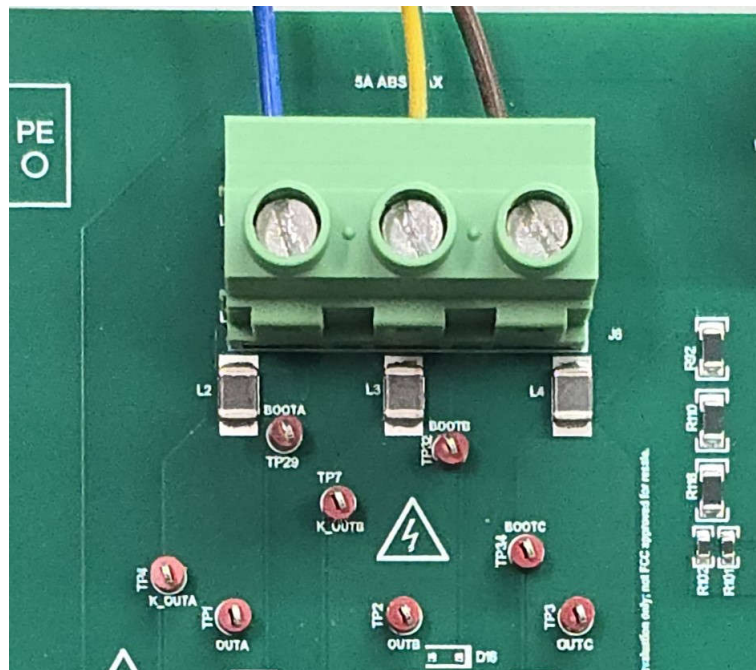

Figure 2-7. Motor Output Phase Connection

WARNING

For motors with hall sensors, motor phase connections must match the hall sensor connection sequence. For example, OUT_A must match HALL_A, OUT_B must match HALL_B, OUT_C must match HALL_C. The phases must also be in sequential order; A, then B, then C.

If the motor phases do not match the hall sensors or the connections are made out of order, then the motor does not spin smoothly and current consumption increases.

2.2 Jumper Configuration
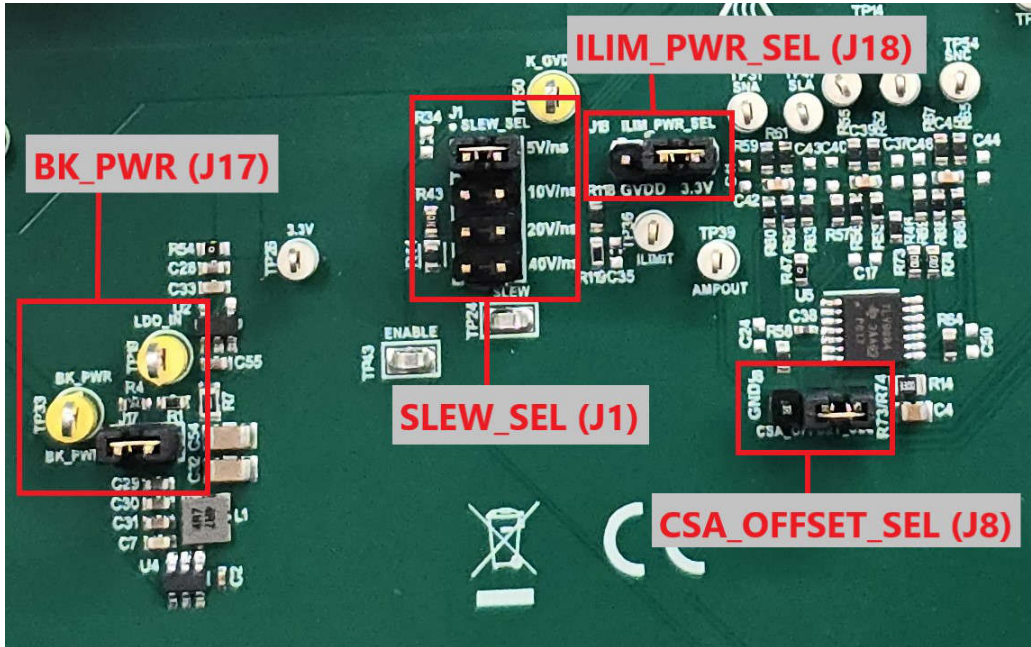
Figure 2-8. DRV7308EVM Jumper Hardware Configurations

Name	Jumper	Description	Setting
SLEW_SEL	J1	User-selectable slew rate	Setting 1: 5V/nS
			Setting 2: 10V/nS
			Setting 3: 20V/nS
			Setting 4: 40V/ns
HALL_PWR_SEL	J2	Hall power input selection	Setting 1: 3.3V
			Setting 2: external power supply
CSA_OFFSET_SEL	J8	CSA offset power selection	Setting 1: CSA offset set to half of CSA supply voltage
			Setting 2: No CSA offset voltage
BK_PWR	J17	Onboard buck output connection	Buck power supplied from GVDD
ILIM_PWR_SEL	J18	ILIMIT setting selection	Setting 1: ILIMIT resistor divider pulled to GVDD
			Setting 2: ILIMIT resistor divider pulled to 3.3V

2.3 Status LEDs

There are LED status indicators on the DRV7308EVM that are designed to express the current operating state of the device.

The DRV7308EVM has three status LEDs on the board. By default, the GVDD_LED lights up when the board is powered on with the auxiliary power. The nFAULT_LED lights up when the driver's fault pin is low, and the MCU_LED (tied to GPIO23) lights up when the LaunchPad is running and can be used for debugging and validation. The table below details the LED descriptions. The LEDs that are on during power up are indicated in bold.

Designator	Name	Color	Description
D2	nFAULT_LED	Red	Lights up when a fault condition has occurred on the DRV7308
D3	**GVDD_LED**	**Green**	**GVDD supplied**
D4	MCU_LED	Orange	MCU running

Note

During power up and power down of the device through the EN pin, the nFAULT pin is held low as the internal regulators are enabled or disabled. After the regulators have enabled or disabled, the nFAULT pin is automatically released.

2.4 EVM Hardware Quick-Start

The DRV7308EVM requires two power supply sources, one with recommended operating voltage of 15V and one with an operating range up to 450V. To setup and power the EVM, follow the sequence below.

1. Mate the DRV7308EVM onto the top half of the LAUNCHXL-F2800137 (LaunchPad headers J1/J3 and J2/J4) as shown in Figure 2-2. The motor connectors face the same direction as the micro-USB connector on the LaunchPad. Connect motor phases to A, B, C to the respective OUT_X connecter on the EVM (J6).
2. Do not turn on the power supply yet. For DC input voltage, connect the motor supply positive side to J5 (VM) and the negative side to J10 (GND),
3. Connect driver supply and ground to GVDD terminal (J9) while making sure the correct polarity is observed.
4. For sensored applications, connect the hall sensors to the appropriate locations on the 5-pin connector J7. Select on-board 3.3V supply or external supply on jumper J2 to choose the hall power source voltage.
5. Adjust the gate current (SLEW_SEL) to the desired setting using the jumper (J1).
6. Connect the micro-USB cable from the computer into the micro-USB connector on the top of the LAUNCHXL-F2800137.
7. Turn on the GVDD power supply, then turn on the VM power supply. The GVDD_LED lights up green if GVDD is properly powered.
8. The device can now be programmed and operated with the desired commutation control method. For further information and training on programming a C2000 LaunchPad, please visit the C2000Ware software page at ti.com.
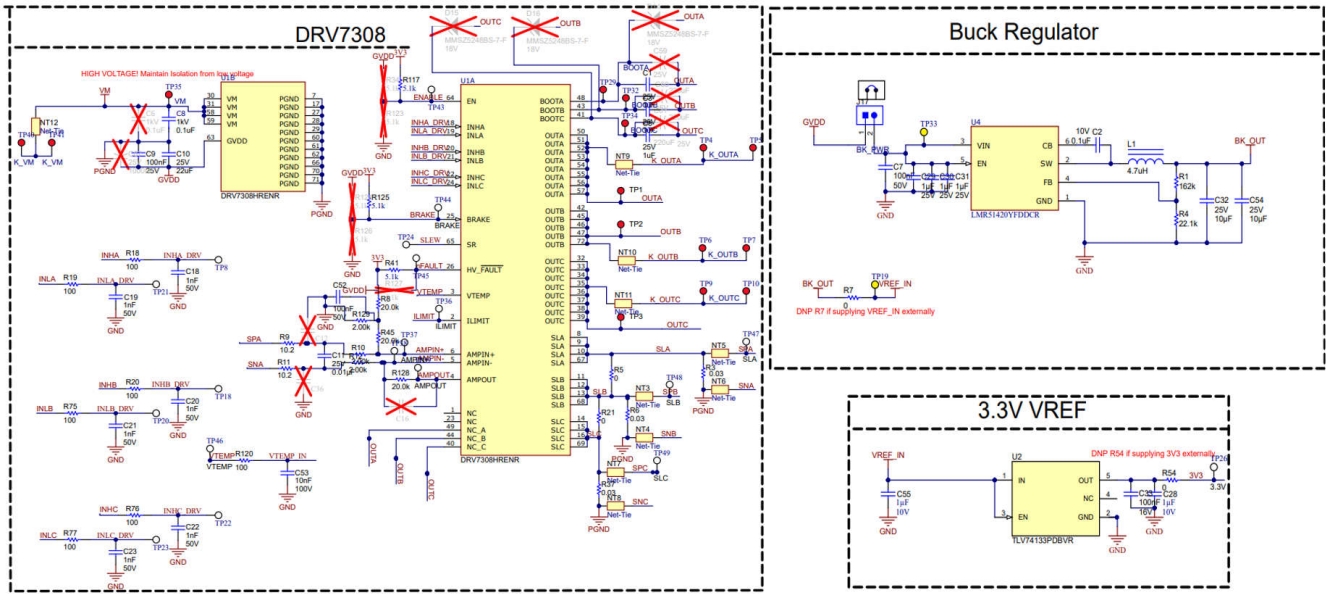
3 Hardware Design Files

3.1 Schematics

Figure 3-1. DRV7308EVM Schematic 1

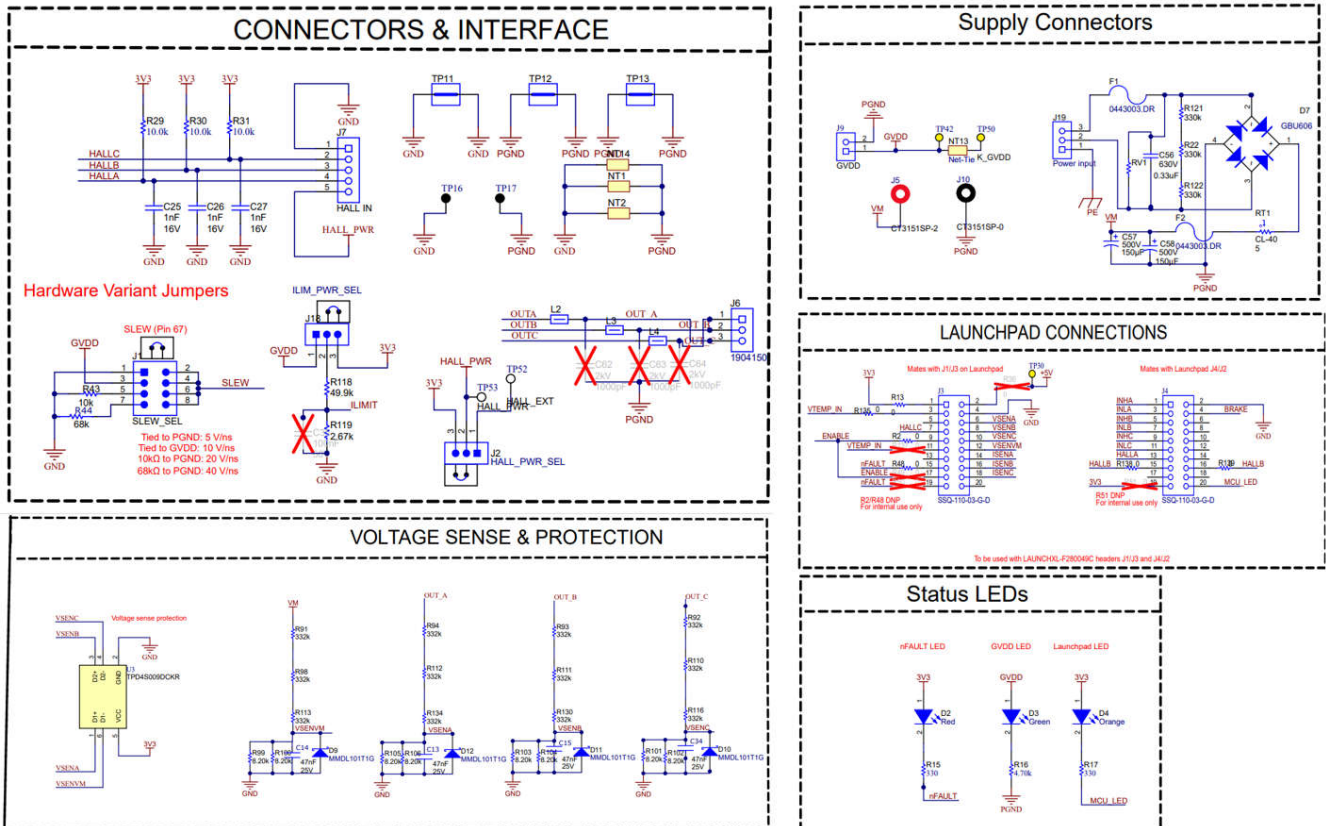**Figure 3-2. DRV7308EVM Schematic 2**

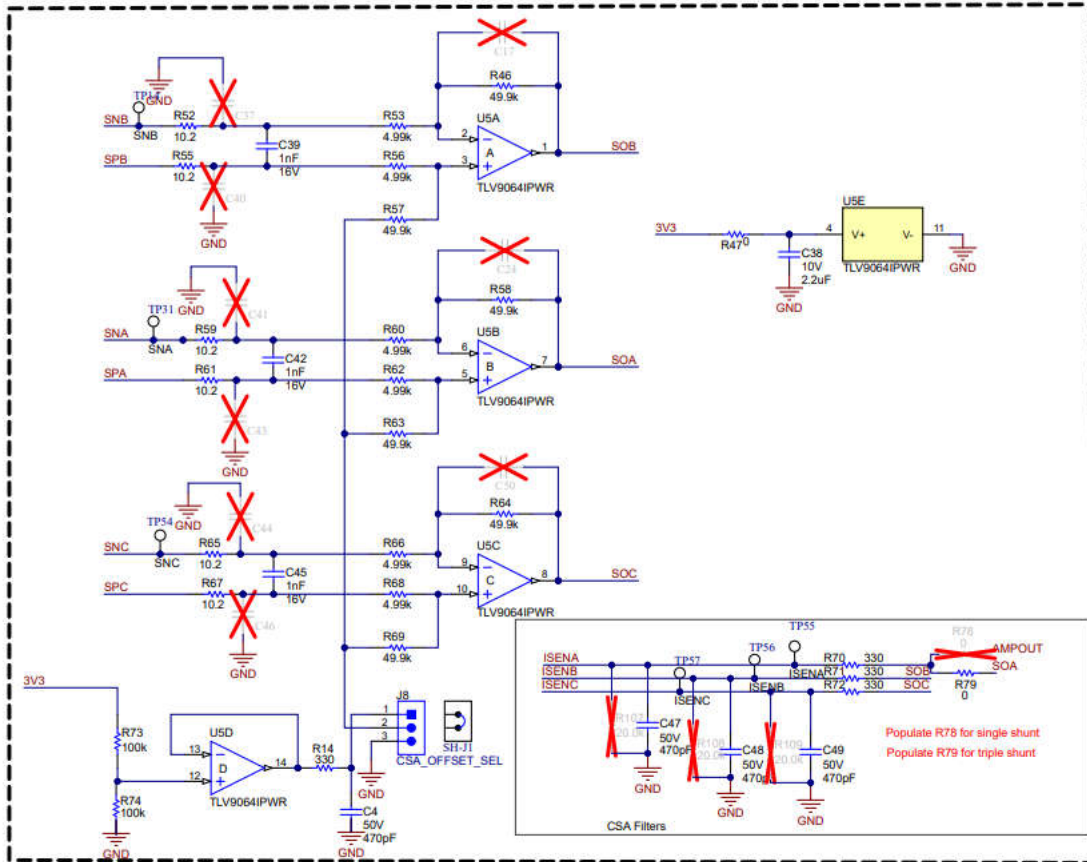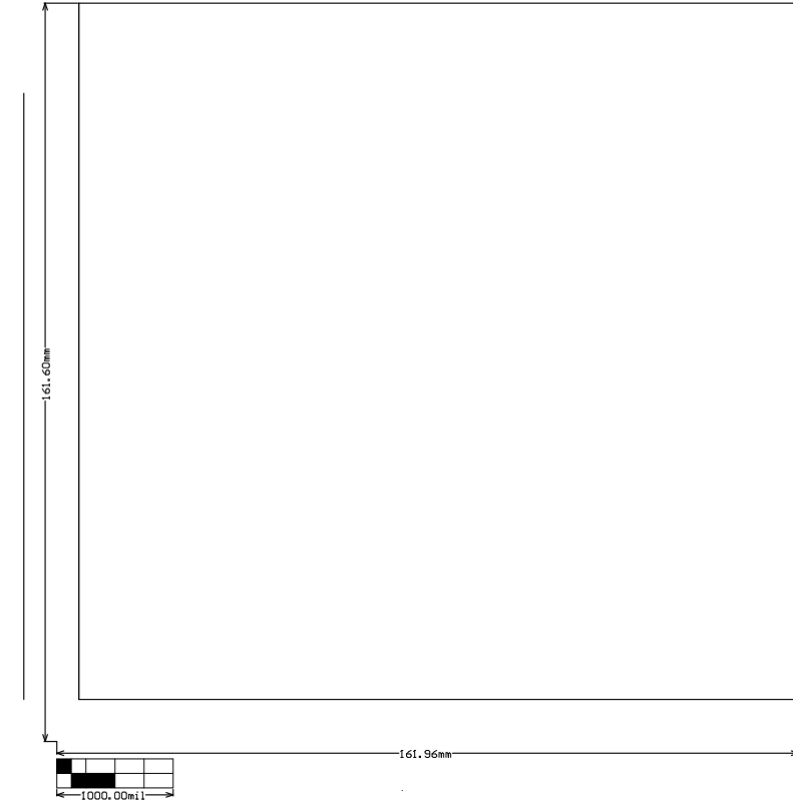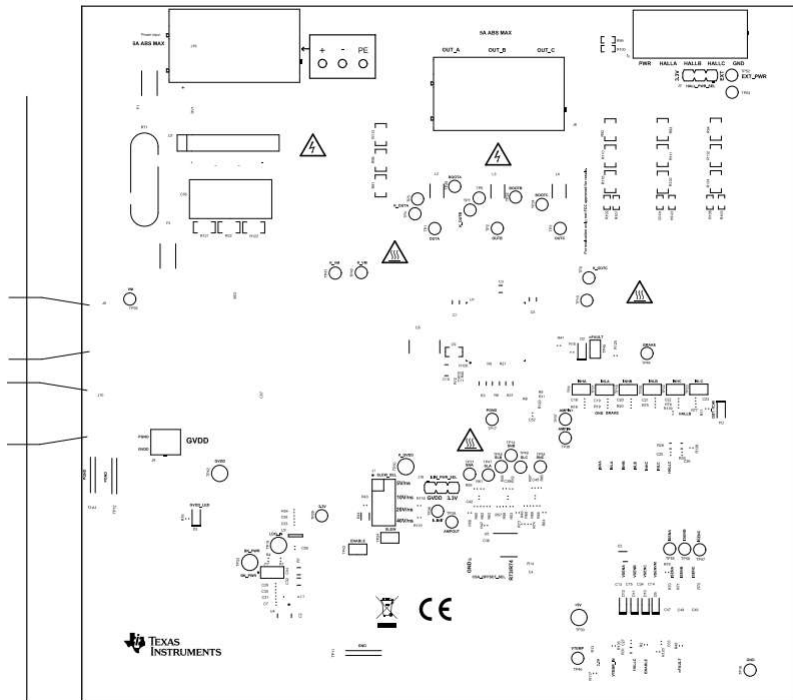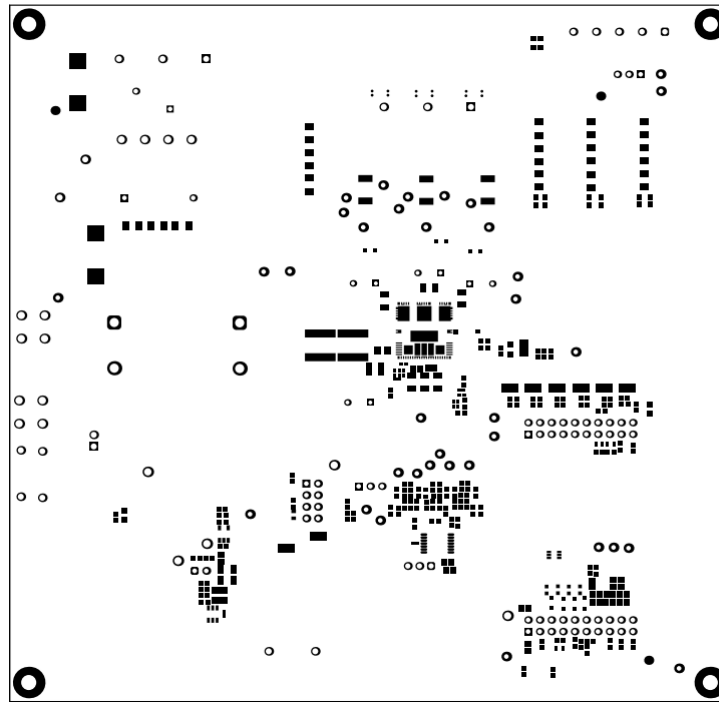**Figure 3-3. DRV7308EVM Schematic 3**
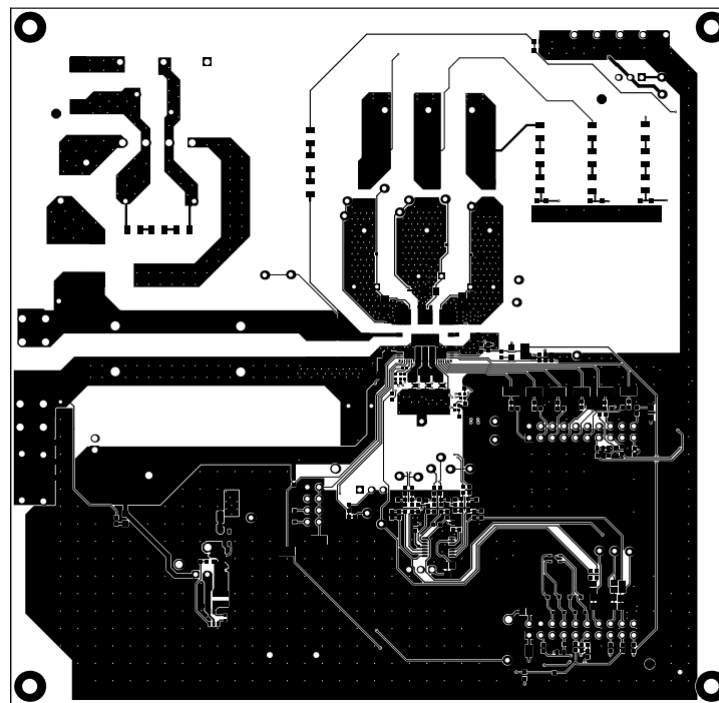
3.2 PCB Layouts

Figure 3-4. DRV7308EVM Layout Board Dimensions

Figure 3-5. EVM Top Overlay

Figure 3-6. EVM Solder Mask
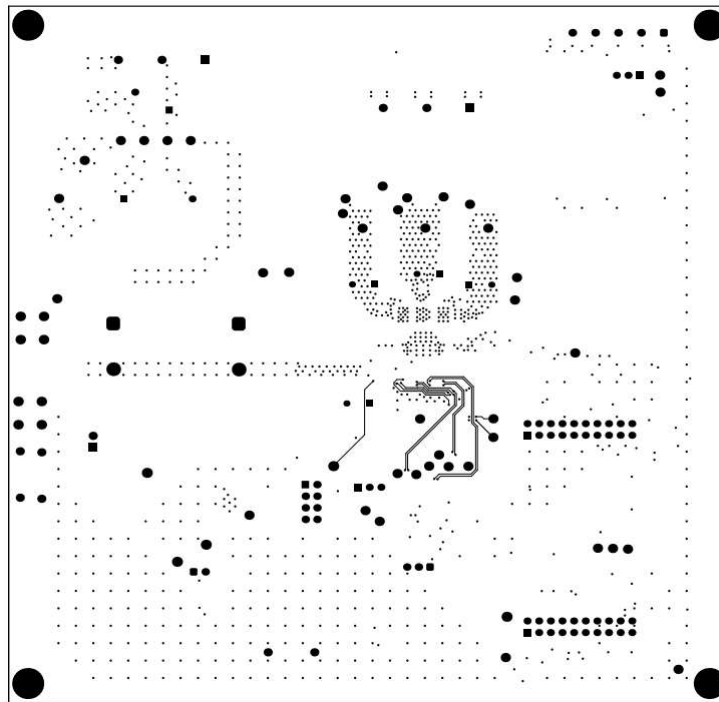

Figure 3-7. EVM Top Layer
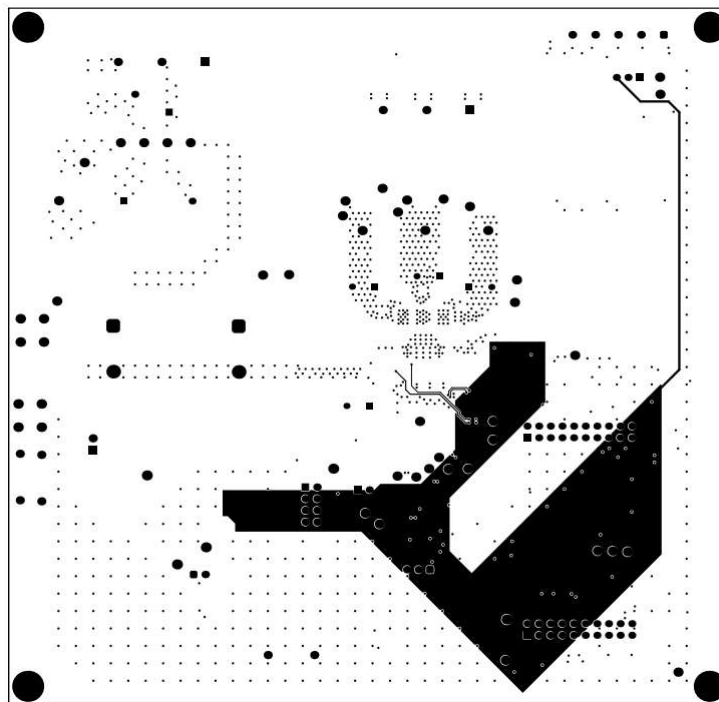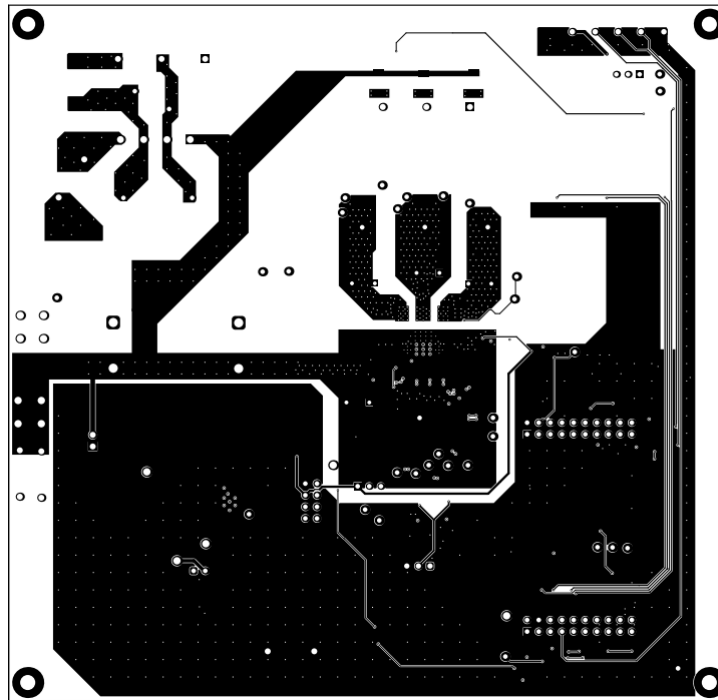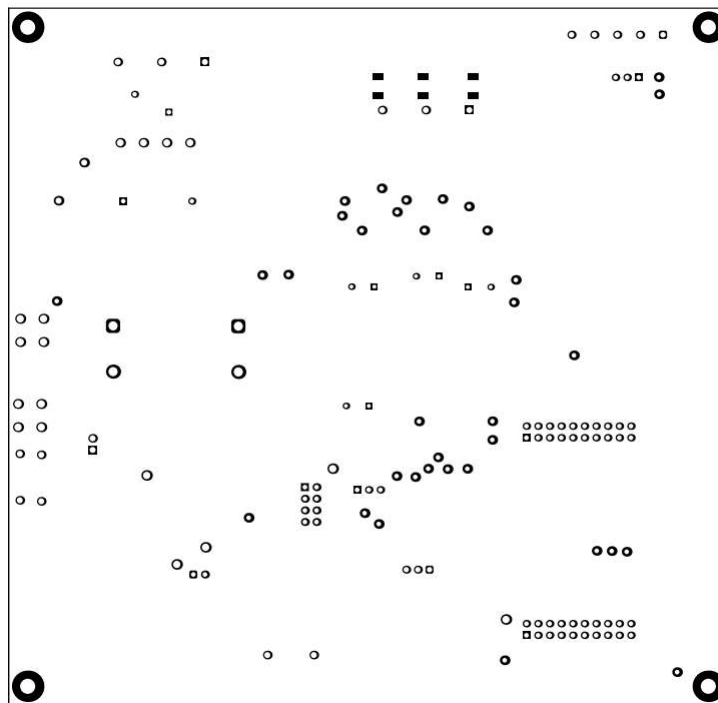
Figure 3-8. EVM Signal 1 Layer

Figure 3-9. EVM Signal 2 Layer

Figure 3-10. EVM Bottom Layer

Figure 3-11. EVM Bottom Solder Mask

3.3 Bill of Materials (BOM)

Table 3-1. Bill of Materials

Designator	Quantity	Description	Part Number	Manufacturer
!PCB1	1	Printed Circuit Board	MD096	Any
C1, C3, C5	3	CAP, CERM, 1uF, 25V, +/- 10%, X7R, 1206	12063C105KAT2A	AVX
C2	1	CAP, CERM, 0.1uF, 10V, +/- 10%, X7R, 0402	CL05B104KP5NNNC	Samsung Electro-Mechanics
C4, C47, C48, C49	4	CAP, CERM, 470pF, 50V, +/- 10%, X7R, 0805	C0805C471K5RACTU	Kemet
C7, C52	2	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0603	885012206095	Wurth Elektronik
C8	1	2225 0.1 uF 1 kV ±10 % Tolerance X7R SMT Multilayer Ceramic Chip Capacitor	VJ2225Y104KXGAT	Vishay Vitramon
C9	1	CAP, CERM, 0.1uF, 25V, +/- 10%, X7R, 0805	08053C104KAT2A	AVX
C10	1	CAP, CERM, 22uF, 25V, +/- 10%, X7R, 1210	GRM32ER71E226KE15L	MuRata
C11	1	CAP, CERM, 0.01µF, 25V,+/- 10%, X7R, 0402	CL05B103KA5NNNC	Samsung Electro-Mechanics
C13, C14, C15, C34	4	0.047µF ±10% 25V Ceramic Capacitor X7R 0603 (1608 Metric)	885012206069	Wurth Electronics
C18, C19, C20, C21, C22, C23	6	CAP, CERM, 1000pF, 50V,+/- 10%, X7R, 0603	885012206083	Wurth Elektronik
C25, C26, C27, C39, C42, C45	6	CAP, CERM, 1000pF, 16V, +/- 10%, X7R, 0603	885012206034	Wurth Elektronik
C28, C55	2	CAP, CERM, 1uF, 10V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	LMK107B7105KAHT	Taiyo Yuden
C29, C30, C31	3	CAP, CERM, 1µF, 25V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E1X7R1E105K080AC	TDK
C32, C54	2	CAP, CERM, 10µF, 25V,+/- 10%, X7R, 1206	C3216X7R1E106K160AB	TDK
C33	1	CAP, CERM, 0.1uF, 16V, +/- 10%, X7R, 0603	EMK107B7104KA-T	Taiyo Yuden
C38	1	CAP, CERM, 2.2uF, 10V, +/- 10%, X5R, 0402	C1005X5R1A225K050BC	TDK
C53	1	CAP, CERM, 0.01uF, 100V, +/- 5%, X7R, 0603	06031C103JAT2A	AVX
C56	1	CAP, Film, 0.33uF, 630V, +/- 20%, TH	B32922C3334M	TDK
C57, C58	2	CAP, AL, 150µF, 500V, +/- 20%, TH	LGN2H151MELA45	Nichicon
D2	1	LED, Red, SMD	LTST-C170KRKT	Lite-On
D3	1	LED, Green, SMD	LTST-C170KGKT	Lite-On
D4	1	LED, Orange, SMD	LTST-C170KFKT	Lite-On

Table 3-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
D7	1	Diode, Switching-Bridge, 600V, 6A, TH	GBU606	Diodes Inc.
D9, D10, D11, D12	4	Diode, Schottky, 7V, 0.01A, SOD-323	MMDL101T1G	ON Semiconductor
F1, F2	2	Fuse, 3A, 250VAC/VDC, SMD	0443003.DR	Littelfuse
H9, H10, H11, H12	4	Standoff, Hex, 25mm Length, M3, Aluminum	24438	Keystone
H13, H14, H15, H16	4	MACHINE SCREW PAN PHILLIPS M3 5mm	MPMS 003 0005 PH	B&F Fastener Supply
J1	1	Header, 100mil, 4x2, Gold, TH	TSW-104-07-G-D	Samtec
J2, J18	2	Header, 2.54mm, 3x1, Tin, TH	68001-403HLF	FCI
J3, J4	2	Receptacle, 2.54mm, 10x2, Gold, TH	SSQ-110-03-G-D	Samtec
J5	1	Banana Jack Insul Nylon Red, R/A, TH	CT3151SP-2	Cal Test Electronics
J6, J19	2	Terminal Block, 9.52mm, 3x1, R/A, TH	1904150	Phoenix Contact
J7	1	Terminal Block, 5mm, 5x1, R/A, TH	1792892	Phoenix Contact
J8	1	Header, 2.54mm, 3x1, Gold, TH	61300311121	Wurth Elektronik
J9	1	Terminal Block, 2.54mm, 2x1, Brass, TH	OSTVN02A150	On-Shore Technology
J10	1	Banana Jack Insul Nylon Black, R/A, TH	CT3151SP-0	Cal Test Electronics
J17	1	Header, 100mil, 2x1, Gold, TH	TSW-102-07-G-S	Samtec
L1	1	Inductor, Shielded, Powdered Iron, 4.7uH, 1.5A, 0.162 ohm, AEC-Q200 Grade 1, SMD	78438335047	Wurth Elektronik
L2, L3, L4	3	RES, 0, 5%, 0.75W, AEC-Q200 Grade 0, 1812	ERJ-12Y0R00U	Panasonic Electronic Components
R1	1	RES, 162 k, 1%, 0.1 W, 0603	CRCW0603162KFKEA	Vishay-Dale
R2, R48, R54, R79, R135, R138, R139	7	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	ERJ-3GEY0R00V	Panasonic
R3, R6, R37	3	RES, 0.03, 1%, 0.5 W, 1206	CSR1206FK30L0	Stackpole Electronics Inc
R4	1	RES, 22.1 k, 0.5%, 0.1 W, 0603	RT0603DRE0722K1L	Yageo America
R5, R21	2	RES, 0, 5%, 0.125 W, 0805	ERJ-6GEY0R00V	Panasonic
R7, R13	2	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6GEY0R00V	Panasonic
R8, R45, R128	3	RES, 20.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040220K0FKED	Vishay-Dale
R9, R11	2	RES, 10.2, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210R2FKED	Vishay-Dale
R10, R12, R129	3	RES, 2.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	ERJ-2RKF2001X	Panasonic
R14, R70, R71, R72	4	RES, 330, 1%, 0.125 W, 0805	CRCW0805330RFKEAC	Vishay-Dale

Table 3-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
R15, R17	2	RES, 330, 0.1%, 0.1 W, AEC-Q200 Grade 0, 0603	ERA3AEB331V	Panasonic
R16	1	RES, 4.70 k, 0.1%, 0.1 W, 0603	RT0603BRD074K7L	Yageo America
R18, R19, R20, R75, R76, R77, R120	7	RES, 100, 1%, 0.1 W, 0603	RC0603FR-07100RL	Yageo
R22, R121, R122	3	RES, 330 k, 1%, 0.25 W, 1206	RC1206FR-07330KL	Yageo America
R29, R30, R31	3	RES, 10.0 k, 0.1%, 0.1 W, AEC-Q200 Grade 1, 0603	TNPW060310K0BEEA	Vishay-Dale
R41, R117, R125	3	RES, 5.1 k, 5%, 0.1 W, 0603	CRCW06035K10JNEA	Vishay-Dale
R43	1	RES, 10 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K0JNEA	Vishay-Dale
R44	1	RES Thick Film, 68kΩ, 1%, 0.1W, 100ppm/°C, 0603	CRCW060368K0FKEA	Vishay
R46, R57, R58, R63, R64, R69, R118	7	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060349K9FKEA	Vishay-Dale
R47	1	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
R52, R55, R59, R61, R65, R67	6	RES, 10.2, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310R2FKEA	Vishay-Dale
R53, R56, R60, R62, R66, R68	6	RES, 4.99 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06034K99FKEA	Vishay-Dale
R73, R74	2	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale
R91, R92, R93, R94, R98, R110, R111, R112, R113, R116, R130, R134	12	RES, 332 k, 1%, 0.25 W, 1206	RC1206FR-07332KL	Yageo America
R99, R100, R101, R102, R103, R104, R105, R106	8	RES, 8.20 k, 1%, 0.1 W, 0603	RC0603FR-078K2L	Yageo
R119	1	RES, 2.67 k, 1%, 0.1 W, 0603	CRCW06032K67FKEA	Vishay-Dale
RT1	1	Thermistor NTC, 5 ohm, 25%, Disc, 220x770 mil	CL-40	GE Sensing
RV1	1	Var MOV 350VAC/460VDC 3500A 560V Radial Bulk	B72210P2351K101	TDK
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5	5	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP9, TP10, TP29, TP32, TP34, TP35, TP40, TP41	15	Test Point, Miniature, Red, TH	5000	Keystone, Keystone Electronics

Table 3-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
TP8, TP18, TP20, TP21, TP22, TP23, TP24, TP43, TP45	9	Test Point, Miniature, SMT	5015	Keystone
TP11, TP12, TP13	3	1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
TP14, TP26, TP31, TP36, TP37, TP38, TP39, TP44, TP46, TP47, TP48, TP49, TP52, TP53, TP54, TP55, TP56, TP57	18	Test Point, Miniature, White, TH	5002	Keystone Electronics
TP16, TP17	2	Test Point, Miniature, Black, TH	5001	Keystone
TP19, TP30, TP33, TP42, TP50	5	Test Point, Compact, Yellow, TH	5009	Keystone Electronics
U1	1	Three-Phase, 650V Integrated GaN FET Motor Driver, VQFN65	DRV7308HRENR	Texas Instruments
U2	1	Low-Dropout Regulator, DBV0005A (SOT-23-5)	TLV74133PDBVR	Texas Instruments
U3	1	4-Channel ESD Solution for High-Speed Differential Interface, DCK0006A (SOT-SC70-6)	TPD4S009DCKR	Texas Instruments
U4	1	SIMPLE SWITCHER 4.5V to 36V, 2A Buck Converter in SOT-23-6 Package	LMR51420YFDDCR	Texas Instruments
U5	1	4 channel, 10MHz, Low-Noise, RRIO, CMOS Operational Amplifier for Cost-Sensitive Systems, PW0014A (TSSOP-14)	TLV9064IPWR	Texas Instruments
C6	0	2225 0.1 uF 1 kV ±10 % Tolerance X7R SMT Multilayer Ceramic Chip Capacitor	VJ2225Y104KXGAT	Vishay Vitramon
C12, C16, C17, C24, C36, C37, C40, C41, C43, C44, C46, C50	0	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0603, X7R, 100pF, 10VDC		Wurth Elektronik
C35	0	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0603	885012206095	Wurth Elektronik
C59, C60, C61	0	CAP, AL, 220uF, 25V, +/- 20%, 0.1 ohm, TH	UBT1E221MPD1TD	Nichicon
C62, C63, C64	0	CAP, CERM, 1000pF, 2000V, +/- 10%, X7R, 1808	GR442QR73D102KW01L	MuRata
C67	0	CAP, AL, 1000uF, 25V, +/- 20%, TH	EKMG250ELL102MJ20S	Chemi-Con
D14, D15, D16	0	Diode, Zener, 18V, 200mW, SOD-323	MMSZ5248BS-7-F	Diodes Inc.

Table 3-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A
R34, R123, R124, R126, R127	0	RES, 5.1 k, 5%, 0.1 W, 0603	CRCW06035K10JNEA	Vishay-Dale
R36	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6GEY0R00V	Panasonic
R49, R50, R51, R78, R137	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	ERJ-3GEY0R00V	Panasonic
R107, R108, R109	0	RES, 20.0 k, 1%, 0.125 W, 0805	CRCW080520K0FKEA	Vishay-Dale

4 Additional Information

4.1 Trademarks

C2000™, LaunchPad™, and BoosterPack™ are trademarks of Texas Instruments.

All trademarks are the property of their respective owners.

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.

【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２４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.

IMPORTANT NOTICE AND DISCLAIMER