EVM User's Guide: TPSI31PXQ1EVM

TPSI31Px-Q1 Evaluation Module

Description

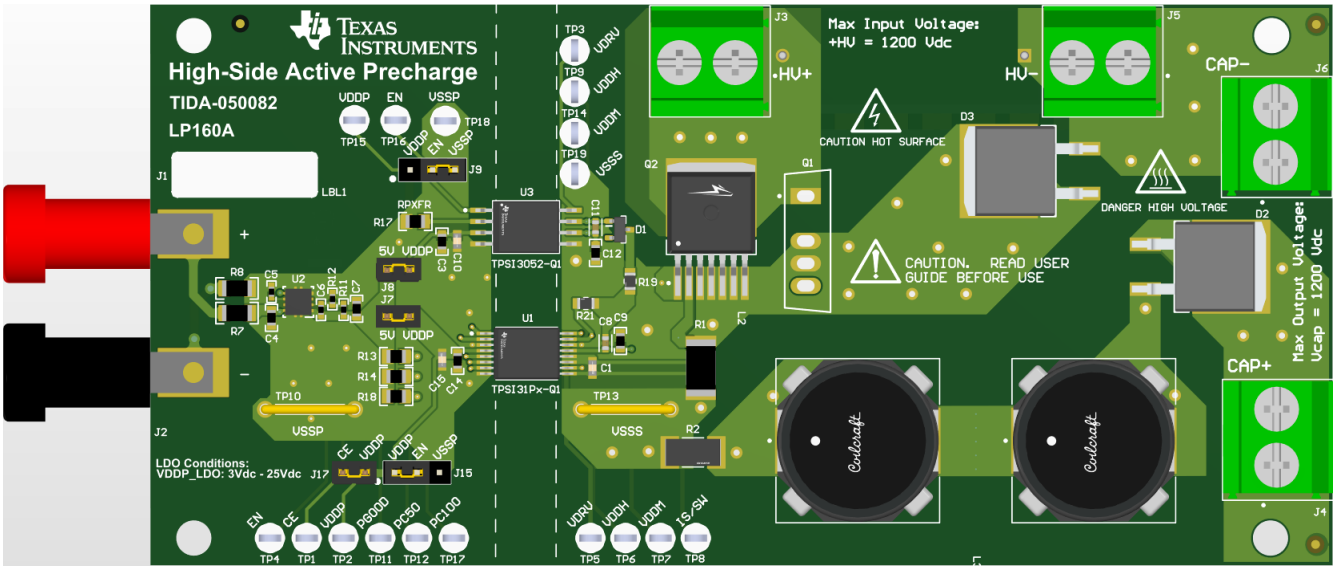
The TPSI31Px-Q1 evaluation module (EVM) helps designers evaluate the operation and performance of the TPSI31Px-Q1 device family in an electric vehicle (EV) or hybrid electric vehicle (HEV) high-side active precharge application for charging a DC-link capacitor. The board features the TPSI31P1-Q1, an isolated switch driver with integrated 15.8V gate supply and comparators to monitor charging current and hysteretically drive the gate, completely on the secondary side with no additional logic needed. The EVM also has the TPSI3052-Q1, an isolated switch driver with integrated 15V gate supply, acting as an isolated power supply to help provide additional switching power to the TPSI31P1-Q1 if needed. The EVM features a buck topology with two HV inductors (each rated for 400V). The EVM also includes an N-Channel 1200V 18A silicon carbide (SiC) MOSFET in a TO-263-7L package. The board contains multiple test points to monitor TPSI31P1-Q1 functionality. In addition, the EVM contains an adjustable 5V LDO to support battery powering.

Features

- Capable of charging 2mF capacitor to 800V in 830ms
- 2.2A_{AVG} / 4A_{PK-PK} adjustable charging current
- Integrated hysteretic charging current control, no additional logic needed
- Ultralow-noise LDO (5V to 20V input) for powering the circuit if adjustable power supply is unavailable
- No isolated secondary supply required
- 5-kVRMS reinforced isolation
- 15.8V gate drive with 1.5A peak source current and 3A peak sink current
- Dual isolated high-speed comparators with integrated voltage reference +/-1.5%

Applications

- Hybrid, electric, and powertrain systems



3D PCB (Top View)

1 Evaluation Module Overview

1.1 Introduction

The TPSI31PxQ1EVM is an evaluation module (EVM) designed to demonstrate the performance and functionality of the TPSI31P1-Q1 device in a high-side active precharge application, charging a DC-link capacitor. The topology in active precharge is similar to that of a buck converter which uses an inductor in series to limit the charging current rise rate (di/dt) and hysteretic control to control the charging current. The TPSI31P1-Q1 integrates the hysteretic control to fully control precharge without need for external logic.

This user's guide provides connectors, test point descriptions, schematic, bill of materials, and board layout of the EVM.

1.2 Kit Contents

- TPSI31Px-Q1 evaluation module circuit

1.3 Specification

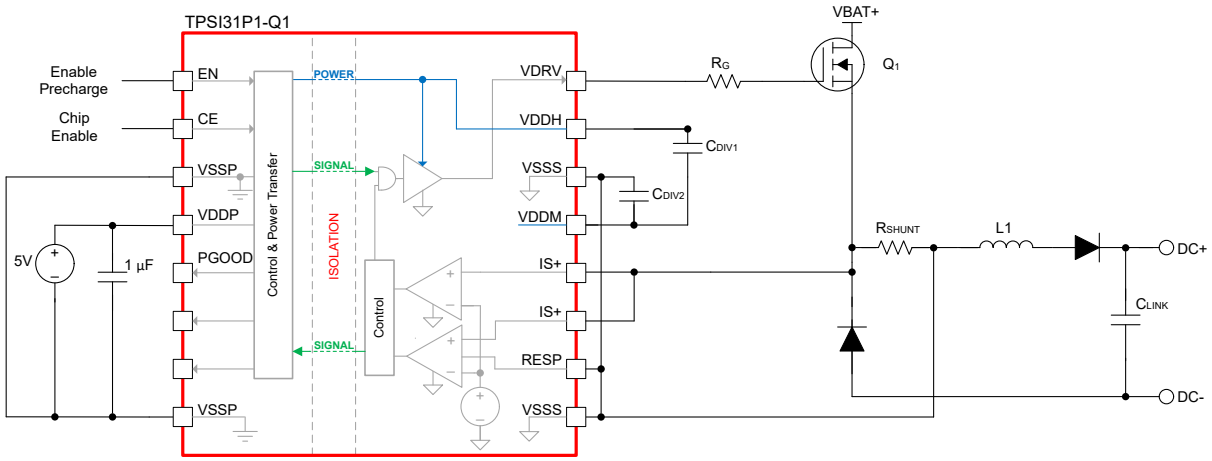


Figure 1-1. TPSI31P1-Q1 Simplified Schematic

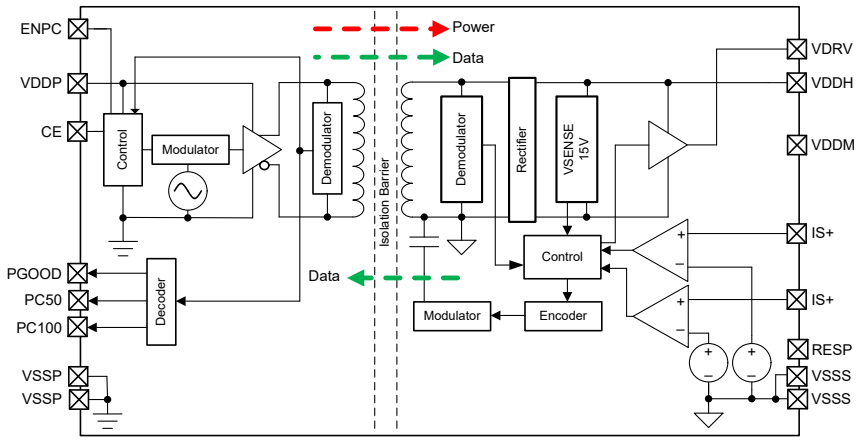


Figure 1-2. TPSI31P1-Q1 Functional Block Diagram

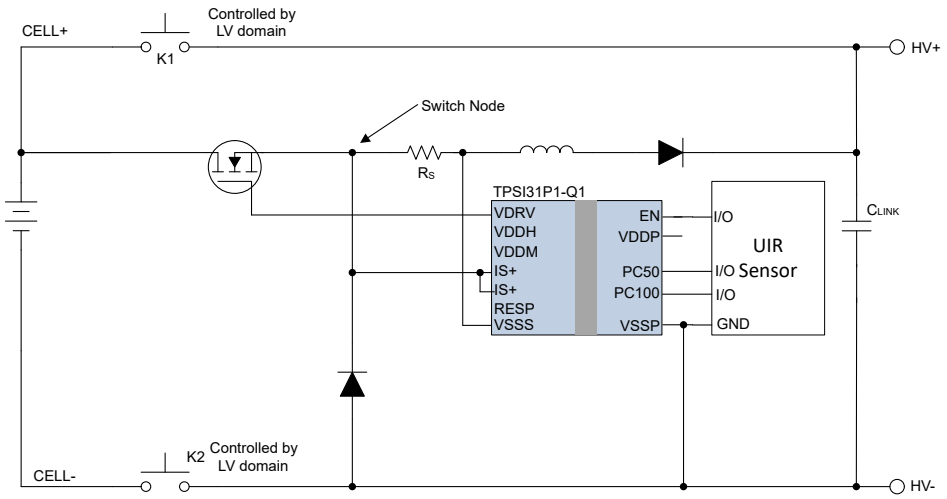


Figure 1-3. TPSI31P1-Q1 Application Schematic

1.4 Device Information

The TPSI31P1-Q1 device is an isolated gate driver with integrated comparators intended for hysteretic current control in charging a DC-link capacitor. When enable (EN) goes high, the driver (VDRV) turns on until the voltage across the comparator (IS+) exceeds 1.2V. Once IS+ exceeds 1.2V, VDRV turns off until IS+ falls below 160mV. Once IS+ falls below 160mV, VDRV turns on, and this cycle repeats until the DC-link capacitor is fully charged.

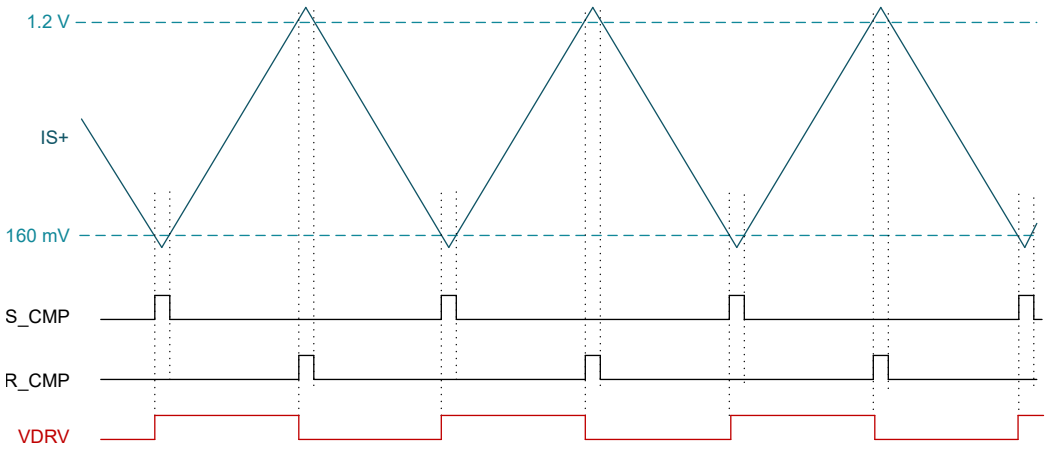


Figure 1-4. TPSI31P1-Q1 Behavior Diagram

2 Hardware

2.1 Additional Images

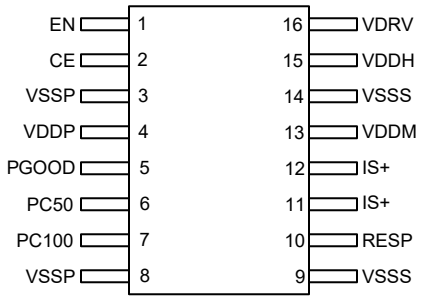


Figure 2-1. TPSI31P1-Q1 DVX Package 16-Pin SSOP (Top View)

2.2 Header Information

Name	Description
J1	Positive supply input for primary side, banana jack
J2	Negative supply input for primary side, banana jack
J3	HV+ supply input, screw terminal
J4	Capacitor- output, screw terminal
J5	HV- supply input, screw terminal
J6	Capacitor+ output, screw terminal

2.3 Jumper Information

Name	Description
J7	TPSI31Px-Q1 VDDP Disconnect
J8	TPSI3052-Q1 VDDP Disconnect
J9	TPSI3052-Q1 EN Select
J15	TPSI31Px-Q1 EN Select
J17	TPSI31Px-Q1 CE Disconnect

2.4 Test Points

Name	Description
TP1	TPSI31P1-Q1 CE signal test point
TP2	TPSI31P1-Q1 VDDP signal test point
TP3	TPSI3052-Q1 VDRV signal test point
TP4	TPSI31P1-Q1 EN signal test point
TP5	TPSI31P1-Q1 VDRV signal test point
TP6	TPSI31P1-Q1 VDDH signal test point
TP7	TPSI31P1-Q1 VDDM signal test point
TP8	TPSI31P1-Q1 IS+ signal test point
TP9	TPSI3052-Q1 VDDH signal test point
TP11	TPSI31P1-Q1 PGOOD signal test point
TP12	TPSI31P1-Q1 PC50 signal test point
TP14	TPSI3052-Q1 VDDM signal test point
TP15	TPSI3052-Q1 VDDP signal test point
TP16	TPSI3052-Q1 EN signal test point
TP17	TPSI31P1-Q1 PC100 signal test point
TP18	TPSI3052-Q1 VSSP signal test point
TP19	TPSI3052-Q1 VSSS signal test point

3 Implementation Results

3.1 Evaluation Setup

A 300mΩ shunt resistor targets 2.26A_{AVG} charging current, shown in equation 1. The charging current behavior is shown in Figure 3-1.

$$I_{PEAK} = \frac{1.2\ V}{300\ m\Omega} = 4\ \ A$$
$$I_{MIN} = \frac{0.160\ V}{300\ m\Omega} = 0.53\ \ A \quad (1)$$
$$I_{AVG} = \frac{I_{PEAK} + I_{MIN}}{2} = 2.26\ \ A$$

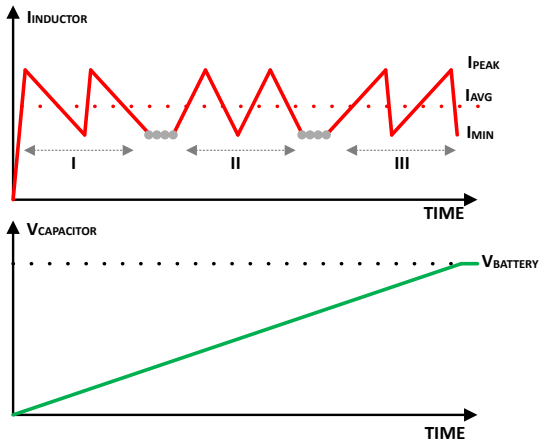


Figure 3-1. Active Precharge Profile

The TPSI31Px-Q1EVM connections for performance results are shown in Figure 3-2.

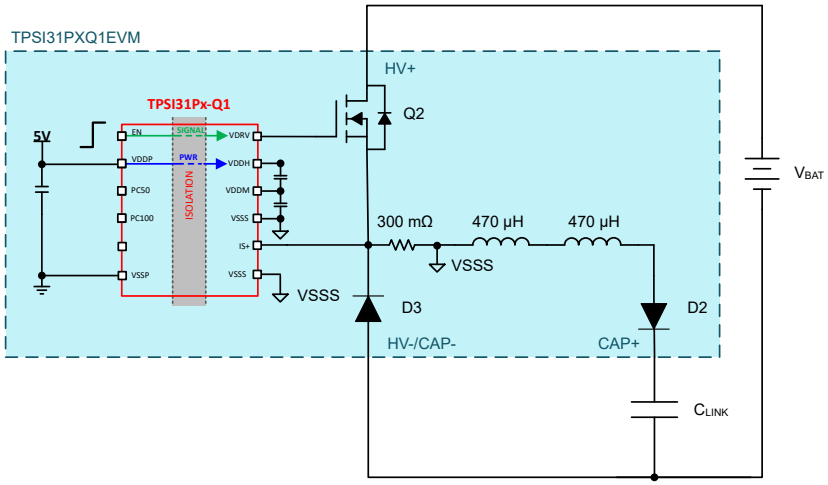


Figure 3-2. TPSI31PxQ1EVM Setup Diagram

3.2 Performance Data and Results

The following waveform shows the TPSI31Px-Q1 EVM precharging a 2mF capacitor to 800V in 830ms. The charge time is slower than intended due to the inductor current saturation and the inductance derating, resulting in lower average charging current ($2.26A_{AVG} \rightarrow 1.93A_{AVG}$).

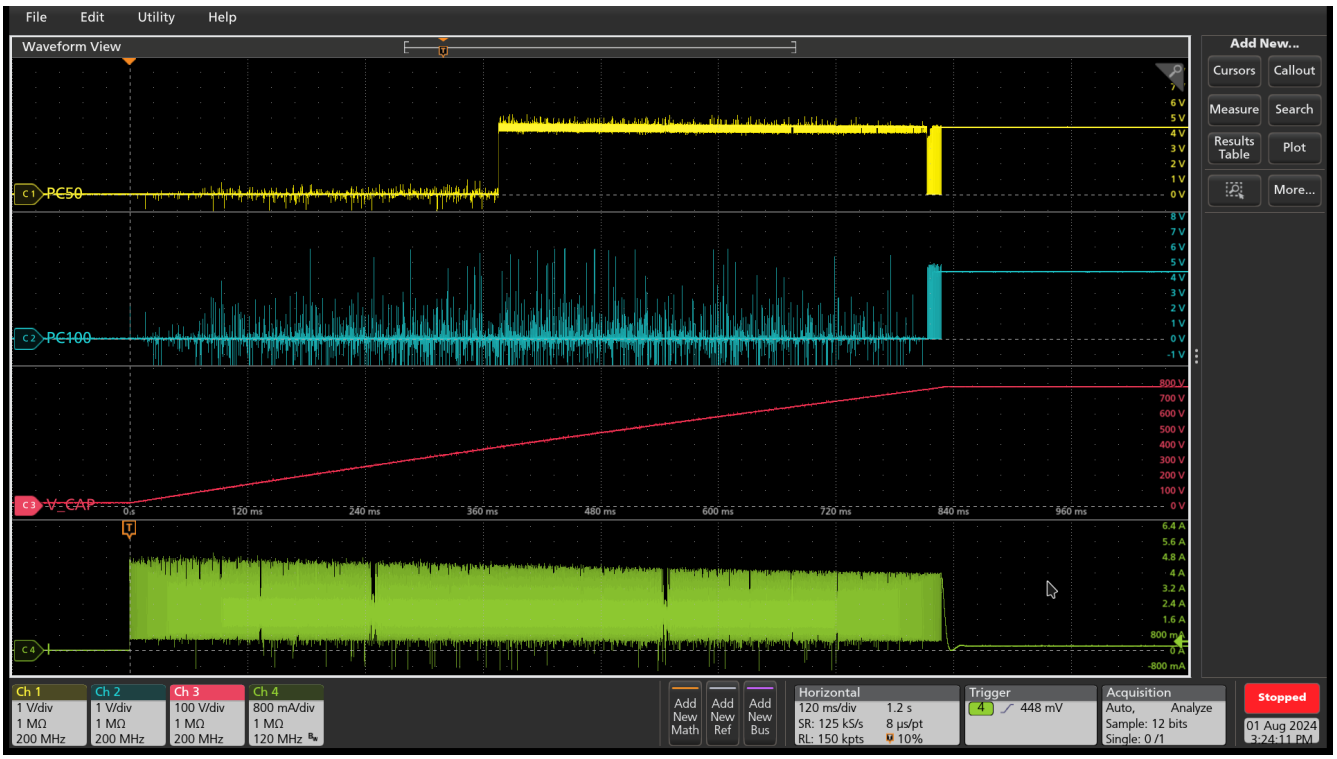


Figure 3-3. 2mF to 800V in 830ms

4 Hardware Design Files

4.1 Schematics

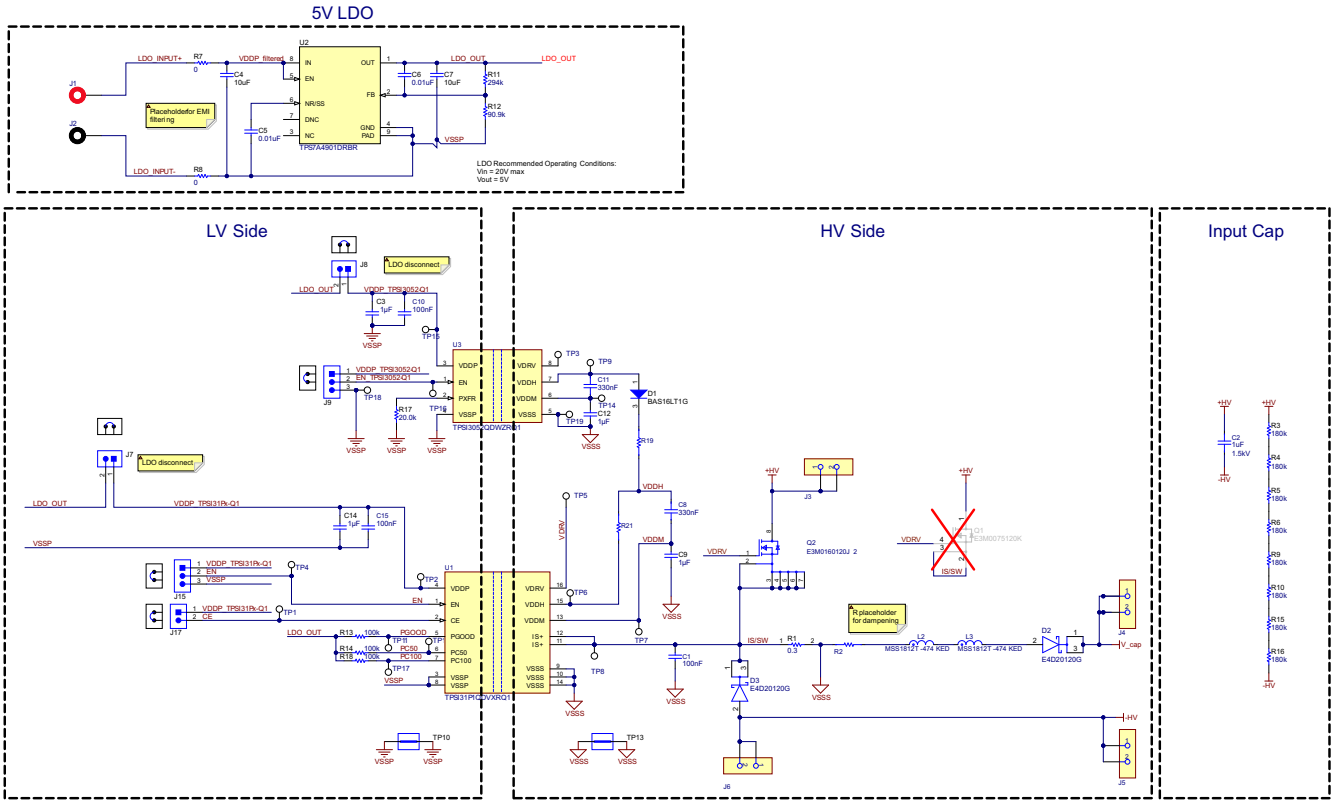


Figure 4-1. TPSI31PxQ1EVM Schematic

4.2 PCB Layouts

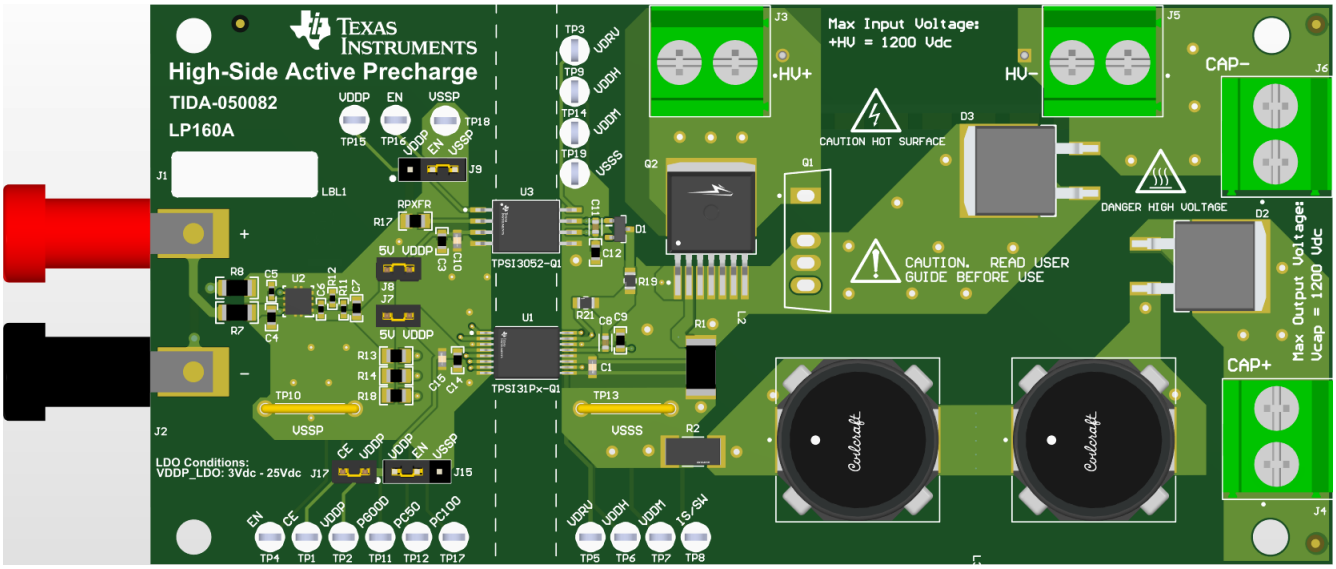


Figure 4-2. 3D (Top View)

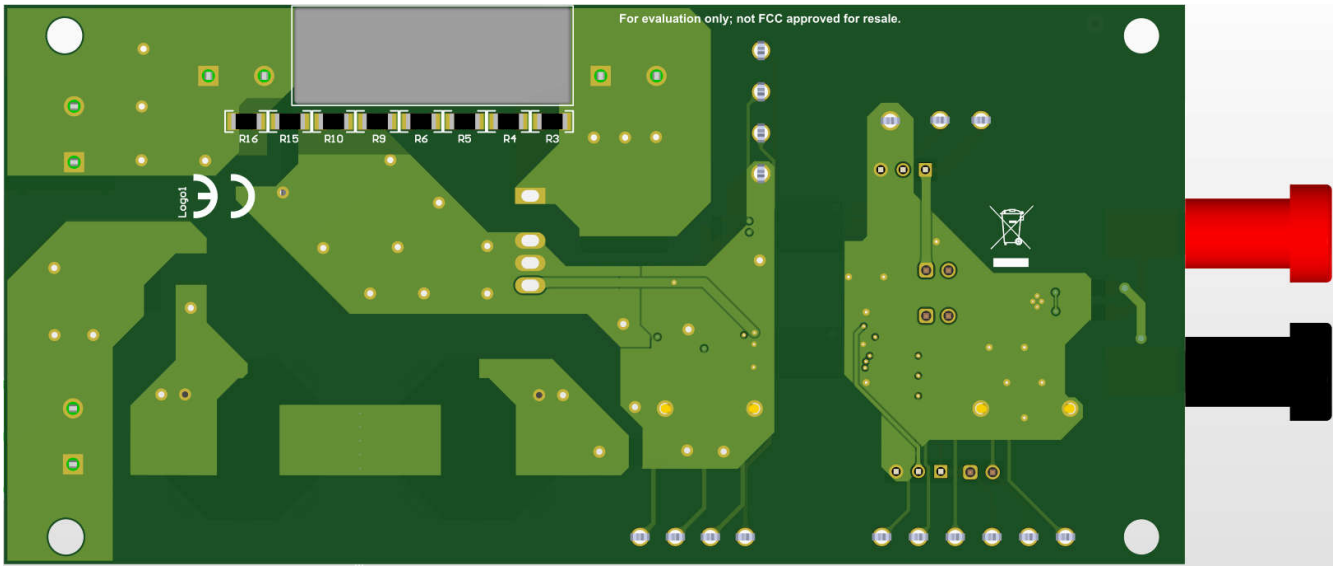


Figure 4-3. 3D (Bottom View)

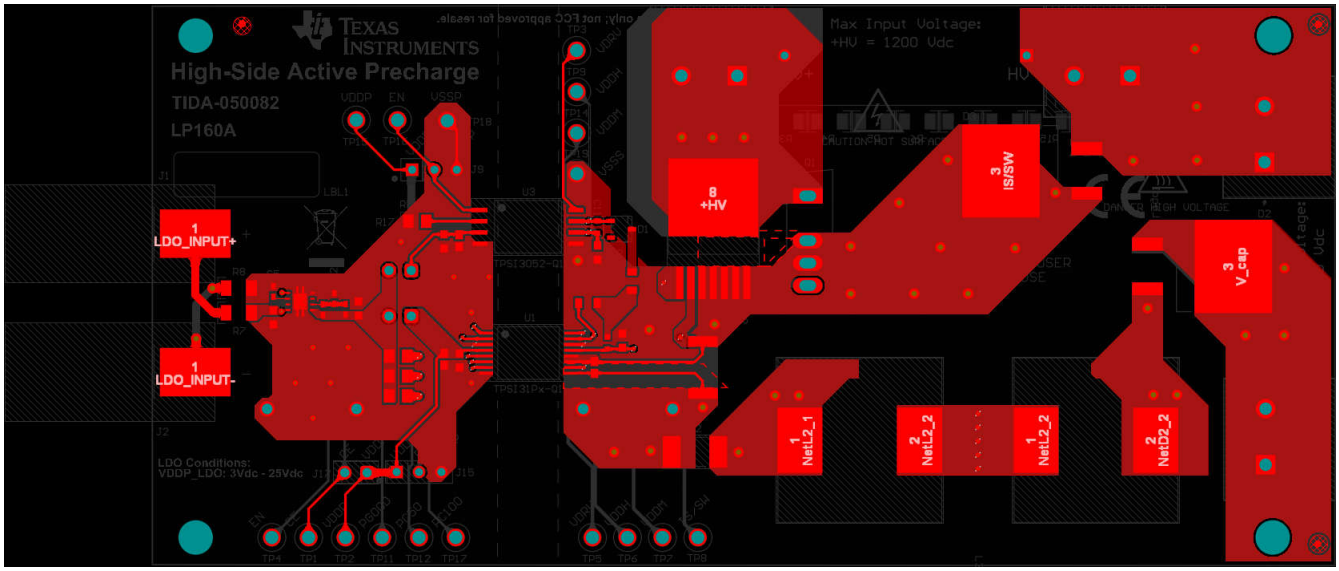


Figure 4-4. PCB Top Layer

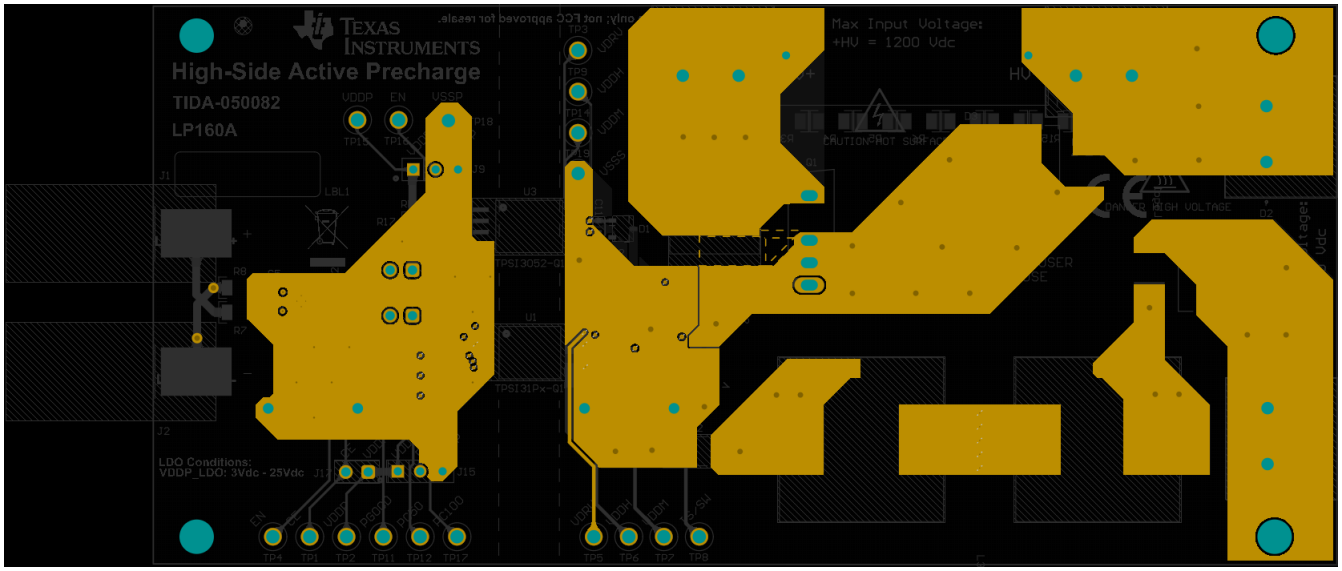


Figure 4-5. PCB Internal Layer 1

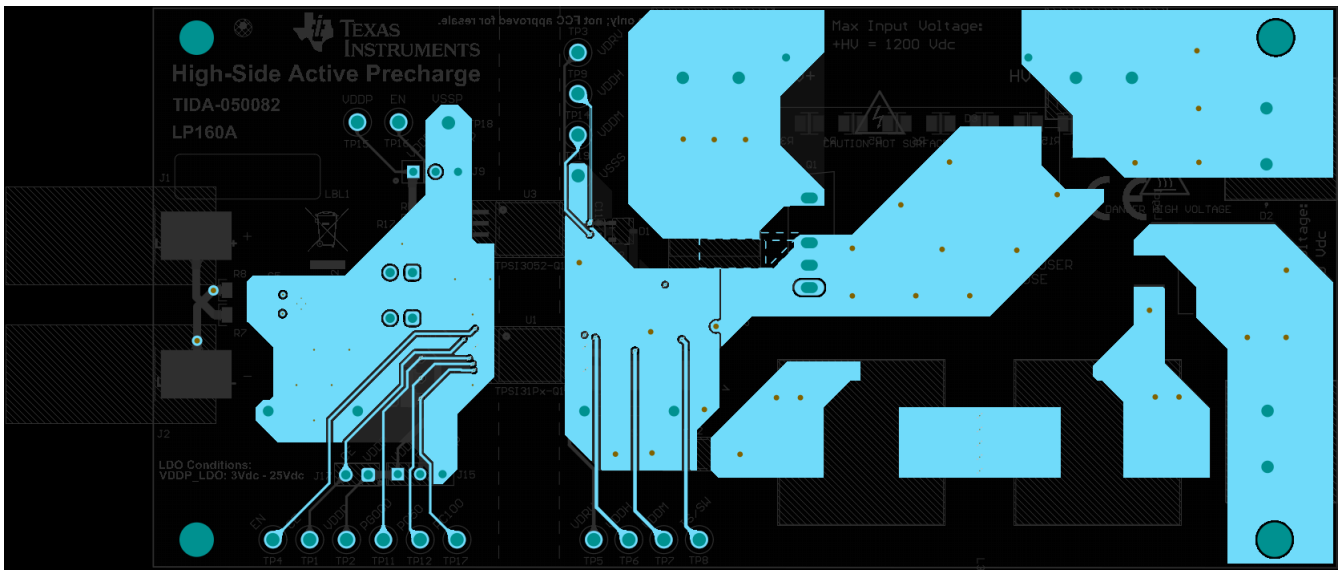


Figure 4-6. PCB Internal Layer 2

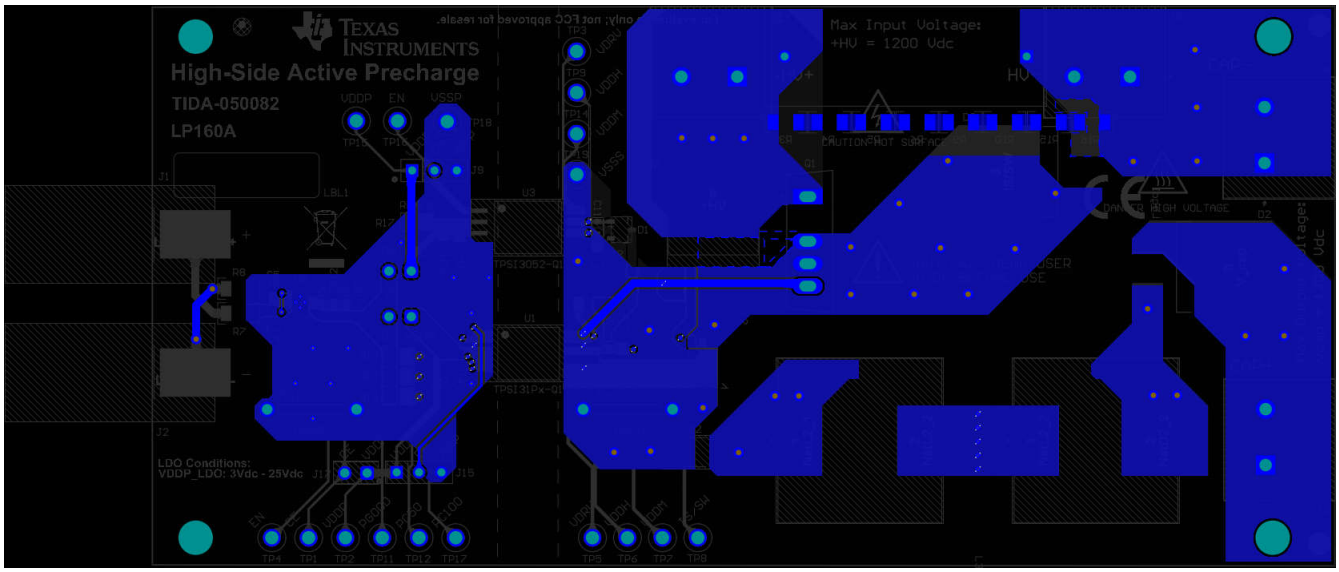


Figure 4-7. PCB Bottom Layer

4.3 Bill of Materials (BOM)

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		TIDA-050082	Any
C1, C10, C15	3		CAP CER 0.1UF 50V X7R 0603	0603	C0603R104K5RAC	Kemet
C2	1	1µF	1µF Film Capacitor 1500V (1.5kV) Polypropylene (PP), Metallized Radial	RADIAL	C4AQSBU4100A1WJ	KEMET
C3, C9, C12, C14	4	1uF	CAP, CERM, 1uF, 25V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E105KA64D	MuRata
C4, C7	2	10uF	CAP, CERM, 10uF, 25V, +/- 20%, X5R, 0603	0603	GRT188R61E106ME13D	MuRata
C5, C6	2	0.01uF	CAP, CERM, 0.01uF, 25V, +/- 10%, X7R, 0402	0402	GRM155R71E103KA01D	MuRata
C8, C11	2	330nF	Cap Ceramic 330nF 25V X7R 10% Pad SMD 0603 +125°C Automotive T/R	0603	CGA3E3X7R1E334K080AB	TDK
D1	1	100V	Diode, Switching, 100V, 0.2A, SOT-23	SOT-23	BAS16LT1G	ON Semiconductor
D2, D3	2		1200V 20A SCHOTTKY DIODE (SING		E4D20120G	
H1, H2, H3, H4	4			250x1500 mil	4810	Keystone
J1	1		Banana Jack Insul Nylon Red, TH	Banana Jack Insul Nylon Red, TH	108-0902-001	Cinch Connectivity
J2	1		Banana Jack Insul Nylon Black, TH	Banana Jack Insul Nylon Black, TH	108-0903-001	Cinch Connectivity
J3, J4, J5, J6	4			CONN_TERM_BLOCK2	6.91251E+11	Wurth Electronics
J7, J8, J17	3		Header, 2.54mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
J9, J15	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
L2, L3	2	470uH	Shielded Power Inductor 470µH ±10% 2.1A 0.23Ohms	SMD2	MSS1812T-474KED	Coilcraft
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
MP1, MP2, MP3, MP4	4			STANDOFF_HEX_THRD_4-40	14HTSP019	Essentra Components
Q2	2		MOSFET N-Channel 1200V 18A (Tc) 104W (Tc) Surface Mount TO-263-7	TO-263-7XL	E3M0160120J2	Wolfspeed
R1	1	0.3	RES, 0.3, 1%, 2 W, 2512	2512	CRM2512-FX-R300ELF	Bourns

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R2	1	200µ	0 Ohms Jumper 100A 2W Chip Resistor 2512 (6432 Metric) Metal Element	2512	JR2512X100E	Ohmite
R3, R4, R5, R6, R9, R10, R15, R16	8	180k	RES, 180 k, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW1206180KJNEA	Vishay-Dale
R7, R8	2	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	ERJ-8GEY0R00V	Panasonic
R11	1	294k	RES, 294 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF2943X	Panasonic
R12	1	90.9k	RES, 90.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF9092X	Panasonic
R13, R14, R18	3	100k	RES, 100 k, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6GEYJ104V	Panasonic
R17	1	20.0k	RES, 20.0 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF2002V	Panasonic
R19, R21	2	0	RES SMD 0 OHM JUMPER 1/8W 0805	0805	RC0805FR-070RL	Yageo
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5	5	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP11, TP12, TP14, TP15, TP16, TP17, TP18, TP19	17		Test Point, White, Through Hole, RoHS, Bulk	5012		Keystone
TP10, TP13	2		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
U1	1		Isolated Automotive Active Pre-charge Controller with Integrated Gate Driver and Bias Supply	SSOP16	TPSI31P1QDVXRQ1	Texas Instruments
U2	1		Vin 3V to 36V, 150mA, Ultra-Low-Noise, High-PSRR Low-Dropout (LDO) Linear Regulator, DRB0008A (VSON-8)	DRB0008A	TPS7A4901DRBR	Texas Instruments
U3	1		Automotive Reinforced Isolated Switch Driver With Integrated 15V Gate Supply	SOIC8	TPSI3052QDWZRQ1	Texas Instruments
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

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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 *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 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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