

EVM User's Guide: TPSI31PXQ1EVM

TPSI31Px-Q1 Evaluation Module



Description

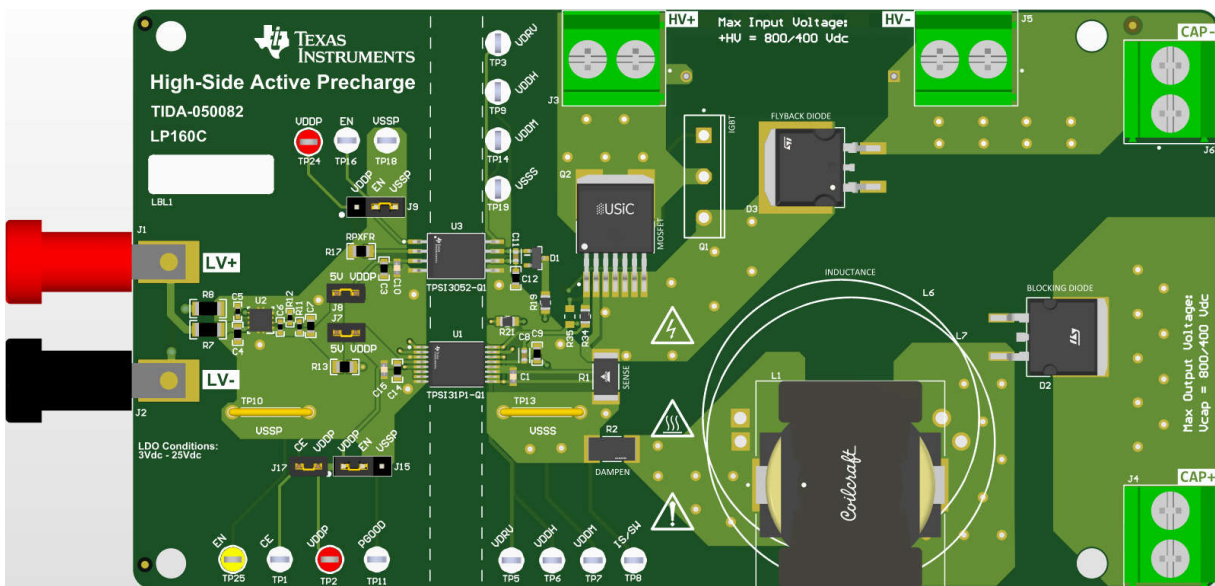
The TPSI31Px-Q1 evaluation module (EVM) helps designers evaluate the operation and performance of the TPSI31Px-Q1 device family. The board features the TPSI31P1-Q1, an isolated switch driver with integrated 17V gate supply and comparators to monitor charging current and hysteretically drive the gate, completely on the secondary side with no additional logic needed. This functionality allows the TPSI31P1 to charge a DC-link capacitor in any application including electric vehicles (EV) or hybrid electric vehicles (HEV) as a high-side active precharge solution. For additional switching power, the TPSI3052, is included in the EVM design, but not required. The TPSI3052 is an isolated switch driver with integrated 17V gate supply which can be used as a supplementary isolated power supply. The EVM features a buck topology using a HV inductor. The EVM also includes an N-Channel silicon carbide (SiC) MOSFET with a small 14nC gate charge which helps us minimize overall switching power needed. The board contains multiple test points to monitor TPSI31P1-Q1 functionality. In addition, the EVM contains an adjustable 5V LDO for flexible power input.

Features

- TPSI31PXQ1EVM for charging 2mF capacitor to 800V within 300ms ($5.5A_{AVG}$)
- TPSI31PXQ1EVM-400 for charging 2mF capacitor to 400V within 180ms ($4.5A_{AVG}$)
- Hysteretic charging current control integrated in TPSI31P1-Q1, no additional logic needed
- Ultra-low-noise LDO (5V to 20V input) for powering the circuit if adjustable power supply is unavailable
- No isolated secondary supply required
- 5kVRMS reinforced isolation
- 17V gate drive with 1.5A peak source current and 3A peak sink current
- Dual isolated high-speed comparators with integrated voltage reference $\pm 1.5\%$

Applications

- [Hybrid, electric, and powertrain systems](#)



PCB Top View: TPSI31PXQ1EVM

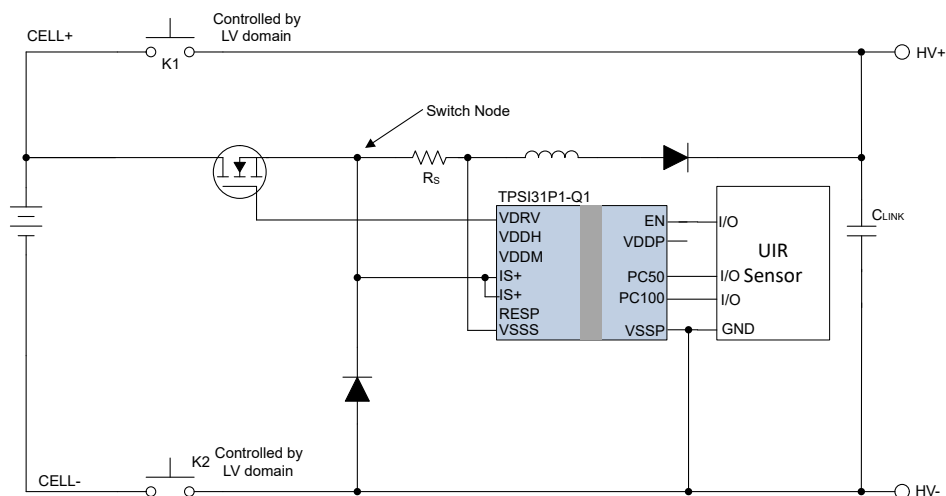


Figure 1-3. TPSI31P1-Q1 Application Schematic

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.

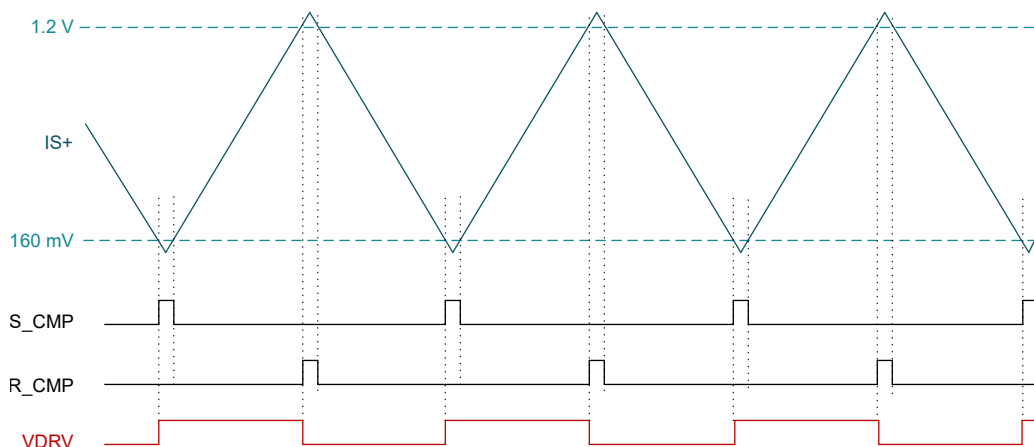


Figure 1-4. TPSI31P1-Q1 Behavior Diagram

2 Hardware

2.1 Additional Images

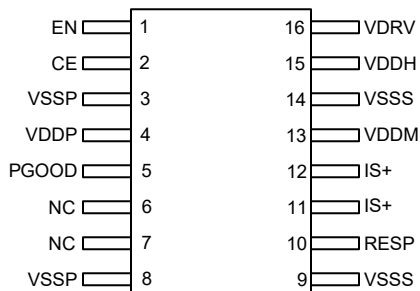


Figure 2-1. TPSI31P1-Q1 DVX Package 16-Pin SSOP (Top View)

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
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/SW signal test point
TP9	TPSI3052-Q1 VDDH signal test point
TP11	TPSI31P1-Q1 PGOOD signal test point
TP14	TPSI3052-Q1 VDDM signal test point
TP16	TPSI3052-Q1 EN signal test point
TP18	TPSI3052-Q1 VSSP signal test point
TP19	TPSI3052-Q1 VSSS signal test point
TP24	TPSI3052-Q1 VDDP signal test point
TP25	TPSI31P1-Q1 EN signal test point

3 Software

TPSI31P1-CALC is a calculator tool helpful for estimating precharge circuit behavior, which is available within the device product folder. The tool allows users to input common precharge requirements such as voltage, capacitance, inductance, and more, to generate output waveforms of the link voltage and inductor current. This software also accounts for user inputs that exceed the TPSI31P1-Q1 power transfer capabilities and accordingly estimates delay resulting from VDDH needing to recover from UVLO. To minimize or remove this delay, the user can choose to add the TPSI3052-Q1 to provide an additional 79mW of switching power by connecting J8.

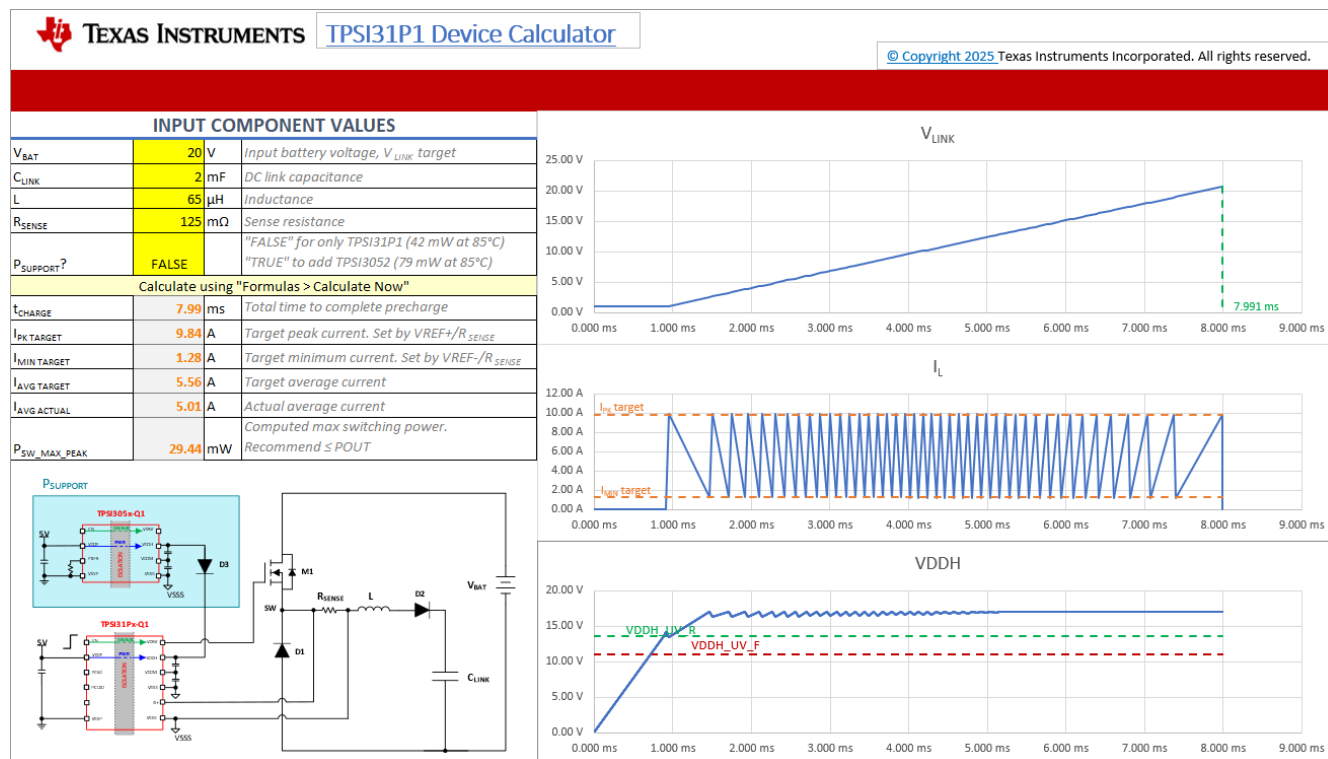


Figure 3-1. TPSI31P1 Device Calculator Example 1, VDDH Not Hitting UVLO

- To help clearly illustrate current charging behavior in the blue waveform, Example 1 depicts a 20V input. Note that the input is not limited to 20V.
- To help clearly illustrate current charging behavior in the blue waveform, Example 2 depicts a 20V input. Note that the input is not limited to 20V.

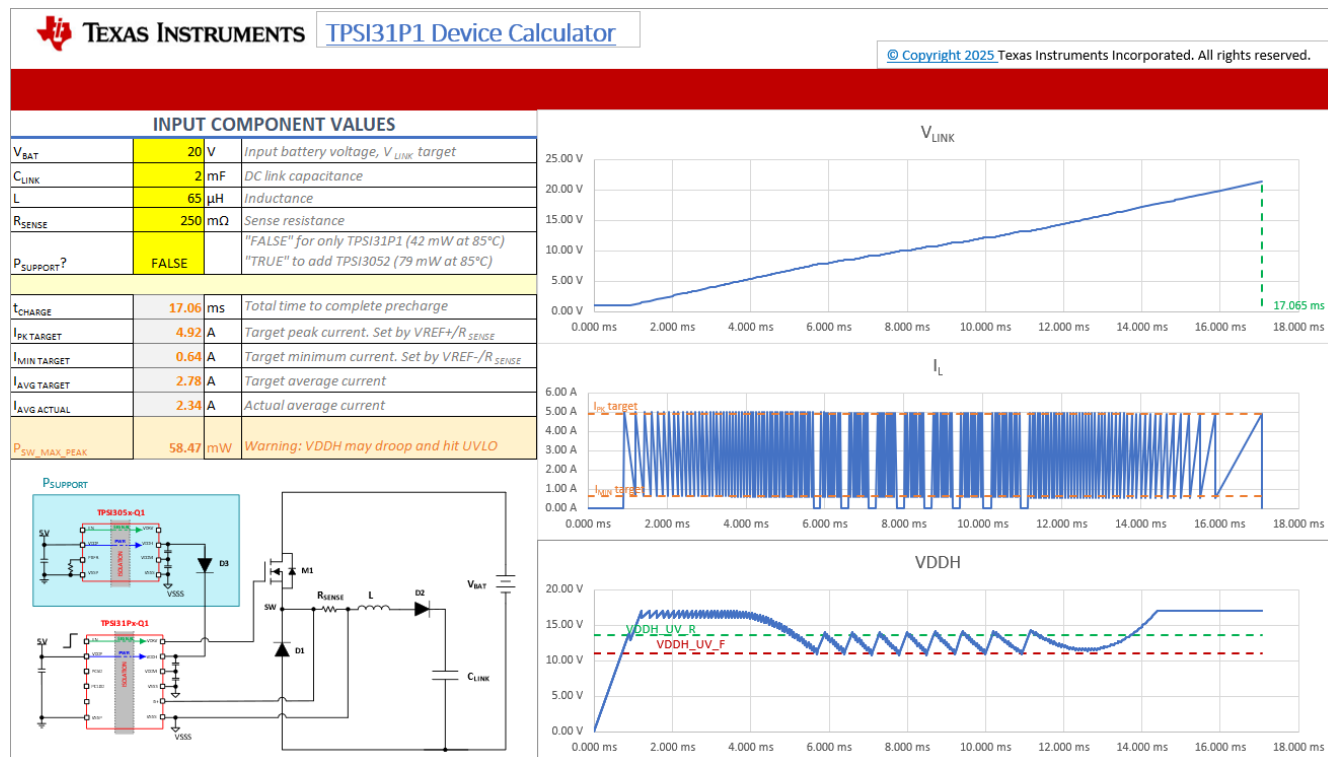


Figure 3-2. TPSI31P1 Device Calculator Example 2, VDDH Hitting UVLO

4 Implementation Results

4.1 Evaluation Setup

Equation 1 shows how to select a shunt resistor based on the desired charging current. A 125mΩ shunt resistor targets 5.5A_{AVG} charging current. A 150mΩ shunt resistor targets 4.5A_{AVG} charging current. The charging current behavior is shown in Figure 4-1.

$$\begin{aligned}
 I_{PEAK} &= \frac{1.2 \text{ V}}{R_{SHUNT}} \\
 I_{MIN} &= \frac{0.160 \text{ V}}{R_{SHUNT}} \\
 I_{AVG} &= \frac{I_{PEAK} + I_{MIN}}{2}
 \end{aligned} \tag{1}$$

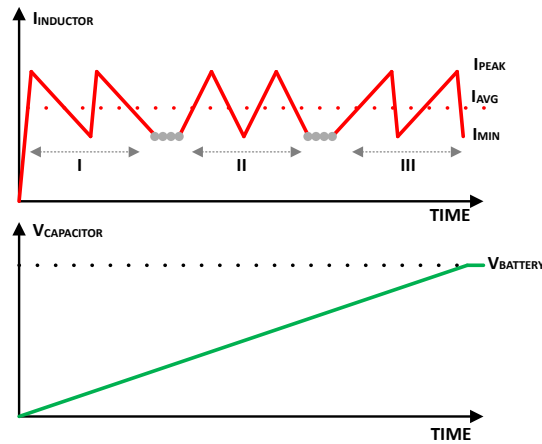


Figure 4-1. Active Precharge Profile

4.2 Performance Data and Results

The following waveforms show the TPSI31PXQ1EVM and TPSI31PXQ1EVM-400 charging a 2mF capacitor to 800V and 400V within 290ms and 180ms, respectively.

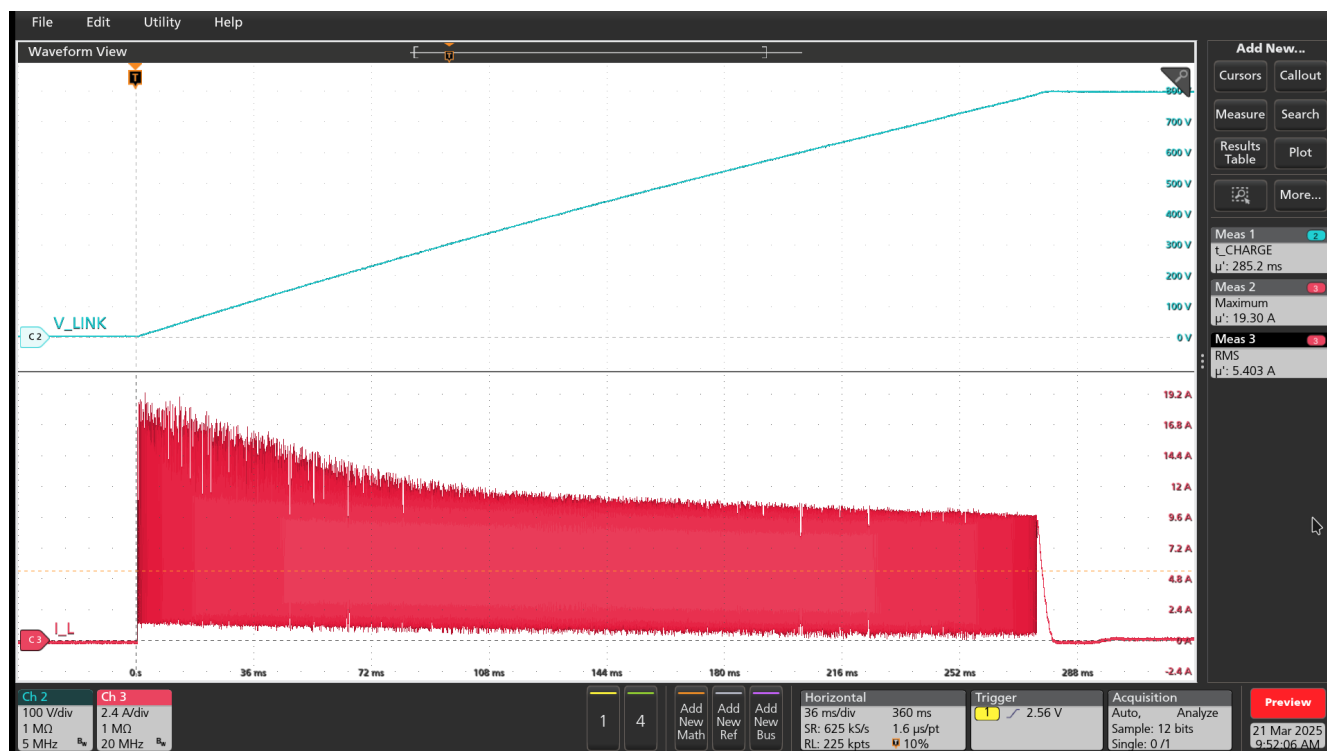


Figure 4-2. 2mF to 800V in 290ms (TPSI31PXQ1EVM)

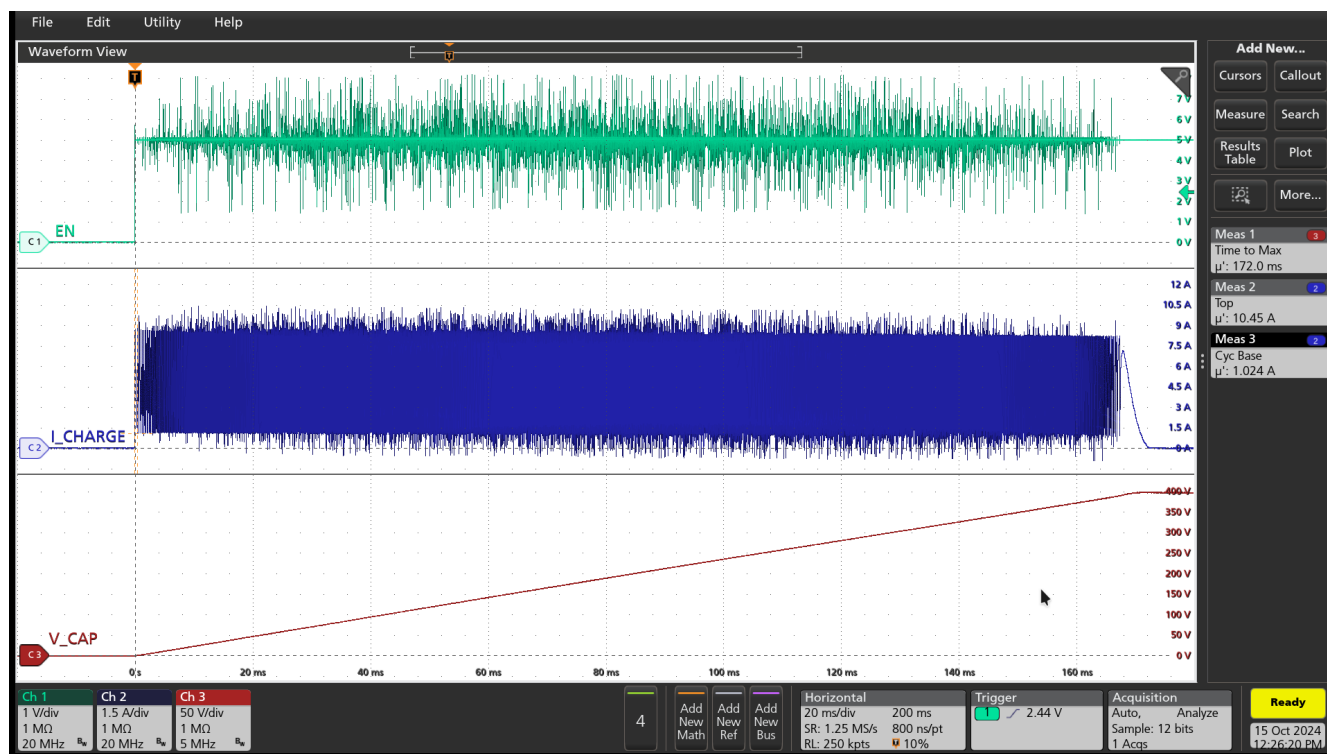


Figure 4-3. 2mF to 400V in 180ms (TPSI31PXQ1EVM-400)

5 Hardware Design Files

5.1 Schematics

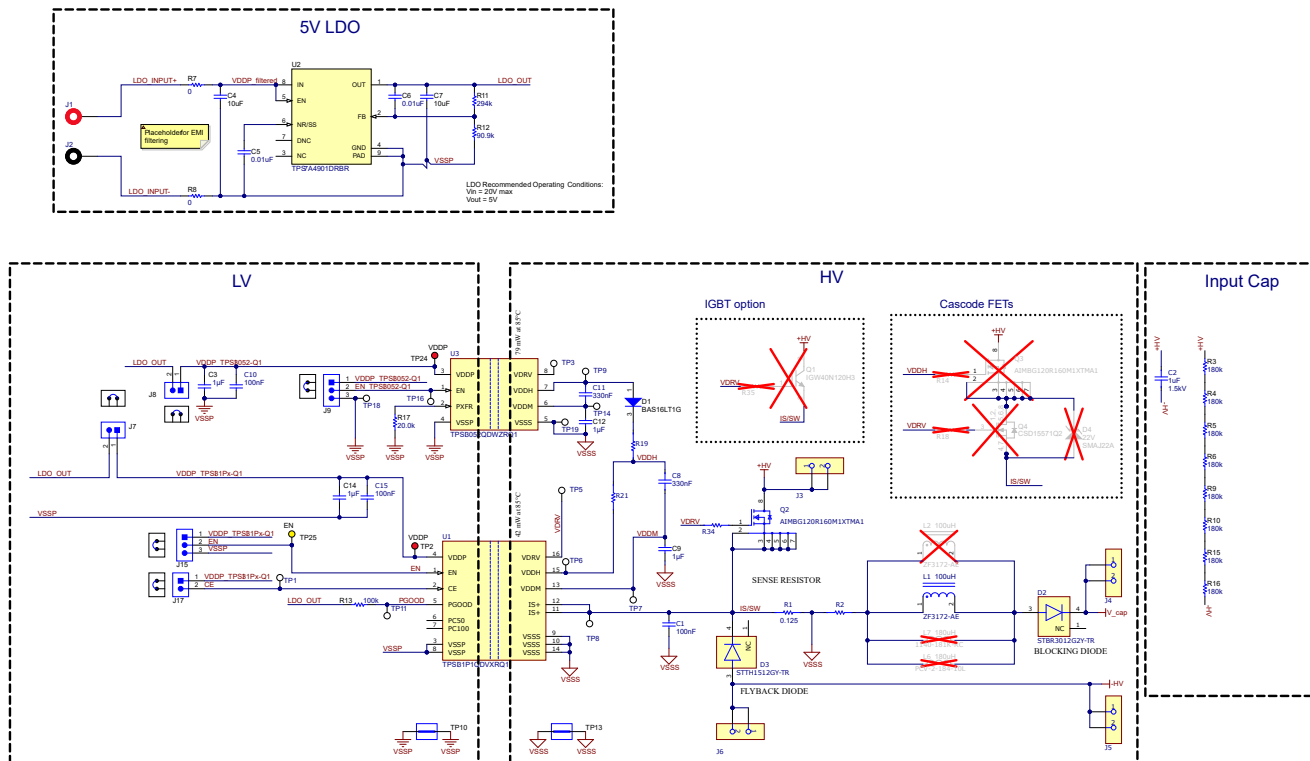


Figure 5-1. TPSI31PXQ1EVM Schematic

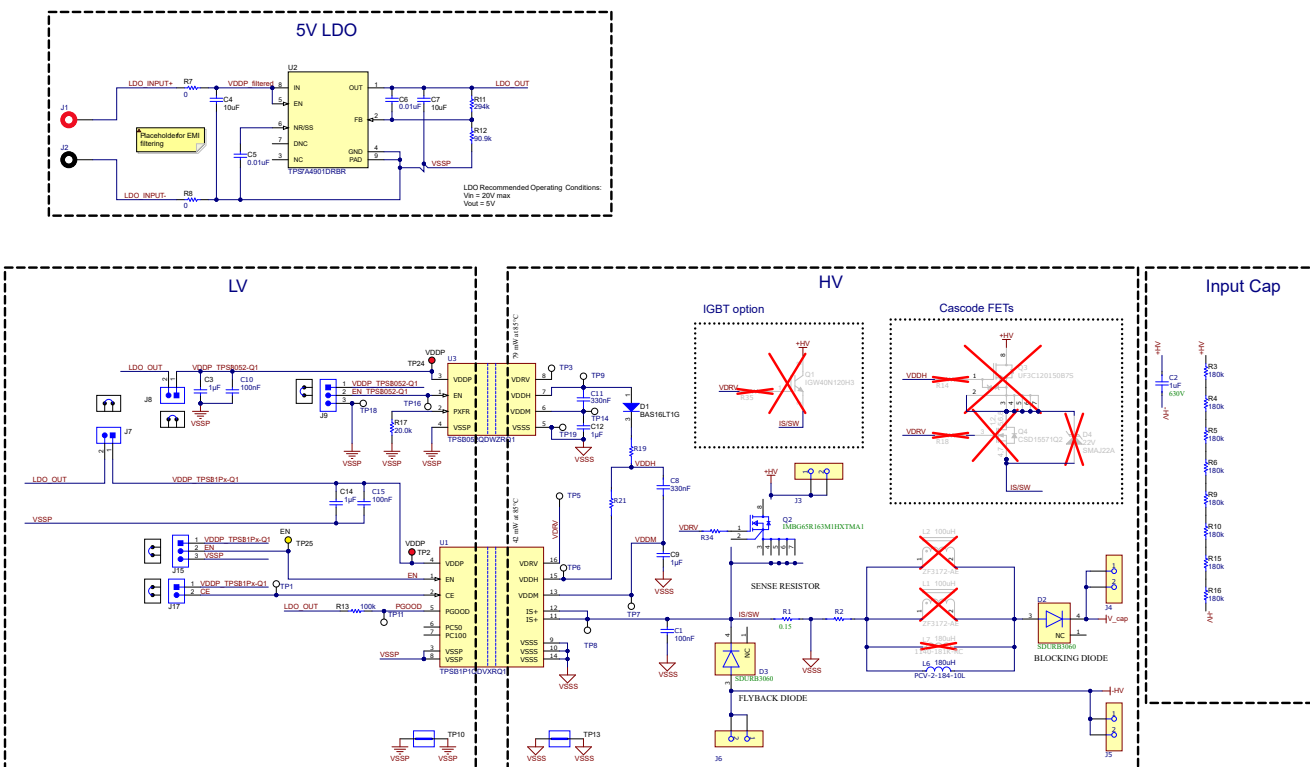


Figure 5-2. TPSI31PXQ1EVM-400 Schematic

5.2 PCB Layouts

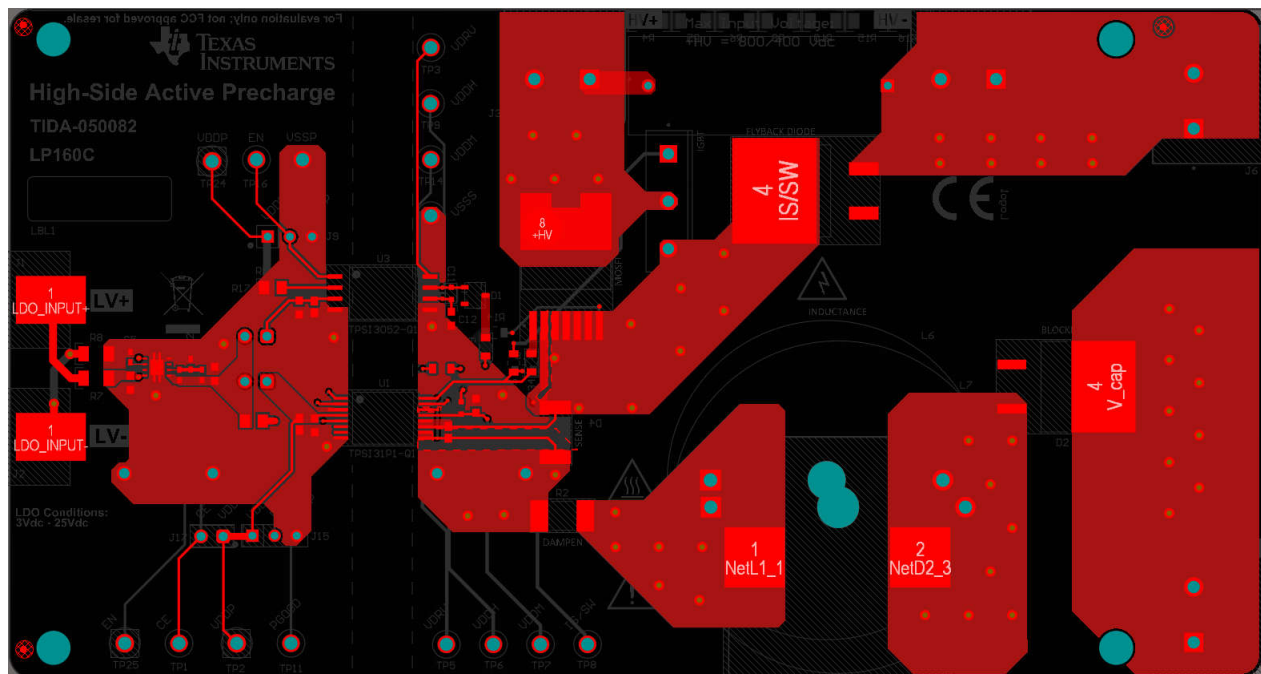


Figure 5-3. PCB Top Layer

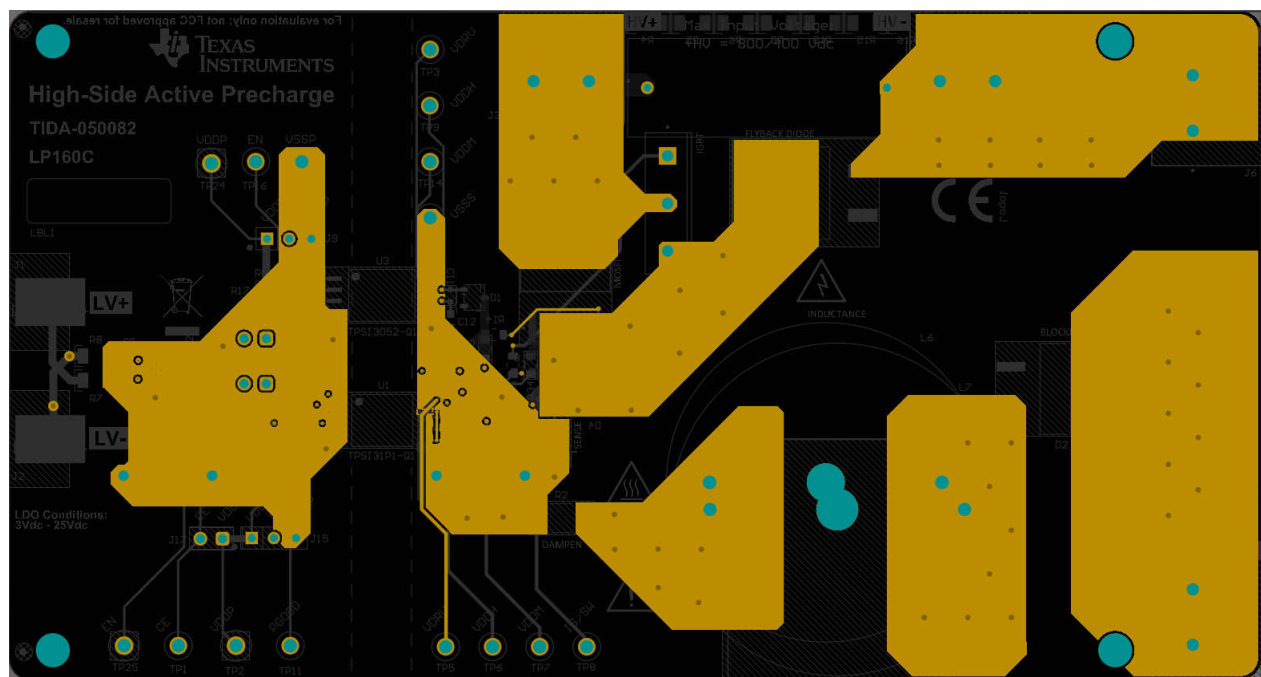


Figure 5-4. PCB Internal Layer 1

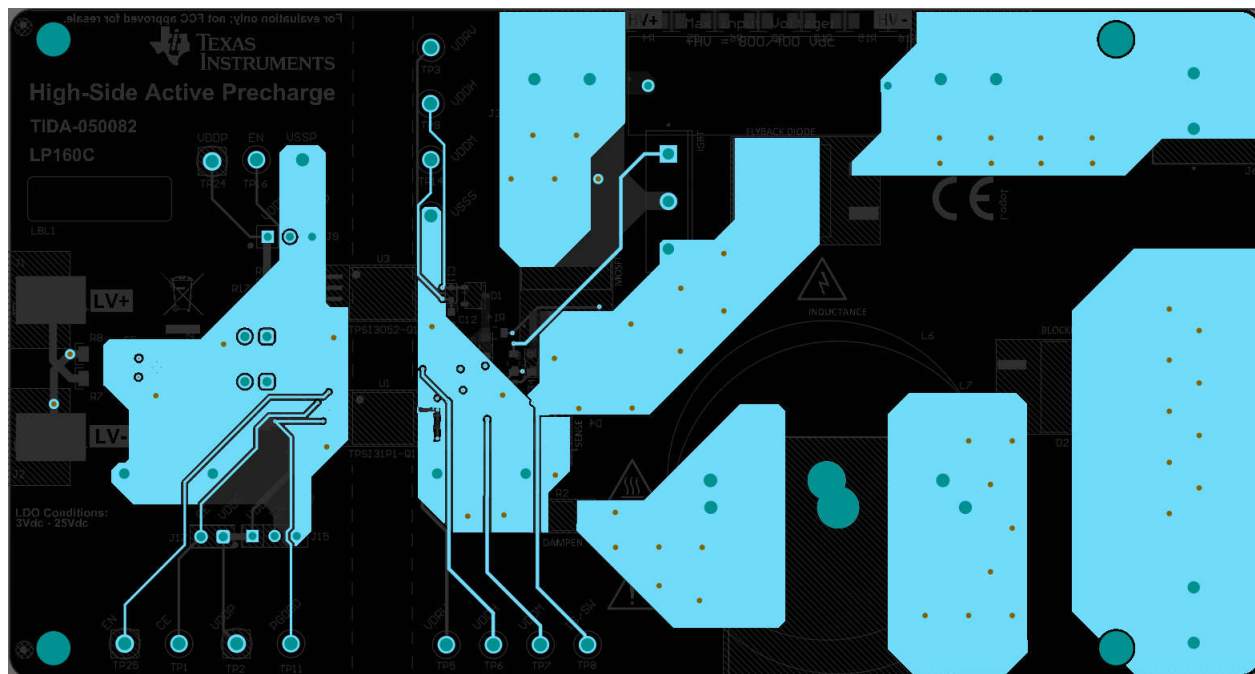


Figure 5-5. PCB Internal Layer 2

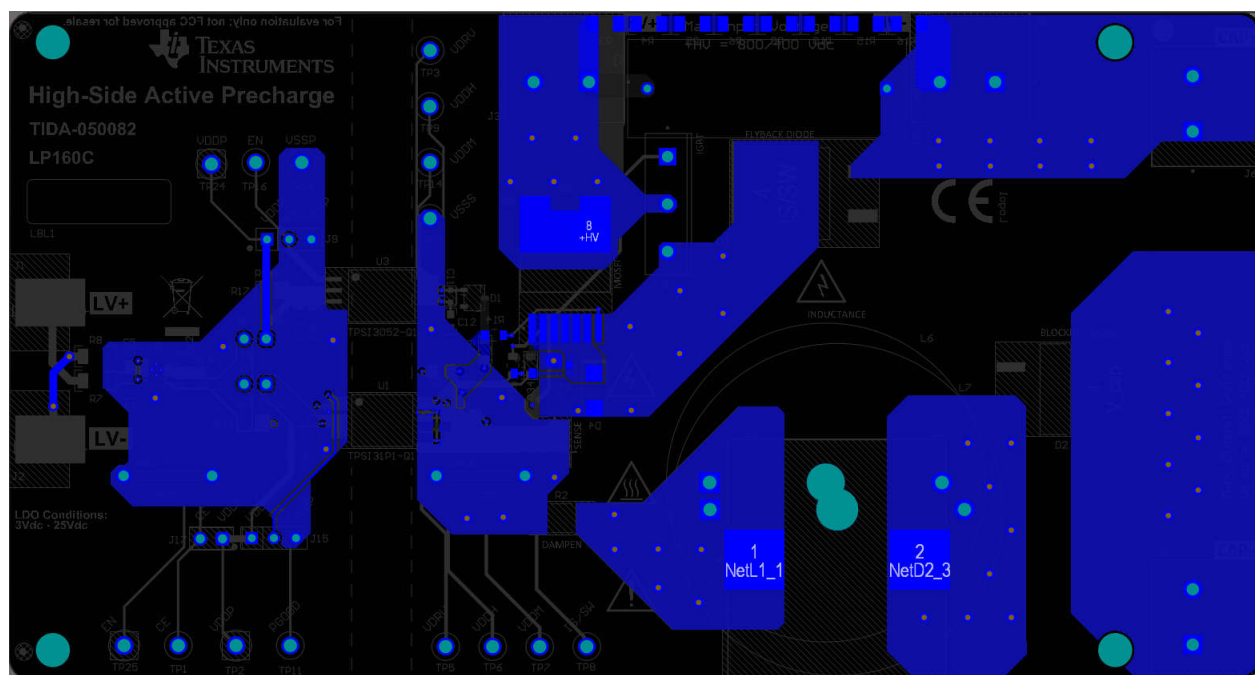


Figure 5-6. PCB Bottom Layer

5.3 Bill of Materials (BOM)

Table 5-1. Bill of Materials (TPSI31PXQ1EVM)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
!PCB1	1		Printed Circuit Board		LP160	Any
C1, C10, C15	3		CAP CER 0.1UF 50V X7R 0603	0603	C0603R104K5RAC	Kemet
C2	1	1µF	CAP FILM 1UF 5% 630VDC RADIAL	RADIAL	ECW-FG2J105J	Panasonic
C3, C9, C12, C14	4	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E105KA64D	MuRata
C4, C7	2	10uF	CAP, CERM, 10 uF, 25 V, +/- 20%, X5R, 0603	0603	GRT188R61E106ME13D	MuRata
C5, C6	2	0.01uF	CAP, CERM, 0.01 uF, 25 V, +/- 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	CGA3E3X7R1E334K080 AB	TDK
D1	1	100V	Diode, Switching, 100 V, 0.2 A, SOT-23	SOT-23	BAS16LT1G	ON Semiconductor
D2	1		600V, 30A, D2PAK, ULTRA FAST REC	D2PAK	SDURB3060	SMC Diode Solutions
D3	1		600V, 30A, D2PAK, ULTRA FAST REC	D2PAK	SDURB3060	SMC Diode Solutions
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
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	Würth Electronics
J7, J8, J17	3		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Würth Elektronik

Table 5-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
J9, J15	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
L6	1	100uH	Power Inductors - Leaded 180uH UnShld 10% 8A 48mOhms	RADIAL	PCV-2-184-10L	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	1		N-Channel 650 V 17A (Tc) 85W (Tc) Surface Mount PG-TO263-7-12	D2PAK7	IMBG65R163M1HXTMA1	Infineon
R1	1	0.12	150 mOhms $\pm 1\%$ 2W Chip Resistor 2512 (6432 Metric) Automotive AEC- Q200, Current Sense Thick Film	2512	CSRN2512FKR150	Stackpole Electronics Inc
R2	1	200 μ	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	1	100k	RES, 100 k, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6GEYJ104V	Panasonic

Table 5-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R17	1	20.0k	RES, 20.0 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF2002V	Panasonic
R19, R21, R34	3	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, TP3, TP5, TP6, TP7, TP8, TP9, TP11, TP14, TP16, TP18, TP19	12		Test Point, White, Through Hole, RoHS, Bulk	5012		Keystone
TP2, TP24	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics
TP10, TP13	2		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
TP25	1		Test Point, Multipurpose, Yellow, TH	Yellow Multipurpose Testpoint	5014	Keystone Electronics
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 15 V Gate Supply	SOIC8	TPSI3052QDWZRQ1	Texas Instruments
L1	0	355uH	355 μ H Unshielded Toroidal Inductor 12.3 A 35mOhm Max Nonstandard Flat Wire	PTH2	760801403	Würth Electronics

Table 5-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
L2, L3, L4, L5	0	470uH	Shielded Power Inductor 470uH ±10% 2.1A 0.23Ohms	SMD2	MSS1812T-474KED	Coilcraft
Q1	0		1200 V High Speed Switching Series Third Generation, PG- TO247-3-44, Tube, Green	PG-TO247-3-44_A	IGW40N120H3	Infineon
R35	0	0	RES SMD 0 OHM JUMPER 1/8W 0805	0805	RC0805FR-070RL	Yageo

Table 5-2. Bill of Materials (TPSI31PXQ1EVM-400)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		LP160	Any		
C1, C10, C15	3		CAP CER 0.1UF 50V X7R 0603	0603	C0603R104K5RAC	Kemet		
C2	1	1uF	Cap Film 1uF 630V PP 5% (31.5 X 9.5 X 18mm) Radial 27.5mm 110C Automotive Bulk	RADIAL	ECW-FG2J105J	Panasonic		
C3, C9, C12, C14	4	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E105KA 64D	MuRata		
C4, C7	2	10uF	CAP, CERM, 10 uF, 25 V, +/- 20%, X5R, 0603	0603	GRT188R61E106ME1 3D	MuRata		
C5, C6	2	0.01uF	CAP, CERM, 0.01 uF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E103KA 01D	MuRata		
C8, C11	2	330nF	Cap Ceramic 330nF 25V X7R 10% Pad SMD 0603 +125°C Automotive T/R	0603	CGA3E3X7R1E334K0 80AB	TDK		
D1	1	100V	Diode, Switching, 100 V, 0.2 A, SOT-23	SOT-23	BAS16LT1G	ON Semiconductor		
D2, D3	2		Diode 600 V 30A Surface Mount D2PAK	D2PAK	SDURB3060	SMC Diode Solutions		

Table 5-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A		
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_BLOC K2	6.91251E+11	Würth Electronics		
J7, J8, J17	3		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Würth Elektronik		
J9, J15	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions		
L6	1	180uH	Power Chokes 180uH 10% 8A 0.048 Ohm	RADIAL	PCV-2-184-10L	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_TH RD_4-40	14HTSP019	Essentra Components		
Q2	1		MOSFET N-Channel 650 V 17A (Tc) 85W (Tc) Surface Mount PG-TO263-7-12	D2PAK-7	IMBG65R163M1HXT MA1	Infineon		
R1	1	0.15	Res Thick Film 2512 0.15Ω 1% 2W ±200ppm/°C Molded SMD Plastic T/R	2512	CSRN2512FKR150	Stackpole Electronics		
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	CRCW1206180KJNE A	Vishay-Dale		
R7, R8	2	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	ERJ-8GEY0R00V	Panasonic		

Table 5-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
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	1	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, R34	3	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	969102-0000-DA	3M
TP1, TP3, TP5, TP6, TP7, TP8, TP9, TP11, TP14, TP16, TP18, TP19	12		Test Point, White, Through Hole, RoHS, Bulk	5012		Keystone		
TP2, TP24	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics		
TP10, TP13	2		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin		
TP25	1		Test Point, Multipurpose, Yellow, TH	Yellow Multipurpose Testpoint	5014	Keystone Electronics		
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	TPS7A4901DRBT	Texas Instruments

Table 5-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
U3	1		Automotive Reinforced Isolated Switch Driver With Integrated 15 V Gate Supply	SOIC8	TPSI3052QDWZRQ1	Texas Instruments		
D4	0	22V	Diode, TVS, Uni, 22 V, 35.5 Vc, 400 W, 11.3 A, SMA	SMA	SMAJ22A	Littelfuse		
L1, L2	0	100uH	Power inductor, PQ26, SMD	SMD2	ZF3172-AE	Coilcraft		
L7	0	180uH	Ind High Current RF Choke Bobbin Core 180uH 10% 1KHz Ferrite 11.4A RDL	RADIAL	1140-181K-RC	Bourns		
Q1	0		1200 V High Speed Switching Series Third Generation, PG-TO247-3-44, Tube, Green	PG-TO247-3-44_A	IGW40N120H3	Infineon		
Q3	0		N-Channel 1200 V 17A (Tc) 136W (Tc) Surface Mount D2PAK-7	D2PAK7	UF3C120150B7S	UnitedSiC		
Q4	0	20V	MOSFET, N-CH, 20 V, 10 A, DQK0006C (WSO6N-6)	DQK0006C	CSD15571Q2	Texas Instruments		None
R14, R18, R35	0	0	RES SMD 0 OHM JUMPER 1/8W 0805	0805	RC0805FR-070RL	Yageo		

6 Additional Information

6.1 Trademarks

All trademarks are the property of their respective owners.

7 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (January 2025) to Revision B (April 2025)	Page
• Updated content to reflect revision C board changes throughout the document.....	1
• Added the <i>Software</i> section to describe the TPSI31P1-CALC calculator tool.....	6

Changes from Revision * (August 2024) to Revision A (January 2025)	Page
• Updated content for new variant TPSI31PXQ1EVM throughout the document.....	1

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

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3.4 European Union

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

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

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

6. *Disclaimers:*

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, INDEMNITY 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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