

EVM User's Guide: TPSI31PXQ1EVM

TPSI31Px-Q1 Evaluation Module



Description

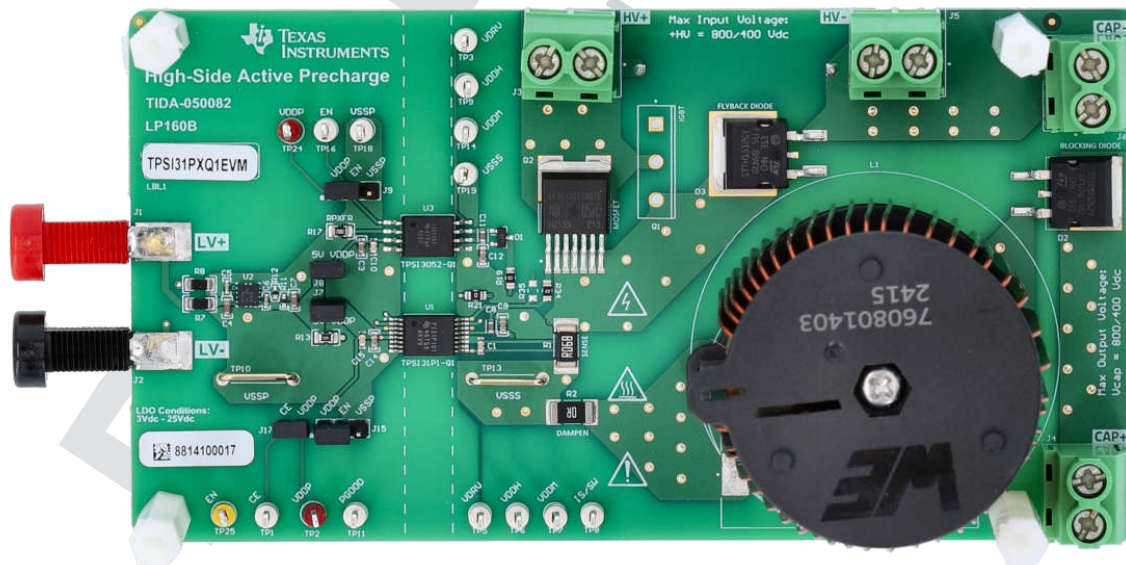
The TPSI31Px-Q1 evaluation module (EVM) helps designers evaluate the operation and performance of the TPSI31Px-Q1 device family in an electric vehicle (EV) or hybrid electric vehicle (HEV) high-side active precharge application for charging a DC-link capacitor. The board features the TPSI31P1-Q1, an 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 using a HV inductor. The EVM also includes an N-Channel 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

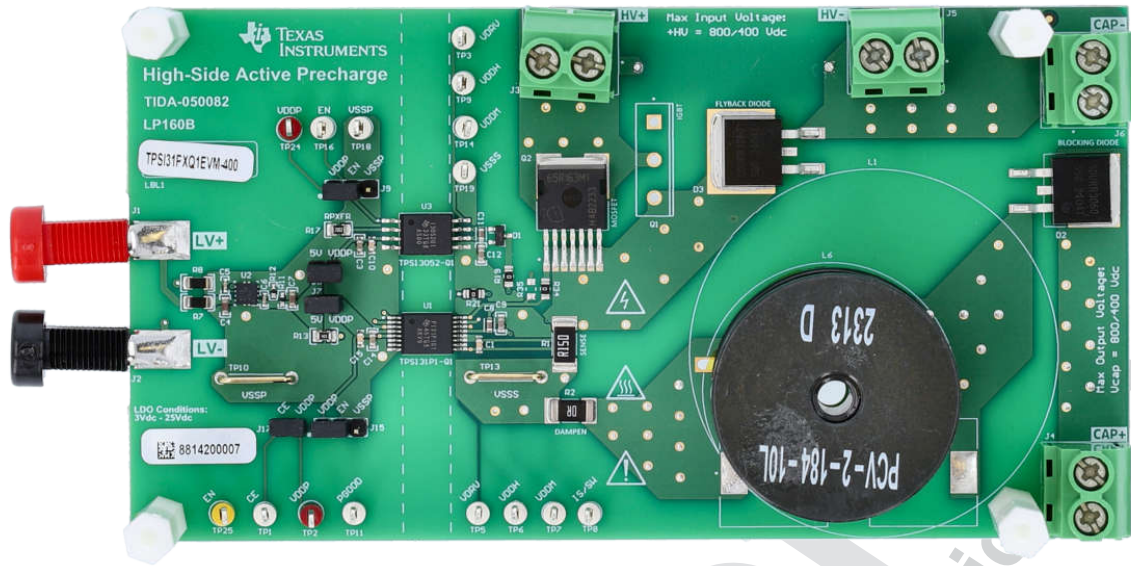
- TPSI31PXQ1EVM for charging 2mF capacitor to 800V in 160ms ($10A_{AVG}$)
- TPSI31PXQ1EVM-400 for charging 2mF capacitor to 400V in 180ms ($4.5A_{AVG}$)
- Integrated hysteretic charging current control, no additional logic needed
- Ultralow-noise LDO (5V to 20V input) for powering the circuit if adjustable power supply is unavailable
- No isolated secondary supply required
- 5kVRMS 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 $\pm 1.5\%$

Applications

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



PCB Top View: TPSI31PXQ1EVM



PCB Top View: TPSI31PXQ1EVM-400

DRAFT
TI Confidential – NDA Restriction

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 hysteric control to control the charging current. The TPSI31P1-Q1 integrates the hysteric 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

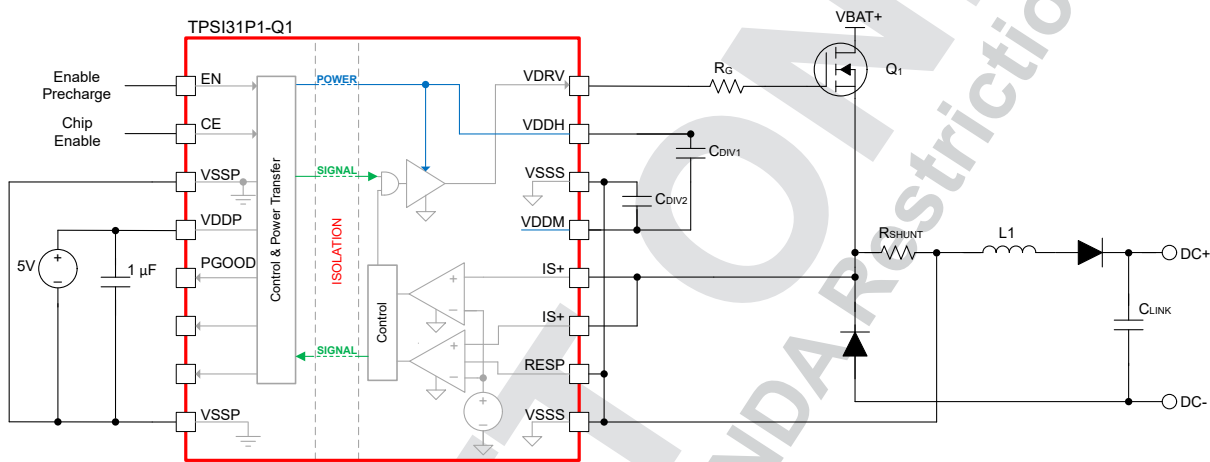


Figure 1-1. TPSI31P1-Q1 Simplified Schematic

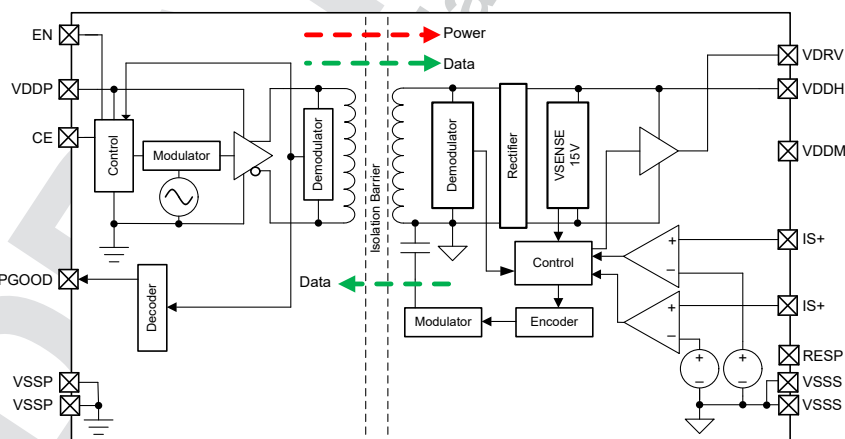


Figure 1-2. TPSI31P1-Q1 Functional Block Diagram

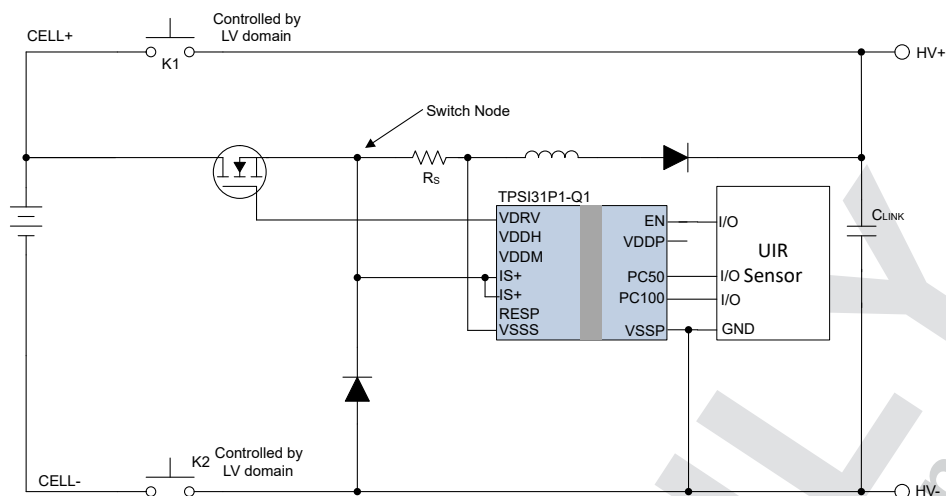


Figure 1-3. TPSI31P1-Q1 Application Schematic

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.

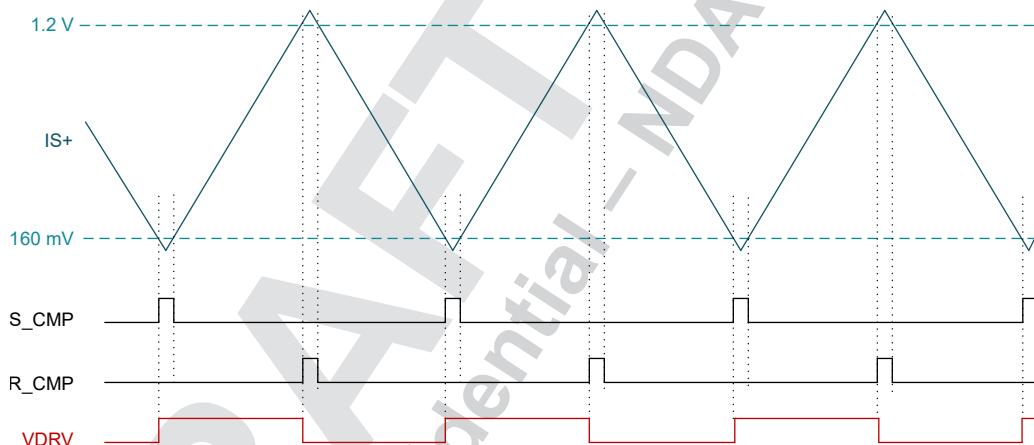


Figure 1-4. TPSI31P1-Q1 Behavior Diagram

2 Hardware

2.1 Additional Images

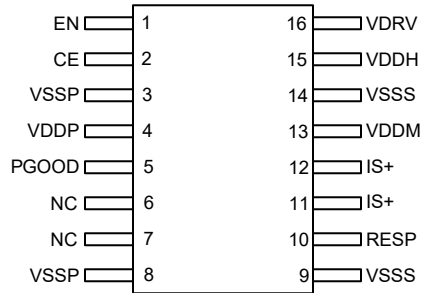


Figure 2-1. TPSI31P1-Q1 DVX Package 16-Pin SSOP (Top View)

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
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

DRAFT

TI Confidential – NDA Restriction

3 Implementation Results

3.1 Evaluation Setup

Equation 1 shows how to select a shunt resistor based on the desired charging current. A 68mΩ shunt resistor targets 10A_{AVG} charging current. A 150mΩ shunt resistor targets 4.5A_{AVG} charging current. The charging current behavior is shown in Figure 3-1.

$$I_{PEAK} = \frac{1.2 V}{R_{SHUNT}} \tag{1}$$

$$I_{MIN} = \frac{0.160 V}{R_{SHUNT}}$$

$$I_{AVG} = \frac{I_{PEAK} + I_{MIN}}{2}$$

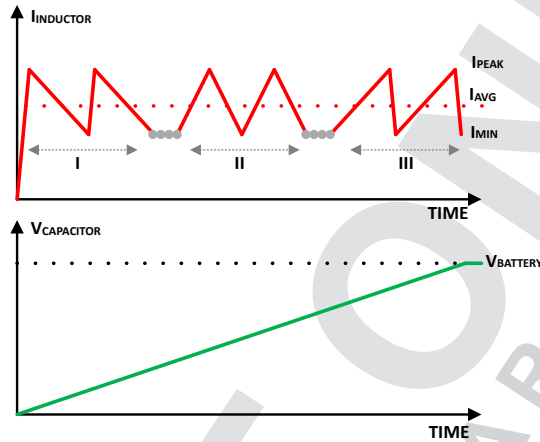


Figure 3-1. Active Precharge Profile

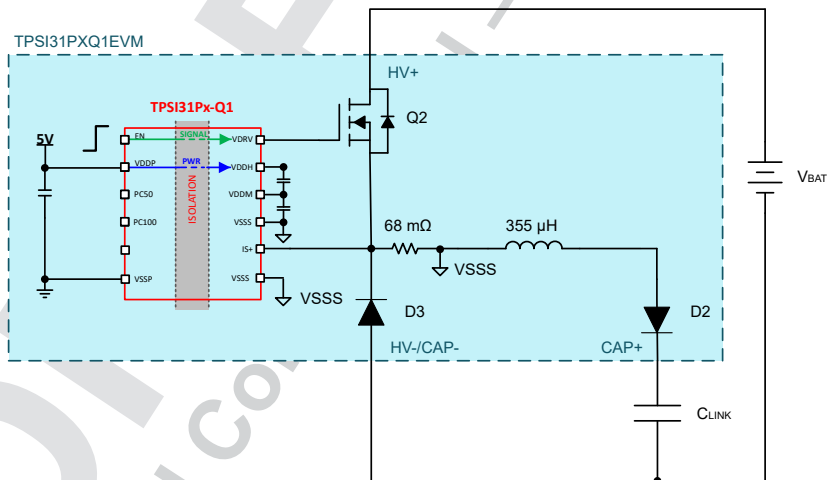


Figure 3-2. TPSI31PXQ1EVM Setup Diagram

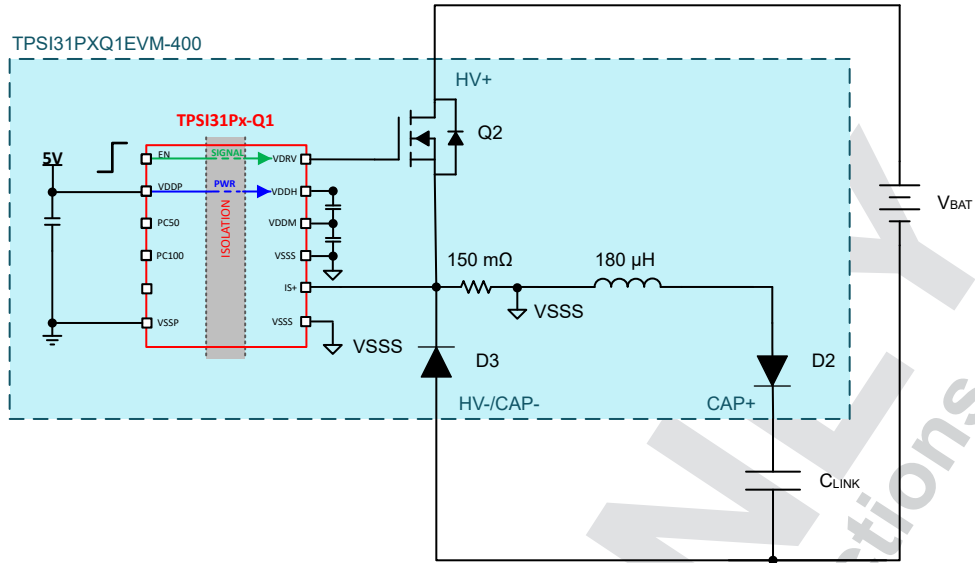


Figure 3-3. TPSI31PXQ1EVM-400 Setup Diagram

3.2 Performance Data and Results

The following waveforms shows the TPSI31PXQ1EVM and TPSI31PXQ1EVM-400 charging a 2mF capacitor to 800V and 400V within 170ms and 180ms, respectively.

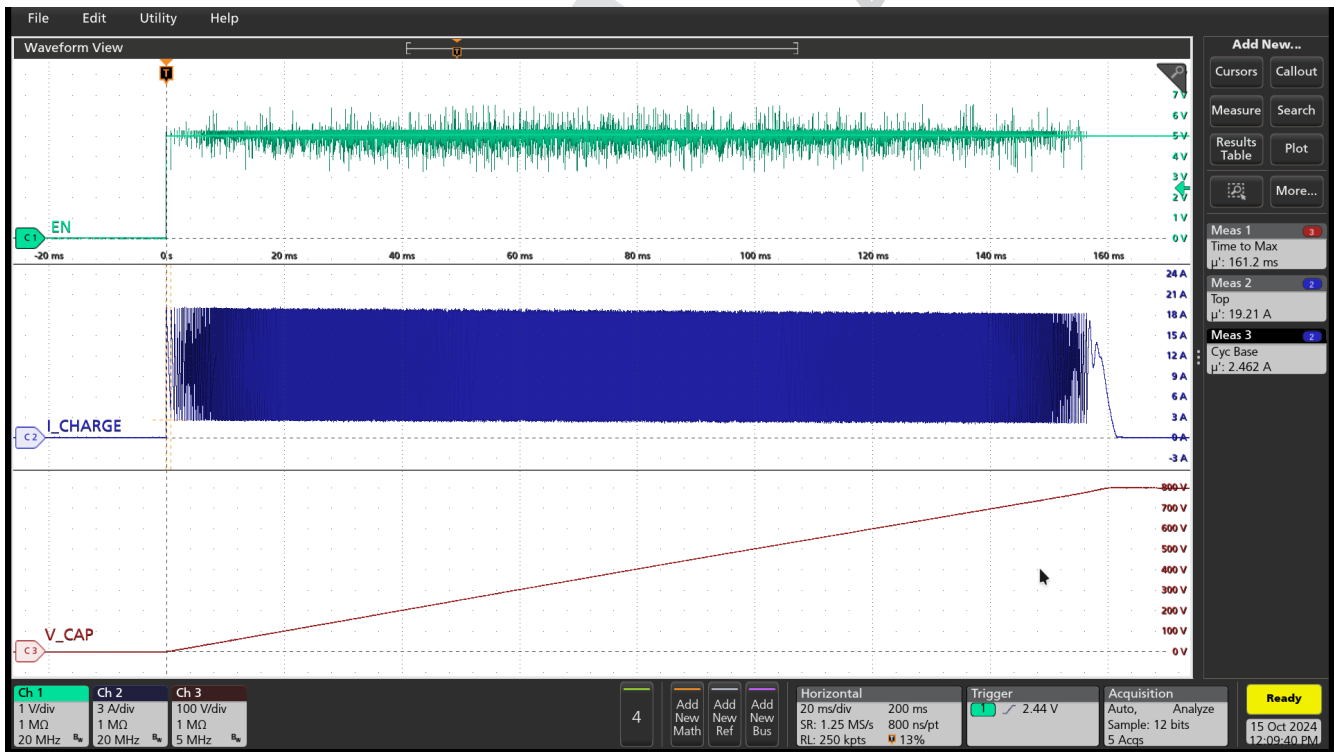


Figure 3-4. 2mF to 800V in 170ms (TPSI31PXQ1EVM)

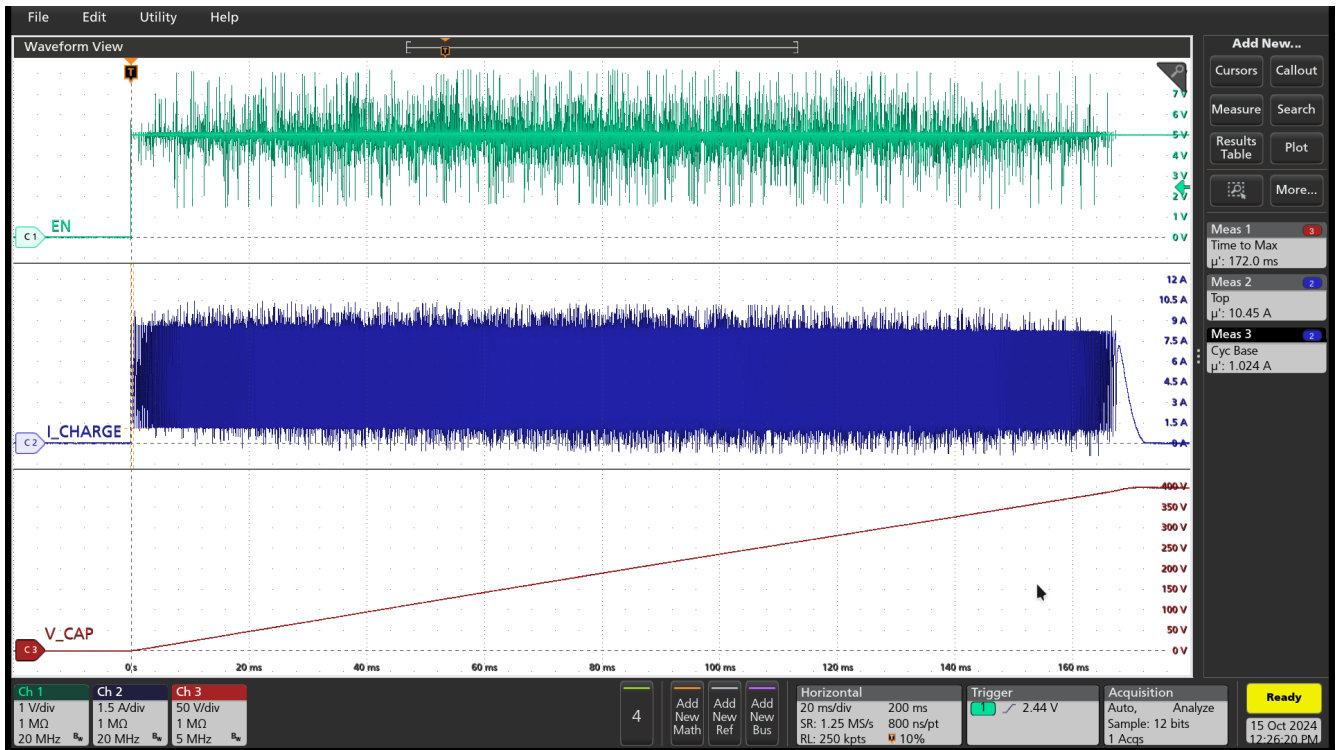


Figure 3-5. 2mF to 400V in 180ms (TPSI31PXQ1EVM-400)

DRAFT
 TI Confidential - NDA Required

4 Hardware Design Files

4.1 Schematics

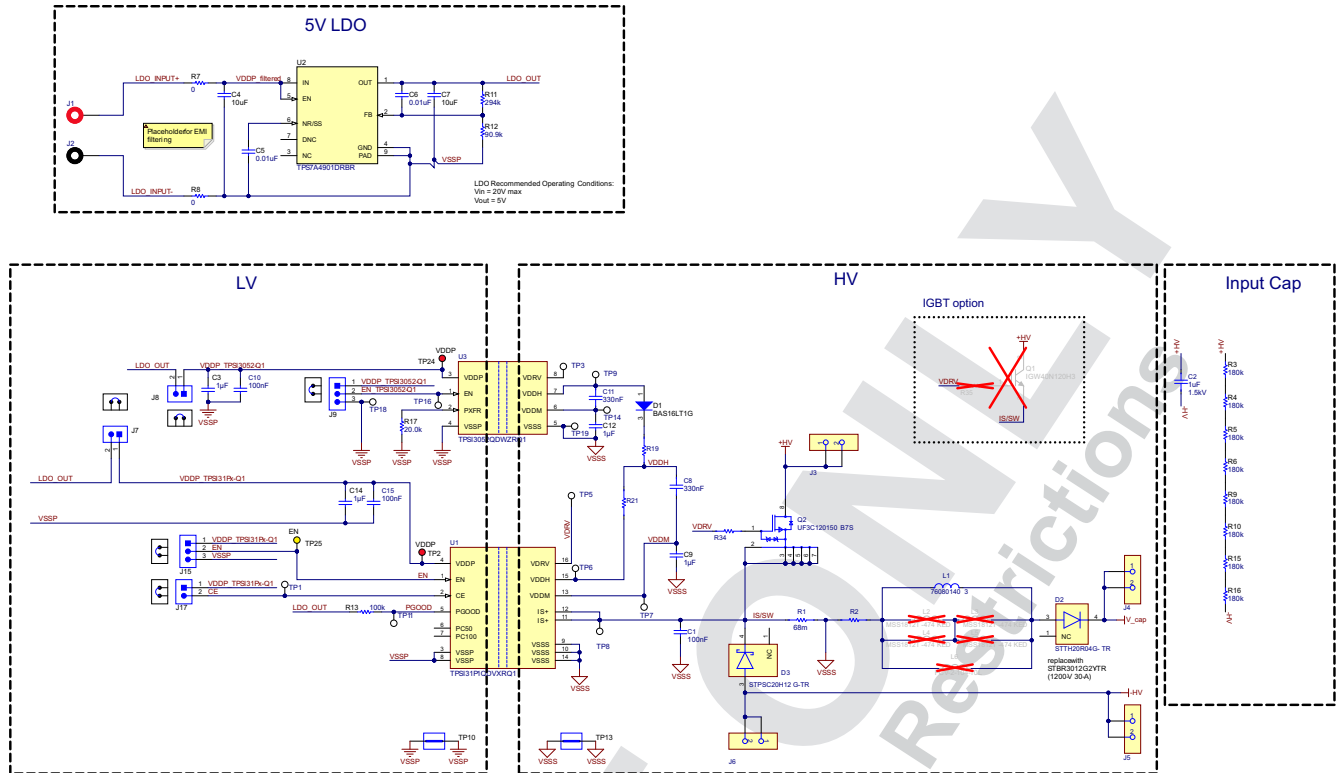


Figure 4-1. TPSI31PXQ1EVM Schematic

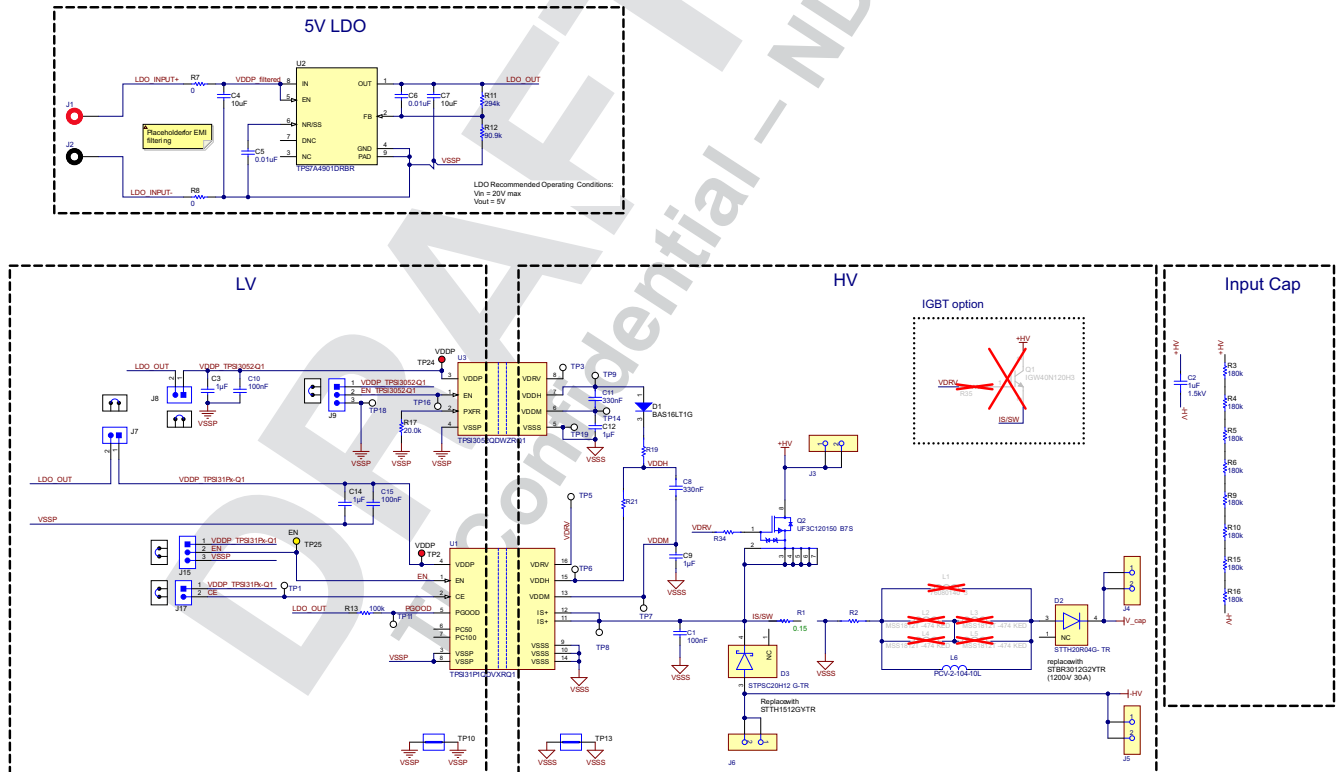


Figure 4-2. TPSI31PXQ1EVM-400 Schematic

4.2 PCB Layouts

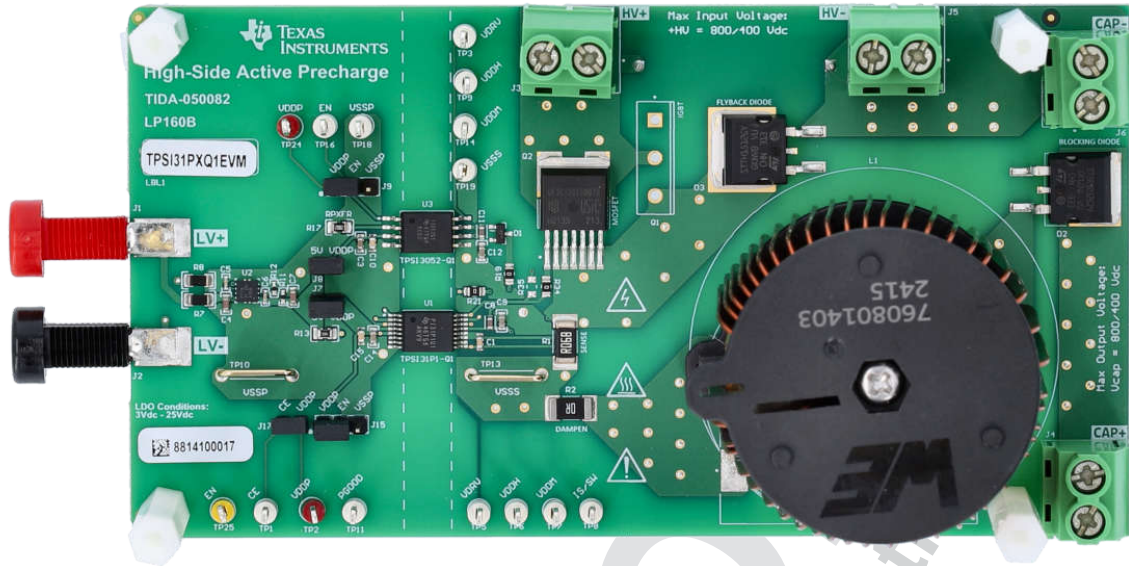


Figure 4-3. 3D (Top View)

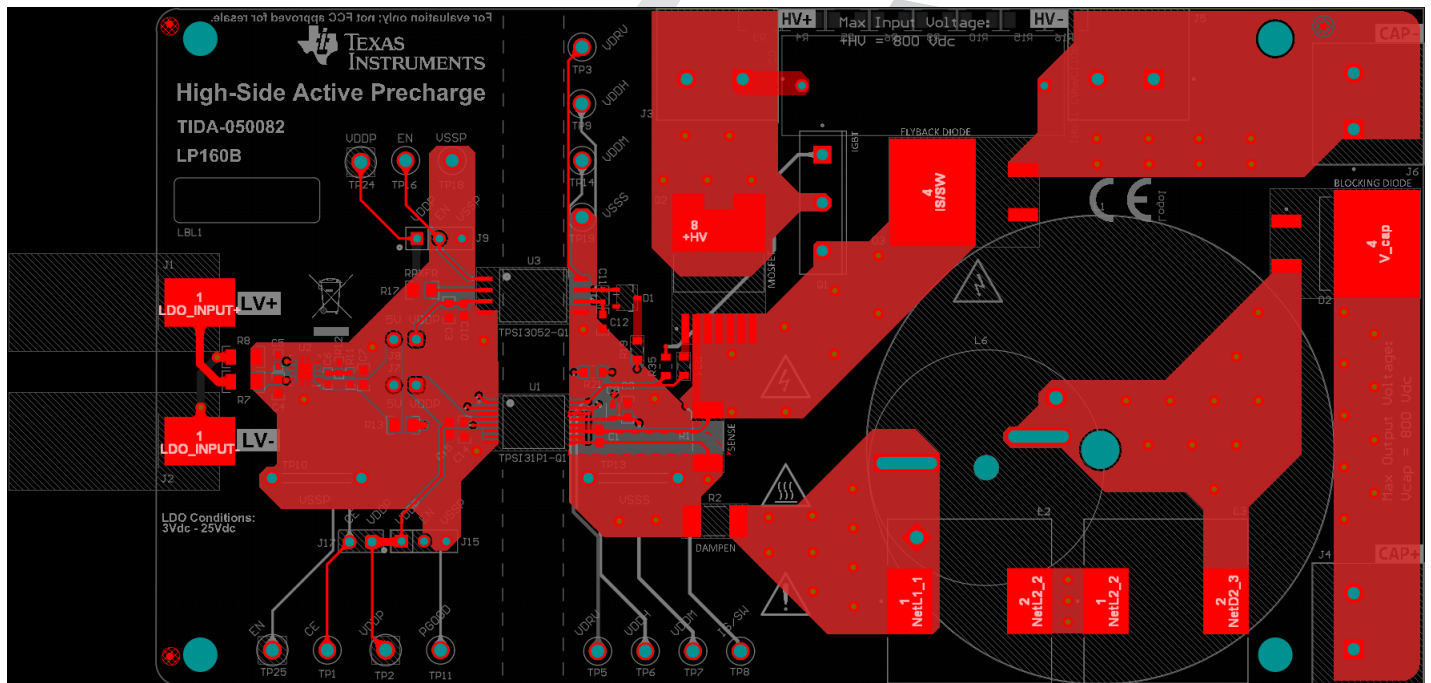


Figure 4-4. PCB Top Layer

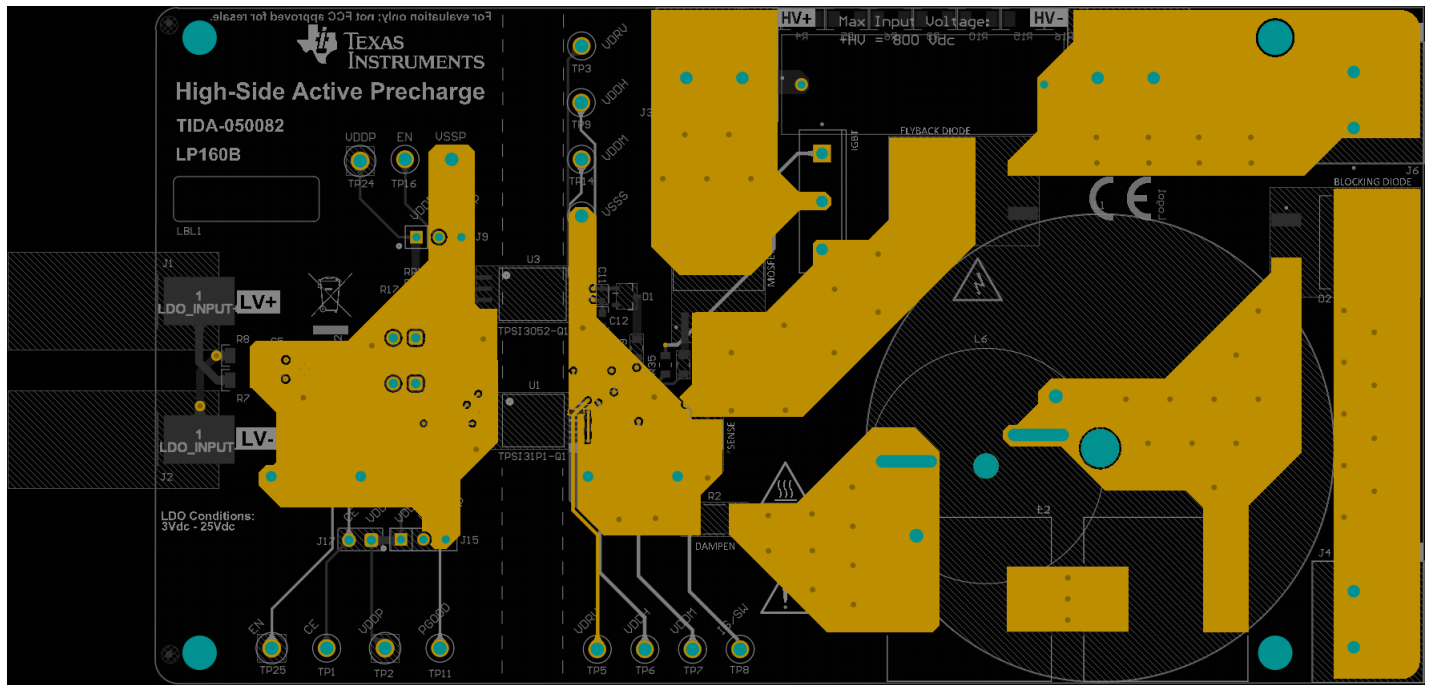


Figure 4-5. PCB Internal Layer 1

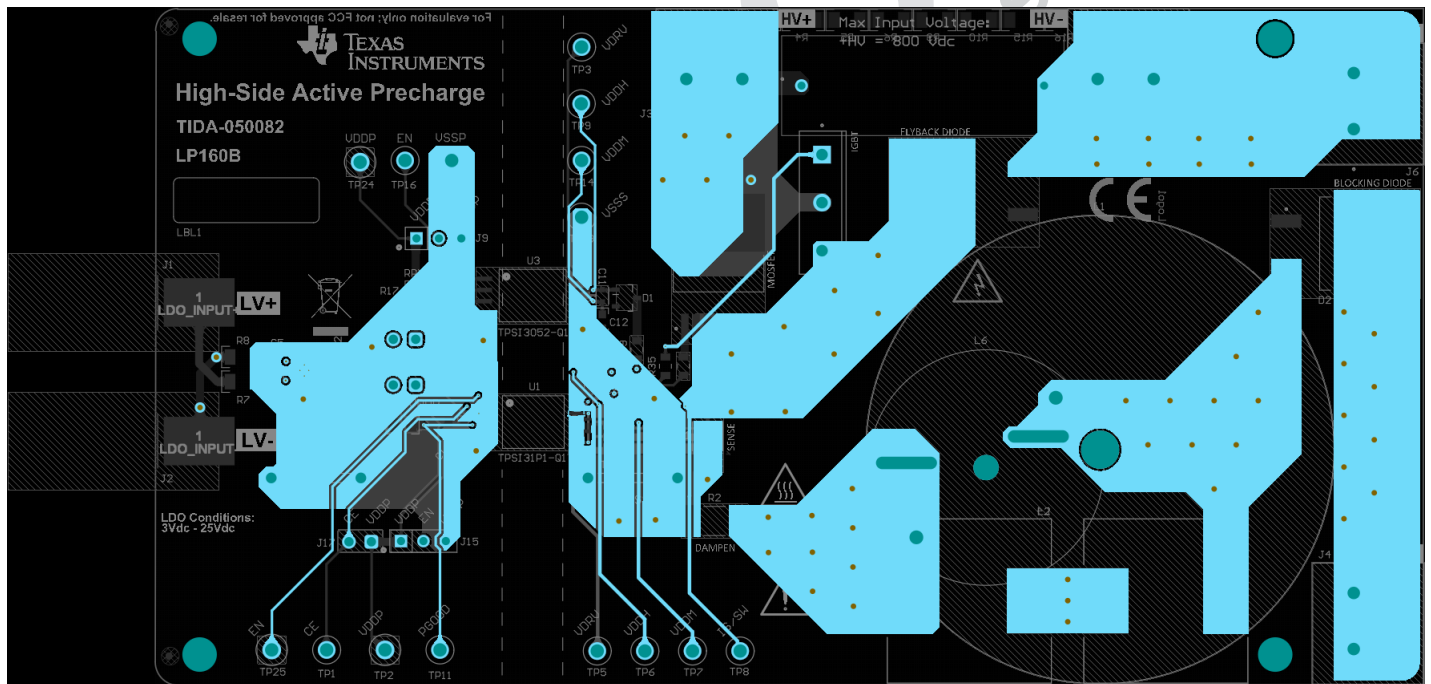


Figure 4-6. PCB Internal Layer 2

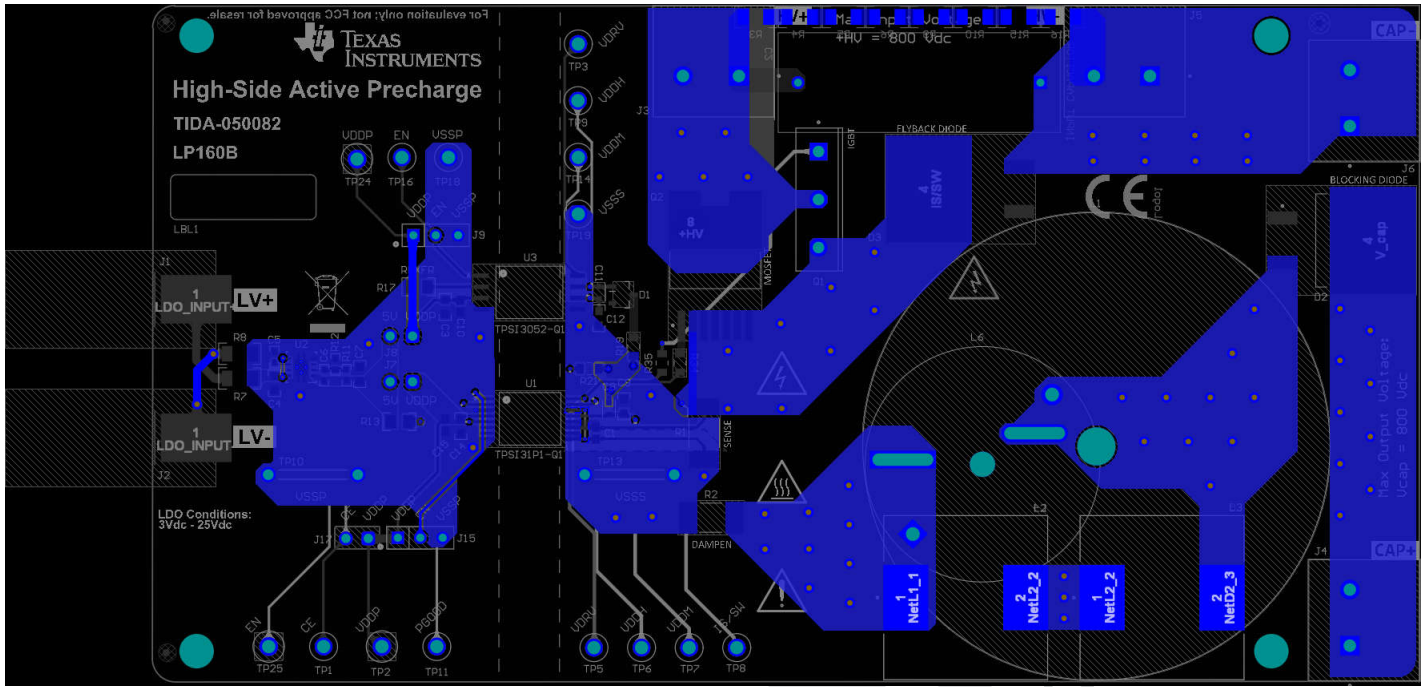


Figure 4-7. PCB Bottom Layer

DRAFT
 TI Confidential - NDA Restriction

4.3 Bill of Materials (BOM)

Table 4-1. 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	1 μF Film Capacitor 1500V (1.5kV) Polypropylene (PP), Metallized Radial	RADIAL	C4AQSBU4100A1WJ	KEMET
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		Diode 1200 V 30A Surface Mount D2PAK HV	D2PAK	STBR3012G2Y-TR	STMicroelectronics
D3	1		DIODE GEN PURP 1.2KV 15A D2PAK	D2PAK	STTH1512GY-TR	STMicroelectronics
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 4-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

J9, J15	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
L1	1	355uH	355 μ H Unshielded Toroidal Inductor 12.3 A 35mOhm Max Nonstandard Flat Wire	PTH2	760801403	Würth Electronics
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 1200 V 17A (Tc) 136W (Tc) Surface Mount D2PAK-7	D2PAK7	UF3C120150B7S	UnitedSiC
R1	1	68m	68 mOhms \pm 1% 3W Chip Resistor 2512 (6432 Metric) Anti-Sulfur, Automotive AEC-Q200, Current Sense Metal Element	2512	TLRP3A30DR068FTE	TE Connectivity
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 4-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

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	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
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
L2, L3, L4, L5	0	470uH	Shielded Power Inductor 470uH ±10% 2.1A 0.23Ohms	SMD2	MSS1812T-474KED	Coilcraft

Table 4-1. Bill of Materials (TPSI31PXQ1EVM) (continued)

L6	0	100uH	Power Inductors - Leaded 100uH UnShld 10% 10.1A 32mOhms	RADIAL	PCV-2-104-10L	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 4-2. Bill of Materials (TPSI31PXQ1EVM-400)

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

Table 4-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

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
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 ±1% 2W Chip Resistor 2512 (6432 Metric) Automotive AEC-Q200, Current Sense Thick Film	2512	CSRN2512FKR150	Stackpole Electronics Inc
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

Table 4-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

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
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

Table 4-2. Bill of Materials (TPSI31PXQ1EVM-400) (continued)

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
L2, L3, L4, L5	0	470uH	Shielded Power Inductor 470 μ H \pm 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

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

6 Revision History

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

Changes from Revision * (August 2024) to Revision A (December 2024)	Page
--	-------------

DRAFT ONLY
TI Confidential – NDA Restrictions

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Copyright © 2024, Texas Instruments Incorporated

DRAFT
TI Confidential – NDA Restrictions