EVM User's Guide: TPSI31PXQ1EVM

TPSI31Px-Q1 Evaluation Module

Description

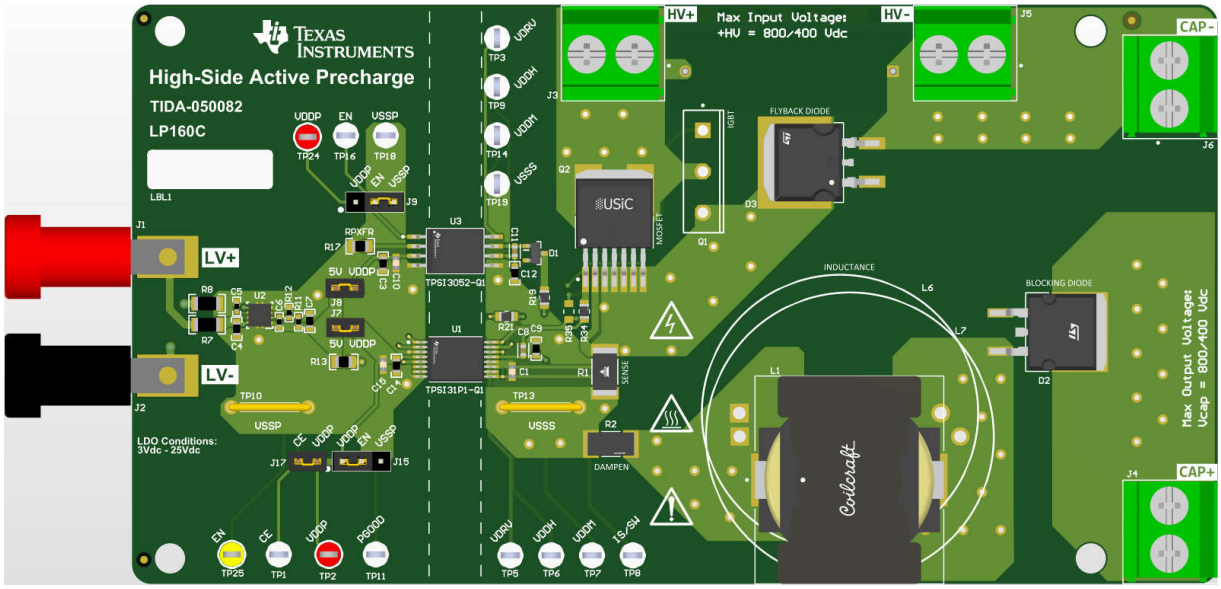
The TPSI31Px-Q1 evaluation module (EVM) helps designers evaluate the operation and performance of the TPSI31Px-Q1 device family. The board features the TPSI31P1-Q1, an isolated switch driver with integrated 17V gate supply and comparators to monitor charging current and hysteretically drive the gate, 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 ±1.5%

Applications

- Hybrid, electric, and powertrain systems



PCB Top View: TPSI31PXQ1EVM

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

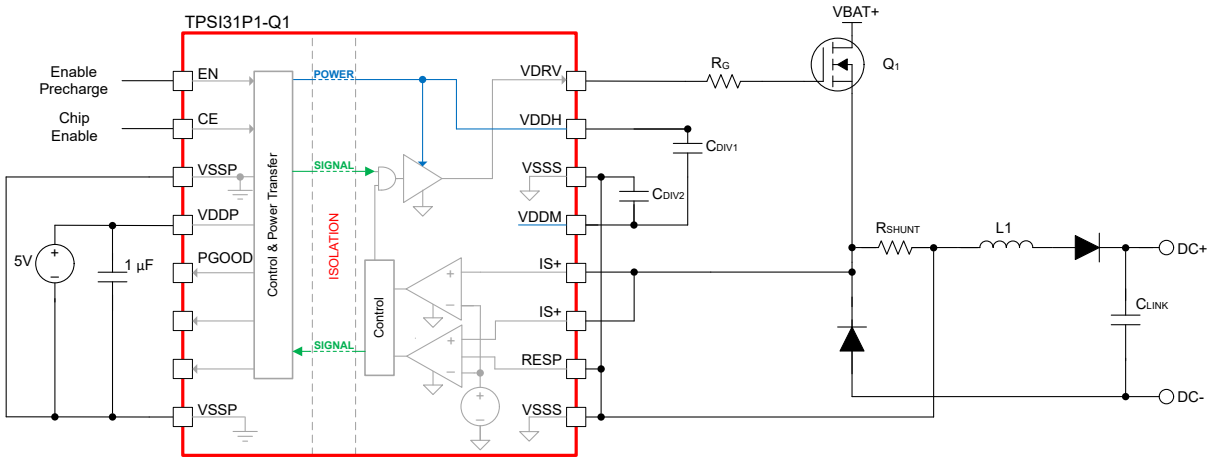


Figure 1-1. TPSI31P1-Q1 Simplified Schematic

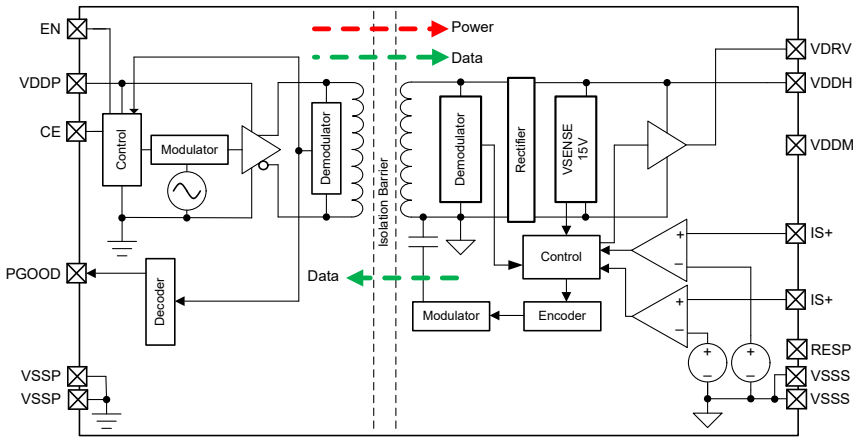


Figure 1-2. TPSI31P1-Q1 Functional Block Diagram

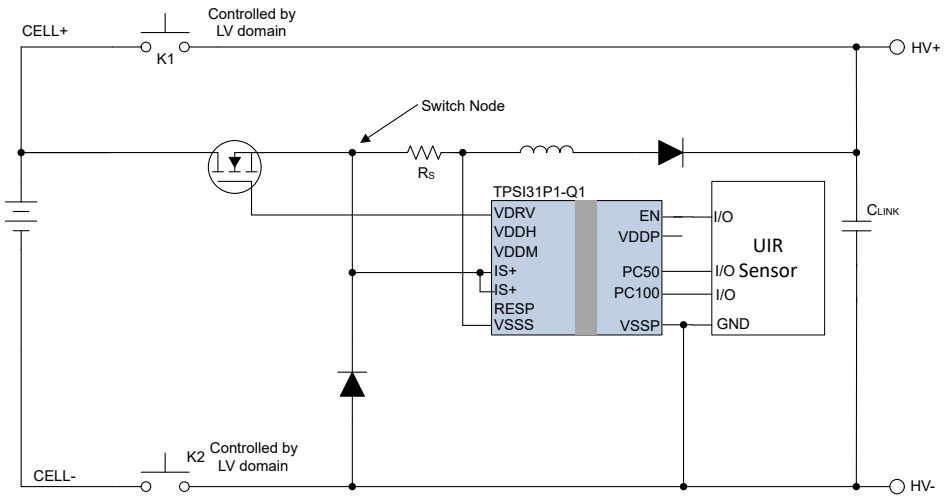


Figure 1-3. TPSI31P1-Q1 Application Schematic

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.

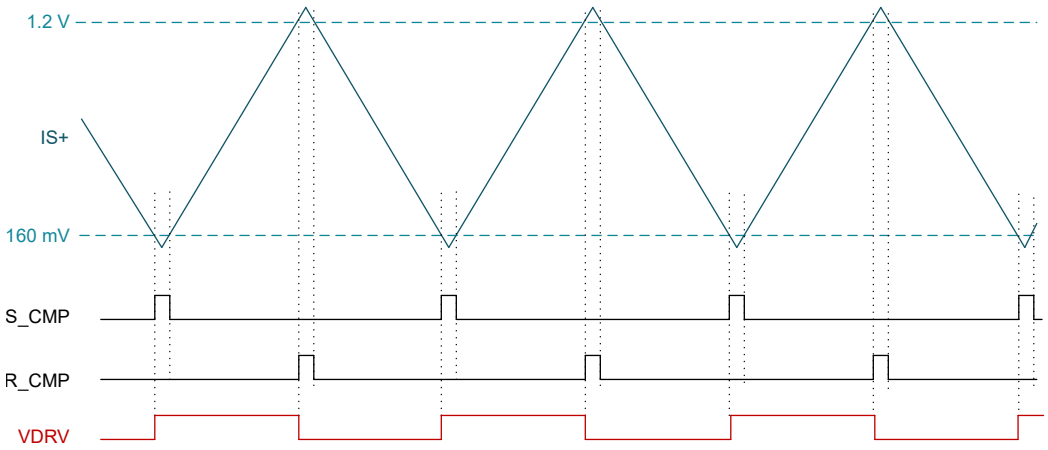


Figure 1-4. TPSI31P1-Q1 Behavior Diagram

2 Hardware

2.1 Additional Images

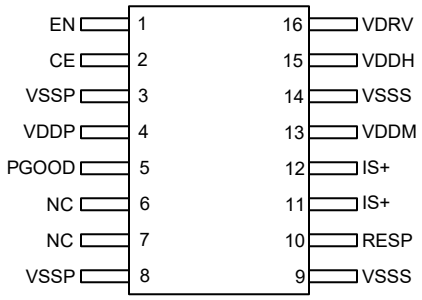


Figure 2-1. TPSI31P1-Q1 DVX Package 16-Pin SSOP (Top View)

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
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.

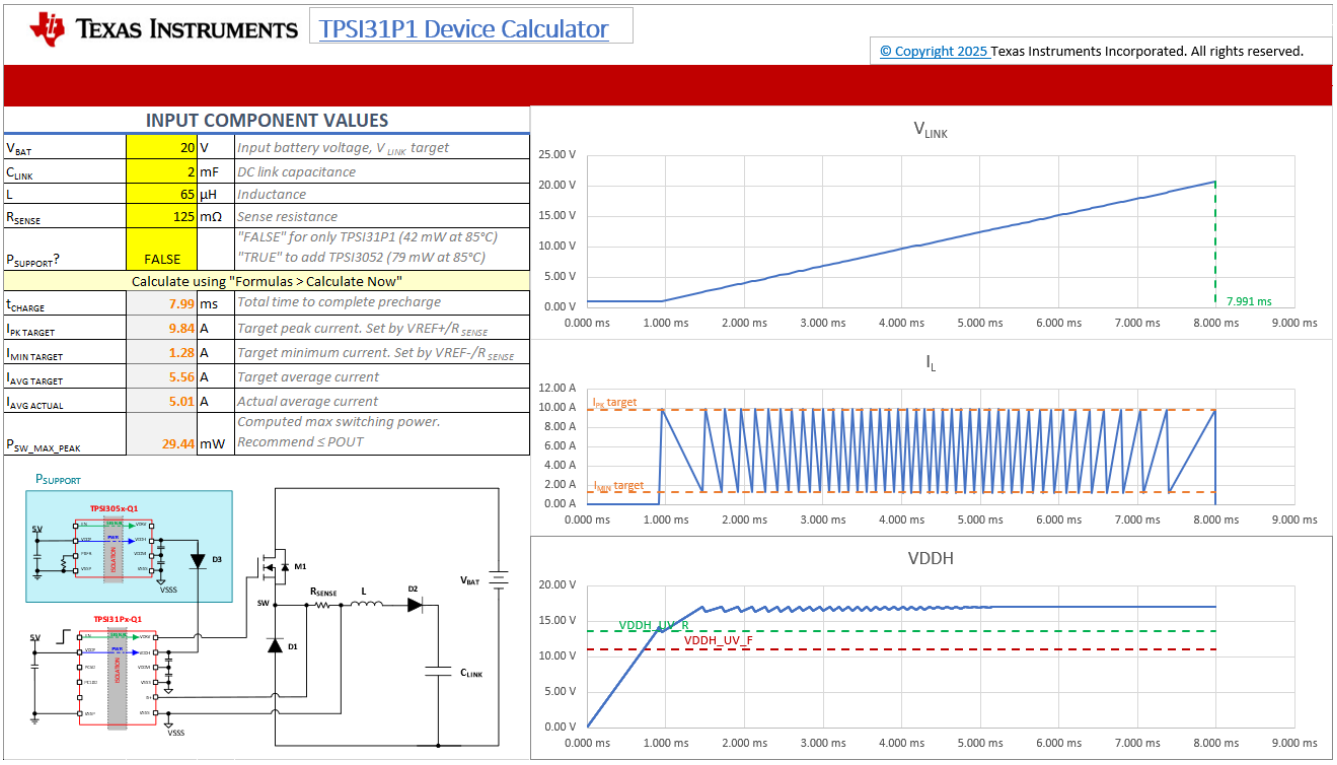


Figure 3-1. TPSI31P1 Device Calculator Example 1, VDDH Not Hitting UVLO

A. 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.

B. 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.

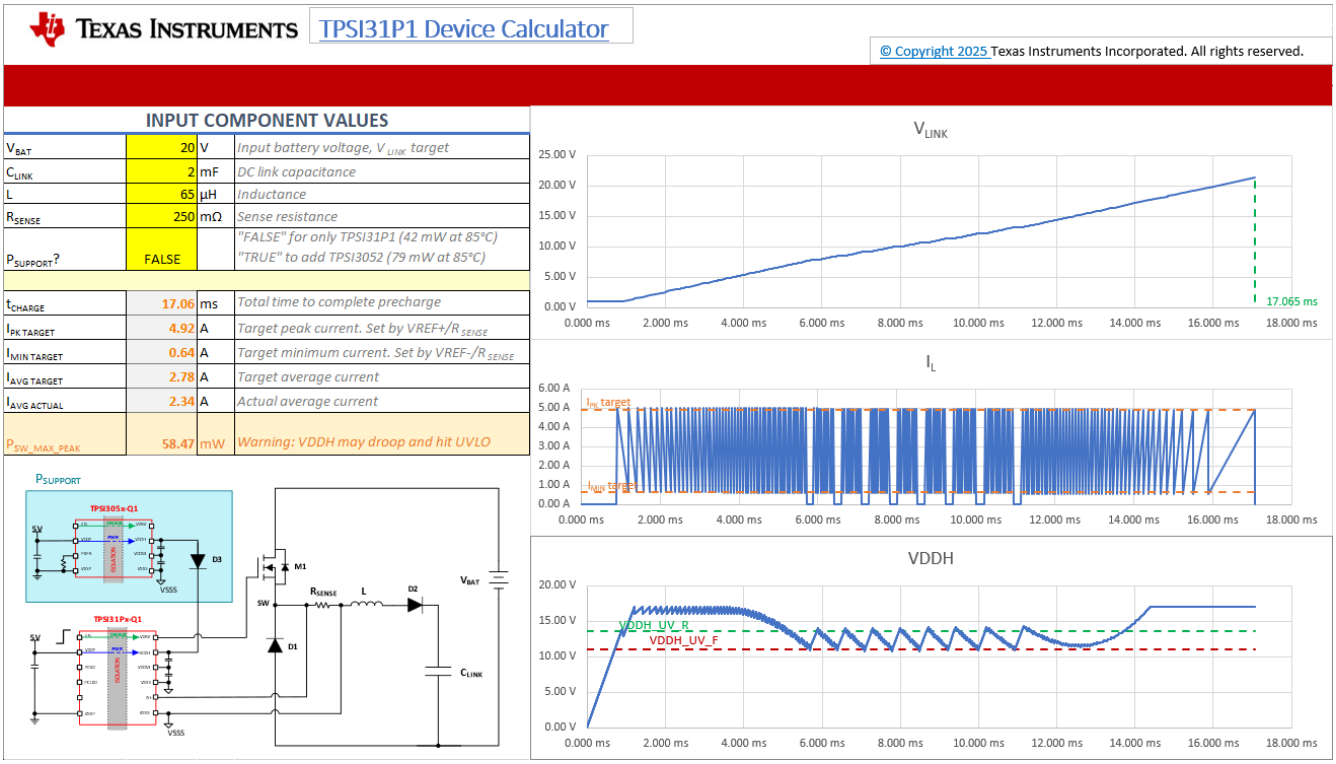


Figure 3-2. TPSI31P1 Device Calculator Example 2, VDDH Hitting UVLO

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.

$$I_{PEAK} = \frac{1.2\ V}{R_{SHUNT}} \quad (1)$$

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

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

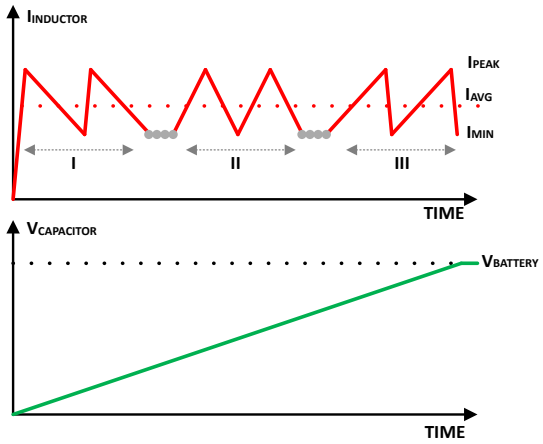


Figure 4-1. Active Precharge Profile

4.2 Performance Data and Results

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

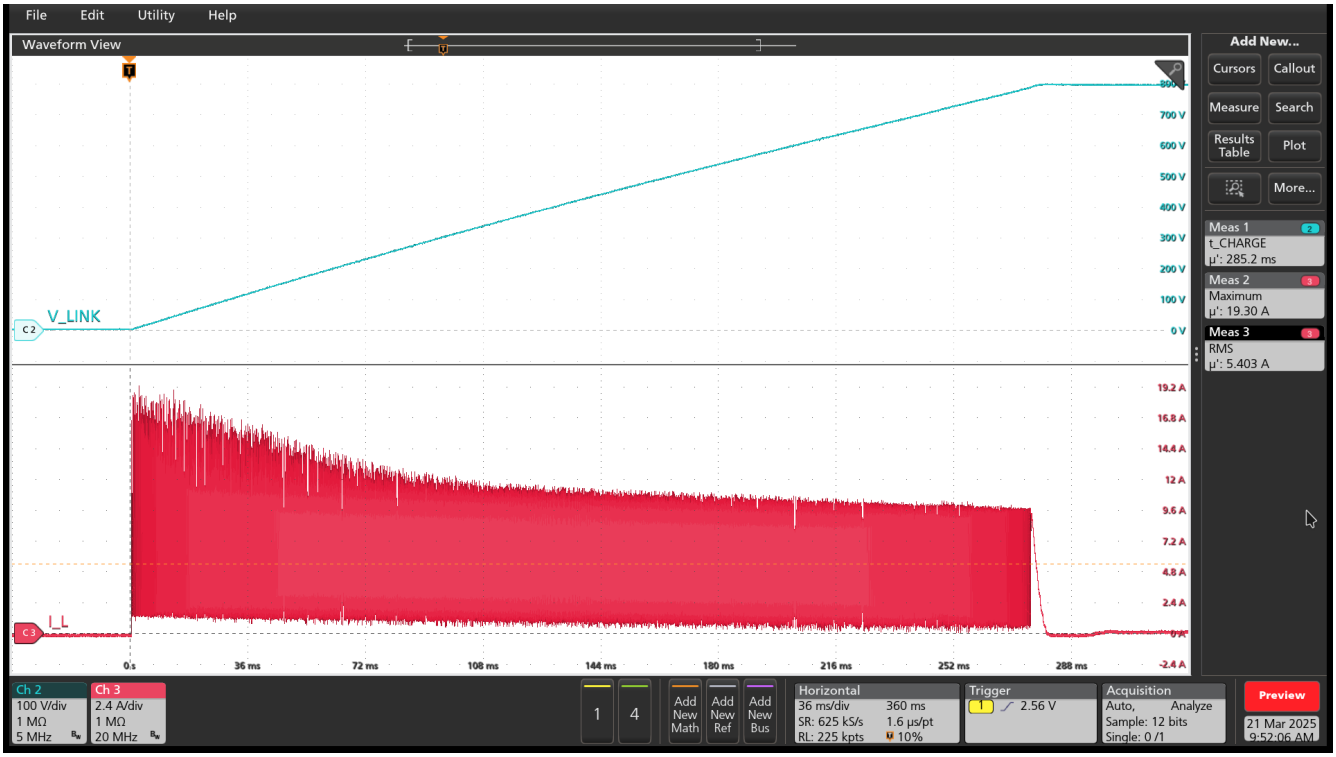


Figure 4-2. 2mF to 800V in 290ms (TPSI31PXQ1EVM)

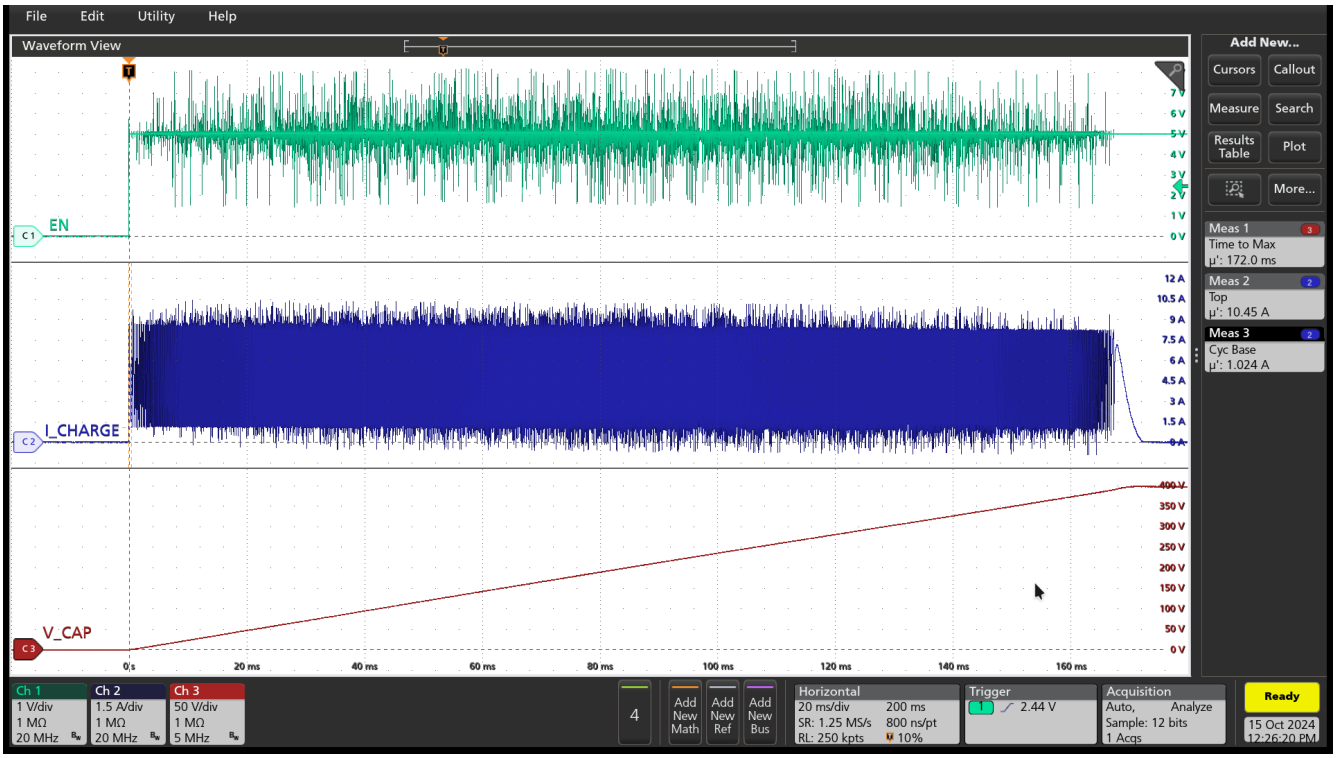


Figure 4-3. 2mF to 400V in 180ms (TPSI31PXQ1EVM-400)

5 Hardware Design Files

5.1 Schematics

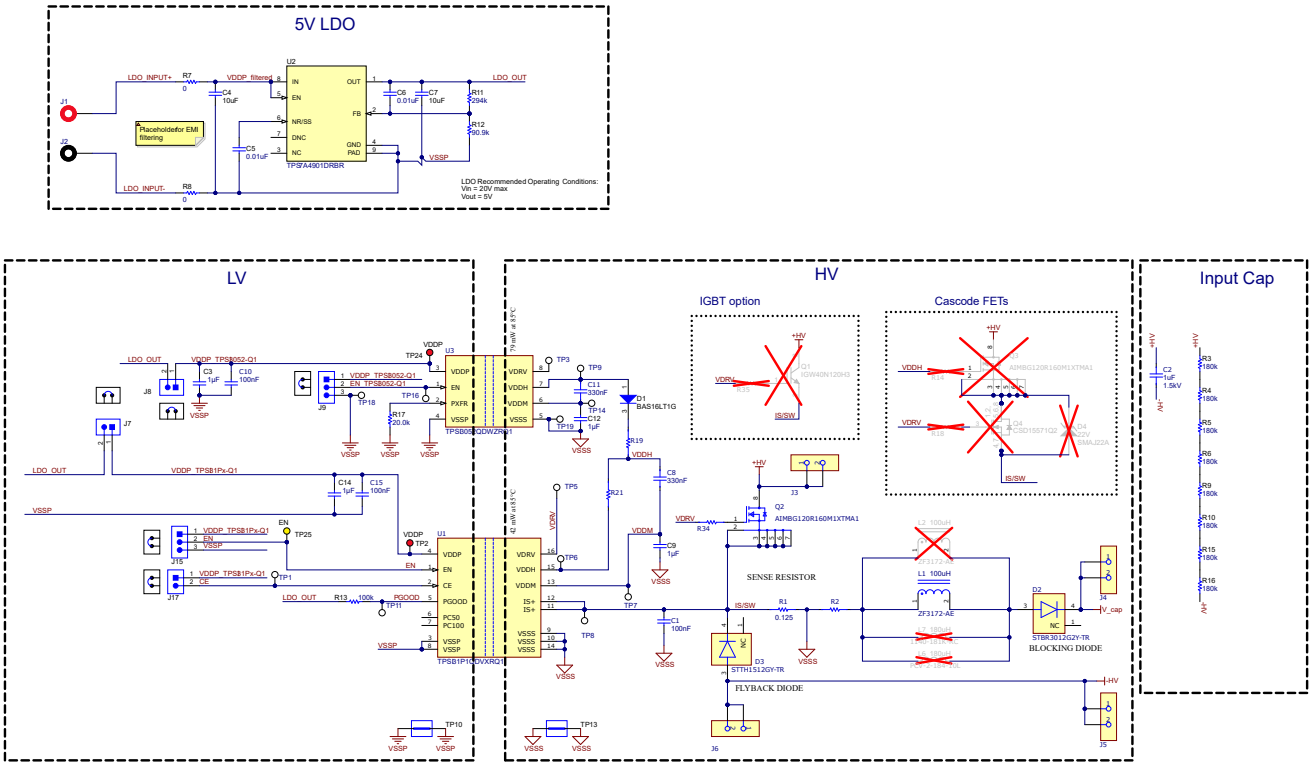


Figure 5-1. TPSI31PXQ1EVM Schematic

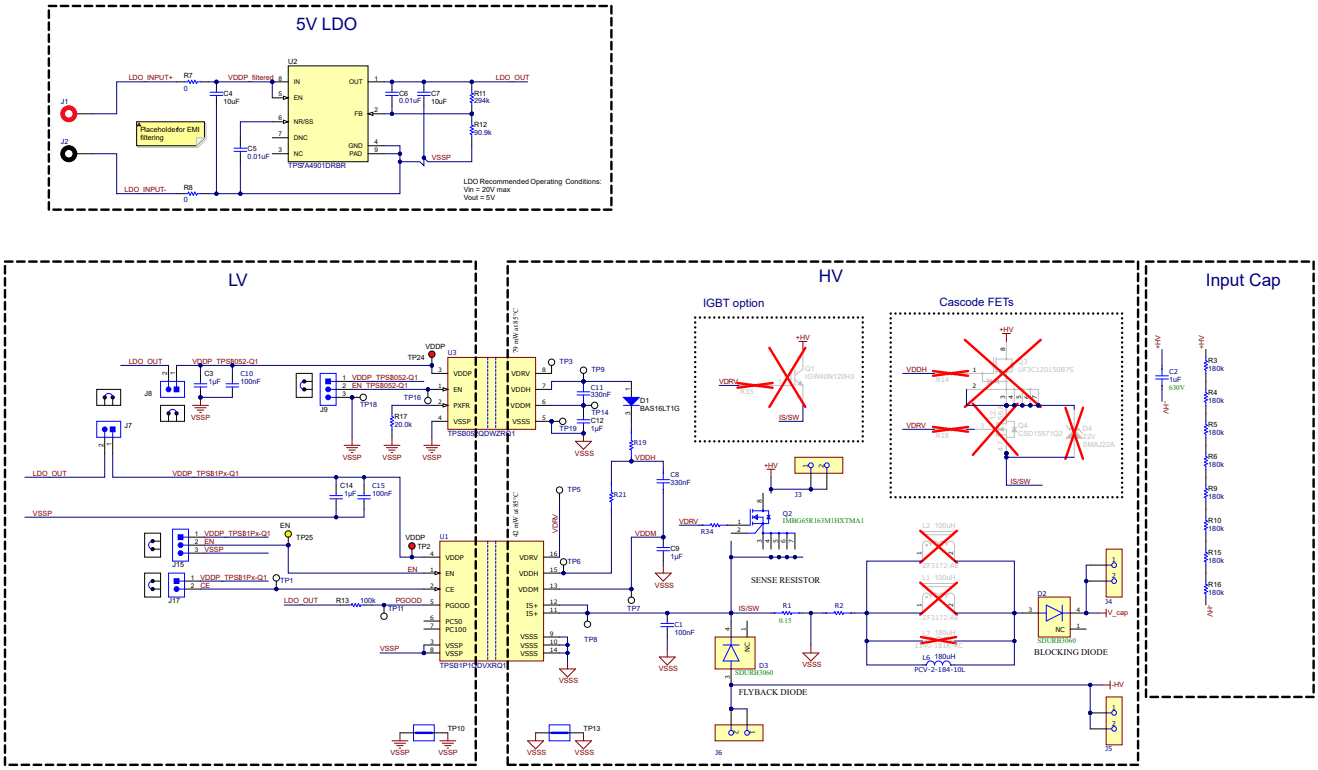


Figure 5-2. TPSI31PXQ1EVM-400 Schematic

5.2 PCB Layouts

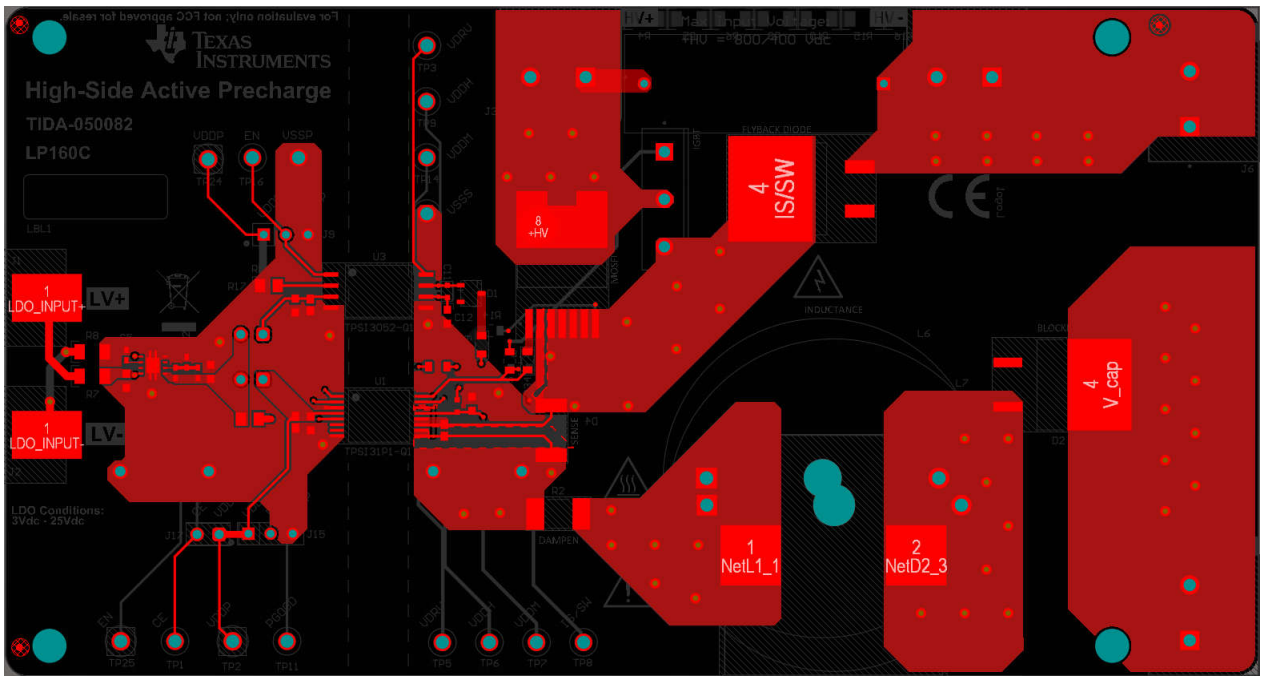


Figure 5-3. PCB Top Layer

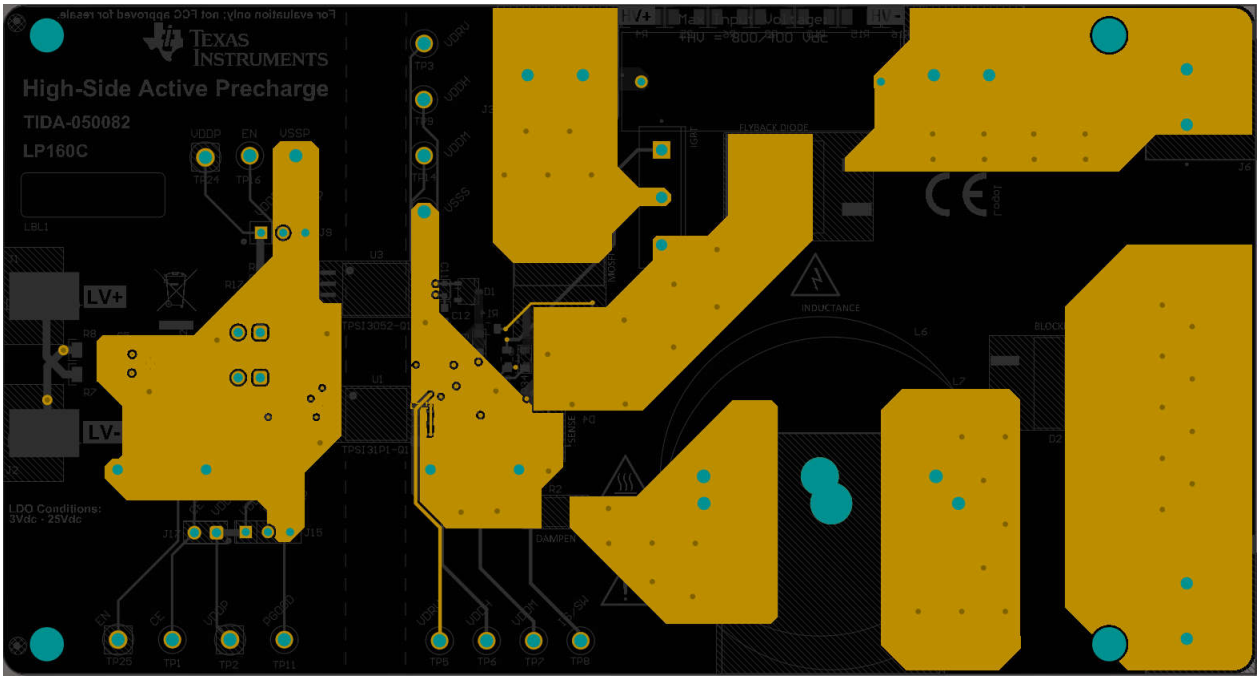


Figure 5-4. PCB Internal Layer 1

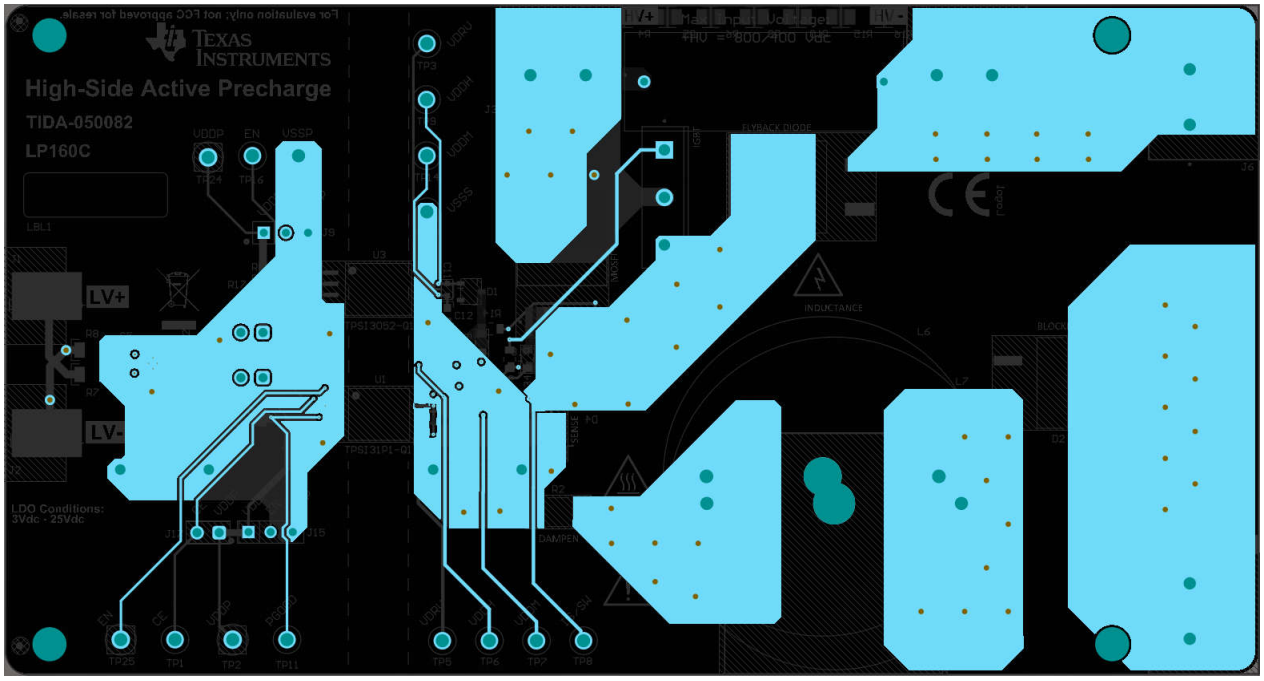


Figure 5-5. PCB Internal Layer 2

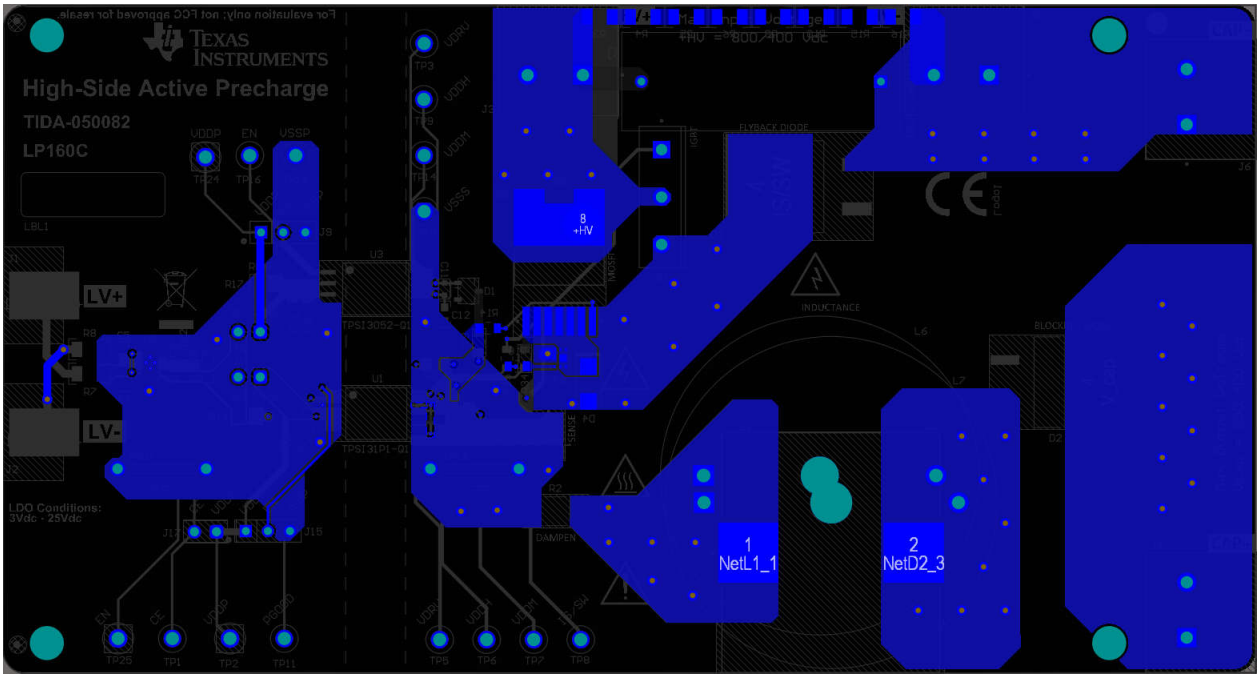


Figure 5-6. PCB Bottom Layer

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	Wurth Electronics
J7, J8, J17	3		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth 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 ±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
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 µH Unshielded Toroidal Inductor 12.3 A 35mOhm Max Nonstandard Flat Wire	PTH2	760801403	Wurth 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 470µH ±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	1µF	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	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	CGA3E3X7R1E334K080AB	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_BLOCK2	6.91251E+11	Wurth Electronics		
J7, J8, J17	3		Header, 2.54 mm, 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		
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_THRD_4-40	14HTSP019	Essentra Components		
Q2	1		MOSFET N-Channel 650 V 17A (Tc) 85W (Tc) Surface Mount PG-TO263-7-12	D2PAK-7	IMBG65R163M1HXTMA1	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	CRCW1206180KJNEA	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 (WSON-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 *Software* 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

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