EVM User's Guide: TPS7H4011QEVM-CVAL

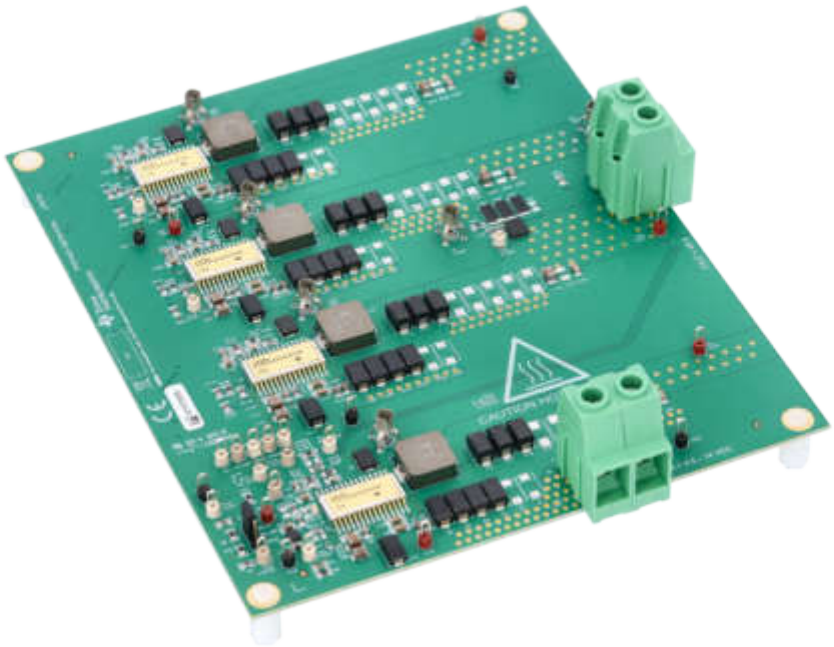
TPS7H4011QEVM-CVAL Evaluation Module

Description

The TPS7H4011QEVM-CVAL demonstrates the parallel, quadrature phase operation of four TPS7H4011-SP buck converters (ceramic package). The EVM provides footprints that can be populated with additional components to allow for testing of customized configurations, as well as test points for easy device configuration, performance validation, and analysis.

Features

- Four-channel operation for up to 48A output current
- Input voltage range from 4.5V to 14V
- Selectable switching frequency
- High-current transient test circuit
- 0.6V ±0.67% voltage reference over line, temperature, and radiation



TPS7H4011QEVM-CVAL

1 Evaluation Module Overview

1.1 Introduction

The TPS7H4011QEVM-CVAL is the four channel version of the Evaluation Module (EVM) for the ceramic package option of the TPS7H4011 and provides a platform to evaluate multi-channel performance. The four-channel configuration provided by this EVM can source up to 48A of load current to a single output. This user's guide provides details about the EVM, including the configuration, schematics, and BOM. The EVM is designed to provide flexibility in configuring the device under different conditions. Footprints for additional components and multiple connection options for monitoring device pins are provided. To configure the devices in a custom configuration, please refer to the TPS7H4011-SP and TPS7H4011-SEP 4.5V to 14V Input 12A Radiation Hardened Synchronous Buck Converter data sheet to calculate values of any passives that need to be changed.

1.2 Kit Contents

- TPS7H4011QEVM-CVAL Board (1)

1.3 Specification

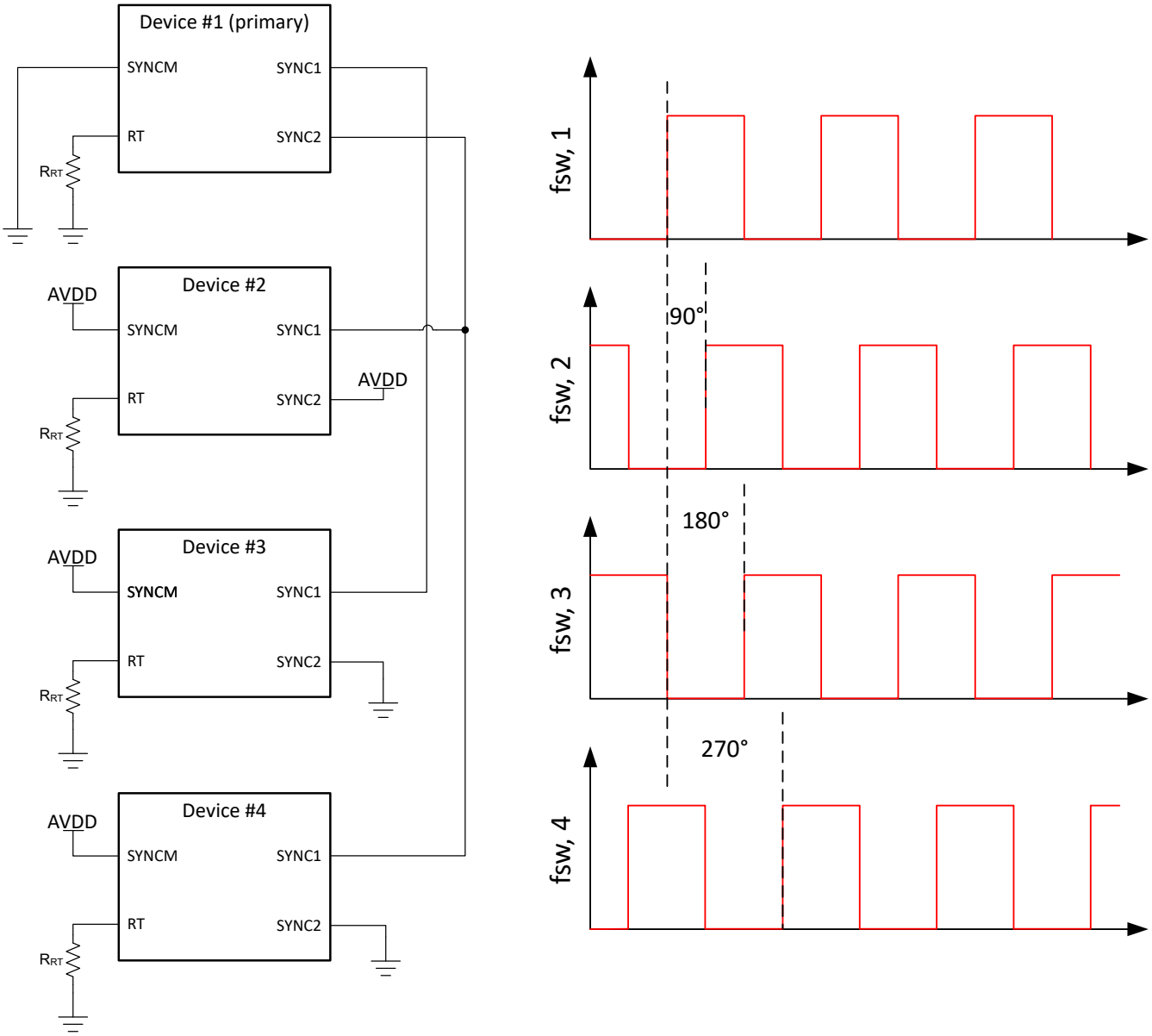


Figure 1-1. Simplified Schematic

Table 1-1. Default Configuration Options

SPECIFICATION	VALUE	DESCRIPTION
Input voltage, VIN	12V	Falls within the recommended device input voltage range of 4.5V to 14V.
Output voltage, VOUT	1.8V	Common voltage within the device output capability. Configurable by changing R26 or R27.
Slope compensation resistor, RSC	787kΩ	Configurable by changing R13.
Switching frequency, FSW	200kHz or 500kHz	Configurable using a jumper on the EVM.
Current limit, ILIM	18.3A per channel	Configured at maximum current limit.

1.4 Device Information

The TPS7H4011 is a 14V, 12A synchronous buck converter optimized for use in a space environment. High efficiency and reduced component count are achieved through peak current mode control. The wide voltage range of the TPS7H4011 enables the device to be used as a point of load regulator to convert directly from a 12V rail. Additionally, various features are included such as differential remote sensing, selectable current limit, a flexible fault input pin, and configurable compensation.

Further information about the TPS7H4011-SP can be found in the TPS7H4011-SP and TPS7H4011-SEP 4.5V to 14V Input 12A Radiation Hardened Synchronous Buck Converter data sheet.

2 Hardware

2.1 Transient Load Circuit

The TPS7H4011QEVM-CVAL provides a transient load circuit using a CSD16408Q5 N-Channel Power MOSFET, along with a 40mΩ load resistance created by 3, 120mΩ chip resistors connected in parallel. While the CSD16408Q5 power MOSFET is capable of conducting the full 48A output current of four TPS7H4011-SP devices, the chip resistors are each rated for only 2W. When utilizing the transient circuit on the TPS7H4011QEVM-CVAL, the signal sent to the MOSFET gate through TP20 (TRANS) can be modulated to keep the average power through the load resistors below the 2W rating.

For additional information on operation of the power MOSFET, please see the N Channel NexFET Power MOSFET data sheet.

2.2 Connector Descriptions

Table 2-1 provides connector descriptions for the TPS7H4011EVM-CVAL.

Table 2-1. Connector Descriptions

REFERENCE DESIGNATOR	FUNCTION	
J1	PVIN	Power input connector
J3	VOUT	Power output connector
J4	FSW_SEL	Jumper for mode selection
J8	VOUT	Compact probe tip connector
J9	TRANS	
J10	SW1	
J105	SW2	
J205	SW3	
J305	SW4	
TP1	PVIN	Test point
TP2	VIN	
TP3	AUX_5V	
TP4, TP5, TP6	VOUT	
TP7	FAULT	
TP8	EN	
TP10	VSNS+	
TP11	VSNS-	
TP12	SS_TR	
TP13	AVDD	
TP14	VCOMP	
TP15	PWRGD	
TP16	SYNC1	
TP17	SYNC2	
TP18	BODE_RXL	
TP19	BODE_INJ	
TP20	TRANS	
TP21, TP22, TP23, TP24, TP25, TP26, TP27	GND	

2.3 Best Practices

The following information is provided to convey best practices while operating this device.

WARNING

Hot surface! Contact can cause burns. Do not touch!

Some components can reach high temperatures > 55°C when the board is powered on. Do not touch the board at any point during operation or immediately after operating, as high temperatures can be present.

3 Implementation Results

Test results are shown in this section for the following:

1. Quadrature Switch Nodes
2. Output Voltage Ripple
3. Soft Start
4. Positive and Negative Load Steps
5. Loop Frequency Response
6. Board Efficiency
7. Current Sharing Equality

3.1 Evaluation Setup

The following tests were performed using the TPS7H4011QEVM-CVAL in the default configuration found in Table 3-1 unless otherwise noted.

Table 3-1. Test Settings

SPECIFICATION	VALUE
VIN	12V
VOUT	1.8V
FSW	500kHz
ILIM	18.3A
RSC	787kΩ

3.2 Switch Nodes

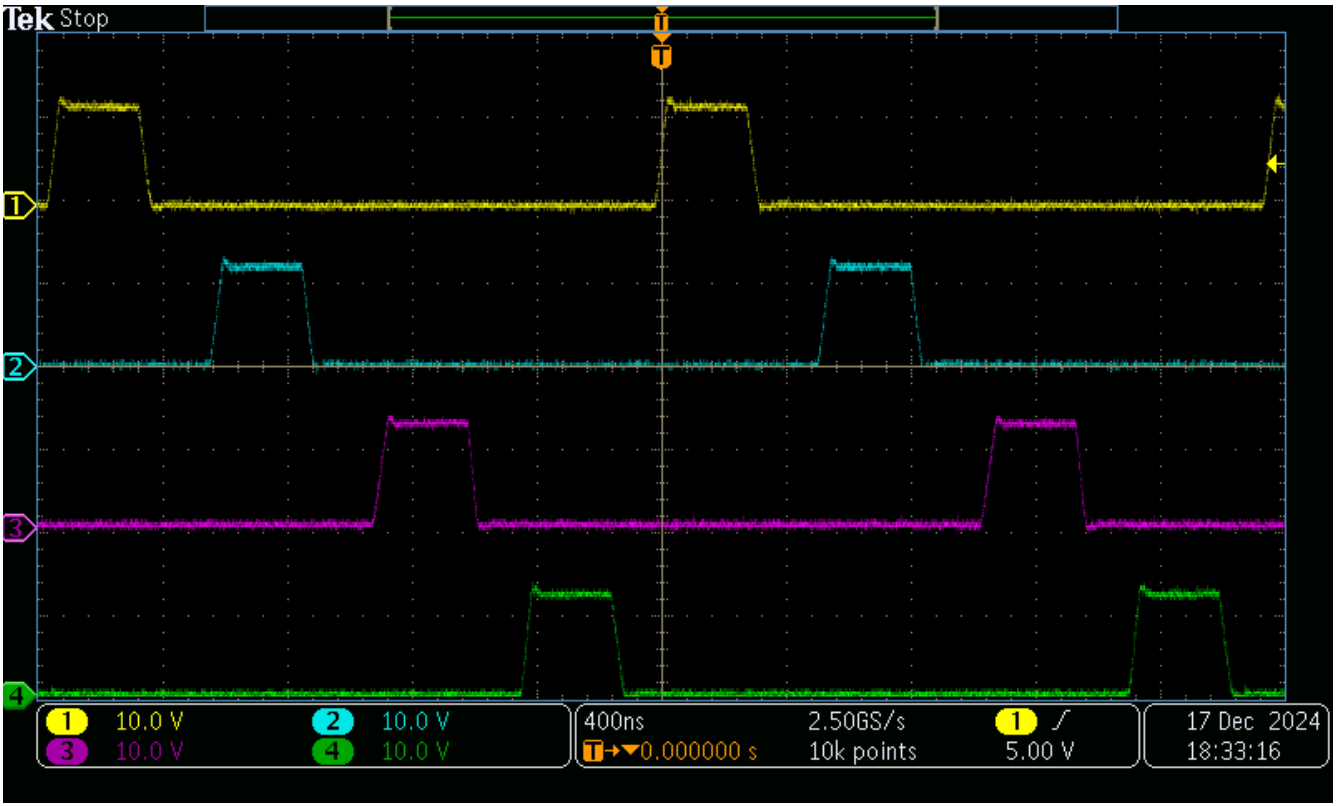


Figure 3-1. Quadrature Switch Nodes

3.3 Output Voltage Ripple

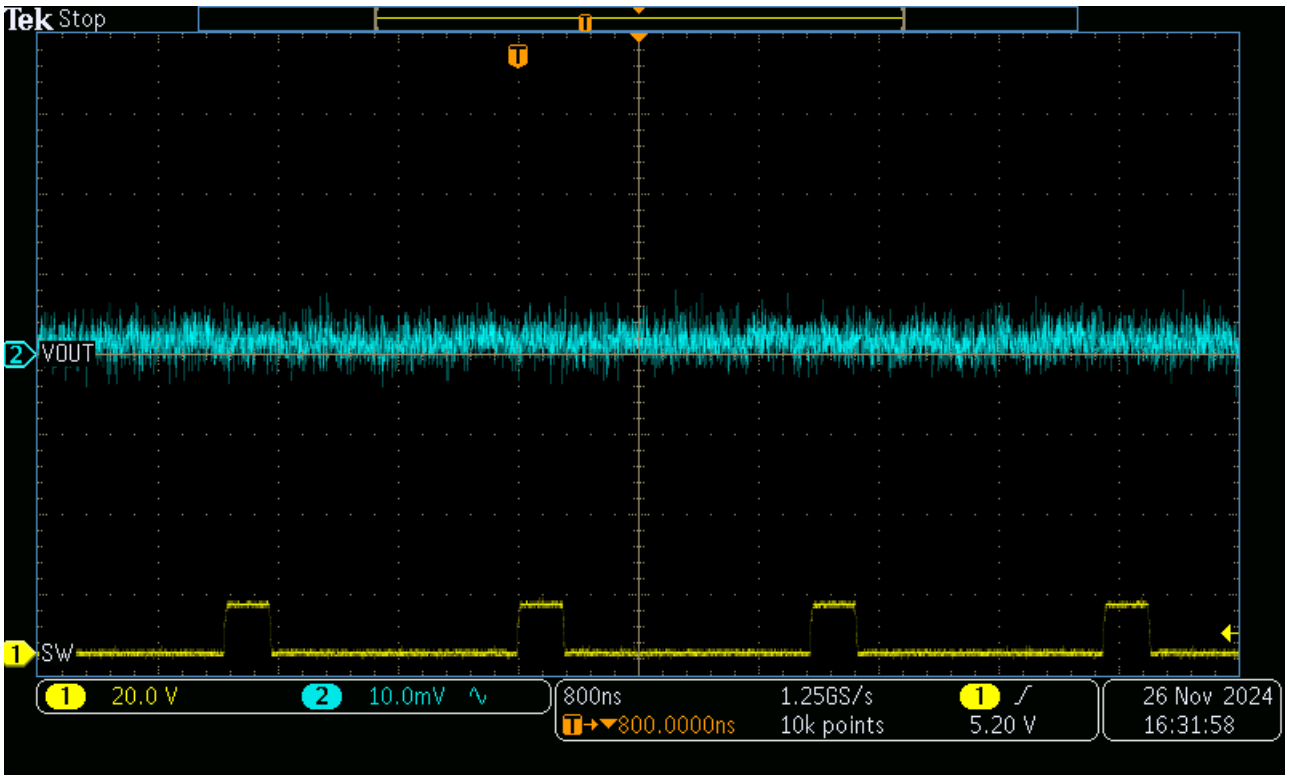


Figure 3-2. Output Voltage Ripple

3.4 Soft Start

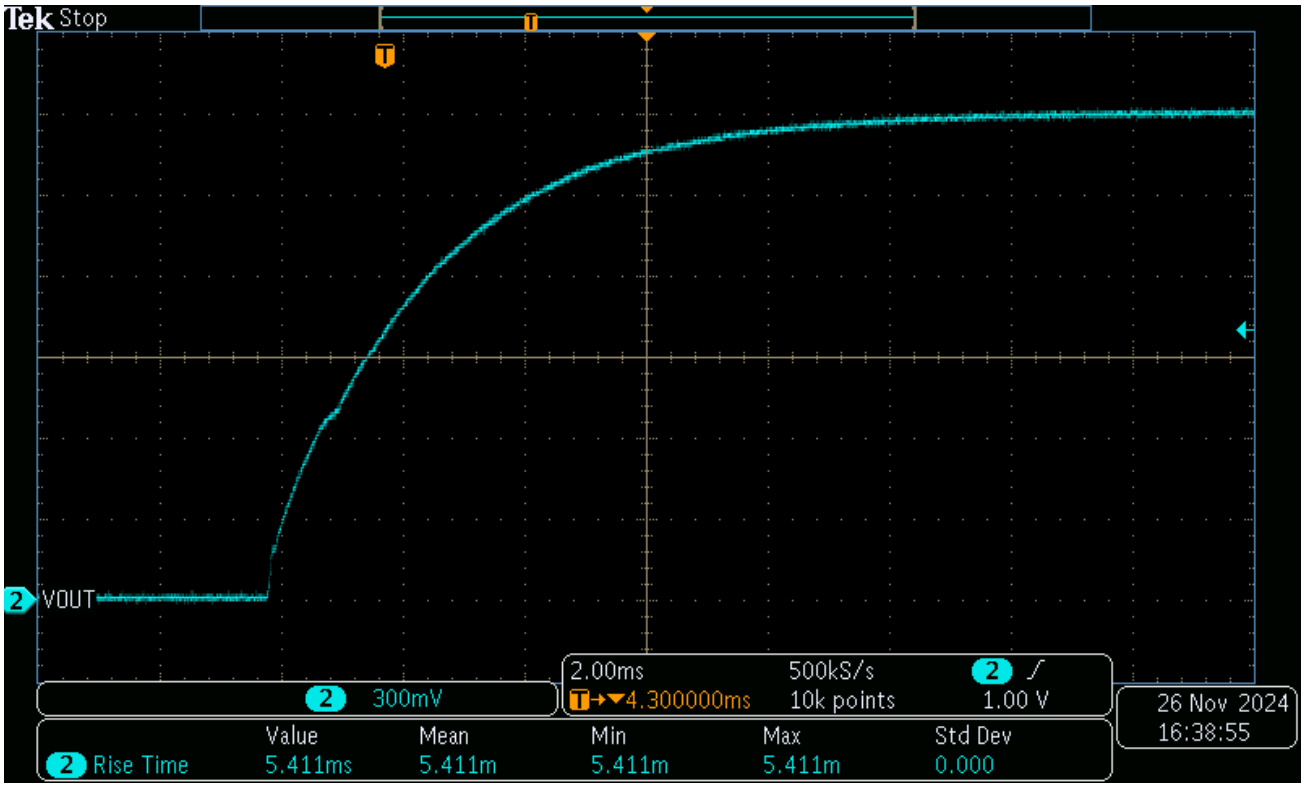


Figure 3-3. Soft Start

3.5 Load Steps

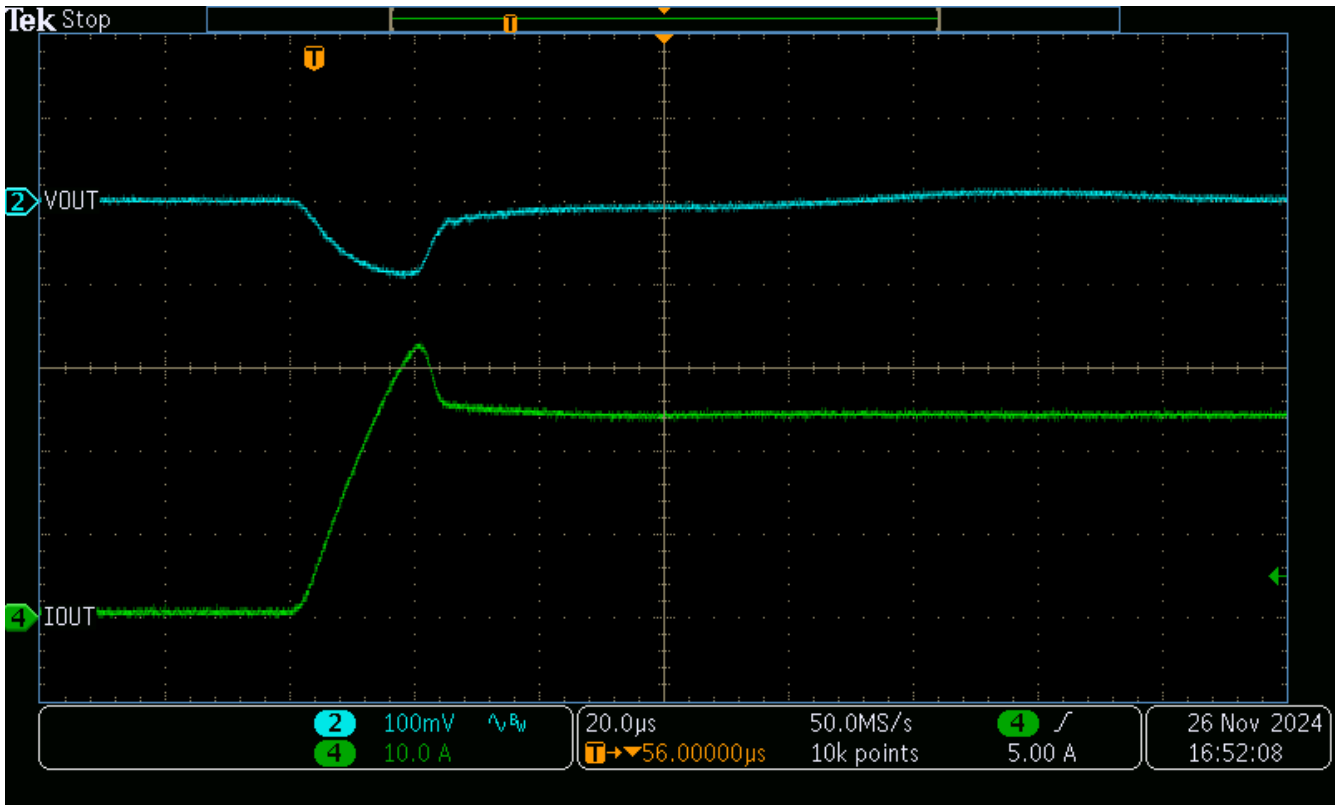


Figure 3-4. Transient Response to Load Step 500mA to 24A

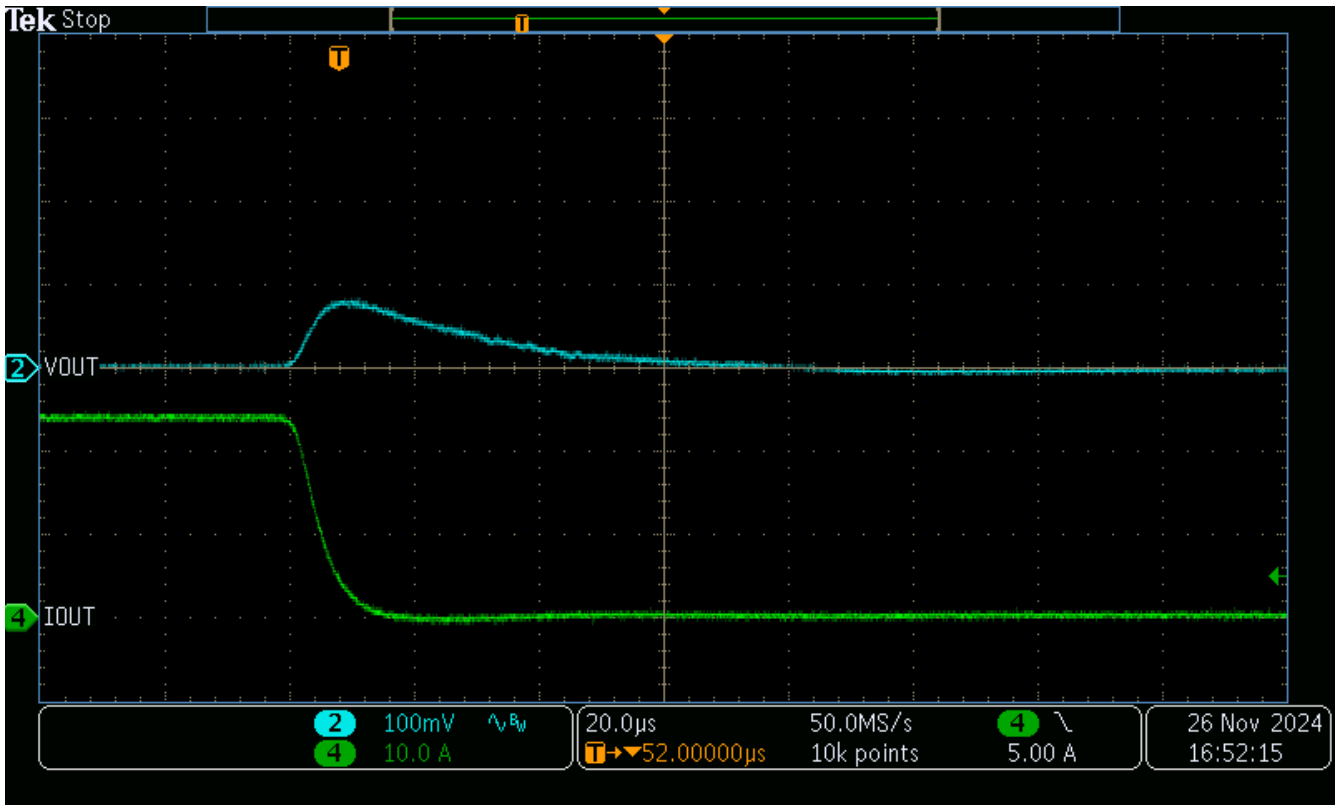


Figure 3-5. Transient Response to Load Step 24A to 500mA

3.6 Bode Plot

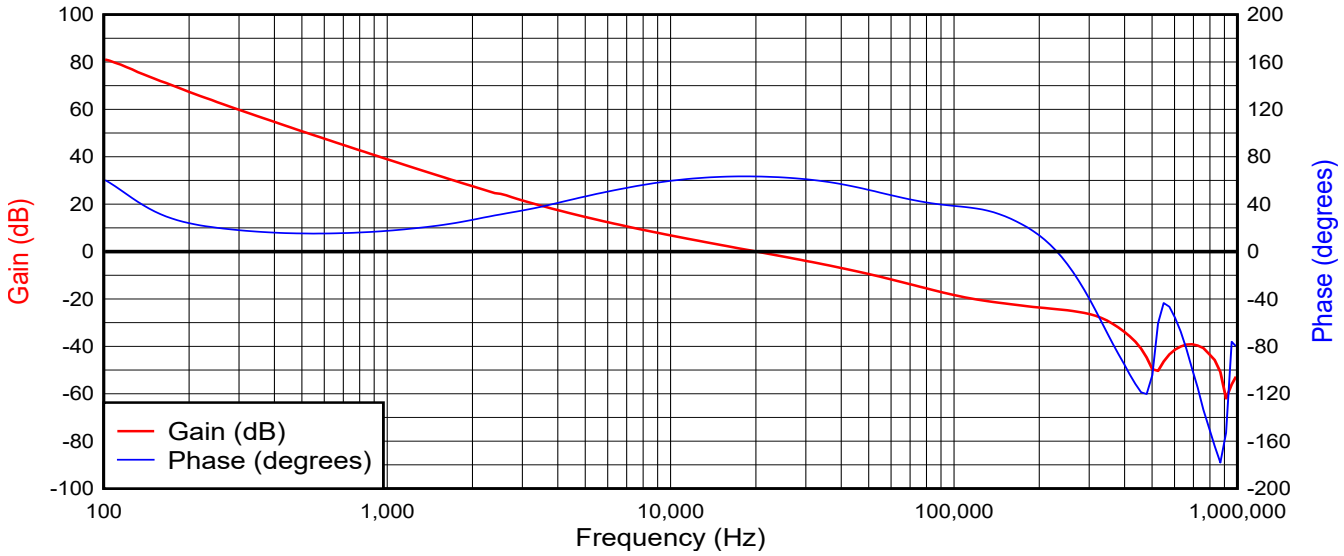


Figure 3-6. Frequency Response IOUT = 24A

3.7 Efficiency Results

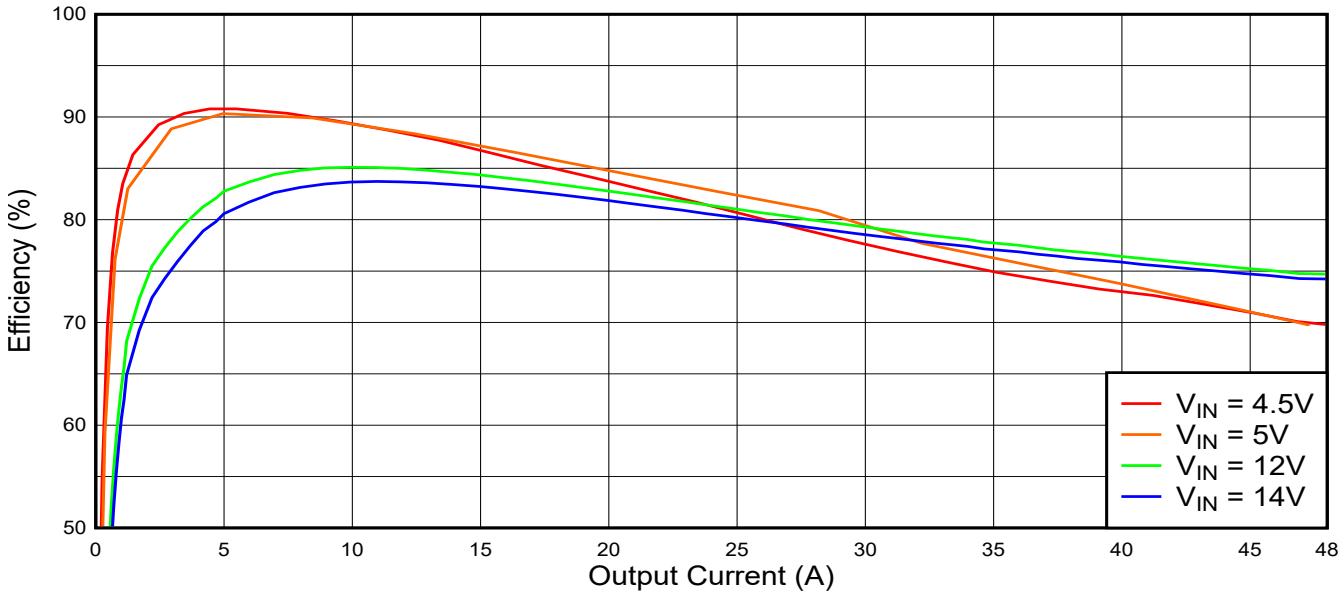


Figure 3-7. Efficiency FSW = 500kHz

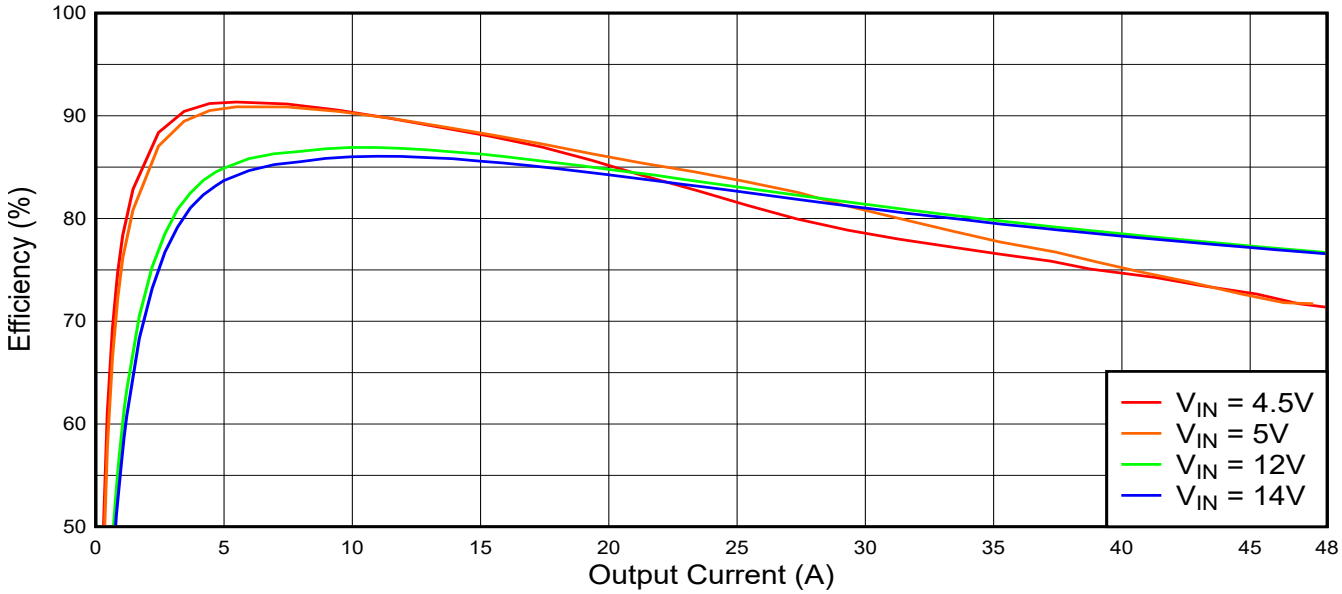


Figure 3-8. Efficiency FSW = 200kHz

3.8 Current Sharing

When multiple devices are in parallel, the best mode of operation is for all devices to deliver the same amount of current to the load. Since the main factor in current sharing equality is the proportional relationship between the power stage transconductance (g_{mps} in the device data sheet) of each device, the current sharing performance of any implementation is dependent on the g_{mps} values of the devices in the parallel system.

The EVM was modified by placing a wire between the inductor and VOUT plane of the EVM to allow current probes to measure the RMS current of each phase during operation. Table Table 3-2 shows the collected data. The second column shows the target RMS current per device, that is the current through each converter if the sharing was equal. The last four columns show the deviation for each device from the target current sharing value as a percentage of the target device current.

Because the current sharing performance of any set of devices is dependent on the g_{mps} values, each EVM has different current sharing characteristics. Therefore, the data provided in Table 3-2 is not the same as other TPS7H4011QEVM-CVAL boards.

Table 3-2. Current Sharing Data

		RMS Current Per Device (A)				Deviation From Target Current (%)			
Total Current (A)	Target Current Per Device (A)	Device 1	Device 2	Device 3	Device 4	Device 1	Device 2	Device 3	Device 4
2.03	0.51	0.51	0.51	0.48	0.53	1.46%	0.13%	-5.95%	4.36%
3.03	0.76	0.77	0.76	0.72	0.78	2.06%	-0.33%	-4.35%	2.62%
3.93	0.98	1.01	0.98	0.95	1.00	2.50%	-0.41%	-3.50%	1.41%
5.11	1.28	1.31	1.27	1.24	1.29	2.72%	-0.91%	-2.61%	0.80%
6.29	1.57	1.62	1.56	1.54	1.58	2.97%	-1.09%	-2.02%	0.14%
7.25	1.81	1.87	1.79	1.78	1.81	2.97%	-1.23%	-1.63%	-0.11%
8.25	2.06	2.12	2.04	2.03	2.06	2.93%	-1.18%	-1.55%	-0.20%
9.22	2.31	2.37	2.27	2.28	2.30	2.96%	-1.50%	-1.25%	-0.21%
10.19	2.55	2.63	2.51	2.52	2.54	3.05%	-1.51%	-1.19%	-0.35%
14.70	3.67	3.79	3.61	3.64	3.65	3.17%	-1.73%	-0.83%	-0.61%
19.44	4.86	5.01	4.78	4.83	4.82	3.19%	-1.73%	-0.70%	-0.77%
24.28	6.07	6.26	5.97	6.03	6.03	3.05%	-1.72%	-0.60%	-0.74%
29.27	7.32	7.53	7.19	7.28	7.27	2.91%	-1.74%	-0.53%	-0.64%
34.12	8.53	8.78	8.38	8.49	8.47	2.97%	-1.79%	-0.50%	-0.68%
38.35	9.59	9.88	9.41	9.54	9.53	3.04%	-1.88%	-0.53%	-0.64%
42.75	10.69	11.02	10.48	10.62	10.63	3.09%	-1.91%	-0.63%	-0.55%
46.94	11.74	12.11	11.49	11.65	11.69	3.17%	-2.06%	-0.72%	-0.38%

4 Hardware Design Files

4.1 Schematics

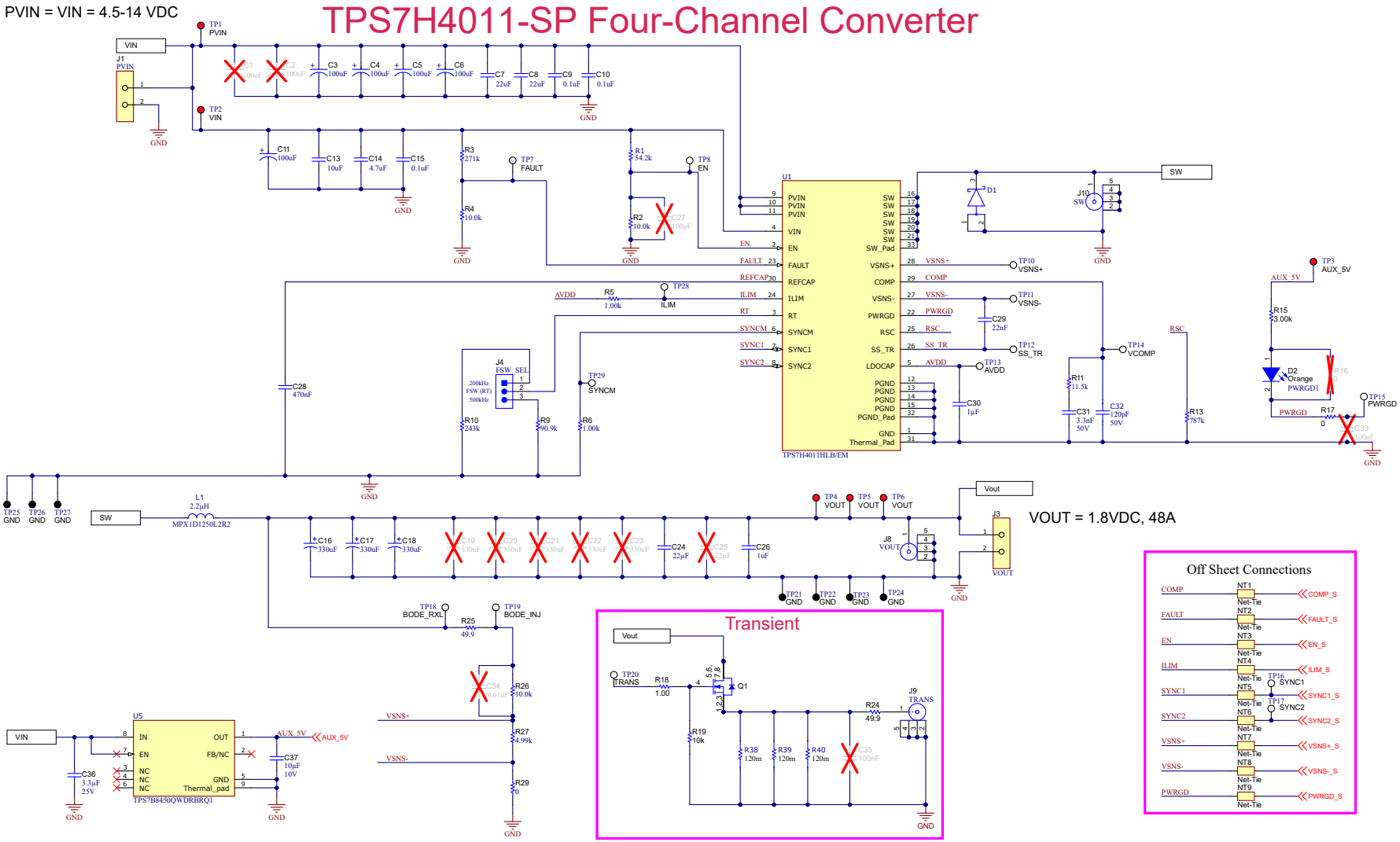


Figure 4-1. EVM Schematic

PVIN = VIN = 4.5-14 VDC

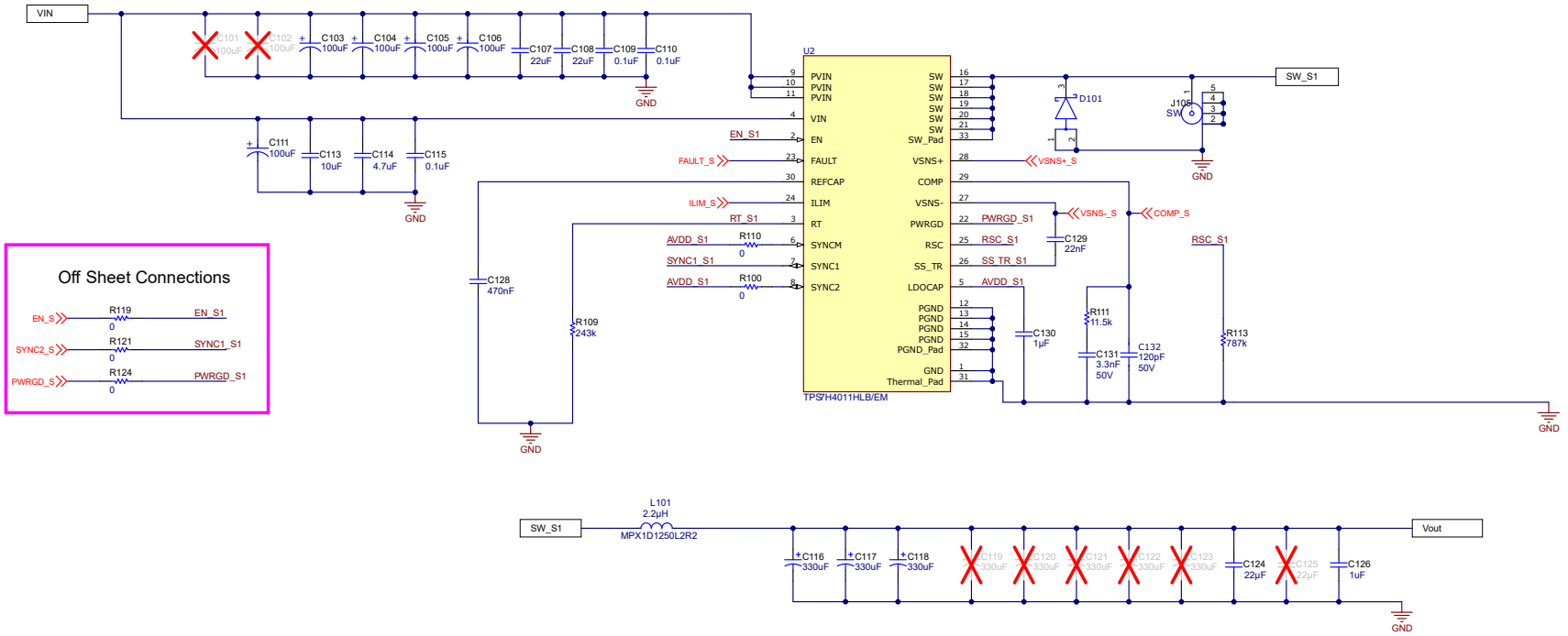


Figure 4-2. EVM Schematic

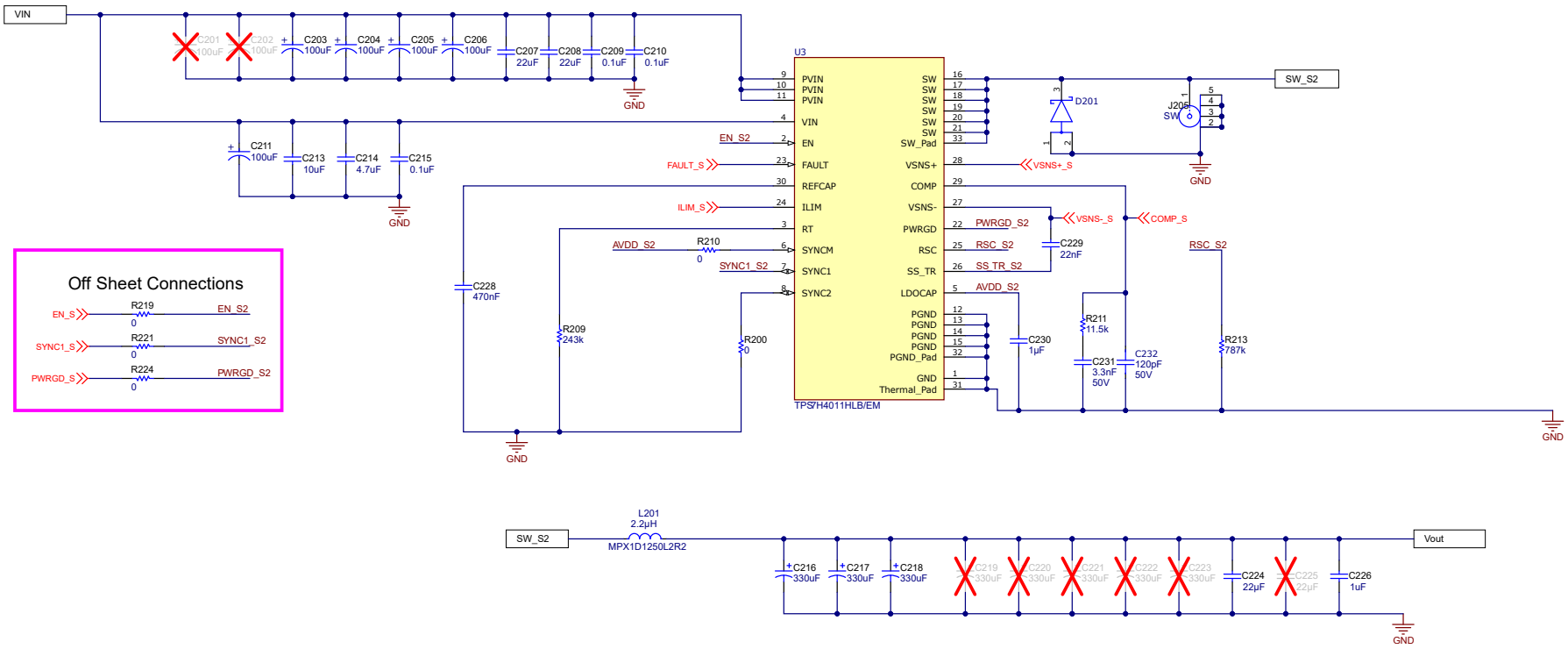


Figure 4-3. EVM Schematic

PVIN = VIN = 4.5-14 VDC

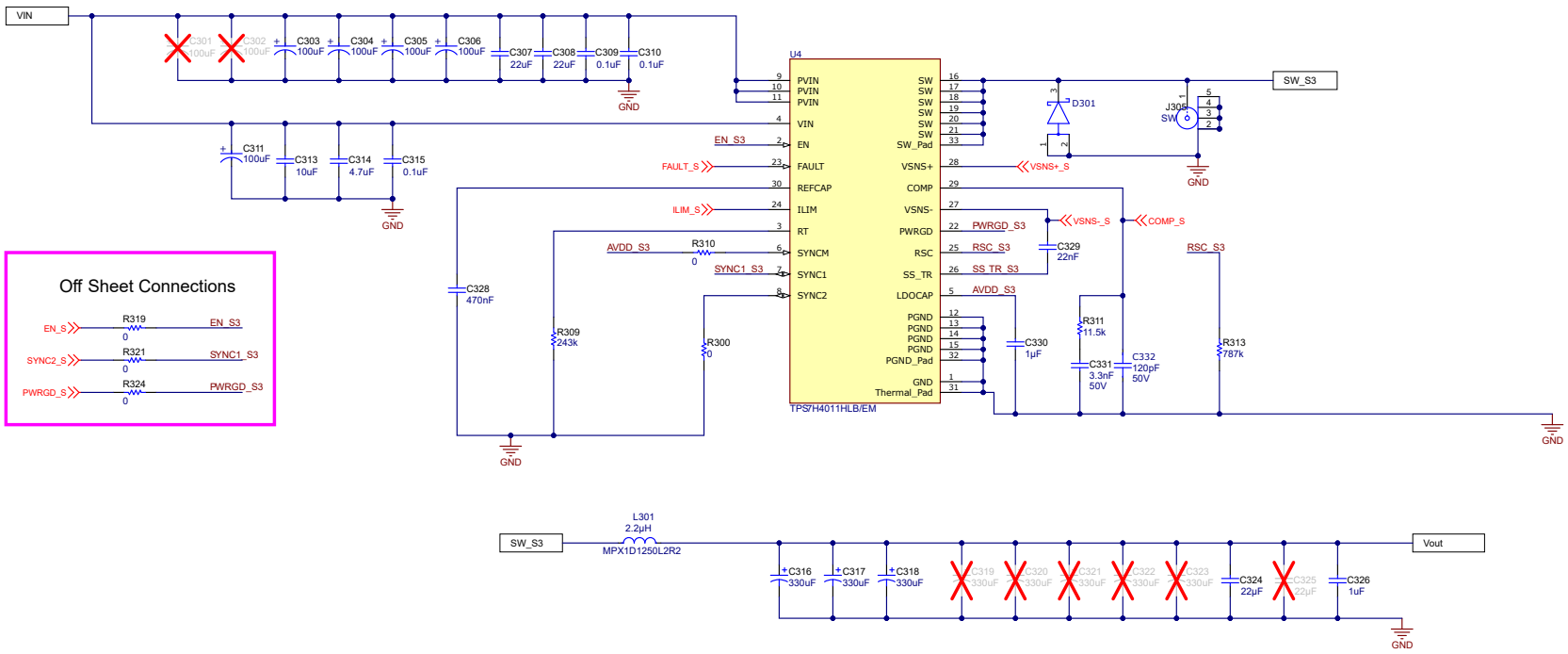


Figure 4-4. EVM Schematic

4.2 PCB Layouts

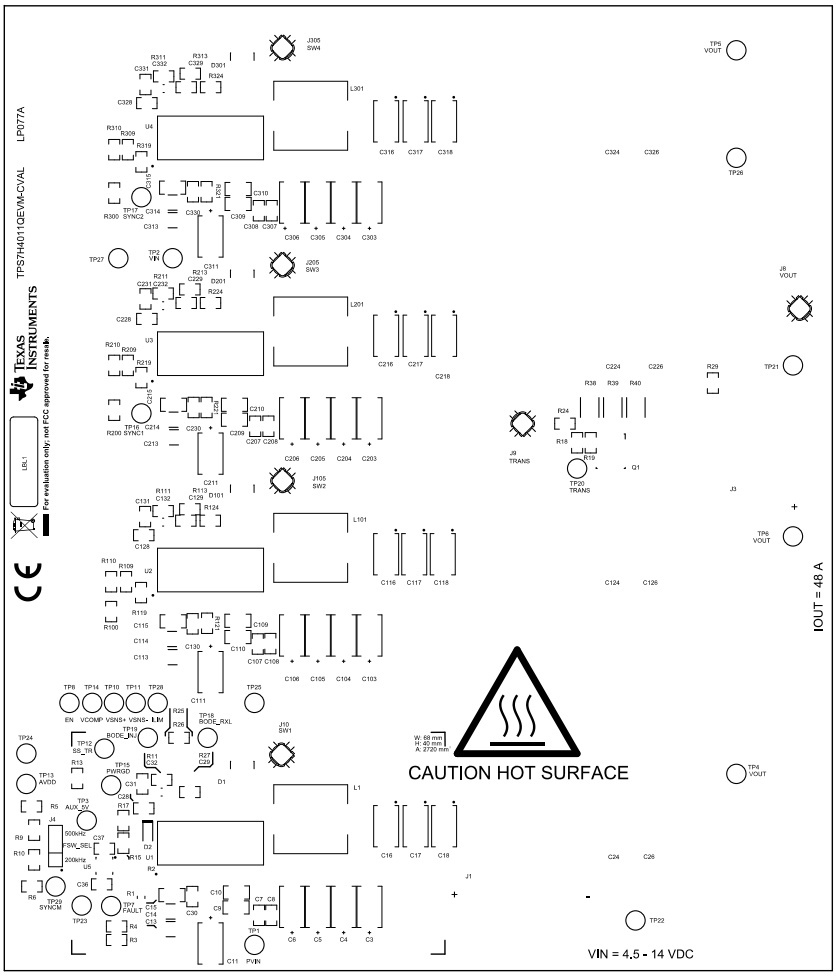


Figure 4-5. Top Overlay

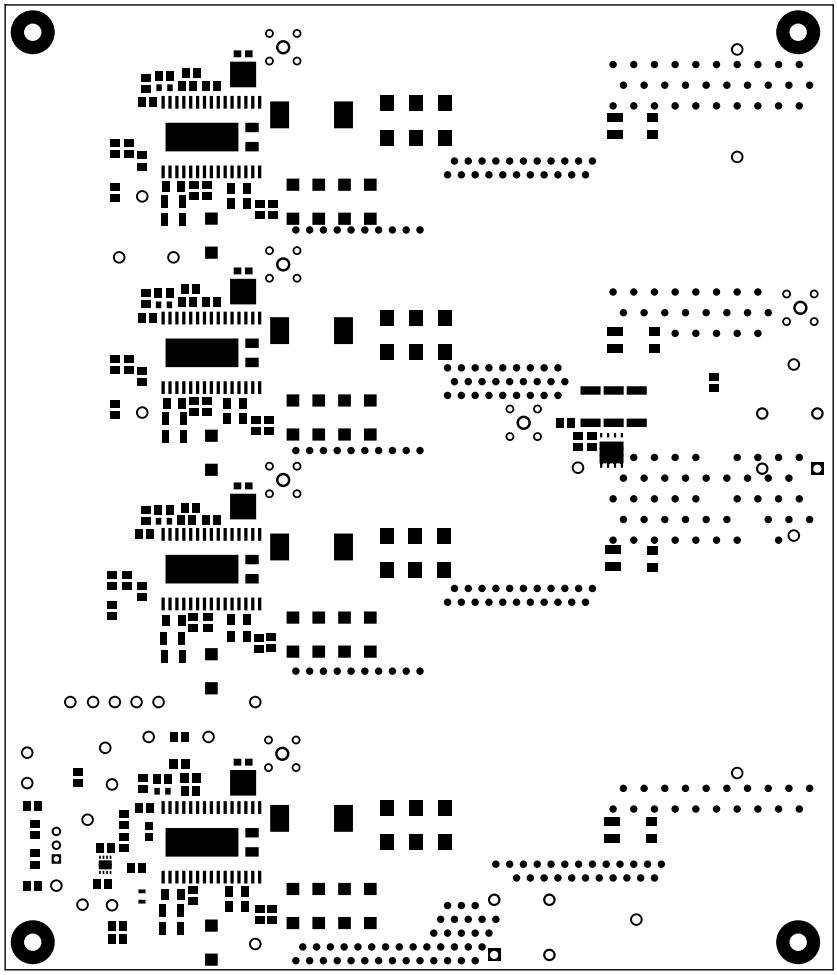


Figure 4-6. Solder Mask (Top View)

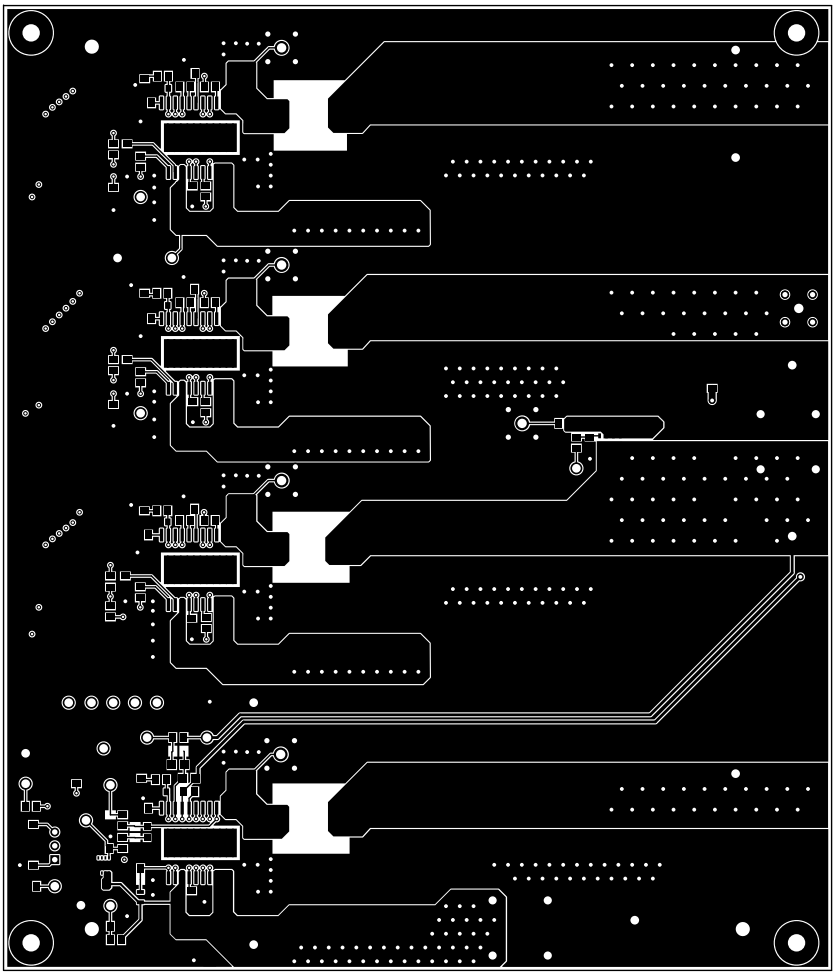


Figure 4-7. Layer 1 (Top View)

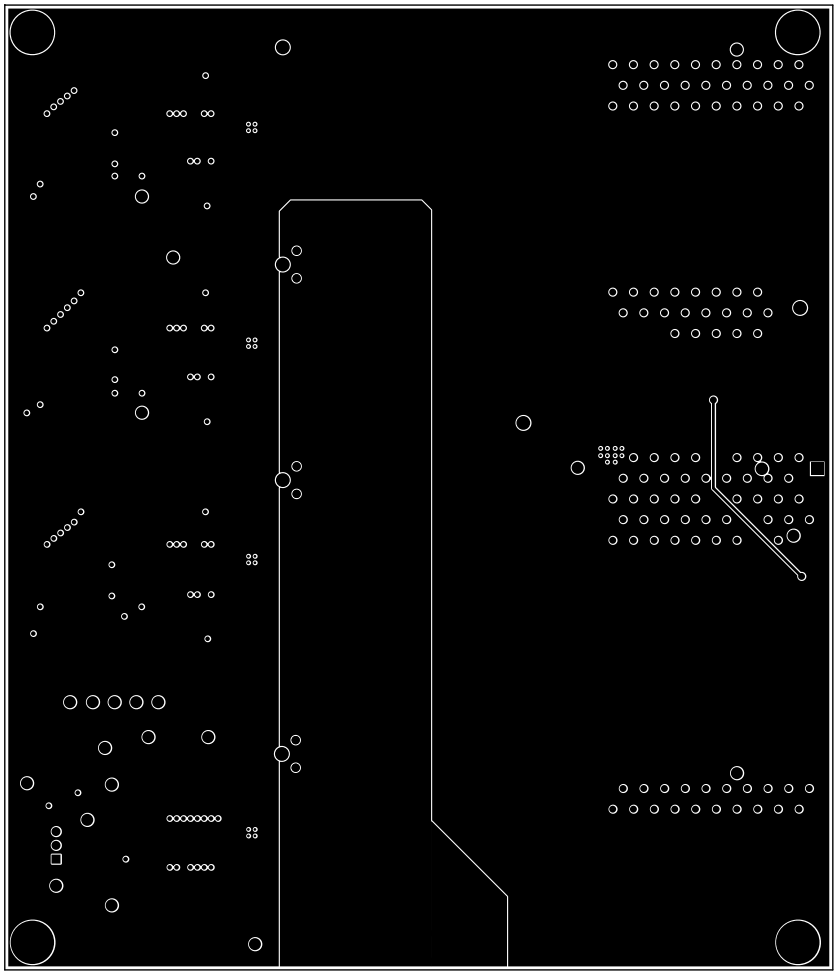


Figure 4-8. Layer 2

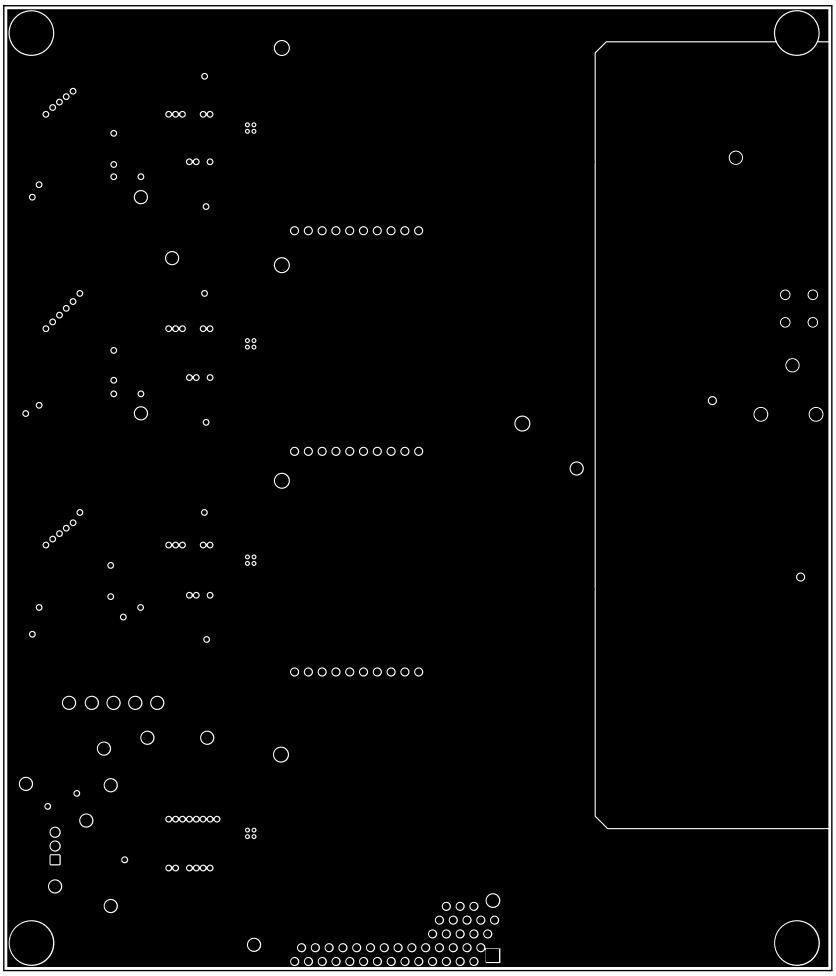


Figure 4-9. Layer 3

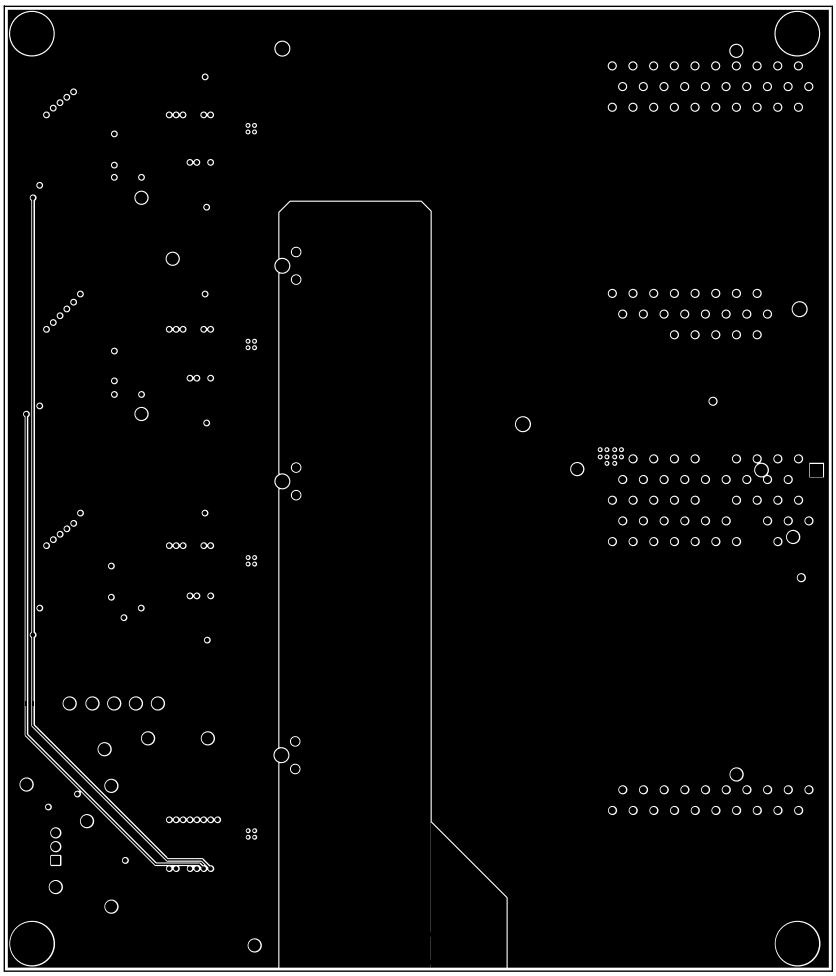


Figure 4-10. Layer 4

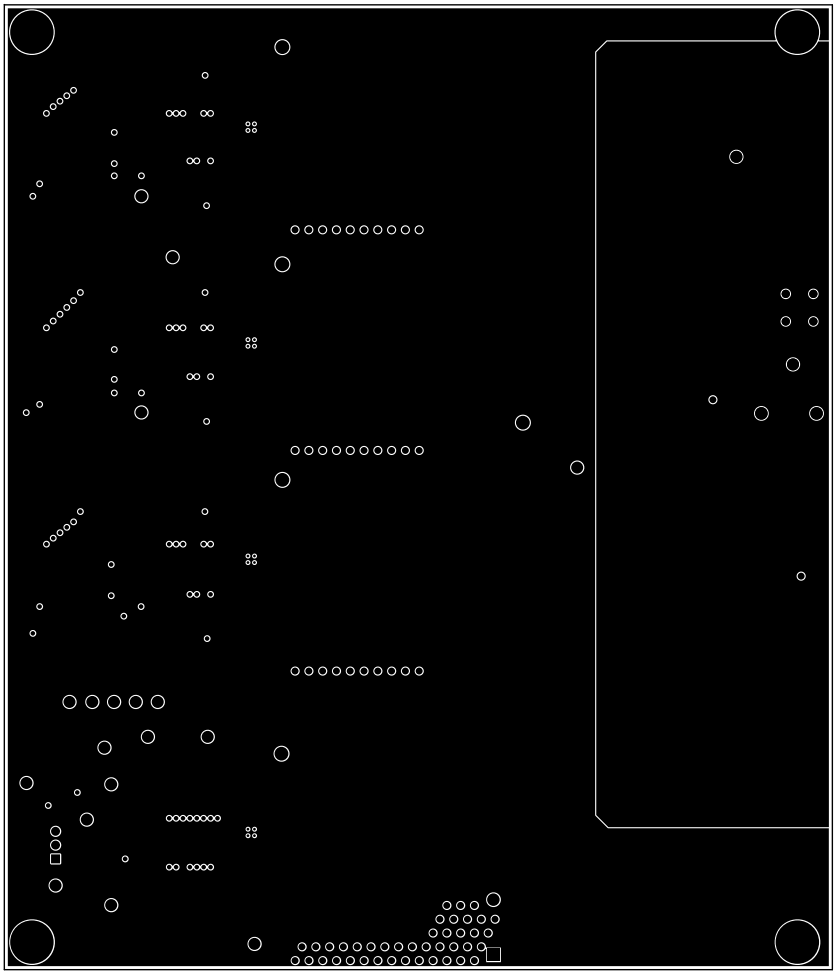


Figure 4-11. Layer 5

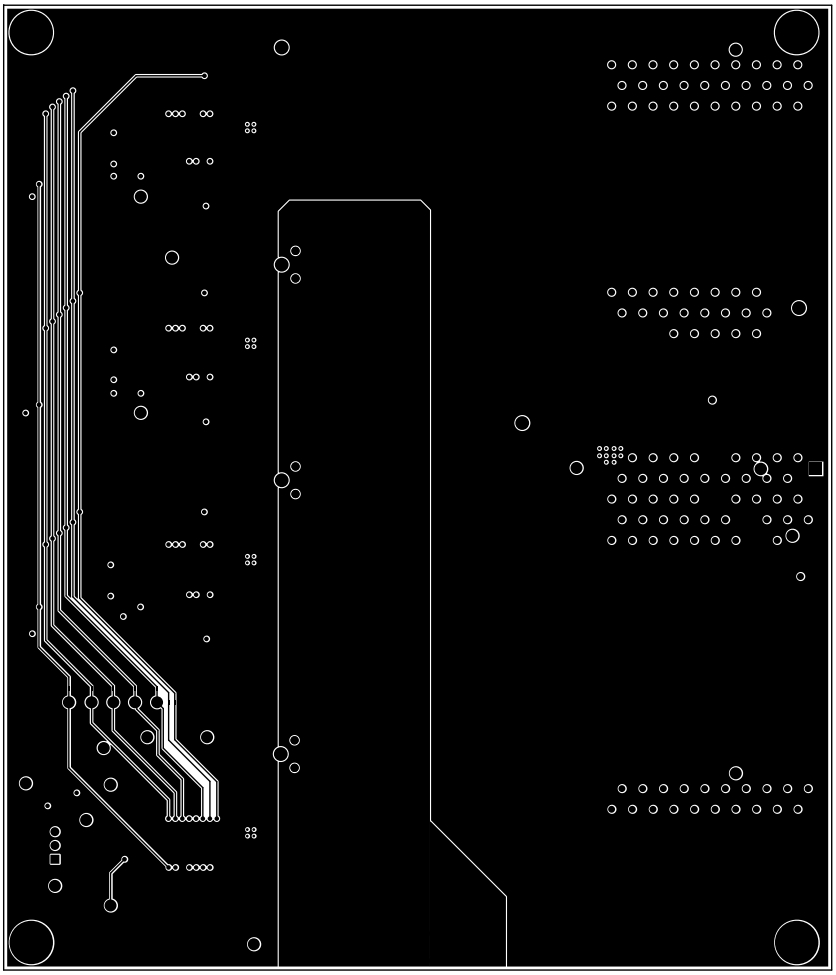


Figure 4-12. Layer 6

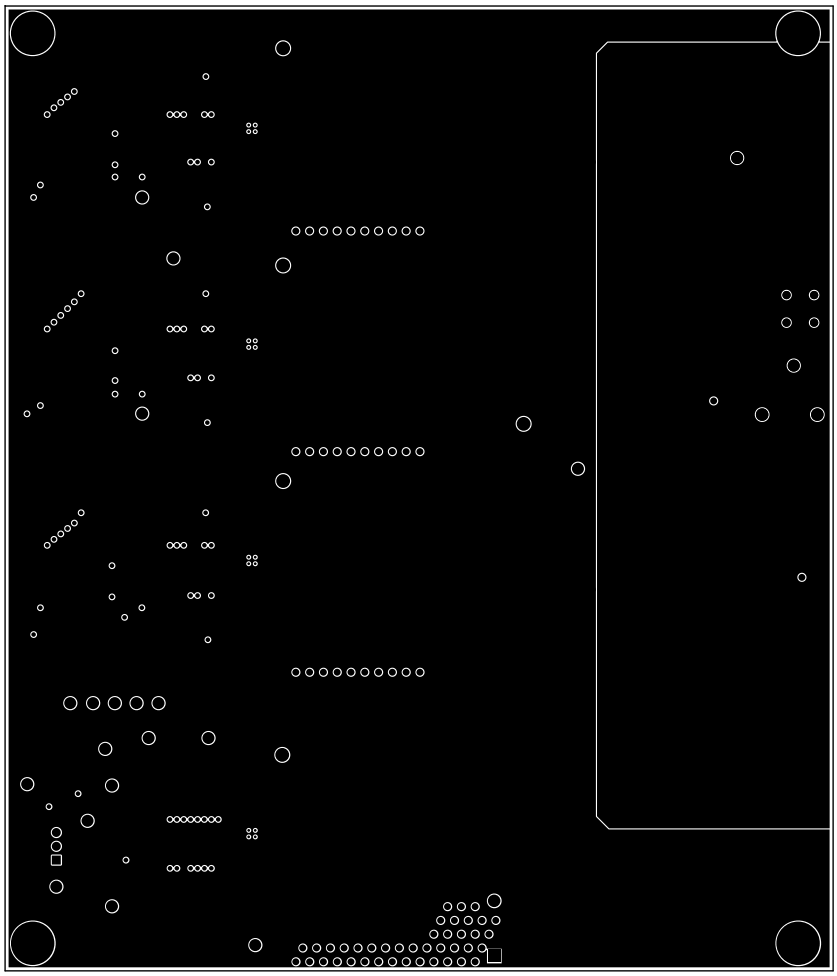


Figure 4-13. Layer 7

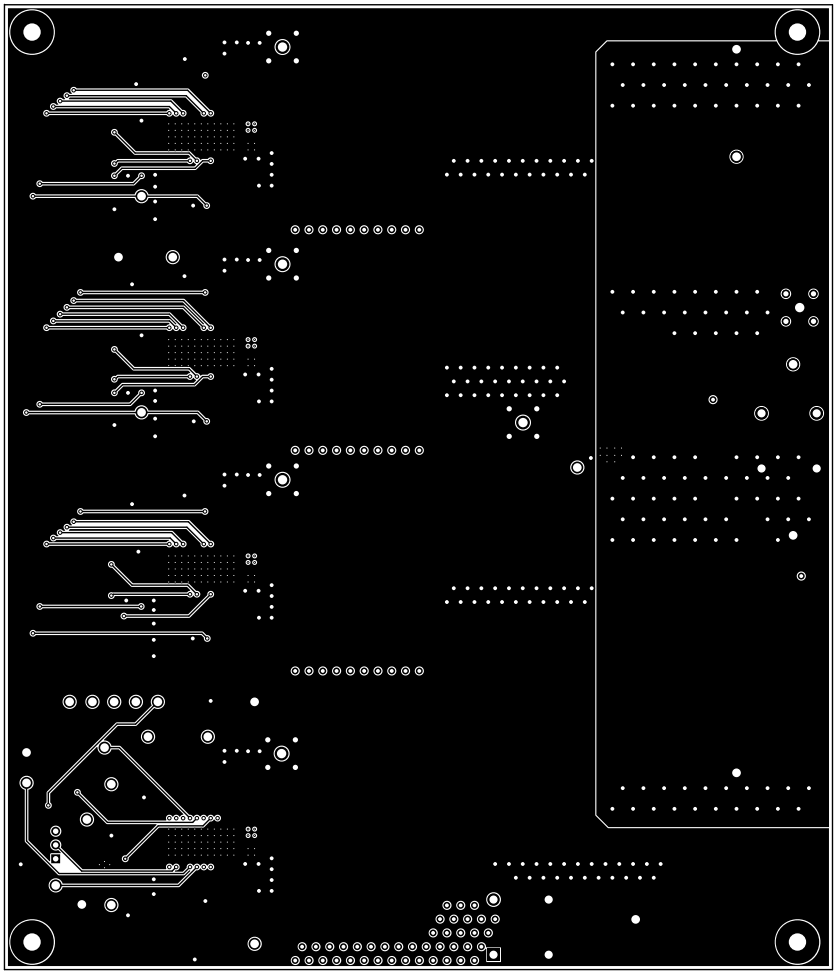


Figure 4-14. Layer 8 (Bottom View)

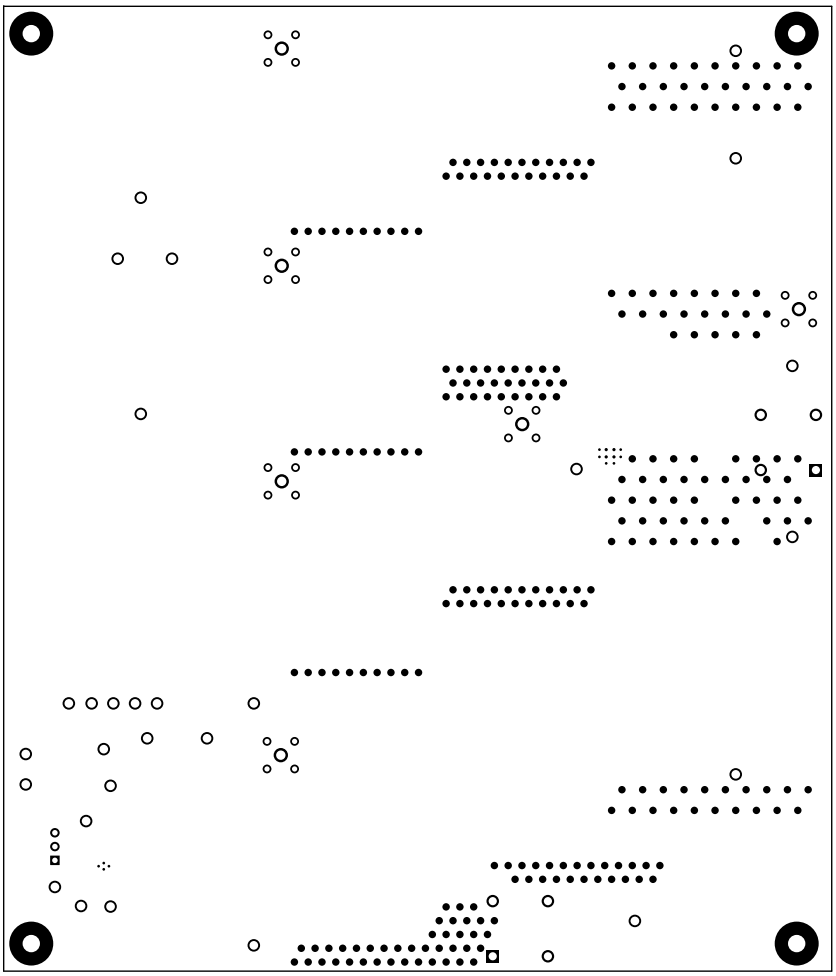


Figure 4-15. Solder Mask (Bottom View)

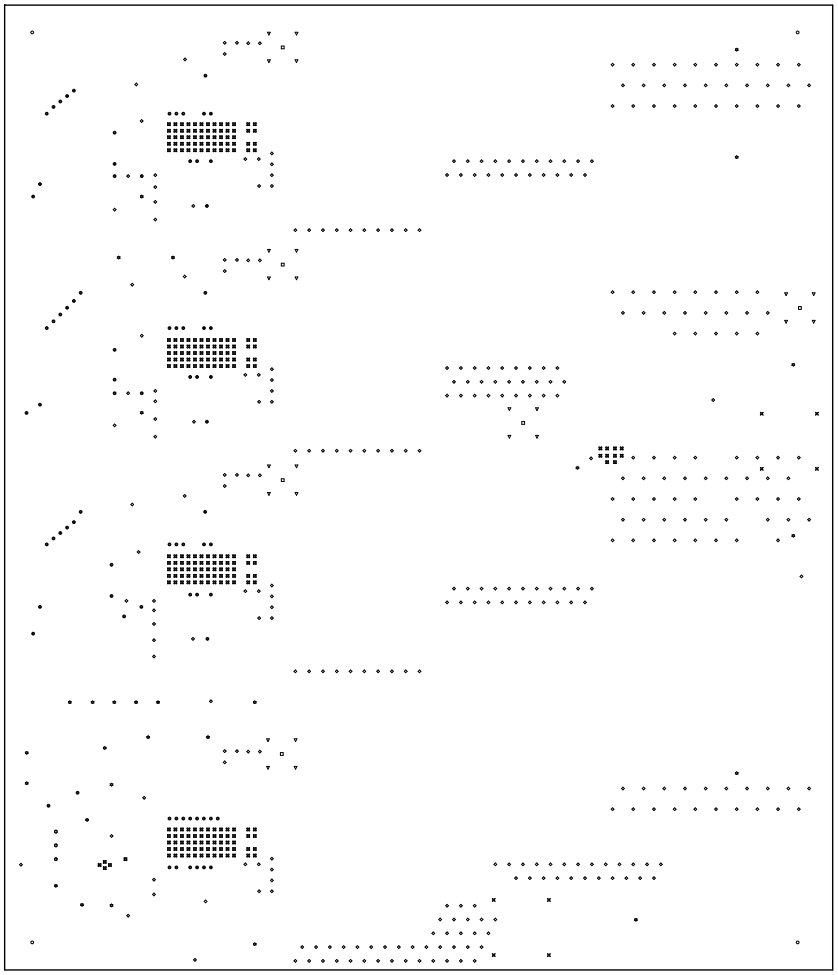


Figure 4-16. Drill Drawing

4.3 Bill of Materials (BOM)

Table 4-1 lists the bill of materials for TPS7H4011QEVM-CVAL.

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C3, C4, C5, C6, C11, C103, C104, C105, C106, C111, C203, C204, C205, C206, C211, C303, C304, C305, C306, C311	20	100µF	Cap Tant Polymer 100uF 25VDC D CASE 20% (7.3 X 4.3 X 2.8mm) SMD 7343-31 0.04 Ohm 105C T/R	2917	T521D107M025ATE040	KEMET
C7, C8, C107, C108, C207, C208, C307, C308	8	22uF	CAP, CERM, 22uF, 25V, +/- 20%, X5R, 0805	0805	GRM21BR61E226ME44L	MuRata
C9, C10, C15, C109, C110, C115, C209, C210, C215, C309, C310, C315	12	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 5%, X7R, 1206	1206	C1206C104J5RACTU	Kemet
C13, C113, C213, C313	4	10uF	CAP, CERM, 10uF, 25V, +/- 10%, X7R, 1210	1210	12103C106KAT2A	AVX
C14, C114, C214, C314	4	4.7uF	CAP, CERM, 4.7uF, 50V, +/- 10%, X7R, 1210	1210	C3225X7R1H475K250AB	TDK
C16, C17, C18, C116, C117, C118, C216, C217, C218, C316, C317, C318	12	330uF	CAP, Tantalum Polymer, 330uF, 10V, +/- 20%, 0.006 ohm, 7343-43 SMD	7343-43	T530X337M010ATE006	Kemet
C24, C124, C224, C324	4	22uF	CAP, CERM, 22µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 1210	1210	CL32B226KOJVPNE	Samsung Electro-Mechanics
C26, C126, C226, C326	4	1uF	CAP, CERM, 1uF, 25V, +/- 10%, X7R, 1206	1206	C1206C105K3RACTU	Kemet
C28, C128, C228, C328	4	0.47uF	CAP, CERM, 0.47uF, 16V, +/- 5%, X7R, 0805	0805	0805YC474JAT2A	AVX
C29, C129, C229, C329	4	0.022uF	CAP, CERM, 0.022uF, 100V, +/- 5%, X7R, 0805	0805	08051C223JAT2A	AVX
C30, C130, C230, C330	4	1uF	CAP, CERM, 1uF, 16V, +/- 10%, X7R, 0805	0805	C0805C105K4RACTU	Kemet
C31, C131, C231, C331	4	3300pF	CAP, CERM, 3300pF, 50V, +/- 10%, X7R, 0805	0805	08055C332KAT2A	AVX
C32, C132, C232, C332	4	120pF	Cap Ceramic 120pF 50V X7R 10% SMD 2.0 x 1.2mm 125 C T/R	0805	08055C121KAT2A	KYOCERA AVX
C36	1	3.3uF	CAP, CERM, 3.3uF, 25V, +/- 10%, X7R, 0805	0805	C2012X7R1E335K125AB	TDK
C37	1	10uF	CAP, CERM, 10µF, 10V,+/- 10%, X7R, AEC-Q200 Grade 1, 0805	0805	GCJ21BR71A106KE01L	MuRata
D1, D101, D201, D301	4		Diode 40V 10A Surface Mount TO-277A (SMPC)	SMPC	SS10P4-M3/86A	Vishay
D2	1	Orange	LED, Orange, SMD	LED_0805	LTST-C170KFKT	Lite-On

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
J1, J3	2		Fixed Terminal Blocks MKDSP 10 HV/ 2-10	HDR2	1929517	Phoenix Contact
J4	1		Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J8, J9, J10, J105, J205, J305	6		Compact Probe Tip Circuit Board Test Points, TH, 25 per	TH Scope Probe	131-5031-00	Tektronix
L1, L101, L201, L301	4	2.2uH	2.2µH Shielded Wirewound Inductor 21A 4.8mOhm Max Nonstandard	SMD2	MPX1D1250L2R2	KEMET
Q1	1	25V	MOSFET, N-CH, 25V, 113A, DQH0008A (VSON-CLIP-8)	DQH0008A	CSD16408Q5	Texas Instruments
R1	1	54.2k	54.2 kOhms ±0.1% 0.26W Chip Resistor 0805 (2012 Metric) Anti-Sulfur, Automotive AEC-Q200, Moisture Resistant Thin Film	0805	TNPW080554K2BEEN	Vishay
R2, R4, R26	3	10.0k	RES, 10.0 k, 0.1%, 0.125 W, 0805	0805	RG2012P-103-B-T5	Susumu Co Ltd
R3	1	271k	RES, 271 k, 0.1%, 0.125 W, 0805	0805	RT0805BRD07271KL	Yageo America
R5, R6	2	1.00k	RES, 1.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF1001V	Panasonic
R9	1	90.9k	RES, 90.9 k, 0.1%, 0.125 W, 0805	0805	RG2012P-9092-B-T5	Susumu Co Ltd
R10, R109, R209, R309	4	243k	RES, 243 k, 0.1%, 0.125 W, 0805	0805	RT0805BRD07243KL	Yageo America
R11, R111, R211, R311	4	11.5k	RES, 11.5 k, 0.1%, 0.125 W, 0805	0805	RT0805BRD0711K5L	Yageo America
R13, R113, R213, R313	4	787k	RES, 787 k, 0.1%, 0.125 W, 0805	0805	RT0805BRD07787KL	Yageo America
R15	1	3.00k	RES, 3.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF3001V	Panasonic
R17, R29, R100, R110, R119, R121, R124, R200, R210, R219, R221, R224, R300, R310, R319, R321, R324	17	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EA	Vishay-Dale
R18	1	1	RES, 1.00, 1%, 0.125 W, 0805	0805	RC0805FR-071RL	Yageo America
R19	1	10k	RES, 10 k, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW080510K0JNEA	Vishay-Dale
R24, R25	2	49.9	RES, 49.9, 0.1%, 0.125 W, 0805	0805	RT0805BRD0749R9L	Yageo America
R27	1	4.99k	RES, 4.99 k, 0.1%, 0.125 W, 0805	0805	RG2012P-4991-B-T5	Susumu Co Ltd

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R38, R39, R40	3	120m	120 mOhms ±1% 2W Chip Resistor 2512 (6432 Metric) Automotive AEC-Q200, Current Sense Metal Element	2512	2019-TLRH3AWTTER120FTR-ND	KOA Speer
TP1, TP2, TP3, TP4, TP5, TP6	6		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics
TP7, TP8, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP28, TP29	15		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics
TP21, TP22, TP23, TP24, TP25, TP26, TP27	7		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone Electronics
U1, U2, U3, U4	4		Radiation-Hardened 4.5V to 14V Input 12A Synchronous Buck Converter	CFP30	TPS7H4011HLB/EM	Texas Instruments
U5	1		Linear Voltage Regulator IC Positive Fixed 1 Output 150mA 8-SON (3x3)	VSON8	TPS7B8450QWDRBRQ1	Texas Instruments

5 Compliance Information

5.1 Compliance and Certifications

- Texas Instruments, TPS7H4011QEVM-CVAL EU RoHS Declaration of Conformity (DoC)

6 Additional Information

6.1 Trademarks

All trademarks are the property of their respective owners.

7 Related Documentation

7.1 Supplemental Content

- Texas Instruments, TPS7H4011-SP 4.5V to 14V Input 12A Radiation Hardened Synchronous Buck Converter data sheet
- Texas Instruments, N-Channel NexFET™ Power MOSFET (CSD16408Q5) data sheet

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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.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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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/lsds/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.

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   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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