User's Guide

TPS7H4002EVM-CVAL Evaluation Module

ABSTRACT

The TPS7H4002EVM-CVAL is the evaluation module (EVM) for the TPS7H4002-SP and provides a platform to electrically evaluate its features. This user's guide provides details about the EVM, its configuration, schematics, and BOM.

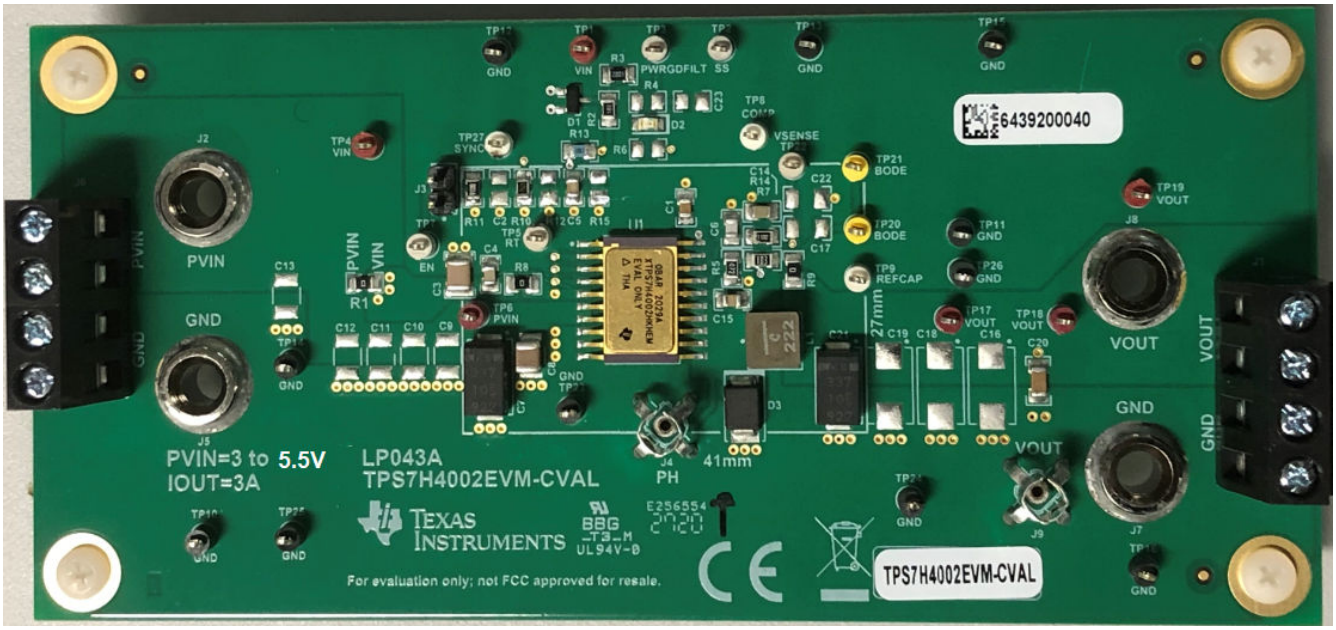

Figure 1-1. TPS7H4002EVM-CVAL

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Trademarks

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1 TPS7H4002EVM-CVAL Overview

The TPS7H4002-SP is a radiation hardened, 3-V to 5.5-V, 3-A synchronous step-down converter with integrated high-side and low-side MOSFETs. High efficiency and efficient usage of space are achieved through low resistance MOSFETs and a current mode control implementation.

The EVM is configured in a default state to accept a 5-V input but can be modified to disable or change the undervoltage lock out (UVLO) protection, allowing for any input voltage from 3 V to 5.5 V. The EVM is also configured for a 2.5-V output at a maximum peak output current of 3 A. Again, the regulated output voltage can be modified by changing one resistor on the board. The TSP7H4002-SP has a dedicated soft start, enable, and power good pins providing design flexibility to meet specific application requirements.

1.1 Features

- 0.807-V ±1.5% voltage reference overtemperature, radiation, and line and load regulation
- Adjustable soft start
- Adjustable input enable and undervoltage lockout (UVLO)
- Power good indicator pin
- Maximum output current of 3 A

1.2 Applications

- Point of load regulation
- Supports harsh environment applications
- Space satellite point of load supply for FPGAs, microcontrollers, data converters, and ASICs
- Space satellite payloads
- Radiation hardened applications

2 TPS7H4002EVM-CVAL Default Configuration

Table 2-1 describes the default configuration of the TPS7H4002EVM-CVAL listing the external components that define the converter design.

Table 2-1. Default EVM Configuration

Parameter	Specifications	Description
Input power supply	5 V	Bound by UVLO enable circuit (R13, R15)
Regulated output voltage	2.5 V	R7 (RTOP) = 10 kΩ, R5 (RBOTTOM) = 4.7 kΩ
L_{OUT}	2.2 µH	Chosen to meet inductor ripple current of 40% (Kind = 0.4)
C_{OUT}	330 µF	Chosen for (1) ESR = 6 mΩ to set output voltage ripple; (2) value used during single event effects testing ensuring regulation maintained with single event upset to switching
Output current	0 to 3 A	By design
Switching frequency	500 kHz	Set by R10 (RT) = 95.3 kΩ
Soft start time constant	≈ 3.2 ms	Set by C1 (Css) = 10 nF
UVLO enable rising	≈ 4.432 V	Set by R13 = 10 kΩ and R15 = 3.4 kΩ
UVLO enable falling	≈ 4.284 V	Set by R13 = 10 kΩ and R15 = 3.4 kΩ
Loop bandwidth	≈ 30 kHz	Set by operational transconductance amplifier (OTA) compensation circuit: R14 (RCOMP) = 11.8 kΩ, C14 (CCOMP) = 22 nF, C6 (CHF) = 22 pF
Loop phase margin	≈ 60°	
Gain margin	≈ –25 dB	

3 TPS7H4002EVM-CVAL Initial Setup

This section provides the test instruments required and the connections to the EVM.

1. Input DC power supply
   a. Set for 5-V DC, 3-A current limit.
   b. Connect the positive output of the DC supply to connector J2 (PVIN) and the negative terminal of the supply to connector J5 for ground.

Note

For more precise measurements, eliminating the IR voltage drop in the input cables is achieved by using a power supply source with sensing ports and connecting between TP6 to PVIN and TP23 to GND.

2. DC electronic load
   a. Connect the positive DC input to connector J8 (VOUT) using a 16-AWG wire.

Note

Wire to the e-load should include at least some part in which the wire gauge can be strapped by the oscilloscope current probe. This will eliminate the need for a setup change to when making transient measurements.

   b. Connect the negative DC input of e-load to connector J7 (GND) using a 16-AWG wire.
   c. Connect voltage monitoring sensing ports of e-load across test points TP17 (VOUT) and TP26 (GND). A voltage meter can be used to monitor this voltage also.
3. Oscilloscope
   a. CH1 - Connect the voltage scope probe to scope probe test point J4 (PH) to monitor the phase node. DC coupled, Full BW, 2 V/div, Rising Edge Trigger at 0.5 V.
   b. CH2 - Connect voltage scope probe to scope probe test point J9 (VOUT) to monitor the output voltage. AC coupled, BW = 20 MHz, 10 mV/div.
   c. CH3 - Connect current scope probe to monitor current through wire connecting J8 (VOUT) and e-load. 5 A/div

Note

Only required for transient load testing

Table 3-1. Summary of Connections

Reference Designator	Silkscreen	Function
J2, J5	PVIN	Input power: J2 = 5 V, J5 = GND (Vsupply)
J8, J7	VOUT	Output current: J8 = VOUT J7 = GND, pin 2 = VOUT ≈ 1 V (e-load)
J6	PH4	Phase switching node scope probe test point (Scope CH-1)
J9	VOUT	VOUT scope probe test point (Scope CH-2)
TP17	VOUT	VOUT test point (e-load monitor)
TP6	PVIN	PVIN test point (Vsupply_sense)
TP18, TP23	GND	GND test points (e-load monitor, Vsupply_sense)

4 TPS7H4002EVM-CVAL Testing

The following tests are described in subsequent sections:

1. Output voltage regulation
2. Output voltage ripple
3. Soft start-up
4. Transient response to positive/negative load step (0 A to 3 A to 0 A)
5. Input voltage ripple
6. Loop frequency response
7. Current limiting

4.1 Output Voltage Regulation

- Turn on the input DC source (5 V)
- Turn on the e-load and sweep the load current from 0 A to 3 A, or higher to observe the margin the device has to the recommended operating condition of 3-A maximum. The monitored output voltage at TP17 (VOUT) is at or near 2.5 V across the entire current load sweep as shown in Figure 4-1.

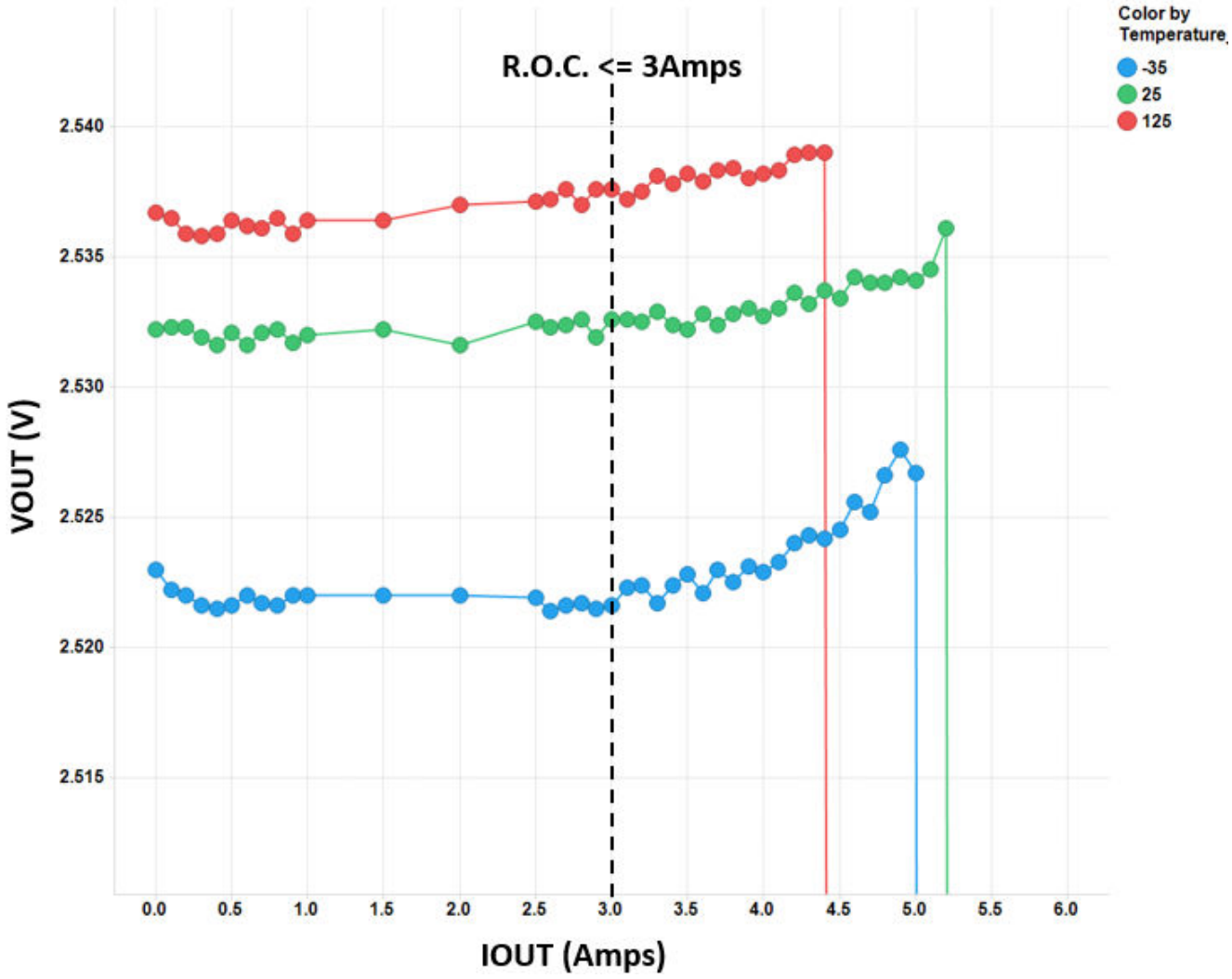

Figure 4-1. Output Voltage Regulation

4.2 Output Voltage Ripple

Display CH1 (PH1) and CH2 (VOUT1) [AC coupled, BW = 20 MHz] on the oscilloscope to monitor the switching phase node and the output voltage ripple as shown in Figure 4-2.

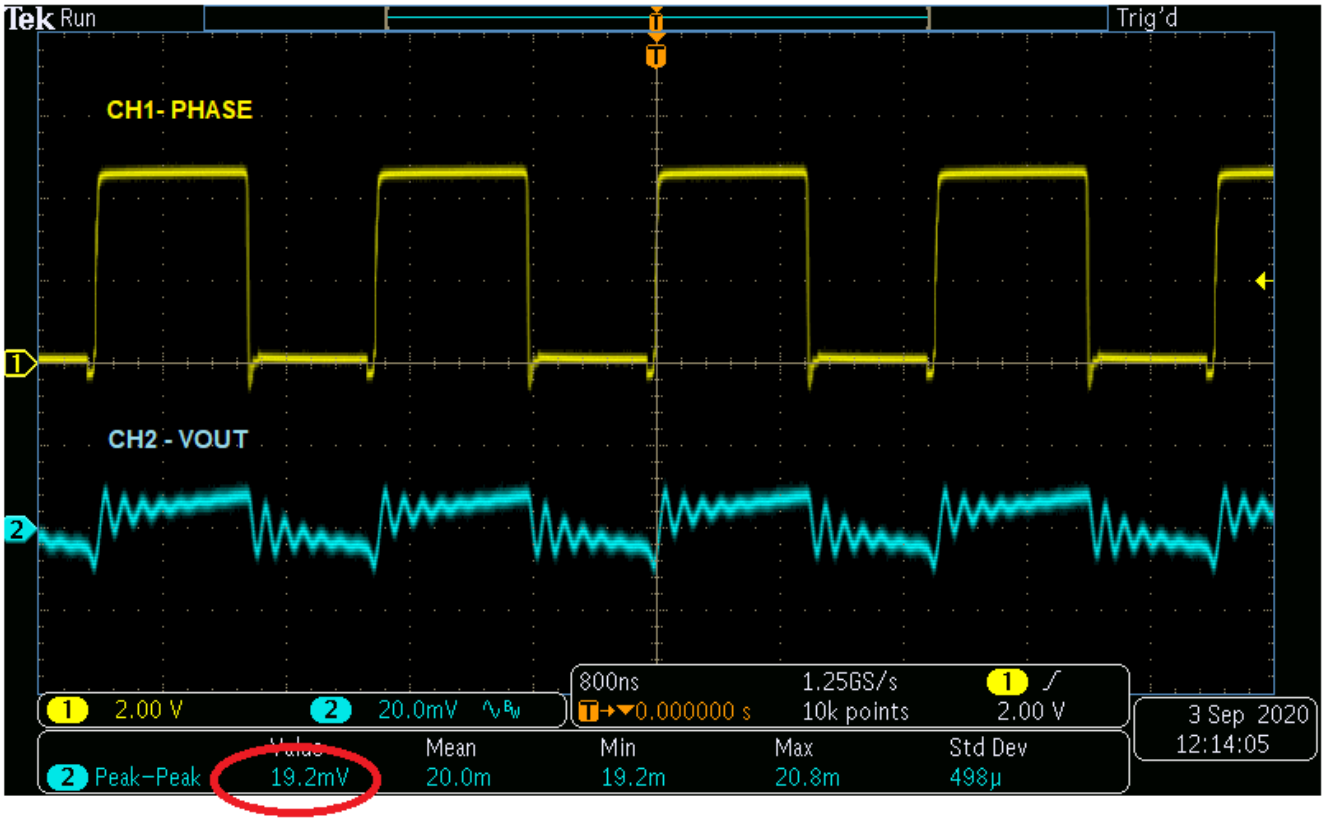

Figure 4-2. Output Voltage Ripple VIN = 5 V, VOUT = 2.5 V, IOUT = 3 A

4.3 Soft Start-up

Display CH1 (PH1) and CH2 (VOUT1) [DC coupled, 500 mV/div] on the oscilloscope to monitor the switching phase and the soft start profile of the output voltage as shown in Figure 4-3.

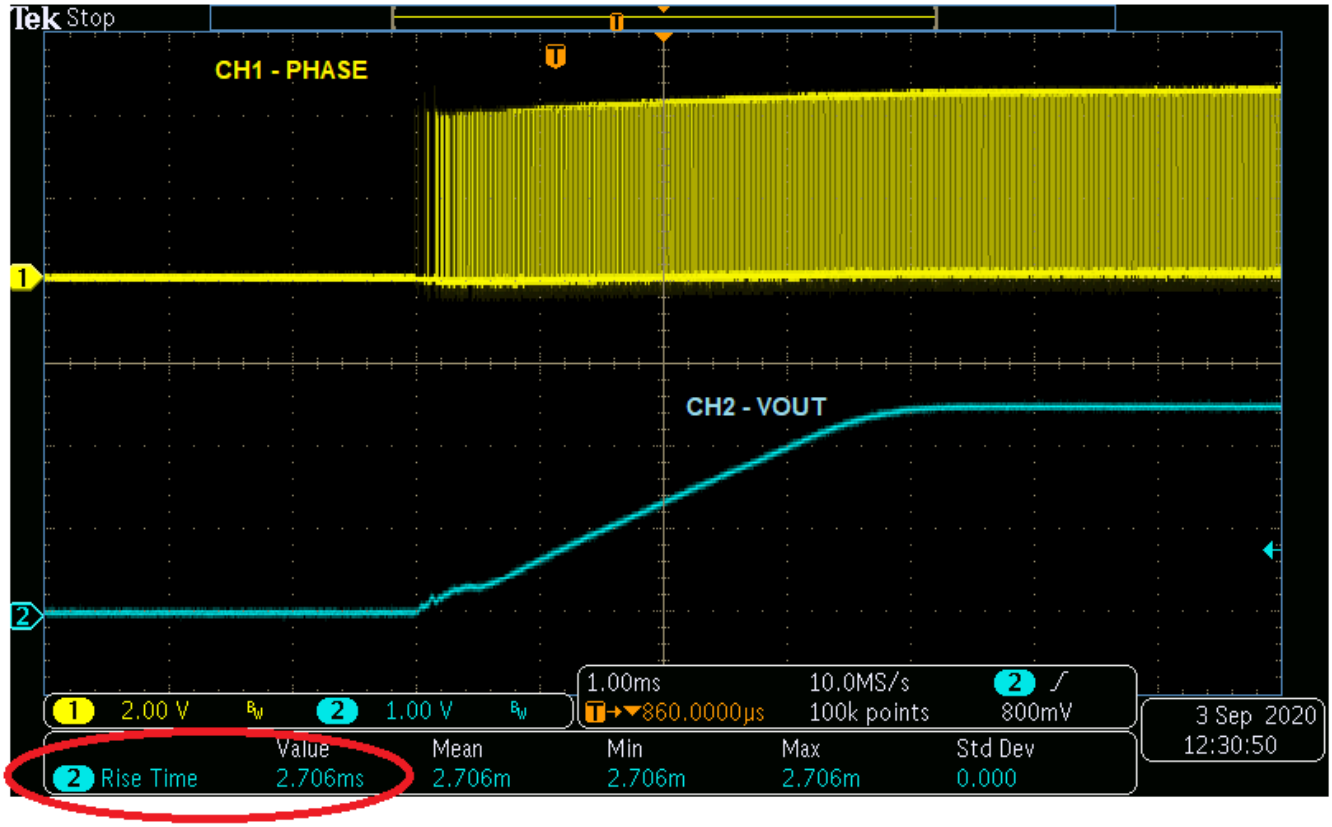

Figure 4-3. Output Soft Start Voltage, VIN = 5 V, VOUT = 2.5 V, IOUT = 3 A

4.4 Transient Response to Positive/Negative Load Step (0 A to 3A to 0A)

- Configure e-load to switch between 0 A and 3 A at a rate of 1 A/µs.
- On the oscilloscope, display CH2 (VOUT) [AC coupled, 50 mV/div] and CH3 (Output Current Probe) [1 A/div, trigger rising edge ≈ 120 mA] with 20 µs/div.

Figure 4-4 shows the response to this load step to be about 50mV, or 2%.

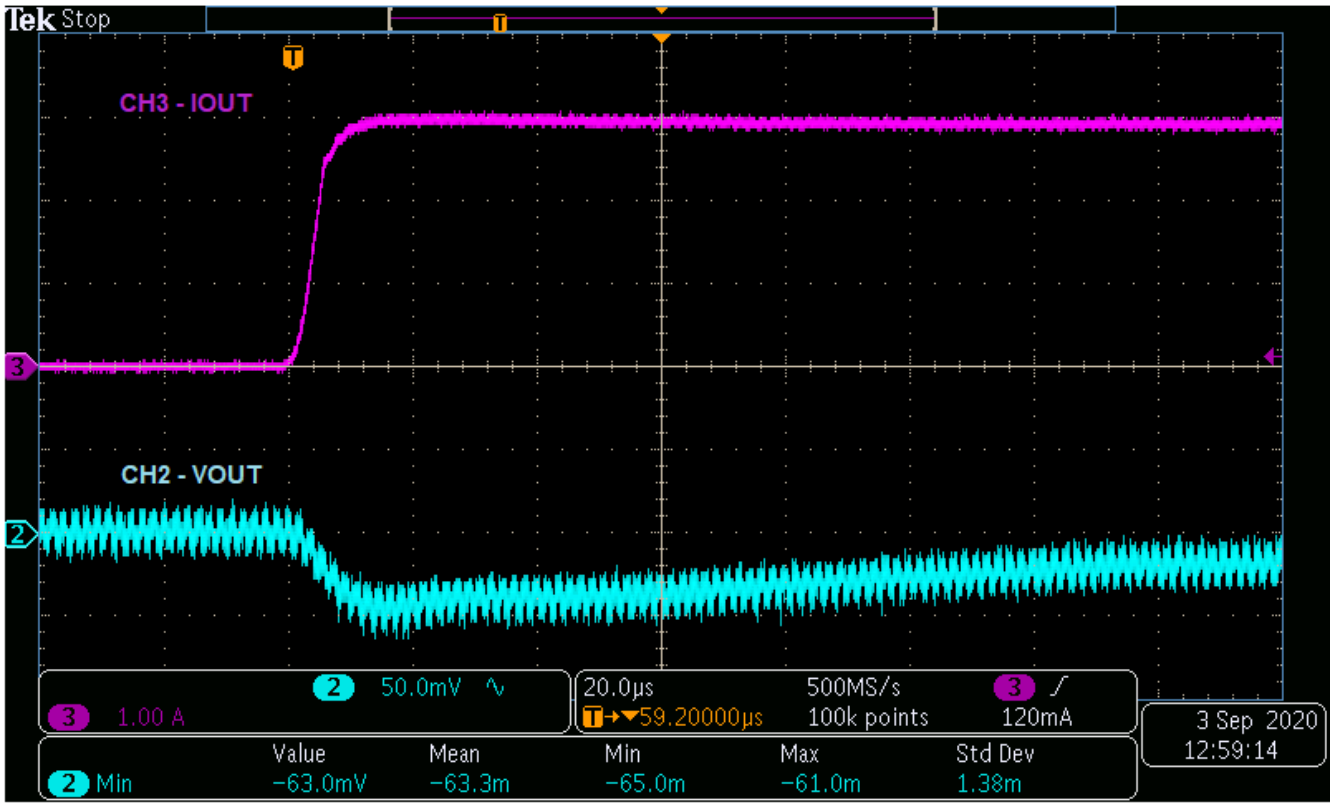

Figure 4-4. Transient Response to Load Step 0 A to 3 A at 1 A/µs

- Change the trigger on CH3 to falling edge to capture the transient response of VOUT to negative current step from 3 A to 0 A as shown in Figure 4-5.

  Again, transient deviation is approximately 50 mV, ignoring peak envelope, or 2%.

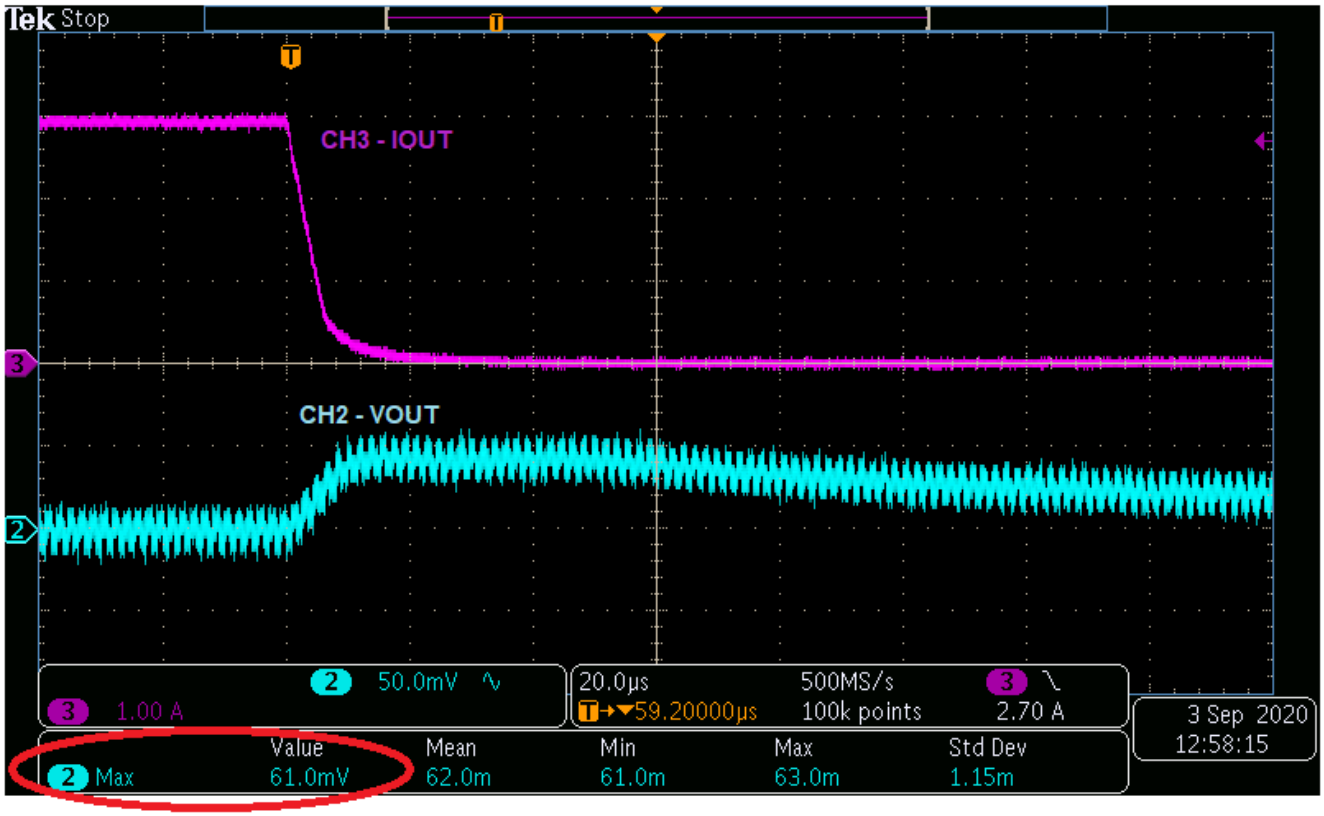

Figure 4-5. Transient Response to Load Step 3 A to 0 A at 1 A/µs

4.5 Input Voltage Ripple

- Trigger CH1 of the oscilloscope on Phase Node and put the CH2 scope probe between test point TP6 (PVIN) and TP23 (GND).

As shown in Figure 4-6, the voltage ripple (ignoring the switching coupling to the input) is approximately 50 mV.

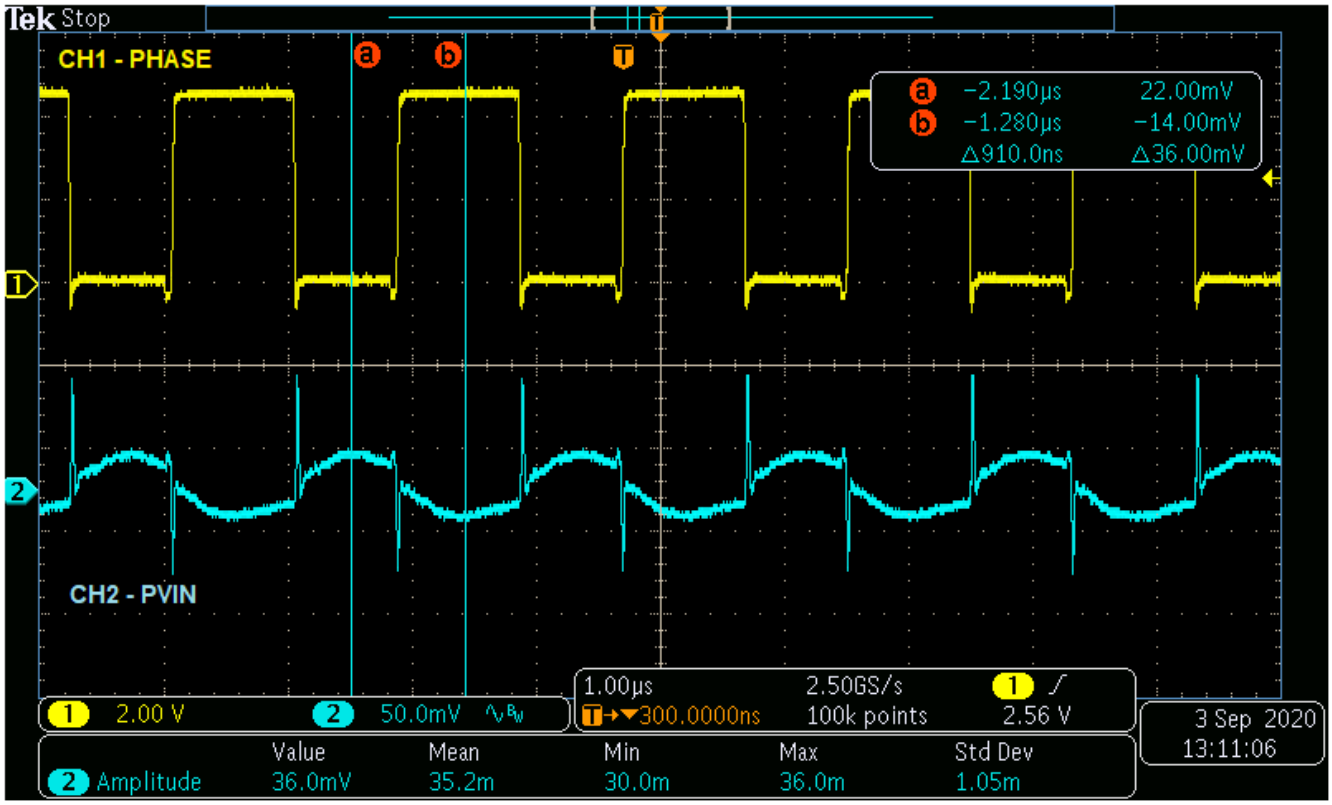

Figure 4-6. Input Voltage Ripple, VIN = 5 V, VOUT = 2.5 V, IOUT = 3 A

4.6 Loop Frequency Response

Measuring the frequency response of the feedback loop requires a unique test setup as well as physical changes to the EVM. The 0-Ω resistor jumper R9, just above the output inductor, L1, must be lifted to break the loop. Both test points TP20 (BODE) and TP15 (VOUT) are used for connections to the Bode100 instruments.

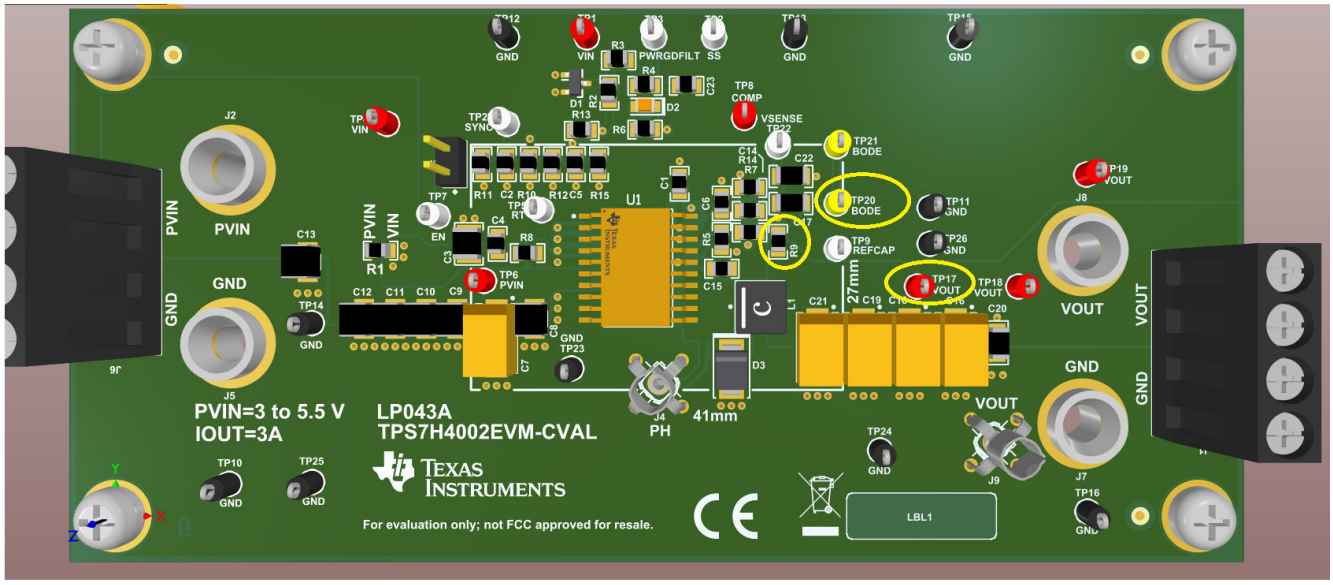

Figure 4-7. EVM Modification to Measure Frequency Response

The test setup which includes several connections to Picotest Bode100 test instruments is shown in Figure 4-8. Measurement results are shown in Figure 4-9 and in Figure 4-10. The CHF, high frequency pole, component of the compensation circuit is optional. Omitting it results in slightly increased phase margin. However, the benefit of including it is that the gain curve is set in a downward trajectory as frequency increases, making a monotonic gain curve more likely to be achieved.

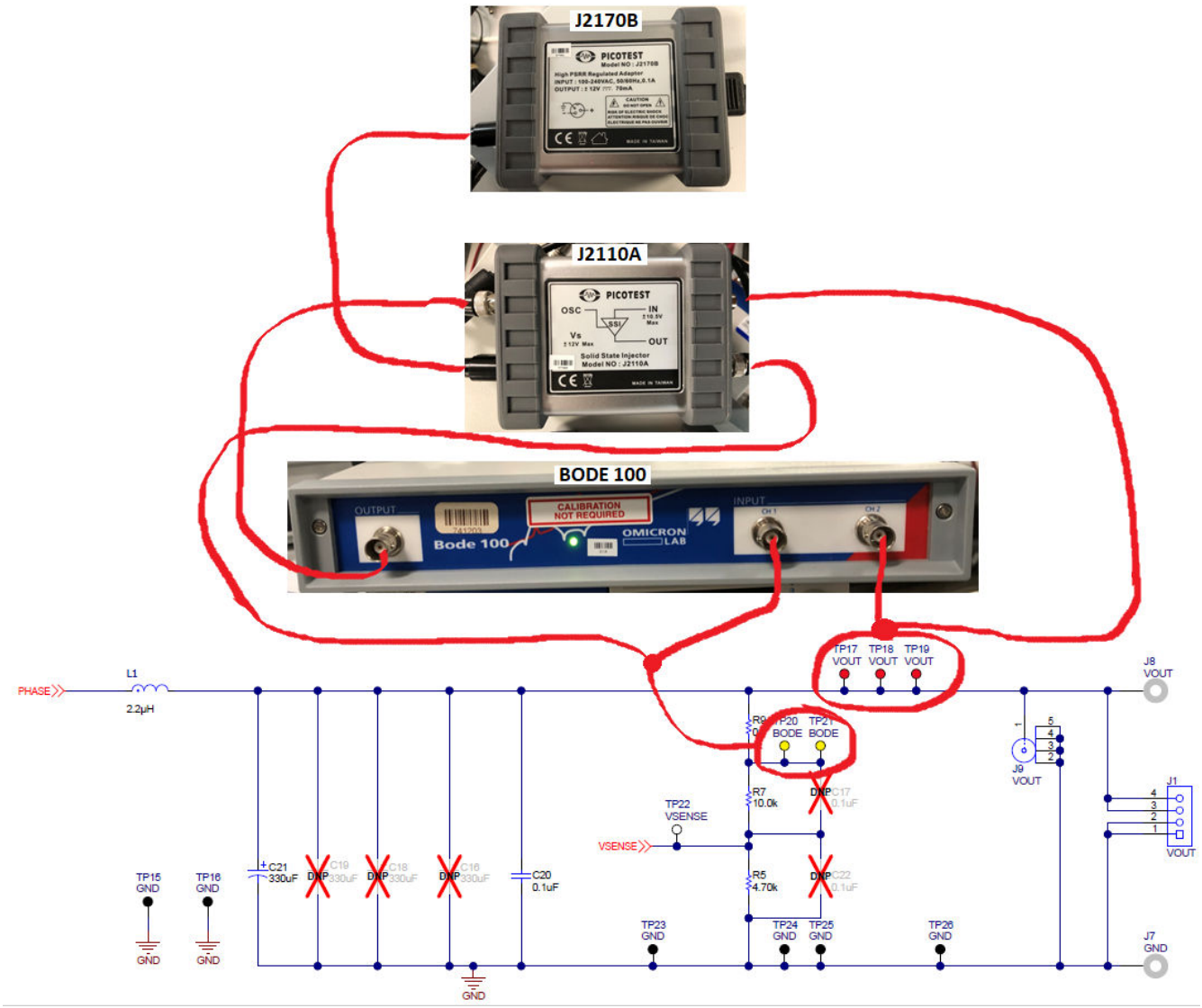

Figure 4-8. Frequency Response Test Setup

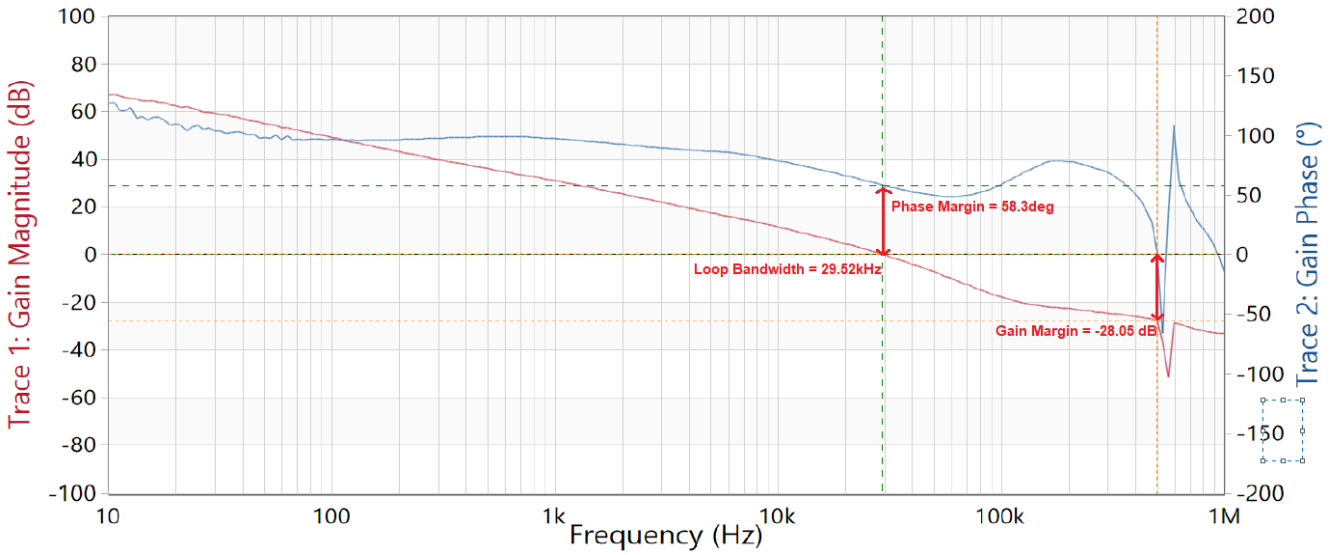

Figure 4-9. Frequency Response IOUT = 3 A

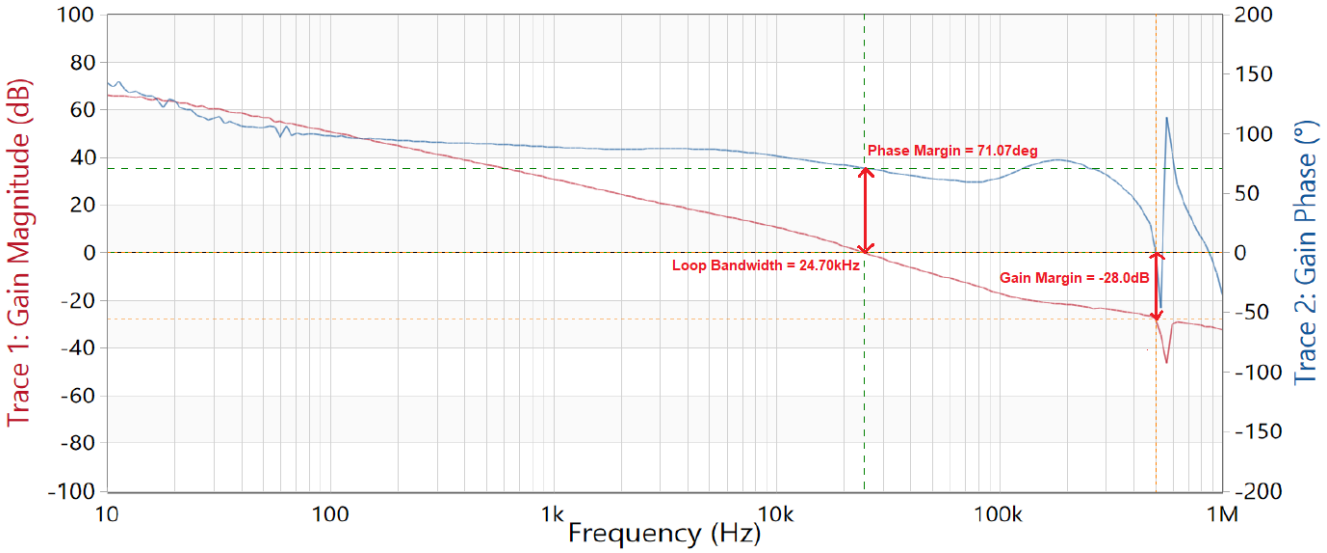

Figure 4-10. Frequency Response IOUT = 0 A

4.7 Current Limiting

Finally, it is worth mentioning the behavior of the device with regards to current limiting. Although, the recommended operating condition (ROC) of the device is to never exceed 3-A peak current, the design is robust enough to handle output currents up to the limiting mechanism of the device, which is typically 5–8 A, without damage to the DUT. This does not mean that external components cannot be damaged so it is imperative that the ratings of these components be in line with intended and, potential, unintended operational conditions.

Figure 4-11 shows what happens when the high-side current limit threshold is exceeded where channel 4 is measuring the output current after the LC output filter. As the output current exceeds the limit threshold, the soft start pin (Channel 3) is pulled low causing the switching node to slow significantly. As soft start voltage drops, the charge on the LC filter is discharged until the steady state threshold current limit is maintained until the fault is removed. Once the fault is removed, and, only after the soft start pin re-establishes a voltage level equal to the VSENSE pin (VOUT), does the device start switching again.

Figure 4-11. High-Side Current Limiting

5 TPS7H4002EVM-CVAL EVM Schematic

Figure 5-1 shows the EVM schematic.

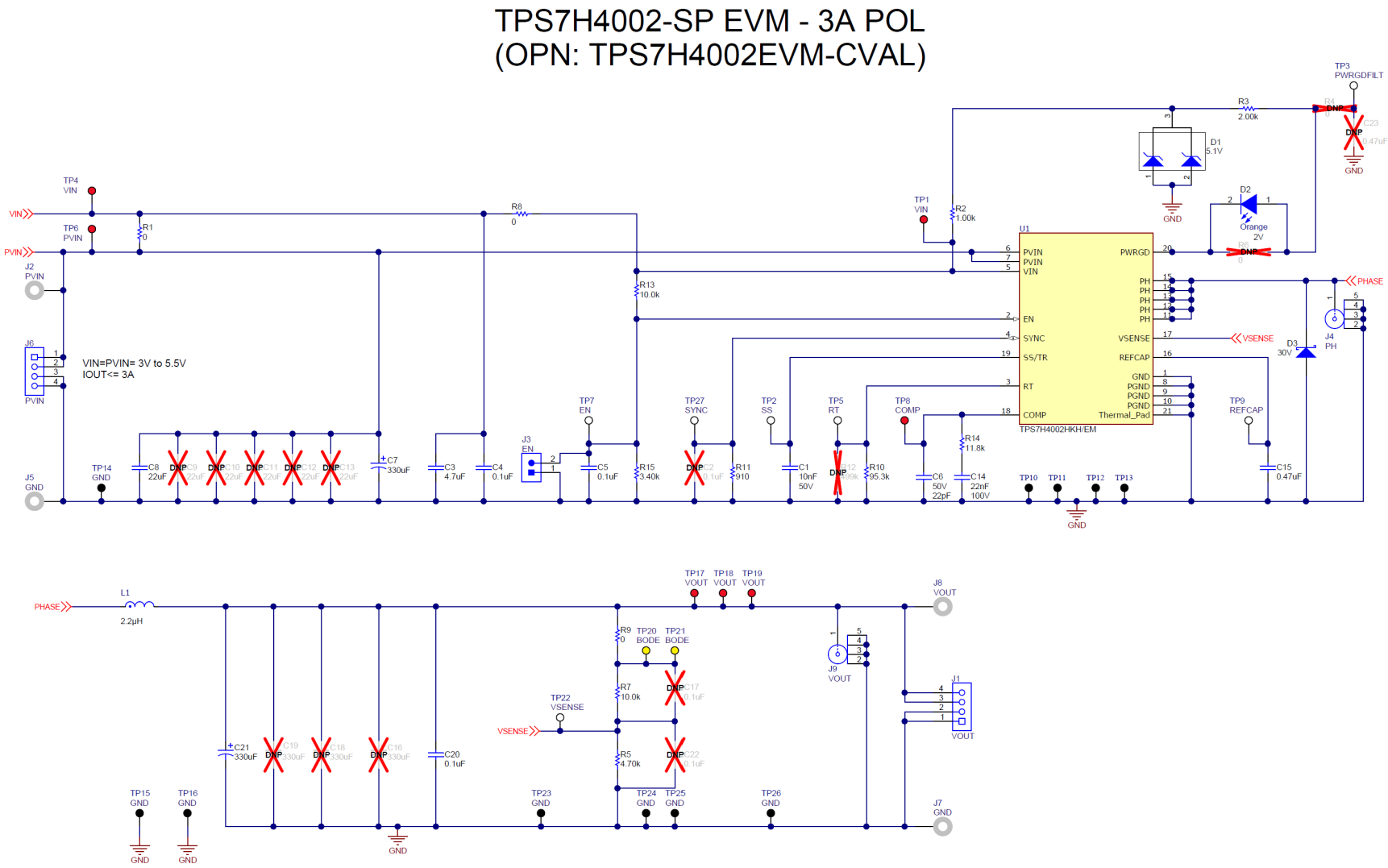

Figure 5-1. TPS7H4002EVM-CVAL EVM Schematic

6 TPS7H4002EVM-CVAL Bill of Materials (BOM)

Table 6-1 displays the EVM BOM.

Table 6-1. TPS7H4002EVM-CVAL Bill of Materials (BOM)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		LP043	Any
C1	1	0.01uF	CAP, CERM, 0.01 uF, 50 V, ±10%, X7R, 0805	0805	C0805C103K5RACTU	Kemet
C3	1	4.7uF	CAP, CERM, 4.7 uF, 10 V, ±10%, X7R, 1210	1210	C1210C475K8RACTU	Kemet
C4, C5	2	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±5%, X7R, 0805	0805	08055C104JAT2A	AVX
C6	1	22pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, 0805	0805	C0805C220J5GACTU	Kemet
C7, C21	2	330uF	CAP, Tantalum Polymer, 330 uF, 10 V, ±20%, 0.006 ohm, 7343-43 SMD	7343-43	T530X337M010ATE006	Kemet
C8	1	22uF	CAP, CERM, 22 uF, 16 V, ±10%, X7R, 1210	1210	C3225X7R1C226K250AC	TDK
C14	1	0.022uF	CAP, CERM, 0.022 uF, 100 V, ±10%, X7R, 0805	0805	08051C223KAT2A	AVX
C15	1	0.47uF	CAP, CERM, 0.47 uF, 50 V, ±10%, X7R, 0805	0805	C2012X7R1H474K125AB	TDK
C20	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±5%, X7R, 1206	1206	C1206C104J5RACTU	Kemet
D1	1	5.1V	Diode, Zener, 5.1 V, 300 mW, AEC-Q101, SOT-23	SOT-23	DZ23C5V1-E3-18	Vishay-Semiconductor
D2	1	Orange	LED, Orange, SMD	LED_0805	LTST-C170KFKT	Lite-On
D3	1	30V	Diode, Schottky, 30 V, 2 A, SMB	SMB	B230-13-F	Diodes Inc.
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J6	2		Terminal Block, 4x1, 5.08mm, TH	4x1 Terminal Block	39544-3004	Molex
J2, J5, J7, J8	4		Standard Banana Jack, Uninsulated, 5.5mm	Keystone_575-4	575-4	Keystone
J3	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
J4, J9	2		Compact Probe Tip Circuit Board Test Points, TH, 25 per	TH Scope Probe	131-5031-00	Tektronix
L1	1		Shielded Power Inductor 2.2µH 12.1A 12.43mOhm Max 2SMD	SMD2	XEL5050-222MEC	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
R1, R8, R9	3	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EA	Vishay-Dale
R2	1	1.00k	RES, 1.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF1001V	Panasonic
R3	1	2.00k	RES, 2.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF2001V	Panasonic
R5	1	4.70k	RES, 4.70 k, 0.1%, 0.125 W, 0805	0805	RG2012P-472-B-T5	Susumu Co Ltd
R7	1	10.0k	RES, 10.0 k, 0.1%, 0.125 W, 0805	0805	RG2012P-103-B-T5	Susumu Co Ltd
R10	1	95.3k	RES, 95.3 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW080595K3FKEA	Vishay-Dale
R11	1	910	RES, 910, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW0805910RJNEA	Vishay-Dale
R13	1	10.0k	RES, 10.0 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW080510K0FKEA	Vishay-Dale
R14	1	11.8k	RES, 11.8 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF1182V	Panasonic
R15	1	3.40k	RES, 3.40 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08053K40FKEA	Vishay-Dale
TP1, TP4, TP6, TP8, TP17, TP18, TP19	7		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone

Table 6-1. TPS7H4002EVM-CVAL Bill of Materials (BOM) (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
TP2, TP3, TP5, TP7, TP9, TP22, TP27	7		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone
TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP23, TP24, TP25, TP26	11		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
TP20, TP21	2		Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint	5004	Keystone
U1	1		Radiation Hardness Assured (RHA) 3-V to 7-V Input, 3-A Synchronous Step Down Converter	CFP20	TPS7H4002HKH/EM	Texas Instruments
C2	0	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±5%, X7R, 0805	0805	08055C104JAT2A	AVX
C9, C10, C11, C12, C13	0	22uF	CAP, CERM, 22 uF, 16 V, ±10%, X7R, 1210	1210	C3225X7R1C226K250AC	TDK
C16, C18, C19	0	330uF	CAP, Tantalum Polymer, 330 uF, 10 V, ±20%, 0.006 ohm, 7343-43 SMD	7343-43	T530X337M010ATE006	Kemet
C17, C22	0	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±5%, X7R, 1206	1206	C1206C104J5RACTU	Kemet
C23	0	0.47uF	CAP, CERM, 0.47 uF, 50 V, ±10%, X7R, 0805	0805	C2012X7R1H474K125AB	TDK
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R4, R6	0	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EA	Vishay-Dale
R12	0	499k	RES, 499 k, 0.1%, 0.125 W, 0805	0805	RG2012P-4993-B-T5	Susumu Co Ltd

7 Board Layout

Figure 7-1 through Figure 7-11 illustrate the layer stack of the TPS7H4002EVM-CVAL board.

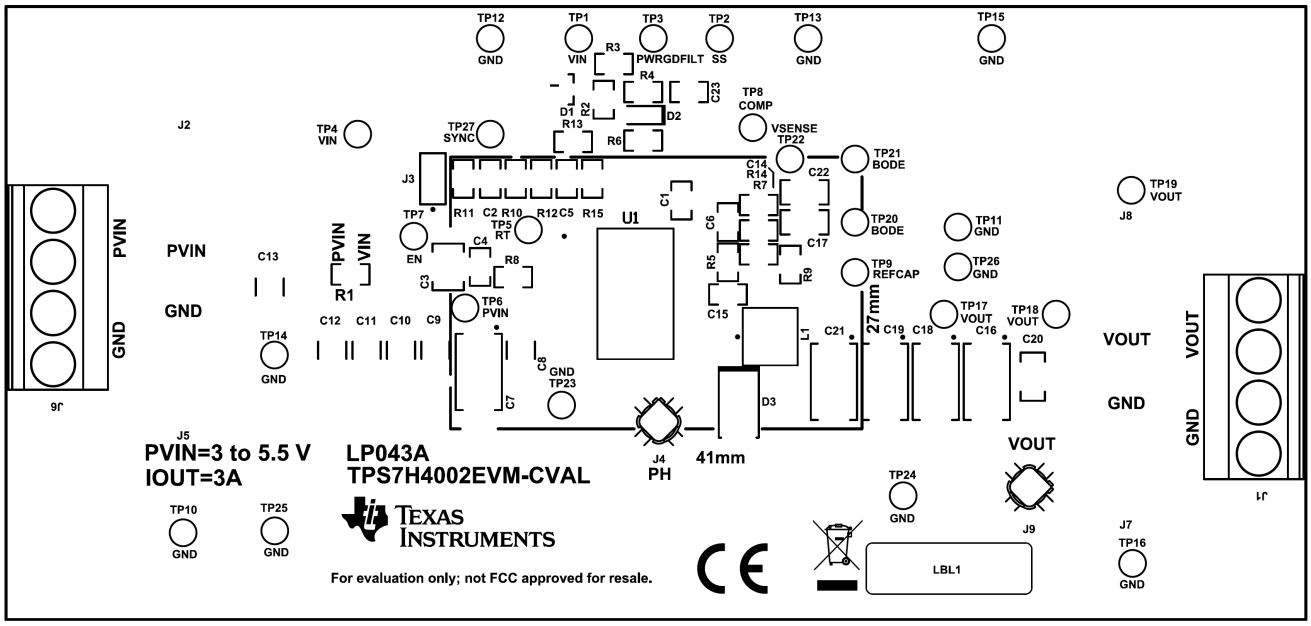

Figure 7-1. Top Overlay

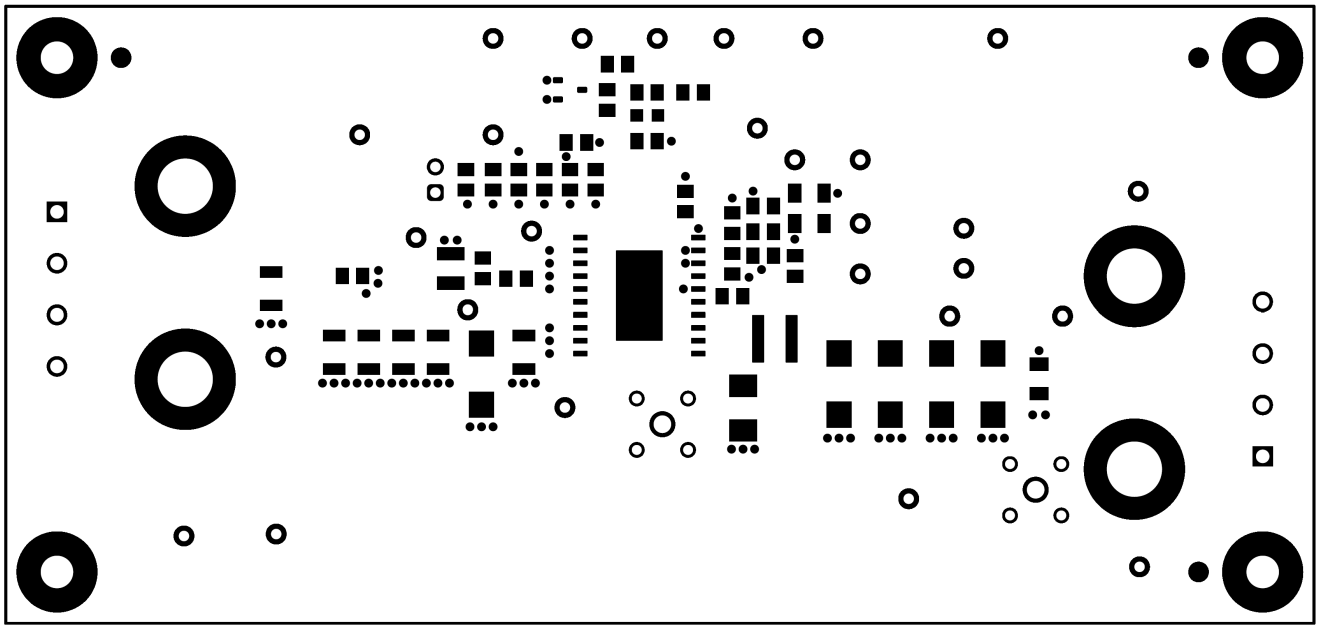

Figure 7-2. Top Solder

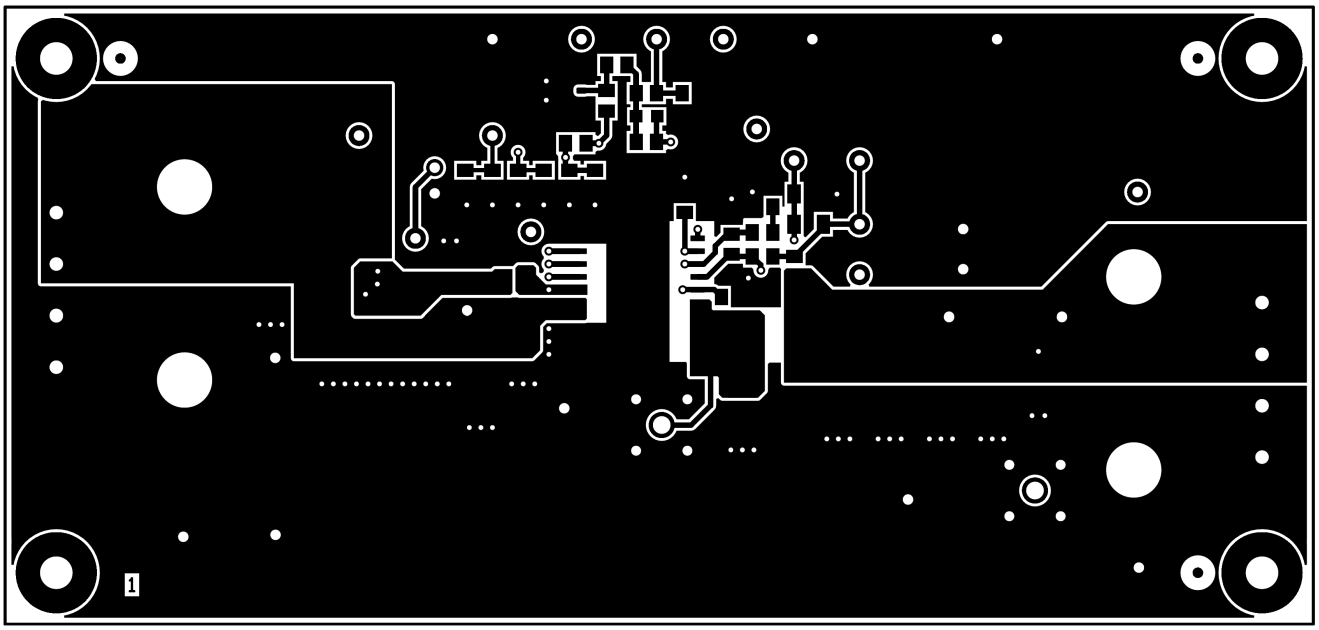

Figure 7-3. Layer 1 -Top Layer

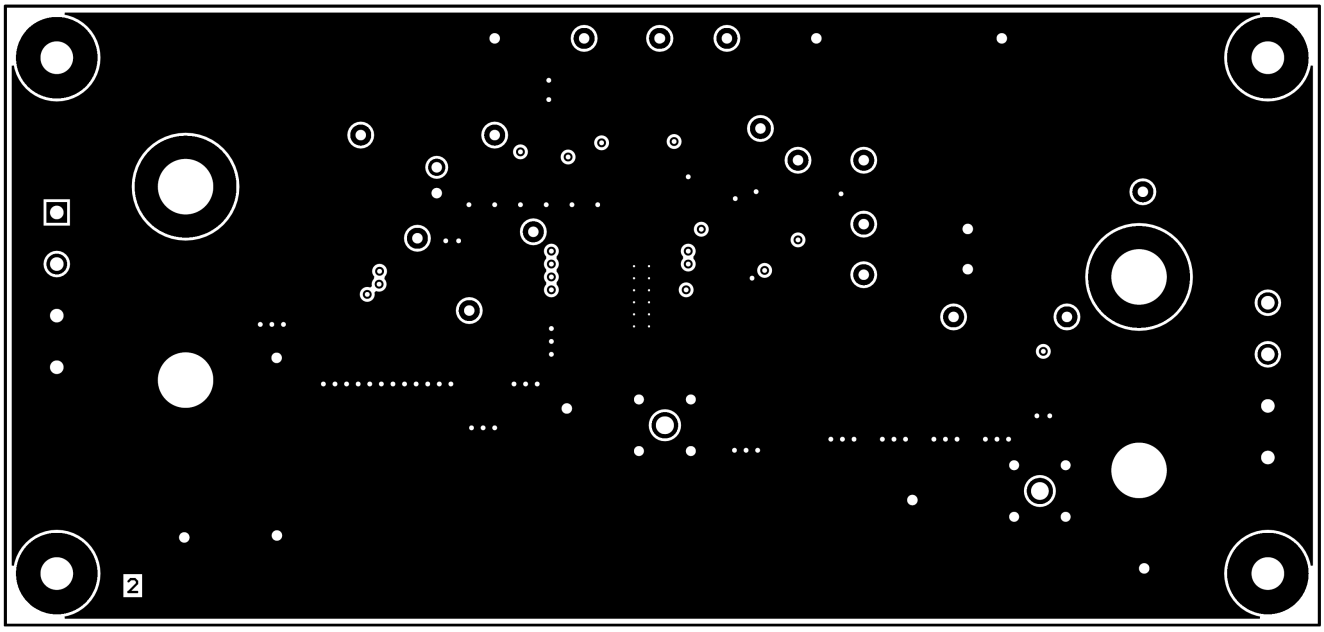

Figure 7-4. Layer 2- GND

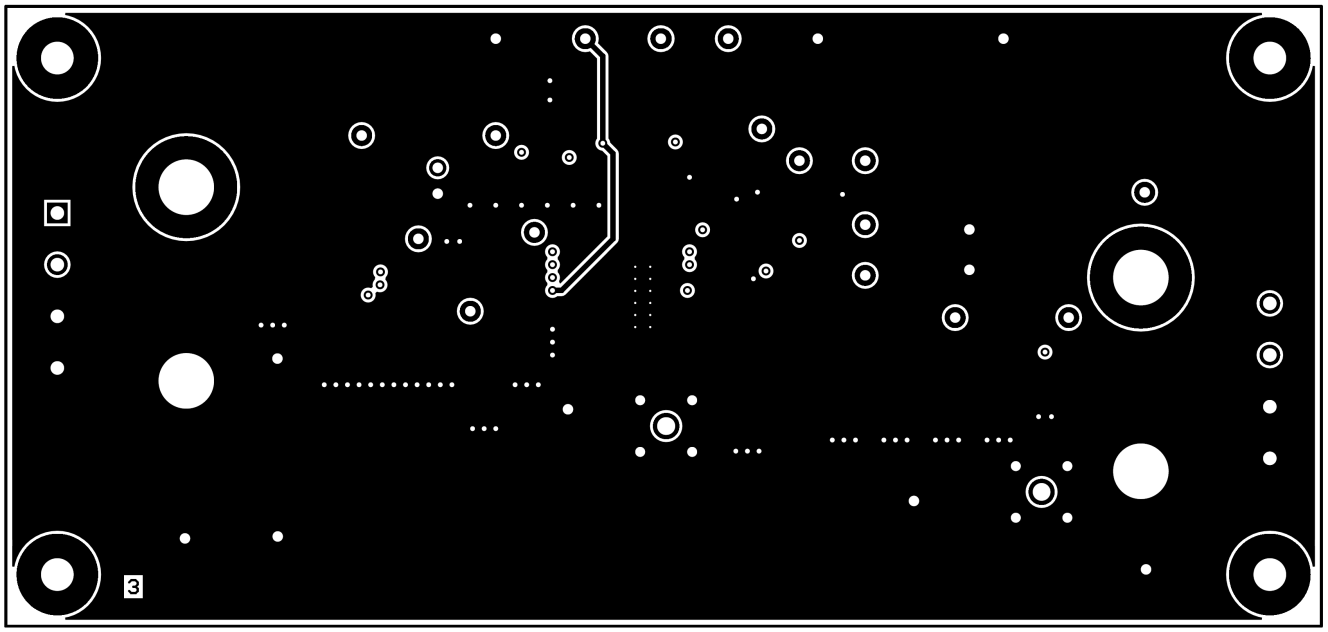

Figure 7-5. Layer Three - Signal

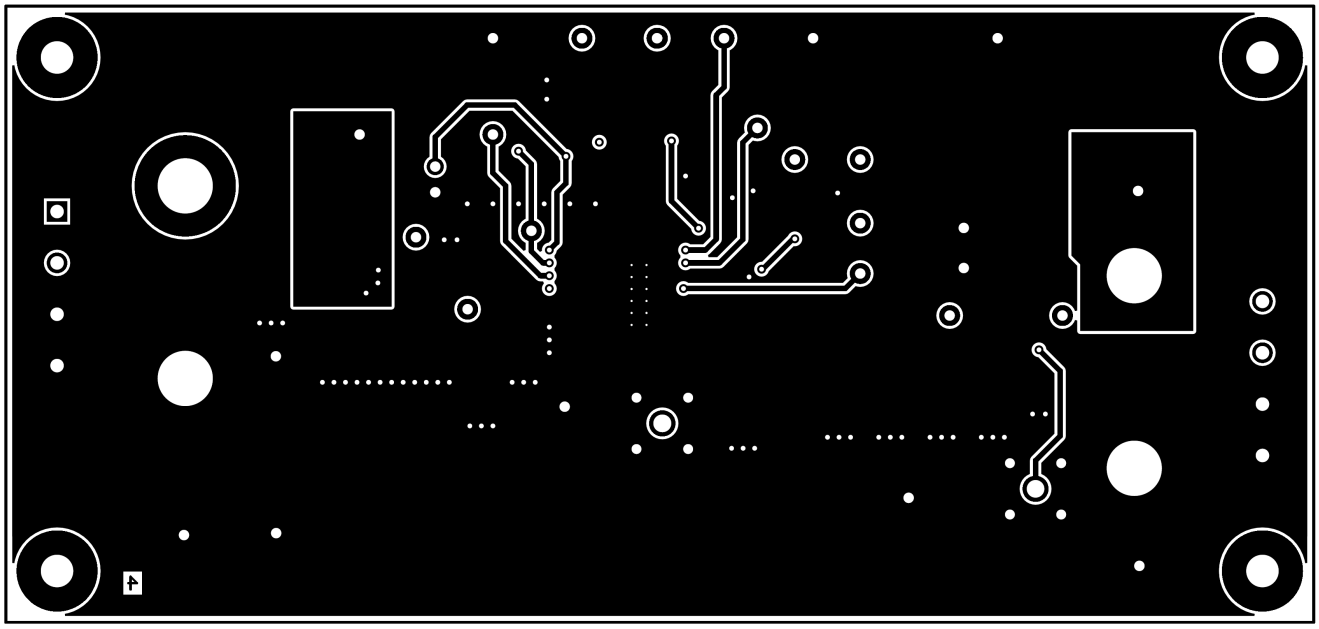

Figure 7-6. Layer Four -Bottom Layer

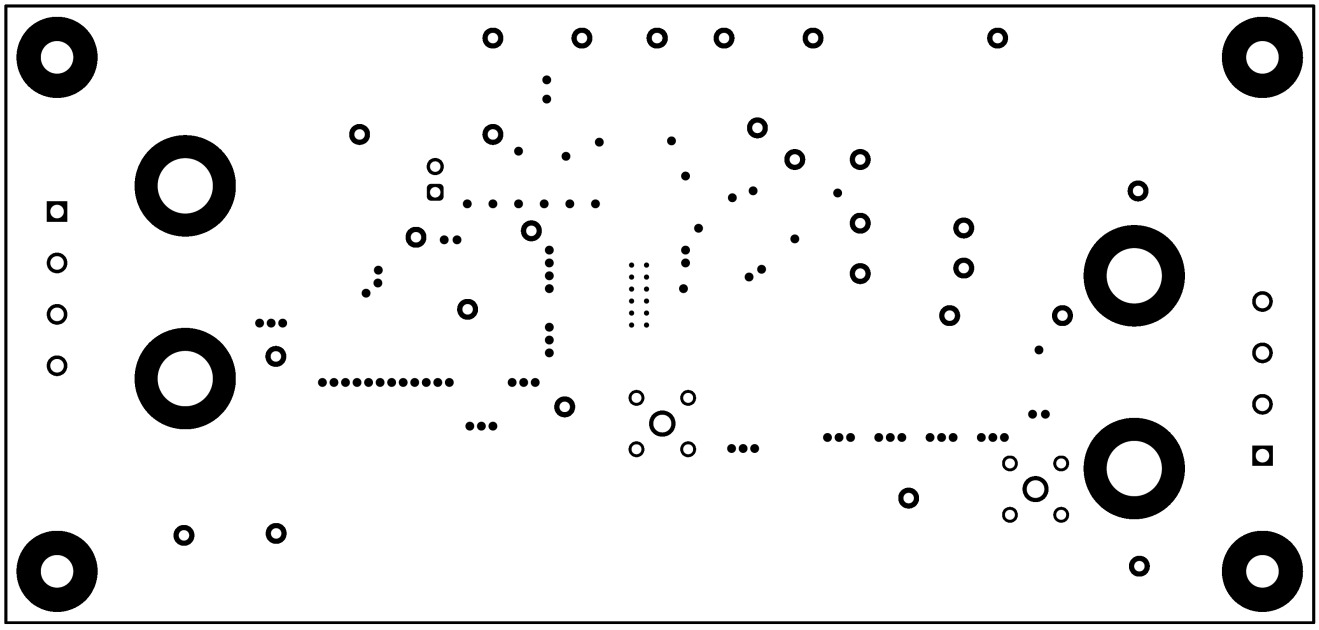

Figure 7-7. Bottom Solder

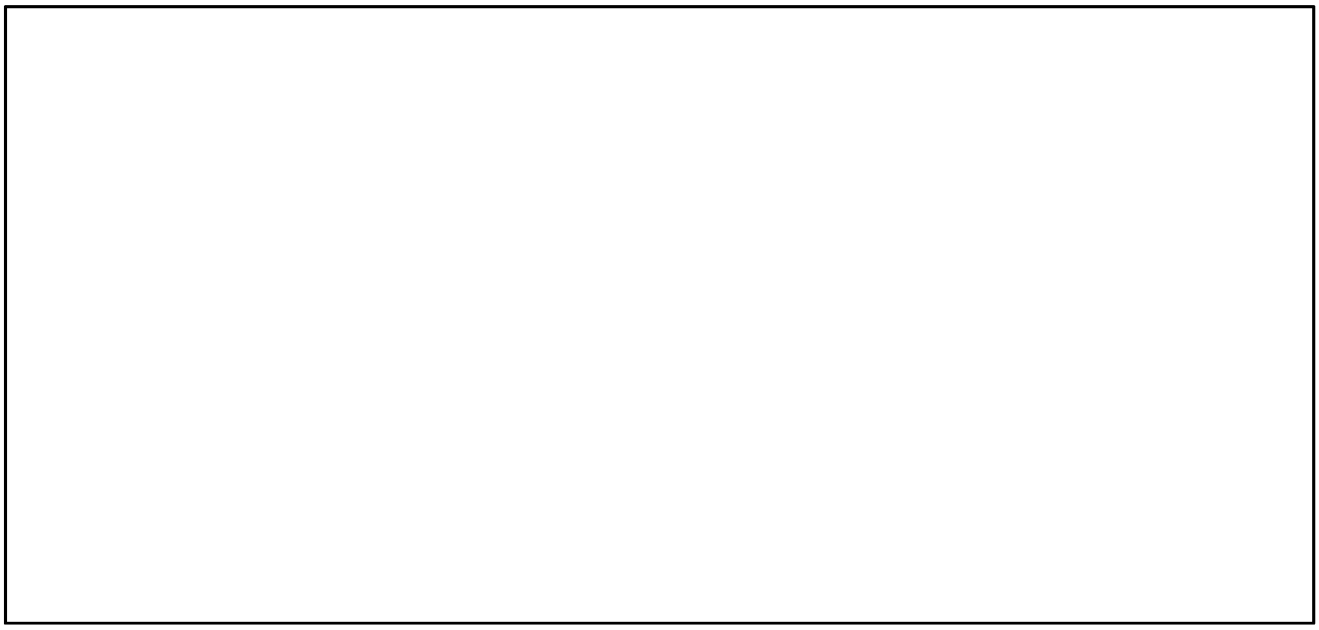

Figure 7-8. Bottom Overlay

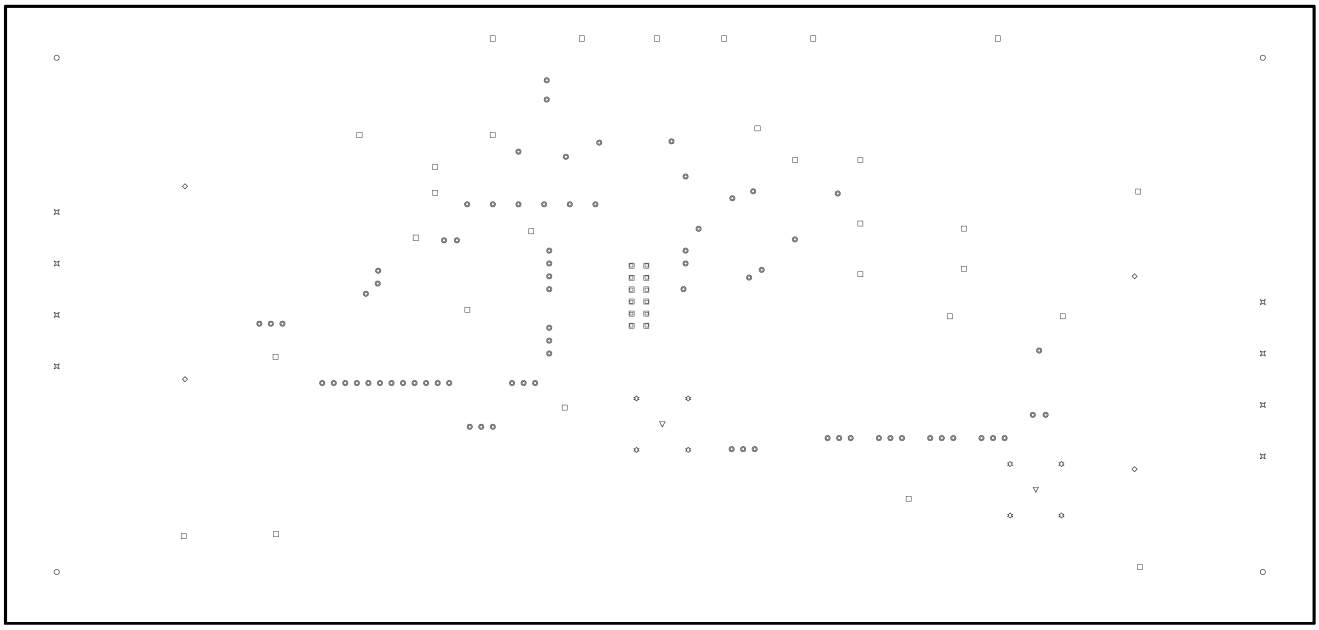

Figure 7-9. Drill Drawing

DRILL CHART:

Symbol	Count	Hole Size	Plated	Hole Type	Tolerance (Mil)
▣	12	7.87mil (0.200mm)	PTH	Round	+0/-7.87
◎	74	18.00mil (0.457mm)	PTH	Round	+0/-18
✡	8	38.00mil (0.965mm)	PTH	Round	+/-3
□	29	40.00mil (1.016mm)	PTH	Round	+/-3
⧓	8	52.00mil (1.321mm)	PTH	Round	+/-3
▽	2	68.00mil (1.727mm)	PTH	Round	+/-3
○	4	125.98mil (3.200mm)	PTH	Round	+/-3
◇	4	214.57mil (5.450mm)	PTH	Round	+/-3
	141 Total				

Figure 7-10. Drill Table

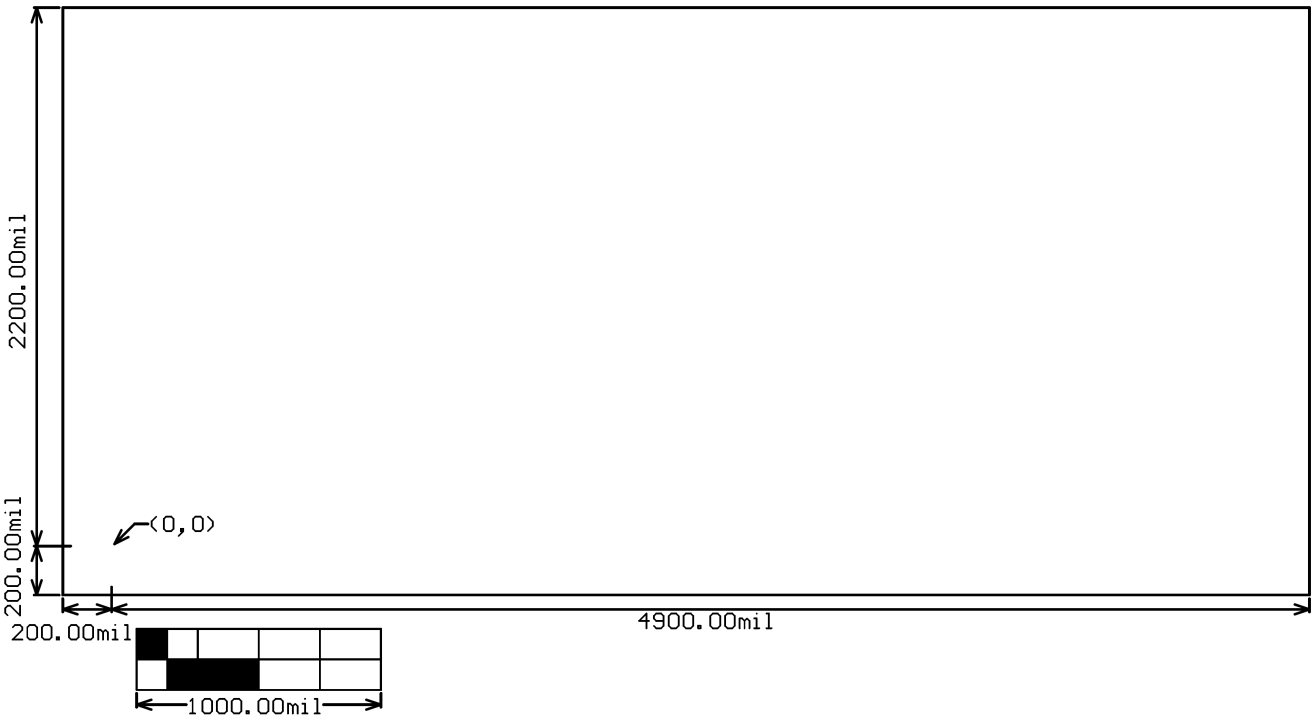

Figure 7-11. Board Dimensions

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