User's Guide

TPS7H4010EVM User's Guide

ABSTRACT

The TPS7H4010-SEP (Space Enhanced Plastic) evaluation module (EVM) with orderable part number TPS7H4010EVM, is designed to help customers evaluate the performance of the TPS7H4010-SEP synchronous step-down voltage converter. The EVM contains two independent buck converter circuits, each of which contains the TPS7H4010-SEP which is in the 30-pin wettable flanks QFN (WQFN) package. The two circuits deliver very accurate output voltages at 1.8 V and 3.3 V with up to 6 A current capacity with exceptional efficiency in a very small solution size. The EVM provides multiple power connectors and test points, as well as mode setting and enable input options, allowing for flexibility in testing.

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Trademarks

All other trademarks are the property of their respective owners.

1 Introduction

1.1 TPS7H4010 Space Enhanced Plastic Evaluation Module

The TPS7H4010-SEP (Space Enhanced Plastic) evaluation module (EVM), shown in Figure 1-1with orderable part number TPS7H4010EVM, is designed to help customers evaluate the performance of the TPS7H4010-SEP synchronous step-down voltage converter. The EVM contains two independent buck converter circuits, each of which contains the TPS7H4010-SEP which is in the 30-pin wettable flanks QFN (WQFN) package, as described in Table 1-1. The two circuits deliver very accurate output voltages at 1.8 V and 3.3 V with up to 6 A current capacity with exceptional efficiency in a very small solution size. The EVM provides multiple power connectors and test points, as well as mode setting and enable input options, allowing for flexibility in testing.

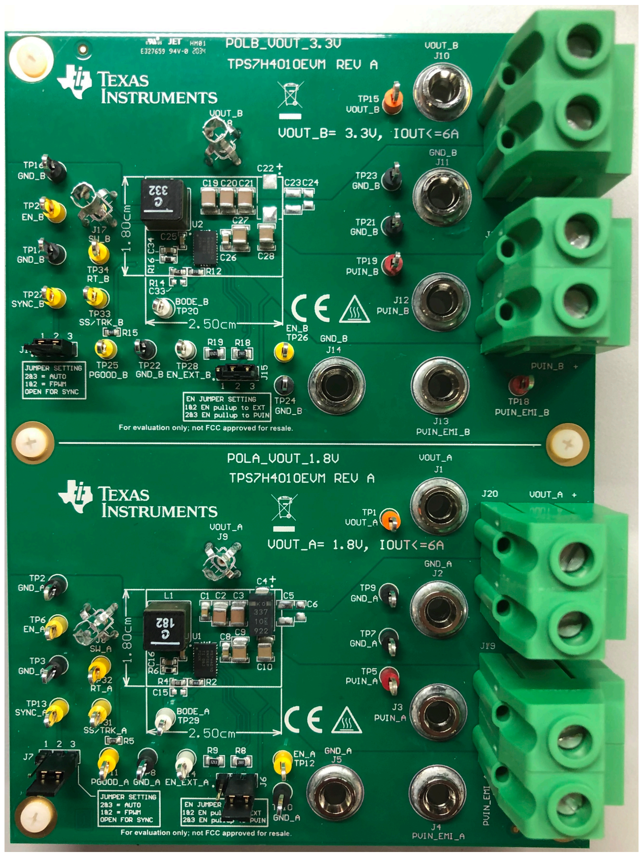

Figure 1-1. TPS7H4010EVM

Table 1-1. Device and Package Configurations

CONVERTER	IC	PACKAGE
U1, U2	TPS7H4010-SEP	30-pin wettable flanks QFN (WQFN) 6 mm × 4 mm × 0.8 mm

1.2 TPS7H4010-SEP Synchronous Step-Down Voltage Converter

The TPS7H4010-SEP is an easy-to-use synchronous step-down DC-DC converter capable of driving up to 6 A of load current from a supply voltage ranging from 3.5 V to 30 V. The TPS7H4010-SEP provides exceptional efficiency and output accuracy in a very small solution size. Peak-current-mode control is employed. Additional features such as adjustable switching frequency, synchronization to an external clock, FPWM option, power-good flag, precision enable, adjustable soft start, and tracking provide both flexible and easy-to-use solutions for a wide range of applications. Automatic frequency foldback at light load and optional external bias improve efficiency over the entire load range. The device requires few external components and has a pinout designed for simple PCB layout with optimal EMI and thermal performance. Protection features of the device include thermal shutdown, input undervoltage lockout, cycle-by-cycle current limiting, and hiccup short-circuit protection.

The pin configuration of the TPS7H4010-SEP is shown in Figure 1-2 and the schematic is shown in Figure 1-3 for your quick reference.

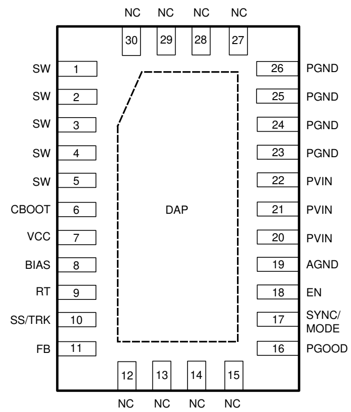

Figure 1-2. TPS7H4010-SEP Pin Configuration (30-Pin WQFN Package Top View)

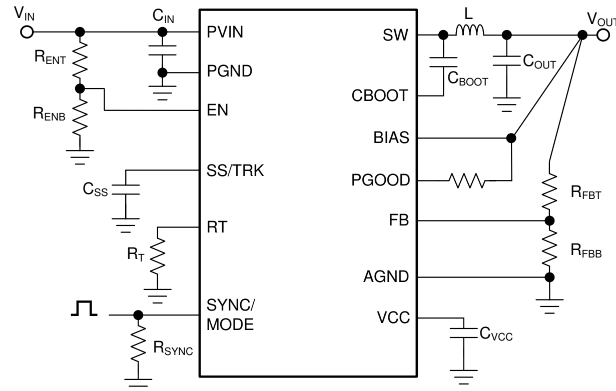

Figure 1-3. TPS7H4010-SEP Schematic

1.3 TPS7H4010-SEP Evaluation Module

The TPS7H4010-SEP evaluation module is orderable part number TPS7H4010EVM. The EVM contains two independent converter circuits targeting two common applications:

- POLA: FSW=500 kHz, PVIN=5 V, VOUT=1.8 V, IOUT=0 A to 6 A
- POLB: FSW=500 kHz, PVIN=12 V, VOUT=3.3 V, IOUT=0 A to 6 A

Although the device operates over a wide PVIN range of 3.5 V to 30 V, the two circuits are optimized for PVIN of 5 V and 12 V. Table 1-2 summarizes the two circuits.

Table 1-2. Converter Circuit Variants

Label	U1/U2	I_{OUT}	Switching Frequency	V_{IN} Range	V_{OUT}
POLA_VOUT_1.8V	TPS7H4010-SEP	6 A	500 kHz	5 to 30 V	1.8 V
POLB_VOUT_3.3V	TPS7H4010-SEP	6 A	500 kHz	5 to 30 V	3.3 V

It is worth noting that the package size of the TPS7H4010-SEP at U1 and U2 is not large enough to hold the full device name. The devices are labeled 'PS7H4010' as shown in graphic below. Despite the device name starting with "P", these devices are production devices and should not be mistaken for protoypes.

Figure 1-4. TPS7H4010-SEP Package Marking

2 Quick Start

The following instructions explain how to quickly setup testing of POLA_VOUT_1.8V circuit. Testing of the POLB_VOUT_3.3V circuit is analogous to this setup with connections moving to that converter circuit. [NOTE: Each converter circuit provides two connection options for PVIN and VOUT. PVIN can be supplied to banana jacks J3/J2 or terminal block J19. VOUT can be connected to banana jacks J1/J2 or terminal block J20. It is recommended to use terminal blocks instead of banana jacks if currents of 5 A or more are being tested.]

1. Connect the input voltage supply between J3, PVIN_A, and J2, GND_A using short, low gauge wires. [Note: For very accurate PVIN control across all load conditions, connect sense lines from power supply to testpoints TP5, PVIN_A, and TP7, GND_A.]
2. Connect the load of the converter between J1, VOUT_A, and J2, GND_A using short, low gauge wires.
3. Set the supply voltage (PVIN) to 5V with a current limit set to 4 A (expect ~2.6 A maximum).
4. Turning on the PVIN power supply, the converter should provide a regulated V_{OUT} = 1.8 V across all current load conditions from 0 A to 6 A.

3 Detailed Descriptions

This section describes the connectors and the test points on the EVM and how to properly connect, set up and use the TPS7H4010EVM. See Figure 1-2 for a top view of the EVM. The "_x" in the table below refers collectively to the the two converter circuits on the PCB: "POL_A" and "POL_B".

VOUT_A (J1 or J20+) VOUT_B (J10 or J22+)
Output voltage of the converter.

VOUT_x banana jack and terminal block connectors connect to the power inductor and the output capacitors. Connect the loading device between VOUT_x and GND_x connectors to provide loading to the converter. Connect the loading device to the board with short and thick wires to handle the large DC output current.

GND_A (J2 or J20-) GND_B (J11 or J22-)
Ground of the converter.

It is connected to the PGND and AGND of the device, as well as the input and output capacitors. GND_x is the current return path for both supply voltage and load. Connect to supply and load grounds with short and thick wires.

PVIN_A (J3 or J19+) PVIN_B (J12 or J21+)
Input voltage to the converter.

PVIN_x connectors and test points connect to the input capacitors and the PVIN pins of the TPS7H4010-SEP. Connect the supply voltage from a power supply or a battery between PVIN_x and GND_x connectors as power input to the board. The voltage range should be higher than 3.5 V for the device to be active. PVIN should be no higher than 30 V to avoid damaging the device. The current limit on the supply should be high enough to provide the needed supply current, otherwise, the power supply will not maintain the desired voltage. The supply voltage should be connected to the board with short and thick wires to handle the pulsing input current. If long cables are used to power up the board, the damping capacitors C14 and C32, located on the bottom side of board, should be added to avoid oscillations between the cable parasitic inductance and the low-ESR ceramic capacitors.

PVIN_EMI_A (J4) PVIN_EMI_B (J13)
Input voltage to input filter of the converter (not installed by default)

If the input filter is desired between the supply voltage and the TPS7H4010-SEP, connect the supply voltage between PVIN_EMI_x and GND_x. The supply voltage should be connected to the board with short and thick wires to handle pulsing input current.

GND_A (J5) GND_B (J14)
Ground connection near the input filter

This is the current return path for the supply connected to PVIN_EMI_x. It provides a direct connection to the input filter capacitors to best filter the conducted noises generated from the PCB. Use PVIN_EMI_x and GND_x connection if input filter is used and conducted EMI test is desired.

POLA_Input Filter (C11, C12, C13, C14, L2) POLB_Input Filter (C29, C30, C31, C32, L4)
Reduces noise from supply voltage

The input filter consists of a C-L-C pi configuration, located on the bottom side of the PCB. To include the input filter in the power path, connect the supply voltage between the PVIN_EMI_x and GND_x connectors. The output of the filter is connected to the PVIN net, which is connected to the PVIN pins of the TPS7H4010-SEP and the input capacitors. Note that the input filter components are not mounted on the PCB by default.

Conducted EMI arises from the normal operation of switching circuits. The ON and OFF actions of the power switches generate large discontinuous currents. The discontinuous currents are present at the input side of buck converters. Voltage ripple generated by discontinuous currents can be conducted to the voltage supply of the buck converter via physical contact of the conductors. Without control, excessive input voltage ripple can compromise operation of the source. The input filter helps to smooth out the voltage perturbations leading to the source.

EN_A (TP12) EN_B (TP26)
Test point to monitor the EN pin of the device

EN_A Jumper (J6) EN_B Jumper (J15)
Set EN pin options

As noted on the board, this jumper selects which voltage is used to enable the device (schematic is shown in Figure 1-3)

1. PIN-1 to PIN-2: EN_x is connected to EN_EXT_x test point through a resistor divider.
2. PIN-2 to PIN-3 (default): EN_x is connected to PVIN_x through a resistor divider.

The default setting is jumper on PIN-2 and PIN-3. The board will start when PVIN is about 3.5 V with this setting. The EN voltage is calculated by Equation 1.

$$V_{EN} = PVIN \times R_{ENB} / (R_{ENT} + R_{ENB}) \quad (1)$$

When PIN-1 and PIN-2 are connected, the EN voltage is calculated by Equation 2.

$$V_{EN} = V_{EN\_EXT} \times R_{ENB} / (R_{ENT} + R_{ENB}) \quad (2)$$

If a resistor divider is not desired, the R_{ENB} can be removed from the board and the EN pin voltage will be equal to either EN_EXT_x or PVIN voltage, depending on the jumper location. It is recommended to keep R_{ENT} as a current limiting and noise filtering resistor at EN pin.

EN_EXT_A (TP14) EN_EXT_B (TP28)
External voltage input to drive EN

When EN_x jumper has PIN-1 and PIN-2 connected, the enable threshold is driven by the voltage on the EN_EXT_x test point. The EN_x pin voltage can be found by Equation 2.

Remove R_{ENB} from the board if it is desired to have the same voltage on the EN pin as the EN_EXT_x voltage (schematic is shown in Figure 1-3).

PGOOD_A (TP11) PGOOD_B (TP25)
Test point to monitor the PGOOD_x pin

PGOOD_x test points are used to monitor the power-good flag. This flag indicates whether the output voltage has reached its regulation level. The PGOOD pin of the device is an open-drain output that is pulled up to V_{OUT} on this board through 100kohm resistor.

MODE_A Jumper (J7) MODE_B Jumper (J16)
Operation mode setting and synchronization clock input

As noted on the PCB, the MODE_x jumper is used to select the desired light-load operation mode.

1. PIN-1 to PIN-2: FPWM mode;
2. PIN-2 to PIN-3 (default): auto mode;
3. Open, connect external clock input to SYNC_x test points (TP13, TP27) for synchronization and FPWM mode.

The default is PIN-2 and PIN-3 connected together and the device will operate in auto mode at light loads. With auto mode, discontinuous conduction mode (DCM) and pulse frequency modulation (PFM) mode are employed at light loads to provide high efficiency. PFM mode also provides very low quiescent current at no load. At heavier load, when inductor current is in DCM or continuous conduction mode (CCM) operation, the switching frequency is determined by the RT resistors (R6, R16) on the board, which is either 500 kHz.

When PIN-1 and PIN-2 are connected, the device operates in the force PWM (FPWM) mode. In FPWM, the inductor current will be in CCM regardless of load. The switching frequency is the same at light loads as that of heavier loads. The switching frequency will be programmed by RT resistors (R6, R16) on the board, which is 500 kHz.

If synchronization to an external clock is desired, leave the MODE_x jumper open and connect the clock input between SYNC_x test points (R13, R27) and a GND test point. The device will operate in FPWM when it is synchronized to an external clock.

SYNC_A (TP13)
SYNC_B (TP27)

Test point to monitor the SYNC/MODE pin and external clock input

The SYNC_x test point can used to monitor the SYNC/MODE pin voltage on the device. It is also the external clock input if synchronization is needed. Connect the external clock input to the SYNC_x test point with the MODE_x jumper open on all pins. The external clock frequency must be between 350 kHz and 2.2 MHz if used. The device operates in FPWM when synchronized to a clock.

VCC_A (TP6)
VCC_B (TP20)

Test point to monitor the VCC pin

This test point is to monitor the voltage at the VCC output.

4 Schematic

The TPS7H4010EVM Schematic is shown in Figure 4-1 below.

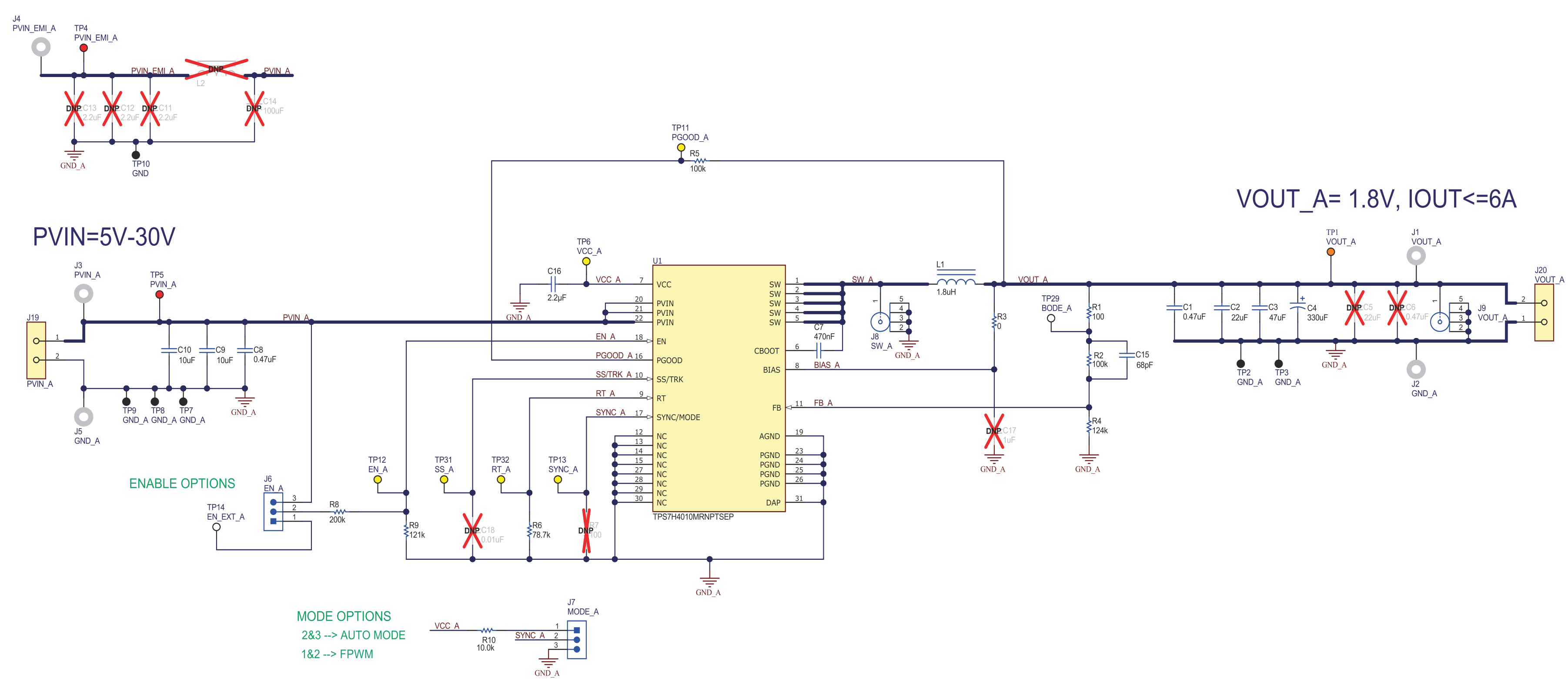

Figure 4-1. TPS7H4010EVM PVIN=5 V, VOUT=1.8 V Schematic

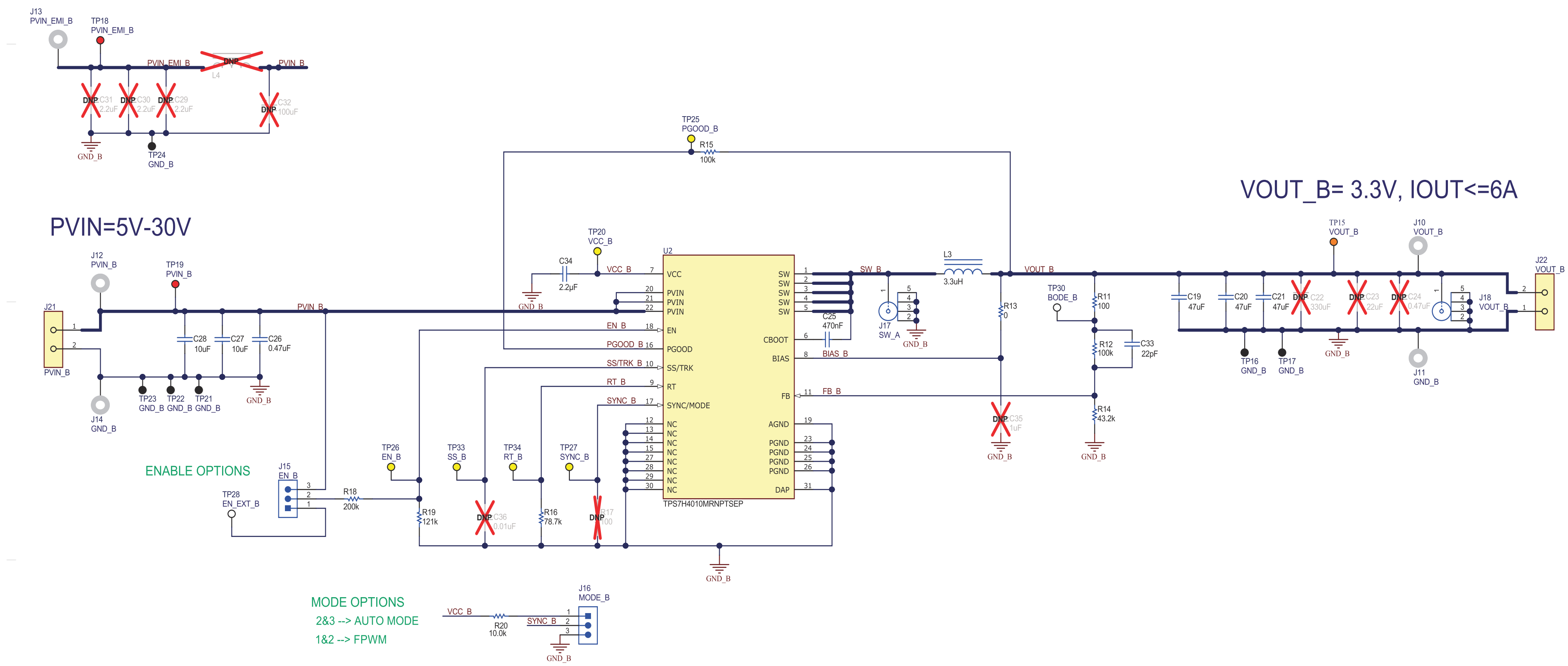

Figure 4-2. TPS7H4010EVM PVIN=12 V, VOUT=3.3 V Schematic

5 Board Layout

Figure 5-1 through Figure 5-5 show the board layout for the TPS7H4010EVM. The EVM offers resistors, capacitors, and test points to configure the output voltage, precision enable pin, set frequency, and external clock synchronization.

The 30-pin WQFN package offers an exposed thermal pad which must be soldered to the copper landing on the PCB for optimal thermal performance. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias under the thermal pad to connect to all four layers.

Test points have been provided for ease of use to connect the power supply, required load, and to monitor critical signals.

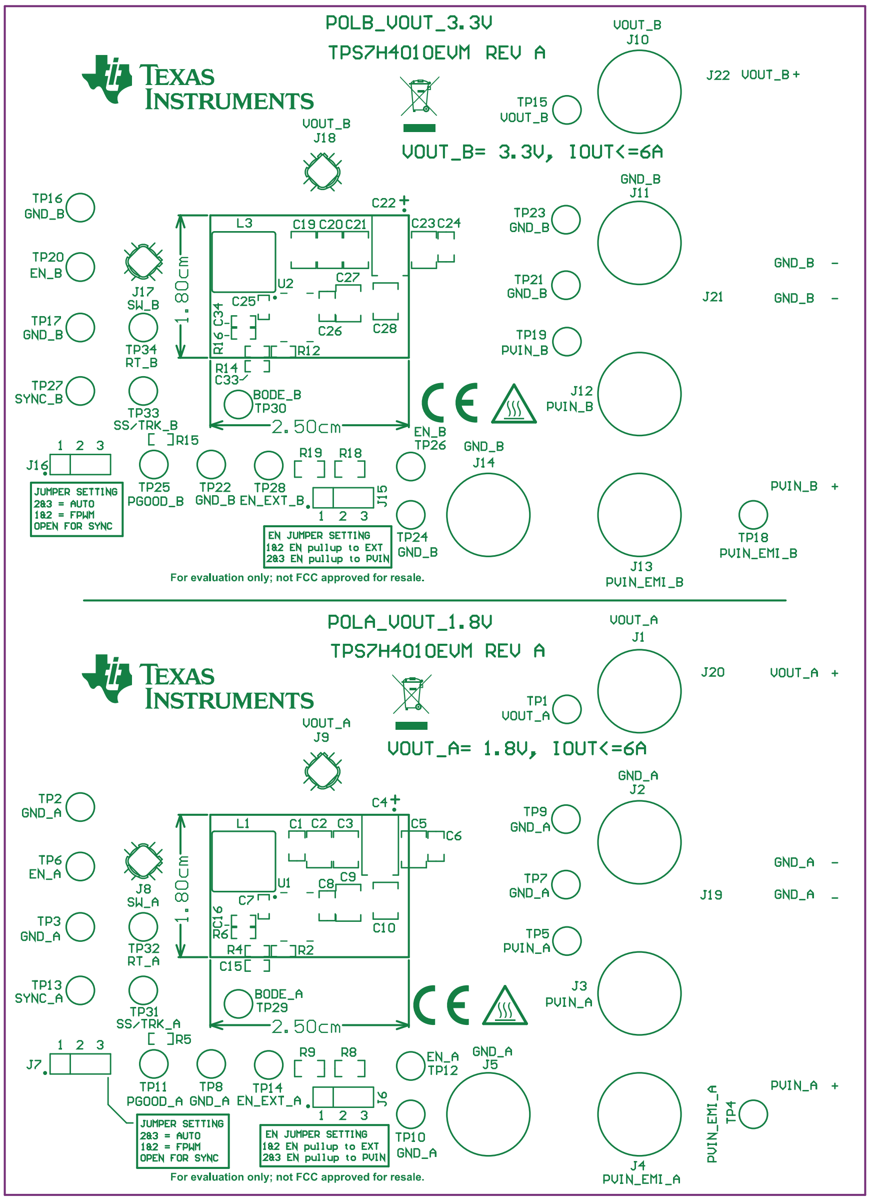

Figure 5-1. Top Layer and Silkscreen Layer

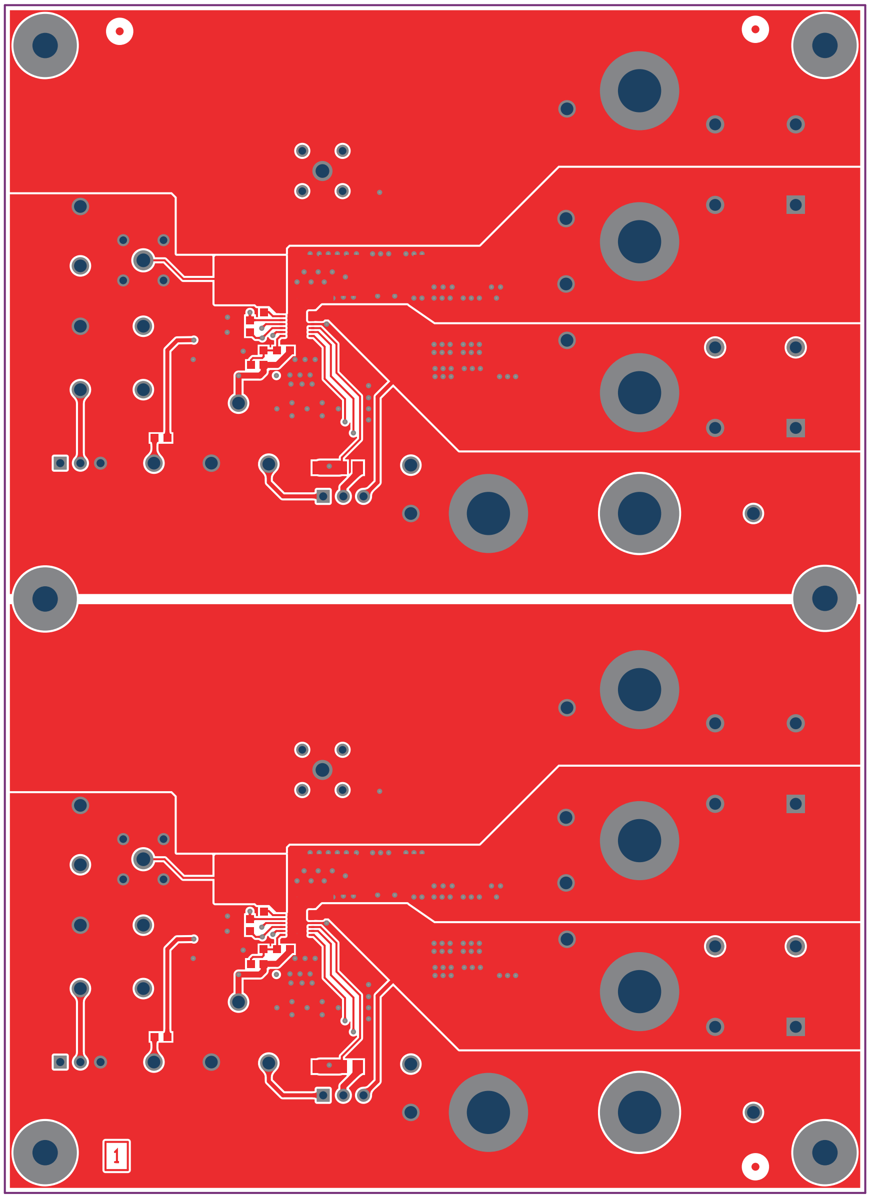

Figure 5-2. Top Layer Routing

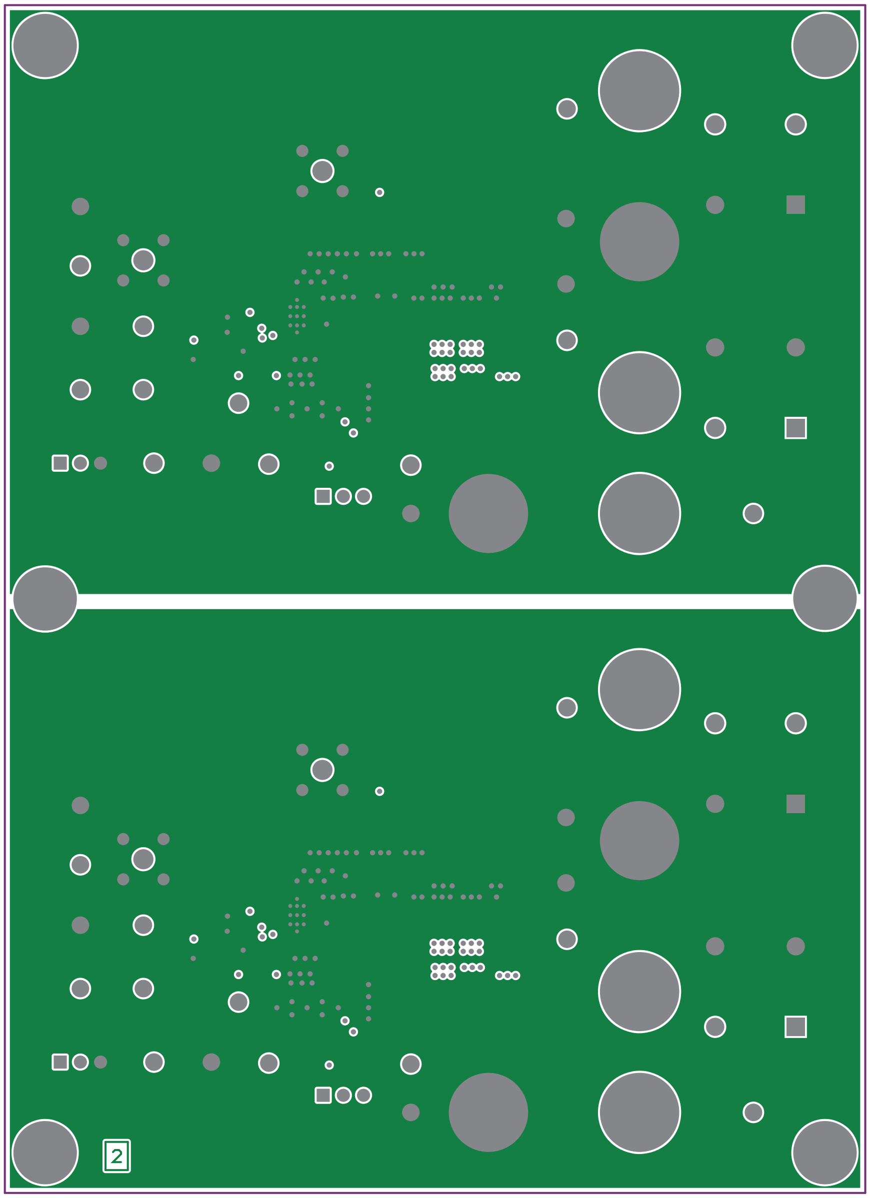

Figure 5-3. Mid-Layer 1 Ground Plane

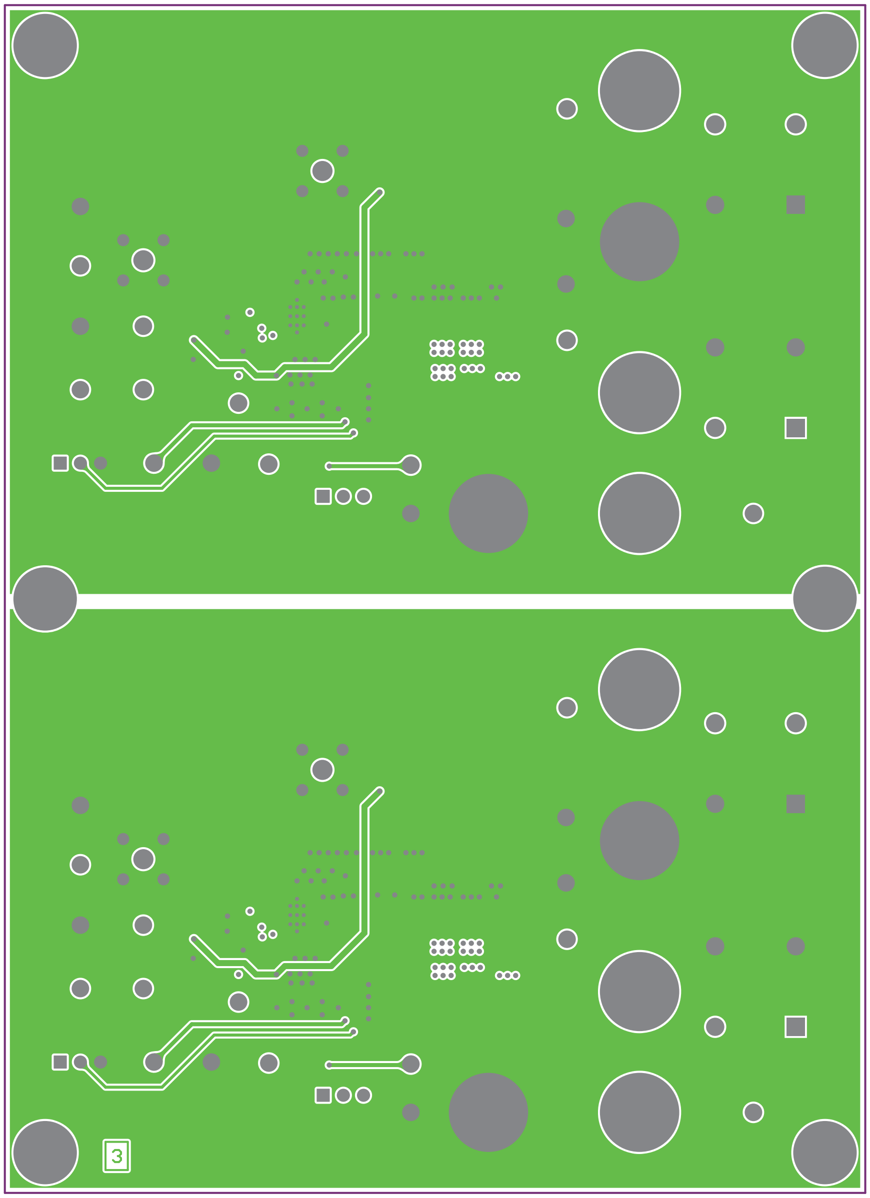

Figure 5-4. Mid-Layer 2 Routing

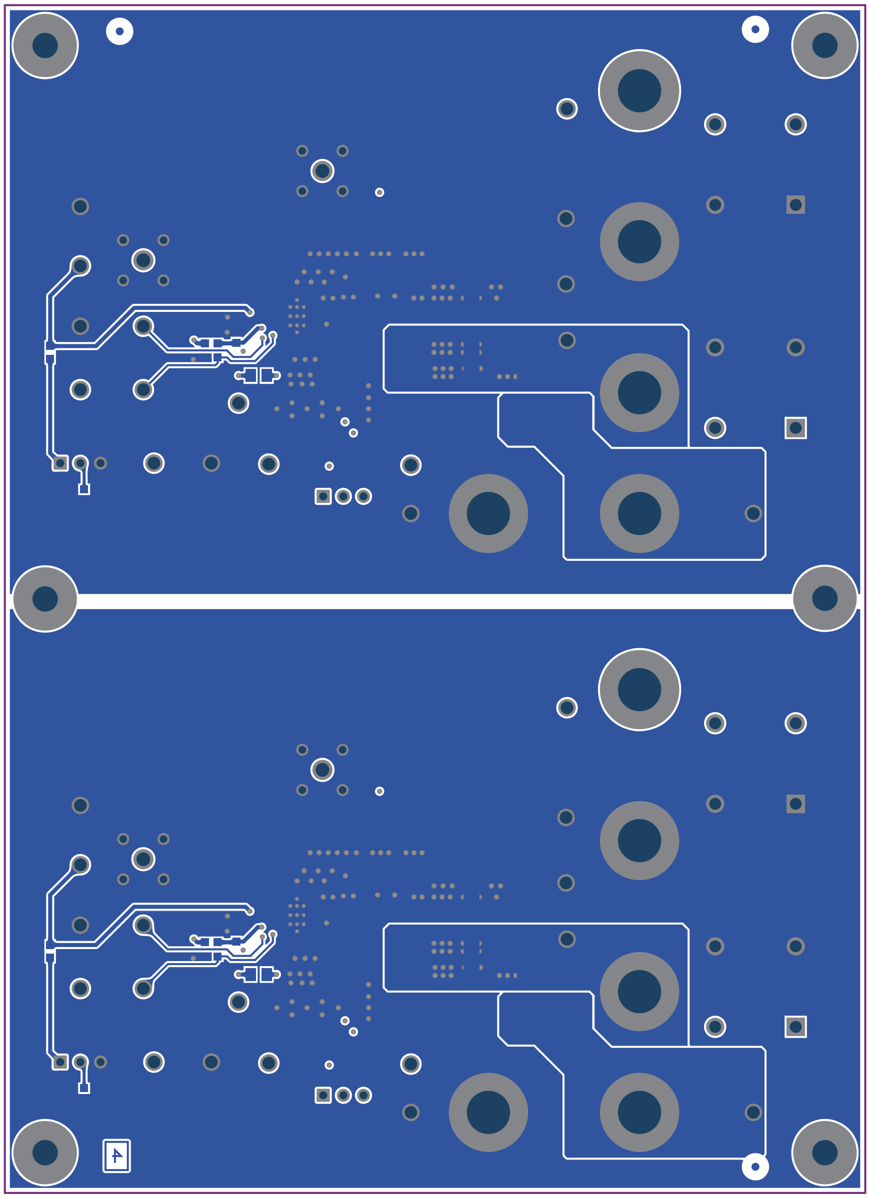

Figure 5-5. Bottom Layer Routing

6 Bill of Materials

The bill of materials (BOM) of the TPS7H4010EVM is shown in Table 6-1 below.

Table 6-1. TPS7H4010EVM BOM

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		LP044	Any
C1, C8, C26	3	0.47 µF	CAP, CERM, 0.47 µF, 50 V, +/– 10%, X7R, 0805	0805	GRM21BR71H474KA88L	MuRata
C2	1	22 µF	CAP, CERM, 22 µF, 16 V, +/–10%, X7R, 1210	1210	GCM32ER71C226KE19L	MuRata
C3, C19, C20, C21	4	47 µF	CAP, CERM, 47 µF, 10 V, +/– 10%, X7R, 1210	1210	GRM32ER71A476KE15L	MuRata
C4	1	330 µF	CAP, Tantalum Polymer, 330 µF, 10 V, +/– 20%, 0.006 ohm, 7343-43 SMD	7343-43	T530X337M010ATE006	Kemet
C7, C25	2	0.47 µF	CAP, CERM, 0.47 µF, 25 V, +/– 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E474KA64D	MuRata
C9, C10, C27, C28	4	10 µF	CAP, CERM, 10 µF, 50 V, +/– 10%, X7R, AEC-Q200 Grade 1, 1210	1210	UMK325AB7106KMHT	Taiyo Yuden
C15	1	68 pF	CAP, CERM, 68 pF, 50 V, +/– 5%, C0G/NP0, 0603	0603	GRM1885C1H680JA01D	MuRata
C16, C34	2	2.2 µF	CAP, CERM, 2.2 µF, 10 V,+/– 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GRM188R71A225KE15J	MuRata
C33	1	22 pF	CAP, CERM, 22 pF, 50 V, +/– 5%, C0G/NP0, 0603	0603	GRM1885C1H220JA01D	MuRata
H1, H2, H3, H4, H5, H6	6		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H7, H8, H9, H10, H11, H12	6		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J2, J3, J4, J5, J10, J11, J12, J13, J14	10		Standard Banana Jack, Uninsulated, 8.9 mm	Keystone575-8	575-8	Keystone
J6, J7, J15, J16	4		Header, 100 mil, 3x1, Gold, TH	Header, 100 mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J8, J9, J17, J18	4		Compact Probe Tip Circuit Board Test Points, TH, 25 per	TH Scope Probe	131-5031-00	Tektronix
J19, J20, J21, J22	4		Fixed Terminal Blocks MKDSP 10 HV/2-10	HDR2	1929517	Phoenix Contact
L1	1	1.8 µH	Inductor, Shielded, Composite, 1.8 µH, 21 A, 0.00405 Ω, SMD	7.2x7x7.5 mm	XAL7070-182MEB	Coilcraft
L3	1	3.3 µH	Inductor, Shielded, Composite, 3.3 µH, 15.1 A, 0.01 Ω, SMD	7.2x7x7.5 mm	XAL7070-332MEB	Coilcraft
R1, R11	2	100 Ω	RES, 100, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW0805100RFKEA	Vishay-Dale
R2, R5, R12, R15	4	100 kΩ	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R3, R13	2	0 Ω	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R4	1	124 kΩ	RES, 124 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603124KFKEA	Vishay-Dale

Table 6-1. TPS7H4010EVM BOM (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R6, R16	2	78.7 kΩ	RES, 78.7 k, 1%, 0.1 W, 0603	0603	RC0603FR-0778K7L	Yageo
R8, R18	2	200 kΩ	RES, 200 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW0805200KFKEA	Vishay-Dale
R9, R19	2	121 kΩ	RES, 121 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW0805121KFKEA	Vishay-Dale
R10, R20	2	10.0 kΩ	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R14	1	43.2 kΩ	RES, 43.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060343K2FKEA	Vishay-Dale
SH-J1, SH-J2, SH-J3, SH-J4	4		Shunt, 100 mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity
TP1, TP15	2		Test Point, Multipurpose, Orange, TH	Orange Multipurpose Testpoint	5013	Keystone
TP2, TP3, TP7, TP8, TP9, TP10, TP16, TP17, TP21, TP22, TP23, TP24	12		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
TP4, TP5, TP18, TP19	4		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP6, TP11, TP12, TP13, TP20, TP25, TP26, TP27, TP31, TP32, TP33, TP34	12		Test Point, Multipurpose, Yellow, TH	Yellow Multipurpose Testpoint	5014	Keystone
TP14, TP28, TP29, TP30	4		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
U1, U2	2		3.5-V to 30-V, 6-A Synchronous Step-Down Voltage Converter	WQFN30	TPS7H4010MRNPTSEP	Texas Instruments

7 TPS7H4010EVM Test Data

7.1 TPS7H4010EVM PVIN=5 V, VOUT=1.8 V, FSW=500 kHz

All data presented is at ambient room temperature (~23C) with device in Auto Mode unless noted otherwise.

Figure 7-1. PVIN=5 V, VOUT=1.8 V, FSW=500 kHz: VOUT vs IOUT

PVIN (V)	IOUT (A)	Output Voltage (V)
5.000	6.000	1.820
5.000	5.000	1.820
5.000	4.000	1.821
5.000	3.000	1.822
5.000	2.000	1.822
5.000	1.000	1.823
5.000	0.900	1.823
5.000	0.800	1.823
5.000	0.700	1.822
5.000	0.600	1.823
5.000	0.500	1.827
5.000	0.400	1.833
5.000	0.300	1.838
5.000	0.200	1.840
5.000	0.100	1.843
5.000	0.000	1.846
Average		1.828
Max Deviation below Avg		-0.431%
Max Deviation above Avg		0.992%

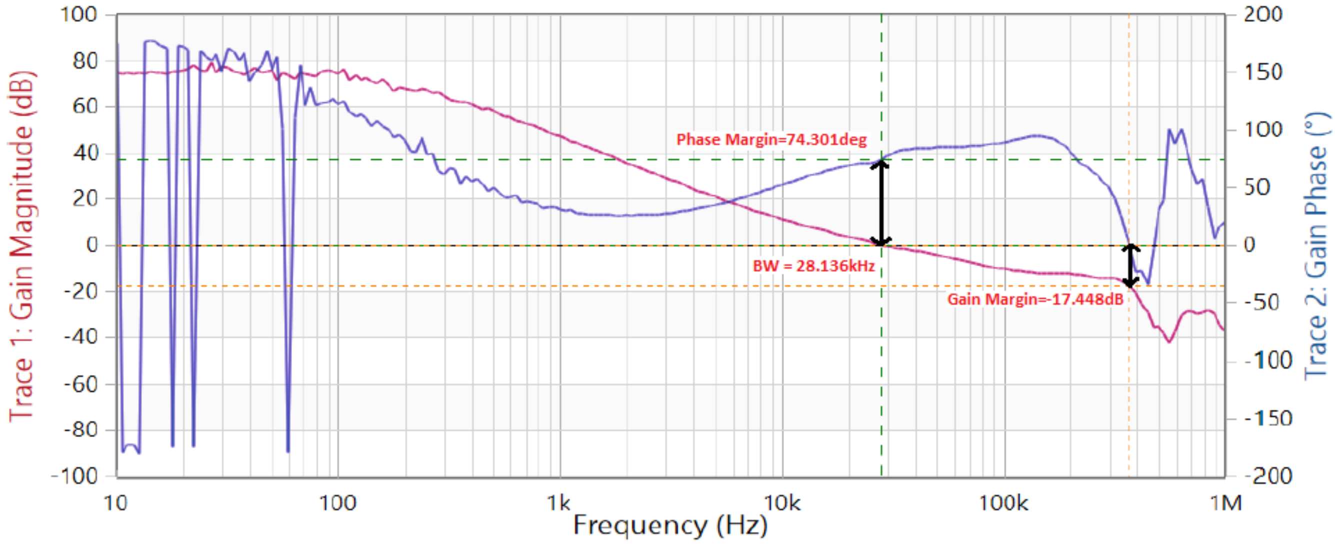

Figure 7-2. PVIN=5 V, VOUT=1.8 V, IOUT=6 A, FSW=500 kHz: Loop Response

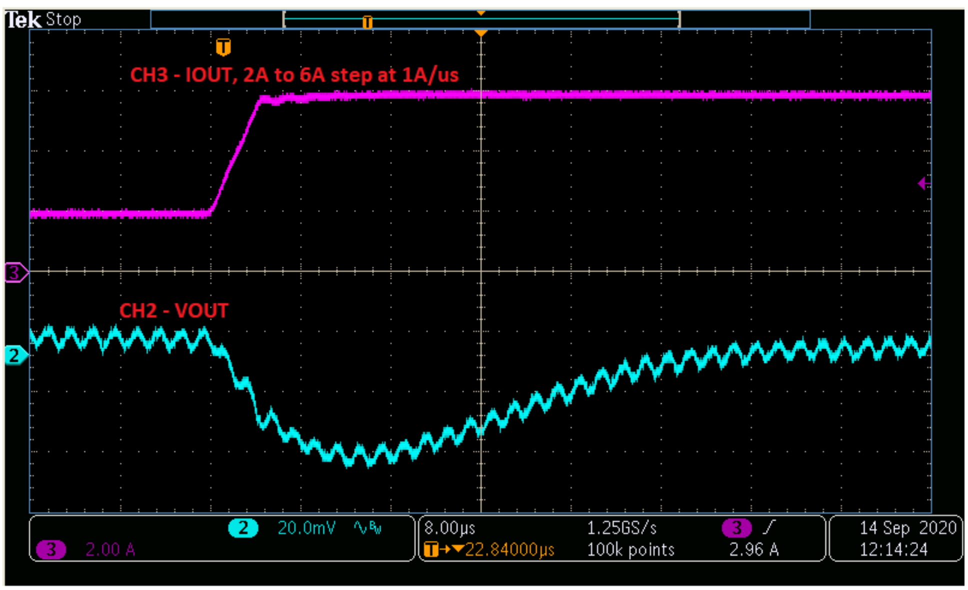

Figure 7-3. PVIN=5 V, VOUT=1.8 V, FSW=500 kHz: Transient Response to current step from 2 A to 6 A at 1 A/us

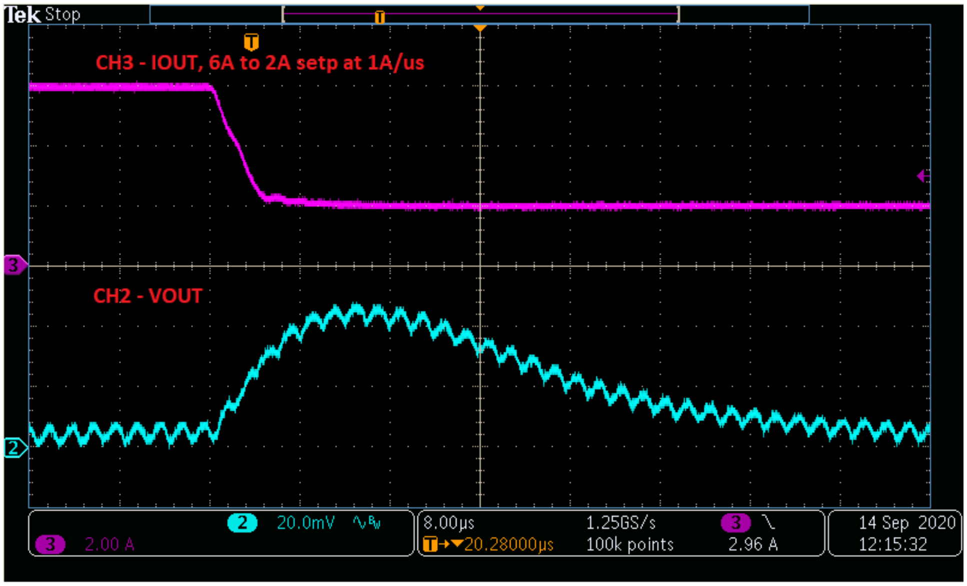

Figure 7-4. PVIN=5 V, VOUT=1.8 V, FSW=500 kHz: Transient Response to current step from 6 A to 2 A at 1 A/us

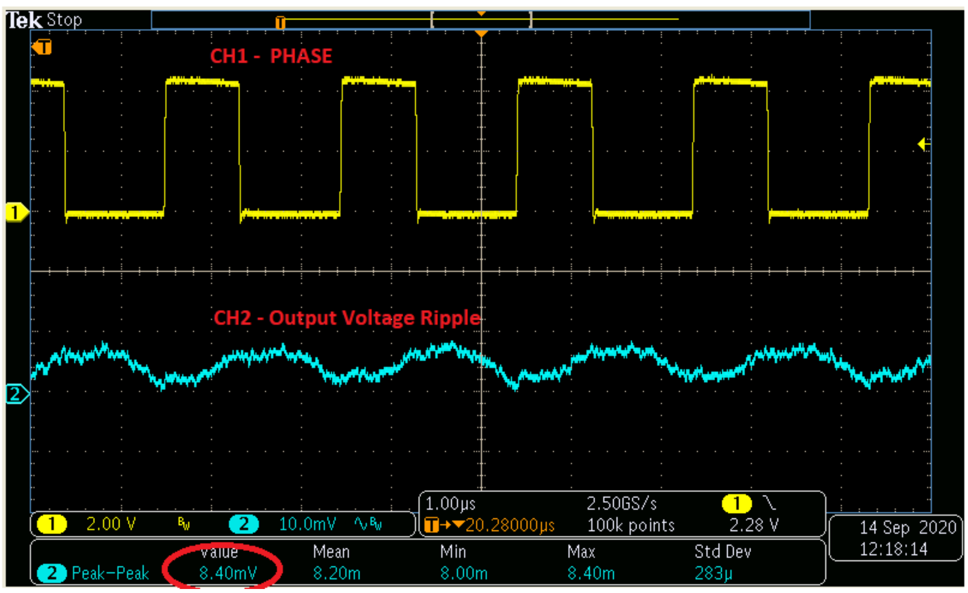

Figure 7-5. PVIN=5 V, VOUT=1.8 V, IOUT=6 A, FSW=500 kHz: Output Voltage Ripple

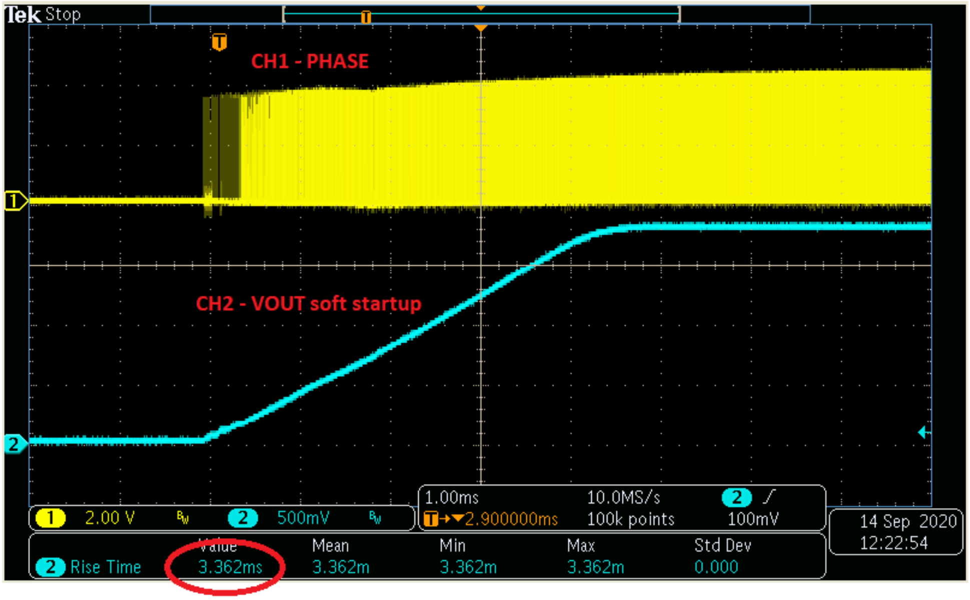

Figure 7-6. PVIN=5 V, VOUT=1.8 V, IOUT=6 A, FSW=500 kHz: Soft Start

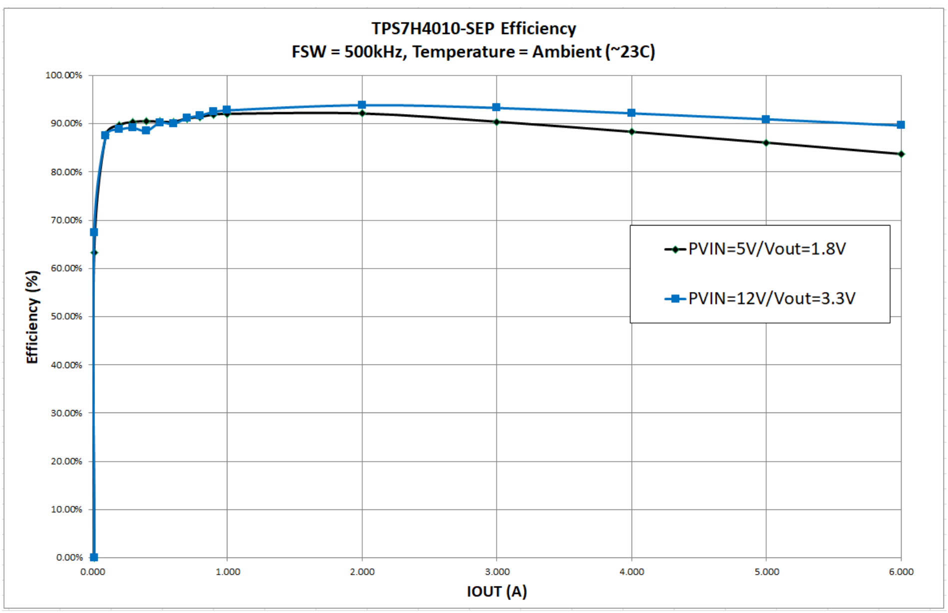

Figure 7-7. FSW=500 kHz: Efficiency vs IOUT

7.2 TPS7H4010EVM PVIN=12 V, VOUT=3.3 V, FSW=500 kHz

All data presented is at ambient room temperature (~23C) with device in Auto Mode unless noted otherwise.

Figure 7-8. PVIN=12 V, VOUT=3.3 V, FSW=500 kHz: VOUT vs IOUT

PVIN (V)	IOUT (A)	Output Voltage (V)
5.000	6.000	3.325
5.000	5.000	3.326
5.000	4.000	3.326
5.000	3.000	3.328
5.000	2.000	3.328
5.000	1.000	3.329
5.000	0.900	3.329
5.000	0.800	3.329
5.000	0.700	3.329
5.000	0.600	3.329
5.000	0.500	3.334
5.000	0.400	3.345
5.000	0.300	3.351
5.000	0.200	3.357
5.000	0.100	3.363
5.000	0.000	3.371
Average		3.337
Max Deviation below Avg		-0.373%
Max Deviation above Avg		1.006%

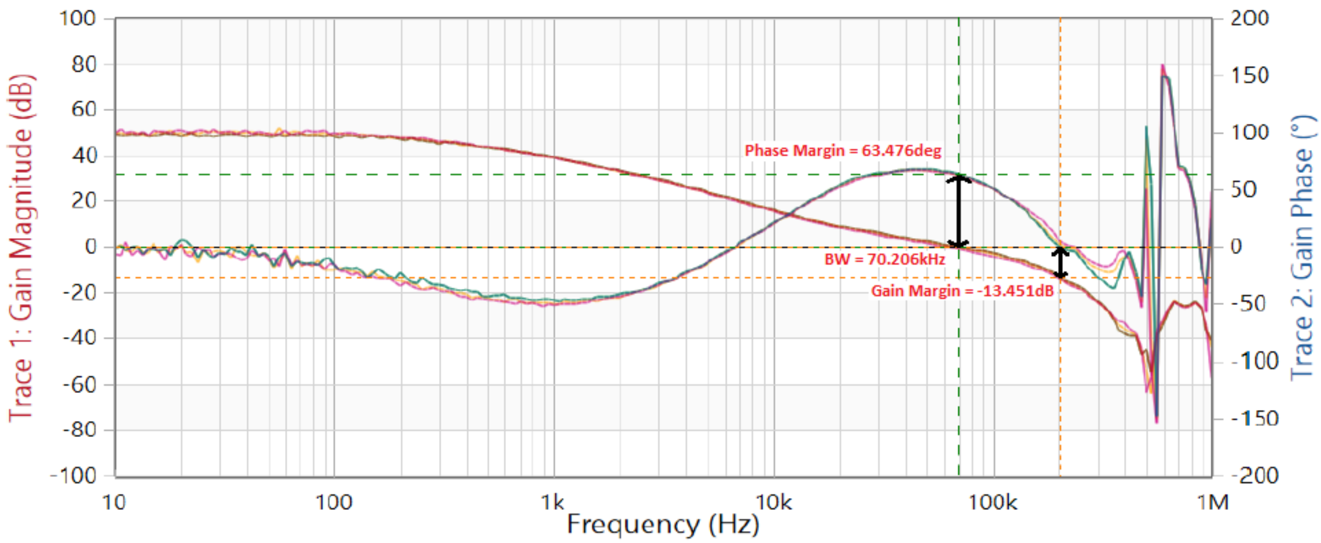

Figure 7-9. PVIN=12 V, VOUT=3.3 V, IOUT=6 A, 3 A, 1 A, FSW=500 kHz: Loop Response

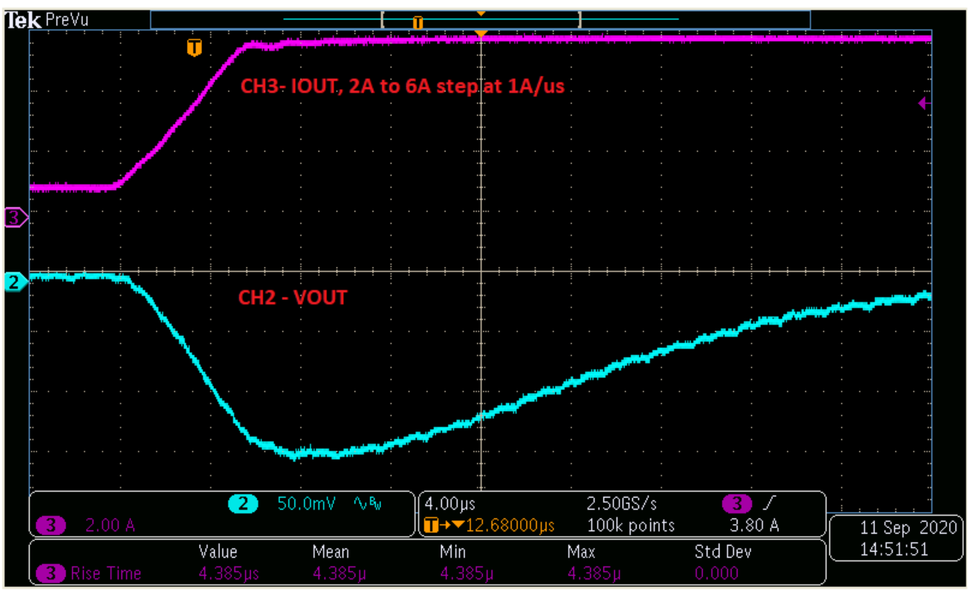

Figure 7-10. PVIN=12 V, VOUT=3.3 V, FSW=500 kHz: Transient Response to current step from 2 A to 6 A at 1 A/us

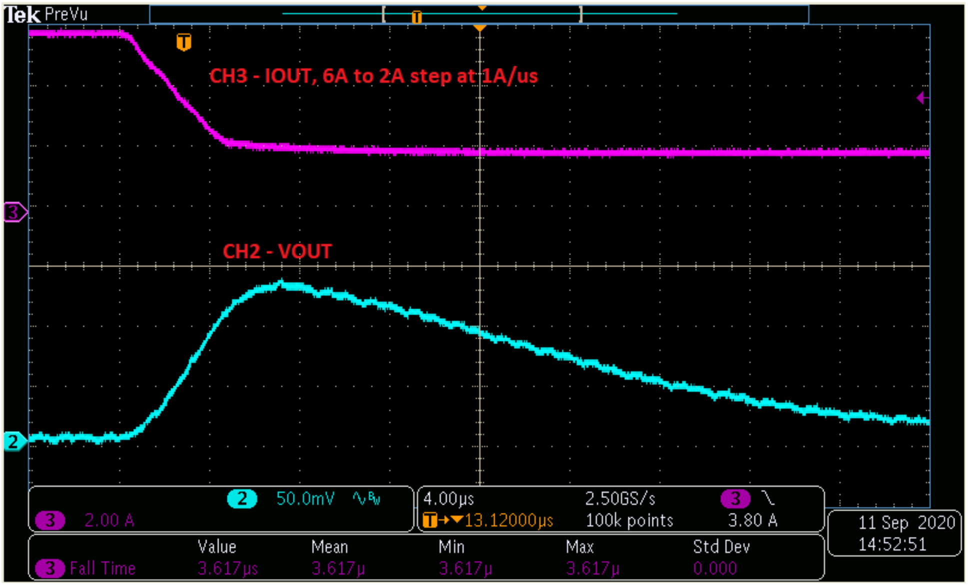

Figure 7-11. PVIN=12 V, VOUT=3.3 V, FSW=500 kHz: Transient Response to current step from 6 A to 2 A at 1 A/us

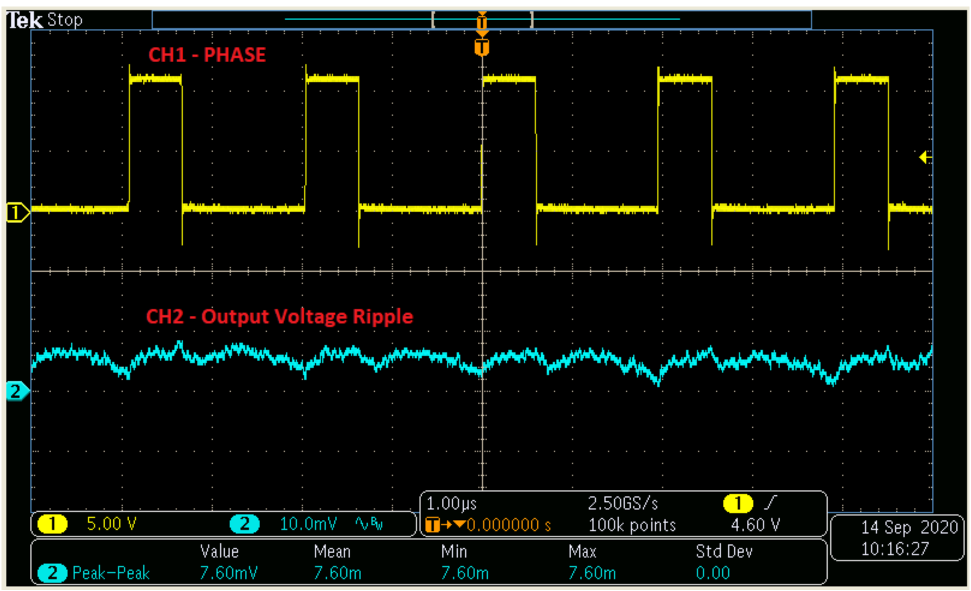

Figure 7-12. PVIN=12 V, VOUT=3.3 V, IOUT= 6 A, FSW=500 kHz: Output Voltage Ripple

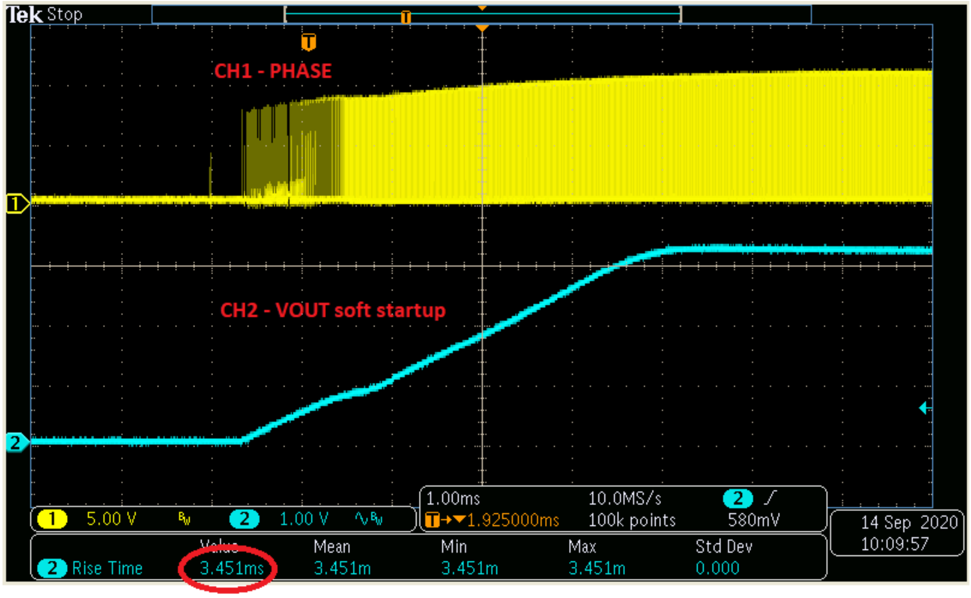

Figure 7-13. PVIN=12 V, VOUT=3.3 V, IOUT= 6 A, FSW=500 kHz: Soft Start

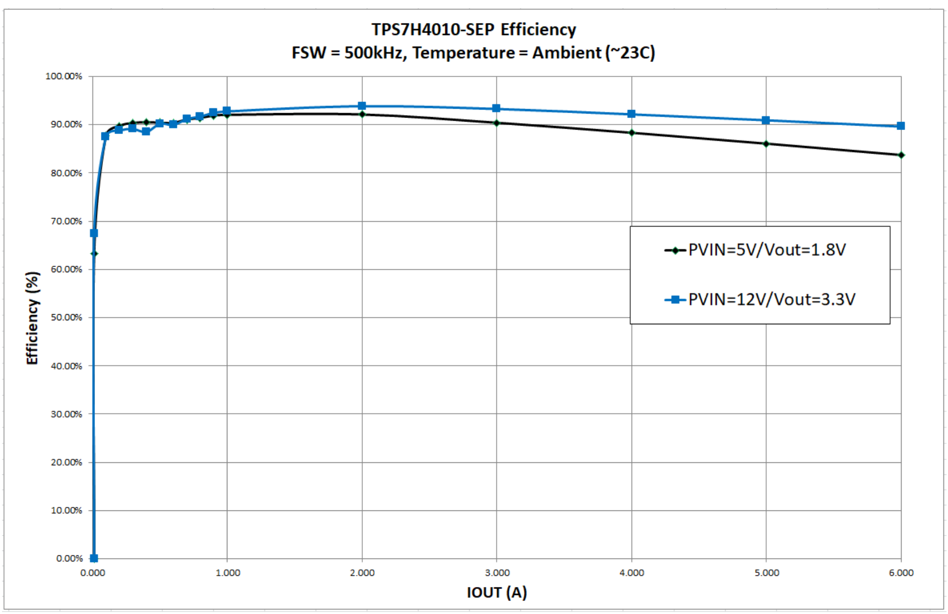

Figure 7-14. FSW=500 kHz: Efficiency vs IOUT

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

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

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

WARNING

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

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

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE 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。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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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3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, 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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