TPS5516xQ1-EVM Evaluation Module for 1-A Single-Inductor Buck-Boost-Converter

The Texas Instruments TPS55160Q1-EVM and TPS55165Q1-EVM evaluation modules (EVMs) help designers evaluate the operation and performance of the TPS55160-Q1 and TPS55165-Q1 1-A single-inductor buck-boost converters. This user's guide describes how to set up and configure the EVMs for operation. This document also provides the board layout, the schematic, and the bill of materials (BoM) for the EVMs.

The TPS55160-Q1 device allows users to set the output voltage from 5.7 V to 9 V through a feedback-divider. The TPS55165-Q1 device has a selectable output voltage of 5 V or 12 V.

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Trademarks

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1 Introduction

The HVL143B is a fully-assembled EVM design for evaluation of TPS55165-Q1 or TPS55160-Q1 1-A single-inductor buck-boost converter. Figure 1 and Figure 2 show the TPS55160Q1-EVM and TPS55165Q1-EVM boards with jumper settings.

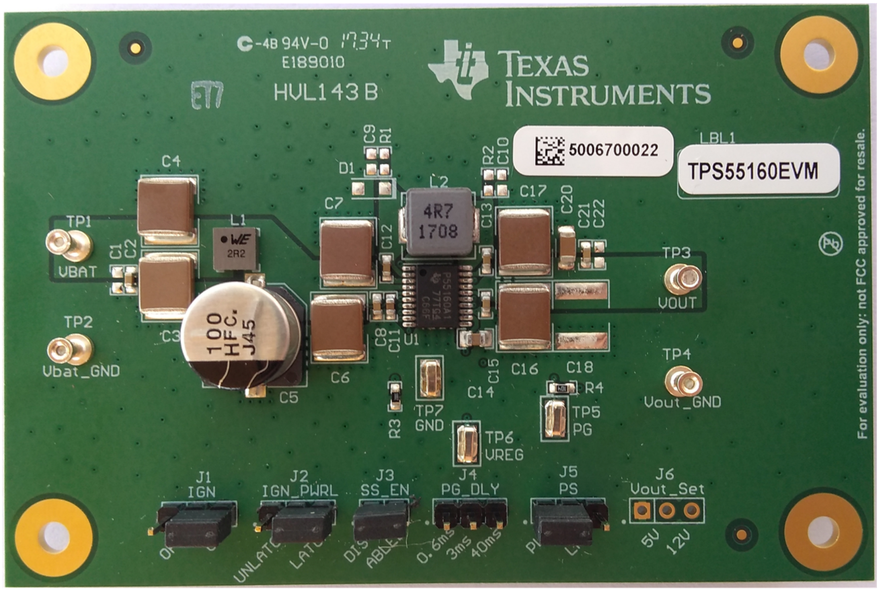

Figure 1. TPS55160Q1-EVM With Jumper Settings

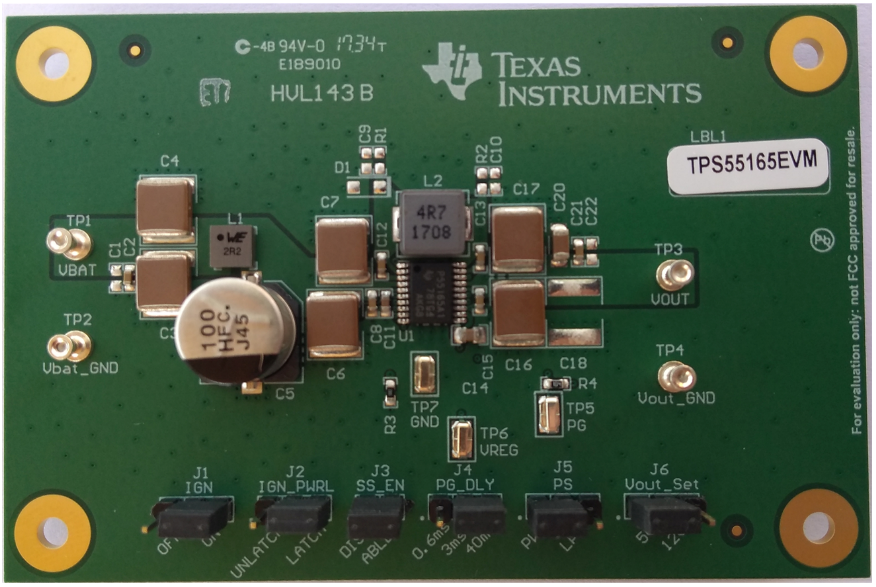

Figure 2. TPS55165Q1-EVM With Jumper Settings

2 Schematic, Bill of Materials, and Layout

This section provides a more detailed description of the schematic, bill of materials (BOM), and layout.

2.1 Schematic

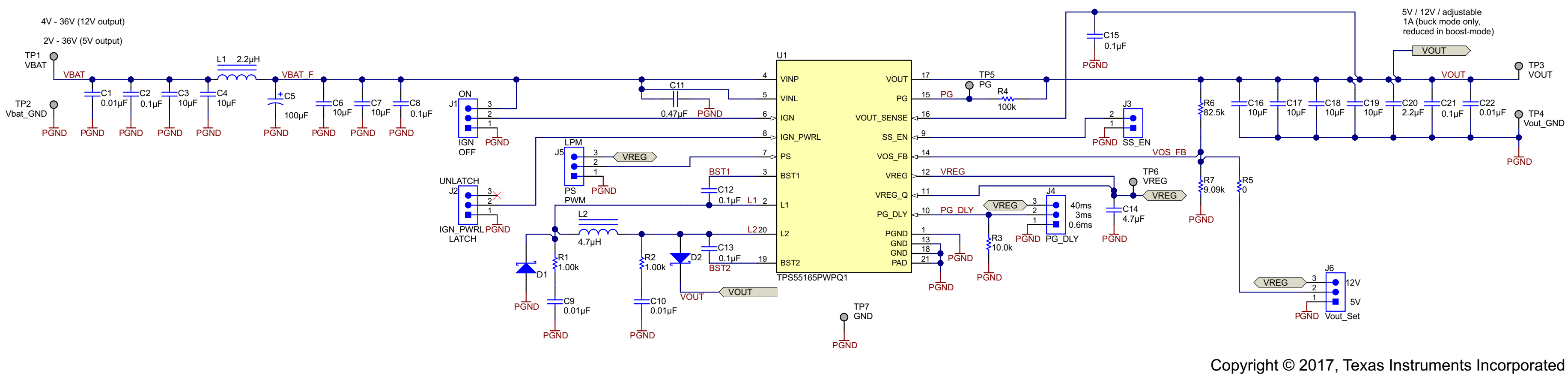

Figure 3. Schematic Diagram—No Variations

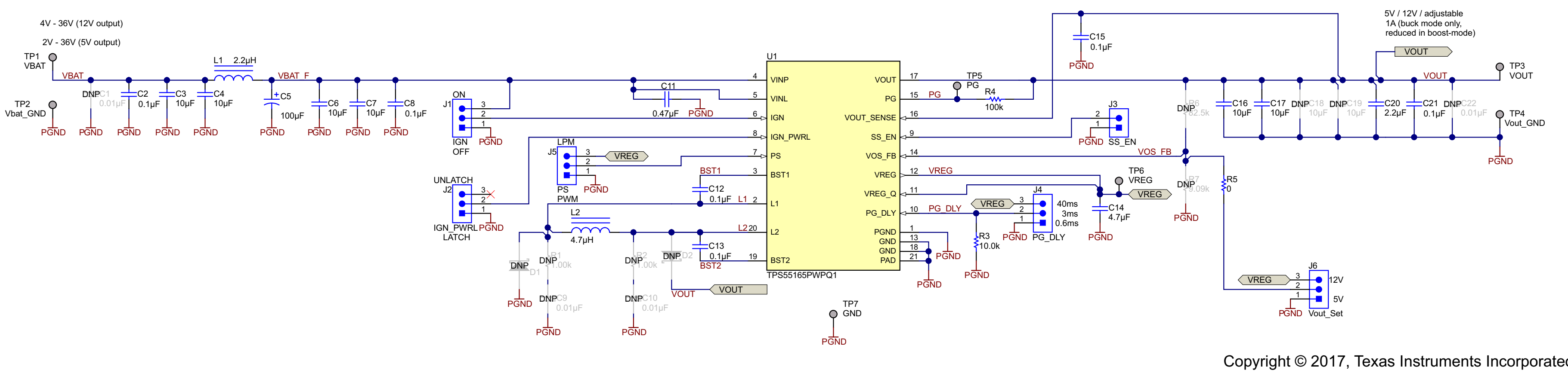

Figure 4. TPS55160Q1-EVM Schematic Diagram—Assembly Option

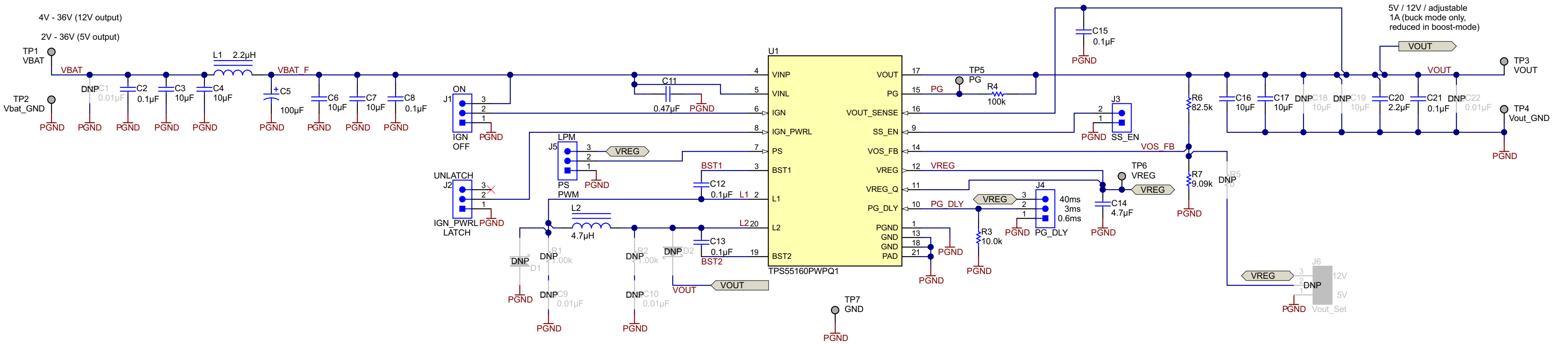

Figure 5. TPS55165Q1-EVM Schematic Diagram—Assembly Option

2.2 Bill of Materials

Table 1. Bill of Materials (BOM)

Designator	Quantityfor TPS55165Q 1-EVM (Variant 001)	Quantityfor TPS55160Q 1-EVM (Variant 002)	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1	1		Printed Circuit Board		HVL143	Any
C2, C8, C12, C13, C15, C21	6	6	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ± 10%, X7R, 0603	0603	GCM188R71H104KA57D	MuRata
C3, C4, C6, C7, C16, C17	6	6	10 µF	CAP, CERM, 10 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 2220	2220	CGA9N3X7R1H106K230KB	TDK
C5	1	1	100 µF	CAP, AL, 100 µF, 50 V, ± 20%, 0.3 ohm, SMD	SMT Radial G	EEE-FC1H101P	Panasonic
C11	1	1	0.47 µF	CAP, CERM, 0.47 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H474K080AE	TDK
C14	1	1	4.7 µF	CAP, CERM, 4.7 µF, 16 V, ± 10%, X7R, AEC-Q200 Grade 1, 0805	0805	GCM21BR71C475KA73K	MuRata
C20	1	1	2.2 µF	CAP, CERM, 2.2 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206	1206	GCM31CR71H225KA55L	MuRata
FID1, FID2, FID3, FID4, FID5, FID6	6	6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H9, H10, H11, H12	4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1	1	1	ON	Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J2	1	1		Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-102-07-G-S	Samtec

Table 1. Bill of Materials (BOM) (continued)

Designator	Quantityfor TPS55165Q 1-EVM (Variant 001)	Quantityfor TPS55160Q 1-EVM (Variant 002)	Value	Description	Package Reference	Part Number	Manufacturer
J3	1	1		Header, 100mil, 2x1, Gold, TH	Header, 100mil, 2x1, TH	HTSW-103-07-G-S	Samtec
J4	1	1	3 ms	Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J5	1	1	LPM	Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J6	1	0	5 V	Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
L1	1	1	2.2 µH	Inductor, Shielded, Powdered Iron, 2.2 µH, 4.7 A, 0.035 ohm, AEC-Q200 Grade 1, SMD	4.1x4.1mm	78438356022	Wurth Elektronik
L2	1	1	4.7 µH	Inductor, Wirewound, 4.7 µH, 5.5 A, 0.04 ohm, AEC-Q200 Grade 0, SMD	7.3 x 6.6 mm	SRP7028A-4R7M	Bourns
LBL1	1	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
R3	1	1	10.0 k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R4	1	1	100 k	RES, 100 k, 5%, 0.1 W, 0603	0603	CRCW0603100KJNEA	Vishay-Dale
R5	1	0	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R6	0	1	82.5 k	RES, 82.5 k, 1%, 0.1 W, 0603	0603	CRCW060382K5FKEA	Vishay-Dale
R7	0	1	9.09 k	RES, 9.09 k, 1%, 0.1 W, 0603	0603	CRCW06039K09FKEA	Vishay-Dale
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5	5	5	1 × 2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M
TP1, TP2, TP3, TP4	4	4		PCB Pin, Swage Mount, TH	PCB Pin (2505-2)	2505-2-00-44-00-00-07-0	Mill-Max
TP5, TP6, TP7	3	3		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1	1		36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step-Down Voltage Regulator, PWP0020P (TSSOP-20)	PWP0020P	TPS55165PWPQ1	Texas Instruments
C1, C9, C10, C22	0	0	0.01 µF	CAP, CERM, 0.01 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71H103KA37D	MuRata
C18, C19	0	0	10 µF	CAP, CERM, 10 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 2220	2220	CGA9N3X7R1H106K230KB	TDK
D1, D2	0	0	60 V	Diode, Schottky, 60 V, 1 A, SOD-123F	SOD-123F	PMEG6010CEH,115	Nexperia
H1, H2, H3, H4	0	0		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	0	0		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
R1, R2	0	0	1.00 k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R6	0	0	82.5 k	RES, 82.5 k, 1%, 0.1 W, 0603	0603	CRCW060382K5FKEA	Vishay-Dale
R7	0	0	9.09 k	RES, 9.09 k, 1%, 0.1 W, 0603	0603	CRCW06039K09FKEA	Vishay-Dale

2.3 Layout and Component Placement

The TPS55160Q1-EVM and TPS55165Q1-EVM share the same PCB which is named HVL143B.

The C1, C18, C19, and C22 capacitors are not installed. Their footprints allow for additional input decoupling or bulk capacitance.

The R6 and R7 resistors are not populated on the TPS55165Q1-EVM. Select the output voltage of either 5V or 12V using J6, which is named Vout_Set.

The R6 and R7 resistors are populated on the TPS55160Q1-EVM. These resistors set the output voltage to 8V. To eliminate the long trace to the J6jumper, which is prone to pick up noise, the R5 resistor and J6 jumper are not assembled on the TPS55160Q1-EVM.

Figure 4, Figure 7, and Figure 8 show the top layout of the EVM, with assembly options for the fixed voltage version (TPS55165Q1-EVM) at the adjustable voltage version (TPS55160Q1-EVM).

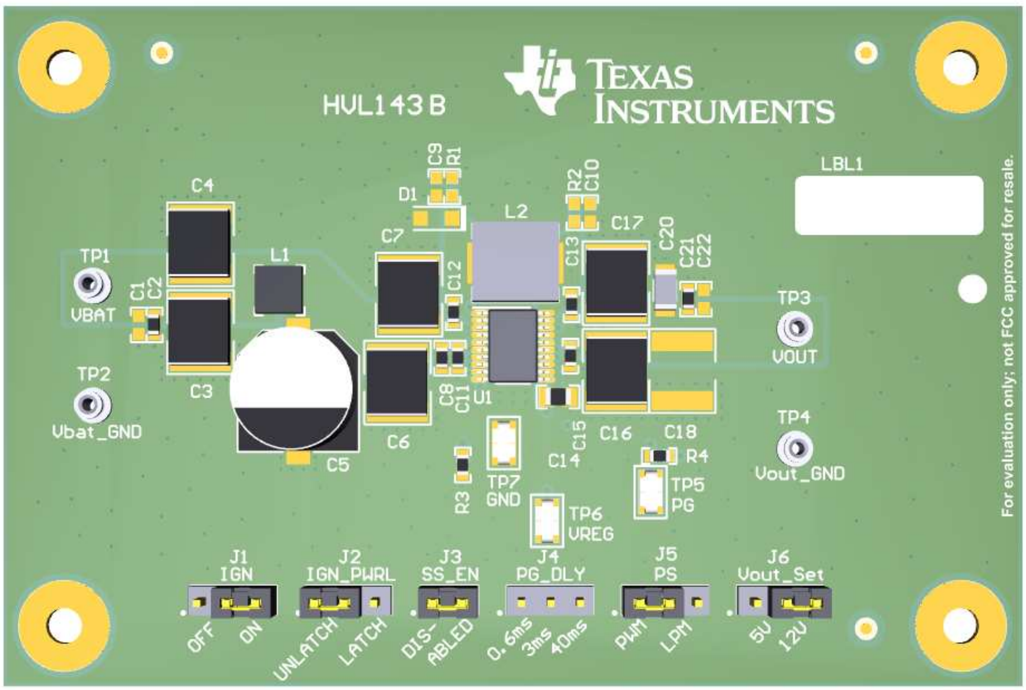

Figure 6. Component Placement—Top

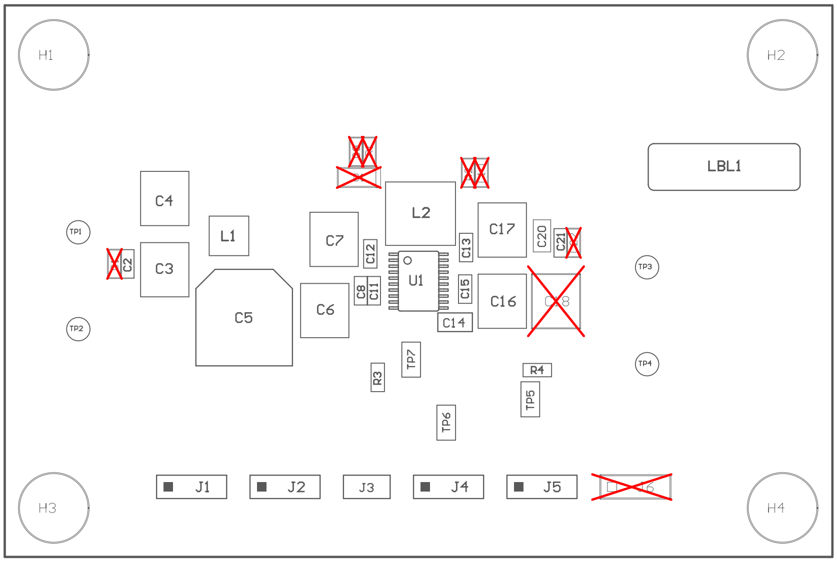

Figure 7. TPS55160Q1-EVM Top Layer—Overview

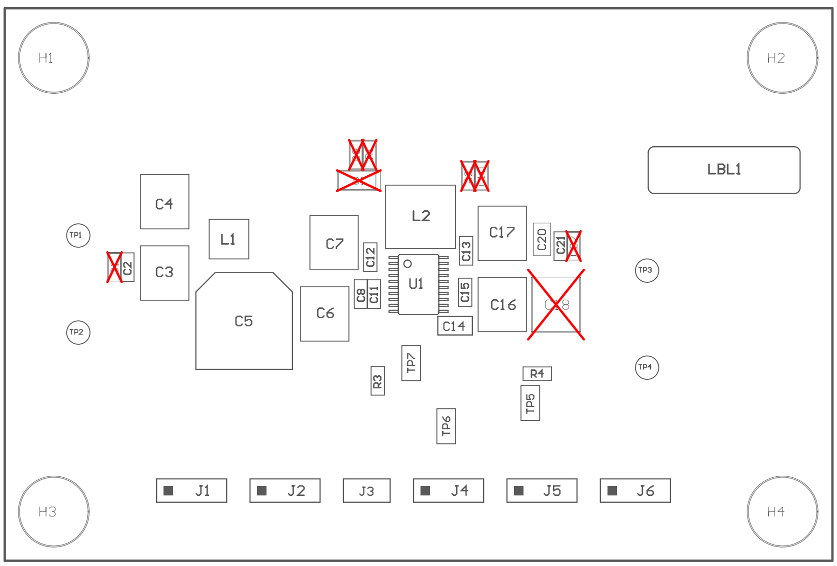

Figure 8. TPS55165Q1-EVM Top Layer—Overview

Figure 9, Figure 10, and Figure 11 show the bottom layout of the EVM, with assembly options for the fixed voltage version (TPS55165Q1-EVM) at the adjustable voltage version (TPS55160Q1-EVM).

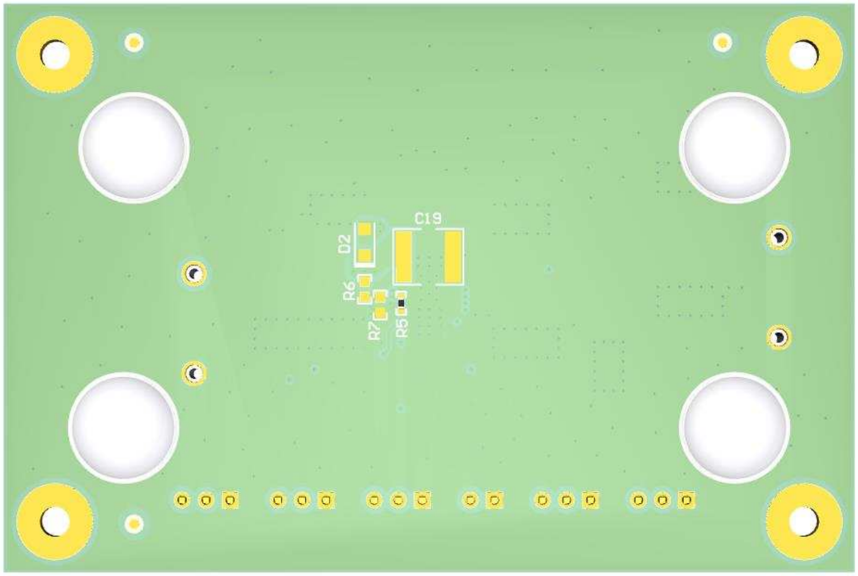

Figure 9. Component Placement—Bottom

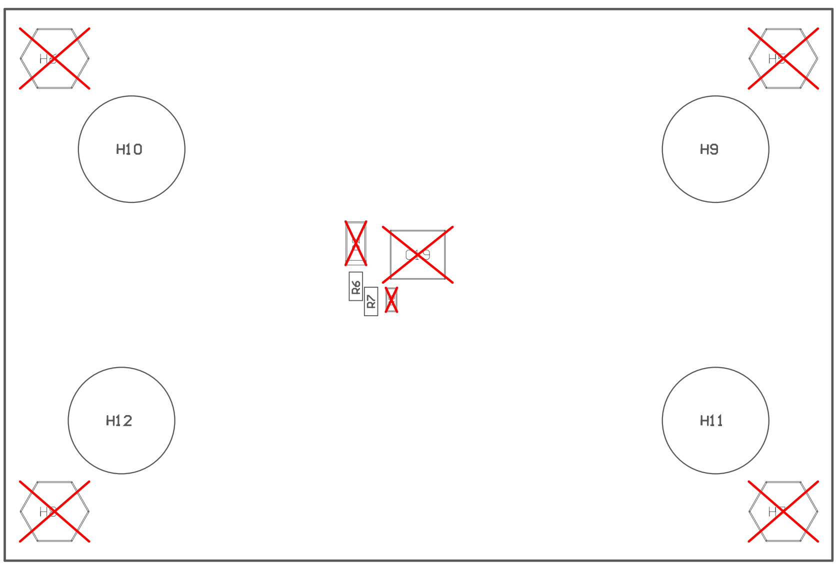

Figure 10. TPS55160Q1-EVM Bottom Layer—Overview

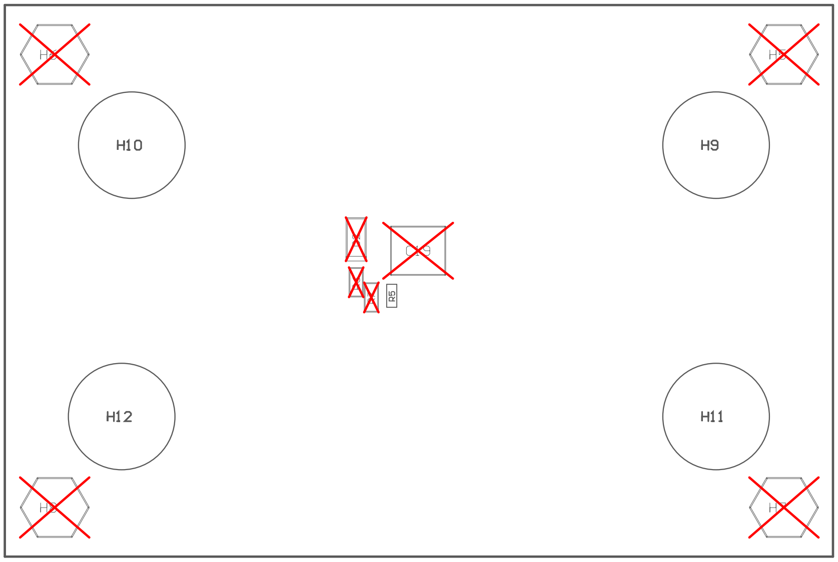

Figure 11. TPS55165Q1-EVM Bottom Layer—Overview

Figure 12, Figure 13, Figure 14, and Figure 15 show the EVM board layers.

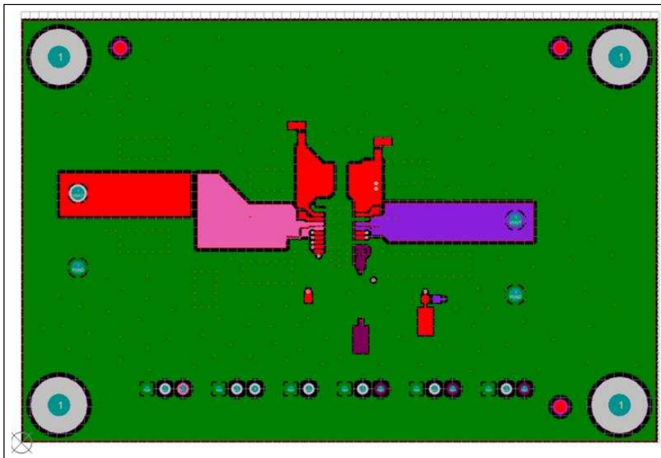

Figure 12. Layout—Top Layer

Figure 13. Layout—Layer 2

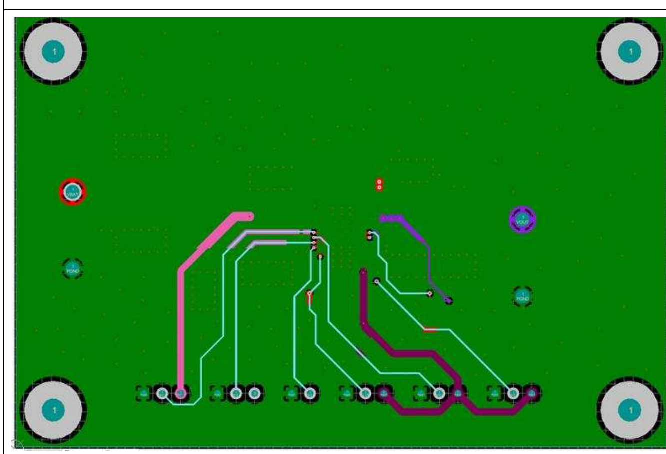

Figure 14. Layout—Layer 3

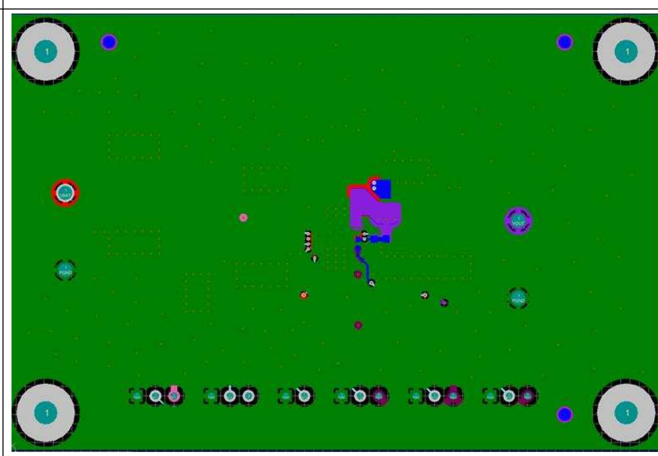

Figure 15. Layout—Bottom Layer

3 Setup and Operation

This section describes the setup and configuration of the EVM for basic operation. This section provides a detailed description of connectors, jumpers, and test points. A description of the typical operation of the EVM is also included.

3.1 Input and Output Connector Descriptions

The EVM has one pair of connectors (turrets) for the input and one pair for the output. Table 2lists all the connectors with their functional description and electrical specification.

Table 2. Terminal Descriptions

TERMINAL	DIRECTION	DESCRIPTION
VBAT (TP1) and Vbat_GND (TP2)	Input	These terminals are the supply-voltage input for the buck-boost converter. The terminals accept an input voltage between 2 V and 36 V.(1)
VOUT (TP3) and Vout_GND (TP4)	Output	VOUT is the output voltage of the buck-boost regulator and supplies 5V or 12V for the TPS55165-Q1 device, depending on the Vout_Set setting. For the TPS55160-Q1 device, the default output voltage is 8V. The selection of the R6 and R7 resistors determines the output voltage. The device delivers a maximum output current of 1 A in buck-mode for a 5-V output. (2)

(1) The initial startup voltage is 5.3 V (typical).

(2) In boost-mode and for higher output voltages, the maximum output current is decreased. For details, refer to the *TPS5516x-Q1 36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step- Down Voltage Regulator* data sheet .

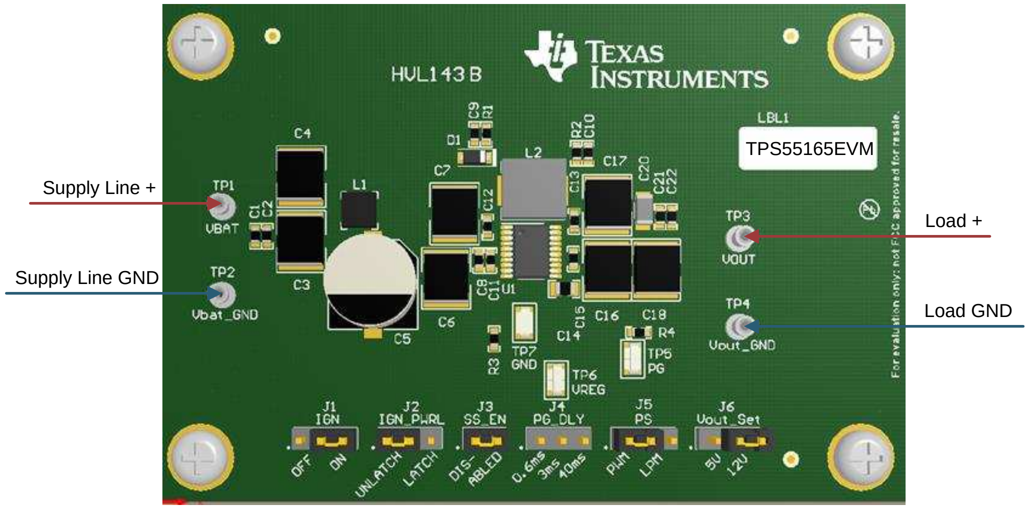

Figure 16. TPS55165Q1-EVM Showing Supply and Load Connections

3.2 Jumper Configuration

3.2.1 IGN

The IGN jumper enables the device. By default, this jumper is set to the ONposition. Put this jumper in the OFFposition to disable the output.

NOTE: The enable and disable thresholds of this pin are higher than the minimum supply voltage (VBAT) that this pin is tied to. The boost itself supports a VBAT supply voltage of 2 V, but the device is disabled if the IGN pin is connected to the VBAT pin. To prevent a shutdown event in this scenario, apply a voltage higher than 3.7 V to the center pin of this jumper or keep the device latched (set the IGN_PWRL jumper to LATCH).

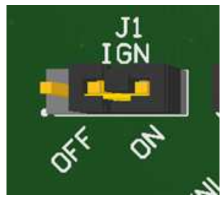

Figure 17. Ignition Jumper Configuration
Default: ON (Device powers up when power is applied)

3.2.2 IGN_PWRL

The IGN_PWRL jumper keeps the device on even if the IGN pin goes low (power-latch function) after the device is enabled by a high signal on the IGN pin. The IGN_PWRL jumper resembles an external MCU signal to keep the TPS5516x-Q1 on after the IGN pin goes low. The default setting of this jumper is LATCH. To disable the latch, move the jumper to UNLATCH.

NOTE: This pin does not enable the device. To activate the regulator, set the IGN to ON (see the IGN description in Section 3.2.1). The purpose of the IGN_PWRL jumper is only as a *keep-alive* to keep the device on.

Figure 18. Power-Latch Jumper Configuration
Default: LATCH

3.2.3 SS_EN

The SS_EN jumper selects if spread-spectrum modulation is enabled. If enabled, spread-spectrum modulation reduces the harmonic peak amplitude. The default of this jumper is DIS-ABLED (spread spectrum disabled). The jumper is installed by default.

NOTE: Spread spectrum modulation is only active in normal mode when the device is in step-down (buck) operation.

To make a jumper change effective, power cycle the supply or turn off the output (move the IGN jumper to OFF while the device is unlatched).

Figure 19. Spread Spectrum Enable Jumper Configuration
Default: Jumper Installed, Spread Spectrum Disabled

3.2.4 PG_DLY

The PG_DLY jumper sets the power-good delay time. This time defines how long before the power-good pin (PG pin, TP3) goes low after the output voltage decreases to less than the PG undervoltage threshold (PGTH_UV). The default of this jumper is 3ms (no jumper installed).

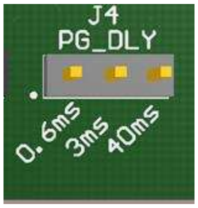

Figure 20. Power-Good Delay Selection Jumper Configuration
Default: Jumper Not Installed, 3-ms Delay

3.2.5 PS

The PS jumper selects between low-power mode (LPM) and pulse-width modulation (PWM). The default of this jumper is PWM.

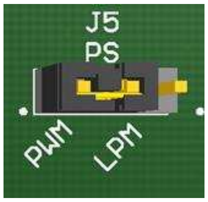

Figure 21. Low-Power-Mode Enable Jumper Configuration
Default: Jumper Set to PWM, LPM Prohibited

3.2.6 Vout_Set

The Vout_Set jumper selects the output voltage for the TPS5516x-Q1 device. For the TPS55165-Q1 device, the default of this jumper is 5V. Move this jumper to 12V select the 12-V output voltage. If no jumper is installed, the output voltage defaults to 5 V.

NOTE: To make a jumper change effective, power cycle the supply or turn off the output (move the IGN jumper to OFF while the device is unlatched).

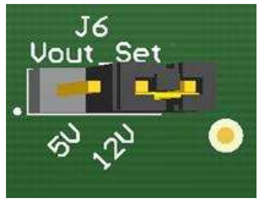

Figure 22. Output Voltage Selection Jumper Configuration Default: 5 V for TPS55165-Q1

The TPS55160-Q1 variant does not have this jumper installed because the output voltage is set by the resistive divider formed by the R6 and R7 resistors on the bottom side of the board. The installed components set the output voltage to 8 V.

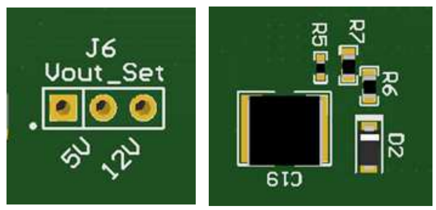

Figure 23. Output Voltage Selection Jumper Configuration Default: 8 V for TPS55160-Q1, Configured by R6 and R7

3.3 Test Point Description

The test points are defined as:

TP5 (PG)— This test point measures the power-good output of the buck-boost converter.

TP6 (VREG)— This test point measures the internal voltage on the VREG pin of the device.

TP7 (GND)— Connect ground-test leads to this test point for sensitive measurements.

The output voltage can be measured at the turrets provided for the output.

3.4 Basic Operation

The input voltage range for the converter is from 2 V to 36 V (5.3 V typical minimum for initial start-up).

For operation of TPS5516xQ1-EVM, configure the jumpers in the default configuration:

- IGN = ON
- IGN_PWRL = Irrelevant as long as the IGN jumper is set to ON (the default of the IGN_PWRL jumper is LATCH)
- SS_EN = Irrelevant for basic operation (default: jumper installed, SS disabled)
- PG_DLY = Irrelevant for basic operation (default: jumper not installed, 3 ms delay)
- PS = PWM
- Vout_Set = (TPS55165-Q1-variant only) Desired output voltage (set this jumper before setting the IGN jumper to ON; the default of the Vout_Set jumper is 5 V for the TPS55165-Q1)

If input voltage is present, the EVM with this configuration delivers an output voltage of 5 V for the TPS55165-Q1 device and 8 V for the TPS55160-Q1 device.

NOTE: In buck mode, the TPS5516x-Q1 device can drive up to 1 A. In boost mode, the maximum output current scales with the input and output voltage (refer to the *TPS5516x-Q1 36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step-Down Voltage Regulator* data sheet).

To change the output voltage on the TPS55165Q1-EVM, follow these steps:

1. Power down the device.
2. Move the Vout_Set jumper to the new position.
3. Power up the device.

The output voltage can also be changed by following these steps on the TPS55165Q1-EVM:

1. Move the IGN jumper to the OFF setting while the device is unlatched.
2. Move the Vout_Set jumper to the new position.
3. Move the IGN jumper to the ON setting.

   If the jumper moves while power is applied and the IGN pin is high or latched, the change in output voltage does not take effect.

To change the output voltage for the adjustable TPS55160-Q1 device, change the resistive divider. Use Equation 1 to calculate the resistor values to change the output voltage.

$$V_{VOUT} = \frac{R6 + R7}{R7} \times 0.8 \text{ V} \quad (1)$$

Assuming the desired output voltage is 8 V and R7 is chosen as 10 kΩ, the value of the R6 resistor is calculated for a desired output voltage as shown in Equation 2.

$$R6 = \left(\frac{V_{VOUT}}{0.8 \text{ V}} \times R7\right) - R7 = \left(\frac{8 \text{ V}}{0.8 \text{ V}} \times 10 \text{ k}\Omega\right) - 10 \text{ k}\Omega = 90 \text{ k}\Omega \quad (2)$$

NOTE: To allow for a suitable feedback current, the total divider resistance must not exceed 1 MΩ.

If the IGN jumper is moved to the OFF position, the device turns off the output if the the IGN_PWRL jumper is unlatched. To keep the device active when the IGN goes low, set the IGN_PWRL jumper to the LATCH position.

If the the IGN_PWRL jumper is latched, the output remains active until the power supply is turned off or the IGN_PWRL jumper is moved to the UNLATCH position while the IGN pin is low.

After the supply is turned on, move the IGN jumper to the ON position to turn on the output again, even if the IGN_PWRL jumper is latched.

The default configuration disables spread-spectrum modulation. To mitigate emissions enable spread-spectrum modulation by removing the jumper on SS_EN and power cycling or turning off and on the IGN jumper while unlatched.

The PG_DLY jumper sets the delay time of the PG output. The default is 3 ms. The PG delay time can be decreased 0.6 ms or increased 40 ms. To change the PG delay time, install the jumper in the respective position. This configuration refers to the $PG_{exttime}$ time (refer to the *TPS5516x-Q1 36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step-Down Voltage Regulator*). The PG pin is not asserted low if the output voltage decreases to less than the PGTH_UV threshold for a time shorter than the $PG_{exttime}$ time. If the supply voltage is decreased, follow the limited output current constraints for a given input-voltage to output-voltage ratio (for details refer to the *TPS5516x-Q1 36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step-Down Voltage Regulator*).

For shutdown, no special requirements apply.

4 Typical Performance

4.1 Efficiency

Figure 24 and Figure 25 show the graphs for typical efficiency.

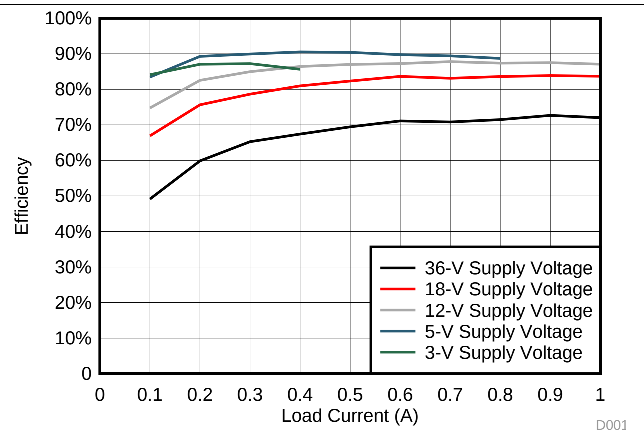

Figure 24. Typical Efficiency for 5-V Output

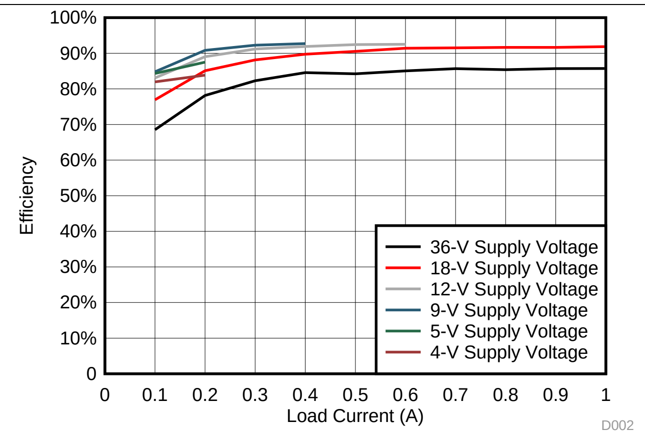

Figure 25. Typical Efficiency for 12-V Output

4.2 Startup Waveforms

Figure 26 and Figure 27 show the typical startup behavior for a 5-V output.

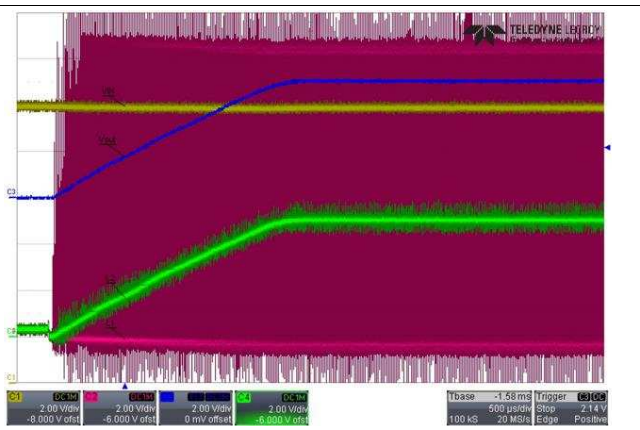

Figure 26. Startup When VIN is Already Present and IGN is Pulled High

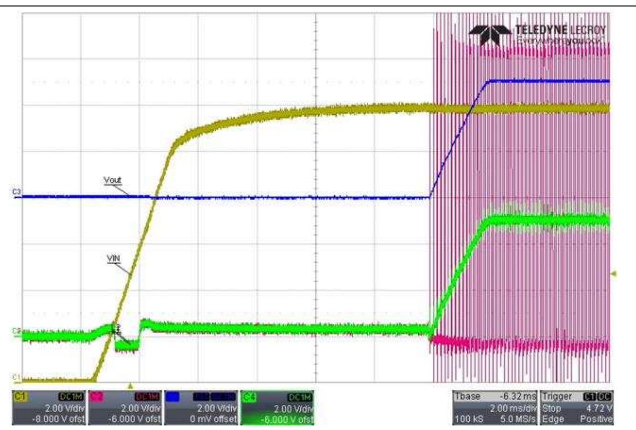

Figure 27. Startup With IGN Tied to VIN and Both Ramp Up

4.3 Switch Node Waveforms in Buck Mode, Boost Mode, and in Buck-Boost Mode

The following graphs show the switch-nodes in the various modes. The modes are determined by the ratio of input voltage to output voltage. In buck mode and boost mode, the device switches at 2 MHz. In buck-boost, both nodes switch interleaved, resulting in a 1-MHz switching frequency per node.

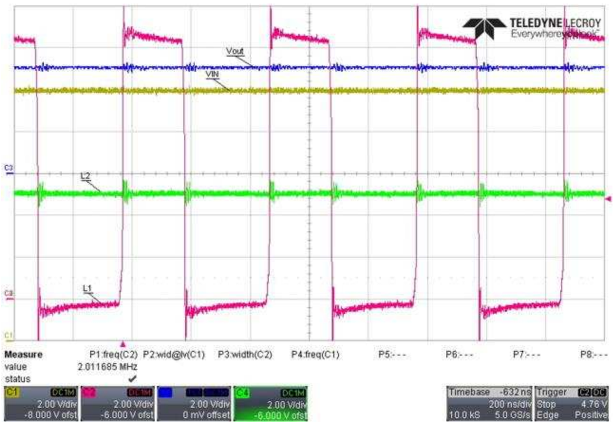

Figure 28. Switch-Nodes in Buck Mode (V_{VIN} = 12 V, V_{VOUT} = 5 V)

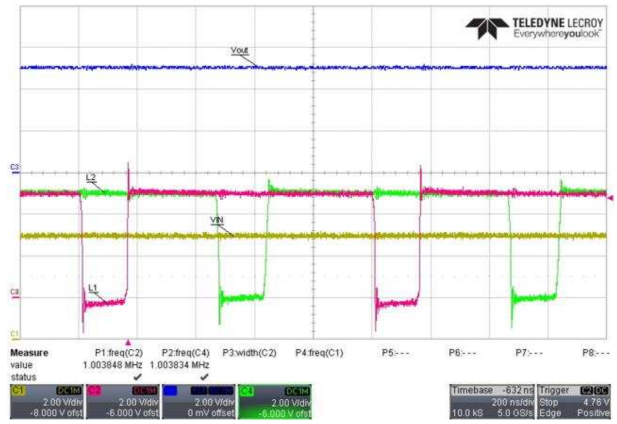

Figure 29. Switch-Nodes in Buck-Boost-Mode (V_{VIN} = 5 V, V_{VOUT} = 5 V)

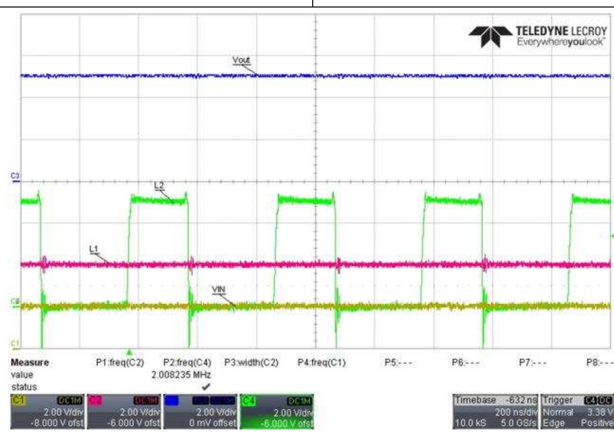

Figure 30. Switch-Nodes in Boost Mode (V_{VIN} = 2.5 V, V_{VOUT} = 5 V)

4.4 Load-Step Response

The following graphs show the load-step responses as taken on the EVM.

NOTE: Different slew-rates, capacitive loading, filtering, and other setups can result in different results (for example, ramp times of several 100 µs decrease the dips to « 100 mV).

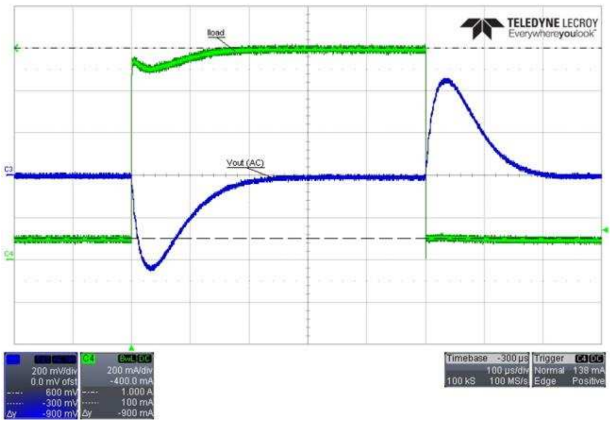

Figure 31. Load-Step Response
V_{VIN} = 12 V, V_{VOUT} = 5 V (Buck Mode), 100 mA-1 A-100 mA

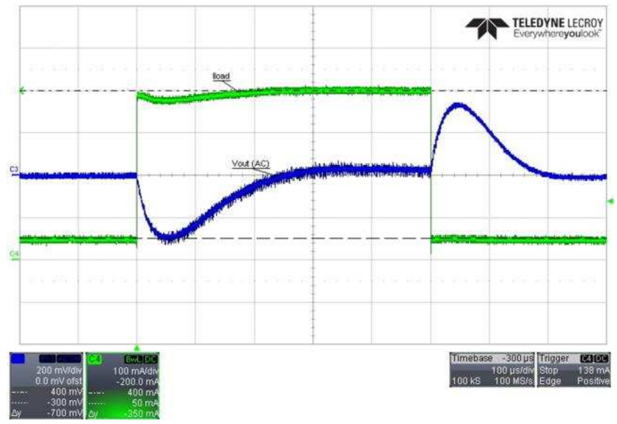

Figure 32. Load-Step Response
V_{VIN} = 2.5 V, V_{VOUT} = 5 V (Boost Mode), 50 mA-400 mA-50 mA

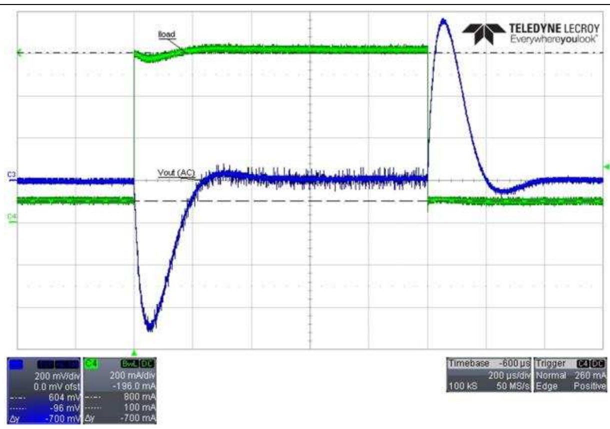

Figure 33. Load-Step Response
V_{VIN} = 14 V, V_{VOUT} = 12 V (Buck Mode), 100 mA-800 mA-100 mA

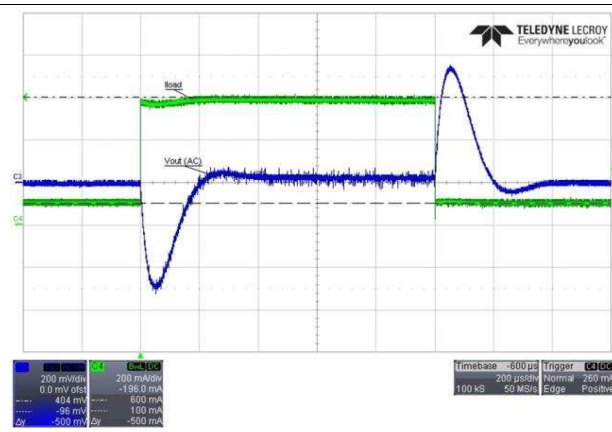

Figure 34. Load-Step Response
V_{VIN} = 12 V, V_{VOUT} = 12 V (Buck-Boost Mode), 100 mA-600 mA-100 mA

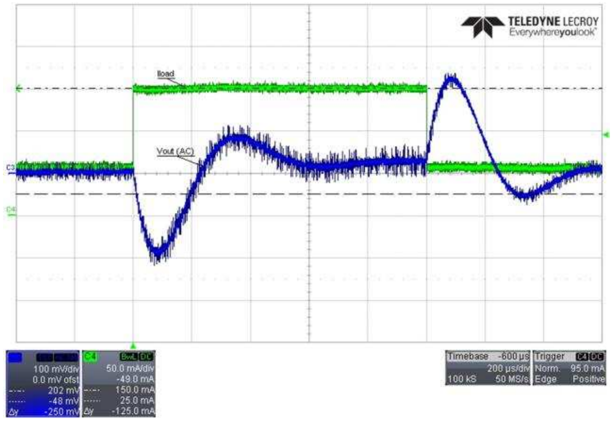

Figure 35. Load-step-response
V_{VIN} = 4 V, V_{VOUT} = 12 V (Boost Mode), 50 mA-150 mA-50 mA

4.5 Line step response / Cranking support

The following graphs show the response of the part to the cold-crank pulse as defined in the OEM specification LV124. The pulse decreases to 3 V, followed by some ringing before recovering to normal input voltage.

These graphs are with a 5-V output at 200-mA load.

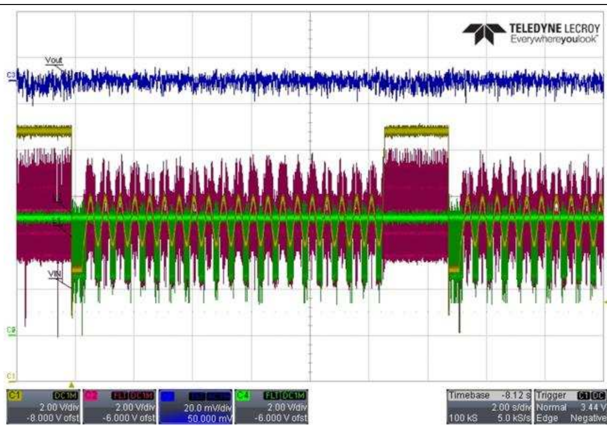

Figure 36. Cranking Pulse Response With 5-V Output, 200-mA Load, 2 s/div

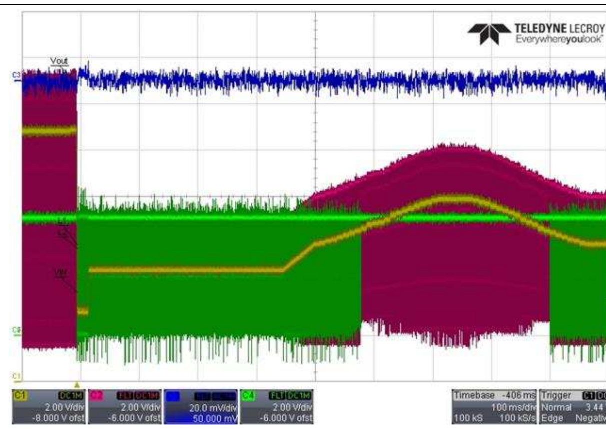

Figure 37. Cranking Pulse Response With 5-V Output, 200-mA Load, Zoom to 100 ms/div

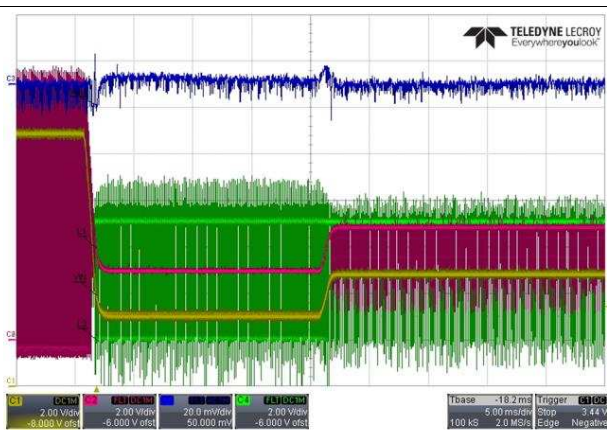

Figure 38. Cranking Pulse Response With 5-V Output, 200-mA Load, Zoom to 5 ms/div

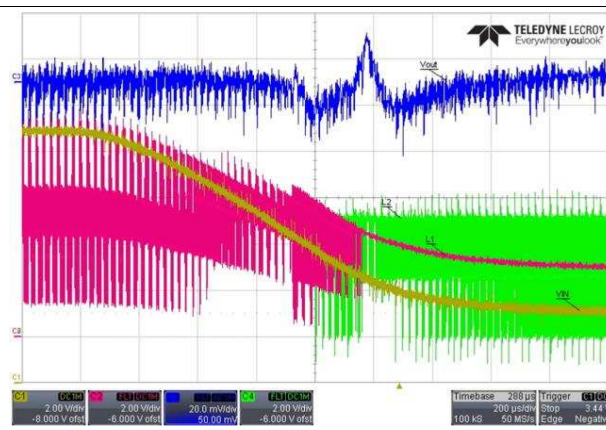

Figure 39. Cranking Pulse Response With 5-V Output, 200-mA load, Zoom to 200 µs/div

5 Related Documentation

Texas Instruments, *TPS5516x-Q1 36-V, 1-A Output, 2-MHz, Single Inductor, Synchronous Step-Up and Step-Down Voltage Regulator* 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.

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   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.

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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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.

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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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