

# **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.

## **Contents**

1	Introduction .....	3
2	Schematic, Bill of Materials, and Layout .....	3
	2.1 Schematic .....	4
	2.2 Bill of Materials .....	5
	2.3 Layout and Component Placement.....	7
3	Setup and Operation .....	11
	3.1 Input and Output Connector Descriptions.....	11
	3.2 Jumper Configuration .....	12
	3.3 Test Point Description .....	14
	3.4 Basic Operation.....	15
4	Typical Performance .....	16
	4.1 Efficiency .....	16
	4.2 Startup Waveforms.....	16
	4.3 Switch Node Waveforms in Buck Mode, Boost Mode, and in Buck-Boost Mode.....	17
	4.4 Load-Step Response .....	18
	4.5 Line step response / Cranking support.....	19
5	Related Documentation.....	20

## **List of Figures**

1	TPS55160Q1-EVM With Jumper Settings.....	3
2	TPS55165Q1-EVM With Jumper Settings.....	3
3	Schematic Diagram—No Variations .....	4
4	TPS55160Q1-EVM Schematic Diagram—Assembly Option .....	4
5	TPS55165Q1-EVM Schematic Diagram—Assembly Option.....	5
6	Component Placement—Top .....	7
7	TPS55160Q1-EVM Top Layer—Overview .....	8
8	TPS55165Q1-EVM Top Layer—Overview .....	8
9	Component Placement—Bottom .....	9
10	TPS55160Q1-EVM Bottom Layer—Overview .....	9
11	TPS55165Q1-EVM Bottom Layer—Overview .....	10
12	Layout—Top Layer.....	10
13	Layout—Layer 2.....	10
14	Layout—Layer 3.....	10
15	Layout—Bottom Layer.....	10

16	TPS55165Q1-EVM Showing Supply and Load Connections .....	11
17	Ignition Jumper Configuration Default: ON (Device powers up when power is applied).....	12
18	Power-Latch Jumper Configuration Default: LATCH .....	12
19	Spread Spectrum Enable Jumper Configuration Default: Jumper Installed, Spread Spectrum Disabled .....	13
20	Power-Good Delay Selection Jumper Configuration Default: Jumper Not Installed, 3-ms Delay .....	13
21	Low-Power-Mode Enable Jumper Configuration Default: Jumper Set to PWM, LPM Prohibited .....	13
22	Output Voltage Selection Jumper Configuration Default: 5 V for TPS55165-Q1 .....	14
23	Output Voltage Selection Jumper Configuration Default: 8 V for TPS55160-Q1, Configured by R6 and R7..	14
24	Typical Efficiency for 5-V Output .....	16
25	Typical Efficiency for 12-V Output .....	16
26	Startup When VIN is Already Present and IGN is Pulled High.....	16
27	Startup With IGN Tied to VIN and Both Ramp Up .....	16
28	Switch-Nodes in Buck Mode ( $V_{VIN} = 12\text{ V}$ , $V_{VOUT} = 5\text{ V}$ ) .....	17
29	Switch-Nodes in Buck-Boost-Mode ( $V_{VIN} = 5\text{ V}$ , $V_{VOUT} = 5\text{ V}$ ) .....	17
30	Switch-Nodes in Boost Mode ( $V_{VIN} = 2.5\text{ V}$ , $V_{VOUT} = 5\text{ V}$ ).....	17
31	Load-Step Response $V_{VIN} = 12\text{ V}$ , $V_{VOUT} = 5\text{ V}$ (Buck Mode), 100 mA-1 A-100 mA .....	18
32	Load-Step Response $V_{VIN} = 2.5\text{ V}$ , $V_{VOUT} = 5\text{ V}$ (Boost Mode), 50 mA-400 mA-50 mA .....	18
33	Load-Step Response $V_{VIN} = 14\text{ V}$ , $V_{VOUT} = 12\text{ V}$ (Buck Mode), 100 mA-800 mA-100 mA .....	18
34	Load-Step Response $V_{VIN} = 12\text{ V}$ , $V_{VOUT} = 12\text{ V}$ (Buck-Boost Mode), 100 mA-600 mA-100 mA.....	18
35	Load-step-response $V_{VIN} = 4\text{ V}$ , $V_{VOUT} = 12\text{ V}$ (Boost Mode), 50 mA-150 mA-50 mA .....	18
36	Cranking Pulse Response With 5-V Output, 200-mA Load, 2 s/div .....	19
37	Cranking Pulse Response With 5-V Output, 200-mA Load, Zoom to 100 ms/div .....	19
38	Cranking Pulse Response With 5-V Output, 200-mA Load, Zoom to 5 ms/div .....	19
39	Cranking Pulse Response With 5-V Output, 200-mA load, Zoom to 200 $\mu\text{s/div}$ .....	19

#### List of Tables

1	Bill of Materials (BOM) .....	5
2	Terminal Descriptions.....	11

#### Trademarks

All trademarks are the property of their respective owners.

## 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**

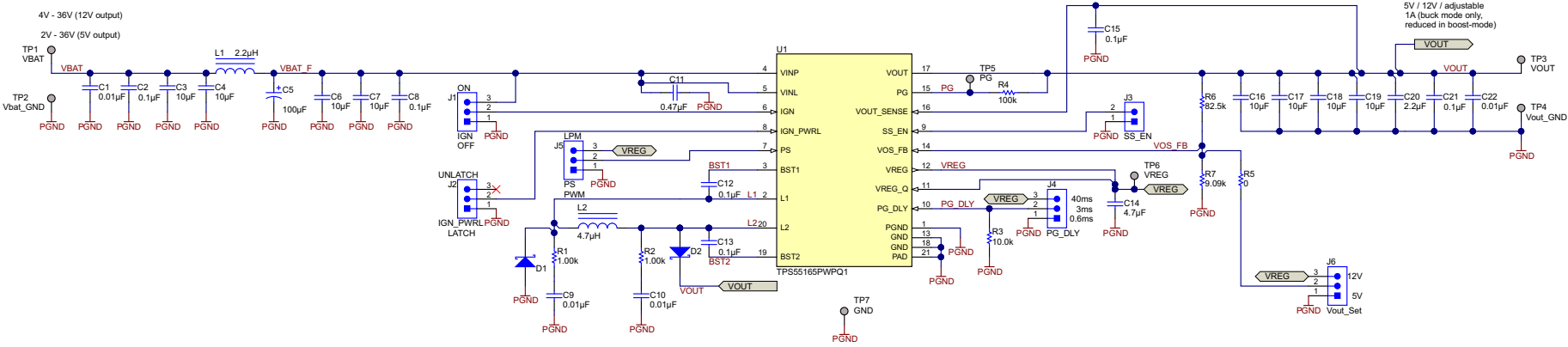


**Figure 2. TPS55165Q1-EVM With Jumper Settings**

## 2 Schematic, Bill of Materials, and Layout

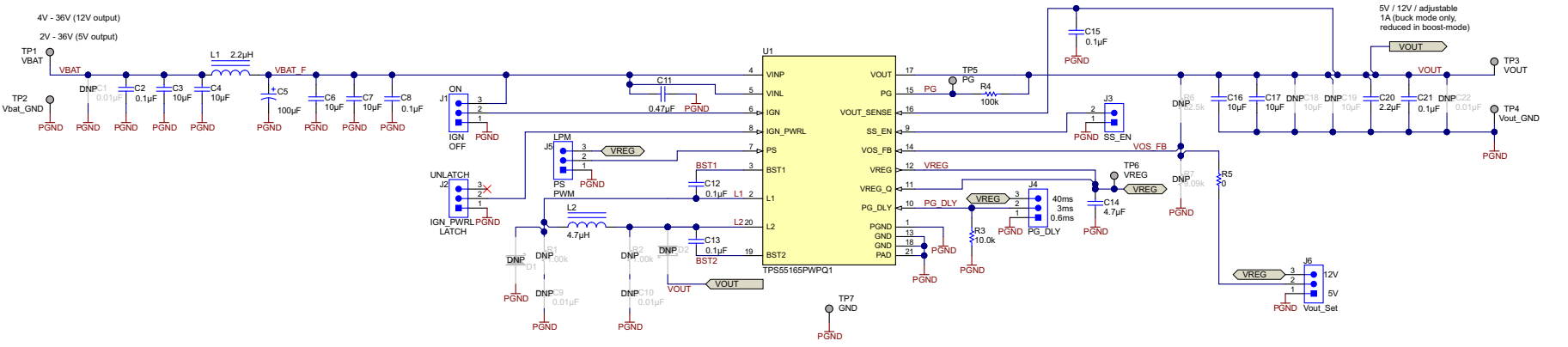
This section provides a more detailed description of the schematic, bill of materials (BOM), and layout.

2.1 Schematic



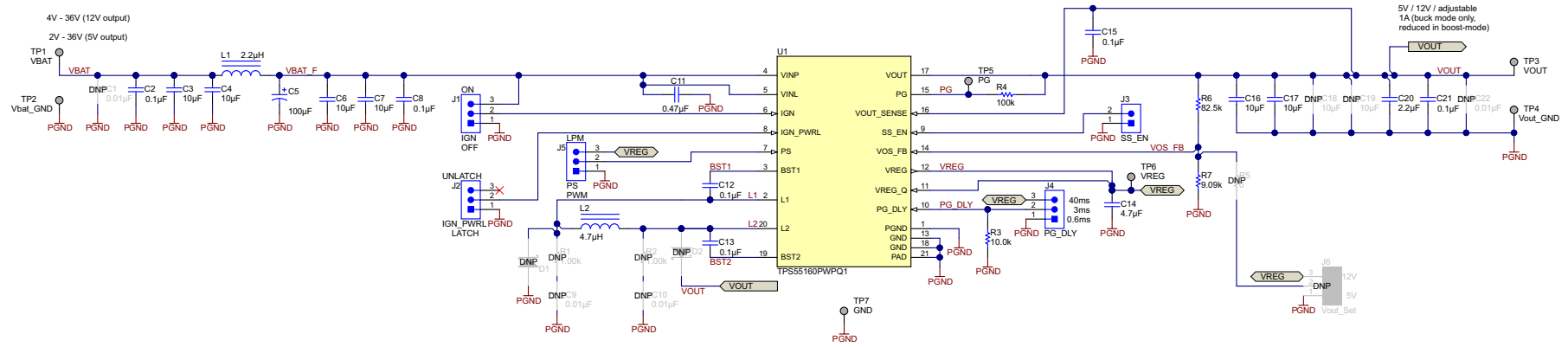
Copyright © 2017, Texas Instruments Incorporated

Figure 3. Schematic Diagram—No Variations



Copyright © 2017, Texas Instruments Incorporated

Figure 4. TPS55160Q1-EVM Schematic Diagram—Assembly Option



Copyright © 2017, Texas Instruments Incorporated

Figure 5. TPS55165Q1-EVM Schematic Diagram—Assembly Option

2.2 Bill of Materials

Table 1. Bill of Materials (BOM)

Designator	Quantity for TPS55165Q 1-EVM (Variant 001)	Quantity for 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 $\mu$ F	CAP, CERM, 0.1 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0603	0603	GCM188R71H104KA57D	MuRata
C3, C4, C6, C7, C16, C17	6	6	10 $\mu$ F	CAP, CERM, 10 $\mu$ F, 50 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 2220	2220	CGA9N3X7R1H106K230KB	TDK
C5	1	1	100 $\mu$ F	CAP, AL, 100 $\mu$ F, 50 V, $\pm$ 20%, 0.3 ohm, SMD	SMT Radial G	EEE-FC1H101P	Panasonic
C11	1	1	0.47 $\mu$ F	CAP, CERM, 0.47 $\mu$ F, 50 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H474K080AE	TDK
C14	1	1	4.7 $\mu$ F	CAP, CERM, 4.7 $\mu$ F, 16 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 0805	0805	GCM21BR71C475KA73K	MuRata
C20	1	1	2.2 $\mu$ F	CAP, CERM, 2.2 $\mu$ F, 50 V, $\pm$ 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	Quantity for TPS55165Q 1-EVM (Variant 001)	Quantity for 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 $\mu$ H	Inductor, Shielded, Powdered Iron, 2.2 $\mu$ H, 4.7 A, 0.035 ohm, AEC-Q200 Grade 1, SMD	4.1x4.1mm	78438356022	Wurth Elektronik
L2	1	1	4.7 $\mu$ H	Inductor, Wirewound, 4.7 $\mu$ H, 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 x 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 $\mu$ F	CAP, CERM, 0.01 $\mu$ F, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71H103KA37D	MuRata
C18, C19	0	0	10 $\mu$ F	CAP, CERM, 10 $\mu$ F, 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

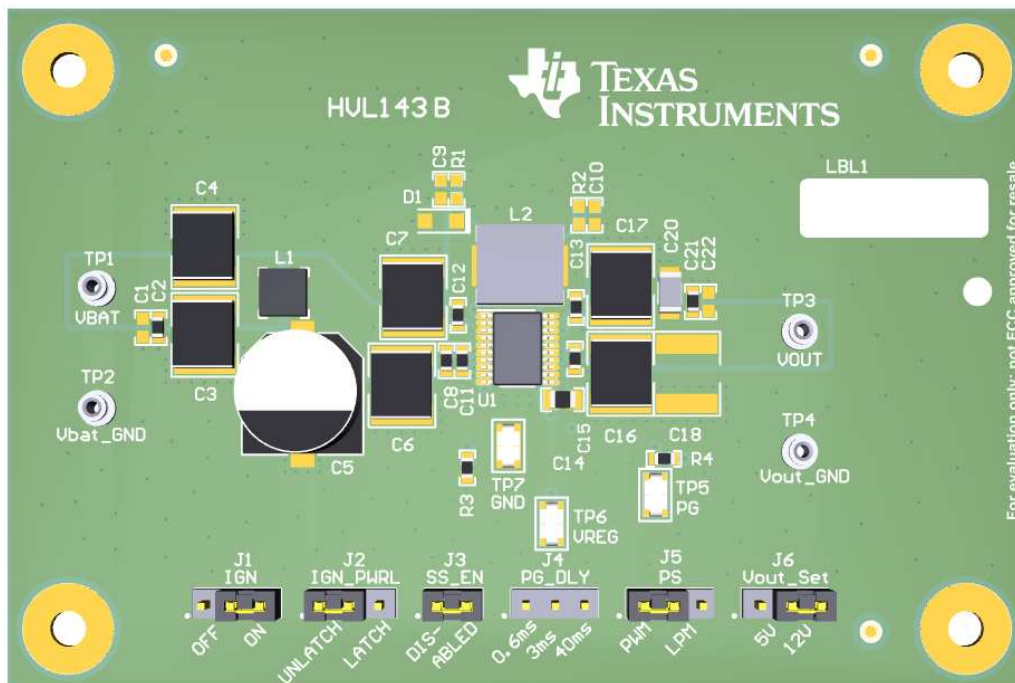
The TPS55160Q1-EVM and TPS55165Q1-EVM share the same PCB which is named HVL143B.

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

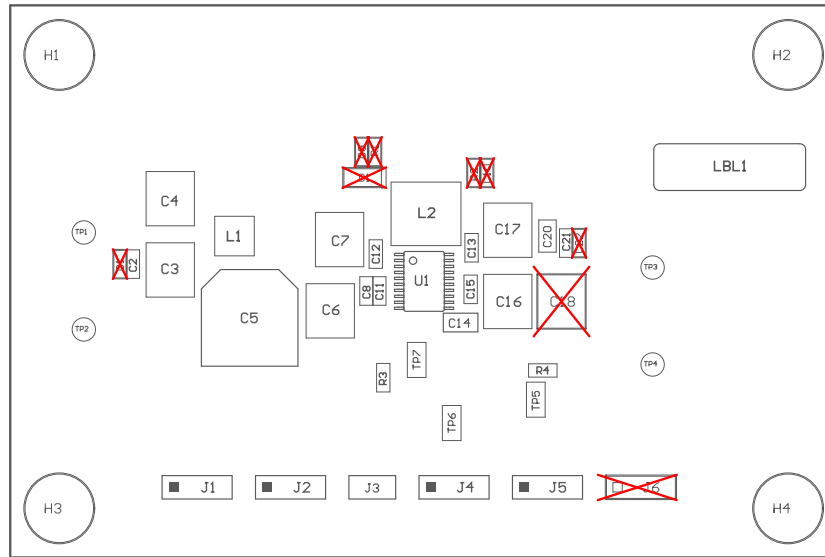
The R6 and R7 resistors are not populated on the TPS55165Q1-EVM. Select the output voltage of either 5V or 12V using J6, which is named Vout\_Set.

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 J6 jumper, which is prone to pick up noise, the R5 resistor and J6 jumper are not assembled on the TPS55160Q1-EVM.

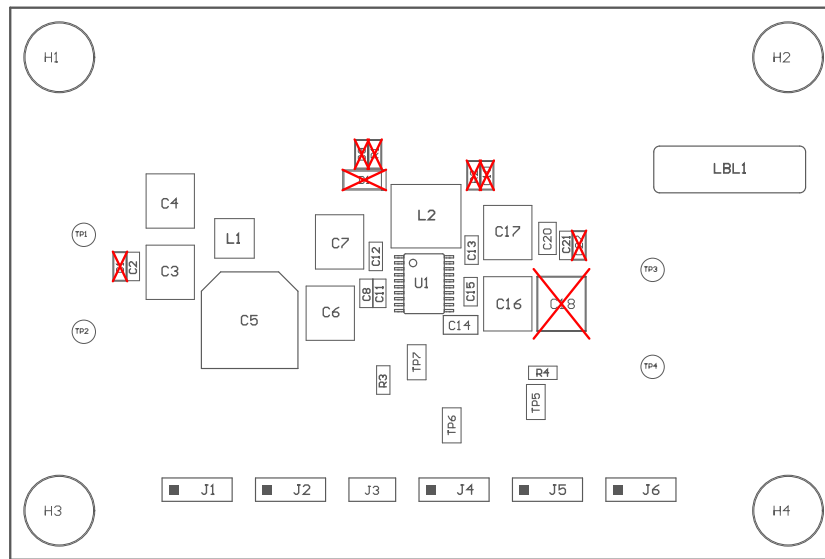
Figure 4, Figure 7, and Figure 8 show the top layout of the EVM, with assembly options for the fixed voltage version (TPS55165Q1-EVM) at the adjustable voltage version (TPS55160Q1-EVM).



**Figure 6. Component Placement—Top**



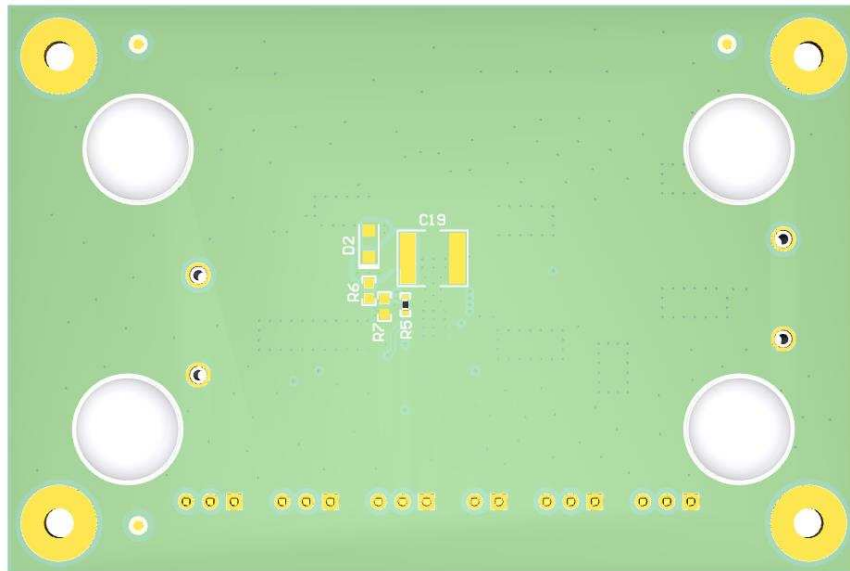
**Figure 7. TPS55160Q1-EVM Top Layer—Overview**



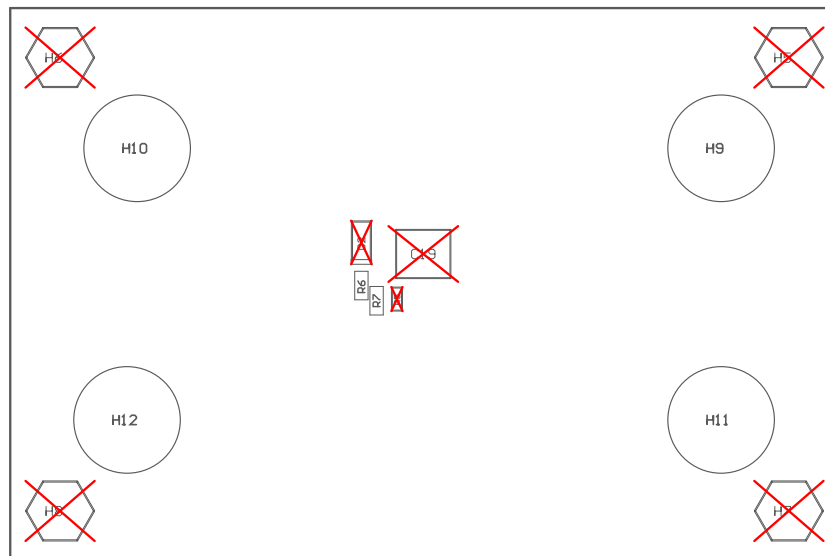
**Figure 8. TPS55165Q1-EVM Top Layer—Overview**



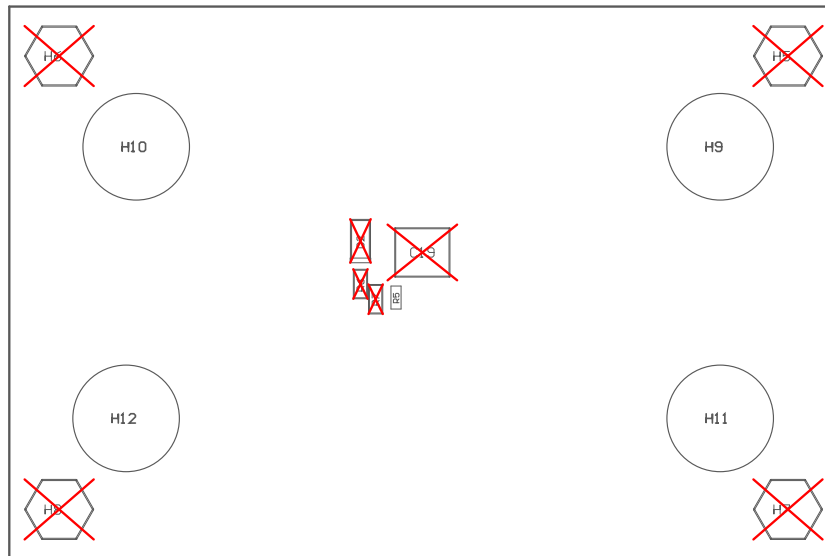
Figure 9, Figure 10, and Figure 11 show the bottom layout of the EVM, with assembly options for the fixed voltage version (TPS55165Q1-EVM) at the adjustable voltage version (TPS55160Q1-EVM).



**Figure 9. Component Placement—Bottom**

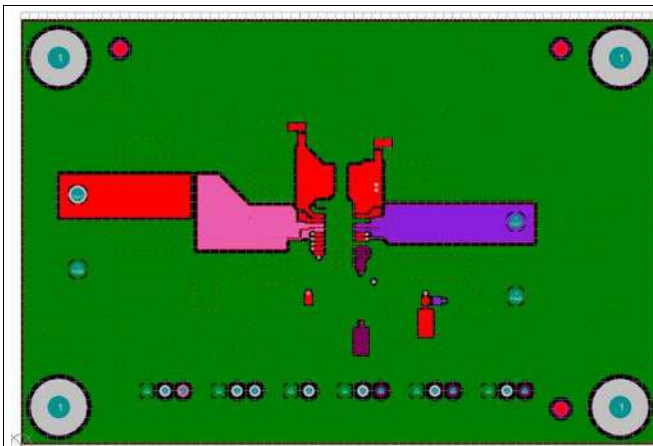


**Figure 10. TPS55160Q1-EVM Bottom Layer—Overview**



**Figure 11. TPS55165Q1-EVM Bottom Layer—Overview**

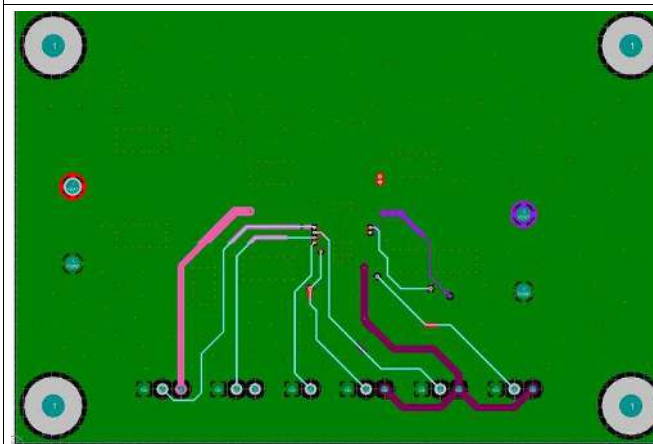
Figure 12, Figure 13, Figure 14, and Figure 15 show the EVM board layers.



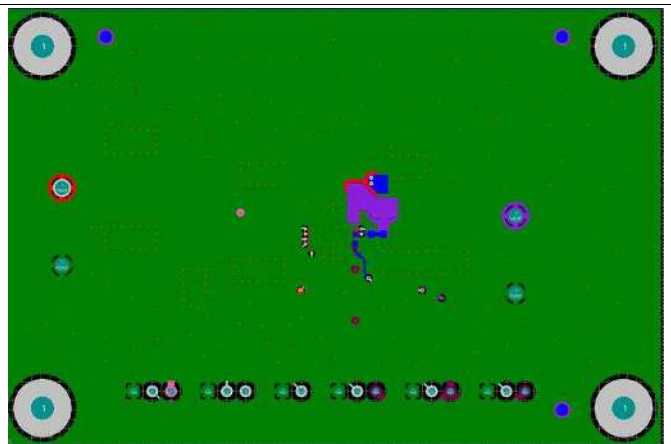
**Figure 12. Layout—Top Layer**



**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

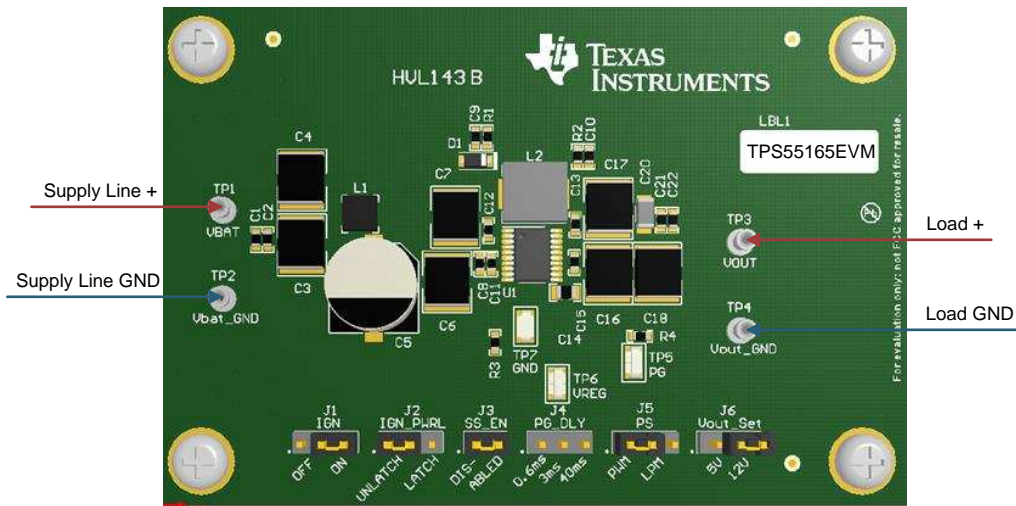
The EVM has one pair of connectors (turrets) for the input and one pair for the output. Table 2 lists all the connectors with their functional description and electrical specification.

**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. <sup>(1)</sup>
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. <sup>(2)</sup>

(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 ON position. Put this jumper in the OFF position 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

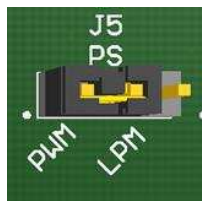
The PG\_DLY jumper sets the power-good delay time. This time defines how long before the power-good pin (PG pin, TP3) goes low after the output voltage decreases to less than the PG undervoltage threshold (PGTH\_UV). The default of this jumper is 3ms (no jumper installed).



**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

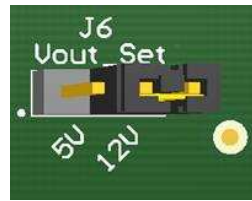
### 3.2.6 Vout\_Set

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.

---

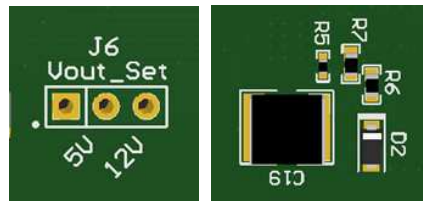
**NOTE:** To make a jumper change effective, power cycle the supply or turn off the output (move the IGN jumper to OFF while the device is unlatched).

---



**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.

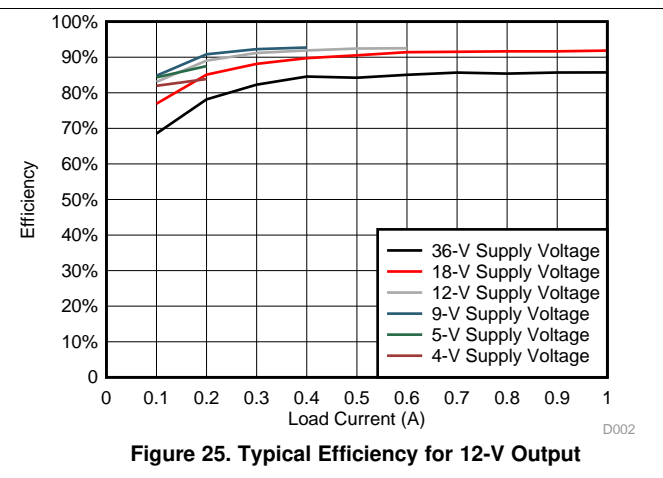
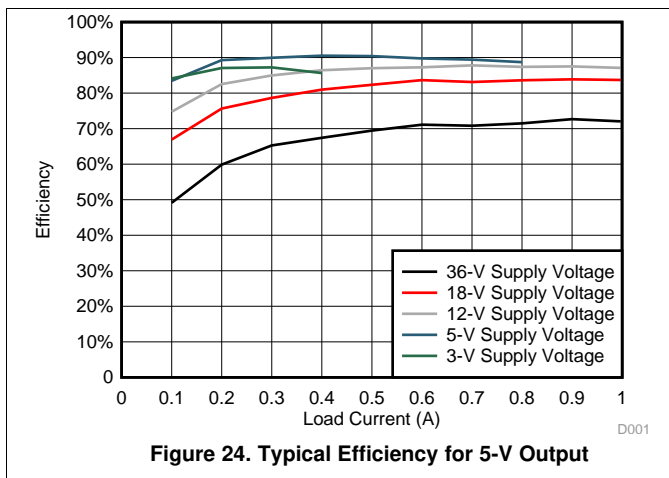
The PG\_DLY jumper sets the delay time of the PG output. The default is 3 ms. The PG delay time can be decreased 0.6 ms or increased 40 ms. To change the PG delay time, install the jumper in the respective position. This configuration refers to the PG<sub>exttime</sub> time (refer to the *TPS5516x-Q1 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<sub>exttime</sub> 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

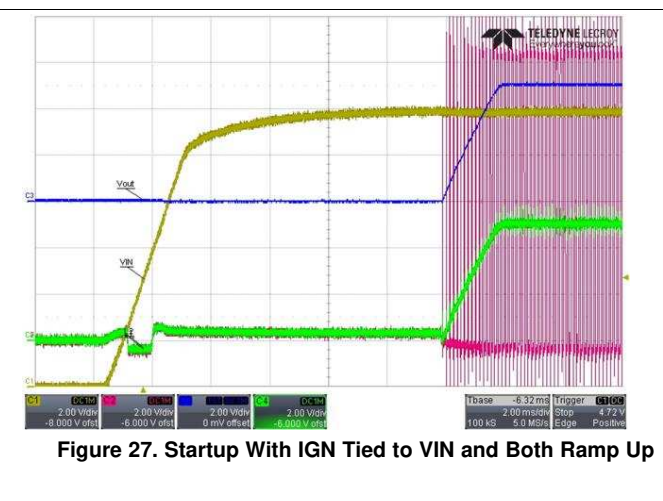
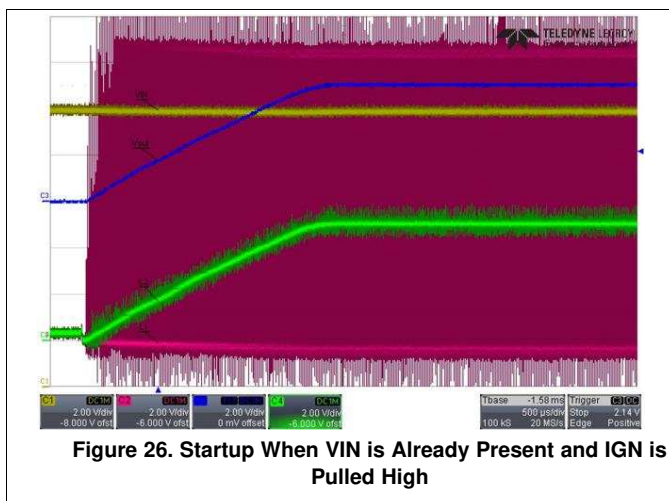
### 4.1 Efficiency

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



### 4.2 Startup Waveforms

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





### 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.

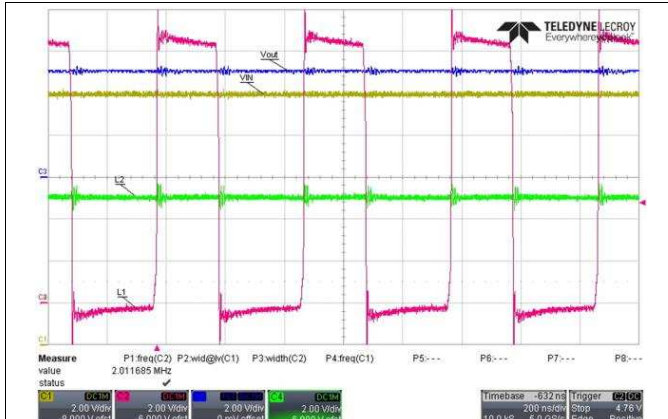


Figure 28. Switch-Nodes in Buck Mode ( $V_{VIN} = 12\text{ V}$ ,  $V_{VOUT} = 5\text{ V}$ )

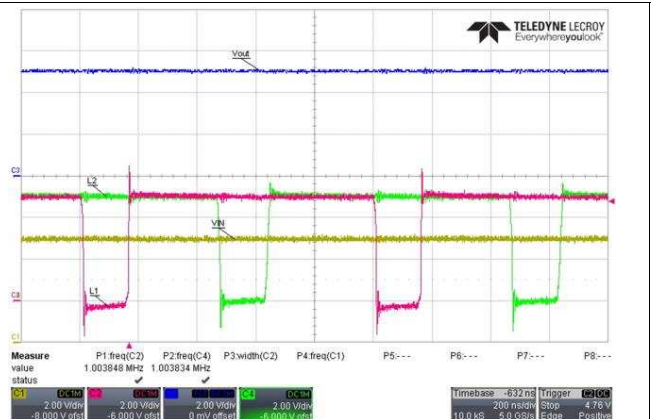


Figure 29. Switch-Nodes in Buck-Boost-Mode ( $V_{VIN} = 5\text{ V}$ ,  $V_{VOUT} = 5\text{ V}$ )

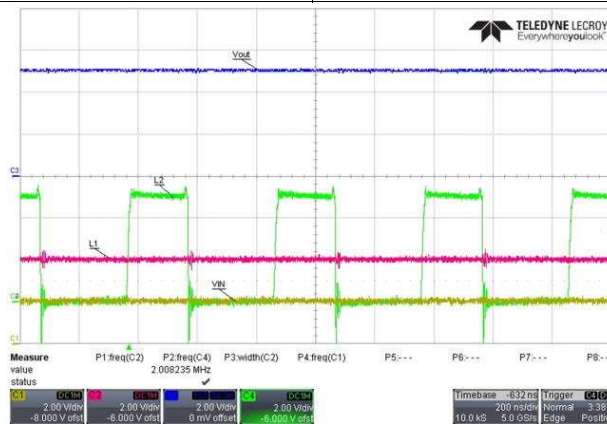
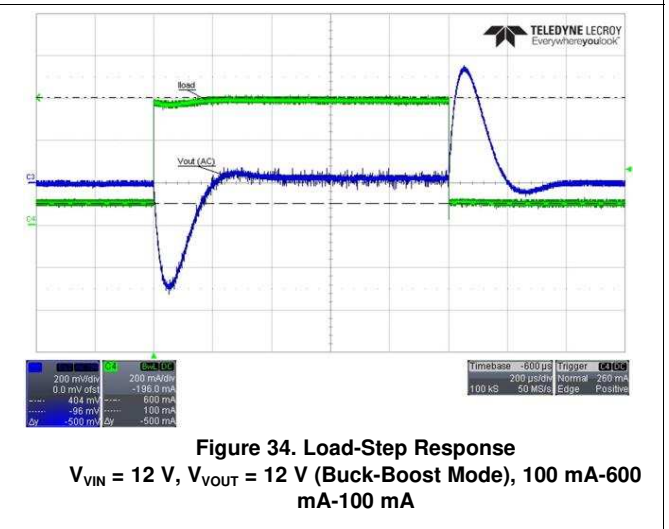
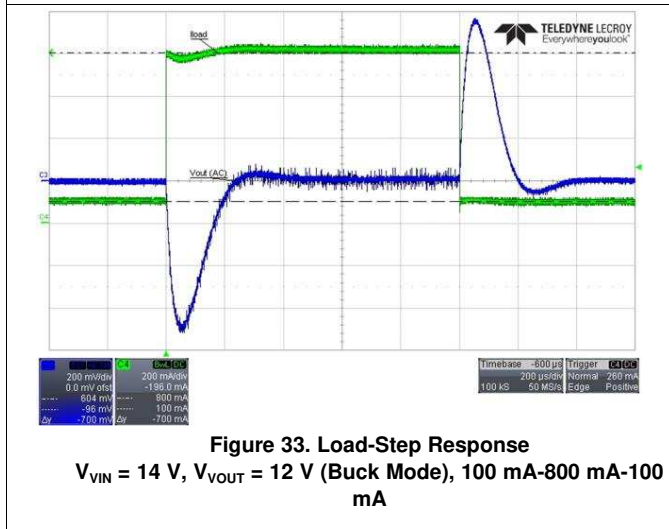
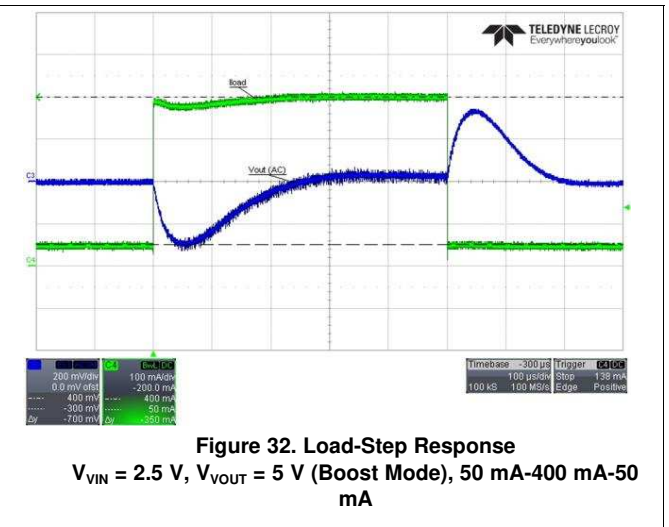
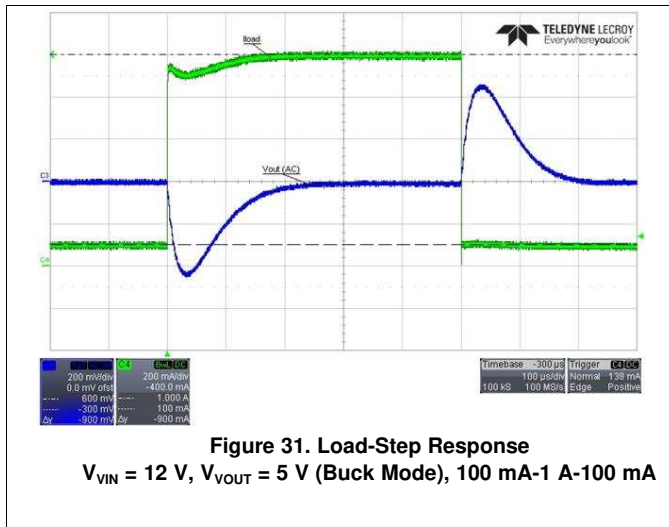


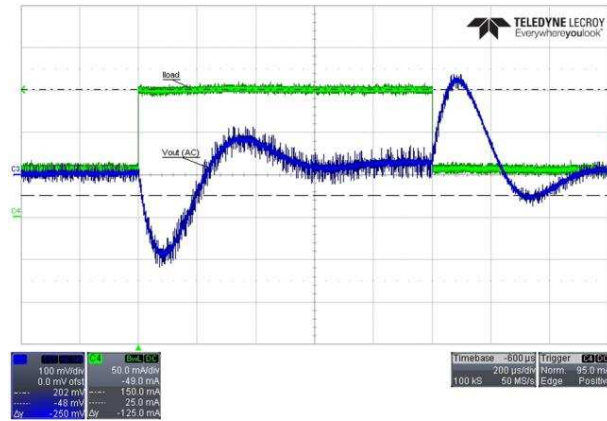
Figure 30. Switch-Nodes in Boost Mode ( $V_{VIN} = 2.5\text{ V}$ ,  $V_{VOUT} = 5\text{ V}$ )

### 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  $\mu$ s decrease the dips to  $\ll$  100 mV).



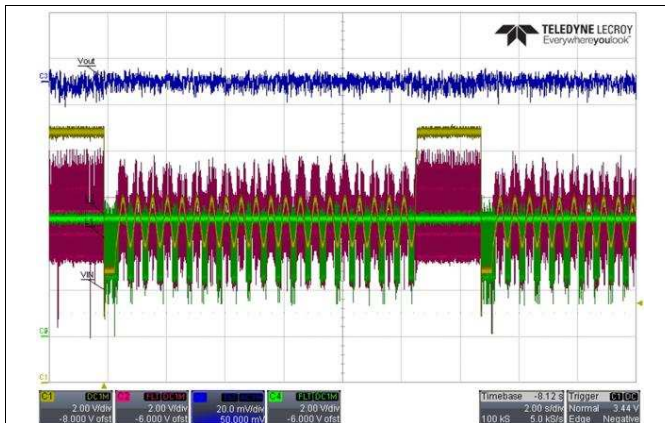


**Figure 35. Load-step-response**  
 $V_{VIN} = 4\text{ V}$ ,  $V_{VOUT} = 12\text{ V}$  (Boost Mode), 50 mA-150 mA-50 mA

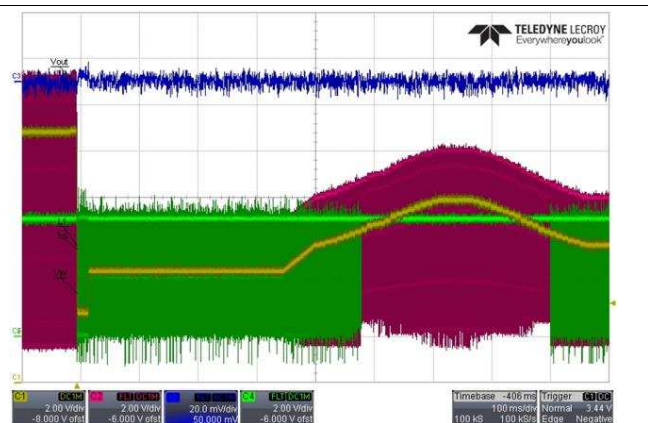
#### 4.5 Line step response / Cranking support

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.

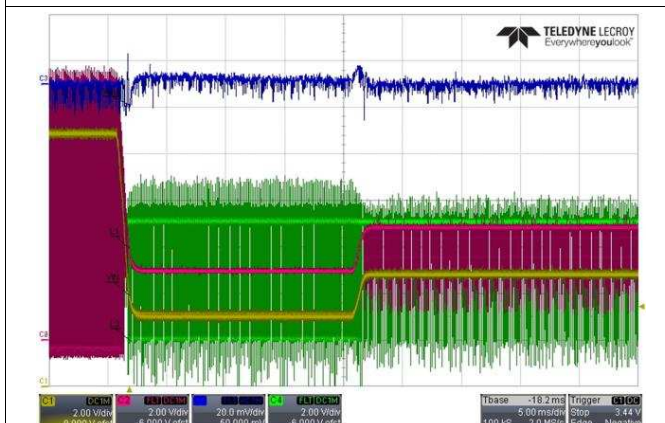
These graphs are with a 5-V output at 200-mA load.



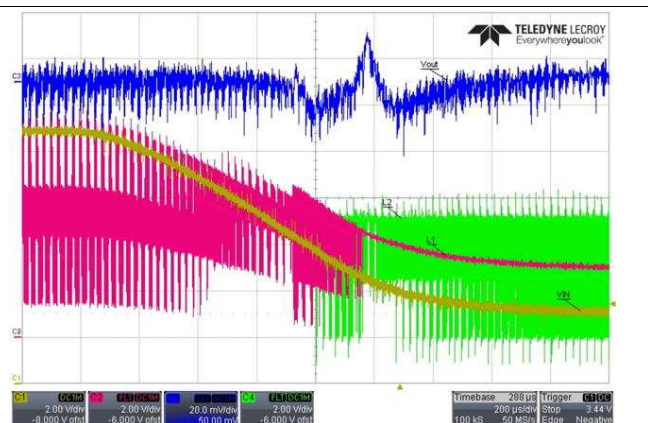
**Figure 36. Cranking Pulse Response With 5-V Output, 200-mA Load, 2 s/div**



**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](#)

## 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 semiconductor 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.
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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。技術適合証明を受けていないものご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号  
西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see [http://www.tij.co.jp/llds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/llds/ti_ja/general/eStore/notice_02.page)  
電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。 [http://www.tij.co.jp/llds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/llds/ti_ja/general/eStore/notice_02.page)

#### 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, INDEMNITY 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.



## IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2017, Texas Instruments Incorporated