LM5164-Q1 EVM User Guide

The LM5164-Q1 EVM is a 100-V DC/DC buck regulator that employs synchronous rectification to achieve high conversion efficiency in a small footprint. The EVM operates over a wide input voltage range of 15 V to 100 V to provide a regulated 12-V output at 300-kHz switching frequency. The output voltage has better than 1.5% setpoint accuracy and is adjustable using an external resistor divider. The module design uses the LM5164-Q1 synchronous buck converter with wide input voltage (wide V_{IN}) range, wide duty-cycle range, integrated high-side and low-side power MOSFETs, cycle-by-cycle overcurrent protection, and precision enable. With AEC-Q100 grade 1 automotive qualification, the LM5164-Q1 is rated to operate over a junction temperature range of –40°C to +150°C. The LM5164-Q1 is available in an 8-pin SO PowerPAD™ package to enable high density, low component count DC/DC solutions. The LM5164-Q1EVM-041 evaluation module is qualified for the LM5164 as well as the LM5164-Q1 buck converter. See Table 1 for package information.

Use the LM5164-Q1 with *WEBENCH® Power Designer* to create a custom regulator design. Furthermore, the user can download the LM5164-Q1 *Quickstart calculator* to optimize component selection and examine predicted efficiency performance across line and load ranges.

Table 1. Device and Package Configurations

CONVERTER	IC	PACKAGE
U1	LM5164-Q1	8-pin SO package with PowerPAD (4.89 mm × 3.90 mm)
	LM5164	

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Trademarks

PowerPAD is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

1   General TI High Voltage Evaluation User Safety Guidelines

Always follow TI's set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center http://support.ti.com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions may result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed-circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

- **Work Area Safety:**
    - Maintain a clean and orderly work area.
    - Qualified observer(s) must be present anytime circuits are energized.
    - Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
    - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50 V_{RMS}/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
    - Use a stable and non-conductive work surface.
    - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

- **Electrical Safety:**

    As a precautionary measure, it is always a good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
    - De-energize the TI HV EVM and all its inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
    - With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
    - When EVM readiness is complete, energize the EVM as intended.

    WARNING: While the EVM is energized, never touch the EVM or its electrical circuits as they could be at high voltages capable of causing electrical shock hazard.

- **Personal Safety:**
  - Wear personal protective equipment, for example, latex gloves and/or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
- **Limitation for Safe Use:**
  - EVMs are not to be used as all or part of a production unit.

Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user guide and the safety-related documents that come with the EVM package before operating this EVM.

CAUTION

Do not leave the EVM powered when unattended.

WARNING

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

WARNING

High Voltage! Electric shock is possible when connecting board to live wire. Board should be handled with care by a professional.

For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

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2 Overview

2.1 *LM5164-Q1 Synchronous Buck Converter*

The LM5164-Q1 step-down switching converter features all the functions needed to implement a low-cost, high-efficiency buck regulator capable of supplying 1 A to the load. An adaptive constant on-time (COT) control scheme and diode emulation mode at light loads enable a no-load supply current as low as 24 μA at 48-V input. With integrated 100-V power MOSFETs, synchronous rectification achieves high conversion efficiency over a wide load current range. Various features incorporated for enhanced reliability and safety include cycle-by-cycle peak current limit, thermal shutdown protection, internal output voltage soft-start timer, 1.5-V precision enable threshold, and an open-drain PGOOD indicator for sequencing and fault reporting.

Figure 1 shows the pin configuration of the LM5164-Q1. Figure 2 presents the regulator schematic for quick reference.
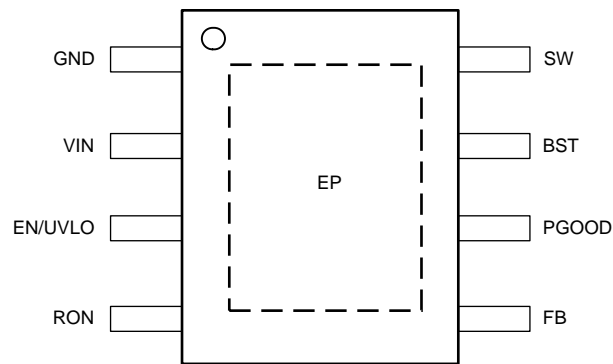
Figure 1. LM5164-Q1 Pin Configuration (8-Pin SO Package with PowerPAD, Top View)
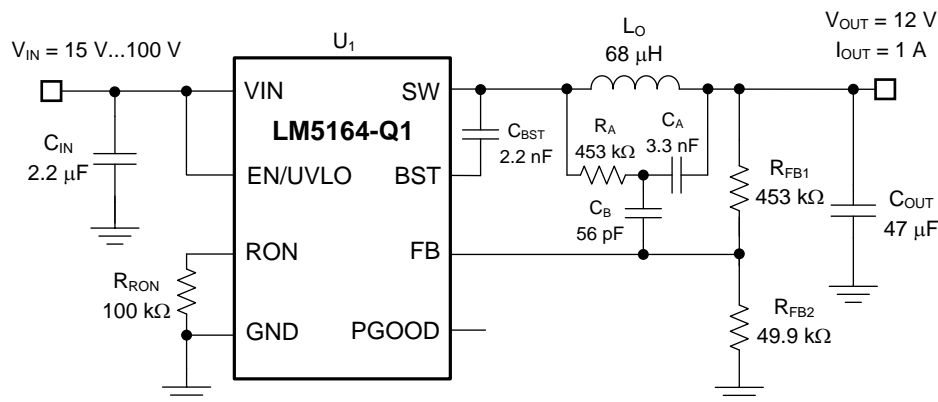
Figure 2. LM5164-Q1 Buck Regulator Simplified Schematic

2.2 *Typical Applications*

- Automotive 48-V Mild Hybrid ECU Bias Supplies
- Automotive DC/DC Converter, PTC Heater, HVAC Compressors
- High Cell Count Battery Packs for E-Bikes, E-Scooters and Drones
- General-Purpose Bias Supplies
- Automotive and Industrial Battery-Powered Equipment

2.3 EVM Performance Specifications

- Tightly-regulated output voltage of 12 V with 1% setpoint accuracy, adjustable from 1.2 V to VIN
- Wide input voltage operating range of 15 V to 100 V
- Ultra-high power conversion efficiency:
  - >90% at an output voltage of 12 V and load current above 3 mA (input voltage 24 V)
- No-load supply current as low as 24 µA (without EN/UVLO resistor divider)
- Integrated 0.7-Ω NMOS buck switch supports 99% duty cycle for low dropout voltage
- Integrated 0.3-Ω NMOS synchronous rectifier eliminates external Schottky diode
- ENABLE and PGOOD terminals with 1-MΩ and 100-kΩ pullups to VIN and VOUT, respectively
- Monotonic pre-bias output voltage startup
- Programmable input UVLO via precision enable (internally set to turn on and off at 1.5 V and 1.4 V, respectively)
- Fully assembled, tested and proven PCB layout

3   EVM Characteristics

Table 2. EVM Electrical Performance Characteristics

Parameter	Test Conditions		MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS						
Input voltage range, V_{VIN}	EVM input voltage operating range		15	48	100	V
Input voltage turn on, $V_{IN(ON)}$				6.0		V
Input voltage turn off, $V_{IN(OFF)}$	Adjusted by EN/UVLO resistors			5.6		V
Input voltage hysteresis, $V_{IN(HYS)}$				0.4		V
Input current, no load, $I_{IN(NL)}$	$I_{OUT} = 0$ A	$V_{IN} = 24$ V		44		µA
		$V_{IN} = 48$ V		60		µA
Input current, disabled, $I_{IN(OFF)}$	$V_{EN/UVLO} = 0$ V	$V_{IN} = 24$ V		29		µA
OUTPUT CHARACTERISTICS						
Output voltage, V_{OUT}[(1)]	V_{OUT} follows V_{IN} for $V_{IN} < 12$V			12.0		V
Output current, I_{OUT}	$V_{VIN} = 15$ V to 100 V		0		1	A
Output voltage regulation, ΔV_{OUT}	Load regulation	$I_{OUT} = 0.1$ A to 1 A		0.75%		
	Line regulation	$V_{VIN} = 15$ V to 100 V		1.5%		
Output voltage ripple, $V_{OUT(AC)}$	$V_{IN} = 48$ V, $I_{OUT} = 1$ A			30		mVp-p
Output overcurrent protection, I_{OCP}	$V_{IN} = 48$ V			1.4		A
Soft-start time, t_{SS}				3		ms
SYSTEM CHARACTERISTICS						
Switching frequency in CCM, $F_{SW(nom)}$	$V_{IN} = 48$ V			300		kHz
Half-load efficiency, η_{HALF}[(1)]	$I_{OUT} = 0.5$ A	$V_{IN} = 24$ V		95%		
Full load efficiency, η_{FULL}	$I_{OUT} = 1$ A	$V_{IN} = 15$ V		93.2%		
		$V_{IN} = 24$ V		93.4%		
		$V_{IN} = 48$ V		92.1%		
		$V_{IN} = 100$ V		86%		

[(1)]   The default output voltage of this EVM is 12 V. Efficiency and other performance metrics will change based on the operating input voltage, output voltage, load current, output capacitance, and other parameters.

4   LM5164-Q1 Evaluation Module

The LM5164-Q1 EVM is configured to deliver 12 V and 1 A at a switching frequency of 300 kHz. As shown in Figure 2, a type 3 ripple generation circuit is used to generate the appropriate voltage ripple on FB. This circuit uses an RC network (consisting of R_A and C_A) between SW and V_{OUT} to create a triangular ramp. This triangular ramp is then AC coupled into the feedback node with capacitor C_B. This method is best suited for applications where low output voltage ripple is required and where ceramic output capacitors are used (since it is not using the output voltage to generate the ripple signal).

4.1   Quick Start Procedure

1. Connect the voltage supply between VIN and GND connectors using short wires.
2. Connect the load of the converter between VOUT and GND connectors using short wires.
3. Set the supply voltage (V_{VIN}) at an appropriate level between 15 V to 100 V. Set the current limit of the supply to an appropriate level as well.
4. Turn on the power supply. The EVM powers up and provides $V_{OUT} = 12$ V.
5. Monitor the output voltage while increasing the load current to 1 A max.

See Figure 3 for the location of the connectors.

Figure 3. LM5164-Q1 EVM Top View

CAUTION

Caution Hot surface.
Contact may cause burns.
Do not touch.
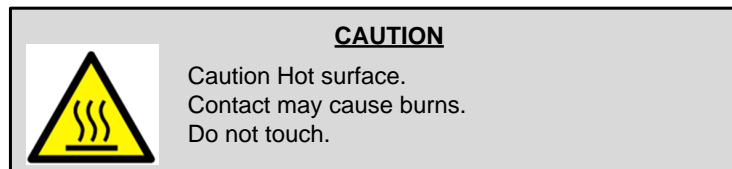
4.2 Detailed Descriptions

This section describes the connectors and the test points on the EVM and how to properly connect, set up and use the LM5164-Q1 EVM. See Figure 3 for a top view of the EVM.

VOUT — Output voltage of the converter.

VOUT connector and test point connected to the power inductor and the output capacitors. Connect the loading device between VOUT and GND connectors to provide loading to the regulator. Connect the loading device to the board with short wires to handle the DC output current.

GND — Ground of the converter.

It is connected to the LM5164-Q1 GND as well as the return terminals of the input and output capacitors. GND is the current return path for both supply voltage and load. Connect to supply and load grounds with short wires.

VIN — Input voltage to the converter.

VIN connector and test point connects to the input capacitors and the VIN pin of the LM5164-Q1. Connect the supply voltage from a power supply or a battery between the VIN and GND connectors. The voltage range should be higher than 6 V for the device to be active. V_{VIN} higher than 15 V provides a regulated 12 V output voltage. To avoid damaging the device V_{VIN} should be no greater than 100 V. The current limit on the supply should be high enough to provide the needed supply current when the output is fully loaded. The supply voltage should be connected to the board with short wires. If long cables are used to power up the board, add a damping capacitor C_8 to avoid oscillation between the cable parasitic inductance and the low-ESR input ceramic capacitors.

VIN-EMI — Input voltage to input filter of the converter.

If an input filter is desired between the supply voltage and the LM5164-Q1, connect the supply voltage between VIN-EMI and GND-EMI. The supply voltage should be connected to the board with short wires.

GND-EMI — Ground connection near the input filter.

This is the current return path for the supply connected to VIN-EMI. It provides a direct connection to the input filter capacitors to filter conducted noise generated by the converter. Use VIN-EMI and GND-EMI connections at the input filter to minimize EMI.

Input Filter— EMI mitigation.

The input filter consists of a filter inductor, ferrite bead and ceramic capacitors. An electrolytic capacitor is included for bulk energy storage and input parallel damping. To include the input filter in the power path, connect the supply voltage between VIN-EMI and GND-EMI. The output side of the filter is connected to the VIN net, which is connected to the LM5164-Q1 VIN pin and input capacitors.

Conducted EMI arises from the turn-on and turn-off transition of power switches that generate large discontinuous currents at the input of the buck converter, resulting in voltage ripple. The input filter helps smooth out this voltage ripple at the regulator input.

EN/UVLO — Test point to monitor the EN/UVLO pin of the device.

This test point is to monitor the voltage on the device EN/UVLO pin.

EN/UVLO Jumper — Set EN/UVLO pin options.

Use this jumper to enable/disable the LM5164-Q1. PIN-1 is connected to GND and PIN-2 is connected to EN/UVLO.

1. Connect PIN-1 to PIN-2 to disable the device.

2. Leave PIN-1 and PIN-2 open for EN/UVLO to be connected to VIN through a resistor divider.

PIN-1 and PIN-2 are not connected in the default setting. Calculate the lower UVLO resistor, R_{UV2}, based on the desired turn-on voltage of 6 V and the selected upper UVLO resistor, R_{UV1}, of 1 MΩ using Equation 1.

$$R_{UV2} = \frac{1.5\,V}{V_{IN(on)} - 1.5\,V} \cdot R_{UV1} = \frac{1.5\,V}{6\,V - 1.5\,V} \cdot 1\,M\Omega = 332\,k\Omega$$

(1)

If a resistor divider is not required, R_{UV2} can be removed such that the EN/UVLO voltage pulls up to the input voltage.

PGOOD — PGOOD jumper.

PGOOD jumper with PIN-1 connected to PGOOD and PIN-2 connected to GND. PIN-1 can be used as a test point to monitor the power-good indicator. This flag indicates whether the output voltage has reached its regulation level. The LM5164-Q1 PGOOD is an open-drain output that is tied to V_{OUT} through resistor R_{10}.

Edge Connector — Additional connector to attach the EVM to a cable harness.

The edge connector provides the option of connecting the EVM to a cable harness if available. It includes the power connections: VIN, VIN-EMI, GND, GND-EMI and VOUT. It also has Kelvin sense connections for VIN, VOUT, and GND. See the schematic in Figure 4 for all signals connected to the edge connector.
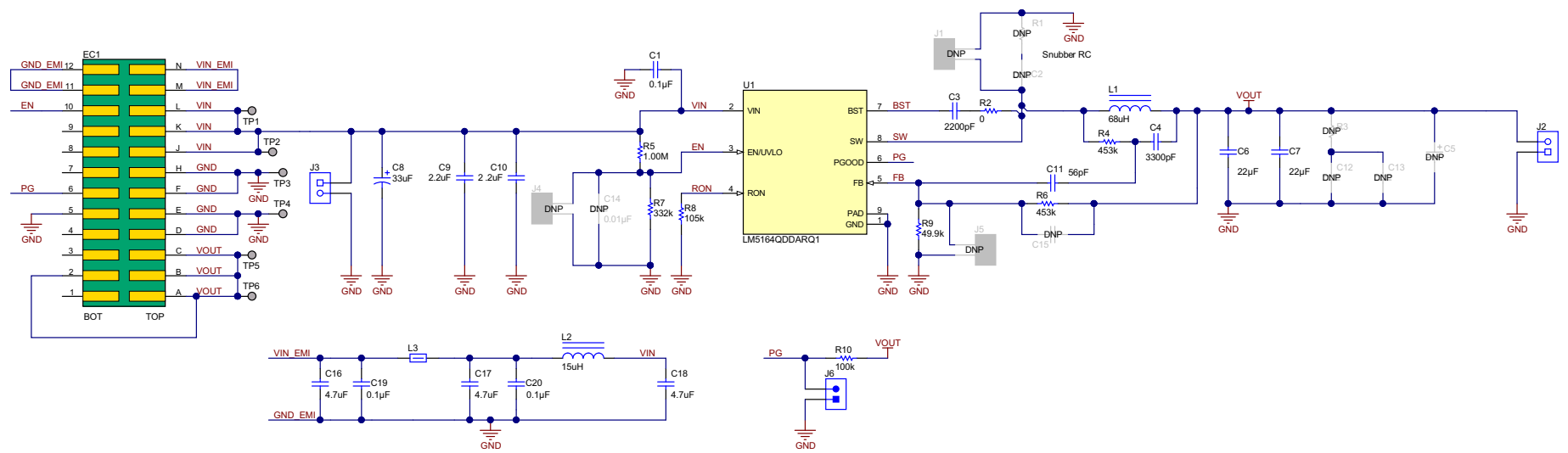
5 Schematic

Figure 4. LM5164-Q1 EVM Schematic

6   PCB Layout

Figure 5 through Figure 8 show the board layout for the LM5164-Q1EVM-041. The EVM offers resistors, capacitors, and test points to configure the output voltage, precision enable, and switching frequency.

The 8-pin SO PowerPAD™ package offers an exposed thermal pad, which must be soldered to the copper landing on the PCB for optimal thermal performance. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias under the thermal pad to connect to all four layers.

Test points have been provided for ease of use to connect the power supply, required load, and to monitor critical signals. The 12-pin edge connector can also be used to facilitate the use of a cable harness if required.
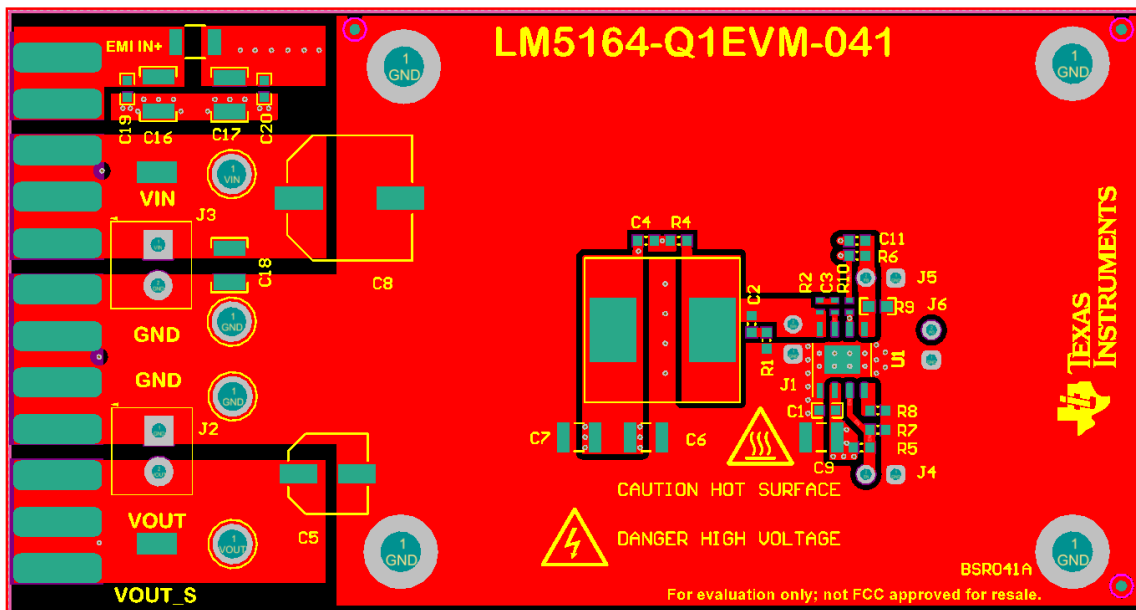

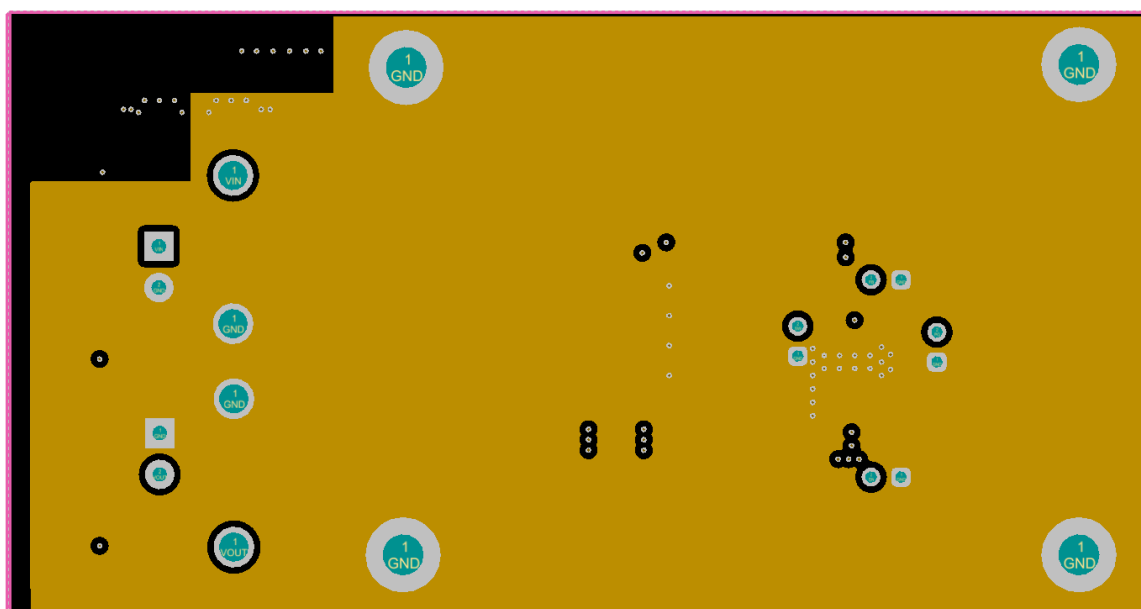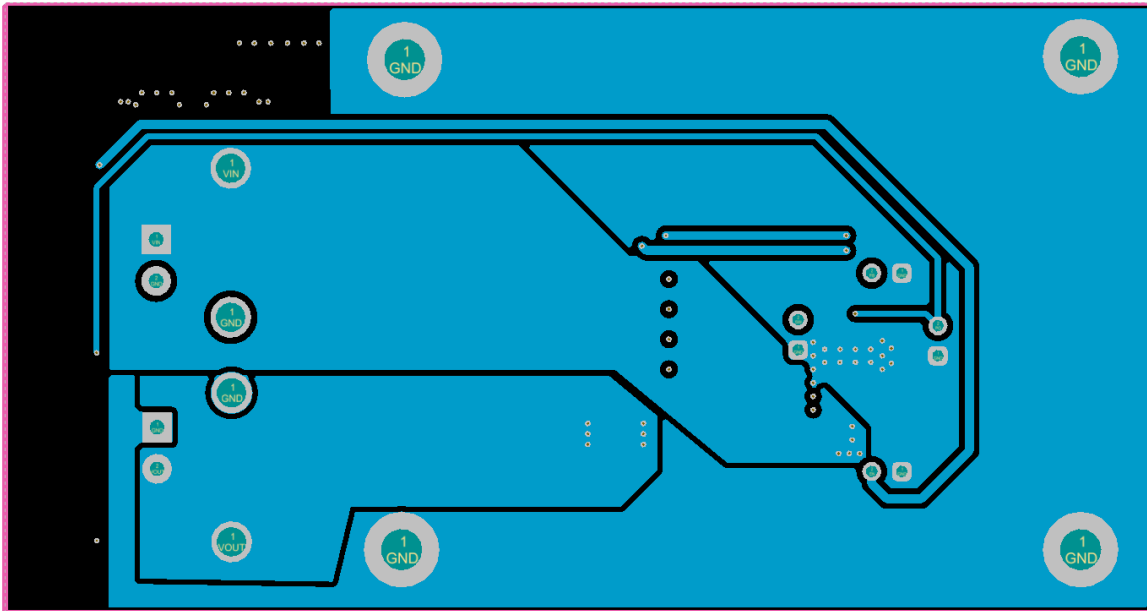**Figure 5. Top Layer and Silkscreen Layer**

Figure 6. Mid-Layer 1 Ground Plane

Figure 7. Mid-Layer 2 Routing
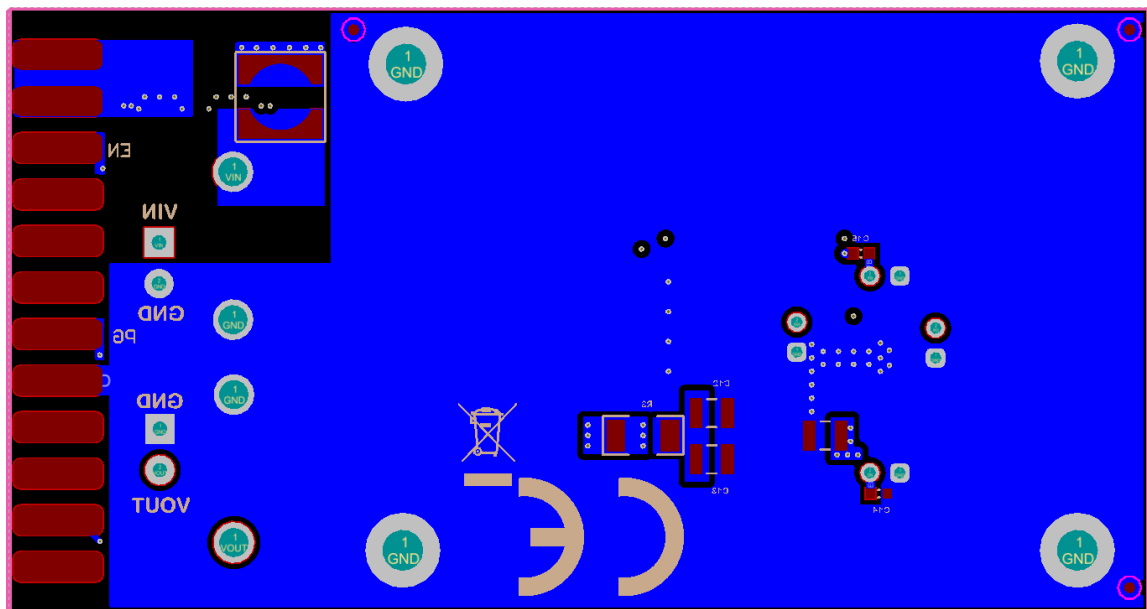
Figure 8. Bottom Layer Routing
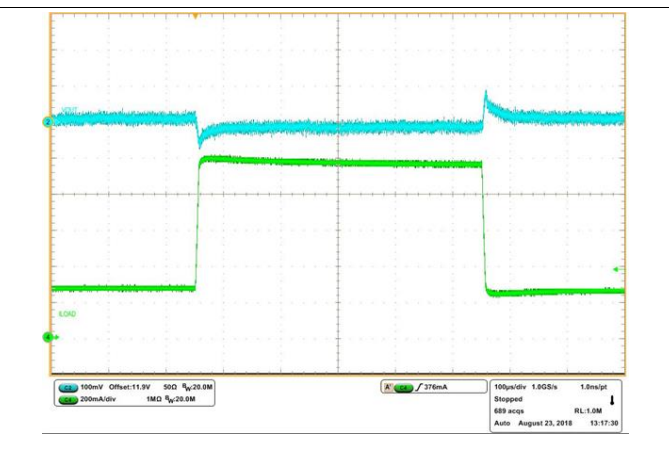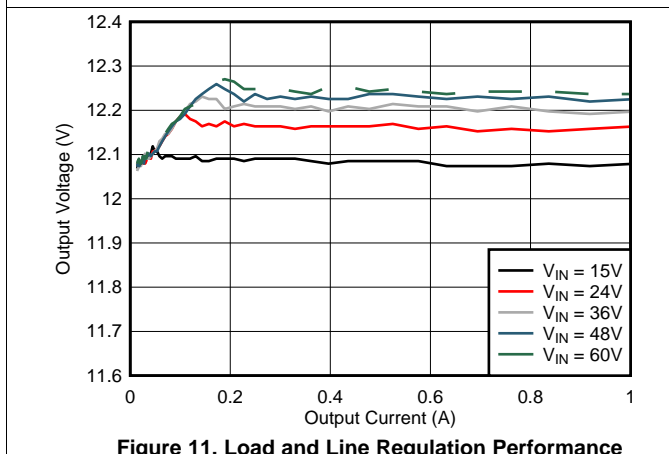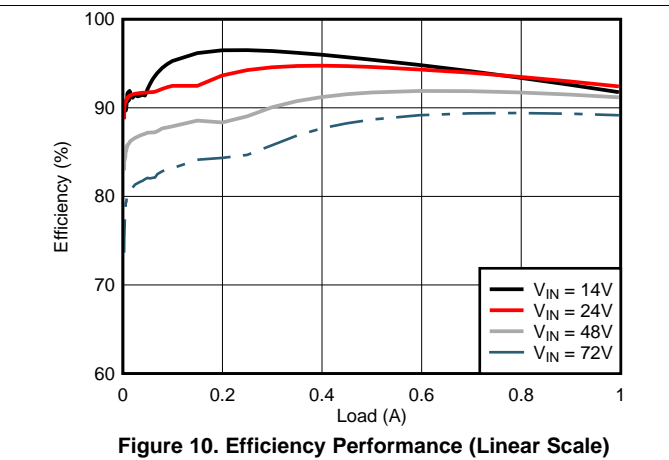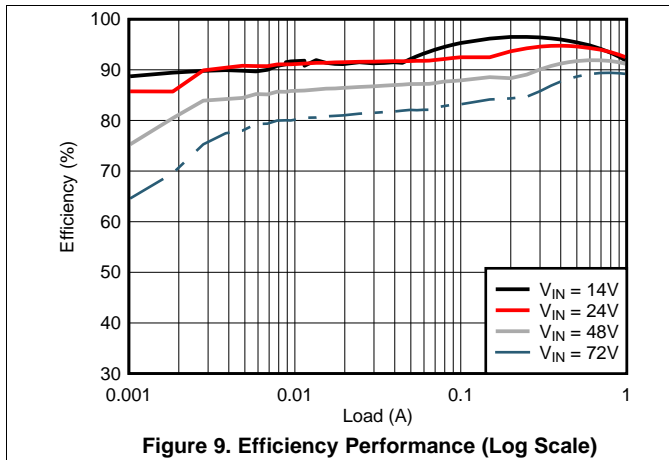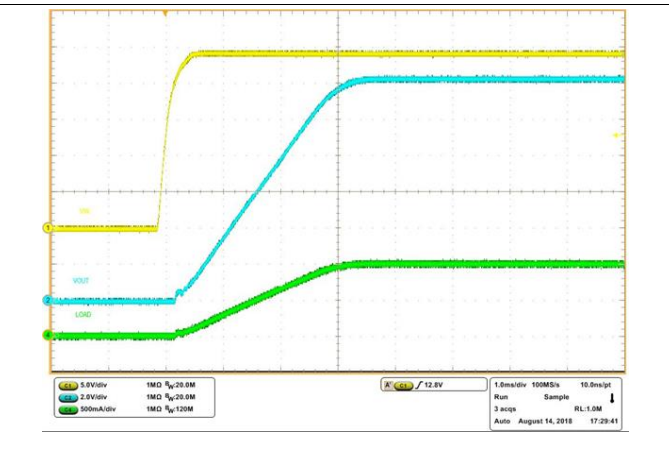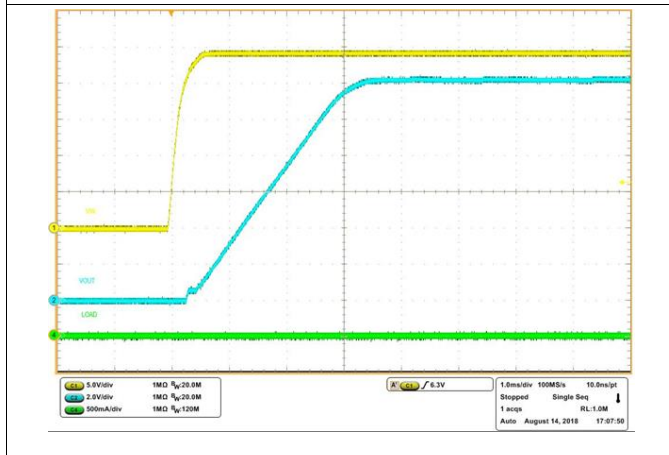
7   Bill of Materials

Table 3. LM5164-Q1 EVM Bill of Materials

Ref Des	Value	Description	Package	Part Number	Vendor	Qty
C1, C19, C20	0.1µF	CAP, CERM, 0.1 µF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	HMK107B7104KAHT	Taiyo Yuden	3
C3	2200pF	CAP, CERM, 2200 pF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0402	0402	GCM155R71H222KA37D	MuRata	1
C4	3300pF	CAP, CERM, 3300 pF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R2A332K080AA	TDK	1
C6, C7	22uF	CAP, CERM, 22 µF, 25 V, ±10%, X5R, AEC-Q200 Grade 3, 1210	1210	GRT32ER61E226KE13L	MuRata	2
C8	33µF	CAP, AL, 33 µF, 100 V, ±20%, 0.7 ohm, AEC-Q200 Grade 2, SMD	SMT Radial G	EEE-FK2A330P	Panasonic	1
C9, C10	2.2µF	CAP, CERM, 2.2 µF, 100 V, ±10%, X7R, AEC-Q200 Grade 1		CGA6N3X7R2A225K230AB	TDK	2
C11	56pF	CAP, CERM, 56 pF, 50 V, ±5%, C0G/NP0	0603	C0603C560J5GACTU	Kemet	1
C16, C17, C18	4.7µF	CAP, CERM, 4.7 µF, 100 V, ±10%, X7S, AEC-Q200 Grade 1, 1210	1210	CGA6M3X7S2A475K200AB	TDK	3
J2, J3		Terminal Block, 3.5mm Pitch, 2x1, TH	7.0 × 8.2 × 6.5mm	ED555/2DS	On-Shore Technology	2
J6		Header, 100mil, 2x1, Gold, TH	2×1 Header	TSW-102-07-G-S	Samtec	1
L1	68µH	Inductor, Shielded Drum Core, Ferrite, 68 µH, 1.8 A, 0.17 ohm, AEC-Q200 Grade 1	MSS1246T	MSS1246T-683MLB	Coilcraft	1
		Inductor, Shielded Drum Core, Ferrite, 68 µH, 2.1 A, 0.11 ohm, AEC-Q200 Grade 1	SRR1260A	SRR1260A-680M	Bourns	
		Inductor, Shielded, 68uH, 1.9A, 0.11ohm AEC-Q200 Grade 1	7447714680	7447714680	Wurth	
		Inductor, Shielded, Powdered Iron, 68uH, 2.3 A, 0.18 ohm	MPT1040-H1	MPT1040-680H1	Delta	
L2	15µH	Inductor, Shielded Drum Core, Ferrite, 15 µH, 1.8 A, 0.05 ohm, AEC-Q200 Grade 3	MSS7341	MSS7341T-153MLB	Coilcraft	1
		Inductor, Shielded Drum Core, Ferrite, 15 µH, 1.5 A, 0.1 ohm, AEC-Q200 Grade 1	744778115	744778115	Wurth	
L3	2000 Ω	Ferrite Bead, 2000 Ω @ 100 MHz, 1.2 A	1210	FBMH3225HM202NT	Taiyo Yuden	1
R2	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0	0402	CRCW04020000Z0ED	Vishay	1
R4, R6	453k	RES, 453 k, 1%, 0.1 W, 0603	0603	RC0603FR-07453KL	Yageo	2
R5	1.00Meg	RES, 1.00 M, 1%, 0.1 W, 0603	0603	RC0603FR-071ML	Yageo	1
R7	332k	RES, 332 k, 1%, 0.1 W, 0603	0603	RC0603FR-07332KL	Yageo	1
R8	105k	RES, 105 k, 0.1%, 0.1 W, 0603	0603	RG1608P-1053-B-T5	Susumu Co Ltd	1
R9	49.9k	RES, 49.9 k, 0.1%, 0.1 W, 0603	0603	RG1608P-4992-B-T5	Susumu Co Ltd	1
R10	100k	RES, 100 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1003X	Panasonic	1
SH-J4	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec	1
TP1, TP6		Test Lead clips and hooks, SMT	Test Point	S1751-46	Harwin	2
TP2, TP3, TP4, TP5	Triple	Terminal, Turret, TH, Triple		1598-2	Keystone	4
U1		100-V, Low I_Q Synchronous Buck Converter	SO-8	LM5164QDDARQ1	TI	1

8 Performance Curves

Figure 9. Efficiency Performance (Log Scale)

Figure 10. Efficiency Performance (Linear Scale)

Figure 11. Load and Line Regulation Performance

V_{VIN} = 24 V   Load = 0.25 A to 1 A, 0.1A/µs

Figure 12. Load Transient Response

V_{VIN} = 24 V   Load = 0 A

Figure 13. No Load Start-up with VIN

V_{VIN} = 24 V   Load = 1 A

Figure 14. Full Load Start-up with VIN
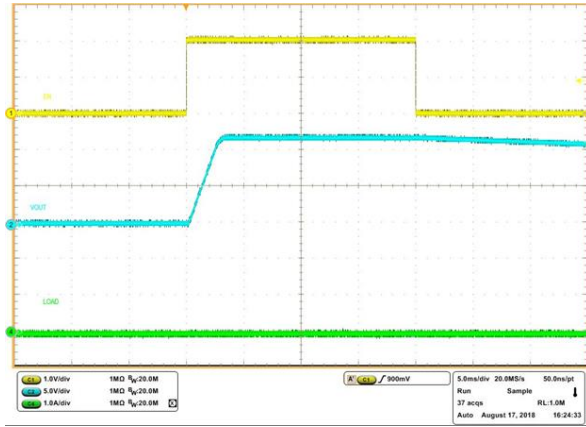
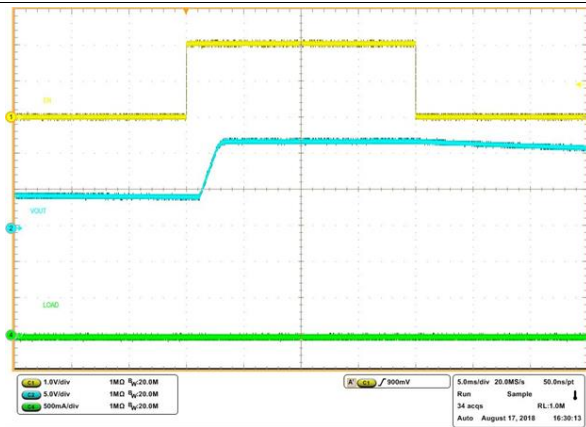V_{VIN} = 24 V   Load = 0 A

Figure 15. No Load Start-up with EN/UVLO
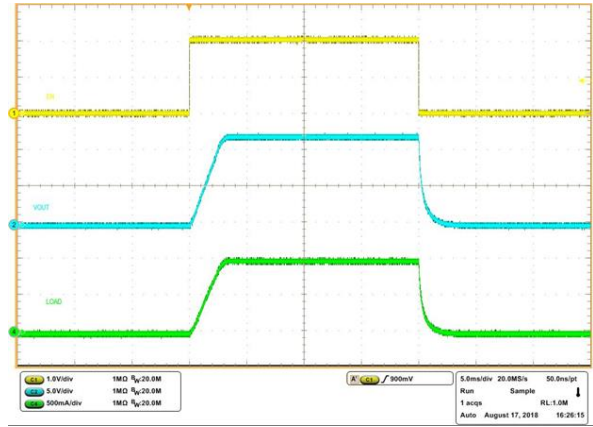
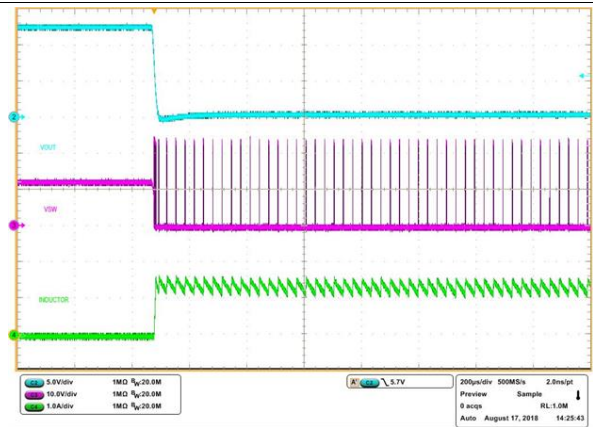V_{VIN} = 24 V   Load = 1 A

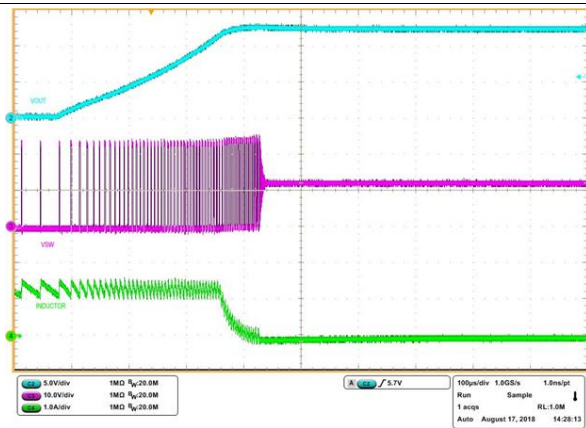**Figure 16. Full Load Start-up/Shutdown with EN/UVLO**

V_{VIN} = 24 V   Load = 0 A

Figure 17. EN/UVLO Start-up in Prebias

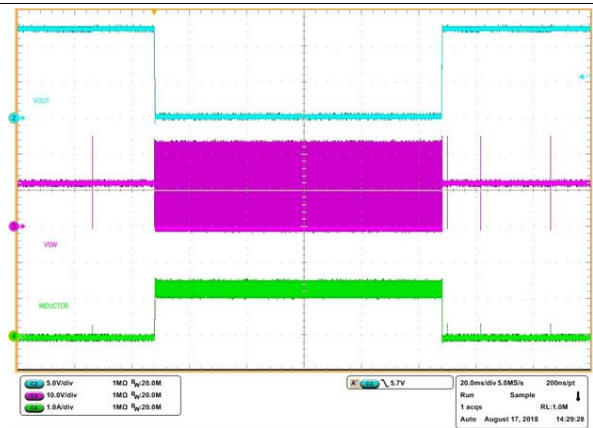V_{VIN} = 24 V   Load = 0 A to short

Figure 18. Short Circuit

V_{VIN} = 24 V   Load = Short to 0 A

Figure 19. Short-Circuit Recovery

V_{VIN} = 24 V   Load = 0 A to Short to 0 A

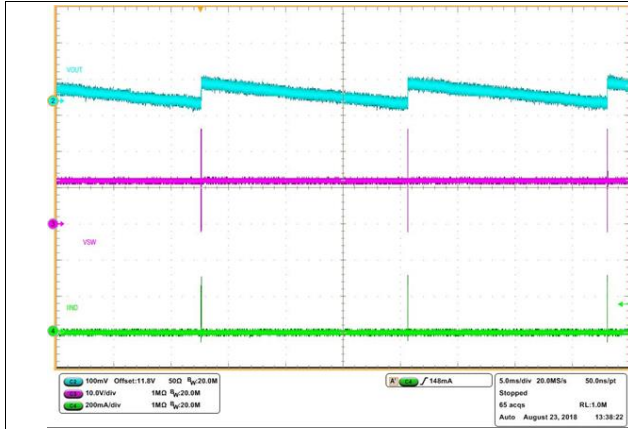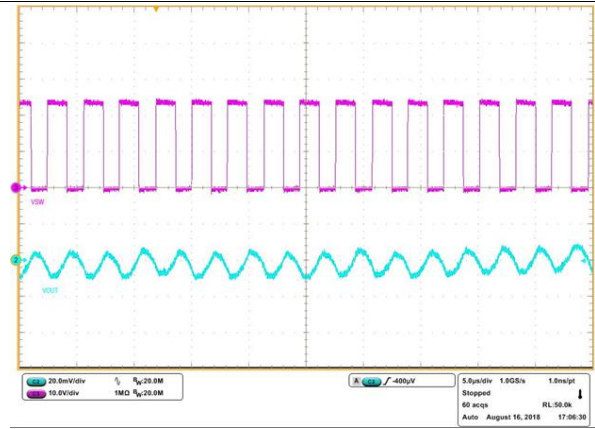**Figure 20. No-Load/Short Circuit and Short-Circuit Recovery**

Figure 21. No-Load Switching

Figure 22. Full-Load Switching
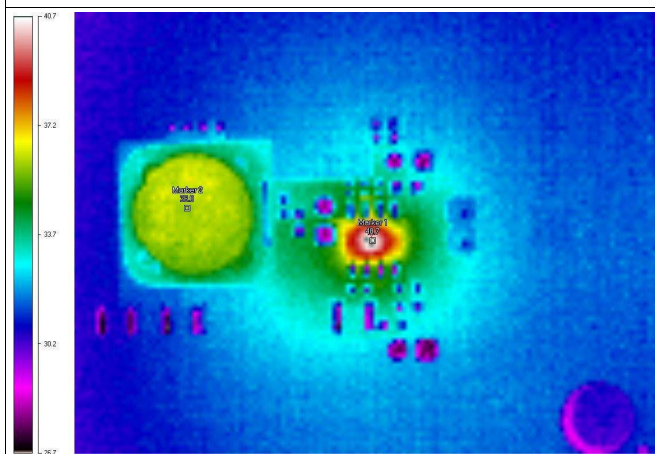
V_{VIN} = 24 V   Load = 1 A

Figure 23. Thermal Performance
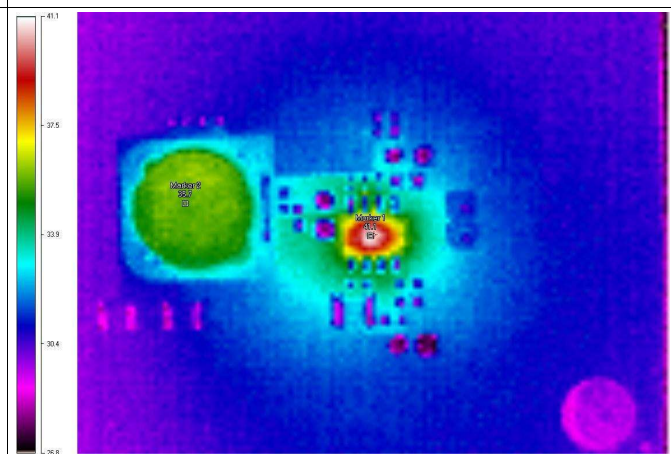
V_{VIN} = 48 V   Load = 1 A

Figure 24. Thermal Performance

V_{IN} = 48 V   Load = 1 A R_1 = 1 Ω, C_2 = 680 pF

**Figure 25. CISPR 25 Class 5 Conducted Emissions Plot,
150 kHz to 30 MHz**

V_{IN} = 48 V   Load = 1 A R_1 = 1 Ω, C_2 = 680 pF

**Figure 26. CISPR 25 Class 5 Conducted Emissions Plot,
30 MHz to 108 MHz**

V_{IN} = 24 V   Load = 1 A R_1 = 1 Ω, C_2 = 680 pF

**Figure 27. CISPR 25 Class 5 Conducted Emissions Plot,
150 kHz to 30 MHz**

V_{IN} = 24 V   Load = 1 A R_1 = 1 Ω, C_2 = 680 pF

**Figure 28. CISPR 25 Class 5 Conducted Emissions Plot,
30 MHz to 108 MHz**

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (September 2018) to A Revision **Page**

STANDARD TERMS FOR EVALUATION MODULES

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

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

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

WARNING

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

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

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

3 *Regulatory Notices:*

  3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

  3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【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
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page
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/lsds/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, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

IMPORTANT NOTICE AND DISCLAIMER