User's Guide

TPSM63610 36-V, 8-A Buck Regulator Evaluation Module User's Guide

ABSTRACT

With an input operating voltage range from 3 V to 36 V and rated output current from 6 A to 8 A, the TPSM63608 and TPSM63610 family of synchronous buck power modules provides flexibility, scalability, and optimized solution size for a wide range of applications. With integrated power MOSFETs, buck inductor and PWM controller, these modules enable DC/DC solutions with high density, low EMI, and increased flexibility. Available EMI mitigation features include dual random spread spectrum (DRSS), RBOOT-configured switch-node slew rate control, and integrated input bypass capacitors.

Table 1-1. TPSM63608 and TPSM63610 Synchronous Buck DC/DC Power Module Family

DC/DC MODULE	RATED I_{OUT}	PACKAGE	DIMENSIONS	FEATURES	EMI MITIGATION
TPSM63608	6 A	B3-QFN (22)	6.5 mm × 7.5 mm	RT adjustable F_{SW}, external synchronization	DRSS, slew-rate control, integrated input, VCC and BOOT capacitors
TPSM63610	8 A				

The TPSM63610EVM uses the TPSM63610 easy-to-use synchronous buck module IC with a wide output voltage range of 1 V to 20 V and an output current up to 8 A. The default output voltage of the EVM is set to 5 V can be adjusted to 3.3 V through a jumper setting.

The solution supports adjustable input voltage UVLO for application-specific power-up and power-down requirements, external clock synchronization to mitigate beat frequencies in noise-sensitive applications, PGOOD indicator for sequencing and output voltage monitoring, pin-selectable spread spectrum control for EMI mitigation, and pin selectable MODE control for light-load performance with AUTO mode or fixed switching frequency with FPWM mode.

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Trademarks

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1 High-Density EVM Description

The TPSM63610EVM features the TPSM63610 synchronous buck power module configured for operation with typical 3-V to 36-V input bus applications. This wide-V_{IN} range DC/DC solution offers outsized voltage rating and operating margin to withstand supply-rail voltage transients.

The output voltage can be set to either 3.3 V or 5 V and switching frequency can each be set to one of five popular values (400 kHz, 700 kHz, 1 MHz, 1.4 MHz, and 2.2 MHz) by using configuration jumpers. Additionally, a resistor placeholder footprint is on the backside of the EVM to allow adjustment of the switching frequency outside of the five jumper settings.

The EVM provides the full 8-A output current rating of the device. The selected input and output capacitors accommodate the entire range of input voltage and the selectable output voltages on the EVM and are available from multiple component vendors. Input and output voltage sense terminals and a test point header facilitate measurement of the following:

- Efficiency and power dissipation
- Line and load regulation
- Load transient response
- Enable ON, OFF
- Bode plot (crossover frequency and phase margin)

The header also provides connections for features such as remote enable (EN), external clock synchronization through mode pin (MODE), power-good monitor (PGOOD), spread-spectrum frequency modulation (SPSP) and AUTO/FPWM mode control (MODE). The recommended PCB layout maximizes thermal performance and minimizes output ripple and noise.

A 0-Ω resistor is placed between RBOOT and CBOOT to short the internal 100-Ω resistor for highest efficiency. Modifying the 0-Ω resistor allows adjustment of the internal resistance to balance EMI and efficiency performance.

1.1 Typical Applications

- Test and measurement, aerospace and defense
- Factory automation and control, power delivery
- Inverting buck-boost (IBB) circuits requiring negative output voltage

2 Test Setup and Procedure

2.1 EVM Connections

Referencing the EVM connections described in Table 2-1, use the recommended test setup in Figure 2-1 to evaluate the TPSM63610. Working at an ESD-protected workstation, make sure that any wrist straps, bootstraps, or mats are connected and referencing the user to earth ground before power is applied to the EVM.

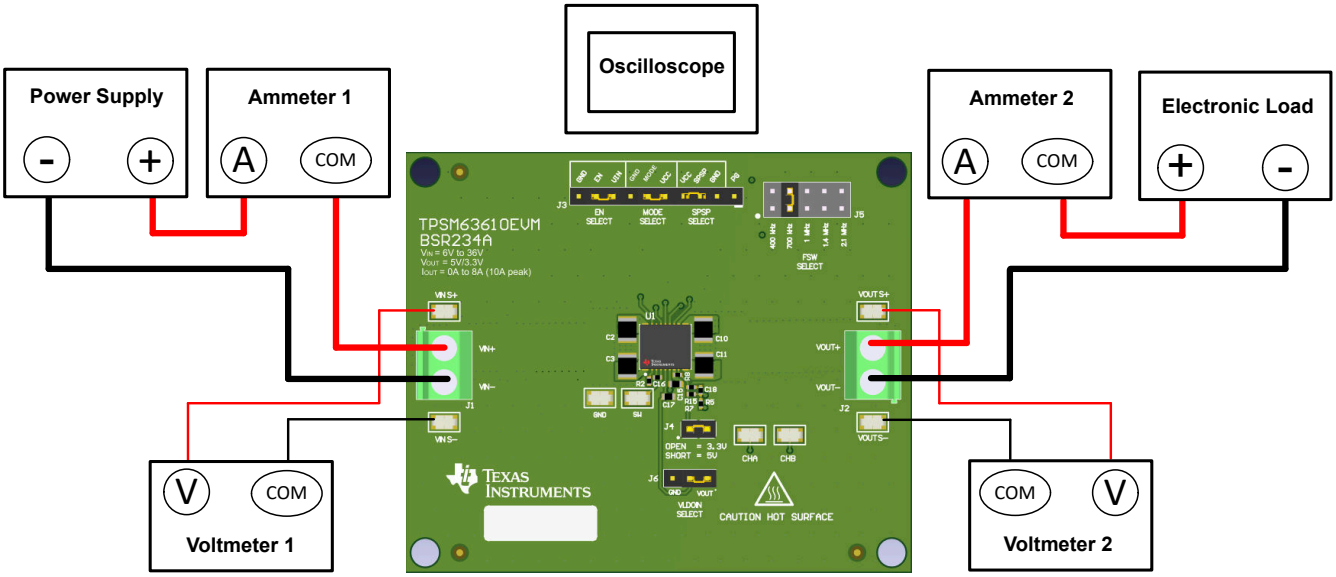


Figure 2-1. EVM Test Setup

Table 2-1. EVM Power Connections

LABEL	DESCRIPTION
VIN+	Positive input power connection
VIN–	Negative input power connection
VOUT+	Positive output power connection
VOUT–	Negative output power connection

Table 2-2. EVM Signal Connections

LABEL	DESCRIPTION
VIN S+	Positive input sense terminal. Connect the multimeter positive lead for measuring efficiency.
VIN S–	Negative input sense terminal. Connect a multimeter negative lead for measuring efficiency.
VOUT S+	Positive output sense terminal. Connect a multimeter positive lead for measuring efficiency and line and load regulation.
VOUT S–	Negative output sense terminal. Connect the multimeter negative lead for measuring efficiency and line and load regulation.
GND	Ground reference point
SW	Switch node monitor output
EN	Precision enable input and input voltage UVLO protection. Tie EN to GND to disable the regulator. Use a logic signal to control EN for remote ON/OFF functionality. Leave EN open for UVLO turn-on thresholds set at 6 V.
MODE	Mode select and synchronization input. For synchronization, connect a valid clock signal to synchronize the switching frequency from 200 kHz to 2.2 MHz. Connect MODE to VCC for FPWM mode. Connect MODE to GND for AUTO mode.
PG	Power-good monitor output. PG is an open-drain flag with a 100-kΩ pullup resistor to VOUT.

Table 2-2. EVM Signal Connections (continued)

LABEL	DESCRIPTION
SPSP	Spread spectrum control. Connect SPSP to GND to disable spread spectrum. Connect SPSP to VCC to enable spread spectrum. Leave SPSP floating to enable spread spectrum with ripple cancellation. Power cycle the device when changing the spread spectrum configuration.
CHA, CHB	Bode plot measurement and signal injection. A 10-Ω resistor from CHA to CHB facilitates oscillator signal injection for bode plot measurement. Remove the jumper and apply a swept-frequency signal between CHA and CHB while measuring the respective response at each terminal for loop gain measurement.

2.2 EVM Setup

- Use the VIN S+ and VIN S– test points along with the VOUT S+ and VOUT S– test points located near the power terminal blocks as voltage monitoring points where voltmeters are connected to measure the input and output voltages, respectively. *Do not use these sense terminals as the input supply or output load connection points.* The PCB traces connected to these sense terminals are not designed to support high currents.
- Header J3 provides access to the following test points:
  - VIN
  - EN
  - MODE
  - PG
  - VCC
  - SPSP

  The MODE test point provides a convenient location to connect an external clock signal. The power-good (PG) test point is available to monitor when a valid output voltage is present on the EVM. Refer to *EVM Connections* for specific information related to the various test points.
- The **VOUT SELECT** header (J4) allows selection of either 3.3 V or 5 V. Before applying power to the EVM, make sure that the jumper is present and properly positioned for the intended output voltage. Always remove input power before changing the jumper settings.
- The **FSW SELECT** header (J5) allows selection of a suitable switching frequency:
  - 400 kHz
  - 700 kHz
  - 1 MHz
  - 1.4 MHz
  - 2.2 MHz

  Before applying power to the EVM, make sure that the jumper is present and properly positioned for the intended switching frequency. Always remove input power before changing the jumper settings.

2.3 Test Equipment

Voltage Source: The input voltage source V_{IN} must be a 36-V variable DC source capable of supplying 6 A.

Multimeters:

- **Voltmeter 1:** Measure the input voltage at VIN S+ to VIN S–.
- **Voltmeter 2:** Measure the output voltage at VOUT S+ to VOUT S–.
- **Ammeter 1:** Measure the input current. Set the ammeter to 1-second aperture time.
- **Ammeter 2:** Measure the output current. Set the ammeter to 1-second aperture time.

Electronic Load: Use an electronic load set to constant-resistance (CR) or constant-current (CC) mode and capable of 0 ADC to 6 ADC. For a no-load input current measurement, disconnect the electronic load as it can draw a small residual current.

Oscilloscope: With the scope set to 20-MHz bandwidth and AC coupling, measure the output voltage ripple directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the ground barrel of the probe through the ground lead to the negative terminal of the capacitor. TI does not recommend using a long-leaded ground connection because this may induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

Safety: Always use caution when touching any circuits that can be live or energized.

2.4 Recommended Test Setup

2.4.1 Input Connections

- Prior to connecting the DC input source, set the current limit of the input supply to 0.1-A maximum. Ensure the input source is initially set to 0 V and connected to the VIN+ and VIN– connection points as shown in Figure 2-1.
- Connect voltmeter 1 at VIN S+ and VIN S– connection points to measure the input voltage.
- Connect ammeter 1 to measure the input current and set it to at least a 0.1-second aperture time.

2.4.2 Output Connections

- Connect an electronic load to the VOUT+ and VOUT– connections as shown in Figure 2-1. Set the load to constant-resistance mode or constant-current mode at 0 A before applying input voltage.
- Connect voltmeter 2 at VOUT S+ and VOUT S– sense points to measure the output voltage.
- Connect ammeter 2 to measure the output current.

2.5 Test Procedure

2.5.1 Line, Load Regulation and Efficiency

- Set up the EVM as described in *Test Setup and Procedure*.
- Set load to constant resistance or constant current mode to sink 0 A.
- Increase the input source voltage from 0 V to 24 V; use voltmeter 1 to measure the input voltage.
- Increase the current limit of the input supply to 8 A.
- Use voltmeter 2 to measure the output voltage, V_{OUT}, and vary the load current from 0 A to 8 A DC; V_{OUT} must remain within the load regulation specification.
- Set the load current to 4 A (50% rated load) and vary the input source voltage from 6 V to 36 V; V_{OUT} must remain within the line regulation specification.
- Set the load current to 8 A (100% rated load) and measure the efficiency at typical input voltages (12 V, 24 V, and 36 V).
- Decrease the load to 0 A. Decrease the input source voltage to 0 V.

CAUTION

Extended operation at high output current can raise component temperatures above 55°C. To avoid risk of a burn injury, do not touch the components until they have cooled sufficiently after disconnecting power.

3 Test Data and Performance Curves

Because actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and can differ from actual field measurements. Unless otherwise indicated, V_{IN} = 24 V, V_{OUT} = 5 V, I_{OUT} = 8 A, and F_{SW} = 1 MHz.

3.1 Efficiency and Load Regulation Performance

This section provides efficiency and load regulation plots for the EVM.

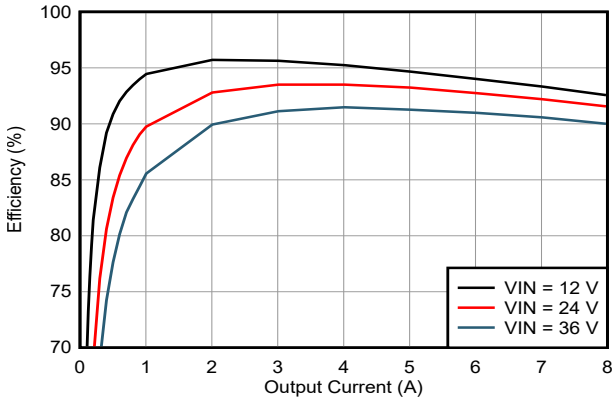


Figure 3-1. Efficiency, V_{OUT} = 5 V, F_{SW} = 1 MHz, FPWM Mode

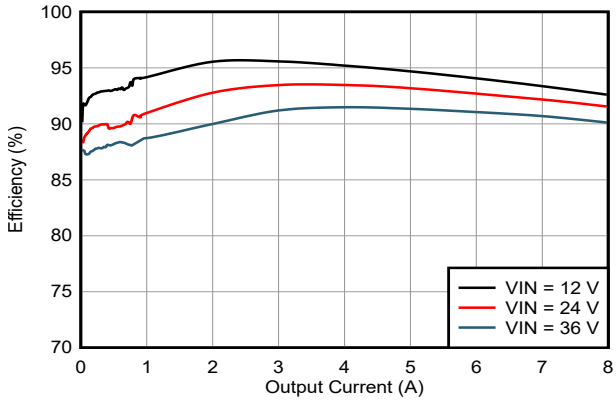


Figure 3-2. Efficiency, V_{OUT} = 5 V, F_{SW} = 1 MHz, AUTO Mode

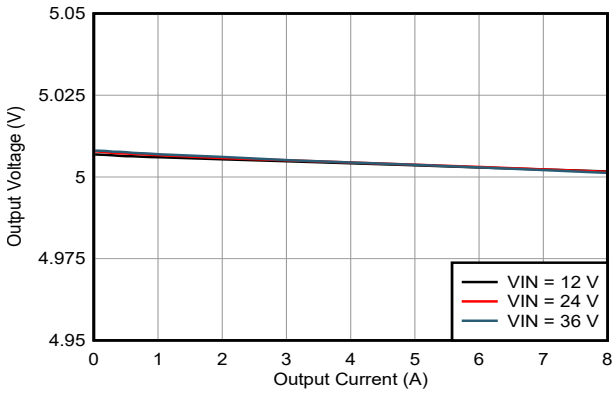


Figure 3-3. Load Regulation, V_{OUT} = 5 V, F_{SW} = 1 MHz, FPWM Mode

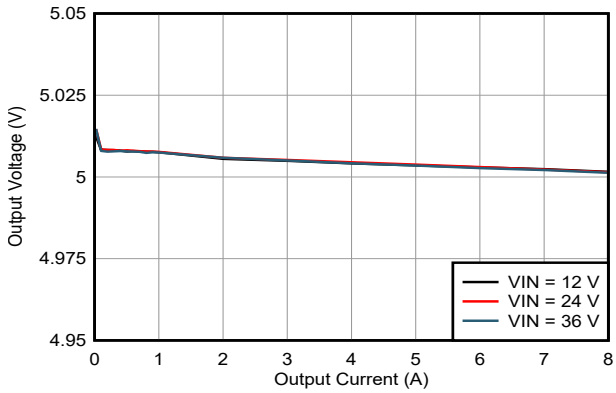


Figure 3-4. Load Regulation, V_{OUT} = 5 V, F_{SW} = 1 MHz, AUTO Mode

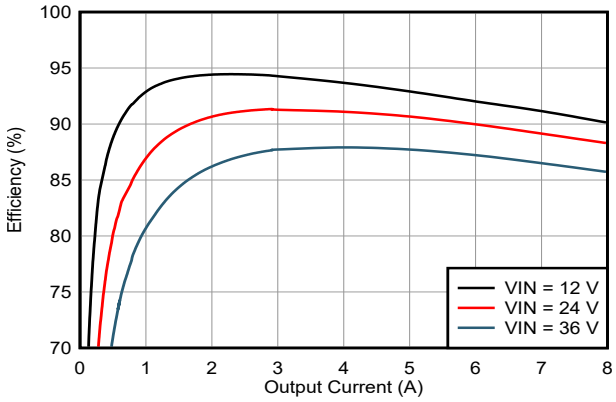


Figure 3-5. Efficiency, V_{OUT} = 3.3 V, F_{SW} = 1 MHz, FPWM Mode

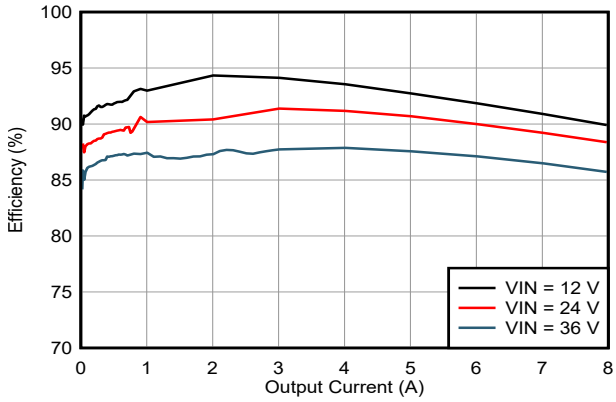


Figure 3-6. Efficiency, V_{OUT} = 3.3 V, F_{SW} = 1 MHz, AUTO Mode

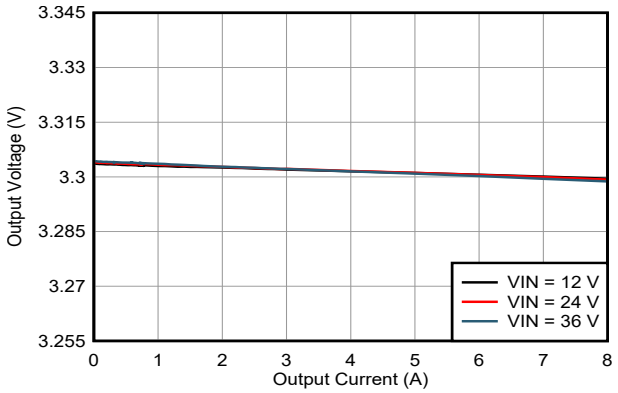


Figure 3-7. Load Regulation, V_{OUT} = 3.3 V, F_{SW} = 1 MHz, FPWM Mode

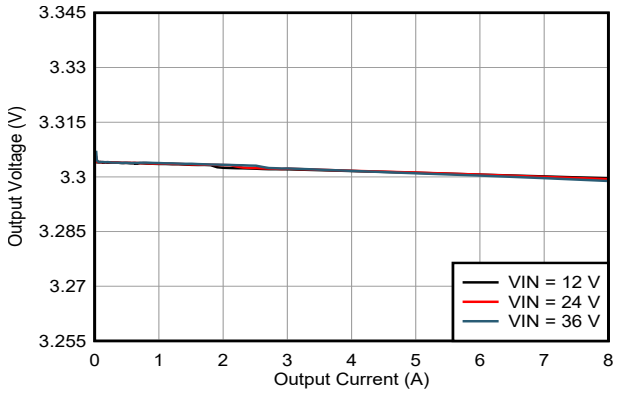


Figure 3-8. Load Regulation, V_{OUT} = 3.3 V, F_{SW} = 1 MHz, AUTO Mode

3.2 Waveforms

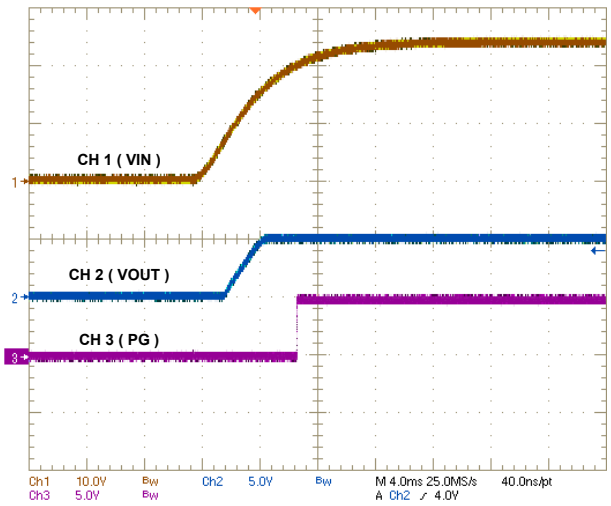


Figure 3-9. Start-Up to V_{IN} = 24 V

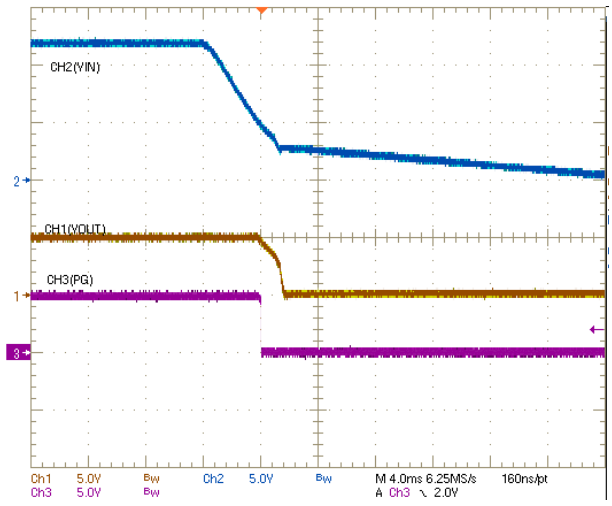


Figure 3-10. Shutdown

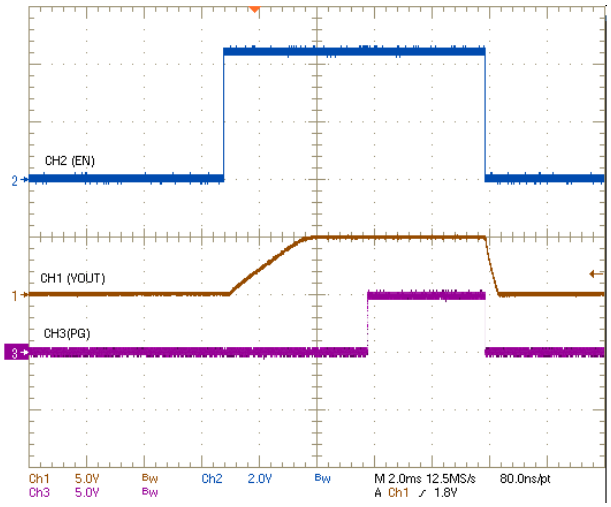


Figure 3-11. Enable ON and OFF

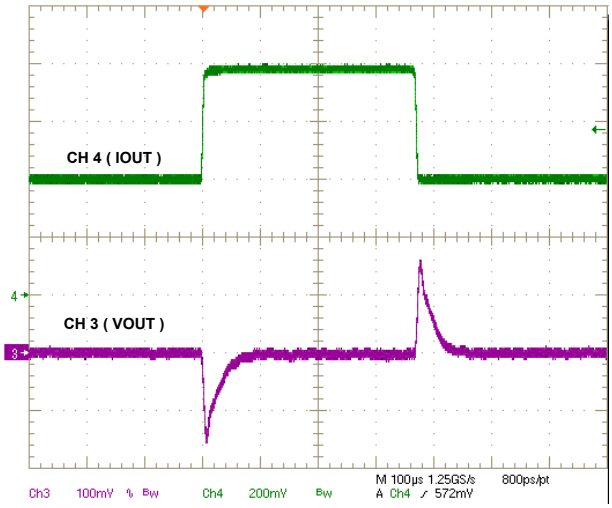
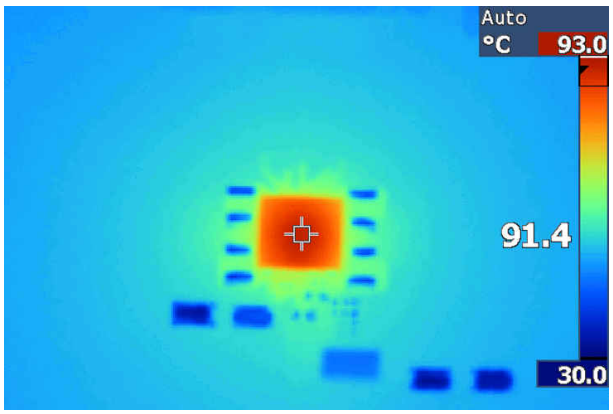
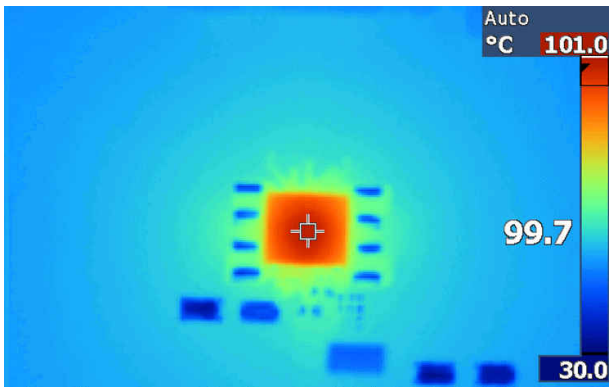


Figure 3-12. Load Transient, 4 A to 8 A at 1 A/µs



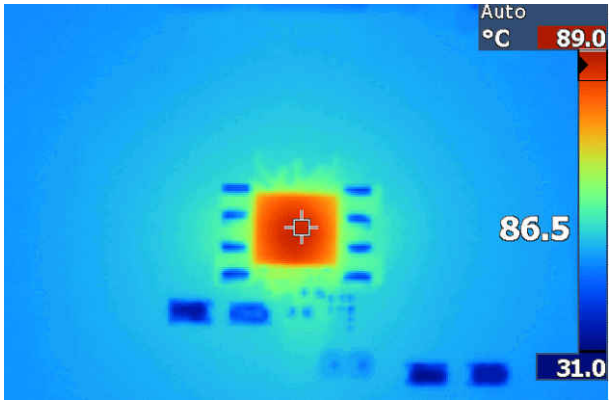
F_{SW} = 1 MHz I_{OUT} = 8 A P_{DIS} = 3.49 W

Figure 3-13. Infrared Thermal Image V_{IN} = 12 V, V_{OUT} = 5 V



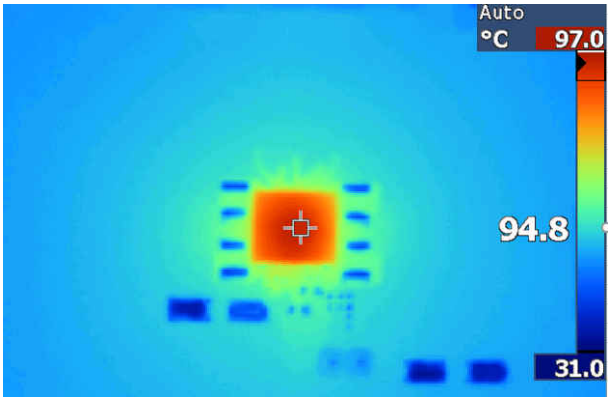
F_{SW} = 1 MHz I_{OUT} = 8 A P_{DIS} = 4.06 W

Figure 3-14. Infrared Thermal Image V_{IN} = 24 V, V_{OUT} = 5 V



F_{SW} = 1 MHz I_{OUT} = 8 A P_{DIS} = 3.27 W

Figure 3-15. Infrared Thermal Image V_{IN} = 12 V, V_{OUT} = 3.3 V



F_{SW} = 1 MHz I_{OUT} = 8 A P_{DIS} = 3.84 W

Figure 3-16. Infrared Thermal Image V_{IN} = 24 V, V_{OUT} = 3.3 V

3.3 Bode Plot

Figure 3-17 provides the bode plot at V_{IN} = 24 V, V_{OUT} = 5 V, F_{SW} = 1 MHz, and I_{OUT} = 8 A. Figure 3-18 shows a typical capacitance versus voltage curve for a 47-µF, 16-V, X6S output capacitor to highlight the *effective* capacitance value of a ceramic. See component details in *Bill of Materials*.

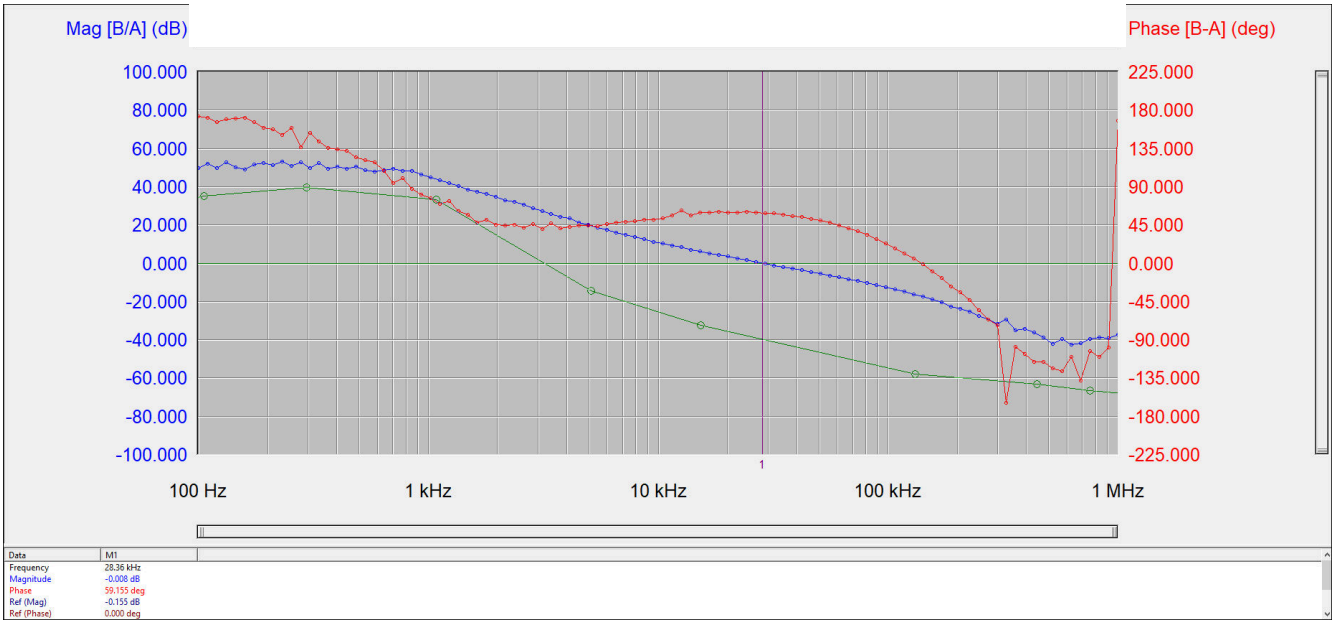


Figure 3-17. Bode Plot With Four 47-µF, 16-V Output Capacitors (110 µF Effective at 5 VDC, 25°C)

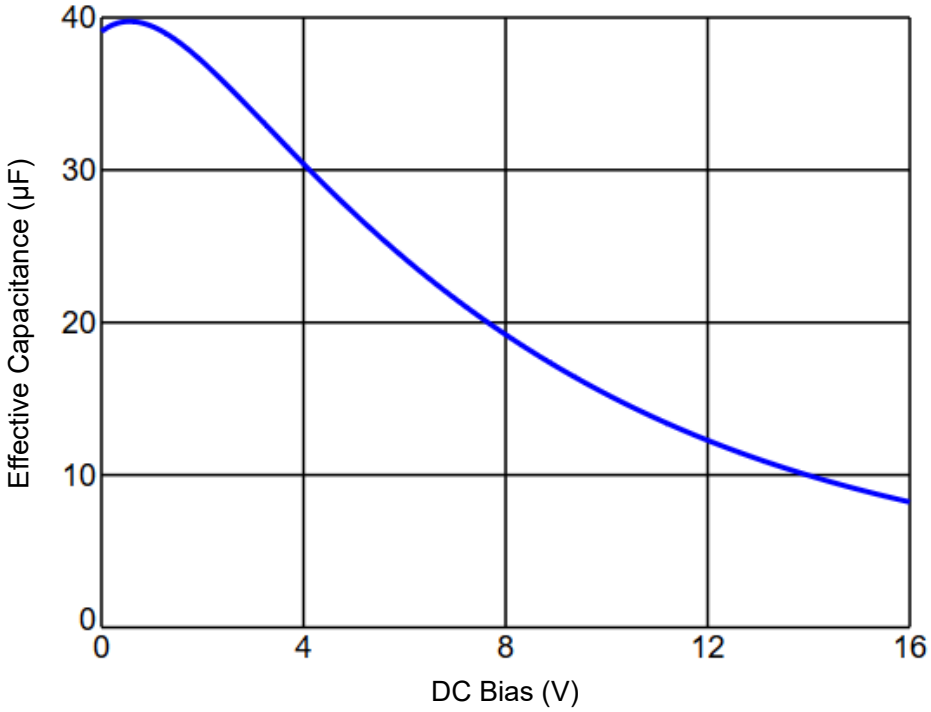
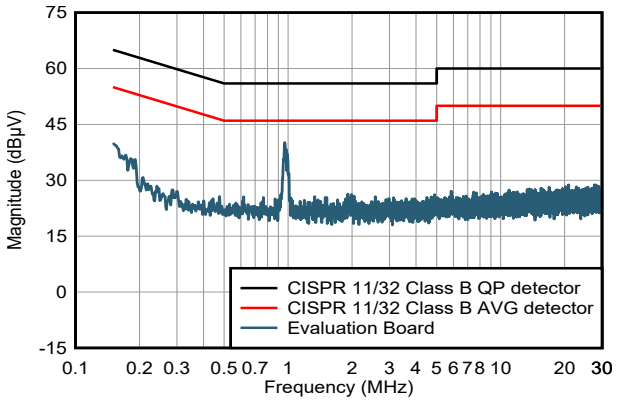


Figure 3-18. Output Capacitor Voltage Derating Curve

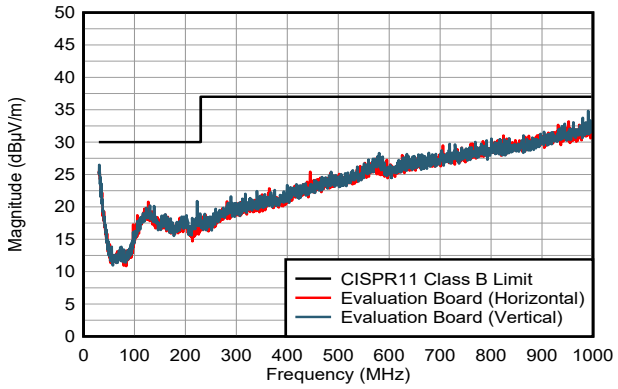
3.4 EMI Performance

See the *Schematic* and *Bill of Materials* for details of the input EMI filter to pass CISPR 11/32 Class B conducted emissions.



Default EVM V_{OUT} = 5 V F_{SW} = 1 MHz

Figure 3-19. CISPR 11/32 Class B Conducted Emissions: V_{IN} = 24 V, SPSP ON



Additional 2 × 10 pF C_{IN} with EMI filter removed V_{OUT} = 5 V F_{SW} = 1 MHz

Figure 3-20. CISPR 11 Class B Radiated Emissions: V_{IN} = 24 V, SPSP ON

4 EVM Documentation

4.1 Schematic

Figure 4-1 illustrates the EVM schematic.

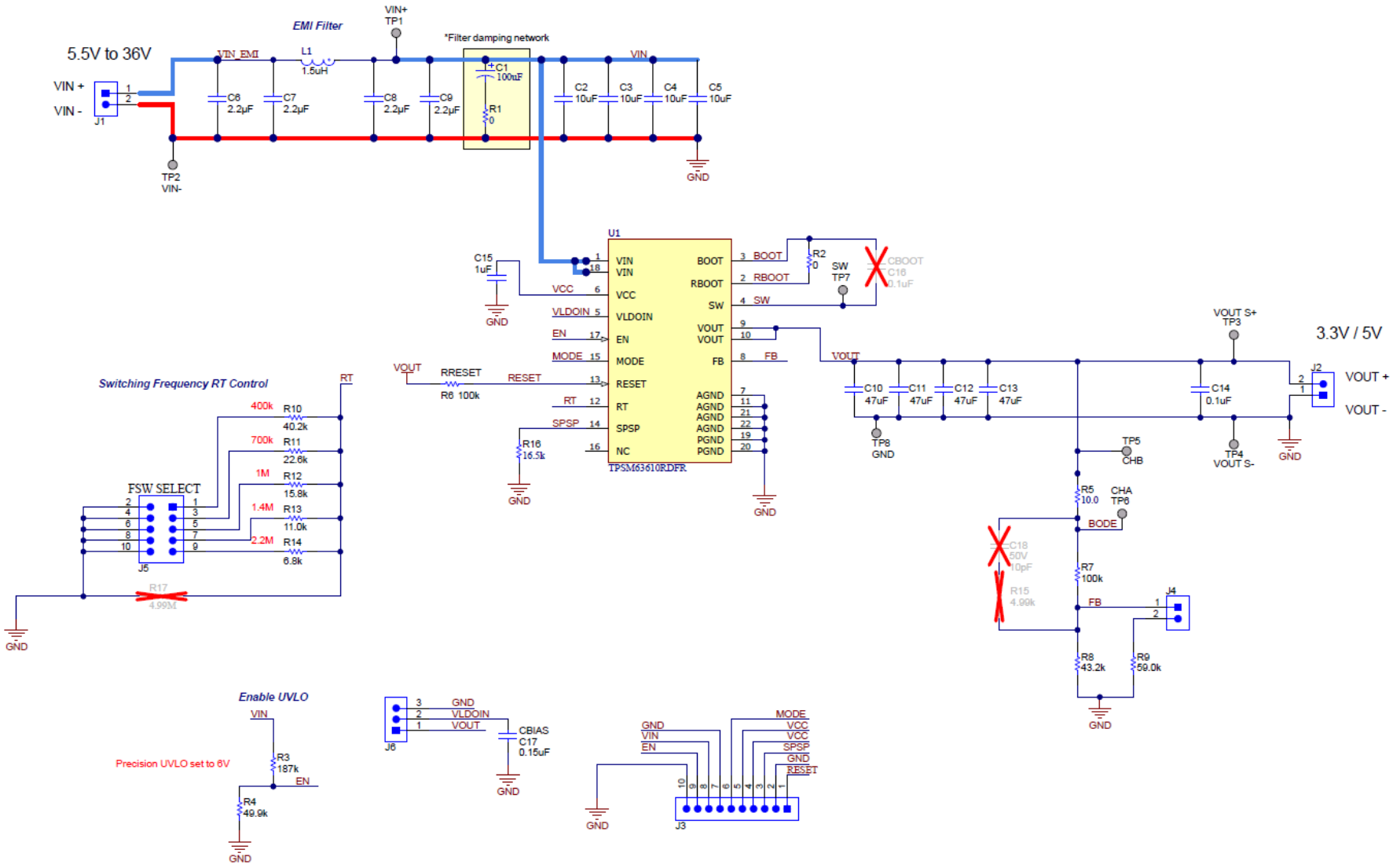


Figure 4-1. EVM Schematic

4.2 Bill of Materials

Table 4-1. Component BOM

REF DES	QTY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
C1	1	100 µF	CAP, AL, 100 µF, 50 V, 0.34 Ω,	8x10	UUD1H101MNL1GS	Nichicon
C2, C3, C4, C5	4	10 µF	CAP, CERM, 10 µF, 50 V, X7R	1210	GRM32ER71H106KA12L	MuRata
C6, C7, C8, C9	4	2.2 µF	CAP, CERM, 2.2 µF, 50 V, X7R	0805	CGA4J3X7R1H225K125AB	TDK
C10, C11, C12, C13	4	47 µF	CAP, CERM, 47 µF, 16 V, X6S	1210	GRM32EC81C476ME15L	MuRata
C14	1	0.1 µF	CAP, CERM, 0.1 µF, 25 V, X7R	0603	CGA3E2X7R1E104K080AA	TDK
C15	1	1 µF	CAP, CERM, 1 µF, 25 V, X7R	0603	C0603C105K3RACTU	Kemet
C16	1	0.1 µF	CAP, CERM, 0.1 µF, 50 V, X7R	0402	CGA2B3X7R1H104K050BB	TDK
C17	1	0.15 µF	CAP, CERM, 0.15 µF, 50 V, X7R	0603	CGA3E3X7R1H154K080AB	TDK
C18	0	10 pF	CAP, CERM, 10 pF, 50 V, C0G/NP0	0402	CGA2B2C0G1H100D050BA	TDK
H1, H2, H3, H4	4		Standoff, Hex, 0.5"L #4-40 Nylon	-	1902C	Keystone
H5, H6, H7, H8	4		Screw, Pan Head , 4-40, 3/8", Nylon	-	NY PMS 440 0038 PH	B&F Fastener Supply
J1, J2	2		TERM BLOCK 2POS 5mm, TH	-	1729018	Phoenix Contact
J3	1		Header, 100mil, 10 × 1, Gold, TH	-	TSW-110-07-G-S	Samtec
J4	1		Header, 100mil, 2 × 1, Gold, TH	-	PBC02SAAN	Sullins Connector Solutions
J5	1		Header, 100mil, 5 × 2, Tin, TH	-	PEC05DAAN	Sullins Connector Solutions
J6	1		Header, 100mil, 3 × 1, Gold, TH	-	PBC03SAAN	Sullins Connector Solutions
L1	1	1.5 µH	Shielded power inductor 1.5 µH, 10.2A 10.5 mΩ Max	-	XGL4030-152MEC	Coilcraft
R1	1	0	RES, 0, 5%, 0.1 W	0603	CRCW06030000Z0EA	Vishay-Dale
R2	1	0	RES, 0, 0%, 0.2 W	0402	CRCW04020000Z0EDHP	Vishay-Dale
R3	1	187 kΩ	RES, 187 kΩ, 1%, 0.1 W	0603	CRCW0603187KFKEA	Vishay-Dale
R4	1	49.9 kΩ	RES, 49.9 kΩ, 1%, 0.1 W	0603	CRCW060349K9FKEA	Vishay-Dale
R5	1	10 Ω	RES, 10.0 Ω, 1%, 0.063 W	0402	CRCW040210R0FKED	Vishay-Dale
R6	1	100 kΩ	RES, 100 kΩ, 1%, 0.1 W	0603	CRCW0603100KFKEA	Vishay-Dale
R7	1	100 kΩ	RES, 100 kΩ, 1%, 0.063 W	0402	CRCW0402100KFKED	Vishay-Dale
R8	1	43.2 kΩ	RES, 43.2 kΩ, 1%, 0.063 W	0402	CRCW040243K2FKED	Vishay-Dale
R9	1	59.0 kΩ	RES, 59.0 kΩ, 1%, 0.063 W	0402	CRCW040259K0FKED	Vishay-Dale
R10	1	40.2 kΩ	RES, 40.2 kΩ, 1%, 0.063 W	0402	CRCW040240K2FKED	Vishay-Dale
R11	1	22.6 kΩ	RES, 22.6 kΩ, 1%, 0.063 W	0402	CRCW040222K6FKED	Vishay-Dale
R12	1	15.8 kΩ	RES, 15.8 kΩ, 1%, 0.063 W	0402	CRCW040215K8FKED	Vishay-Dale
R13	1	11.0 kΩ	RES, 11.0 kΩ, 1%, 0.063 W	0402	CRCW040211K0FKED	Vishay-Dale
R14	1	6.8 kΩ	RES, 6.8 kΩ, 5%, 0.063 W	0402	CRCW04026K80JNED	Vishay-Dale
R15	0	4.99 kΩ	RES, 4.99 kΩ, 1%, 0.063 W	0402	CRCW04024K99FKED	Vishay-Dale
R16	1	16.5 kΩ	RES, 16.5 kΩ, 1%, 0.1 W	0603	CRCW060316K5FKEA	Vishay-Dale

Table 4-1. Component BOM (continued)

REF DES	QTY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
R17	0	4.99 MΩ	RES, 4.99 MΩ, 1%, 0.1 W	0603	CRCW06034M99FKEA	Vishay-Dale
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	6	1 × 2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8	8		Test Point, Miniature, SMT	-	5019	Keystone
U1	1		TPSM63610RDFR	B3QFN-22	TPSM63610RDFR	Texas Instruments

4.3 PCB Layout

Figure 4-2 through Figure 4-7 show the PCB layout images, including 3D views, copper layers, assembly drawings, and layer stackup diagram. The PCB is 62-mils standard thickness with 2-oz copper on all layers.

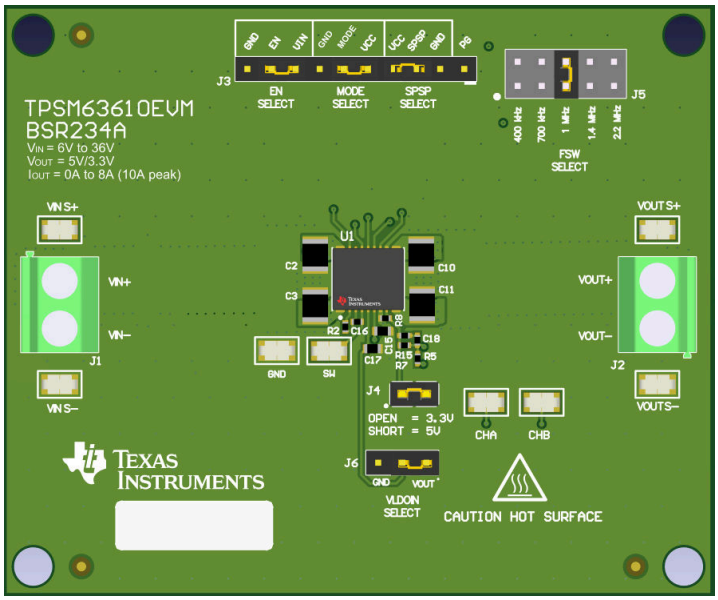


Figure 4-2. 3D Top View

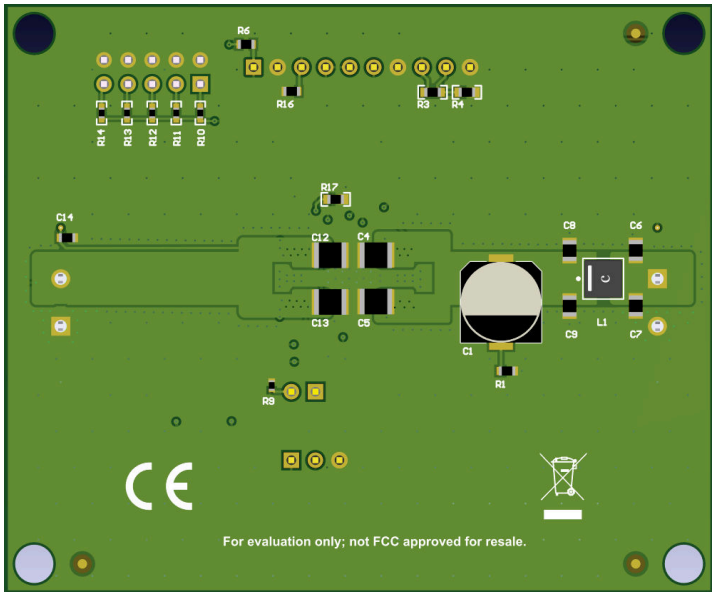


Figure 4-3. 3D Bottom View

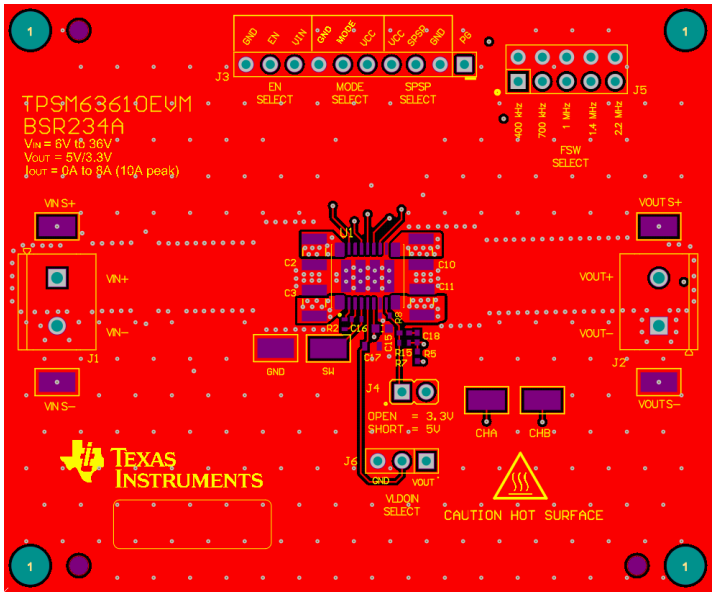


Figure 4-4. Top Layer Copper

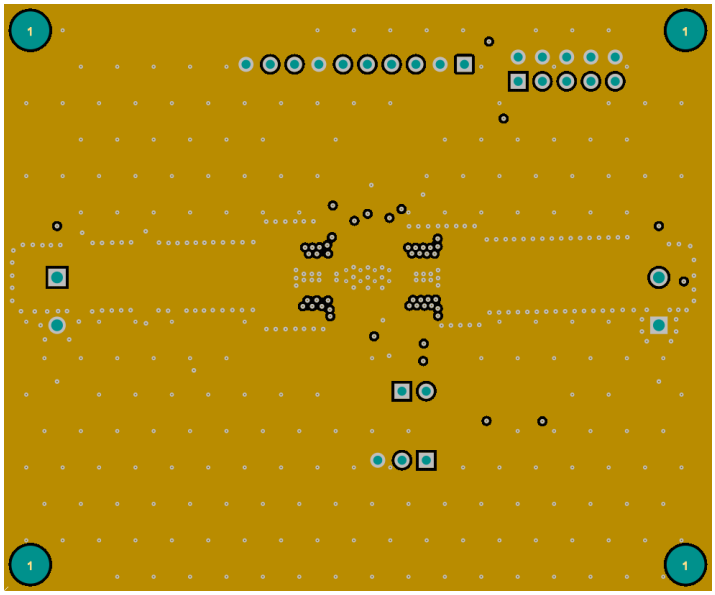


Figure 4-5. Layer 2 Copper

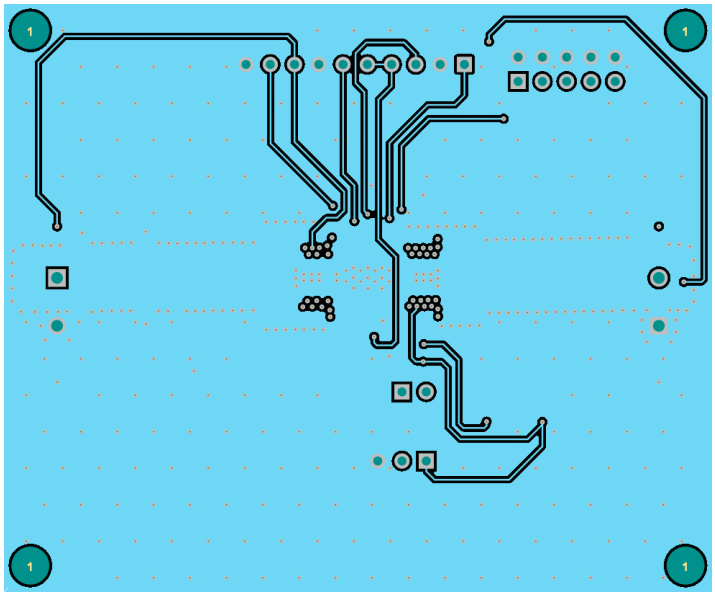


Figure 4-6. Layer 3 Copper

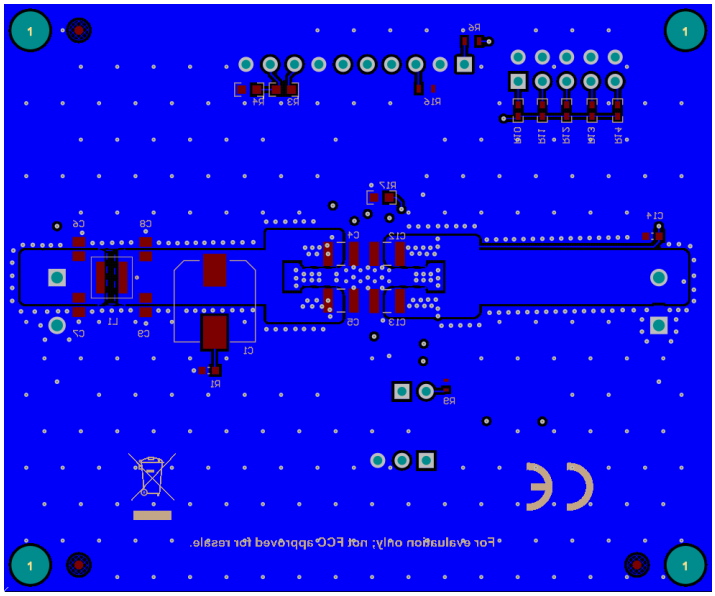


Figure 4-7. Bottom Layer Copper (Viewed From Top)

4.4 Multi-Layer Stackup

#	Name	Material	Type	Weight	Thickness	Dk
	Top Overlay		Overlay			
	Top Solder	Solder Resist	Solder Mask		0.4mil	3.5
1	Top Layer		Signal	2oz	2.8mil	
	Dielectric1	FR-4 High Tg	Core		5mil	4.8
2	Signal Layer 1		Signal	2oz	2.8mil	
	Dielectric3	FR-4 High Tg	Dielectric		40mil	4.8
3	Signal Layer 2		Signal	2oz	2.8mil	
	Dielectric2	FR-4 High Tg	Dielectric		5mil	4.8
4	Bottom Layer		Signal	2oz	2.8mil	
	Bottom Solder	Solder Resist	Solder Mask		0.4mil	3.5
	Bottom Overlay		Overlay			

Figure 4-8. Layer Stackup

5 Device and Documentation Support

5.1 Device Support

5.1.1 Development Support

For development support see the following:

- For TI's reference design library, visit *TI Reference Design library*
- For TI's WEBENCH Design Environment, visit the *WEBENCH® Design Center*
- To design a low-EMI power supply, review TI's comprehensive *EMI Training Series*
- To design an inverting buck-boost (IBB) regulator, visit *DC/DC inverting buck-boost modules*
- TI Reference Designs:
  - *Multiple output power solution for Kintex 7 application*
  - *Arria V power reference design*
  - *Altera Cyclone V SoC power supply reference design*
  - *Space-optimized DC/DC inverting power module reference design with minimal BOM count*
  - *3- to 11.5-V_{IN}, –5-V_{OUT}, 1.5-A inverting power module reference design for small, low-noise systems*
- Technical Articles:
  - *Powering medical imaging applications with DC/DC buck converters*
  - *How to create a programmable output inverting buck-boost regulator*
- To view a related device of this product, see the LM61495 36-V, 10-A synchronous buck converter

5.1.1.1 Custom Design With WEBENCH® Tools

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance.
- Run thermal simulations to understand board thermal performance.
- Export customized schematic and layout into popular CAD formats.
- Print PDF reports for the design, and share the design with colleagues.

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

5.2 Documentation Support

5.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *Innovative DC/DC Power Modules* selection guide
- Texas Instruments, *Enabling Small, Cool and Quiet Power Modules with Enhanced HotRod™ QFN Package Technology* white paper
- Texas Instruments, *Benefits and Trade-offs of Various Power-Module Package Options* white paper
- Texas Instruments, *Simplify Low EMI Design with Power Modules* white paper
- Texas Instruments, *Power Modules for Lab Instrumentation* white paper
- Texas Instruments, *An Engineer's Guide To EMI In DC/DC Regulators* e-book
- Texas Instruments, *Soldering Considerations for Power Modules* application report
- Texas Instruments, *Practical Thermal Design With DC/DC Power Modules* application report
- Texas Instruments, *Using New Thermal Metrics* application report
- Texas Instruments, *AN-2020 Thermal Design By Insight, Not Hindsight* application report
- Texas Instruments, *Using the TPSM53602/3/4 for Negative Output Inverting Buck-Boost Applications* application report

6 Revision History

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

Changes from Revision * (September 2022) to Revision A (October 2022)	Page
• Added infrared thermal images	10
• Changed conducted EMI to radiated EMI for 24-V input	13

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

WARNING

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

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

NOTE:

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

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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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.

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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.

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

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