EVM User's Guide: LMG3624EVM-081

Using the LMG3624EVM-081 65-W USB-C PD High-Density Quasi-Resonant Flyback Converter

Description

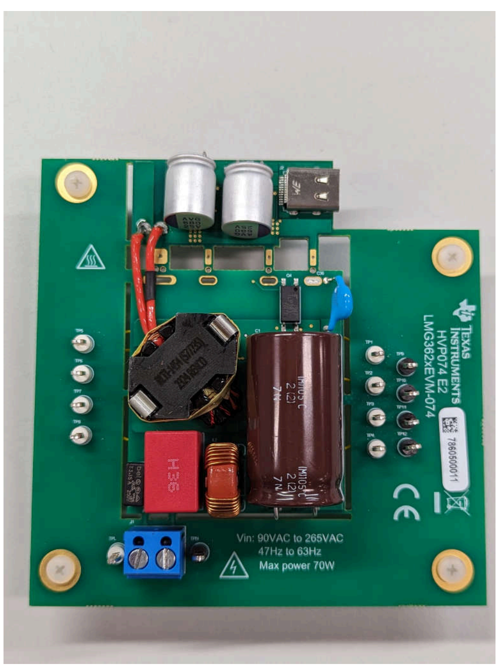
The LMG3624EVM-081 is a 65-W USB-C PD evaluation module (EVM) for evaluating an off-line quasi-resonant flyback adapter for AC/DC adapters, chargers, USB wall outlets, and other applications. The EVM meets CoC Tier 2 and DoE Level 6 efficiency requirements. The EVM is intended for evaluation purposes and is not intended to be an end product. The LMG3624EVM-081 converts input voltage of 90 V_{RMS} to 265 V_{RMS} down to a selectable USB-C PD output voltage 20 V_{DC}, with a max 3.25 A, and to 5 V_{DC}, 9 V_{DC}, and 15 V_{DC}, with a max 3.00-A output current rating. The main device used in this design is the LMG3624, 650-V 170-mΩ integrated GaN FET with current sense emulation.

Features

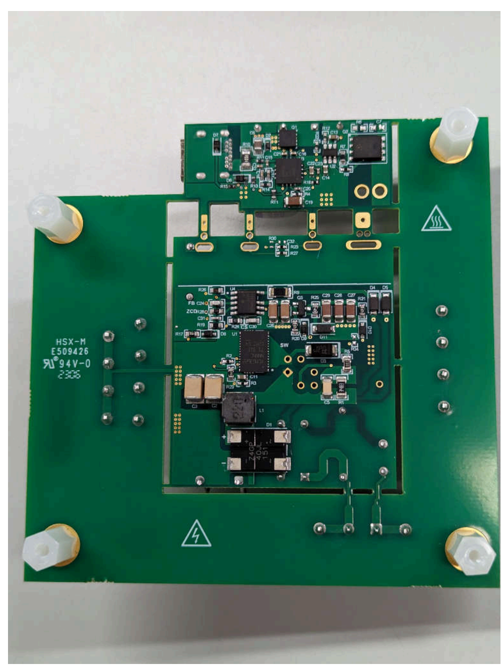
- 93-94% Efficiency under full-load operation under entire input voltage range
- 28W/in^3 Power density enabled by 180-kHz maximum switching frequency
- Current sense emulation greatly reduces power losses associated with traditional current sensing circuitry
- Integration of GaN, driver, OCP, and OTP simplifies design, reduces BOM count, and increases system robustness
- USB-C output enables full system-level evaluation for end-equipments like adapters, notebook chargers, USB wall outlets

Applications

- USB-C PD Power Adapters
- AC-to-DC or DC-to-DC auxiliary power supplies
- High-density AC-to-DC converters / Adapters for notebook computers, tablet computers, TV, and set-top box
- USB-C PPS Power Adapters



LMG3624EVM-081(Top View)



LMG3624EVM-081 (Back View)

1 Evaluation Module Overview

1.1 Introduction

The LMG3624EVM-081 facilitates the evaluation of LMG3624, Integrated GaN FET with current sense emulation, within an AC-DC QR flyback power converter. The EVM is designed for a universal AC input range of 90VAC-265VAC and follows the USB PD 3.0 output protocol of 20 V/15 V/9 V/5 V. This user guide provides a high-voltage safety overview, recommended test setup, resulting efficiency results, thermals, waveforms, and conducted EMI performance.

1.2 Kit Contents

- 65-W USB-C QR Flyback Evaluation Module
- Quick Start Guide
- High Voltage Notice

1.3 Specification

Input	Output	Max Output Power
90VAC-265VAC 47-63 Hz	20 V/3.25A, 15 V/3.00A, 9 V/3.00A, 5 V/3.00A	65 W

1.4 Device Information

The LMG3624 is a 650-V 170-mΩ GaN power FET intended for switch-mode power-supply applications. The LMG3624 simplifies design and reduces component count by integrating the GaN FET and gate driver in a 8-mm by 5.3-mm QFN package. Programmable turn-on slew rates provide EMI and ringing control. The current-sense emulation reduces power dissipation compared to the traditional current sense resistor and allows the low-side thermal pad to be connected to the cooling PCB power ground. The LMG3624 supports converter light-load efficiency requirements and burst-mode operation with low quiescent currents and fast start-up times. Protection features include under-voltage lockout (UVLO), cycle-by-cycle current limit, and overtemperature protection. Overtemperature protection is reported with the open-drain FLT pin.

2 Hardware

2.1 Additional Images

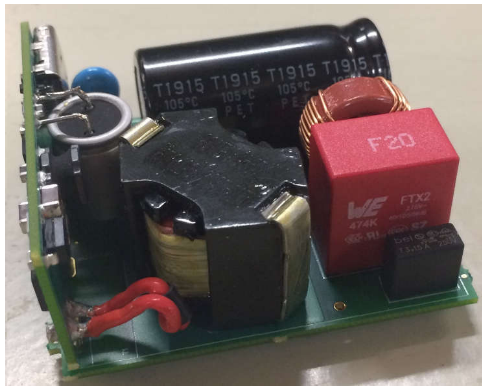


Figure 2-1. High-Density Configuration

2.2 Using the EVM on a Load with USB-C PD Communication

LMG3624EVM-081 comes populated with a USB-C PD controller and requires external connection through an on-board USB-C connector to a USB-C PD load to adjust the board output to obtain 5-V, 9-V, 15-V or 20-V. A USB-C PD communicating load is required to make the board evaluation. An example of such a load is PM125, USB Power Delivery Tester and PassMark Software. Without such a communication load, the board output USB-C connector (J2) does not provide a variable output voltage. To obtain the full load current 3.00-A from 5-V, 9-V and 15-V, a standard USB-C cable can be used, but to obtain 3.25-A at 20-V output, an "E-marker" USB-C cable has to be used. In case the EVM is desired to test on a load without USB-C PD communication, the next section describes how to modify the board to make this test.

2.3 Using the EVM on a Load Without USB-C PD Communication

Normally, a USB-C PD communicated load is required to make evaluation. Without a USB-C PD communication-based load, the board does not provide output voltage on USB-C (J2) connector. In such a case, the board output voltage can be obtained from C8 and C9, but only 5-V and up to 3.00-A can be obtained.

3 Implementation Results

3.1 Electrical Performance Specifications

Table 3-1. LMG3624EVM-081 Electrical Performance Specifications[2]

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input line voltage (RMS)		90	115 / 230	264	V
f_{LINE}	Input line frequency		47	50 / 60	63	Hz
P_{STBY}	Input power at no-load	V_{IN} = 115/230 V_{RMS}, I_{OUT} = 0 A		60/75		mW
$P_{0.25W}$	Input power at 0.25W load	V_{IN} = 115/230 V_{RMS}, P_{OUT} = 250 mW		345/385		mW
OUTPUT CHARACTERISTICS						
V_{OUT}	Output voltage (USB-C PD) V_{IN} = 90 to 264 V_{RMS}	I_{OUT} = 0 to 3.25 A		19.950		V
		I_{OUT} = 0 to 3.00 A		15.050		
				9.050		
				5.050		
I_{OUT}	Full load rated output current V_{IN} = 90 to 264 V_{RMS}	V_{OUT} = 20.0 V		3.250		A
		V_{OUT} = 5.0, 9.0, or 15.0 V		3.000		
V_{OUT_pp}	Output ripple voltage V_{IN} = 115 V / 230 V_{RMS}	V_{OUT} = 20.0 V, I_{OUT} = 0 to 3.25 A		150		mVpp
		V_{OUT} = 15.0 V, I_{OUT} = 0 to 3.00 A		150		
		V_{OUT} = 9.0 V, I_{OUT} = 0 to 3.00 A		150		
		V_{OUT} = 5.0 V, I_{OUT} = 0 to 3.00 A		150		
V_{OUT_Δ}	Output voltage deviation due to load step Up / Down (I_{OUT} step change between 0 and 100% load at 100 Hz rate)	V_{OUT} = 20.0 V		-604 / 340		mVpp
		V_{OUT} = 15.0 V		-584 / 360		
		V_{OUT} = 9.0 V		-404 / 304		
		V_{OUT} = 5.0 V		-404 / 304		
P_{OUT_opp}	Over-power protection threshold	V_{IN} = 90 to 264 V_{RMS}		75		W
SYSTEMS CHARACTERISTICS						
η	Full-load efficiency (V_{IN}= 115/230V_{RMS})	V_{OUT} = 20 V, I_{OUT} = 3.25A		94.2 / 94.0		%
		V_{OUT} = 15 V, I_{OUT} = 3.00A		94.4 / 94.0		
		V_{OUT} = 9 V, I_{OUT} = 3.00A		94.0/ 93.9		
		V_{OUT} = 5 V, I_{OUT} = 3.00A		90.2/ 88.1		
η	4-point average efficiency[1] V_{IN}= 115/230 V_{RMS}	V_{OUT} = 20 V (CoC Tier 2, 89.0%)		94.2 / 93.5		%
		V_{OUT} = 15 V (CoC Tier 2, 88.9%)		94.2 / 92.9		
		V_{OUT} = 9 V (CoC Tier 2, 87.3%)		93.3 / 91.2		
		V_{OUT} = 5 V (CoC Tier 2, 81.8%)		89.5 / 87.0		
η	Efficiency at 10% Load V_{IN}= 115/230 V_{RMS}	V_{OUT} = 20 V (CoC Tier 2, 79.0%)		92.0/ 90.1		%
		V_{OUT} = 15 V (CoC Tier 2, 78.9%)		91.5 / 87.5		
		V_{OUT} = 9 V (CoC Tier 2, 77.3%)		92.0 / 88.0		
		V_{OUT} = 5 V (CoC Tier 2, 72.5%)		86.5 /83.5		
T_{AMB}	Ambient operating temperature range	V_{IN} = 90 to 264 V_{RMS}, I_{OUT} = 0 to 3.00A (5V/9V/15V), or 3.25A (20V)		25		°C

(1) Average efficiency of four load points, I_{OUT} = 100%, 75%, 50% and 25% of rated full-load current for each respective output voltage.
(2) The performance listed in this table is achieved using secondary resonance and based on the test results from a single board.

3.2 Test Setup

3.2.1 Test Setup Requirements

Safety: This evaluation module is not encapsulated and there are accessible voltages that are greater than 50 V_{DC}.

Isolation Input Transformer: A good rated 1:1 isolation transformer shall be used on the inputs to this EVM and be constructed in a manner in which the primary winding are separated from the secondary windings by reinforced insulation, double insulation, or a screen connected to the protective conductor terminal.

WARNING

- If the user is not trained in the proper safety of handling and testing power electronics, then please do not test this evaluation module.
- While the EVM is energized, never touch the EVM or the electrical circuits, as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.
- Caution: Hot surface. Contact can cause burns. Do not touch!
- Read this user's guide thoroughly before making test.

Voltage Source: Isolated AC source or variable AC transformer capable of 264 V_{RMS} and capable of handling 100 W power level. **Warning: Do not apply DC voltage to this board when making test, or damage can happen**.

Voltmeter: Digital voltage meter

Power Analyzer: Capable of measuring 1 mW to 100 W of input power and capable of handling 264-V_{RMS} input voltage. Some power analyzers can require a precision shunt resistor for measuring input current to measure input power of 5 W or less. Please read the power analyzer's user manual for proper measurement setups for full power and for stand-by power.

Oscilloscope:

- 4-Channel, 500 MHz bandwidth.
- Probes capable of handling 600 V.

Output Load: Resistive or electronic load capable of handling 100 W at 20 V.

Recommended Wire Gauge: Insulated 22 AWG to 18 AWG.

WARNING

Caution: Do not leave EVM powered when unattended.

Do not apply DC voltage source to this board or damage can happen.

3.2.2 Test Setup Diagram

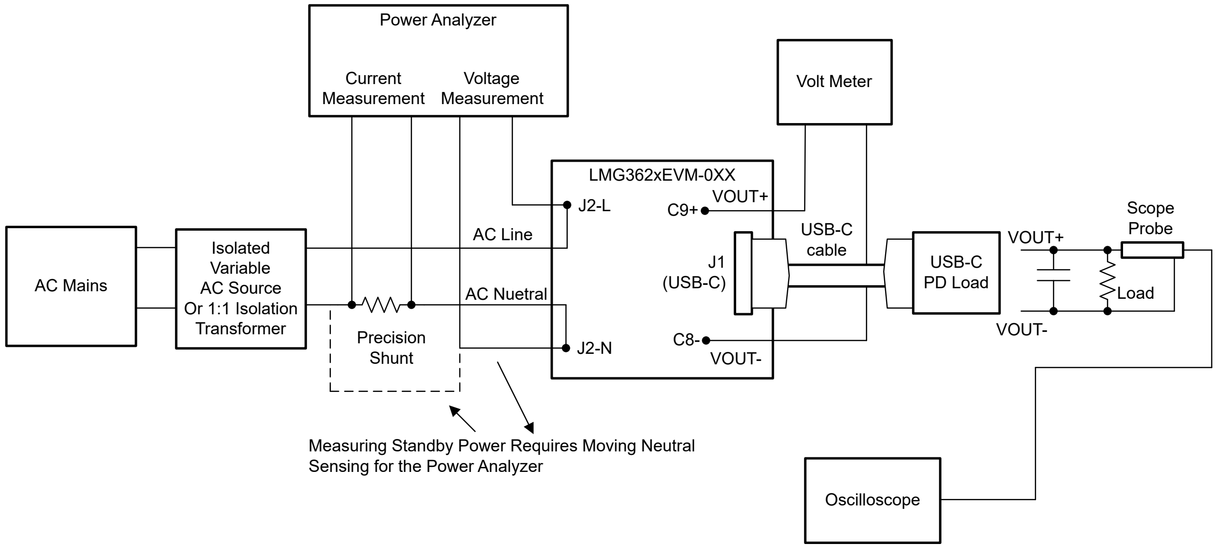


Figure 3-1. LMG3624EVM-081 Test Setup Diagram

3.2.3 Test Points

Table 3-2. Input / Output Terminals and Test Point Functions

Terminals and TEST POINTS		NAME	DESCRIPTION
J2	J2 Terminal	J2	USB-C
J1-L	J1 Terminal	L	AC voltage input - Line
J1-N		N	AC voltage input - Neutral
TPL	Input test points	TPL	AC input monitor - Line
TPN	Input test points	TPN	AC input monitor - Neutral
TP1 to TP4	Floating test points	TP1, TP2, TP3, TP4	Floating, need to solder connections, leave floating if not used.
TP5 to TP8	Floating test points	TP5, TP6, TP7, TP8	Floating, need to solder connections, leave floating if not used.

3.3 Performance Data and Typical Characteristic Curves

3.3.1 Efficiency Result of 4-Point Average on 20-Vout

VIN (VRMS)	PIN (W)	VOUT (V)	IOUT (A)	POUT (W)	PLOSS (W)	Pout %	EFFICIENCY	4-PT AVERAGE EFFICIENCY
90.0	69.8900	20.08	3.250	65.28	4.61	100%	93.4%	
90.0	52.02	20.05	2.442	48.96	3.06	75%	94.1%	
90.0	34.62	20.01	1.630	32.63	1.99	50%	94.2%	
90.1	17.57	19.99	0.822	16.43	1.14	25%	93.5%	
90.1	7.52	19.97	0.334	6.67	0.85	10%	88.7%	
115.0	69.0700	20.08	3.252	65.29	3.78	100%	94.5%	
115.1	51.66	20.05	2.441	48.92	2.74	75%	94.7%	
115.1	34.53	20.02	1.631	32.64	1.89	50%	94.5%	94.3%
115.1	17.57	19.99	0.822	16.44	1.13	25%	93.6%	
115.1	7.29	19.98	0.335	6.69	0.60	10%	91.8%	
230.2	69.1700	20.07	3.249	65.23	3.94	100%	94.3%	
230.3	52.19	20.05	2.441	48.93	3.26	75%	93.8%	
230.3	35.06	20.02	1.631	32.65	2.41	50%	93.1%	93.4%
230.3	17.79	19.99	0.822	16.43	1.36	25%	92.4%	
230.3	7.46	19.97	0.335	6.69	0.77	10%	89.6%	
265.3	69.4400	20.07	3.250	65.23	4.21	100%	93.9%	
265.3	52.3800	20.04	2.439	48.89	3.49	75%	93.3%	
265.3	35.38	20.01	1.630	32.63	2.75	50%	92.2%	
265.3	17.87	19.99	0.822	16.43	1.44	25%	91.9%	
265.3	7.55	19.97	0.335	6.69	0.85	10%	88.7%	
CoC Tier 2, 4-pt average								88.9%
CoC Tier 2, 10%-load								78.9%

3.3.2 Efficiency Result of 4-Point Average at 15-Vout

VIN (VRMS)	PIN (W)	VOUT (V)	IOUT (A)	POUT (W)	PLOSS (W)	Pout %	EFFICIENCY	4-PT AVERAGE EFFICIENCY
90.0	48.2500	15.10	3.002	45.34	2.91	100%	94.0%	
90.0	36.09	15.07	2.256	34.01	2.08	75%	94.2%	
90.0	24.05	15.05	1.508	22.69	1.36	50%	94.3%	
90.1	12.20	15.02	0.760	11.42	0.78	25%	93.6%	
90.1	5.09	15.01	0.310	4.66	0.43	10%	91.5%	
115.1	47.8800	15.10	3.002	45.33	2.55	100%	94.7%	94.2%
115.1	35.91	15.07	2.254	33.97	1.94	75%	94.6%	
115.1	24.01	15.04	1.506	22.66	1.35	50%	94.4%	
115.1	12.24	15.02	0.759	11.39	0.84	25%	93.1%	
115.1	5.08	15.00	0.309	4.64	0.44	10%	91.3%	
230.3	48.3100	15.10	3.002	45.32	2.99	100%	93.8%	92.9%
230.3	36.45	15.07	2.256	34.00	2.45	75%	93.3%	
230.3	24.57	15.04	1.507	22.67	1.90	50%	92.3%	
230.3	12.38	15.02	0.759	11.40	0.98	25%	92.1%	
230.3	5.27	15.00	0.310	4.65	0.62	10%	88.2%	
265.3	48.5400	15.10	3.002	45.32	3.22	100%	93.4%	
265.3	36.6600	15.07	2.255	33.98	2.68	75%	92.7%	
265.3	24.84	15.04	1.508	22.68	2.16	50%	91.3%	
265.4	12.49	15.02	0.759	11.40	1.09	25%	91.3%	
265.4	5.38	15.00	0.312	4.68	0.70	10%	87.0%	
CoC Tier 2, 4-pt average								88.9%
CoC Tier 2, 10%-load								78.9%

3.3.3 Efficiency Result of 4-Point Average at 9-Vout

VIN (VRMS)	PIN (W)	VOUT (V)	IOUT (A)	POUT (W)	PLOSS (W)	Pout %	EFFICIENCY	4-PT AVERAGE EFFICIENCY
90.0	29.0700	9.09	3.005	27.31	1.76	100%	93.9%	
90.1	21.77	9.06	2.258	20.45	1.32	75%	93.9%	
90.1	14.55	9.03	1.510	13.64	0.91	50%	93.8%	
90.1	7.50	9.01	0.762	6.86	0.63	25%	91.5%	
90.1	3.08	8.99	0.312	2.81	0.28	10%	91.1%	
115.1	29.0100	9.09	3.006	27.31	1.70	100%	94.1%	93.7%
115.1	21.75	9.06	2.258	20.46	1.29	75%	94.1%	
115.1	14.55	9.03	1.510	13.64	0.91	50%	93.8%	
115.1	7.40	9.01	0.763	6.87	0.53	25%	92.9%	
115.1	3.10	8.99	0.313	2.81	0.28	10%	90.9%	
230.3	29.4400	9.08	3.005	27.30	2.14	100%	92.7%	92.0%
230.3	22.19	9.06	2.258	20.46	1.73	75%	92.2%	
230.3	14.77	9.03	1.509	13.64	1.13	50%	92.3%	
230.3	7.57	9.01	0.762	6.87	0.70	25%	90.7%	
230.3	3.19	9.00	0.311	2.80	0.39	10%	87.8%	
265.3	29.6400	9.08	3.006	27.31	2.33	100%	92.1%	
265.3	22.4500	9.06	2.260	20.48	1.97	75%	91.2%	
265.4	14.89	9.03	1.509	13.63	1.26	50%	91.6%	
265.3	7.70	9.01	0.763	6.87	0.83	25%	89.2%	
265.4	3.24	8.99	0.313	2.82	0.42	10%	87.1%	
CoC Tier 2, 4-pt average								88.9%
CoC Tier 2, 10%-load								78.9%

3.3.4 Efficiency Result of 4-Point Average at 5-Vout

VIN (VRMS)	PIN (W)	VOUT (V)	IOUT (A)	POUT (W)	PLOSS (W)	Pout %	EFFICIENCY	4-PT AVERAGE EFFICIENCY
90.1	16.7800	5.05	2.993	15.13	1.65	100%	90.2%	
90.1	12.52	5.03	2.246	11.30	1.22	75%	90.2%	
90.1	8.31	5.00	1.498	7.50	0.81	50%	90.2%	
90.1	4.18	4.98	0.751	3.74	0.44	25%	89.5%	
90.1	1.68	4.96	0.302	1.50	0.18	10%	89.0%	
115.1	16.7600	5.05	2.995	15.14	1.62	100%	90.3%	90.0%
115.1	12.51	5.03	2.248	11.31	1.20	75%	90.4%	
115.1	8.33	5.00	1.498	7.50	0.83	50%	90.0%	
115.1	4.18	4.98	0.751	3.74	0.44	25%	89.4%	
115.1	1.70	4.96	0.302	1.50	0.20	10%	88.5%	
230.3	17.1300	5.05	2.997	15.15	1.98	100%	88.4%	87.4%
230.3	12.92	5.03	2.246	11.30	1.62	75%	87.4%	
230.3	8.56	5.00	1.498	7.50	1.06	50%	87.6%	
230.3	4.35	4.98	0.752	3.75	0.60	25%	86.2%	
230.3	1.79	4.96	0.302	1.50	0.29	10%	83.9%	
265.3	17.3500	5.06	2.992	15.12	2.23	100%	87.2%	
265.4	13.1200	5.03	2.248	11.30	1.82	75%	86.2%	
265.4	8.69	5.00	1.498	7.50	1.19	50%	86.3%	
265.4	4.41	4.98	0.753	3.75	0.66	25%	85.1%	
265.4	1.82	4.96	0.302	1.50	0.32	10%	82.4%	
CoC Tier 2, 4-pt average								88.9%
CoC Tier 2, 10%-load								78.9%

3.3.5 Efficiency Typical Results

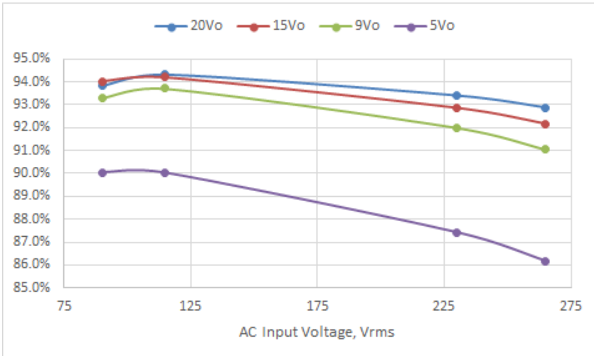


Figure 3-2. 4pt-Average Efficiency vs. Input Voltage

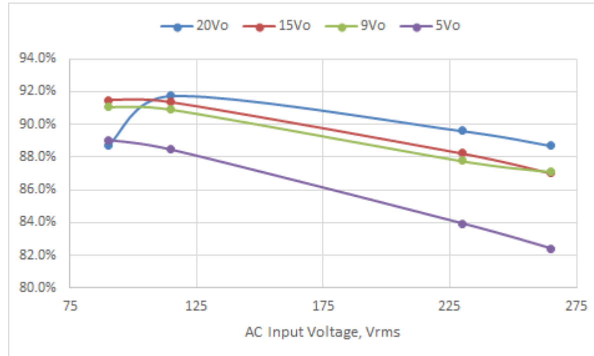


Figure 3-3. Efficiency of 10%-Load vs. Input Voltage

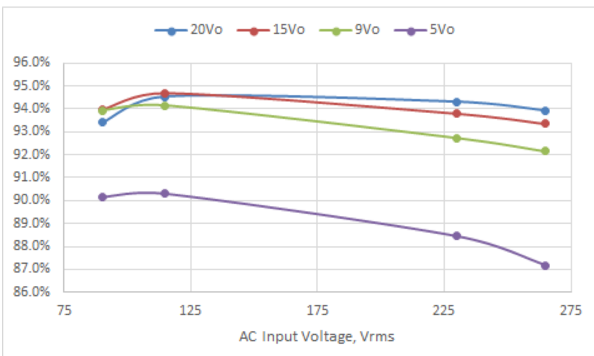


Figure 3-4. Full-load Efficiency vs. Input Voltage

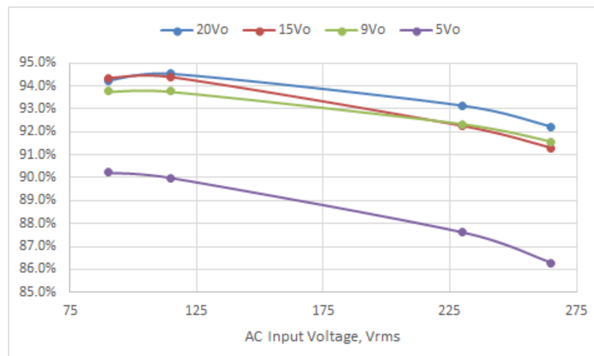


Figure 3-5. Efficiency of 50%-load vs. Input Voltage

3.3.6 Output Characteristics

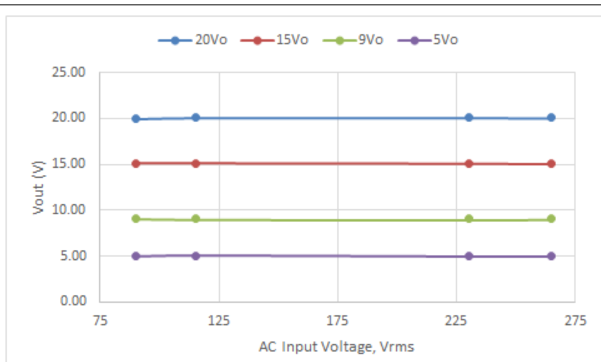


Figure 3-6. V_{OUT} at Full-Load vs Input Voltage

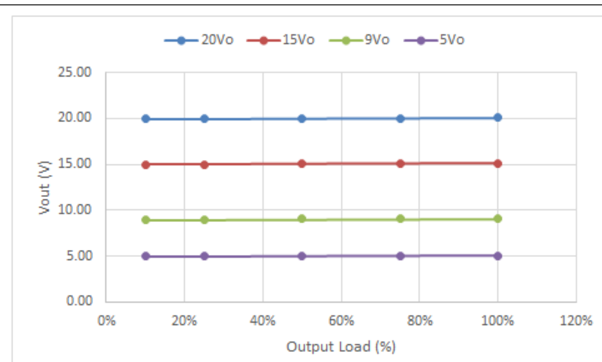


Figure 3-7. V_{OUT} vs Output Current

3.3.7 Switching Frequency

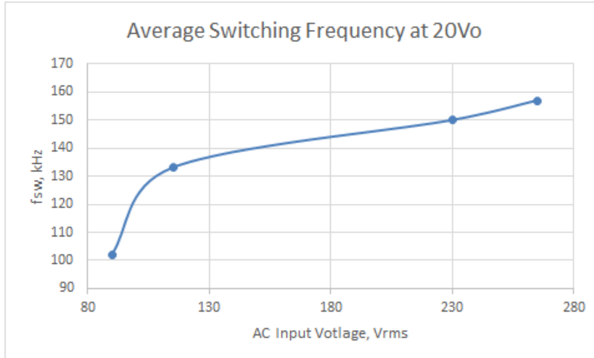


Figure 3-8. Average Switching Frequency vs. Input at 20-Vo Full Load

3.3.8 Key Switching Waveforms

This section shows typical switching waveforms at full load. Yellow = Switch Node, Blue = LMG362X voltage on CS emulation resistor.

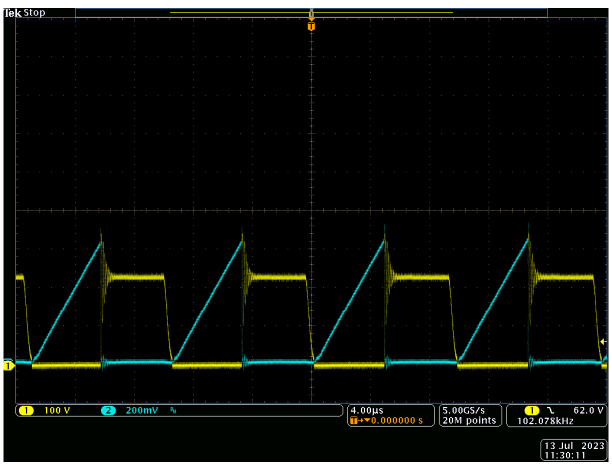


Figure 3-9. Vin = 90Vac, Vout = 20 V

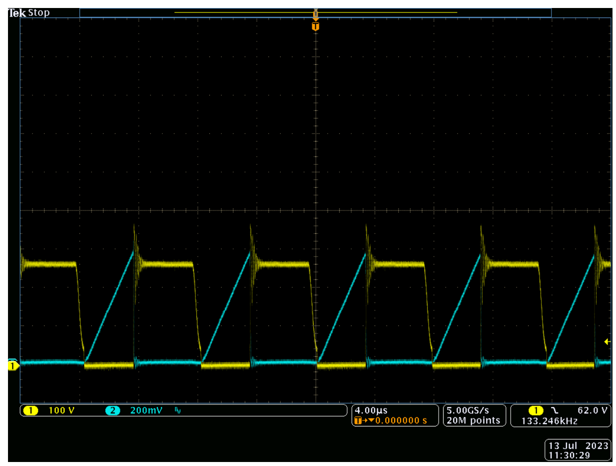


Figure 3-10. Vin = 115Vac, Vout = 20 V

Figure 3-11. Vin = 230Vac, Vout = 20 V

Figure 3-12. Vin = 265Vac, Vout = 20 V

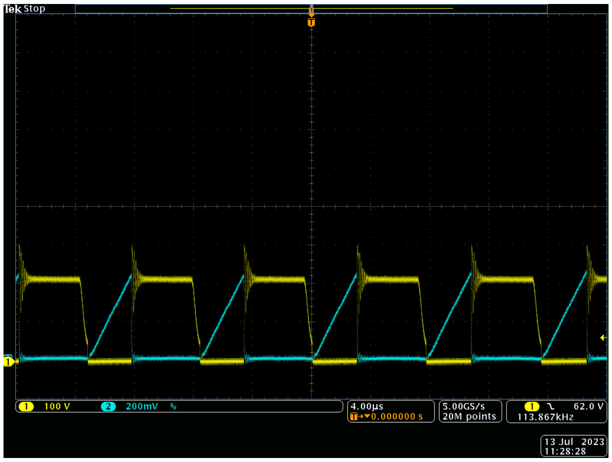


Figure 3-13. Vin = 90Vac, Vout = 15 V

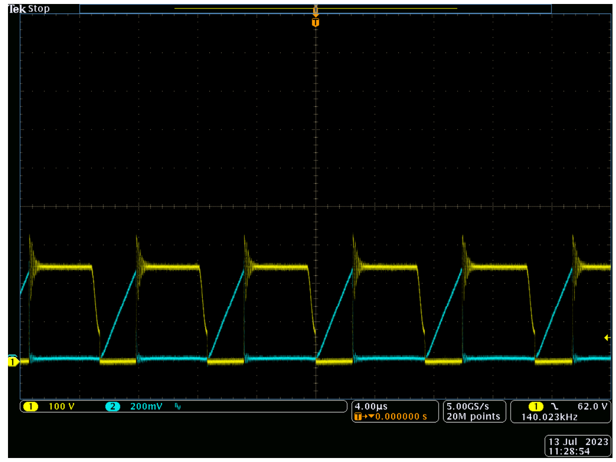


Figure 3-14. Vin = 115Vac, Vout = 15 V

Figure 3-15. Vin = 230Vac, Vout = 15 V

Figure 3-16. Vin = 265Vac, Vout = 15 V

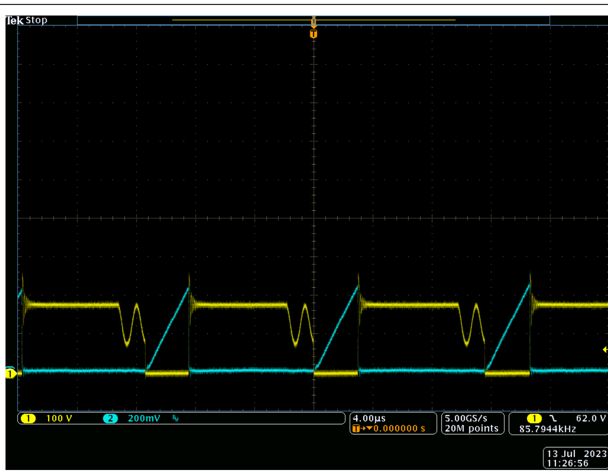


Figure 3-17. Vin = 90Vac, Vout = 9 V

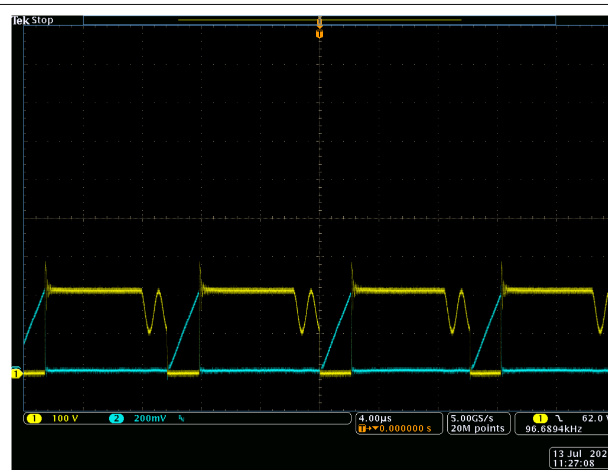


Figure 3-18. Vin = 115Vac, Vout = 9 V

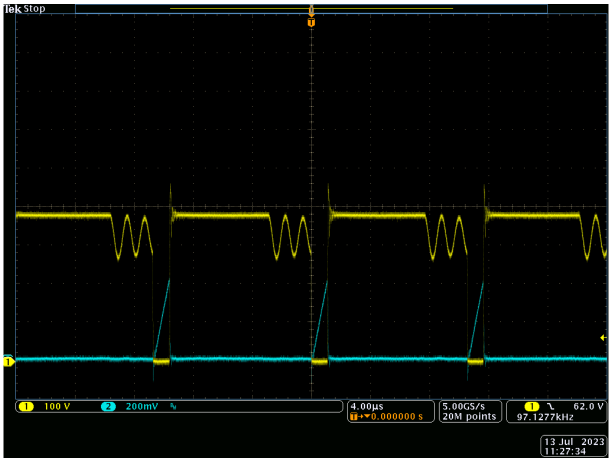


Figure 3-19. Vin = 230Vac, Vout = 9 V

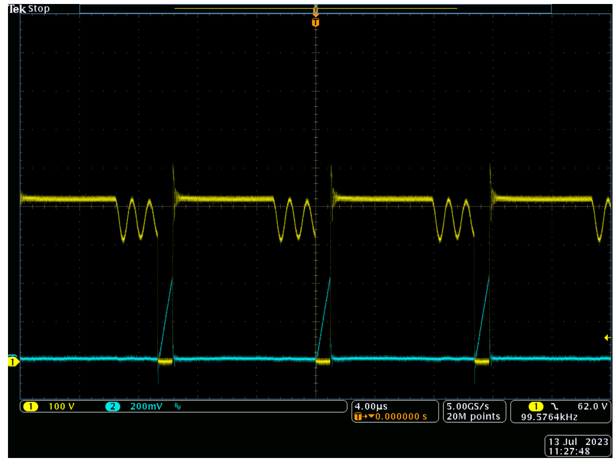


Figure 3-20. Vin = 265Vac, Vout = 9 V

Figure 3-21. Vin = 90Vac, Vout = 5 V

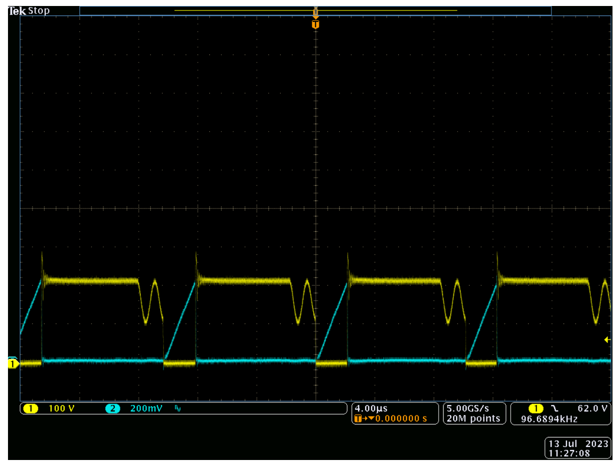


Figure 3-22. Vin = 115Vac, Vout = 5 V

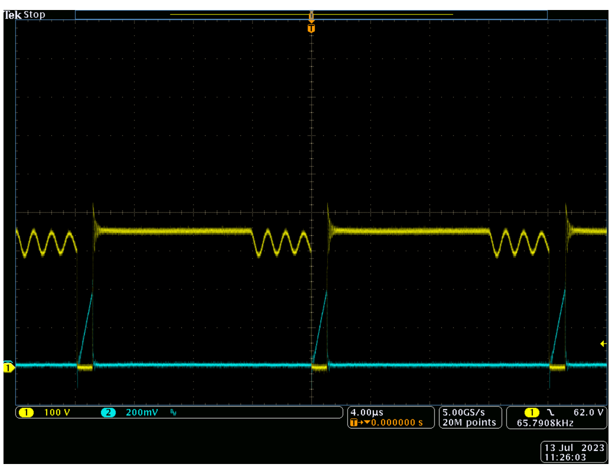


Figure 3-23. Vin = 230Vac, Vout = 5 V

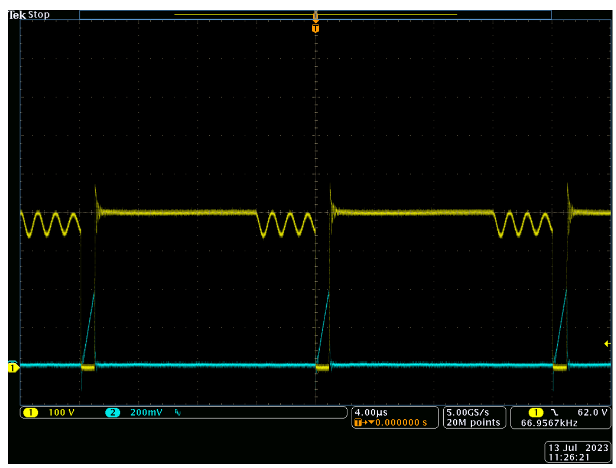


Figure 3-24. Vin = 265Vac, Vout = 5 V

3.3.9 Output Ripple Voltage

Blue = Output Voltage Ripple, Oscilloscope Channel Bandwidth = 20 MHz, Voltage span between two dashed lines is 150 mV. The ripples are with the 100% load condition unless specified in the associated figures.

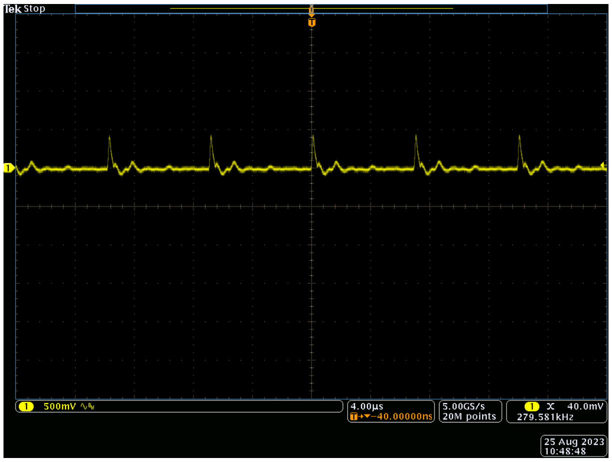


Figure 3-25. Typical Ripple Voltage of V_{OUT} = 20 V

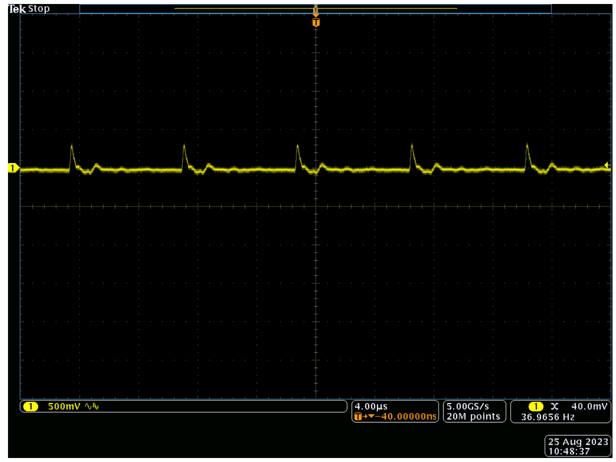


Figure 3-26. Typical Ripple Voltage of V_{OUT} = 15 V

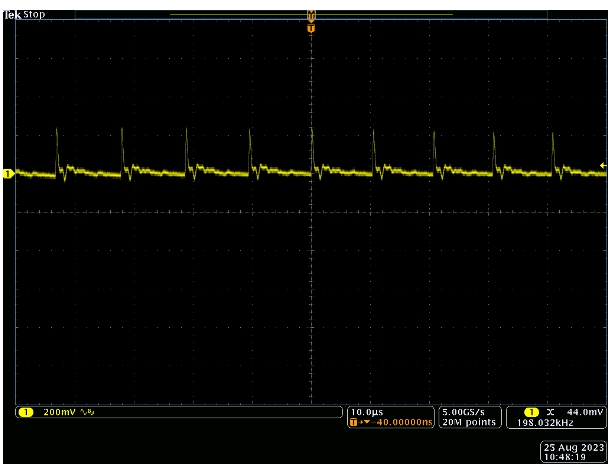


Figure 3-27. Typical Ripple Voltage of V_{OUT} = 9 V

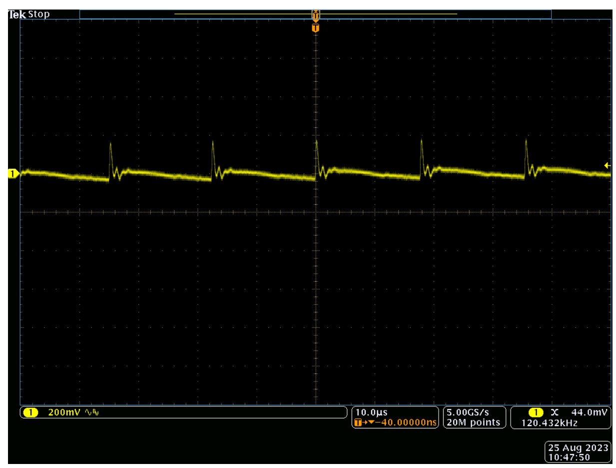


Figure 3-28. Typical Ripple Voltage of V_{OUT} = 5 V

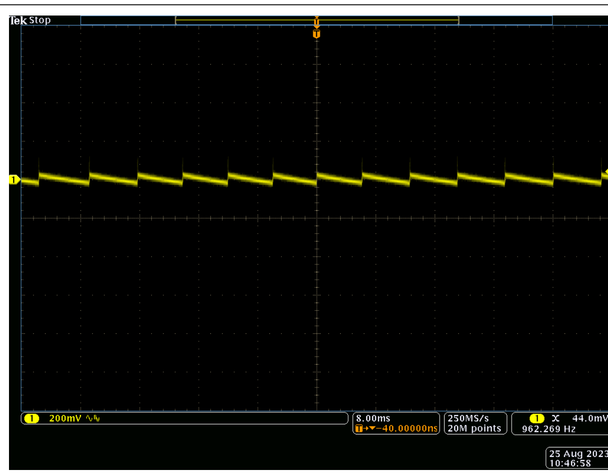


Figure 3-29. Typical Ripple Voltage of V_{OUT} = 5 V at No Load

3.3.10 Load Transient Response

Load transient response at 20 V, 15 V, 9 V, 5 V to show output voltage V_{OUT} deviation when load current step change is between 0 and 100%, at 100-Hz rate.

Yellow = V_{OUT}, Green = Load Current.

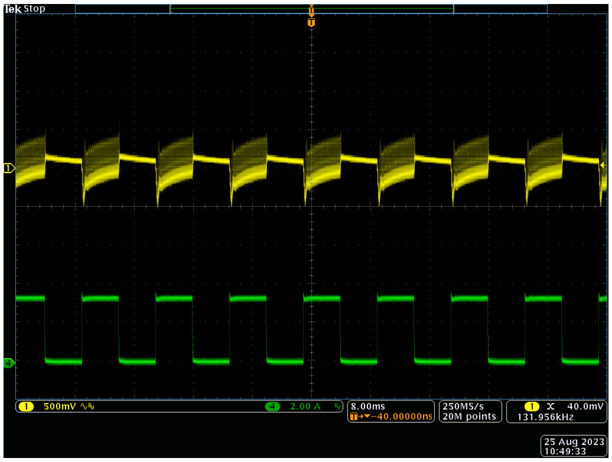


Figure 3-30. Load Transient Response at V_{OUT} = 20 V

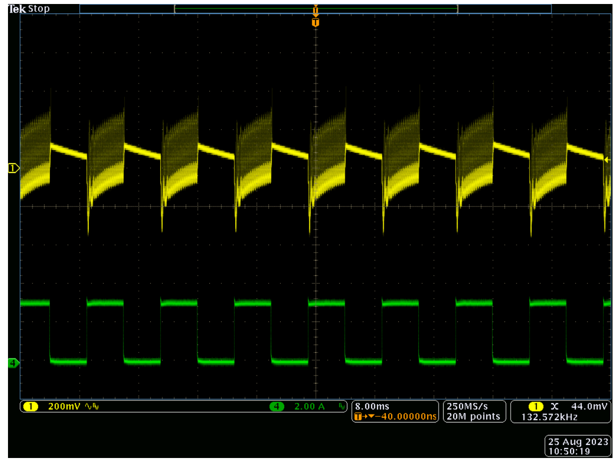


Figure 3-31. Transient Response at V_{OUT} = 15 V

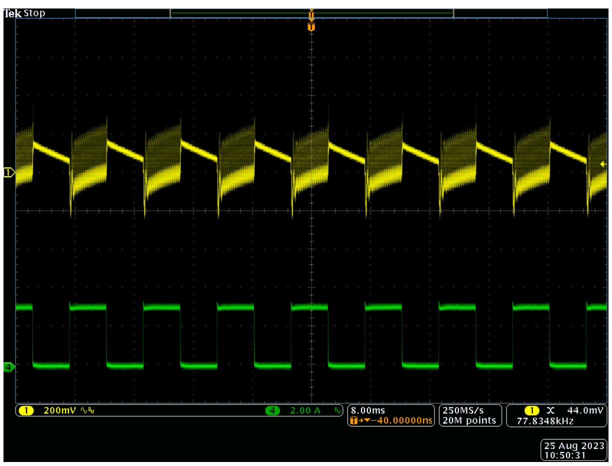


Figure 3-32. Transient Response at V_{OUT} = 9 V

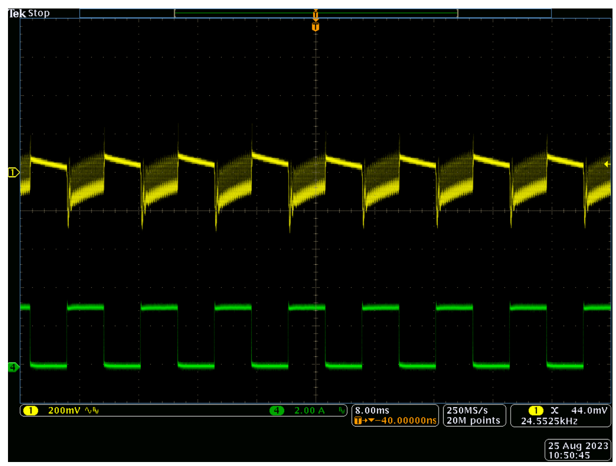


Figure 3-33. Transient Response at V_{OUT} = 5 V

3.3.11 EN55022 Class B Conducted EMI Test Result

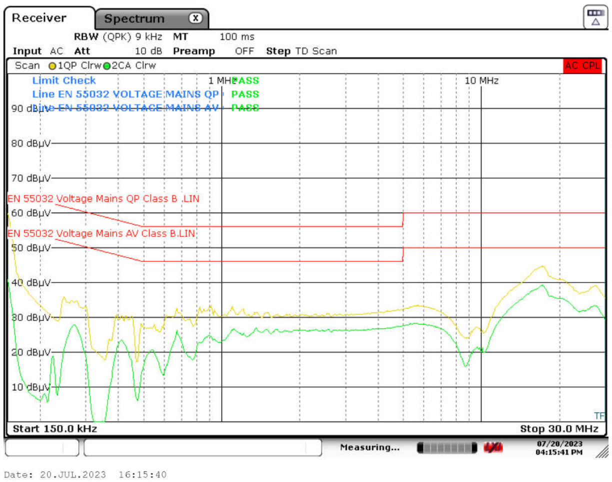


Figure 3-34. VIN = 115 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground)

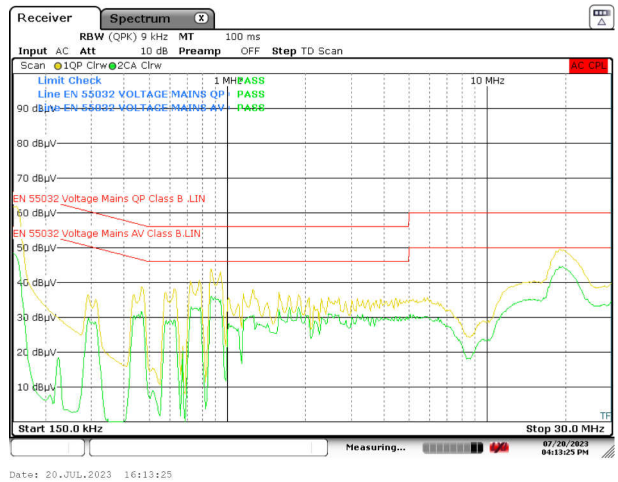


Figure 3-35. VIN = 230 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground)

Note

Please note this was evaluated on an EMI station for pre-qualification purpose only. TI recommends that all final designs be verified by an agency-qualified EMI test house.

3.3.12 Thermal Images at Full Load (20 V and 3.25 A)

Figure 3-36. V_{IN} = 90 V_{AC}, Top Side

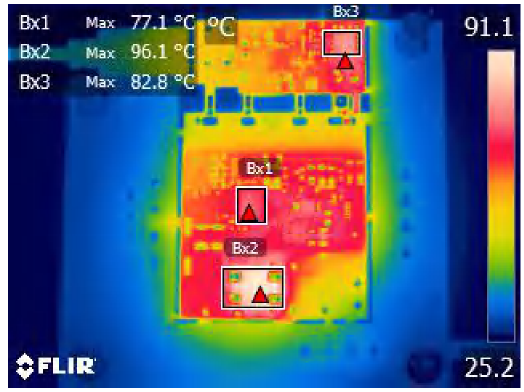


Figure 3-37. V_{IN} = 90 V_{AC}, Bottom Side

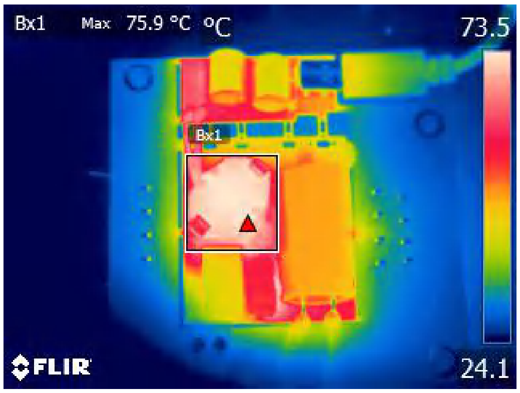


Figure 3-38. V_{IN} = 115 V_{AC}, Top Side

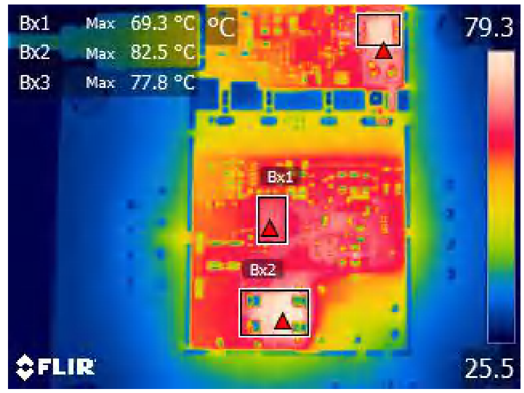


Figure 3-39. V_{IN} = 115 V_{AC}, Bottom Side

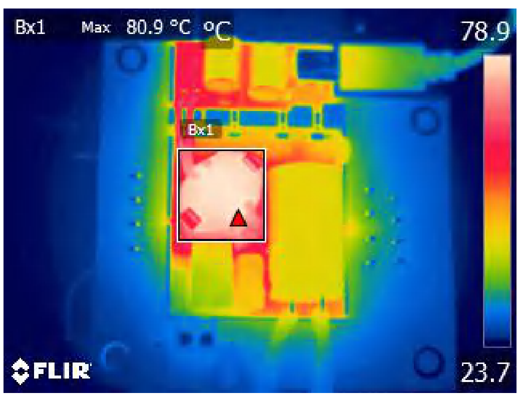


Figure 3-40. V_{IN} = 230 V_{AC}, Top Side

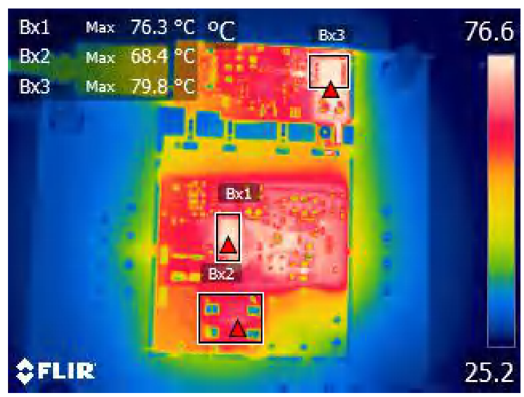


Figure 3-41. V_{IN} = 230 V_{AC}, Bottom Side

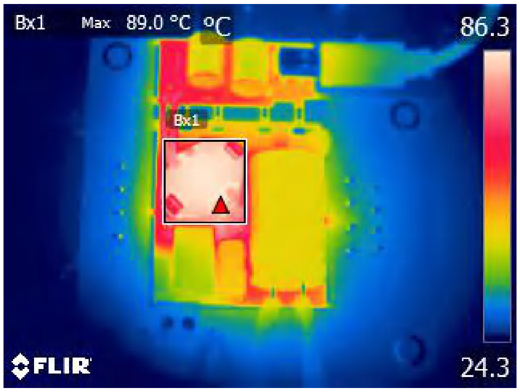


Figure 3-42. V_{IN} = 265 V_{AC}, Top Side

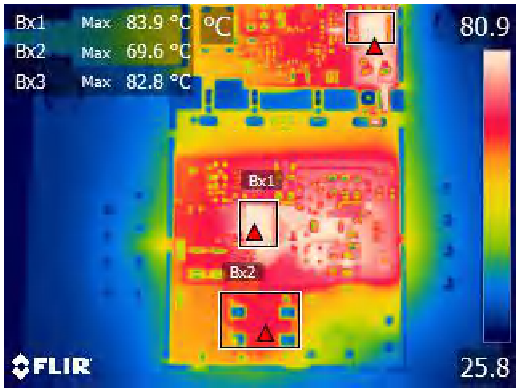


Figure 3-43. V_{IN} = 265 V_{AC}, Bottom Side

4 Hardware Design Files

4.1 Schematics

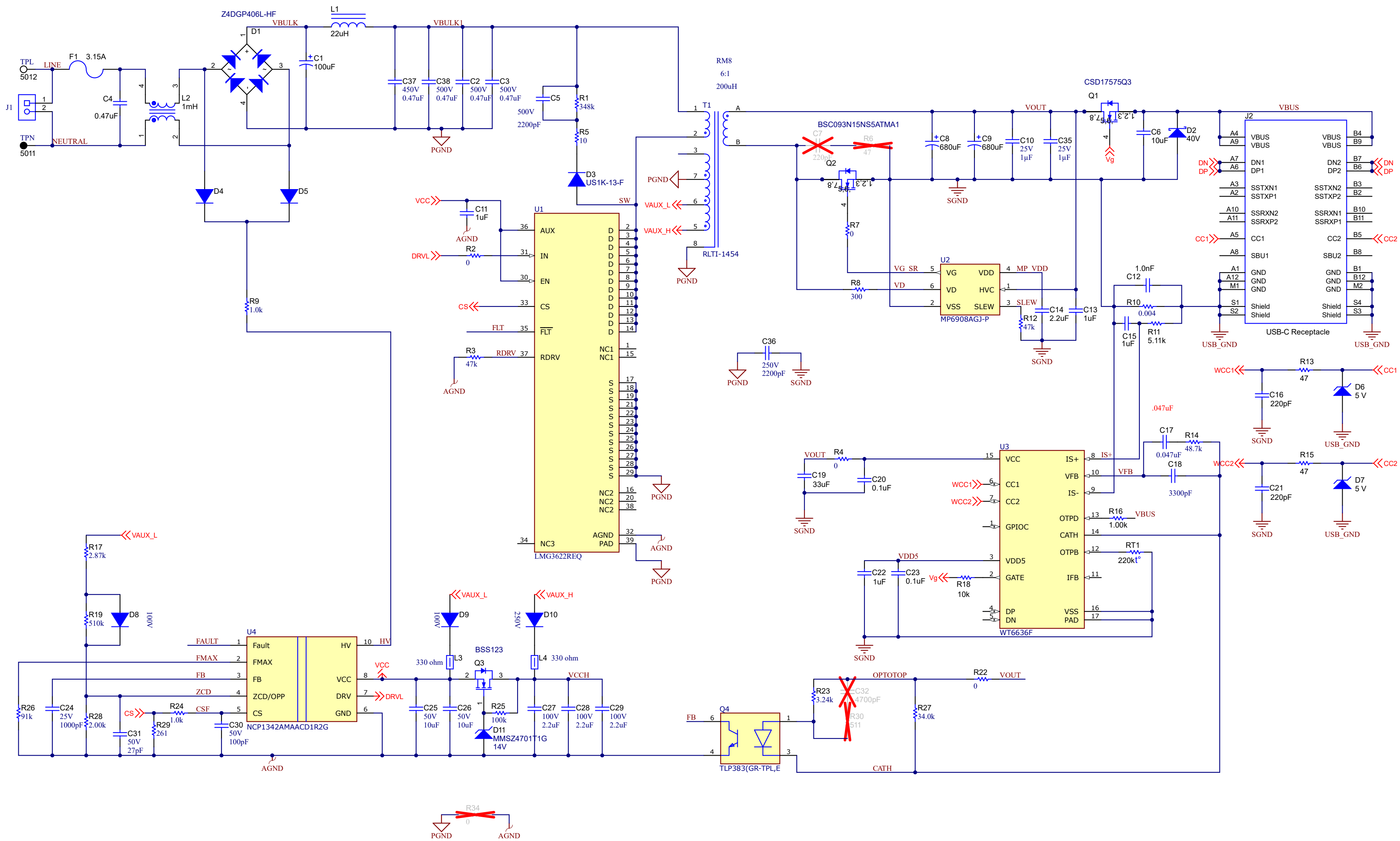


Figure 4-1. LMG3624EVM-081Schematic Diagram

4.2 PCB Layouts

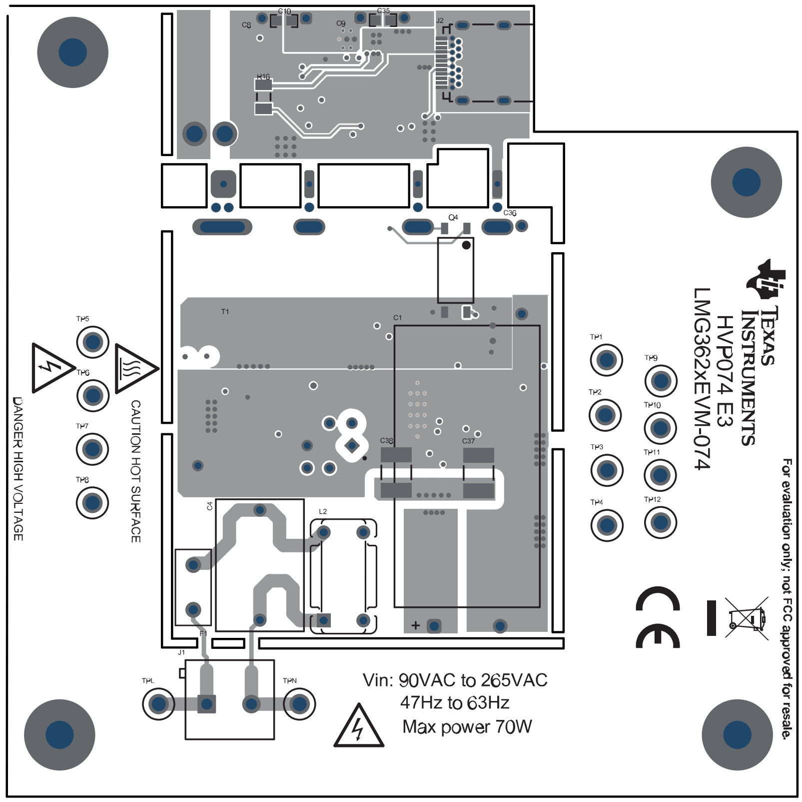


Figure 4-2. EVM Assembly (Top View)

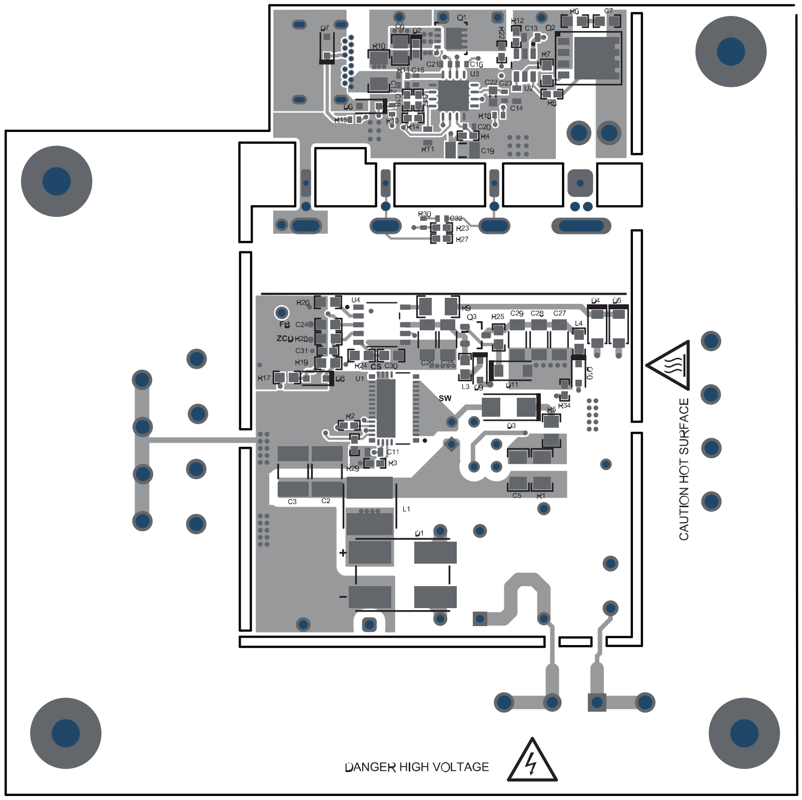


Figure 4-3. EVM Assembly (Bottom View)

4.3 Bill of Materials

Table 4-1 lists the bill of materials for LMG3624EVM-081.

Table 4-1. Bill of Materials

Designator	Qty	Value	Description	Part Number	Manufacturer
C1	1	100uF	CAP, AL, 100 µF, 400 V, +/- 20%, TH	400BXW100MEFR16X30	Rubycon
C2, C3, C38	3	0.47uF	CAP, CERM, 0.47 uF, 500 V, +/- 10%, X7R, 1812	1812Y5000474KXTWS2	Knowles Capacitors
C4	1	0.47uF	CAP, Film, 0.47 µF, 275 V, +/- 10%, TH	8.90324E+11	Wurth Elektronik
C5	1	2200 pF	CAP, CERM, 2200 pF, 500 V, +/- 10%, X7R, 1206	VJ1206Y222KXEAT5Z	Vishay-Vitramon
C6	1	10uF	CAP, CERM, 10 µF, 35 V,+/- 10%, X5R, 0805	GRM21BR6YA106KE43L	MuRata
C8, C9	2	680uF	CAP, Aluminum Polymer, 680 µF, 25 V,+/- 20%, 0.29256 ohm, TH	687AVG025MGBJ	Illinois Capacitor
C10, C35	2	1uF	CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, 0603	C1608X7R1E105K080AE	TDK
C11	1	1uF	CAP, CERM, 1 µF, 25 V, +/- 10%, X7R, 0603	C1608X7R1E105K080AB	TDK
C12	1	1000 pF	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0402	8.85012E+11	Wurth Elektronik
C13	1	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X5R, 0603	GRM188R61E105KA12D	MuRata
C14	1	2.2uF	CAP, CERM, 2.2 uF, 16 V, +/- 10%, X5R, 0603	GRM188R61C225KAAD	MuRata
C15	1	1uF	CAP, CERM, 1 µF, 6.3 V, +/- 20%, X7R, 0402	GRM155R70J105MA12D	MuRata
C16, C21	2	220 pF	CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, 0402	GRM155R71H221KA01D	MuRata
C17	1	0.047uF	CAP, CERM, 0.047 uF, 25 V, +/- 10%, X7R, 0402	GRM155R71E473KA88D	MuRata
C18	1	3300 pF	CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0402	GRM155R71H332KA01D	MuRata
C19	1	33uF	CAP, CERM, 33 µF, 25 V, +/- 20%, X5R, 1206	C3216X5R1E336M160AC	TDK
C20, C23	2	0.1uF	CAP, CERM, 0.1 µF, 25 V, +/- 10%, X7R, 0402	GRM155R71E104KE14D	MuRata
C22	1	1uF	CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, 0603	GCM188R71E105KA64D	MuRata
C24	1	1000 pF	CAP, CERM, 1000 pF, 25 V, +/- 10%, C0G/NP0, 0603	C0603C102K3GACTU	Kemet
C25, C26	2	10uF	CAP, CERM, 10 uF, 50 V, +/- 10%, X5R, 1206	GRM31CR61H106KA12L	MuRata
C27, C28, C29	3	2.2uF	CAP, CERM, 2.2 uF, 100 V, +/- 10%, X7S, 1206	C3216X7S2A225K160AB	TDK
C30	1	100 pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H101JA01D	MuRata

Table 4-1. Bill of Materials (continued)

Designator	Qty	Value	Description	Part Number	Manufacturer
C31	1	27 pF	CAP, CERM, 27 pF, 50 V, +/- 5%, C0G/ NP0, 0402	GRM1555C1H270JA01D	MuRata
C36	1	2200 pF	CAP, CERM, 2200 pF, 250 V,+/- 20%, E, Dia 9 mm	DE1E3RA222MN4AN01F	MuRata
C37	1	0.47uF	CAP, CERM, 0.47 uF, 450 V, +/- 10%, X7T, 1812	C4532X7T2W474K230KA	TDK
D1	1	600 V	Diode, P-N-Bridge, 600 V, 4 A, Z4-D	Z4DGP406L-HF	Comchip Technology
D2	1	40 V	Diode, Schottky, 40 V, 0.2 A, SOD-523	RB521SM-40T2R	Rohm
D3	1	800 V	Diode, Fast Rectifier, 800 V, 1 A, SMA	US1K-13-F	Diodes Inc.
D4, D5	2	600 V	Diode, Ultrafast, 600 V, 1 A, SOD-123FL	UFM15PL-TP	Micro Commercial Components
D6, D7	2	5 V	TVS, 5 V, bidirectional, SOD-323	PESD5V0L1BA,115	NXP Semiconductor
D8, D9	2	100 V	Diode, Switching, 100 V, 150 A, AEC-Q101, SOD-323	1N4148WS-HG3-08	Vishay-Semiconductor
D10	1	250 V	Diode, Switching, 250 V, 0.25 A, AEC-Q101, SOD-323	BAV21WS-7-F	Diodes Inc.
D11	1	14 V	Diode, Zener, 14 V, 500 mW, SOD-123	MMSZ4701T1G	ON Semiconductor
F1	1	3.15A	Fuse, 3.15 A, 250VAC/VDC, TH	RST 3.15-BULK	Bel-Fuse
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
J1	1		Terminal Block, 5.08 mm, 2x1, Brass, TH	ED120/2DS	On-Shore Technology
J2	1	USB-C Receptacle	Connector, Receptacle, USB Type C, R/A	6.32723E+11	Wurth Elektronik
L1	1	22uH	Inductor, Shielded, Ferrite, 22 µH, 1.8 A, 0.089 ohm, SMD	74404064220	Wurth
L2	1	1mH	Coupled inductor, 1 mH, 2 A, 0.045 ohm, TH	744821201	Wurth Elektronik
L3, L4	2	330 ohm	Ferrite Bead, 330 ohm @ 100 MHz, 1.5 A, 0603	BLM18SG331TN1D	MuRata
Q1	1	30 V	MOSFET, N-CH, 30 V, 60 A, DQG0008A (VSON-CLIP-8)	CSD17575Q3	Texas Instruments
Q2	1	150 V	MOSFET, N-CH, 150 V, 87 A, PG-TDSON-8	BSC093N15NS5ATMA1	Infineon Technologies
Q3	1	100 V	MOSFET, N-CH, 100 V, 0.17 A, SOT-23	BSS123	Fairchild Semiconductor
Q4	1		Optoisolator Transistor Output 5000Vrms 1 Channel 6-SO	TLP383(GR-TPL,E	Toshiba
R1	1	348k	RES, 348 k, 1%, 0.25 W, 1206	CRCW1206348KFKEA	Vishay-Dale
R2, R22	2	0	RES, 0, 5%, 0.063 W, 0402	CRCW04020000Z0ED	Vishay-Dale
R3, R12	2	47k	RES, 47 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040247K0JNED	Vishay-Dale
R4	1	0	RES, 300R, 1%, 0.063 W, 0402	CRCW0402300RFKEDC	Vishay-Dale

Table 4-1. Bill of Materials (continued)

Designator	Qty	Value	Description	Part Number	Manufacturer
R5	1	10	RES, 10, 5%, 0.125 W, 0805	CRCW080510R0JNEA	Vishay-Dale
R7	1	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
R8	1	300	RES, 300, 0.1%, 0.063 W, 0402	RG1005P-301-B-T5	Susumu Co Ltd
R9	1	1.0k	RES, 1.0 k, 5%, 0.25 W, 1206	CRCW12061K00JNEA	Vishay-Dale
R10	1	0.004	RES, 0.004, 1%, 1 W, AEC-Q200 Grade 0, 1206	CRF1206-FZ-R004ELF	Bourns
R11	1	5.11k	RES, 5.11 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04025K11FKED	Vishay-Dale
R13, R15	2	47	RES, 47, 5%, 0.063 W, 0402	CRCW040247R0JNED	Vishay-Dale
R14	1	48.7k	RES, 48.7 k, 1%, 0.063 W, 0402	CRCW040248K7FKED	Vishay-Dale
R16	1	1.00k	RES, 1.00 k, 1%, 0.25 W, 1206	RC1206FR-071KL	Yageo America
R17	1	2.87k	RES, 2.87 k, 1%, 0.1 W, 0603	CRCW06032K87FKEA	Vishay-Dale
R18	1	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0JNED	Vishay-Dale
R19	1	510k	RES, 510 k, 5%, 0.1 W, 0603	CRCW0603510KJNEA	Vishay-Dale
R23	1	3.24k	RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04023K24FKED	Vishay-Dale
R24	1	1.0k	RES, 1.0 k, 5%, 0.1 W, 0603	CRCW06031K00JNEA	Vishay-Dale
R25	1	100k	RES, 100 k, 5%, 0.1 W, 0603	CRCW0603100KJNEA	Vishay-Dale
R26	1	91k	RES, 91 k, 5%, 0.1 W, 0603	CRCW060391K0JNEA	Vishay-Dale
R27	1	34.0k	RES, 34.0 k, 1%, 0.063 W, 0402	CRCW040234K0FKED	Vishay-Dale
R28	1	2.00k	RES, 2.00 k, 1%, 0.1 W, 0603	CRCW06032K00FKEA	Vishay-Dale
R29	1	261	RES, 261 1% 0.063 W AEC-Q200 Grade 0, 0402	CRCW0402261RFKED	Vishay-Dale
RT1	1	220k	Thermistor NTC, 220k ohm, 5%, 0603	NCP18WM224J03RB	MuRata
T1	1		T1 for LMG362xEVM-074	RLTI-1454	Renco
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TPL	9		Test Point, Multipurpose, White, TH	5012	Keystone, Keystone Electronics
TP9, TP10, TP11, TP12, TPN	5		Test Point, Multipurpose, Black, TH	5011	Keystone Electronics
U1	1		650-V GaN FET With Integrated Driver and Current Sense Emulation	LMG3624REQ	Texas Instruments
U2	1		FAST TURN-OFF INTELLIGENT RECTIF	MP6908AGJ-P	Monolithic Power Systems
U3	1		USB PD/QC4/QC4+ Controller	WT6636F	Weltrend
U4	1		Converter Offline Flyback Topology 50 kHz	NCP1342AMAACD1R2G	onsemi
C7	0	220 pF	CAP, CERM, 220 pF, 250 V, +/- 10%, X7R, 0603	GRM188R72E221KW07D	MuRata
C32	0	4700 pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0402	GRM155R71H472KA01D	MuRata
R6	0	47	RES, 47, 5%, 0.1 W, 0603	CRCW060347R0JNEA	Vishay-Dale

Table 4-1. Bill of Materials (continued)

Designator	Qty	Value	Description	Part Number	Manufacturer
R30	0	511	RES, 511, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402511RFKED	Vishay-Dale
R34	0	0	RES, 0, 5%, 0.063 W, 0402	CRCW04020000Z0ED	Vishay-Dale

5 Additional Information

5.1 Trademarks

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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

東京都新宿区西新宿６丁目２４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/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。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265