EVM User's Guide: UCC25660EVM-064 UCC256601 UCC256602 UCC256603 UCC256604

UCC25660x Half Bridge LLC Evaluation Module

Description

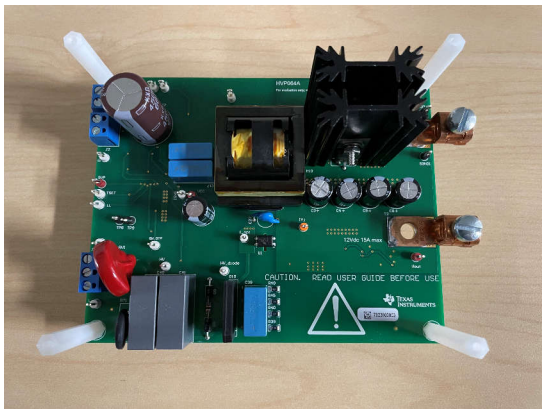
The UCC25660EVM-064 assists designers to evaluate the operation and performance of the UCC25660x LLC Resonant controller (16-pin SOIC package with removed pins for high voltage clearance). This evaluation module demonstrates how UCC25660x controls the LLC resonant half bridge DC-DC converter to achieve high efficiency through out the load and input voltage range.

Features

- IPPC controlled (Input power proportional control) LLC resonant half-bridge DC-DC power conversion
- DC line input from 365 VDC to 410 VDC
- AC input voltage from 85 VDC to 265 VAC
- Regulated 12-VDC typical output
- Full-load power of 180 W, or full-load current of 15 A
- High efficiency
- Enhanced light load management:
  - High frequency pulse skip for improved light load efficiency
  - Low frequency burst for reduced standby power
  - Audible frequency range skip for reduced audible noise
  - User option to disable
  - Integrated PFC on/off control signal
- Combined resonant current and resonant capacitor voltage sensing through one pin
- Adaptive dead-time
- X-capacitor discharge
- Automatic capacitive region avoidance
- Adaptive soft start with minimized inrush current
- Complete sets of protections:
  - Cycle-by-cycle current limit, OCP1 protection
  - Configurable over power protection
  - OVP, internal & external OTP
  - Vin & VCC UVLO
  - Inbuilt 19.5 V VCC Clamp
- Test points to facilitate device and topology evaluation

Applications

- SMPS power supply for TV
- Industrial AC-DC adapters
- Power tools
- Medical power supply
- Multifunctional printer
- Enterprise and cinema projector
- PC power supply
- Gaming console power supply
- Lighting



UCC25660EVM-064 180W LLC Resonant DC-DC Converter (Top View)

1 Evaluation Module Overview

1.1 Introduction

The purpose of the EVM is to aid in evaluation of the UCC25660x LLC resonant controller. The EVM is a stand-alone LLC resonant half-bridge DC-DC power converter designed to operate with DC input from 365 VDC to 410 VDC, AC input from 85 to 265 VRMS, 47 to 63 Hz, and a nominal output of 12 VDC up to 180-W. The EVM is delivered using a diode rectifier at the output. The user has the option to evaluate this converter with a synchronous rectifier (SR) by populating the UCC24624 and SR FETs.

This user's guide describes the UCC25660EVM-064 evaluation module (EVM). The user's guide provides basic evaluation instructions from a viewpoint of system operation of the stand-alone LLC resonant power converter. Please read this user's guide thoroughly before applying power to this board.

1.2 Kit Contents

Table 1-1. UCC25660EVM-064 Kit Contents

Item	Description	Quantity
UCC25660EVM-064	PCB	1

1.3 Specifications

Table 1-2. UCC25660EVM-064 Specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
	INPUT CHARACTERISTICS					
	DC voltage range		365	390	410	VDC
	AC voltage range		85		265	VAC
	AC voltage frequency		47		63	Hz
	Input DC UVLO On			365		VDC
	OUTPUT CHARACTERISTICS					
V_{OUT}	Output voltage - Normal mode	Burst mode threshold to full load = 15 A		12		VDC
I_{OUT}	Output load current	365 to 410 VDC			15	A
	Output voltage ripple	390 VDC and full load = 15 A		120		mVpp
	SYSTEM CHARACTERISTICS					
	Resonant frequency			100		kHz
	Operating temperature	Natural convection		25		°C

1.4 Device Information

The UCC25660x is a fully featured LLC controller with integrated high-voltage gate driver. The UCC25660x has been designed to cover a wide range of applications with specific features added to make the device easy to design for wide input and output voltage operation needs. The device can be paired with a PFC controller to provide a complete power system using a minimum of external components. The resulting power system is designed to meet the most stringent requirements for standby power without the need for a separate standby power converter.

UCC25660x implements a new control algorithm which provides a highly efficient and consistent low power and burst mode. Both the low power and burst mode operation are designed to minimize audible noise while meeting DoE level VI, EuP regulations. The burst power level and hysteresis are programmable and directly relate to input power, simplifying the design and enabling wide input and output voltage operation.

The UCC25660x provides several protection features ranging from cycle-by-cycle protection, capacitive region operation avoidance, external OVP and OTP to enhance the reliability of the LLC power stage.

General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

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

Save all warnings and instructions for future reference.

WARNING

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

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

1. Work Area Safety:
   a. Keep work area clean and orderly.
   b. Qualified observers must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and non-conductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety:
   a. As a precautionary measure, a good engineering practice is to assume that the entire EVM can have fully accessible and active high voltages.
   b. De-energize the TI HV EVM and all the inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   c. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   d. Once EVM readiness is complete, energize the EVM as intended.

   WARNING

   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.
3. Personal Safety
   a. Wear personal protective equipment e.g. latex gloves or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

2 Hardware

2.1 Test Setup

2.1.1 Test Equipment

High Voltage DC Voltage Source: Capable of 365 VDC to 410 VDC, adjustable, with minimum power rating 500 W, or current rating not less than 1 A, with current limit function. The DC voltage source to be used must meet IEC 60950 reinforced insulation requirement.

AC Voltage Source: Capable of single-phase output AC voltage 85 to 265 VAC, 47 to 63 Hz, adjustable, with minimum power rating 100 W and current limit function. The AC voltage source to be used must meet IEC 60950 reinforced insulation requirement.

DC Digital Multimeter: One unit capable of 0-VDC to 450-VDC input range, four digit display preferred; and one unit capable of 0-VDC to 20-VDC input range, four digit display preferred.

Output Load: DC load capable of receiving 0 VDC to 20 VDC, 0 A to 15 A, and 0 W to 300 W or greater, with the capability to display information such as load current and load power.

Oscilloscope: Capable of 500-MHz full bandwidth, digital or analog: if digital, 5 Gsps, or better.

Fan: 200 to 400 LFM forced air cooling is recommended, but not required.

Recommended Wire Gauge: Capable of 25 A, or better than #14 AWG, with the total length of wire less than 8 feet (4 feet input and 4 feet return).

2.1.2 Recommended Test Setup

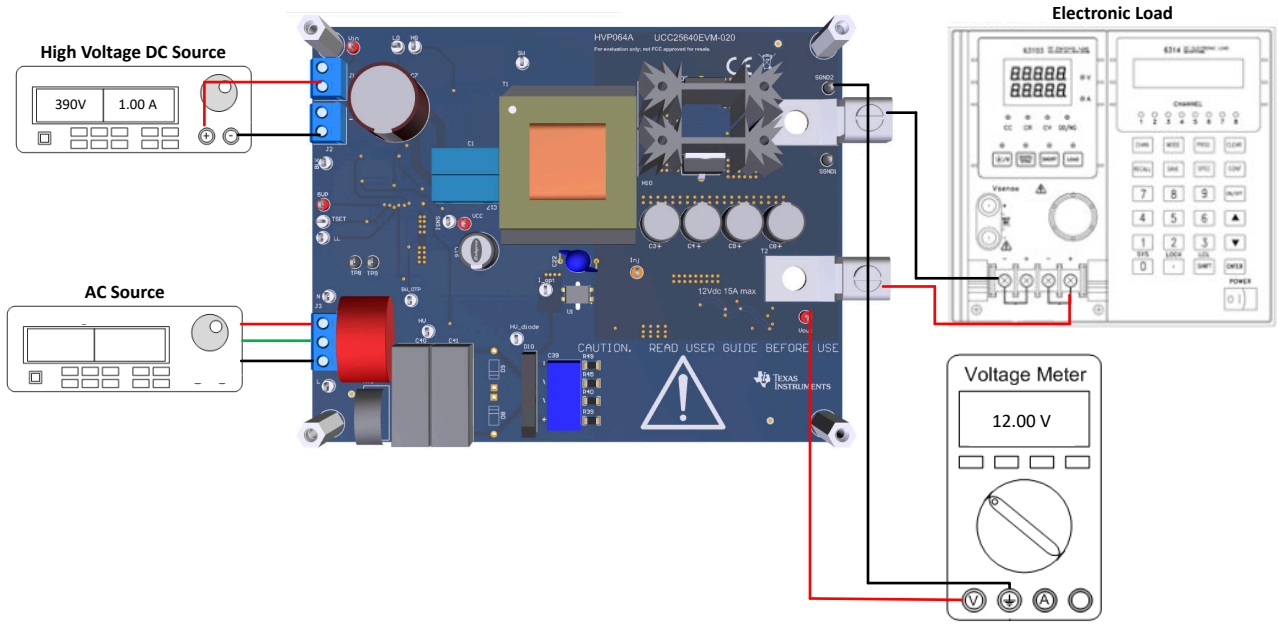


Figure 2-1. UCC25660EVM-064 Test Setup Diagram

WARNING

High voltages that can cause injury exist on this evaluation module (EVM). Please make sure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.

2.2 Using the EVM with UCC256602

UCC25660EVM-064 comes populated with UCC256601. To use this EVM with UCC256602, follow the steps below.

- Replace U4 with UCC256602
- Connect the test points "Vin" to "HV_diode"

- Disconnect the AC voltage source

2.3 Using the EVM with UCC256603

UCC25660EVM-064 comes populated with UCC256601. To use this EVM with UCC256603, follow the steps below.

- Replace U4 with UCC256603
- Remove R5 and R28
- Connect a 12 V DC source between the test points "VCC" and TP8.
- Disconnect the AC voltage source

2.4 Test Points

Table 2-1 lists the EVM test points.

Table 2-1. Test Points

Test Points	Description
Vin	Input voltage positive terminal
HG	Primary-side high side MOSFET gate, Q1
SGND1	Secondary-side ground
SGND2	Secondary-side ground
SW	Primary-side switch node, or the intersection of Q1 and Q3
VCC	Controller Supply input
LG	Primary-side low side MOSFET gate, Q3
TP8	Primary-side ground
TP9	Primary-side ground
Vout	Output voltage positive terminal
Inj	Small signal injection terminal
I_opt	Feedback current measurement
HV	High-voltage start pin
HV_diode	High-voltage start pin
5VP	Regulated 5-V bias
BLK	Input voltage sensing
L	AC line
N	AC neutral
LL	Light-load burst mode thresholds
ISNS	Resonant current sense
OVP_OTP	Bias winding voltage sense/External over temperature protection
TSET	On time min and max programming/ PFC on/off logic

2.5 Terminals

Table 2-2 lists the EVM terminals.

Table 2-2. List of Terminals

Terminal	Name	Description
J1	VIN	Input voltage positive terminal
J2	PGND	Input voltage return terminal
J3	AC Input	3-pin, AC power input, 85–265 V_{RMS}
T2	VOUT	Output voltage positive terminal
T3	SGND	Output voltage ground terminal

2.6 Test Procedure

Use the following steps for the test procedure:

1. Refer to Section 2.1.2 for basic setup. The required equipment for this measurement is listed in Section 2.1.1.
2. Before making electrical connections, visually check the board to make sure there are no suspected spots of damage.
3. Keep the High Voltage DC voltage source output off. Connect this DC source to J1 (+) and J2 (-). This DC voltage source must be isolated and meet the IEC 60950 requirement. Set the DC output voltage within the range specified in Table 1-2, between 365 VDC and 410 VDC; set the DC source current limit to 1 A.

> **CAUTION**
> The board has no fuse installed and relies on the external voltage source current limit to verify circuit protection.

4. Keep the AC voltage source output off. Connect the source with AC_neutral to J3-1, AC_earth to J3-2, and AC_line to J3-3. Isolate the AC voltage source and meet the IEC 60950 requirement. Set the AC output voltage and frequency within the range specified in Table 1-2, between 85 and 265 VAC and 47 to 63 Hz. Set the AC source current limit to 200 mA.
5. Connect an electronic load set to either constant-current mode or constant-resistance mode. The load range is from 0 to 15 A.
6. If the load does not have a current or a power display, TI recommends inserting a current meter between the output voltage and the electronic load.
7. Connect a voltage meter to Vout and SGND1/SGND2 to monitor the output voltage.
8. Turn on the AC source output.
9. Turn on the DC source output.

2.6.1 Equipment Shutdown

Shut down the equipment using the following steps:

1. Shut down the AC voltage source.
2. Shut down the DC voltage source.
3. Shut down the electronic load.

> **WARNING**
> High voltage can still be present on the resonant capacitors after turning off the DC source.

3 Implementation Results

3.1 Performance Data and Typical Characteristic Curves

3.1.1 UCC25660EVM-064 Standalone Standby and Light Load Power

Table 3-1 lists the total standby and light load power measurement for the standalone EVM. The average input power is measured over a 6min interval.

Table 3-1. Standalone Standby Power

I_{OUT} (mA)	V_{OUT} (V)	P_{OUT} (mW)	V_{IN} (V)	P_{IN} (mW)
0	12	0	390	51
10	12	120	390	227.6
20	12	240	390	305.88
50	12	600	390	753.71
100	12	1200	390	1516.4

3.1.2 Efficiency, Load Regulation, Switching Frequency vs Output Current

Table 3-2 gives the efficiency, load regulation, switching frequency data at various input voltage and at different load currents.

Table 3-2. Performance Data

V_{IN} (V)	I_{IN} (mA)	P_{IN} (W)	V_{OUT}(V)	I_{OUT}(A)	Operating Frequency (kHz)	Operating Frequency	Efficiency (%)
390	501.7	195.663	11.997	15	100.5	Normal	91.97191
390	433.2	168.948	11.998	13	101.4	Normal	92.32071
390	374.4	146.016	11.998	11.25	102.2	Normal	92.44021
390	366.2	142.818	11.998	11	102.36	Normal	92.40992
390	299.5	116.805	11.998	9	103.45	Normal	92.44639
390	249.9	97.461	11.998	7.5	103.9	Normal	92.32924
390	233.2	90.948	11.998	7	104.5	Normal	92.34508
390	167.61	65.3679	11.997	5	105.9	Normal	91.76522
390	126.72	49.4208	11.997	3.75	106.9	Normal	91.03201
365	537	196.005	11.995	15	88.4	Normal	91.79613
365	464.2	169.433	11.997	13	89.07	Normal	92.04877
365	401.2	146.438	11.998	11.25	89.67	Normal	92.17382
365	392	143.08	11.998	11	89.78	Normal	92.2407
365	321	117.165	11.998	9	90.48	Normal	92.16234
365	267.9	97.7835	11.998	7.5	90.99	Normal	92.02473
365	250.2	91.323	11.998	7	91.21	Normal	91.96588
365	179.6	65.554	11.998	5	92.02	Normal	91.51234
365	136.23	49.72395	11.997	3.75	92.67	Normal	90.47702
410	476.6	195.406	11.995	15	110.65	Normal	92.07752
410	412.2	169.002	11.997	13	112.27	Normal	92.28352
410	356.3	146.083	11.997	11.25	113.8	Normal	92.39011
410	348.2	142.762	11.998	11	114.14	Normal	92.44617
410	284.9	116.809	11.998	9	116.2	Normal	92.44322
410	237.7	97.457	11.997	7.5	118.14	Normal	92.32533
410	221.9	90.979	11.997	7	118.89	Normal	92.30592
410	159.05	65.2105	11.997	5	122.4	Normal	91.98672
410	120.38	49.3558	11.997	3.75	125.4	Normal	91.1519

3.1.3 Startup

The following waveforms show the output voltage, resonant current sense resistor voltage, and low side gate behavior during startup. 115 VAC, 60 Hz is applied initially to the AC input, then the 390 VDC input is applied to the DC input.

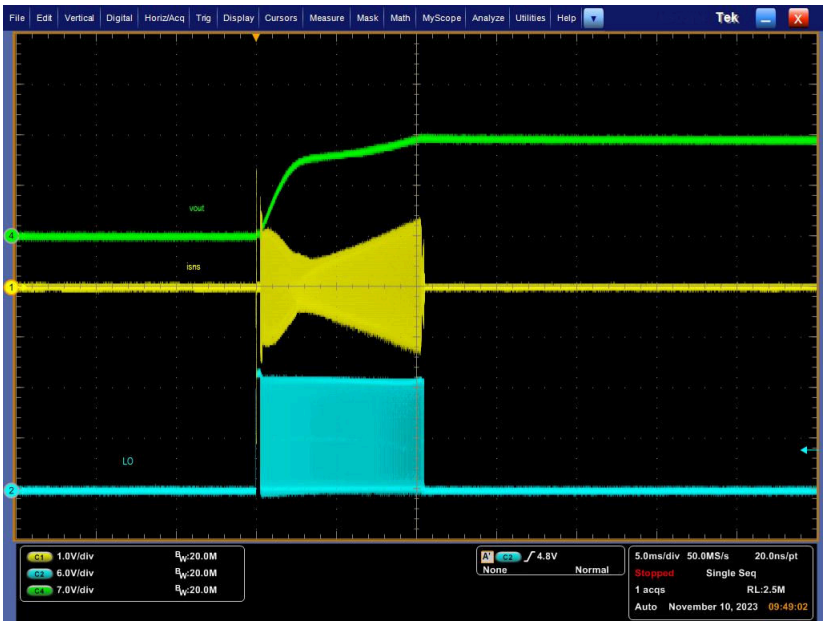


Figure 3-1. No Load (0 A) Startup (Ch1 = ISNS; Ch2 = LO; Ch4 = V_{OUT})

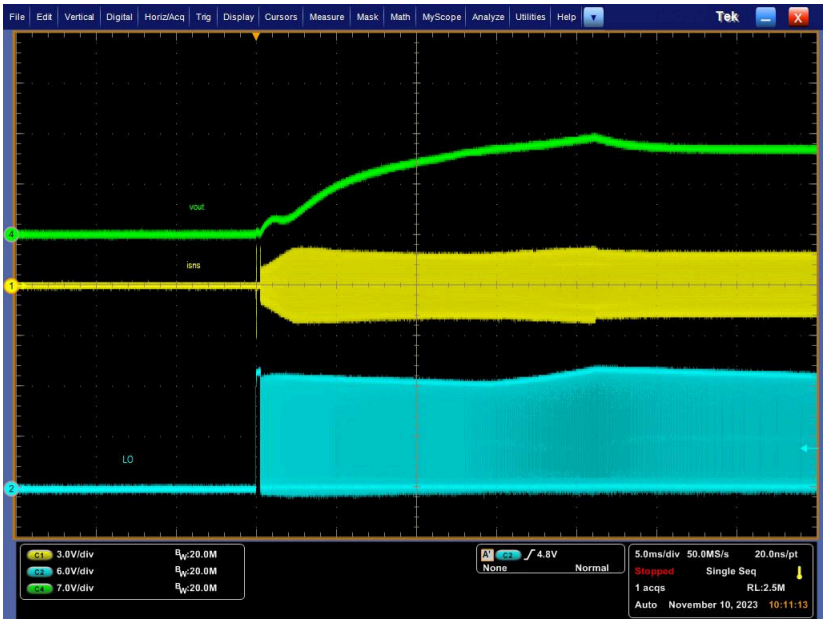


Figure 3-2. Full Load (15 A) Startup (Ch1 = ISNS; Ch2 = LO; Ch4 = V_{OUT})

3.1.4 Enhanced ZCS Avoidance During Soft Start

The following waveforms show the resonant current sense resistor voltage: switch node voltage during startup. 115 VAC, 60 Hz is applied initially to the AC input, then the 390 VDC input is applied to the DC input.

Figure 3-3. Full Load (15 A) Startup (Ch1 = ISNS; Ch3 = SW)

3.1.5 Thermal Image

The following images show the EVM temperature after 20min soak at full load, no forced air and 390Vdc input applied to the DC input.

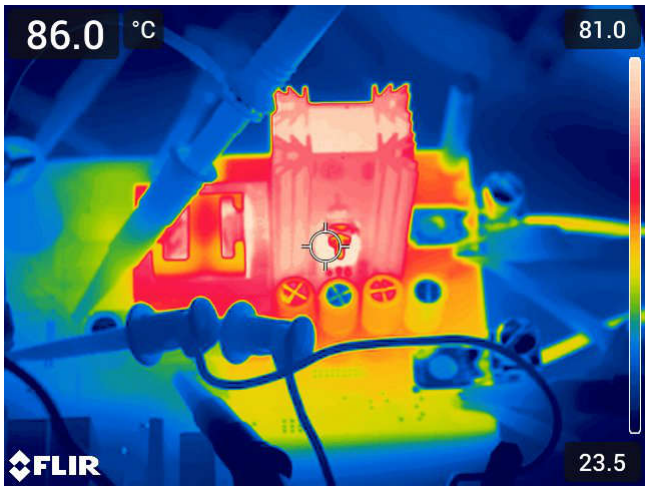


Figure 3-4. Thermal Image Top

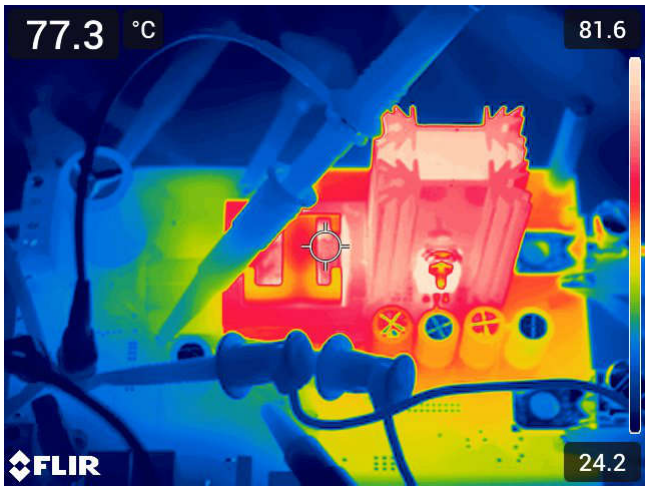


Figure 3-5. Thermal Image Top

Table 3-3. Component Temperature

Component	Temperature (°C)
T1	77.3
D2	86

3.1.6 Output Voltage Ripple

The following waveforms show the output voltage ripple with 115 VAC, 60 Hz applied to the AC input and 390 VDC applied to the DC input. The oscilloscope probe is AC coupled.

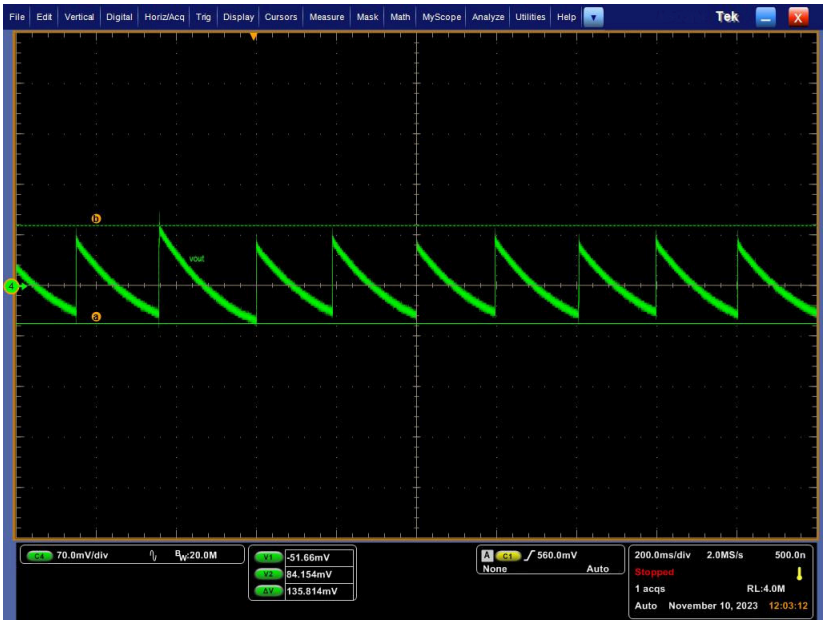


Figure 3-6. No Load (0 A) Output Ripple (Ch4 = V_{OUT})

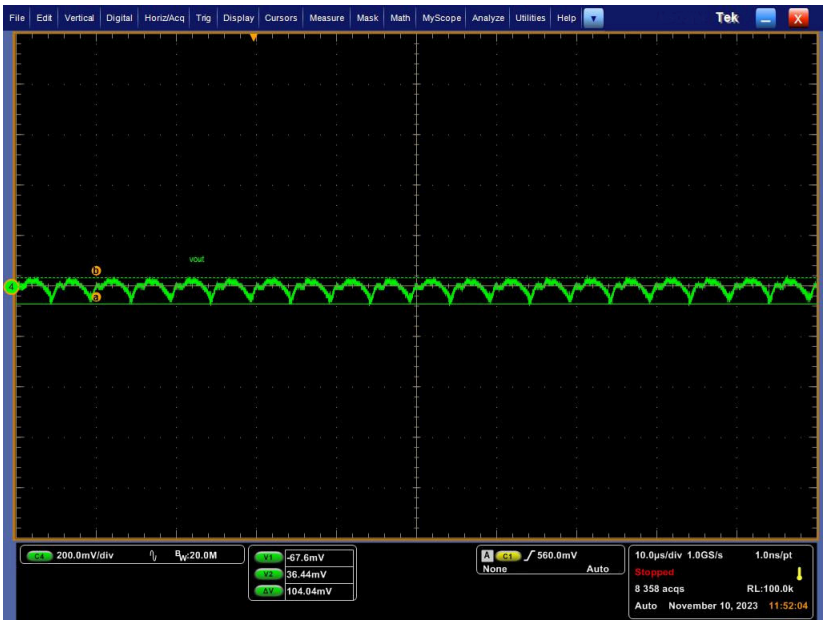


Figure 3-7. Full Load (15 A) Output Ripple (Ch4 = V_{OUT})

3.1.7 Load Transient Response

The following waveforms show the output voltage with 115 VAC, 60 Hz applied to the AC input and 390 VDC applied to the DC input.

Figure 3-8. 10 mA to 15 A Transient (Ch4 = V_{OUT} AC Coupled; Ch1 = I_{OUT})

3.1.8 Loop Response

The following plot shows the loop response with 115 VAC, 60 Hz applied to the AC input and 390 VDC applied to the DC input at full load condition.

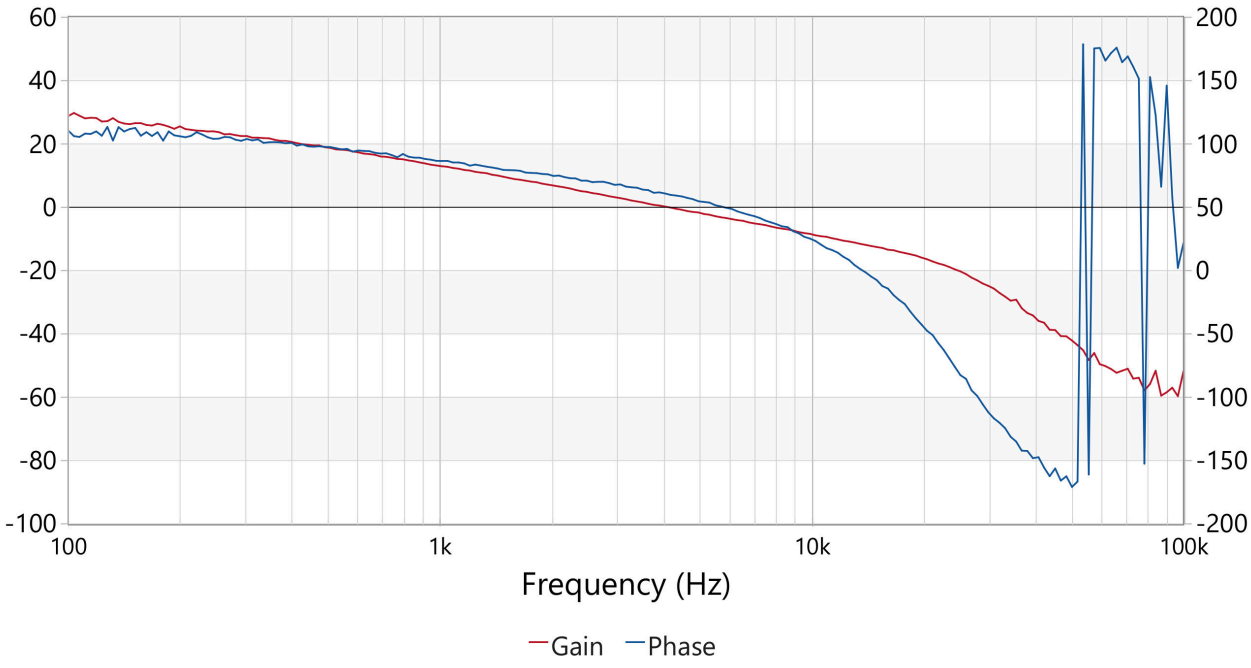


Figure 3-9. Bode Plot at 15 A Load

3.1.9 Steady State

The following waveforms shows the voltage across the 10kohm(I_OPT), voltage across the resonant current sense resistor (I_{SNS}), switch node voltage (SW) and low side gate voltage (LO) with 115 VAC, 60 Hz applied to the AC input and 390 VDC applied to the DC input. Figure 3-10, Figure 3-11, and Figure 3-12 shows the waveforms during normal switching and high frequency burst mode and low frequency burst mode respectively.

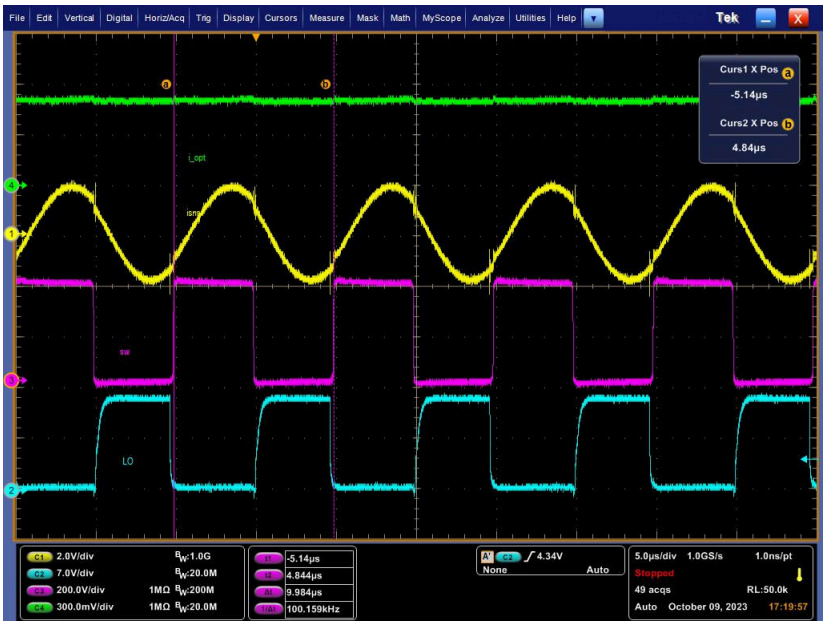


Figure 3-10. Steady State Waveforms at 15 A Load (Ch1= ISNS; Ch2 = LO; Ch3 = SW; Ch4 = I_OPT)

Figure 3-11. Steady State Waveforms at 1 A Load (Ch1= ISNS; Ch2 = LO; Ch3 = SW; Ch4 = I_OPT)

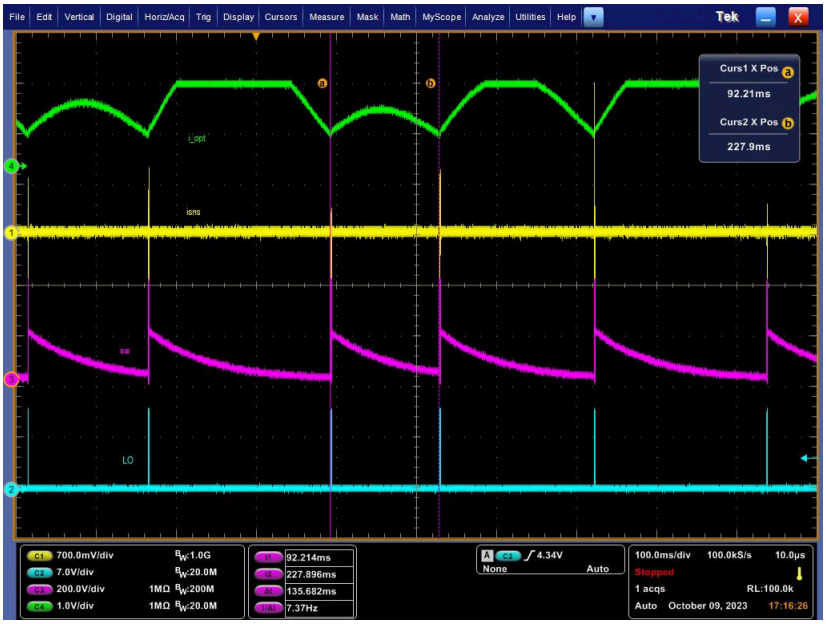


Figure 3-12. Steady State Waveforms at 0 A (Ch1= ISNS; Ch2 = LO; Ch3 = SW; Ch4 = I_OPT)

3.1.10 X-Capacitor Discharge

The following waveform shows the X-Capacitor discharge after the AC input of 265 VAC is disconnected. 390 VDC is applied to the DC input.

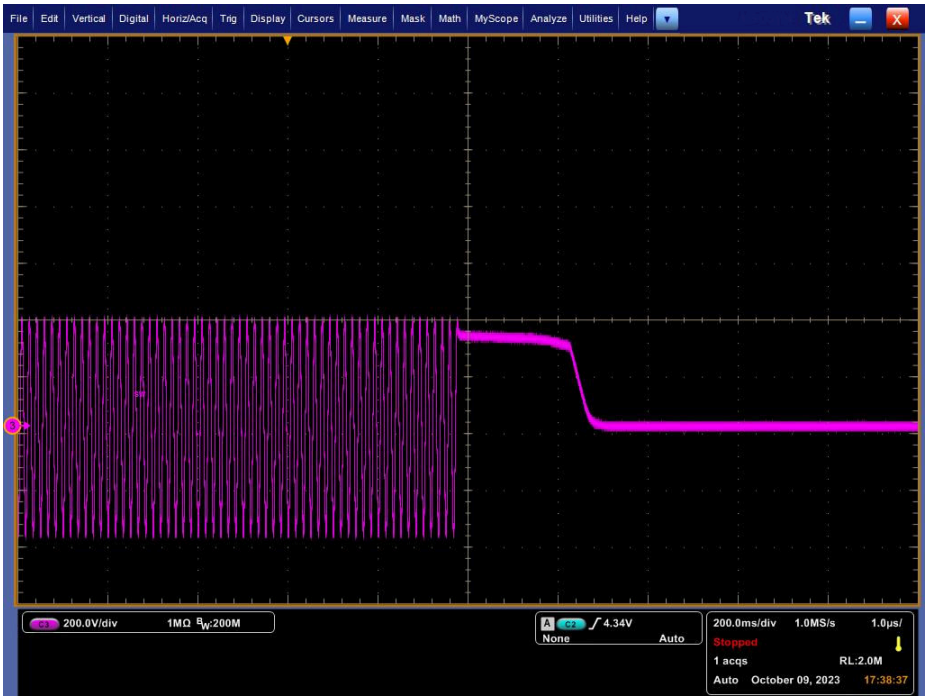


Figure 3-13. X-Cap Discharge (Ch1 = Voltage across X-Cap, C40 and C41)

4 Hardware Design Files

The following section includes hardware design files for UCC25660EVM-064. This section includes the board level schematic, PCB layout and Bill of materials (BOM).

4.1 Schematics

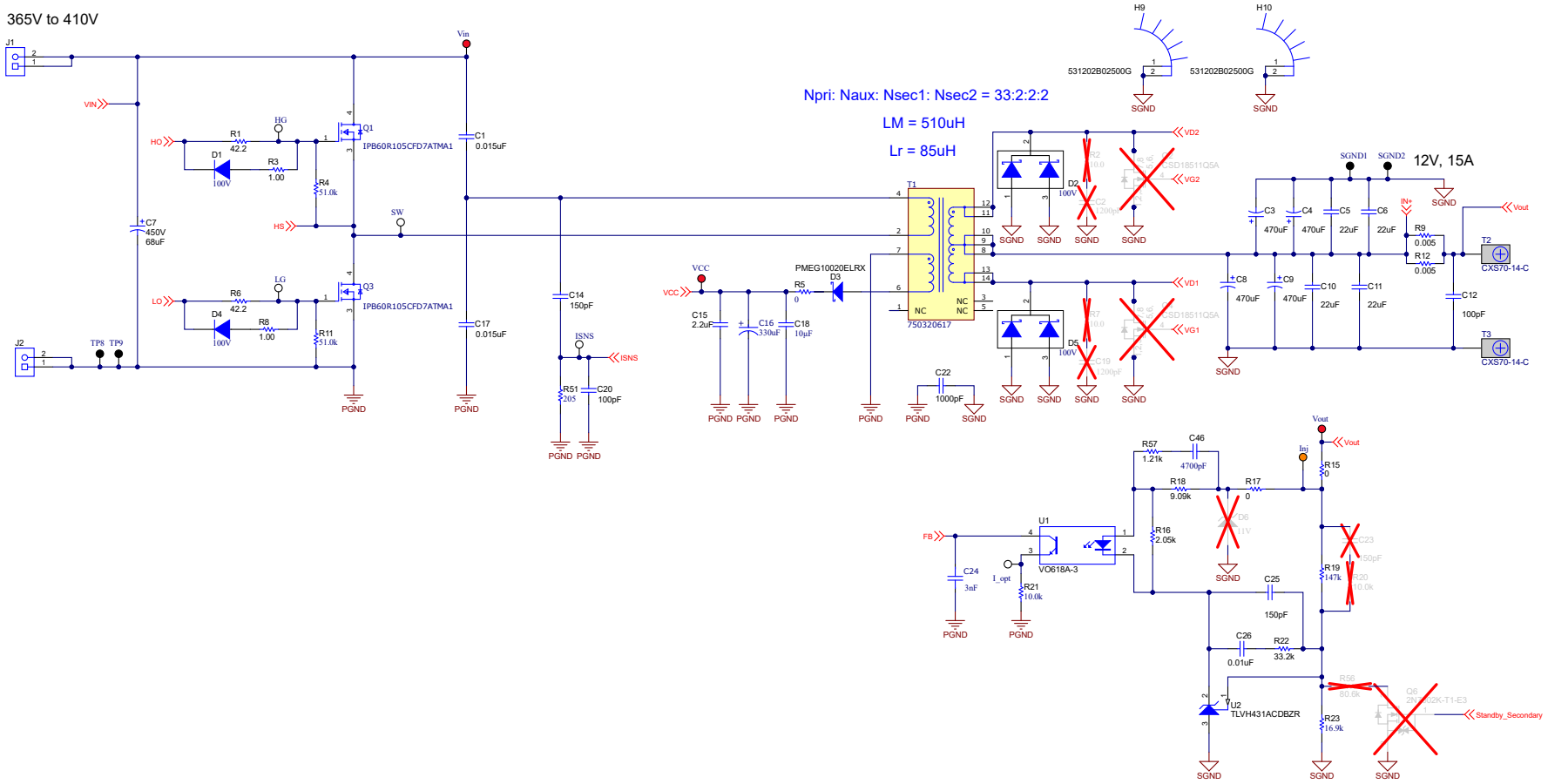


Figure 4-1. UCC25660EVM-064 Power Stage Schematic

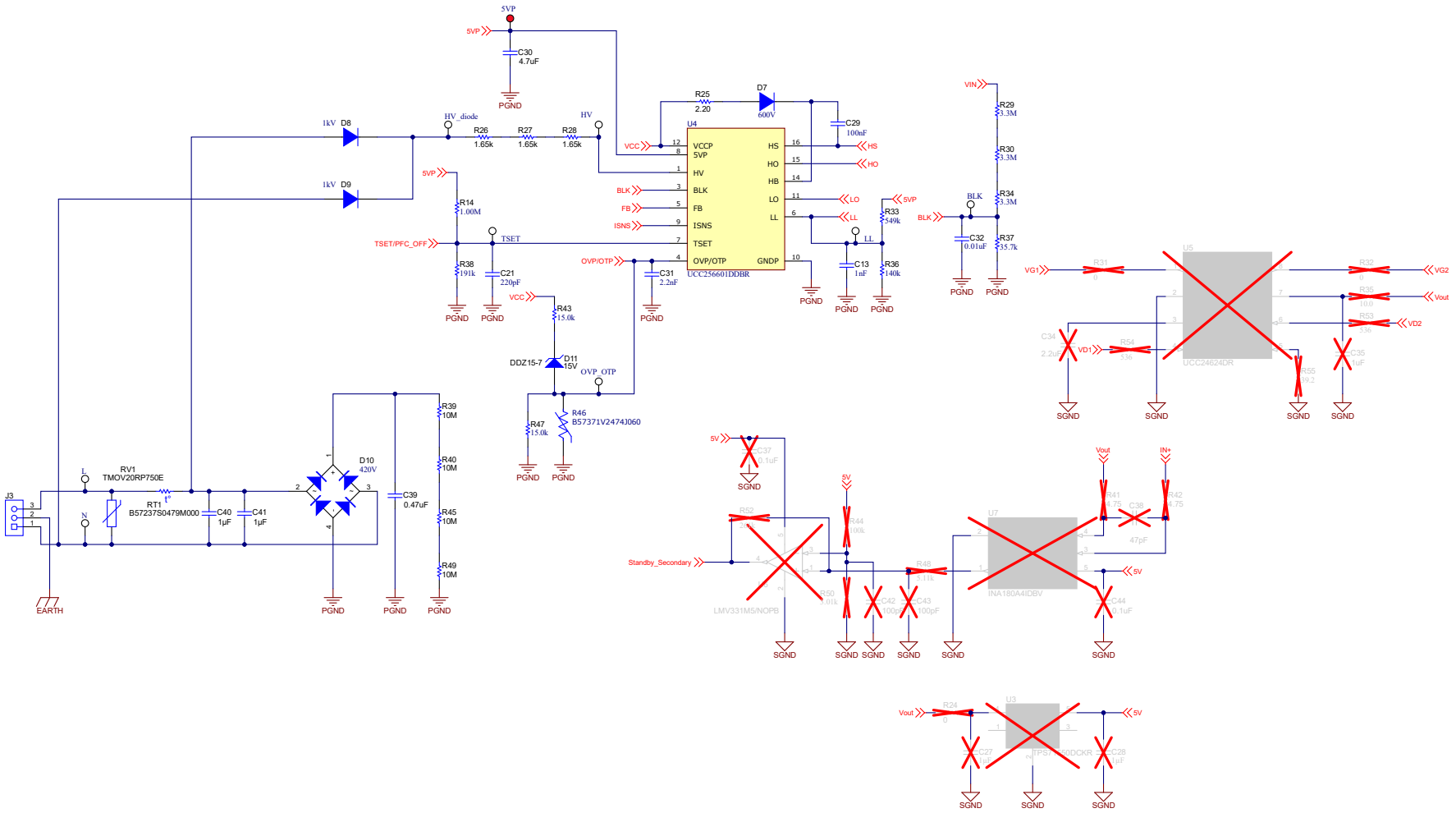


Figure 4-2. UCC25660EVM-064 Control Schematic

4.2 PCB Layouts

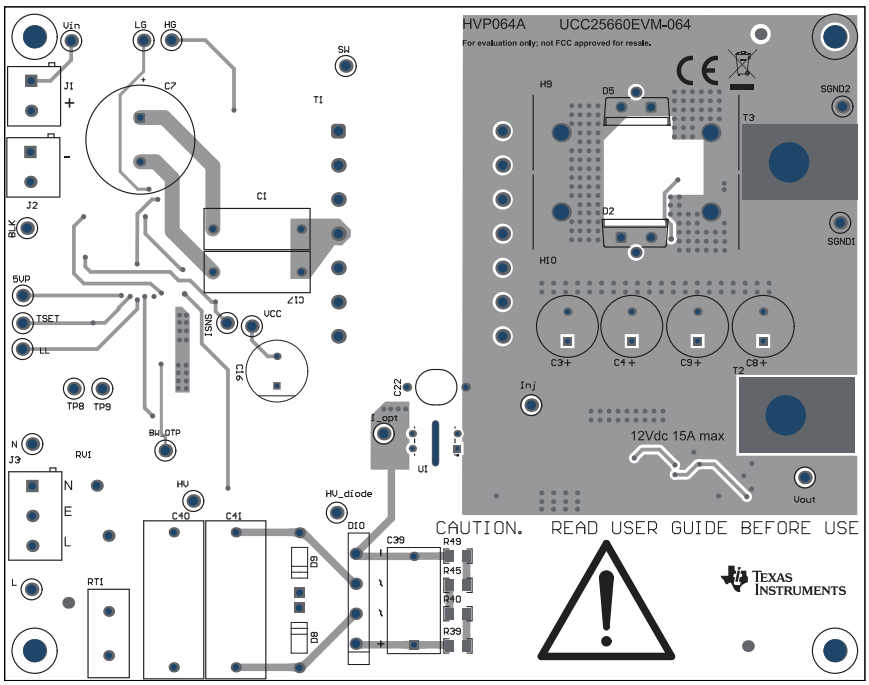


Figure 4-3. UCC25660EVM-064 (Top View)

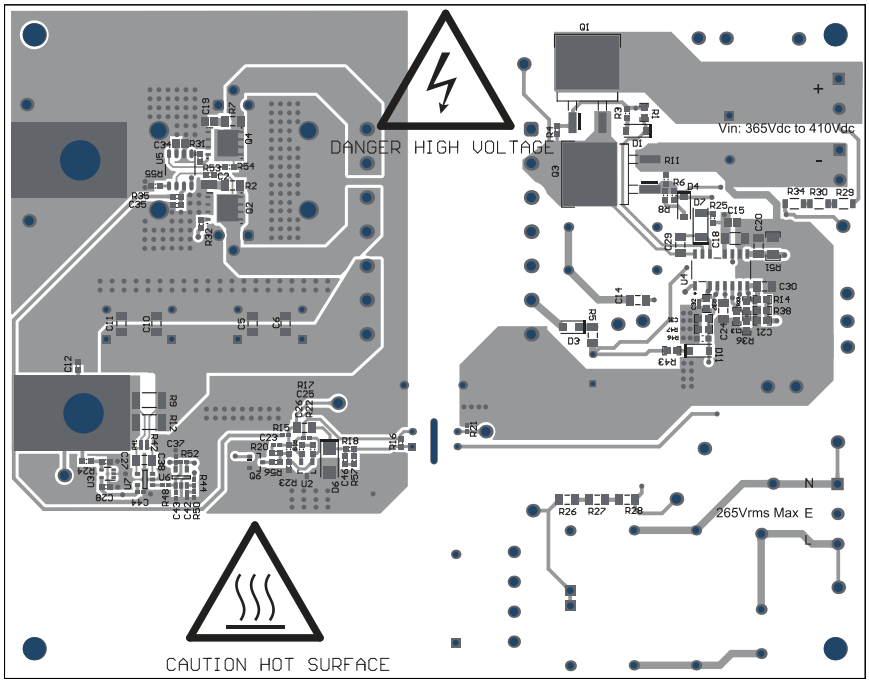


Figure 4-4. UCC25660EVM-064 (Bottom View)

4.3 Bill of Materials

Table 4-1. Bill of Materials

Designator	QTY	Description	Part Number
!PCB1	1	Printed Circuit Board	HVP064
5VP, VCC, Vin, Vout	4	Test Point, Multipurpose, Red, TH	5010
BLK, BW_OTP, HG, HV, HV_diode, I_opt, ISNS, L, LG, LL, N, SW, TSET	13	Test Point, Multipurpose, White, TH	5012
C1, C17	2	CAP, Film, 0.015 uF, 1250 V, +/- 5%, AEC-Q200 Grade 3, TH	B32652A7153J000
C3, C4, C8, C9	4	CAP, AL, 470 uF, 35 V, +/- 20%, 0.03 ohm, TH	UHW1V471MPD
C5, C6, C10, C11	4	CAP, CERM, 22 uF, 25 V, +/- 20%, X5R, 1206_190	C3216X5R1E226M160AB
C7	1	CAP, AL, 68 uF, 450 V, +/- 20%, TH	EKXG451ELL680MMN3S
C12	1	CAP, CERM, 100 pF, 50 V, +/- 1%, C0G/NP0, 0603	06035A101FAT2A
C13	1	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0603	C0603X102K5RACTU
C14	1	CAP, CERM, 150 pF, 630 V, +/- 5%, C0G/NP0, 1206	GRM31A5C2J151JW01D
C15	1	CAP, CERM, 2.2 uF, 35 V, +/- 10%, X7R, 0805	C2012X7R1V225K085AC
C16	1	Cap Aluminum Lytic 330uF 35 V 20% (10 X 16 mm) Radial 5 mm 1430 mA 4000h 105C Bulk	35ZL330MEFC10X16
C18	1	CAP, CERM, 10 µF, 25 V,+/- 5%, X7R, AEC-Q200 Grade 1, 1206	C1206C106J3RACAUTO
C20	1	CAP, CERM, 100 pF, 100 V, +/- 5%, C0G/NP0, 1206	12061A101JAT2A
C21	1	CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, 0603	C0603X221K5RACTU
C22	1	CAP, CERM, 1000 pF, V, +/- 20%, E, D7xT6mm	CD45-E2GA102M-NKA
C24	1	C1206 3,000 pF C0G 5.00% 50 V	C1206C302J5GACTU
C25	1	CAP, CERM, 150 pF, 50 V,+/- 5%, C0G/NP0, 0402	8.85012E+11
C26	1	CAP, CERM, 0.01 uF, 100 V, +/- 5%, X7R, 0603	06031C103JAT2A
C29	1	CAP, CERM, 0.1 uF, 25 V,+/- 5%, C0G/NP0, 1206	GRM31C5C1E104JA01L
C30	1	CAP, CERM, 4.7 uF, 25 V, +/- 10%, X7R, 1206	C3216X7R1E475K085AB
C31	1	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0603	C0603X222K5RACTU
C32	1	CAP, CERM, 0.01 uF, 50 V, +/- 5%, X7R, 0402	C0402C103J5RACTU
C39	1	CAP, Film, 0.47 uF, 630 V, +/- 10%, TH	B32922C3474K
C40, C41	2	CAP, Film, 1 µF, X2 275 VAC, +/- 20%, TH	R46KN410000P0M
C46	1	CAP, CERM, 4700 pF, 100 V, +/- 5%, C0G/NP0, 0603	C0603C472J1GAC7867
D1, D4	2	Diode, Ultrafast, 100 V, 0.15 A, SOD-123	1N4148W-7-F
D2, D5	2	Diode, Schottky, 100 V, 20 A, AEC-Q101, TH	STPS41H100CTY
D3	1	Diode, Schottky, 100 V, 2 A, AEC-Q101, SOD-123W	PMEG10020ELRX
D7	1	Diode, Ultrafast, 600 V, 1 A, AEC-Q101, SMAF	ES1JAF
D8, D9	2	Diode, P-N, 1000 V, 1 A, TH	1N4007-E3/73
D10	1	Diode, Switching-Bridge, 420 V, 8 A, TH	GBU8J-BP
D11	1	Diode, Zener, 15 V, 500 mW, SOD-123	DDZ15-7
H1, H2, H3, H4	4		4824
H5, H6, H7, H8	4		1903C
H9, H10	2		531202B02500G
H13, H14	2		4708
Inj	1	Test Point, Multipurpose, Orange, TH	5013
J1, J2	2	Terminal Block, 5.08 mm, 2x1, Brass, TH	ED120/2DS
J3	1	Terminal Block, 5.08 mm, 3x1, Brass, TH	ED120/3DS
MP1, MP2	2	M3 Pan Head Machine Screw Phillips Drive Stainless Steel	RM3X8MM-2701
MP3, MP4	2	Mounting Kit For TO-220 Heat Sinks	4880SG

Table 4-1. Bill of Materials (continued)

Designator	QTY	Description	Part Number
Q1, Q3	2	Power Transistor MOSFET N-Channel Enhancement 600 V 21 A 3-Pin D2PAK T/R	IPB60R105CFD7ATMA1
R1, R6	2	RES, 42.2, 1%, 0.1 W, 0603	RC0603FR-0742R2L
R3, R8	2	RES, 1.00, 1%, 0.1 W, 0603	RC0603FR-071RL
R4, R11	2	RES, 51.0 k, 1%, 0.1 W, 0603	RC0603FR-0751KL
R5	1	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	ERJ-8GEY0R00V
R9, R12	2	RES, 0.005, 1%, 1.5 W, 2010	CSNL2010FT5L00
R14	1	RES, 1.00 M, 1%, 0.1 W, 0603	RC0603FR-071ML
R15	1	RES, 0, 5%, 0.063 W, 0402	RC0402JR-070RL
R16	1	RES, 2.05 k, 1%, 0.1 W, 0603	RC0603FR-072K05L
R17	1	RES, 0, 0.75 W, AEC-Q200 Grade 0, 1206	CRCW12060000Z0EAHP
R18	1	RES, 9.09 k, 1%, 0.1 W, 0603	RC0603FR-079K09L
R19	1	RES, 147 k, 1%, 0.1 W, 0603	RC0603FR-07147KL
R21	1	RES, 10.0 k, 1%, 0.1 W, 0402	ERJ-2RKF1002X
R22	1	RES, 33.2 k, 1%, 0.1 W, 0603	RC0603FR-0733K2L
R23	1	RES, 16.9 k, 1%, 0.1 W, 0603	RC0603FR-0716K9L
R25	1	RES, 2.20, 1%, 0.1 W, 0603	ERJ-3RQF2R2V
R26, R27, R28	3	RES, 1.65 k, 1%, 0.25 W, AEC-Q200 Grade 0, 1206	CRCW12061K65FKEA
R29, R30, R34	3	3.3 MOhms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200, High Voltage Thick Film	KTR18EZPF3304
R33	1	RES, 549 k, 1%, 0.1 W, 0603	RC0603FR-07549KL
R36	1	RES, 140 k, 1%, 0.1 W, 0603	RC0603FR-07140KL
R37	1	RES, 35.7 k, 0.1%, 0.1 W, 0603	RT0603BRD0735K7L
R38	1	RES, 191 k, 0.1%, 0.1 W, 0603	RT0603BRD07191KL
R39, R40, R45, R49	4	RES, 10 M, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	CRCW120610M0JNEA
R43	1	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL
R46	1	NTC Thermistor 470k 0603 (1608 Metric)	B57371V2474J060
R47	1	RES, 15.0 k, 0.1%, 0.1 W, 0603	RG1608P-153-B-T5
R51	1	RES, 205, 1%, 0.25 W, 1206	RC1206FR-07205RL
R57	1	RES, 1.21 k, 1%, 0.1 W, 0603	RC0603FR-071K21L
RT1	1	Thermistor NTC, 4.70 ohm, 20%, 15x7mm	B57237S0479M000
RV1	1	VARISTOR 1200 V 10KA DISC 20 MM	TMOV20RP750E
SGND1, SGND2, TP8, TP9	4	Test Point, Multipurpose, Black, TH	5011
T1	1	TRANSFORMER-	750320617
T2, T3	2	Terminal 70 A Lug	CXS70-14-C
U1	1	Optocoupler, 5.3 kV, 100-200% CTR, SMT	VO618A-3
U2	1	Low-Voltage Adjustable Precision Shunt Regulator, 129 ppm / degC, 80 mA, 0 to 70 degC, 3-pin SOT-23 (DBZ), Green (RoHS & no Sb/Br)	TLVH431ACDBZR
U4	1	750 kHz Wide VIN/VOUT Range LLC Controller Optimized for Light Load Efficiency	UCC256601DDBR
C2, C19	0	CAP, CERM, 1200 pF, 100 V, +/- 5%, C0G/NP0, 0805	GRM2165C2A122JA01D
C23	0	CAP, CERM, 150 pF, 50 V,+/- 5%, C0G/NP0, 0402	8.85012E+11
C27, C28	0	CAP, CERM, 1 uF, 16 V, +/- 10%, X7R, 0603	EMK107B7105KA-T
C34	0	CAP, CERM, 2.2 uF, 35 V, +/- 10%, X7R, 0805	C2012X7R1V225K085AC
C35	0	CAP, CERM, 1 uF, 16 V, +/- 10%, X7R, 0603	GRM188R71C105KE15D
C37	0	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X5R, 0402	GRM155R61C104KA88D

Table 4-1. Bill of Materials (continued)

Designator	QTY	Description	Part Number
C38	0	CAP, CERM, 47 pF, 500 V, +/- 5%, C0G/NP0, 1206	12067A470JAT2A
C42, C43	0	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0402	GRM1555C1H101JA01D
C44	0	CAP, CERM, 0.1 uF, 25 V, +/- 10%, X5R, 0402	GRM155R61E104KA87D
D6	0	Diode, Zener, 11 V, 1.5 W, SMA	1SMA5926BT3G
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A
Q2, Q4	0	MOSFET, N-CH, 40 V, 100 A, DQJ0008A (VSONP-8)	CSD18511Q5A
Q6	0	MOSFET, N-CH, 60 V, 0.3 A, SOT-23	2N7002K-T1-E3
R2, R7	0	RES, 10.0, 1%, 0.25 W, 1206	RC1206FR-0710RL
R20	0	RES, 10.0 k, 1%, 0.1 W, 0603	ERJ-3EKF1002V
R24, R31, R32	0	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL
R35	0	RES, 10.0, 1%, 0.1 W, 0603	RC0603FR-0710RL
R41, R42	0	RES, 4.75, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04024R75FKED
R44	0	RES, 100 k, 1%, 0.1 W, 0402	ERJ-2RKF1003X
R48	0	RES, 5.11 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04025K11FKED
R50	0	RES, 3.01 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04023K01FKED
R52	0	RES, 261 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402261KFKED
R53, R54	0	RES, 536, 0.1%, 0.1 W, 0603	RT0603BRD07536RL
R55	0	RES, 39.2, 1%, 0.1 W, 0603	RC0603FR-0739R2L
R56	0	RES, 80.6 k, 1%, 0.1 W, 0603	RC0603FR-0780K6L
U3	0	Single Output LDO, 50 mA, Fixed 5 V Output, 3 to 24 V Input, 5-pin SC70 (DCK), -40 to 85 degC, Green (RoHS & no Sb/Br)	TPS71550DCKR
U5	0	High Performance Synchronous Rectifier Driver for LLC Resonant Converter, D0008A (SOIC-8)	UCC24624DR
U6	0	Single General Purpose, Low Voltage, Tiny Pack Comparator, 5-pin SOT-23, Pb-Free	LMV331M5/NOPB
U7	0	Low- and High-Side Measurement, Multichannel, Voltage Output, Current-Sense Amplifier, DBV0005A (SOT-5)	INA180A4IDBV

5 Additional Information

Trademarks

All trademarks are the property of their respective owners.

6 Revision History

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

Changes from Revision * (October 2023) to Revision A (November 2023) **Page**

- Added *Using the EVM with UCC256602* section....4
- Added *Using the EVM with UCC256603* section....5
- Updated Figure 3-1 and Figure 3-2 8
- Updated Figure 3-3 9
- Updated Figure 3-6 and Figure 3-7 10
- Updated Figure 3-8 11
- Added *Loop Response* section....11
- Updated *Schematic* images....15
- Updated *Bill of Materials* table....18

STANDARD TERMS FOR EVALUATION MODULES

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

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

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

WARNING

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

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

NOTE:

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

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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。
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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。

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。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:*

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   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.

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