Using the UCC27712EVM-287

This user's guide describes the characteristics, operation, and use of the UCC27712 evaluation module (EVM). A complete schematic diagram, printed-circuit board layouts, and bill of materials (BOM) are included in this document.

Contents

List of Figures

List of Tables

Trademarks

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Cautions and Warnings

CAUTION:

Caution! Do not leave EVM powered when unattended.

HOT SURFACE:

Caution Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.

HIGH VOLTAGE:

Danger High Voltage! Electric shock is possible when connecting the board to live wire. The board should be handled with care by a professional. For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

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

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

Save all warnings and instructions for future reference.

WARNING

Failure to follow warnings and instructions may 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 suitable 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 observer(s) must be present anytime circuits are energized.
   (c) Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   (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:
   As a precautionary measure, it is always good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   (a) De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   (b) 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.
   (c) Once EVM readiness is complete, energize the EVM as intended.

WARNING

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

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.

1 Introduction

The UCC27712EVM-287 is the evaluation module designed to primarily evaluate the performance of the UCC27712 device. The same board can be used to evaluate other pin-to-pin compatible parts in the supported package. This driver is a 620-V boot voltage, high-side and low-side driver with high source and sink peak currents for driving two N-Channel MOSFETs. The board is developed in such a way that multiple converter topologies such as half-bridge and high-voltage synchronous buck can be configured with it. The low pullup and pulldown resistance of the UCC27712 allows for driving large power MOSFETs with minimized switching losses during the transition through the *Miller Plateau* of the MOSFET. The input of these devices can handle negative voltage which increases robustness and also allows direct interface to gate-drive transformers without using rectification diodes. The inputs are also independent of supply voltage and have a 20-V maximum rating.

2 Description

The UCC27712 evaluation board has two screw terminal blocks that allows connection to the input or bus voltage, HV+, switch node, HS, and the ground, GND. It has two headers, one for the high-side PWM input and the low-side PWM input and the second one for the power supply of the driver. This EVM also has a variety of testing points to easily analyze most of the key features of UCC27712. As the EVM needs to incorporate various test points and MOSFET footprints that can accommodate a wide variety of MOSFETs, the layout is not optimal for very high-power converter configurations. The guidelines for optimal layout can be found in the driver data sheet. The board has small bulk capacitance and ceramic capacitors at the input to facilitate limited testing of the topology, such as synchronous buck. For detailed device information, refer to the UCC27712 data sheet (SLUSCE9).

2.1 Features

The EVM supports the following features:

- UCC27712 gate driver
- Terminal blocks allow easy connection of high voltage input bus HV+, switch node, HS, and ground, GND
- Easily configured into different topologies such as synchronous buck, synchronous boost, and half-bridge converter
- Quickly check the effect of different external components such as bootstrap capacitor, bootstrap diode, gate resistor, gate diode, and so forth
- Allows quick verification of most of the data sheet parameters
- Open loop power stage allows the user to quickly find out whether the application issues are driver related or related to other parameters in the application
- Easily perform chip-level tests by removing power MOSFETs and replacing gate resistors with 0-Ω resistors and replacing gate-to-source resistor with the appropriate load capacitor
- Power stage featuring 650 V, N-Channel MOSFETS
- Features popular pinouts for FETs, D2PACK, and TO-220

2.2 I/O Description

The connection descriptions are listed in Table 1.

Table 1. Connection Descriptions

Connections	Description
J1	High voltage input HV+, GND
J2	Low-side input LI, and high-side input HI
J3	Positive power supply for the lower-gate driver VCC
J4	SW node and GND connection of power MOSFETs

3 Electrical Specifications

The EVM electrical specifications are listed in Table 2.

Table 2. UCC27712EVM-287 Electrical Specifications

Connections	Description
J1	450 V maximum on HV+, 0.2 A or 65 W maximum(1)
J2	5-V to 20-V PWM signals
J3	10-V to 17-V VCC operating voltage range
J4	0 to 450 V Pk Maximum SW node, 60 W maximum(1)

(1) The UCC27712EVM-287 has limited thermal dissipation capability. The 65-W maximum input power and 60-W output power applies to soft switching conditions only. Any testing in hard switching, or loads above 60 W should only be for very short periods (less than 20 seconds) to capture information of interest.

4 Test Setup

4.1 Definitions

This procedure details how to configure the UCC27712 evaluation board. Refer to the UCC27712EVM schematic, Figure 10 for details. Within this test procedure, the following naming conventions are used:

DMM: Digital Multimeters

UUT: Unit Under Test

EVM: Evaluation module assembly, in this case the UUT

4.2 Equipment

4.2.1 Power Supplies

Two DC power supplies. One with voltage and current above 25 V and 1 A, for example: Agilent E3634A. One with voltage above 450 V and power above 65 W.

4.2.2 Function Generators

One two-channel function generator over 20 MHz, for example, Tektronics AFG3252.

4.2.3 Scope Probes

Two 300-V scope probes, 500-MHz bandwidth or better. One differential probe with 500 V or better common mode voltage rating, such as Tektronics THDP0200.

4.3 Equipment Setup

4.3.1 DC Power Supply Settings

- DC power supply #1
  - Voltage setting: 12 V
  - Current limit: 0.05 A
- DC power supply #2
  - Voltage setting: 0 V (initial setting)
  - Current limit: 0.05 A

4.3.2 Digital Multimeter Settings

- Digital multimeter #1
  - DC current measurement, auto-range. Expected current is within 1 mA to 18 mA
- Digital multimeter #2
  - DC current measurement, auto-range, expected current is within 2 mA to 37 mA

4.3.3 Two-Channel Function Generator Settings

Table 3 shows the two-channel function generator settings.

Table 3. Two-Channel Function Generator Settings

Channel	Mode	Frequency	Duty Cycle	Delay	High	Low	Output Impedance
Channel A	Pulse	100 kHz	20%	0 ns	5 V	0 V	High Z
Channel B			70%	2.5 µs			

4.3.4 Oscilloscope Setting

Table 4 displays the oscilloscope settings.

Table 4. Oscilloscope Settings

Channel	Bandwidth	Coupling	Termination	Scale Settings	Inverting
Channel 2	500 MHz or above	DC	1 MΩ or automatic	10× or automatic	OFF
Channel 3					
Channel 4					

4.3.5 Bench Setup Diagram

The current bench setup diagram includes the function generator and oscilloscope connections.

Use the following connection procedure, and Figure 1 can be used as a reference:

1. Make sure all the outputs of the function generator, voltage source are disabled before connection.
2. Apply function generator channel-A channel on J2, PWMIN.
3. Apply function generator channel-B channel on J2, PWMINx.
4. Power supply #1: positive node connected to input of DMM #1 and DMM #1 output connected to J3 pin 1. Negative node connected to J3 pin 2.
5. Power supply #2: positive node connected to input of DMM #2 and DMM #2 output connected to J1 pin 2 (marked as HV), negative node of power supply #2 connected directly to J1 pin 1 (marked as GND).
6. Connect oscilloscope Ch-2 differential probe to test points marked as GH↔HS, smaller measurement loop is preferred.
7. Connect oscilloscope Ch-3 probes to test points marked as GL↔GND, smaller measurement loop is preferred.
8. Connect oscilloscope Ch-4 probes to test points marked as HS↔GND, smaller measurement loop is preferred.

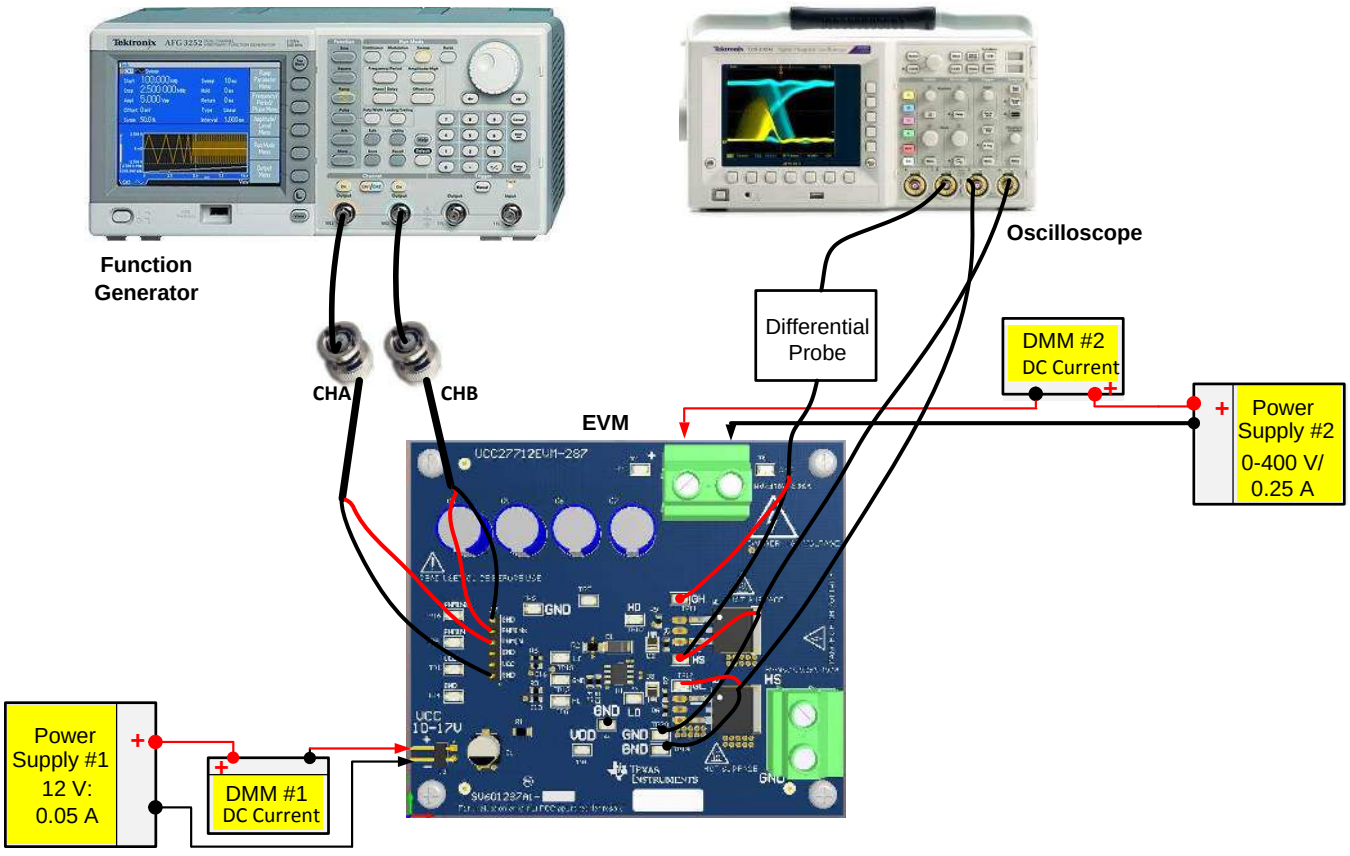

Figure 1. Bench Setup Diagram and Configuration

5 Power Up and Power Down Procedure

5.1 Power Up

Use the following power-up steps:

1. Before proceeding to the power-up test procedure, please make sure that Figure 1 is implemented for setting up all the equipment. Use Figure 1 as a reference.
2. Enable supply #1. If the current on DMM #1 is < 2 mA, proceed to the next step.
3. Enable function generator two-channel output channel-A and channel-B.
4. The following output and measurement should be observed:
   (a) A stable pulse output on channel-2 and channel-3 on the oscilloscope, refer to Figure 2
   (b) The frequency measurement should be 100 kHz ±2 kHz
   (c) DMM #1 measurement should read 15 mA, ±2 mA
5. Enable supply #2, and increase from 0 V to 400 V (or desired target). If the current on DMM #1 is less than 22 mA and the current in DMM #2 is less than 37 mA, it is normal operation; otherwise, the EVM fails.
6. The following output and measurement should be observed:
   (a) A stable pulse output on channel-2, channel-3, and channel-4 on the oscilloscope, refer to Figure 3
   (b) The frequency measurement should be 100 kHz ±2 kHz.
   (c) DMM #1 measurement should read 18 mA ±4 mA, DMM #2 measurement should read 33 mA ±4 mA

5.2 Power Down

Use the following power down steps:

1. Disable power supply #2
2. Disable function generator
3. Disable power supply #1
4. Disconnect cables and probes

6 Typical Performance Waveforms

6.1 Operational Waveforms.

The waveforms in Figure 2 through Figure 5 were observed with the setup explained in Section 4.

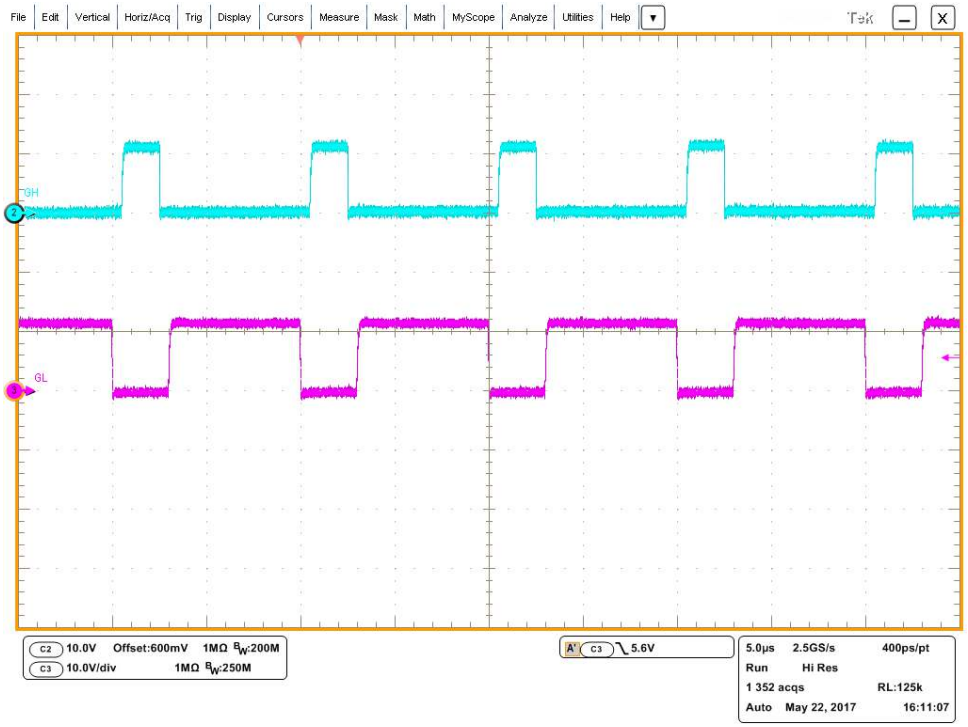

Figure 2. GH and GL, VHV = 0 V

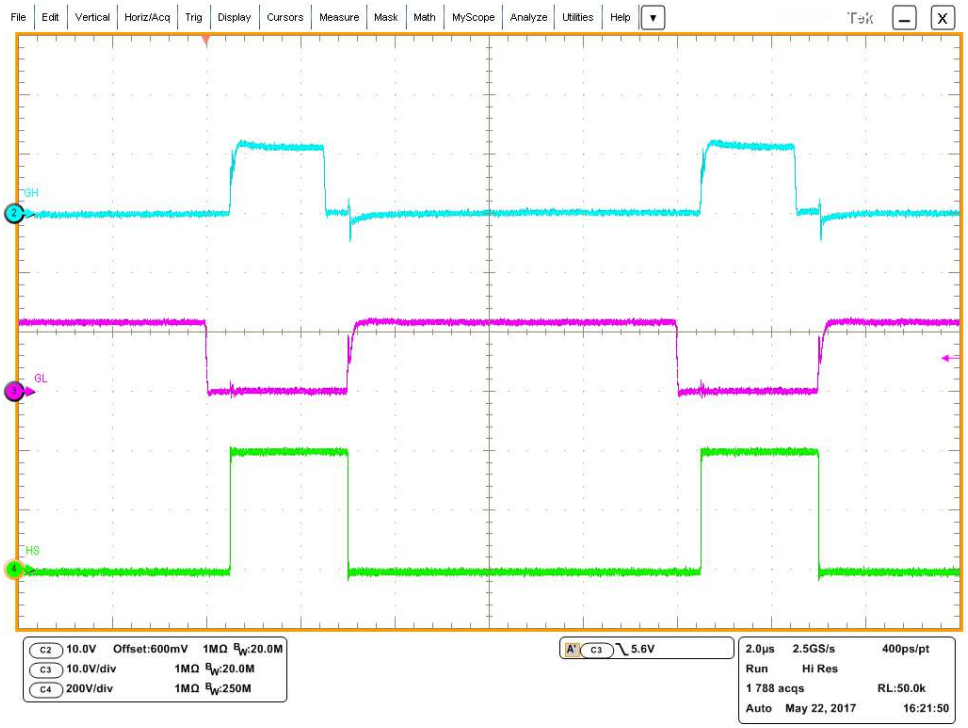

Figure 3. GH, GL and HS, VHV = 400 V

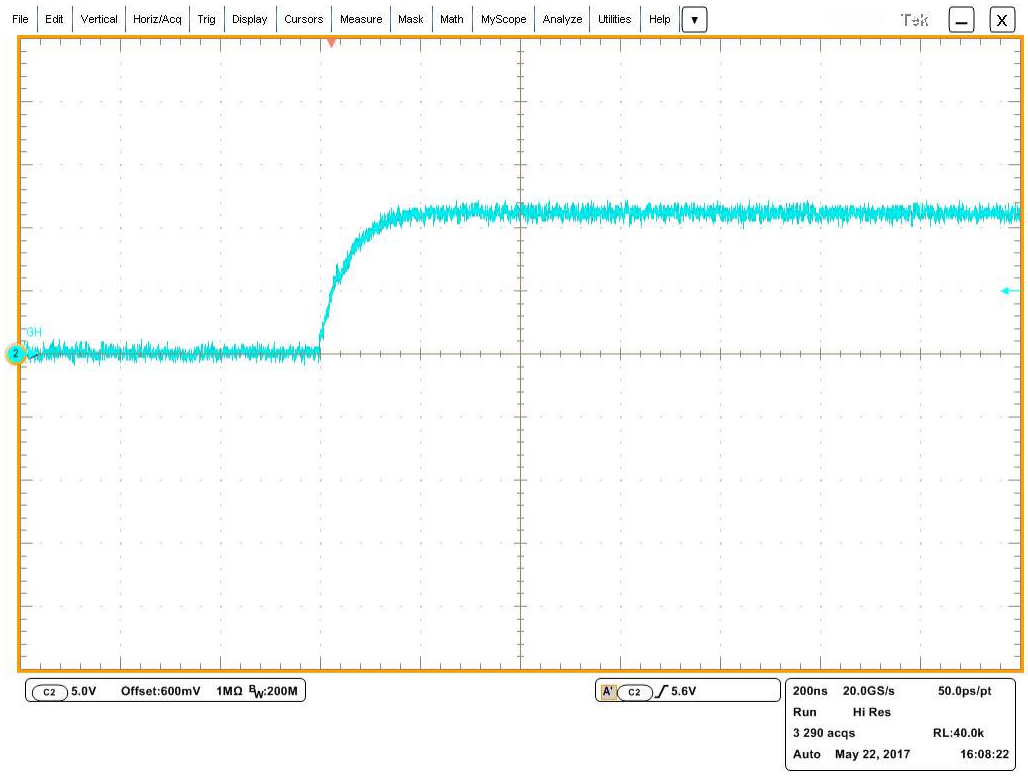

Figure 4. GH Rise Time

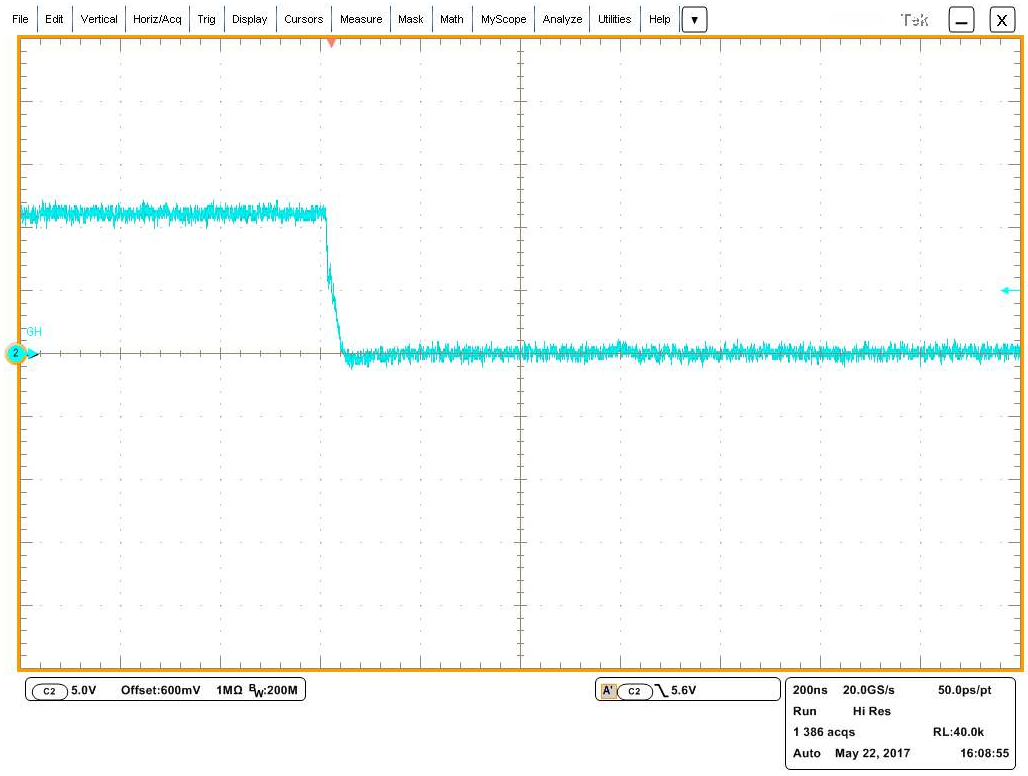

Figure 5. GH Fall Time

6.2 Propagation Delays

Figure 6 and Figure 7 illustrate the propagation delay waveforms.

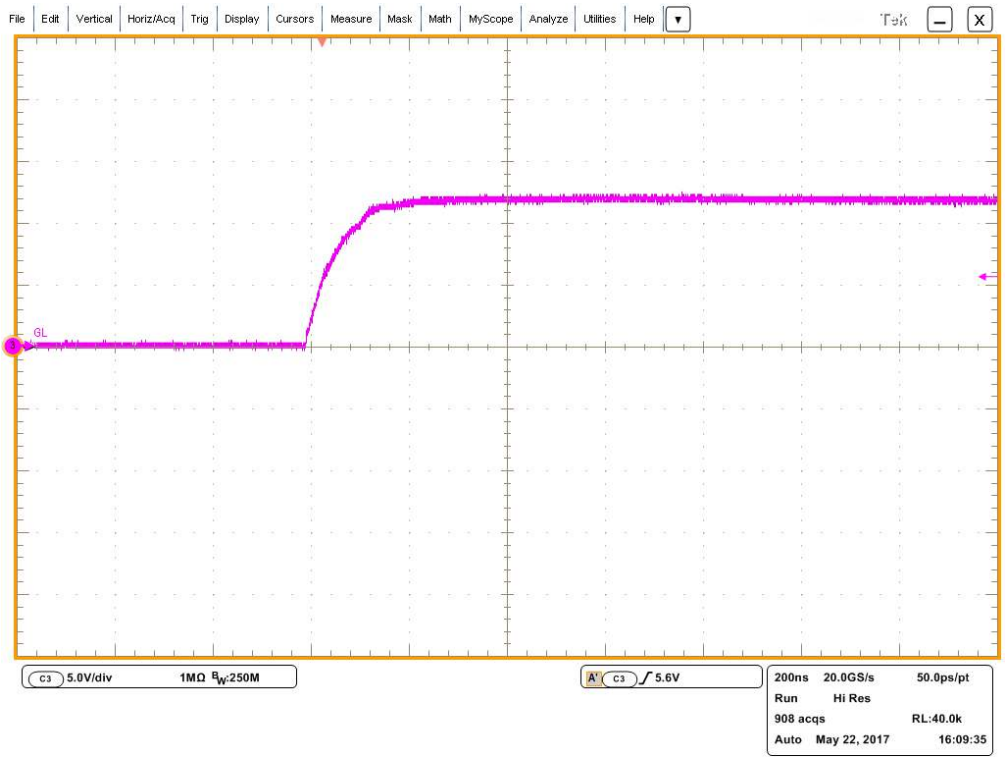

Figure 6. GL Rise Time

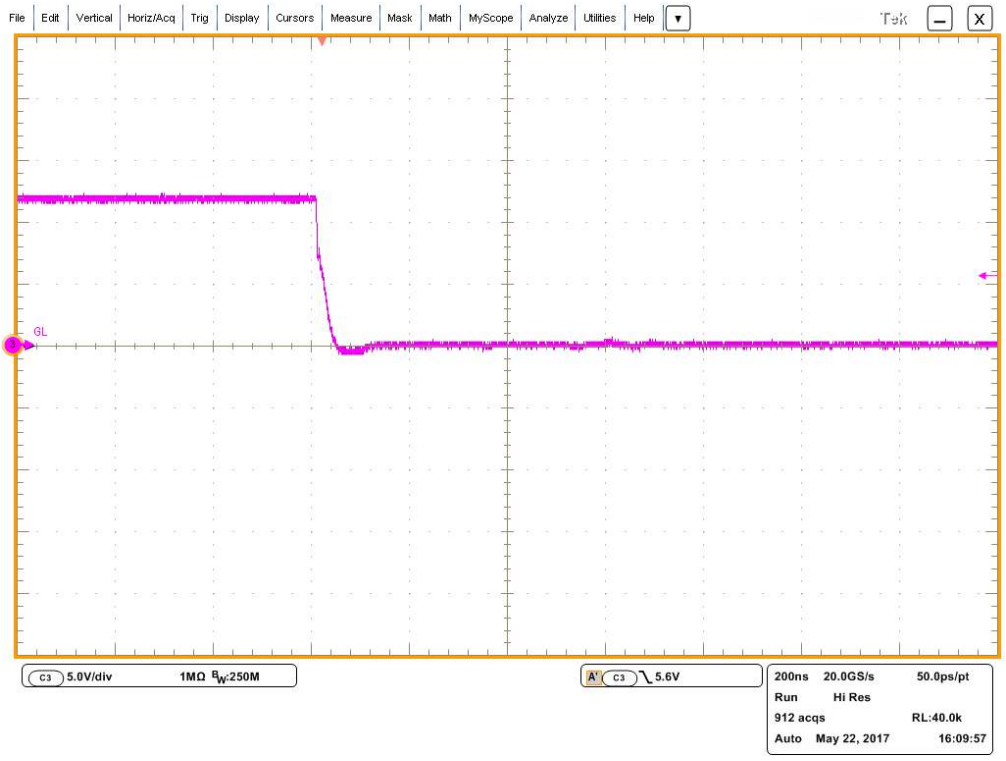

Figure 7. GL Fall Time

6.3 Configuring the UCC27712 EVM Into a Synchronous Buck Converter

The UCC27712EVM can easily be used to form a synchronous buck converter by connecting an inductor, capacitor, and load to the EVM as shown in Figure 8. The inductor, capacitor, and load are not supplied with the EVM. Connect up to 450 V on the bus supply HV+; this will be the input of the buck converter. The UCC27712EVM brings its switch node out onto HS in order to connect external components.

The board has been tested when configured as a synchronous buck converter with a 330-µH inductor and two 220-µF capacitors connected to the HS and GND connection point as shown in Figure 8. Inductor current, high-side gate drive, low-side gate drive, and HS voltage waveforms are shown in Figure 9. The scope waveforms shown are with limited bandwidth to limit common-mode noise. A film capacitor is recommended at the buck output for high-frequency filtering.

One can notice the high-frequency noise on the board with the oscilloscope set to high bandwidth. The buck converter design is found in many publicly-available literature articles. It should be noted that there is no heat sink on the power MOSFET; therefore, for high-power testing, TI recommends adding a heat sink. Gate resistors can be increased to reduce the dv/dt related noise. The board comes with a limited input electrolytic capacitance installed. A provision is added to the board if a different source and sink capability is desired by choosing different gate-resistor and diode-resistor values.

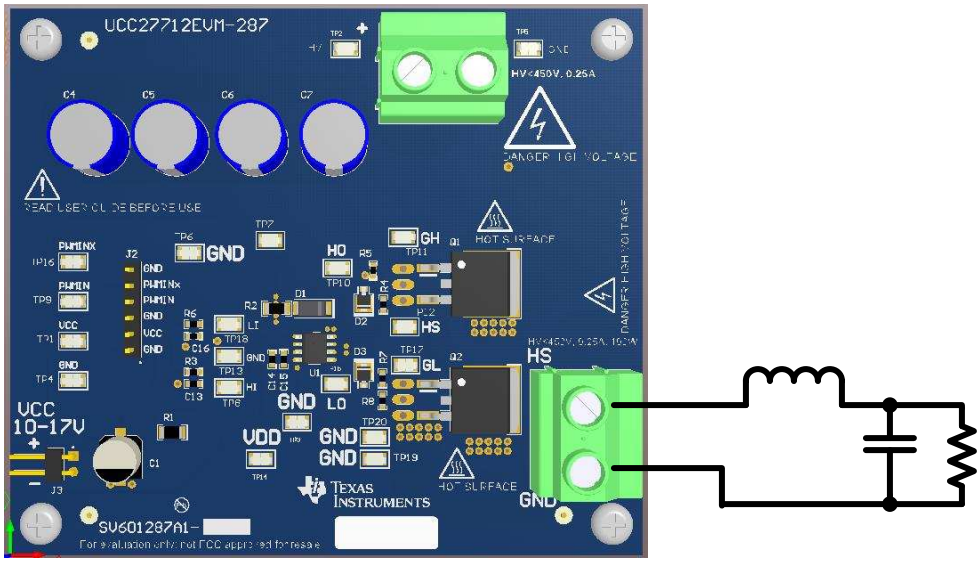

Figure 8. Buck Converter Example

Table 5. UCC27712 Parameters

Parameters	Value
Output voltage (V_{OUT})	80 V
Output current (I_{OUT})	0.75 A
Input voltage (V_{IN})	400 V
Switching frequency $f_{(SW)}$	100 kHz
$P_{O(max)}$	60 W

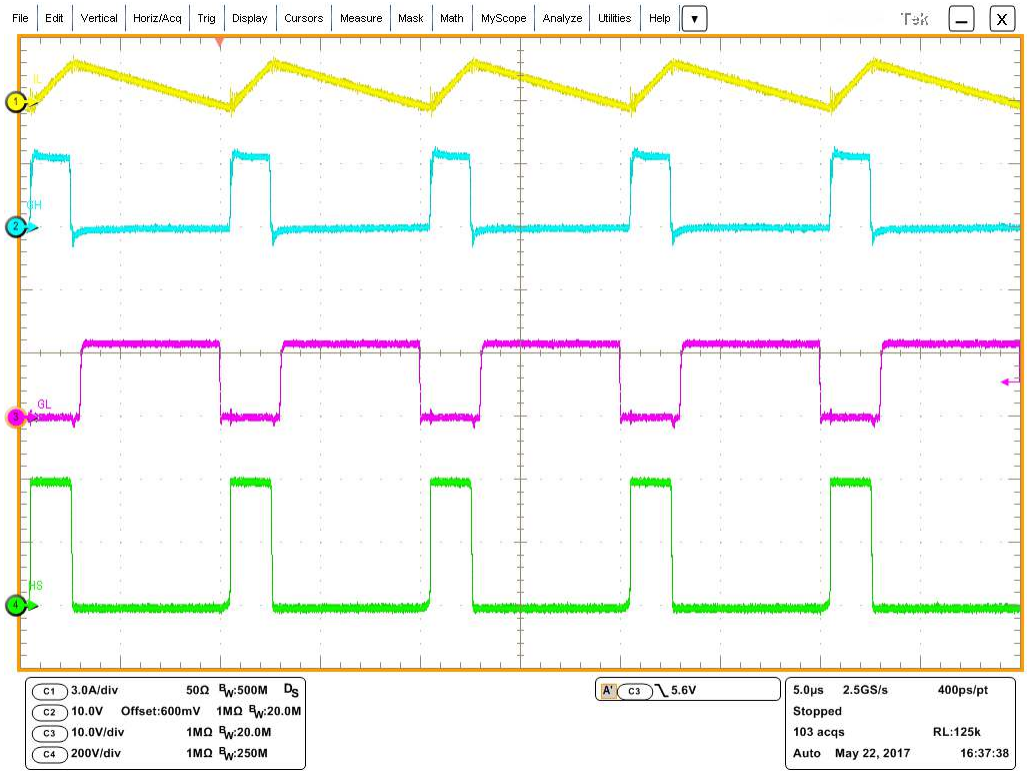

Figure 9. Buck Converter IL, GH, GL, and HS

Table 6. Waveform Figure Channel Descriptions

Channel	Description
CH 1	Inductor current
CH 2	GH, High-side MOSFET VGS
CH 3	GL, Low-side MOSFET VGS
CH 4	HS, Power stage switch node

7 Schematic

Figure 10 illustrates the UCC27712 schematic.

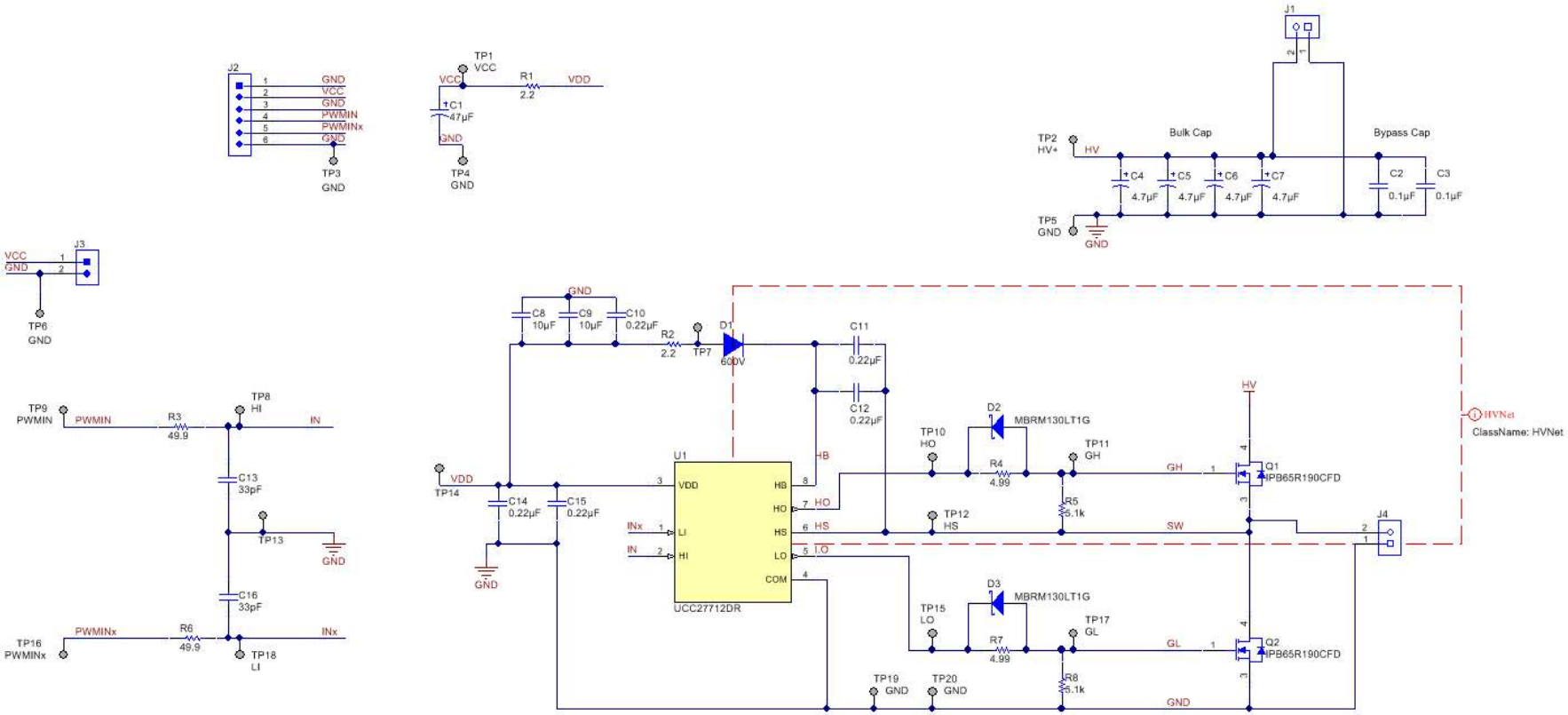

Figure 10. UCC27712 Schematic

8 Layout Diagrams

Figure 11 through Figure 14 illustrate the EVM layout diagrams.

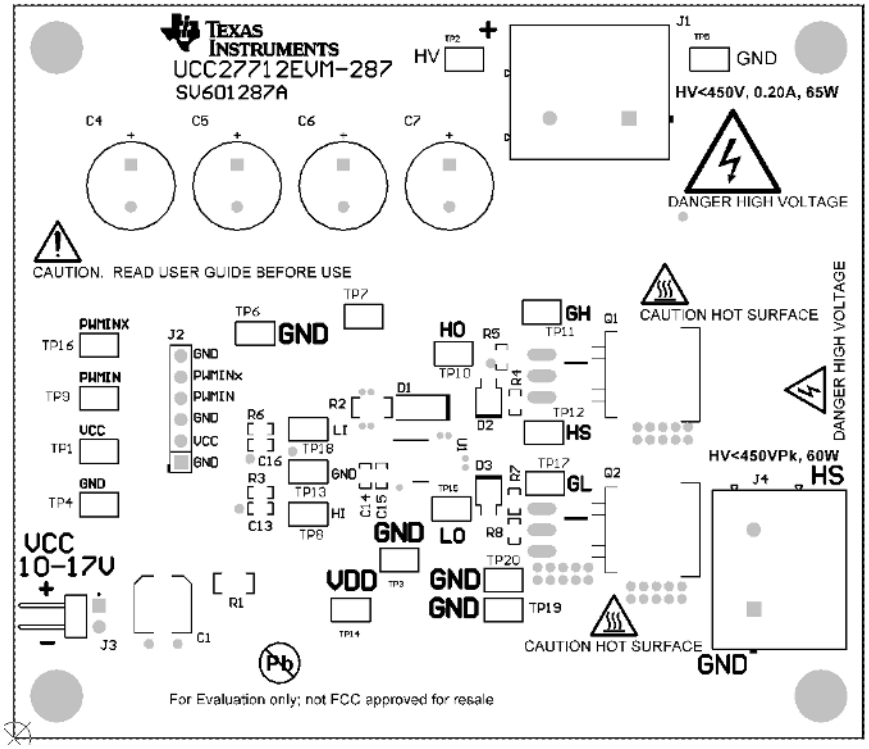

Figure 11. Assembly Top Layer

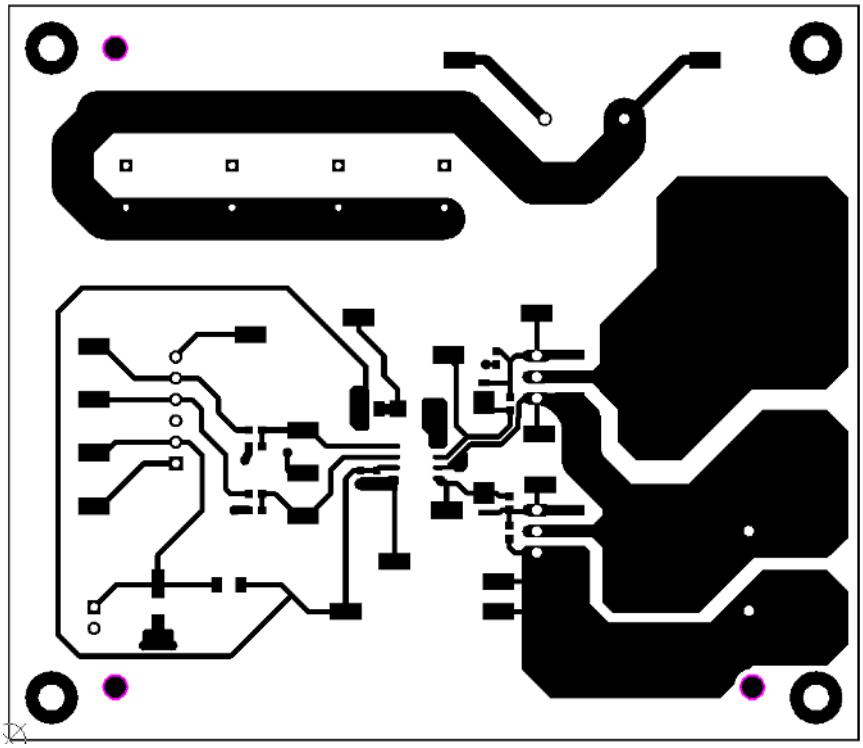

Figure 12. Top Layer

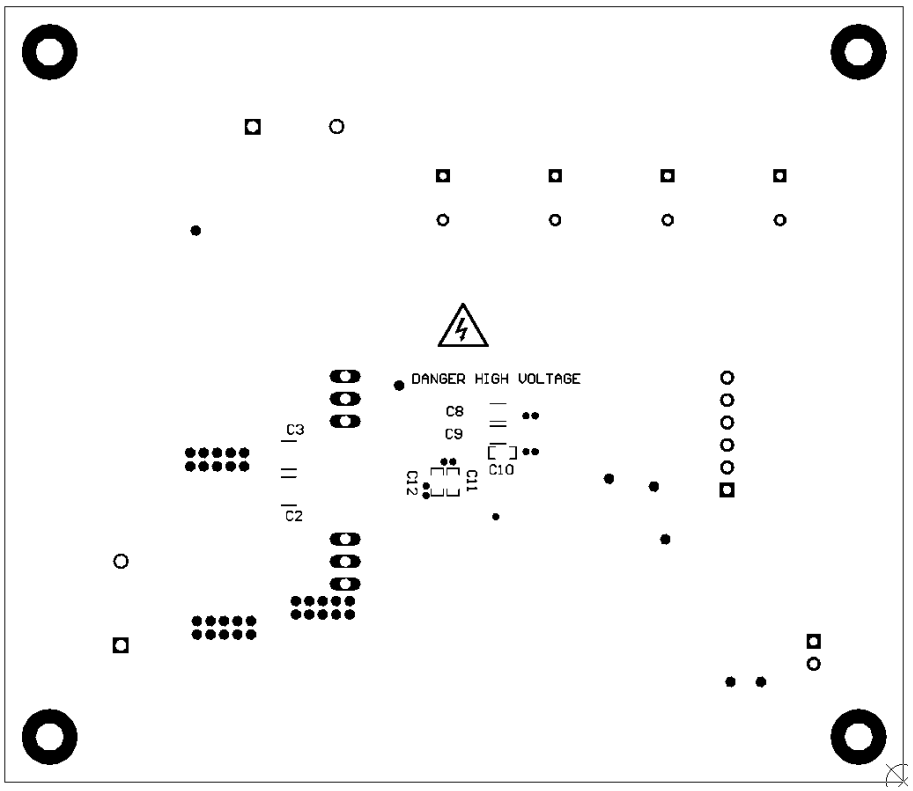

Figure 13. Bottom Overlay

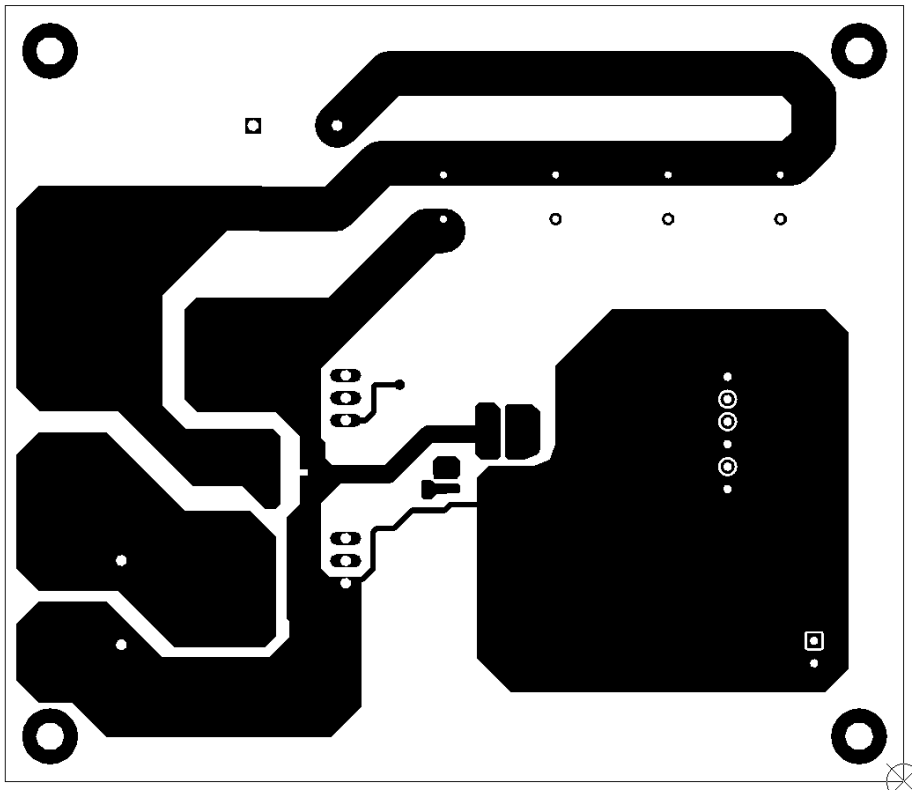

Figure 14. Bottom Layer

9 Bill of Materials

Table 7 lists the UCC27712EVM-287 BOM.

Table 7. UCC27712EVM-287 Bill of Materials

QTY	Designator	Description	Manufacturer	Part Number
1	!PCB1	Printed Circuit Board	Any	SV601287
1	C1	CAP, AL, 47 µF, 50 V, +/- 20%, 0.68 ohm, SMD	Nichicon	UUD1H470MCL1GS
2	C2, C3	CAP, CERM, 0.1 µF, 630 V, +/- 10%, X7R, 1812	Murata	GRM43DR72J104KW01L
4	C4, C5, C6, C7	CAP, AL, 4.7 µF, 450 V, +/- 20%, 135 ohm, TH	Kemet	ESH475M450AH2AA
2	C8, C9	CAP, CERM, 10 µF, 35 V, +/- 20%, X7R, 1206_190	TDK	C3216X7R1V106M160AC
5	C10, C11, C12, C14, C15	CAP, CERM, 0.22 µF, 50 V, +/- 10%, X7R, 0603	TDK	C1608X7R1H224K080AB
2	C13, C16	CAP, CERM, 33 pF, 50 V, +/- 5%, C0G/NP0, 0603	TDK	C1608C0G1H330J
1	D1	Diode, Ultrafast, 600 V, 1 A, AEC-Q101, SMA	ON Semiconductor	MURA160T3G
2	D2, D3	Diode, Schottky, 30 V, 1 A, POWERMITE	ON Semiconductor	MBRM130LT1G
4	H1, H2, H3, H4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	B&F Fastener Supply	NY PMS 440 0025 PH
4	H5, H6, H7, H8	Standoff, Hex, 0.5"L #4-40 Nylon	Keystone	1902C
2	J1, J4	Terminal Block, 9.52mm, 2x1, R/A, TH	Phoenix Contact	1902547
1	J2	Header, 100mil, 6x1, Gold, TH	Samtec	TSW-106-07-G-S
1	J3	Header, 100mil, 2x1, Gold, R/A, TH	Samtec	TSW-102-08-G-S-RA
2	Q1, Q2	MOSFET, N-CH, 650 V, 17.5 A, DDPAK	Infineon Technologies	IPB65R190CFD
2	R1, R2	RES, 2.2, 5%, 0.25 W, 1206	Vishay-Dale	CRCW12062R20JNEA
2	R3, R6	RES, 49.9, 1%, 0.1 W, 0603	Vishay-Dale	CRCW060349R9FKEA
2	R4, R7	RES, 4.99, 1%, 0.1 W, 0603	Vishay-Dale	CRCW06034R99FKEA
2	R5, R8	RES, 5.1 k, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06035K10JNEA
20	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20	Test Point, Miniature, SMT	Keystone	5019
1	U1	620-V High-Side Low-Side Gate Driver with 2.5A Peak Output and RobustDrive, D0008A (SOIC-8)	Texas Instruments	UCC27712DR

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

3 *Regulatory Notices:*

   3.1 *United States*

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

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

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

      CAUTION

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

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

      FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

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

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2. 実験局の免許を取得後ご使用いただく。
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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

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.

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