Using the UCC23513EVM-014

User's Guide

![Texas Instruments logo]

Using the UCC23513EVM-014

1   Introduction

UCC23513EVM-014 evaluation module is designed for evaluation of TI's 5-kV$_{RMS}$ isolated single-channel gate driver with opto-compatible input, UCC23513. The input is current driven, requiring between 7 mA and 16 mA for device turn-on, and can be reverse biased for turn-off. The device is capable of 4-A source and 5-A sink peak output current for driving Si MOSFETs, IGBTs and WBG devices, i.e. SiC and GaN transistors. This user guide covers UCC23513EVM-014, which is used for evaluation of UCC23513.

Developed for high voltage applications where isolation and reliability is required, the UCC23513 delivers reinforced isolation of 5 kV$_{RMS}$ and a surge immunity tested up to 8 kV along with a common mode transient immunity (CMTI) greater than 100 V/ns. It offers lower propagation delay, lower part to part delay skew, higher CMTI, smaller Pulse Width Distortion and higher operating temperature, which provides significant performance upgrade over opto isolated gate drivers, while still maintaining pin to pin compatibility.

The input current and voltage characteristics of the *e*-diode™ functionally mimics the primary side of an opto-isolator. The output side VCC has a wide recommended operating range from 15-V to 33-V and allows the device to be used in a low-side or high-side configuration along with bipolar supplies for SiC Power FETs. The pin-to-pin compatibility enables designers to use UCC23513 in existing designs and new designs for motor drives, industrial power supplies, solar inverters, and UPS.

2   Description

The UCC23513EVM-014 evaluation board utilizes a SN74LVC2G17DBVR (dual Schmitt-Trigger buffer) to drive signal current on the primary side of the device. The board is populated with clips and 2-position headers for flexibility in connecting power and signal inputs, along with signal test points and large GND vias to enable installation of ground springs. The PCB layout is optimized with minimal loop area in the input and output paths and showcases design for high voltage between primary side and secondary side with 8mm creepage. For detail device information, please refer to UCC23513 datasheet and TI's Isolated gate driver solutions.

2.1   Features

- Evaluation module for UCC23513 in stretched SO-6 package
- 5-V input buffer, and 15-V to 33-V VCC power supply range
- 4-A and 5-A source/sink current capability
- 5-kV$_{RMS}$ Isolation for 1 minute per UL 1577
- CMOS compatible input for buffer
- Buffer disconnect headers for custom input drive solution
- PCB layout showcases high voltage isolation design between primary side and secondary side
- Unpopulated pads for bootstrap supply, split supply, and turn on/turn off resistance

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(1)   *e*-diode is a trademark of Texas Instruments.

2.2   I/O Description

Table 1. Jumpers Setting

PINS	DESCRIPTION
J1–1	Anode Buffer input
J1–2	GND input
J2–1	Cathode Buffer input
J2–2	GND input
J3–1	Anode Buffer Jumper
J3–2	Anode Buffer Jumper
J4–1	Cathode Buffer Jumper
J4–2	Cathode Buffer Jumper
J5–1	Cathode Resistor to GND Jumper
J5–2	Cathode Resistor to GND Jumper
J6–1	VG to 1nF Load Jumper
J6–2	VG to 1nF Load Jumper
J7–1	VG to 180nF Load Jumper
J7–2	VG to 180nF Load Jumper
P1–1	+5V Buffer Supply
P1-2	GND
P2-1	+15V-33V Output Side Supply
P2-2	VSS

2.3   Jumpers (Shunt) Options

Table 2. Jumpers Setting

JACK	Jumper Setting Options		FACTORY SETTING
J1	Option A:	Jumper not installed, IN/PWM signal provided by external signal	Option A
	Option B:	Jumper on J1-1 and J1-2 set Anode Buffer Input low	
J2	Option A:	Jumper on J2-1 and J2-2 set Cathode Buffer Input low	Option A
	Option B:	Jumper not installed, IN/PWM signal provided by external signal	
J3	Option A:	Jumper on J3-1 and J3-2, pass signal to Anode Resistor	Option A
	Option B:	Jumper not installed, Anode_R left floating for external drive	
J4	Option A:	Jumper on J4-1 and J4-2, pass signal to Cathode Resistor	Option A
	Option B:	Jumper not installed, Cathode_R left floating for external drive	
J5	Option A:	Jumper not installed, Cathode_R left floating from GND	Option A
	Option B:	Jumper on J5-1 and J5-2, ties Cathode_R to GND	
J6	Option A:	Jumper installed, VG tied to 1nF test load	Option A
	Option B:	Jumper not installed, VG floating	
J7	Option A:	Jumper not installed, VG floating	Option A
	Option B:	Jumper installed, VG tied to 180nF test load	

3 Electrical Specifications

Table 3. UCC23513EVM-014 Electrical Specifications

DESCRIPTION		MIN	TYP	MAX	UNIT
V_{DD}	Primary-side power supply	4.5		5.5	V
V_{CC}	Driver output power supply	15		33	V
F_S	Switching frequency	0		1	MHz
T_J	Operating junction temperature range	−55		150	°C

4 Test Summary

In this section, UCC23513EVM-014 is tested in its default configuration. Different Jumper settings, PWM signal input options and voltage source settings can be found in Section 3 Electrical Specifications.

4.1 Definitions

This procedure details how to configure the UCC23513 evaluation board. Within this test procedure the following naming conventions are followed. Refer to the UCC23513EVM-014 Schematic, Section 7, for details.

V_{XX}: External voltage supply name.

$V_{(TPxx)}$: Voltage at test point TPxx. For example, V(TP12) means the voltage at TP12.

$V_{(Jxx)}$: Voltage at jack terminal Jxx.

$J_{xx(yy)}$: Terminal or pin yy of jack xx.

DMM: Digital multi-meters.

UUT: Unit under test

EVM: Evaluation module assembly, in this case the UUT assembly drawings have location for jumpers, test points and individual components.

4.2 Equipment

4.2.1 Power Supplies

Two DC power supply with voltage/current above 5-V/0.1-A and 35-V/0.5-A, for example: Agilent E3634A;

4.2.2 Function Generators

One function generator over 1 MHz, for example, Tektronics AFG3252

4.3 Equipment Setup

4.3.1 DC Power Supply Settings
- DC power supply #1
  - Voltage setting: 5-V
  - Current limit: 0.05-A
- DC power supply #2
  - Voltage setting: 15-V for UCC23513
  - Current limit: 0.1 A

4.3.2 Digital Multi-Meter Settings
- Digital multi-meter #1

– DC current measurement, auto-range.
• Digital multi-meter #2
  – DC current measurement, auto-range.

4.3.3 Function Generator Settings

Table 4. Function Generator Settings

	MODE	FREQUENCY	DUTY	DELAY	HIGH	LOW	OUTPUT IMPEDANCE
Channel Output	Pulse	DC ~ 100 kHz	50%	0 ns	5 V	0 V	High Z

4.3.4 Oscilloscope Setting

Table 5. Oscilloscope Settings

	BANDWIDTH	COUPLING	TERMINATION	SCALE SETTINGS	INVERTING
Channel A	500 MHz or above	DC	1 MΩ or automatic	10× or automatic	OFF
Channel B	500 MHz or above	DC	1 MΩ or automatic	10× or automatic	OFF

4.3.5 Jumper (Shunt) Settings

Default shunt configuration should be adequate for this test.
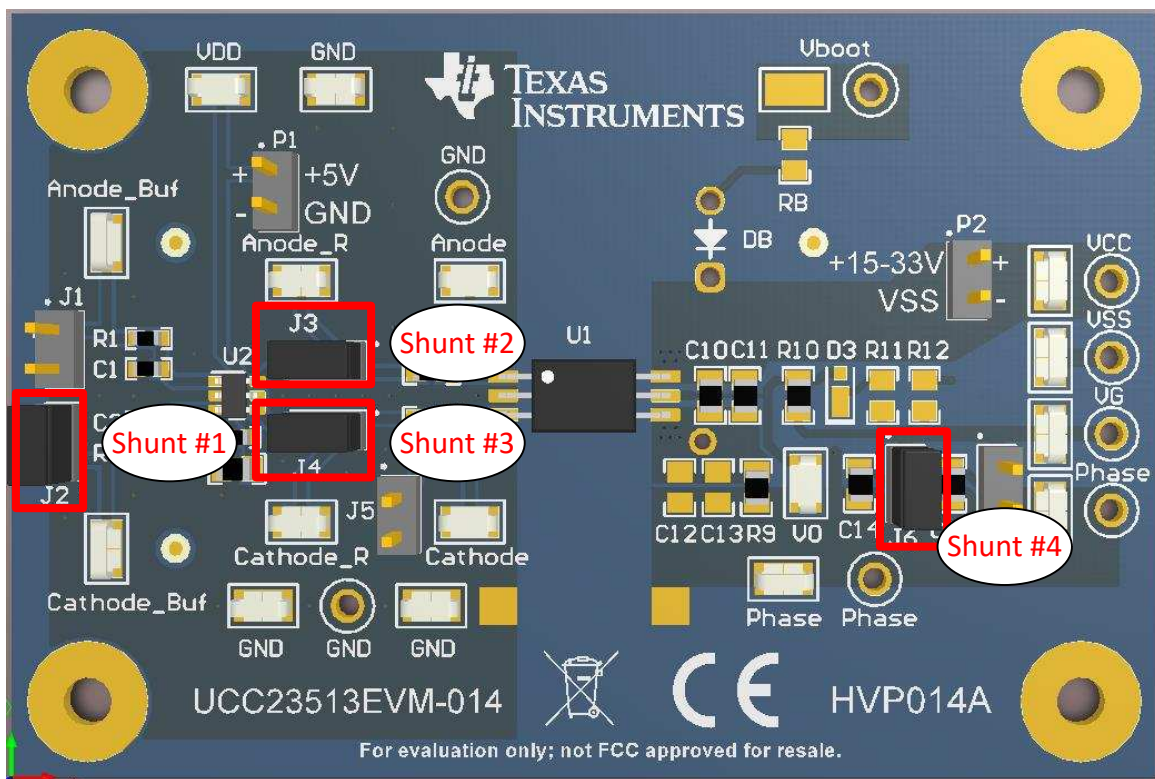
Figure 1. Default Jumper Settings

4.3.6   Bench Setup Diagram

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

Please follow the connection procedure below, and Figure 2 can be used as a reference.

- Make sure the output of the function generator and voltage sources are disabled before connection;
- Function generator channel applied on J1-1 ←→ J1-2, see in Figure 2;
- Power supply #1: positive node connected to input of DMM #1 with DMM #1 output connected to P1-1 (or VDD), and negative node applied on P1-2 (or GND);
- Power supply #2: positive node connected to input of DMM #2 with DMM #2 output connected to P2-1 (or VCC), negative node connected directly to P2-2 (or VSS);
- Oscilloscope channel-A probes Anode_R ←→ GND, smaller measurement loop is preferred;
- Oscilloscope channel-B probes VG (or J7-1) ←→ VSS, smaller measurement loop is preferred;
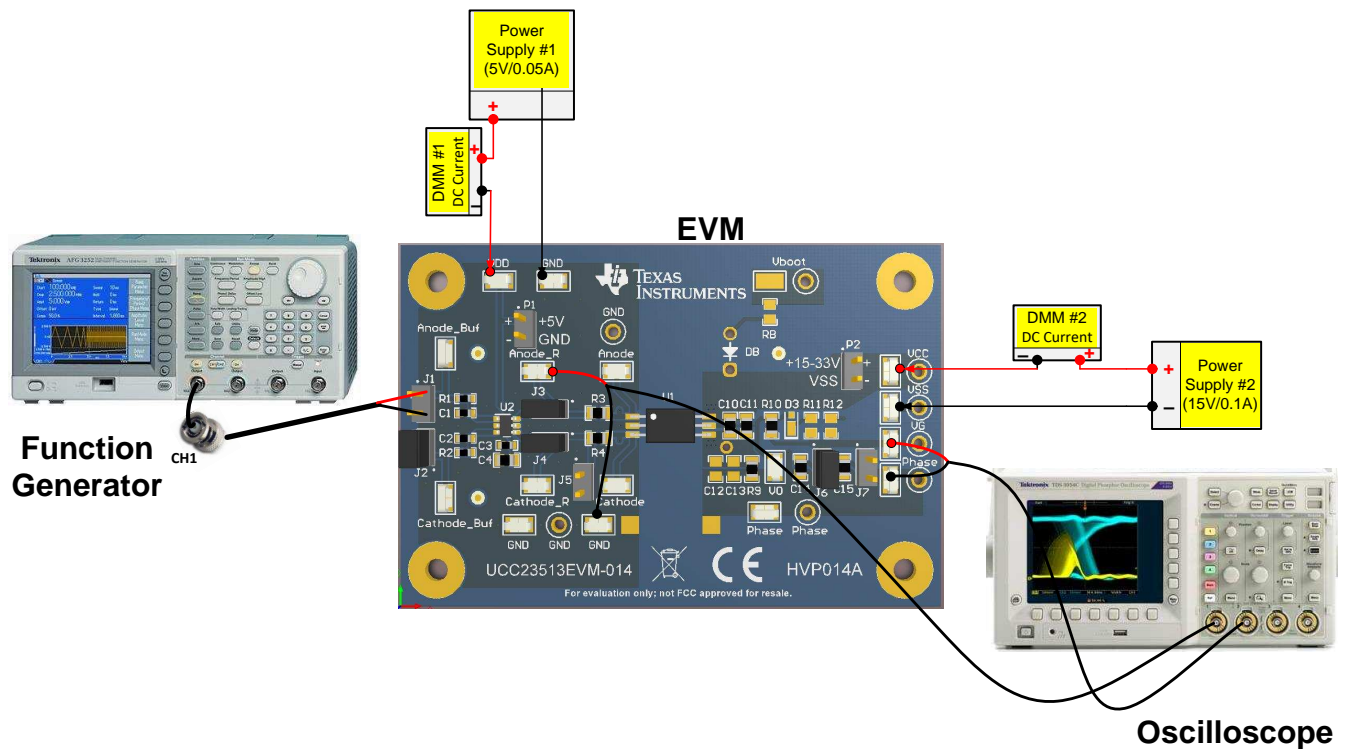
Figure 2. Bench Setup Diagram and Configuration

5   Power Up and Power Down Procedure

5.1   Power Up (C_L=1000pF)

1. Before proceeding to the power up procedure, please make sure that Section 4.3.6 is implemented for setting up all the equipment. Figure 3 could be used as reference;

2. Enable supply #1;

3. Enable supply #2, the quiescent current on DMM1 and DMM2 ranges in 1 mA ~ 3 mA if everything is set correctly;

4. Enable function generator output;

5. There will be:

    1. Stable pulse output on the channel-A and channel-B in the oscilloscope, refer to Figure 3;

    2. Scope frequency measurement is same as function generator output;

    3. DMM #1 and #2 should read measurement results around 5-10 mA under no load conditions. For more information about operating current, please refer to UCC23513 Datasheet.
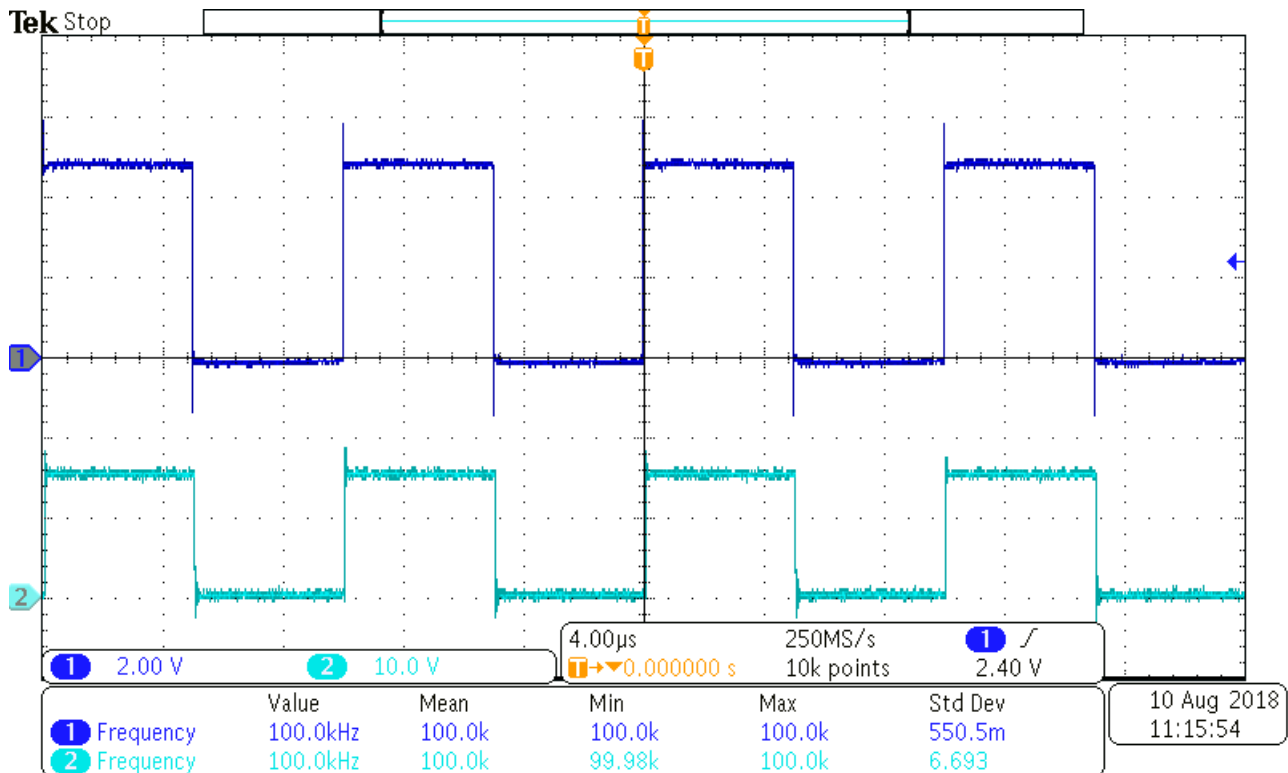
Figure 3. Example Input and Output Waveforms (Ch1 is PWM Input, Ch2 is outputs)

5.2   Power Down

1. Disable function generator;

2. Disable power supply #2;

3. Disable power supply #1;

4. Disconnect cables and probes;

6 Test Waveforms with Different Input/Output Configurations

6.1 Input Side Reverse Bias

The default configuration grounds input to cathode buffer. Cathode buffer can alternatively be driven with a function generator to reverse bias input diode on turn-off. With J2 jumper (shunt) removed, cathode and anode buffers are driven 180º out of phase which showcases reverse blocking capability of UCC23513.
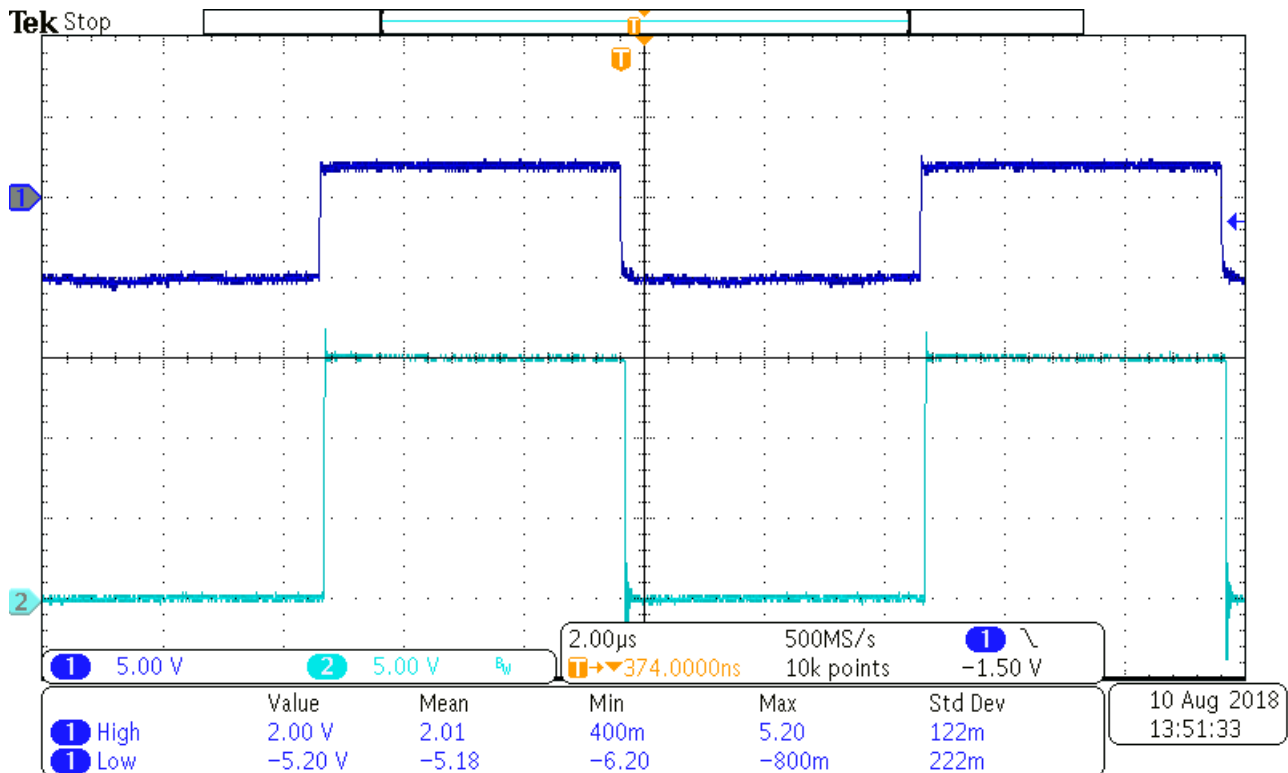

Figure 4. Input e-Diode driven +/-5V
(Ch1 is PWM Input, Ch2 is output)

6.2 Output Split Supply

The output can be configured to provide split supply operation through two unique methods.

Single supply: Remove R9 and install C6=C7=1uF, R7 = 7.5k, D2 = 5.1V Zener, and R8 jumper.

Dual supply: Remove R9 and install C11=0.1uF, C12 = 2.2uF, apply V+ from VCC to VSS, and V- from VSS to Phase.

These configurations allows output operation from -5V off, to VCC-5V on which is commonly found in SiC power stage configurations. The following capture shows operation with the latter method.
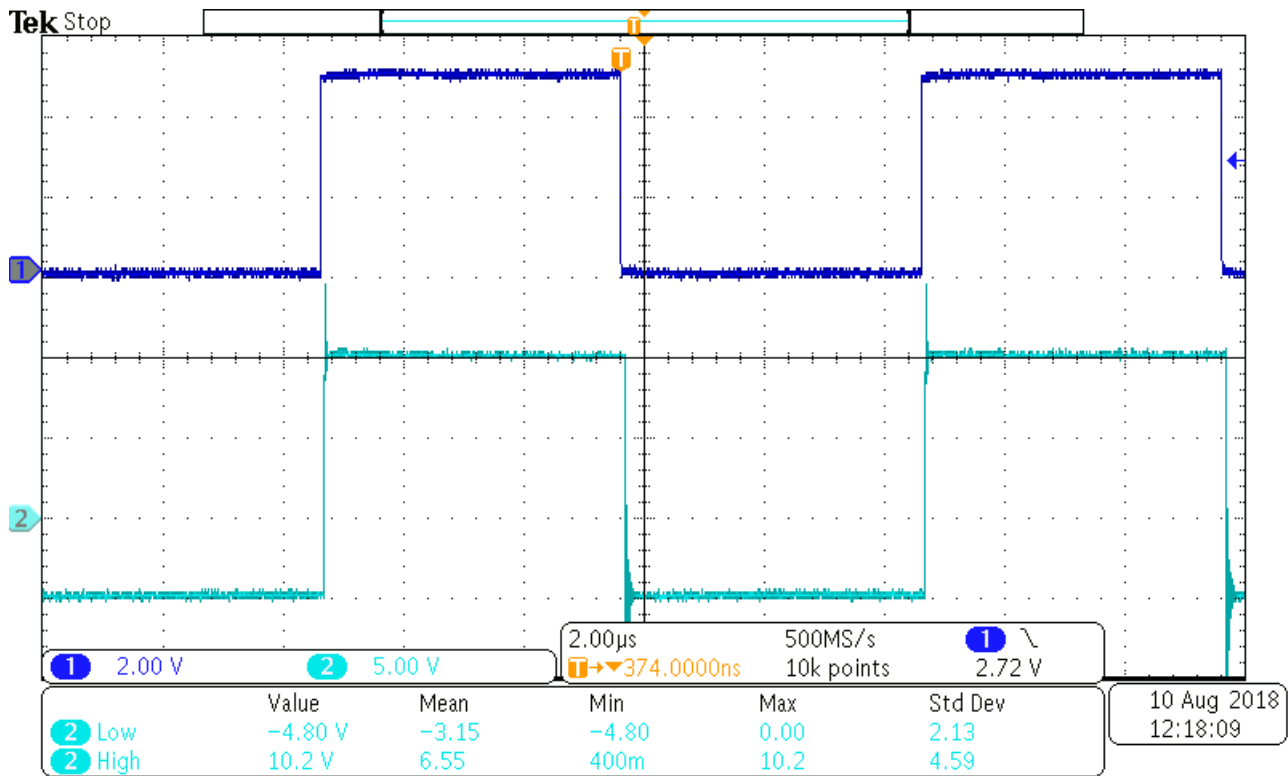
**Figure 5. Output Split Supply Operation
(Ch1 is PWM Input, Ch2 is output)**

6.3 *Peak Output Current Measurement Using 180nF Load*

The output can be configured to measure peak output current by moving the jumper from J6 to J7. This jumpers in a 180nF load capacitor, C15, which can be used to indirectly measure the output current as seen in the tech note,Understanding Peak Source and Sink Current Parameters. Input PWM is set to 200 Hz to avoid excessive power dissipation in the driver.
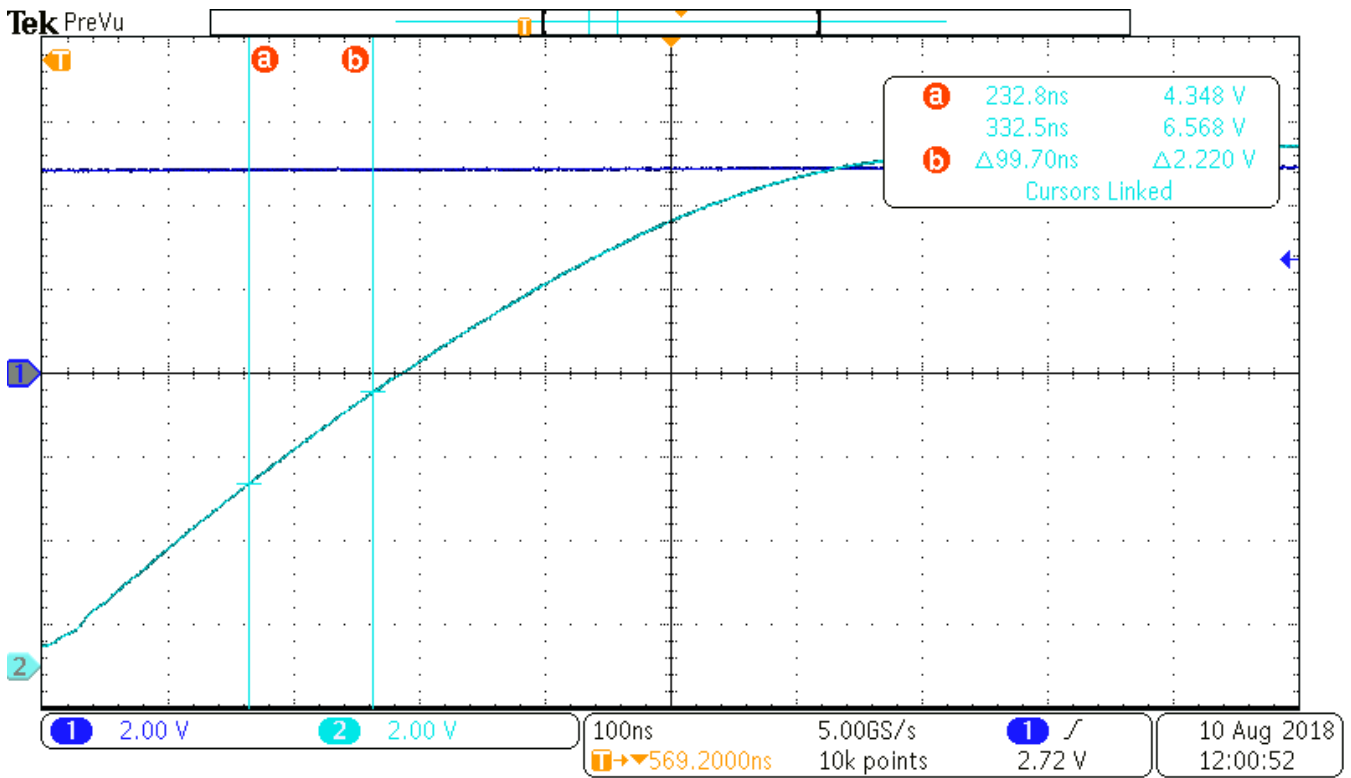
Figure 6. Source dv/dt Measurement
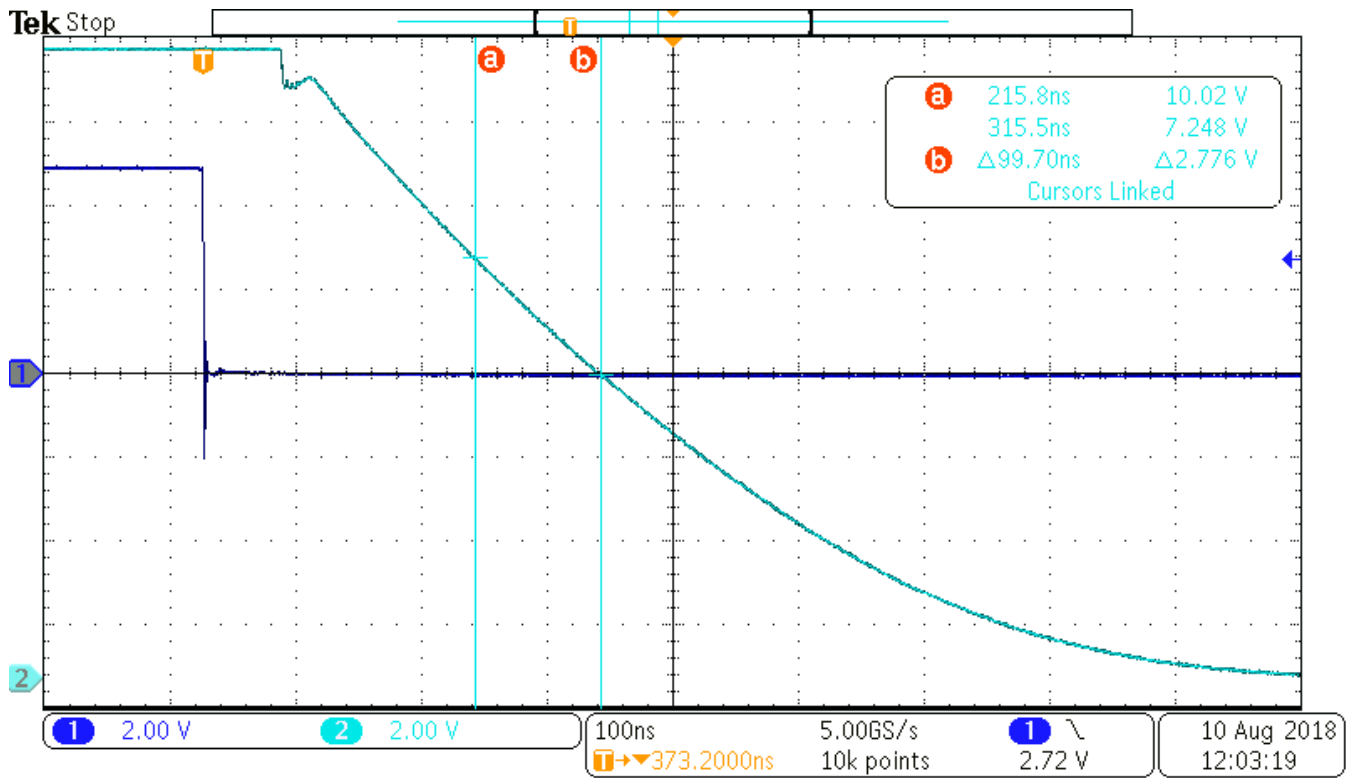
Peak source current is calculated at 4.008A.

Figure 7. Sink dv/dt Measurement

Peak sink current is calculated at 5.011A.

7 Schematic
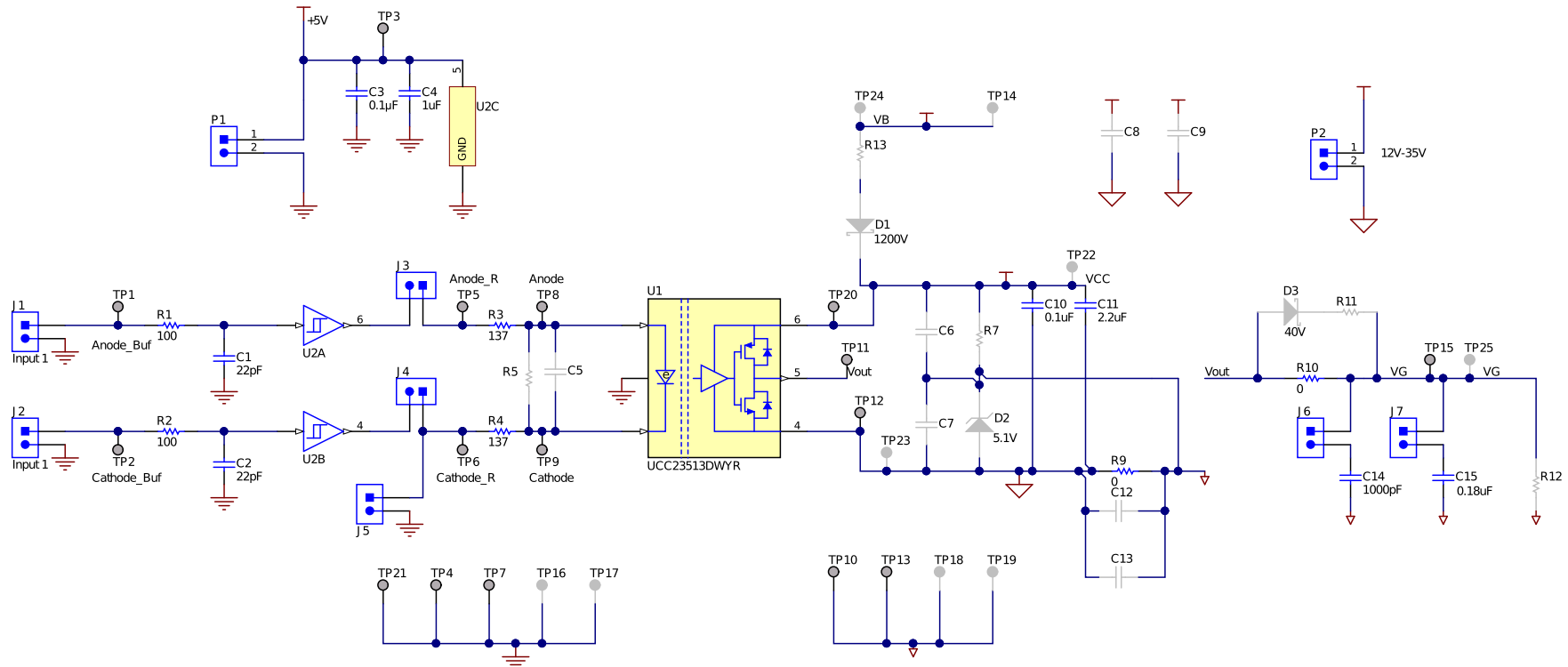
Figure 8 shows only the schematic diagram for UCC23513EVM-014.

Figure 8. UCC23513EVM-014 Schematic

8 Layout Diagrams

The PCB layout information for UCC23513EVM-014 is shown in Figure 9, Figure 10, Figure 11 and Figure 12.

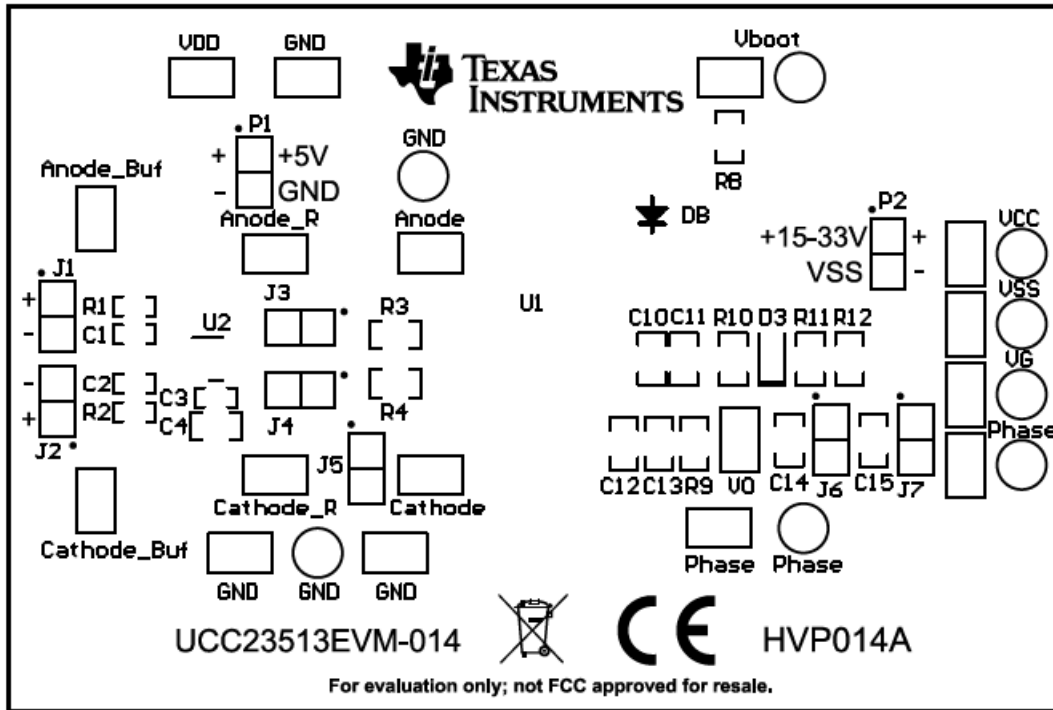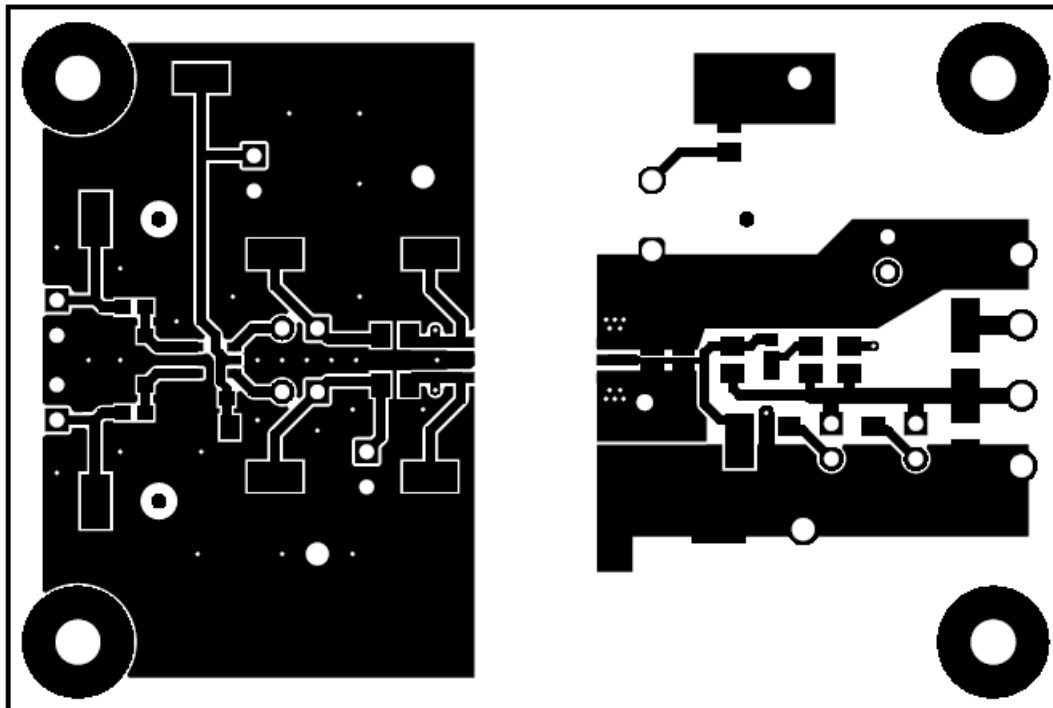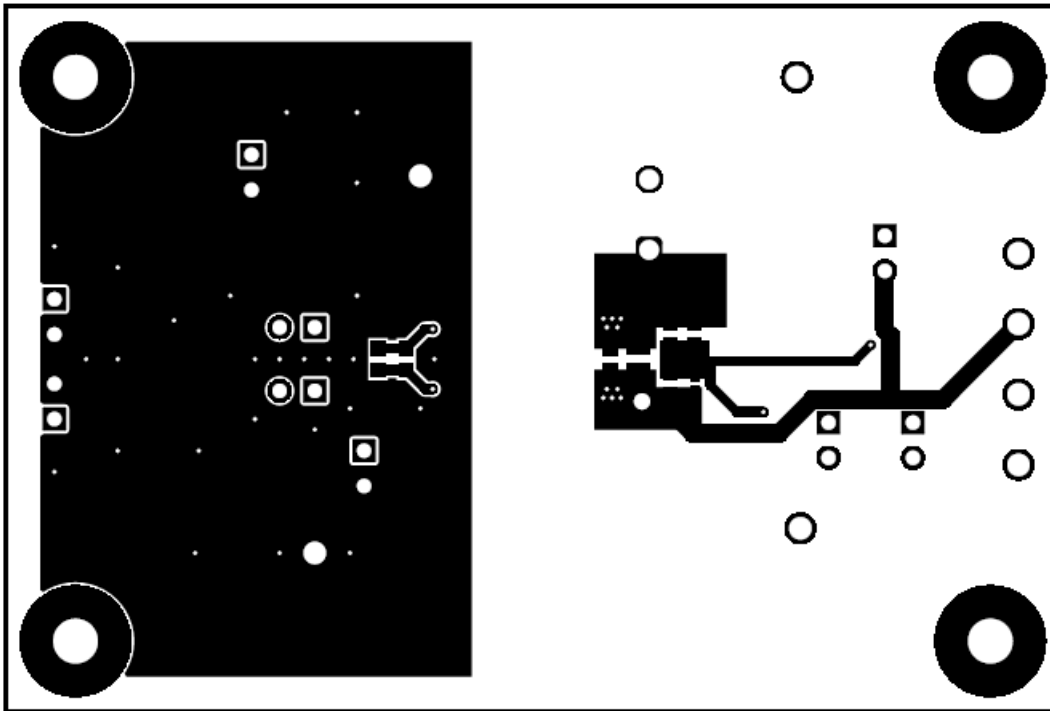**Figure 9. Top Overlay**

Figure 10. Top Layer
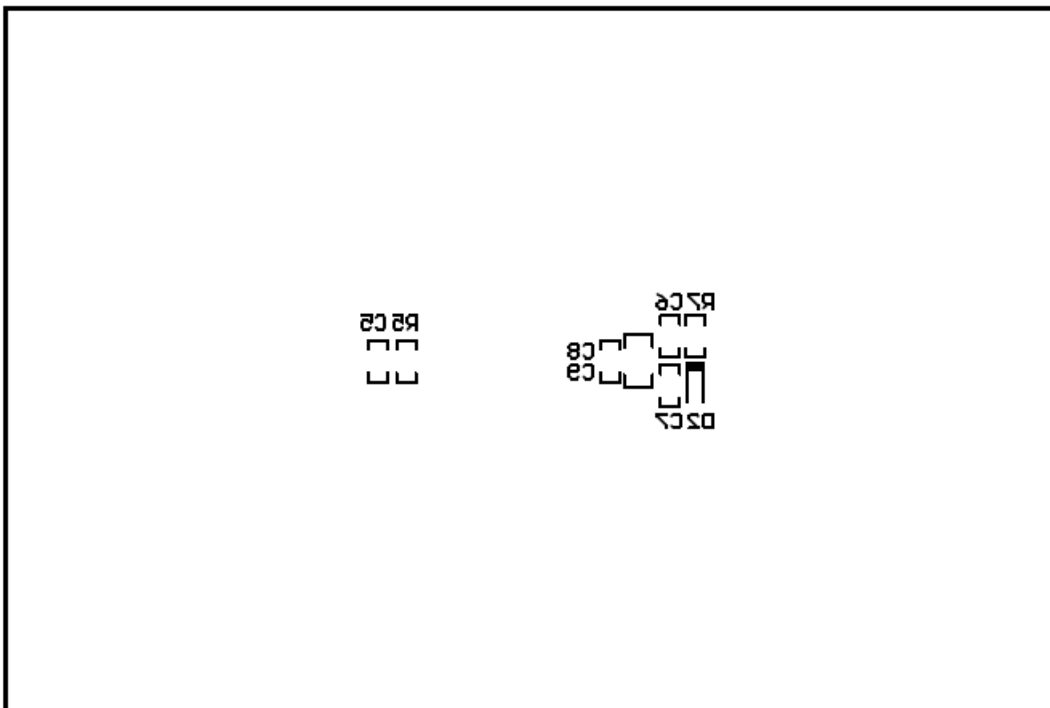
Figure 11. Bottom Layer

Figure 12. Bottom Overlay

9   List of Materials

Table 6. UCC23513EVM-014 List of Materials

Quantity	Designator	Description	Part Number	Manufacturer
1	U1	5-kVRMS, 3-A Single Channel Isolated Gate Driver with Opto Compatible Input, DWY0006A (SOIC-6)	UCC23513DWYR	Texas Instruments
1	U2	Dual Schmitt-Trigger Buffer, DBV0006A, LARGE T&R	SN74LVC2G17DBVR	Texas Instruments
2	C1, C2	CAP, CERM, 22 pF, 100 V, +/- 5%, C0G/NP0, 0603	Std	Std
1	C3	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	Std	Std
1	C4	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0805	Std	Std
1	C10	CAP, CERM, 0.1 uF, 50 V, +/- 20%, X7R, 0805	Std	Std
1	C11	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X5R, 0805	Std	Std
1	C14	CAP, CERM, 1000 pF, 50 V, +/- 1%, C0G/NP0, 0805	Std	Std
1	C15	CAP, CERM, 0.18 uF, 50 V, +/- 10%, X7R, 0805	Std	Std
9	J1, J2, J3, J4, J5, J6, J7, P1, P2	Header, 100mil, 2x1, Gold, TH	Std	Std
2	R1, R2	RES, 100, 1%, 0.1 W, 0603	Std	Std
2	R3, R4	RES, 137, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	Std	Std
2	R9, R10	RES, 0, 5%, 0.125 W, 0805	Std	Std
4	SH-J2, SH-J3, SH-J4, SH-J6	Shunt, 100mil, Flash Gold, Black	Std	Std
16	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP15, TP20, TP21	Test Point, Miniature, SMT	Std	Std
0	C5, C6, C7	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0603	Std	Std
0	C8	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0603	Std	Std
0	C9, C12, C13	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0805	Std	Std
0	D1	Diode, Schottky, 1200 V, 8 A, TH	Std	Std
0	D2	Diode, Zener, 5.1 V, 300 mW, SOD-523	Std	Std
0	D3	Diode, Schottky, 40 V, 1 A, MicroSMP	Std	Std
0	H1, H3, H5, H7	Standoff, Hex, 0.5"L #4-40 Nylon	Std	Std
0	H2, H4, H6, H8	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Std	Std
0	R5	RES, 1.0 k, 5%, 0.1 W, 0603	Std	Std
0	R7	RES, 7.50 k, 1%, 0.1 W, 0603	Std	Std
0	R11	RES, 10.0, 1%, 0.125 W, 0805	Std	Std
0	R12	RES, 4.7 k, 5%, 0.125 W, 0805	Std	Std
0	R13	RES, 10, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	Std	Std
0	TP14	Test Point, Miniature, SMT	Std	Std
0	TP16, TP17, TP18, TP19, TP22, TP23, TP24, TP25	Test Point, Compact, Black, TH	Std	Std

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Revision History

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

Changes from Original (Oct. 2018) to A Revision **Page**

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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

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

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

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

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

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3. 技術基準適合証明を取得後ご使用いただく。

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　　　　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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

3.4 *European Union*

> 3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:
>
> This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4   *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

> 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
>
> 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

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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.

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