

# **Automotive Cranking Simulator User's Guide**

The Texas Instruments HVAL068A automotive cranking simulator helps designers evaluate the performance of automotive power supplies. This document describes the setup, input and output connections of the board, and the firmware as well. Included are the board layout, schematic, and bill of materials.

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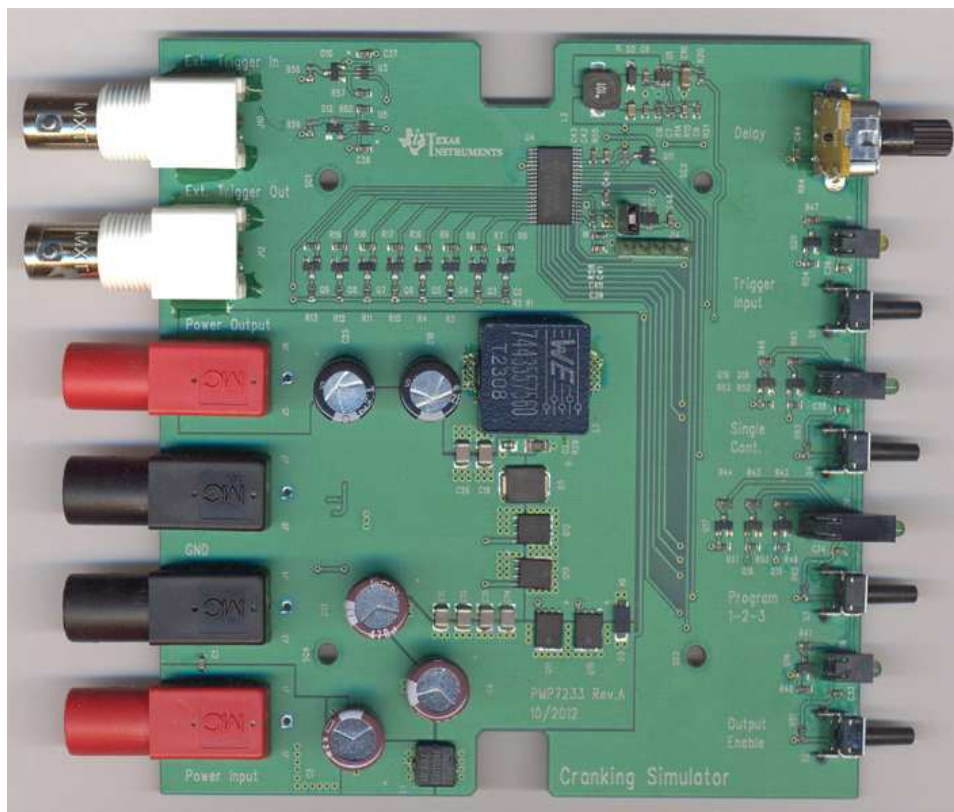
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## 1 Introduction

Electronic engineers working in the automotive area are sooner or later faced with a cranking test pulse. These test pulses describe the drop of the battery voltage during cranking of the engine, and each car manufacturer has its own standard for them. The attachment of many electronic circuits to the battery results in cranking pulses impacting them. In some applications like the navigation or multimedia system, an interruption of operation due to the drop of the input voltage is unwanted or even unacceptable. In this case, the most-often-used solution is placing a boost converter in front of the circuit to provide a stable input voltage for the electronics.

During the development process, one must test the functionality of this kind of pre-booster (as, for example, in the TPS43330) to ensure a fast start-up and a clean and stable output voltage for the subsequent electronics, like point-of-load converters. Also, point-of-load converters which are directly connected to the battery require testing, as the input voltage can drop very fast and the converter must react fast enough to keep the output voltage constant.

To test automotive electronic systems with up to 50 W of input power with different standardized cranking pulses, one can use the HVAL068A board.



**Figure 1. HVAL068A EVM Board**

## 2 Setup

This section describes the jumpers and connectors on the EVM as well and how properly to connect, set up, and use the HVAL068A cranking simulator.

## 2.1 Board Overview

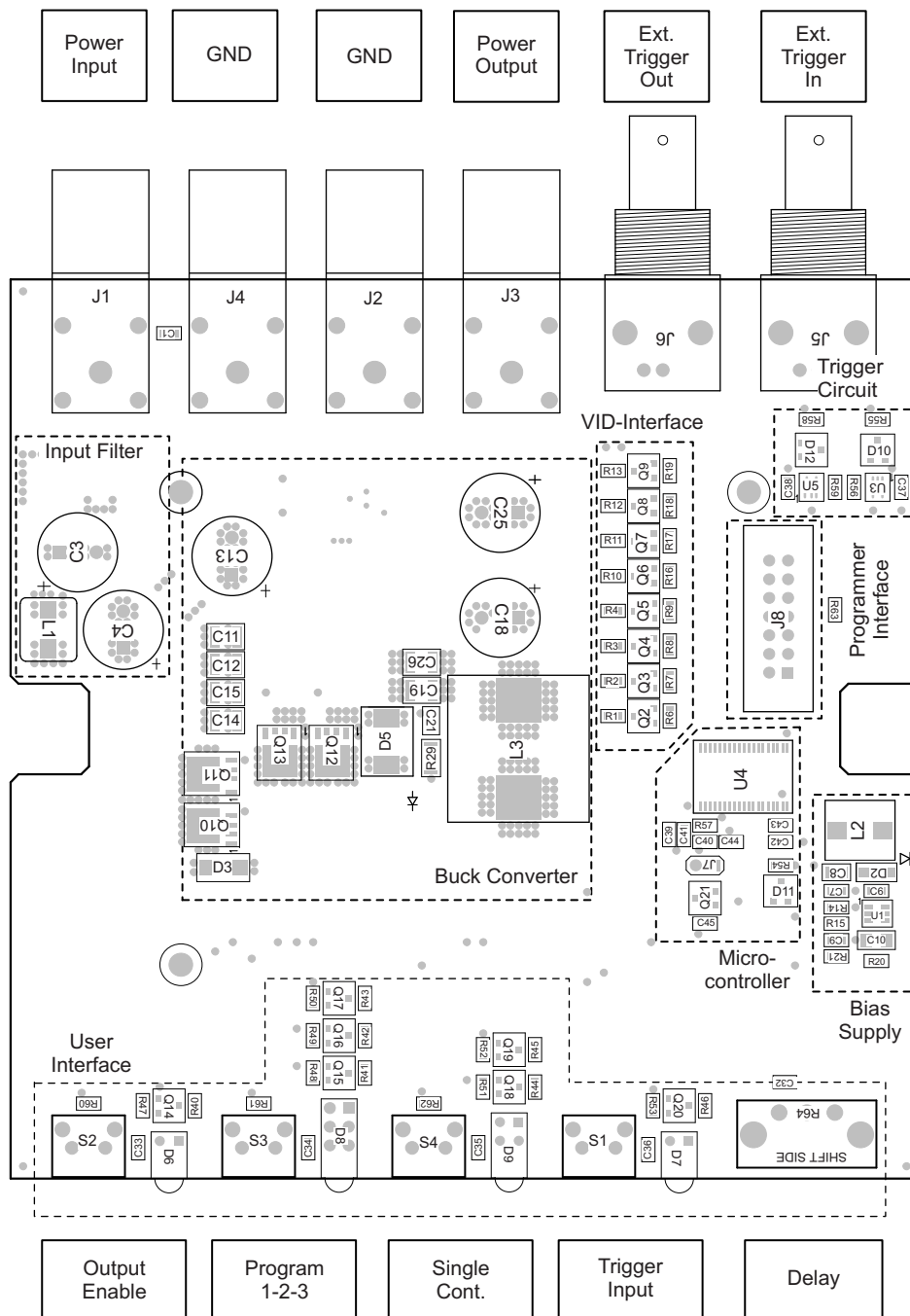


Figure 2. Board Overview

The board consists basically of eight sub-circuits:

- An input filter to reduce the noise of the buck converter on the input cabling as well as active reverse-polarity protection
- A synchronous buck converter providing the power for the output
- A VID interface to adjust the output voltage of the buck converter
- A trigger circuit providing an external trigger signal when a pulse is generated, as well as a trigger input to start a pulse from an external signal source
- A user interface with push-buttons and LEDs

- A bias power supply to supply the microcontroller and all other circuitry
- A microcontroller to control the complete system
- A programmer interface to program and debug the microcontroller by Spy-Bi-Wire

## 2.2 Input/Output connector Description

### 2.2.1 Terminals

**Power Input** is the input plug for the board. Adjacent to it is the GND reference ground. Use those banana plugs to attach the EVM to a power supply which provides 24 V and at least 3 A.

**Power Output** is the output plug for the board. Adjacent to it is the GND reference ground. Use those banana plugs to attach the load or device under test to the board.

**Ext. Trigger Out** is a BNC connector providing the trigger output signal. The board generates a rectangular trigger pulse (0 V to 3.3 V) with a duration of 10 ms at the beginning of each cranking pulse for easily triggering an oscilloscope.

**Ext. Trigger In** is a BNC connector for a trigger input signal. A rising edge (>2 V, 5 V max.) generates a pulse on the output.

### 2.2.2 User Interface

**Output Enable** is a push-button to enable the buck converter and therefore provide a voltage on the output. Adjacent to it is a green LED showing the status (on – enabled, off – disabled).

**Program** is a push-button to select one of the three programs. Adjacent to it are three green LEDs showing the selected program (1, 2, or 3).

**Single Cont.** is a push-button to select between single or continuous pulse generation. Adjacent to it are two green LEDs showing the selected mode (S or C).

**Trigger** is a push-button to start generating a single pulse or continuous pulses. Adjacent to it is a yellow LED which is on as long as pulse generation continues.

**Delay** is a potentiometer to set the delay between pulses in continuous mode.

### 2.2.3 Jumpers

**J13** is the jumper to disconnect the supply voltage supervisor (TPS3809K33) from the reset line of the microcontroller. The debugging and programming processes use the reset line for communication between the debugger interface and the microcontroller. To give full control over this line to the debugger interface requires disconnection of the supply voltage supervisor, as it has a push-pull output and not an open-drain output.

### 2.2.4 Programmer Interface

**J14** is the connector for the debugger interface for debugging and programming the microcontroller. The pin configuration fits the MSP430 USB Debugging Interface (MSP-FET430UIF).

## 3 Operation

The supply voltage range for the board is 20 V to 28 V dc. The power supply must be capable of providing at least 3 A. The output voltage range is 2 V to 15 V dc (limited by the hardware) at 50 W of output power, maximum.

After applying the supply voltage, no voltage is present on the Power Output connector and the following LEDs are shining:

- Program – 1 (Program 1 selected)
- Single Cont. – S (Single mode selected)

By pressing the Output Enable push-button, the buck converters start to operate and the default output voltage for program 1 is present on the output connector (12.6 V).

To start generating a pulse, press the Trigger Input push-button. The resulting pulse lasts approximately 10 seconds, during which time the adjacent LED is always on. To abort generating the pulse, press the Trigger Input push-button again. Then the output voltage goes back to the default value (12.6 V) and the LED turns off.

The Program 1-2-3 push-button selects one of the three available programs. Each keystroke counts one program up. After selecting the third program, the next keystroke jumps back to program 1.

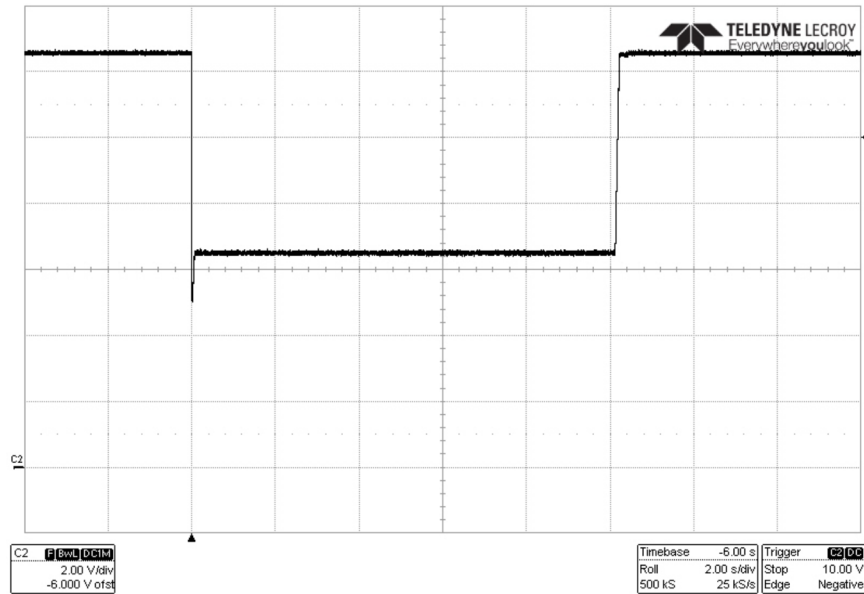


Figure 3. Program 1, 2 s/div – DaimlerChrysler Engine-Cranking Test Pulse, DC-10615

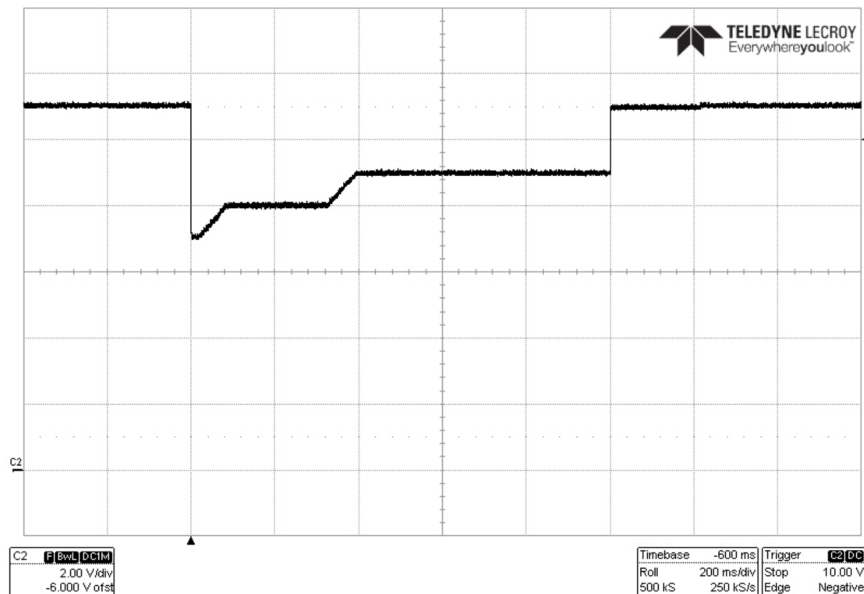
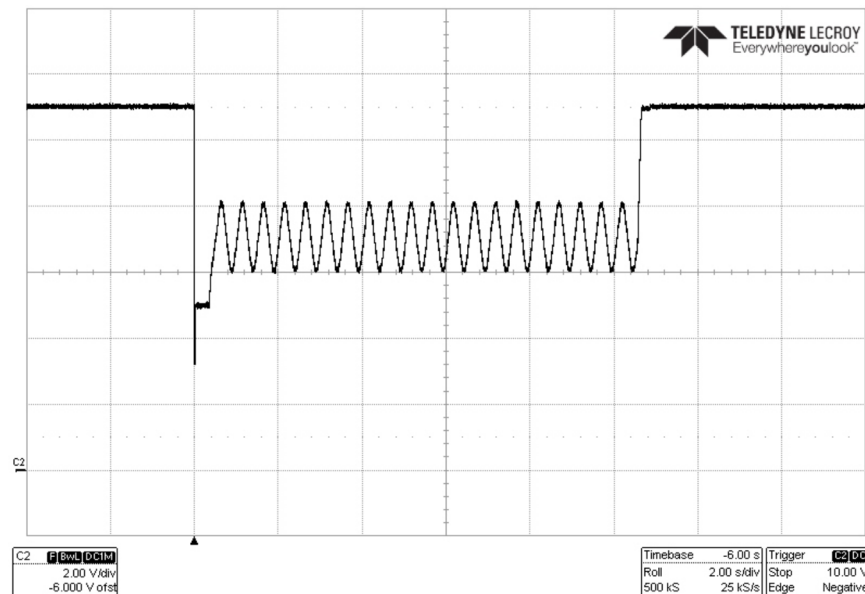


Figure 4. Program 2, 200 ms/div – Volkswagen Warm-Start Test Pulse, VW80000



**Figure 5. Program 3, 2 s/div – Volkswagen Cold-Start Test Pulse, VW80000**

The Single Cont. push-button selects between generating a single pulse on an input trigger event (push-button or external trigger input) or continuous pulses until the next input trigger event.

In continuous mode, the Delay potentiometer adjusts the delay between successive pulses. At the counterclockwise limit, the delay is 0 seconds; at the clockwise limit it is around 2 s. The gradient between those two limits is linear.

Changing the program is only possible while no pulse generation is in progress. If the program is changed during pulse generation, the board registers and stores the new program selection, but the change does not occur until completion or aborting of the present pulse and occurrence of a new input trigger event.

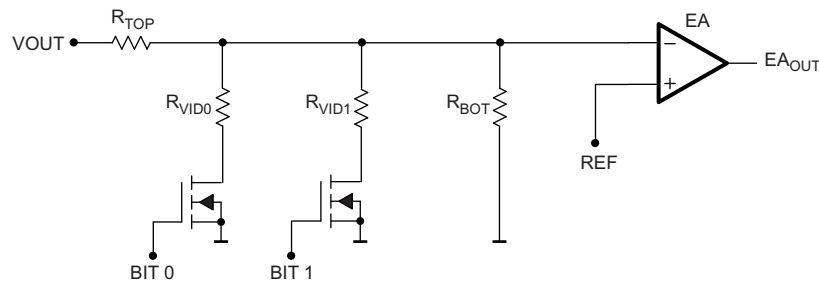
Changing the mode from single to continuous is also only possible while pulse generation is not in progress. In the case of a mode change during pulse generation, the board registers and stores the new mode, but the change does not occur until completion or aborting of the present pulse and occurrence of a new input trigger event.

If the board is working in continuous mode, pressing the Single Cont. push-button switches the C LED off and the S LED on. The generation of the present pulse finishes and after that, the output voltage goes back to the default value. Now, for a single pulse, a new input trigger event is necessary.

The Output Enable push-button enables and disables the output voltage independent of the selected program, mode, trigger event, or anything else. With it, one can always switch the buck converter directly on or off.

## 4 VID Interface

To change the output voltage of a converter during operation, several approaches are possible. Probably achievement of the fastest output voltage changes can be by using a VID interface (dynamic voltage identification), known from the area of powering DSPs (digital signal processors). Depending on the processor load, the VID interface adjusts core voltage to increase the computing power or to reduce the losses.



**Figure 6. VID Interface**

One can change the output voltage of a converter either by changing the reference voltage or the voltage, which is compared with the reference voltage. The reference voltage is usually fixed and not accessible on the controller, necessitating use of the second method. The circuit contains several additional resistors in parallel with the low-side resistor of the voltage divider, with small FETs to switch them on and off.

The addition of eight resistors and FETs in this circuit results in a resolution of 51 mV within the output voltage range of 2 V to 15 V.

A microcontroller, MSP430F2274, controls the VID interface as well as the complete system. The MCU has three different hard-programmed cranking pulses.

- DaimlerChrysler Engine-Cranking Test Pulse, DC-10615
- Volkswagen Warm-Start Test Pulse, VW80000
- Volkswagen Cold-Start Test Pulse, VW80000

#### 4.1 Modifying the Cranking Pulses

Changing the implemented cranking pulses to your own needs requires modifying the source code of the firmware. This section describes how to adapt the firmware.

Import the zip file containing the original firmware into Code Composer Studio (CCS) using the *Import* function. For more information on this topic, use the *Help* function of CCS. Also ensure that the version of CCS in use is the latest.

The firmware project contains several files. To change the pulses, only the pulse.c file requires modification. Inside this file, the three functions

- void generate\_pulse\_program\_1(void)
- void generate\_pulse\_program\_2(void)
- void generate\_pulse\_program\_3(void)

define the form of the pulses. They simply contain the commands for setting the output voltage according to the specified pulse with delays in between.

Because the normal program which handles the user inputs is interrupt-based, the use of delays is the simplest solution for defining the pulses.

When using delays, in theory the program cannot be aborted if the trigger button is pressed during the generation of a cranking pulse. Therefore adding the command

```
if( stop_pulse() ) return;
```

each several hundred microseconds allows checking for trigger-button actuation during the generation of a pulse. If trigger-button activation is detected, the command aborts generation of the pulse.

The output voltage can be changed by the VID interface between 1.99 V and 15.12 V. For lower or higher voltages, change the resistors of the VID interface.

The VID interface has a width of 8 bits, which results in 256 steps (0 equals 1.99 V, 255 equals 15.12 V); one step equals approximately 51.5 mV. One can calculate the decimal value for a specific output voltage, 6 V for example, using this formula:



$$\text{Decimal}_{\text{value}} = \frac{V_{\text{OUT}} - 1.99 \text{ V}}{51.5 \text{ mV}} = \frac{6.00 \text{ V} - 1.99 \text{ V}}{51.5 \text{ mV}} \approx 78 \quad (1)$$

To set the output voltage to 6 V, write a value of 78 into the register of the output port connected to the VID interface using the command

```
VID_POUT = 78;
```

The VID\_POUT definition is the output register of port 1 (P1OUT).

An Excel® sheet containing the precise calculations for all 256 steps and also examples for generating sinusoidal waveforms is available on <http://www.ti.com/tool/pmp7233>.

The *pulse.c* file also contains three test functions, which are not used but show an easy method for generating a rectangular, a saw tooth, and a sinusoidal waveform.

- void generate\_pulse\_test\_mode\_1(void) — Rectangular waveform
- void generate\_pulse\_test\_mode\_2(void) — Sawtooth waveform
- void generate\_pulse\_test\_mode\_3(void) — Sinusoidal waveform

## 4.2 Programming the Microcontroller

Debugging the program and flashing the microcontroller requires a debugger to connect the EVM with the computer. One can either use the MSP430 USB Debugging Interface (MSP-FET430UIF) or the inexpensive MSP430 LaunchPad (MSP-EXP430G2). Either option uses the Spy-Bi-Wire interface to save pins on the microcontroller instead of using a true JTAG connection.

### 4.2.1 Using the USB Debugging Interface

1. Remove jumper J13, close to the microcontroller, to disconnect the reset line from the supply voltage supervisor TPS3809K33-Q1
2. Connect the EVM to a power supply (24 V).
3. Connect the USB debugging interface and J14 of the EVM using a ribbon cable.
4. Start Code Composer Studio and import the project (HVL068A\_software.zip).
5. Select the project and press F11 or click on *Debug HVL068A – Cranking Simulator*
6. After programming of the microcontroller is finished, press F8 to start the program.
7. Debugging can be aborted by pressing CTRL + F2.
8. Unplug the USB cable from the computer.
9. Remove the ribbon cable between the EVM and the USB debugging interface.
10. Insert jumper J13 on the EVM.
11. The EVM is now ready to be used with the new firmware.

### 4.2.2 Using the MSP430 LaunchPad

1. Remove all five jumpers (VCC, TEST, RST, RXD, TXD) of J3 on the LaunchPad.
2. Remove jumper J13, close to the microcontroller, to disconnect the reset line from the supply voltage supervisor TPS3809K33-Q1.
3. Make sure that the EVM is **NOT** connected to a power supply.
4. Connect the EVM and LaunchPad as follows using jumper cables.

EVM	LaunchPad	Description
J14-4	J3 VCC (emulation side)	Voltage to supply the MSP430 from LaunchPad
J14-8	J3 TEST (emulation side)	Spy-Bi-Wire test clock
J14-1	J3 RST (emulation side)	Spy-Bi-Wire test data input/output
J14-9	J6 GND (MSP-EXP430G2 side)	Ground connection



5. Connect the LaunchPad to the computer using the USB cable.
  - (a) The microcontroller is now supplied by the LaunchPad and the LEDs Program 1 and Single Cont. S are shining.
  - (b) The user interface (push-buttons, LEDs) is working.
6. Start Code Composer Studio and import the project (HVL068A\_software.zip).
7. Select the project and press F11 or click on **Debug HVL068A – Cranking Simulator**.
8. After programming of the microcontroller is finished, press F8 to start the program.
9. Debugging can be aborted by pressing CTRL + F2.
10. Unplug the USB cable from the computer.
11. Remove the four jumper cables between the EVM and the LaunchPad.
12. Insert jumper J13 on the EVM.
13. The EVM is now ready to be used with the new firmware.

## 5 Mechanical Parts and Housing

The shape of the board fits into a standard housing. Addition of the following components makes the board into a complete tool, including labeled front and back cover.

**Table 1. Optional Mechanical Housing**

Count	Description	Manufacturer Part Number	Manufacturer	Distributor	Distributor Part Number
1	Box, ABS, black 5.29 × 5.32 × 2.01 in. (13.4 × 13.5 × 5.11 cm)	1598BBK	Hammond Manufacturing	Digikey	HM163-ND
2	Jam nut, 0.623 in. (1.58 cm), brass, 1/2-28	1-329631-2	TE Connectivity	Digikey	A1128-ND
1	Knob, 6-mm	CR-R3A-5C6-T18	Multicomp	Farnell (GER)	1441148
1	Front panel, aluminum	Custom drawing	Schaeffer AG (GER, Berlin) or Front Panel Express (US, Seattle)	–	–
1	Back panel, aluminum	Custom drawing	Schaeffer AG (GER, Berlin) or Front Panel Express (US, Seattle)	–	–

The mechanical data for the front and back panels are available on <http://www.ti.com/tool/pmp7233>.

## 6 Board Layout

Figure 7, Figure 8, Figure 9, and Figure 10 show the board layout for the HVL068A Cranking Simulator EVM.

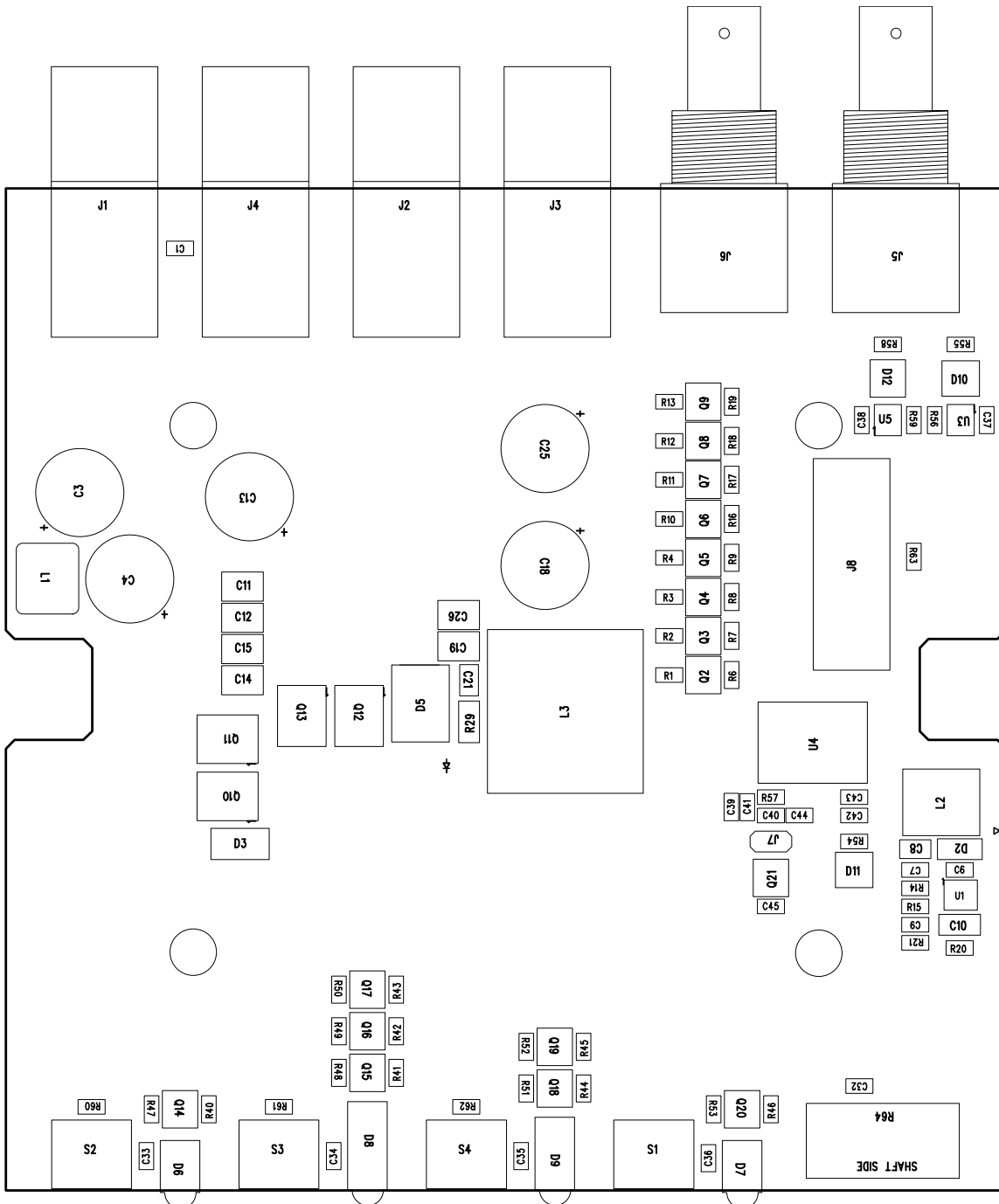
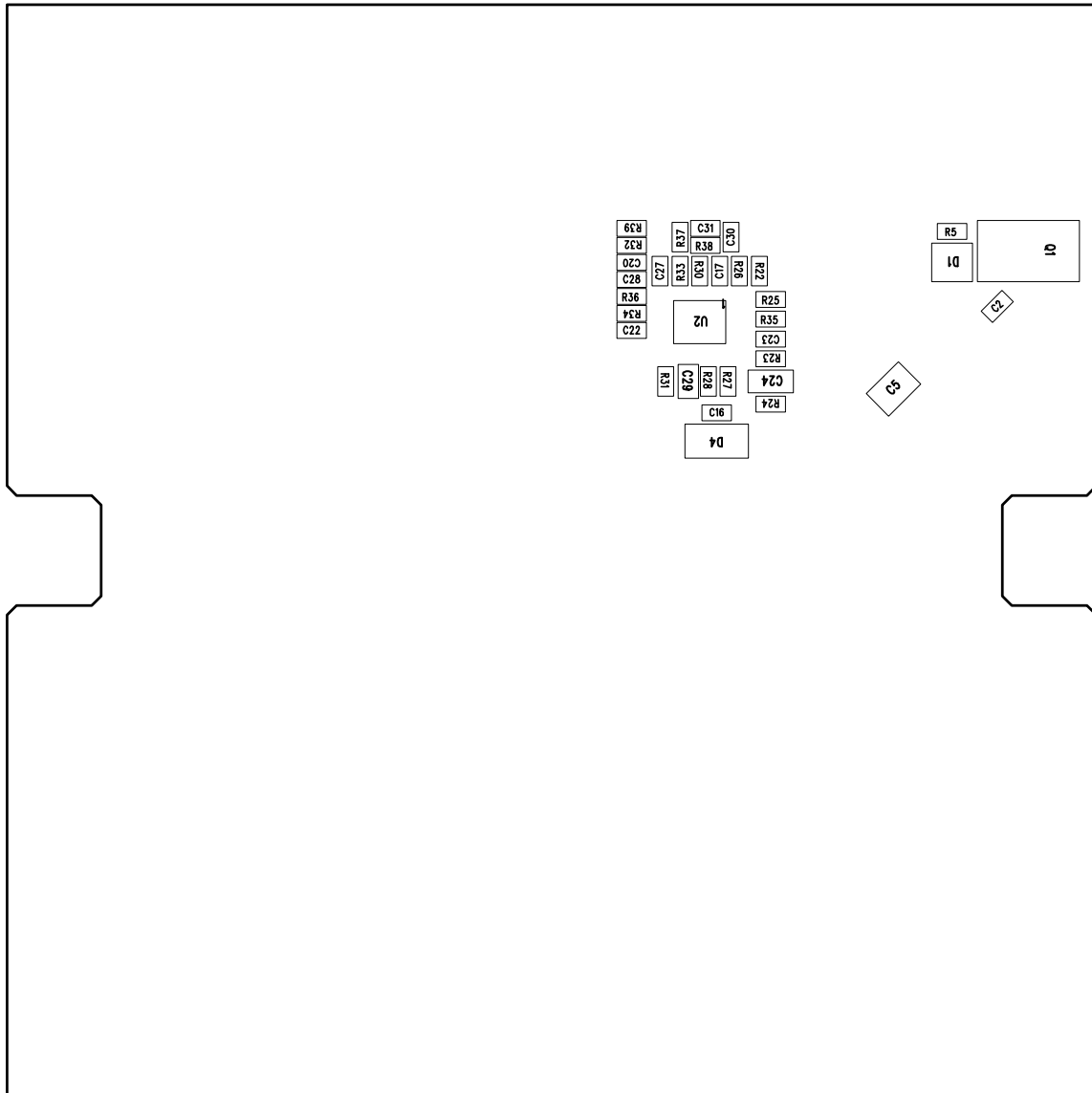


Figure 7. Top Assembly Layer



**Figure 8. Bottom Assembly Layer**

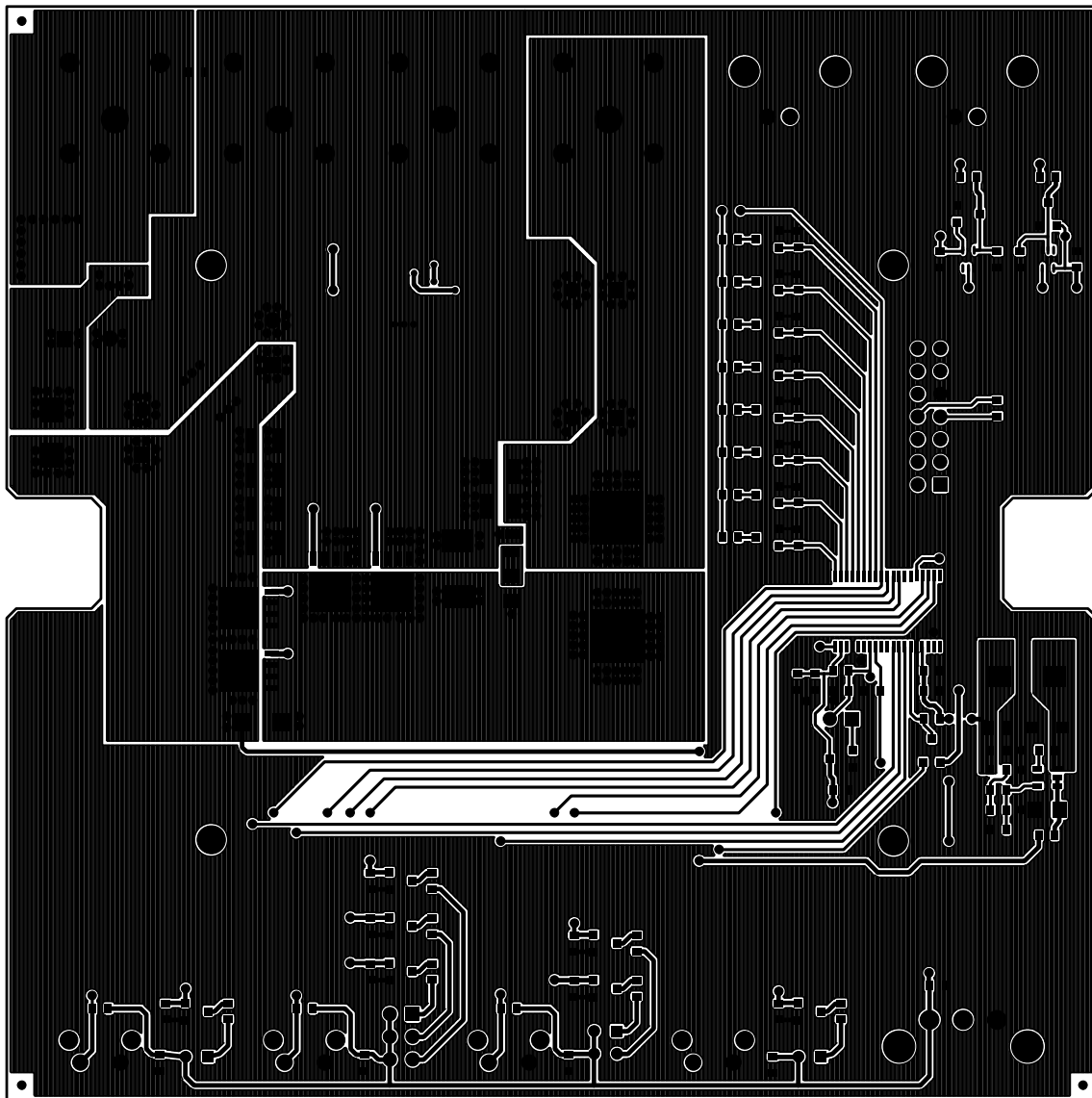
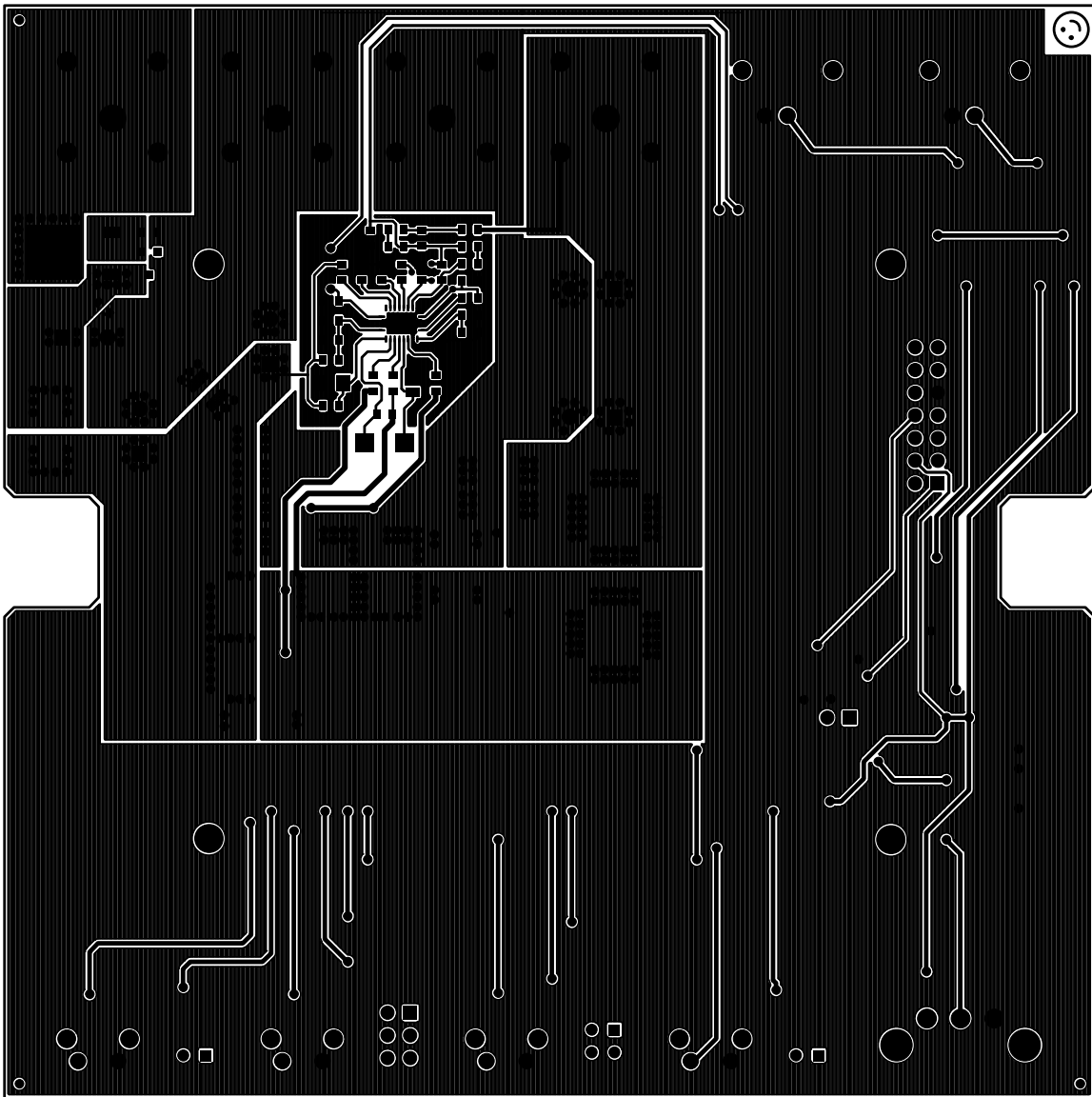


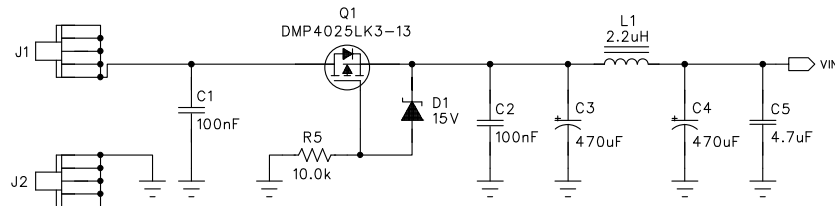
Figure 9. Top Layer Routing



**Figure 10. Bottom Layer Routing**

7 Schematics

Input  
20..28V, 24V nom.



8-Bit VID-Interface for 2.15V output  
7: 909R, 6: 1.82k, 5: 3.65k, 4: 7.32k  
3: 14.7k, 2: 29.4k, 1: 59.0k, 0: 118k

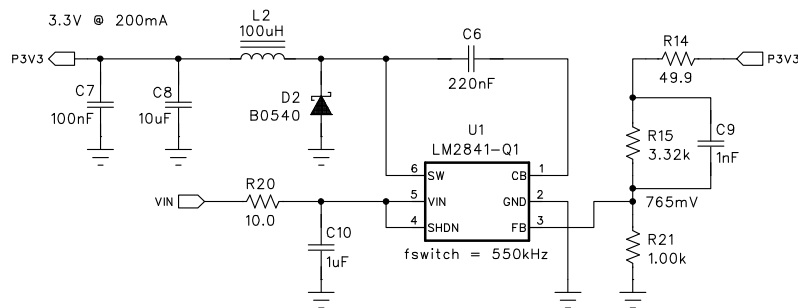
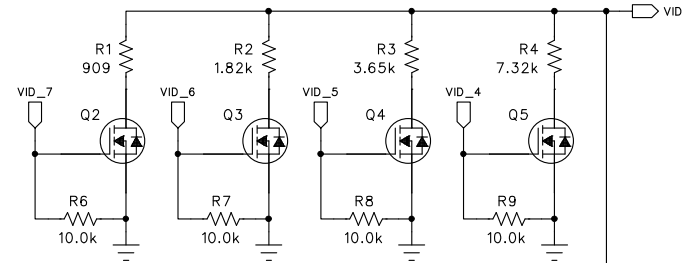
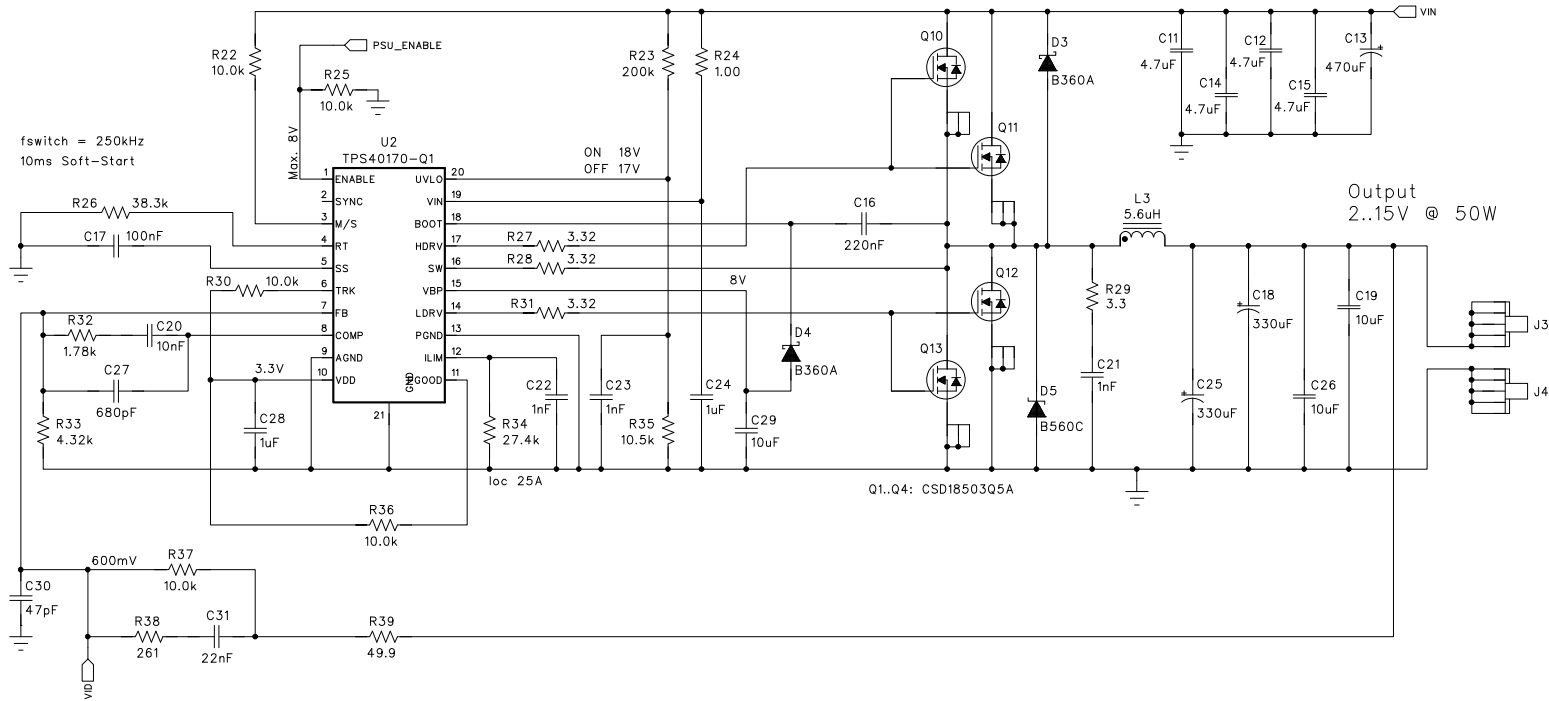


Figure 11. Input Filter, Bias Supply, VID-Interface (Schematic 1 of 4)



**Figure 12. Adjustable Synchronous Buck Converter (Schematic 2 of 4)**



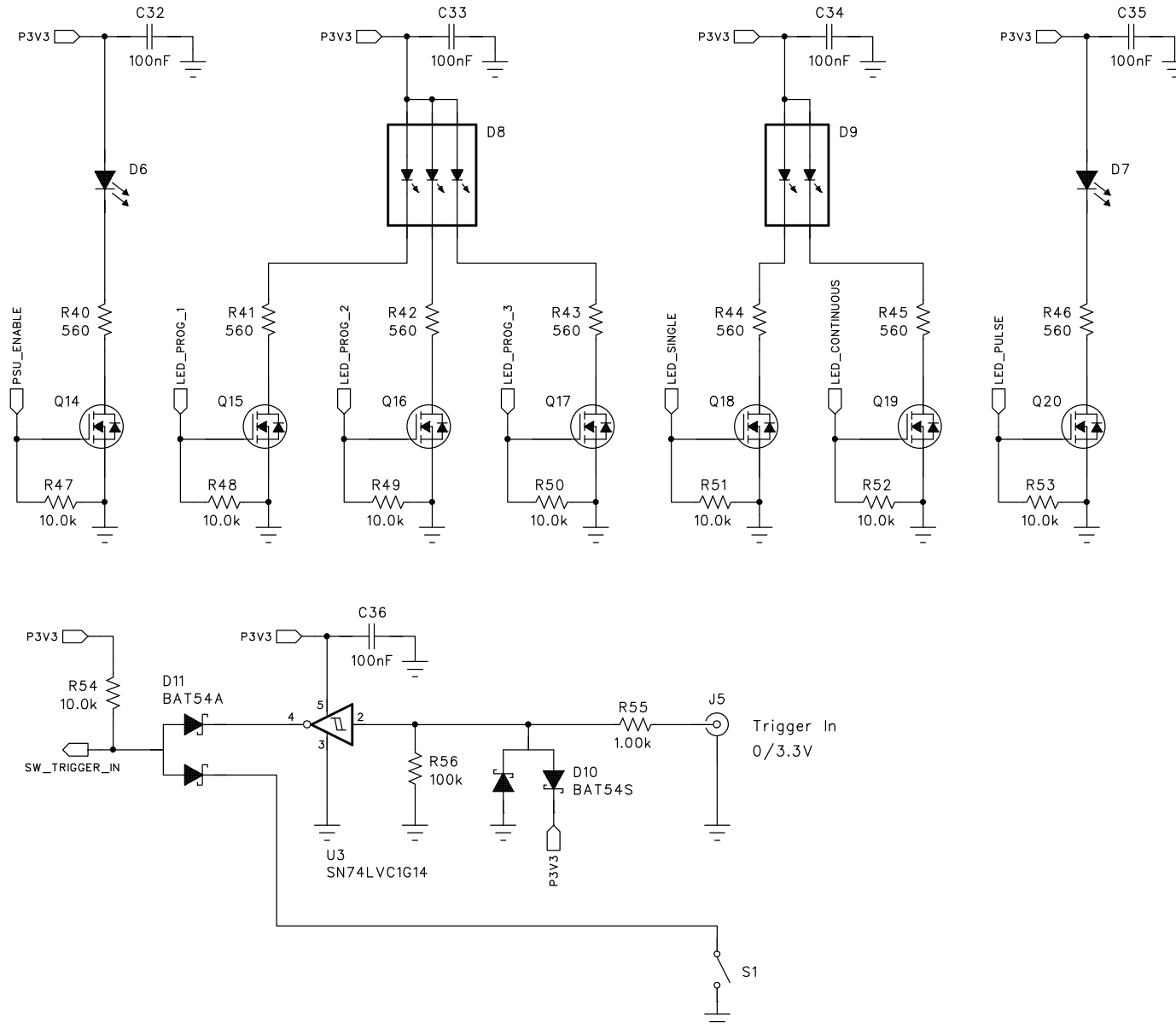


Figure 13. LEDs, Trigger Input (Schematic 3 of 4)

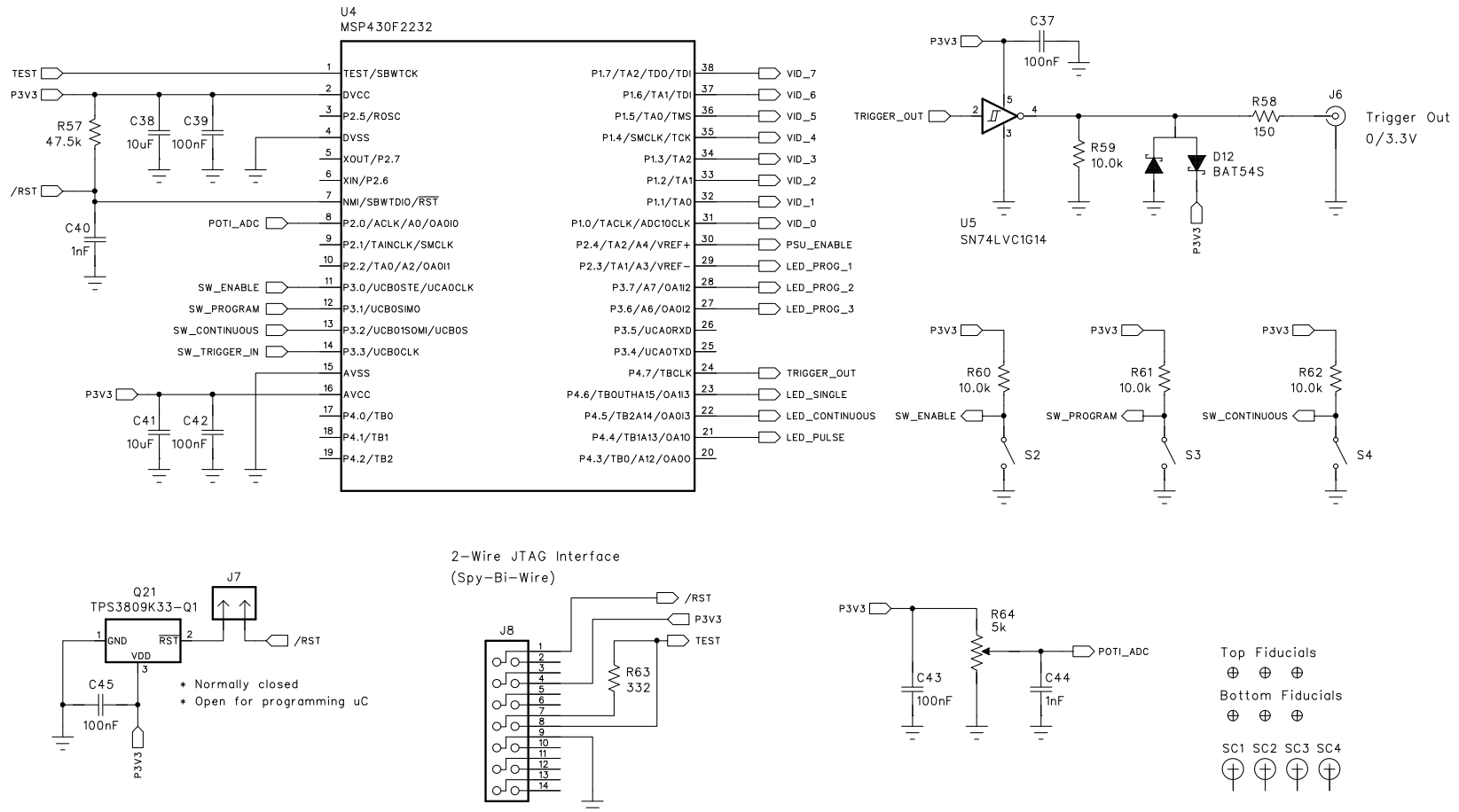


Figure 14. Microcontroller, Trigger Output, Switches, JTAG Interface, Reset Circuit (Schematic 4 of 4)

## 8 Bill of Materials

**Table 2. Bill of Materials**

Count	RefDes	Value	Description	Part Number	Manufacturer
14	C1, C2, C7, C17, C32–C37, C39, C42, C43, C45	100 nF	Capacitor, ceramic, 50-V, X7R, 10%	CL10B104KB8SFNC	Samsung Electro-Mechanics America, Inc
3	C3, C4, C13	470 µF	Capacitor, electrolytic, 35-V, 28mΩ, 1.76A	EKZM350ELL471MJ16S	United Chemi-Con
5	C5, C11, C12, C14, C15	4.7 µF	Capacitor, ceramic, 50-V, X7R, 10%	CL32B475KBUYNNE	Samsung Electro-Mechanics America, Inc
2	C6, C16	220 nF	Capacitor, ceramic, 50-V, X5R, 10%	CL10A224KB8NNNC	Samsung Electro-Mechanics America, Inc
2	C8, C29	10 µF	Capacitor, ceramic, 16-V, X5R, 10%	CL21A106KOFNNNE	Samsung Electro-Mechanics America, Inc
5	C9, C22, C23, C40, C44	1 nF	Capacitor, ceramic, 50-V, X7R, 10%	CL10B102KB8SFNC	Samsung Electro-Mechanics America, Inc
2	C10, C24	1 µF	Capacitor, ceramic, 50-V, X7R, 10%	CL31B105KBHNNNE	Samsung Electro-Mechanics America, Inc
2	C18, C25	330 µF	Capacitor, electrolytic, 25-V, 27-mΩ, 1.4-A	25ZLG330MEFC10X12.5	Rubycon
2	C19, C26	10 µF	Capacitor, ceramic, 25-V, X5R, 10%	CL32A106KAULNNE	Samsung Electro-Mechanics America, Inc
1	C20	10 nF	Capacitor, ceramic, 50-V, X7R, 10%	CL10B103KB8NNNC	Samsung Electro-Mechanics America, Inc
1	C21	1 nF	Capacitor, ceramic, 50-V, X7R, 10%	CL21B102KBANNNC	Samsung Electro-Mechanics America, Inc
1	C27	680 pF	Capacitor, ceramic, 50-V, X7R, 10%	CL10B681KB8NNNC	Samsung Electro-Mechanics America, Inc
1	C28	1 µF	Capacitor, ceramic, 16-V, X5R, 10%	CL10A105KO8NNNC	Samsung Electro-Mechanics America, Inc
1	C30	47 pF	Capacitor, ceramic, 50-V, NP0, 5%	CL10C470JB8NCNC	Samsung Electro-Mechanics America, Inc
1	C31	22 nF	Capacitor, ceramic, 50-V, X7R, 10%	CL10B223KB8NNNC	Samsung Electro-Mechanics America, Inc
2	C38, C41	10 µF	Capacitor, ceramic, 6.3-V, X5R, 20%	CL10A106MQ8NNNC	Samsung Electro-Mechanics America, Inc
1	D1	15 V	Diode, Zener, 15-V, 225-mW	BZX84C15-7-F	Diodes Inc.
1	D2	B0540	Diode, Schottky, 40-V, 0.5-A	B0540W-7-F	Diodes Inc.
2	D3, D4	B360A	Diode, Schottky, 60-V, 3-A	B360A-13-F	Diodes Inc.
1	D5	B560C	Diode, Schottky, 60-V, 5-A	B560C-13-F	Diodes Inc.
1	D6	WP934CB/GD	LED, right angle, green	WP934CB/GD	Kingbright Company LLC
1	D7	WP934CB/YD	LED, right angle, yellow	WP934CB/YD	Kingbright Company LLC
1	D8	WP934SA/3GD	LED, tri-level, green	WP934SA/3GD	Kingbright Company LLC
1	D9	WP934EB/2GD	LED, bi-level, green	WP934EB/2GD	Kingbright Company LLC
2	D10, D12	BAT54S	Diode, dual Schottky, 30-V, 200-mA	BAT54S-7-F	Diodes Inc.
1	D11	BAT54A	Diode, dual Schottky, 30-V, 200-mA	BAT54A-7-F	Diodes Inc.
2	J1, J3	23.3200-22	Connector, banana plug, red	23.3200-22	Multi Contact
2	J2, J4	23.3200-21	Connector, banana plug, black	23.3200-21	Multi Contact
2	J5, J6	731000131	Connector, right-angle BNC, PCB mount	731000131	Molex Inc
1	J7	PEC02SAAN	Header, male 2-pin, 100-mil (2.54-mm) spacing,	M20-9990246	Harwin Inc
1	J8	2514-6002UB	Header, 2 × 7 pin, 100-mil (2.54-mm) spacing, straight, 4 wall	302-S141	On Shore Technology Inc
1	L1	2.2 µH	Inductor, power, 12-mΩ, 9-A rms, 13-A sat.	744311220	Würth Electronics Inc
1	L2	100 µH	Inductor, SMT, 1-Ω, 0.65-A rms, 0.50-A sat.	744778520	Würth Electronics Inc
1	L3	5.6 µH	Inductor, 2.8-mΩ, 25-A rms, 27-A sat.	7443557560	Würth Electronics Inc
1	Q1	DMP4025LK3-13	MOSFET, P-ch., 40-V, 6.7-A, 25-mΩ	DMP4025LK3-13	Diodes Inc.
15	Q2, Q9, Q14–Q20	2N7002	MOSFET, N-ch., 60-V, 115-mA, 1.2-Ω	2N7002-7-F	Diodes Inc.
4	Q10–Q13	CSD18503Q5A	MOSFET, N-ch., 40-V, 3.4-mΩ, 27-nC	CSD18503Q5A	Texas Instruments

**Table 2. Bill of Materials (continued)**

Count	RefDes	Value	Description	Part Number	Manufacturer
1	Q21	TPS3809K33-Q1	IC, supply voltage supervisor, 3.3-V	TPS3809K33QDBVR Q1	Texas Instruments
1	R1	909 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07909RL	Yaego
1	R2	1.82 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-071K82L	Yaego
1	R3	3.65 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-073K65L	Yaego
1	R4	7.32 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-077K32L	Yaego
26	R5–R9, R16–R19, R22–R25, R30, R36, R37, R47–R54, R59–R62	10.0 k $\Omega$	Resistor, Chip, 1/16W, 1%	RC0603FR-0710KL	Yaego
1	R10	14.7 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0714K7L	Yaego
1	R11	29.4 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0729K4L	Yaego
1	R12	59.0 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0759KL	Yaego
1	R13	118 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07118KL	Yaego
2	R14, R39	49.9 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0749R9L	Yaego
1	R15	3.32 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-073K32L	Yaego
1	R20	10.0 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0710RL	Yaego
2	R21, R55	1.00 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-071KL	Yaego
1	R23	200 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07200KL	Yaego
1	R24	1.00 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-071RL	Yaego
1	R26	38.3 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0738K3L	Yaego
3	R27, R28, R31	3.32 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-073R32L	Yaego
1	R29	3.3 $\Omega$	Resistor, chip, 1/4W, 10%	RC1206JR-073R3L	Yaego
1	R32	1.78 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-071K78L	Yaego
1	R33	4.32 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-074K32L	Yaego
1	R34	27.4 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0727K4L	Yaego
1	R35	10.5 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0710K5L	Yaego
1	R38	261 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07261RL	Yaego
7	R40–R46	560 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07560RL	Yaego
1	R56	100 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07100KL	Yaego
1	R57	47.5 k $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-0747K5L	Yaego
1	R58	150 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07150RL	Yaego
1	R63	332 $\Omega$	Resistor, chip, 1/10-W, 1%	RC0603FR-07332RL	Yaego
1	R64	5 k $\Omega$	Potentiometer, carbon, 1/8-W, vert. adjust	296XD502B1N	CTS Electrocomponents
4	S1–S4	FSMRA7JH	Switch, tactile	FSMRA7JH	TE Connectivity
1	U1	LM2841-Q1	IC, step-down dc-dc regulator, 300-mA	LM2841XQMK/NOPB	Texas Instruments
1	U2	TPS40170-Q1	IC, 4.5-V–60-V sync. PWM buck controller	TPS40170QRGYRQ1	Texas Instruments
2	U3, U5	SN74LVC1G14	IC, single Schmitt-trigger inverter	SN74LVC1G14DCKR	Texas Instruments
1	U4	MSP430F2232	IC, mixed-signal microcontroller	MSP430F2232IDAR	Texas Instruments

## STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.
  - 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 semiconductor 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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.
  - 2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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:*

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

#### Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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。
3. 技術基準適合証明を取得後ご使用いただく。

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#### 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 WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (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 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 AND CONDITIONS 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 MADE, CONCEIVED OR ACQUIRED PRIOR TO OR AFTER DELIVERY OF THE EVM.

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 AND CONDITIONS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

8.1 *General Limitations.* IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS AND CONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, 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 ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

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

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TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
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Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
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