TPS92682EVM Constant Current Two-channel Boost And Boost-to-Battery

User's Guide

Literature Number: SLUUC13A
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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/customer 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.

TPS92682EVM Constant Current Two-channel Boost and Boost-to-Battery

This user's guide describes the specifications, board connection description, characteristics, operation, and use of the TPS92682-Q1 constant current (CC) mode in boost and boost-to-battery configurations. The TPS92682-Q1 device implements a fixed-frequency peak current mode control technique with programmable switching frequency, slope compensation, and soft-start. Additional features include wide input voltage range (4.5 V to 65 V), programmable spread spectrum frequency modulation, programmable fault handling, and adjustable output current setting. A complete schematic diagram, printed circuit board layouts, and bill of materials are included in this document.

1 Trademarks

SimpleLink, LaunchPad are trademarks of Texas Instruments.

2 Description

The TPS92682EVM-70 solution provides a two channel, constant current boost and boost-to-battery LED current regulator which is configurable via serial peripheral interface (SPI). The EVM is designed to operate with an input voltage in the range of 6.5 V to 20 V. The EVM provides maximum output power of 25 W for boost channel and 15 W for the boost-to-battery channel. The TPS92682EVM-70 provides high efficiency, SPI programmable fault handling, I_{LED} setting, and spread-spectrum. The channel-1 of the EVM is configured as CC boost and channel-2 as CC boost-to-battery.

2.1 Typical Applications

This document outlines the operation and implementation of the TPS92682-Q1 as a two-channel boost and boost-to-battery LED current regulator with the specifications listed in Table 3. For applications with a different input voltage range or different I_{LED} range, refer to the TPS92682-Q1 data sheet. The MSP-EXP432E401Y SimpleLink™ Ethernet MSP432E401Y MCU LaunchPad™ Development Kit controls the TPS92682EVM-70 evaluation board. The MSP-EXP432E401Y is available on TI website. However, any SPI controller can be used to program the TPS92682EVM board. Ensure that the LaunchPad board from TI has been programmed before running the GUI. The programming instructions are provided in Section 7.

2.2 Warnings

Observe the following precaution when using the TPS92682EVM-70 evaluation module.

Caution hot surface. Contact may cause burns. Do not touch.

2.3 Connector Description

Table 1 describes the connectors and Table 2 lists the test points on the EVM and how to properly connect, set up, and use the TPS92682EVM-70.

Figure 1 shows the connection diagram and the default jumper locations of the TPS92682EVM-70.

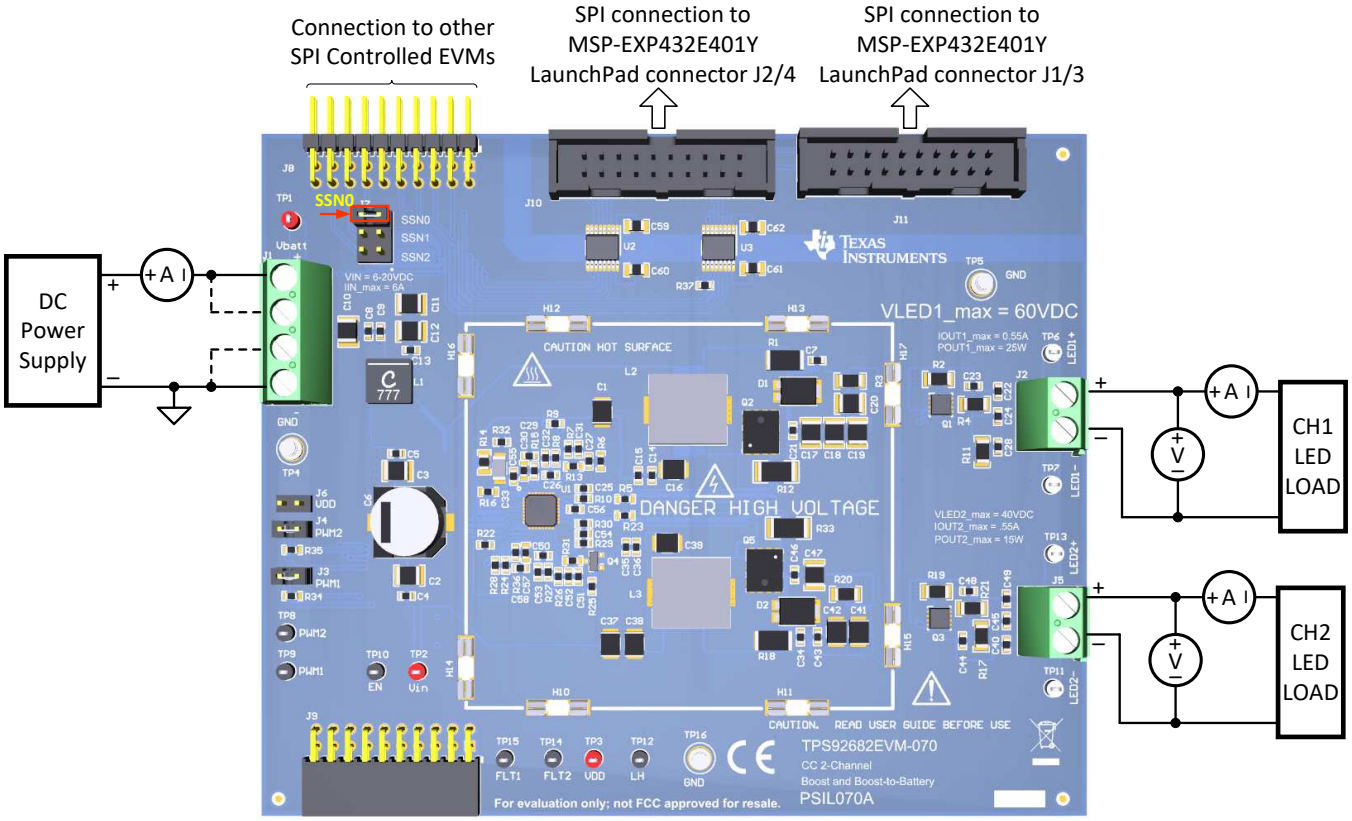


Figure 1. Component Connections

Table 1. Connector Descriptions

Connector	Label	Description
J10	SPI control from the MSP-EXP432E401Y LaunchPad	J10 and J11 allow attachment of a header cable for SPI control of the TPS92682-Q1 to the TI SimpleLink™ Ethernet MSP-EXP432E401Y MCU LaunchPad™ Development Kit, part number MSP-EXP432E401Y
J11		
J8	SPI control signals to other SPI controlled EVM	J8 and J9 allow star connection of TPS92682EVM-70 boards to each other with one MSP-EXP432E401Y control board.
J9		
J1	VIN, GND	J1 connects the input power to the TPS92682EVM-070. The board silkscreen identifies VIN pins with "Vbatt" and the "GND" markings.
J2	Channel-1 and Channel-2 and GND	J2 is connected to the channel-1 output and J5 is connected to the channel-2 output of the TPS92682EVM-070.
J5		
J6	VDD jumper	J6 is a jumper provided to share VDD with other SPI controlled EVM, in case a digital supply is needed. For the operation of this EVM, leave this jumper open.
J3	PWM1 and PWM2 jumpers	J3 and J4 are jumpers to apply external PWM signals to the two channels. When the jumpers are removed and the R28 and R29 zero-Ω resistors are installed, the PWM signals can be generated from the MSP-EXP432E401Y controller board. When the jumpers are populated (by default), the PWM1 and PWM2 pins of the TPS92682-Q1 are connected to VDD. The PWM signals can be used for PWM-dimming of the LED current.
J4		
J7	SSN configuration jumper	J7 allows configuration of the SSN chip select line, when multiple chips on the same SPI bus are used. By default, evaluation module is configured to be connected to the SSN0 of the MSP-EXP432E401Y controller board.

Table 2. Test Points

Test Point	Description
Metal turrets	All metal turrets are grounds.
VBAT	The VBAT test point allows for voltage measurement of the external power supply applied to the evaluation board.
VIN	The VIN test point allows for voltage measurement of the power applied to the boost and boost-to-battery channels after the EMI filter.
VDD	The VDD test point allows for voltage measurement of the VDD output of the TPS92682-Q1.
LH	The LH test point allows for applying a voltage to the LH pin and placing the TPS92682-Q1 in Limp Home mode
FLT1	The FLT1 test point can be used to monitor the fault occurrence of the channel-1. When a fault occurs, FLT1 voltage level goes low. Note that during power up, FLT1 is low (due to POR). The Fault pins can be reset by setting bit-7 of the EN register 0x00.
FLT2	The FLT2 test point can be used to monitor the fault occurrence of the channel-2. When a fault occurs, FLT2 voltage level goes low. Note that during power up, FLT2 is low (due to POR). The Fault pins can be reset by setting bit-7 of the EN register 0x00. The FLT2 test point can also be used for synchronizing of the TPS92682-Q1 with an external clock.
EN	EN test point is connected to the EN-pin of the TPS92682-Q1 device
PWM1	PWM1 test point is connected to the PWM1-pin of the TPS92682-Q1 device
PWM2	PWM2 test point is connected to the PWM2-pin of the TPS92682-Q1 device
LED1+	The LED1+ test point allows for voltage measurement of the channel-1 (boost) LED positive output.
LED1-	The LED1- test point is connected to the channel-1 (boost) LED negative output. This test point is connected to the EVM ground via a zero-Ω resistor
LED2+	The LED2+ test point is connected to the channel-2 (boost-to-battery) LED positive output.
LED2-	The LED2- test point is connected to the channel-2 (boost-to-battery) LED negative output.

3 REACH Compliance

In compliance with the Article 33 provision of the EU REACH regulation we are notifying you that this EVM includes component(s) containing at least one substance of very high concern (SVHC) above 0.1%. These uses from Texas Instruments do not exceed 1 ton per year. The SVHC speciifications are:

Component Manufacturer	Component part number	SVHC Substance	SVHC CAS (when available)
PHOENIX CONTACT GmbH & Co. KG	1715721 and 1715747	Lead (Pb)	7439-92-1

4 Performance Specifications

This section provides the performance specifications and requirements for the boost and boost-to-battery LED current regulators.

4.1 Boost Current Regulator

The Table 3 provides the EVM electrical performance specifications for the boost current regulator, channel-1.

Table 3. TPS92682EVM-070 Boost Channel Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage, V_{IN}		6.5	12	20	V
Maximum Input Current, I_{IN}				4	A
Output Characteristics					
LED forward voltage, $V_{F(LED)}$		2.8	3.0	3.2	V

Table 3. TPS92682EVM-070 Boost Channel Performance Specifications (continued)

Parameter	Test Conditions	MIN	TYP	MAX	UNITS
Number of LEDs N_{LED}			12		
Output voltage V_{OUT}	LED+ to LED–			60	
Maximum output current, I_{LED}				0.55	A
Maximum Output Power, P_{OUT}				25	W
PWM dimming frequency f_{PWM}			400		Hz
Systems Characteristics					
Switching frequency F_{SW}			400		kHz
Dither modulation f_{DM}		400		600	Hz
Output over-voltage threshold $V_{O(OV)}$				60	V

4.2 Boost-to-Battery Current Regulator

The Table 4 provides the EVM electrical performance specifications for the boost-to-battery current regulator, channel-2.

Table 4. TPS92682EVM-070 Boost-to-Battery Channel Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage, V_{IN}		6.5	12	20	V
Maximum Input Current, I_{IN}				2	A
Output Characteristics					
LED forward voltage, $V_{F(LED)}$		2.8	3.0	3.2	V
Number of LEDs N_{LED}			6		
Output voltage V_{OUT}	LED+ to LED–			40	V
Maximum output current, I_{LED}				0.55	A
Maximum Output Power, P_{OUT}				15	W
PWM dimming frequency f_{PWM}			400		Hz
Systems Characteristics					
Switching frequency F_{SW}			400		kHz
Dither modulation f_{DM}		400		600	Hz
Output over-voltage threshold $V_{O(OV)}$				40	V

5 Performance Data and Typical Characteristic Curves

Figure 2 and Figure 3 show the efficiency results for the boost and boost-to-battery vs. LED current, I_{LED}. The results show different number of series connected LEDs in the output. It is important to note that the efficiency results include the power loss in the input EMI filter.

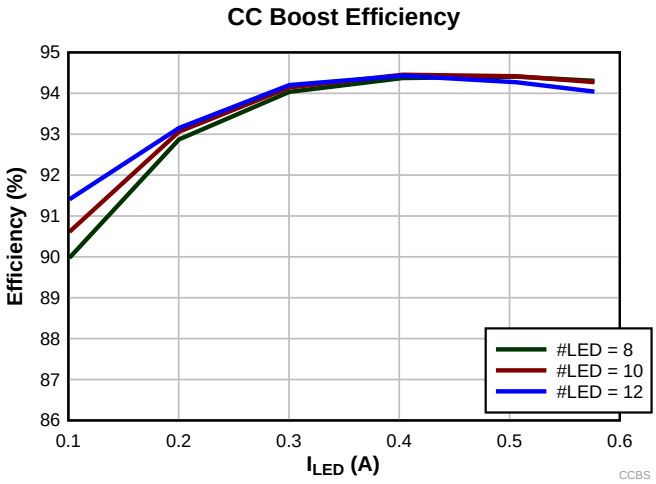


Figure 2. CC Boost Efficiency for V_{IN} = 12 V

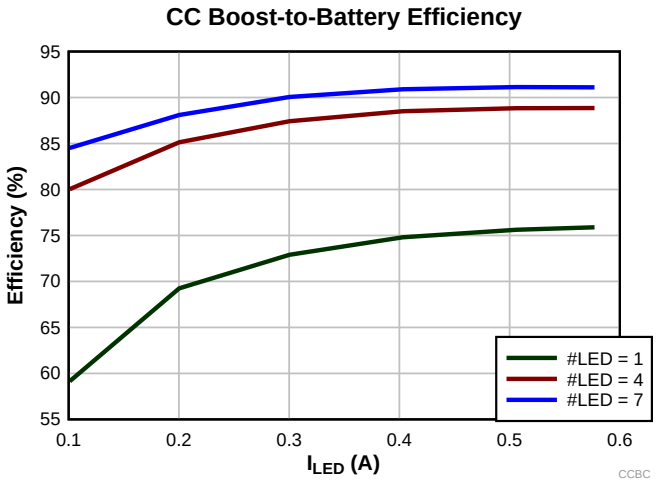


Figure 3. CC Buck-Boost Efficiency for V_{IN} = 12 V

5.1 Startup Waveforms

Figure 4 and Figure 5 show the startup waveforms, I_{LED} and Compensator voltage of the boost and boost-to-battery channels. In this setup, a string of 12×LEDs are connected to the output of the boost and 6×LEDs to the output of the boost-to-battery channel.

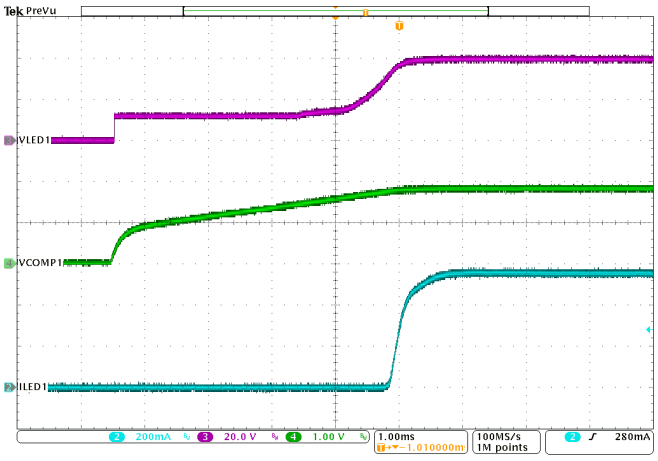


Figure 4. Softstart waveforms for CHxSS3:0 = 7

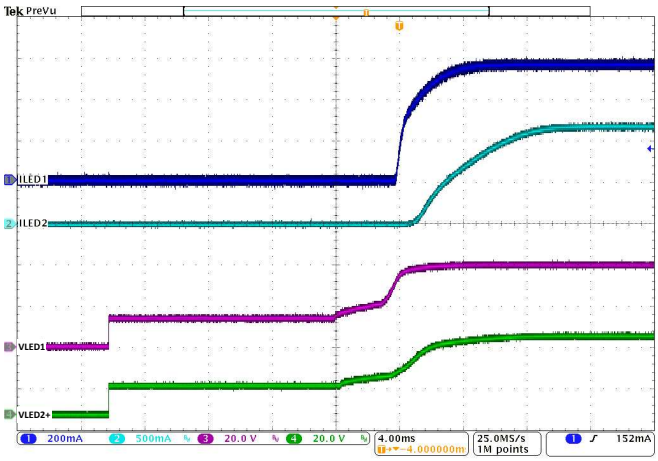
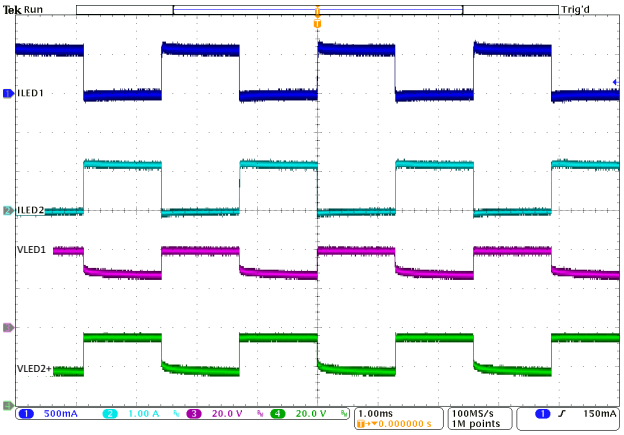


Figure 5. Softstart waveforms for CHxSS3:0 = 31

5.2 PWM Dimming

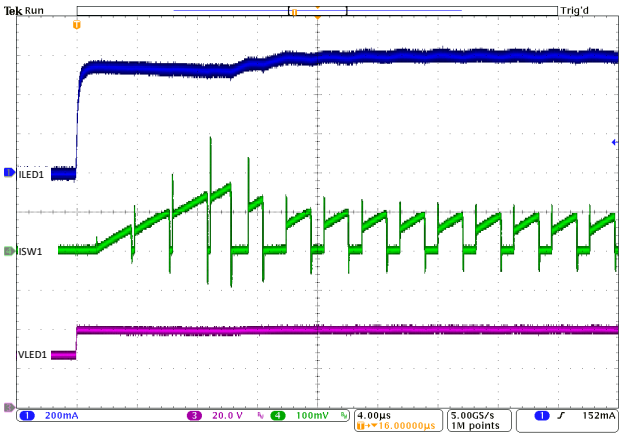
Figure 6 shows PWM dimming of the two boost and boost-to-battery channels of the TPS92682EVM-070. The I_{LED} is programmed to its maximum value. A string of 12×LEDs connected to the output of the boost and 6×LEDs to the output of the boost-to-battery channels. When internal PWM dimming counter is used, the two channels, by default, have 180° phase-shift.



V_{IN} = 12 V

Figure 6. CC Boost and Boost-to-Battery PWM Dimming

Figure 7 shows the switch current across the sense resistor at the rising edge of the PWM dimming for the boost channel.



V_{IN} = 12 V, and V_{OUT} = 40 V

Figure 7. CC Boost Switch Current Sense

5.3 Faults

TPS92682-Q1 include various fault handling and diagnostic features. Figure 8 and Figure 9 show the LED short protection for CC boost channel and LED open protection for the boost-to-battery channel.

As shown in Figure 8, when a short across the LED load occurs, the overcurrent (OC) protection is triggered (if OC Fault is enabled), the COMP-pin is pulled low, and the associated channel is turned off. The channel remains off for the programmed main fault timer (MFT), when the channel performs a soft-start sequence.

As shown in Figure 9, when open LED load occurs, the load voltage increases above the programmed overvoltage (OV) threshold, and the associated channel turns off. The channel remains off until the load voltage drops below a OV hysteresis value, when the channel performs a soft-start sequence. Set the OV threshold by programming the OV register and the OV detection resistor dividers.

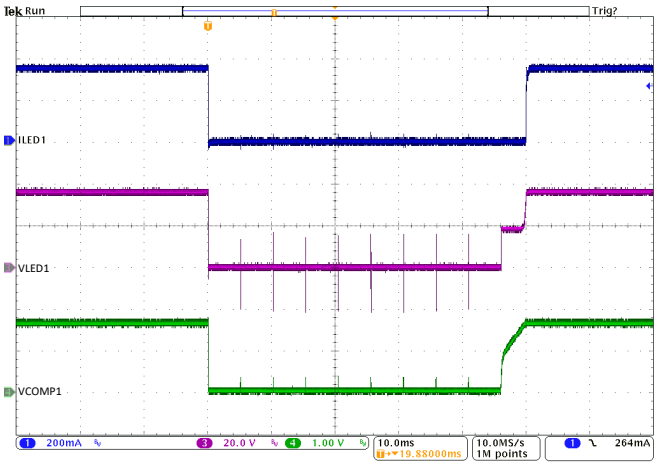


Figure 8. CC Boost LED Short Over-Current Protection

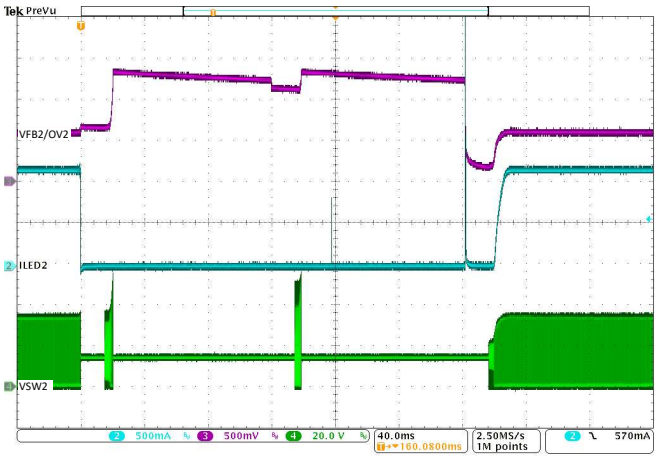
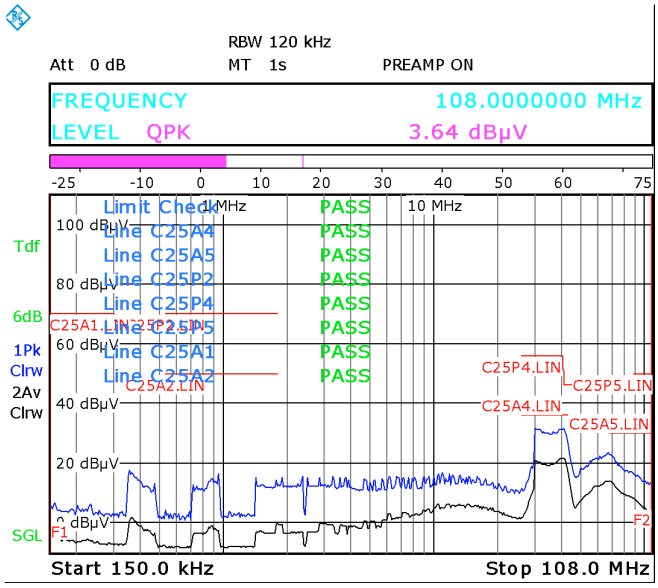


Figure 9. CC Boost-to-Battery LED Open Over-Voltage Protection

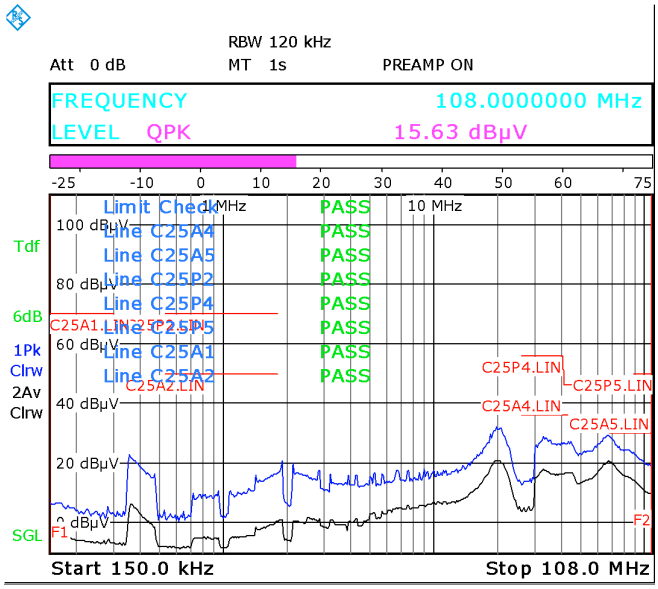
5.4 EMI Scan

Figure 10 shows the conducted EMI for the boost channel with 12 series connected LED load and I_{LED} = 570 mA. Figure 11 shows the conducted EMI for the boost-to-battery channel with 6 series connected LED load and I_{LED} = 570 mA.



VIN = 12 V, FMMAG = 3, FMFREQ = 5

Figure 10. CC Boost Conducted EMI Scan



VIN = 12 V, FMMAG = 1, FMFREQ = 5

Figure 11. CC Boost-to-Battery Conducted EMI Scan

6 Schematic, PCB Layout, and Bill of Materials

This section contains TPS92682EVM-70 schematics, PCB layouts, and bill of materials (BOM).

6.1 Schematic

Figure 12 illustrates the TPS92682EVM-70 schematic.

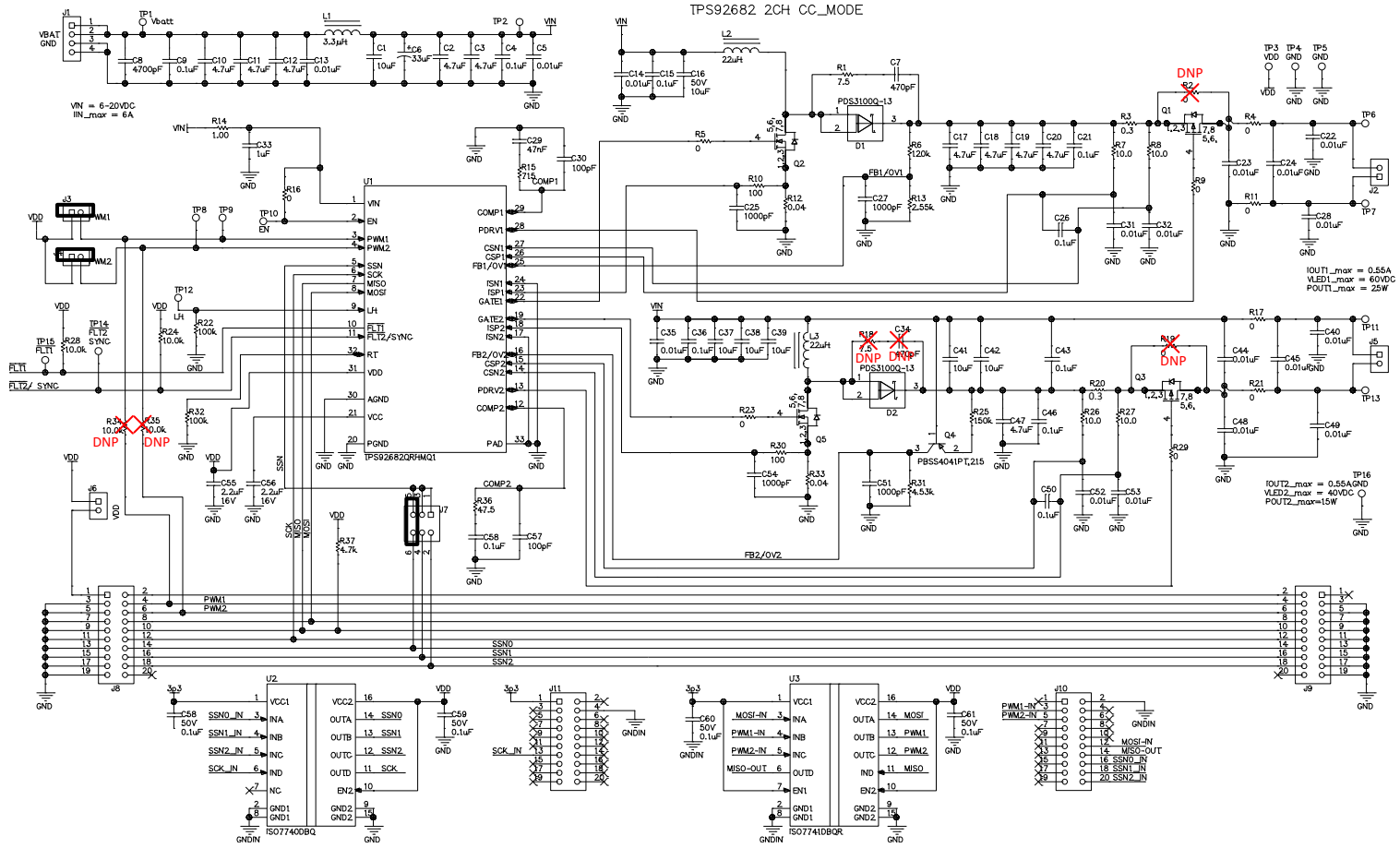


Figure 12. TPS92682EVM-70 Schematic

6.2 Layout

The TPS92682EVM-70 is a four-layer board. Figure 13, Figure 14, Figure 15, Figure 16 and Figure 17 illustrate the assembly, the top, the inner-layer1, the inner-layer2 and the bottom side of the TPS92682EVM-70 PCB layout. The Inner-layer 1 is a ground plane and there is no routing on this layer.

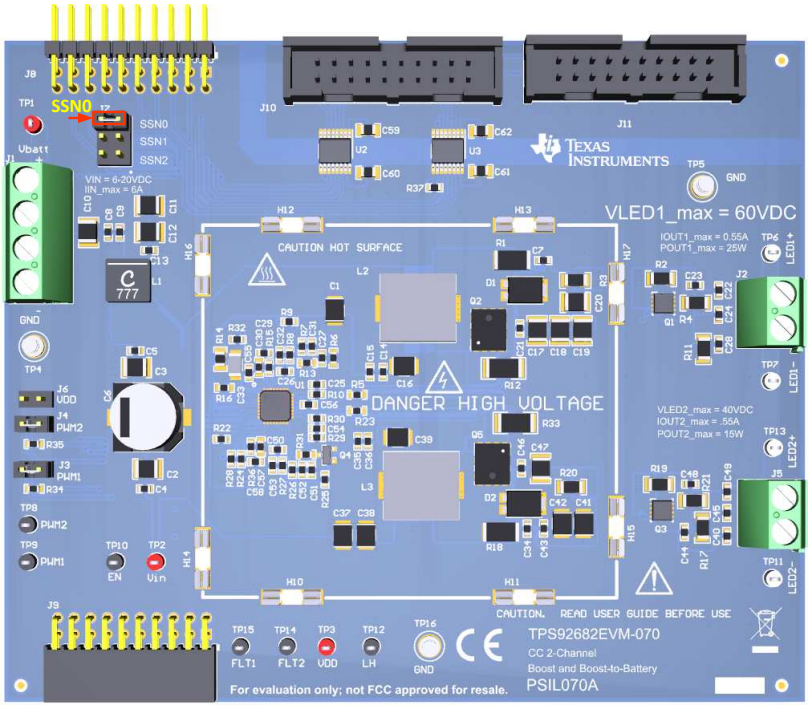


Figure 13. TPS92682EVM-70 Assembly

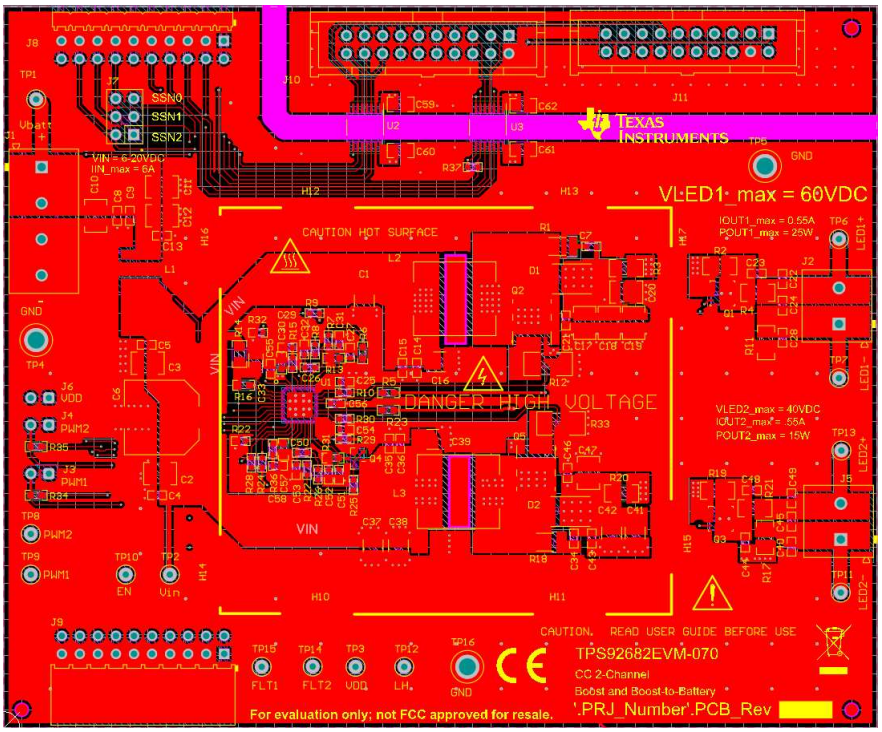


Figure 14. TPS92682EVM-70 Top Layer and Top Overlay (Top View)

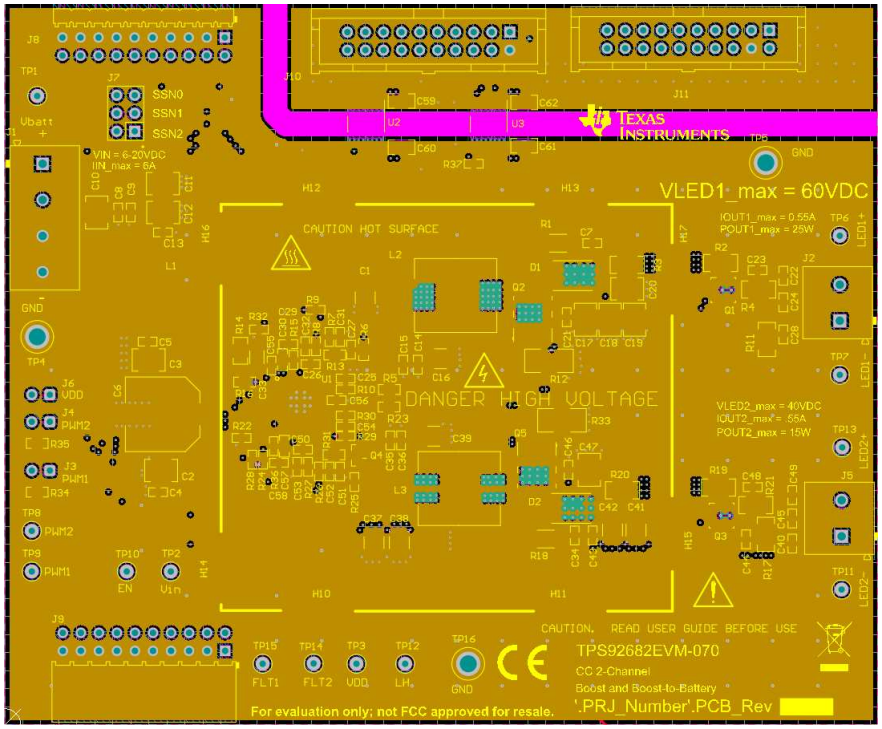


Figure 15. TPS92682EVM-70 Inner-layer 1

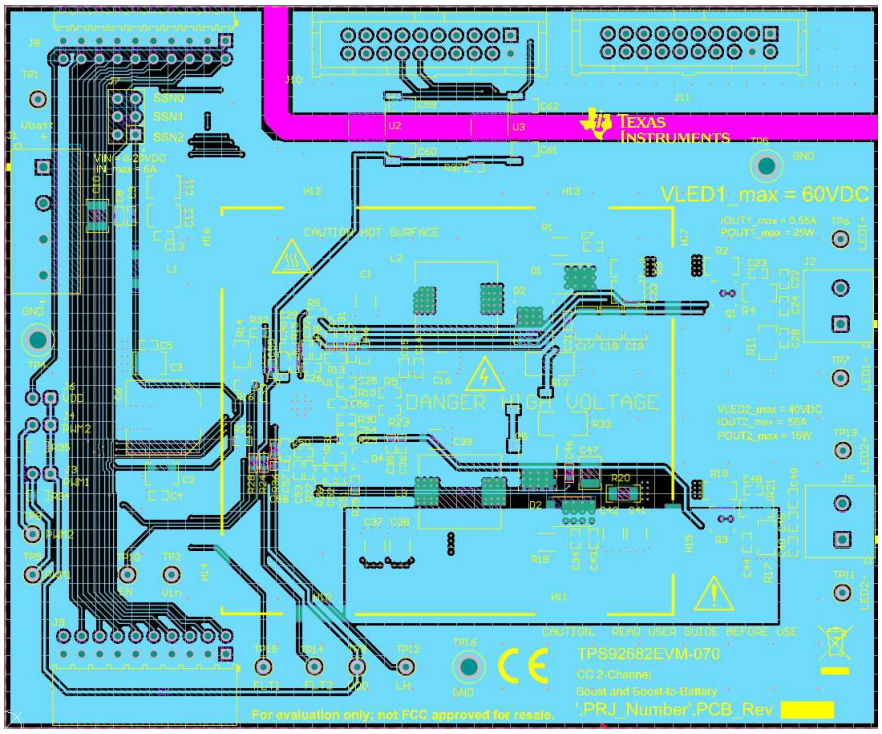


Figure 16. TPS92682EVM-70 Inner-layer 2

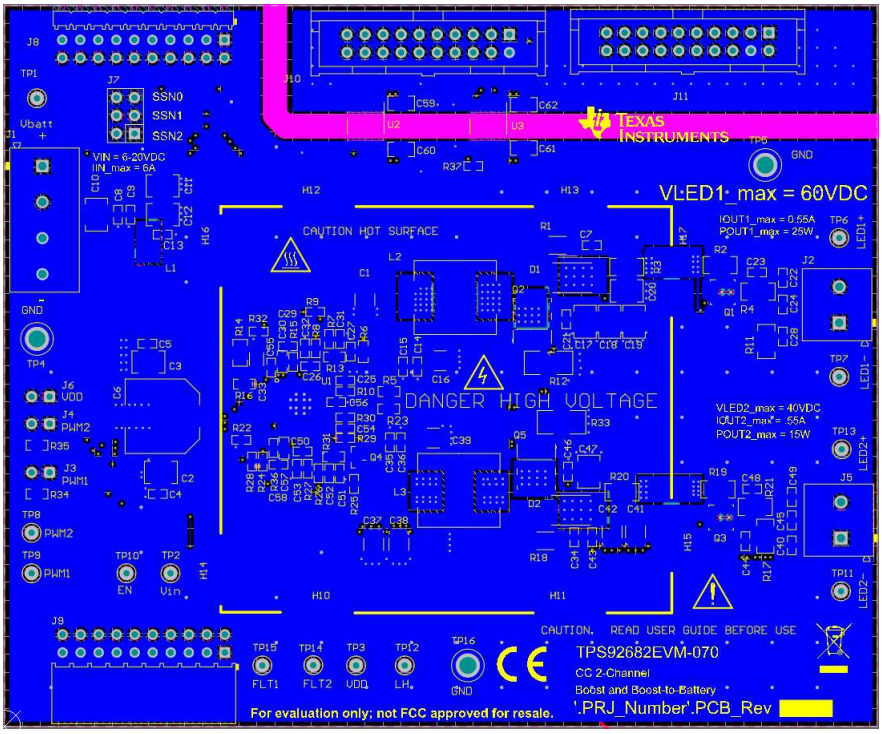


Figure 17. TPS92682EVM-70 Bottom Layer (Bottom View)

6.3 Bill of Materials

Table 5 lists the TPS92682EVM-70 bill of materials.

Table 5. TPS92682EVM-70 Bill of Materials

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
C1, C16, C37, C38, C39, C41, C42	7	10 µF	CAP, CERM, 10 uF, 50 V, ±20%, X7R	1210	C3225X7R1H106M250AC	TDK
C2, C3, C10, C11, C12, C17, C18, C19, C20, C47	10	4.7 µF	CAP, CERM, 4.7 uF, 100 V, ±10%, X7S	1210	C3225X7S2A475K200AB	TDK
C4, C9, C15, C21, C26, C36, C43, C46, C50	9	0.1 µF	CAP, CERM, 0.1 uF, 100 V, ±10%, X7R	0603	GRM188R72A104KA35D	MuRata
C5, C13, C14, C22, C23, C24, C28, C31, C32, C35, C40, C44, C45, C48, C49, C52, C53	17	0.01 µF	CAP, CERM, 0.01 uF, 100 V, ±10%, X7R, AEC-Q200 Grade 1	0603	CGA3E2X7R2A103K080AA	TDK
C6	1	33 µF	CAP, AL, 33 uF, 100 V, ±20%, AEC-Q200 Grade 2, SMD	D10xL10mm	MAL215097904E3	Vishay
C7	1	470 pF	CAP, CERM, 470 pF, 100 V, ±5%, C0G/NP0	0603	GRM1885C2A471JA01D	MuRata
C8	1	4700 pF	CAP, CERM, 4700 pF, 100 V, ±10%, X7R, AEC-Q200 Grade 1	0603	CGA3E2X7R2A472K080AA	TDK
C25, C27, C51, C54	4	1000 pF	CAP, CERM, 1000 pF, 50 V, ±10%, X7R	0603	GRM188R71H102KA01D	MuRata
C29	1	0.047 µF	CAP, CERM, 0.047 uF, 25 V, ±10%, X7R	0603	GRM188R71E473KA01D	MuRata
C30, C57	2	100 pF	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, 0603	0603	885012006057	Wurth Elektronik
C33	1	1 µF	CAP, CERM, 1 uF, 100 V, ±10%, X7R	1206	CL31B105KCHNNNE	Samsung
C55, C56	2	2.2 µF	CAP, CERM, 2.2 uF, 16 V, ±10%, X7R	0603	GRM188Z71C225KE43	MuRata
C58	1	0.1 µF	CAP, CERM, 0.1 uF, 100 V, ±10%, X7S, AEC-Q200 Grade 1	0603	CGA3E3X7S2A104K080AB	TDK
C59, C60, C61, C62	4	0.1 µF	CAP, CERM, 0.1 uF, 50 V, ±10%, X7R	0805	C0805C104K5RACTU	Kemet
D1, D2	2	100 V	Diode, Schottky, 100 V, 3 A, AEC-Q101	POWERDI5	PDS3100Q-13	Diodes Inc
H10, H12, H13, H14, H15, H16, H17, H18	8		RFI SHIELD CLIP TIN SMD		S2711-46R	Harwin
J1	1		Terminal Block, 5.08 mm, 4x1, TH	4POS Terminal Block	1715747	Phoenix Contact
J2, J5	2		Terminal Block, 5.08 mm, 2x1, TH	2POS Terminal Block	1715721	Phoenix Contact
J3, J4, J6	3		Header, 100 mil, Gold, TH	2x1	TSW-102-07-G-S	Samtec
J7	1		Header, 100 mil, Gold, TH	3x1	TSW-103-07-G-D	Samtec
J8	1		Header, 2.54 mm, Tin, R/A, TH	10x2	TSW-110-08-T-D-RA	Samtec
J9	1		Receptacle, 2.5 mm, Gold, R/A, TH	10x2	SSW-110-02-G-D-RA	Samtec
J10, J11	2		Header (shrouded), 100 mil, Gold, TH	10x2	5103309-5	TE Connectivity

Table 5. TPS92682EVM-70 Bill of Materials (continued)

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
L1	1	3.3 µH	Inductor, Shielded, Composite, 3.3 µH, 8 A, 0.02081 Ω, AEC-Q200 Grade 1, SMD	6.4x3.1x6.6	XAL6030-332MEB	Coilcraft
L2, L3	2	22 µH	Inductor, Shielded Drum Core, Powdered Iron, 22 uH, 4.1 A, 0.0705 Ω, AEC-Q200 Grade 0, SMD	10.2x4.0x10.2	IHLP4040DZER220M8A	Vishay
Q1, Q3	2	- 60 V	MOSFET, P-CH, -60 V, -3.6 A	PowerPAK 1212	SI7415DN-T1-GE3	Vishay
Q2, Q5	2	100 V	MOSFET, N-CH, 100 V, 20 A, AEC-Q101	8-PowerVDFN	STL8N10LF3	STMicroelectronics
Q4	1	60 V	Transistor, PNP, 60 V, 2.7 A, AEC-Q101	SOT-23	PBSS4041PT,215	NXP
R1	1	7.5 Ω	RES, 7.5, 5%, 0.75 W, AEC-Q200 Grade 0	2010	CRCW20107R50JNEF	Vishay
R3, R20	1	0.3 Ω	RES, 0.3, 1%, 0.5 W, AEC-Q200 Grade 1	1206	ERJ8BQFR30V	Panasonic
R4, R11, R17, R21	4	0	RES, 0, 5%, 0.25 W	1206	RC1206JR-070RL	Yageo America
R5, R9, R16, R23, R29	5	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW06030000Z0EA	Vishay
R6	1	120 kΩ	RES, 120 k, 0.1%, 0.1 W	0603	RT0603BRD07120KL	Yageo America
R7, R8, R26, R27	4	10 Ω	RES, 10.0, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW060310R0FKEA	Vishay
R10, R30	2	100 Ω	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW0603100RFKEA	Vishay
R12, R33	2	0.04 Ω	RES, 0.04, 1%, 1 W	2010	CSRN2010FK40L0	Stackpole
R13	1	2.55 kΩ	RES, 2.55 k, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW06032K55FKEA	Vishay
R14	1	1.0 Ω	RES, 1.00, 1%, 0.125 W, AEC-Q200 Grade 0	0805	CRCW08051R00FKEA	Vishay
R15	1	715 Ω	RES, 715, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW0603715RFKEA	Vishay
R22, R32	2	100 kΩ	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW0603100KFKEA	Vishay
R24, R28	2	10 kΩ	RES, 10 k, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW060310K0FKEA	Vishay
R25	1	150 kΩ	RES, 150 k, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW0603150KFKEA	Vishay
R31	1	4.53 kΩ	RES, 4.53 k, 1%, 0.1 W, AEC-Q200 Grade 0	0603	ERJ-3EKF4531V	Panasonic
R36	1	47.5 Ω	RES, 47.5, 1%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW060347R5FKEA	Vishay
R37	1	4.7 kΩ	RES, 4.7 k, 5%, 0.1 W, AEC-Q200 Grade 0	0603	CRCW06034K70JNEA	Vishay
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7	7		Shunt, 2.54mm, Gold, Black	2x1, 2.54mm	60900213421	Wurth Elektronik
TP1, TP2, TP3	3		Test Point, Miniature, Red, TH	TH	5000	keystone
TP4, TP5, TP16	3		Terminal, Turret, TH, Double	Turret	1502-2	keystone
TP6, TP7, TP11, TP13	4		Test Point, Miniature, White, TH	TH	5002	keystone
TP8, TP9, TP10, TP12, TP14, TP15	6		Test Point, Miniature, Black, TH	TH	5001	keystone
U1	1		Dual Channel Constant Voltage and Constant Current Controller with SPI Interface, RHM0032C (VQFNP-32)	RHM0032C	TPS92682QRHMQ1	Texas Instruments

Table 5. TPS92682EVM-70 Bill of Materials (continued)

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
U2	1		High-Speed, Low-Power, Robust EMC Quad-Channel Digital Isolator, DBQ0016A (SSOP-16)	DBQ0016A	ISO7740DBQ	Texas Instruments
U3	1		High Speed, Robust EMC Quad-Channel Digital Isolators, DBQ0016A (SSOP-16)	DBQ0016A	ISO7741DBQR	Texas Instruments

7 Software

This section describes the installation of the GUI software and the drivers needed to operate the TPS92682EVM-70.

7.1 Demonstration Kit Software Installation for MSP-EXP432E401Y LaunchPad Board

1. Righ-click on *TPS92682 LaunchPad Evaluation Software Installer.exe* and select **Run As Administrator**.
2. *Windows Account Control* asks to allow the program to make changes to the computer. Click **Yes**.
3. Select **Agree** to the installation license terms and install in the recommended location.
4. Installation may take a while, as it may need to install Microsoft .NET Framework.
5. If the installer asks to reboot after installing Microsoft .NET, click **restart later** to complete the driver installation.
6. After running the *TPS92682 LaunchPad Evaluation Software Installer.exe*, the evaluation software window appears as shown in Figure 18.

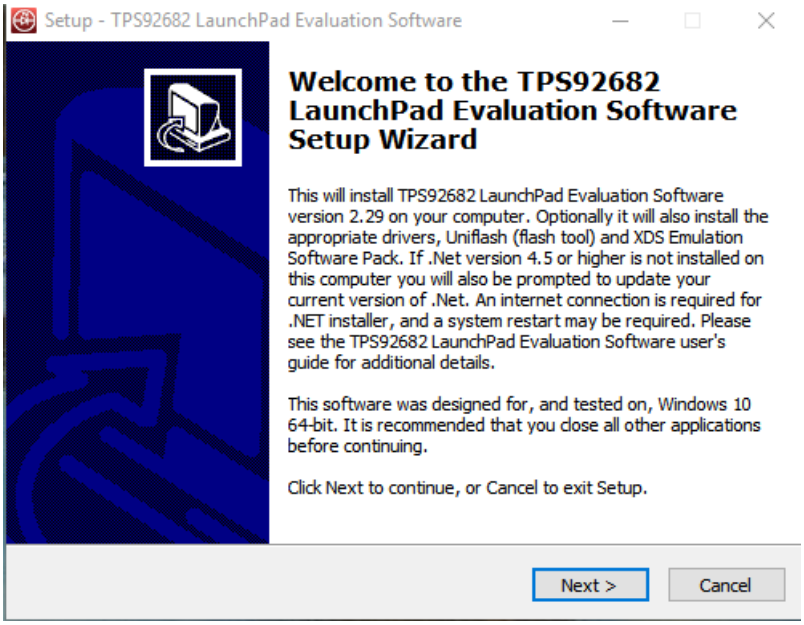


Figure 18. Setup Screen 1

Click **Next >** to install.

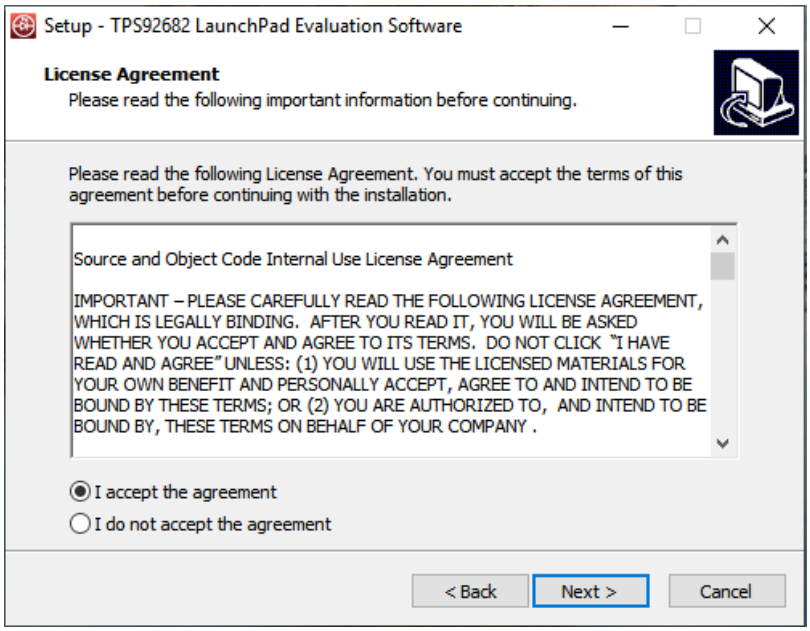


Figure 19. Setup Screen 2

Click **Next >** to accept the License Agreement.

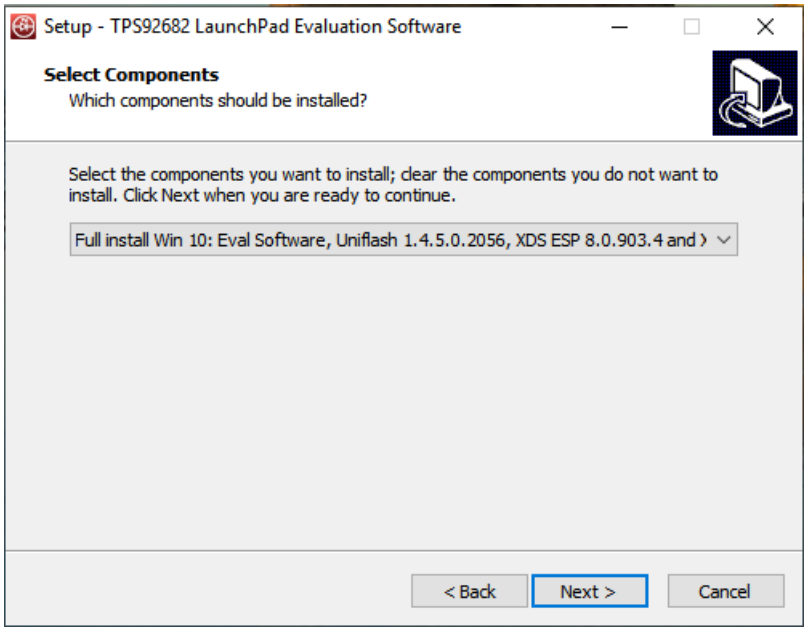


Figure 20. Setup Screen 3

Select **Full Install** and click **Next >** to install the evaluation software, the UniFlash, and the required XDS drivers. Full installation for both Windows 10 and 7 are provided.

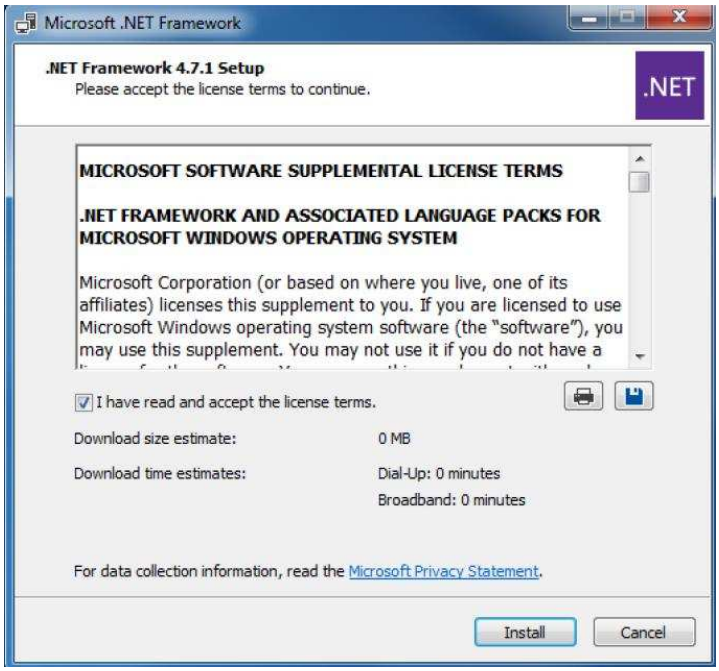


Figure 21. Setup Screen 4

If .NET Framework 4.5 or higher does not exist on the computer, the .NET Framework installation begins. Installation of .NET Framework will take several minutes. If .NET Framework 4.5 or higher exists on the computer, the installation jumps to the XDS driver installation.

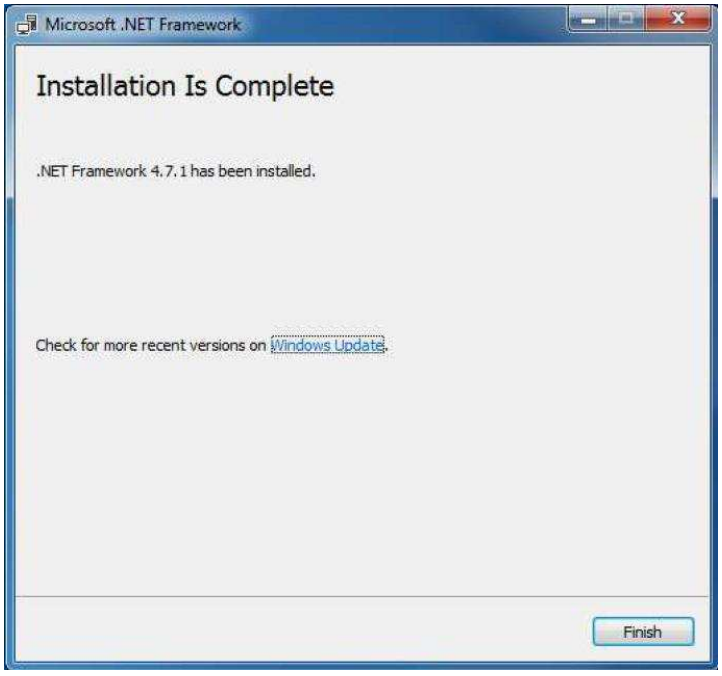


Figure 22. Setup Screen 5

A window appears indicating the completion of the .NET Framework installation.

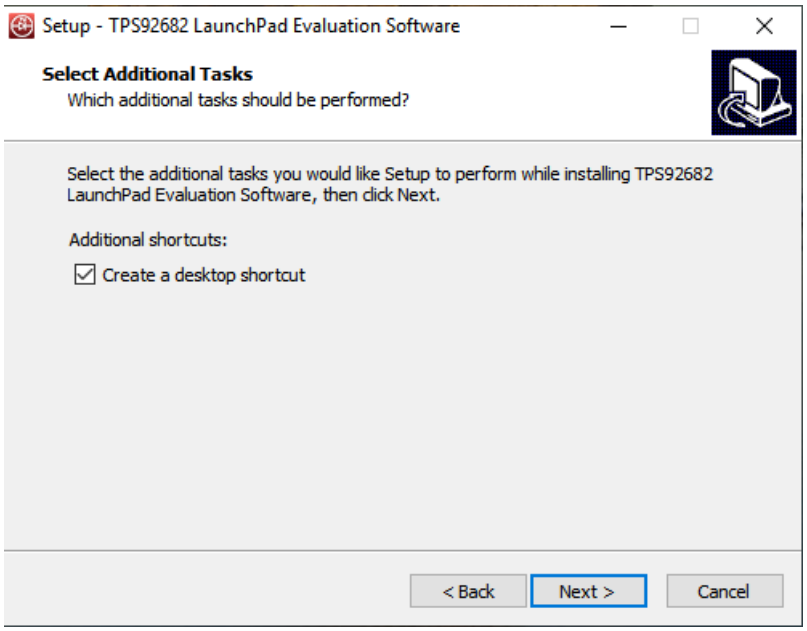


Figure 23. Setup Screen 6

Click **Next >** to continue the installation.

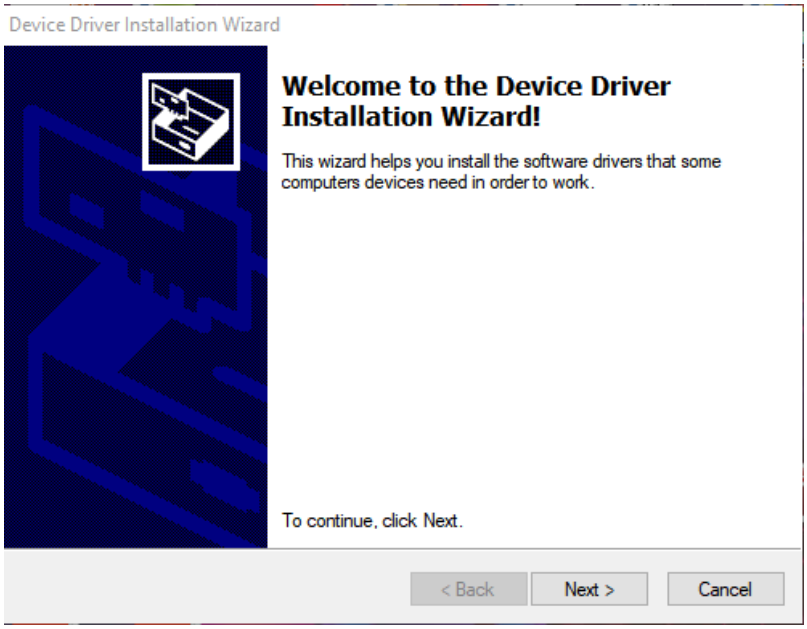


Figure 24. Setup Screen 7

Click **Next >** to install the XDS driver.

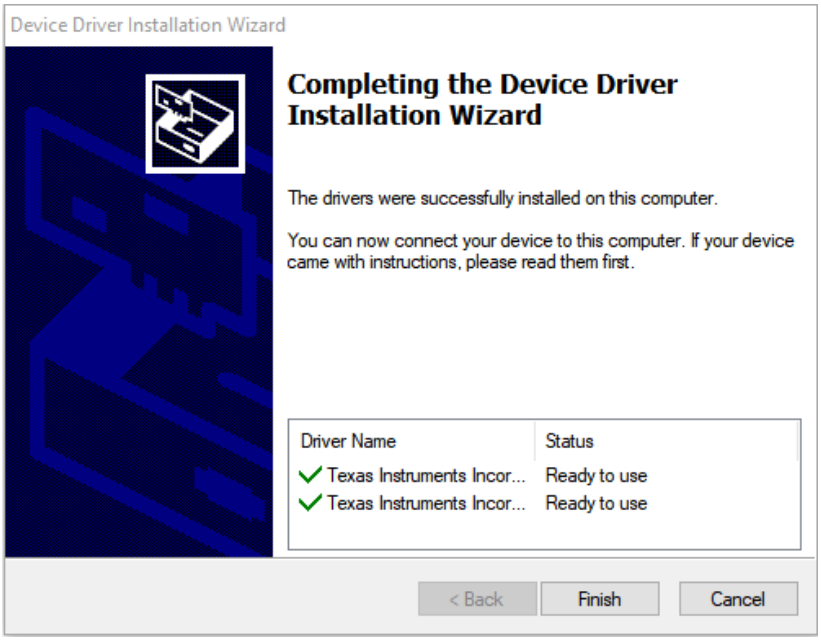


Figure 25. Setup Screen 8

The completion of the XDS driver installation is shown in Figure 25.

The TI-Emulators installation starts at this point. This will install the necessary drivers for running the application. In the next few steps as shown in Figure 26, Figure 27 and Figure 28 click **Next >** to perform the installation.

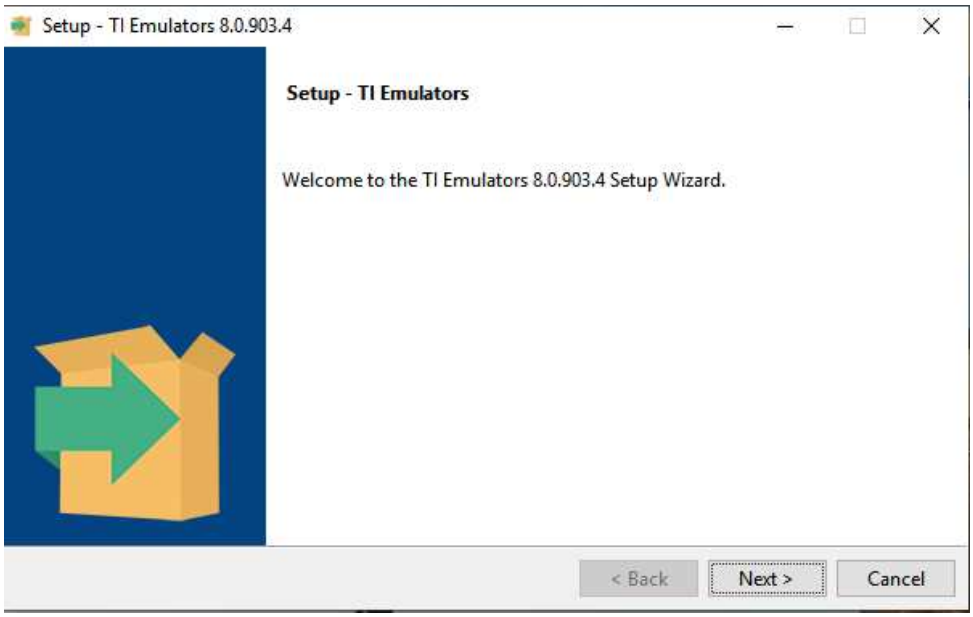


Figure 26. Setup Screen 9

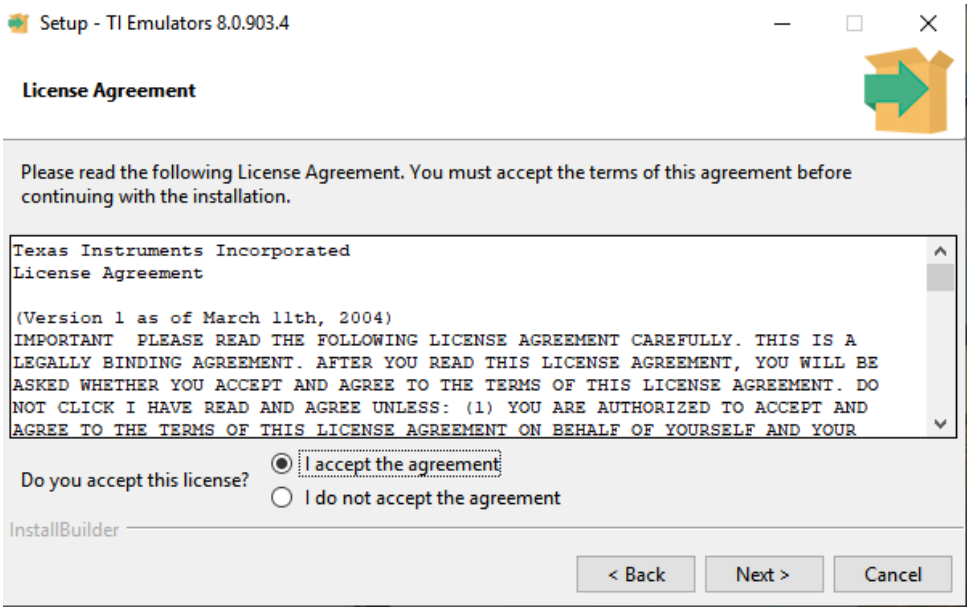


Figure 27. Setup Screen 10

Accept the license agreement in Figure 27.

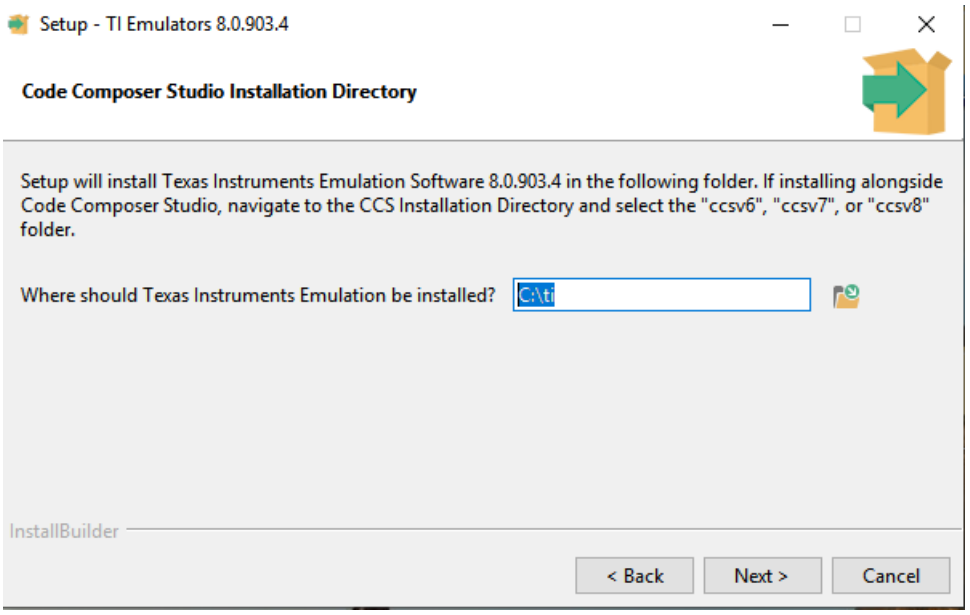


Figure 28. Setup Screen 11

In the next few windows click **Next >**, and if prompted by Windows Security about software installation as shown in Figure 29, select **Install**.

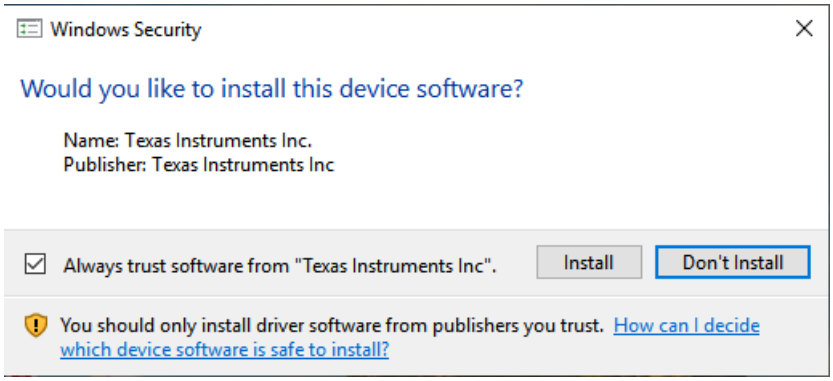


Figure 29. Setup Screen 12

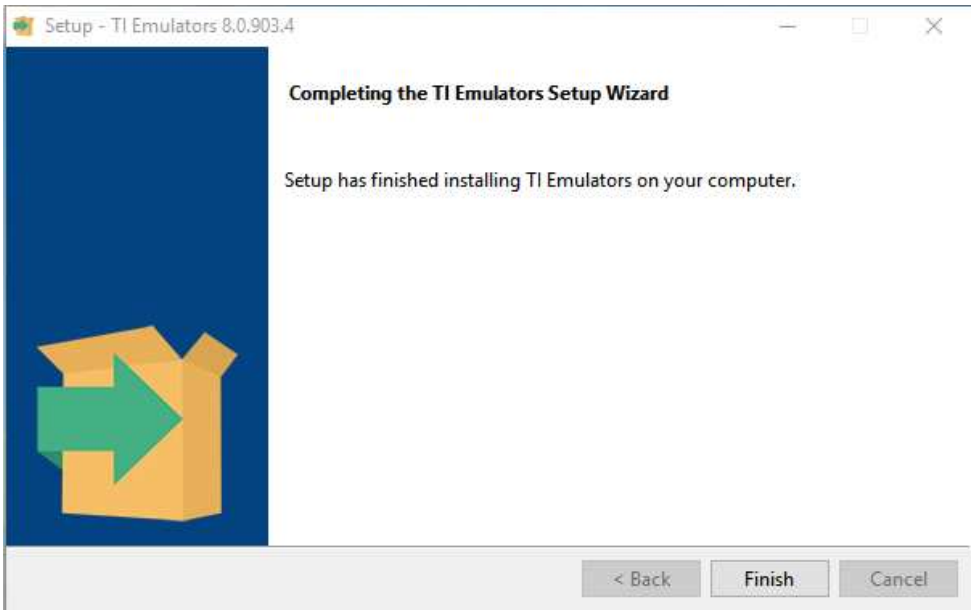


Figure 30. Setup Screen 13

The screen showing the completion of the TI Emulators installation is shown in Figure 30. Click on **Finish** to move to the next step.

The UniFlash installation starts at this point. UniFlash is required to program the LaunchPad. In the next few steps as shown in Figure 31, Figure 32 and Figure 33 click **Next >** to start the installation.

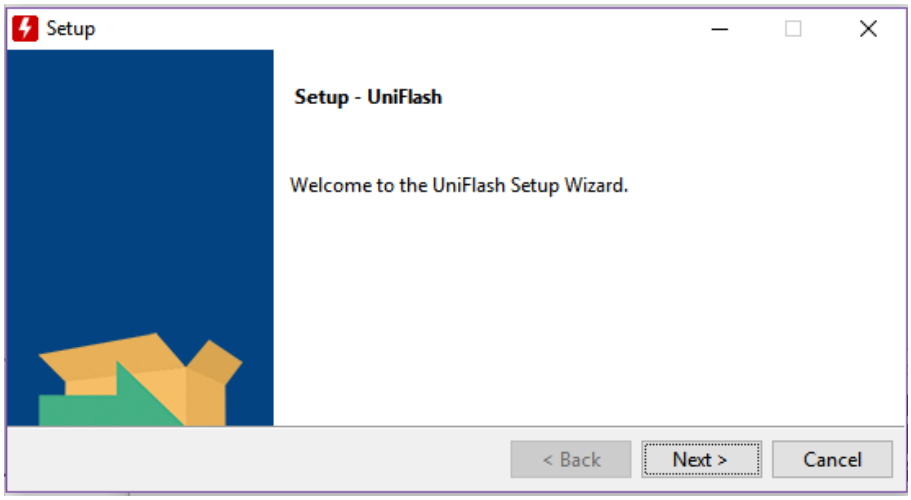


Figure 31. Setup Screen 14

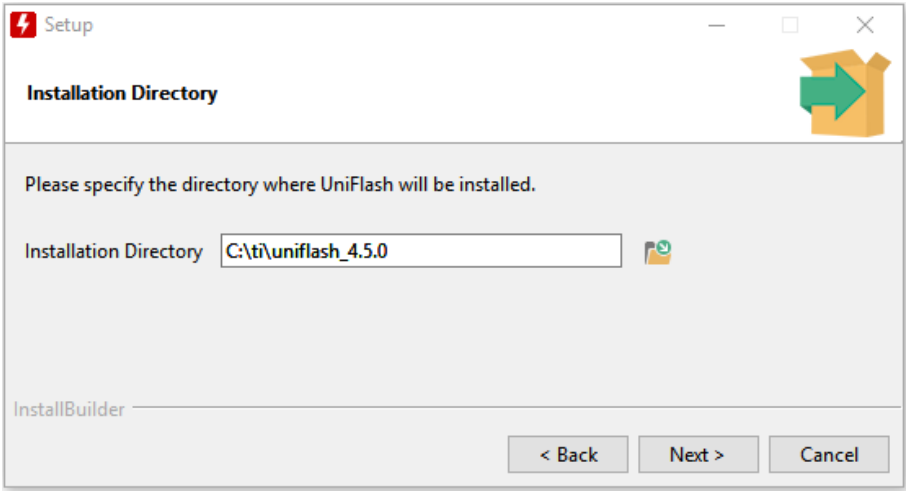


Figure 32. Setup Screen 15

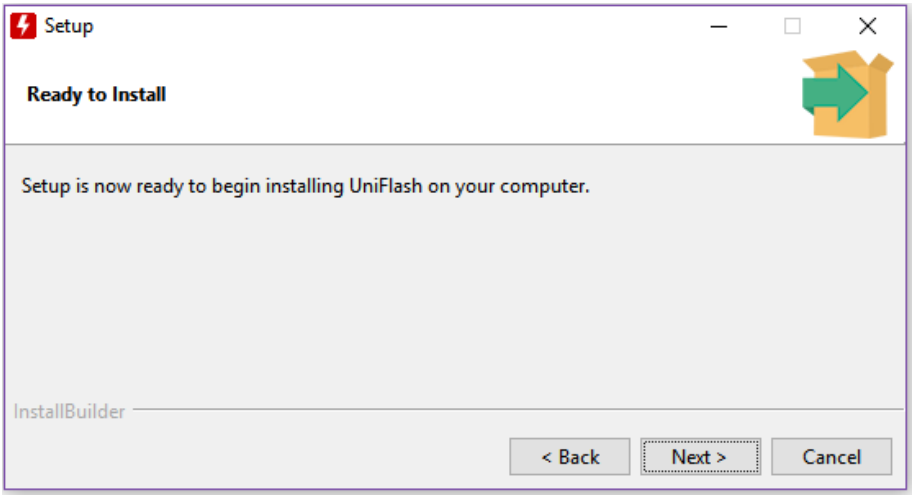


Figure 33. Setup Screen 16

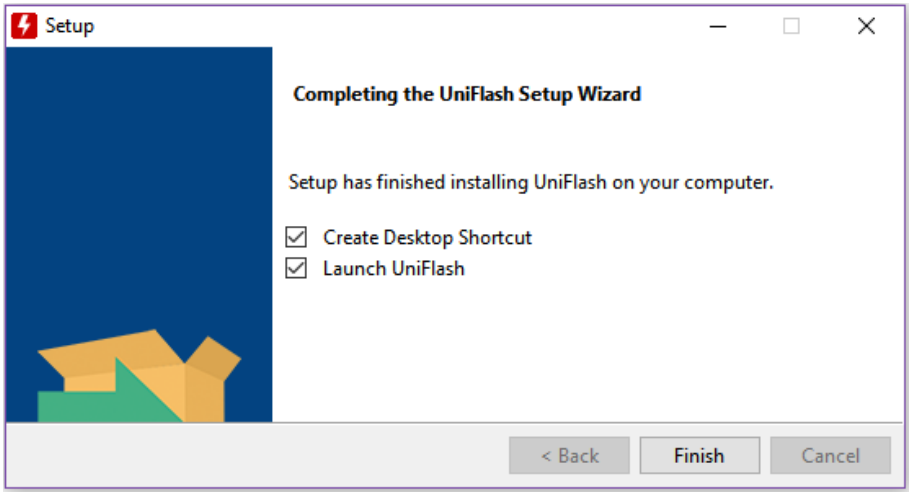


Figure 34. Setup Screen 17

When UniFlash installation completes, click **Finish** to launch the UniFlash and program the LaunchPad.

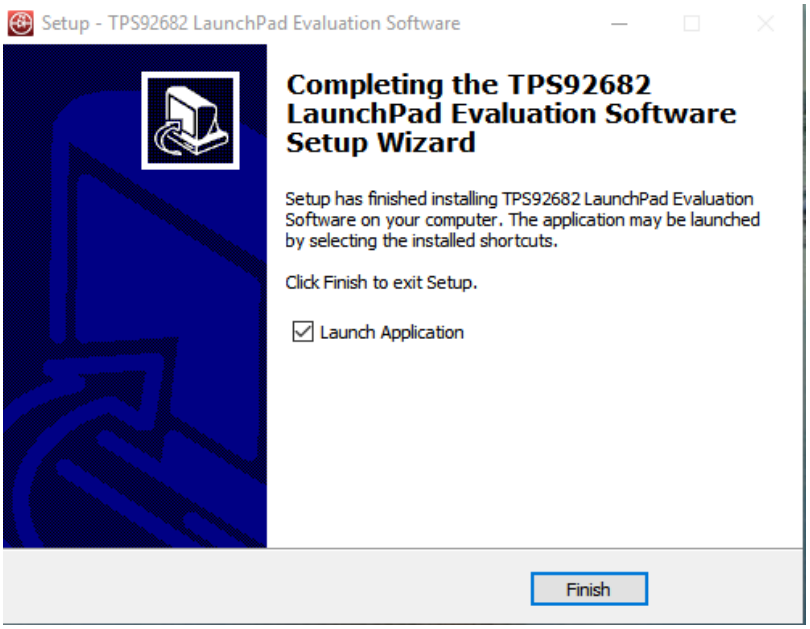


Figure 35. Setup Screen 18

Figure 35 shows the completion notification of the TPS92682-Q1 Evaluation Software. Un-check the **Launch Application** and click **Finish**.

7.2 Installation Error Recovery

If the screen shown in Figure 36 appears, follow the steps below to install an unsigned driver one time.

- Click **Start** and select **Settings**.
- Select **Update and Security**.
- Select **Recovery**.
- Click **Restart Now** under **Advanced Startup**.
- Click **Troubleshoot**.
- Select **Advanced Options**.

- Select **Startup Settings**.
- Click **Restart**.
- On the **Startup Settings** screen, press **F7** during reboot to disable driver signature enforcement. The host computer restarts.
- Repeat the entire reinstallation process.
- A message appears informing that installing .NET failed. Close that window and continue.
- Click **Install unsigned drivers** twice.

After restarting a second time, the host computer resets, which requires all drivers to be digitally signed the next time a default installation executes, unless these steps are repeated.

Figure 36. Driver Installation Error

7.3 Programming the MSP-EXP432E401Y LaunchPad Board

The LaunchPad Board must be programmed using the UniFlash before running the GUI. Connect the included Micro-USB cable to the USB port of the PC and the LaunchPad as shown in Figure 37. Connect a jumper between PINs 3 and 4 of the JP1 as shown in Figure 37.

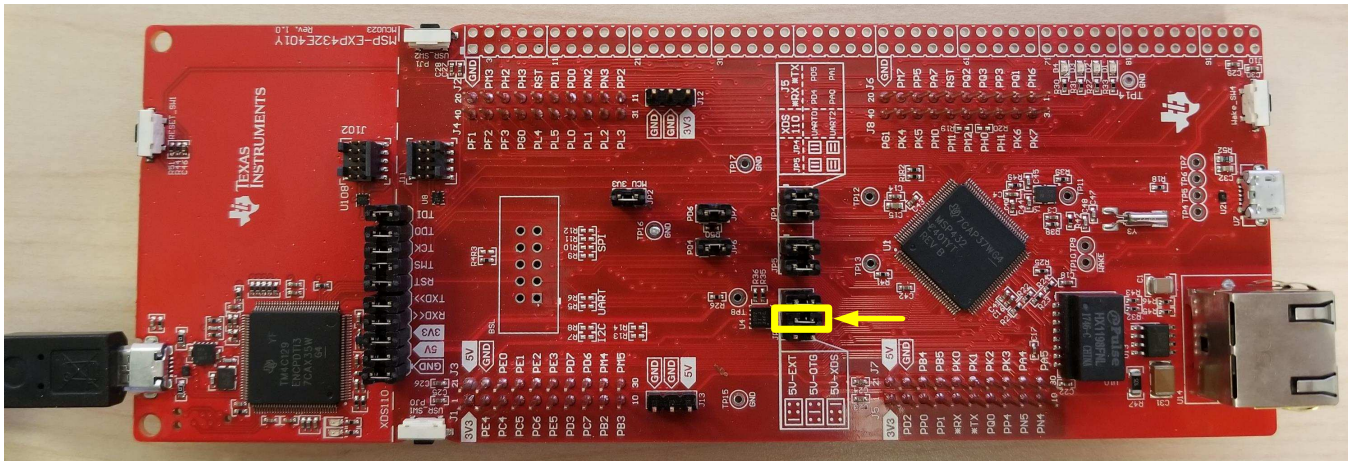


Figure 37. LaunchPad Connection for Programming

Typically, the installed UniFlash program opens at the end of the software setup shown in Figure 34. If the UniFlash program is not open, launch the program. The window shown in Figure 38 opens.

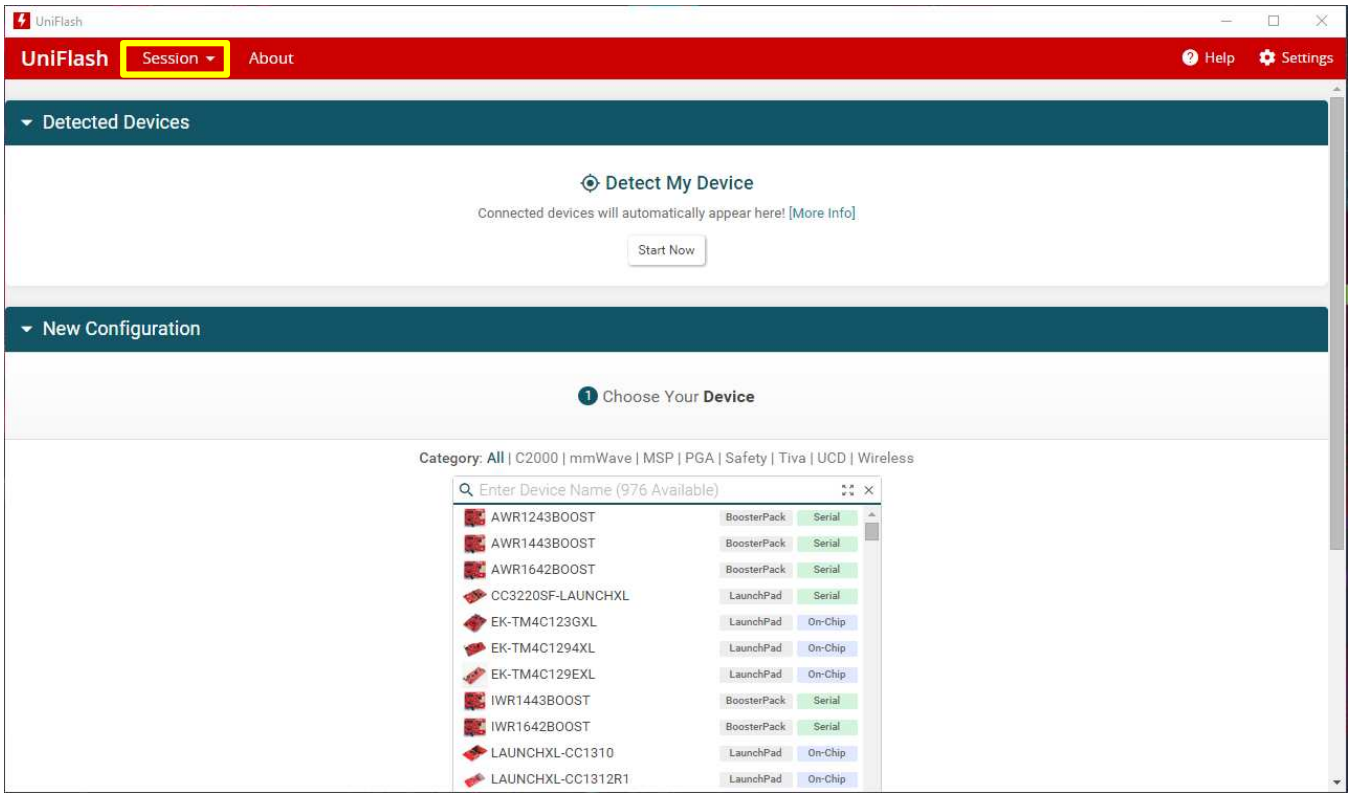


Figure 38. UniFlash Programming, Step 1

Click **Session** shown in Figure 38 and select **Load Session**.

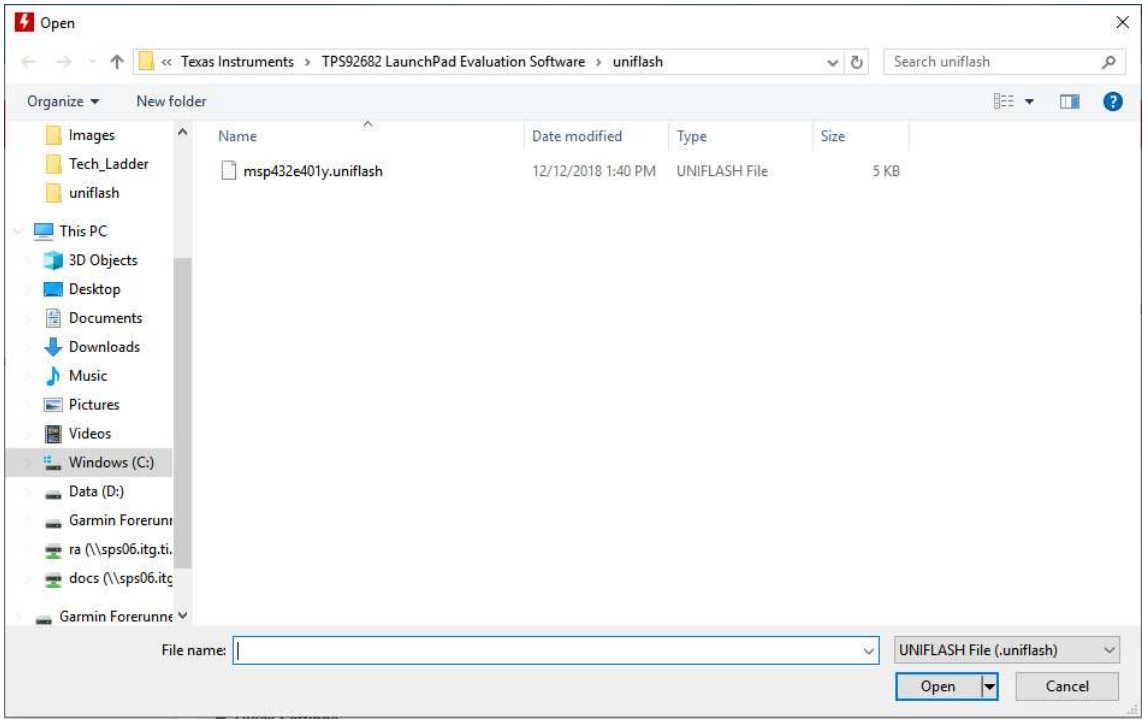


Figure 39. UniFlash Programming, Step 2

As shown in Figure 39, navigate to the *":\Texas Instruments\TPS92682 LaunchPad Evaluation Software\uniflash"* location and select the **msp432e401y.uniflash** file.

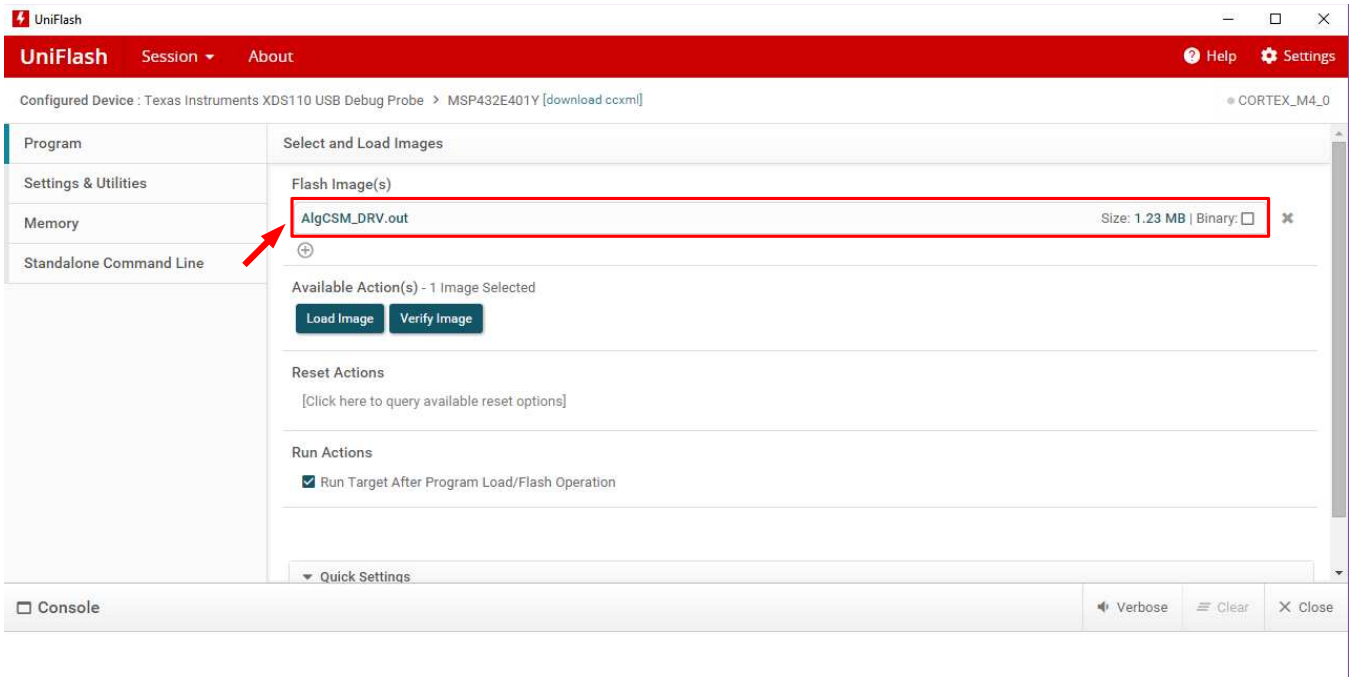


Figure 40. UniFlash Programming, Step 3

Click on the flash image file shown in the red box of Figure 40. Navigate to the *":\Texas Instruments\TPS92682 LaunchPad Evaluation Software\uniflash"* location and select the **AlgCSM_DRV.out** file as shown in Figure 41.

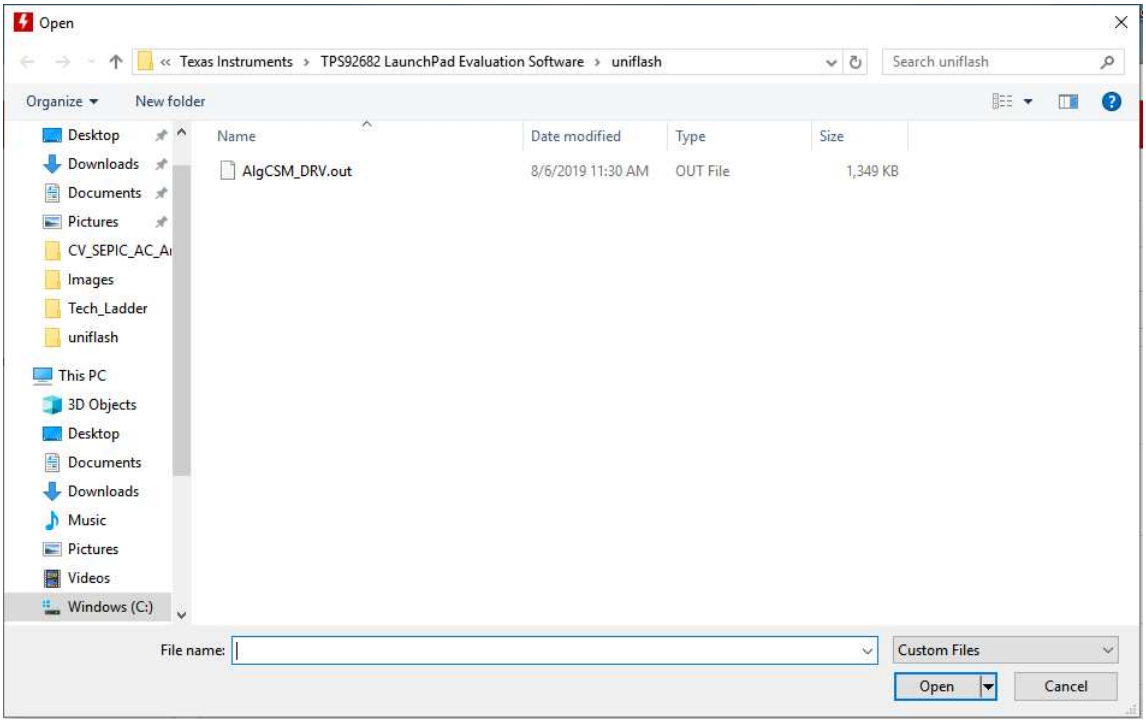


Figure 41. UniFlash Programming, Step 4

Click **Load Image**. After the program is loaded into the LaunchPad, a message appears in the console that the *Program Load completed successfully*, as shown in Figure 42.

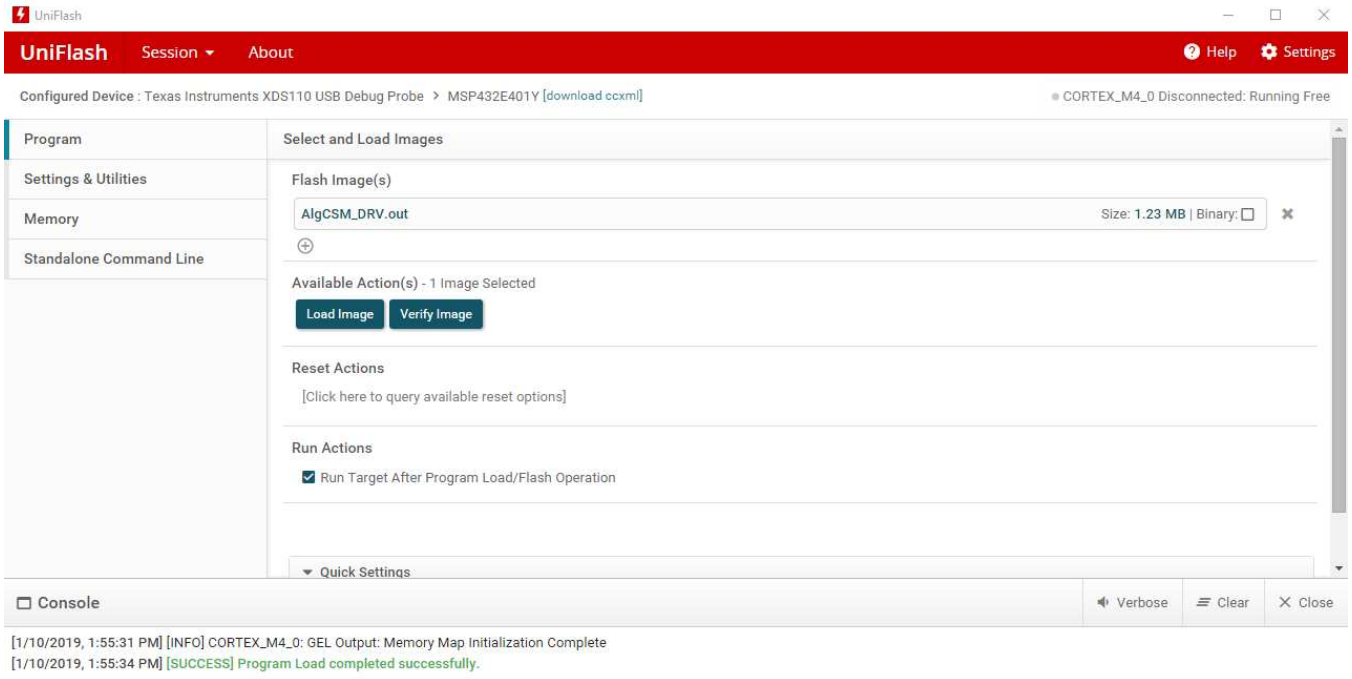


Figure 42. UniFlash Programming, Step 5

Close the UniFlash program, disconnect the Micro-USB from the LaunchPad and connect it to the USB port U7 on the other side of the LaunchPad, as shown in Figure 43.

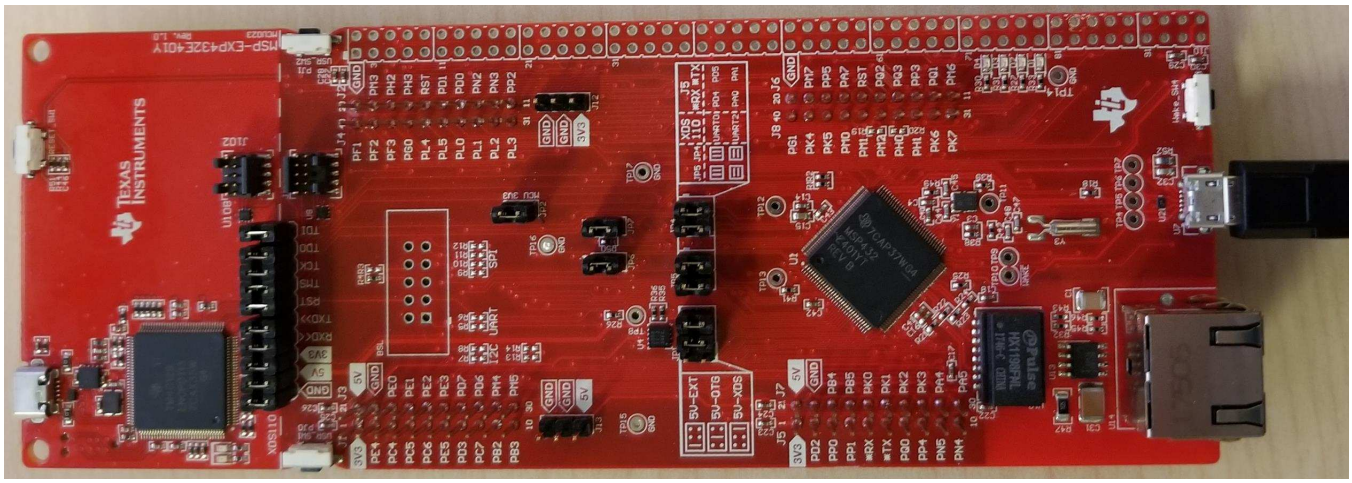


Figure 43. LaunchPad Connection for GUI Operation

8 TPS92682EVM-70 Power UP and Operation

To start the EVM operation, connect the header J10 on TPS92682EVM-70 to the header J2/J4 on the LaunchPad, and the header J11 to the header J1/J3, using two included ribbon cables as shown in Figure 44.

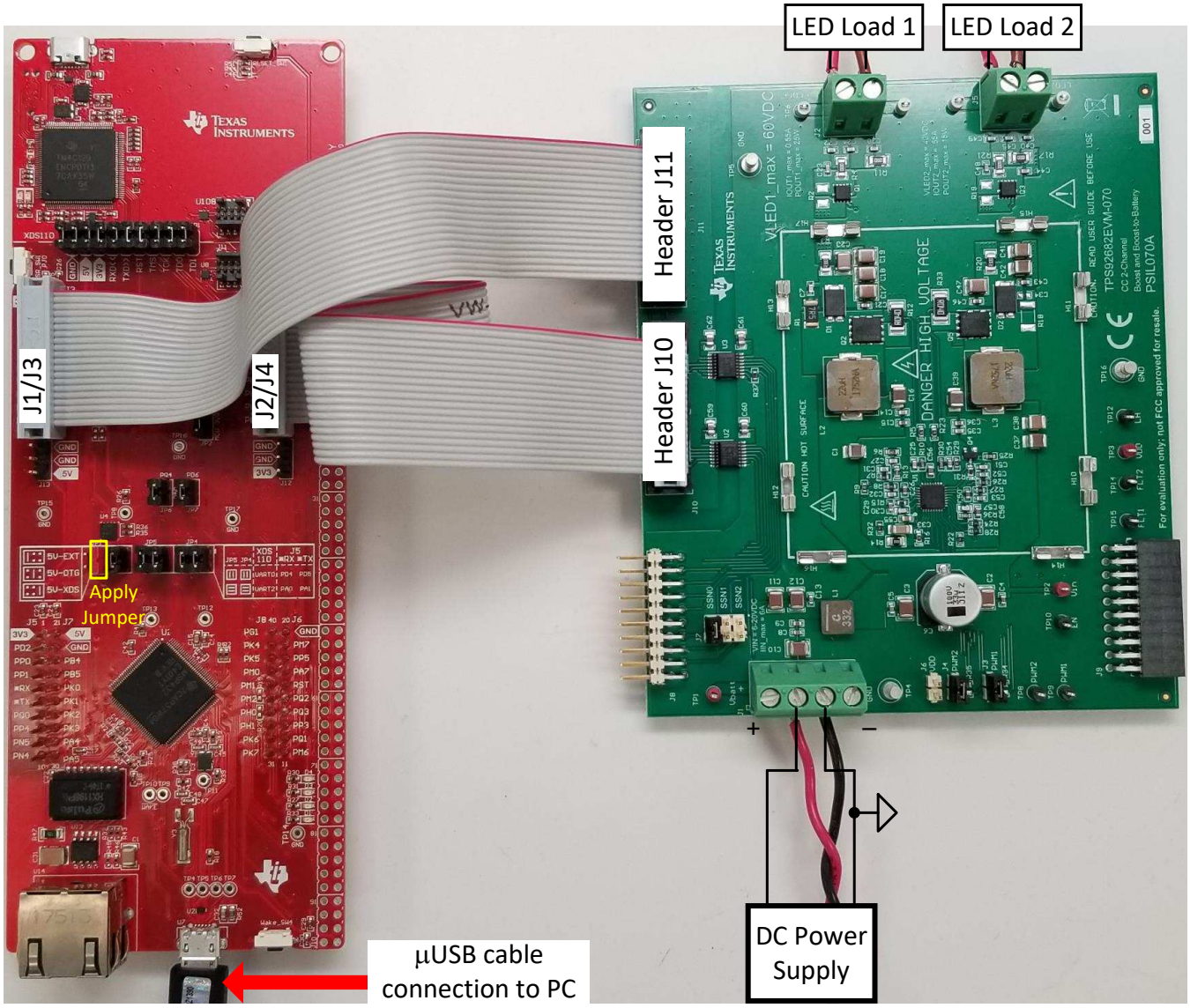


Figure 44. LaunchPad Connection to TPS92682EVM-70

Apply power (12 V) to the TPS92682EVM-70 board (terminal J1). Connect LED loads to the outputs of the EVM (terminal J2 and J5). Ensure that the loads are such that the maximum input and output current, maximum output power and maximum output voltage indicated on the EVM are not exceeded.

Run the program **LED_Controller_GUI_LP.exe**, located at the *":\Texas Instruments\TPS92682 LaunchPad Evaluation Software"*, to start the GUI. The window shown in Figure 45 opens.

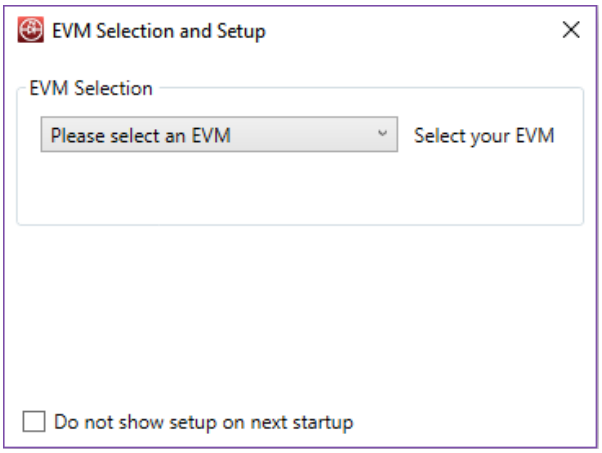


Figure 45. GUI Setup Screen 1

Click the EVM selection dropdown box. Select **TPS92682 CC - PSIL070**.

Figure 46. GUI Setup Screen 2

On the screen shown in Figure 46, select 1 as the number of devices. A new tab appears as shown in Figure 47. Select **682** for Device Type. Select **0** for Desired Address. Click **Add Device**.

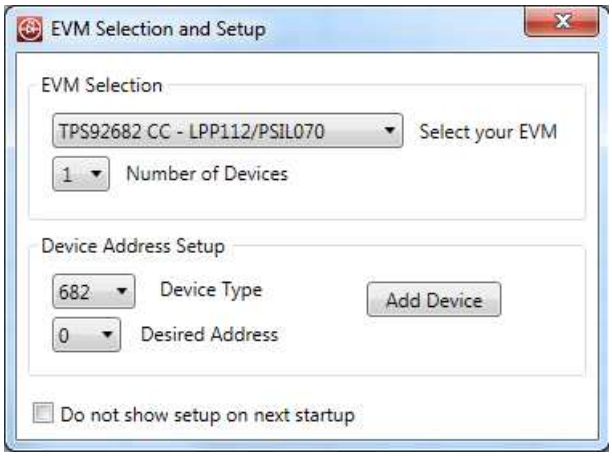


Figure 47. GUI Setup Screen 3

The main GUI window appears as shown in Figure 48. This window includes three sub-windows:

- MCU Control Box (1): includes controls for external PWM
- SPI Command Box (2): is used to manually read from and write to the registers on the SPI BUS
- Devices Box (3): is the main GUI control window to configure the TPS92682-Q1 device

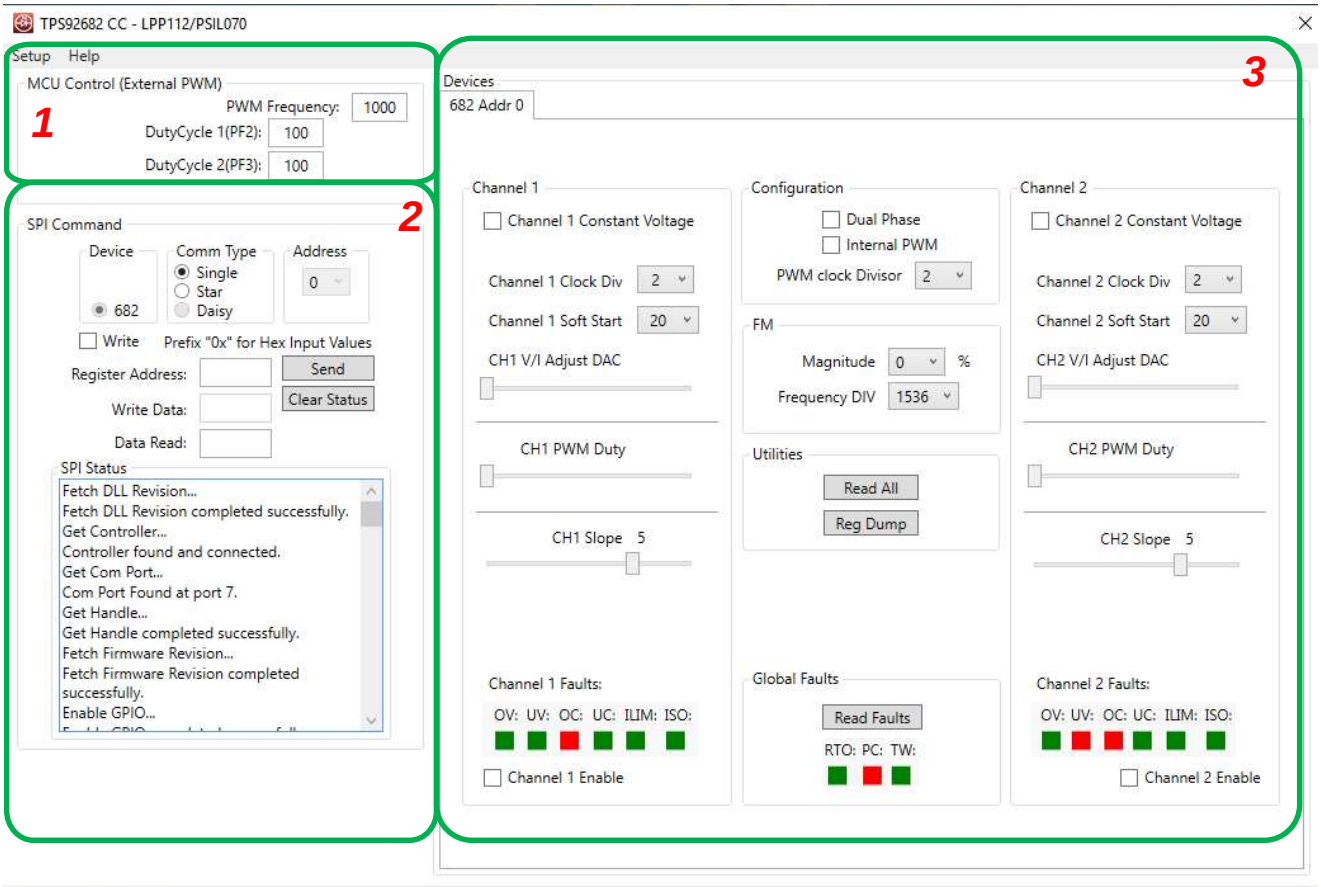


Figure 48. GUI, Main Window

8.1 SPI Command

The SPI command box, allow access to the *read from* and *write to* registers. In order to ensure connection to the TPS92682-Q1, perform the following steps as shown in Figure 49.

1. Write the register address zero in the *Register Address* box: 0x00.
2. Click **Send** *twice*.

   The default value (0x3C) for the register 0 shows in the SPI Status window.

To write to a register, select the **Write** check-box. Write the desired data in the *Write Data* box shown in Figure 49. Click **Send** to write the data to the associated register address.

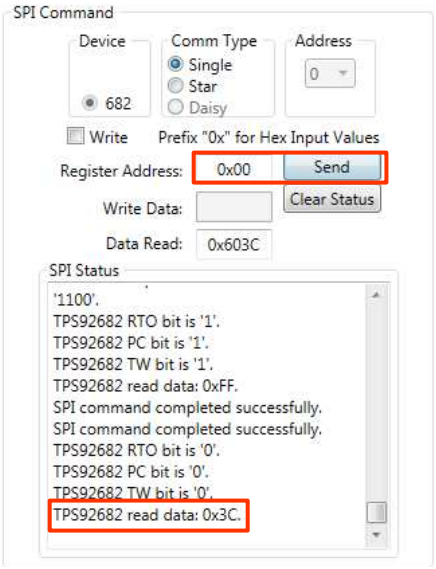


Figure 49. SPI Command Window

8.2 GUI Devices Window

In TPS92682EVM-70, channel-1 is configured as a CC mode boost converter and channel-2 as a CC mode boost-to-battery. The settings shown in red in Figure 50 can be used to configure and turn on and regulate the LED current of the two channels.

Figure 50. Devices Window

Apply the settings shown in Figure 51.

1. Select the Internal PWM box to set the PWM dimming to internal.
2. To set the switching frequency, f_{SW} to 400kHz, do not change the Channel Clock Div from the default value of 2.
3. Enter the Channel 1 and Channel 2 Soft Start value to **100**.
4. Enter the desired value for the CH1 and CH2 V/I Adjust DAC. This DAC controls the I_{LED} current. For TPS92682EVM-070, the DAC maximum value of 255 corresponds with an I_{LED} of approximately 570 mA. The relation between I_{LED} and the DAC value is shown in Equation 1.

$$I_{LED} = \frac{VIADJ \times 0.171}{255 \times R_{CS}} \quad (1)$$

   where

   - R_{CS} is the current sense resistor (R3 for channel-1 and R20 for channel-2)
5. The EVM generates the internal PWM using a 10-bit DAC counter. Set the PWM duty cycle to a value between zero and 1023 for PWM dimming. In order to turn on the LEDs with 100% duty cycle, set the PWM DAC value to 1023.
6. By default CHx-Slope is set to code "5", which corresponds to 250 mV of peak slope. For the TPS92682EVM-70, it is recommended to set the slopes for both channels to a code "1" or "2" as shown in Figure 51

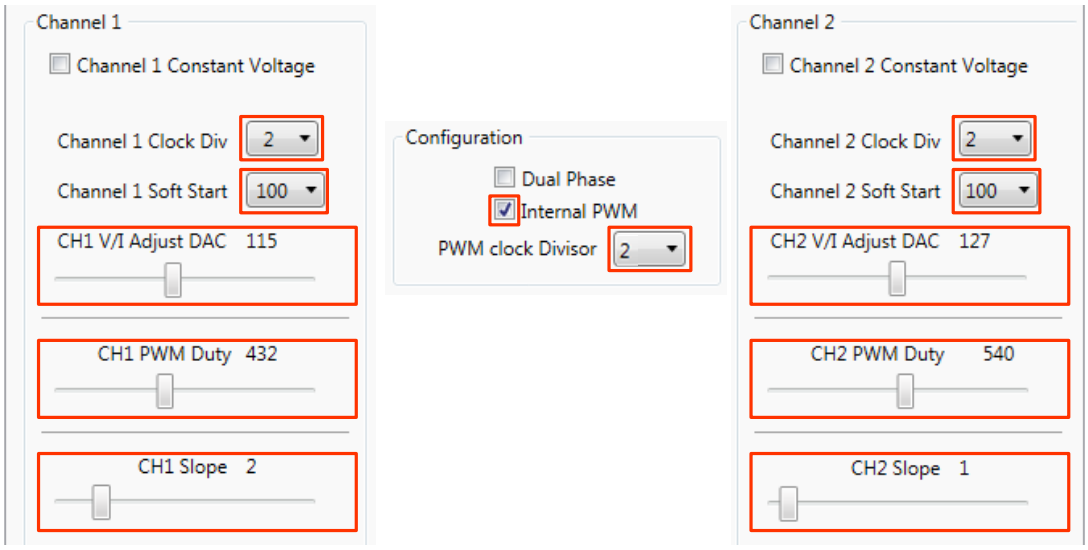


Figure 51. Devices Window Setting

After applying these settings, the fault status registers FLT1 (0x11) and FLT2 (0x12) must be checked. Before enabling and turning on the outputs, the fault registers must be read (cleared). The Power Cycle (PC) bit must be cleared in order for the TPS92682-Q1 is enabled. The fault status can be obtained by pushing the **Read Faults** button in Figure 52.

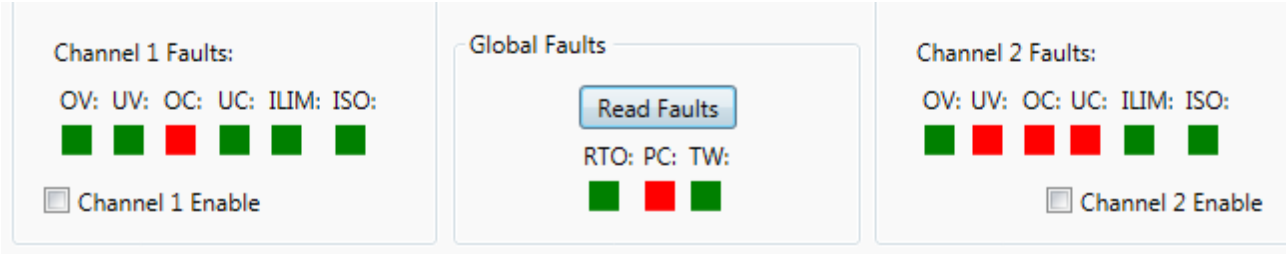


Figure 52. Fault Status after Pushing the Read Faults Once

The first time the Read Fault button is pushed, the previous status of the fault registers are shown and the faults are cleared. The second time the Read Faults button is pushed, the cleared faults will change to green as shown in Figure 53.

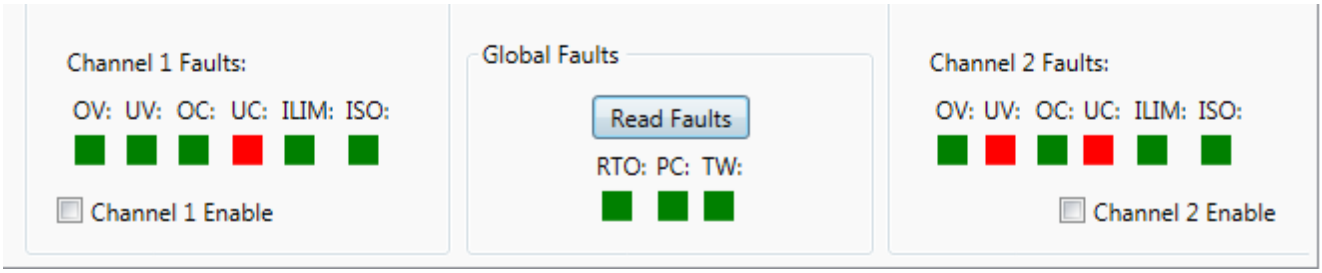


Figure 53. Fault Status after Pushing the Read Faults Twice

Some of the faults or diagnostic bits, as undercurrent (UC) and undervoltage (UV) may remain red as the channels are not turned on. For example for channel-2 (boost-to-battery), the output undervoltage (UV) remains red as the load voltage is initially zero. Therefore, this fault is disabled by default until the soft-start sequence is complete. The output overvoltage (OV), cycle-by-cycle current limit (ILIM), IS Open (ISO), RT Open (RTO), Power Cycle (PC) and Thermal Warning (TW) should be cleared (change status to green) before enabling the channels.

Before enabling the channels, make sure to connect LED loads to the outputs of the TPS92682EVM-070. By setting the Channel 1 and Channel 2 Enable check boxes, the two channels are turned on. At this point after clicking **Read Faults**, for 100% PWM duty cycle, all faults as shown in Figure 54 are cleared.

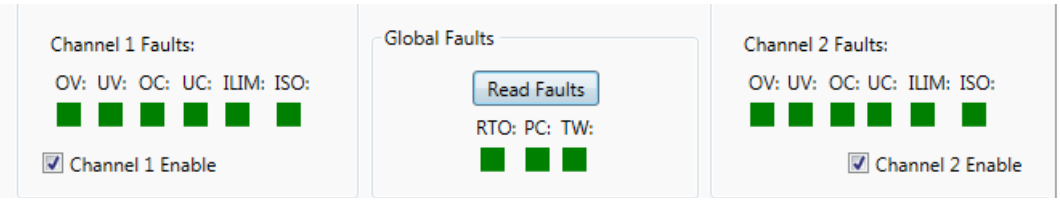


Figure 54. Enabling the EVM

In some cases, for PWM duty cycles of less than 100%, the UC diagnostic bit may continue to display as red.

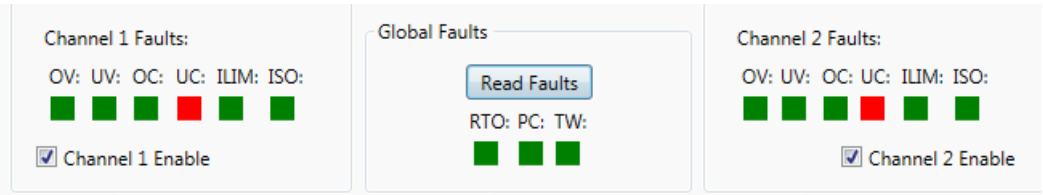


Figure 55. Fault Status

To turn off the channels, de-select the Channel 1 and Channel 2 Enable.

If a power cycle occurs, all the registers reset to default values. In this case, it is necessary to repeat all the steps described in Section 8 before re-enabling the converter.

Revision History

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

Changes from Original (May 2019) to A Revision	Page
• Updated *Figures 18 to 20*	22
• Updated *Figure 23*	25
• Updated *Figures 26 to 30*	26
• Updated *Figure 35*	30
• Updated *Figure 39 and Figure 41*	33
• Updated *Figure 48 and Figure 49*	38

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WARNING

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

NOTE:

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

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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*

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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

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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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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.

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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.

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