TMP23xEVM User's Guide

The TMP23xEVM evaluation kit is a plug and play system to test and evaluate the TMP23x analog temperature sensor. The TMP23x devices are a family of precision CMOS integrated-circuit linear analog temperature sensors with an output voltage proportional to temperature, making them suitable for many analog temperature sensing applications. This user's guide describes the characteristics, operation, and use of the TMP23xEVM evaluation board. In particular, this user's guide discusses how to set up and configure the software, reviews the hardware, and reviews various aspects of the software operation. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the TMP23xEVM.

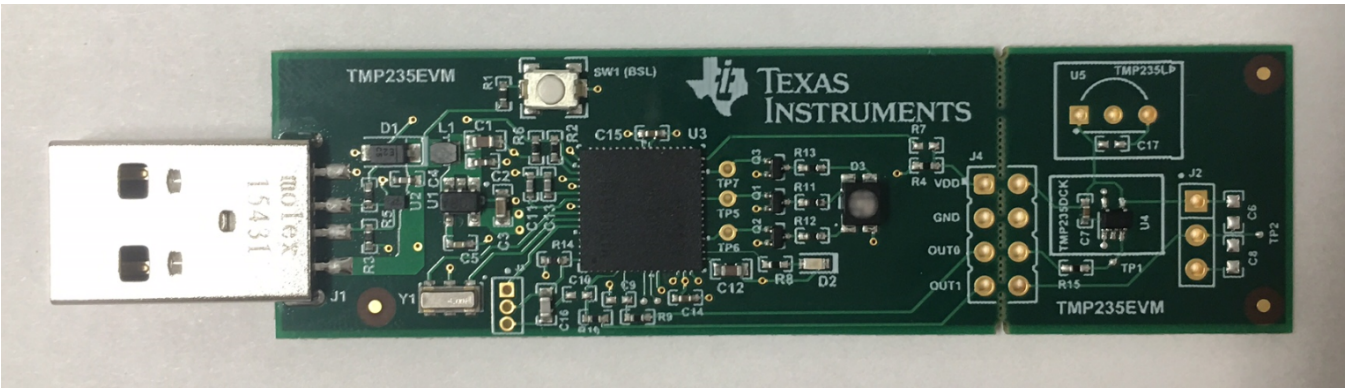

Figure 1. TMP235EVM Top View

Figure 2. TMP235EVM Bottom View

NOTE: There are two variants of the TMP23xEVMs: TMP235EVM and TMP236EVM. No major hardware differences between the two EVMs. Thus, the example pictures in this user's guide will only show the TMP235EVM variant. Each EVM variant is clearly marked on the silkscreen.

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Trademarks

Windows is a registered trademark of Microsoft Corporation.
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1 Overview

The TMP23xEVM evaluation kit is a plug and play system to test and evaluate the TMP23x analog temperature sensor. The EVM uses a USB interface for control and data logging, and can be to plugged into a PC USB port. With the simple GUI, temperature measurements can be displayed in realtime after the EVM is attached to a PC and the GUI is started. The EVM hosts a MSP430F5528 microcontroller which acts as a bridge between the PC USB interface and the analog interface to the TMP23x device. The sensor section of the PCB may be separated from the main PCB to support prototyping in a system where the sensor is remotely located from the host controller. The TMP23xEVM does not require calibration, nor does it require any software programming - only the TMP23xEVM GUI must be installed. The EVM also supports a second sensing channel for comparison purposes. Temperature data can be logged and exported in CSV format.

1.1 EVM Kit Contents

Table 1 details the contents of the EVM kit, and Figure 3 illustrates all of the included hardware. Refer to Section 2.3 for the recommended operation conditions. Contact the nearest Texas Instruments Product Information Center to you if any component is missing. TI highly recommends checking the TI website at http://www.ti.com to verify that you have the latest versions of the related software.

Table 1. EVM Kit Contents

ITEM	QUANTITY
TMP23xEVM	1
USB Cable Extender	1

Figure 3. Hardware Included With the EVM Kit

1.2 REACH

CAUTION

This EVM includes a crystal component (CSTCR4M00G15L99-R0) that contains >0.1% of Lead Titanium Oxide CAS# 12626-81-2 listed in EU REACH as a Substance of Very High Concern. For more information, contact the component manufacturer.

1.3 Related Documentation From Texas Instruments

The following documents provide information regarding Texas Instruments integrated circuits used in the assembly of the TMP23xEVM. This user's guide is available from the TI website under literature number SBOU190. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions may be available from the TI website at www.ti.com, or call the Texas Instruments Literature Response Center at (800) 477-8924, or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Table 2. Related Documentation

DOCUMENT	LITERATURE NUMBER
TMP235 Product Data Sheet	SBOS857

2 EVM Hardware

This section discusses the EVM hardware design.

2.1 EVM Theory of Operation

The EVM consists of two sections that can be separated by breaking the PCB at the perforations. The red dashed lines in Figure 4 represent the breakable connections on the PCB. The left section contains a standard USB Type A connector, an ESD protection block, a 3.3-V LDO, a MSP430 microcontroller with an integrated 12-bit SAR Analog-to-Digital Converter (ADC), LED indicators, and an optional low-pass filter block. The right section features the TMP23x device.

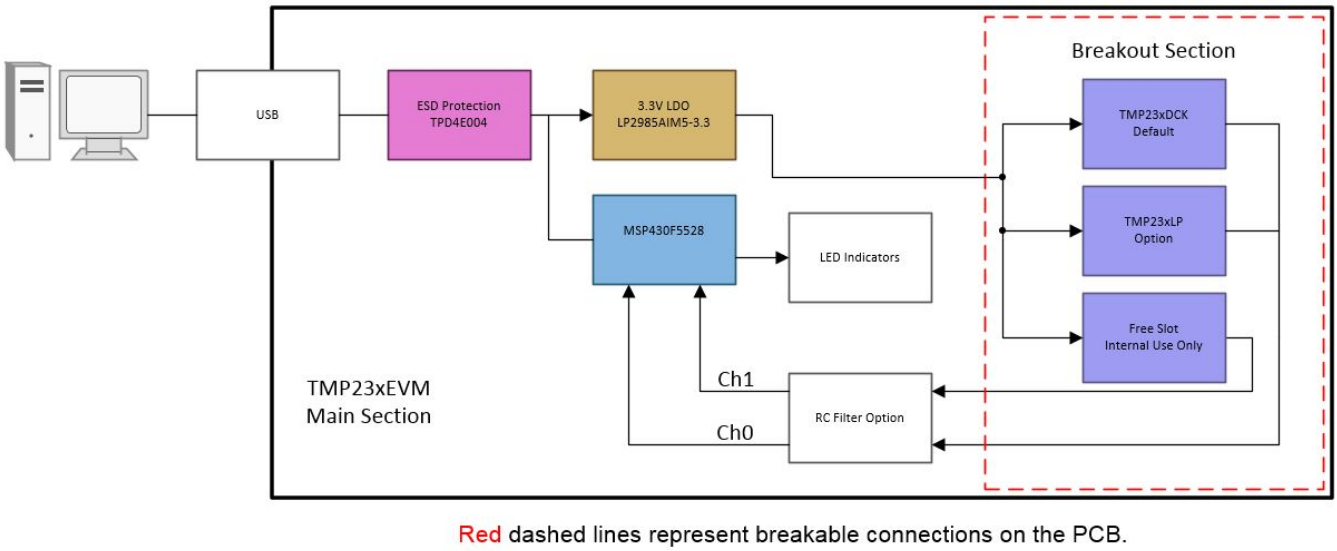

Figure 4. EVM Block Diagram

2.2 Connecting the EVM to a Computer

Figure 5 shows the typical response when connecting the EVM board to a PC USB port for the first time. Typically, the computer responds with a *Found New Hardware, USB device* pop-up dialog. The pop-up window then typically changes to *Found New Hardware, USB Human Interface Device*. This pop-up indicates that the device is ready to be used. The EVM uses the human interface device drivers that are part of the Microsoft Windows® operating system.

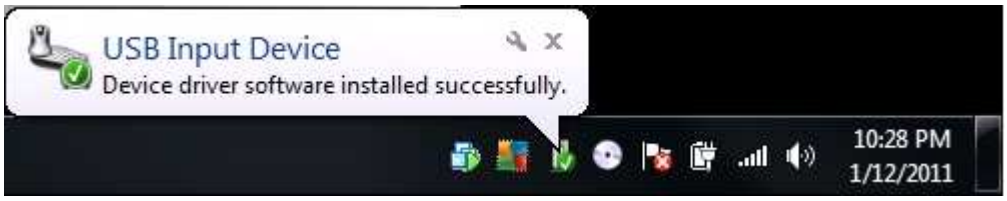

Figure 5. USB Device Driver Installation

In some cases, the Windows *Add Hardware Wizard* is shown. If this prompt occurs, allow the system device manager to install the human interface drivers by clicking *Yes* when requested to install drivers. Windows confirms installation of the drivers with the message shown in Figure 5.

2.3 Operating Conditions

Table 3. Recommended Operating Conditions

PARAMETER	TEST CONDITIONS	MIN	NOM	MAX	UNIT
Operating free-air temperature	Main section	–40	25	80	°C
Operating free-air temperature	USB Extension Cable	NA	25	80	°C
Operating free-air temperature	Breakout section (TMP235 variant)	–40	25	150	°C
Operating free-air temperature	Breakout section (TMP236 variant)	–10	25	125	°C

The EVM main section and the included USB extension cable can only operate up to 80°C. To evaluate the TMP235 device at its maximum specified operating temperature of 150°C, the user must break off the breakout section of the EVM. The TMP236 device is specified to 125°C. Use the unpopulated pin hole header J4 and a cable (not included in the kit) to thermally isolate the two EVM sections.

CAUTION

Many components on the EVM are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap at an approved ESD workstation.

2.4 EVM Features

This section describes some of the hardware features present on the EVM. Refer to Figure 6 for the various designators described in this section.

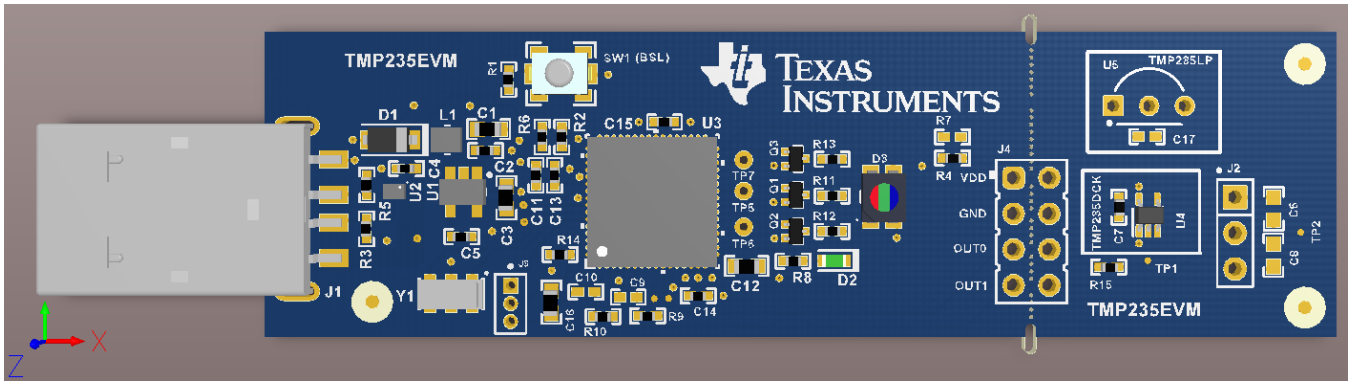

Figure 6. EVM 3D Top View

NOTE: The common names for the DCK and LP packages are SC-70 and TO-92, respectively.

2.4.1 USB2ANY Firmware

The USB2ANY firmware (FW) included in the EVM is based on MSP430F5528. The microcontroller is preloaded with FW that enables its use as a USB2ANY converter. Push button SW1 and unpopulated pin hole header J3 are available for Bootloader (BSL) and Spy-Bi-Wire (SBW) programming, respectively. However, the included FW is necessary for correct operation of the EVM-GUI software. Instruction for updating the FW can be found in Section 5.

2.4.2 ESD Protection

The EVM features an ESD protection circuit based on the TPD4E004 device.

2.4.3 LDO

The EVM is powered from the USB rail. The USB 5-V rail is regulated to 3.3 V with the LP2985AIM5-3.3 device. The 3.3-V powers both MSP430 microcontroller and the sensor. The sensor supply current can be monitored by replacing R4 with a current meter.

2.4.4 LED Indicators

There are two LED indicators on the EVM. The RGB LED (D3) provides a visual feedback of the ambient temperature. The RGB LED becomes more red as the temperature gets warmer and more blue as the temperature gets cooler. The LED intensity is modulated with a 1-kHz PWM signal. The green LED (D2) provides a heartbeat letting the user know the ADC is active.

2.4.5 RC Filter Options

The TMP23x device can be directly interfaced with the MSP430 12-bit SAR ADC without the need for an external capacitor. However, the TMP23xEVM is designed to support a simple RC low-pass filter (R9 and C9 for Ch0; R10 and C10 for Ch1). The RC filter can be used to suppress electrical interference and to optimize ADC performance. In most analog designs, a filter capacitor is recommended. For a typical design, TI recommends a 0.1-μF external capacitor.

2.4.6 Dual-Channel Mode

The EVM supports up to two analog inputs. Ch0 is the primary ADC channel and Ch1 is the secondary ADC channel. Ch0 is designed to support either the SC-70 package (U4) or the TO-92 package (U5). The default package on the EVM is the SC-70. To evaluate the TO-92 package, either U4 or R15 will have to be depopulated from the EVM. Refer to the schematic in Figure 18 for more details. Ch1 is an optional analog input channel, which can support a device in the TO-92 package (J2). This dual-channel feature enables the user to compare two devices at once.

3 EVM Software Setup

This section discusses how to install the EVM software.

3.1 Operating Systems for the EVM Software

The EVM software is tested on the Microsoft Windows 7 and 10 operating systems (OS) with United States and European regional settings. The software also functions on other Windows operating systems.

3.2 EVM Software Installation

The EVM software is available through the TMP235EVM product folder on the TI website.

1. Go to the TMP235EVM web page on the TI website and scroll down to the *Software* section to download the latest evaluation software.
2. Unzip the downloaded file into a known directory and run the *Setup_TMP23xEVM_GUI_x_x.exe* file]. The EVM software installer then begins the installation process, as shown in Figure 7.

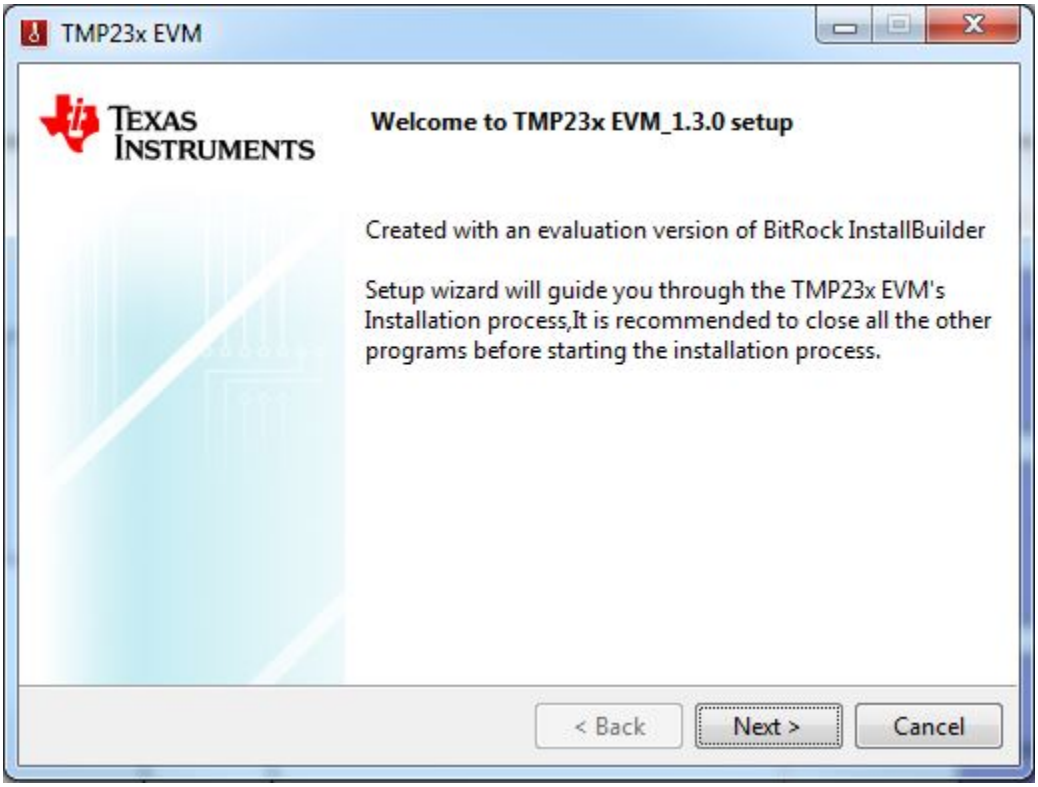

Figure 7. TMP23x EVM Installation Wizard

3. Follow the on-screen instructions by clicking the *Next* button to install the software.

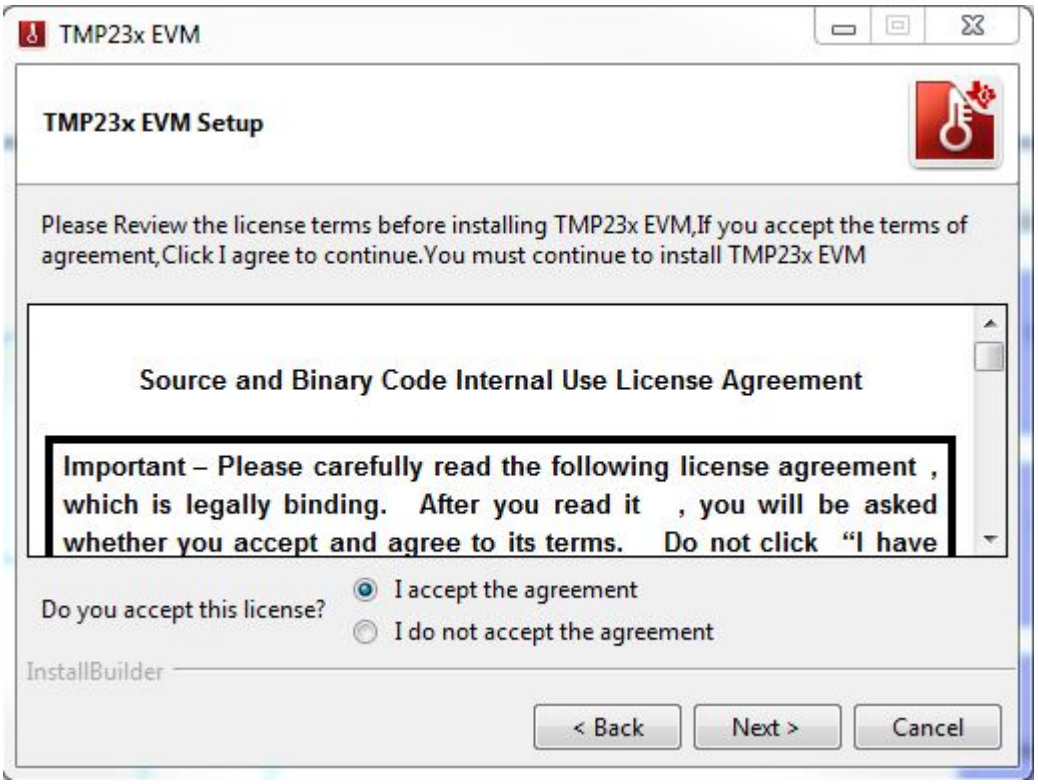

Figure 8. TMP23x EVM License Agreement

4. Following this option, two license agreements are presented that must be accepted.

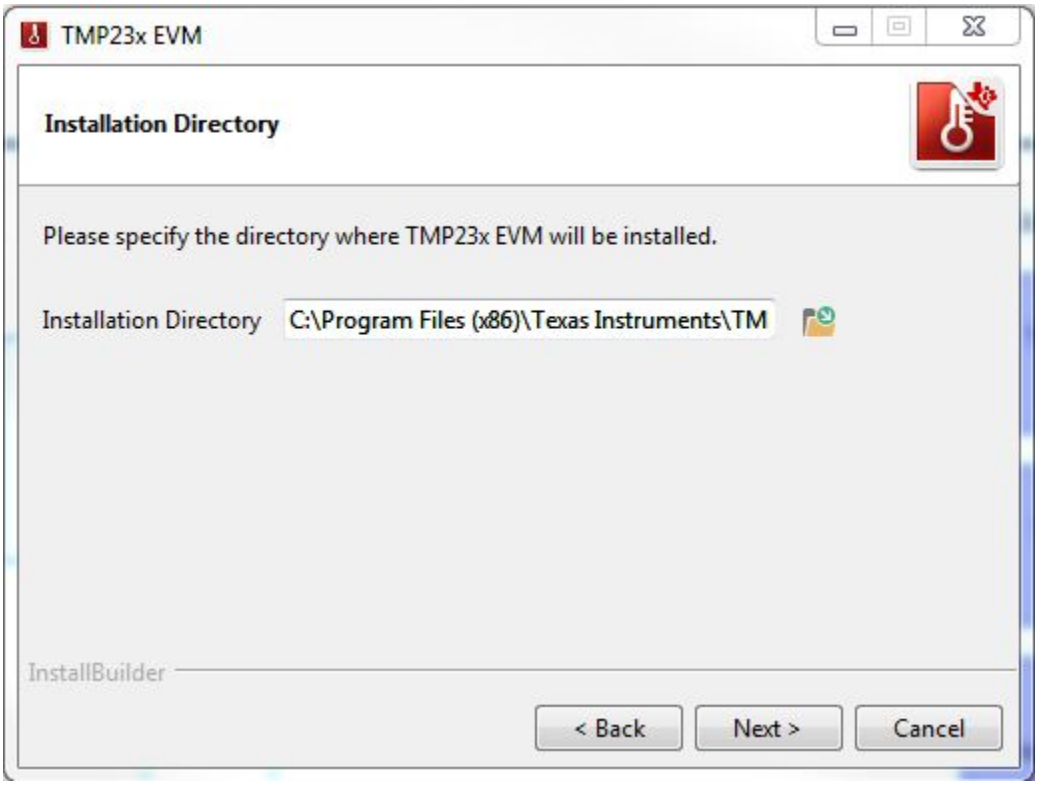

Figure 9. TMP23x EVM Installation Directory

5. Click on the *Next* button to accept the default installation directory.

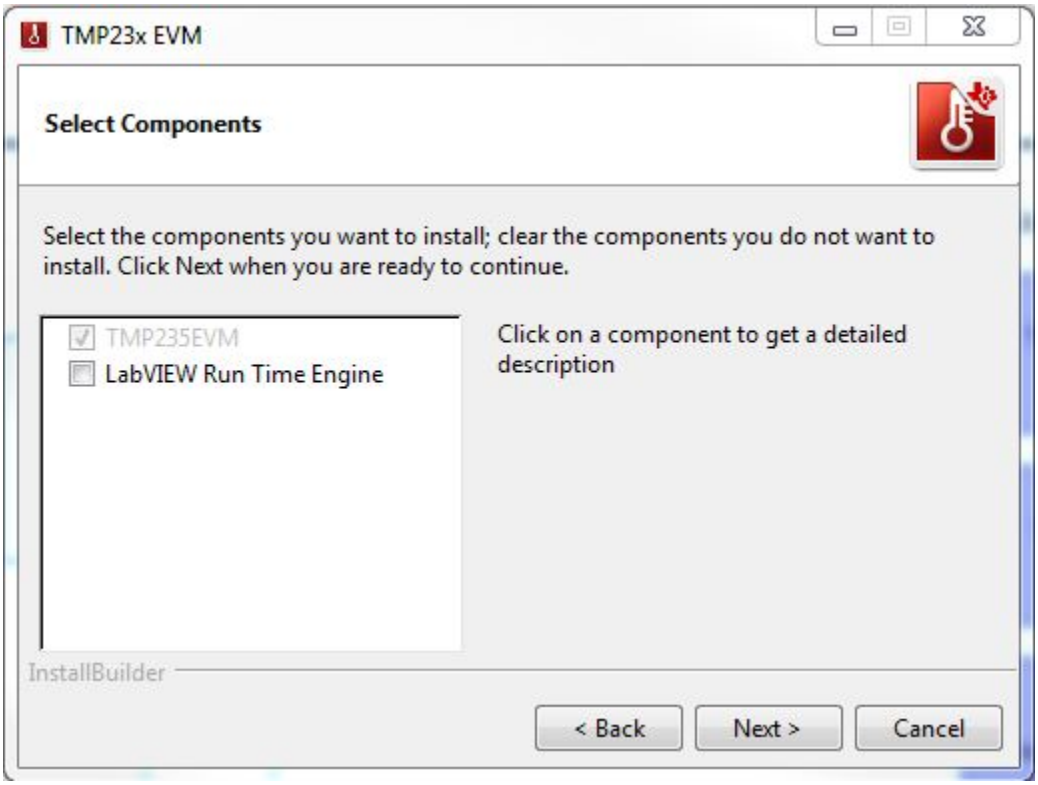

Figure 10. TMP23x EVM Select Components

6. If it is the first installation, ensure the *LabVIEW Run Time Engine* (LVRTE) is selected in Figure 10. TMP23xEVM software requires LabVIEW 2016 runtime engine for proper operation.
7. When installing the LVRTE, the user will be prompted to configure the proxy. Some server requires the user to configure the proxy before authorized users can gain access to the web. If so, please provide your server address and port number. If the server doesn't require the proxy server, just simply delete the default address and port number.

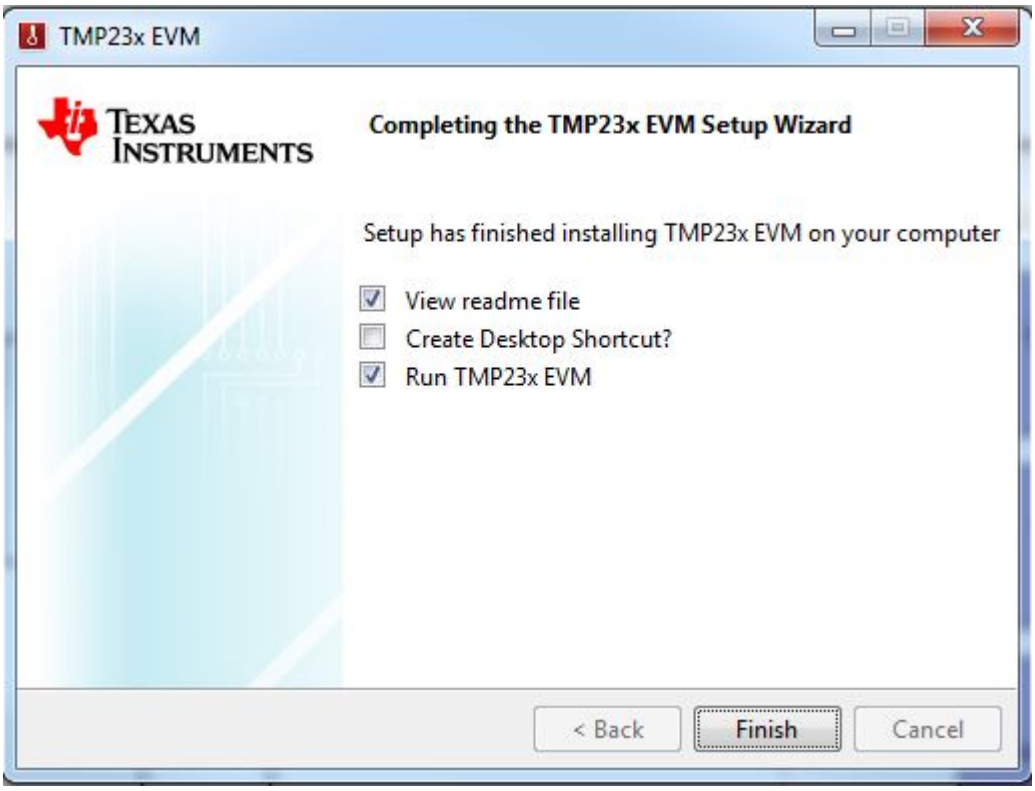

Figure 11. TMP23x EVM Installation Finish

8. When the installation is finished, click the *Finish* button. This will launch the GUI application.

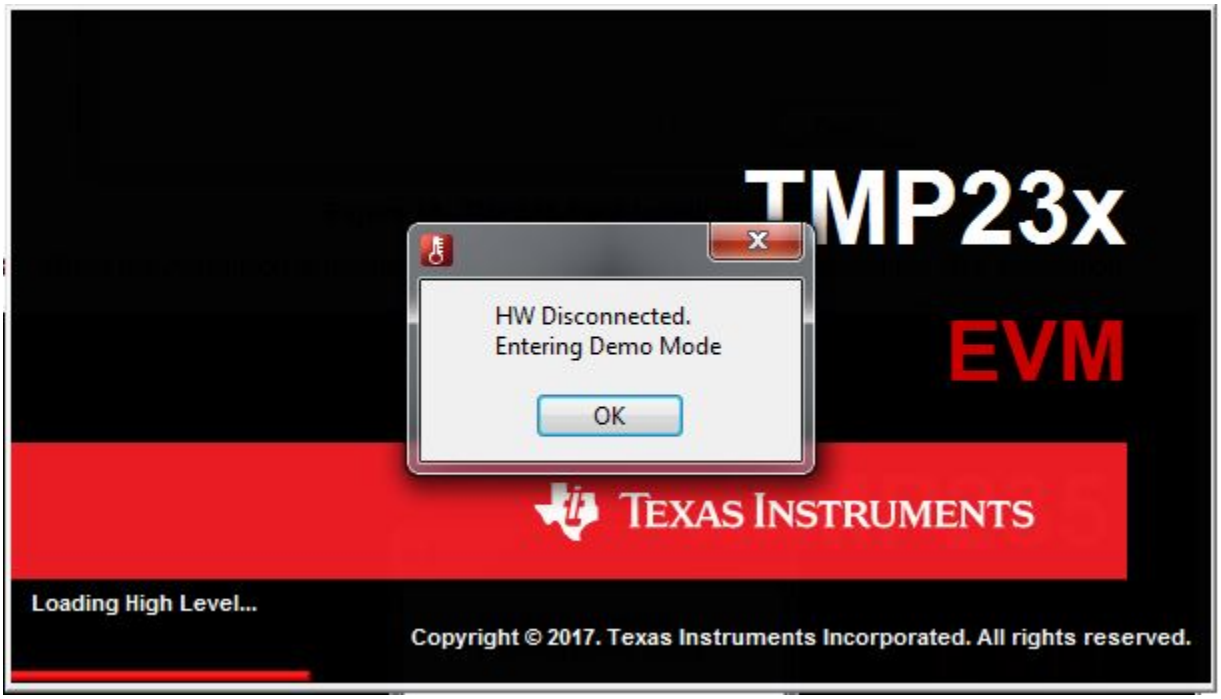

Figure 12. Launching Application in Demo Mode

9. If the EVM hardware isn't plugged in, the application will start in *Demo Mode*.

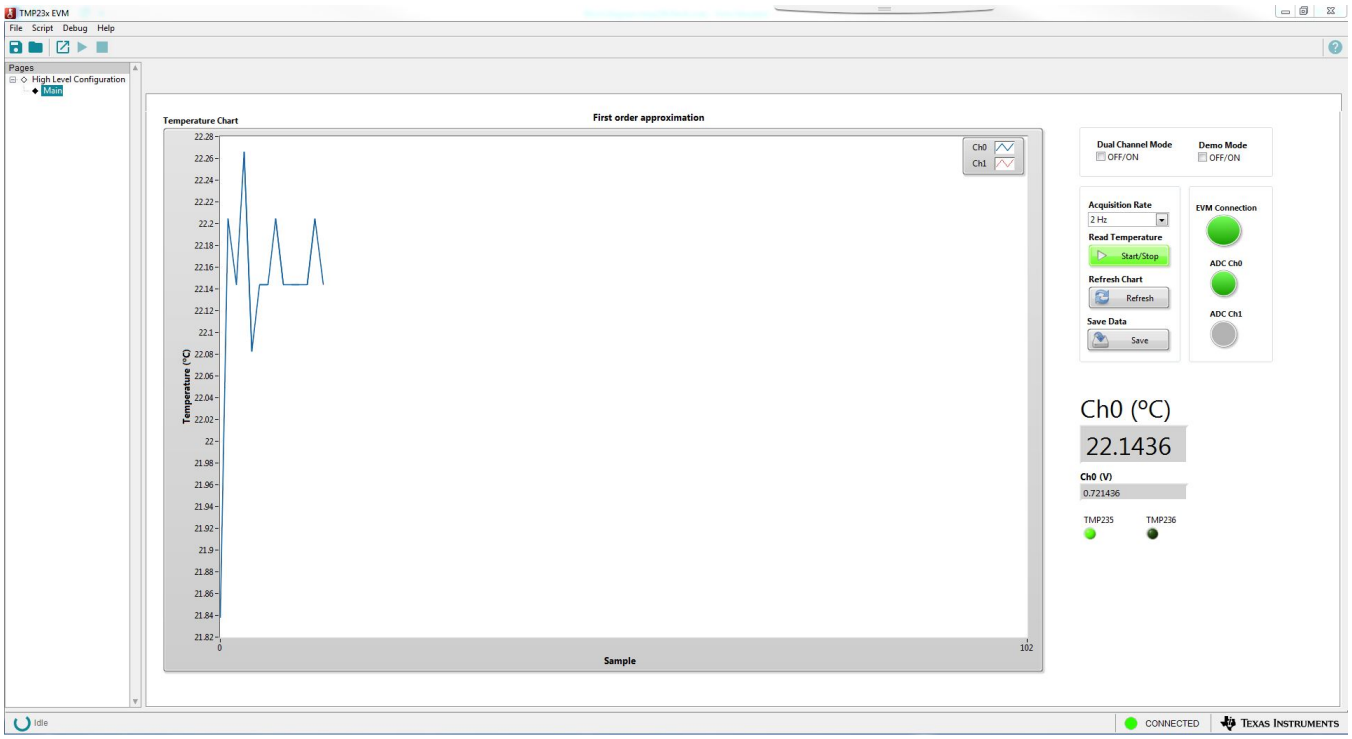

Figure 13. Normal Evaluation Mode

10. The user can enter *Evaluation Mode* when both the EVM hardware is connected to the USB port and the *Demo Mode* setting is off.

4 EVM Software Overview

This section discusses how to use the EVM software.

4.1 Demo Mode

The application will automatically enter *Demo Mode* when no EVM hardware is connected. The user can also force the application into *Demo Mode* by checking the appropriate box. In *Demo Mode*, the user can examine various software functions without requiring a physical EVM plugged in.

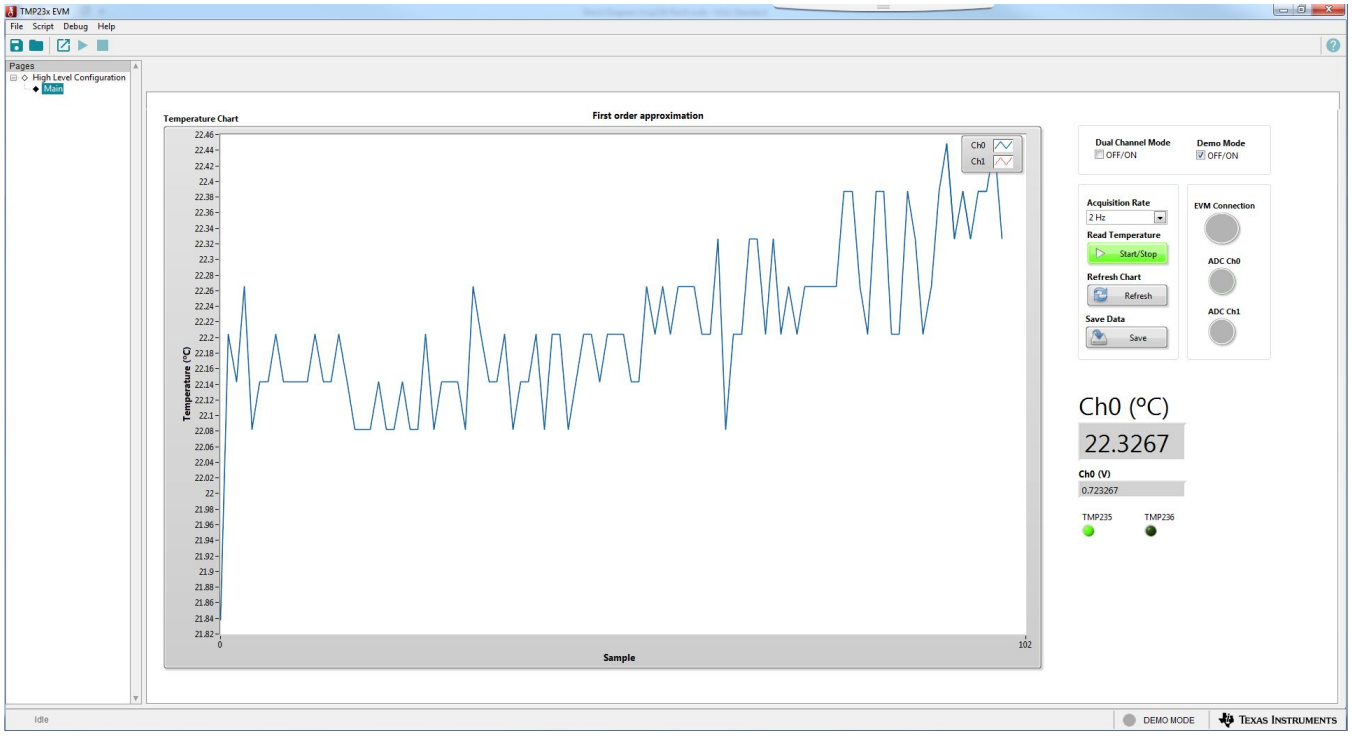

Figure 14. Demo Mode

4.2 Evaluation Mode

Evaluation Mode is the default single-channel evaluation mode when the EVM is plugged in the USB port. The virtual green LED indicators will only show ADC Ch0 as active. Temperature data are streamed on the chart. Depending on the TMP23xEVM variant the user has plugged in, the corresponding TMP235 or TMP236 status LED will be on. For TMP235 variant, the analog reading from the ADC is converted to temperature with the following first-order approximation equation:

$$T(V) = \frac{V_{adc} - 0.5\ V}{0.01\frac{V}{^{o}C}}[^{o}C] \quad (1)$$

For the TMP236 variant, the analog reading from the ADC is converted to temperature with the following first-order approximation equation:

$$T(V) = \frac{V_{ADC} - 0.4\ V}{0.0195\frac{V}{^{o}C}} \quad (2)$$

Alternative methods to convert ADC readings into temperature including second-order approximation and look-up tables can be found in the product datasheet. These methods will yield better accuracy compared to the first-order approximation.

4.3 Dual-Channel Mode

When *Dual Channel Mode* is selected, both ADC channels will be active and the application will change in appearance to reflect this new setting. The virtual green LED indicators will show both ADC channels as active. Similar to *Evaluation Mode* the ADC readings in *Dual Channel Mode* will be converted to temperature using first-order approximation.

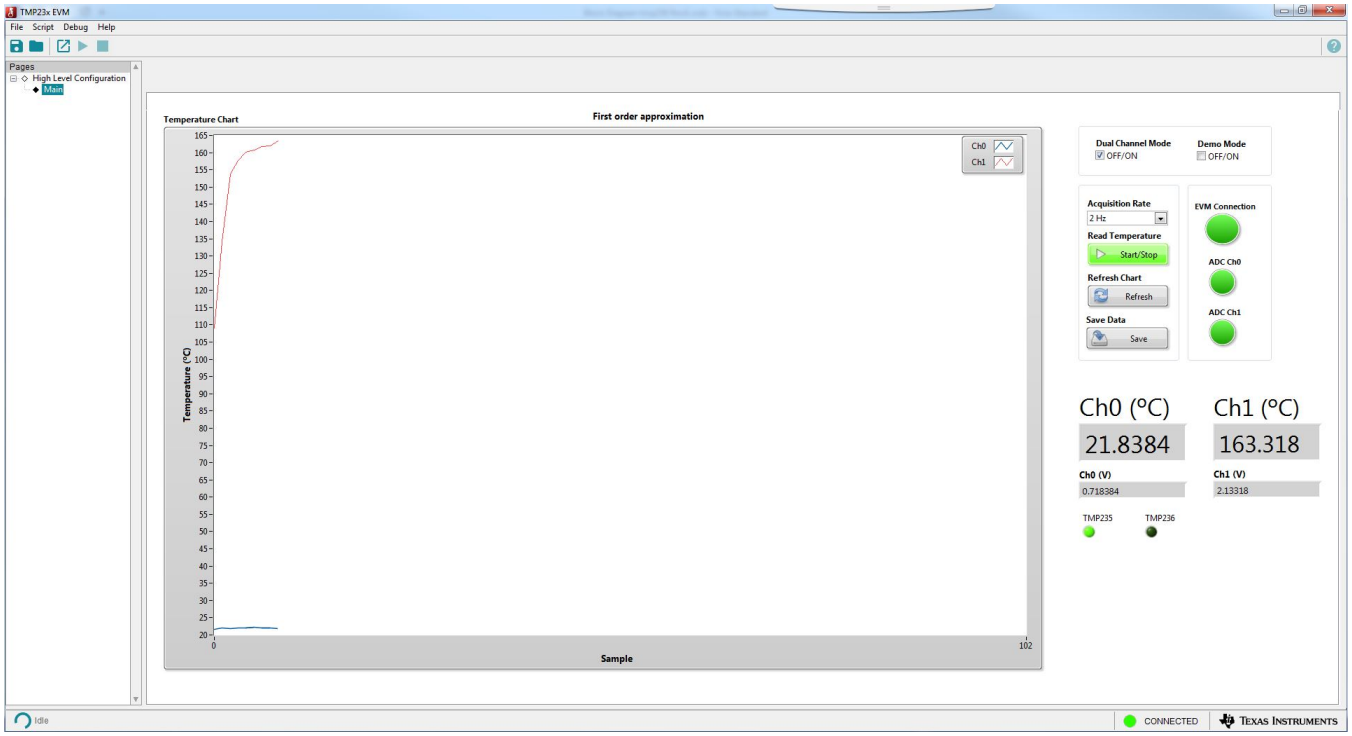

Figure 15. Dual-Channel Mode

4.4 Chart Settings

4.4.1 Acquisition Rate

The user can change the data acquisition rate by selecting one of the rates in the drop-down menu. The default rate is 2 Hz.

4.4.2 Start and Stop

The *Start/Stop* button allows the user to either start or stop the charting. By default, the application will launch with the chart active.

4.4.3 Additional Settings

A number of chart settings are available when right-clicking on the chart including the chart's autoscale feature.

4.4.4 Chart Refresh

The chart can be refreshed by clicking on the *Refresh* button. Note that the chart will automatically refresh itself whenever the user changes the EVM mode.

4.4.5 Save Data

Data acquired can be exported to a CSV file. ADC code, voltage, and temperature are exported.

5 EVM Firmware Update

This section discusses how to update the EVM firmware.

CAUTION

The TMP235EVM software must be installed before performing any tasks.

1. Install TMP23xEVM Software
2. Launch Python_Firmware_UpgraderGUI.exe located in C:\Program Files (x86)\Texas Instruments\TMP23xEVM\Python_Firmware_Upgrader\Python_Firmware_UpgraderGUI.exe
3. Locate USB2ANY_F5528.txt firmware located in C:\Program Files (x86)\Texas Instruments\TMP23xEVM\Firmware\USB2ANY_F5528.txt
4. Hold down SW1 (BSL) on the unit while plugging the EVM into the PC's USB port.
5. In the Upgrader program, click File > Rescan HID Bus…
6. If the Upgrader does not report *ready…* as shown below, then unplug EVM from the PC's USB port and go back to Step 4.

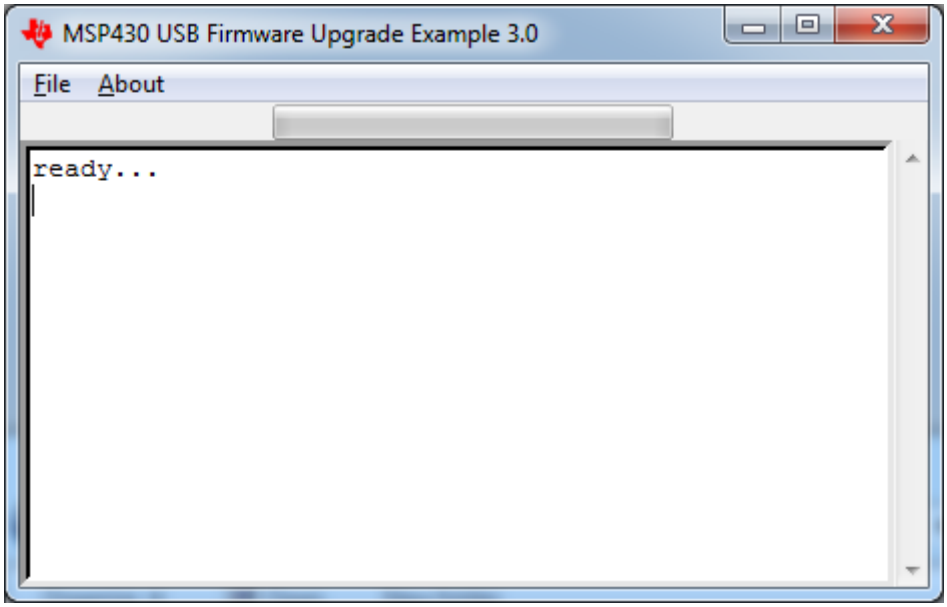

Figure 16. BSL Ready

7. In the Upgrader program, click File > Open User Firmware…
8. Navigate to USB2ANY_F5528.txt and open it.
9. Wait for programming to complete.
10. Verify that the Upgrader output indicates *Programming: OK* twice as shown below.

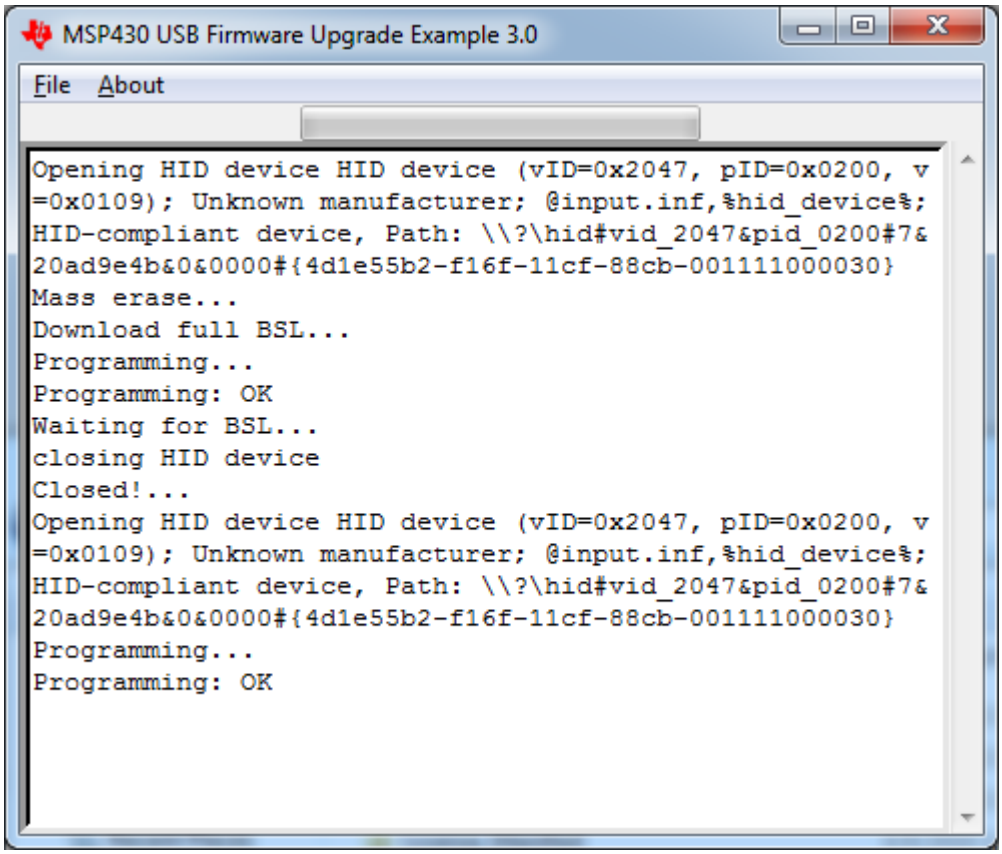

Figure 17. FW Upload Success

11. Lastly, launch TMP23xEVM Software from the Windows Start Menu to verify operation.

6 EVM Documentation

This section contains the schematic diagram, layout, and complete bill of materials (BOM) for the EVM.

6.1 EVM Schematic

Figure 18 shows the schematic for the TMP235EVM board. The TMP236EVM design is virtually the same and is not shown here. The main difference is that TMP236EVM has the MSP430's P6.6 pin tied to GND and the EVM GUI software uses this fact to determine which temperature conversion function to use.

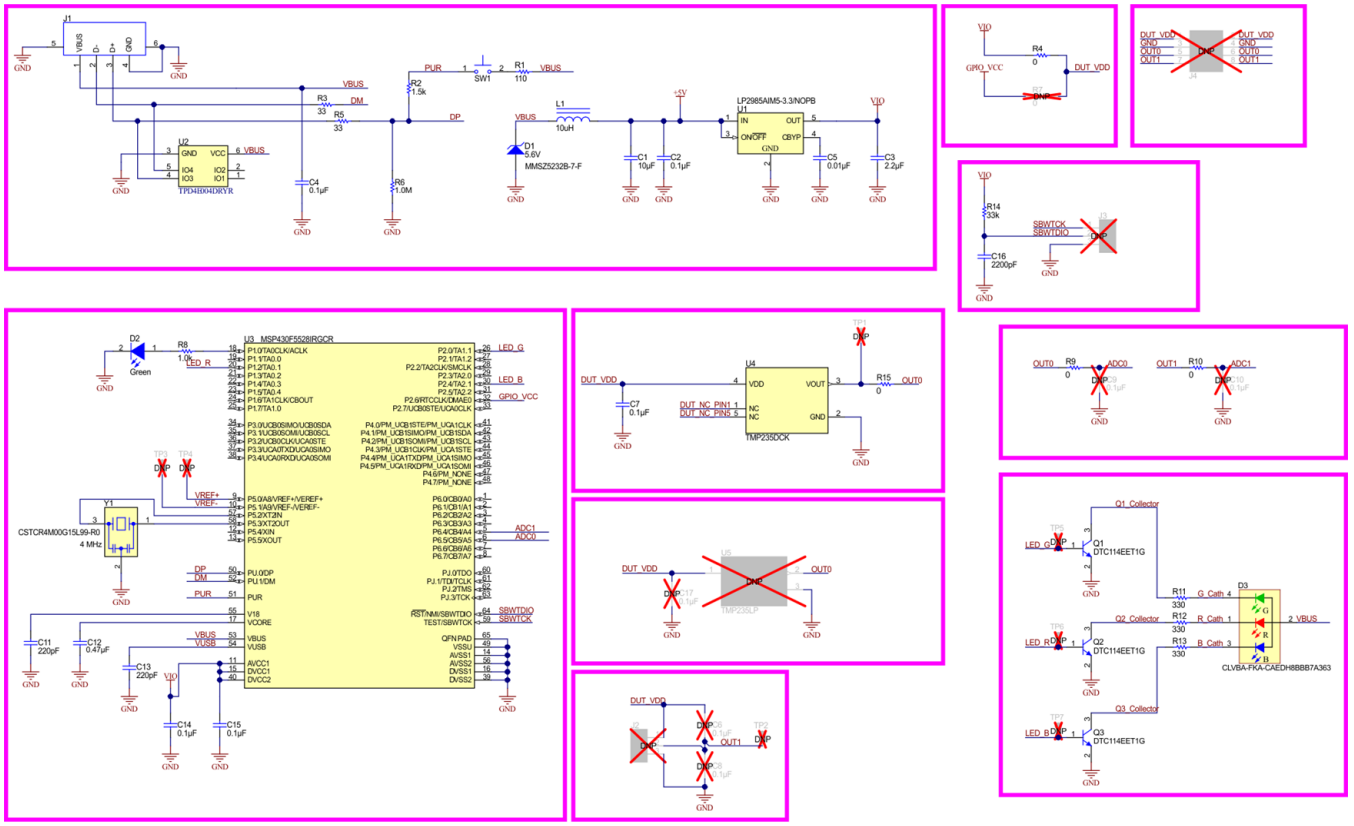

Figure 18. EVM Schematic

6.2 EVM PCB Layout

Figure 19 through Figure 24 show the layout for the TMP235EVM board.

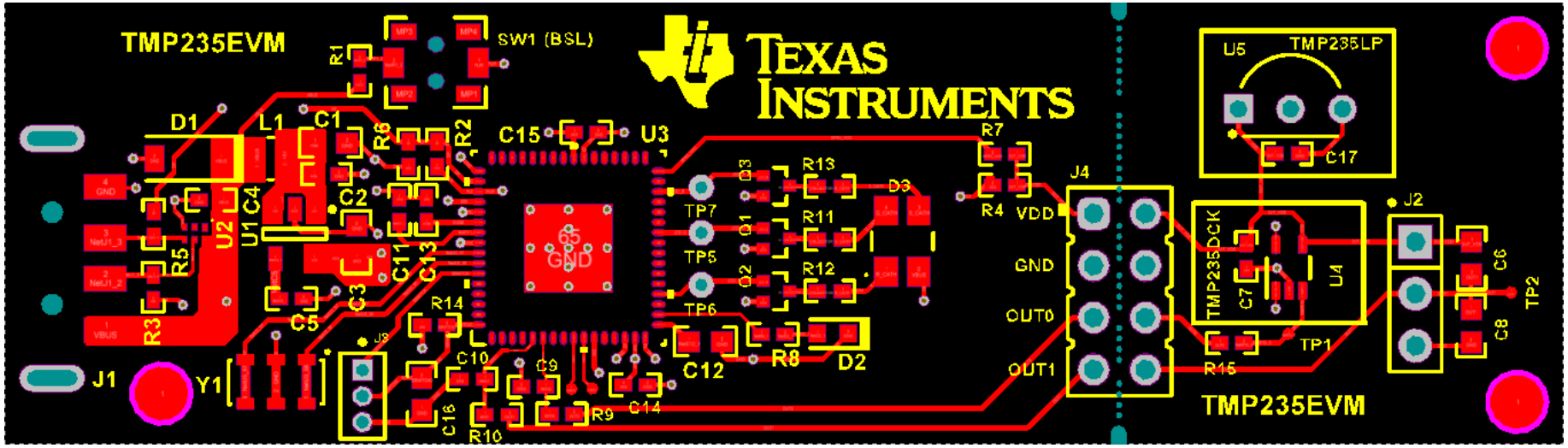

Figure 19. Top Layers

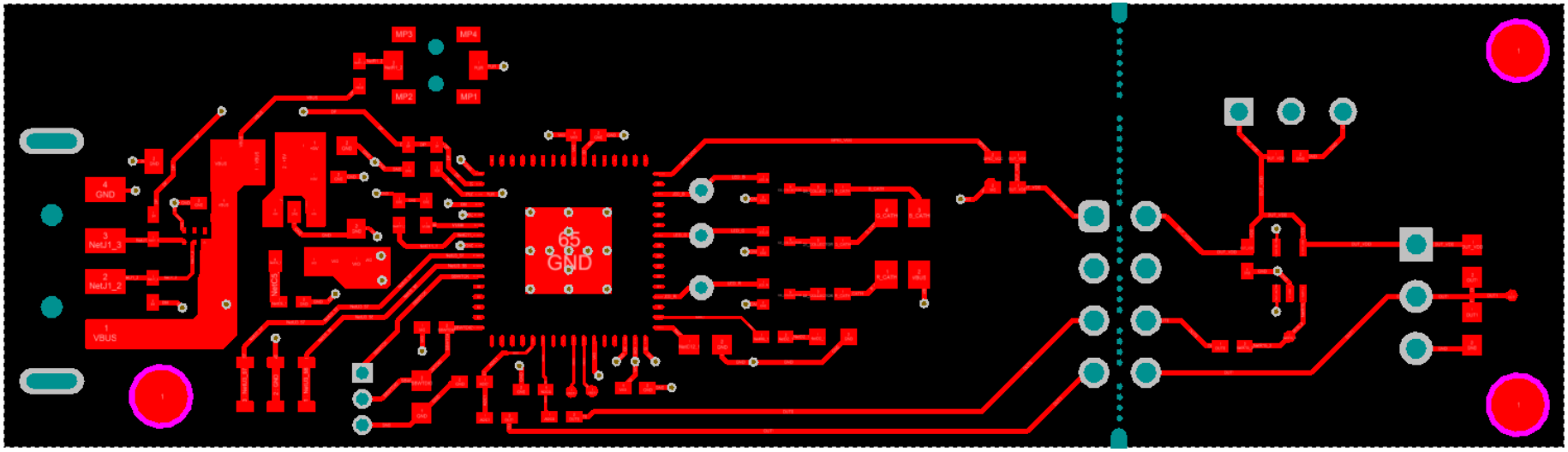

Figure 20. Top Signal Layer

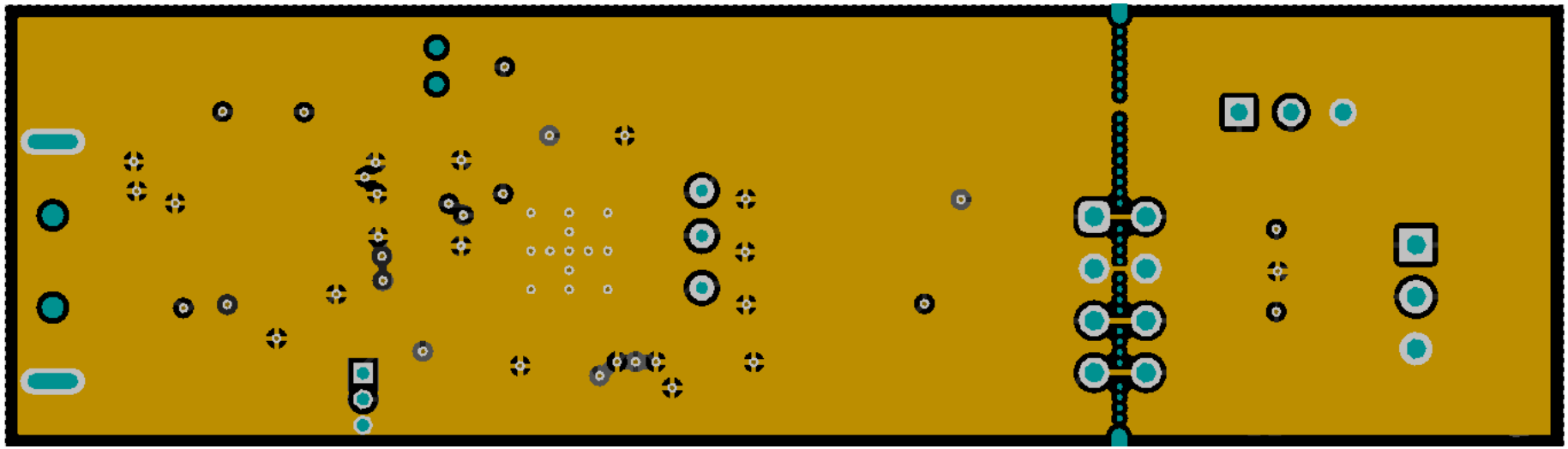

Figure 21. Ground Layer

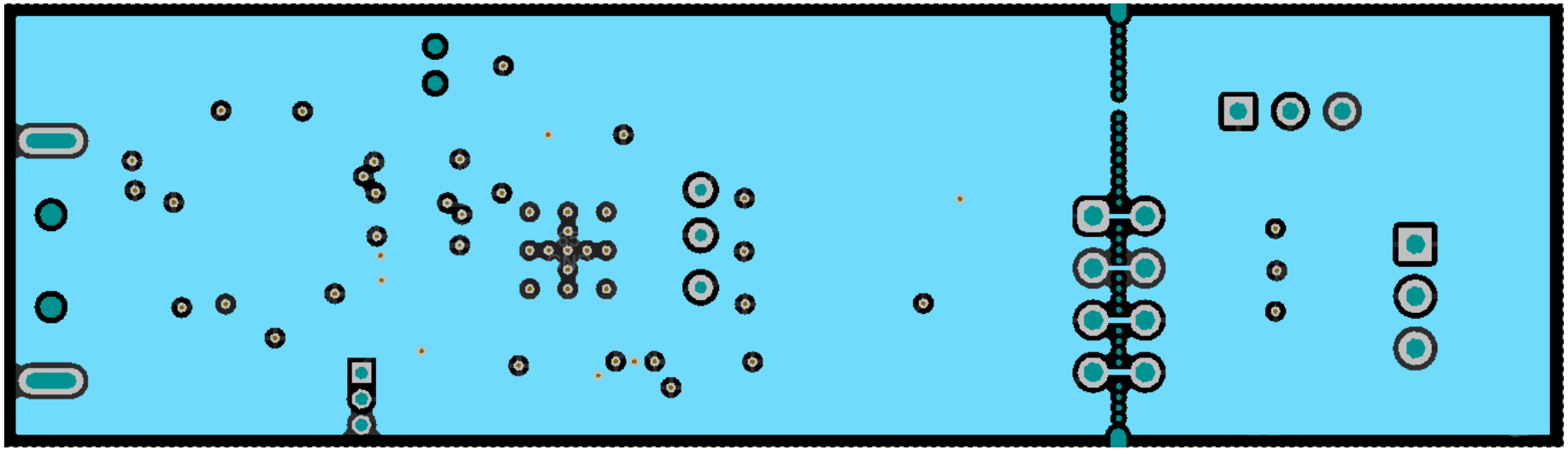

Figure 22. Power Layer

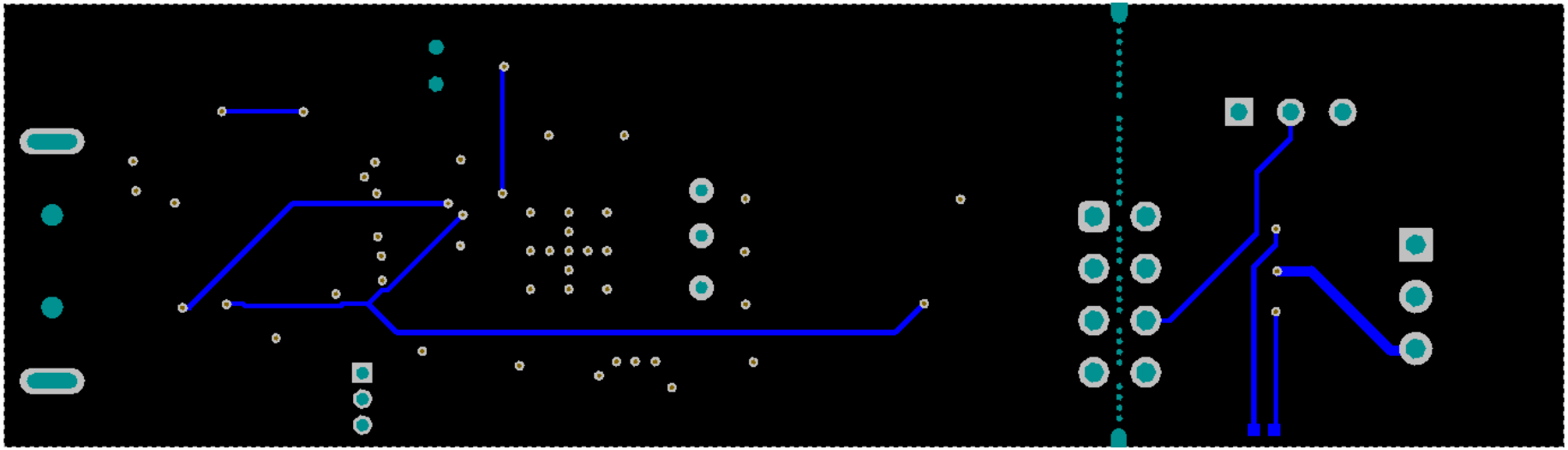

Figure 23. Bottom Signal Layer

Figure 24. Bottom Layers

6.3 EVM Bill of Materials

Table 4 lists the bill of materials for the EVM.

Table 4. EVM Bill of Materials

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
!PCB	1		Printed Circuit Board		MHR059	Any
C1	1	10uF	CAP, CERM, 10 µF, 10 V,+/- 20%, X5R, 0603	0603	C1608X5R1A106M080AC	TDK
C2, C4, C7, C14, C15	5	0.1uF	CAP, CERM, 0.1 µF, 16 V,+/- 5%, X7R, 0402	0402	GRM155R71C104JA88D	MuRata
C3	1	2.2uF	CAP, CERM, 2.2 µF, 10 V,+/- 10%, X5R, 0603	0603	C0603C225K8PACTU	Kemet
C5	1	0.01uF	CAP, CERM, 0.01 µF, 16 V,+/- 10%, X7R, 0402	0402	GRM155R71C103KA01D	MuRata
C11, C13	2	220pF	CAP, CERM, 220 pF, 50 V,+/- 5%, C0G/NP0, 0402	0402	GRM1555C1H221JA01D	MuRata
C12	1	0.47uF	CAP, CERM, 0.47 µF, 10 V,+/- 10%, X7R, 0603	0603	C0603C474K8RACTU	Kemet
C16	1	2200pF	CAP, CERM, 2200 pF, 50 V,+/- 10%, X7R, 0603	0603	C0603X222K5RACTU	Kemet
D1	1	5.6V	Diode, Zener, 5.6 V, 500 mW, SOD-123	SOD-123	MMSZ5232B-7-F	Diodes Inc.
D2	1	Green	LED, Green, SMD	LED_0603	LTST-C191TGKT	Lite-On
D3	1	Rgb	LED, Rgb, SMD	SMD, 3.2x2.8mm	CLVBA-FKA-CAEDH8BBB7A363	Cree
J1	1		Connector, Plug, USB Type A, R/A, Top Mount SMT	Edge mount USB A CONN	48037-2200	Molex
L1	1	10uH	Inductor, Shielded, Ferrite, 10 µH, 0.4 A, 1.38 ohm, SMD	2.0x0.95x1.6mm	VLS201610ET-100M	TDK
Q1, Q2, Q3	3	50 V	Transistor, NPN, 50 V, 0.1 A, AEC-Q101, SOT-416	SOT-416	DTC114EET1G	ON Semiconductor
R1	1	110	RES, 110, 5%, 0.063 W, 0402	0402	CRCW0402110RJNED	Vishay-Dale
R2	1	1.5k	RES, 1.5 k, 5%, 0.063 W, 0402	0402	CRCW04021K50JNED	Vishay-Dale
R3, R5	2	33	RES, 33, 5%, 0.063 W, 0402	0402	CRCW040233R0JNED	Vishay-Dale
R4, R9, R10, R15	4	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R6	1	1.0Meg	RES, 1.0 M, 5%, 0.063 W, 0402	0402	CRCW04021M00JNED	Vishay-Dale
R8	1	1.0k	RES, 1.0 k, 5%, 0.063 W, 0402	0402	CRCW04021K00JNED	Vishay-Dale
R11, R12, R13	3	330	RES, 330, 5%, 0.063 W, 0402	0402	CRCW0402330RJNED	Vishay-Dale
R14	1	33k	RES, 33 k, 5%, 0.063 W, 0402	0402	CRCW040233K0JNED	Vishay-Dale
SW1	1		Switch, SPST-NO, Off-Mom, 0.05A, 12VDC, SMD	3.9x2.9mm	PTS820 J20M SMTR LFS	C&K Components
U1	1		Micropower 150 mA Low-Noise Ultra Low-Dropout Regulator, 5-pin SOT-23, Pb-Free	MF05A	LP2985AIM5-3.3/NOPB	Texas Instruments
U2	1		ESD-Protection Array for High-Speed Data Interfaces, 4 Channels, -40 to +85 degC, 6-pin SON (DRY), Green (RoHS & no Sb/Br)	DRY0006A	TPD4E004DRYR	Texas Instruments
U3	1		25 MHz Mixed Signal Microcontroller with 128 KB Flash, 8192 B SRAM and 47 GPIOs, -40 to 85 degC, 64-pin QFN (RGC), Green (RoHS & no Sb/Br)	RGC0064B	MSP430F5528IRGCR	Texas Instruments

Table 4. EVM Bill of Materials (continued)

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
U4	1		TMP235DCK, DCK0005A (SOT-SC70-5)	DCK0005A	TMP235DCK	Texas Instruments
Y1	1		Resonator, 4 MHz, 39pF SMD	4.5x1.2x2 mm	CSTCR4M00G15L99-R0	MuRata
C6, C8	0	0.1uF	CAP, CERM, 0.1 µF, 16 V,+/- 5%, X7R, 0603	0603	0603YC104JAT2A	AVX
C9, C10, C17	0	0.1uF	CAP, CERM, 0.1 µF, 16 V,+/- 5%, X7R, 0402	0402	GRM155R71C104JA88D	MuRata
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
J2	0		Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
J3	0		Header, 50mil, 3x1, Gold, TH	Header, 1.27 mm, 3x1, Gold, Straight, TH	850-10-003-10-001000	Mill-Max
J4	0		Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH	TSW-104-08-L-D	Samtec
R7	0	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
TP1, TP2, TP3, TP4, TP5, TP6, TP7	0		TEST POINT. No entry in BOM.	N/A		
U5	0		TMP235LP, LP0003A (TO-92-3)	LP0003A	TMP235LP	Texas Instruments

Revision History

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

Changes from Original (September 2017) to A Revision	Page
• Added TMP236EVM to the user's guide	1
• Changed TMP235 maximum specified operating temperature from: 125°C to: 150°C	6
• Added equations to *Evaluation Mode* section	13

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