

TPS274C65 USB EVM - Application Level EVM



ABSTRACT

The TPS274C65EVM is an application level evaluation module made to showcase the powerful power delivery features of the TPS274C65 industrial high-side switch. The TPS274C65EVM is meant to mimic a real-world industrial end-application and thus comes with features such as an integrated TM4C ARM Cortex-M4F microcontroller, digital isolation, multiple high-side switches connected to the MCU via SPI, and compact layout design with limited test-points.

Table of Contents

1 Description	2
2 Get Started	2
3 Features	2
4 Applications	2
5 Introduction	3
6 TPS274C65 Configurator Software	4
6.1 Software Usage	4
6.2 Header File	13
7 Hardware Design Files	14
7.1 Schematics	14
7.2 PCB Layouts	16
8 Bill of Materials (BOM)	20
9 Additional Information	21
9.1 Trademarks	21

1 Description

The TPS274C65EVM is an application level evaluation module made to showcase the powerful power delivery features of the TPS274C65 industrial high-side switch. The TPS274C65EVM is meant to mimic a real-world industrial end-application and thus comes with features such as an integrated TM4C ARM Cortex-M4F microcontroller, digital isolation, multiple high-side switches connected to the MCU via SPI, and compact layout design with limited test-points. In addition to the hardware EVM, a software package of both the firmware running on the TM4C microcontroller (written in embedded C) and a host GUI with source code are provided to be used as a reference in the end application.

2 Get Started

1. Download and unzip the **TPS274C65 Configurator** for Windows
2. Plug in a power supply (the TPS274C65 supports 12V to 36V nominal) to the **VS (J3)** banana jack and connect ground to the **GND terminal (J8)**
3. Connect relevant loads and ground connections to the output terminals of the TPS274C65USB EVM
4. Connect the TPS274C65USB EVM via USB to host computer
5. Open the TPS274C65 Configurator and use the program as described in this guide

The TPS274C65USB EVM requires a standard USB connection to a host computer for interaction between the host software and the embedded firmware running on the TM4C123 microcontroller. The interface is written using standard Windows HID libraries so no driver installation is needed. Besides powering the microcontroller and relevant digital components, the USB power is isolated from the high-side switch and high-current components via the ISO7763DWR reinforced digital isolation.

Please refer to the TPS274C65 datasheet for the exact power supply requirements for proper operation of the TPS274C65 high-side switches. While the high-side switches will protect against over-current events and thermal faults, over voltage conditions outside what the TPS274C65 was designed for could potentially cause damage and should not be applied to the board.

3 Features

- 2 x TPS274C65 65mΩ quad-channel industrial high-side switches placed in "addressable SPI" configuration
- Integrated TM4C123 ARM Cortex-M4F microcontroller with USB host interface
- Full-featured and lightweight Windows host GUI for device configuration and monitoring
- Complete digital isolation from digital and high-current rails using the ISO7763DWR reinforced isolation device

4 Applications

- Industrial PLC Systems
 - Digital Output Modules
 - IOLink Master Ports
 - Sensor Supplies

5 Introduction

The TPS274C65USBEVM is an application level evaluation module made to showcase the powerful power delivery features of the TPS274C65 industrial high-side switch. The TPS274C65USBEVM is meant to mimic a real-world industrial end-application and thus comes with features such as an integrated TM4C ARM Cortex-M4F microcontroller, digital isolation, multiple high-side switches connected to the MCU via SPI, and compact layout design with limited test-points. In addition to the hardware EVM, a software package of both the firmware running on the TM4C microcontroller (written in embedded C) and a host GUI with source code are provided to be used as a reference in the end application.

Features include:

- 2 x TPS274C65 65mΩ quad-channel industrial high-side switches placed in "addressable SPI" configuration
 - Provides 8x total independent output channels with parallel configurations supported
 - Adjustable current limit with special inrush duration control for capacitive charging
 - Integrated ADC allowing for high-accuracy reporting of current sense, FET temperature, and input/output voltage
- Integrated TM4C123 ARM Cortex-M4F microcontroller with USB host interface
 - Plug-and-play operation using USB-HID with no need for customer driver installation
 - Pre-programmed firmware with no need for an external debugger
 - External programming of custom firmware possible via 10-pin ARM debugger
- Full-featured and lightweight Windows host GUI for device configuration and monitoring
 - Ability to configure/change all register settings of both TPS274C65 devices including current limit, diagnostic configurations, etc.
 - Reporting/sensing of load current, FET temperature, and input/output voltage with active graphing
 - Fault monitoring and reporting for full array of fault conditions such as current limit, thermal faults, open load/wirebreak, etc.
- Complete digital isolation from digital and high-current rails using the ISO7763DWR reinforced isolation device

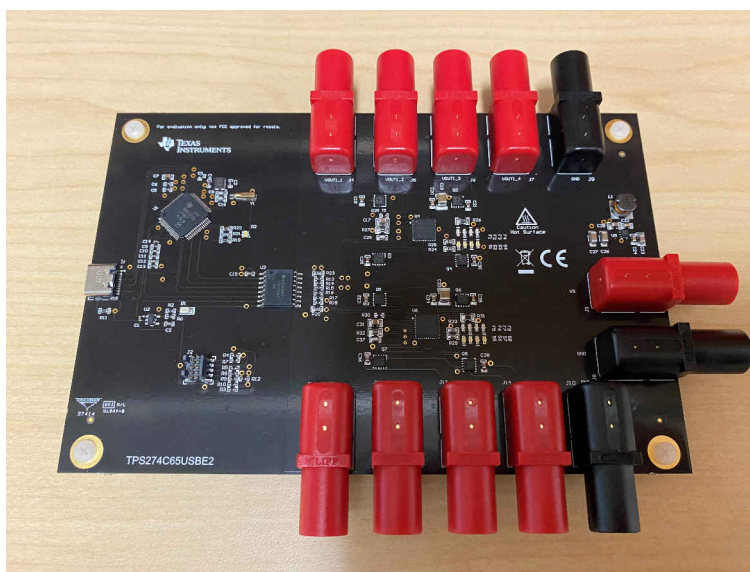


Figure 5-1. Board Image

6 TPS274C65 Configurator Software

6.1 Software Usage

Once you open the TPS274C65 Configurator software a connection to the EVM will automatically start to be initiated:

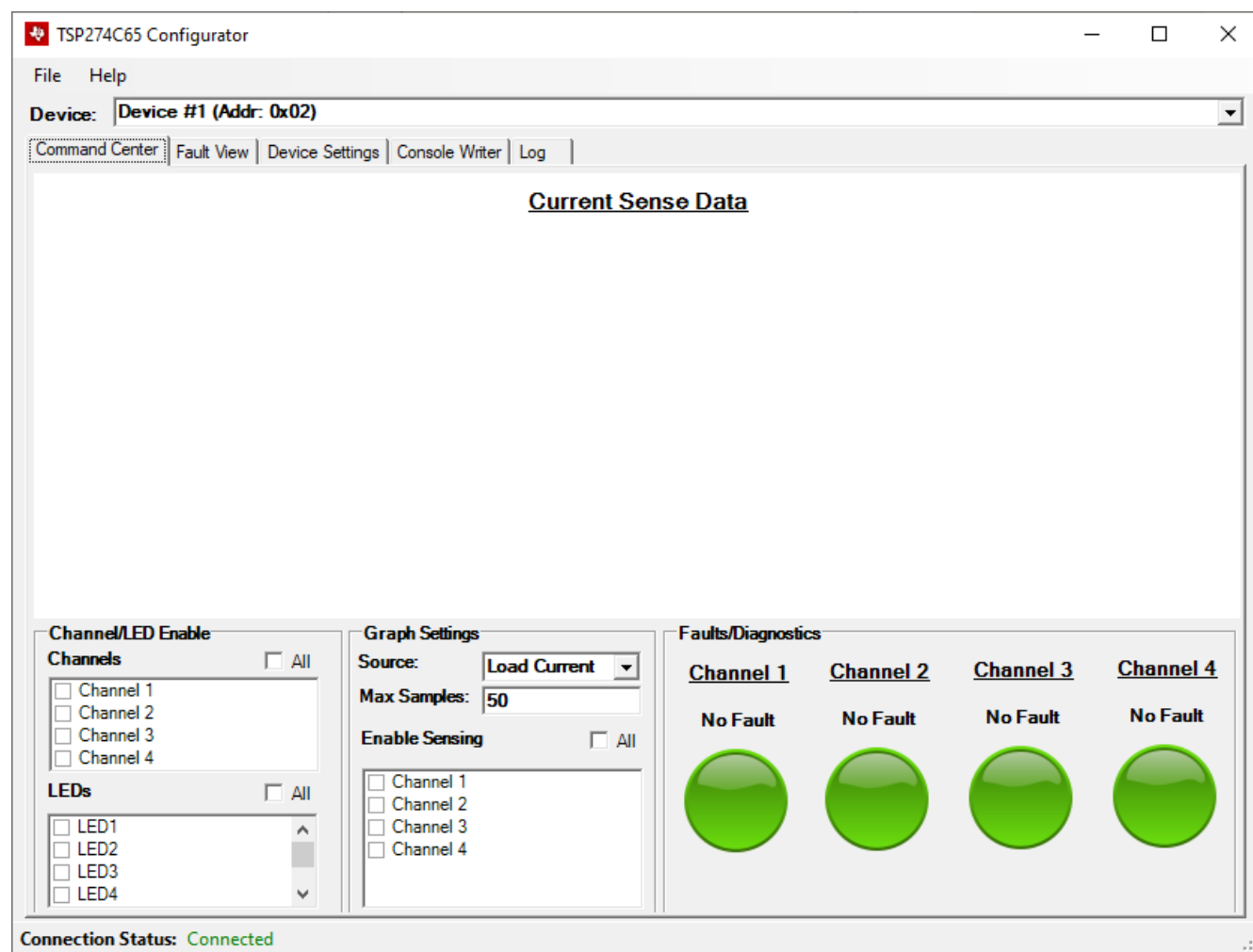


Figure 6-1. Configurator on Startup

The configurator software will automatically detect when the EVM is plugged into or removed from the host system without any drivers. The connection status will automatically be indicated on the bottom of the task strip under the **Connection Status** label. If the software cannot find the EVM it will show as disconnected and all controls will be disabled:

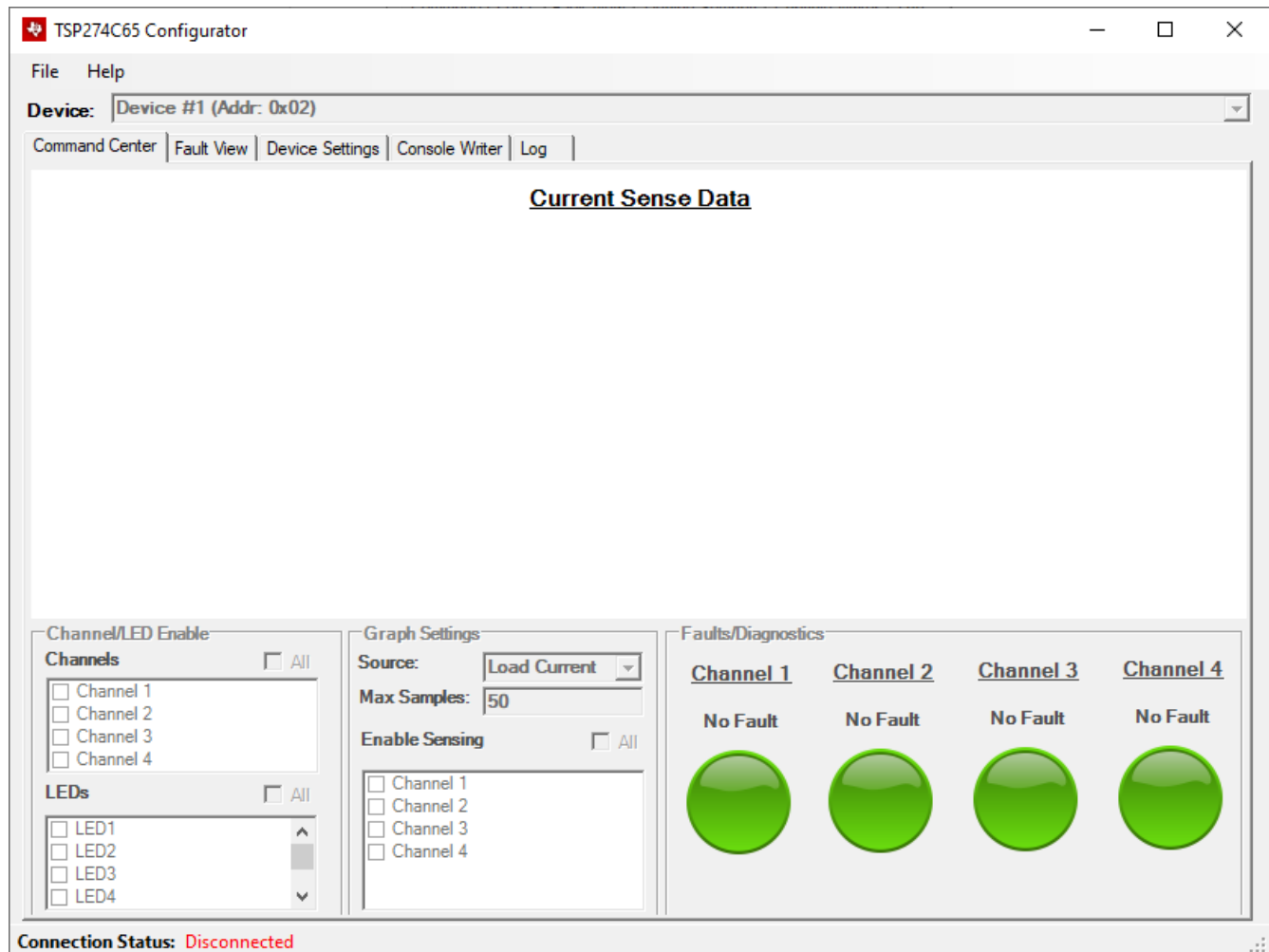


Figure 6-2. Disconnected Device

As the TPS274C65USBEVM contains two separate TPS274C65 high-side switches, the **Device** selector combo box on the top of the screen is used to switch views between the two devices. When switching between devices, all information on the current screen is automatically read from the register map of the device without the need for any manual interaction. There are two devices on the TPS274C65EVM:

- Device #1 (Addr: 0x02)
- Device #2 (Addr: 0x05)

The device's address are configured using the resistors on **R26** and **R35** of the EVM. If the user wishes to change the address of the device, these resistors must be changed on the EVM in accordance to the datasheet parameters.

To turn on and off channels for the high-side switch, simply check the boxes under the **Channels** group. Whenever a single box is checked, the program will communicate with the MCU on the EVM to turn on the selected channel. The MCU will automatically construct the relevant SPI packet and send it to the high-side switch. Similarly, clicking any of the boxes under the **LEDs** group will toggle the LEDs connected to the TPS274C65's debug LED outputs.

To enable real-time sensing/graphing of the TPS274C65's integrated ADC results, the user should enable sensing by checking any of the **Channel** boxes under **Enable Sensing**. This will start a polling thread in the background to periodically sample and read the results of the **ADC_RESULT** registers in the TPS274C65. Note that by enabling sensing, the device automatically enables the **ADC_EN** bit of the **DEV_CONFIG5** register of the selected device so that relevant data can be read. The user can choose to graph the following different sources via the Source combo box:

- Load current
- FET Temperature
- Output Voltage

Note that when sensing is enabled, input voltage will automatically be displayed on the task strip at the bottom of the window. Additionally, the numerical value of the current sample will be displayed below the **Channel** label in the **Faults/Diagnostics** group when sensing is enabled. An example of a light load current being graphed can be seen below:

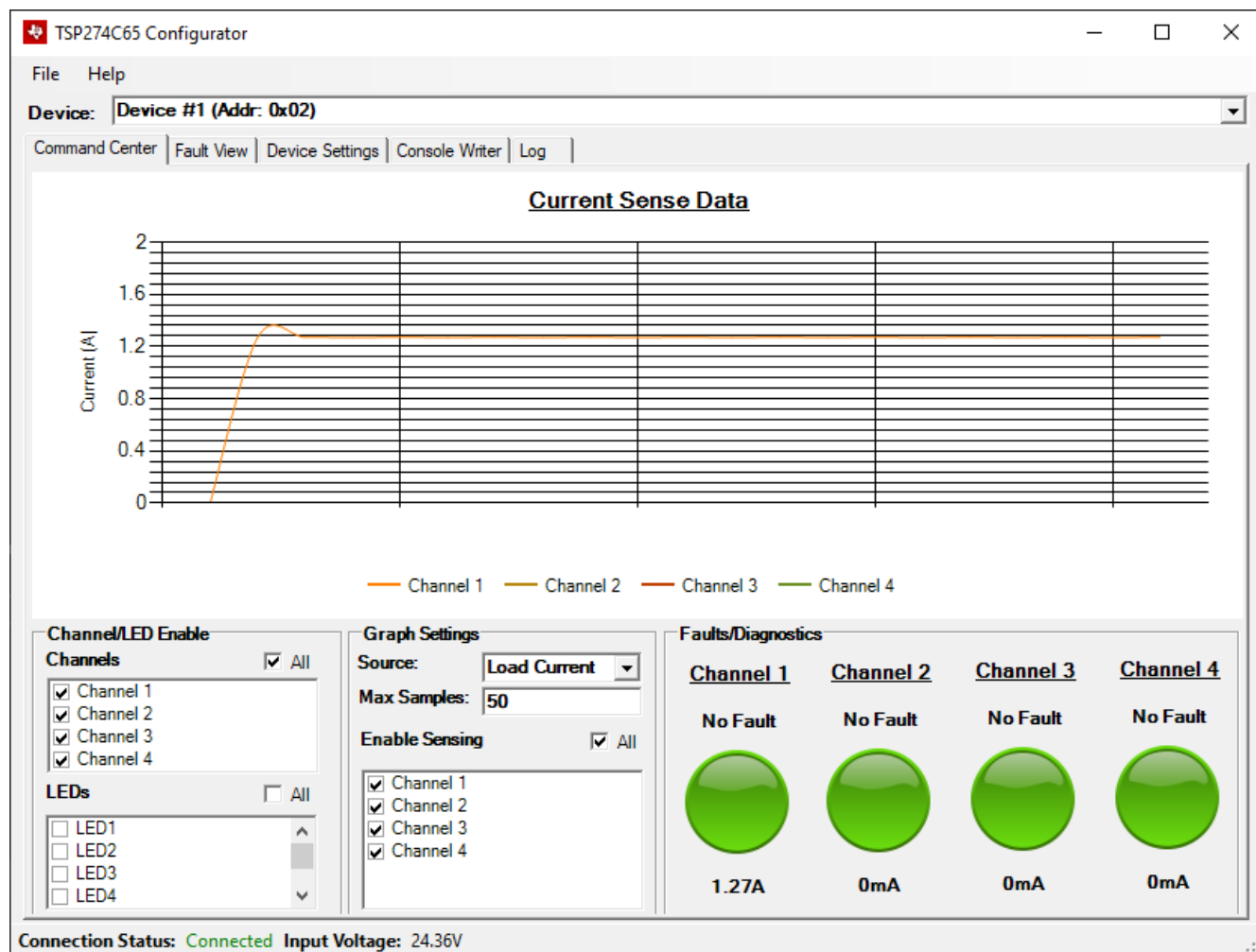


Figure 6-3. Light Load Current

The maximum number of samples that are collected/stored on the graph can be adjusted via the **Max Samples** box.

The **Fault/Diagnostics** group shows a high-level representation of the per-channel fault status. Specifically, these fault statuses mirror the values in the **FAULT_CH_STAT** register of the device. A background thread is running that automatically updates the graphic representations. If a fault exists in the system the indicator turns red and if no fault exists the indicator is green. An example of a faulted channel (in this case current limit) can be seen below:

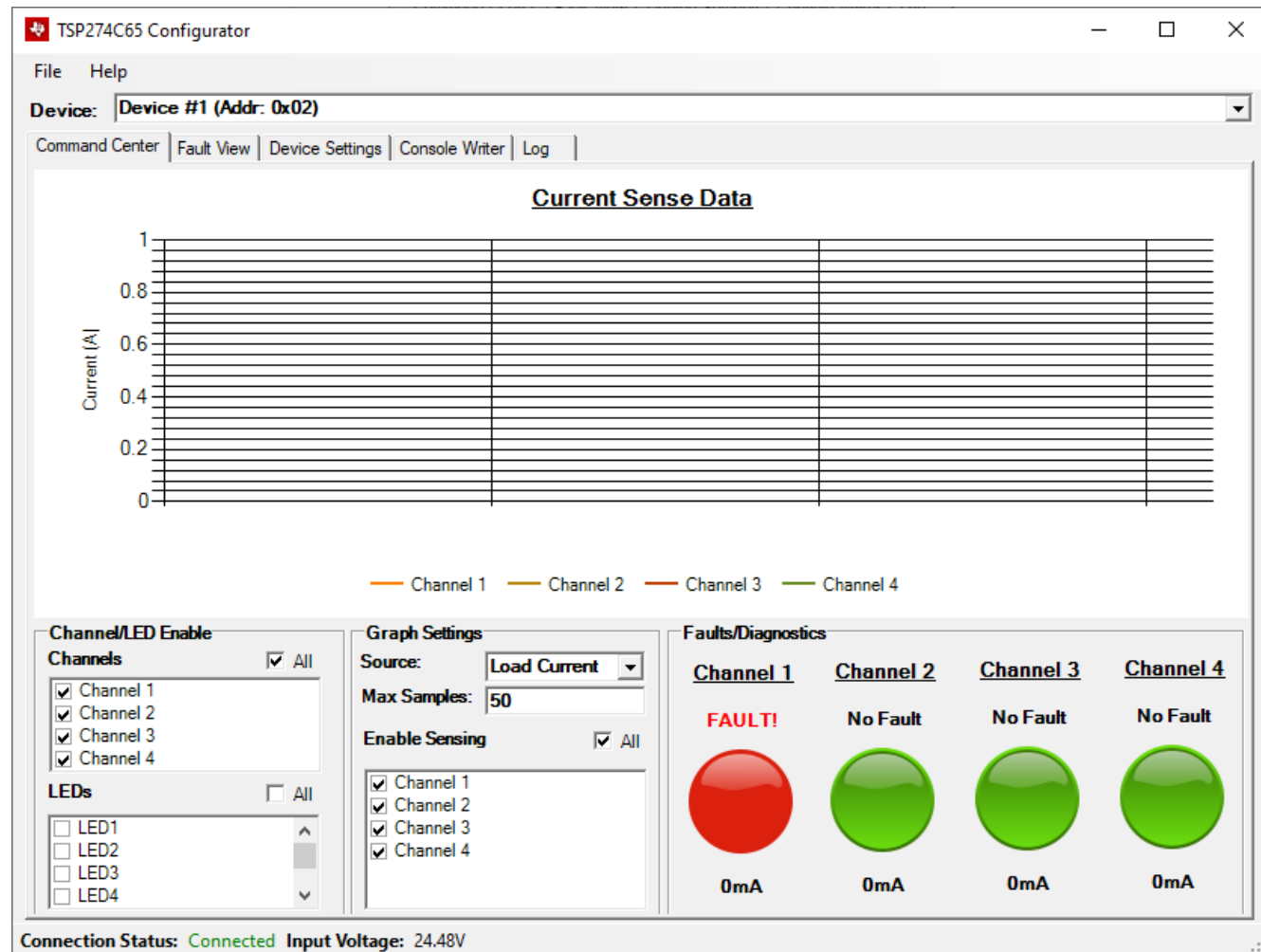


Figure 6-4. Faulted Channel

Note that if you click the fault icon the navigation will automatically change to the detailed **Fault View**:

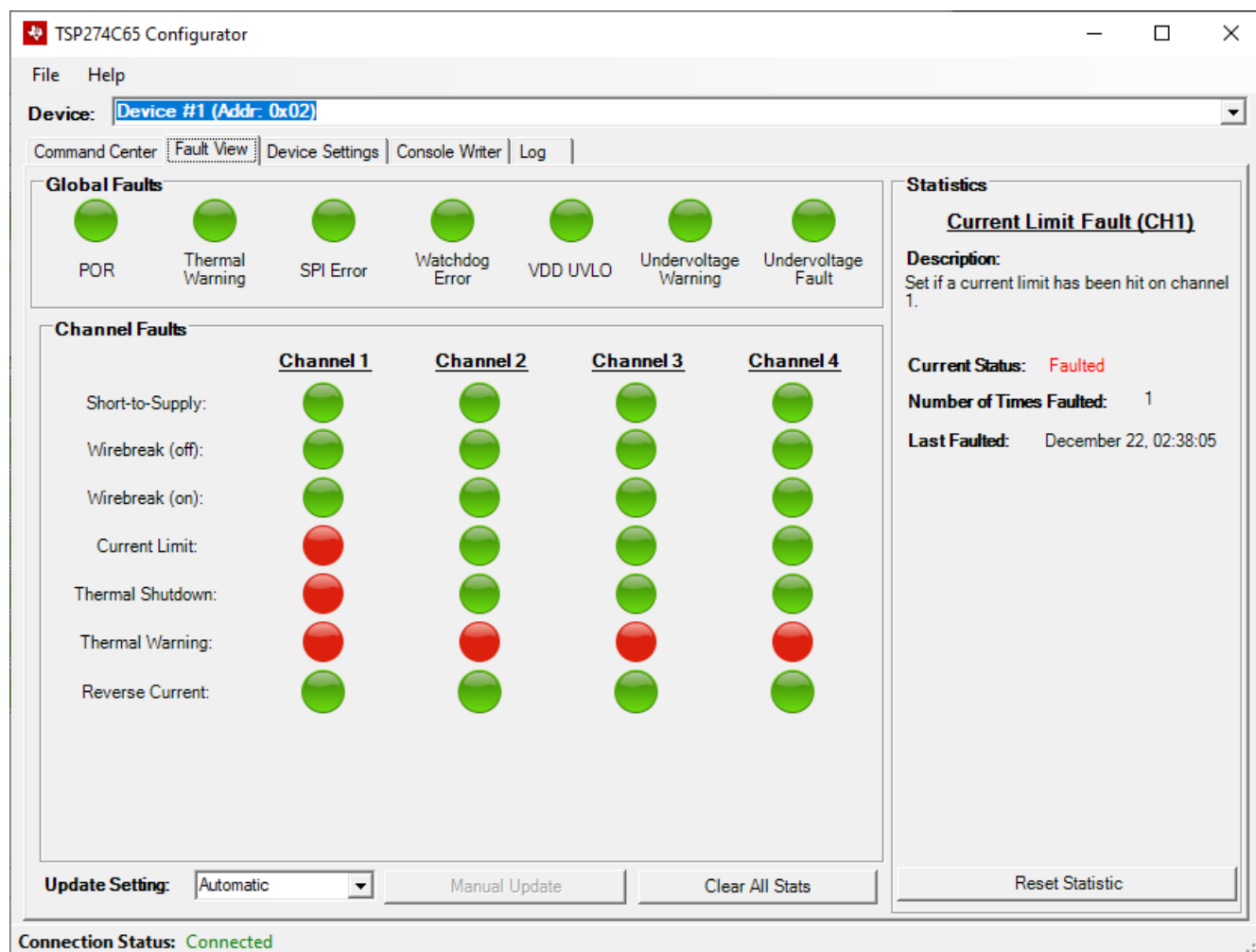


Figure 6-5. Fault View

The fault view of the device contains a detailed report of each fault in the system on both a global level and a per-channel level. This view simply aggregates the following registers from the TPS274C65's register map:

- FAULT_TYPE_STAT (represented in **Global Faults**)
- SHRT_VS_CH_STAT (Short-to-Supply)
- WB_OFF_CH_STAT (Wirebreak (off))
- WB_ON_CH_STAT (Wirebreak (on))
- ILIMIT_CH_STAT (Current Limit)
- THERMAL_SD_CH_STAT (Thermal Shutdown)
- THERMAL_WRN_CH_STAT (Thermal Warning)
- RVRS_BLK_CH_STAT (Reverse Current)

For detailed descriptions of all of these faults and what they indicate, refer to the TPS274C65 datasheet. Note that when you click any of the fault indicator icons the **Statistics** pane is updated on the right of the window to reflect the selected fault. In the statistics view, the user is able to see how many times the specific fault occurred as well as when the fault last occurred. To reset the local statistic data, the user can either click **Reset Statistic** to reset the individual statistic or **Clear all Stats** to reset all of the local statistics.

For many of the faults (such as POR), reading the fault status will clear the bit in the fault status register. Because of this, the user has the ability to switch between **Manual** and **Automatic** update mode. In automatic mode, a background task automatically polls the high-side switch's fault registers and reports the fault status via the fault view. To switch to manual mode, change the **Update Setting** combo box to **Manual**. This will enable the **Manual Update** button. When this button is clicked all statistics for the selected TPS274C65 device are updated manually.

The next tab controls all of the settings of the device.

The screenshot shows the TPS274C65 Configurator software window. The 'Device' dropdown is set to 'Device #1 (Addr: 0x02)'. The 'Device Settings' tab is selected, showing various configuration options for the device. The interface is divided into several sections: Current Limit, Device Settings, Fault/Diagnostics, Fault Masking, and Sensing. The 'Current Limit' section has settings for Channels 1 and 2 (Limit: 0.4A, Duration: 0ms) and Channels 3 and 4 (Limit: 1.6A, Duration: 0ms). The 'Device Settings' section includes Wire Break (off) Pull-up Current (50uA), Wire Break (on) Threshold (0.96mA), Wire Break Blanking Time (0.4ms), Thermal Shutdown Retry (Latched), Parallel Channels (1 and 2, 3 and 4), Watchdog (Enable, Duration: 400us timeout), Watchdog State Keep (Enable), Default Watchdog Channel State (1, 2, 3, 4), Reverse Current Blocking (RCB) (Enabled), Reverse Current Blocking Channel Enable (1, 2, 3, 4), and Fault Bit Latching (Enabled). The 'Fault/Diagnostics' section has checkboxes for Wirebreak (On) Enable, Wirebreak (Off) Enable, Short-to-VS Enable, and Fault Masking (SPI Error, Watchdog Error, Current Limit, Reverse Current, Short-to-VS, Wire Break Off, Wire Break On, Under Voltage). The 'Sensing' section has checkboxes for ADC Enable, Conversion Enable (Current, In Voltage, Out Voltage, Temperature), Current Sense Range (<= 800mA, > 800mA), and Sense Sources (Junction Temperature, Output Voltage, Load Current). The 'Connection Status' at the bottom is 'Connected'.

Figure 6-6. Device Settings

For the specific meaning of each one these settings, please refer to the TPS274C65 datasheet. Specifically, each setting closely mirrors the register map settings of the device. It is important to note that some settings will not be able to be changed when the device has channels actively enabled. When a channel is enabled, the affected settings will be grayed out to prevent interaction from the use. The controls on the device settings page are active. This means that as soon as you change a value, the relevant change will be persisted to the microcontroller and to the high-side switch.

The **Console Writer** tab gives the user the ability to perform direct read/write operations to the selected TPS274C65.

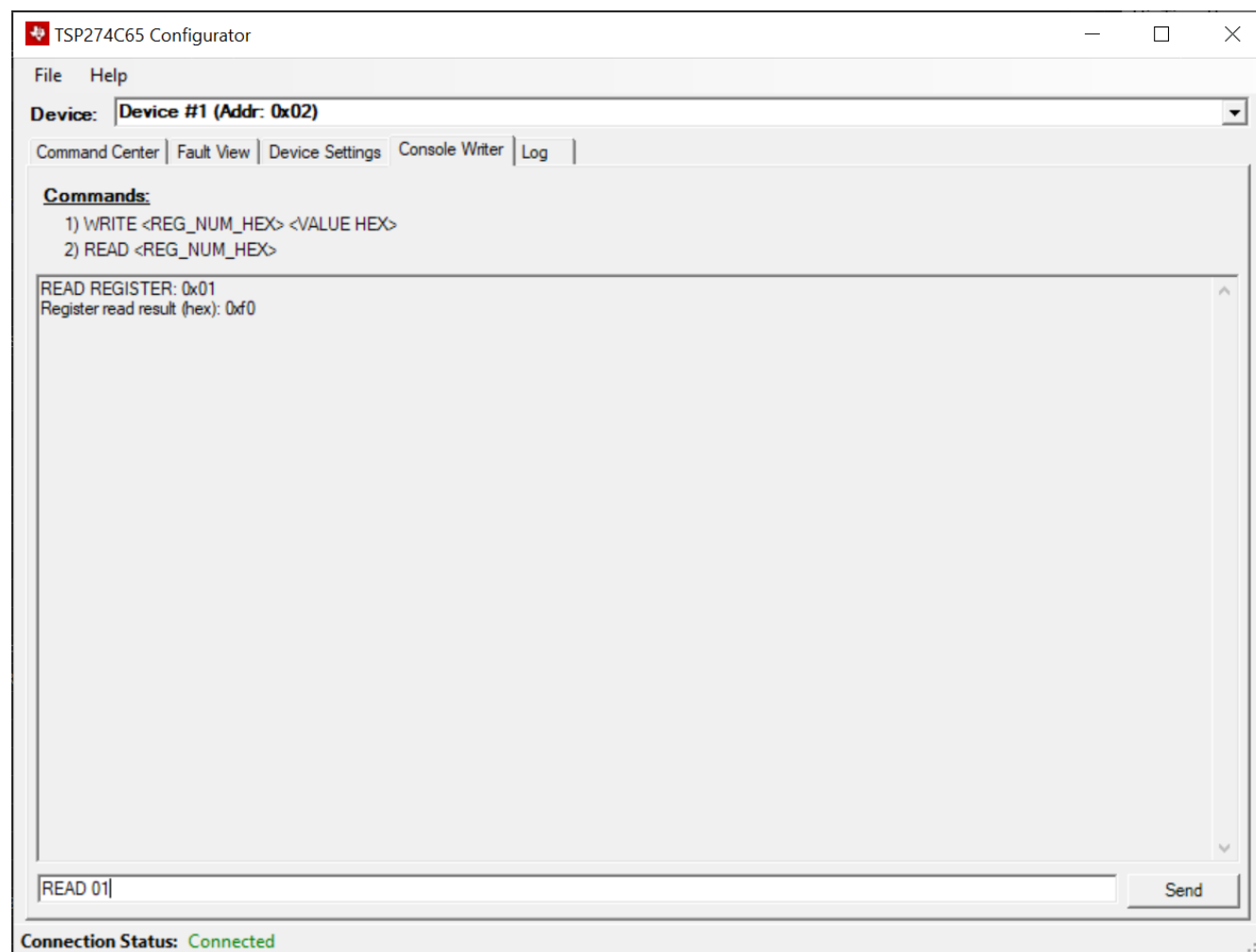


Figure 6-7. Register Read

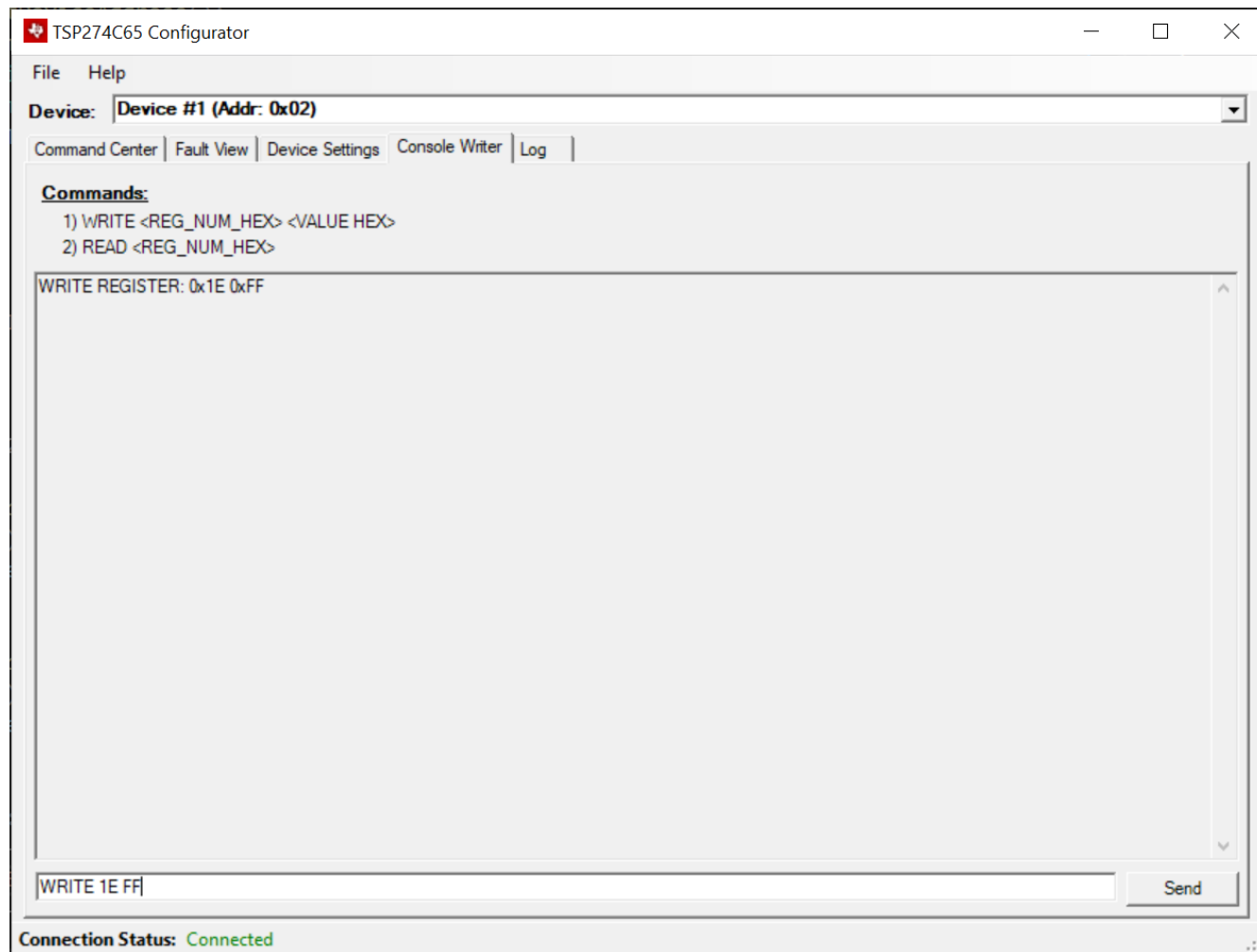


Figure 6-8. Register Write

This provides a direct way to manipulate the bitwise settings of the TPS274C65's register map without any interaction with functional controls. Examples on how to read/write directly to the high-side switch's register maps can be seen in the screenshots above.

The last tab of the application is the device log. This tab simply keeps a timestamped record of all events that have happened on the configurator tool.

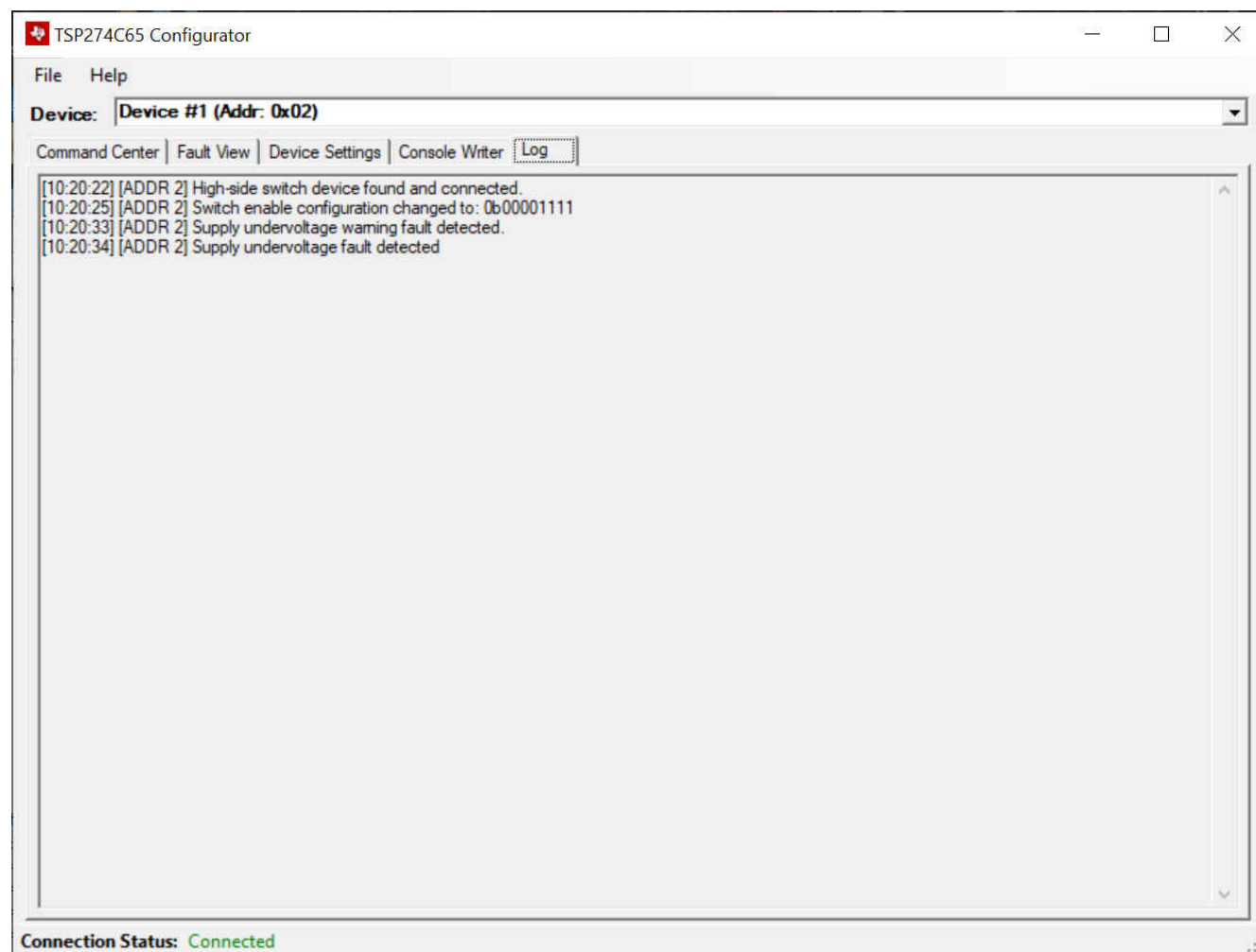


Figure 6-9. Device Log

Another feature that the TPS274C65 Configurator tool has is the ability to save/load configurations. This allows the user to export/import all of the configured settings of the device for ease-of-use. Note that this functionality is only available when the TPS274C65USB EVM is connected. To access this feature, simply click the relevant function on the **File** menu. The exported configuration file is a simple ASCII text file with the configuration of both high-side switches on the board.

6.2 Header File

A header file written in C is available to use with TPS274C65 software development. This header file was generated from the register map of the TPS274C65's datasheet and allows the user to configure and control every bit in the TPS274C65's configuration space. This header file can be found on the TPS274C65's product page.

Each register address is defined using a #define with a description of the register. The SW_STATE example can be seen below:

```
/* ----- TPS274C65_SW_STATE (0x1D) ----- */
/* DESCRIPTION: The register sets the switch state (ON/OFF) of each output
 *              channel. The switch state bits in the SPI frame are ignored when a write
 *              to this register is performed (only the contents of the DATA_IN field
 *              of the SPI frame are used to update the switch state) */

#define TPS274C65_SW_STATE_REG 0x1D
```

Additionally, a union is defined for each register address that allows the user to access the register's contents either in bit-wise or byte-wise. The struct definition for the SW_STATE register can be seen below.

```
typedef union
{
    uint8_t byte;
    struct
    {
        /* Set this bit to 1 to turn on the FET and CH1 output ON */
        unsigned CH1_ON : 1;
        /* Set this bit to 1 to turn on the FET and CH2 output ON */
        unsigned CH2_ON : 1;
        /* Set this bit to 1 to turn on the FET and CH3 output ON */
        unsigned CH3_ON : 1;
        /* Set this bit to 1 to turn on the FET and CH4 output ON */
        unsigned CH4_ON : 1;
        /* Reserved */
        unsigned RESERVED_30 : 4;
    } bits;
} TPS274C65_SW_STATE;
```

An example of using the bit-wise operation to set CH1 to enabled can be seen below:

```
#include "tps274c65.h"
#include <stdio.h>

int main()
{
    TPS274C65_SW_STATE enableReg;

    enableReg.bits.CH1_ON = 1;

    printf("\nChannel Enable: 0x%x\n", enableReg.byte);

    return 0;
}
```

... while a byte-wise example can be seen below:

```
#include "tps274c65.h"
#include <stdio.h>

int main()
{
    TPS274C65_SW_STATE enableReg;

    enableReg.byte = 0x01;

    printf("\nChannel Enable: 0x%x\n", enableReg.byte);

    return 0;
}
```

7 Hardware Design Files

7.1 Schematics

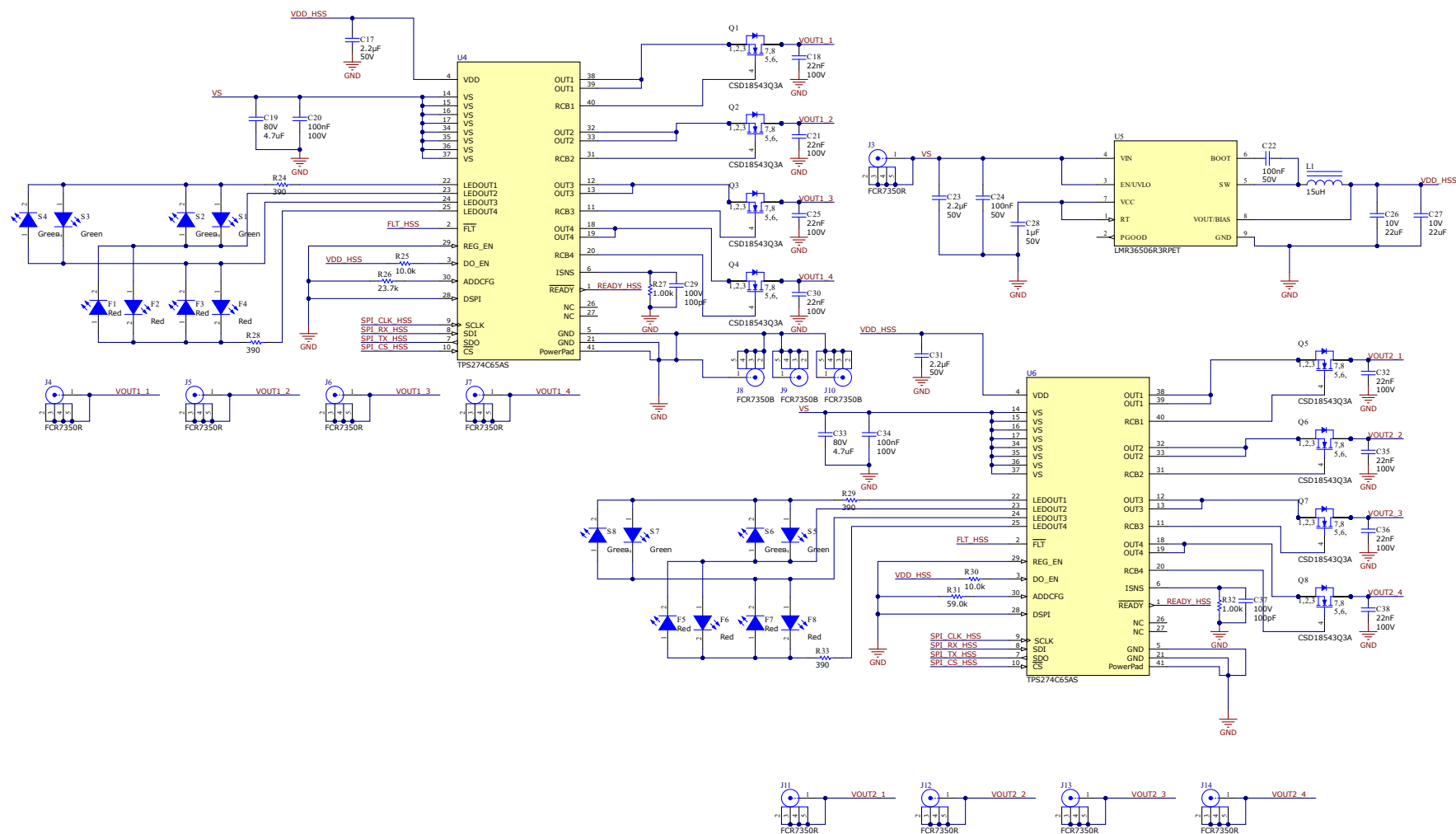


Figure 7-1. High-Side Switch Schematic

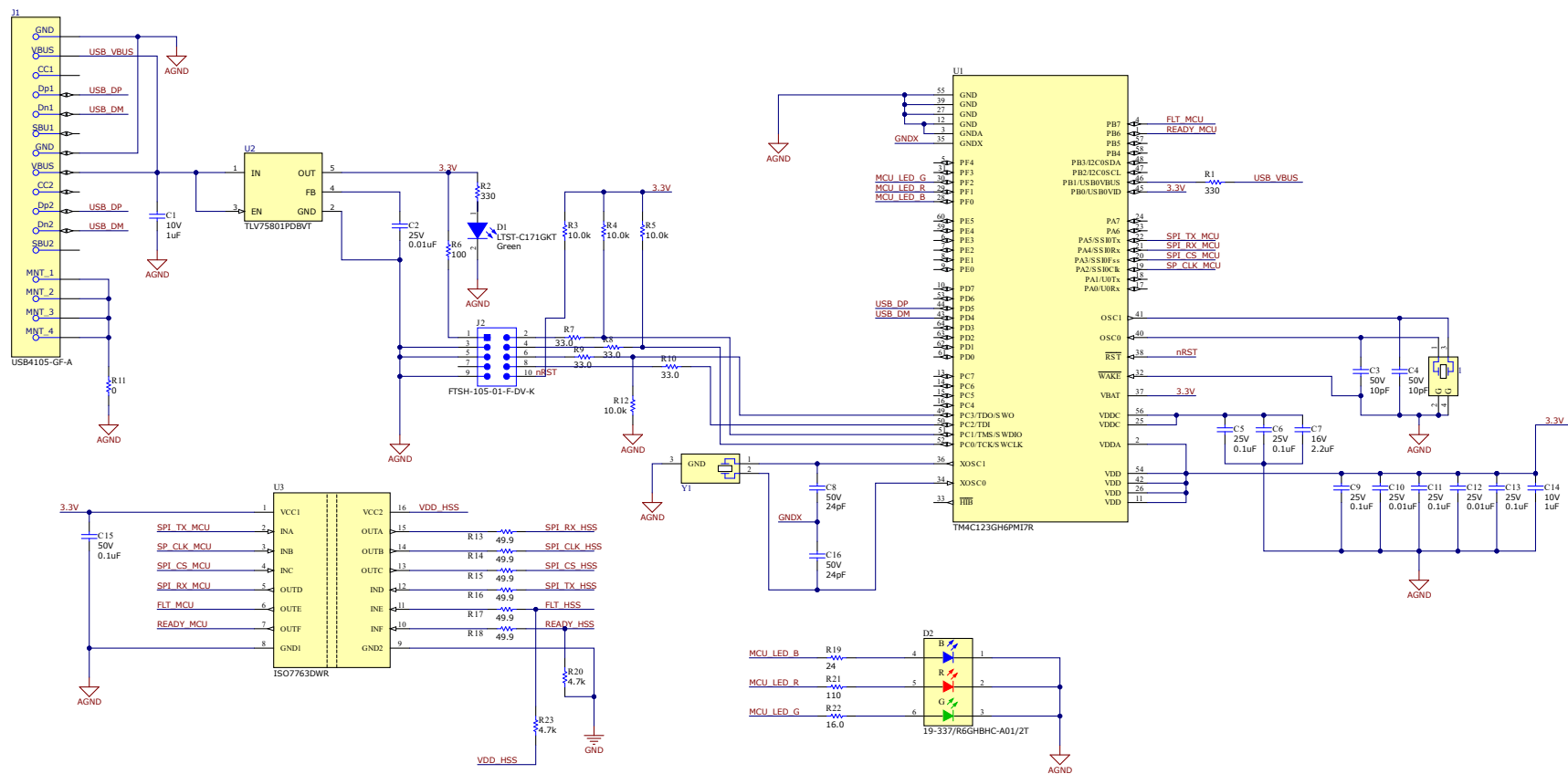


Figure 7-2. MCU Schematic

For evaluation only; not FCC approved for resale.

TEXAS INSTRUMENTS

TPS274C65USBE1

Caution Hot Surface

CE

Figure 7-3. Top Layer



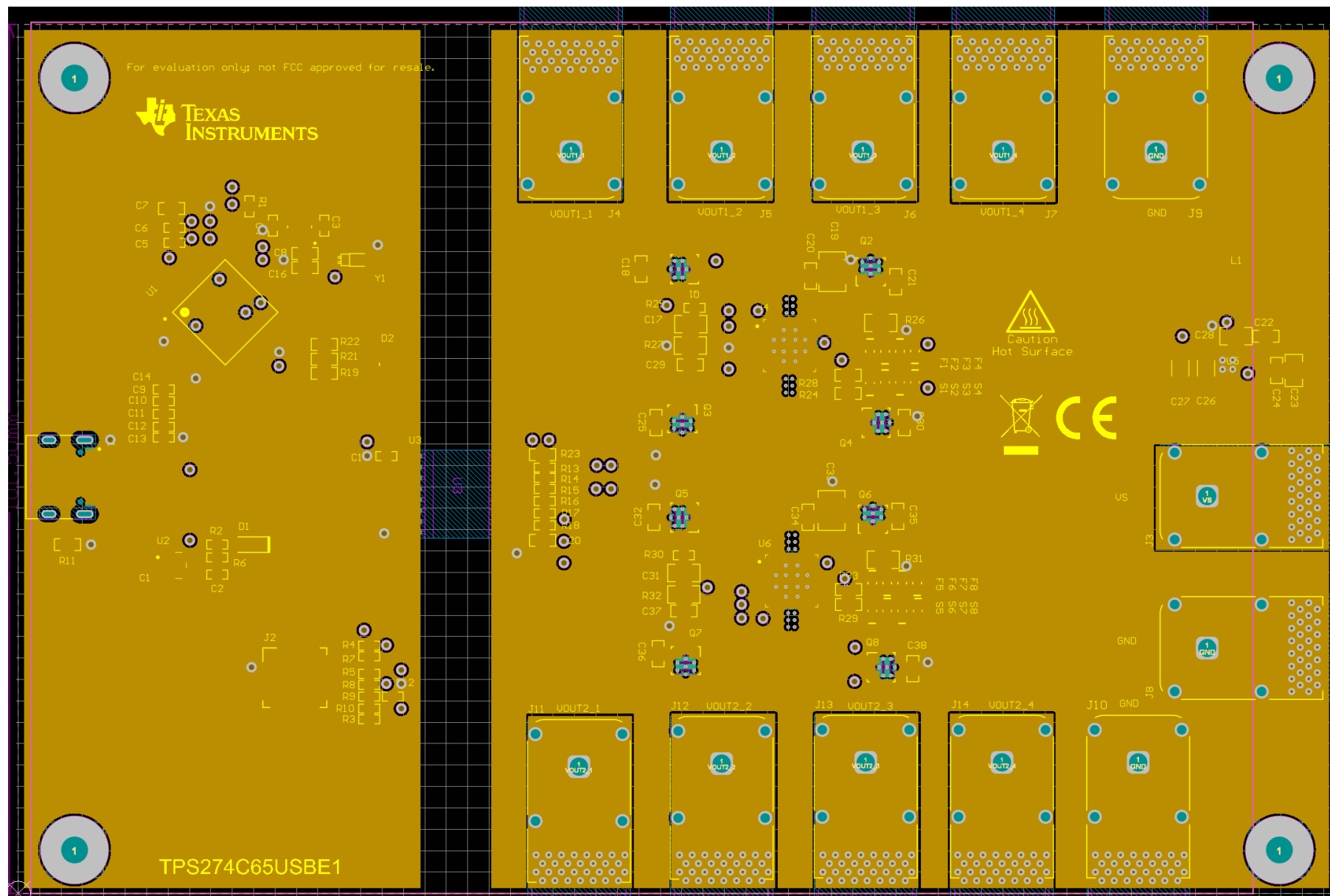


Figure 7-5. Ground Layer

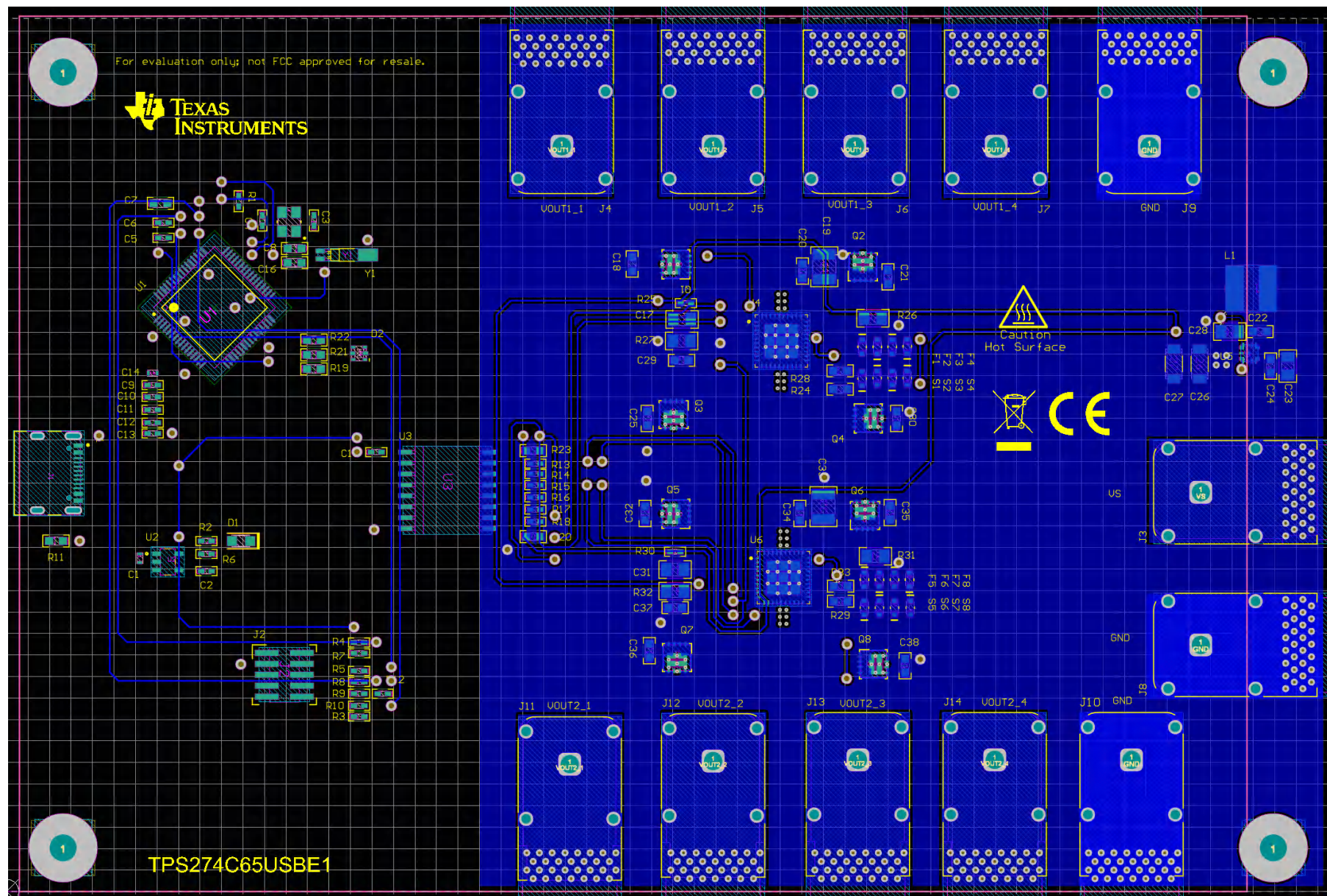


Figure 7-6. Bottom Layer

8 Bill of Materials (BOM)

Designator	Quantity	Description	PartNumber	Manufacturer
!PCB1	1	Printed Circuit Board	TPS274C65USB	Any
1	1	Crystal, 16 MHz, 8pF, SMD, 3.2x0.75x2.5mm	NX3225GA-16.000M-STD-CRG-1	NDK
C1, C14	2	CAP, CERM, 1 uF, 10 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0402	GCM155C71A105KE38D	MuRata
C2, C10, C12	3	CAP, CERM, 0.01 uF, 25 V, +/- 10%, X7R, 0402	GCM155R71E103KA37D	MuRata
C3, C4	2	CAP, CERM, 10 pF, 50 V, +/- 1%, C0G/NP0, 0402	GRM1555C1H100FA01D	MuRata
C5, C6, C9, C11, C13	5	CAP, CERM, 0.1 uF, 25 V, +/- 10%, X5R, 0402	GRM155R61E104KA87D	MuRata
C7	1	CAP, CERM, 2.2 uF, 16 V, +/- 10%, X5R, 0603	GRM188R61C225KE15D	MuRata
C8, C16	2	CAP, CERM, 24 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H240JA01D	MuRata
C15	1	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0402	C1005X7R1H104K050BB	TDK
C17, C31	2	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0805	CGA4J3X7R1H225K125A B	TDK
C18, C21, C25, C30, C32, C35, C36, C38	8	CAP, CERM, 0.022 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E2X7R2A223K080A A	TDK
C19, C33	2	CAP, CERM, 4.7 uF, 80 V, +/- 10%, X7R, 1210	GRM32ER71K475KE14L	MuRata
C20, C34	2	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCJ188R72A104KA01D	MuRata
C22, C24	2	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0603	C1608X7R1H104K080AA	TDK
C23	1	CAP, CERM, 2.2 uF, 50 V, +/- 20%, X7R, 0805	C2012X7R1H225M125AC	TDK
C26, C27	2	CAP, CERM, 22 uF, 10 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206	GCM31CR71A226KE02	MuRata
C28	1	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0805	8.85012E+11	Wurth Elektronik
C29, C37	2	CAP, CERM, 100 pF, 100 V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	GCM1885C2A101JA16D	MuRata
D1	1	LED, Green, SMD, 0805	LTST-C171GKT	Lite-On
D2	1	LED, RGB, SMD, 1.6x1.6mm	19-337/R6GHBHC-A01/2T	Everlight
F1, F2, F3, F4, F5, F6, F7, F8	8	LED, Red, SMD, 2-Leads, Body 1.3x0.8mm	LS L29K-G1J2-1-Z	OSRAM
H1, H2, H3, H4	4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
J1	1	USB - C (Type - C) USB 2.0 Receptacle Connector 24 Position Surface Mount, Right Angle; Through Hole, CONN_USB_9MM58_7MM53	USB4105-GF-A	GCT
J2	1	Header (Shrouded), 1.27mm, 5x2, Gold, SMT	FTSH-105-01-F-DV-K	Samtec
J3, J4, J5, J6, J7, J11, J12, J13, J14	9	Panel Socket, 24A, R/A, Gold, TH	FCR7350R	Cliff Electronic Components
J8, J9, J10	3	Panel Socket, 24A, R/A, Gold, TH	FCR7350B	Cliff Electronic Components

L1	1	Inductor, Drum Core, Ferrite, 15 uH, 1.5 A, 0.12 ohm, SMD, 5.8x4.5x5.2mm	NPI54C150MTRF	NIC Components
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	8	MOSFET, N-CH, 60 V, 35 A, DNH0008A (VSONP-8)	CSD18543Q3A	Texas Instruments
R1, R2	2	RES, 330, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402330RFKED	Vishay-Dale
R3, R4, R5, R12, R25, R30	6	RES, 10.0 k, 1%, 0.063 W, 0402	RC0402FR-0710KL	Yageo America
R6	1	RES, 100, 1%, 0.1 W, 0402	ERJ-2RKF1000X	Panasonic
R7, R8, R9, R10	4	RES, 33.0, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	RMCF0402FT33R0	Stackpole Electronics Inc
R11	1	RES, 0, 5%, 0.1 W, 0603	ERJ-3GEY0R00V	Panasonic
R13, R14, R15, R16, R17, R18	6	RES, 49.9, 1%, 0.063 W, 0402	RC0402FR-0749R9L	Yageo America
R19	1	RES, 24, 5%, 0.1 W, 0603	CRCW060324R0JNEA	Vishay-Dale
R20, R23	2	RES, 4.7 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	ERJ-3GEYJ472V	Panasonic
R21	1	RES, 110, 0.5%, 0.1 W, 0603	RT0603DRE07110RL	Yageo America
R22	1	RES, 16.0, 0.1%, 0.1 W, 0603	RT0603BRD0716RL	Yageo America
R24, R28, R29, R33	4	RES, 390, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603390RJNEA	Vishay-Dale
R26	1	RES, 23.7 k, 0.1%, 0.125 W, 0805	RT0805BRD0723K7L	Yageo America
R27, R32	2	RES, 1.00 k, 1%, 0.25 W, 0805	ERJ-P06F1001V	Panasonic
R31	1	RES, 59.0 k, 0.1%, 0.125 W, 0805	RT0805BRD0759KL	Yageo America
S1, S2, S3, S4, S5, S6, S7, S8	8	LED, Green, SMD, 1.7x0.65x0.8mm	LG L29K-G2J1-24-Z	OSRAM
U1	1	High performance 32-bit ARM(R) Cortex(R)-M4F based MCU, PM0064A (LQFP-64)	TM4C123GH6PMI7R	Texas Instruments
U2	1	Linear Voltage Regulator IC 1 Output 500mA SOT-23-5	TLV75801PDBVT	Texas Instruments
U3	1	High Speed, Robust EMC, Reinforced Six-Channel Digital Isolator, DW0016B (SOIC-16)	ISO7763DWR	Texas Instruments
U4, U6	2	65-mΩ, Quad-Channel Smart High-Side Switch with SPI interface and Diagnostics, VQFN40	TPS274C65AS	Texas Instruments
U5	1	LMR36503/06-Q1 Wide Input 60-V Synchronous, DC-DC Buck Converter, RPE0009A (VQFN-9)	LMR36506R3RPET	Texas Instruments
Y1	1	Crystal, 32.768 kHz, 12.5pF, SMD, 1.4x1.4x5.0mm	MS3V-T1R 32.768KHZ +/-20PPM 12.5PF	Micro Crystal AG

9 Additional Information

9.1 Trademarks

All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
 - 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 semiconductors 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 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 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 a nonconforming EVM if (a) the nonconformity was 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, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits 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 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 DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 Regulatory Notices:

3.1 United States

3.1.1 Notice applicable to EVMs not FCC-Approved:

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 Canada

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/sds/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。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

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

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

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

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
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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東京都新宿区西新宿 6 丁目 2 4 番 1 号
西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/sds/ti_ja/general/eStore/notice_02.page

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3.4 European Union

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

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

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

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS 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 EPIDEMIC FAILURE WARRANTY OR 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 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, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

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. 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 OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM 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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