User's Guide

TPS274C65 USB EVM - Application Level EVM

TEXAS INSTRUMENTS

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.

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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 TPS274C65USBEVM
4. Connect the TPS274C65USBEVM via USB to host computer
5. Open the TPS274C65 Configurator and use the program as described in this guide

The TPS274C65USBEVM 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

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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

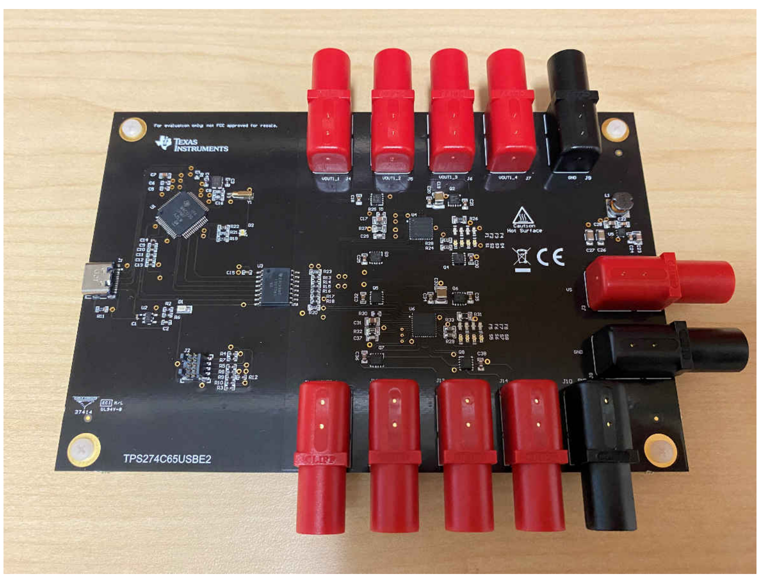

Figure 5-1. Board Image

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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:

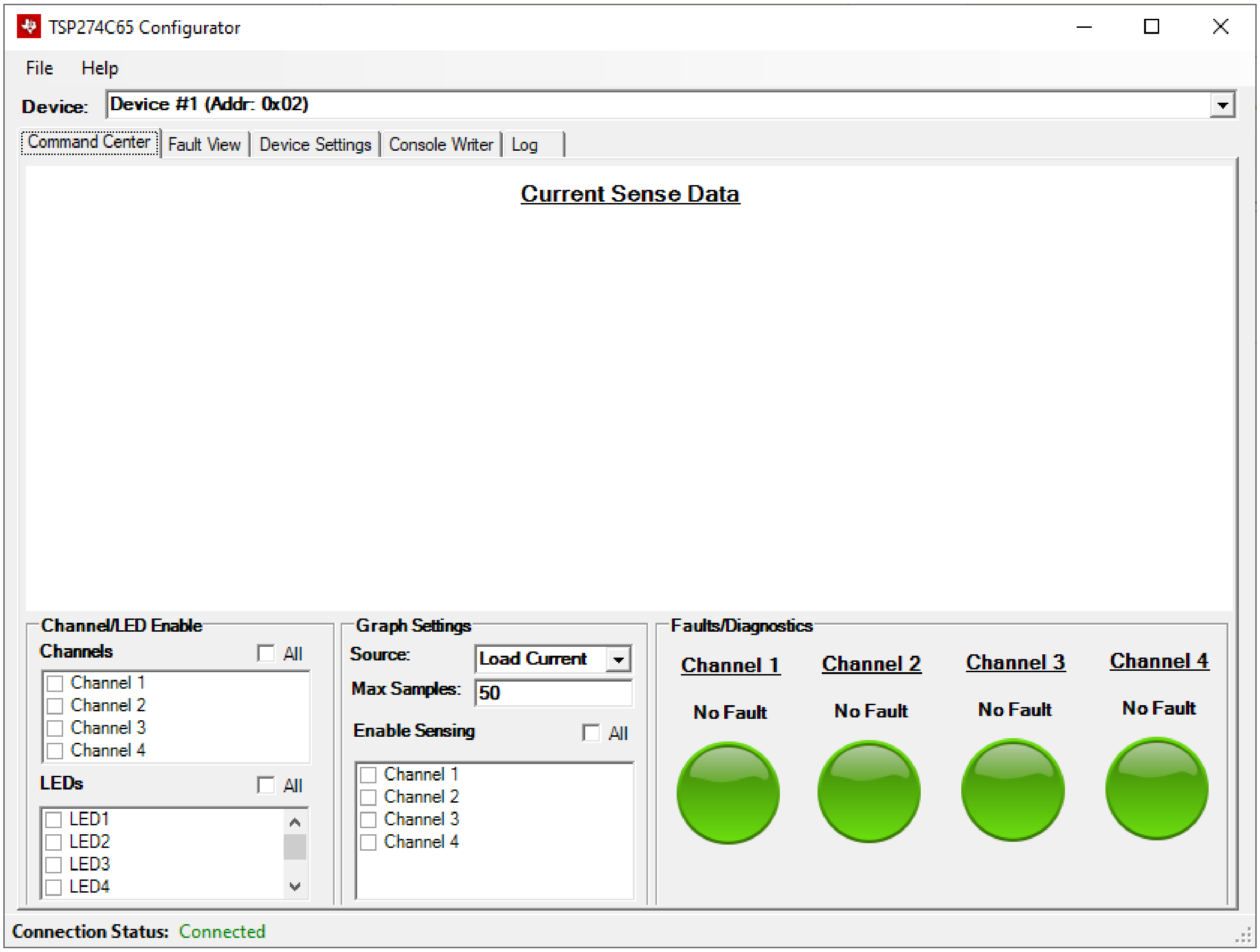

Figure 6-1. Configurator on Startup

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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:

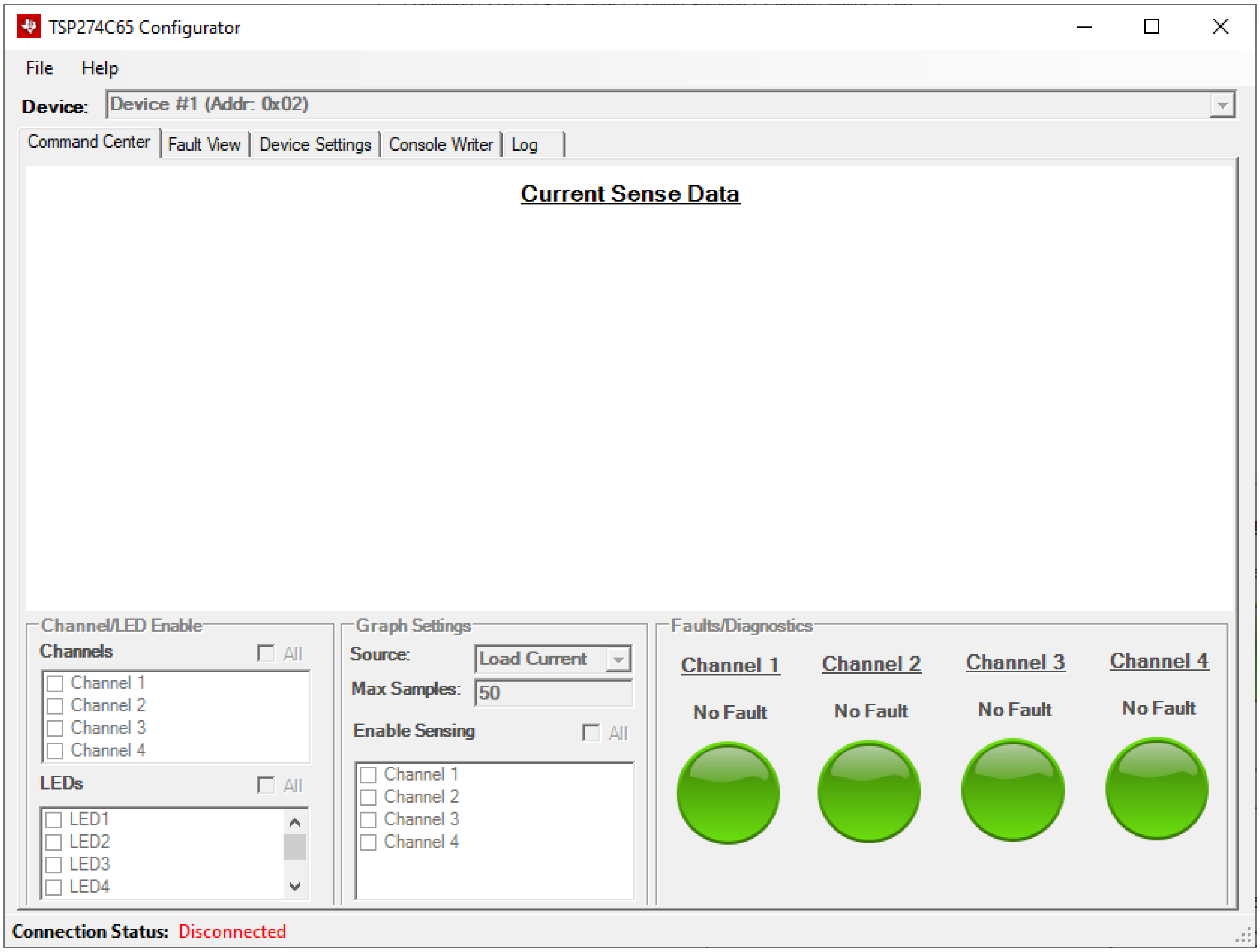

Figure 6-2. Disconnected Device

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.

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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:

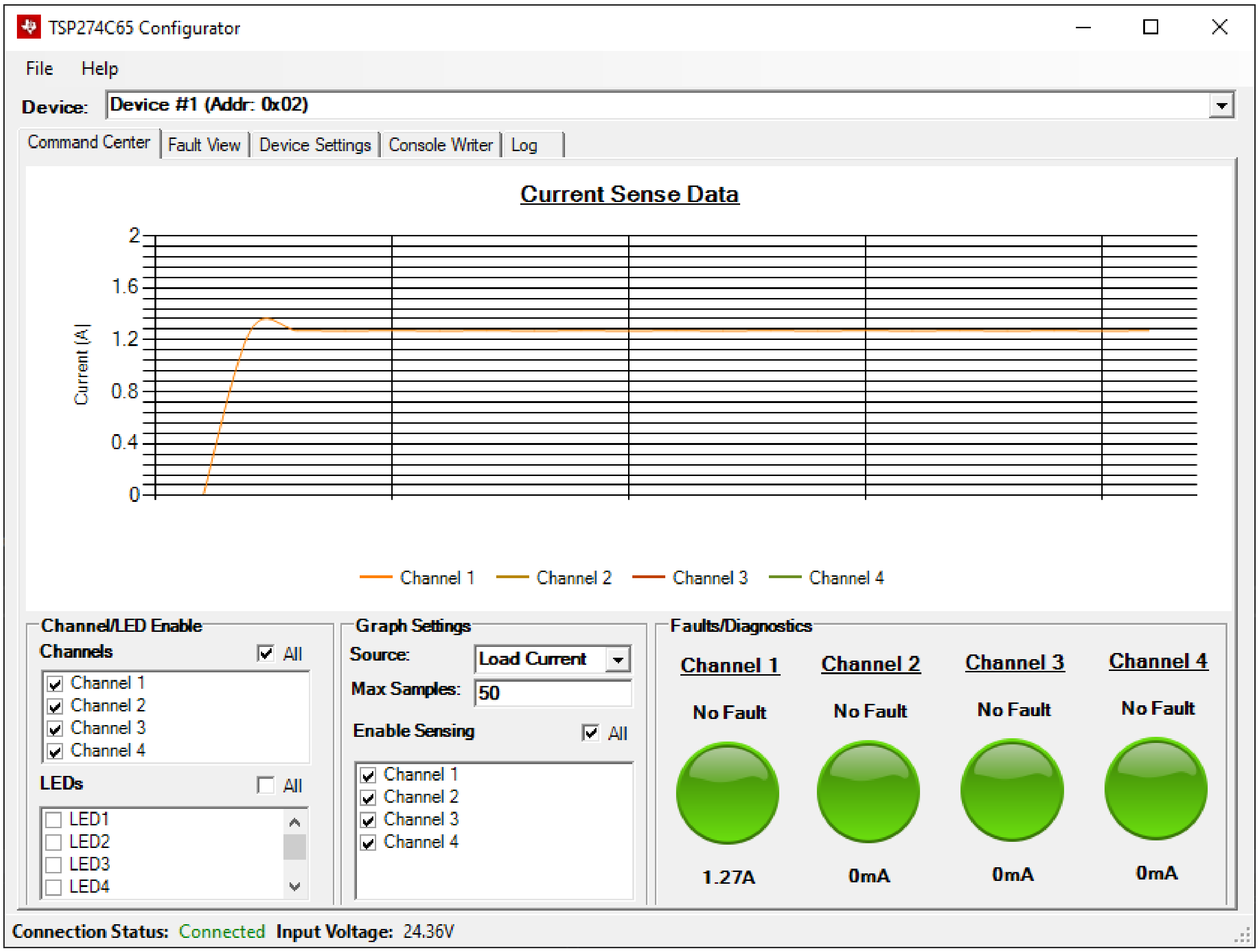

Figure 6-3. Light Load Current

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

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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:

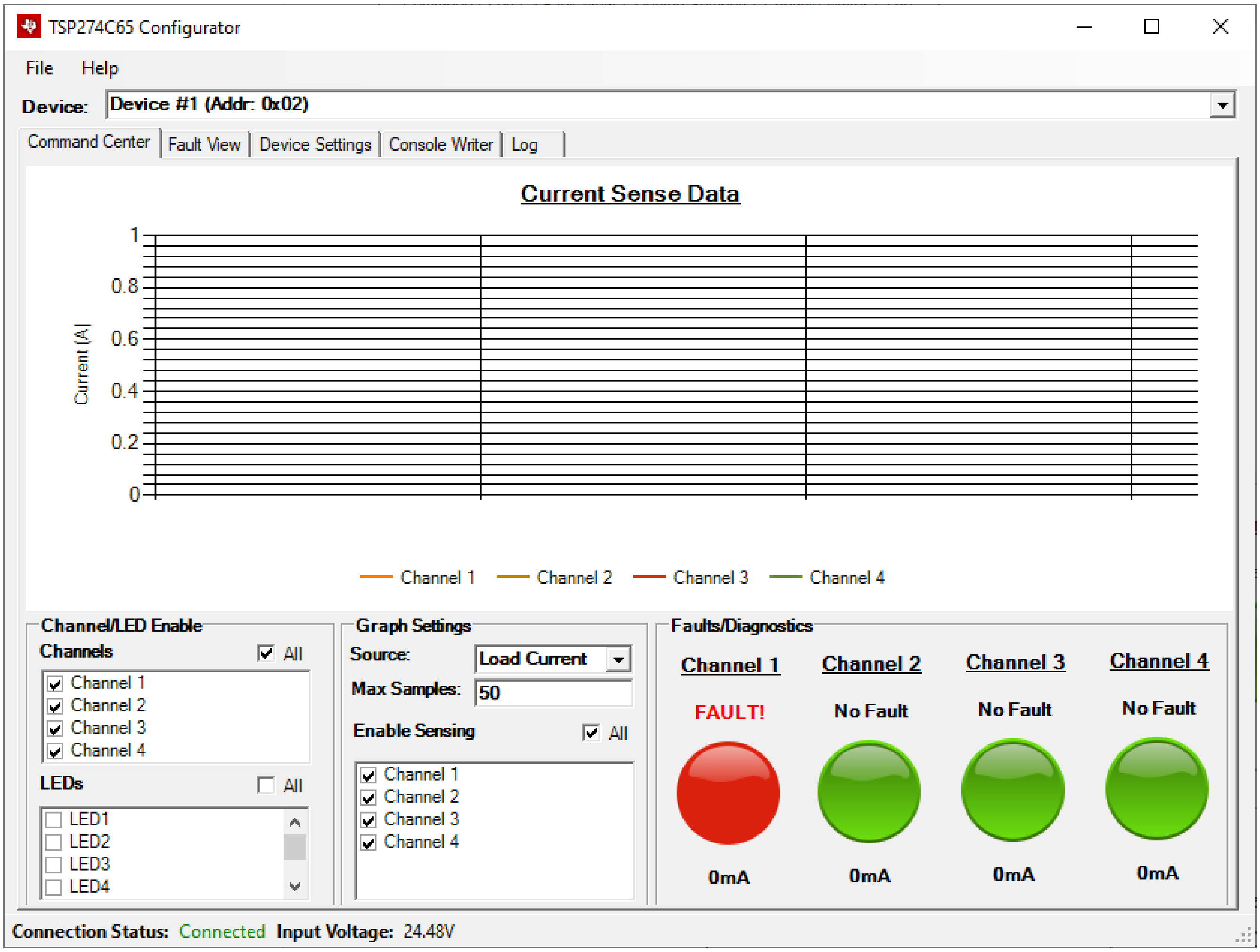

Figure 6-4. Faulted Channel

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

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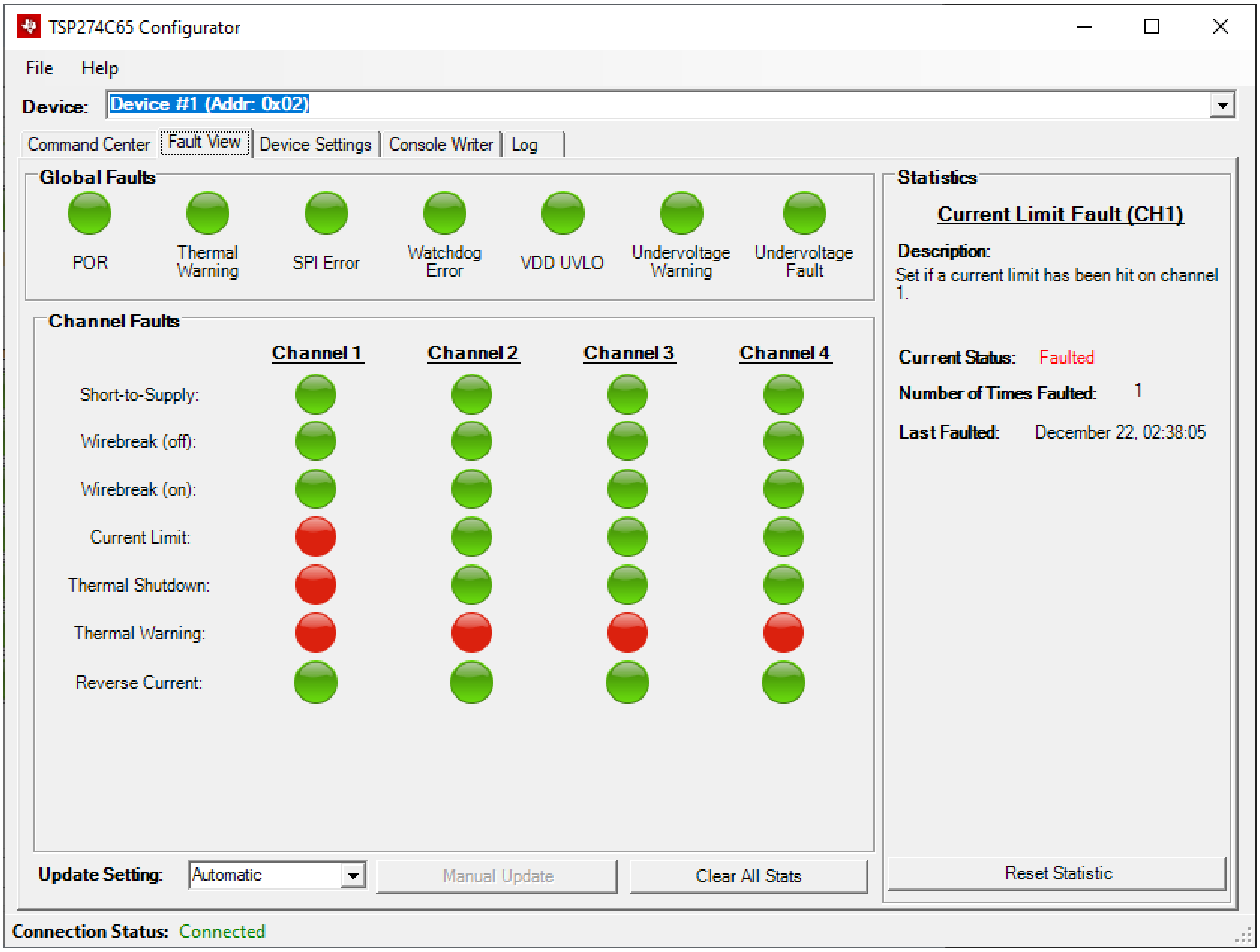

Figure 6-5. Fault View

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.

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

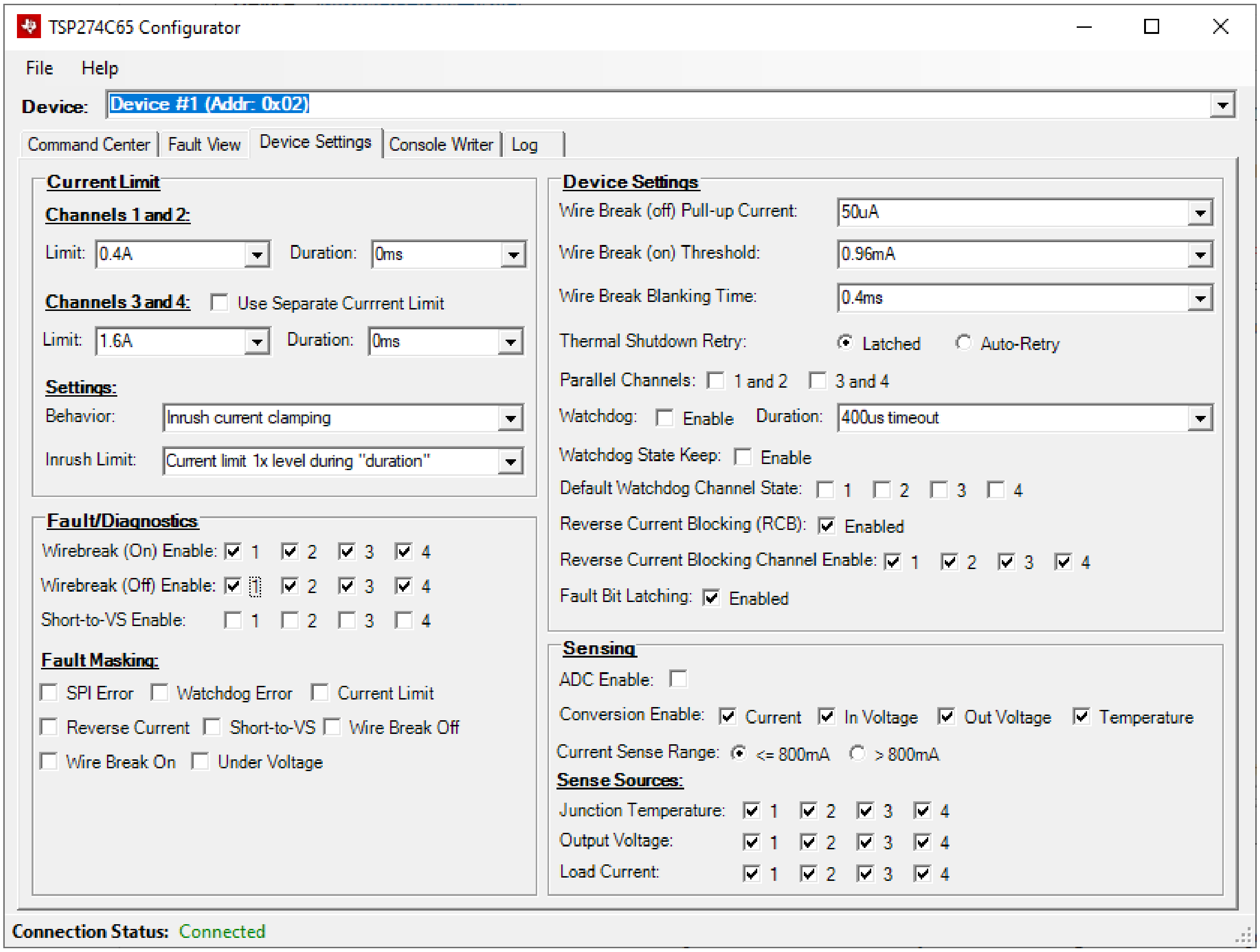

Figure 6-6. Device Settings

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.

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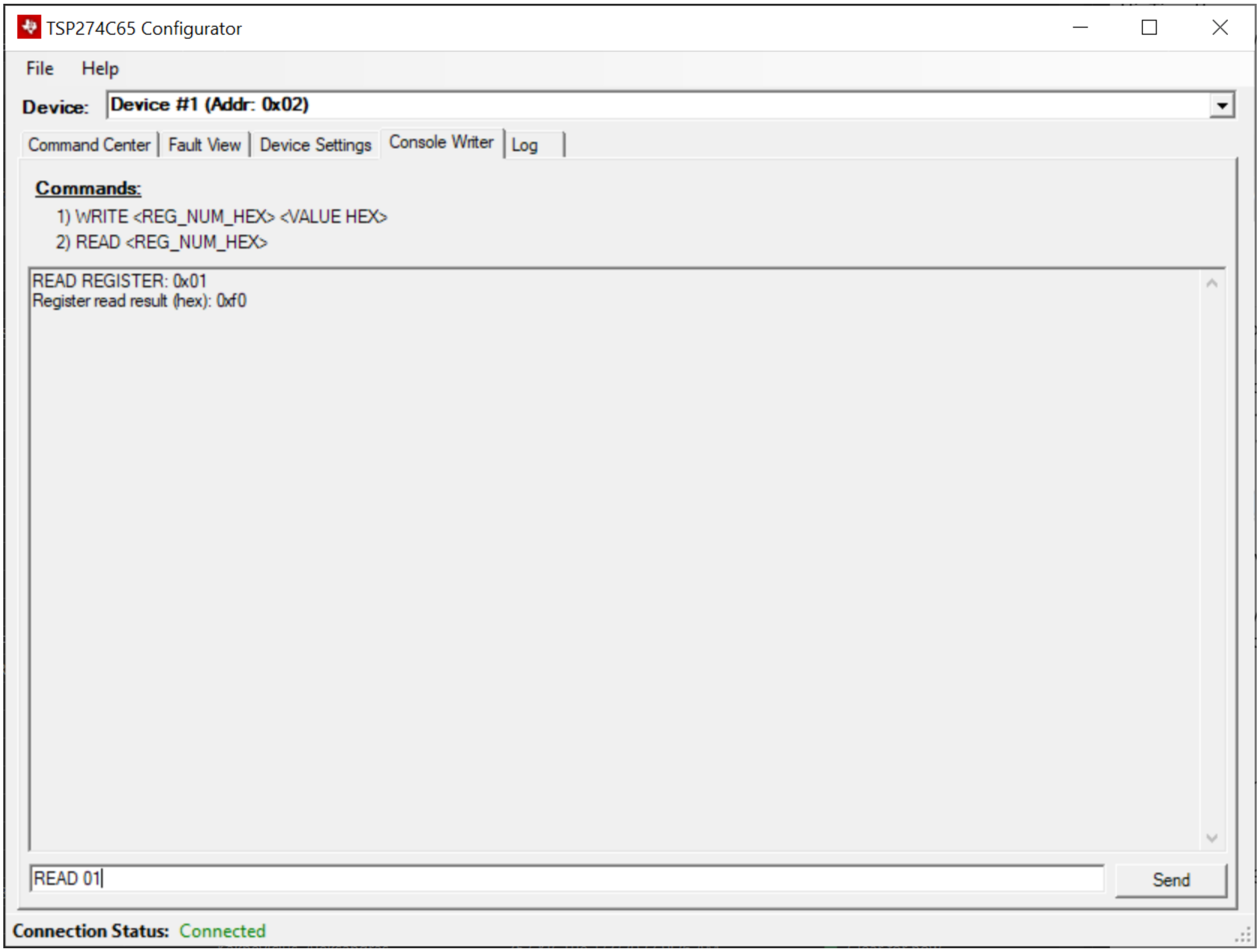

Figure 6-7. Register Read

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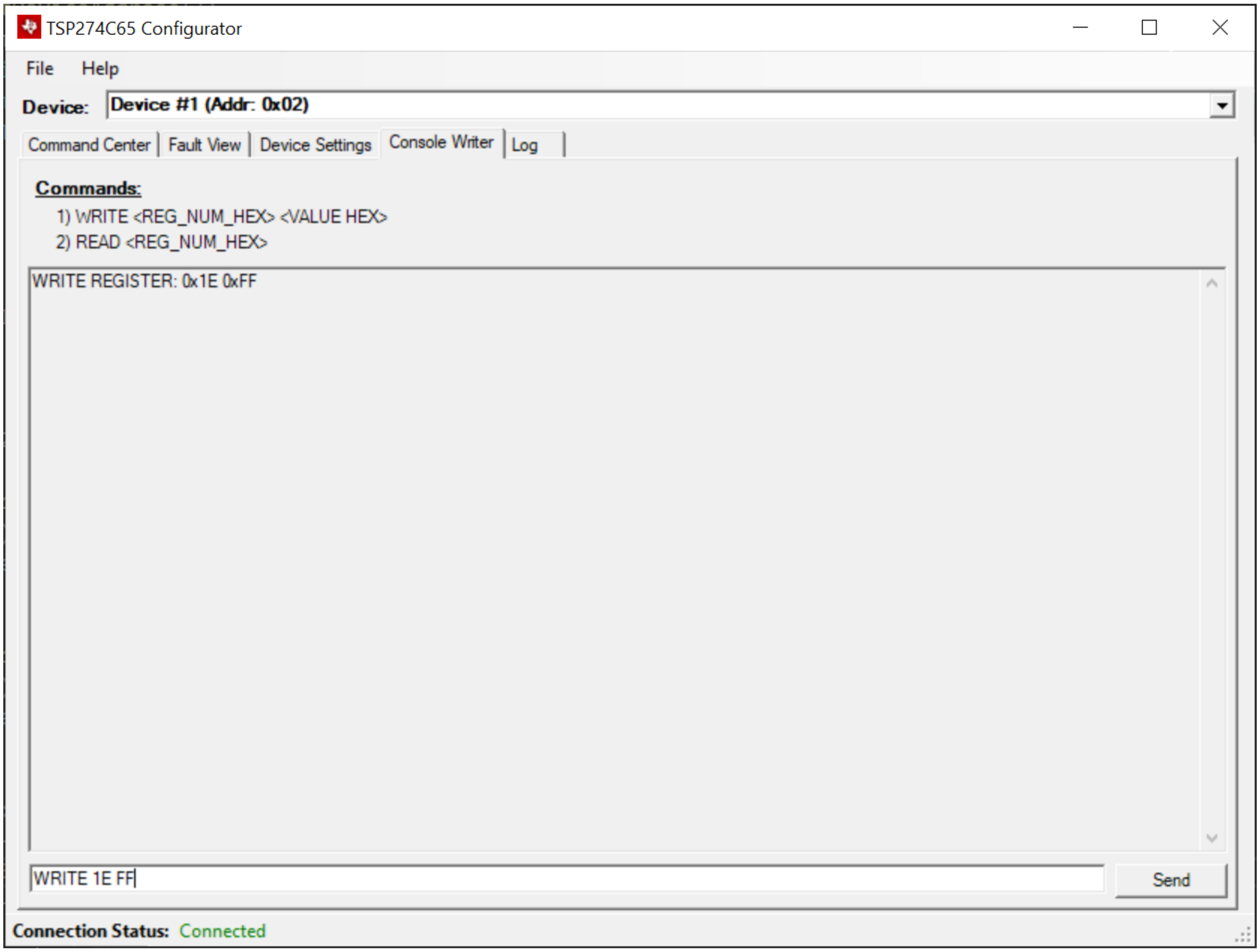

Figure 6-8. Register Write

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.

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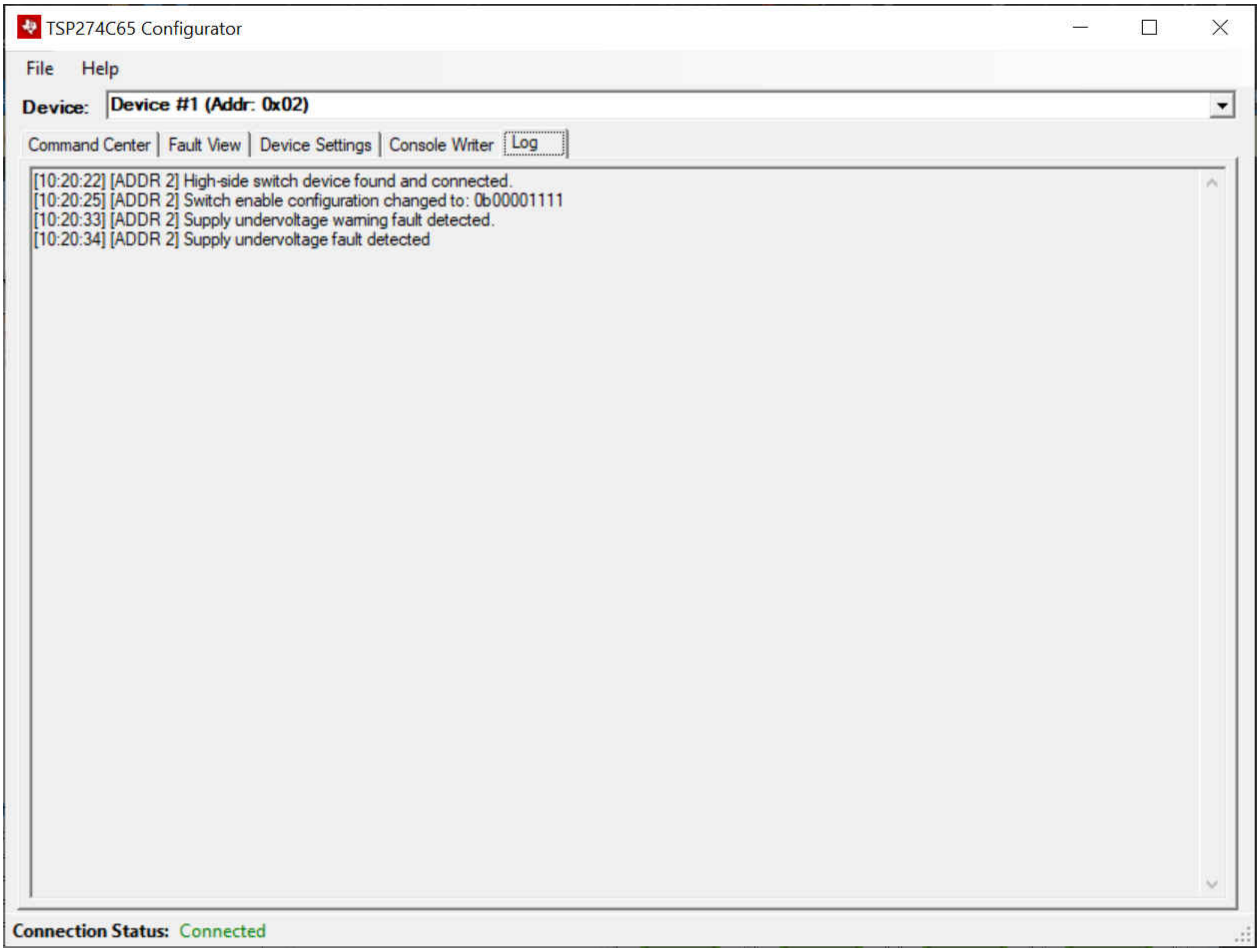

Figure 6-9. Device Log

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.

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6.2 Header File

A header files 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;
}
```


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7 Hardware Design Files

7.1 Schematics

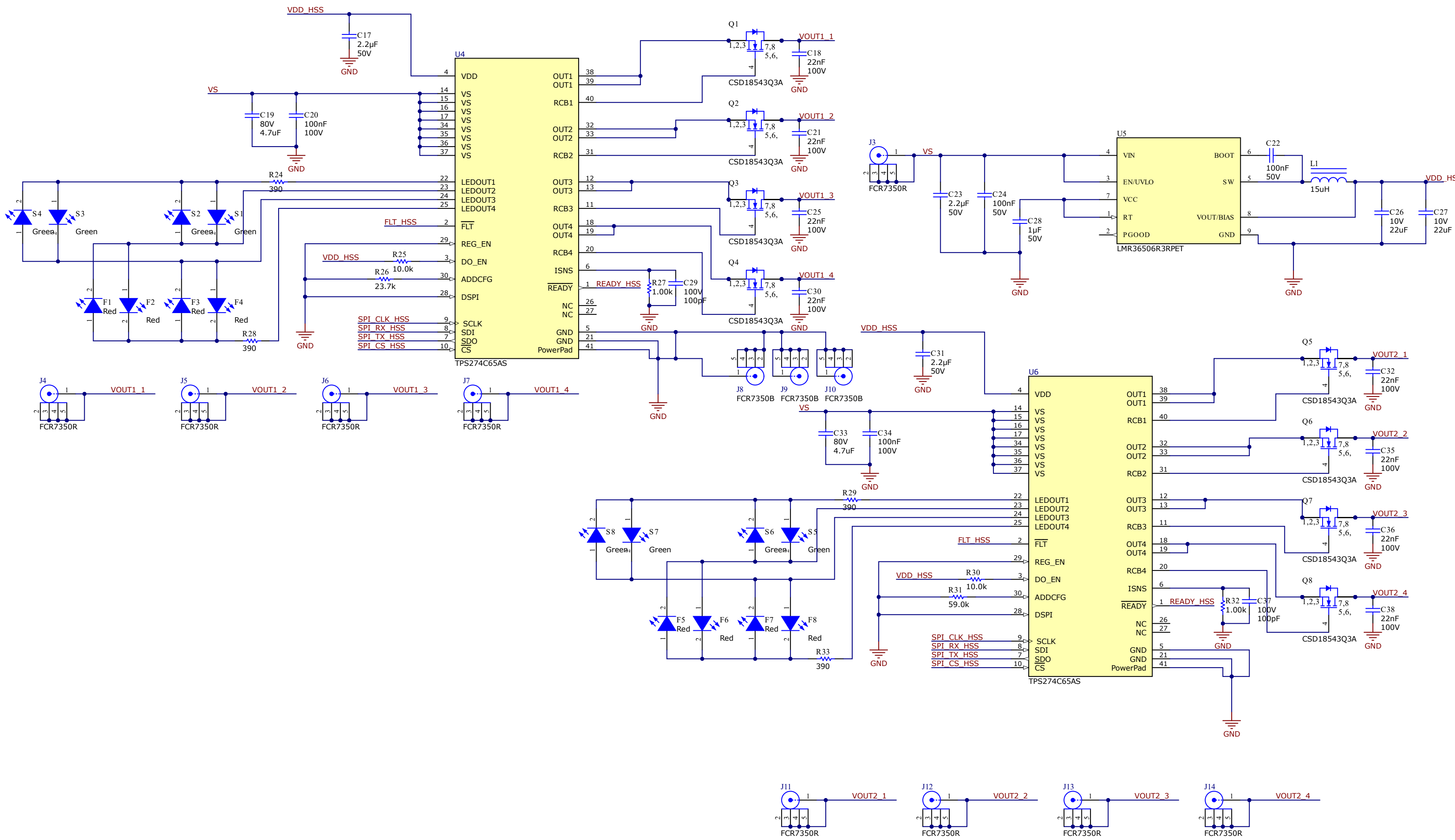

Figure 7-1. High-Side Switch Schematic

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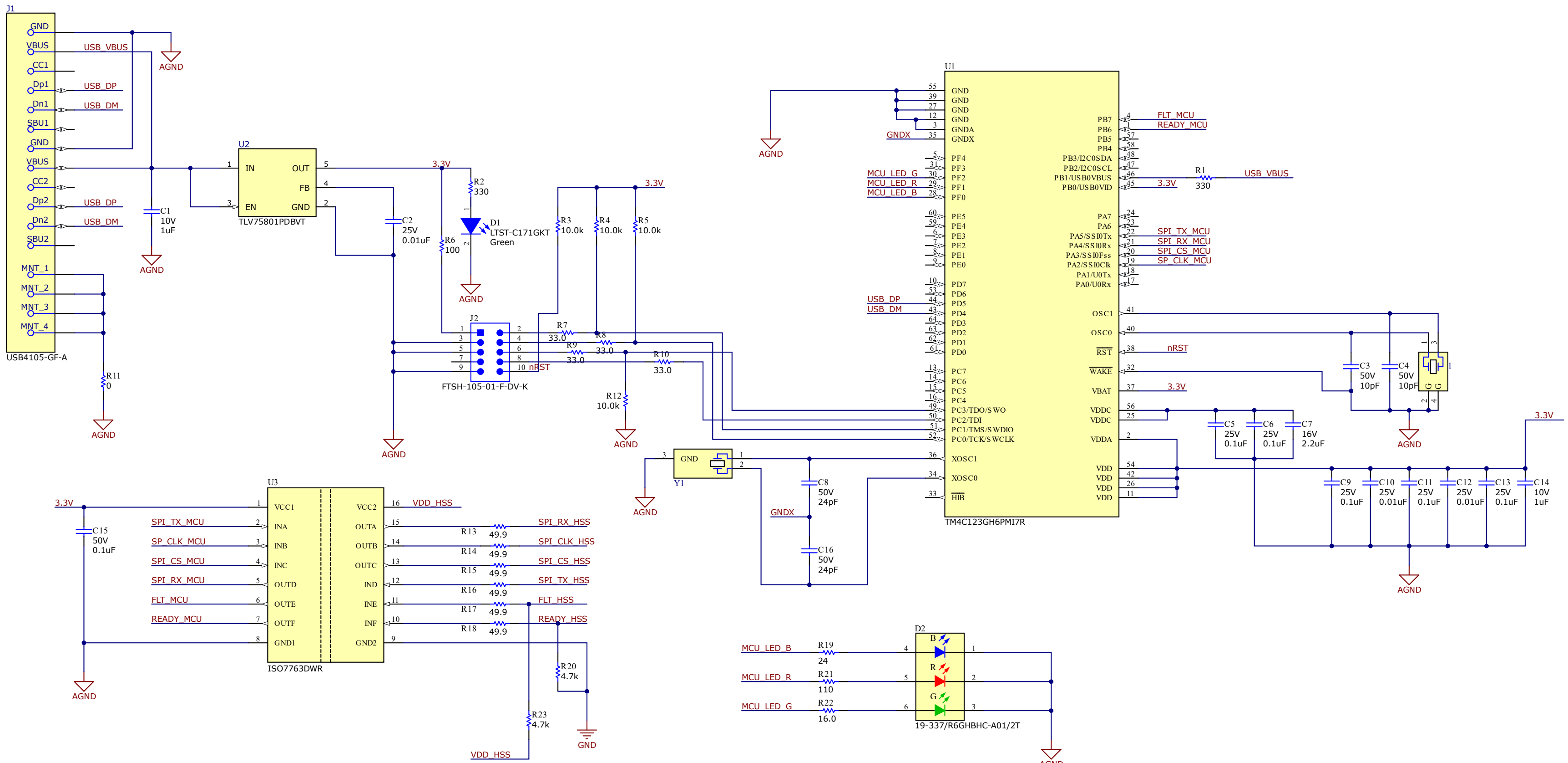

Figure 7-2. MCU Schematic

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7.2 PCB Layouts

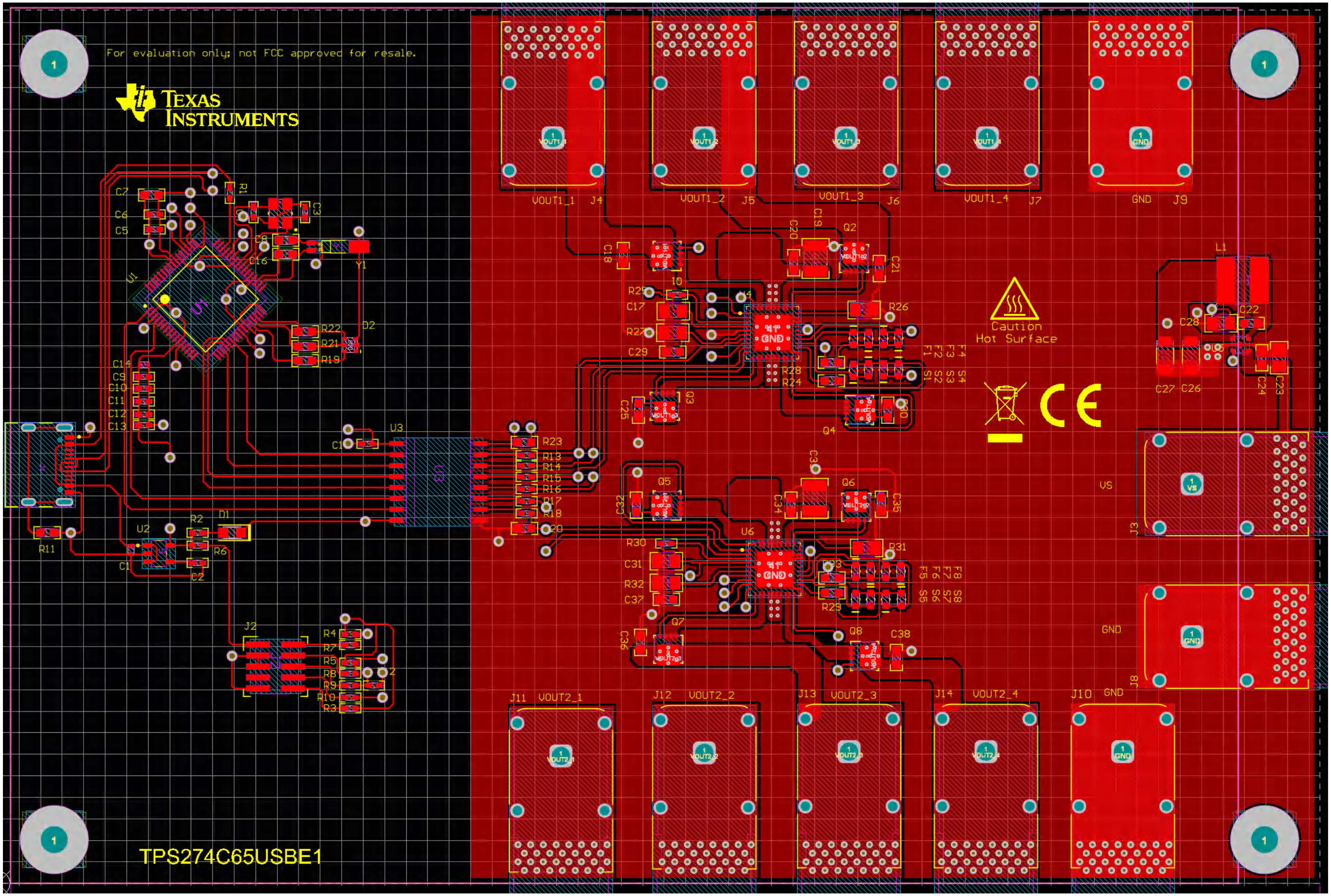

Figure 7-3. Top Layer

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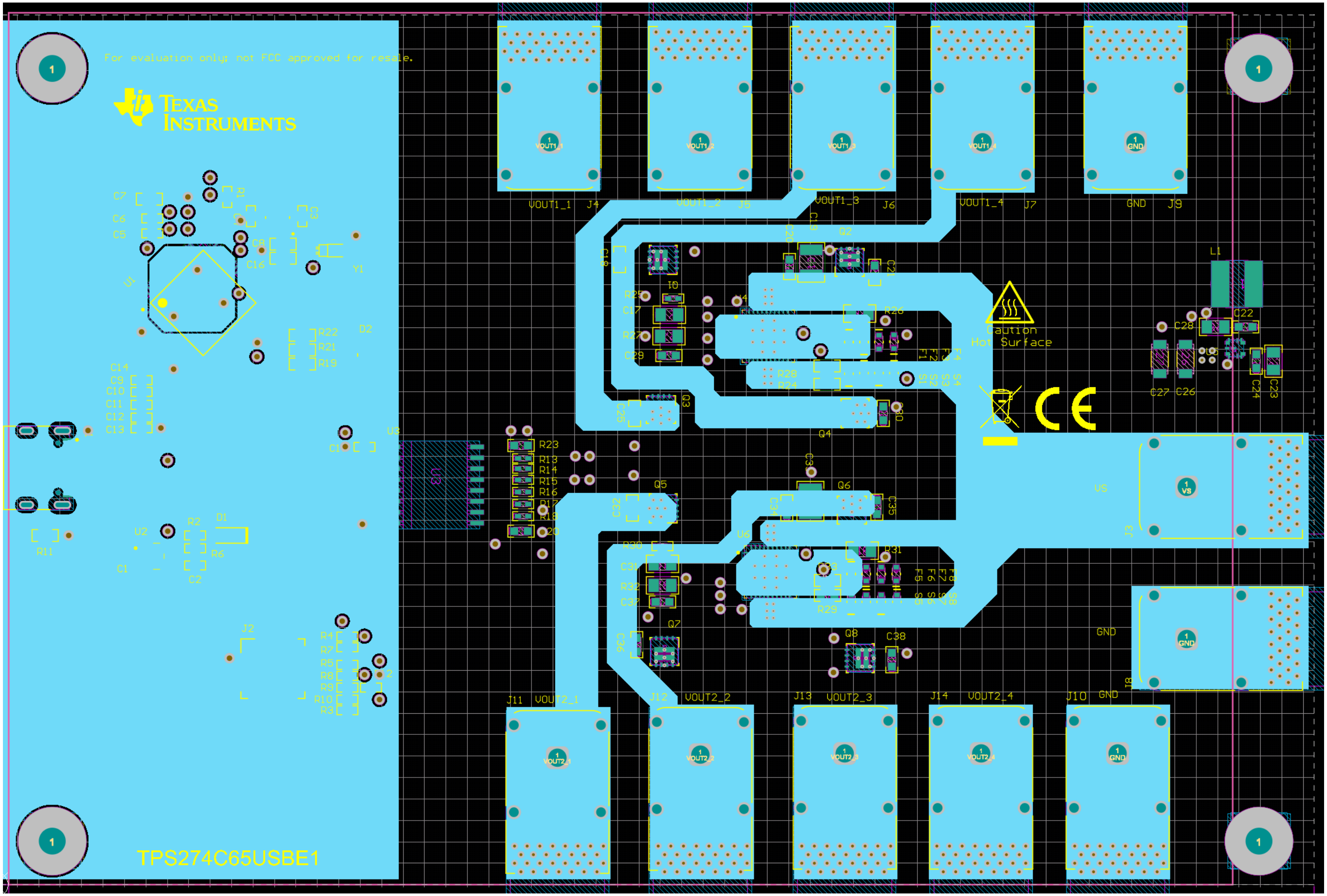

Figure 7-4. Power Layer

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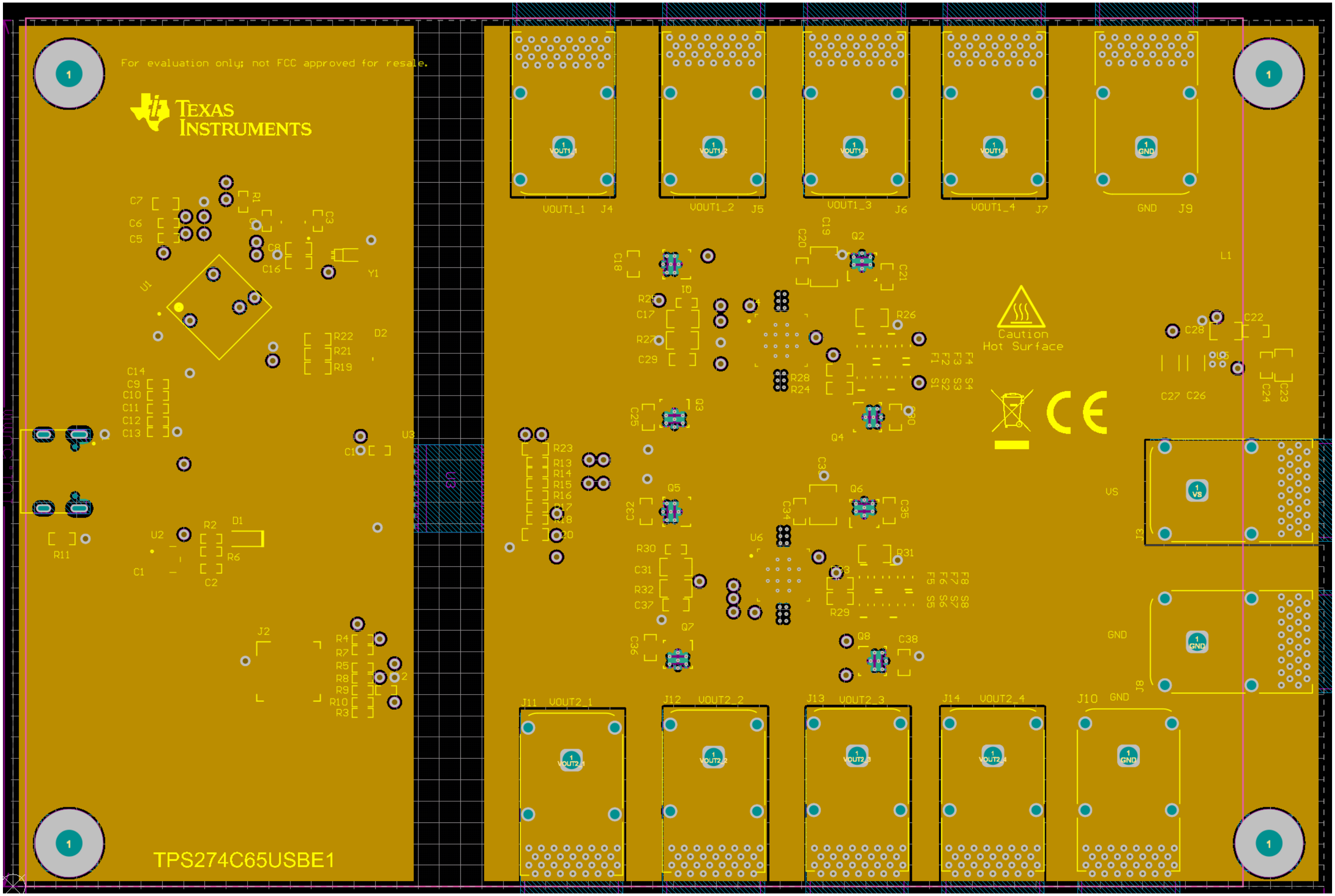

Figure 7-5. Ground Layer

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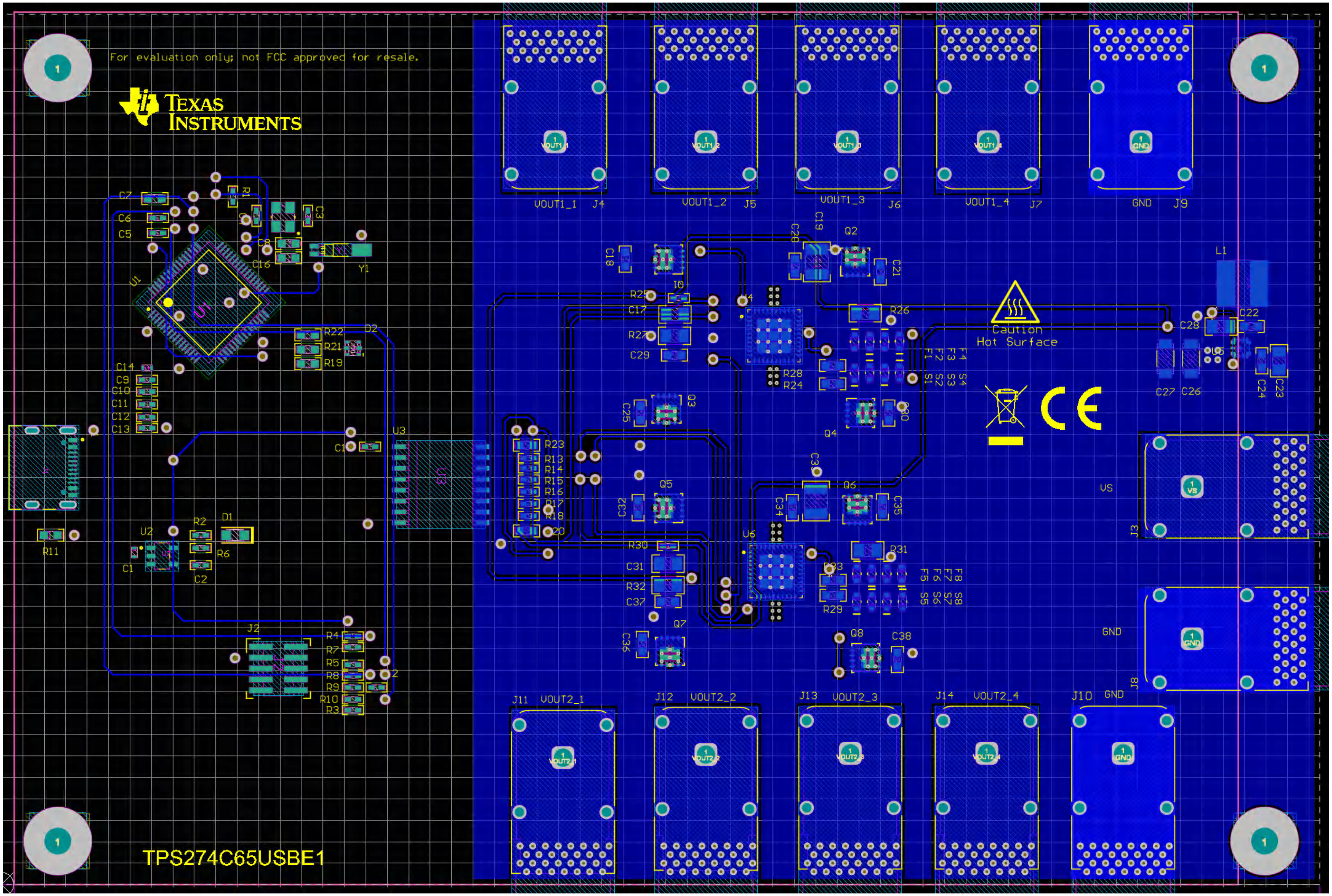

Figure 7-6. Bottom Layer

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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	CGA4J3X7R1H225K125AB	TDK
C18, C21, C25, C30, C32, C35, C36, C38	8	CAP, CERM, 0.022 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E2X7R2A223K080AA	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

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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

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