EVM User's Guide: TPS7B78EVM-131

TPS7B780x-Q1 Evaluation Module

Description

The TPS7B78EVM-131 is an evaluation module (EVM) designed for easy measurement and setup of the TPS7B780x-Q1 family of automotive-qualified LDOs with diagnostics and I^2C interfaces. The EVM includes a USB to I^2C adapter, high-speed load transient test circuit, provisions for input and output current measurement, and jumpers to configure the TPS7B780x-Q1.

Get Started

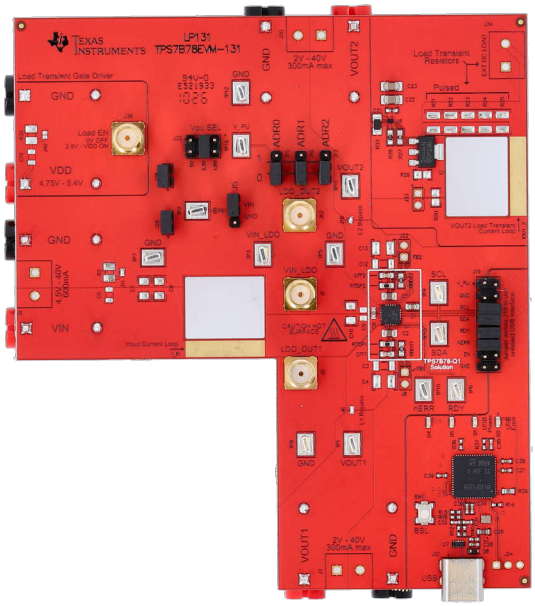
1. Order the TPS7B78EVM-131
2. Open the GUI from the TPS7B78EVM-131 gallery page
3. Connect the EVM to a computer
4. Connect the EVM to a suitable power supply
5. Refer to the TPS7B7802-Q1 datasheet or TPS7B7801-Q1 datasheet for IC details
6. Visit our E2E forums for support or questions

Features

- Easy to use cloud-based GUI is available on the web or can be downloaded for offline use
- Evaluate I^2C communications with integrated USB to I^2C converter or an external I^2C controller
- Onboard load transient test circuit allows easy evaluation of regulator transient performance
- Provisions for series inductors in both LDO outputs
- I^2C address configurable by jumpers

Applications

- Powering Low Noise Amplifiers in Automotive Head Units
- Powering Camera Modules in Surround View System ECUs
- Powering Active Noise Cancellation Microphones in Automotive Head Units
- Powering Hands-Free Microphones in Automotive Head Units



TPS7B78EVM-131

1 Evaluation Module Overview

1.1 Introduction

The TPS7B780x-Q1 Evaluation Module (EVM) helps designers evaluate the operation and performance of the TPS7B780x-Q1 family of automotive-qualified single- and dual-channel Diagnostic LDOs. The EVM includes an on board MSP430F5528 microcontroller that interfaces with both the host computer and the TPS7B780x-Q1. For ease of use, the microcontroller may be disconnected, allowing connections to the user's own microcontroller or other I^2C interface.

This user's guide describes the characteristics, operation, and use of the TPS7B780x-Q1 Evaluation Module evaluation board by explaining how to set up and configure the software, describing the hardware, and reviewing various aspects of the software operation. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the TPS7B780x-Q1 Evaluation Module. This user's guide also provides information on the operating procedure, input and output connections, an electrical schematic, printed-circuit board (PCB) layout drawings, and a parts list for the EVM.

1.2 Kit Contents

Table 1-1 details the contents of the EVM kit. Contact the Texas Instruments Customer Support Center if any components are missing. TI highly recommends that users check the TI website at www.ti.com to verify that the latest versions of the related software is downloaded.

Table 1-1. EVM Kit Contents

ITEM	QUANTITY
TPS7B78EVM-131 test board	1
1-meter USB-A to USB-C cable	1

1.3 Specifications

The TPS7B78EVM-131 is intended to support basic functional evaluation of the device. The EVM can be used for AC, DC, and transient measurements, as well as to evaluate I^2C communication with the TPS7B780x-Q1. The layout is designed to showcase the transient performance of the device and optimize thermal performance and heat dissipation.

Table 1-2 defines the absolute maximum thermal conditions for the EVM. These limits must be considered when evaluating the performance of the device at extreme temperatures.

Table 1-3 defines the power supply requirements for the EVM. To avoid damaging the EVM, do not exceed maximum voltage ratings.

Table 1-4 defines the output specifications for the two output channels of the EVM.

Table 1-2. Thermal Specifications

Conditions	Recommended operating free-air temperature, T_A	TPS7B780x-Q1 Absolute maximum junction temperature, T_J
Onboard USB to I^2C converter active (USB cable connected)	-25°C to 85°C	150°C
Onboard USB to I^2C converter not used (USB cable not connected)	-25°C to 110°C	150°C

Table 1-3. Power Supply Specifications

Supply Name	Nominal Voltage	Voltage Range	Maximum Input Current
VIN supply to TPS7B780x-Q1	12V	4.5V to 40V	600mA
VDD supply to onboard load transient circuit (1)	5V	4.75V to 5.4V	100mA
V_PU pullup supply for I^2C bus and open-drain outputs (1)	3.3V	1.8V to 5.0V	25mA

(1) Optional power supply connection. See Section 2.6 for more information.

Table 1-4. Output Specifications

Output Name	Voltage Range	Maximum Load Current
VOUT1	2V to 39V (1) (2)	300mA
VOUT2	2V to 39V (1) (2)	300mA

(1) Maximum output voltage is limited by dropout voltage and VIN. Consult device data sheet for more information.
(2) Maximum output voltage is limited to 27.5V when TPS7B780x-Q1 is configured to use internal feedback. Consult device data sheet for more information

1.4 Device Information

The TPS7B780x-Q1 family of devices are single-channel (TPS7B7801Q1) or dual-channel (TPS7B7802Q1), high voltage low-dropout regulators with an integrated ADCs and I^2C interfaces. The family of devices has a wide input voltage operating range, and is designed to protect against a 45V input voltage load dump scenarios. They are an excellent choice to provide power to remotely located low-noise amplifiers (LNAs) associated with FM/DAB/GNSS antennas, microphones, and camera modules over coaxial cables in an automotive environment. Each channel can provide up to 300mA of output current and an adjustable output voltage from 2V to 40V configured either via external resistors or over I^2C.

The integrated 10-bit ADC allows the user to continuously monitor the input voltage, output voltage, junction temperature and load current. The high accuracy current sense circuitry across the current range allows this device to detect and distinguish between open, normal, and short-circuit conditions without further calibration. Each channel also offers adjustable current limit that can be set via I^2C communication.

2 Hardware

2.1 Overview

The EVM includes a number of features to allow the user to evaluate the performance of the TPS7B780x-Q1.

Figure 2-1 highlights several key components of the EVM. The components are explained in further detail in the sections below.

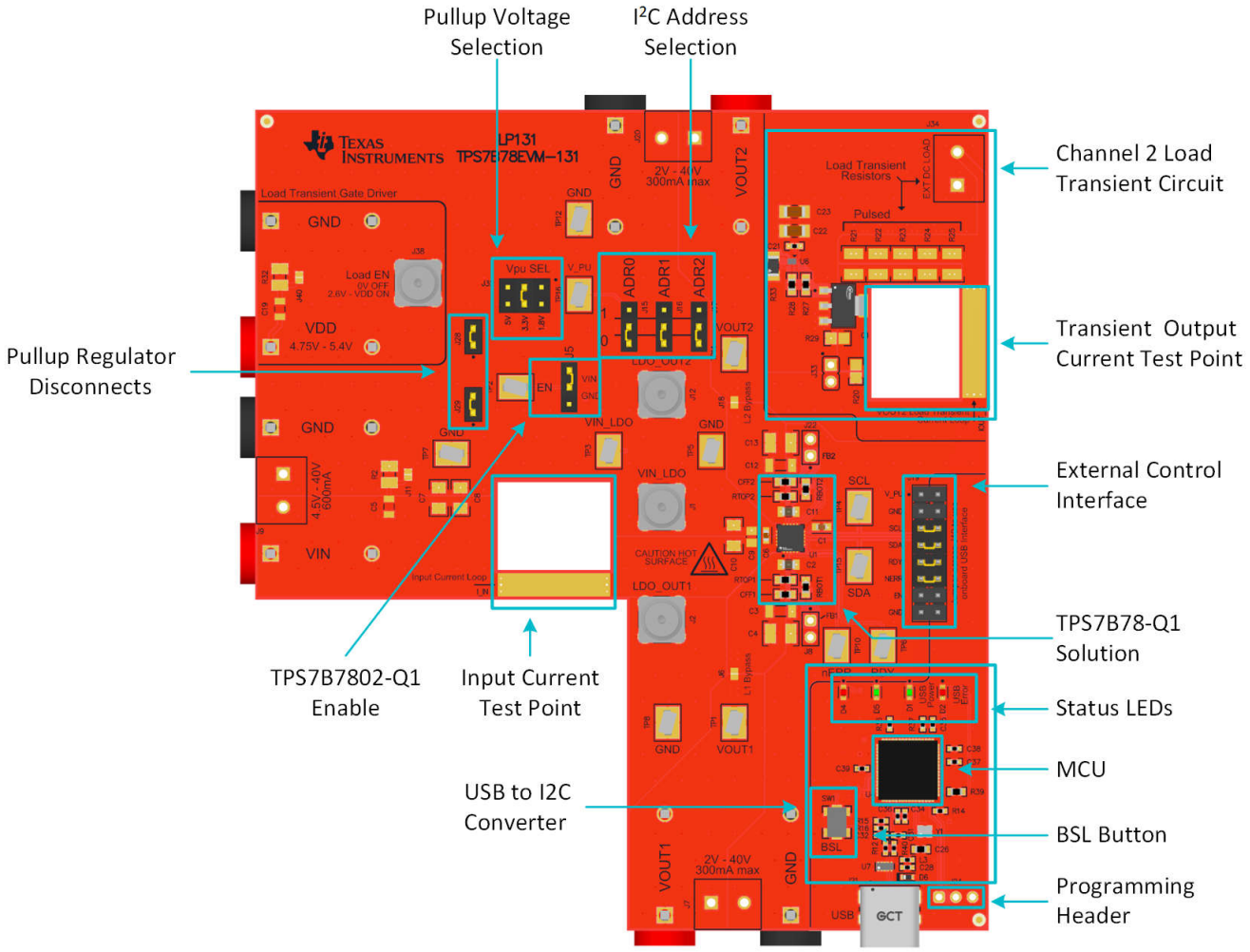


Figure 2-1. TPS7B78EVM-131 Key Features

2.2 TPS7B780x-Q1

The area highlighted as "TPS7B78Q1 Solution" on the EVM indicates the size of a typical compact TPS7B780x-Q1 implementation, including input and output capacitors and optional external feedback resistors. Jumpers and external interfaces relevant to the TPS7B780x-Q1 are detailed in the following sections.

2.2.1 TPS7B780x-Q1 Jumpers

Four jumpers help directly configure the operation of the TPS7B780x-Q1:

- **ADRx**: The three ADR jumpers collectively configure the I²C address of the TPS7B780x-Q1 by setting the three least-significant bits of the 7-bit I²C address. See Table 2-1 for more information.
  - **J15** (ADR0): Configures bit 0 of the device address
  - **J16** (ADR1): Configures bit 1 of the device address
  - **J17** (ADR2): Configures bit 2 of the device address

- **Enable**: This jumper enables or disables the TPS7B780x-Q1.
  - **J5** (EN): Enables the device by connecting EN to VIN or disables the device by connecting EN to GND

Table 2-1. Address Options

J17 (ADR2) Setting	J16 (ADR1) Setting	J15 (ADR0) Setting	7-bit I^2C Address
0	0	0	0x48
0	0	1	0x49
0	1	0	0x4A
0	1	1	0x4B
1	0	0	0x4C
1	0	1	0x4D
1	1	0	0x4E
1	1	1	0x4F

2.2.2 TPS7B780x-Q1 Interfaces

- **VIN**: 4.5V to 40V EVM power supply. Maximum input current is 600mA
  - **J3** (VIN) / **J13** (GND): Banana jacks J3 and J13 come pre-installed and are used to supply power to the EVM
  - **J9**: J9 does not come preinstalled. A terminal block can be installed at J9 as an alternate connection to supply power to the EVM
- **VOUT1**: 2V to 40V output voltage from channel 1 (OUT1) of the TPS7B7802Q1. This connection can be used to apply a load current to channel 1 and monitor the output voltage of the channel. This connection is not used for the TPS7B7801Q1
  - **J4** (VOUT1) / **J10** (GND): Banana jacks J4 and J10 come pre-installed and can be used to connect a load to OUT1 of the TPS7B780x-Q1
  - **J7**: J7 does not come preinstalled. A terminal block can be installed at J7 as an alternate means to connect an external load to OUT1 of the TPS7B780x-Q1
- **VOUT2**: 2V to 40V output voltage from channel 2 (OUT2) of the TPS7B780x-Q1. This connection can be used to apply a load current to channel 2 and monitor the output voltage of the channel. This is the only output channel on the TPS7B7801Q1
  - **J14** (VOUT2) / **J23** (GND): Banana jacks J14 and J23 come pre-installed and can be used to connect a load to OUT2 of the TPS7B780x-Q1
  - **J20**: J20 does not come preinstalled. A terminal block can be installed at J20 as an alternate means to connect an external load to OUT2 of the TPS7B780x-Q1
- **VIN_LDO**: This connection is used to monitor input voltage directly at the input capacitor (C6) of the TPS7B780x-Q1
  - **J1**: J1 does not come preinstalled. An SMA connector can be installed at J1 to allow measurement of the input capacitor voltage.
- **LDO_OUT1**: This connection is used to monitor output voltage for channel 1 directly at the output capacitor (C2) of the TPS7B780x-Q1
  - **J2**: J2 does not come preinstalled. An SMA connector can be installed at J2 to allow measurement of the output capacitor voltage for channel 1.
- **LDO_OUT2**: This connection is used to monitor output voltage for channel 2 directly at the output capacitor (C11) of the TPS7B7802Q1. This is the only output channel on the TPS7B7801Q1
  - **J12**: J12 does not come preinstalled. An SMA connector can be installed at J12 to allow measurement of the output capacitor voltage for channel 1.
- **FB1**: This connection is used to monitor the voltage from the feedback resistor divider for channel 1. This connection is not used for the TPS7B7801Q1
  - **J8**: J8 does not come preinstalled. A 0.1 inch (2.54mm) pitch 2 pin header can be installed at J8 if desired.

- **FB2**: This connection is used to monitor the voltage from the feedback resistor divider for channel 2 of the TPS7B7802Q1. This is the only feedback divider for the TPS7B7801
  - **J22**: J22 does not come preinstalled. A 0.1 inch (2.54mm) pitch 2 pin header can be installed at J22 if desired.
- **Input Current Loop**
  - **I_IN**: An AC/DC oscilloscope current clamp probe can optionally be connected through this loop to monitor input current to the TPS7B780x-Q1. This loop is sized to accommodate many common probes capable of accepting a 5mm conductor.

2.3 Pullup Regulator

The EVM incorporates an auxiliary power supply featuring the TPS7C84Q1 to provide the V_PU supply used by the digital interface of the TPS7B780x-Q1. The V_PU supply is used to pull up the I^2C bus as well as the RDY and nERR status outputs from the device.

2.3.1 Pullup Regulator Jumpers

The following jumpers are provided to configure the V_PU regulator:

- **J32** (Vpu_SEL): Pullup Supply Voltage Selection - This jumper configures V_PU as a 1.8V, 3.3V, or 5V supply.
- **J28** - This jumper disconnects the output of U3, the onboard pullup supply LDO, from the rest of the circuitry on the EVM. This jumper must be populated for normal operation of the EVM unless an external V_PU power supply is provided (either at test point TP16 or through pins 1 or 2 of header J19).
- **J29** - This jumper disconnects the input of U3, the onboard pullup supply LDO, from VIN. This jumper must be populated for normal operation of the EVM unless jumper J28 is removed and an external V_PU power supply is provided.

2.4 USB-to-I^2C Adapter

The EVM incorporates a USB to I^2C adapter based on the MSP430F5528 MCU to allow easier evaluation of the TPS7B780x-Q1. The jumpers, interfaces, and LEDs corresponding to the USB interface are described in further detail in the following sections.

2.4.1 USB-to-I^2C Adapter Jumpers

The following jumpers are provided to configure the USB-to-I^2C Adapter:

- **J19** - This jumper connects the onboard USB to I^2C adapter to the TPS7B780x-Q1. For normal operation, connect jumpers across pins 5 and 6 (SCL), 7 and 8 (SDA), 9 and 10 (RDY), and 11 and 12 (NERR). These jumpers can be removed if an external I^2C adapter is used as described in Using an External I2C Adapter

2.4.2 USB-to-I^2C Adapter Interfaces

The following jumpers are provided to configure the USB-to-I^2C adapter:

- **J21** (USB): If using the onboard USB to I^2C adapter, connect a USB-C cable between J21 and the user's PC
- **J19**: Jumper block J19 can also be used to connect an external I^2C adapter. See Using an External I2C Adapter for more information
- **J24**: The unpopulated header, J24, is provided for Spy-Bi-Wire access to the MSP430F5528. The TPS7B78EVM-131 comes pre-loaded with firmware that is necessary for the correct operation of the USB interface and PC GUI software. TI does not recommend that users access this header or reprogram the device

Using an External I^2C Adapter

If operation with an external I^2C adapter or microcontroller is desired, the jumpers on J19 can be removed and connections made between the external I^2C adapter and the pins on the left-hand side of this header as detailed in Table 2-2. Additional connection points are provided to supply an external pullup supply (V_PU) and to provide an external EN signal to the device. Pin 1 of J19 is the topmost pin on the left side of J19 and is marked with a black dot on the top silkscreen.

Even-numbered pins on the right-hand side of J19 connect to the MSP430F5528. If using an external I^{2}C adapter, TI does not recommend making connections to the even-numbered pins.

Table 2-2. J19 External Connections

J19 Pin	Electrical Function
1	V_PU pullup supply
3	GND
5	SCL
7	SDA
9	RDY
11	NERR
13	EN
15	GND

2.4.3 USB-to-I^{2}C Adapter LEDs

Four status LEDs are present on the EVM. All four require USB power to be connected to function.

- **D4** (nERR): This red LED illuminates if the active-low error output from the TPS7B780x-Q1 is pulled low, indicating a fault condition
- **D5** (RDY): This green LED illuminates when the TPS7B780x-Q1 has powered up and is ready to communicate over I^{2}C
- **D1** (USB Power): This green LED illuminates when the USB interface is connected and receiving 5V power
- **D2** (USB Error): This red LED indicates the status of the onboard USB interface as described in Table 2-3

Table 2-3. USB Error LED Mode of Operation

USB Error (D2) Status	MSP430F5528 Mode of Operation
Off	EVM is connected to the EVM GUI
Solid	EVM is plugged into PC but is not ready for communication
4 rapid blinks	EVM has just been plugged in and is initializing
Blinking in bursts of 4 blinks	EVM is plugged into PC, not connected to EVM GUI
Steady blinking	Connected to USB power

2.4.4 USB-to-I^{2}C Adapter BSL Pushbutton

The TPS7B78EVM-131 includes push button SW1, which allows the MCU to enter USB BSL (bootstrap loader) mode for firmware updates. To enter USB BSL mode, connect the EVM to a PC USB port while holding down SW1.

TI does not recommend that users reprogram the device, as the TPS7B78EVM-131 comes pre-loaded with firmware that is necessary for the correct operation of the USB interface and PC GUI software.

2.5 Load Transient Circuit

The EVM includes a circuit to evaluate transient load regulation in the user's application. This transient load circuit is available on channel 2 of the TPS7B7802Q1, or on the output of the TPS7B7801Q1.

The load transient circuit uses an ultra-fast low-side gate driver, the LMG1020, to rapidly switch MOSFET Q1, connecting a transient load resistance to the LDO output. Other connections allow a steady-state DC load to be applied. The load transient circuit can be used in two configurations, described below.

The ultra-fast output rise time and fall time of the LMG1020 (typically 375ps rising and 350ps falling) allow for extremely fast rising and falling load current profiles to be evaluated.

The AEC-Q100 qualified LMG1020Q1 is available for automotive applications.

Typical configuration

The typical configuration allows for load current to be measured at current measurement point IOUT_2 using common clamp-style oscilloscope current probes. In this configuration, the steady-state DC load is connected to terminal block J34 and the transient load resistance is installed in one or more of resistors R21, R22, R23, R24, or R25.

High-speed configuration

The inductance of the current measurement loop in the typical configuration described above can limit the risetime of the load current. If faster transients are needed, the high-speed configuration can be used instead.

In this configuration, the transient load is provided by R20 and the steady-state DC load is provided by the series combination of R20 and R29. In this configuration, J33 is provided for differential voltage measurement across R20, from which load current can be calculated.

2.5.1 Using the Load Transient Circuit

- Install an SMA connector at J38
- *(optional)* Install a terminal block at J34 to more easily change DC load resistors
- *(optional)* Install an SMA connector at J12 to monitor the output voltage across the output capacitor (C11) of channel 2 of the TPS7B780x-Q1
- Install an appropriate resistance to provide the desired DC steady-state load at R29 or J34
- Install an appropriate resistance to provide the desired peak transient load at R21. If additional power dissipation is needed, up to 5 resistors can installed in parallel at R21 through R25.
- *(optional)* Connect an oscilloscope current clamp probe to loop IOUT_2 to measure output current
- Connect an oscilloscope probe between test point TP11 (VOUT2) and TP5 (GND) to measure output voltage.
  - Connect the oscilloscope to SMA connector J12 (LDO_OUT2) to measure output voltage across the output capacitor if desired.
- Connect a 5V DC power supply capable of providing 100mA between J37 (VDD) and J41 (GND) to power the LMG1020
- Connect a trigger source capable of providing a 3.3V output to J38. TI recommends either a function generator configured for 0-3.3V square wave output or a DC power supply configured for 3.3V output.
- With the channel 2 output of the TPS7B780x-Q1 enabled and configured for the desired output voltage and current limit, applying 3.3V at J38 enables the transient load, while applying 0V leaves only the DC steady-state load connected to the output of channel 2.

2.5.2 Load Transient Circuit Interfaces

- **VDD**: load transient circuit 5V supply. Accepts a supply voltage between 4.75V and 5.4V at 100mA
  - **J37** (VDD) / **J41** (GND): Connect an external 5V power supply to these connections to power the onboard load transient circuit.
- **Load EN**: 0V to 3.3V square wave trigger input for the load transient circuit. Applying 0V disables the transient load. Applying 3.3V enables the transient load. Input voltage on this connection must not exceed VDD.
  - **J38**: J38 does not come preinstalled. An SMA connector must be installed at J38 to allow the load transient circuit to be used.
- **EXT DC LOAD**: External DC load resistor or electronic load connection.
  - **J34**: J34 does not come preinstalled. If using the load transient circuit, a terminal block can be installed at J34 to connect an external DC load for load transient testing.
- **V_LOAD**: Measurement point for voltage drop across optional load resistor R20
  - **J33**: The added inductance from the load transient current loop can limit transient rise times. For very fast transient tests, J33 is provided to measure voltage drop across load resistor R20 and calculate load current.

- **VOUT2 Load Transient Current Loop**: Measurement loop for current from VOUT2 into the load transient circuit
  - **IOUT_2**: An optional AC/DC oscilloscope current clamp probe can be connected through this loop to monitor transient output current from channel 2. This loop is sized to accommodate many common probes capable of accepting a 5mm conductor.

2.6 EVM Setup

1. Connect a DC power supply capable of providing 4.5V to 40V at 600mA to the VIN terminals - positive to J3 (VIN), negative to J13 (GND)
2. Configure the power supply for 12V output
3. Connect a USB-A to USB-C cable between J21 (USB) and your PC
4. Enable the DC power supply
5. Launch the TPS7B780x-Q1 GUI and follow any further setup instructions
6. Apply a load between VOUT1 (J4) and GND (J10) for channel 1
7. Apply a load between VOUT2 (J14) and GND (J23) for channel 2

2.7 Test Points

I_IN - This cutout is sized for a typical 5mm-wire-diameter AC/DC current probe to be used to monitor input current to the EVM

IOUT_2 - This cutout is sized for a typical 5mm-wire-diameter AC/DC current probe to be used to monitor output current from TPS7B7802Q1 OUT2 (or OUT on the TPS7B7801Q1) through the load transient circuit

TP2/EN - This test point allows measurement of the enable signal of the regulator

TP3/VIN_LDO - This test point allows measurement of the input voltage close to the VIN pins of the regulator

TP1/VOUT1 - This test point allows measurement of the output voltage from channel 1 of the TPS7B7802Q1. This test point is not connected on the TPS7B7801Q1

TP11/VOUT2 - This test point allows measurement of the output voltage from channel 2 of the TPS7B7802Q1. This is the only output on TPS7B7801Q1

TP15/SDA - This test point allows measurement of the serial data signal between the regulator and the I^2C adapter

TP4/SCL - This test point allows measurement of the serial clock signal between the regulator and the I^2C adapter

TP6/RDY - This test point allows measurement of the RDY signal from the regulator

TP10/nERR - This test point allows measurement of the active low nERR signal from the regulator

TP5, TP7, TP8, TP9, TP12 - GND - GND is the ground return for the regulator. The EVM provides 5 GND test points to allow the user to power up the EVM or to attach an oscilloscope or multimeter ground lead

TP13/3V3 - This test point allows measurement of the 3.3V regulator which powers the onboard USB to I^2C adapter.

TP16/V_PU - This test point allows measurement of the I^2C/RDY/nERR pullup voltage.

TP14/U6 IN– - This test point allows an external signal to be connected to the IN- pin of the gate driver for the onboard load transient circuit. This test point is not populated by default.

2.8 Required Equipment for Basic Evaluation

1. Power supply capable of supplying 600mA at 4.5V to 40V. For typical evaluation setups, TI recommends a power supply capable of supplying 12V at 1A.
2. Computer running the TPS7B780x-Q1 GUI (either online through TI GUI Composer, or installed as a stand-alone program).
3. Multimeter to measure DC output voltages or oscilloscope to measure AC output characteristics.
4. *(optional)* Load resistors or DC electronic load.
5. *(optional)* DC power supply capable of supplying 5V at 100mA to power the load transient circuit.
6. *(optional)* Signal generator to act as a trigger source for the load transient circuit.

3 Software

3.1 Software Download

The PC GUI Software for the TPS7B78EVM-131 runs on TI's GUI Composer framework. The software is available as a live version which runs in your browser, and is available as a download for offline use. The software is compatible with Windows®, Mac®, and Linux® operating systems.

3.1.1 Live Software on dev.ti.com

The live software currently works on Chrome, Firefox, Safari, and Edge browsers. Internet Explorer is not supported. Users can access the live version through one of the following actions:

- Go to the TPS7B78EVM-131 tool page and click on the Launch button for the GUI software
- Go to the TPS7B780x-Q1 GUI Gallery Page

Click on the application icon within the gallery to launch the software. Click on the prompt to install the TI Cloud Agent Bridge browser plugin.

3.1.2 Offline Software

3.1.2.1 Download From dev.ti.com

Users can access the latest version of the offline software by navigating to the live version as noted above. Look for the download icon and download both the application and runtime for the operating system as shown in the Gallery Download:

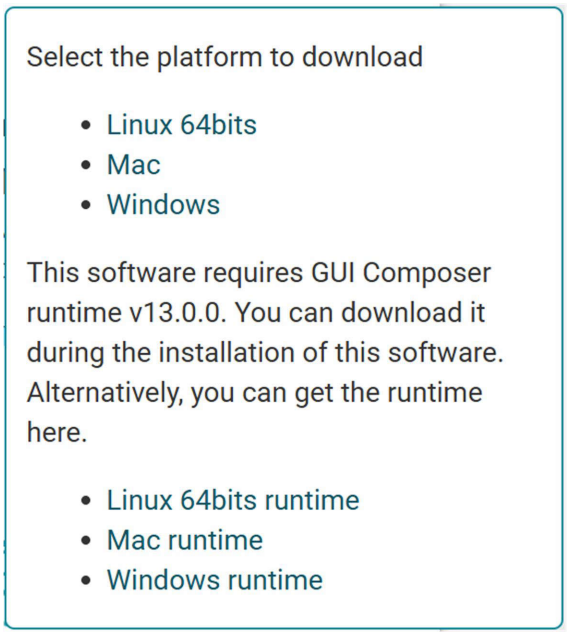


Figure 3-1. Download Pop-Up

3.2 Home Tab

The Home Tab is shown at software launch. From here, you can access the Quick Setup, Monitor, ADC Graph, and Register tabs which are explained below. The icons on the left side of the screen are shortcuts to the tabs.

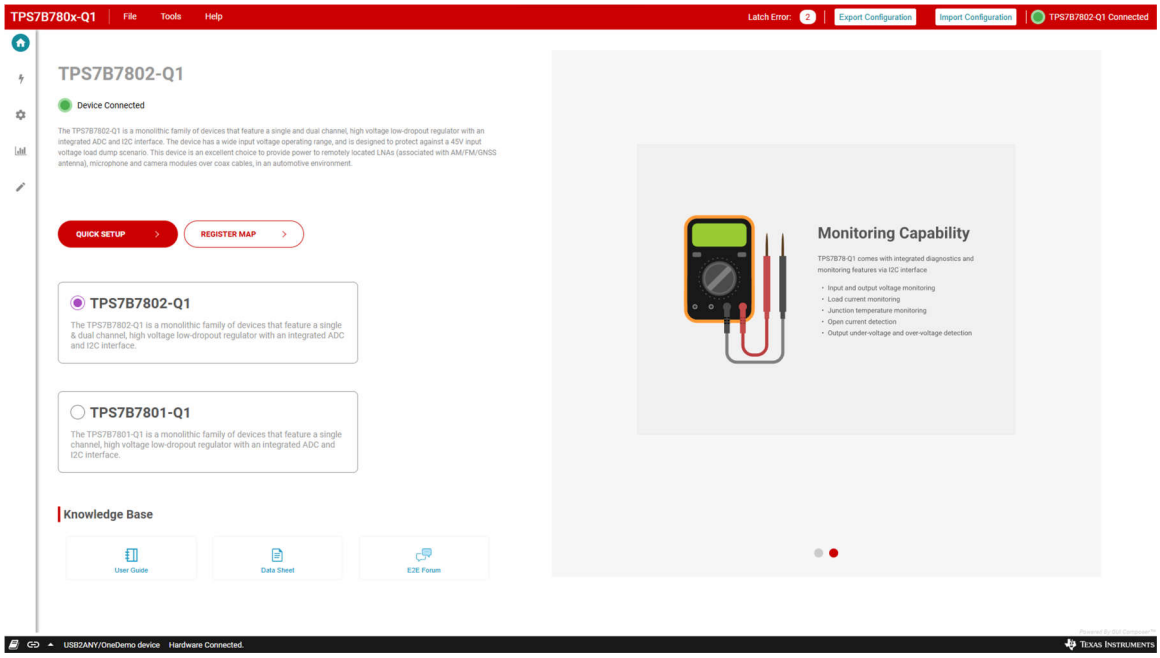


Figure 3-2. Home

3.3 Quick Setup Tab

The Quick Setup tab walks the user through the basic setup steps required to power up and connect to the EVM.

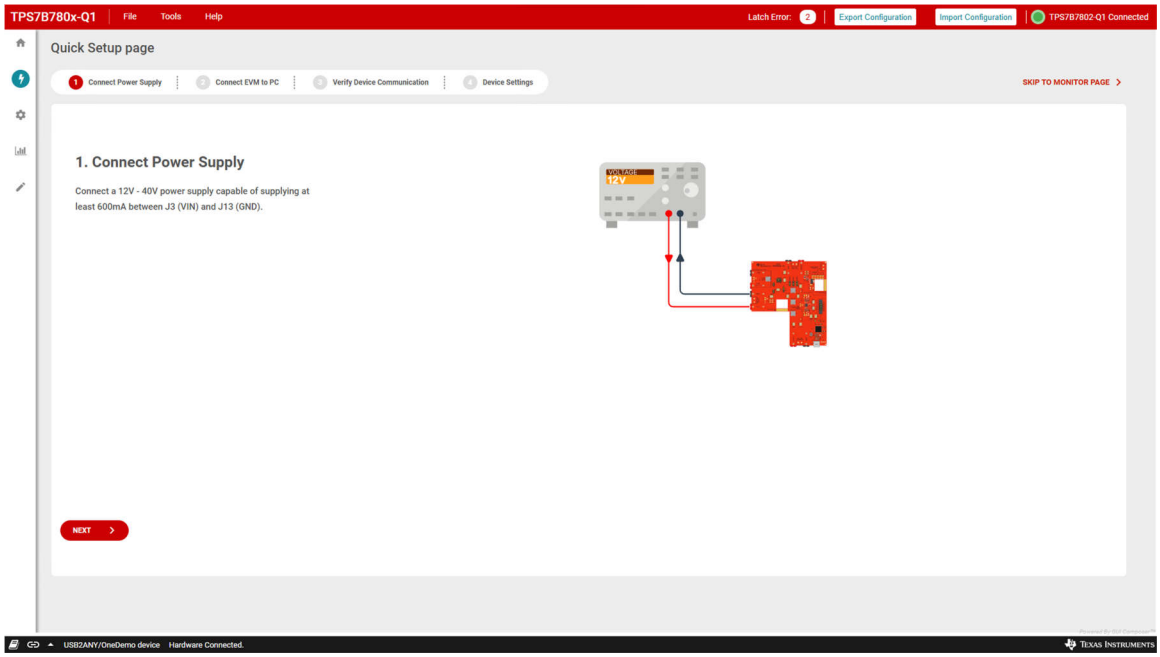


Figure 3-3. Quick Setup

3.4 Monitor Tab - Dashboard Page

The Dashboard page of the Monitor Tab displays the error status and real-time input voltage, output voltage, output current, and junction temperature of the TPS7B780x-Q1.

Each Latched Error field contains a reset button which allows the latched field to be cleared.

This page also provides links at the right side to issue a software reset to the TPS7B780x-Q1, configure the Error Mask settings for the device, and reset all of the latched error register bits.

The Parameters section at the bottom of this page changes in appearance when different ADC modes are selected. The image below shows the typical mode with both channel 1 and channel 2 ADC reads enabled.

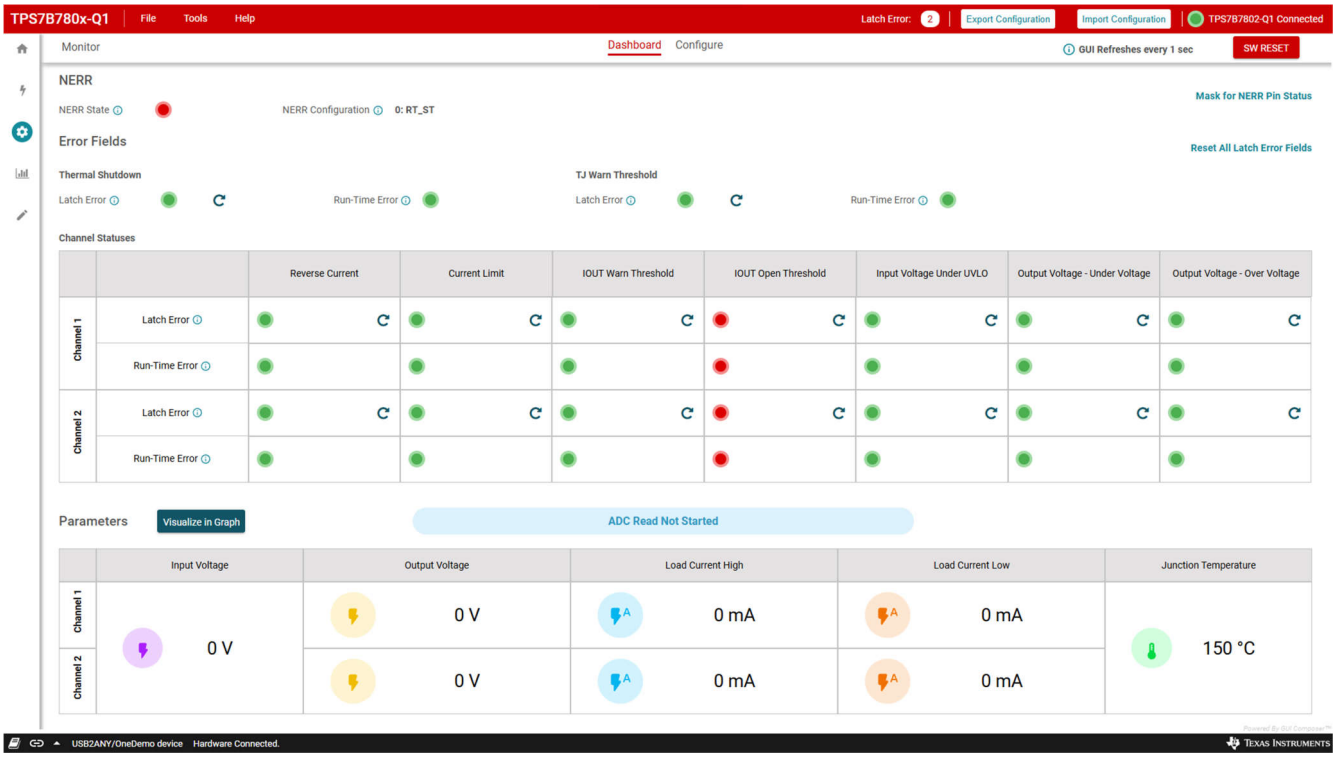


Figure 3-4. Dashboard Page

3.5 Monitor Tab - Configure Page

The Configure Page of the monitor tab allows the user to configure settings for the TPS7B780x-Q1, including output voltage, feedback pin modes, current limits, and ADC settings. Changes made on this page take effect immediately.

The ADC Functionality section of this page allows the user to configure the ADC mode of the TPS7B780x-Q1 - enabling either continuous or single-measurement conversion modes for either or both of the output channels.

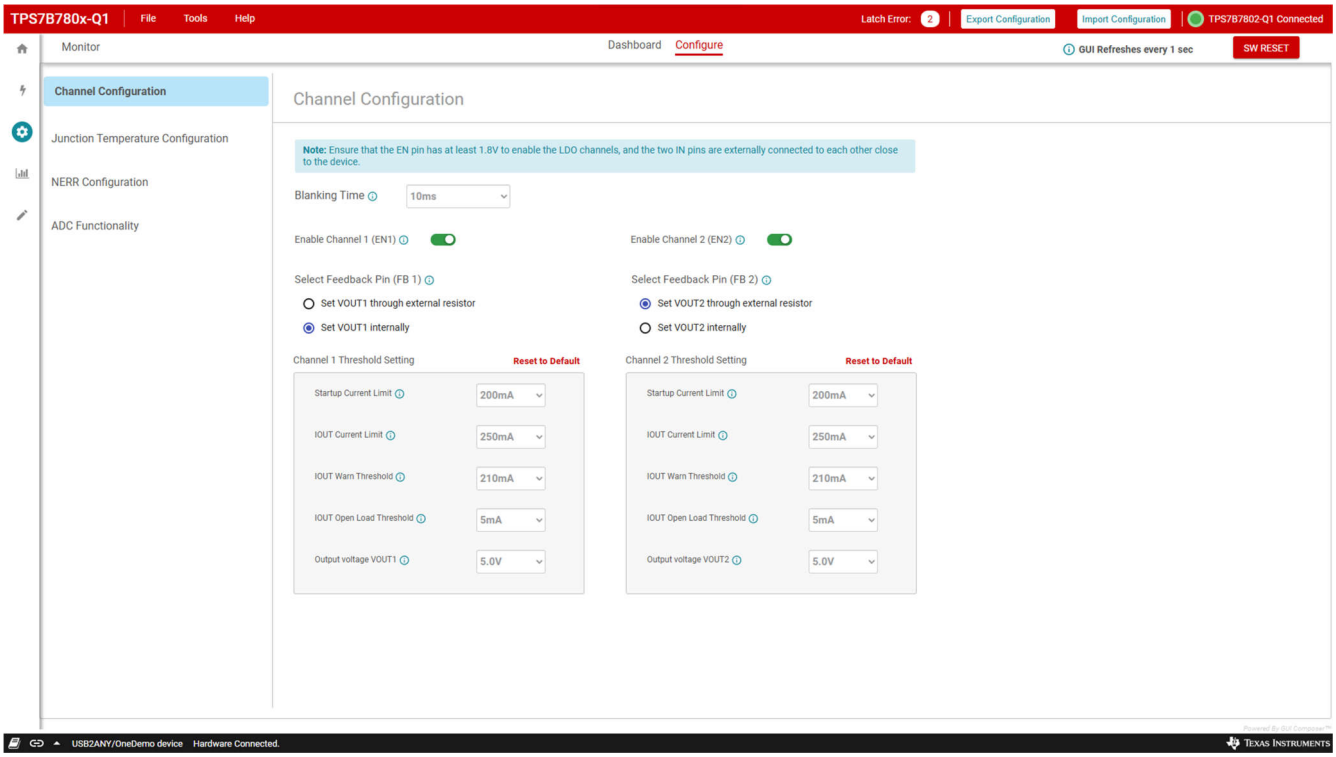


Figure 3-5. Configure Page

3.6 ADC Graph Tab

The ADC Graph provides a strip chart view of the last 100 polled samples from each of the measurement registers of the TPS7B780x-Q1 . This polling rate can be configured on the Registers Tab. A quick link to the ADC configuration settings is provided at the bottom right of this page.

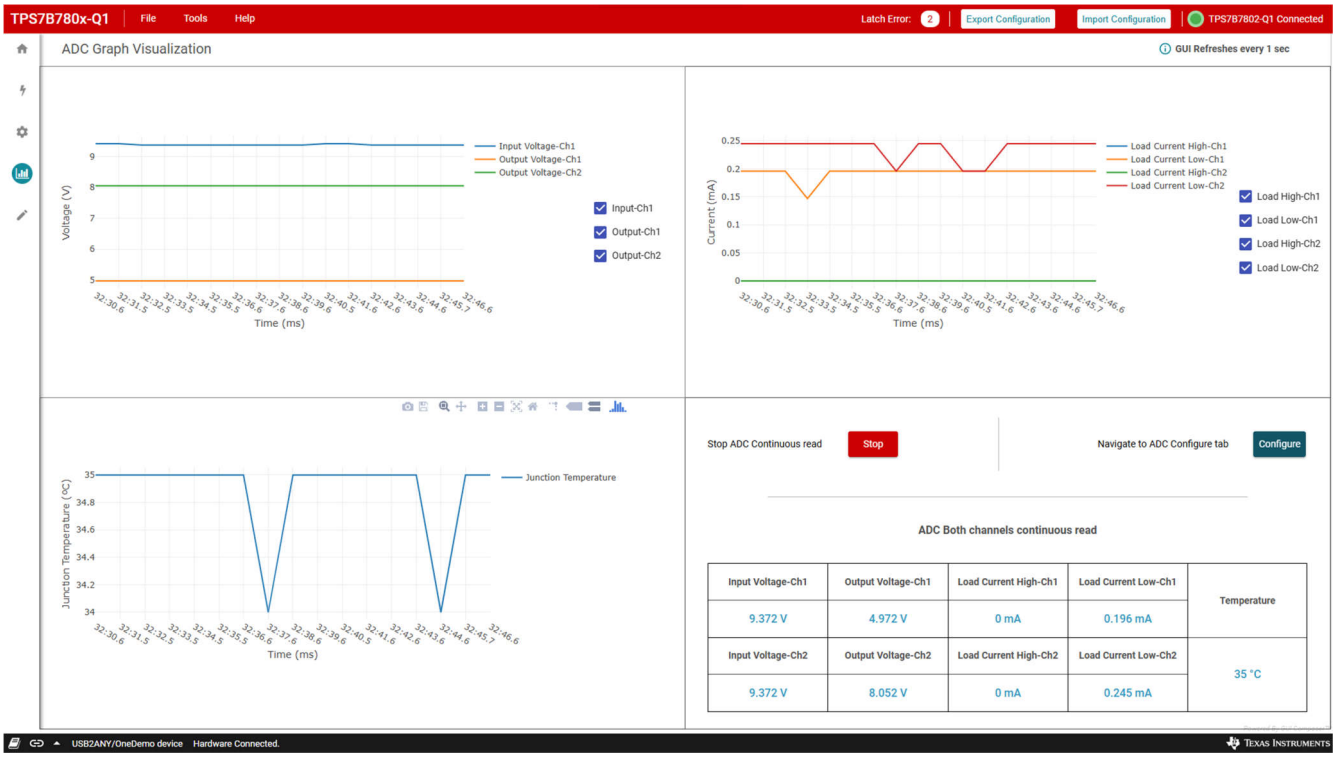


Figure 3-6. ADC Graph

3.7 Registers Tab

The Registers tab interacts with the registers and bits within the TPS7B780x-Q1 device. For more information on each register/bit, click on a register name to see what each bit defines.

The Auto Read drop-down box configures polling of register contents. By default, the GUI polls the registers at a 1 second interval. When Auto Read is Off, click Read Register to fetch the contents of the highlighted register. Read All Registers can be used to fetch the contents of all registers at once. This polling rate also affects the update rate of the ADC Graph Tab

By default, changes to register contents in the GUI are immediately written to the TPS7B780x-Q1. If desired, the Immediate Write drop-down box at the upper right corner of the GUI can be changed to Deferred Write. In this mode, register changes are only written to the TPS7B780x-Q1 when either the Write Register or Write All Registers buttons are clicked.

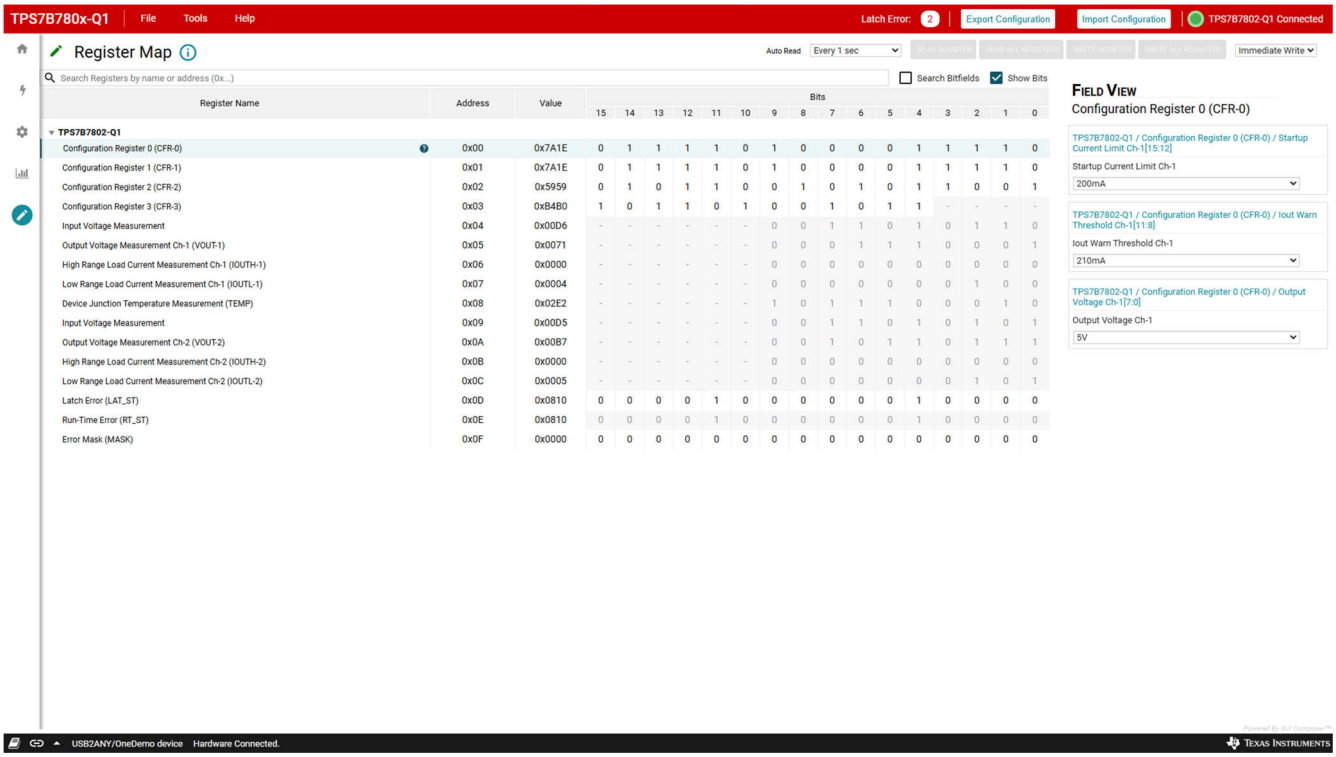


Figure 3-7. Register Map

4 Hardware Design Files

4.1 Schematics

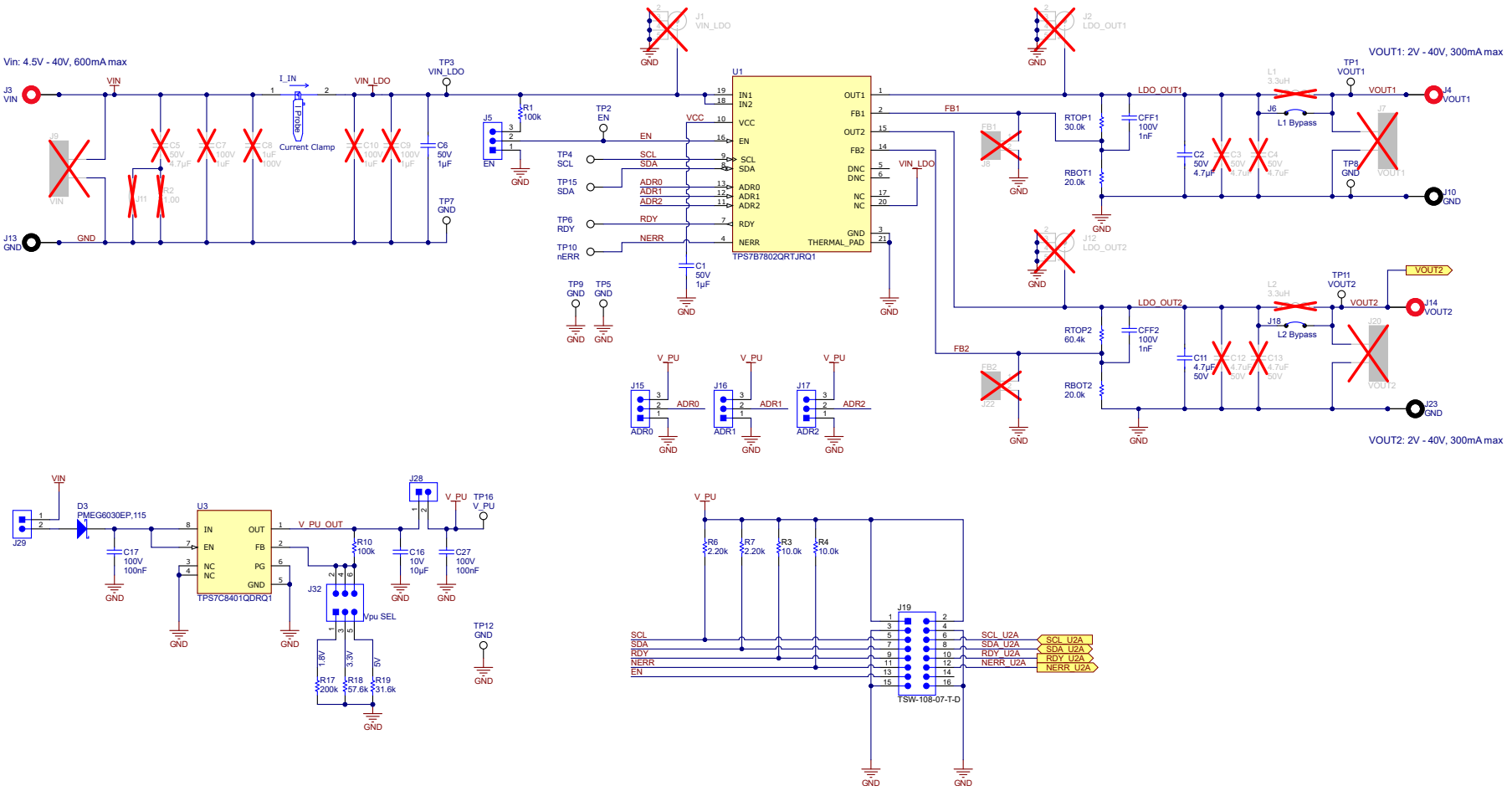


Figure 4-1. Schematic - TPS7B780x-Q1 Circuitry

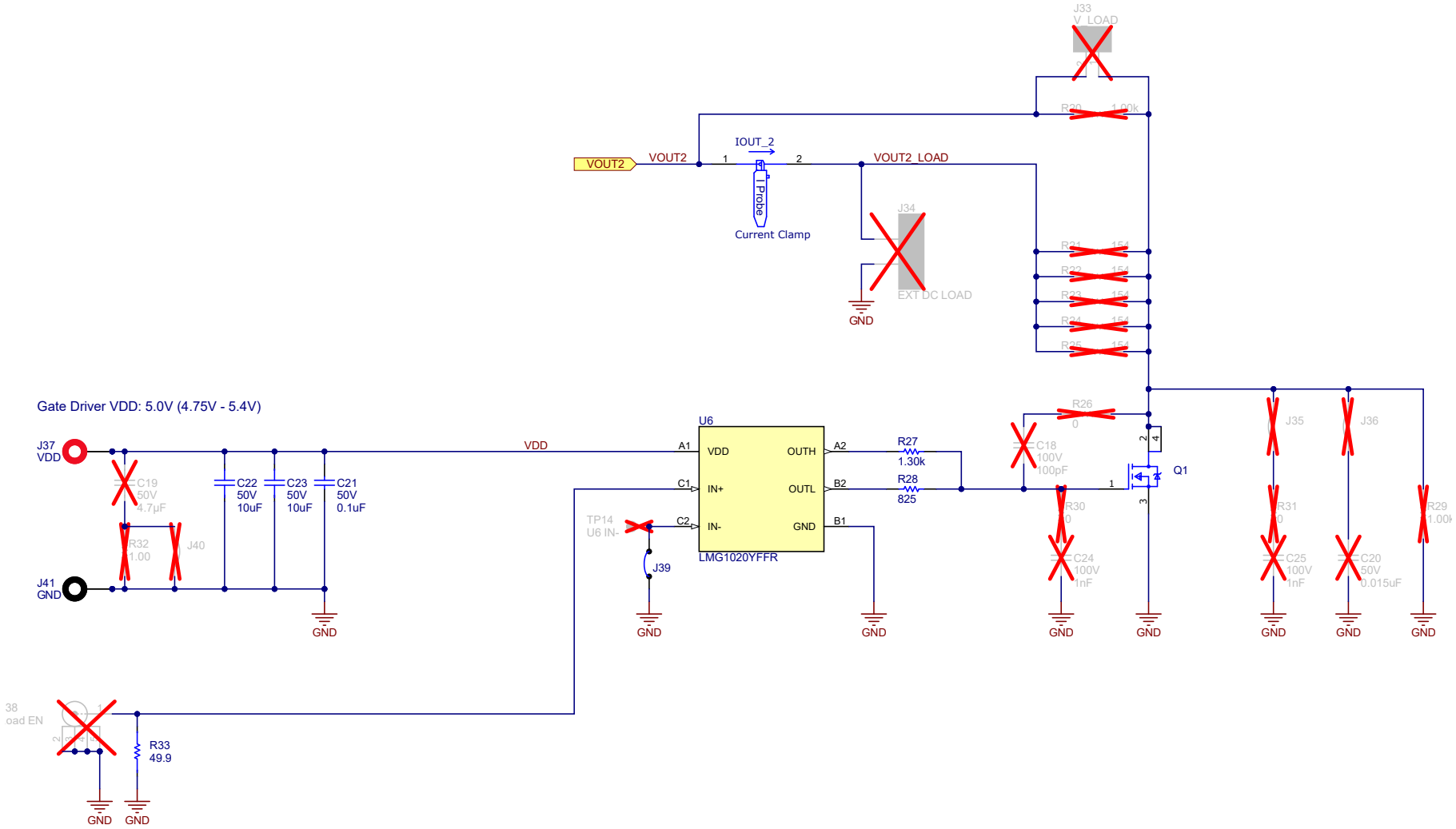


Figure 4-2. Schematic - Load Transient Circuit

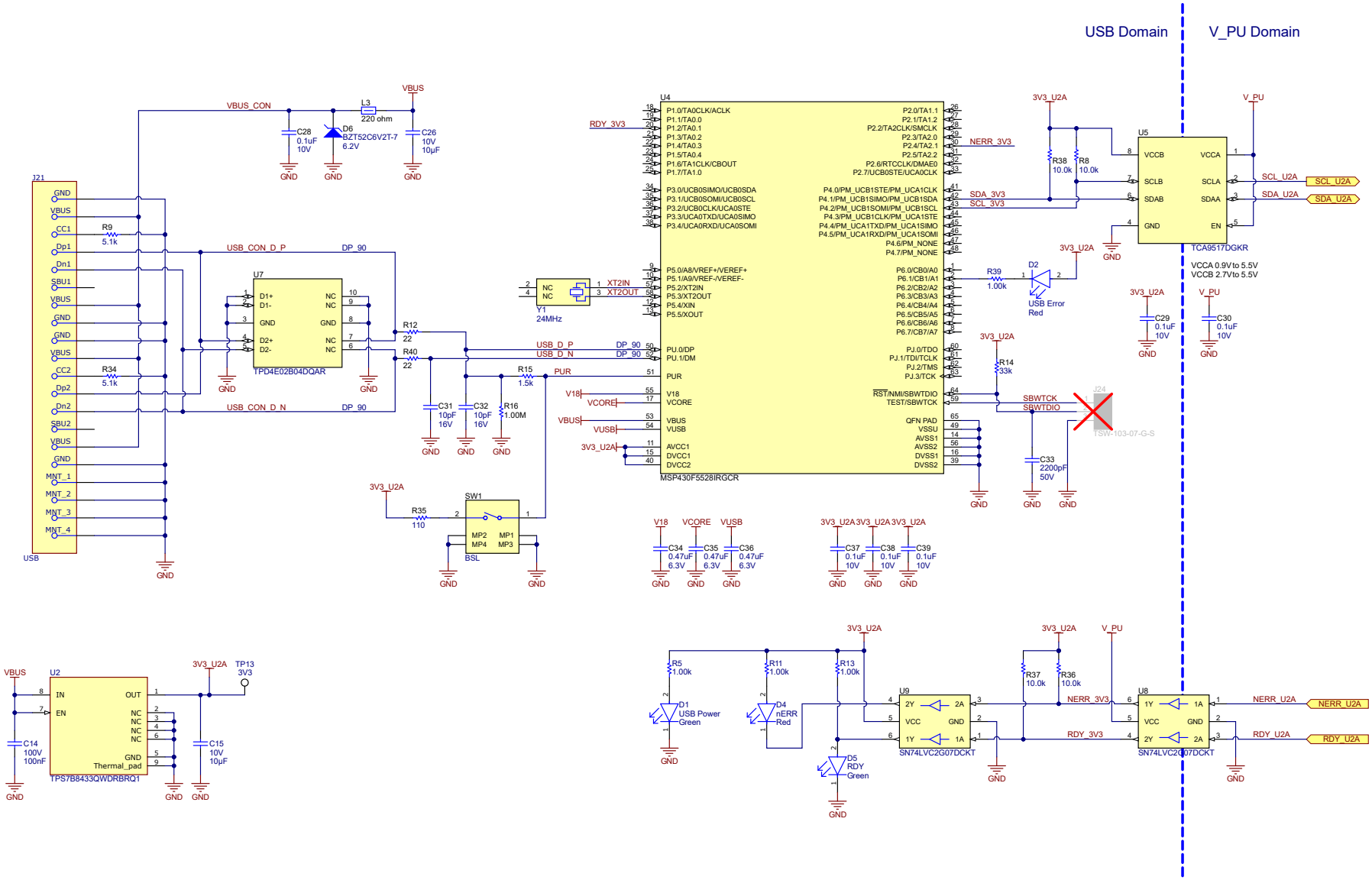


Figure 4-3. Schematic - USB-to-I²C Adapter

4.2 PCB Layouts

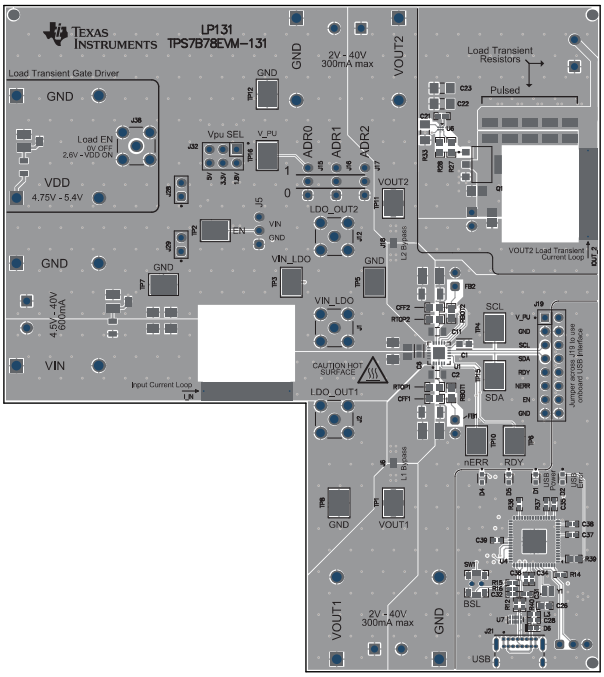


Figure 4-4. Layer 1 (Top Layer)

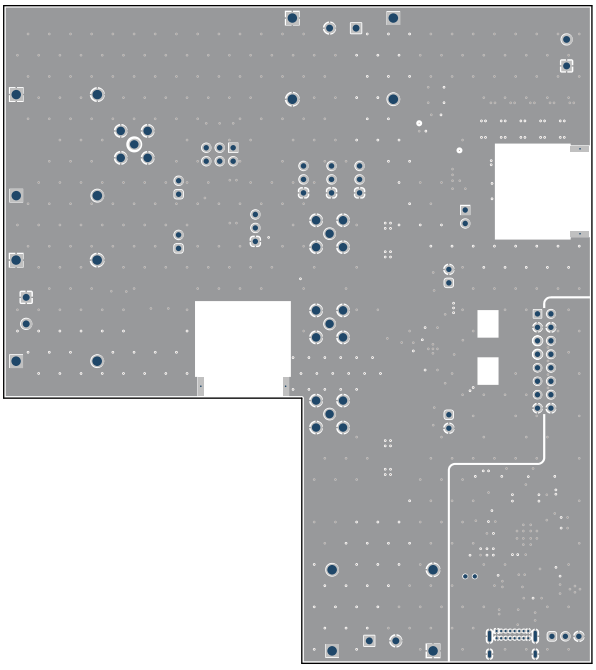


Figure 4-5. Layer 2

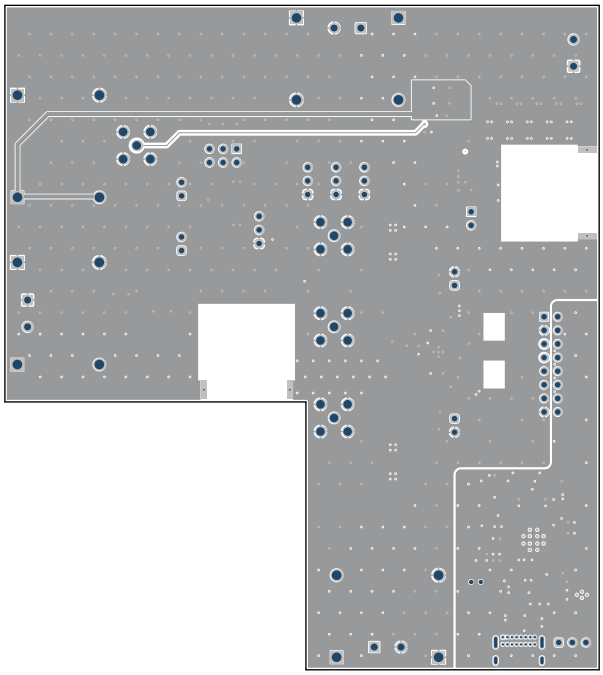


Figure 4-6. Layer 3

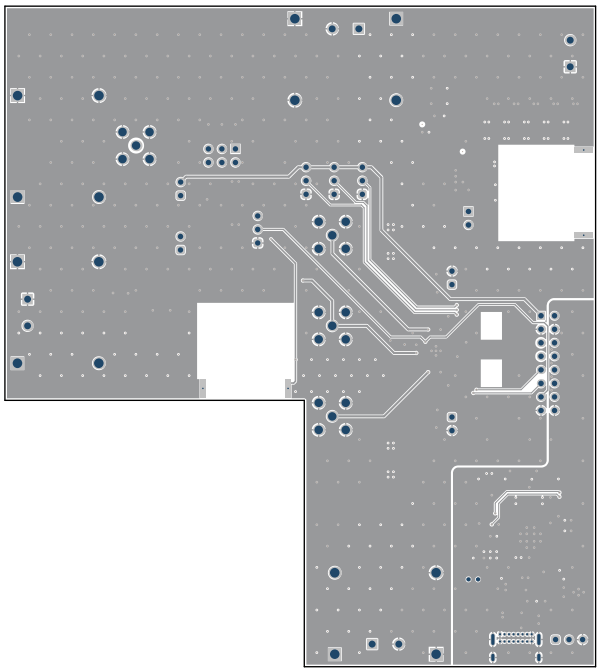


Figure 4-7. Layer 4

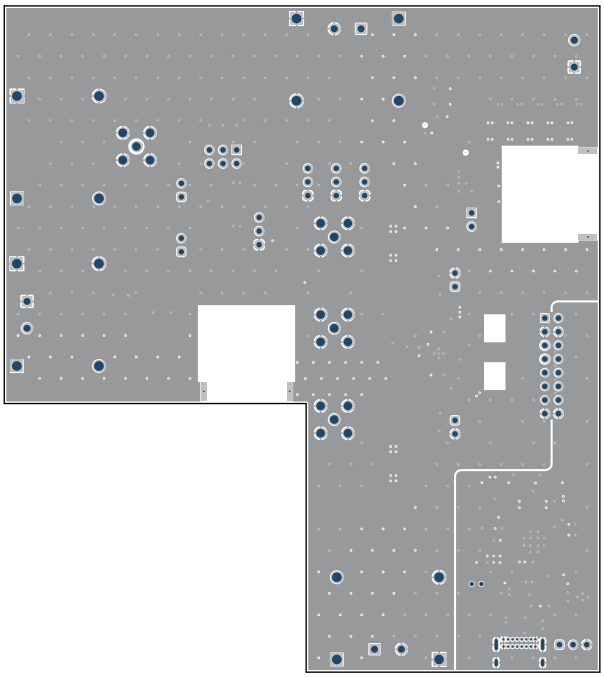


Figure 4-8. Layer 5

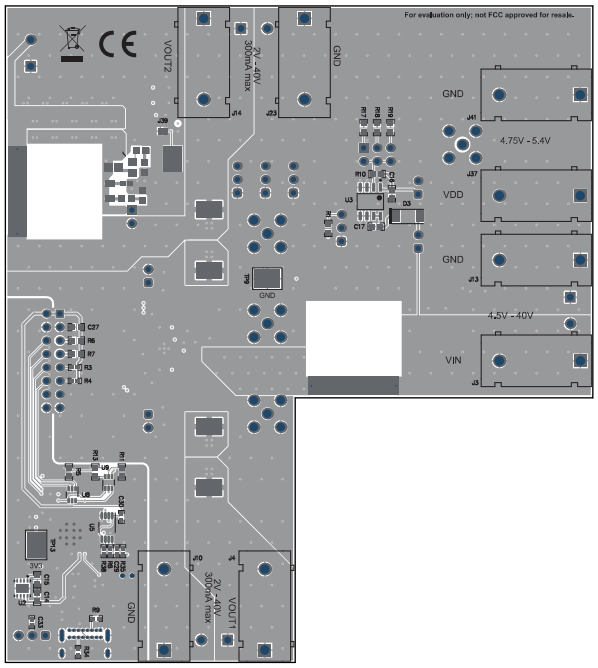


Figure 4-9. Layer 6 (Bottom Layer) - Viewed From Bottom Side

4.3 Bill of Materials (BOM)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		LP131	Any		
C1	1	1µF	1µF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	0603	GMC10X7R105K50NT	Cal-Chip Electronics		
C2, C11	2	4.7µF	Cap Ceramic 4.7uF 50V X7R 10% Pad SMD 0805 +125°C Automotive T/R	0805	CGA4J1X7R1H475K125AC	TDK Corporation		
C6	1	1µF	1µF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	0603	CC0603KRX7R9BB105	YAGEO		
C14, C17, C27	3	0.1uF	CAP, CERM, 0.1µF, 100V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	HMK107B7104KAHT	Taiyo Yuden		
C15, C16, C26	3		Chip Multilayer Ceramic Capacitors for General Purpose	0603	GRM188Z71A106KA73D	Murata		
C21	1	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0402	0402	C1005X7R1H104K050BB	TDK		
C22, C23	2	10µF	10µF ±10% 50V Ceramic Capacitor X7R 1206 (3216 Metric)	1206	GMC31X7R106K50NT	Cal-Chip Electronics		
C28, C29, C30, C37, C38, C39	6	0.1uF	CAP, CERM, 0.1uF, 10V,+/- 10%, X5R, 0402	0402	LMK105BJ104KV-F	Taiyo Yuden		
C31, C32	2	10pF	CAP, CERM, 10pF, 16V,+/- 10%, C0G, 0402	0402	C0402C100K4GACTU	Kemet		
C33	1	2200pF	CAP, CERM, 2200pF, 50V, +/- 5%, X7R, 0402	0402	CL05B222JB5NNNC	Samsung Electro-Mechanics		
C34, C35, C36	3	0.47uF	CAP, CERM, 0.47uF, 6.3V, +/- 10%, X7R, 0402	0402	JMK105B7474KVHF	Taiyo Yuden		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
CFF1, CFF2	2	1000pF	CAP, CERM, 1000pF, 100V, +/-10%, X7R, 0603	0603	06031C102KAT2A	AVX		
D1, D5	2		LED GREEN DIFFUSED CHIP SMD	0603	HSMG-C191	Broadcom		
D2, D4	2		Red 631nm LED Indication - Discrete 2.2V 0603 (1608 Metric)	0603	HSMZ-C190	Broadcom		
D3	1	60V	Diode, Schottky, 60V, 3A, SOD-128	SOD-128	PMEG6030EP,115	Nexperia		
D6	1	6.2V	Diode, Zener, 6.2V, 300mW, SOD-523	SOD-523	BZT52C6V2T-7	Diodes Inc.		
J3, J4, J14, J37	4		Standard Banana Jack, insulated, 10A, red	571-0500	571-0500	DEM Manufacturing		
J5, J15, J16, J17	4		Header, 100mil, 3x1, Gold, TH	3x1 Header	TSW-103-07G-S	Samtec		
J6, J18, J39	3		Jumper, SMT	shorting jumper, SMT	JMP-36-30X40SMT	Any		
J10, J13, J23, J41	4		Standard Banana Jack, insulated, 10A, black	571-0100	571-0100	DEM Manufacturing		
J19	1		Connector Header Through Hole 16 position 0.100" (2.54mm)	HDR16	TSW-108-07T-D	Samtec		
J21	1		USB - C (Type - C) USB 2.0 Receptacle Connector 16 Position Through Hole, Right Angle	PTH_USB-C	USB4085GF-A	Global Connector Technology		
J28, J29	2		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07G-S	Samtec		
J32	1		Header, 100mil, 3x2, Gold, TH	3x2 Header	TSW-103-07G-D	Samtec		
L3	1	220ohm	Ferrite Bead, 220ohm @ 100MHz, 0.45A, 0402	0402	BLM15AG221SN1D	MuRata		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
Q1	1		N-Channel 100V 1.2A (Ta) 1.8W (Ta) Surface Mount PG-SOT223-4	SOT223	BSP296NH6327XTSA1	Infineon		
R1	1	100k	RES, 100k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale		
R3, R4, R8, R36, R37, R38	6	10.0k	RES, 10.0k, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale		
R5, R11, R13, R39	4	1.00k	RES, 1.00k, 1%, 0.1W, 0603	0603	RC0603FR-071KL	Yageo		
R6, R7	2	2.20k	RES, 2.20k, 1%, 0.1W, 0603	0603	RC0603FR-072K2L	Yageo		
R9, R34	2	5.1k	RES, 5.1k, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04025K10JNED	Vishay-Dale		
R10	1	100k	RES, 100k, 1%, 0.1W, 0603	0603	RC0603FR-07100KL	Yageo		
R12, R40	2	22	RES, 22, 5%, 0.1W, AEC-Q200 Grade 0, 0402	0402	ERJ-2GEJ220X	Panasonic		
R14	1	33k	RES, 33k, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW040233K0JNED	Vishay-Dale		
R15	1	1.5k	RES, 1.5k, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K50JNED	Vishay-Dale		
R16	1	1.00Meg	RES, 1.00M, 1%, 0.063W, AEC-Q200 Grade 0, 0402	0402	RMCF0402FT1M00	Stackpole Electronics Inc		
R17	1	200k	RES, 200k, 1%, 0.1W, 0603	0603	RC0603FR-07200KL	Yageo		
R18	1	57.6k	RES, 57.6k, 1%, 0.1W, 0603	0603	RC0603FR-0757K6L	Yageo		
R19	1	31.6k	RES, 31.6k, 1%, 0.1W, 0603	0603	RC0603FR-0731K6L	Yageo		
R27	1	1.30k	RES, 1.30k, 1%, 0.1W, 0603	0603	RC0603FR-071K3L	Yageo		
R28	1	825	RES, 825, 1%, 0.1W, AEC-Q200 Grade 0, 0603	0603	CRCW0603825RFKEA	Vishay-Dale		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
R33	1	49.9	RES Thick Film, 49.9Ω, 1%, 0.75W, 100ppm/°C, 1206	1206	CRCW120649R9FKEAHP	Vishay Dale		
R35	1	110	RES, 110, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW0402110RJNED	Vishay-Dale		
RBOT1, RBOT2	2	20.0k	RES, 20.0k, 0.5%, 0.1W, 0603	0603	MCR03EZPD2002	Rohm		
RTOP1	1	30.0k	RES, 30.0k, 0.5%, 0.1W, AEC-Q200 Grade 0, 0603	0603	ERA-3AED303V	Panasonic		
RTOP2	1	60.4k	RES, 60.4k, 0.5%, 0.1W, AEC-Q200 Grade 0, 0603	0603	ERA-3AED6042V	Panasonic		
SH-J5, SH-J15, SH-J16, SH-J17, SH-J19.11, SH-J19.5, SH-J19.7, SH-J19.9, SH-J28, SH-J29, SH-J32	11	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec	969102-0000DA	3M
SW1	1		Switch, SPST-NO, Off-Mom, 0.05A, 12VDC, SMD	3.9x2.9mm	PTS820J20M SMTR LFS	C&K Components		
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP15, TP16	15		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone Electronics		
U1	1		Florence, Automotive, Single- and Dual-Channel Antenna LDO With I2C Diagnostics	WQFN20	TPS7B7802QRTJRQ1	Texas Instruments		
U2	1		TPS7B8433QWDRBRQ1	SON8	TPS7B8433QWDRBRQ1	Texas Instruments		
U3	1		Automotive 150mA 40V low-dropout linear regulator with power good and wide output voltage range 8-SOIC -40 to 125	SOIC8	TPS7C8401QDRQ1	Texas Instruments		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
U4	1		16-Bit Ultra-Low-Power Microcontroller, 128KB Flash, 8KB RAM, USB, 12Bit ADC, 2 USCIs, 32Bit HW MPY, RGC0064B (VQFN-64)	RGC0064B	MSP430F5528IRGCR	Texas Instruments		
U5	1		Level-Shifting I2C Bus Repeater, DGK0008A (VSSOP-8)	DGK0008A	TCA9517DGKR	Texas Instruments		Texas Instruments
U6	1		5V, 7A/5A Low Side GaN Driver With 60MHz/1ns Speed, YFF0006AEAE (DSBGA-6)	YFF0006AEAE	LMG1020YFFR	Texas Instruments	LMG1020YFFT	Texas Instruments
U7	1		4-Channel ESD Protection Diode for USB Type-C and HDMI 2.0, DQA0010A (USON-10)	DQA0010A	TPD4E02B04DQAR	Texas Instruments		Texas Instruments
U8, U9	2		Dual Buffer/Driver with Open-Drain Output, DCK0006A (SOT-SC70-6)	DCK0006A	SN74LVC2G07DCKT	Texas Instruments	SN74LVC2G07DCKR	Texas Instruments
Y1	1		Crystal, 24MHz, SMD	2x1.6mm	XRCGB24M000F2P00R0	MuRata		
C3, C12	0		4.7µF ±10% 50V Ceramic Capacitor X7R 1206 (3216 Metric)	1206	8.85012E+11	Wurth Electronics		
C4, C13	0	4.7uF	CAP, CERM, 4.7uF, 50V, +/- 10%, X7R, 1210	1210	GRM32ER71H475KA88L	MuRata		
C5, C19	0	4.7µF	Cap Ceramic 4.7uF 50V X7R 10% Pad SMD 0805 +125°C Automotive T/R	0805	CGA4J1X7R1H475K125AC	TDK Corporation		
C7, C8, C10	0	1uF	CAP, CERM, 1uF, 100V, +/- 10%, X7R, 1206	1206	C3216X7R2A105K160AA	TDK		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
C9	0	1uF	CAP, CERM, 1µF, 100V,+/- 10%, X7R, AEC-Q200 Grade 1, 0805	0805	KAF21KR72A105KU	AVX		
C18	0	100pF	CAP, CERM, 100pF, 100V, +/- 5%, X7R, 0805	0805	C0805C101J1RACTU	Kemet		
C20	0	0.015uF	CAP, CERM, 0.015uF, 50V, +/- 10%, X7R, 0402	0402	GRM155R71H153KA12D	MuRata		
C24, C25	0	1000pF	CAP, CERM, 1000pF, 100V, +/- 5%, X7R, 0603	0603	06031C102JAT2A	AVX		
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A		
J1, J2, J12, J38	0		SMA Jack, Straight, 50Ohm, Gold, TH	TH, 5-Leads, Body 7x7mm	SMA-J-P-H-ST-TH1	Samtec		
J7, J9, J20, J34	0		TERM BLK 2POS SIDE ENTRY 5MM PCB	HDR2	6.91138E+11	Würth Elektronik		
J8, J22	0		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07G-S	Samtec		
J11, J35, J36, J40	0		Jumper, SMT	shorting jumper, SMT	JMP-36-30X40SMT	Any		
J24	0		Header, 100mil, 3x1, Gold, TH	3x1 Header	TSW-103-07G-S	Samtec		
J33	0		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions		
L1, L2	0	3.3uH	Automotive Inductors, High Saturation Series 3.3uH 18A 6.8mΩ 20%	SMT_INDUCTOR_13MM259_12MM9	IHLP5050FDER3R3MA1	Vishay		
R2, R32	0	1	RES, 1.00, 1%, 0.333W, AEC-Q200 Grade 1, 0805	0805	RL1220S-1R0F	Susumu Co Ltd		
R20, R29	0	1.00k	RES, 1.00k, 1%, 0.125W, AEC-Q200 Grade 0, 0805	0805	ERJ-6ENF1001V	Panasonic		
R21, R22, R23, R24, R25	0	154	RES, 154, 1%, 0.5W, 1210	1210	RC1210FR-07154RL	Yageo		

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
R26	0	0	RES, 0, 5%, 0.125W, AEC-Q200 Grade 0, 0805	0805	ERJ-6GEY0R00V	Panasonic		
R30, R31	0	0	RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc		
TP14	0		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone Electronics		

5 Additional Information

5.1 Trademarks

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Mac® is a registered trademark of Apple Inc.
Linux® is a registered trademark of Linus Torvalds.
All trademarks are the property of their respective owners.

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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 DEGREDATION 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/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。

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.

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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。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

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/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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, INDEMITY 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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