TPS2388EVM-612: PoE, PSE, TPS2388 Evaluation Module

This user's guide describes the TPS2388 evaluation module (TPS2388EVM-612 or EVM). The EVM contains evaluation and reference circuitry for the TPS2388. The TPS2388 is a Power-over-Ethernet (PoE) device for power sourcing equipment (PSE).

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1 Description

The TPS2388EVM-612 features the octal channel, TPS2388, IEEE 802.3at PoE PSE controller. The EVM consists of a motherboard (TPS2388EVM-612) and daughter board (TPS2388EVM-016) containing one TPS2388 device. The TPS2388EVM-612 provides a multi-port base platform interface for TPS2388EVM-016, MSP-EXP430G2 (LaunchPad™), and USB2ANY (USB Interface Adapter).

1.1 Features

- Eight IEEE802.3at, Type 2 (30 W) ports with 1000BASE-T (gigabit Ethernet data pass through)
- Two non-standard, high power ports with 1000BASE-T (gigabit Ethernet data pass through)
- 100% passed Sifos compliance test
- Single DC power supply input
- On board 3.3-V regulator
- On board I^2C interface to both TPS2388PW devices from either USB2ANY or MSP-EXP430G2.
- Port ON status LEDs
- User test points

1.2 Applications

- Ethernet switches and routers
- Surveillance VDRs
- High power PoE
- PoE pass-through systems

2 Quick Start

2.1 Input Power

2.1.1 Input Power (Labeled VPWR)

DC input voltage is provided through J1 (screw jack). A dc power supply with sufficient current capacity can power the EVM.

CAUTION

Reverse voltage protection is not provided; ensure that the correct polarity is applied to J1.

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This dc input is labeled *VPWR* in the schematics and is used for port VBUS as well as for the TPS2388 device. The VPWR connections to the PoE ports are not fused. Each two pair port is capable of furnishing at least 30 W and each four pair port can furnish 60 W.

The minimum PSE port voltage is 44 VDC for type 1 and 50 V for type 2. The nominal dc voltage at VPWR is 48 VDC for a type 1 and 54 VDC for a type 2. During evaluation, choose the appropriate dc power supply for the type 1 or type 2 environment.

2.1.2 Local 3.3 V (Labeled 3.3 V)

Local 3.3 V for local devices (labeled as 3.3 V) is provided by the onboard LM5019 buck converter. The LM5019 provides a basic power-on sequence and provides a well-controlled and consistent startup. In addition to 48 V, the TPS2388 requires 3.3 V for the digital circuitry and this is routed up to TPS2388EVM-016 over the connector interface.

2.1.3 External 3.3 V (Labeled 3.3 V_USB)

The TPS2388EVM-612 provides galvanic isolation between PoE power side and host side using digital isolators (ISO7241CD). The host side power is provided either from J2 (from USB2ANY) or J5 (from LaunchPad). The current consumption is 6-mA typical, and 12-mA maximum.

CAUTION

Do not use USB2ANY and LaunchPad simultaneously.

Table 1. TPS2388EVM-612 Voltage Rail Current Requirements

Voltage Rail	Typical (mA)	Maximum (mA)
3.3 V_USB	2.5	3
3.3 V	25	30
VPWR (Miscellaneous)	35	57
VPWR (8x Type 1 Output Ports)	2992	3142
VPWR (8x Type 2 Output Ports)	5160	5418
VPWR Total (8x Type 1 Ports)	3027	3202
VPWR Total (8x Type 2 Ports)	5195	5478

2.2 PoE Port Interfaces

Configure the TPS2388 device with the host in order to get operational. Control the TPS2388 device through the GUI or an external MCU. The host must configure the TPS2388 and send power on command after a valid PD is connected to the port.

2.2.1 Standard 30 W, IEEE802.3 at Type 2 Ports

Four standard ports are provided at J19, J20, J8, and J7 for two-pair ports 1, 2, 3, and 4, respectively. The power furnished is according to alternative A with MDI-X polarity.

2.2.2 Nonstandard 60-W Ports

Two non-standard, four-pair ports (J21 and J9) are provided. J21 is four pair port 1 and J9 is four pair port 2. The power furnished is according to alternative A with MDI-X polarity and alternative B on a single port connector. A PD which can process power on all of the Ethernet conductors (refer to *Dual TPS2378 PD for 51-W High-Power Four-Pair PoE*) can power on and consume up to 60 W. A single PD can be powered as well with proper operations (the Semi-Auto Mode reference code has the capability to power on both single PD and dual PD). The Virtual Auto Mode reference code disables these high power ports completely, since it is intended for use on IEEE802.3at compliant (2-pair) ports only.

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2.3 I²C Interfaces

The EVM provides two I²C interfaces to the TPS2388.

2.3.1 USB2ANY

J2 provides an interface with the USB2ANY adapter when using a PC and GUI.

2.3.2 MSP-EXP430G2

J3, J4, and J5 provide an interface with the MSP-EXP430G2 or LaunchPad when using a PC to develop custom power management code.

2.4 Basic Test Setup Using USB2ANY for I²C Interface (Semi-Auto Mode Operation With I²C Monitoring)

An I²C interface is provided through J2 to the TPS2388 devices on the TPS2388EVM-016. The USB2ANY adapter (not included) can be used with any TI GUI which uses USB2ANY to read and write over an I²C bus.

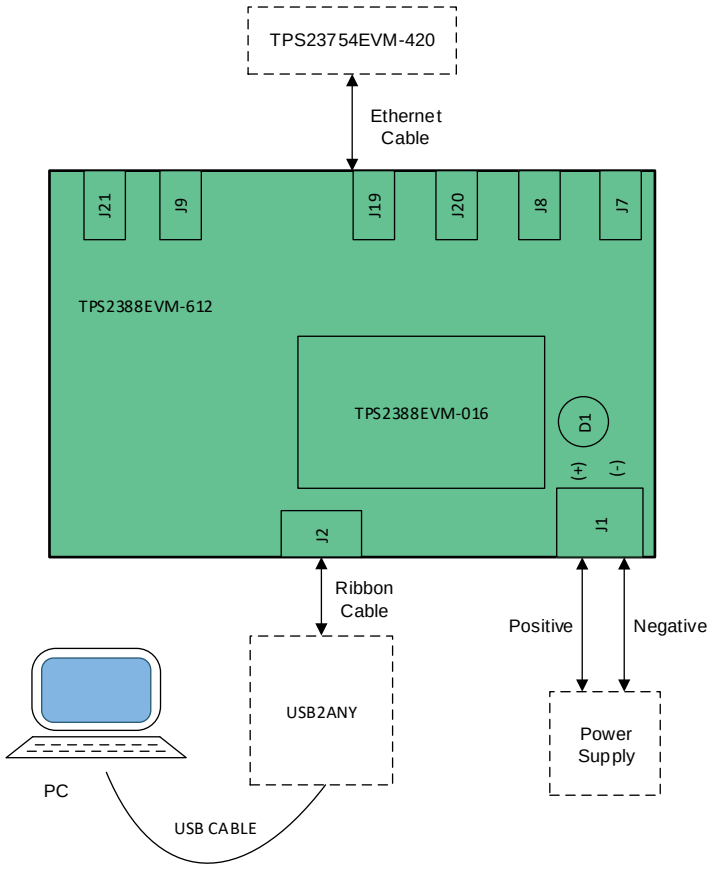


Figure 1. Basic Setup Using USB2ANY

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2.5 Advanced Test Setup Using MSP-EX430G2 (LaunchPad™)

The LaunchPad (not included) running a custom software program can communicate with the TPS2388 device on the TPS2388EVM-016 . Figure 2 shows the advanced setup using LaunchPad.

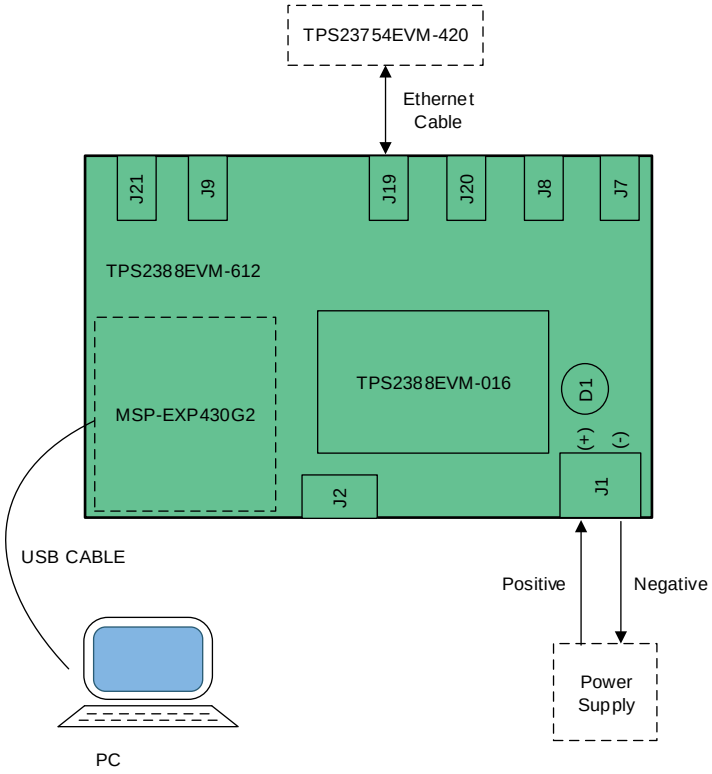


Figure 2. Advanced Setup Using LaunchPad™

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3 General Use Features

3.1 EVM Input/Output Connectors and Switches

Table 2 lists the EVM input and output connectors.

Table 2. EVM Input/Output Connectors

Connector or Switch	Label	Description
J1	J1	DC power supply screw jack. (44–57 VDC, 5 A). Use a 48 VDC (nominal) for type 1 and 54 VDC (nominal) for type 2 PSE operation.
J2	J2	Ribbon cable connection to USB2ANY adapter
J3	J3	LaunchPad control (mates with LaunchPad J1)
J4	J4	LaunchPad I^2C (mates with LaunchPad J2)
J5	J5	LaunchPad power (mates with LaunchPad J6)
J6	J6	TPS2388EVM-016 control (mates with TPS2388EVM-016 J3)
J17	J17	TPS2388EVM-016 port 5-8 (mates with TPS2388EVM-016 J2)
J18	J18	TPS2388EVM-016 port 1-4 (mates with TPS2388EVM-016 J1)
J22	J22	Two-pair port 1 data only
J19	2 Pair Port 1	Two-pair port 1 power and data
J23	J23	Two-pair port 2 data only
J20	2 Pair Port 2	Two-pair port 2 power and data
J11	J11	Two-pair port 3 data only
J8	2 Pair Port 3	Two-pair port 3 power and data
J10	J10	Two-pair port 4 data only
J7	2 Pair Port 4	Two-pair port 4 power and data
J24	J24	Four-pair port 1 data only
J21	4 Pair Port 1	Four-pair port 1 power and data
J12	J12	Four-pair port 2 data only
J9	4 Pair Port 2	Four-pair port 2 power and data
J29	J29	Chassis ground tie point

3.2 EVM LEDs

Table 3 lists the EVM LEDs and their descriptions.

Table 3. EVM LEDs

LED	Color	Label	Description
D1	GREEN	48V	48-V ON indicator
D16	BLUE	D16	Two-pair port 1 power is ON. For J19 supplier #1 (see the bill of materials (BOM)), J19 internal port LED is active. For supplier #2, D16 is active.
D17	BLUE	D17	Two-pair port 2 power is ON. For J20 supplier #1 (see the BOM), J20 internal port LED is active. For supplier #2, D17 is active.
D13	BLUE	D13	Two-pair port 3 power is ON. For J8 supplier #1 (see the BOM), J8 internal port LED is active. For supplier #2, D13 is active.
D12	BLUE	D12	Two-pair port 4 power is ON. For J7 supplier #1 (see the BOM), J7 internal port LED is active. For supplier #2, D12 is active.
D18	BLUE	D18	Four-pair port 1A power is ON. For J21 supplier #1 (see the BOM), J21 internal port LED is active. For supplier #2, D18 is active.
D14	BLUE	D14	Four-pair port 2A power is ON. For J9 supplier #1 (see the BOM), J9 internal port LED is active. For supplier #2, D14 is active.

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3.3 EVM Test Points

Table 4 lists and describes the EVM test points.

Table 4. EVM Test Points

TP	Color	Label	Description
Motherboard: TPS2388EVM-612			
TP1	RED	VPWR	Used for VPWR
TP2	RED	3.3 V	Used for TPS2388 VDD
TP3	SMT	GND	VPWR ground
TP4	WHT	SDA	I^2C Data from LaunchPad and USB-TO-GPIO
TP5	WHT	SCL	I^2C Clock from LaunchPad and USB-TO-GPIO
TP6	WHT	PSE_SDAO	I^2C data out from TPS2388
TP7	WHT	PSE_SCL	I^2C clock to TPS2388
TP8	WHT	PSE_SDAI	I^2C data in to TPS2388
TP9	BLK	GND1	Ground from LaunchPad and USB-TO-GPIO
TP11	SMT	TP11	Chassis ground test point
TP14	SMT	GND	VPWR ground test point
TP15	SMT	GND	VPWR ground test point
TP16	SMT	GND	VPWR ground test point
Daughterboard: TPS2388EVM-016			
TP2	RED	2P4D	Two-pair port 4 DRAIN
TP3	WHT	2P4G	Two-pair port 4 GATE
TP4	WHT	4P1AG	Four-pair port 1A GATE
TP5	RED	4P1AD	Four-pair port 1A DRAIN
TP6	RED	4P1BD	Four-pair port 1B DRAIN
TP7	WHT	4P1BG	Four-pair port 1B GATE
TP1	BLK	GND	VPWR ground
TP8	SMT	GND	VPWR ground

3.4 EVM Test Jumpers

The EVM is equipped with shunts on the jumper positions identified in Table 5, in the *Default Pin Position* column. Shunts can be moved and removed, as required, during use.

Table 5. EVM Jumpers(1)

Jumper	Default Pin Position	Label	Description
Motherboard: TPS2388EVM-612			
J27	1-2	P1	Two-pair port 1 LED bias
J28	1-2	P2	Two-pair port 2 LED bias
J16	1-2	P3	Two-pair port 3 LED bias
J15	1-2	P4	Two-pair port 4 LED bias
J26	1-2	P5	Four-pair port 1A LED bias
J25	1-2	P6	Four-pair port 1B LED bias
J14	1-2	P7	Four-pair port 2A LED bias
J13	1-2	P8	Four-pair port 2B LED bias
Daughterboard: TPS2388EVM-016			
J4	1-2;3-4;5-6;7-8	NA	I2C A1-A4 address lines

(1) Remove the jumpers on the mother board when doing SIFOS or UNH DC MPS testing.

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4 TPS2388EVM-612 Host Setup

4.1 TPS2388EVM-612 GUI Setup

4.1.1 TPS2388EVM-612 GUI Installation

TI's TPS2388EVM GUI is used with the TPS2388EVM-612 to provide real-time feedback on port telemetry. Download the TPS2388EVM GUI from the *TPS2388 product folder* page in the *Tools & software* section.

Follow the onscreen instructions to complete the installation. The TPS2388 GUI uses the USB2ANY as an interface between the PC USB port and the TPS2388EVM-612 J2 connector (I^2C interface). Before starting the TPS2388 GUI, make sure the USB2ANY is properly connected to TPS2388EVM-612 and the EVM is supplied with a 44-V to 57-V power supply as Figure 1 shows.

4.1.2 TPS2388EVM-612 GUI Operation

Start the TPS2388EVM GUI by double clicking the GUI icon. A window like Figure 3 comes up.

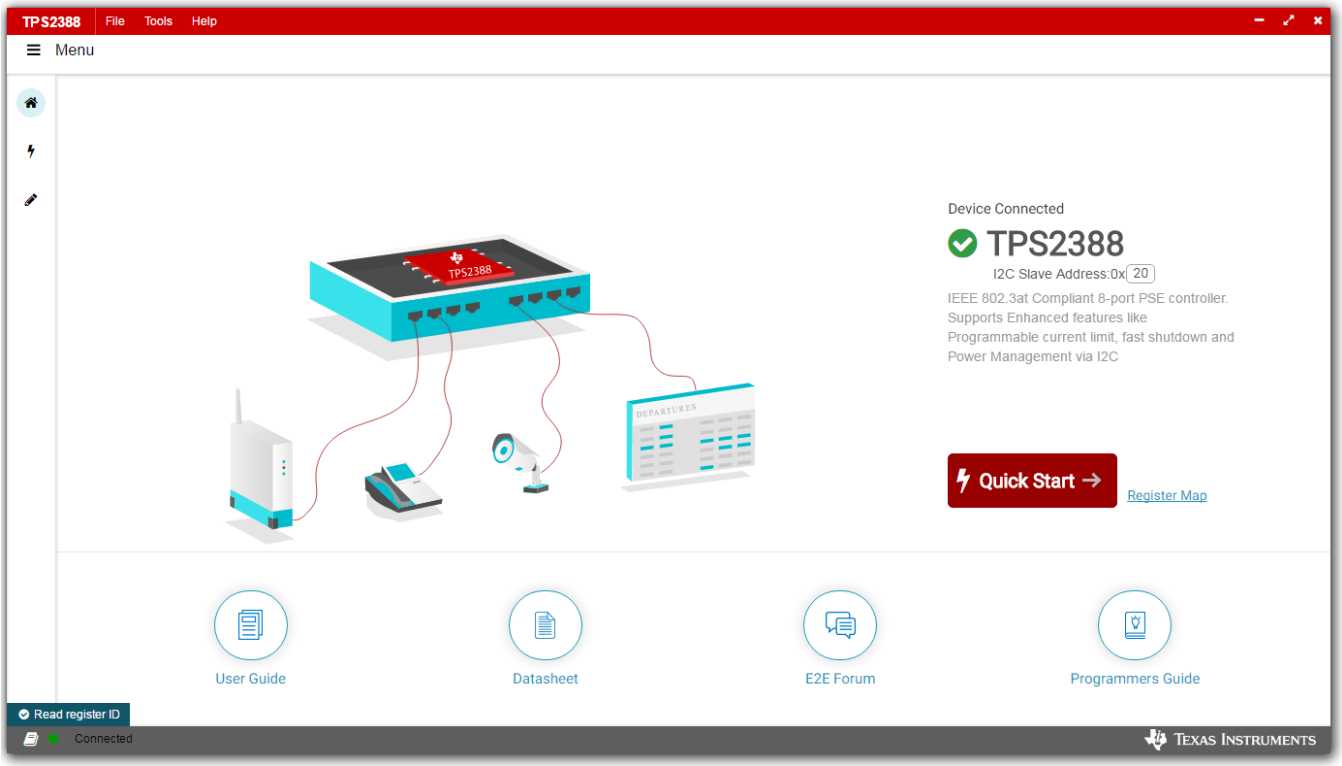


Figure 3. TPS2388EVM GUI Startup Window

The default device address in the GUI is set to 0x20 which matches the default configuration of the EVM (J4 on the daughter card is installed with jumpers). The GUI sets the TPS2388 in configuration B mode (see the *GENERAL MASK Register* section of *TPS2388 IEEE 802.3at 8-Port Power-over-Ethernet PSE* for details). The address can be programed through the A1 to A4 pins and the I^2C address setting in the GUI needs to match the hardware configuration. See the *Pin Status Register* section of the data sheet for details.

The startup page contains links to the EVM user's guide, TPS2388 data sheet, E2E forum, and MSP430 reference code. Four popular PD end-equipment images are connected to the PSE switch. Links to the recommended PD device for each end equipment are also provided.

Once *Device Connected* displays, click *Quick Start*.

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On the page displayed in Figure 4, each port can be configured separately by clicking each RJ45 connector. Holding shift and selecting multiple ports can also apply the same settings to all ports. By default, the TPS2388 is configured in *Semi-Auto Mode*. In the GUI, *Virtual Auto Mode* is another option, if the ports are configured as 30 W, or lower. In *Virtual Auto Mode*, the GUI turns on ports after a valid PD is detected and classified.

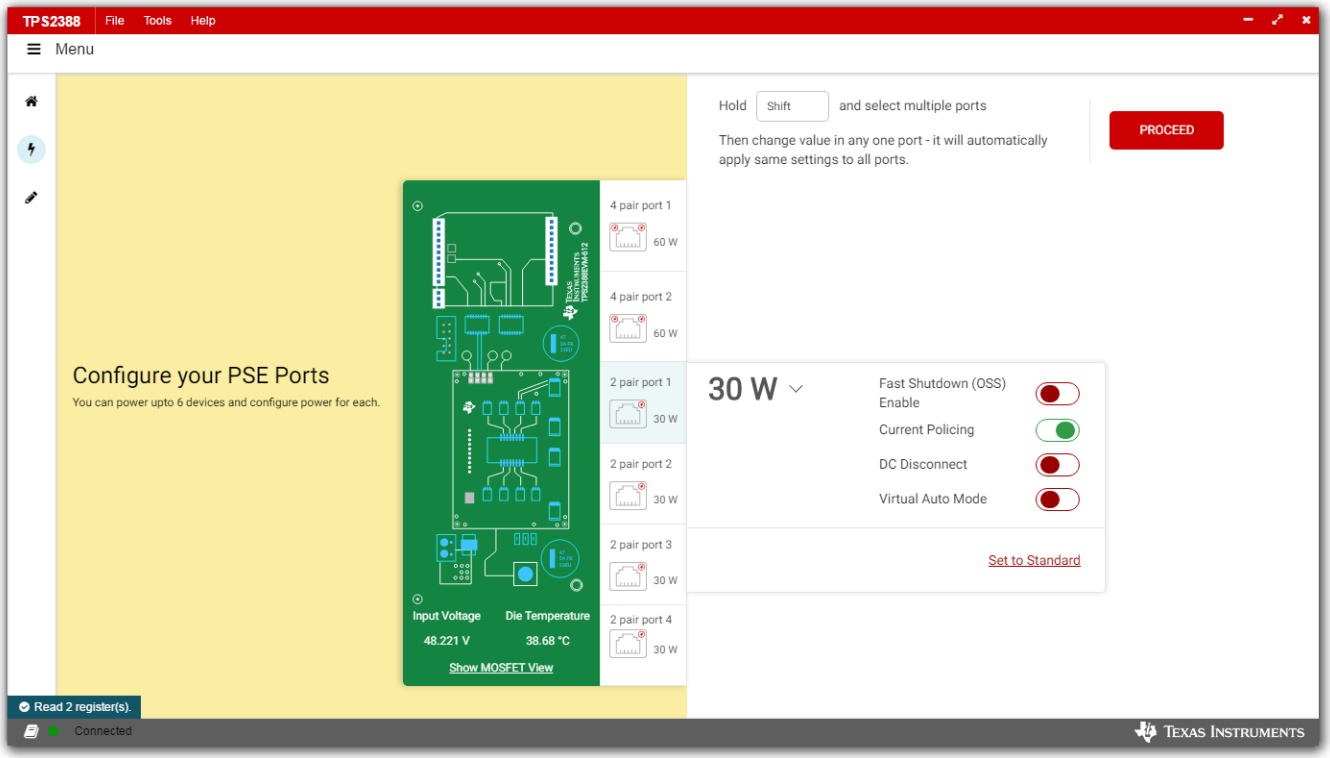


Figure 4. TPS2388EVM GUI Quick Start Window

Upon finishing configuration, press the *PROCEED* button.

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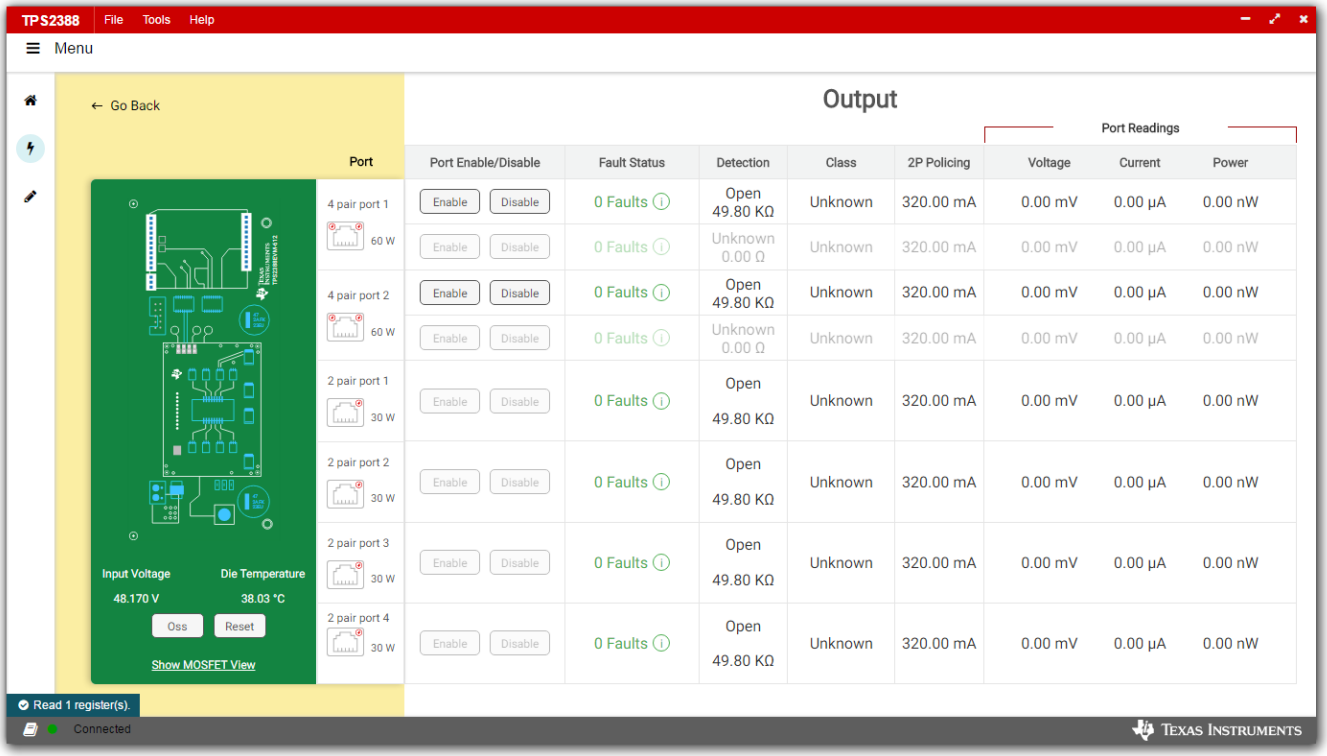


Figure 5. Device Configuration and Telemetry Page

The status of each port is shown on the configuration and telemetry page. The configuration of the ports can also be edited on this page by clicking the RJ45 connector as shown in Figure 6.

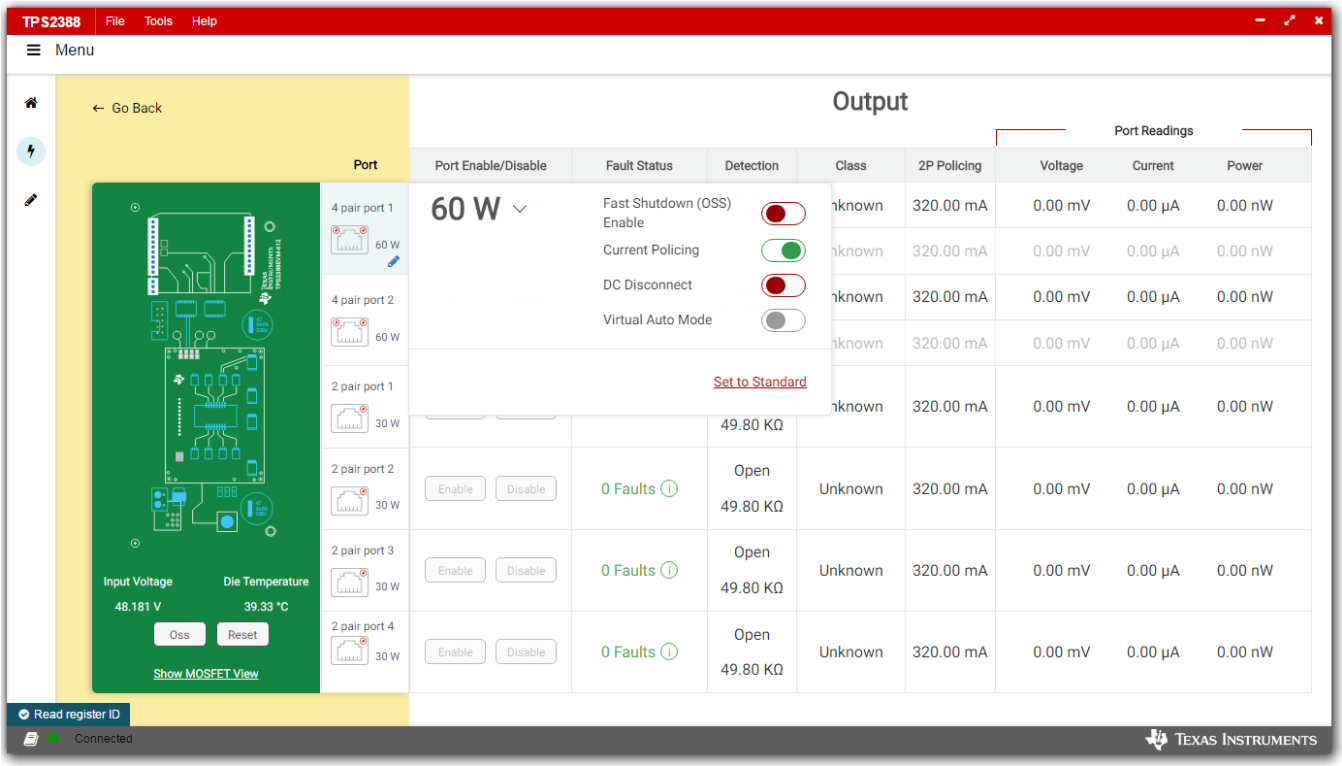


Figure 6. Device Configuration and Telemetry Page With Edit

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If the port is configured in *Virtual Auto Mode*, the port is turned on automatically by the GUI after connecting a valid PD. If not configured in *Virtual Auto Mode*, a port enable command is required. The port can be turned on only when the PD has valid detection and classification results.

The GUI also provides access to every register of the device in register map.

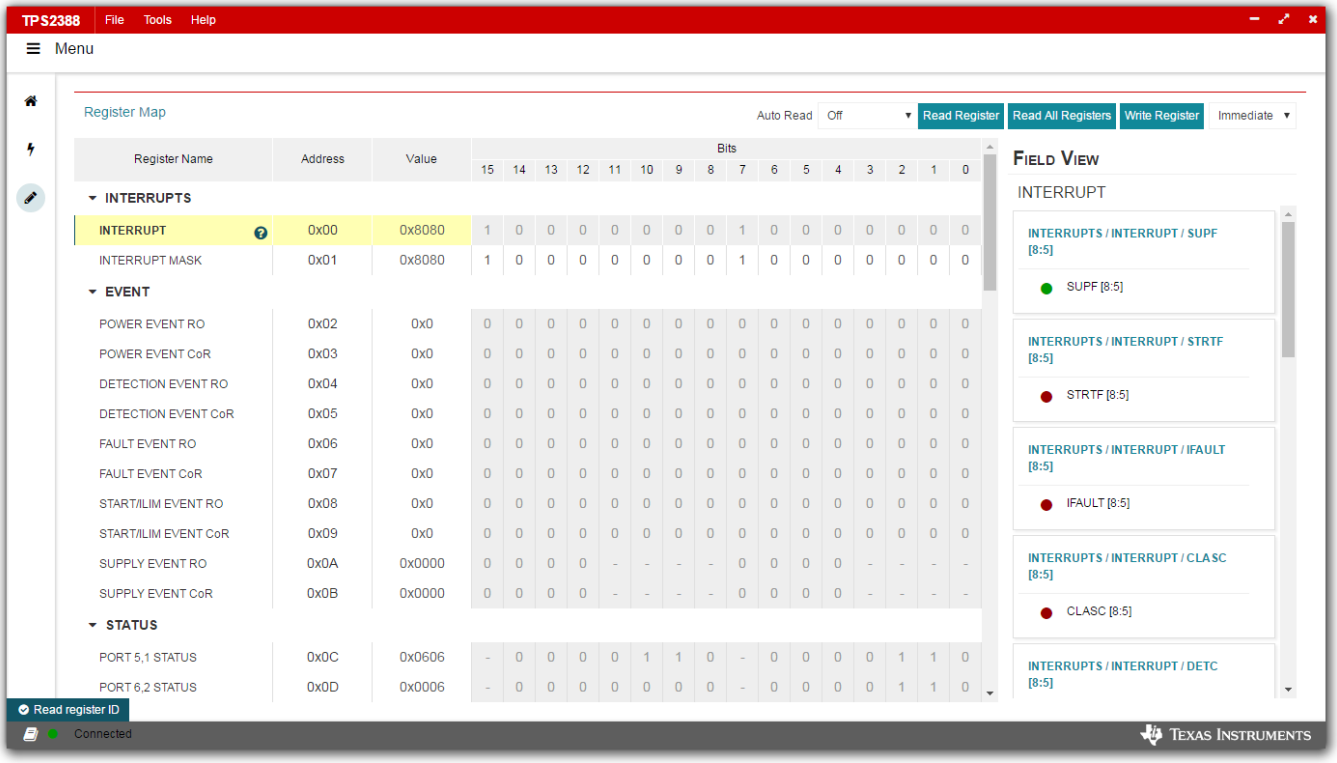


Figure 7. Register Map

4.2 MSP-EXP430G2 Setup

The TPS2388EVM-612 accepts the MSP-EXP430G2 evaluation module when the application requires management of the TPS2388 devices with an external controller. Before inserting the MSP-EXP430G2 into the TPS2388EVM-612, make the following jumper changes and ensure that the target MSP430 (MSP430G2553) device is installed:

1. Remove the shunt on J5 in the P1.6 slot
2. Remove the shunts on J3 in the RXD and TXD slot. Re-install these in the vertical position as described in MSP-EXP430G2 LaunchPad Development Kit
3. Install MSP-EXP430G2 onto TPS2388EVM-612 and ensure that the USB2ANY ribbon cable is **not** installed into J2
4. Connect the PC to the LaunchPad as shown in Figure 2
5. The source code was developed for the MSP430 LaunchPad Development Kit (MSP-EXP430G2 http://www.ti.com/tool/msp-exp430g2) using the Code Composer Studio™ (CCS) version 7.1.0 (http://www.ti.com/tool/ccstudio-msp430) development environment. The target MSP430 can be programmed within this environment. The reference code can be downloaded from the TPS2388 product folder on TI.com.
6. Once CCS is installed, use the basic set of instructions listed in Section 4.2.1 to import, build, and run the project. CCS version 7.1.0 is used in the following examples. Note that a terminal program such as HyperTerminal or Teraterm is required to view the output from the EVM when it is running.

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4.2.1 Basic CCS and Terminal Setup

1. Launch the CCS program on the PC: Start → Texas Instruments → Code Composer Studio 7.1.0 → Code Composer Studio 7.1.0
2. *OK* the workspace location and CCS starts
3. Import the project: File → Import Existing CCS Eclipse Project
4. Navigate to the project location, then click the **Finish** button
5. Set the active project: Project, Build Configurations, Set Active, Virtual-Auto, or Semi-Auto
6. Build the project by clicking the hammer symbol
7. Launch debug session from CCS to activate the current project: Run, Debug (or F11).
8. Run the active project: Run, Resume (or play button, F8)
9. Determine the PC COM port connected to the LaunchPad by going into the Device Manager Ports (COM and LPT) section. Launch the terminal program.
10. Once the terminal program is properly connected to the LaunchPad running the POE firmware, then text similar to Figure 8 appears (If it does not appear at first, try to close Tera Term and reopen).

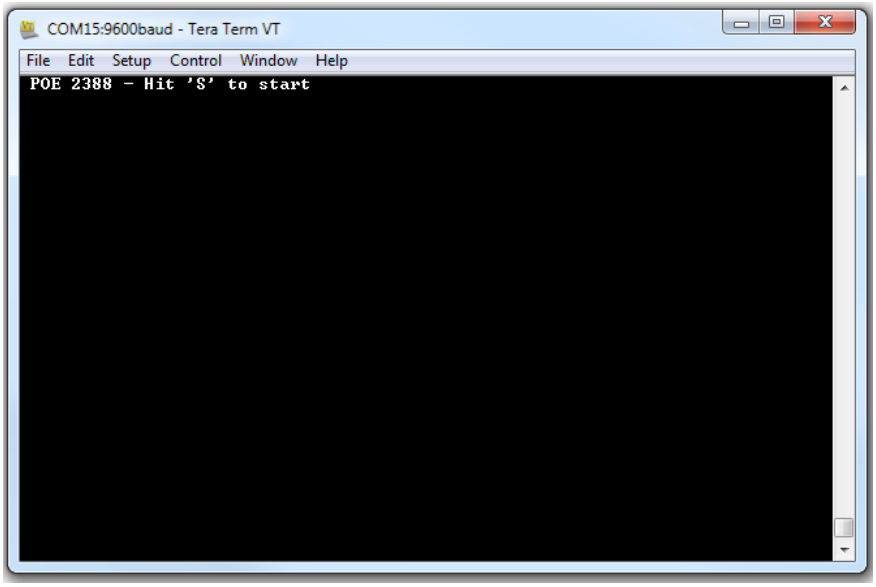


Figure 8. Hit 'S' to Start

11. Pressing the “S” key on the keyboard starts the program

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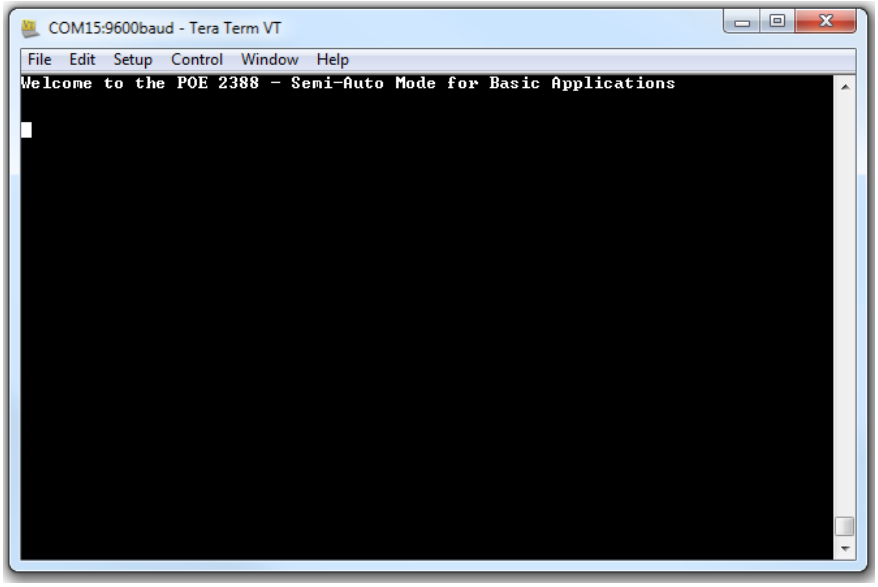


Figure 9. Program Started

12. The TPS2388EVM-612 is now waiting for a PD load to be installed. As ports are installed, the firmware automatically detects, classifies, and powers up the port as shown in Figure 10. Port status is updated on the screen approximately every 10 seconds.

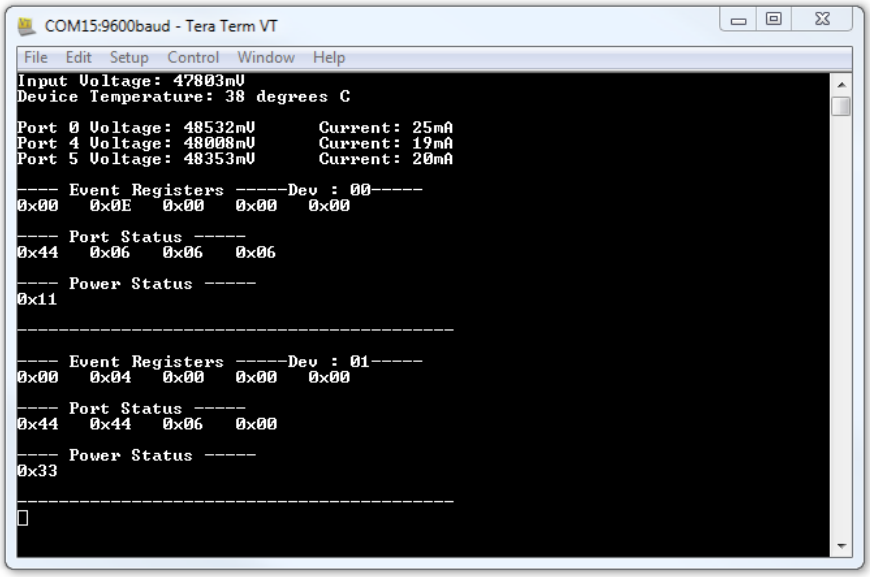


Figure 10. Terminal Response With Connected Ports

13. In similar fashion, the builds for *Virtual Auto Mode* operation can be configured and launched. The terminal welcome screen indicates which build is running on the LaunchPad.

4.3 MSP430 Reference Code

4.3.1 Overview

There is a MSP430 reference code offered under the TPS2388 product folder on TI.com for basic applications. Customers can download the code for free and develop their own system software starting from here.

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The system software supports the following features:

- Fully compliant to IEEE802.3at PoE specification
- Virtual Auto-Mode operation
- Device detection and classification
- DC disconnect
- Faults reporting

4.3.2 Semi-Auto Mode Reference code

The reference code can support PSE systems with up to 48 ports. It keeps track of all system level parameters as well as port level parameters for each TPS2388 device within the system.

The main actions are interrupts triggered. As long as the MSP430 receives an interrupt signal from TPS2388 devices, it checks the interrupt status and proceeds with related actions.

The system software also keeps track of system and devices error conditions that occur, as well as any events that affect the port states. The MSP430 communicates with the PC through UART, reporting parameters and status of the port.

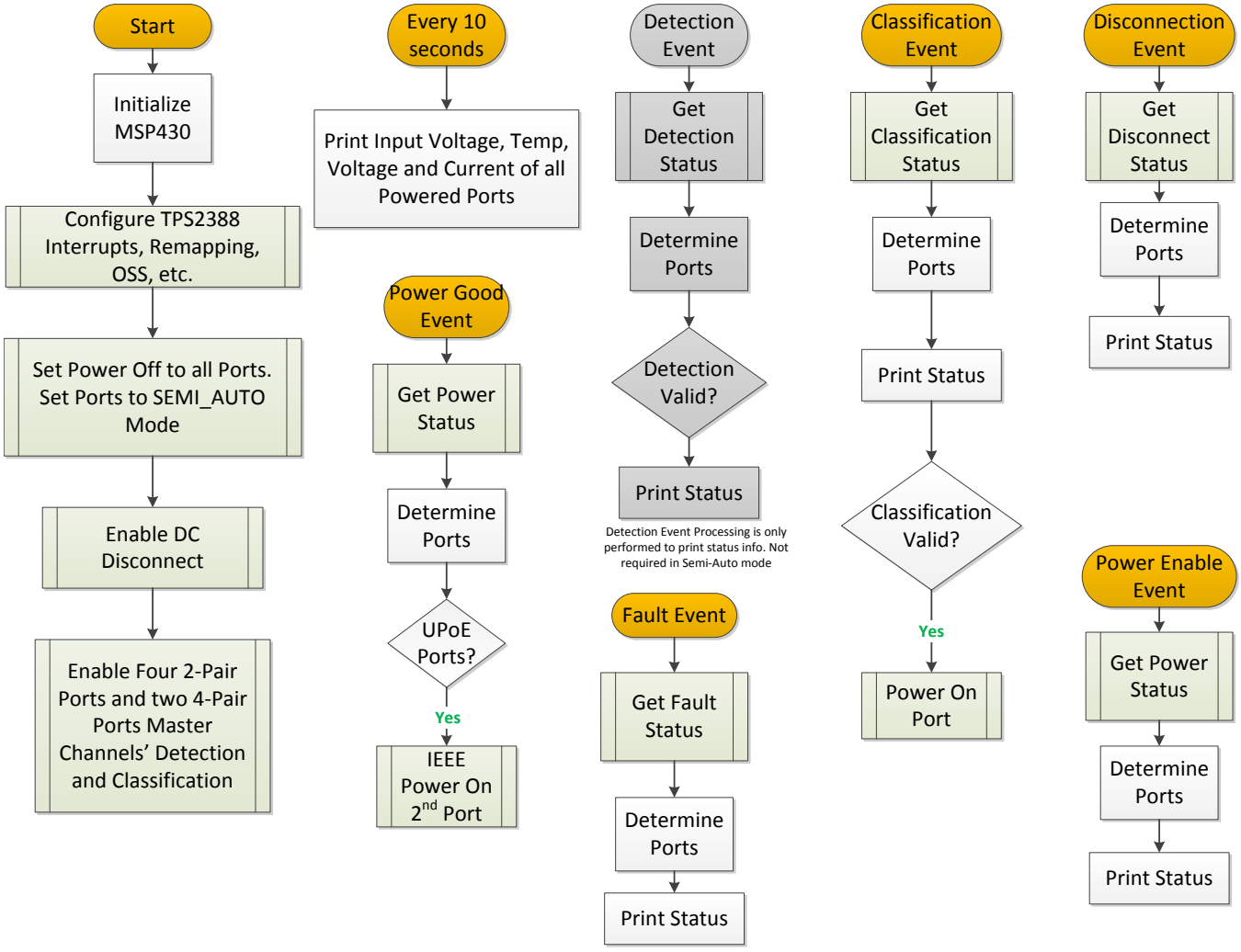


Figure 11. Semi-Auto Mode Reference Code Structure

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4.3.3 Virtual Auto Mode Reference Code

Since the TPS2388 does not have *Auto Mode*, the main purpose of *Virtual Auto Mode* reference code is to operate the TPS2388 like Auto Mode by sending simple I^2C commands. It is more beneficial to small PSE systems with lower port count, since it does not need complex system control. For example, NVR applications.

CAUTION

The *Virtual Auto Mode* reference code disables channel 5–8 completely since it is intended for use on IEEE802.3at compliant (2-pair) ports only. So nothing will be powered on when you connect to the 4 pair ports.

To enable the channel 5-8 for an 8 IEEE832.3at port system working in Virtual Auto Mode, you can go to main_virtual_auto.c and add another loop with I2C address of channel 5-8.

The 800-ms delay is intended to provide sufficient time to allow the previous turn on commands to complete before sending another (800 ms per virtual “quad”). If there are three TPS2388 devices in the system, the delay would be 400 ms / 3 = 133 ms.

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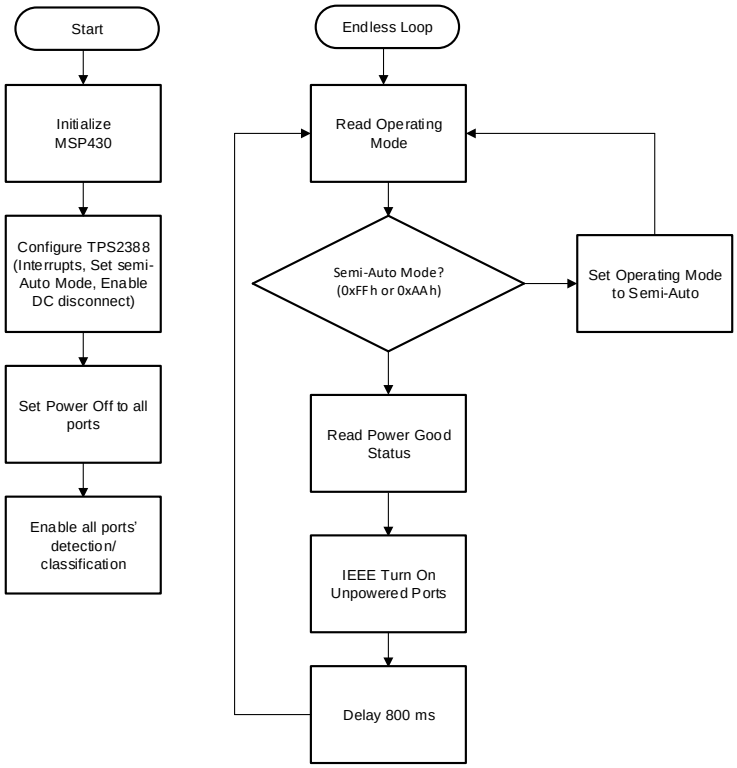


Figure 12. Virtual Auto Mode Reference Code Structure

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4.3.4 Multi-Port Power Management Module

Multi-Port Power Management methods are used to manage the distribution and prioritization of PDs. Power Management itself is not defined by the IEEE specification. Instead, it is a policy that takes advantage of the POE specification as it defines such terms as port and system power. The goals of *Multi-Port Power Management* in a POE enabled system are two-fold:

- Power as many PDs as possible
- Limit power cycling of PDs

In many systems, the maximum system power available limits the total number of ports that may be powered. For example, each PD can draw a maximum of 30 W, and a 48-port system can draw more than 1440 W total system power. If the maximum system power available is less than 1440 W, then Power Management becomes necessary so that the available system power may be used in the most efficient manner while meeting the goals. In this reference code, Multi-Port Power Management Module is implemented in Semi-Auto Mode reference code (main_semi-auto.c).

4.3.4.1 Definitions and Formulas

Table 6 defines terms used in the Power Management algorithm.

Table 6. Terminology

Term	Definition
sysPower	The current total power consumed by PDs
portPowerEstimate	The estimated power the current port (finished detection and classification) is going to consume
lowestPrioPort	The lowest priority port among all turned on ports
powerOffPort	Port is powered off
powerOnPort	Port is turned on

4.3.4.2 State Definitions

The Power Management algorithm operates as a state machine, whereby the algorithm is a certain state at any given point in time. Table 7 shows the state definitions for the algorithm.

Table 7. State Definitions

State	Definition
PM_CHECK	Calculate the total power of the existing ON ports, get current port estimate power, compare total power + port estimate power and Power budget
PM_POWERUP	Power up current port
PM_OVERLIMIT	Power demand has exceeded the power budget. Calculate whether the remaining power is enough to turn on current port after turning off all lower priority ports.
PM_POWERDOWN	Power down the lowest priority port. Entered from PM_OVERLIMIT.

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4.3.4.3 Function Definitions

The power management function is called after a valid classification is performed. It includes the functions in Table 8 to implement the algorithm.

Table 8. Function Definitions

Function	Definition
uint32_t PM_calSysPower(void)	Calculate current total power consumed by PDs
uint8_t PM_getActLowestPrioPort(void)	Find lowest priority port among all ports that are turned on
uint32_t PM_getPowerofPortsHigherPriority(uint8_t PM_sysPortNumber)	Calculate total power of ports that have the same or higher priority
uint32_t PM_getRequestPower(uint8_t PM_sysPortNumber)	Get estimate power of current port (finished detection and classification) is going to consume based on classification results
void PM_powerManagement(uint8_t PM_sysPortNumber)	Power management function called in main function
void PM_monitorSysPower(void) **NOTE:** running in background, software interrupt triggered	Real-time check if current total power consumed by PDs exceeds power budget (to prevent load step change on any ports)

4.3.4.4 User Configurable Parameters

The PPM module gives the user some flexibility to configure. Table 9 shows the user-configurable parameters.

Table 9. User-Configurable Parameters

Term	Definition	Location
#define PM_EN	Enable PPM feature. Enable=1, disable=0.	power_manage.h
#define PM_POWER_BUDGET	Total system power budget. Unit: mW	power_manage.h
#define NUM_OF_TPS238x	Total number of TPS2388 in the system	system_init.h
#define PM_POWER_MONITOR_TIMER	The timer that the host uses to monitor the actual system power	system_init.h
#define PM_DETECT_CLASS_RESTART_TIMER	The timer that the host uses to restart detection and classification of the ports which are turned off	system_init.h
uint8_t i2cAddList[NUM_OF_TPS238x]	I2C address of TPS2388	system_init.c
uint8_t PM_setPriority[NUM_OF_TPS238x * PM_NUM_OF_PORT]	The port priority setting of each port	system_init.c

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4.3.4.5 Design Flow

The Power Management algorithm is shown in the flow chart in Figure 13.

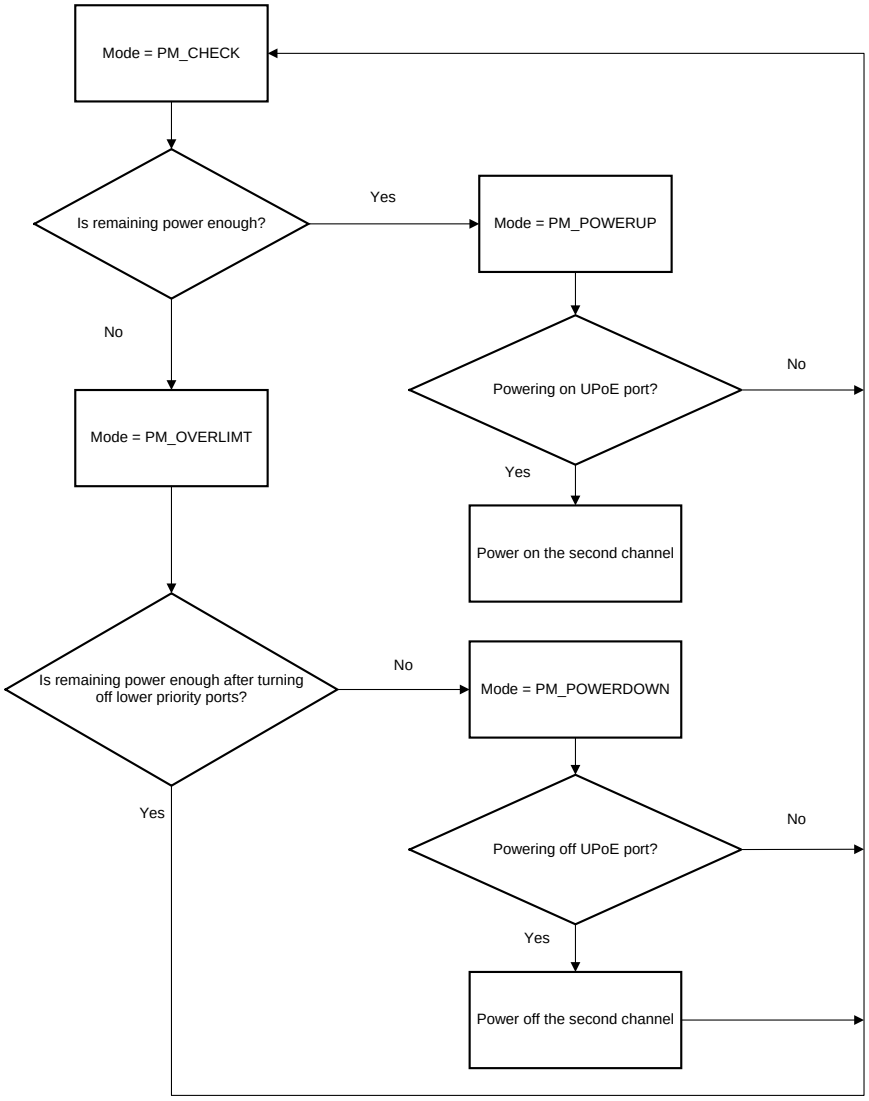


Figure 13. Power on Decision Flow Chart

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Real-time system power monitor to protect the system when step change happens on any ports (1s timer triggered):

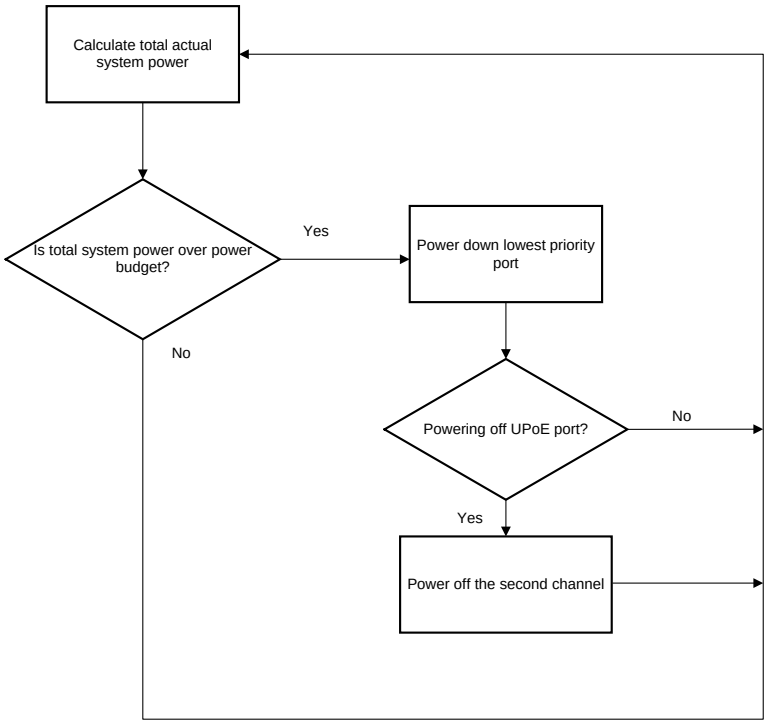


Figure 14. System Power Monitor Flow Chart

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4.3.4.6 Pseudo-Code

The *Power Management* algorithm is represented by the following pseudo-code.

```
This part will be inserted after each port's successful classification
if (Mode == Check)
{
   Get RequesPortPower;
   Calculate SystemPower;
   if (SystemPower + RequesPorttPower > PowerBudget)
    {
       Mode = OverLimit;
    }
    else
    {
       Mode = PowerUp;
    }
}

if (Mode == OverLimit)
{
   Get lowest priority port;
   if (PowerofHigherPriorityPorts + RequesPorttPower <= PowerBudget))
   {
        Mode = PowerDown;

    }
   else
   {
    Mode = Check;
   }
}

if (Mode == PowerDown)
{
     Power down the port with lowest priority;
     if(powering down the UPoE port)
     {
        Power down the second channel;
     }
     Restart port's detection/classification;

     Mode = Check;
}

if (Mode == PowerUp)
{
     Power on the port which is requesting power;
     if(powering on the UPoE port)
     {
        Power on the second channel;
     }
     Mode = Check;
}
This part will be inserted in a timer(every 1s or 2s) intrerrupt

 if (system power > PowerBudget)
 {
     Turn off the port with lowest priority;

     if(powering down the UPoE port)
     {
        Power down the second channel;
     }

     Restart port's detection/classification;
 }
```


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5 EVM Schematic, Layout Guidelines and PCB Assembly, Layer Plots

This section contains the TPS2388EVM-612 schematic, layout guidelines, and printed-circuit board (PCB) assembly and layer plots.

5.1 Schematic

Figure 15 through Figure 17 illustrate the TPS2388EVM-613 schematics.

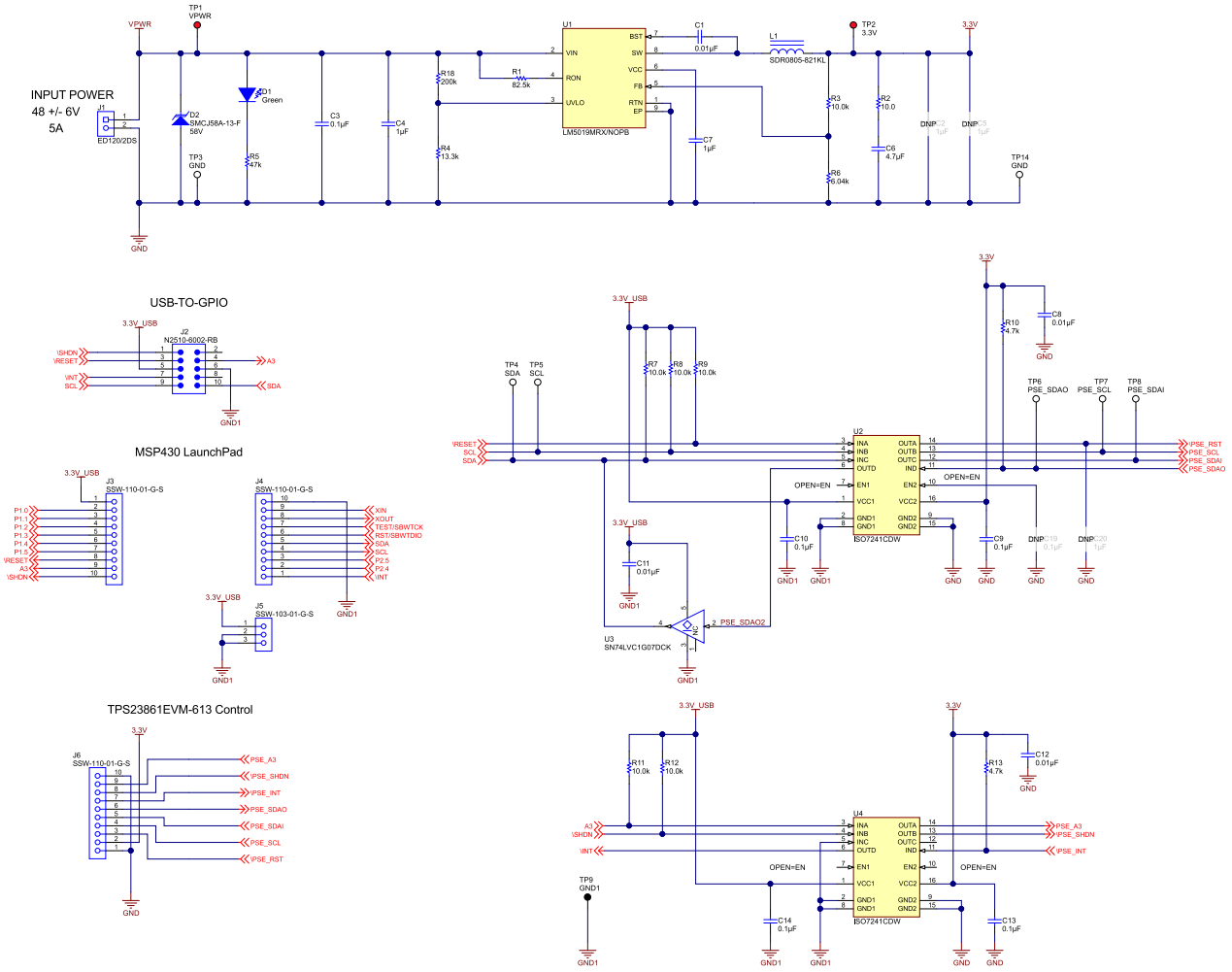


Figure 15. TPS2388EVM-612 (Motherboard) Schematic: Control

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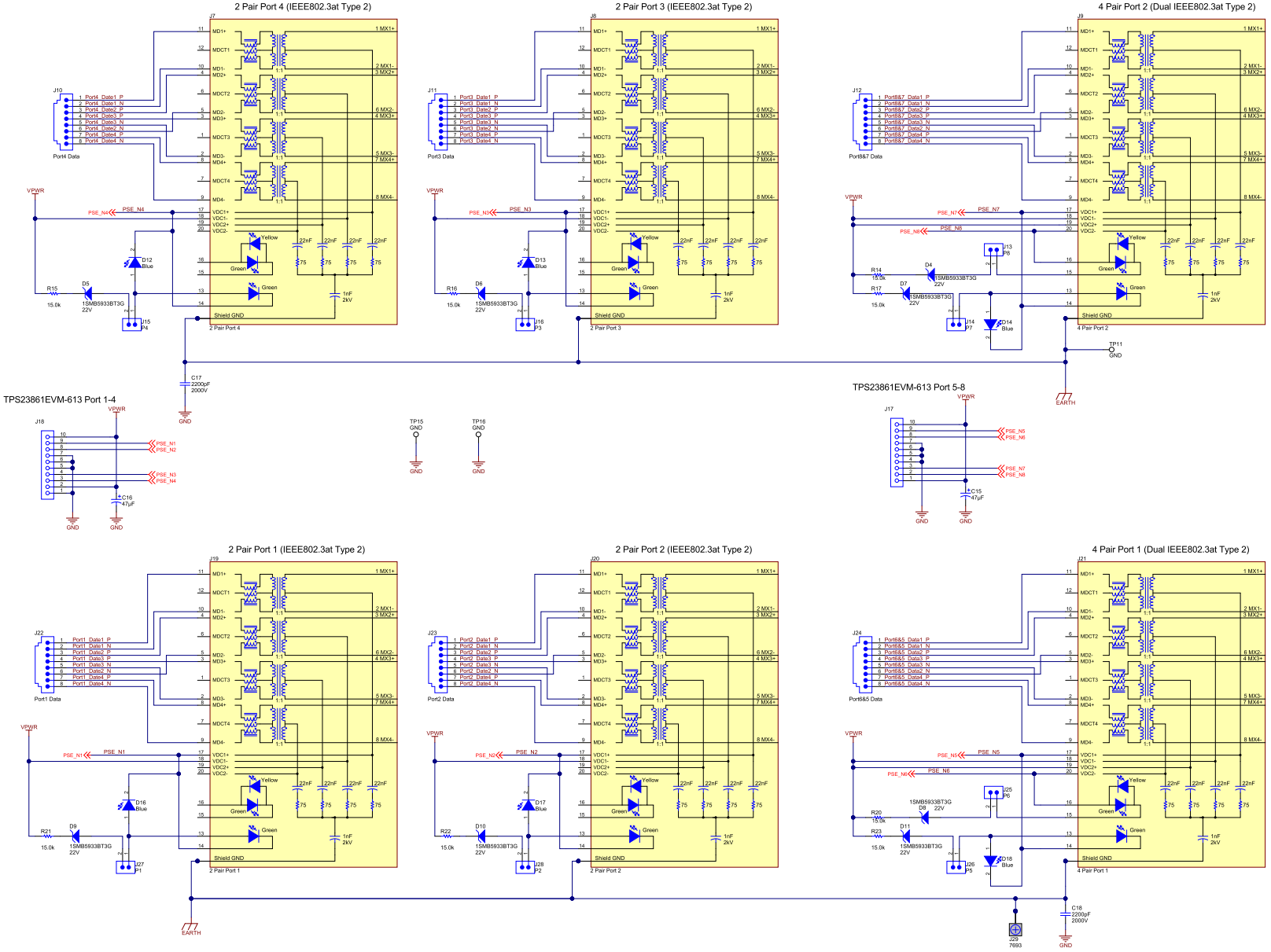


Figure 16. TPS2388EVM-612 (Motherboard) Schematic: Power Ports

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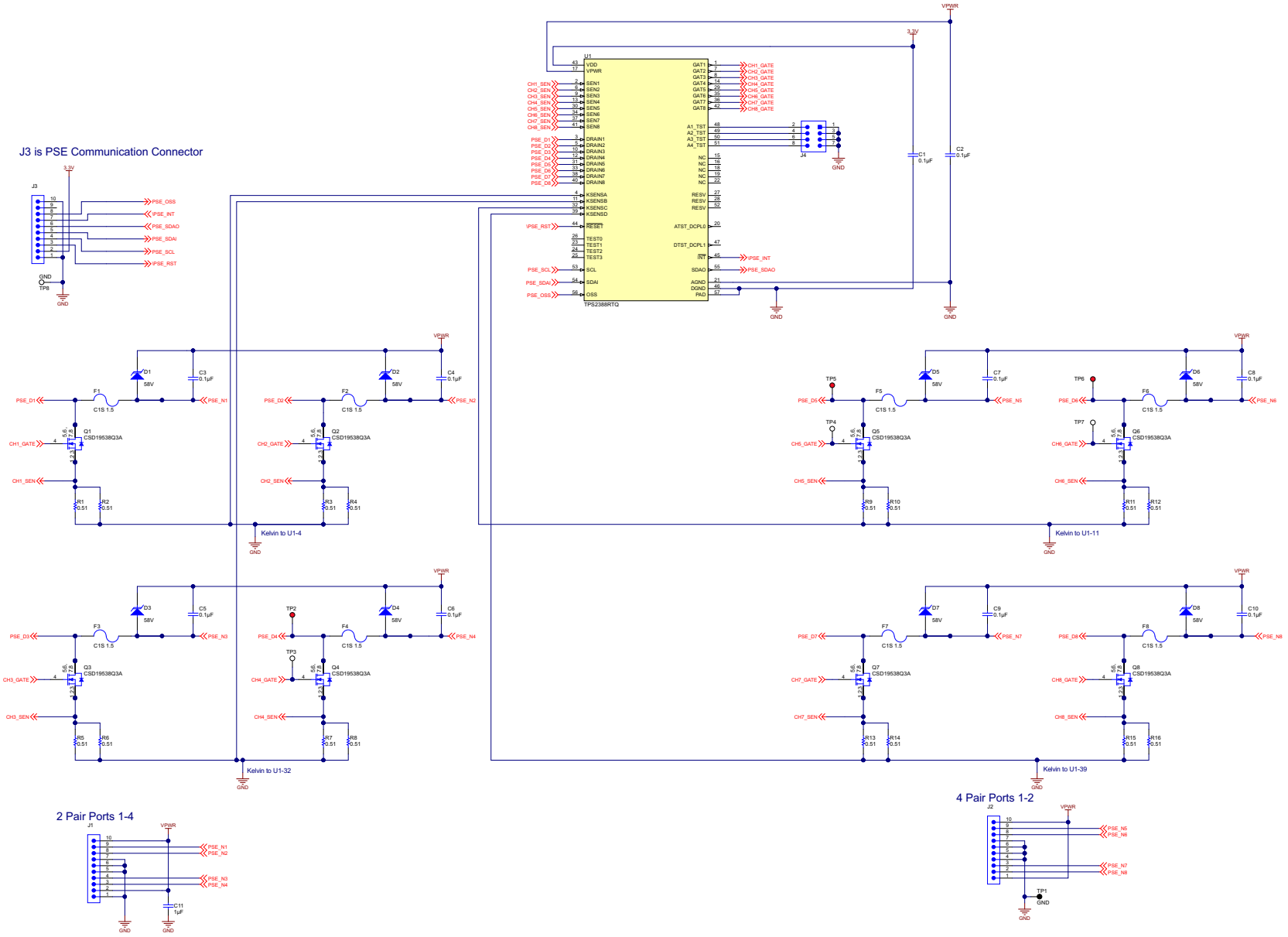


Figure 17. TPS2388EVM-016 (Daughterboard) Schematic

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5.2 Layout Guidelines

5.2.1 Supply Voltage Decoupling

Provide power supply pin bypass to the TPS2388 device as follows:

- 0.1 µF, 100 V, X7R ceramic at pin 28 (VPWR)
- 0.1 µF, 50 V, X7R ceramic at pin 1 (VDD)

5.2.2 Port Current Kelvin Sensing

KSENSA is shared between SEN1 and SEN2, while KSENSB is shared between SEN3 and SEN4. In order to optimize the accuracy of the measurement, the PCB layout must be done carefully to minimize the impact of PCB trace resistance. Refer to Figure 24 as an example.

5.2.3 Ground Plane Spacing and Isolation (GND, GND1, and EARTH nets)

Appropriate spacing should be provided between the GND, GND1, and EARTH nets as shown in Figure 20.

5.3 PCB Drawings

Figure 18 through Figure 26 show the PCB layouts and assemblies for this EVM.

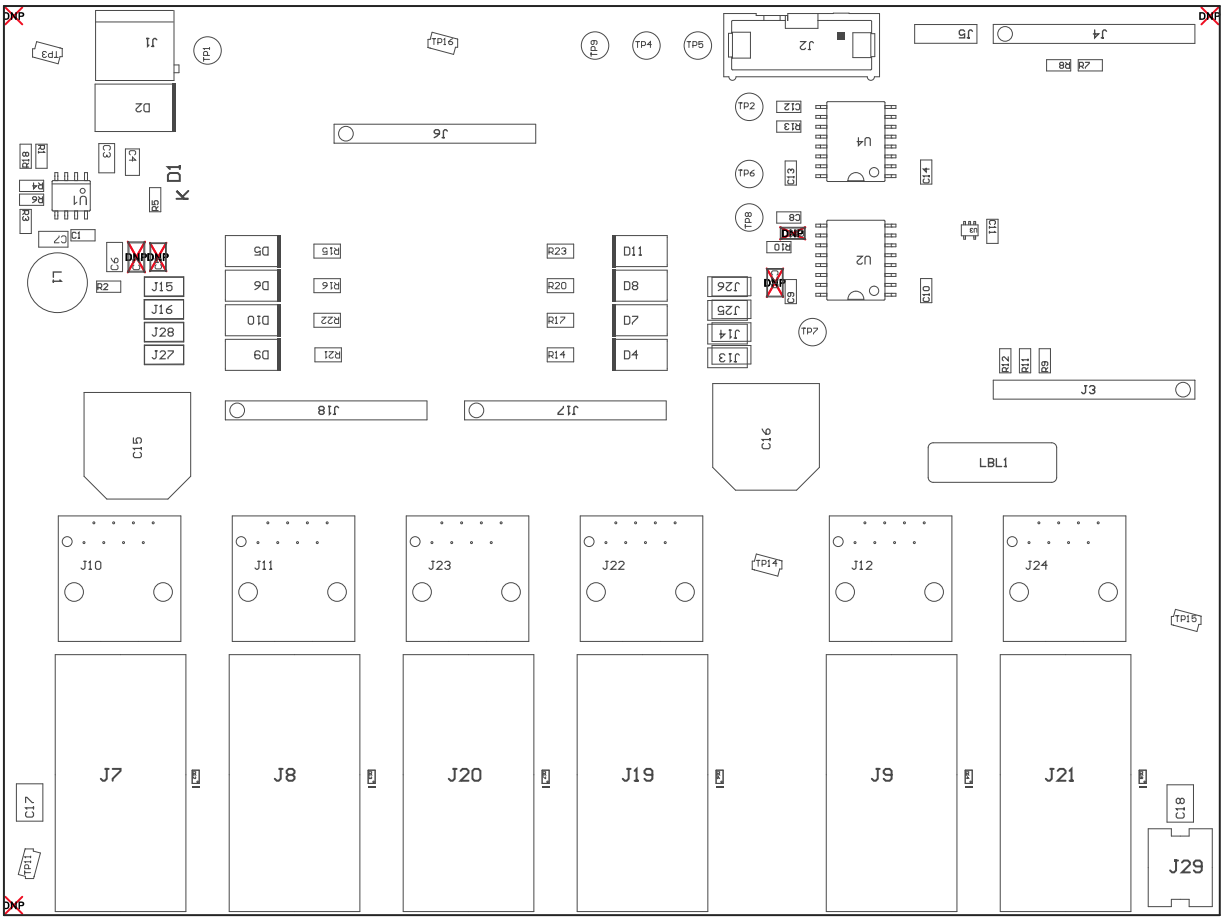


Figure 18. TPS2388EVM-612 (Motherboard) Top Side Assembly

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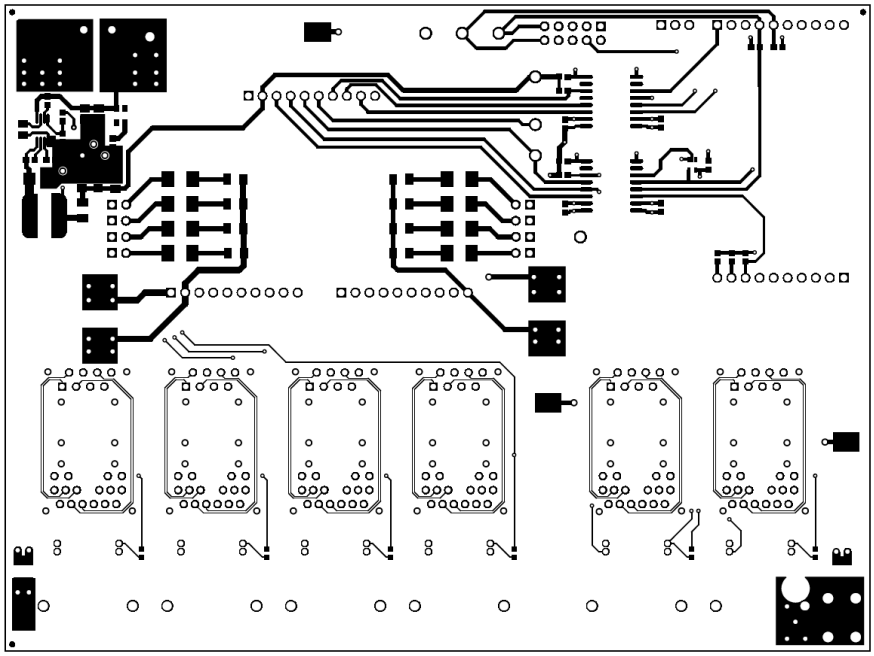


Figure 19. TPS2388EVM-612 (Motherboard) Top Side Routing

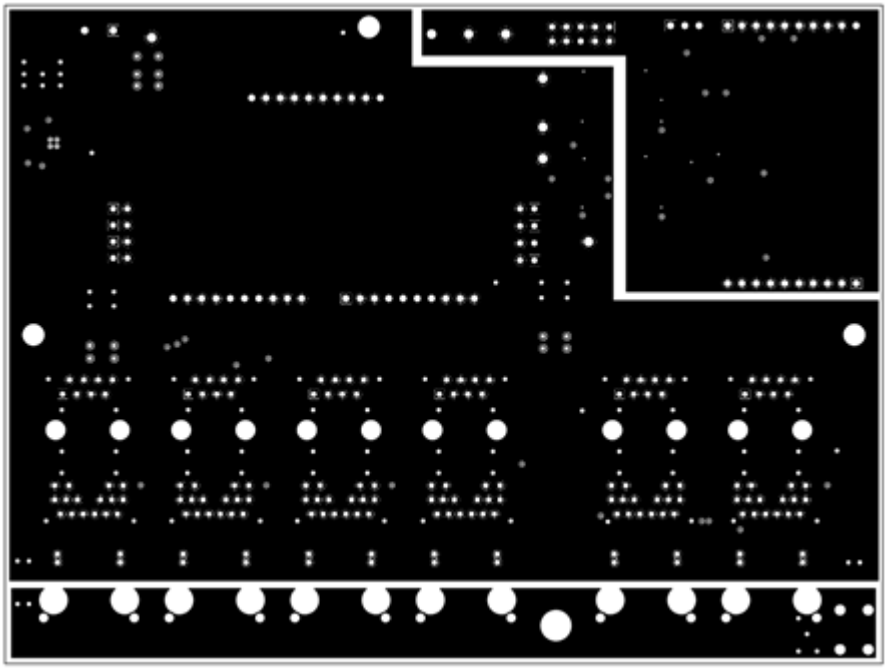


Figure 20. TPS2388EVM-612 (Motherboard) Layer 2 Routing

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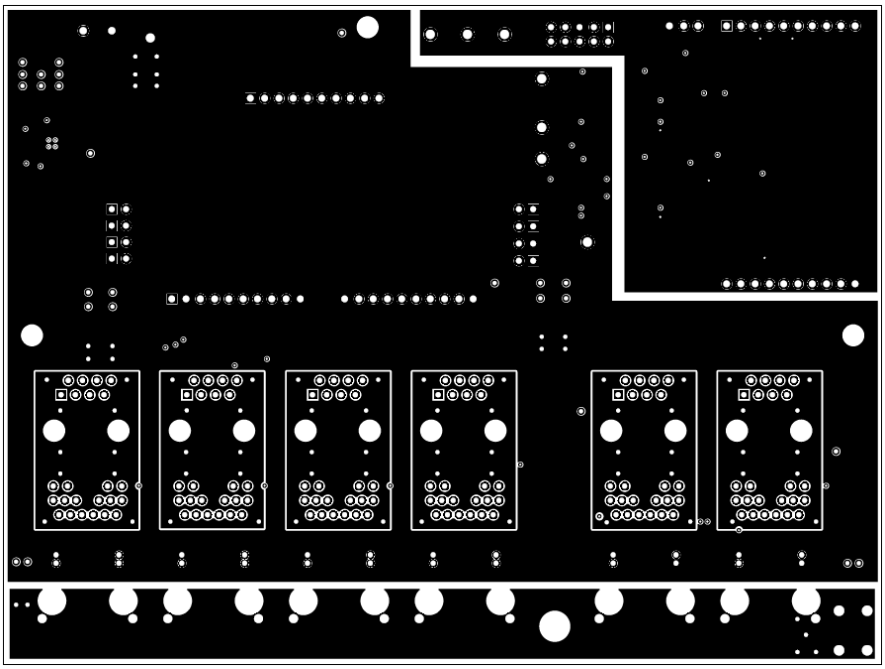


Figure 21. TPS2388EVM-612 (Motherboard) Layer 3 Routing

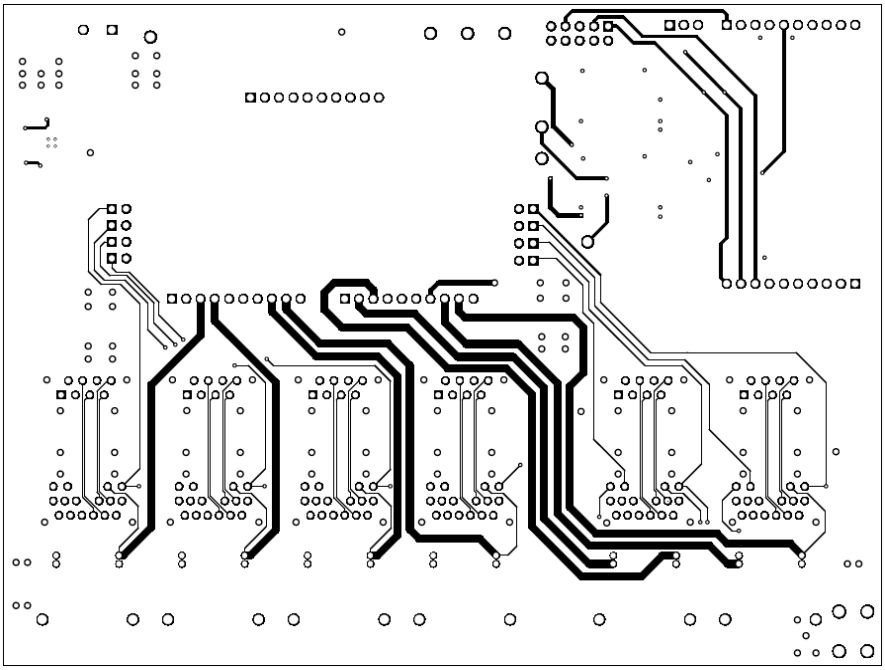


Figure 22. TPS2388EVM-612 (Motherboard) Bottom Side Routing

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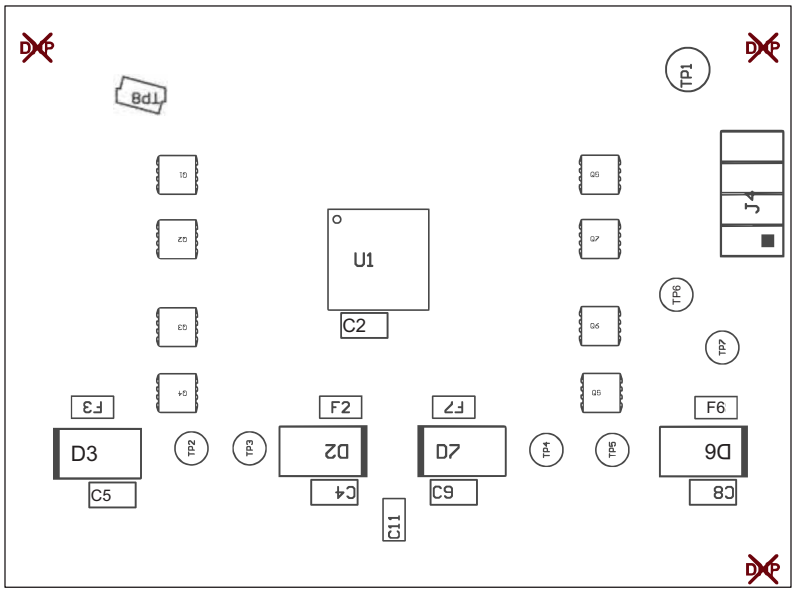


Figure 23. TPS2388EVM-016 (Daughterboard) Top Side Assembly

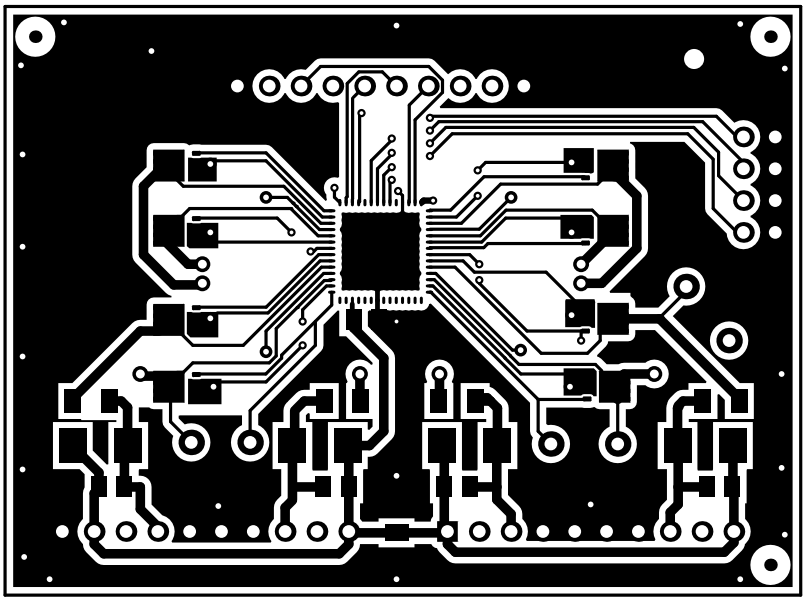


Figure 24. TPS2388EVM-016 (Daughterboard) Top Side Routing

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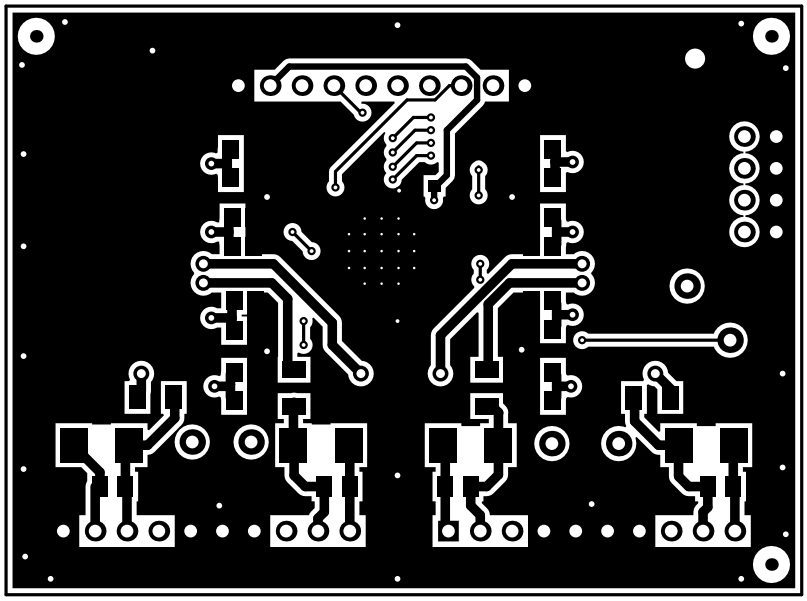


Figure 25. TPS2388EVM-016 (Daughterboard) Bottom Side Routing

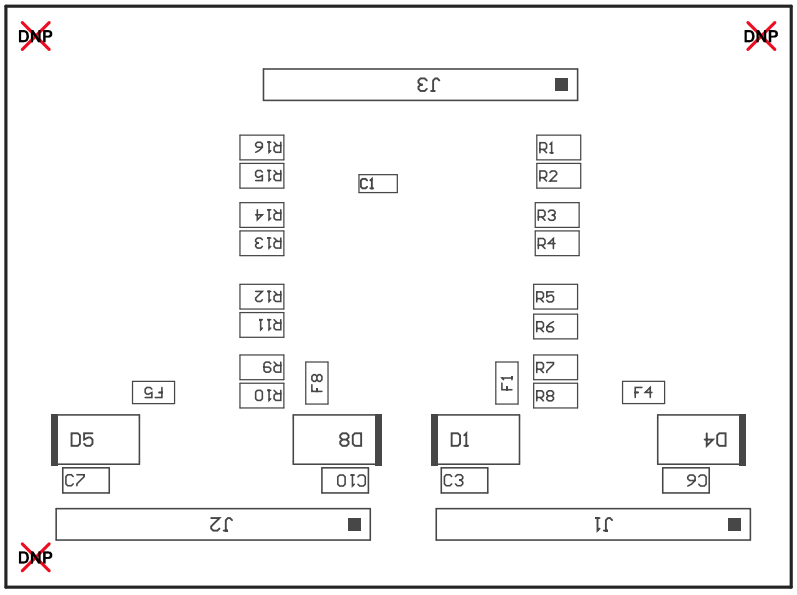


Figure 26. TPS2388EVM-016 (Daughterboard) Bottom Side Assembly

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6 Bill of Materials

The bill of materials (BOM) for the TPS2388EVM-612 and TPS2388EVM-016 are listed in Table 10 and Table 11, respectively.

Table 10. TPS2388EVM-612 Bill of Materials(1)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB	1		Printed Circuit Board		PWR612	Any		
C1, C8, C11, C12	4	0.01uF	CAP, CERM, 0.01uF, 100V, ±10%, X7R, 0603	0603	06031C103KAT2A	AVX		
C3	1	0.1uF	CAP, CERM, 0.1uF, 100V, ±10%, X7R, 0805	0805	C2012X7R2A104K	TDK		
C4	1	1uF	CAP, CERM, 1uF, 100V, ±10%, X7R, 1206	1206	GRM31CR72A105KA01L	Murata		
C6	1	4.7uF	CAP, CERM, 4.7 µF, 10 V, ±10%, X5R, 0805	0805	C0805C475K8PACTU	Kemet		
C7	1	1uF	CAP, CERM, 1uF, 10V, ±10%, X7R, 0805	0805	0805ZC105KAT2A	AVX		
C9, C10, C13, C14	4	0.1uF	CAP, CERM, 0.1uF, 50V, ±10%, X7R, 0603	0603	06035C104KAT2A	AVX		
C15, C16	2	47uF	CAP, AL, 47uF, 100V, ±20%, 0.32 ohm, SMD	SMT Radial H13	EEV-FK2A470Q	Panasonic		
C17, C18	2	2200pF	CAP, CERM, 2200pF, 2000V, ±10%, X7R, 1812	1812	C4532X7R3D222K	TDK		
D1	1	Green	LED, Green, SMD	Power TOPLED w/lens	LT E63C-CADB-35-L-Z	OSRAM		
D2	1	58V	Diode, TVS, Uni, 58V, 1500W, SMC	SMC	SMCJ58A-13-F	Diodes Inc.		
D4, D5, D6, D7, D8, D9, D10, D11	8	22V	Diode, Zener, 22V, 550mW, SMB	SMB	1SMB5933BT3G	ON Semiconductor		
D12, D13, D14, D16, D17, D18	6	Blue	LED, Blue, SMD	BLUE 0603 LED	LB Q39G-L2N2-35-1	OSRAM		
H1, H2, H3, H4, H5, H6, H7, H8, H9	9		Bumpon, Cylindrical, 0.312 X 0.200, Black	Black Bumpon	SJ61A1	3M		
H15	1		PSIL016 Daughter card. Build Files Included With Project Files	Used in PnP output and some BOM reports	PSIL016 Daughter card	Used in BOM report	PSIL016 Daughter card	-
J1	1		Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block	ED120/2DS	On-Shore Technology		
J2	1		Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	5x2 Shrouded header	N2510-6002-RB	3M		
J3, J4, J6, J17, J18	5		Connector, Receptacle, 100mil, 10x1, Gold plated, TH	HEADER, RECEPTACLE, 100mil, 10x1	SSW-110-01-G-S	Samtec, Inc.		
J5	1		Receptacle 100mil 3x1, Gold, TH	Receptacle, 100mil, 3x1	SSW-103-01-G-S	Samtec, Inc.		
J7, J8, J9, J19, J20, J21	6		RJ-45 with integrated magnetics	RJ-45 Jack	JK0-0177NL	Pulse Engineering	7499511611 or 7499511611A	Wurth Elektronik
J10, J11, J12, J22, J23, J24	6		RJ-45, Vertical, TH	RJ-45 Jack, 8Pos Right Angle	SS-7188V-A-NF	Stewart Connector		
J13, J14, J15, J16, J25, J26, J27, J28	8		Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	TSW-102-07-G-S	TSW-102-07-G-S	Samtec, Inc.		
J29	1	15A	Terminal screw, vertical, snap-in	7693	7693	Keystone		
L1	1	820uH	Inductor, Drum Core, Ferrite, 820 µH, 0.23 A, 4 ohm, SMD	SDR0805	SDR0805-821KL	Bourns		
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W	THT-14-423-10	Brady	-	-
R1	1	82.5k	RES, 82.5 k, 1%, 0.1 W, 0603	0603	CRCW060382K5FKEA	Vishay-Dale		
R2	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale		
R3, R7, R8, R9, R11, R12	6	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		

(1) Unless otherwise noted in the Alternate Part Number or Alternate Manufacturer columns, all parts may be substituted with equivalents.

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Table 10. TPS2388EVM-612 Bill of Materials[(1)] (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R4	1	13.3k	RES, 13.3k ohm, 1%, 0.1W, 0603	0603	CRCW060313K3FKEA	Vishay-Dale		
R5	1	47k	RES, 47k ohm, 5%, 0.1W, 0603	0603	CRCW060347K0JNEA	Vishay-Dale		
R6	1	6.04k	RES, 6.04k ohm, 1%, 0.1W, 0603	0603	CRCW06036K04FKEA	Vishay-Dale		
R10, R13	2	4.7k	RES, 4.7k ohm, 5%, 0.1W, 0603	0603	CRCW06034K70JNEA	Vishay-Dale		
R14, R15, R16, R17, R20, R21, R22, R23	8	7.50k	RES, 7.50k ohm, 1%, 0.25W, 1206	1206	CRCW12067K50FKEA	Vishay-Dale		
R18	1	200k	RES, 200k ohm, 1%, 0.1W, 0603	0603	CRCW0603200KFKEA	Vishay-Dale		
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8	8	1x2	Shunt, 100mil, Flash Gold, Black	Closed Top 100mil Shunt	SPC02SYAN	Sullins Connector Solutions		
TP1, TP2	2	Red	Test Point, Multipurpose, Red, TH	Keystone5010	5010	Keystone		
TP3, TP11, TP14, TP15, TP16	5	SMT	Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone		
TP4, TP5, TP6, TP7, TP8	5	White	Test Point, Multipurpose, White, TH	Keystone5012	5012	Keystone		
TP9	1	Black	Test Point, Multipurpose, Black, TH	Keystone5011	5011	Keystone		
U1	1		100V, 100mA Constant On-Time Synchronous Buck Regulator, DDA0008B	DDA0008B	LM5019MRX/NOPB	Texas Instruments	LM5019MR/NOPB	Texas Instruments
U2, U4	2		25 Mbps Quad Channels, 3 / 1, Digital Isolator, 3.3 V / 5 V, -40 to +125 degC, 16-pin SOIC (DW), Green (RoHS & no Sb/Br)	DW0016A	ISO7241CDW	Texas Instruments	Equivalent	None
U3	1		SINGLE BUFFER/DRIVER WITH OPEN-DRAIN OUTPUT, DCK0005A	DCK0005A	SN74LVC1G07DCK	Texas Instruments		None
C2, C5, C20	0	1uF	CAP, CERM, 1uF, 10V, ±10%, X7R, 0805	0805	0805ZC105KAT2A	AVX		
C19	0	0.1uF	CAP, CERM, 0.1uF, 50V, ±10%, X7R, 0603	0603	06035C104KAT2A	AVX		
H14	0		PWR613 Daughter Card. Build File Included With Project Files	Used in PnP output and some BOM reports	PWR613 Daughter Card	Used in BOM report	PWR613 Daughter card	-

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Table 11. TPS2388EVM-016 Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		PSIL016	Any
C1	1	0.1uF	CAP, CERM, 0.1uF, 50V, ±10%, X7R, 0603	0603	06035C104KAT2A	AVX
C2, C3, C4, C5, C6, C7, C8, C9, C10	9	0.1uF	CAP, CERM, 0.1uF, 100V, ±10%, X7R, 0805	0805	C2012X7R2A104K	TDK
C11	1	1uF	CAP, CERM, 1uF, 100V, ±10%, X7R, 1206	1206	GRM31CR72A105KA01L	Murata
D1, D2, D3, D4, D5, D6, D7, D8	8	58V	Diode, TVS, Uni, 58V, 600W, SMB	SMB	SMBJ58A-13-F	Diodes Inc.
F1, F2, F3, F4, F5, F6, F7, F8	8		Fuse, 1.5A, 63V, SMD	1206	C1S 1.5	Bel Fuse
J1, J2, J3	3		Header, TH, 100mil, 10x1, Gold plated, 230 mil above insulator	TSW-110-07-G-S	TSW-110-07-G-S	Samtec, Inc.
J4	1		Header, 100mil, 4x2, Gold, TH	4x2 Header	TSW-104-07-G-D	Samtec
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	8	100V	MOSFET, N-CH, 100 V, 5 A, DNH0008A (VSONP-8)	DNH0008A	CSD19538Q3A	Texas Instruments
R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16	16	0.51	RES, 0.51 ohm, 1%, 0.25W, 0805	0805	CRM0805-FX-R510ELF	Bourns
SH-J1, SH-J2, SH-J3, SH-J4	4	1x2	Shunt, 100mil, Flash Gold, Black	Closed Top 100mil Shunt	SPC02SYAN	Sullins Connector Solutions
TP1	1	Black	Test Point, Multipurpose, Black, TH	Keystone5011	5011	Keystone
TP2, TP5, TP6	3	Red	Test Point, Miniature, Red, TH	Keystone5000	5000	Keystone
TP3, TP4, TP7	3	White	Test Point, Miniature, White, TH	Keystone5002	5002	Keystone
TP8	1	SMT	Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
U1	1		OCTAL IEEE 802.3at POWER-OVER-ETHERNET PSE CONTROLLER, RTQ0056E (VQFN-56)	RTQ0056E	TPS2388RTQ	Texas Instruments
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

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Revision History

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

Changes from B Revision (April 2018) to C Revision **Page**

- Replaced Figure 23 28

Changes from A Revision (October 2017) to B Revision **Page**

- Replaced Figure 16 23

Changes from Original (August 2017) to A Revision **Page**

- Added the *TPS2388EVM-612 GUI Setup section.* 8
- Added the sentence before the *Virtual Auto Mode Reference Code Structure* image 15
- Added the *Multi-Port Power Management Module* section 17
- Updated *Power on Decision Flow Chart* image 19
- Updated *System Power Monitor Flow Chart* image 20
- Updated *Pseudo-Code* 21

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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.

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   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 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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。

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東京都新宿区西新宿 6 丁目 2 4 番 1 号
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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
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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, 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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