User's Guide

TPS65994 EVM User Guide

ABSTRACT

This document is the user guide for the TPS65994 Evaluation Module. The TPS65994 EVM allows for evaluation of the TPS65994 IC (WCSP and QFN package) functionality as part of a stand-alone testing kit and for development and testing of USB Type-C™ and Power Delivery (PD) end products.

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Trademarks

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1 About this Manual

This user's guide describes the TPS65994 EVM. The guide consists of an introduction, setup instructions, the EVM schematic, board layouts, component views, internal power (PWR) and ground (GND) plane layouts, and a bill of materials (BOM). Refer to TPS65994QFNEVM schematic, board layouts, component views when evaluating TPS65994 QFN package.

2 Items Required for Operation

The following items are required to use the TPS65994 EVM:

- TPS65994 data sheet
- TPS65994 EVM
- TPS65994 Application Customization Tool
- 20-V barrel jack adapter or DC power supply
- Passive USB Type-C™ cables
- USB Type-A to USB Micro-B cable
- USB Type-A to USB Type-B cable
- Mini-DisplayPort to DisplayPort cables
- DP-Expansion Board
- Notebook with USB 2.0, USB 3.0, and DP capabilities

3 Introduction

The TPS65994 is a stand-alone USB Type-C and Power Delivery (PD) controller providing cable plug and orientation detection at the USB Type-C connector. Upon cable plug and orientation detection, the TPS65994 communicates on the CC line using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS65994 enables the appropriate power path and configures external multiplexers and alternate mode settings. This user guide describes how the TPS65994 EVM can be used to test DisplayPort alternate mode as well as USB Data. This guide also contains testing procedures of DP alternate mode as well as various PD power configurations. The EVM is customizable through the TPS65994 Configuration Tool. Additionally, the EVM is equipped with Tiva MCU and Aardvark connector to SPI or I2C interfaces for debugging and development.

4 Setup

This section describes the various EVM features and how to test these features. Schematic screen shots, pictures, and block diagrams are provided as necessary.

4.1 Switch, Push Button, Connector, and Test Point Descriptions

Components described in this section are listed with respect to the EVM from left to right and top to bottom. Related components are listed simultaneously.

4.1.1 Power Path Jumper Configuration

Out of the box, the TPS65994 EVM has jumper configuration for a TPS65994 device. With this configuration, the two internal power paths are configured as Source paths for their respective USB Type-C ports. The two external power paths are configured as Sink paths for their respective USB Type-C ports. When using the TPS65994 EVM, use a TPS65994 template in the TPS65994 Application Customization Tool.

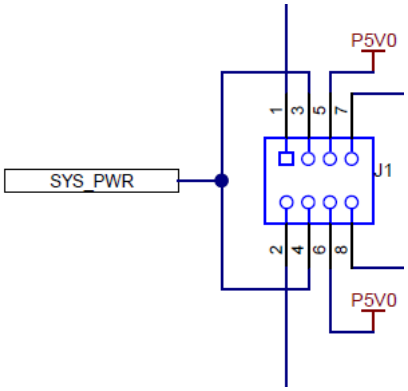


Figure 4-1. TPS65994 Power Path Jumper Configuration

4.1.2 Expansion Ports

J7 and J8 are the connectors for 10G-EXPANSION-EVM Source Board for port A and B respectively. Connect 10G-EXPANSION-EVM Source Board to evaluate DisplayPort and USB 3.2 Data. Both ports can support DP at the same time.

Note

TPS65994 can only support DP_DFP mode. TPS65994 EVM will work with 10G-EXPANSION-EVM Source Board only.

4.1.3 ADCINx Settings

4.1.3.1 S1 and S2: ADCIN1 and ADCIN2

The TPS65994 EVM has a switch (S1) that can be used to configure the ADCIN1 and ADCIN2 pin strapping settings of the TPS65994. ADCIN1 is controlled through S1 and ADCIN2 is controlled through S2. Refer to TPS65994 datasheet to see different ADCINx configurations. Table 4-1 highlights the switch settings to enable the different ADCINx configurations. With all switches on S1 and S2 disabled, switches S4A and S4B can be used to directly short the ADCINx pin to LDO_1V5. The schematic for the ADCIN1 and ADCIN2 configuration switches can be seen in Figure 4-2.

Table 4-1. S1 and S2: ADCIN1 and ADCIN2 Switch Settings

ADCINx Switch Settings				
1	2	3	4	Setting
0	0	0	0	0
0	0	1	1	1
0	1	0	1	2
0	1	1	1	3
0	0	1	0	4

Table 4-1. S1 and S2: ADCIN1 and ADCIN2 Switch Settings (continued)

ADCINx Switch Settings				
0	1	0	0	5
1	0	0	0	6
1	1	0	0	7

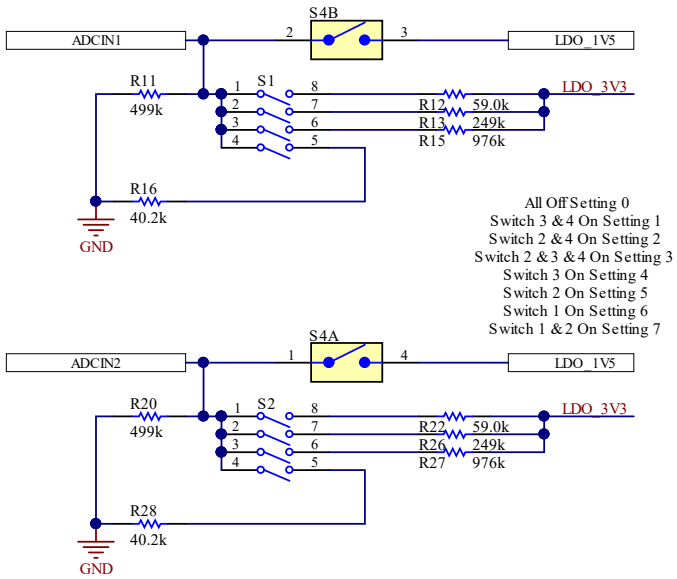


Figure 4-2. ADCIN1 and ADCIN2 Configuration Schematic

4.1.4 J2: Barrel Jack Power Connector

The barrel jack power connector accepts a 19-V to 20-V DC supply. A standard notebook adapter (or similar adapter) provides the required power. This input provides the PP_EXT power rail 19-V to 20-V.

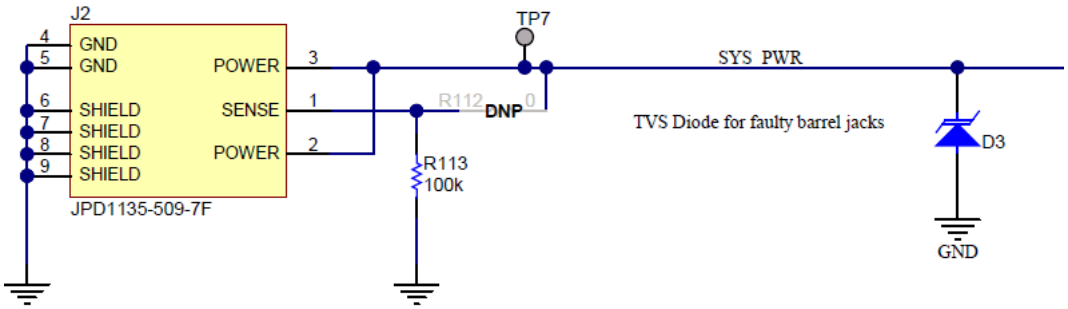


Figure 4-3. Barrel Jack (J2) Schematic

4.1.5 USB Type-C™ Connector (J3_PA, J3_PB)

The TPS65994 EVM has two full feature USB Type-C receptacles (port A/B) and routes VBUS, SSTX and SSRX pairs, SBU1 and SBU2 pairs, and D+ and D– signals. The TPS65994 device can be used in self-powered and bus-powered configurations for added flexibility. When self-powered, the EVM can provide up to 15 W (5 V, at 3 A) of power per port via the internal PP5V power path. The EVM is also capable of sinking 100 W (20 V, at 5 A) of power via the external PP_EXT power path. The internal power path is used for sourcing power and the external power path is used for sinking power.

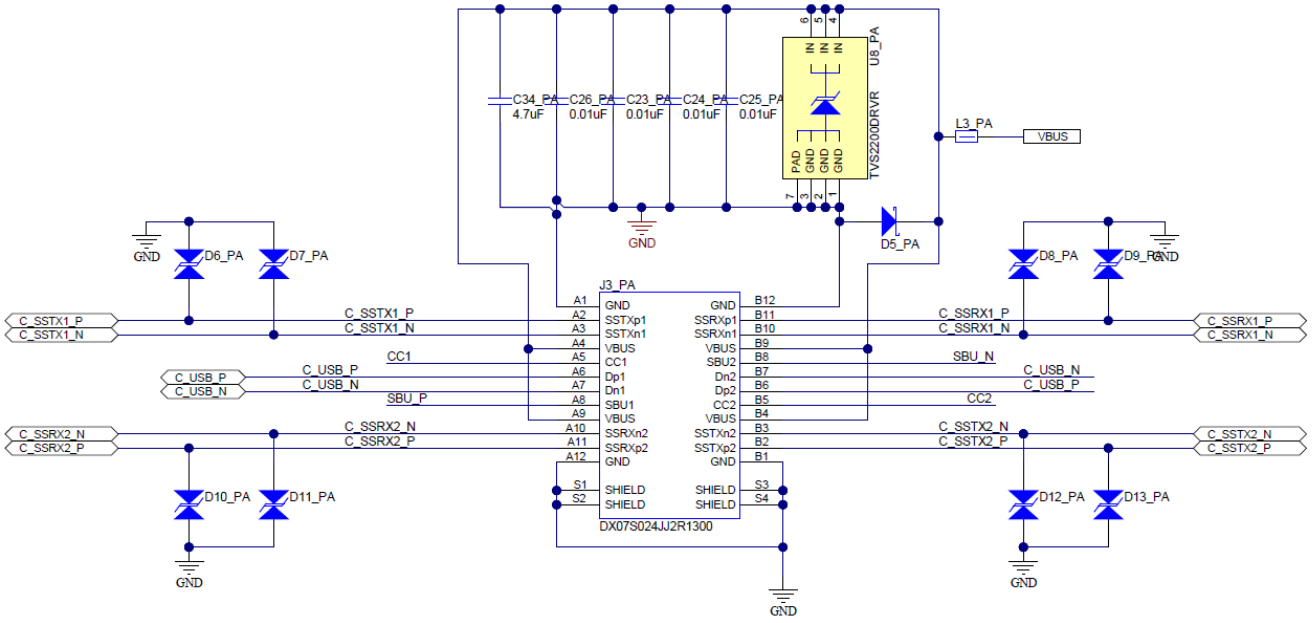


Figure 4-4. USB Type-C™ Receptacle (J3_PA) Schematic

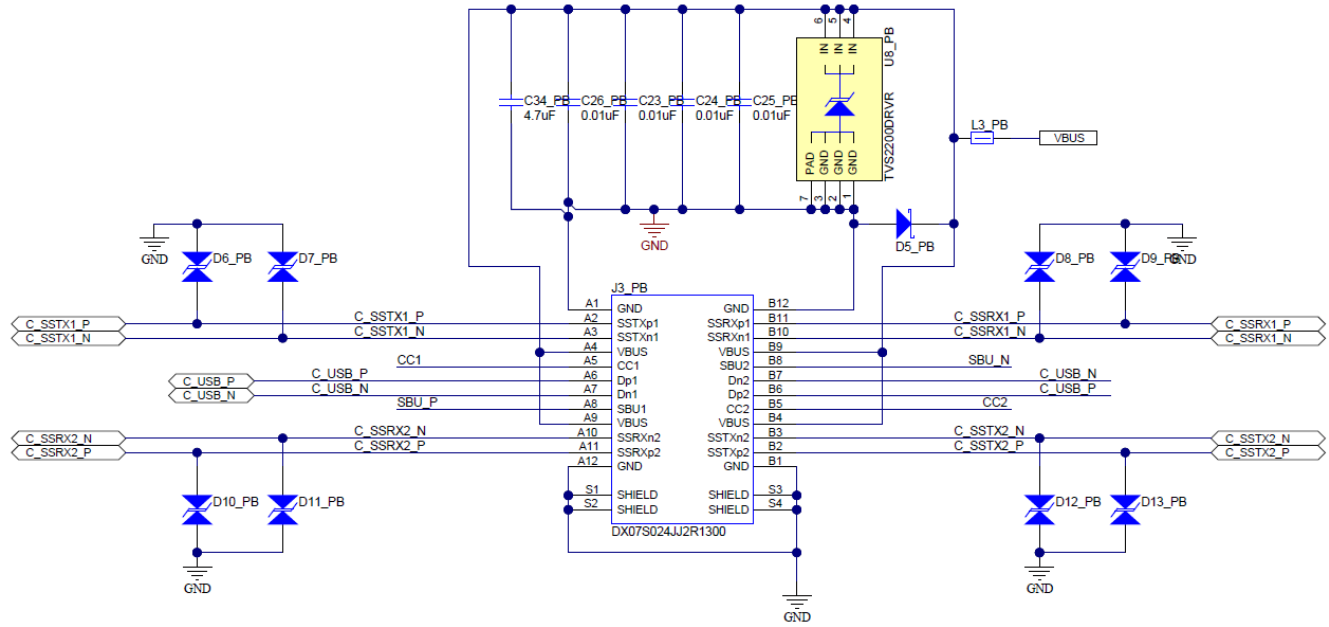


Figure 4-5. USB Type-C™ Receptacle (J3_PB) Schematic

4.1.6 USB Micro B Connector (J6)

J6, the micro-B receptacle connects the Tiva to the PC for the TPS65994 Customization GUI. Use a standard USB micro-B to Type-A cable to make this connection. LED D24 turns on when VBUS is present on the Tiva board.

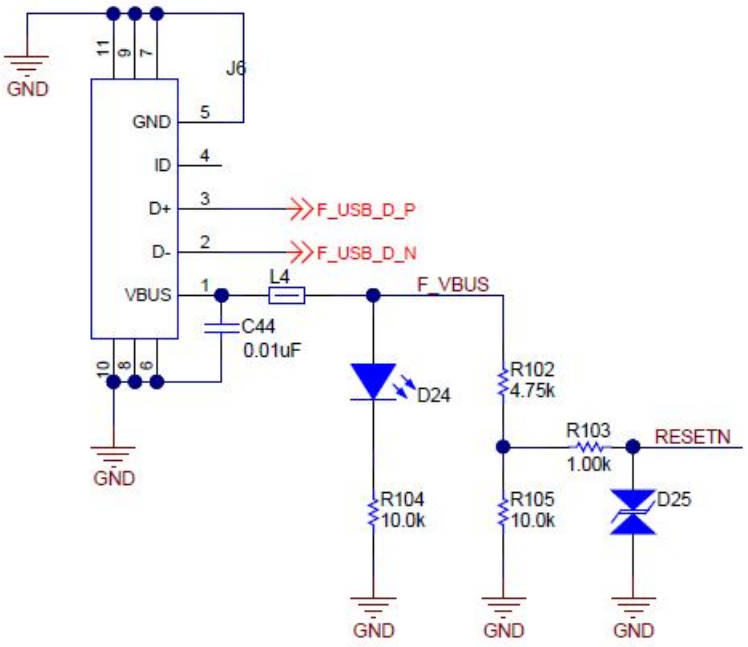


Figure 4-6. USB Micro-B Receptacle (J6) Schematic

4.1.7 TP8 (5V), J10 (3.3V), TP7 (SYS_PWR)

Use the TP8, and J10 test points to measure the output voltage of the onboard DC/DC converters. These DC/DC converters produce the required voltage rails for full functionality of the EVM including power delivery, powering internal and external circuits, and so forth. These test points allow the user to verify the system supplies on the TPS65994EVM. LDO_1V5 is internally generated for internal circuitry. Use P3V3 to supply VIN_3V3 which then supplies LDO_3V3. Also, use LDO_3V3 as a low power output for external flash memory. In bus-powered conditions, or self-powered conditions, LDO_3V3 is active. TP7 test point is provided to verify input voltage of barrel jack connector.

4.1.8 Aardvark Connector (J9)

This connector matches the Total Phase® Aardvark that allows the user to access the I2C pins on the TPS65994EVM using the I2C Master capabilities. U6 is used to swap between I2C1 or I2C3 connected to the aardvark connector. S3 is used to control which way the 2 to 1 MUX will be set. If S3 is disabled, by default, I2C1 would be connected to the Aardvark header. When S3 is enabled, I2C3 would be connected to the Aardvark header.

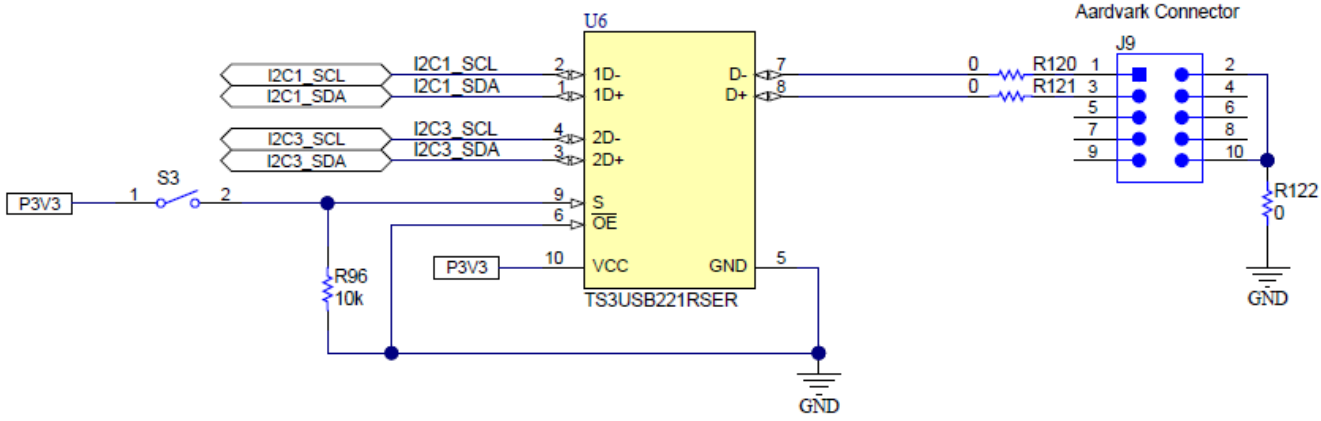


Figure 4-7. Aardvark Connector (J9) Schematic

4.1.9 TP10, TP11, TP12, TP13: GND Test Points

TP10, TP11, TP12, TP13 GND test points are provided for attaching an oscilloscope or multimeter, as well as for load testing. These test points are connected to the board GND planes through multiple vias.

4.1.10 TP2, TP3, TP4, TP5: CC1 and CC2 Test Points

Test points CC1 and CC2 are used to tie a PD protocol analyzer for PD BMC data or to verify the BMC signal integrity with an oscilloscope (depending on the cable orientation). Use a multimeter or oscilloscope to measure VCONN when an electronically marked USB Type-C cable is connected. Use these test points to attach an external load on VCONN.

4.1.11 TP1, TP6: VBUS Test Points

The VBUS test points are used to measure VBUS at each USB Type-C port A/B connector. With PD power possibly going up to 20 V, use caution when connecting and disconnecting probes on the TPS65994EVM. The VBUS test point is capable of drawing up to 3 A for an external load. Note that a PD power contract with the necessary capability must be negotiated in order to draw current from the VBUS test point.

4.1.12 J4 and J5 (Bottom of EVM): Signal Headers

These headers allow the user to probe many different signals on the TPS65994EVM. Note that some of the header pins are not connected unless a 0-Ω option resistor is placed.

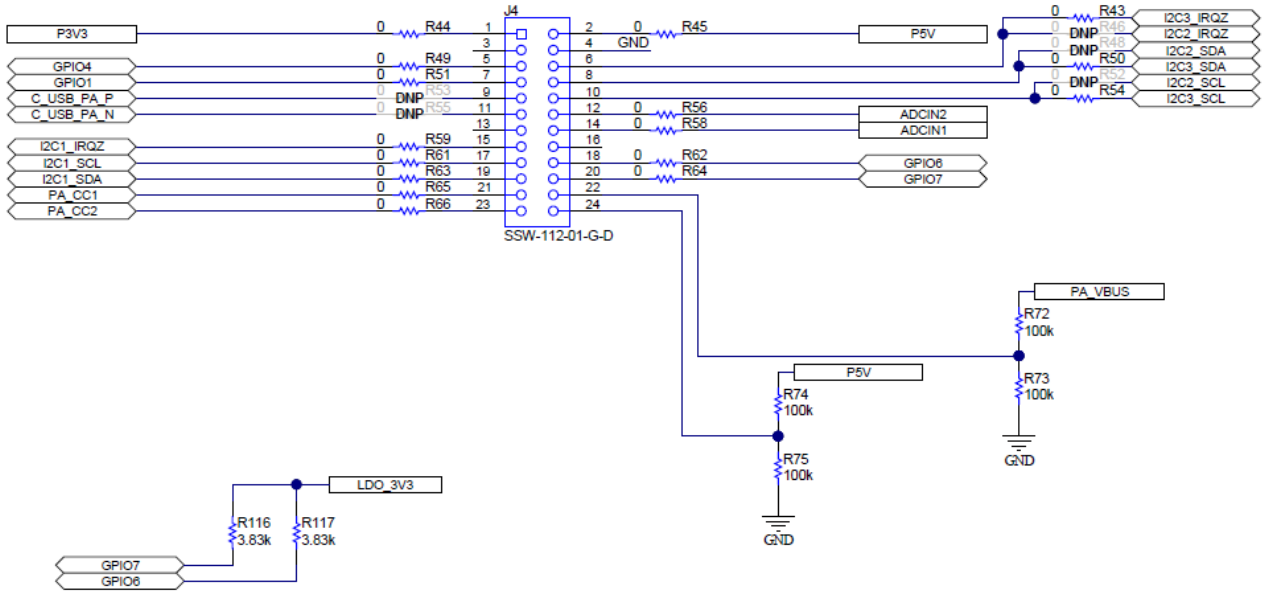


Figure 4-8. Debug Header (J4) Schematic

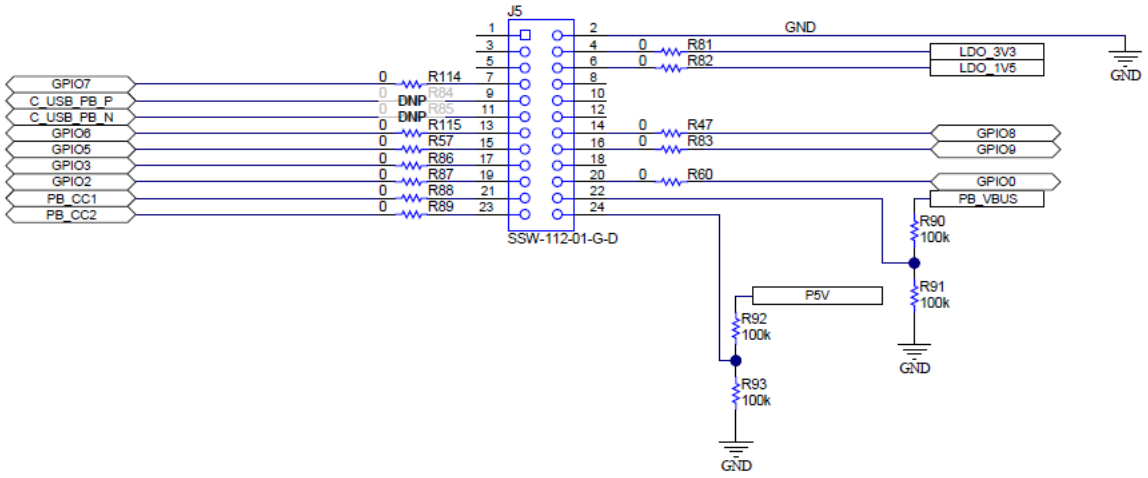


Figure 4-9. Debug Header (J5) Schematic

4.2 LED Indicators Description

The EVM has multiple LEDs to notify the user what type of connection is present. The LEDs are separated into 2 groups: MUX control LEDS and Status LEDs. All LEDs are enabled with general purpose I/O (GPIO); therefore, each must be enabled separately via configuration, if configuring a custom image

4.2.1 MUX Control LEDs

Table 4-2. Port A MUX CTL LED

LED Indicator	GPIO	Function
D15 - PA_HPD	GPIO1	HPD
D17 - PA_USB3	GPIO3	USB 3.0 Event
D18 - PA_DP_Mode	GPIO4	DP Mode Select Event
D23 - PA_POL	GPIO9	Cable Orientation Event

Table 4-3. Port B MUX CTL LED

LED Indicator	GPIO	Function
D14 - PB_HPD	GPIO0	HPD
D19 - PB_USB3	GPIO5	USB 3.0 Event
D22 - PB_DP_Mode	GPIO8	DP Mode Select Event
D16 - PB_POL	GPIO2	Cable Orientation Event

4.2.2 Status LEDs

D1 and D2 LEDs indicate when VBUS voltage is present on port A and port B respectively. They also provide a voltage discharge path for high to low PD contracts. D4 LED indicates SYS_PWR, when a barrel jack is connected at J2.

5 Tiva USB to I2C Bridge Support Integration

The Tiva microcontroller allows for a reliable USB to I2C connection. This section covers how to flash application firmware to EEPROM using the Tiva microcontroller and how to enter the debug mode using the Tiva microcontroller.

5.1 Flash Application Firmware to EEPROM

This section provides the steps to flash the application firmware to EEPROM.

1. Open the Application Customization Tool and Start a New Project

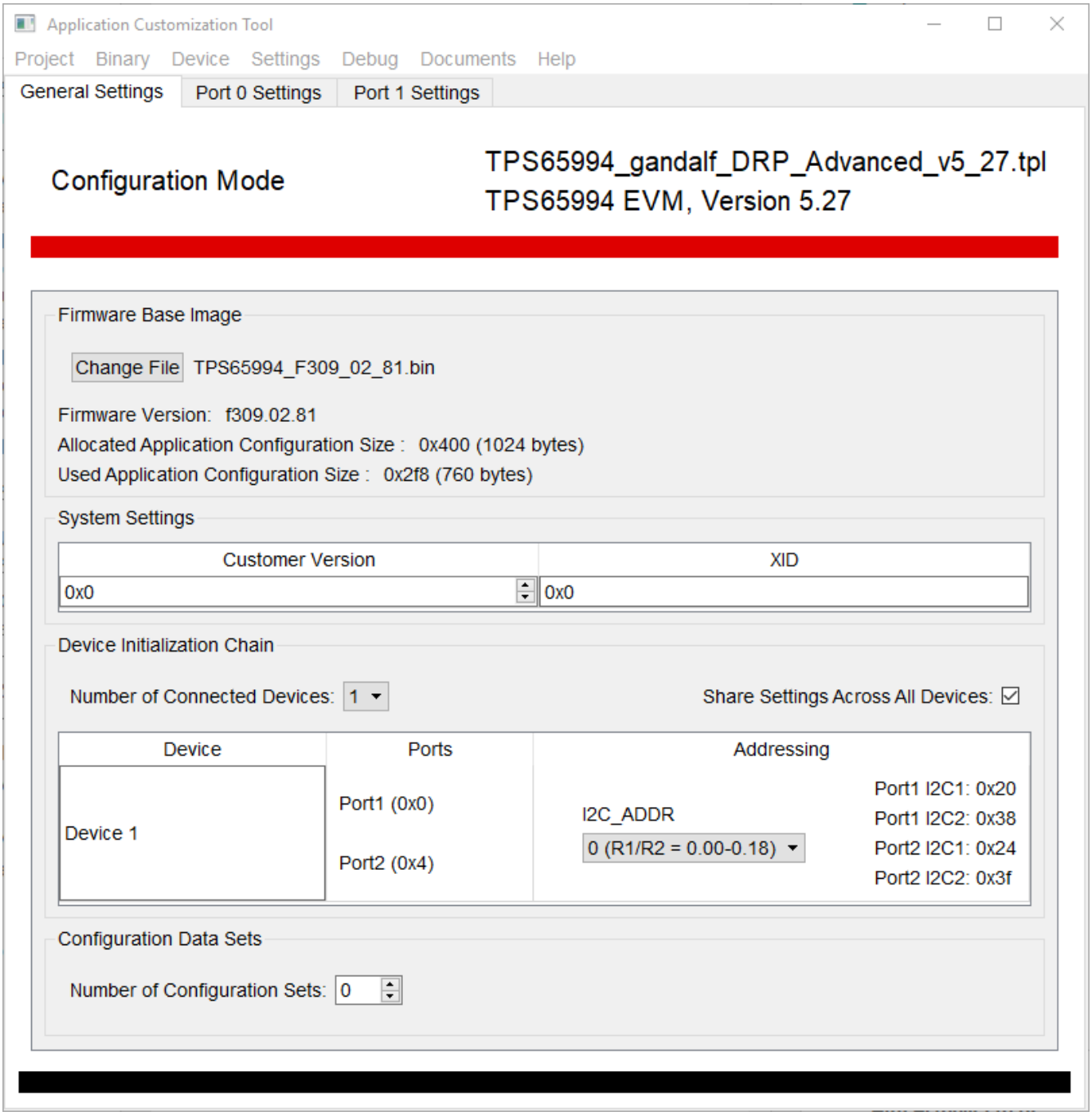


Figure 5-1. Application Customization Tool

2. Create a project by modifying the registers according to your needs. For example, I/O Config (register 0x5c) allows for user-defined GPIOs.

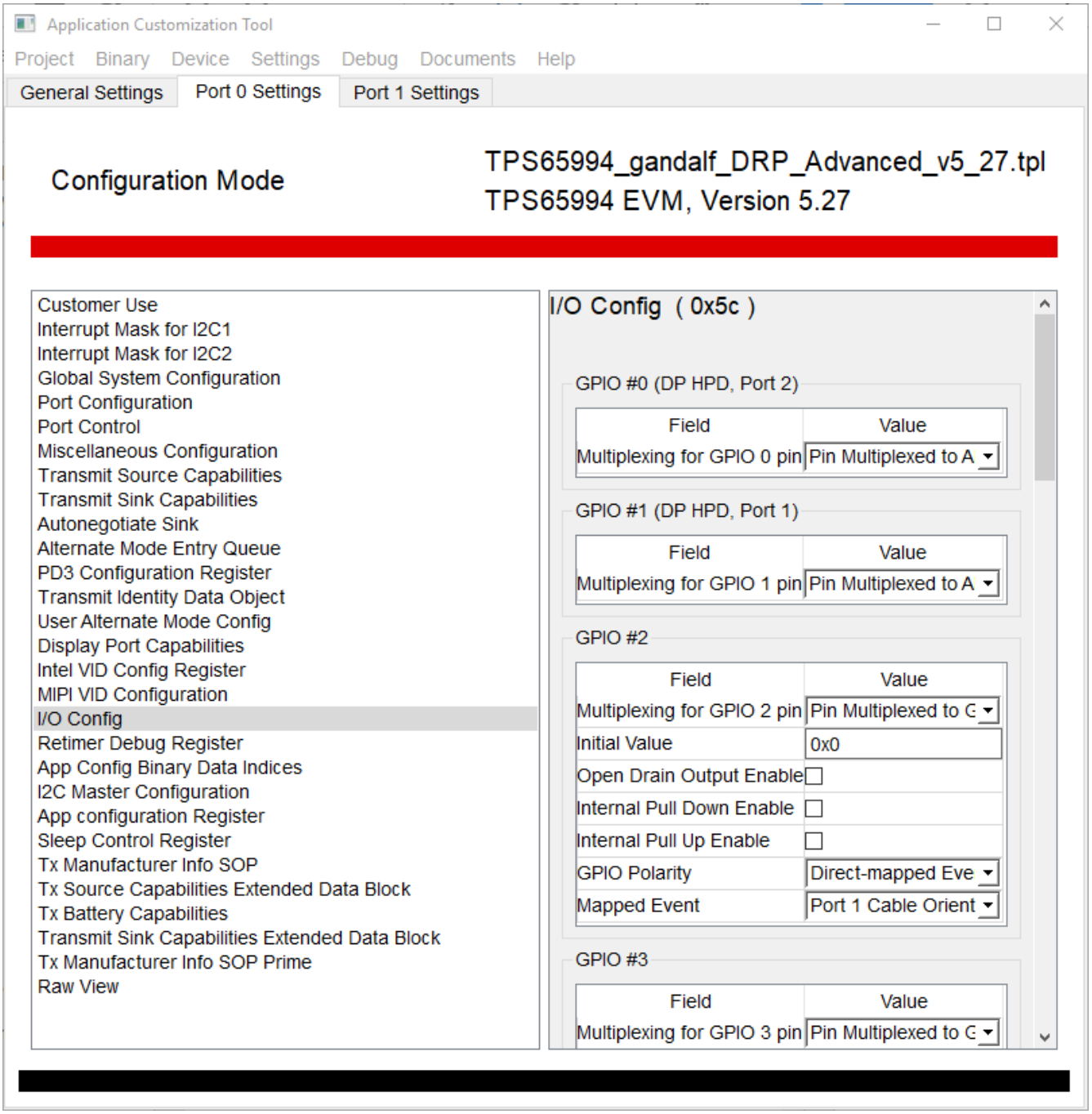


Figure 5-2. I/O Config Register

3. After defining the registers, use the *Device* tab and flash app firmware to EEPROM to load the new configurations to the device. Ensure that the correct adapter is selected. For this case, select the Tiva adapter.

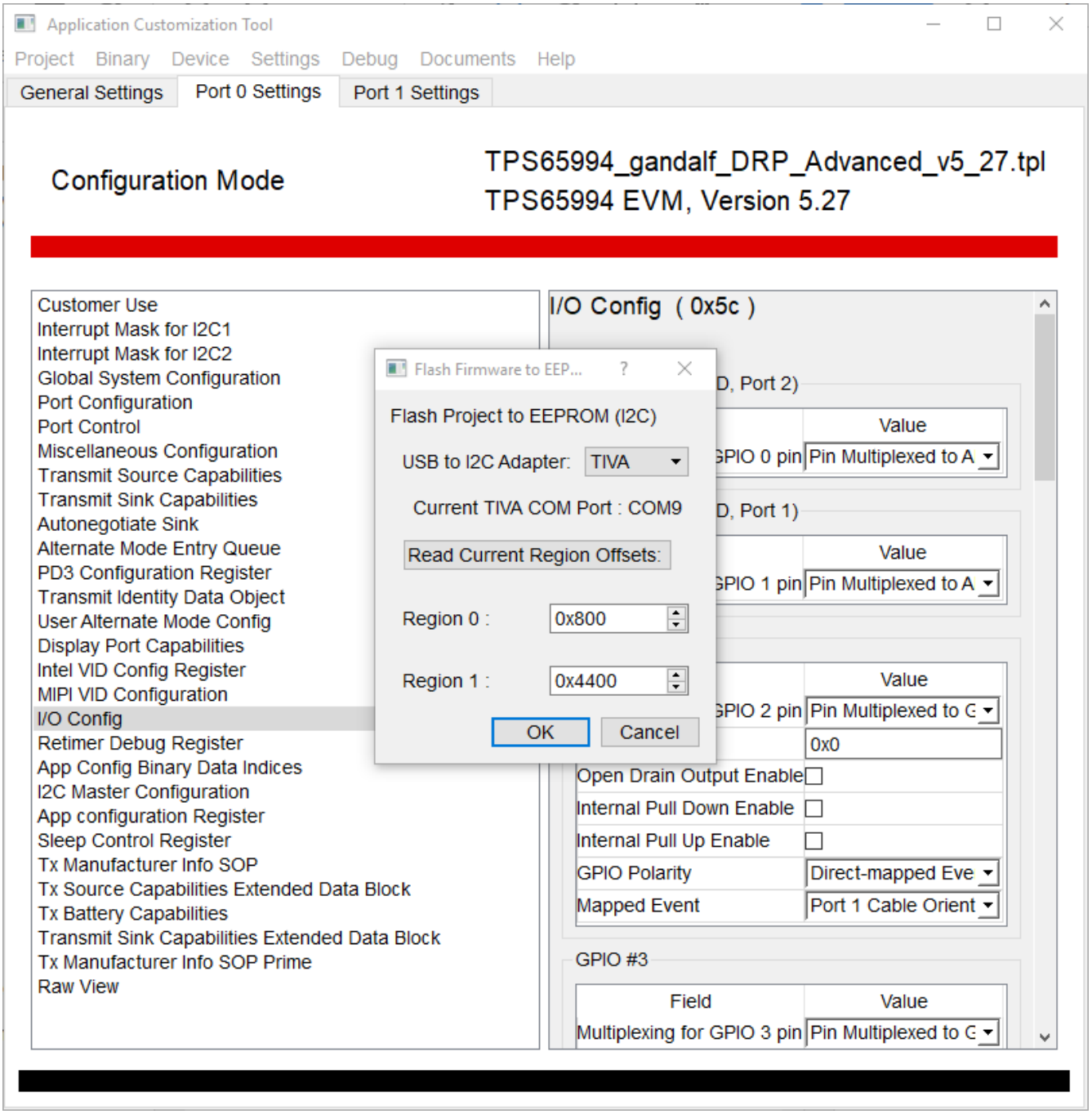


Figure 5-3. Flash Project to EEPROM (I2C)

5.2 Entering Debug Mode

This section provides the steps for using Debug mode.

1. Ensure the USB to I2C/SPI adapter is selected accordingly with the device being used. In this case select the Tiva adapter. Sweep I2C address range to discover the port addresses.

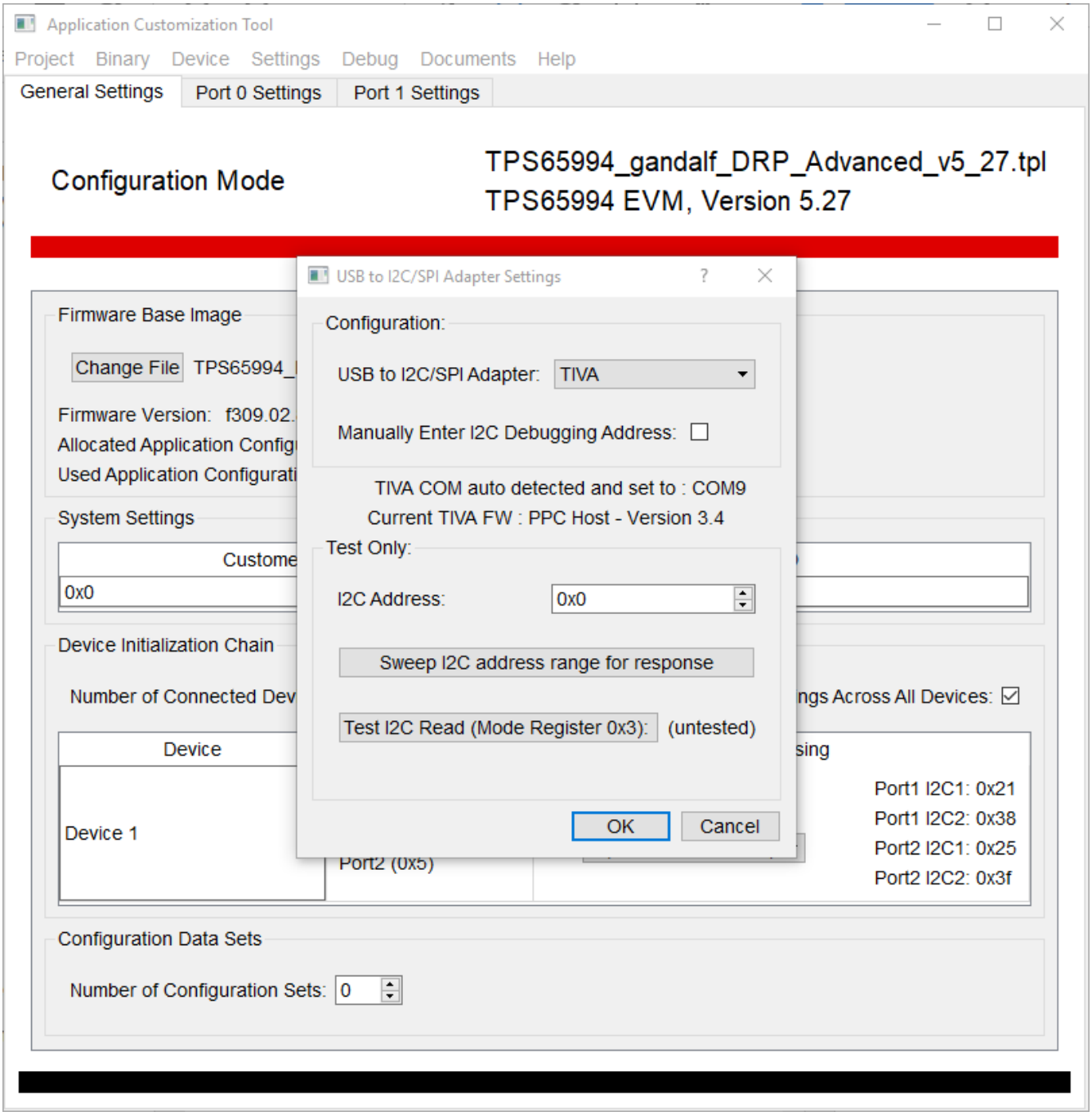


Figure 5-4. USB to I2C/SPI Adapter Settings

2. I2C address sweep results.

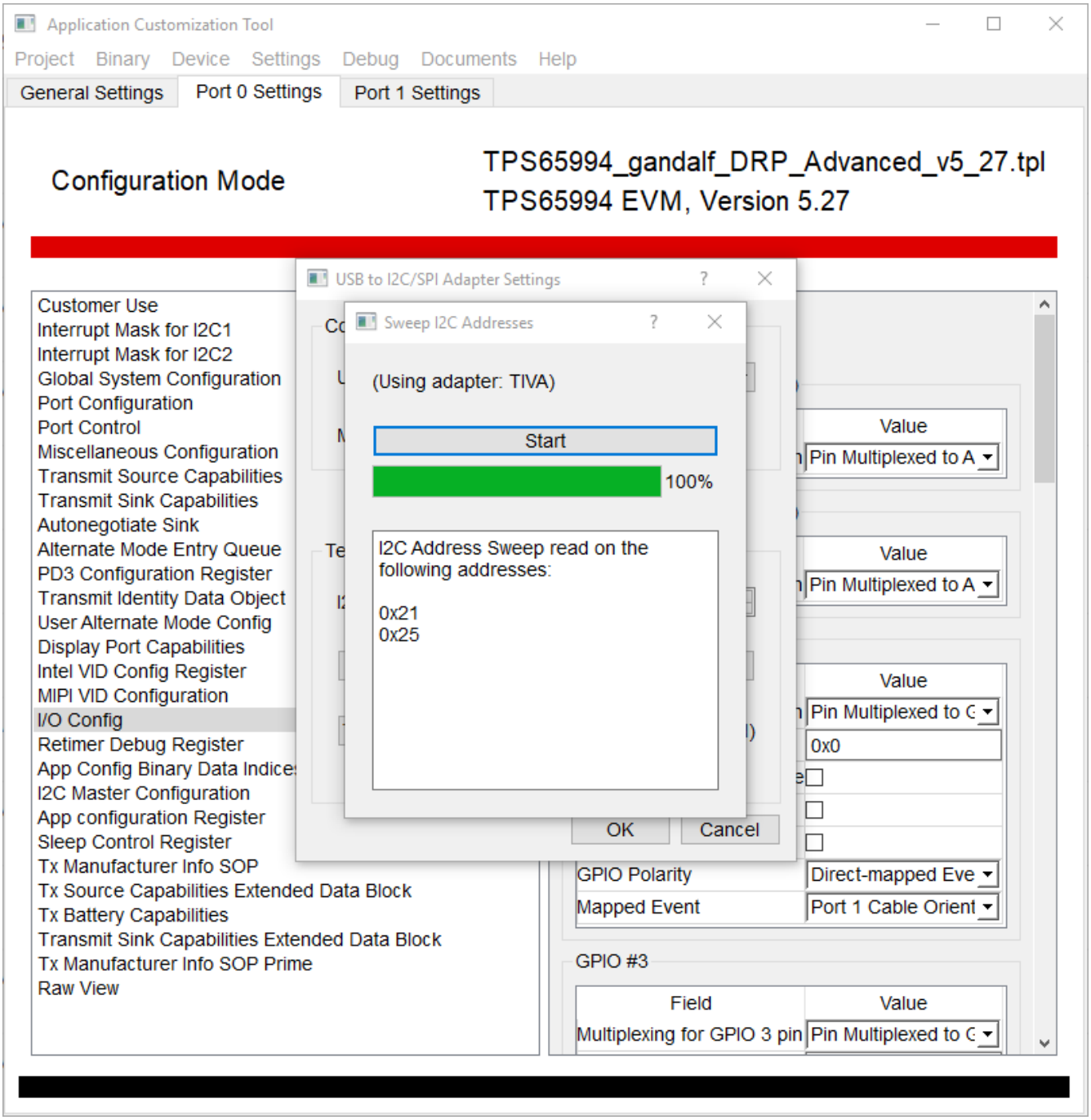


Figure 5-5. I2C Addresses

3. Once on debug mode, ensure that I2C_ADDR is within the required range for the addresses.

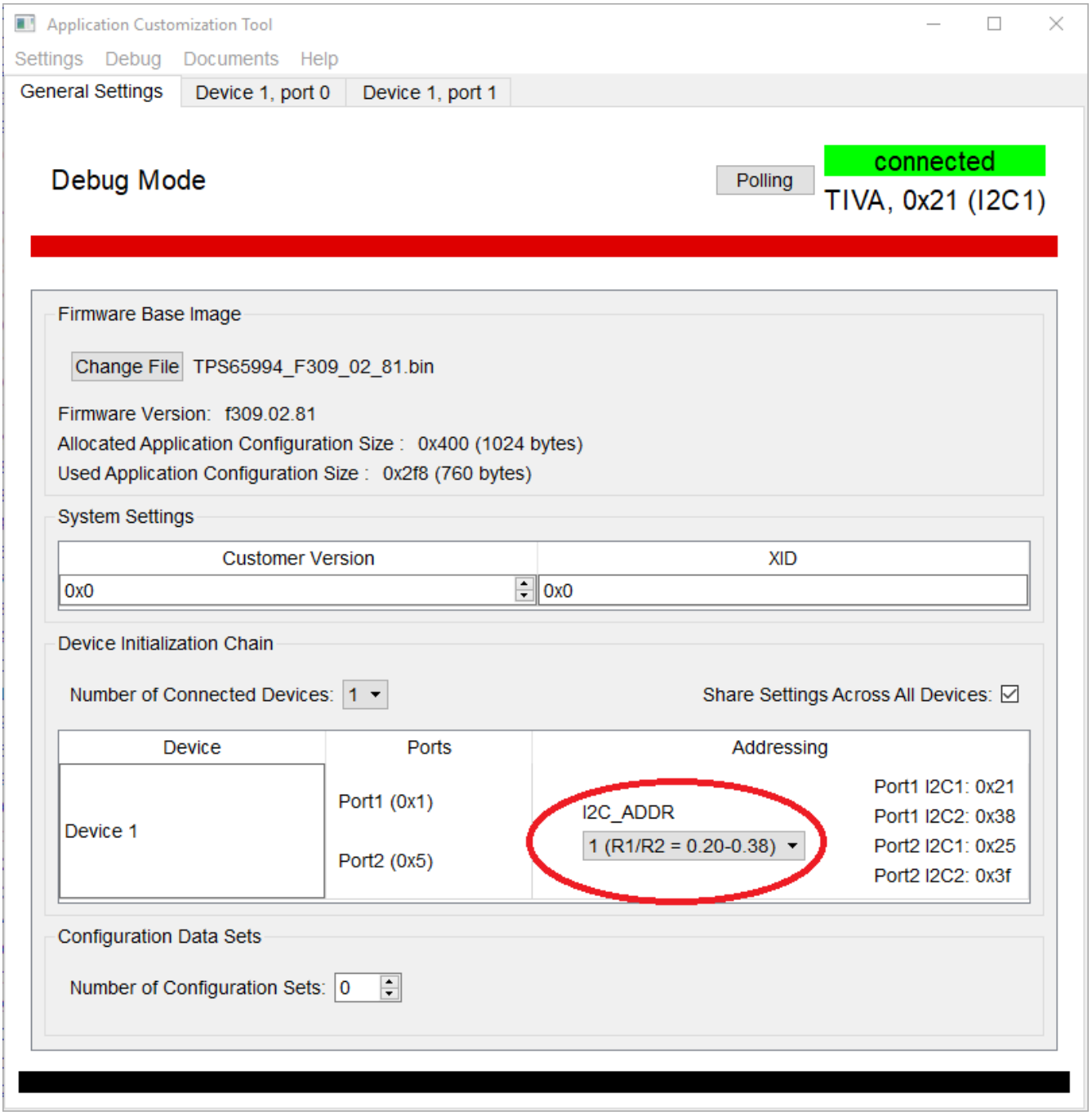


Figure 5-6. Addressing range

4. Ensure that the registers are defined as expected by navigating through the *Configuration Registers* tab. The *Debug Registers* tab provides the run-time information on the registers. Finally, the *Commands* tab allows for the execution of defined commands in run-time. The following example shows the Transmit Source Capabilities (register 0x32) information.

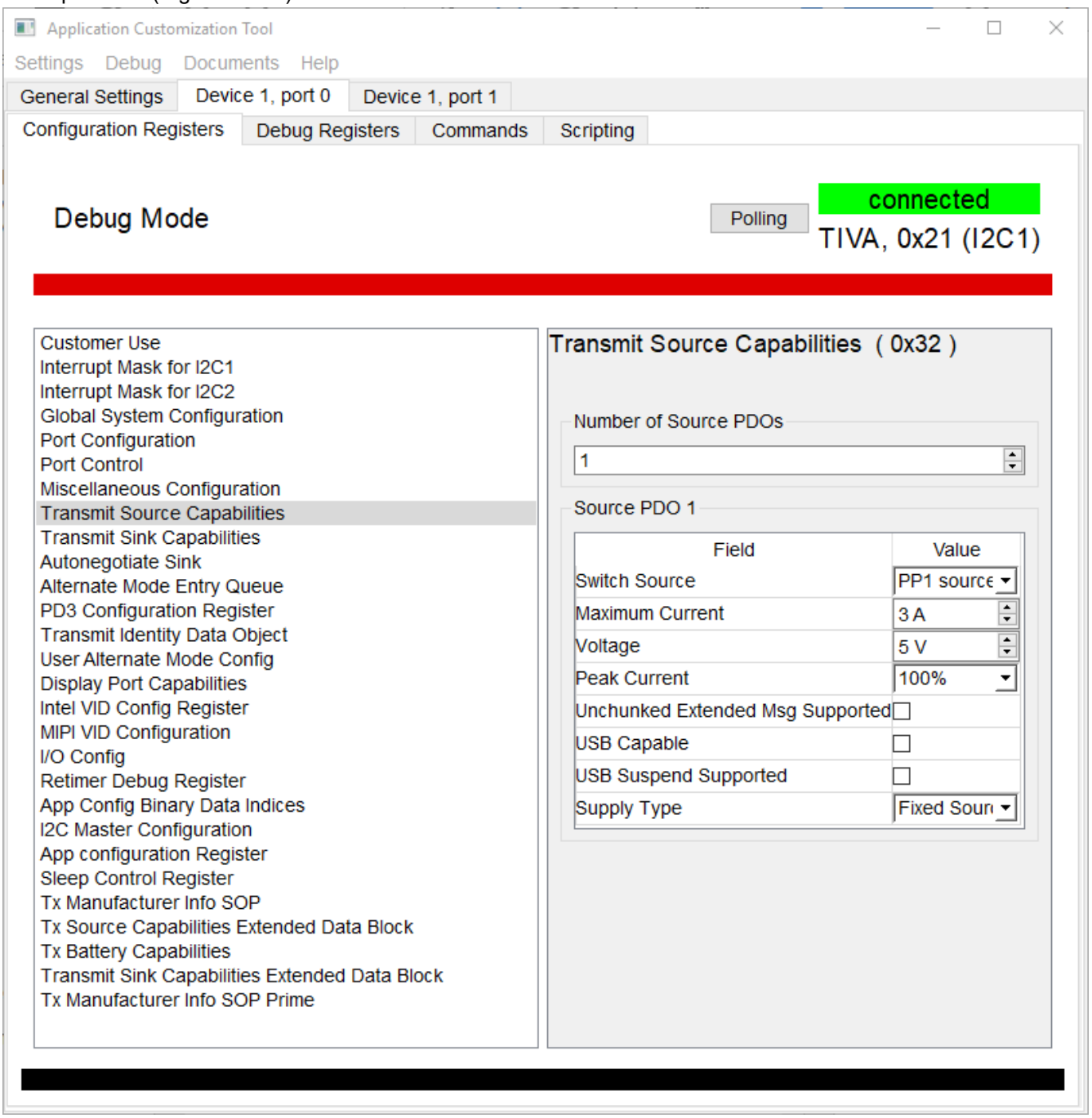


Figure 5-7. Transmit Source Capabilities

For more information about how to use the Application Customization Tool, refer to the GUI user's guide.

6 Using the TPS65994EVM

This section discusses the pre-loaded or recovery firmware, getting started, and debugging the EVM.

6.1 Powering the TPS65994EVM

The main power supply for the EVM is the barrel jack (J2), which accepts 19 V to 20 V via a barrel jack adapter. The EVM can also be powered with an external power supply on SYS_PWR (TP7). The input voltage can range from 5 V to 20 V, but the appropriate power profile for PP_EXT should be configured in the firmware using the configuration tool. The EVM can also be bus-powered from the USB Type-C connector and accepts 5 V to 20 V on VBUS, depending on the sink configuration.

6.2 Firmware Configurations

Out of the box, the TPS65994EVM is configured to emulate a dual-port laptop computer. For each port, the internal power switch is configured for sourcing, and the external high current power switch is configured for sinking. Both ports are configured for data DFP.

7 Connecting the EVM

7.1 Connecting to Various Devices

Various USB Type-C cables can be used to connect the EVM to a legacy Type-A device, legacy Type-A host, or USB Type-C device or host.

7.1.1 Connecting to a Legacy Type-A Device

Using a USB Type-C to Type-A cable allows for connection to a legacy USB device, such as a flash-drive. The TPS65994 can act as a host passing the DP or USB connection by using the SS MUX and USB HUB present on the DP-Expansion board.. **Figure Below** shows how the notebook, DP and USB receptacle, TPS65988EVM, cable, and flash drive are connected.

7.1.2 Connecting to USB Type-C™ Devices

Using a USB Type-C cable allows for connection to USB and DP devices. When a TPS65994EVM is used with a TPS6598x-EVM as DP source and sink boards respectively, a complete USB Type-C system can be verified. The test setup requires a DP and USB source to provide data to the sink board, and a DP-Expansion board. A DP monitor and USB device can now be connected to the sink board. Note that USB and DisplayPort video quality may degrade due to the use of multiple connectors and cables. **Figure Below** highlights this feature.

7.1.3 Testing DisplayPort Alternate Mode and USB 2.0 and USB 3.0

The DisplayPort alternate mode can be tested with a non-USB Type-C notebook, allowing the user to simulate a DisplayPort DFP_D (video source) or UFP_D (video sink).

7.1.3.1 Required Hardware

The following hardware is required to test the DP alternate mode and USB 3.0:

- A Microsoft® Windows® PC with a USB Type-A receptacle and DisplayPort video output
  - USB 2.0 or USB 3.0 Type-A to Type-B cable
  - USB 2.0 or USB 3.0, or USB Type-C flash drive
  - USB 2.0 Type-A to micro USB cable
- USB Type-C cable
- Monitor with DisplayPort Input
- Mini DisplayPort to DisplayPort cable or USB Type-C to DisplayPort cable
- FTDI board (used for programming the TPS695994EVM and interfacing with configuration tool)
- Dell laptop power supply (model # 492-BBGP)

Use the TPS65994EVM with a DP-Expansion board to test DP alternate mode as well as USB data using the default firmware. To do so, connect a DP source from a laptop to the TPS65994EVM through the DP-Expansion Board. Next, connect a USB Type-B to USB Type-A cable from the TPS65994EVM to a Windows computer. To test DP, connect a mini-DP to DP cable to a monitor from the DP-Expansion board, and a USB Type-C to USB Type-C cable from laptop to TPS65994EVM. To test USB functionality, either connect a USB Type-C flash drive to the other USB Type-C port on the TPS65994EVM or plug in a Type-A flash drive on the DP-EXPANSION-EVM. The monitor displays what is present from the DP source. The flash drive enumerates on the windows PC. Table 7 explains this test setup.

8 Debugging the EVM

This section discusses various debugging examples. Testing and debugging approaches on the EVM can be applied to an actual system to help identify any issues.

8.1 Connection Not Established

The following checks help resolve issues when connecting the EVM to another EVM or USB Type-C device and no status LEDs are on:

- Verify that a firmware image is loaded in on the TPS65994 using the TPS65994 Configuration Tool
- Verify the CC lines are toggling for Dual-Role Port functionality
- Verify the following system supplies:
  - System_3V3 and VIN_3V3: 3.3 V
  - System_5V : 5 V
  - Barrel jack and SYS_PWR: 20 V
  - LDO_3V3: 3.3 V
- Verify that the devices connected are compatible. The following are some of the compatible connections:
  - Dual-Role Port → UFP
  - Dual-Role Port → DFP
  - DFP → UFP
- Verify that VBUS is reaching 5 V when connected

8.2 Resetting Behavior

Improper configurations and shorts can cause a USB Type-C PD system to constantly reset. The following checks should be used to debug these types of issues:

- Verify that the essential power paths have the correct voltages:
  - System_3V3 and System_5V
  - System Power: 20 V (or the appropriate configured voltage)
- Probe VBUS, CC1, and CC2 to check for any anomalies.
- When there is a short on VBUS, the initial 5 V on VBUS is not present
- Check for a small spike on VBUS during a plug event to verify that the PP or PP_EXT switch is closed and is then opened, once an overcurrent condition is detected.

9 TPS65994EVM Schematics

Figure 9-1 through Figure 9-7 show the TPS65994EVM schematics.

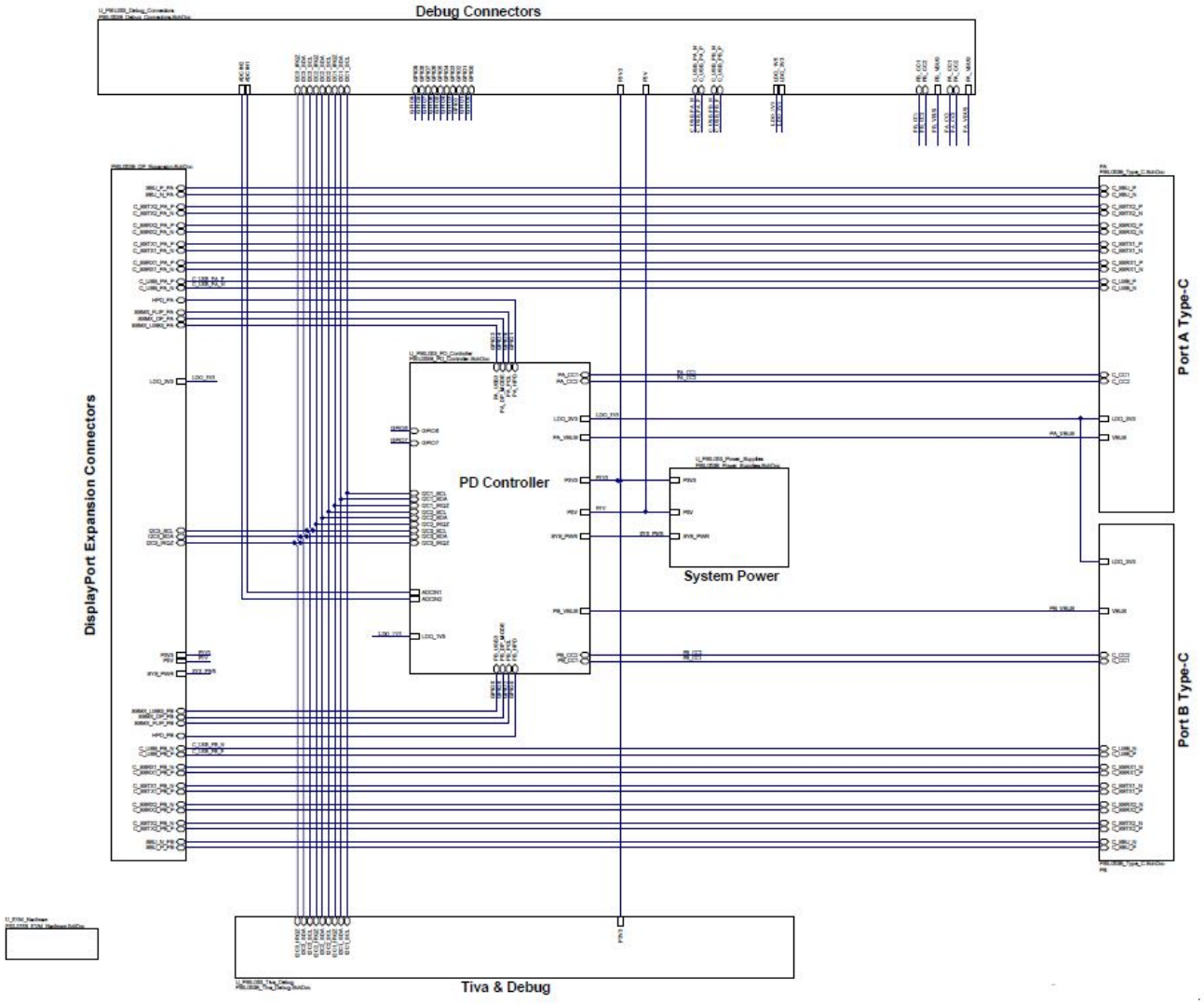


Figure 9-1. TPS65994EVM Block Diagram

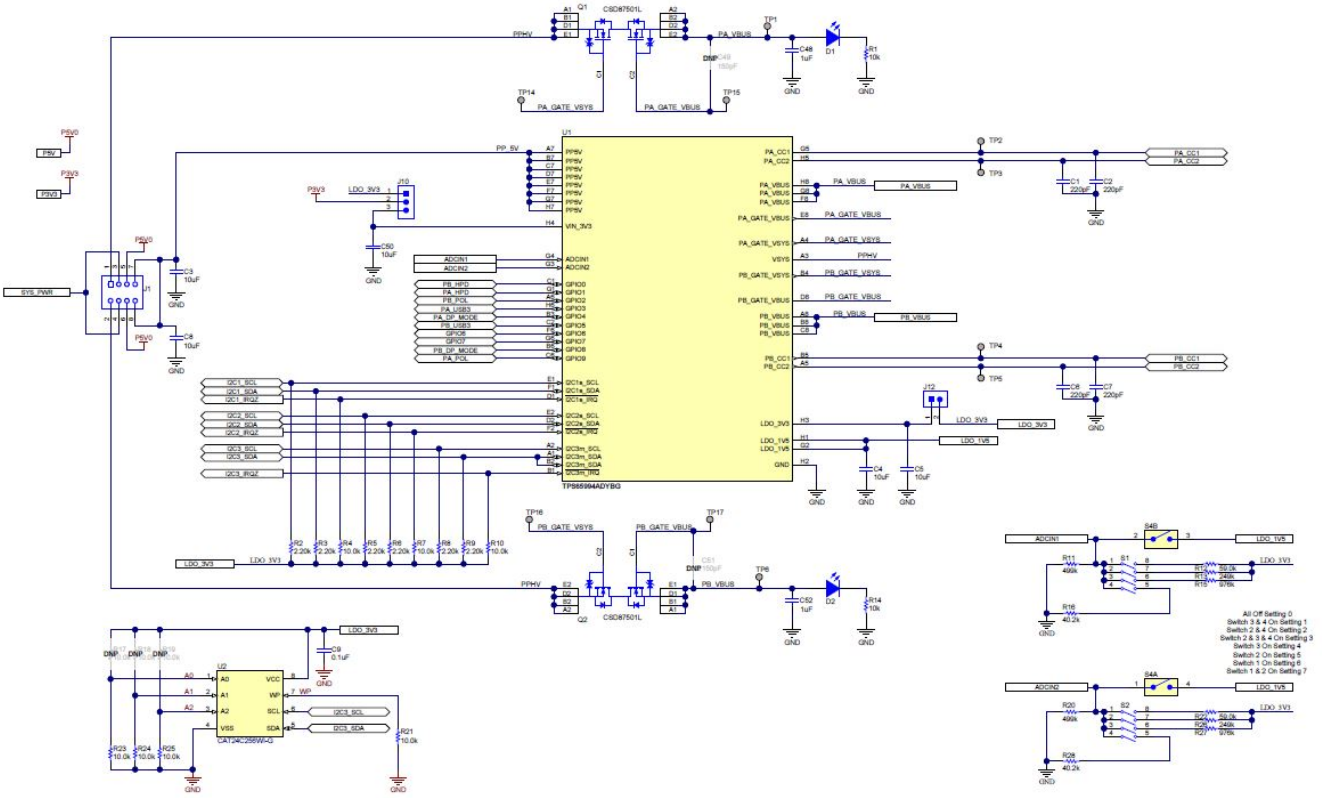


Figure 9-2. TPS65994EVM PD Controller

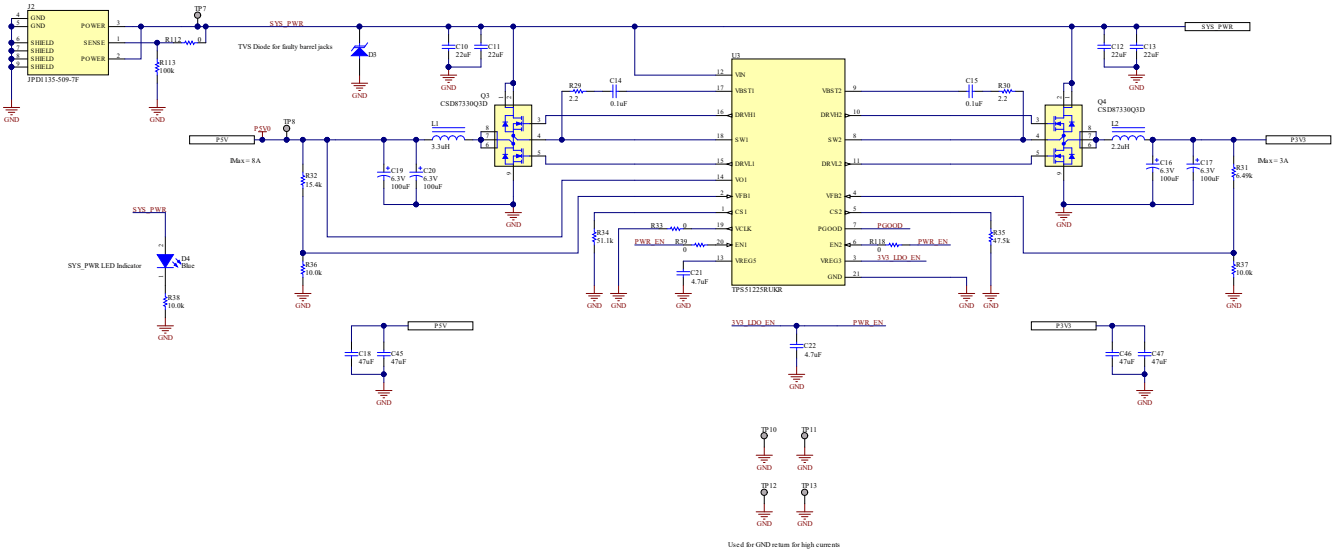
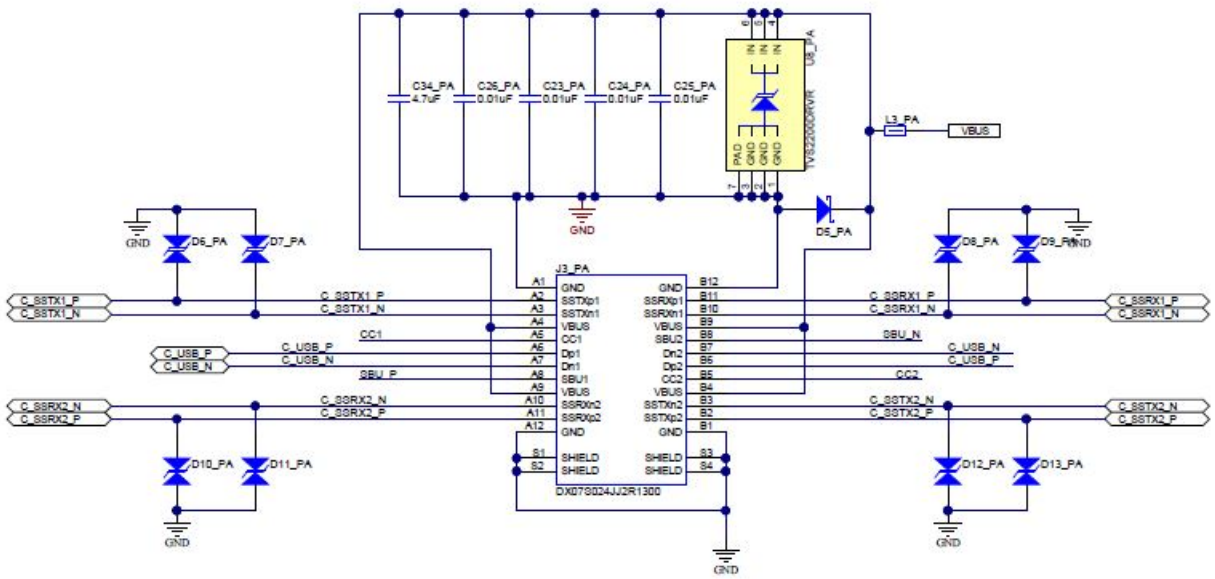
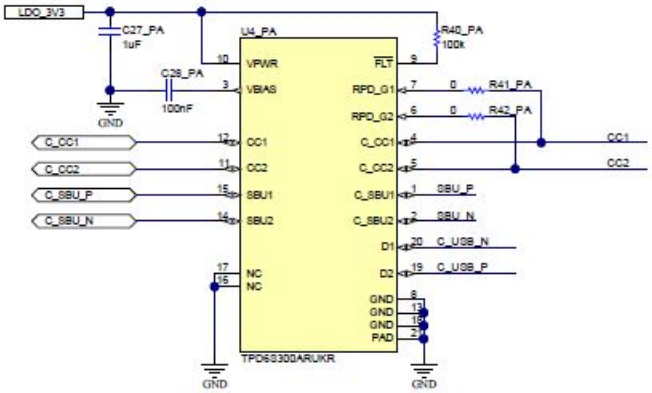


Figure 9-3. TPS65994EVM Power Supplies





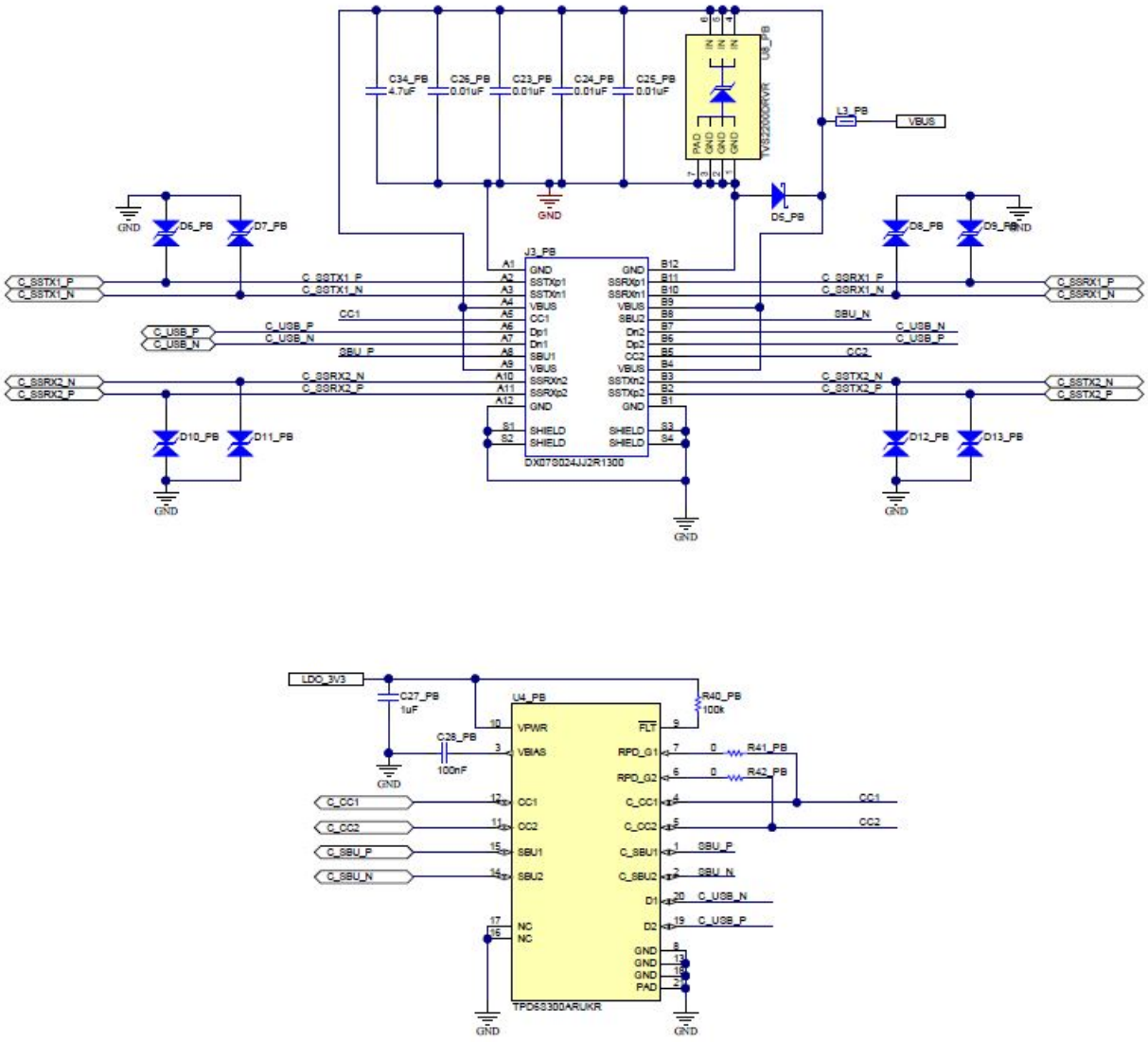


Figure 9-4. TPS65994EVM USB Type-C™ Connector

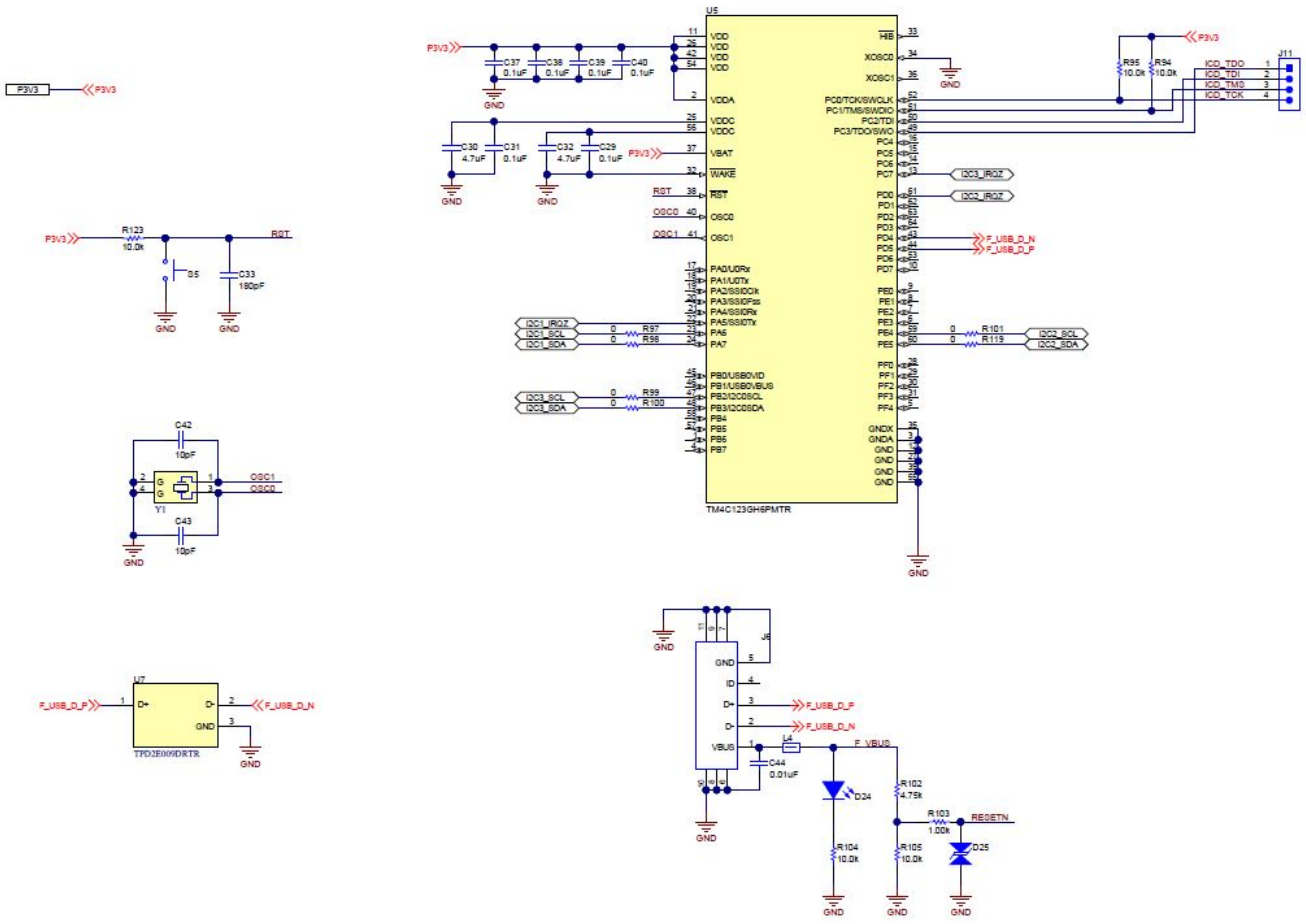


Figure 9-5. TPS65994EVM Tiva Debug

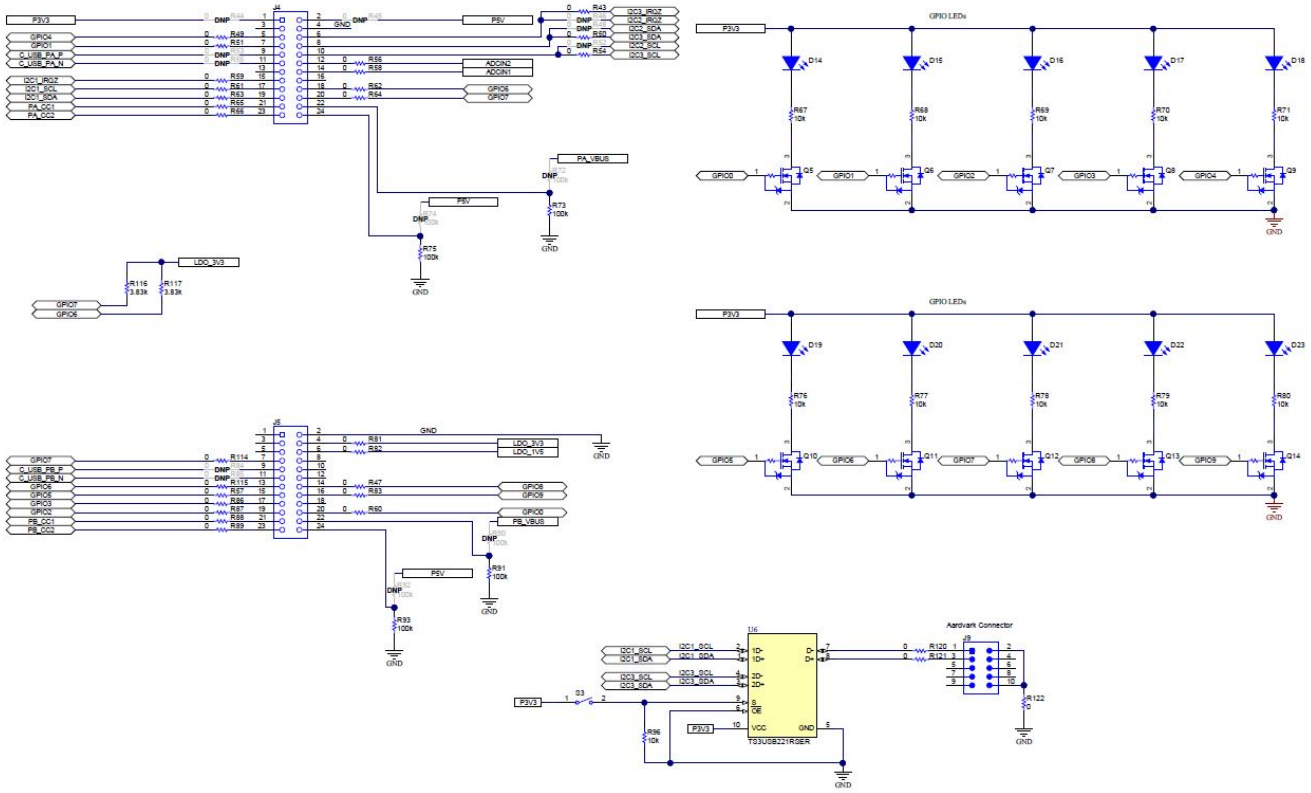


Figure 9-6. TPS65994EVM Connectors

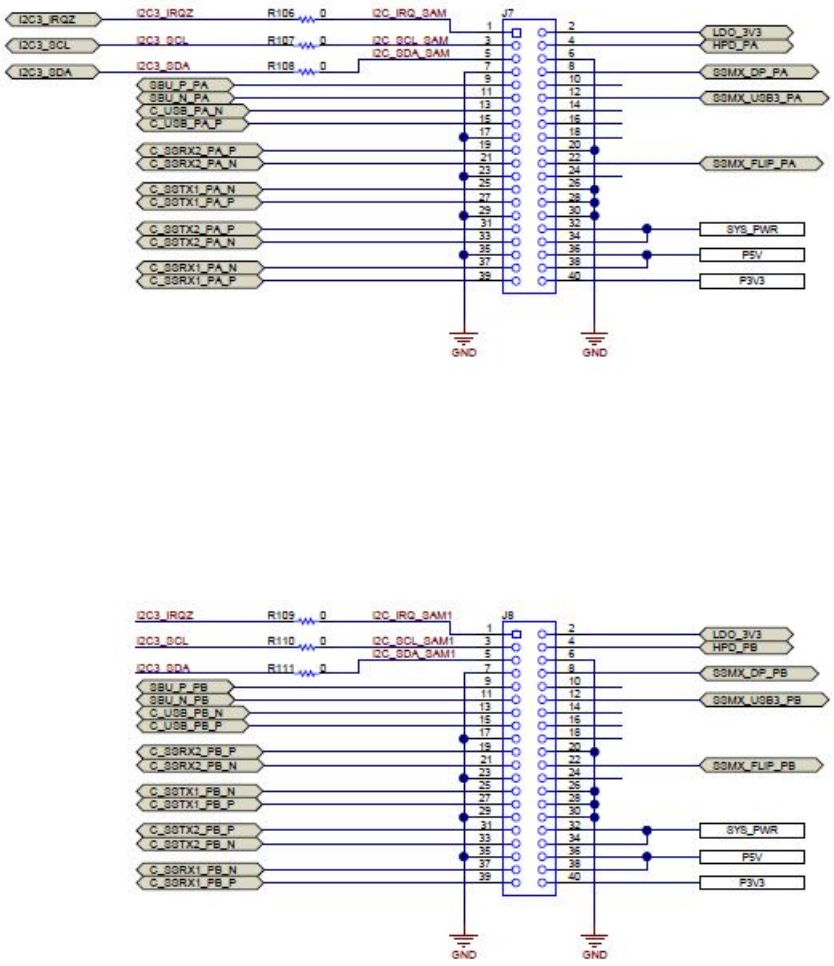


Figure 9-7. TPS65994EVM Expansion Connector

10 TPS65994EVM Board Layout

Figure 10-1 through Figure 10-10 show the TPS65994EVM board layout images.

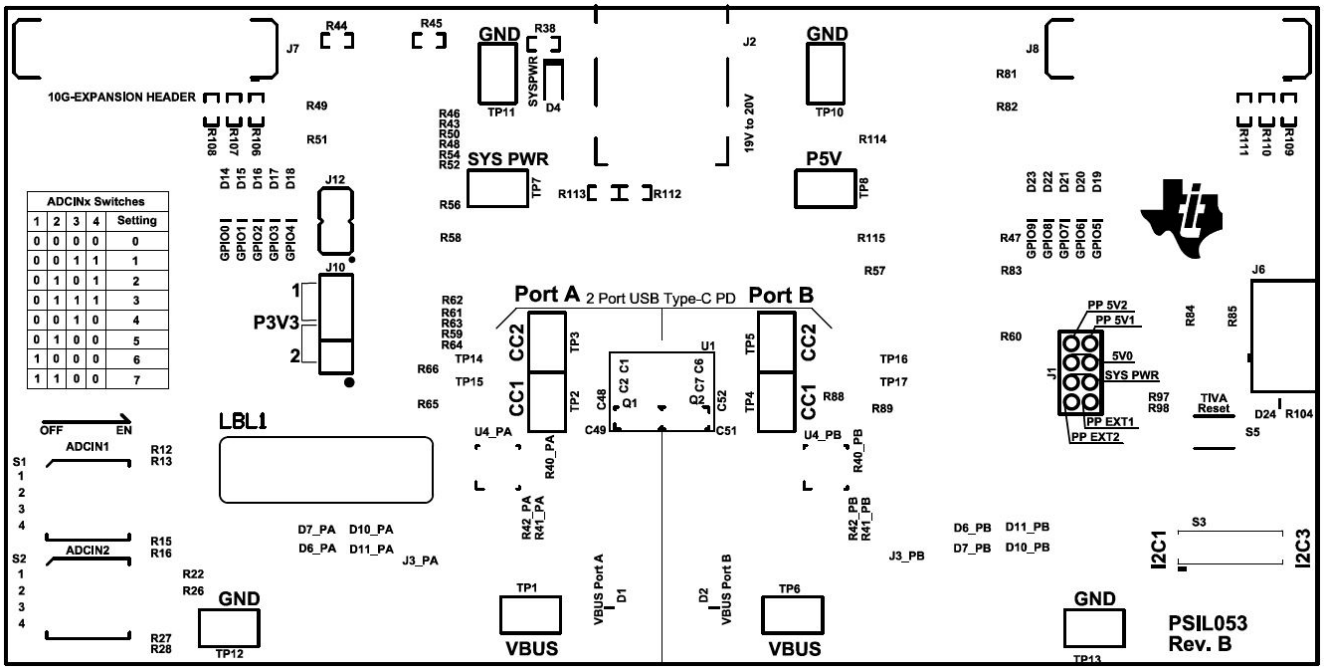


Figure 10-1. TPS65994EVM Top Silk Screen

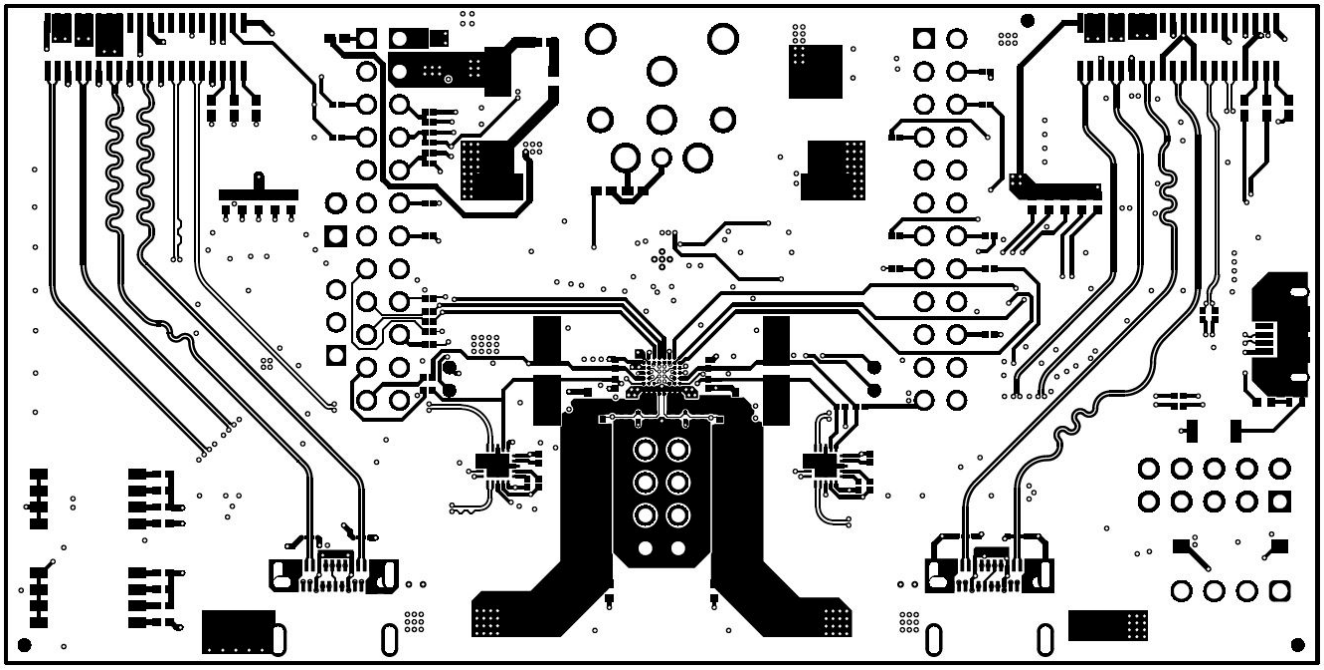


Figure 10-2. TPS65994EVM Top Layer

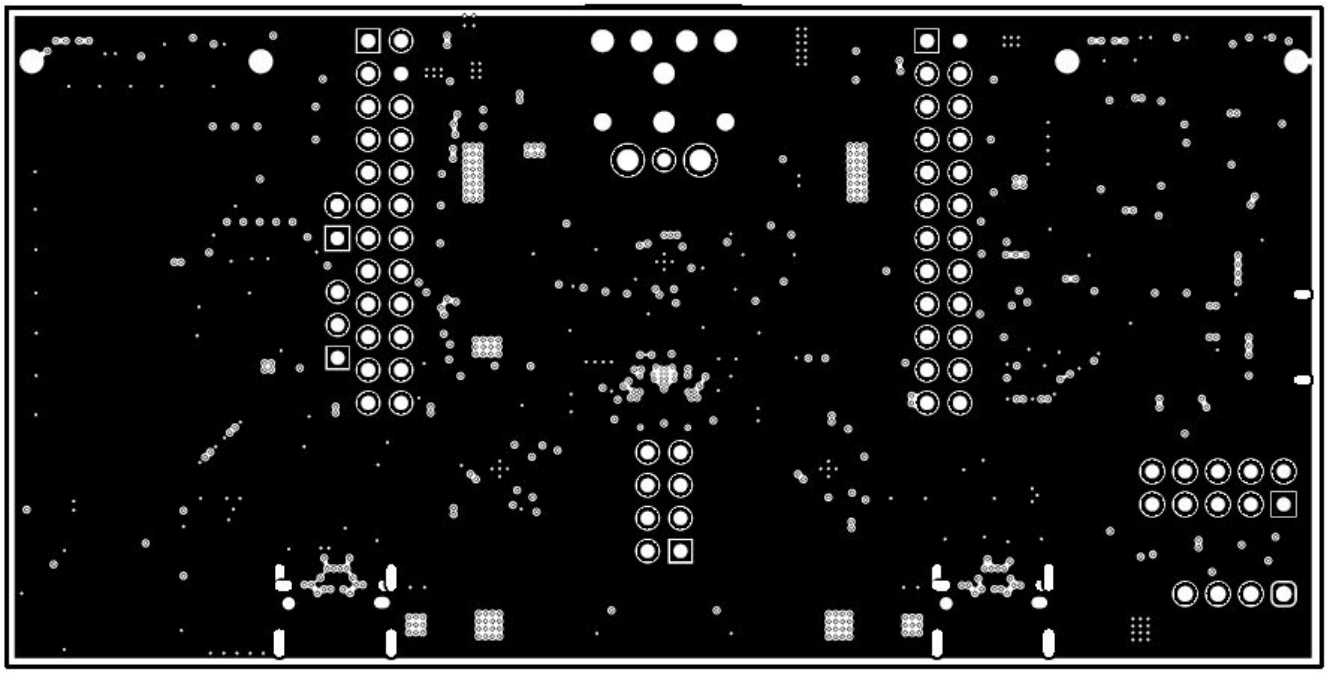


Figure 10-3. TPS65994EVM GND Plane 1

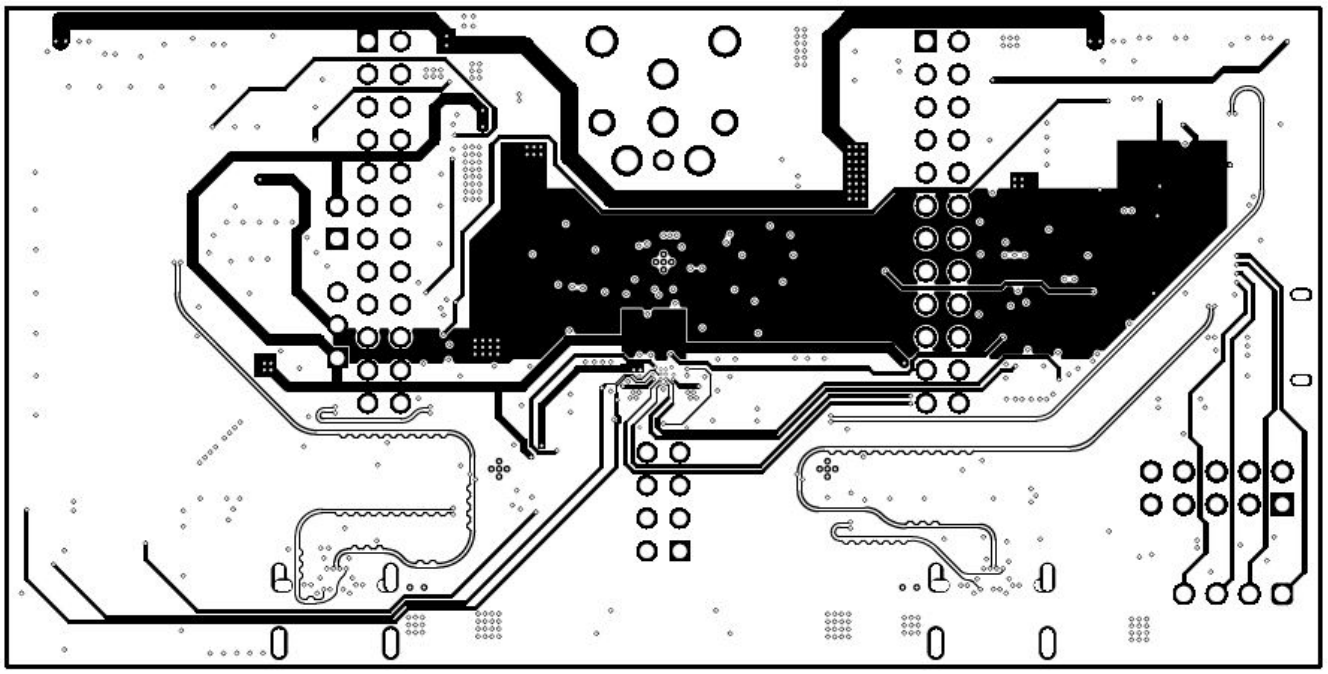


Figure 10-4. TPS65994EVM High Speed Layer

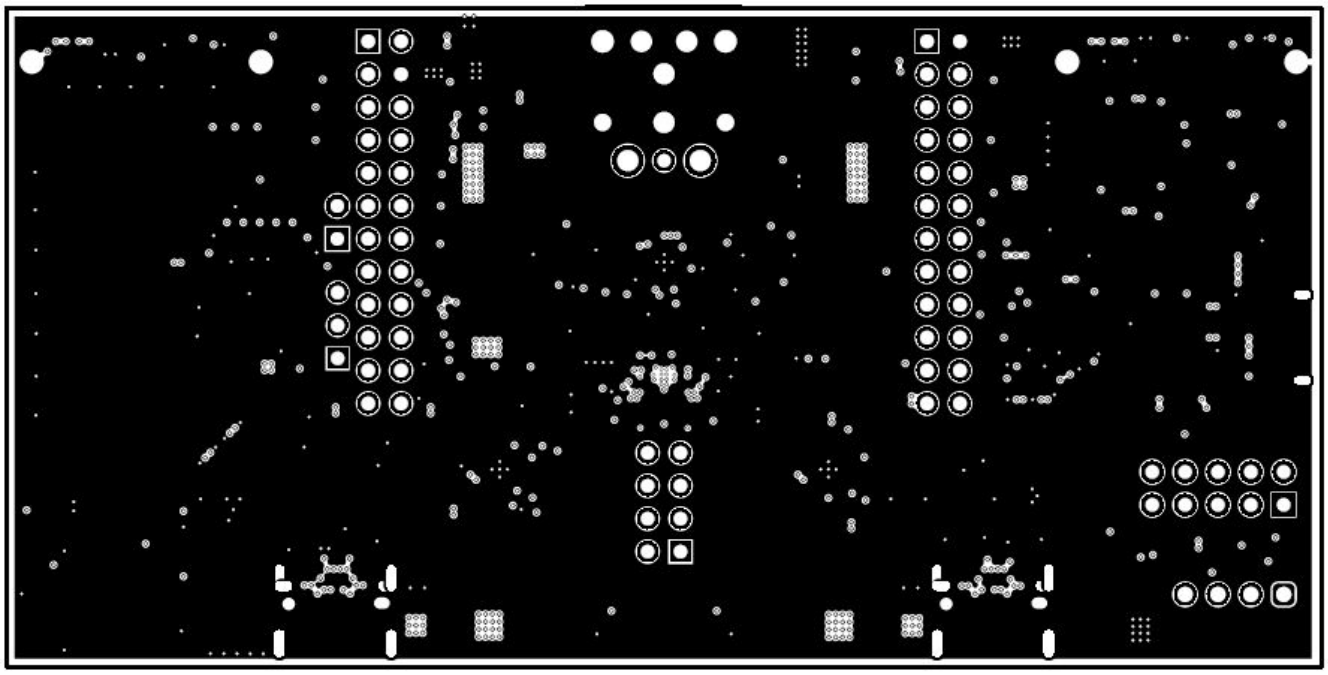


Figure 10-5. TPS65994EVM GND Plane 2

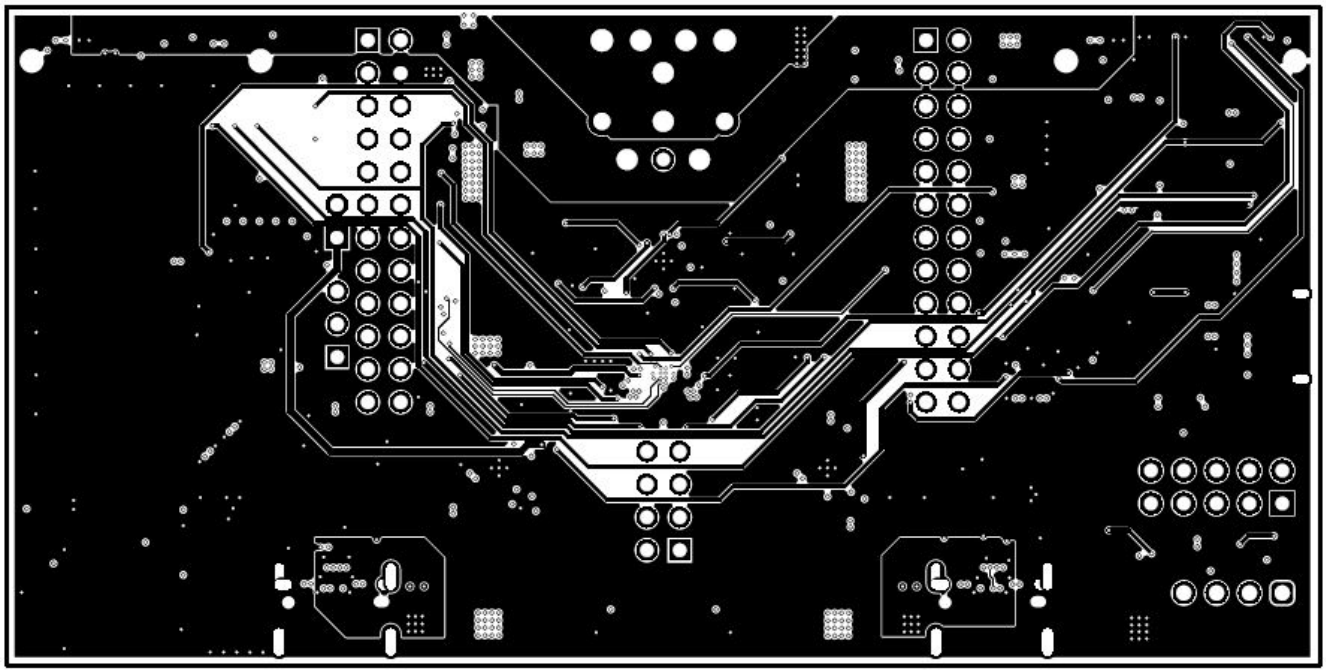


Figure 10-6. TPS65994EVM Power 1 Layer

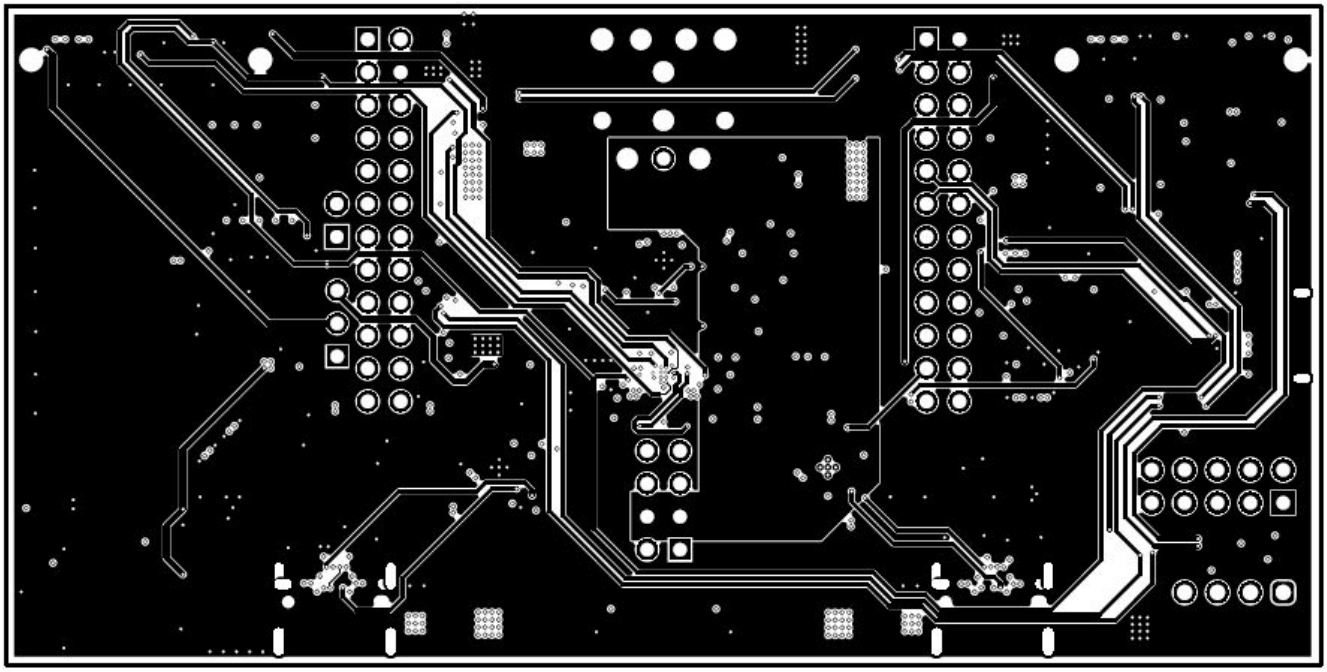


Figure 10-7. TPS65994EVM Power 2 Layer

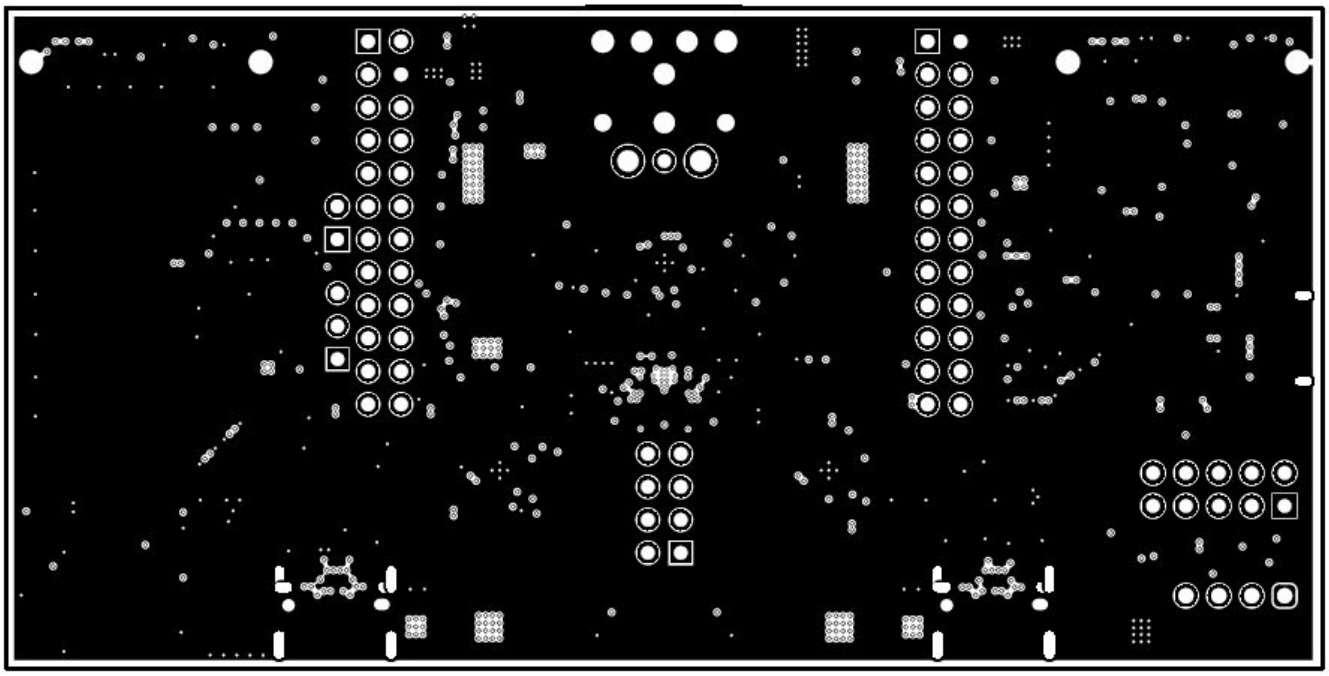


Figure 10-8. TPS65994EVM GND Plane 3

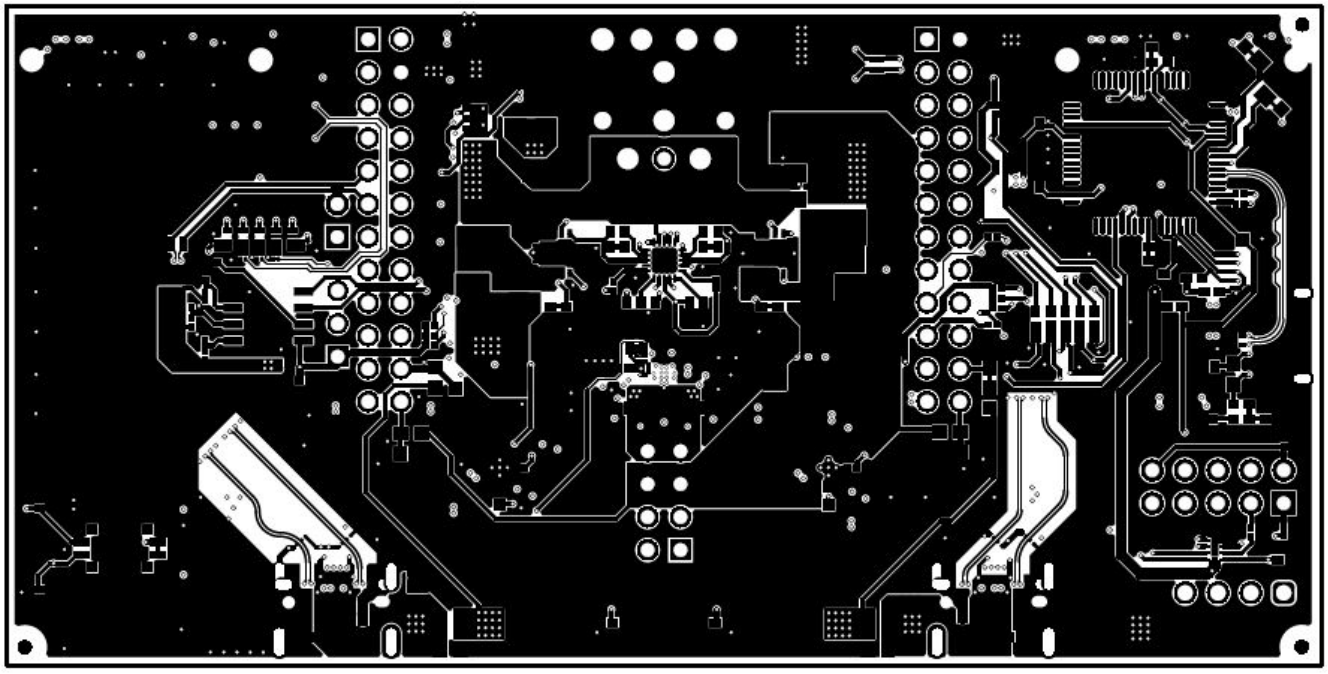


Figure 10-9. TPS65994EVM Bottom Layer

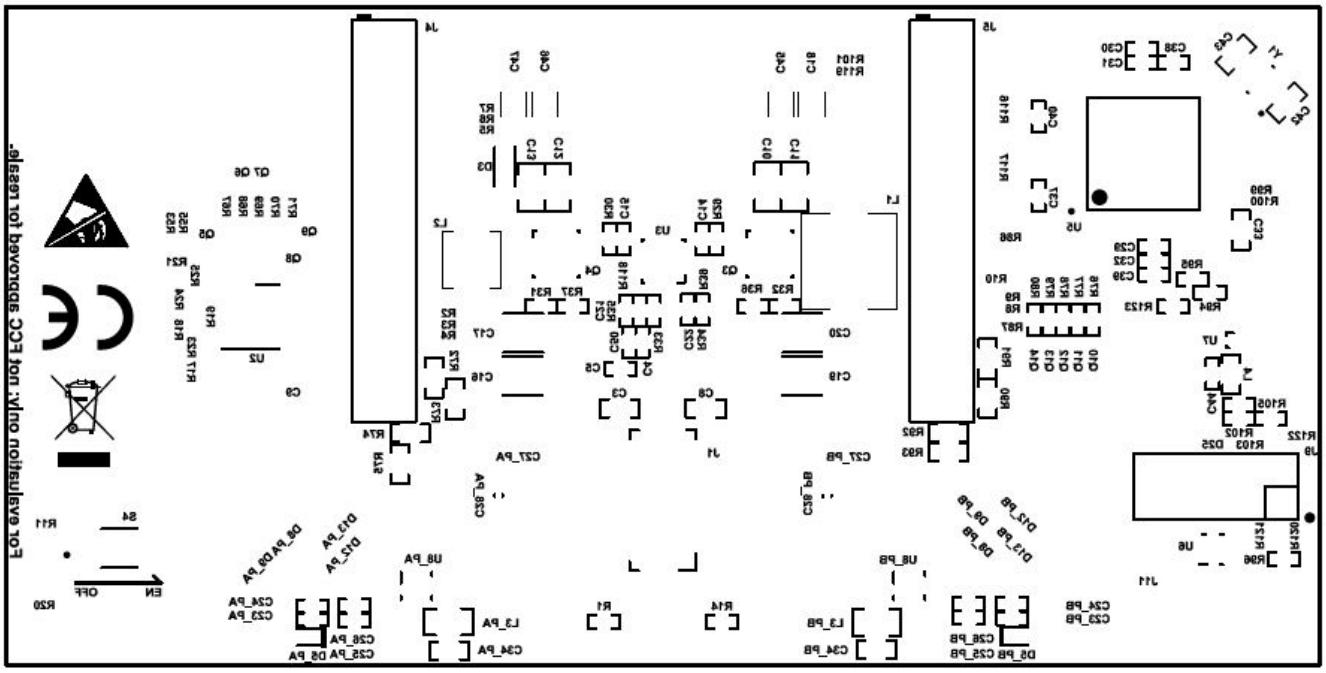


Figure 10-10. TPS65994EVM Bottom Silk Screen

11 TPS65994EVM Bill of Materials

Table 11-1 lists the TPS65994EVM bill of materials.

Table 11-1. TPS65994EVM BOM

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		PSIL053	Any
C1, C2, C6, C7	4	220pF	CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0201	0201	CGA1A2X7R1H221K030BA	TDK
C3, C8	2	10uF	CAP, CERM, 10 uF, 25 V, +/- 20%, X5R, 0603	0603	GRM188R61E106MA73D	MuRata
C4, C5, C50	3	10uF	CAP, CERM, 10 uF, 10 V, +/- 20%, X5R, 0402	0402	CL05A106MP5NUNC	Samsung Electro-Mechanics
C9, C29, C31, C37, C38, C39, C40	7	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0402	0402	C1005X7R1H104K050BB	TDK
C10, C11, C12, C13	4	22uF	CAP, CERM, 22 uF, 35 V, +/- 20%, X5R, 0805	0805	C2012X5R1V226M125AC	TDK
C14, C15	2	0.1uF	CAP, CERM, 0.1 uF, 35 V, +/- 10%, X5R, 0402	0402	GMK105BJ104KV-F	Taiyo Yuden
C16, C17, C19, C20	4	100uF	CAP, TA, 100 uF, 6.3 V, +/- 20%, 0.015 ohm, SMD	3528-21	T520B107M006ATE015	Kemet
C18, C45, C46, C47	4	47uF	CAP, CERM, 47 uF, 10 V, +/- 20%, X5R, 1206	1206	C3216X5R1A476M160AB	TDK
C21, C22	2	4.7uF	CAP, CERM, 4.7 uF, 6.3 V, +/- 20%, X5R, 0402	0402	GRM155R60J475ME87D	MuRata
C23_PA, C23_PB, C24_PA, C24_PB, C25_PA, C25_PB, C26_PA, C26_PB, C44	9	0.01uF	CAP, CERM, 0.01 uF, 50 V, +/- 5%, X7R, 0402	0402	C0402C103J5RACTU	Kemet
C27_PA, C27_PB	2	1uF	CAP, CERM, 1 uF, 6.3 V, +/- 20%, X5R, 0201	0201	GRM033R60J105MEA2D	MuRata
C28_PA, C28_PB	2	0.1uF	CAP, CERM, 0.1 uF, 100 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCJ188R72A104KA01D	MuRata
C30, C32	2	4.7uF	CAP, CERM, 4.7 uF, 10 V, +/- 20%, X5R, 0402	0402	C1005X5R1A475M050BC	TDK
C33	1	180pF	CAP, CERM, 180 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	06035A181JAT2A	AVX
C34_PA, C34_PB	2	4.7uF	CAP, CERM, 4.7 uF, 35 V, +/- 10%, X5R, 0603	0603	GRM188R6YA475KE15D	MuRata
C42, C43	2	10pF	CAP, CERM, 10 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	06035A100JAT2A	AVX
C48, C52	2	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X5R, 0402	0402	GRM155R6YA105KE11D	MuRata
D1, D2, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24	13	White	LED, White, SMD	0402, White	LW QH8G-Q2S2-3K5L-1	OSRAM
D3	1	24V	Diode, TVS, Bi, 24 V, 70 Vc, SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	PESD24VL1BA,115	NXP Semiconductor
D4	1	Blue	LED, Blue, SMD	LED_0603	150060BS75000	Wurth Elektronik
D5_PA, D5_PB	2	30V	Diode, Schottky, 30 V, 2 A, 2-XFDFN	2-XFDFN	NSR20F30NXT5G	ON Semiconductor
D6_PA, D6_PB, D7_PA, D7_PB, D8_PA, D8_PB, D9_PA, D9_PB, D10_PA, D10_PB, D11_PA, D11_PB, D12_PA, D12_PB, D13_PA, D13_PB	16		1-Channel ESD Protection Diode for USB Type-C and Thunderbolt 3, DPL0002A (X2SON-2)	DPL0002A	TPD1E01B04DPLR	Texas Instruments

Table 11-1. TPS65994EVM BOM (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
D25	1		1-Channel ESD Protection Diode With Low Dynamic Resistance and Low Clamping Voltage, DPY0002A (X1SON-2)	DPY0002A	TPD1E1B04DPYR	Texas Instruments
J1	1		Receptacle, 2.54mm, 4x2, Gold, TH	Receptacle, 2.54mm, 4x2, TH	SSQ-104-03-G-D	Samtec
J2	1		Connector, DC Power Jack, R/A, 3 Pos, TH	Power connector	JPD1135-509-7F	Foxconn
J3_PA, J3_PB	2		Receptacle, USB 3.1 Type C, R/A, Gold, SMT	Receptacle, USB 3.1 Type C, R/A, SMT	DX07S024JJ2R1300	JAE Electronics
J4, J5	2		Receptacle, 12x2, 2.54mm, Gold, TH	Receptacle, 12x2, 2.54mm, TH	SSW-112-01-G-D	Samtec
J6	1		Connector, Receptacle, USB Micro B, R/A, SMT	Connector, Receptacle, USB Micro B, R/A, SMT	10118193-0001LF	FCI
J7, J8	2		Socket, 0.8mm, 20x2, Gold, SMT	Socket, 0.8mm, 20x2, Gold, SMT	LSEM-120-03.0-F-DV-A-N-K-TR	Samtec
J9	1		Header, 100mil, 5x2, Tin, TH	Header, 5x2, 100mil, Tin	PEC05DAAN	Sullins Connector Solutions
J10	1		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
J11	1		Header, 2.54 mm, 4x1, Gold, TH	Header, 2.54mm, 4x1, TH	61300411121	Wurth Elektronik
J12	1		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
L1	1	3.3uH	Inductor, Shielded Drum Core, Superflux, 3.3 uH, 8 A, 0.0096 ohm, SMD	6.9x4.8x6.9mm	744314330	Wurth Elektronik
L2	1	2.2uH	Inductor, Shielded Drum Core, Powdered Iron, 2.2 uH, 3.25 A, 0.051 ohm, SMD	4.45x1.8x4.06mm	74437324022	Wurth Elektronik
L3_PA, L3_PB	2	22 ohm	Ferrite Bead, 22 ohm @ 100 MHz, 6 A, 0805	0805	742792021	Wurth Elektronik
L4	1	26 ohm	Ferrite Bead, 26 ohm @ 100 MHz, 6.5 A, 0603	0603	74279228260	Wurth Elektronik
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1, Q2	2	30V	MOSFET, 2-CH, N-CH, 30 V, A, YJG0010A (PICOSTAR-10)	YJG0010A	CSD87501L	Texas Instruments
Q3, Q4	2	30V	MOSFET, 2-CH, N-CH, 30 V, 20 A, DQZ0008A (LSON-CLIP-8)	DQZ0008A	CSD87330Q3D	Texas Instruments
Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14	10	20V	MOSFET, N-CH, 20 V, 0.5 A, YJM0003A (PICOSTAR-3)	YJM0003A	CSD15380F3	Texas Instruments
R1, R14, R67, R68, R69, R70, R71, R76, R77, R78, R79, R80, R96	13	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R2, R3, R5, R6, R8, R9	6	2.20k	RES, 2.20 k, 1%, 0.05 W, 0201	0201	CRCW02012K20FKED	Vishay-Dale
R4, R7, R10, R21, R23, R24, R25	7	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale
R11, R20	2	499k	RES, 499 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402499KFKED	Vishay-Dale
R12, R22	2	59.0k	RES, 59.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040259K0FKED	Vishay-Dale
R13, R26	2	249k	RES, 249 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402249KFKED	Vishay-Dale
R15, R27	2	976k	RES, 976 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402976KFKED	Vishay-Dale
R16, R28	2	40.2k	RES, 40.2 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040240K2FKED	Vishay-Dale

Table 11-1. TPS65994EVM BOM (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
R29, R30	2	2.2	RES, 2.2, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022R20JNED	Vishay-Dale
R31	1	6.49k	RES, 6.49 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04026K49FKED	Vishay-Dale
R32	1	15.4k	RES, 15.4 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040215K4FKED	Vishay-Dale
R34	1	51.1k	RES, 51.1 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040251K1FKED	Vishay-Dale
R35	1	47.5k	RES, 47.5 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040247K5FKED	Vishay-Dale
R36, R37, R38, R94, R95, R104, R105, R123	8	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R39, R41_PA, R41_PB, R42_PA, R42_PB, R43, R47, R49, R50, R51, R54, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R81, R82, R83, R86, R87, R88, R89, R97, R98, R99, R100, R101, R114, R115, R118, R119, R120, R121, R122	41	0	RES, 0, 5%, 0.05 W, 0201	0201	CRCW02010000Z0ED	Vishay-Dale
R40_PA, R40_PB	2	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale
R73, R75, R91, R93	4	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R102	1	4.75k	RES, 4.75 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04024K75FKED	Vishay-Dale
R103	1	1.00k	RES, 1.00 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K00FKED	Vishay-Dale
R106, R107, R108, R109, R110, R111	6	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R113	1	100k	RES, 100 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100KFKED	Vishay-Dale
R116, R117	2	3.83k	RES, 3.83 k, 1%, 0.05 W, 0201	0201	CRCW02013K83FKED	Vishay-Dale
S1, S2	2		DIP Switch, SPST 4Pos, Slide, SMT	6.2x2.0x6.2mm	TDA04H0SB1	C&K Components
S3	1		Switch, Slide, SPST, Top Slide, SMT	Switch, Single Top Slide, 2.5x8x2.5mm	CHS-01TB	Copal Electronics
S4	1		DIP Switch, SPST, 2Pos, Slide, SMT	SW, 4.7x1.45x3mm	CVS-02TB	Copal Electronics
S5	1		SWITCH TACTILE SPST-NO 0.05A 12V	3x1.6x2.5mm	B3U-1000P	Omron Electronic Components
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	6		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP10, TP11, TP12, TP13	12		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1		Dual Port USB Type-C and USB PD Controller with Integrated Source Power Switches	DSBGA50	TPS65994ADYBG	Texas Instruments
U2	1		256 kb I2C CMOS Serial EEPROM, SOIC-8	SOIC-8	CAT24C256WI-G	ON Semiconductor
U3	1		Dual Synchronous Step-Down Controller with 5-V and 3.3-V LDOs, RUK0020B (WQFN-20)	RUK0020B	TPS51225RUKR	Texas Instruments
U4_PA, U4_PB	2		USB Type-C Port Protector: Short-to-VBUS Overvoltage and IEC ESD Protection, RUK0020B (WQFN-20)	RUK0020B	TPD6S300ARUKR	Texas Instruments

Table 11-1. TPS65994EVM BOM (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U5	1		Tiva C Series Microcontroller, 256 KB Flash, 32 KB SRAM, 12 Bit, 12 Channels, -40 to 105 degC, 64-Pin LQFP (PM), Green (RoHS & no Sb/Br), Tape and Reel	PM0064A	TM4C123GH6PMTR	Texas Instruments
U6	1		High-Speed USB 2.0 (480 Mbps) 1:2 Multiplexer / Demultiplexer Switch with Single Enable, 6 ohm RON, 2.5 to 3.3V, -40 to 85 degC, 10-Pin UQFN (RSE), Green (RoHS & no Sb/Br)	RSE0010A	TS3USB221RSER	Texas Instruments
U7	1		ESD Protection Array for High-Speed Data Interfaces, 2 Channels, -40 to +85 degC, 3-pin SOT (DRT), Green (RoHS & no Sb/Br)	DRT0003A	TPD2E009DRTR	Texas Instruments
U8_PA, U8_PB	2		22-V Precision Surge Protection Clamp, DRV0006A (WSON-6)	DRV0006A	TVS2200DRVR	Texas Instruments
Y1	1		Crystal, 16 MHz, 8pF, SMD	3.2x0.75x2.5mm	NX3225GA-16.000M-STD-CRG-1	NDK
C49, C51	0	150pF	CAP, CERM, 150 pF, 50 V, +/- 10%, X7R, 0201	0201	GRM033R71H151KA12D	MuRata
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R17, R18, R19	0	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale
R33, R112	0	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R44, R45	0	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R46, R48, R52, R53, R55, R84, R85	0	0	RES, 0, 5%, 0.05 W, 0201	0201	CRCW02010000Z0ED	Vishay-Dale
R72, R74, R90, R92	0	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale

12 TPS65994QFNEVM Schematics

Figure 12-1 through Figure 12-7 illustrate the TPS65994QFNEVM schematics.

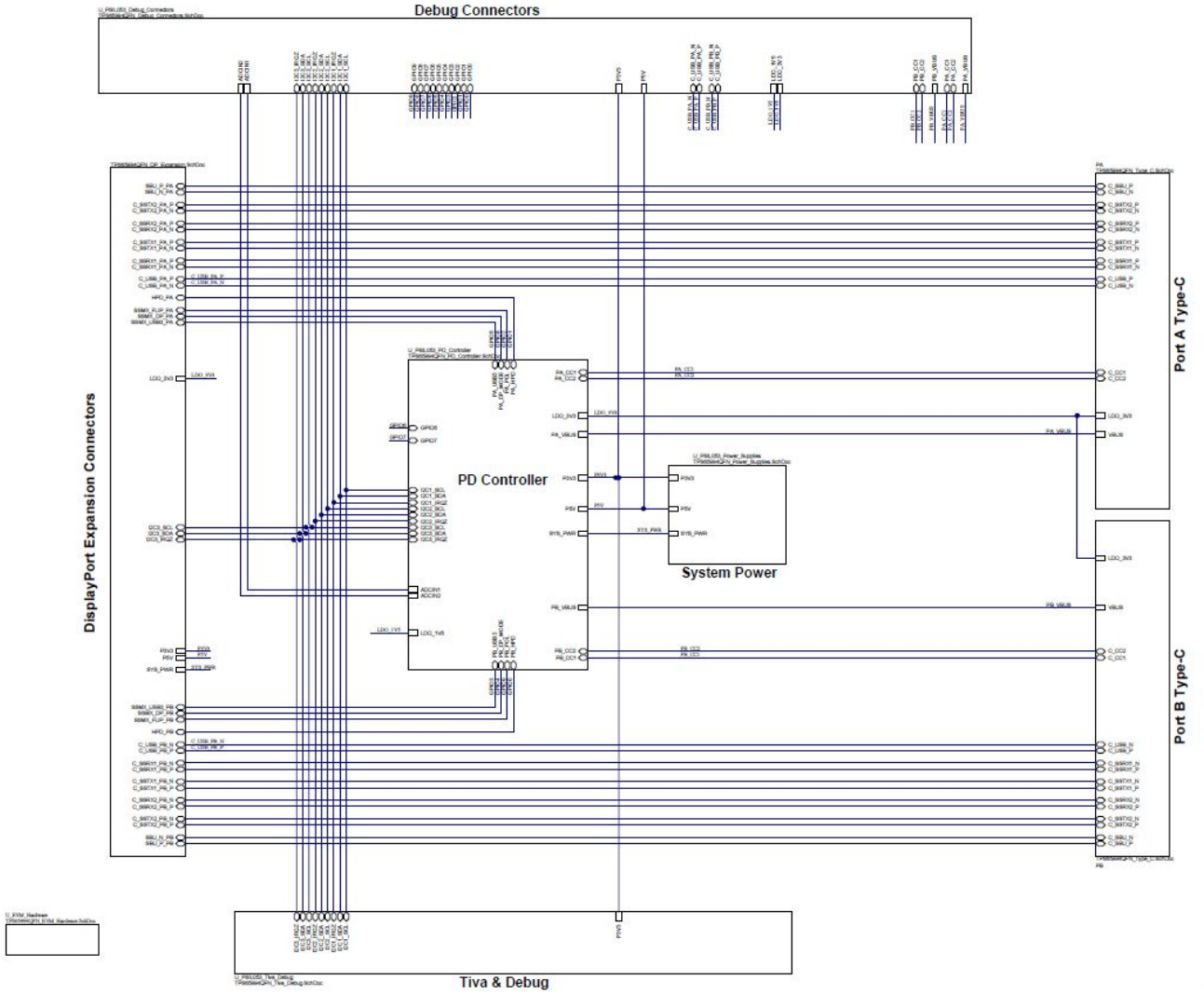


Figure 12-1. TPS65994QFNEVM Block Diagram

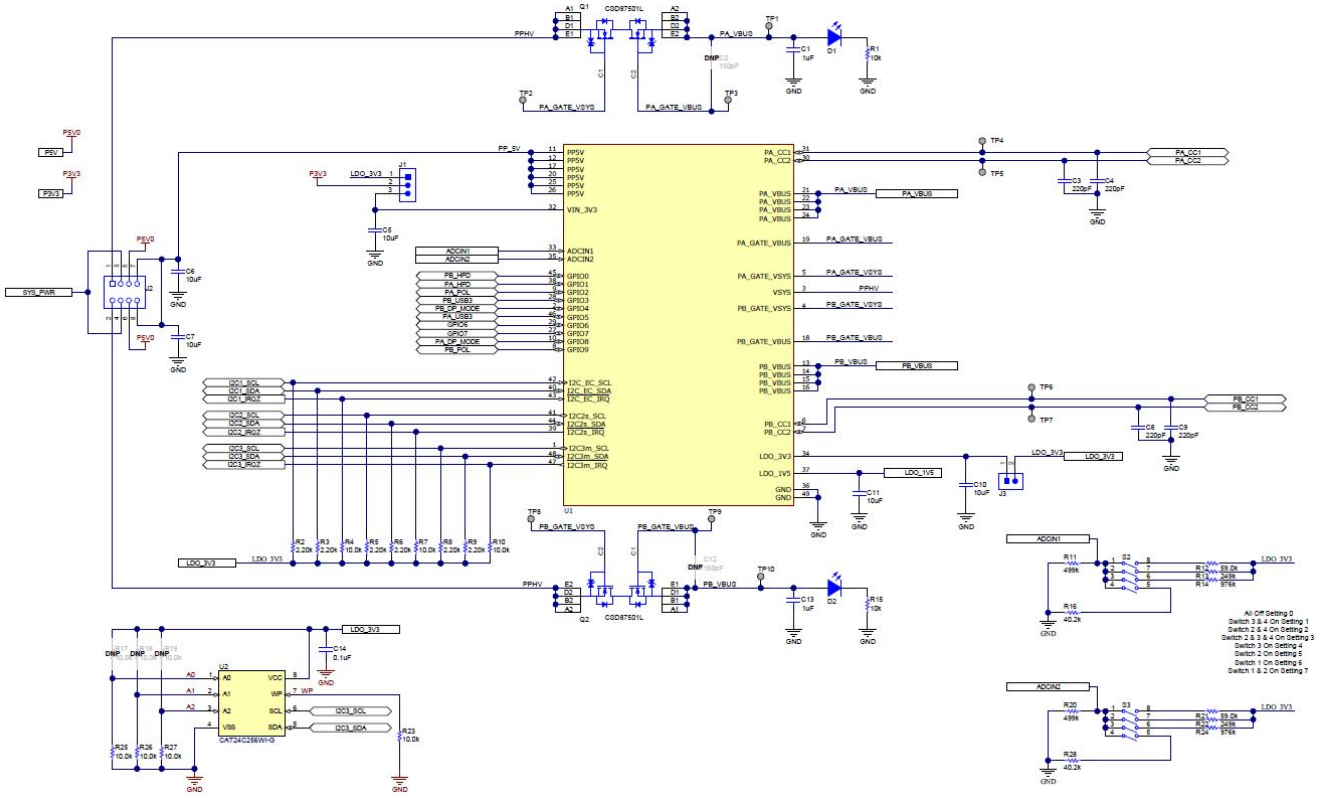


Figure 12-2. TPS65994QFNEVM PD Controller

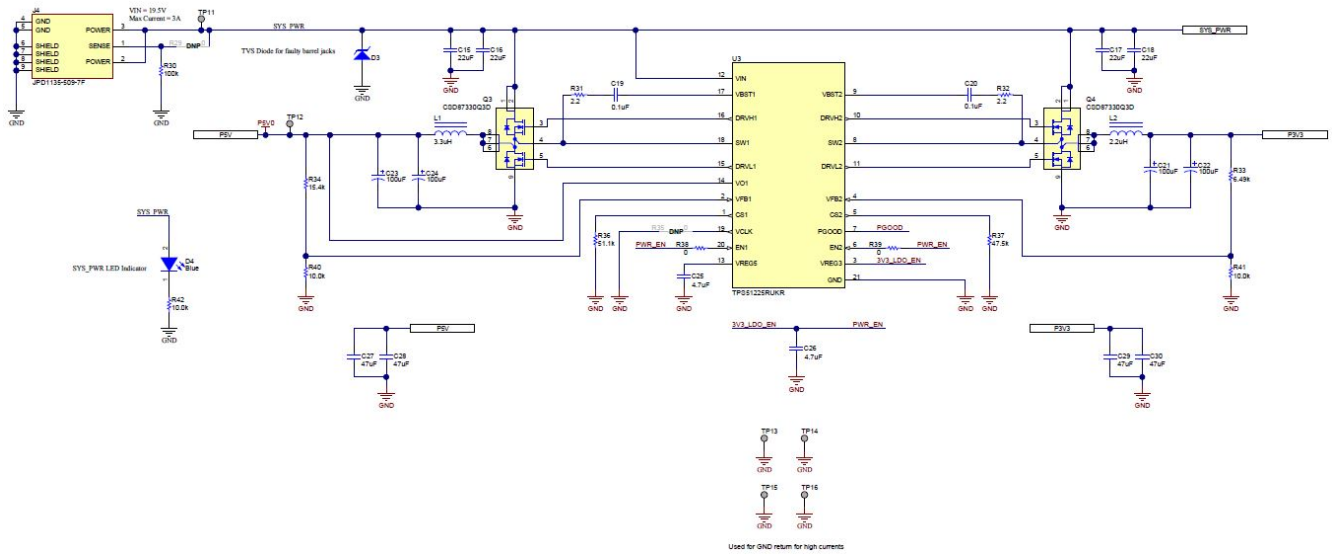
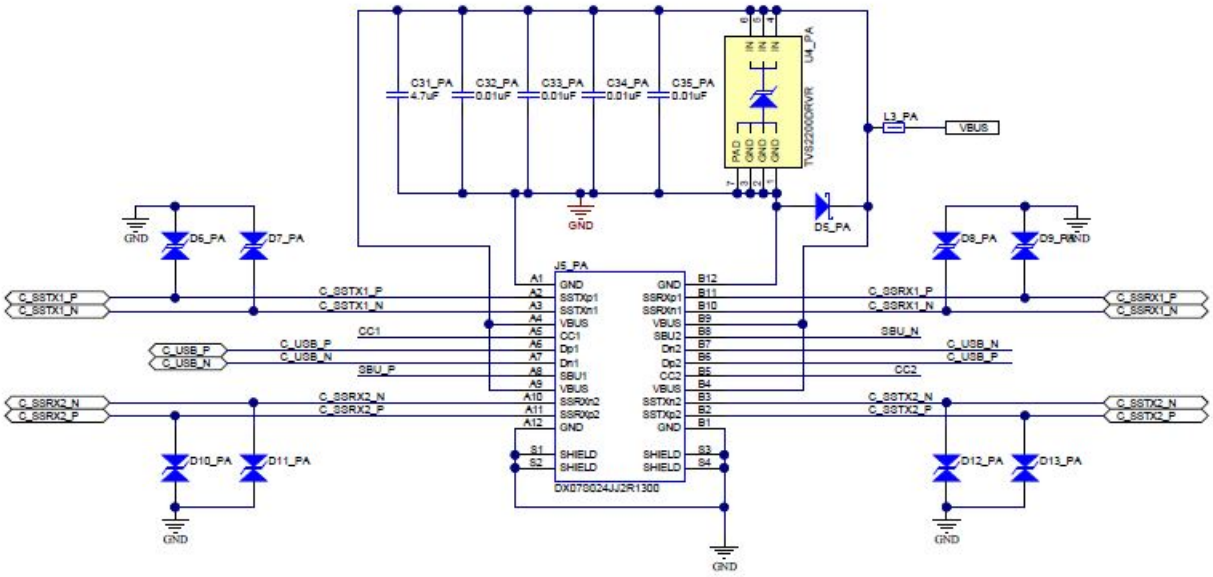
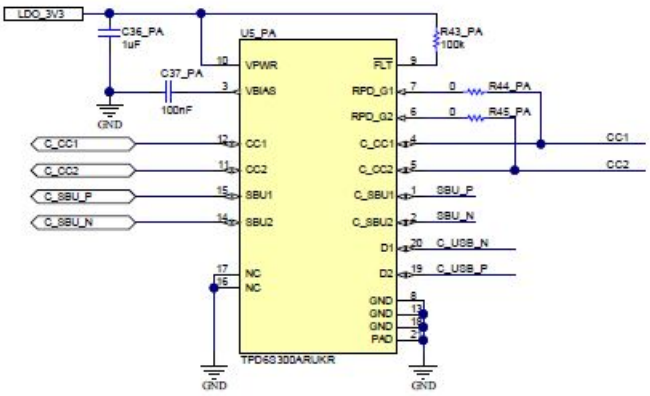


Figure 12-3. TPS65994QFNEVM Power Supplies





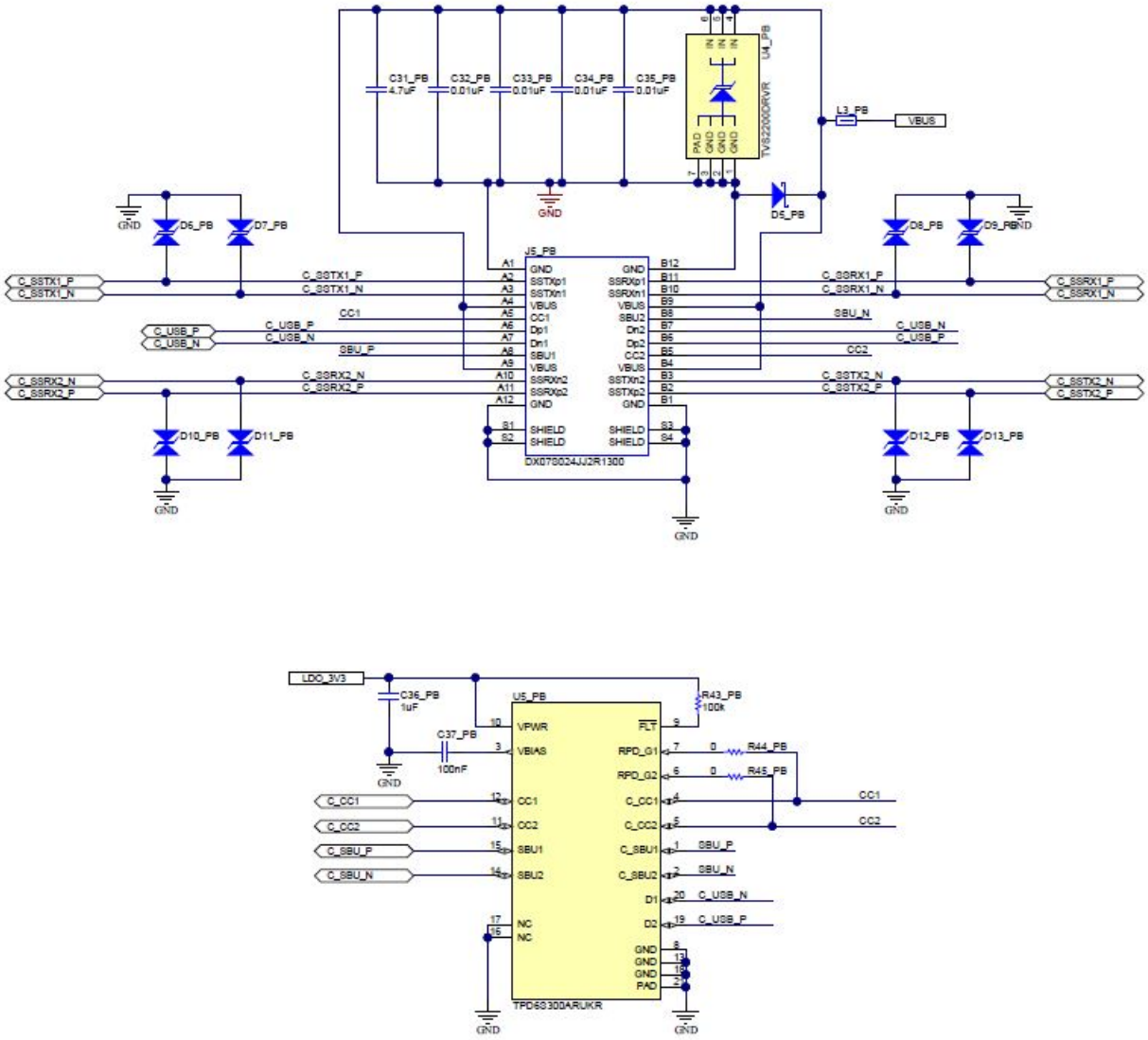


Figure 12-4. TPS65994QFNEVM USB Type-C™ Connector

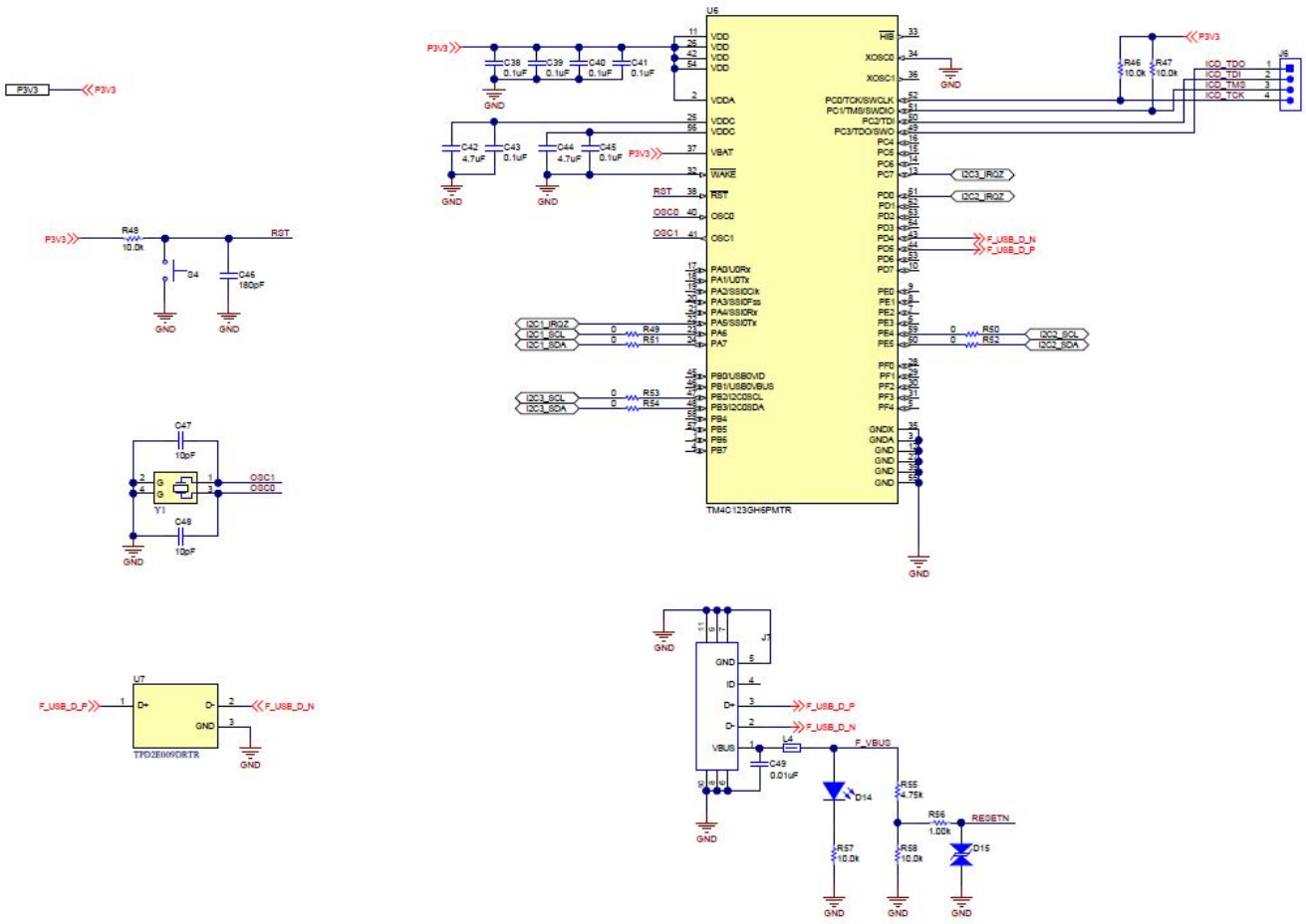


Figure 12-5. TPS65994QFNEVM Tiva Debug

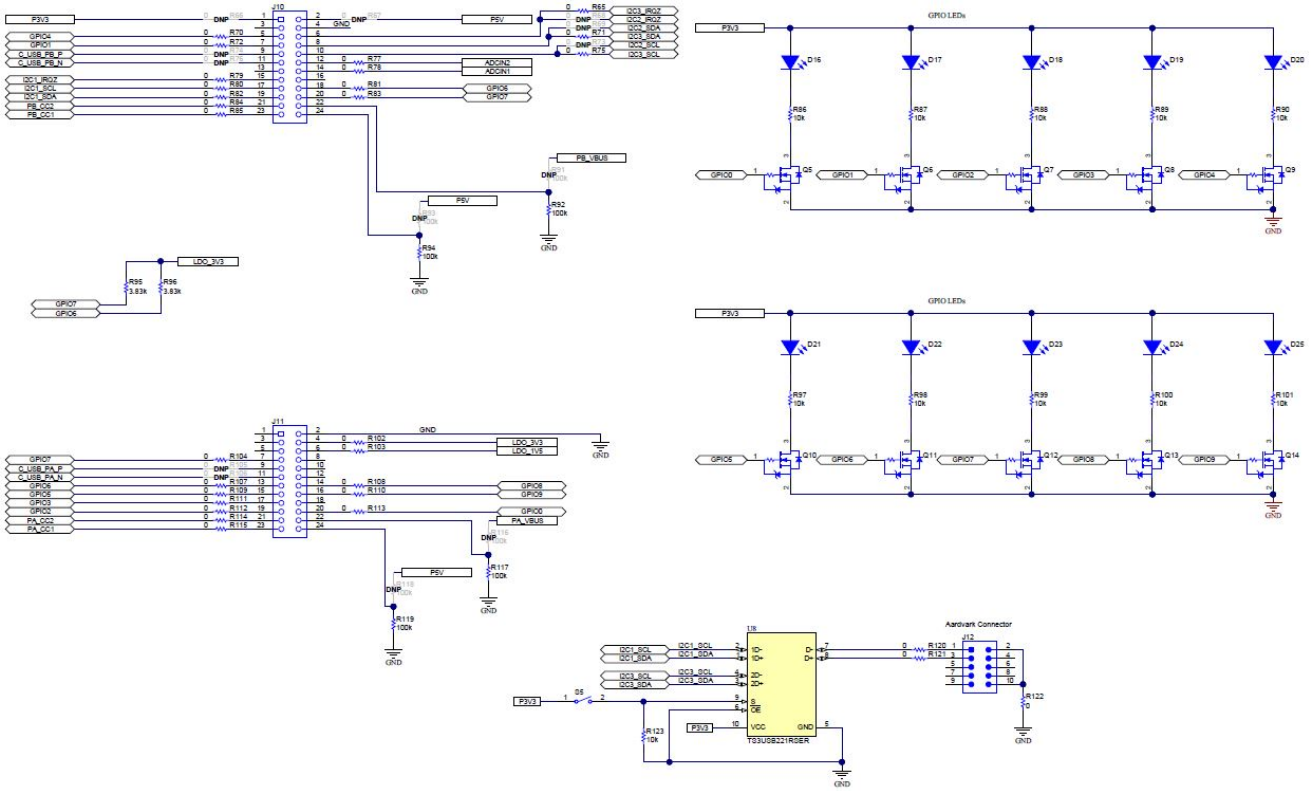


Figure 12-6. TPS65994QFNEVM Connectors

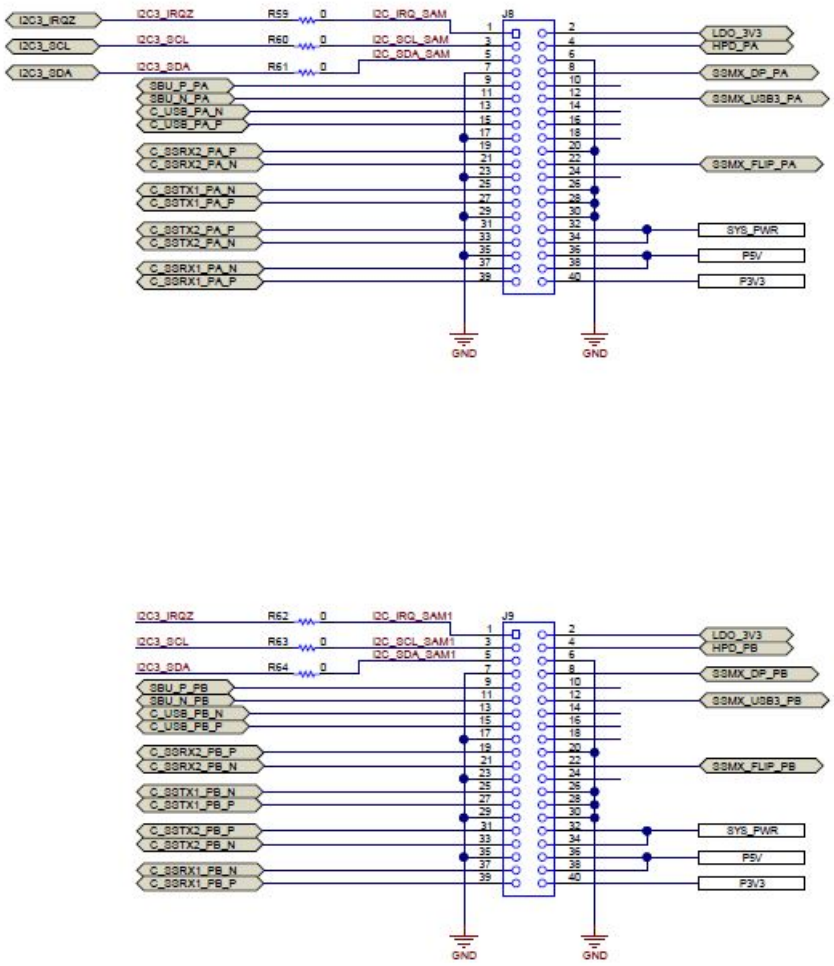


Figure 12-7. TPS65994QFNEVM Expansion Connector

13 TPS65994QFNEVM Board Layout

Figure 13-1 through Figure 13-10 show the TPS65994QFNEVM board layout images.

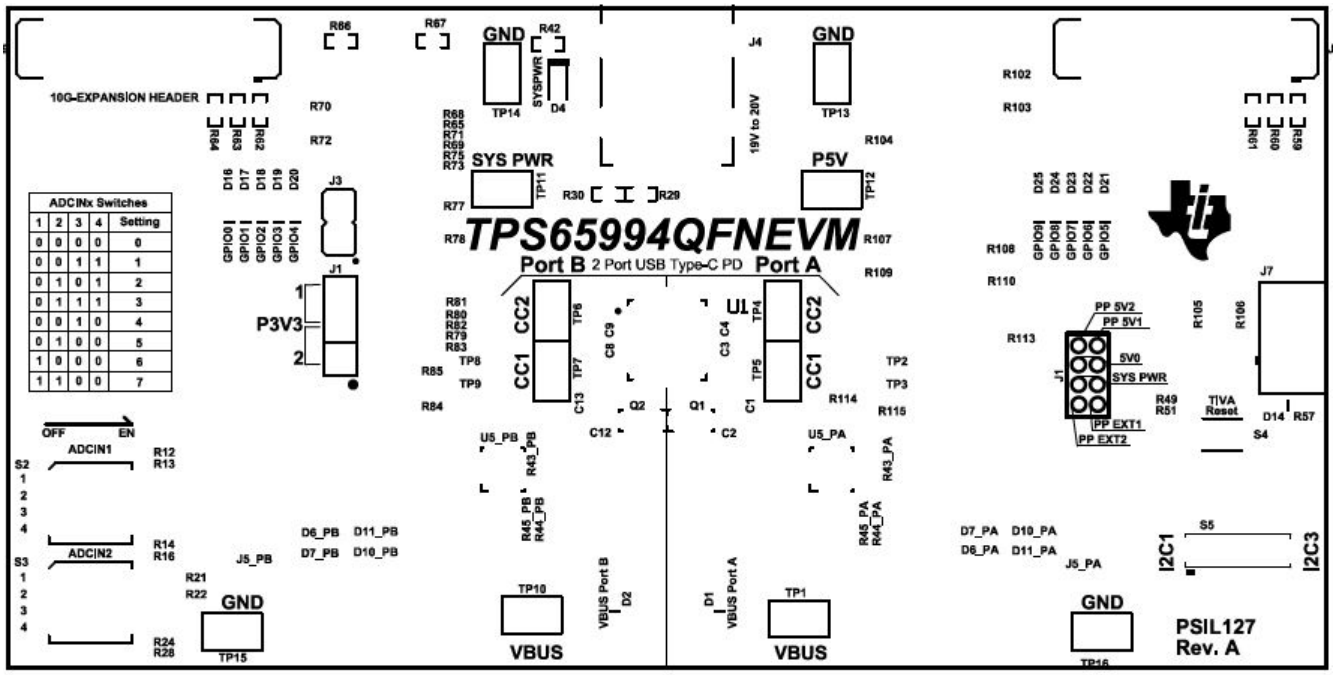


Figure 13-1. TPS65994QFNEVM Top Silk Screen

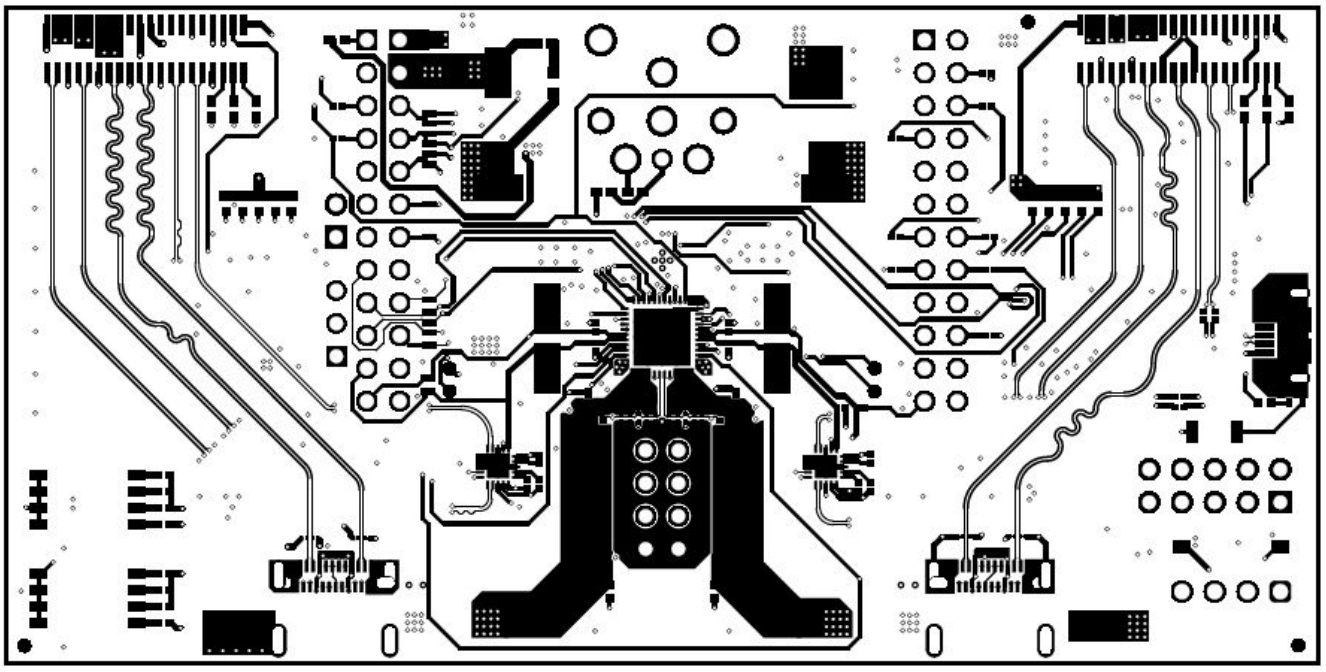


Figure 13-2. TPS65994QFNEVM Top Layer

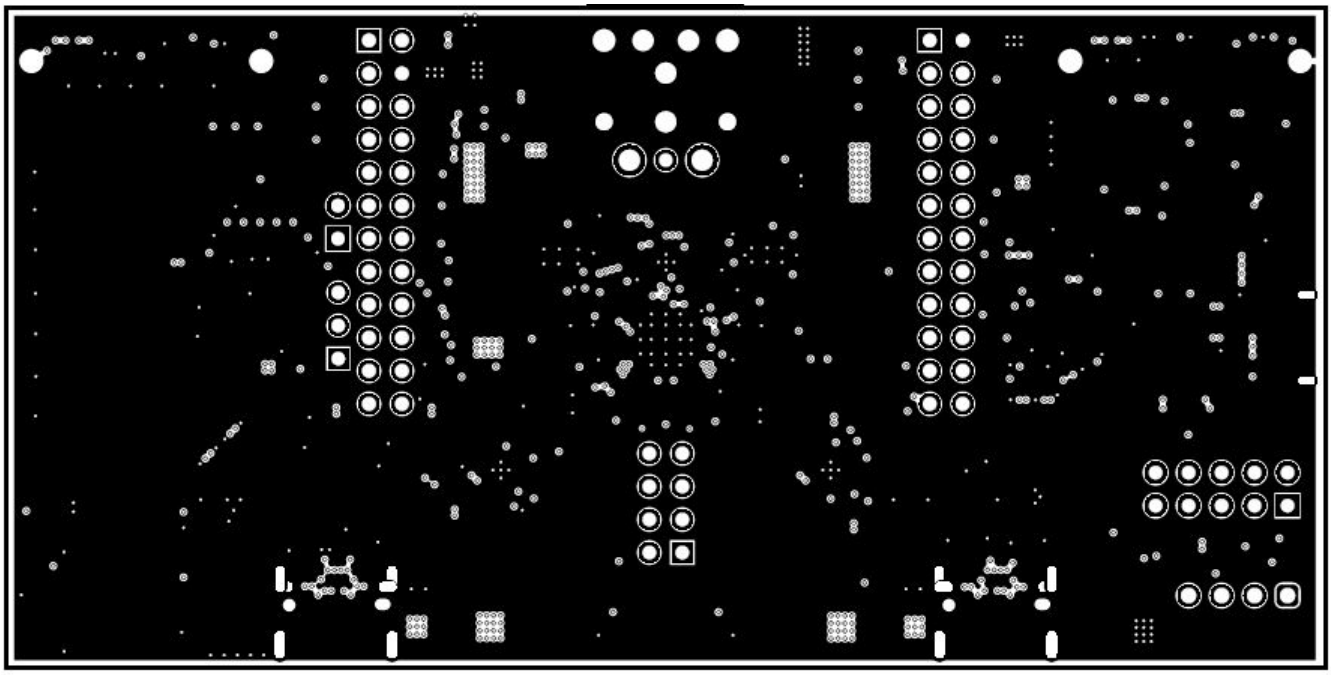


Figure 13-3. TPS65994QFNEVM GND Plane 1

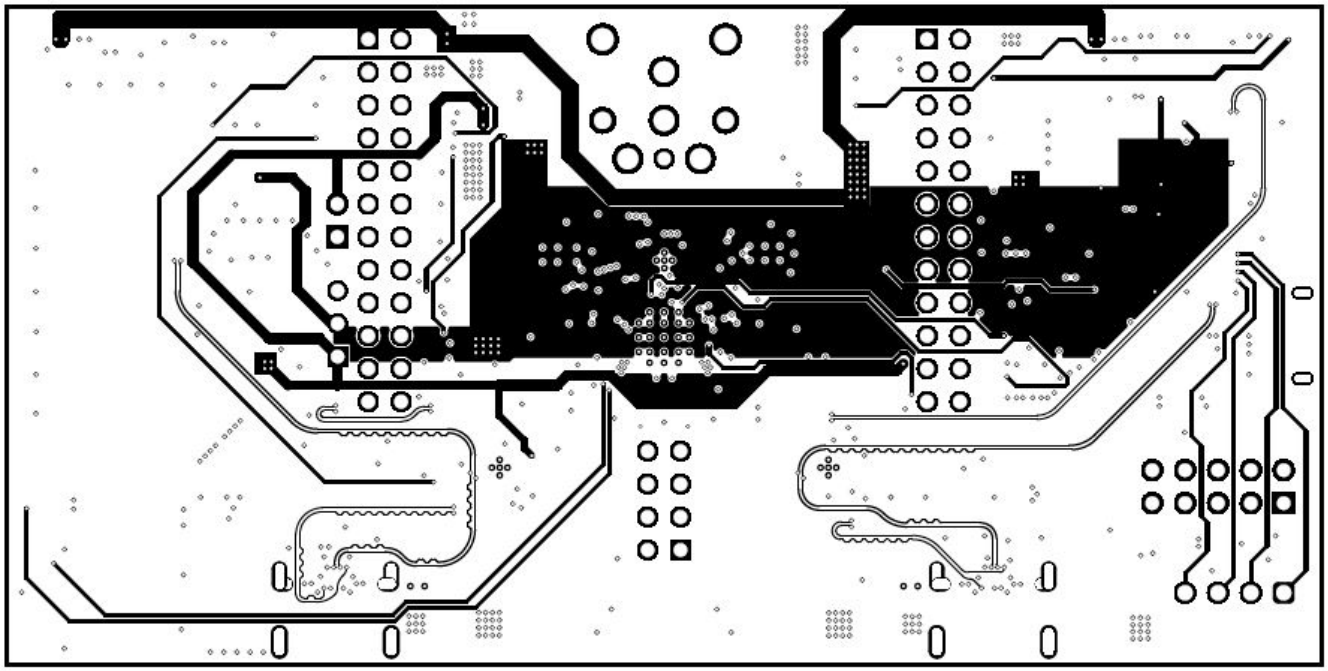


Figure 13-4. TPS65994QFNEVM High Speed Layer

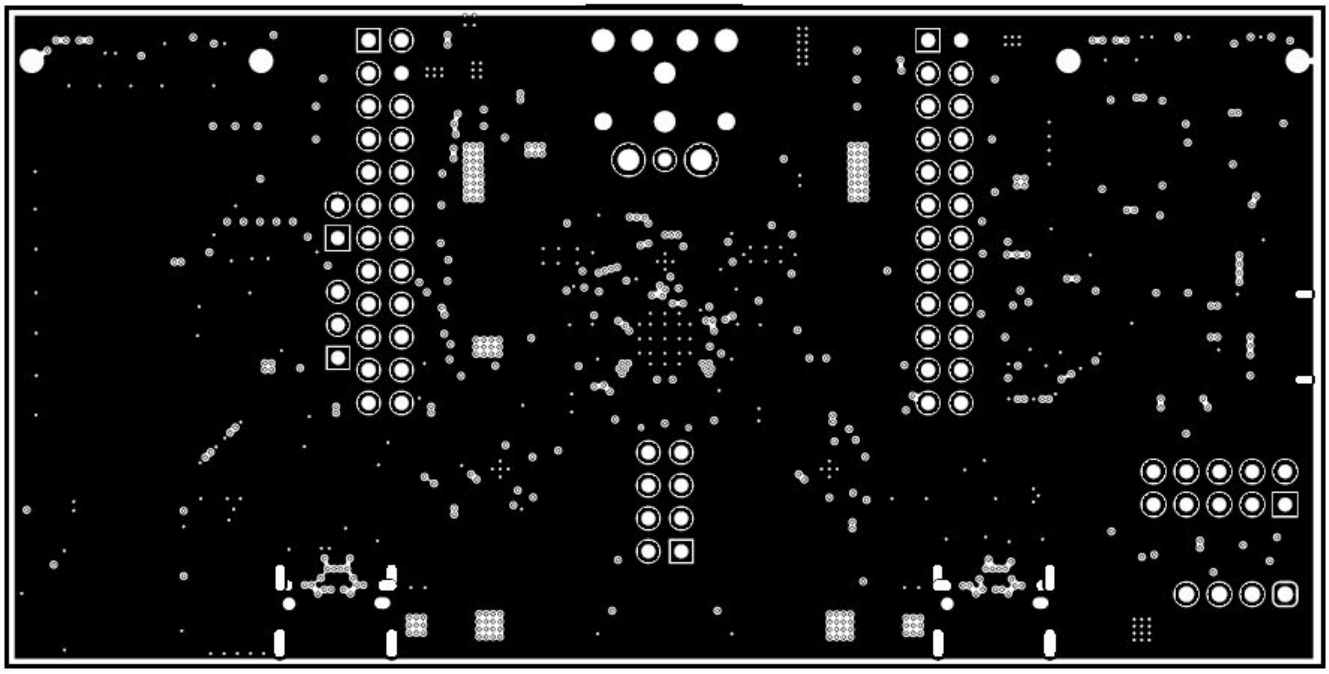


Figure 13-5. TPS65994QFNEVM GND Plane 2

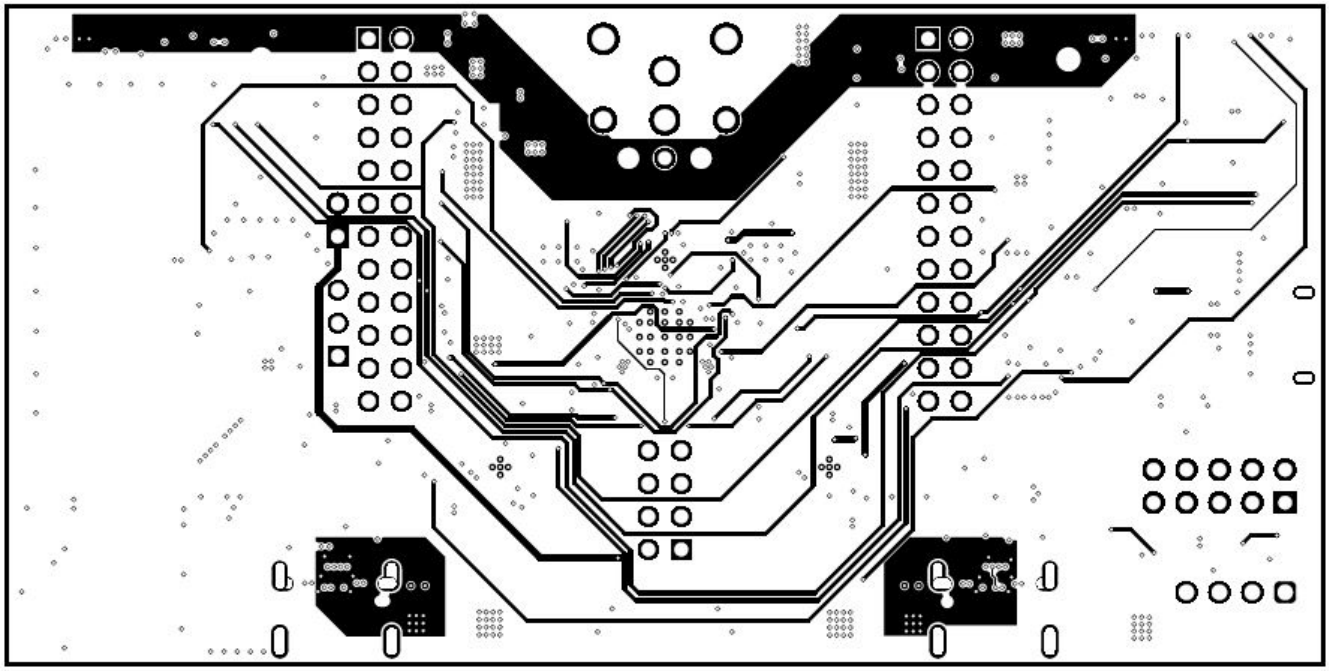


Figure 13-6. TPS65994QFNEVM Power 1 Layer

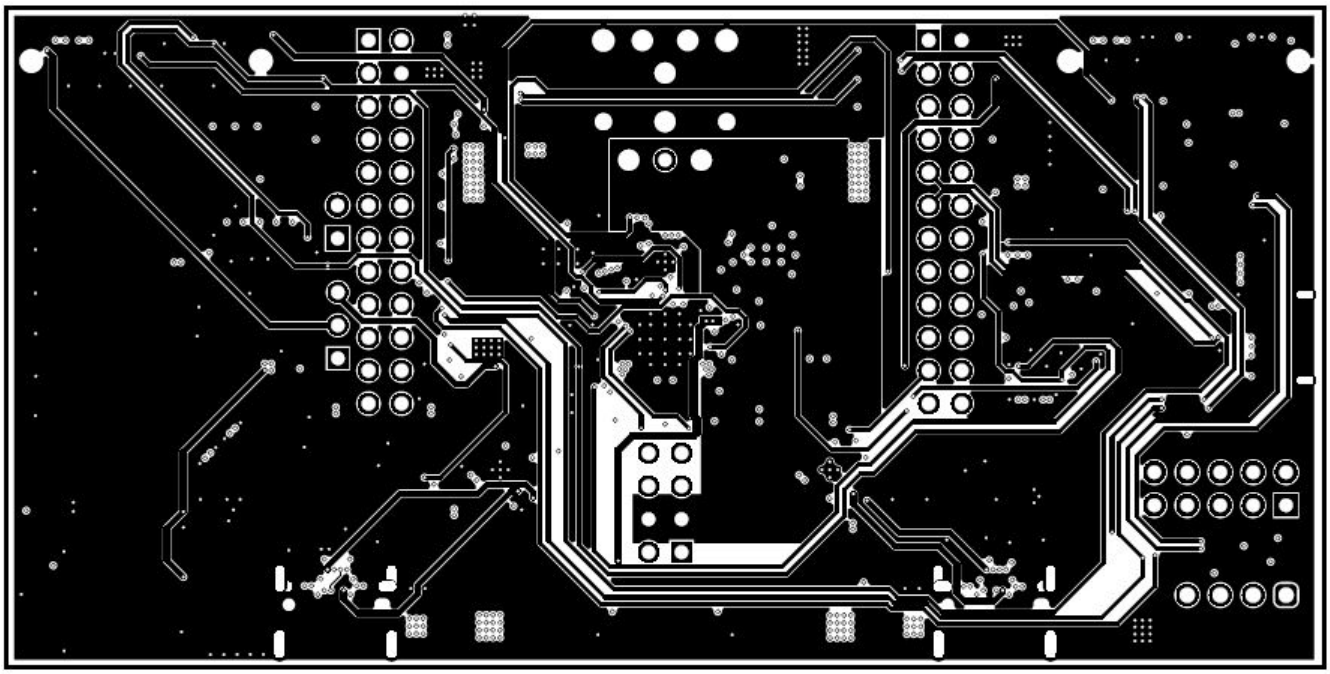


Figure 13-7. TPS65994QFNEVM Power 2 Layer

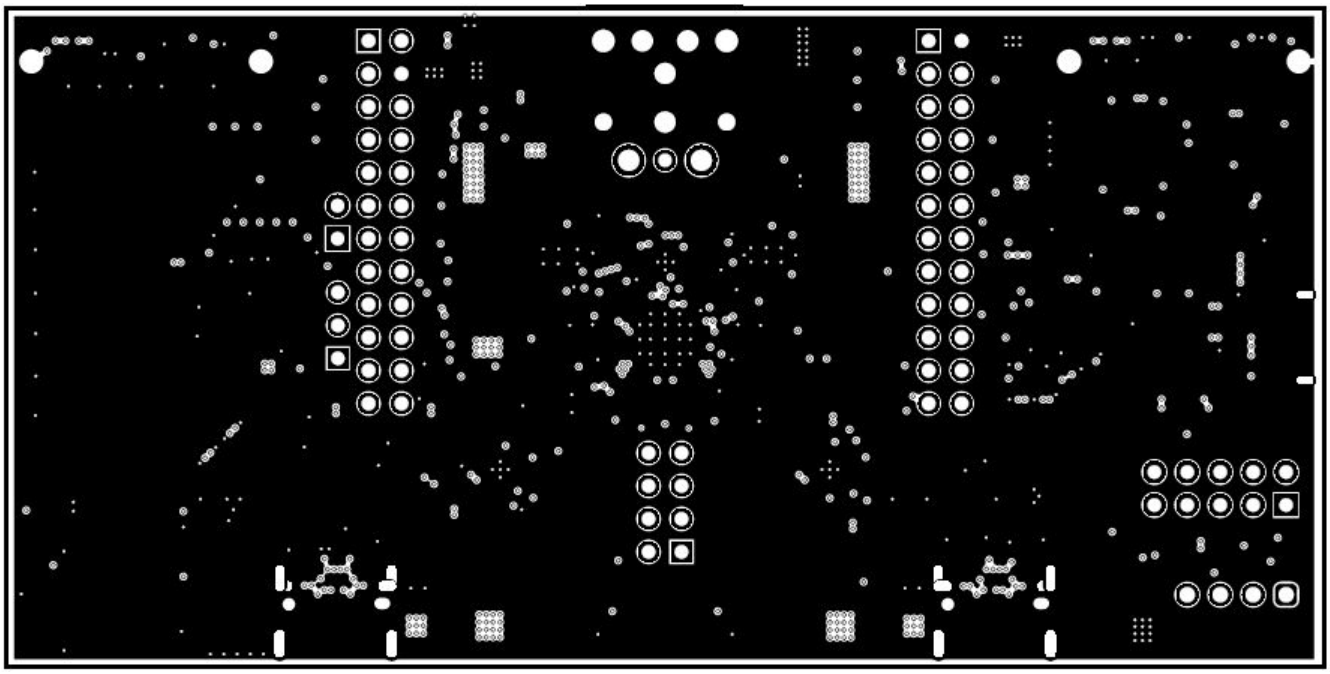


Figure 13-8. TPS65994QFNEVM GND Plane 3

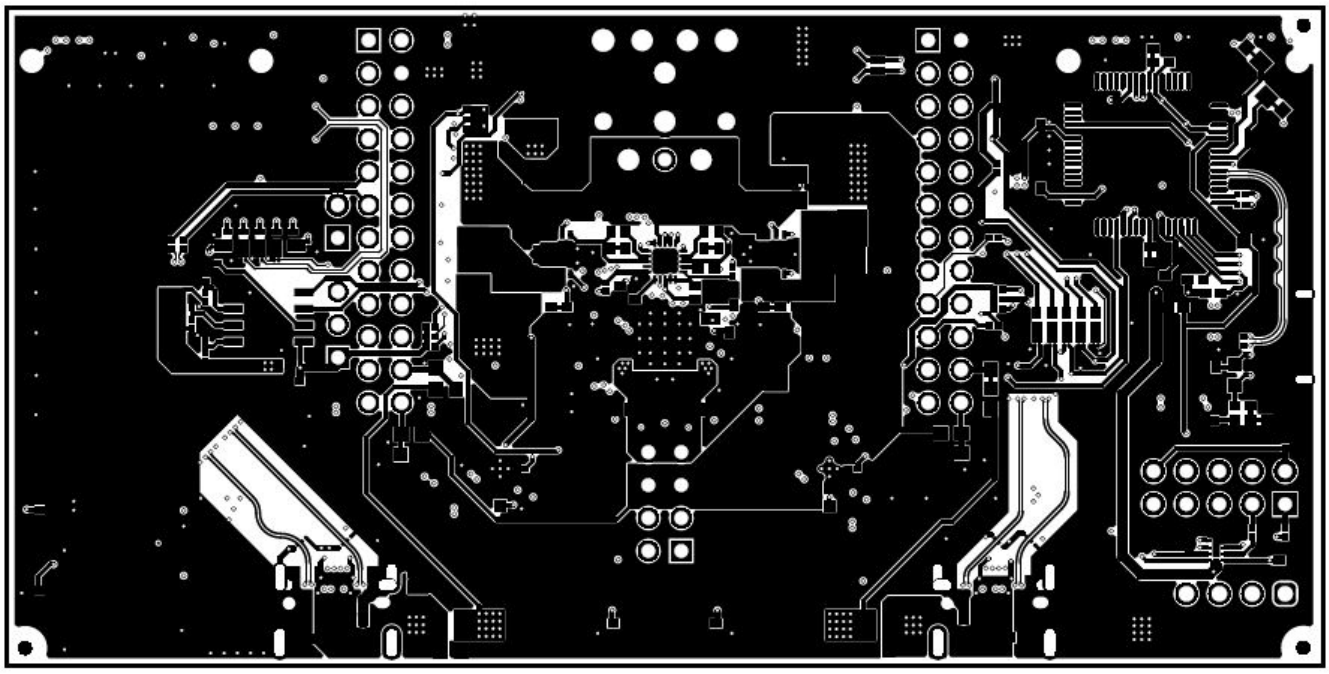


Figure 13-9. TPS65994QFNEVM Bottom Layer

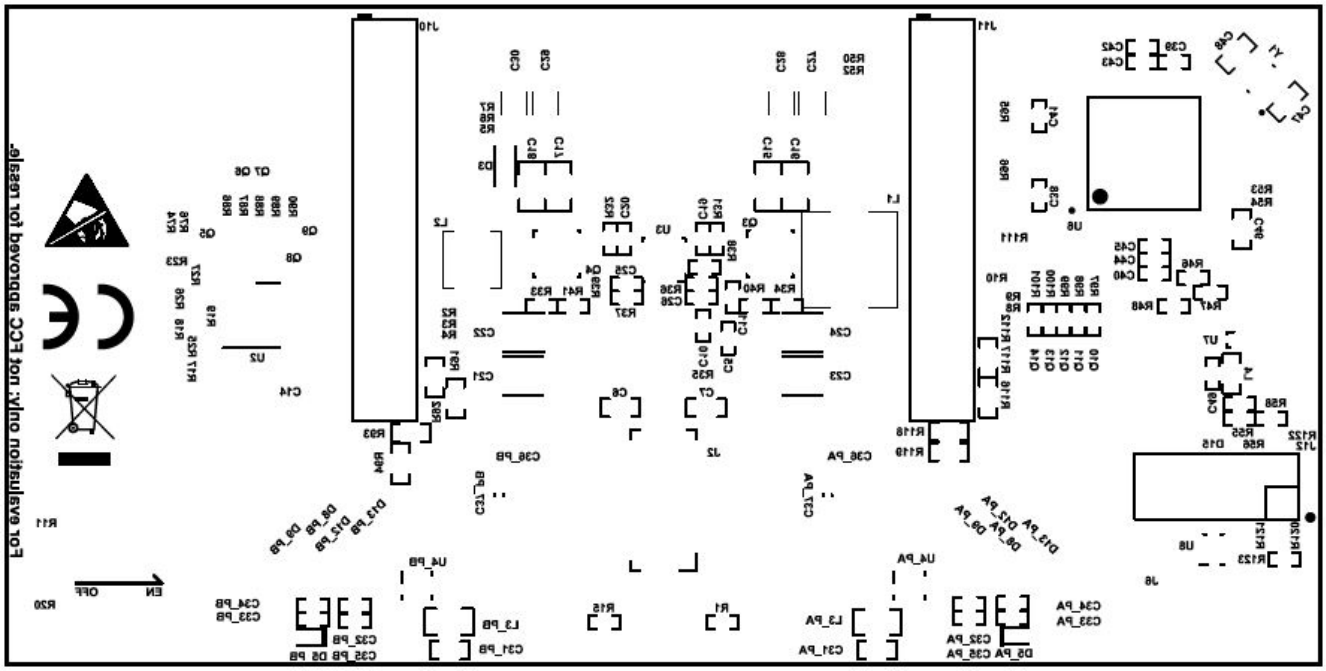


Figure 13-10. TPS65994QFNEVM Bottom Silk Screen

14 TPS65994QFNEVM Bill of Materials

Table 14-1 lists the EVM bill of materials.

Table 14-1. TPS65994QFNEVM Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		PSIL127	Any
C1, C13	2	1uF	CAP, CERM, 1 uF, 35 V, ±±10%, X5R, 0402	0402	GRM155R6YA105KE11D	MuRata
C3, C4, C8, C9	4	220pF	CAP, CERM, 220 pF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0201	0201	CGA1A2X7R1H221K030BA	TDK
C5, C10, C11	3	10uF	CAP, CERM, 10 uF, 10 V, ±20%, X5R, 0402	0402	CL05A106MP5NUNC	Samsung Electro-Mechanics
C6, C7	2	10uF	CAP, CERM, 10 uF, 25 V, ±20%, X5R, 0603	0603	GRM188R61E106MA73D	MuRata
C14, C38, C39, C40, C41, C43, C45	7	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H104K050BB	TDK
C15, C16, C17, C18	4	22uF	CAP, CERM, 22 uF, 25 V, ±20%, X5R, 0805	0805	GRM21BR61E226ME44L	MuRata
C19, C20	2	0.1uF	CAP, CERM, 0.1 uF, 35 V, ±10%, X5R, 0402	0402	GMK105BJ104KV-F	Taiyo Yuden
C21, C22, C23, C24	4	100uF	CAP, TA, 100 uF, 6.3 V, ±20%, 0.015 ohm, SMD	3528-21	T520B107M006ATE015	Kemet
C25, C26	2	4.7uF	CAP, CERM, 4.7 uF, 6.3 V, ±20%, X5R, 0402	0402	GRM155R60J475ME87D	MuRata
C27, C28, C29, C30	4	47uF	CAP, CERM, 47 uF, 10 V, ±20%, X5R, 1206	1206	C3216X5R1A476M160AB	TDK
C31_PA, C31_PB	2	4.7uF	CAP, CERM, 4.7 uF, 35 V, ±10%, X5R, 0603	0603	GRM188R6YA475KE15D	MuRata
C32_PA, C32_PB, C33_PA, C33_PB, C34_PA, C34_PB, C35_PA, C35_PB, C49	9	0.01uF	CAP, CERM, 0.01 uF, 50 V, ±5%, X7R, 0402	0402	C0402C103J5RACTU	Kemet
C36_PA, C36_PB	2	1uF	CAP, CERM, 1 uF, 6.3 V, ±20%, X5R, 0201	0201	GRM033R60J105MEA2D	MuRata
C37_PA, C37_PB	2	0.1uF	CAP, CERM, 0.1 uF, 100 V,±10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCJ188R72A104KA01D	MuRata
C42, C44	2	4.7uF	CAP, CERM, 4.7 uF, 10 V, ±20%, X5R, 0402	0402	C1005X5R1A475M050BC	TDK
C46	1	180pF	CAP, CERM, 180 pF, 50 V, ±5%, C0G/NP0, 0603	0603	06035A181JAT2A	AVX
C47, C48	2	10pF	CAP, CERM, 10 pF, 50 V, ±5%, C0G/NP0, 0603	0603	06035A100JAT2A	AVX
D1, D2, D14, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25	13	White	LED, White, SMD	0402, White	LW QH8G-Q2S2-3K5L-1	OSRAM
D3	1	24V	Diode, TVS, Bi, 24 V, 70 Vc, SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	PESD24VL1BA,115	NXP Semiconductor
D4	1	Blue	LED, Blue, SMD	LED_0603	150060BS75000	Wurth Elektronik
D5_PA, D5_PB	2	30V	Diode, Schottky, 30 V, 2 A, 2-XFDFN	2-XFDFN	NSR20F30NXT5G	ON Semiconductor
D6_PA, D6_PB, D7_PA, D7_PB, D8_PA, D8_PB, D9_PA, D9_PB, D10_PA, D10_PB, D11_PA, D11_PB, D12_PA, D12_PB, D13_PA, D13_PB	16		1-Channel ESD Protection Diode for USB Type-C and Thunderbolt 3, DPL0002A (X2SON-2)	DPL0002A	TPD1E01B04DPLR	Texas Instruments

Table 14-1. TPS65994QFNEVM Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
D15	1		1-Channel ESD Protection Diode With Low Dynamic Resistance and Low Clamping Voltage, DPY0002A (X1SON-2)	DPY0002A	TPD1E1B04DPYR	Texas Instruments
J1	1		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
J2	1		Receptacle, 2.54mm, 4x2, Gold, TH	Receptacle, 2.54mm, 4x2, TH	SSQ-104-03-G-D	Samtec
J3	1		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
J4	1		Connector, DC Power Jack, R/A, 3 Pos, TH	Power connector	JPD1135-509-7F	Foxconn
J5_PA, J5_PB	2		Receptacle, USB 3.1 Type C, R/A, Gold, SMT	Receptacle, USB 3.1 Type C, R/A, SMT	DX07S024JJ2R1300	JAE Electronics
J6	1		Header, 2.54 mm, 4x1, Gold, TH	Header, 2.54mm, 4x1, TH	61300411121	Wurth Elektronik
J7	1		Connector, Receptacle, USB Micro B, R/A, SMT	Connector, Receptacle, USB Micro B, R/A, SMT	10118193-0001LF	FCI
J8, J9	2		Socket, 0.8mm, 20x2, Gold, SMT	Socket, 0.8mm, 20x2, Gold, SMT	LSEM-120-03.0-F-DV-A-N-K-TR	Samtec
J10, J11	2		Receptacle, 12x2, 2.54mm, Gold, TH	Receptacle, 12x2, 2.54mm, TH	SSW-112-01-G-D	Samtec
J12	1		Header, 100mil, 5x2, Tin, TH	Header, 5x2, 100mil, Tin	PEC05DAAN	Sullins Connector Solutions
L1	1	3.3uH	Inductor, Shielded Drum Core, Superflux, 3.3 uH, 8 A, 0.0096 ohm, SMD	6.9x4.8x6.9mm	744314330	Wurth Elektronik
L2	1	2.2uH	Inductor, Shielded Drum Core, Powdered Iron, 2.2 uH, 3.25 A, 0.051 ohm, SMD	4.45x1.8x4.06mm	74437324022	Wurth Elektronik
L3_PA, L3_PB	2	22 ohm	Ferrite Bead, 22 ohm @ 100 MHz, 6 A, 0805	0805	742792021	Wurth Elektronik
L4	1	26 ohm	Ferrite Bead, 26 ohm @ 100 MHz, 6.5 A, 0603	0603	74279228260	Wurth Elektronik
Q1, Q2	2	30V	MOSFET, 2-CH, N-CH, 30 V, A, YJG0010A (PICOSTAR-10)	YJG0010A	CSD87501L	Texas Instruments
Q3, Q4	2	30V	MOSFET, 2-CH, N-CH, 30 V, 20 A, DQZ0008A (LSON-CLIP-8)	DQZ0008A	CSD87330Q3D	Texas Instruments
Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14	10	20V	MOSFET, N-CH, 20 V, 0.5 A, YJM0003A (PICOSTAR-3)	YJM0003A	CSD15380F3	Texas Instruments
R1, R15, R86, R87, R88, R89, R90, R97, R98, R99, R100, R101, R123	13	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R2, R3, R5, R6, R8, R9	6	2.20k	RES, 2.20 k, 1%, 0.05 W, 0201	0201	CRCW02012K20FKED	Vishay-Dale
R4, R7, R10, R23, R25, R26, R27	7	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale
R11, R20	2	499k	RES, 499 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402499KFKED	Vishay-Dale
R12, R21	2	59.0k	RES, 59.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040259K0FKED	Vishay-Dale
R13, R22	2	249k	RES, 249 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402249KFKED	Vishay-Dale
R14, R24	2	976k	RES, 976 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402976KFKED	Vishay-Dale
R16, R28	2	40.2k	RES, 40.2 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040240K2FKED	Vishay-Dale
R30	1	100k	RES, 100 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100KFKED	Vishay-Dale

Table 14-1. TPS65994QFNEVM Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
R31, R32	2	2.2	RES, 2.2, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022R20JNED	Vishay-Dale
R33	1	6.49k	RES, 6.49 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04026K49FKED	Vishay-Dale
R34	1	15.4k	RES, 15.4 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040215K4FKED	Vishay-Dale
R36	1	51.1k	RES, 51.1 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040251K1FKED	Vishay-Dale
R37	1	47.5k	RES, 47.5 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040247K5FKED	Vishay-Dale
R38, R39, R44_PA, R44_PB, R45_PA, R45_PB, R49, R50, R51, R52, R53, R54, R65, R70, R71, R72, R75, R77, R78, R79, R80, R81, R82, R83, R84, R85, R102, R103, R104, R107, R108, R109, R110, R111, R112, R113, R114, R115, R120, R121, R122	41	0	RES, 0, 5%, 0.05 W, 0201	0201	CRCW02010000Z0ED	Vishay-Dale
R40, R41, R42, R46, R47, R48, R57, R58	8	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R43_PA, R43_PB	2	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale
R55	1	4.75k	RES, 4.75 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04024K75FKED	Vishay-Dale
R56	1	1.00k	RES, 1.00 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K00FKED	Vishay-Dale
R59, R60, R61, R62, R63, R64	6	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R92, R94, R117, R119	4	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R95, R96	2	3.83k	RES, 3.83 k, 1%, 0.05 W, 0201	0201	CRCW02013K83FKED	Vishay-Dale
S2, S3	2		DIP Switch, SPST 4Pos, Slide, SMT	6.2x2.0x6.2mm	TDA04H0SB1	C&K Components
S4	1		SWITCH TACTILE SPST-NO 0.05A 12V	3x1.6x2.5mm	B3U-1000P	Omron Electronic Components
S5	1		Switch, Slide, SPST, Top Slide, SMT	Switch, Single Top Slide, 2.5x8x2.5mm	CHS-01TB	Copal Electronics
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	6		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
TP1, TP4, TP5, TP6, TP7, TP10, TP11, TP12, TP13, TP14, TP15, TP16	12		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1		Dual Port USB Type-C and USB PD Controller with Integrated Source Power Switches	VQFN48		Texas instruments
U2	1		256 kb I2C CMOS Serial EEPROM, SOIC-8	SOIC-8	CAT24C256WI-G	ON Semiconductor
U3	1		Dual Synchronous Step-Down Controller with 5-V and 3.3-V LDOs, RUK0020B (WQFN-20)	RUK0020B	TPS51225RUKR	Texas Instruments
U4_PA, U4_PB	2		22-V Precision Surge Protection Clamp, DRV0006A (WSON-6)	DRV0006A	TVS2200DRVR	Texas Instruments

Table 14-1. TPS65994QFNEVM Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U5_PA, U5_PB	2		USB Type-C Port Protector: Short-to-VBUS Overvoltage and IEC ESD Protection, RUK0020B (WQFN-20)	RUK0020B	TPD6S300ARUKR	Texas Instruments
U6	1		Tiva C Series Microcontroller, 256 KB Flash, 32 KB SRAM, 12 Bit, 12 Channels, -40 to 105 degC, 64-Pin LQFP (PM), Green (RoHS & no Sb/Br), Tape and Reel	PM0064A	TM4C123GH6PMTR	Texas Instruments
U7	1		ESD Protection Array for High-Speed Data Interfaces, 2 Channels, -40 to +85 degC, 3-pin SOT (DRT), Green (RoHS & no Sb/Br)	DRT0003A	TPD2E009DRTR	Texas Instruments
U8	1		High-Speed USB 2.0 (480 Mbps) 1:2 Multiplexer / Demultiplexer Switch with Single Enable, 6 ohm RON, 2.5 to 3.3V, -40 to 85 degC, 10-Pin UQFN (RSE), Green (RoHS & no Sb/Br)	RSE0010A	TS3USB221RSER	Texas Instruments
Y1	1		Crystal, 16 MHz, 8pF, SMD	3.2x0.75x2.5mm	NX3225GA-16.000M-STD-CRG-1	NDK
C2, C12	0	150pF	CAP, CERM, 150 pF, 50 V, ±10%, X7R, 0201	0201	GRM033R71H151KA12D	MuRata
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R17, R18, R19	0	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale
R29, R35	0	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R66, R67	0	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R68, R69, R73, R74, R76, R105, R106	0	0	RES, 0, 5%, 0.05 W, 0201	0201	CRCW02010000Z0ED	Vishay-Dale
R91, R93, R116, R118	0	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale

15 Revision History

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

Changes from Revision B (September 2020) to Revision C (January 2021)	Page
• Added TPS65994QFN statement	3
• Replaced FTDI with TIVA MCU	3
• Replaced *USB Type-C™ Receptacle (J3_PB) Schematic*	6
• Added Tiva USB to I2C Bridge Support Integration section	10
• Removed FTDI Board from required hardware section	18
• Updated TPS65994EVM Schematic section	20
• Updated TPS65994EVM Board Layout section	27
• Updated TPS65994EVM Bill of Materials section	32
• Added TPS65994QFNEVM Schematics	36
• Added TPS65994QFNEVM Board Layout	44
• Added TPS65994QFNEVM Bill of Materials	49

Changes from Revision A (May 2020) to Revision B (September 2020)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	3

Changes from Revision * (April 2020) to Revision A (May 2020)	Page
• Added package types (WCSP and QFN)	3

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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.

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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
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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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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