User's Guide

TPS65988 Evaluation Module

ABSTRACT

This document is the user guide for the TPS65988 Evaluation Module (TPS65988EVM). The TPS65988EVM allows for evaluation of the TPS65988 IC as part of a stand-alone testing kit and for development and testing of USB Type-C and Power Delivery (PD) end products. Out of the box, the TPS65988EVM is configured to emulate a dual-port laptop computer. Both ports can be used to source or sink power, and both are dual-role ports (DRP) but only support data as a downstream-facing port (DFP) host. When different configurations are required to test your system, use the *TPS65988 Application Configuration* software tool to create a configuration or load a different configuration template (see Figure 1-1). The TPS65988EVM uses a control MUX (HD3SS3412) to route DisplayPort™ (DP) and a USB HUB (TUSB8020) to route USB signals to the appropriate port A or port A (port A/B). The control MUX and USB HUB are connected to a SuperSpeed (SS) MUX (TUSB546) which routes the appropriate DP lanes and USB 3.0 signals according to cable orientation and *Alternate Mode* selection. Figure 1-2 highlights these features.

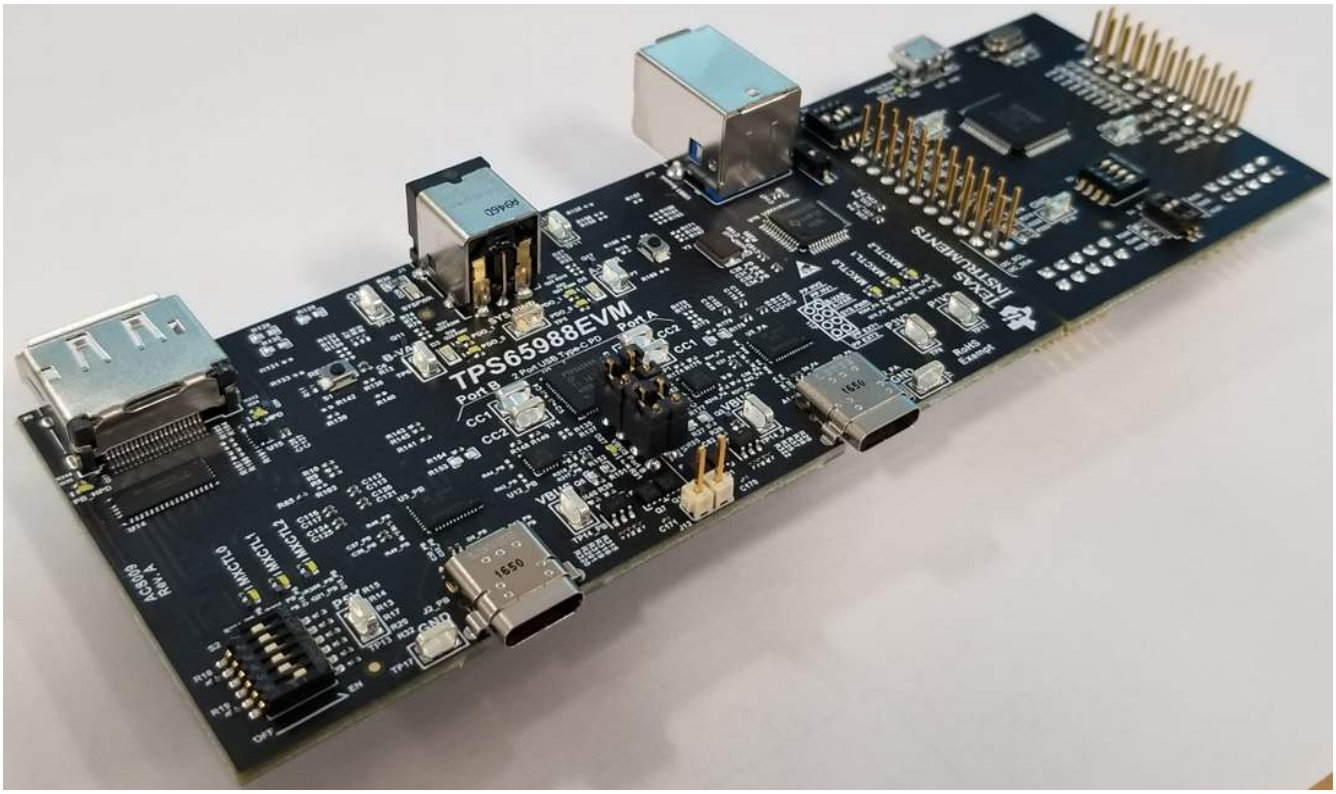

Figure 1-1. TPS65988EVM

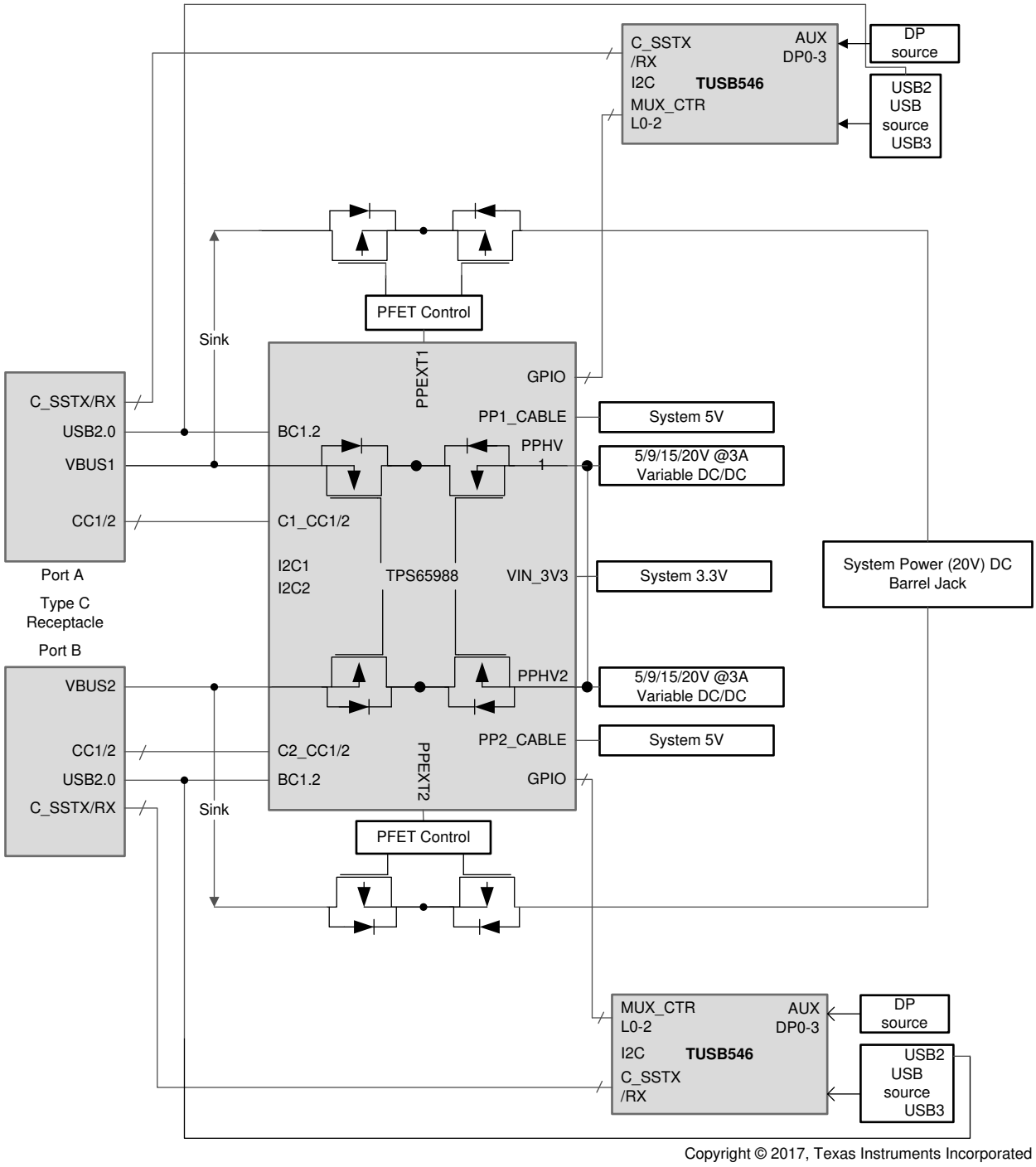

Figure 1-2. TPS65988EVM Block Diagram

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1 About this Manual

This user's guide describes the TPS65988EVM. 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).

2 Information About Cautions and Warnings

ATTENTION
STATIC SENSITIVE DEVICES

HANDLE ONLY AT
STATIC SAFE WORK STATIONS

CAUTION

This EVM contains components that can potentially be damaged by electrostatic discharge. Always transport and store the EVM in the supplied ESD bag when not in use. Handle using an antistatic wristband. Operate on an antistatic work surface. For more information on proper handling, see *Electrostatic Discharge (ESD)*.

3 Items Required for Operation

The following items are required to use the TPS65988EVM:

- TPS65988 data sheet
- TPS65988EVM
- *TPS65988 Application Customization Tool*
- 20-V barrel jack adapter or DC power supply (model # 492-BBGP)
- 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
- Notebook with USB 2.0, USB 3.0, and DP capabilities

4 Introduction

The TPS65988 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 TPS65988 communicates on the CC line using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS65988 enables the appropriate power path and configures external multiplexers and alternate mode settings.

This user guide describes how the TPS65988EVM 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 *TPS65988 Configuration Tool*. Additionally, the EVM is equipped with a Future Technology Devices International® (FTDI®) board and Aardvark connector to SPI or I^2C interfaces for debugging and development.

5 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.

5.1 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.

5.1.1 Power Path Jumper Configuration

The TPS65988EVM allows for analysis of TPS65987D and TPS65987S platforms through the adjustment of jumpers on J11 and J12.

5.1.1.1 TPS65988 Jumper Configuration

Out of the box, the TPS65988EVM has jumper configuration for a TPS65988 device. With this configuration, the two internal power paths are configured as Source paths for their respective Type-C ports. The two external power paths are configured as Sink paths for their respective Type-C ports. When using the TPS65988EVM, use a TPS65988 template in the TPS6598x Application Customization Tool. Refer to Figure 5-1 and Figure 5-2 for the TPS65988 Jumper Configuration.

Figure 5-1. TPS65988 Jumper Configuration

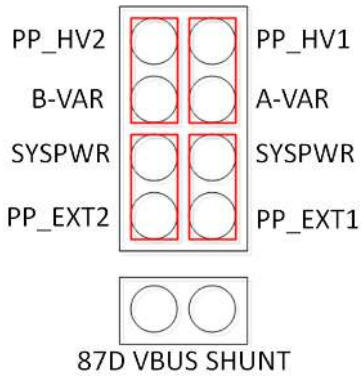


Figure 5-2. TPS65988 Jumper Configuration Net Names

5.1.1.2 TPS65987D Jumper Configuration

To use the TPS65988EVM to perform as a TPS65987D, the jumpers on J11 and J12 needs to be adjusted. Place a jumper on J12 to short the two VBUS nodes together. In this use case, one of the internal power paths is used as a source path and the other internal power path is used as a sink path. The TPS65987D supports one Type-C port and contains 2 internal power paths. The TPS65988 can be configured to act as a TPS65987D through the use of a TPS65987D Configuration Template in the TPS6598x Application Customization Tool. In this configuration, PPHV2 is used as the Source path for the Type-C port, it is connected to the net B-Var which is the Variable DC/DC used for Port B in the TPS65988 configuration. PPHV1 is used for the Sink path on the TPS65987D. PPHV1 connects to the net SYSPWR in this configuration. Refer to Figure 5-3 and Figure 5-4 for the TPS65987D Jumper Configuration. When the TPS65988EVM is configured as a TPS65987D, only Port A is functional.

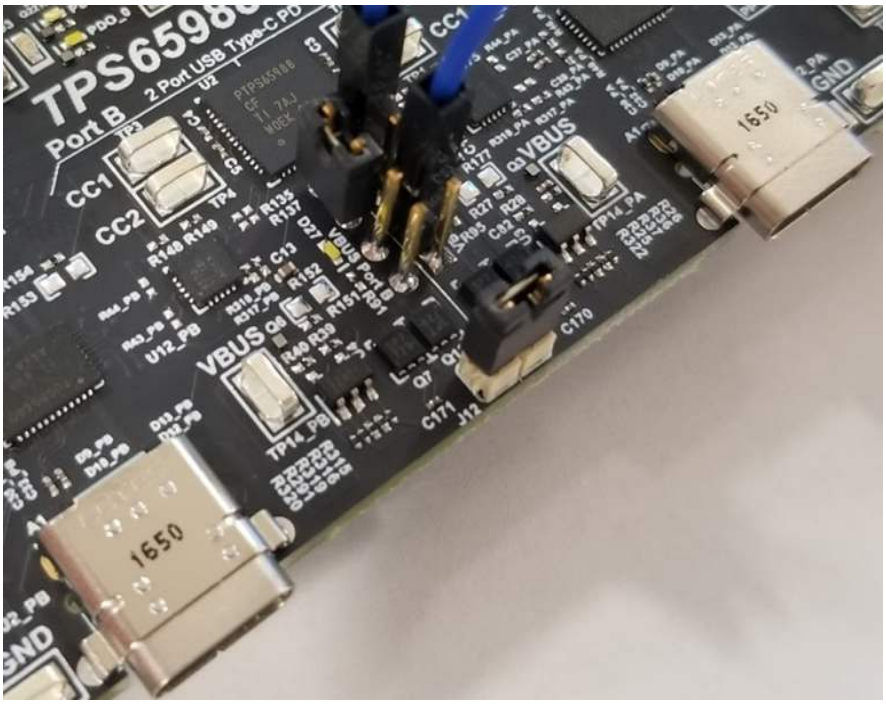


Figure 5-3. TPS65987D Jumper Configuration

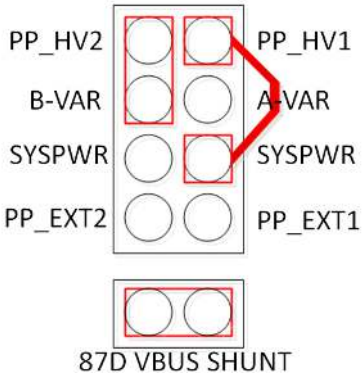


Figure 5-4. TPS65987D Jumper Configuration Net Names

5.1.1.3 TPS65987S Jumper Configuration

To emulate a TPS65987S with the TPS65988EVM, the jumpers on J11 need to be adjusted. The TPS65987S supports one Type-C port and contains one internal power path. When using the TPS65988EVM to emulate a TPS65987S, the internal power path (PPHV1) is used as the Source Path and one of the external power paths is used as the sink path. The TPS65988 can be configured to act as a TPS65987S through the use of a TPS65987S Configuration Template in the TPS6598x Application Customization Tool. Refer to Figure 5-5 and Figure 5-6 for the TPS65987D Jumper Configuration. When the TPS65988EVM is configured as a TPS65987S, only Port A is functional.

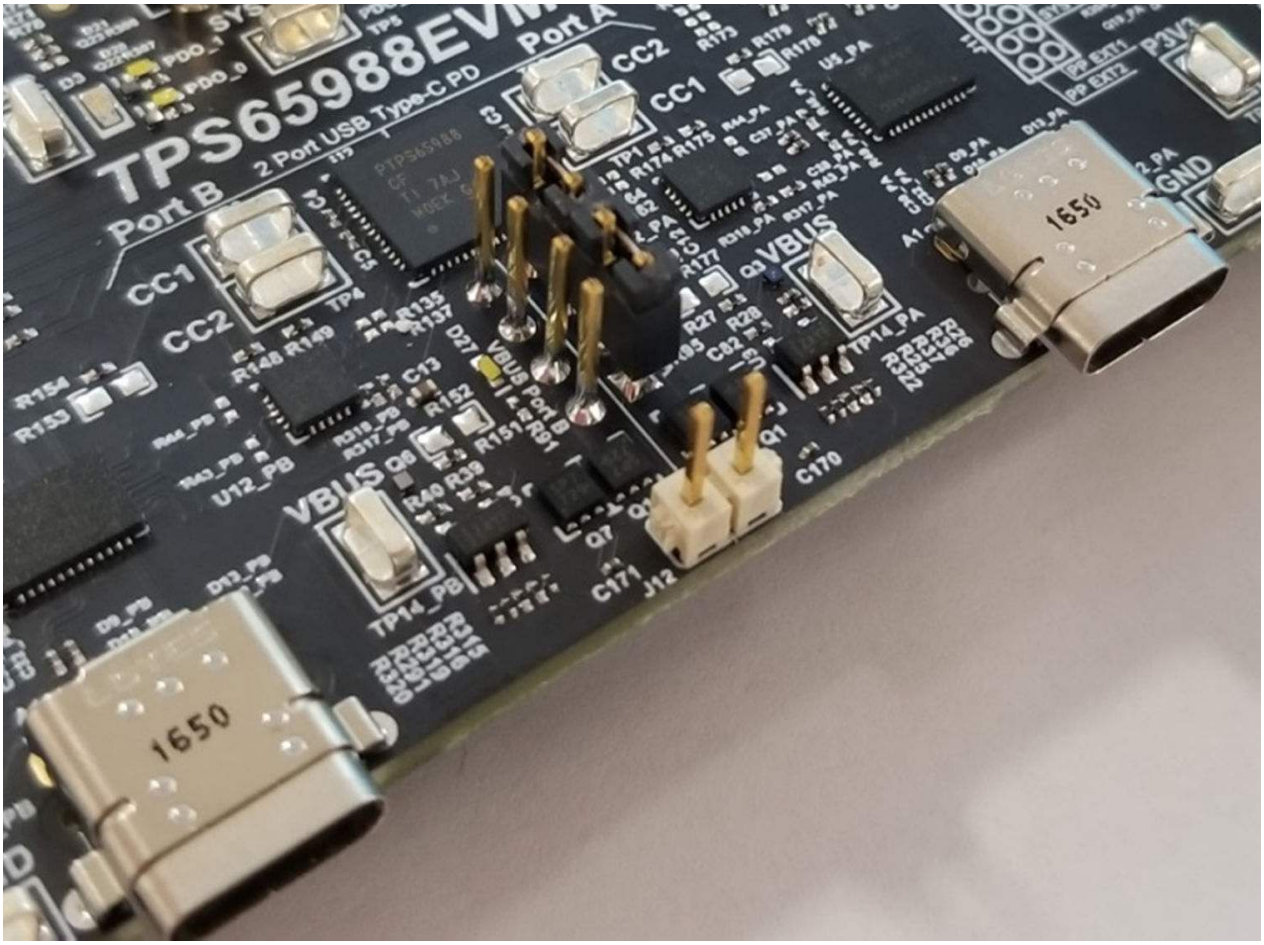


Figure 5-5. TPS65987S Jumper Configuration

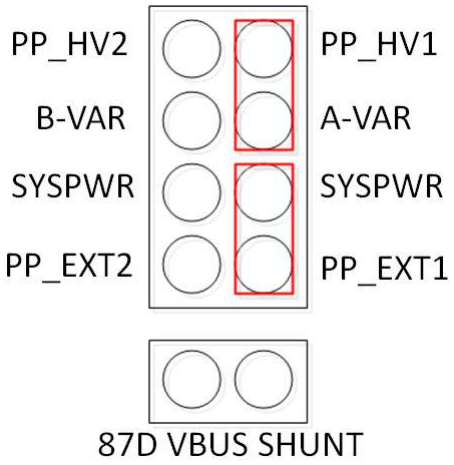


Figure 5-6. TPS65987S Jumper Configuration Net Names

5.1.2 DP Source Receptacle

The DP source receptacle routes DP lanes for port A/B, AUX for port A/B, HPD for port A/B, as well as DP port A/B select. The HD3SS3412 is used to MUX the DP source from the full-size DP receptacle to the USB Type-C alternate mode MUX (TUSB546) for port A/B. Only one of the ports can support DP at a time. The DP source MUX is controlled by GPIO0 that allocates the DP source signals to the appropriate port. Figure 5-7 shows the DP source MUX Configuration

Note

Only one DP source can be used on either port A or port B at the same time.

Figure 5-7. DisplayPort™ Source Schematic Block

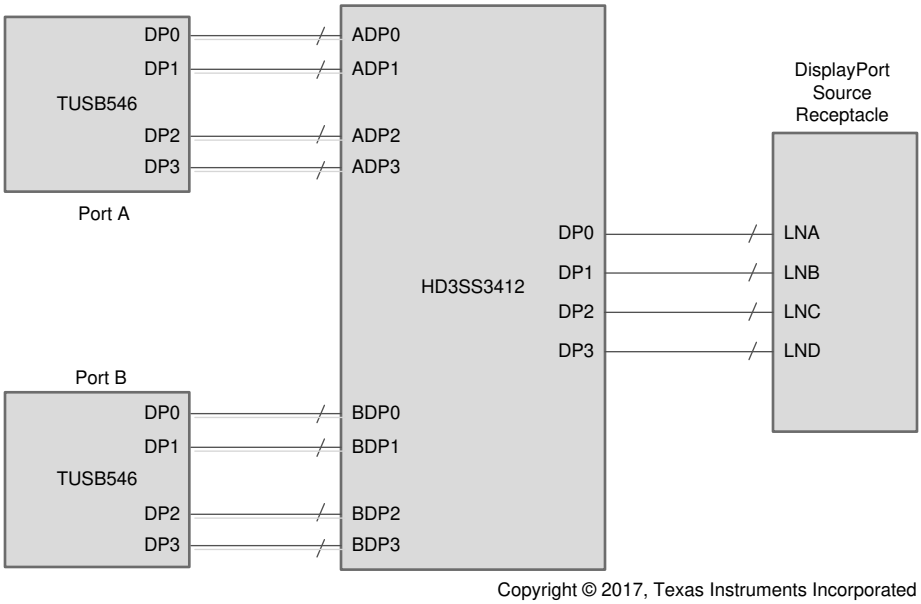


Figure 5-8. DisplayPort™ Source Block Diagram

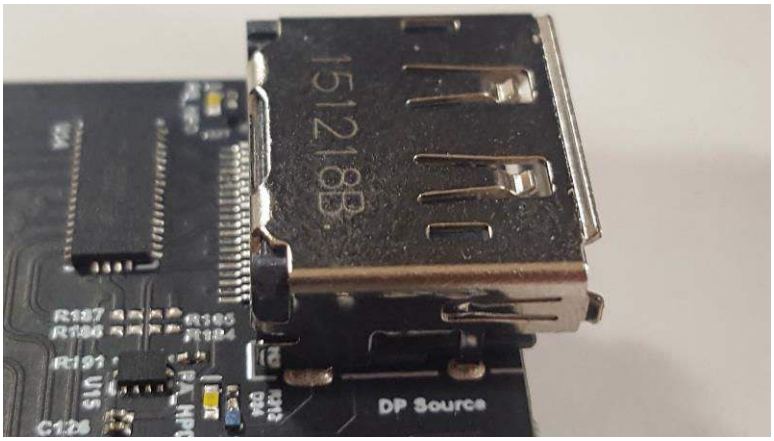


Figure 5-9. DisplayPort™ Source Receptacle

5.1.3 S1 HRESET Push-Button

S1 is located on the top-left corner of the EVM. This switch is a push-button that pulls the HRESET pin (39) of the TPS65988 high when pressed. Releasing the push-button pulls HRESET low again, and the TPS65988 goes through a soft reset, which consists of reloading firmware (FW) from RAM. If a valid configuration is present in the RAM, the TPS65988 does not reload the configuration from the external flash. Figure 5-10 highlights these features.

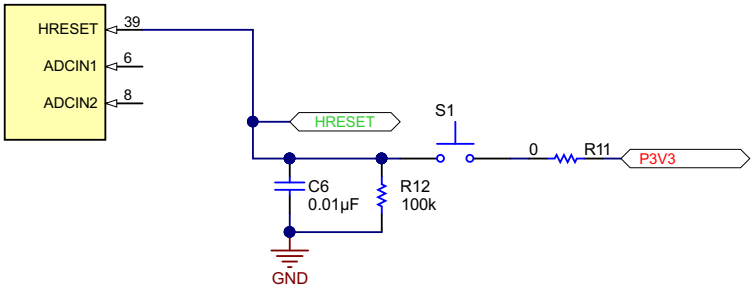


Figure 5-10. HRESET Push-Button (S1) Schematic

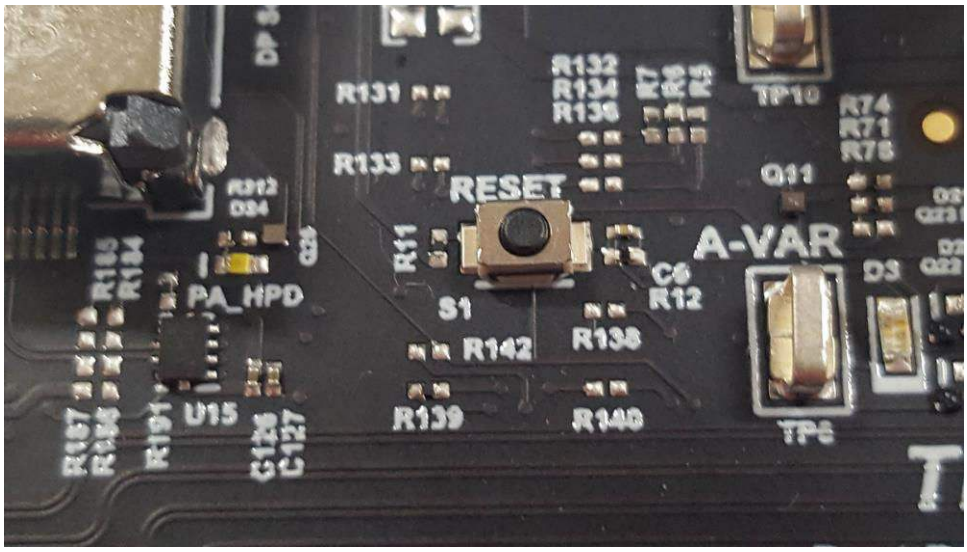


Figure 5-11. HRESET Push-Button (S1)

5.1.4 S6 SPI MISO Pull Down Button

S6 is located on the top right corner of the EVM. This push button switch holds the SPI Miso line to GND. This button is to be used when booting the device. If this button is pressed when the device is booting, the TPS65988 does not load its configuration from the SPI Flash, but instead boots into a default ROM configuration.

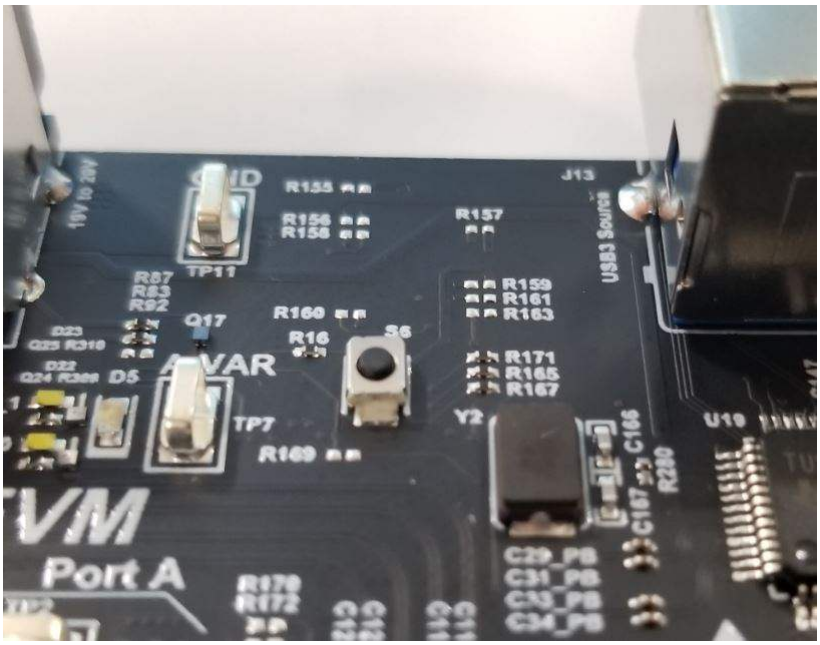


Figure 5-12. SPI-MISO Pull Down Switch

5.1.5 S3: FTDI® Enable and Disable

The dip switch, S3, has 4 switches. The switches labeled 3.3V (switch 3) and 5V (switch 4) pass the supply from the FTDI board micro-B receptacle from the BoosterPack header (J6) and vice versa. The *Force Enable* (switch 1 and switch 2) switch controls the reset on the FTDI device. When switch 1 is closed, the FTDI is held in reset until the TPS65988 has successfully loaded the firmware. When switch 2 is closed, the FTDI can be reset externally by pin 8 on the FTDI board header J7. By default, all switches are opened and in the upward position. Figure 5-13 highlights these features.

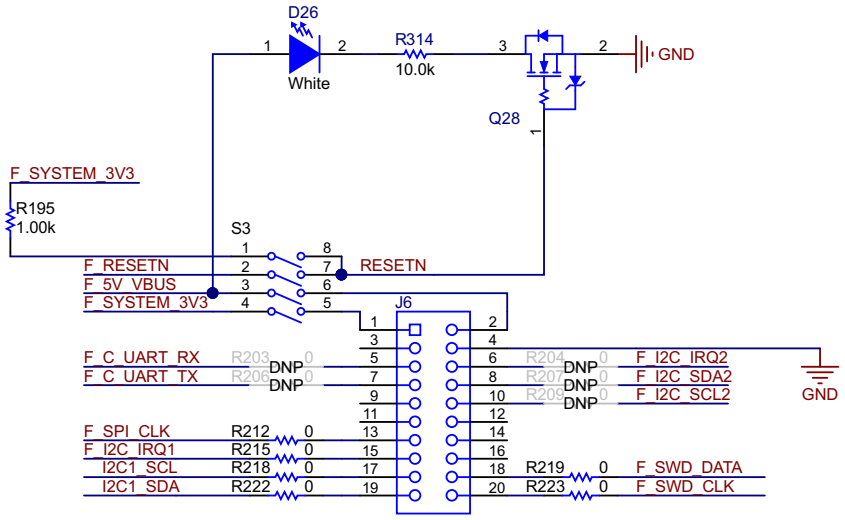


Figure 5-13. FTDI® Dip Switch (S3) Schematic

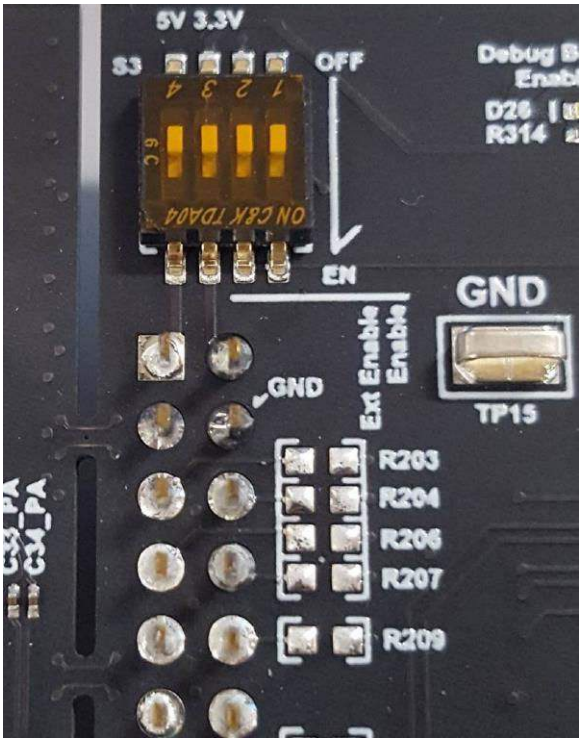


Figure 5-14. FTDI® Dip Switch (S3)

5.1.6 S2: SPI , I²C, and BusPowerZ Configurations

The TPS65988EVM has a dip switch (S2) that can be used to configure the I²C addresses and BusPower settings of the device. Switch1 through Switch3 are used to set the I2C address of the TPS65988 by adjusting the voltage divider seen at ADCIN2. Refer to the TPS65988 datasheet to see the different I²C address configurations. The default switch setting for Switch 1 through switch 3 is open, resulting in a 0x38 I²C address. Switch4 through Switch6 adjusts the BusPowerZ setting by adjusting the voltage divider on ADCIN1. Refer to the TPS65988 datasheet to see the different BusPowerZ configurations. Figure 5-15 highlights the default switch setting of S2.

Figure 5-15. I²C and BusPower DIP Switch (S2)

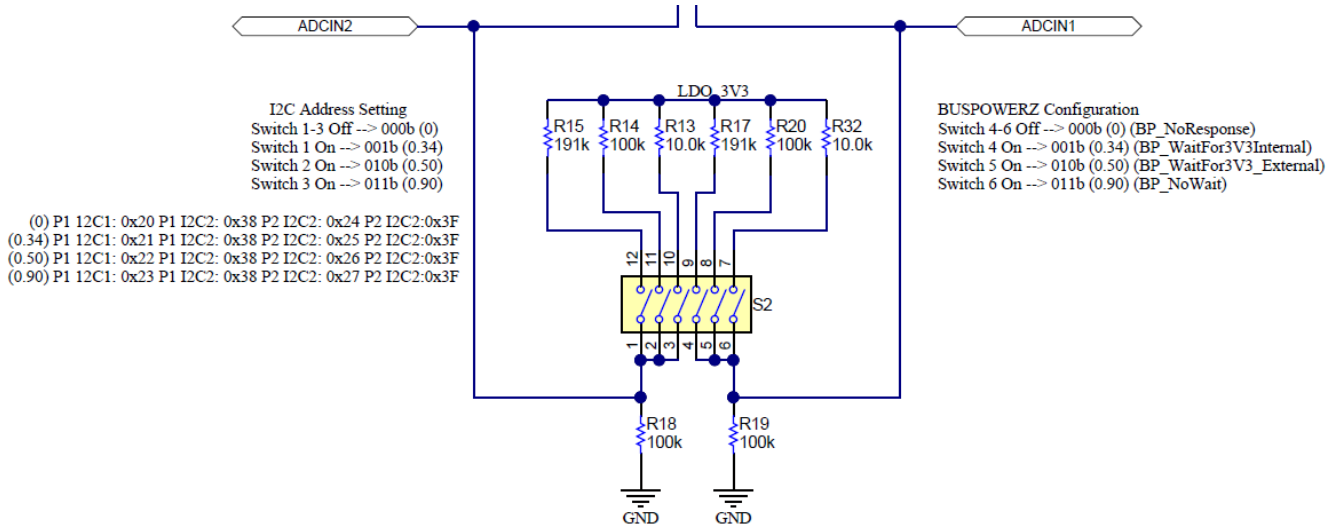


Figure 5-16. I²C DIP Switch (S2) Schematic

5.1.7 J1: Barrel Jack Power Connector

The barrel jack power connector accepts a 19-V to 20-V DC supply. A standard Dell or HP notebook adapter (or similar adapter) provides the required power. This input provides the PP_HV power rail 19-V to 20-V for high power PD contracts up to 60 W per port or 120 W, total. An appropriate power adapter greater than 120 W must

be used for high-power PD. For example, the Dell® 130-W Part Number: 492-BBGP. Figure 5-17 highlights these features.

WARNING

The barrel jack input is high voltage.

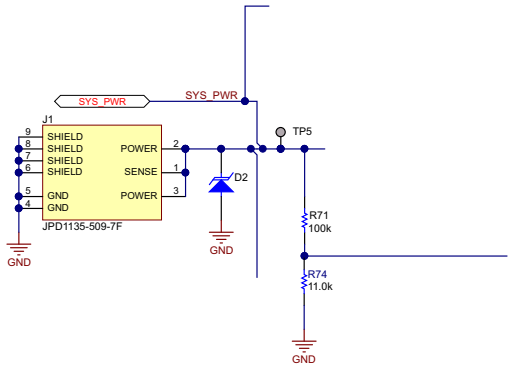


Figure 5-17. Barrel Jack (J1) Schematic

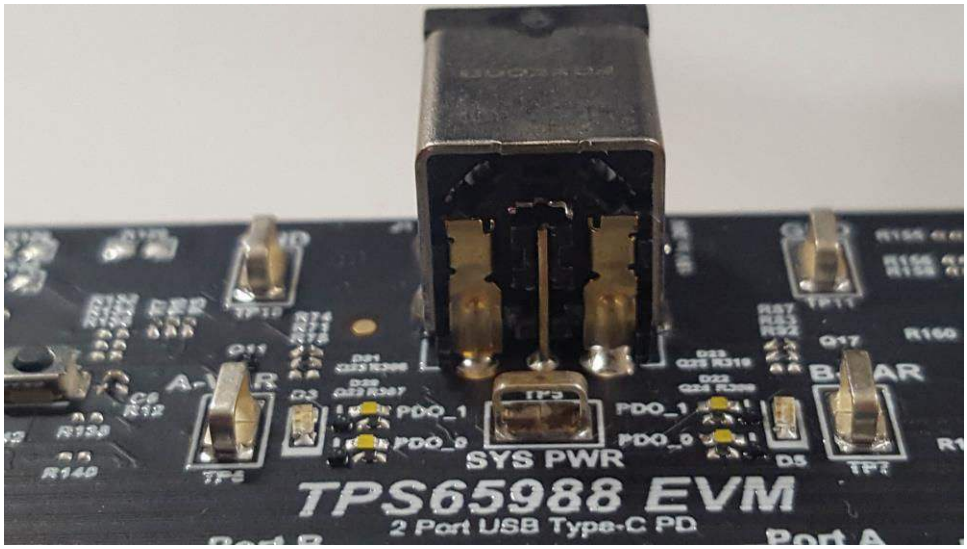


Figure 5-18. Barrel Jack (J1)

5.1.8 Barrel Jack Detect

The TPS65988EVM is capable of requesting a power role swap when the barrel jack is connected on an EVM that is currently bus-powered. The barrel jack voltage is sensed by a comparator, which drives GPIO1 (BJ_DETECT) on the TPS65988. By default, the *Barrel Jack Detect* is not enabled. To enable *Barrel Jack Detect* place R109 and refer to the *TPS65988 Utilities Tool User Guide* and *TPS65988 Firmware User Guide*. Figure 5-19 highlights these features.

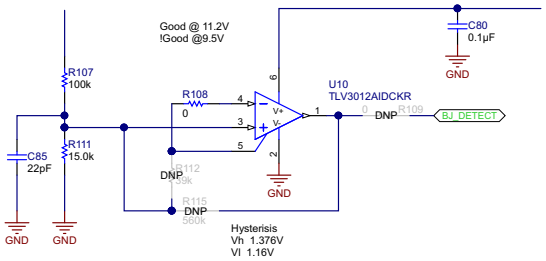


Figure 5-19. Barrel Jack Detect Schematic

5.1.9 USB Type B Connector (J11)

J11 is the Type-B connection to the PC for testing USB 2.0 or USB 3.0 functionality. A Type-A to Type-B cable can be used to connect the EVM to the USB port on a computer. This connector provides the USB data to the USB HUB on the TPS65988EVM. Figure 5-20 through Figure 5-22 highlight these features.

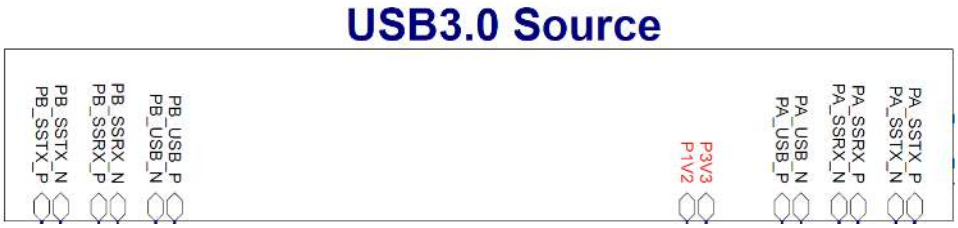


Figure 5-20. USB Type-B Receptacle (J11) Schematic

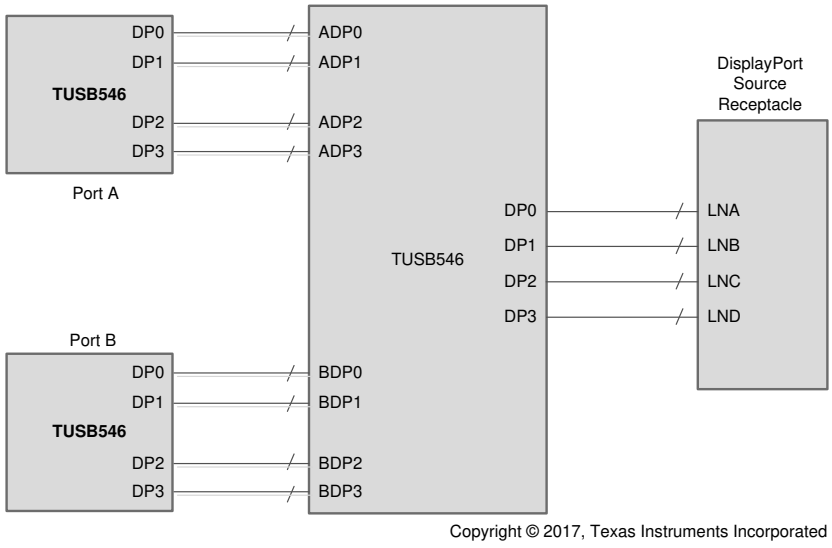


Figure 5-21. USB (J11) Block Diagram

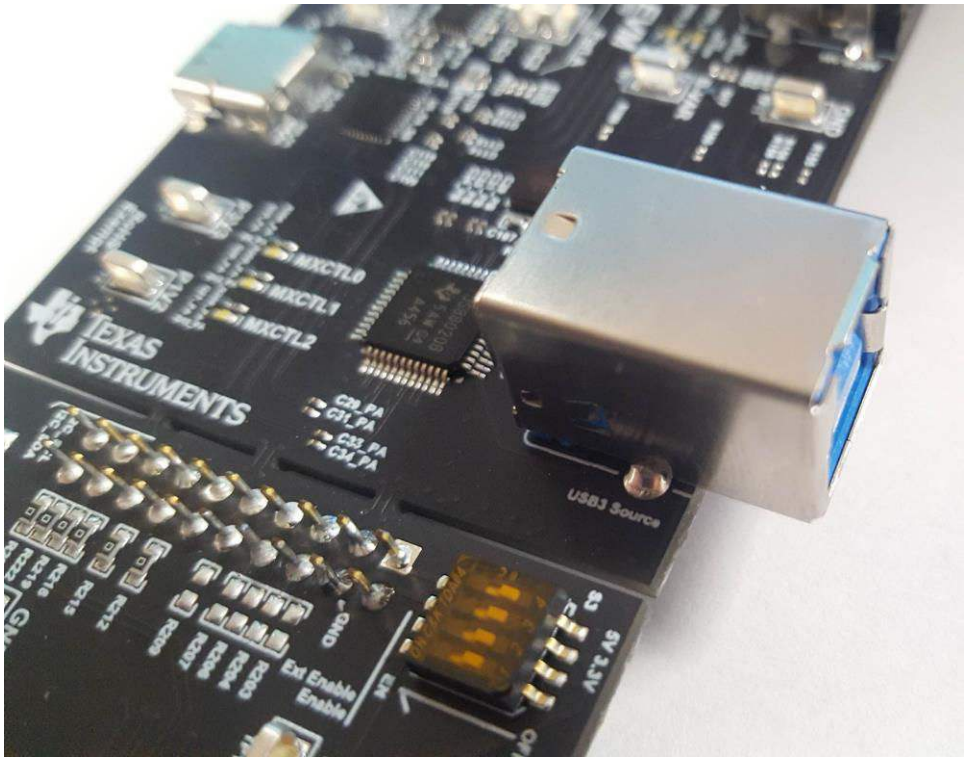


Figure 5-22. USB Type-B Receptacle (J11)

5.1.10 USB Type-C™ Connector (J2)

The TPS65988EVM 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 TPS65988 device can be used in self-powered and bus-powered configurations for added flexibility. When self-powered, the EVM can provide up to 60 W (20 V, at 3 A) of power per port via the internal high voltage power path. The EVM is also capable of sinking 100 W (20 V, at 5 A) of power via the external power path. The internal power path is used for sourcing power and the external power path is used for sinking power. Figure 5-23 and Figure 5-24 highlight these features.

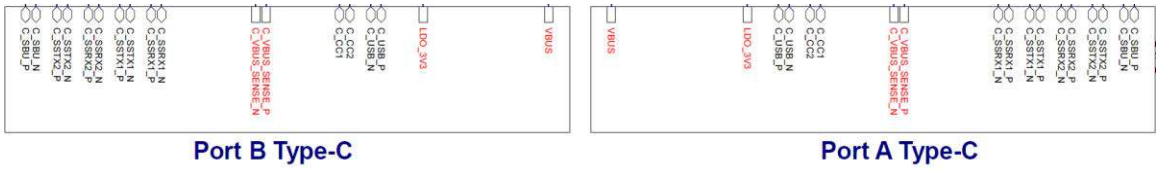


Figure 5-23. USB Type-C™ Receptacles (J2) Schematic

Figure 5-24. USB Type-C™ Receptacles (J2)

5.1.11 USB Micro B Connector (J9)

J9, the micro-B receptacle connects the FTDI to the PC for the *TPS65988 Customization GUI*. Use a standard USB micro-B to Type-A cable to make this connection. The *Debug Board Enable* LED turns on when VBUS is present on the FTDI board. Figure 5-25 and Figure 5-26 highlight these features.

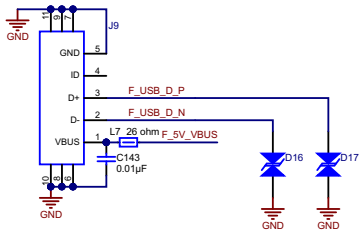


Figure 5-25. USB Micro-B Receptacle (J9) Schematic

Figure 5-26. USB Micro-B Receptacle (J9)

5.1.12 TP13 (5 V), TP8 (3.3 V), and TP12 (1.2 V)

Use the TP13, TP8, and TP12 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 TPS65988EVM. LDO_1V8 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, P3V3 and LDO_3V3 are active. P3V3 has the ability to operate at 4 V to compensate for IR drop through the USB Type-C cable. The P5V supply can operate at 4.5 V at 100% duty cycle, but it is intended to supply the 5 V at 3 A when the barrel jack or system power is connected to the EVM. P5V powers PP_CABLE for both ports as well as the VBUS current sense IC for both ports. Figure 5-27 highlights these test points.

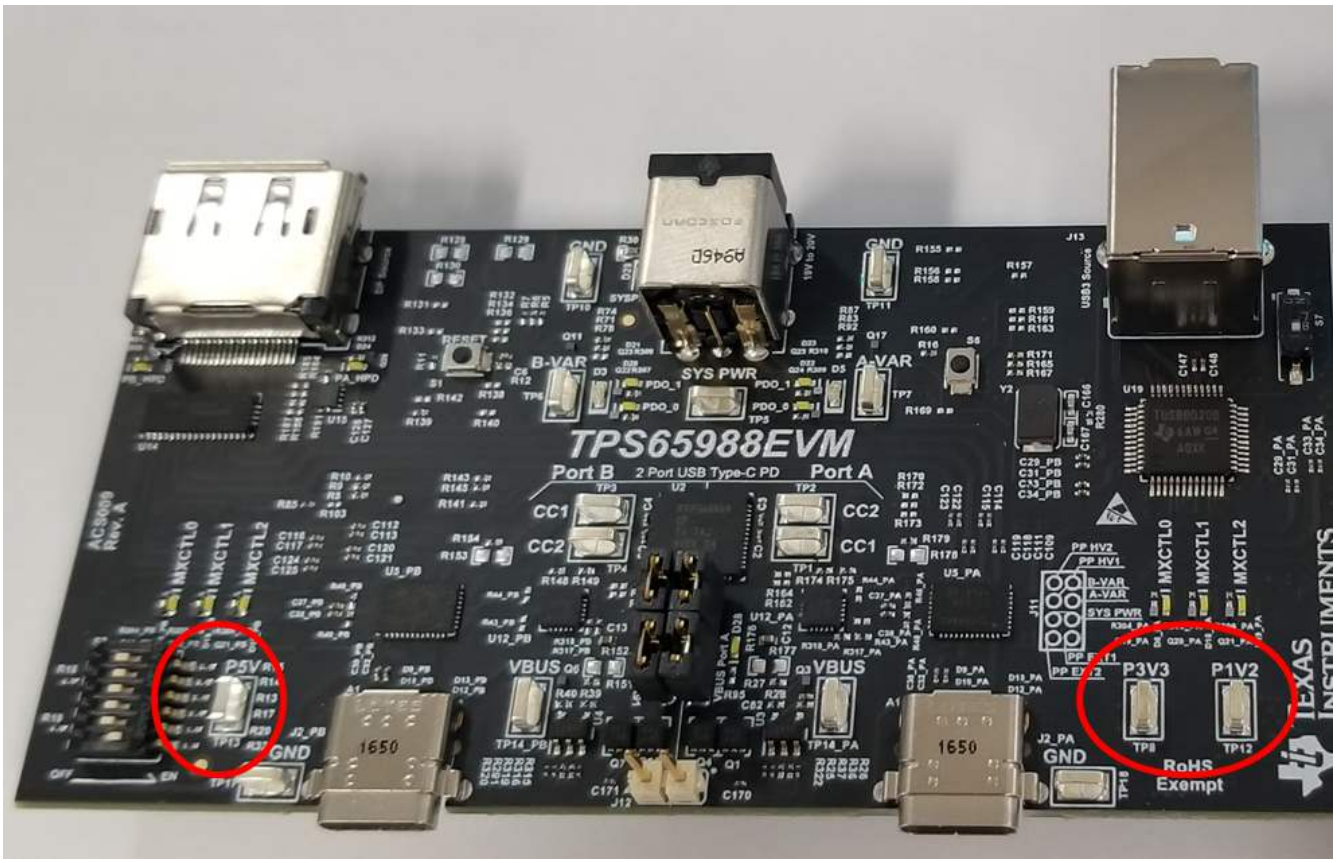


Figure 5-27. TP13 (5 V), TP8 (3.3 V), and TP12 (1.2 V)

5.1.13 Aardvark™ Connector (J10)

This connector matches the Total Phase® Aardvark that allows the user to access the I^2C and SPI pins on the TPS65988EVM using the SPI, I^2C master, or both capabilities. Figure 5-28 and Figure 5-29 highlight theses features.

Note

The FT4232 loads the I^2C or SPI pins when powered. TI recommends leaving the FT4232 in reset by having the *Force Enable* switches (switch 1 and switch 2) in the disabled (up) position.

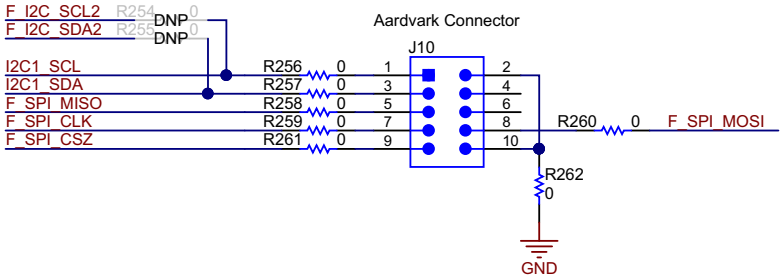


Figure 5-28. Aardvark™ Connector (J10) Schematic

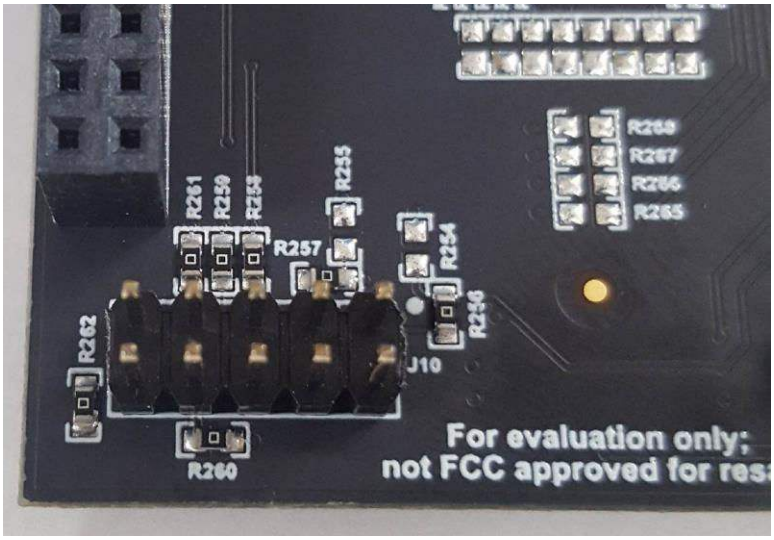


Figure 5-29. Aardvark™ Connector (J10)

5.1.14 TP10, TP11, TP15, TP16, TP17, TP18, TP9: GND Test Points

TP15, TP16, and TP9 GND Test Points are provided for attaching an oscilloscope or multi-meter. Test Points TP10, TP11, TP17, and TP18 (circled in orange) are used for load testing. These Test Points are connected to the board GND planes through multiple vias.Figure 5-30 highlights these features.

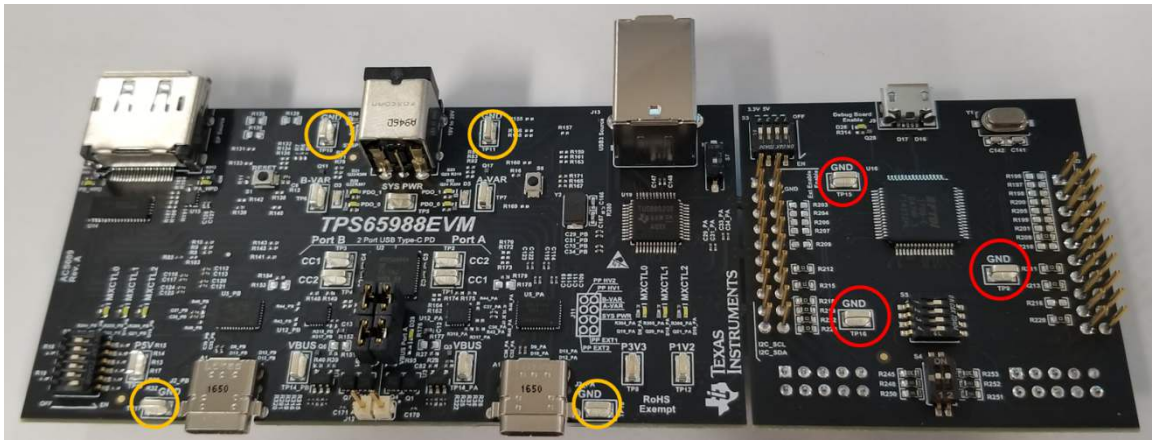


Figure 5-30. TP10, TP11, TP15, TP16, TP17, TP18, TP9: GND Test Points

5.1.15 TP1, TP2, TP3 and TP4 – 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. Figure 5-31 and Figure 5-32 the highlight these features.

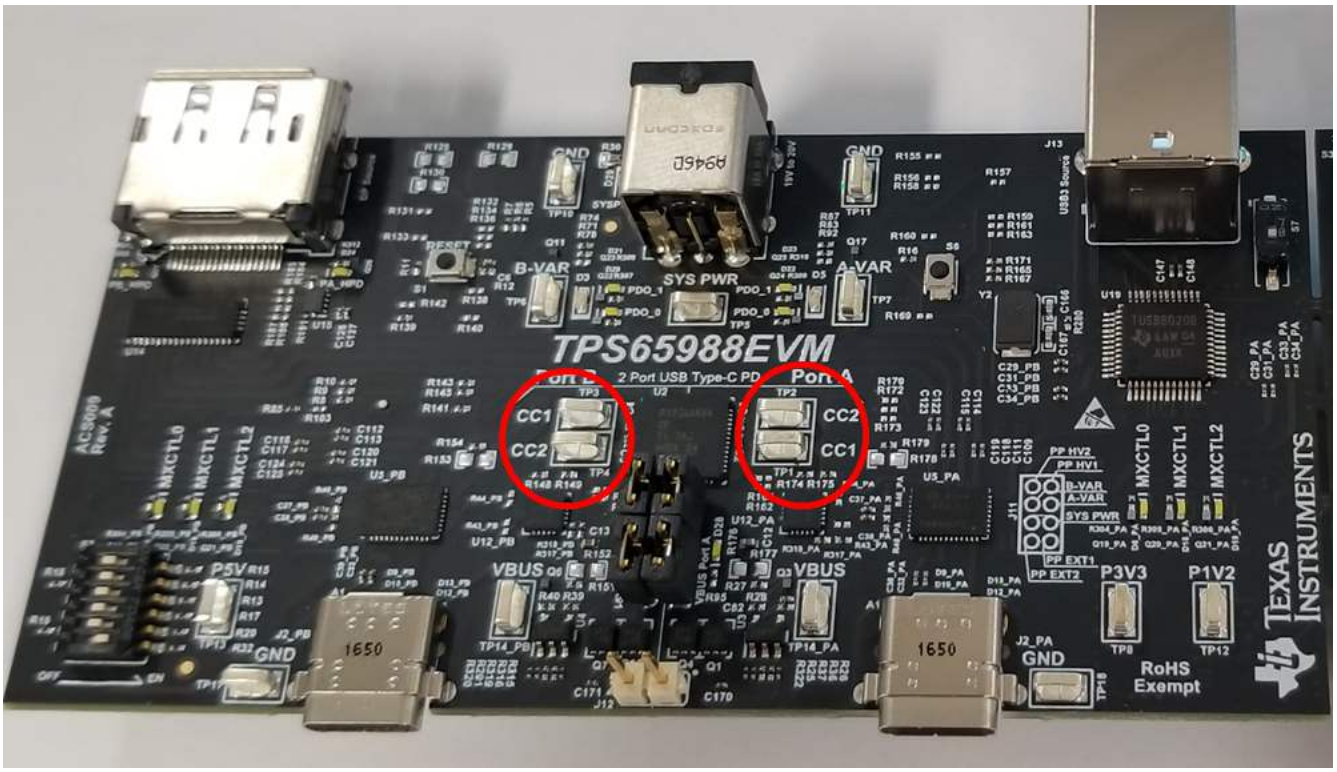


Figure 5-31. TP1, TP2, TP3 and TP4 – CC1 and CC2 Test Points

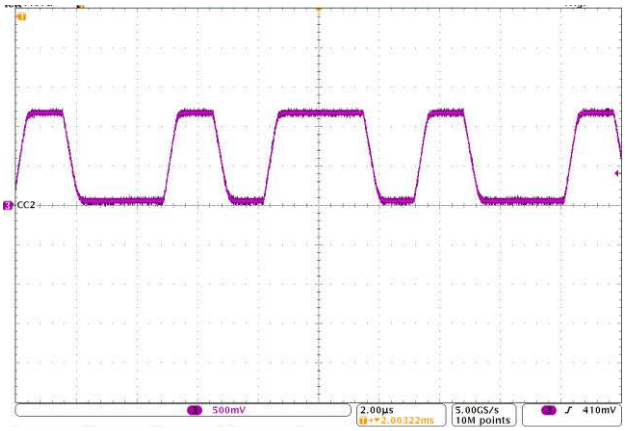


Figure 5-32. TPS65988 BMC Data

5.1.16 TP14 (PA and PB): VBUS Test Point

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 TPS65988EVM. 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. Refer to the *TPS65988 Configuration Tool User Guide* for configuration instructions. Figure 5-33 and Figure 5-34 highlights these features.

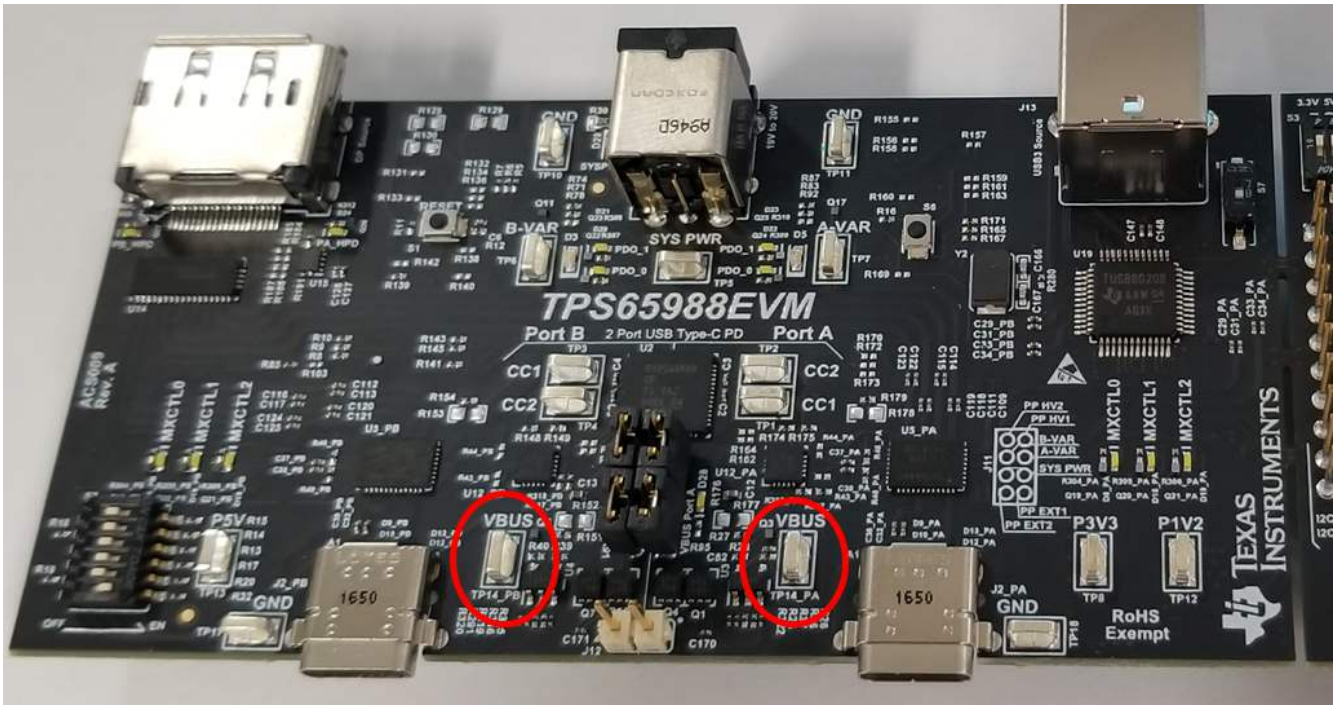


Figure 5-33. VBUS Test Points: TP14

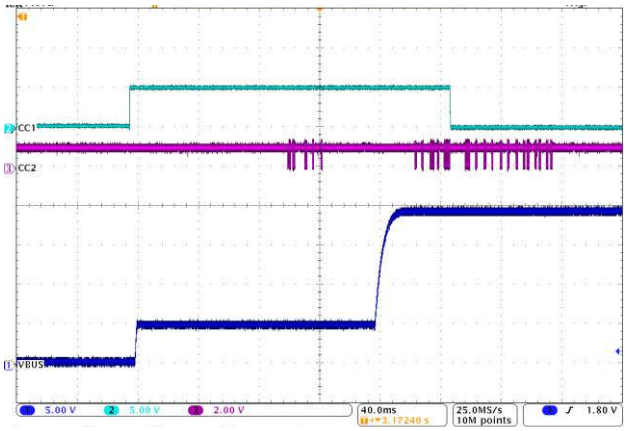


Figure 5-34. TPS65988 VBUS Voltage Transition

5.1.17 TP7, TP6, and TP5: A-VAR, B-VAR, and System Power Test Points Respectively

Test point A-VAR (TP7) is the output of the variable DC/DC for port A. Test point B-VAR (TP6) is the output of the variable DC/DC for port B. These test points are provided for attaching an oscilloscope, multimeter, or external supply. System power (TP5) can be in the operating range of 5–20 V, any voltage lower than 20 V decreases the sourcing power capabilities. Figure 5-35 highlights these features.

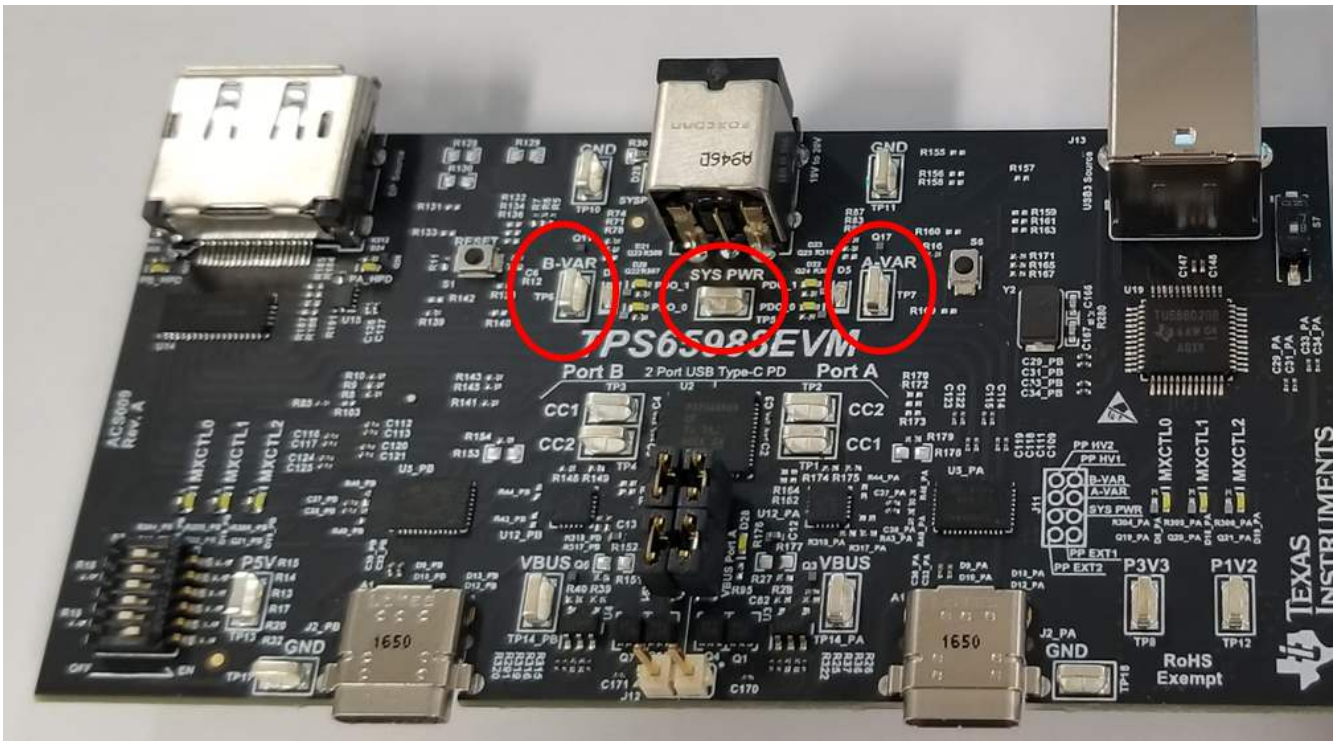


Figure 5-35. A-Var, B-Var and System Power Test Points: TP7, TP6, and TP5

5.1.18 J3 and J4 (Bottom of EVM): Signal Headers

These headers allow the user to probe many different signals on the TPS65988EVM. Note that some of the header pins are not connected unless a 0-Ω option resistor is placed. Figure 5-36 highlights these features.

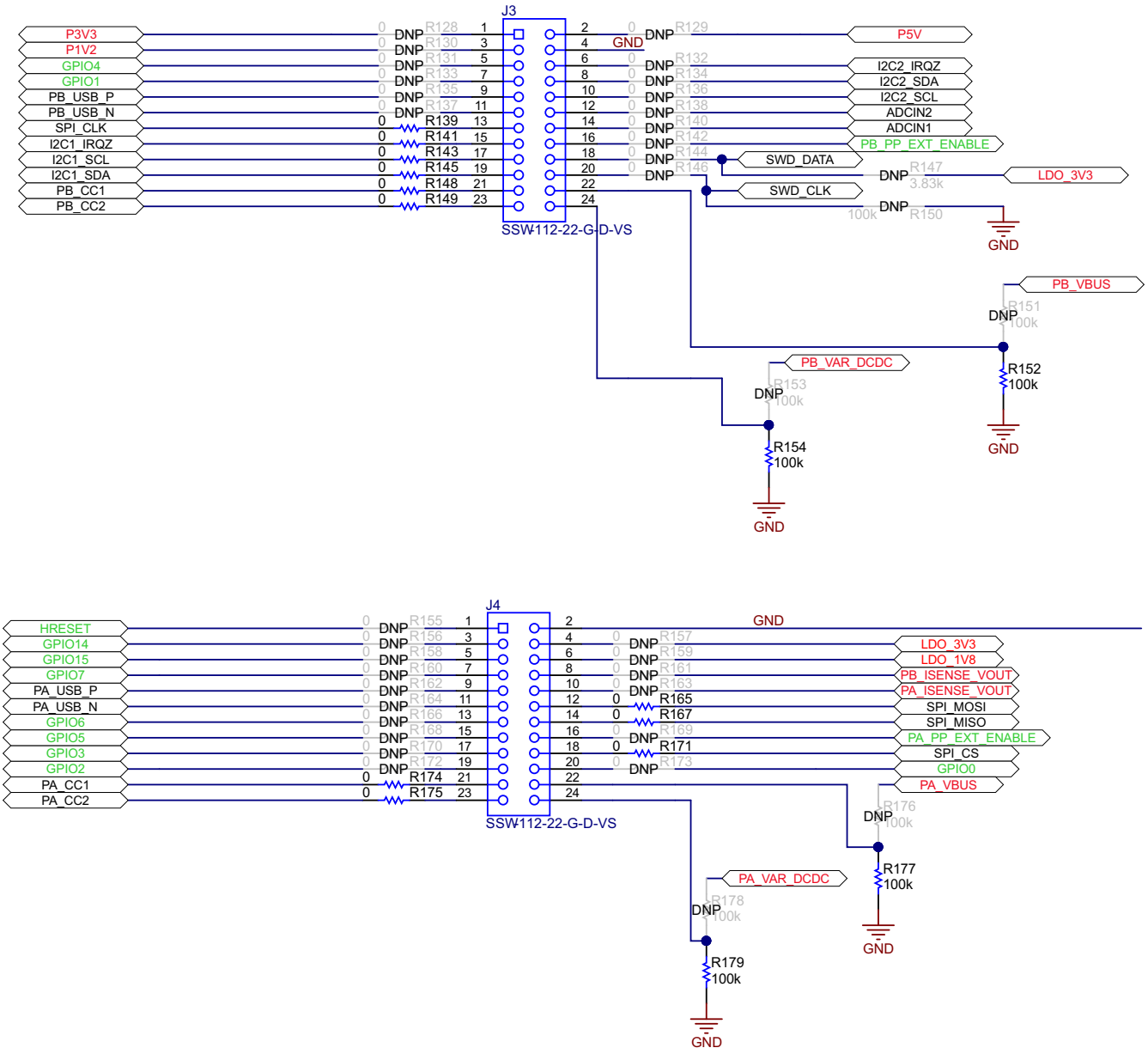


Figure 5-36. BoosterPack™ Headers (J3 and J4)

5.2 LED Indicators Description

The EVM has multiple LEDs to notify the user what type of connection is present. The LEDs are separated into two groups: MUX control LEDs (MXCTL0–2) 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 (see *TPS65988 Configuration Tool User Guide*). By default MXCTL0 LED is on when the connected device supports USB3.0, MXCTL1 LED is on when DisplayPort Alternate Mode is entered. MXCTL2 highlights the orientation of the cable. When MXCTL2 LED is on, CC2 is connected. When MXCTL2 LED is off, CC1 is connected.

5.2.1 MXCTL0-2 and HPD LEDs (SS MUX Control LED)

These LEDs correspond to the MUX control signals needed for the SS MUX on either USB Type-C port. Figure 5-37 and Figure 5-38 Table 5-1 highlight these features and Table 5-1 and Table 5-2 summarize the LED behavior.

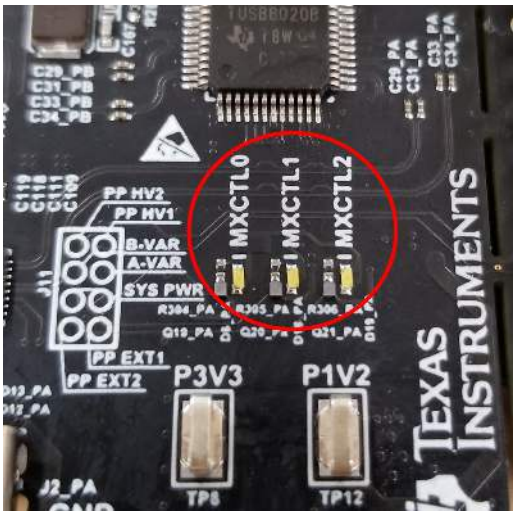


Figure 5-37. MUX Control LEDs

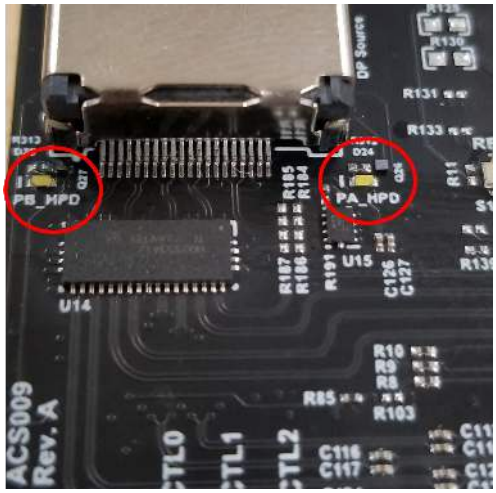


Figure 5-38. HPD Port A/B LEDs

Table 5-1. Port A SS MUX Control LED Functions

LED Indicator	GPIO	Function
D6 - MXCTL0	GPIO6	USB 3.0 event
D18 - MXCTL1	GPIO5	DP mode event
D19 - MXCTL2	GPIO7	Cable orientation event
D24 - PA_HPD	GPIO3	HPD

Table 5-2. Port B SS MUX Control LED Functions

LED Indicator	GPIO	Function
D6 - MXCTL0	GPIO_1	USB 3.0 event
D18 - MXCTL1	GPIO_0	DP mode event
D19 - MXCTL2	GPIO_2	Cable orientation event
D25 - PB_HPD	GPIO_4	HPD

5.2.2 Status LEDs

LEDs, D5 and D3, are for the variable DC/DC on port A, and port B, respectively. When powering up the EVM, these LEDs lights up blue. They also provide a voltage discharge path for high to low PD contracts. For higher voltage PD contracts, D5 and D3 are brighter. Figure 5-39 highlights these features and Table 5-3 summarizes the LED behavior.

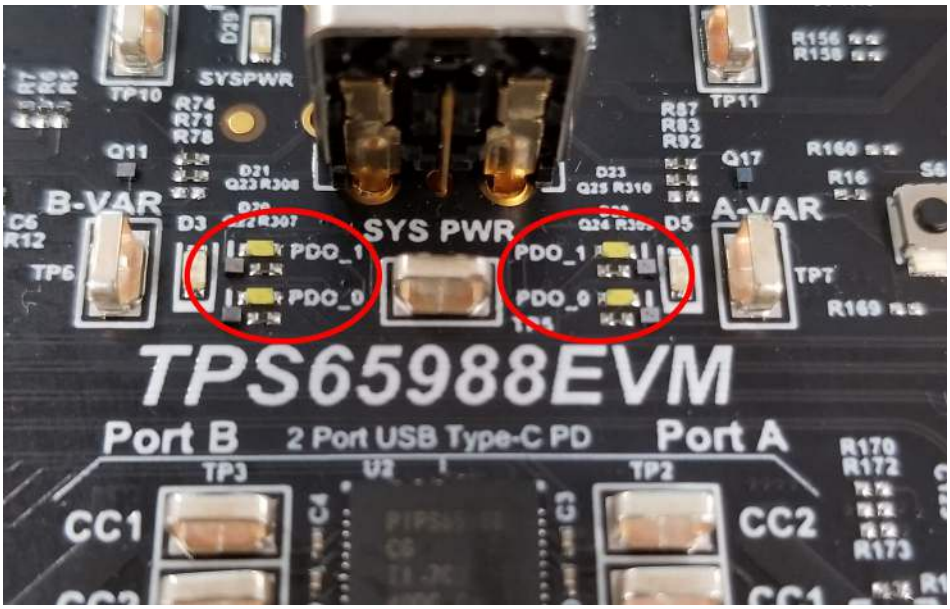


Figure 5-39. PDO Port A/B LEDs

Table 5-3. Variable DC/DC Control Port A/B Functions

LED Indicator	GPIO	Function
D20 - PA_PDO0	GPIO_12	PDO TT bit 0
D21 - PA_PDO1	GPIO_13	PDO TT bit 1
D23 - PB_PDO1	GPIO_14	PDO TT bit 1
D22 - PB_PDO0	GPIO_15	PDO TT bit 0
D5 - PA_VAR_DCDC	GPIO_16	VAR-A enable
D3 - PB_VAR_DCDC	GPIO_17	VAR-B enable

The PDO LEDs in Table 5-4 are high, depending on which PDO is negotiated. By activating these LEDs, the output voltage of the variable DC/DC can be changed. Table 5-4 summarizes the PDO LED behavior.

Table 5-4. PDO LED 0 and PDO LED 1 Truth Table

PDO	PDO LED 1	PDO LED 0	R1	R2	Output Voltage
PDO 1 (5 V)	0	0	60.4 kΩ	19.1 kΩ	5.15 V
PDO 2 (9 V)	0	1	60.4 kΩ	9.27 kΩ	9.26 V
PDO 3 (15 V)	1	0	60.4 kΩ	5.2 kΩ	15.62 V
PDO 4 (20 V)	1	1	60.4 kΩ	4.04 kΩ	19.78 V

5.2.3 S2 Switch Bank Functionality

The I^2C address setting must match the configuration generated by the TPS65988 configuration tool. Table 5-5 summarizes the I^2C address settings. To adjust the dead battery boot behavior, the setting on ADCIN1 can be adjusted. Table 5-6 summarizes the ADCIN1 settings. The specific settings for each divider ratio is discussed in the *TPS65988 datasheet*.

Table 5-5. I^2C Address Setting

Switch	On, Off	Bits	Divider Ratio
1-3	Off	000b	0.00
1	On	001b	0.34
2	On	010b	0.50
3	On	011b	0.90

Table 5-6. ADCIN1 Setting

Switch	On, Off	Bits	Divider Ratio
4-6	Off	000b	0.00
4	On	001b	0.34
5	On	010b	0.50
6	On	011b	0.90

6 Using the TPS65988EVM

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

6.1 Powering the TPS65988EVM

The main power supply for the EVM is the barrel jack (J1), 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 (TP5). The input voltage can range from 5 V to 20 V, but the appropriate power profile for PP_HV 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 TPS65988EVM is configured to emulate a dual-port laptop computer. Both ports are used to source or sink power, and both ports are data DFP. If different configurations are required to test your system, use the *TPS65988 Application Configuration GUI* tool to create a configuration or load a different configuration template.

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 TPS65988 can act as a host passing the DP or USB connection by using the SS MUX and USB HUB. Figure 7-1 shows how the notebook, DP and USB receptacle, TPS65988EVM, cable, and flash drive are connected.

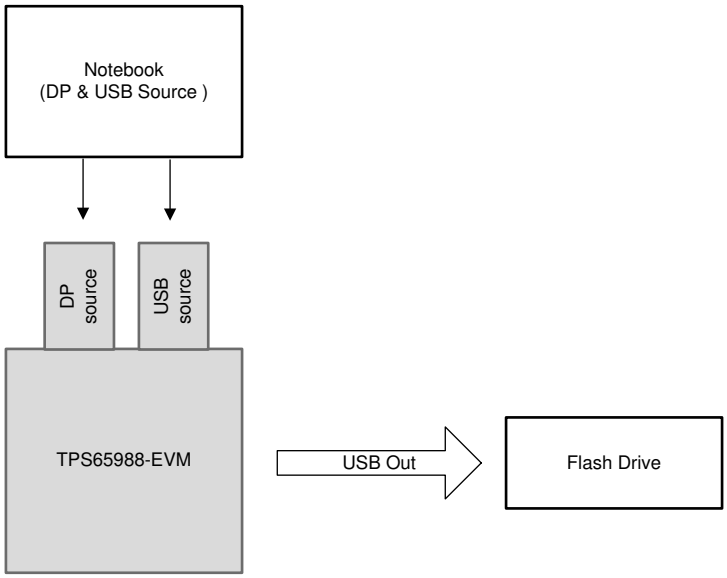


Figure 7-1. Connecting EVM to Type-A Device

7.1.2 Connecting to USB Type-C™ Devices

Using a USB Type-C cable allows for connection to USB and DP devices. Figure 7-2 shows how a source setup can be connected to a DP or USB data-capable device, such as a USB Type-C or Type-A flash drive, USB Type-C to DP directly plugged in port A/B, Type-A flash drive, USB Type-C to DP, HDMI dongle or USB Type-C docking system.

Note

The TPS65988 can only be DP and USB 3.0 host or source.

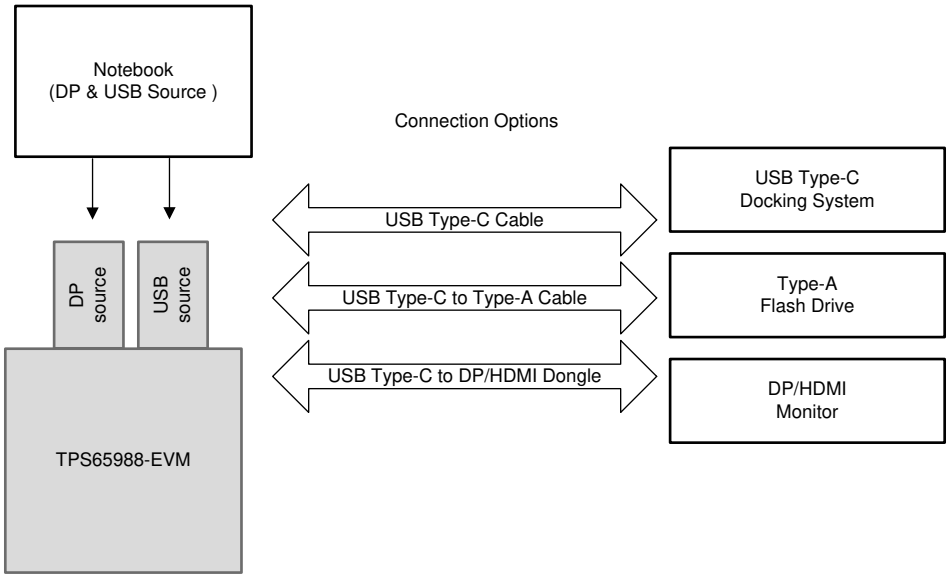


Figure 7-2. Connecting EVM to USB Type-C™ Devices

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 TPS695988EVM and interfacing with configuration tool)
- Dell laptop power supply (model # 492-BBGP)

Use the TPS65988EVM 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 TPS65988EVM through the DP receptacle on the EVM. Next, connect a USB Type-B to USB Type-A cable from the TPS65988EVM to a Windows computer. To test DP, connect a USB Type-C to DP cable from one of the USB Type-C ports to a DP monitor. To test USB functionality, connect a USB Type-C flash drive to the other USB Type-C port on the TPS65988EVM. The monitor displays what is present from the DP source. The flash drive enumerates on the windows PC. Table 7-1 explains this test setup.

Table 7-1. DisplayPort™ and USB Test Setup

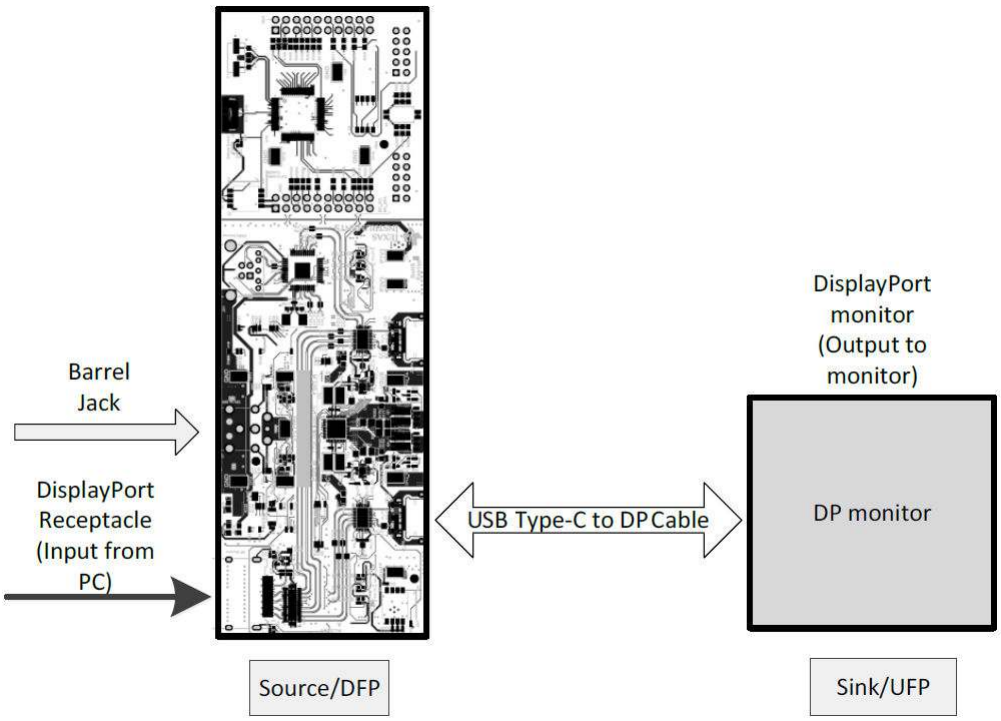
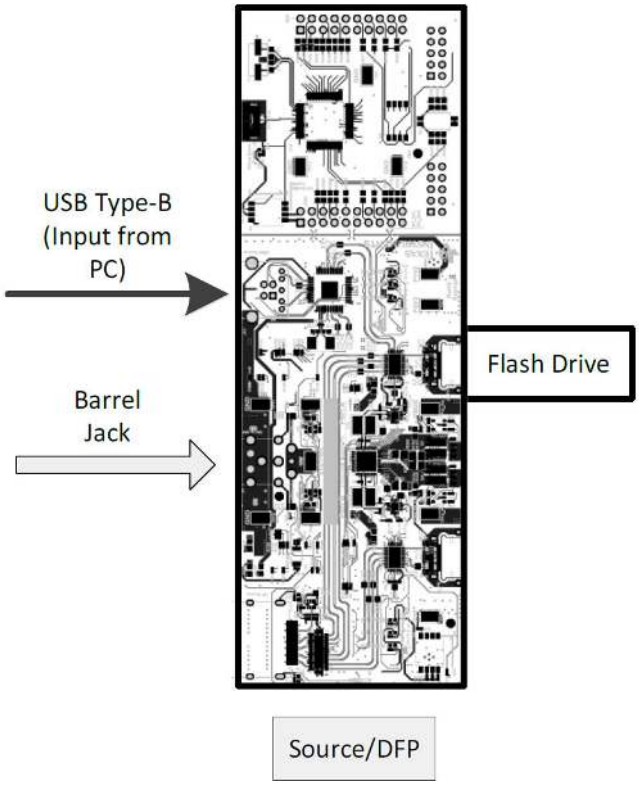
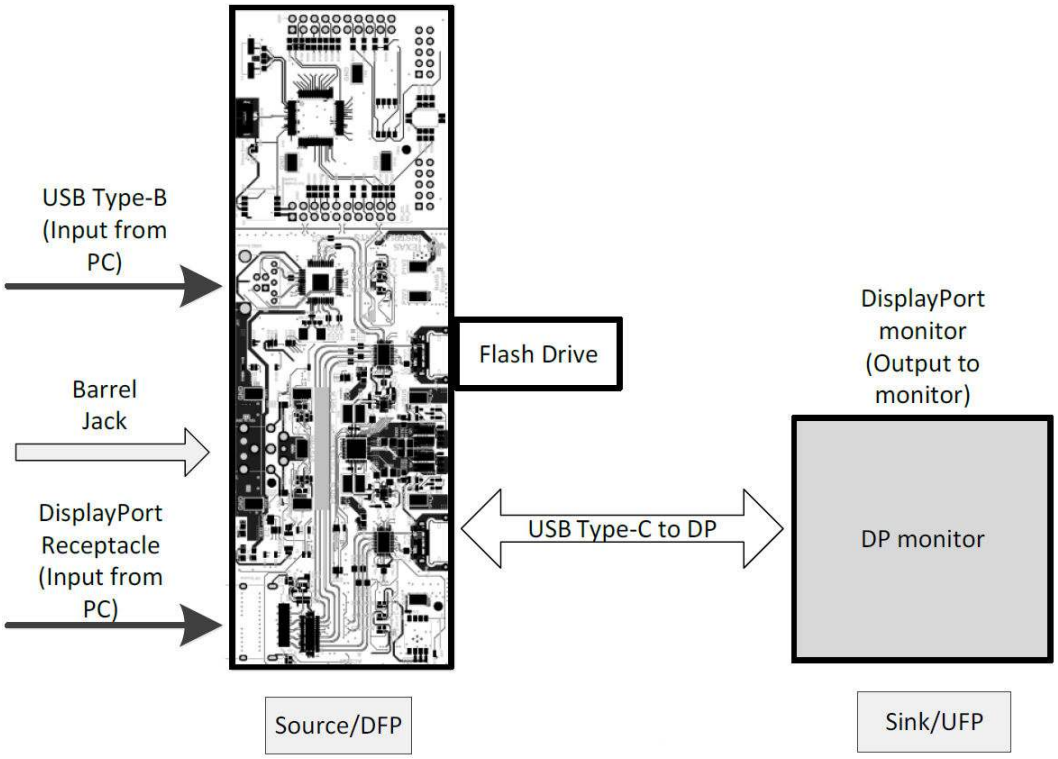
Test Setup	Pass Criteria
DP can be connected from port A/B with a USB Type-C to DP cable.	
USB can be connected to Port A/B directly with a Type-C Flash Drive	

Table 7-1. DisplayPort™ and USB Test Setup (continued)

<table>
<tr><th>Test Setup</th><th>Pass Criteria</th></tr>
<tr><td>Connect a type C cable from DP and USB can be tested simultaneously with the TPS65988EVM setup to the right.</td><td> 
</td></tr>
<tr><td>Observe TPS65988EVM LEDs.</td><td>
<table>
<tr><th>LED Name</th><th>Event Mapping</th><th>Source x988 LED Status</th></tr>
<tr><td>MXCTL0</td><td>USB3</td><td>ON</td></tr>
<tr><td>MXCTL1</td><td>DP</td><td>ON</td></tr>
<tr><td>MXCTL2</td><td>POL</td><td>ON/OFF</td></tr>
<tr><td>HPD</td><td>X</td><td>ON</td></tr>
<tr><td>Variable DC/DC</td><td>X</td><td>A/B ON</td></tr>
</table>
</td></tr>
<tr><td>Check for video on DP monitor and verify USB flash drive enumerates on the PC.</td><td>Successfully copy and paste a file to and from the USB flash drive. Extend the PC to the DP monitor and play video to verify video stream.</td></tr>
<tr><td>Verify the voltages on the DP source board.</td><td>
<table>
<tr><th>Source Test Point</th><th>Test Point Name</th><th>Voltage</th></tr>
<tr><td>TP12</td><td>P1V2</td><td>1.2 V</td></tr>
<tr><td>TP8</td><td>P3V3</td><td>3.3 V</td></tr>
<tr><td>TP13</td><td>P5V</td><td>5 V</td></tr>
<tr><td>TP5</td><td>SYS_PWR</td><td>20 V</td></tr>
</table>
</td></tr>
</table>

If video is displayed on the monitor, it is confirmed that DP alternate mode is entered. Similarly, if the USB flash drive can be read by the attached PC, it is confirmed that USB data is functioning properly. USB 3.0 data can be confirmed by observing LED MUX_CTRL0 in the high state.

7.2 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.

7.2.1 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 TPS65988 using the *TPS65988 Configuration Tool*
- Verify the CC lines are toggling for *Dual-Role Port* functionality (see Figure 7-3)
- Verify the following system supplies:
  - System_3V3 and VIN_3V3: 3.3 V
  - System_5V and PP_CABLE: 5 V
  - Barrel jack and SYS_PWR: 20 V
  - LDO_3V3: 3.3 V
  - LDO_1V8: 1.8 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, (see Figure 7-4)

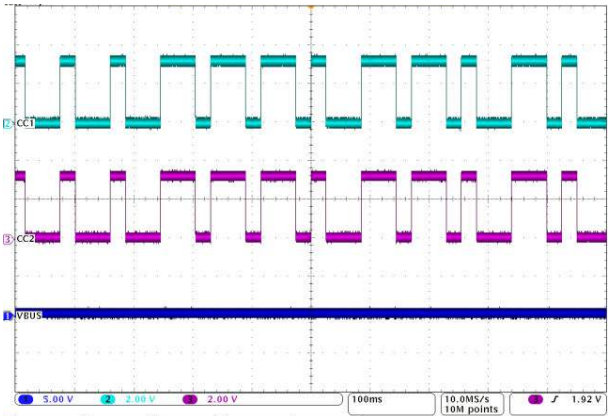


Figure 7-3. DRP CC1 and CC2 Toggling

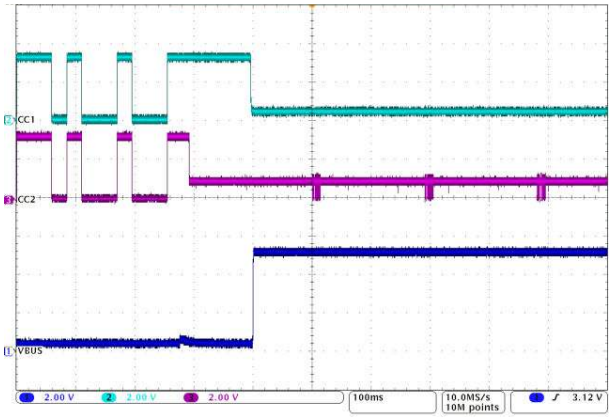


Figure 7-4. USB Type-C™ Connection and VBUS

7.2.2 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. Figure 7-5 shows a successful power contract.
- 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_HV or PP_EXT switch is closed and is then opened, once an overcurrent condition is detected.

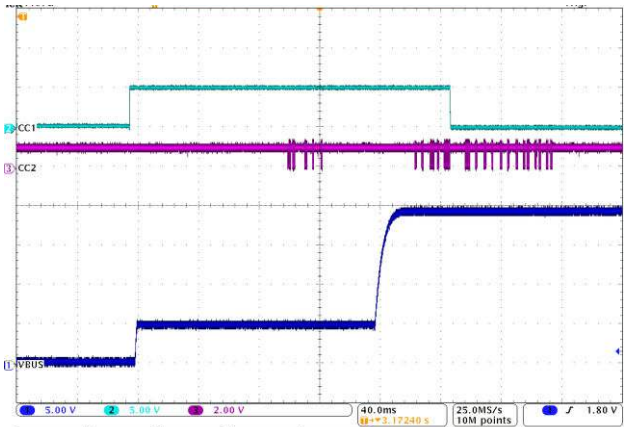


Figure 7-5. USB Type-C™ Connection and PD Negotiation

8 REACH Compliance

In compliance with the Article 33 provision of the EU REACH regulation, the user is notified that this EVM includes component(s) containing at least one Substance of Very High Concern (SVHC) above 0.1%. The substance use from Texas Instruments does not exceed 1 ton per year. The SVHCs are shown in Table 8-1.

Table 8-1. REACH Compliance

Component Manufacturer	Component part number	SVHC Substance	SVHC CAS (when available)
Abracon	ABM3-24.000MHZ-D2Y-T	Diboron Trioxide	1303-86-2
Abracon	ABM3-24.000MHZ-D2Y-T	Lead Oxide	1317-36-8

9 TPS65988EVM Schematic

Figure 9-1 shows the block diagram of the main components of the TPS65988EVM. The main schematic blocks port A/B control MUX and SS MUX, USB HUB, power paths, power supplies, USB Type-C receptacles, processor, BoosterPack headers, and hardware.

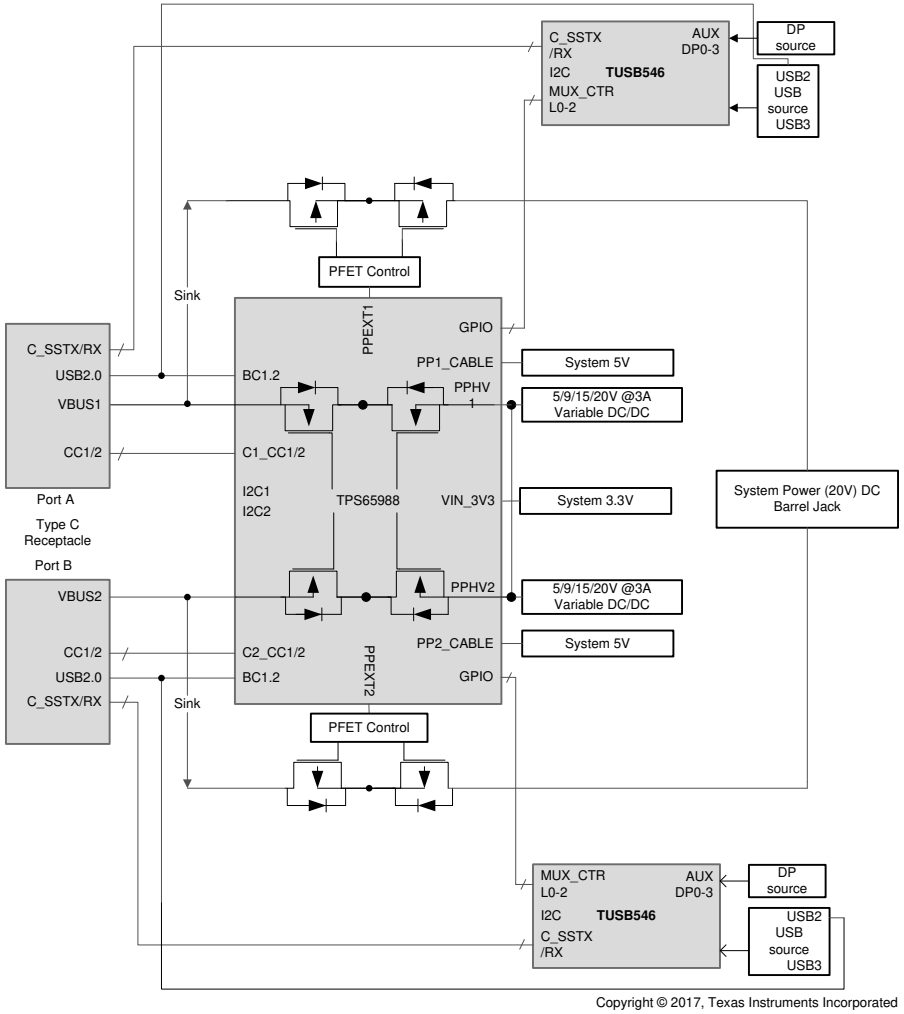


Figure 9-1. TPS65988EVM Block Diagram

Figure 9-2 illustrates the processor block showing the USB Type-C PD controller and contains connections for GPIOs, D+ and D-, CC1 and CC2, HRESET, I^{2}C lines, SPI for flash memory, and ADC1 and ADC2.

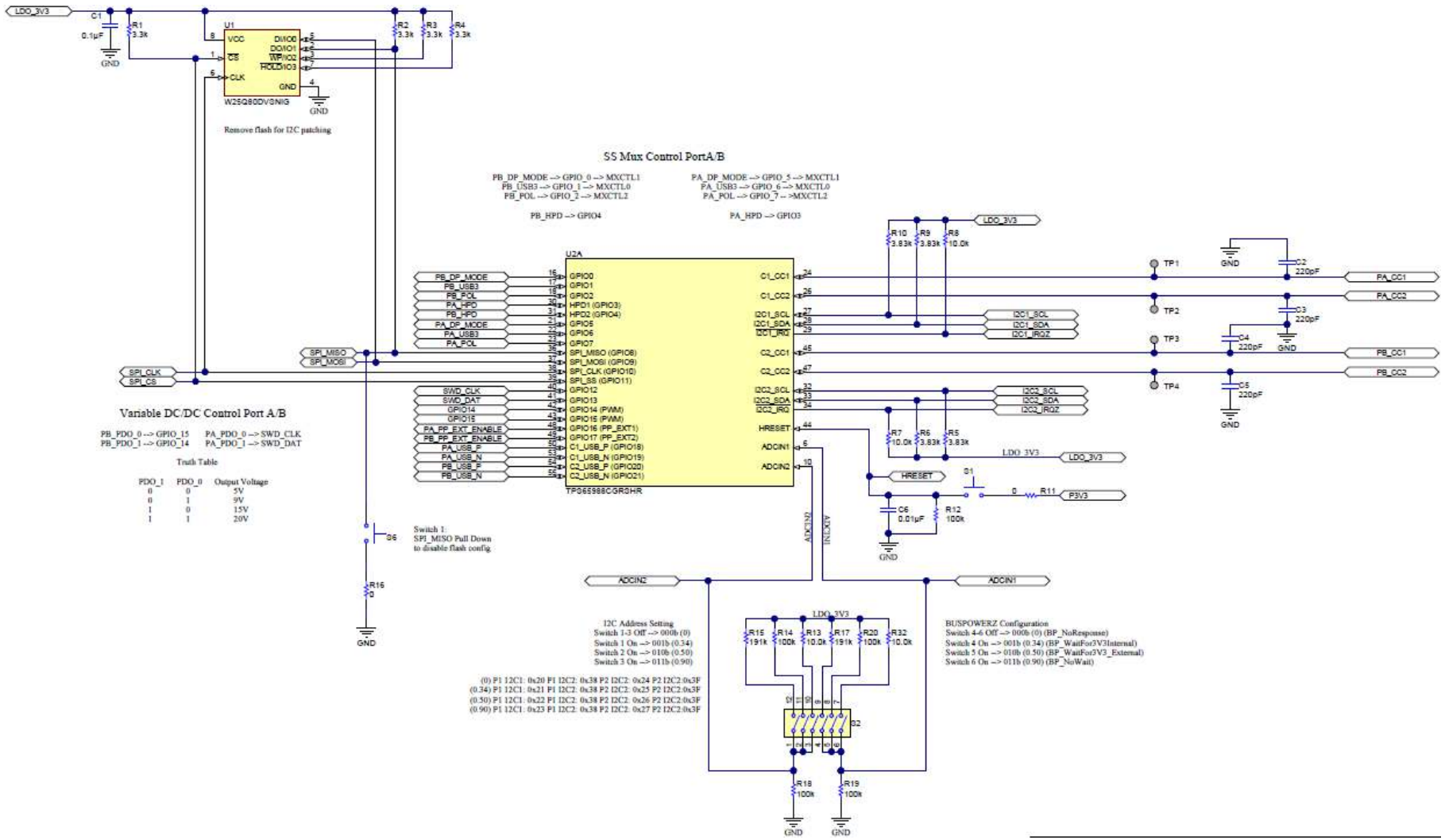


Figure 9-2. TPS65988EVM Processor Block

Figure 9-3 shows the power path block, which contains the power portion of the TPS65988 and the required passives. The external power path consists of back-to-back PMOS with RCP circuit. The internal power path is used for sourcing power and the external power path is used for sinking power. The TPS65988 power path can provide power to VBUS or consume power from VBUS.

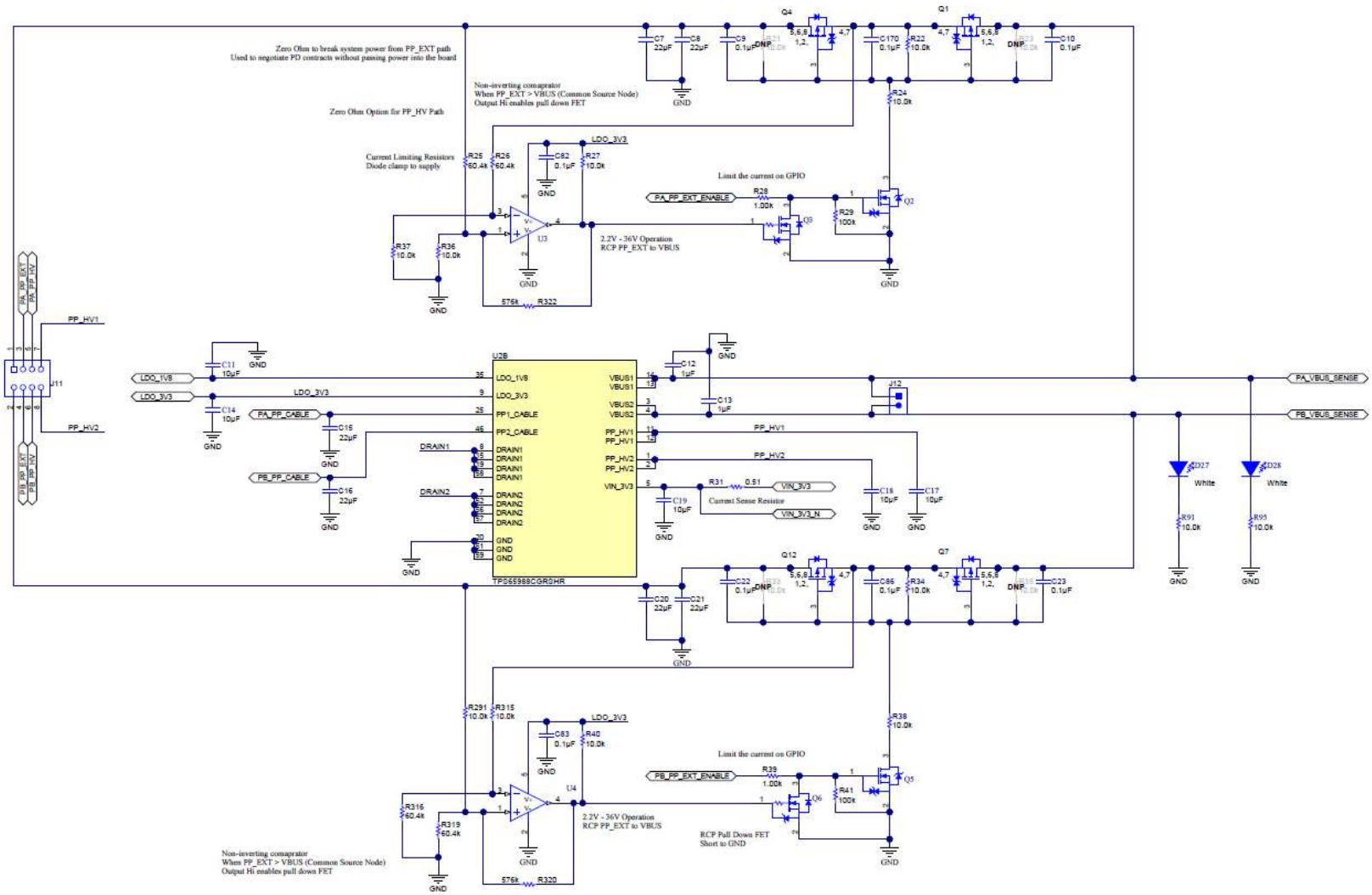


Figure 9-3. TPS65988EVM Power Path Block

Figure 9-4 shows the power supply block, which has all of the onboard supplies generated and the comparator circuit for barrel-jack detection. There are two variable supplies that generate 5, 9, 15, and 20 V. There are three DC/DC converters that generate 1.2, 3.3, and 5 V. The minimum voltage for SYS_PWR is 5 V; however, this also decreases VBUS maximum power capabilities. When using a lower voltage, the comparator circuit may have to be adjusted to trip at a lower voltage for proper barrel jack detection.

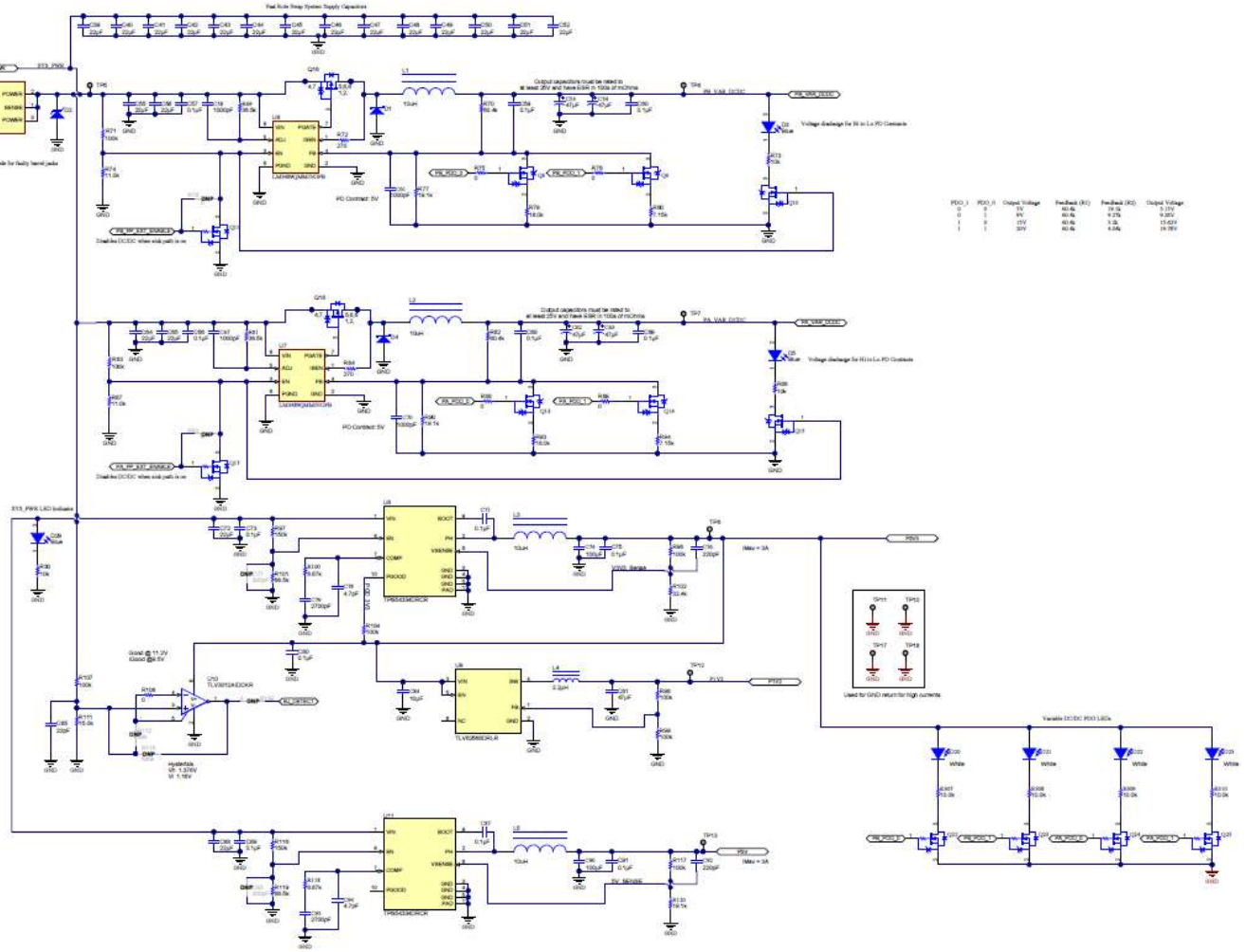


Figure 9-4. TPS65988EVM Power Supply Block

Figure 9-5 shows the DisplayPort Mux used to switch the DisplayPort signals to either USB Type-C Port.

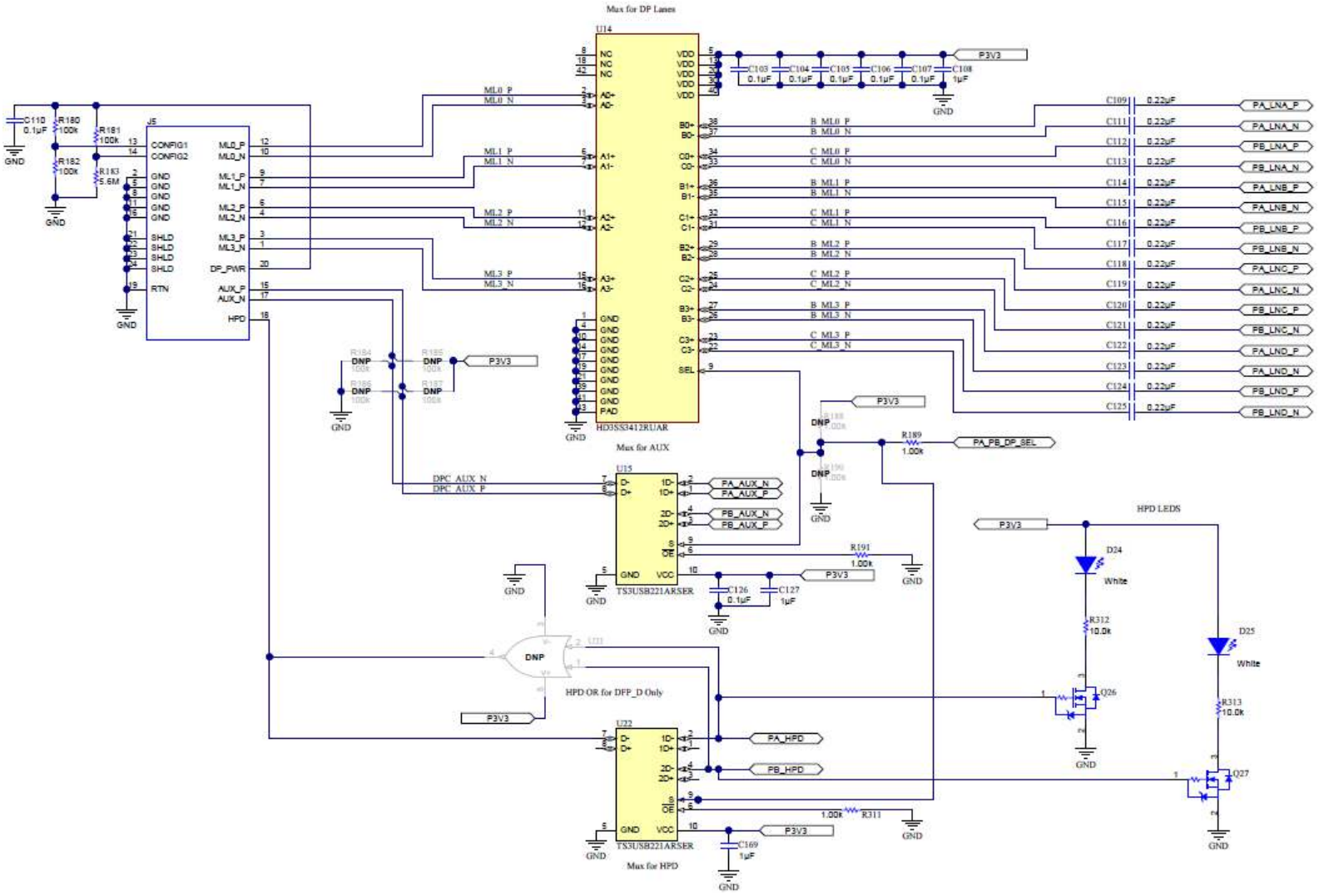


Figure 9-5. TPS65988EVM DisplayPort Mux

Figure 9-6 shows the SS MUX block for port A which connects the DP and USB signals from the DP and USB receptacle. Operating from the system 3.3-V rail, the SS MUX is used for configurations C, D, and E from DisplayPort. Achieve configurations through GPIO or I^{2}C. As the host, the SS MUX is capable of USB 3.1 data rates up to 5 Gbps and DP 1.4 up to 8.1 Gbps with 2 or 4 DP lanes.

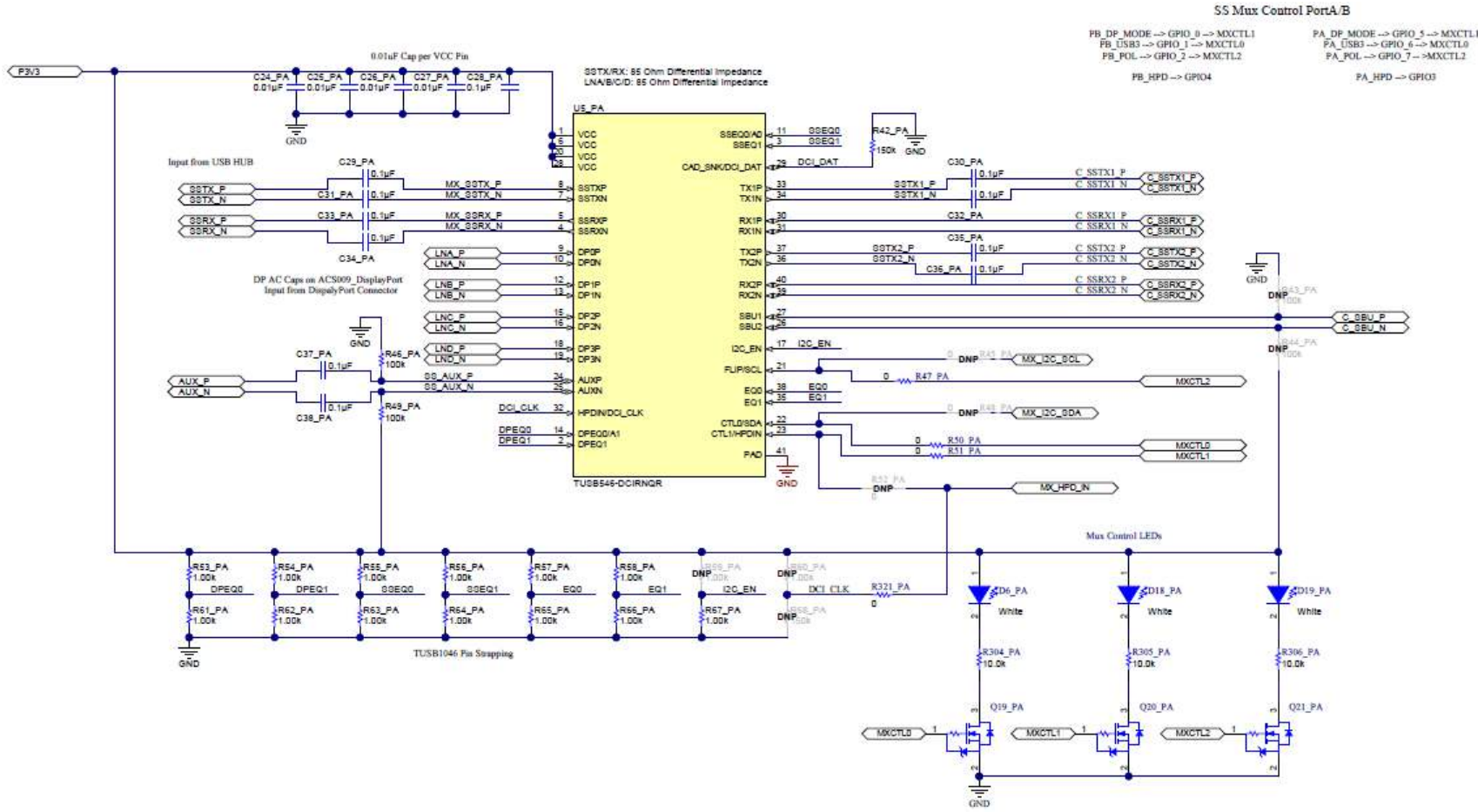


Figure 9-6. TPS65988EVM SS MUX Block Port A

Figure 9-7 shows the SS MUX block for port B which connects the DP and USB signals from the DP and USB receptacle. Operating from the system 3.3-V rail, the SS MUX is used for configurations C, D, and E from DisplayPort. Achieve configurations through GPIO or I^{2}C. As the host, the SS MUX is capable of USB 3.1 data rates up to 5 Gbps and DP 1.4 up to 8.1 Gbps with 2 or 4 DP lanes.

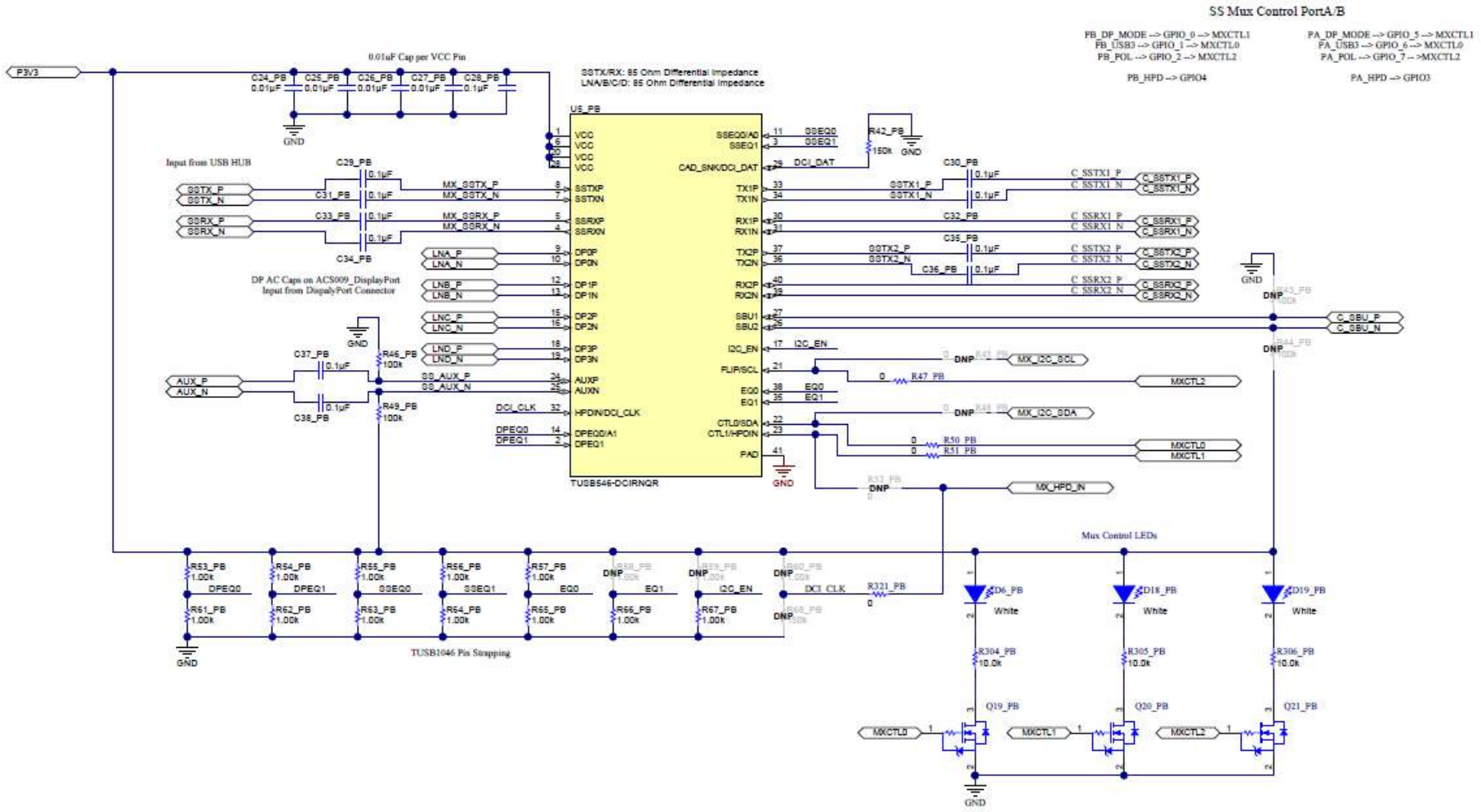


Figure 9-7. TPS65988EVM SS MUX Block Port B

Figure 9-8 shows the USB HUB, which contains the connections from the USB source receptacle.

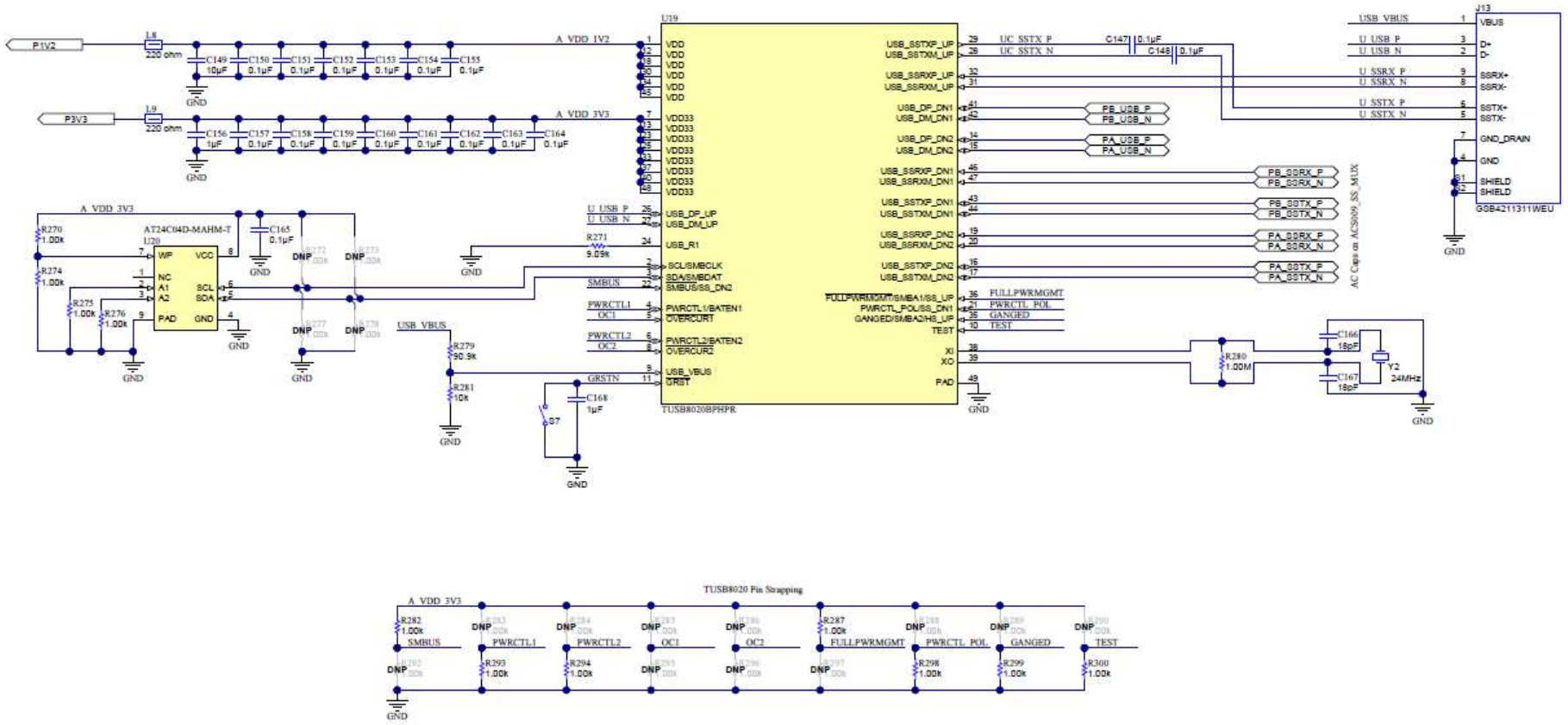


Figure 9-8. TPS65988EVM USB HUB

Figure 9-9 shows the USB Type-C block, which includes the USB Type-C port A and ESD protection.

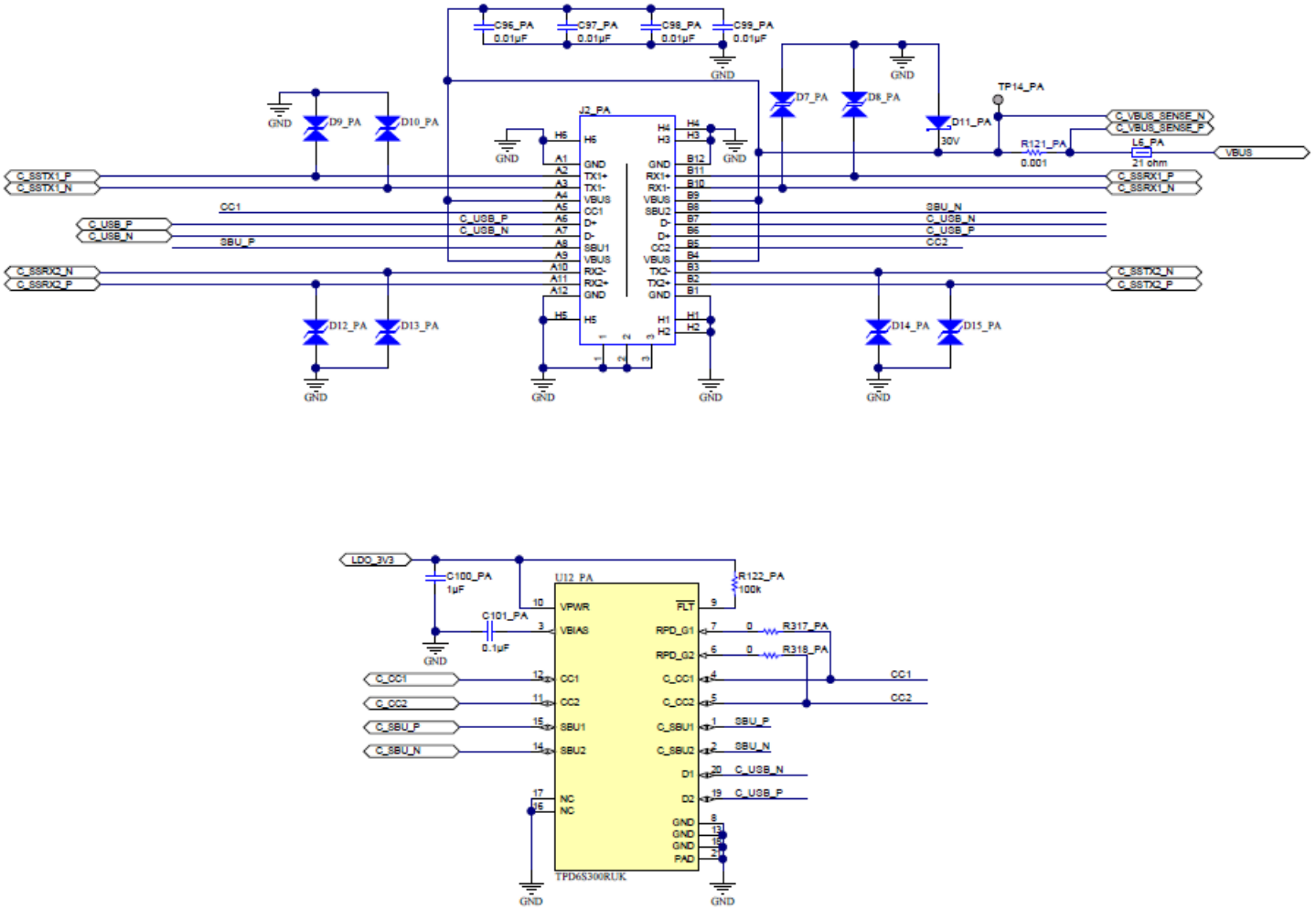


Figure 9-9. TPS65988EVM USB Type-C™ Port-A Block

Figure 9-10 shows the USB Type-C block, which includes the USB Type-C port B and ESD protection.

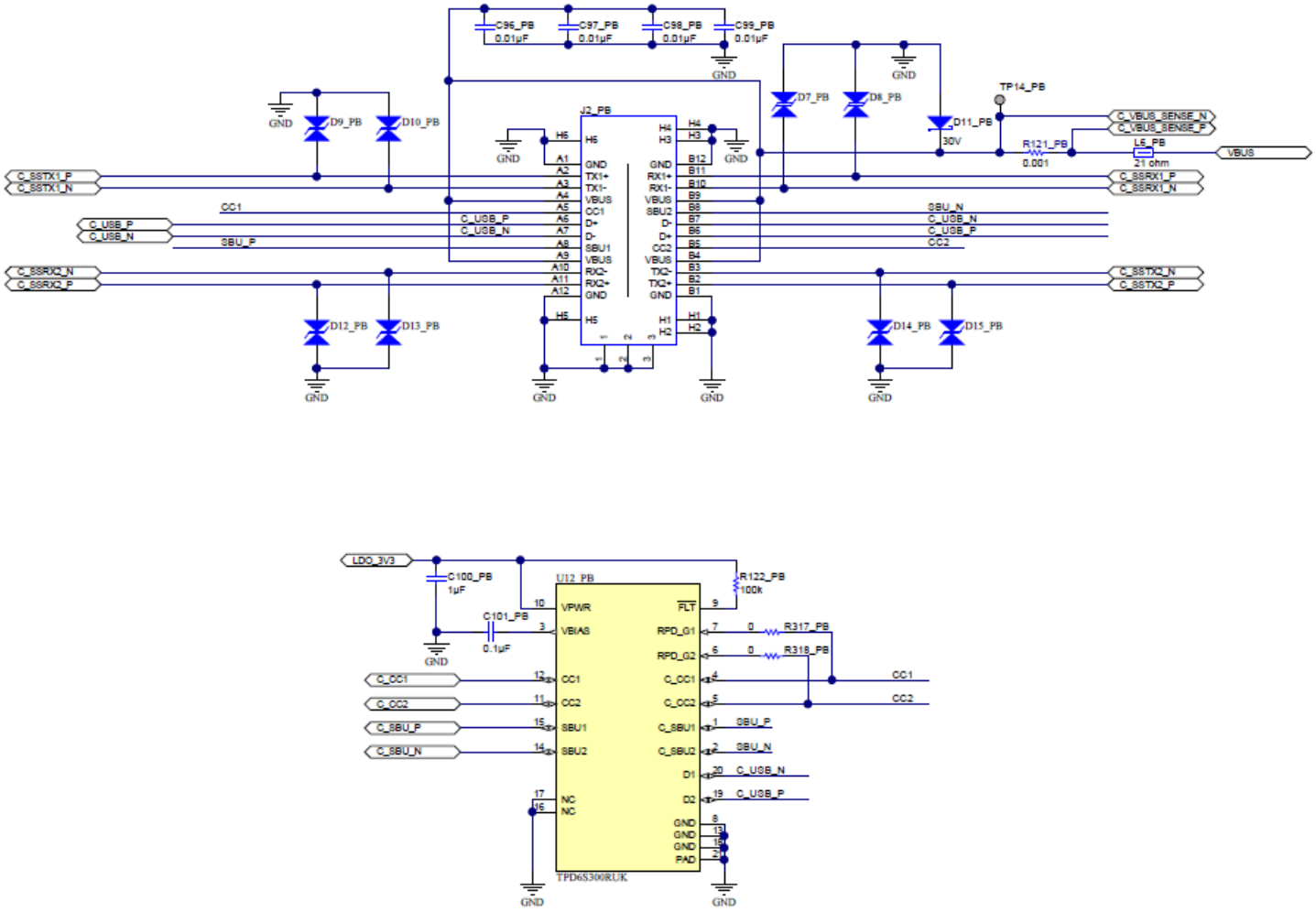


Figure 9-10. TPS65988EVM USB Type-C™ Port B Block

Figure 9-11 shows the FTDI block, which contain the connections from the FTDI board.

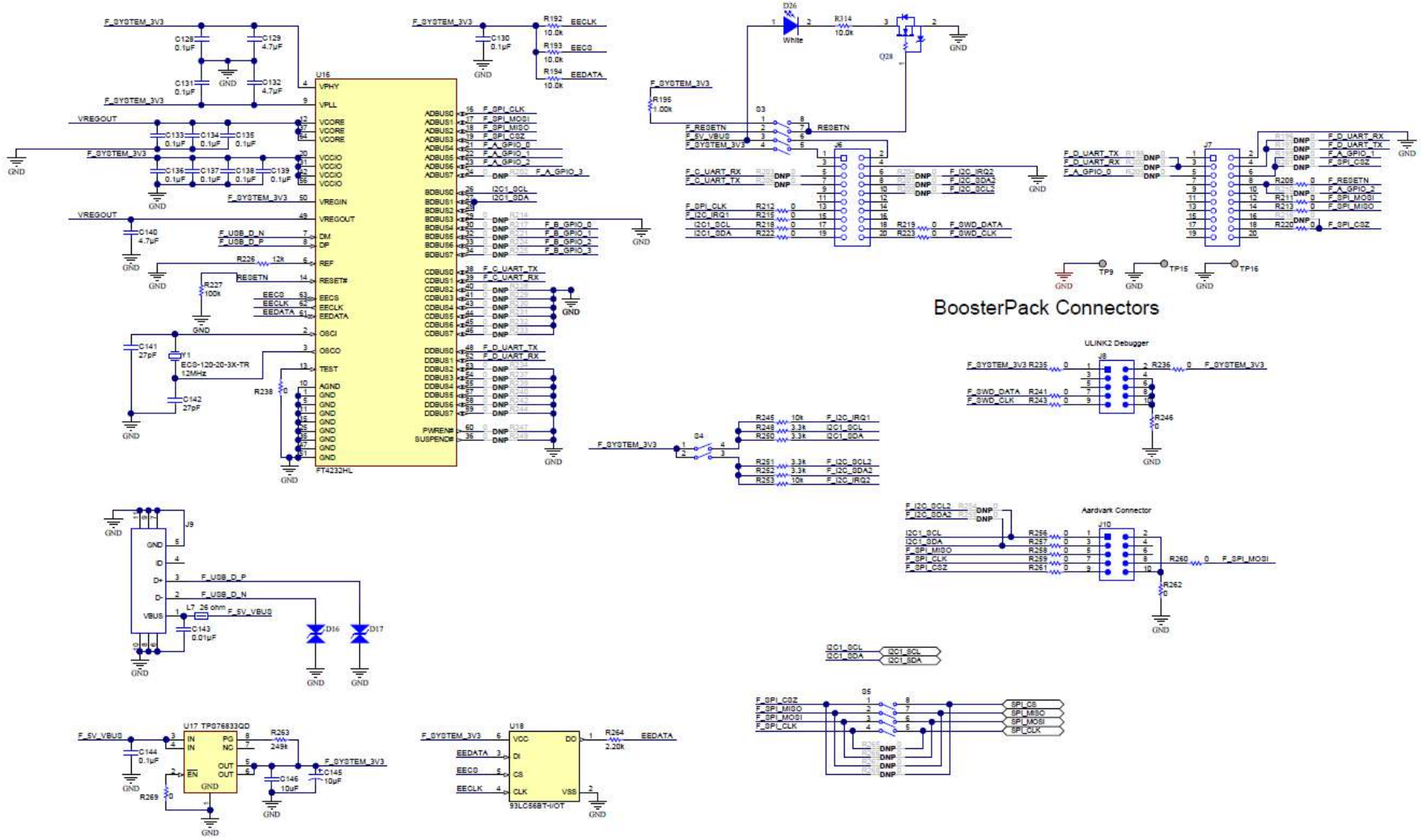


Figure 9-11. TPS65988EVM FTDI® Connector Block

Figure 9-12 and Figure 9-13 show the current sense block, which contain the sense connections to VBUS and VIN_3V3 for port A and port B.

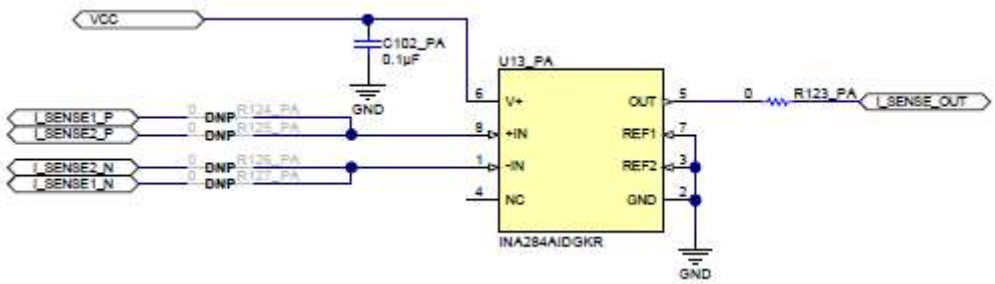


Figure 9-12. TPS65988EVM Current Sense Block Port A

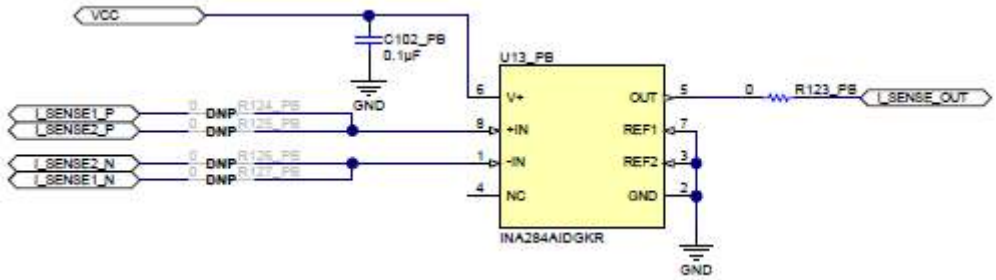


Figure 9-13. TPS65988EVM Current Sense Block Port B

Figure 9-14 shows the BoosterPack headers block, which contain the connections to the BoosterPack headers.

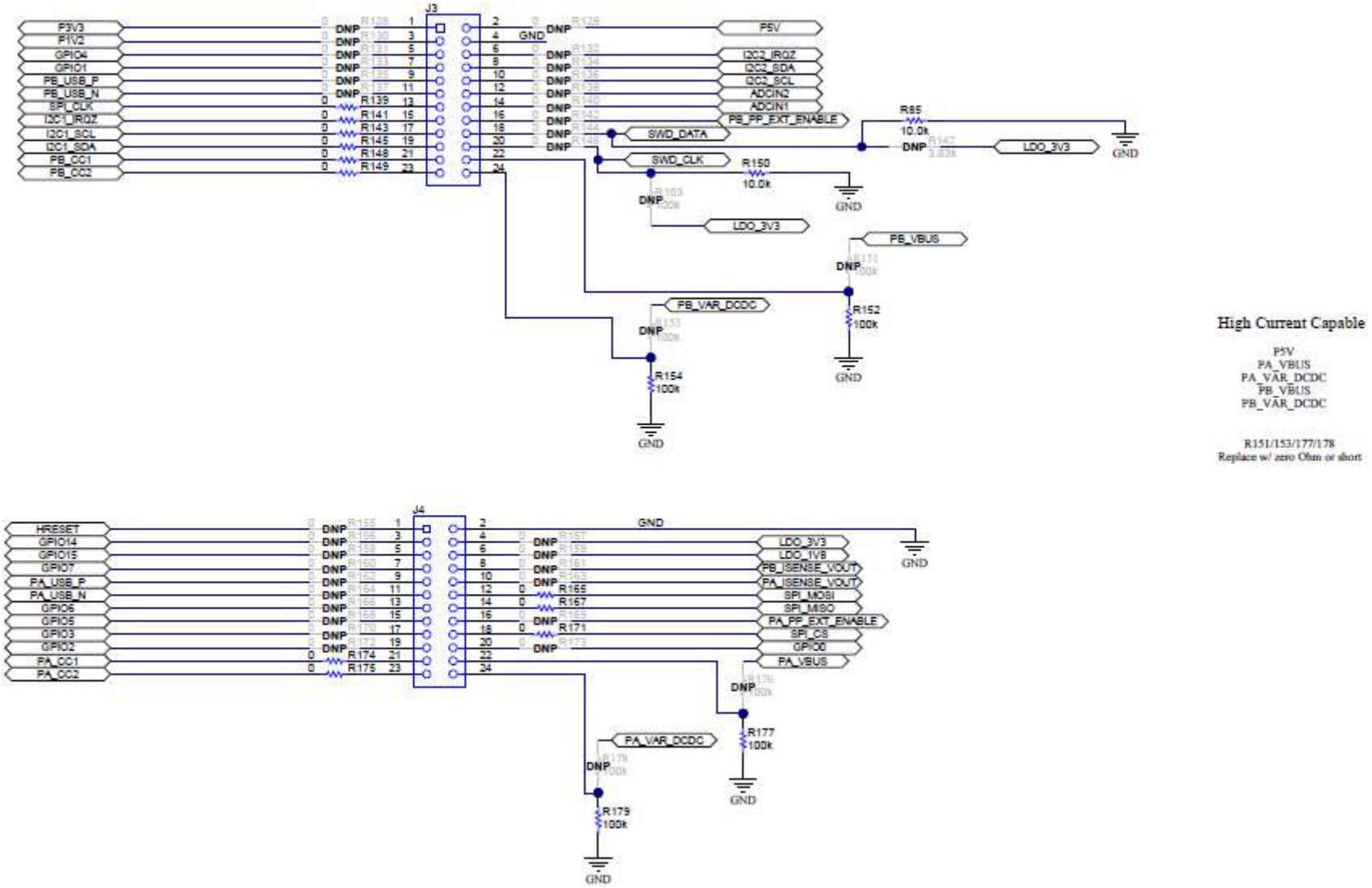


Figure 9-14. TPS65988EVM BoosterPack Header Block

10 TPS65988EVM Board Layout

Figure 9-1 through Figure 10-12 contain the PCB layouts of the TPS65988EVM.

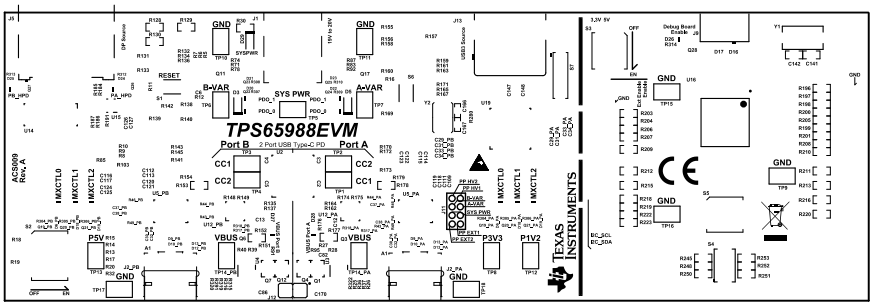


Figure 10-1. TPS65988EVM Top Overlay

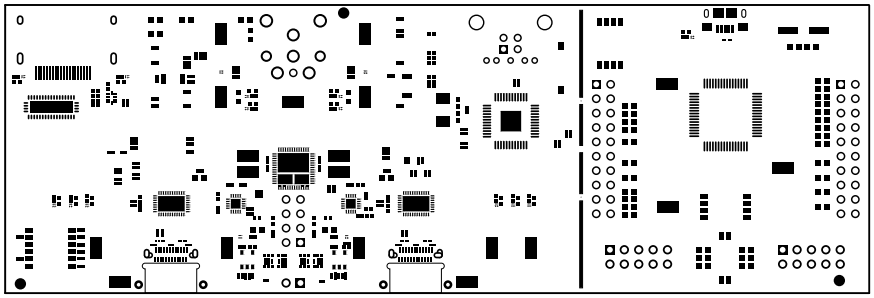


Figure 10-2. TPS65988EVM Solder

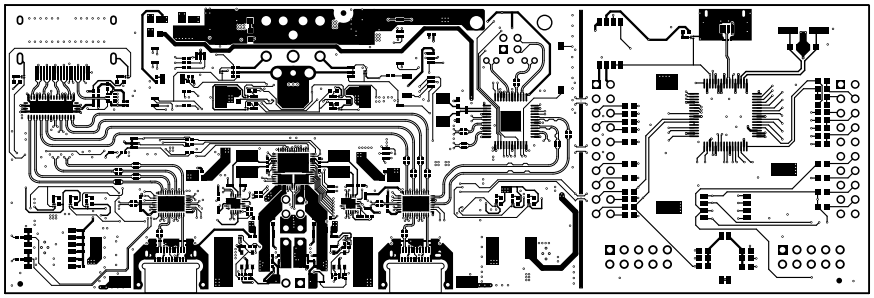


Figure 10-3. TPS65988EVM Top Layer SSTXRX1

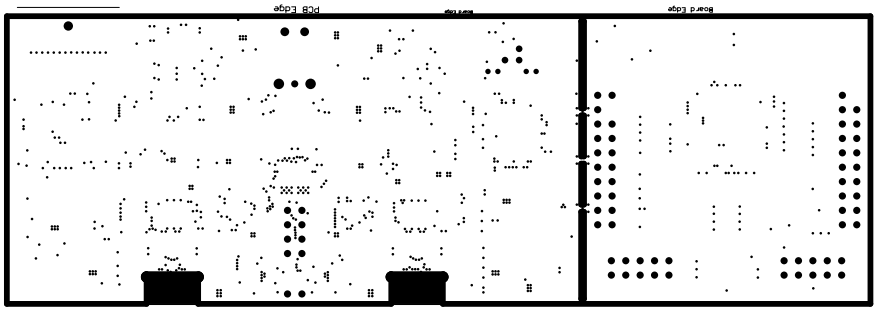


Figure 10-4. TPS65988EVM GND Plane 1

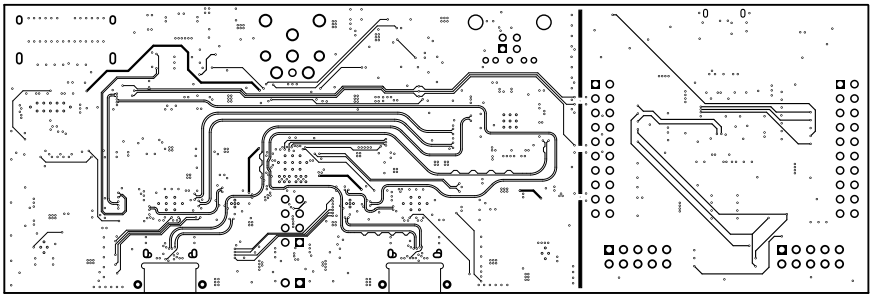


Figure 10-5. TPS65988EVM High Speed

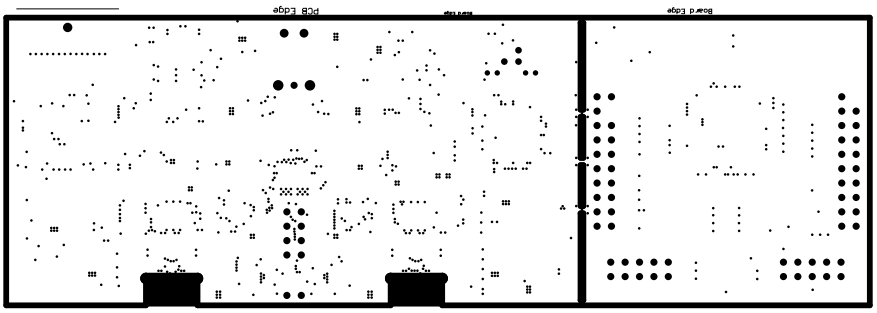


Figure 10-6. TPS65988EVM GND Plane 2

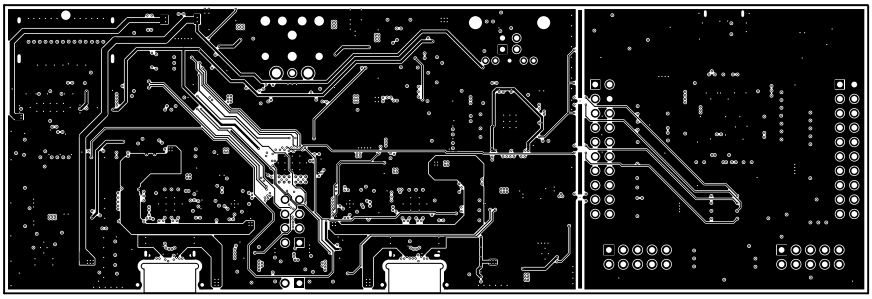


Figure 10-7. TPS65988EVM Power 1

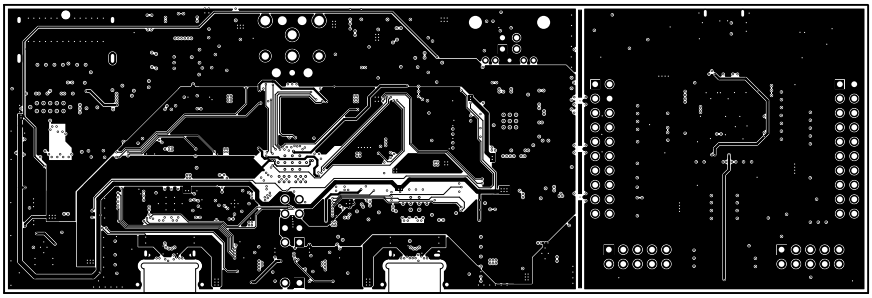


Figure 10-8. TPS65988EVM Power 2

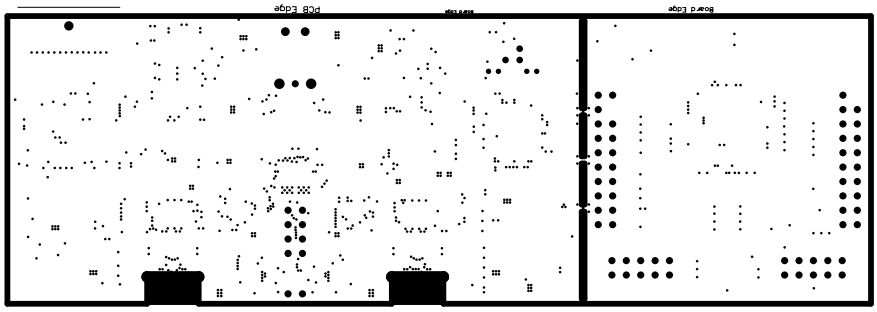


Figure 10-9. TPS65988EVM GND Plane 3

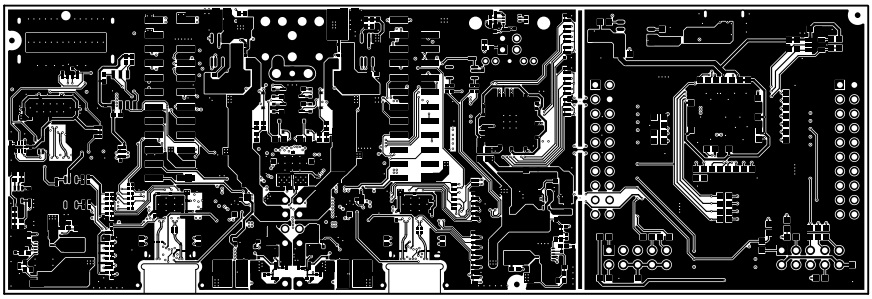


Figure 10-10. TPS65988EVM SSTXRX2

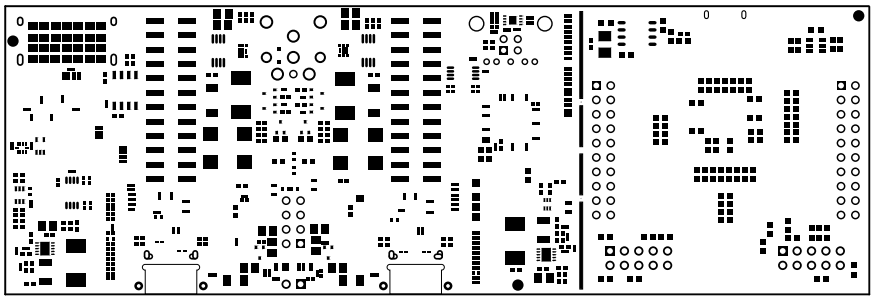


Figure 10-11. TPS65988EVM Solder Mask

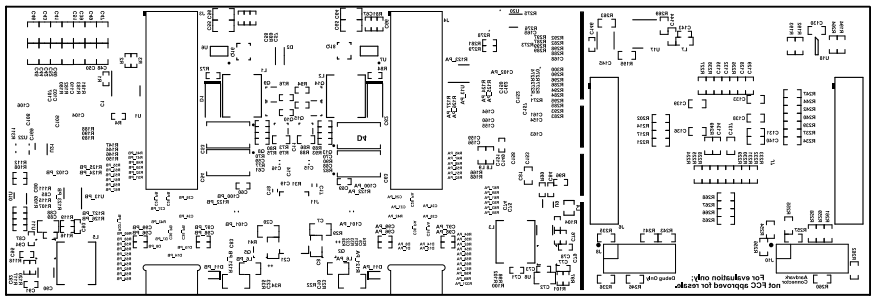


Figure 10-12. TPS65988EVM Bottom Layer Component View

11 TPS65988EVM Bill of Materials

Table 11-1 lists the TPS65988EVM BOM.

Table 11-1. TPS65988EVM Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		ACS009	Any	-	-
C1, C24_PA_SS, C24_PB_SS, C25_PA_SS, C25_PB_SS, C26_PA_SS, C26_PB_SS, C27_PA_SS, C27_PB_SS, C28_PA_SS, C28_PB_SS, C29_PA_SS, C29_PB_SS, C30_PA_SS, C30_PB_SS, C31_PA_SS, C31_PB_SS, C32_PA_SS, C32_PB_SS, C33_PA_SS, C33_PB_SS, C34_PA_SS, C34_PB_SS, C35_PA_SS, C35_PB_SS, C36_PA_SS, C36_PB_SS, C37_PA_SS, C37_PB_SS, C38_PA_SS, C38_PB_SS, C110, C147, C148	34	0.1uF	CAP, CERM, 0.1 µF, 10 V, +/- 10%, X5R, 0201	0201	CL03A104KP3NNNC	Samsung Electro-Mechanics		
C2, C3, C4, C5	4	220pF	CAP, CERM, 220 pF, 25 V, +/- 10%, X7R, 0201	0201	GRM033R71E221KA01D	Murata		
C6	1	0.01uF	CAP, CERM, 0.01 µF, 10 V, +/- 10%, X5R, 0201	0201	GRM033R61A103KA01D	Murata		
C7, C8, C20, C21, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50, C51, C52, C55, C56, C64, C65, C72, C88	24	22uF	CAP, CERM, 22 µF, 35 V, +/- 20%, X5R, 0805	0805	C2012X5R1V226M125AC	TDK		
C9, C10, C22, C23, C102_PA_CS, C102_PB_CS, C103, C104, C105, C106, C107, C126, C150, C151, C152, C153, C154, C155, C157, C158, C159, C160, C161, C162, C163, C164, C165, C170, C171	29	0.1uF	CAP, CERM, 0.1 µF, 25 V, +/- 10%, X5R, 0201	0201	GRM033R61E104KE14J	Murata		
C11, C14, C19, C149	4	10uF	CAP, CERM, 10 µF, 10 V, +/- 20%, X5R, 0402	0402	CL05A106MP5NUNC	Samsung Electro-Mechanics		
C12, C13	2	1uF	CAP, CERM, 1 µF, 35 V, +/- 10%, JB, 0402	0402	C1005JB1V105K050BC	TDK		
C15, C16	2	22uF	CAP, CERM, 22 µF, 10 V, +/- 20%, X5R, 0603	0603	C1608X5R1A226M080AC	TDK		
C17, C18	2	10uF	CAP, CERM, 10 µF, 25 V, +/- 20%, X5R, 0603	0603	GRM188R61E106MA73D	Murata		
C53, C54, C62, C63	4	47uF	CAP, TA, 47 µF, 35 V, +/- 10%, 0.3 ohm, SMD	7343-43	T521X107M025ATE060	Kemet		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
C57, C59, C60, C66, C68, C69, C73, C82, C84, C89	10	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0402	0402	C1005X7R1H104K050BB	TDK		
C58, C61, C67, C70	4	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 1%, C0G/NP0, 0402	0402	GRM1555C1H102FA01D	Murata		
C71, C87	2	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H104K050BB	TDK		
C74, C83, C90	3	100uF	CAP, CERM, 100 µF, 10 V, +/- 20%, X5R, 1210	1210	C1210C107M8PACTU	Wurth Elektronik		
C75, C91	2	0.1uF	CAP, CERM, 0.1 µF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E104KE14D	Murata		
C76, C92	2	220pF	CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0201	0201	CGA1A2X7R1H221K030BA	TDK		
C78, C94	2	4.7pF	CAP, CERM, 4.7 pF, 50 V, +/- 5%, C0G/NP0, 0201	0201	GRM0335C1H4R7CA01D	Murata		
C79, C95	2	2700pF	CAP, CERM, 2700 pF, 10 V, +/- 10%, X5R, 0201	0201	GRM033R61A272KA01D	Murata		
C80	1	0.1uF	CAP, CERM, 0.1 µF, 35 V, +/- 10%, X5R, 0402	0402	GMK105BJ104KV-F	Taiyo Yuden		
C81	1	47uF	CAP, CERM, 47 µF, 6.3 V, +/- 20%, X5R, 0603	0603	GRM188R60J476ME15D	Murata		
C85	1	22pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402	C1005C0G1H220J050BA	TDK		
C86	1	0.047uF	CAP, CERM, 0.047 µF, 16 V, +/- 10%, X5R, 0201	0201	GRM033R61C473KE84D	Murata		
C96_PA, C96_PB, C97_PA, C97_PB, C98_PA, C98_PB, C99_PA, C99_PB	8	0.01uF	CAP, CERM, 0.01 µF, 50 V, +/- 10%, X7R, 0402	0402	GRM155R71H103KA88D	Murata		
C100_PA, C100_PB	2	1uF	CAP, CERM, 1 µF, 6.3 V, +/- 20%, X5R, 0201	0201	GRM033R60J105MEA2D	Murata		
C101_PA, C101_PB	2	0.1uF	CAP, CERM, 0.1 µF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A104KA35D	Murata		
C108, C127, C156, C168, C169	5	1uF	CAP, CERM, 1 µF, 10 V, +/- 20%, X5R, 0201	0201	CL03A105MP3NSNC	Samsung Electro-Mechanics		
C109, C111, C112, C113, C114, C115, C116, C117, C118, C119, C120, C121, C122, C123, C124, C125	16	0.22uF	CAP, CERM, 0.22 µF, 10 V, +/- 20%, X5R, 0201	0201	LMK063BJ224MP-F	Taiyo Yuden		
C128, C130, C131, C133, C134, C135, C136, C137, C138, C139, C144	11	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H104KA93D	Murata		
C129, C132, C140	3	4.7uF	CAP, CERM, 4.7 µF, 25 V, +/- 10%, X5R, 0603	0603	GRM188R61E475KE11D	Murata		
C141, C142	2	27pF	CAP, CERM, 27 pF, 50 V, +/- 1%, C0G/NP0, 0603	0603	CL10C270FB8NNNC	Samsung Electro-Mechanics		
C143	1	0.01uF	CAP, CERM, 0.01 µF, 50 V, +/- 5%, X7R, 0402	0402	C0402C103J5RACTU	Kemet		
C145	1	10uF	CAP, TA, 10 µF, 10 V, +/- 10%, 2.5 ohm, SMD	3528-21	293D106X9010B2TE3	Vishay-Sprague		
C146	1	10uF	CAP, CERM, 10 µF, 10 V, +/- 20%, X5R, 0402	0402	GRM155R61A106ME21D	Murata		
C166, C167	2	18pF	CAP, CERM, 18 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402	GRM1555C1H180JA01D	Murata		
D1, D4	2	30V	Diode, Schottky, 30 V, 5 A, SOD-128	SOD-128	PMEG3050EP,115	NXP Semiconductor		
D2	1	24V	Diode, TVS, Bi, 24 V, 200 W, SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	PESD24VL1BA,115	NXP Semiconductor		
D3, D5	2	Blue	LED, Blue, SMD	0.8x1.6mm	19-213/BHC-AN1P2/3T	Everlight		
D6_PA_SS, D6_PB_SS, D18_PA_SS, D18_PB_SS, D19_PA_SS, D19_PB_SS, D20, D21, D22, D23, D24, D25, D26	13	White	LED, White, SMD	0402, White	LW QH8G-Q2S2-3K5L-1	OSRAM		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
D7_PA, D7_PB, D8_PA, D8_PB, D9_PA, D9_PB, D10_PA, D10_PB, D12_PA, D12_PB, D13_PA, D13_PB, D14_PA, D14_PB, D15_PA, D15_PB, D16, D17	18		1 Channel ESD Protection Diode for High Speed Data Lines up to 20Gbps, DPL0002A	DPL0002A	TPD1E01B04DPLR	Texas Instruments	TPD1E01B04DPLT	Texas Instruments
D11_PA, D11_PB	2	30V	Diode, Schottky, 30 V, 2 A, 2-XFDFN	2-XFDFN	NSR20F30NXT5G	ON Semiconductor		
FID1, FID2, FID3, FID4, FID5, FID6	6		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A		
J1	1		Connector, DC Power Jack, R/A, 3 Pos, TH	Power connector	JPD1135-509-7F	Foxconn		
J2_PA, J2_PB	2		Connector, Receptacle, USB Type C, R/A, SMT	Connector, Receptacle, USB Type C, SMT	20-0000016-01	Lintes Technology		
J3, J4	2		Receptacle, 12x2, 2.54mm, Gold, SMT	Receptacle, 12x2, 2.54mm, SMT	SSW-112-22-G-D-VS	Samtec		
J5	1		Receptacle, HDMI, 20 Pos, R/A, SMT	Receptacle, HDMI, 20 Pos, R/A, SMT	47272-0001	Molex		
J6, J7	2		Receptacle, 2.54 mm, 10x2, Gold, TH	Receptacle, 2.54 mm, 10x2, TH	CRD-081413-A-G	Major League Electronics		
J8, J10	2		Header, 100mil, 5x2, Tin, TH	Header, 5x2, 100mil, Tin	PEC05DAAN	Sullins Connector Solutions		
J9	1		Receptacle, Micro-USB Type B, 0.65 mm, 5x1, R/A, Bottom Mount SMT	Receptacle, 0.65mm, 5x1, R/A, SMT	47346-1001	Molex		
J11	1		Connector, Receptacle, USB 3.1 Type B, R/A, TH	Connector, Receptacle, USB 3.1 Type B, R/A, TH	GSB4211311WEU	Amphenol Canada		
L1, L2, L3, L5	4	10uH		7.2 mm x 6.65 mm	ASPI-0630LR-100M-T15	ABRACON	-	-
L4	1	1uH	Inductor, Shielded, Metal Composite, 1 µH, 3.3 A, 0.04 ohm, SMD	2.5x1.2x2mm	DFE252012F-1R0M=P2	Murata Toko		
L6_PA, L6_PB	2	21 ohm	Ferrite Bead, 21 ohm @ 100MHz, 6A, 0805	0805	FBMJ2125HM210NT	Taiyo Yuden		
L7	1	26 ohm	Ferrite Bead, 26 ohm @ 100 MHz, 6 A, 0603	0603	BLM18SG260TN1D	Murata		
L8, L9	2	220 ohm	Ferrite Bead, 220 ohm @ 100 MHz, 2.5 A, 0603	0603	BLM18SG221TN1D	Murata		
Q1, Q4, Q7, Q12	4	-30V	MOSFET, P-CH, -30 V, -60 A, 610x604x515mm	610x604x515mm	SI7997DP-T1-GE3	Vishay-Siliconix		None
Q2, Q5, Q8, Q9, Q10, Q13, Q14, Q15, Q16, Q18	10	30V	MOSFET, N-CH, 30 V, 0.35 A, AEC-Q101, SOT-323	SOT-323	NX3008NBKW,115	NXP Semiconductor		None
Q3, Q6, Q11, Q17, Q19_PA_SS, Q19_PB_SS, Q20_PA_SS, Q20_PB_SS, Q21_PA_SS, Q21_PB_SS, Q22, Q23, Q24, Q25, Q26, Q27, Q28	17	20V	MOSFET, N-CH, 20 V, 0.5 A, YJM0003A (PICOSTAR-3)	YJM0003A	CSD15380F3	Texas Instruments		None
R1, R2, R3, R4	4	3.3k	RES, 3.3 k, 5%, 0.063 W, 0402	0402	CRCW04023K30JNED	Vishay-Dale		
R5, R6, R9, R10	4	3.83k	RES, 3.83 k, 1%, 0.05 W, 0201	0201	CRCW02013K83FKED	Vishay-Dale		
R7, R8	2	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	MCR006YRTF1002	Rohm		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R11, R16, R47_PA_SS, R47_PB_SS, R50_PA_SS, R50_PB_SS, R51_PA_SS, R51_PB_SS, R75, R76, R88, R89, R113, R123_PA_CS, R123_PB_CS, R124_PA_CS, R124_PB_CS, R127_PA_CS, R127_PB_CS, R139, R141, R143, R145, R148, R149, R165, R167, R171, R174, R175, R317_PA, R317_PB, R318_PA, R318_PB, R321_PA_SS, R321_PB_SS	36	0	RES, 0, 5%, 0.05 W, 0201	0201	ERJ-1GE0R00C	Panasonic		
R12, R14, R18, R19, R29, R41, R46_PA_SS, R46_PB_SS, R49_PA_SS, R49_PB_SS, R71, R83, R96, R104, R106, R122_PA, R122_PB, R152, R154, R177, R179, R180, R181, R182	24	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale		
R13, R17, R22, R24, R25, R26, R27, R34, R36, R37, R38, R40, R85, R91, R99, R103, R304_PA_SS, R304_PB_SS, R305_PA_SS, R305_PB_SS, R306_PA_SS, R306_PB_SS, R307, R308, R309, R310, R312, R313, R314, R323, R324, R325, R326	33	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale		
R15	1	191k	RES, 191 k, 1%, 0.05 W, 0201	0201	RC0201FR-07191KL	Yageo America		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R28, R39, R53_PA_SS, R53_PB_SS, R54_PA_SS, R54_PB_SS, R55_PA_SS, R55_PB_SS, R56_PA_SS, R56_PB_SS, R57_PA_SS, R57_PB_SS, R58_PA_SS, R61_PA_SS, R61_PB_SS, R62_PA_SS, R62_PB_SS, R63_PA_SS, R63_PB_SS, R64_PA_SS, R64_PB_SS, R65_PA_SS, R65_PB_SS, R66_PA_SS, R66_PB_SS, R67_PA_SS, R67_PB_SS, R189, R191, R270, R274, R275, R276, R282, R287, R293, R294, R298, R299, R300, R311	41	1.00k	RES, 1.00 k, 1%, 0.05 W, 0201	0201	CRCW02011K00FKED	Vishay-Dale		
R31	1	0.51	RES, 0.51, 1%, 0.125 W, 0402	0402	ERJ-2BQFR51X	Panasonic		
R42_PA_SS, R42_PB_SS, R97, R116	4	150k	RES, 150 k, 1%, 0.063 W, 0402	0402	CRCW0402150KFKED	Vishay-Dale		
R69, R81	2	36.5k	RES, 36.5 k, 1%, 0.063 W, 0402	0402	CRCW040236K5FKED	Vishay-Dale		
R70, R82	2	60.4k	RES, 60.4 k, 1%, 0.063 W, 0402	0402	CRCW040260K4FKED	Vishay-Dale		
R72, R84	2	270	RES, 270, 5%, 0.063 W, 0402	0402	CRCW0402270RJNED	Vishay-Dale		
R73, R86	2	1.00k	RES, 1.00 k, 0.1%, 0.1 W, 0603	0603	RT0603BRB071KL	Yageo America		
R74, R87	2	11.0k	RES, 11.0 k, 1%, 0.05 W, 0201	0201	CRCW020111K0FKED	Vishay-Dale		
R77, R90, R120	3	19.1k	RES, 19.1 k, 1%, 0.063 W, 0402	0402	CRCW040219K1FKED	Vishay-Dale		
R79, R93	2	18.0k	RES, 18.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040218K0FKED	Vishay-Dale		
R80, R94	2	7.15k	RES, 7.15 k, 1%, 0.063 W, 0402	0402	CRCW04027K15FKED	Vishay-Dale		
R98, R107, R117	3	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale		
R100, R118	2	8.87k	RES, 8.87 k, 1%, 0.063 W, 0402	0402	CRCW04028K87FKED	Vishay-Dale		
R101, R119	2	66.5k	RES, 66.5 k, 1%, 0.063 W, 0402	0402	CRCW040266K5FKED	Vishay-Dale		
R102	1	32.4k	RES, 32.4 k, 1%, 0.063 W, 0402	0402	CRCW040232K4FKED	Vishay-Dale		
R108	1	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale		
R110	1	7.50k	RES, 7.50 k, 1%, 0.063 W, 0402	0402	CRCW04027K50FKED	Vishay-Dale		
R111, R114	2	15.0k	RES, 15.0 k, 1%, 0.063 W, 0402	0402	CRCW040215K0FKED	Vishay-Dale		
R121_PA, R121_PB	2	0.001	RES, 0.001, 1%, 1 W, AEC-Q200 Grade 0, 1206	1206	CSNL1206FT1L00	Stackpole Electronics Inc		
R183	1	5.6Meg	RES, 5.6 M, 5%, 0.05 W, 0201	0201	MCR006YRTJ565	Rohm		
R192, R193, R194	3	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0710KL	Yageo America		
R195	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R208, R211, R212, R213, R215, R218, R219, R220, R222, R223, R235, R236, R238, R241, R243, R246, R256, R257, R258, R259, R260, R261, R262, R269	24	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale		
R226	1	12k	RES, 12 k, 5%, 0.1 W, 0603	0603	CRCW060312K0JNEA	Vishay-Dale		
R227	1	100k	RES, 100 k, 5%, 0.1 W, 0603	0603	CRCW0603100KJNEA	Vishay-Dale		
R245, R253	2	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	RC1608J103CS	Samsung Electro-Mechanics		
R248, R250, R251, R252	4	3.3k	RES, 3.3 k, 5%, 0.1 W, 0603	0603	CRCW06033K30JNEA	Vishay-Dale		
R263	1	249k	RES, 249 k, 1%, 0.1 W, 0603	0603	CRCW0603249KFKEA	Vishay-Dale		
R264	1	2.20k	RES, 2.20 k, 1%, 0.1 W, 0603	0603	RC0603FR-072K2L	Yageo America		
R271	1	9.09k	RES, 9.09 k, 1%, 0.05 W, 0201	0201	CRCW02019K09FKED	Vishay-Dale		
R279	1	90.9k	RES, 90.9 k, 1%, 0.063 W, 0402	0402	CRCW040290K9FKED	Vishay-Dale		
R280	1	1.00Meg	RES, 1.00 M, 1%, 0.05 W, AEC-Q200 Grade 0, 0201	0201	RK73H1HTTC1004F	KOA Speer		
R281	1	10k	RES, 10 k, 5%, 0.063 W, 0402	0402	CRCW040210K0JNED	Vishay-Dale		
R302, R303, R315, R316	4	0	RES, 0, 5%, 0.125 W, 0805	0805	ERJ-6GEY0R00V	Panasonic		
R322, R327	2	576k	RES, 576 k, 1%, 0.05 W, 0201	0201	RC0201FR-07576KL	Yageo America		
S1	1		SWITCH TACTILE SPST-NO 0.05A 12V	3x1.6x2.5mm	B3U-1000P	Omron Electronic Components		
S2, S3, S5	3		DIP Switch, SPST 4Pos, Slide, SMT	6.2x2.0x6.2mm	TDA04H0SB1	C&K Components		
S4	1		Switch, SPST, 2 Pos, 25mA, 24VDC, SMD	3.71x5.8mm	218-2LPST	CTS Electrocomponents		
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14_PA, TP14_PB, TP15, TP16	17		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone		
U1	1		3V, 8Mbit, Serial Flash Memory with Dual and Qual SPI, SOIC-8	SOIC-8	W25Q80DVSNIG	Winbond		
U2	1		Dual Port USB Type-C & USB PD Controller with Integrated Power Switches Internal Datasheet, RSL0048D	RSL0048D	TPS65988RSL	Texas Instruments		Texas Instruments
U3, U4	2		2.2-V to 36-V, microPower Comparator, DBV0005A	DBV0005A	TLV1701AIDBVR	Texas Instruments	TLV1701AIDBVT	Texas Instruments
U5_PA_SS, U5_PB_SS	2		USB Type-C DP ALT Mode Linear Redriver Xpoint Switch, RNQ0040A	RNQ0040A	TUSB546-DCIRNQR	Texas Instruments	TUSB546-DCIRNQT	Texas Instruments
U6, U7	2		Hysteretic PFET Buck Controller with Enable Pin, 8-pin MSOP, Pb-Free	MUA08A	LM3489QMM/NOPB	Texas Instruments		
U8, U11	2		4.2 V TO 28 V INPUT, 3 A OUTPUT, SYNCHRONOUS SWIFT™ STEP DOWN VOLTAGE CONVERTER, DRC0010J	DRC0010J	TPS54334DRCR	Texas Instruments	TPS54334DRCT	Texas Instruments
U9	1		2A High Efficiency Step Down Converter with iDCS-Control, Forced PWM Mode and Programmable Switching Frequency, RWK0011B	RWK0011B	TPS62097RWKR	Texas Instruments	TPS62097RWKT	Texas Instruments
U10	1		Nanopower, 1.8V, Comparator with Voltage Reference, DCK0006A	DCK0006A	TLV3012AIDCKR	Texas Instruments	TLV3012AIDCKT	Texas Instruments
U12_PA, U12_PB	2		USB Type C Interface Protector: Short-to-VBUS Over Voltage and IEC 61000-4-2 ESD Protection, RUK0020B	RUK0020B	TPD6S300RUK	Texas Instruments		Texas Instruments
U13_PA_CS, U13_PB_CS	2		High-Accuracy, Wide Common-Mode Range, Bidirectional Current Shunt Monitors, Zero-Drift Series, DGK0008A	DGK0008A	INA284AIDGKR	Texas Instruments	INA284AIDGKT	Texas Instruments

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
U14	1		4-Channel High-Performance Differential Switch, RUA0042A	RUA0042A	HD3SS3412RUAR	Texas Instruments	HD3SS3412RUAT	Texas Instruments
U15, U22	2		ESD Protected,High-Speed USB 2.0 (480-Mbps) 1:2 Multiplexer / Demultiplexer Switch, 1:2 MUX / DeMUX, 6 ohm RON, 2.5 to 3.3 V, -40 to 85 degC, 10-Pin UQFN (RSE), Green (RoHS & no Sb/Br)	RSE0010A	TS3USB221ARSER	Texas Instruments	Equivalent	Texas Instruments
U16	1		Quad High Speed USB to Multipurpose UART/MPSSE IC	LQFP_10x10mm	FT4232HL	FTDI		
U17	1		Single Output Fast Transient Response LDO, 1 A, Fixed 3.3 V Output, 2.7 to 10 V Input, with Low IQ, 8-pin SOIC (D), -40 to 125 degC, Green (RoHS ampersand no Sb/Br)	D0008A	TPS76833QD	Texas Instruments	Equivalent	None
U18	1		2K Microwire Compatible Serial EEPROM, SOT-23-6	SOT-23-6	93LC56B-I/OT	Microchip		
U19	1		Two-Port USB 3.0 Hub, PHP0048E	PHP0048E	TUSB8020BPHPR	Texas Instruments	TUSB8020BPHP	Texas Instruments
U20	1		EEPROM 4KBIT 1MHZ,8UDFN	UDFN-8	AT24C04D-MAHM-T	Atmel		
Y1	1		CRYSTAL, 12MHz, 20pF, SMD	7x2.3x4.1mm	ECS-120-20-3X-TR	ECS Inc.		
Y2	1		Crystal, 24 MHz, 18 pF, SMD	ABM3	ABM3-24.000MHZ-D2W-T	Abracon Corporation		
C77, C93	0	300pF	CAP, CERM, 300 pF, 25 V, +/- 5%, C0G/NP0, 0402	0402	GRM1555C1E301JA01D	Murata		
R20, R30, R32, R319, R320	0	0	RES, 0, 5%, 0.125 W, 0805	0805	ERJ-6GEY0R00V	Panasonic		
R21, R23, R33, R35	0	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	CRCW020110K0FKED	Vishay-Dale		
R43_PA_SS, R43_PB_SS, R44_PA_SS, R44_PB_SS, R150, R184, R185, R186, R187	0	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale		
R45_PA_SS, R45_PB_SS, R48_PA_SS, R48_PB_SS, R52_PA_SS, R52_PB_SS, R78, R92, R95, R105, R109, R125_PA_CS, R125_PB_CS, R126_PA_CS, R126_PB_CS, R131, R132, R133, R134, R135, R136, R137, R138, R140, R142, R144, R146, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R166, R168, R169, R170, R172, R173, R291	0	0	RES, 0, 5%, 0.05 W, 0201	0201	ERJ-1GE0R00C	Panasonic		
R58_PB_SS, R59_PA_SS, R59_PB_SS, R60_PA_SS, R60_PB_SS, R188, R190, R272, R273, R277, R278, R283, R284, R285, R286, R288, R289, R290, R292, R295, R296, R297, R301	0	1.00k	RES, 1.00 k, 1%, 0.05 W, 0201	0201	CRCW02011K00FKED	Vishay-Dale		
R68_PA_SS, R68_PB_SS	0	150k	RES, 150 k, 1%, 0.063 W, 0402	0402	CRCW0402150KFKED	Vishay-Dale		
R112	0	39k	RES, 39 k, 5%, 0.063 W, 0402	0402	CRCW040239K0JNED	Vishay-Dale		
R115	0	560k	RES, 560 k, 5%, 0.063 W, 0402	0402	CRCW0402560KJNED	Vishay-Dale		

Table 11-1. TPS65988EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R128, R129, R130, R196, R197, R198, R199, R200, R201, R202, R203, R204, R205, R206, R207, R209, R210, R214, R216, R217, R221, R224, R225, R228, R229, R230, R231, R232, R233, R234, R237, R239, R240, R242, R244, R247, R249, R254, R255, R265, R266, R267, R268	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale		
R147	0	3.83k	RES, 3.83 k, 1%, 0.05 W, 0201	0201	CRCW02013K83FKED	Vishay-Dale		
R151, R153, R176, R178	0	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale		
U21	0		Single 2-Input Positive-OR Gate, DCK0005A	DCK0005A	SN74AHC1G32TDCKRQ1	Texas Instruments		Texas Instruments
	Notes:	Unless otherwise noted in the *Alternate Part Number* or *Alternate Manufacturer* columns, all parts may be substituted with equivalents.						

12 Revision History

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

Changes from Revision A (June 2018) to Revision B (November 2020)	Page
• Added the *REACH Compliance* section	37
• Changed the images in the *TPS65988EVM Board Layout* section	51

Changes from Revision * (June 2017) to Revision A (June 2018)	Page
• Overall rework of this user's guide for revision A from Section 4 to Section 9	5

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