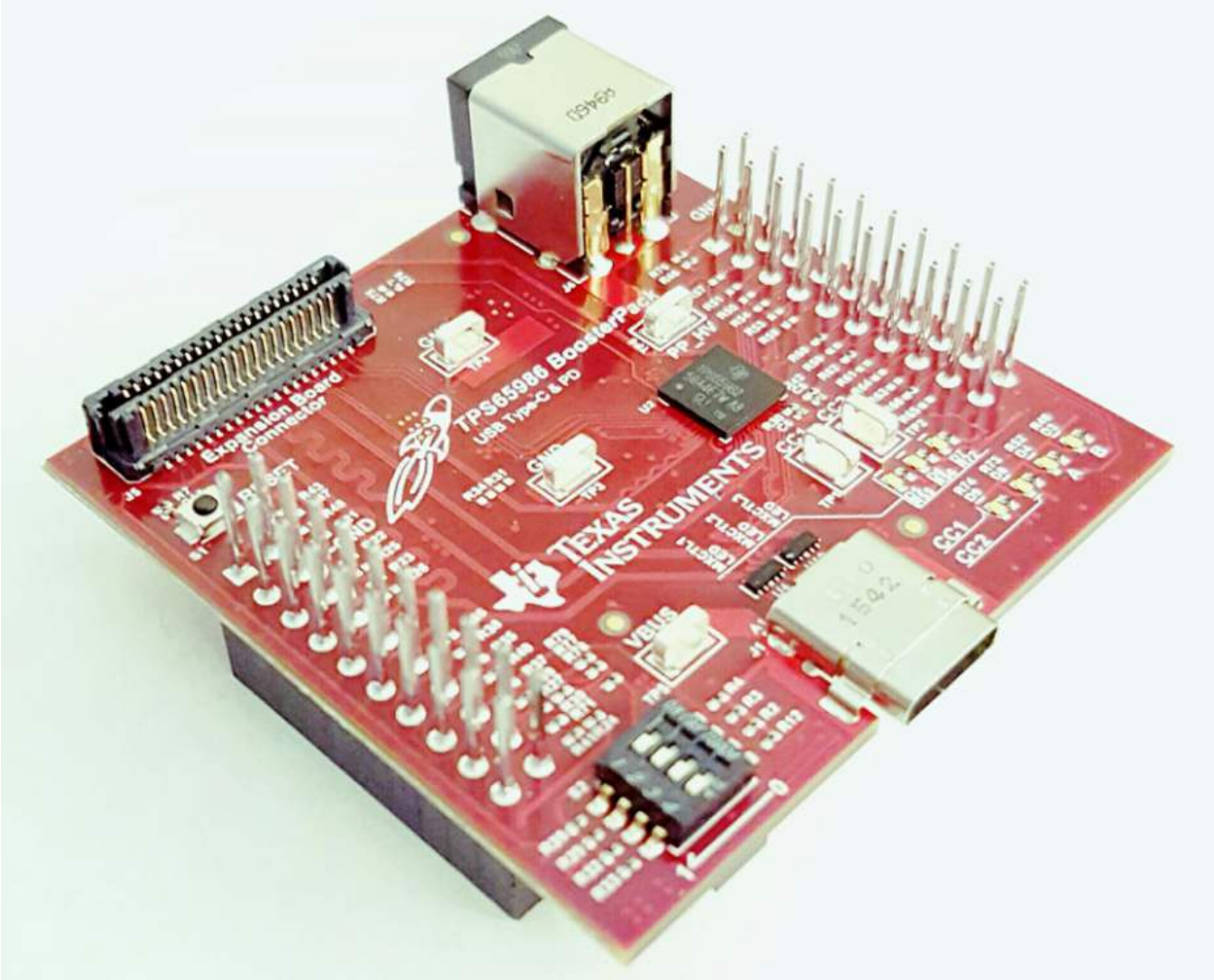
TPS65986 EVM User's Guide

This document is the user's guide for the TPS65986 evaluation module (TPS65986EVM). The TPS65986EVM allows for evaluation of the TPS65986 device as part of a stand-alone testing kit and for development and testing of USB Type-C and power-delivery (PD) end products.



1 About this Manual

This user's guide describes the TPS65986EVM. 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 TPS65986EVM:

- TPS65986 data sheet (*TPS65986 USB Type-C and USB PD Controller and Power Switch*)
- TPS65986EVM
- DP-EXPANSION-EVM (*DP-EXPANSION-EVM User Guide*)
  - Testing for DisplayPort, USB data, or both
  - Mini DisplayPort to DisplayPort cable
  - USB3.0 Standard-A to -B cable
- TotalPhase Aardvark I^2C/SPI Host Adapter and USB Standard-B to -A cable
  - TPS65986 register access, firmware updating, firmware testing, or a combination of these
  - TPS6598x Utilities GUI
- TPS6598x Configuration GUI (www.ti.com/tool/tps6598x-config)
- Barrel-jack adapter or DC power supply
- USB Type-C cable
- USB Type-C to Standard-A cable

4 Introduction

The TPS65986 device 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 detection, the TPS65986 device communicates on the CC wire using the USB PD protocol. When cable detection and USB-PD negotiation are complete, the TPS65986 device enables the appropriate power path and configures alternate mode settings for internal and (optional) external multiplexers.

This user's guide describes the TPS65986EVM and the capabilities of the EVM with the DP-EXPANSION-EVM. This guide also contains testing procedures of various PD-power and alternate mode configurations. The EVM comes with pre-loaded configurations for *out of the box* functionality and is also customizable through the TPS6598x Configuration Tool. The TPS65986EVM is a module-based design, allowing the user to design a custom board to prototype a Type-C PD product using the TPS65986 device. The EVM has four main connectors which are the Type-C receptacle, barrel-jack power, expansion-board connector,

and two BoosterPack headers. The Type-C receptacle is a full-feature port, with power, SSTX, SSRX, SBU1, SBU2, DP, and DN signals. The TPS65986 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 of power (20 V, 3 A). The EVM is also capable of sinking 60 W of power (20 V, 3 A) when the device is in powered, dead battery, or consumer mode. The EVM can perform a power-role swap to provide power when the barrel jack (external power) is connected. The expansion board connector routes the power, SSTX, SSRX, USB_RP_P, USB_RP_N, AUX_P, AUX_N, HPD, I^2C, and GPIO control for the DP-EXPANSION-EVM. The BoosterPack headers give access to the GPIO, 3.3-V and 5-V rails, SPI pins, I^2C, AUX_P, AUX_N, USB_RP_P, and USB_RP_N. The BoosterPack headers are configured for mounting on any TI MCU LaunchPad™ development kit. Custom PCBs may be built as a mechanical interface to the Aardvark if the I^2C, SPI, and GND pins of the BoosterPack headers are wired to the associated pins on a 10-pin male header to mate with the Aardvark.

5 Setup

This section describes the various EVM features and how to test the various configurations.

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

5.1.1 S2 Switch Bank

This switch bank is used to configure the EVM with the pre-loaded firmware. A total of 8 configurations are set by the state of the switches on S2. The top switch represents bit 0 and the bottom switch represents bit 3. The left position is low and the right position is high when looking at the EVM with the Type-C receptacle facing down. Bit 0, bit 1, and bit 2 are used for setting the configuration, and bit 3 is reserved for future use (should always be set low for now). Bit 0, bit 1, bit 2, and bit 3 are connected to GPIO1, DEBUG3, DEBUG4, and GPIO5 respectively. The high position is pulled up through an 11-kΩ resistor to LD0_3V3, and GPIO1, DEBUG3, DEBUG4, and GPIO5 are pulled down through a 100-kΩ resistor.

5.1.1.1 S2: DisplayPort Pin Assignment C to Pin Assignment D Switch

The TPS65986EVM allows for Configuration ID 0 to toggle between 4-lane DisplayPort, 2-lane DisplayPort, and USB3.0 Multifunction. The first switch in S2 is used to toggle between configurations and does not change the configuration that was selected within Table 2. When switched to the right position, the TPS65986EVM changes the configuration to prefer USB3.0 Multifunction and renegotiates the DisplayPort alternate mode. When switched back to the left position, the TPS65986EVM changes the configuration to not prefer USB3.0 Multifunction and renegotiates the DisplayPort alternate mode.

5.1.2 S1 HRESET Push-Button

S1 is located on the top-left corner of the EVM, under the *Expansion Board Connector*. This switch is a push-button that pulls the HRESET pin (D6), of the TPS65986 device high when pressed. Releasing the push-button pulls HRESET low again, and the TPS65986 device goes through a hardware reset, which consists of reloading firmware from the non-volatile memory of the external flash. When changing a configuration on S2, S1 can be used to reset the TPS65986 device, which loads the updated configurations without disconnecting power from the EVM.

5.1.3 J4: Barrel-Jack Power Connector

The barrel-jack power connector accepts a 19-V to 20-V DC supply. A standard Dell or HP notebook adaptor (or similar adaptor) provides the required power. This input provides the PP_HV power rail with the 19 V to 20 V for high-power PD contracts up to 60 W. Select an appropriate power-capable adapter of 60-W operation. For example, the 130-W Dell part number 492-BBGP could be used.

5.1.3.1 Barrel Jack Detect

The TPS65986EVM is capable of requesting a power-role swap when the barrel jack is connected on an EVM that is currently bus powered which is valid for the configuration IDs that are capable of delivering power. The barrel jack voltage is sensed by a comparator, which drives GPIO2 on the TPS65986 device. For enabling barrel jack detect or other GPIOs, refer to *TPS6598x Utilities Tool User Guide* and *TPS65982 and TPS65986 Firmware User's Guide*.

5.1.4 TP3 and TP4: GND Test Points

Two GND test points are provided for attaching an oscilloscope, multi-meter, or external load GND. These test points are connected to the board GND planes through 4 vias.

5.1.5 TP1 and TP2: CC1/CC2 Test Points

These test points can be 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). A multi-meter or oscilloscope can be used to measure VCONN when an electronically marked Type-C cable is connected. These test points are not intended to provide an external load on VCONN. Figure 1 shows the BMC data oscilloscope capture.

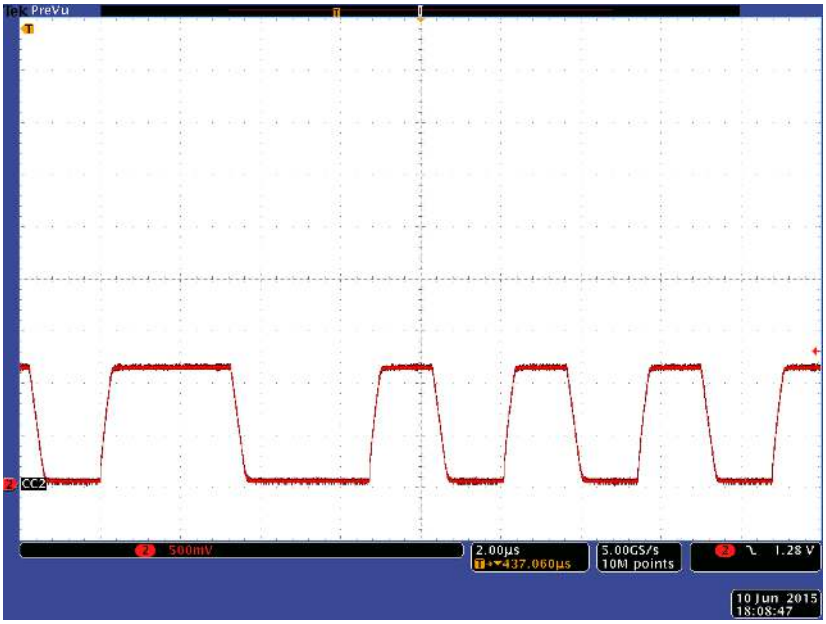


Figure 1. TPS65986 BMC Data

5.1.6 TP5: VBUS Test Point

The VBUS test point is used to measure VBUS at the connector.

CAUTION

With PD power possibly going up to 20 V, use caution when connecting and disconnecting probes on the TPS65986EVM. The VBUS test point is capable of drawing up to 3 A for an external load.

A PD-power contract with the necessary capability must be negotiated to draw current from the VBUS test point. Refer to *TPS6598x Configuration GUI User Guide* for configuration instruction. Figure 2 shows the VBUS voltage during PD power negotiation.

Figure 2. TPS65986 VBUS Voltage Transition

5.1.7 TP6: PP_HV Test Point

This test point is the same power rail as the barrel jack, and it can be used to either provide power to the TPS65986EVM or measure the voltage supply for the PP_HV. When a custom configuration is created using the TPS6598x Configuration Tool, the voltage of PP_HV can be set to a minimum of 12 V for high-voltage contracts. The pre-loaded TPS65986EVM firmware expects to have 20 V at PP_HV (or on barrel jack) for the configured power capabilities. The PP_HV test point can also be used to sink power when acting as a consumer or a bus powered device. PP_HV is capable of sinking up to 3 A when acting as a consumer.

5.1.8 J2 and J3: BoosterPack Headers

These headers allow the EVM to be connected to any TI MCU LaunchPad™ development kit. See Figure 29 for names of all connections.

NOTE: Some of the header pins are not connected unless a 0-Ω option resistor is placed.

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 (MXCTL1-3) and status LEDs.

NOTE: The LEDs are enabled through GPIO in the pre-loaded firmware. Therefore, each must be enabled separately if configuring a custom image (see *TPS6598x Configuration GUI User Guide* and *TPS65982 and TPS65986 Firmware User's Guide*).

5.2.1 MXCTL1-3 LEDs (Super-Speed Mux Contol LED)

These LEDs correspond to the GPIOs required to drive a super-speed multiplexer for the SSTX and SSRX signals to a Type-C connector. Table 1 summarizes the LED behavior according to the type of connection.

Table 1. MXCTLx LED Functions

LED Indicator	GPIO	Function
MXCTL1	GPIO_0	Plug Present
MXCTL2	GPIO_3	HD3SS460 AMSEL
MXCTL3	GPIO_6	DP Connection

5.2.2 Status LEDs

The status LEDs indicate the cable orientation, the voltage present on VBUS, and the type of connection. The CC1 and CC2 LEDs indicate the orientation of the Type-C cable (only one of these LEDs turns on at a time). LED A is on when 5 V is sourced on VBUS and blinks when a high-voltage contract is in place (when acting as a source or sink of power). LED B indicates if a USB3 connection is present.

6 Using the TPS65986EVM

This section describes the EVM configurations on the pre-loaded firmware, getting started, and debugging the EVM.

6.1 Powering the TPS65986EVM

The main power supply for the EVM is J1 barrel jack, which accepts 19 V to 20 V through a barrel jack adaptor. The EVM can also be powered with an external power supply on TP6. The input voltage can range to 12 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 powered from a TI MCU LaunchPad™ development kit by placing R30 and R31 with 0-Ω resistors. If powering with a LaunchPad™ development kit, the EVM does not support high-voltage contracts or provide high currents at 5 V because of the limited power capability. The EVM can also be bus powered from the Type-C connector and accepts 5 V to 20 V on VBUS, depending on the sink configuration.

6.2 Firmware Configurations

The EVM is shipped with a preloaded firmware image that supports various Type-C and PD products. The firmware is loaded at start-up and the configuration is defined by the state of the S2 switch (see Section 5.1.1). The top three switches in the switch bank represent B0, B1, and B2, respectively (see Figure 3). The top switch is used for toggling between DisplayPort configurations for 2-lane DP, USB3 multi-function, and 4-lane DP after the configuration in the table has been loaded. Table 2 lists the eight configurations on the EVM.

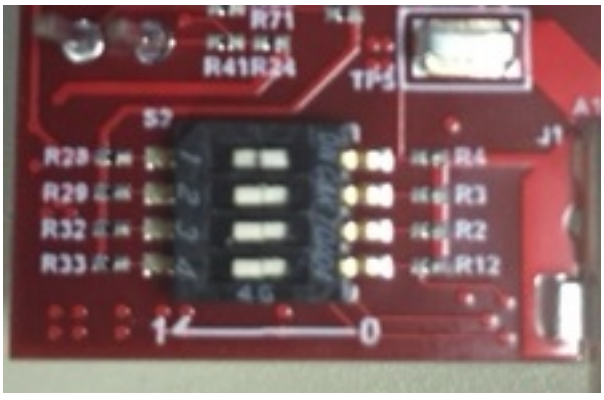


Figure 3. S2 Switch Board

Table 2. TPS65986EVM Configuration Table

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
0	■ ← 0 ■ ← 0 ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Self-powered docking system	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV
1	1 → ■ ■ ← 0 ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	—	—	5 at 0	12 to 20 at 2	—	DFP_D Config C, D and E	DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Sink PR Swap to Src - Accept PR Swap to Snk - Accept	Initiate DR swap to DFP Initiate PR swap to Snk	Notebook system	Source: 5 V at 3-A PP_5V0 Sink: PP_HV
2	■ ← 0 1 → ■ ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	DFP_D Config C, D and E	DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to DFP Initiate PR swap to Src	Add-in card	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV
3	1 → ■ 1 → ■ ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	—	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Charging hard drive	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV
4	■ ← 0 ■ ← 0 1 → ■ ■ ← 0	UFP Rp/Rd	—	—	—	—	5 at 0.9	—	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Sink PR Swap to Src - Reject PR Swap to Snk - Accept	—	Display dongle	Sink: PP_HV
5	1 → ■ ■ ← 0 1 → ■ ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0.9	12 to 20 at 2	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Mini-dock and multifunction dongle	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV Sink: PP_HV
6	■ ← 0 1 → ■ 1 → ■ ■ ← 0	DFP Rp	3	5 at 3	20 at 3	—	—	—	—	—	DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Source PR Swap to Src - Accept PR Swap to Snk - Reject	—	DFP only host	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV
7	1 → ■ 1 → ■ 1 → ■ ■ ← 0	UFP Rd	—	—	—	—	5 at 3	12 at 3	20 at 3	—	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Sink PR Swap to Src - Reject PR Swap to Snk - Accept	—	UFP only host	Sink: PP_HV

6.2.1 Configuration ID 0: Self-Powered Docking System

This configuration represents a docking system that is connected to an external source of power. The configuration is a DRP product that accepts power-role swaps to source and data-role swaps to UFP. The firmware is also configured to automatically request a power-role swap to source or data-role swap to UFP when appropriate.

Table 3. Configuration ID 0

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
0	■ ← 0 ■ ← 0 ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Self-powered docking system	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV

6.2.1.1 Power Configurations

This configuration supports sourcing up to 60 W and has two source profiles. This configuration can provide 5 V at 3 A and 20 V at 3 A through the PP_HV path. This configuration only requests a 5-V at 0 A contract as a sink because it is a docking system that is externally powered.

6.2.1.2 Data Configurations

This configuration is a UFP in terms of data for USB and DisplayPort functionality. When connected to another DisplayPort UFP_D product, the DisplayPort alternate mode is not established because two UFP_D products are connected. The ideal connections are to a DFP_D DisplayPort product or a USB Host. The DP-EXPANSION-EVM (DisplayPort sink board) allows the user to use the USB and DisplayPort signals.

6.2.2 Configuration ID 1: Notebook System

This configuration represents a notebook system that is battery powered. The configuration is a DRP product that accepts power-role swaps to source or sink and data-role swaps to DFP. The firmware is also configured to automatically request a power-role swap to sink or data-role swap to DFP when appropriate. This configuration rejects any data-role swaps to UFP because it is a data host.

Table 4. Configuration ID 1

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
1	1→ ■ ■ ← 0 ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	—	—	5 at 0	12 to 20 at 2	—	DFP_D Config C, D and E	DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Sink PR Swap to Src - Accept PR Swap to Snk - Accept	Initiate DR swap to DFP Initiate PR swap to Snk	Notebook system	Source: 5 V at 3-A PP_5V0 Sink: PP_HV

6.2.2.1 Power Configurations

This configuration supports sourcing up to 15 W and has one source profile. This configuration can provide 5 V at 3 A, and has two sink profiles through the PP_HV path: 5 V at 0 A and 12 V to 20 V at 2 A. When an appropriate source capability is advertised, it requests a high-voltage contract because the notebook requires a higher voltage to charge.

6.2.2.2 Data Configurations

This configuration is a DFP in terms of data for USB and DisplayPort functionality. When connected to another DisplayPort DFP_D product, the DisplayPort alternate mode is not established because of two DFP_D products being connected. The ideal connections are to a UFP_D DisplayPort product or a USB device. The DP-EXPANSION-EVM (DisplayPort source board) allows the user to use the USB and DisplayPort signals into a legacy notebook.

6.2.3 6.2.3 Configuration ID 2: Add-In Card

This configuration represents an add-in card or motherboard host that is self-powered. The configuration is a DRP product that accepts power-role swaps to source and data-role swaps to DFP. The firmware is also configured to automatically request a power-role swap to source or data-role swap to DFP when appropriate. This configuration rejects a data-role swap to UFP because it is a data host.

Table 5. Configuration ID 2

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
2	■ ← 0 1→ ■ ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	DFP_D Config C, D and E	DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to DFP Initiate PR swap to Src	Add-in card	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV

6.2.3.1 Power Configurations

This configuration supports sourcing up to 60 W and has two source profiles. This configuration can provide 5 V at 3 A and 20 V at 3 A through the PP_HV path. This configuration only requests a 5 V at 0 A contract because it is an add-in card or motherboard that is externally powered.

6.2.3.2 Data Configurations

This configuration is a DFP in terms of data for USB and DisplayPort functionality. When connected to another DisplayPort DFP_D product, the DisplayPort alternate mode is not established because two DFP_D products are connected. The ideal connections are to a UFP_D DisplayPort product or a USB device. The DP-EXPANSION-EVM (DisplayPort source board) allows the user to route the USB and DisplayPort signals into a legacy notebook.

6.2.4 Configuration ID 3: Charging Hard Drive

This configuration represents a charging hard drive that is self-powered. The configuration is a DRP product that accepts power-role swaps to source and data-role swaps to UFP. The firmware is configured to automatically request a power-role swap to source or data-role swap to DFP when appropriate. The configuration rejects a data-role swap to DFP because it is a data device.

Table 6. Configuration ID 3

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
3	1→ ■ 1→ ■ ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0	—	—	—	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Charging hard drive	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV

6.2.4.1 Power Configurations

This configuration supports sourcing up to 60 W and has two source profiles. The configuration can provide 5 V at 3 A and 20 V at 3 A through the PP_HV path. This configuration only requests a 5 V at 0 A contract because it is a hard drive that is externally powered.

6.2.4.2 Data Configurations

This configuration is a UFP in terms of data for USB data only. The DP-EXPANSION-EVM(DisplayPort source board) can be used to bring out the USB signals.

6.2.5 Configuration ID 4: Display Dongle

This configuration represents a display dongle that is bus-powered only. The configuration is a UFP product that accepts power-role swaps to sink and data-role swaps to UFP. This configuration rejects a data-role swap to DFP because it is a data device.

Table 7. Configuration ID 4

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
4	■ ← 0 ■ ← 0 1 → ■ ■ ← 0	UFP Rp/Rd	—	—	—	—	5 at 0.9	—	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Sink PR Swap to Src - Reject PR Swap to Snk - Accept	—	Display dongle	Sink: PP_HV

6.2.5.1 Power Configurations

This configuration does not support source profiles. It will request a 5-V at 900 mA contract to connect as a bus powered device to all existing Type-C PD notebooks.

6.2.5.2 Data Configurations

This configuration is a UFP in terms of data for USB and DisplayPort functionality. When connected to another DisplayPort UFP_D product, the DisplayPort alternate mode is not established because two UFP_D products are connected. The ideal connections are to a DFP_D DisplayPort product or a USB host. The DP-EXPANSION-EVM (DisplayPort sink board) can be used to route the USB and DisplayPort signals.

6.2.6 Configuration ID 5: Mini-Dock or Multifunction Dongle

This configuration represents a mini-docking system or multifunction dongle device that can be self or bus powered. This configuration is a DRP product that accepts power-role swaps to source and data-role swaps to UFP. The firmware is also configured to automatically request a power-role swap to source or data-role swap to UFP when appropriate. The configuration rejects a data-role swaps to DFP because it is a device.

Table 8. Configuration ID 5

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
5	1 → ■ ■ ← 0 1 → ■ ■ ← 0	DRP Rp/Rd	3	5 at 3	20 at 3	—	5 at 0.9	12 to 20 at 2	—	UFP_D Config C and D	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Source PR Swap to Src - Accept PR Swap to Snk - Reject	Initiate DR swap to UFP Initiate PR swap to Src	Mini-dock and multifunction dongle	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV Sink: PP_HV

6.2.6.1 Power Configurations

This configuration supports sourcing up to 60 W and has two source profiles. The configuration can provide 5 V at 3 A and 20 V at 3 A through the PP_HV path. This configuration requests a 5 V at 900 mA contract to connect as a bus powered device to all existing Type-C PD notebooks.

6.2.6.2 Data Configurations

This configuration is a UFP in terms of data for USB and DisplayPort functionality. When connected to another DisplayPort UFP_D product, the DisplayPort alternate mode is not established because two UFP_D products are connected. The ideal connections are to a DFP_D DisplayPort product or a USB host. The DP-EXPANSION-EVM (DisplayPort sink board) can be used to bring out the USB and DisplayPort signals.

6.2.7 Configuration ID 6: DFP Only Host

This configuration represents a DFP only host that is self-powered. The DFP product rejects a data-role swap to UFP and a power-role swap to sink.

Table 9. Configuration ID 6

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
6	■ ← 0 1→ ■ 1→ ■ ■ ← 0	DFP Rp	3	5 at 3	20 at 3	—	—	—	—		DFP DR Swap to DFP - Accept DR Swap to UFP - Reject	Source PR Swap to Src - Accept PR Swap to Snk - Reject	—	DFP only host	Source: 5 V at 3-A PP_5V0 Source: 20 V at 3-A PP_HV

6.2.7.1 Power Configurations

This configuration supports sourcing up to 60 W and has two source profiles. The configuration can provide 5 V at 3 A and 20 V at 3 A through the PP_HV path. This configuration is a DFP only and does not have sink power profiles.

6.2.7.2 Data Configurations

This configuration is a DFP in terms of data for USB only. The DP-EXPANSION-EVM (DisplayPort source board) can be used to route the USB signal into a legacy notebook.

6.2.8 Configuration ID 7: UFP Only Device

This configuration represents a UFP only device that is bus powered. The UFP product rejects a data-role swap to DFP and a power-role swap to source.

Table 10. Configuration ID 7

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			DP Support	PD Control Response		PD Control	Application	FET Paths Used
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A		Data Role Preferred	Power Role Preferred	Initiated DR/PR Swaps		
7	1→ ■ 1→ ■ 1→ ■ ■ ← 0	UFP Rd	—	—	—	—	5 at 3	12 at 3	20 at 3	—	UFP DR Swap to DFP - Reject DR Swap to UFP - Accept	Sink PR Swap to Src - Reject PR Swap to Snk - Accept	—	UFP only host	Sink: PP_HV

6.2.8.1 Power Configurations

This configuration is UFP only and does not have source profiles. This configuration supports three sink profiles: 5 V at 3 A, 12 V at 3 A, and 20 V at 3 A.

6.2.8.2 Data Configurations

This configuration is a UFP in terms of data for USB only. The DP-EXPANSION-EVM (DisplayPort sink board) can be used to route the USB signals.

6.3 Connecting the TPS65986EVM

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

6.3.1 Connecting to a Legacy Type-A Host

Using a Type-A plug to Type-C cable allows connection to a legacy host. When the billboarding and endpoint functions are enabled on the EVM, the user can access the registers and update the firmware by using the TPS6598x Utilities GUI. The EVM can be powered from the Type-A to Type-C cable and does not require a power-supply function with the TPS65986x Utilities GUI. Figure 4 shows how the TPS65986 device is connected to a notebook with the TPS6598x Utilities GUI.

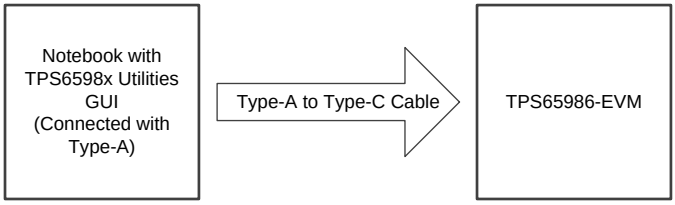


Figure 4. Connecting EVM to Legacy Host

6.3.2 Connecting to a Legacy Type-A Device

Using a Type-C to Type-A receptacle cable allows for connection to a legacy USB device, such as a flash-drive. The TPS65986 device cannot act as a host but can pass the USB connection to a host by using the DP-EXPANSION-EVM (DisplayPort source board). Figure 5 shows how the notebook, DP-EXPANSION-EVM, TPS65986EVM, cable, and flash drive are connected

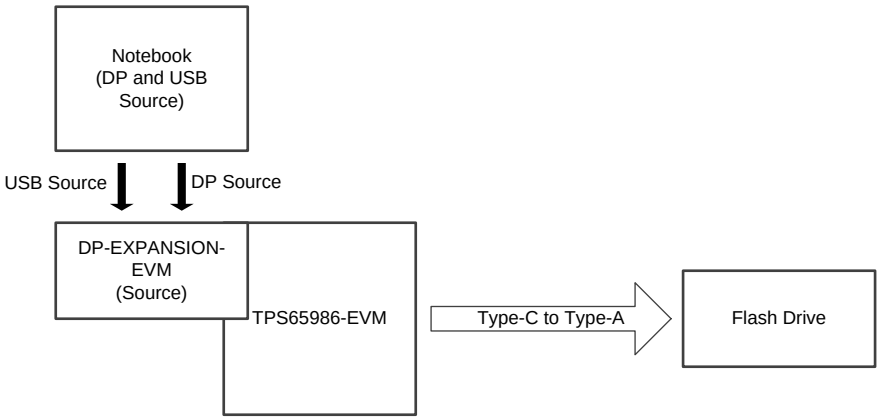


Figure 5. Connecting EVM to Type-A Device

6.3.3 Connecting to Type-C Devices

Using a Type-C cable allows for connection to a Type-C device or host. When two TPS65986EVMs are used with the DP-EXPANSION-EVM (source and sink boards), a complete Type-C system can be verified. The DisplayPort alternate mode is entered when the two setups appropriately configure as defined in Table 2. The source setup requires a USB source with DisplayPort to provide data to the sink board. A monitor can be connected to sink board, along with a USB device to connect to the source board. Figure 6 shows how the boards are connected.

NOTE: Signal integrity can be a factor on USB and DisplayPort video quality because of going through multiple connectors and cables.

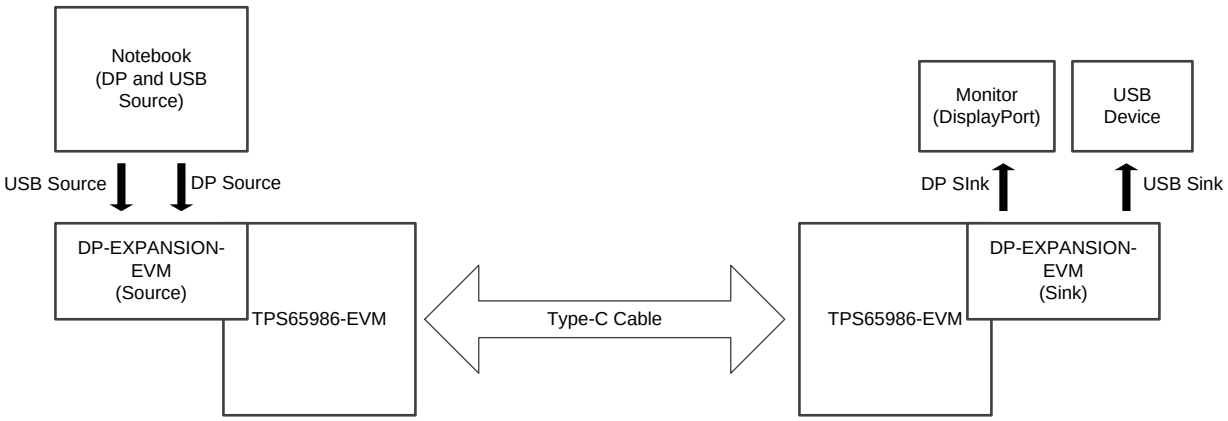


Figure 6. Connecting EVM to EVM for Type-C System

Figure 7 shows how a source setup can be connected to a Type-C device (DisplayPort, USB, or both), such as a Type-C flash drive, Type-C to DisplayPort dongle, Type-C to HDMI, or Type-C docking system.

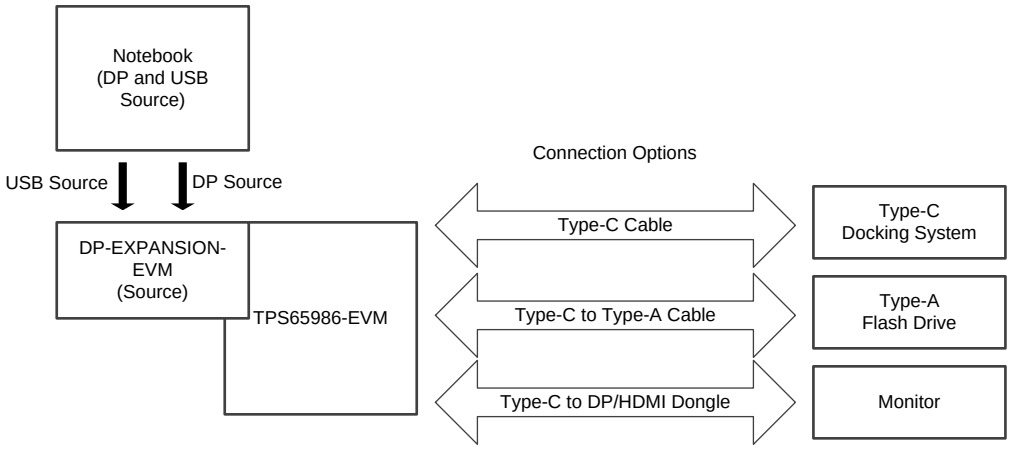


Figure 7. Connecting EVM to Type-C Devices

Figure 8 shows how a sink setup can be connected to a Type-C host, such as MacBook or ChromeBook Pixel, to enter the DisplayPort alternate mode. The sink allows DisplayPort and USB connections to the notebooks.

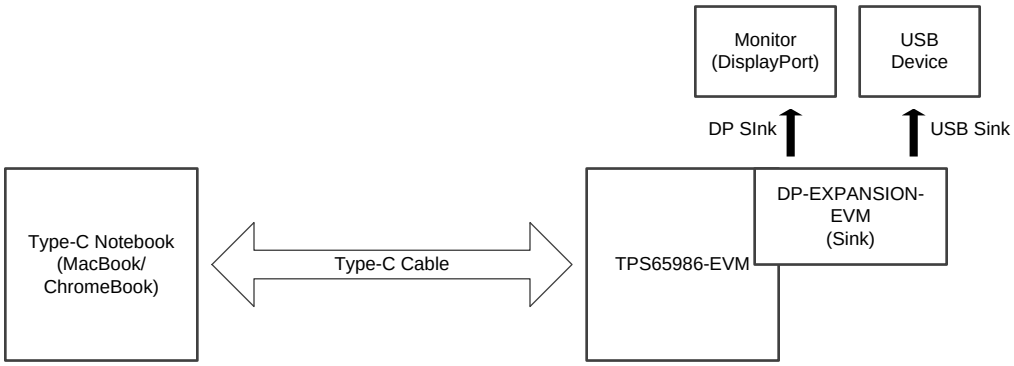


Figure 8. Connecting EVM to Type-C Host

6.3.4 Testing DisplayPort Alternate Mode

The DisplayPort alternate mode can be tested with a non-Type-C notebook, allowing the user to simulate a DisplayPort DFP_D (video source) or UFP_D (video sink). Table 11 lists the testing flow used to verify DisplayPort functionality with two TPS65986EVMs and the DP-EXPANSION-EVM (DIsplayPort source and sink boards).

CAUTION

Do not connect the DP-EXPANSION-EVM to the TPS65986EVM when the barrel jack is connected—this may result in a short if the J5 expansion board connectors are misaligned.

The required hardware is listed as follows:

- A Windows PC with a USB Type-A receptacle and DisplayPort video output
  - USB3.0 Type-A to Type-B cable
  - USB3.0 flash drive
  - USB2.0 Type-A to Type-B cable
- USB Type-C Cable
- 1080p Monitor with DisplayPort input
- Mini DisplayPort to DisplayPort cable
- Aardvark I²C/SPI Host Adapter (Used for programming the TPS695986-EVM and interfacing with Utilities GUI)
- ACS002 DP-EXPANSION-EVM (source and sink board)
- Two TPS65986EVMs with base firmware (preloaded before shipping)
- Dell laptop power-supply model: DA130PE1-00

Table 11. DisplayPort Testing Table

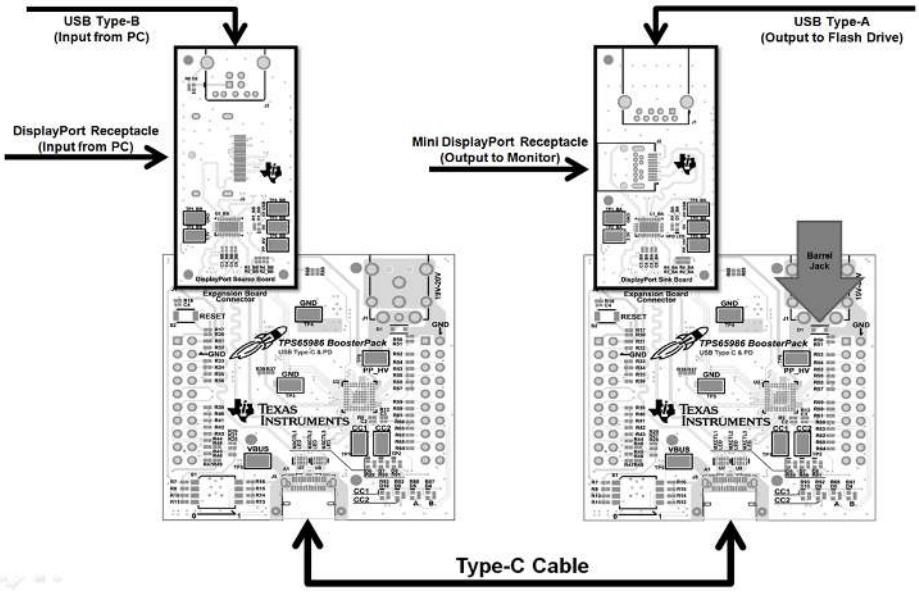
Test Step	Pass Criteria
Left switch setting: B0: → B1: ← B2: ← Right switch setting: B0: ← B1: ← B2: ←	
Connect the ACS002 DisplayPort source board to board on left output of the PC and USB3.0 output of the PC.	DisplayPort source board should be connected to the DisplayPort

Table 11. DisplayPort Testing Table (continued)

Test Step	Pass Criteria
Connect the ACS002 DisplayPort sink board to board on right of the monitor and to a USB3.0 flash drive.	DisplayPort sink board should be connected to the DisplayPort input
Connect the two EVM setups with a Type-C cable and connect barrel jack	EVMs negotiate a high-voltage 20-V contract (on VBUS) and enter the DisplayPort alternate mode.
Check for video on DisplayPort monitor and verify USB flash drive is accessible	Successfully copy and paste a file to and from the USB flash drive. Extend the PC to the DisplayPort monitor and play video to verify video stream.

6.4 Debugging the EVM

This section describes various debugging examples.

NOTE: The testing and debugging approaches on the EVM can be applied to an actual system to help identify any issues.

6.4.1 Connection Not Established

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

- Verify that a firmware image is loaded in on the TPS65986 device using the TPS6598x Utilities GUI.
- Verify the CC lines are toggling for dual-role port functionality (see Figure 9).
- Verify the following system supplies:
  - VIN_3V3: 3.3 V
  - LDO_3V3: 3.3 V
  - LDO_1V8D/A: 1.8 V
  - PP_5 V0/PP_CABLE: 5 V
  - PP_HV: 20 V
- Verify that the devices connected are compatible (see Table 2). Some of the compatible connections are listed as follows:
  - Dual Role Port → UFP
  - Dual Role Port → DFP
  - DFP → UFP
- Verify that VBUS is reaching 5 V when connected (see Figure 10)

.

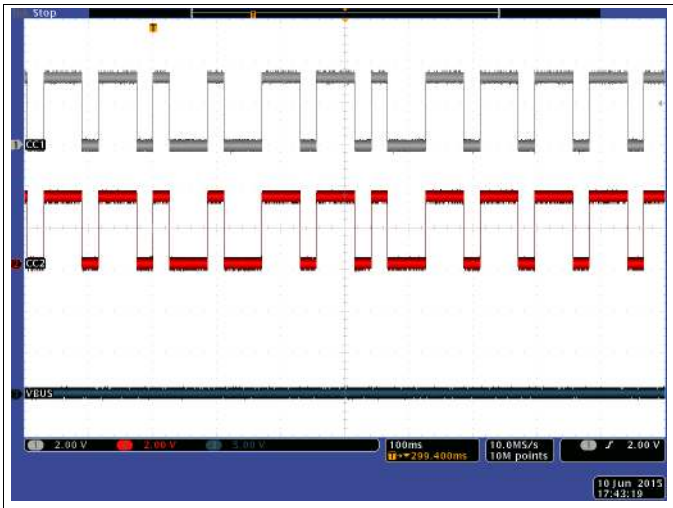


Figure 9. DRP CC1 and CC2 Toggling

Figure 10. Type-C Connection and VBUS

6.4.2 Reseting Behavior

Improper configurations and shorts can cause a Type-C PD system to constantly reset. Use the following checks to debug these types of issues:

- Verify that the required power paths have the correct voltages:
  - PP_5 V0/PP_CABLE: 5 V
  - PP_HV: 20 V (or appropriately configured voltage)
- Probe VBUS, CC1, and CC2 to check for any anomalies. Figure 11 shows a successful power contract.
- When a short occurs on VBUS, the initial 5 V on VBUS is not present.
- Check for a small spike during a cable attach event to verify that the 5-V switch is closed and is opened once the overcurrent event is detected.

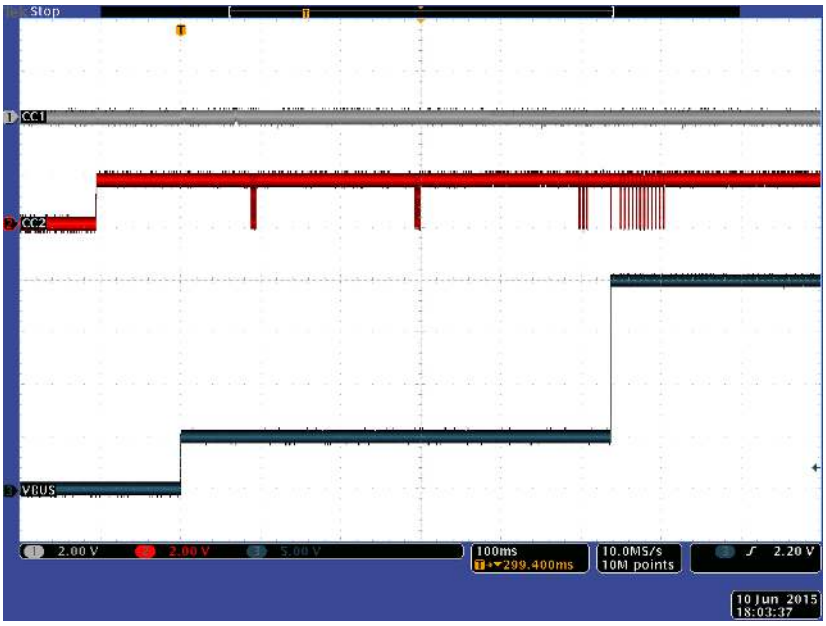


Figure 11. Type-C Connection and PD Negotiation

7 Programming the TPS65986EVM Firmware

This section describes loading firmware onto the TPS65986EVM, using the Aardvark adapter as the hardware interface and explains that there are multiple interface options available in the software GUI.

NOTE: Other methods of firmware loading are available and are discussed in the TPS6598x Utilities Tool User Guide. For example, when performing firmware updates in the field the TPS65986 will act as the SPI Master and firmware data is written to the TPS65986 using I^2C.

7.1 Connecting the TPS65986EVM to the Aardvark SPI Pins with Jumper Wires

Wire the Aardvark SPI pins to the corresponding SPI pins on the TPS65986EVM J2 and J3 headers as shown in Figure 12. Note that Figure 12 matches the Top view of headers J2 and J3 of the TPS65986EVM and jumper wires may be connected to the Top (pins) *or* Bottom (receptacle) side of the BoosterPack headers. This method is used to directly program the SPI Flash from the Aardvark, bypassing the TPS65986EVM, either to write a firmware image on a blank SPI Flash IC or during debug when multiple firmware images are written in a short period of time to test the effects of firmware configuration settings.

NOTE: Once wire connections are made, connect the Dell Power Adapter (Barrel Jack AC Adapter) to the TPS65986EVM to power up the board.

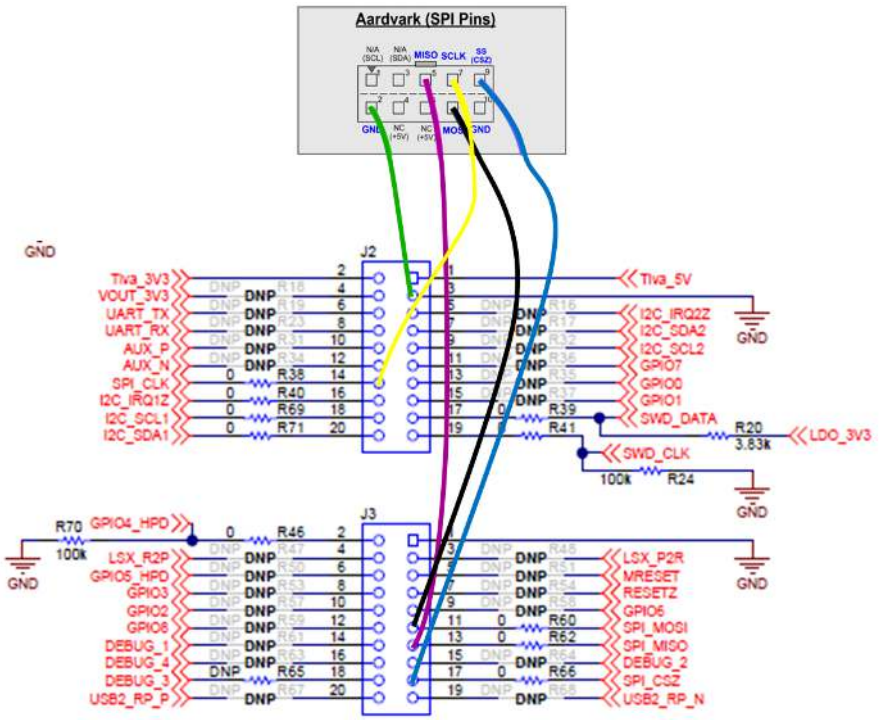


Figure 12. Aardvark Wired to SPI Pins of TPS65986EVM J2 & J3 Headers

7.2 Establishing a Connection to the TPS65986EVM Using the Host Interface SW Tool

Use the following steps to connect the software (SW) of the **Host Interface Utility Tool** to the TPS65986EVM through the interface adapter (Aardvark, FTDI-based, or USB Endpoint):

Step 1. Open the TPS6598x Utilities GUI, click the *Configure* link on the left side of the GUI, verify the settings, and confirm connection by clicking the *Test Configuration Settings* button (see Figure 13). When using an Aardvark adapter, select *Aardvark* for **USB to I2C/SPI Adapter** and *Port 0* for both **I2C Port** and **SPI Port**.

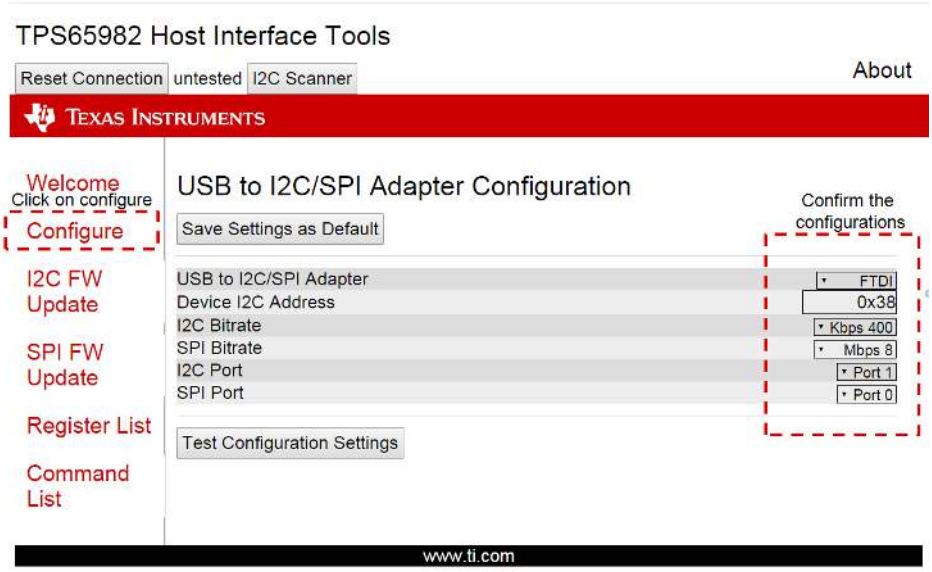


Figure 13. FTDI-based Adapter Configuration Settings

Step 2. Wait until the results are displayed in the *Connection Results* section. An EVM that does not have firmware displays *BOOT* after the *Mode Register returns* field (see Figure 14).

Step 3. Click the *Save Settings as Default* button to save configuration settings.

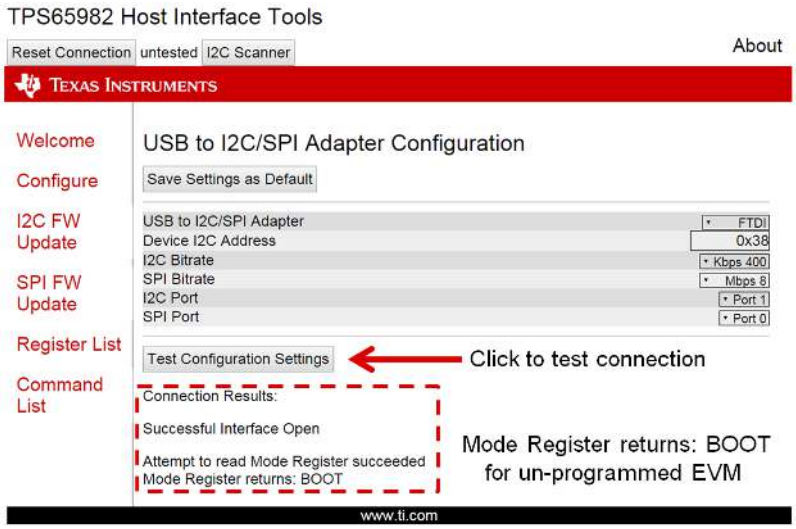


Figure 14. Host Interface Adapter Configuration Test (Error-Free Results)

7.3 Loading the EVM Firmware

Use the following steps to load the EVM firmware:

Step 1. Click the *SPI FW Update* link on the left side of the GUI (see Figure 15).

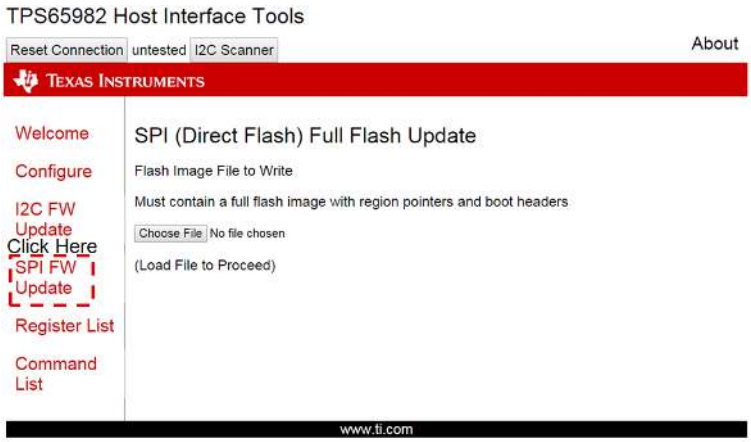


Figure 15. SPI Firmware Update Screen

Step 2. Choose the TPS65986EVM firmware image to load by clicking on the *Choose File* button (see Figure 16). Select the appropriate EVM image (2 region binary file) in the window and verify that it is 191 KB in size. Click the *Open* button to load the file to the TPS6598x Utilities GUI (see Figure 17).

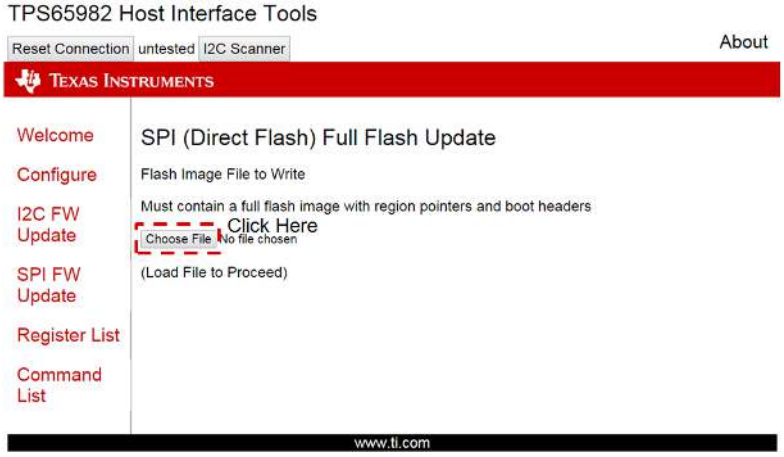


Figure 16. SPI Firmware Update—Choose File

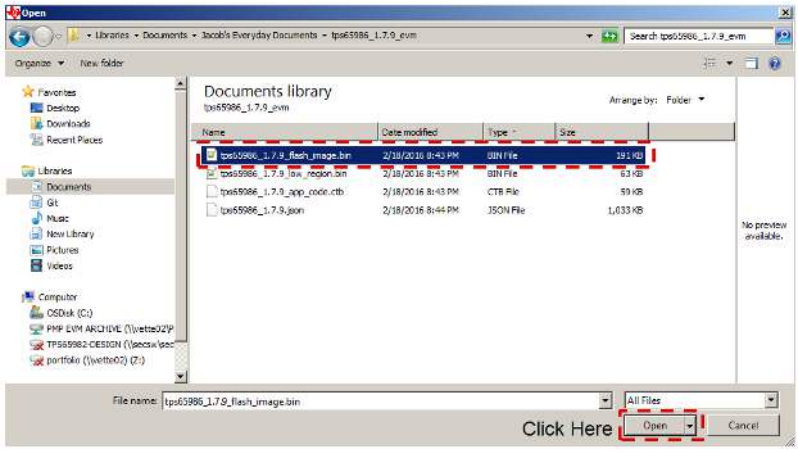


Figure 17. Figure 19. SPI Firmware Update—Select Flash Image (191-KB .bin file)

Step 3. Click the *Program Flash Image* button (see Figure 18).

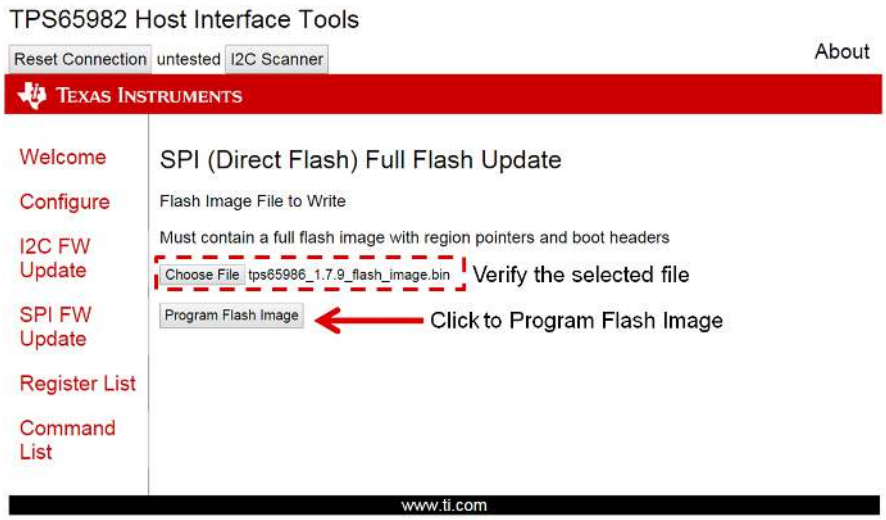


Figure 18. SPI Firmware Update—Start Flash Update

Step 4. Wait until the programming process is complete.

Step 5. Verify that the firmware was successfully loaded. Figure 19 shows a successful firmware update.

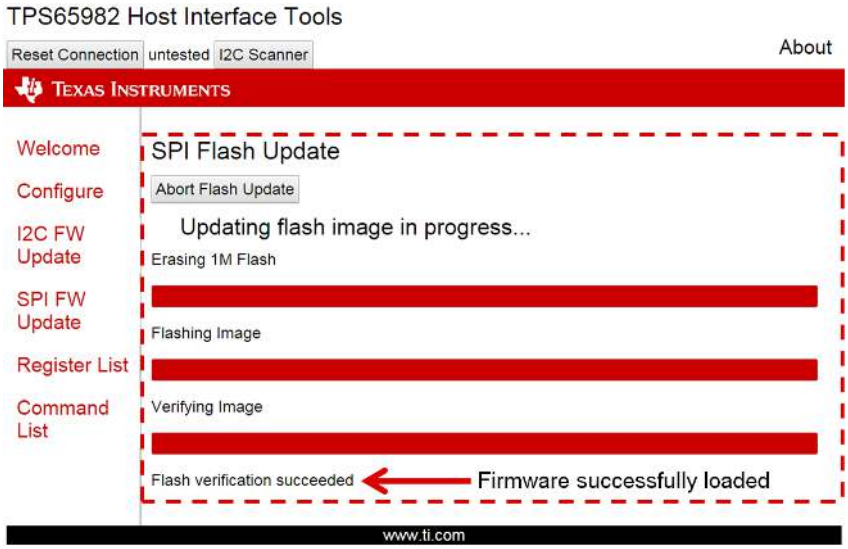


Figure 19. SPI Firmware Update—Firmware Update Complete

Step 6. Press the RESET button (S1) on the top-left side of the TPS65986EVM. Pressing this button causes the EVM to load the new firmware from flash. Failure to press the Reset button will result in the TPS65986 continuing to run the previous firmware in volatile memory until a power cycle occurs or the Reset button is pressed, even though the new firmware image is successfully written into the Flash IC's non-volatile memory.

Step 7. On the TPS6598x Utilities GUI, click the *Register List* link on the left side of the GUI and then click *MODE* (see .Figure 20). This register will check the I^2C communication and verify that the firmware was loaded on the EVM.

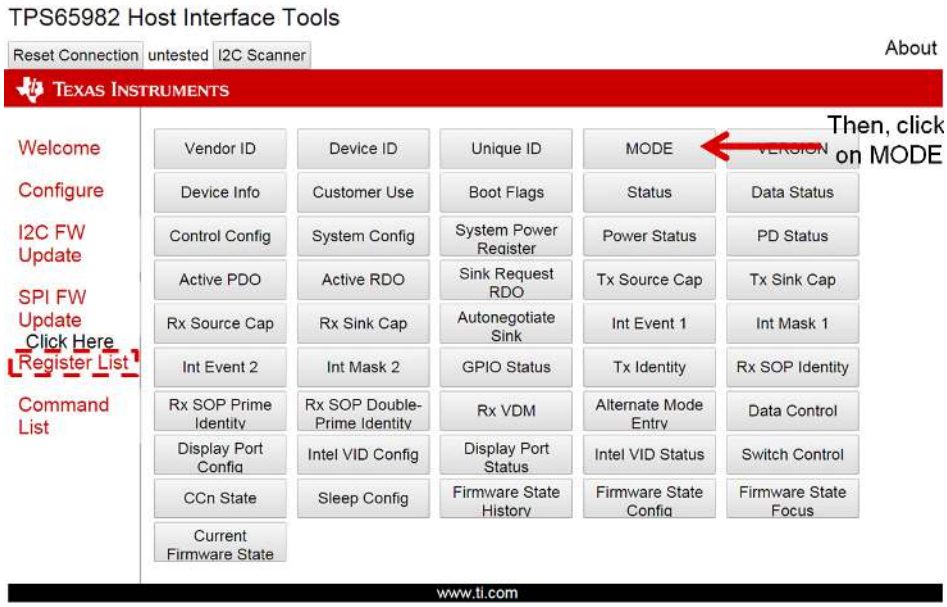


Figure 20. Register List

Step 8. Verify the that the MODE register reads *APP* (see Figure 21).

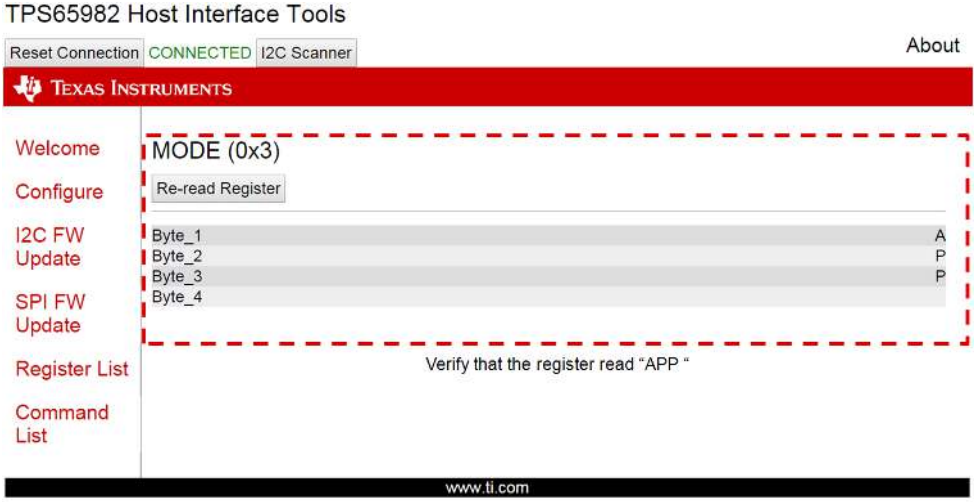


Figure 21. Mode Register

8 TPS65986EVM Schematic

Figure 22 shows the block diagram of the main components of the TPS65986EVM. The main schematic blocks are the processor (Figure 23), power path (Figure 24), power supply (Figure 25), LED indicators (Figure 26), Type-C (Figure 27), inter PCB (Figure 28), booster connectors (Figure 29), and hardware. The main power comes from the barrel jack (J4) and has a TVS diode (D1) for any transient voltage spikes introduced by connecting the barrel jack.

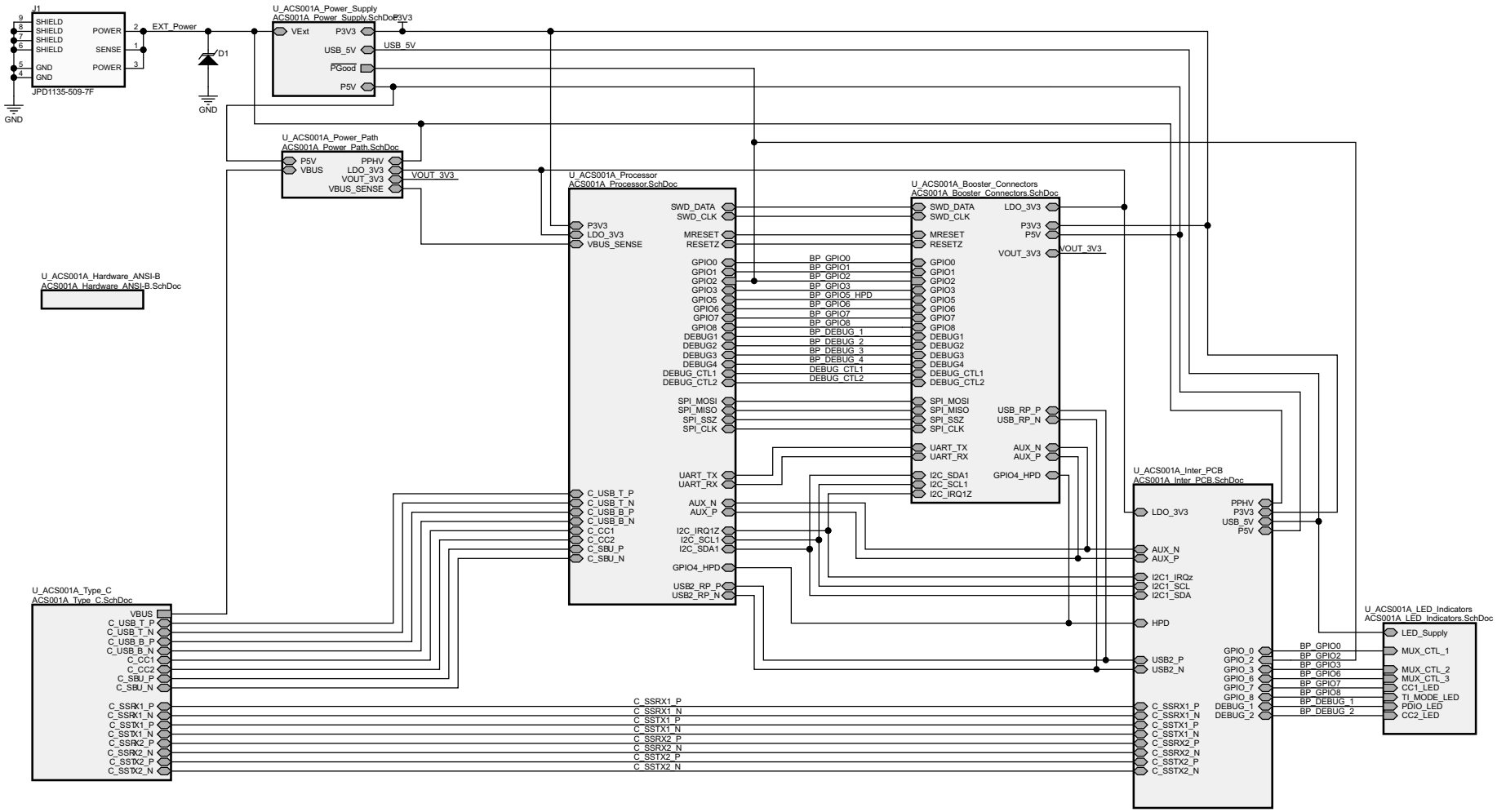


Figure 22. TPS65986EVM Block Diagram

Figure 23 shows the processor block, which contains the TPS65986 PD protocol functions, flash for the TPS65986 device, S2 for the firmware configuration, and the required passives.

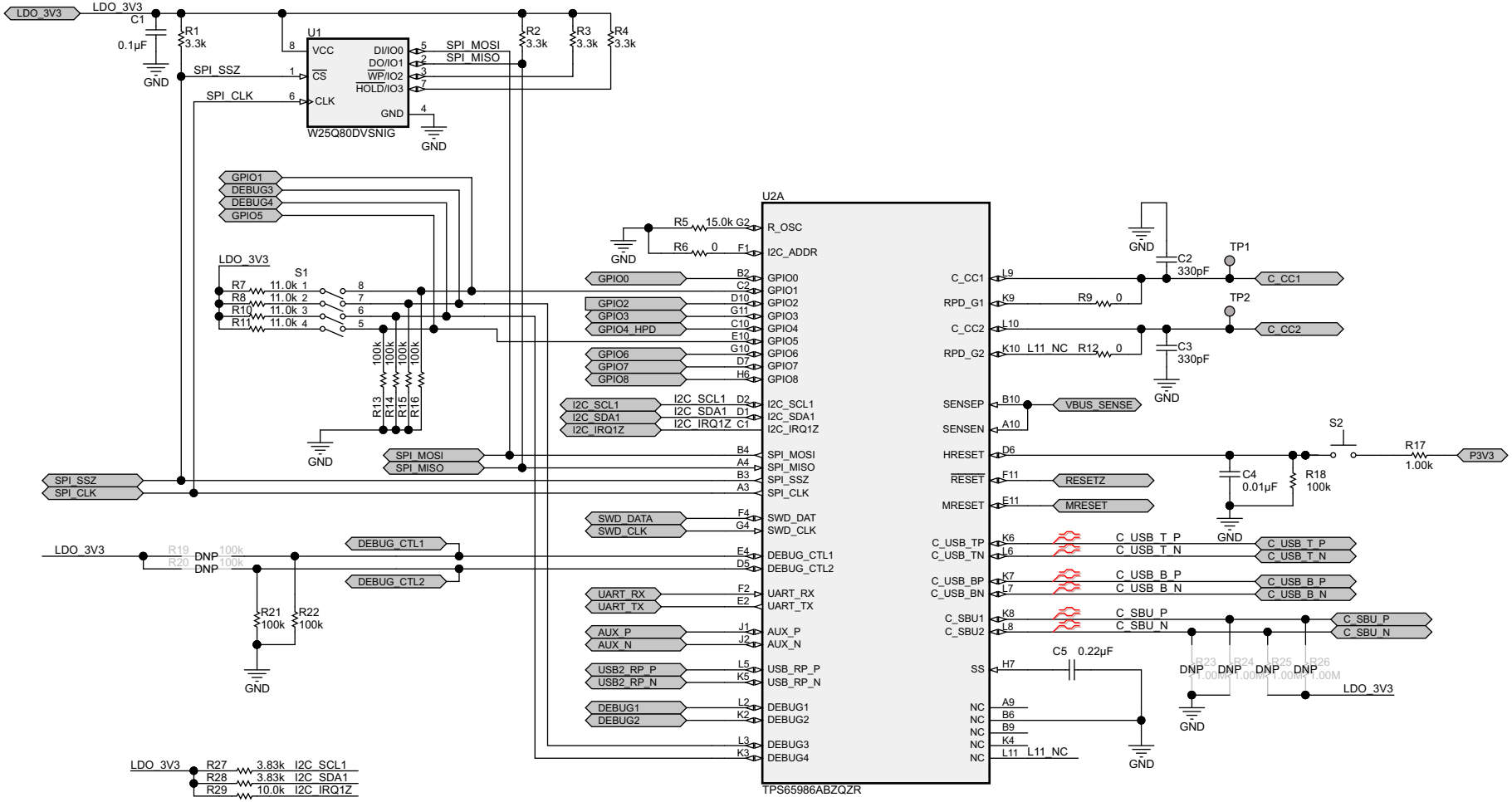


Figure 23. TPS65986EVM Processor Block

Figure 24 shows the power-path block, which contains the power portion of the TPS65986 device and the required passives.

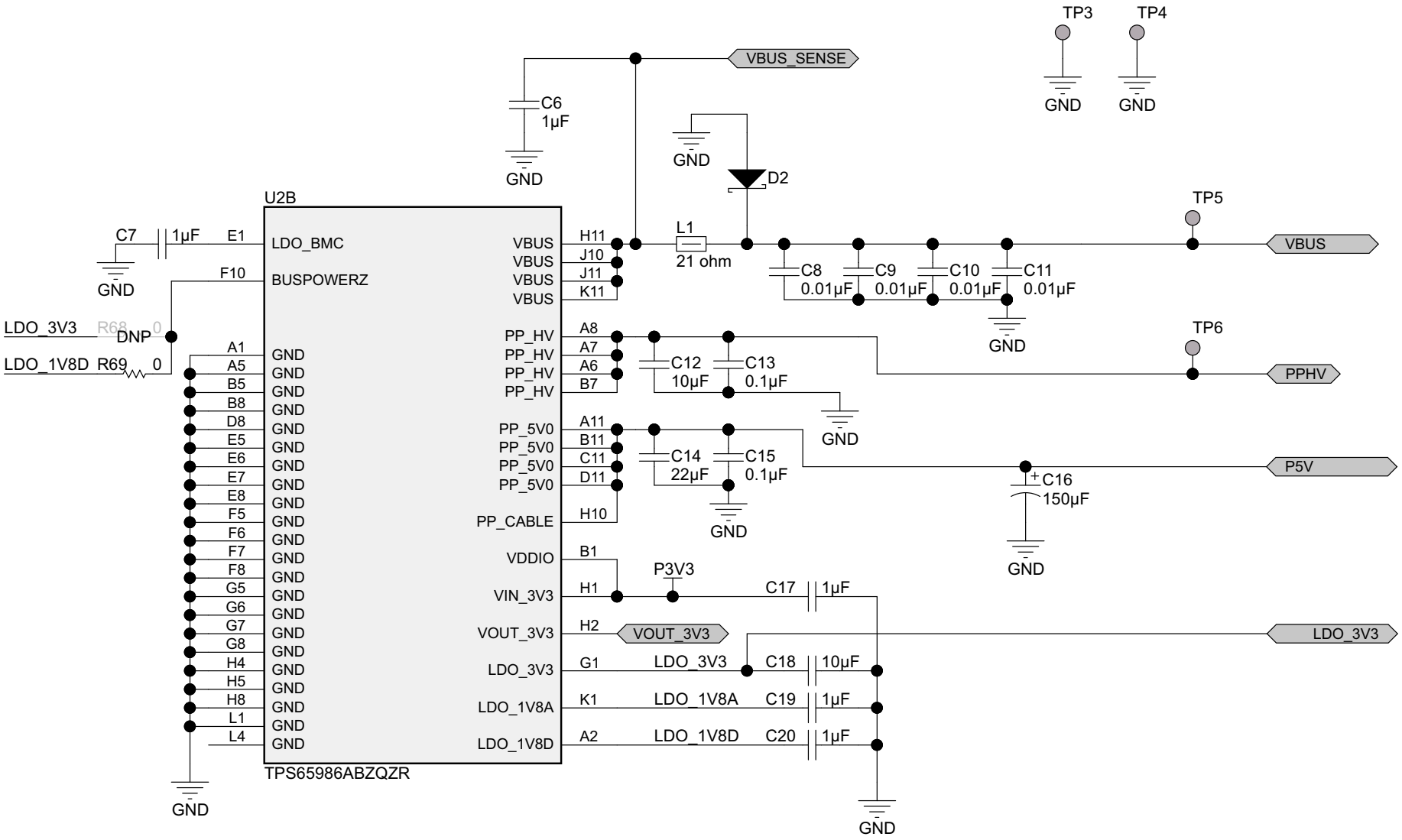


Figure 24. TPS65986EVM Power Path Block

Figure 25 shows the power-supply block, which has all of the board supplies generated and the comparator circuit for barrel jack detection. This block generates two 5-V supplies and one 3.3-V supply. The P3V3 rail is on in bus-powered and self-powered conditions, and it has the ability to operate at 4 V to compensate for IR drop through the 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 (J4) is connected to the EVM only. USB_5 V is supplied by a boost converter from the main 3.3-V rail and is intended to ensure there is 5 V for the USB DFP port on the DP-EXPANSION_EVM, when acting bus-powered or self-powered. The minimum voltage for VExt is 12 V. When using a lower voltage, the comparator circuit can be adjusted to trip at a lower voltage for proper barrel jack detection.

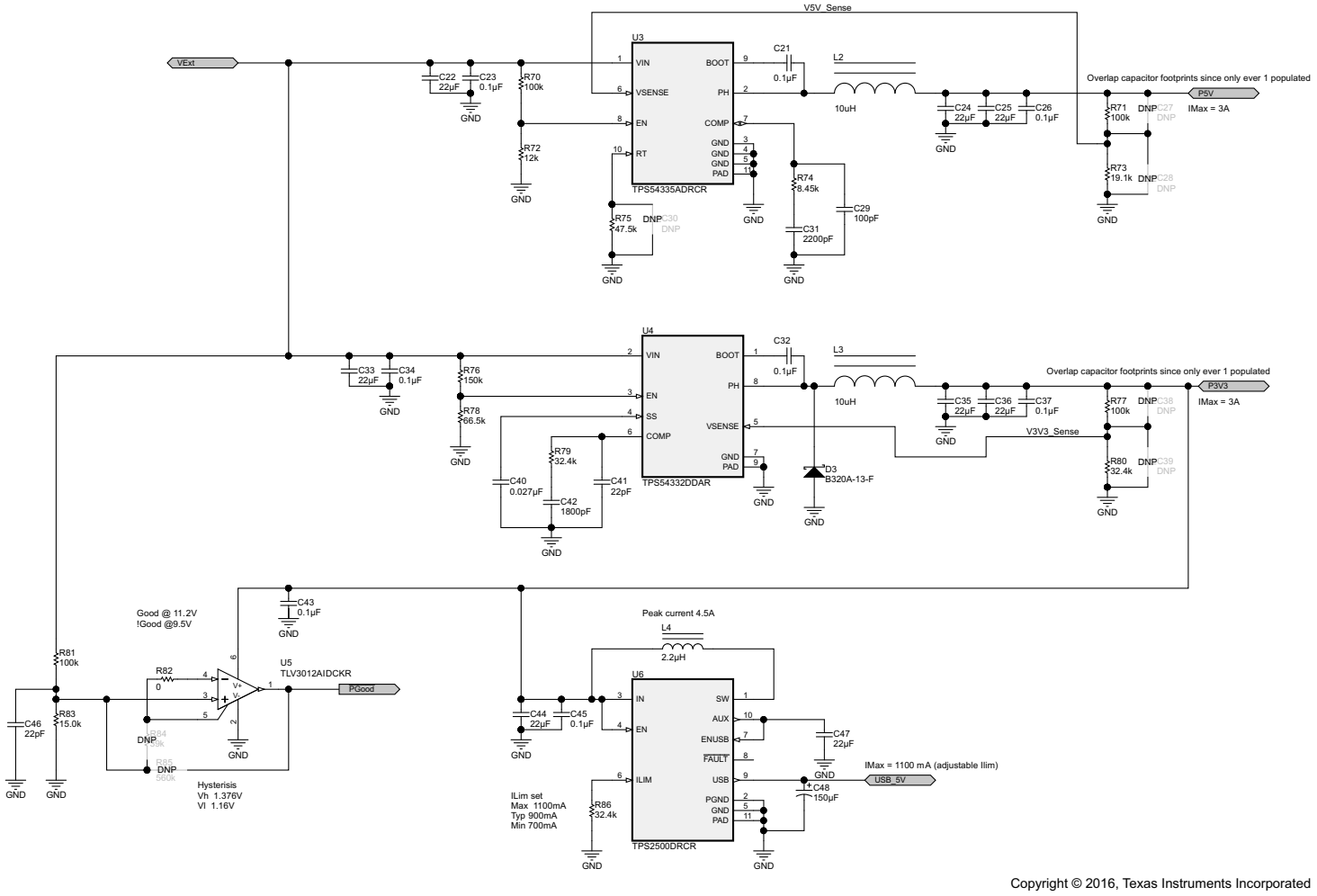


Figure 25. TPS65986EVM Power Supply Block

Figure 26 shows the LED indicators block, which contains the LEDs and GPIO control scheme.

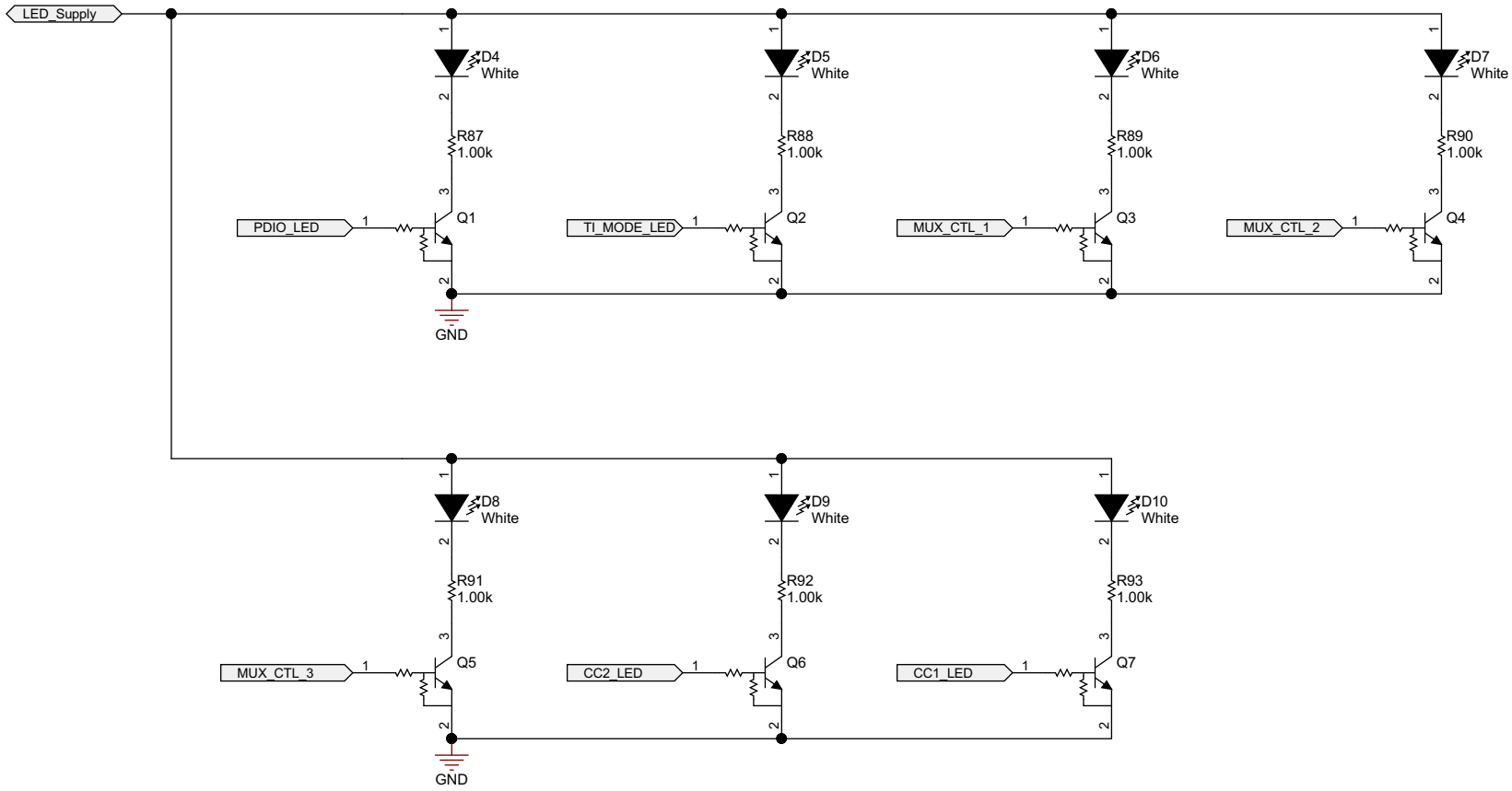


Figure 26. TPS65986EVM LED Indicators Block

Figure 27 shows the Type-C block, which includes the Type-C connector and ESD protection.

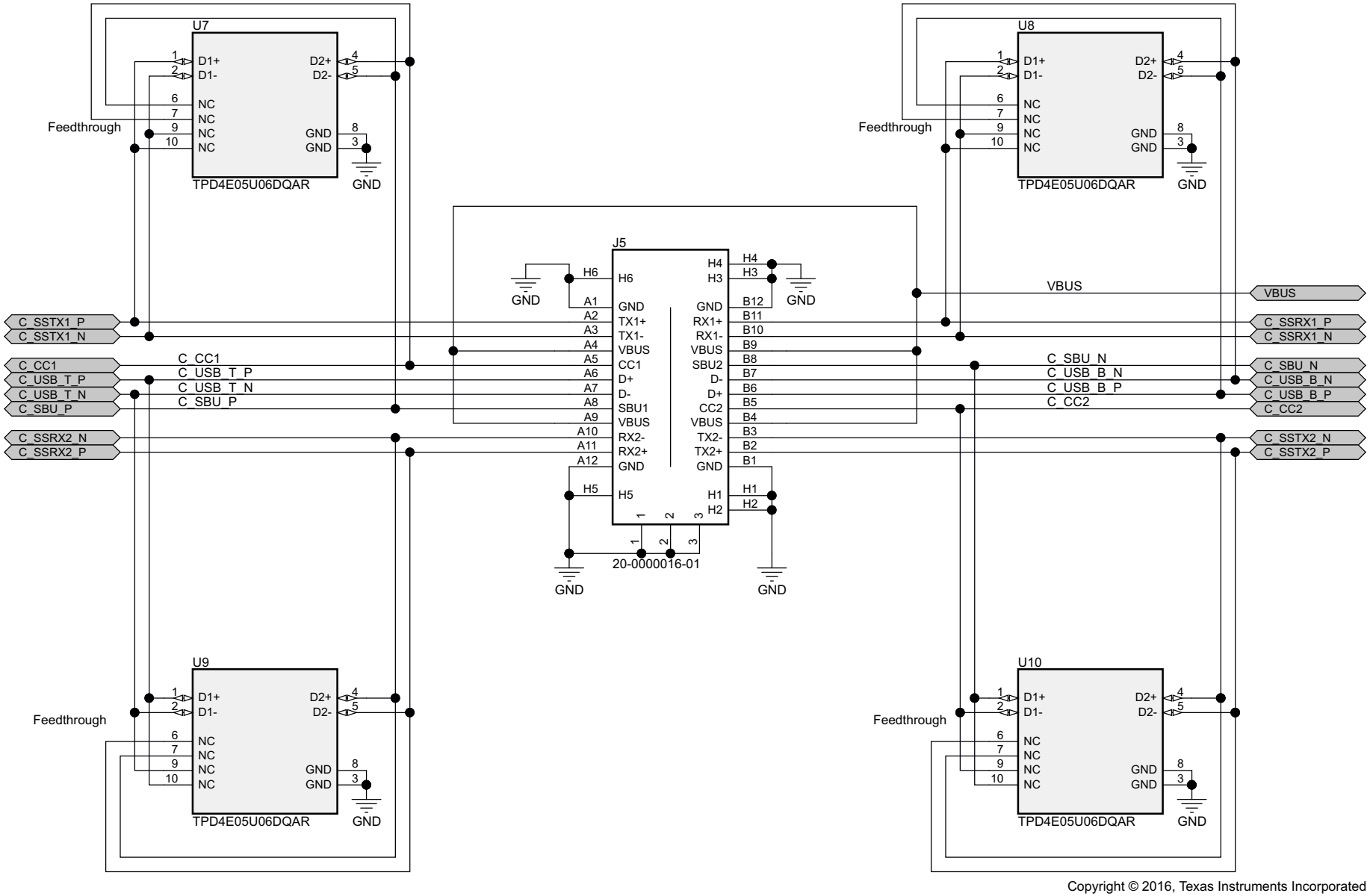


Figure 27. TPS65986EVM Type-C Block

Figure 28 shows the inter PCB block, which has the connections that go to the DP-EXPANSION-EVM.

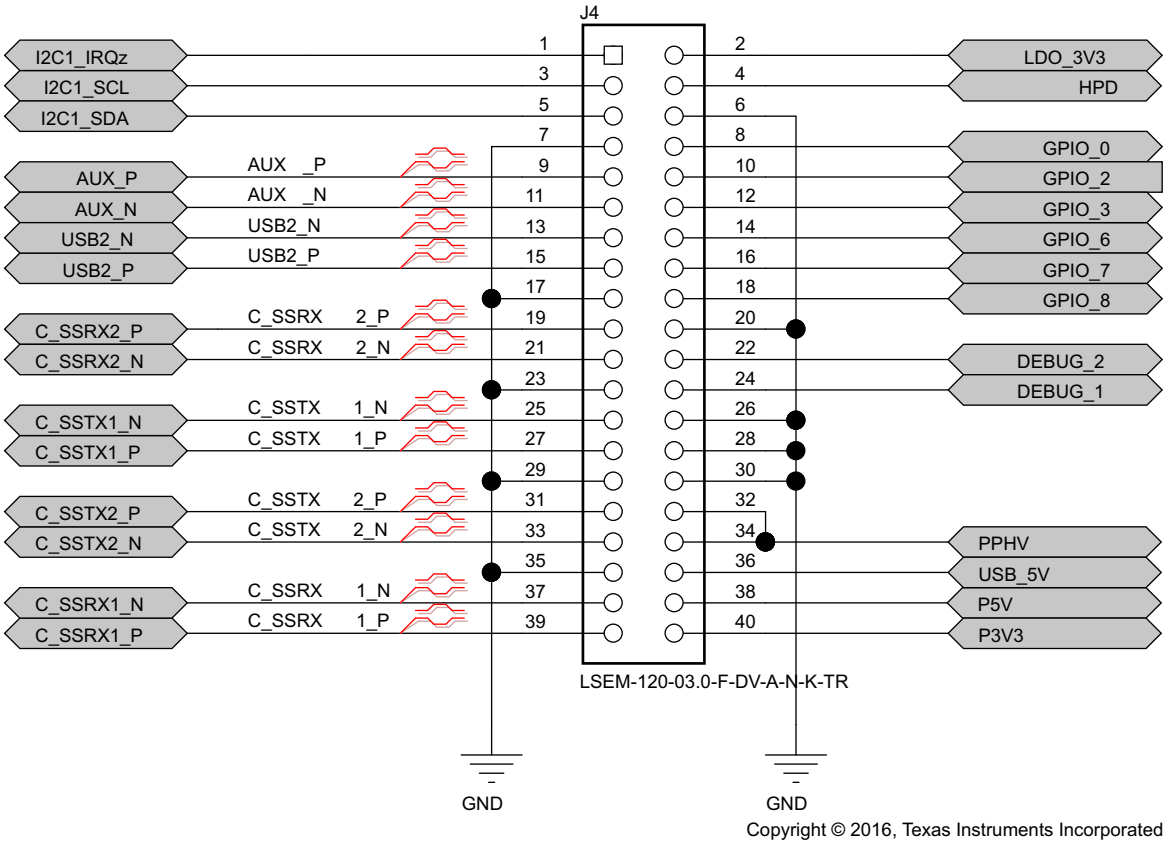


Figure 28. TPS65986EVM Inter PCB Block

Figure 29 shows the booster connectors block, which contain the connections to the BoosterPack headers.

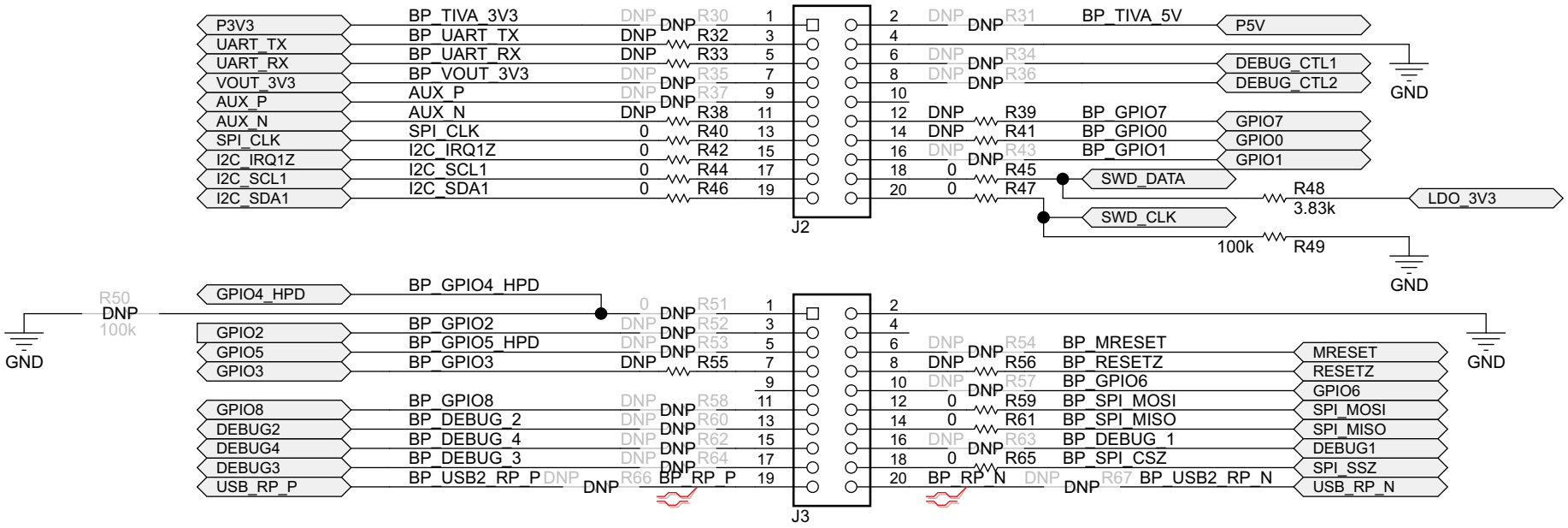


Figure 29. TPS65986EVM Booster Connector Block

9 TPS65986EVM Board Layout

The following figures contain the PCB layouts of the TPS65986EVM.

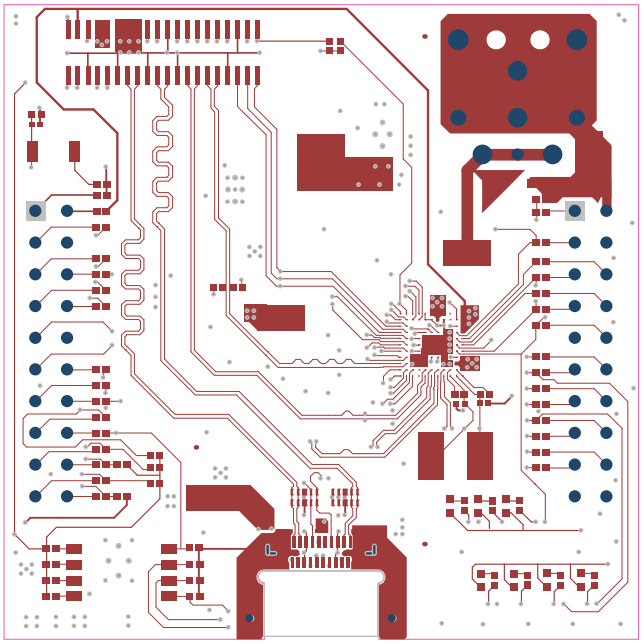


Figure 30. TPS65986EVM Top Layer

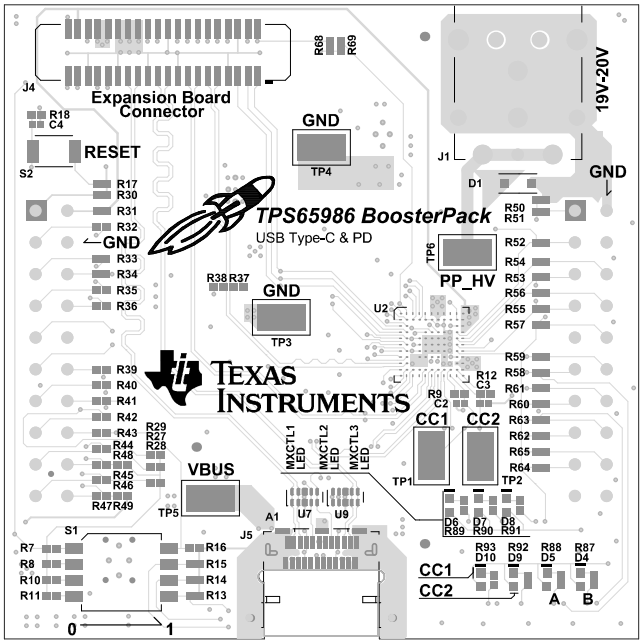


Figure 31. TPS65986EVM Top Layer Component View

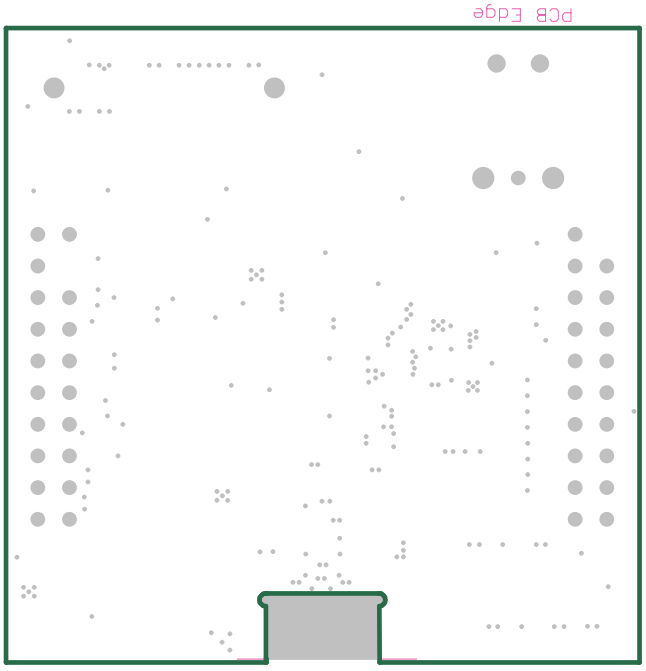


Figure 32. TPS65986EVM GND Plane 1

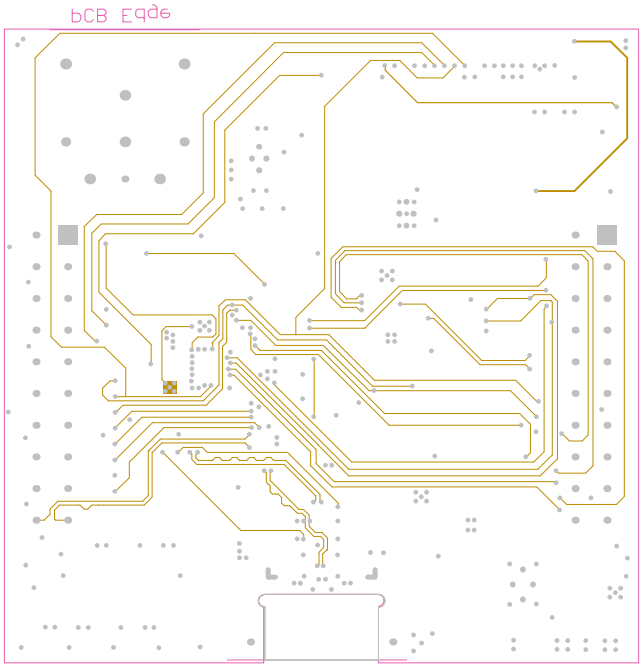


Figure 33. TPS65986EVM Mid Layer 1

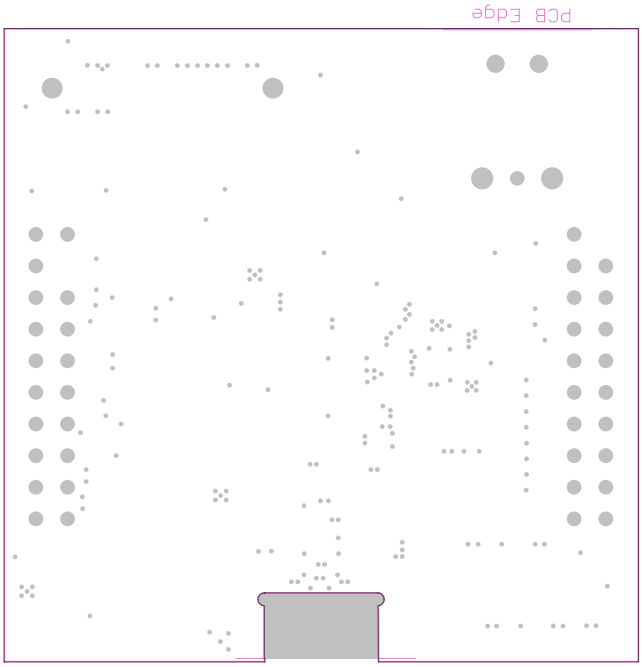


Figure 34. TPS65986EVM GND Plane 2

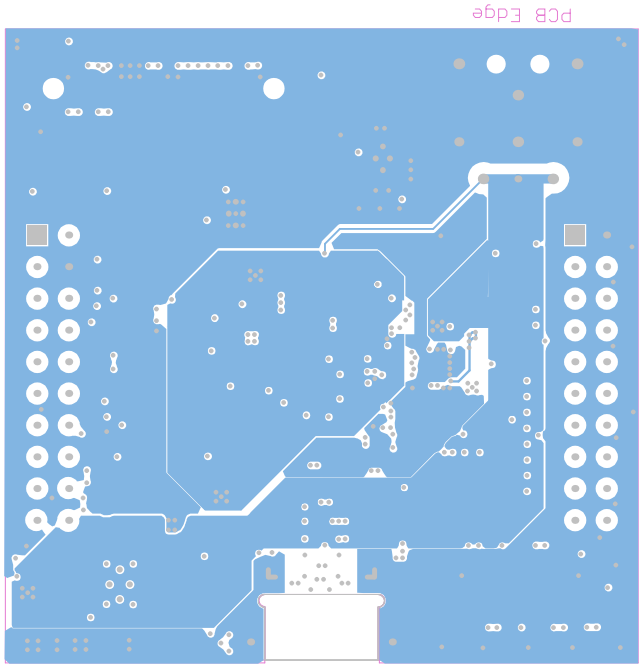


Figure 35. TPS65986EVM Mid Layer 2

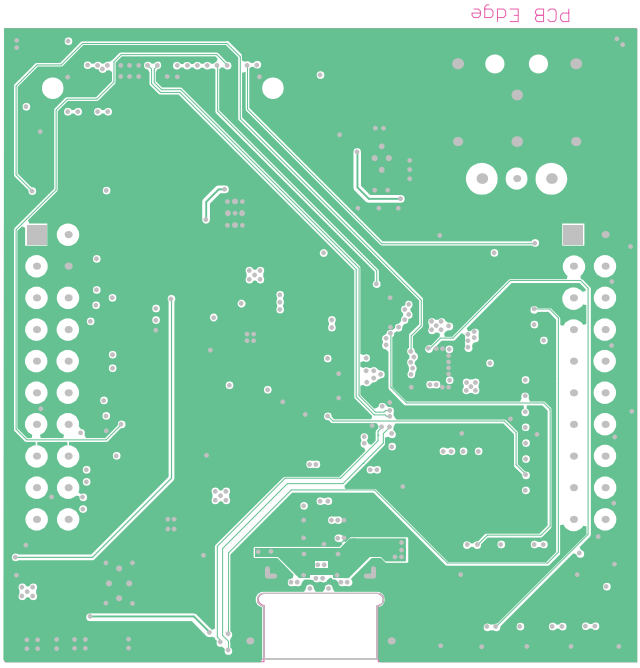


Figure 36. TPS65986EVM Mid Layer 3

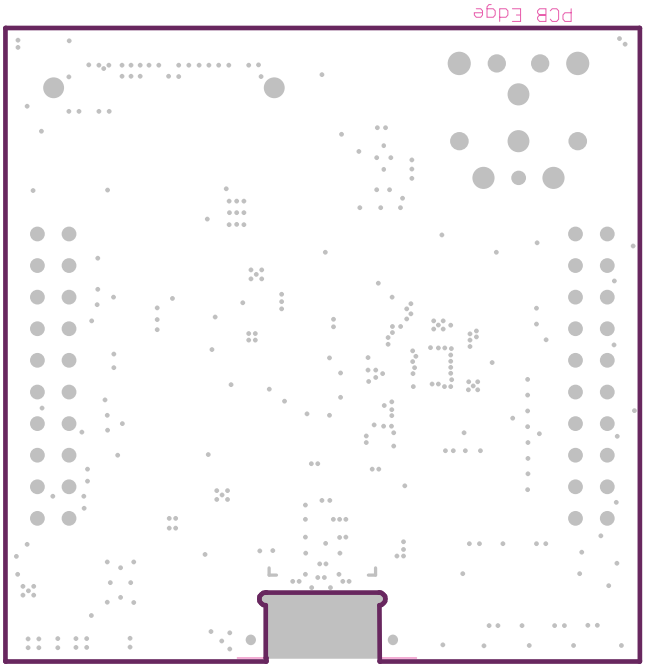


Figure 37. TPS65986EVM GND Plane 3

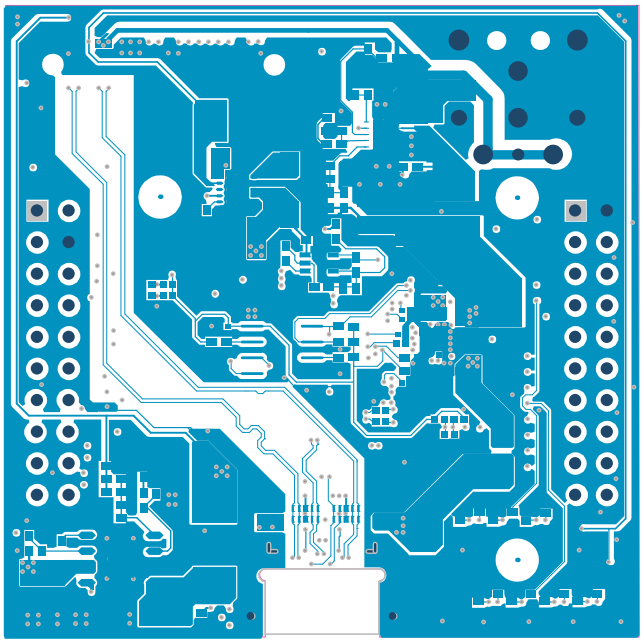


Figure 38. TPS65986EVM Bottom Layer

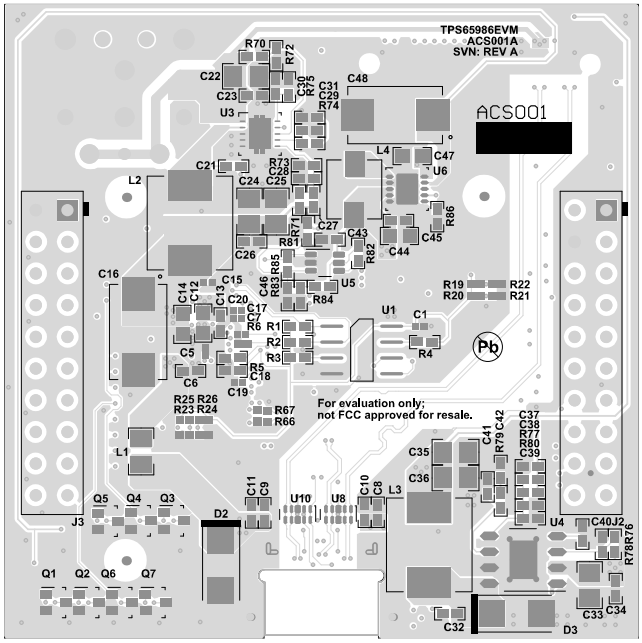


Figure 39. TPS65986EVM Bottom Layer Component View

10 TPS65986EVM Bill of Materials

Table 12 list the bill of materials (BOM) for the TPS65986EVM.

Table 12. BOM

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number[1]	Alternate Manufacturer[1]
!PCB1	1		Printed Circuit Board		ACS001	Any		
C1, C15	2	0.1µF	CAP, CERM, 0.1 µF, 10 V, ±10%, X5R, 0201	0201	CL03 A104KP3NNNC	Samsung		
C2, C3	2	330pF	CAP, CERM, 330 pF, 16 V, ±10%, X7R, 0201	0201	GRM033R71C331KA01D	MuRata		
C4	1	0.01µF	CAP, CERM, 0.01 µF, 10 V, ±10%, X5R, 0201	0201	GRM033R61A103KA01D	MuRata		
C5	1	0.22µF	CAP, CERM, 0.22 µF, 6.3 V, ±20%, X5R, 0201	0201	GRM033R60J224ME90	MuRata		
C6	1	1µF	CAP, CERM, 1 µF, 35 V, ±10%, JB, 0402	0402	C1005JB1V105K050BC	TDK		
C7, C17, C19, C20	4	1µF	CAP, CERM, 1 µF, 10 V, ±20%, X5R, 0201	0201	CL03 A105MP3NSNC	Samsung		
C8, C9, C10, C11	4	0.01µF	CAP, CERM, 0.01 µF, 50 V, ±10%, X7R, 0402	0402	GRM155R71H103KA88D	MuRata		
C12	1	10µF	CAP, CERM, 10 µF, 25 V, ±20%, X5R, 0603	0603	GRM188R61E106MA73	MuRata		
C13	1	0.1µF	CAP, CERM, 0.1 µF, 50 V, ±20%, C0G/NP0, 0402	0402	C1005X7R1H104M	TDK		
C14, C44, C47	3	22µF	CAP, CERM, 22 µF, 10 V, ±20%, X5R, 0603	0603	GRM188R61A226ME15D	MuRata		
C16, C48	2	150µF	CAP, TA, 150 µF, 16 V, ±10%, 0.1 ohm, SMD	7343-31	TPSD157K016R0100	AVX		
C18	1	10µF	CAP, CERM, 10 µF, 10 V, ±20%, X5R, 0402	0402	CL05A106MP5NUNC	Samsung		
C21, C23, C26, C32, C34, C43, C45	7	0.1µF	CAP, CERM, 0.1µF, 50V, +/-20%, C0G/NP0, 0402	0402	C1005X7R1H104M	TDK		
C22, C24, C25, C33, C35, C36	6	22µF	CAP, CERM, 22 µF, 35 V, ±20%, X5R, 0805	0805	C2012X5R1V226M125AC	TDK		
C29	1	100pF	CAP, CERM, 100 pF, 50 V, ±10%, X7R, 0402	0402	CC0402KRX7R9BB101	Yageo America		
C31	1	2200pF	CAP, CERM, 2200 pF, 50 V, ±10%, X5R, 0402	0402	GRM155R61H222KA01D	MuRata		
C37	1	0.1µF	CAP, CERM, 0.1 µF, 25 V, ±10%, X7R, 0402	0402	GRM155R71E104KE14D	MuRata		
C40	1	0.027µF	CAP, CERM, 0.027 µF, 25 V, ±10%, X7R, 0402	0402	GRM155R71E273KA88D	MuRata		
C41, C46	2	22pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, 0402	0402	C1005C0G1H220J050BA	TDK		
C42	1	1800pF	CAP, CERM, 1800 pF, 50 V, ±10%, X7R, 0402	0402	GRM155R71H182KA01D	MuRata		
D1	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		
D2	1	40V	Diode, Schottky, 40 V, 3 A, SMA	SMA	B340 A-13-F	Diodes Inc.		

(1) Unless otherwise noted in the alternate part number and alternate manufacturer columns, all parts may be substituted with equivalents.

Table 12. BOM (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number[1]	Alternate Manufacturer[1]
D3	1	20 V	Diode, Schottky, 20 V, 3 A, SMA	SMA	B320 A-13-F	Diodes Inc.		
D4, D5, D6, D7, D8, D9, D10	7	White	LED, White, SMD	0402, White	LW QH8G-Q2S2-3K5L-1	OSRAM		
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, J3	2		Receptacle, 2.54mm, 10x2, Tin, TH	Receptacle, 2.54mm, 10x2, TH	SSQ-110-03-T-D	Samtec		
J4	1		Socket, 0.8mm, 20x2, Gold, SMT	Socket, 0.8mm, 20x2, Gold, SMT	LSEM-120-03.0-F-DV-A-N-K-TR	Samtec		
J5	1		Connector, Receptacle, USB Type C, R/A, SMT	Connector, Receptacle, USB Type C, SMT	20-0000016-01	Lintes Technology		
L1	1	21 ohm	Ferrite Bead, 21 ohm @ 100MHz, 6A, 0805	0805	FBMJ2125HM210NT	Taiyo Yuden		
L2, L3	2	10uH		7.2 mm x 6.65 mm	ASPI-0630LR-100M-T15	ABRACON		
L4	1	2.2uH	Inductor, Flat Wire, Powdered Iron, 2.2 µH, 4 A, 0.033 ohm, SMD	Inductor, 4.8x2x4mm	SRP4020-2R2M	Bourns		
Q1, Q2, Q3, Q4, Q5, Q6, Q7	7	50 V	Transistor, NPN, 50 V, 0.05 A, SOT-323	SOT-323	DTC114EUAT106	Rohm		
R1, R2, R3, R4	4	3.3k	RES, 3.3 k, 5%, 0.063 W, 0402	0402	CRCW04023K30JNED	Vishay-Dale		
R5, R83	2	15.0k	RES, 15.0 k, 1%, 0.063 W, 0402	0402	CRCW040215K0FKED	Vishay-Dale		
R6, R9, R12, R32, R33, R38, R39, R40, R41, R42, R44, R45, R46, R47, R55, R56, R59, R61, R65, R69	20	0	RES, 0, 5%, 0.05 W, 0201	0201	ERJ-1GE0R00C	Panasonic		
R7, R8, R10, R11	4	11.0k	RES, 11.0 k, 1%, 0.05 W, 0201	0201	CRCW020111K0FKED	Vishay-Dale		
R13, R14, R15, R16, R18, R21, R22, R49	8	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale		
R17, R87, R88, R89, R90, R91, R92, R93	8	1.00k	RES, 1.00 k, 1%, 0.05 W, 0201	0201	CRCW02011K00FKED	Vishay-Dale		
R27, R28, R48	3	3.83k	RES, 3.83 k, 1%, 0.05 W, 0201	0201	CRCW02013K83FKED	Vishay-Dale		
R29	1	10.0k	RES, 10.0 k, 1%, 0.05 W, 0201	0201	MCR006YRTF1002	Rohm		
R70	1	100k	RES, 100 k, 5%, 0.063 W, 0402	0402	CRCW0402100KJNED	Vishay-Dale		
R71, R77, R81	3	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale		
R72	1	12k	RES, 12 k, 5%, 0.063 W, 0402	0402	CRCW040212K0JNED	Vishay-Dale		
R73	1	19.1k	RES, 19.1 k, 1%, 0.063 W, 0402	0402	CRCW040219K1FKED	Vishay-Dale		
R74	1	8.45k	RES, 8.45 k, 1%, 0.063 W, 0402	0402	CRCW04028K45FKED	Vishay-Dale		
R75	1	47.5k	RES, 47.5 k, 1%, 0.063 W, 0402	0402	CRCW040247K5FKED	Vishay-Dale		

Table 12. BOM (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number[1]	Alternate Manufacturer[1]
R76	1	150k	RES, 150 k, 1%, 0.063 W, 0402	0402	CRCW0402150KFKED	Vishay-Dale		
R78	1	66.5k	RES, 66.5 k, 1%, 0.063 W, 0402	0402	CRCW040266K5FKED	Vishay-Dale		
R79, R80, R86	3	32.4k	RES, 32.4 k, 1%, 0.063 W, 0402	0402	CRCW040232K4FKED	Vishay-Dale		
R82	1	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale		
S1	1		DIP Switch, SPST 4Pos, Slide, SMT	6.2x2.0x6.2mm	TDA04H0SB1	CandK Components		
S2	1		SWITCH TACTILE SPST-NO 0.05A 12 V	3x1.6x2.5mm	B3U-1000P	Omron Electronic Components		
TP1, TP2, TP3, TP4, TP5, TP6	6		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		USB Type-C and USB PD Controller and Power Switch, ZQZ0096A	ZQZ0096A	TPS65986ABZQZR	Texas Instruments		Texas Instruments
U3	1		4.5- to 28-V Input, 3-A Output, Synchronous SWIFT Step-Down DC-DC Converter, DRC0010J	DRC0010J	TPS54335ADRCR	Texas Instruments	TPS54335ADRCT	Texas Instruments
U4	1		3.5-A, 28-V, 1-MHz, Step-Down DC-DC Converter With Eco-Mode, DDA0008H	DDA0008H	TPS54332DDAR	Texas Instruments	TPS54332DDA	Texas Instruments
U5	1		Nanopower, 1.8V, Comparator with Voltage Reference, DCK0006A	DCK0006A	TLV3012 AIDCKR	Texas Instruments	TLV3012 AIDCKT	Texas Instruments
U6	1		Integrated USB Power Switch with Boost Converter, DRC0010J	DRC0010J	TPS2500DRCR	Texas Instruments	TPS2500DRCT	Texas Instruments
U7, U8, U9, U10	4		1, 4, 6 CHANNEL PROTECTION SOLUTION FOR SUPER-SPEED (UP TO 6 GBPS) INTERFACE, DQA0010 A	DQA0010 A	TPD4E05U06DQAR	Texas Instruments		Texas Instruments
C27, C28, C30, C38, C39	0	120pF	CAP, CERM, 120 pF, 50 V, ±5%, C0G/NP0, 0402	0402	GRM1555C1H121JA01D	MuRata		
R19, R20, R50	0	100k	RES, 100 k, 1%, 0.05 W, 0201	0201	CRCW0201100KFKED	Vishay-Dale		
R23, R24, R25, R26	0	1.00Meg	RES, 1.00 M, 1%, 0.05 W, AEC-Q200 Grade 0, 0201	0201	RK73H1HTTC1004F	KOA Speer		
R30, R31, R34, R35, R36, R37, R43, R51, R52, R53, R54, R57, R58, R60, R62, R63, R64, R66, R67, R68	0	0	RES, 0, 5%, 0.05 W, 0201	0201	ERJ-1GE0R00C	Panasonic		
R84	0	39k	RES, 39 k, 5%, 0.063 W, 0402	0402	CRCW040239K0JNED	Vishay-Dale		
R85	0	560k	RES, 560 k, 5%, 0.063 W, 0402	0402	CRCW0402560KJNED	Vishay-Dale		

Revision History

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

Changes from Original (June 2016) to A Revision	Page
• Deleted references to *USB2MANY* board and replaced with *Aardvark* or *FTDI-based adapter*	2

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software

   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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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

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

東京都新宿区西新宿６丁目２４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

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.

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