

TI Designs USB Type-C™ and Power Delivery Multiport-Adapter Reference Design



Description

The TIDA-03027 reference design offers a multiport adapter solution that enables products with a USB Type-C™ interface to connect to **HDMI 2.0 and USB 3.0 Type-A interfaces**. The design also includes an **additional USB Type-C full-feature receptacle**, which allows the user to simultaneously connect USB Type-C chargers (up to 20 V, 3 A) or devices. This feature set is particularly useful as a peripheral to notebook, tablet, and phone systems with a single USB Type-C interface.

Resources

TIDA-03027	Design Folder
TPS65983BB	Product Folder
TUSB8041	Product Folder
HD3SS3212	Product Folder
TPD8S300	Product Folder
LM3489	Product Folder
TPD1E01B04	Product Folder
TS3USB221	Product Folder
CSD87501L	Product Folder
TPS54334	Product Folder
TPS2500	Product Folder
TPS62065	Product Folder
TPD13S523	Product Folder
TPS65986EVM	Tools Folder



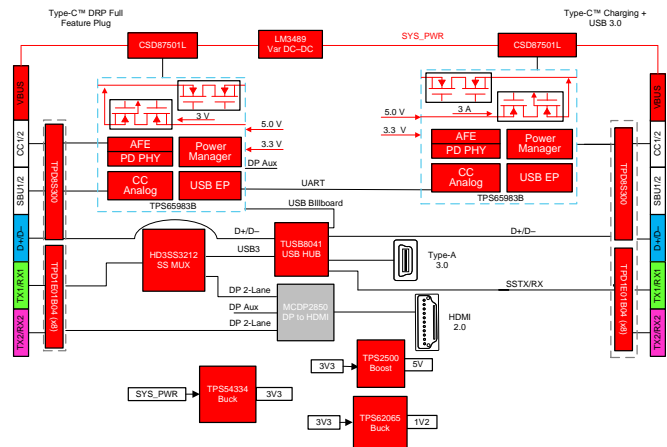
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Features

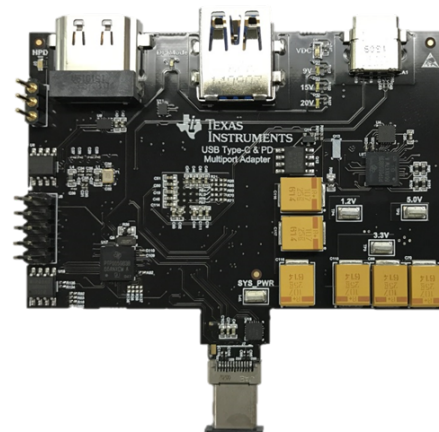
- USB Type-C and PD Full-Feature Plug
- Bi-Directional Power (up to 20 V, 3 A)
- Fast Role-Swap Capable
- Video (up to 4K) Through HDMI 2.0
- USB 3.0 Through USB Type-A or USB Type-C™ Receptacle
- **Aardvark Connector for Debug and Flash Update**
- **Flash Update Over USB Type-C™ Through USB 2.0 Endpoint**

Applications

- Evaluation of USB Type-C Multiport Adapter and Dongle Solutions With Video, Charging, and Data Capabilities



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1 System Overview

1.1 System Description

The TIDA-03027 reference design showcases a Type-C plug that allows a notebook, tablet, or phone to simultaneously interface with HDMI 2.0, USB 3.0 Type-A, and USB Type-C systems (chargers and devices). Thus, the board serves as a multiport adapter for USB Type-C hosts. This board features USB 3.0 data, video, and charging (up to 20 V, 3 A) over a single, USB Type-C plug connection.

The USB Type-C plug and receptacle both interface with a **TPS65983B device**, which handles power delivery negotiations and controls the primary power field-effect transistors (FETs). Two SuperSpeed lanes (SSTX/RX2) are routed directly to a DisplayPort (DP) to HDMI converter. The other SuperSpeed lanes (SSTX/RX1) are routed to the **HD3SS3212**, which demuxes the signals between the DP-to-HDMI converter and the TUSB8041 USB 3.0 HUB. This routing allows the TPS65983B device to control between four-lanes of DP-to-HDMI and two-lanes of DP-to-HDMI + USB3.0 (for Type-A and Type-C data connections).

The TUSB8041 is a USB 3.0 HUB, which receives high-speed and SuperSpeed signals from the upstream USB Type-C plug. This device expands the USB Type-C host signals to four ports, which allows simultaneous USB 3.0 or USB 2.0 enumeration at the Type-C and Type-A receptacle ports. This device also enables the USB Type-C plug to utilize the USB 2.0 low-speed endpoint feature of the TPS65983B.

The power path between the USB Type-C plug and receptacle ports is controlled by the **LM3489 variable DC-DC converter**. The TPS65983B device controls the output voltage of the LM3489 device, depending on the power contract that is negotiated with the USB Type-C host. This feature is particularly useful when there is a mismatch in power contracts between a USB Type-C host and charger.

Both USB Type-C interfaces utilize the **TPS83S00 and TPD1E01B04 electrostatic discharge (ESD) devices** for signal input-output (I/O) protection. The USB Type-A interface uses single-bit ESD (TPD1E01B04) for I/O protection. The HDMI interface is protected using the **TPD13S523**, which is an integrated 13-channel ESD and current-limiting device.

This reference design can serve to evaluate multiport adapter and dongle solutions that feature power, data, and video capabilities (see [Figure 1](#)). The design can also be used to evaluate the USB Type-C host capabilities of notebooks, tablets, and phones.

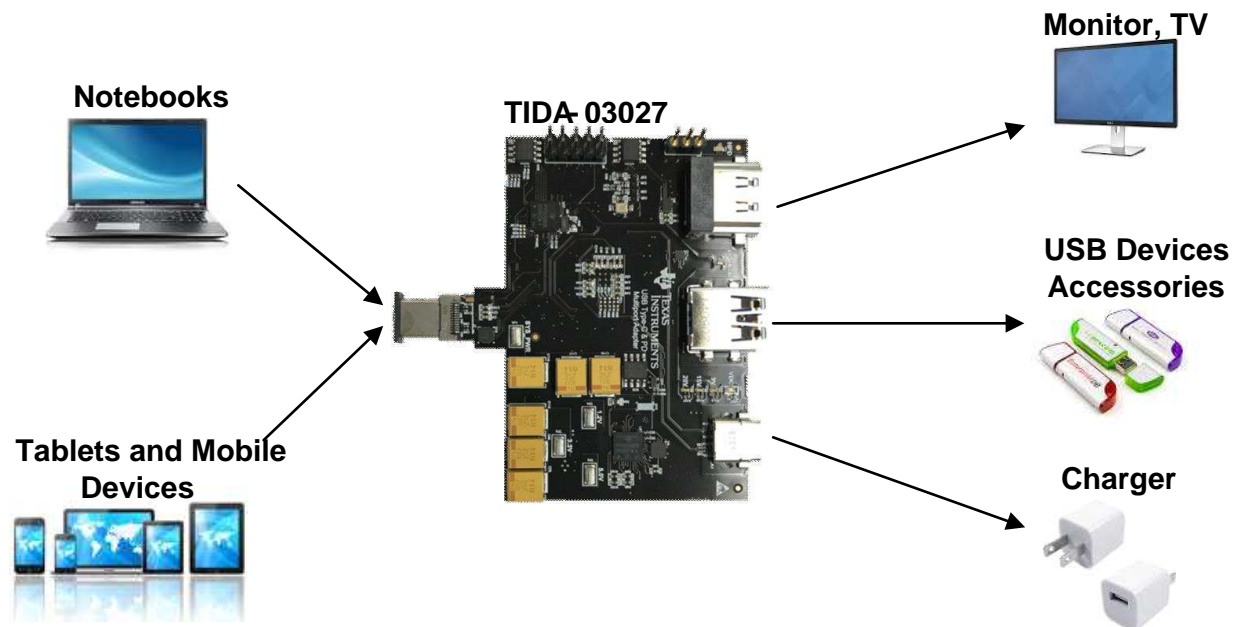


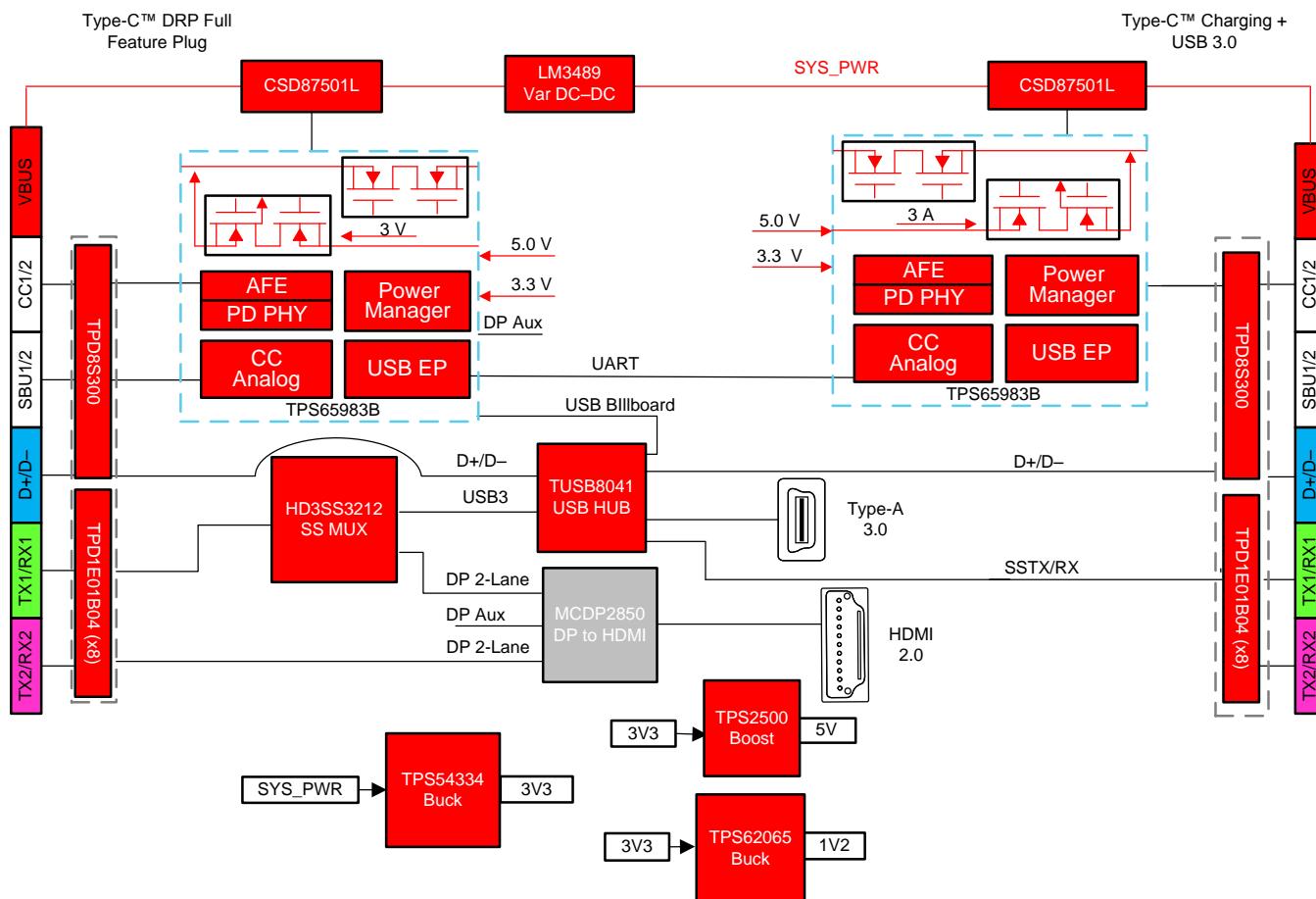
Figure 1. TIDA-03027 Ecosystem

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
USB Type-C™ plug source capabilities	—	5 V, 9 V, 15 V, or 20 V (up to 3 A)
USB Type-C™ plug sink capabilities	—	5 V, .9 A
USB Type-C™ receptacle source capabilities	—	5 V, .9 A
USB Type-C™ receptacle sink capabilities	—	5 V or 20 V (up to 3 A)

1.3 Block Diagram



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Figure 2. TIDA-03027 Block Diagram

1.4 Highlighted Products

1.4.1 TPS65983B

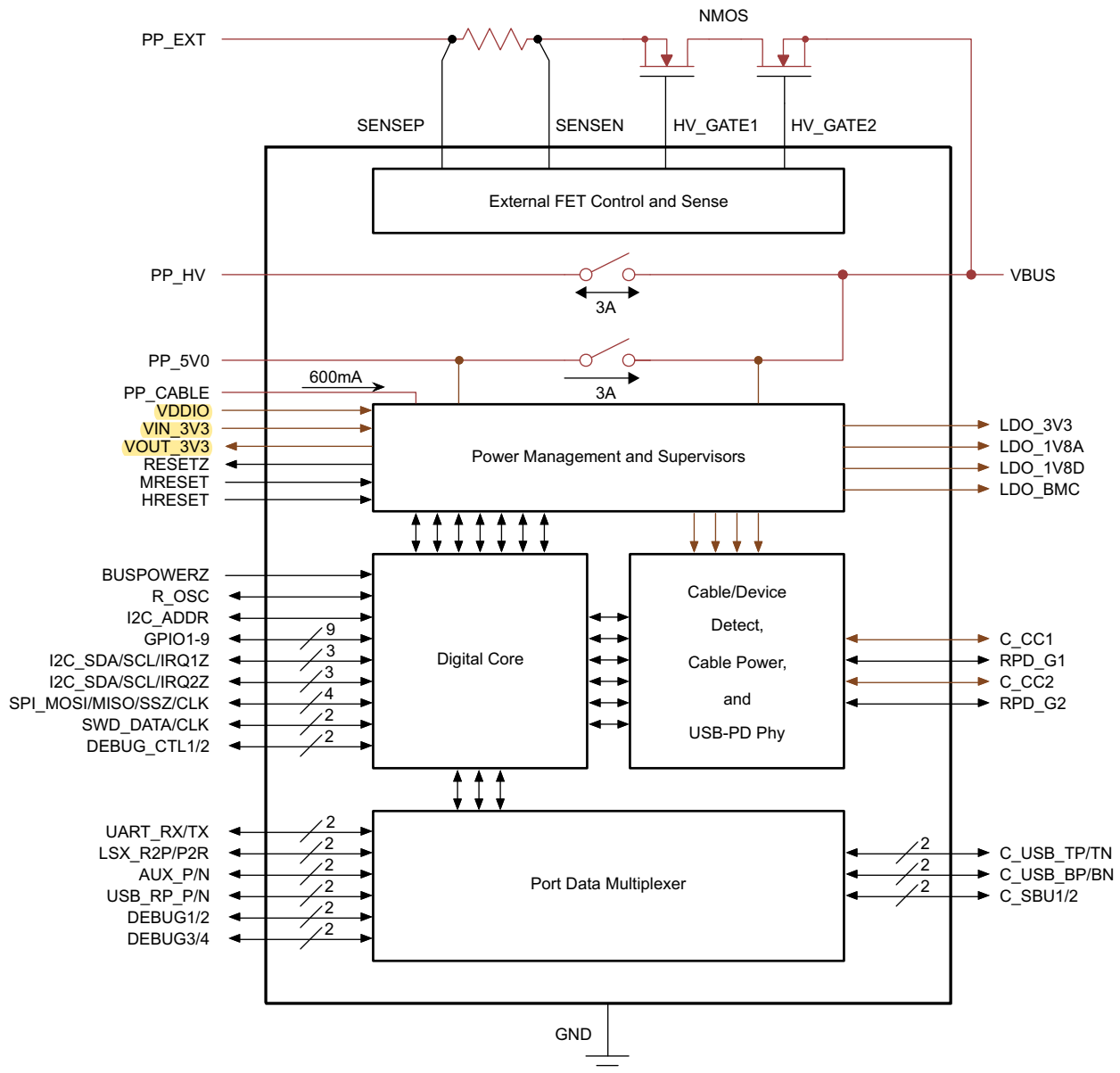
The TPS65983B is a stand-alone USB Type-C and power delivery (PD) controller which provides cable plug and orientation detection at the USB Type-C connector (see Figure 3). Upon cable detection, the TPS65983B device communicates on the CC wire using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS65983B enables the appropriate power path and configures alternate mode settings for internal and (optional) external multiplexers.

The mixed-signal front end on the CC pins advertises default (500 mA), 1.5 A, or 3 A for Type-C power sources, detects a plug event and determines the USB Type-C cable orientation, and autonomously negotiates USB PD contracts by adhering to the specified bi-phase marked coding (BMC) and physical layer (PHY) protocol.

The port power switch provides up to 3 A downstream at 5 V for legacy and Type-C USB power. An additional bidirectional switch path provides USB PD power up to 3 A at a maximum of 20 V as either a source (host), sink (device), or source-sink.

The TPS65983B is also an upstream-facing port (UFP), downstream-facing port (DFP), or dual-role port for data. The port data multiplexer passes data to or from the top or bottom D+/D– signal pair at the port for USB 2.0 HS and has a USB 2.0 low-speed endpoint. Additionally, the sideband-use (SBU) signal pair is used for auxiliary or alternate modes of communication (DisplayPort or Thunderbolt, for example).

The power management circuitry utilizes a 3.3 voltage inside the system and also uses VBUS to start up and negotiate power for a dead-battery or no-battery condition.



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Figure 3. TPS65983B Block Diagram

1.4.2 TUSB8041

The TUSB8041 is a four-port USB 3.0 hub (see [Figure 4](#)). The device provides simultaneous SuperSpeed USB and high-speed or full-speed connections on the upstream port and provides SuperSpeed USB, high-speed, full-speed, or low-speed connections on the downstream ports. When the upstream port is connected to an electrical environment that only supports high-speed or full-speed and low-speed connections, SuperSpeed USB connectivity is disabled on the downstream ports. When the upstream port is connected to an electrical environment that only supports full-speed and low-speed connections, SuperSpeed USB and high-speed connectivity are disabled on the downstream ports.

The TUSB8041 supports per port or ganged power switching and over-current protection, and supports battery charging applications.

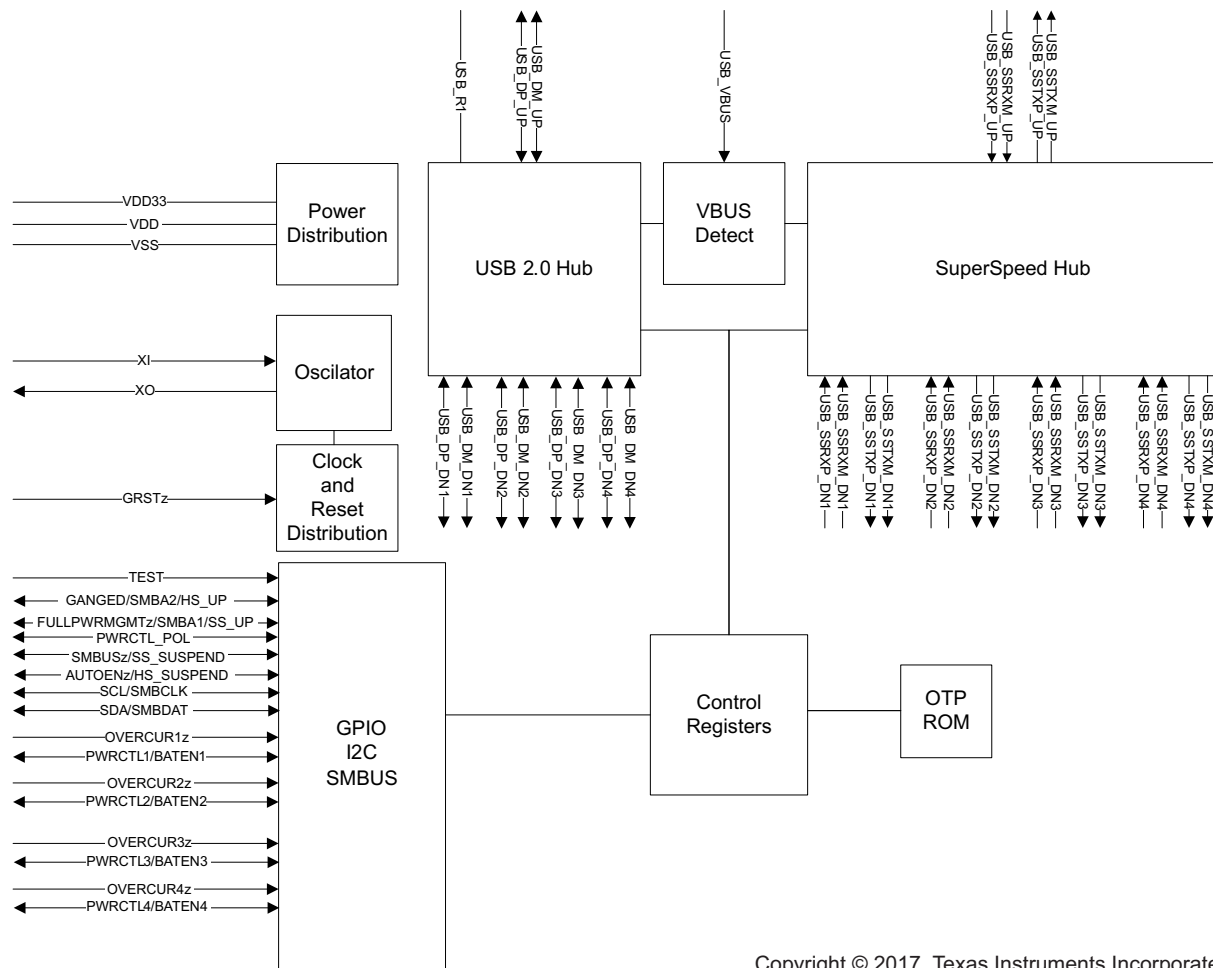
An individually port-power-controlled hub switches power ON or OFF to each downstream port as requested by the USB host. Also, when an individually port-power-controlled hub senses an overcurrent event, the power is only switched off to the affected downstream port.

A ganged hub switches power on to all its downstream ports when power is required to be on for any port. The power to the downstream ports is not switched off unless all ports are in a state that allows power to be removed. When a ganged hub senses an overcurrent event, the power is switched off to all downstream ports.

The TUSB8041 downstream ports provide support for battery charging applications by providing battery charging downstream port (CDP) handshaking support. The device also supports a dedicated charging port (DCP) mode when the upstream port is not connected. The DCP mode supports USB devices which support with the USB Battery Charging and Chinese Telecommunications Industry Standard YD/T 1591-2009. In addition, an automatic mode provides transparent support for battery charging devices and devices supporting divider-mode charging solutions when the upstream port is not connected.

The TUSB8041 provides pin-strap configuration for some features including battery charging support, and also provides customization through one-time programmable read-only memory (OTP ROM), I²C EEPROM, or through an I²C or system management bus (SMBus) slave interface for product ID (PID), vendor ID (VID), and custom port and PHY configurations. Custom string support is also available when using an I²C EEPROM or the I²C or SMBus slave interface.

The device is available in a 64-pin RGC package and is offered in a commercial version (TUSB8041) for operation over a temperature range of 0°C to 70°C, and in an industrial version (TUSB8041I) for operation over a temperature range of –40°C to 85°C.



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Figure 4. TUSB8041 Block Diagram

1.4.3 HD3SS3212

The HD3SS3212 is a high-speed, bidirectional passive switch in mux or demux configurations suited for USB Type-C™ applications supporting USB 3.1 generation 1 and generation 2 data rates (see Figure 5). Based on the control pin SEL, the device provides the capability to switch on differential channels between Port B or Port C to Port A.

The HD3SS3212 is a generic, analog-differential passive switch that can work for any high-speed interface applications requiring a common-mode voltage range of 0 V to 2 V and differential signaling with differential amplitude up to 1800 mVpp. The device employs adaptive tracking that ensures the channel remains unchanged for the entire common-mode voltage range.

Excellent dynamic characteristics of the device allow high-speed switching with minimum attenuation to the signal eye diagram with very little added jitter. The device consumes <2 mW of power when operational and has a shutdown mode exercisable by the OEn pin resulting in <20 µW.

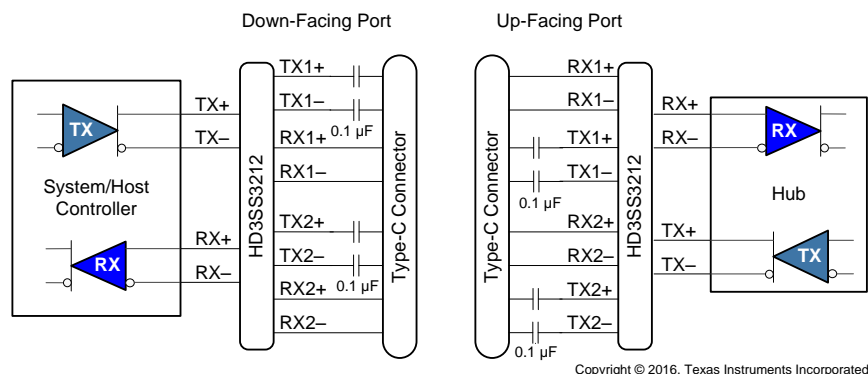


Figure 5. HD3SS3212 Block Diagram

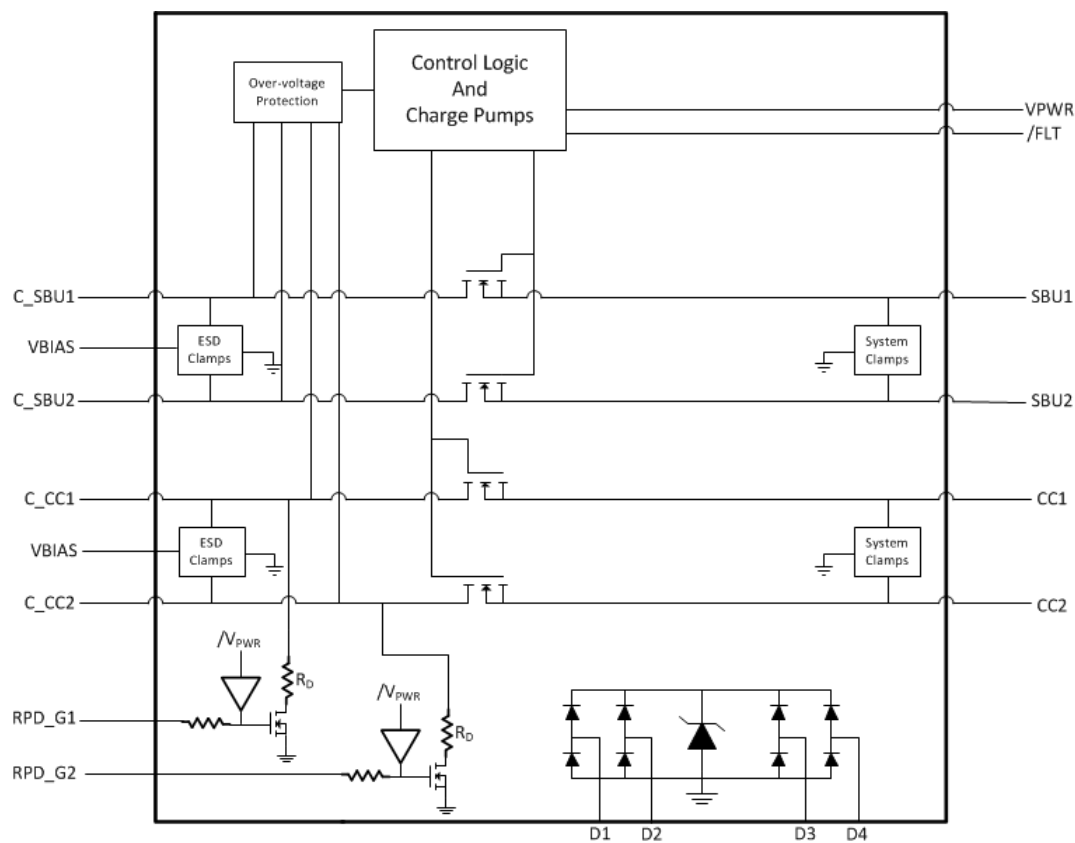
1.4.4 TPD8S300

The TPD8S300 is a single-chip USB Type-C port protection solution that provides 20-V short-to-VBUS overvoltage and International Electrotechnical Commission (IEC) standard ESD protection (see Figure 6).

Since the release of the USB Type-C connector, many products and accessories for USB Type-C have been released which do not meet the USB Type-C specification. One example of this is USB Type-C power delivery adaptors that only place 20 V on the VBUS line. Another concern for USB Type-C is that mechanical twisting and sliding of the connector can short pins because of the close proximity they have in this small connector. This close proximity can cause the 20-V VBUS to be shorted to the CC and SBU pins. Also, because of the close proximity of the pins in the Type-C connector, there is a heightened concern that debris and moisture can cause the 20-V VBUS pin to be shorted to the CC and SBU pins.

These non-ideal equipment and mechanical events make it necessary for the CC and SBU pins to be 20-V tolerant, even though they only operate at 5 V or lower. The TPD8S300 enables the CC and SBU pins to be 20-V tolerant without interfering with normal operation by providing overvoltage protection on the CC and SBU pins. The device places high-voltage FETs in series on the SBU and CC lines. When a voltage above the overvoltage protection (OVP) threshold is detected on these lines, the high-voltage switches are opened up, isolating the rest of the system from the high-voltage condition present on the connector.

Finally, most systems require IEC 61000-4-2 system-level ESD protection for their external pins. The TPD8S300 device integrates IEC 61000-4-2 ESD protection for the CC1, CC2, SBU1, SBU2, DP_T (top-side D+), DM_T (top-side D-), DP_B (bottom-side D+), DM_B (bottom-side D-) pins, removing the requirement to place high-voltage transient voltage suppression (TVS) diodes externally on the connector.



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Figure 6. TPD8S300 Block Diagram

2 Getting Started

2.1 System Setup

The board can be powered by the USB Type-C host, such as a notebook or tablet, through the USB Type-C plug at 5 V (bus-powered mode). The board can also be powered by a USB Type-C charger through the USB Type-C receptacle (charging mode). TI recommends to only connect this reference design to TI's evaluation modules (such as the TPS65986EVM) and USB Type-C or PD compliant products. [Table 2](#) lists the products that were tested with this reference design.

Table 2. Products Tested with TIDA-03027

PRODUCTS	DESCRIPTION
TPS65986EVM + DP-expansion-EVM	Connected through the USB Type-C™ plug to verify data, video, and charging capabilities with various products. This EVM combination allows any notebook with USB Type-A and DisplayPort connections to be utilized as the USB Type-C™ host.
TPS65981EVM + DP-expansion-EVM	Connected through the USB Type-C™ plug to verify data, video, and charging capabilities with various products. This EVM combination allows any notebook with USB Type-A and DisplayPort connections to be utilized as the USB Type-C™ host.
Macbook® computer (2015 model) + Apple charger	Connected through the USB Type-C™ plug to verify data, video, and charging capabilities with various products.
Dell Latitude™ 7000 Series 2-in-1 laptop	Connected through the USB Type-C™ plug to verify data, video, and charging capabilities with various products.
ASUS® PB287 28" LCD monitor	Connected through the HDMI 2.0 port to verify video connection. This test was performed using various notebook hosts and the capabilities were verified with and without a USB Type-C™ charger connected.
ViewSonic™ VS15562 24" 1080P monitor	Connected through the HDMI 2.0 port to verify video connection. This test was performed using various notebook hosts and the capabilities were verified with and without a USB Type-C™ charger connected.
Apple® iPhone® 6 mobile digital device - 16GB	Connected through the USB Type-A port to validate charging and data capabilities. This test was performed using various notebook hosts and the capabilities were verified with and without a USB Type-C™ charger connected.
HTC One® A9 smartphone - 32GB	Connected through the USB Type-A port to validate charging and data capabilities. This test was performed using various notebook hosts and the capabilities were verified with and without a USB Type-C™ charger connected.
Samsung™ T3 portable SSD - 250GB	Connected through the USB Type-C™ receptacle port to validate data capabilities. This test was performed using various notebook hosts.
SanDisk® 64GB USB Type-C™ flashdrive	Connected through the USB Type-C™ receptacle port to validate data capabilities. This test was performed using various notebook hosts.

2.2 Connectors

This section addresses the capabilities in terms of each connector and port (see [Table 3](#)).

Table 3. Connector and Port Capabilities

CONNECTOR	FUNCTIONALITY
USB Type-C™ plug (J7)	This is a full-feature plug that allows a USB Type-C™ host (notebook, tablet, and so forth) to interface with the video, data, and charging capabilities of the other ports. If no charger is connected to the multiport adapter, the host powers from the 5 V provided by the USB Type-C™ host. If the multiport adapter is connected to a charger, it can provide all PD 3.0 charging voltages (5/9/15/20V) to the USB Type-C™ host (depending on the power provided by the charger).
USB Type-C™ receptacle (J2)	This receptacle allows the USB Type-C™ host to interface with USB 3.0 devices, such as flash drives and phones. It also accepts USB Type-C™ power adapters to charge the USB Type-C™ host.
HDMI 2.0 receptacle (J3)	This receptacle allows the USB Type-C™ host to interface with HDMI 2.0 monitors. The video alternates between two lanes and four lanes depending on the types of devices that are connected to the USB Type-C™ and USB Type-A receptacles.
USB 3.0 Type-A receptacle (J4)	This receptacle allows the USB Type-C™ host to interface with USB 3.0 devices, such as flash drives and phones.
Aardvark connector (J6)	This connects to the serial peripheral interface (SPI) and I ² C pins on the TPS65983B device, which are used for programming and interfacing with the TPS65983B firmware. The user may utilize this functionality by purchasing a TotalPhase Aardark™ (USB → I ² C/SPI adapter) and downloading Texas Instrument's TPS6598x host interface utility tool.
MCDP2850 UART connector (J1)	This connects to the universal asynchronous receiver and transmitter (UART) pins on the MCDP2850, which are used for programming and interfacing with the MCDP2850 firmware.

2.3 Aardvark Connection

When evaluating the multiport adapter, it is helpful to use the TotalPhase Aardvark™ (USB → I²C/SPI adapter) to interface with the TPS65983B firmware. This adapter can be used to read or write to any register over I²C, execute 4CC commands over I²C, or program customized firmware onto the serial peripheral interface (SPI) flash. Firmware customization is not recommended as it may not be compatible with the multiport adapter hardware. The Aardvark adapter is connected as shown in [Figure 7](#) shows:

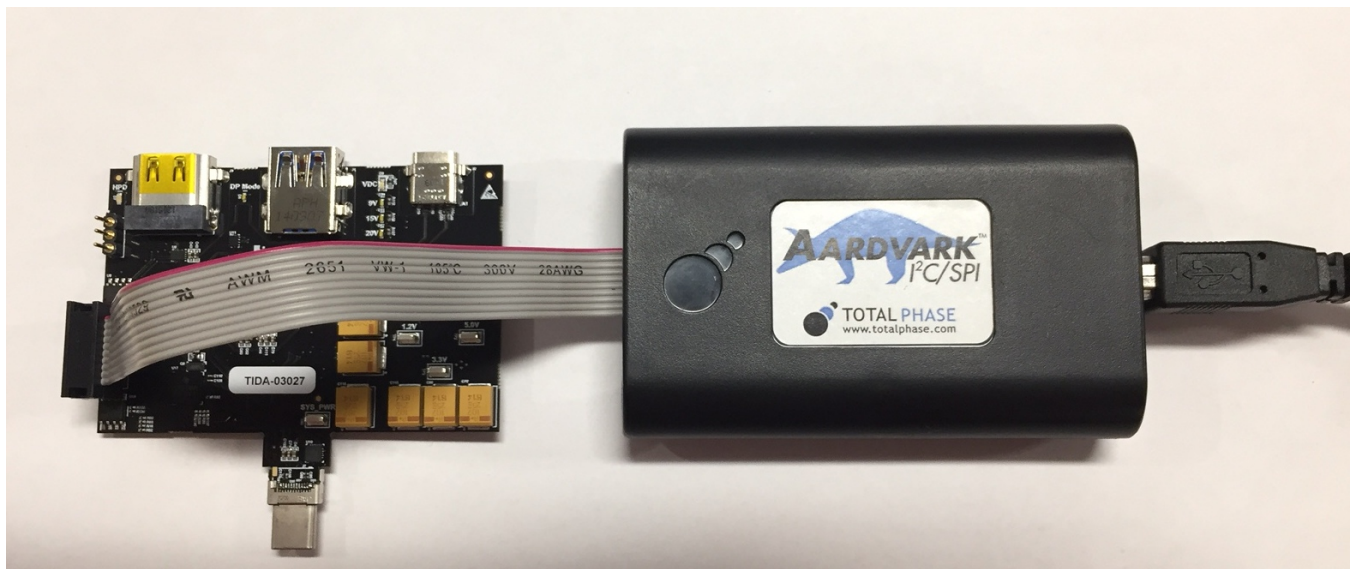


Figure 7. TotalPhase Aardvark™ Connection to TIDA-03027

3 Testing and Results

This TI design offers equipment with various means for quantitative and qualitative validation.

3.1 LED Indicators

When the board has been powered, various light-emitting diodes (LEDs) notify the user of the current USB Type-C power delivery modes (see [Table 4](#)).

Table 4. LED Indicators

LED	DESCRIPTION
VDC	This indicates that the variable DC-DC is active. This action occurs when a USB Type-C™ receptacle is sinking power (when a charger is connected).
9V	This indicates that a 9V is being provided to the USB Type-C™ host through the USB Type-C™ plug.
15V	This indicates that a 15V is being provided to the USB Type-C™ host through the USB Type-C™ plug.
20V	This indicates that a 20V is being provided to the USB Type-C™ host through the USB Type-C™ plug.
DP Mode	This indicates that DisplayPort Alternate Mode has been entered.
HPD	This indicates that an HDMI connection has been detected.

3.2 Test Points

The board is also populated with test points to validate the various power rails (see [Table 5](#)).

Table 5. Test Points

TEST POINT	DESCRIPTION
TP1: SYS PWR	This test point is located on the system power rail. If the board is powered by a USB Type-C™ host, it measures at 5 V. If powered by a USB Type-C™ charger, it indicates the voltage that has been negotiated.
TP2: 5V	This test point is at the output of the 5-V boost converter (TPS2500).
TP3: 3.3V	This test point is at the output of the 3.3-V buck converter (TPS54334).
TP4: 1.2V	This test point is at the output of the 1.2-V buck converter (TPS62065).

3.3 Power-up Sequence

By measuring the power rail test points (TP2-4) when powering up the board, it is possible to see the power-up sequence. As [Figure 8](#) shows, the 3.3-V rail levels off before the 5-V and 1.2-V converters are enabled. This sequence has been designed to maximize efficiency and reduce cost.

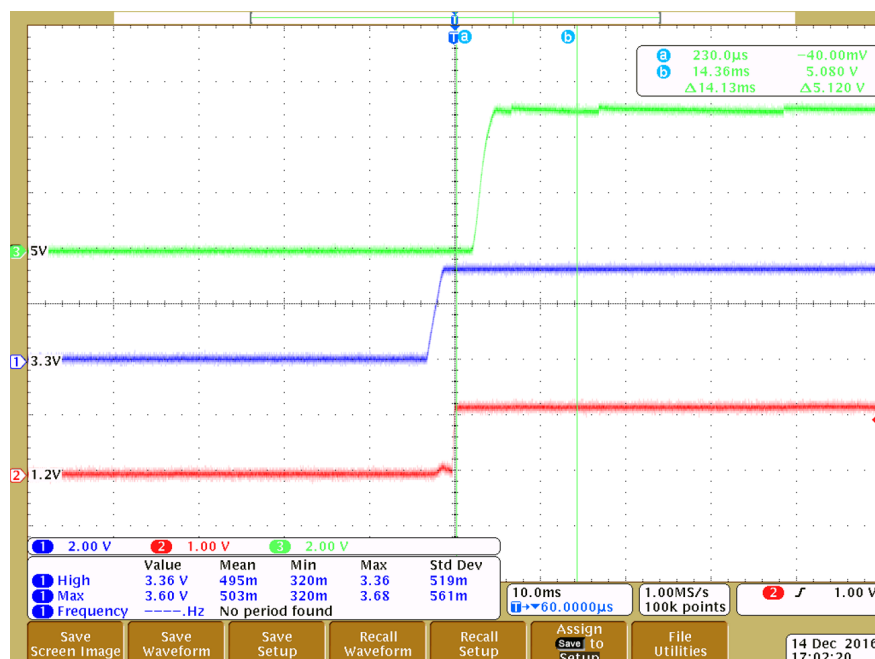


Figure 8. Power-up Sequence

3.4 Charger Connection

By measuring the SYS_PWR test point (TP1), it is possible to see the power that is coming into the system from the USB Type-C plug or receptacle. When a USB Type-C host (notebook, tablet, and so forth) is connected, the SYS_PWR rail should be at 5 V. If a USB Type-C charger is connected, the SYS_PWR voltage transitions to the voltage negotiated by the charger. As Figure 9 shows, this particular charger negotiates a 20-V contract upon connection to the multiport adapter.

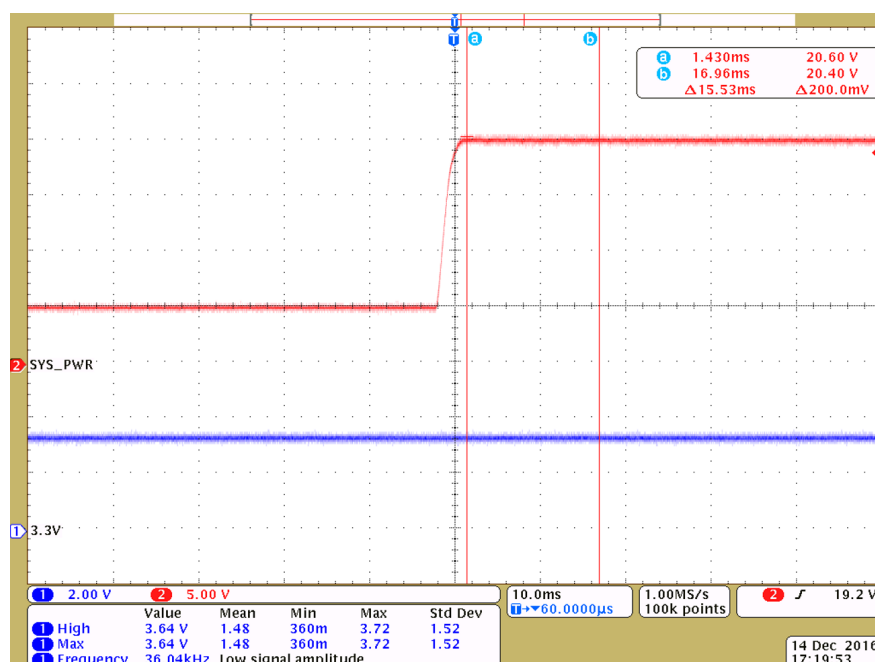


Figure 9. Voltage Transition upon Charger Connection

4 Design Files

4.1 Schematics

To download the schematics, see the design files at [TIDA-03027](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-03027](#).

4.3 Altium Project

To download the Altium project files, see the design files at [TIDA-03027](#).

4.4 Gerber Files

To download the Gerber files, see the design files at [TIDA-03027](#).

4.5 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-03027](#).

5 Related Documentation

1. Texas Instruments, [TPS65986 EVM User's Guide](#), TPS65986 EVM User's Guide (SLVUAN9)
2. Texas Instruments, [TPS6598x Utilities Tool User's Guide](#), TPS6598x Application Report (SLVA701)

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