

# TI Designs: TIDA-01620

## USB-C™ to DisplayPort Active Cable Reference Design



### Description

The USB-C™ to DisplayPort Active Cable reference design is a framework that can enable DisplayPort video signaling over a USB-C™ connection. Traditionally, DisplayPort connectors are the only way to transfer DisplayPort video, but this connector is large. It is not ideal for small electronics. A smaller USB Type-C connector allows DisplayPort video to transfer from smaller electronics, but these cables are shorter ranging from 1 – 2 meters in length. This design features DisplayPort video transfers over 5-meter cables with a single USB-C™ cable connection, enabling –DisplayPort communication between legacy DisplayPort sink to new USB-C™ source.

### Features

- Bi-directional USB-C™ to DisplayPort
- Supports VESA DisplayPort Alt Mode to USB-C™ UFP and DFP configuration
- Integrated USB Billboard
- Operates over entire VCONN range of 2.7V to 5.5V
- Supports up to 5 meter DisplayPort cable

### Applications

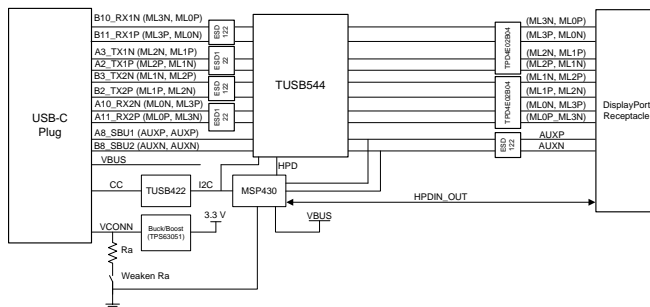
- Cable Converters
- Dongles

### Resources

<a href="#">TIDA-01620</a>	Design Folder
<a href="#">TUSB544</a>	Product Folder
<a href="#">TUSB422</a>	Product Folder
<a href="#">TPS63051</a>	Product Folder
<a href="#">MSP430F5528</a>	Product Folder
<a href="#">TPD4E05U06</a>	Product Folder
<a href="#">TPD4E02B04</a>	Product Folder
<a href="#">ESD122</a>	Product Folder



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## 1 System Description

The USB-C™ DP Active Cable reference design is a framework that can enable DisplayPort video signaling over a USB-C™ connection. This design features DisplayPort video transfers over DisplayPort Cables, up to 5 meters in length, over a single USB-C™ cable connection. This enables DisplayPort communication between legacy DisplayPort sink to new USB-C™ source that have DisplayPort functionality. USB-C™ to DisplayPort cables are typically passive and are therefore bi-directional but these passive cables are typically short (1m to 2m). In order to extend cable length, a passive cable must be made active through use of a signal conditioner. This reference design enables an active bi-directional USB-C™ to DisplayPort cable/converter for USB-C™ alternative mode applications.

## 2 System Overview

### 2.1 Block Diagram

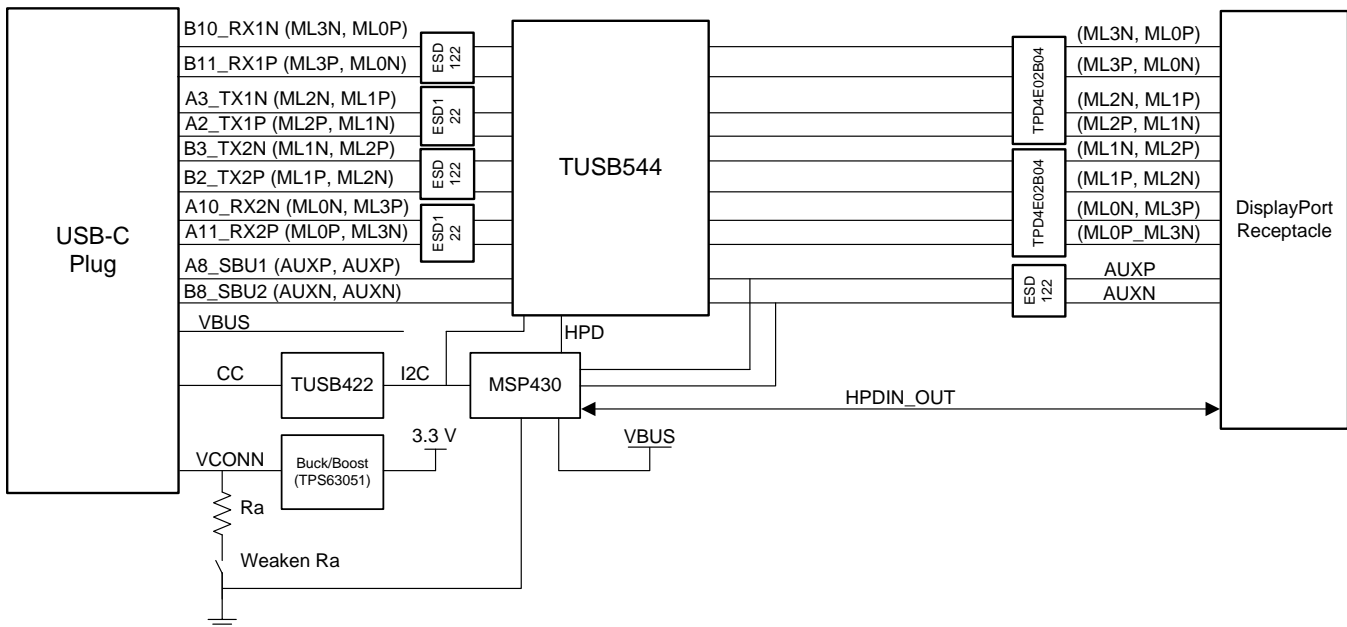


Figure 1. TIDA-01620 Block Diagram

### 2.2 Design Considerations

This USB-C™ to DisplayPort Active Cable design is created to be compliant to VESA DisplayPort Alt Mode specification. Several key considerations must be taken into account when considering designs that enable USB-C™ with DisplayPort Alt Mode. Designs of this nature should:

- Use minimal power (<1 W) such that power can be completely sourced from USB-C™ VCONN pin <sup>(1)</sup>.
- Present a USB Billboard in order to notify USB host of ALT Mode capability.
- Support both pin assignment C and E as specified by VESA DisplayPort Alt Mode specification.

These features should be implemented in USB-C™ to DisplayPort designs in order to be compliant with VESA DisplayPort Alt Mode specification. For complete details on the considerations above, refer to "VESA DisplayPort Alt Mode on USB Type-C Standard (DisplayPort Alt Mode)" specification.

<sup>(1)</sup> This design sources power from both VCONN and VBUS, slight modification must be made to be source power from Vconn only.

## 2.3 Highlighted Products

### 2.3.1 TUSB544: USB TYPE-C™ 8.1 Gbps Multi-Protocol Linear Redriver

The TUSB544 is a USB Type-C Alt Mode redriver switch supporting data rates up to 8.1 Gbps. This protocol-agnostic linear redriver is capable of supporting USB Type-C Alt Mode interfaces including VESA DisplayPort.

The TUSB544 provides several levels of receive linear equalization to compensate for inter symbol interference (ISI) due to cable and PCB board trace loss. All four lanes of the TUSB544 are reversible making it a versatile signal conditioner that can be used in many applications. TUSB544 redriver function allows this design to support up to 5 meter cables.

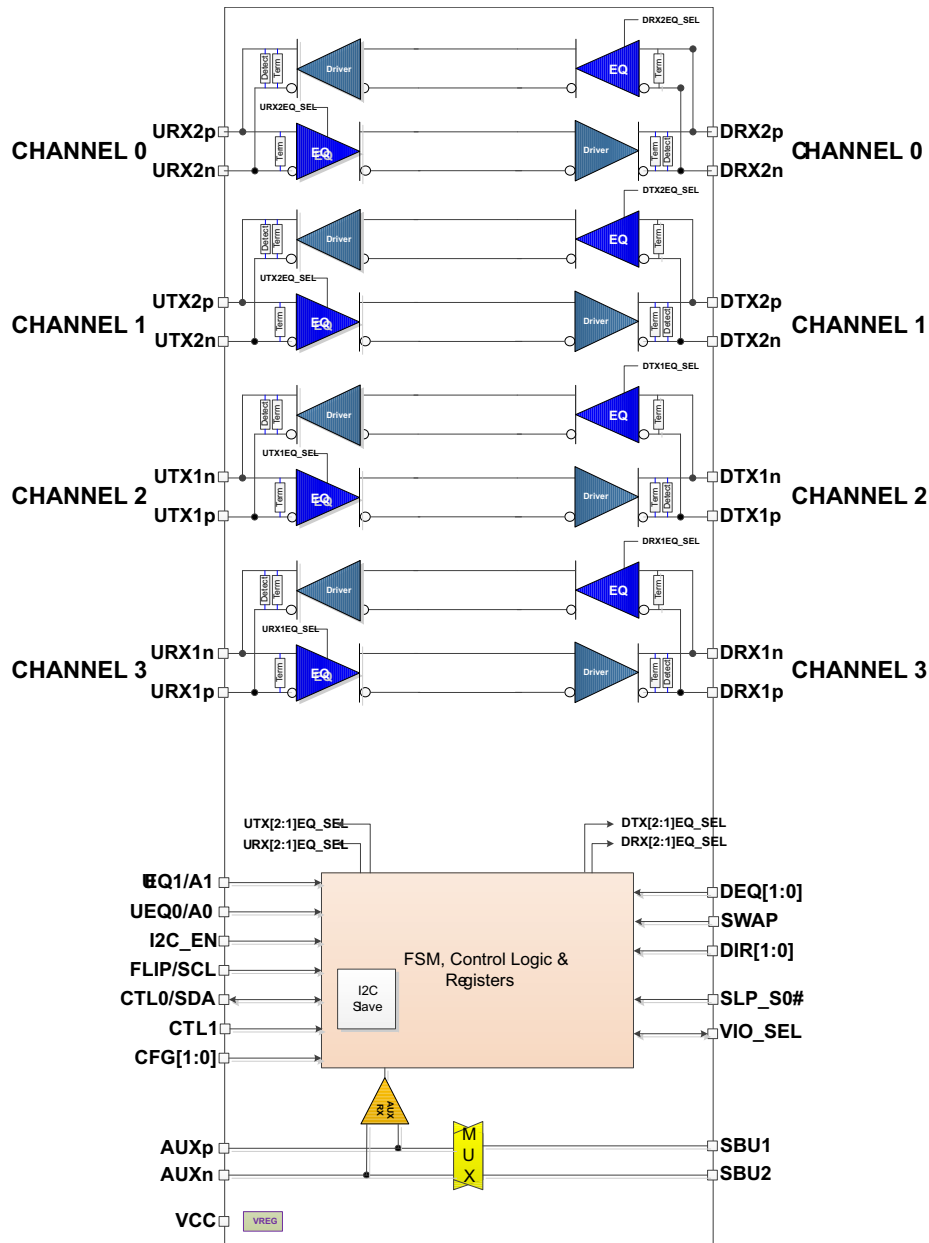
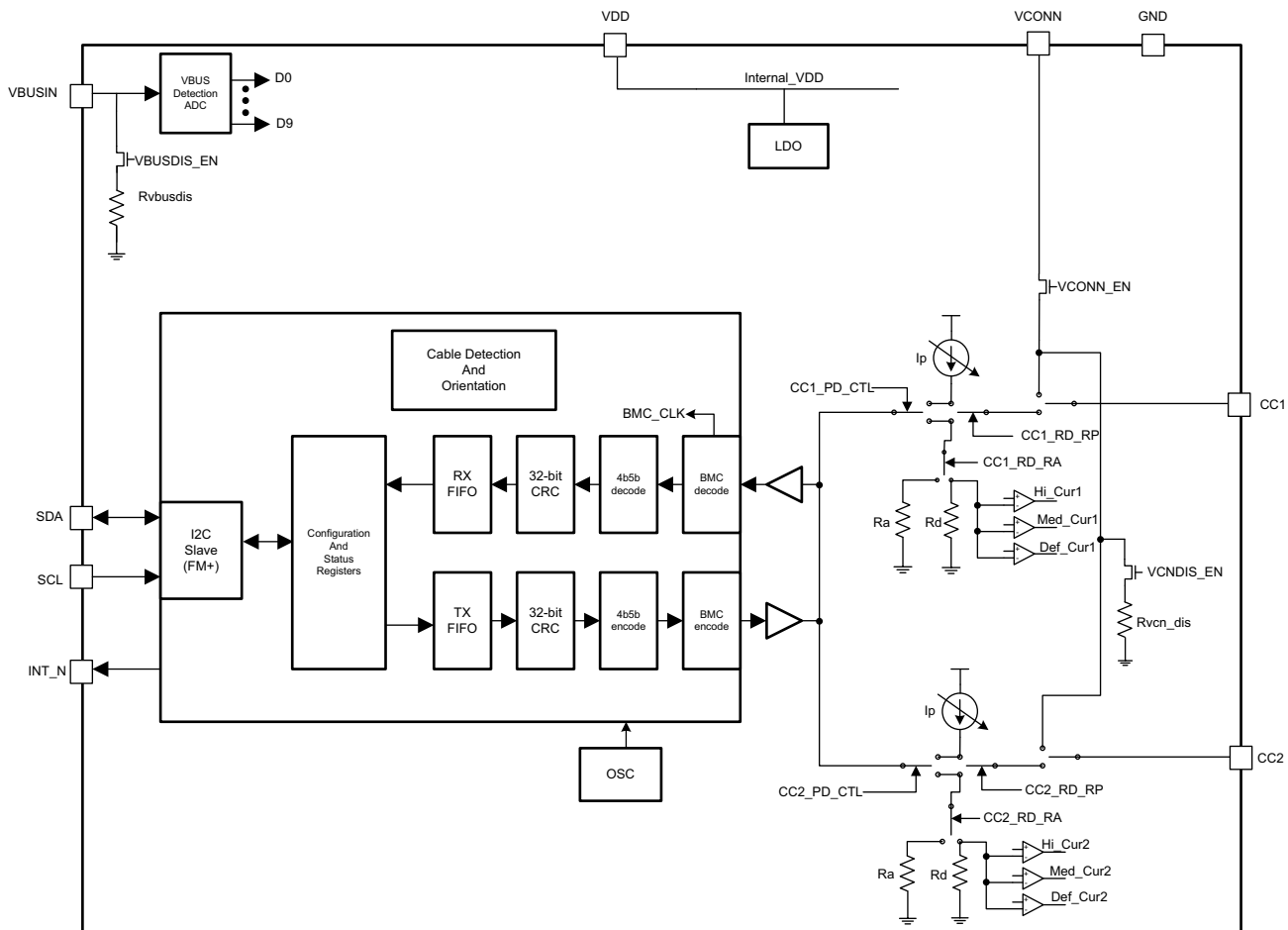


Figure 2. TUSB544 Functional Block Diagram

### 2.3.2 TUSB422: USB Type-C™ Port Control with Power Delivery

TUSB422 is a USB PD PHY that enables a USB Type-C port with the Configuration Channel (CC) logic needed for USB Type-C ecosystems. It integrates the physical layer of the USB BMC power delivery (PD) protocol to allow up to 100-W of power and support for alternate mode interfaces. An external microprocessor, containing USB Type-C Port Manager (TCPM), communicates with the TUSB422 through an I2C interface.

The TUSB422 integrates 2.5 Watt switch to provide VCONN power for an active cable. The device also provides VCONN discharge function. The TUSB422 also supports USB Type-C optional features such as audio and debug accessory.

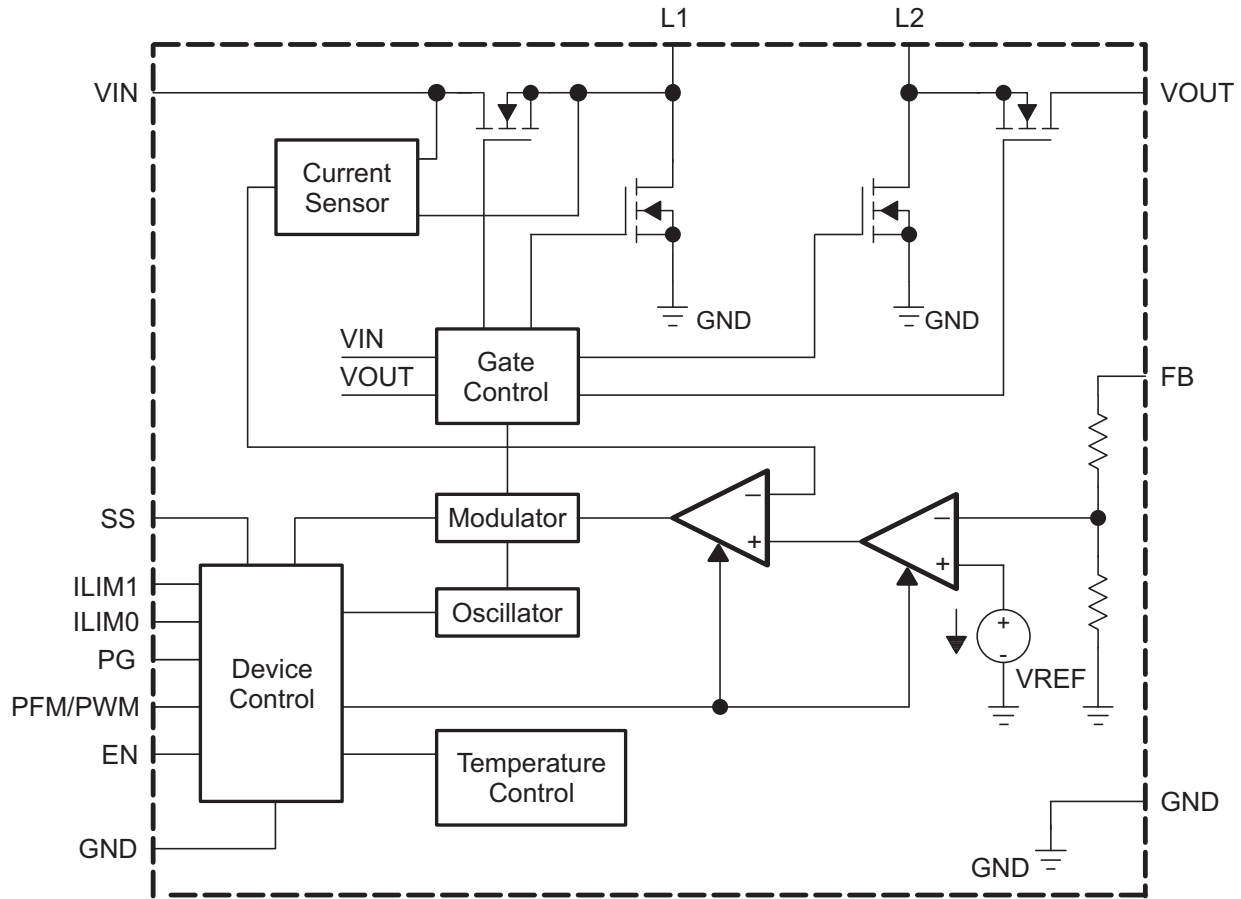


**Figure 3. TUSB422 Functional Block Diagram**

**2.3.3 TPS63051: Single Inductor Buck-Boost With 1-A Switches and Adjustable Soft Start**

The TPS63051 family of devices is a high efficiency, low quiescent-current buck-boost converter, suitable for applications where the input voltage is higher or lower than the output. Continuous output current can go as high as 500 mA in boost mode and as high as 1 A in buck mode. The maximum average current in the switches is limited to a typical value of 1 A. The TPS63051 regulates the output voltage over the complete input voltage range by automatically switching between buck or boost mode depending on the input voltage, ensuring seamless transition between modes.

The buck-boost converter is based on a fixed-frequency, pulse-width-modulation (PWM) controller using synchronous rectification to obtain the highest efficiency. At low load currents, the converter enters Power Save Mode to maintain high efficiency over the complete load current range.



**Figure 4. TPS63051 Functional Block Diagram**

### 2.3.4 MSP430F5528: Mixed-Signal Micro-controllers

The TI MSP430™ family of ultra-low-power micro-controllers consists of several devices featuring peripheral sets targeted for a variety of applications. The architecture, combined with extensive low-power modes, is optimized to achieve extended battery life in portable measurement applications. The micro-controller features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows the devices to wake up from low-power modes to active mode in 3.5 μs (typical).

The MSP430F5528 micro-controller has integrated USB and PHY supporting USB 2.0, four 16-bit timers, a high-performance 12-bit analog-to-digital converter (ADC), two universal serial communication interfaces (USCI), a hardware multiplier, DMA, a real-time clock (RTC) module with alarm capabilities, and 47 I/O pins.

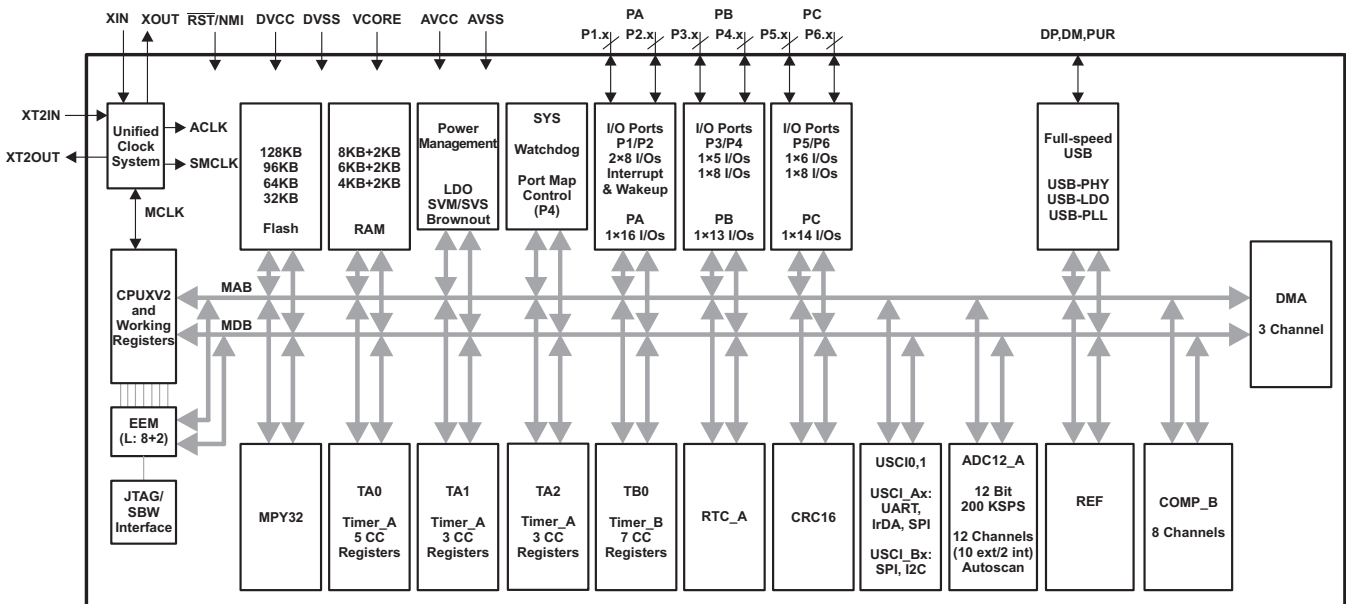


Figure 5. MSP430F5528 Functional Block Diagram

### 2.3.5 TPD4E05U06: 4 Channel ESD Protection Device for Super-Speed (Up to 6 Gbps) Interface

The TPD4E05U06 is a family of uni-directional Transient Voltage Suppressor (TVS) based Electrostatic Discharge (ESD) protection diodes with ultra-low capacitance. Each device can dissipate ESD strikes above the maximum level specified by the IEC 61000-4-2 international standard. The TPD4E05U06 ultra-low loading capacitance makes it ideal for protecting any high-speed signal pins. Typical applications for TPD4E05U06 includes high speed signal lines in USB 3.0 and DisplayPort.

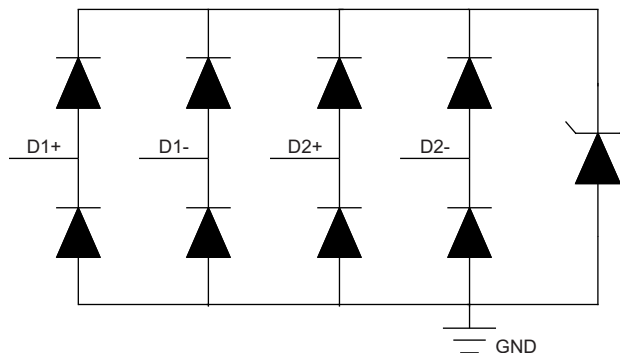


Figure 6. TPD4E05U06 Functional Block Diagram

### 2.3.6 TPD4E02B04: 4-Channel ESD Protection Diode for USB Type-C and HDMI 2.0

The TPD4E02B04 is a bidirectional TVS ESD protection diode array for USB Type-C and HDMI 2.0 circuit protection. The TPD4E02B04 is rated to dissipate ESD strikes at the maximum level specified in the IEC 61000-4-2 international standard (Level 4). This device features a 0.25-pF IO capacitance per channel making it ideal for protecting high-speed interfaces up to 10 Gbps such as USB 3.1 Gen2. The low dynamic resistance and low clamping voltage ensure system level protection against transient events.

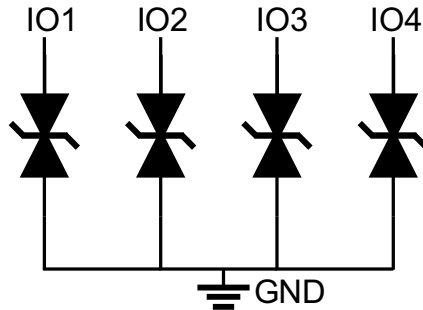


Figure 7. TPD4E02B04 Functional Block Diagram

### 2.3.7 ESD122: 2-Channel ESD Protection Diode for USB Type-C and HDMI 2.0

The ESD122 is a bidirectional TVS ESD protection diode array for USB Type-C and HDMI 2.0 circuit protection. The ESD122 is rated to dissipate contact ESD strikes at the maximum level specified in the IEC 61000-4-2 international standard (17-kV Contact, 17-kV Air-gap). This device features a low IO capacitance per channel and pin-out to suit symmetric differential high-speed signal routing making it ideal for protecting high-speed interfaces up to 10 Gbps such as USB 3.1 Gen2.

The ESD122 is an ideal ESD solution for the USB Type-C Tx/Rx lines. Since the USB Type-C connector has two layers, using 4- channel ESD devices require VIAs which degrade the signal integrity. Using four ESD122 (2-Ch) devices minimize the number of VIAs and simplify the PCB board layout.

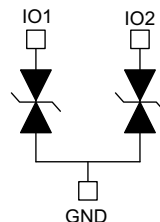


Figure 8. ESD122 Functional Block Diagram

### 3 Hardware, Software, Testing Requirements, and Test Results

#### 3.1 Required Hardware and Software

##### 3.1.1 Hardware

Required hardware to correctly operate this design:

- Displayport cable ( Up to 10m)
- USB-C™ port enabled for DisplyPort Alt Mode. See [Figure 9](#) for example.



**Figure 9. Example USB-C™ Port with DisplyPort Functionality. (Marked with DisplyPort logo)**

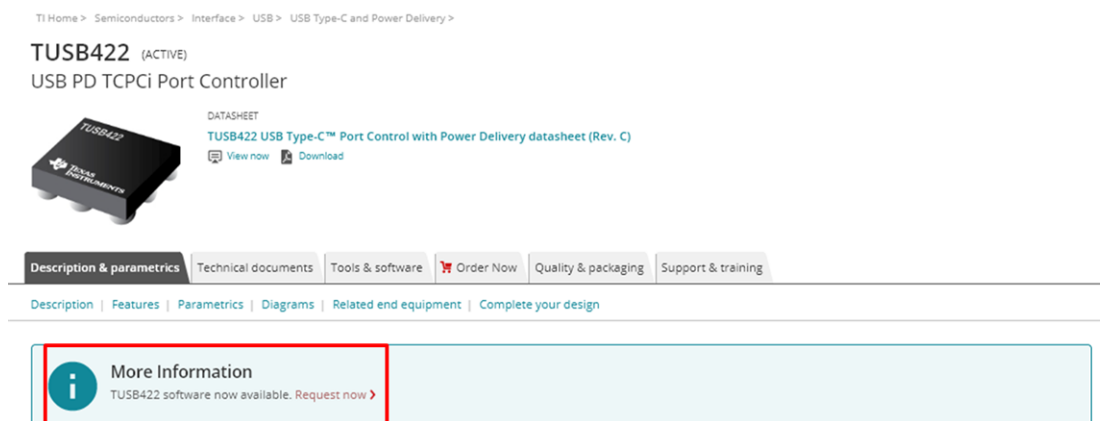
##### 3.1.2 Software

Required software to correctly operate this design:

- USB-C™ to DisplyPort Binary File
  - Download from TIDA-01620 Product page under.

Source Code for this binary file can be obtained by following these steps:

1. Request SW from [TUSB422 product page](#).



**Figure 10. TUSB422 Source Code Location on Product Page**

2. Download TUSB422 UFP-only MCU code.
3. Project is setup for IAR Embedded Workbench <sup>(2)</sup>
4. Follow the file path below to find the project file for this design.  
 TUSB422\tusb422\_tcpm\_ufl\app\UFP\IAR\DP\_DONGLE\_MSP430F5528.eww

<sup>(2)</sup> Third party software IAR Embedded Workbench for MSP430 Version 6.40.1 was used to create source code for this design.



### 3.1.3 How to Program USB-C™ to DisplyPort Active Cable Design

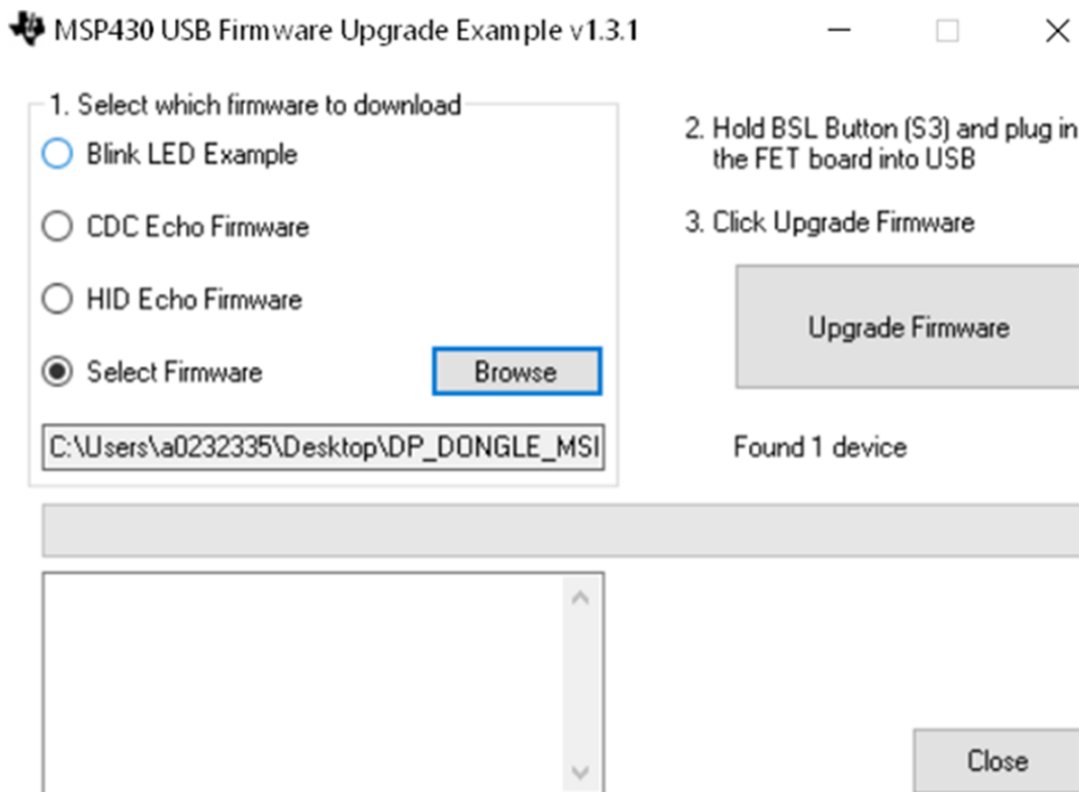
Read the following step-by-step instructions on programming the USB-C™ to DisplyPort Active Cable Design through USB. This must be done in order to use this design as intended.

1. Download and install MSP430\_USB\_Firmware\_Upgrade\_Example-1.3.1.1-Setup.exe from [this link](#).
2. Download the firmware located from the USB-C™ to DisplyPort Active Cable Design product page.
3. Turn SW1 to the “ON” position on the design before plugging the design into the USB-C™ port.
4. Run the MPS430 USB Firmware Upgrade program that was installed in the first step. NOTE: GUI should say “Found 1 device” if the design that was plugged in was properly enumerated.



**Figure 11. Example Screen of MSP430 Programming Software Start-Up Screen**

5. Click "Select Firmware" and browse for firmware download in second step. Select this firmware.
6. Click “Upgrade Firmware” to program the USB-C™ to DisplyPort Active Cable Design with software download in the second step.



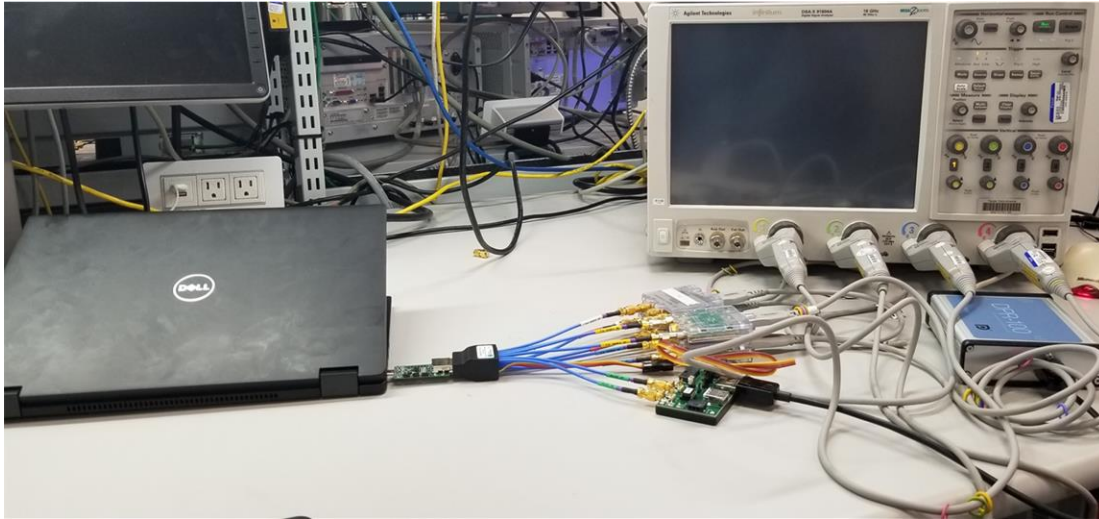
**Figure 12. Example Screen of MSP430 Programming Software Programming Menu**

7. The design is now programmed and user must flip SW1 back to the “OFF” position to use design in proper manner.
  - a. See [Section 3.2.2](#) "Quick Start Guide for USB-C™ DisplyPort Active Cable Design" for steps on setting up system for functional testing.

### 3.2 Test and Results

This section gives brief demonstration of how this design was tested and a Quick Start guide on how to use this design for functional and inter-op testing.

#### 3.2.1 Test Setup



**Figure 13. DisplayPort Compliance Eye Setup**

#### 3.2.2 Quick Start Guide for USB-C™ DisplyPort Active Cable Design

Once programmed follow the steps below to use the USB-C™ DisplyPort Active Cable Design.

1. Plug DisplyPort cable into DisplyPort receptacle on the USB-C™ to DisplyPort Active Cable Design and DisplyPort monitor/sink.



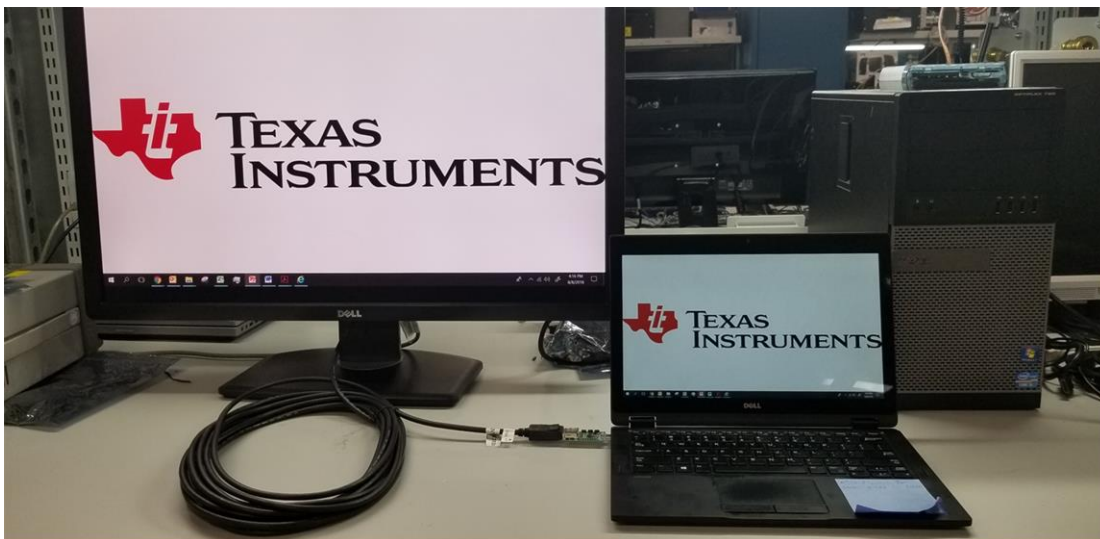
**Figure 14. DisplyPort cable connected to USB-C™ DisplyPort Active Cable Design**

2. Plug USB-C™ side of USB-C™ to DisplyPort Active Cable Design into the a USB-C™ source that is enabled for DisplyPort ALT mode.



**Figure 15. USB-C™ to DisplyPort Active Cable Design Fully Connected**

3. DisplyPort Monitor/ Sink should now be displaying image from the USB-C™ source.



**Figure 16. USB-C™ to DisplyPort Active Cable Design Displaying Image With Long Cable**

### 3.2.3 Test Results

#### 3.2.3.1 USB-C™ to DisplayPort Active Cable Design for DisplayPort Eye Diagrams

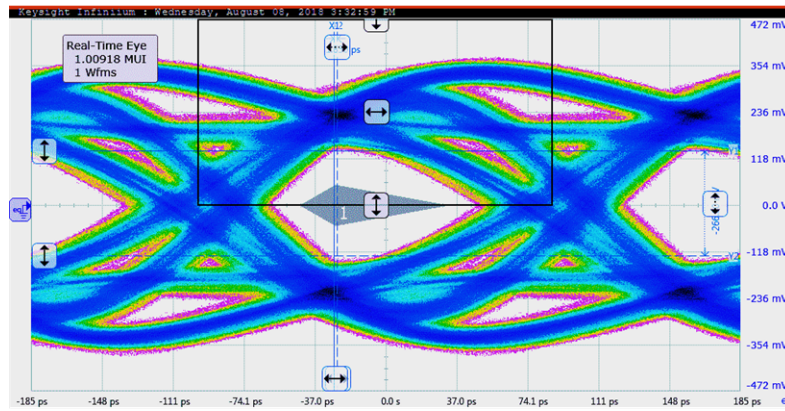


Figure 17. 5.4 Gbps TP3\_EQ Eye Diagram with Cable Model Embedded

## 4 Design Files

### 4.1 Schematics

To download the schematics, see the design files at [TIDA-01620](#).

### 4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-01620](#).

### 4.3 PCB Layout Files

To download the layer plots, see the design files at [TIDA-01620](#).

### 4.4 Gerber Files

To download the Gerber files, see the design files at [TIDA-01620](#).

## 5 Software Files

To download the software files, see the design files at [TIDA-01620](#).

## 6 Related Documentation

- [TUSB544 USB TYPE-C™ 8.1 Gbps Multi-Protocol Linear Redriver Datasheet](#)
- [TUSB422 USB Type-C™ Port Control with Power Delivery Datasheet](#)
- [TPS6305x Single Inductor Buck-Boost With 1-A Switches and Adjustable Soft Start Datasheet](#)
- [MSP430F552x, MSP430F551x Mixed-Signal Microcontrollers Datasheet](#)
- [TPDxE05U06 1, 4, 6 Channel ESD Protection Device for Super-Speed \(Up to 6 Gbps\) Interface Datasheet](#)
- [TPD4E02B04 4-Channel ESD Protection Diode for USB Type-C and HDMI 2.0 Datasheet](#)
- [ESD122 2-Channel ESD Protection Diode for USB Type-C and HDMI 2.0 Datasheet](#)
- [VESA DisplayPort Alt Mode on USB Type-C Standard \(DisplayPort Alt Mode\)](#)

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
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