Application Note

Solving Signal Integrity Challenges with USB2 Redrivers

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ABSTRACT

This application note examines why the use of a redriver is needed for signal conditioning in a USB 2.0 system design, and how to incorporate a redriver to simplify designs and meet USB 2.0 compliance.

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1 Introduction

Since the inception in 1996, Universal Serial Bus (USB) has become one of the most successful wired interfaces adopted by a wide range of electronics devices and equipment across industries, such as personal electronics, automotive, industrial, and enterprise systems. Even though USB data rates have evolved to support higher bandwidths over the years, currently achieving 10Gbps per lane, it has kept the backwards compatibility of the USB 2.0 specification with up to 480Mbps data rate for many low bandwidth applications. Even at the lower USB high speed data rate of 480Mbps, USB signals are subject to signal degradation over cables, trace loss, and passive components in the data path, which can result in USB 2.0 compliance failures. Figure 1-1 shows an example.

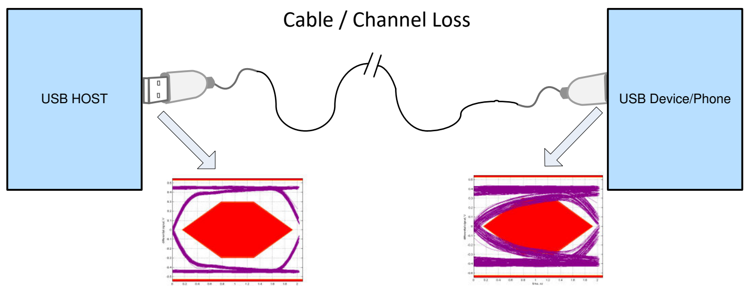

Figure 1-1. Signal Integrity Degradation

To help mitigate the signal degradation that comes with these factors, a USB 2.0 redriver can be used to help boost the signal as it travels from the USB host to the USB device. This USB 2.0 redriver monitors the signals that travel underneath it, and upon detecting a High-Speed (HS) signal, begins boosting the signal of the device. This boost targets two areas of the redriver, the DC Levels, VHigh and VLow, which tend to decrease over longer cable and travel lengths, and the AC aspects of the rising and falling edge, which can tend to slow down at longer lengths, leading to less margin around the mask of an eye diagram, which is typically used to help determine the integrity of a USB 2.0 Signal.

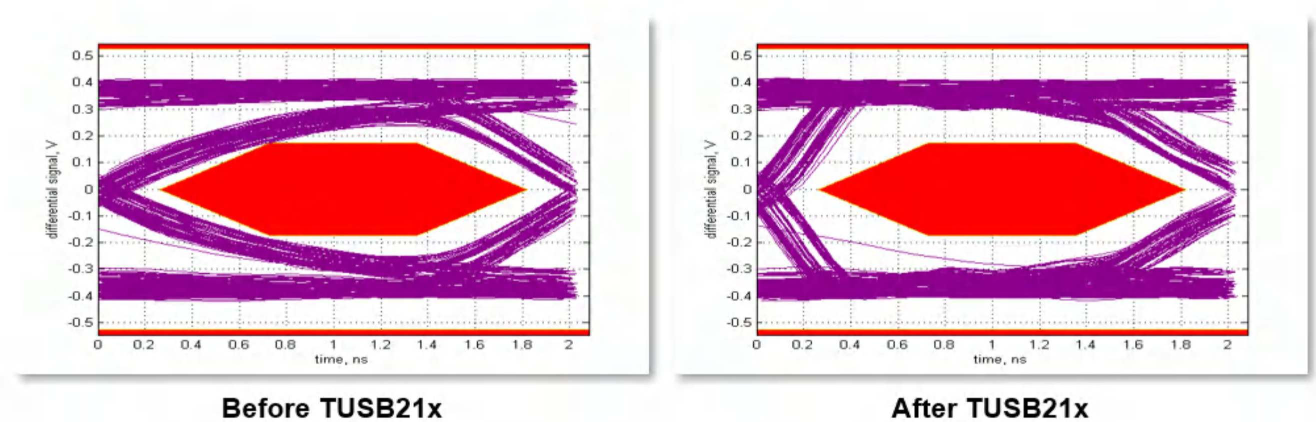

Figure 1-2. Redriver Eye Diagram Comparison

2 USB 2.0 Signal Integrity Challenges

USB 2.0 supports up to 480 Mbps high speed data rate along with battery charging protocols. USB 2.0 is a DC coupled system with wide signal swing. The USB 2.0 data path typically has many passive and active components such as switches, charging controllers, and protection devices. These components, though designed to be as negligible in loss to a signal's quality as possible, can still have an effect on signals as they pass through. If these signals are already degraded in quality as is, then this small amount of loss that can be picked up from, say, a multiplexor or ESD diode, can easily push the signal to the point of being non-compliant.

Aside from these components, there are also characteristics in a board design which can attribute to the amount of loss in a signal. At the base level, the trace of a USB data path incurs some loss into the signal, with the

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effectiveness of the design having the ability to affect how much loss exactly. A poorly designed board may have improper routing techniques, an incorrect differential impedance due to improper width between the pair or trace width, or trace-length mismatch which will all impact the signal.

Finally, there's also the external factors, like the cables and connectors being used. These all introduce some form of loss to the signal as they pass through them. Multiple connectors in a signal path, such as from host to device with a USB connector or board to board with a ribbon cable connector, can easily degrade the signal by a fair margin. Additionally, certain USB cables or even vendor-specific cables may have their USB 2.0 lanes routed straight rather than in a twisted pair, which directly affects the differential impedance of the USB 2.0 signal and can cause extensive signal degradation.

3 Choosing to Use a USB 2.0 Redriver

With all those different potential causes for signal degradation of a USB 2,0 signal, the question of whether to use a USB 2.0 redriver and where to use it becomes an important one. Often, designers hesitate under the assumption that adding a redriver can require an extensive rework, and if the redriver does not work, this can require another rework to correct the changes made. Thankfully, a USB 2.0 redriver is actually one of the easier redrivers to implement. USB 2.0 redriver come in a small form factor and flow through trace routing can be used in the board design. Figure 3-1 shows the flow-through design.

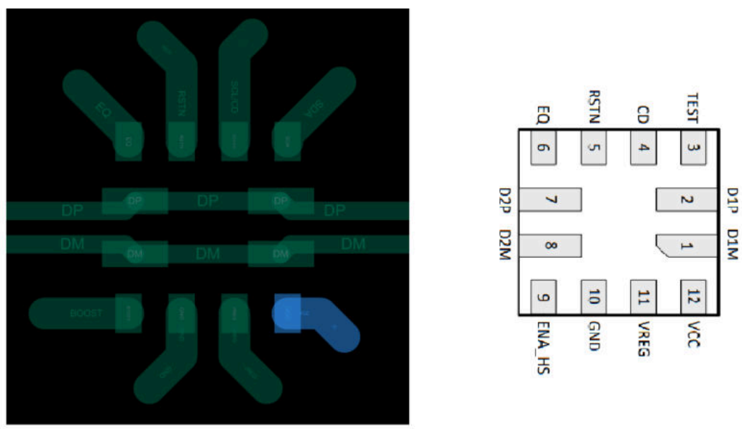

Figure 3-1. Flow-Through Design

Essentially, this flow-through trace routing means that a USB 2.0 redriver does not need to directly integrate a signal through the device as an input to be boosted and then output back onto a trace, but can instead passively monitor the signal as it passes under the redriver. That way, the PCB trace of a board does not need to be extensively reworked to incorporate a USB 2.0 redriver, and if the redriver is not necessary, the redriver can be removed with no worries about whether the trace can be affected or not. Additionally, a USB 2.0 redriver comes in a smaller form-factor, causing it to take up a minimal amount of space in a signal, and is easy to setup, with 1-2 configuration pins at most.

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4 Redrivers in Automotive

Many automotive applications require long cable reach for smart phone data communication and charging between head unit or media hub ports. USB2.0 does not guarantee compliance beyond 1.5m cable length, in such applications we need to add re-drivers to preserve the signal integrity.

The applications where USB2.0 re-drivers can be used in automotive are:

- Firmware update using USB2.0
- Connecting to external music to the infotainment unit

AUTOMOTIVE USB CHARGE: (A to C point)

- The signal transmission of D+ and D- from the SOC is connected to a mobile phone through a USB interface. This can enable applications like car-play on the mobile phone.

DIGITAL COCKPIT PROCESSING UNIT: (A to B point)

- USB2.0 re-driver needed as the USB rear seat plug (charger) is about 1.5m distance from head-unit so they needed re-driver to make sure signal integrity and pass compliance, else eye-diagram test can fail.

Systems sending USB2 data must pass a near-end USB 2.0 compliance eye diagram at the connector located at the far end of the cable, that is The Remote Port.

System fails USB 2.0 compliance when in channel is loss is high, for example, during high temperatures or when using long cables. USB2.0 does not guarantee compliance beyond 1.5m, hence re-driver is needed. User's personal device cannot communicate with vehicle head unit.

The TUSB21x-Q1 can be implemented to enable support of up to a five-meter cable to pass USB 2.0 near-endeye testing, CarPlay, and Android auto compliance.

Different Automotive Applications of USB2.0 shows a typical car where we see the various points where signal transmission occurs. From A to C for automotive USB charge, and from A to B for a digital cockpit processing unit. The long distance between the various points warrants the use of a USB2.0 re-driver.

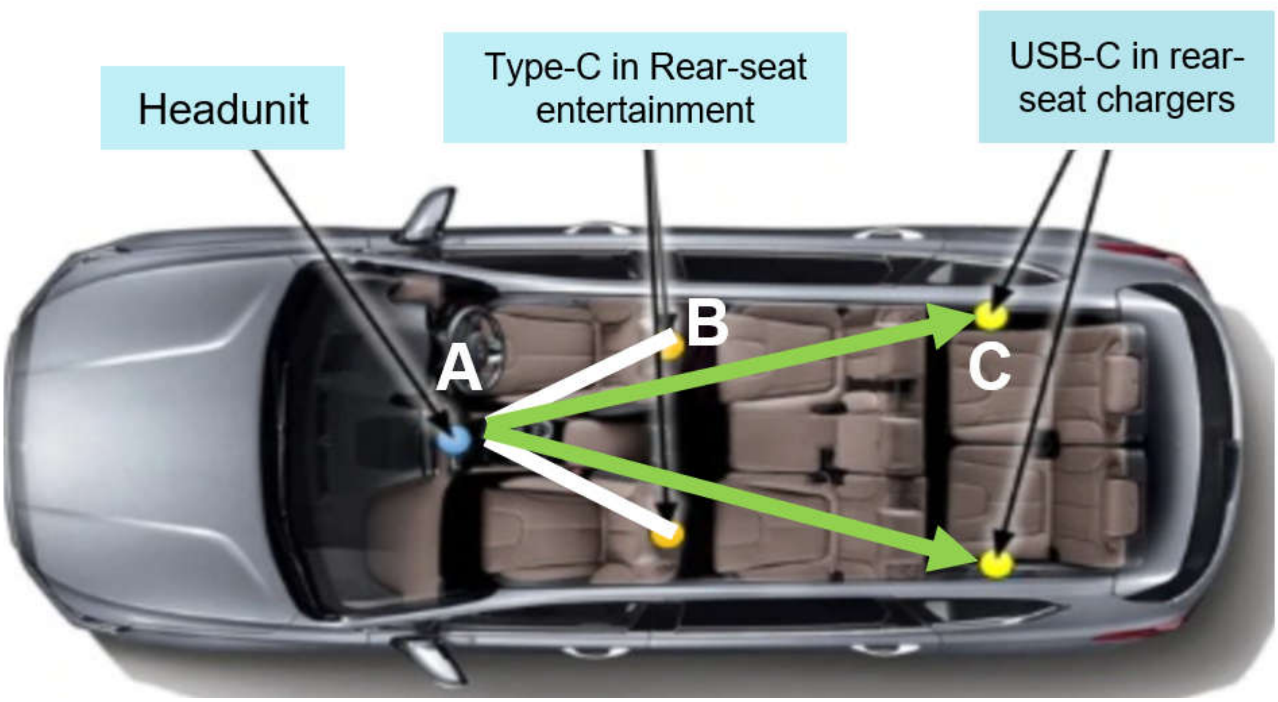

Figure 4-1. Different Automotive Applications of USB2.0

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Figure 4-2 shows a passing near-end eye diagram using the TUSB217 with a 5m cable. The TUSB217 is also capable of passing the near-end eye diagram across various different cable lengths up to 5m with a single configuration (with typical 28AWG USB cables).

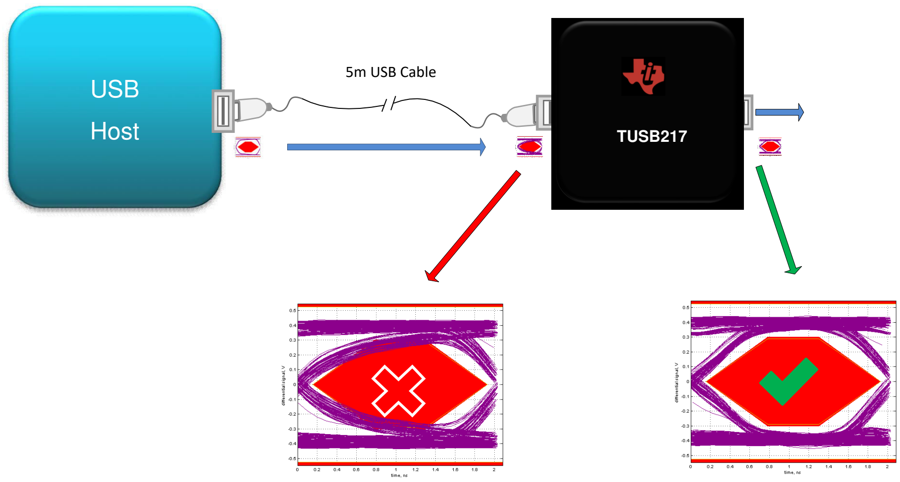

Figure 4-2. TUSB217 Signal Recovery

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5 Redrivers in Enterprise

Another application which requires the use of USB2 redrivers is rack servers for data storage and use. While most data stored in rack servers travels at higher data rates according to PCIE protocol, consumer and commercial rack servers use USB2 data and type-A consumer facing ports to control mouse and keyboard accessories as well as to enable programming, analysis, and debugging within the server. While consumer electronics continue to adopt higher data rates such as USB3/4 to enable quicker download and data access, certain applications in rack servers do not require the adaptation from USB2 to higher data rates. The impact of increasing data rates for programming and debugging applications is minimal, and USB2 offers the advantages of simplicity and low cost.

In rack servers, the distance of the USB2 data path varies because a user can need to access USB2 data anywhere from the top to bottom of the rack. Distance and temperature contribute to signal loss and distortion, and therefore, the system runs the risk of failing USB compliance. TI offers a broad portfolio of USB2 redrivers which boost the signal to restore signal quality and enable USB2 compliance in rack server applications.

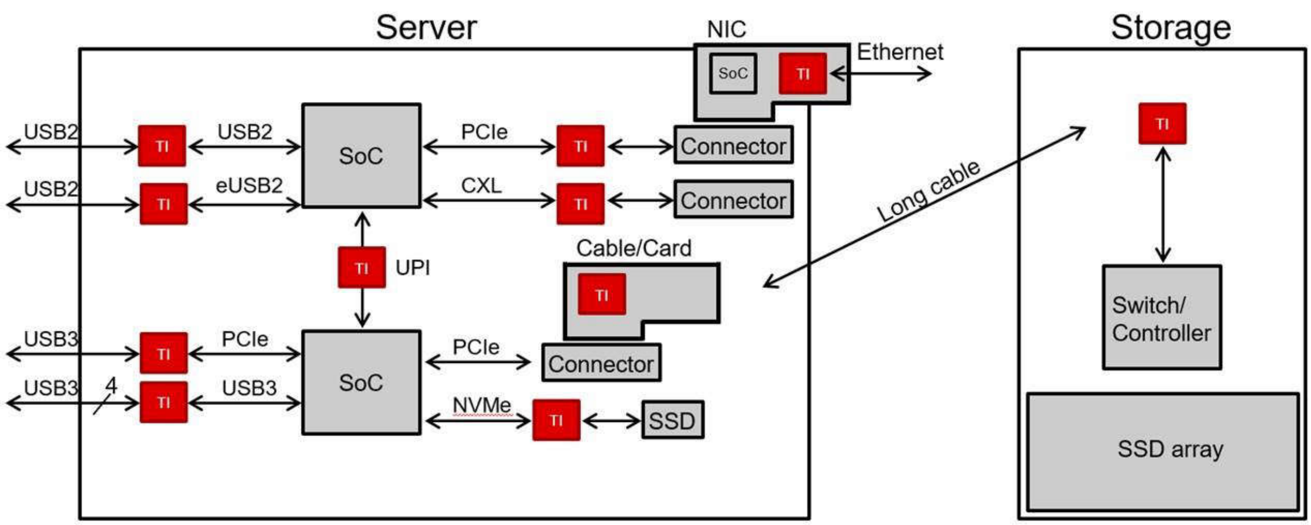

Figure 5-1. Example Enterprise Application of a USB2 Redriver

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6 Redrivers in Medical

The backend ports of medical equipment's backends have USB ports for data-transfer. In equipment such as ultrasound and X-ray depending upon the resolution of the live images being transferred & depending on the screen size being transferred to, lower speed USB can be used for smaller screen. For premium ultrasound usually Type-C and USB3.1 (higher data-rates) are used.

Figure 6-1 shows a Standard ultrasound which has Type-C for data-transfer. Since the Type-C port is external, any cable length can be interfaced with the Type-C port causing the need of re-driver between the processor and the Type-C port to preserve signal-integrity.

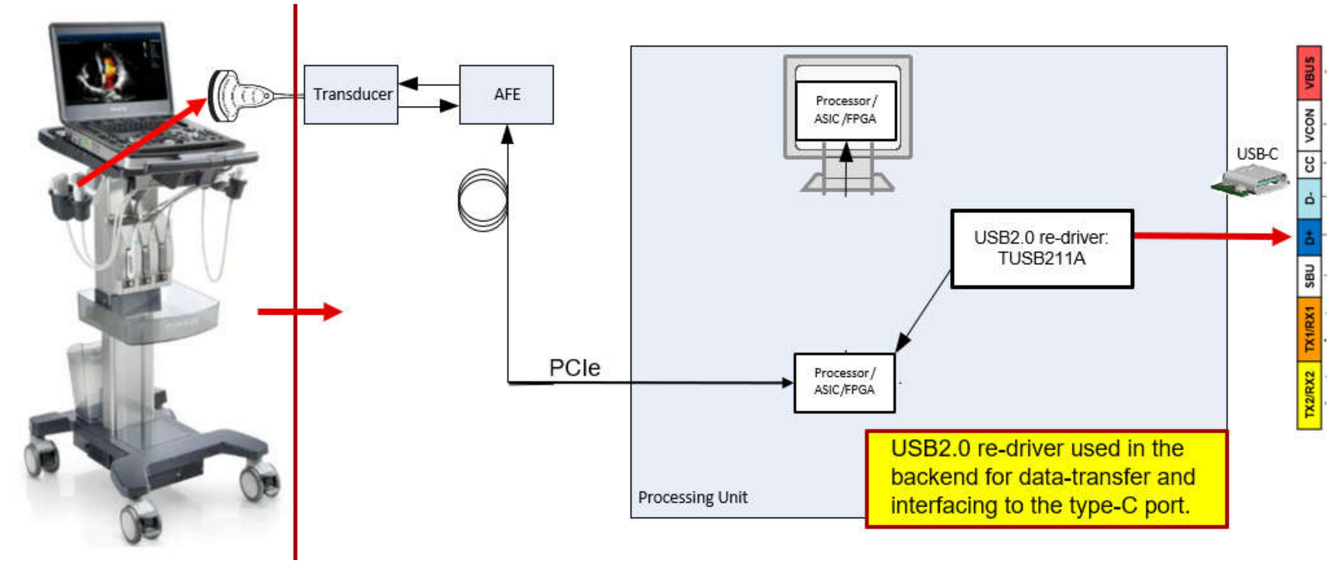

Figure 6-1. Ultrasound Example Application of a USB Redriver

Figure 6-2 shows an X-ray machine which has Type-C for data-transfer. Since the type-C port is external, any cable length can be interfaced with the Type-C port causing the need of re-driver between the processor and the Type-C port to preserve signal-integrity.

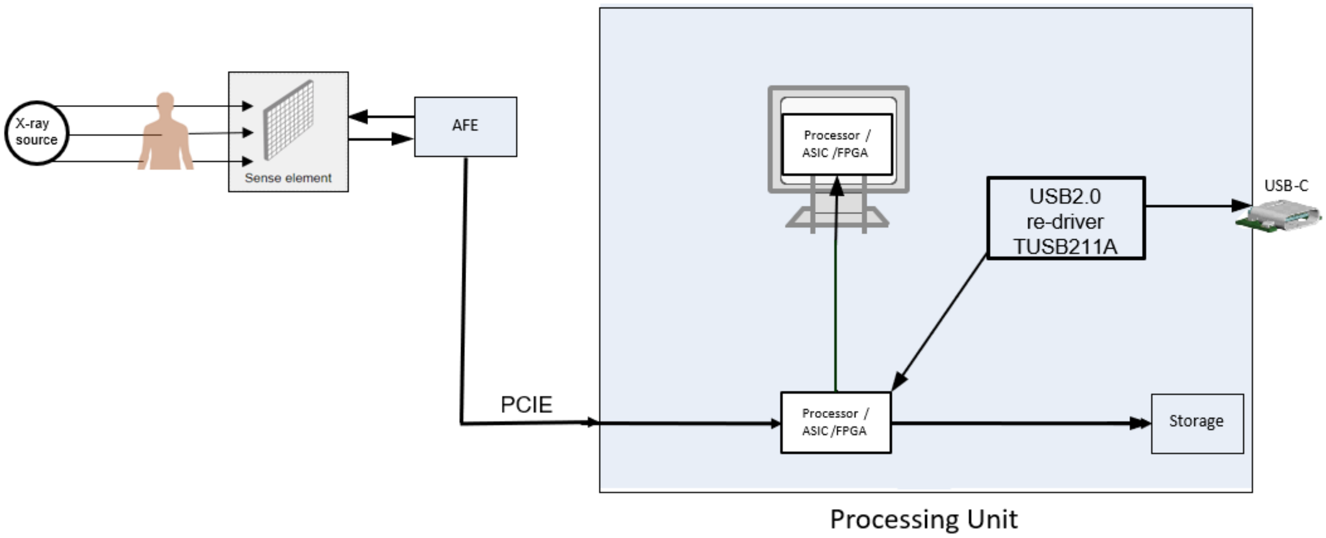

Figure 6-2. X-Ray Example Application of a USB Redriver

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7 Re-drivers in Personal Electronics

As developers of personal electronics are upgrading to higher speeds including USB3/4 for data transfer, in tandem they are adopting the USB Type-C® connector as the method of interface. To name a few applications, phones, laptops, desktops, monitors, docking stations, and virtual reality gaming systems are using USB Type-C connectors for charging, as well as video and data transfer.

The USB Type-C connector includes signal paths for USB3/4 and USB2. To qualify as a USB product and use the standard USB Type-C connector, USB-IF requires that a system is backwards compatible. In other words, USB SuperSpeed (10Gbps) applications must support USB SuperSpeed (5Gbps) and USB Hi-Speed (480Mbps). In practice, since USB is backwards compatible protocol, by default the USB connection can search for and connect through the highest data rate supported. If this connection is not found or lost, the USB connection can search for and connect through the next highest data rate and so on. Therefore, backwards compatibility acts as a built-in insurance program, offering lower speed support if the highest speed does not connect successfully.

Achieving USB2 compliance is also a requirement in USB Type-C ports because the user can connect a device that only supports USB Hi-Speed (5Gbps).

Passing USB compliance becomes a challenge when USB Type-C ports are consumer facing because the user can connect their device through a cable of unknown length and quality. Because of these unknowns, designers of personal electronics must create robust systems that can compensate for loss and pass USB compliance consistently no matter what is plugged into their system!

TI offers a broad portfolio of USB redrivers which boost the signal to restore signal quality and enable USB compliance in personal electronics. For personal electronics applications that require BC charging, TI's USB2 redriver, TUSB217A, offer an integrated BC 1.2 Charging Downstream Port (CDP) and Dedicated Charging Port (DCP) controllers that dynamically changes per DCP/CDP pin.

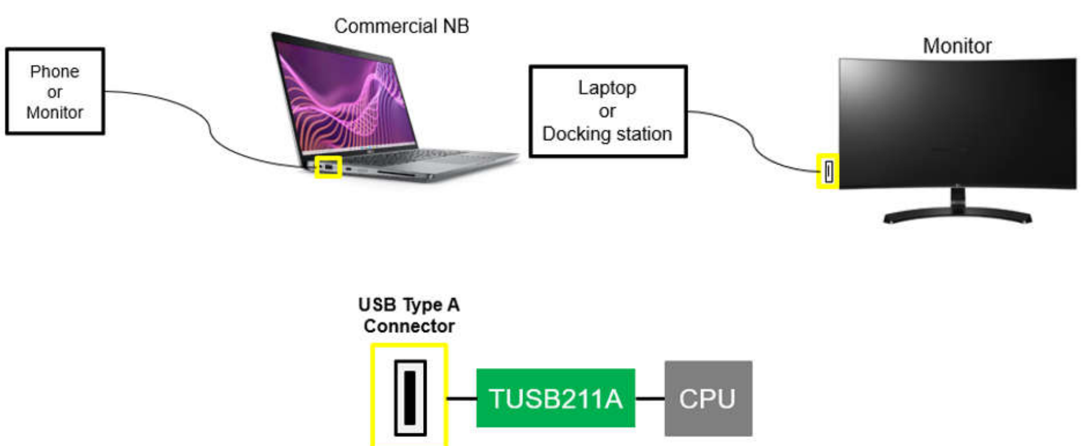

Figure 7-1. Examples of USB2 Redriver Applications in Personal Electronics

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8 Re-drivers in other applications

Wherever there is an external USB2.0 port, cables of unknown lengths can be plugged into the USB2.0 port, which can cause the risk of failing USB2.0 compliance. One such application is in lightning to USB-C applications.

Lightning to USB Type-C USB2 Redriver Application shows how a TI-redriver can be used in between the Lightning to Type-C connector to handle cables of unknown length between them.

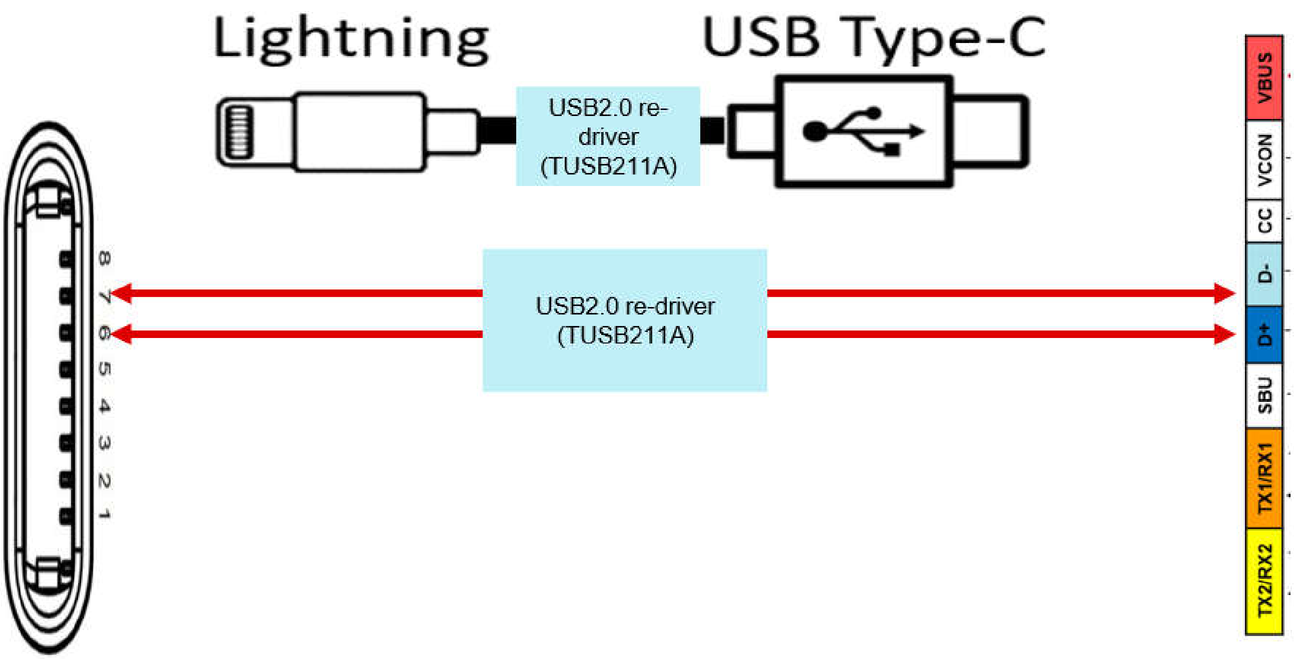

Figure 8-1. Lightning to USB Type-C USB2 Redriver Application

The USB re-driver is in an adapter, meant to adapt Lightning to USB-C, allowing Lightning based accessories to interface with the new Phone/ipad USB-C ports.

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9 Facilitating Easy Use of TUSB211A Using the TUSB211PICO-EVM

The TUSB211PICO-EVM evaluation module (EVM) is designed to provide a simple means of demonstrating the signal conditioning capability of the TUSB211 device on an existing board designed without the TUSB211 footprint. The EVM is preconfigured and simply connects DP and DM signals (likely at the connector) with wires soldered from the EVM to traces or connector pins. The TUSB211 Pico EVM is powered from the VBUS or an external 3.3-V supply both connected through headers on the EVM. TUSB211 Pico EVM has the following features:

- Plug-and-play design
- EQ setting configurable through resistor
- The TUSB211 Pico EVM includes headers for different power options to provide power to the device
- Is pre-configured simple DP and DM connections
- Powered from the VBUS or an external 3.3V supply

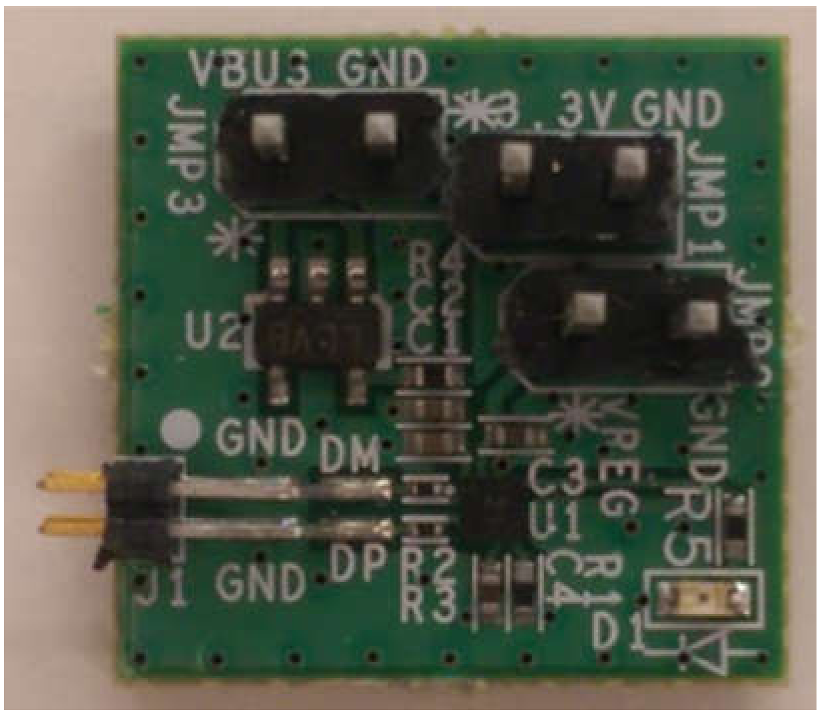

Figure 9-1. TUSB211PICO-EVM

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10 Summary

The Texas Instruments USB2 redriver family provides a highly efficient signal conditioning solution for wide varieties of applications to achieve instant USB compliance.

The TUSB217A is the high performance redriver capable of recovering the signal loss from a five meter cable to aid in passing USB 2.0 and CarPlay compliance testing.

The TUSB211A has a small footprint with flow though trace routing to ease the design effort and help achieve instant USB compliance.

11 References

- Texas Instruments, *TUSB211A USB 2.0 High Speed Conditioner,* data sheet.
- Texas Instruments, *TUSB217-Q1 USB High Speed Signal Conditioner,* data sheet.

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12 Revision History

Changes from Revision * (April 2019) to Revision A (August 2024) **Page**

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