Application Note

Design of a 140W Automotive Two-Port USB-C PD System with DisplayPort Alt Mode over FPD-Link

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Abstract

Modern automotive infotainment and digital cockpit systems increasingly rely on USB Type-C ports to deliver both power and high-resolution video to passenger devices. This application note describes a two-port, 140W USB Power Delivery system with DisplayPort™ Alt Mode support, designed to operate reliably from a 12V automotive battery rail. It explains the system architecture, covering both the power delivery path—built around the TPS26744E-Q1 PD controller and LM251772-Q1 buck-boost converter—and the video path, which uses the TUSB564-Q1 redriver, TS3DV642 switch, and an FPD-Link serializer to route high-speed signals to a remote display. Design considerations, efficiency, and thermal performance data from a validated implementation are included to help engineers adapt this architecture to their own automotive USB-C power and video applications.

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1 Introduction

Modern vehicle cabins increasingly offer USB Type-C ports that deliver both power and high-resolution video to passenger devices — but doing so inside a vehicle means solving two different problems at once.

The first is power and thermal: the automotive 12V rail is unregulated and can sag or spike with cranking and load-dump events, yet the system must still convert up to 140W across two ports inside a compact, airflow-limited enclosure. Conversion efficiency and thermal margin are tightly linked here and may require derating at high temperature or low input voltage to keep components within safe limits.

The second is signal integrity: the video path must carry a high-speed DisplayPort signal through connector transitions and re-driving circuitry, then over a longer automotive cable run to a remote display — all while sharing a board with a high-current switching converter. Noise immunity and layout discipline are as critical here as efficiency is to the power path.

This application note presents a validated reference design addressing both challenges in a single two-port, 140W USB-C Power Delivery system with DisplayPort Alt Mode support, giving automotive engineers a proven starting point for digital cockpit and infotainment USB-C implementations.

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2 Detailed Description

2.1 System Overview

The design splits into two paths sharing a common USB-C connector: a power path that negotiates and delivers USB PD power, and a video path that detects switches and transports DisplayPort Alt Mode video. Both paths are duplicated across two independent ports, allowing the system to source power and video simultaneously on each connector.

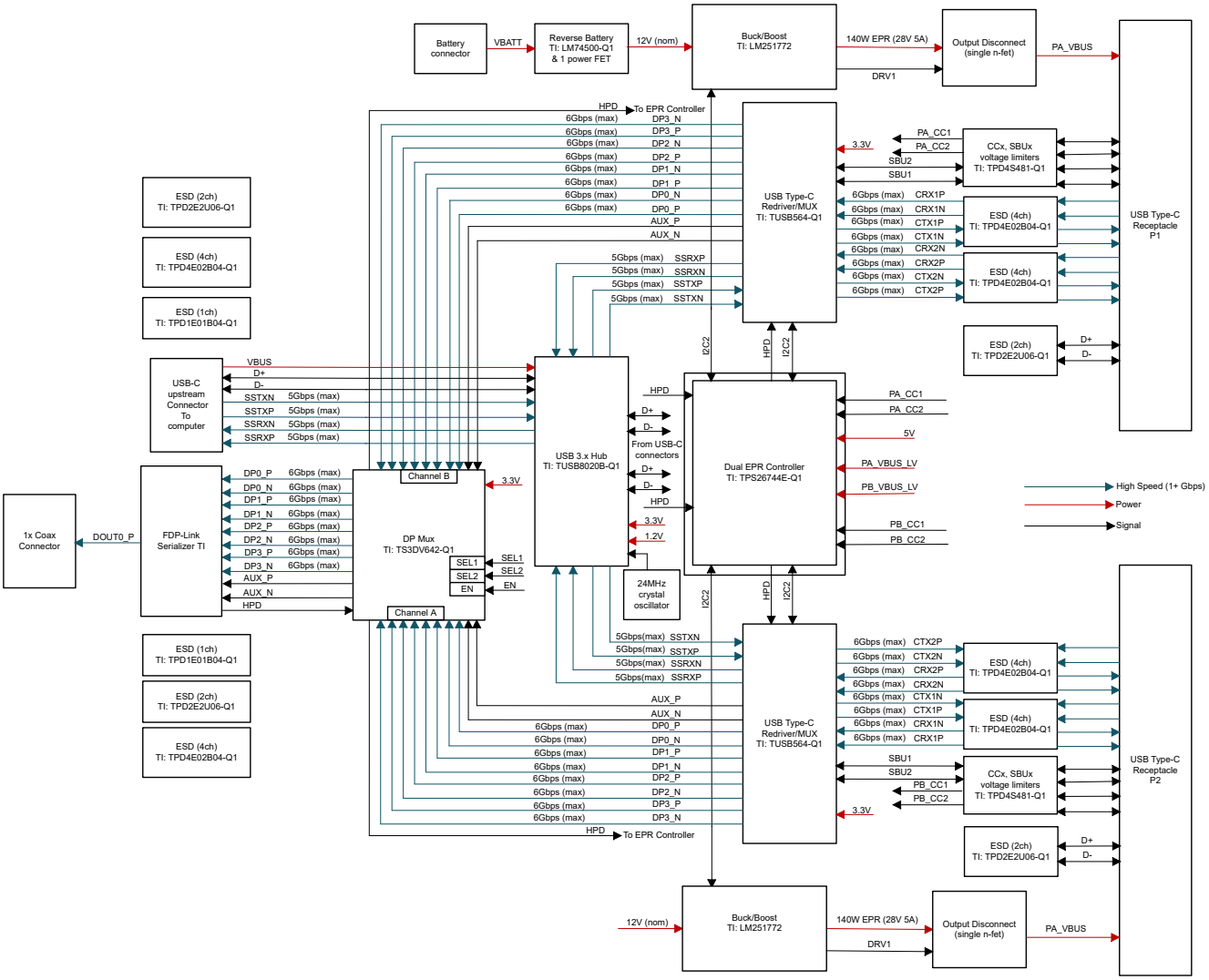


Figure 2-1. System Block Diagram

Figure 2-1 shows TPS26744E-Q1, LM251772, TUSB564-Q1, TS3DV642, and FPD-Link serializer in context. Red arrows indicate power transfer paths, blue arrows indicate high-speed data signals, and black arrows indicate control signals.

Performance data presented in this section was measured on the physical reference design board PMP31344.

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2.2 Power Path

The power path is built around the TPS26744E-Q1 USB Type-C and USB PD controller, which manages connector detection, PD contract negotiation, and protection, paired with the LM51772 wide-input buck-boost converter, which regulates the output rail to the voltage negotiated by the controller.

The PD contract negotiation and voltage hand-off proceed in three steps:

- Detection: When a device is plugged into the USB-C connector, the TPS26744E-Q1 detects its presence and orientation through the CC1/CC2 lines.
- Negotiation: The TPS26744E-Q1 and the attached device exchange PD messages over the CC lines to negotiate the power contract — agreeing on the output voltage (5V–28V) and current limit that the port delivers.
- Voltage set-point hand-off: Once the contract is agreed, the TPS26744E-Q1 communicates the negotiated voltage to the LM51772 over I2C, writing the new output voltage set-point directly into the converter's feedback/voltage-control registers. The LM51772 then regulates its buck-boost stage to that target, sourcing up to 140W per port from the nominal 12 V automotive input.

The LM51772 was configured to switch at 450kHz for all efficiency and thermal characterization described below.

Efficiency was characterized at 12V input across the full 5V–28V output range, with the converter (single port) switching at 450 kHz.

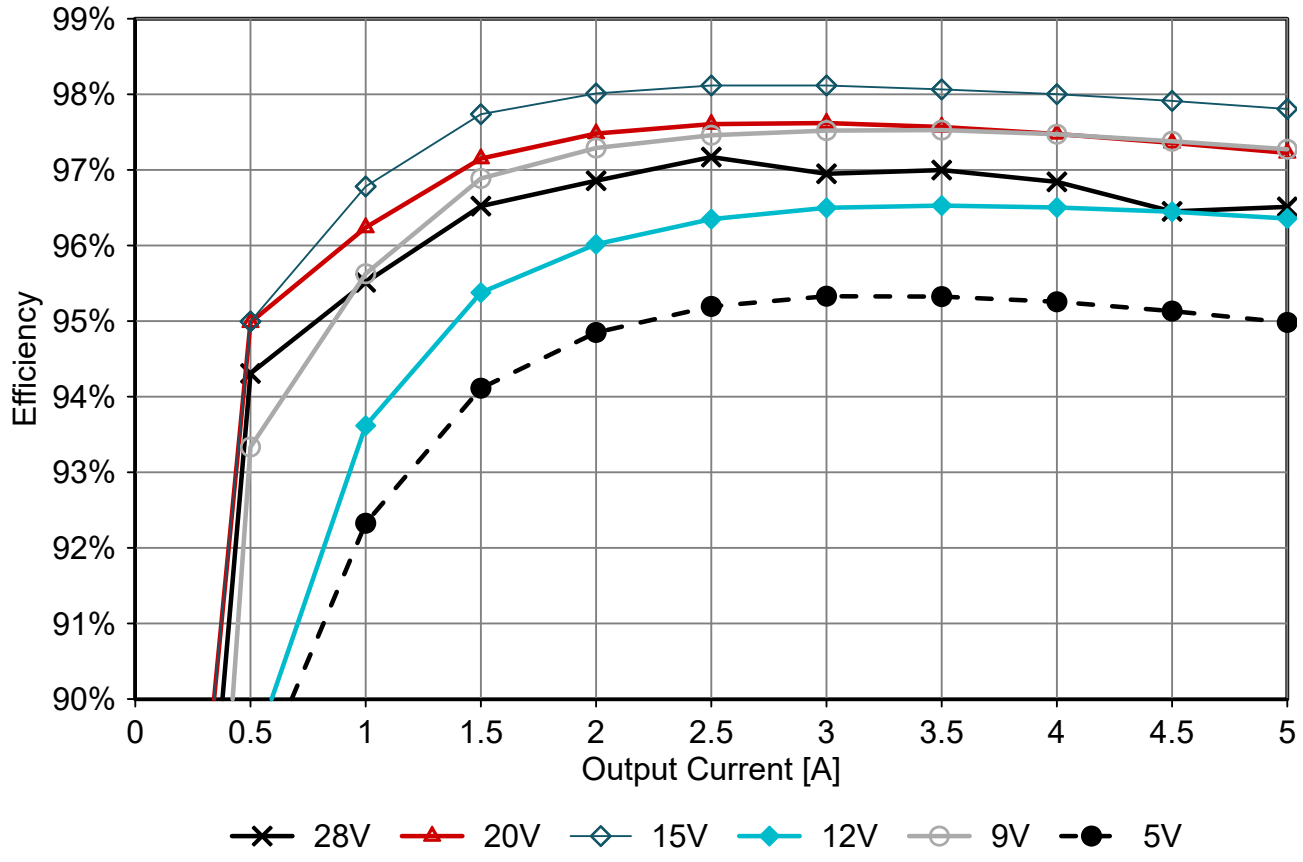


Figure 2-2. Buck-Boost Efficiency Across the Output Range at 12V Input, 450kHz Switching Frequency

In the efficiency graph, 88mA were subtracted to the measured input current. This value represents the board quiescent current when Vin is supplied and LM251772 is disabled.

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Thermal performance was evaluated at four representative operating points — 25W in buck mode (12V and 20V input), and 140W in boost mode (9V and 12V input) — all at the same 450kHz switching frequency, single port operation.

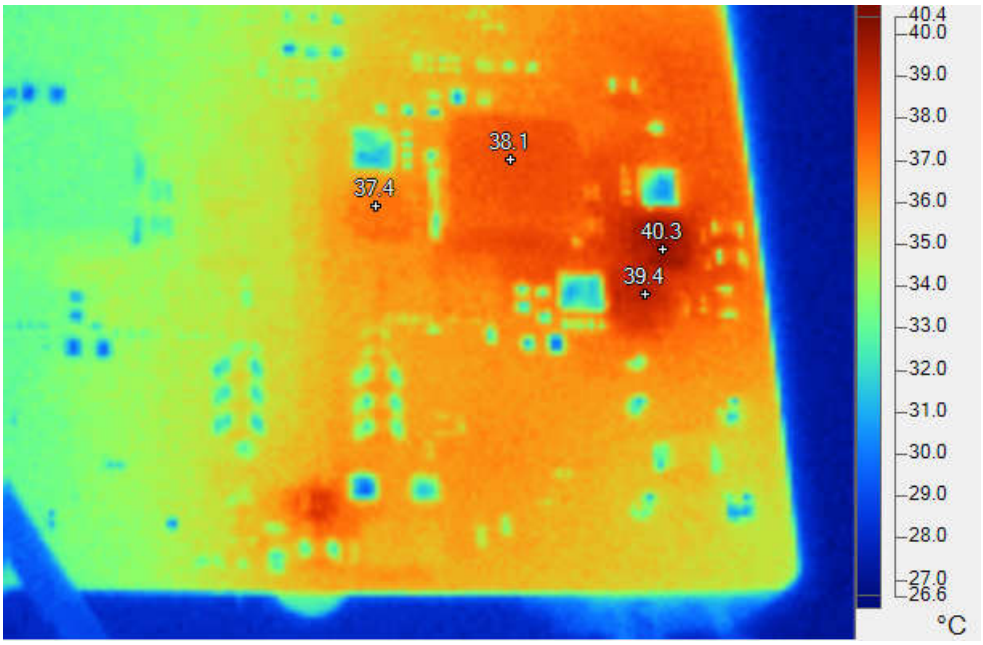


Figure 2-3. Thermal Image at 12Vin, 5Vout, 5A – 25W (Boost Rectifier 37ºC, Inductor 38ºC, Buck Mosfet 40ºC, Buck Rectifier 39ºC)

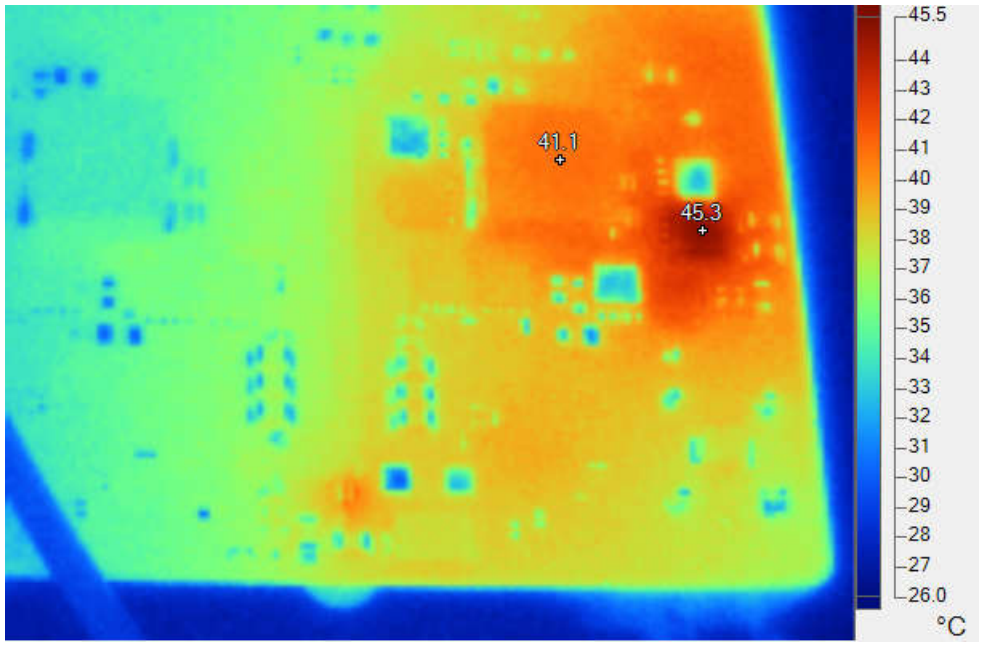


Figure 2-4. Thermal Image at 20Vin, 5Vout, 5A – 25W (Inductor 41ºC, Buck Mosfet 45ºC)

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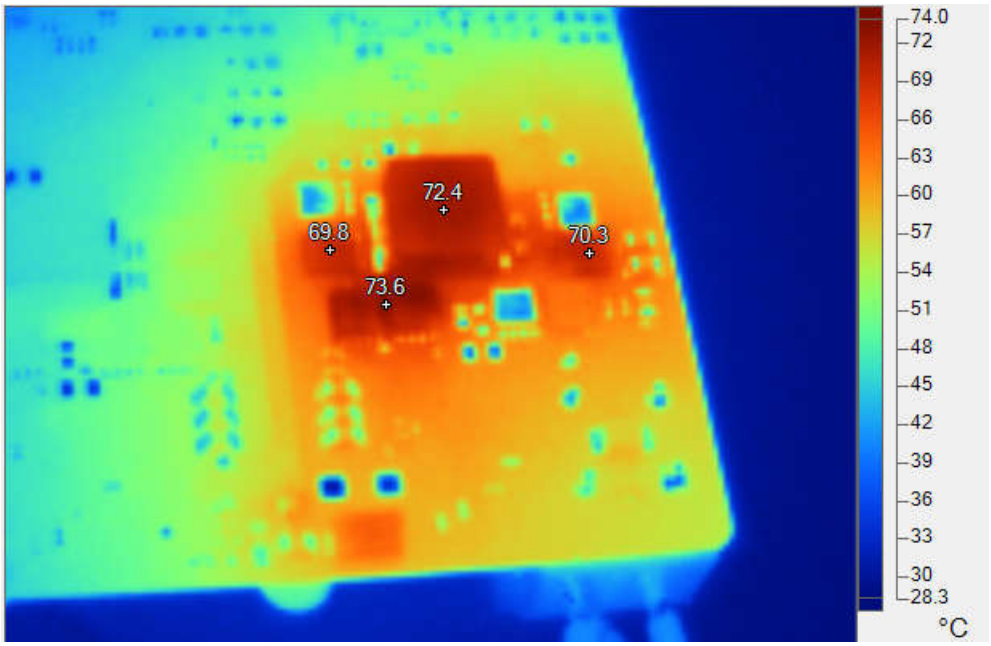


Figure 2-5. Thermal Image at 12Vin, 28Vout, 5A – 140W (Boost Mosfets 74ºC, Inductor 72ºC, Buck Mosfet 70ºC)

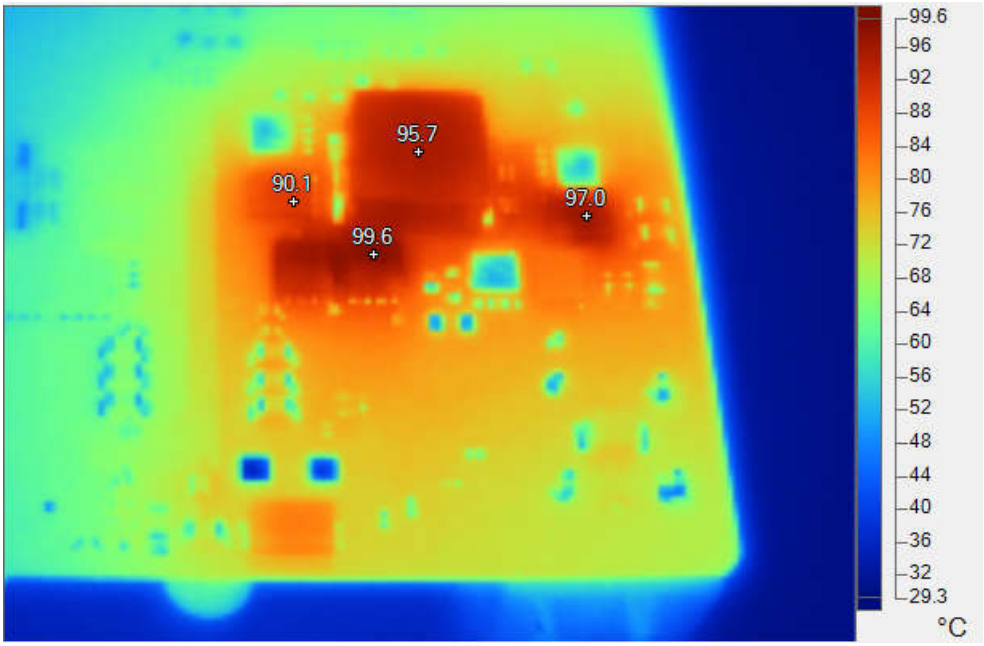


Figure 2-6. Thermal Image at 9Vin, 28Vout, 5A – 140W (Boost Mosfets 100ºC, Inductor 96ºC, Buck Mosfet 97ºC)

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2.3 Video Path

While the power path manages energy delivery, the video path is responsible for preserving signal integrity for high-speed DisplayPort and USB 3.2 traffic routed through the USB-C connector. Two devices condition and route these signals before they reach the connector, while FPD-Link serializer transmits the video over a coaxial cable to the display side of the system.

The TUSB564-Q1 is a linear redriver that compensates for channel loss on the high-speed differential pairs. It applies up to 11.6dB of equalization, enough to recover signal integrity for DisplayPort data rates up to 8.1Gbps and USB 3.2 data rates up to 5Gbps, ensuring the signal reaching the Type-C connector meets the eye-diagram and jitter requirements of both protocols.

The TS3DV642 sits downstream as a differential signal switch, muxing the high-speed pairs at the connector interface. This allows the system to route either DisplayPort or USB 3.2 traffic to the Type-C pins depending on the Alt Mode negotiation outcome, without introducing additional signal degradation.

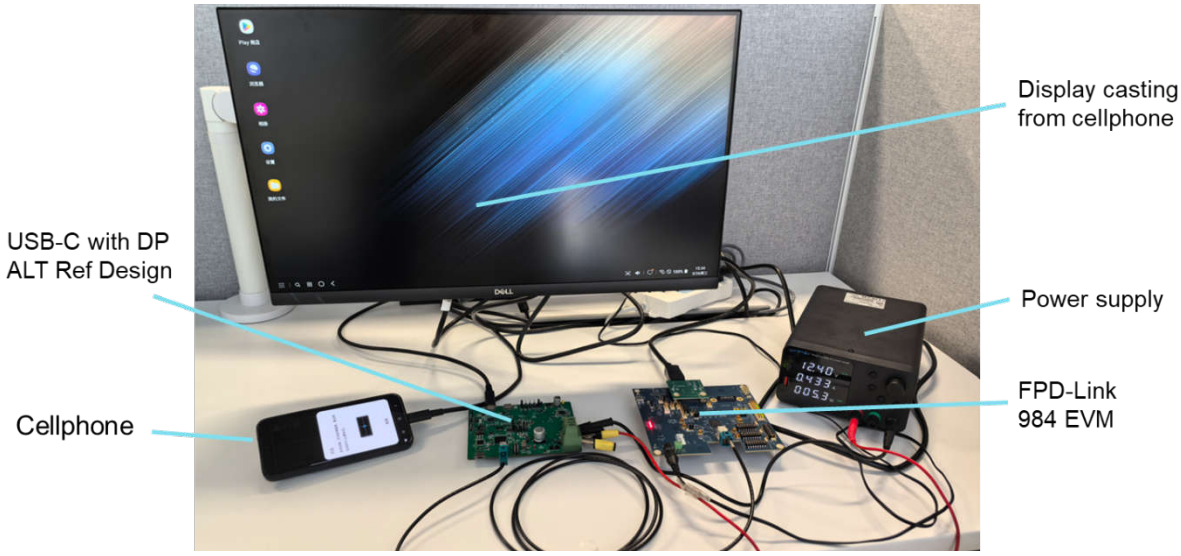


Figure 2-7. USB-C With DP ALT Mode – Setup

The video path was validated using the USB-C/DP Alt Mode board (comprising the TPS26744E-Q1, TUSB564-Q1, TS3DV642, and the FPD-Link serializer) paired with a UH984 EVM driving a display over the FPD-Link interface. The TPS26744E-Q1 is programmed to manage PD communication and USB/DP mode selection over the CC line, while the FPD-Link serializer's firmware and register configuration (for both serializer and deserializer) are loaded via its external SPI flash. With this configuration active, a USB Type-C source such as a phone or laptop can connect to the board and cast its display output end-to-end through the DP Alt Mode and FPD-Link signal chain to the display.

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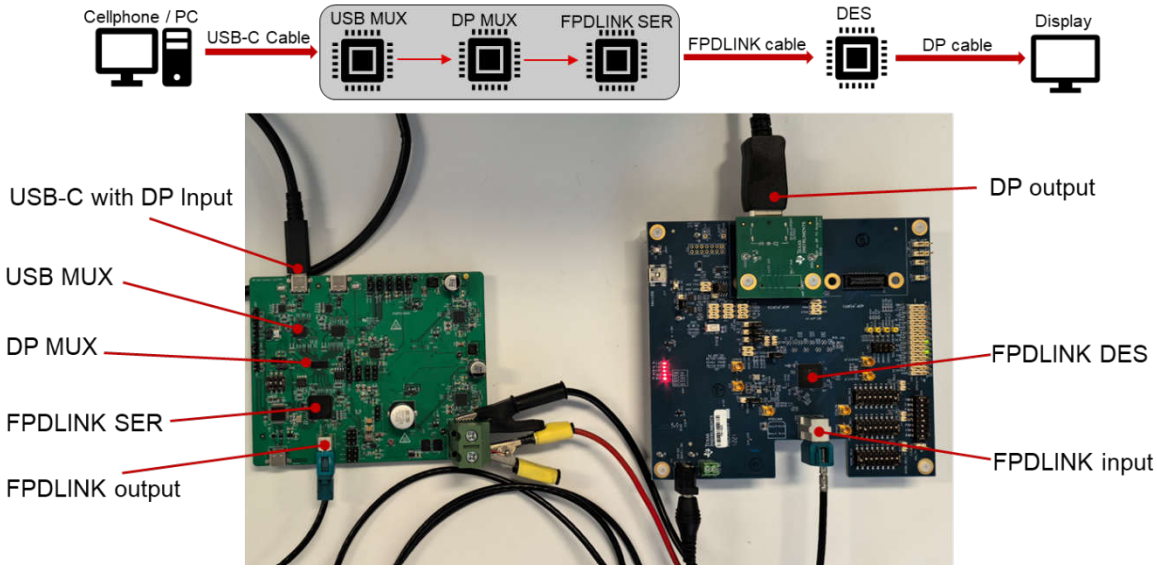


Figure 2-8. USB-C With DP ALT Mode - Signal Chain

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3 Summary

This reference design provides a validated, automotive-qualified solution for 140W two-port USB-C Power Delivery with simultaneous DisplayPort Alt Mode support over FPD-Link. The TPS26744E-Q1/LM51772 power path delivers efficient buck-boost conversion across the full 5V–28V output range, while the TUSB564-Q1/ TS3DV642/FPD-Link serializer video path preserves signal integrity for high-speed DisplayPort and USB 3.2 traffic. The design was validated end-to-end, including live display casting through the FPD-Link interface.

A few system-level considerations are worth noting for integration. Thermally, the boost MOSFET runs hottest under worst-case conditions (9V input, 28V output, 140W), reaching 100°C — the primary margin to watch in enclosed automotive environments. Systems expected to operate near this corner for extended periods should budget for power derating at high ambient temperature and low input voltage. More broadly, because the power and video paths share the same board and connector, system-level integration should account for their combined thermal and electrical interaction rather than treating each path in isolation.

Taken together, these results and considerations make this application note a complete reference for engineers designing automotive digital cockpit and infotainment systems around this architecture.

4 References

1. Texas Instruments, *TPS26744E-Q1 Automotive Dual-Port USB Type-C® PD Controller with 240W EPR and DisplayPort™ overUSB Type-C®*, datasheet.
2. Texas Instruments, *LM251772-Q1 Buck-boost Controller for USB-PD*, datasheet.
3. Texas Instruments, *TUSB564-Q1 Automotive USB Type-C® DP Alt Mode 8.1Gbps Sink-Side Linear Redriver Crosspoint Switch*, datasheet.

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