Test Report: PMP31344

Automotive, 12V Input, 140W Two-Port USB Power Delivery With DisplayPort™ Alt Mode Reference Design

Description

This reference design represents an automotive USB Extended Power Range (EPR) system, providing both power and digital communication to two USB Type-C® ports. When connecting a USB-C cable, the TPS26744E-Q1 negotiates a target output voltage and maximum current with the plugged-in device. The controller then enables and properly drives a buck boost controller (LM251772), that handles the power transfer.

From the communication side, the TPS26744E-Q1 can negotiate with the connected USB device, for example, cellphones or laptops for USB-DP mode selection. Then the display casting is enabled through USB multiplexer (MUX) (TUSB564-Q1), DP MUX (TS3DV642), and Flat Panel Display (FPD)-Link serializer.

Resources

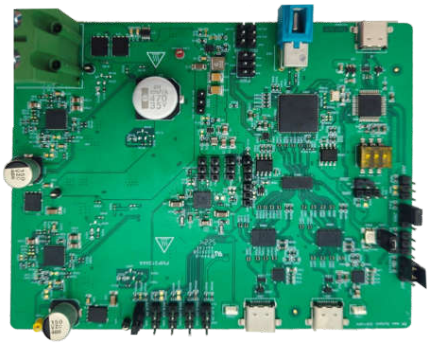
PMP31344	Design Folder
LM251772, TPS26744E-Q1, LM74500-Q1	Product Folder
TPS628501-Q1, TLV713P-Q1, LMR60430-Q1	Product Folder
TUSB8020B-Q1, TPD4E02B04-Q1, TS3DV642	Product Folder
TUSB564-Q1, TPD4S481-Q1	Product Folder
SN74LVC1G32-Q1, TPD2E2U06-Q1	Product Folder

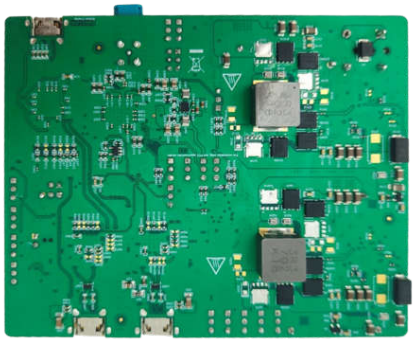
Features

- 12V battery system
- Dual ports USB PD charging, 140W per port
- Supports USB DP ALT mode
- DP to FPD-Link bridge to support remote display casting

Applications

- Automotive USB charging
- Automotive media hub
- Digital cockpit processing unit





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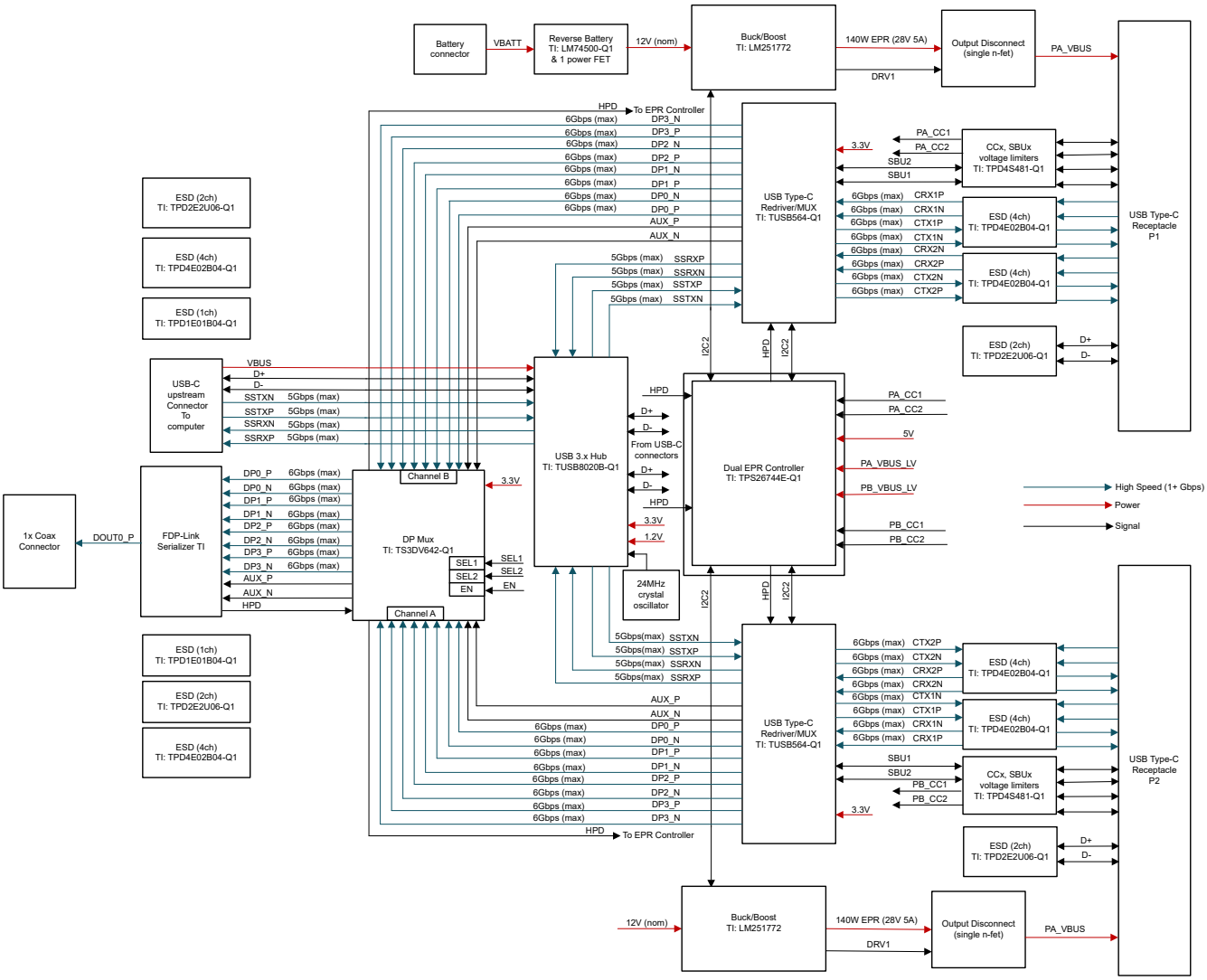

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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Table Voltage and Current Requirements

Parameters	Specifications
V_{IN}	9V to 20V
V_{OUT}	5V to 28V
I_{OUT}	5A

1.2 Dimensions

The board dimension is 122.23mm × 97.65mm.

1.3 Precautions

WARNING

Board surface is hot. Do not touch. Contact can cause burns.

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2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1. In the efficiency graph, 88mA were subtracted to the measured input current. This value represents the board quiescent current when V_{in} is supplied and LM251772 is disabled.

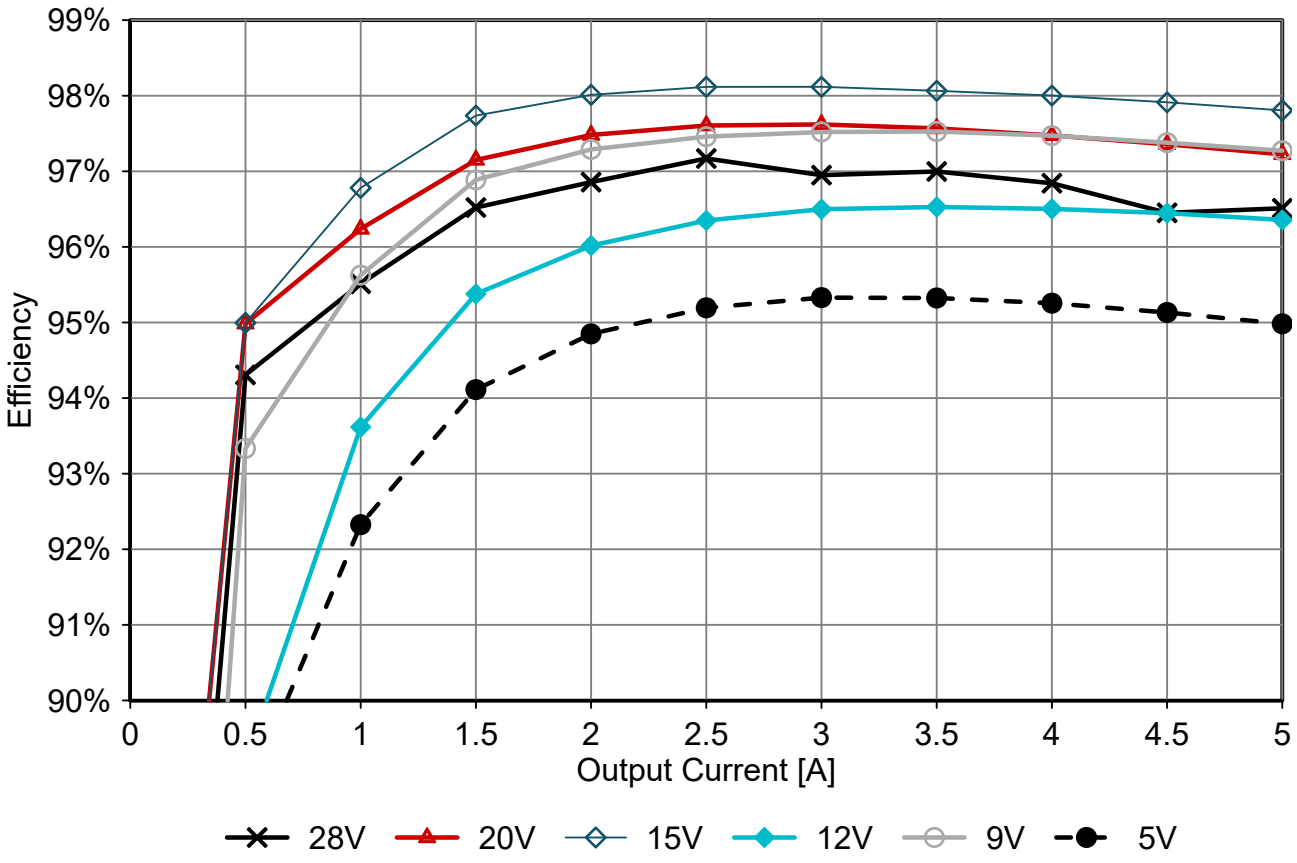

Figure 2-1. Efficiency Graph at 12V Input

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2.2 Efficiency Data

Efficiency data is shown in

- 28V Output Voltage
- 20V Output Voltage
- 15V Output Voltage
- 12V Output Voltage
- 9V Output Voltage
- 5V Output Voltage

2.2.1 28V Output Voltage

Table 2-1. Table Efficiency Data for 28V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.29	27.91	0.10	3.48	2.79	0.69	80.2%
12.00	1.23	27.91	0.50	14.80	13.95	0.84	94.3%
12.00	2.43	27.90	1.00	29.22	27.90	1.31	95.5%
12.00	3.61	27.91	1.50	43.37	41.86	1.51	96.5%
12.00	4.80	27.91	2.00	57.63	55.82	1.81	96.9%
12.00	6.00	27.91	2.51	71.95	69.91	2.04	97.2%
12.00	7.20	27.91	3.00	86.36	83.73	2.63	96.9%
12.00	8.41	27.91	3.51	100.85	97.83	3.03	97.0%
12.00	9.62	27.91	4.01	115.43	111.78	3.64	96.8%
12.01	10.65	27.91	4.42	127.91	123.37	4.54	96.5%
11.96	12.12	27.91	5.01	144.89	139.84	5.05	96.5%

2.2.2 20V Output Voltage

Table 2-2. Table Efficiency Data for 20V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.20	19.95	0.10	2.42	2.00	0.43	82.4%
12.00	0.88	19.95	0.50	10.50	9.98	0.53	95.0%
12.00	1.73	19.95	1.00	20.73	19.95	0.78	96.2%
12.00	2.57	19.95	1.50	30.81	29.93	0.88	97.2%
12.00	3.41	19.95	2.00	40.94	39.91	1.03	97.5%
12.00	4.26	19.95	2.50	51.11	49.88	1.22	97.6%
12.00	5.11	19.95	3.00	61.32	59.86	1.46	97.6%
12.00	5.97	19.95	3.50	71.58	69.83	1.74	97.6%
12.00	6.82	19.95	4.00	81.88	79.82	2.07	97.5%
12.00	7.69	19.95	4.50	92.23	89.79	2.44	97.4%
12.00	8.55	19.95	5.00	102.62	99.77	2.85	97.2%

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2.2.3 15V Output Voltage

Table 2-3. Table Efficiency Data for 15V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.15	14.98	0.10	1.82	1.50	0.32	82.4%
12.00	0.66	14.98	0.50	7.88	7.49	0.39	95.0%
12.00	1.29	14.97	1.00	15.47	14.97	0.50	96.8%
12.00	1.92	14.98	1.50	22.98	22.46	0.52	97.7%
12.00	2.55	14.97	2.00	30.56	29.95	0.61	98.0%
12.00	3.18	14.97	2.50	38.15	37.44	0.72	98.1%
12.00	3.82	14.97	3.00	45.79	44.92	0.86	98.1%
12.00	4.45	14.97	3.50	53.44	52.41	1.03	98.1%
12.00	5.09	14.97	4.00	61.12	59.90	1.22	98.0%
12.00	5.74	14.97	4.50	68.82	67.38	1.44	97.9%
12.00	6.38	14.97	5.00	76.55	74.87	1.68	97.8%

2.2.4 12V Output Voltage

Table 2-4. Table Efficiency Data for 12V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.15	11.99	0.10	1.83	1.20	0.63	65.5%
12.00	0.56	11.99	0.50	6.72	5.99	0.73	89.2%
12.00	1.07	11.99	1.00	12.81	11.99	0.82	93.6%
12.00	1.57	11.99	1.50	18.86	17.98	0.87	95.4%
12.00	2.08	11.99	2.00	24.97	23.98	0.99	96.0%
12.00	2.59	11.99	2.50	31.11	29.97	1.14	96.3%
12.00	3.11	11.99	3.00	37.27	35.97	1.31	96.5%
12.00	3.62	11.99	3.50	43.47	41.96	1.51	96.5%
12.00	4.14	11.99	4.00	49.70	47.96	1.74	96.5%
12.00	4.66	11.99	4.50	55.94	53.95	1.99	96.4%
12.00	5.18	11.99	5.00	62.21	59.95	2.27	96.4%

2.2.5 9V Output Voltage

Table 2-5. Table Efficiency Data for 9V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.10	9.00	0.10	1.18	0.90	0.28	76.1%
12.00	0.40	9.00	0.50	4.82	4.50	0.32	93.3%
12.00	0.78	9.00	1.00	9.42	9.00	0.41	95.6%
12.00	1.16	9.00	1.50	13.94	13.51	0.43	96.9%
12.00	1.54	9.00	2.00	18.51	18.01	0.50	97.3%
12.00	1.92	9.00	2.50	23.09	22.51	0.59	97.5%
12.00	2.31	9.00	3.00	27.70	27.01	0.69	97.5%
12.00	2.69	9.00	3.50	32.31	31.51	0.80	97.5%
12.00	3.08	9.00	4.00	36.95	36.01	0.93	97.5%
12.00	3.47	9.00	4.50	41.60	40.51	1.09	97.4%
12.00	3.86	9.00	5.00	46.28	45.01	1.26	97.3%

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2.2.6 5V Output Voltage

Table 2-6. Table Efficiency Data for 5V Output Voltage

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.07	5.01	0.10	0.78	0.50	0.28	63.9%
12.00	0.24	5.01	0.50	2.82	2.51	0.32	88.7%
12.00	0.45	5.01	1.00	5.43	5.01	0.42	92.3%
12.00	0.67	5.01	1.50	7.99	7.52	0.47	94.1%
12.00	0.88	5.01	2.00	10.56	10.02	0.54	94.8%
12.00	1.10	5.01	2.50	13.16	12.53	0.63	95.2%
12.00	1.31	5.01	3.00	15.77	15.03	0.74	95.3%
12.00	1.53	5.01	3.50	18.40	17.54	0.86	95.3%
12.00	1.75	5.01	4.00	21.04	20.04	1.00	95.3%
12.00	1.97	5.01	4.50	23.69	22.54	1.15	95.1%
12.00	2.20	5.01	5.00	26.37	25.05	1.32	95.0%

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2.3 Thermal Images

2.3.1 Buck Mode

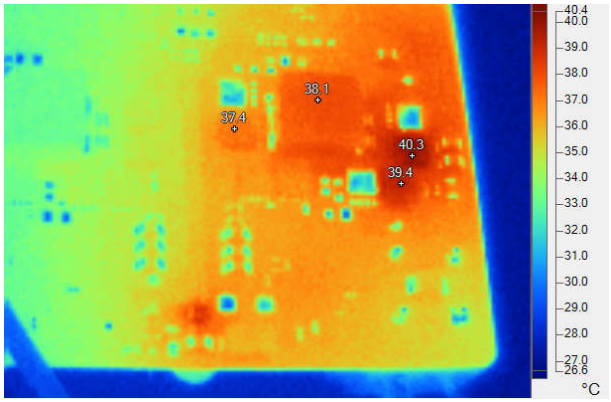

Figure 2-2. Thermal Image at 12V_{in}, 5V_{out}, 5A – 25W (Boost Rectifier 37ºC, Inductor 38ºC, Buck Mosfet 40ºC, Buck Rectifier 39ºC)

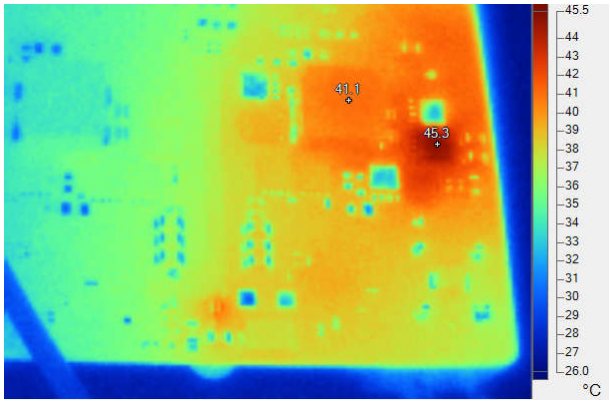

Figure 2-3. Thermal Image at 20V_{in}, 5V_{out}, 5A – 25W (Inductor 41ºC, Buck Mosfet 45ºC)

2.3.2 Boost Mode

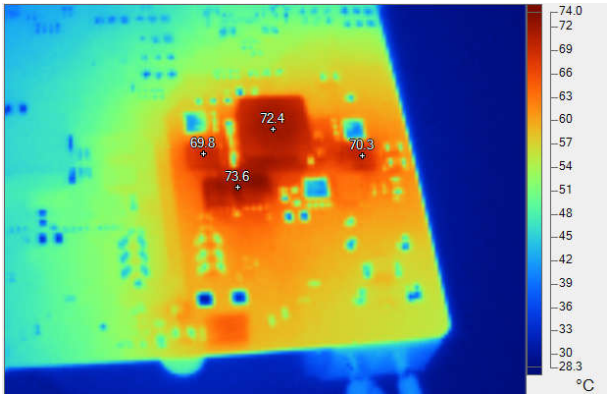

Figure 2-4. Thermal Image at 12V_{in}, 28V_{out}, 5A – 140W (Boost Mosfets 74ºC, Inductor 72ºC, Buck Mosfet 70ºC)

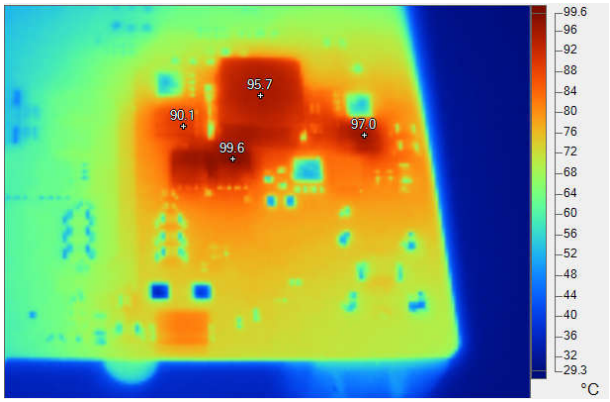

Figure 2-5. Thermal Image at 9V_{in}, 28V_{out}, 5A – 140W (Boost Mosfets 100ºC, Inductor 96ºC, Buck Mosfet 97ºC)

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2.4 Bode Plots

Bode plots are shown in Figure 2-6 through Figure 2-9.

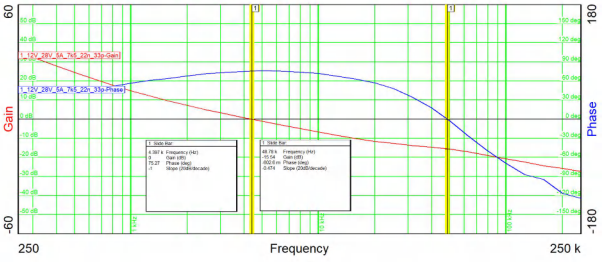

Figure 2-6. V_{in}, 28V_{out}, 5A Load Current: fco 4.4kHz, 75º Phase Margin, -15.5dB Gain Margin

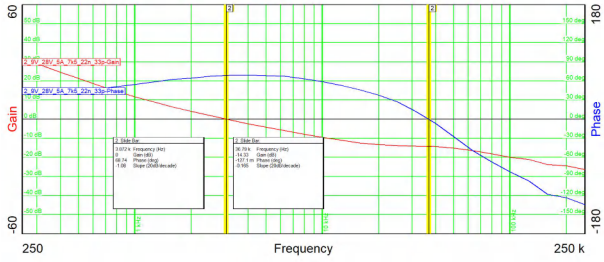

Figure 2-7. V_{in}, 28V_{out}, 5A Load Current: fco 3kHz, 68º Phase Margin, -14.3dB Gain Margin

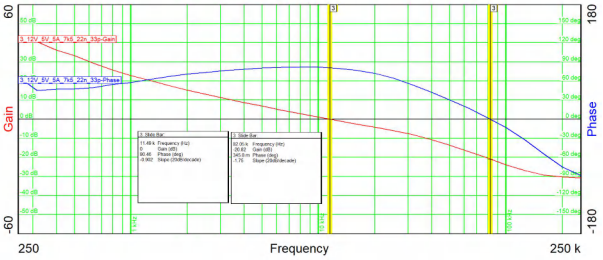

Figure 2-8. V_{in}, 5V_{out}, 5A Load Current: fco 11.5kHz, 80º Phase Margin, -20dB Gain Margin

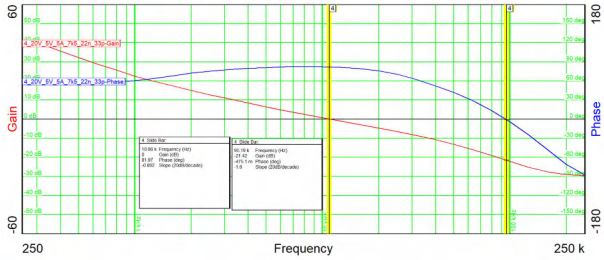

Figure 2-9. V_{in}, 5V_{out}, 5A Load Current: fco 10.8kHz, 82º Phase Margin, -21dB Gain Margin

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2.5 Digital Communications: USB-C With DP ALT Mode

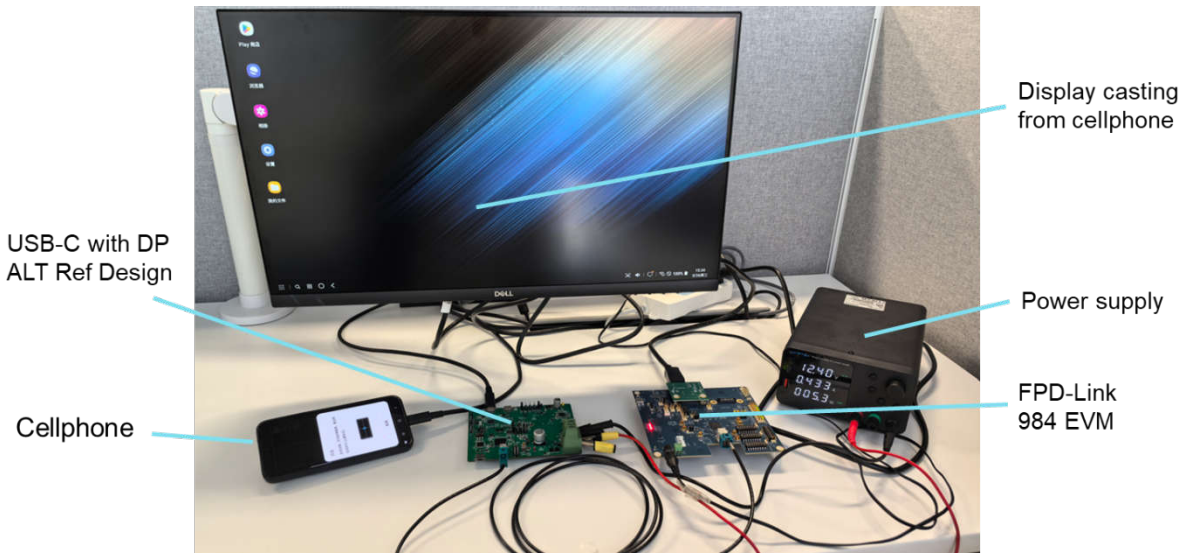

Figure 2-10. USB-C With DP ALT Mode – Setup

The system topology includes the USB-C with DP ALT mode ref board (TPS26744E, TUSB564, TS3DV642, FPD-Link Serializer) and a UH984 EVM connected to a display:

- Firmware is programmed to TPS26744E for PD communication and USB/DP mode selection over CC line
- The firmware is programmed to FPD-Link Serializer external SPI Flash
- The register configurations are programmed into both FPD-Link serializer and de-serializer
- Connect cellphone/laptop through USB Type-C for display casting

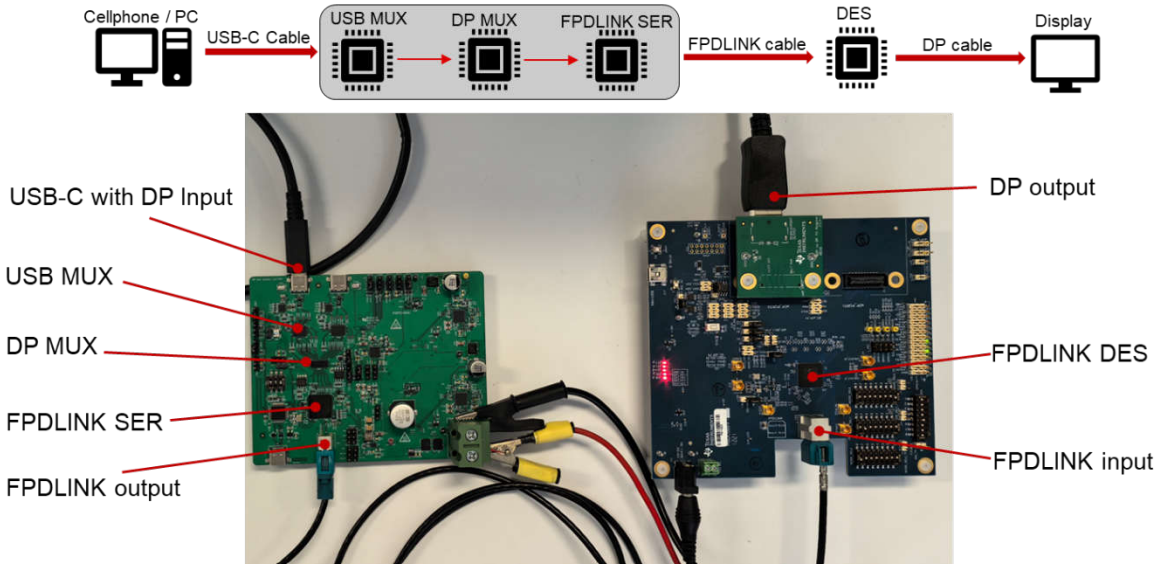

Figure 2-11. USB-C With DP ALT Mode - Signal Chain

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3 Waveforms

3.1 Switching

Switching behavior is shown in Figure 3-1 through Figure 3-4.

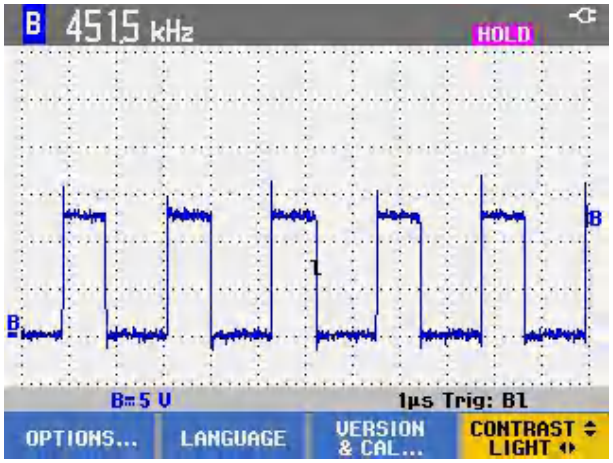

Figure 3-1. CHB: Buck Switching Node at $12V_{in}$, $5V_{out}$ and 5A Load Current [Scale: 5V/div, 1us/div]

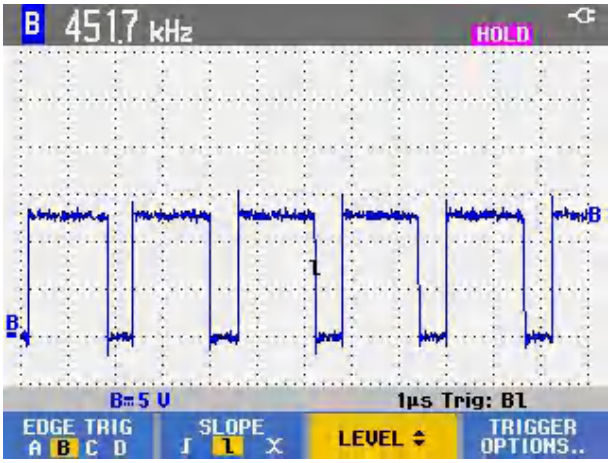

Figure 3-2. CHB: Buck Switching Node at $12V_{in}$, $9V_{out}$ and 5A Load Current [Scale: 5V/div, 1us/div]

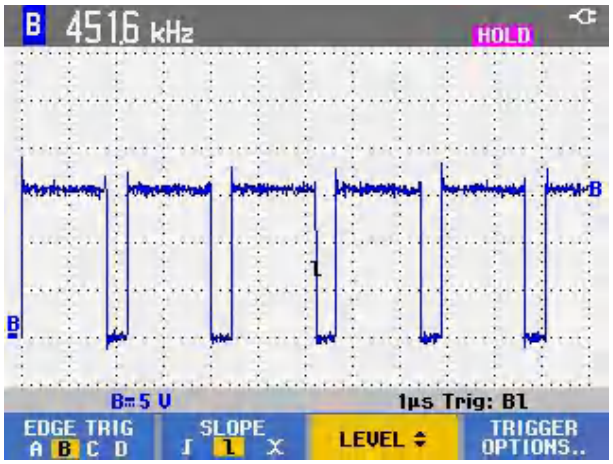

Figure 3-3. CHB Boost Switching Node at $12V_{in}$, $15V_{out}$ and 5A Load Current [Scale: 5V/div, 1us/div]

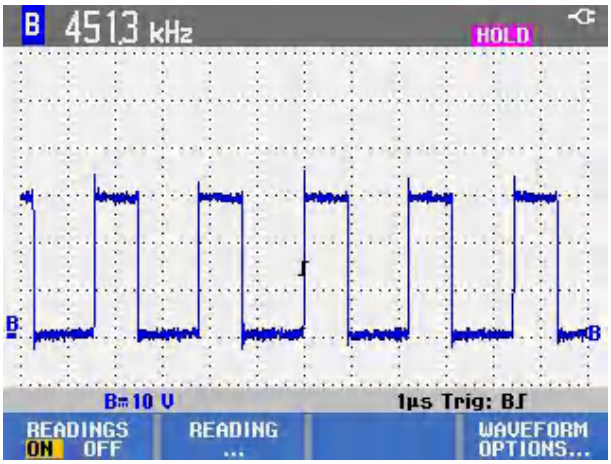

Figure 3-4. CHB Boost Switching Node at $12V_{in}$, $28V_{out}$ and 5A Load Current [Scale: 5V/div, 1us/div]

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3.2 Output Voltage Ripple

Output voltage ripple is shown in Figure 3-5 through Figure 3-8.

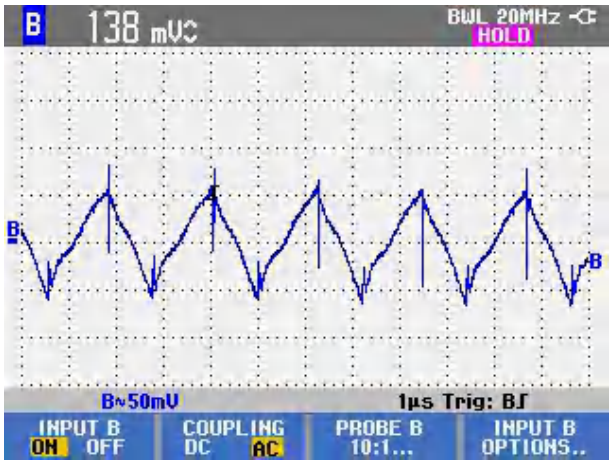

Figure 3-5. CHB: DC-Coupled Input Voltage at $12V_{in}$, $5V_{out}$, 5A Load, BW Limited (20MHz) [Scale: 50mV/div, 1us/div]

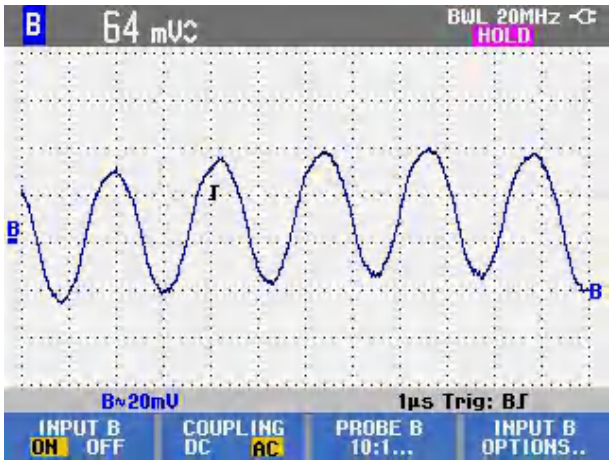

Figure 3-6. CHB: DC-Coupled Input Voltage at $12V_{in}$, $28V_{out}$, 5A Load, BW Limited (20MHz) [Scale: 20mV/div, 1us/div]

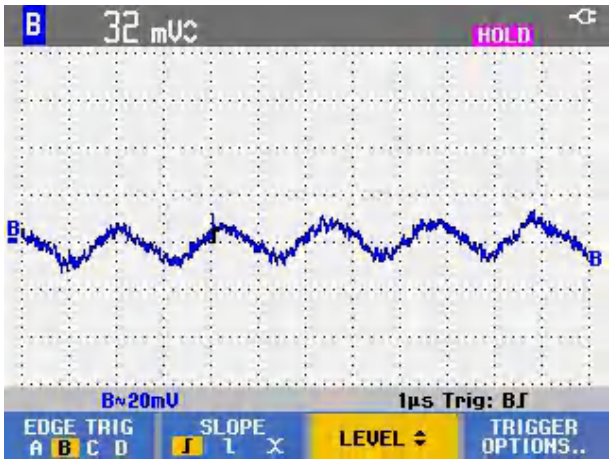

Figure 3-7. CHB: DC-Coupled Output Voltage at $12V_{in}$, $5V_{out}$, 5A Load [Scale: 20mV/div, 1us/div]

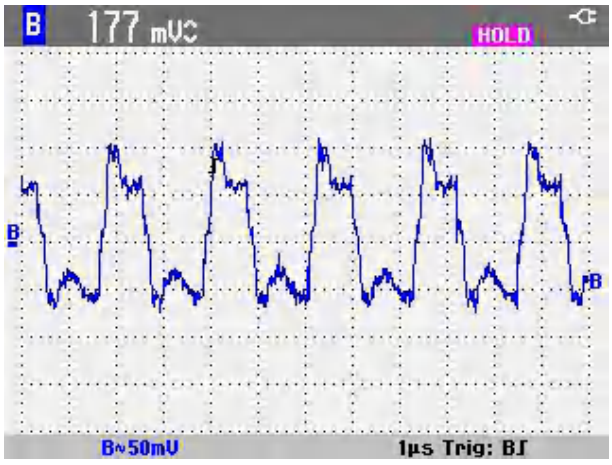

Figure 3-8. CHB: DC-Coupled Output Voltage at $12V_{in}$, $28V_{out}$, 5A Load [Scale: 50mV/div, 1us/div]

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3.3 Load Transients

Load transient response is shown in Figure 3-9 through Figure 3-12.

- CHB: AC-coupled output voltage
- CHC: Output current

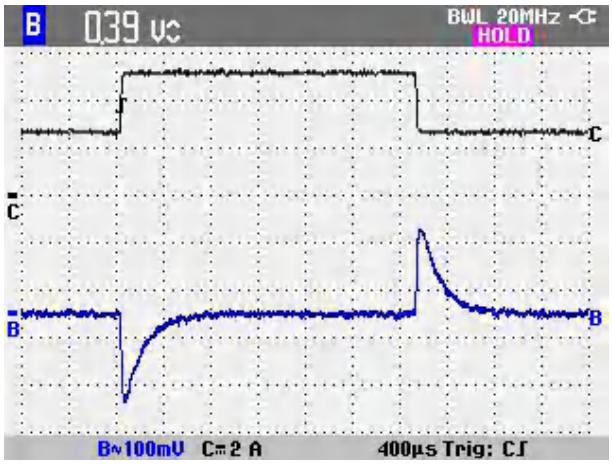

Figure 3-9. Load Transient 2.5A to 5A, $12V_{in}$, $5V_{out}$

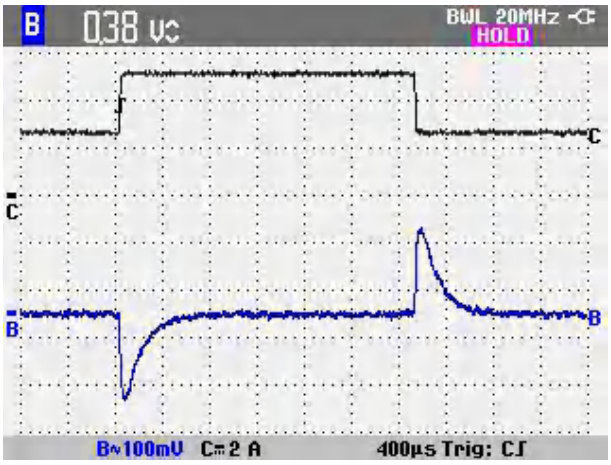

Figure 3-10. Load Transient 2.5A to 5A, $12V_{in}$, $9V_{out}$

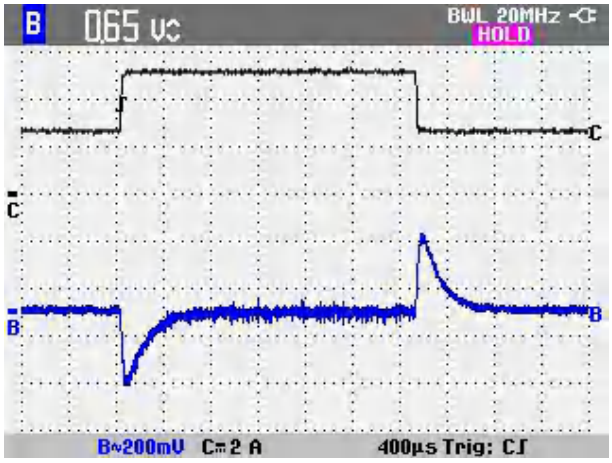

Figure 3-11. Load Transient 2.5A to 5A, $12V_{in}$, $15V_{out}$

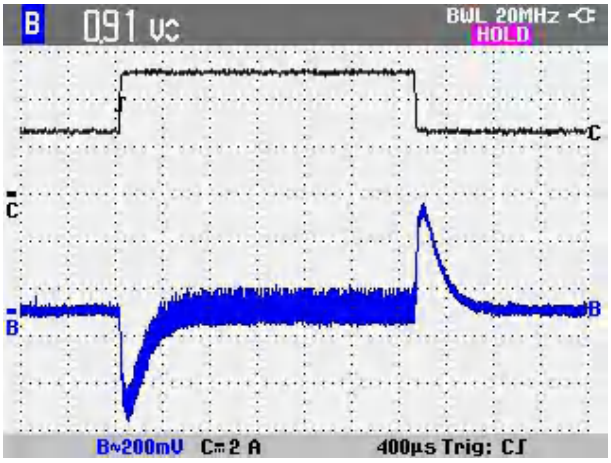

Figure 3-12. Load Transient 2.5A to 5A, $12V_{in}$, $28V_{out}$

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