Test Report: PMP40934

CISPR 25, Class 5, 400-kHz-Rated, 60-W Automotive, Single USB Type-C PD Charger Reference Design

Description

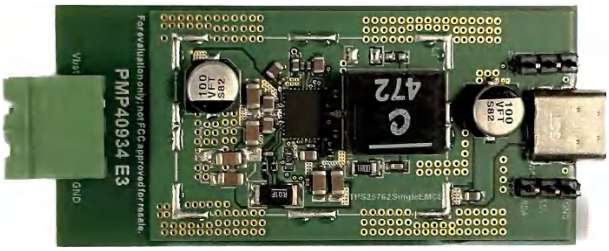
This reference design is an EMI-optimized design for an automotive USB Type-C® power delivery (PD) charger with a single output. The TPS25762-Q1 is used as DC-DC regulator and port controller. The PCB layout is optimized to pass stringent CISPR 25 Class 5 Conducted Electromagnetic Interference (EMI) standards. This reference design has already been tested to CISPR 25 Class 5 conducted EMI standards, which accelerates customer design time.

Features

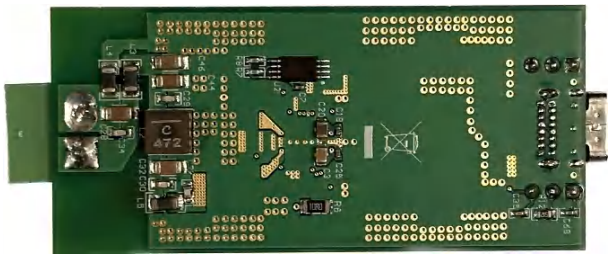
- Compliant to CISPR 25 Class 5 EMI standard
- High efficiency with 95.78% peak efficiency
- Cost-efficient without common-mode inductor

Applications

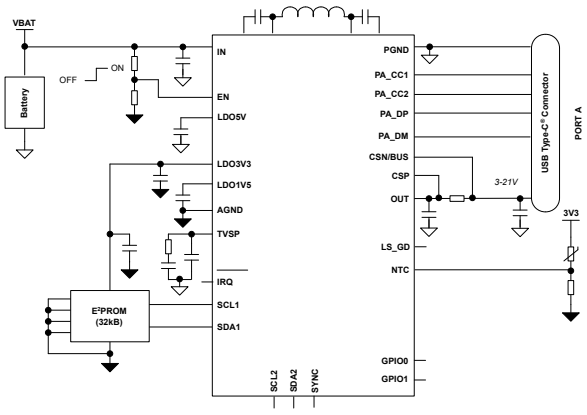
- Automotive USB charge



Board Photo (Top)



Board Photo (Bottom)



Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

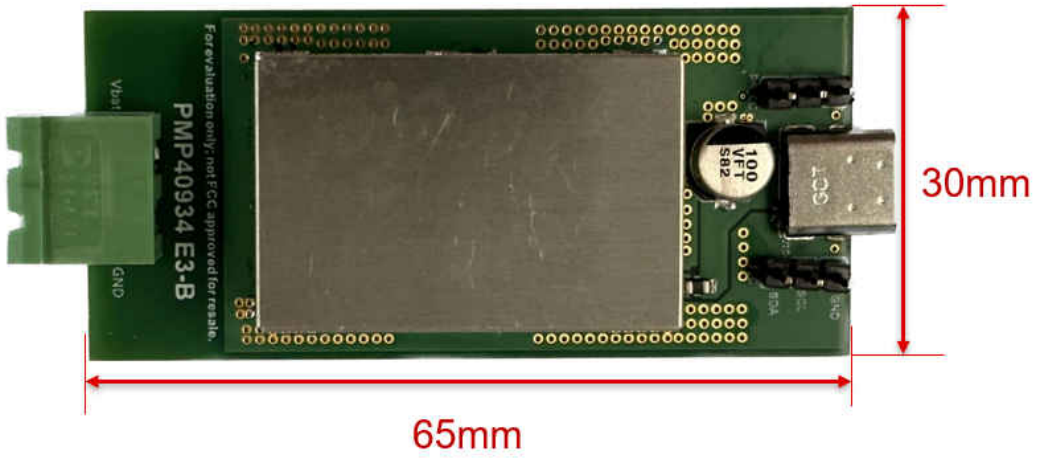
Parameter	Specifications
Input Voltage	13.5 Vdc
PA_BUS Output Voltage	5 VDC, 9 VDC, 15 VDC, 20 VDC
PA_BUS Maximum Output Current	3 A
Switching Frequency	400 kHz

1.2 Required Equipment

- Multimeter (current): Fluke 287C
- Multimeter (voltage): Fluke 287C
- DC Source: Chroma 62006P-100-25
- E-Load: Chroma 63103A module
- Oscilloscope: Tektronix DPO4104B
- Electrical Thermography: Fluke TiS55
- Thermal Data Acquisition: Agilent 34970A

1.3 Dimensions

The board dimensions are 65 mm (length) × 30 mm (width) × 10 mm (height, ignore J1).



The board image as represented here is not actual size.

Figure 1-1. Board Dimensions

2 Testing and Results

2.1 Efficiency Graphs

The following image shows the efficiency graph.

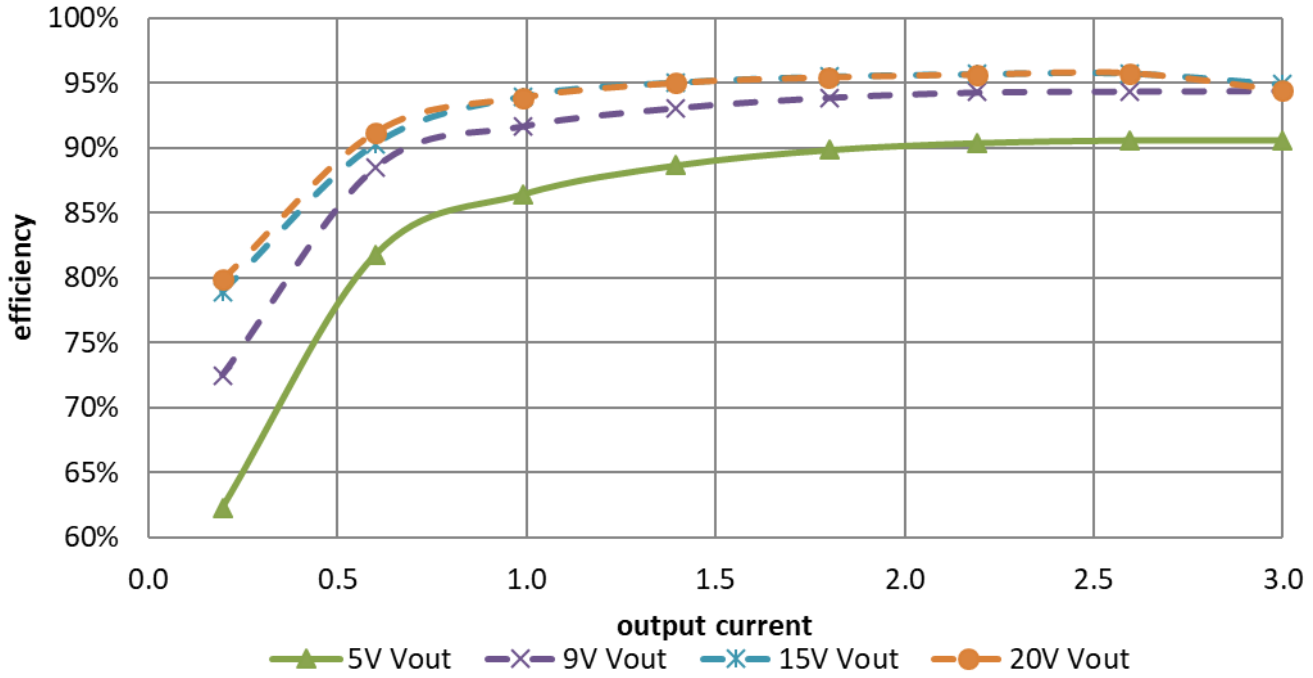


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

V_{IN} (V)	I_{IN} (A)	P_{IN}(W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(W)	Efficiency
13.503	0.117	1.580	4.9967	0.1969	0.984	62.28%
13.496	0.272	3.671	4.9967	0.6009	3.003	81.80%
13.488	0.425	5.733	4.9964	0.9919	4.956	86.45%
13.481	0.583	7.859	4.9956	1.395	6.969	88.67%
13.474	0.743	10.011	4.9951	1.8009	8.996	89.86%
13.466	0.899	12.106	4.9946	2.1909	10.943	90.39%
13.459	1.063	14.307	4.9939	2.5959	12.964	90.61%
13.451	1.229	16.531	4.9933	3.0000	14.980	90.61%
13.516	0.181	2.446	9.0019	0.1969	1.772	72.45%
13.507	0.453	6.119	8.9987	0.6019	5.416	88.52%
13.497	0.721	9.731	8.9957	0.9919	8.923	91.69%
13.487	0.999	13.474	8.9913	1.3950	12.543	93.09%
13.477	1.279	17.237	8.9875	1.8009	16.186	93.90%
13.467	1.549	20.860	8.9830	2.1900	19.673	94.31%
13.457	1.835	24.694	8.9788	2.5959	23.308	94.39%
13.447	2.121	28.521	8.9746	3.0009	26.932	94.43%
13.512	0.277	3.743	14.9967	0.1969	2.953	78.89%
13.496	0.739	9.974	14.9920	0.6009	9.009	90.33%

V_{IN} (V)	I_{IN} (A)	P_{IN}(W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(W)	Efficiency
13.481	1.172	15.800	14.9880	0.9909	14.852	94.00%
13.464	1.633	21.987	14.9837	1.3950	20.902	95.07%
13.447	2.099	28.225	14.9790	1.8000	26.962	95.53%
13.431	2.551	34.262	14.9750	2.1900	32.795	95.72%
13.413	3.024	40.561	14.9703	2.5950	38.848	95.78%
13.515	3.500	47.303	14.9648	3.0000	44.894	94.91%
13.508	0.363	4.903	19.9907	0.1959	3.916	79.87%
13.486	0.975	13.149	19.9867	0.6000	11.992	91.20%
13.465	1.565	21.073	19.9827	0.9900	19.783	93.88%
13.443	2.181	29.319	19.9784	1.3941	27.852	95.00%
13.420	2.806	37.657	19.9736	1.7991	35.935	95.43%
13.398	3.413	45.727	19.9700	2.1900	43.734	95.64%
13.373	4.048	54.134	19.9662	2.5960	51.832	95.75%
13.514	4.693	63.421	19.9614	3.0000	59.884	94.42%

2.3 Thermal Images

The following figures show the thermal images. The ambient temperature is 25°C, and the thermal images were taken with 13.5-V input and the output at a full load of 3 A. The controller was operated for approximately 30 minutes before thermal images were taken to make sure the thermal steady state was reached. The board uses 4-layer PCB, the top and bottom layers of copper are 2 oz, and the middle layers of copper are 1oz.

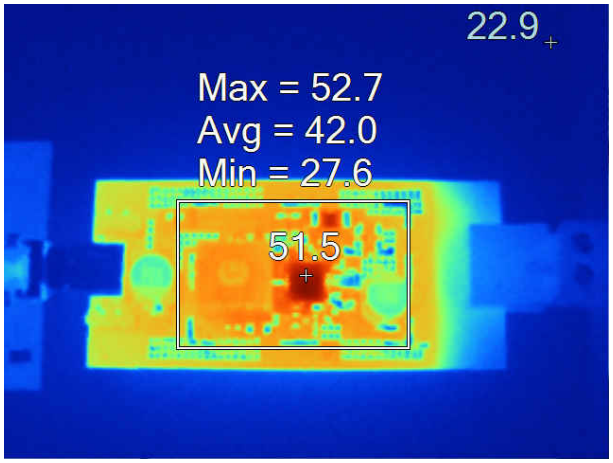


Figure 2-2. Top Side Thermal Image, 5-V, 3-A Load

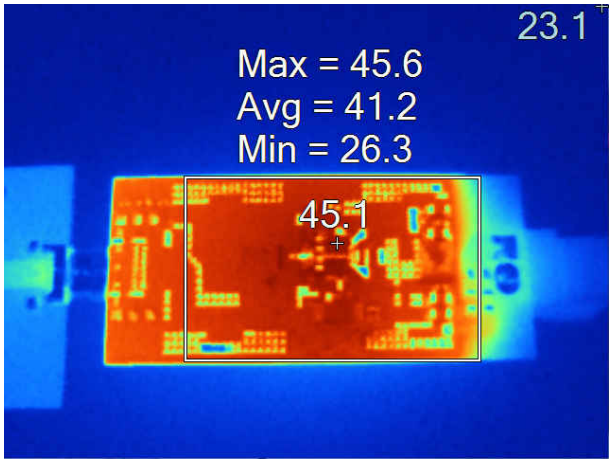


Figure 2-3. Bottom Side Thermal Image, 5-V, 3-A Load

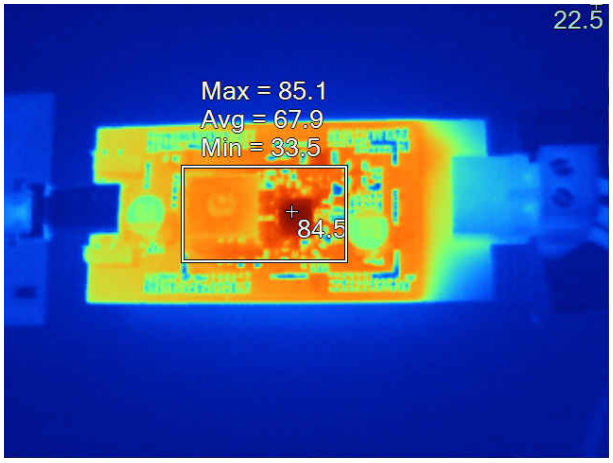


Figure 2-4. Top Side Thermal Image, 20-V, 3-A Load

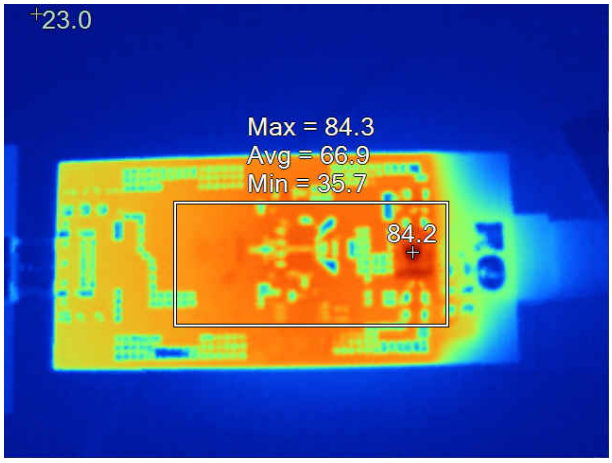


Figure 2-5. Bottom Side Thermal Image, 20-V, 3-A Load

2.4 Bode Plots

Table 2-1. Phase Margin and Gain Margin

V_{IN}	V_{OUT}	Phase Margin (°)	Gain Margin (dB)
9 V	5 V	68.989	14.606
9 V	9 V	57.768	10.269
9 V	15 V	52.433	11.264
13.5 V	5 V	71.098	15.637
13.5 V	9 V	66.037	14.908
13.5 V	15 V	61.061	8.555
13.5 V	20 V	58.445	10.692
16 V	5 V	71.659	15.843
16 V	9 V	68.851	14.14
16 V	15 V	64.409	11.835
16 V	20 V	59.821	8.923

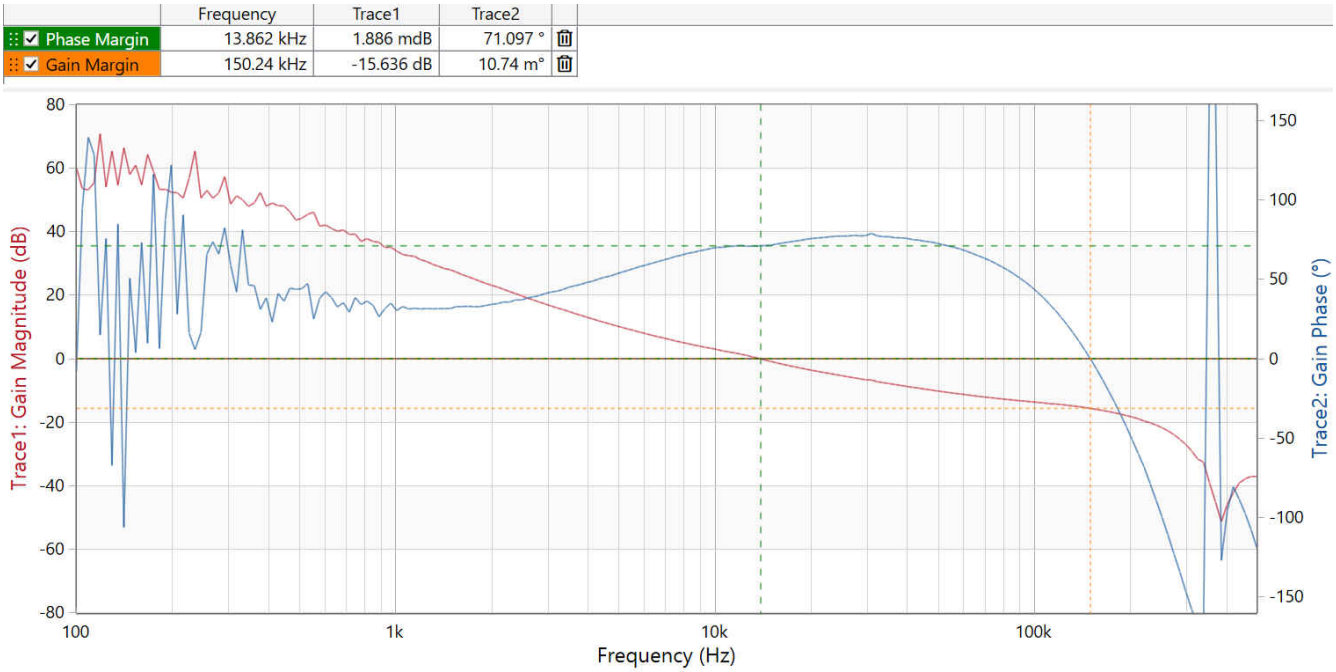


Figure 2-6. Bode Plot, 13.5-V Input, 5-V, 3-A Load

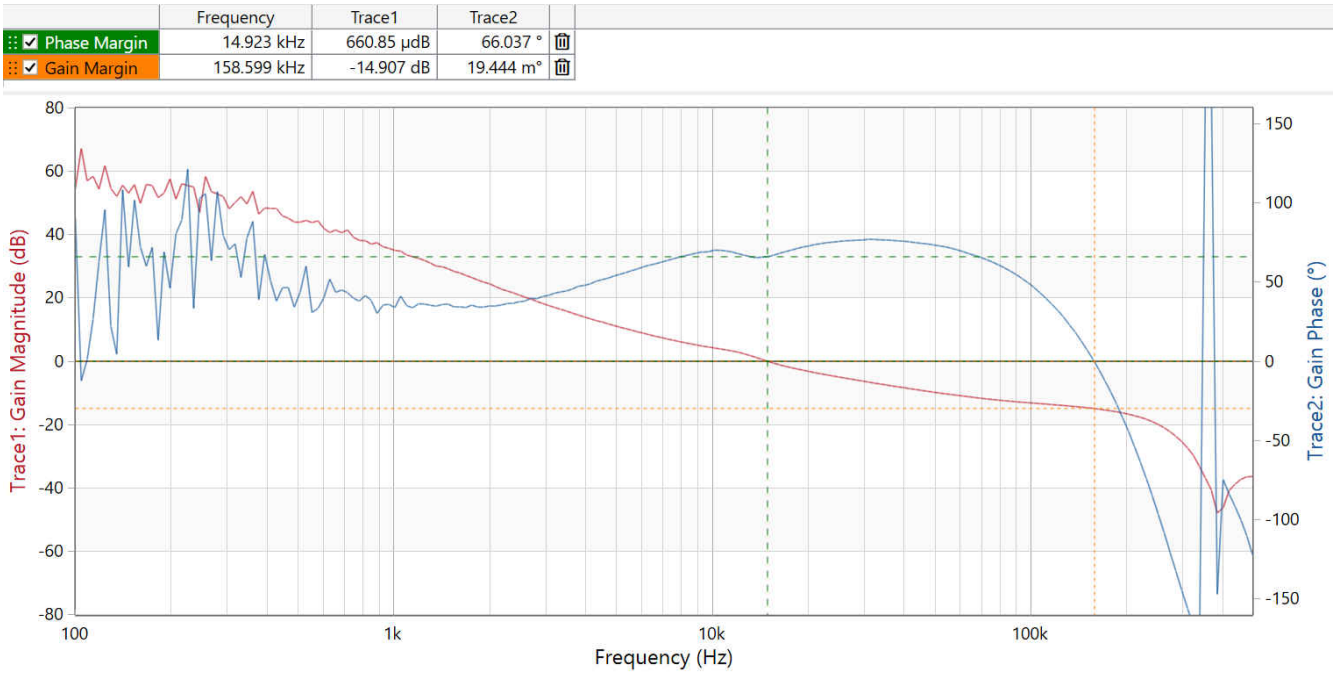


Figure 2-7. Bode Plot, 13.5-V Input, 9-V, 3-A Load

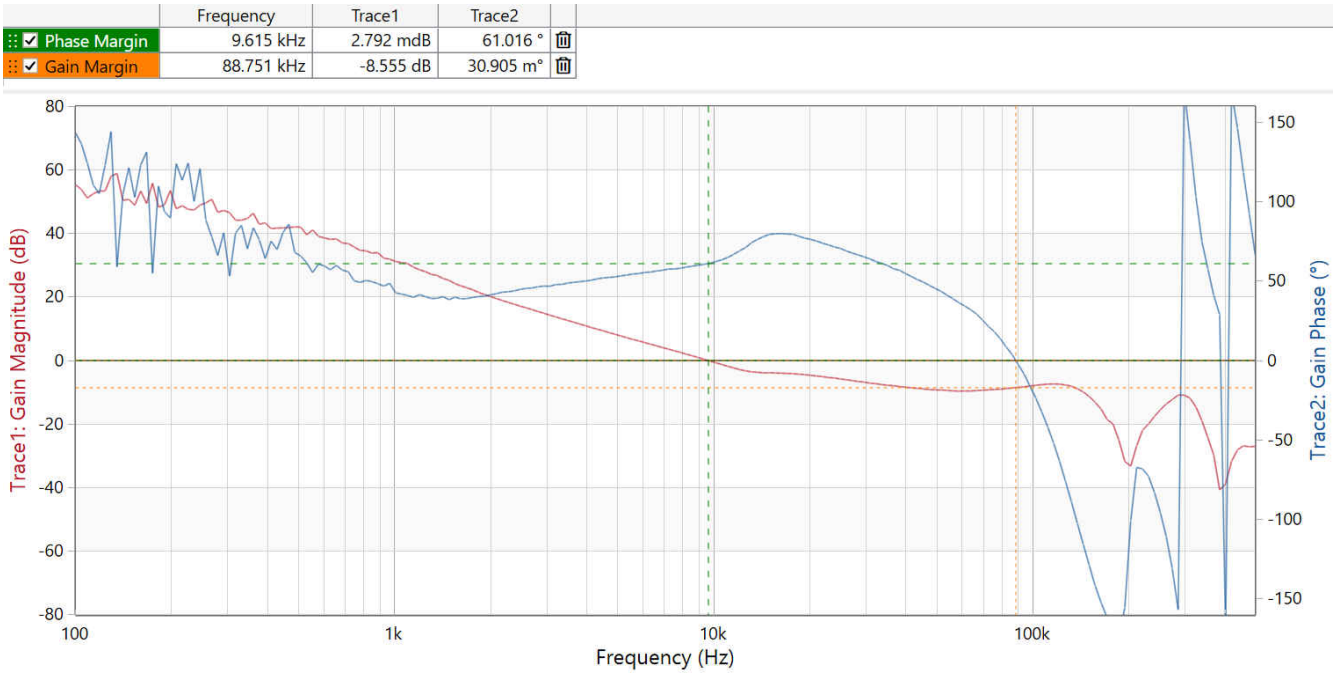


Figure 2-8. Bode Plot, 13.5-V Input, 15-V, 3-A Load

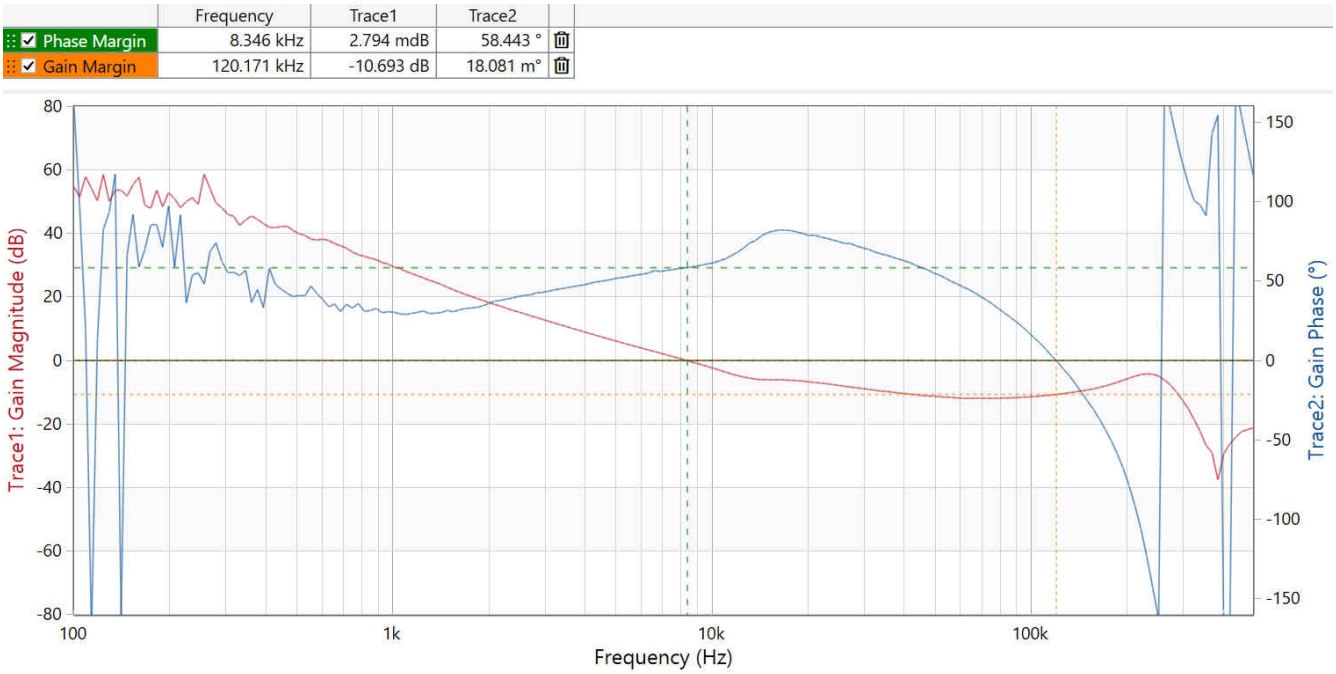


Figure 2-9. Bode Plot, 13.5-V Input, 20-V, 3-A Load

2.5 EMI

The conducted emissions are tested to the CISPR 25 class 5 standards. The CISPR 25 class-5 compliance was achieved without a common-mode choke. The waveforms of EMI test results are shown in following pictures.

The following images illustrate the EMI performance from 150 kHz to 108 MHz. Additionally, in every image:
Line 1: CISPR 25 Class 5 peak limits; Line 2: CISPR 25 Class 5 average limits;
Line 3: Peak detection result; Line 4: Average detection result.

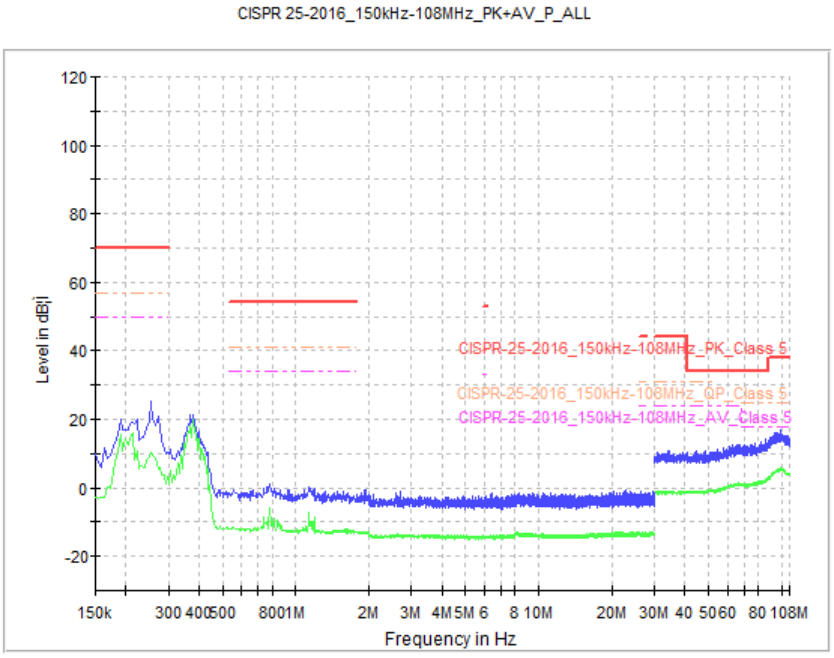


Figure 2-10. EMI Performance, 13.5-V Input, 5-V, 3-A Load, Positive Line

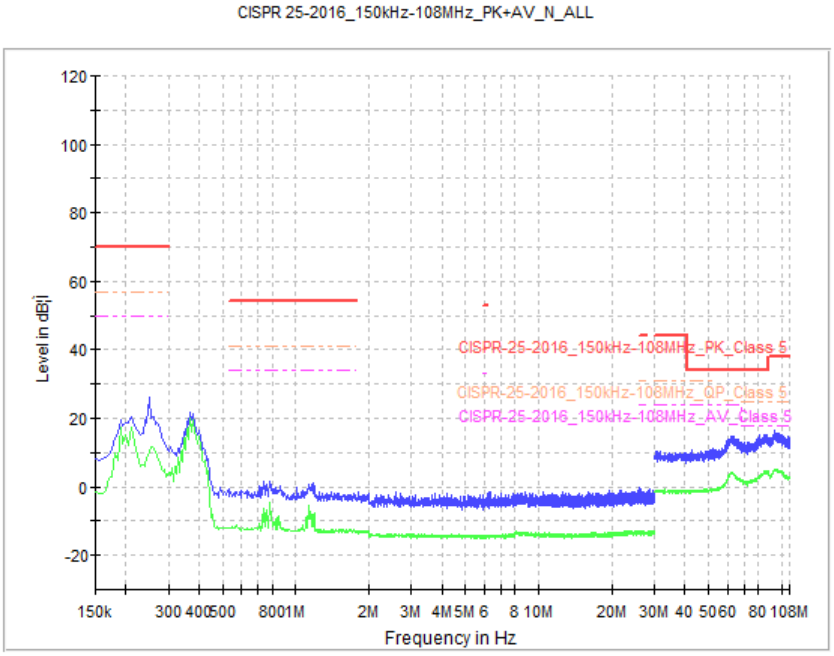


Figure 2-11. EMI Performance, 13.5-V Input, 5-V, 3-A Load, Negative Line

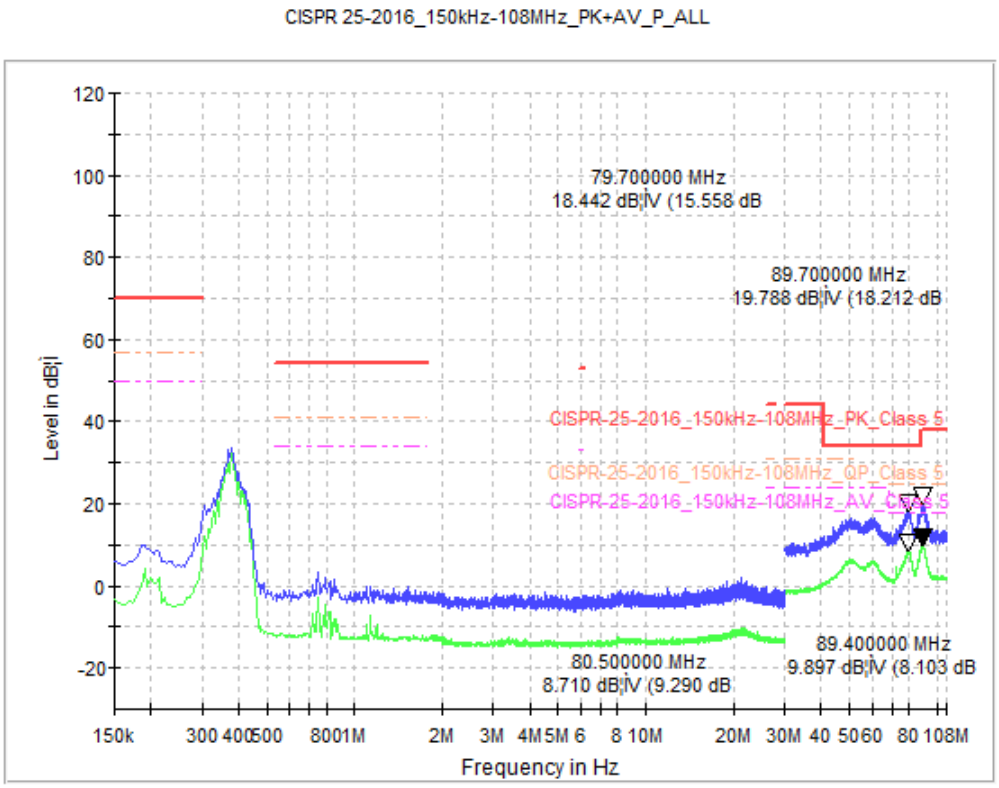


Figure 2-12. EMI Performance, 13.5-V Input, 9-V, 3-A Load, Positive Line

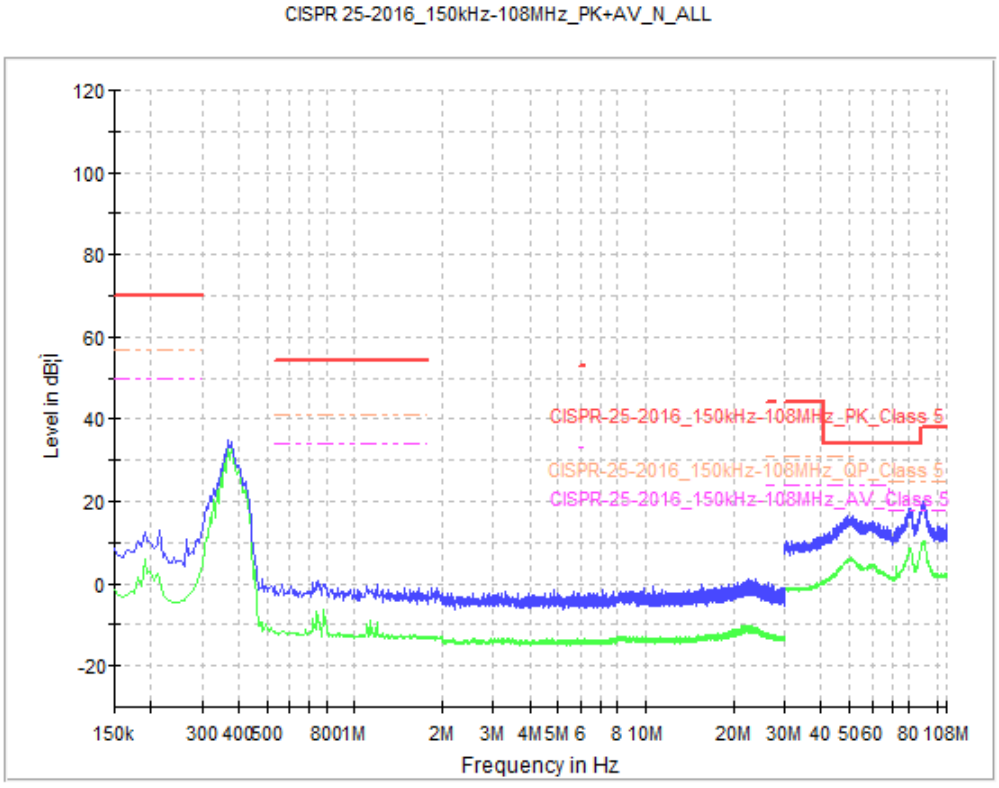


Figure 2-13. EMI Performance, 13.5-V Input, 9-V, 3-A Load, Negative Line

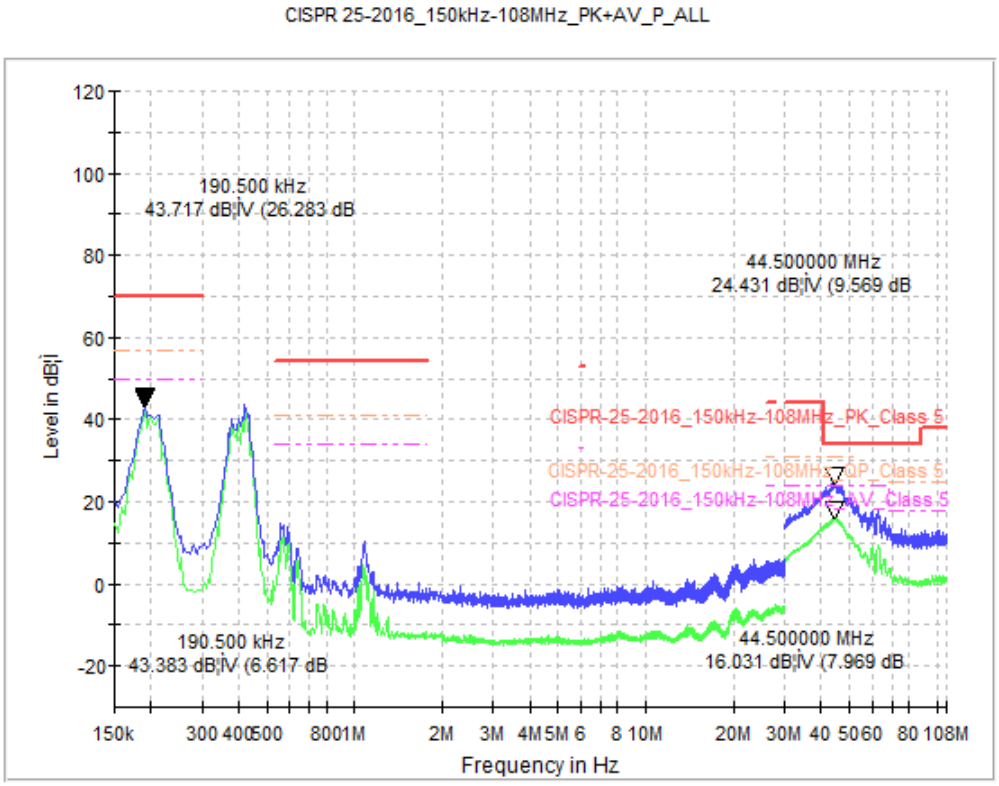


Figure 2-14. EMI Performance, 13.5-V Input, 15-V, 3-A Load, Positive Line

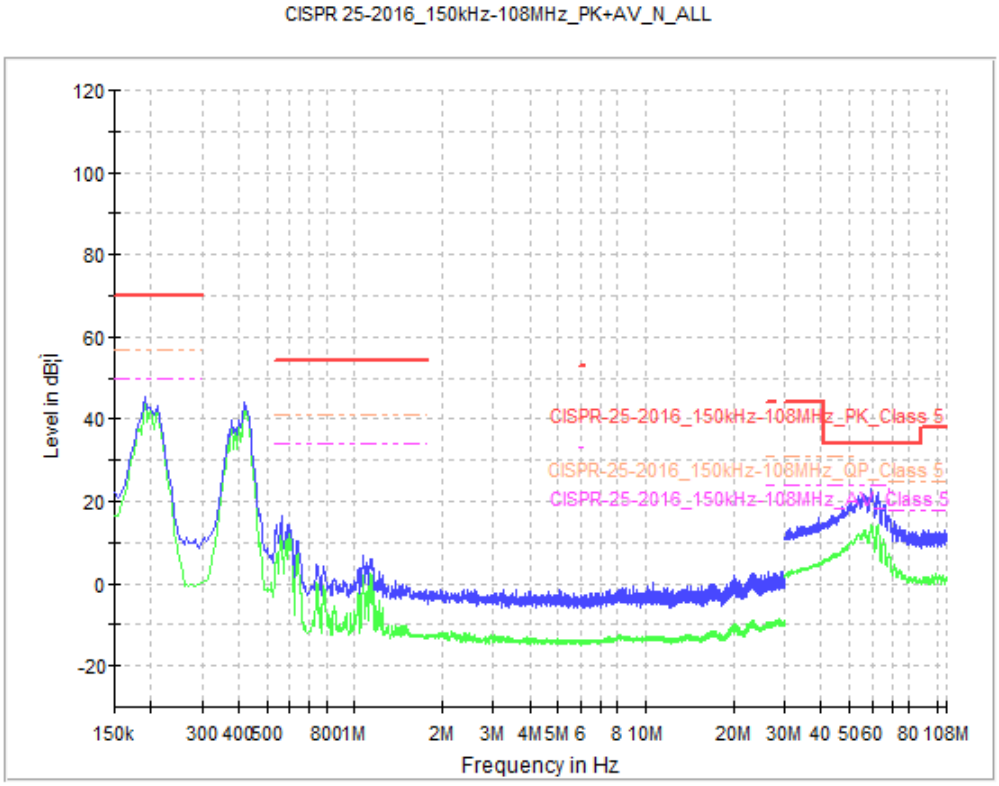


Figure 2-15. EMI Performance, 13.5-V Input, 15-V, 3-A Load, Negative Line

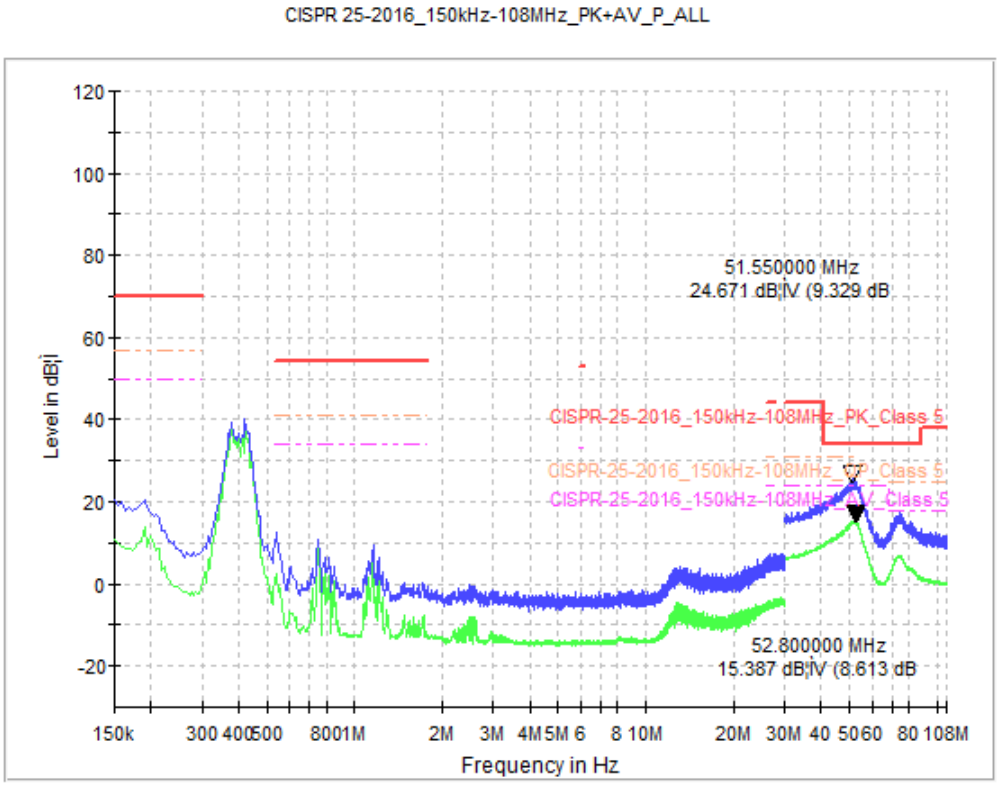


Figure 2-16. EMI Performance, 13.5-V Input, 20-V, 3-A Load, Positive Line

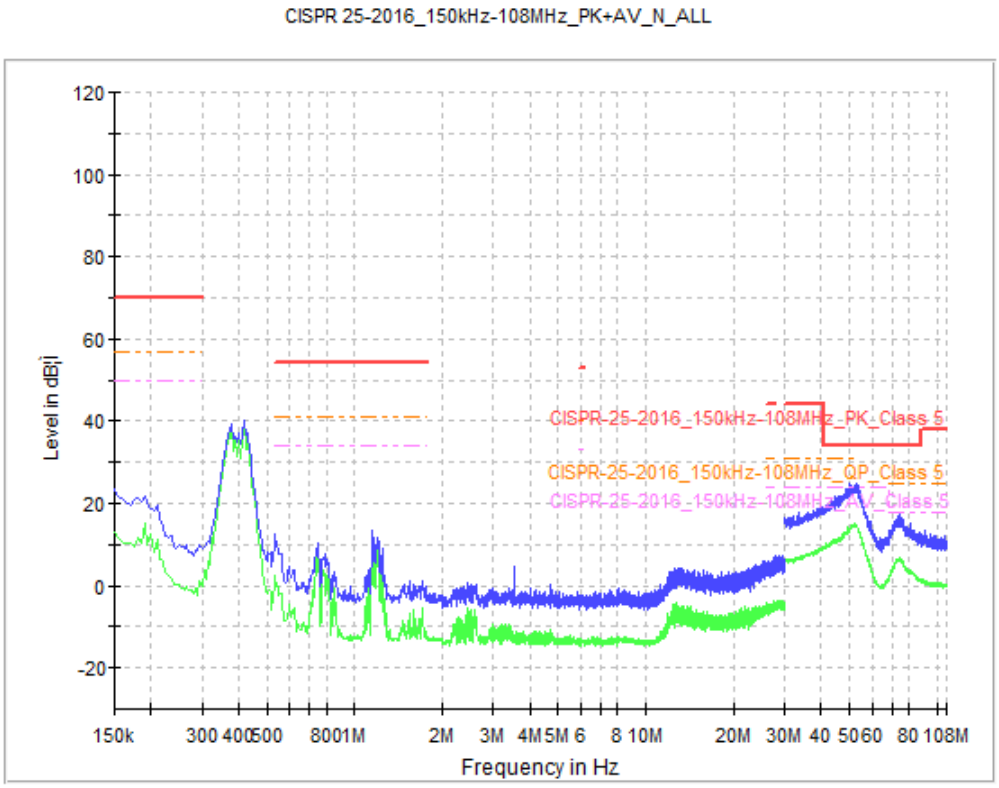


Figure 2-17. EMI Performance, 13.5-V Input, 20-V, 3-A Load, Negative Line

The margin of each EMI test result is shown in the following table.

Table 2-2. EMI Test Results

V_{IN} (V)	V_{OUT} (V)	Measurement Line	Margin (dB)
13.5	5	Positive line	13.1
13.5	5	Negative line	13.1
13.5	9	Positive line	8.7
13.5	9	Negative line	8.5
13.5	15	Positive line	6.6
13.5	15	Negative line	6.6
13.5	20	Positive line	8.6
13.5	20	Negative line	8.6

3 Waveforms

3.1 Switching

The waveforms of switching nodes at full load condition are shown in following pictures.

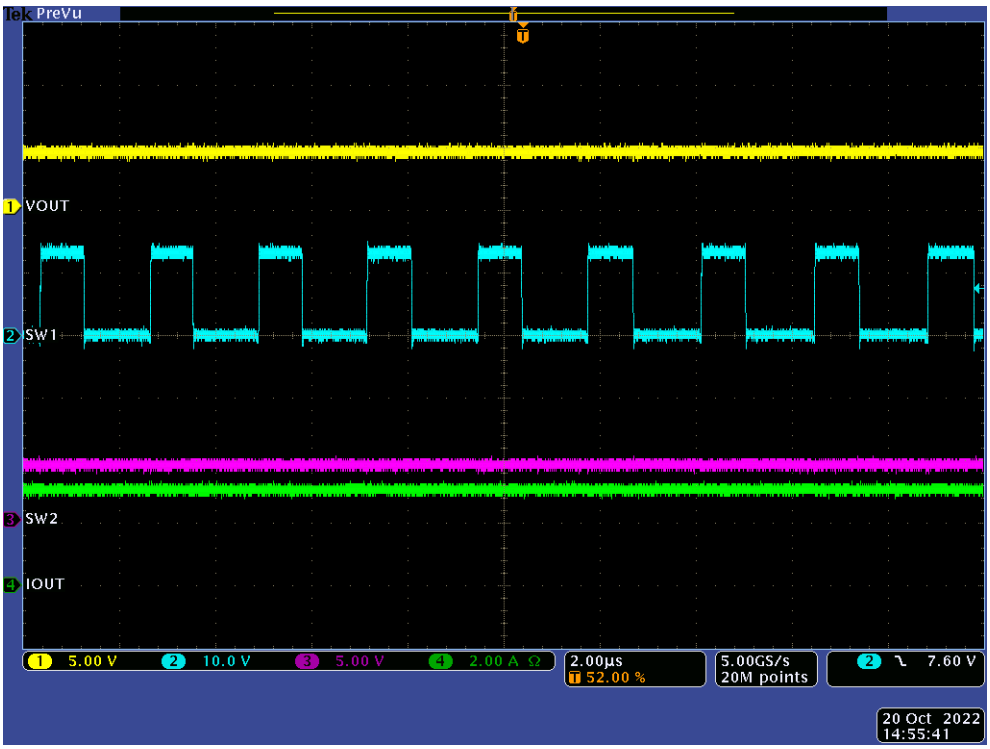


Figure 3-1. Switch-Node Voltage, 13.5-V Input, 5-V, 3-A Load

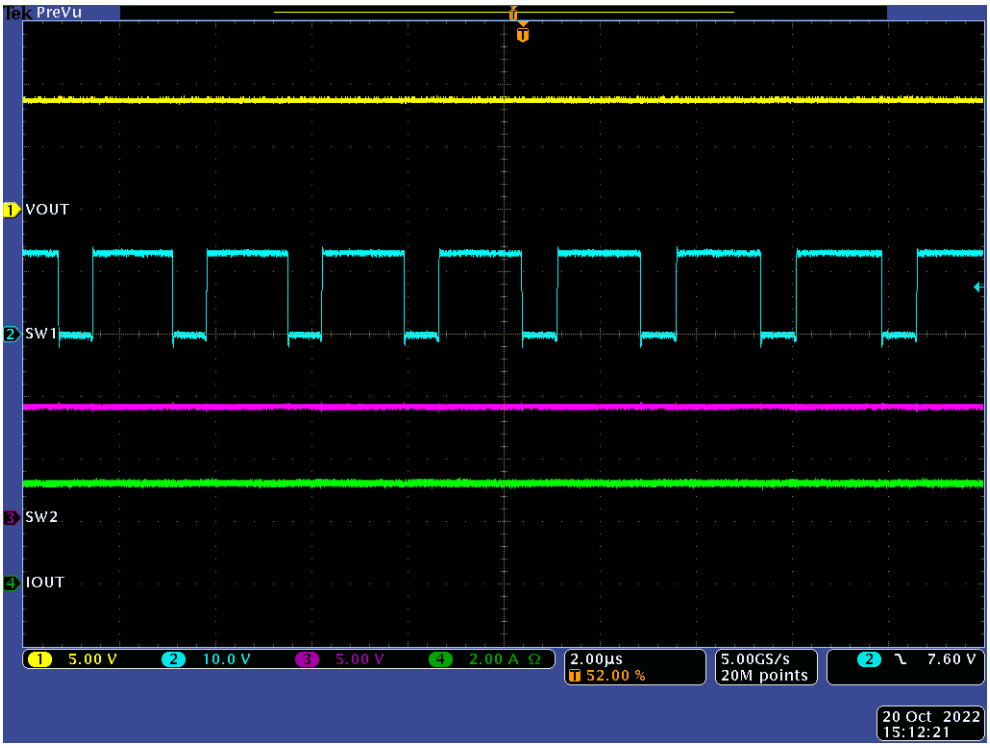


Figure 3-2. Switch-Node Voltage, 13.5-V Input, 9-V, 3-A Load

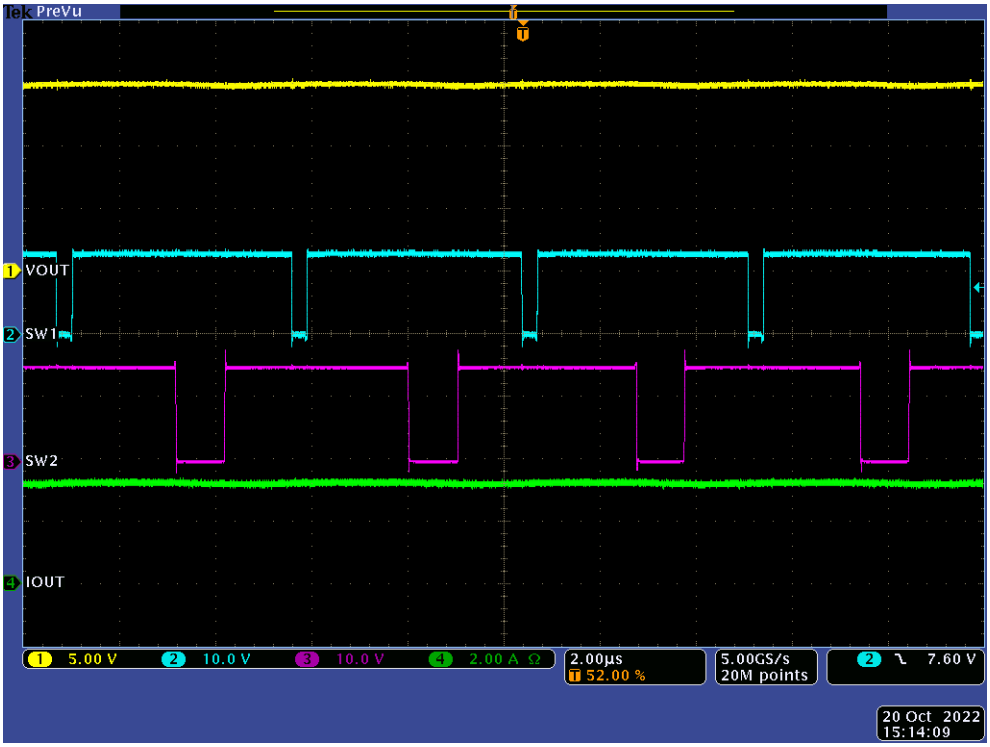


Figure 3-3. Switch-Node Voltage, 13.5-V Input, 15-V, 3-A Load

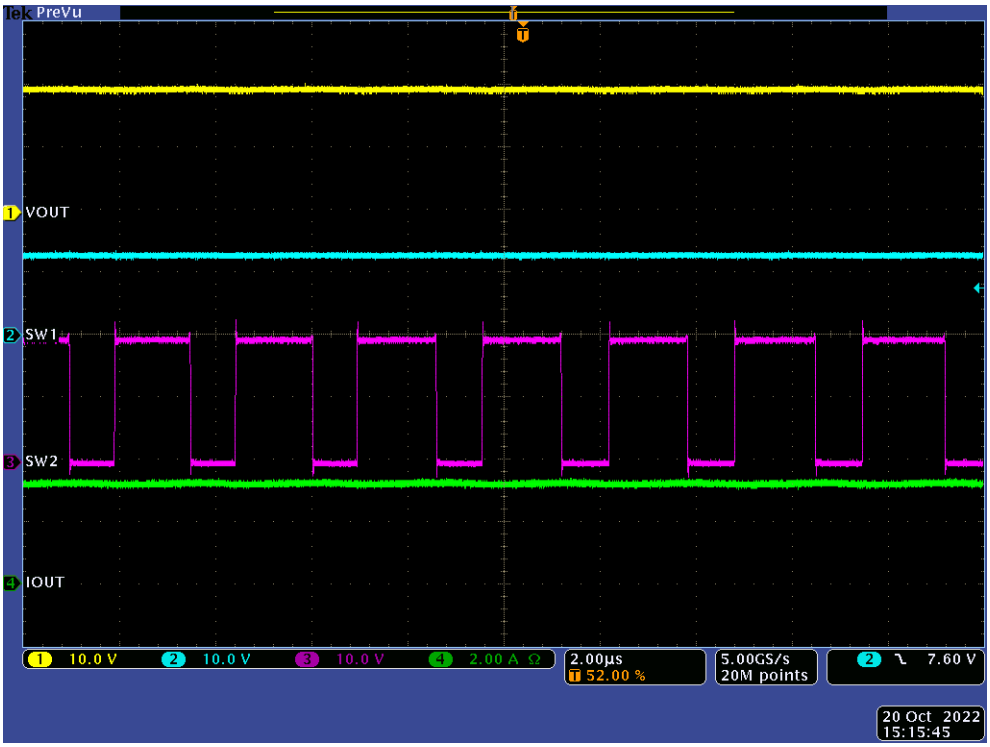


Figure 3-4. Switch-Node Voltage, 13.5-V Input, 20-V, 3-A Load

3.2 Output Voltage Ripple

The waveforms of output AC ripples at full load condition are shown in the images in this section. The following guidelines apply to each picture:
CH1: V_{OUT_AC}, CH2: V_{OUT_DC}, CH4: I_{OUT}

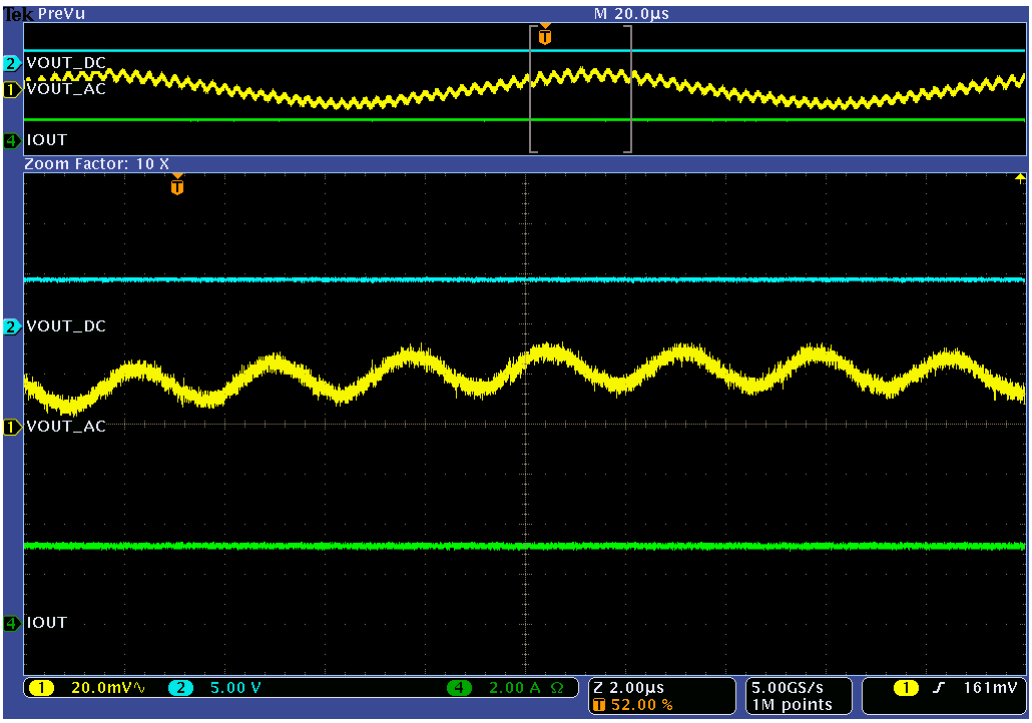


Figure 3-5. Output Voltage Ripple, 13.5-V Input, 5-V, 3-A Load

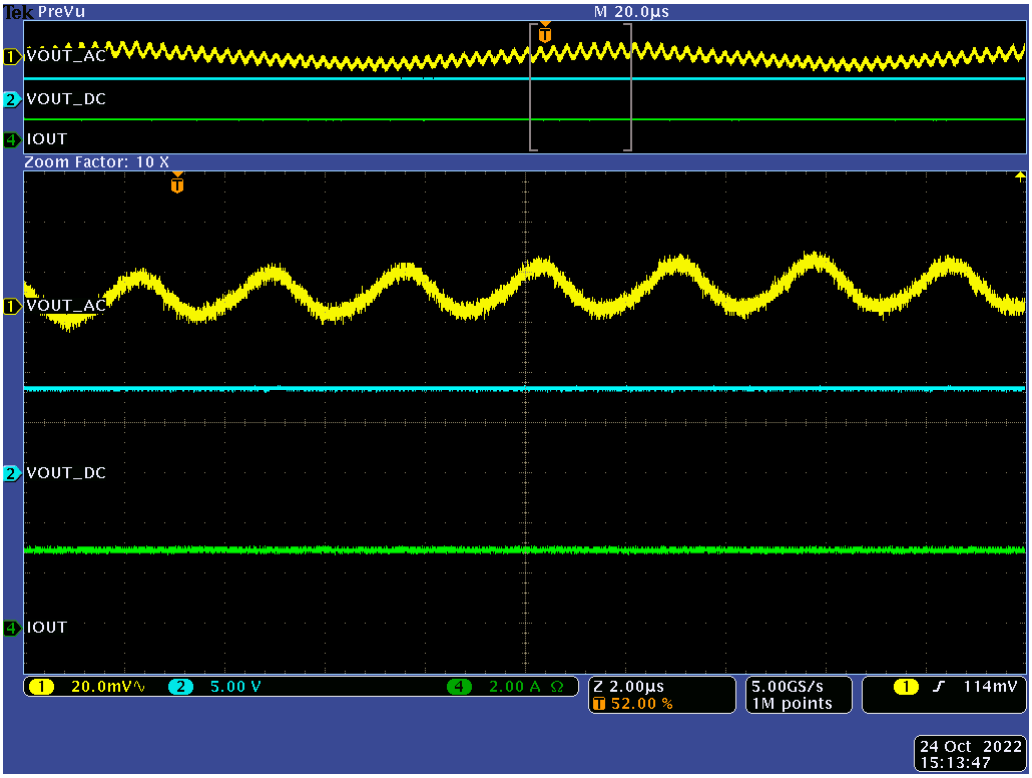


Figure 3-6. Output Voltage Ripple, 13.5-V Input, 9-V, 3-A Load

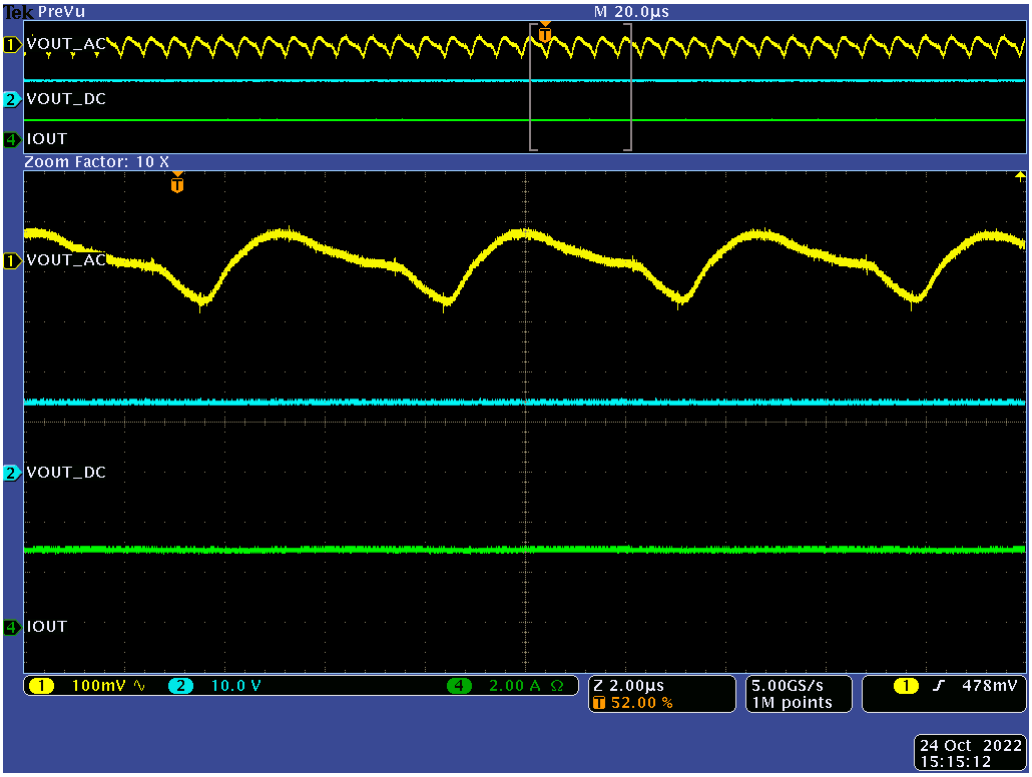


Figure 3-7. Output Voltage Ripple, 13.5-V Input, 15-V, 3-A Load

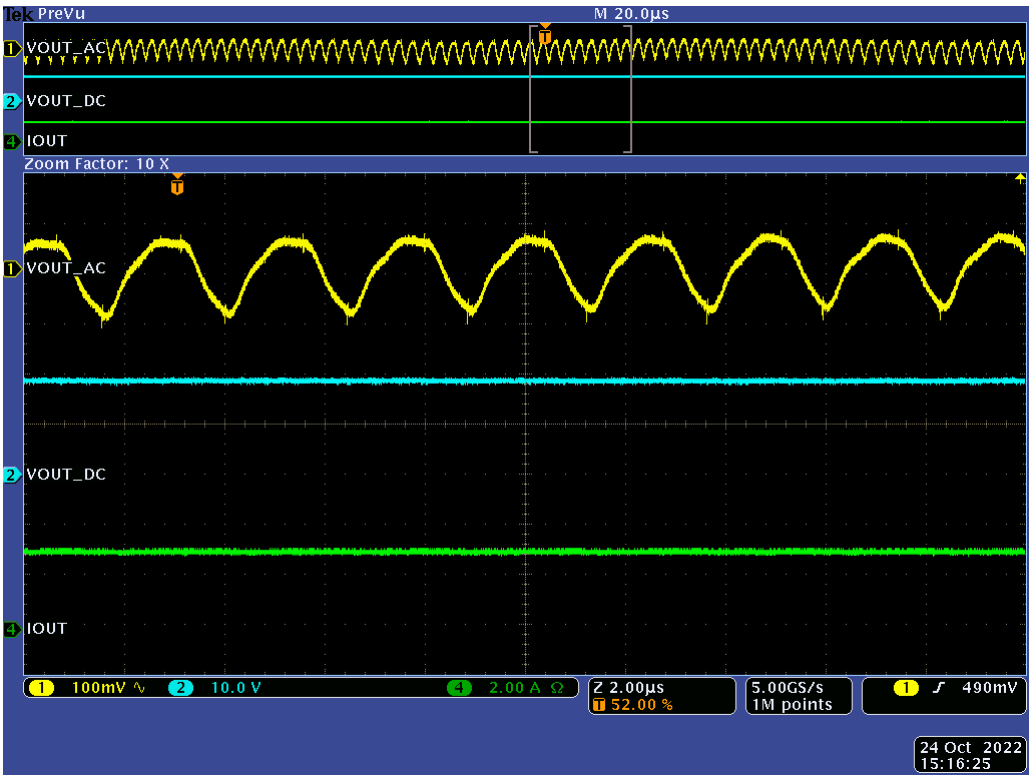


Figure 3-8. Output Voltage Ripple, 13.5-V Input, 20-V, 3-A Load

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