Test Report: PMP41092

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

Description

This reference design is a 60W automotive charger for dual USB Type-C® power delivery (PD) with 45W maximum power per port. The TPS25772-Q1 is used as a dual USB Type-C PD controller with a buck-boost regulator. The TPS55289-Q1 is used as a buck-boost regulator for another port.

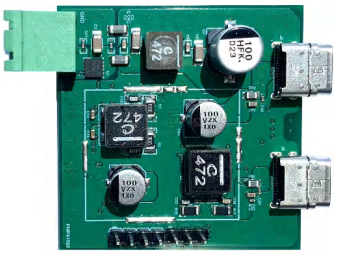
The board maximum efficiency is 95.3%. The board is compliant with the stringent CISPR 25 Class 5 conducted and radiated electromagnetic interference (EMI). The board has a compact form factor of 45mm by 45mm.

Features

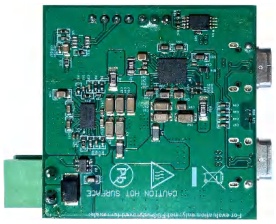
- 60W dual USB Type-C ports changer
- Compliance with CISPR 25 Class 5 conducted and radiated EMI standard
- High-efficiency with 95.3% peak efficiency
- Cost efficient without common mode inductor
- Compact form factor of 45mm by 45mm

Applications

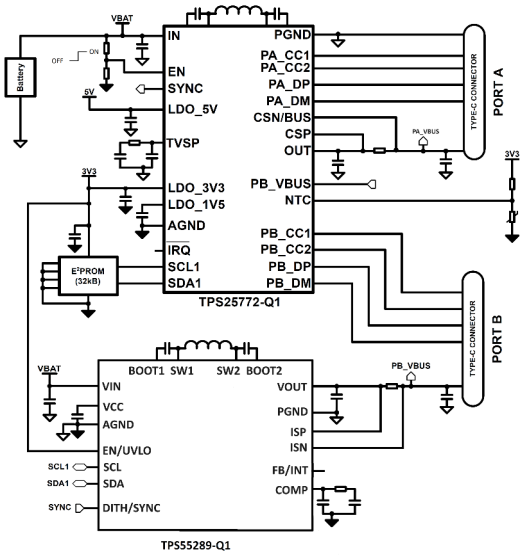
- Automotive USB charge



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	14VDC
PA_BUS Output Voltage	5VDC, 9VDC, 15VDC, 20VDC
PA_BUS Maximum Output Current	3A
PA_BUS Maximum Output Power	45W
PB_BUS Output Voltage	5VDC, 9VDC, 15VDC, 20VDC
PB_BUS Maximum Output Current	3A
PB_BUS Maximum Output Power	45W
Switching Frequency	400kHz

1.2 Required Equipment

- Multimeter: Fluke 287C
- DC Source: Chroma 62006P-100-50
- E-Load: Chroma 63103A module
- Oscilloscope: Tektronix DPO4104B
- Electrical thermography: Fluke TiS55

1.3 Dimensions

The board dimensions are 45mm (length) by 40mm (width) by 10.2mm (height).

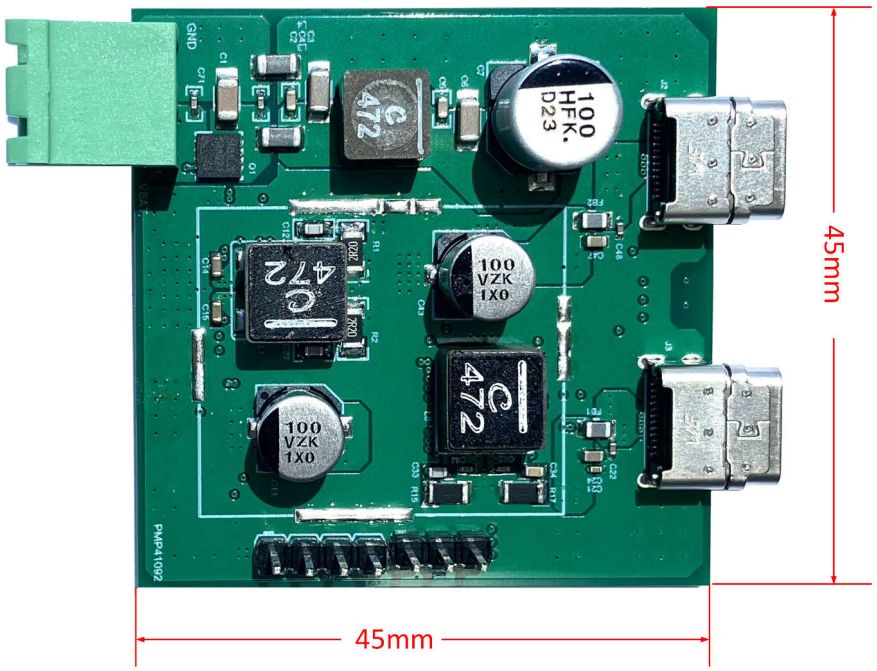


Figure 1-1. Board Dimensions

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1.

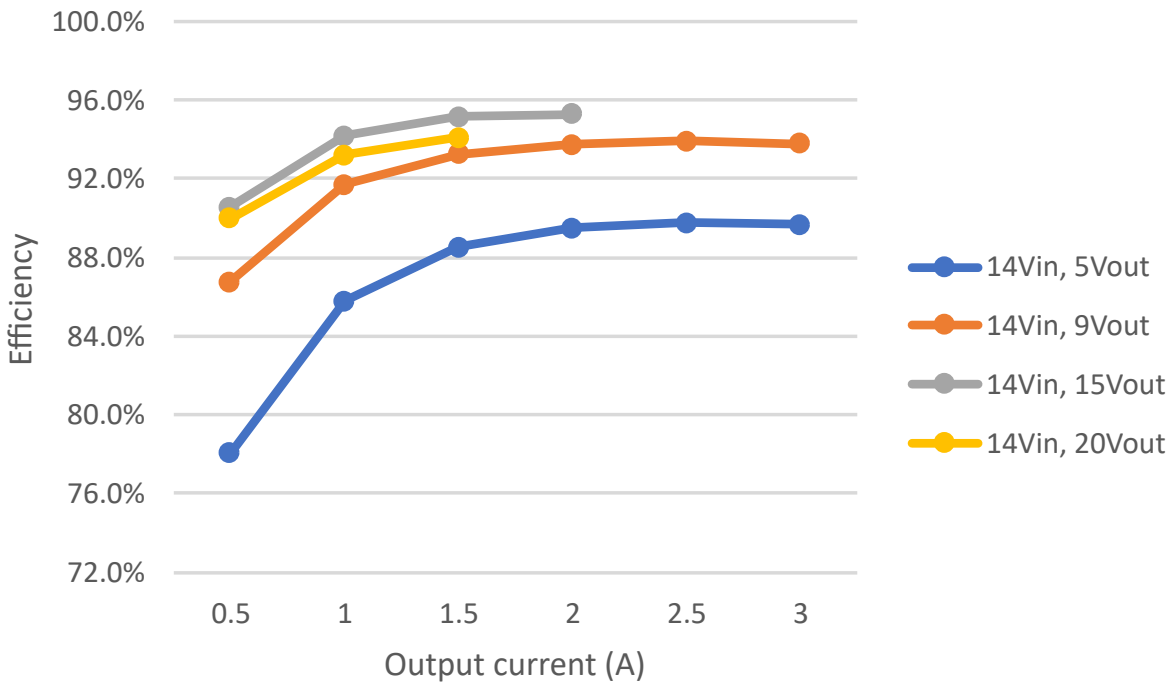


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Efficiency data is shown in Table 2-1.

Table 2-1. Efficiency Data

V_{IN} (V)	I_{IN} (A)	V_{PA_BUS} (V)	I_{PA_BUS} (A)	V_{PB_BUS} (V)	I_{PB_BUS} (A)	Efficiency
14.016	0.095	5.01	0	5.078	0	0.0%
13.92	0.462	5.006	0.4978	5.07	0.4986	78.0%
14.02	0.833	5.001	0.9928	5.0625	0.998	85.8%
13.966	1.220	4.996	1.502	5.06	1.497	88.5%
13.909	1.610	4.9913	1.995	5.05	1.996	89.5%
13.954	1.997	4.985	2.492	5.039	2.499	89.8%
13.987	2.396	4.98	3	5.04	2.999	89.7%
14.023	0.091	9.025	0	8.97	0	0.0%
14.105	0.733	9.02	0.4978	8.969	0.4986	86.7%
14.021	1.392	9.015	0.9928	8.96	0.998	91.7%
13.933	2.072	9.01	1.502	8.945	1.497	93.3%
13.957	2.737	9	1.995	8.945	1.996	93.7%
13.982	3.409	8.995	2.492	8.9375	2.499	93.9%
13.956	4.108	8.99	3	8.93	2.999	93.8%
14.023	0.091	15.024	0	14.938	0	0.0%
14.003	1.173	15.02	0.4938	14.945	0.499	90.6%
13.989	2.263	15.015	0.9928	14.938	0.998	94.2%
13.97	3.379	15.005	1.502	14.93	1.498	95.1%
13.964	4.489	15	1.995	14.922	1.997	95.3%
13.924	0.142	20.025	0	19.922	0	0.0%
13.978	1.584	20.02	0.4988	19.922	0.4989	90.0%
13.968	3.051	20.02	0.991	19.91	0.998	93.2%
13.995	4.545	20.014	1.5	19.906	1.4977	94.1%

2.3 Thermal Images

The thermal images are shown in Figure 2-2 through Figure 2-5. The ambient temperature is 25°C, and the thermal images were taken with a 14V input. The controller was operated for approximately 30 minutes before thermal images were taken to verify the thermal steady state was reached.

The board copper of the top and bottom layers is 2oz, and the copper of the middle layers is 1oz.

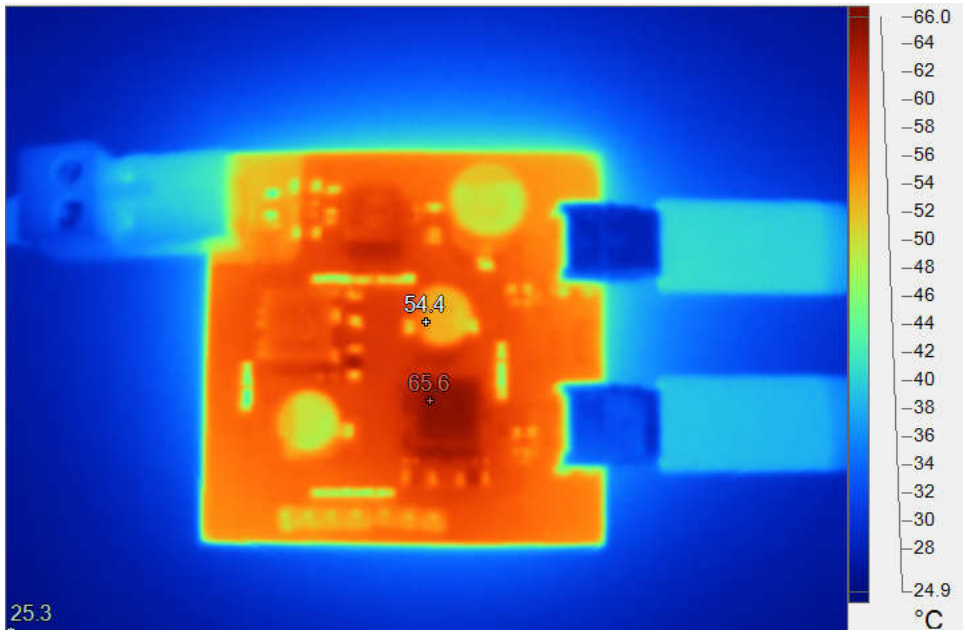


Figure 2-2. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A

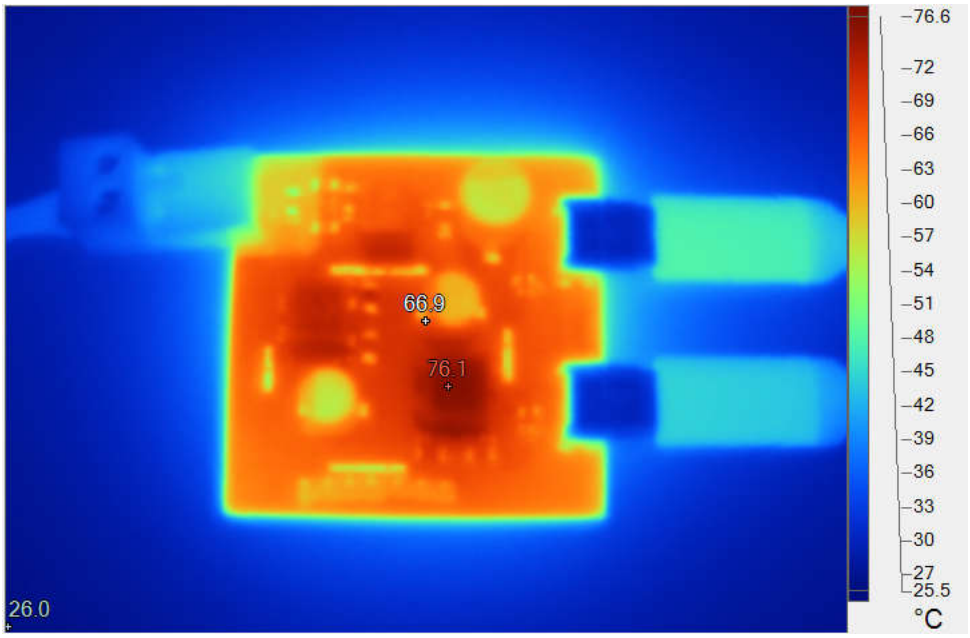


Figure 2-3. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A

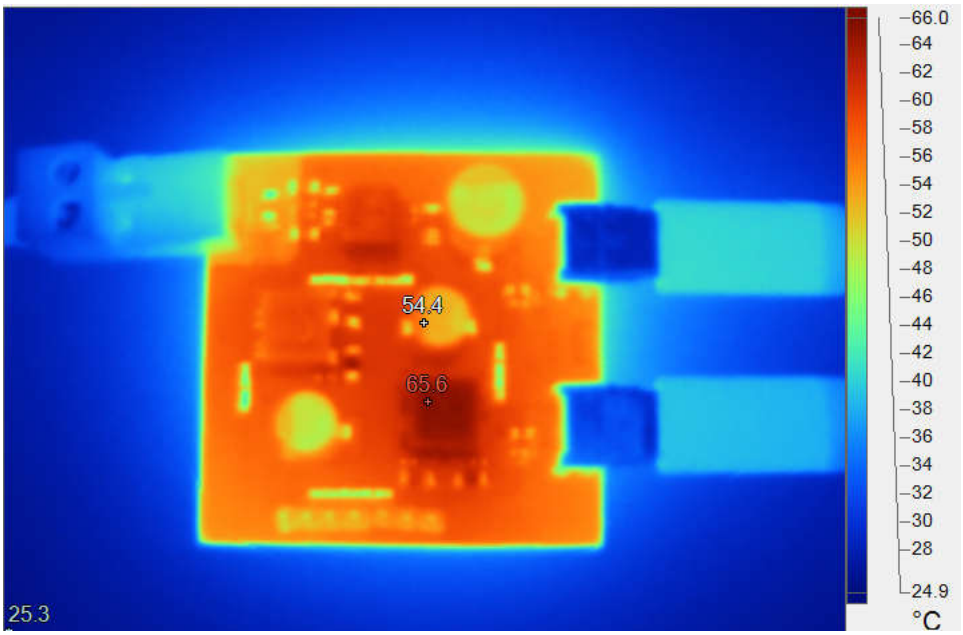


Figure 2-4. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A

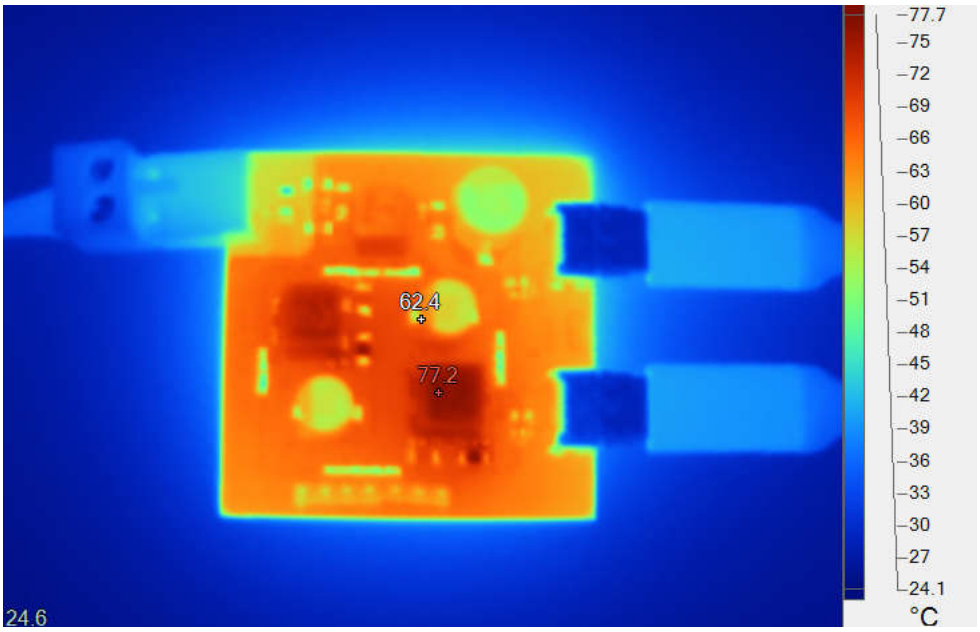


Figure 2-5. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A

2.4 Bode Plots

The TPS25772-Q1 bode plots are shown in Figure 2-6 through Figure 2-9.

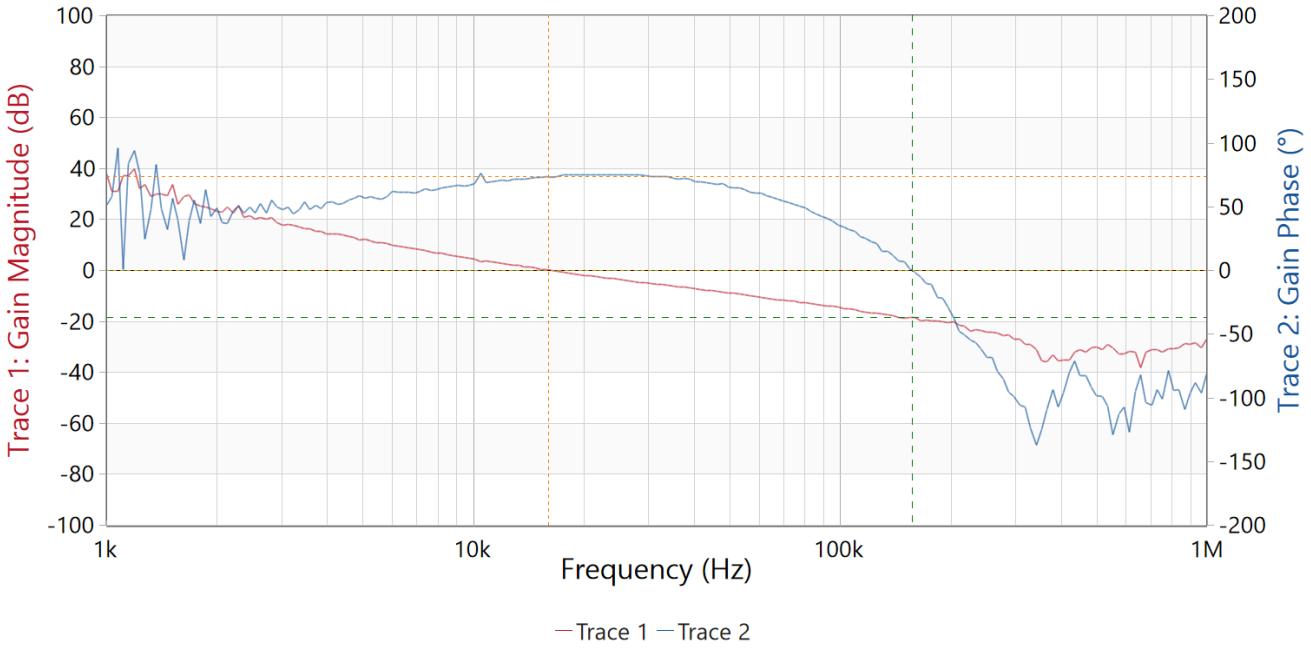


Figure 2-6. TPS25772-Q1 14VIN, 5V 3A OUT Bode Plots

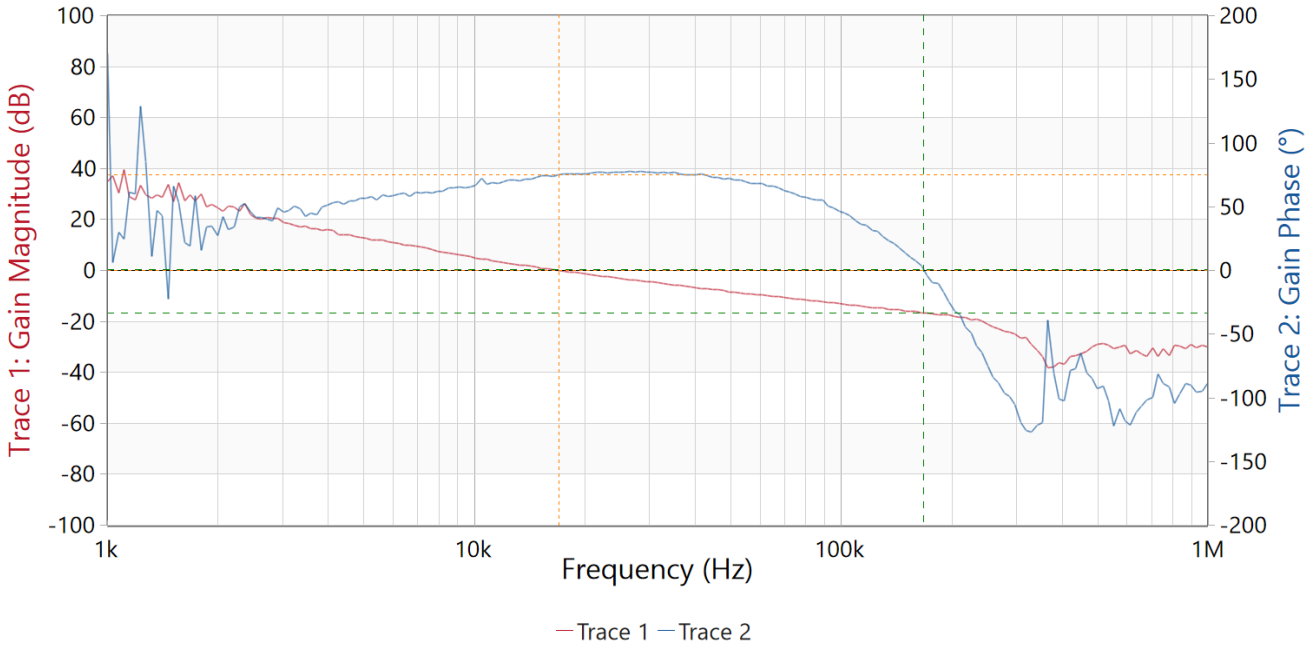


Figure 2-7. TPS25772-Q1 14VIN, 9V 3A OUT Bode Plots

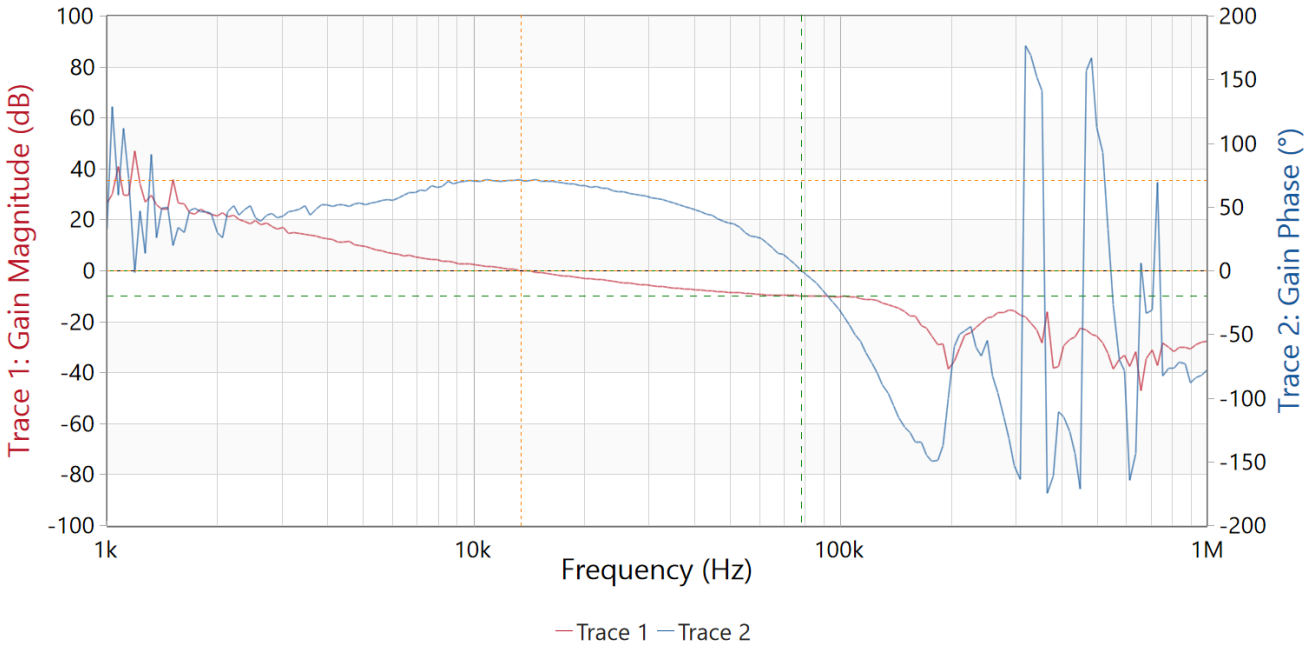


Figure 2-8. TPS25772-Q1 14VIN, 15V 3A OUT Bode Plots

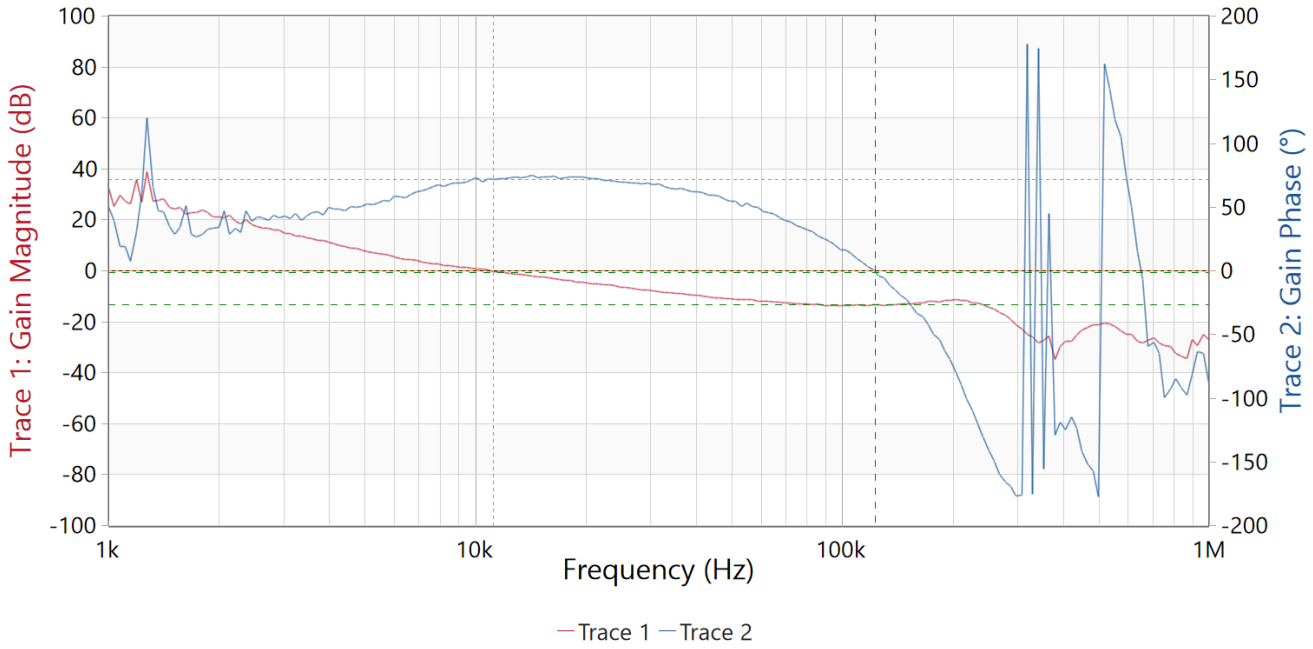


Figure 2-9. TPS25772-Q1 14VIN, 20V 2.25A OUT Bode Plots

The TPS55289-Q1 bode plots are shown in Figure 2-10 through Figure 2-13.

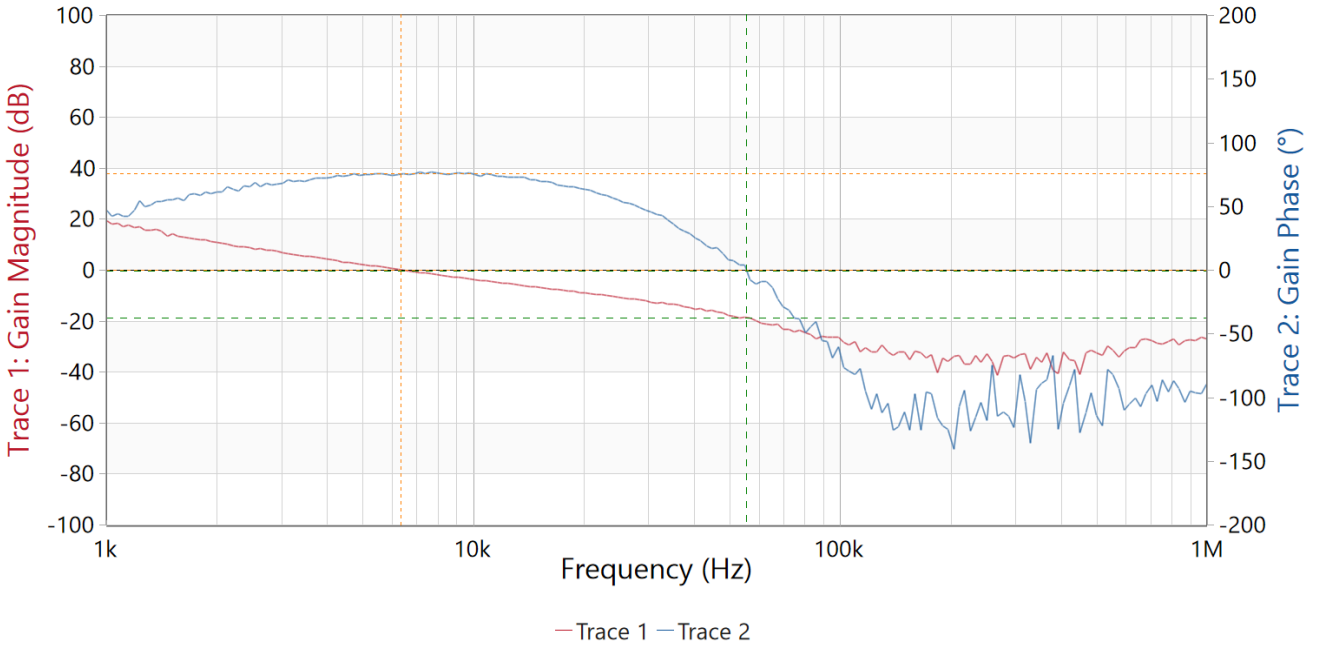


Figure 2-10. TPS55289-Q1 14VIN, 5V 3A OUT Bode Plots

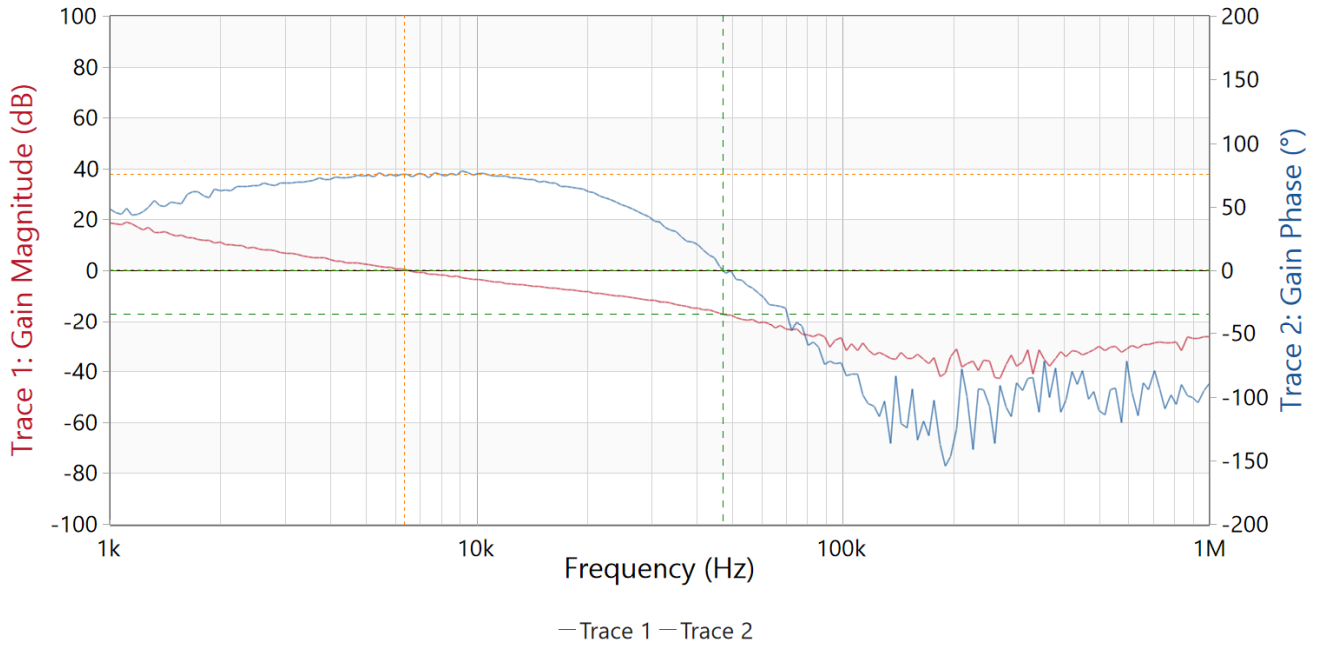


Figure 2-11. TPS55289-Q1 14VIN, 9V 3A OUT Bode Plots

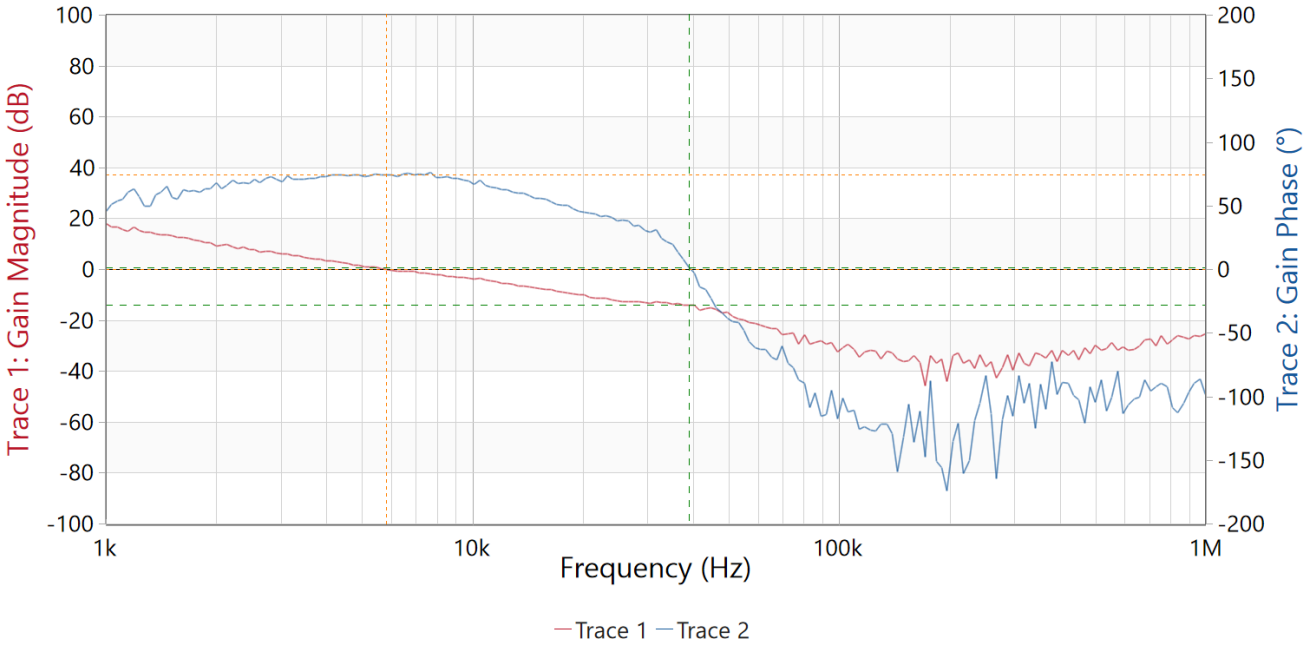


Figure 2-12. TPS55289-Q1 14VIN, 15V 3A OUT Bode Plots

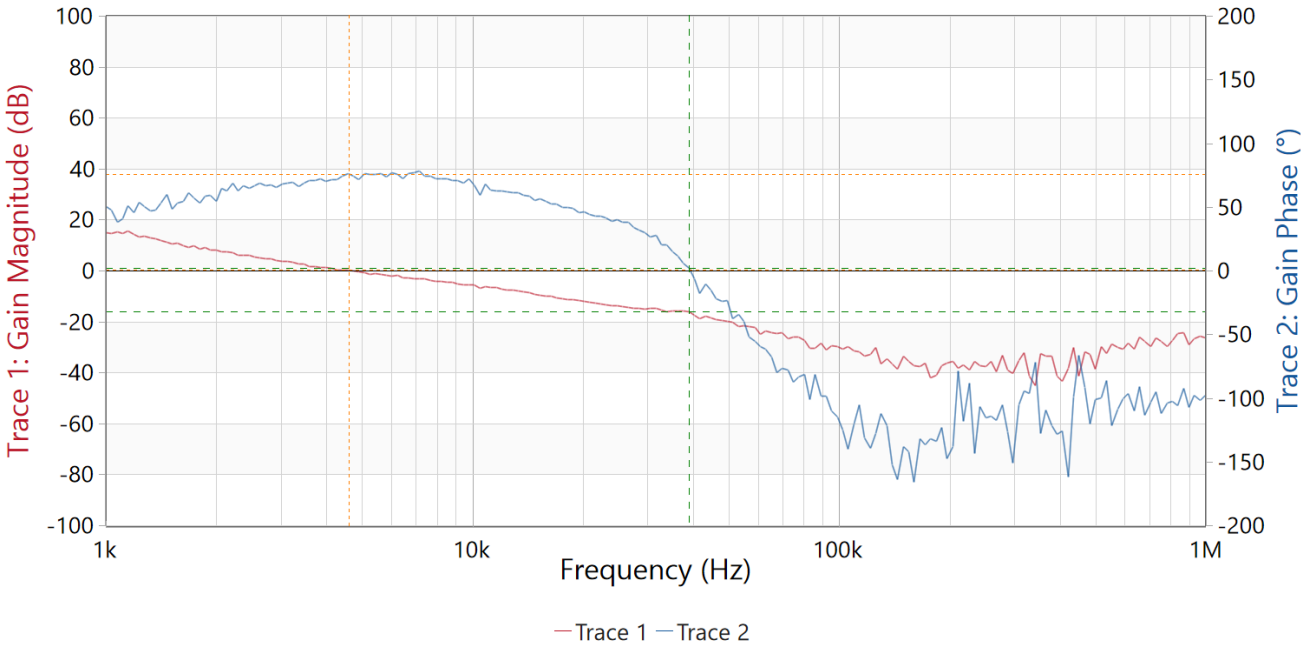


Figure 2-13. TPS55289-Q1 14VIN, 20V 2.25A OUT Bode Plots

2.5 EMI

The emissions are tested to be compliant with the CISPR 25 Class 5 standards. The CISPR 25 Class 5 conducted and radiated EMI compliance was achieved. Figure 2-14 through Figure 2-43 show the waveforms of the EMI test results at 14V input.

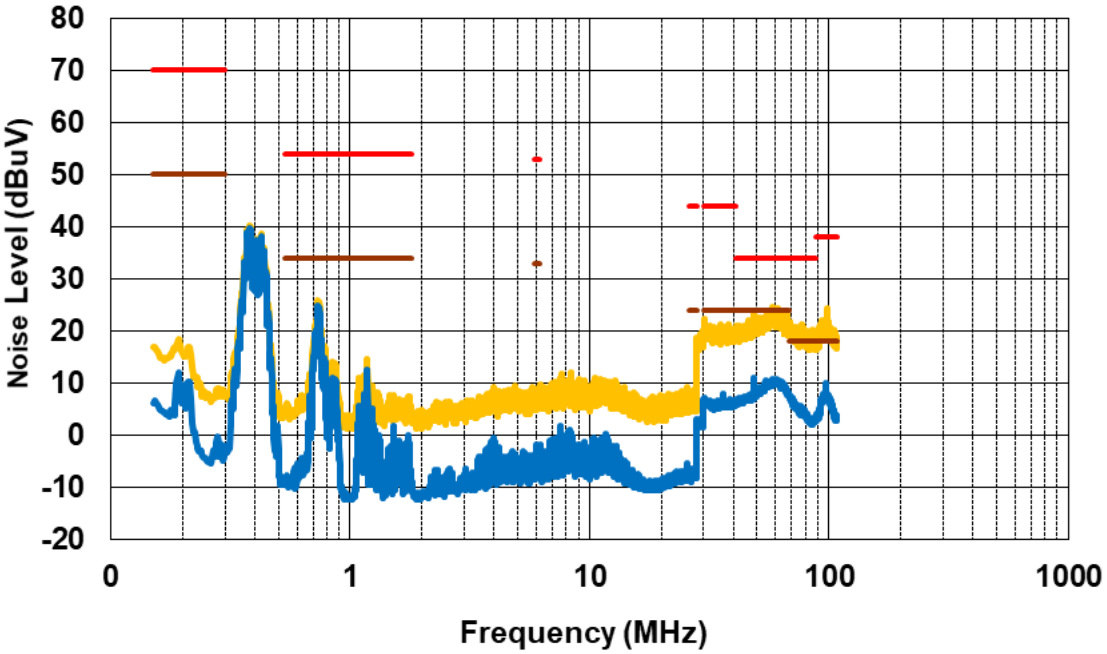


Figure 2-14. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Positive Line

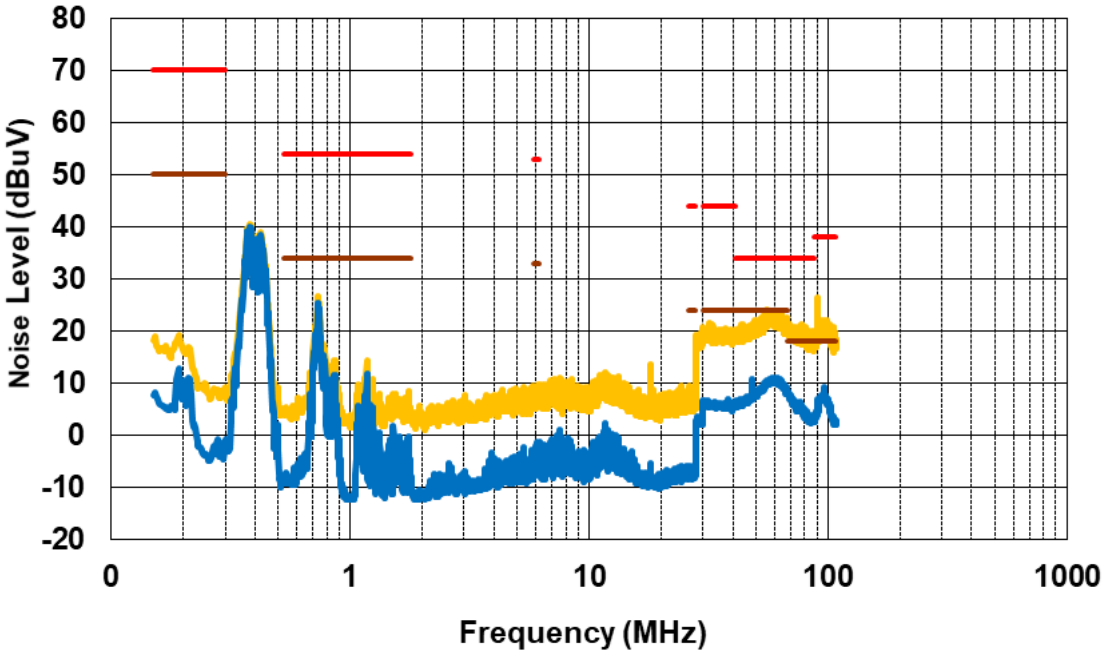


Figure 2-15. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Negative Line

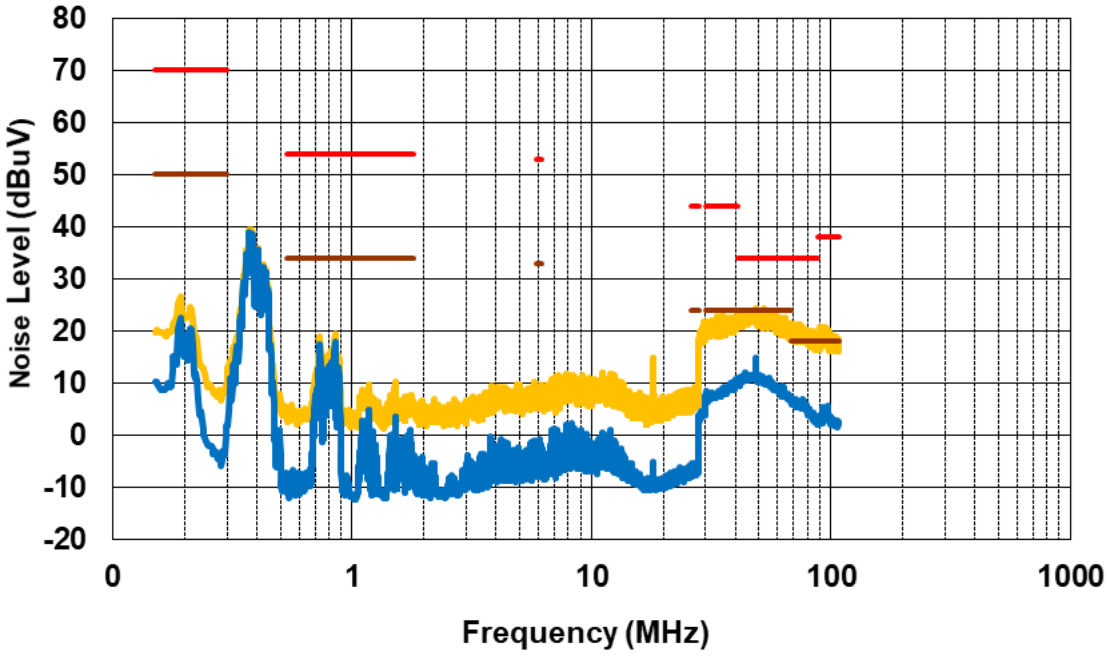


Figure 2-16. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Positive Line

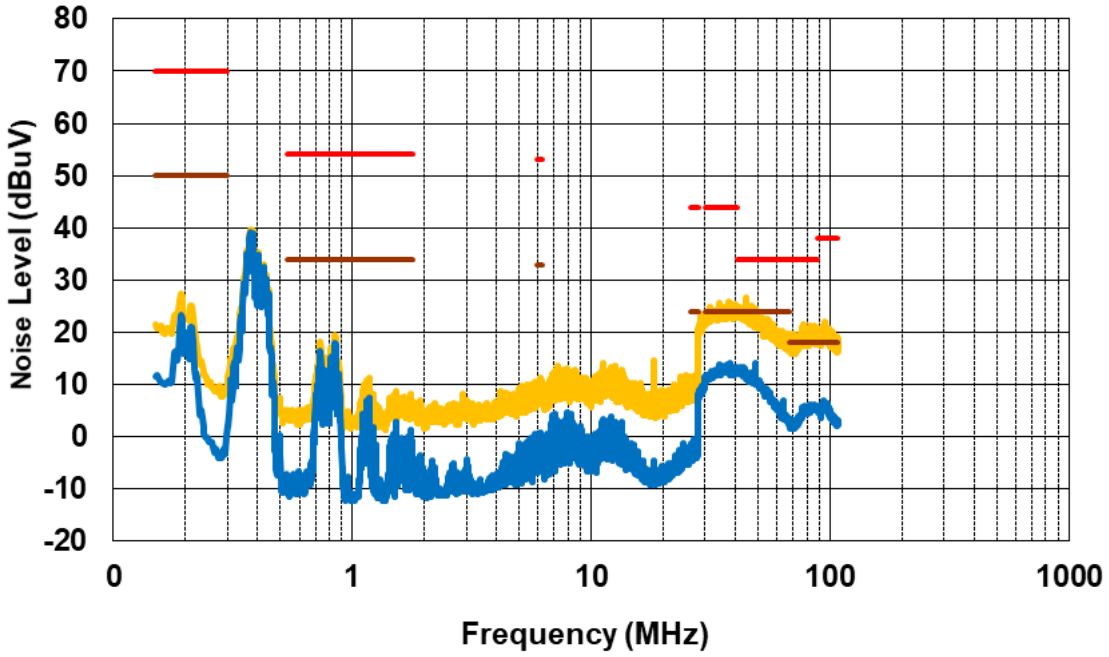


Figure 2-17. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Negative Line

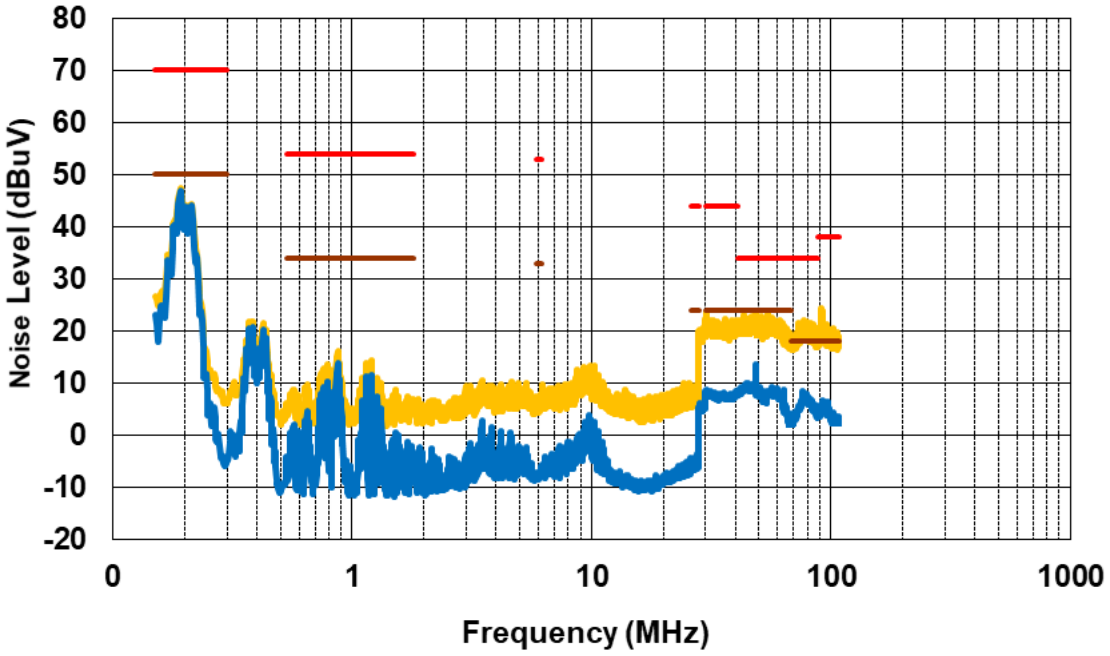


Figure 2-18. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A, Positive Line

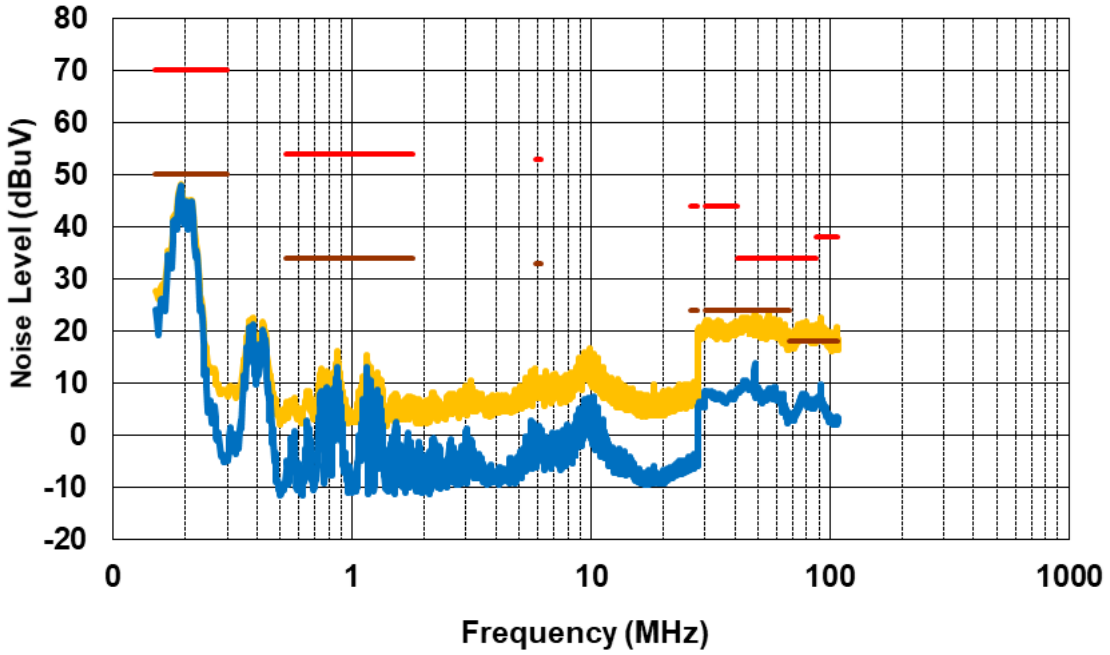


Figure 2-19. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A, Negative Line

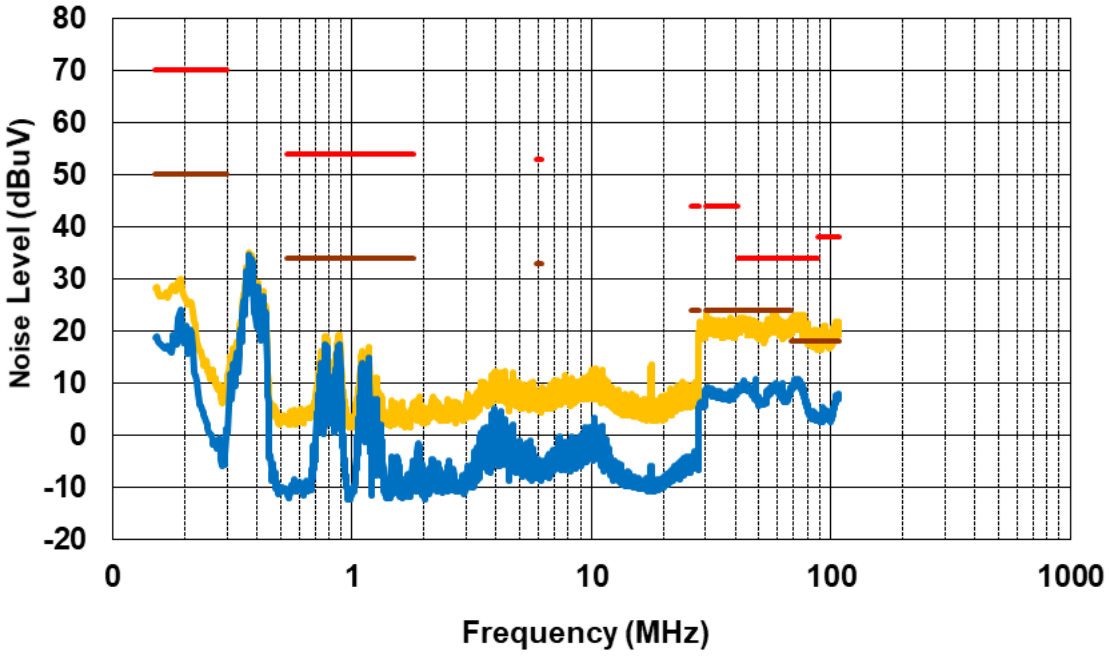


Figure 2-20. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A, Positive Line

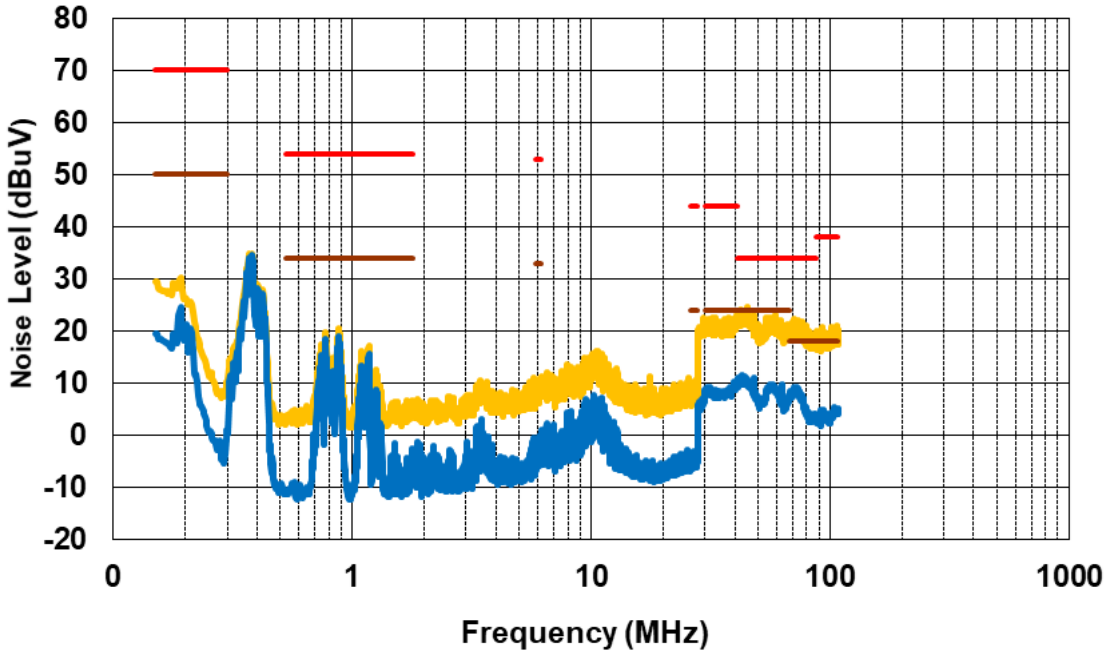


Figure 2-21. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A, Negative Line

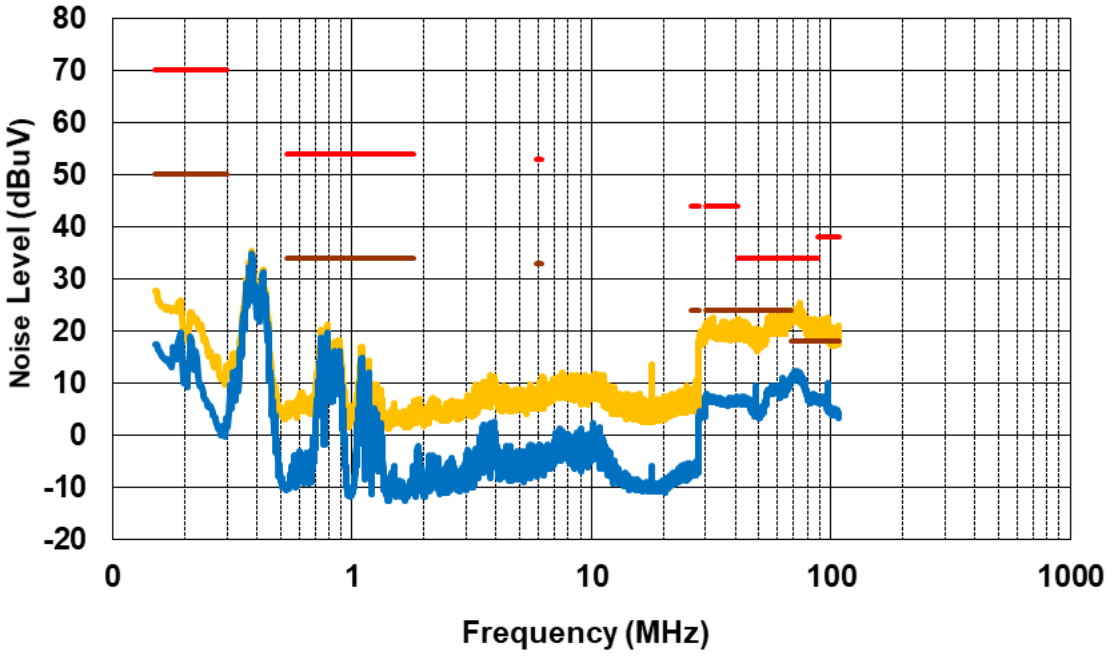


Figure 2-22. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 2.25A, I_{PB_BUS} = 0.75A, Positive Line

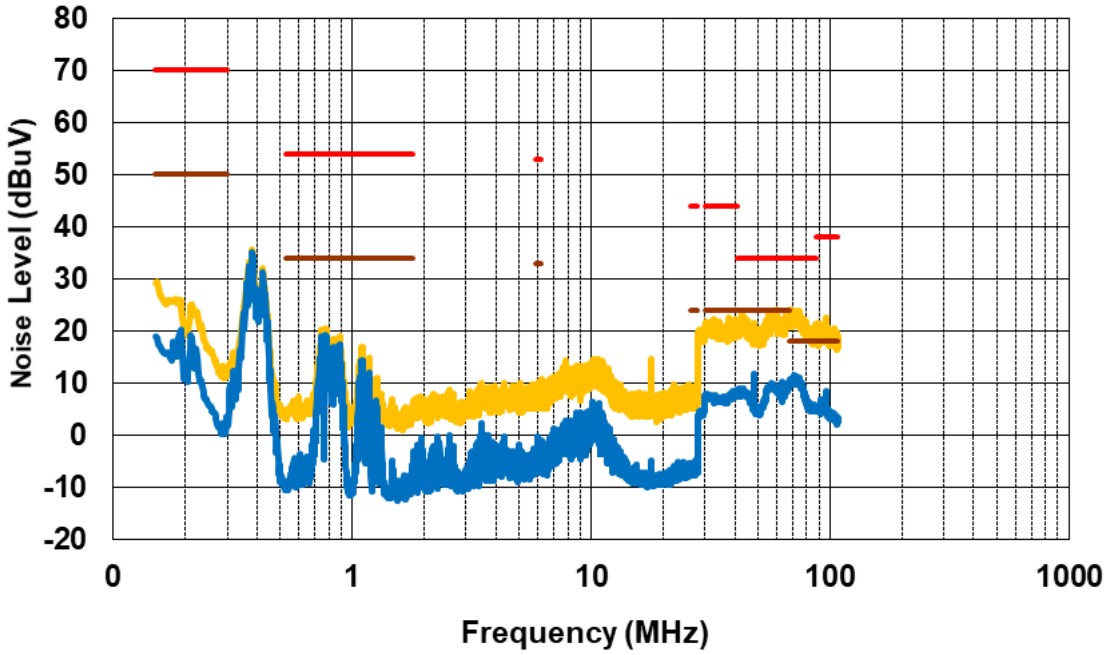


Figure 2-23. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 2.25A, I_{PB_BUS} = 0.75A, Negative Line

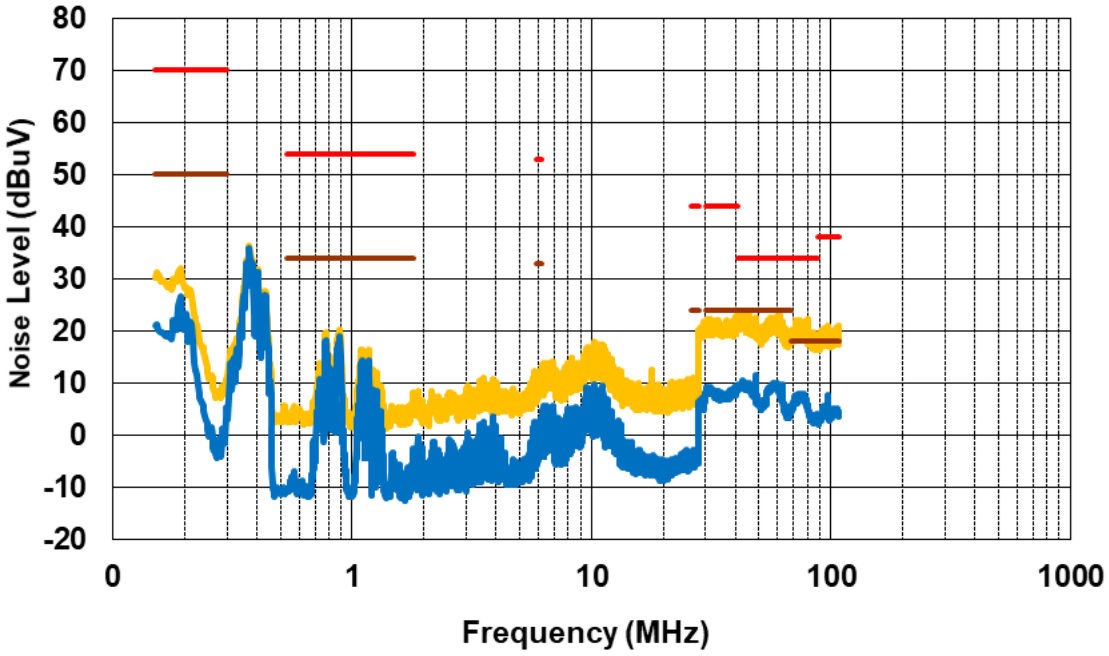


Figure 2-24. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 0.75A, I_{PB_BUS} = 2.25A, Positive Line

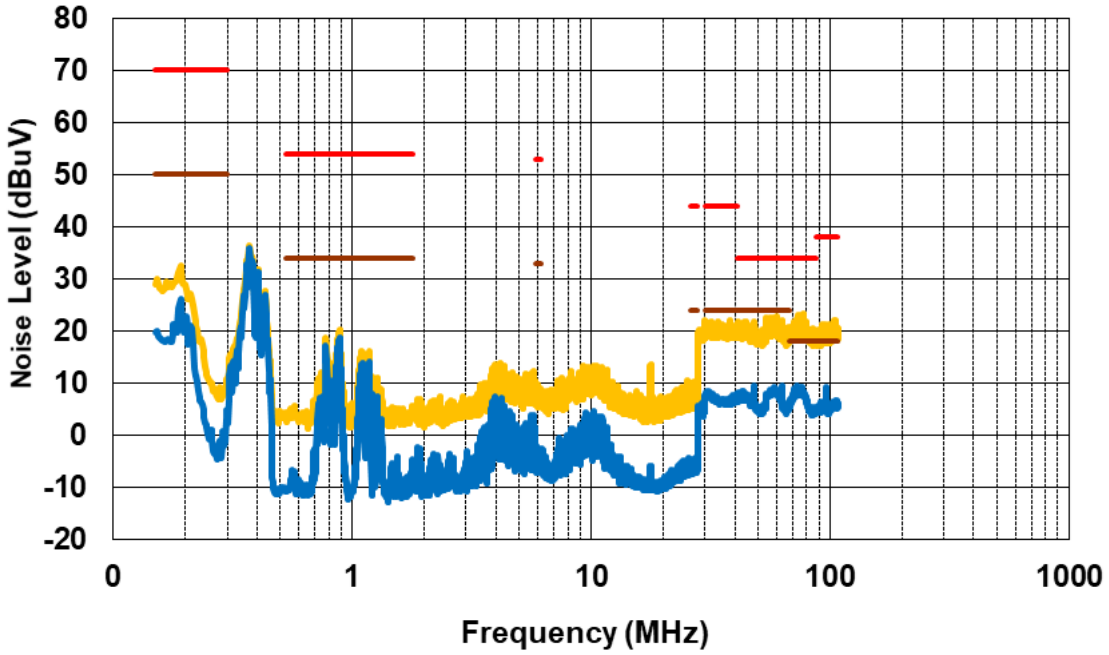


Figure 2-25. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 0.75A, I_{PB_BUS} = 2.25A, Negative Line

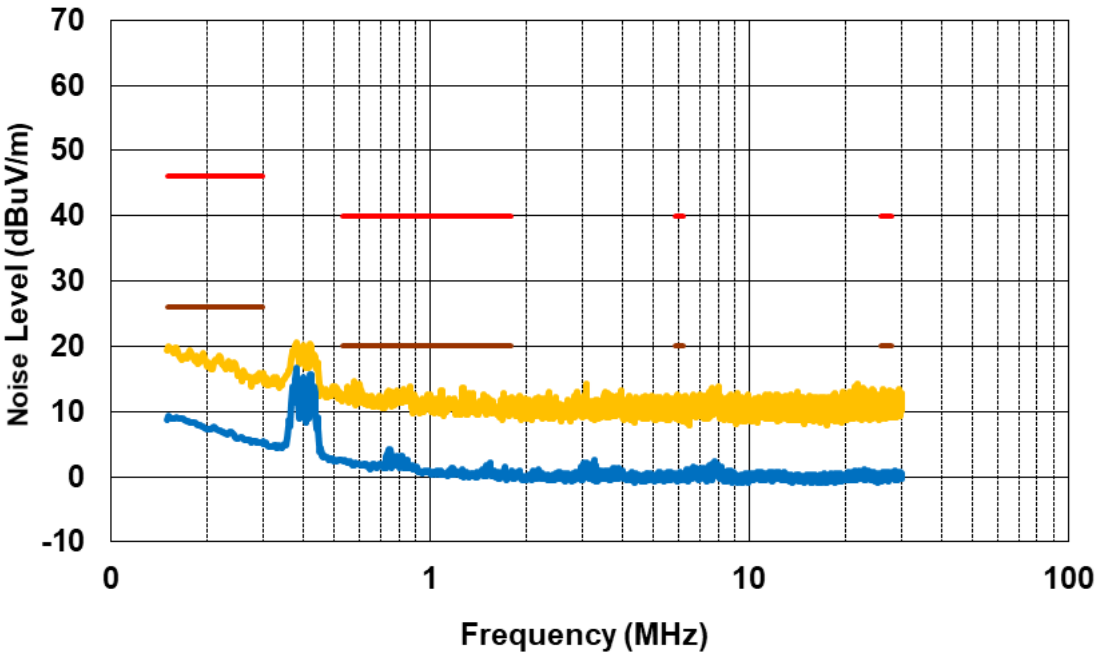


Figure 2-26. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A

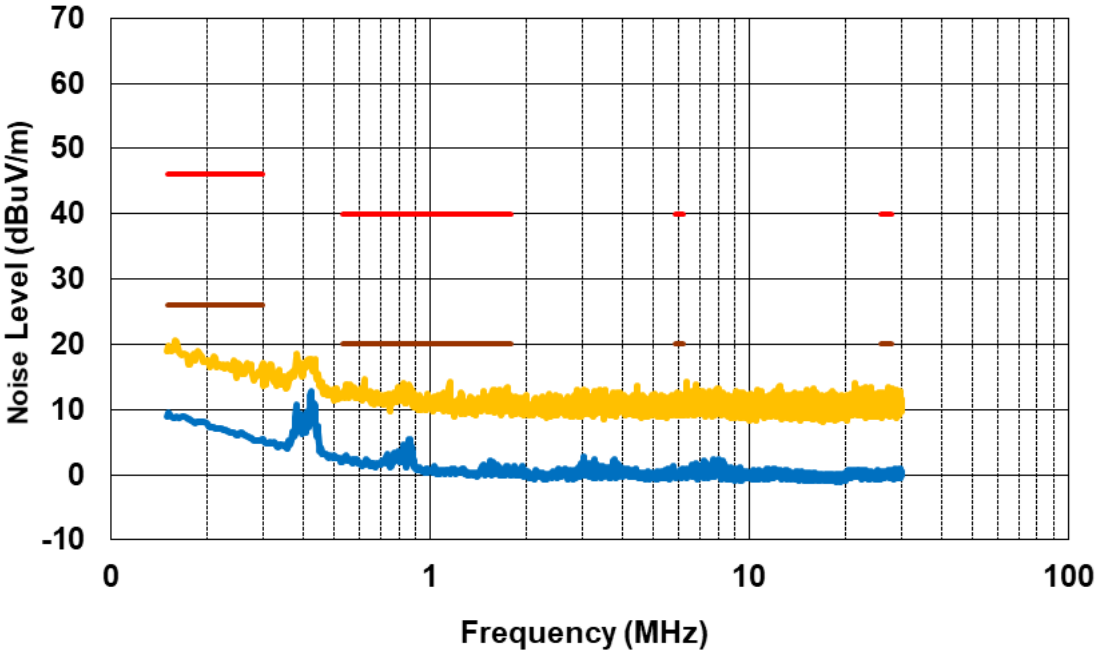


Figure 2-27. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A

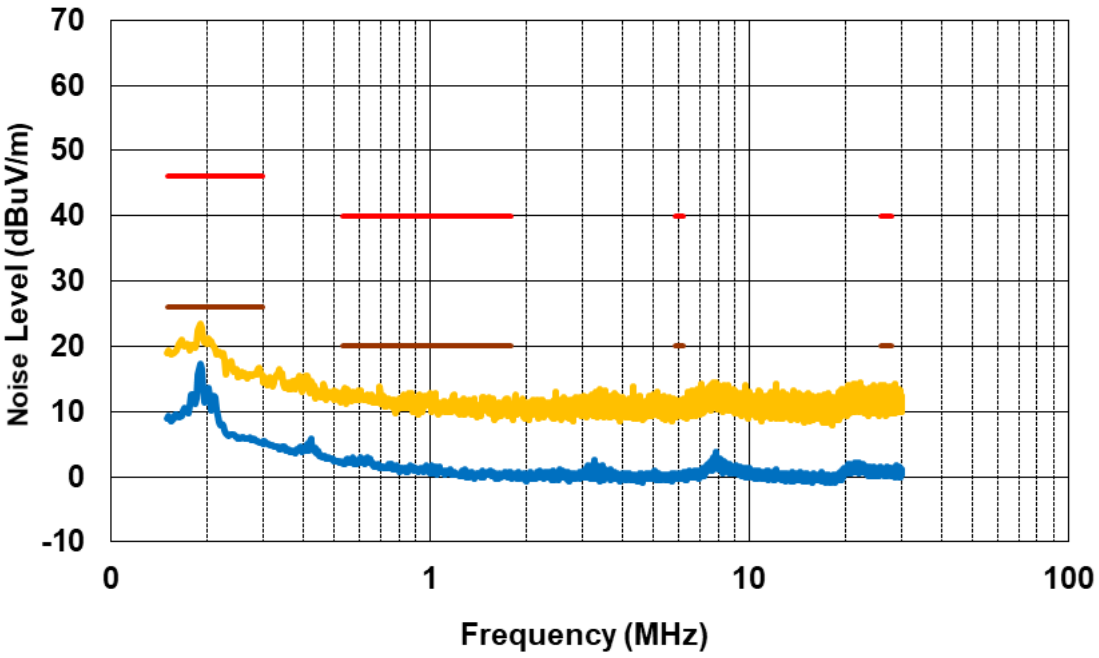


Figure 2-28. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A

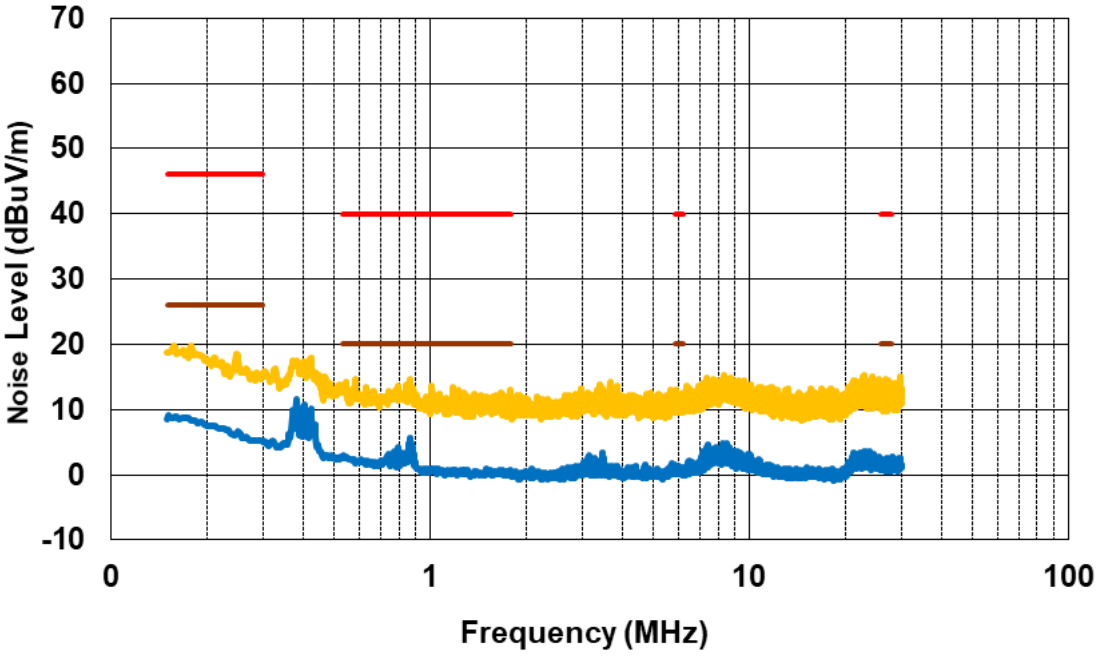


Figure 2-29. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A

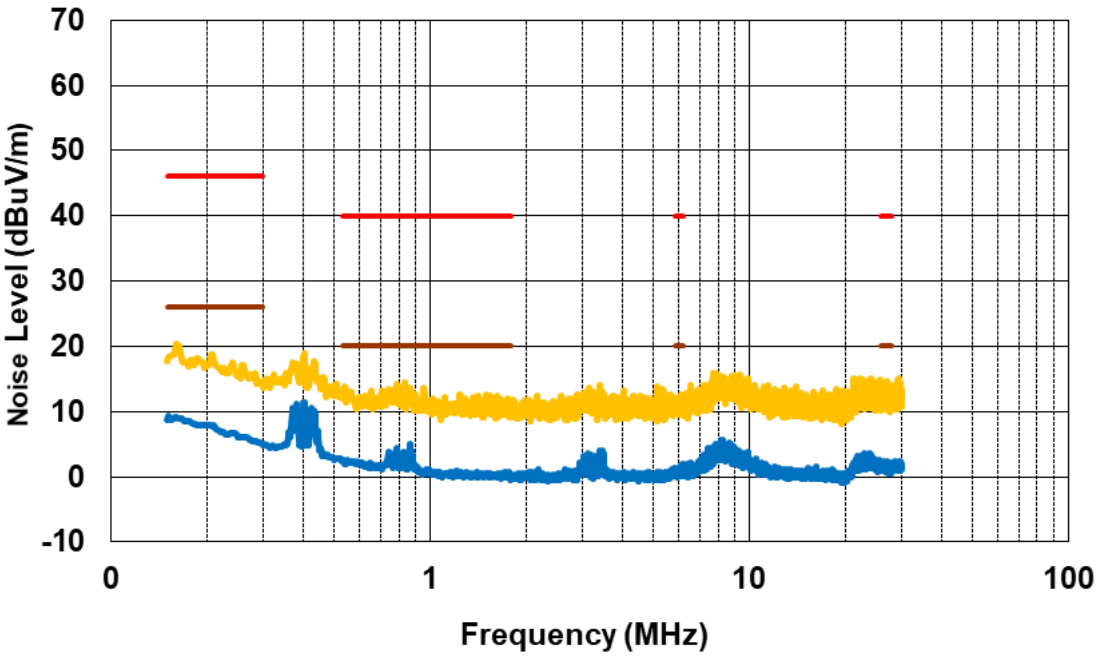


Figure 2-30. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 2.25A, I_{PB_BUS} = 0.75A

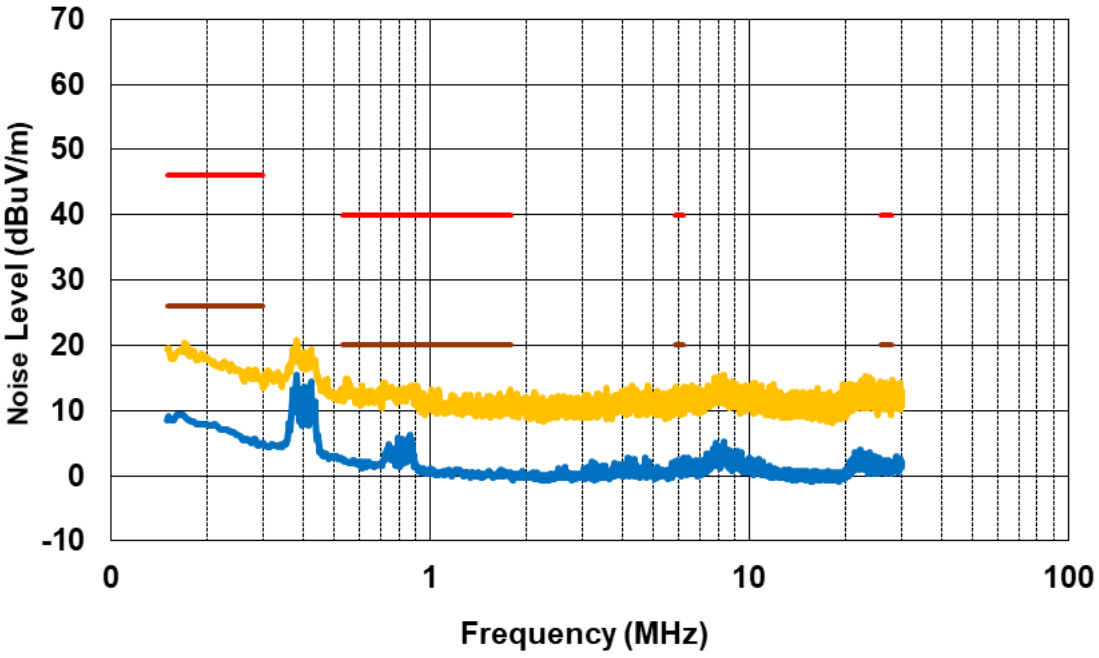


Figure 2-31. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 0.75A, I_{PB_BUS} = 2.25A

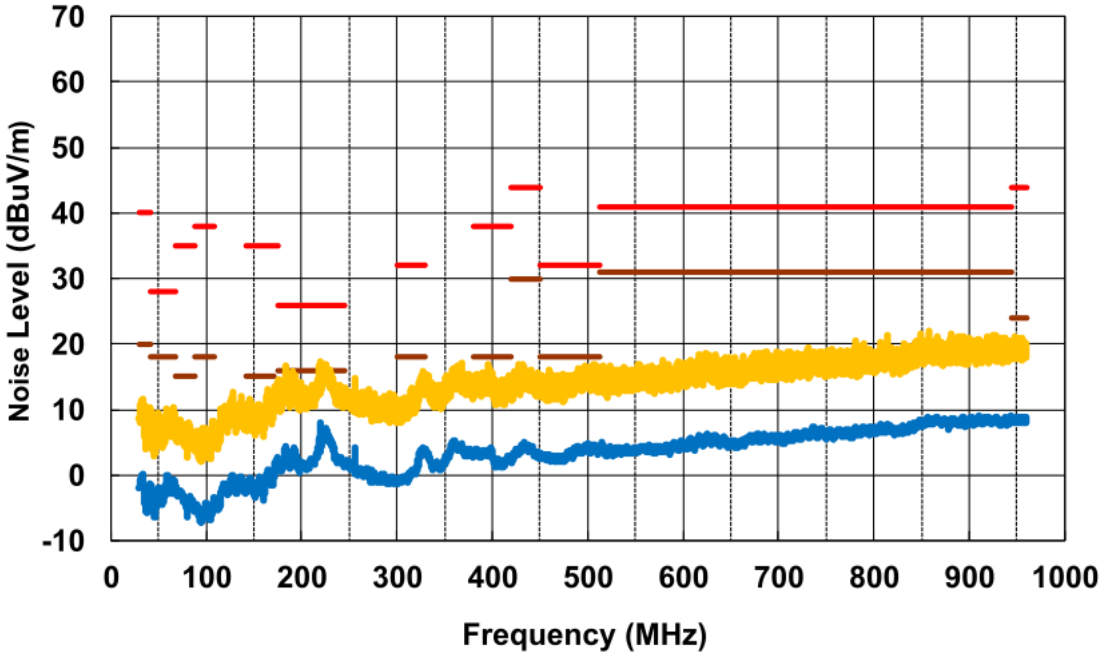


Figure 2-32. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Horizontal

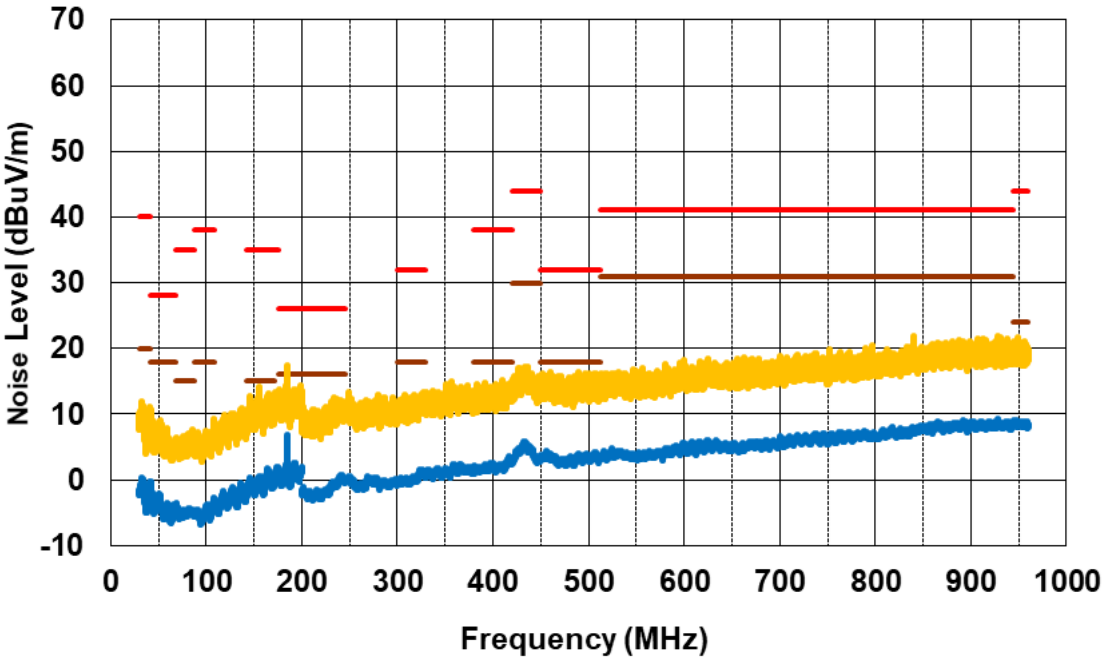


Figure 2-33. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Vertical

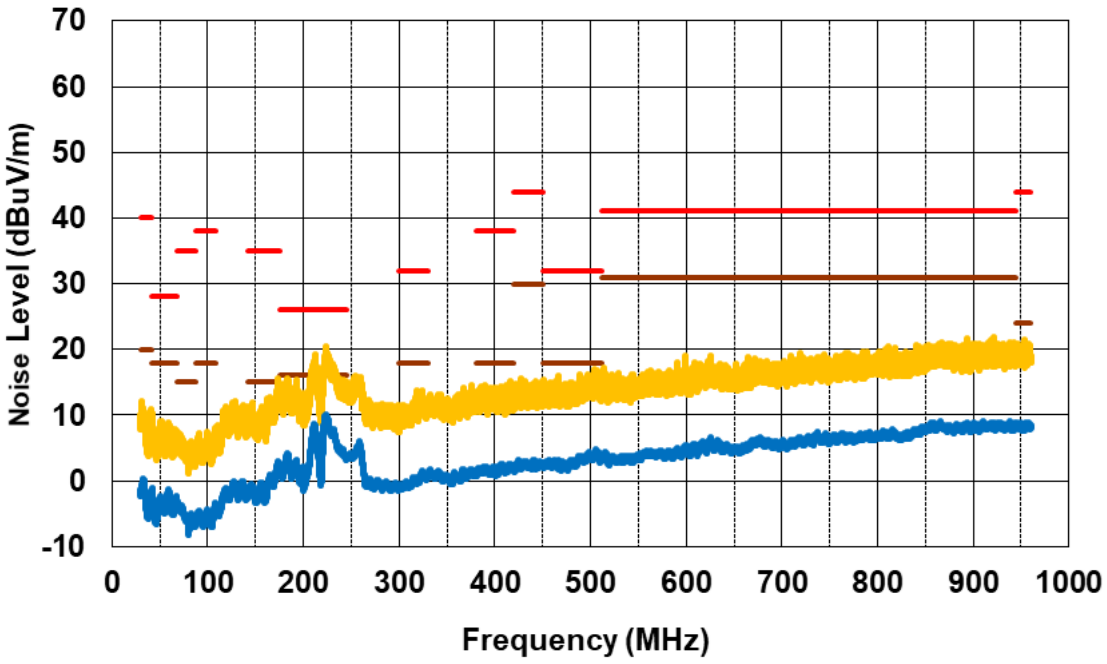


Figure 2-34. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Horizontal

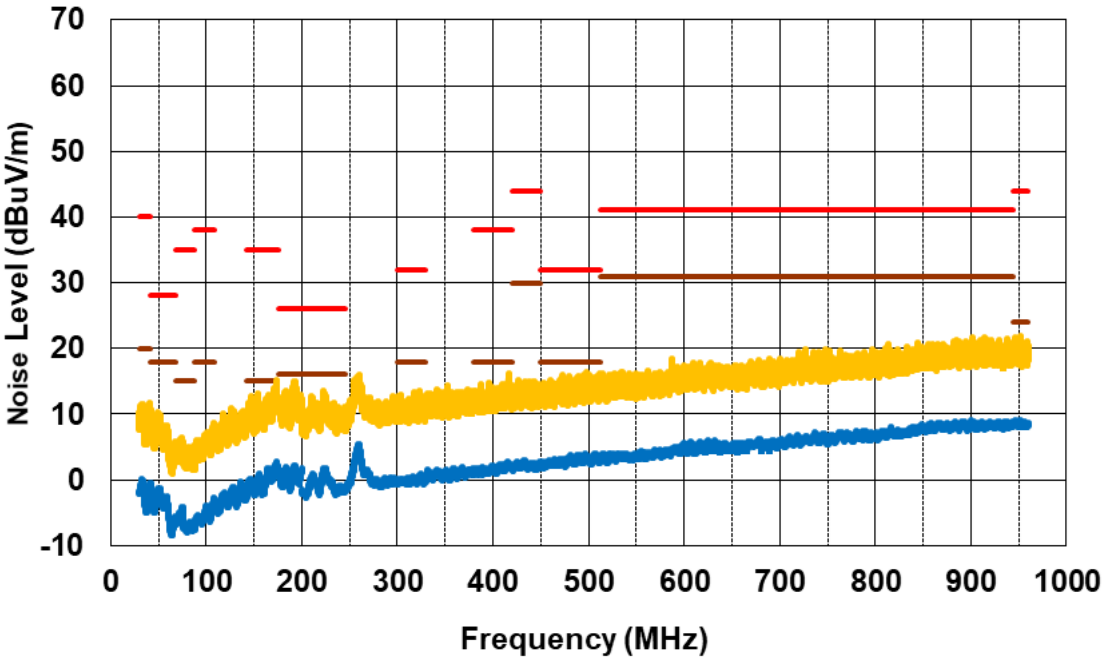


Figure 2-35. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Vertical

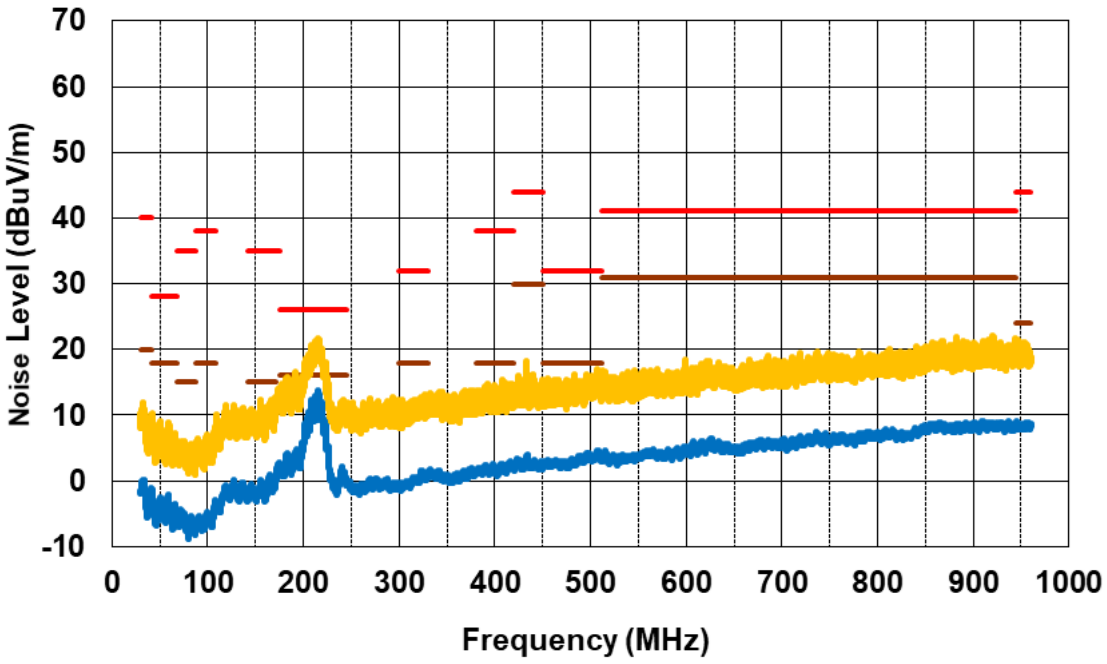


Figure 2-36. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A, Horizontal

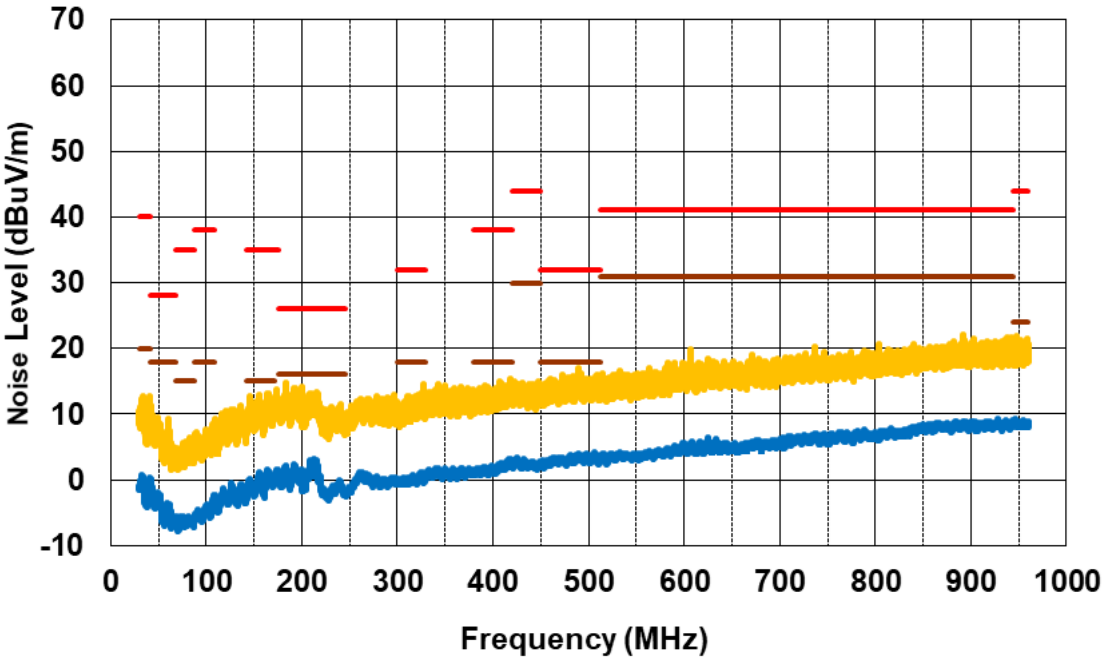


Figure 2-37. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 2A, Vertical

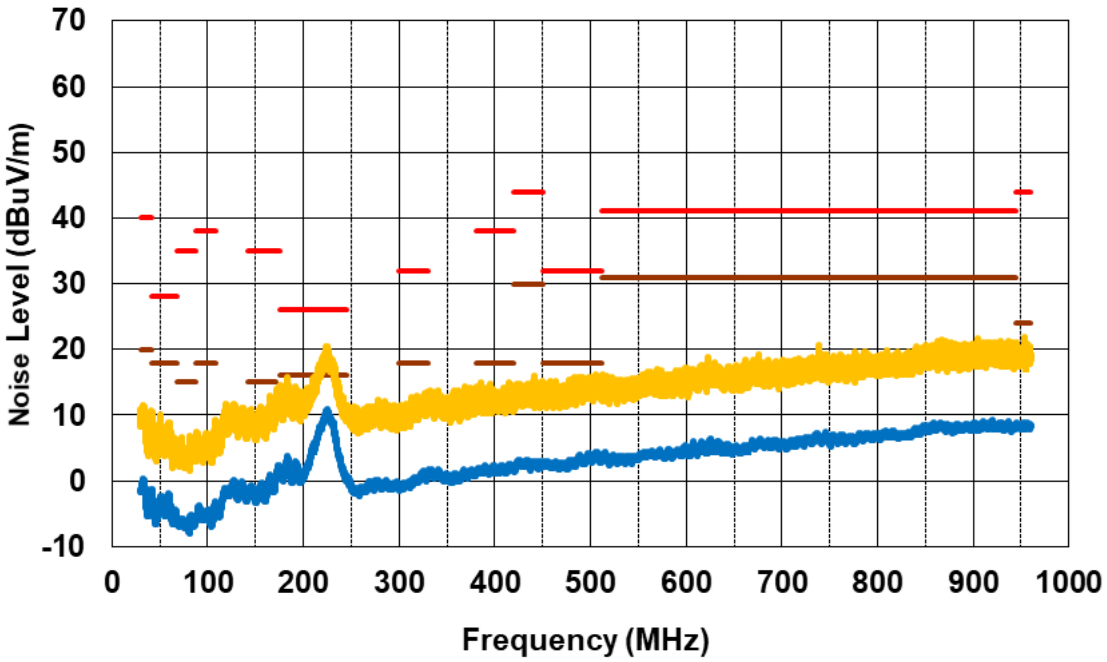


Figure 2-38. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A, Horizontal

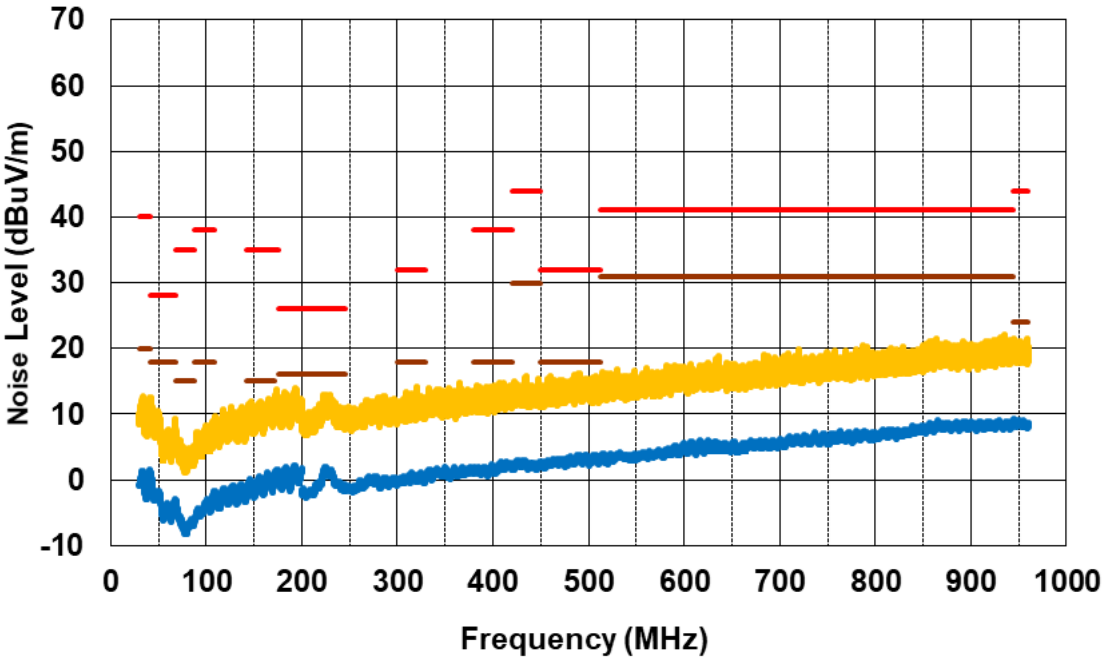


Figure 2-39. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 1.5A, Vertical

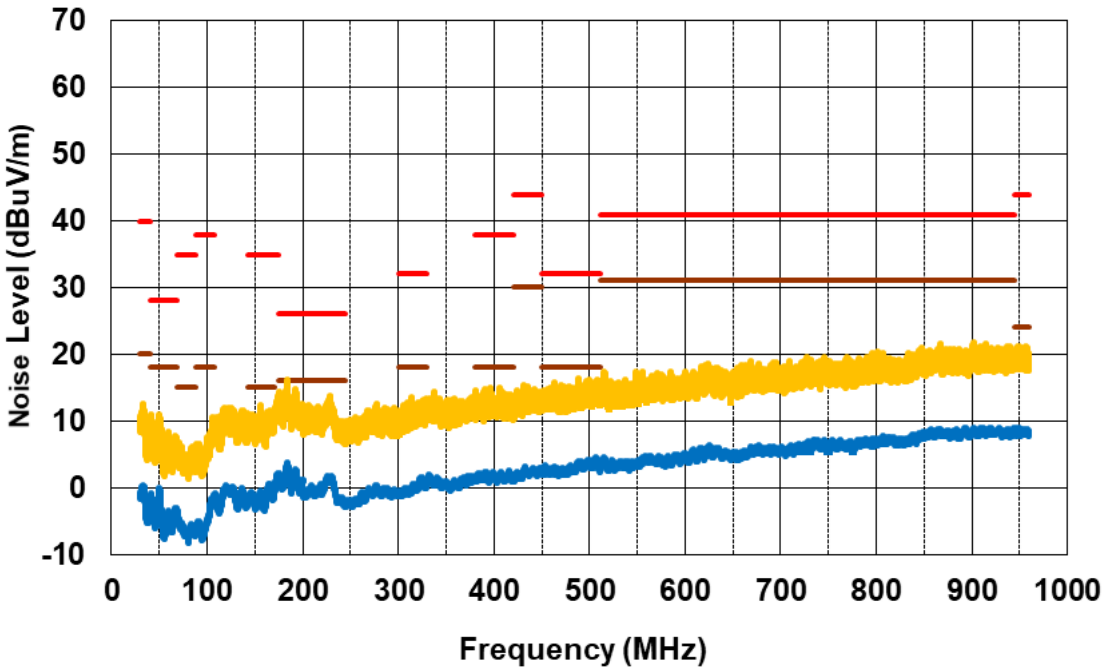


Figure 2-40. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 2.25A, I_{PB_BUS} = 0.75A, Horizontal

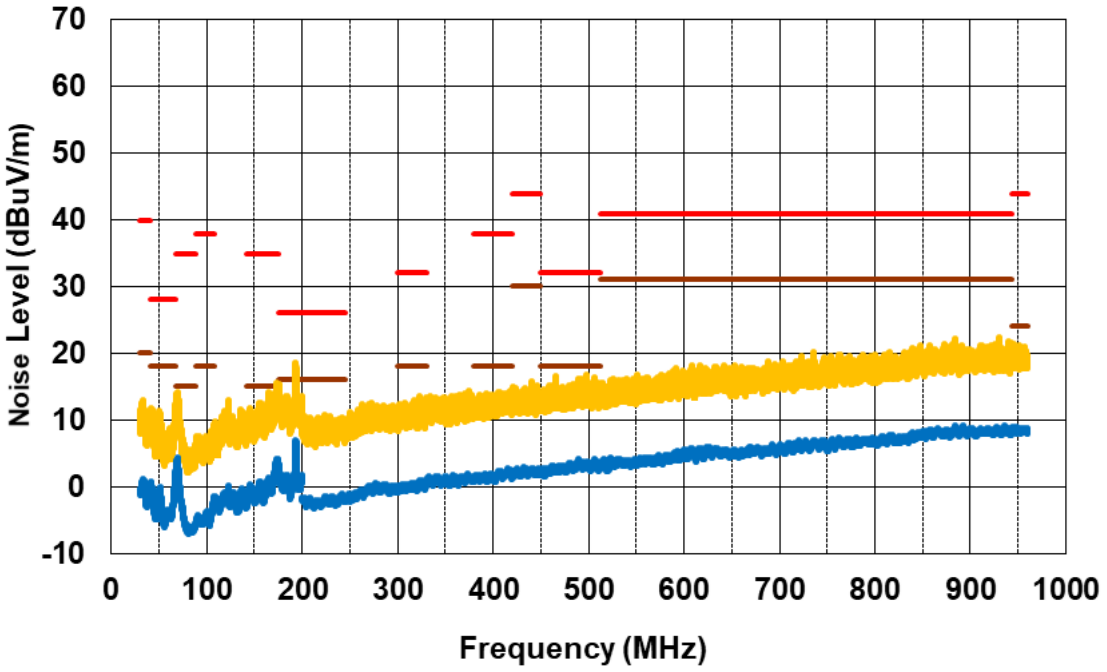


Figure 2-41. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 2.25A, I_{PB_BUS} = 0.75A, Vertical

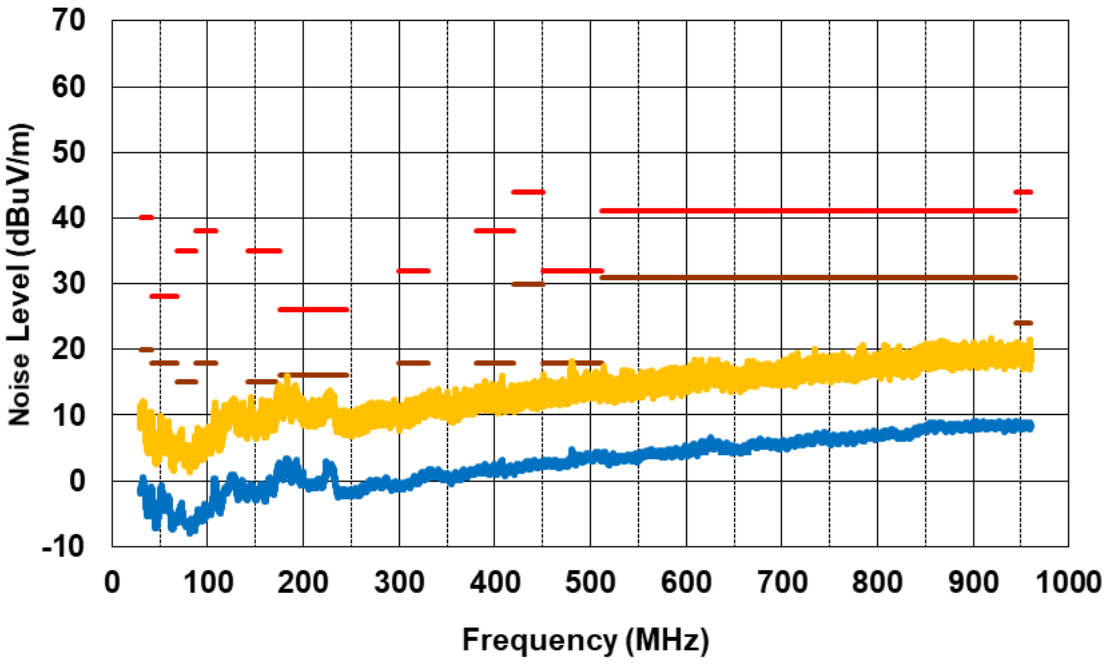


Figure 2-42. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 0.75A, I_{PB_BUS} = 2.25A, Horizontal

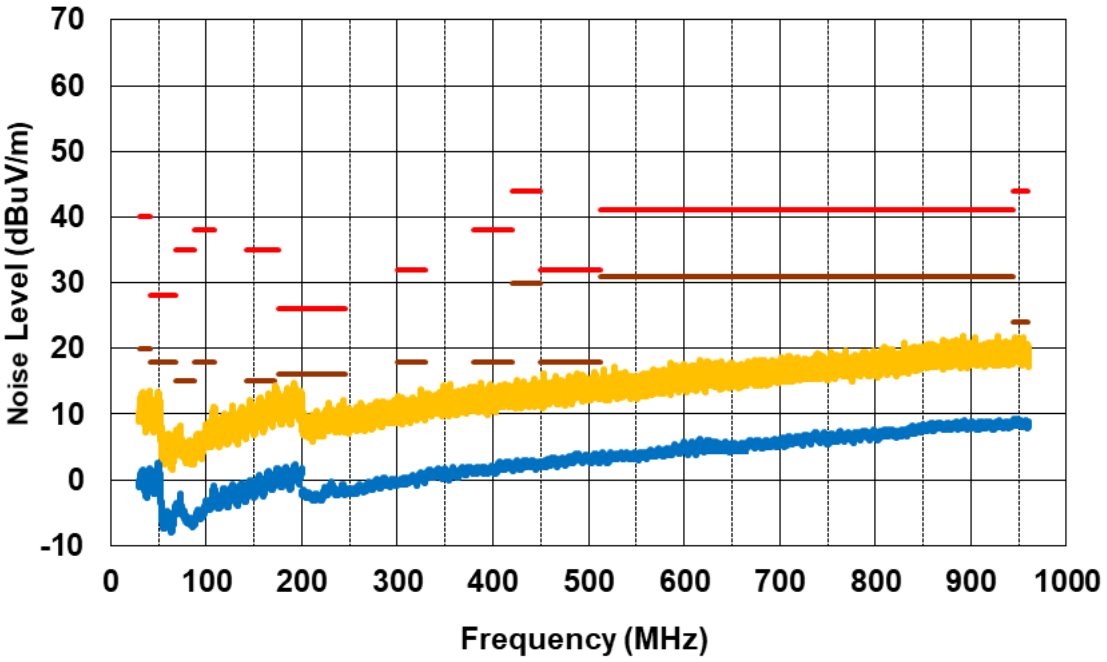


Figure 2-43. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 0.75A, I_{PB_BUS} = 2.25A, Vertical

3 Waveforms

3.1 Switching

The waveforms of switching nodes at different output voltages with full load conditions are shown in Figure 3-1 through Figure 3-8.

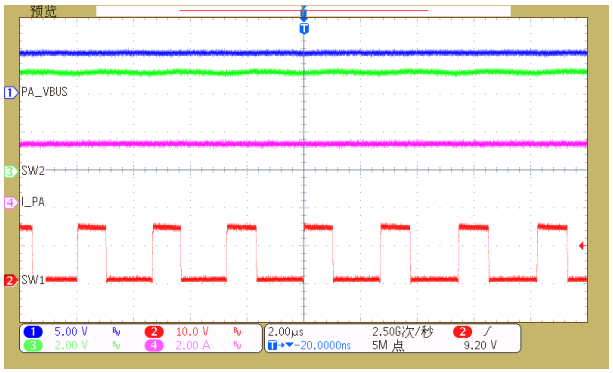


Figure 3-1. PORTA, 14V Input, 5V, 3A Load

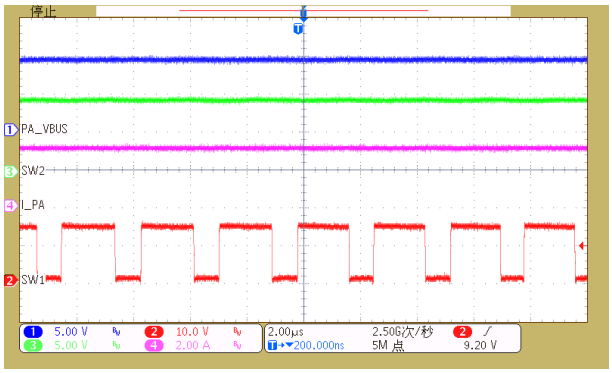


Figure 3-2. PORTA, 14V Input, 9V, 3A Load

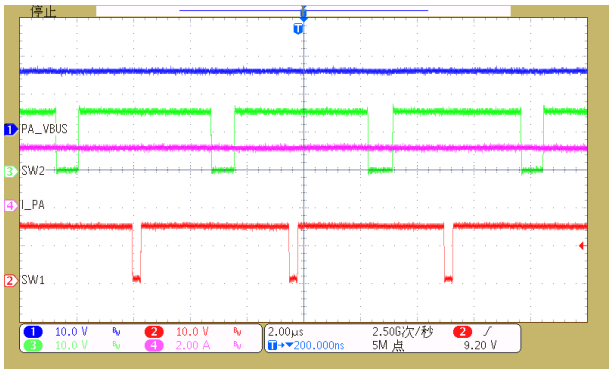


Figure 3-3. PORTA, 14V Input, 15V, 3A Load

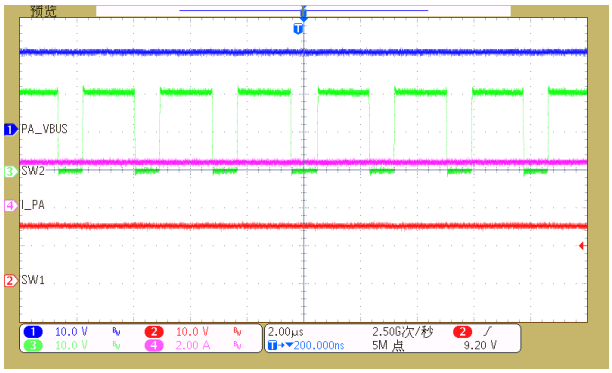


Figure 3-4. PORTA, 14V Input, 20V, 2.25A Load

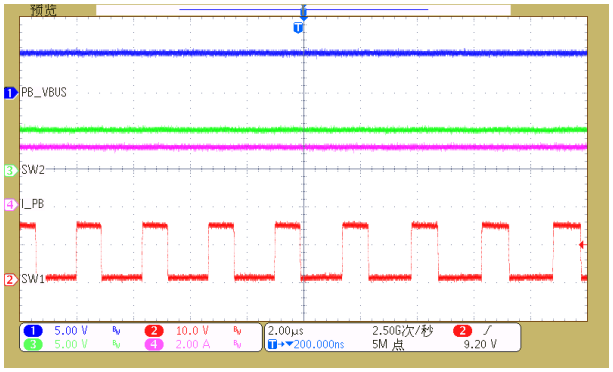


Figure 3-5. PORTB, 14V Input, 5V, 3A Load

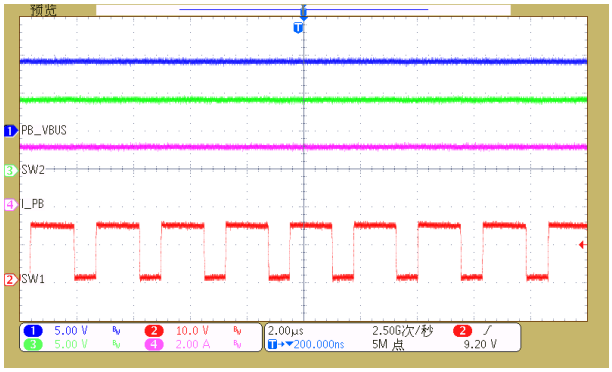


Figure 3-6. PORTB, 14V Input, 9V, 3A Load

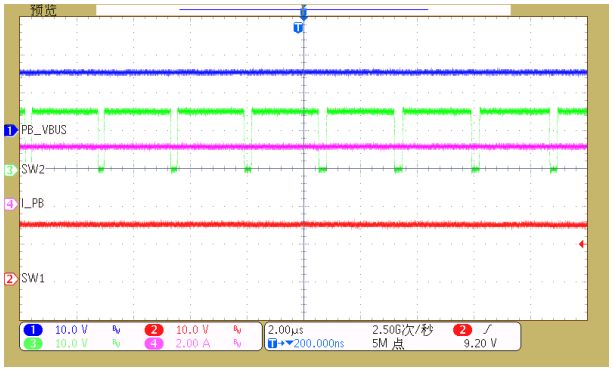


Figure 3-7. PORTB, 14V Input, 15V, 3A Load

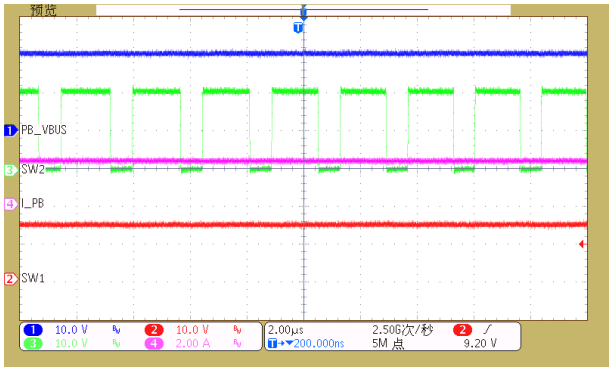


Figure 3-8. PORTB, 14V Input, 20V, 2.25A Load

3.2 Output Voltage Ripple

The waveforms of output AC ripples at different output voltages with full load conditions are shown in Figure 3-9 through Figure 3-20.

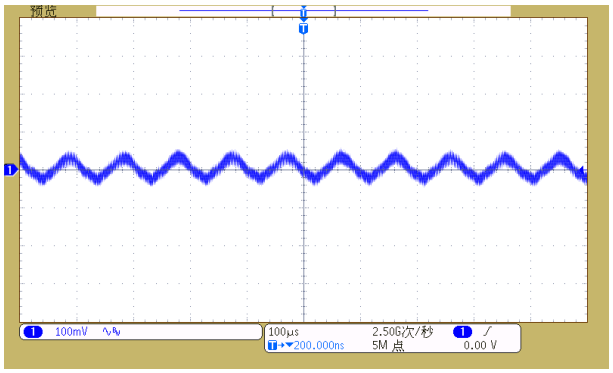


Figure 3-9. Output Voltage Ripple, PORTA, 14V Input, 5V, 3A Load

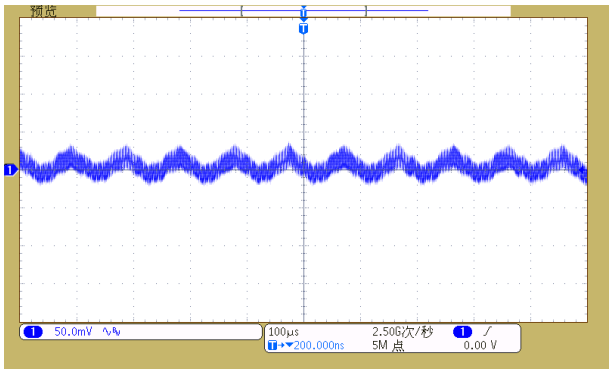


Figure 3-10. Output Voltage Ripple, PORTA, 14V Input, 9V, 3A Load

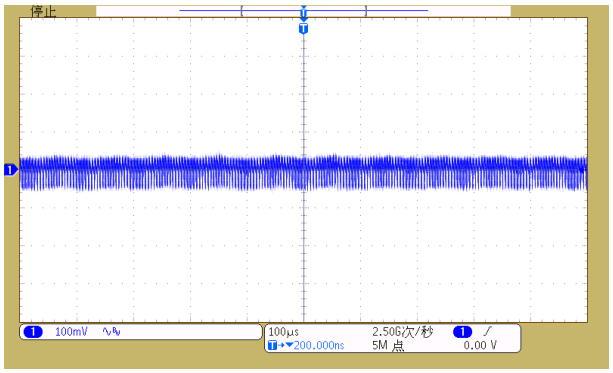


Figure 3-11. Output Voltage Ripple, PORTA, 14V Input, 15V, 2A Load

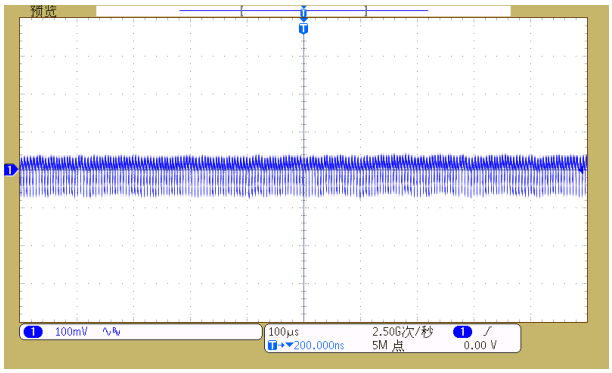


Figure 3-12. Output Voltage Ripple, PORTA, 14V Input, 15V, 3A Load

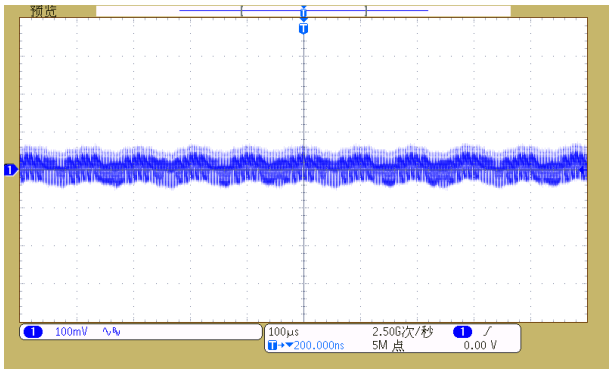


Figure 3-13. Output Voltage Ripple, PORTA, 14V Input, 20V, 1.5A Load

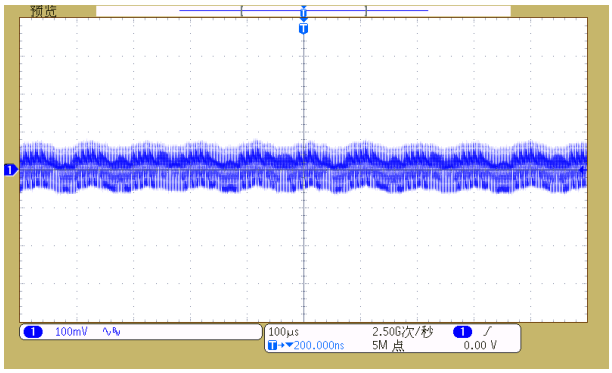


Figure 3-14. Output Voltage Ripple, PORTA, 14V Input, 20V, 2.25A Load

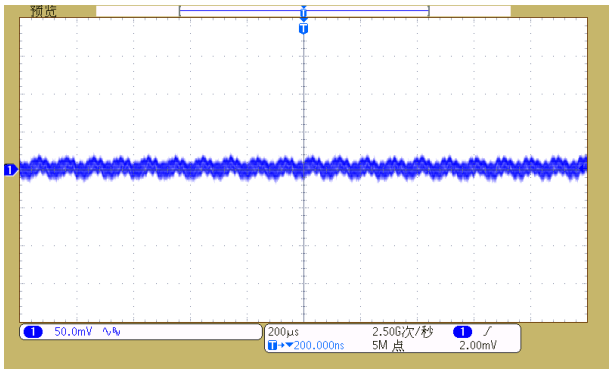


Figure 3-15. Output Voltage Ripple, PORTB, 14V Input, 5V, 3A Load

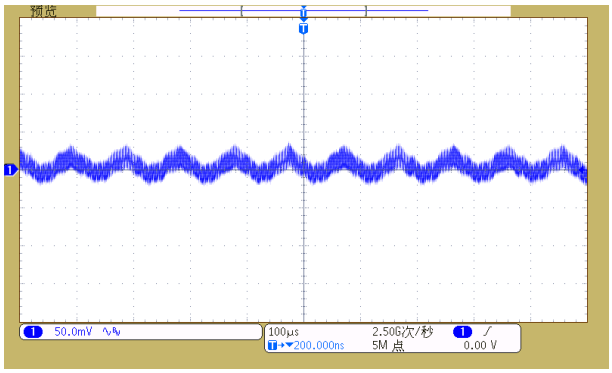


Figure 3-16. Output Voltage Ripple, PORTB, 14V Input, 9V, 3A Load

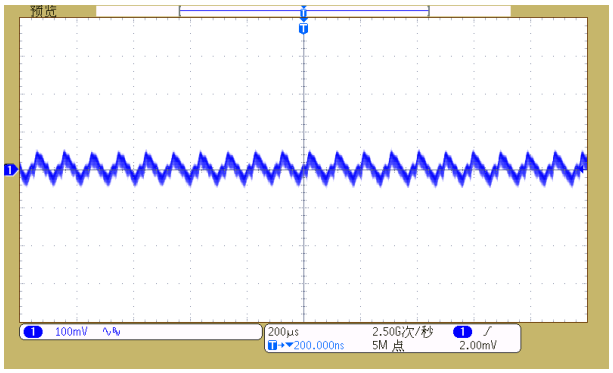


Figure 3-17. Output Voltage Ripple, PORTB, 14V Input, 15V, 2A Load

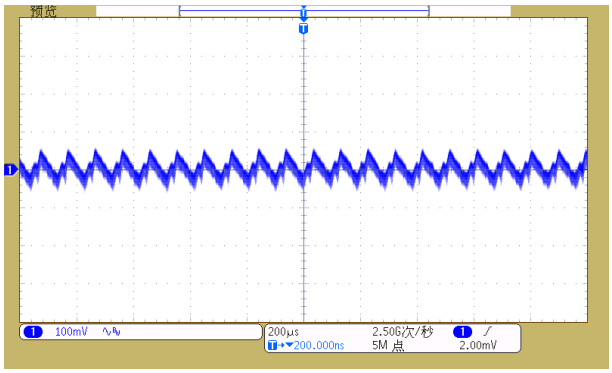


Figure 3-18. Output Voltage Ripple, PORTB, 14V Input, 15V, 3A Load

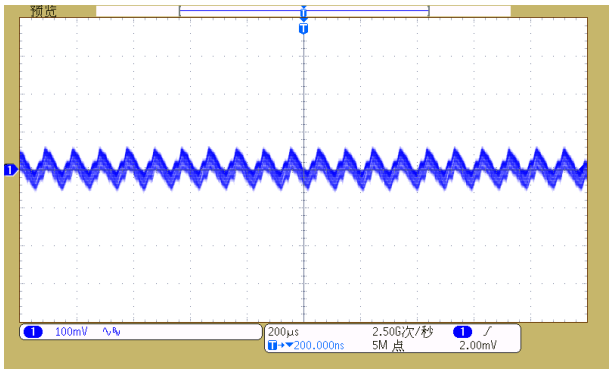


Figure 3-19. Output Voltage Ripple, PORTB, 14V Input, 20V, 1.5A Load

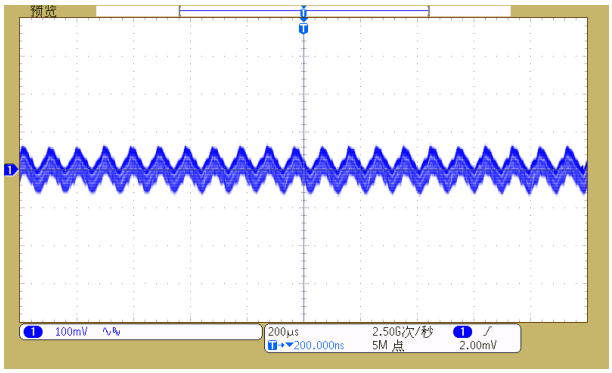


Figure 3-20. Output Voltage Ripple, PORTB, 14V Input, 20V, 2.25A Load

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