Test Report: PMP41094

CISPR 25 Class 5, 400kHz-Rated, 90W Automotive Dual USB Type-C® and USB PD Charger Reference Design

Description

This reference design is a 90W automotive charger for dual USB Type-C® power delivery (PD) with 60W 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 design uses the TUSB4020BI-Q1 two-port USB 2.0 hub which provides USB high-speed and full-speed connections.

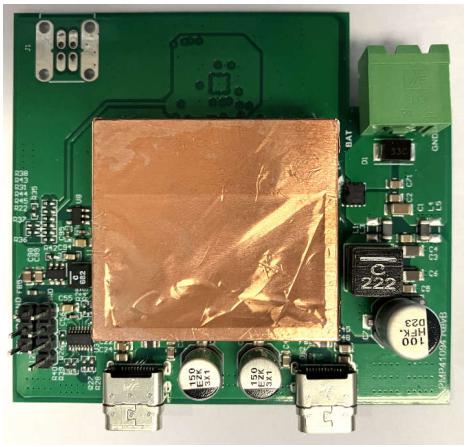
The board maximum efficiency is 96.1%. The board is compliant with the stringent CISPR 25 Class 5 conducted and radiated electromagnetic interference (EMI).

Features

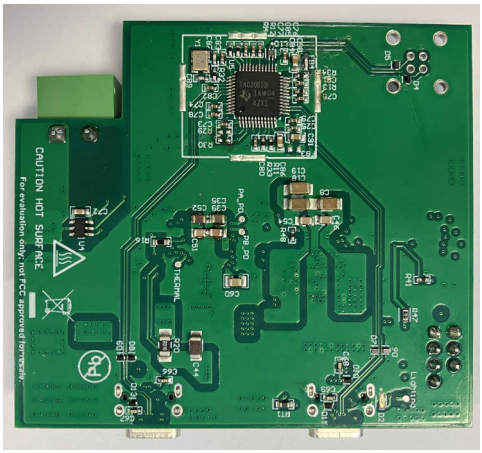
- 90W dual USB Type-C ports charger
- Compliance with CISPR 25 Class 5 conducted and radiated EMI standard
- High-efficiency with 96.1% peak efficiency
- Cost efficient without common mode inductor
- Compact form factor of 63.9mm by 71.8mm

Applications

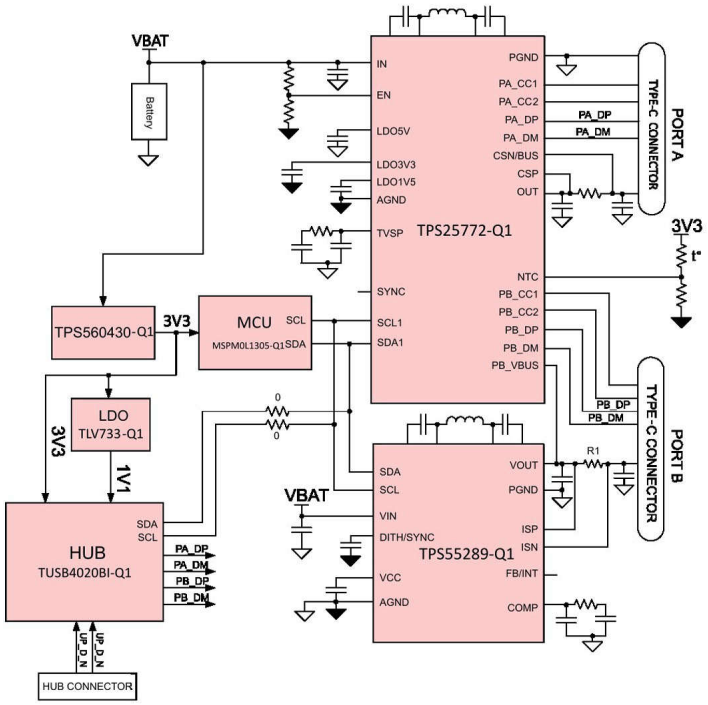
- Automotive USB charge



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	60W
PB_BUS Output Voltage	5VDC, 9VDC, 15VDC, 20VDC
PB_BUS Maximum Output Current	3A
PB_BUS Maximum Output Power	60W
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 63.9mm (length) by 71.8mm (width) by 10.2mm (height).

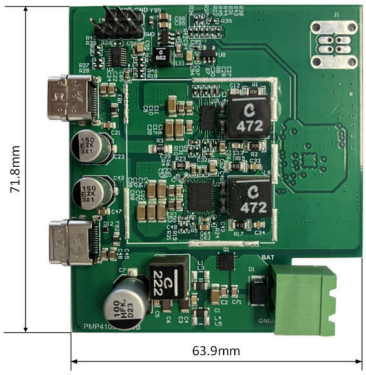


Figure 1-1. Board Dimensions

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1.

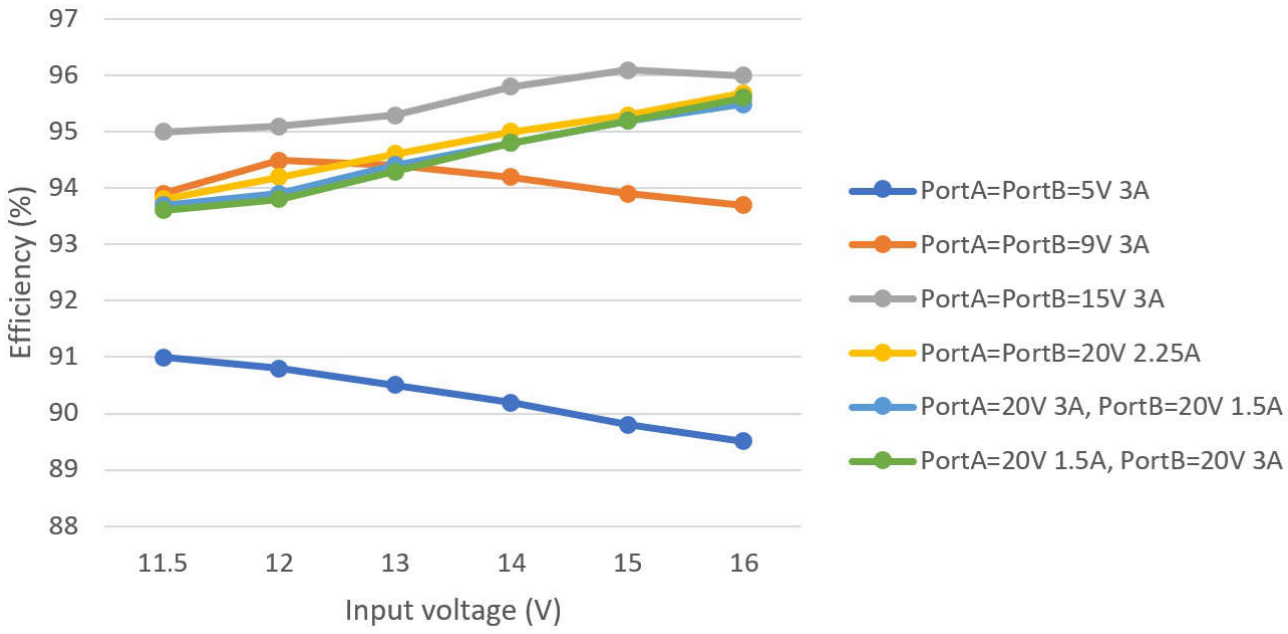


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Efficiency data is shown in Table 2-1.

Table 2-1. Efficiency Data

VIN (V)	IIN (A)	VPA_BUS (V)	IPA_BUS (A)	VPA_BUS (V)	IPA_BUS (A)	Ploss (A)	Efficiency(%)
11.99	2.752	4.941	2.996	5.063	2.995	3.025	90.8
13	2.547	4.941	2.996	5.063	2.995	3.137	90.5
14	2.373	4.941	2.996	5.063	2.995	3.263	90.2
15.01	2.222	4.941	2.996	5.063	2.995	3.386	89.8
15.98	2.095	4.94	2.996	5.063	2.995	3.513	89.5
11.5	4.966	8.944	2.996	8.953	2.995	3.474	93.9
12.51	4.531	8.944	2.994	8.953	2.995	3.095	94.5
13.02	4.359	8.944	2.994	8.953	2.995	3.166	94.4
13.98	4.069	8.944	2.994	8.953	2.995	3.304	94.2
15	3.805	8.944	2.994	8.953	2.995	3.458	93.9
16.01	3.575	8.943	2.994	8.953	2.995	3.627	93.7
11.51	8.185	14.94	2.994	14.94	2.996	4.722	95
11.97	7.854	14.93	2.994	14.93	2.996	4.58	95.1
13	7.22	14.93	2.994	14.93	2.996	4.416	95.3
14.02	6.661	14.93	2.994	14.93	2.996	3.961	95.8
14.99	6.211	14.93	2.994	14.93	2.996	3.676	96.1
15.96	5.838	14.93	2.993	14.93	2.996	3.751	96
11.5	8.288	19.92	2.24	19.95	2.246	5.896	93.8
12.02	7.909	19.92	2.245	19.95	2.246	5.53	94.2
12.99	7.282	19.92	2.245	19.94	2.246	5.107	94.6
14.02	6.72	19.92	2.245	19.94	2.246	4.707	95
14.99	6.262	19.92	2.243	19.94	2.246	4.4	95.3
16.01	5.842	19.92	2.243	19.94	2.246	4.063	95.7
11.5	8.304	19.91	2.993	19.95	1.496	6.055	93.7
12.02	7.926	19.91	2.993	19.95	1.496	5.801	93.9
12.99	7.293	19.91	2.993	19.95	1.496	5.308	94.4
14.02	6.729	19.91	2.993	19.95	1.496	4.886	94.8
14.99	6.267	19.91	2.993	19.95	1.496	4.506	95.2
15.96	5.866	19.91	2.993	19.95	1.496	4.186	95.5
11.5	8.316	19.93	1.496	19.94	2.996	6.088	93.6
12.02	7.948	19.93	1.496	19.94	2.996	5.956	93.8
12.99	7.309	19.93	1.496	19.94	2.996	5.409	94.3
14.02	6.74	19.93	1.496	19.94	2.996	4.925	94.8
14.94	6.3	19.93	1.496	19.94	2.996	4.553	95.2
15.96	5.872	19.93	1.496	19.94	2.996	4.158	95.6

2.3 Thermal Images

The thermal images are shown in Figure 2-2 through Figure 2-4. 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.

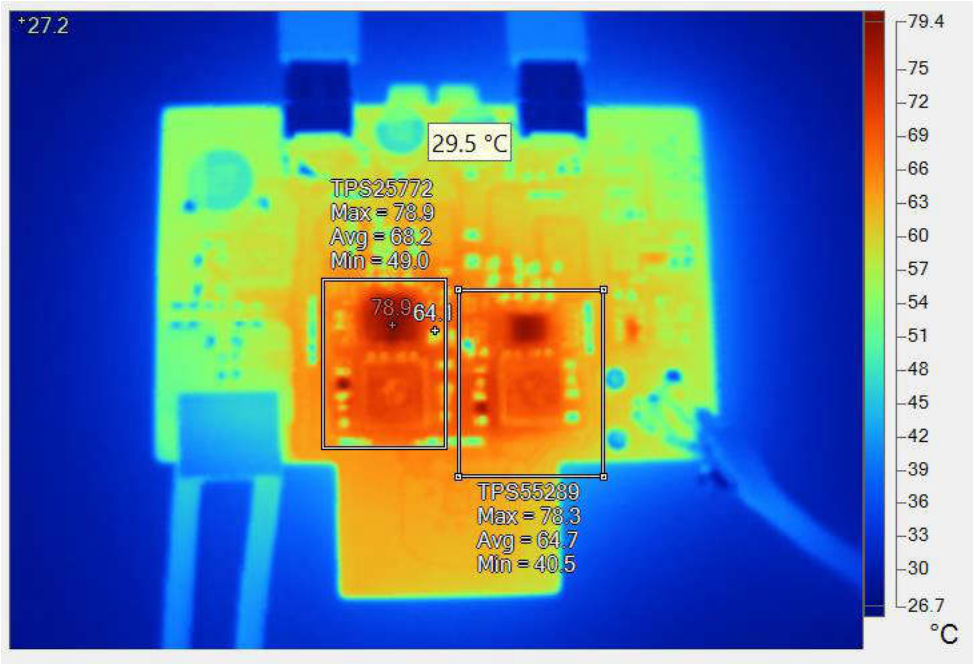


Figure 2-2. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A

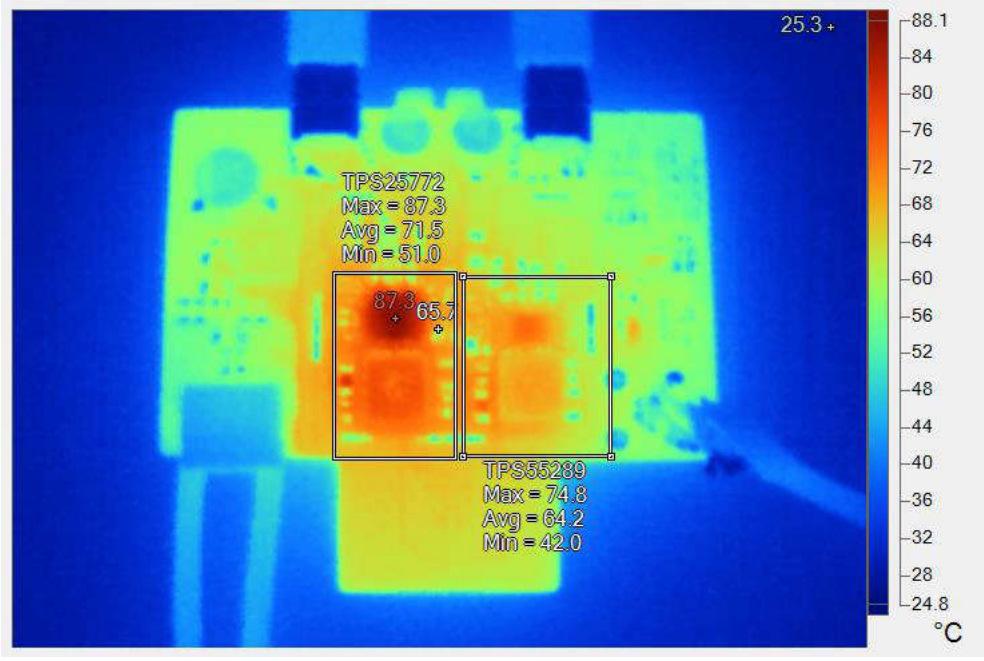


Figure 2-3. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A

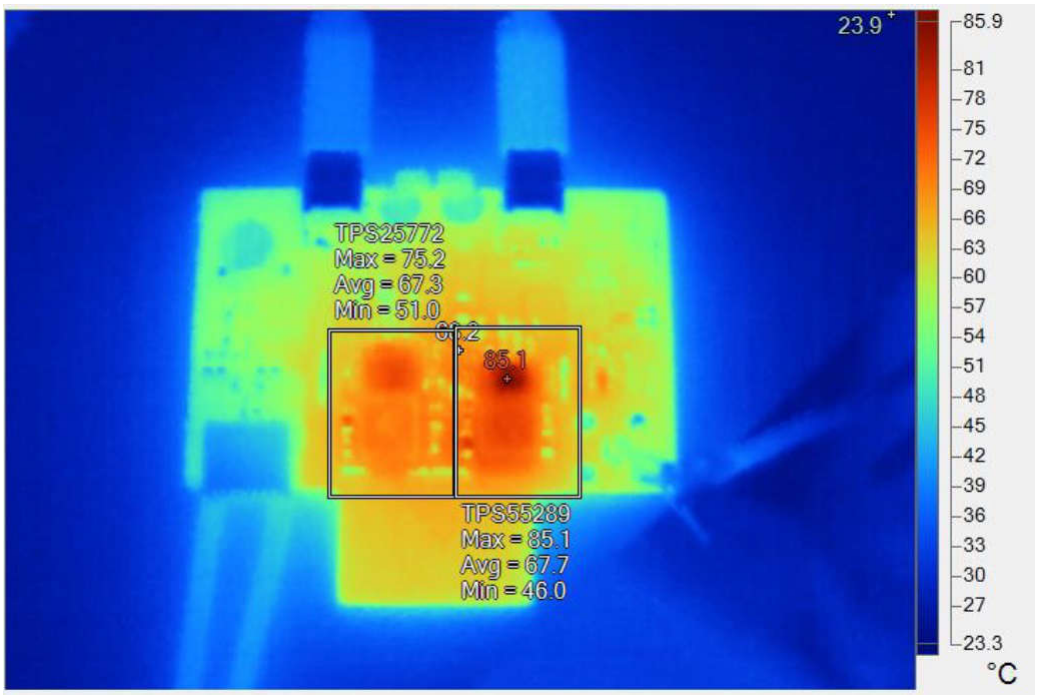


Figure 2-4. Top Side Thermal Image, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A

2.4 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 2-5 through Figure 2-34 show the waveforms of the EMI test results at 14V input.

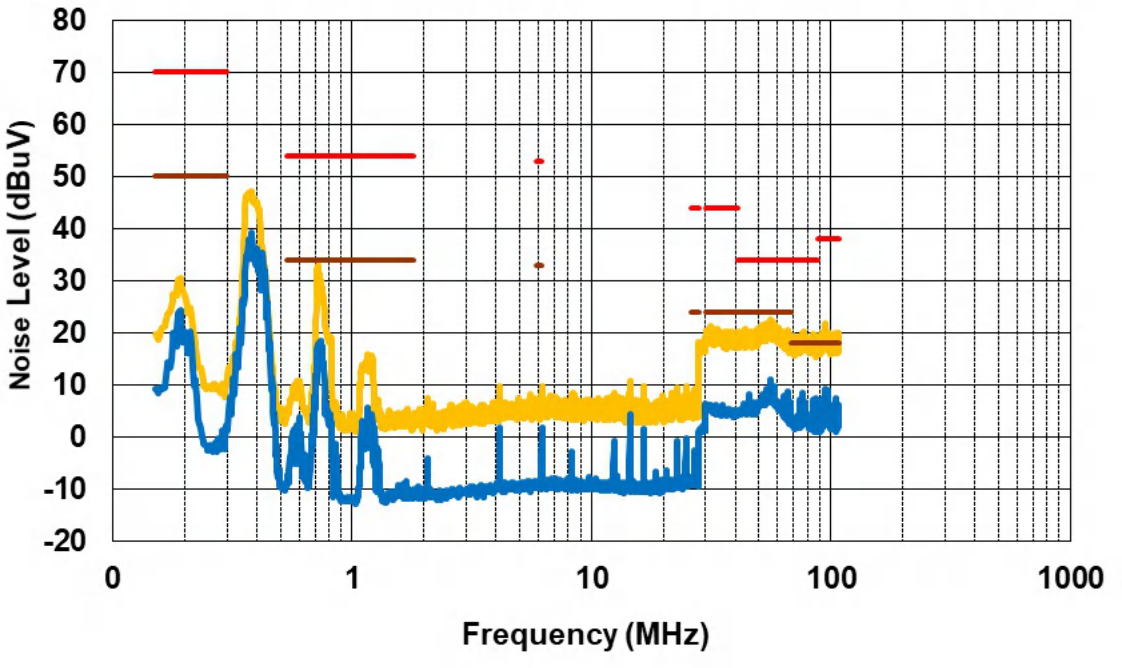


Figure 2-5. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Positive Line

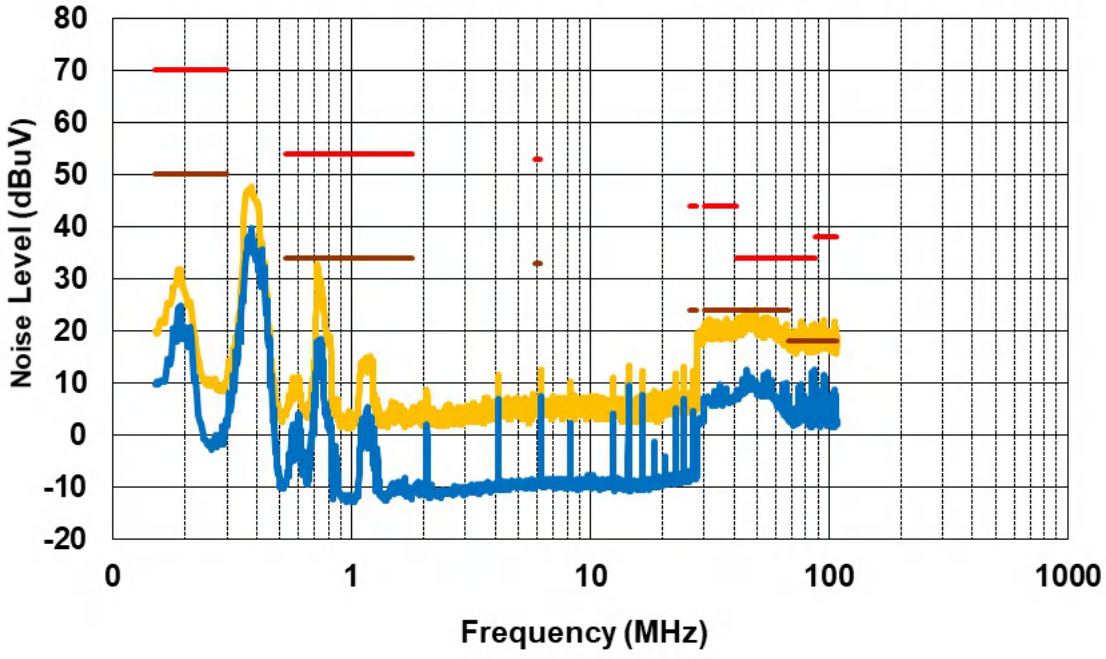


Figure 2-6. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Negative Line

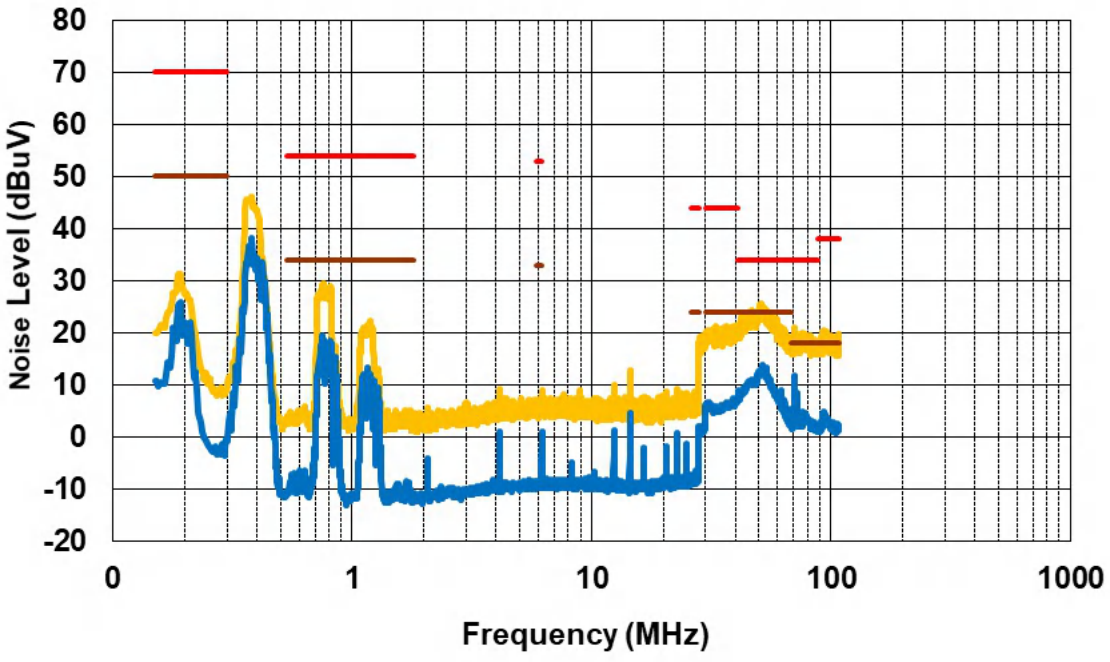


Figure 2-7. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Positive Line

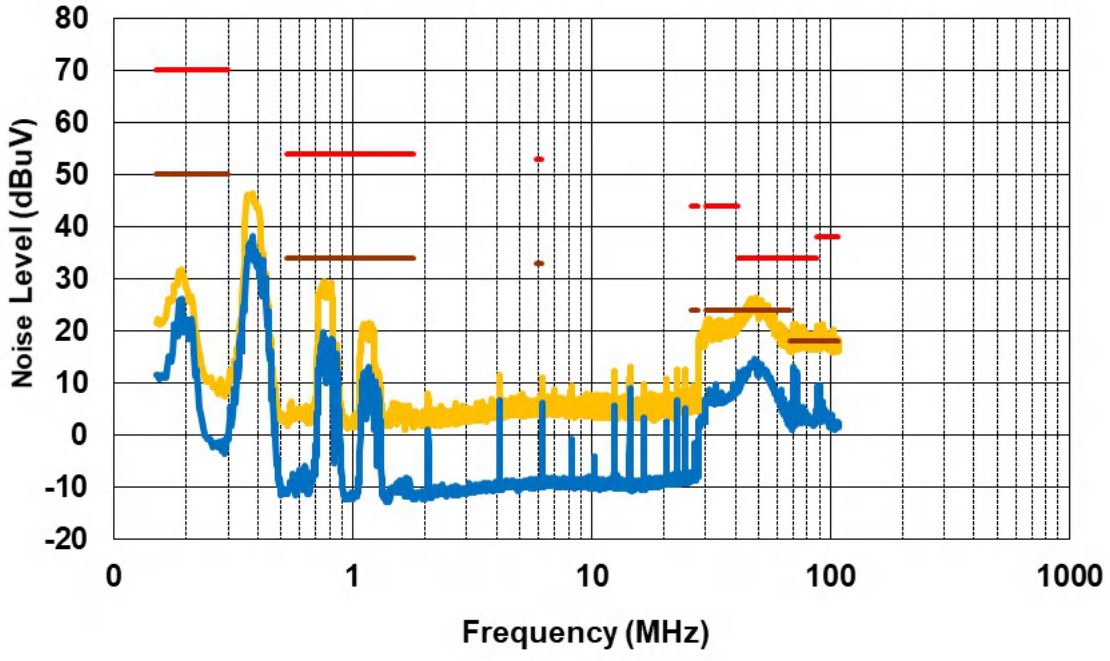


Figure 2-8. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Negative Line

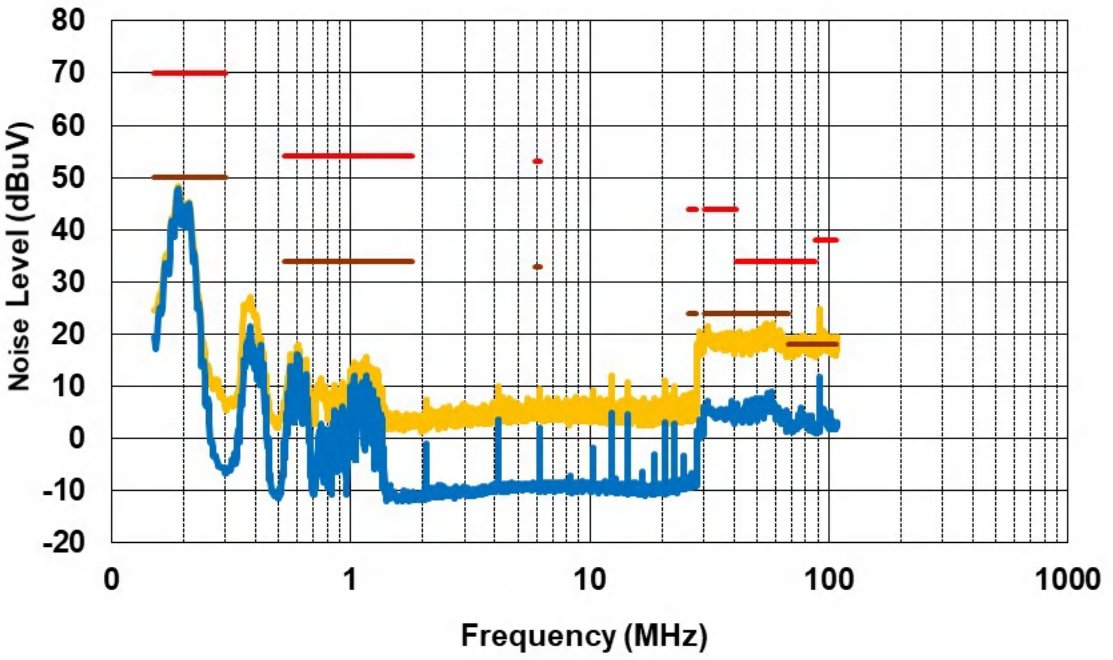


Figure 2-9. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 3A, Positive Line

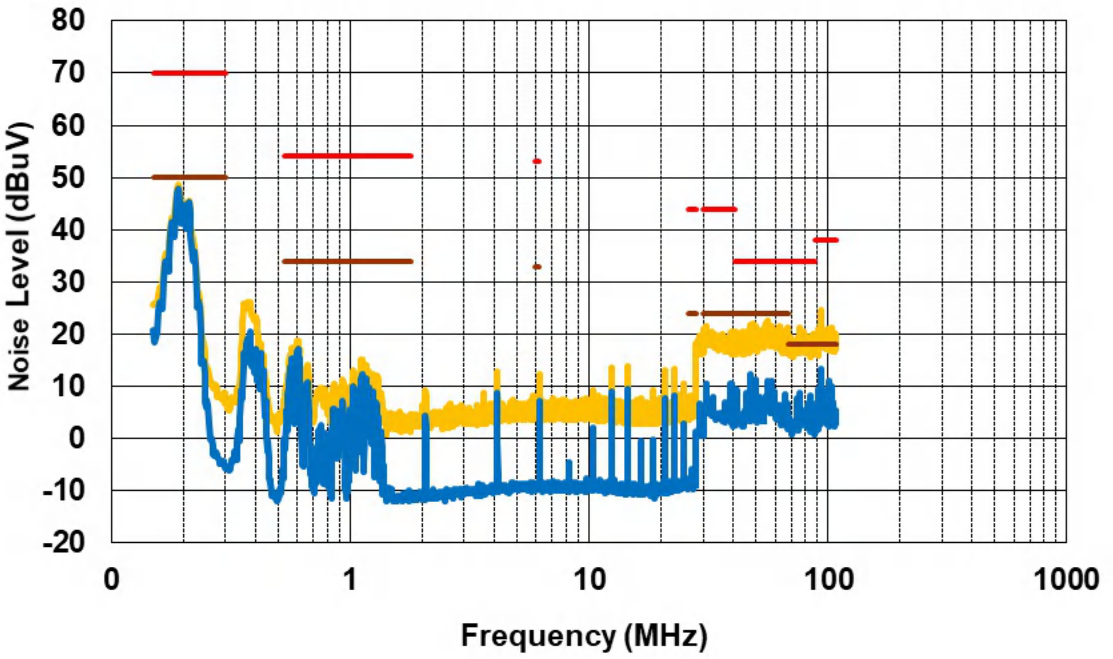


Figure 2-10. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 3A, Negative Line

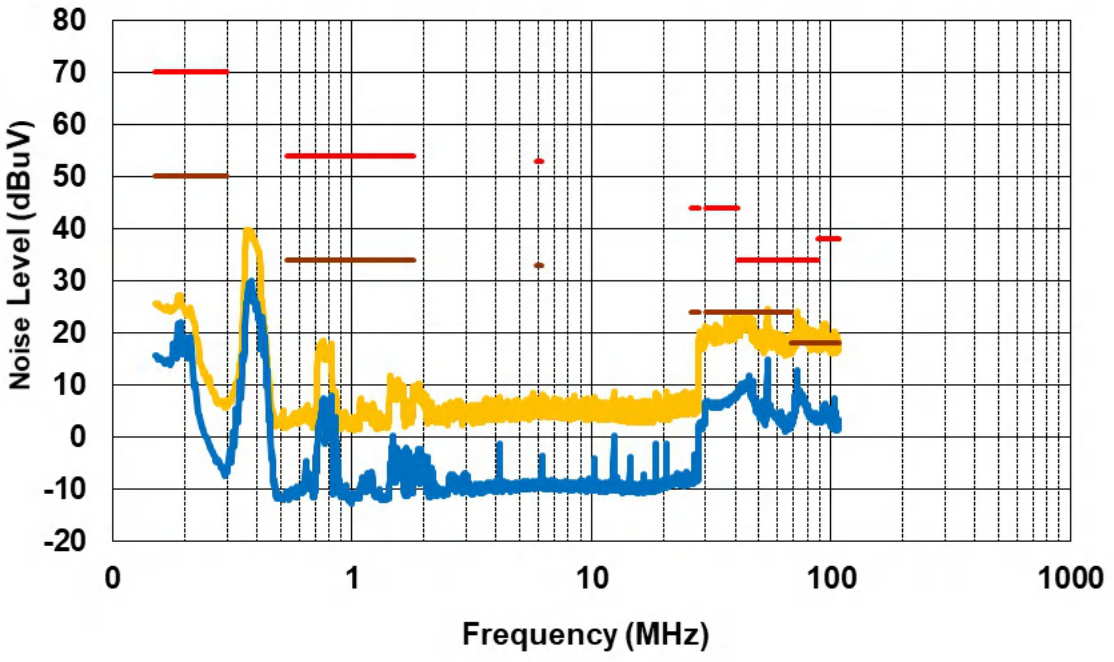


Figure 2-11. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A, Positive Line

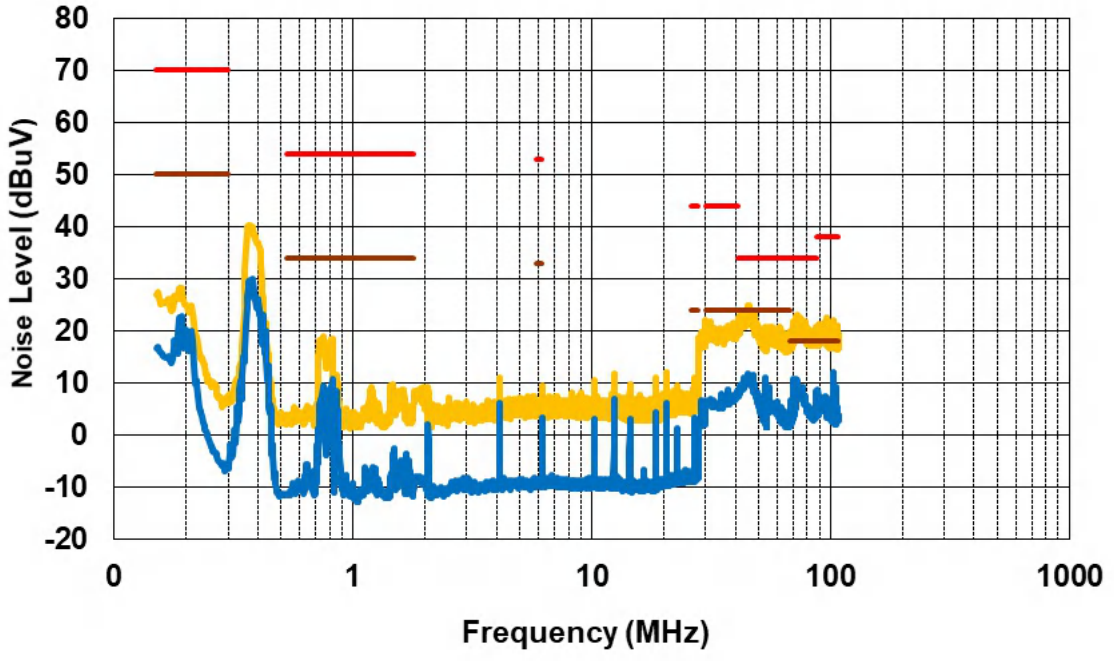


Figure 2-12. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A, Negative Line

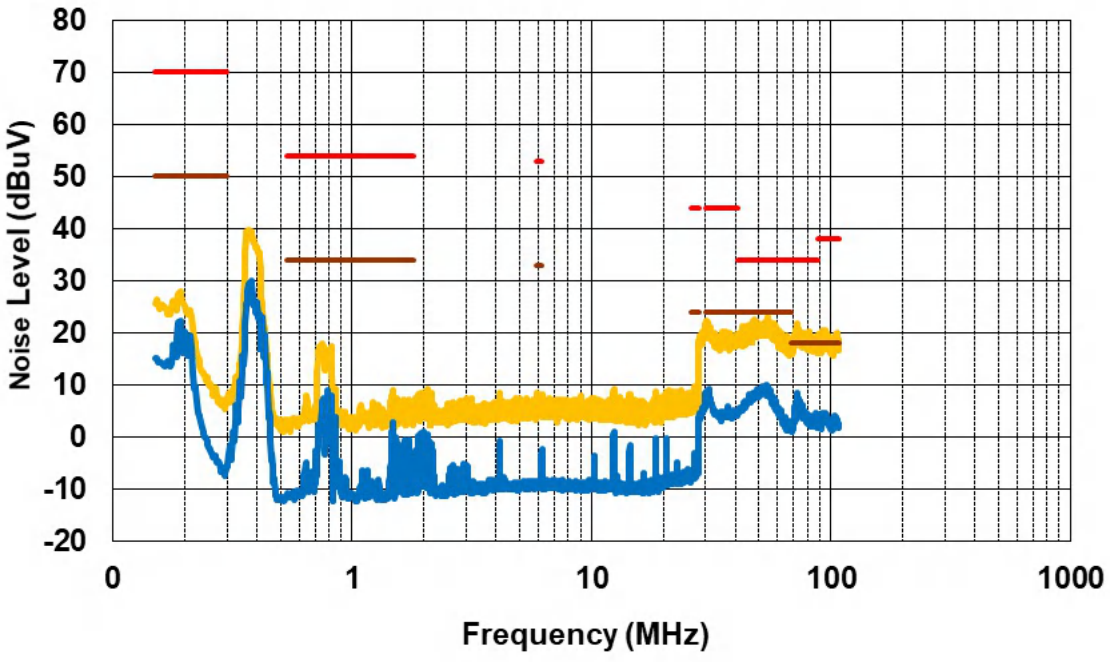


Figure 2-13. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A, Positive Line

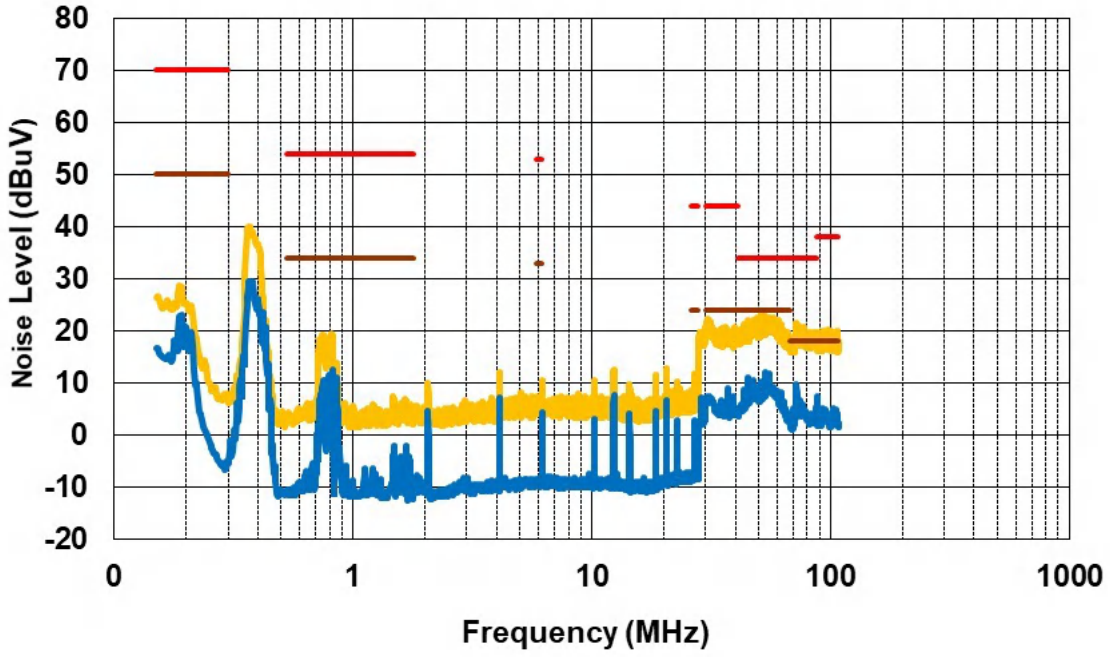


Figure 2-14. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A, Negative Line

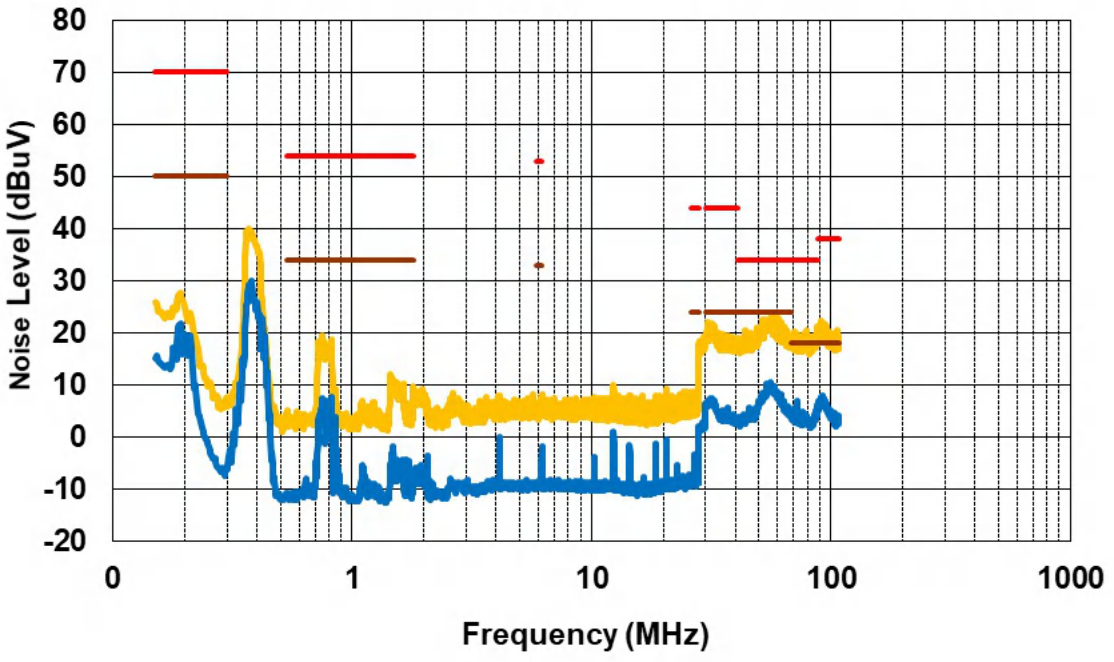


Figure 2-15. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A, Positive Line

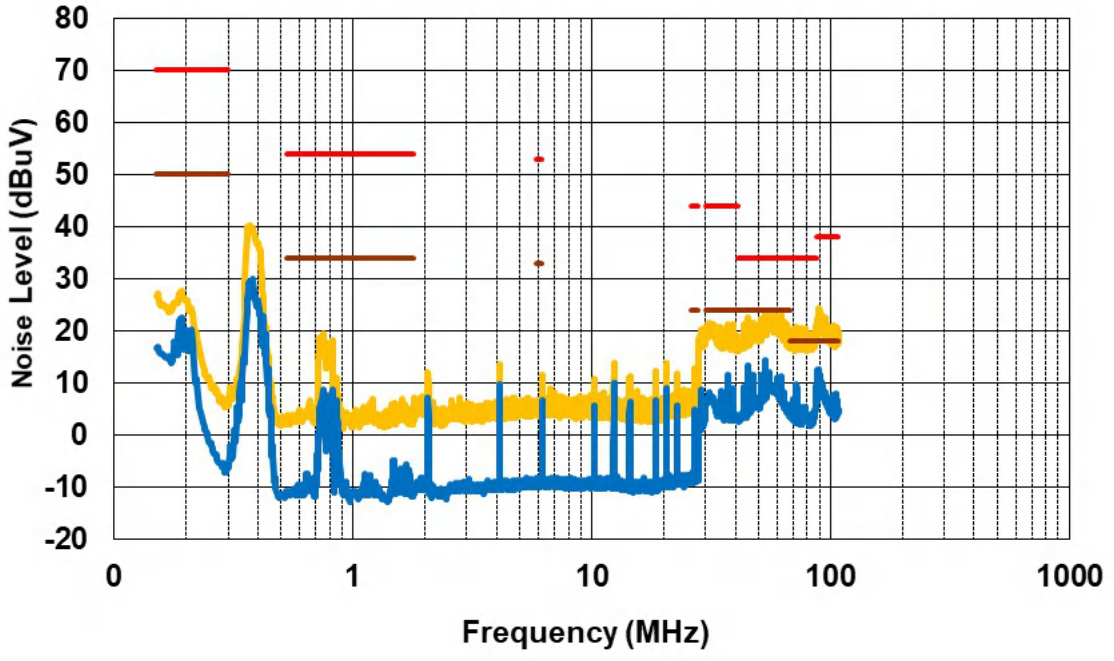


Figure 2-16. Conducted EMI, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A, Negative Line

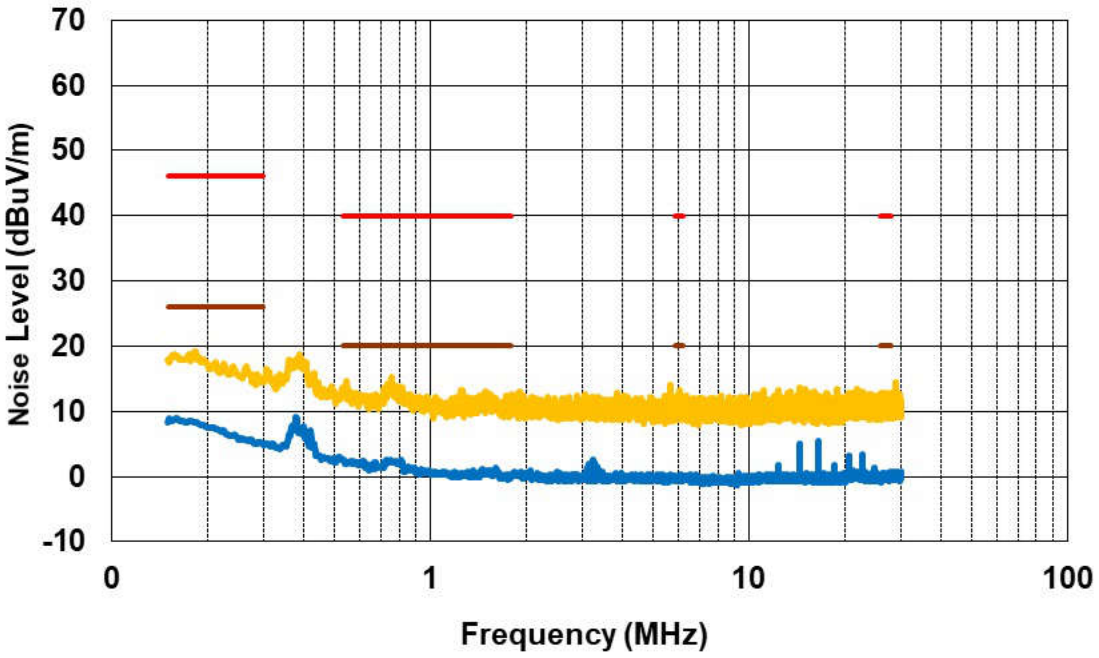


Figure 2-17. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A

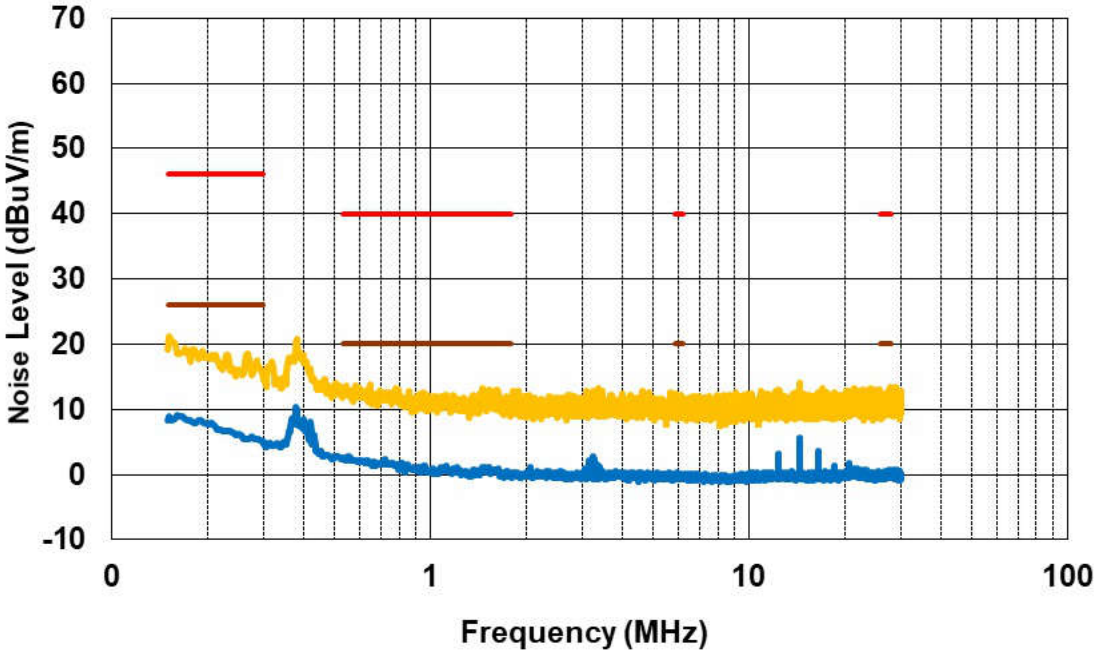


Figure 2-18. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A

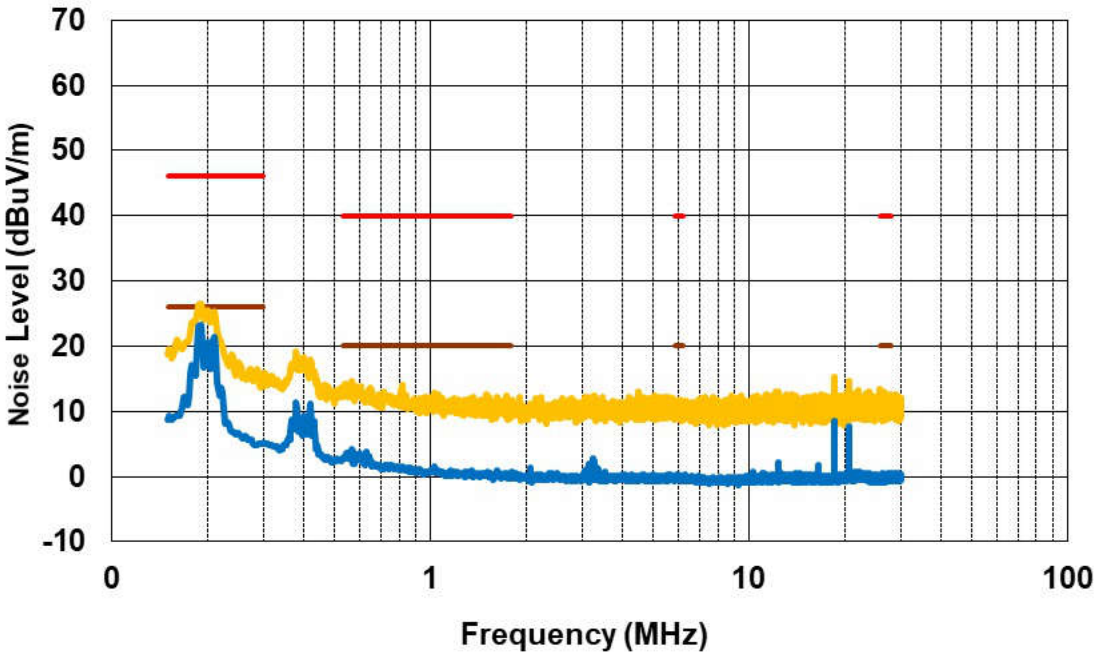


Figure 2-19. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 3A

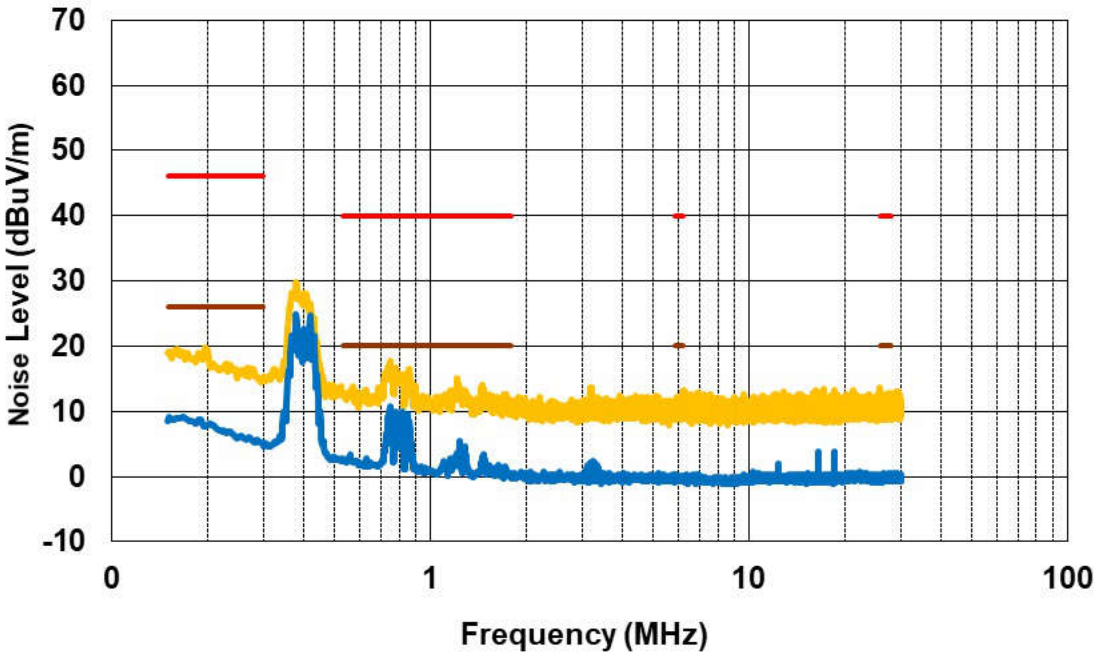


Figure 2-20. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A

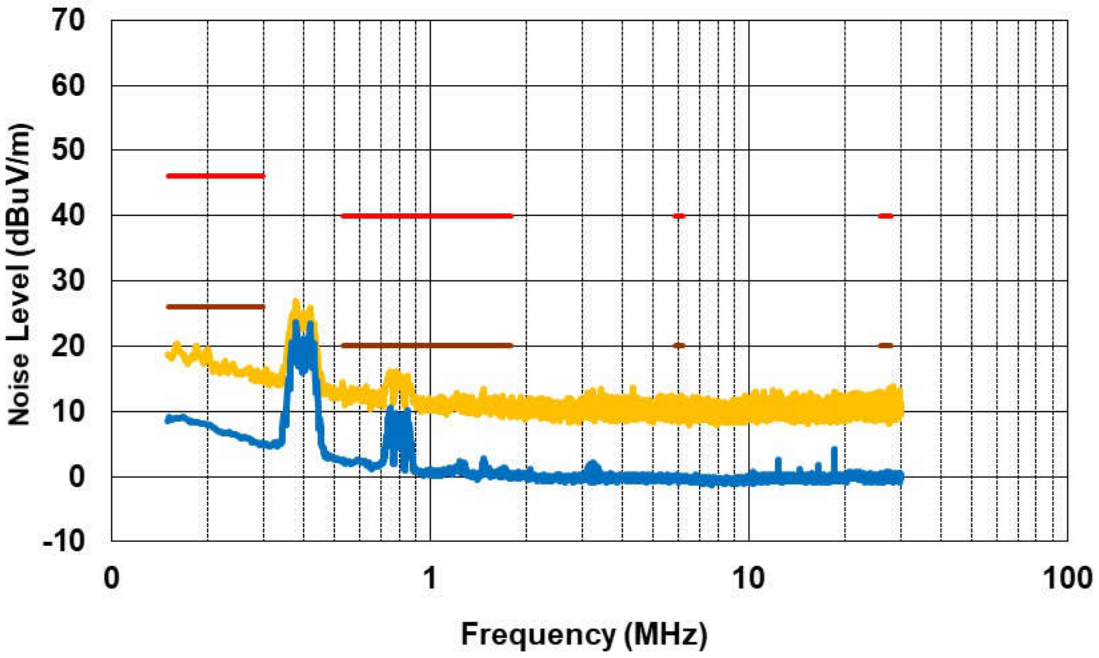


Figure 2-21. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A

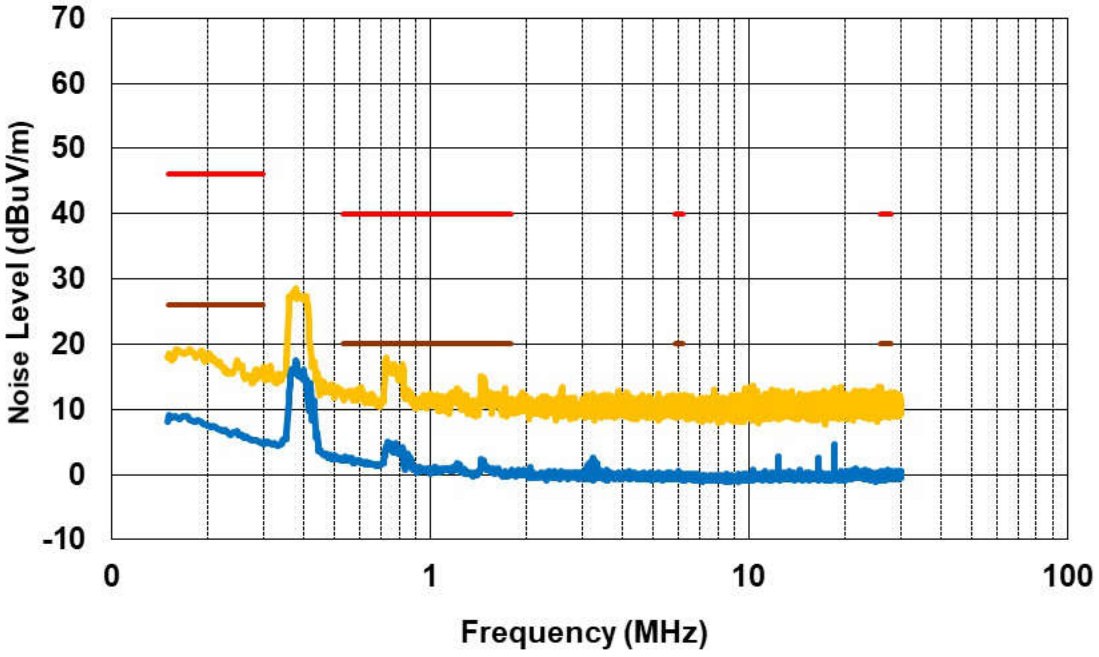


Figure 2-22. Radiated EMI From 150kHz to 30MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A

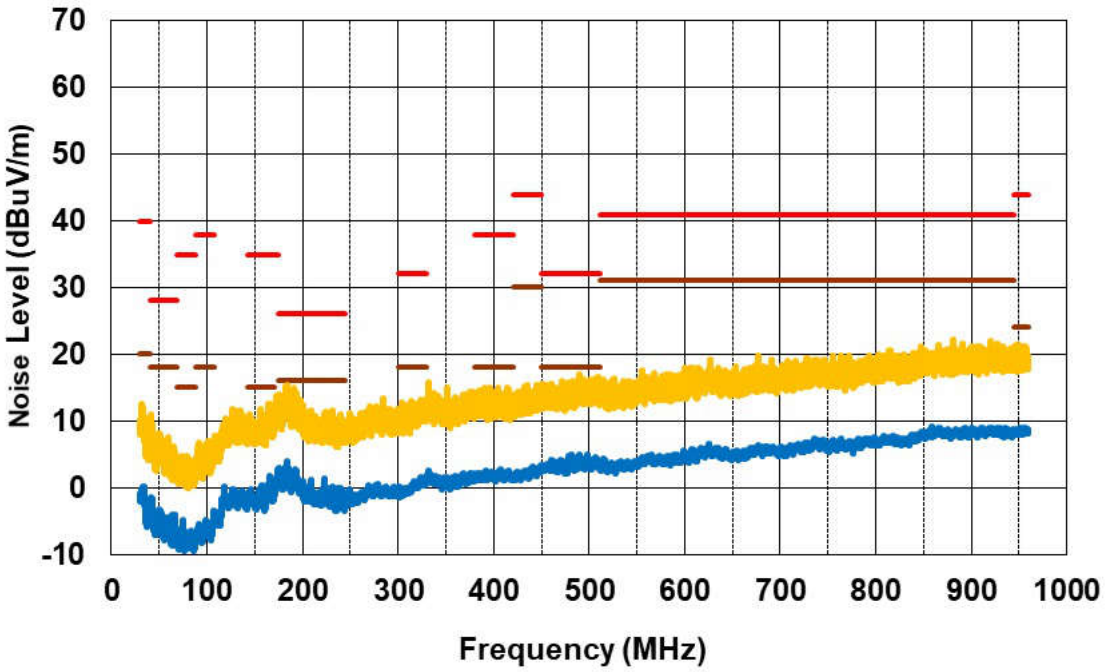


Figure 2-23. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Horizontal

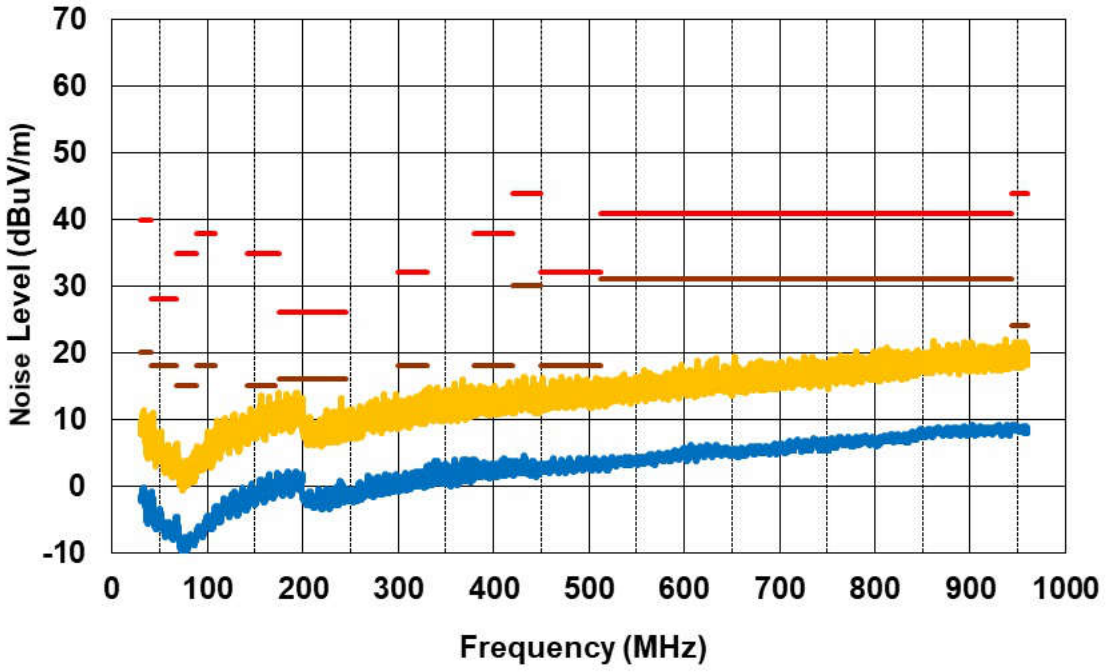


Figure 2-24. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 5V, I_{PA_BUS} = I_{PB_BUS} = 3A, Vertical

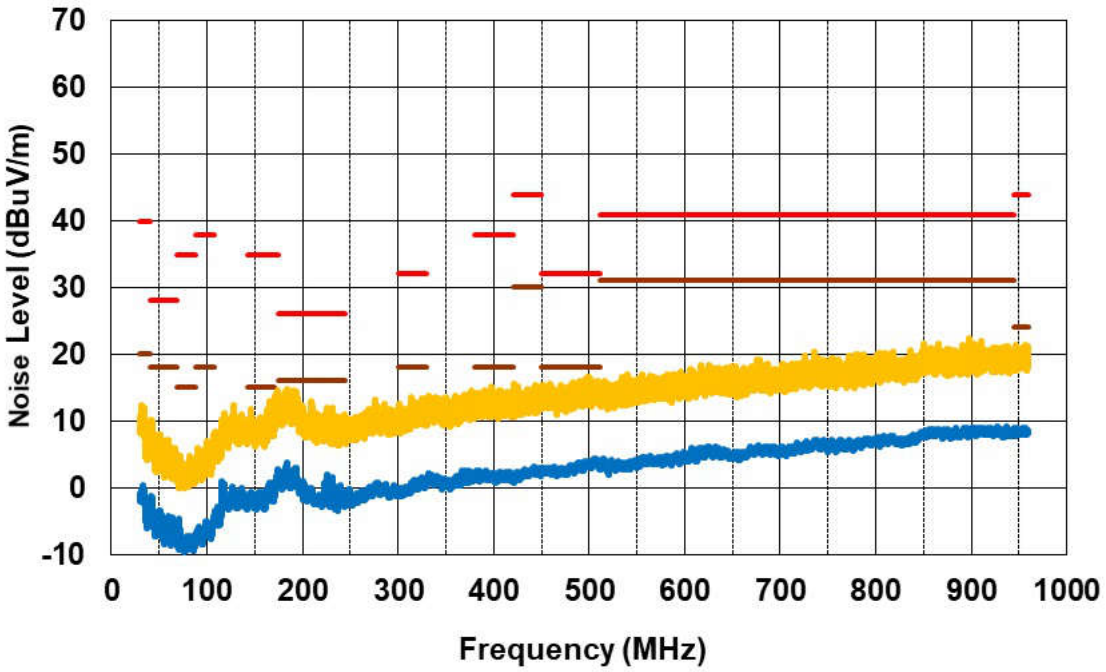


Figure 2-25. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Horizontal

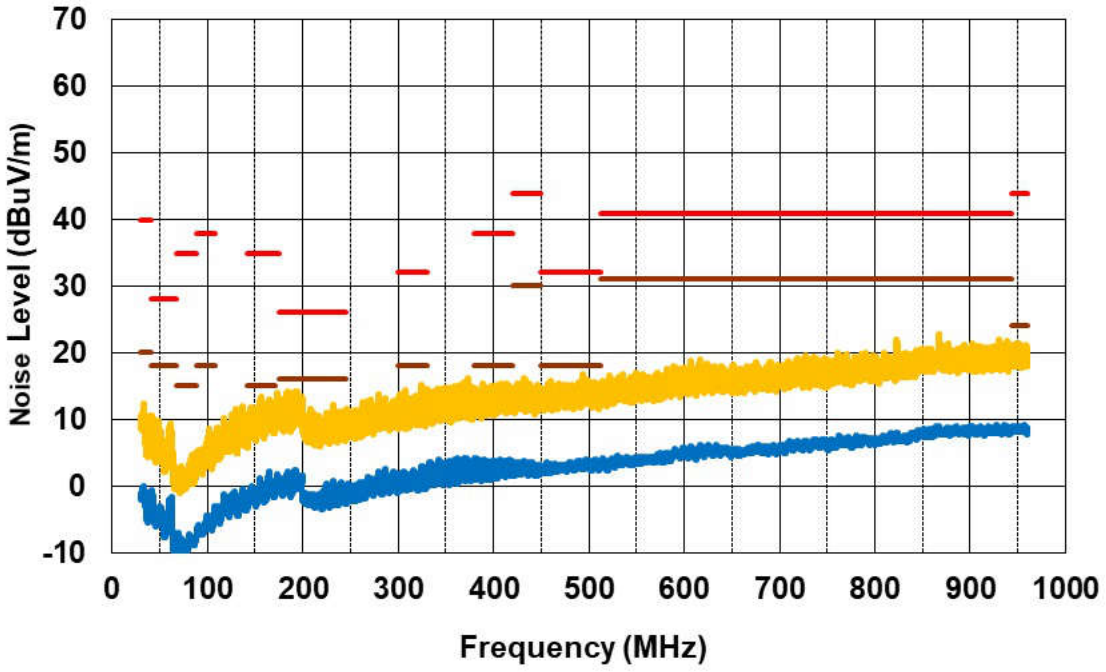


Figure 2-26. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 9V, I_{PA_BUS} = I_{PB_BUS} = 3A, Vertical

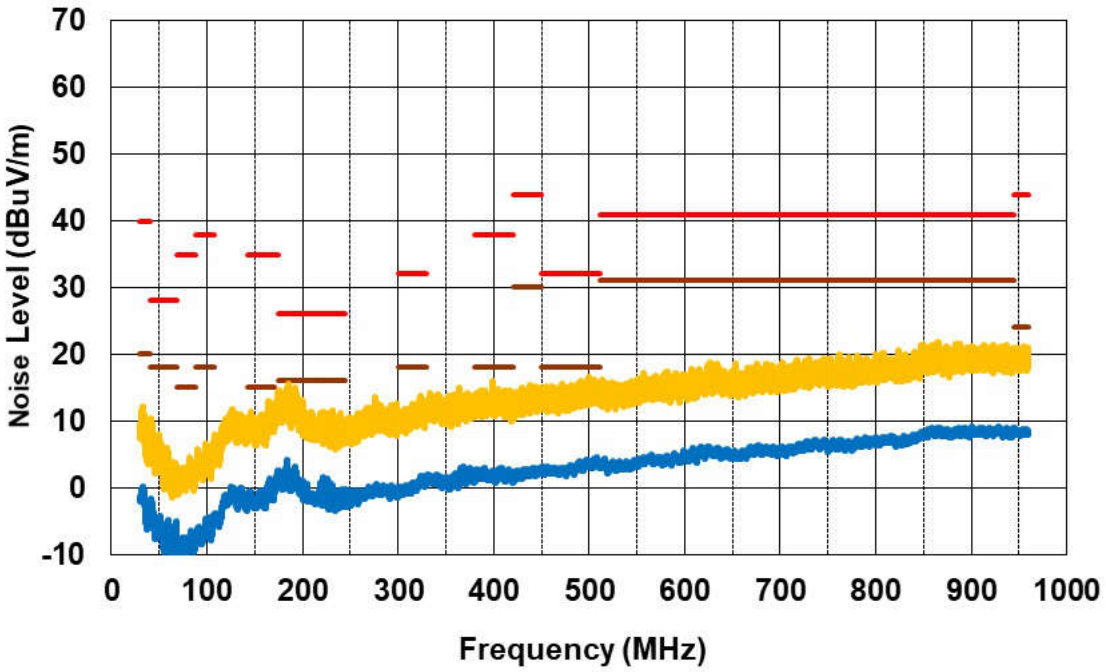


Figure 2-27. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 3A, Horizontal

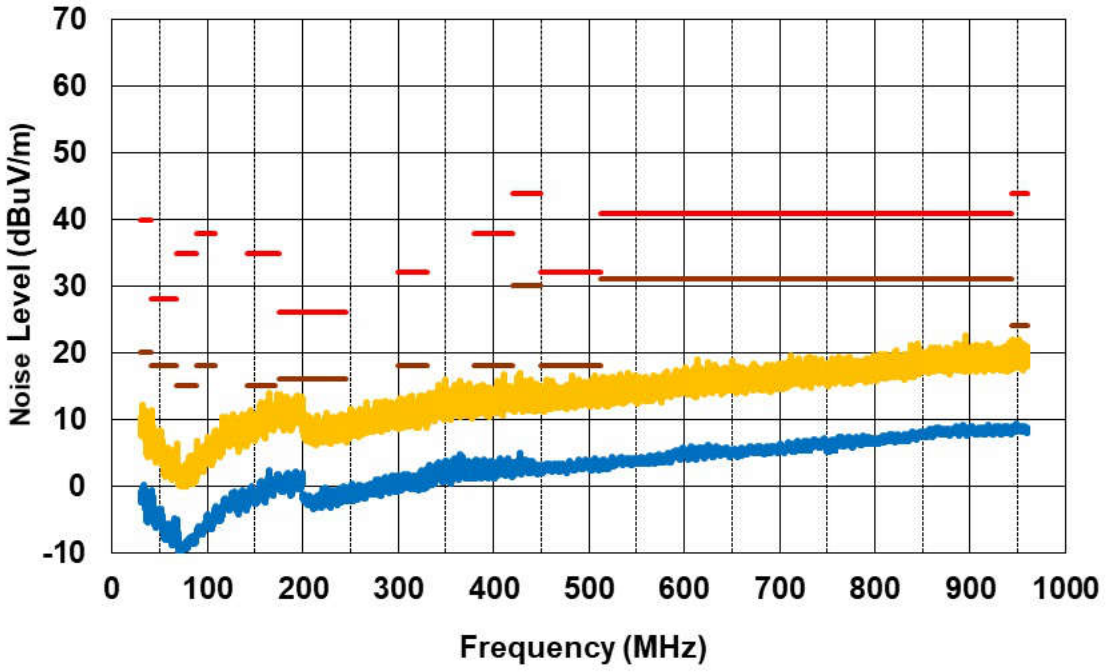


Figure 2-28. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 15V, I_{PA_BUS} = I_{PB_BUS} = 3A, Vertical

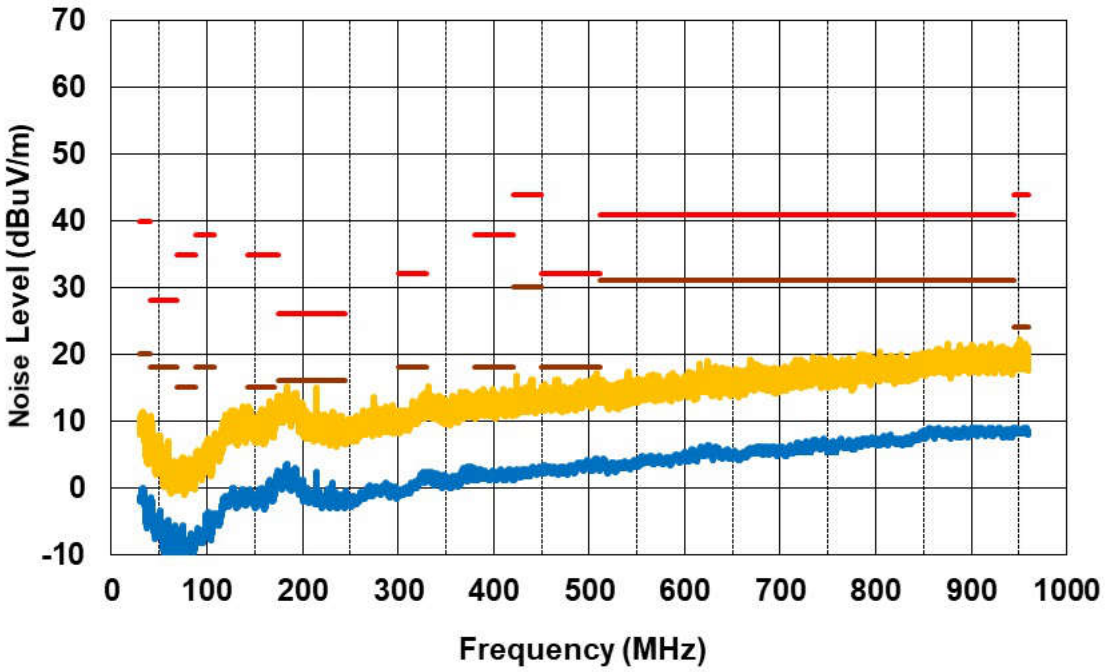


Figure 2-29. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A, Horizontal

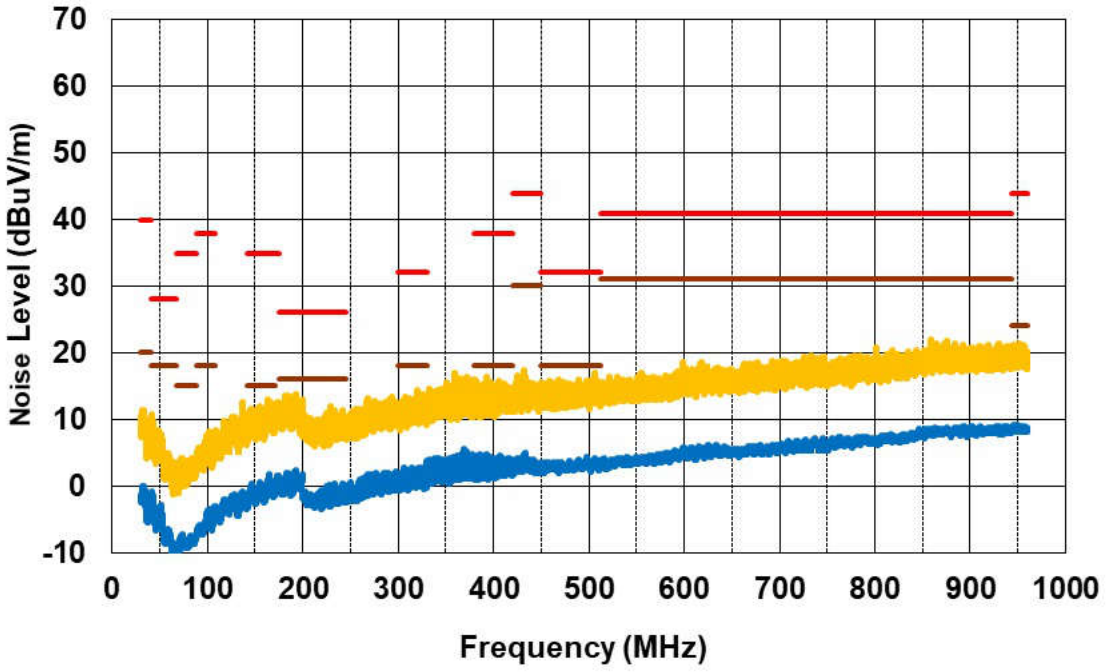


Figure 2-30. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = I_{PB_BUS} = 2.25A, Vertical

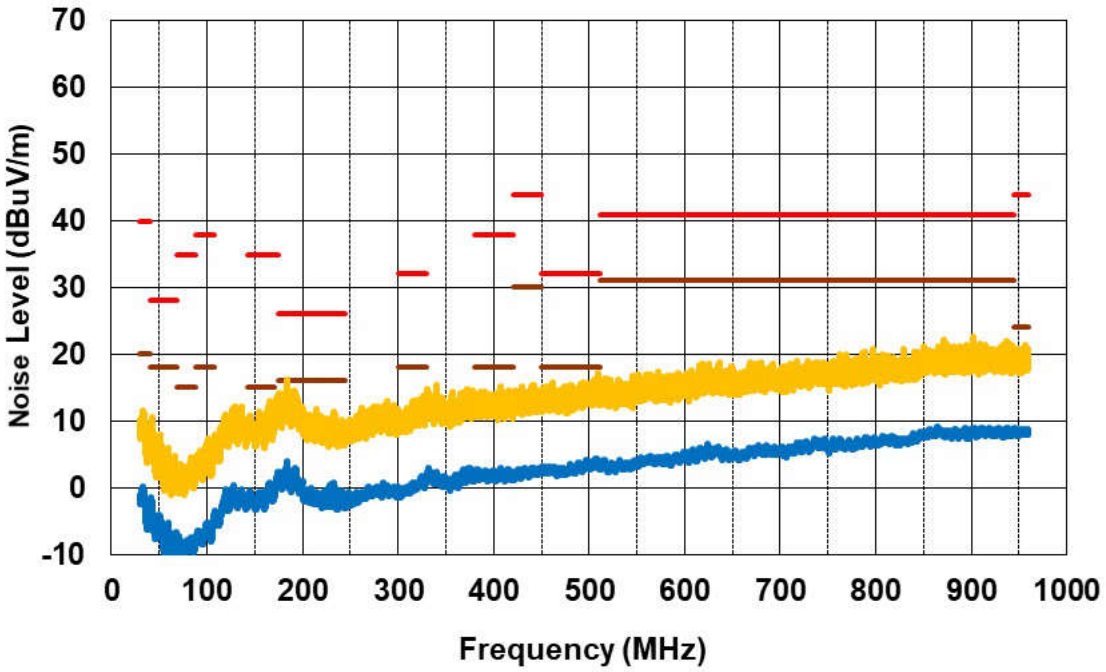


Figure 2-31. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A, Horizontal

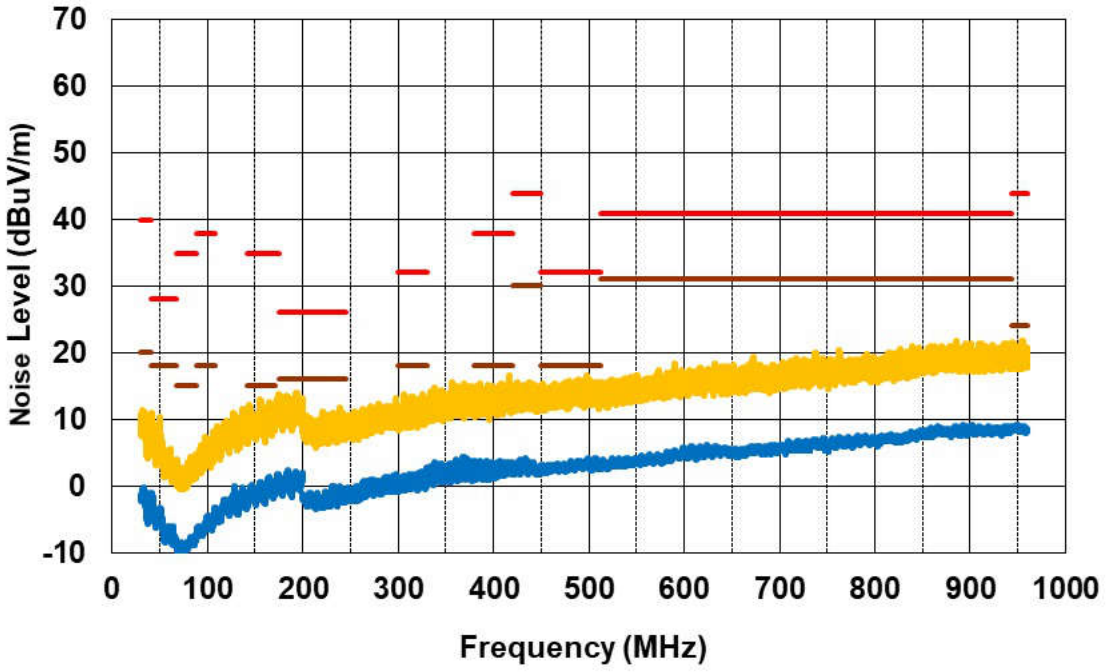


Figure 2-32. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 3A, I_{PB_BUS} = 1.5A, Vertical

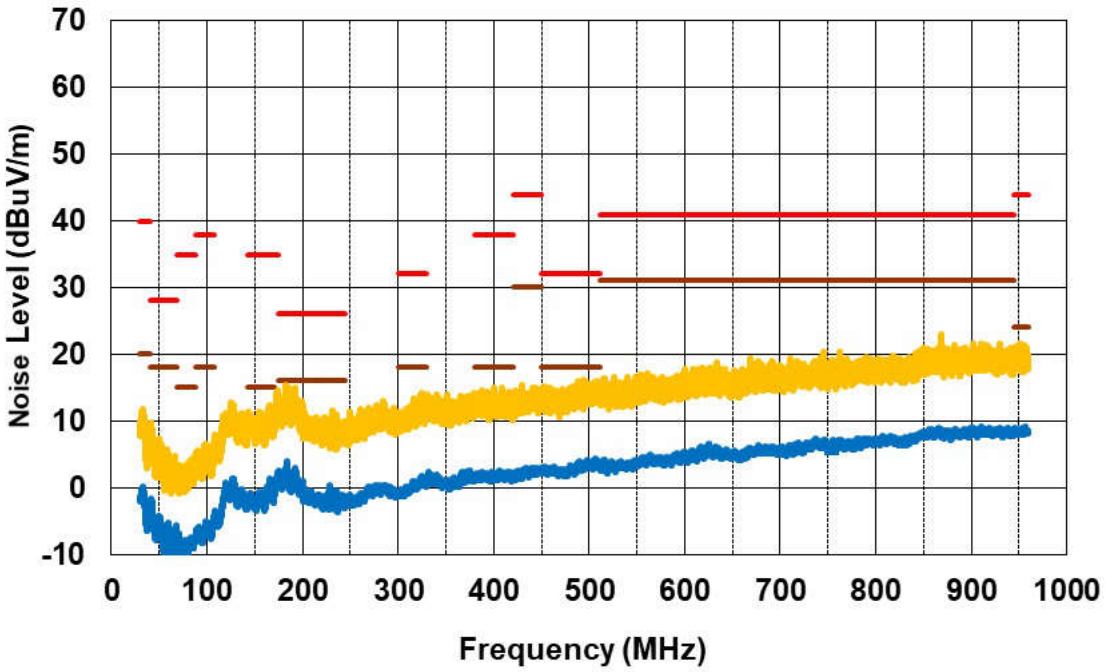


Figure 2-33. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A, Horizontal

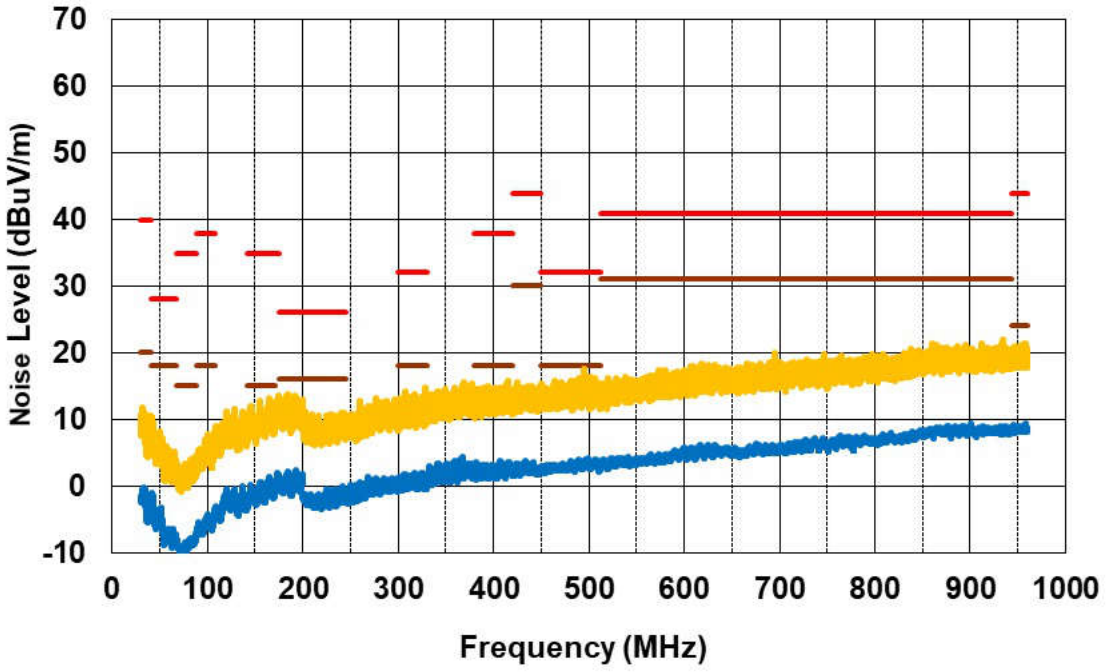


Figure 2-34. Radiated EMI From 30MHz to 1000MHz, V_{PA_BUS} = V_{PB_BUS} = 20V, I_{PA_BUS} = 1.5A, I_{PB_BUS} = 3A, Vertical

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.

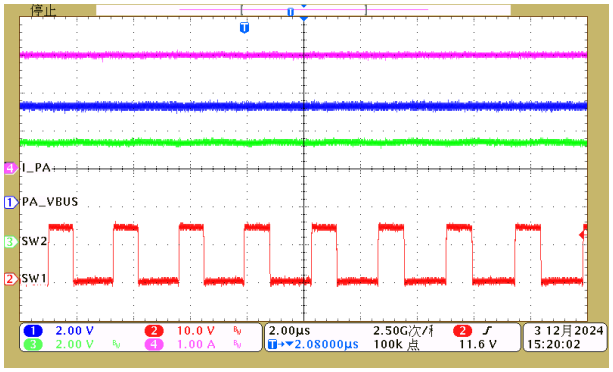


Figure 3-1. PORTA, 14V Input, 5V, 3A Load

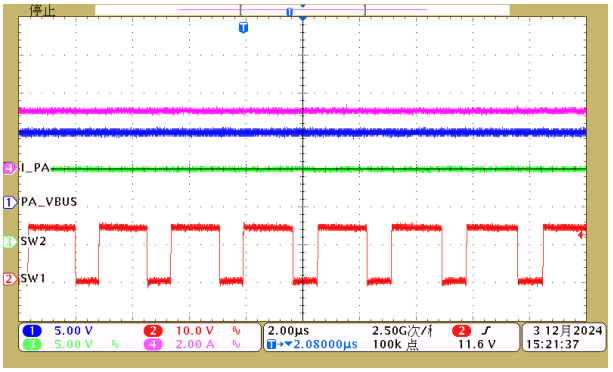


Figure 3-2. PORTA, 14V Input, 9V, 3A Load

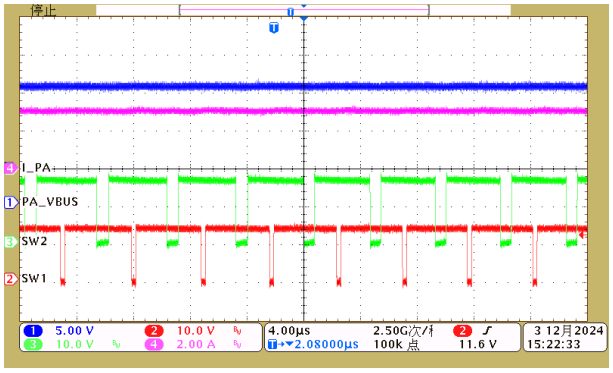


Figure 3-3. PORTA, 14V Input, 15V, 3A Load

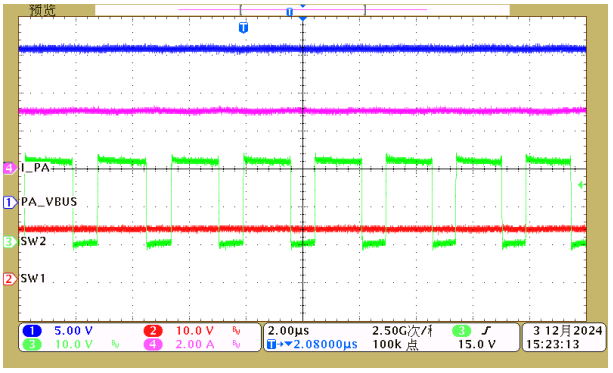


Figure 3-4. PORTA, 14V Input, 20V, 3A Load

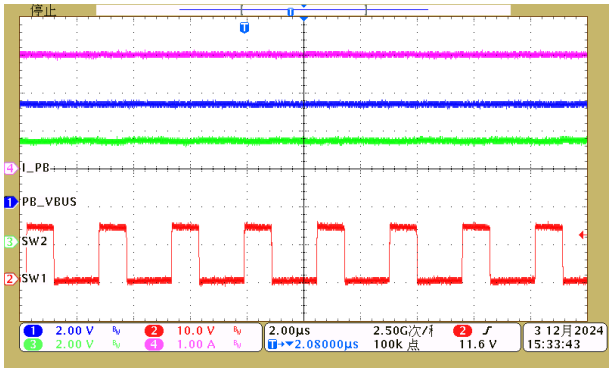


Figure 3-5. PORTB, 14V Input, 5V, 3A Load

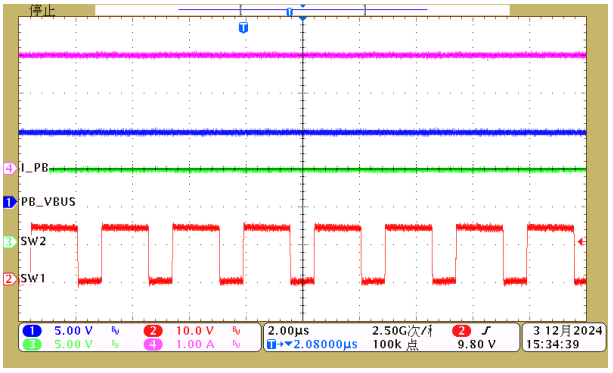


Figure 3-6. PORTB, 14V Input, 9V, 3A Load

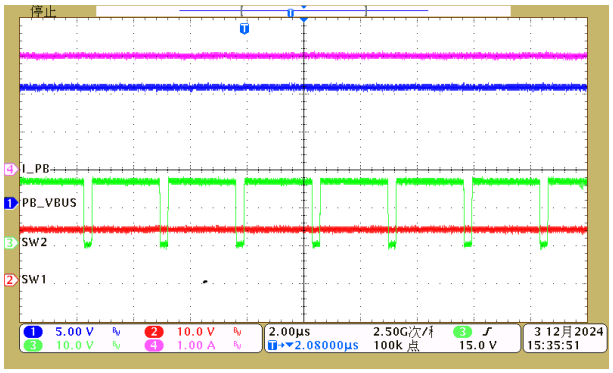


Figure 3-7. PORTB, 14V Input, 15V, 3A Load

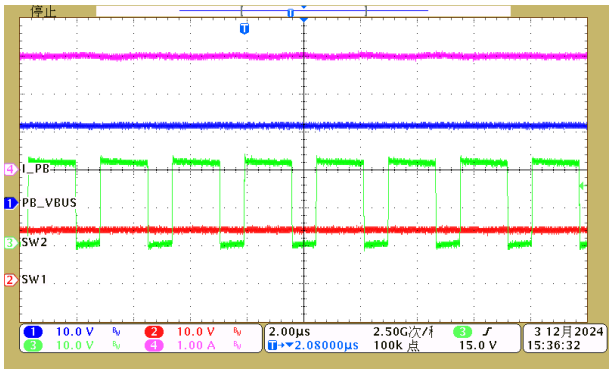


Figure 3-8. PORTB, 14V Input, 20V, 3A Load

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 3-18.

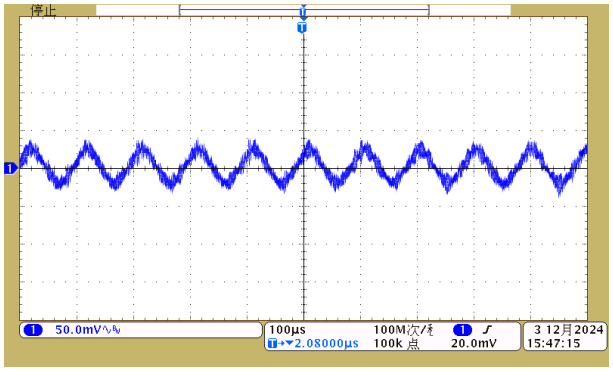


Figure 3-9. Output Voltage Ripple, PORTA, 14V Input, 5V, 3A Load

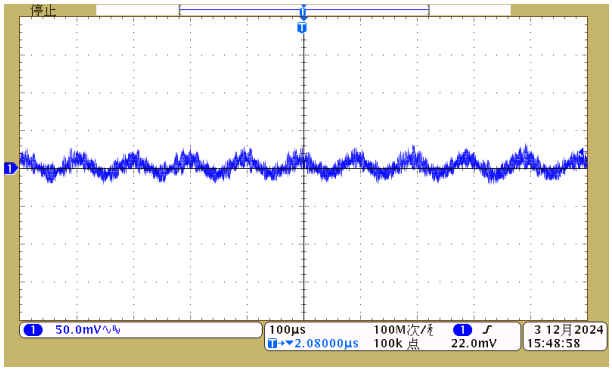


Figure 3-10. Output Voltage Ripple, PORTA, 14V Input, 9V, 3A Load

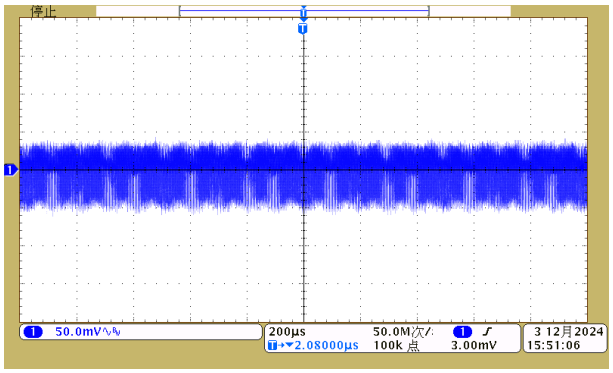


Figure 3-11. Output Voltage Ripple, PORTA, 14V Input, 15V, 3A Load

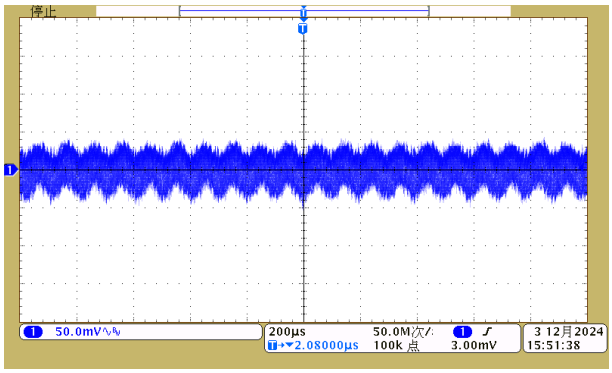


Figure 3-12. Output Voltage Ripple, PORTA, 14V Input, 20V, 2.25A Load

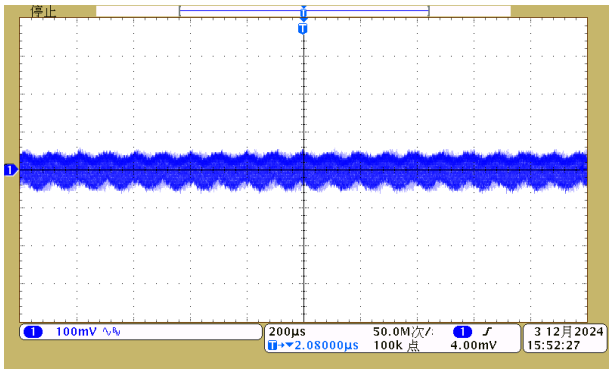


Figure 3-13. Output Voltage Ripple, PORTA, 14V Input, 20V, 3A Load

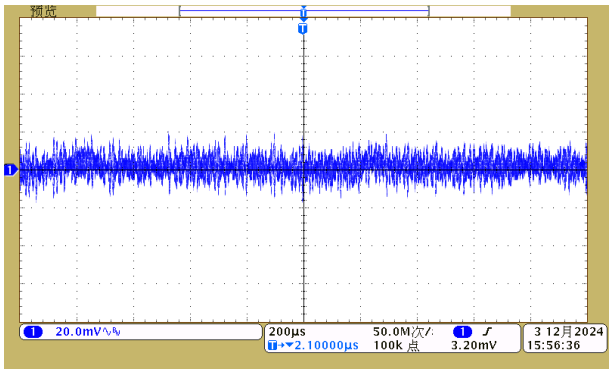


Figure 3-14. Output Voltage Ripple, PORTB, 14V Input, 5V, 3A Load

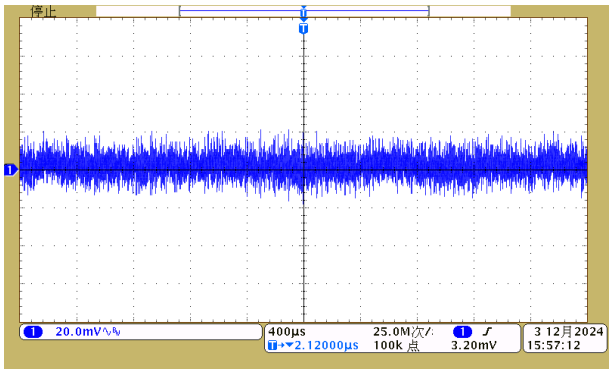


Figure 3-15. Output Voltage Ripple, PORTB, 14V Input, 9V, 3A Load

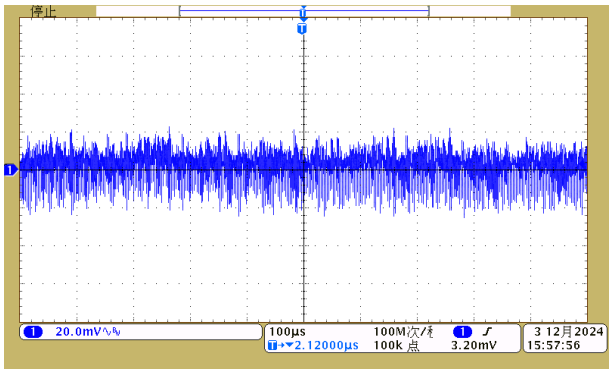


Figure 3-16. Output Voltage Ripple, PORTB, 14V Input, 15V, 3A Load

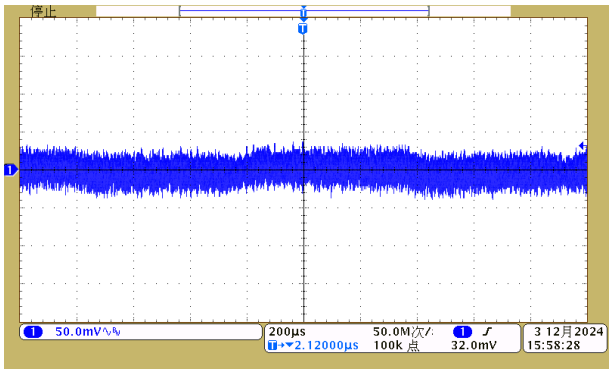


Figure 3-17. Output Voltage Ripple, PORTB, 14V Input, 20V, 2.25A Load

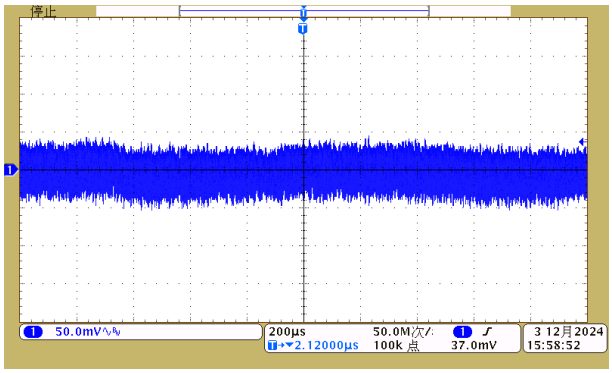


Figure 3-18. Output Voltage Ripple, PORTB, 14V Input, 20V, 3A Load

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