

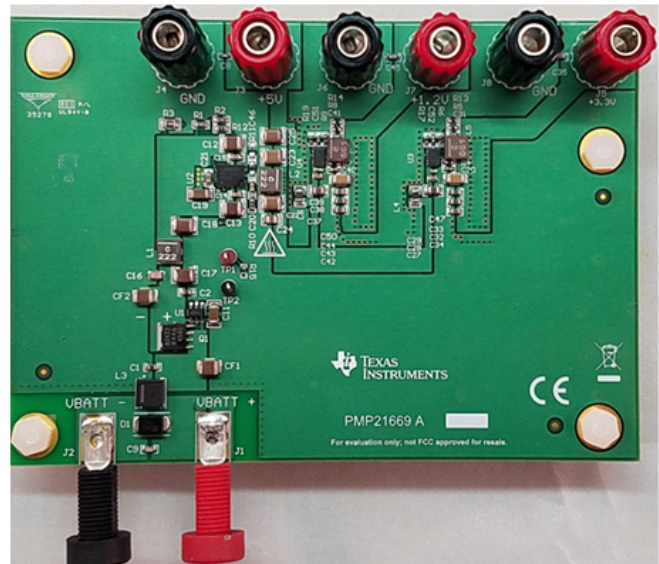
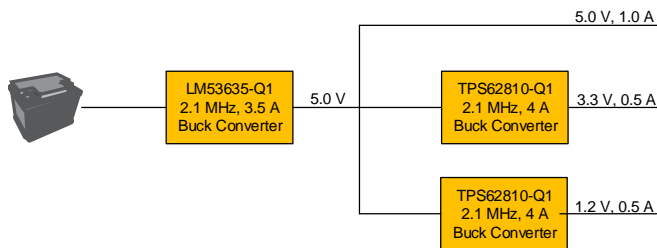
Test Report: PMP21669

Automotive instrument cluster power reference design with three outputs



Description

This reference design implements an automotive power supply solution for use in analog gauge clusters, hybrid clusters, and cluster display systems. It provides 5-V, 3.3-V, and 1.2-V outputs suitable for powering all subsystems within an automotive instrument cluster, a cluster display, or an automotive remote touch display.



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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
V_{IN}	6 to 35 V, Typ. 12 V
V_{OUT1}	5 V at 1 A
V_{OUT2}	1.2 V at 0.5 A
V_{OUT3}	3.3 V at 0.5 A
Nominal switching frequency	2.1 MHz

1.2 Required Equipment

- Power supply
- Electronic load
- Oscilloscope
- Frequency response analyzer

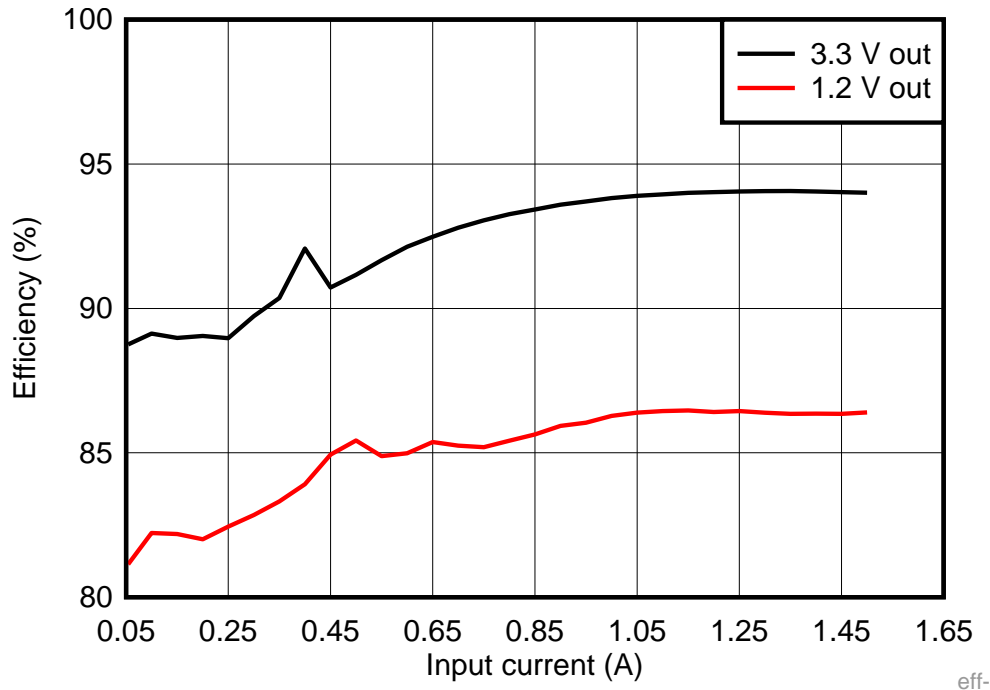
2 Testing and Results

This board includes the LM53635-Q1 for the 12-V to 5-V supply and two TPS62810-Q1 for the 5-V to 3.3-V and 1.2-V supplies. Testing for the two TPS62810-Q1 circuits used a separate connection to a bench power supply that provided 5 V to isolate the performance of these two regulators from the 5-V regulator.

2.1 Efficiency Graphs

The efficiency of the converters is shown in the following images.

Figure 1. 3.3-V and 1.2-V Output Efficiency Versus Output Current



The TPS62810-Q1 circuits for 3.3 V and 1.2 V were tested with a bench supply providing 5 V. The outputs were tested to 1.5 A. At the rated load of 0.5 A, the 1.2-V supply was 84% efficient and the 3.3-V supply was 91% efficient. The input current for the 1.2-V supply was 145 mA and the input current for the 3.3-V supply was 374 mA.

Table 2. Efficiency Data for the TPS62810-Q1 1.2-V Regulator

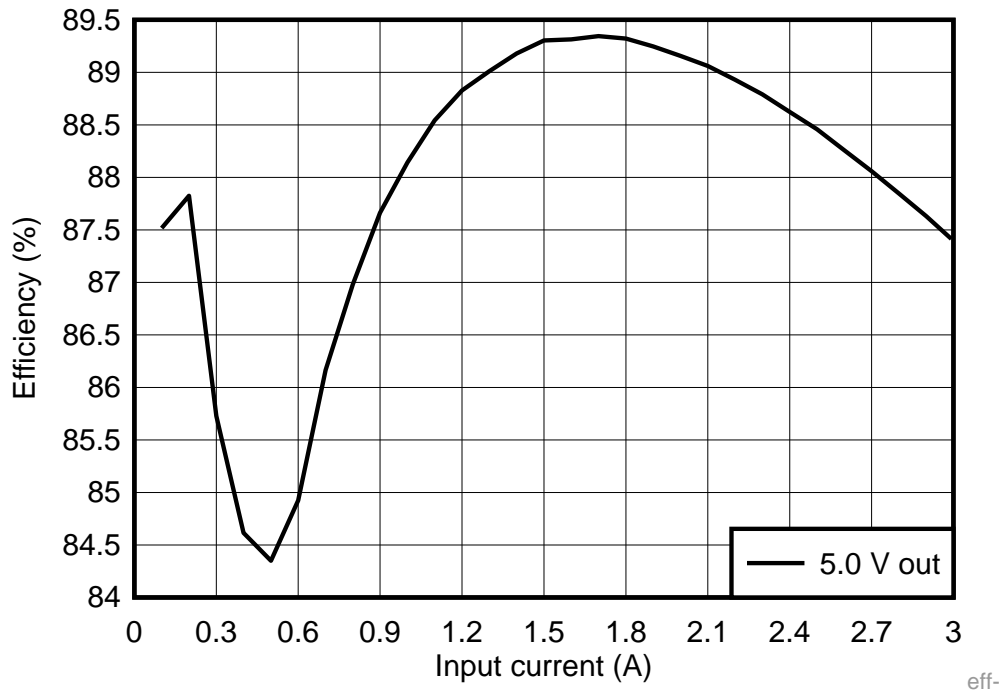
V_{IN}	I_{VIN}	V_{OUT}	I_{LOAD}	EFFICIENCY (%)
5.120	0.034	1.202	0.116	79.3
5.119	0.063	1.204	0.217	80.5
5.117	0.091	1.205	0.317	81.5
5.116	0.118	1.203	0.417	83.3
5.115	0.145	1.202	0.516	83.7
5.113	0.172	1.200	0.617	84.4
5.112	0.199	1.199	0.717	84.6
5.111	0.225	1.198	0.817	85.1
5.109	0.251	1.197	0.917	85.6
5.108	0.277	1.196	1.018	85.9
5.107	0.304	1.195	1.118	86.0
5.105	0.331	1.194	1.218	86.0
5.104	0.359	1.194	1.318	85.8
5.102	0.387	1.193	1.418	85.7
5.101	0.414	1.192	1.518	85.7

Table 3. Efficiency Data for the TPS62810-Q1 3.3-V Regulator

V_{IN}	I_{VIN}	V_{OUT}	I_{LOAD}	EFFICIENCY (%)
5.116	0.099	3.356	0.114	75.9
5.112	0.165	3.341	0.215	85.2
5.108	0.231	3.335	0.315	89.1
5.103	0.304	3.344	0.416	89.6
5.099	0.374	3.358	0.516	91.0
5.095	0.442	3.356	0.616	91.8
5.091	0.510	3.354	0.716	92.6
5.087	0.578	3.353	0.816	93.0
5.083	0.647	3.351	0.917	93.4
5.079	0.717	3.350	1.017	93.6
5.075	0.787	3.348	1.117	93.7
5.071	0.856	3.347	1.217	93.8
5.066	0.927	3.346	1.317	93.8
5.062	0.998	3.345	1.417	93.8
5.058	1.069	3.344	1.517	93.8

The total load for the 5-V supply will be 1 A for the load current plus 145 mA for the 1.2-V supply and 374 mA for the 3.3-V supply. Therefore, the total required output current from the 5-V supply is 1.519 A.

Figure 2. 5-V Output Efficiency Versus Output Current



The LM53635-Q1 on this board is configured to work in AUTO mode. The converter switches to PFM at light loads. Therefore, the efficiency curve goes up when output current is 0.5 A or less. This test was run with the 3.3-V and 1.2-V supplies disconnected. As stated previously, the total output current for the 5-V supply will be 1.519 A when all of the supplies are fully loaded. With a 1.5-A load, the 5-V supply has an efficiency of 89.3%.

Table 4. Efficiency Data for the LM53635-Q1 5-V Regulator

V_{IN}	I_{VIN}	V_{OUT}	I_{LOAD}	EFFICIENCY (%)
11.999	0.001	5.062	0.000	8.7
11.999	0.054	5.049	0.114	88.5
12.000	0.102	5.041	0.215	88.6
12.000	0.153	5.027	0.315	86.5
12.000	0.205	5.007	0.415	84.5
12.000	0.256	4.989	0.515	83.7
12.000	0.301	4.988	0.616	84.9
12.001	0.346	4.987	0.716	86.1
12.001	0.390	4.986	0.816	87.0
12.001	0.435	4.985	0.917	87.6
12.001	0.479	4.984	1.017	88.1
12.001	0.524	4.983	1.117	88.5
12.002	0.569	4.981	1.217	88.8
12.002	0.614	4.980	1.317	89.0
12.002	0.659	4.979	1.418	89.2
12.002	0.705	4.979	1.517	89.3
12.002	0.751	4.978	1.618	89.4
12.002	0.797	4.977	1.718	89.4
12.003	0.843	4.976	1.818	89.4
12.003	0.890	4.975	1.918	89.3
12.003	0.937	4.973	2.018	89.3
12.003	0.984	4.972	2.118	89.2
12.004	1.031	4.970	2.218	89.0
12.004	1.079	4.969	2.318	88.9
12.004	1.127	4.967	2.418	88.8
12.004	1.176	4.966	2.519	88.6
12.004	1.224	4.964	2.618	88.5
12.005	1.273	4.963	2.719	88.3
12.005	1.323	4.961	2.819	88.1
12.005	1.373	4.959	2.919	87.9
12.005	1.422	4.957	3.019	87.7

2.2 Thermal Images

The following thermal images show the LM53635-Q1 and two TPS62810-Q1 are working at the same time. This measurement was taken after 20 minutes of operation. Input voltage for the 5-V supply is 12 V. The LM53635-Q1 reached a case temperature of 62.4°C. The TPS62810-Q1 in the 3.3-V supply reached a case temperature of 50.9°C. The TPS62810-Q1 in the 1.2-V supply reached a case temperature of 46.5°C.

POWER LINE	LOAD
5-V output	1.5 A total: 5-Ω resistor and two TPS62810-Q1 supplies form the load
3.3-V output	0.5 A: 6.6-Ω resistor load
1.2-V output	0.5 A: 2.4-Ω resistor load

Figure 3. LM53635-Q1 Thermal Image at 5-V Output Voltage and 1-A Load Plus the Inputs of Two TPS62810-Q1 Regulators

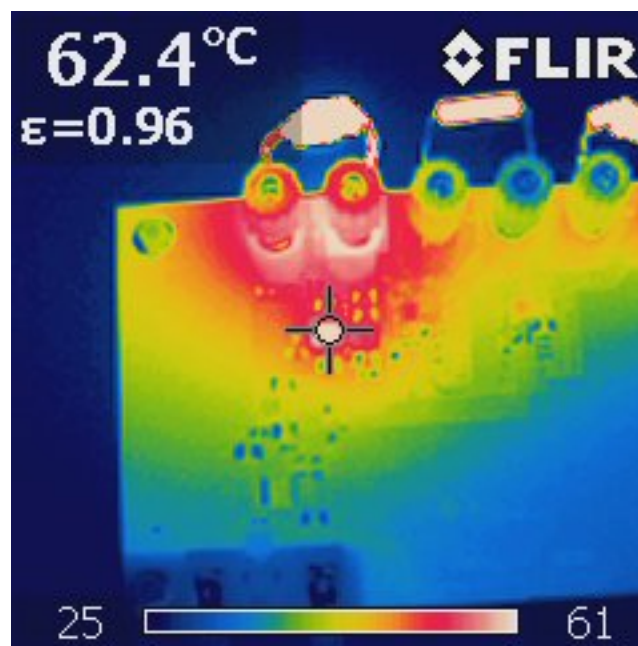


Figure 4. TPS62810-Q1 Thermal Image at 3.3-V Output Voltage and 0.5-A Current

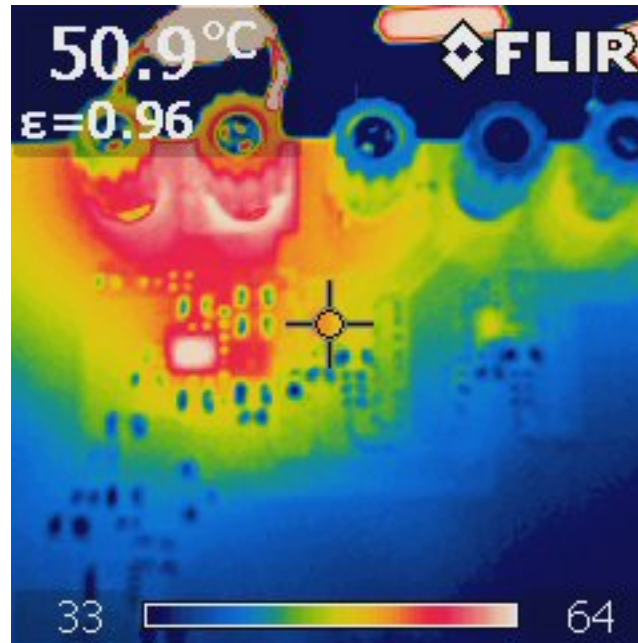
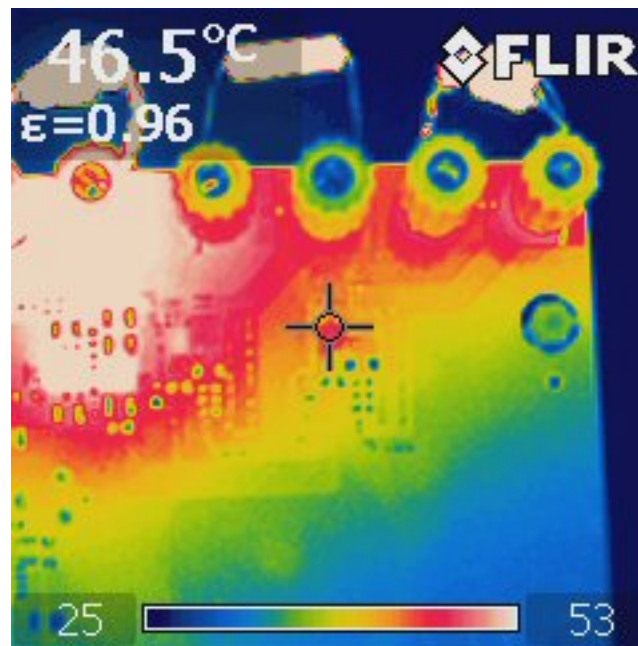


Figure 5. TPS62810-Q1 Thermal Image at 1.2-V Output Voltage and 0.5-A Current

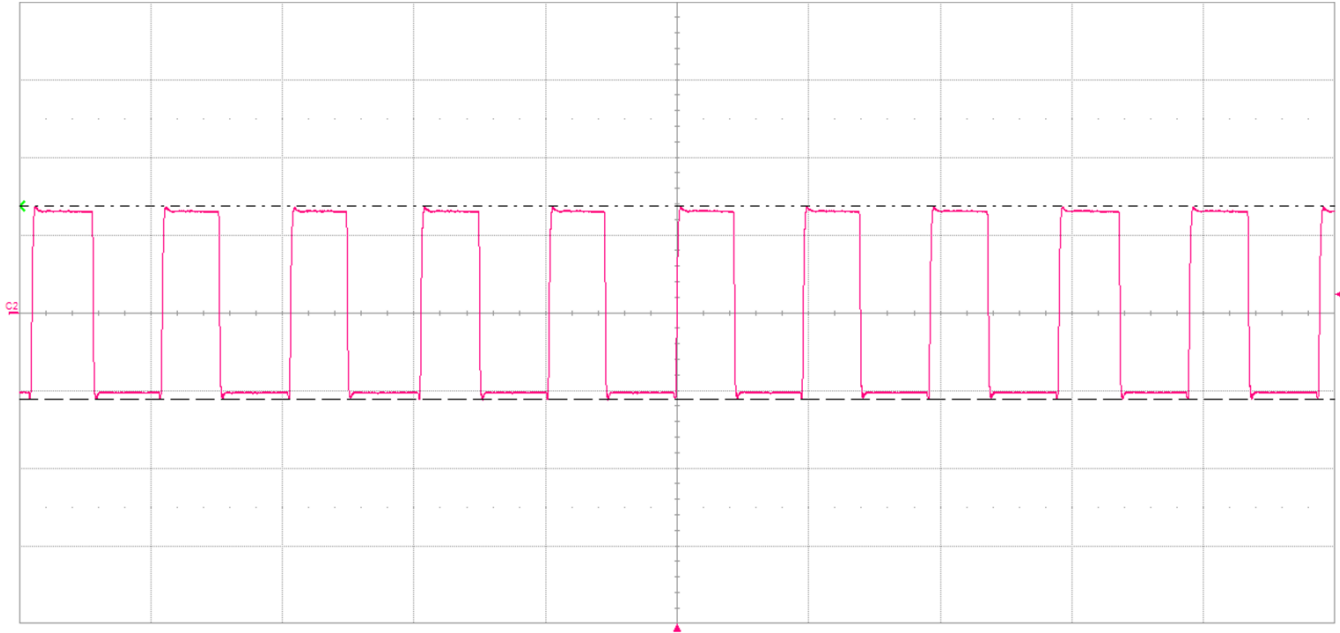


3 Switching Waveforms

The following images show the switching waveforms. An electronic load and a power supply were used in this measurement. Output voltage was measured for each power line.

3.1 5-V Output Voltage (LM53635-Q1)

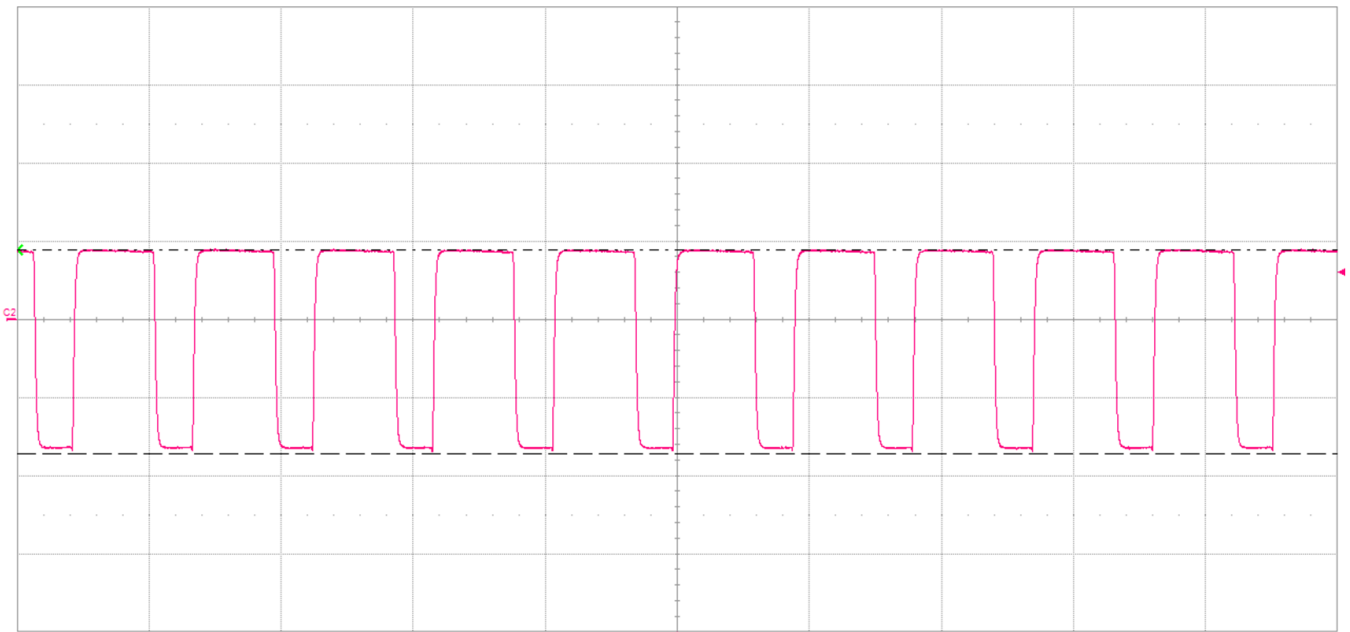
Figure 6. Switching Waveform at 1-A Load Current



Channel 2 – Red: Switching Node – (5.0 V/Div, 0.5 us/Div)

3.2 3.3-V Output Voltage (TPS62810-Q1)

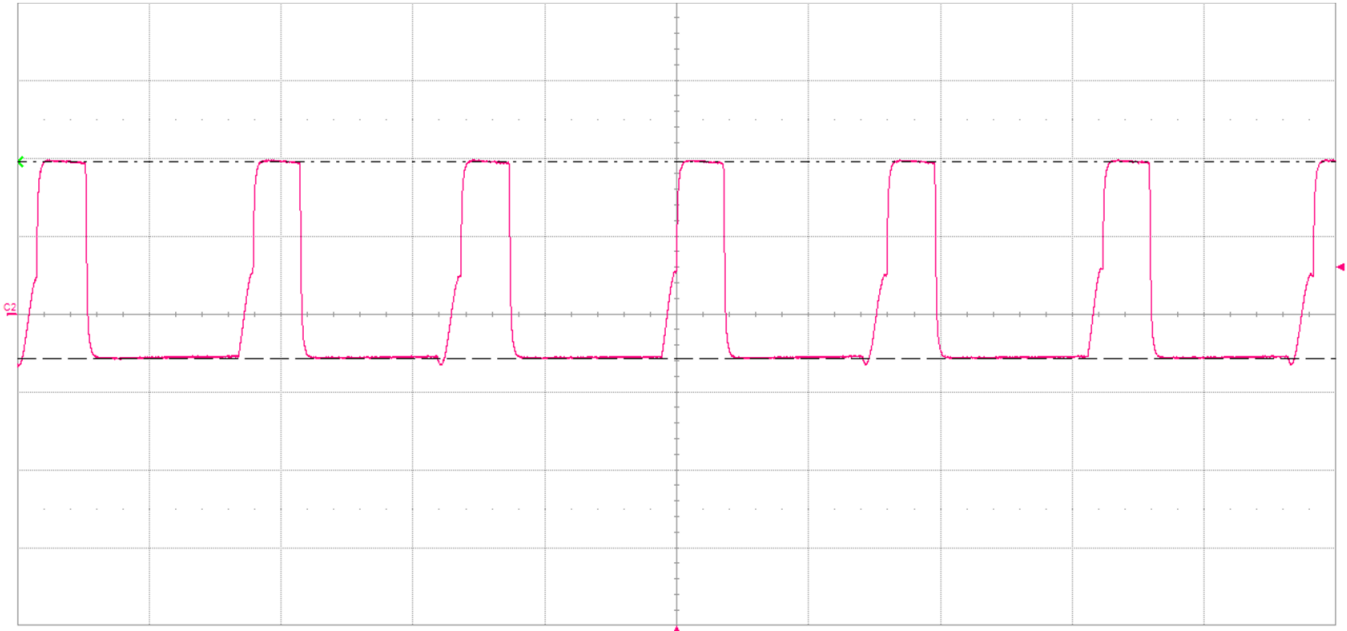
Figure 7. Switching Waveform at 0.5-A Load Current



Channel 2 – Red: Switching Node – (2.0 V/Div, 0.5 us/Div)

3.3 1.2-V Output Voltage (TPS62810-Q1)

Figure 8. Switching Waveform at 0.5-A Load Current



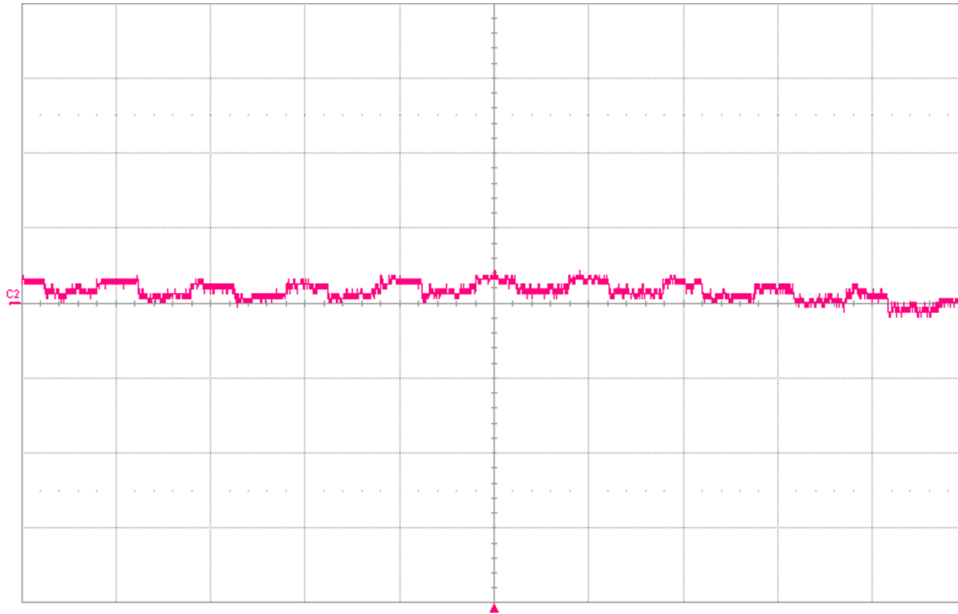
Channel 2 – Red: Switching Node – (2.0 V/Div, 0.5us /Div)

4 Output Ripple

The following images show the output ripple for each output. An electronic load was used in this measurement. The TPS62810-Q1 supplies were disconnected from the LM53635-Q1 supply and powered with an external supply.

4.1 5-V Output Voltage (LM53635-Q1)

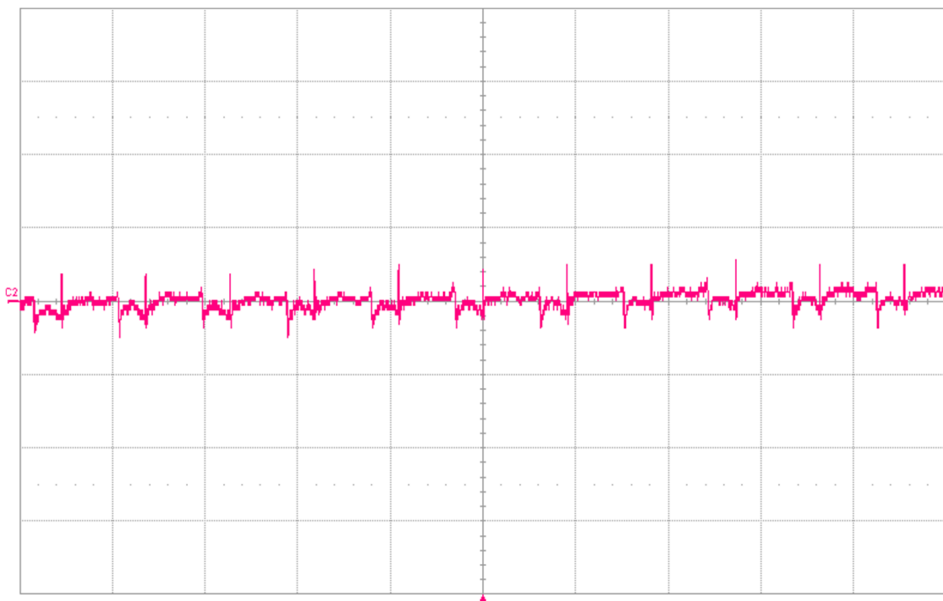
Figure 9. Output Ripple at 1.5-A Load Current



Channel 2 – Red: Output Ripple – (10 mV/Div, 0.5 us/Div). Output ripple is about 5 mV_{p-p}.

4.2 3.3-V Output Voltage (TPS62810-Q1)

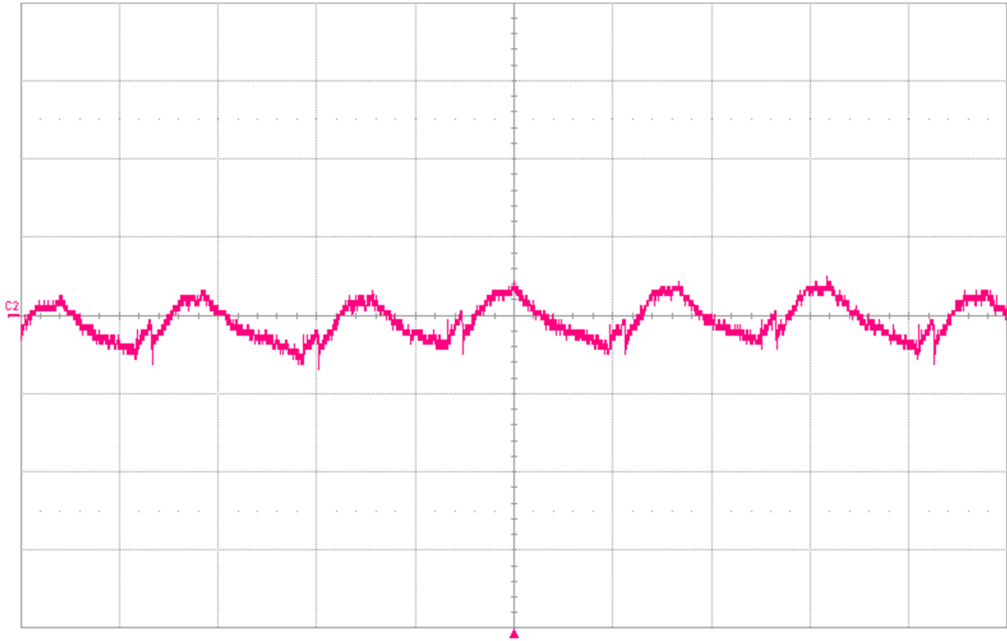
Figure 10. Output Ripple at 0.5-A Load Current



Channel 2 – Red: Output Ripple – (200 mV/Div, 0.5 us/Div). Output ripple is about 10 mV_{p-p}.

4.3 1.2-V Output Voltage (TPS62810-Q1)

Figure 11. Output Ripple at 0.5-A Load Current

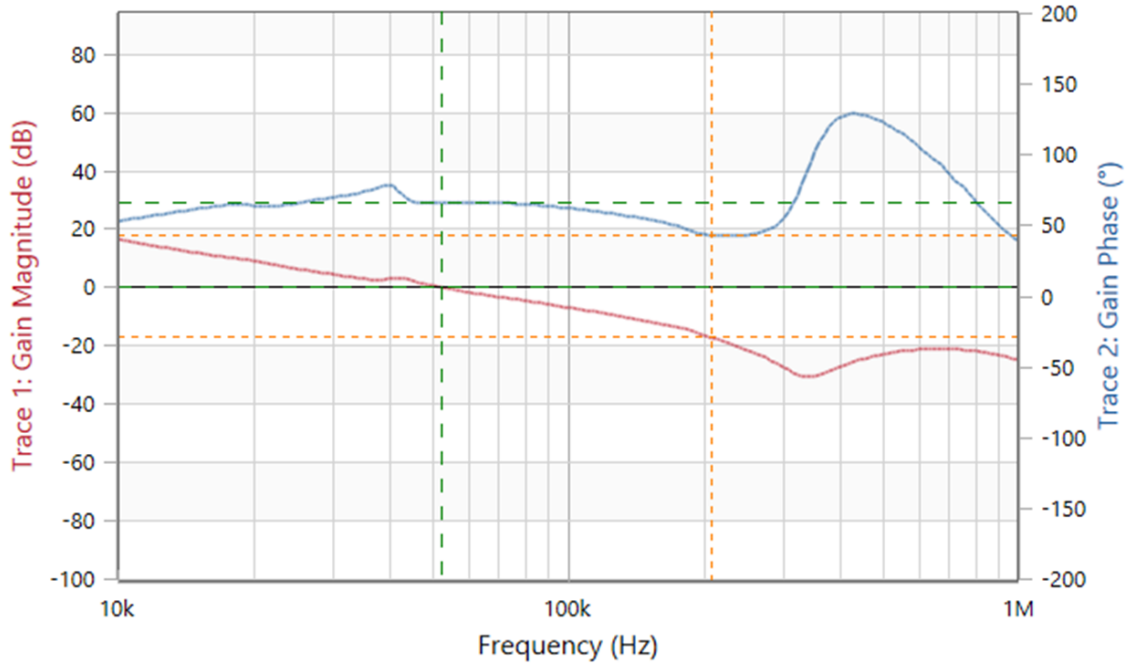


Channel 2 – Red: Output Ripple – (200 mV/Div, 0.5 us/Div). Output ripple is about 10 mV_{p-p}.

5 Bode Plots

5.1 5-V Output Voltage (LM53635-Q1)

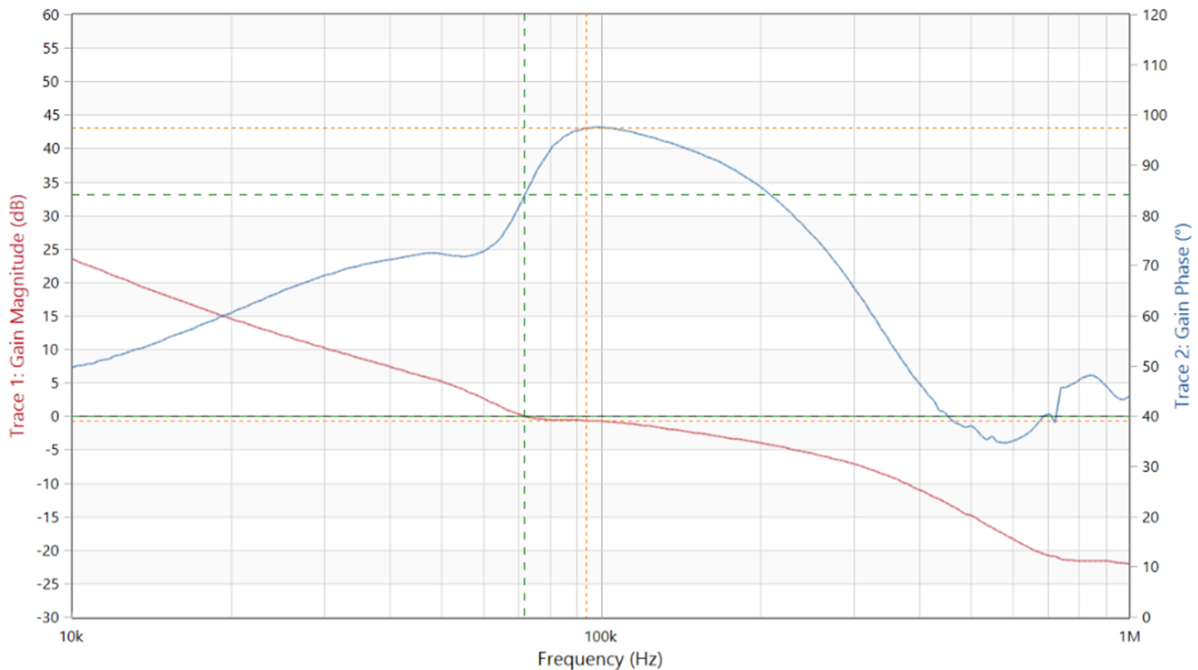
Figure 12. Bode Plot of 5-V Output Voltage



Phase Margin = 52.3 degrees

5.2 3.3-V Output Voltage (TPS62810)

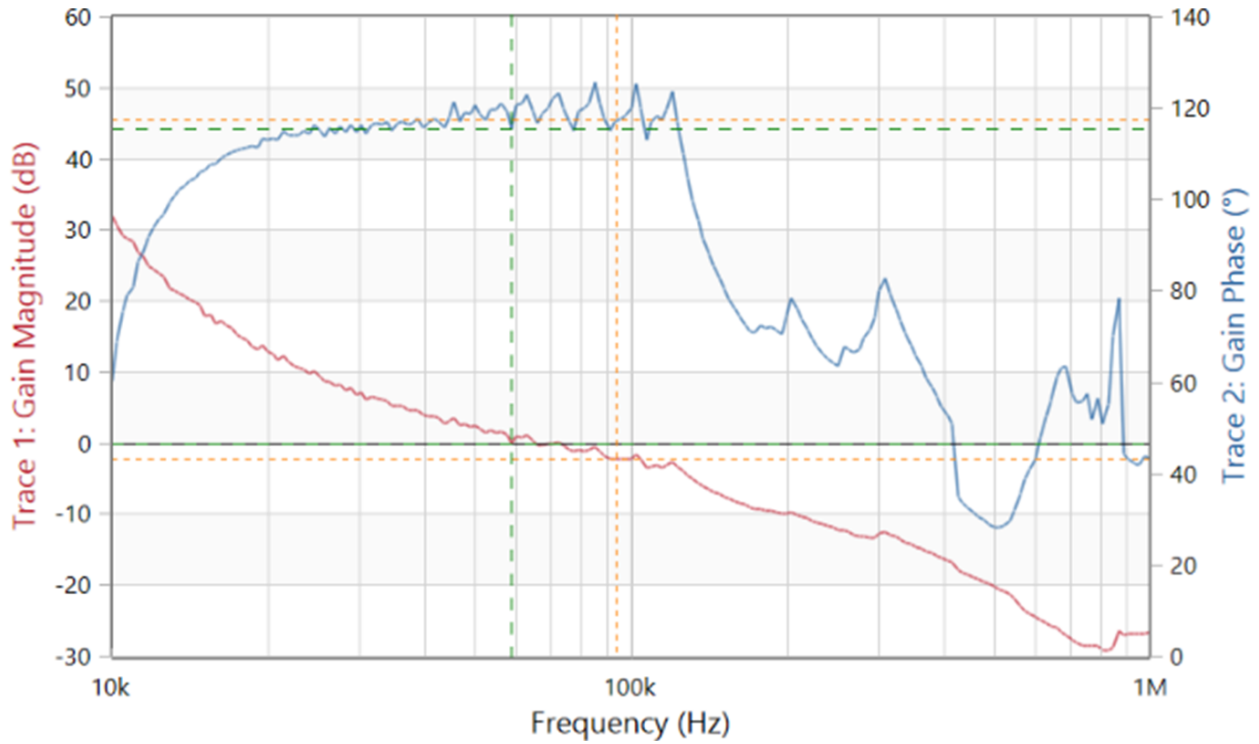
Figure 13. Bode Plot of 3.3-V Output Voltage



Phase Margin = 84 degrees

5.3 1.2-V Output Voltage (TPS62810)

Figure 14. Bode Plot of 1.2-V Output Voltage



Phase Margin = 115 degrees

6 Load Transient

The following images show the load step transient test results. An electronic load was used for each measurement. The TPS62810-Q1 supplies were disconnected from the LM53635-Q1 supply and powered with a separate bench power supply for all tests.

6.1 5-V Output Voltage (LM53635-Q1)

Load step current was switched continuously from 0.5 A to 1 A.

Figure 15. Load Transient for 5-V Output Voltage - Increasing Current

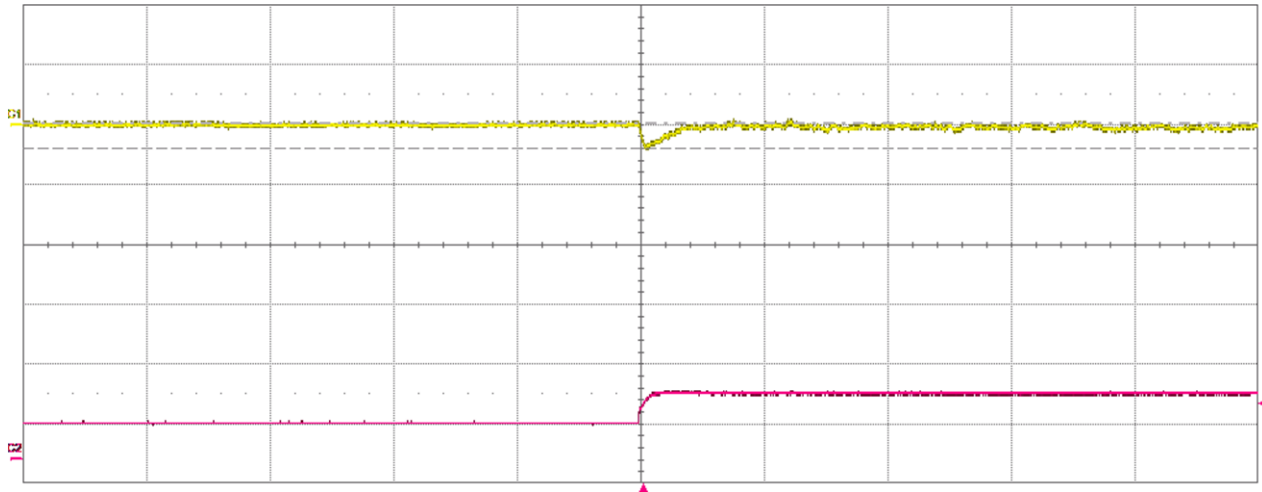
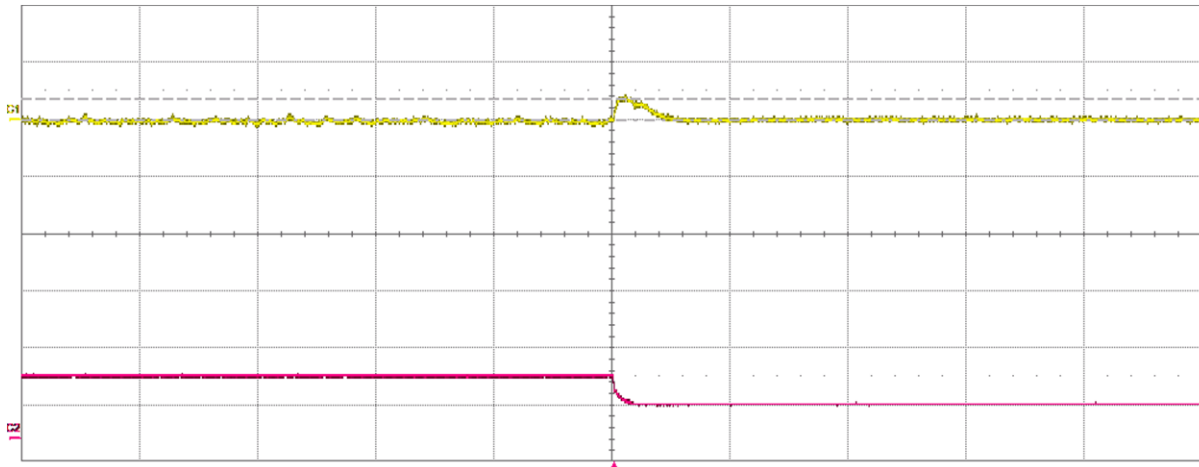


Figure 16. Load Transient for 5-V Output Voltage - Decreasing Current



6.2 3.3-V Output Voltage (TPS62810-Q1)

Load current was switched continuously from 0.1 A to 1 A.

Figure 17. Load Transient for 3.3-V Output Voltage - Increasing Current

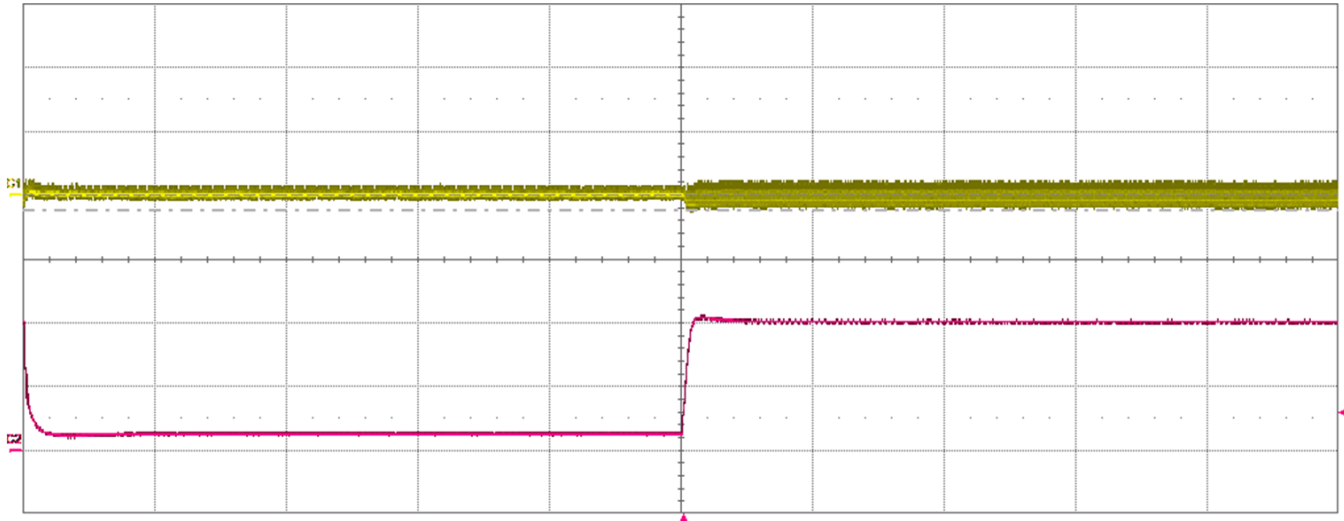
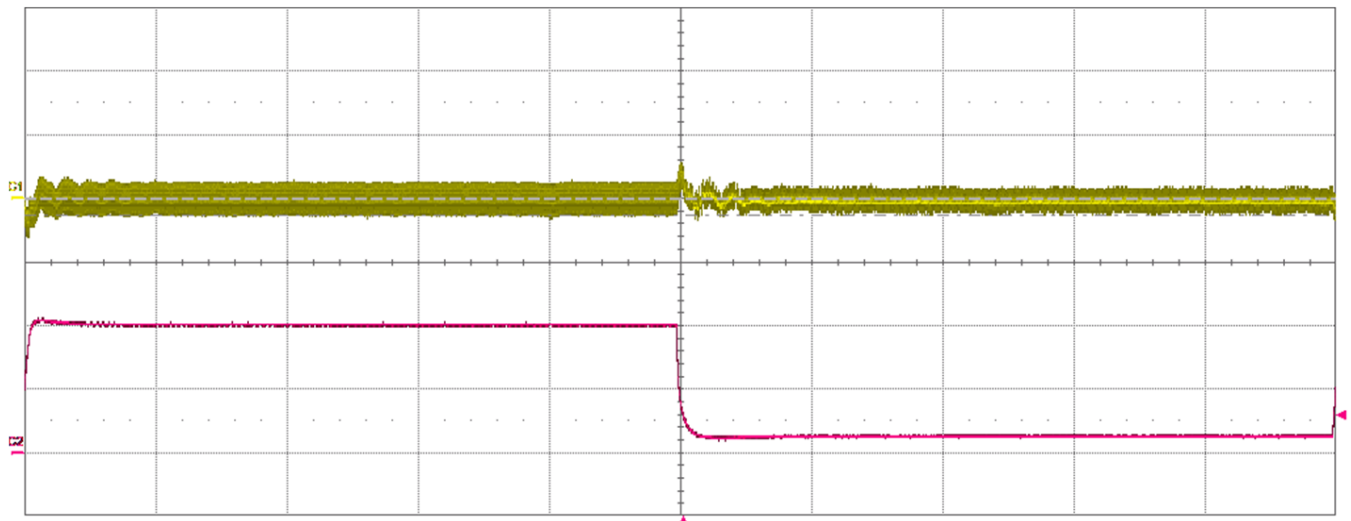


Figure 18. Load Transient for 3.3-V Output Voltage - Decreasing Current



6.3 1.2-V Output Voltage (TPS62810-Q1)

Load current was switched continuously from 0.1 A to 1 A.

Figure 19. Load Transient for 1.2-V Output Voltage - Increasing Current

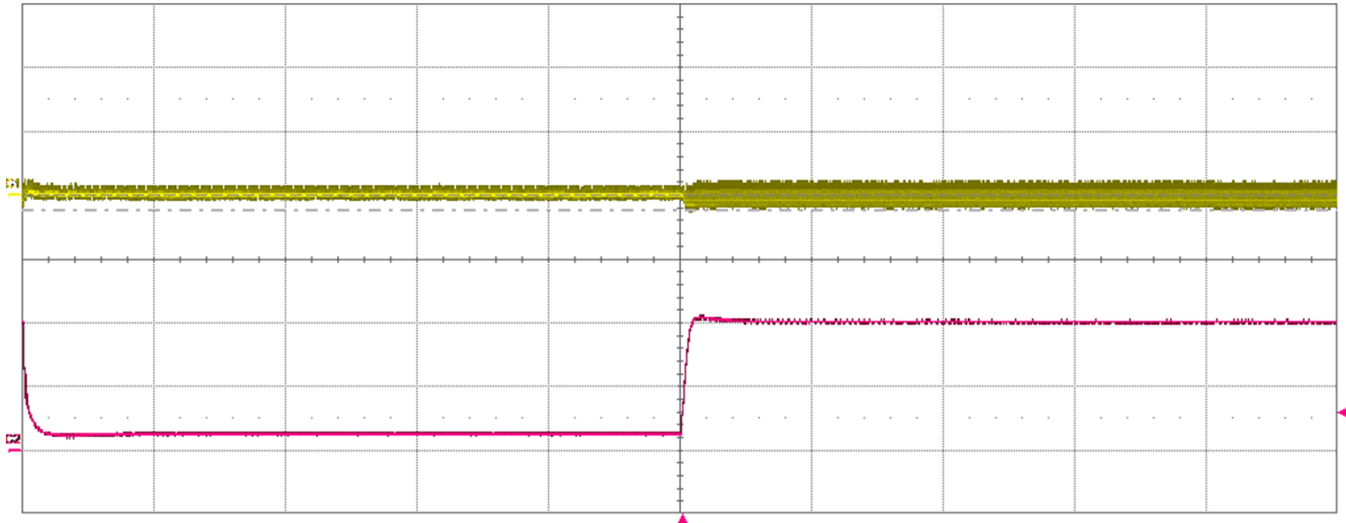
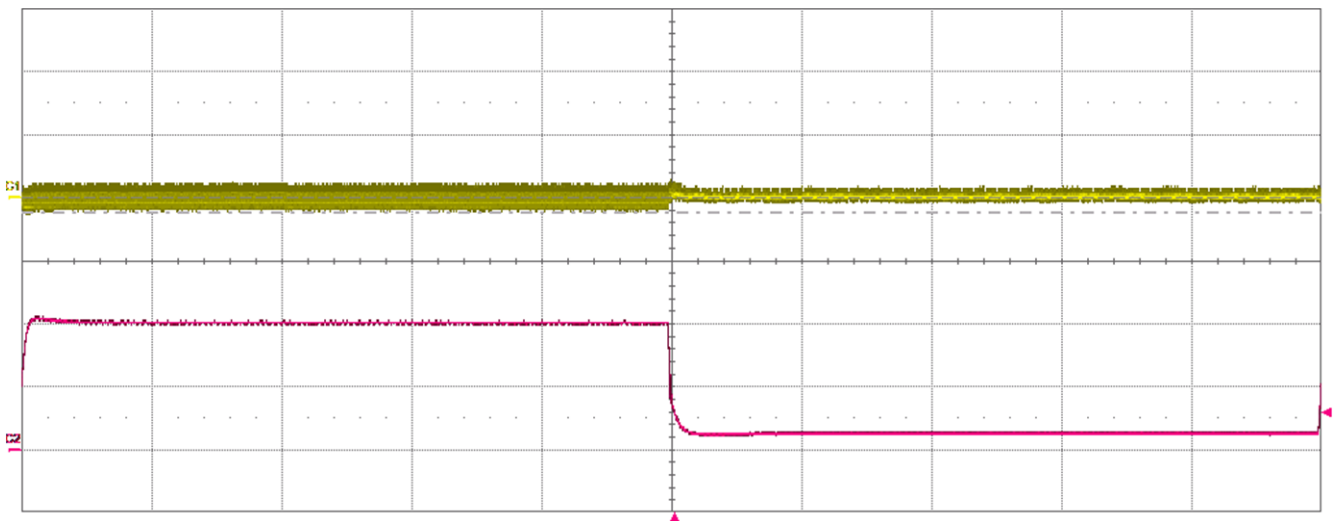


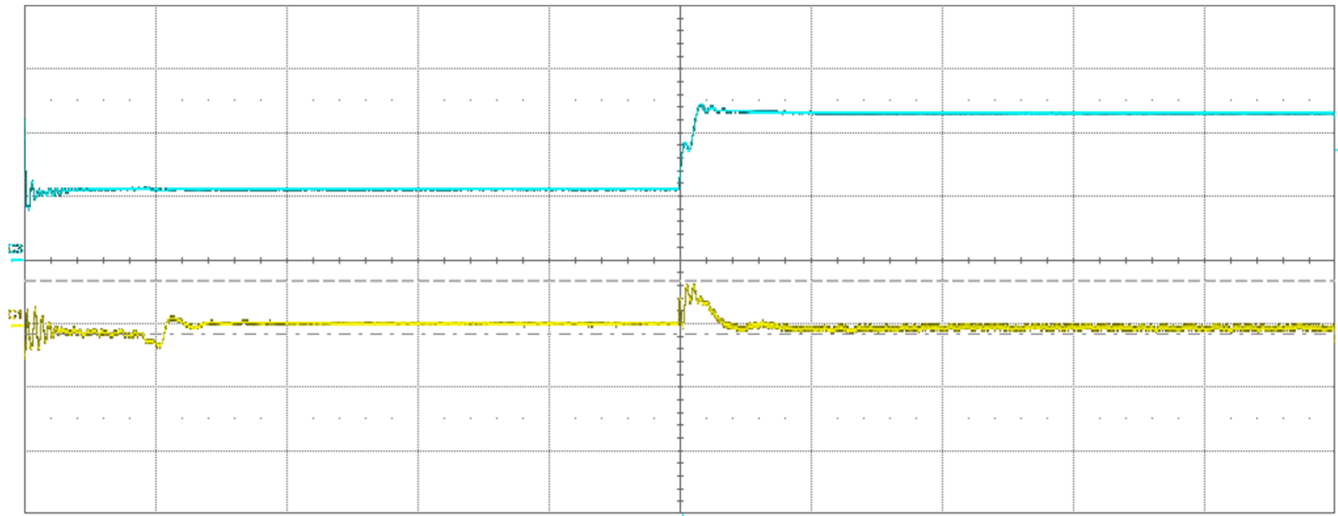
Figure 20. Load Transient for 1.2-V Output Voltage - Decreasing Current



7 Line Transient

The following images show the line transients on the 5-V output. The input voltage was varied from 6 V to 12 V while the supply had a 1.5-A load. The TPS62810-Q1 supplies were disconnected from the LM53635-Q1 supply during the tests.

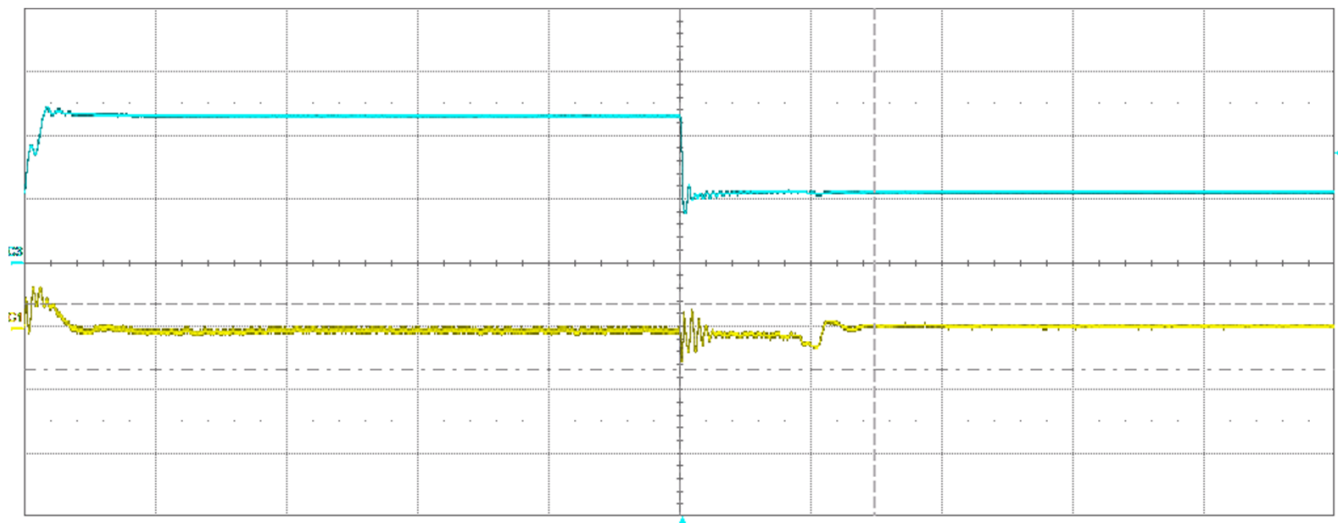
Figure 21. Line Transient - Increasing Voltage



Channel 1– Yellow: Output Voltage – (100 mV/Div, 200 us/Div)

Channel 3 – Blue: Output Current – (5 V/Div, 200 us/Div)

Figure 22. Line Transient - Decreasing Voltage



Channel 1– Yellow: Output Voltage – (100 mV/Div, 200 us/Div)

Channel 3 – Blue: Output Current – (5 V/Div, 200 us/Div)

8 EMI Testing

EMI radiated and conducted emissions tests in accordance with CISPR25 were performed on this design. For these tests, the TPS62810-Q1 supplies were powered from the LM53635-Q1 power supply and all power supplies were loaded to their rated output currents. The design passed the CISPR25 Class 5 limits for all of the tests performed.

8.1 Conducted Emissions

Figure 23. Conducted Emissions, Line Side

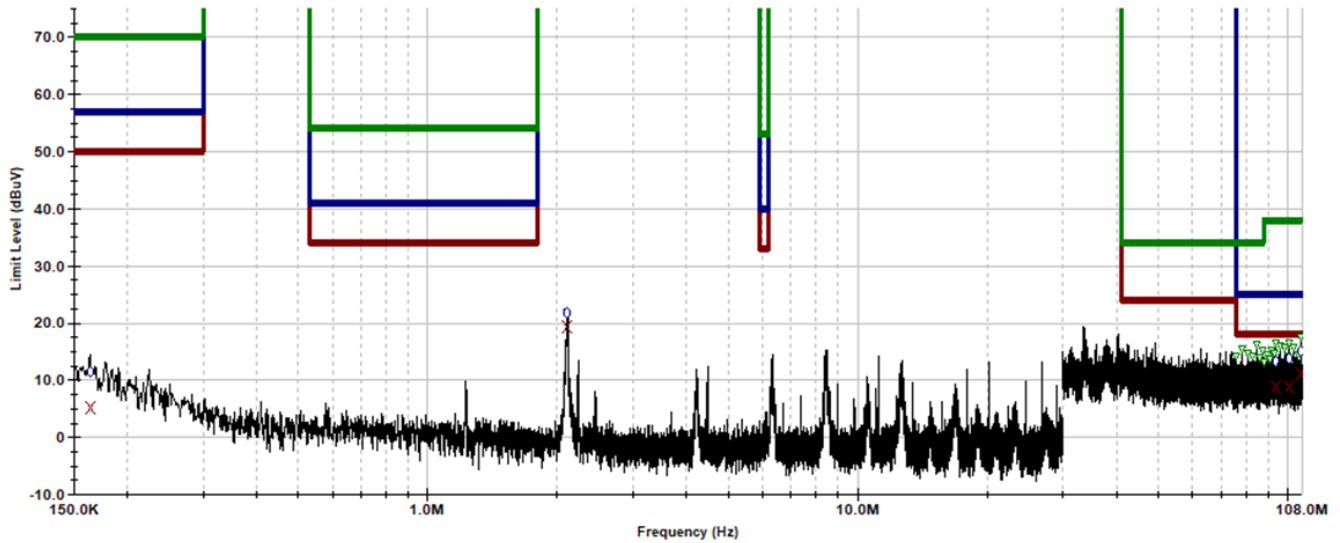
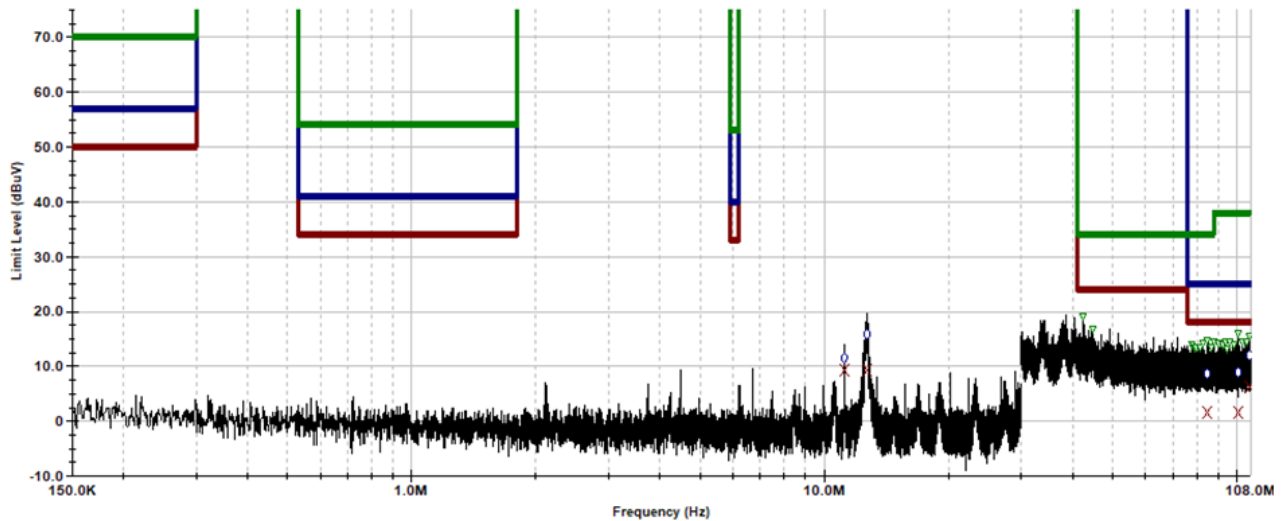


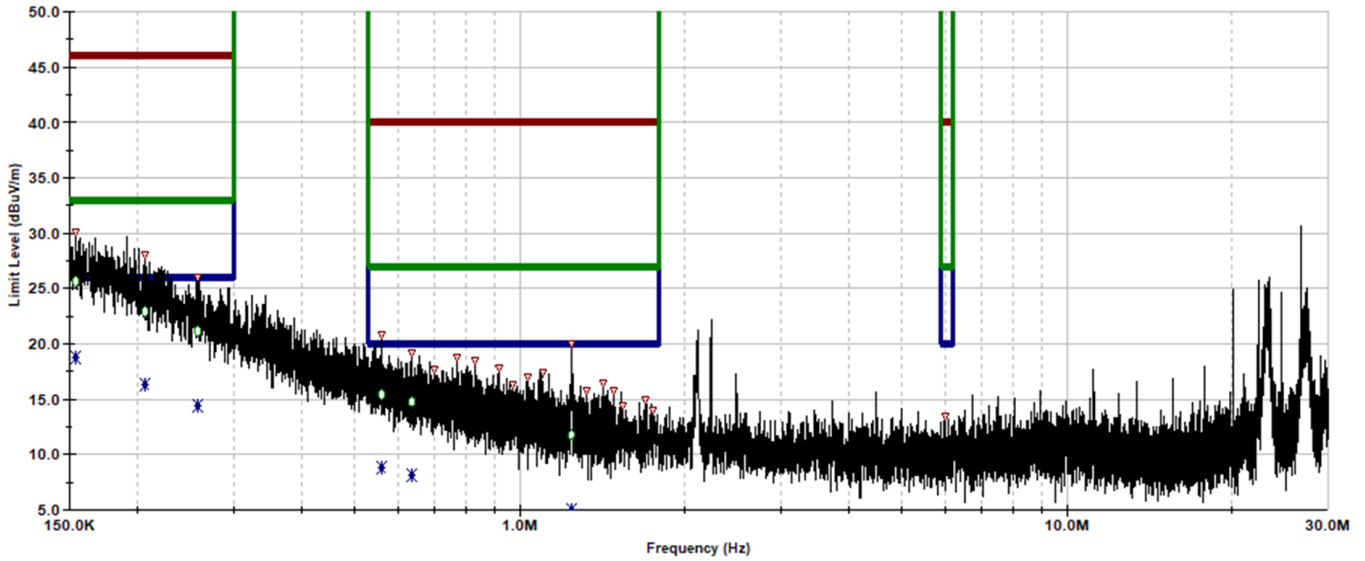
Figure 24. Conducted Emissions, Return Side



8.2 Radiated Emissions

8.2.1 150 kHz to 30 MHz

Figure 25. Radiated Emissions, 150 kHz to 30 MHz



8.2.2 30 MHz to 200 MHz

Figure 26. Radiated Emissions, 30 MHz to 200 MHz, Horizontal Polarization

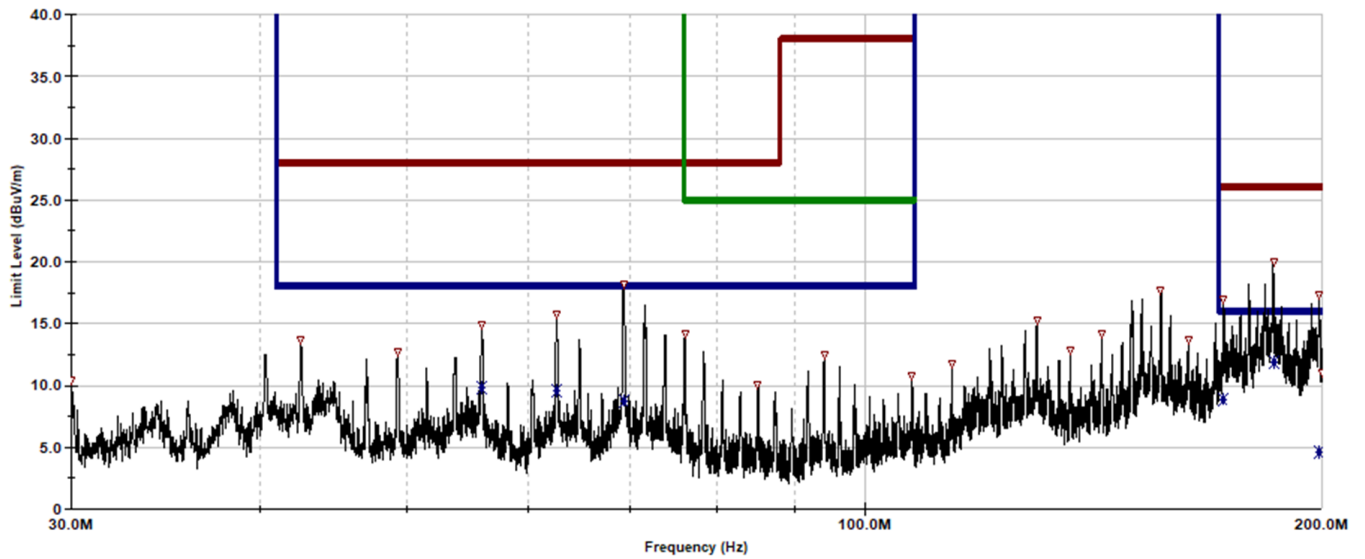
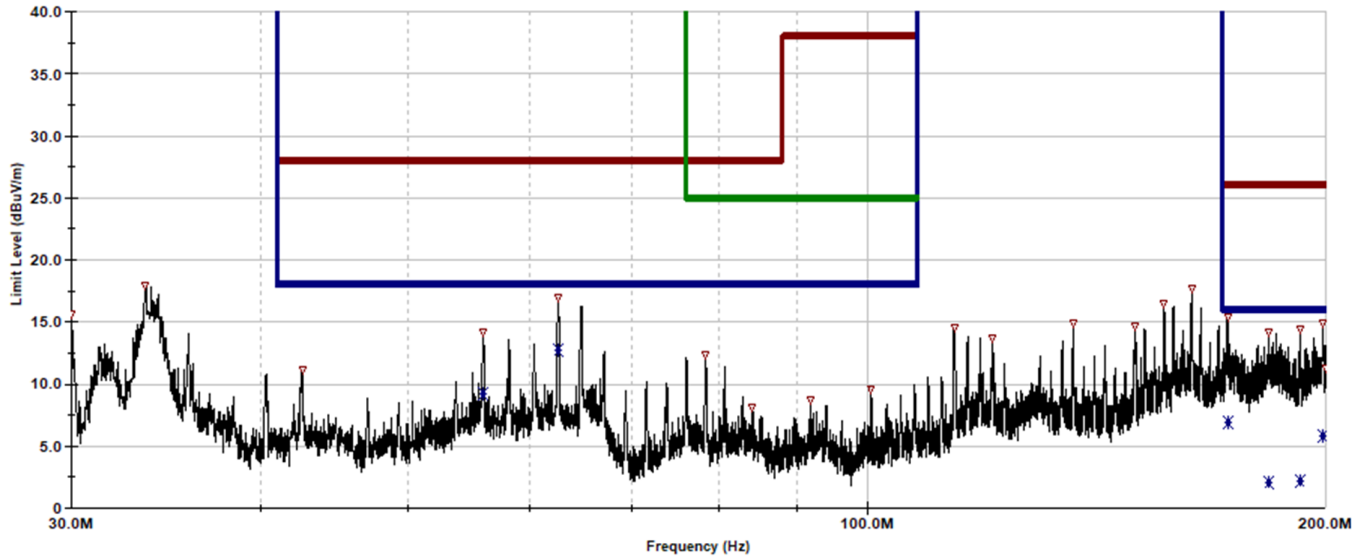


Figure 27. Radiated Emissions, 30 MHz to 200 MHz, Vertical Polarization



8.2.3 200 MHz to 1 GHz

Figure 28. Radiated Emissions, 200 MHz to 1000 MHz, Horizontal Polarization

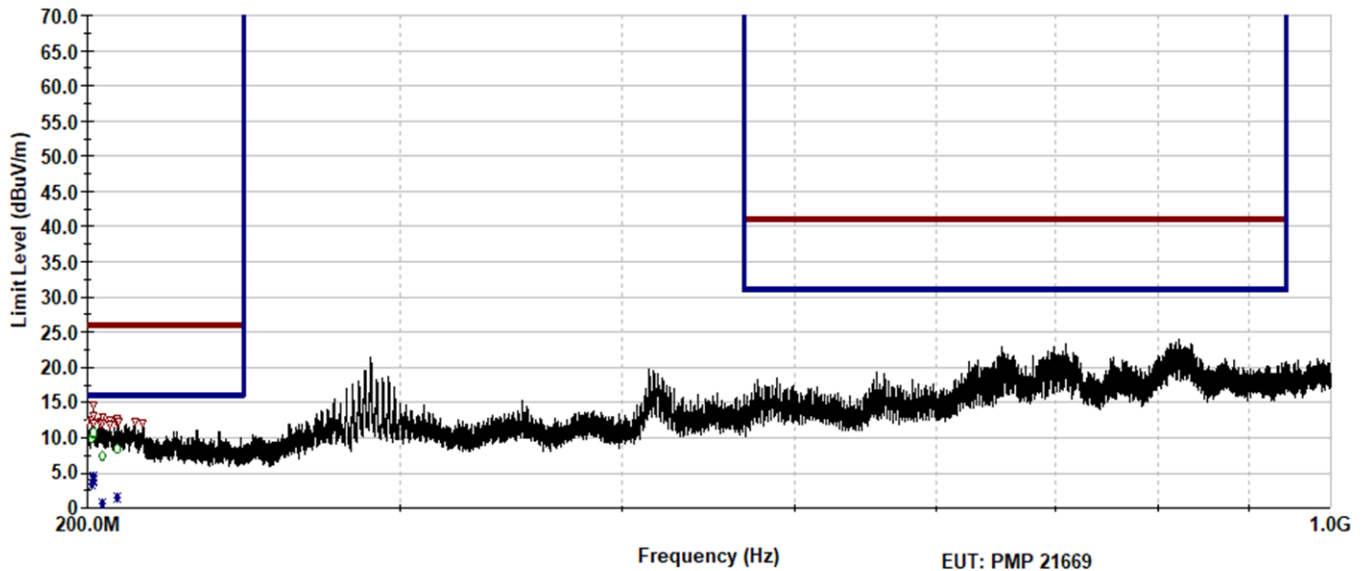
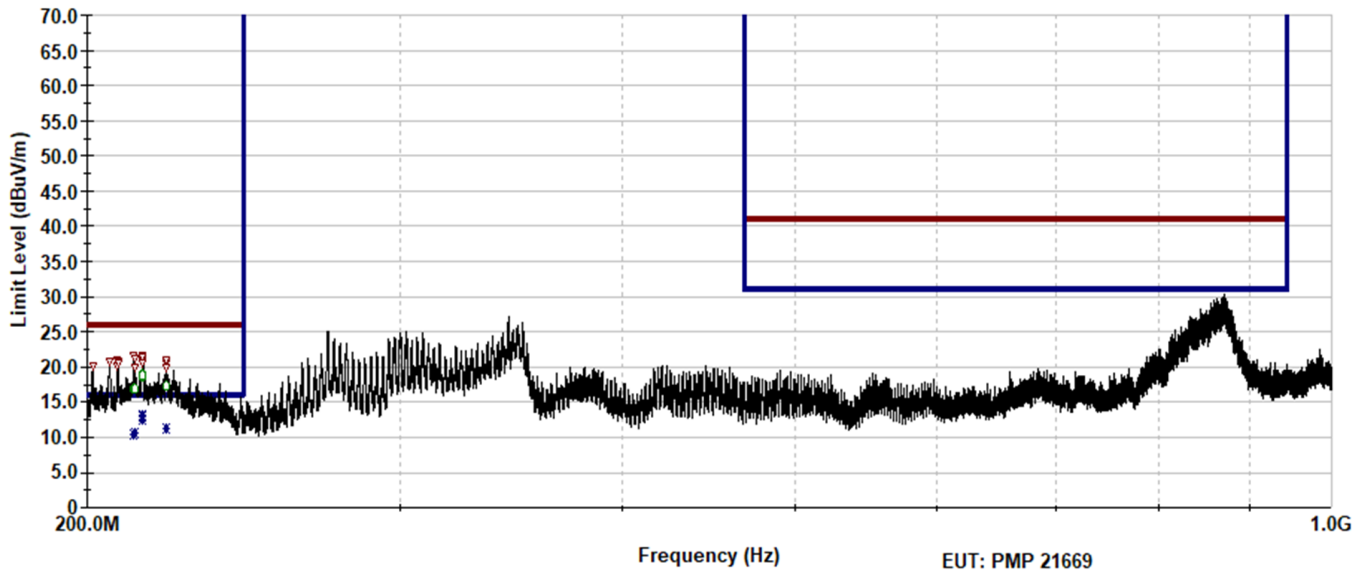


Figure 29. Radiated Emissions, 200 MHz to 1000 MHz, Vertical Polarization



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