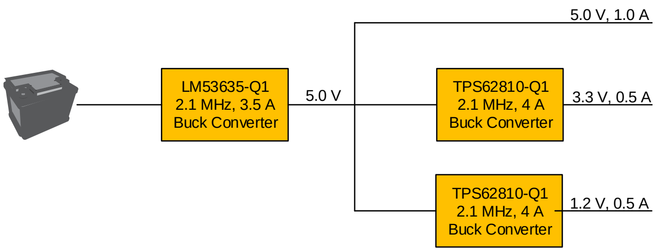
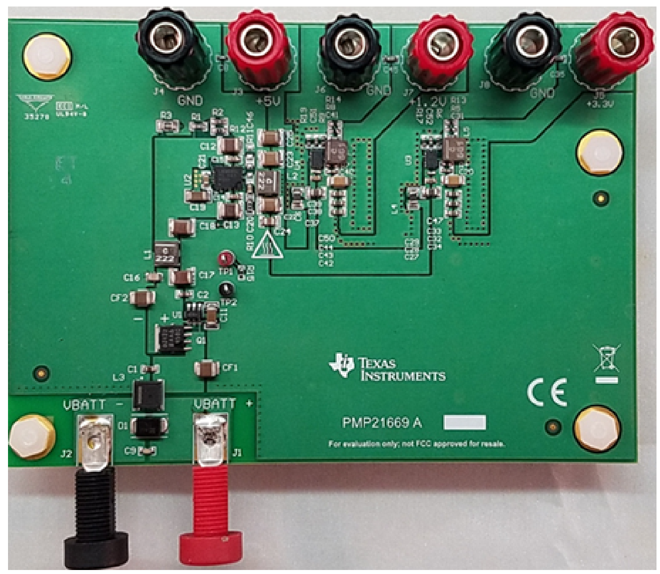
# Test Report: PMP21669
# Automotive instrument cluster power reference design with three outputs

## 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

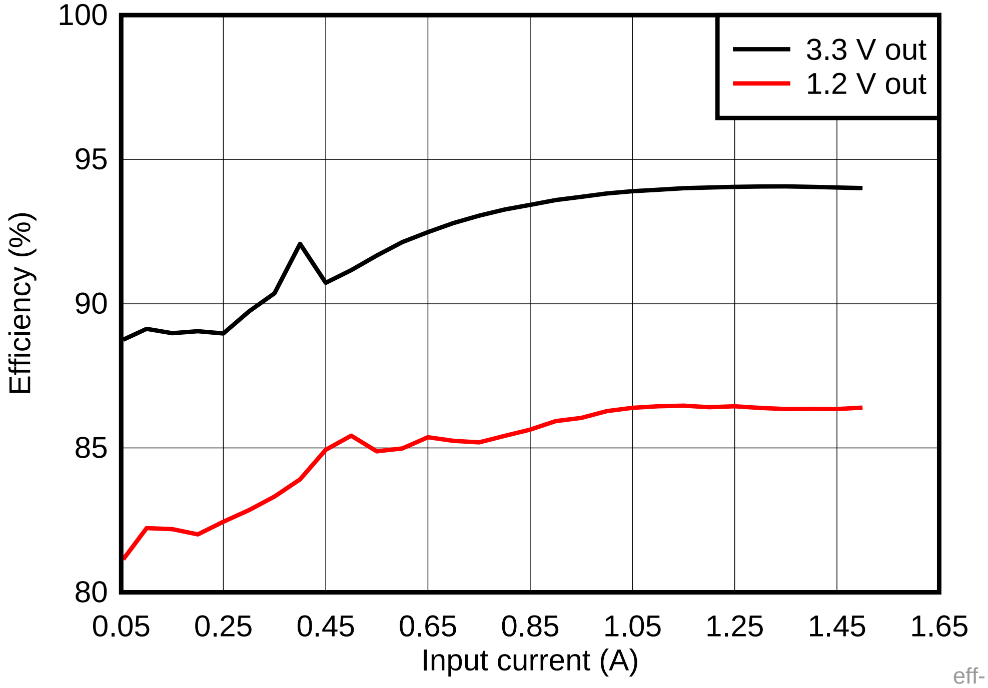
## 2 Testing and Results

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

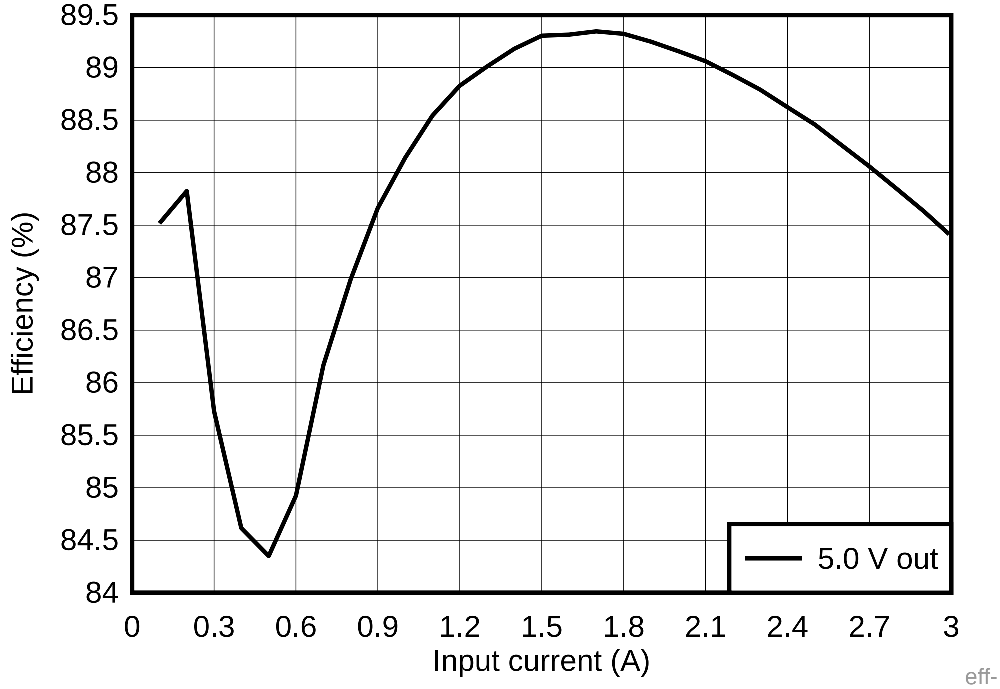
| $V_{IN}$ | $I_{VIN}$ | $V_{OUT}$ | $I_{LOAD}$ | EFFICIENCY (%) |
|---|---|---|---|---|
| 5.120 | 0.034 | 1.202 | 0.116 | 79.3 |
| 5.119 | 0.063 | 1.204 | 0.217 | 80.5 |
| 5.117 | 0.091 | 1.205 | 0.317 | 81.5 |
| 5.116 | 0.118 | 1.203 | 0.417 | 83.3 |
| 5.115 | 0.145 | 1.202 | 0.516 | 83.7 |
| 5.113 | 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**

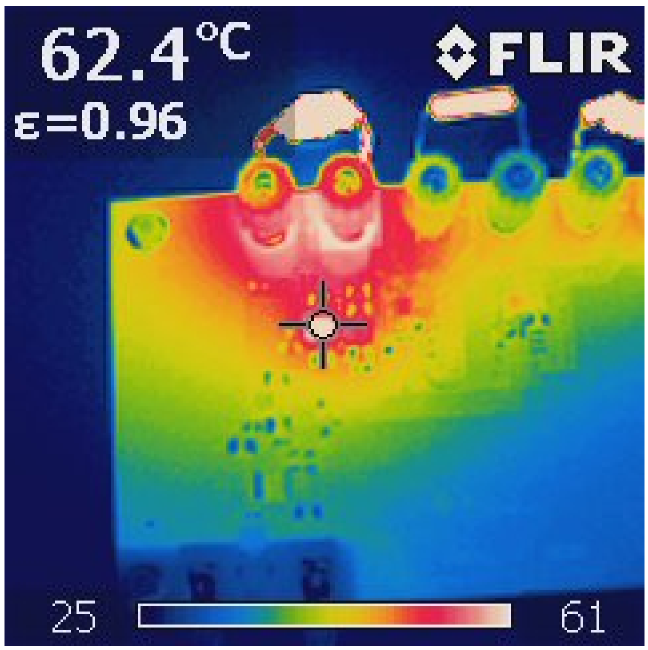


**Figure 4. TPS62810-Q1 Thermal Image at 3.3-V Output Voltage and 0.5-A Current**

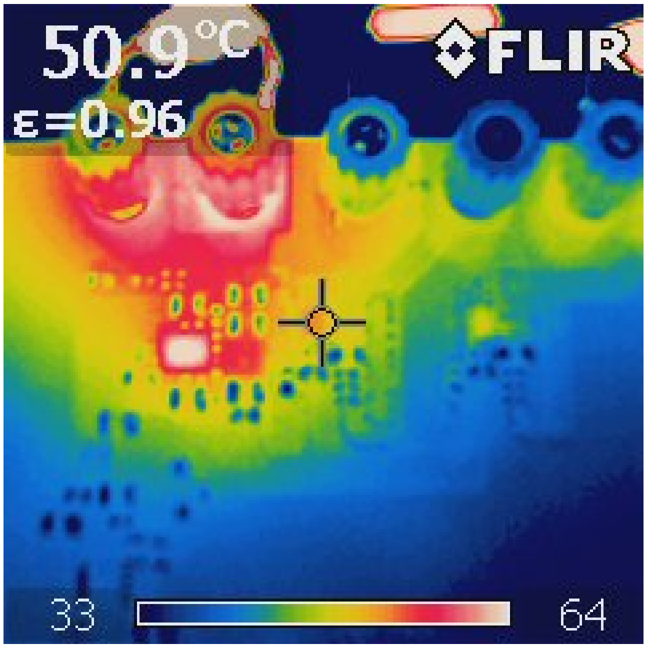
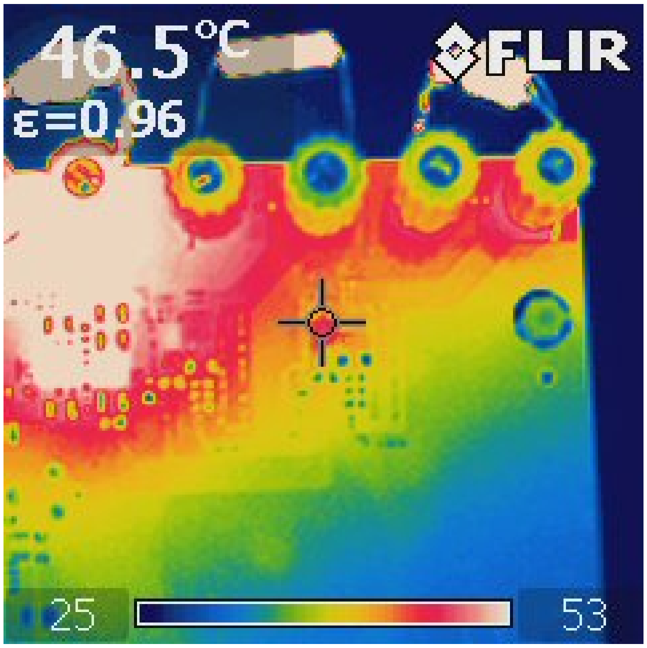



**Figure 5. TPS62810-Q1 Thermal Image at 1.2-V Output Voltage and 0.5-A Current**

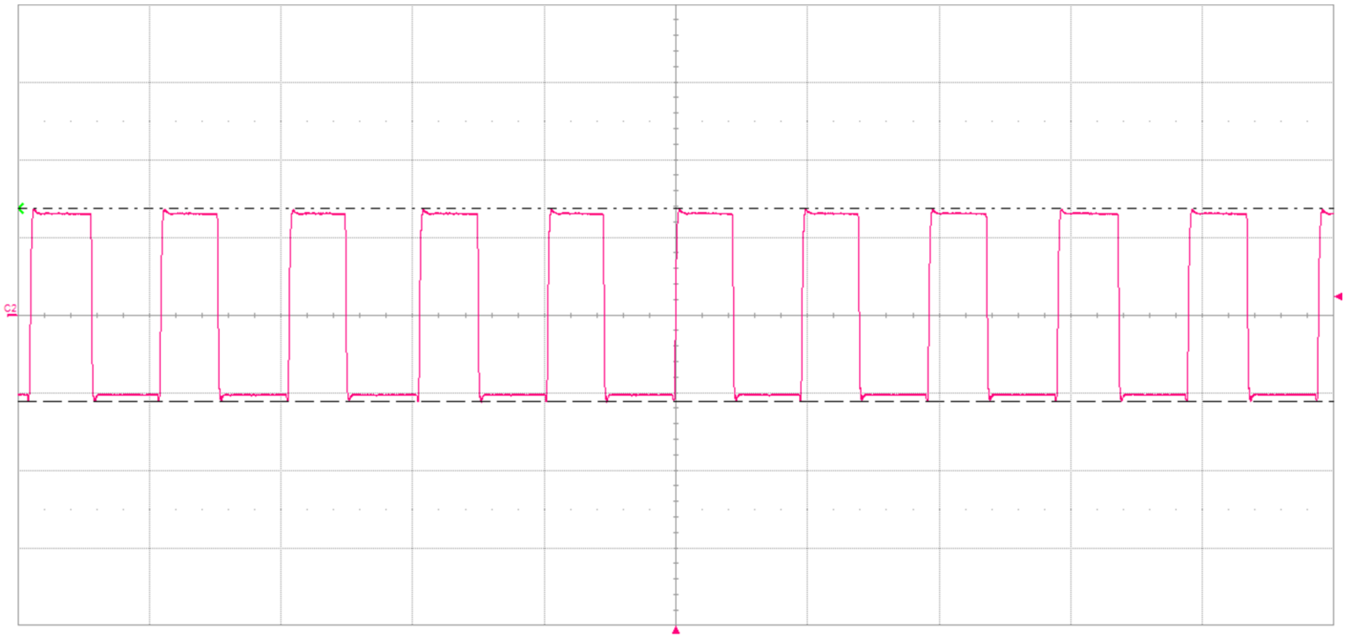


# 3 Switching Waveforms

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)*

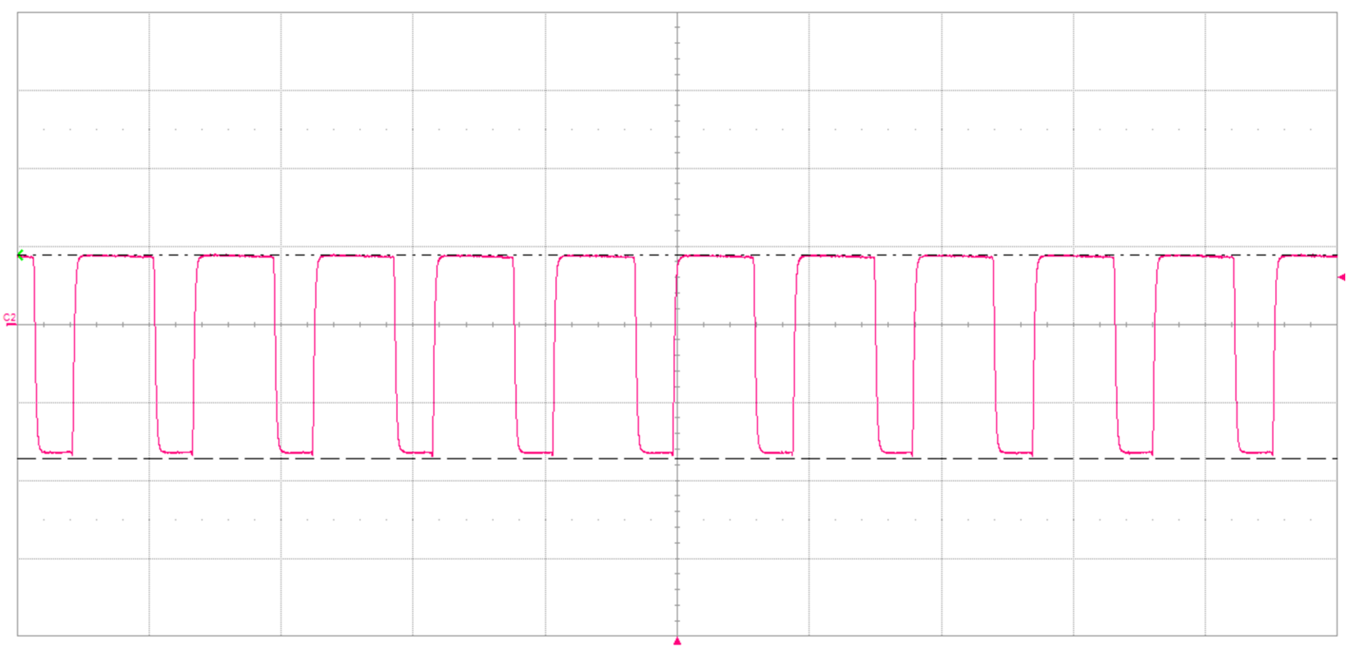
**Figure 6. Switching Waveform at 1-A Load Current**



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

## *3.2 3.3-V Output Voltage (TPS62810-Q1)*

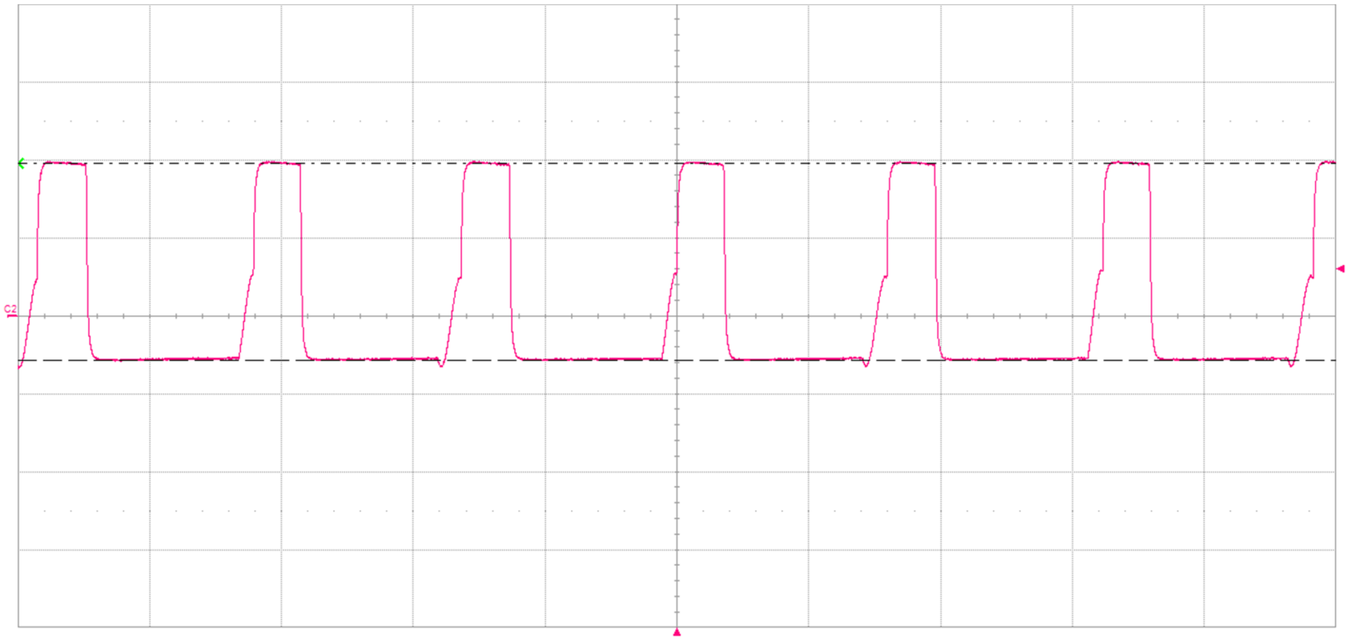
**Figure 7. Switching Waveform at 0.5-A Load Current**



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**



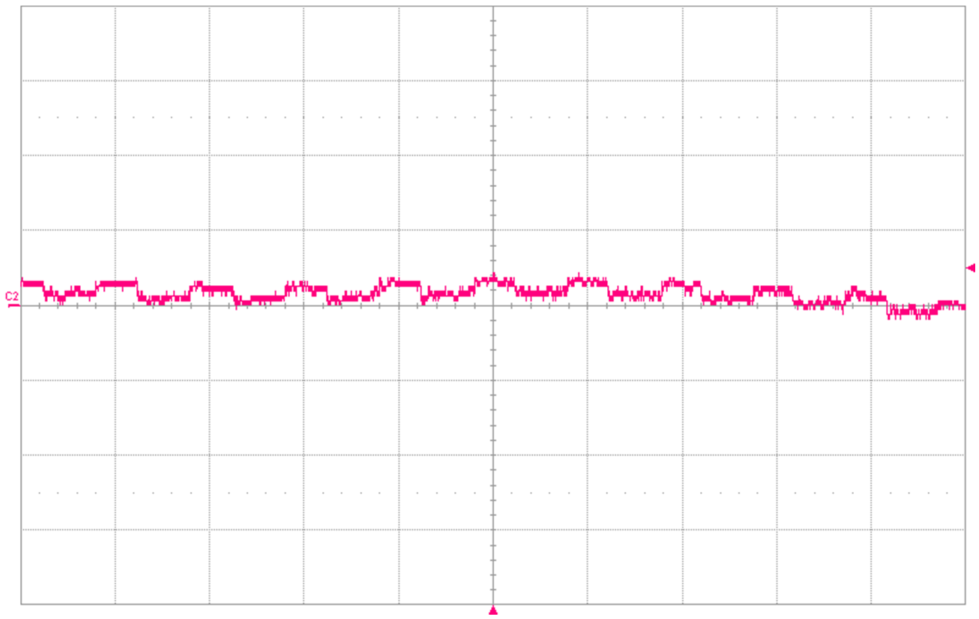
Channel 2 – Red: Switching Node – (2.0 V/Div, 0.5us /Div)

# 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)

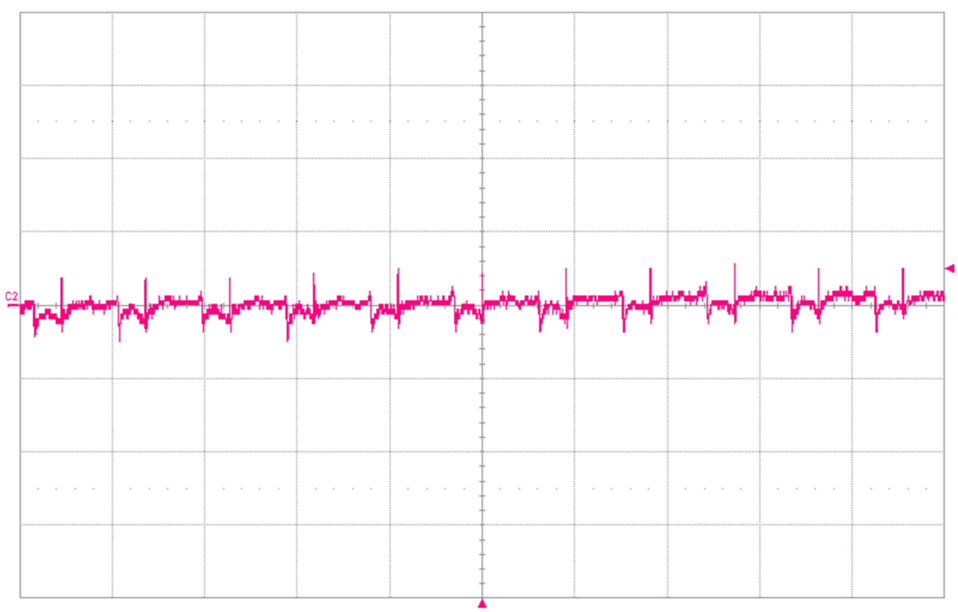
**Figure 9. Output Ripple at 1.5-A Load Current**




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)

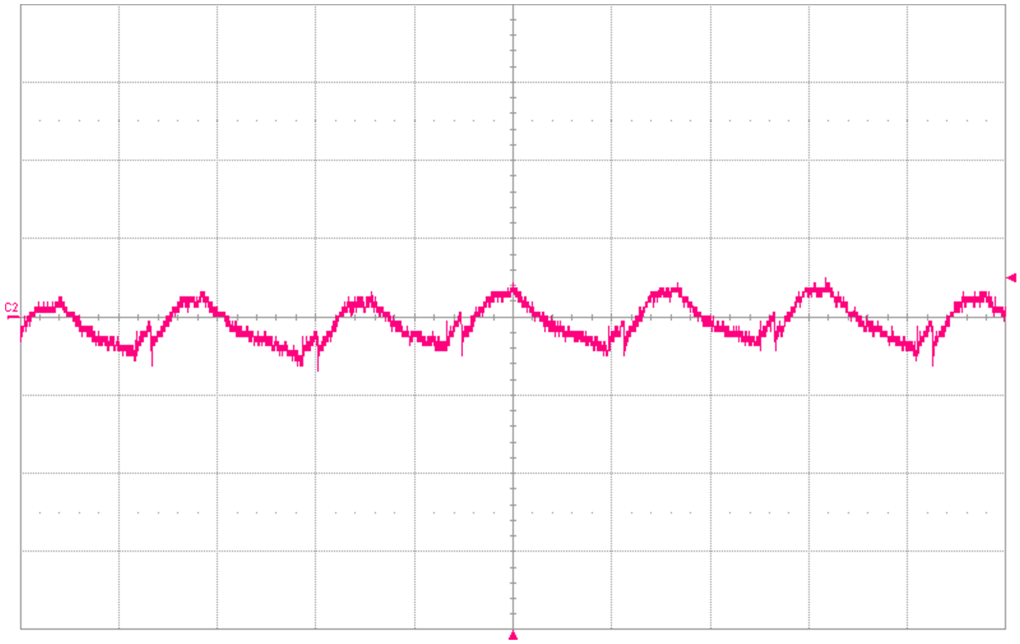
**Figure 10. Output Ripple at 0.5-A Load Current**




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**

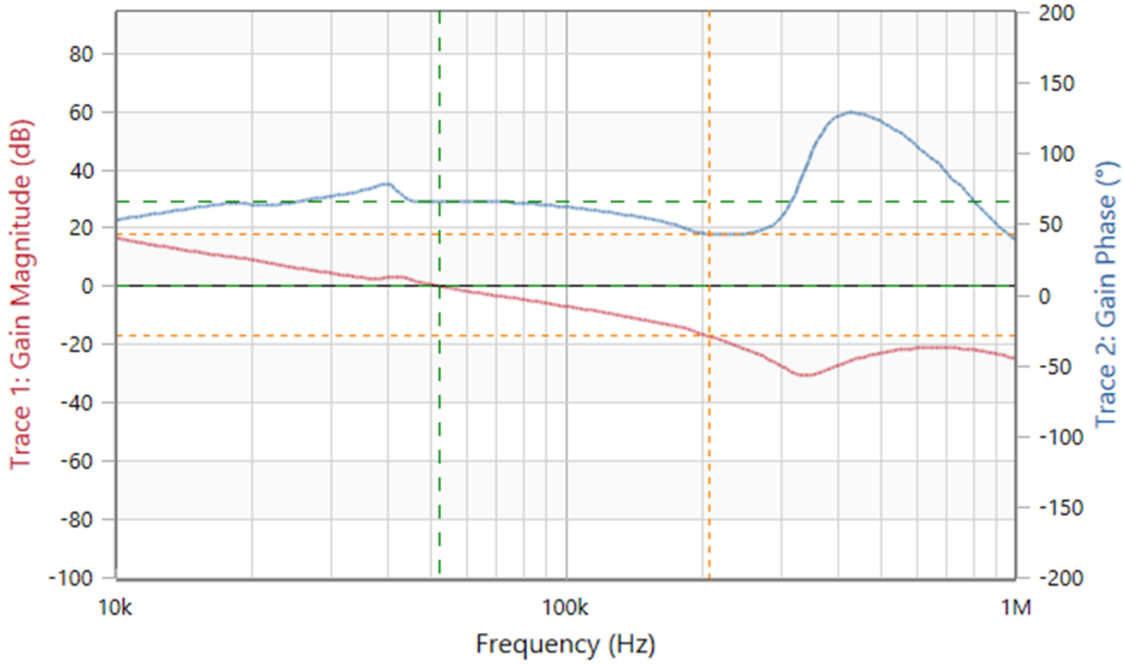



Channel 2 – Red: Output Ripple – (200 mV/Div, 0.5 us/Div). Output ripple is about 10 $mV_{p-p}$.

# 5 Bode Plots

## 5.1 5-V Output Voltage (LM53635-Q1)

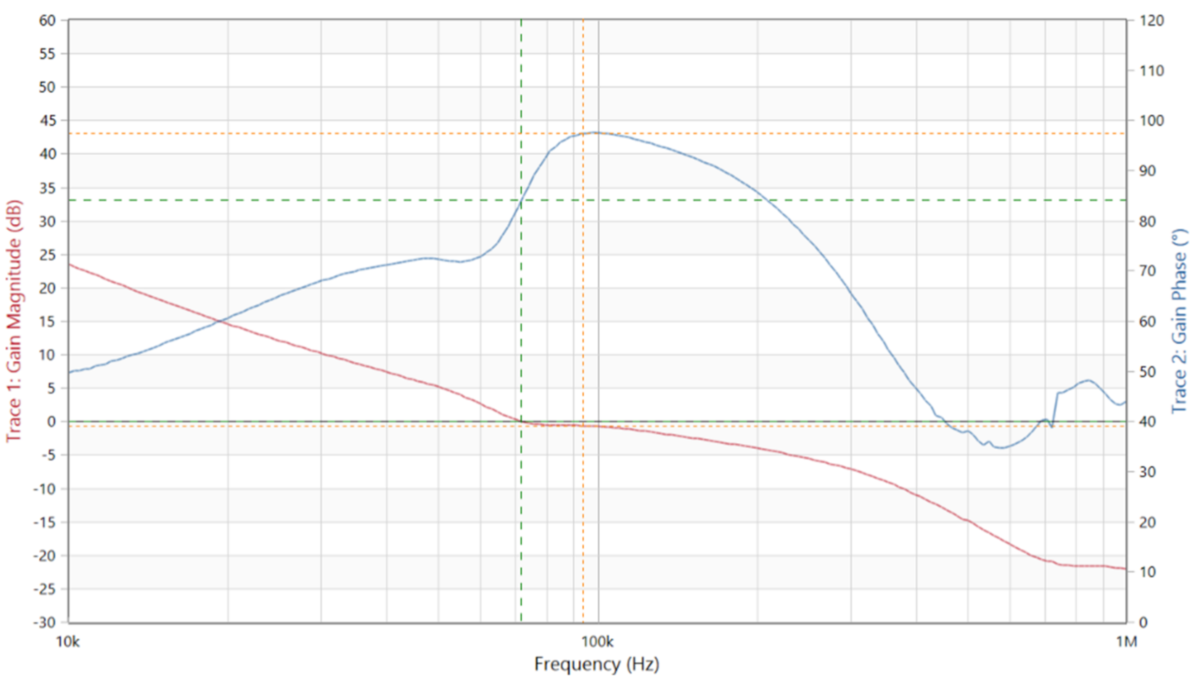
**Figure 12. Bode Plot of 5-V Output Voltage**




Phase Margin = 52.3 degrees

## 5.2 3.3-V Output Voltage (TPS62810)

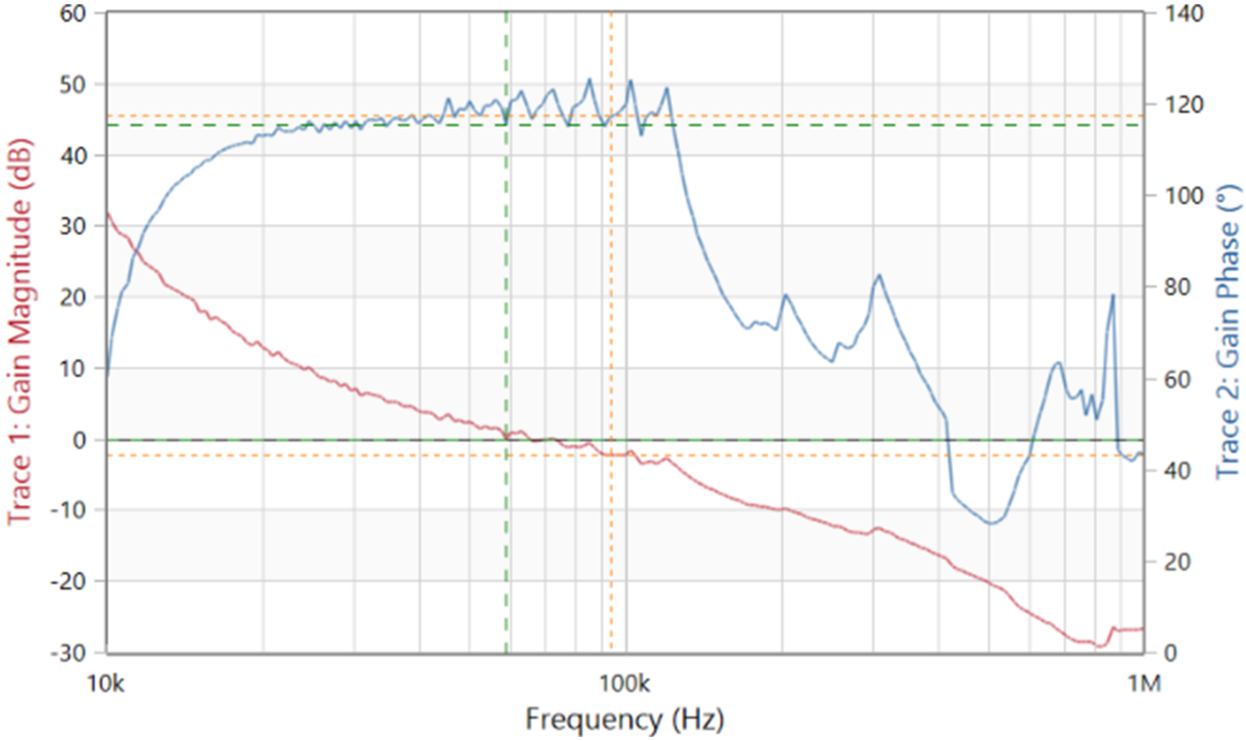
**Figure 13. Bode Plot of 3.3-V Output Voltage**




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**

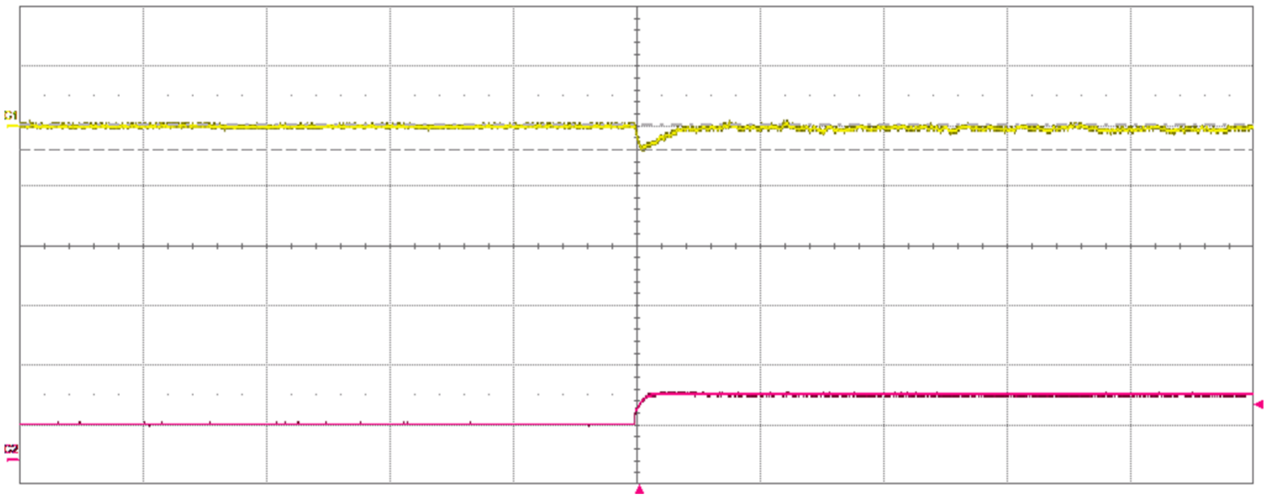
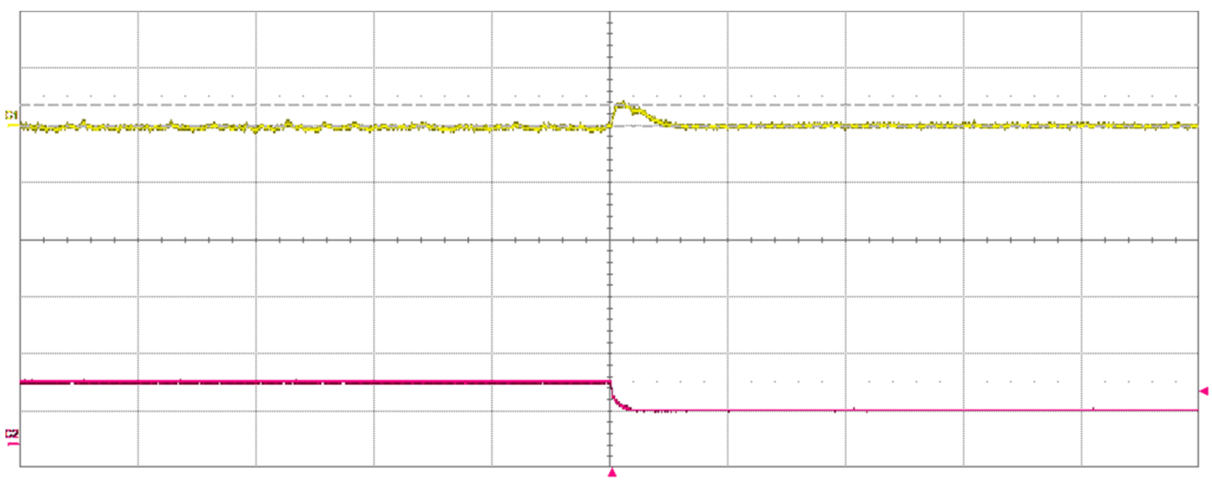


**Figure 16. Load Transient for 5-V Output Voltage - Decreasing Current**



### *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**

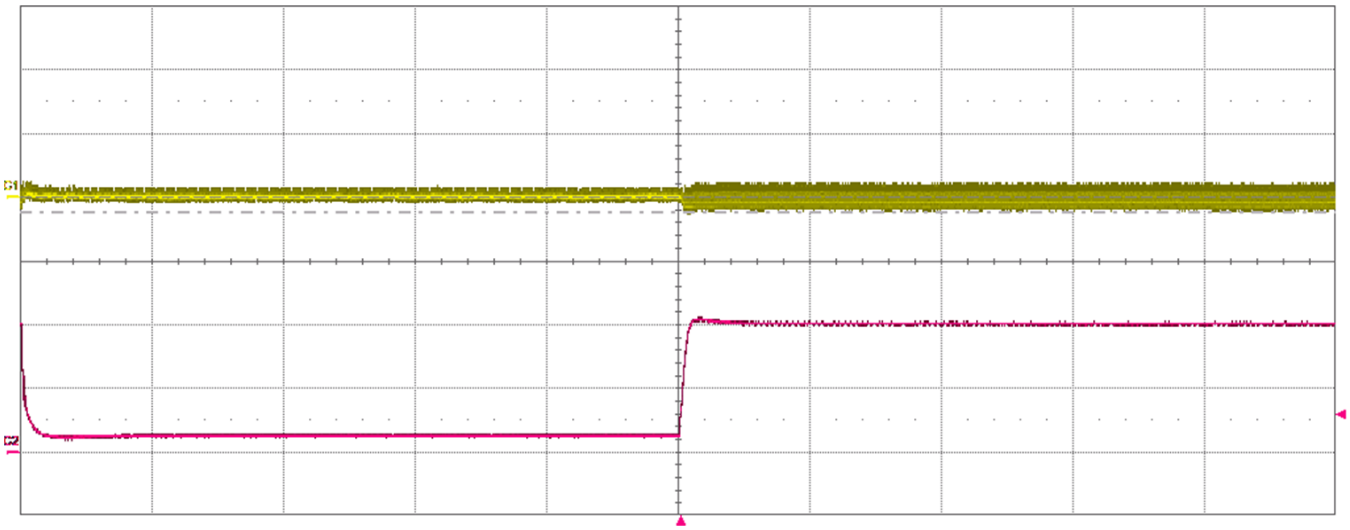
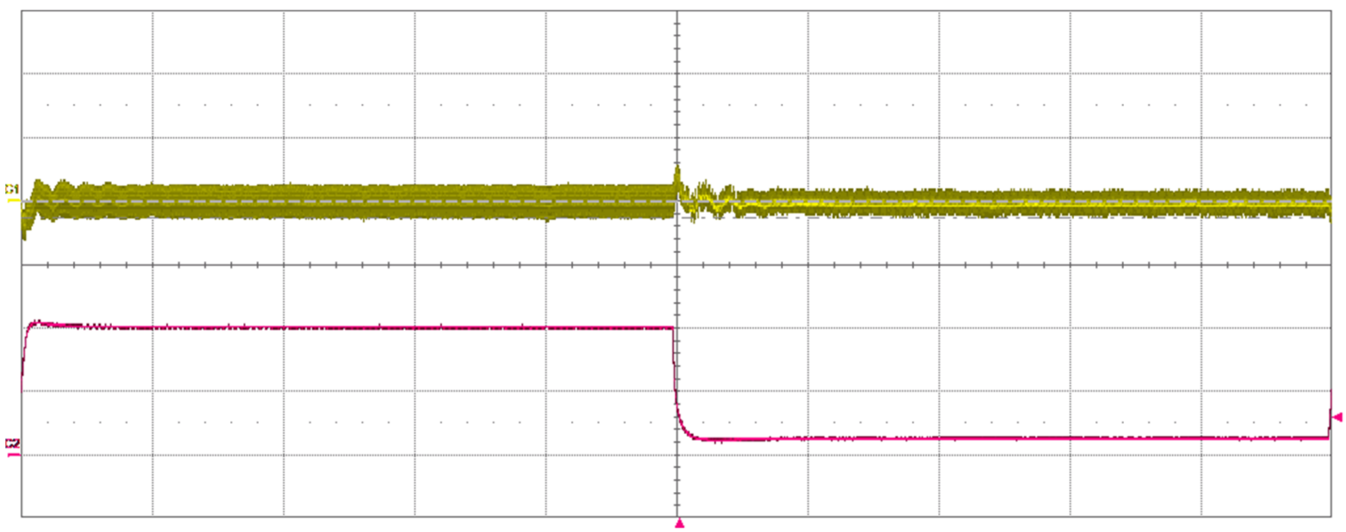


**Figure 18. Load Transient for 3.3-V Output Voltage - Decreasing Current**



### 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**

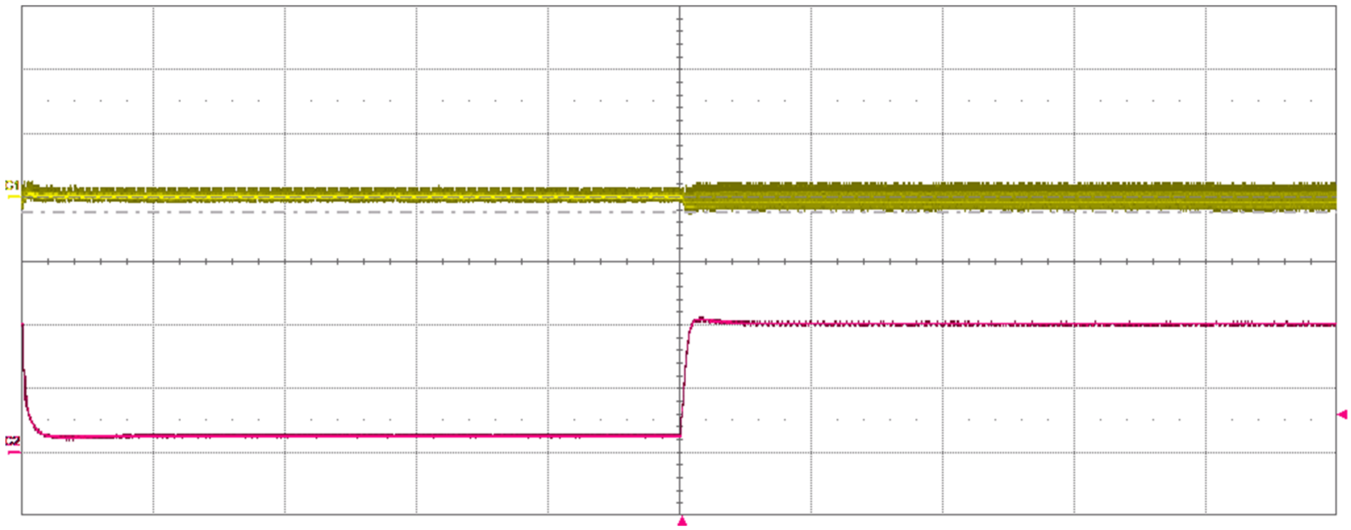
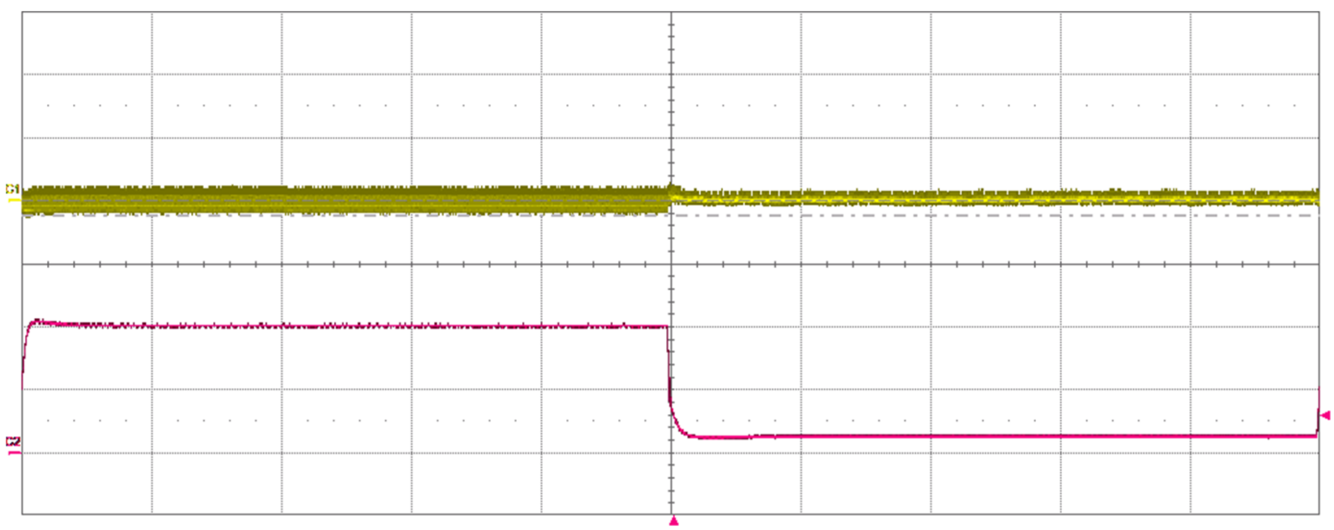


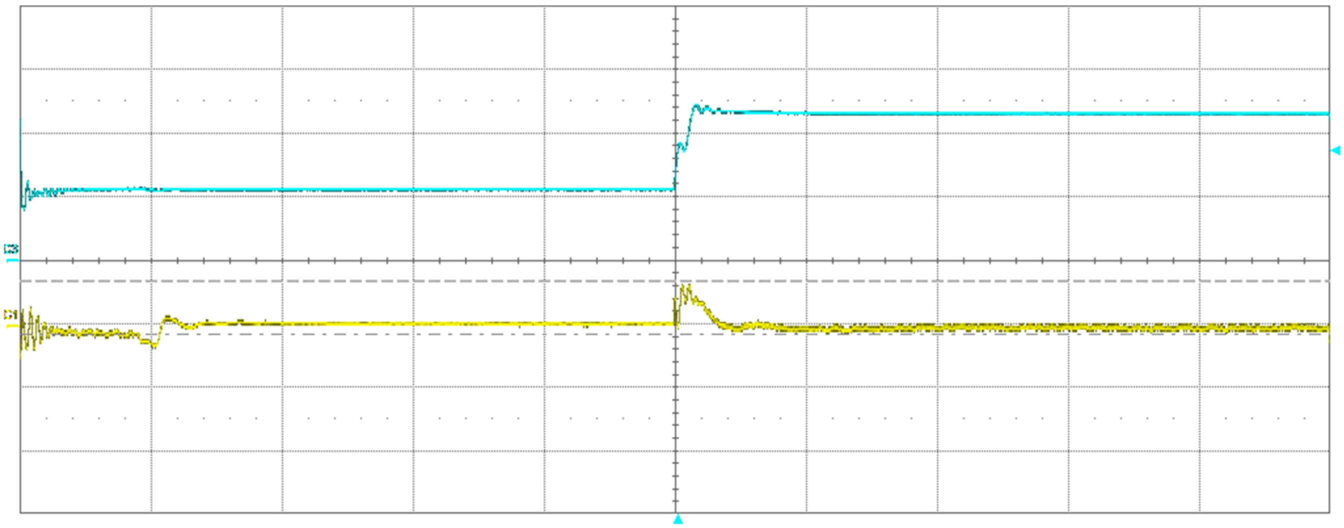
**Figure 20. Load Transient for 1.2-V Output Voltage - Decreasing Current**



## 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.

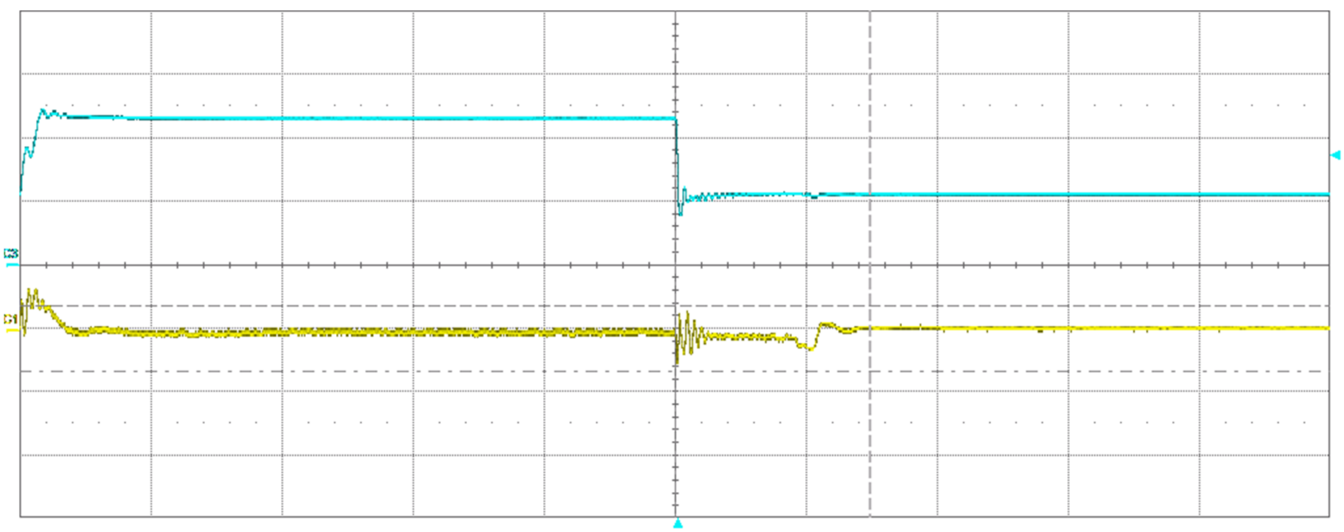
**Figure 21. Line Transient - Increasing Voltage**



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**

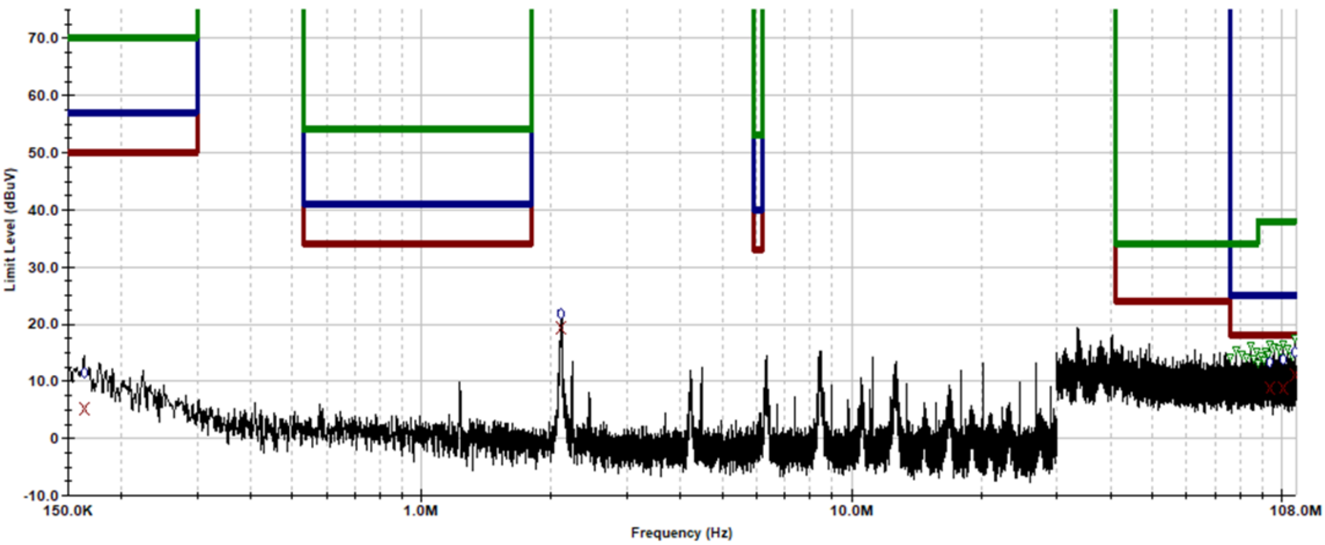
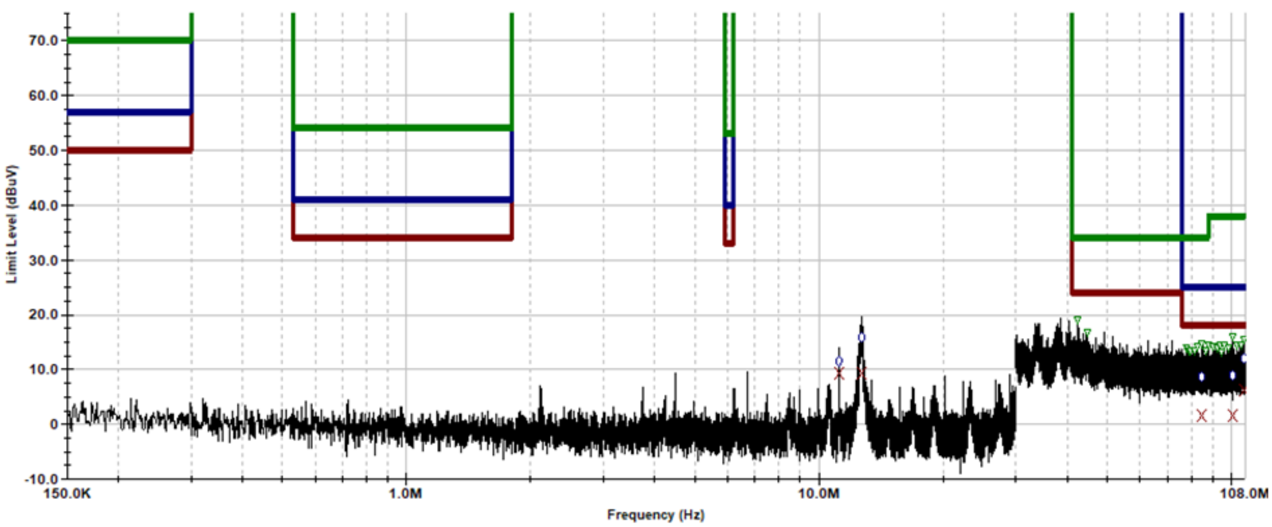


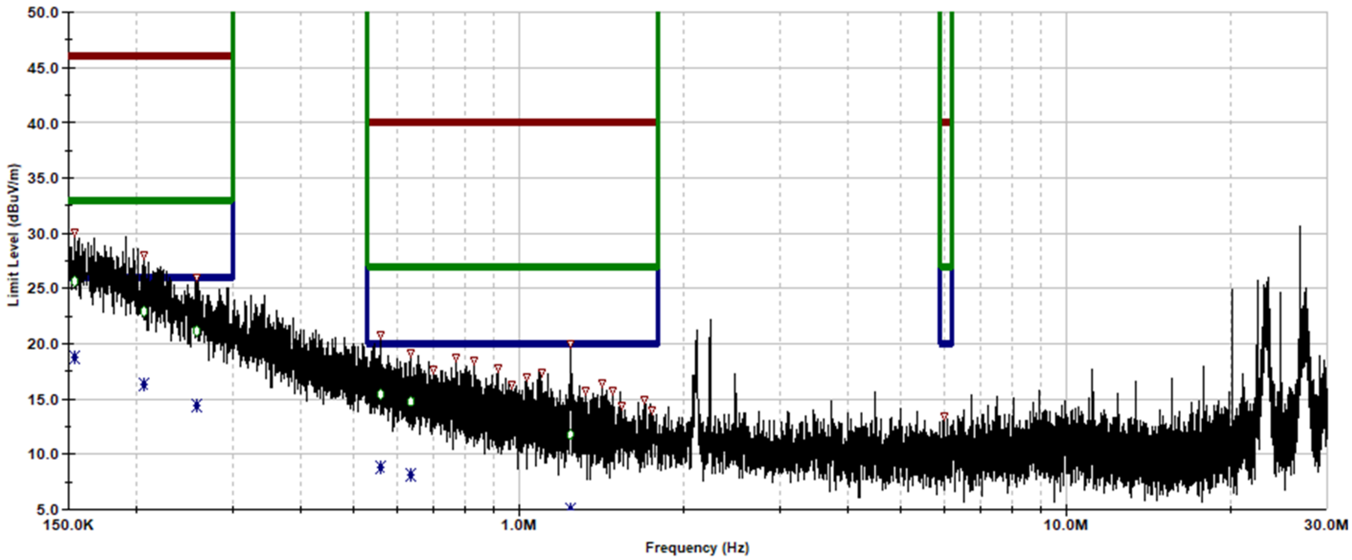

**Figure 24. Conducted Emissions, Return Side**



## 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**

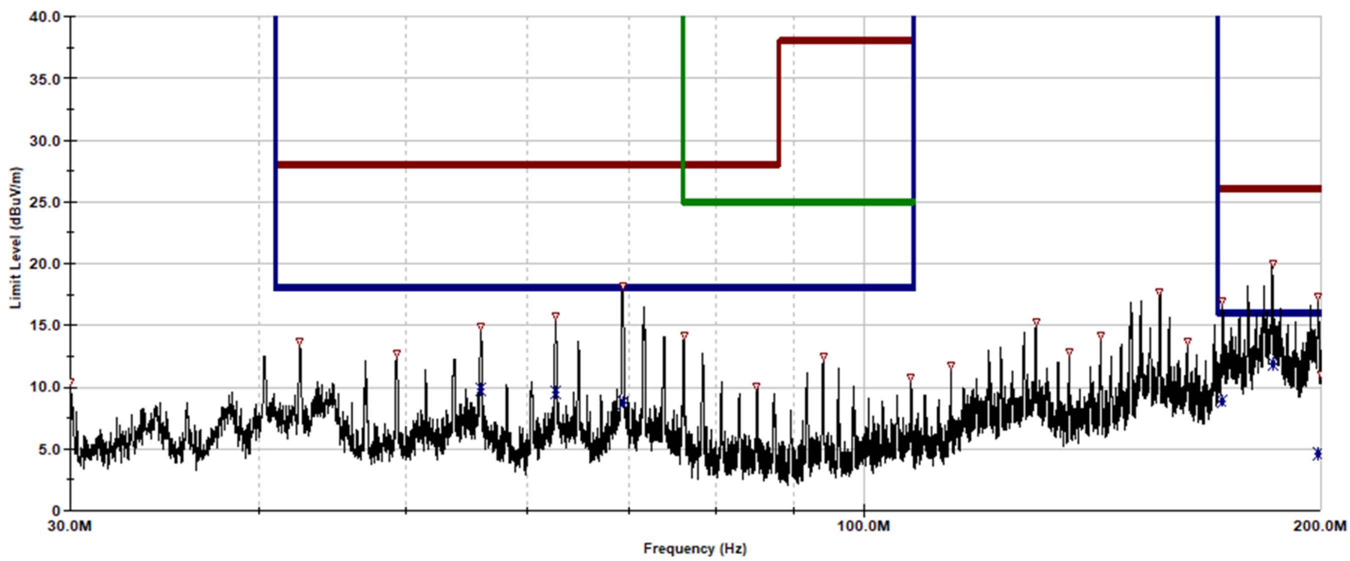
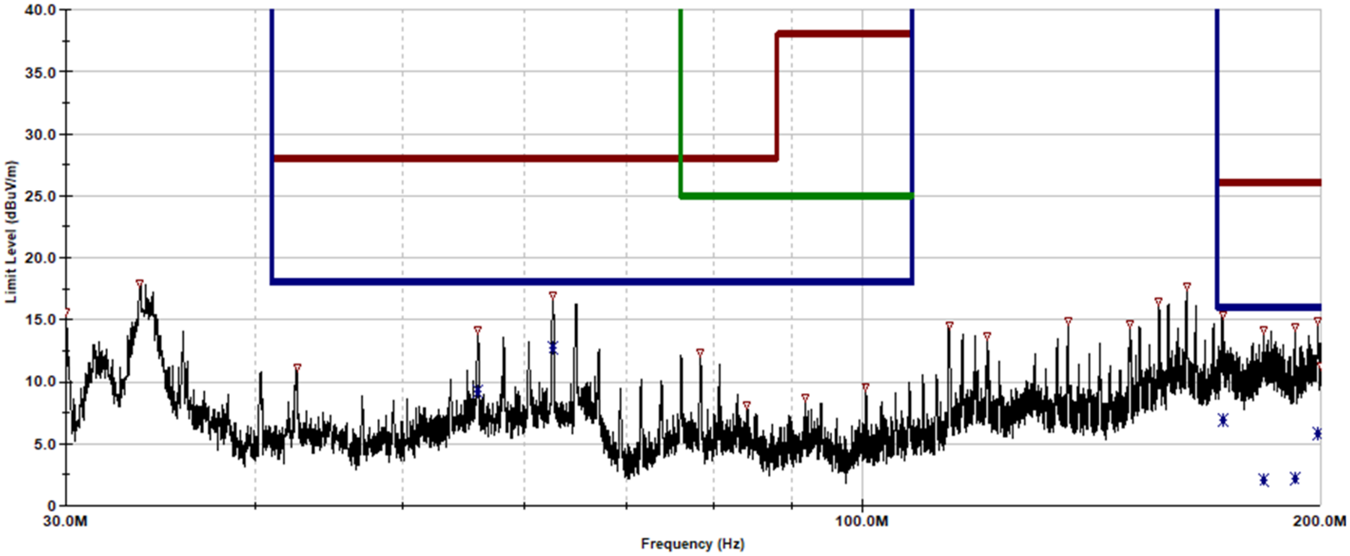


**Figure 27. Radiated Emissions, 30 MHz to 200 MHz, Vertical Polarization**




### 8.2.3 200 MHz to 1 GHz

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

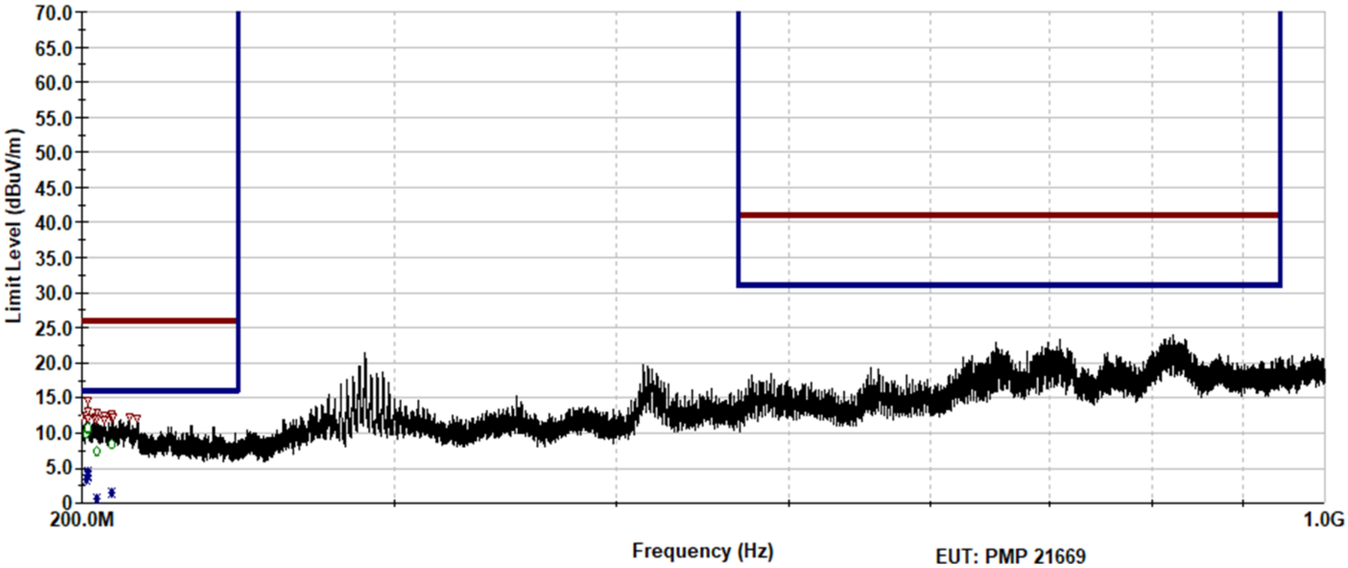


**Figure 29. Radiated Emissions, 200 MHz to 1000 MHz, Vertical Polarization**