Application Report
SNVA813–February 2018

Using the LP8860-Q1 for Low EMI Automotive Designs

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ABSTRACT

The LP8860-Q1 device is an automotive high-efficiency, four-channel LED driver with a boost controller typically used in automotive backlight applications such as infotainment and instrument clusters. Automotive electronics must comply with EMI regulations, and CISPR 25 standards are normally followed for measurements. This application note depicts the impact of various component and device register level changes on conducted EMI emissions. Measurement plots shown in *Section 4* of this application note were taken at an external compliance laboratory and provide a good idea for the level of conducted emission from the LP8860 EMI EVM. Note that measurements shown in other sections of this application note were taken in an in-house measurement setup, which is not fully calibrated to standard requirements. These measurements taken from the in-house setup are useful for gaining insight into how various changes may impact EMI but they should not be used for drawing any conclusions about absolute level of conducted emissions.

Contents

List of Figures

Trademarks

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1 Test Setup and Conditions

1.1 EVM Layout and Schematic

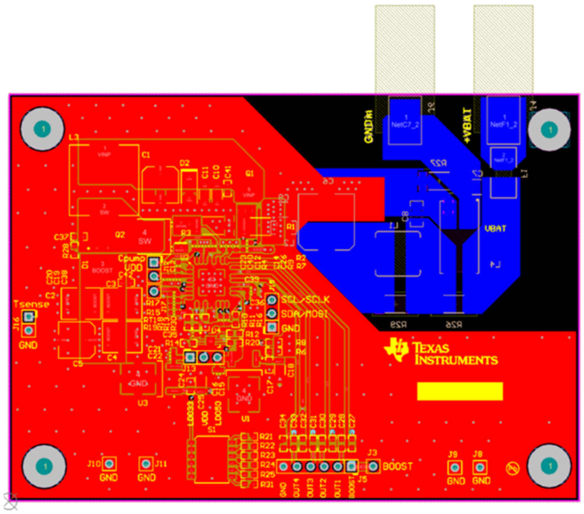

Figure 1. Top Layer of PCB Layout of LP8860-Q1 EMI Test Board

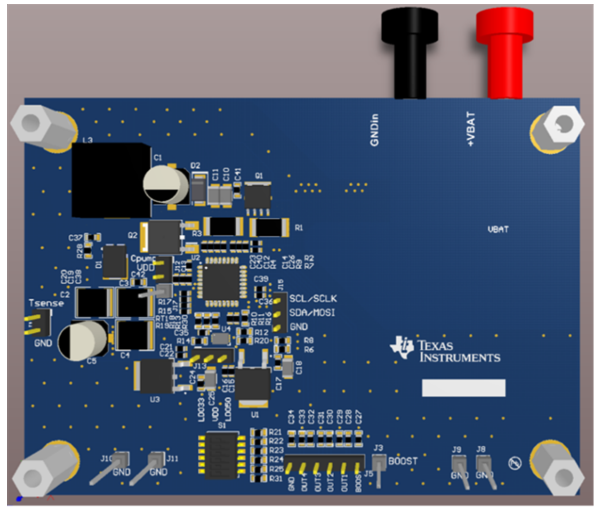

Figure 2. Top View of LP8860-Q1 EMI Test Board

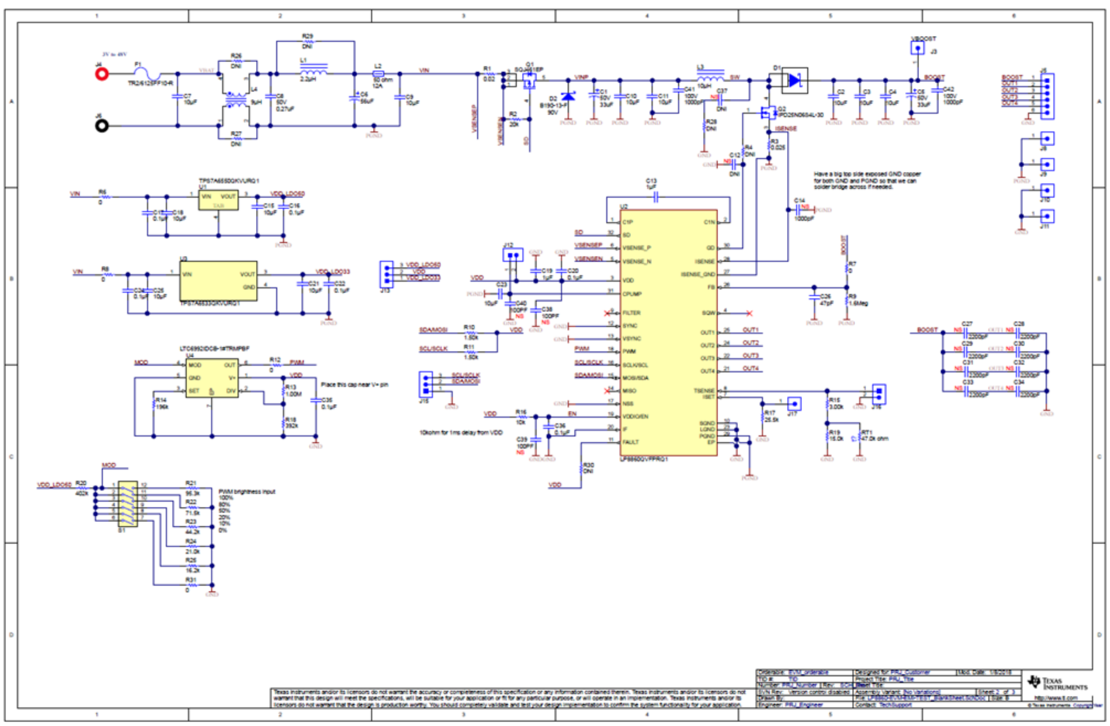

Figure 3. Schematic of LP8860-Q1 EMI Test Board

1.2 Diagram of Test Setup

Under CISPR 25 Standards, the setup in Figure 4 was prepared for the LP8860-Q1 EMI test board.

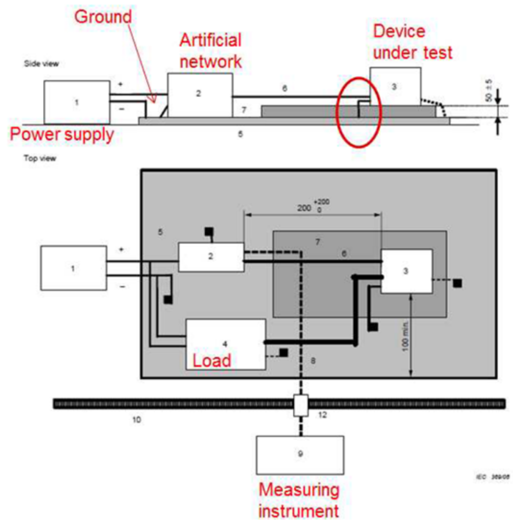

Figure 4. Schematic of LP8860-Q1 EMI Test Board

1.3 Equipment and Testing Conditions

The default conditions for the LP8860-Q1 EVM defined below were used in an internal debugging chamber.

- Equipment : Rhode and Schwarz Spectrum Analyzer
- Frequency ranges measured
  - Low frequency: 150 kHz to 30 MHz
  - High frequency: 30 MHz to 108 MHz
- Default setting parameters
  - V_{IN} = 12 V
  - V_{OUT} = 36 V, 11 LEDs
  - Switching frequency: 2.2 MHz
  - LED channels: 4
  - LED current per string: 120 mA
  - Boost input filters (pi filter, common mode choke, and ferrite bead) used
  - Snubbers used
  - Spread spectrum disabled
  - Charge pump enabled

2 Overview of Tests

VARIATIONS	DETAILS
Boost switching frequency	300 kHz and default: 2.2 MHz (boost inductor, boost input capacitance and boost output capacitance were adjusted to correct values for SW frequency)
Boost input filter : Pi filter	Use or bypass
Boost input filter : Common mode choke	Use or bypass
Boost input filter : Ferrite bead	Use or bypass
Snubber on gate drive of SW FET, R4, C12	Use or not, Default : 5 Ω + 220 pF
Snubber on SW node, R28, C37	Use or not, Default : 5 Ω + 220 pF
Capacitors between boost out and LED drivers	Use 220 pF or not
Capacitors between LED drivers and GND	Use 220 pF or not
Spread spectrum	Enabled or not
LED current per string	120 mA, 80 mA
Dimming	100%, 10%
V_{IN}	12 V or 9 V

3 Results for Conducted EMI Testing and Variations

3.1 Boost Switching Frequency

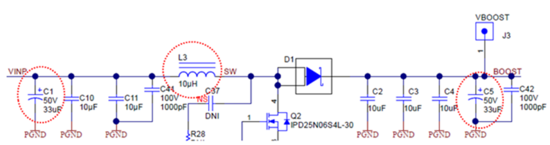

Figure 5. Boost Section of LP8860-Q1 EMI Test Board

Changing the boost switching frequency generally has the impact of moving the EMI peaks at that specific switching frequency and its harmonics to a different frequency range. If the application permits, changing the switching frequency can be an effective tool to move EMI peaks from the lower limit range to possibly a higher limit range. In addition, board parasitic and circuit element resonances may impact EMI behavior when switching frequency is changed and can possibly provide better EMI results. Changing the switching frequency can also help in avoiding system level interference with other components in the system.

Boost inductor, boost input capacitance and boost output capacitance were adjusted accordingly for the specified switching frequency. For the 300 kHz switching frequency, a 22-µH inductor with all input and output capacitors populated. For the 2.2-MHz switching frequency, a 10-µH inductor was used and C1 (33 µF) and C5 (33 µF) were both removed.

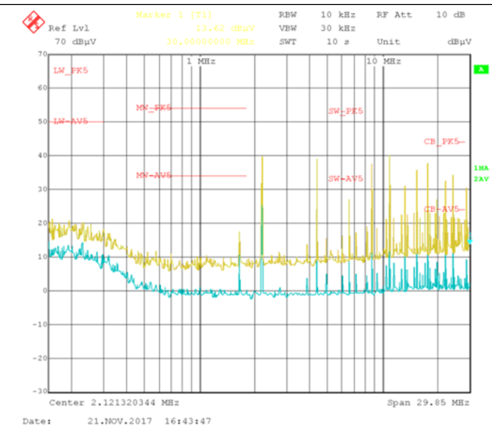

Figure 6. Low Frequency: f_{SW} = 2.2 MHz

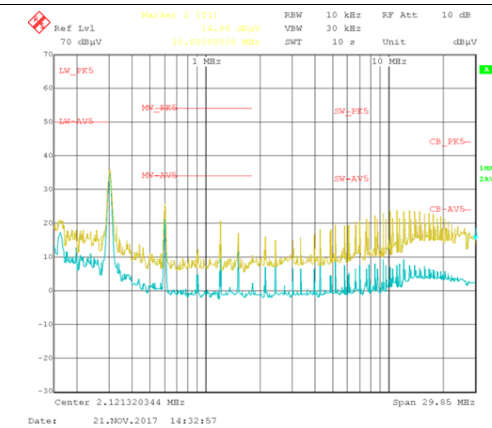

Figure 7. Low Frequency: f_{SW} = 300 kHz

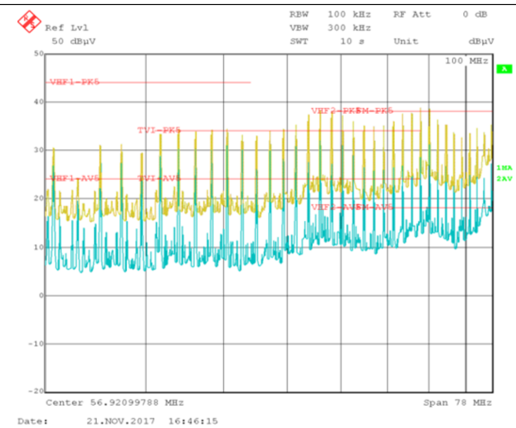

Figure 8. High Frequency: f_{SW} = 2.2 MHz

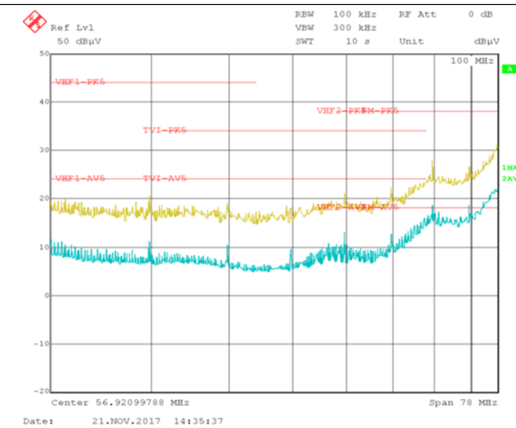

Figure 9. High Frequency: f_{SW} = 300 kHz

3.2 Boost Input Filter: Pi Filter

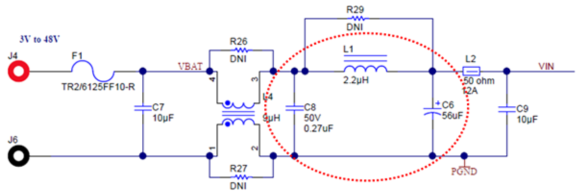

Figure 10. Circuit With Boost Input Filter: Pi Filter

The Pi filter is placed at the boost input of the EVM. The filter uses a 2.2-µH inductor in between a 0.27-µF capacitor at the input and 56-µF capacitor at the output. Small and large capacitors were selected for this pi filter to reject both high and low frequencies thus reducing EMI as shown in the following test results. Values of these components can be appropriately changed to achieve EMI reduction at any given frequency of interest. See AN-2162 Simple Success With Conducted EMI From DC-DC Converters for filter component selection.

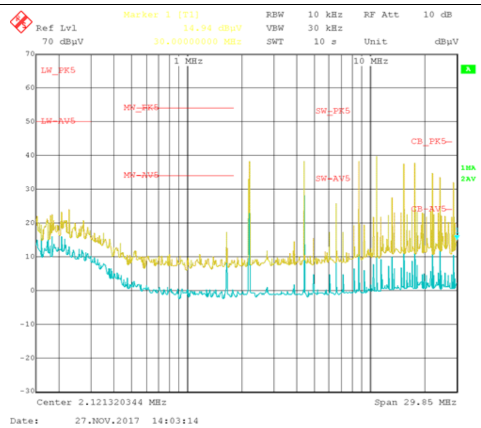

Figure 11. Low Frequency: Pi Filter Used

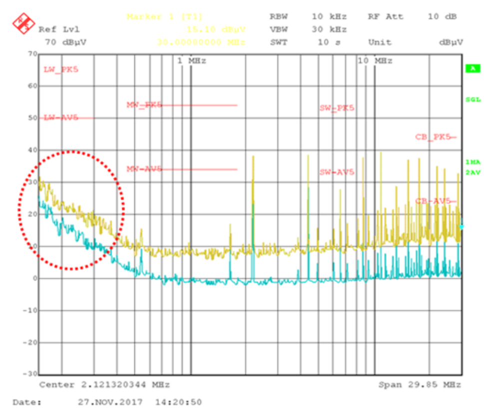

Figure 12. Low Frequency: Bypassed Pi Filter

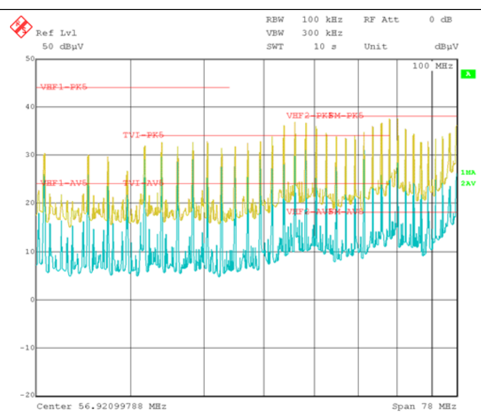

Figure 13. High Frequency: Pi Filter Used

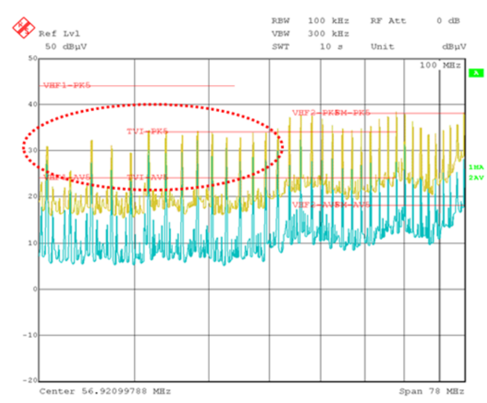

Figure 14. High Frequency: Bypassed Pi Filter

3.3 Boost Input Filter: CM Choke

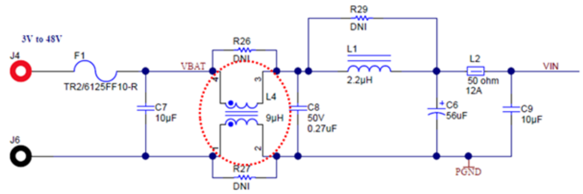

Figure 15. Circuit With Boost Input Filter: CM Choke

Due to the switching mechanism of boost converter circuits, the coupling of high-frequency currents to both line and neutral signal paths is a common scenario. For this reason, employing a common-mode choke at input/output terminals of the system can provide significant reduction in conducted noise. A common-mode choke has both line and neutral windings wound on a common ferrite core, which helps in presenting higher impedance to noise currents compared to inductors wound on separate cores. Various common-mode chokes are available and present high impedance at different frequencies. Consult data sheet impedance graphs to choose an appropriate component for a particular need. This EVM uses a 9-µH inductance common-mode choke in its design which is placed at the input of the power supply to the boost converter. The following results show a significant difference with and without the common-mode choke.

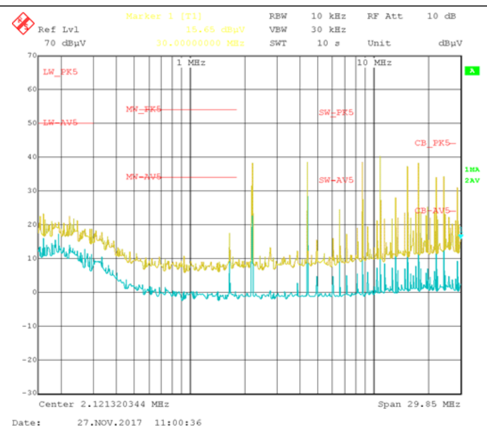

Figure 16. Low Frequency: Used CM Choke

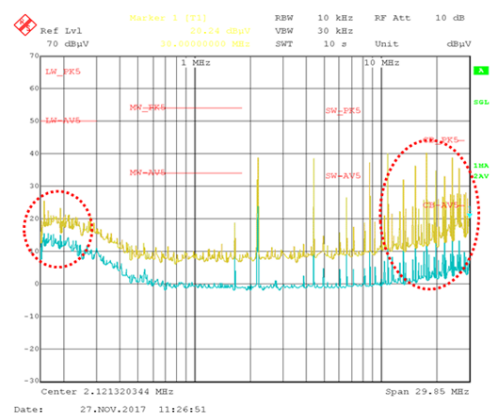

Figure 17. Low Frequency: Bypassed CM Choke

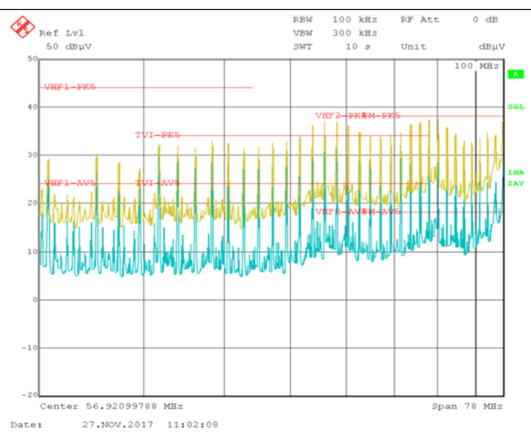

Figure 18. High Frequency: Used CM Choke

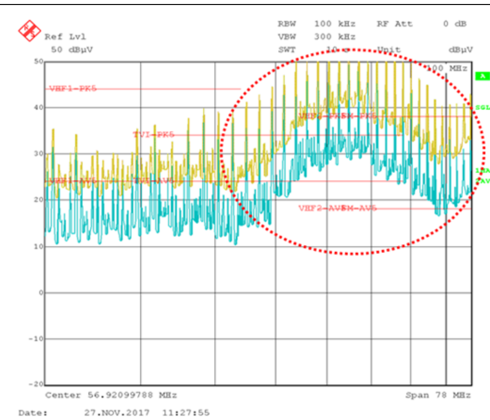

Figure 19. High Frequency: Bypassed CM Choke

3.4 Boost Input Filter: Ferrite Bead

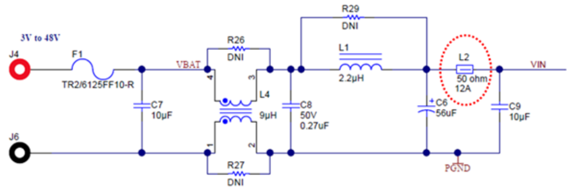

Figure 20. Circuit With Boost Input Filter: Ferrite Bead

A ferrite-bead filter is placed in series with the power supply of the boost converter to provide additional attenuation to noise. Similar to a common-mode choke, many different ferrite bead components are available to address various frequency ranges. Consult component data sheets to select the appropriate component for application needs. In addition to appropriate impedance characteristics, check the current-handling capability of the ferrite bead to ensure adequacy for a particular application.

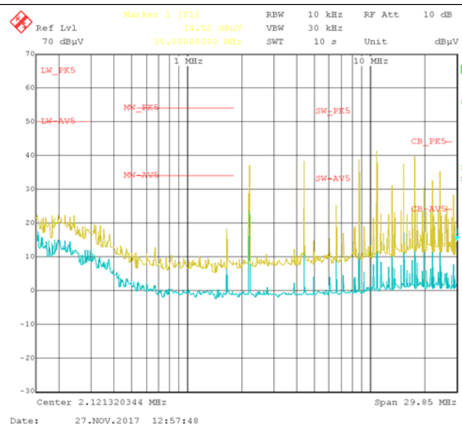

Figure 21. Low Frequency: Used Ferrite Bead

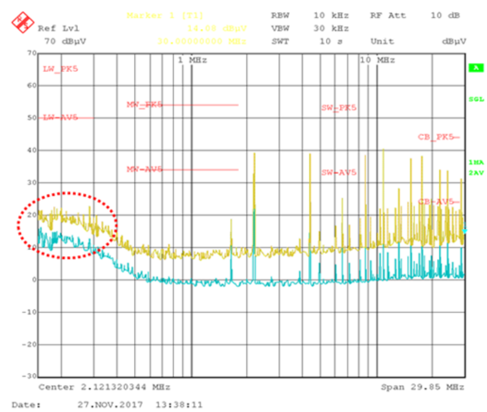

Figure 22. Low Frequency: Bypassed Ferrite Bead

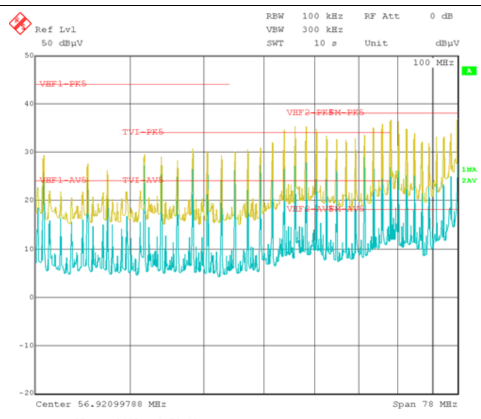

Figure 23. High Frequency: Used Ferrite Bead

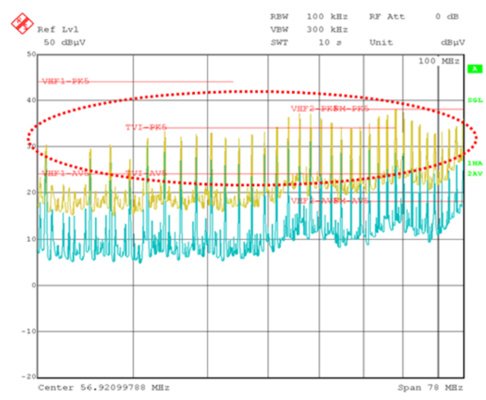

Figure 24. High Frequency: Bypassed Ferrite Bead

3.5 Snubbers

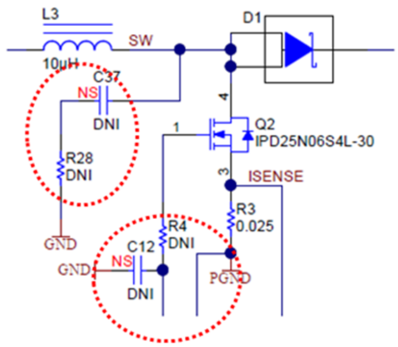

Figure 25. Circuit Using Snubbers

Snubbers on fast switching nodes can be used to reduce rise/fall times of the signal and can be an effective tool to reduce EMI. Choose values carefully so that rise and fall times are not excessively slowed. Slower rise/fall times can lead to higher power dissipation in the switching device, thereby reducing overall efficiency. They are also a concern for thermal and heat dissipation.

This EVM uses two snubbers. A 5-Ω resistor, 220-pF capacitor (R4 and C12) are placed on the gate driver of the switching FET while a second 5-Ω resistor, 220-pF capacitor (R28 and C37) are placed on the switching node of the boost.

3.5.1 On-Gate Drive of Switching FET

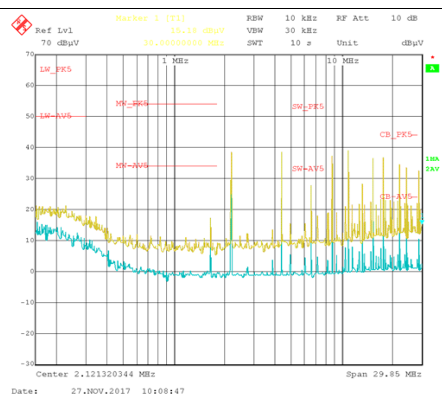

Figure 26. Low Frequency: Populated Snubber on GD of SW FET

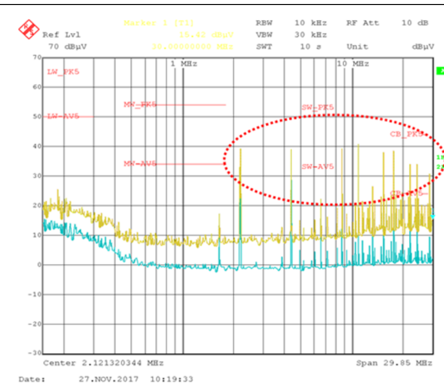

Figure 27. Low Frequency: Unpopulated Snubber on GD of SW FET

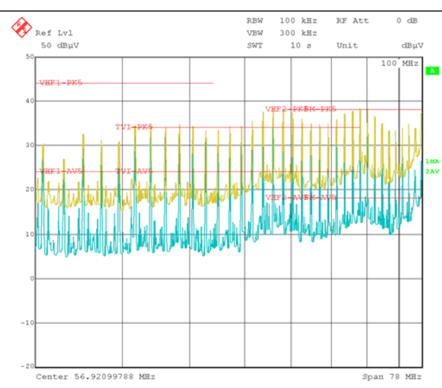

Figure 28. High Frequency: Populated Snubber on GD of SW FET

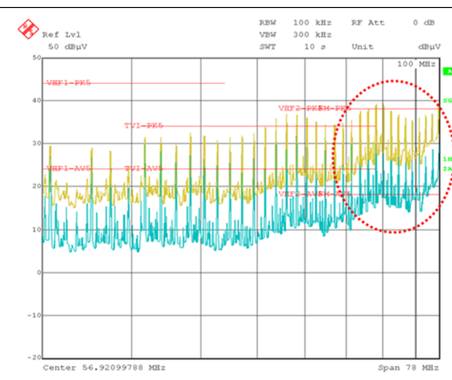

Figure 29. Low Frequency: Unpopulated Snubber on GD of SW FET

3.5.2 Snubber on SW Node

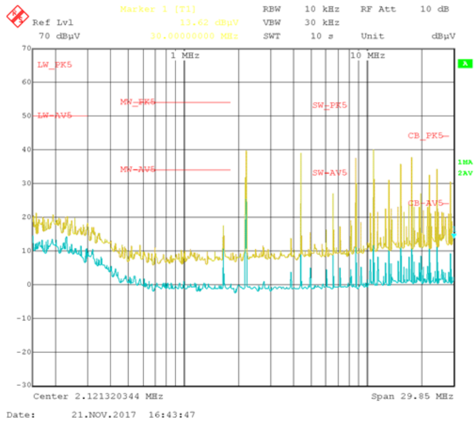

Figure 30. Low Frequency: Used Snubber on SW Node

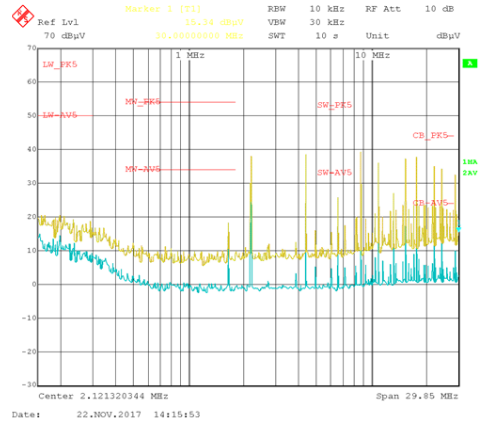

Figure 31. Low Frequency: Removed Snubber on SW Node

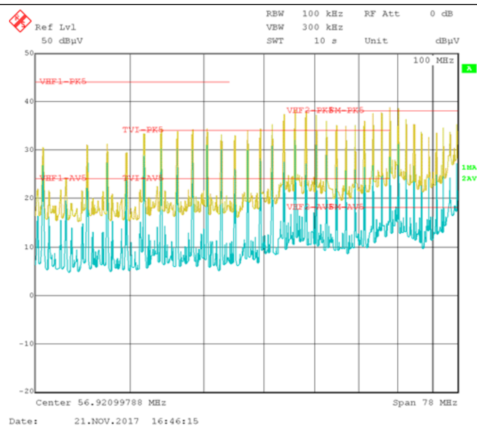

Figure 32. High Frequency: Used Snubber on SW Node

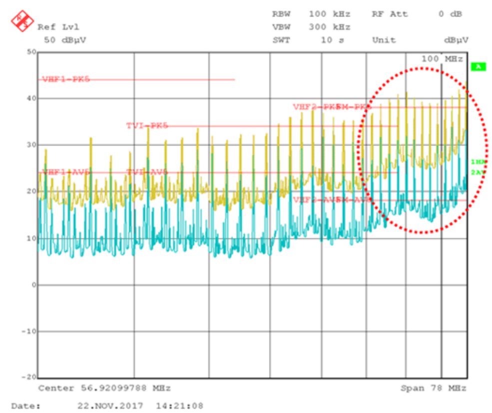

Figure 33. High Frequency: Removed Snubber on SW Node

3.6 Capacitors Between Boost Out and LED Drive

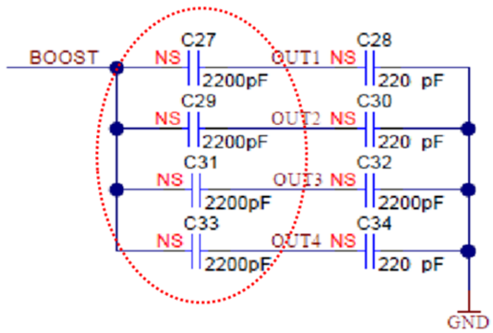

Figure 34. Circuit With Capacitors Between Boost Out and LED Drive

This variation includes 2.2-nF capacitors placed in between the boost and output of LED drivers. The capacitors provide protection in the case of a short at the boost output and prevent ESD damage. While this option is available for protection in the case of an accidental short between boost output and current sinks, it generally increases the EMI and is not recommended from a purely EMI perspective.

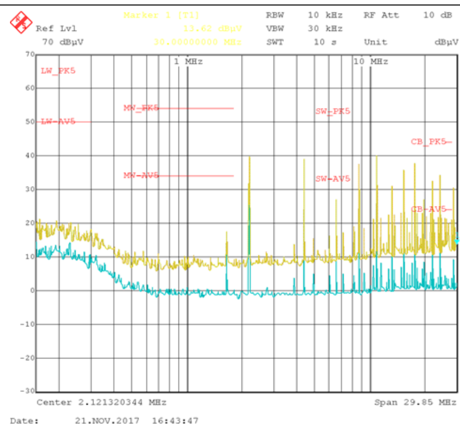

Figure 35. Low Frequency: No Capacitors

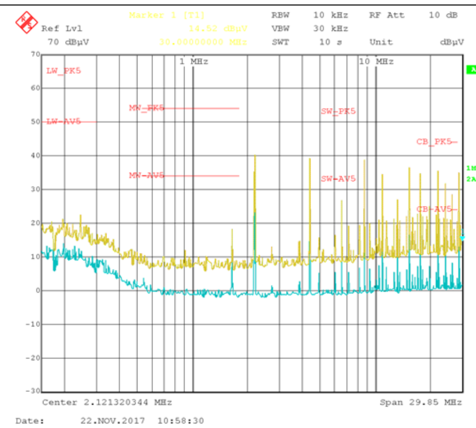

Figure 36. Low Frequency: Capacitors between Boost OUT and LED Drivers

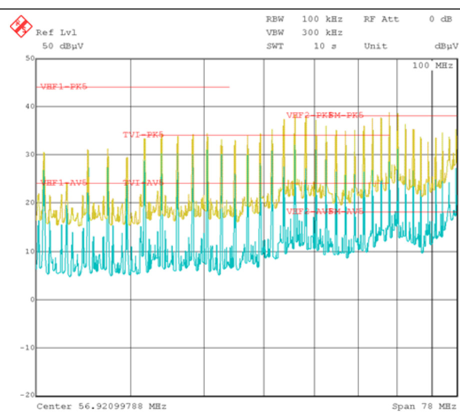

Figure 37. High Frequency: No Capacitors

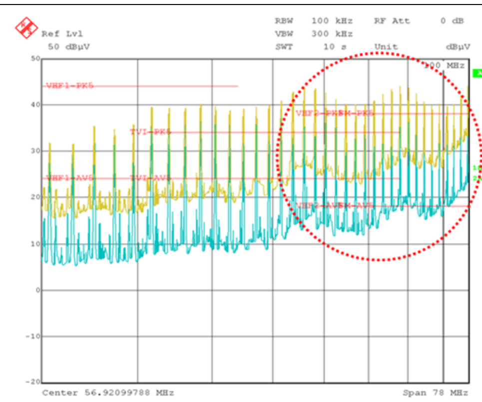

Figure 38. High Frequency: Capacitors Between Boost OUT and LED Drivers

3.7 Capacitors Between LED Drivers and GND

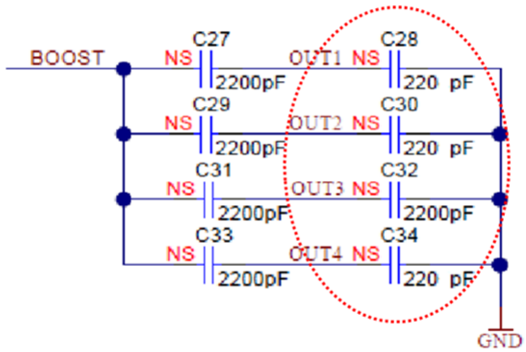

Figure 39. Circuit With Capacitors Between LED Drivers and GND

This variation includes 220-pF capacitors connected between LED driver inputs and ground. These capacitors are used to slow down LED current edge and lower its ripple to achieve accurate current control. By using these capacitors, EMI levels can be attenuated; however, take care not to excessively slow down the LED current rise time. The rise time defines the minimum current pulse width and limits the highest achievable dimming ratio.

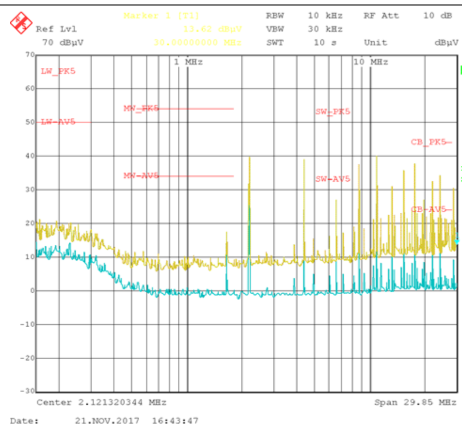

Figure 40. Low Frequency: No Capacitors

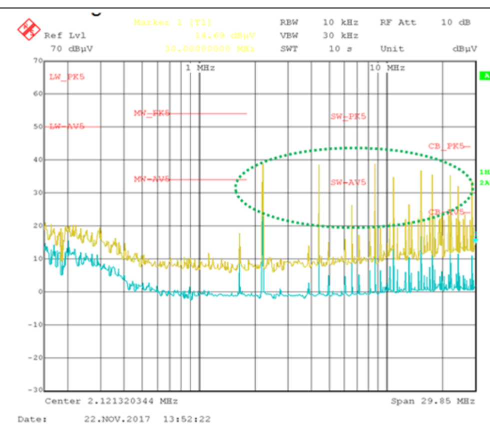

Figure 41. Low Frequency: Capacitors between LED Drivers and GND

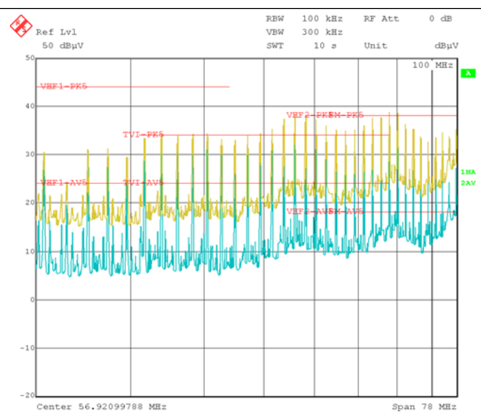

Figure 42. High Frequency: No Capacitors

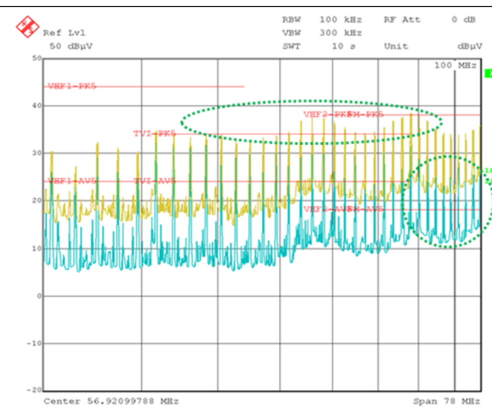

Figure 43. High Frequency: Capacitors between LED Drivers and GND

3.8 Spread Spectrum: On or Off

The LP8860-Q1 EVM has a feature for dithering or spreading the switching frequency in a wider bandwidth. Spreading the energy of the switching frequency over a wider bandwidth has the impact of reducing the peak energy at one frequency. This reduces the spikes at the switching frequency and its harmonics, which in turn generally reduces EMI. When enabled, the test results revealed that the EMI from the average measurements over high frequencies were significantly reduced.

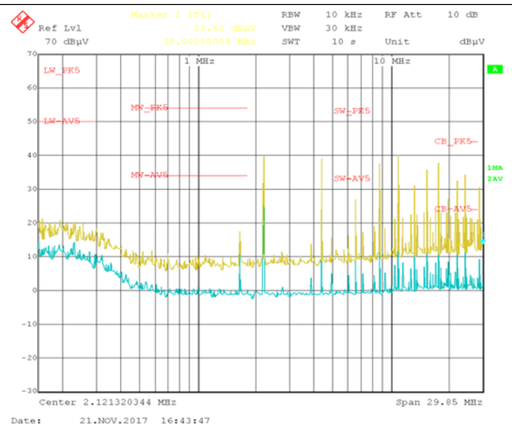

Figure 44. Low Frequency: Spread Spectrum Disabled

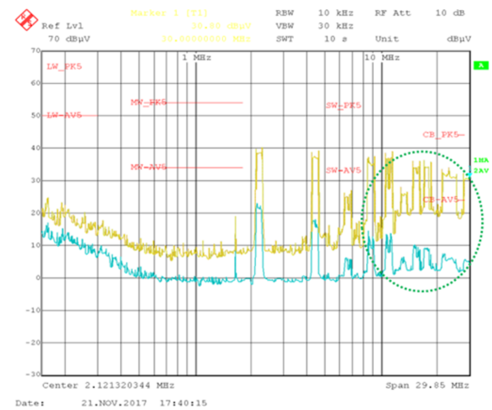

Figure 45. Low Frequency: Spread Spectrum Enabled

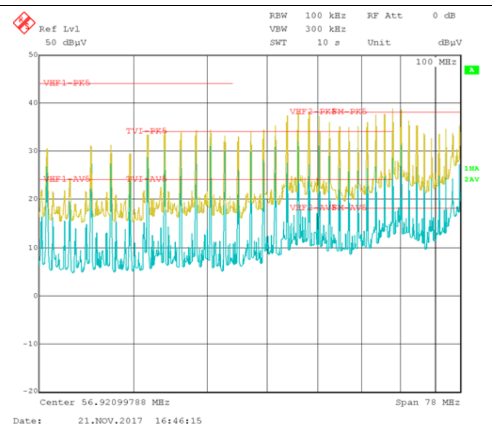

Figure 46. High Frequency: Spread Spectrum Disabled

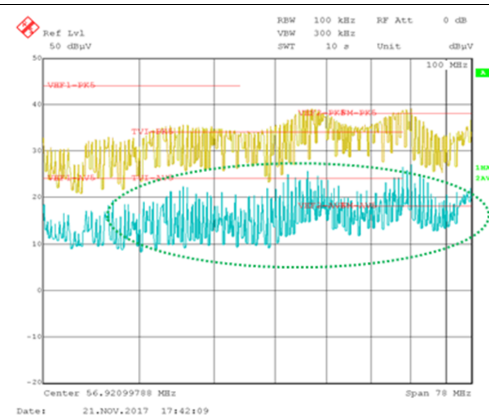

Figure 47. High Frequency: Spread Spectrum Enabled

3.9 LED Current per String

LED current on all strings was reduced from its maximum 120 mA to 80 mA. The results show EMI reduction in the higher frequencies range.

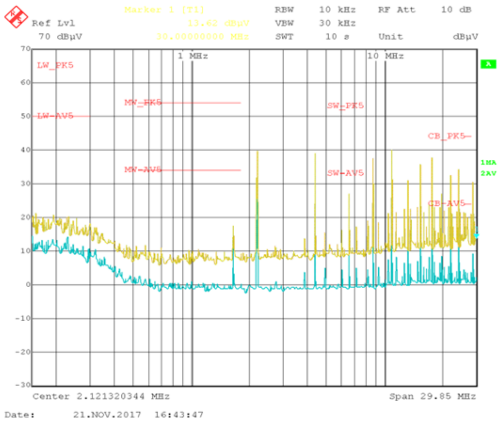

Figure 48. Low Frequency: 120 mA

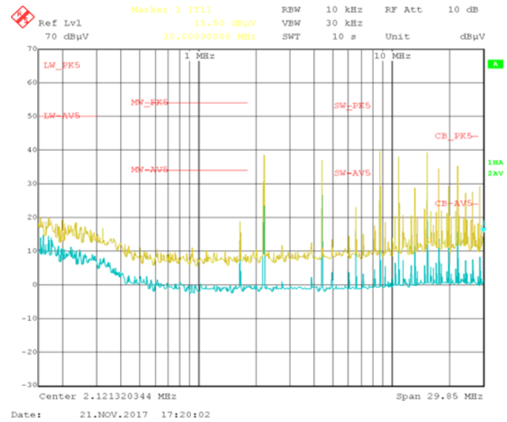

Figure 49. Low Frequency: 80 mA

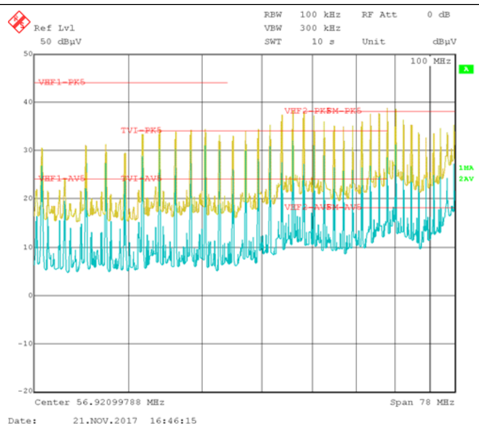

Figure 50. High Frequency: 120 mA

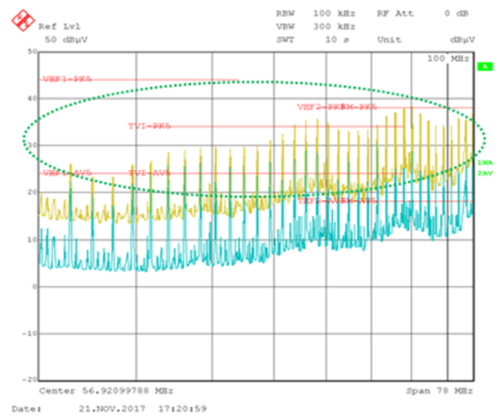

Figure 51. High Frequency: 80 mA

3.10 Dimming

Dimming was reduced from 100% to 10% by varying the PWM duty cycle to show its large impact on EMI on the LP8860-Q1 EMI test board. As expected, due to LED current being on all the time and not switching at 100% PWM duty cycle, EMI levels are generally lower.

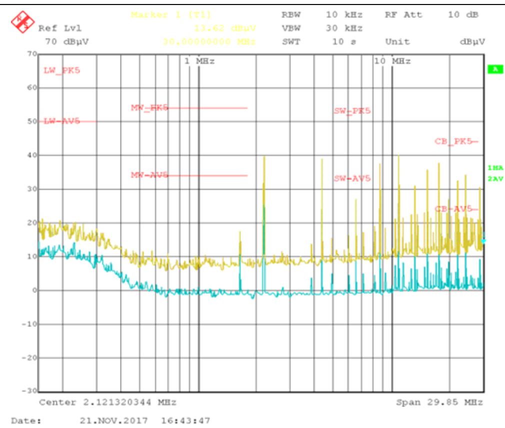

Figure 52. Low Frequency: 100% Brightness

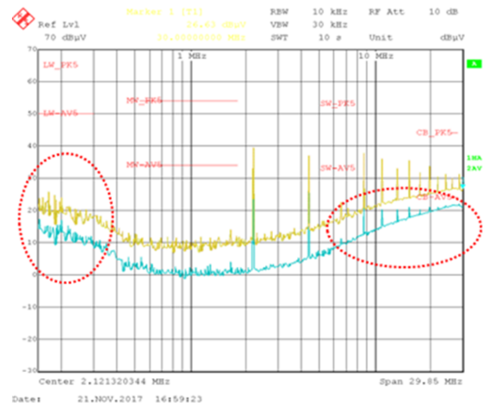

Figure 53. Low Frequency: 10% Brightness

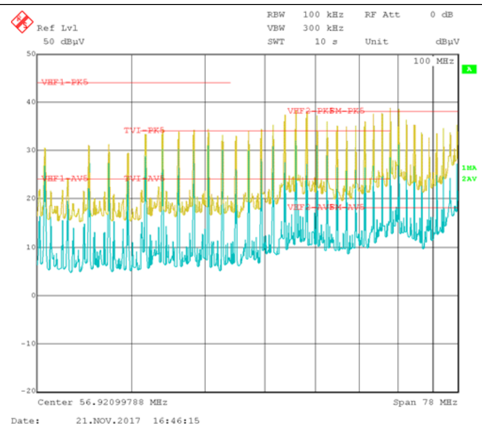

Figure 54. High Frequency: 100% Brightness

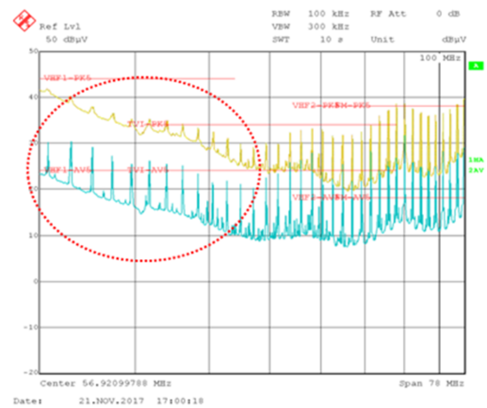

Figure 55. High Frequency: 10% Brightness

3.11 Input Voltage (V_{IN})

The input voltage was reduced from 12 V to 9 V to observe the effects on EMI. As the input voltage decreased, the switching current increased resulting in increased EMI.

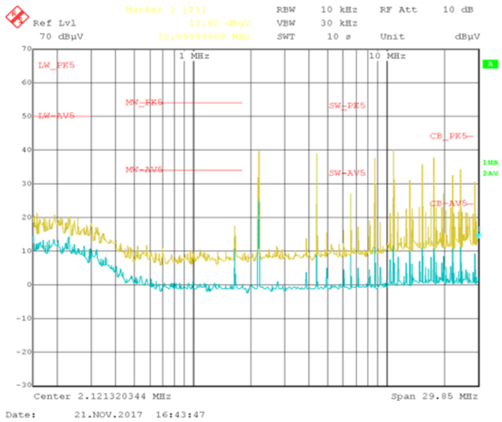

Figure 56. Low Frequency: V_{IN} = 12 V

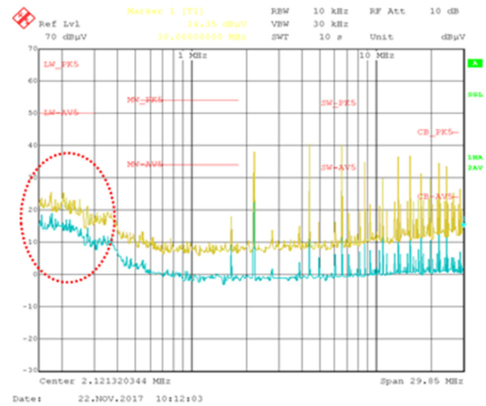

Figure 57. Low Frequency: V_{IN} = 9 V

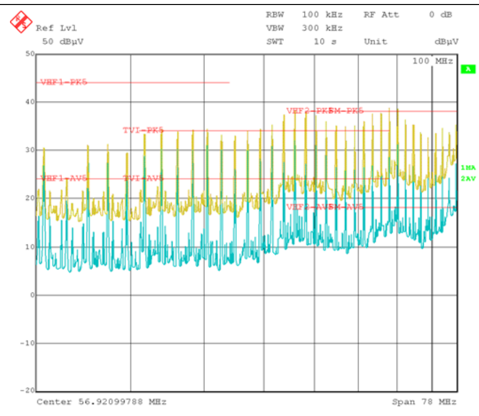

Figure 58. High Frequency: V_{IN} = 12 V

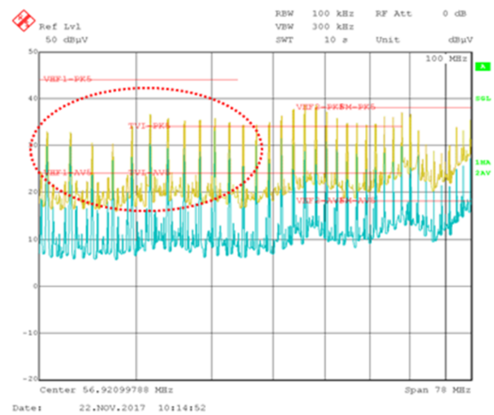

Figure 59. High Frequency: V_{IN} = 9 V

4 Conducted Emissions Measurements at External Compliance Laboratory

The following plots show the results of conducted emissions testing performed at an external compliance laboratory. These results provide good indication that with proper design techniques, EMI compliance success can be achieved with the LP8860-Q1 device.

Test conditions for this testing are as follows:

2.2-MHz EEPROM Configurations:

- Switching frequency : 2.2MHz
- 2x charge pump enabled
- Spread spectrum disabled
- V_{DD} : 3.3 V
- 4 LED strings, 10 LEDs/string
- Maximum LED current per channel : 120 mA
- Brightness control : PWM input pin
- PWM dimming frequency : 4.883 KHz
- Internal 5MHz oscillator used

400-kHz EEPROM Configuration

- Switching frequency : 400 KHz
- 2× charge pump enabled
- Spread spectrum enabled
- V_{DD} : 3.3V
- 4 LED strings, 10 LEDs/string
- Maximum LED current per channel : 120 mA
- Brightness control : PWM input pin
- PWM dimming frequency : 4.883 KHz
- Internal 5-MHz oscillator used

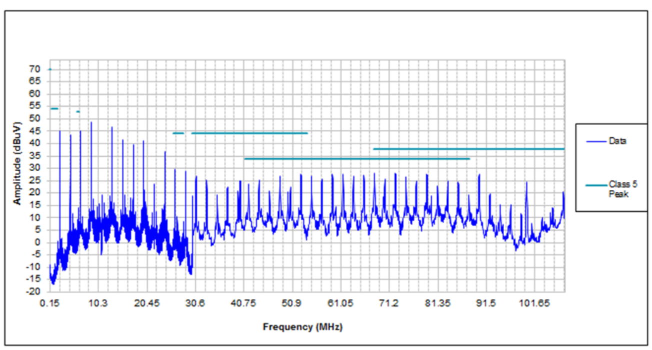

Figure 60. Conducted Emissions for 2.2-MHz Line

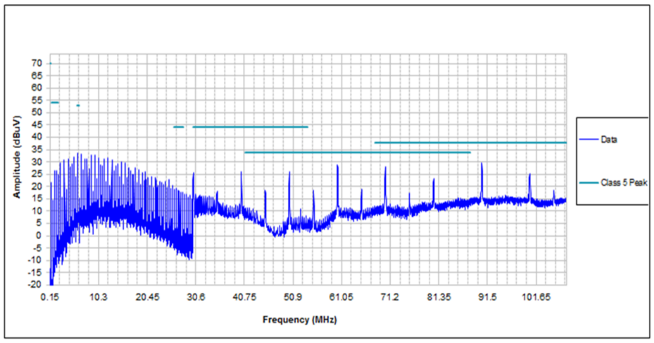

Figure 61. Conducted Emissions for 2.2-MHz Return

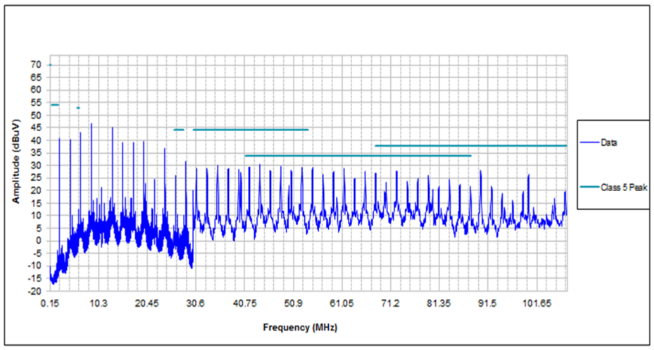

Figure 62. Conducted Emissions for 400-kHz Line

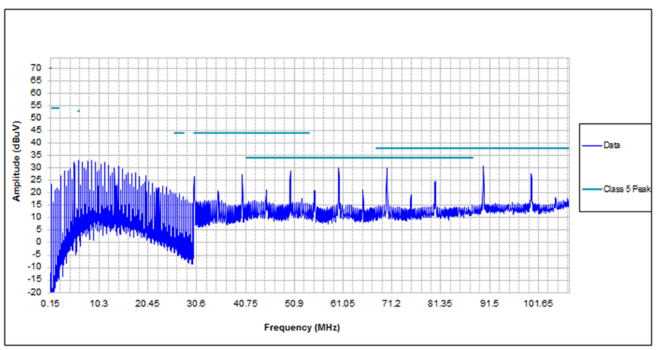

Figure 63. Conducted Emissions for 400-kHz Return

5 Summary

This application note compiles EMI measurements taken under varying board conditions to show relative impact of the changes. This should aid system designers in coming up with appropriate tradeoffs to achieve high performing emissions compliant backlight designs. As pointed out in various sections of this document, care should be taken and impacts should be well understood when implementing EMI solutions so as not to cause performance or system reliability issues. The setup of these measurements is not calibrated and absolute readings of the emissions plot are not meaningful. The collected data should be used as reference to see the relative impact of board level changes on conducted emissions.

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