LP8866-Q1 Typical Design Guidelines to Achieve CISPR 25 Class 5 Conducted and Radiated Emissions Compliance

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ABSTRACT

Electromagnetic Compatibility (EMC) is of increasing importance as the number of electronic/electrical components used in vehicles increases. The radio disturbances produced by components/modules in a vehicle should be mitigated to provide protection for receivers installed in the same vehicle. This application report describes a typical design using LP8866-Q1 which can conform to the CISPR 25, class 5 conducted and radiated emissions limits.

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1 Typical Reference Design

1.1 Design Overview

The LP8866-Q1 is an automotive high-voltage LED driver for automotive infotainment, clusters, HUD and other automotive display LED backlight applications. It integrates a boost controller and six current sinks. A reference board is built to evaluate its Electromagnetic Interference (EMI) performance. The schematic and board layout are shown in Figure 1, Figure 2 and Figure 3. A four-layer board is used with two internal ground planes. A LED load board is connected to the LP8866-Q1 driver board with seven 20-cm long jumper wires to simulate the load configuration in the real application.

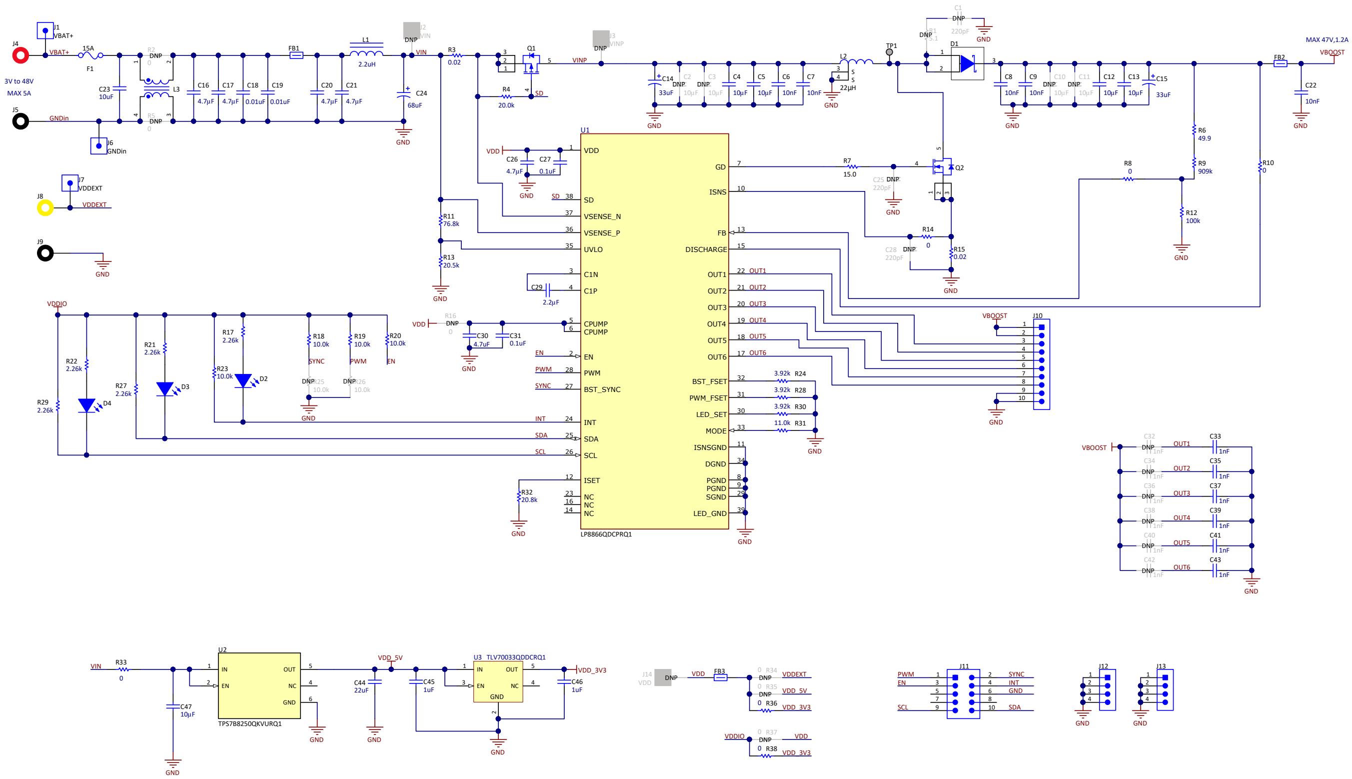


Figure 1. LP8866-Q1 Reference Design Schematic

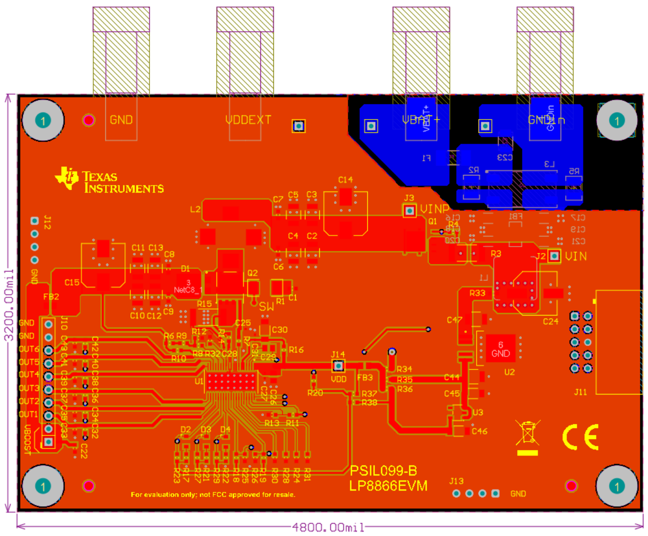


Figure 2. Layout - Top Layer

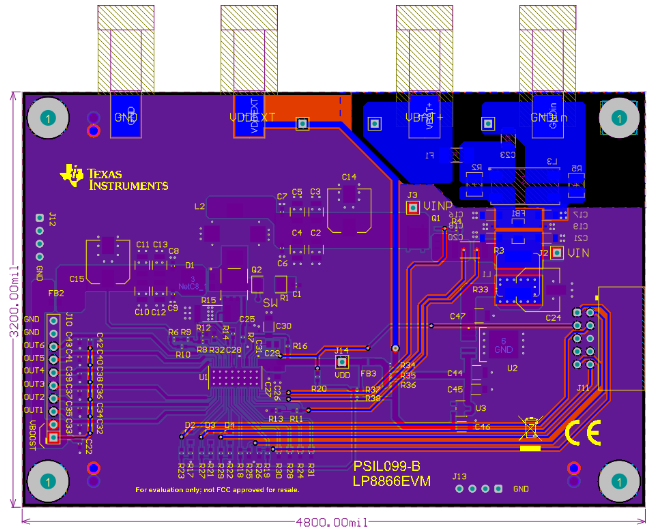


Figure 3. Layout - Bottom Layer

1.2 Test Condition

Input voltage is 13.5 V. Switching frequency is set to 400 kHz. LED current is 150 mA/channel. 8 LEDs are connected in one string. Boost output voltage is 25 V.

1.3 CISPR 25 Measurement Results

The electromagnetic emission measurements are performed on the reference board in accordance with CISPR 25: 2016. All test setup and test procedure comply with the CISPR 25 specification.

Figure 4 shows the conducted emissions measurement results in the frequency range of 150 kHz to 245 MHz. Current probe method is used. The emissions are measured with the probe positioned 50 mm and 750 mm from the Equipment Under Test (EUT). Here we only provide the results at 50 mm position. Green lines represent the CISPR 25: 2016 Class 5 peak limits and measurement results. Red lines represent the CISPR 25: 2016 Class 5 average limits and measurement results. Measurement with quasi-peak detector is not performed.

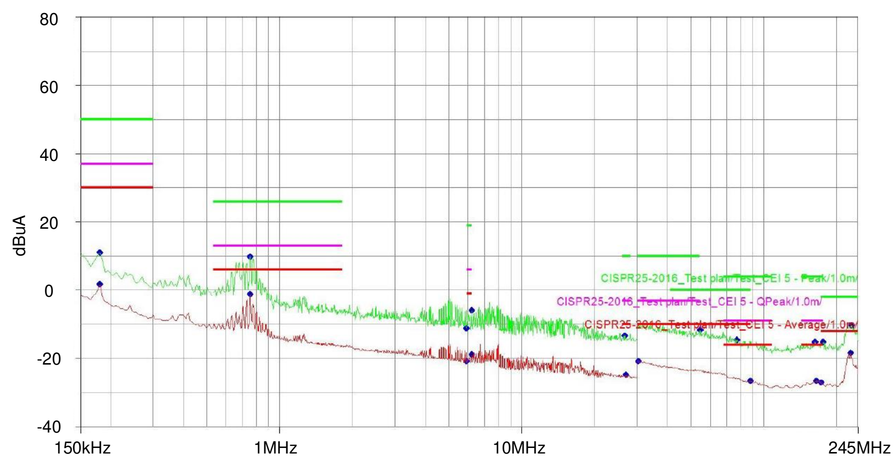


Figure 4. CISPR 25 Class 5 Conducted Emission Limits And Measurement Results

The ambient noise level of conducted emissions is measured, as shown in Figure 5. The ambient noise requirement can be met. Note that the disturbances in frequency range from 500 kHz to 900 kHz come from the effect of the ambient noise and it may vary sometimes. So it could be ignored during the following comparisons.

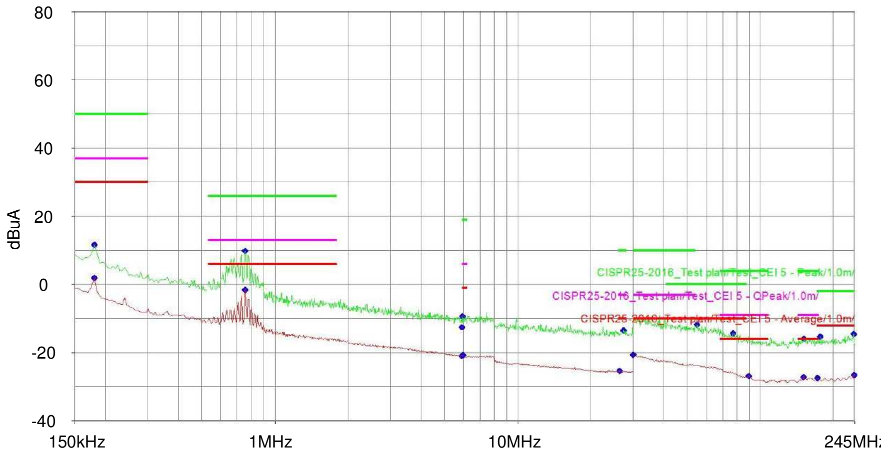


Figure 5. CISPR 25 Class 5 Conducted Emission Limits And Ambient Noise

Figure 6 shows the radiated emissions measurement results in the frequency range of 150 kHz to 2.5 GHz. Absorber-lined shielded enclosure (ALSE) method is used. Only vertical polarization measurement results are shown in this application report.

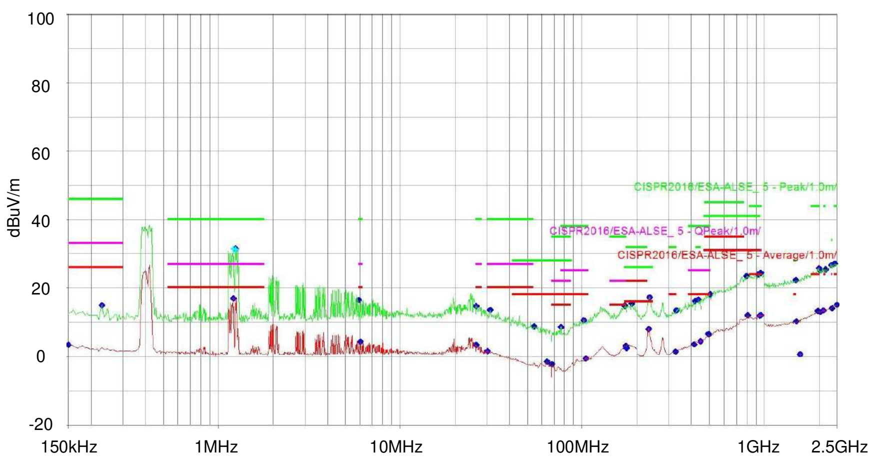


Figure 6. CISPR 25 Class 5 Radiated Emission Limits And Measurement Results

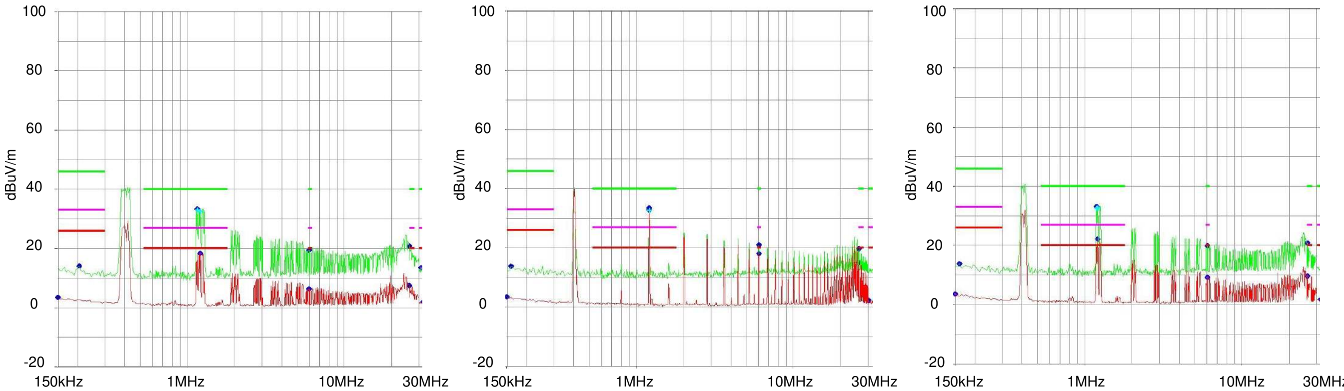
Results show that both conducted and radiated emissions measurement results are below the class 5 peak and average limits, which is the most stringent level. It's suggested to follow the schematic and layout of the reference design in order to pass the EMI test. Deviation from this design and its effect are analyzed in Section 2.

2 EMI Mitigation Techniques Discussion

In this section we'll look at the effects of several different techniques and measures to see how they impact the EMI performance of this design. Conducted emissions (current probe method) and radiated emissions measurements are performed. In this case, the current probe method is used to measure conducted emissions on the input power supply wire harness. It measures the common mode current on the power lines which is closely correlated to the radiated emissions from the wires. In this case, the conducted emission measurement result is well correlated to the radiated emission measurement result in the frequency range of 30 MHz to 300 MHz, so the conducted/radiated EMI comparisons are shown together.

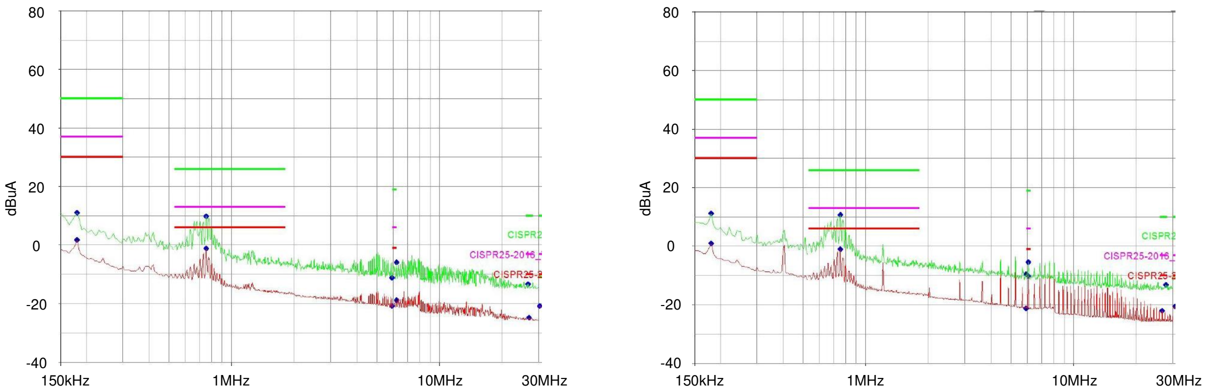
2.1 Spread Spectrum

Spread spectrum technique is widely used in Switched-Mode Power Supplies (SMPS) to reduce EMI around the switching frequency and its harmonics by dispersing the spectral energy of the switching signals. The spread spectrum variation range of the LP8866-Q1 device is programmable from ± 3.3% to ± 7.2% from the central switching frequency. The default variation is ± 5.3%. It can be seen from Figure 7 that enabling the spread spectrum feature of ± 5.3% variation can reduce the third switching frequency harmonics (1.2 MHz) radiated emissions average data by up to 14.48 dB and ± 5.3% variation can contribute to 3.86 dB lower result compared with ± 3.3% variation.



(a) Spread spectrum enabled (± 5.3% variation)
(b) Spread spectrum enabled (± 3.3% variation)
(c) Spread spectrum disabled

Figure 7. Radiated Emissions: Spread Spectrum

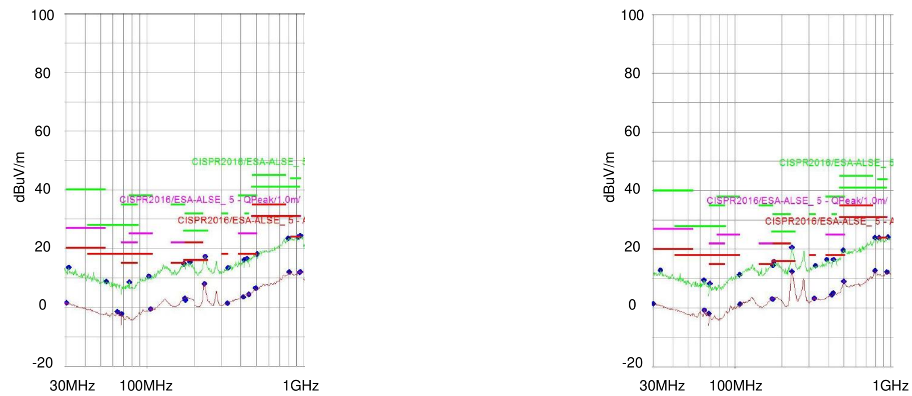


(a) Spread spectrum enabled (± 5.3% variation)
(b) Spread spectrum disabled

Figure 8. Conducted Emissions: Spread Spectrum

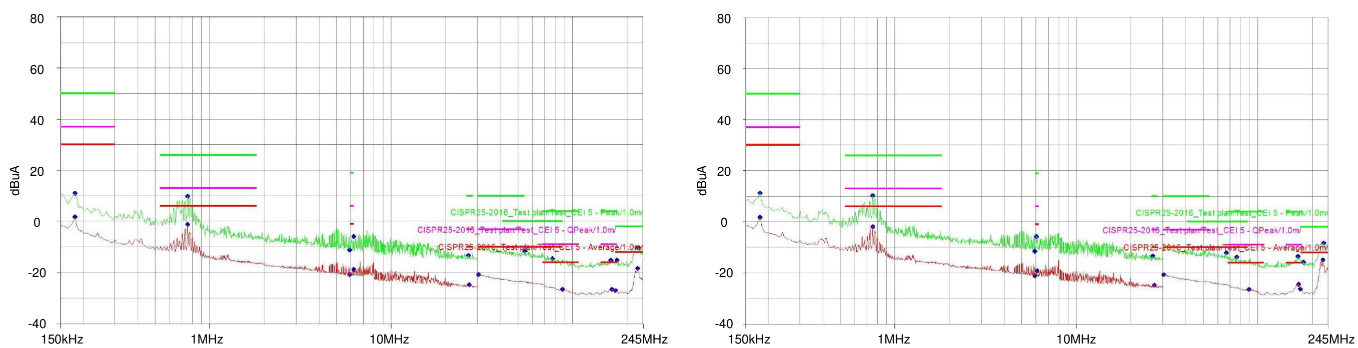
2.2 Gate Resistor

The high frequency switching behaviors in SMPS bring the most noise in EMI test. For LED backlight driver with external MOSFET like LP8866-Q1, it's able to slow the switching speed by increasing the value of external gate resistor R7. The downside of this approach is that the switching losses will be increased due to the longer turn-on and turn-off time. It is therefore important to select a gate resistor by trading off the EMI and thermal performance. The EMI measurement results with 15-Ω and 10-Ω gate resistors are shown in Figure 9 and Figure 10.



(a) With 15-Ω external gate resistor (b) With 10-Ω external gate resistor

Figure 9. Radiated Emissions: Gate Resistor

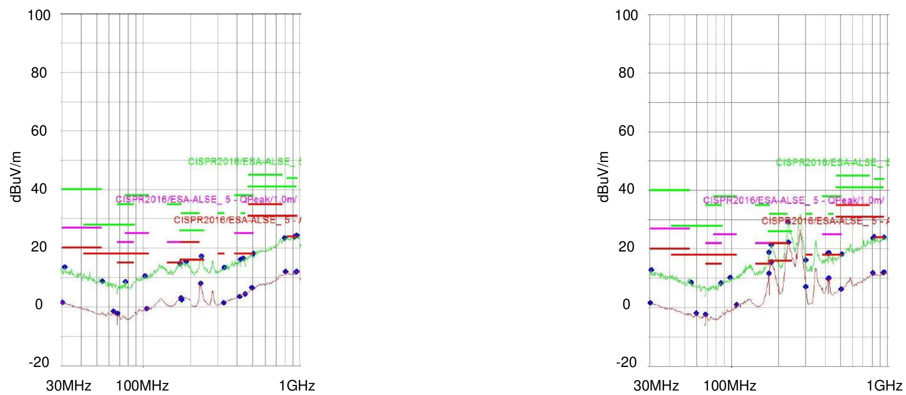


(a) With 15-Ω external gate resistor (b) With 10-Ω external gate resistor

Figure 10. Conducted Emissions: Gate Resistor

2.3 LED Current Sink Capacitors

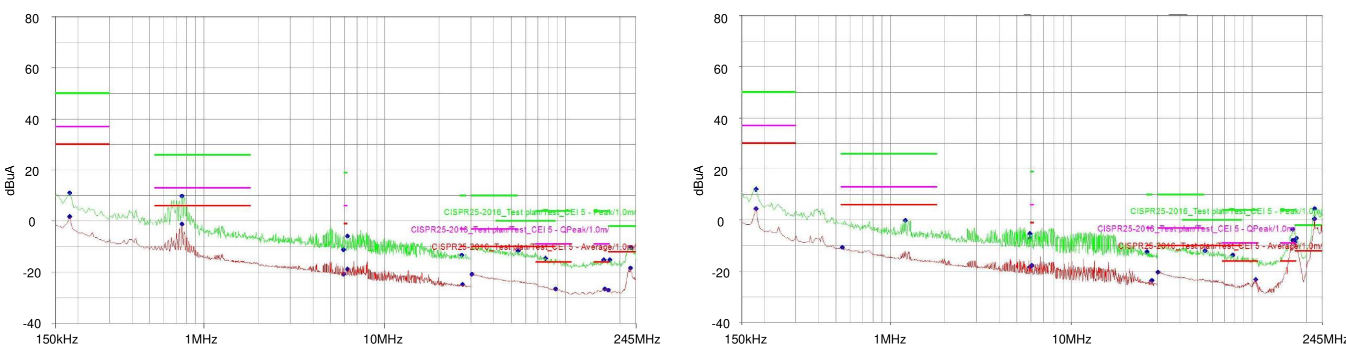
Since the LED driver board is connected to the LED load with a 20-cm long wire harness, these wires can act as efficient antennas in the region of a few hundred MHz. It is of high importance to place bypass capacitors close to the connector on the LED driver board to prevent the wires from radiating noise. A 1-nF capacitor is recommended to be placed at each LP8866-Q1 OUTx pin to ground. Figure 11 and Figure 12 show a substantial improvement in EMI with these capacitors.



(a) With 1-nF capacitors from current sinks to ground

(b) Without 1-nF capacitors from current sinks to ground

Figure 11. Radiated Emissions: LED Current Sink Capacitors



(a) With 1-nF capacitors from current sinks to ground

(b) Without 1-nF capacitors from current sinks to ground

Figure 12. Conducted Emissions: LED Current Sink Capacitors

2.4 Layout Consideration

A optimized layout is crucial for EMI reduction. Critical current loops need to be minimized. Minimum loop area for high frequencies can be achieved when return current flows in the ground plane just under the top-layer power traces, if the ground plane is intact under these traces. So a solid internal plane for ground (return) should be built. To minimize the current loop for high frequencies, put a small high-frequency capacitor as near as possible to the boost diode. And place vias to internal ground planes close to the capacitors' GND pin, as shown in Figure 13. An experiment is performed to place C8 and C9, two 10-nF high-frequency ceramic capacitors, on the footprint of C10 and C11 and the conducted/radiated emissions measurement results are compared in Figure 14 and Figure 15.

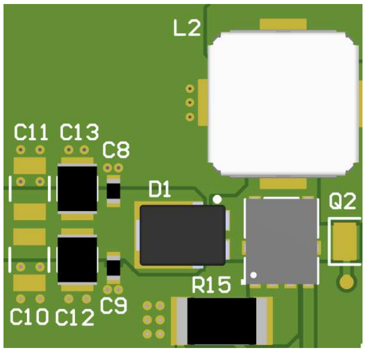
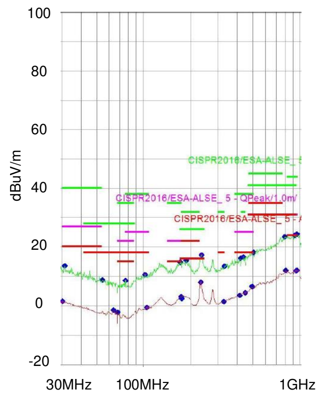
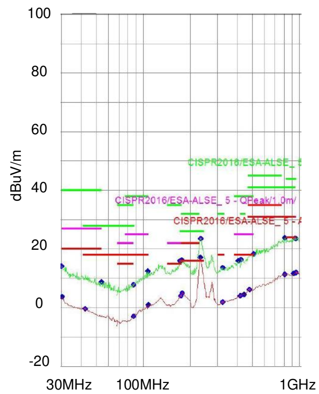


Figure 13. Boost Critical Loop Layout

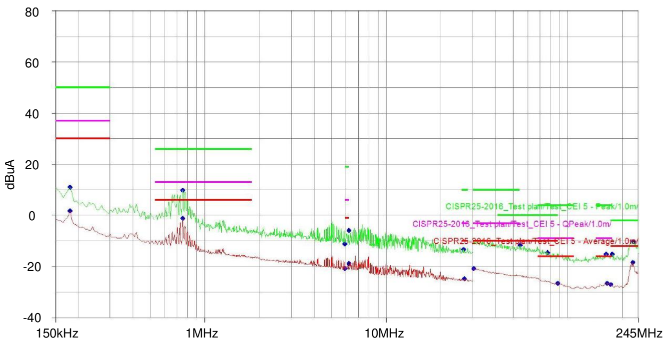


(a) C8 and C9 in original position

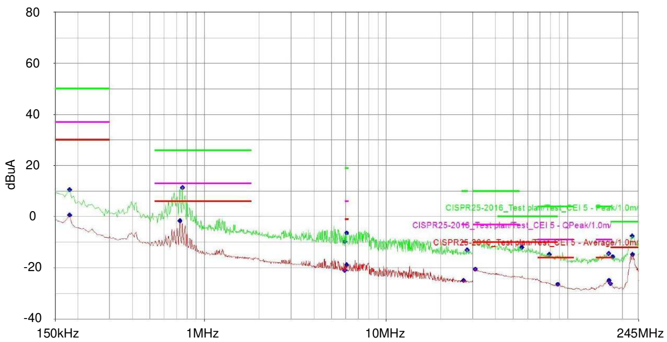


(b) C8 and C9 on footprint of C10 and C11

Figure 14. Radiated Emissions: Boost Output Capacitor Placement



(a) C8 and C9 in original position



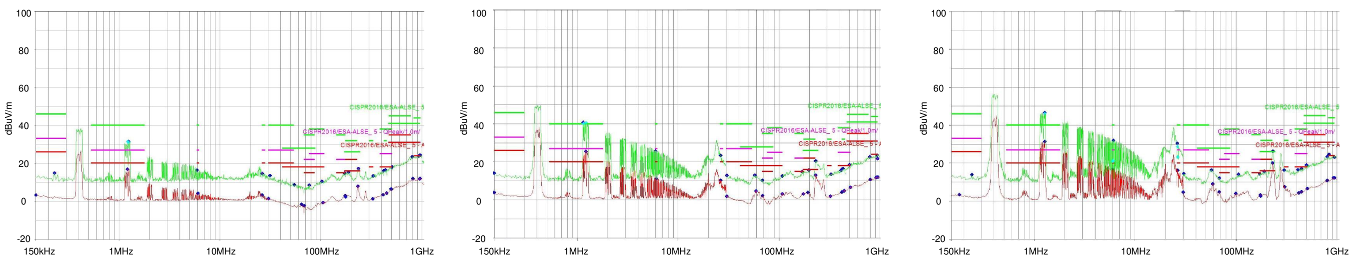
(b) C8 and C9 on footprint of C10 and C11

Figure 15. Conducted Emissions: Boost Output Capacitor Placement

2.5 Inductor Selection

In the cases where there's no metal shielding used in the EUT, the radiated emissions at the switching frequency harmonics are mainly radiated from the boost inductor. Inductor shielding can help mitigate the emissions in this frequency range. Shielded construction inductors should be used. And a type of molded inductors have better EMI performance compared with wirewound ones.

In this reference design with LP8866-Q1, an inductor with e-field shield is selected and maximum e-field reduction is realized when the shield is connected to ground. Experiments prove that the e-field shielded inductor can further improve the EMI performance. Comparisons of measurement results with different types of inductors are shown in Figure 16 and Figure 17. It can also be seen that the inductor selection impacts the whole frequency range till 300 MHz.

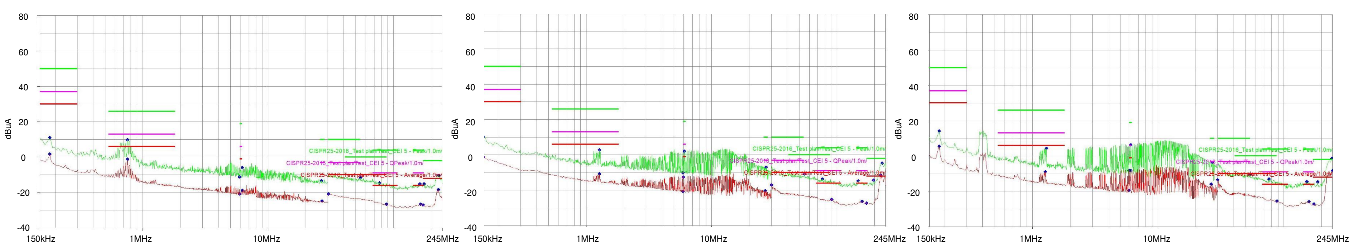


(a) E-field shielded inductor

(b) Molded shielded inductor without e-field shield

(c) Wirewound shielded inductor without e-field shield

Figure 16. Radiated Emissions: Inductor Selection



(a) E-field shielded inductor

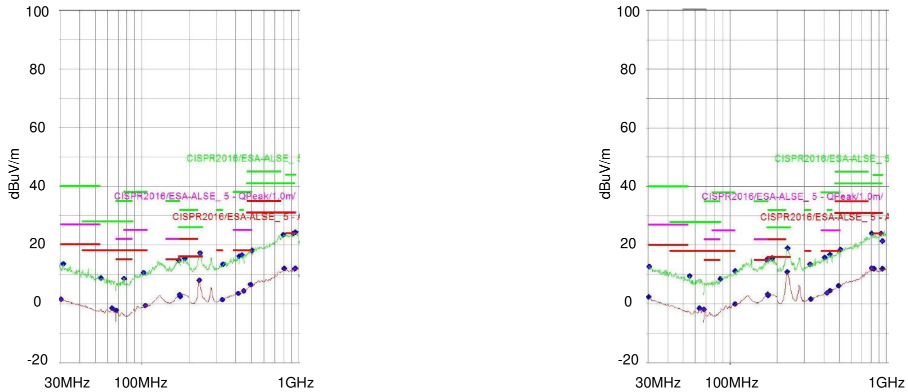
(b) Molded shielded inductor without e-field shield

(c) Wirewound shielded inductor without e-field shield

Figure 17. Conducted Emissions: Inductor Selection

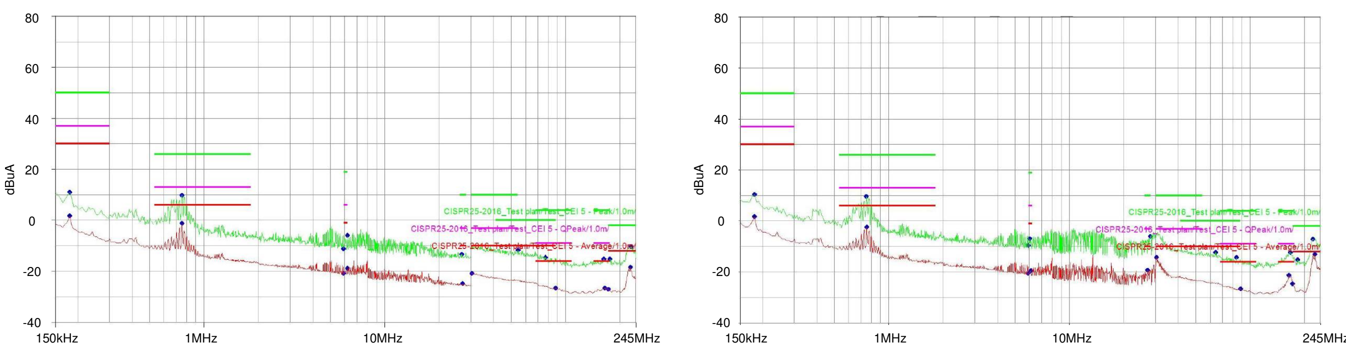
2.6 Boost Output Ferrite Bead

The ferrite bead FB2 connected at the boost output has a high impedance value at frequencies of around 100 MHz, which can suppress the noise in this frequency range and help reduce the conducted/radiated EMI, as shown in Figure 18 and Figure 19.



(a) With ferrite bead (b) Without ferrite bead

Figure 18. Radiated Emissions: Boost Output Ferrite Bead

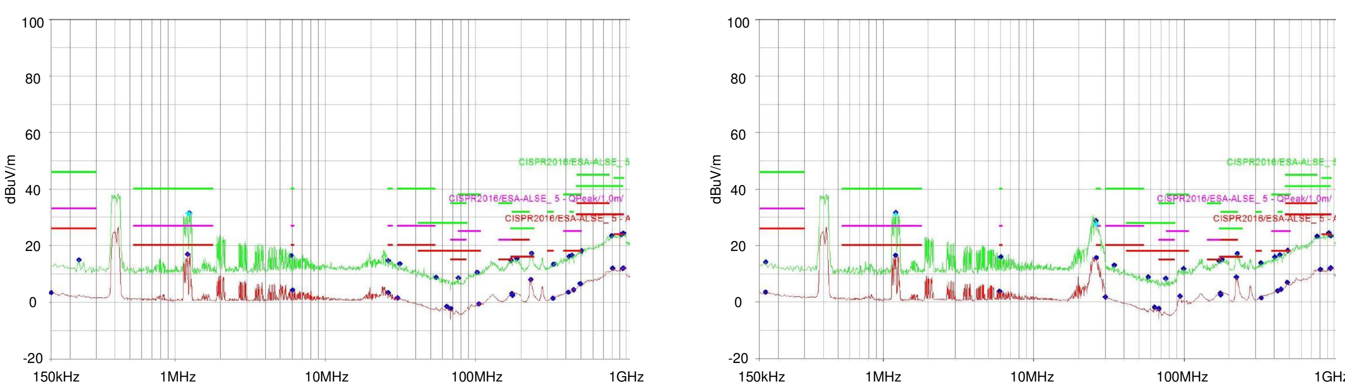


(a) With ferrite bead (b) Without ferrite bead

Figure 19. Conducted Emissions: Boost Output Ferrite Bead

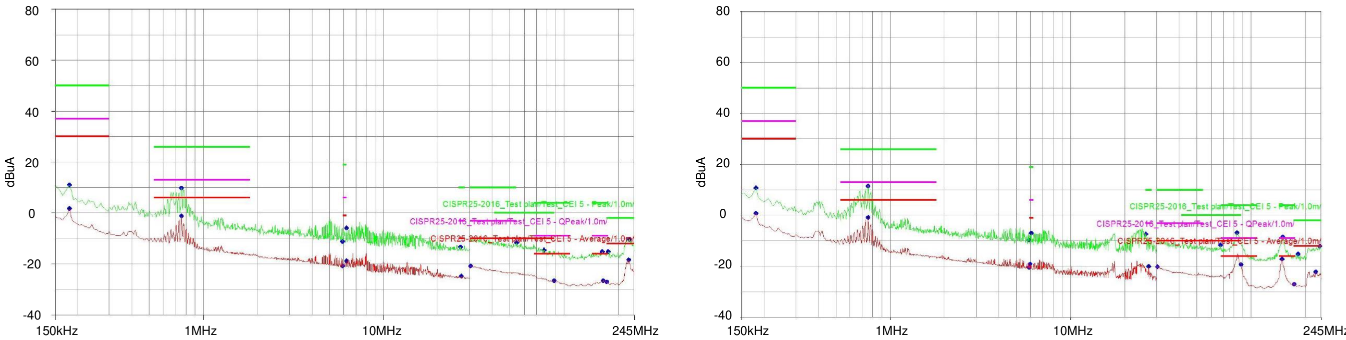
2.7 Common Mode Filter

Since this application report only summaries the techniques to improve radiated and current method conducted EMI, which mainly comes from the common mode noise, it won't discuss the design of the input differential mode filter, which has been verified to make little difference. The measurement results with and without the common mode choke are shown in Figure 20 and Figure 21.



(a) With common mode choke (b) Without common mode choke

Figure 20. Radiated Emissions: Common Mode Filter



(a) With common mode choke (b) Without common mode choke

Figure 21. Conducted Emissions: Common Mode Filter

3 Summary

This application report provided a reference design with LP8866-Q1 which complies with the CISPR 25 class 5 limits and identified the effects of different mitigation techniques on the EMI performance. All measures can be considered in combination with trade-off among EMI performance, cost, size, thermal, etc. when planning the LED backlight driver design and layout.