Application Note

How to pass CISPR25 Class 5 for UCC33420-Q1

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ABSTRACT

UCC33xx0-Q1 is a family of integrated isolated bias (IIB), DC/DC modules operating at 64MHz, switching frequency. Due to its high frequency, aiming low EMI can be a challenge if the appropriate layout and EMI components are not utilized. This app note is intended to explain how to pass CISPR25, class 5 for UCC33xx0-Q1 family. Guidelines for proper setup, EMI filter component selection and PCB layout to meet the CISPR 25 standard and achieve low emissions for both Conducted Emissions (CE) and Radiated Emissions (RE) are presented. Passing the limits of CISPR25 are required for automotive applications such as traction inverters, HEV/EV charging, Battery Management Systems (BMS) and on-board chargers (OBC). The target audience is field applications, systems and application engineers as well as any engineer interested in EMI for DC/DC converters.

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1 Introduction

Smaller DC/DC bias supplies, such as IIB modules with small component footprint and high-power density are becoming more in demand in numerous applications. IC level transformers with remarkable isolation technologies using high frequency power conversion are the main technology drivers enabling smaller IC packages and higher power density. UCC33xx0-Q1 family of devices is part of this trend with its ultra-small 4x5x1- mm^3 package and 64MHz switching frequency.

In order to deliver the power from the primary to the secondary side, UCC33xx0-Q1 use a burst frequency in the range of 100-500kHz depending on the load condition. The burst frequency can be explained as low frequency buckets and within these buckets, the device switches at a high frequency of 64MHz.

Proper setup for CE and RE is crucial to keep emissions below the limits. A tightly coupled connection must be present to connect the LISNs to the DUT. The switching frequency 64MHz is next to the VHF band for CISPR25 CE and RE and to mitigate emissions at this frequency, a HF pi filter using a 2xDM inductor was designed. The HF harmonics of the fundamental 64MHz is present in the 30-200MHz RE when using a Logarithmic Periodic Antenna (LPA). In this case two ferrite beads (FB) were selected to mitigate these frequencies. Finally, a proper layout using PCB Faraday shield, Keep Out Zone (KOZ), copper cut below DM inductors and FB and proper distribution of the ground planes helped to keep the switching frequency and its harmonics below the limits.

CISPR25 class 5 is the most stringent EMI standard for automotive applications.

2 Setup, EMI Filter and Layout

2.1 Setup

To avoid coupling of the H filed coming from the integrated transformer of UCC33xx0-Q1 to the LISN, it is recommended to have tightly coupled connections between the positive and the return of the switching loop. The switching loop starts at the 12V battery supply. The switching loop goes through the LISN, and the loop finally connects to the input of the DUT PCB. The following images show an example of tight connections for the whole switching loop for CE and RE.

Figure 2-1. CISPR 25 CE Setup

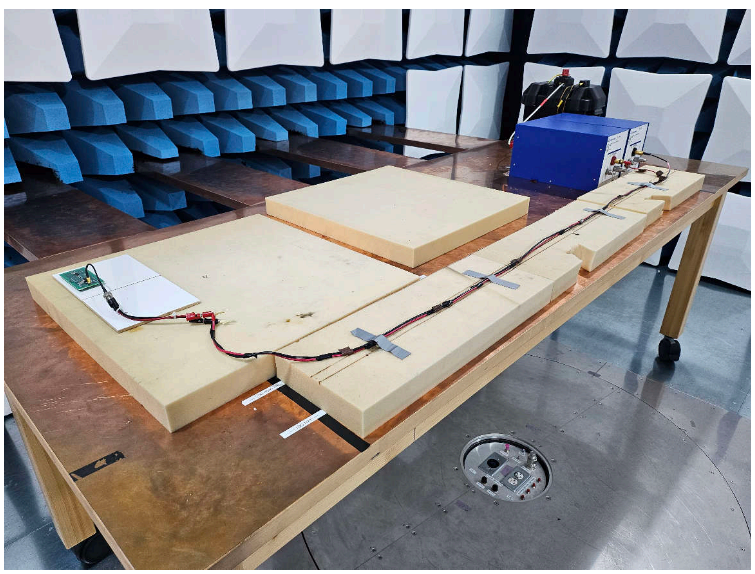

Figure 2-2. CISPR 25 RE Setup

Comparison between tightly coupled connection and open loop connection; the following images show the difference between tightly coupled and open loop connection for UCC33420-Q1 CE Pout=0.5W.

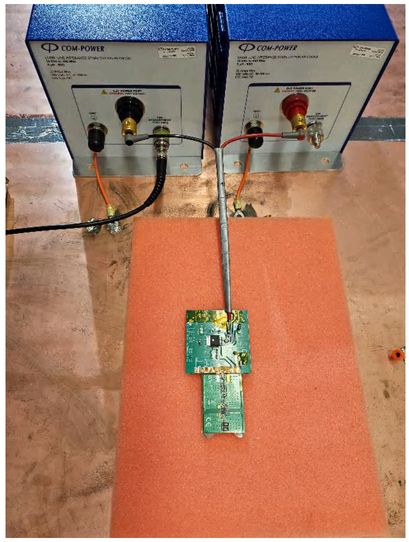

Figure 2-3. Tightly Coupled Leads

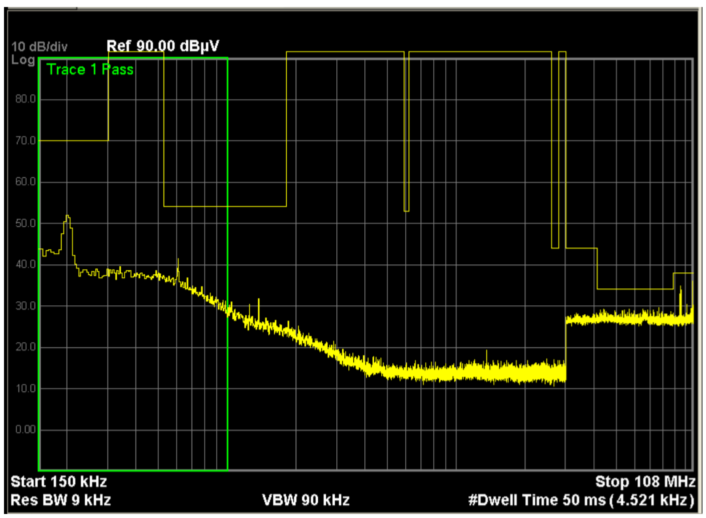

Figure 2-4. CISPR 25 CE Tightly Coupled Leads, Pout=0.5W

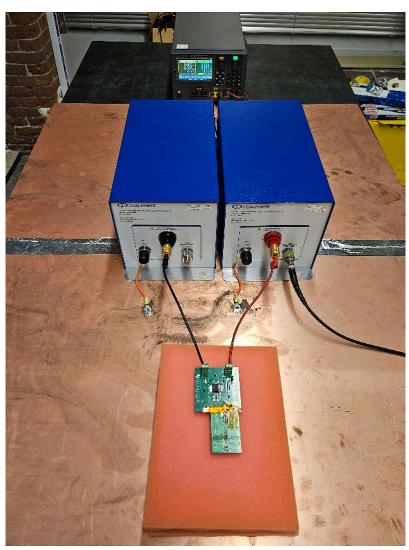

Figure 2-5. Opened Leads

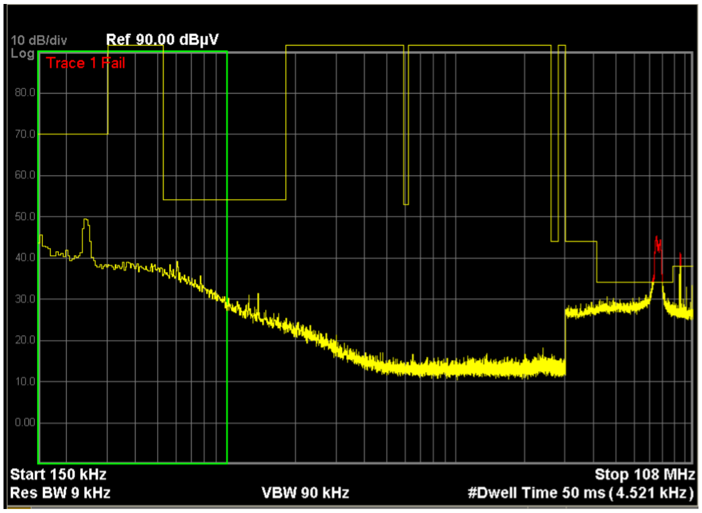

Figure 2-6. CISPR 25 CE Opened Leads, Pout=0.5W

2.2 EMI Filter

To mitigate the noise coming from the switching frequency fsw=64MHz, we used a pi filter with a dual DM inductor (top and bottom). The reason of the dual inductor is the impedance match at the switching loop to avoid high CM noise. The selection of the inductor was done based on impedance vs. frequency plot, shielding, size and current rating. A 2.2uH with high SRF (self-resonant frequency) fully shielded 0806 molded inductor was selected. Table 2-1 shows the DM inductor selection by power level.

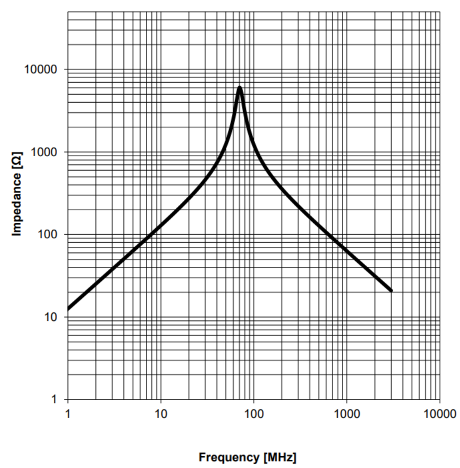

Figure 2-7. Impedance vs. Frequency - DM Inductor

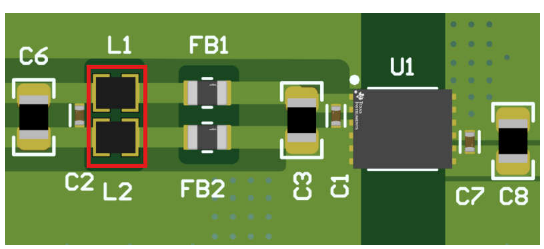

Figure 2-8. Dual DM Inductor in the PCB

Table 2-1. DM Inductor selection

Power Level	DM Inductor
0.5W	PN:74479763222; 2.2uH, 0603, 800mA

Table 2-1. DM Inductor selection (continued)

Power Level	DM Inductor
1W	PN:74438343022; 2.2uH, 2mmx1.6mm, 1.65A

An 0402 50V 15nF capacitor with high SRF was placed at the left side of the inductors. This capacitor was used to form the pi filter with the inductors and the 15nF connected next to the input pins.

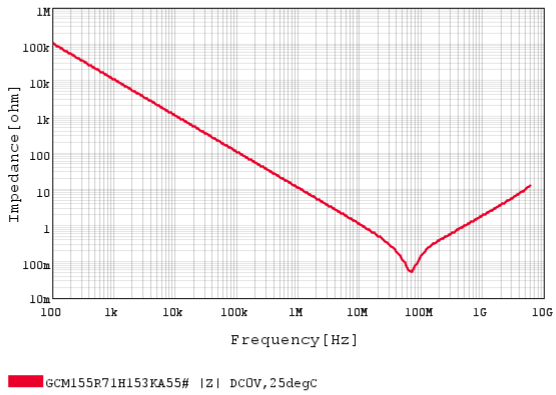

Figure 2-9. Impedance vs. Frequency - 0402 15nF

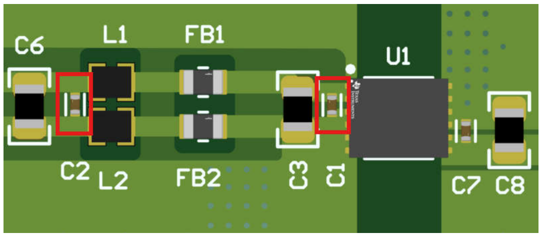

Figure 2-10. 0402 15nF capacitors in the PCB

FB are needed to mitigate the HF current harmonics that are present in the range of 200MHz-1GHz. 0603, 800mA ferrite beads with an impedance of 925 Ω at 600MHz, fully shielded were selected to achieve low EMI at this range. These ferrite beads were placed next to the DUT for better H filed mitigation at high frequencies.

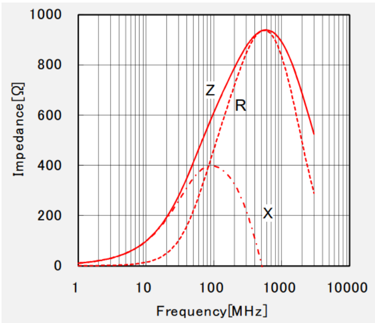

Figure 2-11. Impedance vs. Frequency - FB

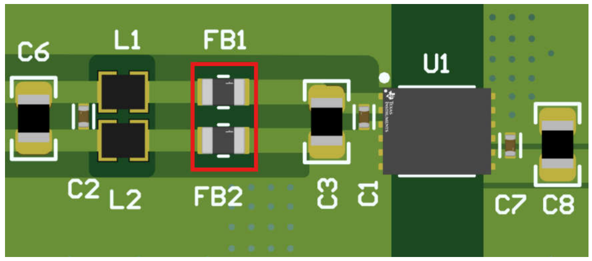

Figure 2-12. FB in the PCB

Comparison with and without FB: Figure 2-13 and Figure 2-14 show the comparison with and without FB for UCC33420-Q1 RE Pout=0.5W.

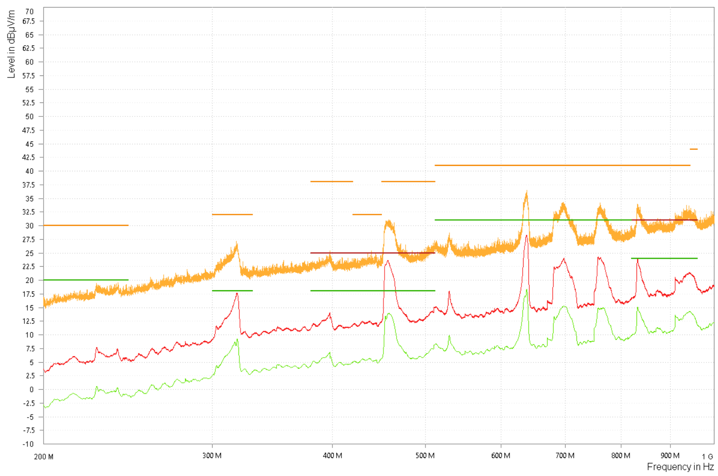

Figure 2-13. CISPR25 RE LPA with FB, Pout=0.5W

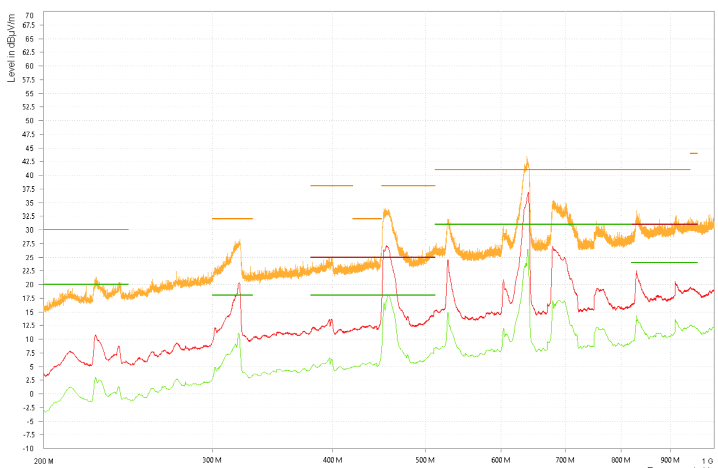

Figure 2-14. CISPR25 RE LPA without FB, Pout=0.5W

Finally, an 0805 10uH bypass cap was placed at the left side of the switching loop to form a low frequency pi filter with the DM inductors and the 10uF bypass cap next to the input pins of the device. The target frequency is the burst frequency of the device which is in the range of 100-500kHz depending on the load.

2.3 PCB Layout

The placement of ground planes on both primary and secondary side provides low impedance at the return of the switching loop when used to connect the ground pins of the device. What is more, these planes act as Faraday shields, mitigating the H field coming from the transformer. Apply the largest copper area that the design allows.

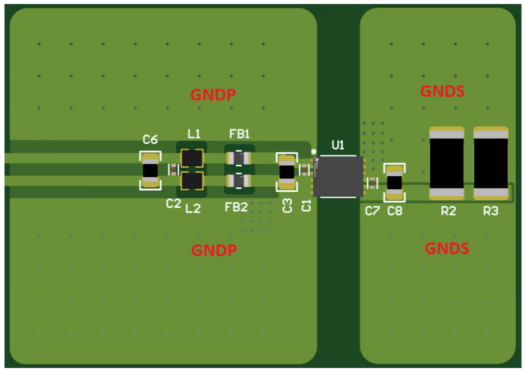

Figure 2-15. Ground Planes in PCB

To prevent any bypass of the HF currents through the layout parasitic capacitance, it is recommended removing copper underneath the DM inductors and FBs. For the same reason, we recommend a 1mm KOZ around the EMI filter area.

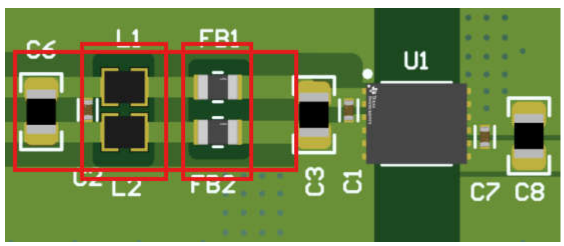

Figure 2-16. KOZ and Copper Cut Under DM Inductors and FB

Due to the impedance match on both sides of the switching loop (positive and return), the CM noise is minimized, and the switching loop distance does not affect the EMI at the LISN. Because of this, it is recommended to keep the switching loop as short to keep a low footprint design. In this case, a 1.5mm distance for the switching loop is selected.

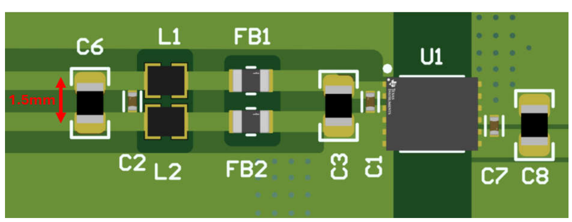

Figure 2-17. Switching Loop Distance

2.4 Faraday Shield

PCB Faraday shield is a technique used to mitigate the H filed coming from the integrated transformer. It consists on placing conductive copper from an inner or bottom layer underneath the device. This Faraday shield induces currents that generate a H field of the opposite direction than the original one. To prevent any bypass of these induced currents, we also recommend having an approximate 4mm clearance between the primary and secondary ground planes. This is achieved by pulling back the primary ground plane 4mm from the extended secondary ground plane. In a 2-layer PCB, this clearance is needed to keep isolation requirements. In a 4-layer PCB, the Faraday shield can be placed in an inner layer but the 4mm clearance is still required. The frequency target of this shield is between 500MHz-1GHz.

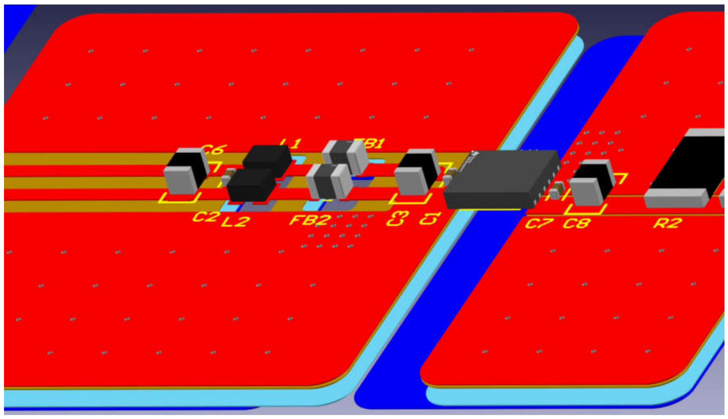

Figure 2-18. 3D View of the Faraday Shield

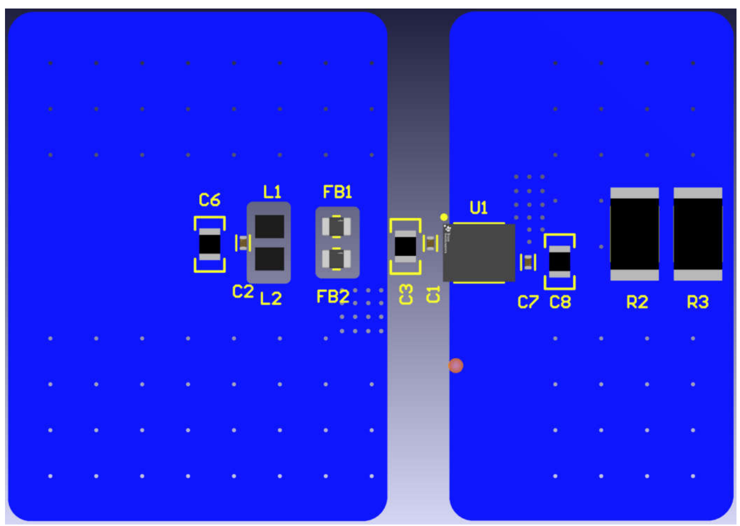

Figure 2-19. 2D View of the Faraday Shield

2.5 Schematic

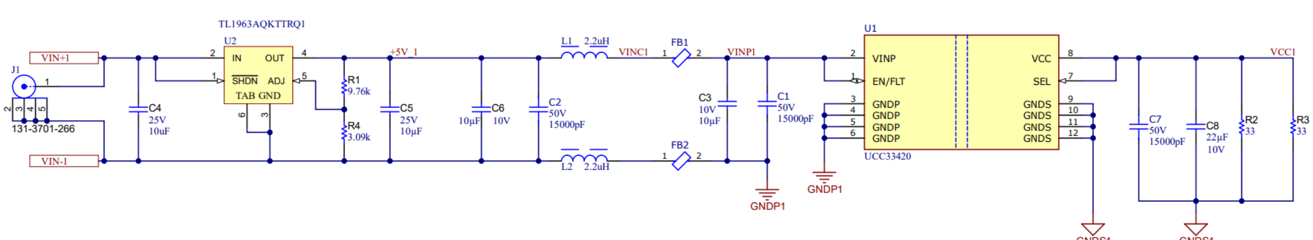

Figure 2-20. Schematic UCC33420-Q1 CISPR 25

2.6 Layout

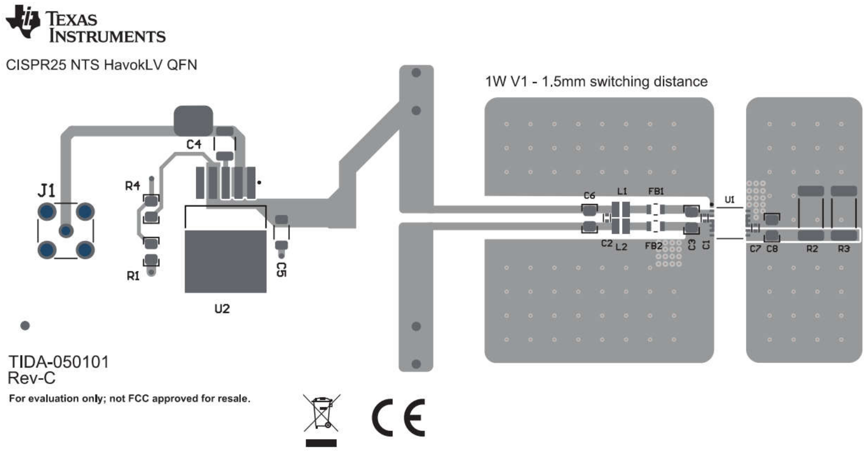

Figure 2-21. Top layer CISPR 25

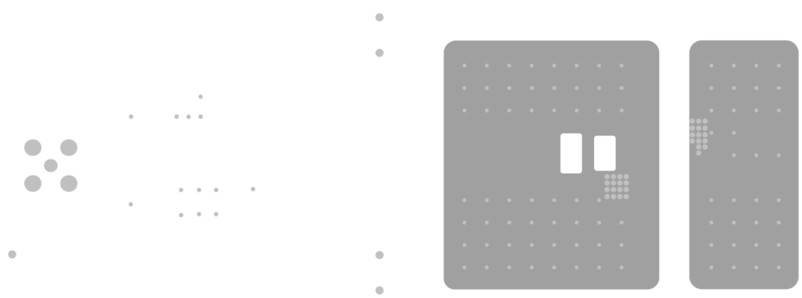

Figure 2-22. Inner layers CISPR 25

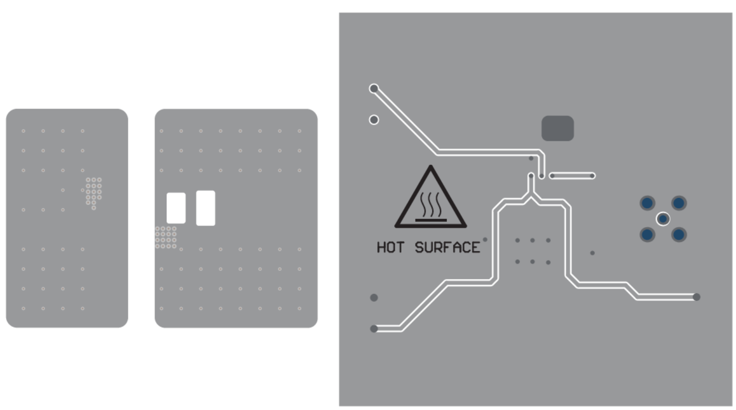

Figure 2-23. Bottom layer CISPR 25

2.7 EMI Results

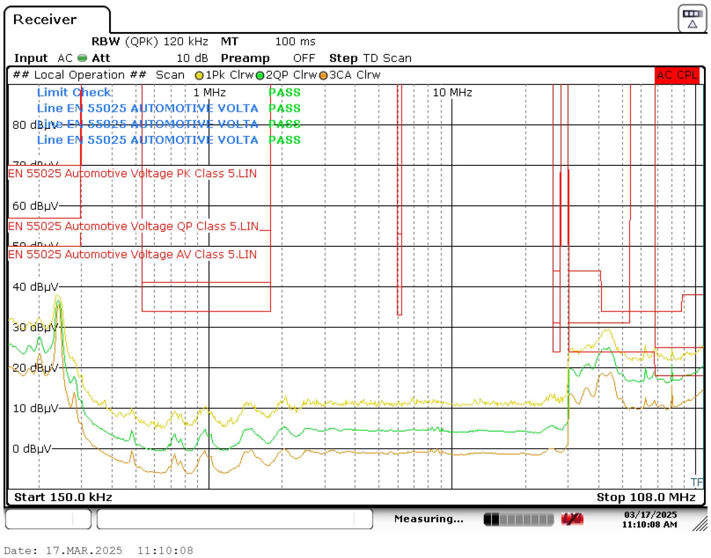

Figure 2-24. CISPR 25 CE Pout=1W

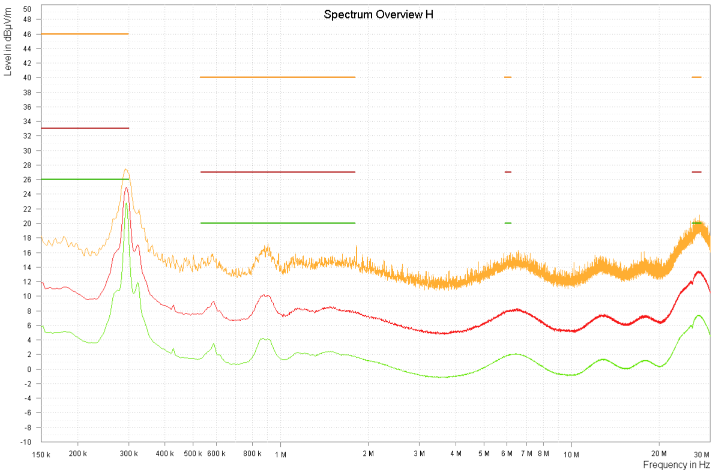

Figure 2-25. CISPR 25 RE Monopole Pout=1W

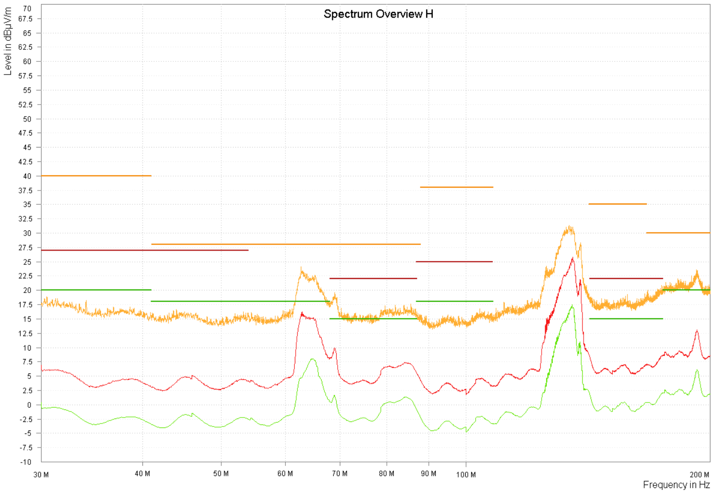

Figure 2-26. CISPR 25 RE Bicon Pout=1W

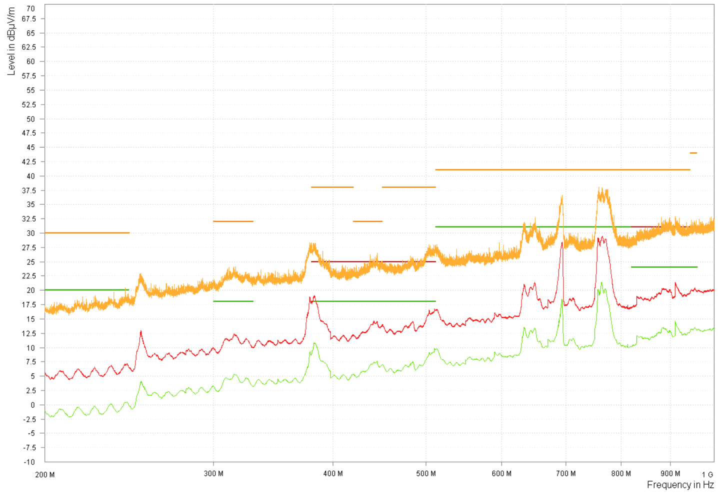

Figure 2-27. CISPR 25 RE LPA Pout=1W

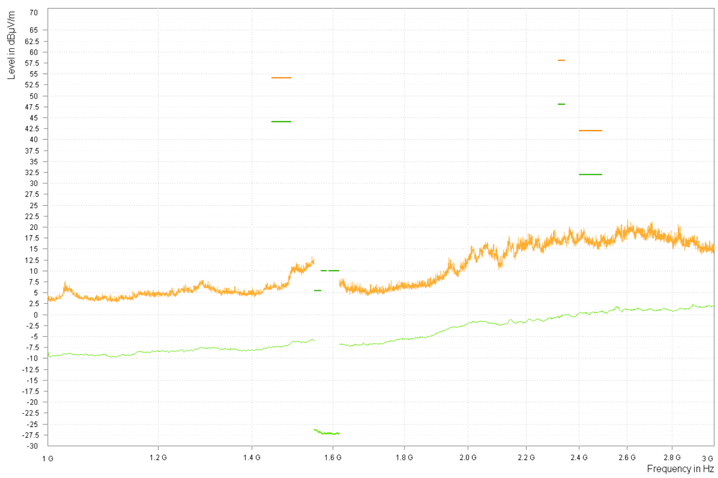

Figure 2-28. CISPR 25 RE Horn Pout=1W

2.8 Bill of Materials: BOM

Table 2-2. Bill of Materials: BOM

Designator	Quantity	Part Number	Manufacturer	Description
PCB1	1	TIDA-050101	Any	Printed Circuit Board
C1, C2, C7	3	GCM155R71H153KA55D	Murata	CAP, CERM, 0.015µF, 50V, ±10% X7R 0402 (1005 Metric)
C3, C6	2	GCJ21BR71A106KE01L	MuRata	CAP, CERM, 10 µF, 10 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0805
C4	1	GCM32ER71E106KA57L	MuRata	CAP, CERM, 10 uF, 25 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1210
C5	1	GRM31CR61E106MA12L	MuRata	CAP, CERM, 10 µF, 25 V,+/- 20%, X5R, 1206
C8	1	GRM21BZ71A226ME15L	MuRata	CAP, CERM, 22 uF, 10 V, +/- 20%, X7R, 0805
FB1, FB2	2	LCMGA160808T601RG	Murata	600 Ohms @ 100 MHz 1 Power Line Ferrite Bead 0603 (1608 Metric) 900mA 170mOhm
J1	1	131-3701-266	Cinch Connectivity	Connector, SMB, Jack, 50 ohm, TH
L1, L2	2	74438343022	Wurth Elektronik	WE-MAPI SMT Power Inductor, size 2010, 2.2uH, 1.1A, 270mOhm
R1	1	RT0805BRD079K76L	Yageo America	RES, 9.76 k, 0.1%, 0.125 W, 0805
R2, R3	2	CRCW251233R0JNEG	Vishay-Dale	RES, 33, 5%, 1 W, AEC-Q200 Grade 0, 2512
R4	1	RT0805BRD073K09L	Yageo America	RES, 3.09 k, 0.1%, 0.125 W, 0805
U1	1	UCC33420QRAQRQ1	Texas Instruments	1.5W, High-Density, >3 kVRMS Isolated DC-DC Converter
U2	1	TL1963AQKTTRQ1	Texas Instruments	Single Output Fast Transient Response LDO, 1.5 A, Adjustable 1.21 to 20 V Output, 2.1 to 20 V Input, 5-pin DDPAK (KTT), -40 to 125 degC, Green (RoHS & no Sb/Br)

3 Summary

UCC33xx0-Q1 family passes CISPR25 Class 5 due to proper EMI filter selection and PCB layout. CE is passing due to the use of a tightly coupled connection using a "T-shape" cable and the selection of a HF pi filter with a dual DM inductor. RE is passing due to the use of the FB in the EMI filter and PCB layout techniques like Faraday shield, use of ground planes, KOZ and copper cut underneath the DM inductors and FB.

4 References

1. International Electrotechnical Commission, *CISPR25 - International Standards*, standards.
2. Texas Instruments, *An overview of conducted EMI specifications for power supplies*, marketing white paper.
3. Texas Instruments, *UCC33420-Q1*, product page.
4. Texas Instruments, *How to pass CISPR 32 Class B for UCC33420-Q1*, application note.

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