Application Note

Passing CISPR-25 Radiated and Conduction Emissions Using the TPS65035x-Q1

Phil Yi, Gerard Copeland

ABSTRACT

This application note provides a summary of the CISPR-25 Conducted and Radiated Emissions test results using the TPS650350-Q1 Power Management Integrated Circuit (PMIC) for automotive camera applications. This device is capable of passing CISPR-25 and other automotive electromagnetic-compatibility (EMC) test specifications. Similar results can be achieved using other devices in the TPS65035x-Q1 family. Due to an advanced spread spectrum clocking (SSC) feature, these devices can pass EMC tests without needing a fully-optimized layout, allowing for more flexible component placement and routing as required by the camera application.

Table of Contents

1 Introduction....2
2 Spread Spectrum....2
3 Schematics and Printed Circuit Board (PCB) Description....3
4 Design Considerations....8
5 Summary....9
6 Conducted and Radiated Emission Average and Peak Plots....10
7 References....14

List of Figures

Figure 2-1. Spread Bands of Harmonics in Modulated Square Signals....2
Figure 2-2. TPS650350-Q1 SSC Conducted Emission Comparison....3
Figure 3-1. CISPR-25 EMC Test Setup....3
Figure 3-2. DUT Schematics....4
Figure 3-3. Printed Circuit Board Top Layer....6
Figure 3-4. Printed Circuit Board Layer 2 (Ground Plane)....6
Figure 3-5. Printed Circuit Board Layer 3....7
Figure 3-6. Printed Circuit Board Layer 4....7
Figure 3-7. Printed Circuit Board Layer 5....8
Figure 3-8. Printed Circuit Board Bottom Layer....8
Figure 4-1. Top Layer - Zoom....9
Figure 6-1. Conducted Emissions 0.15 MHz to 108 MHz....10
Figure 6-2. Radiated Emissions – Rod Antenna 0.15 MHz to 30 MHz....11
Figure 6-3. Radiated Emissions – Bicon Horizontal Antenna 30 MHz to 200 MHz....11
Figure 6-4. Radiated Emissions – Bicon Vertical Antenna 30 MHz to 200 MHz....12
Figure 6-5. Radiated Emissions - Logarithmic Horizontal Antenna 200 MHz to 1000 MHz....12
Figure 6-6. Radiated Emissions - Logarithmic Vertical Antenna 200 MHz to 1000 MHz....13
Figure 6-7. Radiated Emissions – Horn Antenna Measurement 1 to 2.5 GHz....13

List of Tables

Table 3-1. Bill of Materials....4
Table 5-1. Emissions Test Operating Conditions....9

Trademarks

All trademarks are the property of their respective owners.

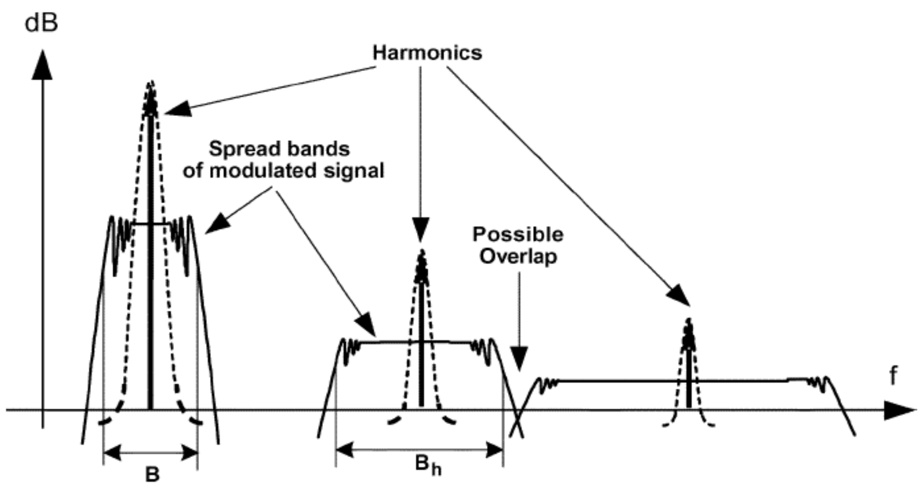
1 Introduction

This application report illustrates the EMI/EMC performance of the TPS650350-Q1 and relevant circuits in automotive applications using example schematics and layout design. With this example, the TPS650350-Q1 and associated components pass the CISPR-25 *Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers* conducted emission in the 0.15 MHz to 108 MHz frequency range, and radiated emission in the 0.15 MHz to 1000 MHz frequency range.

2 Spread Spectrum

The TPS650350-Q1, TPS650351-Q1, TPS650352-Q1, and TPS650353-Q1 are a family of PMICs for camera applications. Each device includes three step-down (buck) converters and one low dropout (LDO) regulator. The three buck converters are capable of spread spectrum clocking (SSC), a feature that modulates the switching frequency of each converter to spread the power that can cause EMI. This internal modulation spreads the operating frequency from 2.0 MHz to 2.5 MHz with a center frequency of 2.25 MHz and can be enabled or disabled with a single register write through I2C communication.

The goal of spread spectrum architecture is to spread out emitted RF energy over a larger frequency range. Spreading the operating frequency of the buck converters results in a more continuous power spectra that is lower in peak amplitude, as shown in Figure 2-1. This peak reduction is possible because the time integral of the curve (the EMI energy emitted by the circuit) remains constant whether spread spectrum is enabled or disabled.



$$B = 2 \cdot f_m \cdot (1 + m_f) = 2 \cdot (\Delta f_c + f_m)$$

$$B_h = 2 \cdot f_m \cdot (1 + m_f \cdot h)$$

Figure 2-1. Spread Bands of Harmonics in Modulated Square Signals

Figure 2-2 compares the conducted emission performance with SSC enabled and disabled using the TPS650350-Q1 and the example layout discussed in this application report.

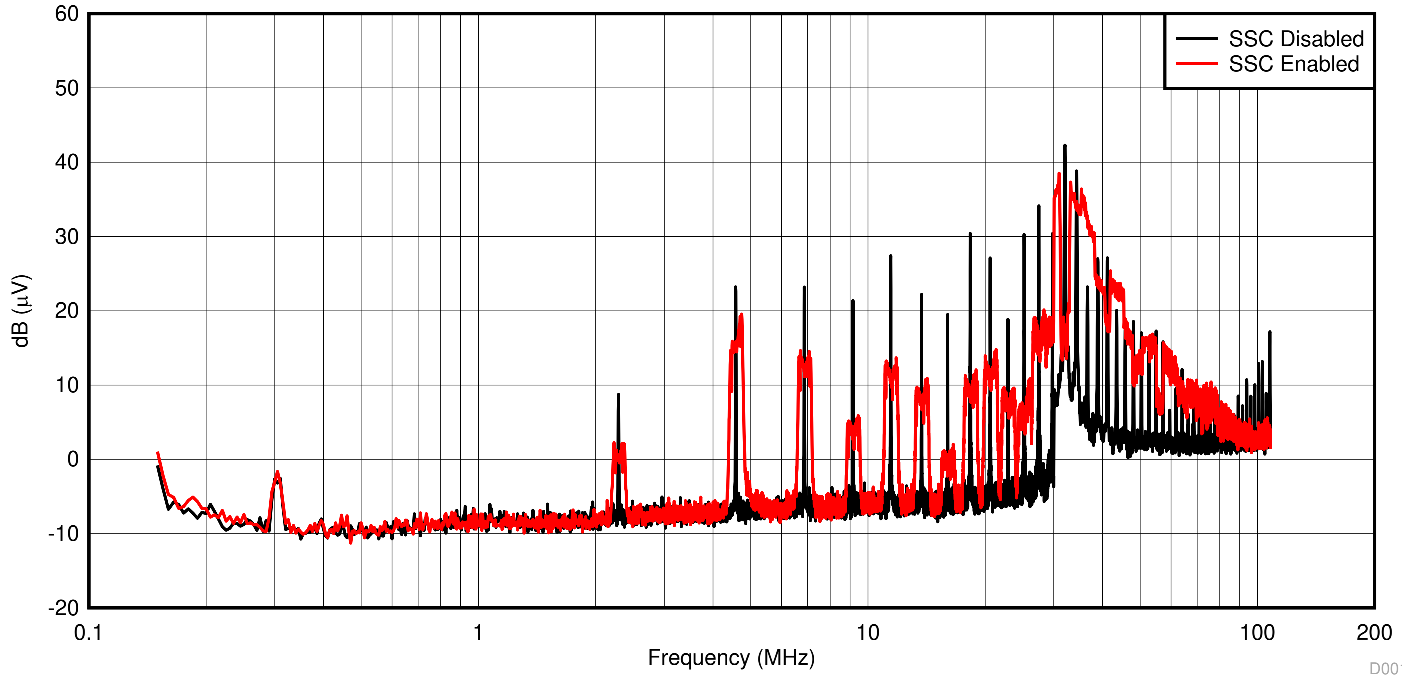


Figure 2-2. TPS650350-Q1 SSC Conducted Emission Comparison

3 Schematics and Printed Circuit Board (PCB) Description

This layout is derived from a compact camera module reference design. All non-power related components have been removed from the original design, and the remaining power solution was tested according to the CISPR-25 automotive specification. A power over coax (POC) filter is included on both ends of the harness (FPD-Link coax cable) to replicate the expected EMI in a typical automotive camera application. The schematic and layout for the POC filter on the receiver side are taken from the *Automotive Camera PMIC Power Supply Reference Design with Power Over Coax Filter* reference design. The schematic and layout for the POC filter on the DUT-side is shown in Figure 3-2. As intended for a camera module reference design, the layout balances the tradeoffs between PCB area and EMI performance. For example, some components for the low-voltage buck converters are located on the layer opposite of the PMIC to minimize the total area occupied by the power solution. These are less critical for EMI performance compared to the mid-voltage buck converter.

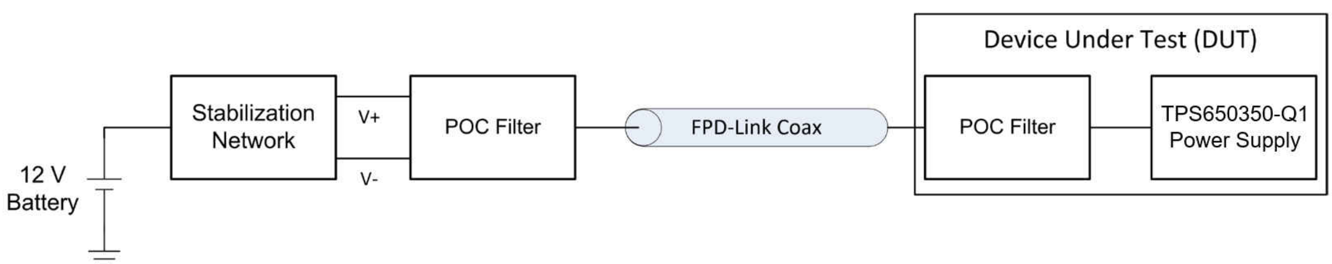


Figure 3-1. CISPR-25 EMC Test Setup

3.1 Schematics

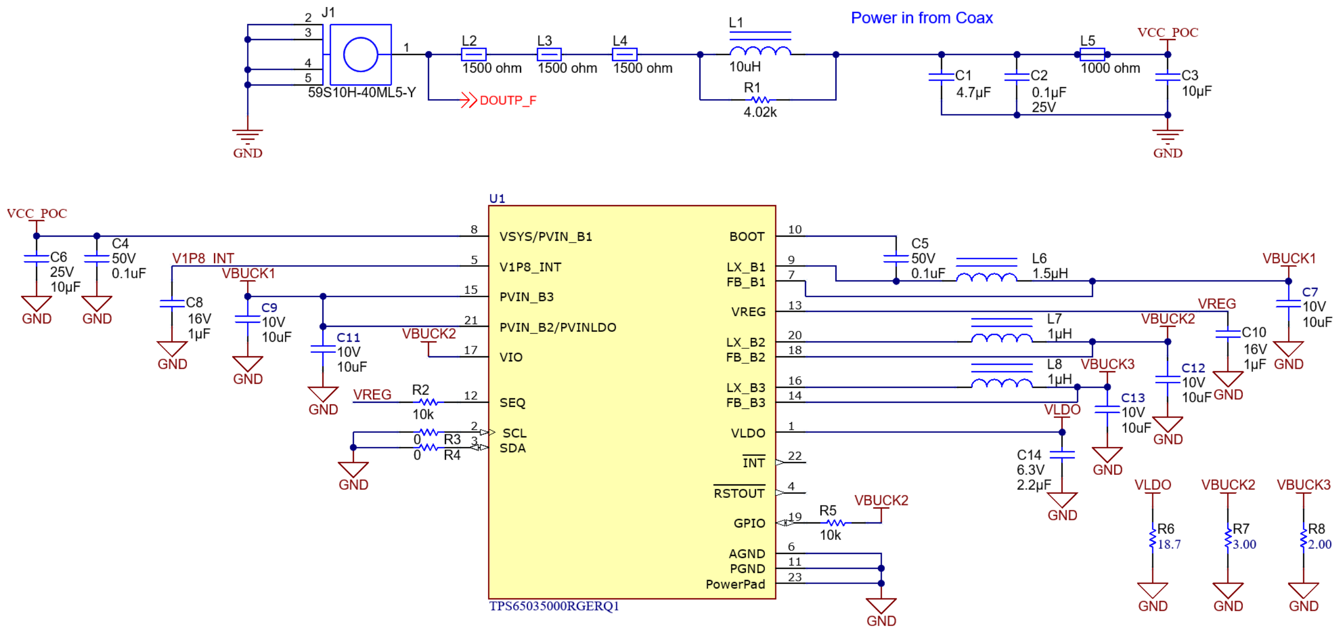


Figure 3-2. DUT Schematics

3.2 Bill of Materials

Table 3-1. Bill of Materials

Item	Designator	Quantity	Part Number	Manufacturer	Description
1	!PCB1	1	TIDA-050062	Any	Printed Circuit Board
2	C1	1	CGA4J1X7R1E475M125AC	TDK Corporation	CAP, CERM, 4.7 µF, 25 V, ±20%, X7R, 0805
3	C2	1	C1005X7R1E104K050BB	TDK Corporation	CAP, CERM, 0.1 µF, 25 V, ±10%, X7R, 0402
4	C3, C6	2	GRM21BZ71E106KE15L	MuRata	CAP, CERM, 10 µF, 25 V, ±10%, X7R, 0805
5	C4	1	CGA2B3X7R1H104M050BB	TDK	0.1 µF ±20% 50V Ceramic Capacitor X7R 0402
6	C7, C9, C10, C11, C12.	5	GRM188Z71A106MA73D	MuRata	CAP, CERM, 10 µF, 16 V, ±20%, X7R, 0603
7	C7, C9	2	CGA3E1X7R1C105K080AC	TDK	1 µF ±10% 16V Ceramic Capacitor X7R 0603
8	J1	1	59S10H-40ML5-Z	Rosenberger	Connector, HF, 50 Ω, TH
9	L1	1	LQH3NPZ100MJRL	MuRata	10 µH Shielded Drum Core, Wirewound Inductor 1.2 A 288mOhm Max 1212 (3030 Metric)
10	L2, L3, L4	3	BLM18HE152SN1D	MuRata	Ferrite Bead, 1500 Ω at 100 MHz, 0.5 A, 0603
11	L5	1	BLM18AG102SN1D	MuRata	Ferrite Bead, 1000 ohm @ 100 MHz, 0.4 A, 0603
12	L6	1	TFM201610ALMA1R5MTAA	TDK	Inductor, Shielded, Metal Composite, 1.5 µH, 3.1 A, 0.06 Ω, AEC-Q200 Grade 0, SMD
13	L7, L8	2	TFM201610ALMA1R0MTAA	TDK	Inductor, Shielded, Metal Composite, 1 µH, 3.1 A, 0.06 Ω, AEC-Q200 Grade 0, SMD
14	R1	1	CRCW06034K02FKEA	Vishay-Dale	RES, 4.02 k, 1%, 0.1 W, 0603

Table 3-1. Bill of Materials (continued)

Item	Designator	Quantity	Part Number	Manufacturer	Description
15	U1	1	TPS650350QRGEQ1	Texas Instruments	Automotive Camera PMIC, RGE0024K (VQFN -22)
16	R5	1	CRCW040210K0JNED	Vishay-Dale	ES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402
17	R2, R3, R6, R7	4	CRM2512-FX-1R00ELF	Bourns	RES, 1.00, 1%, 2 W, 6.3x3.1 mm

3.3 Board Layout

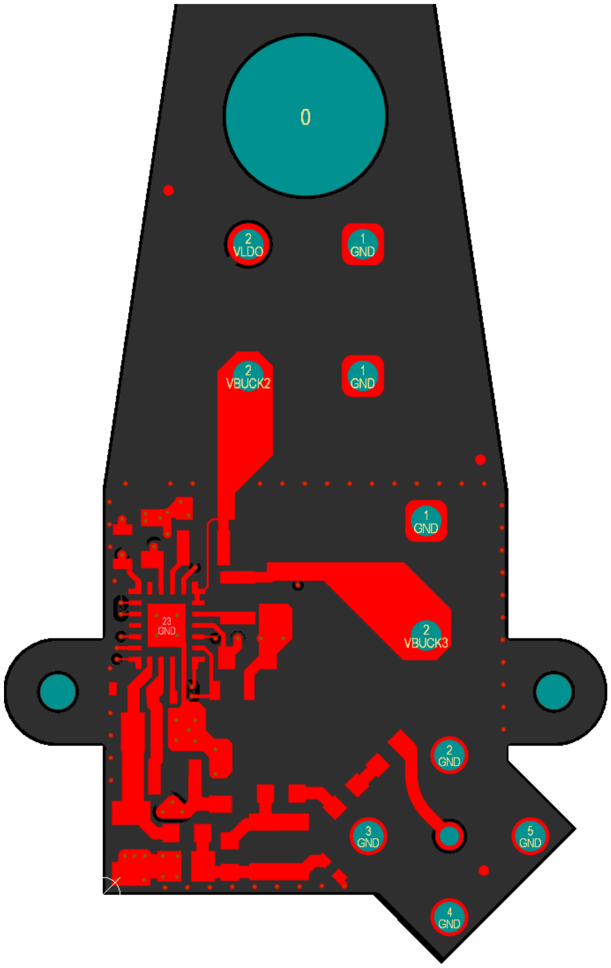


Figure 3-3. Printed Circuit Board Top Layer

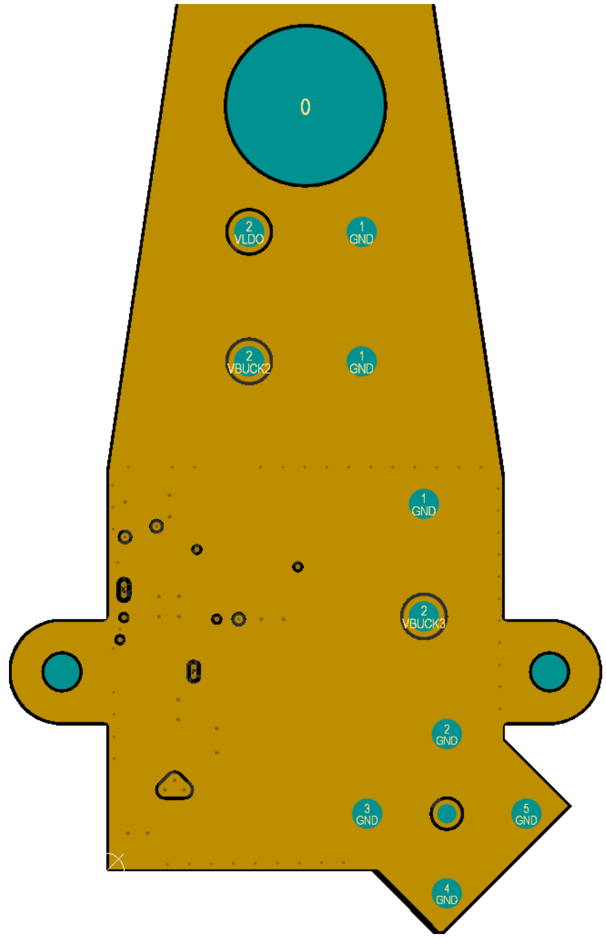


Figure 3-4. Printed Circuit Board Layer 2 (Ground Plane)

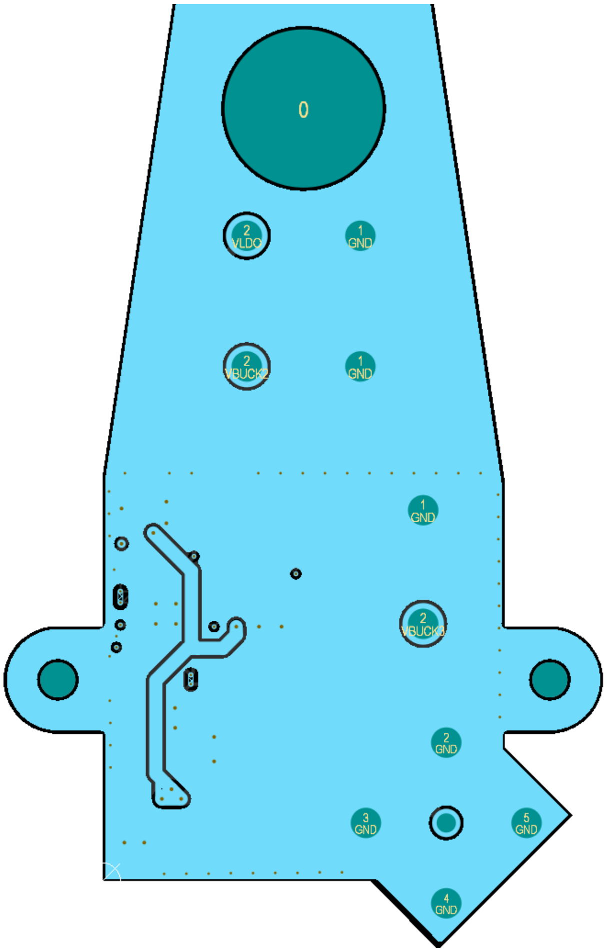


Figure 3-5. Printed Circuit Board Layer 3

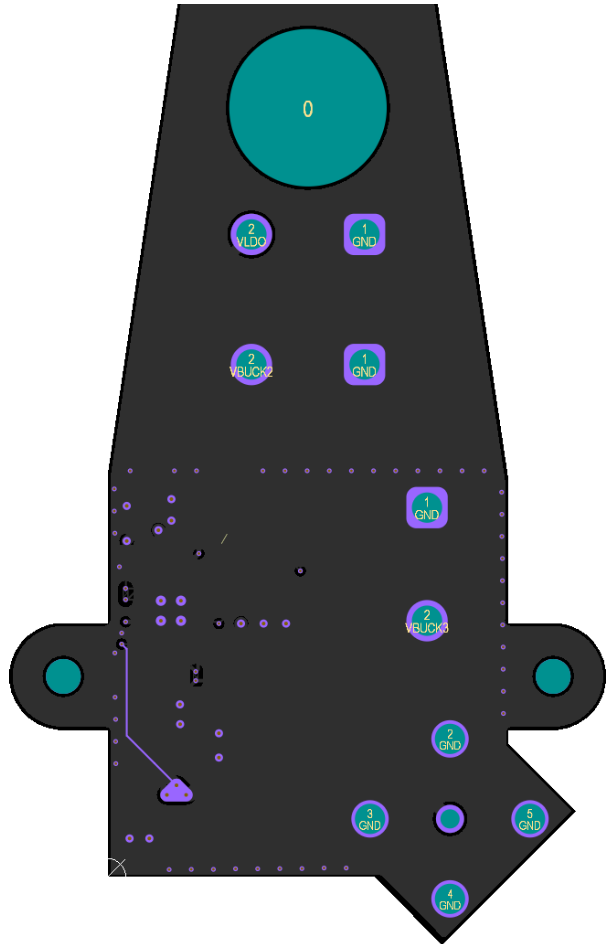


Figure 3-6. Printed Circuit Board Layer 4

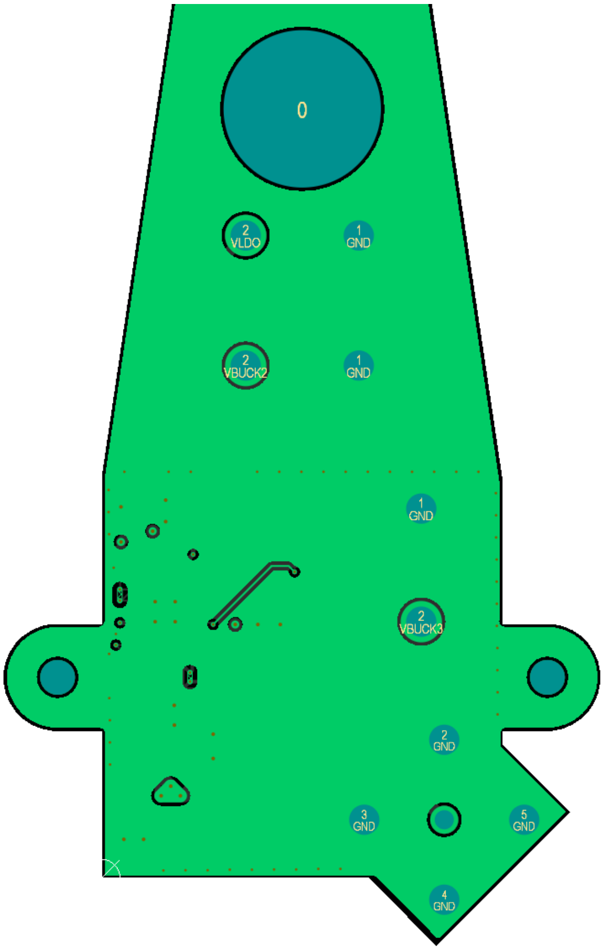


Figure 3-7. Printed Circuit Board Layer 5

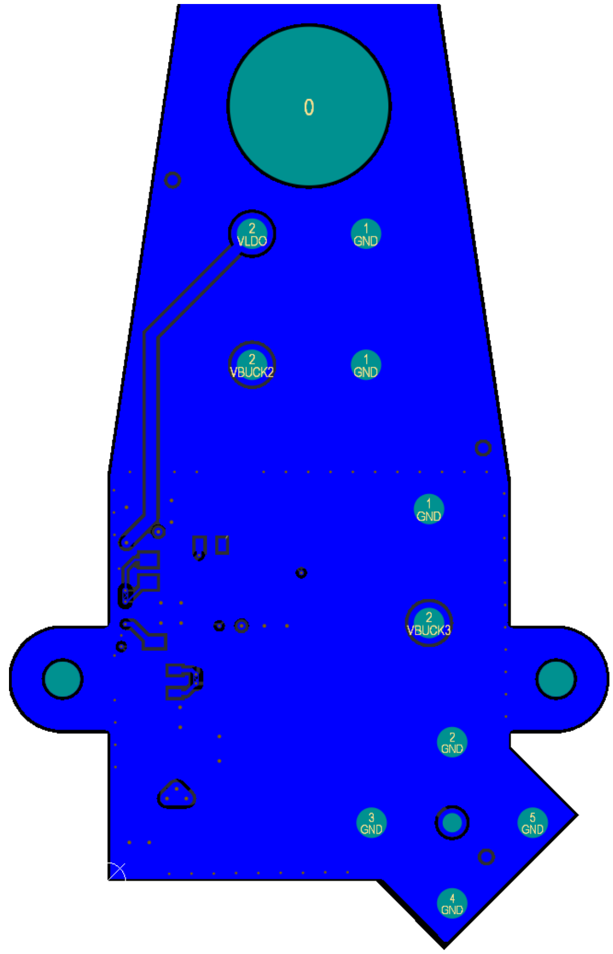


Figure 3-8. Printed Circuit Board Bottom Layer

4 Design Considerations

Automotive camera modules are typically as small as possible to support placement in remote regions of the vehicle. A designer may need to sacrifice some layout best practices in terms of conducted and radiated emissions in order to meet stringent size constraints. The SSC feature of the TPS650350-Q1 allows for a sub-optimal layout while still passing CISPR-25 emissions testing specifications.

Design considerations for this layout to reduce emissions include:

1. Minimize the loop area between the buck converter input capacitors and the thermal pad of the PMIC. Smaller decoupling capacitors are placed closer to the device pins.
2. Minimize the loop area between the input capacitor, output inductor, and output capacitor of each buck converter.
3. The mid-voltage buck converter (Buck 1) has the highest priority for external component placement on the PCB.
4. The input capacitors for the low-voltage buck converters (Buck 2 and Buck 3) have the next highest placement priority.
5. External components for the less EMI critical converter can be placed on the opposite side. In this case the less critical converter is Buck 2 because it has a higher output voltage (1.8 V).
6. Incorporate multiple solid ground planes with low impedance connections to the ground pours on the external component layers.

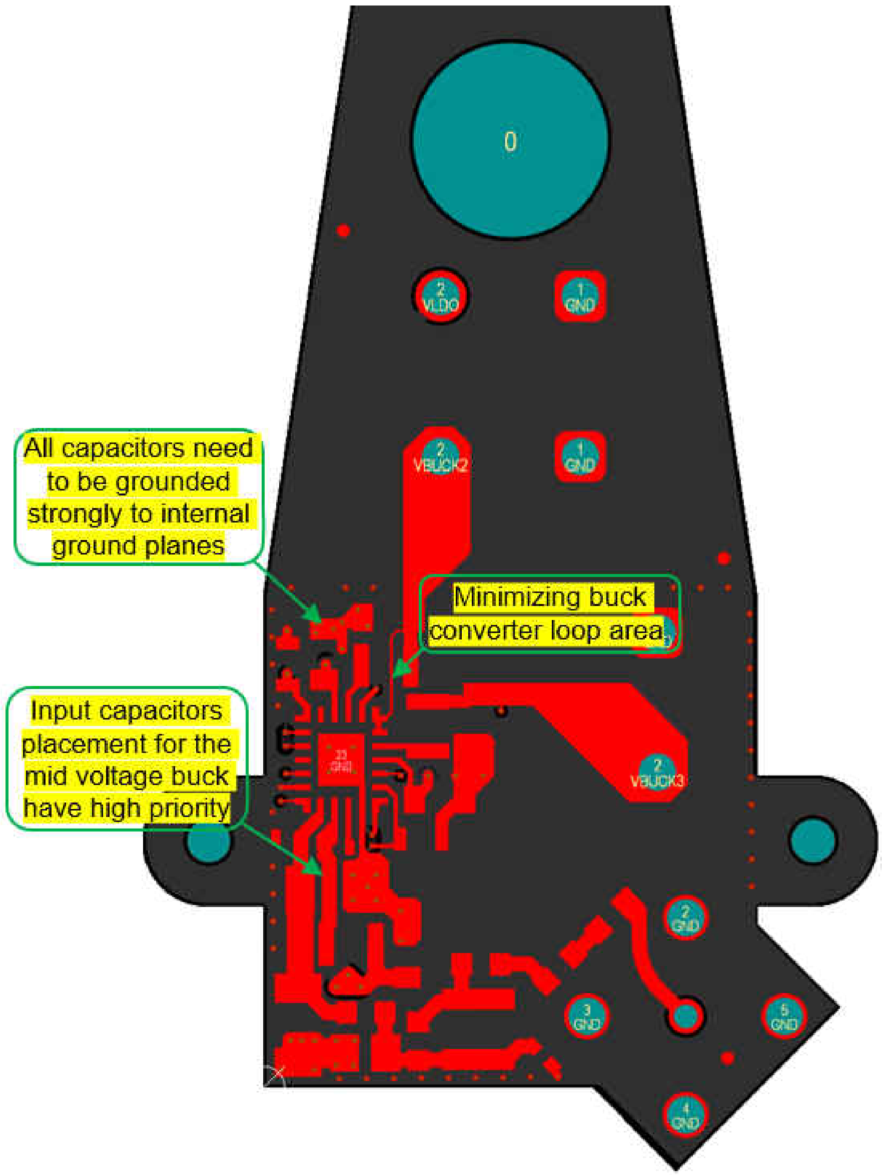


Figure 4-1. Top Layer - Zoom

5 Summary

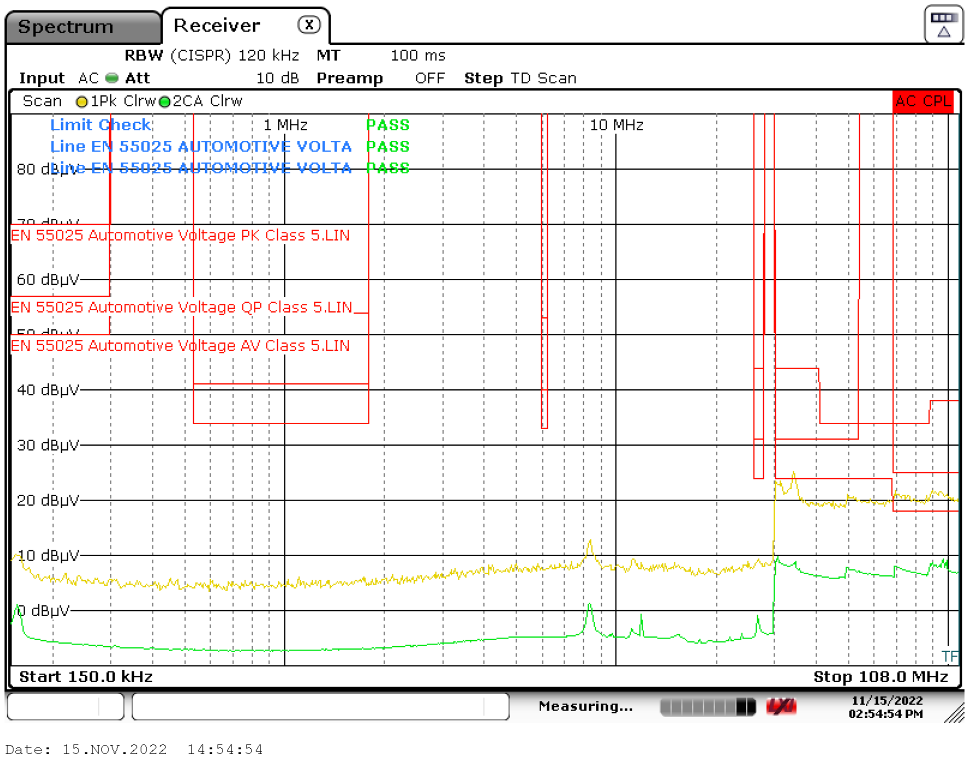
The TPS65035x-Q1 device family passes the CISPR25 Class-5 Conducted and Radiated Emissions required for automotive applications. Passing results can be achieved using the integrated SSC feature combined with the design and layout considerations described in Section 3 and Section 4. The operating conditions are given in Table 5-1.

Table 5-1. Emissions Test Operating Conditions

Regulator	Output Voltage (V)	Output Current (mA)
Buck 1	3.3	770[(1)]
Buck 2	1.8	600
Buck 3	1.2	600
LDO	2.8	150

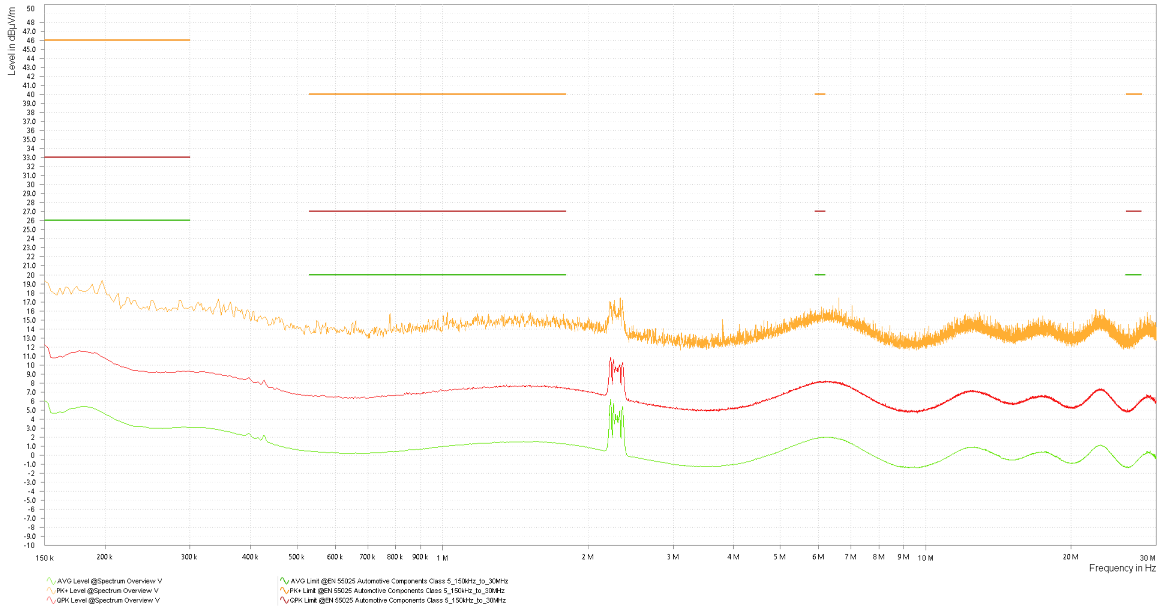
(1) The output current for Buck 1 is comprised of the input currents for Buck 2, Buck 3, and the LDO. There is no additional loading on the 3.3 V rail.

6 Conducted and Radiated Emission Average and Peak Plots



Yellow Trace - PK
Green Trace - AVG

Figure 6-1. Conducted Emissions 0.15 MHz to 108 MHz

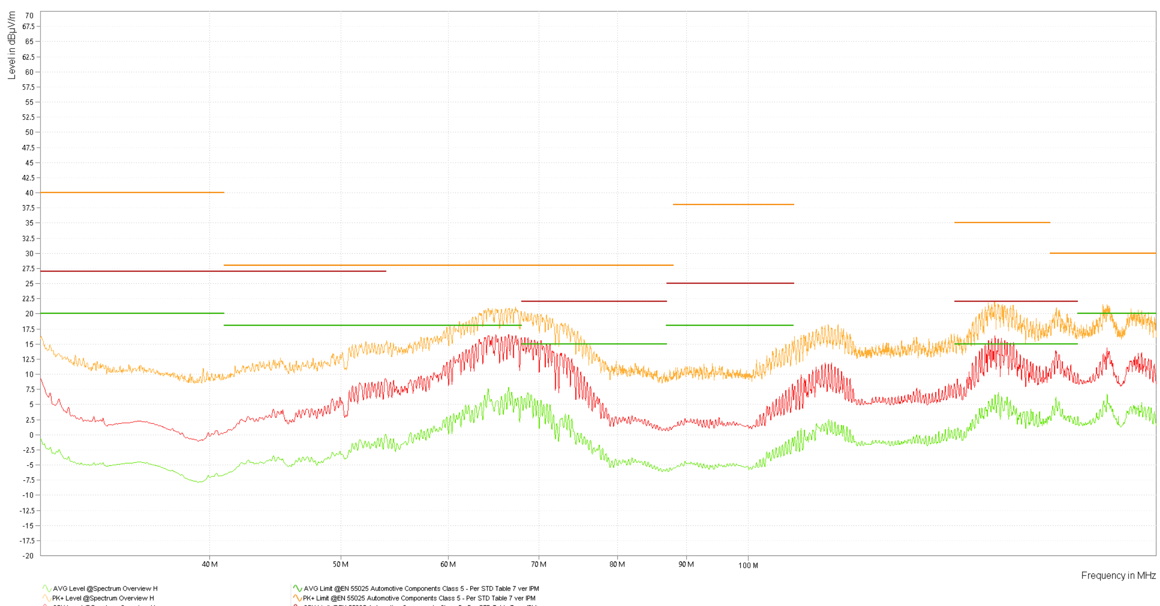


Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-2. Radiated Emissions – Rod Antenna 0.15 MHz to 30 MHz

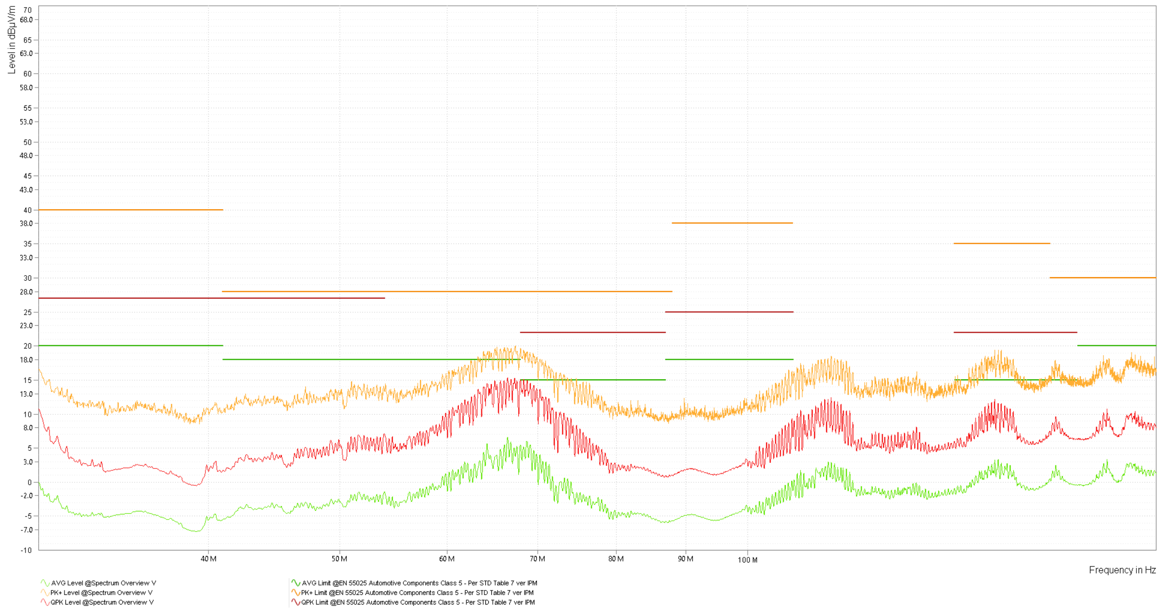


Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-3. Radiated Emissions – Bicon Horizontal Antenna 30 MHz to 200 MHz

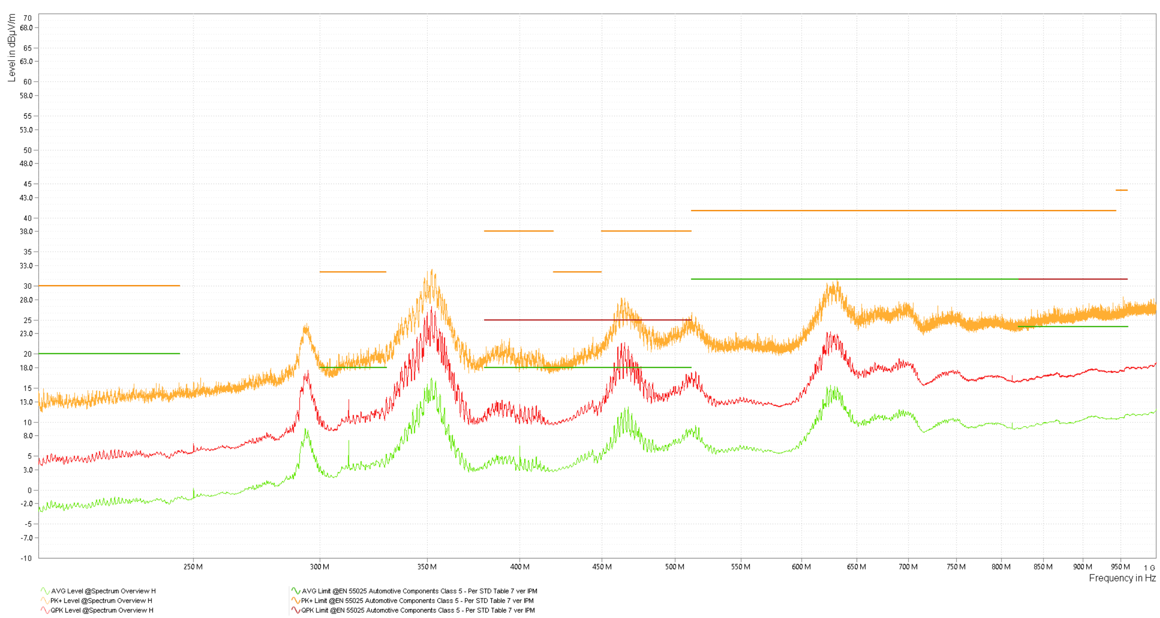


Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-4. Radiated Emissions – Bicon Vertical Antenna 30 MHz to 200 MHz

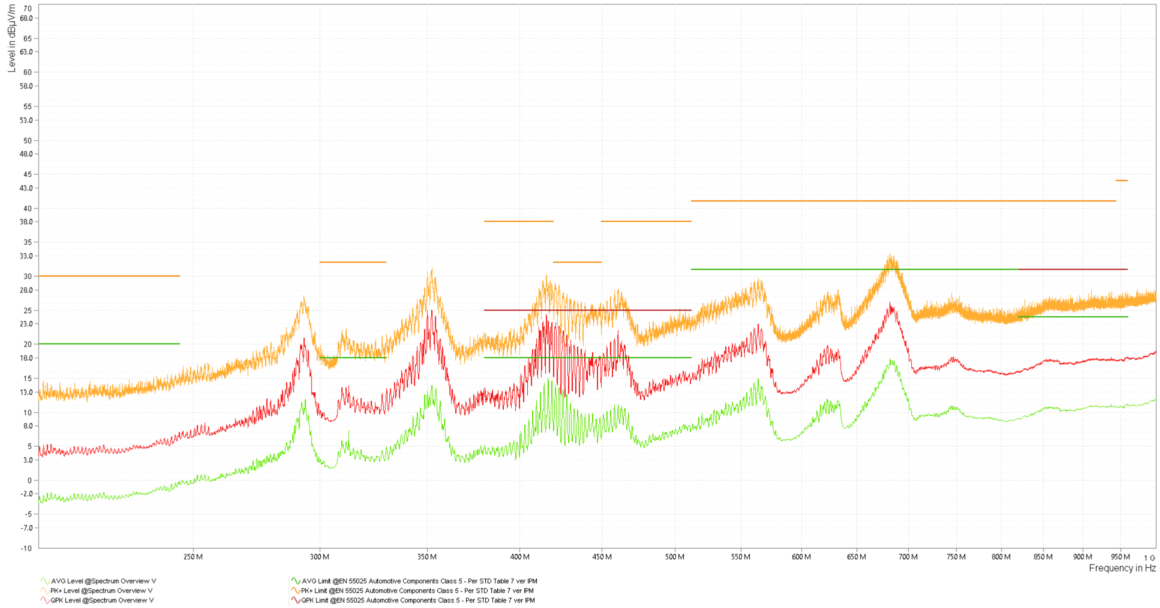


Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-5. Radiated Emissions - Logarithmic Horizontal Antenna 200 MHz to 1000 MHz

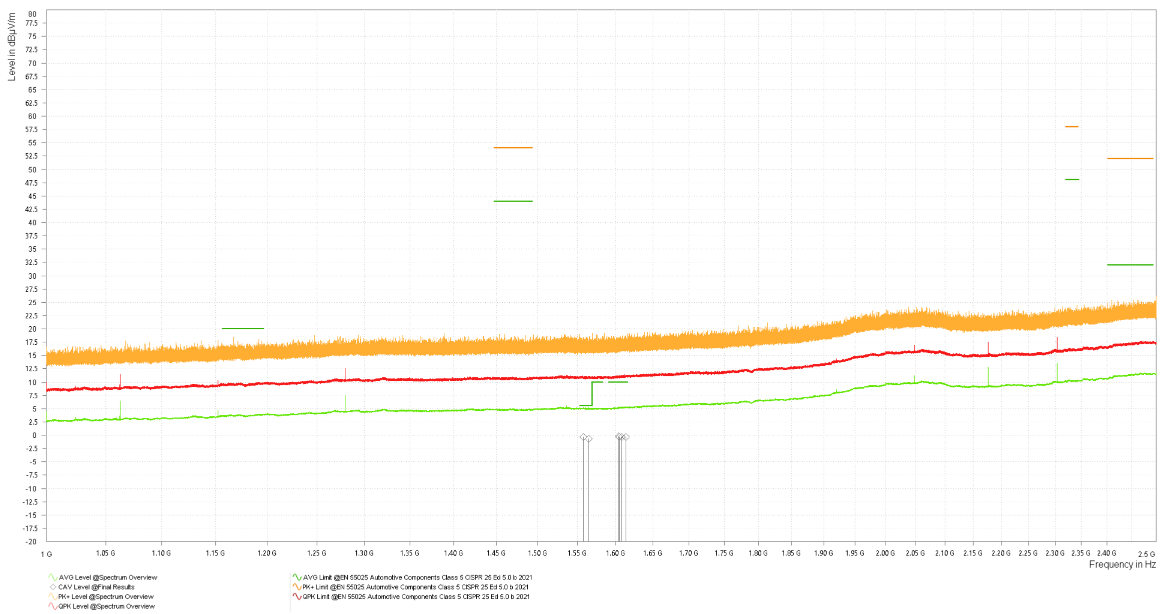


Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-6. Radiated Emissions - Logarithmic Vertical Antenna 200 MHz to 1000 MHz



Green track: AVG

Yellow track: PK

Red track: QPK

Figure 6-7. Radiated Emissions – Horn Antenna Measurement 1 to 2.5 GHz

7 References

1. CISPR, *Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers*, CISPR 25:2021, fourth edition (or EN IEC 55025:2022).
2. IEEE Xplore®. *EMI Reduction in Switched Power Converters Using Frequency Modulation Techniques*, in IEEE Transactions on Electromagnetic Compatibility, Vol. 4, No. 3, August 2005, pp 569-576 by Josep Balcells, Alfonso Santolaria, Antonio Orlandi, David González, Javier Gago.
3. Texas Instruments, *Automotive Camera PMIC Power Supply Reference Design with Power Over Coax Filter*.