AL8866QEV4-EMC User Guide

High-Performance Buck-Boost 1A Demo Board

General Description

The AL8866Q is a Buck-Boost, Boost, Buck, and SEPIC (single-ended primary-inductance converter) DC-switching controller that is designed to drive an external MOSFET for high-power automotive LED applications such as automotive front lighting. The AL8866Q operates within a wide input power supply range from 4.5V to 85V.

The device is based on a fixed-frequency, peak current-mode control architecture to incorporate a spread spectrum frequency modulation technique and achieve low EMI performance.

It modulates LED current with analog or PWM dimming techniques. An analog dimming response over a 100:1 linear range is obtained by varying the voltage at the DIM pin. PWM dimming is achieved by directly modulating the same DIM pin with the desired duty cycle.

The AL8866Q integrates a soft-start function, which limits the current through the inductor and external power switch during initialization startup. It gradually increases the inductor and switch current to minimize potential overvoltage and overcurrent at the output.

The device, with an open-drain fault output, indicates when protection conditions trigger such as LED output overvoltage, LED output open/short, cycle-by-cycle overcurrent protection, sense resistor and inductor/diode short, diode open, and thermal shutdown.

The AL8866Q is available in the enhanced thermal SO-8EP and wettable U-DFN3030-10 packages. The demoboard below uses the SO-8 package.

Key Features

- Wide Input Voltage Range from 4.5V to 85V
- Pre-Fixed 400kHz Switching Frequency (Factory Set)
- Spread Spectrum Frequency Modulation for Low EMI
- Analog Dimming Range: 1% to 100%
- 100% Dimming Level, ±3% Current Accuracy
- 20% Dimming Level, ±12% Current Accuracy
- PWM Dimming Ratio 100:1 at 200Hz PWM Frequency
- Programmable Soft Start
- Fault Status Indication for Protection
- Output Overvoltage and LED Open-Circuit Protection
- Output Undervoltage and LED Short-Circuit Protection
- Cycle-by-Cycle Overcurrent Limitation Protection
- Sense Resistor Shorted-Circuit Protection
- Diode/Inductor Shorted-Circuit Protection
- Diode Open Circuit Protection
- Thermal Shutdown
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **The AL8866Q is suitable for automotive applications requiring specific change control; this part is AEC-Q100 qualified, PPAP capable, and manufactured in IATF 16949 certified facilities. https://www.diodes.com/quality/product-definitions/**

Applications

- Automotive front lighting
- Automotive high beams, low beams
- Automotive daytime running lights
- Automotive fog lights, turn lights, and position lights
- Other automotive LED lighting

AL8866QEV4-EMC Specifications

Parameter	Value
Input Voltage	9VDC to 16VDC
LED Current	1A
Number of LEDs	1~6pcs
XY Dimension	80mm x 80mm

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Evaluation Board

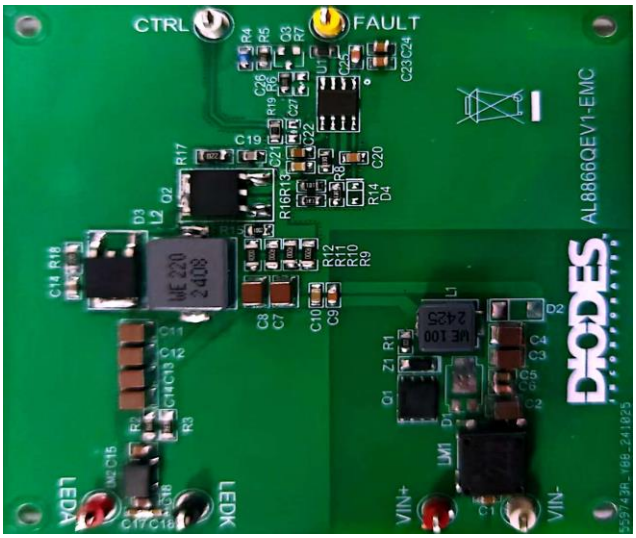


Figure 1: Top View

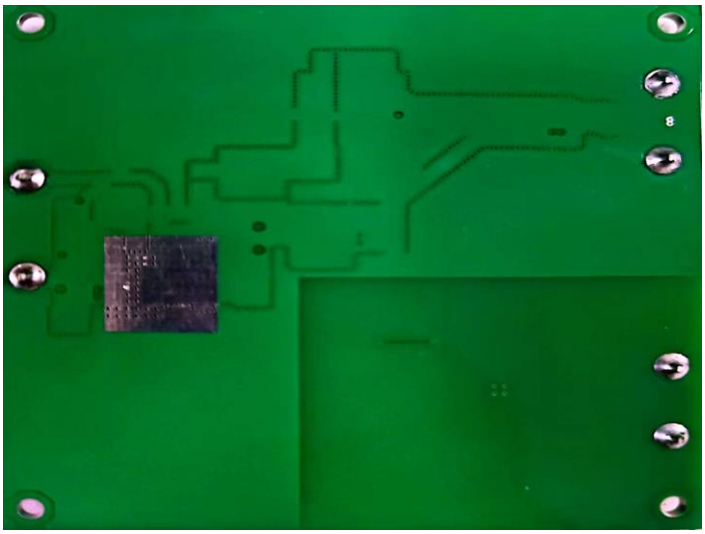


Figure 2: Bottom View

Connection Instructions

- DC Positive Input: Red Test Point (VIN+)
- DC Negative Input: White Test Point (VIN-)
- CTRL Signal Input: White Test Point (CTRL)
- GND Signal Input: Black Test Point (GND)
- Positive Output: Red Test Point (LEDA)
- Negative Output: Black Test Point (LEDK)
- FAULT Signal Input: Yellow Test Point (FAULT)

Board Layout

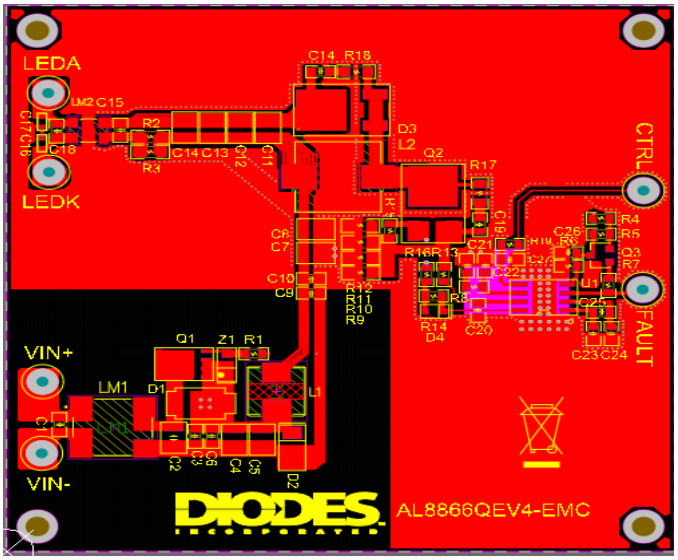


Figure 3: PCB Layout Top View

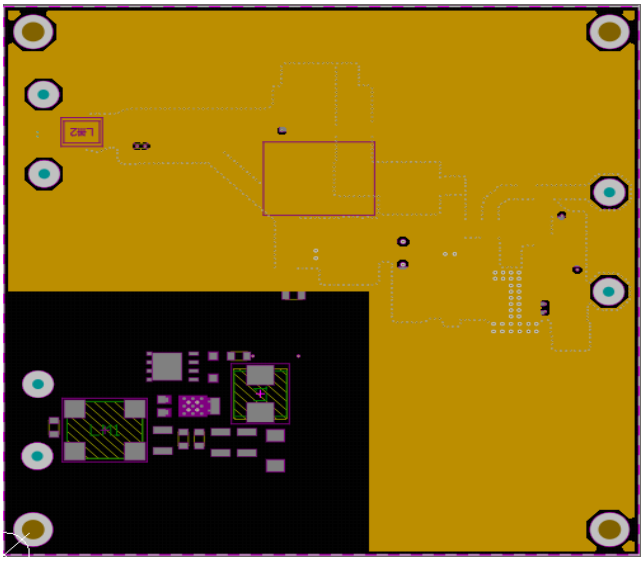


Figure 4: PCB Layout GND View

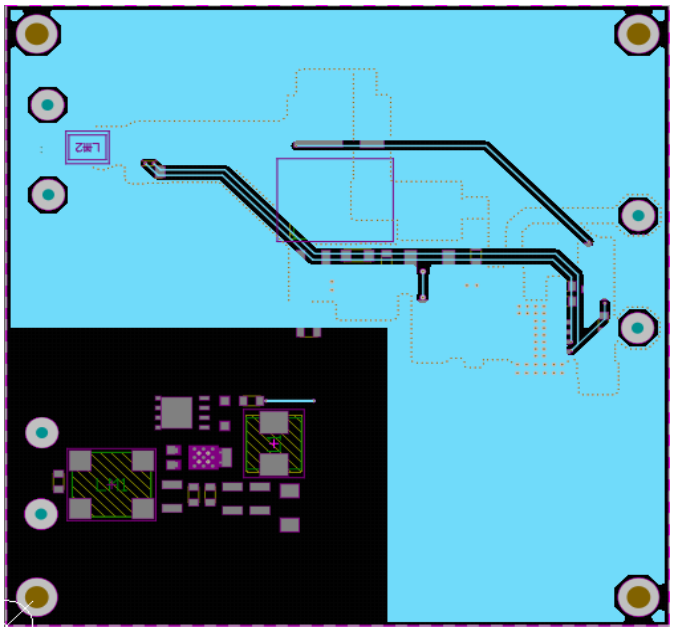


Figure 5: PCB Layout MID View

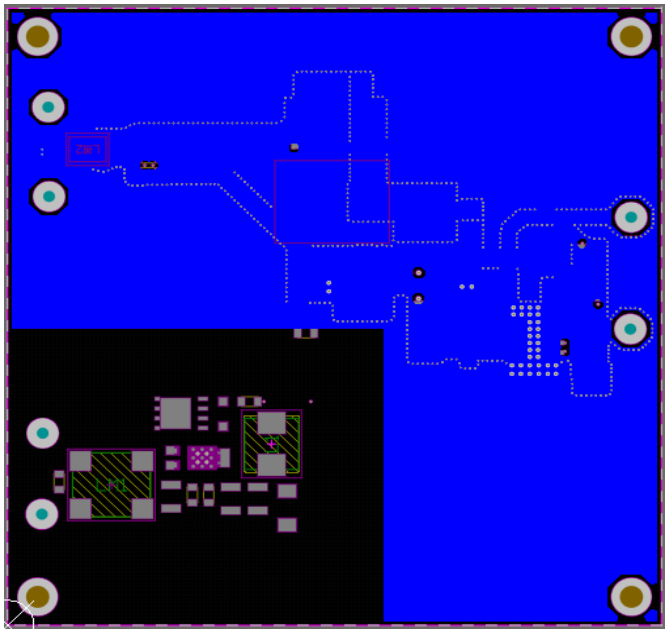


Figure 6: PCB Layout Bottom View

Quick Start Guide

1. Ensure that the power supply and the CTRL signal are switched OFF or disconnected.
2. Connect the LED power supply to the test points “VIN+” and “VIN-”.
3. Connect the LED string anode to the test point “LEDA”.
4. Connect the LED string cathode to the test point “LEDK”.
5. Turn on the LED power supply. The LED string will light on and output the preset current.
6. Dimming mode: Connect the PWM/Analog signal to “CTRL” and “GND”.

Schematic

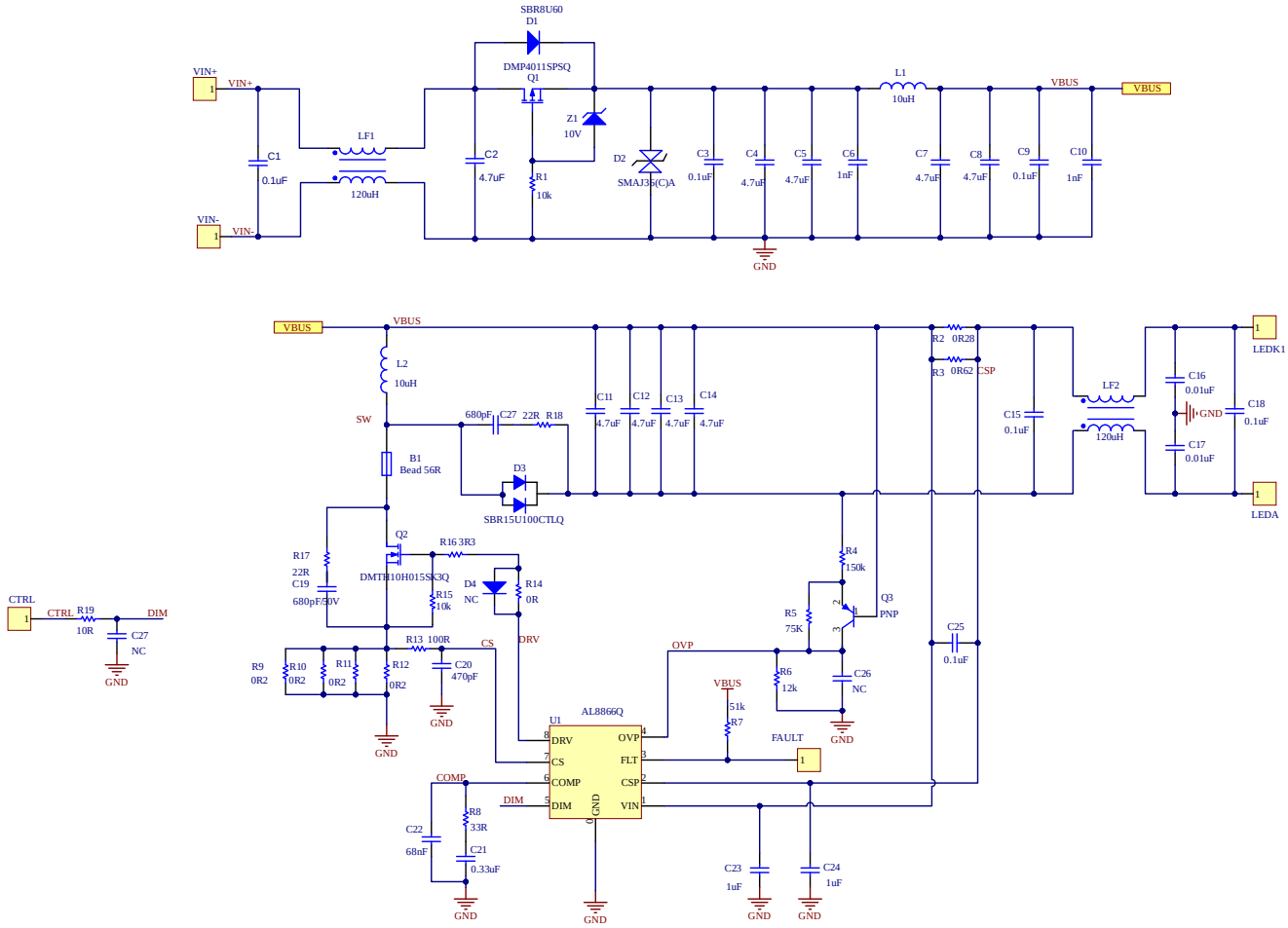


Figure 7: Schematic Circuit

Bill of Materials

Number	Designator	Description	Quantity
1	C1, C3, C9, C15, C18, C25	Cap, X7R, 100nF, 50V, 0805	6
2	C2, C4, C5, C7, C8, C9, C11, C12, C13, C14	Cap, X7R, 4.7uF, 100V,1210	10
3	C6, C10,	Cap, X7R, 1nF, 50V,0805	2
4	C16, C17	Cap, X7R, 10nF, 50V,0603	2
5	C19, C27	Cap, X7R, 680pF, 50V,0805	2
6	C20	Cap, X7R, 470pF, 50V,0805	1
7	C22	Cap, X7R, 68nF, 50V,0805	1
8	C21	Cap, X7R, 330nF, 50V,0805	1
9	C23, C24	Cap, X7R, 1uF, 50V,0805	2
10	R1, R15	Resistor 10k 1% 0805	2
11	R2, R3	Resistor 0R39 1% 1206	2
12	R4	Resistor 150K 1% 0805	1
13	R5	Resistor 75k 1% 0805	1
14	R6	Resistor 12k 1% 0805	1
15	R7	Resistor 51k 1% 0805	1
16	R8	Resistor 33R 1% 0805	1
17	R9, R10, R11, R12	Resistor 0R2 1% 1/2W 1206	4
18	R13	Resistor 100R 1% 0805	1
19	R14, R16	Resistor 3R3 1% 0805	2
20	R17, R18	Resistor 22R 1% 0805	2
21	R19	Resistor 10R 1% 0805	1
22	LEDA, VIN+	Connector, Red color	2
23	LEDK1	Connector, Black color	1
24	VIN-, CTRL	Connector, White color	2
25	FAULT	Connector, Yellow color	1
26	D2	Diode TVS SMAJ36CA 36V SMB DIODES	1
27	D3	Diode SBR15U100CTLQ DPAK DIODES	1
28	Z1	Diode BZT52C10Q 10V SOD123 DIODES	1
29	L1	Inductor SMD 10uH 6.4A, 74437349100 WURTH	1
30	L2	Inductor SMD 22uH 5A, 74437368220 WURTH	1
31	LM1	Common Inductor SMD 1K@100MHz, 2.5A, 744273102 WURTH	1
32	LM2	Common Inductor SMD 90R@100MHz, 2.0A, 744235900 WURTH	1
33	Q1	P-MOS, DMP4011SPSQ, DI5060 DIODES	1
34	Q2	N-MOS, DMTH10H015SK3Q DPAK DIODES	1
35	U1	IC AL8866Q SO-8 DIODES	1
36	PCB	PCB FR4 4sides, 1.6mm 2OZ, 80X80mm	1

System Efficiency

Figure 8 shows the efficiency curve. The efficiency is measured with a 12V DC input and 6*LED as the load.

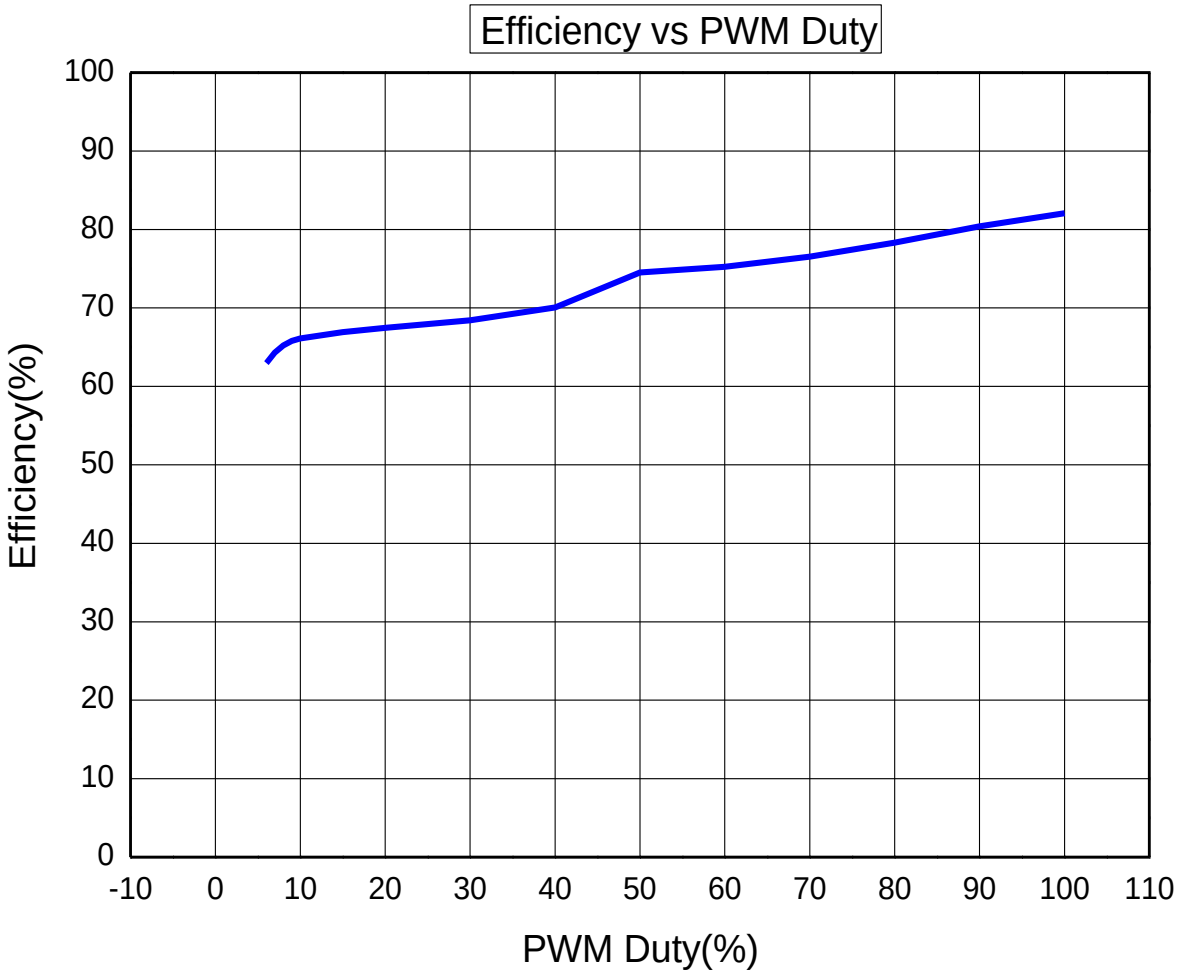


Figure 8: Efficiency Curve

PWM Dimming Performance

The AL8866Q can support PWM dimming with frequencies ranging from 200Hz to 20 kHz. Figure 9 shows the dimming curve with measured data. The AL8866Q dimming linearity is quite good with a PWM duty from 1% to 100%.

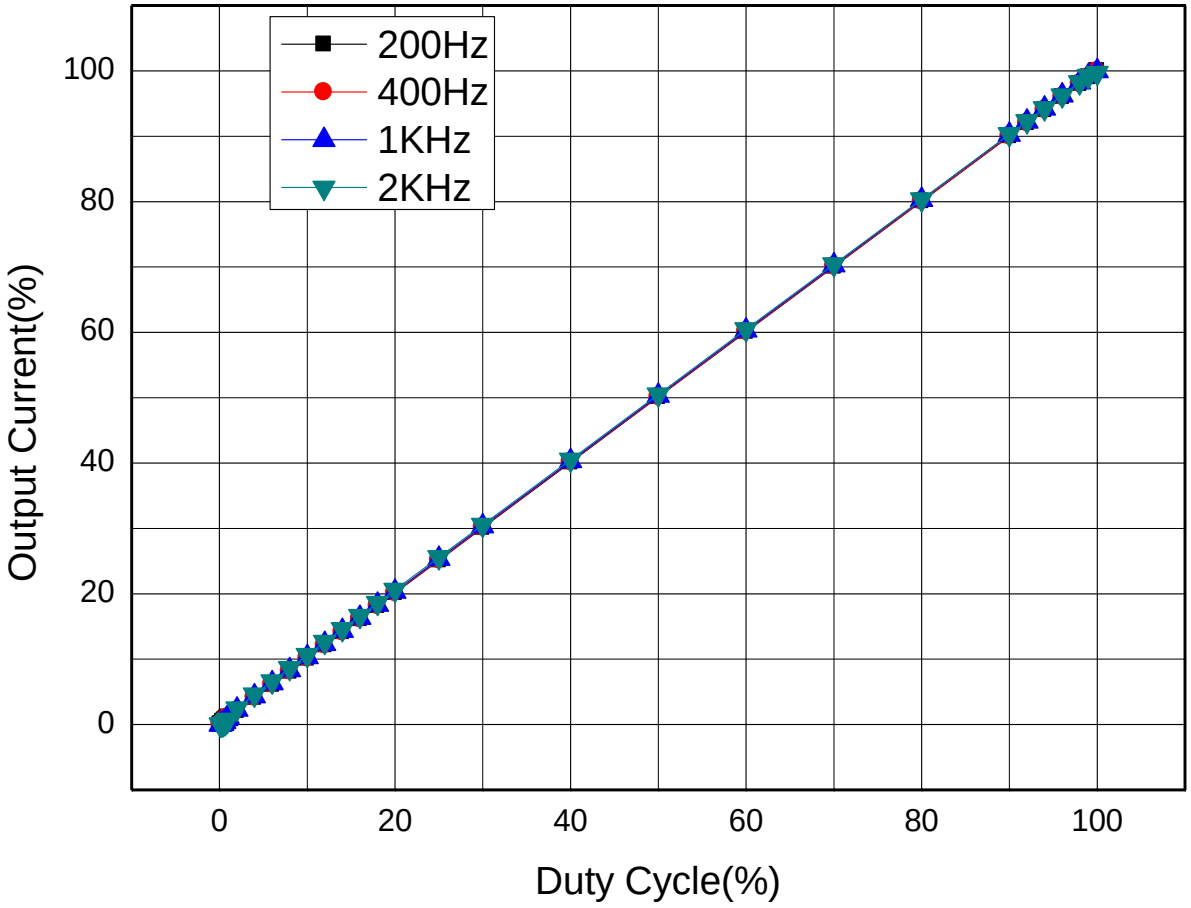


Figure 9: LED Current Percentage vs. PWM Duty

Analog Dimming Performance

The AL8866Q can support analog dimming with a CTRL voltage from 0.3V to 2.5V. Figure 10 shows the dimming curve with measured data.

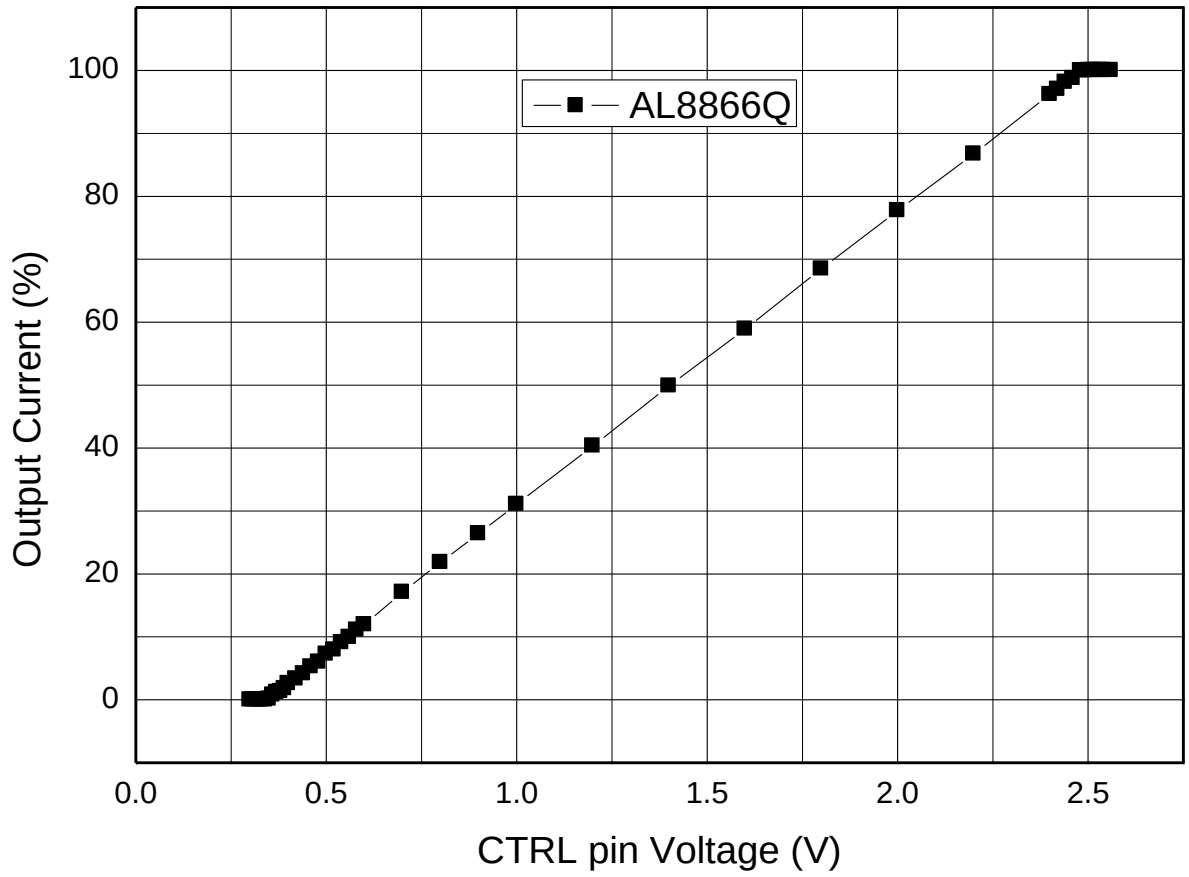


Figure 10: LED Current vs. CTRL Pin Voltage

LED Open Protection

To prevent damaging the components, the AL8866Q features output overvoltage protection. When the LED string is open, the output voltage and VOVP will immediately increase. The AL8866Q will enter hiccup mode once VOVP exceeds 2V.

Figure 11 and Figure 12 illustrate the LED open protection procedure. In the waveform, channel 1 (**yellow**) is the VPWMO signal, channel 2 (**red**) is the Vout Voltage, channel 3 (**blue**) is the VOVP, and channel 4 (**green**) is the VGATE. As seen from the waveforms: LED opens, system enters hiccup mode, LED connects, then the system resumes normal operation.

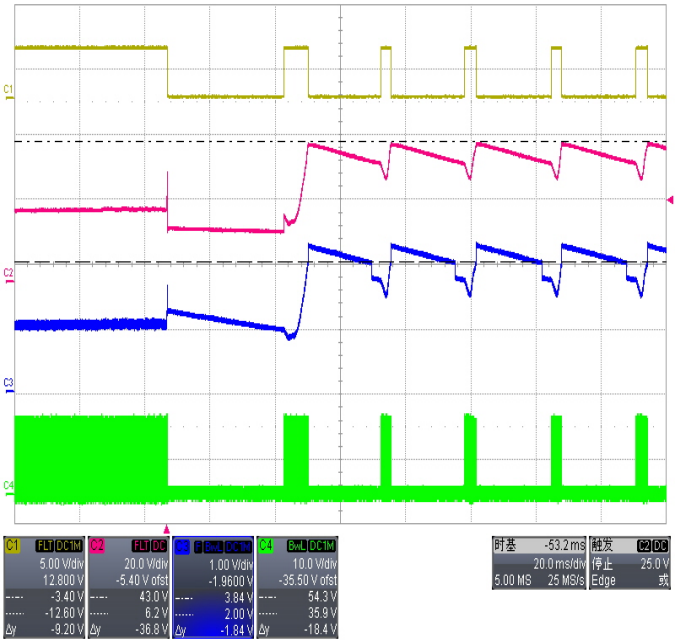


Figure 11: LED Open Expanded

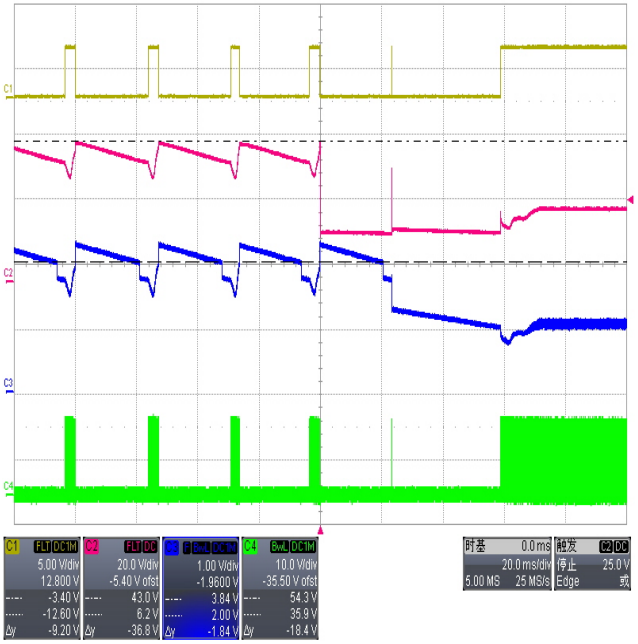


Figure 12: LED Open Removed

LED Short Protection

The AL8866Q features output LED short-circuit protection. When the LED string (LED+ to LED-) shorts, the voltage on the output capacitor decreases rapidly. Meanwhile, VOVP decreases correspondingly. When the voltage drop on the output current sense resistor, RLED, exceeds 0.36V, the output short condition will be detected.

Figure 13 and Figure 14 depict the LED short protection procedure. In the waveforms, channel 1 (**yellow**) is the PWMO signal, channel 2 (**red**) is the CS signal, channel 3 (**blue**) is the GATE signal, and channel 4 (**green**) is the LED current. As seen from the waveforms: when the LED short circuits and once the output short-circuit is detected, the switching driver will be shut down and the device will enter hiccup mode. After 30ms, the device restarts to check if the short condition is removed. If the short condition still exists, VLED should be very low. If VOVP is lower than 0.2V for 60ms, the output undervoltage protection (UVP) will activate and the device will stop switching.

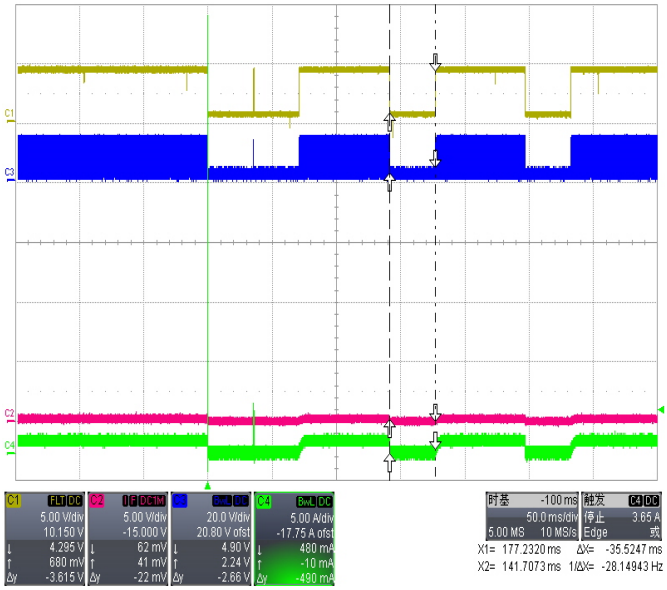


Figure 13: LED Open Expanded

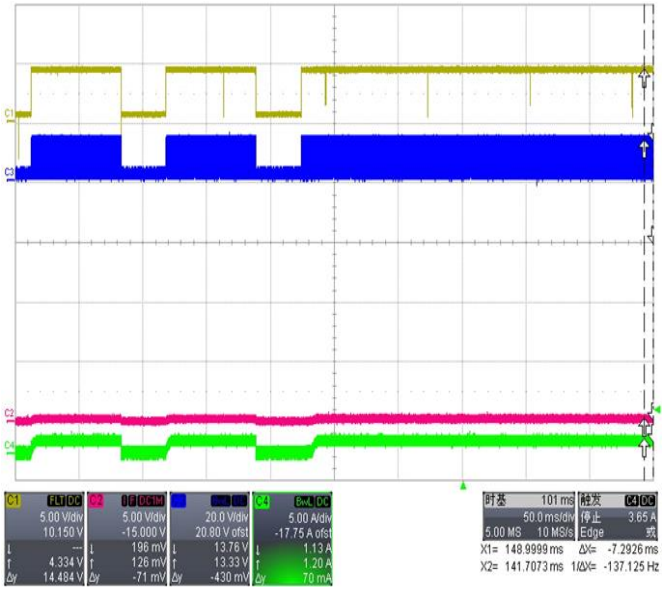
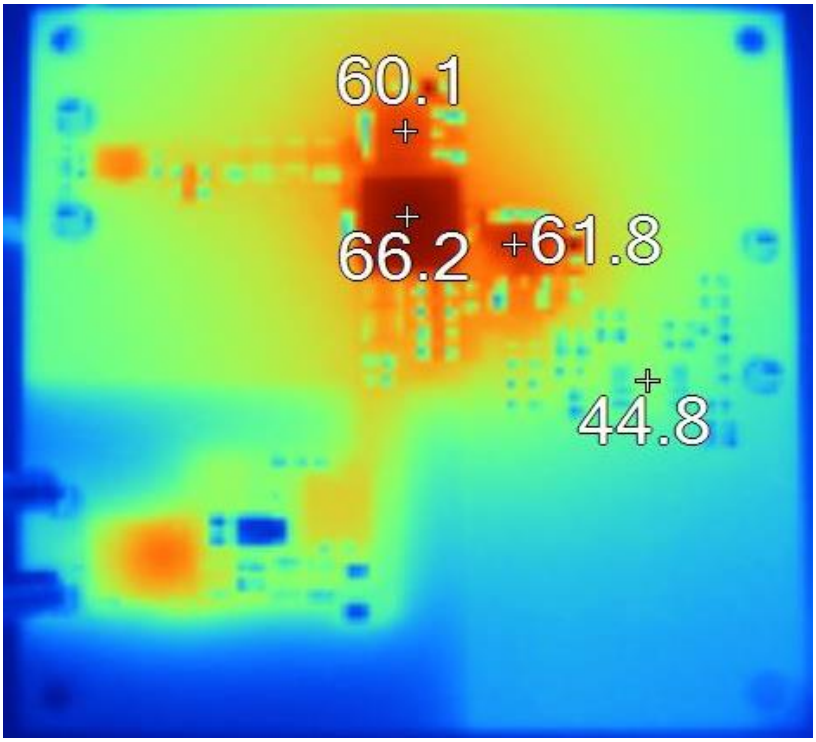


Figure 14: LED Open Removed

Thermal Test:

Test condition: V_{IN}= 12V, V_O=18V (6LEDs), Ta=26.6°C

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Efficiency (%)	Power Inductor Temp. (°C)	Diode Temp. (°C)	MOS Temp. (°C)	IC Temp. (°C)
12	1.7473	17.634	0.989	82.07	66.2	60.1	61.8	44.8



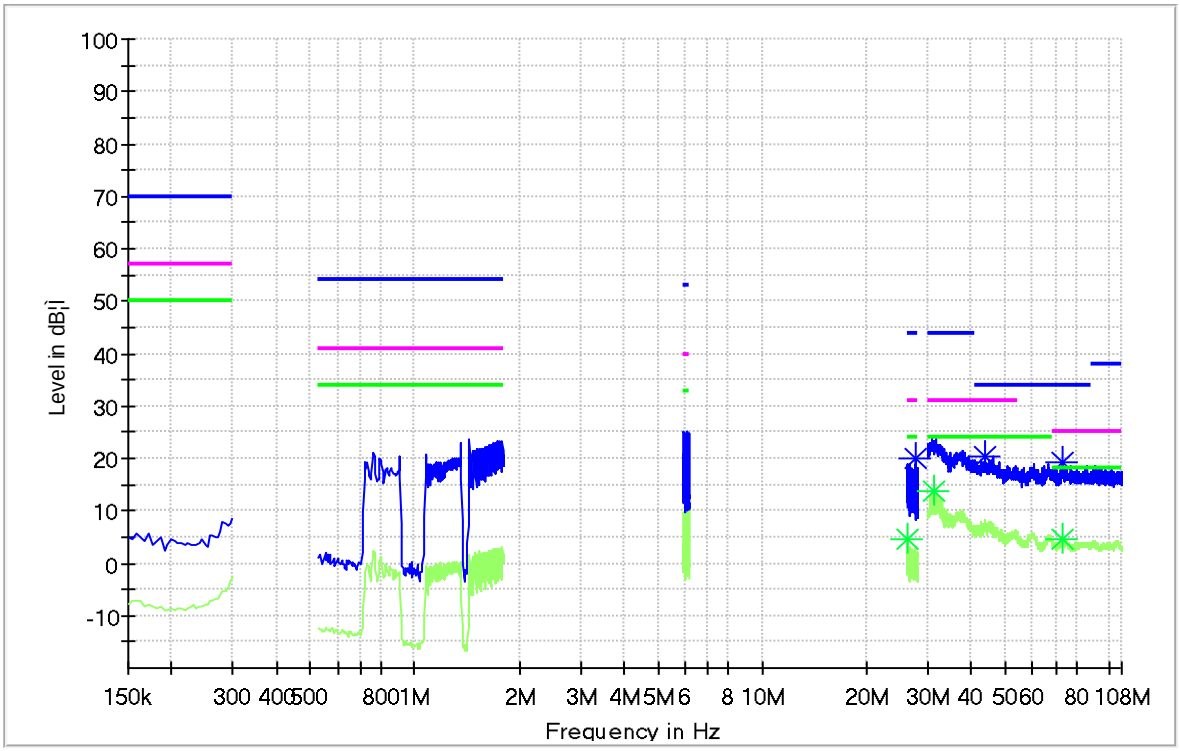
BCI Test

The EVB passes ISO11452-4 200mA BCI test without LED flicker nor output current decrease.

Conductive Emission Test

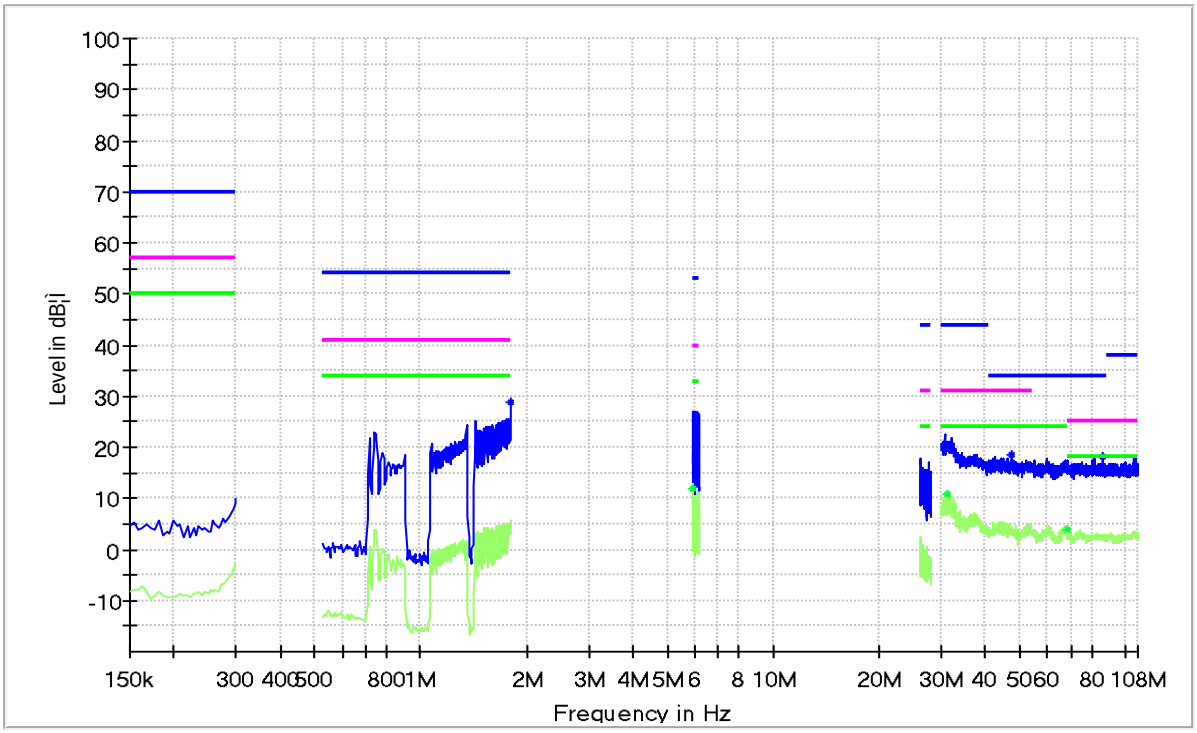
Test condition: V_{IN}= 12V, V_O=18V (6LEDs), Io=1.0A

1. CE+_0.15-28MHz CISPR 25 Class 5_Pass_10.15dB Margin



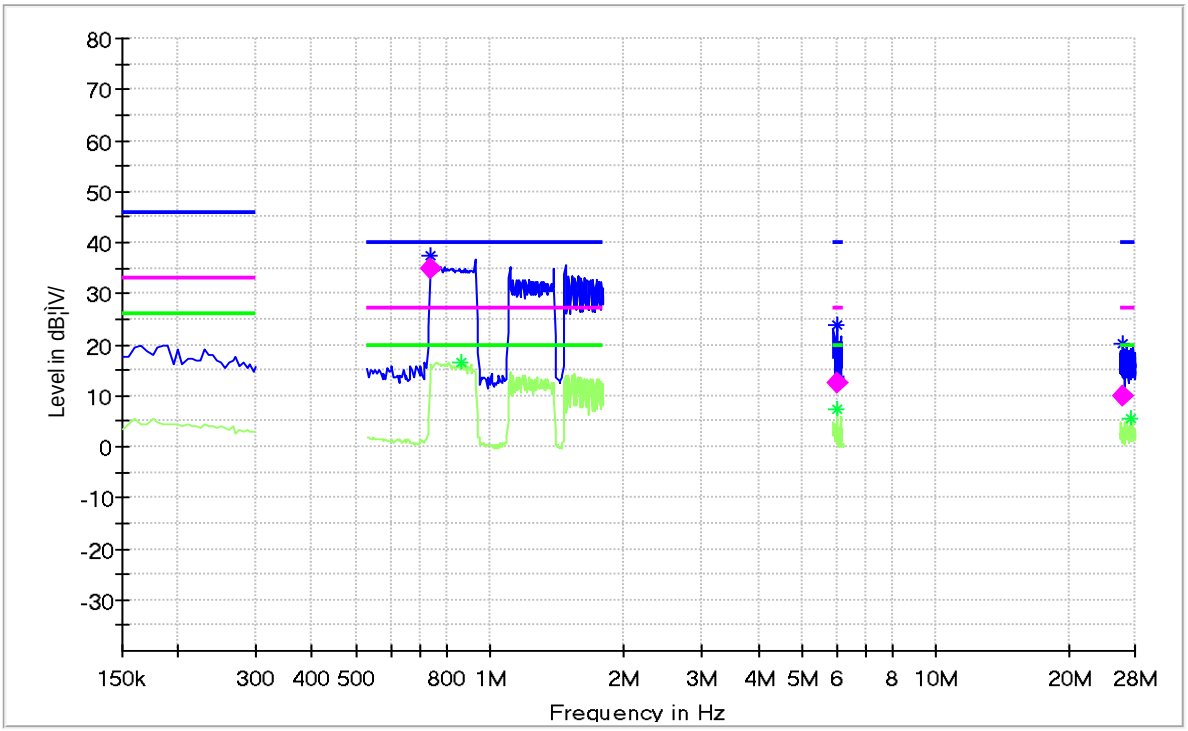
Frequency (MHz)	MaxPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)
26.202500	-	4.70	24.00	19.30	-	-
27.552500	20.01	-	44.00	23.99	-	-
31.200000	-	13.85	24.00	10.15	-	-
43.900000	20.38	-	34.00	13.62	-	-
73.050000	19.12	-	34.00	14.88	-	-
73.400000	-	4.68	18.00	13.32	-	-
Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth

2. CE-_0.15-108MHz CISPR 25 Class 5_Pass_13.12dB Margin



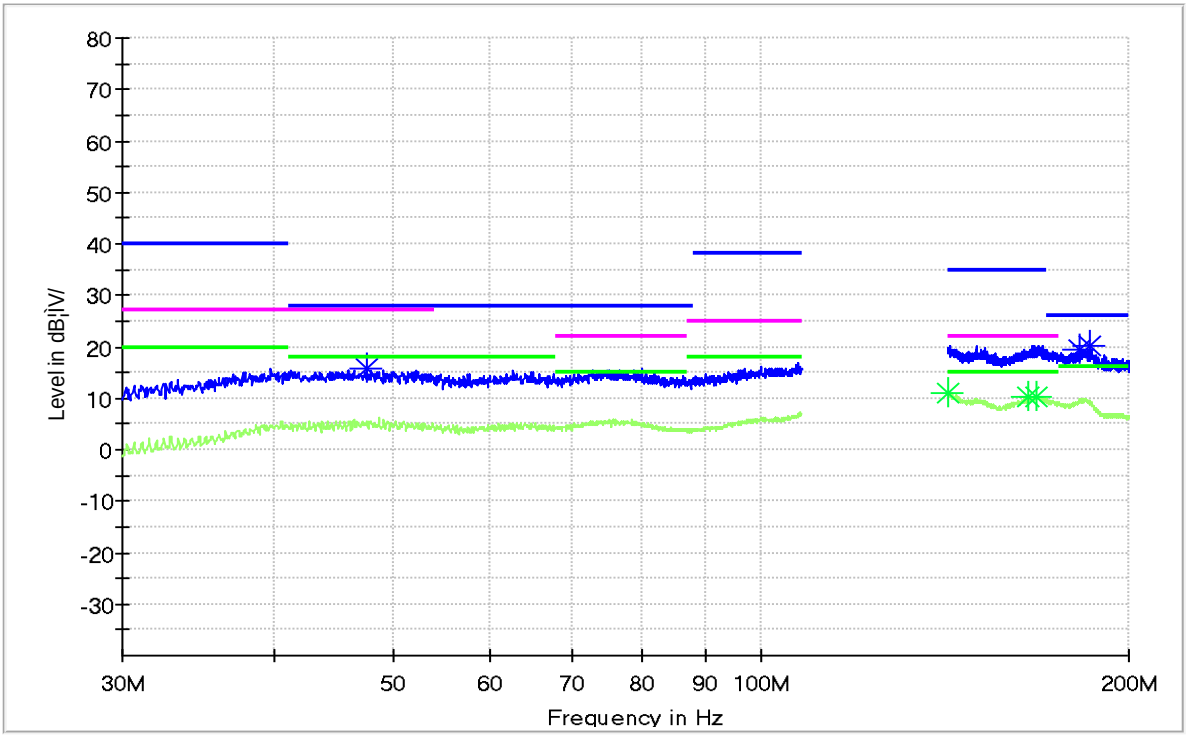
Frequency (MHz)	MaxPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)
1.800000	28.75	-	54.00	25.25	-	-
5.927000	-	12.04	33.00	20.96	-	-
31.050000	-	10.88	24.00	13.12	-	-
47.250000	18.64	-	34.00	15.36	-	-
68.150000	-	3.75	18.00	14.25	-	-
85.900000	18.31	-	34.00	15.69	-	-

3. RE_0.15-28M CISPR 25 Class 5_Pass_2.55dB Margin



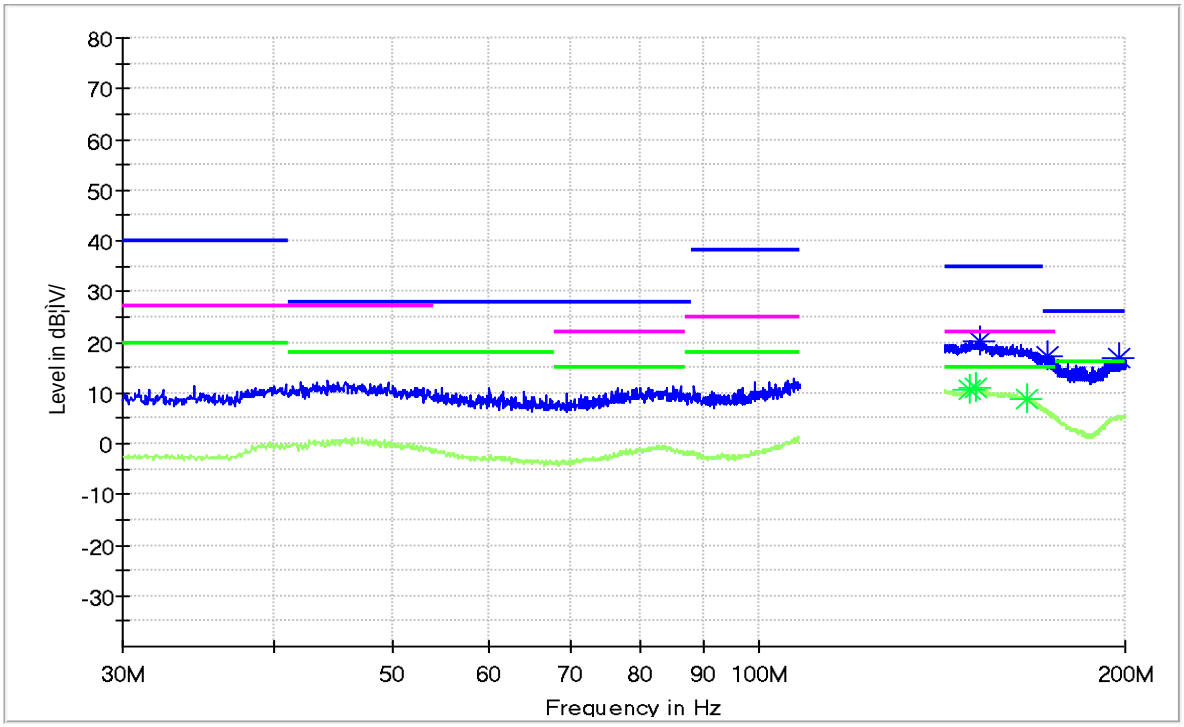
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
0.740000	37.45	-	40.00	2.55	-	-	V	12.6
0.860000	-	16.43	20.00	3.57	-	-	V	12.6
6.020000	-	7.29	20.00	12.71	-	-	V	12.9
6.025000	23.79	-	40.00	16.21	-	-	V	12.9
26.400000	20.23	-	40.00	19.77	-	-	V	13.0
27.325000	-	5.67	20.00	14.33	-	-	V	13.0

4. RE_30-200M_ Horizontal _CISPR 25 Class 5_Pass_3.93dB Margin



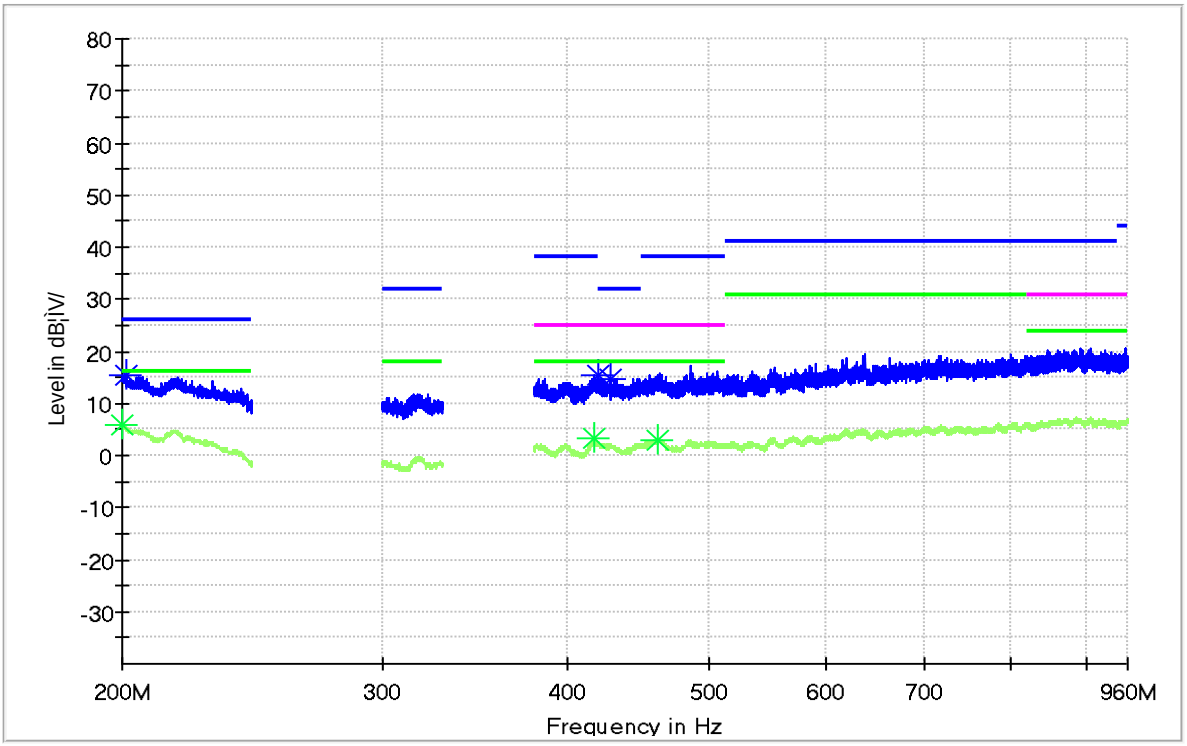
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
47.550000	15.64	-	28.00	12.36	-	-	H	-13.5
142.350000	-	11.07	15.00	3.93	-	-	H	-11.4
165.650000	-	10.10	15.00	4.90	-	-	H	-10.0
168.300000	-	10.42	15.00	4.58	-	-	H	-9.8
182.000000	19.61	-	26.00	6.39	-	-	H	-9.6
186.000000	20.24	-	26.00	5.76	-	-	H	-9.0

5. RE_30-200M_ Vertical _CISPR 25 Class 5_Pass_4.07dB Margin



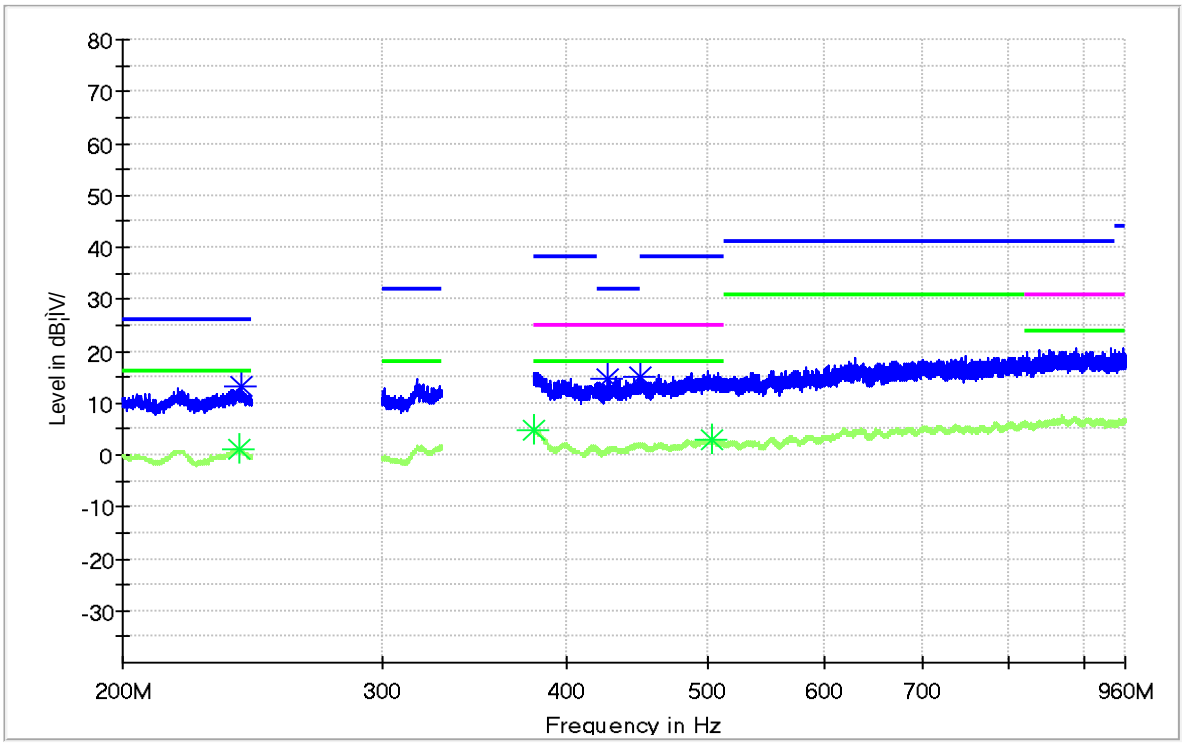
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
148.800000	-	10.80	15.00	4.20	-	-	V	-10.7
150.600000	-	10.93	15.00	4.07	-	-	V	-10.4
151.800000	20.32	-	35.00	14.68	-	-	V	-10.3
166.300000	-	8.93	15.00	6.07	-	-	V	-9.9
172.500000	17.38	-	26.00	8.62	-	-	V	-9.9
198.050000	16.98	-	26.00	9.02	-	-	V	-8.6

6. RE_200-960M_ Horizontal _CISPR 25 Class 5_Pass_10.03dB Margin



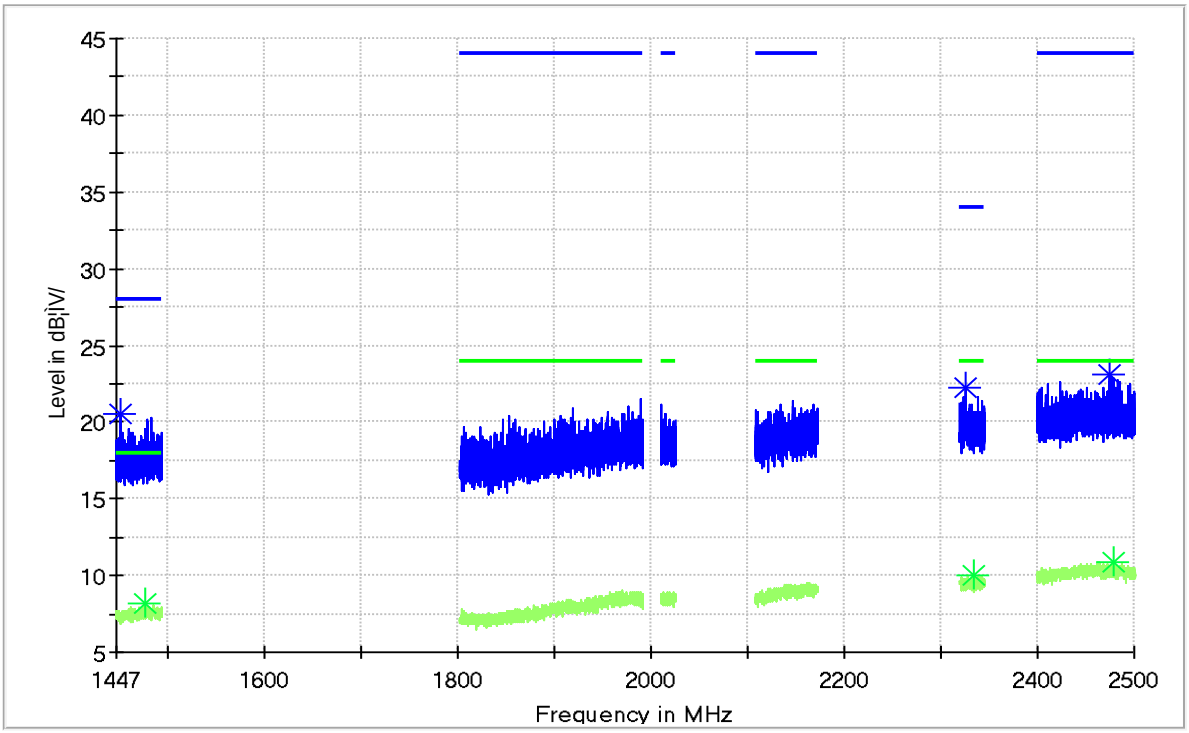
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
200.050000	-	5.97	16.00	10.03	-	-	H	-13.2
201.200000	15.53	-	26.00	10.47	-	-	H	-13.2
418.200000	-	3.16	18.00	14.84	-	-	H	-7.6
420.700000	15.26	-	32.00	16.74	-	-	H	-7.7
428.900000	14.81	-	32.00	17.19	-	-	H	-7.9
461.350000	-	3.11	18.00	14.89	-	-	H	-7.4

7. RE_200-960M Vertical _CISPR 25 Class 5_Pass_12.68dB Margin



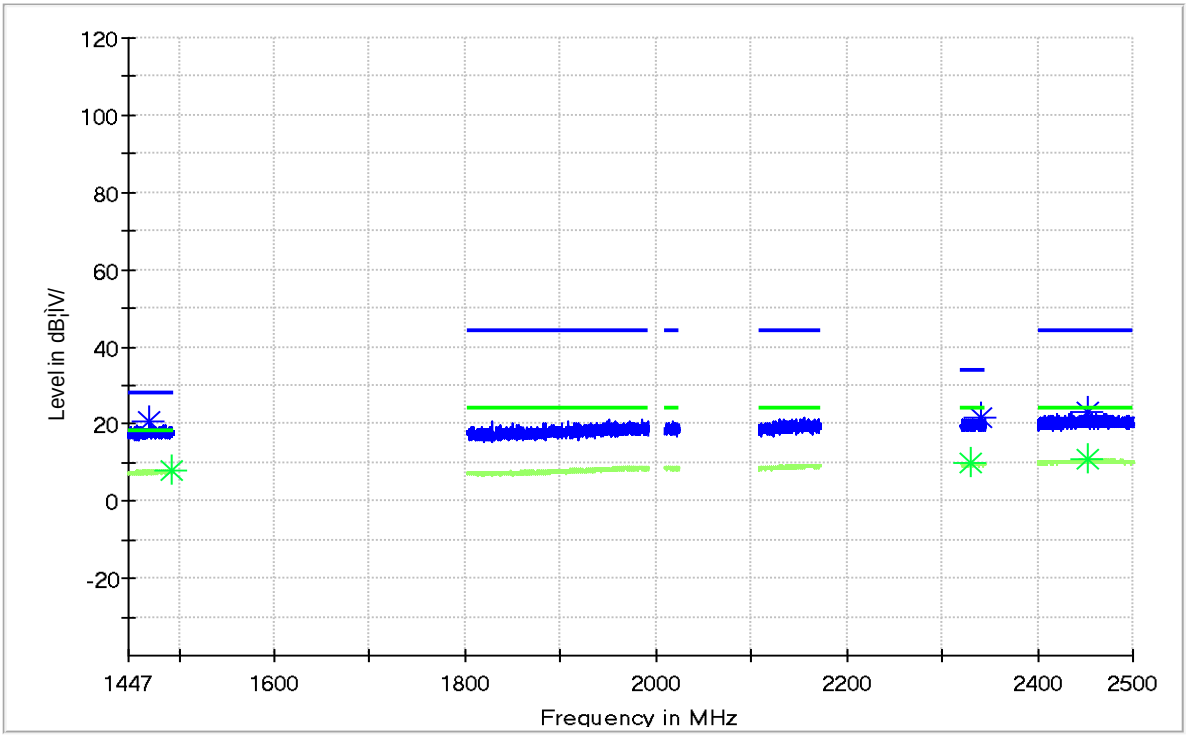
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
240.000000	-	1.20	16.00	14.80	-	-	V	-12.4
240.750000	13.32	-	26.00	12.68	-	-	V	-12.5
380.150000	-	4.94	18.00	13.06	-	-	V	-9.0
427.400000	14.55	-	32.00	17.45	-	-	V	-8.0
449.950000	15.19	-	32.00	16.81	-	-	V	-7.0
502.600000	-	3.05	18.00	14.95	-	-	V	-6.5

8. RE_1447-2500M Horizontal _CISPR 25 Class 5_Pass_7.51dB Margin



Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
1450.750000	20.49	-	28.00	7.51	5.0	120.000	H	-12.0
1476.800000	-	8.20	18.00	9.80	5.0	120.000	H	-12.0
2326.000000	22.24	-	34.00	11.76	5.0	120.000	H	-9.4
2334.750000	-	9.98	24.00	14.02	5.0	120.000	H	-9.4
2474.750000	23.16	-	44.00	20.84	5.0	120.000	H	-8.6
2478.000000	-	10.93	24.00	13.07	5.0	120.000	H	-8.6

9. RE_1447-2500M Vertical _CISPR 25 Class 5_Pass_7.53dB Margin



Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas._Time (ms)	Bandwidth (kHz)	Pol	Corr. (dB/m)
1468.100000	20.47	-	28.00	7.53	5.0	120.000	V	-12.0
1492.550000	-	8.12	18.00	9.88	5.0	120.000	V	-12.0
2330.650000	-	10.00	24.00	14.00	5.0	120.000	V	-9.4
2339.650000	21.64	-	34.00	12.36	5.0	120.000	V	-9.4
2452.700000	-	10.95	24.00	13.05	5.0	120.000	V	-8.6
2452.750000	23.34	-	44.00	20.66	5.0	120.000	V	-8.6

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