# AL8859QEV1 User Guide
## 60V Multiphase Boost Controller

## General Description

This demonstration board utilizes the AL8859Q to build a highly efficient boost controller for the front power stage of LED drivers. It is designed for automotive matrix front lighting applications like high beams, low beams, DRLs (daytime running lights), turn indicators, fog lights, static cornering, and more. Together with high-current LED drivers, the AL8859Q can provide a complete solution to drive multiple LED strings of up to 60V.

This user guide contains a bill of materials that describes the parts used on this board. A schematic and PCB layout is also included, along with measured system performance characteristics and test waveforms. These materials can be used as a reference design for your products to improve their time to market.

## Key Features

- AEC-Q100 Grade 1 Qualified
- Multiphase booster controller integrated single chip
- Functional-safety capable
- Active input filter with low current ripple from battery
- Spread spectrum with low EMI emission
- Soft-start
- SPI interface
- Fail Safe Operating (FSO) mode, Stand-Alone mode
- Integrated failure diagnostics

## Applications

- Adaptive head lights
- Daytime running lights (DRLs)
- Position or park lights
- Turn indicators
- Fog lights
- Static cornering

## Specifications

| Parameter | Value |
|---|---|
| Input Voltage | 9V~16Vdc |
| Output Power | 100W |
| Output Current | 2000mA |
| Output Voltage | 50V |
| Dimension | 122mm*70mm*38mm |
| RoHS Compliance | Yes |

## Evaluation Board

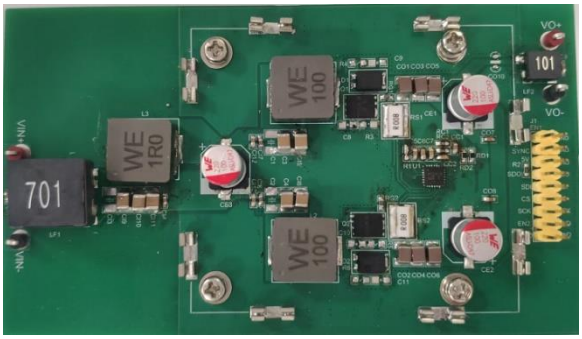


**Figure 1: Top View**

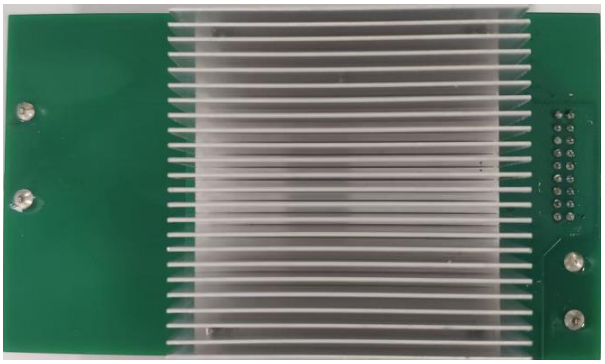

**Figure 2: Bottom View**

**Connection Instructions:**

DC Positive Input: Red Test Point (VIN+)
DC Negative Input: Black Test Point (VIN-)
PWM Signal Input: J1-SYNC and J1-GND
Enable1 Input: J1-EN1 and J1-GND
Enable2 Input: J1-EN2 and J1-GND
Positive Output: Red Test Point (VO+)
Negative Output: Black Test Point (VO-)


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## Board Layout

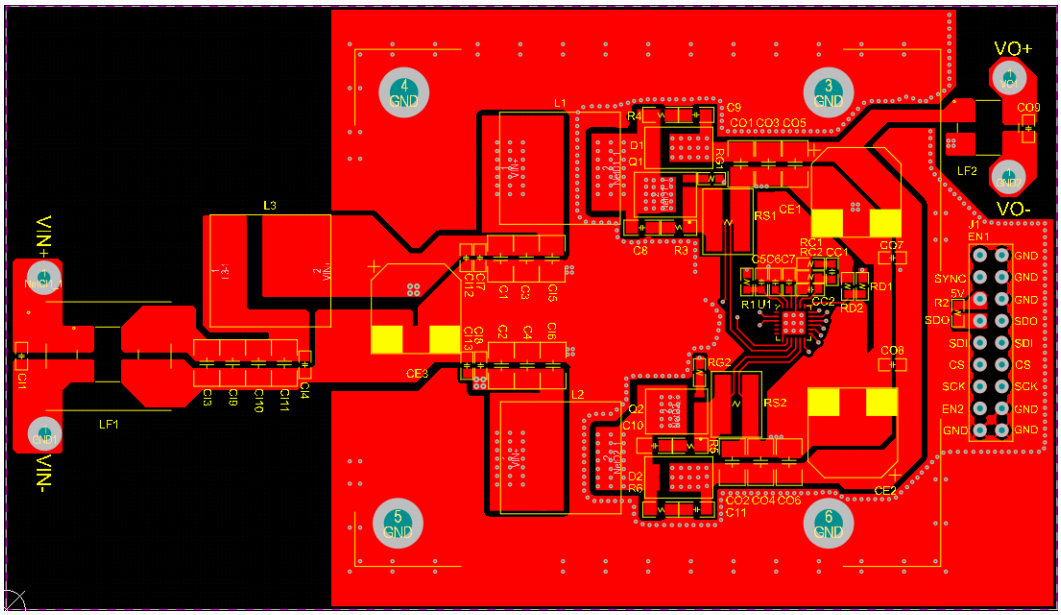


**Figure 3: PCB Layout Top View**

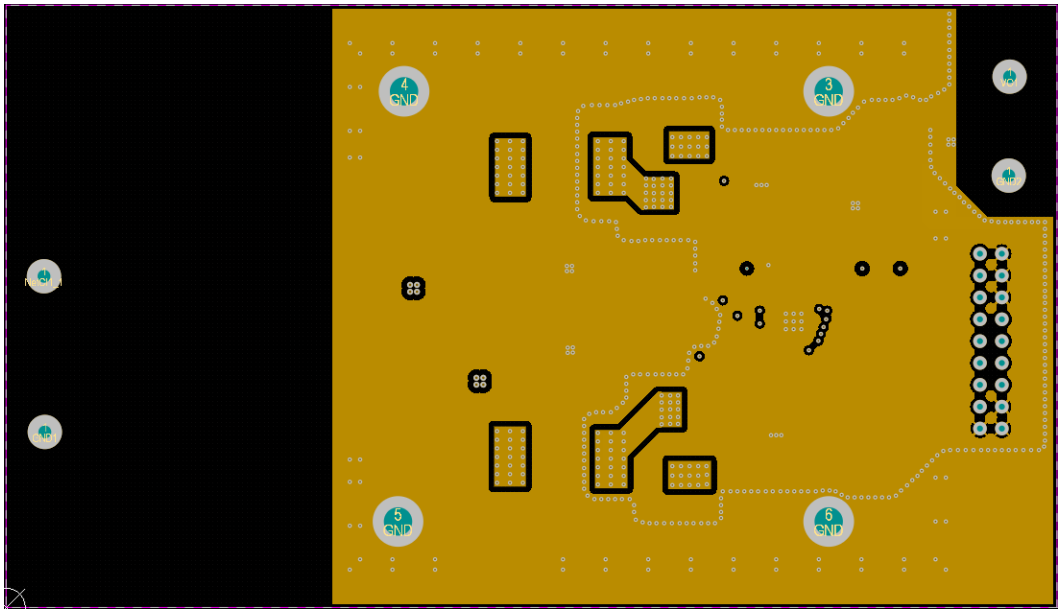


**Figure 4: PCB Layout MidLayer1 View**


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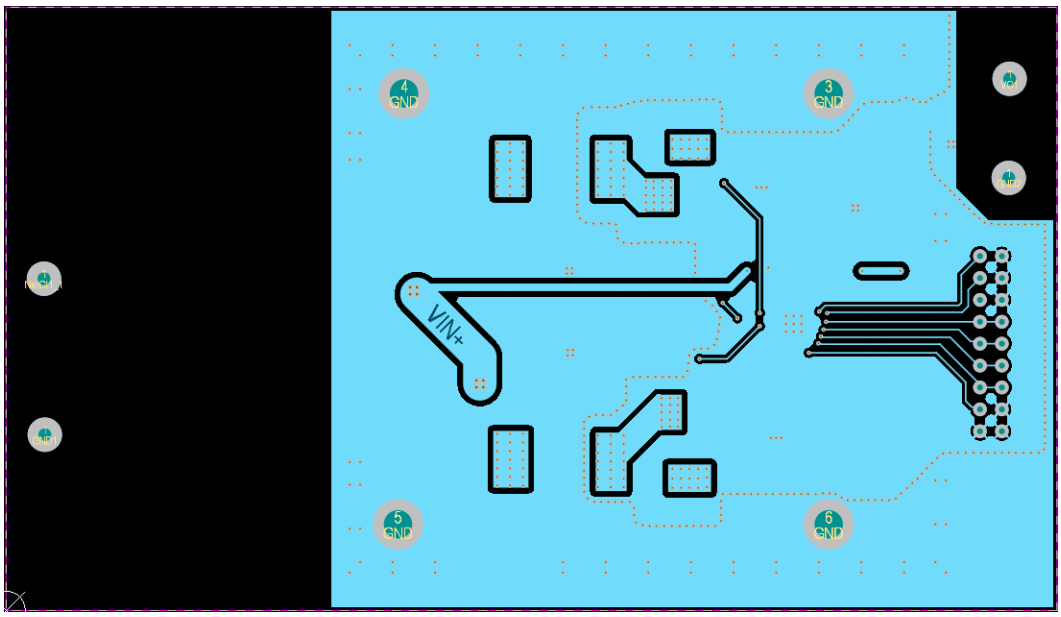


**Figure 5: PCB Layout MidLayer2 View**

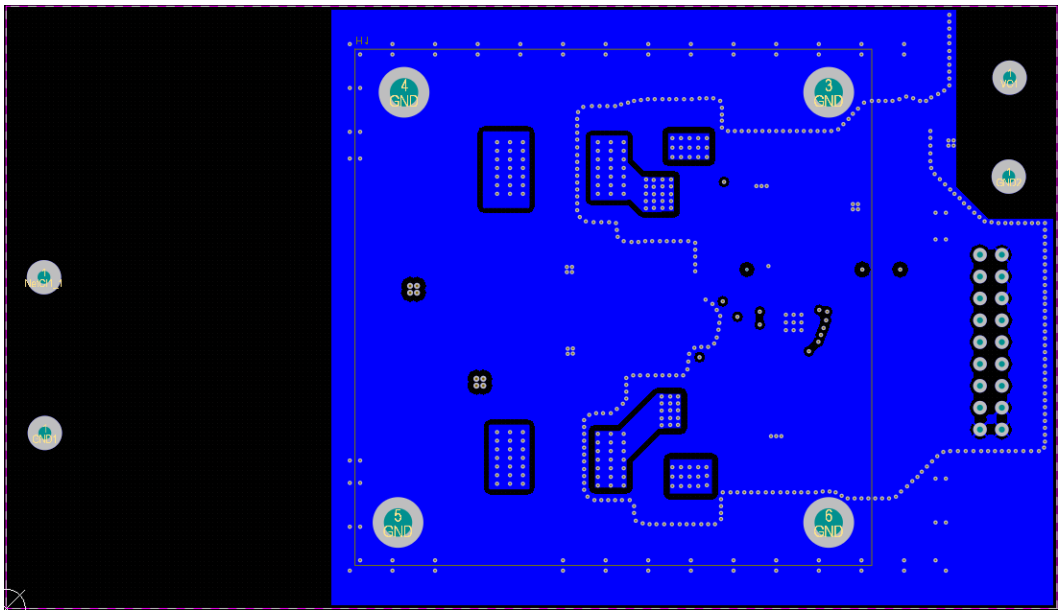


**Figure 6: PCB Layout Bottom View**


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## Quick Start Guide

1. Ensure that the power supply and external clock signal are switched OFF or disconnected.
2. Connect the Battery (12Vdc) supply to the test point “VIN+” and “VIN-”.
3. Connect the Enable1 input (5Vdc) to the “J1-EN1” and “J1-GND”.
4. Connect external clock signal (5Vmax, 400kHz, 50%) to the “J1-SYNC” and “J1-GND”.
5. Connect the load positive to the test point “VO+”.
6. Connect the load negative to the test point “VO-”.
7. If the demo board does not have an MCU, the demo board will output CV50V,2A according to the default parameters.
8. If the user wants to enter FSO mode, follow the steps below:
   a. Connect the Enable2 input (5Vdc) to the “J1-EN2” and “J1-GND”
   b. Turn on the Enable2 power supply and then turn off; the device will enter FSO mode
   c. If you want to exit FSO mode, turn on the Enable2 power supply
9. If the demo board has an MCU, you can modify the data of the registers through the MCU using the steps below:
   a. Connect the input (5Vdc) to the “J1-5V” and “J1-GND”
   b. Connect the MISO of the MCU to the “J1-MISO”
   c. Connect the MOSI of the MCU to the “J1-MOSI”
   d. Connect the SCK of the MCU to the “J1-SCK”
   e. Connect the CS of the MCU to the “J1-CS”
   f. Connect the GND of the MCU to the “J1-GND”

**Register-100W**

| ADDR | bit9 | bit8 | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0x01 | BOOST_DIV3 | VBOOST_VGATE_TH | VDRIVE_VSETPOINT[3:0] | | | | BOOST_OTA_GAIN[1:0] | | BOOST_SKCL[1:0] | |
| | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 0x02 | 0 | BOOST_SLPCTRL[2:0] | | | BOOST_VLIMTH3[1:0] | | BOOST_VLIMTH2[1:0] | | BOOST_VLIMTH1[1:0] | |
| | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0x03 | BOOST_MULTI_PHASE_MD[1:0] | | BOOST_SRCINV | BOOST_OVERVOLTSD_THR[6:0] | | | | | | |
| | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x04 | FSO_BST_FREQ[2:0] | | | BOOST_VSETPOINT[6:0] | | | | | | |
| | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0x05 | TSD_AUT_RCVR_EN | ADC_TEMP_THR[2:0] | | | FSO_MD[2:0] | | | BOOST3_EN | BOOST2_EN | BOOST1_EN |
| | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |
| 0x06 | BOOST_OV_REACT[1:0] | | VBOOST_TON_SET[2:0] | | | VBOOST_TOFF_SET[2:0] | | | FSO_ENABLE_SEL | VDD_ENA |
| | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 0x07 | P_DISTRIBUTION2[4:0] | | | | | P_DISTRIBUTION1[4:0] | | | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x08 | 0 | VDRIVE_UV_THR[2:0] | | | P_DISTRIBUTION3[4:0]* | | | | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |


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## Schematic

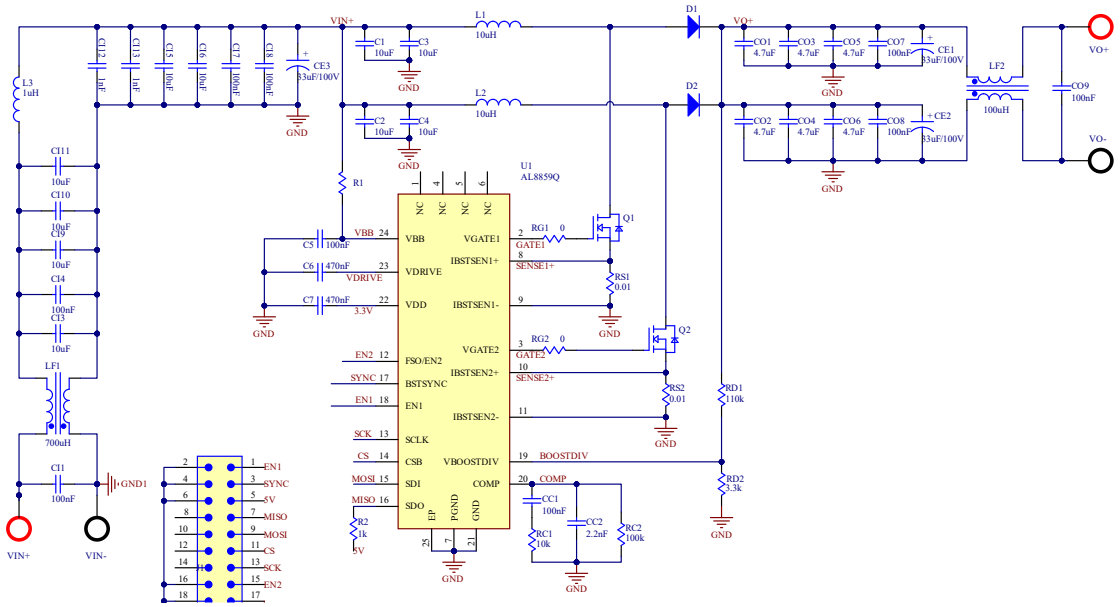


**Figure 7: Schematic Circuit**


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## Bill of Materials

| Designator | Description | Package | Manufacturer | Manufacturer P/N | Quantity |
|---|---|---|---|---|---|
| U1 | AL8859QA0, Boost controller | QFN4040 | Diodes | AL8859QA0DKCW24-13 | 1 |
| L1, L2 | LHCA 10uH, 20%, 15.9A, 15mΩ, 13*13 | SMD | Wurth | 784373865100 | 2 |
| L3 | LHCA 1uH, 20%, 44.8A, 15mΩ, 13*14 | SMD | Wurth | 784373865010 | 1 |
| LF1 | CM inductor SCM-1513-701-F 700R@100MHz | SMD | 冀晏 | SCM-1513-701-F | 1 |
| LF2 | CM inductor SCM-7060-101-F 100R@100MHz, Ji Yan | SMD | 冀晏 | SCM-7060-101-F | 1 |
| Q1, Q2 | DMTH8028LPSWQ, 41.7A, 80V, 25mΩ | PowerDI5060-8 | Diodes Incorporated | DMTH8028LPSWQ | 2 |
| D1, D2 | PDS5100Q,5A,100V | PowerDI5 | Diodes Incorporated | PDS5100HQ | 2 |
| RS1, RS2 | Resistor, SMT,0.008 ohm, 1225, 1% | 1225 | - | - | 2 |
| R1 | Resistor, SMT, 0 ohm, 0603, 5% | 0603 | - | - | 1 |
| R2 | Resistor, SMT,1K ohm, 0603, 5% | 0603 | - | - | 1 |
| RC1 | Resistor, SMT,10K ohm, 0603, 5% | 0603 | - | - | 1 |
| RC2 | Resistor, SMT,100K ohm, 0603, 5% | 0603 | - | - | 1 |
| RD1 | Resistor, SMT,107K ohm, 0603, 1% | 0603 | - | - | 1 |
| RD2 | Resistor, SMT,3.24K ohm, 0603, 1% | 0603 | - | - | 1 |
| RG1, RG2 | Resistor, SMT,2.2 ohm, 0603, 1% | 0603 | - | - | 2 |
| CO1, CO2, CO3, CO4, CO5, CO6 | Cap, Cer, 4.7uF, 100V, X7S, 1210, -55°C~125°C, AEC-Q200 | 1210 | muRata | GCJ32DC72A475KE01L | 6 |
| C1, C2, C3, C4, CI5, CI6, CI9, CI10, CI11 | Cap, Cer, 10uF, 100V, X7S, 1210, -55°C~125°C, AEC-Q200 | 1210 | muRata | GCJ32DC72A106KE01L | 9 |
| CI1, CO7, CO8, CO9, CC1, C5 | Cap, Cer, 100nF, 100V, X7R, 0603, -55°C~125°C, AEC-Q200 | 0603 | TDK | CGA3E2X7R2A104K080AA | 6 |
| CI4, CI7, CI8 | Cap, Cer, 68nF, 100V, X7R, 0603, -55°C~125°C, AEC-Q200 | 0603 | TDK | CGA3E2X7R2A683K080AA | 3 |
| CI12, CI13 | Cap, Cer, 1nF, 100V, X7R, 0603, -55°C~125°C, AEC-Q200, | 0603 | TDK | CGA3E2X7R2A102K080AA | 2 |
| C6, C7 | Cap, Cer, 470nF, 100V, X7R, 0603, -55°C~125°C, AEC-Q200 | 0603 | TDK | CGA3E2X7R2A474K080AA | 2 |
| CC2 | Cap, Cer, 100V, X7R, 0603, -55°C~125°C, AEC-Q200 | 0603 | TDK | CGA3E2X7R2A682K080AA | 1 |
| CE1, CE2, CE3 | Ecap MH 22uF 100V Φ8mm 20% | SMD | Aishi | EMH1KM220FB0D00T | 1 |
| J1 | 9P*2 | DIP | - | - | 1 |
| VIN+, VO+ | Connector, Red color | DIP | - | - | 2 |
| VIN-, VO- | Connector, Black color | DIP | - | - | 2 |
| H1 | Heatsink 60*60*25mm | - | - | - | 1 |
| Thermal Pad | 60*60mm | - | Wurth | 404035125 | 1 |
| Shielding cover bracket | 8.79*2.28*3.55mm, copper alloy, tin-plated | - | HARWIN | S2711-46R | 8 |
| Metal shielding cover | 68*60*16mm, thickness 0.5mm | - | - | - | 1 |
| Screw | M3*5mm | - | - | - | 4 |


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## System Efficiency

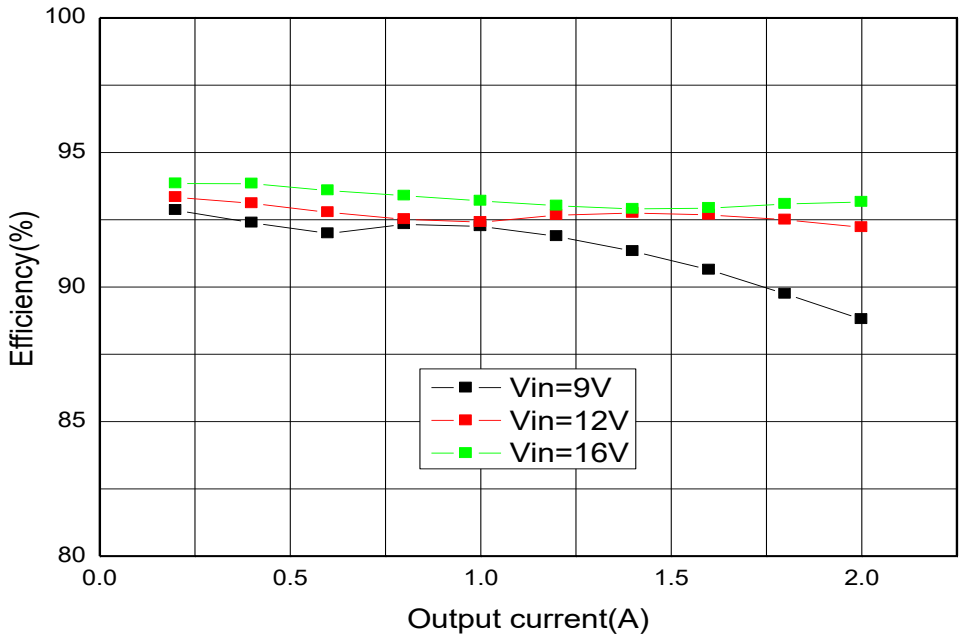


**Figure 8: Efficiency vs Out Current**

| Output Current (A) | Efficiency (%) | | |
|---|---|---|---|
| | Vin=9V | Vin=12V | Vin=16V |
| 0.2 | 92.86 | 93.34 | 93.85 |
| 0.4 | 92.39 | 93.11 | 93.84 |
| 0.6 | 91.99 | 92.78 | 93.59 |
| 0.8 | 92.33 | 92.52 | 93.39 |
| 1.0 | 92.25 | 92.41 | 93.20 |
| 1.2 | 91.89 | 92.67 | 93.02 |
| 1.4 | 91.33 | 92.75 | 92.90 |
| 1.6 | 90.64 | 92.68 | 92.93 |
| 1.8 | 89.74 | 92.50 | 93.09 |
| 2.0 | 88.80 | 92.22 | 93.16 |


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## System Line Regulation

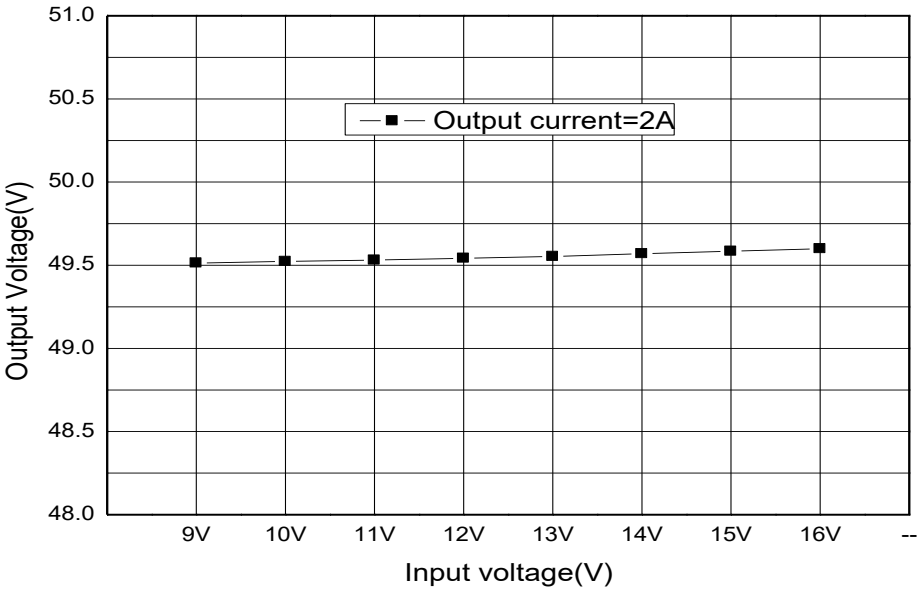


**Figure 9: Output Voltage vs Input Voltage**

## System Load Regulation

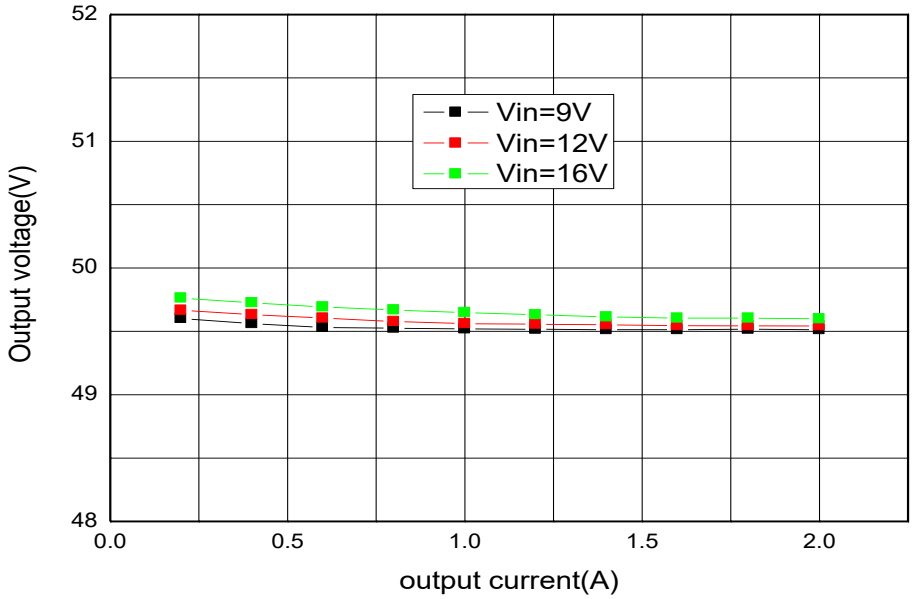


**Figure 10: Output Voltage vs Out Current**


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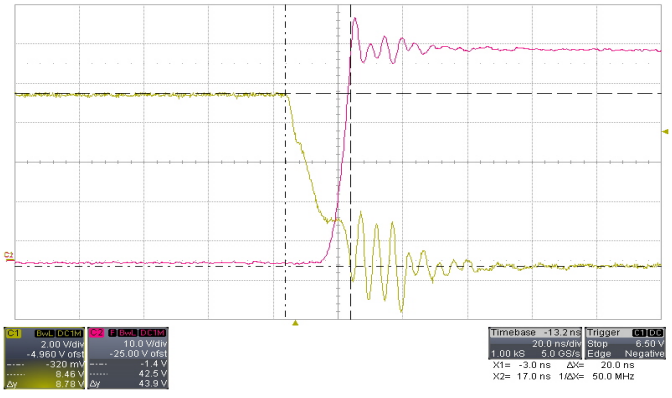
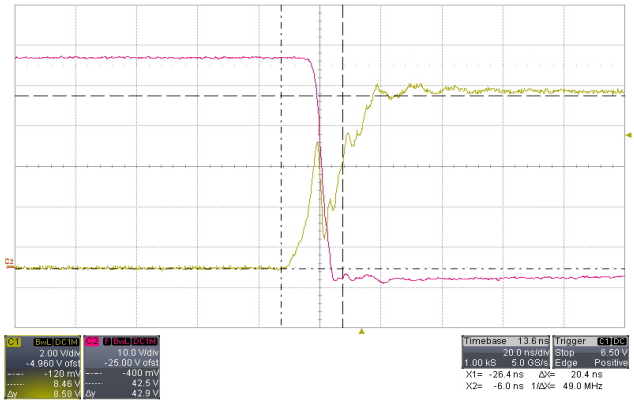
## System Waveform

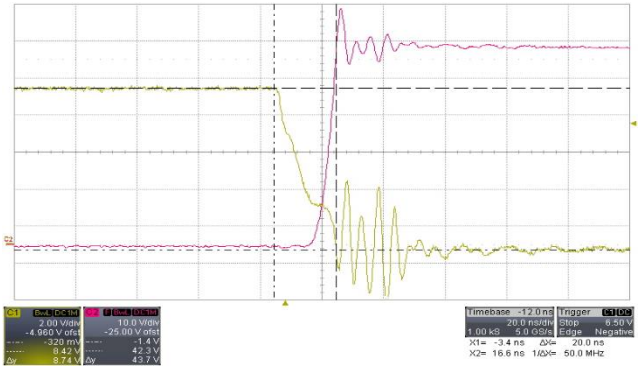
Gate Drive



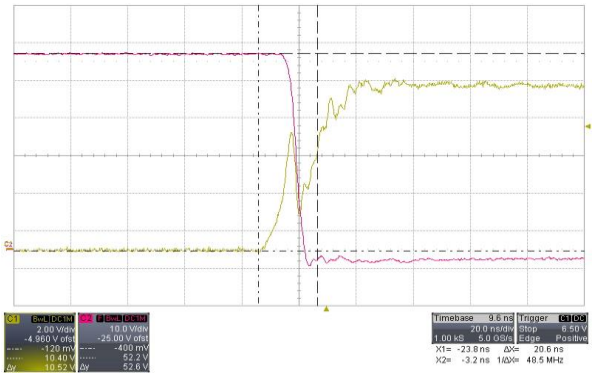
Q1 rising edge Tr=20ns



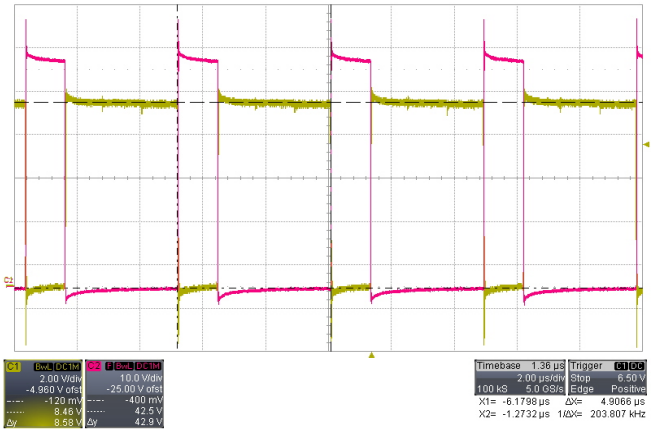
Q1 falling edge Tf=20.4ns



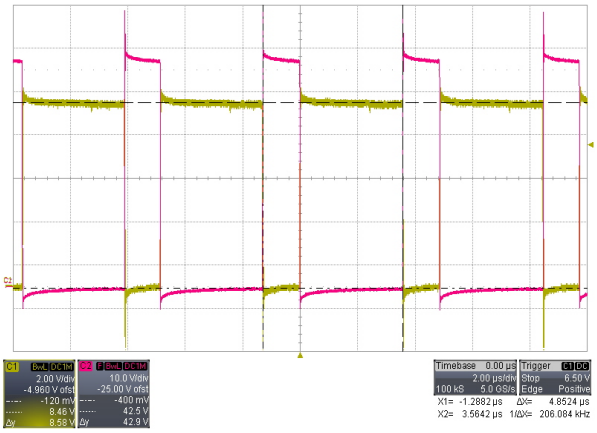
Q2 rising edge Tr=20ns



Q2 falling edge Tf=20.6ns



Q1 frequency f=203.8kHz



Q2 frequency f=206kHz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## Output Ripple

Vout

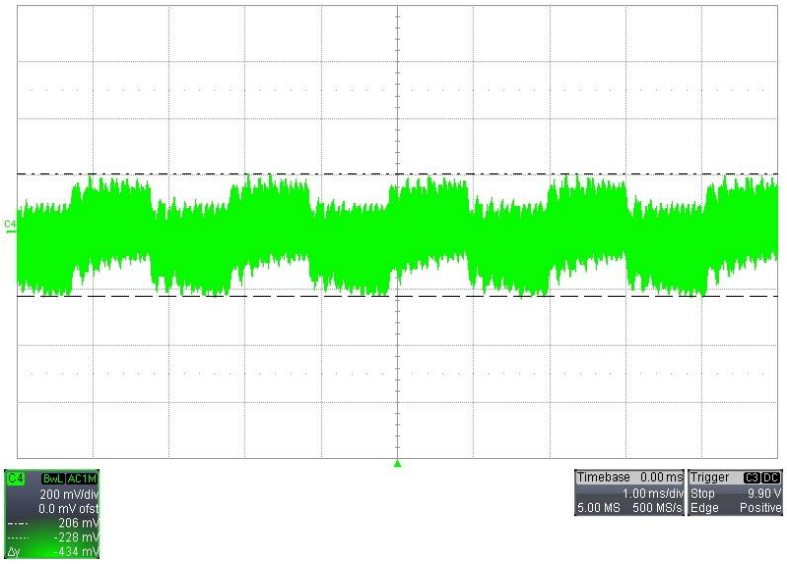


**Figure 11: Output Ripple=±0.4%**

## Start up Vin

Vdrive | Vin | Vgate | VDD

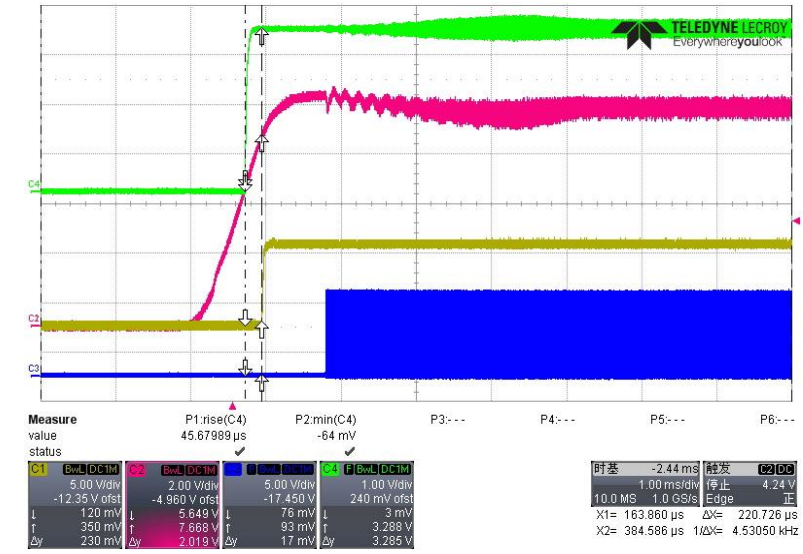


**Figure 12: Vin=9V**


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## Dynamic Hysteresis

**Vgate** | **VDD**

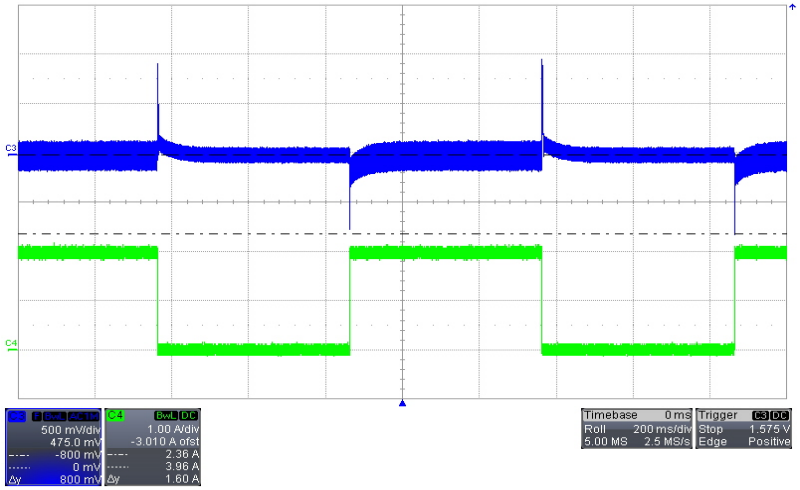


**Figure 12: $V_{undershoot}$=0.8V**

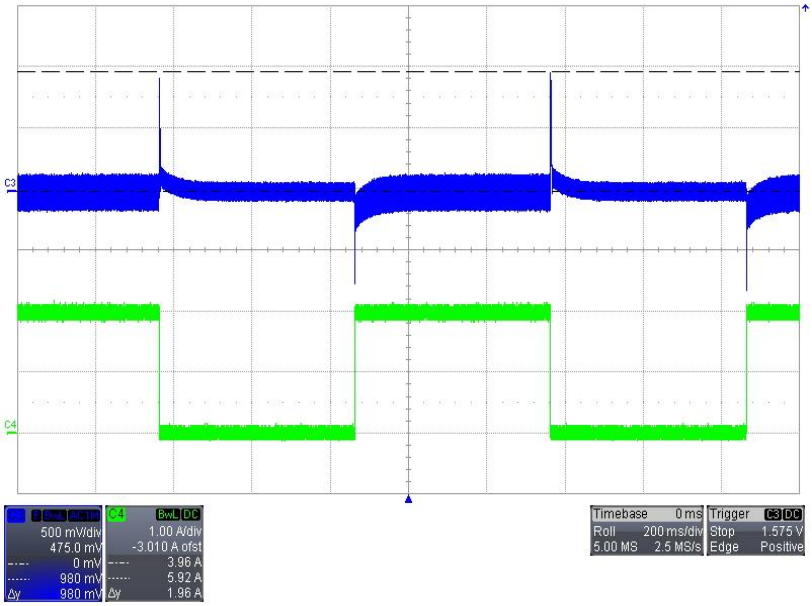


**Figure 13: $V_{overshoot}$=0.98V**


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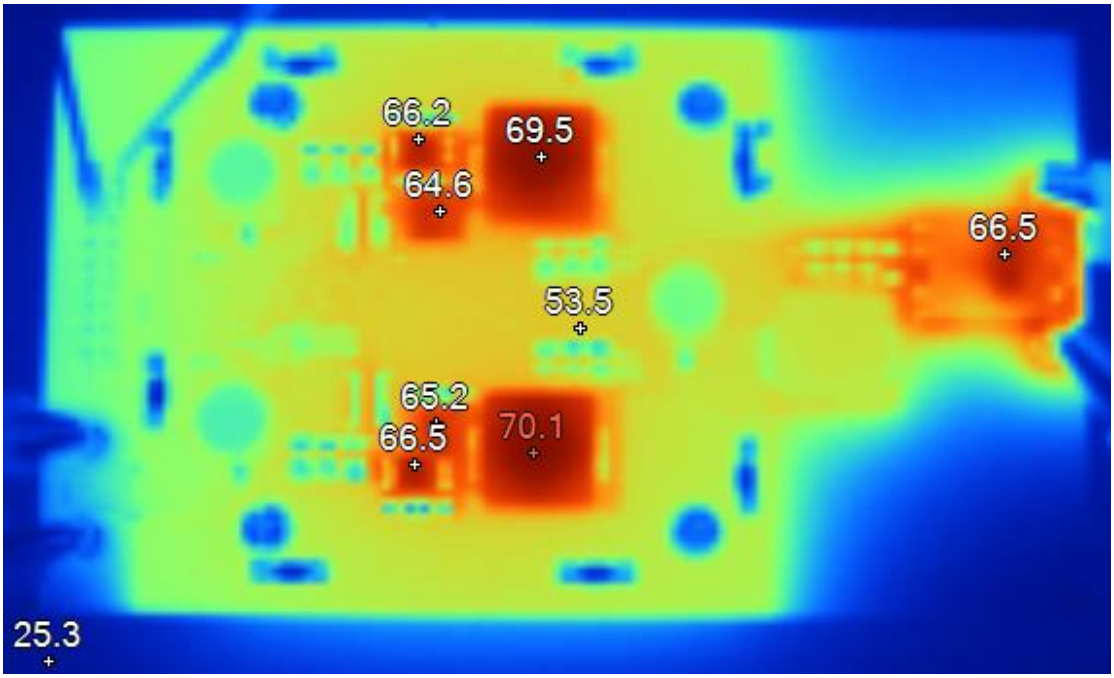
## Thermal Test

Test condition: $V_{IN}$= 12V, $V_O$=50V, Ta=28.1℃

| Vin (V) | Iin (A) | Vout (V) | Iout (A) | Efficiency (%) | Power Inductor L1 Temp (℃) | Power Inductor L2 Temp (℃) |
|---|---|---|---|---|---|---|
| 13.5 | 7.808 | 49.278 | 1.9978 | 93.4 | 70.1 | 70.1 |
| MOS Q1 Temp (℃) | MOS Q2 Temp (℃) | Diode D1 Temp (℃) | Diode D2 Temp (℃) | EMC Inductor LF1 Temp (℃) | Ambient Temp (℃) | - |
| 65.2 | 64.6 | 66.5 | 66.2 | 66.5 | 25.3 | - |





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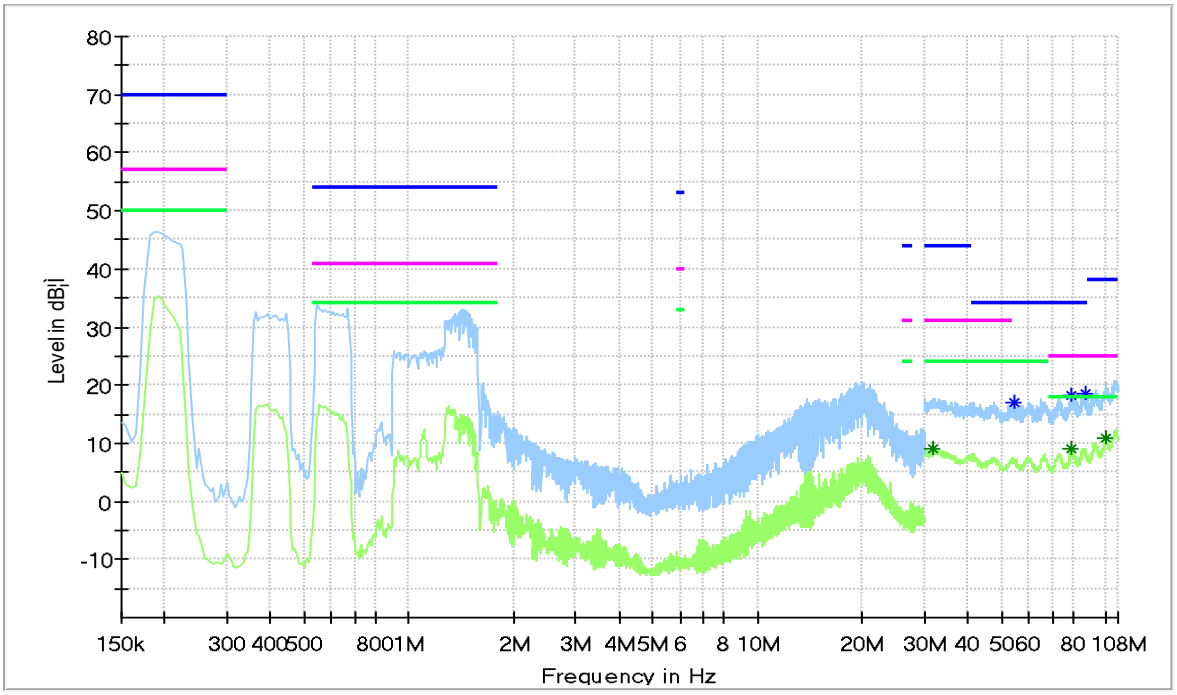
## Conductive Emission Test

Test condition: $V_{IN}$= 12V, $V_O$=6.6V (2LEDs), Io=1.5A

1. CE+_0.15-28MHz CISPR 25 Class 5_Pass_7.1dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Line | Corr. |
|---|---|---|---|---|---|---|
| MHz | dBµV | dBµV | dBµV | dB | - | dB |
| 31.700000 | - | 9.03 | 24.00 | 14.97 | Single Line | 0.9 |
| 54.150000 | 17.06 | - | 34.00 | 16.94 | Single Line | 1.2 |
| 79.600000 | - | 8.94 | 18.00 | 9.06 | Single Line | 1.7 |
| 79.750000 | 18.15 | - | 34.00 | 15.85 | Single Line | 1.7 |
| 87.400000 | 18.60 | - | 34.00 | 15.40 | Single Line | 1.8 |
| 99.500000 | - | 10.90 | 18.00 | 7.10 | Single Line | 2.0 |

**Figure 14: Conduction Emission Line + 0.15-108MHz**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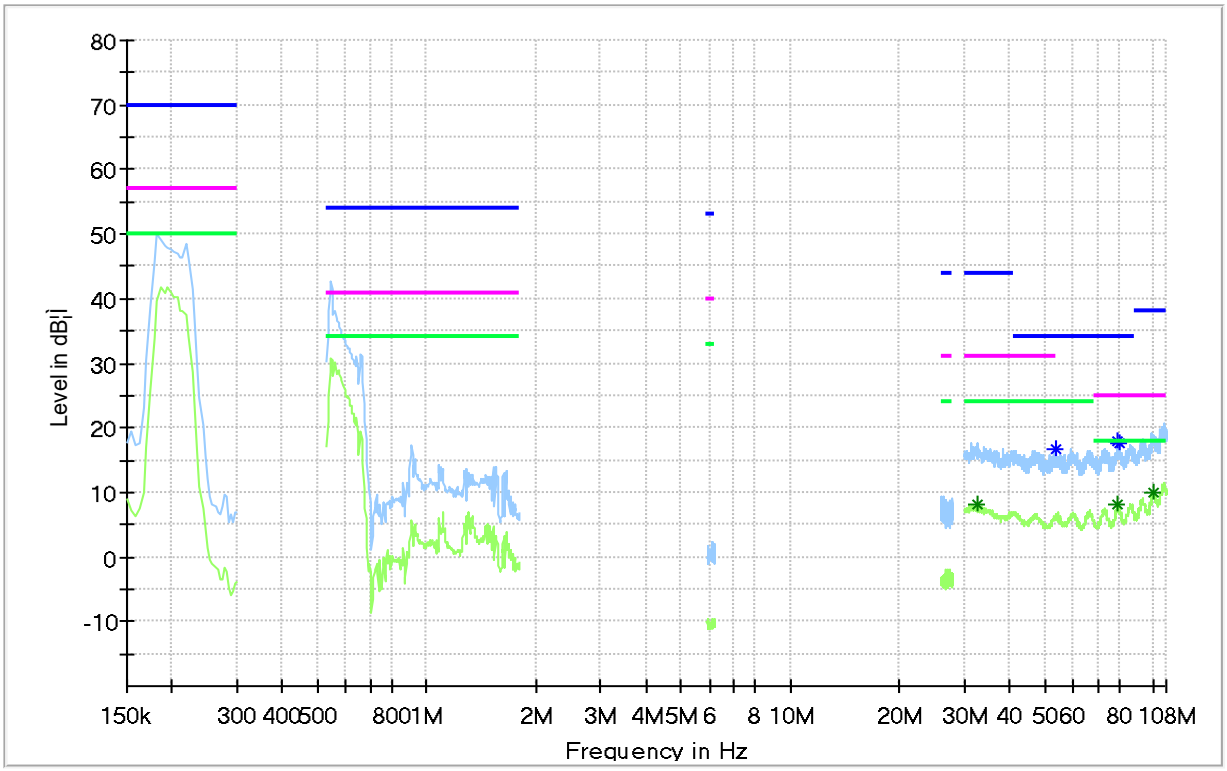
2. CE-_0.15-108MHz CISPR 25 Class 5_Pass_8.12dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Line | Corr. |
|---|---|---|---|---|---|---|
| MHz | dBµV | dBµV | dBµV | dB | - | dB |
| 32.720000 | - | 8.06 | 24.00 | 15.94 | Single Line | 0.9 |
| 53.560000 | 16.60 | - | 34.00 | 17.40 | Single Line | 1.2 |
| 79.680000 | - | 8.18 | 18.00 | 9.82 | Single Line | 1.7 |
| 79.720000 | 17.84 | - | 34.00 | 16.16 | Single Line | 1.7 |
| 80.200000 | 17.48 | - | 34.00 | 16.52 | Single Line | 1.7 |
| 99.000000 | - | 9.88 | 18.00 | 8.12 | Single Line | 2.0 |

**Figure 15: Conduction Emission, Line - 0.15-108MHz**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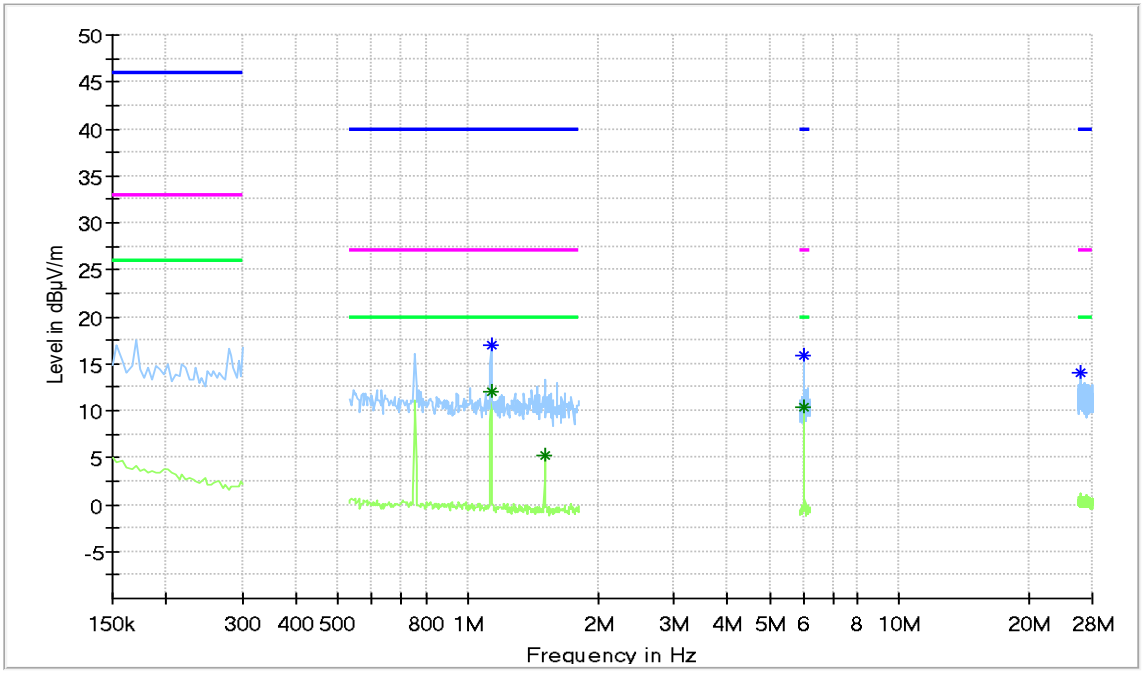
## Radiation Emission Test

1. RE_0.15-28M CISPR 25 Class 5_Pass_8.05dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | - | dB/m |
| 1.130000 | - | 11.96 | 20.00 | 8.05 | - | V | 10.0 |
| 1.130000 | 16.98 | - | 40.00 | 23.02 | - | V | 10.0 |
| 1.506000 | - | 5.25 | 20.00 | 14.75 | - | V | 10.0 |
| 6.024000 | 15.93 | - | 40.00 | 24.07 | - | V | 10.2 |
| 6.024000 | - | 10.32 | 20.00 | 9.68 | - | V | 10.2 |
| 26.332000 | 14.09 | - | 40.00 | 25.91 | - | V | 10.5 |

**Figure 16: Radiation Emission, Monopole Vertical Antenna 0.15-28MHz**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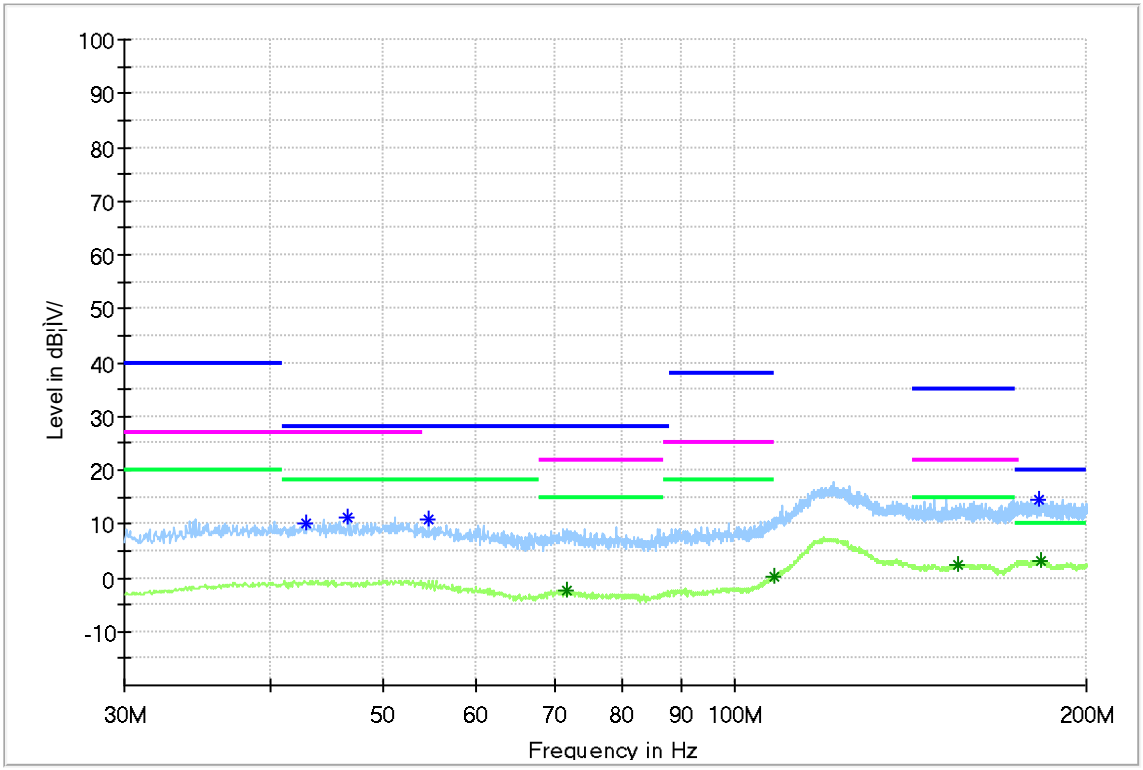
2. RE_30-200M_ Horizontal _CISPR 25 Class 5_Pass_5.67dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | | dB/m |
| 43.000000 | 10.19 | - | 28.00 | 17.81 | - | H | -13.3 |
| 46.600000 | 11.17 | - | 28.00 | 16.83 | - | H | -13.6 |
| 54.700000 | 10.89 | - | 28.00 | 17.11 | - | H | -14.5 |
| 71.800000 | - | -2.25 | 15.00 | 17.25 | - | H | -15.3 |
| 108.000000 | - | 0.31 | 18.00 | 17.69 | - | H | -13.2 |
| 155.000000 | - | 2.48 | 15.00 | 12.52 | - | H | -10.8 |
| 182.100000 | 14.33 | - | 20.00 | 5.67 | | H | -9.8 |
| 182.950000 | - | 3.21 | 10.00 | 6.79 | | H | -9.8 |

**Figure 17: Radiation Emission, Dipole Horizontal Antenna 30-200MHz**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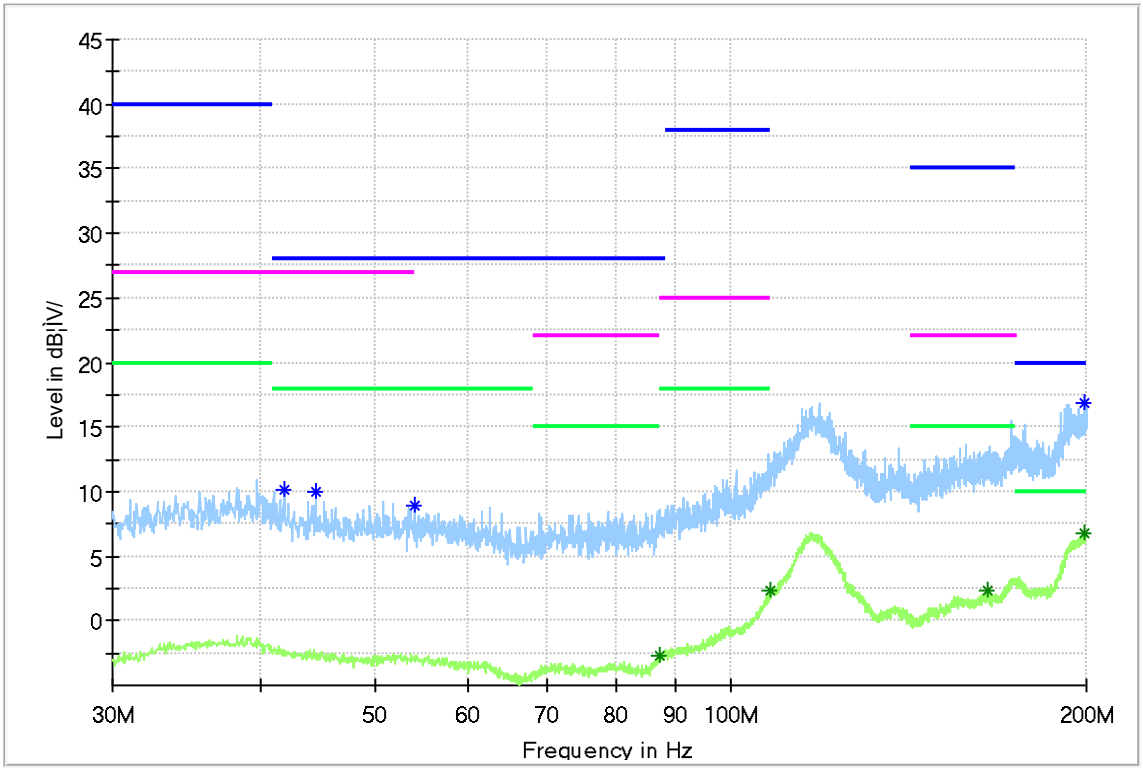
3. RE_30-200M_ Vertical _CISPR 25 Class 5_Pass_3.14dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | | dB/m |
| 41.950000 | 10.09 | - | 28.00 | 17.91 | - | V | -13.2 |
| 44.600000 | 10.06 | - | 28.00 | 17.94 | - | V | -13.4 |
| 54.000000 | 8.95 | - | 28.00 | 19.05 | - | V | -14.4 |
| 86.950000 | - | -2.64 | 15.00 | 17.64 | - | V | -14.6 |
| 108.000000 | - | 2.36 | 18.00 | 15.64 | - | V | -13.2 |
| 165.250000 | - | 2.33 | 15.00 | 12.67 | - | V | -10.3 |
| 199.200000 | 16.86 | - | 20.00 | 3.14 | | V | -8.8 |
| 199.200000 | - | 6.80 | 10.00 | 3.20 | | V | -8.8 |

**Figure 18: Radiation Emission, Dipole Vertical Antenna 30-200MHz**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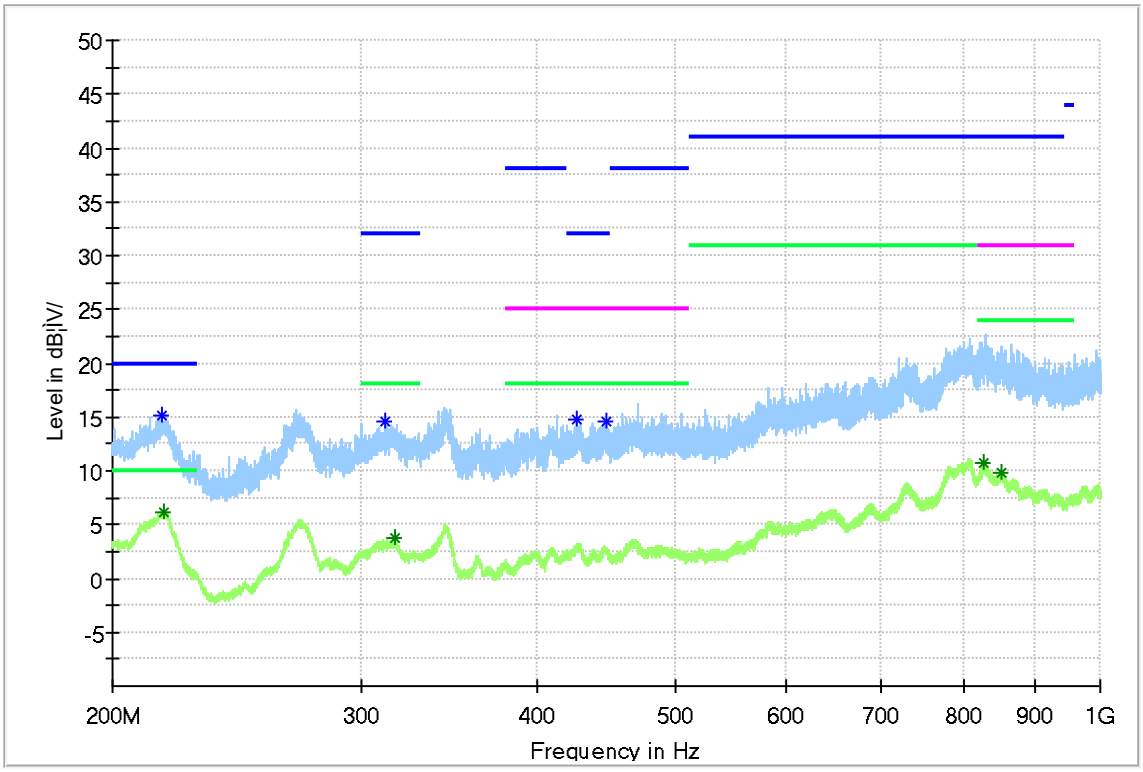
4. RE_200-1000M_ Horizontal _CISPR 25 Class 5_Pass_3.89dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | - | dB/m |
| 216.700000 | 15.21 | - | 20.00 | 4.79 | - | H | -13.5 |
| 217.600000 | - | 6.11 | 10.00 | 3.89 | - | H | -13.4 |
| 311.400000 | 14.66 | - | 32.00 | 17.34 | - | H | -10.7 |
| 316.750000 | - | 3.70 | 18.00 | 14.30 | - | H | -10.5 |
| 426.350000 | 14.82 | - | 32.00 | 17.18 | - | H | -8.0 |
| 447.800000 | 14.64 | - | 32.00 | 17.36 | - | H | -7.1 |
| 827.850000 | - | 10.67 | 24.00 | 13.33 | | H | -1.6 |
| 851.900000 | - | 9.75 | 24.00 | 14.25 | | H | -1.3 |

**Figure 19: Radiation Emission, Log-Periodic Horizontal Antenna 200-960MHz**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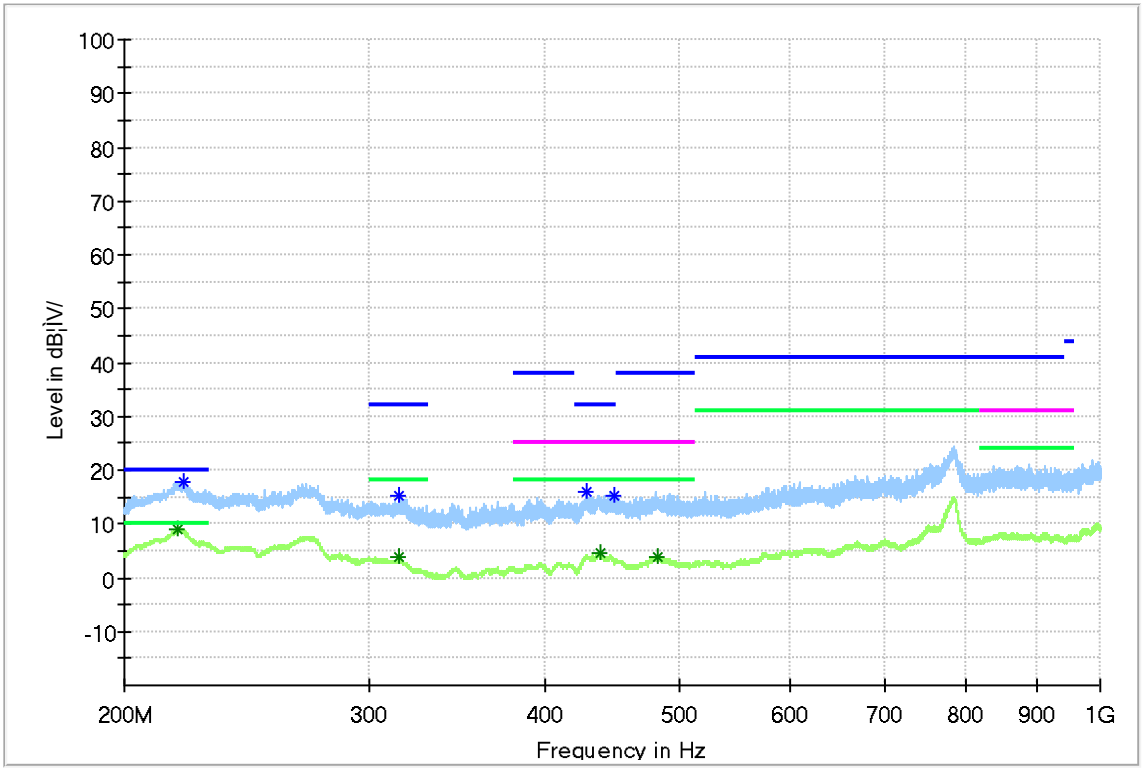
5. RE_200-1000M Vertical _CISPR 25 Class 5_Pass_0.98dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | | dB/m |
| 218.550000 | - | 9.02 | 10.00 | 0.98 | - | V | -13.4 |
| 220.700000 | 17.88 | - | 20.00 | 2.12 | - | V | -13.2 |
| 314.200000 | - | 3.78 | 18.00 | 14.22 | - | V | -10.6 |
| 314.600000 | 15.37 | - | 32.00 | 16.63 | - | V | -10.6 |
| 428.900000 | 15.94 | - | 32.00 | 16.06 | - | V | -7.9 |
| 439.100000 | - | 4.48 | 18.00 | 13.52 | - | V | -7.4 |
| 449.250000 | 15.40 | - | 32.00 | 16.60 | | V | -7.1 |
| 481.250000 | - | 4.01 | 18.00 | 13.99 | | V | -6.7 |

**Figure 20: Radiation Emission, Log-Periodic Vertical Antenna 200-960MHz**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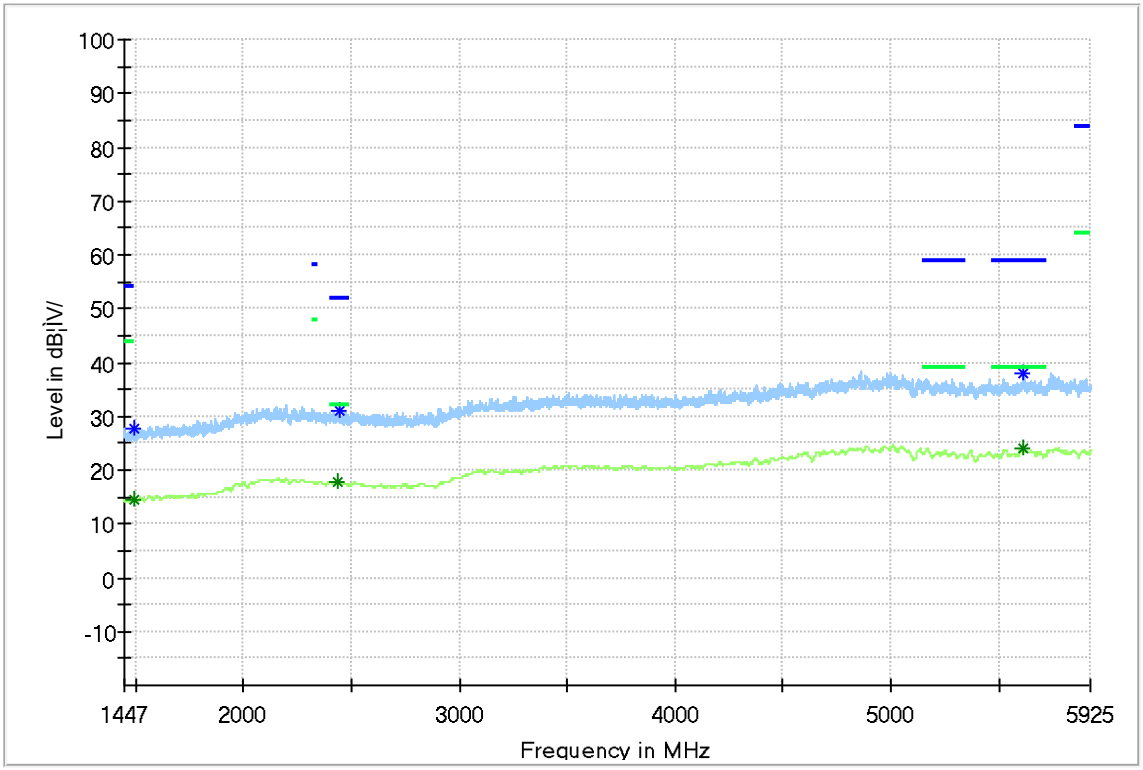
6. RE_1447-5925M Horizontal _CISPR 25 Class 5_Pass_14.14dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | - | dB/m |
| 1488.500000 | - | 14.61 | 44.00 | 29.39 | - | H | -17.6 |
| 1489.500000 | 27.82 | - | 54.00 | 26.18 | - | H | -17.6 |
| 2433.000000 | - | 17.86 | 32.00 | 14.14 | - | H | -13.0 |
| 2443.500000 | 31.17 | - | 52.00 | 20.83 | - | H | -13.0 |
| 5613.000000 | - | 24.15 | 39.00 | 14.85 | - | H | -4.4 |
| 5618.000000 | 37.87 | - | 59.00 | 21.13 | - | H | -4.6 |

**Figure 21: Radiation Emission, Horn Horizontal Antenna 14470-5925MHz**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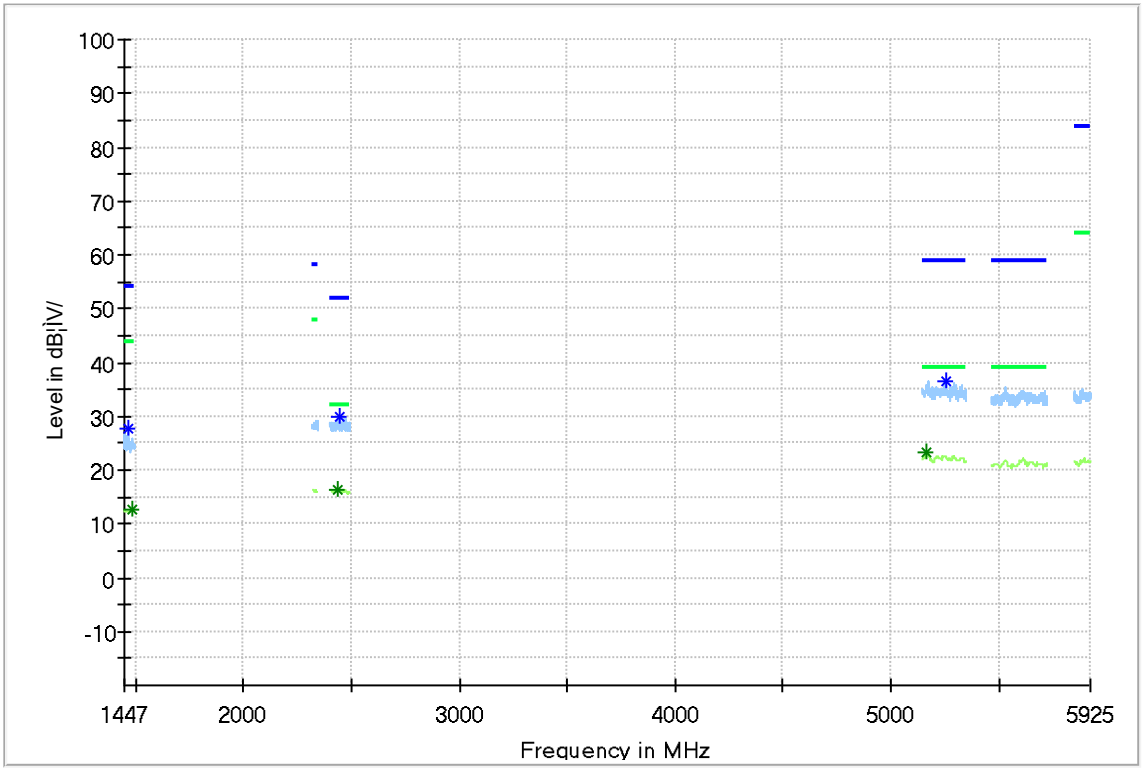
7. RE_1447-5925M Vertical _CISPR 25 Class 5_Pass_15.57dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | - | dB/m |
| 1463.500000 | 27.88 | - | 54.00 | 26.12 | - | V | -19.7 |
| 1485.000000 | - | 12.73 | 44.00 | 31.27 | - | V | -19.5 |
| 2440.000000 | - | 16.43 | 32.00 | 15.57 | - | V | -14.6 |
| 2446.000000 | 29.77 | - | 52.00 | 22.23 | - | V | -14.7 |
| 5168.000000 | - | 23.15 | 39.00 | 15.85 | - | V | -5.9 |
| 5252.000000 | 36.67 | - | 59.00 | 22.33 | - | V | -6.0 |

**Figure 22: Radiation Emission, Horn Vertical Antenna** 1447-**5925MHz**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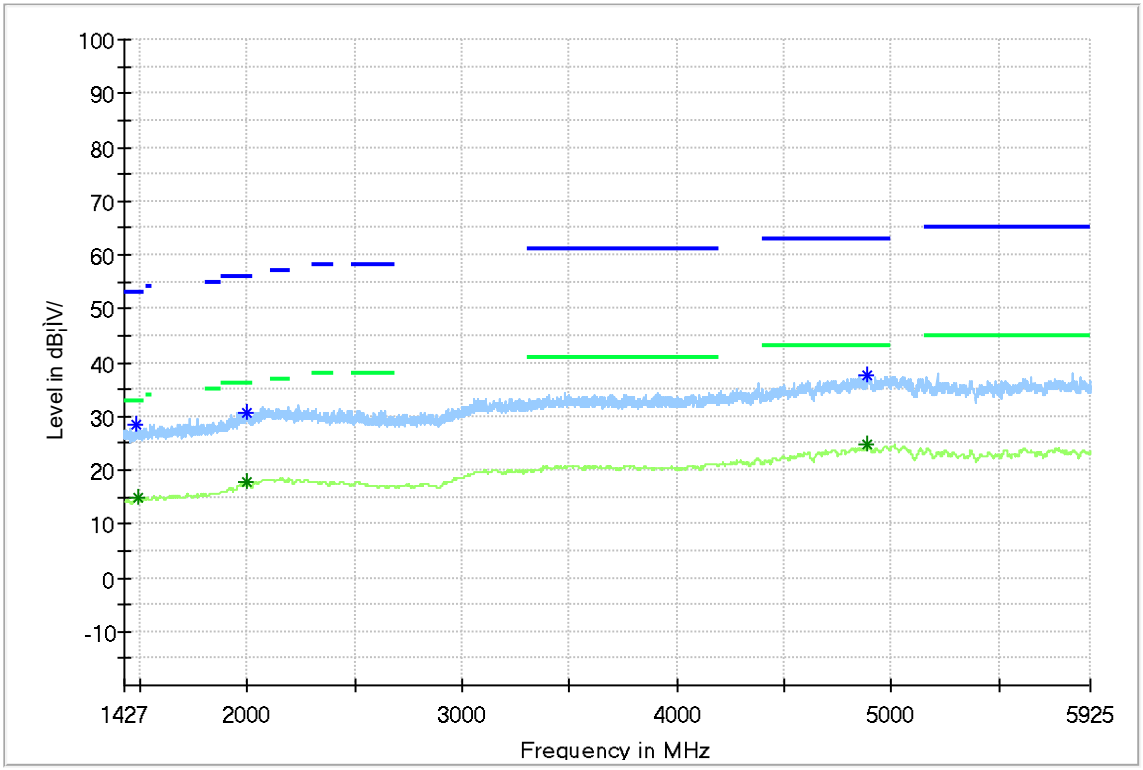
8. RE_1427-5925M Horizontal _CISPR 25 Class 5_Pass_1M_18.32dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | - | dB/m |
| 1481.000000 | 28.49 | - | 53.00 | 24.51 | - | H | -17.8 |
| 1487.000000 | - | 14.68 | 33.00 | 18.32 | - | H | -17.6 |
| 1996.500000 | - | 17.66 | 36.00 | 18.34 | - | H | -13.9 |
| 1997.500000 | 30.75 | - | 56.00 | 25.25 | - | H | -14.0 |
| 4887.500000 | 37.73 | - | 63.00 | 25.27 | - | H | -4.2 |
| 4889.000000 | - | 24.60 | 43.00 | 18.40 | - | H | -4.2 |

**Figure 23: Radiation Emission, Horn Horizontal Antenna 1427-5925MHz**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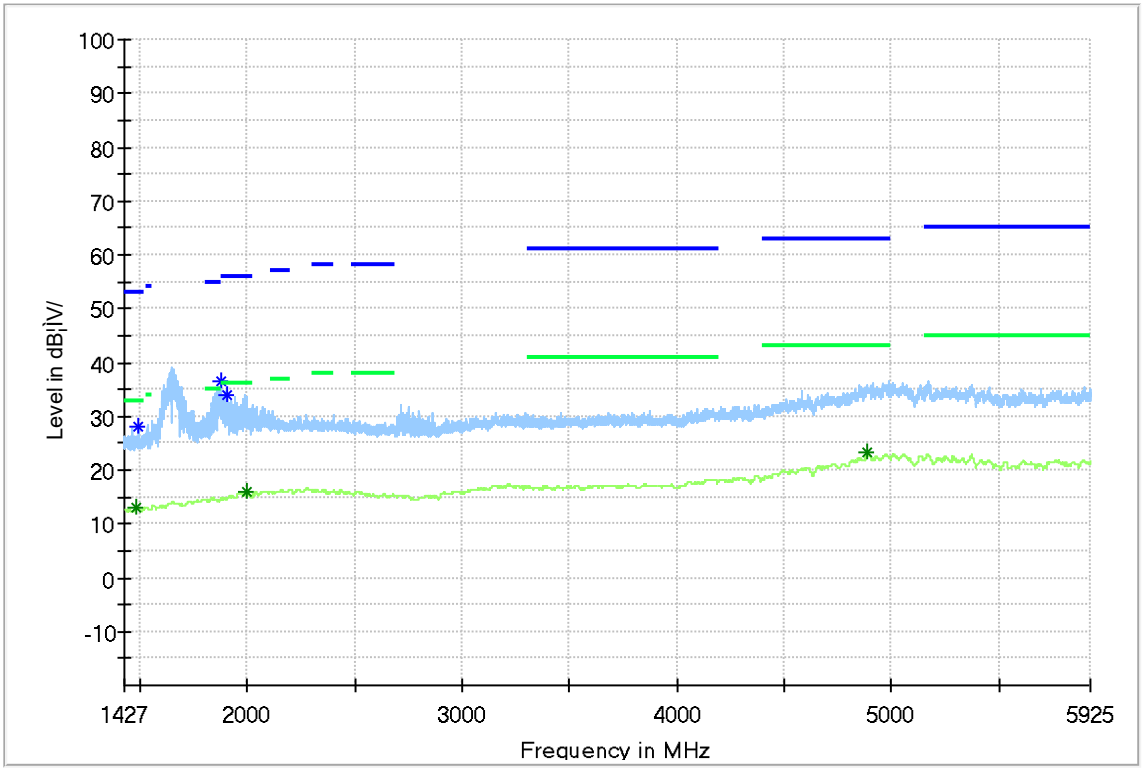
9. RE_1427-5925M Vertical _CISPR 25 Class 5_Pass_1M_18.47dB Margin




| Frequency | MaxPeak | Average | Limit | Margin | Meas._Time | Pol | Corr. |
|---|---|---|---|---|---|---|---|
| MHz | dBµV/m | dBµV/m | dBµV/m | dB | ms | | dB/m |
| 1486.500000 | - | 12.87 | 33.00 | 20.13 | - | V | -19.4 |
| 1495.500000 | 27.94 | - | 53.00 | 25.06 | - | V | -19.4 |
| 1873.500000 | 36.53 | - | 55.00 | 18.47 | - | V | -17.1 |
| 1904.000000 | 33.90 | - | 56.00 | 22.10 | - | V | -16.9 |
| 1996.500000 | - | 15.97 | 36.00 | 20.03 | - | V | -15.8 |
| 4888.500000 | - | 23.14 | 43.00 | 19.86 | - | V | -5.6 |

**Figure 24: Radiation Emission, Horn Vertical Antenna** 1427-**5925MHz**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