AL8891QEV1 User Guide
Buck 2A LED Driver

General Description

The AL8891Q is a high-efficiency, compact, synchronous step-down LED driver employing an adaptive on-time PWM controller with an average current loop and internal compensation. It operates from an input voltage from 4.5V to 65V and delivers up to 2A of output current. The switching frequency is adjustable from 200kHz to 2.5MHz by an external resistor.

The AL8891Q incorporates full fault detection and protection, including cycle-by-cycle peak and valley current clamping, LED short and open protection, inductor short and open protection, RCS short protection, LED+ short to battery protection, and thermal shut down.

The AL8891Q simplifies board layout and reduces space requirements with its high level of integration and minimal need for external components, making it ideal for distributed power architectures.

The AL8891Q is available in the standard Green TSSOP-16EP package.

Applications

- Automotive exterior LED lighting
- Commercial and industrial agriculture vehicle applications
- LED Driver modules
- Industrial LED drivers

Key Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified with the Following Results
  - Device Temperature Grade 1: -40°C to +125°C TA
  - Device HBM ESD Classification Level H1C
  - Device CDM ESD Classification Level C3B
- Input voltage range from 4.5V to 65V
- Integrated high-side 200mΩ and low-side 130mΩ MOSFETs with up to 2A output current
- Drive up to 16 LEDs in buck mode
- ±4% LED current accuracy
- PWM and Analog dimming
- Adaptive on time PWM with average current loop
- Cycle-by-cycle current protection
- LED open and short protection
- Overtemperature thermal protection and Auto-restart
- **Totally Lead-Free & Fully RoHS Compliant**
- **Halogen and Antimony Free. “Green” Device**

Specifications

Parameter	Value
Input Voltage	4.5V~65Vdc
Output Current	2A
Output Voltage	1~16 LEDS
Dimension	80mm*80mm
RoHS Compliance	Yes

Configuration

This section introduces the input and output interfaces, test points, and jumper settings of the AL8891QEVM.

Figure 1 is the top view of the EVM, showing the locations of components, input and output connectors, test points, and jumpers.

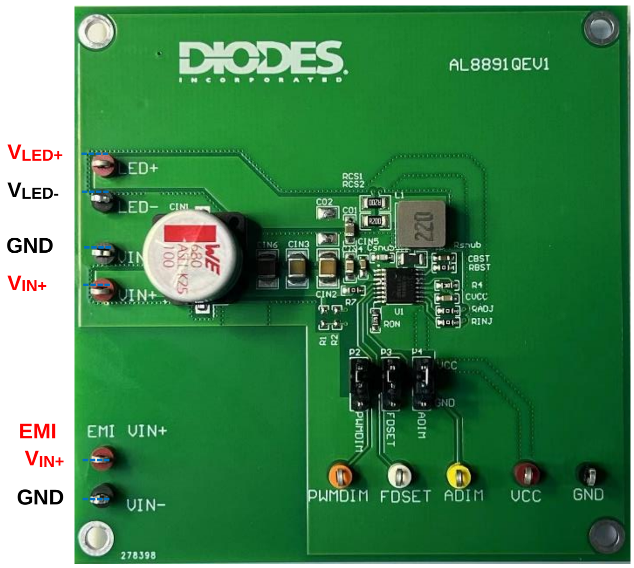


Figure 1: AL8891Q EVM Top View

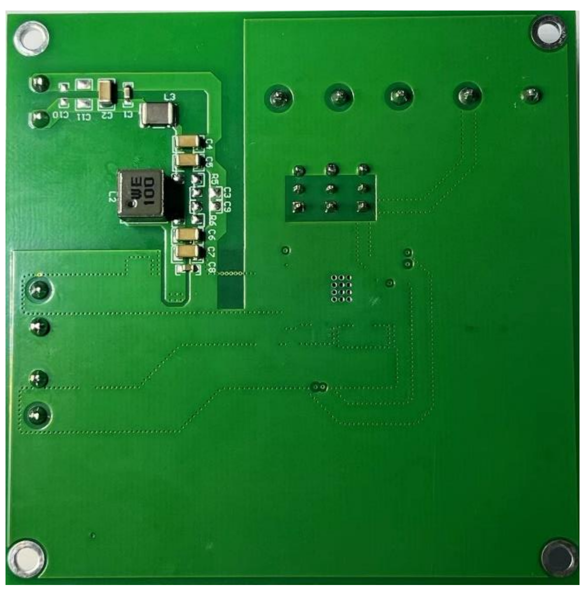


Figure 2: AL8891Q EVM Bottom View

Interfaces And Test Points

Input and Output Connectors

- J1 – Input connector, the input voltage range is from 4.5V to 65V.
- J2 – Output connector, it connects the LED load.
- J3 – Input connector when do EMI test, the input power supplies to the chip by passing through the filter circuit. The input voltage range is from 4.5V to 65V.

Test Points

- GND – Ground pins, they are connected to GND plane.
- LED+S – LED+ sense points.
- LED-S – LED- sense points.
- VINS – VIN sense points.
- GNDS – GND sense points for VIN test.
- VCC – Internal VCC regulator that powers the control circuits. It is decoupled to GND with 1μF ceramic capacitor.
- PWMDIM – PWM dimming input pin, connect to a pulse signal to dim, or connect to a high-level voltage to enable MOSFET switching when PWM dimming is not in use.
- ADIM – Analog dimming input pin, connect to an adjustable analog voltage when analog dimming is in use. Connect to a high-level voltage when analog dimming is not in use.
- FDSET – Set VIN rising threshold to mask LED open fault. Connect to an external divider to detect VIN rising condition. When the voltage of FDSET is higher than VFDSET (the typical value is 2.0V), then enable the LED open fault detection.

Jumpers

- P2 – PWMDIM jumper, PWMDIM can be connected to VCC or GND by jumper cap.
- P3 – FDSET jumper, FDSET can be connected to VCC or GND by jumper cap. The LED open fault is masked when FDSET is connected to GND. The LED open fault is detected when FDSET connected to VCC.
- P4 – ADIM jumper, ADIM can be connected to VCC or GND by jumper cap. The device will output 2A current when ADIM connected to VCC, and the device will clamp LED current to 0.15A when ADIM connected to GND.

Operating

When supplying a voltage in the range from 4.5V to 65V to the input connector, connect the LED string to the output connector, P2 tie to VCC, and then the EVM will operate with the default switching frequency.

Evaluation Board Schematic

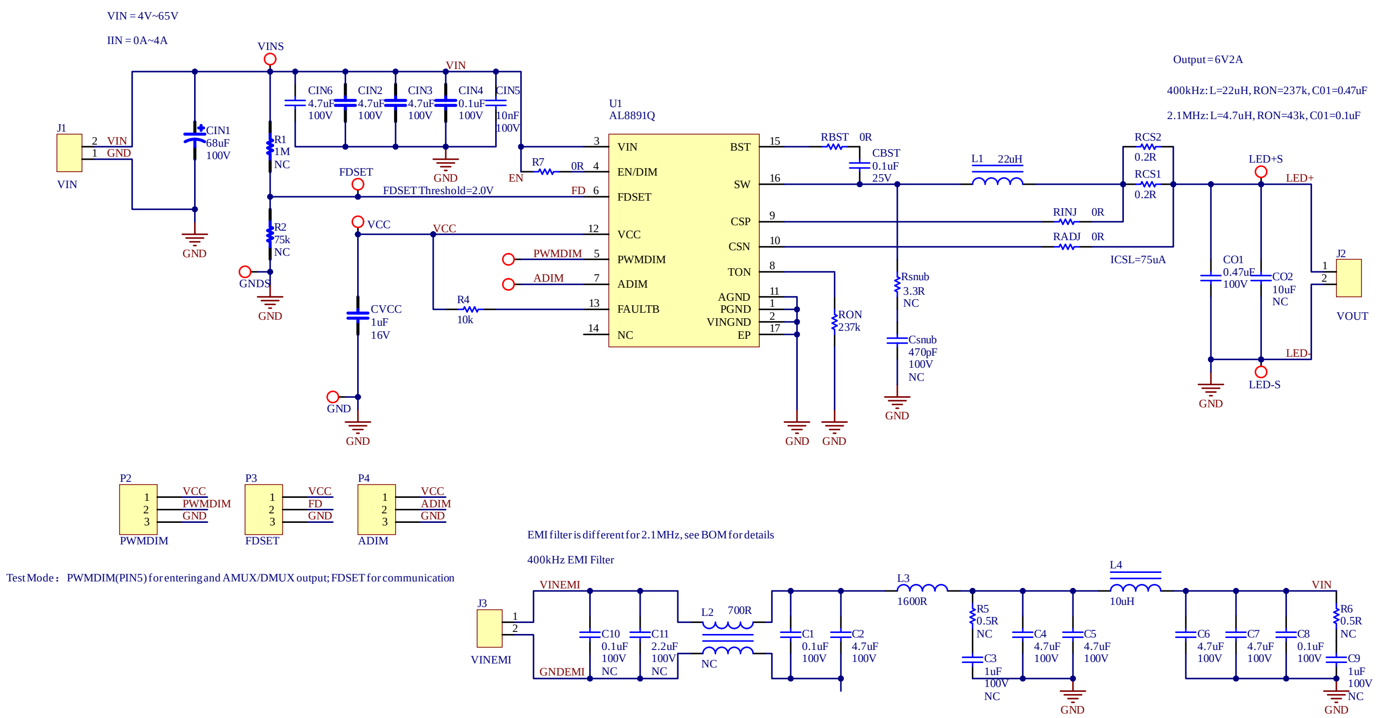


Figure 3. AL8891Q Schematic

Note: 1. The components labeled with NC are unplaced.

Bill Of Materials

Table 1. Bill of Materials for 400kHz

Designator	Description	Value	Footprint	Manufacturer	Manufacturer P/N	Quantity
C1, C8	Ceramic Capacitor 100V X7R 10%	0.1uF/100V	0603	Murata	GRM188R72A104KA35	2
C2, C4, C5, C6, C7	Ceramic Capacitor 100V X7R 10%	4.7uF/100V	1206	Murata	GRM31CZ72A475KE11	5
CBST	Ceramic Capacitor 25V X8R 10%	0.1uF/25V	0603	Murata	GCM188R91E104KA37	1
CIN1	ASEH140680M100DVCTGE 000	68uF/100V	Pol_Cap_125	Wurth	865060862006	1
CIN2, CIN3, CIN6	Ceramic Capacitor 100V X7S 10%	4.7uF/100V	1210	Murata	GCM32DC72A475KE02L	3
CIN4	Ceramic Capacitor 100V X7R 10%	0.1uF/100V	0805	Murata	GCM21BR72A104KA37	1
CIN5	Ceramic Capacitor 100V X7R 10%	10nF/100V	0603	Murata	GCM188R72A103KA37	1
CVCC	Ceramic Capacitor 16V X7R 10%	1uF/16V	0603	Murata	GCM188R71C105KA64J	1
Csnub	Ceramic Capacitor 100V X7R 10%	470pF/100V	0603	Murata	GCM1885C2A471JA16	1
CO1	Ceramic Capacitor 100V X7R 10%	0.47uF/100V	0805	Murata	GRM21BR72A474KA73L	1
J1, J2, J3	LZ1V-5.08-2P-1Y-00A	-	CON-LZ1V-5.08-2P	-	-	3
L1	DCR=46.9mΩ, Isat=5.1A	22uH	XGL6060	Coilcraft	XGL6060-223MEC	1
L2	DCR=0.035Ω	880R	1812	Wurth	74279252	1
L3	DCR=26.5mΩ, Isat=5A	10uH	XAL6060	Wurth	74439346100	1
P2, P3, P4	-	-	HDR1X3	Wurth	61300311121	3
R4	1% 0.1W	10kohm	0603	Yageo	RC0603FR-0710KL	1
R7, RBST, RADJ, RINJ	1% 0.1W	0R	0603	Yageo	RC0603FR-070RL	4
RON	1% 0.1W	237kohm	0603	Yageo	RC0603FR-07237KL	1
RCS1, RCS2	1% 0.5W	0.2R	1206	Yageo	PT1206FR-7W0R2L	2
Rsnub	1% 0.75W	3R3	1206	Vishay	CRCW12063R30FKEAHP	1
TP1, TP3, TP21	Black Test Point	-	TP	-	-	3
TP2, TP20	Red Test Point	-	TP	-	-	2
TP4, TP6, TP9	Yellow Test Point	-	TP	-	-	3
TP5	Orange Test Point	-	TP	-	-	1
U1	-	-	TSSOP-EP16	Diodes	AL8891Q	1

Layout

The AL8891Q EVM PCB includes four layers. The copper thickness of the top and bottom layers is 2oz, and the copper thickness of the internal layer is 0.5oz. The heat dissipation pads of the AL8891Q are connected to each layer through array vias to accelerate chip heat dissipation. The layout of each layer is shown in Figure 4 to Figure 7.

Radiated EMI is generated by the high di/dt components of the pulsing currents in switching converters. The larger the area covered by the path of a pulsing current; the more electromagnetic emission is generated. The key to minimize radiated EMI is to minimize the area of the pulsing current path. Thus, placing high-frequency ceramic bypass capacitor(s) as close as possible to the VIN and VINGND pins is necessary.

In addition, high dv/dt occurs on the SW node during switching, so the trace between the SW pin and the inductor should be as short as possible, and just wide enough to carry the load current without excessive heating. Short and thick traces are highly recommended to minimize parasitic resistance. Besides, sensitive signal lines should be kept away from SW traces.

The following guidelines are provided to help users design a PCB with the best power-conversion performance and thermal performance, with minimized generation of unwanted EMI.

1. Place a high-frequency ceramic bypass CIN as close as possible to the VIN and VINGND pins; a ceramic capacitor in a small package (such as 0603) is still needed even if multiple input capacitors are implemented.
2. The high-current loop consisting of VIN, VOUT, and PGND should be as compact as possible.
3. The bypass capacitors of VCC should be arranged close to the VCC pin and return to the PGND pin with the shortest connection.
4. It is recommended to use a four-layer board with 2oz top and bottom layers, and a dedicated ground plane on the middle layer. For heat dissipation purposes, use a minimum of 3 by 4 arrays of 10 mil thermal vias to connect the thermal pad to the system ground plane.
5. The SW and BST nodes contain a lot of high-frequency noise, so the connection of the pins should be as short as possible. Meanwhile, there should be sufficient width to conduct the current.
6. Sensitive analog signals, such as CSP and CSN, must be placed far away from the noisy nodes. The ground plane can be used as a shielding layer while routing these sensitive signals.
7. The TON resistor must be located as close to the pin as possible.

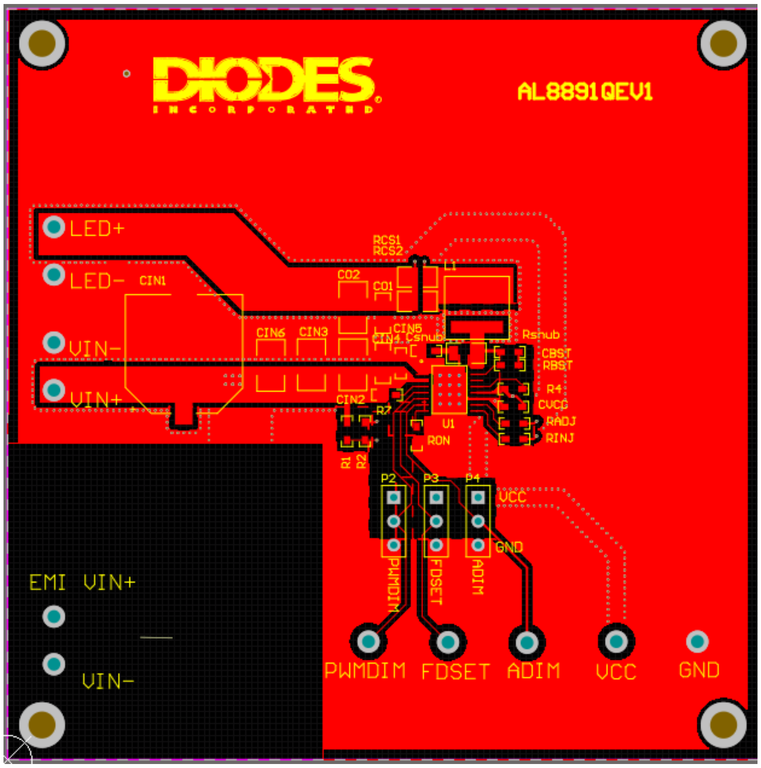


Figure 4. AL8891Q Top Layer (Top View)

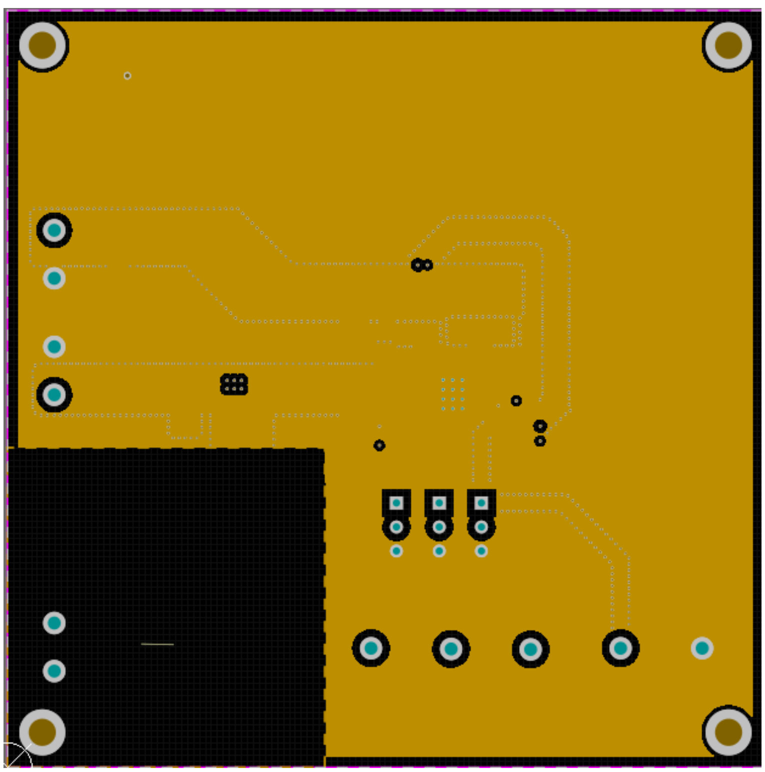


Figure 5. AL8891Q Second Layer (Top View)

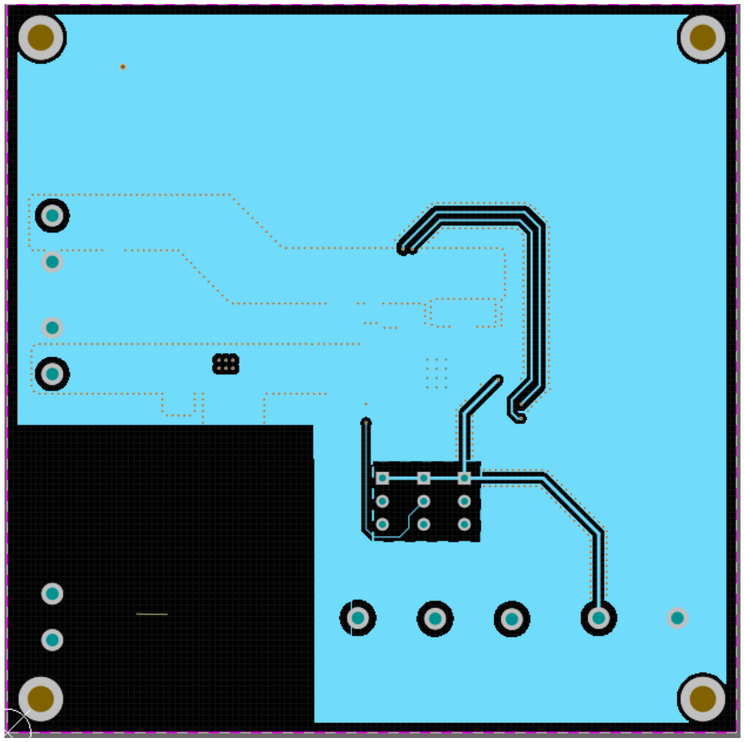


Figure 6. AL8891Q Third Layer (Top View)

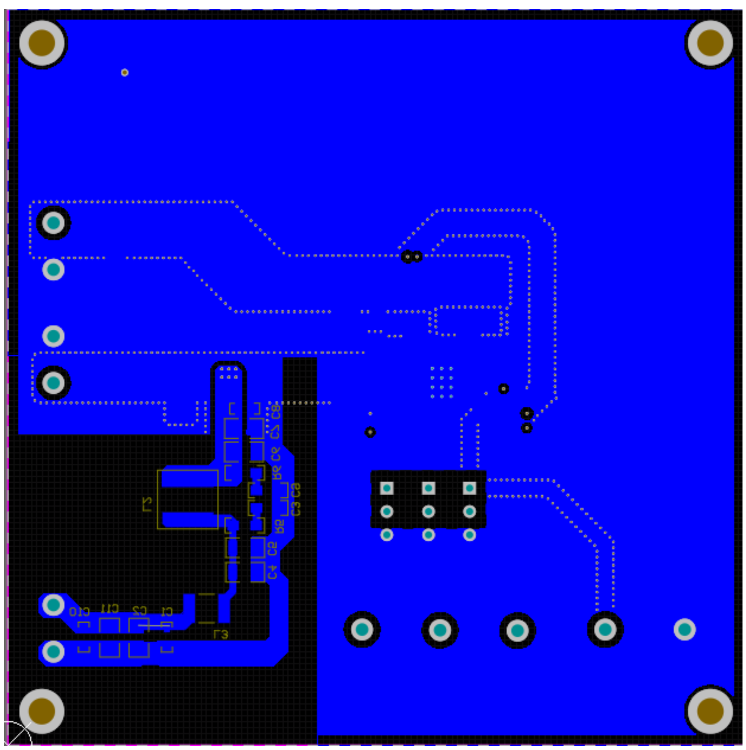


Figure 7. AL8891Q Bottom Layer (Top View)

System Performance

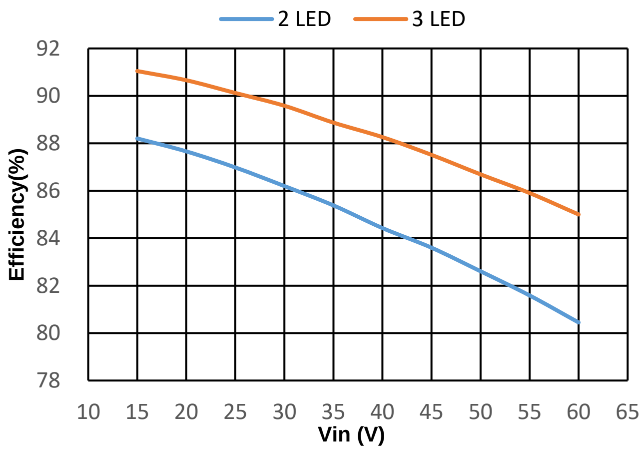


Figure 8. Efficiency vs. Input Voltage No EMI Circuit

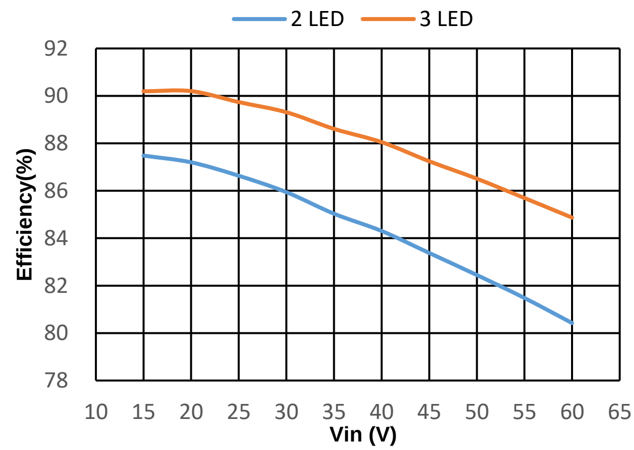


Figure 9. Efficiency vs. Input Voltage Add EMI Circuit

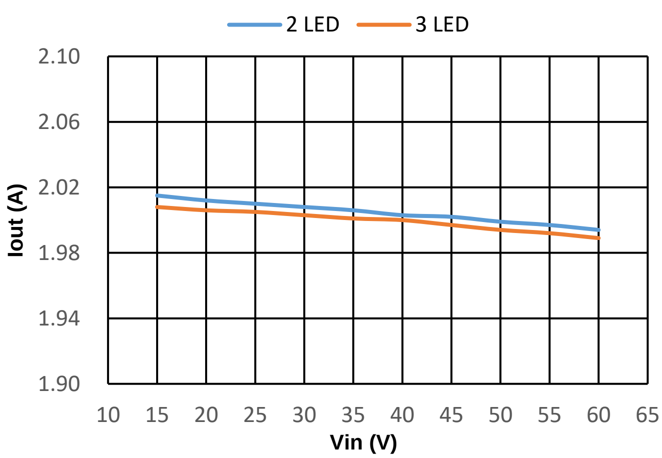


Figure 10. Line Regulation

Figure 11. PWM Dimming Curve (Vin=24V Vout=2 LEDS)

Waveforms

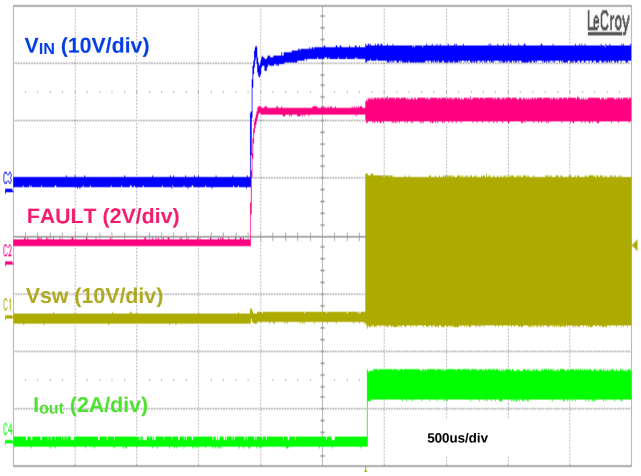


Figure 12. Turn On (Vin=24V Vout=2 LEDS)

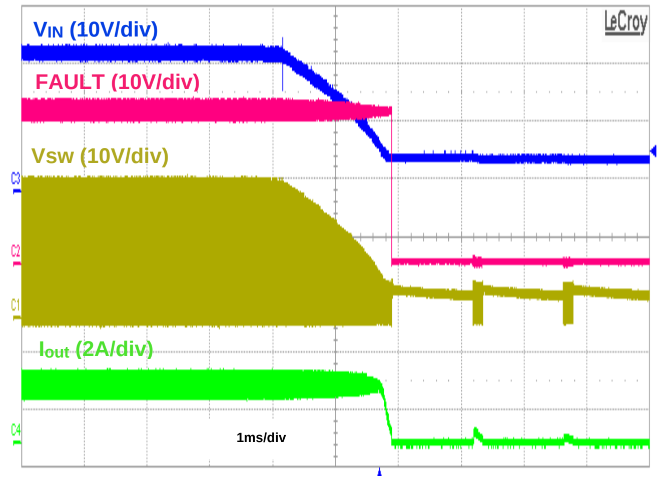


Figure 13. Turn Off (Vin=24V Vout=2 LEDS)

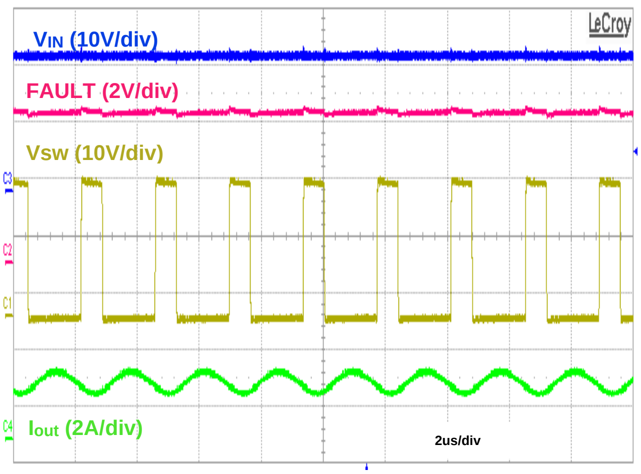


Figure 14. Stable Waveform (Vin=24V Vout=2 LEDS)

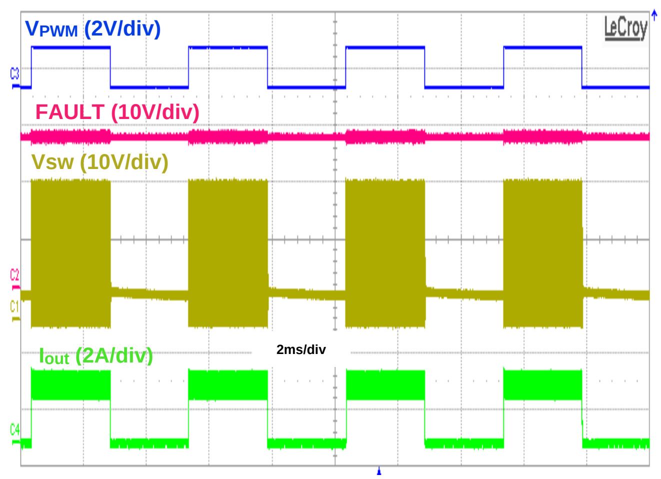


Figure 15. PWM Dimming 50%Duty 200HZ (Vin=24V Vout=2 LEDS)

Thermal Test

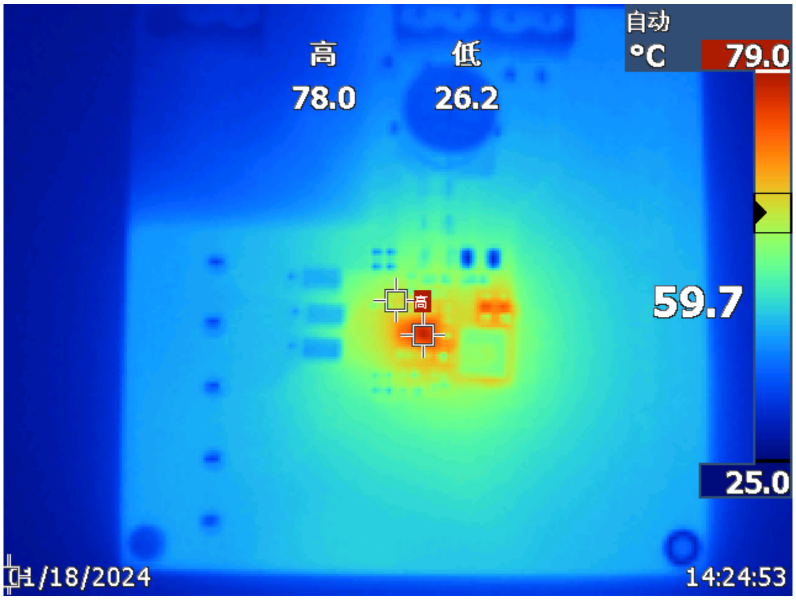


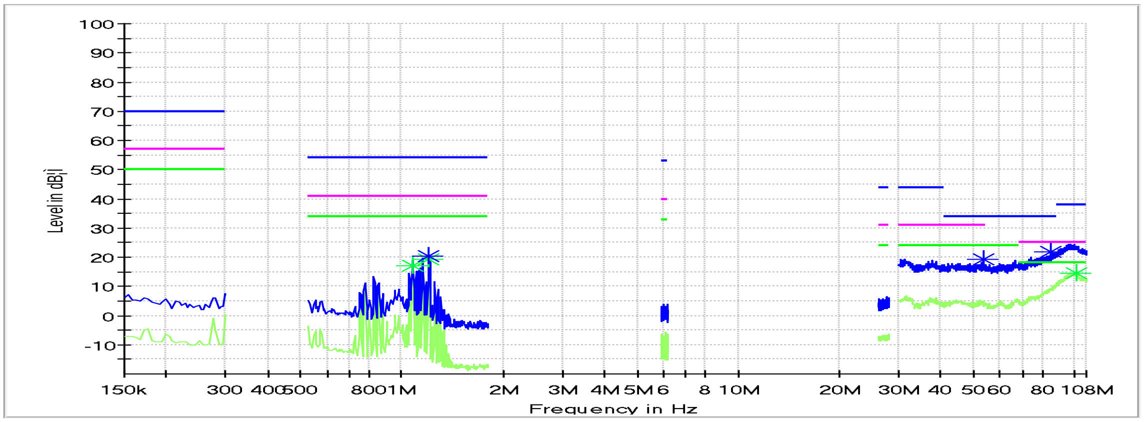
Figure16. Thermal Test

IC Tc = 79C degree @ ambient = 25C degree, temperature rise is 54C degree.
Tested in VIN=24V, VLED=7V (2 LEDS), ILED=2A

EMI Test

CE Test for Class 5

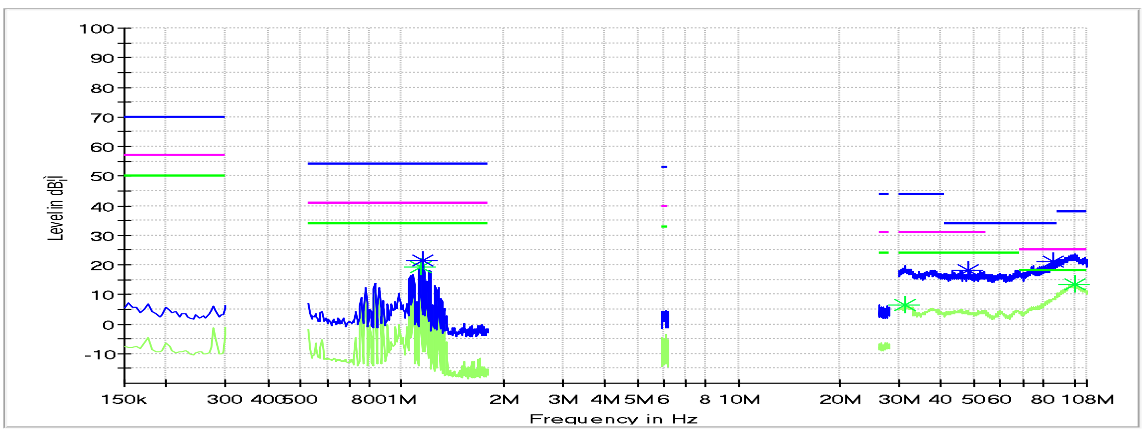
1，VCE+（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Line	Corr.
MHz	dBµV	dBµV	dBµV	dB	ms	kHz		dB
1.079000	---	17.12	34.00	16.88	---	---	Single Line	0.3
1.205000	---	19.19	34.00	14.81	---	---	Single Line	0.3
1.205000	20.22	---	54.00	33.78	---	---	Single Line	0.3
53.150000	19.32	---	34.00	14.68	---	---	Single Line	1.5
85.100000	21.73	---	34.00	12.27	---	---	Single Line	2.0
100.300000	---	14.51	18.00	3.49	---	---	Single Line	2.2

2，VCE-（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）

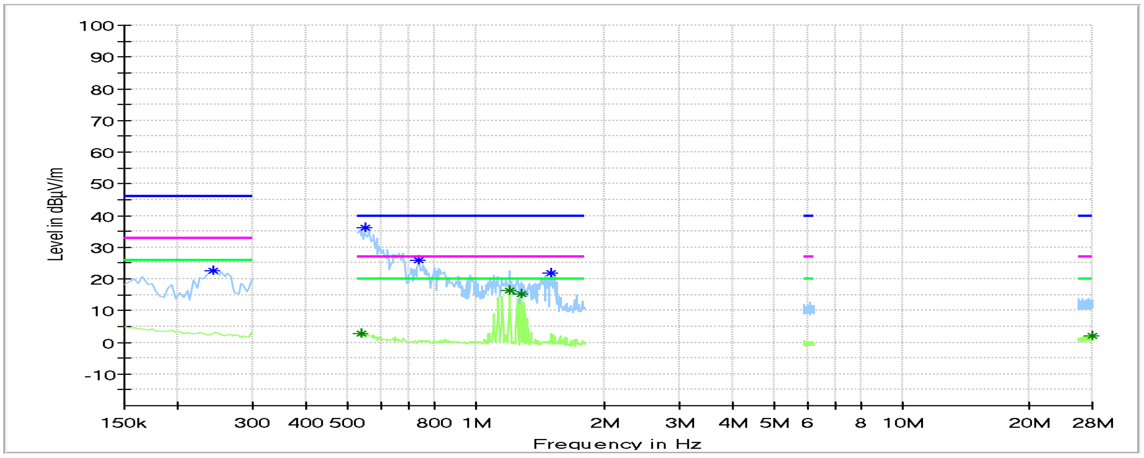


Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Line	Corr.
MHz	dBµV	dBµV	dBµV	dB	ms	kHz		dB
1.133000	---	19.18	34.00	14.82	---	---	Single Line	0.3
1.160000	21.31	---	54.00	32.69	---	---	Single Line	0.3
31.350000	---	6.38	24.00	17.62	---	---	Single Line	1.1
47.800000	18.16	---	34.00	15.84	---	---	Single Line	1.2
85.350000	21.18	---	34.00	12.82	---	---	Single Line	1.5
100.050000	---	13.36	18.00	4.64	---	---	Single Line	1.7

RE Test For Class 5

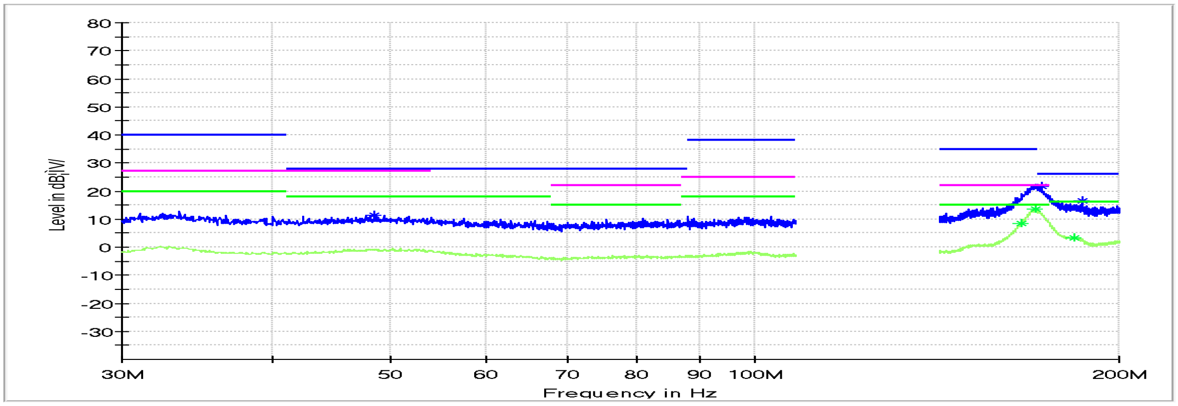
3，RE 150K-28MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Line	Corr.
MHz	dBµV	dBµV	dBµV	dB	ms	kHz		dB
0.242000	22.42	---	46.00	23.58	---	---	V	10.0
0.542000	---	2.91	20.00	17.09	---	---	V	10.1
0.550000	36.30	---	40.00	3.70	---	---	V	10.1
0.738000	25.84	---	40.00	14.16	---	---	V	10.0
1.202000	---	16.30	20.00	3.70	---	---	V	10.0
1.278000	---	15.20	20.00	4.80	---	---	V	10.0
1.502000	21.90	---	40.00	18.10	---	---	V	10.0
27.976000	---	1.88	20.00	18.12	---	---	V	10.3

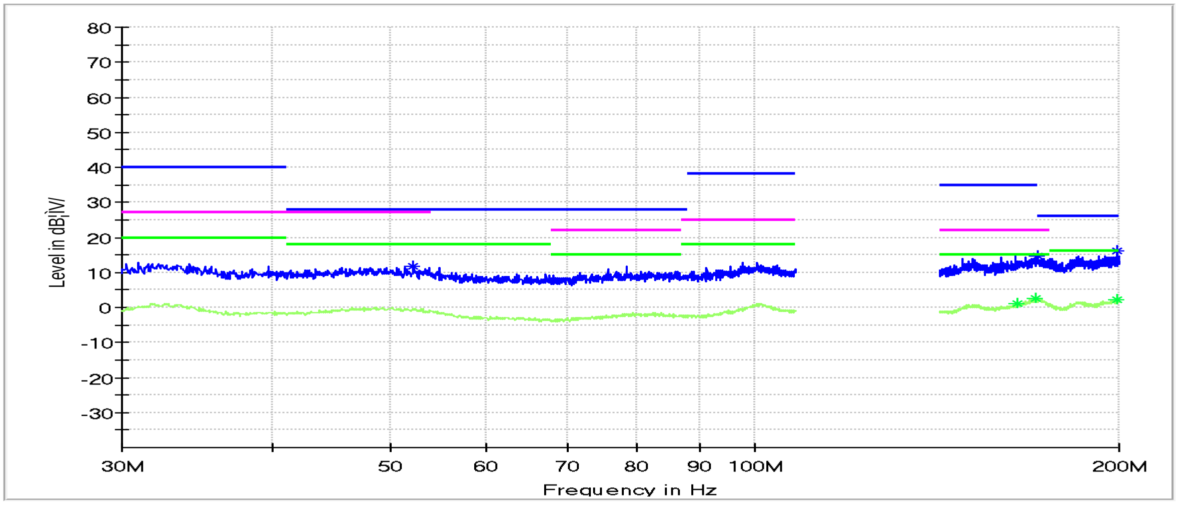
4，RE Horizontal 30-200MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
48.500000	11.43	---	28.00	16.57	---	---	H	-13.5
165.850000	---	8.48	15.00	6.52	---	---	H	-10.0
170.800000	---	13.46	15.00	1.54	---	---	H	-9.8
172.700000	21.62	---	26.00	4.38	---	---	H	-9.9
183.950000	---	3.45	16.00	12.55	---	---	H	-9.3
186.200000	16.37	---	26.00	9.63	---	---	H	-9.0

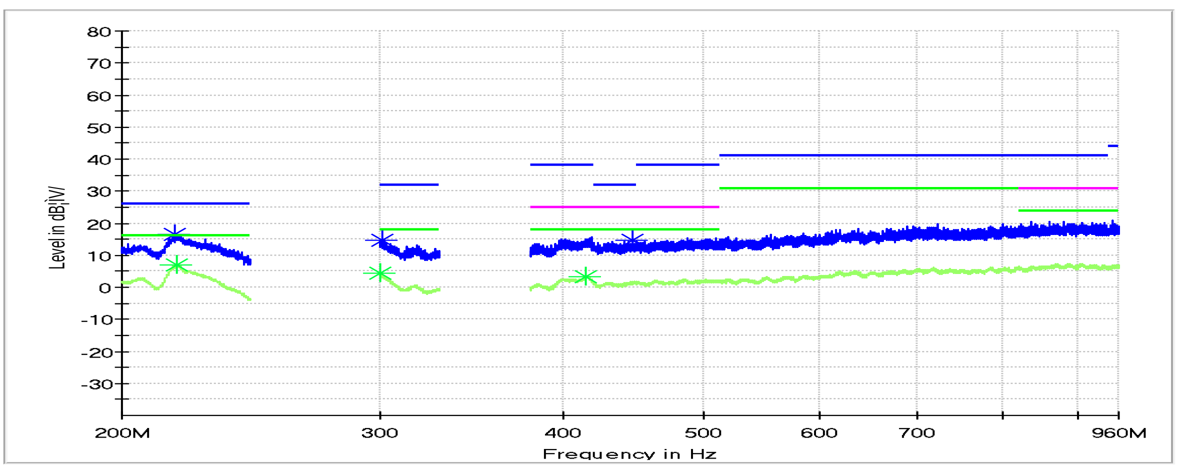
5, RE Vertical 30-200MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
52.250000	11.92	---	28.00	16.08	---	---	V	-13.7
165.100000	---	1.23	15.00	13.77	---	---	V	-10.1
170.900000	---	2.51	15.00	12.49	---	---	V	-9.8
171.350000	14.67	---	26.00	11.33	---	---	V	-9.8
199.250000	---	2.26	16.00	13.74	---	---	V	-8.4
199.250000	16.05	---	26.00	9.95	---	---	V	-8.4

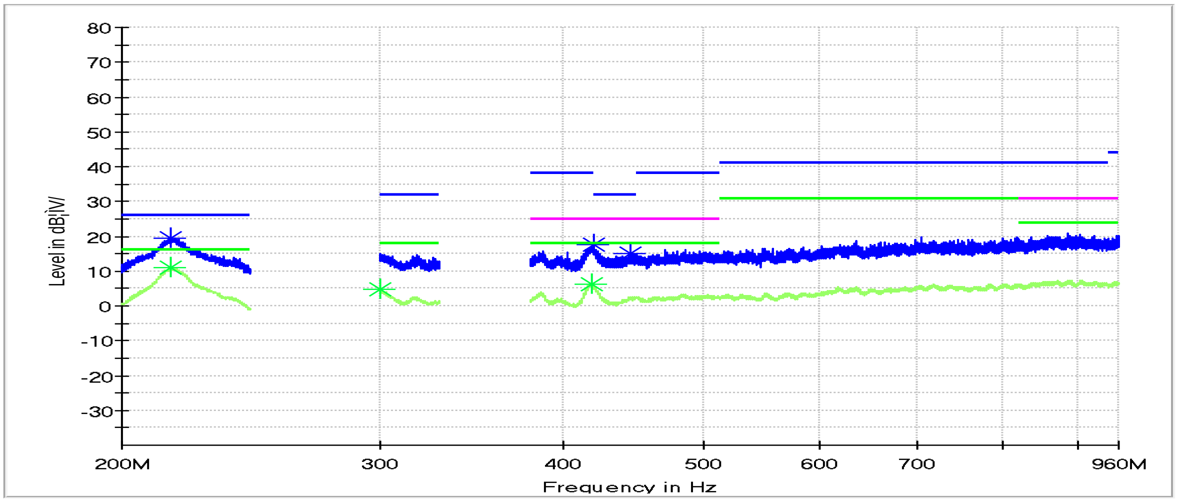
6, RE Horizontal 200-960MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
217.500000	16.42	---	26.00	9.58	---	---	H	-13.0
217.850000	---	6.91	16.00	9.09	---	---	H	-13.0
300.400000	---	4.27	18.00	13.73	---	---	H	-10.5
301.300000	14.79	---	32.00	17.21	---	---	H	-10.5
415.500000	---	3.44	18.00	14.56	---	---	H	-7.8
199.250000	16.05	---	26.00	9.95	---	---	V	-8.4

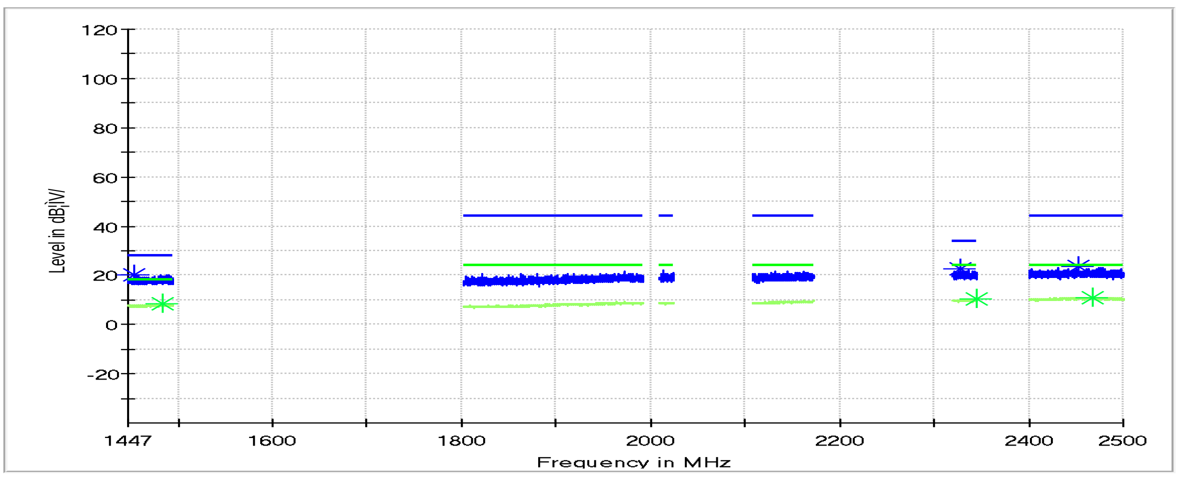
7, RE Vertical 200-960MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
215.850000	19.60	---	26.00	6.40	---	---	V	-13.2
216.100000	---	11.03	16.00	4.97	---	---	V	-13.2
300.050000	---	4.69	18.00	13.31	---	---	V	-10.6
419.100000	---	6.31	18.00	11.69	---	---	V	-7.6
420.800000	17.49	---	32.00	14.51	---	---	V	-7.7
444.850000	15.17	---	32.00	16.83	---	---	V	-7.5

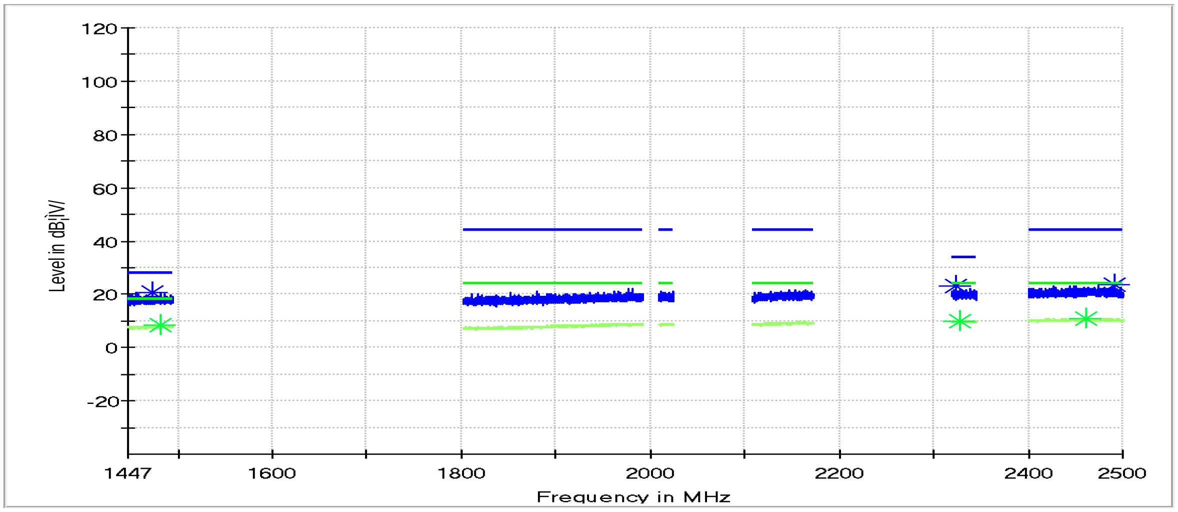
8, RE Horizontal 1447-2500MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
1454.050000	20.32	---	28.00	7.68	5.0	120.000	H	-12.0
1483.600000	---	8.37	18.00	9.63	5.0	120.000	H	-12.0
2327.100000	22.56	---	34.00	11.44	5.0	120.000	H	-9.4
2344.150000	---	10.17	24.00	13.83	5.0	120.000	H	-9.3
2452.450000	23.40	---	44.00	20.60	5.0	120.000	H	-8.6
2467.200000	---	11.08	24.00	12.92	5.0	120.000	H	-8.6

9, RE Vertical 1447-2500MHz（Tested in VIN=13.5V, VLED=6.6V (2 LEDS), ILED=2A）



Critical_Freqs

Frequency	MaxPeak	Average	Limit	Margin	Meas._Time	Bandwidth	Pol	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz		dB/m
1472.800000	20.79	---	28.00	7.21	5.0	120.000	V	-12.0
1481.300000	---	8.28	18.00	9.72	5.0	120.000	V	-12.0
2323.350000	23.11	---	34.00	10.89	5.0	120.000	V	-9.4
2328.700000	---	10.11	24.00	13.89	5.0	120.000	V	-9.4
2462.300000	---	10.97	24.00	13.03	5.0	120.000	V	-8.6
2491.900000	23.47	---	44.00	20.53	5.0	120.000	V	-8.6

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