FEB-L009 User Guide

FL6961

Evaluation Board

Featured Fairchild Product: FL6961

http://www.fairchildsemi.com/evalboard/

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The following user guide supports the demonstration kit for the FL6961. It should be used in conjunction with the FL6961 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document describes the proposed solution for an universal LED ballast using the FL6961 CRM PFC controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 700mA @ 24Vmax. This document contains general description of FL6961, the power supply specification, schematic, bill of materials and the typical operating characteristics.

1.1. General Description of FL6961

The FL6961 is an active power factor correction (PFC) controller for boost PFC applications that operates in critical conduction mode (CRM). It uses the voltage mode PWM that compares an internal ramp signal with the error amplifier output to generate MOSFET turn-off signal. Because the voltage-mode CRM PFC controller does not need rectified AC line voltage information, it saves the power loss of the input voltage sensing network necessary for the current-mode CRM PFC controller.

1.2. Features of FL6961

Boundary Mode PFC Controller
Low Input Current THD
Controlled On-time PWM
Zero Current Detection
Cycle-by-cycle Current Limiting
Leading-edge blanking instead of RC filtering
Low Start-up Current: 10uA (typical)
Low Operating Current: 4.5mA (typical)
Feedback Open-Loop Protection
Programmable Maximum On-Time (MOT)
Output Over-Voltage Clamping Protection
Clamped Gate Output Voltage 16.5V

1.3. Internal Block Diagram of FL6961

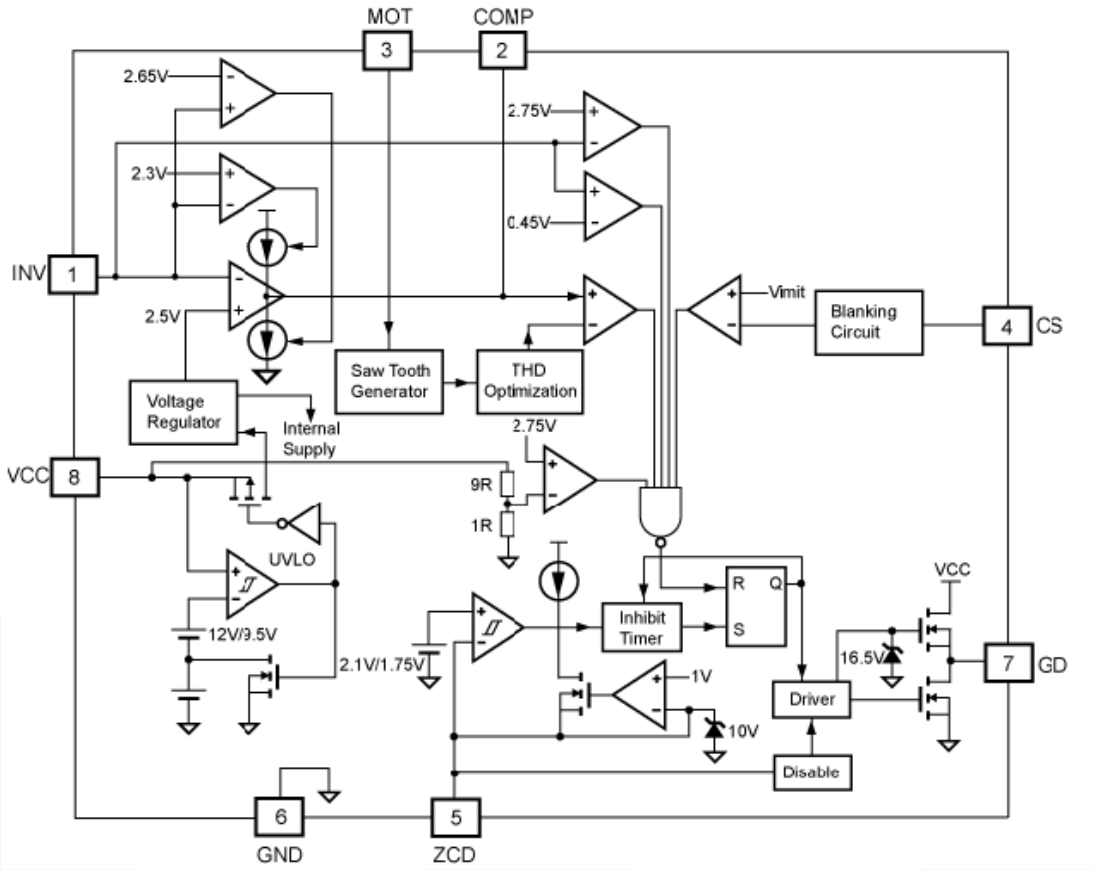


Figure 1. Internal Block Diagram of FL6961

2. General Specifications for Evaluation Board

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Main Controller	**FL6961**
Input Voltage Range	90Vac~265Vac
Input Voltage Frequency	47Hz~63Hz
Rated Output Power	16.8W
Rated Output Voltage	24V
Rated Output Current	0.7A
Application	LED Lighting Bulb
Board Size [mm] (LengthXWidthXHeight)	110X50X27

All data of the evaluation board were measured under a condition where the board was enclosed in a case and external temperature was around 25℃.

2.1. A Photograph of the Evaluation Board

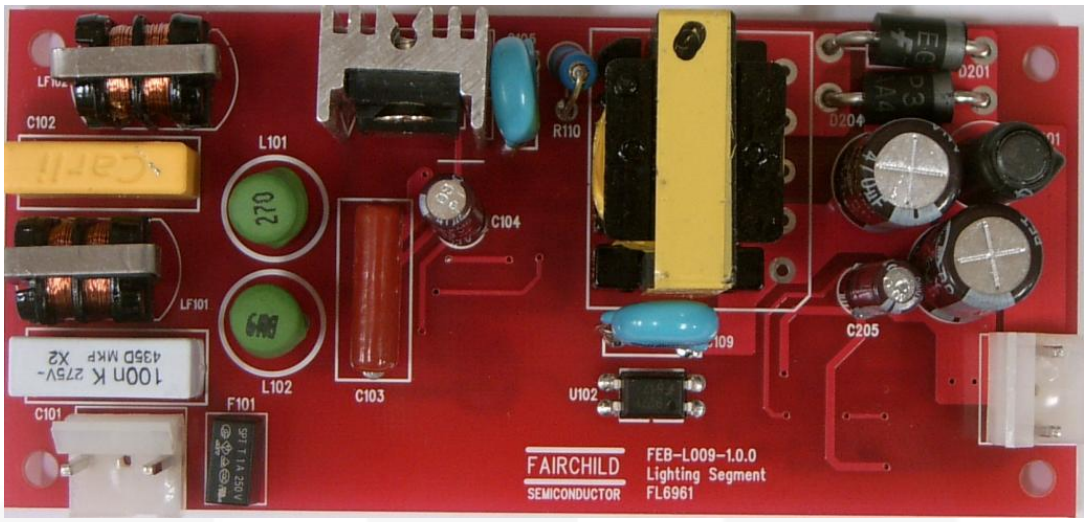


Figure 2. Top View of Evaluation Board

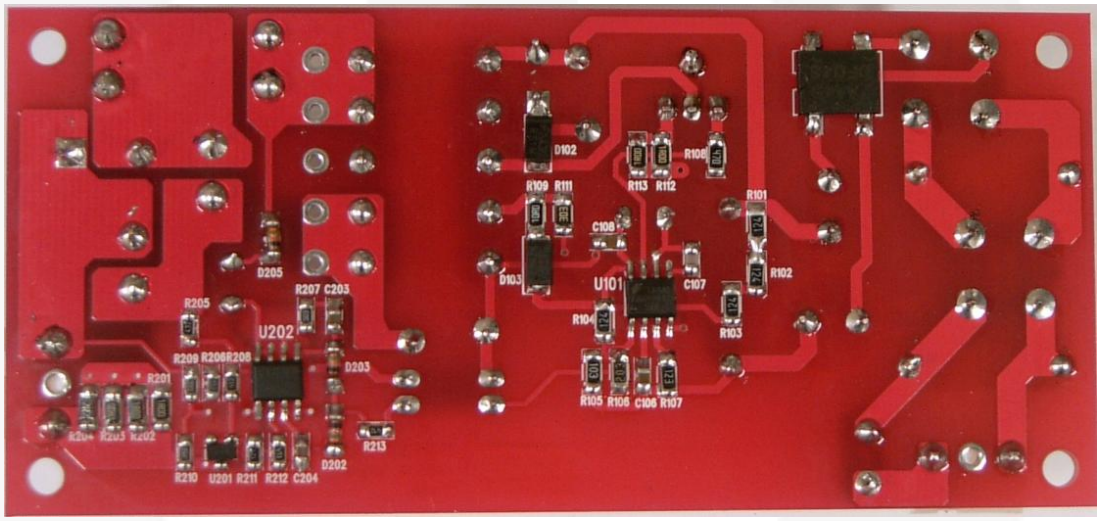
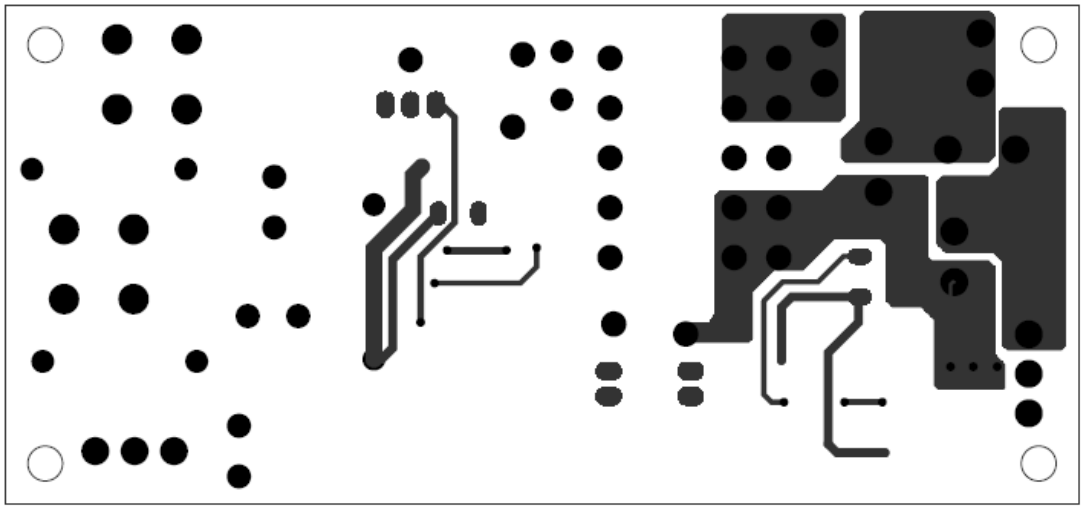
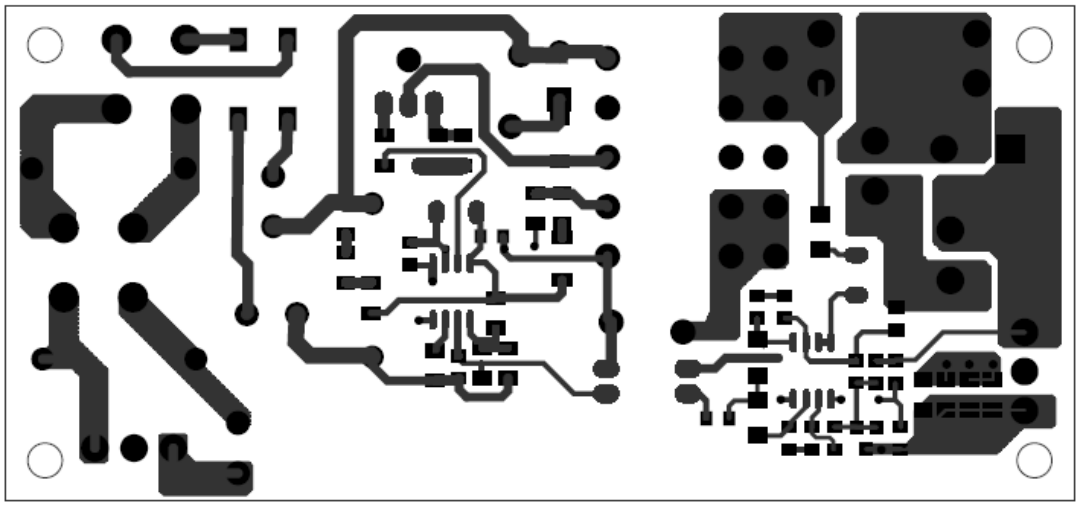


Figure 3. Bottom View of Evaluation Board

2.2. Printed Circuit Board



Top side view of reference board



Bottom side view of reference board

Figure 4. PCB(Printed Circuit Board) pattern of reference board

2.3. Schematic of the Evaluation Board

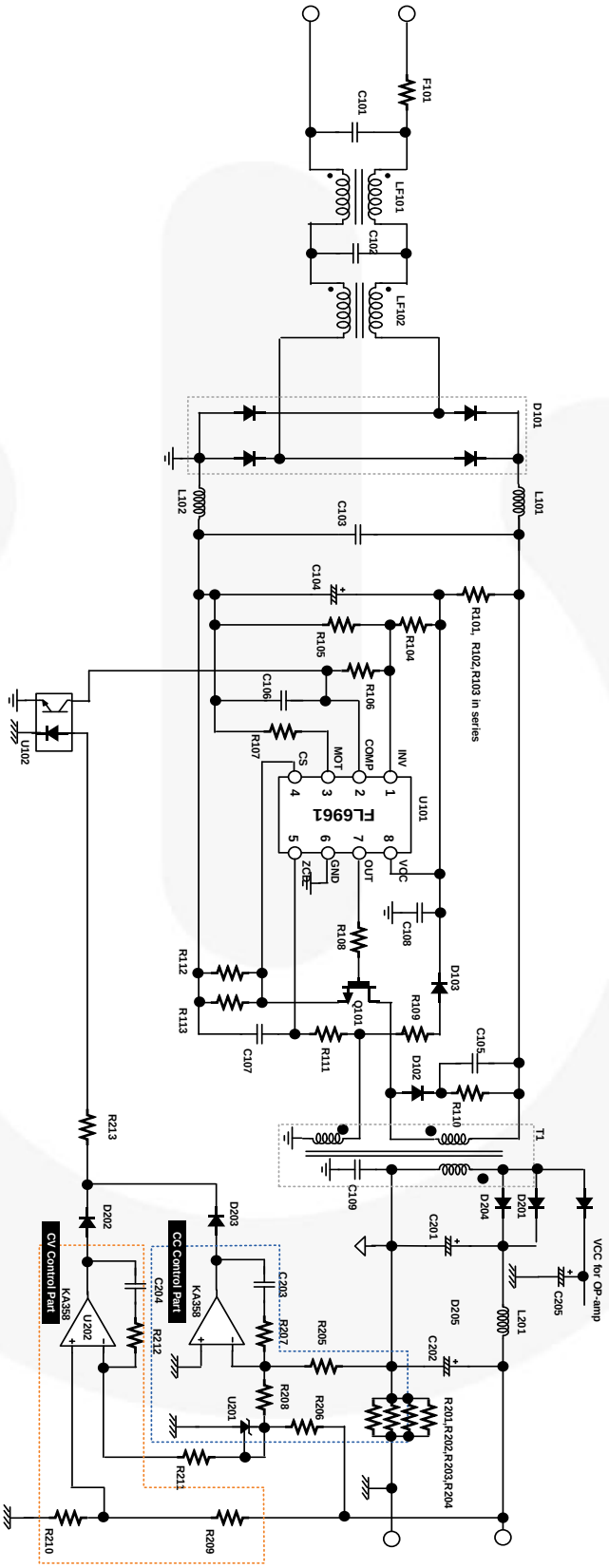


Figure 5. FL6961 Schematic

2.4. Bill of Material

Item Number	Part Reference	Value	Quantity	Description (Manufacturer)
1	U101	FL6961	1	CRM PFC controller (Fairchild Product)
2	U102	FOD817	1	Opto-coupler (Fairchild Product)
3	U201	KA431	1	Shunt regulator (Fairchild Product)
4	U202	KA358A(LM2904)	1	Dual OP Amp (Fairchild Product)
5	Q101	FQPF3N80C	1	800V/3A MOSFET (Fairchild Product)
6	D101	DF04	1	1.5A SMD bridge diode (Fairchild Product)
7	D102,	RS1M	1	1000V/1A Ultra fast recovery diode (Fairchild Product)
8	D103	RS1G	1	400V/1A fast recovery diode (Fairchild Product)
9	D201, D204	EGP30D	2	200V/3A Ultra fast recovery diode (Fairchild Product)
10	D202, D203, D205	LL4148	3	General purpose diode (Fairchild Product)
11	R101,R102,R103	120KΩ	3	SMD Resistor1206
12	R104	120kΩ	1	SMD Resistor1206
13	R105	10KΩ	1	SMD Resistor1206
14	R106	20KΩ	1	SMD Resistor1206
15	R107	9.1kΩ	1	SMD Resistor1206
16	R108	47Ω	1	SMD Resistor 1206
17	R109	10Ω	1	SMD Resistor 1206
18	R110	220KΩ	1	2W
19	R111	30KΩ	1	SMD Resistor 1206
20	R112,R113	1Ω	2	SMD Resistor 1206
21	R201,R202,R203	1Ω	3	SMD Resistor 1206
22	R204	2.2Ω	1	SMD Resistor 0806
23	R205	4.3KΩ	1	SMD Resistor 0806
24	R206	1.5KΩ	1	SMD Resistor 0806
25	R207	30KΩ	1	SMD Resistor 0806
26	R208	51KΩ	1	SMD Resistor 0806
27	R209	33KΩ	1	SMD Resistor 0806
28	R210	3.9KΩ	1	SMD Resistor 0806
29	R211	120KΩ	1	SMD Resistor 0806
30	R212	47KΩ	1	SMD Resistor 0806
31	R213	4.7KΩ	1	SMD Resistor 0806

Item Number	Part Reference	Value	Quantity	Description (Manufacturer)
33	C101	100nF/250V	1	X – Capacitor
34	C102	47nF/250V	1	X – Capacitor
35	C103	100nF/630V	1	Film Capacitor
36	C104	47uF/35V	1	Electrolytic capacitor
37	C105	2.2nF/1kV	1	Y-Capacitor
38	C106	2.2uF	1	SMD Capacitor 0805
39	C107	30pF	1	SMD Capacitor 0805
40	C108	100nF	1	SMD Capacitor 0805
41	C201,C202	470uF/35V	2	Electrolytic capacitor
42	C203	1uF	1	SMD Capacitor 0805
43	C204	470nF	1	SMD Capacitor 0805
44	C205	10uF/35V	1	Electrolytic capacitor
45	LF101,LF102	80mH	2	Line filter
46	L101	27uH	1	Line filter
47	L102	6.8uH	1	Line filter
48	L201	5uH	1	Output Inductor
49	F101	1A/250V	1	Fuse
50	T1	EE2525S	1	1mH

2.5. Connections Transformer and Winding Specifications

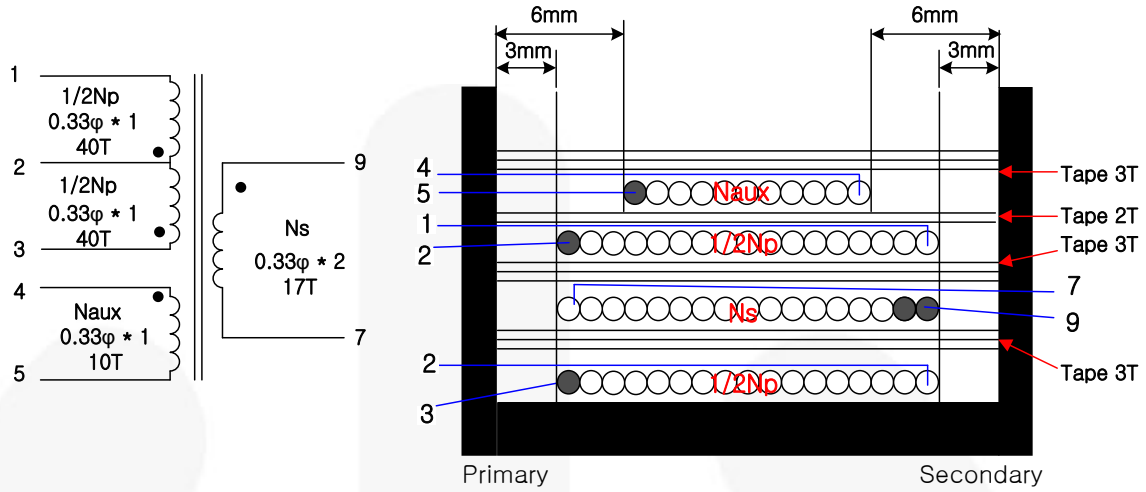


Figure 6. Transformer specifications & construction. [EE2525]

Table 2. Winding specifications.

No	Winding	Pin(S → F)	Wire	Turns	Winding Method
1	1/2Np	3 → 2	0.33φ×1	40Ts	Solenoid winding
2	Insulation : Polyester Tape t = 0.025mm, 1Layers				
3	Ns	9 → 7	0.33φ×2	17Ts	Solenoid winding
4	Insulation : Polyester Tape t = 0.025mm, 3Layers				
5	1/2Np	2→ 1	0.33φ×1	40 Ts	Solenoid winding
6	Insulation : Polyester Tape t = 0.025mm, 3Layers				
7	Naux	4 →5	0.33φ×1	10 Ts	Center Solenoid winding
8	Insulation : Polyester Tape t = 0.025mm, 3Layers				

Table 3. Electrical Characteristics.

	Pin	Spec.	Remark
Inductance	3– 1	1mH ±7%	1kHz, 1V
Leakage	3- 1	10 uH Max	Short all output pins

3. Test Condition & test equipment

Table 4. test condition & test equipment

Ambient Temperature	T_A = 25°C, Open flame
Test Equipment	AC Source : PCR500L by Kikusui Electronic Load : PLZ334WH by Kikusui Power Meter : 2574R series by Xitron Oscilloscope : DPO7104 by Tektronix EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer : CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03 (3W) by Everlight
Test condition	All of the results in this test report are tested by using the electronic load. If there isn't any kind of notation.

3.1. Electrical Performances

The figure 7 shows we can get at least 74% system efficiency with universal input condition at rated output LED load.

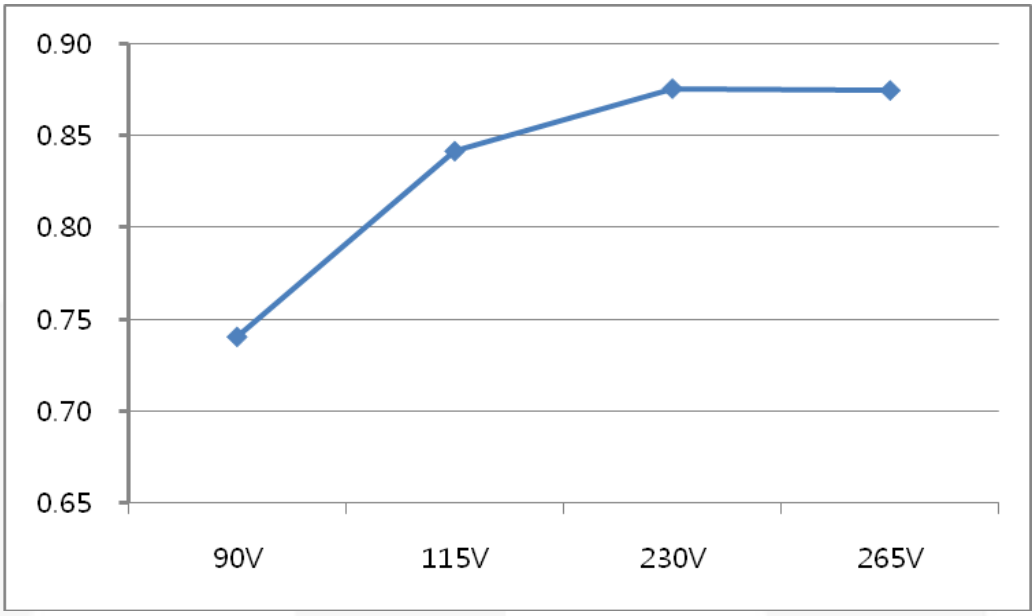


Figure 7. System Efficiency

Input Voltage [Vac]	90V	115V	230V	265V
Input Power [W]	21.67	19.07	18.33	18.85
Output Power [W]	16.05	16.05	16.05	16.05
Efficiency [%]	74	84	88	87

The figure 8 shows that we can always get over 92% PF results with universal input condition as rated output LED load.

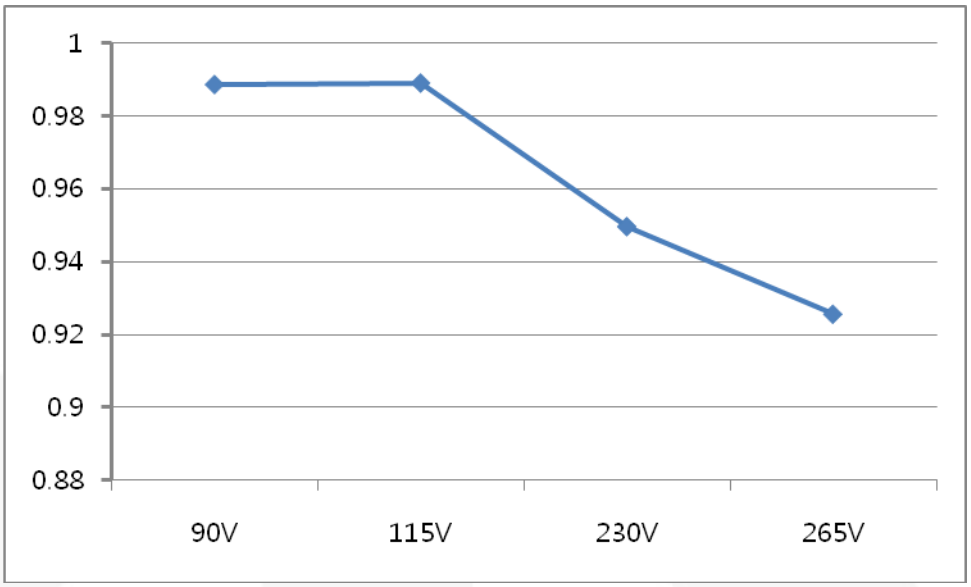


Figure 8. Power Factor

Input Voltage [Vac]	90V	115V	230V	265V
PF	0.98	0.98	0.95	0.93
ATHD[%]	14.72	13.5	20.5	21.4

The figure 9 and Table 5 and 6 show the typical CC/CV performance on board. As you can see, we can always see very stable CC performance in wide input range.

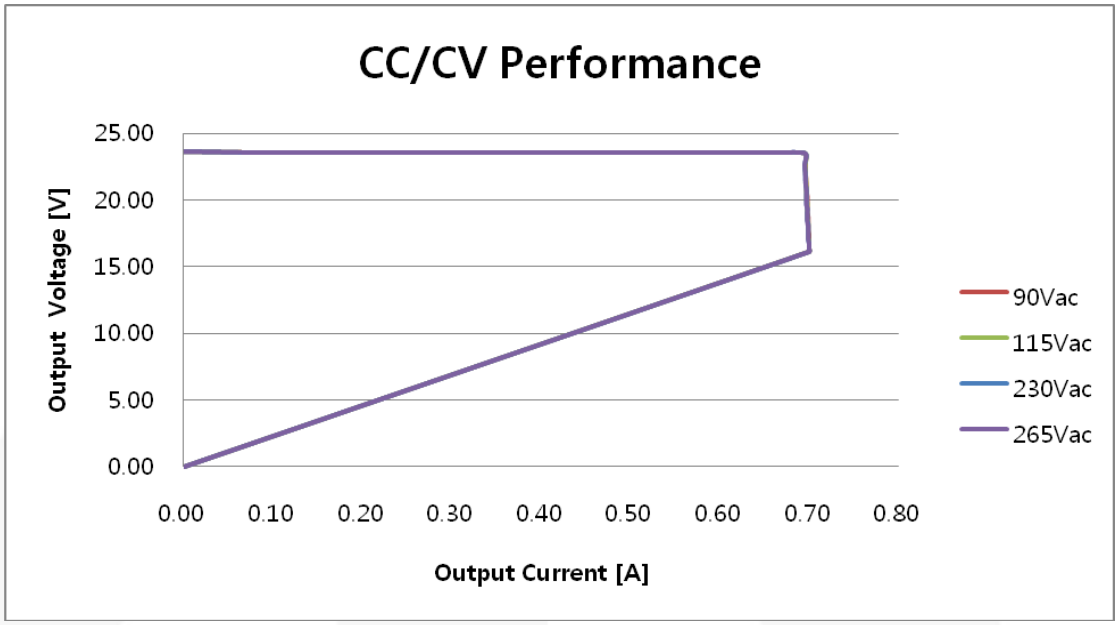


Figure 9. CC/CV Performance

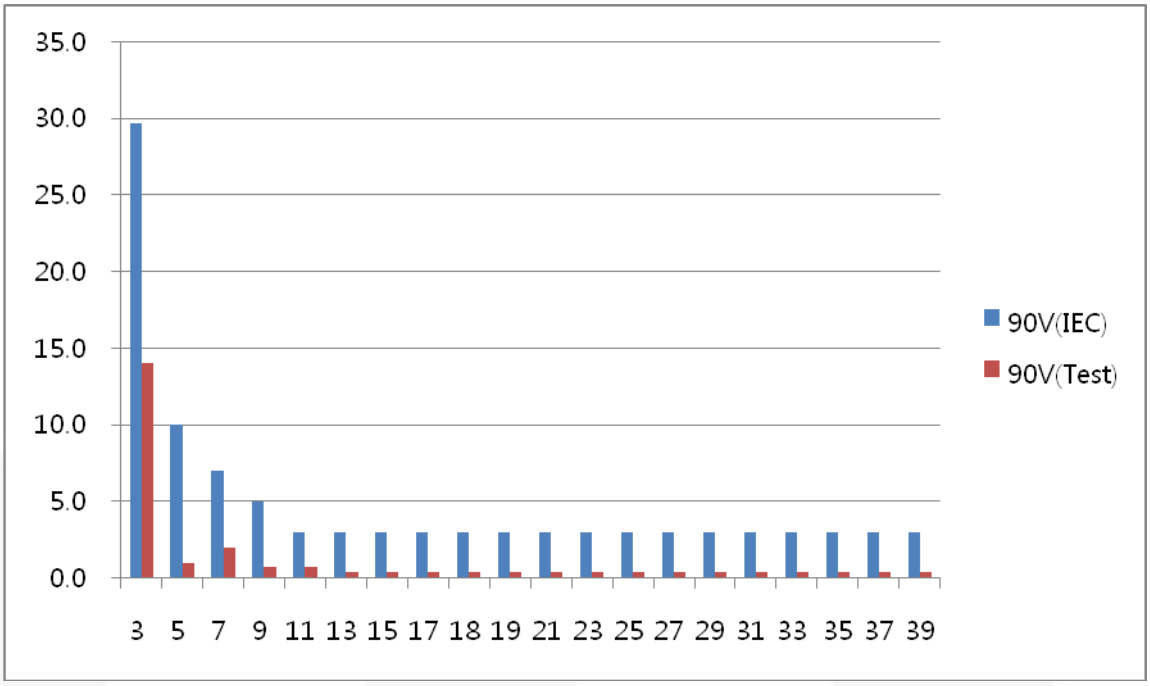
Table 5. Output Voltage Regulation Performance in CV region

CV	Input Voltage	90V	115V	230V	265V
	Max. output	23.60	23.60	23.60	23.60
	Min. output	23.53	23.53	23.53	23.53
	Diff.	0.07	0.07	0.07	0.07
	Avg	23.53	23.53	23.53	23.53
	Deviation[%]	0.31	0.30	0.31	0.30

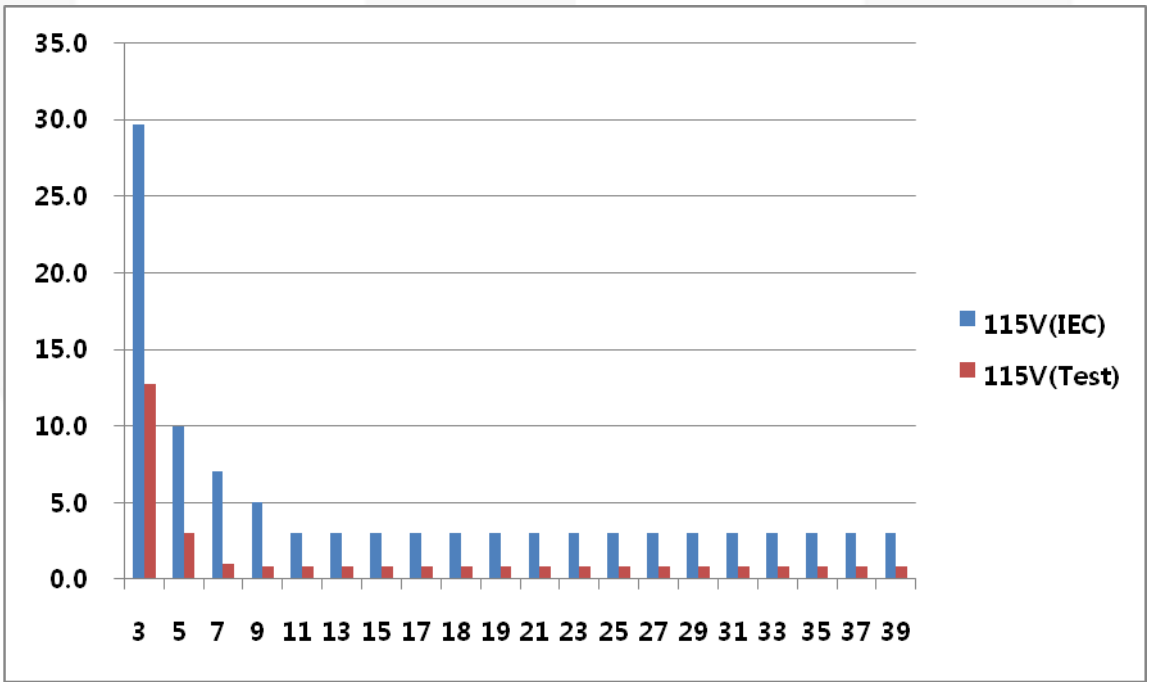
Table 6. Output Current Regulation Performance in CC region

CC	Input Voltage	90V	115V	230V	265V
	Max. output	0.70	0.70	0.70	0.70
	Min. output	0.69	0.69	0.69	0.69
	Diff	0.01	0.01	0.01	0.01
	Avg	0.70	0.70	0.70	0.70
	Deviation[%]	1.72	1.72	1.72	1.72

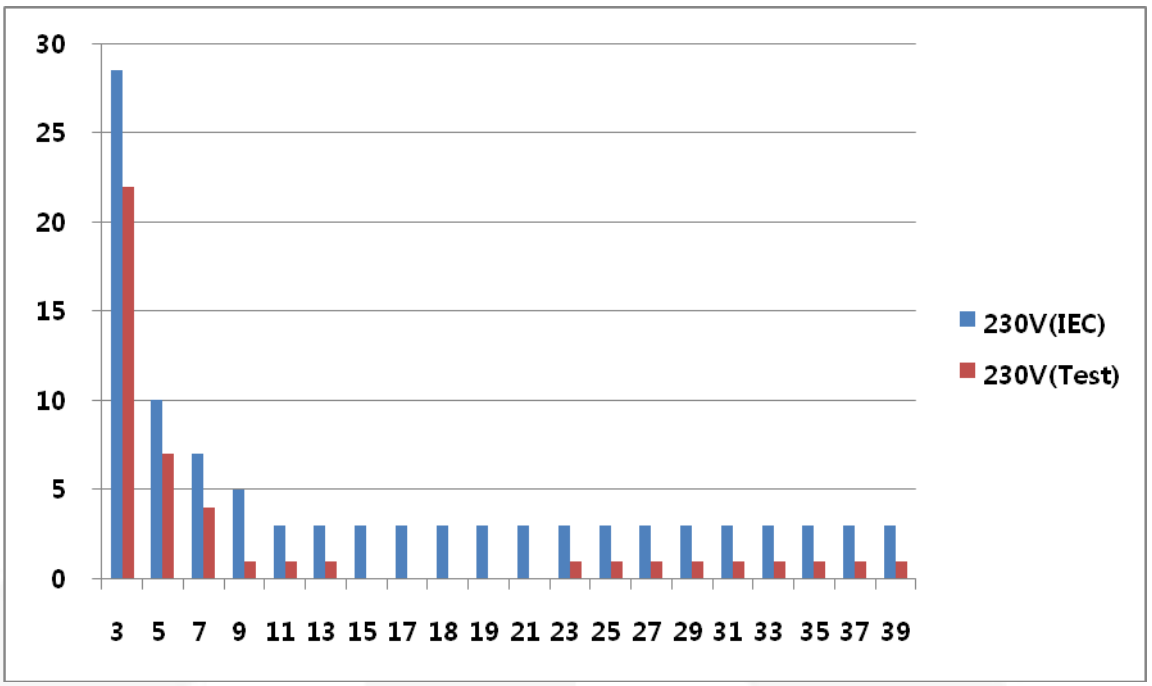
The figure 10 shows the test results of FL6961 evalutaiton board. All of the results can meet the international regulation at rated LED load condition.



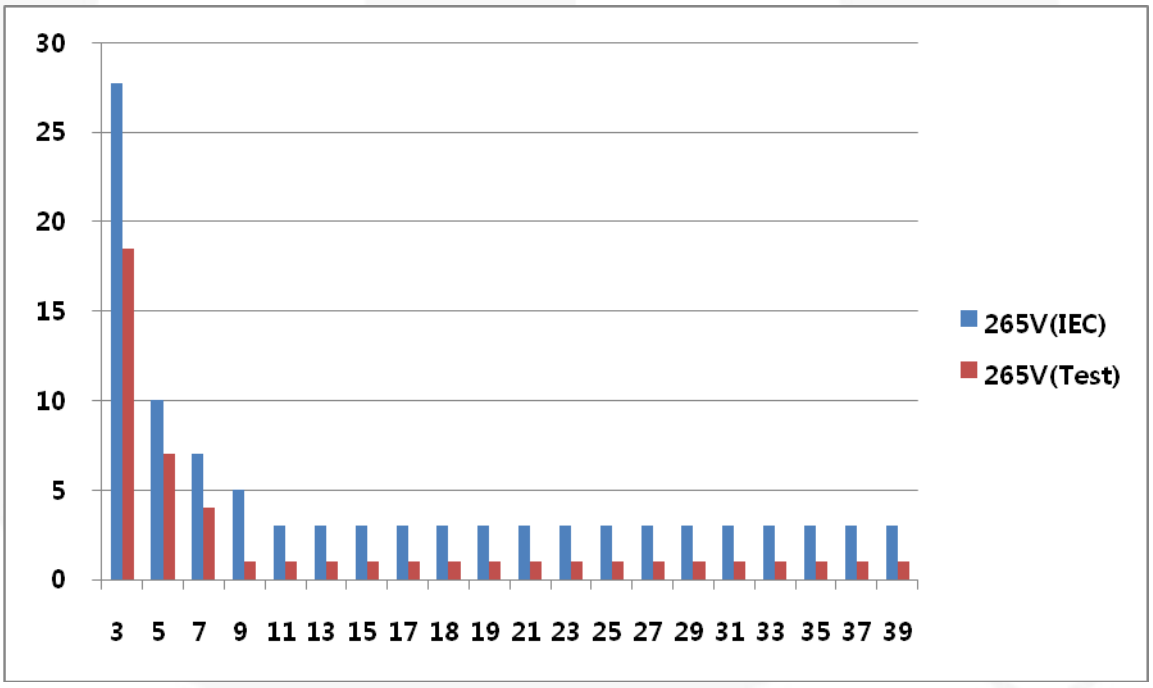
a) THD Performance Results at 90V



b) THD Performance Results at 115V



c) THD Performance Results at 230V

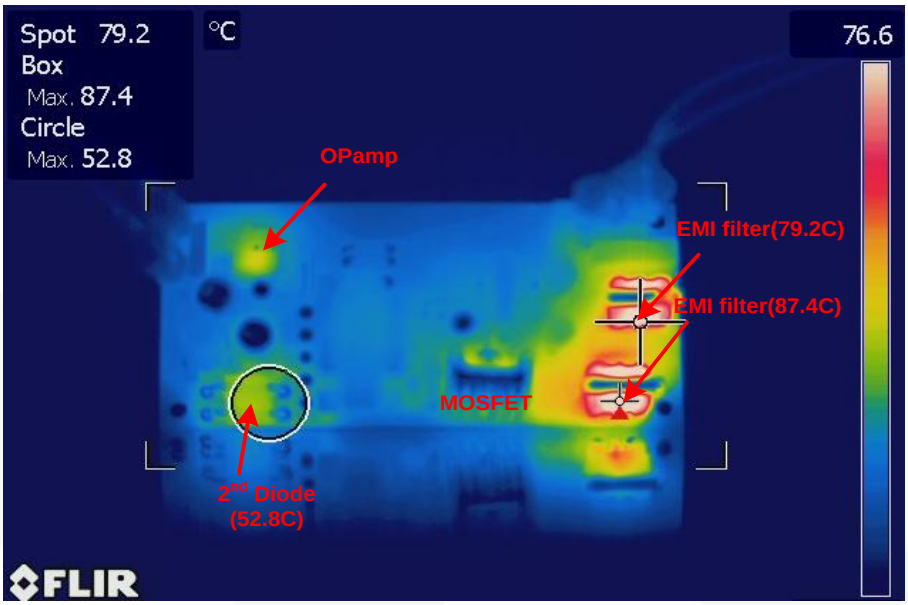


d) THD Performance Results at 265V

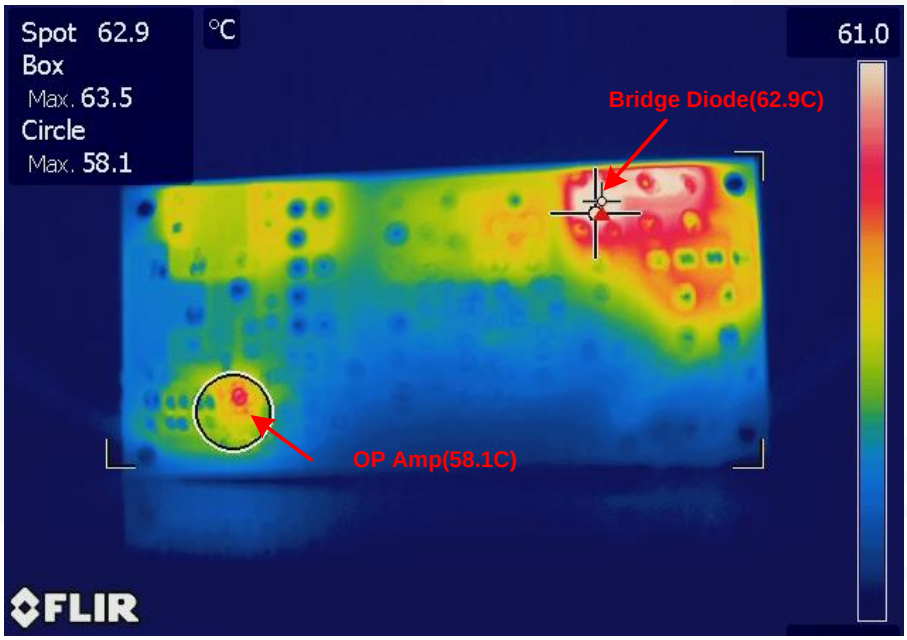
Figure 10. THD Performance Results

3.2. Temperature Checking Results on Board

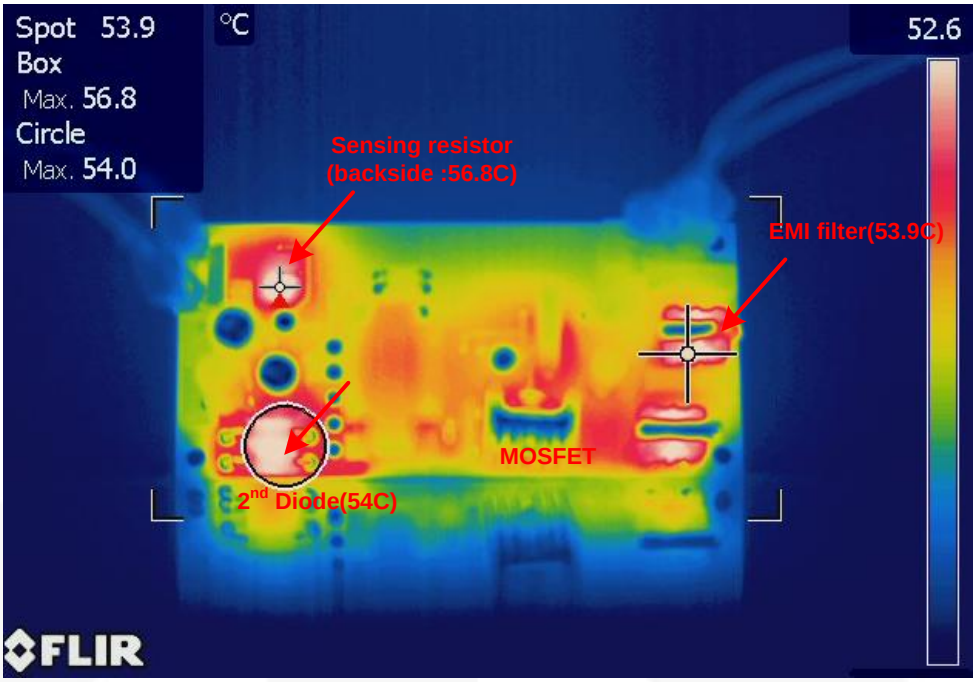
The figure 11 shows the temperature checking results on board in min. and max. input voltage condition at rated LED load condition.



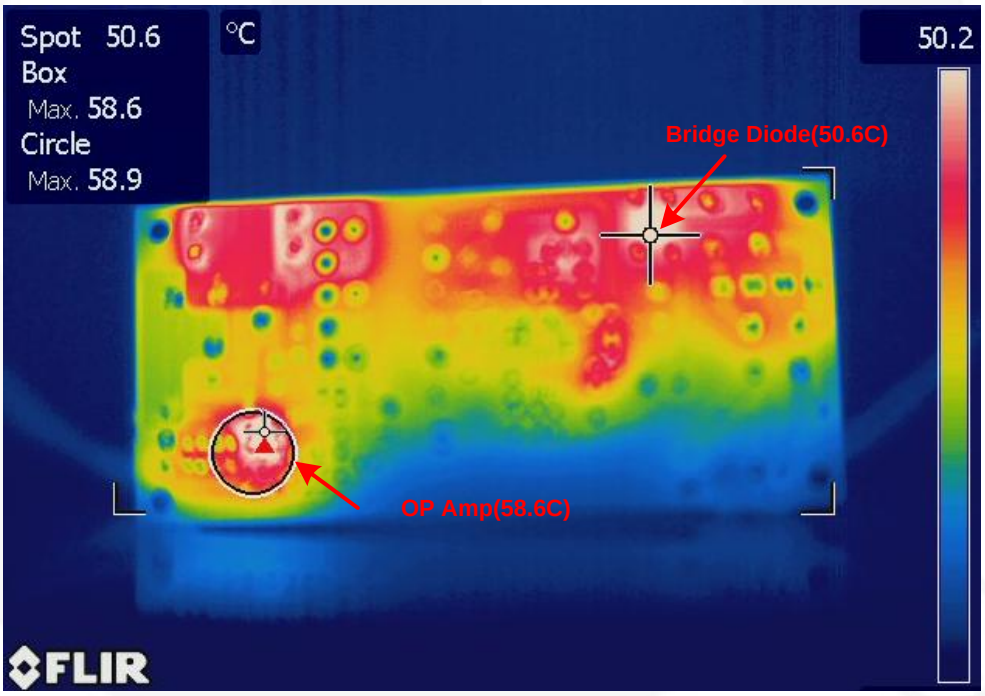
a) Top side test results at 90Vac input condition



b) Back side test results at 90Vac input condition



c) Top side test results at 265Vac input condition

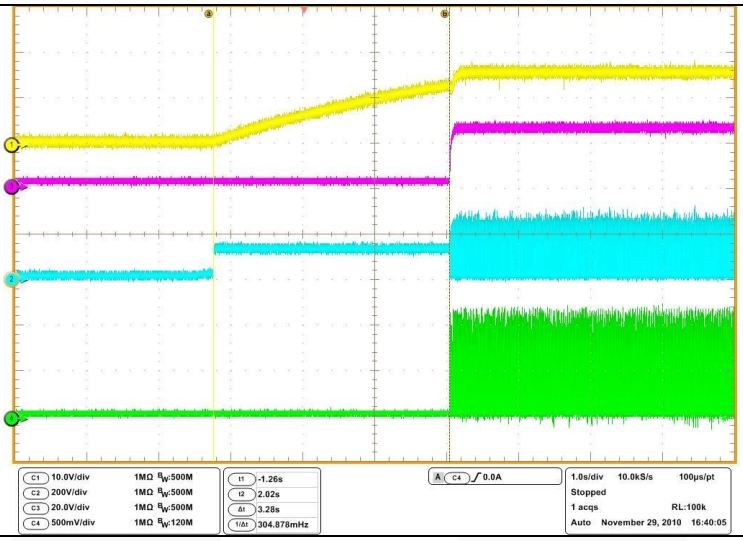
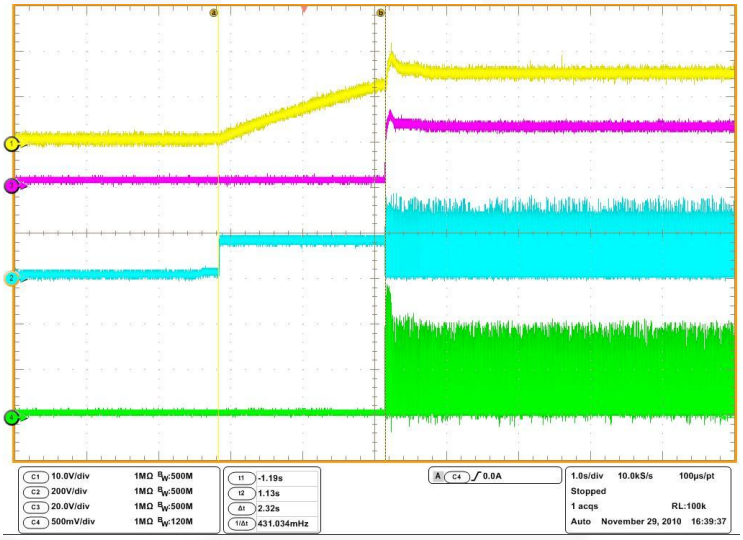


d) Bottom side test results at 265Vac input condition

Figure 11. Thermal Performance Results

3.3. Operation Waveforms

The figure 12 shows the typical start-up performance on board. We can get a little bit long start-up time to release UVLO function on IC at 90V condition rather than 265V condition and this time normally depends on starting resistor and capacitor on board.

CH1 : VCC [10V/div] CH2 : V_{DS} [200V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.5A/div] time : [0.5s/div]	
	Turn on time @ 90V_{AC} : 3.28s
CH1 : VCC [10V/div] CH2 : V_{DS} [200V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.5A/div] time : [0.5s/div]	
	Start up time @ 115V_{AC} : 2.32s

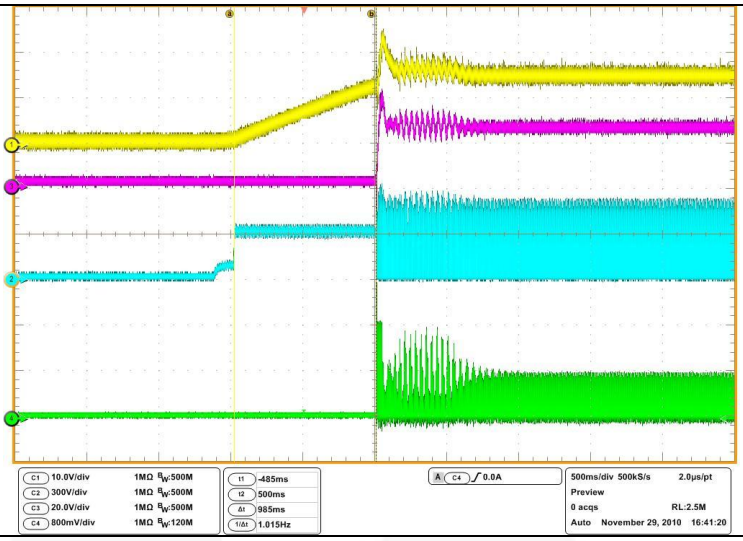
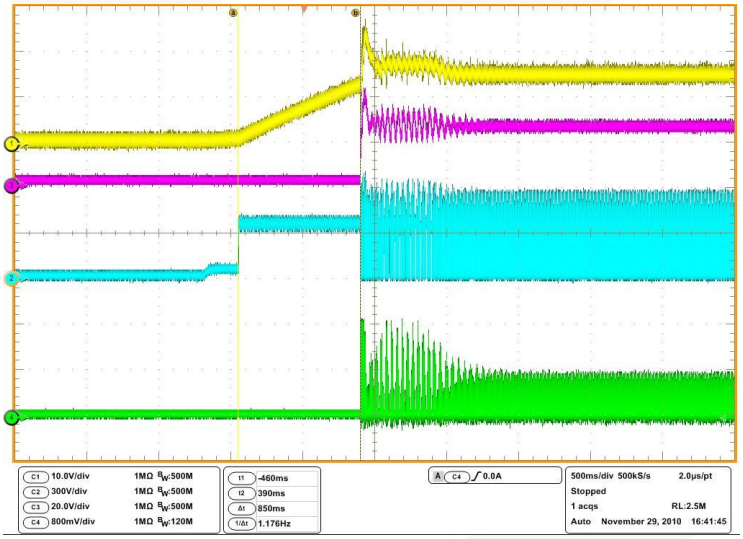
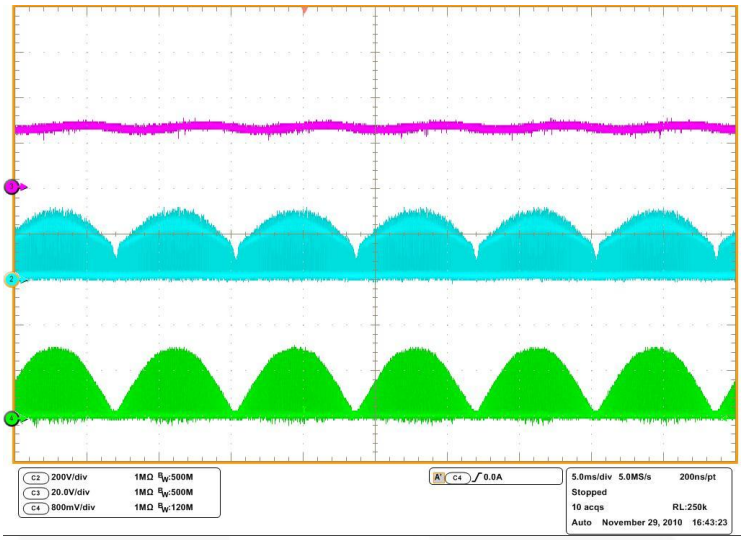
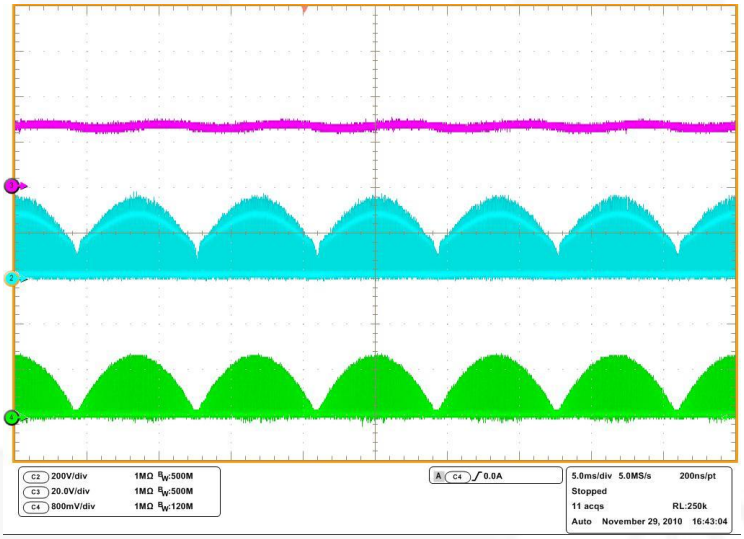
CH1 : VCC [10V/div] CH2 : V_{DS} [300V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.8A/div] time : [0.5s/div]	
	Turn on time @ 230V_{AC} : 0.985s
CH1 : VCC [10V/div] CH2 : V_{DS} [300V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.8A/div] time : [0.5s/div]	
	Start up time @ 265V_{AC} : 0.85s

Figure 12. Start-up Characteristics

Start-up time	85Vac	115Vac	230Vac	265Vac
Time [s]	3.28	2.32	0.985	0.85

The figure 13 shows the normal operation waveform on board at different input voltage condition. The output voltage always keeps wanted output level with 120Hz ripple voltage.

CH2 : V_{DS} [200V/div] **CH3 : V_{OUT}[20V/div]** **CH4 : I_{DS} [0.8A/div]** **time: [5ms/div]**	
Normal operation @ 90Vac	
CH2 : V_{DS} [200V/div] **CH3 : V_{OUT}[20V/div]** **CH4 : I_{DS} [0.8A/div]** **time : [5ms/div]**	
Normal operation @ 115Vac	

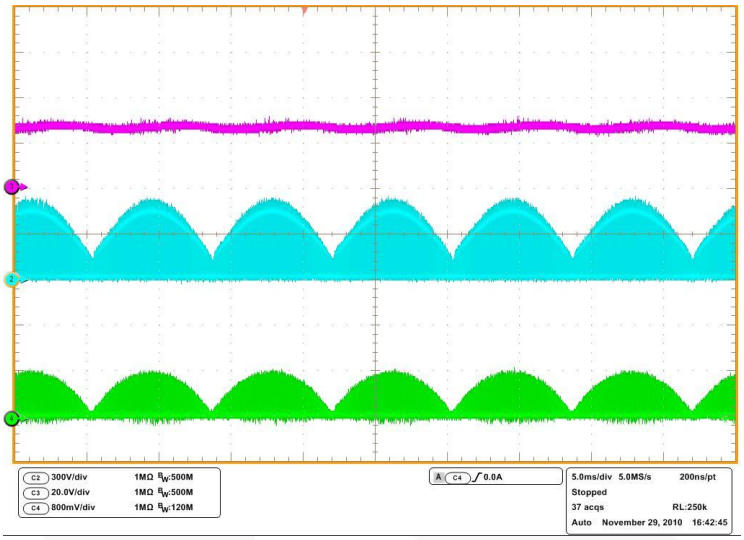
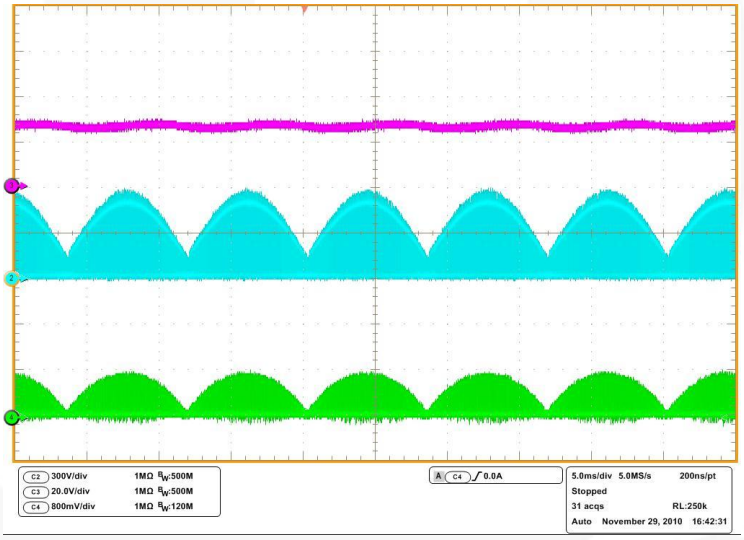
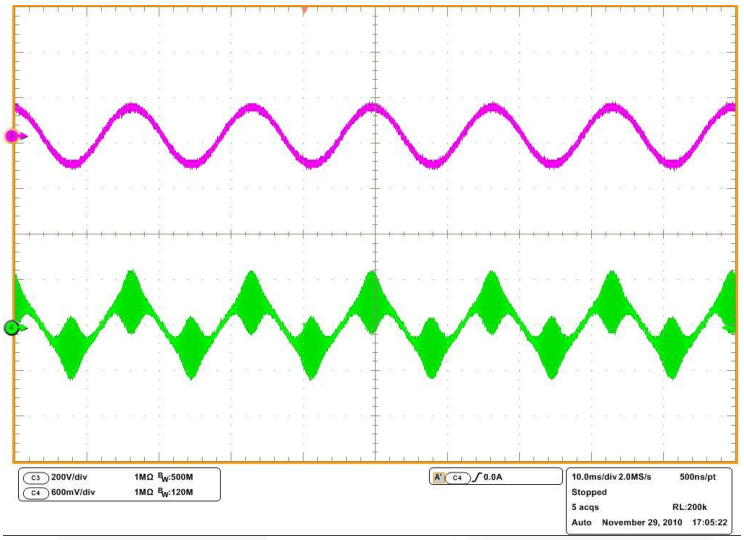
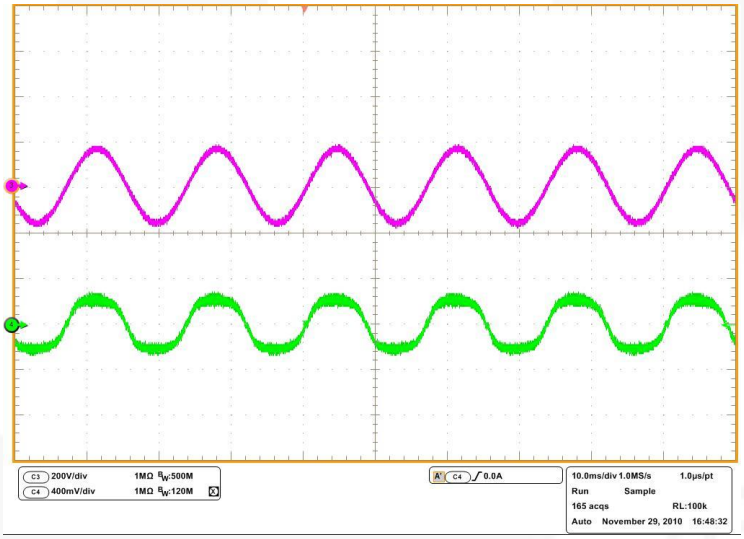
CH2 : V_{DS} [300V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.8A/div] time: [5ms/div]	
Normal operation @ 230Vac	
CH2 : V_{DS} [300V/div] CH3 : V_{OUT}[20V/div] CH4 : I_{DS} [0.8A/div] time : [5ms/div]	
Normal operation @ 265Vac	

Figure 13. Normal Operation

The figure 14 shows the input current waveforms on board at different input voltage condition.

CH3 : V_{AC}[200V/div] **CH4 : I_{AC} [0.6A/div]** **time : [10ms/div]**	
Normal operation @ 90Vac	
CH3 : V_{AC}[200V/div] **CH4 : I_{AC} [0.4A/div]** **time : [10ms/div]**	
Normal operation @ 115Vac	

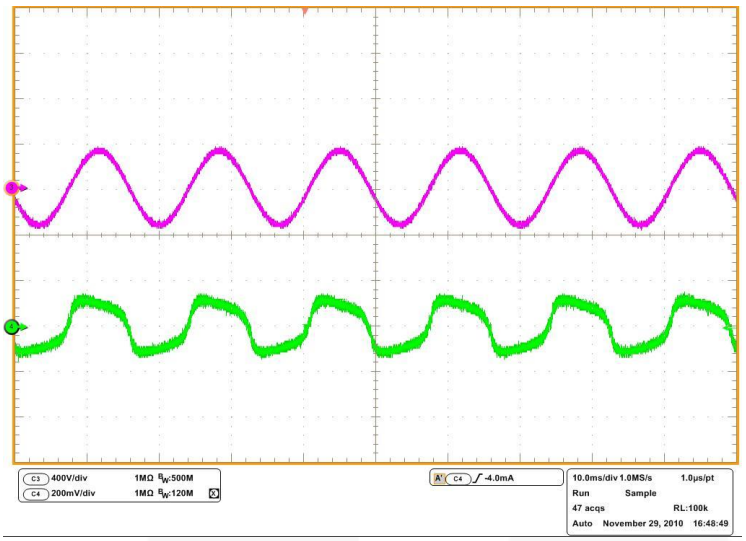
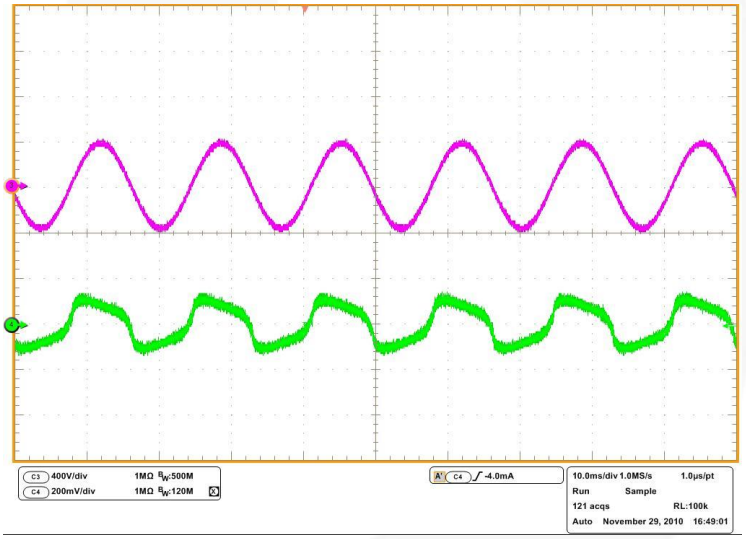
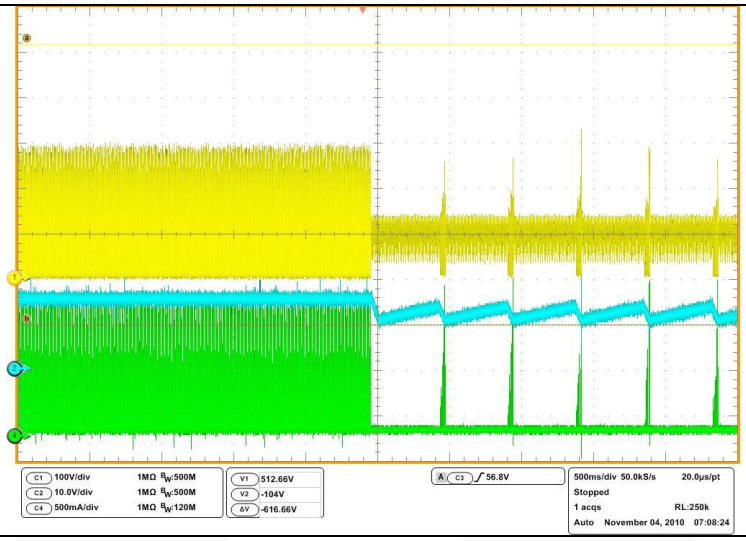
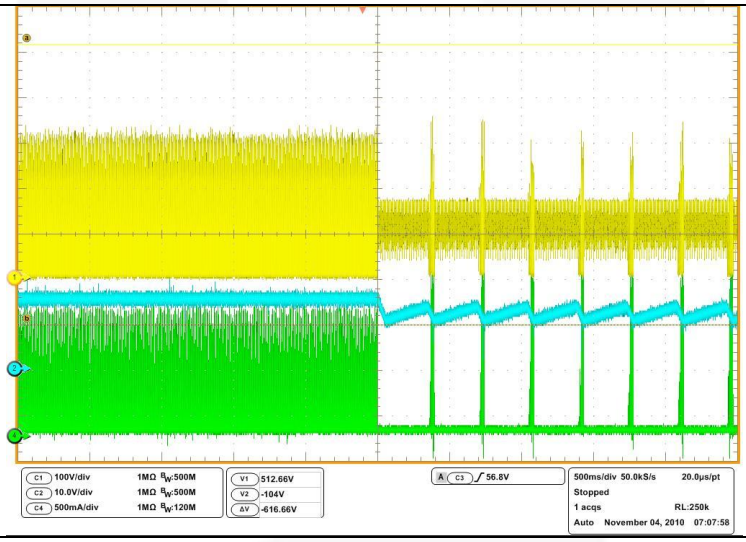
CH3 : V_{AC}[400V/div] **CH4 : I_{AC} [0.2A/div]** **time : [10ms/div]**	
Normal operation @ 230Vac	
CH3 : V_{AC}[400V/div] **CH4 : I_{AC} [0.2A/div]** **time : [10ms/div])**	
Normal operation @ 265Vac	

Figure 14. Normal Operation

3.4. Protection & voltage stress

The figure 15 shows the typical output waveforms at short load condition. The IC repeats ON and OFF function at this mode..

CH1 : V_{DS} [100V/div] CH2 : VCC[10V/div] CH4 : I_{DS} [0.5A/div] time : [500ms/div]	
Output short @ 90Vac	
CH1 : V_{DS} [100V/div] CH2 : VCC[10V/div] CH4 : I_{DS} [0.5A/div] time : [500ms/div]	
Output short @ 115Vac	

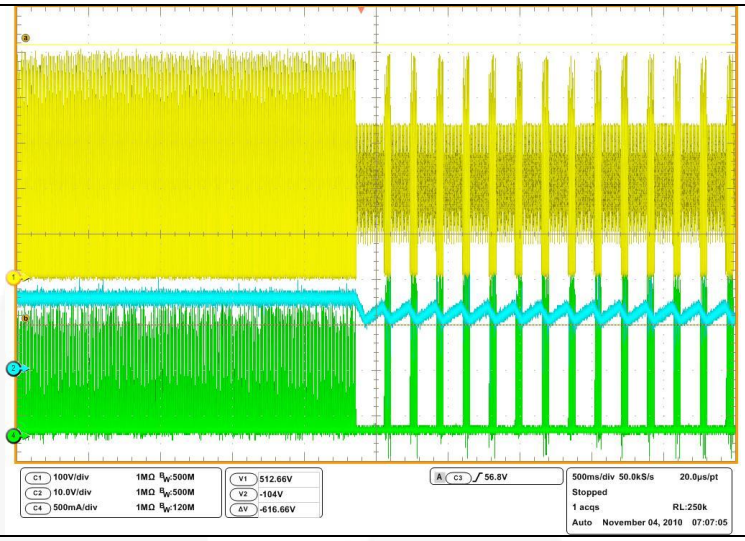
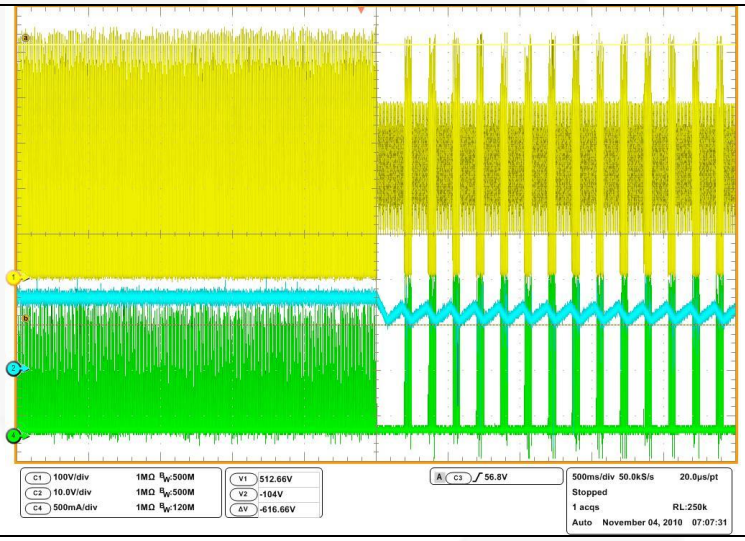
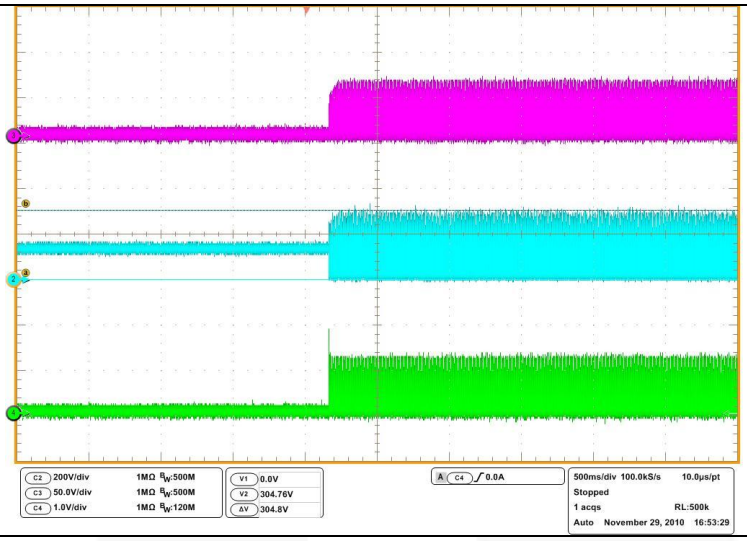
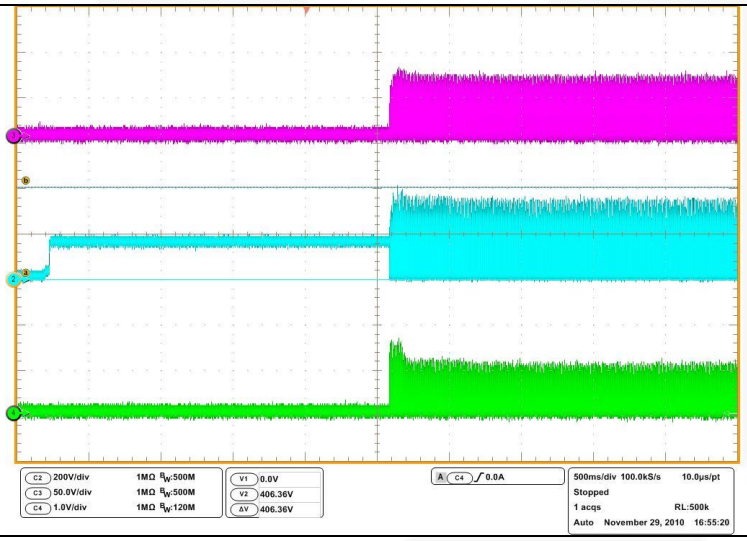
CH1 : V_{DS} [100V/div] CH2 : VCC[10V/div] CH4 : I_{DS} [0.5A/div] time : [500ms/div]	
Output short @ 230Vac	
CH1 : V_{DS} [100V/div] CH2 : VCC[10V/div] CH4 : I_{DS} [0.5A/div] time : [500ms/div]	
Output short @ 265Vac	

Figure 15. Output Short Protection

The figure 16 shows the voltage stress on MOSFET at start-up time with rated load condition.

Test condition	MOSFET Voltage Stress at Start-up Period
	Full load 90Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$V_{DS,Max}$: 304.76V
	Full load 115Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$V_{DS,Max}$: 406.36V

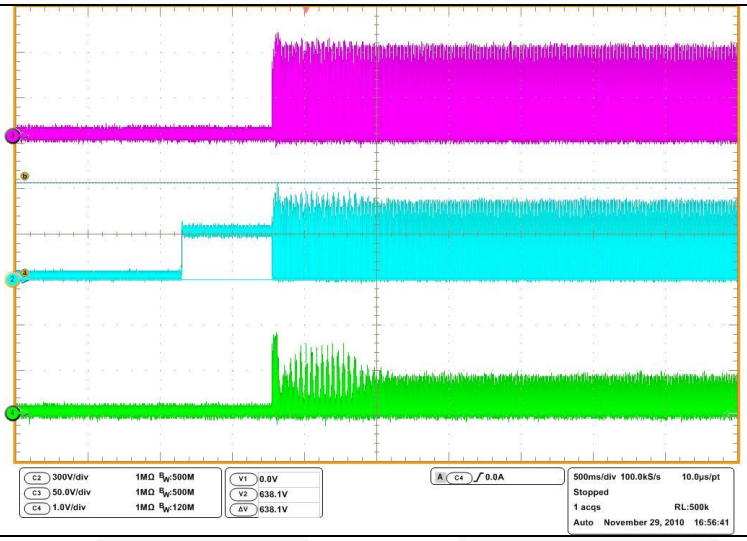
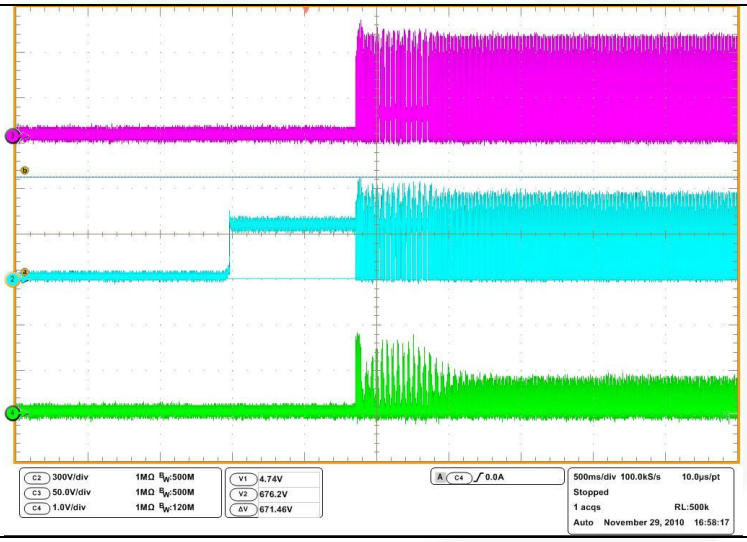
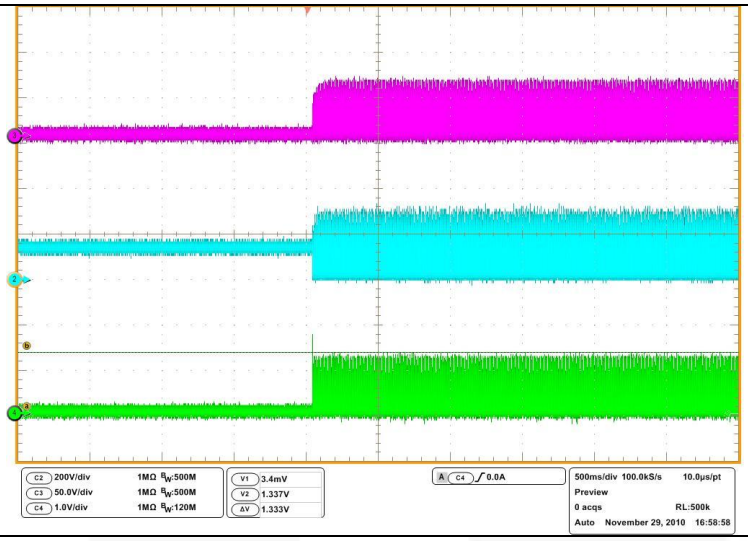
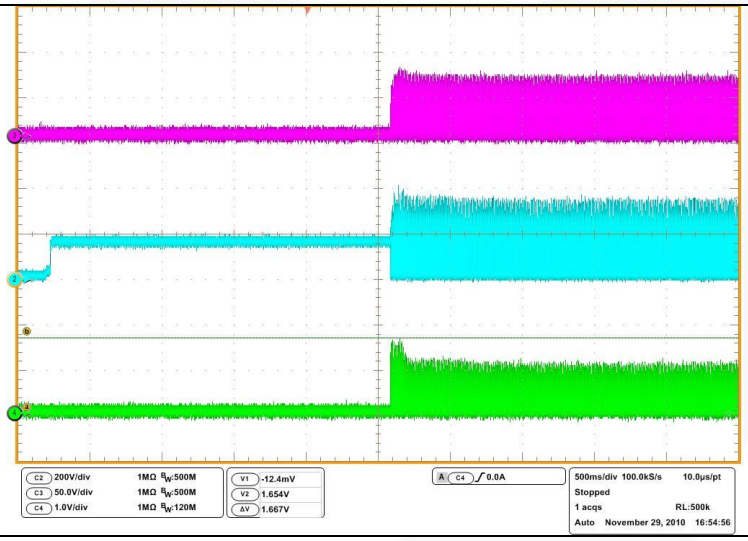
Test condition	MOSFET Voltage Stress at Start-up Period
	Full load 230Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$V_{DS,Max}$: 638.1V
	Full load 115Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$V_{DS,Max}$: 676.2V

Figure 16. MOSFET Voltage Stress

The figure 17shows the current stress on MOSFET at start-up time with rated load condition.

Test condition	MOSFET Current Stress at Start-up Period
	Full load 90Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$I_{DS,Max}$: 1.337A
	Full load 115Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$I_{DS,Max}$: 1.654A

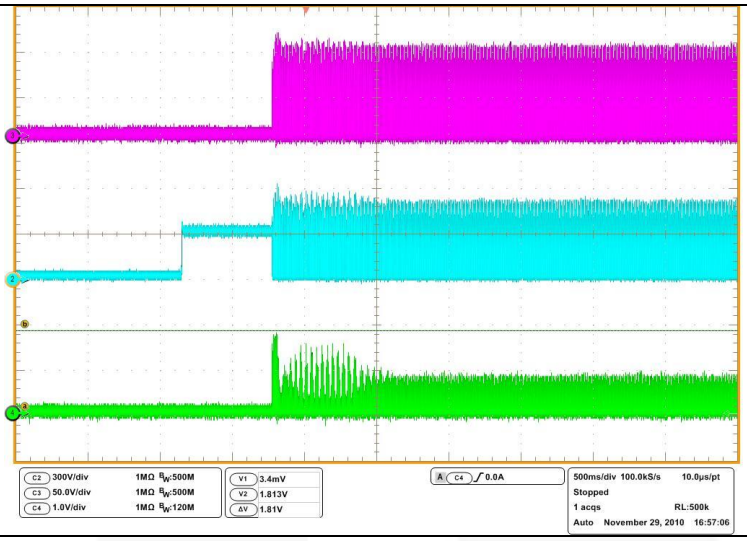
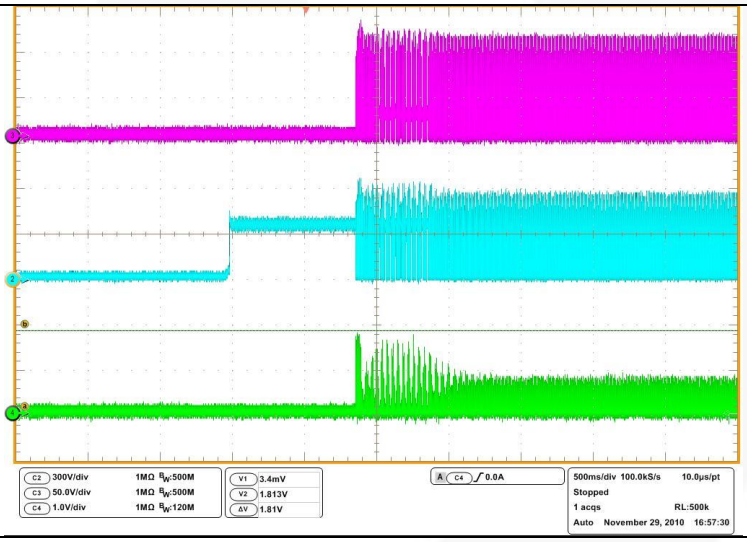
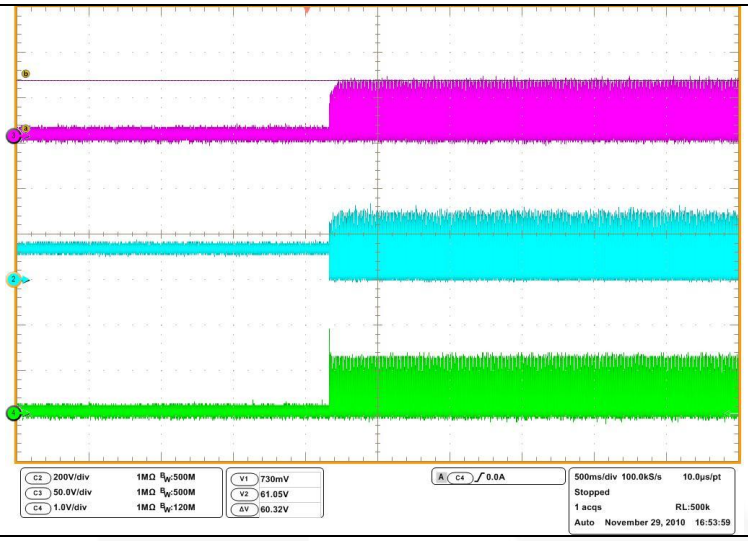
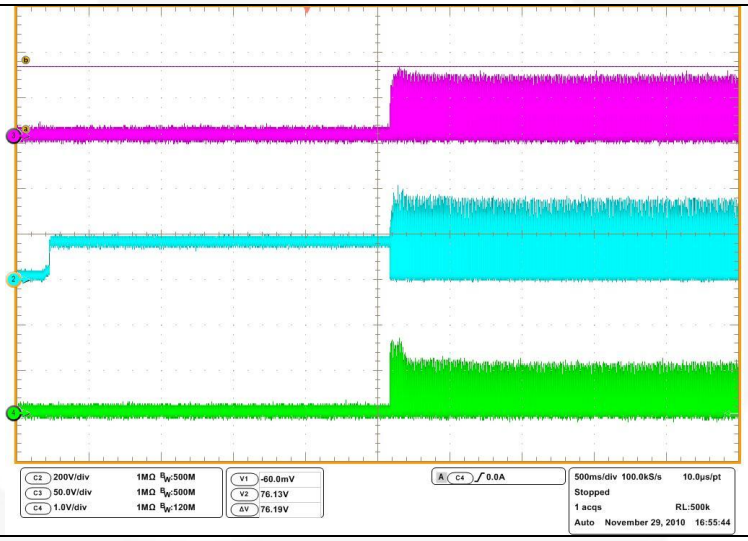
Test condition	MOSFET Current Stress at Start-up Period
	Full load 230Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$I_{DS,Max}$: 1.81A
	Full load 115Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$I_{DS,Max}$: 1.81A

Figure 17. MOSFET Current Stress

The figure 18 shows the voltage stress on diode at start-up time with rated load condition and summarized all things at table 5.

Test condition	Diode Stress at Start-up Period
	Full load 90Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$V_{Diode,Max}$: 61.05V
	Full load 115Vac
CH2 : V_{DS} [200V/div] **CH3 : V_{AK} [50V/div]** **CH4 : I_{DS} [1A/div]** **Time [500ms/div]**	
	$V_{Diode,,Max}$: 76.13V

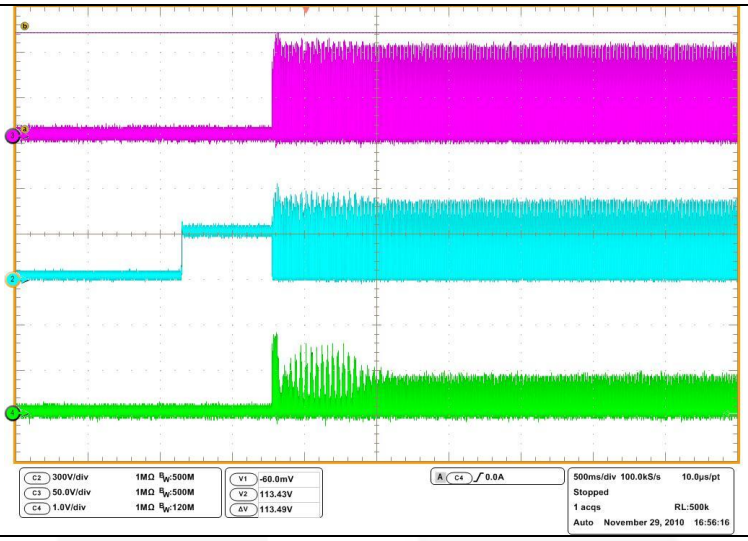
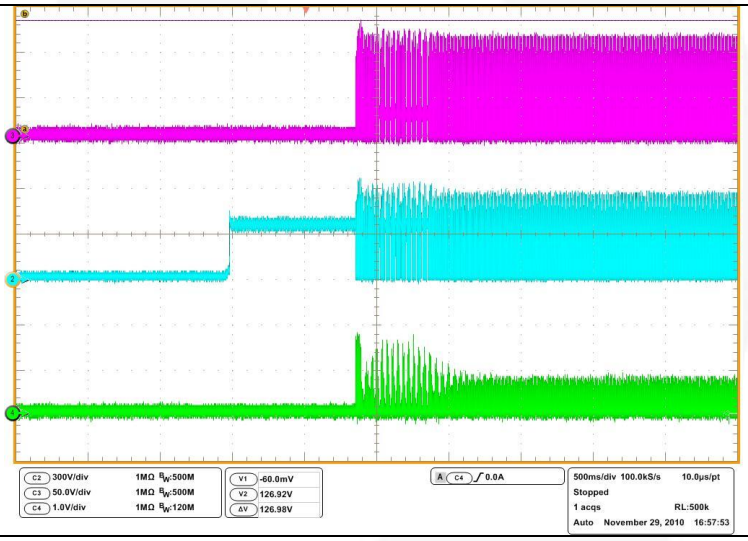
Test condition	Diode Stress at Start-up Period
	Full load 230Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$V_{Diode,Max}$: 113.43V
	Full load 265Vac
CH2 : V_{DS} [300V/div] CH3 : V_{AK} [50V/div] CH4 : I_{DS} [1A/div] Time [500ms/div]	
	$V_{Diode,Max}$: 126.92V

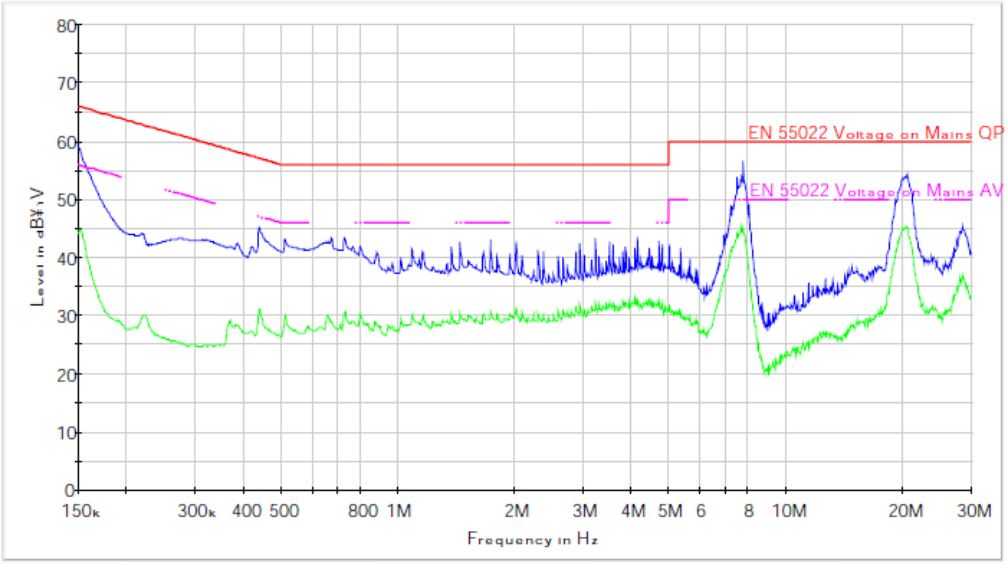
Figure 18. DIODE Voltage Stress

Table 7. test condition & test equipment

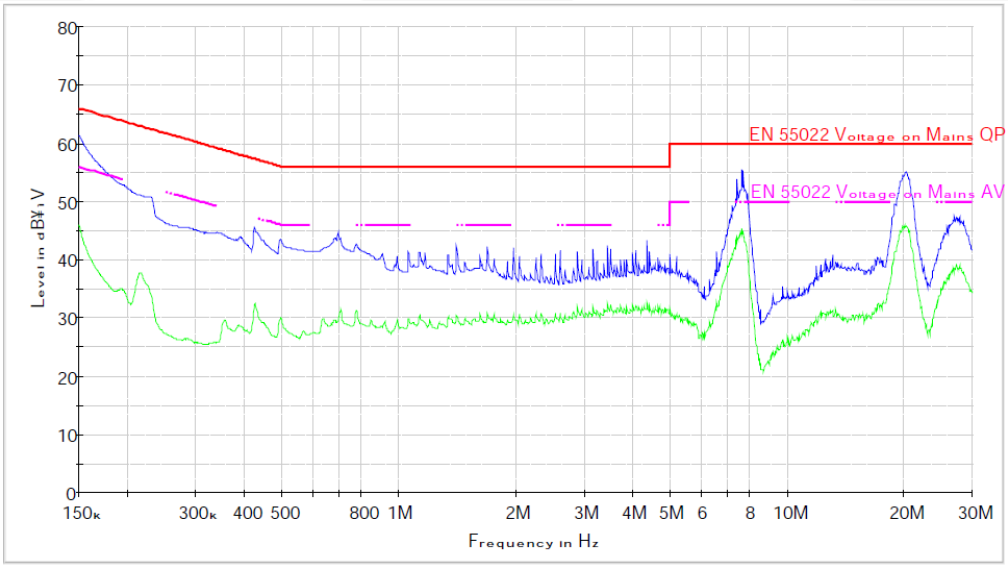
	90Vac	115Vac	230Vac	265Vac
$V_{DS,max}$ [V]	304.76	406.36	638.1	676.2
$I_{DS,max}$ [A]	1.337	1.654	1.81	1.81
$V_{AK,max}$ [V]	61.05	76.13	113.43	126.92

3.5. EMI : Conducted Emission

The all measurement was conducted in observance of CISPR22 criteria and this regulation is tighter than CISPR15 regulation for lighting application. So, we can think the FL6961 board also can meet lighting application regulation.



Conducted Emission-Line @ 220Vac, Full load (24V/700mA;6 Series LEDs)



Conducted Emission-Neutral @ 220Vac, Full load (24V/700mA;6 Series LEDs)

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