



User Guide for
FEB_L015
Evaluation Board

Universal Input 8.4W LED Ballast Controller

Featured Fairchild Product: FL103M

***Direct questions or comments
about this evaluation board to:
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Fairchild Semiconductor.com

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This user guide supports the evaluation kit for the FL103M. It should be used in conjunction with the FL103M 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 input 8.4W LED ballast using the FL103M PSR controller and the FQU2N60C QFET®. The input voltage range is $85V_{RMS} - 265V_{RMS}$ and there is one DC output with a constant current of 350mA at $24V_{MAX}$. This document contains a general description of FL103M, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. Description

This third-generation Primary-Side-Regulation (PSR) and highly integrated PWM controller provides features to enhance the performance of LED illumination.

The proprietary topology, TRUECURRENT™, enables precise CC regulation and simplified circuit design for LED illumination applications. The result is lower-cost and smaller LED lighting compared to a conventional design or a linear transformer.

To minimize standby power consumption, the proprietary Green Mode provides off-time modulation to linearly decrease PWM frequency under light-load conditions. Green Mode assists the power supply in meeting the power conservation requirements.

By using the FL103, LED illumination can be implemented with few external components and minimized cost.

1.2. Features

- Low Standby Power: < 30mW
- High-Voltage Startup
- Few External Components
- Constant-Voltage (CV) and Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Green-Mode: Linearly-Decreasing PWM Frequency
- Fixed PWM Frequency at 50kHz and 33kHz, Frequency Hopping to Solve EMI Problems
- Peak-Current-Mode Control in CV Mode
- Cycle-by-Cycle Current Limiting
- V_{DD} Over-Voltage Protection (OVP)
- V_{DD} Under-Voltage Lockout (UVLO)
- Adjustable Brownout Detector
- Gate Output Maximum Voltage Clamped at 15V
- Thermal Shutdown (TSD) Protection
- Available in the 8-Lead SOIC Package

1.3. Internal Block Diagram

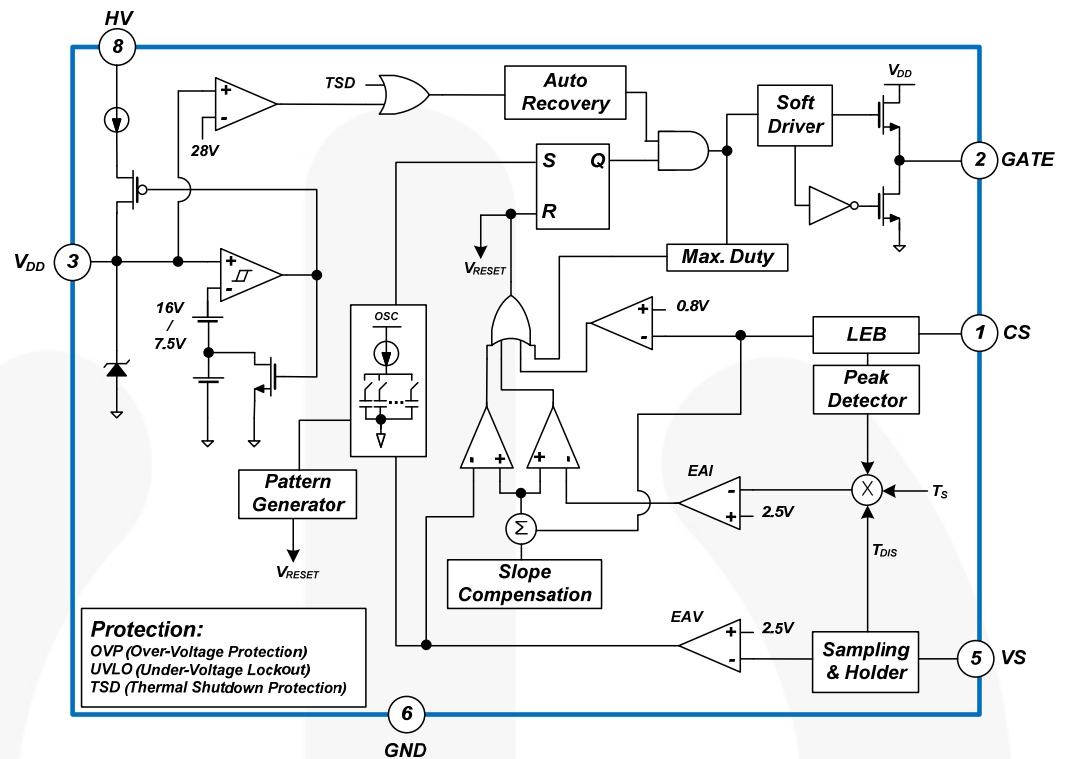


Figure 1. Block Diagram

2. General Specification for Evaluation Board

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°C.

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Main Controller		FL103M
Input	Frequency Range	50Hz ~ 60Hz
	Voltage Range	85V _{AC} ~ 265V _{AC}
Output	Power	< 8.4W
	Voltage	< 24V
	Current	Typ. 0.35A
Efficiency	< 87%	
Conduction EMI	Meet Margin of EN55022 conducted EMI: > 7dBuV	
Board Dimensions	53mm x 25mm (Neck: 15mm x 15mm)	

2.1. Photographs of the Evaluation Board

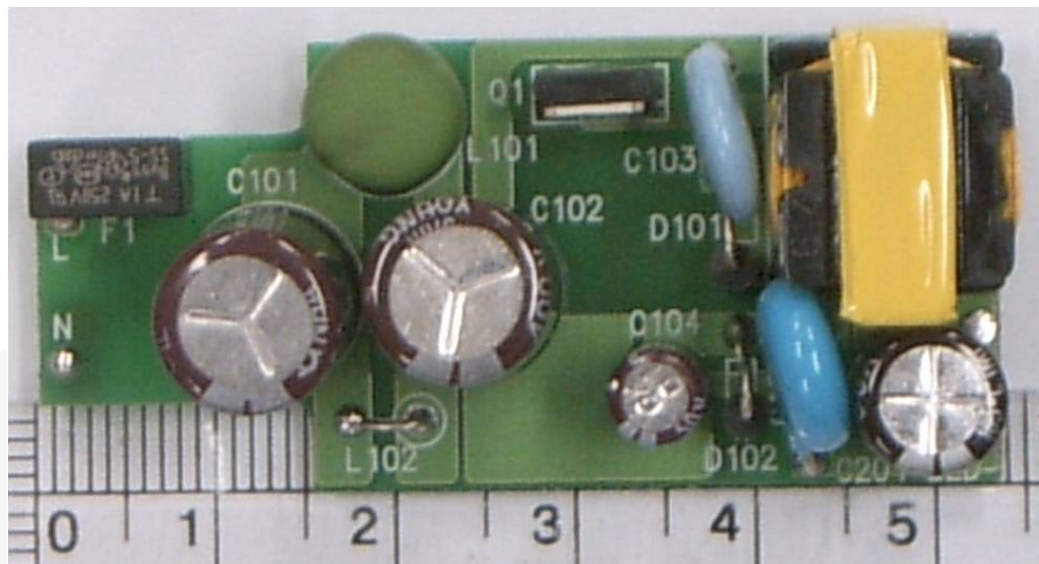


Figure 2. Top View

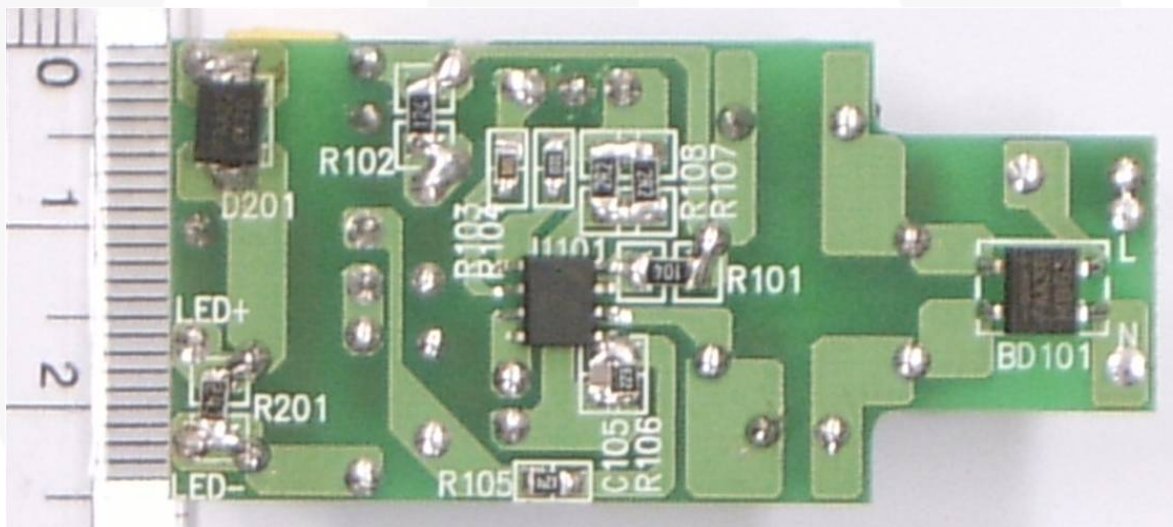


Figure 3. Bottom View

2.2. Printed Circuit Board

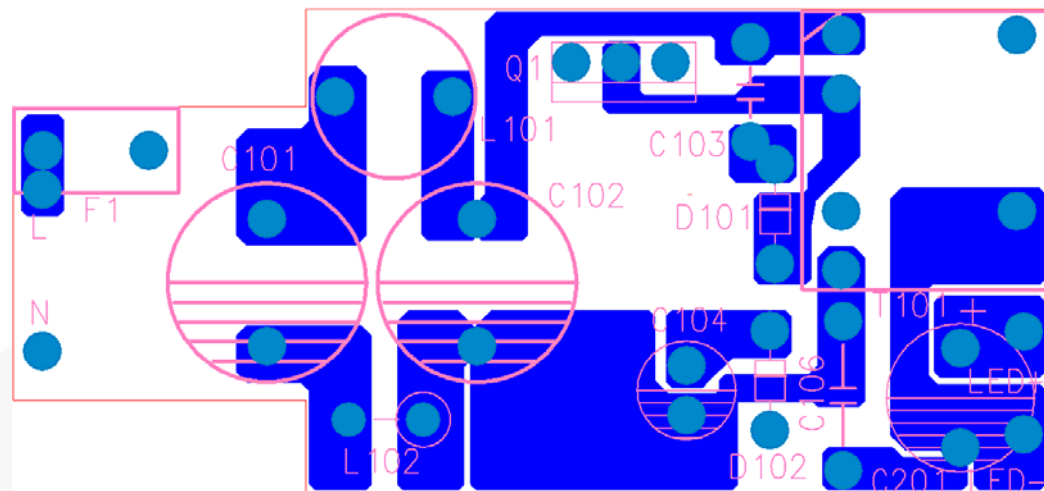


Figure 4. Printed PCB, Top Side

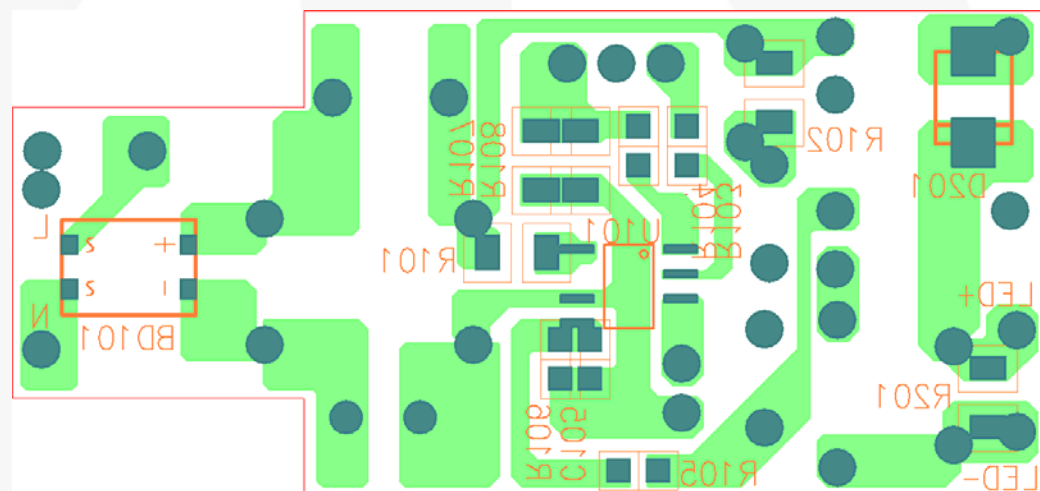


Figure 5. Printed PCB, Bottom Side

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3. Bill of Materials

Table 2. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	U101	FL103M	1	Controller, SOP-8	Fairchild Semiconductor
2	Q101	FQU2N60C	1	600V/2A MOSFET, I-PAK,	Fairchild
3	T101	EE1614S	1	Transformer, Lm = 1.13mH	TDK
4	F1	SS-5-1A	1	250V/1A Fuse	Bussmann
5	L101	R08102KT00	2	1mH Filter Inductor, 8Φ	Bosung
6	L102	Short	0	Short	
7	BD101	MB6S	1	600V/0.5A Bridge Rectifier, SOIC-4	Fairchild Semiconductor
8	D101, D102	1N4007	2	1kV/1A Rectifier, DO-41	Fairchild Semiconductor
9	D201	ES2D	1	200V/2A Fast Rectifier, SMB/DO-214AA	Fairchild Semiconductor
10	C101, C102	KMG 10μF/400V	2	Electrolytic Capacitor, 105°C	Samyoung
11	C103	3A472K	1	4.7nF/1kV Ceramic Capacitor	Samwha
12	C104	KMG 10μF/50V	1	Electrolytic Capacitor, 105°C	Samyoung
13	C105	C0805C470J5GACTU	1	47pF/50V SMD Capacitor 2012	Kemet
14	C106	SCFz2E472M10BW	1	472/250V Y-Capacitor	Samwha
15	C201	WB 100μF/35V	1	Ultra-Low Impedance Electrolytic Capacitor, 105°C	Samwha
16	R101	RC1206JR-07100KL	1	100KΩ SMD Resistor 3216	Yageo
17	R102	RC1206JR-07120KL	1	120KΩ SMD Resistor 3216	Yageo
18	R103	RC0805JR-0710RL	1	10Ω SMD Resistor 2012	Yageo
19	R104	RC0805JR-07100RL	1	100Ω SMD Resistor 2012	Yageo
20	R105	RC0805JR-07120KL	1	120KΩ SMD Resistor 2012	Yageo
21	R106	RC0805JR-0722KL	1	22KΩ SMD Resistor 2012	Yageo
22	R107, R108	RC1206JR-072R2L	2	2.2Ω SMD Resistor 3216	Yageo
23	R201	RC1206JR-0724KL	1	24KΩ SMD Resistor 3216	Yageo

4. Transformer and Winding Specifications

- Core: EE1614S (PC-40)
- Bobbin: 10 Pins

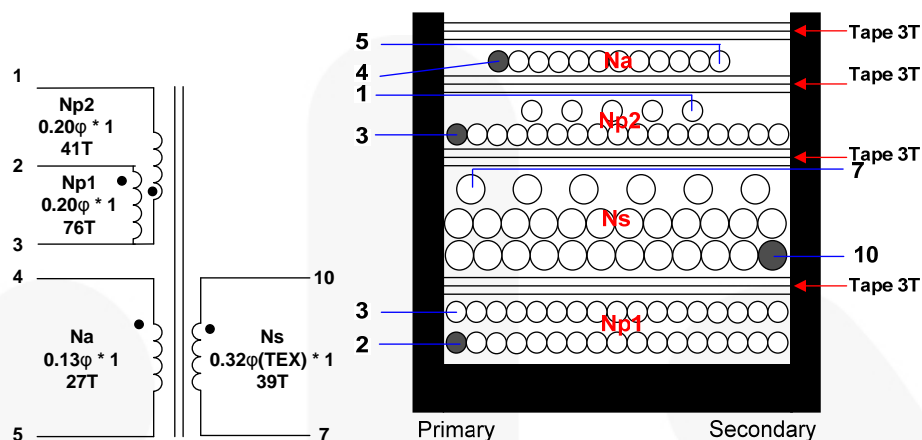


Figure 7. Transformer Specifications & Construction

Table 3. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np1	2 → 3	0.20 Φ * 1	76	Solenoid Winding
2	Insulation: Polyester Tape t = 0.05 mm, 3-Layer				
3	Ns	10 → 7	0.32 Φ (TEX) * 1	39	Solenoid Winding
4	Insulation: Polyester Tape t = 0.05 mm, 3-Layer				
5	Np2	3 → 1	0.20 Φ * 1	41	Solenoid Winding
6	Insulation: Polyester Tape t = 0.05 mm, 3-Layer				
7	Na	4 → 5	0.13 Φ * 1	27	Center Solenoid Winding
8	Outer Insulation: Polyester Tape t = 0.05 mm, 3-Layer				

Table 4. Electrical Characteristics

	Pin	Specification	Remark
Inductance	4 - 5	1.13mH \pm 7%	1kHz, 1V
Leakage	4 - 5	Max. 20 μ H	Short All Output Pins

5. Test Conditions & Test Equipment

Table 5. Test Conditions & Test Equipment

Evaluation Board #	FEBL015
Test Date	
Test Temperature	
Test Equipments	AC Power Source: ES2000S by PSTATIONES Power Analyzer: DZ4000 by YOKOGAWA Electronic Load: PLZ303WH by KIKUSUI Automatic Power Tester: ATS3000 by BOB Multimeter: 2002 by KEITHLEY Oscilloscope: 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Therna CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03(3W) by Everlight

6. Performance of Evaluation Board

6.1. Input Power at Minimum Load Condition

Test Condition: Measure the input power and output voltage at open load.

Table 6. Test Results

Input Voltage	Input Power	Output Voltage	Remark
85V _{AC} / 60Hz	0.092W	26.62V	< 0.3W
110V _{AC} / 60Hz	0.094W	26.63V	
230V _{AC} / 50Hz	0.101W	26.64V	
265V _{AC} / 50Hz	0.091W	26.27V	

Waveforms: Yellow (V_{DS}), Red (V_{DD})

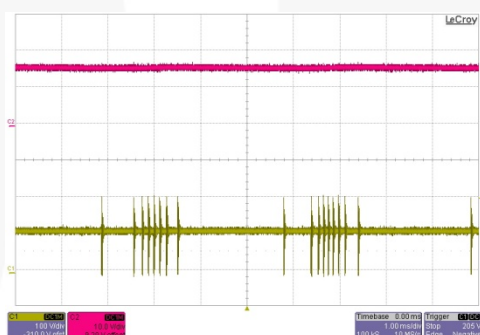
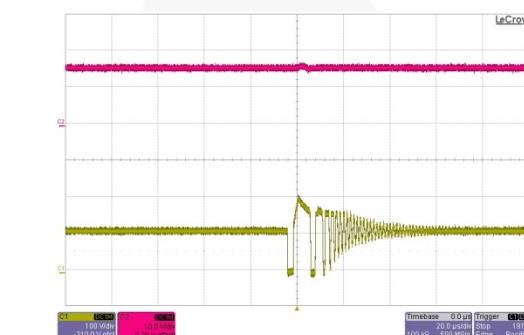


Figure 8.



85V_{AC} / 60Hz

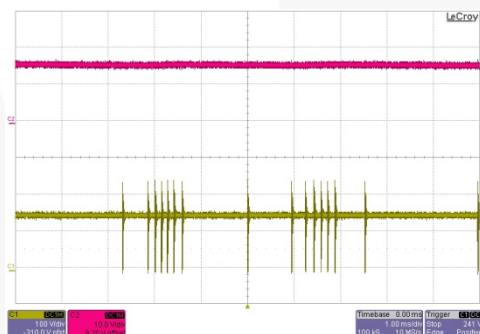
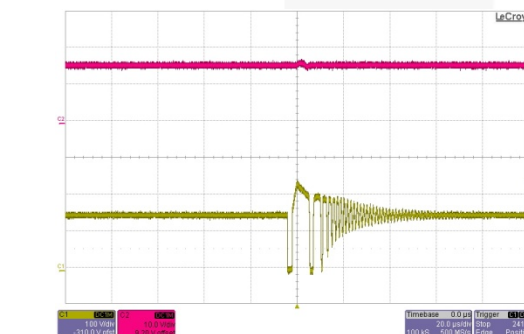


Figure 9.



110V_{AC} / 60Hz

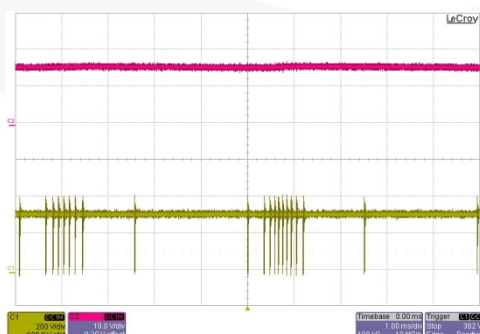
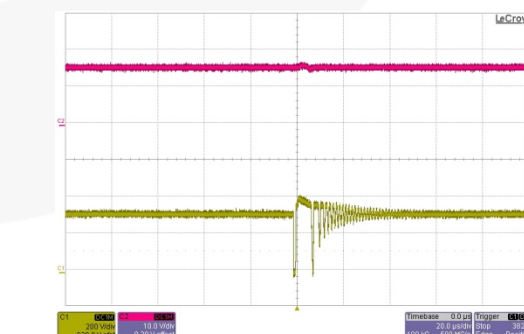


Figure 10.



230V_{AC} / 50Hz

Waveforms: Yellow (V_{DS}), Red (V_{DD})

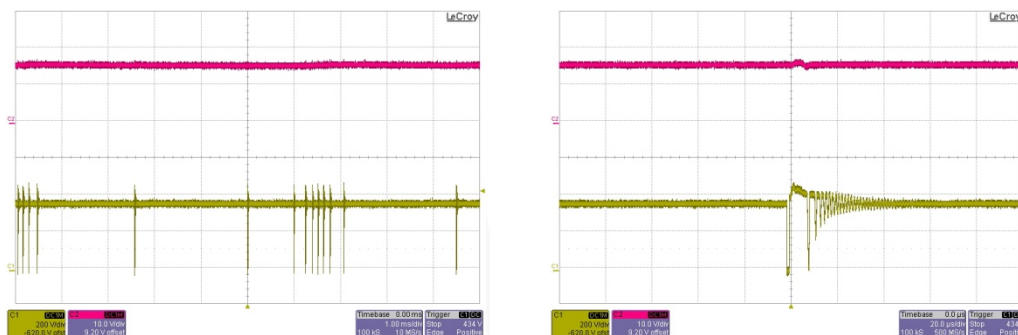


Figure 11. 265V_{AC} / 50Hz

6.2. Startup Time

Test Condition: Connect seven LEDs and measure the time interval between AC plug-in and stable output.

Table 7. Test Results

Input Voltage	Turn-On Time
85V _{AC} / 60Hz	213ms
110V _{AC} / 60Hz	160ms
230V _{AC} / 50Hz	98ms
265V _{AC} / 50Hz	96ms

Waveform: Yellow (V_{DS}), Blue (V_O), Green (I_O)

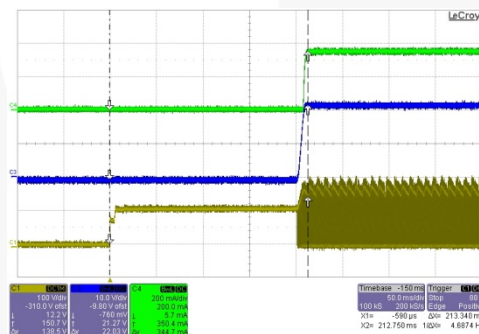


Figure 12. 85V_{AC} / 60Hz

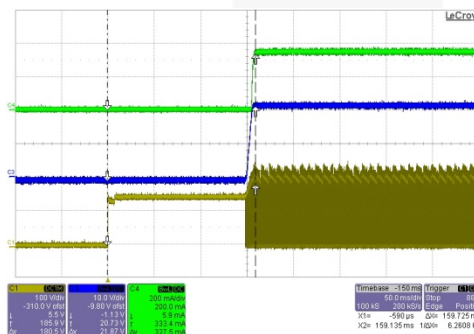


Figure 13. 110V_{AC} / 60Hz

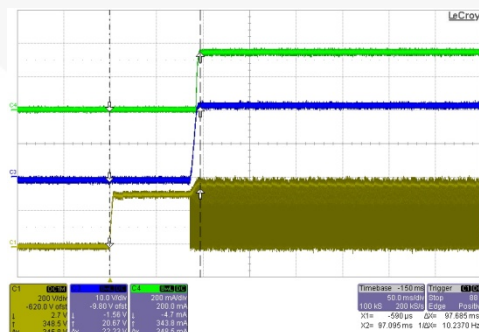


Figure 14. 230V_{AC} / 50Hz

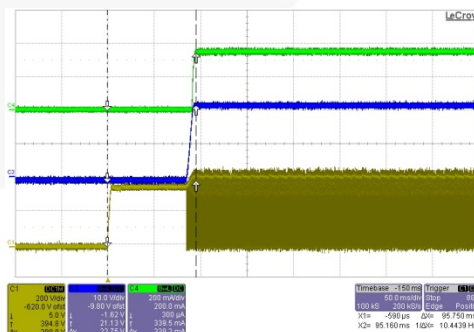


Figure 15. 265V_{AC} / 50Hz

6.3. Input Current

Test Condition: Connect seven LEDs and measure the AC input current.

Table 8. Test Result

Input Voltage	Input Current
85V _{AC} / 60Hz	185mA
110V _{AC} / 60Hz	155mA
230V _{AC} / 50Hz	98mA
265V _{AC} / 50Hz	92mA

Waveform: Yellow (V_{DS}), Red (V_{DD}), Green (I_O)

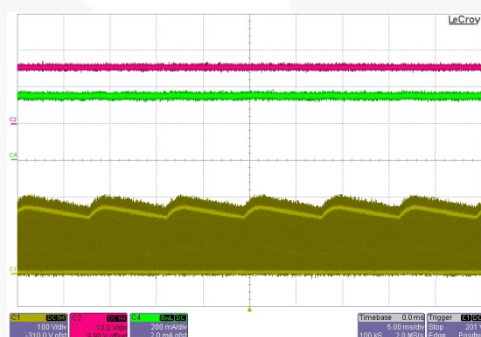


Figure 16. 85V_{AC} / 60Hz

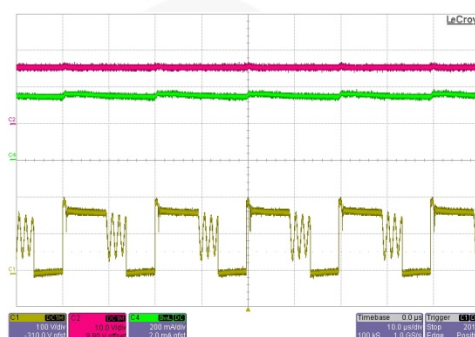


Figure 17. 110V_{AC} / 60Hz

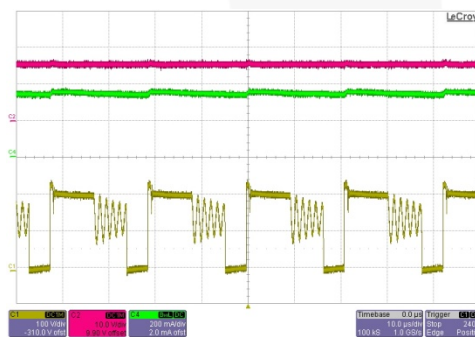
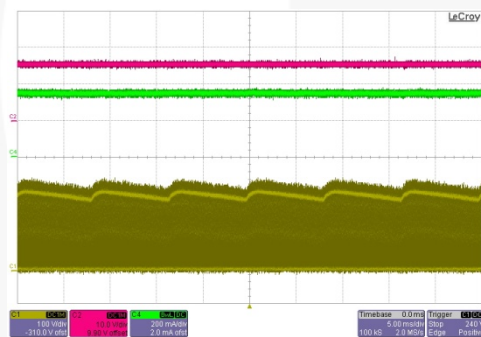


Figure 18. 230V_{AC} / 50Hz

Waveform: Yellow (V_{DS}), Red (V_{DD}), Green (I_O)

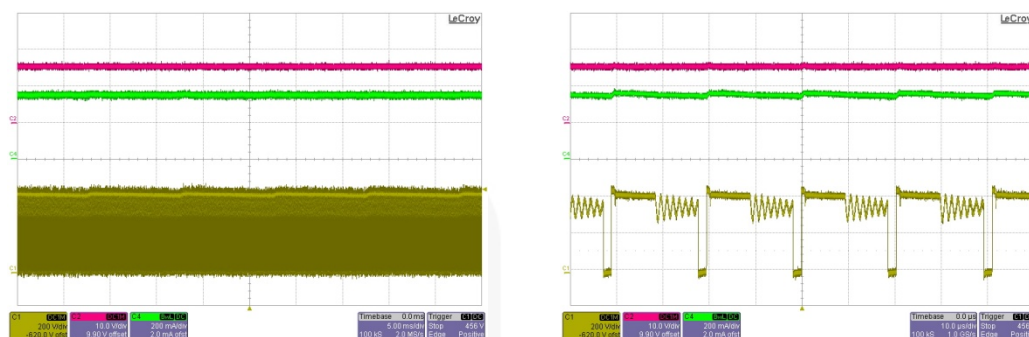


Figure 19. 265V_{AC} / 50Hz

6.4. Output Ripple & Noise

Test Condition: Connect seven LEDs. Ripple and noise are measured by using 20MHz bandwidth limited oscilloscope with a 10 μ F / 50V capacitor paralleled with a high-frequency 0.1 μ F capacitor across each output.

Table 9. Test Result

Input Voltage	Ripple Source	Voltage Ripple	Current Ripple
85V _{AC} / 60Hz	AC Source	256mV _{P-P}	30mA _{P-P}
	Main Frequency	205mV _{P-P}	27mA _{P-P}
110V _{AC} / 60Hz	AC Source	218mV _{P-P}	29mA _{P-P}
	Main Frequency	211mV _{P-P}	29mA _{P-P}
230V _{AC} / 50Hz	AC Source	211mV _{P-P}	27mA _{P-P}
	Main Frequency	205mV _{P-P}	29mA _{P-P}
265V _{AC} / 50Hz	AC Source	224mV _{P-P}	30mA _{P-P}
	Main Frequency	198mV _{P-P}	27mA _{P-P}

Waveforms: Red (V_O), Green (I_O)

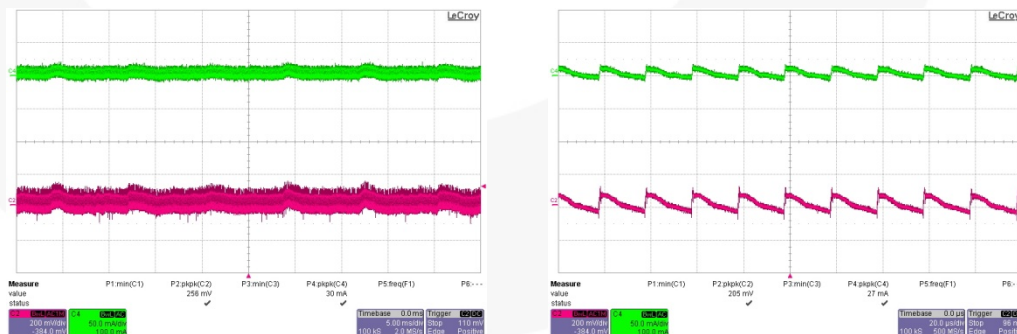


Figure 20. 85V_{AC} / 60Hz

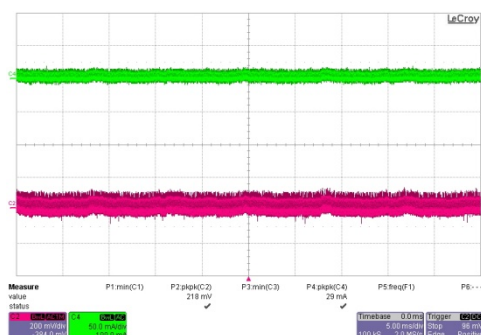


Figure 21. 110V_{AC} / 60Hz

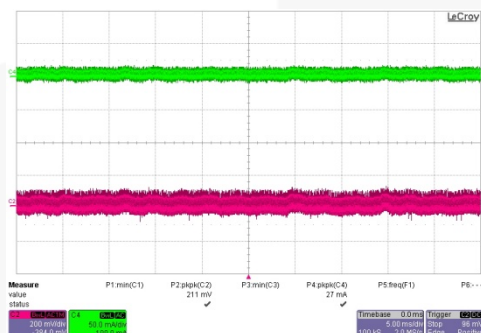
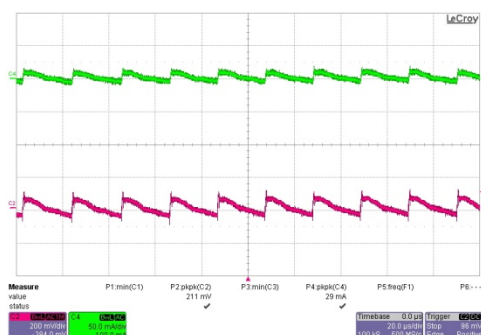


Figure 22. 230V_{AC} / 50Hz

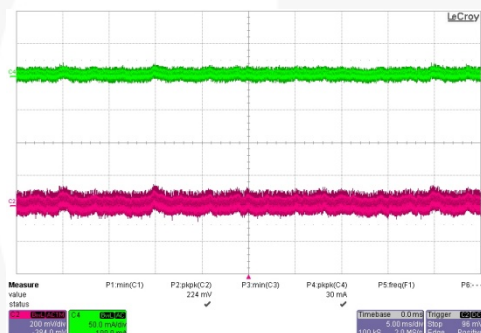
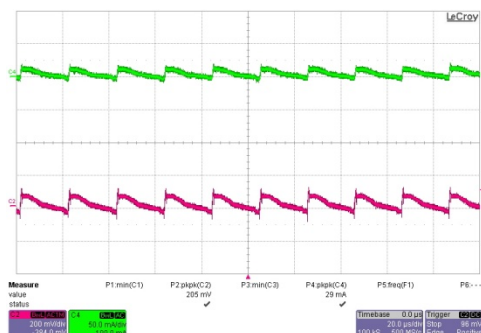
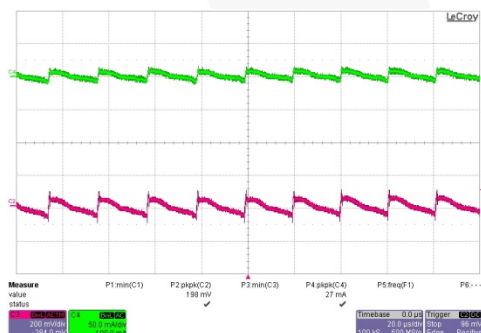


Figure 23. 265V_{AC} / 50Hz



6.5. Short-Circuit Protection (SCP)

Test Condition: Connect seven LEDs and measure input power on short circuit in “Hiccup” Mode operation.

Table 10. Test Results

Input Voltage	Input Power at SCP
85V _{AC} / 60Hz	0.116W
110V _{AC} / 60Hz	0.180W
230V _{AC} / 50Hz	0.426W
265V _{AC} / 50Hz	0.520W

Waveforms: Yellow (V_{DS}), Red (V_{DD}), Green (V_O)

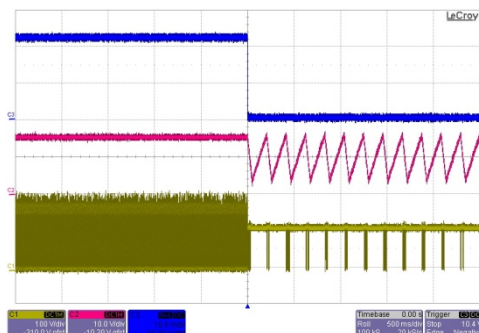


Figure 24. 230V_{AC} / 60Hz

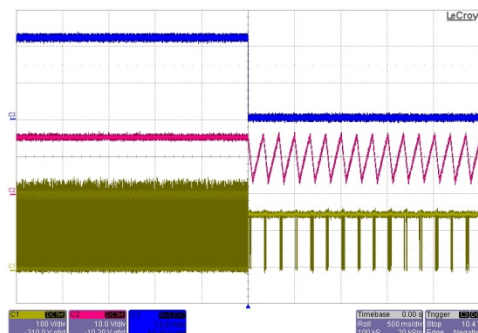


Figure 25. 110V_{AC} / 60Hz

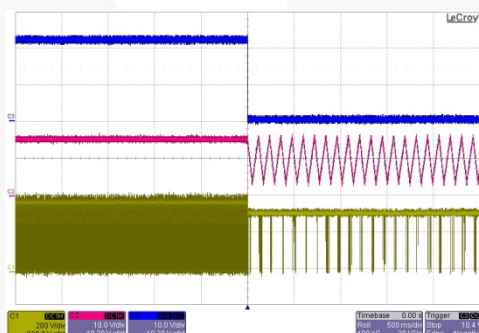


Figure 26. 230V_{AC} / 50Hz

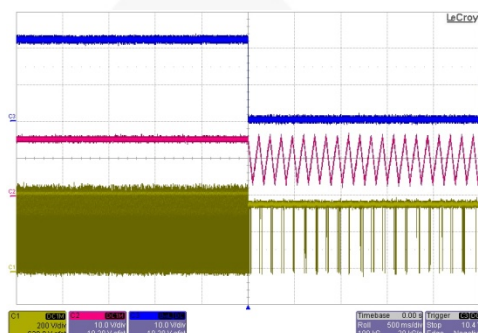


Figure 27. 265V_{AC} / 50Hz

6.6. Voltage & Current Stress on MOSFET

Test Condition: Connect seven LEDs and measure the voltage and current stress on the MOSFET.

Table 11. Test Results

		85V _{AC} / 60Hz	110V _{AC} / 60Hz	230V _{AC} / 50Hz	265V _{AC} / 50Hz
Power On	V	217V	247V	430V	478V
	I	590mA	590mA	590mA	590mA
Normal	V	221V	257V	443V	481V
	I	606mA	590mA	606mA	590mA
Short Circuit	V	136V	171V	348V	402V
	I	290mA	290mA	380mA	460mA
Power Off	V	137V	137V	152V	152V
	I	580mA	580mA	580mA	580mA

Waveform: Yellow (V_{DS}), Green (I_D)

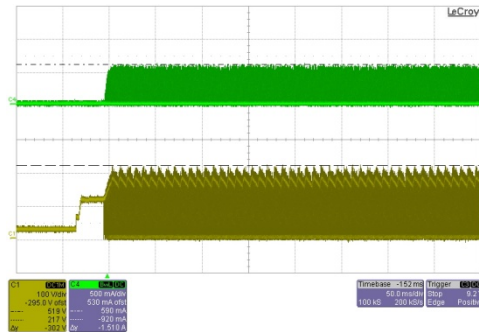


Figure 28. 85V_{AC} / 60Hz; Power On

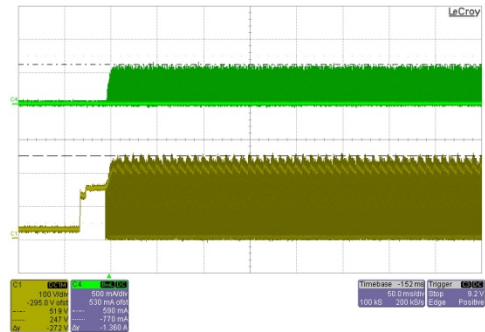


Figure 29. 110V_{AC} / 60Hz; Power On

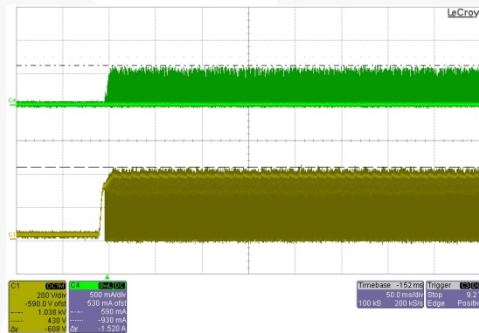


Figure 30. 230V_{AC} / 50Hz; Power On

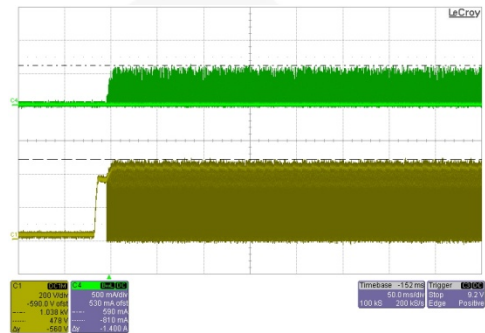


Figure 31. 265V_{AC} / 50Hz; Power On

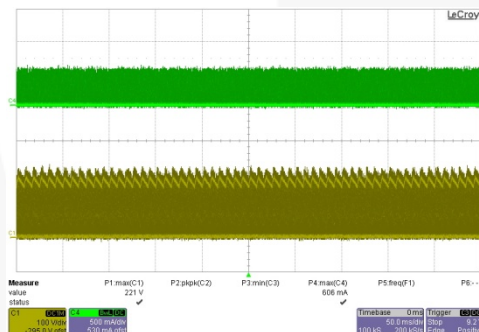


Figure 32. 85V_{AC} / 60Hz; Normal Operation

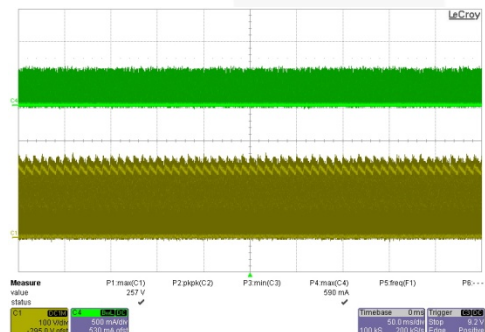


Figure 33. 110V_{AC} / 60Hz; Normal Operation

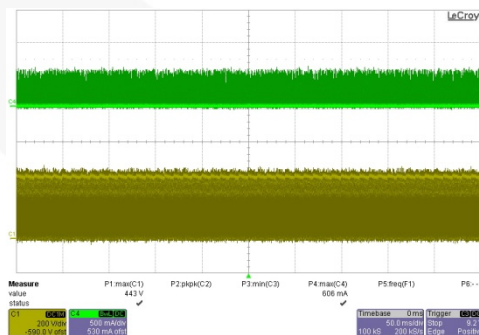


Figure 34. 230V_{AC} / 50Hz; Normal Operation

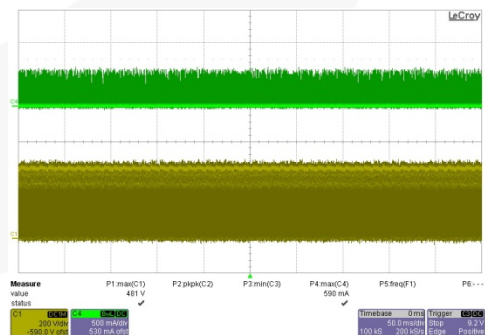


Figure 35. 265V_{AC} / 50Hz; Normal Operation

Waveform: Yellow (V_{DS}), Green (I_D)

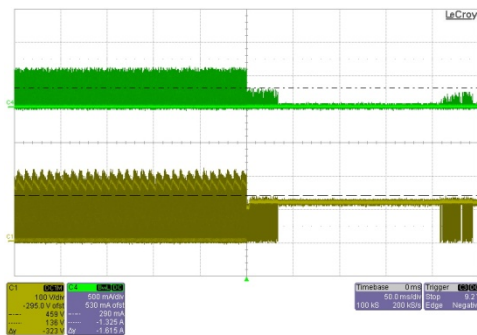


Figure 36. 85V_{AC} / 60Hz; Short Circuit

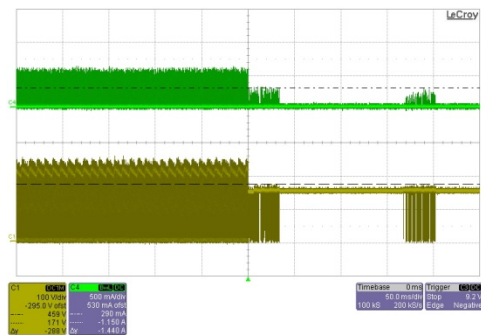


Figure 37. 110V_{AC} / 60Hz; Short Circuit

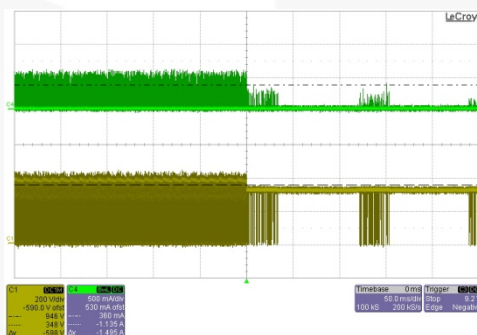


Figure 38. 230V_{AC} / 50Hz; Short Circuit

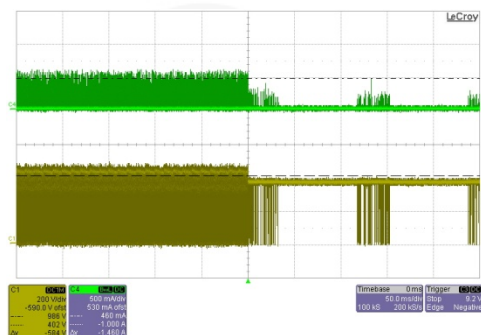


Figure 39. 265V_{AC} / 50Hz; Short Circuit

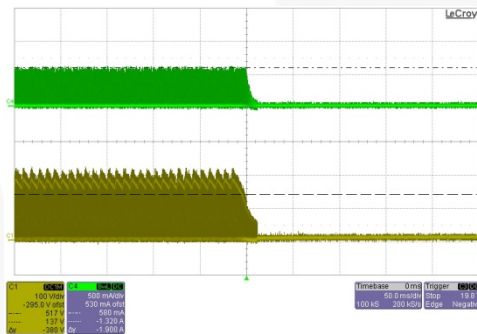


Figure 40. 85V_{AC} / 60Hz; Power Off

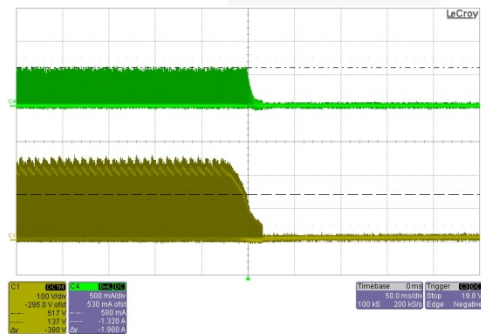


Figure 41. 110V_{AC} / 60Hz; Power Off

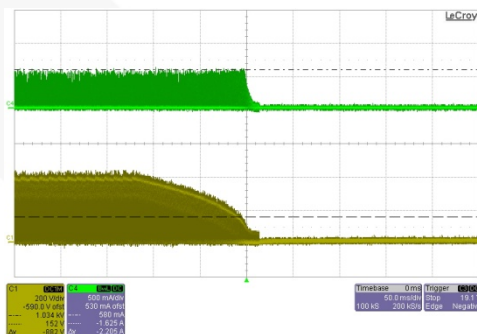


Figure 42. 230V_{AC} / 50Hz; Power Off

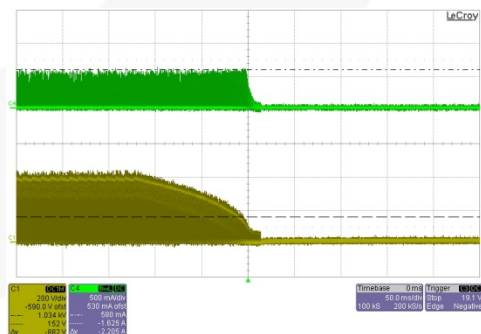


Figure 43. 265V_{AC} / 50Hz; Power Off

6.7. Voltage & Current Stress on Secondary Rectifier

Test Condition: Connect seven LEDs and measure the voltage and current stress on the secondary rectifier.

Table 12. Test Results

		85V _{AC} / 60Hz	110V _{AC} / 60Hz	230V _{AC} / 50Hz	265V _{AC} / 50Hz
Power On	V	59.5V	77.0V	131.0V	149.0V
	I	2.48A	2.28A	2.28A	2.28A
Normal	V	68V	79V	136V	161V
	I	2.42A	2.39A	2.36A	2.39A
Short Circuit	V	79.5V	97.0V	170.0V	176.0V
	I	1.12A	1.16A	1.37A	1.42A
Power Off	V	38V	38V	45V	45V
	I	2.34A	2.34A	2.34A	2.34A

Waveform: Yellow (V_{AK}), Green (I_{AK})

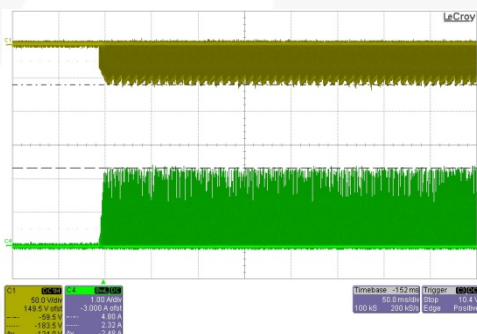


Figure 44. 85V_{AC} / 60Hz; Power On

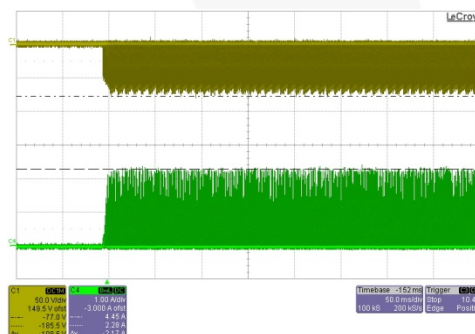


Figure 45. 110V_{AC} / 60Hz; Power On

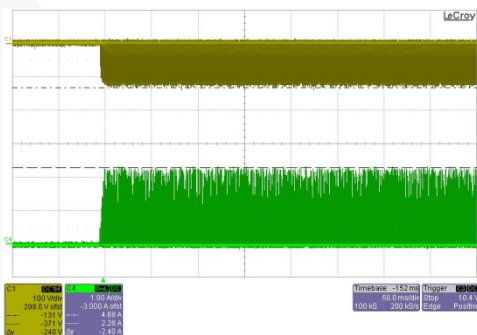


Figure 46. 230V_{AC} / 50Hz; Power On

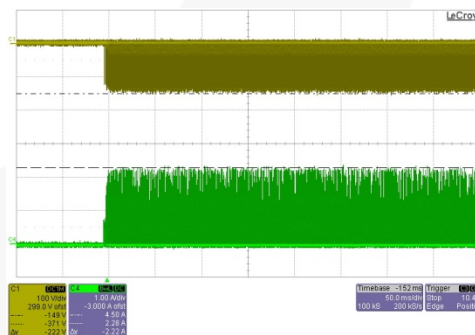


Figure 47. 265V_{AC} / 50Hz; Power On

Waveform: Yellow (V_{AK}), Green (I_{AK})

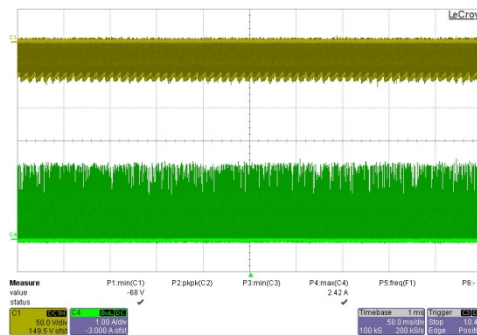


Figure 48. 85V_{AC} / 60Hz; Normal Operation

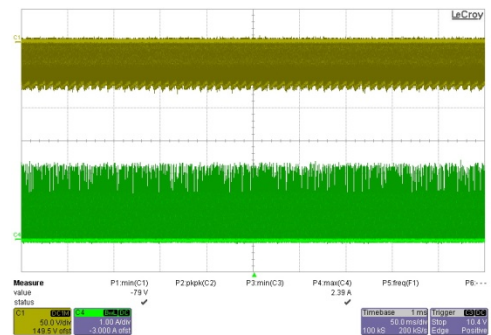


Figure 49. 110V_{AC} / 60Hz; Normal Operation

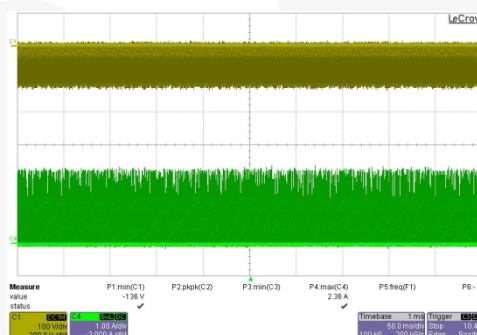


Figure 50. 230V_{AC} / 50Hz; Normal Operation

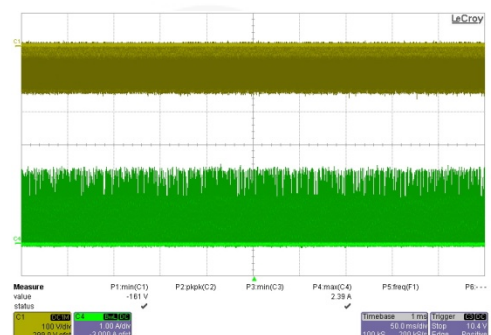


Figure 51. 265V_{AC} / 50Hz; Normal Operation

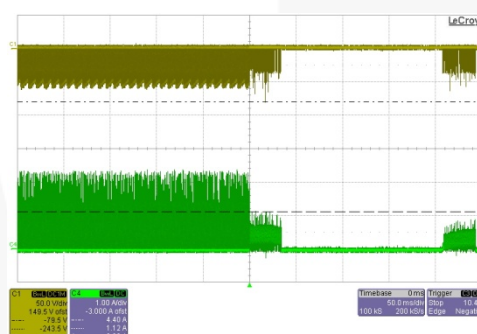


Figure 52. 85V_{AC} / 60Hz; Short Circuit

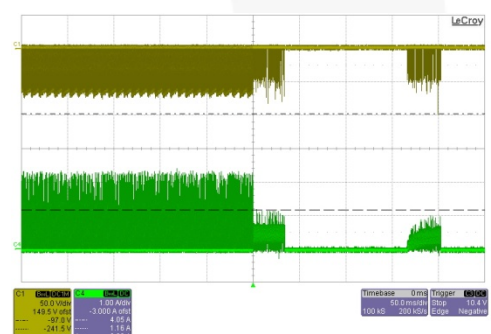


Figure 53. 110V_{AC} / 60Hz; Short Circuit

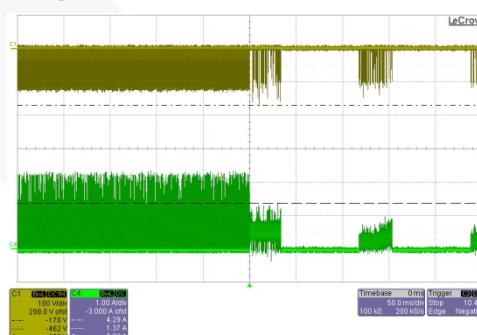


Figure 54. 230V_{AC} / 50Hz; Short Circuit

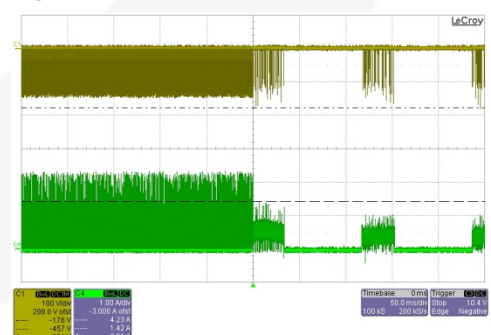


Figure 55. 265V_{AC} / 50Hz; Short Circuit

Waveform: Yellow (V_{AK}), Green (I_{AK})

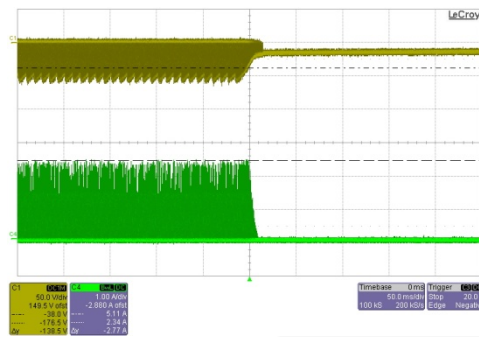


Figure 56. 85V_{AC} / 60Hz; Power Off

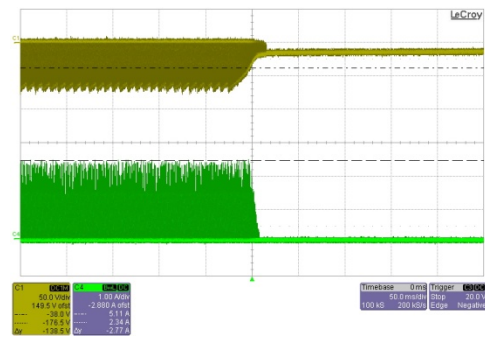


Figure 57. 110V_{AC} / 60Hz; Power Off

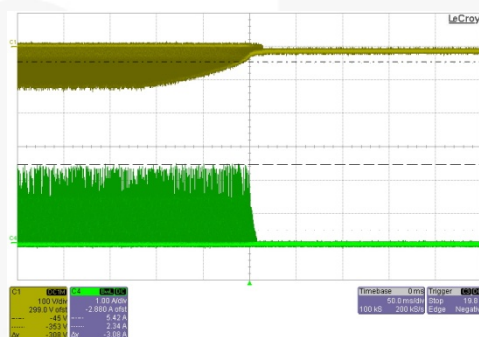


Figure 58. 230V_{AC} / 50Hz; Power Off

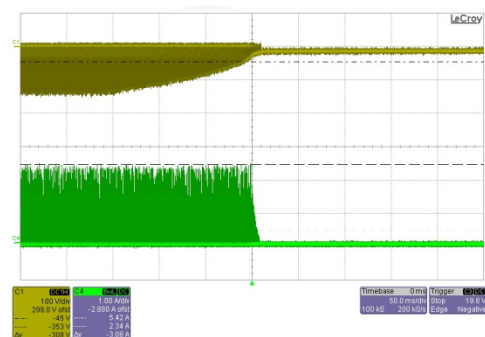


Figure 59. 265V_{AC} / 50Hz; Power Off

6.8. Constant Current Tolerance Using Electric Load (CR)

Test Condition: Aging five seconds at minimum load and measure the output current and output voltage. Each load / one second interval. Load is CR mode of electric load.

Table 13. Test Results

Input Voltage	Minimum Current	Maximum Current	Tolerance	Remark
85V _{AC} / 60Hz	346mA	350mA	1.14%	< 10%
110V _{AC} / 60Hz	346mA	348mA	0.57%	
230V _{AC} / 50Hz	343mA	350mA	2.00%	
265V _{AC} / 50Hz	343mA	349mA	1.72%	
Total	343mA	350mA	2.00%	

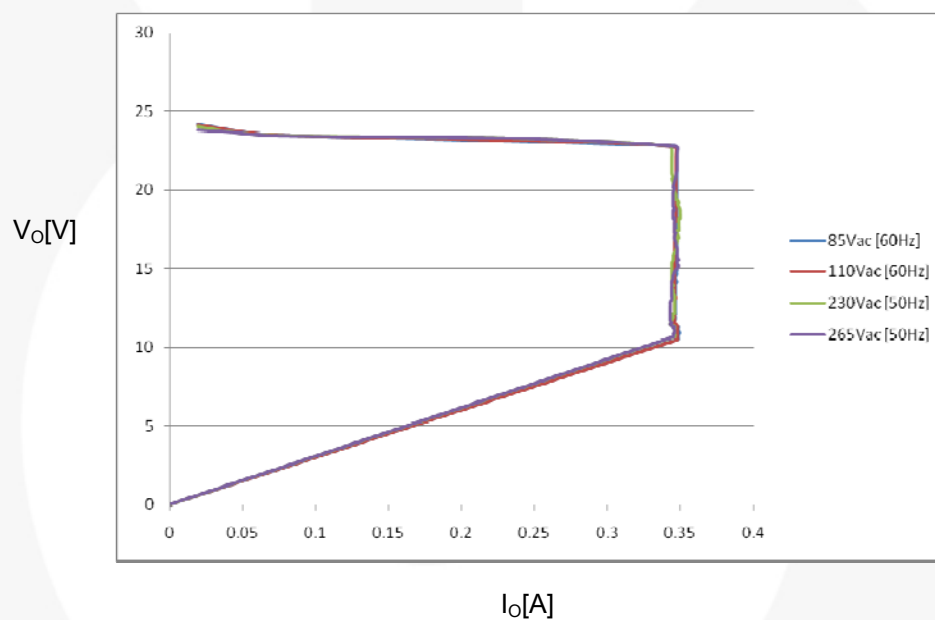


Figure 60. CC / CV Curve

6.9. Constant Current Tolerance Using Electric Load (CV)

Test Condition: Fixed output voltage and variable input voltage. Measure output current.
load is CV Mode of electric load.

Table 14. Deviation by Input Voltage

V _o [V]	Min. Current	Max. Current	Tolerance	Remark
22.5	349mA	353mA	1.19%	< 10%
22.0	349mA	353mA	1.27%	
21.5	349mA	353mA	1.33%	
21.0	348mA	354mA	1.44%	
20.5	349mA	353mA	1.61%	
20.0	349mA	355mA	1.55%	
19.5	349mA	354mA	1.41%	
19.0	349mA	353mA	1.22%	
18.5	349mA	354mA	1.47%	
18.0	349mA	356mA	1.86%	
Total	348mA	356mA	2.02%	

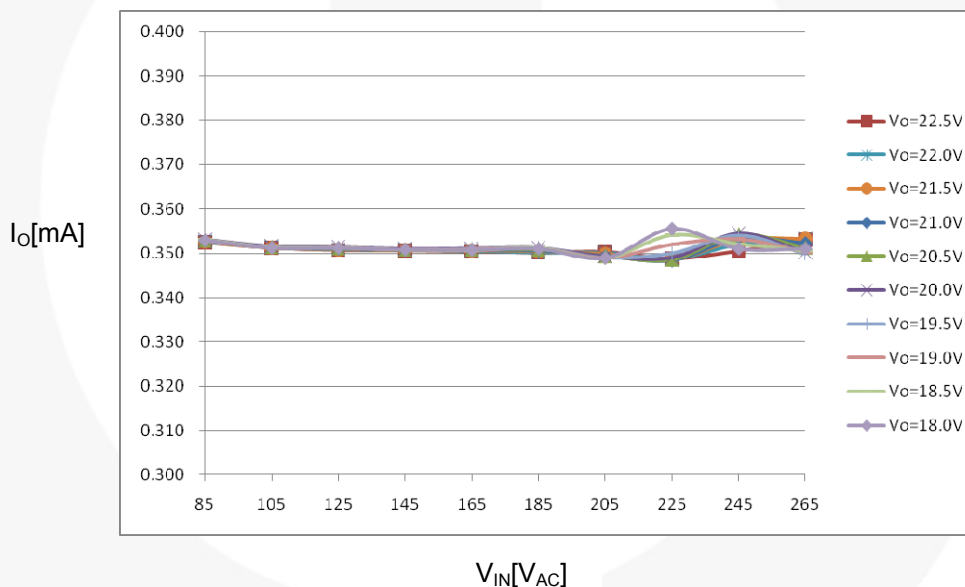


Figure 61. Deviation Curve

6.10. Constant Current Toleration Using LED Load

Test Condition: Age five minutes at 85V_{AC} and measure the output current and output voltage. Load is LED.

Table 15. Deviation by Input Voltage

LEDs	Minimum Current	Maximum Current	Tolerance	Remark
7-LED	343mA	347mA	1.27%	< 10%
6-LED	343mA	348mA	1.52%	
5-LED	342mA	349mA	2.01%	
4-LED	347mA	350mA	1.06%	

Table 16. Deviation by All Conditions (LEDs & Input Voltage)

Input Voltage	Minimum Current	Maximum Current	Tolerance
85V _{AC}	346mA	349mA	0.92%
105V _{AC}	345mA	348mA	1.03%
125V _{AC}	345mA	348mA	1.06%
145V _{AC}	345mA	348mA	0.86%
165V _{AC}	344mA	348mA	0.89%
185V _{AC}	342mA	350mA	2.34%
205V _{AC}	343mA	349mA	1.78%
225V _{AC}	343mA	348mA	1.55%
245V _{AC}	344mA	347mA	0.78%
265V _{AC}	345mA	349mA	1.18%
Total	342mA	350mA	2.34%

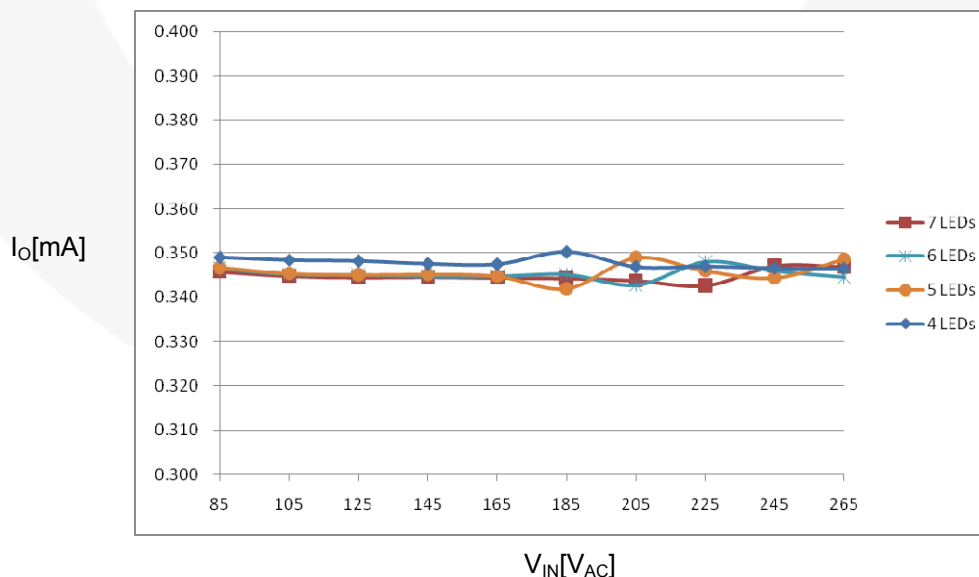


Figure 62. Deviation Curve

6.11. Efficiency

Test Condition: Connect seven LEDs and measure the input and output power after 30 minutes aging.

Table 17. Test Results

Input Voltage	Input Power	Output Power	Efficiency
85V _{AC} / 60Hz	8.781W	7.460W	84.96%
110V _{AC} / 60Hz	8.626W	7.440W	86.24%
230V _{AC} / 50Hz	8.464W	7.372W	87.10%
265V _{AC} / 50Hz	8.617W	7.490W	86.92%

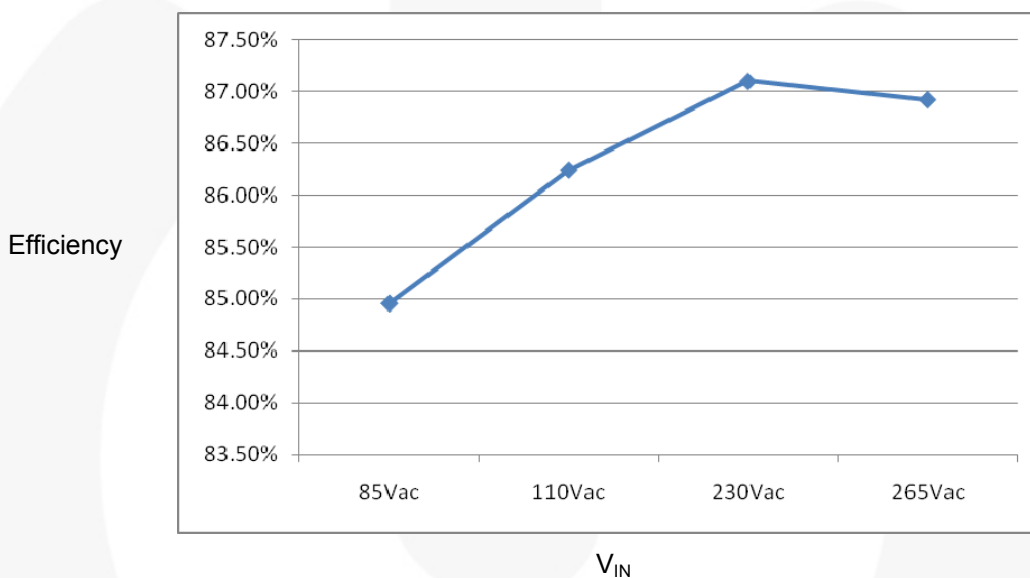


Figure 63. Efficiency Curve

6.12. Temperature

Test Condition: Connect seven LEDs and measure the saturated temperature.

Table 18. Test Results

	85V _{AC} / 60Hz	265V _{AC} / 50Hz	Remark
MOSFET	50.8°C	48.4°C	Top-Side Circle
Transformer	50.7°C	51.5°C	Top-Side Box
RCD Snubber	50.2°C	49.0°C	Top-Side Spot
FL103M	45.9°C	42.8°C	Bottom-Side Circle
Secondary Rectifier	59.2°C	58.9°C	Top-Side Box
Current-Sense Resistors	39.9°C	39.5°C	Bottom-Side Spot

Temperature Photos

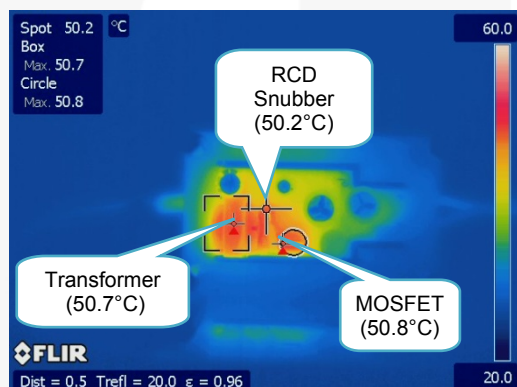


Figure 64. 85V_{AC} / 60Hz; Top Side

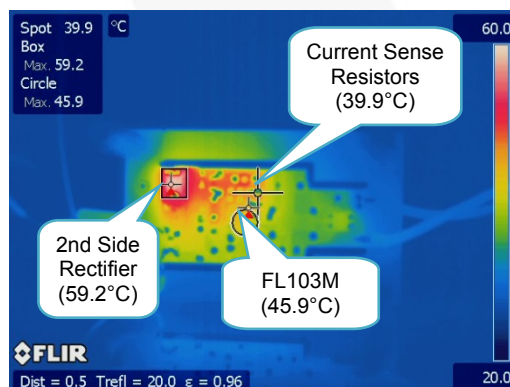


Figure 65. 265V_{AC} / 60Hz; Bottom Side

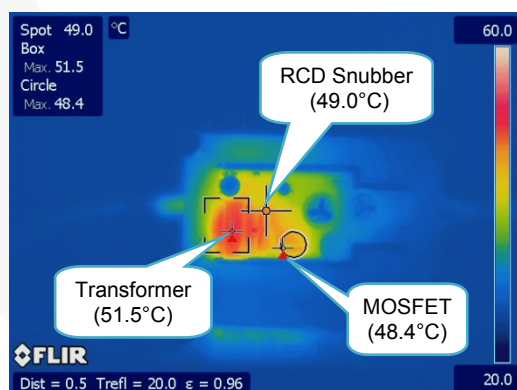


Figure 66. 265V_{AC} / 50Hz; Top Side

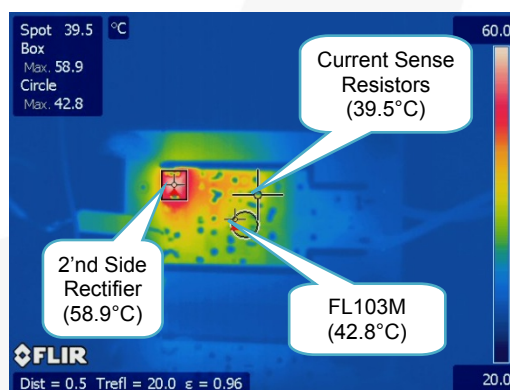


Figure 67. 265V_{AC} / 50Hz; Bottom Side

6.13. EMI

Test Conditions:

- Frequency Subrange: 150kHz - 30MHz,
- Measuring: QuasiPeak; Average
- Load is 7 LEDs

Table 19. Test Results

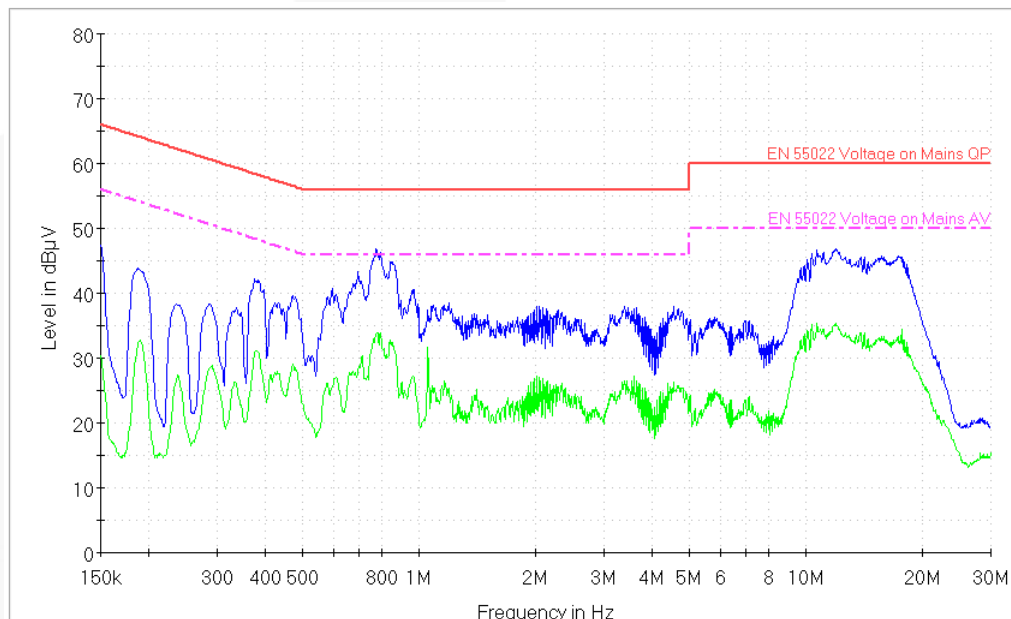


Figure 68. Conduction Line: 110V_{AC} / 60Hz

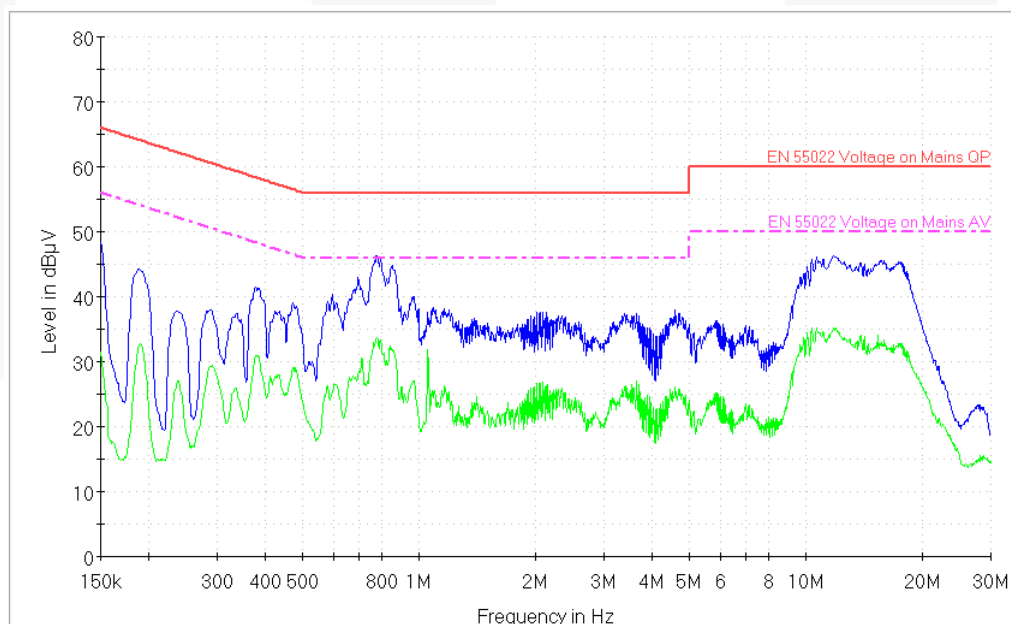


Figure 69. Conduction Neutral: 110V_{AC} / 60Hz

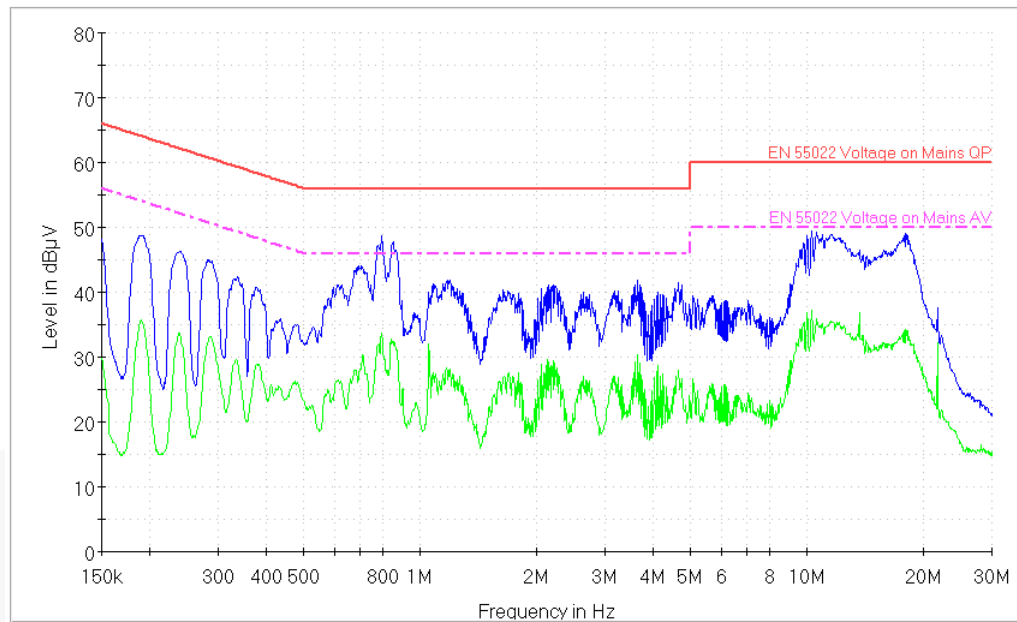


Figure 70. Conduction Line: 220V_{AC} / 60Hz

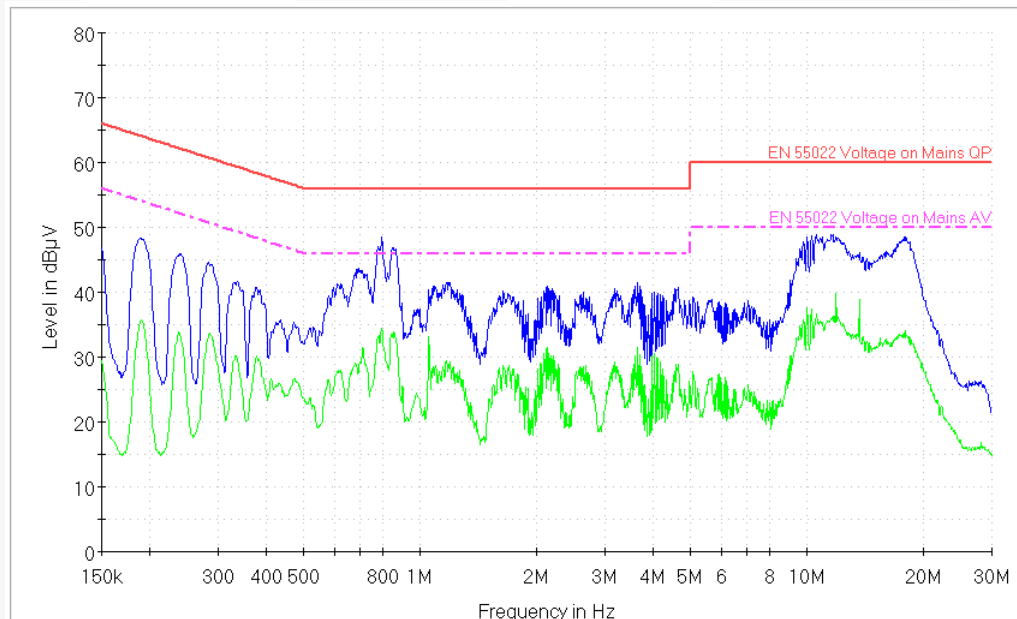


Figure 71. Conduction Neutral: 220V_{AC} / 60Hz



7. Revision History

Rev.	Date	Description
1.0.0	June 2011	Initial Release
1.0.1	July 2011	Reduced PCB Type & Size: Square → Bulb, 62 x 41 mm ² → 53 x 25 mm ²
1.0.2	May 2012	Update Block Diagram & BOM

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