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User Guide for

FEBFLS3247N_L42U010A

10 W LED Driver at Universal Line

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FLS3247N

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Table of Contents

This user guide supports the evaluation kit for the FLS3247N. It should be used in conjunction with the FLS3247N 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 a universal line voltage LED ballast using the FLS3247N Primary-Side Regulator (PSR) single-stage controller with switching MOSFET. The input voltage range is 90 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 400 mA at 25 V_{MAX}. This document contains a general description of the FLS3247N, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description

The FLS3247N is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Primary-Side Regulation (PSR) and single-stage topology minimize cost and reduce external components, such as input bulk capacitor and feedback circuitry. To improve power factor and Total Harmonic Distortion (THD), constant on-time control is utilized with an internal error amplifier and a low-bandwidth compensator. Precise constant-current control regulates accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee Discontinuous Conduction Mode (DCM) operation with high efficiency and simple design. FLS3247N provides open-LED, short-LED, and over-temperature protections.

1.2. Features

- Cost-Effective Solution without Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction (PFC)
- Integrated Power MOSFET
- Accurate Constant-Current (CC) Control: Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control for Better Efficiency and Simple Design
- Open-/Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20 µA
- Low Operating Current: 5 mA
- V_{DD} Over-Voltage Protection
- V_{DD} Under-Voltage Lockout (UVLO)
- Application Voltage Range: 80 V_{AC} ~ 308 V_{AC}

1.3. Internal Block Diagram

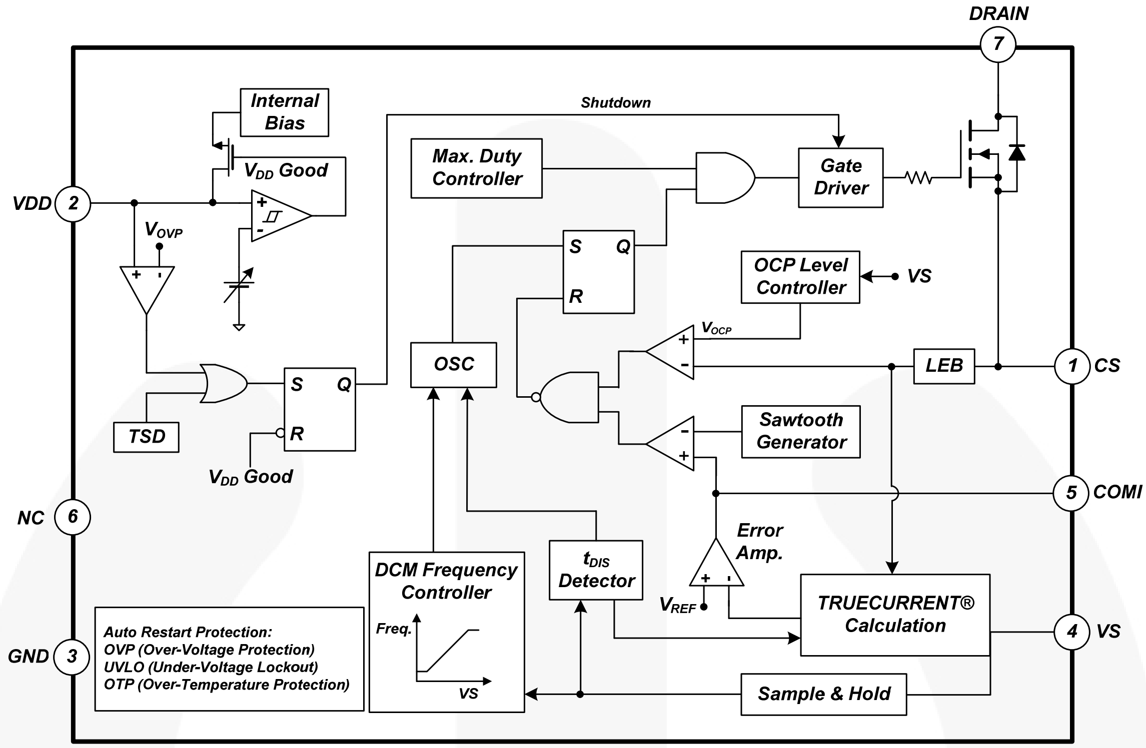

Figure 1. Internal Block Diagram of FLS3247N

2. Specifications for Evaluation Board

Table 1. Evaluation Board Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90 V	Minimum Input Voltage
		$V_{IN.MAX}$	265 V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	120 V/ 230 V	Nominal Input Voltage
	Frequency	f_{IN}	60 Hz / 50 Hz	Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	11 V	Minimum Output Voltage
		$V_{OUT.MAX}$	28 V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	25 V	Rated Output Voltage
	Current	$I_{OUT.NOMINAL}$	400 mA	Rated Output Current
		CC Deviation	< ±2.85%	Line Input Voltage Change: 90~265 V_{AC}
			< ±2.85%	Output Voltage Change: 11~28 V
Efficiency		Eff_{90VAC}	84.27%	Efficiency at 90 V_{AC} Line Voltage
		Eff_{120VAC}	86.29%	Efficiency at 120 V_{AC} Line Input Voltage
		Eff_{140VAC}	86.74%	Efficiency at 140 V_{AC} Line Input Voltage
		Eff_{180VAC}	86.83%	Efficiency at 180 V_{AC} Line Input Voltage
		Eff_{230VAC}	86.16%	Efficiency at 230 V_{AC} Line Input Voltage
		Eff_{265VAC}	85.41%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.98 / 13.87%	PF/THD at 90 V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.98 / 12.53%	PF/THD at 120 V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.97 / 13.58%	PF/THD at 140 V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.96 / 13.85%	PF/THD at 180 V_{AC} Line Input Voltage
		PF/THD_{230VAC}	0.93 / 16.88%	PF/THD at 230 V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.91 / 18.60%	PF/THD at 265 V_{AC} Line Input Voltage
Temperature	FLS3217N	$T_{FLS3217N}$	57.4ºC	Main Controller & MOSFET Temperature
	Rectifier	$T_{Rectifier}$	57.8ºC	Secondary Diode Temperature

All data of the evaluation board was measured with the board was enclosed in a case and external temperature around 25°C.

3. Photographs

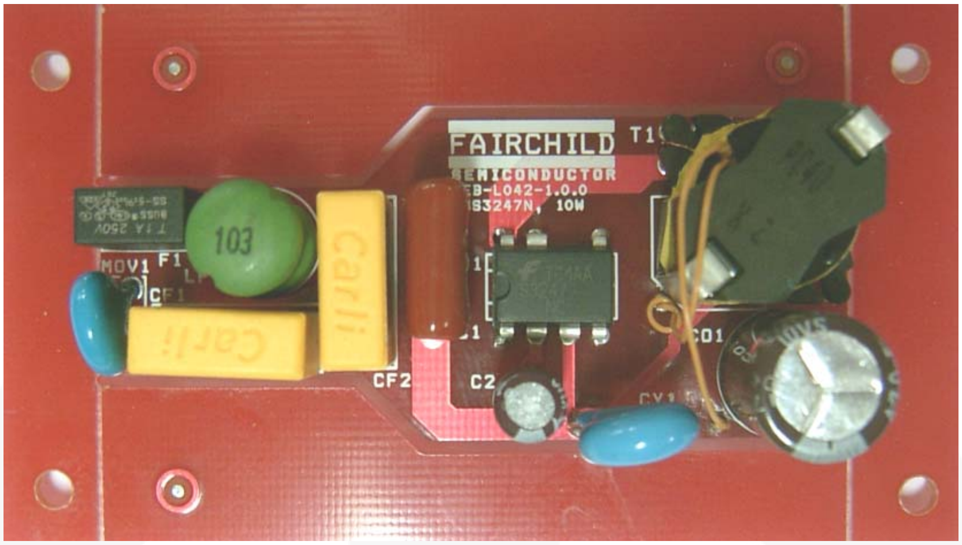

Figure 2. Top View Dimensions: 59 mm (L) ×25.5 mm (W) × 20.0 mm (H)

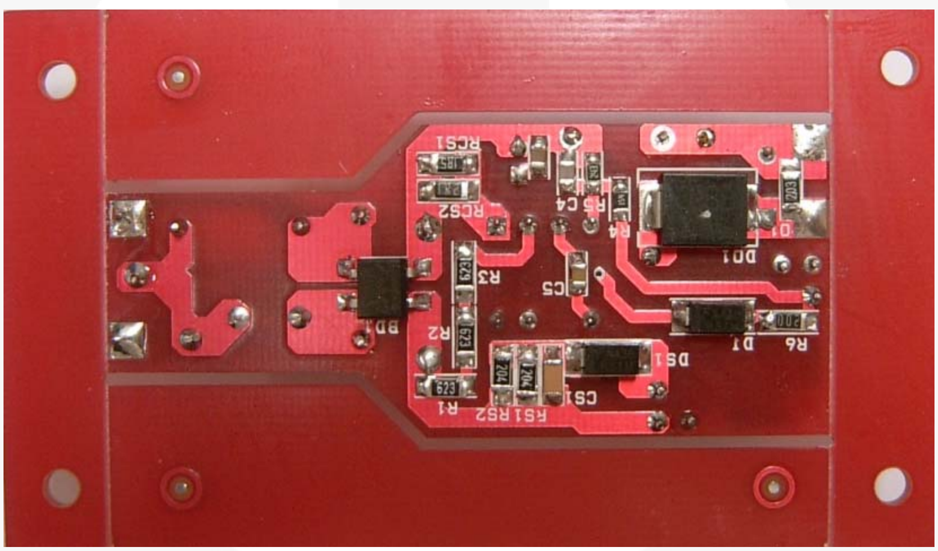

Figure 3. Bottom View Dimensions: 59 mm (L) ×25.5 mm (W) × 20.0 mm (H)

4. Printed Circuit Board

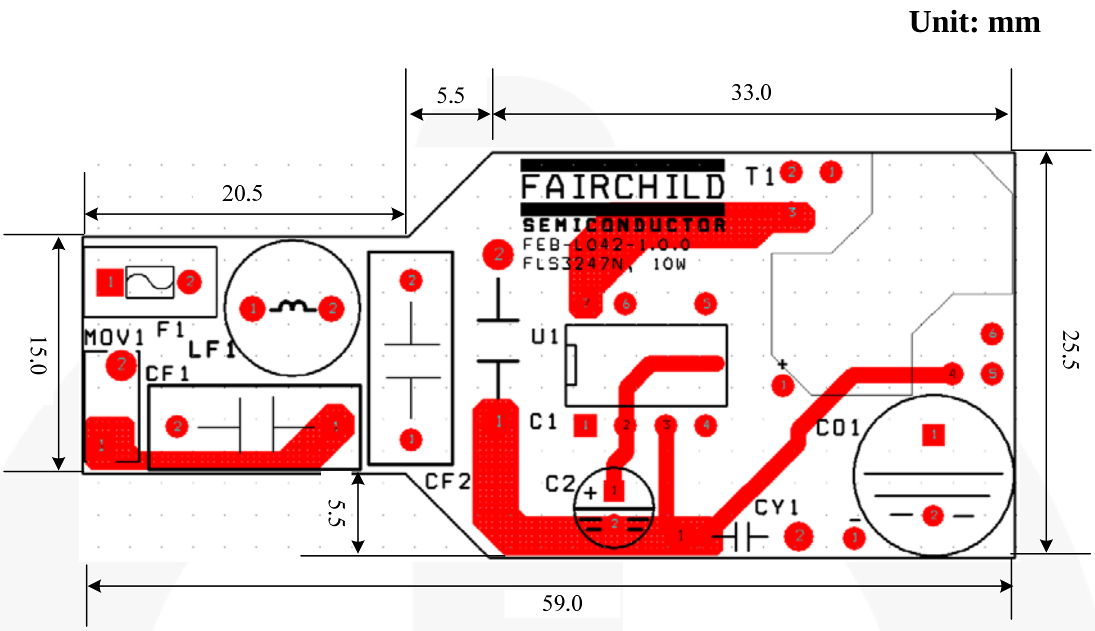

Figure 4. Top Side

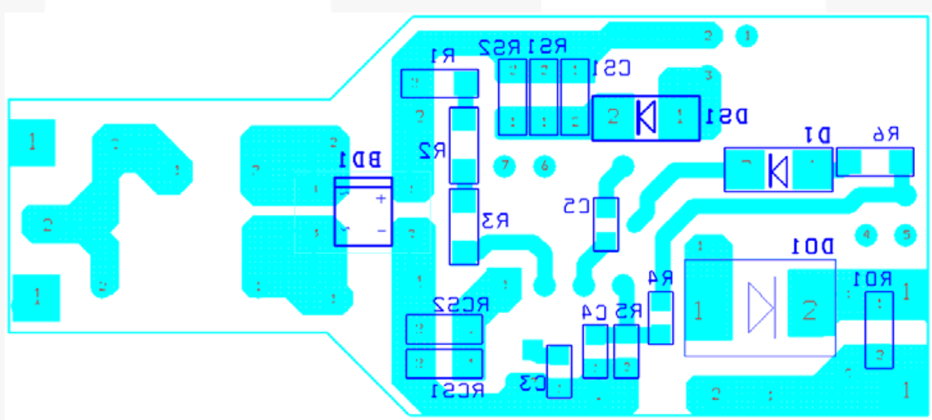

Figure 5. Bottom View

5. Schematic

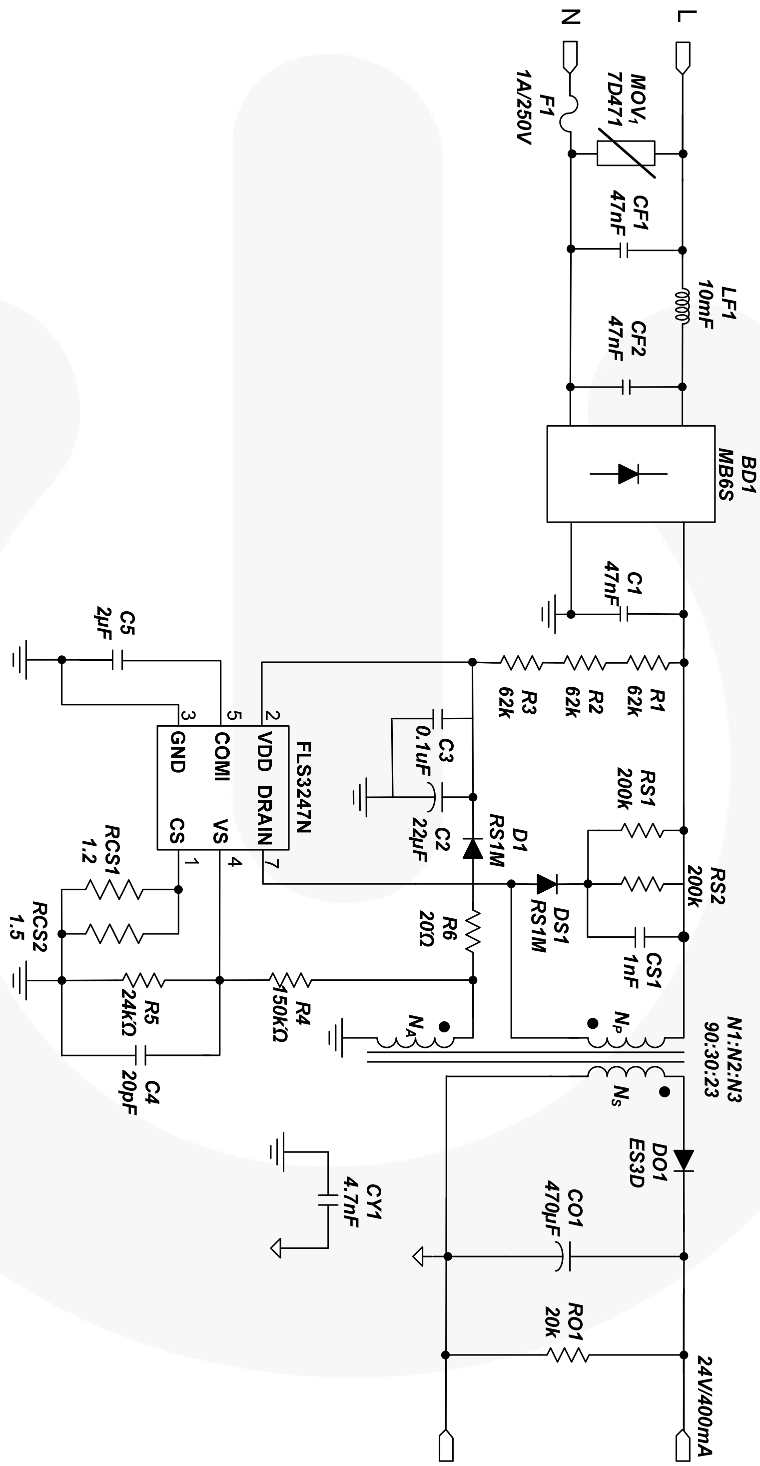

Figure 6. Evaluation Board Schematic

6. Bill of Materials

Item No.	Part Reference	Value	Qty.	Description	Manufacturer
1	BD1	MB6S	1	Bridge Diode	Fairchild Semiconducto
2	CF1, CF2	PX473K3IC2	2	47 nF / 275 V_{AC}, X-Capacitor	Carli
3	CS1	C1206C102KDRACTU	1	1 nF / 1 kV, SMD Capacitor 3216	Samwha
4	CY1	SCFZ2E472M10BW	1	4.7 nF / 250 V, Y-Capacitor	Samwha
5	CO1	KMG 470 µF/ 35 V	1	470 µF / 35 V, Electrolytic Capacitor	Samyoung
6	C1	MPE 630V473K	1	47 nF / 630 V, Film Capacitor	Sungho
7	C2	KMG 22 µF / 35 V	1	22 µF / 35 V, Electrolytic Capacitor	Samyoung
8	C3	C0805C104K3RACTU	1	0.1 µF / 25 V, SMD Capacitor 2012	Kemet
9	C4	C0805C200M3GACTU	1	20 pF / 25 V, SMD Capacitor 2012	Kemet
10	C5	C1206C205K3PACTU	1	2 µF / 25 V, SMD Capacitor 2012	Kemet
11	DS1, D1	RS1M	2	1 A / 1000 V, Diode	Fairchild Semiconductor
12	DO1	ES3D	1	3 A / 200 V, Fast Rectifier	Fairchild Semiconductor
13	F1	SS-5-1 A	1	1 A / 250 V, Fuse	Bussmann
14	LF1	R06103KT00	1	10 mH, 8Ø Filter Inductor	Bosung
15	MOV1	SVC 471D07	1	Varistor	Samwha
16	RS1, RS2	RC1206JR-07200KL	2	200 kΩ, SMD Resistor 3216	Yageo
17	RCS1	RC1206JR-071R5L	1	1.2 Ω, SMD Resistor 3216	Yageo
18	RCS2	RC1206JR-071R2L	1	1.5 Ω, SMD Resistor 3216	Yageo
19	RO1	RC1206JR-0720KL	1	20 kΩ, SMD Resistor 3216	Yageo
20	R1, R2, R3	RC1206JR-0762KL	3	62 kΩ, SMD Resistor 3216	Yageo
21	R4	RC1206JR-07150KL	1	150 kΩ, SMD Resistor 3216	Yageo
22	R5	RC1206JR-0724KL	1	24 kΩ, SMD Resistor 3216	Yageo
23	R6	RC1206JR-0720RL	1	20 Ω, SMD Resistor 3216	Yageo
24	T1	RM6	1	Transformer	TDK
25	U1	FLS3247N	1	Main Controller	Fairchild Semiconductor

7. Transformer Design

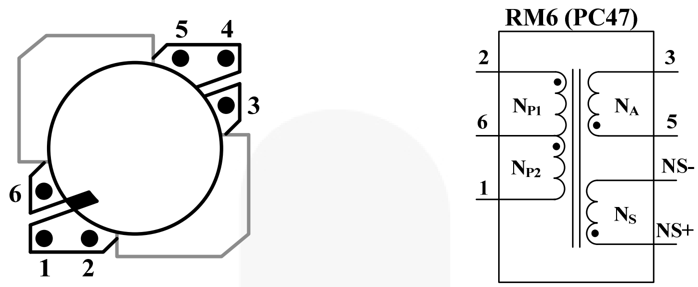

Figure 7. Transformer Bobbin Structure and Pin Configuration

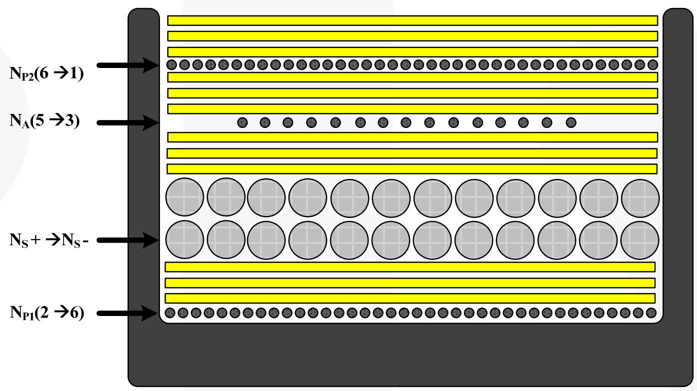

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	2 → 6	0.15φ	60 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
3	N_S	NS + → NS-	0.25φ (TIW)	30 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
5	N_A	5 → 3	0.13φ	23 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
7	N_{P2}	6 → 1	0.15φ	30 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 6-Layer				

Table 3. Electrical Characteristics.

	Pin	Specification	Remark
Inductance	2 – 1	1.1 mH ±10%	60 kHz, 1 V
Leakage	2 – 1	14 µH	60 kHz, 1 V Short All Output Pins

8. Performance of Evaluation Board

Table 4. Test Condition & Equipments

Ambient Temperature	T_A = 25°C
Test Equipment	AC Power Source: PCR500L by Kikusui Power Analyzer: PZ4000000 by Yokogawa Electronic Load: PLZ303WH by KIKUSUI Multi Meter: 2002 by KEITHLEY, 45 by FLUKE Oscilloscope: 104Xi by LeCroy Thermometer: Thermal CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03 (3 W) by Everlight

8.1. Startup

The startup time is 0.89 s at V_{IN} = 90 V_{AC}. The results were measured using actual LED load. Startup time, C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

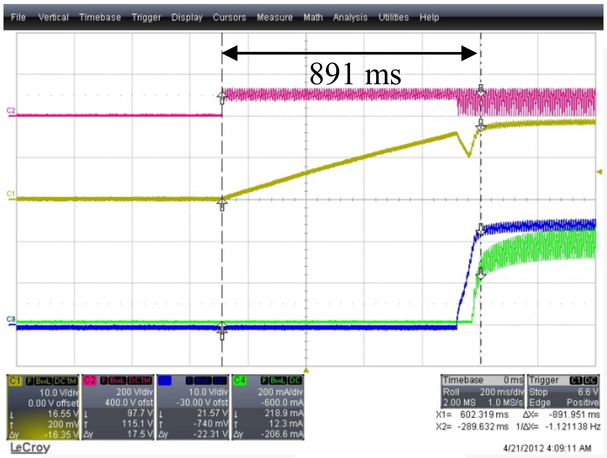

Figure 9. V_{IN} = 90 V_{AC} / 60 Hz

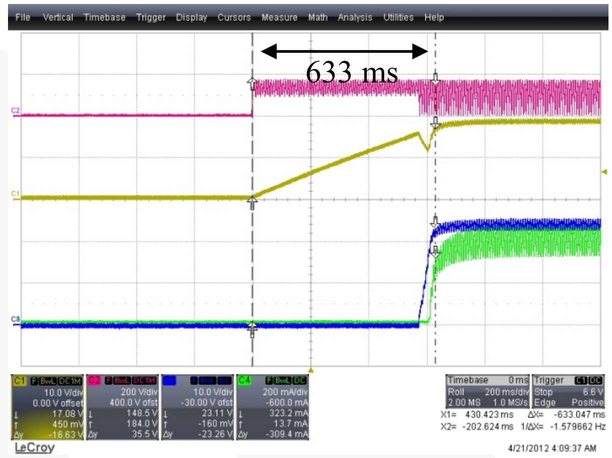

Figure 10. V_{IN} = 120 V_{AC} / 60 Hz

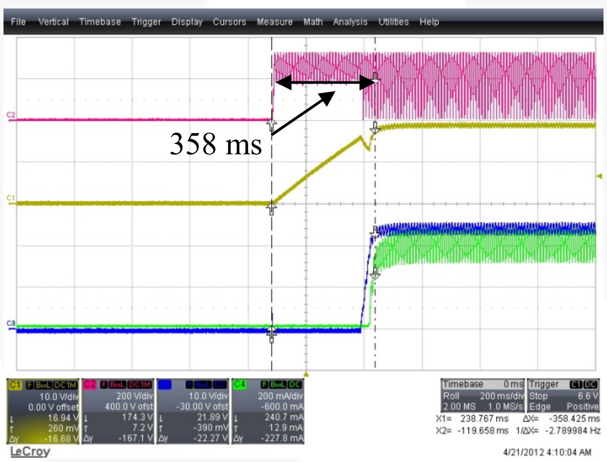

Figure 11. V_{IN} = 230 V_{AC} / 50 Hz

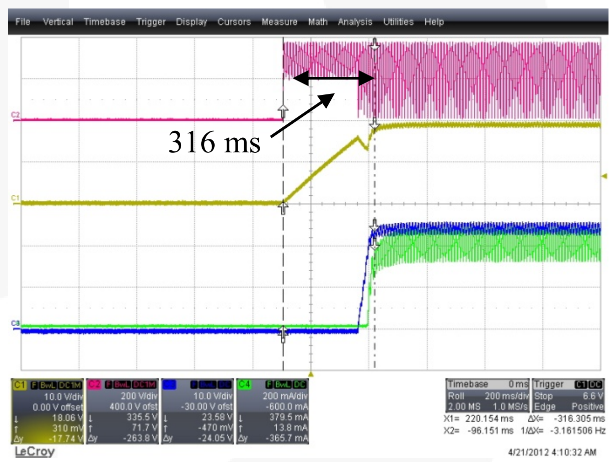

Figure 12. V_{IN} = 265 V_{AC} / 50 Hz

8.2. Operation Waveforms

Output current ripple is under ±80 mA with a rated output current of 400 mA. The results were measured using actual LED load. Operation waveforms: V_{OUT}: [25 V], I_{OUT}: [400 mA], C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

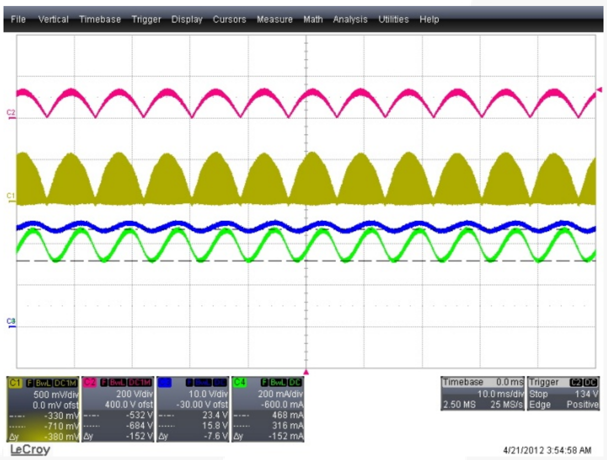

Figure 13. V_{IN} = 90 V_{AC} / 60 Hz

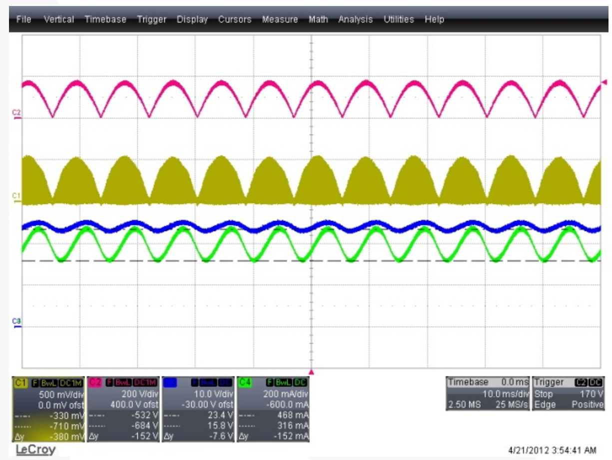

Figure 14. V_{IN} = 120 V_{AC} / 60 Hz

Figure 15. V_{IN} = 230 V_{AC} / 50 Hz

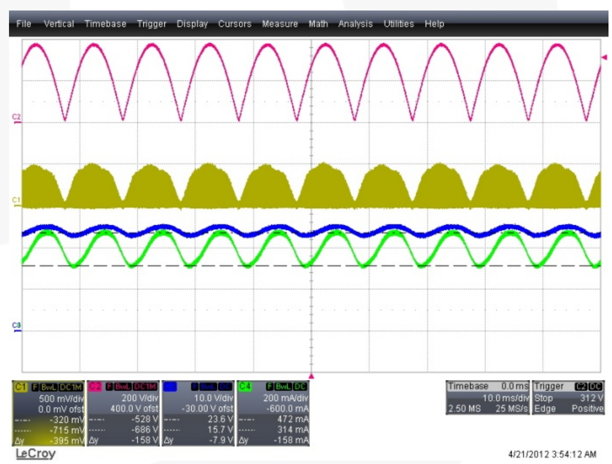

Figure 16. V_{IN} = 265 V_{AC} / 50 Hz

8.3. Constant Current Regulation

Constant current deviation in the wide output voltage range from 11 V to 28 V is less than ±2.85% at each line input voltage. Line regulation 24 V is less than ±2.85%. The results were measured by using E-load.

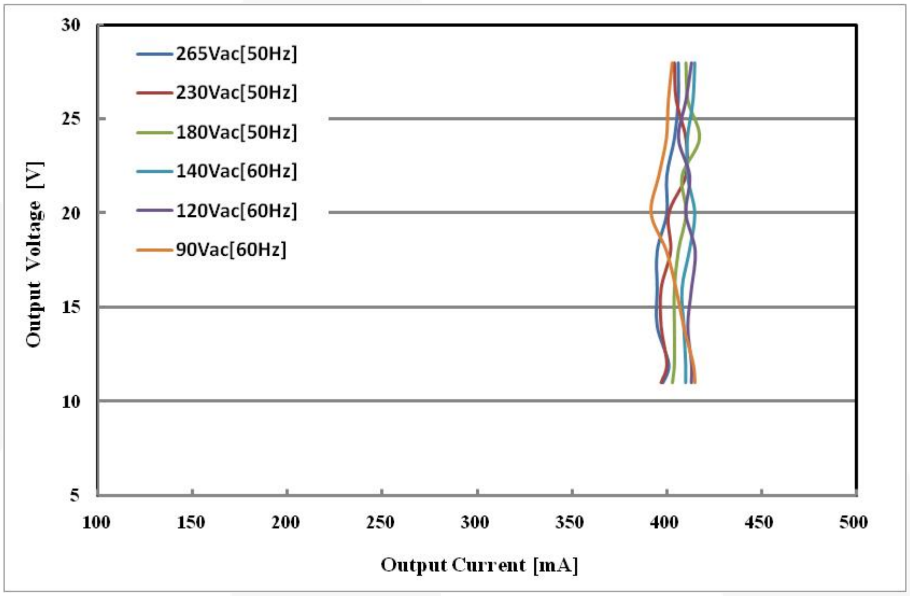

Figure 17. Constant Current Regulation – Measured by E-Load [CR Mode]

Table 5. Constant Current Regulation by Output Voltage Change (11~28 V)

Input Voltage	Min. Current	Max. Current	Tolerance
90 V_{AC} [60 Hz]	392 mA	415 mA	±2.85%
120 V_{AC} [60 Hz]	406 mA	415 mA	±1.10%
140 V_{AC} [60 Hz]	408 mA	415 mA	±0.85%
180 V_{AC} [50 Hz]	403 mA	417 mA	±1.71%
230 V_{AC} [50 Hz]	397 mA	410 mA	±1.61%
265 V_{AC} [50 Hz]	395 mA	410 mA	±1.37%

Table 6. Constant Current Regulation by Line Voltage Change (90~265 V_{AC})

Output Voltage	90 V_{AC} [60 Hz]	120 V_{AC} [60 Hz]	140 V_{AC} [60 Hz]	180 V_{AC} [50 Hz]	220 V_{AC} [50 Hz]	265 V_{AC} [50 Hz]	Tolerance
26 V	401 mA	410 mA	414 mA	411 mA	405 mA	406 mA	±1.60%
24 V	400 mA	406 mA	411 mA	417 mA	410 mA	404 mA	±2.08%
22 V	396 mA	412 mA	411 mA	408 mA	410 mA	400 mA	±1.98%
20 V	392 mA	410 mA	415 mA	410 mA	401 mA	400 mA	±2.85%

8.4. Short-LED Protections

In short-LED condition, the OCP level is reduced from 0.7 V to 0.2 V because FLS3247N lowers OCP level when V_S voltage is less than 0.4 V during output diode conduction time. The results were measured using actual LED load. Short-LED condition: C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

Figure 18. V_{IN} = 90 V_{AC} / 60 Hz

Figure 19. V_{IN} = 120 V_{AC} / 60 Hz

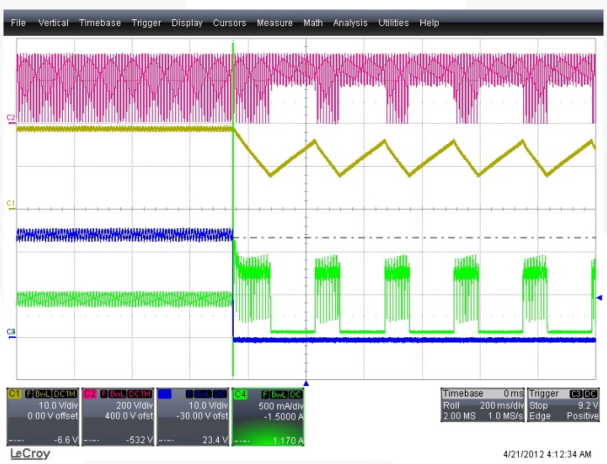

Figure 20. V_{IN} = 230 V_{AC} / 50 Hz

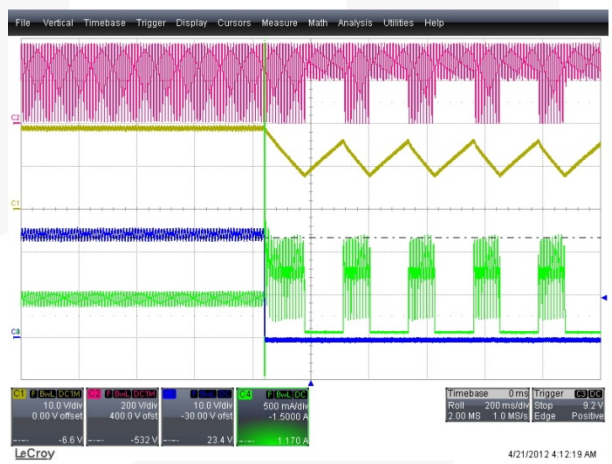

Figure 21. V_{IN} = 265 V_{AC} / 50 Hz

8.5. Open-LED Protections

In open-LED condition, output voltage is limited around 30 V by OVP in V_{DD}. Output over-voltage protection level can be controlled by the turns ratio of auxiliary and secondary windings. The results were measured using actual LED load. Open-LED condition: C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

Figure 22. V_{IN} = 90 V_{AC} / 60 Hz

Figure 23. V_{IN} = 120 V_{AC} / 60 Hz

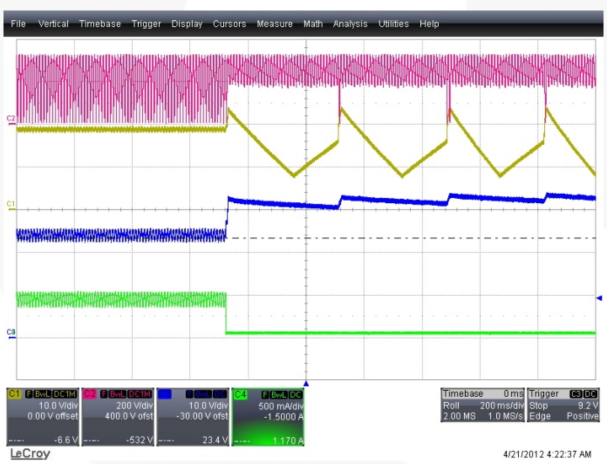

Figure 24. V_{IN} = 230 V_{AC} / 50 Hz

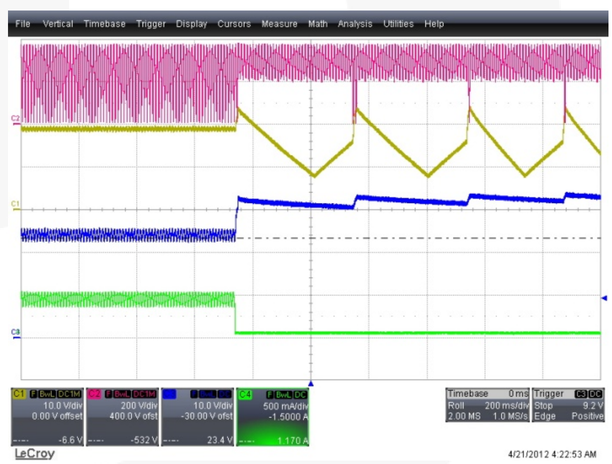

Figure 25. V_{IN} = 265 V_{AC} / 50 Hz

8.6. System Efficiency

Power efficiency is 84.27% ~ 86.74% in 90 ~ 265 V_{AC} input voltage range. The results were measured 30 minutes after startup using actual LED load.

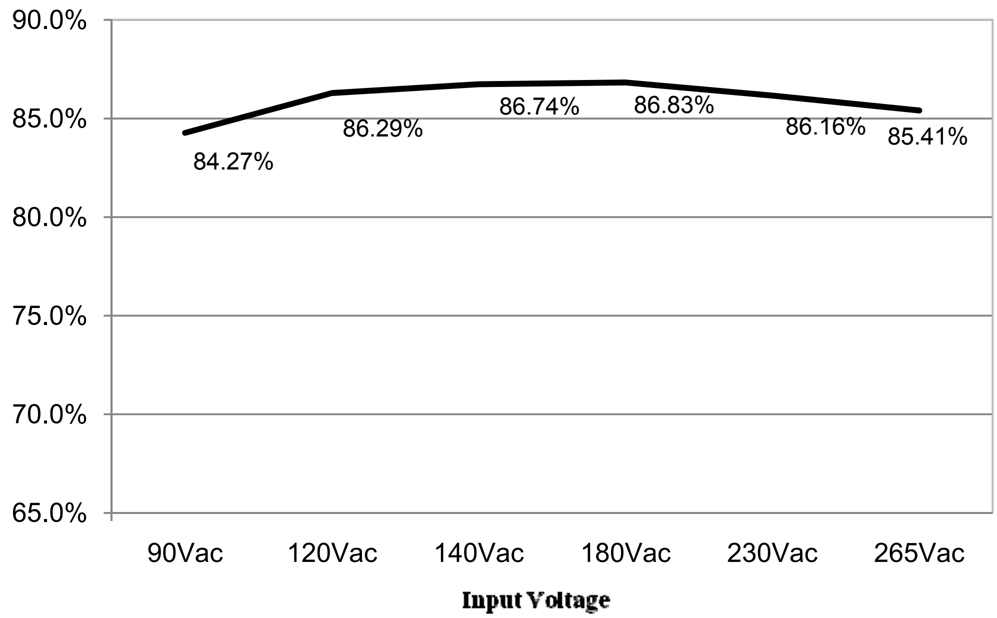

Figure 26. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90 V_{AC} [60 Hz]	11.80 W	404 mA	24.64 V	9.94 W	84.27%
120 V_{AC} [60 Hz]	11.67 W	408 mA	24.67 V	10.07 W	86.29%
140 V_{AC} [60 Hz]	11.84 W	415 mA	24.75 V	10.27 W	86.74%
180 V_{AC} [50 Hz]	11.83 W	415 mA	24.74 V	10.27 W	86.83%
220 V_{AC} [50 Hz]	11.62 W	407 mA	24.63 V	10.01 W	86.16%
265 V_{AC} [50 Hz]	11.74 W	407 mA	24.63 V	10.03 W	85.41%

8.7. Power Factor (PF) and Total Harmonic Distortion (THD)

FLS3217N shows excellent power factor and total harmonic distortion performance. Power factor is very high with enough margin from 0.9. THD is less than the 20% of the specification. The results were measured 30 minutes after startup using actual LED load.

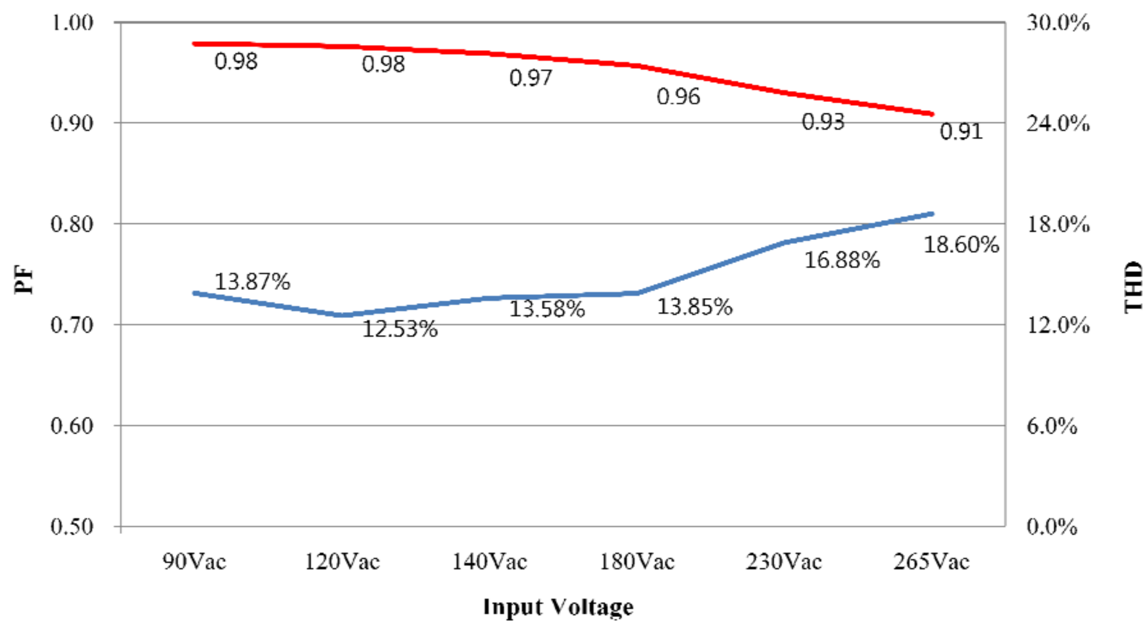

Figure 27. Power Factor and Total Harmonic Distortion

Table 8. Power Factor and Total Harmonic Distortion

Input Voltage	Output Current	Output Voltage	Power Factor	THD
90 V_{AC} [60 Hz]	404 mA	24.64 V	0.98	13.87%
120 V_{AC} [60 Hz]	408 mA	24.67 V	0.98	12.53%
140 V_{AC} [60 Hz]	415 mA	24.75 V	0.97	13.58%
180 V_{AC} [50 Hz]	415 mA	24.74 V	0.96	13.85%
220 V_{AC} [50 Hz]	407 mA	24.63 V	0.93	16.88%
265 V_{AC} [50 Hz]	407 mA	24.63 V	0.91	18.60%

8.8. Operating Temperature

Temperature of the all components on this board is less than 57.8ºC. The results were measured 60 minutes after startup using actual LED load.

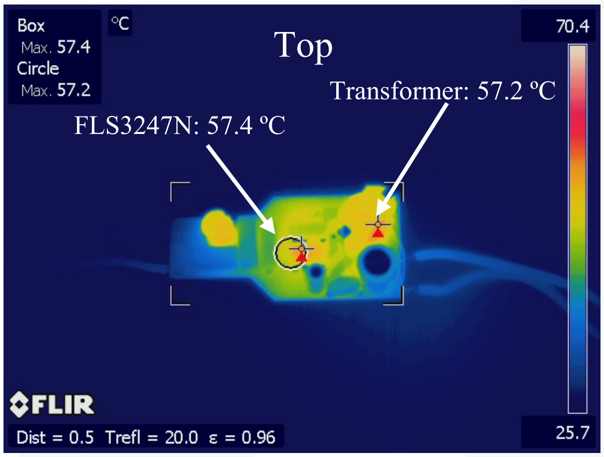

Figure 28. Board Temperature Top; V_{IN} [90 V_{AC}], V_{OUT} [25 V], I_{OUT} [400 mA]

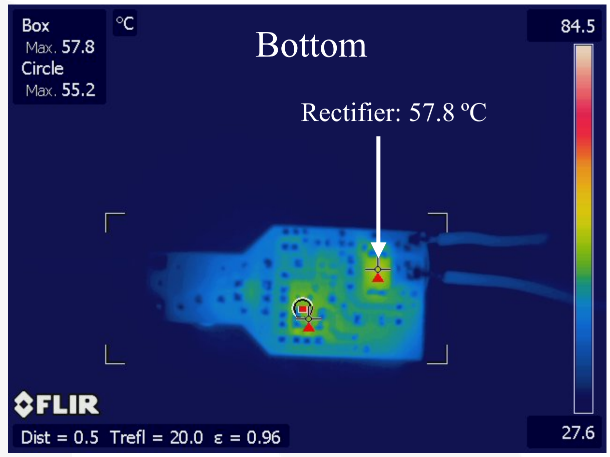

Figure 29. Board Temperature Bottom; V_{IN} [90 V_{AC}], V_{OUT} [25 V], I_{OUT} [400 mA]

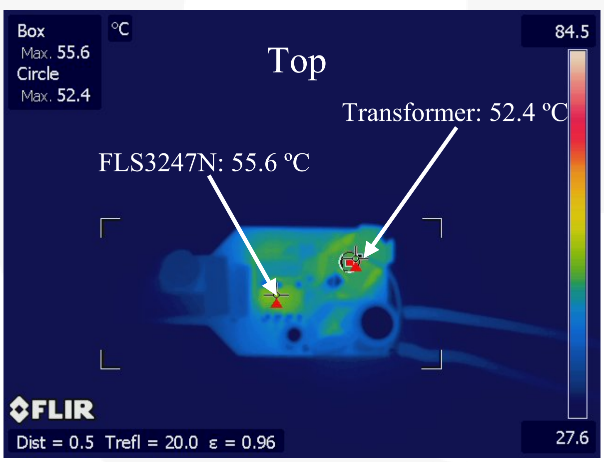

Figure 30. Board Temperature Top; V_{IN} [265 V_{AC}], V_{OUT} [25 V], I_{OUT} [400 mA]

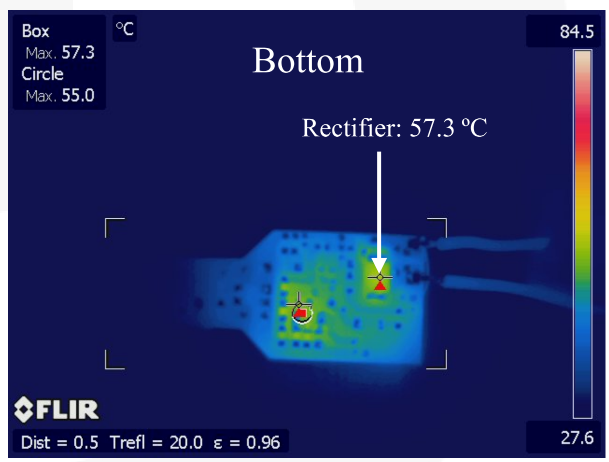

Figure 31. Board Temperature Bottom, V_{IN} [265 V_{AC}], V_{OUT} [25 V], I_{OUT} [400 mA]

8.1. Electromagnetic Interference (EMI)

All measurement was conducted in observance of EN55022 criteria. The results were measured 30 minutes after startup using actual LED load.

Test Results

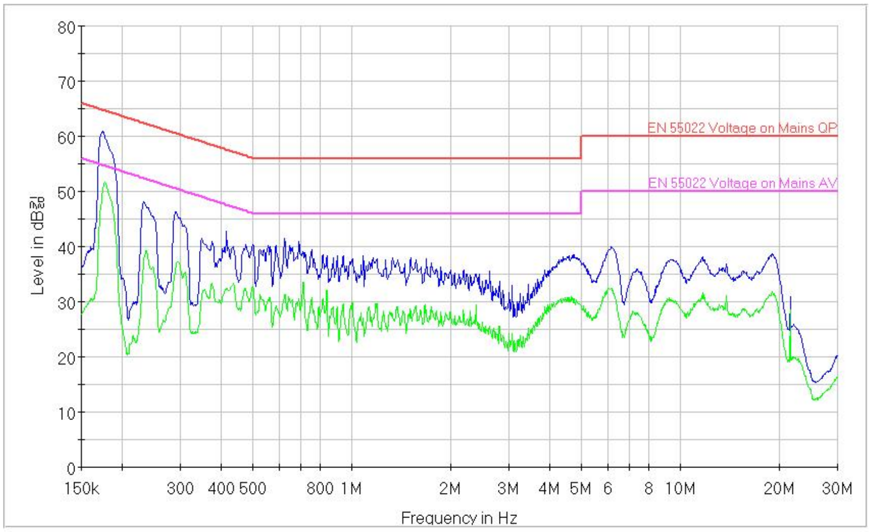

Figure 32. V_{IN} = 110 V_{AC}, V_{OUT} [25 V], I_{OUT} [400 mA]

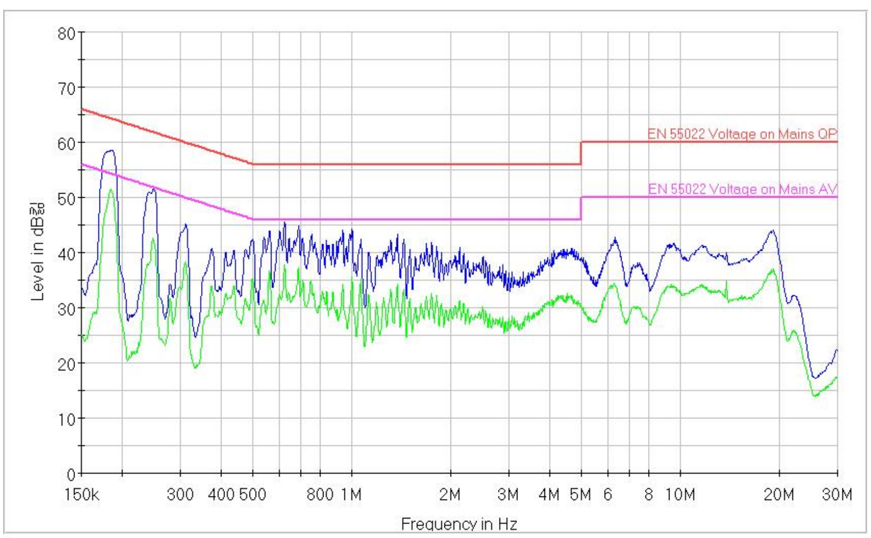

Figure 33. V_{IN} = 220 V_{AC}, V_{OUT} [25 V], I_{OUT} [400 mA]

9. Revision History

Rev.	Date	Description
1.0.0	June 2011	Initial Release
1.0.1	Oct. 2012	Modified, edited, formatted document. Changed User Guide number from FEB-L042 to FEBFLS3247N_L42U010A

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