User Guide for

FEB-L041
Evaluation Board

6.5W LED Driver

Featured Fairchild Product:
FLS3217N

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

Fairchild Semiconductor.com

Table of Contents

This user guide supports the evaluation kit for the FLS3217N. It should be used in conjunction with the FLS3217N 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 universal line voltage LED ballast using the FLS3217N Primary-Side Regulator (PSR) single-stage controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 270mA at $24V_{MAX}$. This document contains a general description of the FLS3217N, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description

The FLS3217N is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Primary-side regulation and single-stage topology minimize cost, reduce external components and such as input bulk capacitor and feedback circuitry. To improve power factor and 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 higher efficiency and simple design. FLS3217N provides protections such as open LED, short LED and over temperature.

1.2. Features

- Cost-Effective Solution without input bulk capacitor or feedback circuitry
- Power Factor Correction
- 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: 20µA
- Low Operating Current: 5mA
- V_{DD} Over-Voltage Protection
- V_{DD} Under-Voltage Lockout (UVLO)
- Application Voltage Range: $80V_{AC}$ ~ $308V_{AC}$

1.3. Internal Block Diagram

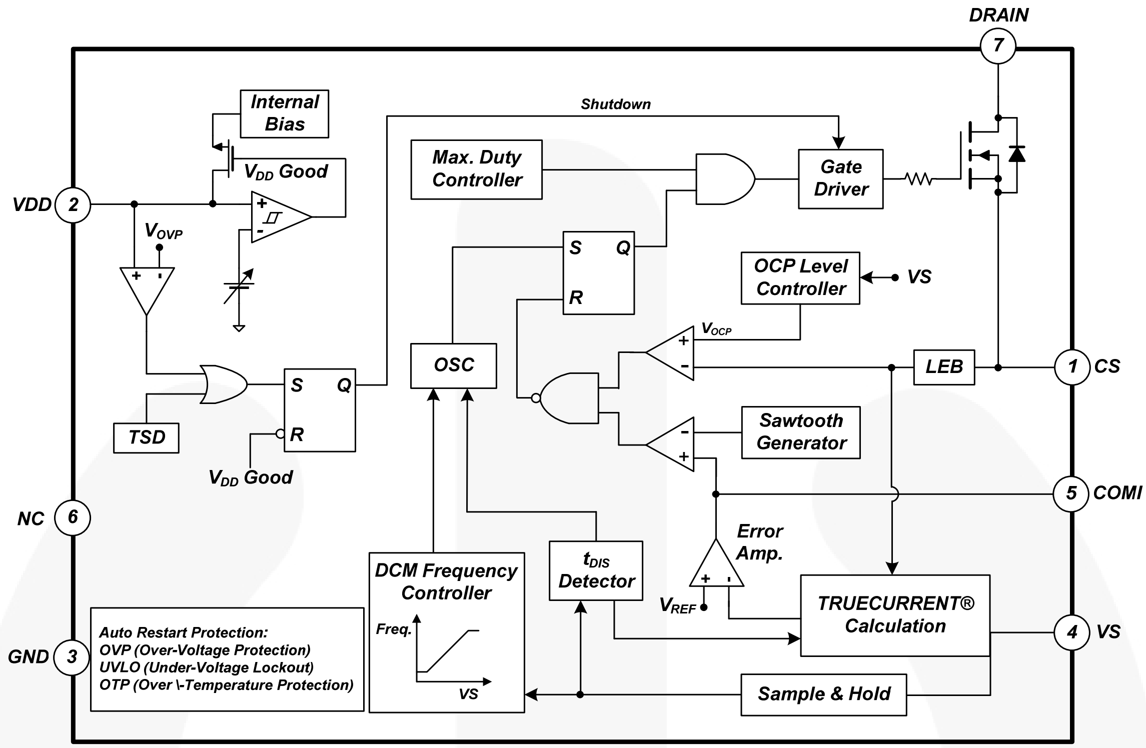

Figure 1. Internal Block Diagram

2. General Specifications for Evaluation Board

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

Table 1. Evaluation Board Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90V	Minimum Input Voltage
		$V_{IN.MAX}$	265V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	120V / 230V	Nominal Input Voltage
	Frequency	f_{IN}	60Hz / 50Hz	Line Frequency
Output	**Voltage Current**	$V_{OUT.MIN}$	11V	Minimum Output Voltage
		$V_{OUT.MAX}$	28V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	24V	Rated Output Voltage
		$I_{OUT.NOMINAL}$	270mA	Rated Output Current
	Current	CC Deviation	< ±2.78%	Line Input Voltage Change: 90~265V_{AC}
			< ±2.60%	Output Voltage Change: 11~28V
Efficiency		Eff_{90VAC}	84.96%	Efficiency at 90V_{AC} Line Voltage
		Eff_{120VAC}	86.55%	Efficiency at 120V_{AC} Line Input Voltage
		Eff_{140VAC}	86.86%	Efficiency at 140V_{AC} Line Input Voltage
		Eff_{180VAC}	86.90%	Efficiency at 180V_{AC} Line Input Voltage
		Eff_{230VAC}	86.19%	Efficiency at 230V_{AC} Line Input Voltage
		Eff_{265VAC}	85.35%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.99 / 12.71%	PF/THD at 90V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.99 / 10.46%	PF/THD at 120V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.98 / 11.10%	PF/THD at 140V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.97 / 14.01%	PF/THD at 180V_{AC} Line Input Voltage
		PF/THD_{230VAC}	0.94 / 16.47%	PF/THD at 230V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.91 / 18.89%	PF/THD at 265V_{AC} Line Input Voltage
Temperature	FLS3217N	$T_{FLS3217N}$	54.9ºC	Main Controller Temperature
	Rectifier	$T_{Rectifier}$	47.7ºC	Secondary Diode Temperature

2.1. Photographs of Evaluation Board

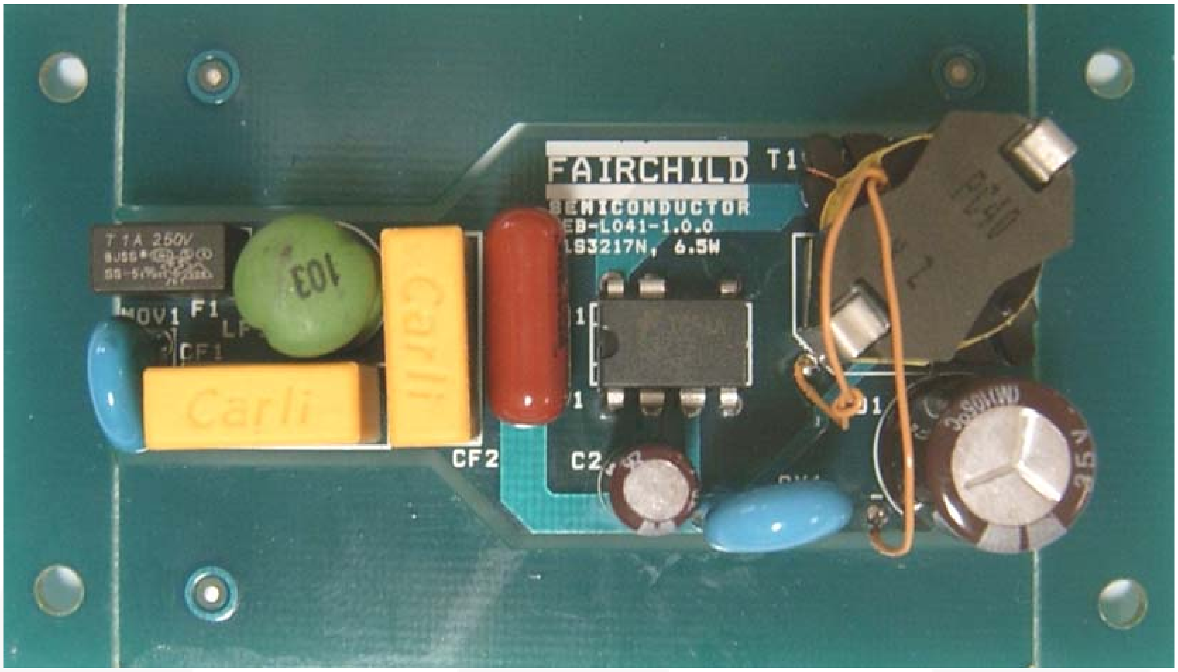

Figure 2. Top View (Dimensions: 59.9mm (L) x 25.5mm (W) x 15.0mm (H))

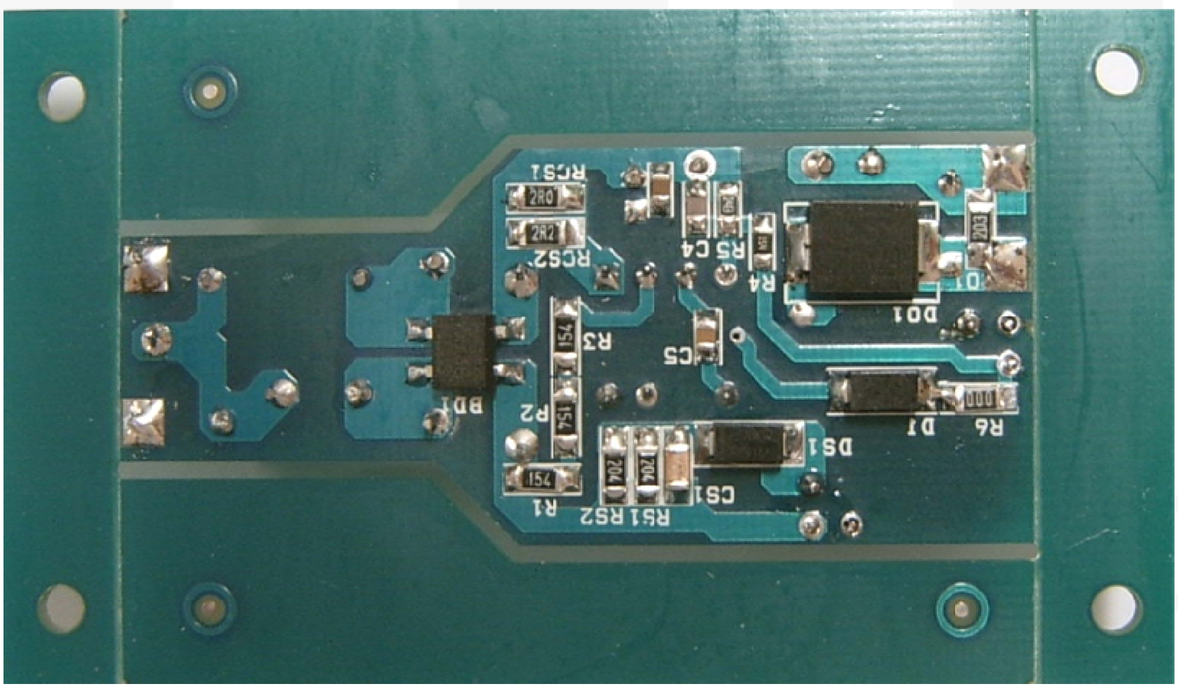

Figure 3. Bottom View (Dimensions: 59.9mm (L) x 25.5mm (W) x 15.0mm (H))

2.2. Printed Circuit Board

Unit: mm

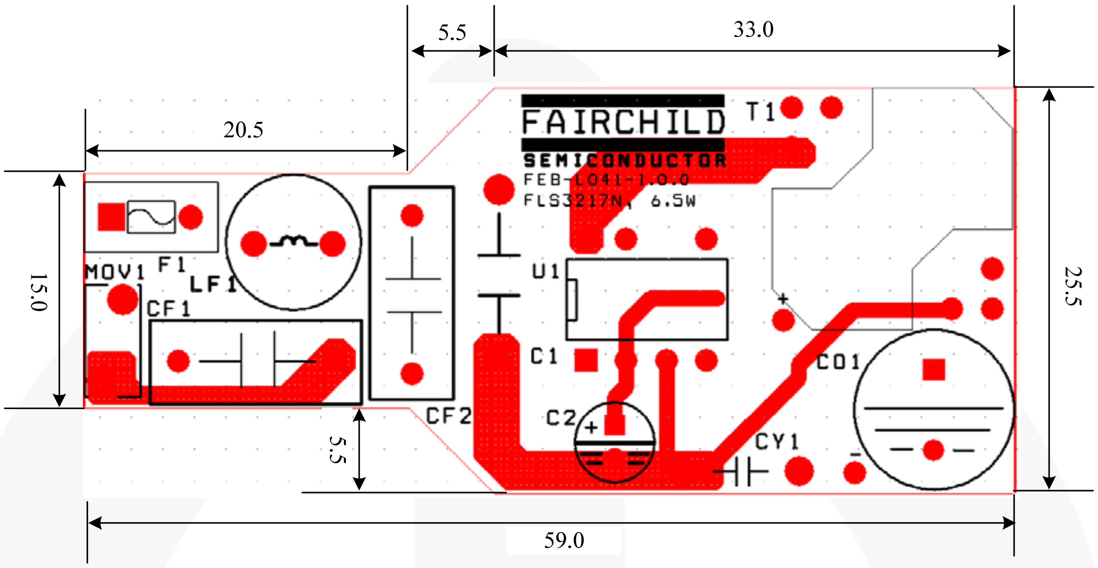

Figure 4. Top Side

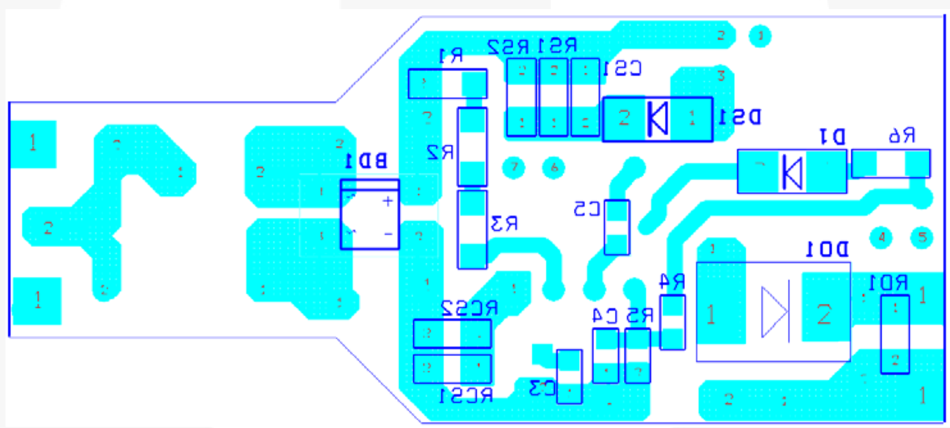

Figure 5. Bottom Side

2.3. Schematic

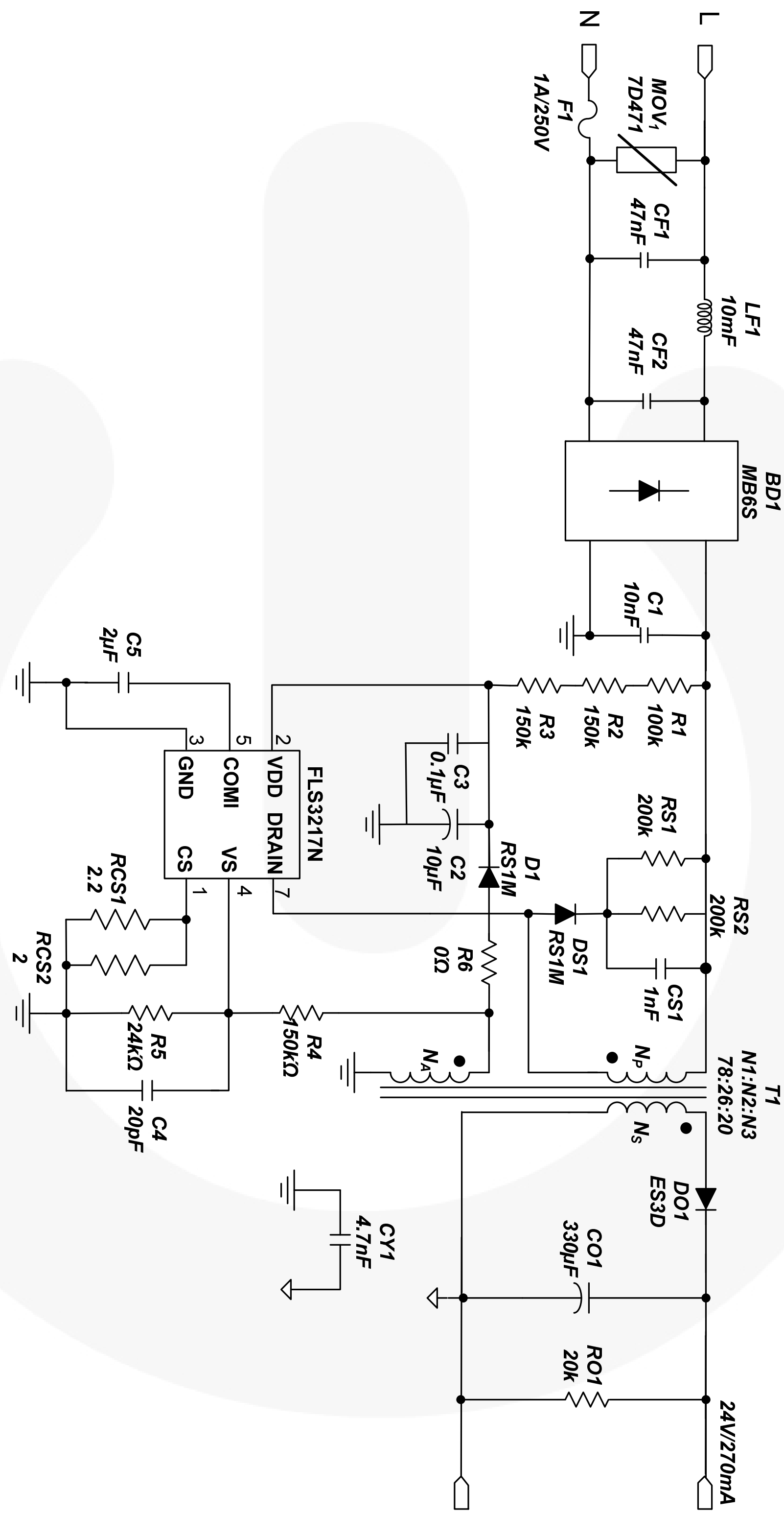

Figure 6. Evaluation Board Schematic

2.4. Bill of Materials

Item No.	Part Reference	Value	Qty.	Description	Manufacturer
1	BD1	MB6S	1	Bridge Diode	Fairchild Semiconductor
2	CF1, CF2	PX473K3IC2	2	473 / 275V_{AC}, X-Capacitor	Carli
3	CS1	C1206C102KDRACTU	1	102 / 1kV, SMD Capacitor 3216	Samwha
4	CY1	SCFz2E472M10BW	1	472 / 250V, Y-Capacitor	Samwha
5	CO1	KMG 330µF / 35V	1	330µF / 35V, Electrolytic Capacitor	Samyoung
6	C1	MPE 400V / 103K	1	103 / 400V, Film Capacitor	Sungho
7	C2	KMG 10µF / 35V	1	10µF / 35V, Electrolytic Capacitor	Samyoung
8	C3	C0805C104K3RACTU	1	104 / 25V, SMD Capacitor 2012	Kemet
9	C4	C0805C200M3GACTU	1	200 / 25V, SMD Capacitor 2012	Kemet
10	C5	C1206C205K3PACTU	1	205 / 25V, SMD Capacitor 2012	Kemet
11	DS1, D1	RS1M	2	1A / 1000V, Diode	Fairchild Semiconductor
12	DO1	ES3D	1	3A / 200V, Fast Rectifier	Fairchild Semiconductor
13	F1	SS-5-1A	1	1A / 250V, Fuse	Bussmann
14	LF1	R06103KT00	1	10mH, 8Ø Filter inductor	Bosung
15	MOV1	SVC 471D07	1	Varistor	Samwha
16	RS1, RS2	RC1206JR-07200KL	2	200kΩ, SMD Resistor 3216	Yageo
17	RCS1	RC1206JR-072R2L	1	2.2Ω, SMD Resistor 3216	Yageo
18	RCS2	RC1206JR-072RL	1	2.0Ω, SMD Resistor 3216	Yageo
19	RO1	RC1206JR-0720KL	1	20kΩ, SMD Resistor 3216	Yageo
20	R2, R3, R4	RC1206JR-07150KL	3	150kΩ, SMD Resistor 3216	Yageo
21	R1	RC1206JR-07100KL	1	100kΩ, SMD Resistor 3216	Yageo
22	R5	RC1206JR-0724KL	1	24kΩ, SMD Resistor 3216	Yageo
23	R6	RC1206JR-070RL	1	0Ω, SMD Resistor 3216	Yageo
24	T1	RM6	1	Transformer	TDK
25	U1	FLS3217N	1	Main Controller	Fairchild Semiconductor

2.5. Transformer Design

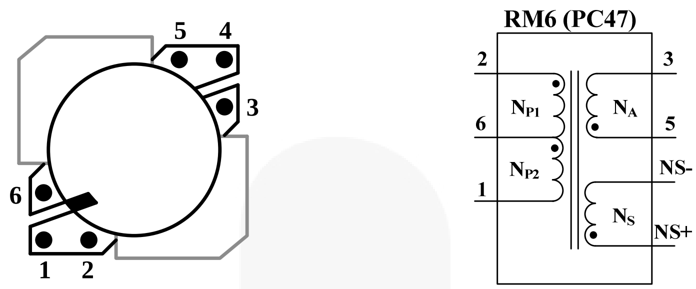

Figure 7. Transformer Bobbin Structure and Pin Configuration

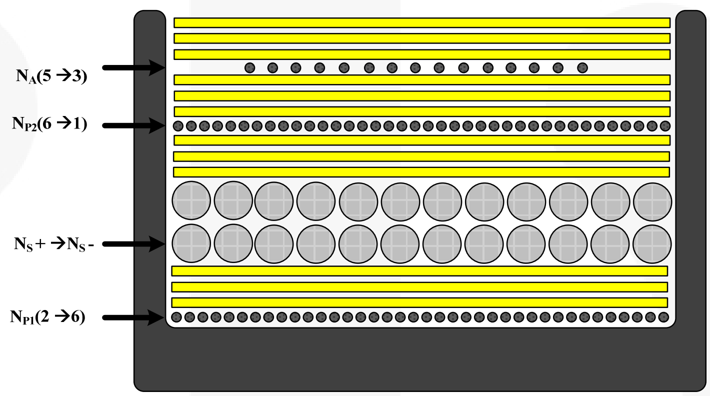

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	2 → 6	0.2φ	52 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
3	N_S	NS + → NS-	0.25φ (TIW)	26 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
5	N_{P1}	6 → 1	0.2φ	26 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
7	N_A	5 → 3	0.2φ	20 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025mm, 6-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	2 – 1	1.4mH ±10%	60kHz, 1V
Leakage	2 – 1	10µH	60kHz, 1V Short All Output Pins

3. 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-P01(1W) by Everlight

3.1. Startup

Startup time is 0.92s at V_{IN}=90V_{AC}. The results were measured using actual LED load. Startup time, C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

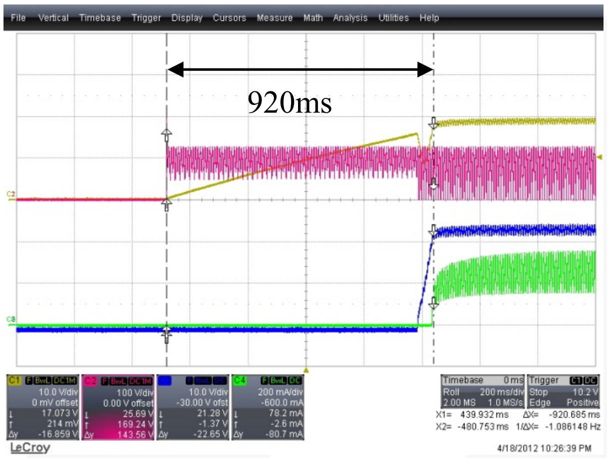

Figure 9. V_{IN}=90V_{AC} / 60Hz

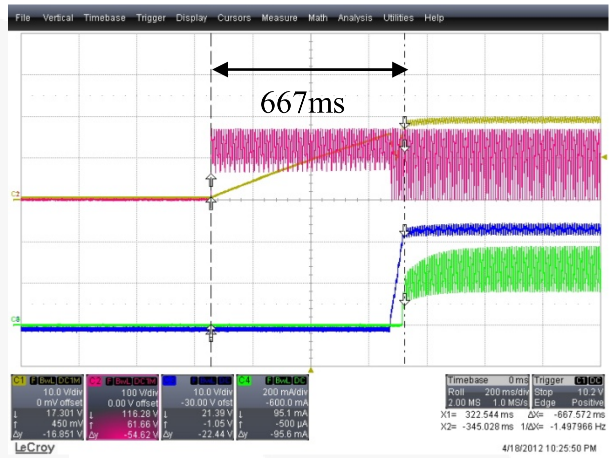

Figure 10. V_{IN}=120V_{AC} / 60Hz

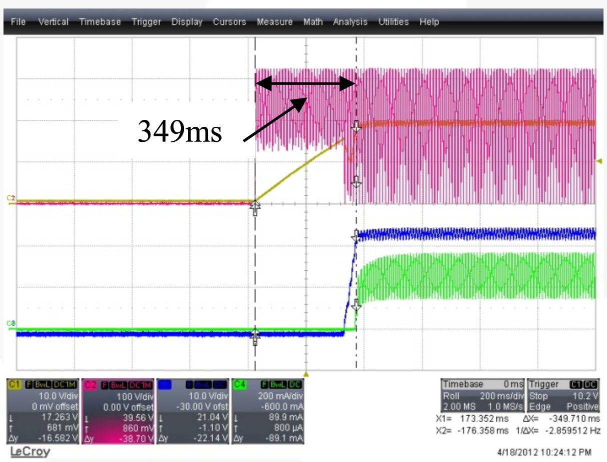

Figure 11. V_{IN}=230V_{AC} / 50Hz

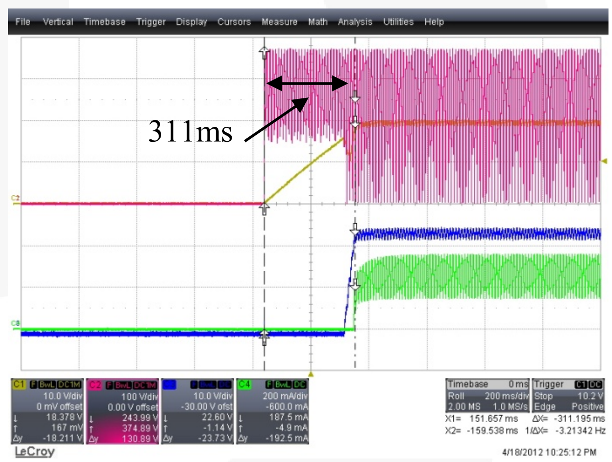

Figure 12. V_{IN}=265V_{AC} / 50Hz

3.2. Operation Waveforms

Output current ripple is under ±220mA with a rated output current of 270mA. The results were measured using actual LED load. Operation waveforms; V_{OUT}: [24V], I_{OUT}: [270mA], C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

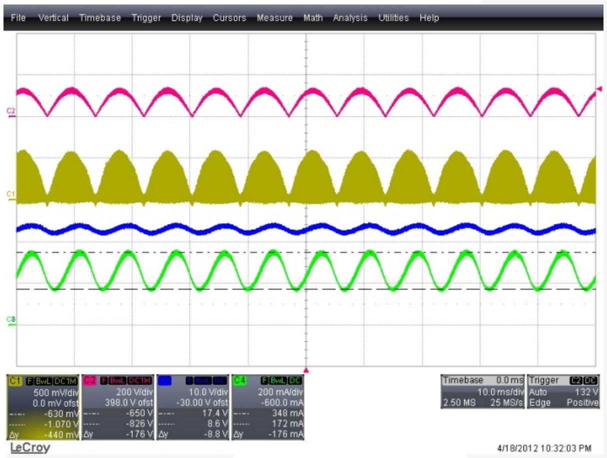

Figure 13. V_{IN}=90V_{AC} / 60Hz

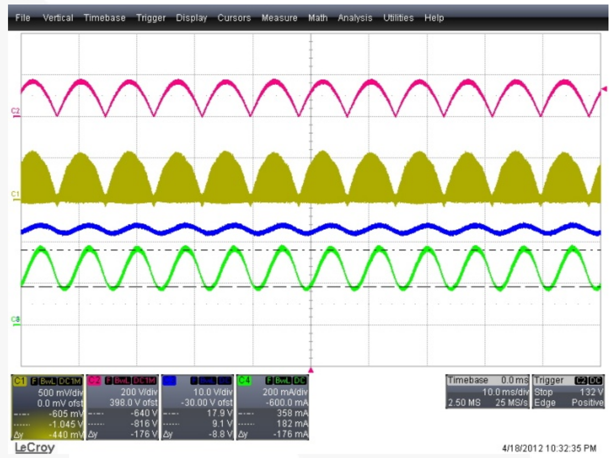

Figure 14. V_{IN}=120V_{AC} / 60Hz

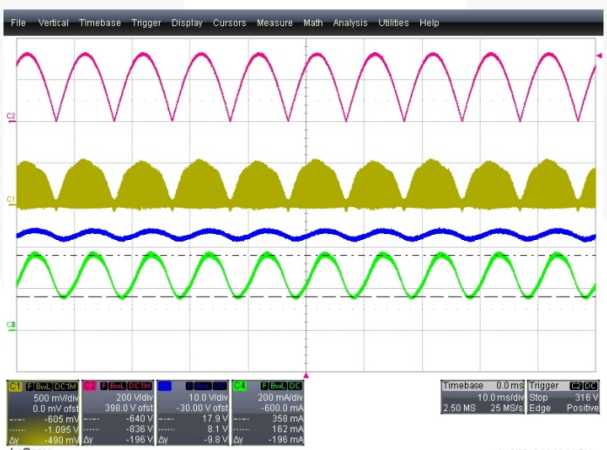

Figure 15. V_{IN}=220V_{AC} / 50Hz

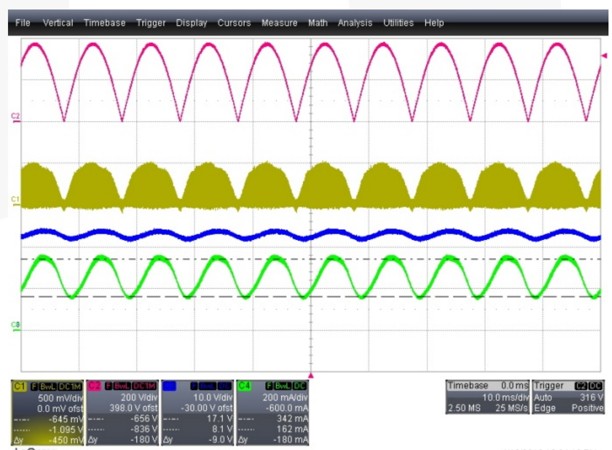

Figure 16. V_{IN}=265V_{AC} / 50Hz

3.3. Constant Current Regulation

Constant current deviation in the wide output voltage range from 11V to 28V is less than 2.8% at each line input voltage. Line regulation at the rated output voltage (24V) is less than 2.6%. The results were measured using E-load.

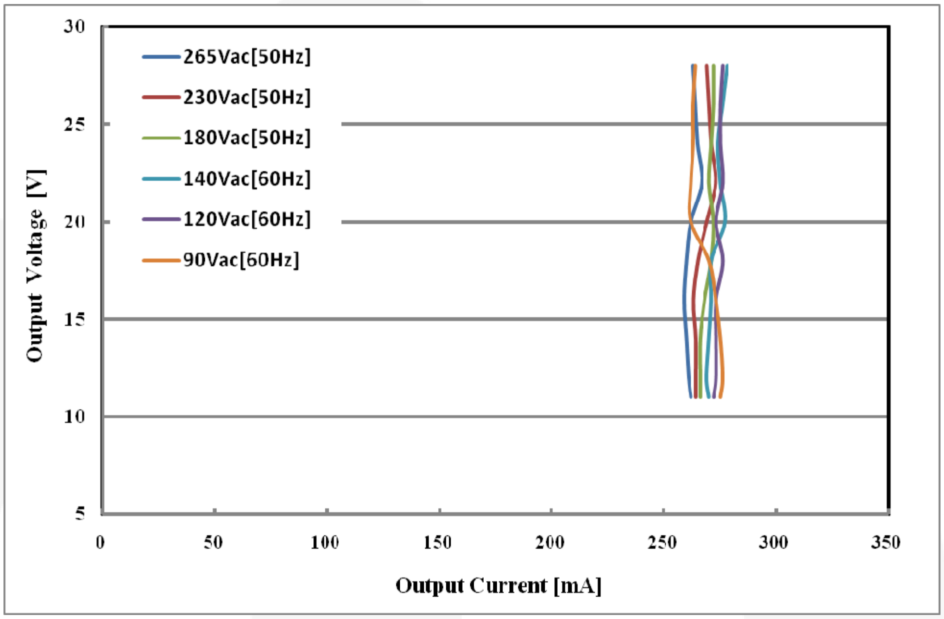

Figure 17. Constant Current Regulation – Measured by E-Load [CR Mode]

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

Input Voltage	Min. Current	Max. Current	Tolerance
$90V_{AC}$ [60Hz]	262mA	276mA	±2.60%
$120V_{AC}$ [60Hz]	272mA	276mA	±0.73%
$140V_{AC}$ [60Hz]	269mA	278mA	±1.65%
$180V_{AC}$ [50Hz]	266mA	272mA	±1.12%
$230V_{AC}$ [50Hz]	263mA	273mA	±1.87%
$265V_{AC}$ [50Hz]	259mA	267mA	±1.52%

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

Output Voltage	$90V_{AC}$ [60Hz]	$120V_{AC}$ [60Hz]	$140V_{AC}$ [60Hz]	$180V_{AC}$ [50Hz]	$220V_{AC}$ [50Hz]	$265V_{AC}$ [50Hz]	Tolerance
26V	263mA	275mA	274mA	272mA	270mA	264mA	±2.41%
24V	263mA	275mA	275mA	271mA	271mA	265mA	±2.23%
22V	262mA	276mA	277mA	270mA	273mA	267mA	±2.60%
20V	262mA	273mA	271mA	272mA	269mA	262mA	±2.78%

3.4. Short-LED / Open LED Protections

In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because FLS3217N lowers OCP level when V_S voltage is less than 0.4V 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}=90V_{AC} / 60Hz

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

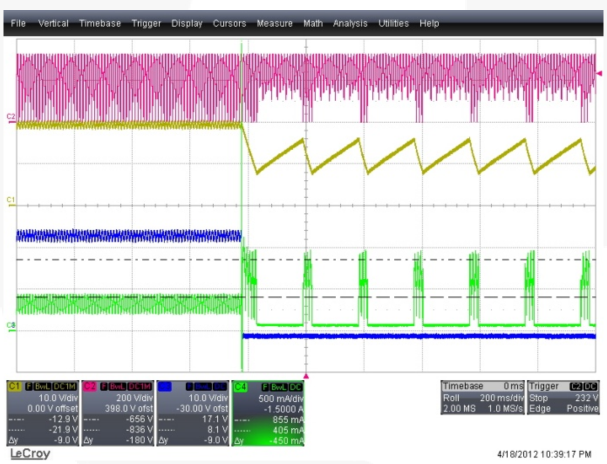

Figure 20. V_{IN}=230V_{AC} / 50Hz

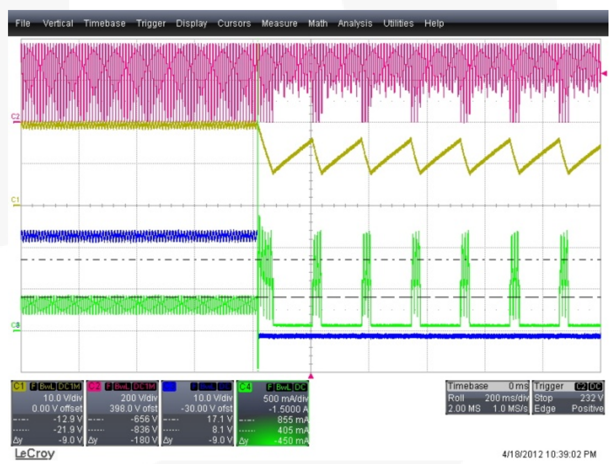

Figure 21. V_{IN}=265V_{AC} / 50Hz

In open-LED condition, output voltage is limited around 30V 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 by using actual LED load. Open-LED condition; C1: [V_{DD}], C2: [V_{IN}], C3: [V_{OUT}], C4: [I_{OUT}].

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

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

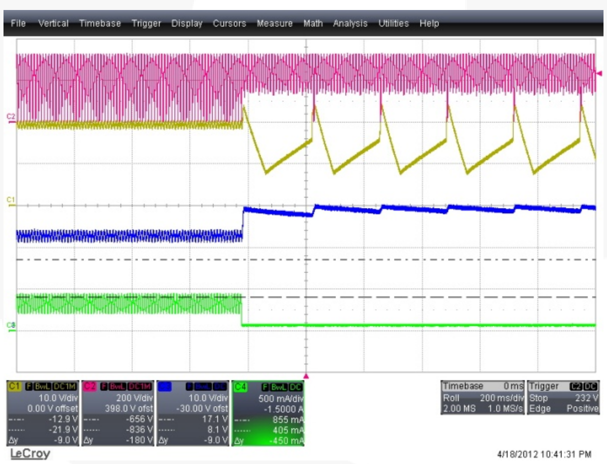

Figure 24. V_{IN}=230V_{AC} / 50Hz

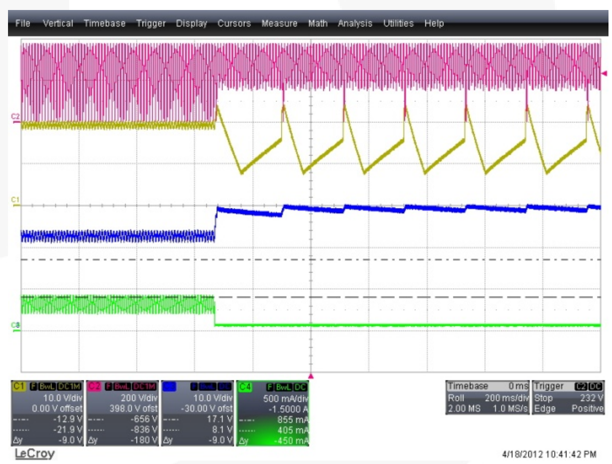

Figure 25. V_{IN}=265V_{AC} / 50Hz

3.5. System Efficiency

Power efficiency is 84.96% ~ 86.90% in 90 ~ 265V_{AC} input voltage range. The results were measured 30 minutes after startup using actual LED load.

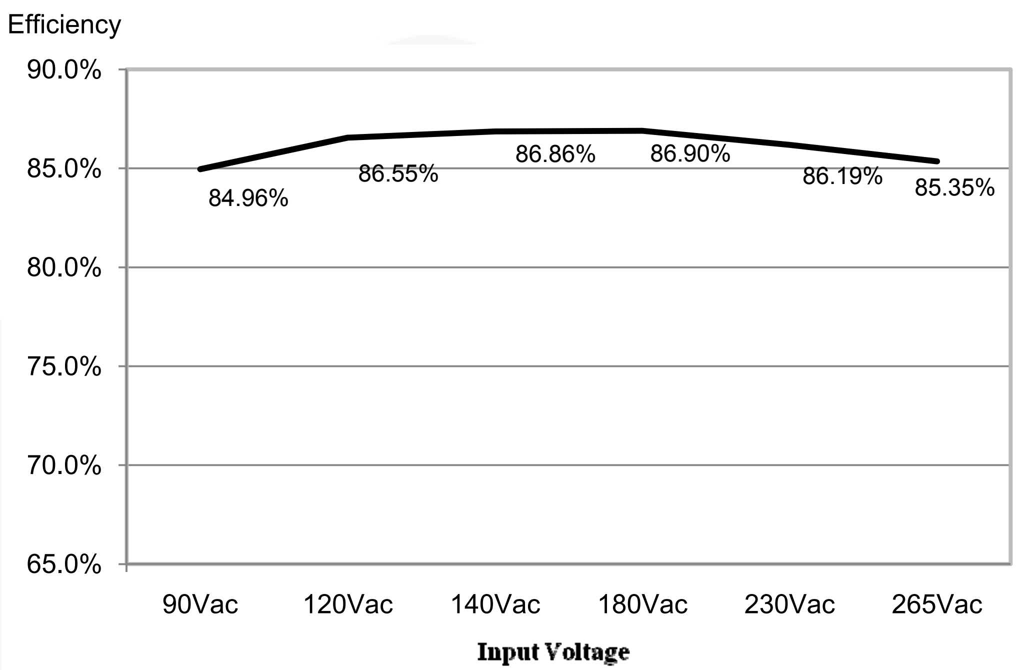

Figure 26. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90V_{AC} [60Hz]	7.46W	264mA	24.02V	6.34W	84.96%
120V_{AC} [60Hz]	7.72W	277mA	24.13V	6.68W	86.55%
140V_{AC} [60Hz]	7.65W	275mA	24.12V	6.65W	86.86%
180V_{AC} [50Hz]	7.54W	272mA	24.07V	6.55W	86.90%
220V_{AC} [50Hz]	7.56W	271mA	24.06V	6.52W	86.19%
265V_{AC} [50Hz]	7.49W	266mA	24.02V	6.39W	85.35%

3.6. Power Factor and Total Harmonic Distortion

FLS3217N shows excellent power factor and performance. Total harmonic discharge is much less than the 20% specification. The results were measured 30 minutes after startup by using actual LED load.

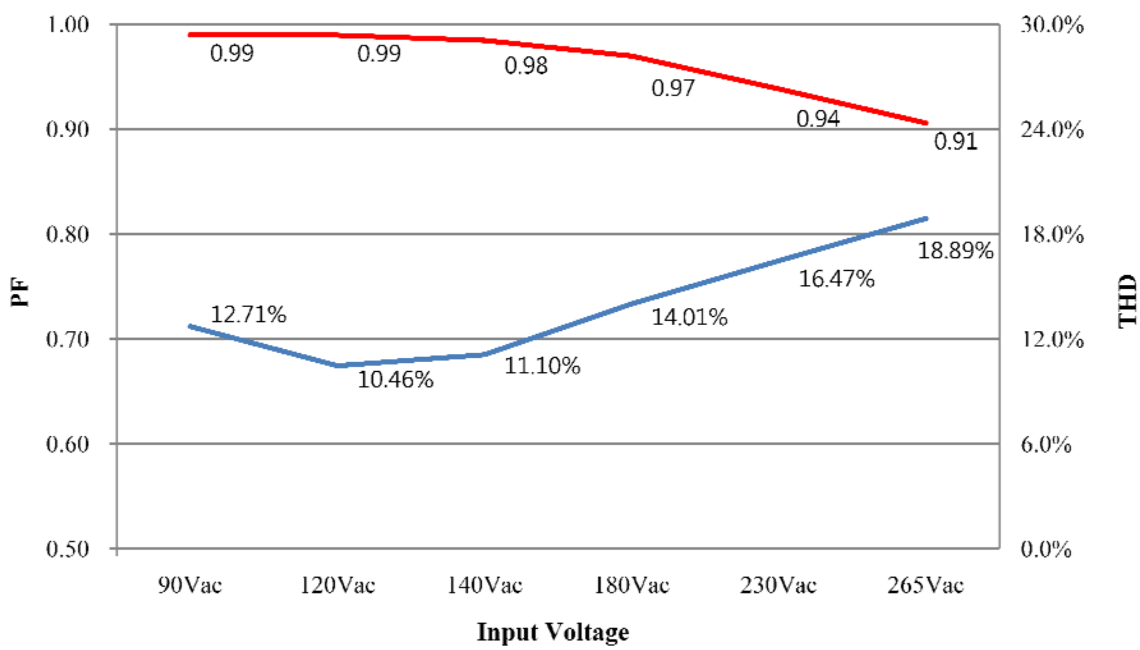

Figure 27. Power Factor and Total Harmonic Distortion

Table 8. Power Factor and Total Harmonic Distortion

Input Voltage	Output Current	Output Voltage	Power Factor	THD
$90V_{AC}$ [60Hz]	264mA	24.02V	0.99	12.71%
$120V_{AC}$ [60Hz]	277mA	24.13V	0.99	10.46%
$140V_{AC}$ [60Hz]	275mA	24.12V	0.98	11.10%
$180V_{AC}$ [50Hz]	272mA	24.07V	0.97	14.01%
$230V_{AC}$ [50Hz]	271mA	24.06V	0.94	16.47%
$265V_{AC}$ [50Hz]	266mA	24.02V	0.91	18.89%

3.7. Operating Temperature

Temperature of the all components on this board is less than 55ºC. The results were measured 60 minutes after startup using actual LED load.

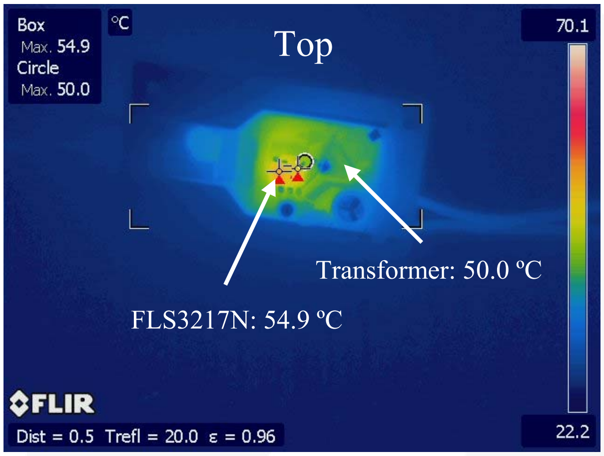

Figure 28. Board Temperature Top; V_{IN} [90V_{AC}], V_{OUT} [24V], I_{OUT} [270mA]

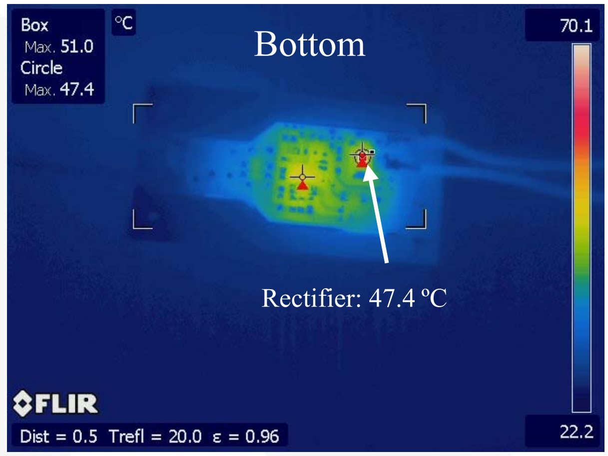

Figure 29. Board Temperature Bottom; V_{IN} [90V_{AC}], V_{OUT} [24V], I_{OUT} [270mA]

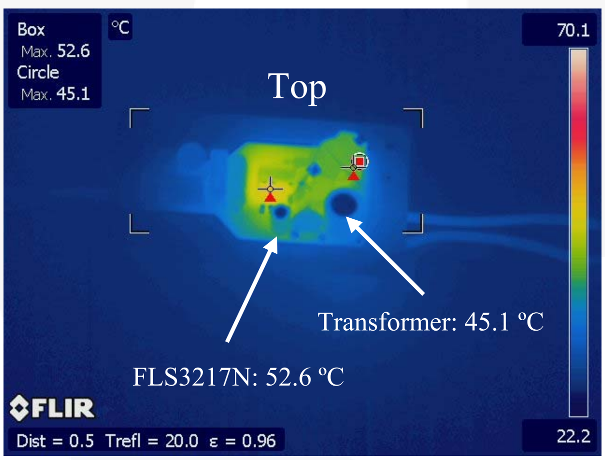

Figure 30. Board Temperature Top; V_{IN} [265V_{AC}], V_{OUT} [24V], I_{OUT} [270mA]

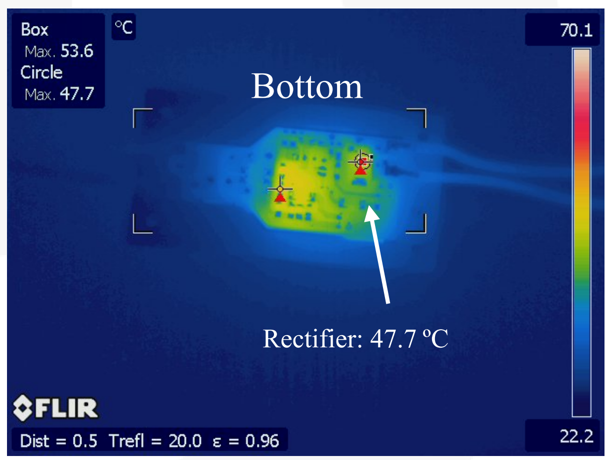

Figure 31. Board Temperature Bottom, V_{IN} [265V_{AC}], V_{OUT} [24V], I_{OUT} [270mA]

3.8. Electromagnetic Interference (EMI)

The all measurement was conducted in observance of EN55022 criteria. The results were measured 60 minutes after startup by using actual LED load.

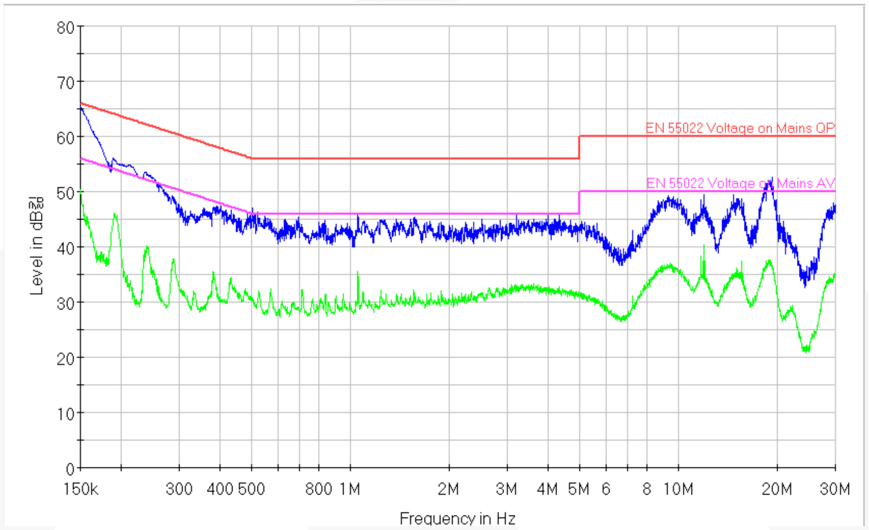

Figure 32. V_{IN}=110V_{AC}, V_{OUT} [24V], I_{OUT} [270mA]

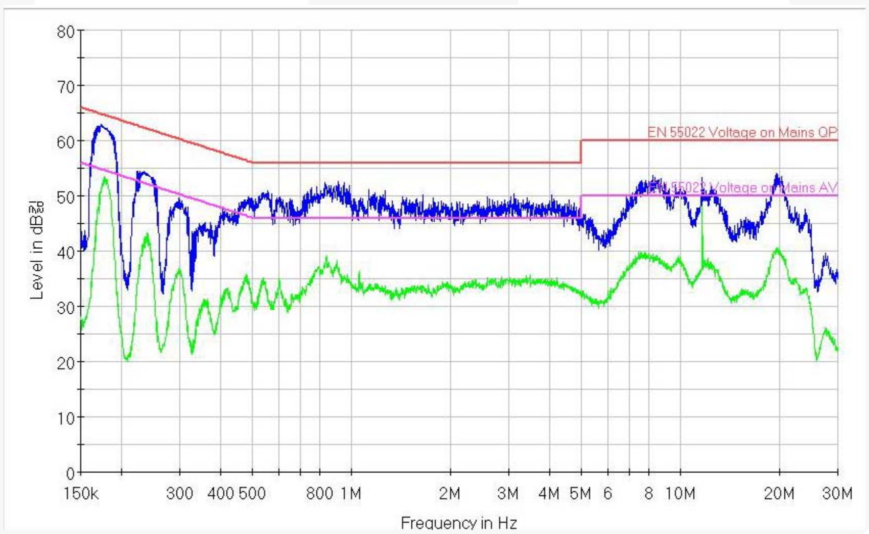

Figure 33. V_{IN}=220V_{AC}, V_{OUT} [24V], I_{OUT} [270mA]

4. Revision History

Rev.	Date	Description
1.0.0	June 2012	Initial Release