User Guide for

FEBFL7733A_L53U021A

High PF and Low THD Buck-Boost LED Driver for 21 W Tube-Type LED Lamp

Featured Fairchild Product:

FL7733A

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 FL7733A. It should be used in conjunction with the FL7733A 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 an universal AC input voltage LED driver designed with buck-boost converter using the FL7733A Primary-Side Regulation (PSR) single-stage controller. The input voltage range is 90 V_{RMS} ~ 277 V_{RMS} and there is one DC output with a constant current of 300 mA at 70 V. This document contains a general description of the FL7733A, the power supply solution specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description of FL7733A

The FL7733A is an active Power Factor Correction (PFC) controller for use in single-stage flyback topology or buck-boost topology. Primary-side regulation and single-stage topology minimize cost by reducing external components such as the input bulk capacitor and secondary side feedback circuitry. To improve Power Factor (PF) 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 provides accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by the output voltage to guarantee Discontinuous Current Mode (DCM) operation, resulting in high efficiency and simple designs. The FL7733A also provides open-LED, short-LED, and over-temperature protection functions.

1.2. Controller Features

High Performance

- < ±3% Total Constant Current Tolerance Over All Conditions
  < ±1% Over Universal Line Voltage Variation
  < ±1% from 50% to 100% Load Voltage Variation
  < ±1% with ±20% Magnetizing Inductance Variation
- Primary-Side Regulation (PSR) Control for Cost-Effective Solution without Requiring Input Bulk Capacitor and Secondary Feedback Circuitry
- Application Input Voltage Range: 80 V_{AC} - 308 V_{AC}
- High PF and Low THD Over Universal Line Input Range
- Fast <200 ms Startup (at 90 V_{AC}) using Internal High-Voltage Startup with VDD Regulation
- Adaptive Feedback Loop Control for Startup without Overshoot

High Reliability

- LED Short / Open Protection
- Output Diode Short Protection
- Sensing Resistor Short / Open Protection
- V_{DD} Over-Voltage Protection (OVP)
- V_{DD} Under-Voltage Lockout (UVLO)
- Over-Temperature Protection (OTP)
- All Protections by Auto Restart
- Cycle-by-Cycle Current Limit
- Application Voltage Range: 80 V_{AC} ~ 308 V_{AC}

1.3. Controller Internal Block Diagram

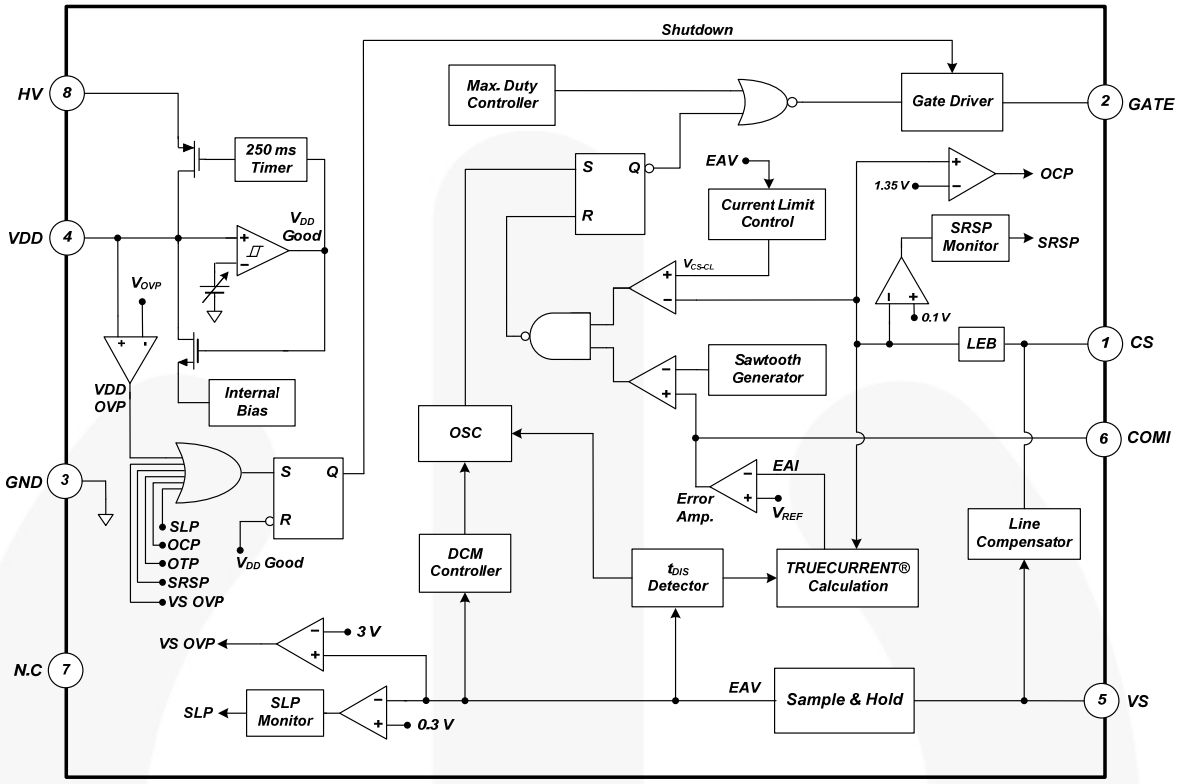

Figure 1. Block Diagram of the FL7733A

2. General 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 AC Line Input Voltage
		$V_{IN.MAX}$	277 V	Maximum AC Line Input Voltage
		$V_{IN.NOMINAL}$	120 V / 230 V	Nominal AC Line Input Voltage
	Frequency	f_{IN}	60 Hz / 50 Hz	AC Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	35 V	Minimum Output Voltage
		$V_{OUT.MAX}$	80 V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	70 V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	300 mA	Nominal Output Current
		Max. CC Tolerance	±0.85%	Line Input Voltage Change: 90 ~ 277 V_{AC}
			±0.68%	Output Voltage Change: 35 ~ 80 V
Efficiency		Eff_{90VAC}	89.72%	Efficiency at 90 V_{AC} Input Voltage
		Eff_{120VAC}	91.63%	Efficiency at 120 V_{AC} Input Voltage
		Eff_{140VAC}	92.28%	Efficiency at 140 V_{AC} Input Voltage
		Eff_{180VAC}	92.97%	Efficiency at 180 V_{AC} Input Voltage
		Eff_{230VAC}	93.24%	Efficiency at 230 V_{AC} Input Voltage
		Eff_{277VAC}	93.20%	Efficiency at 277 V_{AC} Input Voltage
PF/THD		$PF / THD_{90\ VAC}$	0.996 / 8.31%	PF / THD at 90 V_{AC} Input Voltage
		$PF / THD_{120\ VAC}$	0.997 / 5.87%	PF / THD at 120 V_{AC} Input Voltage
		$PF / THD_{140\ VAC}$	0.996 / 4.54%	PF / THD at 140 V_{AC} Input Voltage
		$PF / THD_{180\ VAC}$	0.993 / 4.64%	PF / THD at 180 V_{AC} Input Voltage
		$PF / THD_{230\ VAC}$	0.984 / 6.30%	PF / THD at 230 V_{AC} Input Voltage
		$PF / THD_{277\ VAC}$	0.970 / 8.22%	PF / THD at 277 V_{AC} Input Voltage
Max. Temperature Open-Frame (T_A = 25ºC)	**Bride Diode**	$T_{B\text{-}Diode}$	49.8°C	Bridge Diode Temperature
	FL7733A	$T_{FL7733A}$	53.6°C	FL7733A Temperature
	MOSFET	T_{MOSFET}	65.2°C	Main MOSFET Temperature
	Rectifier	$T_{Rectifier}$	65.8°C	Buck Boost Diode Temperature
	Transformer	T_{TRANS}	53.9°C	Transformer Temperature

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

3. Evaluation Board

Dimensions: 284 (L) × 17 (W) × 12 (H) [mm]

Figure 2. Top / Bottom of Evaluation Board

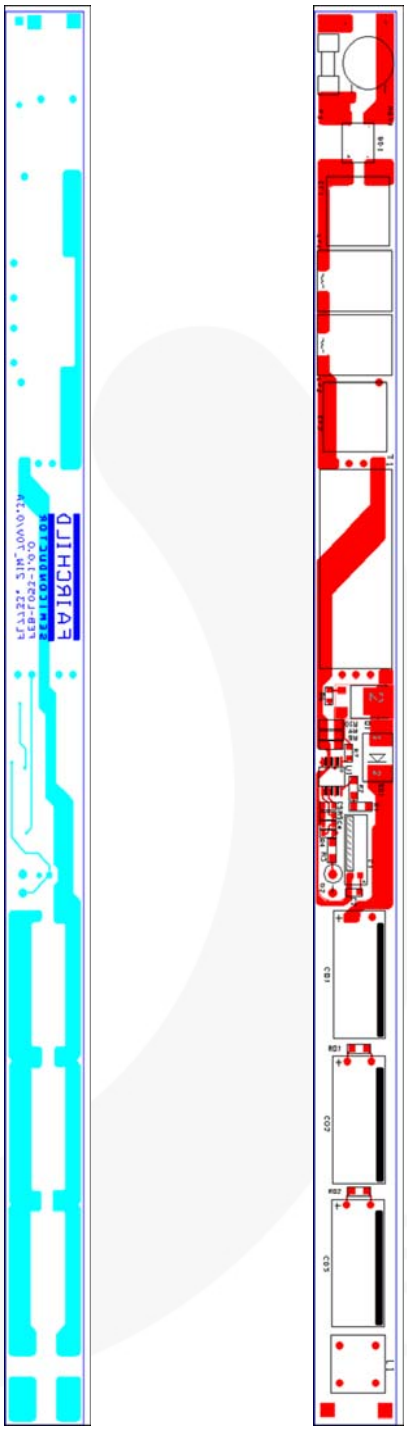

Figure 3. PCB Pattern Top / Bottom of Evaluation Board

4. Schematic

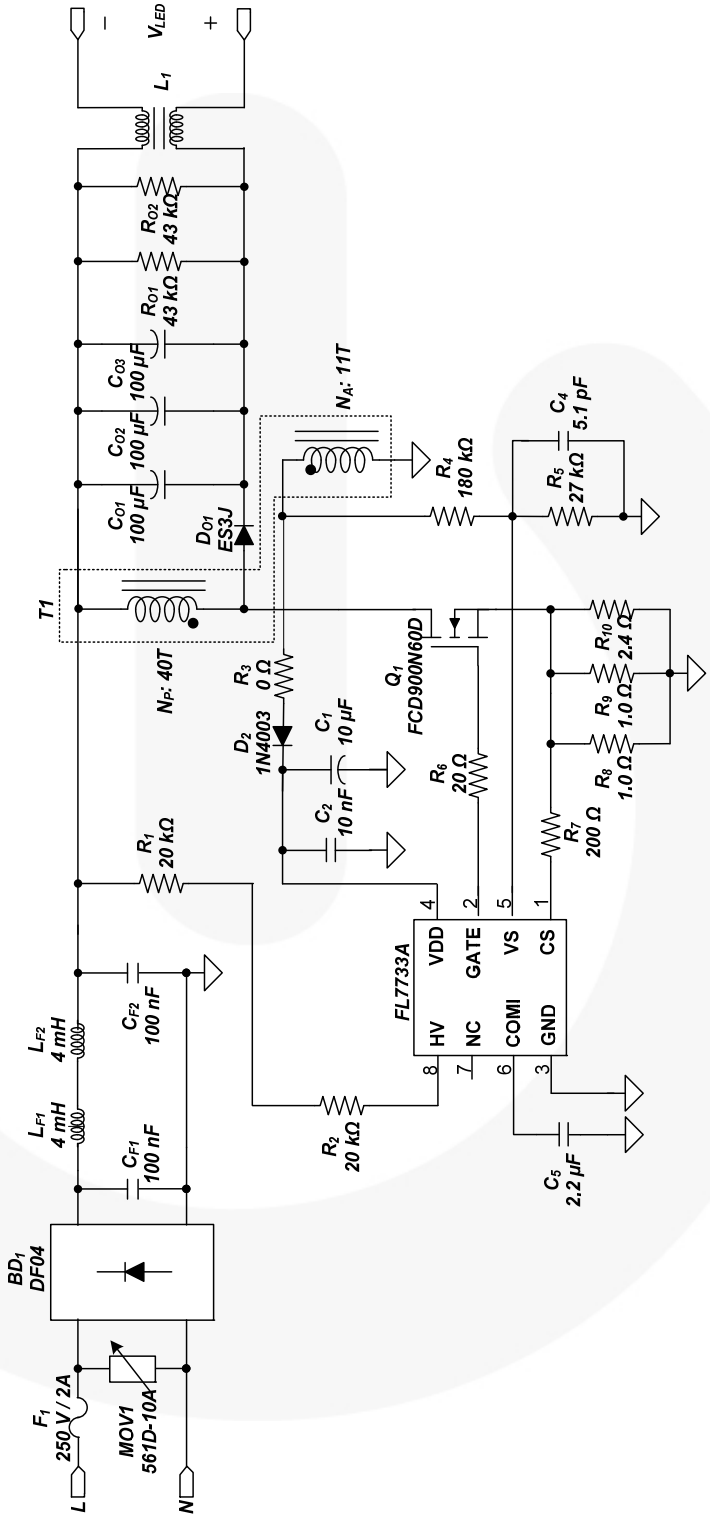

Figure 4. Evaluation Board Schematic

5. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	BD1	DF06S	1	1.5 A / 600 V Bridge Diode	Fairchild Semiconductor
2	CF1, CF2	MPE 400V104K	2	100 nF / 400 V MPE Film Capacitor	Sungho
3	C1	KMG 10 µF / 35V	1	10 µF / 35 V Electrolytic Capacitor	Samyoung
4	C2	C0805C104K5RACTU	1	100 nF / 50 V SMD Capacitor 0805	Kemet
5	C4	C0805C519C3GACTU	1	5.1 pF / 25 V, SMD Capacitor 0805	Kemet
6	C5	C0805C225K4RACTU	1	2.2 µF / 16 V SMD Capacitor 0805	Kemet
7	Co1, Co2, Co3	KMG 100 µF / 100 V	3	100 µF / 100 V Electrolytic Capacitor	Samyoung
8	D2	1N4003	1	200 V / 1 A, General Purpose Rectifier	Fairchild Semiconductor
9	Do1	ES3J	1	600 V / 3 A, Fast Rectifier	Fairchild Semiconductor
10	F1	0672002.MXE	1	2 A / 250 V, Fuse	Littelfuse
11	LF1, LF2	R10402KT00	2	4 mH Inductor, 10Ø	Hanamelec
12	L1	LF10S-501-2A	1	500 µH Common Choke	Hanamelec
13	MOV1	SVC 561D-10A	1	Metal Oxide Varistor	Samwha
14	Q1	FCD900N60Z	1	4.5 A / 600 V Main MOSFET	Fairchild Semiconductor
15	R1, R2	RC1206JR-0720KL	2	20 kΩ SMD Resistor 1206	Yageo
16	R3	RC1206JR-070RL	1	0 Ω SMD Resistor 1206	Yageo
17	R4	RC0805FR-07150RL	1	180 kΩ SMD Resistor 0805	Yageo
18	R5	RC0805FR-0724RL	1	27 kΩ SMD Resistor 0805	Yageo
19	R6	RC0805JR-0720RL	1	20 Ω SMD Resistor 0805	Yageo
20	R7	RC0805JR-07200RL	1	200 Ω SMD Resistor 0805	Yageo
21	R8, R9	RC1206JR-071R0L	2	1.0 Ω SMD Resistor 1206	Yageo
22	R10	RC1206JR-072R4L	1	2.4 Ω SMD Resistor 1206	Yageo
23	Ro1, Ro2	RC1206JR-0743kL	2	43 kΩ SMD Resistor 1206	Yageo
24	T1	EEW1328	1	Transformer, 450 µH	Sejin-Electronics
25	U1	FL7733AMX	1	Single Stage PSR Controller	Fairchild Semiconductor

6. Transformer Design

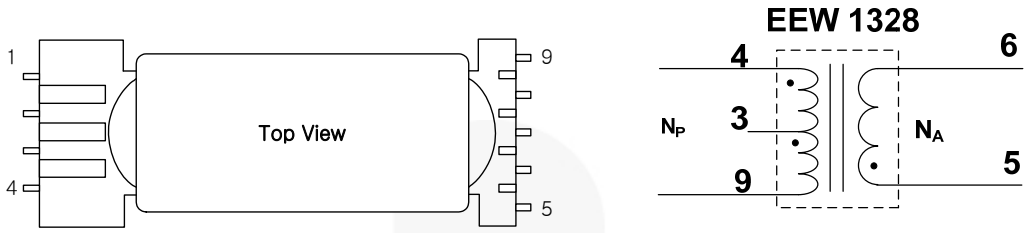

Figure 5. Transformer Bobbin Structure and Pin Configuration

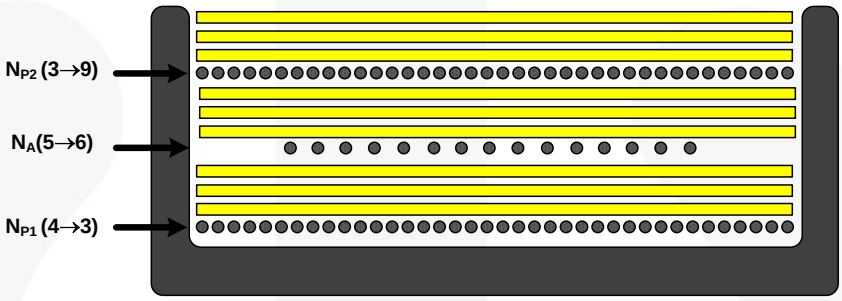

Figure 6. Transformer Winding Structure

Table 2. Winding Specifications

No	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	4→ 3	0.33Ø	22 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	Na	5→ 6	0.25Ø [TIW]	11 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3 Layer				
5	N_{P2}	3→9	0.33Ø	18 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Spec.	Remark
Inductance	4–9	450 µH ± 10%	60 kHz, 1 V
Leakage		Max. 5 µH	60 kHz, 1 V Short All Output Pins

7. Performance of Evaluation Board

7.1. Test Condition & Equipments

Ambient Temperature	**T_A = 25°C**
Test Equipment	AC Power Source: PCR500L by Kikusui Power Analyzer: PZ4000 by YOKOGAWA Oscilloscope: WaveRunner 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Therma CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03(3W) by Everlight

7.2. Startup

Figure 7 and Figure 8 show the overall startup performance at rated output load. The output current of buck boost converter starts flowing after about 0.2 s and 0.13 s for input voltage 90 V_{AC} and 277 V_{AC} condition when the AC input power switch turns on; CH1: V_{DD} (10 V / div), CH2: V_{IN} (100 V / div), CH3: V_{OUT} (50 V / div), CH4: I_{OUT} (200 mA / div), Time Scale: (100 ms / div), Load: 4 parallel * 24 series-LEDs.

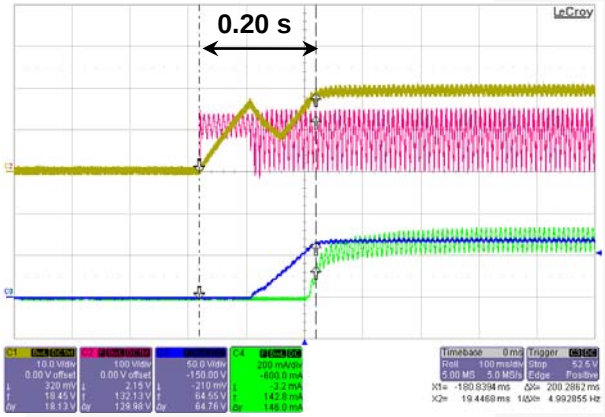

Figure 7. V_{IN} = 90 V_{AC} / 60 Hz

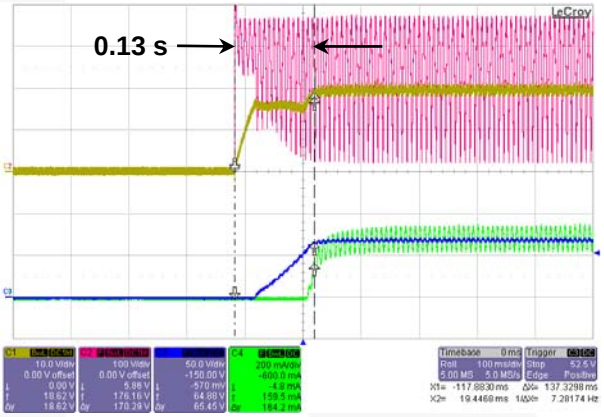

Figure 8. V_{IN} = 277 V_{AC} / 50 Hz

7.3. Operation Waveforms

Figure 9 to Figure 12 show AC input and output waveforms at rated output load. CH1: I_{IN} (500 mA / div), CH2: V_{IN} (100 V / div), CH3: V_{OUT} (20 V / div), CH4: I_{OUT} (200 mA / div), Time Scale: (5 ms / div), Load: 4 parallel * 24 series-LEDs.

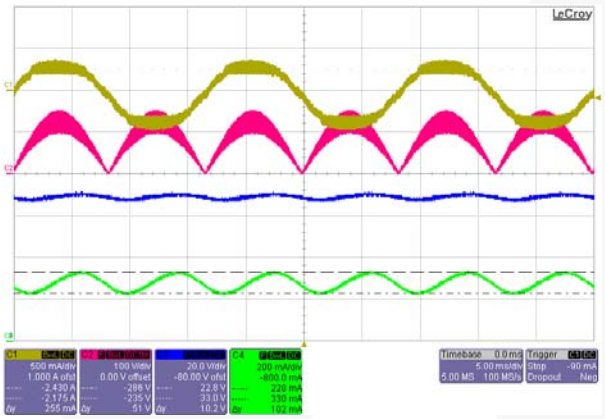

Figure 9. V_{IN} = 90 V_{AC} / 60 Hz

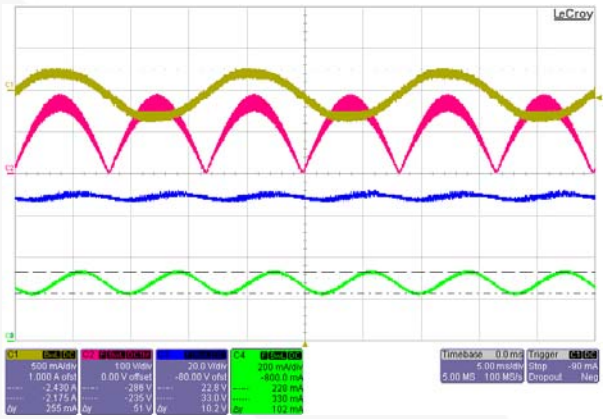

Figure 10. V_{IN} = 120 V_{AC} / 60 Hz

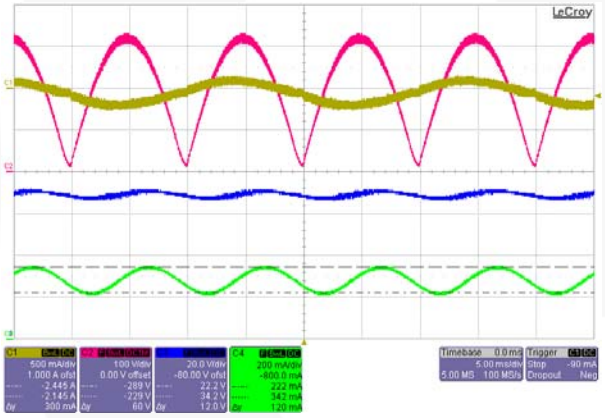

Figure 11. V_{IN} = 230 V_{AC} / 50 Hz

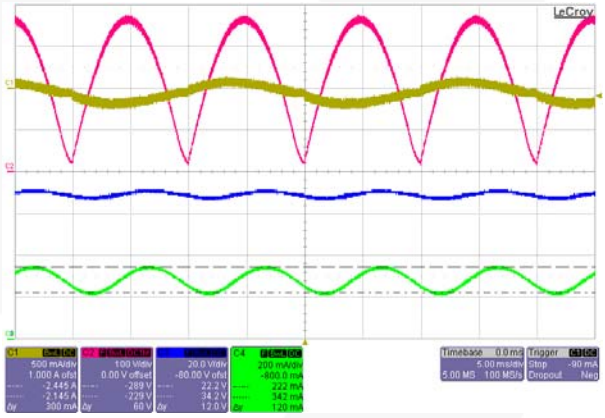

Figure 12. V_{IN} = 277 V_{AC} / 50 Hz

Figure 13 to Figure 16 show key waveforms of single stage buck boost converter operation for line voltages at rated output load. CH1: I_{DS} (1.00 A / div), CH2: $V_{Buck/Boost-Diode}$ (200 V / div), CH3: V_{DS} (200 V / div), CH4: $I_{Buck/Boost-Diode}$ (1.00 A / div), Load: 4 parallel * 24 series-LEDs.

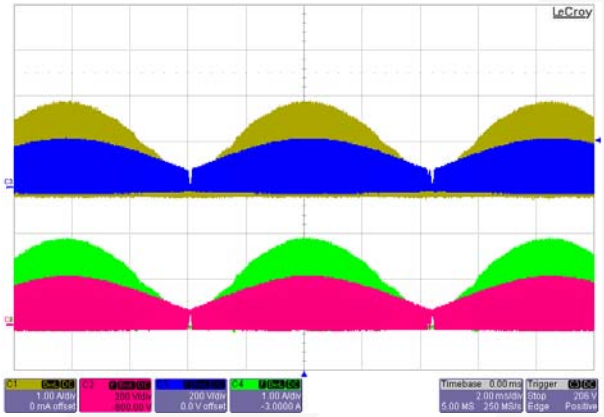

Figure 13. V_{IN} = 90 V_{AC} / 60 Hz, [2.0 ms / div]

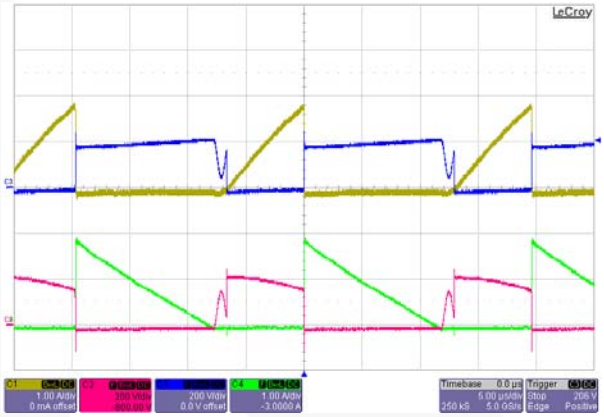

Figure 14. V_{IN} = 90 V_{AC} / 60 Hz, [5.0 µs / div]

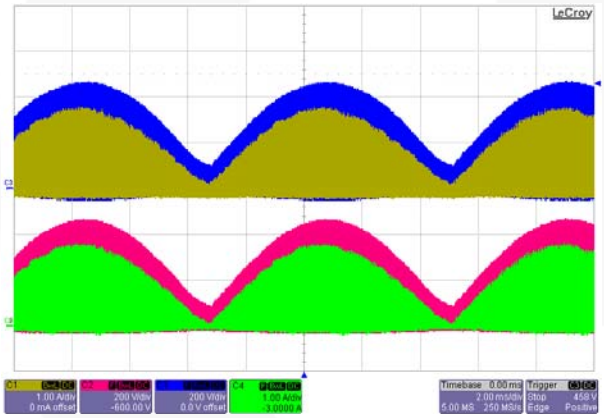

Figure 15. V_{IN} = 277 V_{AC} / 60 Hz, [2.0 ms / div]

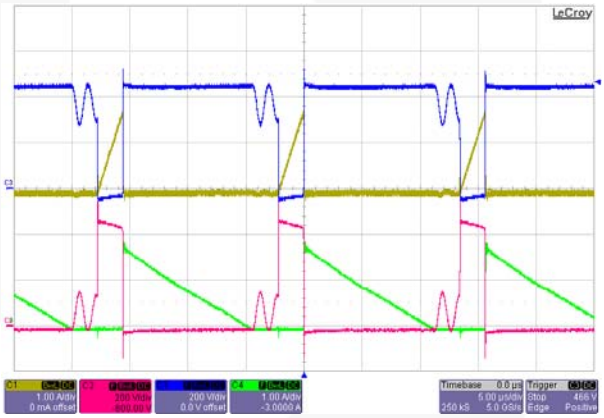

Figure 16. V_{IN} = 277 V_{AC} / 60 Hz, [5.0 µs / div]

7.4. Constant-Current Regulation

Constant-current deviation in the wide output voltage range from 35 V to 80 V is less than ±0.68% at each line input voltage. Line regulation is less than ±0.85%. The results were measured using E-load [CR Mode].

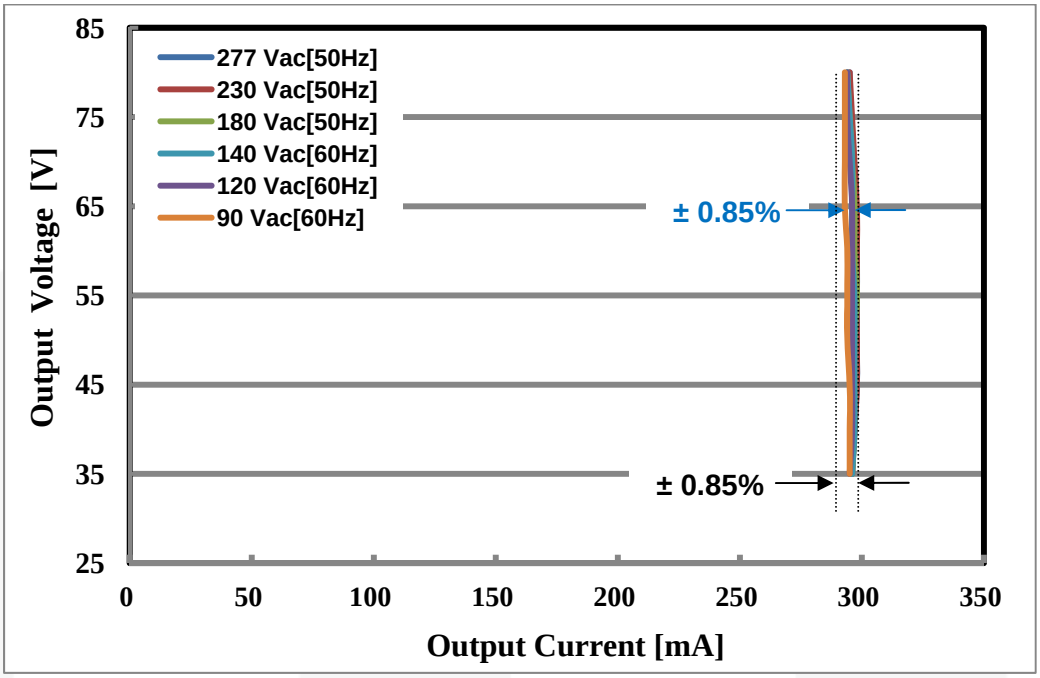

Figure 17. Constant-Current Regulation – Measured by E-Load

Table 4. Constant-Current Regulation by Output Voltage Change (35 V ~ 80 V)

Input Voltage	Min. Current	Max. Current	Tolerance
90 V_{AC} [60Hz]	293 mA	295 mA	±0.51%
120 V_{AC} [60Hz]	294 mA	296 mA	±0.51%
140 V_{AC} [60Hz]	294 mA	297 mA	±0.68%
180 V_{AC} [50Hz]	294 mA	298 mA	±0.51%
230 V_{AC} [50Hz]	295 mA	298 mA	±0.34%
277 V_{AC} [50Hz]	295 mA	298 mA	±0.34%

Table 5. Constant-Current Regulation by Line Voltage Change (90 ~ 277 V_{AC})

Output Voltage	90 V_{AC} [60 Hz]	120 V_{AC} [60 Hz]	140 V_{AC} [60 Hz]	180 V_{AC} [50 Hz]	230 V_{AC} [50 Hz]	277 V_{AC} [50 Hz]	Tolerance
75 V	293 mA	294 mA	296 mA	295 mA	296 mA	295 mA	±0.51%
70 V	293 mA	295 mA	296 mA	296 mA	297 mA	296 mA	±0.68%
65 V	293 mA	296 mA	296 mA	297 mA	298 mA	297 mA	±0.85%

7.5. Short / Open-LED Protections

Figure 18 to Figure 21 show waveforms for protections operated when the LED is shorted and recovered. Once the LED short occurs, SCP is triggered and VDD starts hiccup mode with JFET regulation times [250 ms]. This lasts until the fault condition is eliminated. Systems can restart automatically when returned to normal condition. ; CH1: V_{DD} (10 V / div), CH2: V_{IN} (100 V / div), CH3: V_{GATE} (10 V / div), I_{OUT} (200 mA / div), Time Scale: (0.5 s / div).

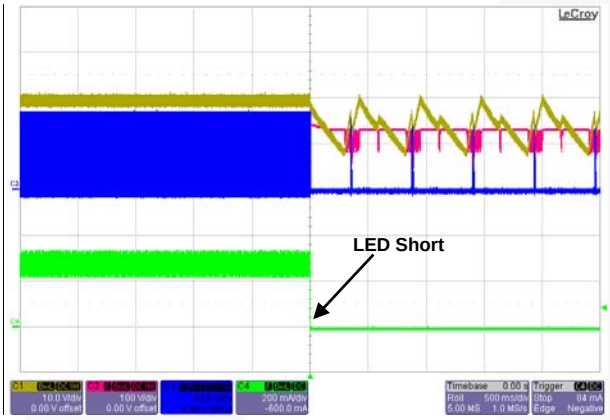

Figure 18. V_{IN} = 90 V_{AC} / 60 Hz, [LED Short]

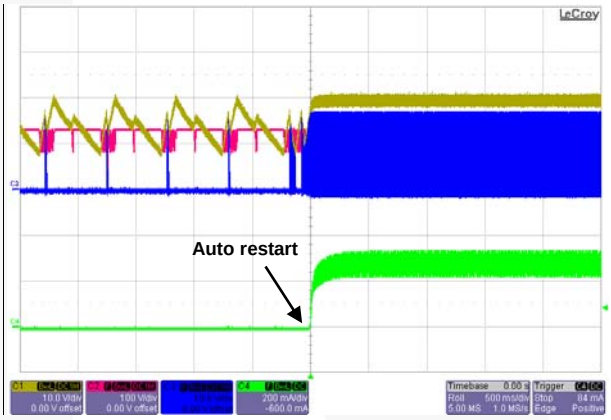

Figure 19. V_{IN} = 90 V_{AC} / 60 Hz, [LED Restore]

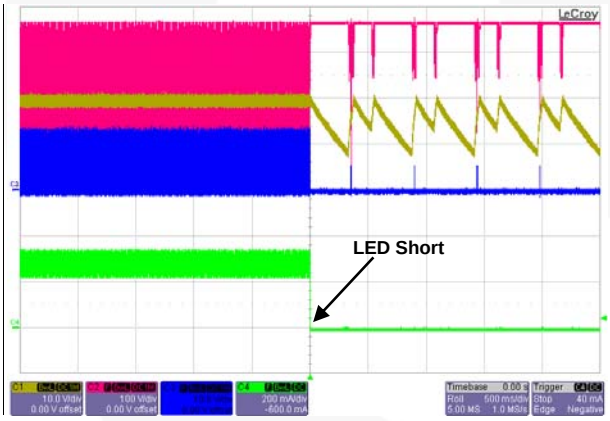

Figure 20. V_{IN} = 277 V_{AC} / 50 Hz, [LED Short]

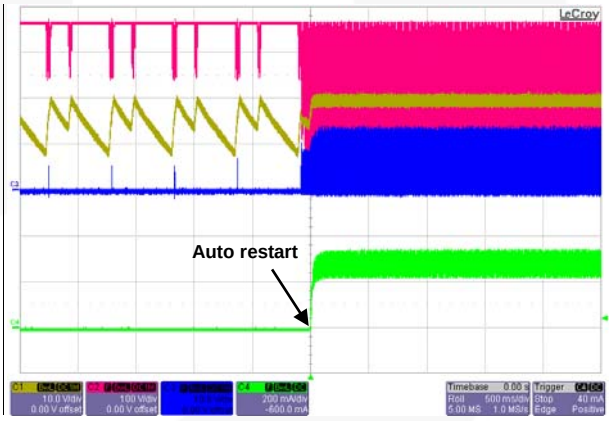

Figure 21. V_{IN} = 277 V_{AC} / 50 Hz, [LED Restore]

Figure 22 to Figure 25 show waveforms for protections operated when the LED is opened and recovered. Once the LED has opened, VS OVP or VDD OVP are triggered and VDD starts hiccup mode with JFET regulation times [250 ms]. This lasts until the fault condition is eliminated. Systems can restart automatically when returned to normal condition. CH1: V_{DD} (10 V / div), CH2: V_{IN} (100 V / div), CH3: V_{GATE} (10 V / div), V_{OUT} (50 V / div), Time Scale: (0.5 s / div).

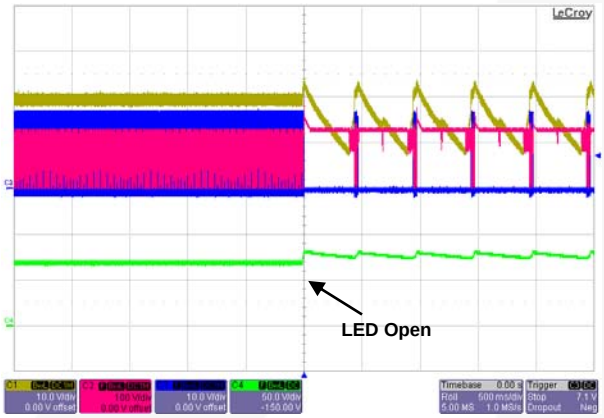

Figure 22. V_{IN} = 90 V_{AC} / 60 Hz, [LED Open]

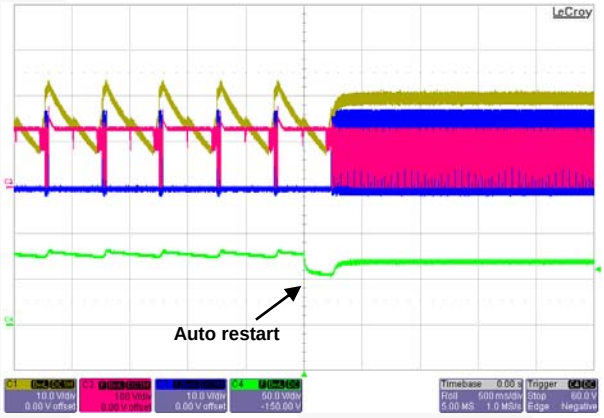

Figure 23. V_{IN} = 90 V_{AC} / 60 Hz, [LED Restore]

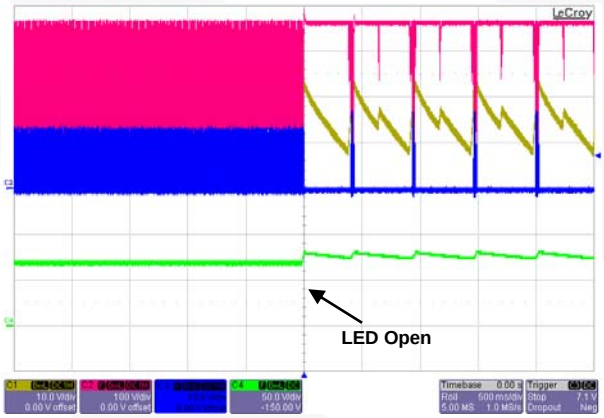

Figure 24. V_{IN} = 277 V_{AC} / 50 Hz, [LED Open]

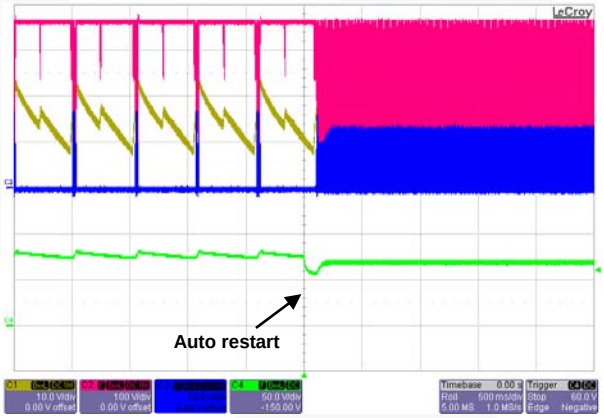

Figure 25. V_{IN} = 277 V_{AC} / 50 Hz, [LED Restore]

Note:

1. When the LED load is re-connected after open-LED condition, the output capacitor is quickly discharged through the LED load and the inrush current by the discharge could destroy the LED load.

7.6. Efficiency

System efficiency is 89.72% ~ 93.24% over input voltages 90 ~ 277 V_{AC}. The results were measured using actual rated LED loads at 30 minutes after startup.

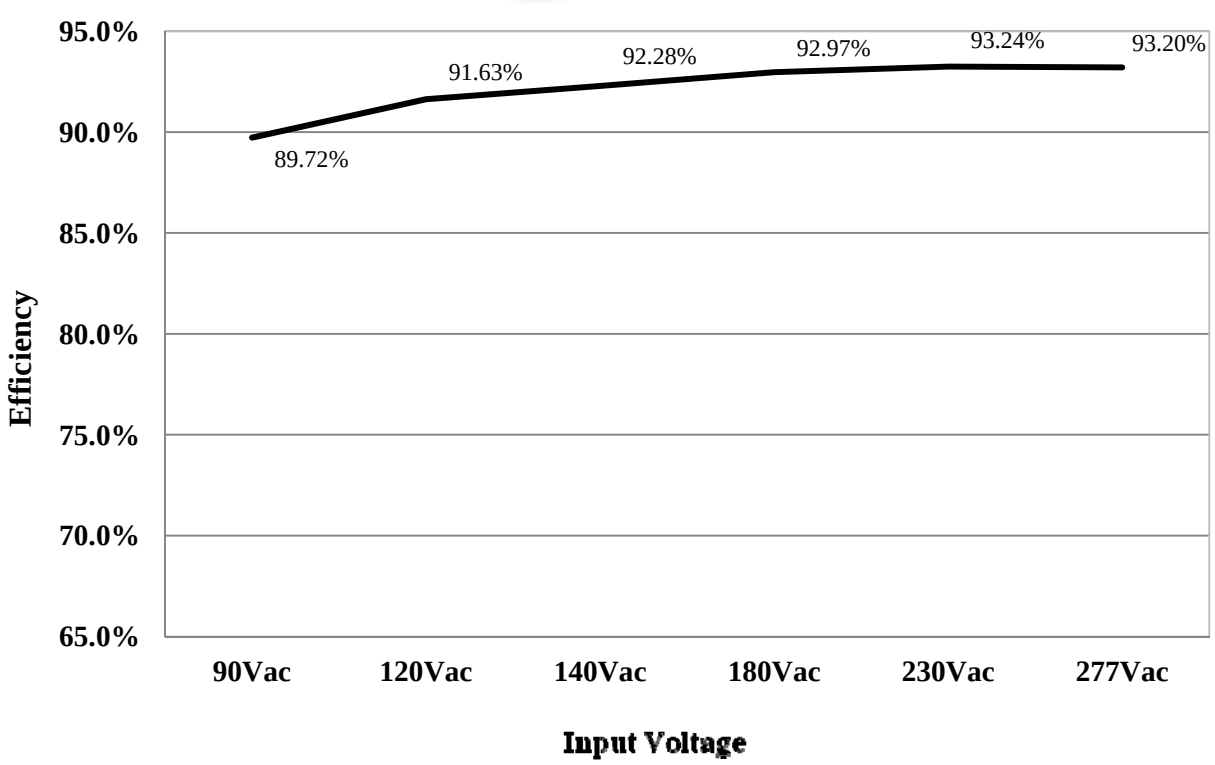

Figure 26. System Efficiency

Table 6. System Efficiency

Input Voltage	Input Power [W]	Output Current [mA]	Output Voltage [V]	Output Power [W]	Efficiency
90 V_{AC} [60 Hz]	22.23	0.284	70.33	19.95	89.72%
120 V_{AC} [60 Hz]	21.86	0.285	70.33	20.03	91.63%
140 V_{AC} [60 Hz]	21.74	0.285	70.32	20.06	92.28%
180 V_{AC} [50 Hz]	21.73	0.287	70.34	20.20	92.97%
230 V_{AC} [50 Hz]	21.76	0.288	70.35	20.29	93.24%
277 V_{AC} [50 Hz]	21.84	0.289	70.36	20.36	93.20%

7.7. Power Factor (PF) & Total Harmonic Distortion (THD)

The FL7733A evaluation board shows excellent PF and THD performance. THD is less than 10%. The results were measured using actual rated LED loads at 10 minutes after startup.

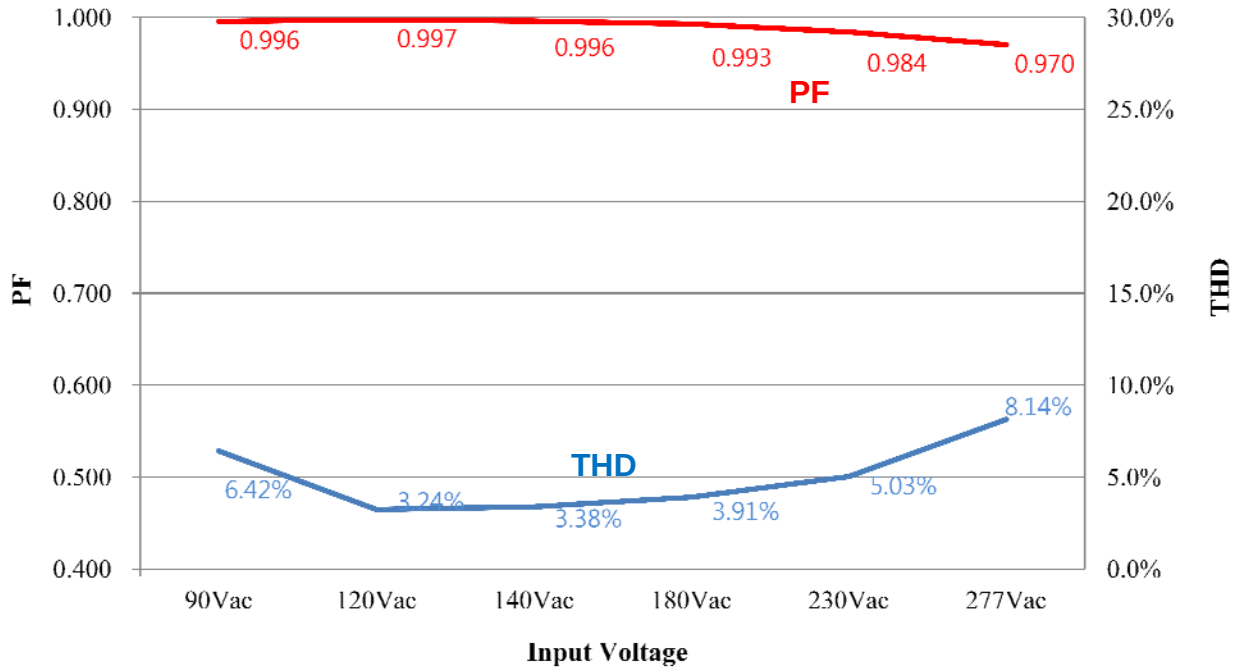

Figure 27. Power Factor & Total Harmonic Distortion

Table 7. Power Factor & Total Harmonic Distortion

Input Voltage	Output Current [mA]	Output Voltage [V]	PF	THD
90 V_{AC} [60 Hz]	0.284	70.33	0.996	8.31%
120 V_{AC} [60 Hz]	0.285	70.33	0.997	5.87%
140 V_{AC} [60 Hz]	0.285	70.32	0.996	4.54%
180 V_{AC} [50 Hz]	0.287	70.34	0.993	4.64%
230 V_{AC} [50 Hz]	0.288	70.35	0.984	6.30%
277 V_{AC} [50 Hz]	0.289	70.36	0.970	8.22%

7.8. Harmonics

Figure 28 to Figure 31 show current harmonics measured using actual rated LED loads.

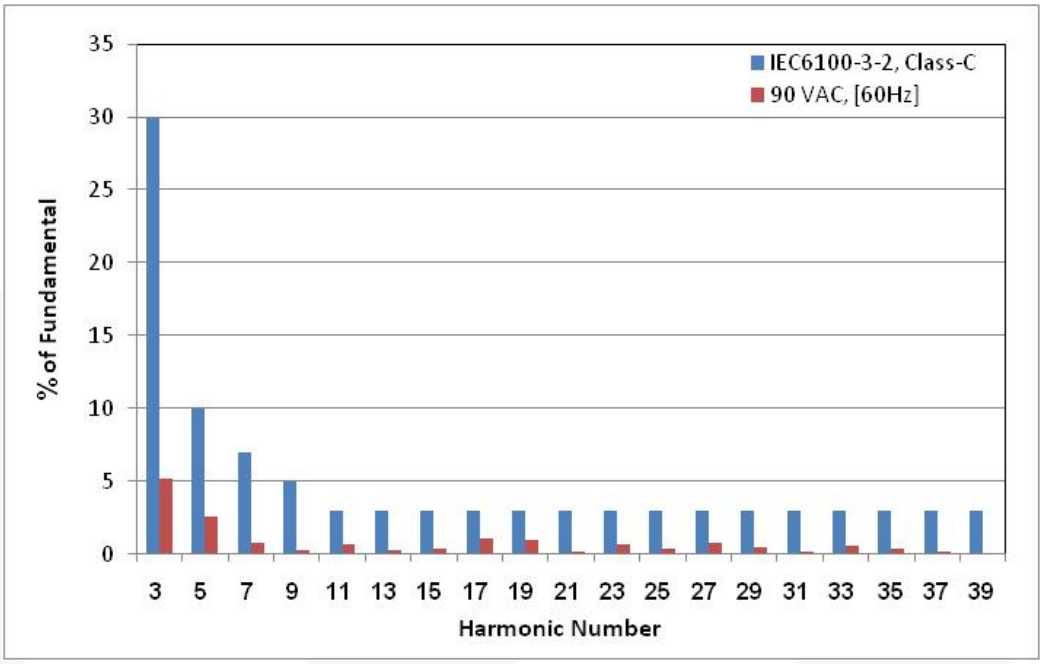

Figure 28. V_{IN} = 90 V_{AC} / 60 Hz

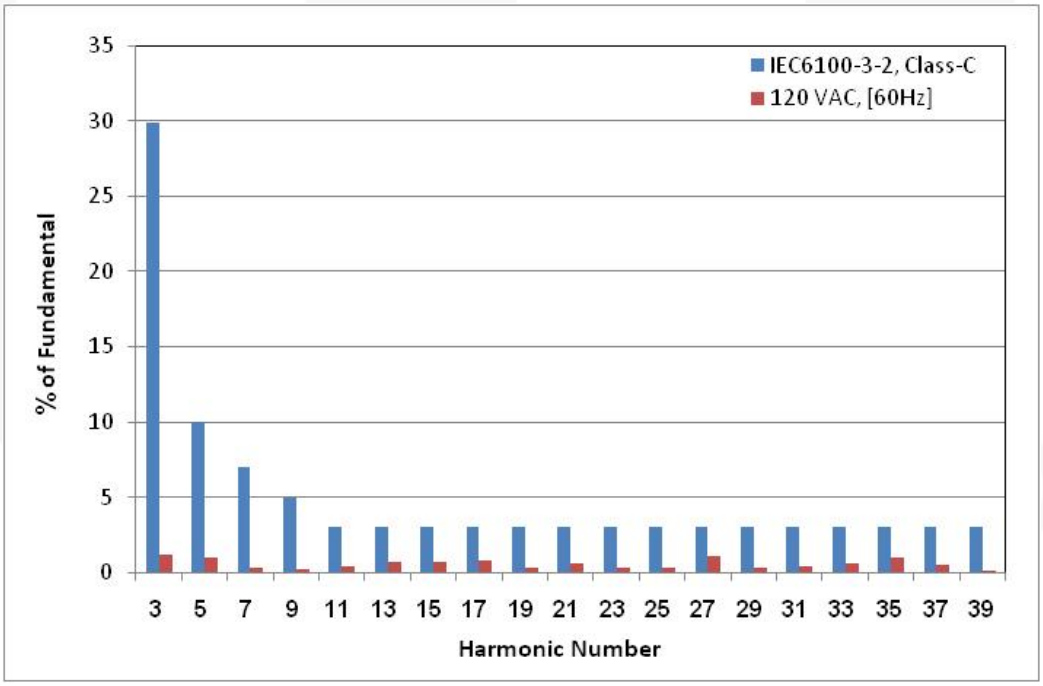

Figure 29. V_{IN} = 120 V_{AC} / 60 Hz

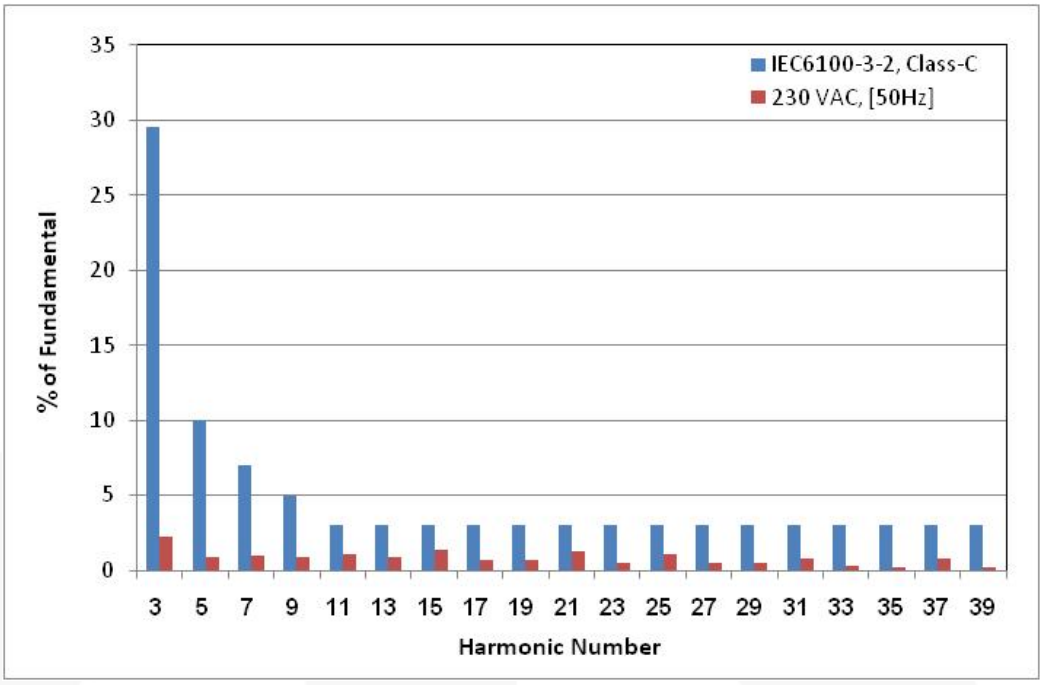

Figure 30. V_{IN} = 230 V_{AC} / 50 Hz

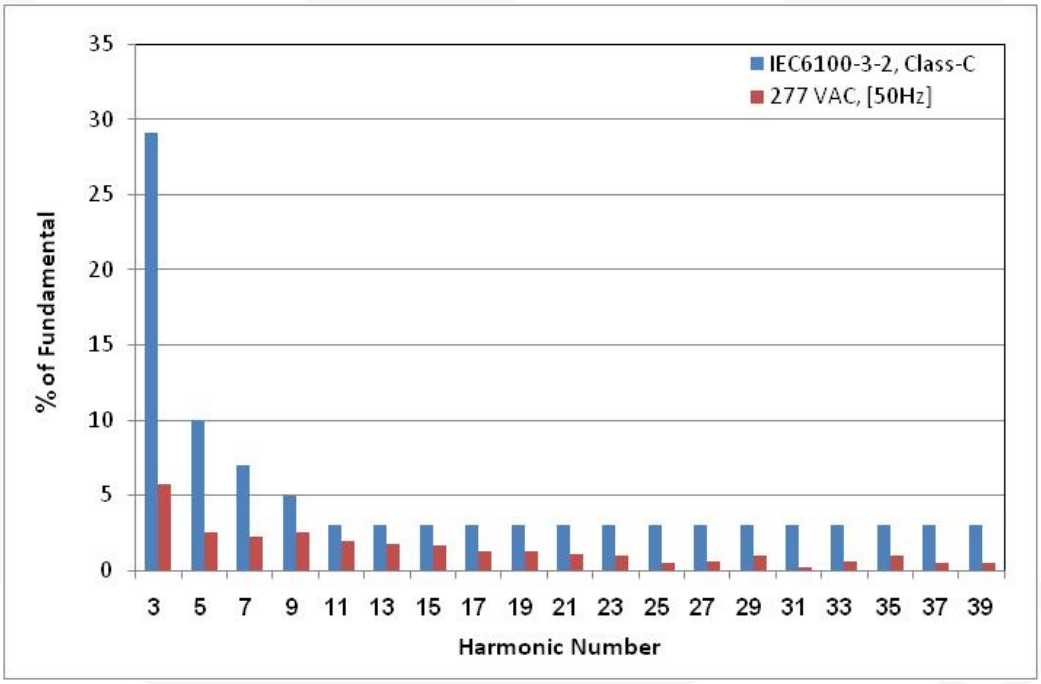

Figure 31. V_{IN} = 277 V_{AC} / 50 Hz

7.9. Operating Temperature

The results were measured using actual rated LED loads 60 minutes after startup.

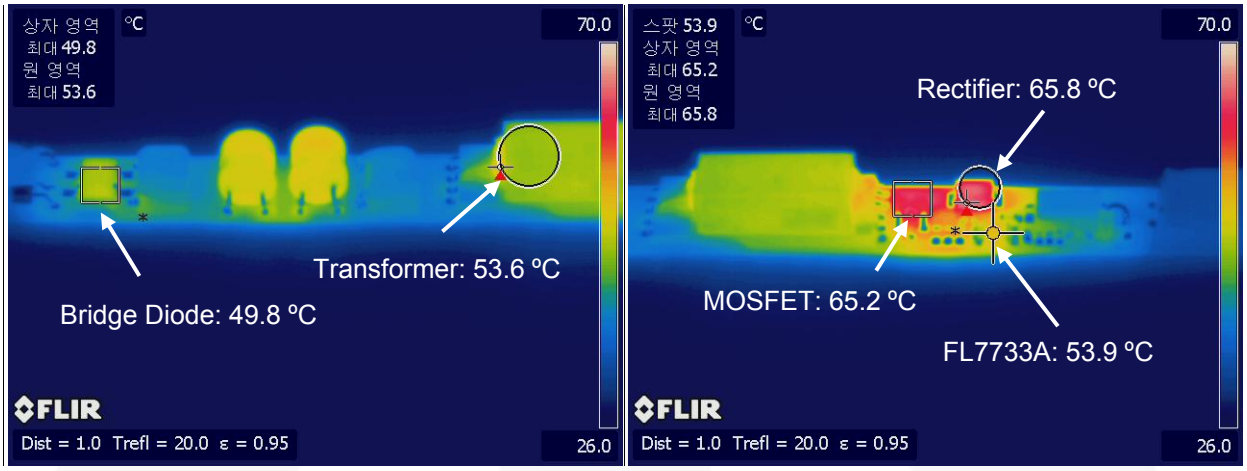

Figure 32. V_{IN} = 90 V_{AC} / 60 Hz

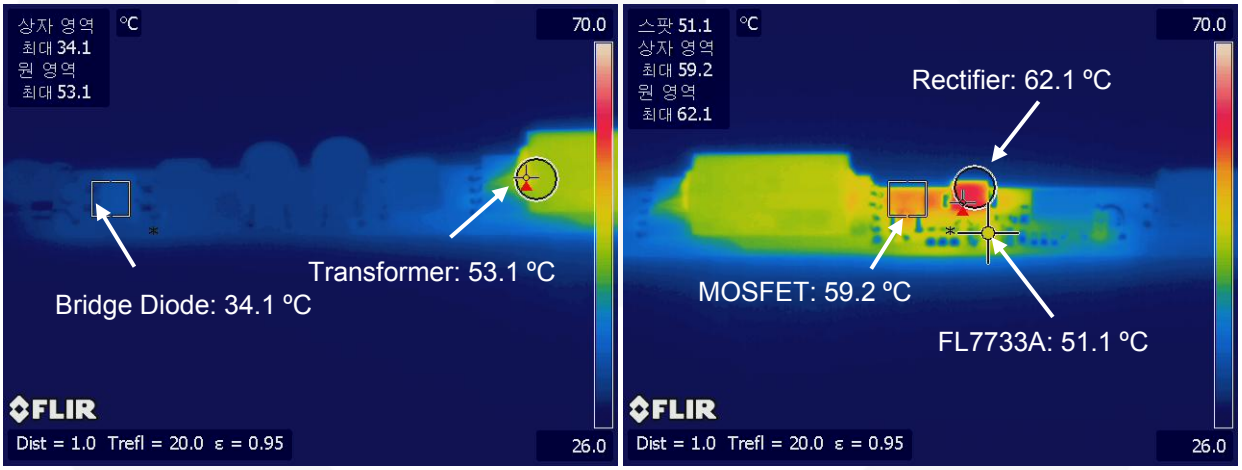

Figure 33. V_{IN} = 277 V_{AC} / 50 Hz

Note:

2. The IC temperature can be improved by the PCB layout.

7.10. Electromagnetic Interference (EMI)

All measurements were conducted in observance of EN55022 criteria.

The results were measured using actual rated LED loads 30 minutes after startup.

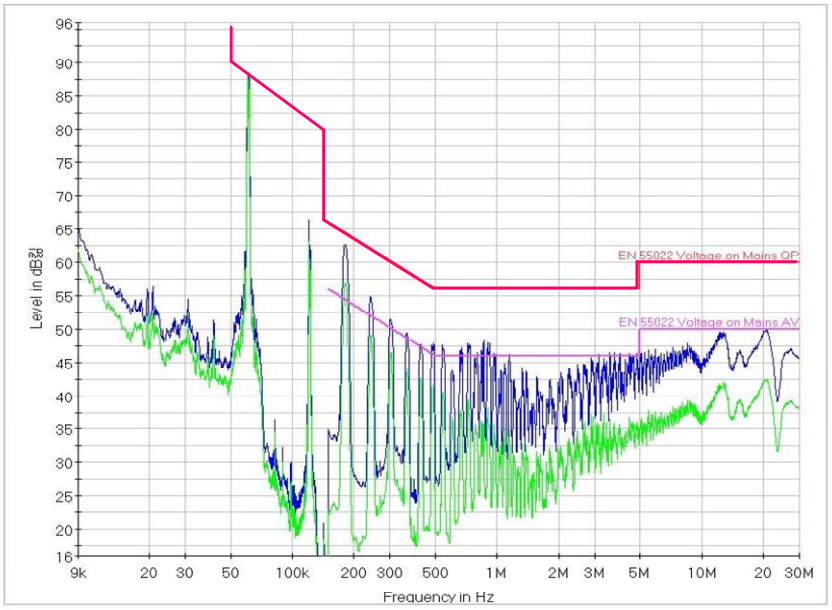

Figure 34. V_{IN} [110 V_{AC}, Neutral]

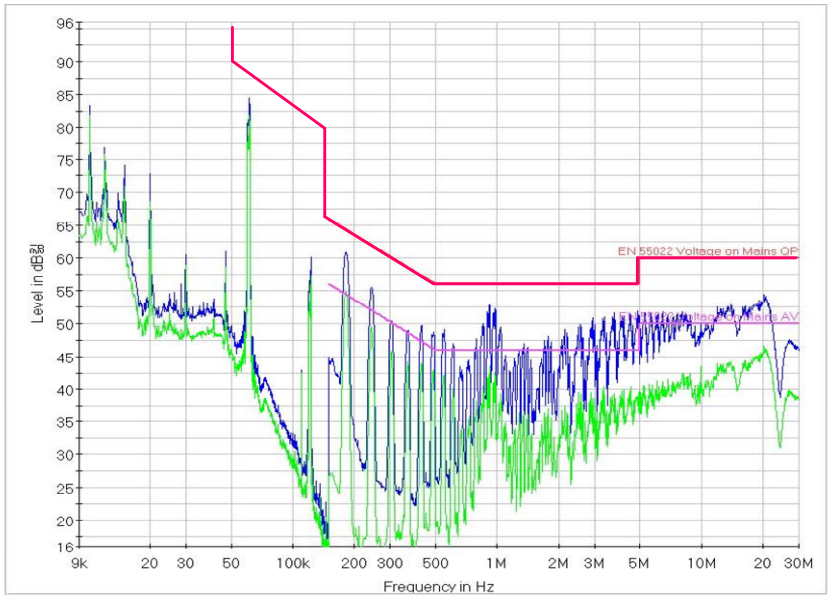

Figure 35. V_{IN} [220 V_{AC}, Live]

8. Revision History

Rev.	Date	Description
1.0	Oct.2014	Initial Release

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