User Guide for

FEBFL7732_L29U021A

21 W T8 LED Lamp at Universal Line Using Buck-Boost

Featured Fairchild Product: FL7732

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[Fairchild Semiconductor.com](http://www.fairchildsemi.com)

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This user guide supports the evaluation kit for the FL7732. It should be used in conjunction with the FL7732 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 T8 LED lamp using the FL7732 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is 90 V_{RMS} – 265 V_{RMS}. There is one DC output with a constant current of 300 mA at 70 V. This document contains a general description of the FL7732, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description

The FL7732 is an active Power Factor Correction (PFC) controller using single-stage flyback or buck-boost topology. Primary-side regulation and single-stage topology reduce external components, such as input bulk capacitor and feedback circuitry, and minimize cost. To improve power factor and Total Harmonic Discharge (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 DCM operation with high efficiency and simple design. The FL7732 provides open-LED, short-LED, and over-temperature protections.

1.2. Features

- Cost-Effective Solution: No Input Bulk Capacitor and Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (CC) Control
- Linear Frequency Control for Better Efficiency and Simpler Design
- Open-LED Protection
- Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection (OTP) with Auto Restart
- Low Startup Current: 20 µA
- Low Operating Current: 5 mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18 V
- SOP-8 Package

1.3. Internal Block Diagram

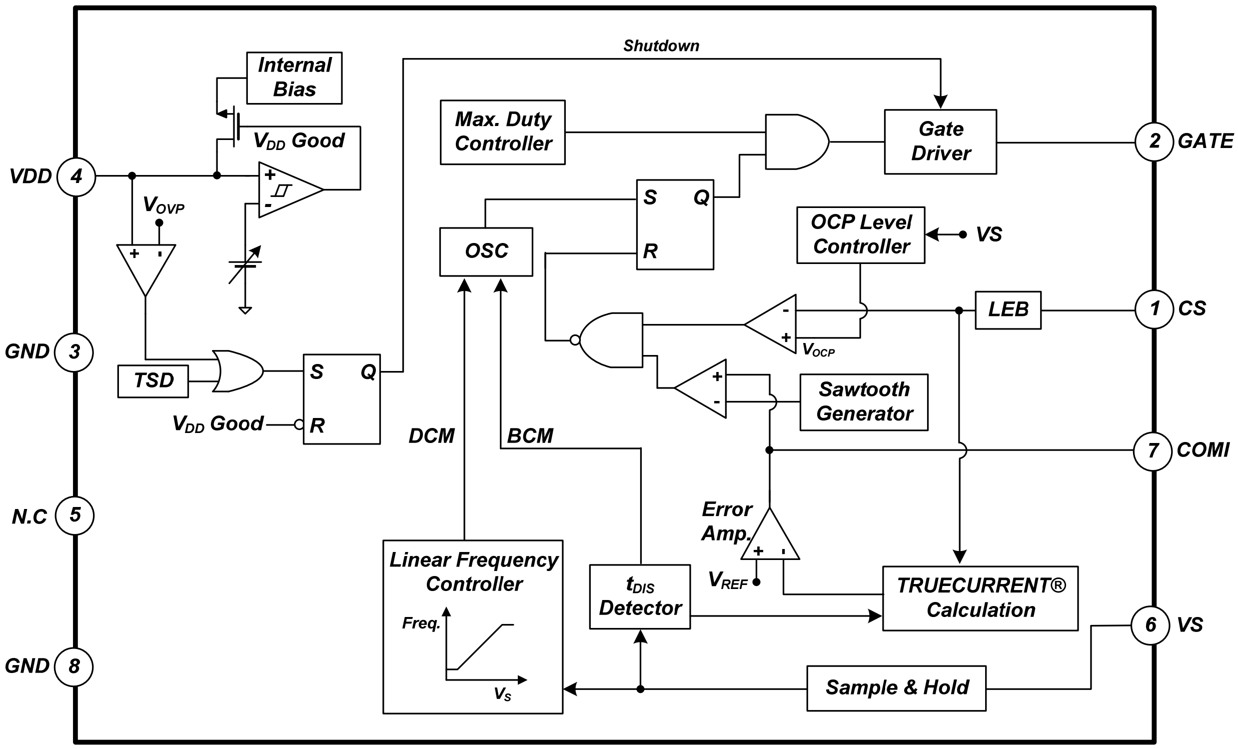

Figure 1. Block Diagram of FL7732

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 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**	$V_{OUT.MIN}$	40 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
		CC Deviation	< ±3.30%	Line Input Voltage Change: 90 V_{AC} ~ 265 V_{AC}
			< ±2.65%	Output Voltage Change: 40 V ~ 80 V
Efficiency		Eff_{90VAC}	90.23%	Efficiency at 90 V_{AC} Line Input Voltage
		Eff_{120VAC}	91.88%	Efficiency at 120 V_{AC} Line Input Voltage
		Eff_{140VAC}	92.40%	Efficiency at 140 V_{AC} Line Input Voltage
		Eff_{180VAC}	92.99%	Efficiency at 180 V_{AC} Line Input Voltage
		Eff_{230VAC}	92.83%	Efficiency at 230 V_{AC} Line Input Voltage
		Eff_{265VAC}	92.42%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF / THD_{90VAC}	0.989 / 12.69%	PF / THD at 90 V_{AC} Line Input Voltage
		PF / THD_{120VAC}	0.992 / 11.14%	PF / THD at 120 V_{AC} Line Input Voltage
		PF / THD_{140VAC}	0.988 / 12.21%	PF / THD at 140 V_{AC} Line Input Voltage
		PF / THD_{180VAC}	0.980 / 15.67%	PF / THD at 180 V_{AC} Line Input Voltage
		PF / THD_{230VAC}	0.964 / 20.48%	PF / THD at 230 V_{AC} Line Input Voltage
		PF / THD_{265VAC}	0.950 / 23.31%	PF / THD at 265 V_{AC} Line Input Voltage
Temperature	**MOSFET**	T_{MOSFET}	55.1°C	Primary MOSFET Temperature
	Output Diode	T_{DIODE}	58.4°C	Secondary Diode Temperature

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

3. Photographs and Printed Circuit Board

Dimensions: 284 (L) × 17 (W) × 10 (H) [mm].

Figure 2. Top / Bottom of Evaluation Board

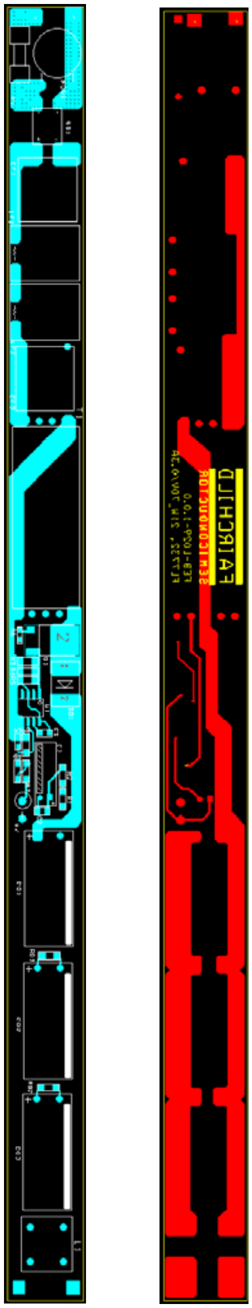

Figure 3. PCB Pattern Top / Bottom of Evaluation Board

4. Schematic

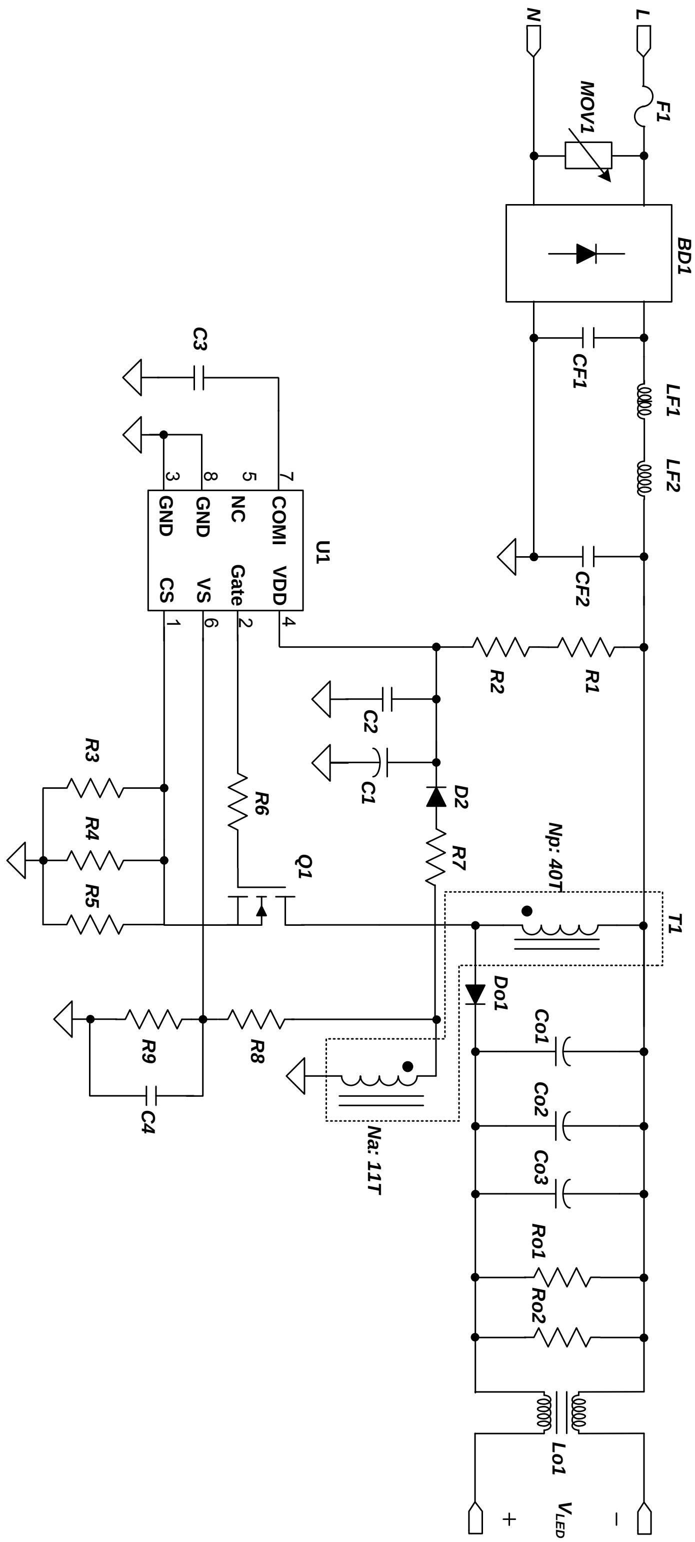

Figure 4. Evaluation Board Schematic

5. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	BD1	DF06S	1	1.5 A / 600 V Bridge Diode	
2	CF1, CF2	MPE 400 V 104 K	2	100 nF / 400 V MPE Film Capacitor	Sungho
3	C1	KMG 22 µF / 35 V	1	22 µF / 35 V Electrolytic Capacitor	Samyoung
4	C2	C0805C104K5RACTU	1	0.1 µF / 50 V SMD Capacitor 2012	Kemet
5	C3	C1206C225K3PACTU	1	2.2 µF / 25 V SMD Capacitor 2012	Kemet
6	C4	C0805C200J3GACTU	1	20 pF / 25 V, SMD Capacitor 2012	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	SS-5-1A	1	1 A / 250 V, Fuse	Littelfuse
11	LF1, LF2	R10402KT00	2	4 mH Inductor, 10Ø	Hanamelec
12	L1	LF10S-501-2A	1	500 µH	Hanamelec
13	MOV1	10D471K	1	VARISTOR 470 V 10MM RADIAL	Bourns Inc.
14	Q1	FCD900N60Z	1	4.5 A / 600 V Main MOSFET	Fairchild Semiconductor
15	R1, R2	RC1206JR-07100KL	2	100 kΩ SMD Resistor 3216	Yageo
16	R3	RC1206JR-071R1L	1	1.1 Ω SMD Resistor 3216	Yageo
17	R4, R5	RC1206FR-071RL	2	1.0 Ω SMD Resistor 3216	Yageo
18	R6	RC0805JR-0720RL	1	20 Ω SMD Resistor 2012	Yageo
19	R7	RC1206JR-070RL	1	0 Ω SMD Resistor 3216	Yageo
20	R8	RC1206JR-07150KL	1	150 kΩ SMD Resistor 3216	Yageo
21	R9	RC1206JR-0724KL	1	24 kΩ SMD Resistor 3216	Yageo
22	Ro1, Ro2	RC1206JR-0743kL	2	43 kΩ SMD Resistor 3216	Yageo
23	T1	EEW1328	1	Transformer, 450 µH	Sejin-electronics
24	U1	FL7732M_F116	1	Main PSR Controller	Fairchild Semiconductor

6. Transformer Design

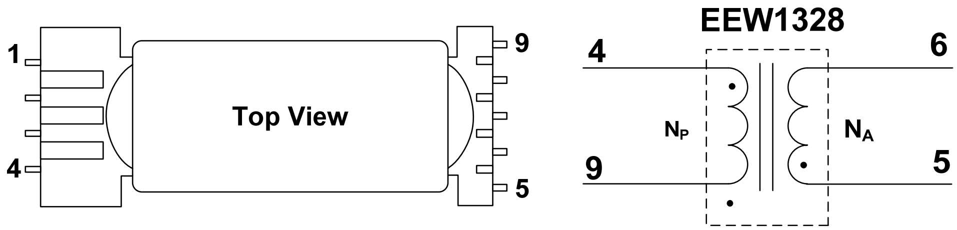

Figure 5. Transformer Bobbin Structure and Pin Configuration

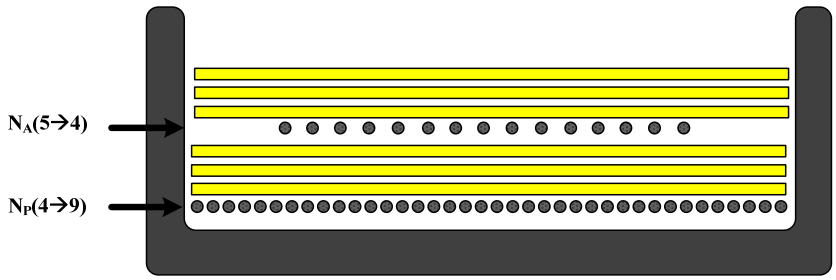

Figure 6. Transformer Winding Structure

Table 2. Winding Specifications

No	Winding	Pin(S → F)	Wire	Turns	Winding Method
1	Np	4→ 9	0.33Ø	40 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				

Table 3. Electrical Characteristics.

	Pin	Specification	Remark
Inductance	4– 9	450 μH ± 10%	60 kHz, 1 V
Leakage		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

Startup time is 0.88 s (V_{IN} = 90 V_{AC}) ~ 0.35 s (V_{IN} = 265 V_{AC}).

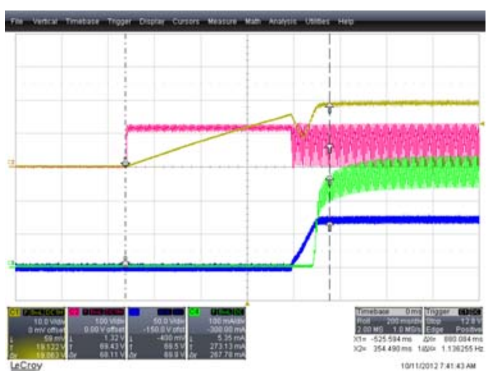

Figure 7. V_{IN} = 90 V_{AC} / 60 Hz, Startup Time at LED (70 V / 300 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

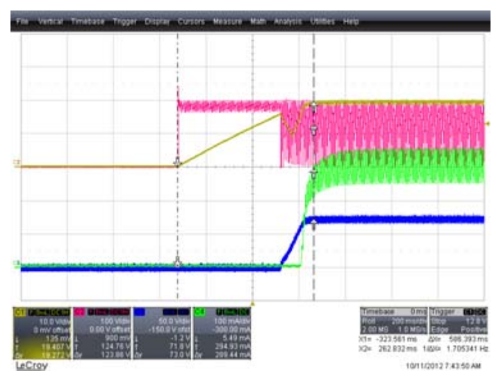

Figure 8. V_{IN} = 120 V_{AC} / 60 Hz Startup Time at LED (70 V / 300 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

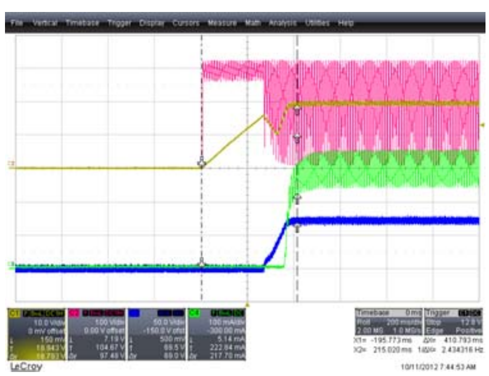

Figure 9. V_{IN} = 230 V_{AC} / 50 Hz, Startup Time at LED (70 V / 300 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

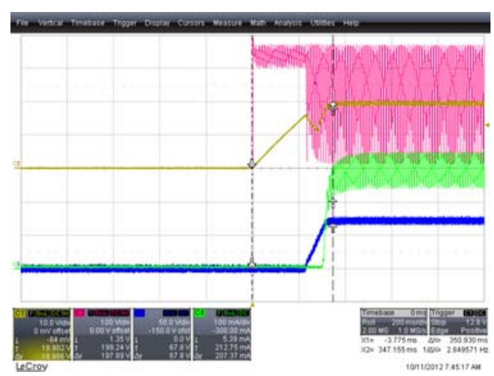

Figure 10.V_{IN} = 265 V_{AC} / 50 Hz, Startup Time at LED (70 V / 300 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

7.3. Operation Waveforms

Output current ripple is under 52 mAp-p at rated output current.

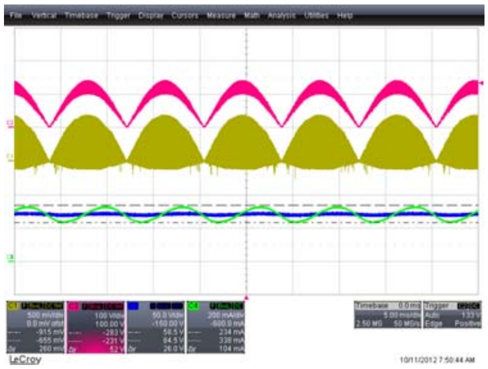

Figure 11. V_{IN}= 90 V_{AC} / 60 Hz, Operation Waveforms at LED (70 V / 300 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

Figure 12.V_{IN} = 120 V_{AC} / 60 Hz Operation Waveforms at LED (70 V / 300 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

Figure 13. V_{IN} = 230 V_{AC} / 50 Hz, Operation Waveforms at LED (70 V / 300 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

Figure 14.V_{IN} = 265 V_{AC} / 50 Hz, Operation Waveforms at LED (70 V / 300 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

7.4. Constant-Current Regulation

Constant-current deviation in the wide output voltage range from 40 V to 80 V is less than ±2.7% at each line input voltage. Line regulation is less than ±3.5%. The results were measured using E-load [CR Mode].

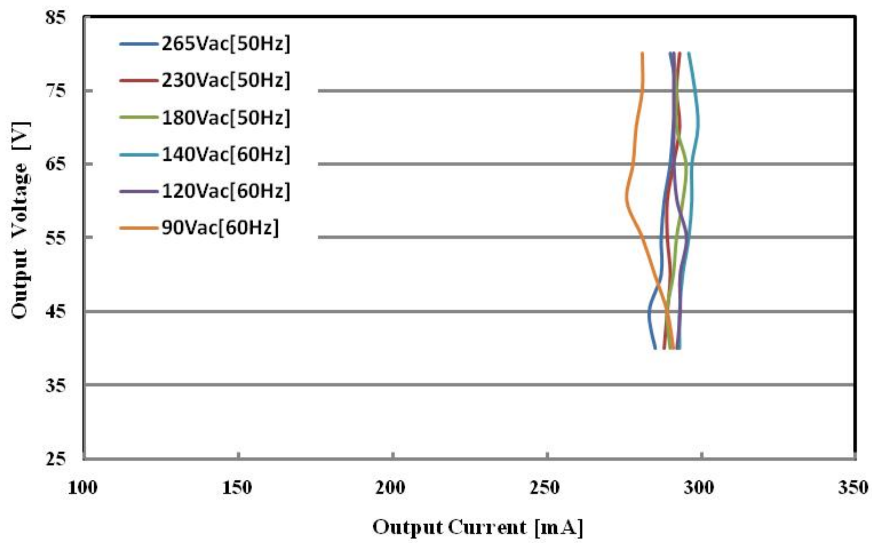

Figure 15. Constant-Current Regulation – Measured by E-Load

Table 4. Constant-Current Regulation by Output Voltage Change (40 V ~ 80 V)

Input Voltage	Min. Current [A]	Max. Current [A]	Tolerance
90 V_{AC} [60 Hz]	0.283	0.292	±1.57%
120 V_{AC} [60 Hz]	0.288	0.293	±0.86%
140 V_{AC} [60 Hz]	0.289	0.295	±1.03%
180 V_{AC} [50 Hz]	0.293	0.299	±1.01%
230 V_{AC} [50 Hz]	0.291	0.295	±0.68%
265 V_{AC} [50 Hz]	0.276	0.291	±2.65%

Table 5. Constant-Current Regulation by Line Voltage Change (90 V_{AC} ~ 265 V_{AC})

Output Voltage	90 V_{AC}	120 V_{AC}	140 V_{AC}	180 V_{AC}	230 V_{AC}	265 V_{AC}	Tolerance
75 V	0.281 A	0.291 A	0.298 A	0.292 A	0.292 A	0.292 A	±2.94%
70 V	0.279 A	0.291 A	0.299 A	0.292 A	0.293 A	0.291 A	±3.46%
65 V	0.278 A	0.291 A	0.297 A	0.295 A	0.291 A	0.290 A	±3.30%

7.5. Open-LED and Short-LED Protections

In short-LED condition, the OCP level is reduced from 0.7 V to 0.2 V because the FL7732 lowers the OCP level when the V_S voltage is less than 0.4 V during output diode conduction time. The results were measured using actual LED load.

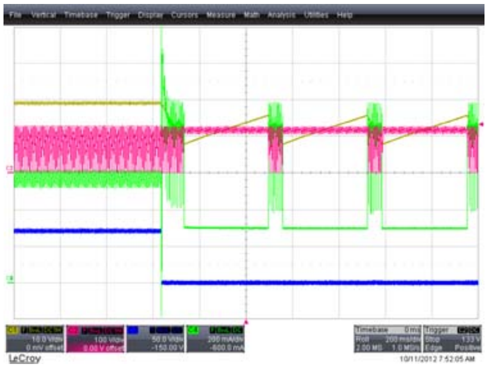

Figure 16. V_{IN} = 90 V_{AC} / 60 Hz, Short-LED; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

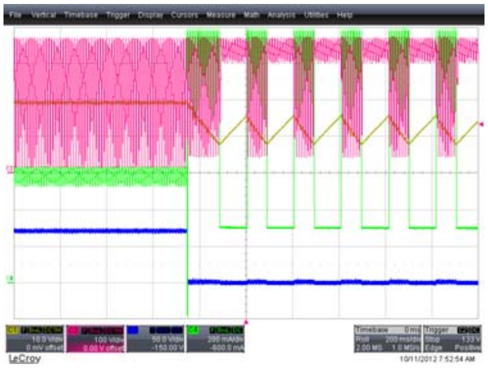

Figure 17.V_{IN} = 265 V_{AC} / 50 Hz, Short-LED Short-LED; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

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 turn ratio of the auxiliary and secondary windings.

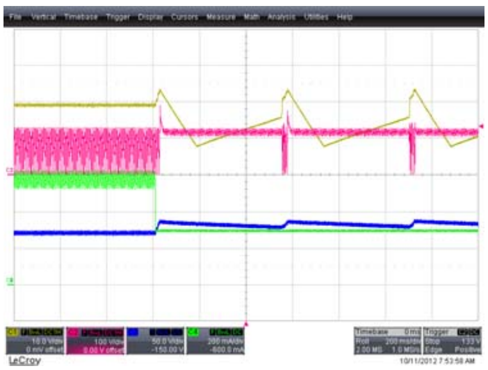

Figure 18. V_{IN} = 90 V_{AC} / 60 Hz, Open-LED; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

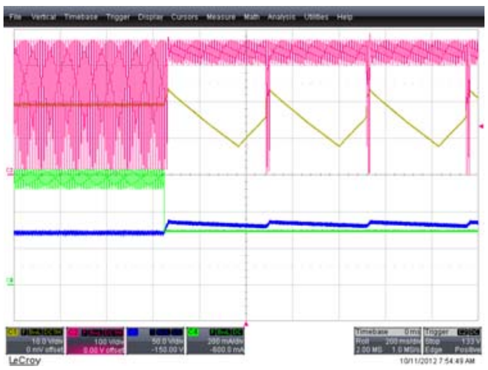

Figure 19.V_{IN} = 265 V_{AC} / 50 Hz, Open-LED; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

7.6. System Efficiency

System efficiency is 90.23% ~ 92.99% in 90 V_{AC} ~ 265 V_{AC} input voltage range. The results were measured after 30 minutes since startup by using LED load.

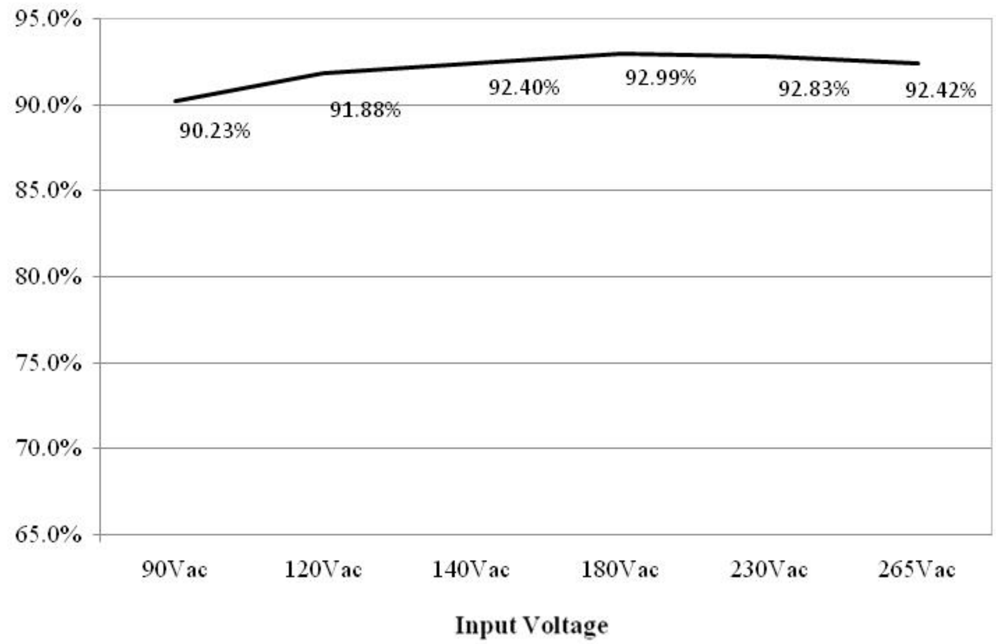

Figure 20. System Efficiency

Table 6. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90 V_{AC} [60 Hz]	23.03	0.290	71.56	20.78	90.23%
120 V_{AC} [60 Hz]	23.62	0.303	71.72	21.70	91.88%
140 V_{AC} [60 Hz]	23.78	0.306	71.71	21.97	92.40%
180 V_{AC} [50 Hz]	23.31	0.303	71.54	21.68	92.99%
230 V_{AC} [50 Hz]	23.08	0.300	71.42	21.43	92.83%
265 V_{AC} [50 Hz]	23.03	0.295	71.27	21.05	92.42%

7.7. Power Factor & Total Harmonic Distortion (THD)

FL7732 shows excellent THD performance. THD is much less than 30% of the specification. Power factor is very high, with enough margins from 0.9. The results were measured 30 minutes after startup using LED load.

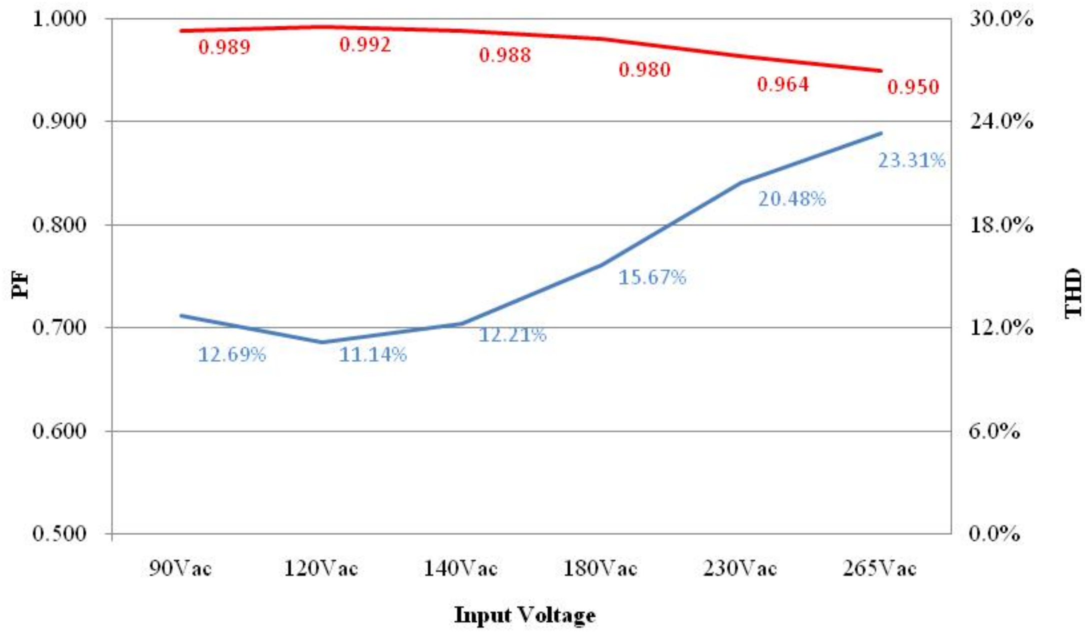

Figure 21. Power Factor & Total Harmonic Distortion

Table 7. Power Factor & Total Harmonic Distortion

Input Voltage	PF	THD
90 V_{AC} [60 Hz]	0.989	12.69%
120 V_{AC} [60 Hz]	0.992	11.14%
140 V_{AC} [60 Hz]	0.988	12.21%
180 V_{AC} [50 Hz]	0.980	15.67%
230 V_{AC} [50 Hz]	0.964	20.48%
265 V_{AC} [50 Hz]	0.950	23.31%

7.8. Operating Temperature

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

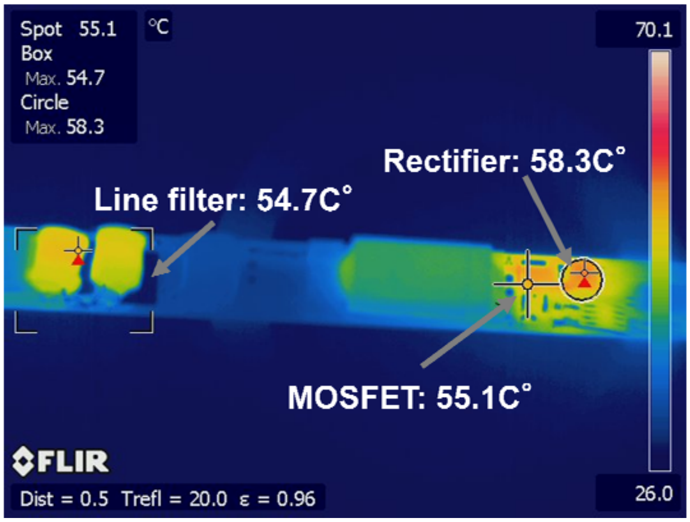

Figure 22. Board Temperature – V_{IN} [90 V_{AC} / 60 Hz], LED (70 V / 300 mA)

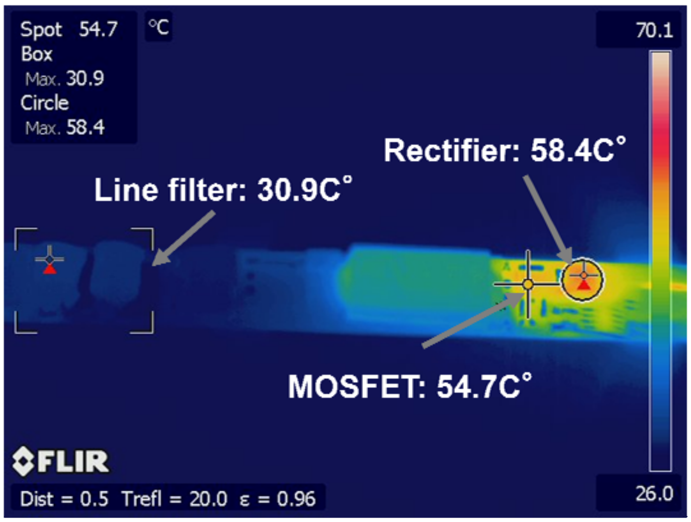

Figure 23. Board Temperature – V_{IN} [265 V_{AC} / 50 Hz], LED (70 V / 300 mA)

7.9. Electromagnetic Interference (EMI)

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

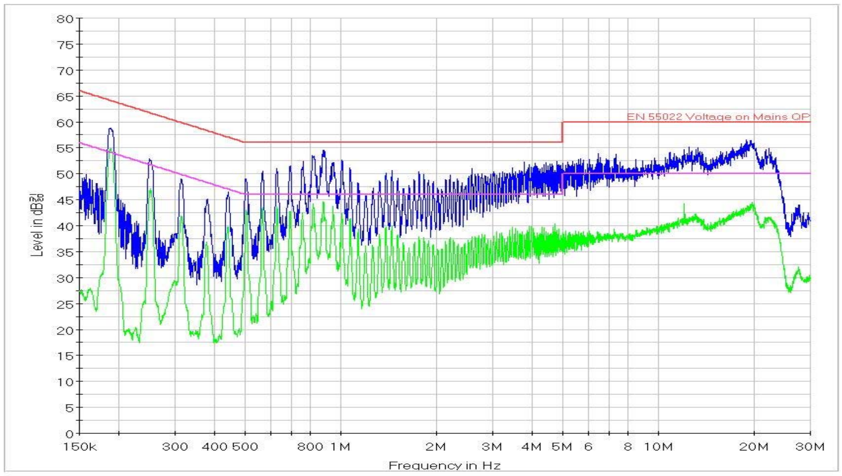

Figure 24. EMI Results – LED (70 V / 300 mA), Conduction Live; V_{IN} = 230 V_{AC}

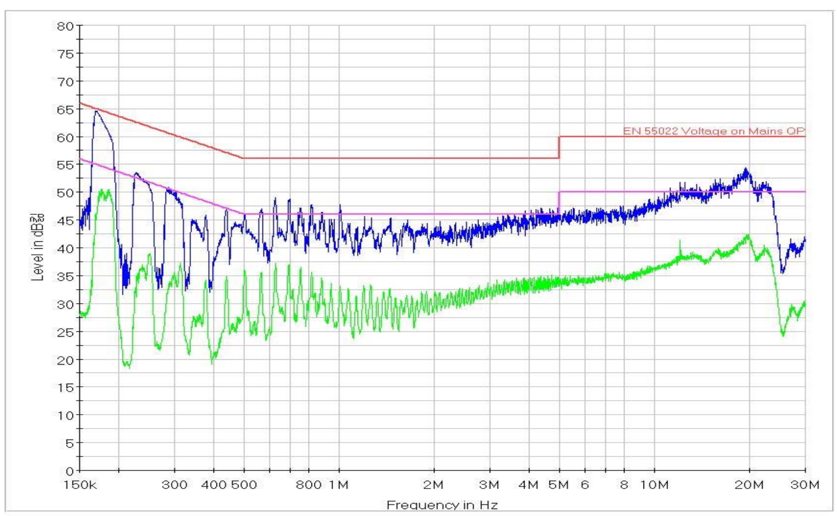

Figure 25. EMI Results – LED (70 V / 300 mA), Conduction Neutral; V_{IN} = 110 V_{AC}

8. Revision History

Rev.	Date	Description
1.0.0	Nov 2012	Initial Release