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User Guide for
FEBFL7732_L28U008A

8.4 W LED Driver at Universal Line
Using Buck-Boost

Featured Fairchild Product:
FL7732

***Direct questions or comments
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Fairchild Semiconductor.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 universal line voltage LED driver using the FL7732 Primary Side Regulator (PSR) buck boost controller. The input voltage range is $90 V_{RMS} - 265 V_{RMS}$ and there is one DC output with a constant current of 140 mA at $60 V_{MAX}$. This document contains a general description of the FL7732, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. Description

The FL7732 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Primary-side regulation 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 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. FL7732 provides protections such as open-LED, short-LED, and over-temperature.

1.2. Features

- Cost-Effective Solution: No 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 Improves Efficiency and Simplifies Design
- Open-/ Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20 μ A
- Low Operating Current: 5 mA
- V_{DD} Over-Voltage Protection (OVP)
- V_{DD} Under-Voltage Lockout (UVLO)
- Application Voltage Range: $80 V_{AC} \sim 308 V_{AC}$

1.3. Internal Block Diagram

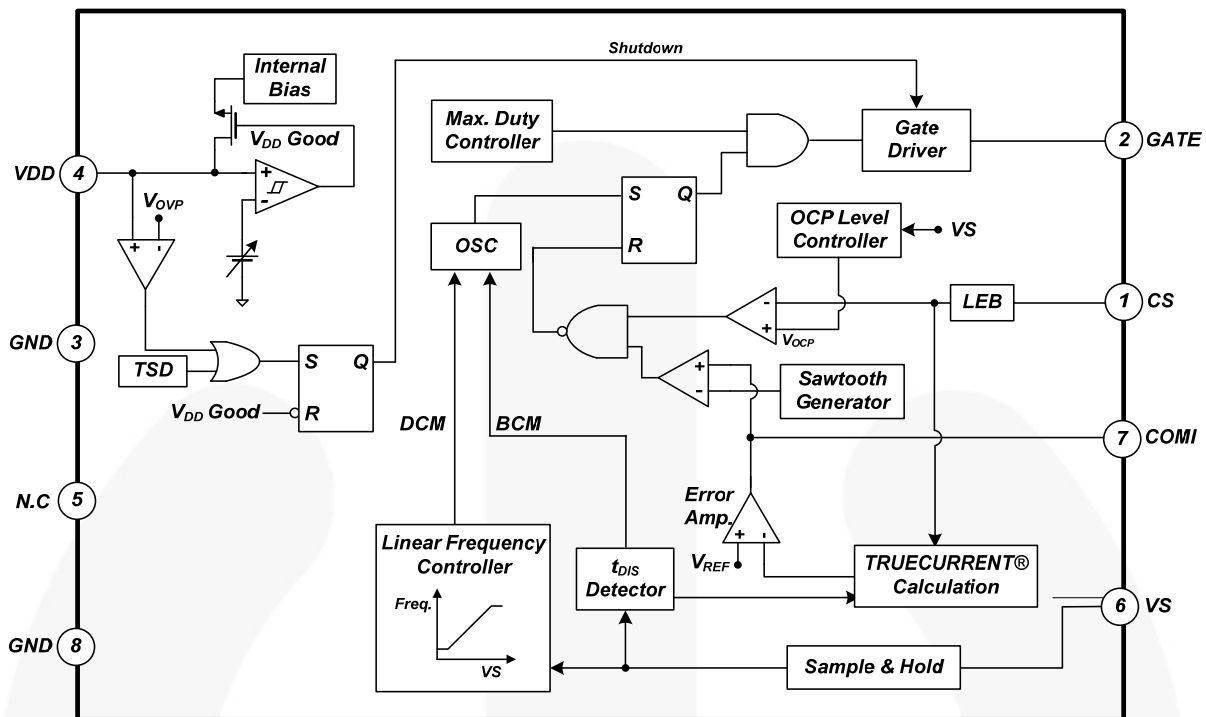


Figure 1. Block Diagram

2. Specifications for Evaluation Board

Table 1. 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 Current	V _{OUT.MIN}	11 V	Minimum Output Voltage
		V _{OUT.MAX}	75 V	Maximum Output Voltage
		V _{OUT.NOMINAL}	60 V	Rated Output Voltage
		I _{OUT.NOMINAL}	140 mA	Rated Output Current
	Current	CC Deviation	< ±3.27%	Line Input Voltage Change: 90 ~265 V _{AC}
			< ±2.19%	Output Voltage Change: 35 ~75 V
Efficiency		Eff _{90VAC}	88.96%	Efficiency at 90 V _{AC} Line Voltage
		Eff _{120VAC}	90.75%	Efficiency at 120 V _{AC} Line Input Voltage
		Eff _{140VAC}	90.93%	Efficiency at 140 V _{AC} Line Input Voltage
		Eff _{180VAC}	90.89%	Efficiency at 180 V _{AC} Line Input Voltage
		Eff _{230VAC}	89.49%	Efficiency at 230 V _{AC} Line Input Voltage
		Eff _{265VAC}	88.81%	Efficiency at 265 V _{AC} Line Input Voltage
PF/THD		PF / THD _{90VAC}	0.981 / 16.08%	PF / THD at 90 V _{AC} Line Input Voltage
		PF / THD _{120VAC}	0.977 / 17.29%	PF / THD at 120 V _{AC} Line Input Voltage
		PF / THD _{140VAC}	0.973 / 17.85%	PF / THD at 140 V _{AC} Line Input Voltage
		PF / THD _{180VAC}	0.958 / 19.68%	PF / THD at 180 V _{AC} Line Input Voltage
		PF / THD _{230VAC}	0.934 / 21.41%	PF / THD at 230 V _{AC} Line Input Voltage
		PF / THD _{265VAC}	0.901 / 24.80%	PF / THD at 265 V _{AC} Line Input Voltage
Temperature	FL7732	T _{FL7732}	53.7°C	Main Controller Temperature
	MOSFET	T _{MOSFET}	56.3°C	MOSFET
	Rectifier	T _{Rectifier}	47.1°C	Secondary Diode Temperature

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

3. Photographs

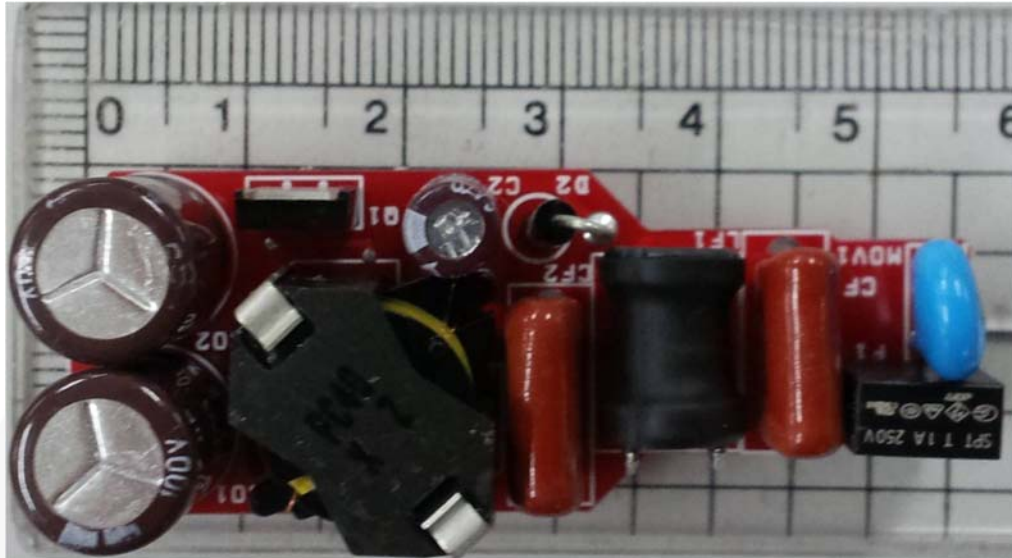


Figure 2. Top View (Dimensions: 55.2 mm (L) x 21.0 mm (W) x 15.0 mm (H))

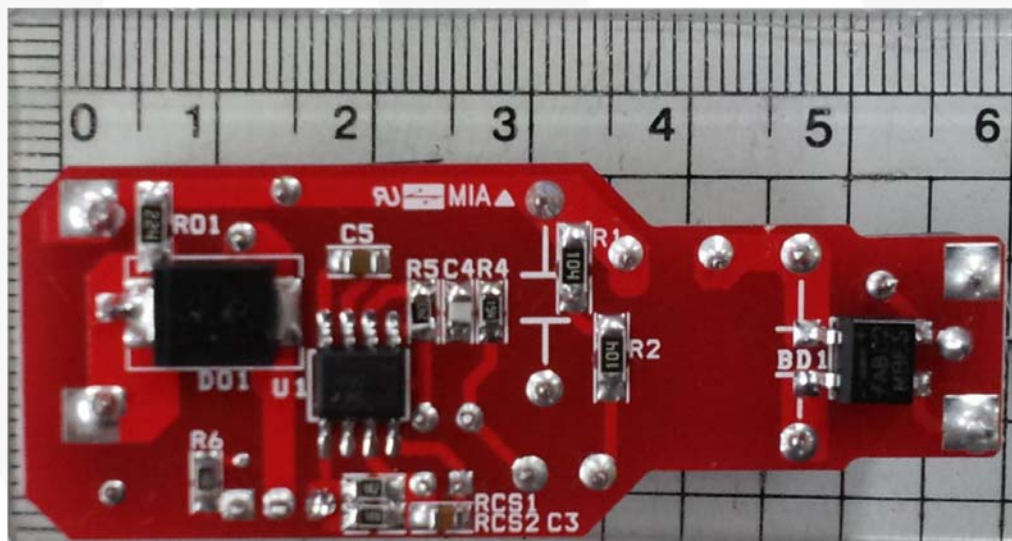


Figure 3. Bottom View (Dimensions: 55.2 mm (L) x 21.0 mm (W) x 15.0 mm (H))

5. Schematic

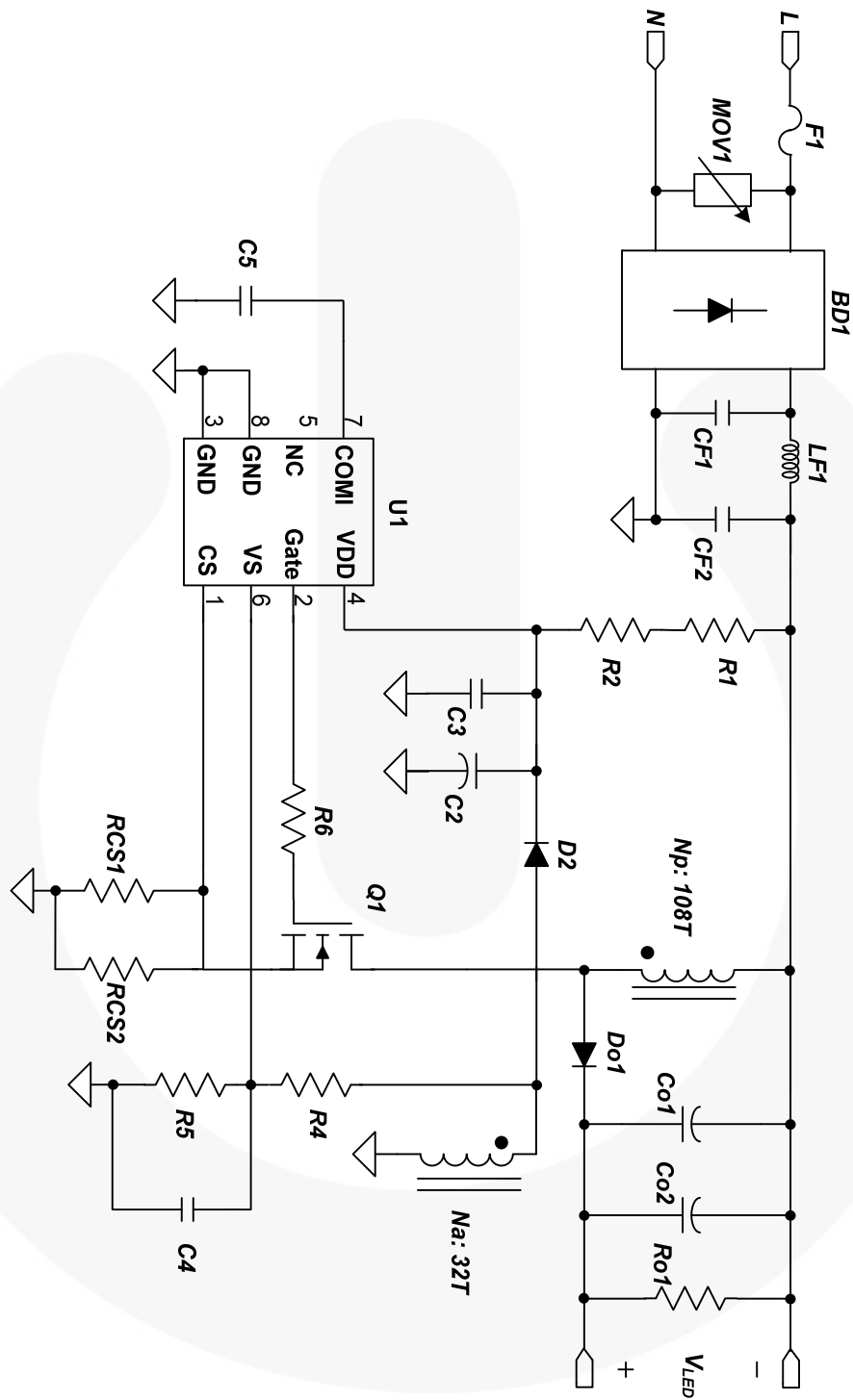


Figure 6. Schematic

6. Bill of Materials

Item No.	Part Reference	Part No.	Qty.	Description	Manufacturer
1	BD1	MB6S	1	Bridge Diode	Fairchild Semiconductor
2	CF1, CF2	MPE400V683K	2	68 nF / 400 V, Film Capacitor	Sungho
3	CO1, CO2	KMG 47 μ F / 100 V	1	47 μ F / 100 V, Electrolytic Capacitor	Samyoung
4	C2	KMG 10 μ F / 35 V	1	10 μ F / 35 V, Electrolytic Capacitor	Samyoung
5	C3	C0805C104K3RACTU	1	0.1 μ F / 25 V, SMD Capacitor 2012	Kemet
6	C4	C0805C200M3GACTU	1	20 pF / 25 V, SMD Capacitor 2012	Kemet
7	C5	C1206C105K3PACTU	1	1 μ F / 25 V, SMD Capacitor 2012	Kemet
8	D2	1N4003	1	1 A / 200 V, Diode	Fairchild Semiconductor
9	DO1	ES3J	1	3 A / 600 V, Fast Rectifier	Fairchild Semiconductor
10	F1	SS-5-1A	1	1 A / 250 V, Fuse	Bussmann
11	LF1	R06153KT00	1	15 mH, 8 $\varnothing$ Filter Inductor	Bosung
12	MOV1	SVC 471D07	1	Varistor	Samwha
13	C2	KMG 10 μ F / 35 V	1	10 μ F / 35 V, Electrolytic Capacitor	Samyoung
14	RCS1	RC0805JR-071R2L	1	1.2 Ω , SMD Resistor 2012	Yageo
15	RCS2	RC0805JR-071R8L	1	1.8 Ω , SMD Resistor 2012	Yageo
16	RO1	RC1206JR-07220KL	1	220 k Ω , SMD Resistor 3216	Yageo
17	R1, R2	RC1206JR-07100KL	2	100 k Ω , SMD Resistor 3216	Yageo
18	R4	RC0805JR-07150KL	1	150 k Ω , SMD Resistor 2012	Yageo
19	R5	RC1206JR-0724KL	1	24 k Ω , SMD Resistor 3216	Yageo
20	R6	RC0805JR-0710RL	1	10 Ω , SMD Resistor 2012	Yageo
21	T1	RM6	1	Transformer	TDK
22	Q1	FQU5N60C	1	2.8 A / 600 V, MOSFET	Fairchild Semiconductor
23	U1	FL7732_F116	1	Main Controller	Fairchild Semiconductor

7. Transformer Design

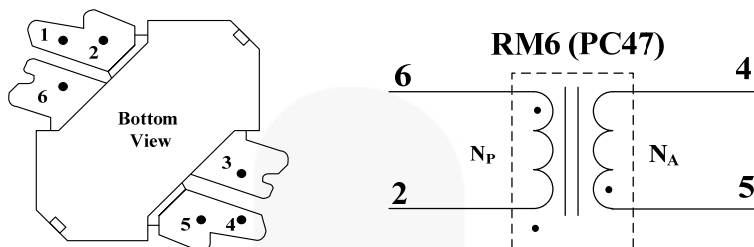


Figure 7. Transformer Bobbin Structure and Pin Configuration

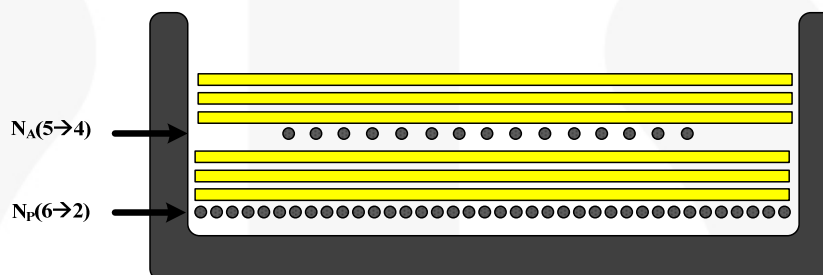


Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np	6 → 2	0.25Ø	108 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	Na	5 → 4	0.13Ø	32 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	6 – 2	1.4 mH ±10%	60 kHz, 1 V
Leakage		15 µH	60 kHz, 1 V Short All Output Pins

8. Performance of Evaluation Board

Table 4. Electrical Characteristics

Ambient Temperature	$T_A = 25^{\circ}\text{C}$
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: Samsung LED 1W

8.1. Startup

Startup time is 0.38 s at $V_{IN} = 90 \text{ V}_{AC}$. The results were measured using actual LED load. C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], and C4 [I_{OUT}].

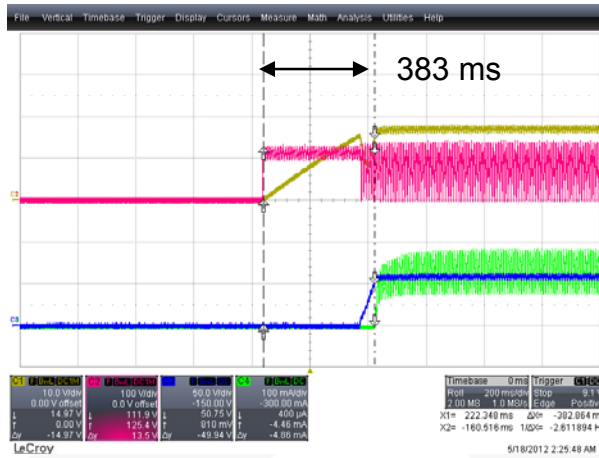


Figure 9. $V_{IN} = 90 \text{ V}_{AC} / 60 \text{ Hz}$

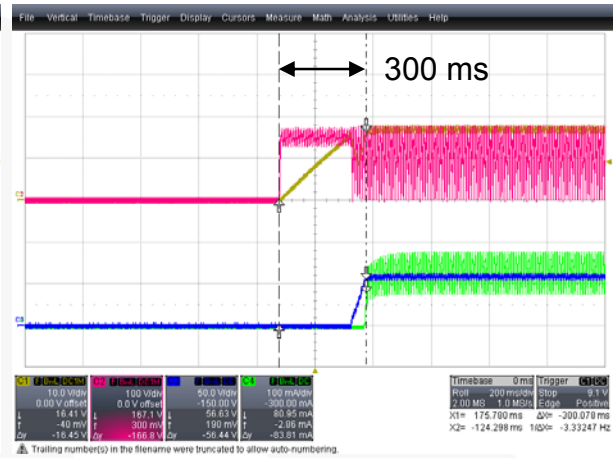


Figure 10. $V_{IN} = 120 \text{ V}_{AC} / 60 \text{ Hz}$

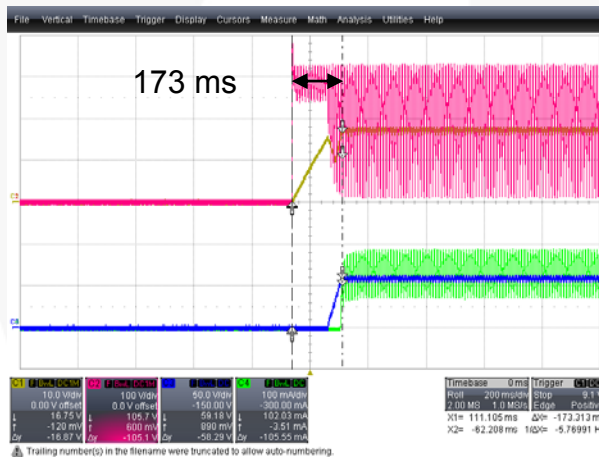


Figure 11. $V_{IN} = 230 \text{ V}_{AC} / 50 \text{ Hz}$

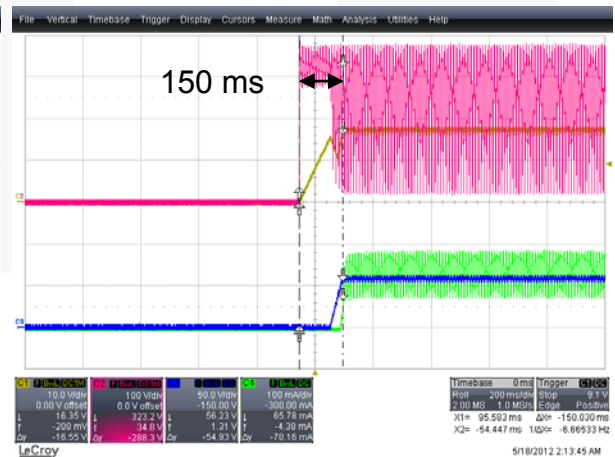


Figure 12. $V_{IN} = 265 \text{ V}_{AC} / 50 \text{ Hz}$

8.2. Operation Waveforms

The results were measured using actual LED load. C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], and C4 [I_{OUT}].

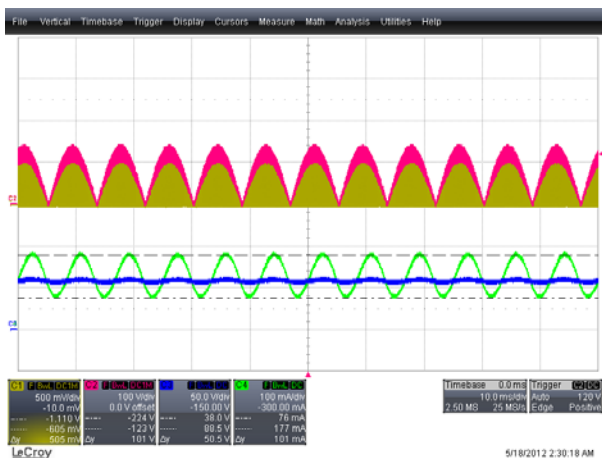


Figure 13. $V_{IN} = 90 V_{AC} / 60 \text{ Hz}$

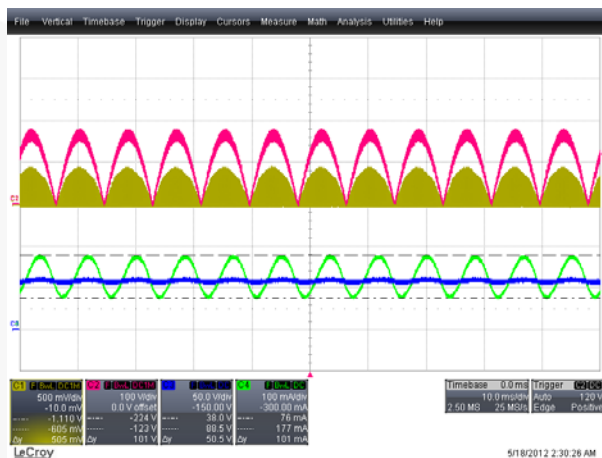


Figure 14. $V_{IN} = 120 V_{AC} / 60 \text{ Hz}$

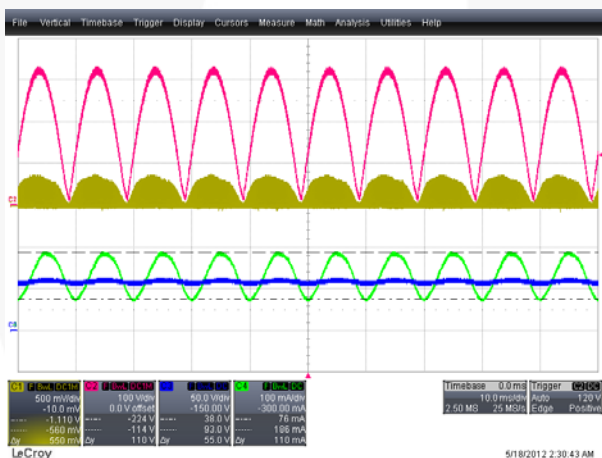


Figure 15. $V_{IN} = 230 V_{AC} / 50 \text{ Hz}$

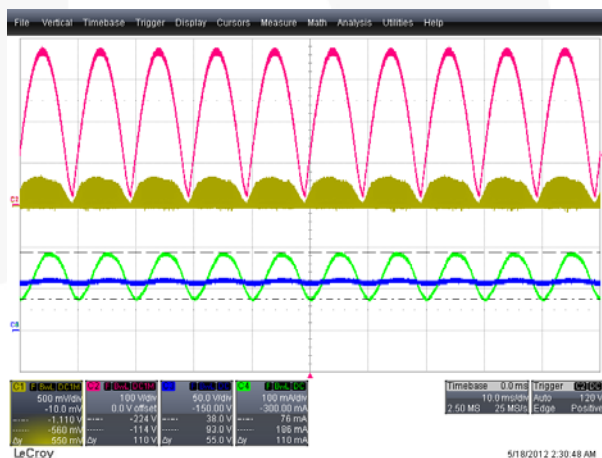


Figure 16. $V_{IN} = 265 V_{AC} / 50 \text{ Hz}$

8.3. Constant-Current Regulation

Constant Current (CC) deviation in the wide output voltage range from 35 V to 75 V is less than 2.2% at each line input voltage. Line regulation at the rated output voltage (60 V) is less than 2.2%. The results were measured by using E-load.

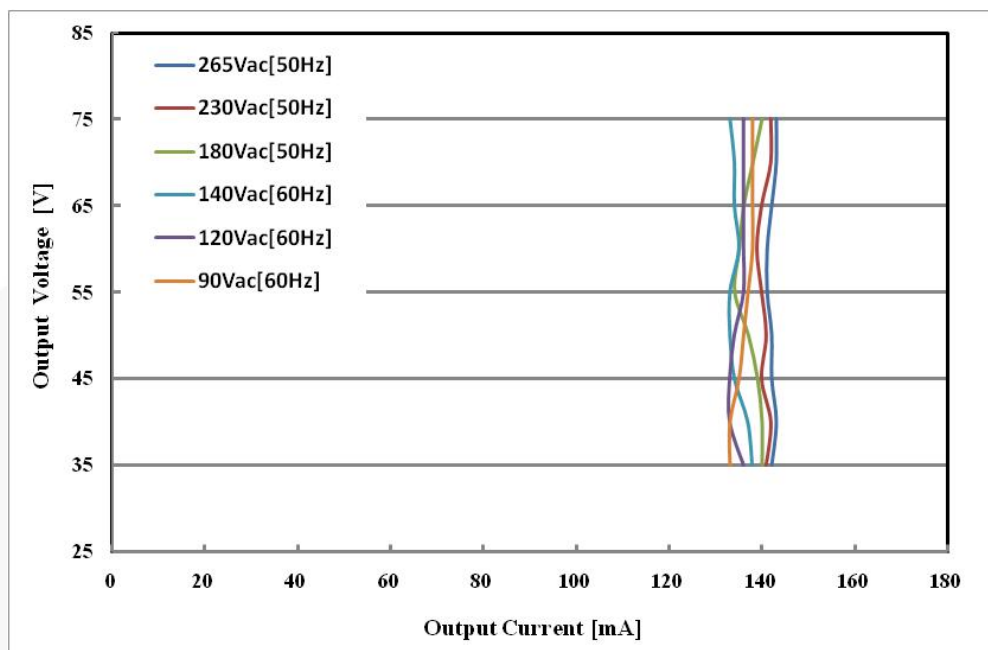


Figure 17. Constant-Current Regulation – Measured by E-LOAD [CR Mode]

Table 5. Constant-Current Regulation by Output Voltage Change (35~75 V)

Input Voltage	Min. Current	Max. Current	Tolerance
90 V _{AC} [60 Hz]	133 mA	138 mA	±1.85%
120 V _{AC} [60 Hz]	133 mA	136 mA	±1.12%
140 V _{AC} [60 Hz]	133 mA	138 mA	±1.85%
180 V _{AC} [50 Hz]	134 mA	140 mA	±2.19%
230 V _{AC} [50 Hz]	139 mA	142 mA	±1.07%
265 V _{AC} [50 Hz]	141 mA	143 mA	±0.70%

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
65 V	138 mA	136 mA	134 mA	138 mA	142 mA	143 mA	±2.90%
60 V	138 mA	136 mA	135 mA	136 mA	140 mA	142 mA	±2.17%
55 V	138 mA	136 mA	133 mA	135 mA	139 mA	141 mA	±2.92%
50 V	137 mA	136 mA	133 mA	134 mA	140 mA	141 mA	±3.27%

8.4. Short- / Open-LED Protections

In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because FL7732 lowers the OCP level when the V_S voltage is less than 0.4V during output diode conduction time. The results were measured using actual LED load. C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], and C4 [I_{OUT}].



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



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

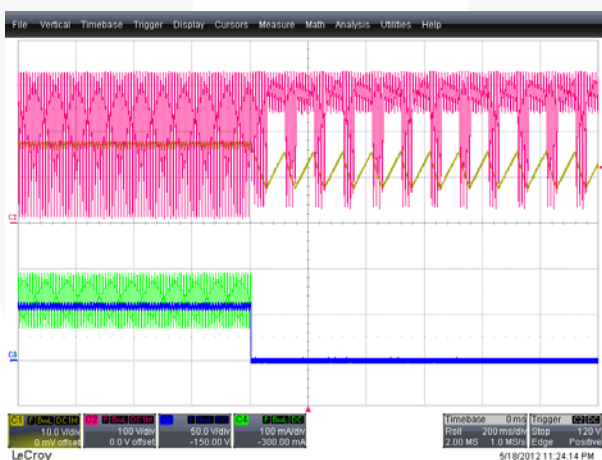


Figure 20. $V_{IN} = 230V_{AC} / 50Hz$

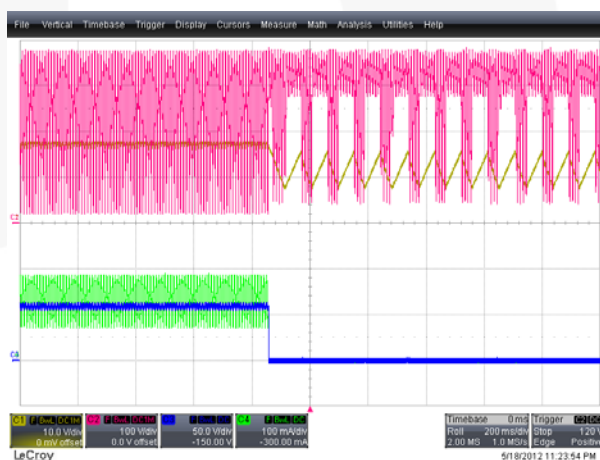


Figure 21. $V_{IN} = 265V_{AC} / 50Hz$

In open-LED condition, the output voltage is limited around 75 V by OVP in V_{DD} . The output over-voltage protection level can be controlled by the turn ratio of the auxiliary and secondary windings. The results were measured by using actual LED load. C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], and C4 [I_{OUT}].

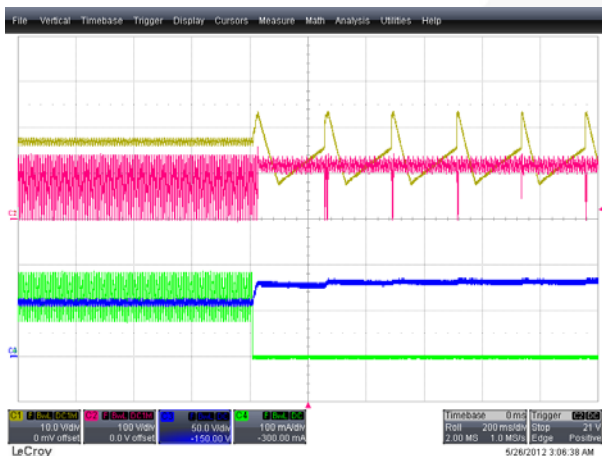


Figure 22. $V_{IN} = 90 V_{AC} / 60 \text{ Hz}$

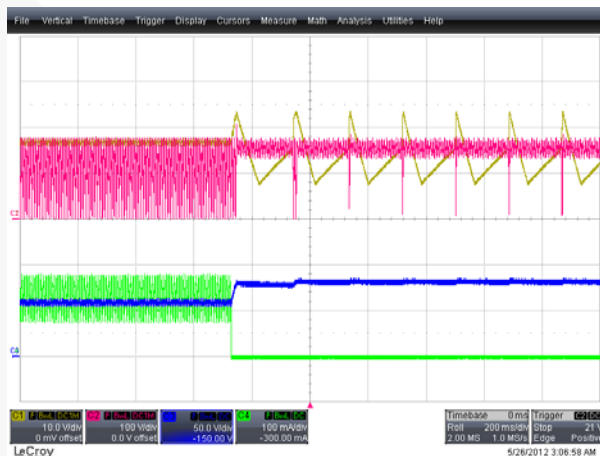


Figure 23. $V_{IN} = 120 V_{AC} / 60 \text{ Hz}$

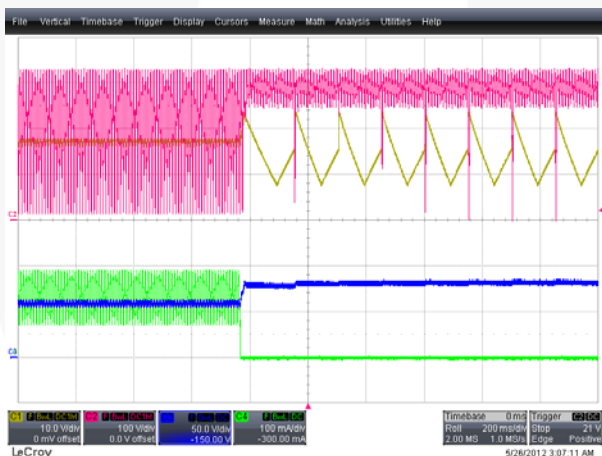


Figure 24. $V_{IN} = 230 V_{AC} / 50 \text{ Hz}$

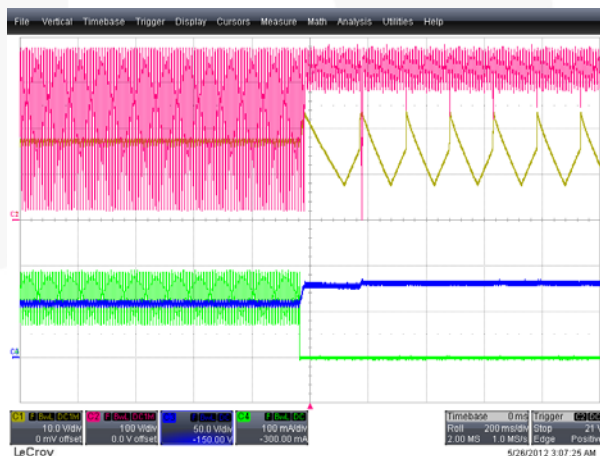


Figure 25. $V_{IN} = 265 V_{AC} / 50 \text{ Hz}$

8.5. System Efficiency

Power efficiency is 88.81% ~ 90.93% in the 90 ~ 265 V_{AC} input voltage range. The results were measured after 30 minutes since startup by using actual LED load.

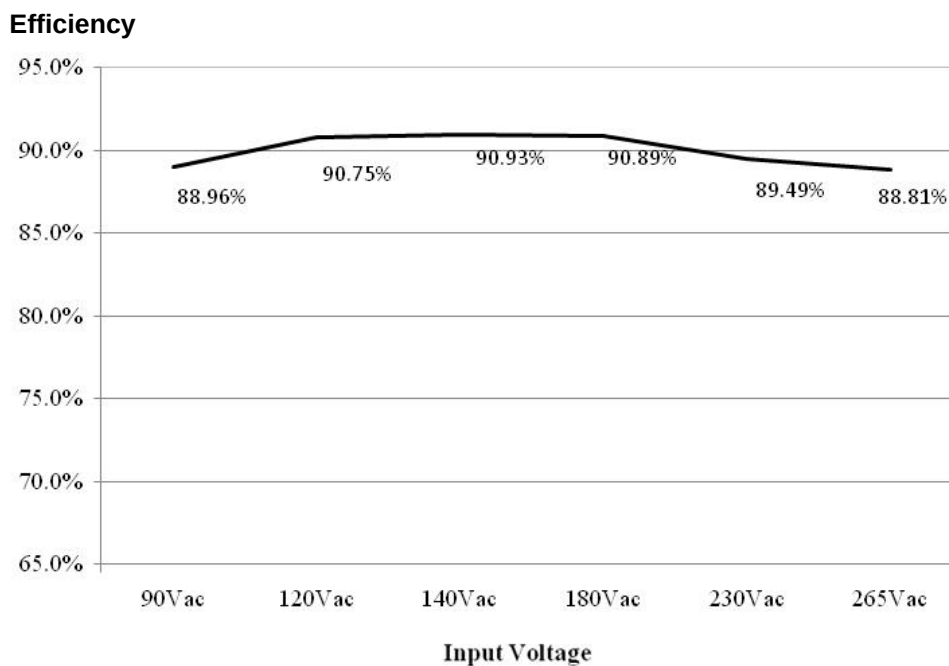


Figure 26. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90 V _{AC} [60 Hz]	8.93 W	135 mA	58.84 V	7.94 W	88.96%
120 V _{AC} [60 Hz]	8.58 W	132 mA	58.78 V	7.79 W	90.75%
140 V _{AC} [60 Hz]	8.46 W	131 mA	58.72 V	7.69 W	90.93%
180 V _{AC} [50 Hz]	8.76 W	135 mA	58.81 V	7.96 W	90.89%
230 V _{AC} [50 Hz]	9.08 W	138 mA	58.91 V	8.13 W	89.49%
265 V _{AC} [50 Hz]	9.24 W	139 mA	58.95 V	8.21 W	88.81%

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

FL7732 shows excellent power factor and performance. Total harmonic distortion is less than 25%. The results were measured after 30 minutes since startup by using actual LED load.

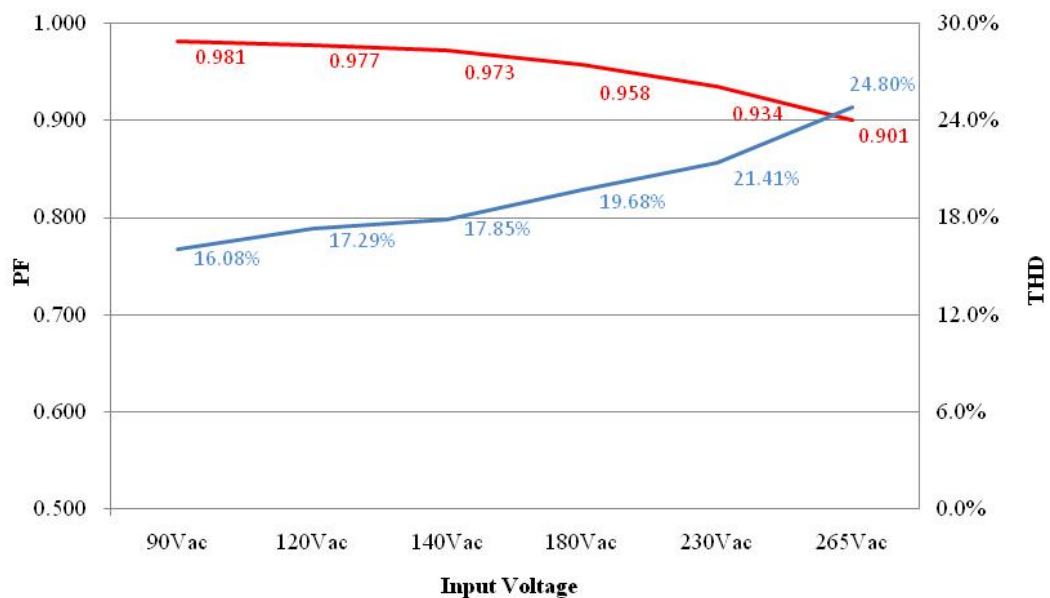


Figure 27. Power Factor and Total Harmonic Distortion

Table 8. Power Factor and Total Harmonic Distortion

Input Voltage	Output Current	Output Voltage	Power Factor	THD
90 V _{AC} [60 Hz]	135 mA	58.84 V	0.981	16.08%
120 V _{AC} [60 Hz]	132 mA	58.78 V	0.977	17.29%
140 V _{AC} [60 Hz]	131 mA	58.72 V	0.973	17.85%
180 V _{AC} [50 Hz]	135 mA	58.81 V	0.958	19.68%
230 V _{AC} [50 Hz]	138 mA	58.91 V	0.934	21.41%
265 V _{AC} [50 Hz]	139 mA	58.95 V	0.901	24.80%

8.7. Operating Temperature

Temperatures of the all components on this board are less than 57°C. The results were measured after 60 minutes since startup by using actual LED load.

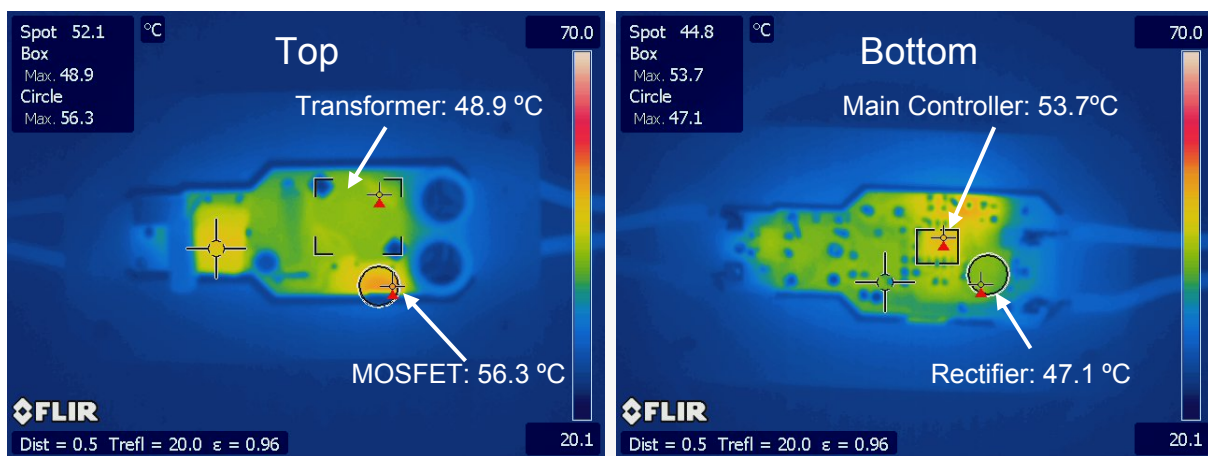


Figure 28. Board Temperature – V_{IN} [90 V_{AC}], V_{OUT} [60 V], I_{OUT} [140 mA]

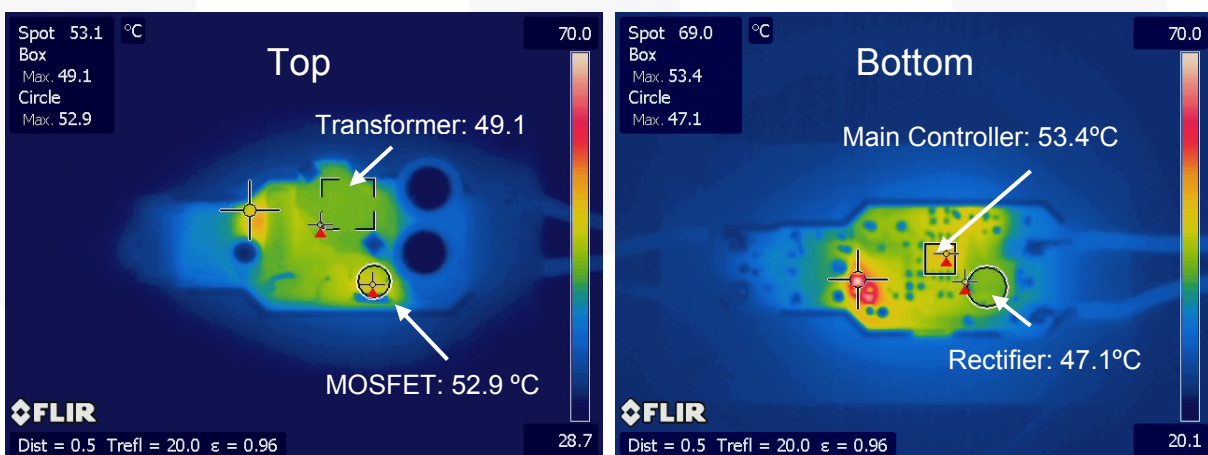


Figure 29. Board Temperature – V_{IN} [265 V_{AC}], V_{OUT} [60 V], I_{OUT} [140 mA]

8.8. Electromagnetic Interference (EMI)

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

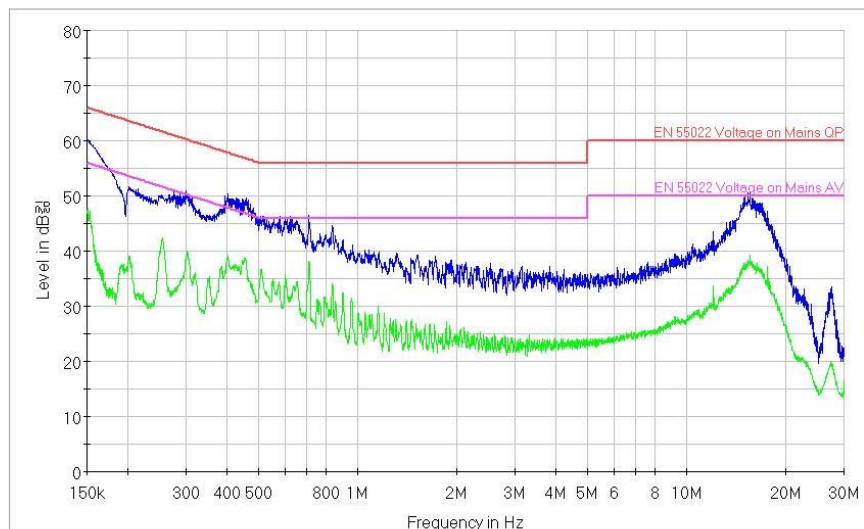


Figure 30. $V_{OUT} [60 V]$, $I_{OUT} [140 mA]$, $V_{IN}=110 V_{AC}$

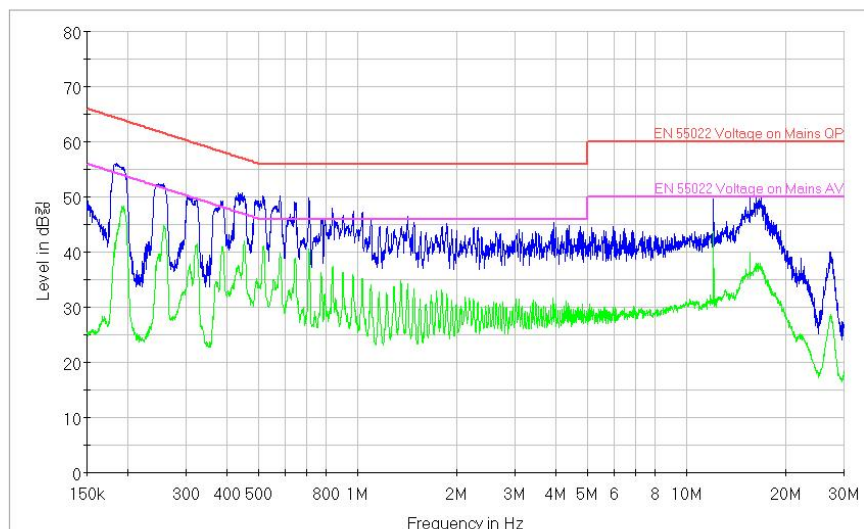


Figure 31. $V_{OUT} [60 V]$, $I_{OUT} [140 mA]$, $V_{IN}=220 V_{AC}$

9. Revision History

Rev.	Date	Description
1.0.0	July 2012	Initial Release
1.0.1	Nov. 2012	Modified, edited, formatted document. Changed User Guide number from FEB-L028 to FEBFL7732_L28U008A

WARNING AND DISCLAIMER

Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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