User Guide for

FEBFL7732_L25U008B

8.4 W LED Driver at Universal Line

Featured Fairchild Product:

FL7732

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 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 ballast using the FL7732 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is 90 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 350 mA at 24 V_{MAX}. This document contains general description of FL7732, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. General Description of FL7732

The FL7732 is an active Power Factor Correction (PFC) controller using single-stage flyback 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 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 DCM operation with high efficiency and simple design. FL7732 provides open-LED, short-LED, and over-temperature protections.

1.2. Features

- Cost-Effective Solution: No Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction
- Accurate Constant-Current (CC) Control, Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control Improves Efficiency and Simplifies Design
- Open-LED Protection
- 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} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18 V
- SOP-8

1.3. Internal Block Diagram

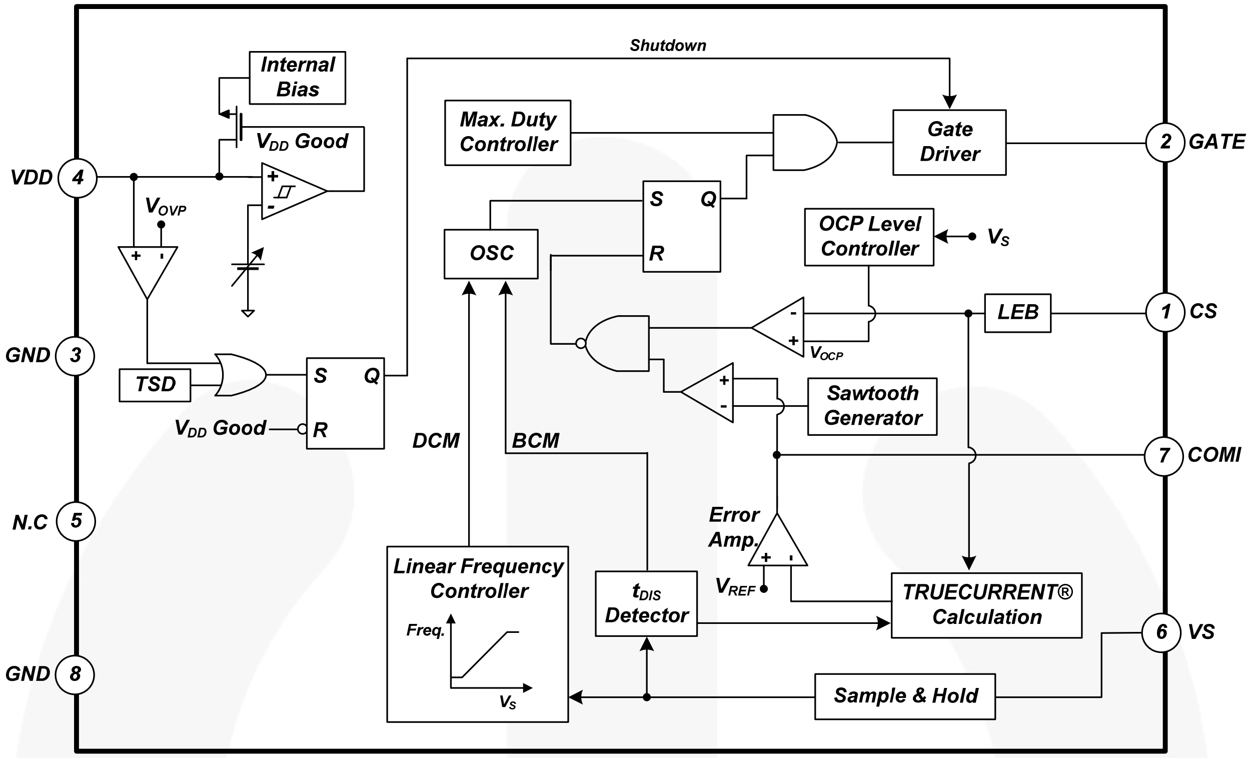

Figure 1. Block Diagram of FL7732

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
		$V_{IN.NOMINAL}$	110 V / 220 V	Nominal Input Voltage
	Frequency	f_{IN}	60 Hz / 50 Hz	Line Frequency
Output	Voltage	$V_{OUT.MIN}$	12 V	Minimum Output Voltage
		$V_{OUT.MAX}$	28 V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	24 V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	350 mA	Nominal Output Current
		CC Deviation	< ±3.17%	Line Input Voltage Change: 90~265 V_{AC}
			< ±1.93%	Output Voltage Change: 12~24 V
Efficiency		Eff_{90VAC}	87.51%	Efficiency at 90 V_{AC} Line Input Voltage
		Eff_{120VAC}	88.76%	Efficiency at 120 V_{AC} Line Input Voltage
		Eff_{140VAC}	89.39%	Efficiency at 140 V_{AC} Line Input Voltage
		Eff_{180VAC}	89.59%	Efficiency at 180 V_{AC} Line Input Voltage
		Eff_{220VAC}	89.20%	Efficiency at 220 V_{AC} Line Input Voltage
		Eff_{265VAC}	88.40%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.998/10.04%	PF / THD at 90 V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.995/10.04%	PF / THD at 120 V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.991/11.83%	PF / THD at 140 V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.982/15.29%	PF / THD at 180 V_{AC} Line Input Voltage
		PF/THD_{220VAC}	0.964/18.19%	PF / THD at 220 V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.935/22.05%	PF / THD at 265 V_{AC} Line Input Voltage
Temperature	FL7732	T_{FL7732}	50.8°C	Open-Frame Condition (T_A = 25°C) FL7732 Temperature
	Primary MOSFET	T_{MOSFET}	57.3°C	Primary MOSFET Temperature
	Secondary Diode	T_{DIODE}	56.2°C	Secondary Diode Temperature
	Transformer	$T_{TRANSFORMER}$	52.3°C	Transformer Temperature

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

3. Evaluation Board

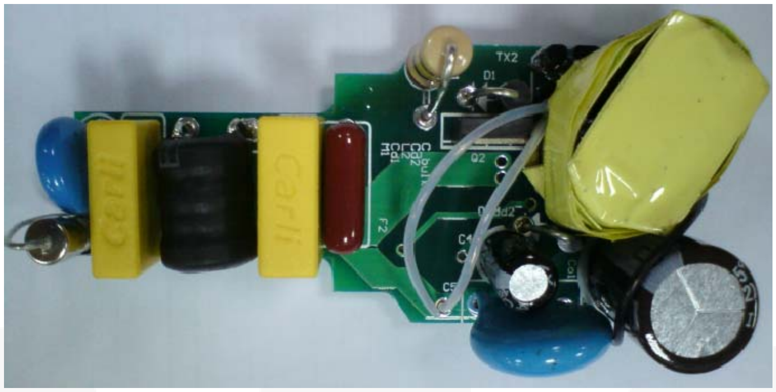

Figure 2. Top View (Dimensions: 58.0 mm (L) x 26.5 mm (W) x 18.0 mm (H)

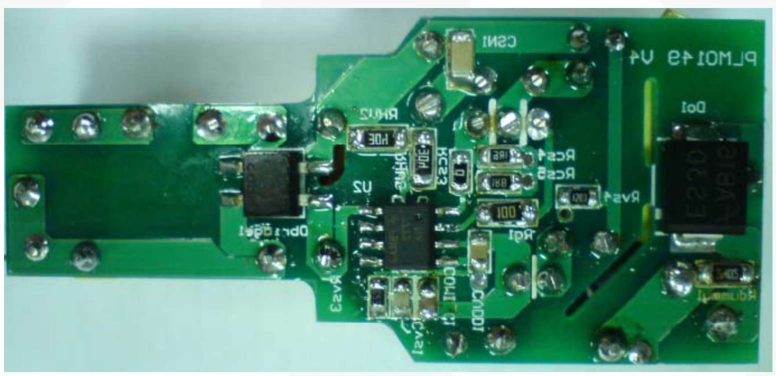

Figure 3. Bottom View (Dimensions:58.0 mm (L) x 26.5 mm (W) x 18.0 mm (H)

4. Printed Circuit Board

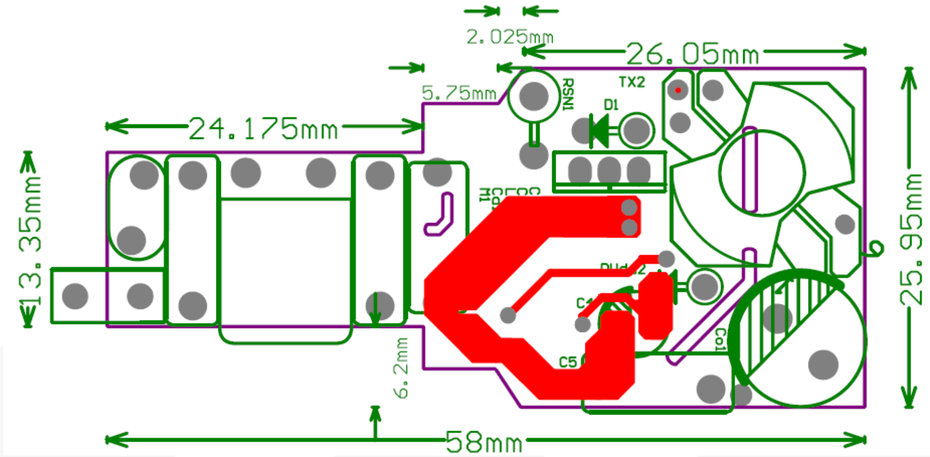

Figure 4. Top Pattern

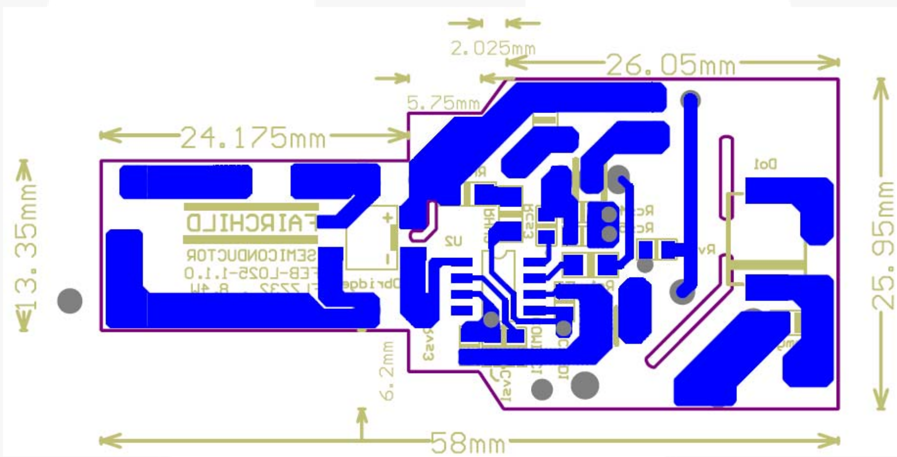

Figure 5. Bottom Pattern

5. Schematic of the Evaluation Board

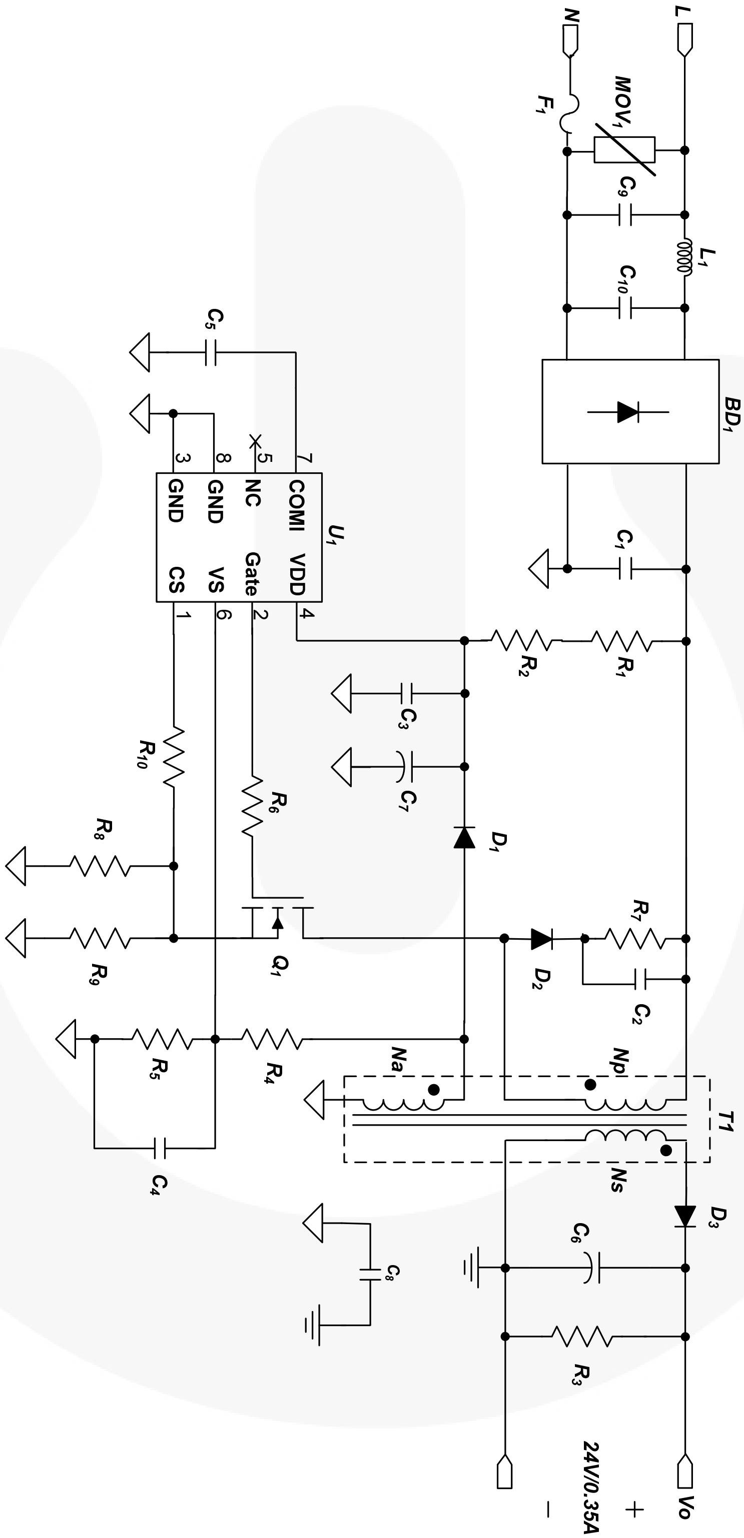

Figure 6. Schematic

6. Bill of Materials

Item No.	Part Reference	Part No.	Qty.	Description	Manufacturer
1	BD1	MB6S	1	0.5 A / 600 V Bridge Diode	Fairchild Semiconductor
2	Q1	FQU5N60CTU	1	2.8 A / 600 V Main Switch	Fairchild Semiconductor
3	U1	FL7732_F116	1	Main Controller	Fairchild Semiconductor
4	F1	SS-5-1A	1	250 V / 1 A Fuse	Bussmann
5	M1	SVC 471 D-07A	1	Metal Oxide Varistor	Samwha
6	L1	R08123KT00	1	12 mH Filter Inductor, 8Φ	Bosung
7	D1, D2	1N4007	2	1 A / 1000 V Diode	Fairchild Semiconductor
8	D3	ES3D	1	3 A / 200 V Fast Rectifier	Fairchild Semiconductor
9	C1	ECW-F2W104JAQ	1	0.1 µF / 450 V Film Capacitor	Panasonic - ECG
10	C2	C1206C103KCRACTU	1	10 nF / 500 V SMD Capacitor 3216	Kemet
11	C3	C0805C103K5RACTU	1	10 nF / 50 V SMD Capacitor 2012	Kemet
12	C4	C0805C220J5GACTU	1	22 pF / 50 V SMD Capacitor 2012	Kemet
13	C5	C0805C105Z3VACTU	1	1 µF / 25 V SMD Capacitor 2012	Kemet
14	C6	KMG 470 µF/35V	1	470 µF / 35 V Electrolytic Capacitor	Samyoung
15	C7	KMG 10 µF/50V	1	10 µF / 50 V Electrolytic Capacitor	Samyoung
16	C8	SCFz2E472M10BW	1	4.7 nF / 250 V Y-Capacitor	Samwha
17	C9	MPX AC275V 223K	1	22 nF / 275 V_{AC} X-Capacitor	Carli
18	C10	MPX AC275V 333K	1	33 nF / 275 V_{AC} X-Capacitor	Carli
19	R1, R2	RC1206JR-07300KL	2	300 kΩ SMD Resistor 3216	Yageo
20	R3	RC1206JR-0724KL	1	24 kΩ SMD Resistor 3216	Yageo
21	R4	RC0805FR-07150KL	1	150 kΩ SMD Resistor 2012	Yageo
22	R5	RC0805JR-0722KL	1	22 kΩ SMD Resistor 2012	Yageo
23	R6	RC1206JR-0710RL	1	10 Ω SMD Resistor 3216	Yageo
24	R7	RSMF1JT200K	1	200 kΩ / 1W Metal Oxide Film Resistor	Stackpole Electrical
25	R8	RC0805JR-071R6L	1	1.6 Ω SMD Resistor 2012	Yageo
26	R9	RC0805JR-071R8L	1	1.8 Ω SMD Resistor 2012	Yageo
27	R10	RC0805JR-070RL	1	0 Ω SMD Resistor 2012	Yageo
28	T1	RM Core	1	1 mH RM6 Transformer	TDK

7. Transformer Design

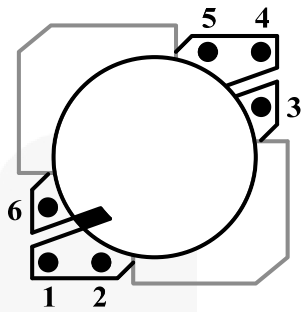

Figure 7. Transformer Bobbin Structure

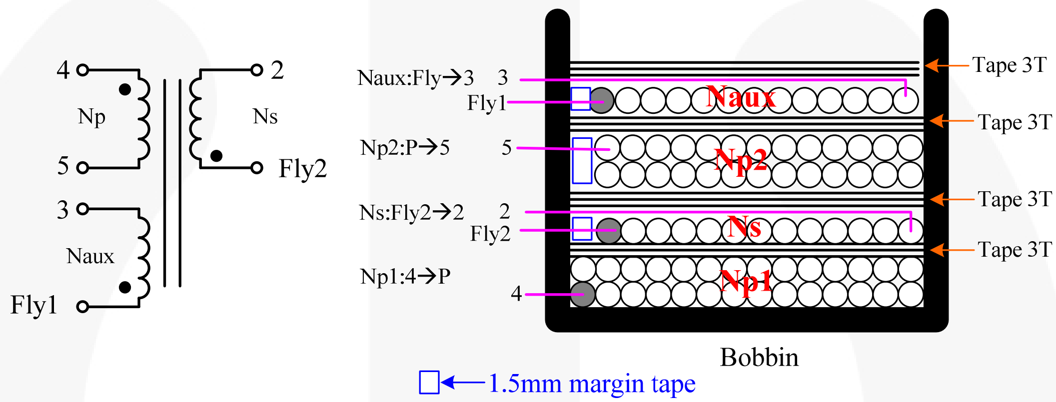

Figure 8. Pin Configuration and Transformer Winding Structure

Note:
1. Fly 1 connects to the primary side ground and Fly 2 connects to the secondary-side ground directly.

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	4 → P	0.2φ	36 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	N_S	Fly2 → 2	0.32φ	24 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	N_{P2}	P → 5	0.2φ	36 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
7	NA	Fly1 → 3	0.12φ	18 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	4 – 5	1 mH ±10%	50 kHz, 1V
Leakage	4 – 5	13 µH	50 kHz, 1V 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: ES2000S by PSTATIONES Power Analyzer: PZ4000 by YOKOGAWA Multi Meter: 2002 by KEITHLEY : 8842A by LIKE Oscilloscope: WaveRunner 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Fluke Ti20 LED: EHP-AX08EL/GT01H-P01(1 W) by Everlight

8.1. Startup

Startup time is 926 ms (V_{IN} = 90 V_{AC}) ~ 315 ms (V_{IN} = 265 V_{AC}). The results were measured by using 8-LED load. Startup Time at 8-LED (24 V / 350 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

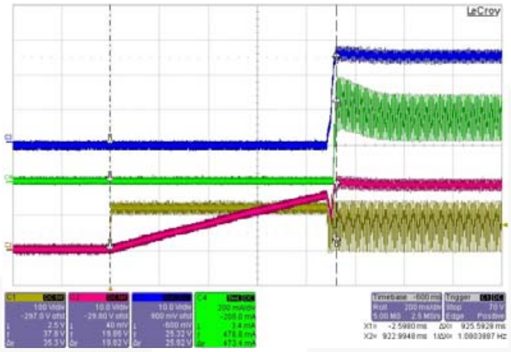

Figure 9. V_{IN} = 90 V_{AC} / 60 Hz

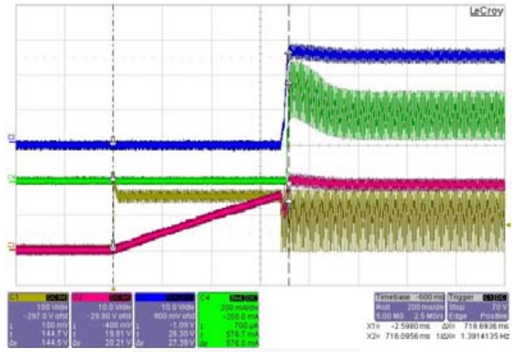

Figure 10. V_{IN} = 115 V_{AC} / 60 Hz

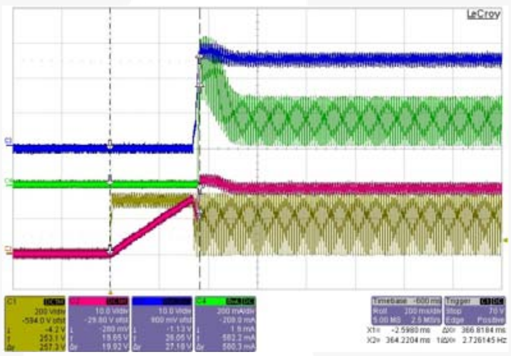

Figure 11. V_{IN} = 230 V_{AC} / 50 Hz

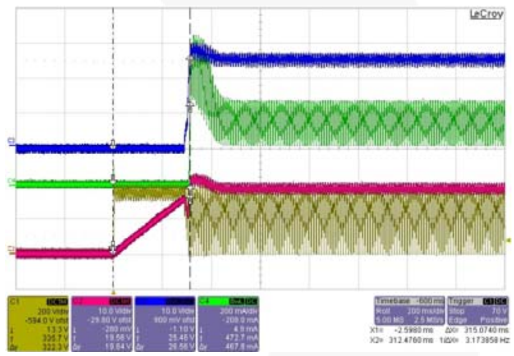

Figure 12. V_{IN} = 265 V_{AC} / 50 Hz

8.2. Operation Waveforms

Output current ripple is under 160 mAp-p with a rated output current of 350 mA. The results were measured by using actual 8-LED load. Operation Waveforms at 8-LED (24 V / 350 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

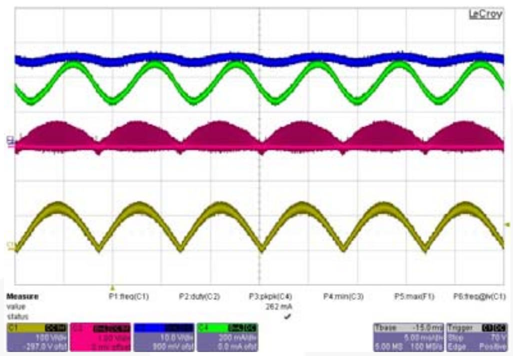

Figure 13. V_{IN} = 90 V_{AC} / 60 Hz

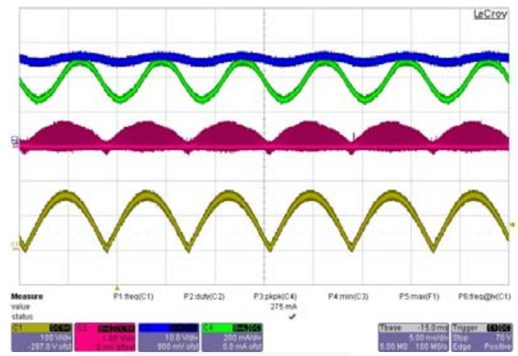

Figure 14. V_{IN} = 115 V_{AC} / 60 Hz

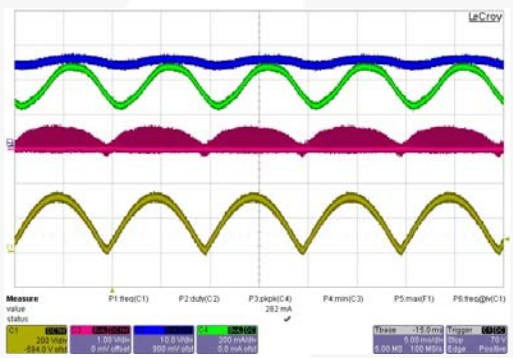

Figure 15. V_{IN} = 230 V_{AC} / 50 Hz

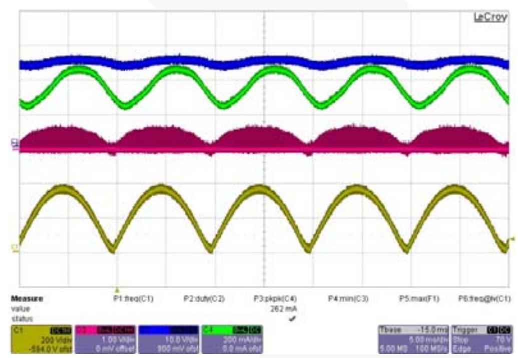

Figure 16. V_{IN} = 265 V_{AC} / 50 Hz

8.3. Constant-Current Regulation

Constant-current deviation in the wide output voltage range from 12 V to 24 V is less than ±1.93% at each line input voltage. Line regulation at the rated 6-LED is less than ±3.17%. The results were measured by using LED load.

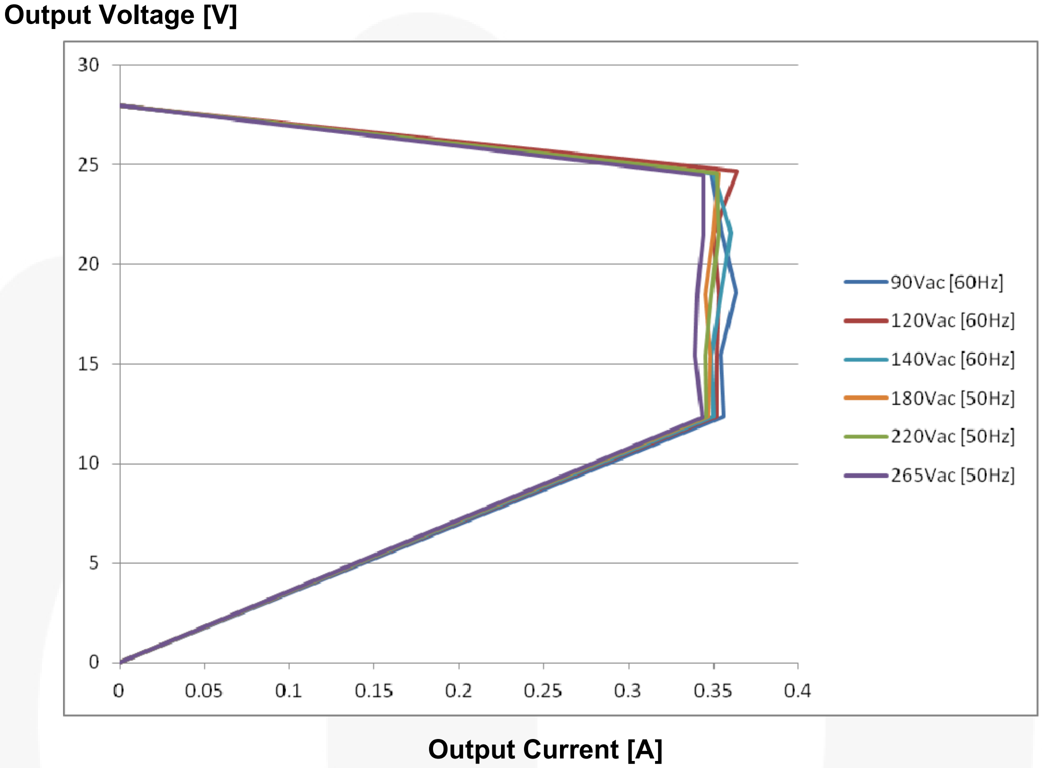

Figure 17. Constant Current Regulation, Measured by LED Load

Table 5. Constant Current Regulation by Output Voltage Change (12~24 V)

Input Voltage	Min. Current [A]	Max. Current [A]	Tolerance
90 V_{AC} / 60 Hz	0.349	0.363	±1.93%
120 V_{AC} / 60 Hz	0.350	0.364	±1.92%
140 V_{AC} / 60 Hz	0.349	0.360	±1.53%
180 V_{AC} / 50 Hz	0.345	0.353	±1.13%
220 V_{AC} / 50 Hz	0.345	0.353	±1.13%
265 V_{AC} / 50 Hz	0.339	0.344	±0.73%

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
24.5 V	0.349 A	0.364 A	0.350 A	0.353 A	0.352 A	0.344 A	±2.75%
21.5 V	0.355 A	0.350 A	0.360 A	0.350 A	0.353 A	0.344 A	±2.22%
18.5 V	0.363 A	0.353 A	0.354 A	0.345 A	0.349 A	0.340 A	±3.17%

8.4. Open / Short-LED Protections

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

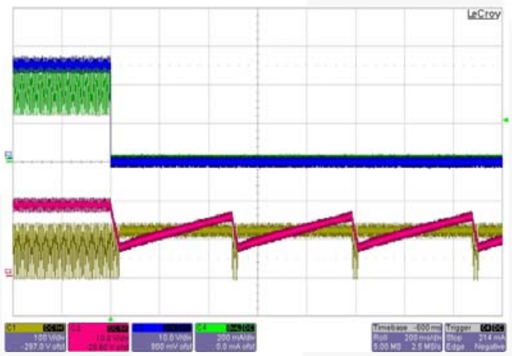

Figure 18. V_{IN} = 90 V_{AC} / 60 Hz

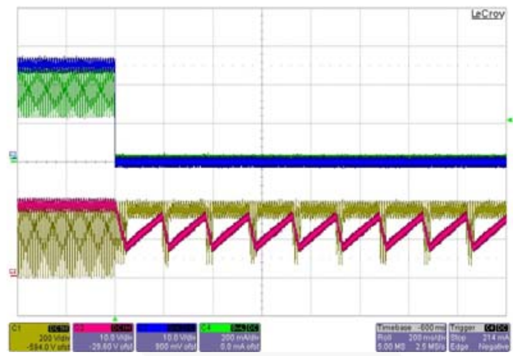

Figure 19. V_{IN} = 265 V_{AC} / 50 Hz

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. Open-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

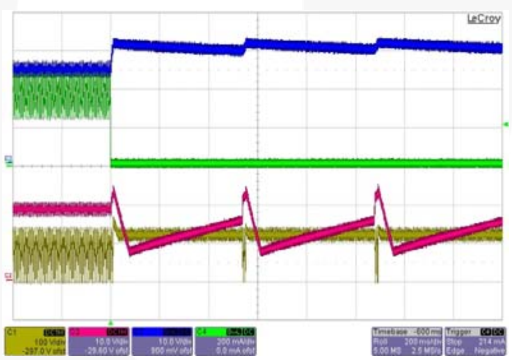

Figure 20. V_{IN} = 90 V_{AC} / 60 Hz

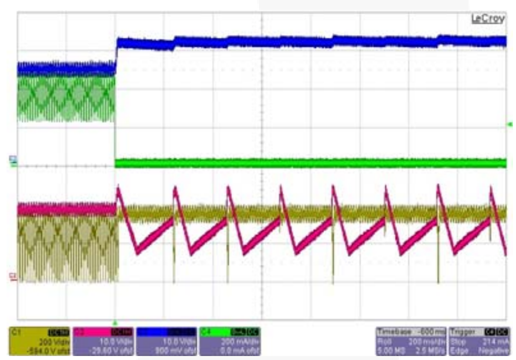

Figure 21. V_{IN} = 265 V_{AC} / 50 Hz

8.5. System Efficiency

The system efficiency is 87.51 ~ 89.59% in 90 ~ 265 V_{AC} input voltage range. The results were measured at 30 minutes after startup by using LED load.

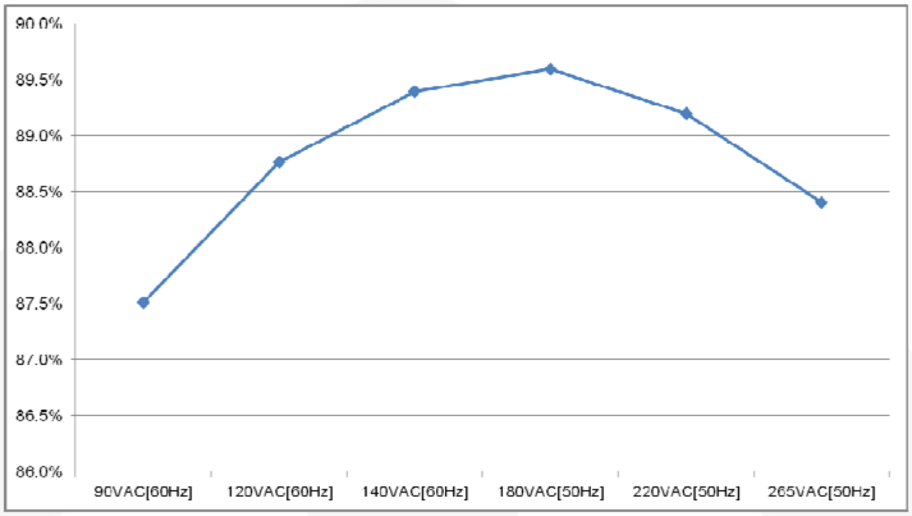

Figure 22. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90 V_{AC} [60 Hz]	9.935	0.354	24.56	8.694	87.51%
120 V_{AC} [60 Hz]	10.196	0.367	24.66	9.050	88.76%
140 V_{AC} [60 Hz]	9.663	0.352	24.54	8.638	89.39%
180 V_{AC} [50 Hz]	9.677	0.353	24.56	8.670	89.59%
220 V_{AC} [50 Hz]	9.708	0.353	24.53	8.659	89.20%
265 V_{AC} [50 Hz]	9.550	0.345	24.47	8.442	88.40%

8.6. Total Harmonic Discharge (THD)

FL7732 shows excellent THD performance. THD is less than 25% of the specification. Power Factor is very high; with enough margin from the 0.9 specification. The results were measured at 30 minutes after startup.

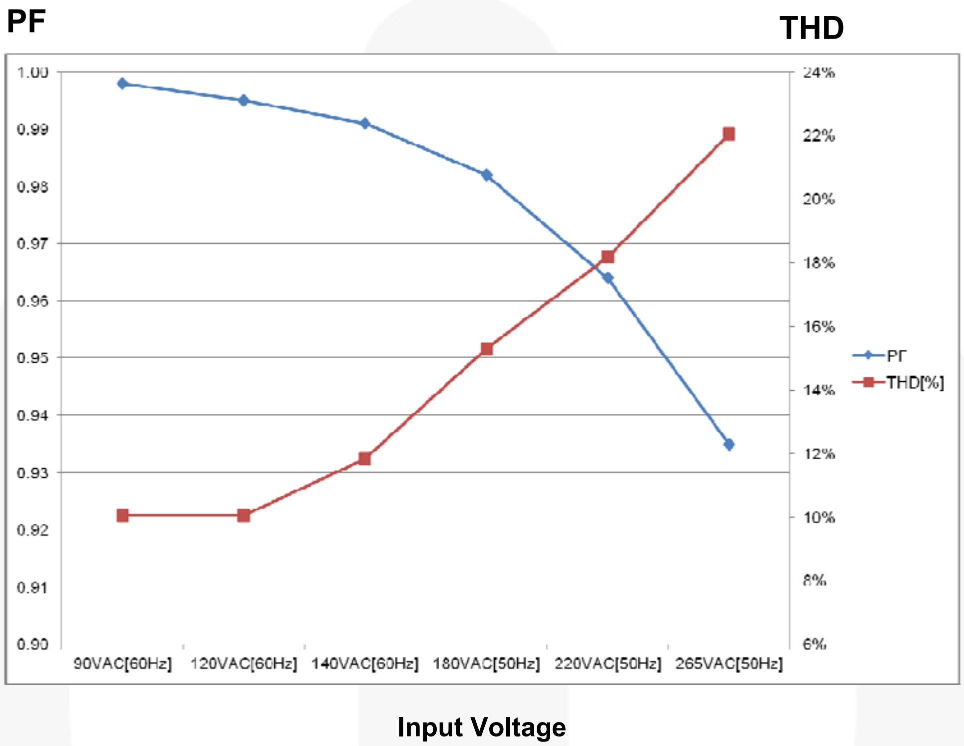

Figure 23. Power Factor and Total Harmonic Discharge

Table 8. Power Factor and Total Harmonic Discharge

Input Voltage	PF	THD
90 V_{AC} [60 Hz]	0.998	10.04%
120 V_{AC} [60 Hz]	0.995	10.04%
140 V_{AC} [60 Hz]	0.991	11.83%
180 V_{AC} [50 Hz]	0.982	15.29%
220 V_{AC} [50 Hz]	0.964	18.19%
265 V_{AC} [50 Hz]	0.935	22.05%

8.7. Operating Temperature

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

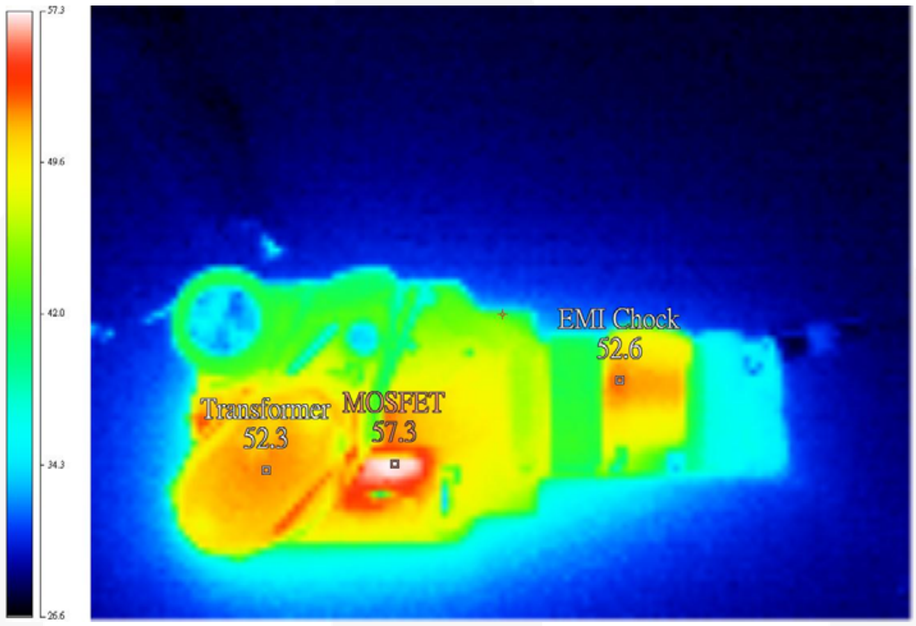

Figure 24. Board Temperature - Top View, V_{IN} [90 V_{AC}] I_{OUT} [350 mA]

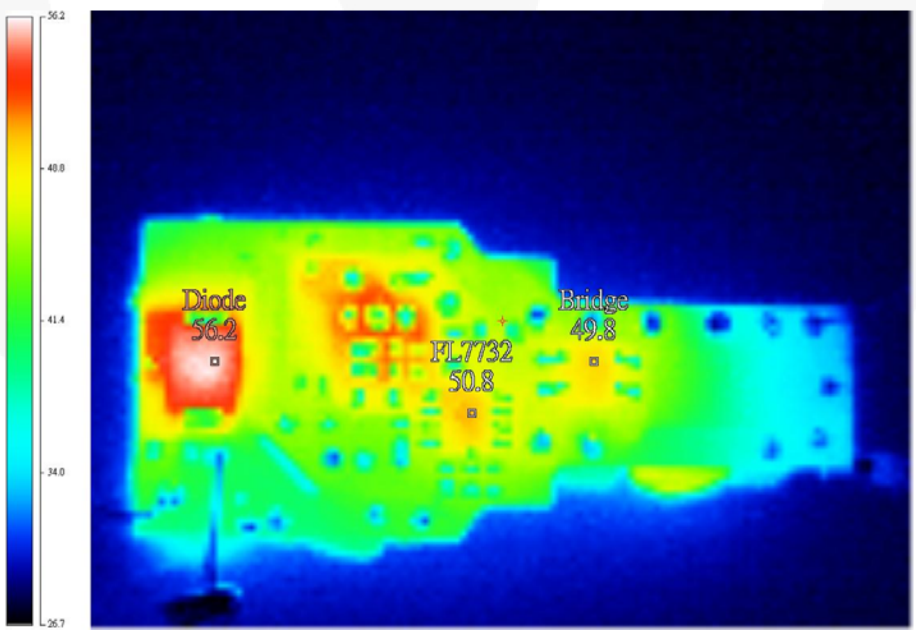

Figure 25. Board Temperature - Bottom View, V_{IN} [90 V_{AC}] I_{OUT} [350 mA]

8.8. Electromagnetic Interference (EMI)

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

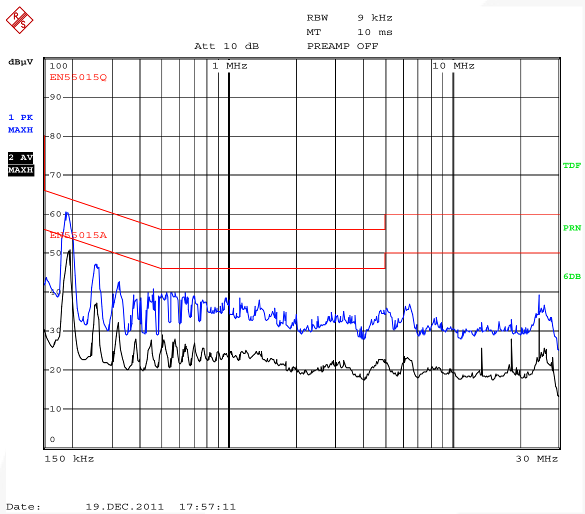

Figure 26. LIVE - V_{IN} = 115 V_{AC},V_{OUT} [24 V], I_{OUT} [350 mA]

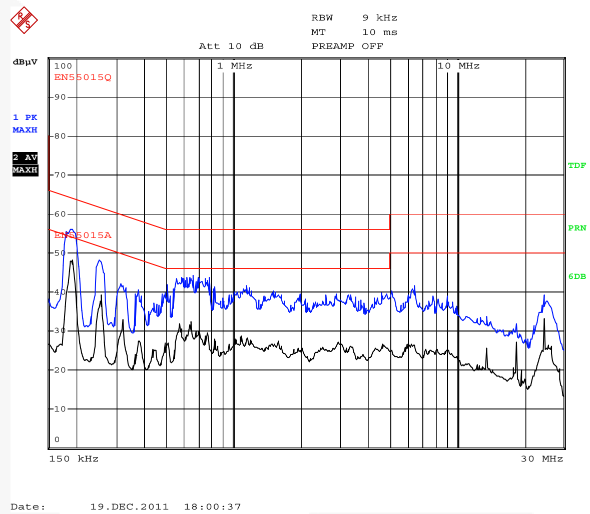

Figure 27. LIVE - V_{IN} = 230 V_{AC},V_{OUT} [24 V], I_{OUT} [350 mA]

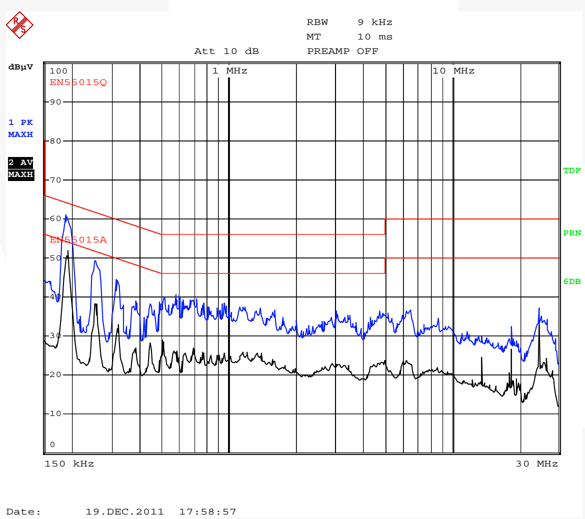

Figure 28. LIVE - V_{IN} = 115 V_{AC}, V_{OUT} [24 V], I_{OUT} [350 mA]

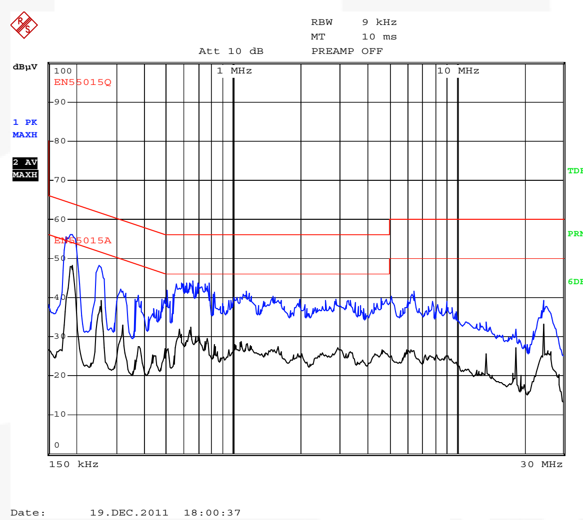

Figure 29. LIVE - V_{IN} = 230 V_{AC}, V_{OUT} [24 V], I_{OUT} [350 mA]

9. Revision History

Rev.	Date	Description
1.0.0	April 2012	Initial Release
1.1.0	June 2012	Manufacturer & Part number are added in BOM FL7732 is changed to FL7732MY_F116 (no frequency hopping) PF/THD at 50Hz is added EMI test result is updated
1.1.1	Sep. 2012	Modified, edited, formatted document. Changed User Guide number from FEB_L025 to FEBFL7732_L25U008B
1.1.2	Sep. 2012	Modified main title at page 1