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User Guide for

FEBFL7732_L26U017B

16.8 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

1. Introduction 3
   1.1. General Description of FL7732 3
   1.2. Features 3
   1.3. Internal Block Diagram 4
2. Specifications for Evaluation Board 5
3. Photographs 6
4. Printed Circuit Board 7
5. Schematic 8
6. Bill of Materials 9
7. Transformer Design 10
8. Performance of Evaluation Board 11
   8.1. Startup 12
   8.2. Operation Waveforms 13
   8.3. Constant-Current Regulation 14
   8.4. Short / Open-LED Protections 15
   8.5. Efficiency 16
   8.6. Power Factor (PF) & Total Harmonic Distortion (THD) 17
   8.7. Operating Temperature 18
   8.8. Electromagnetic Interference (EMI) 19
9. Revision History 20

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 Diver 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 700 mA at 24 V. 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

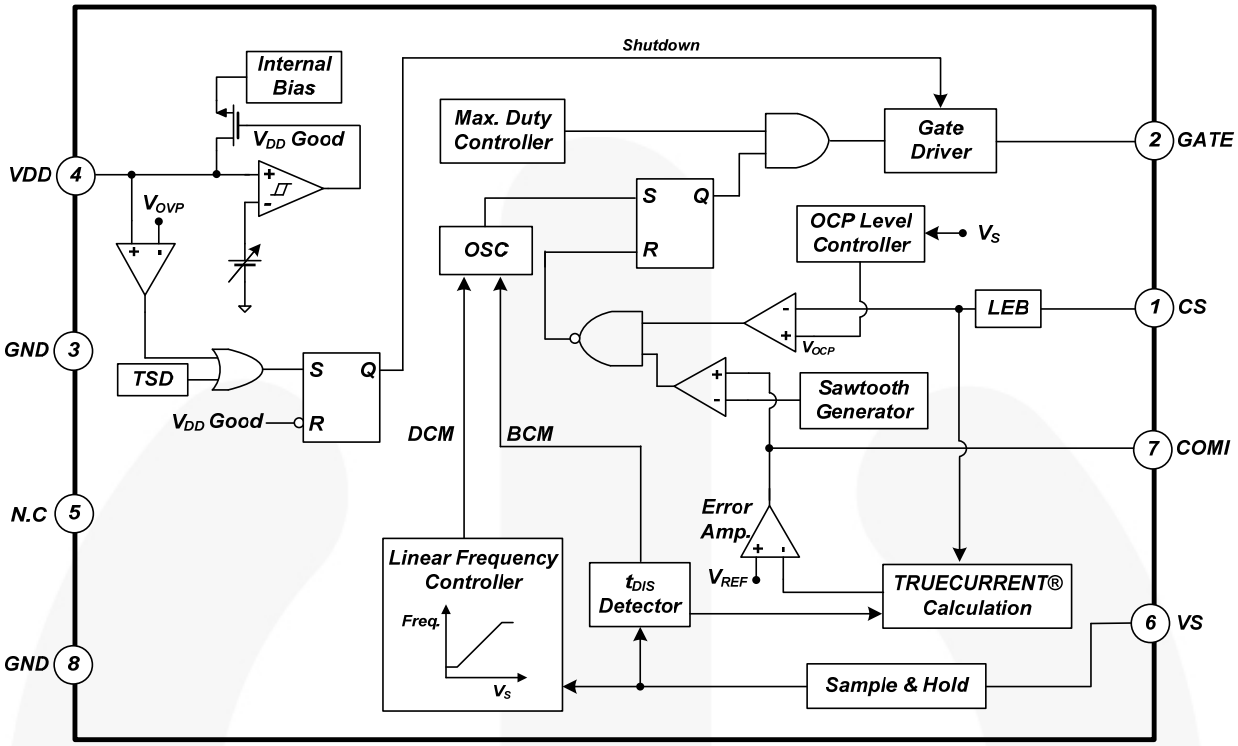

Figure 1. Block Diagram of FL7732

2. Specifications for Evaluation Board

Table 1. Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90 V_{AC}	Minimum Input Voltage
		$V_{IN.MAX}$	265 V_{AC}	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110 V / 220 V	Nominal Input Voltage
	Frequency	f_{IN}	60 Hz / 50 Hz	Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	11 V	Minimum Output Voltage
		$V_{OUT.MAX}$	28 V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	24 V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	700 mA	Nominal Output Current
		CC Deviation	< ±2.94%	Line Input Voltage Change: 90~265 V_{AC}
			< ±2.88%	Output Voltage Change: 11~28 V
Efficiency		Eff_{90VAC}	86.45%	Efficiency at 90 V_{AC} Line Input Voltage
		Eff_{120VAC}	88.45%	Efficiency at 120 V_{AC} Line Input Voltage
		Eff_{140VAC}	88.76%	Efficiency at 140 V_{AC} Line Input Voltage
		Eff_{180VAC}	89.03%	Efficiency at 180 V_{AC} Line Input Voltage
		Eff_{220VAC}	88.77%	Efficiency at 220 V_{AC} Line Input Voltage
		Eff_{265VAC}	87.87%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.984/15.29%	PF/THD at 90 V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.986/14.27%	PF/THD at 120 V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.984/13.61%	PF/THD at 140 V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.978/14.12%	PF/THD at 180 V_{AC} Line Input Voltage
		PF/THD_{230VAC}	0.955/17.69%	PF/THD at 230 V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.936/19.91%	PF/THD at 265 V_{AC} Line Input Voltage
Temperature	**FL7732**	T_{FL7732}	54.7ºC	Open-Frame Condition (T_A = 25ºC) FL7732 Temperature
	Primary MOSFET	T_{MOSFET}	63.0ºC	Primary MOSFET Temperature
	Secondary Diode	T_{DIODE}	70.5ºC	Secondary Diode Temperature
	Transformer	$T_{TRANSFORMER}$	59.7ºC	Transformer Temperature

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

3. Photographs

[Dimensions: 79 mm (L) x 30 mm (W) x 20 mm (H)]

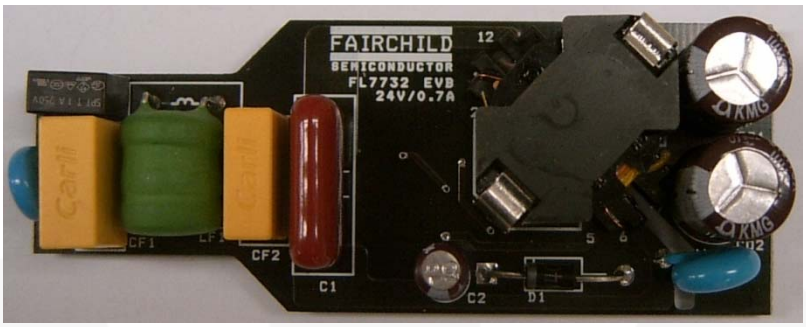

Figure 2. Top View

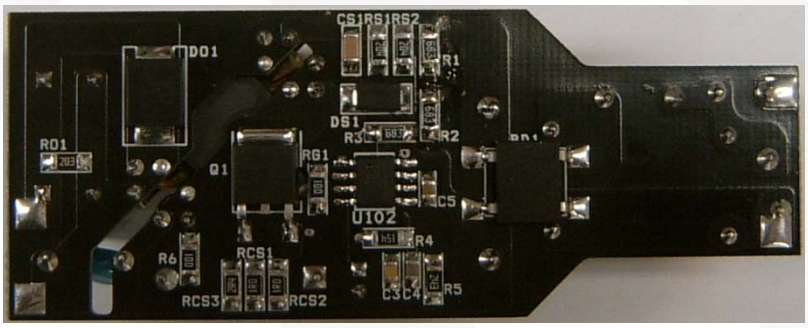

Figure 3. Bottom View

4. Printed Circuit Board

Unit: mm

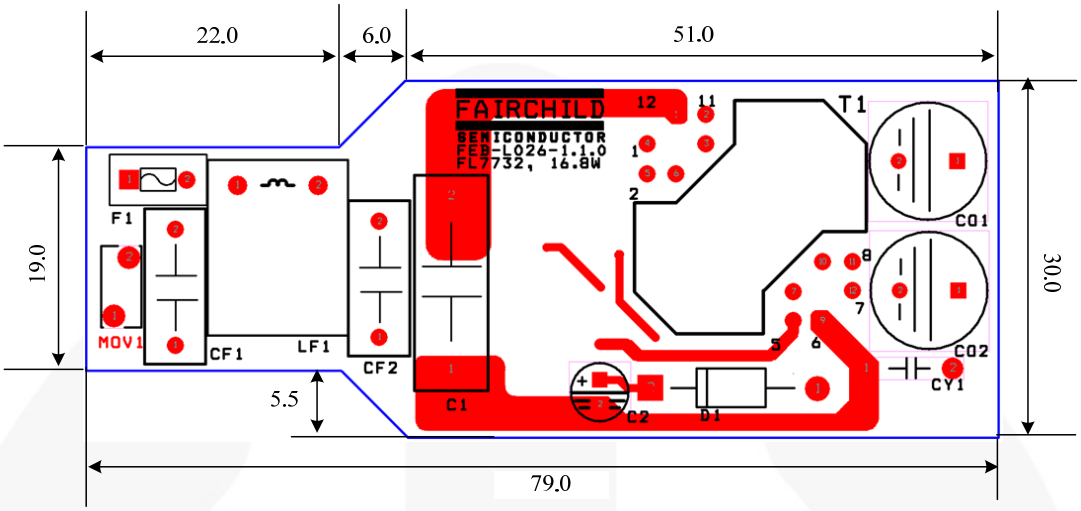

Figure 4. Top Pattern

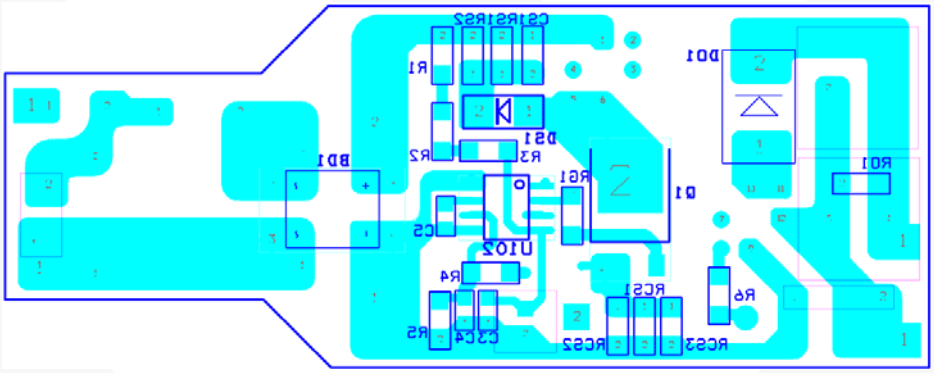

Figure 5. Bottom Pattern

5. Schematic

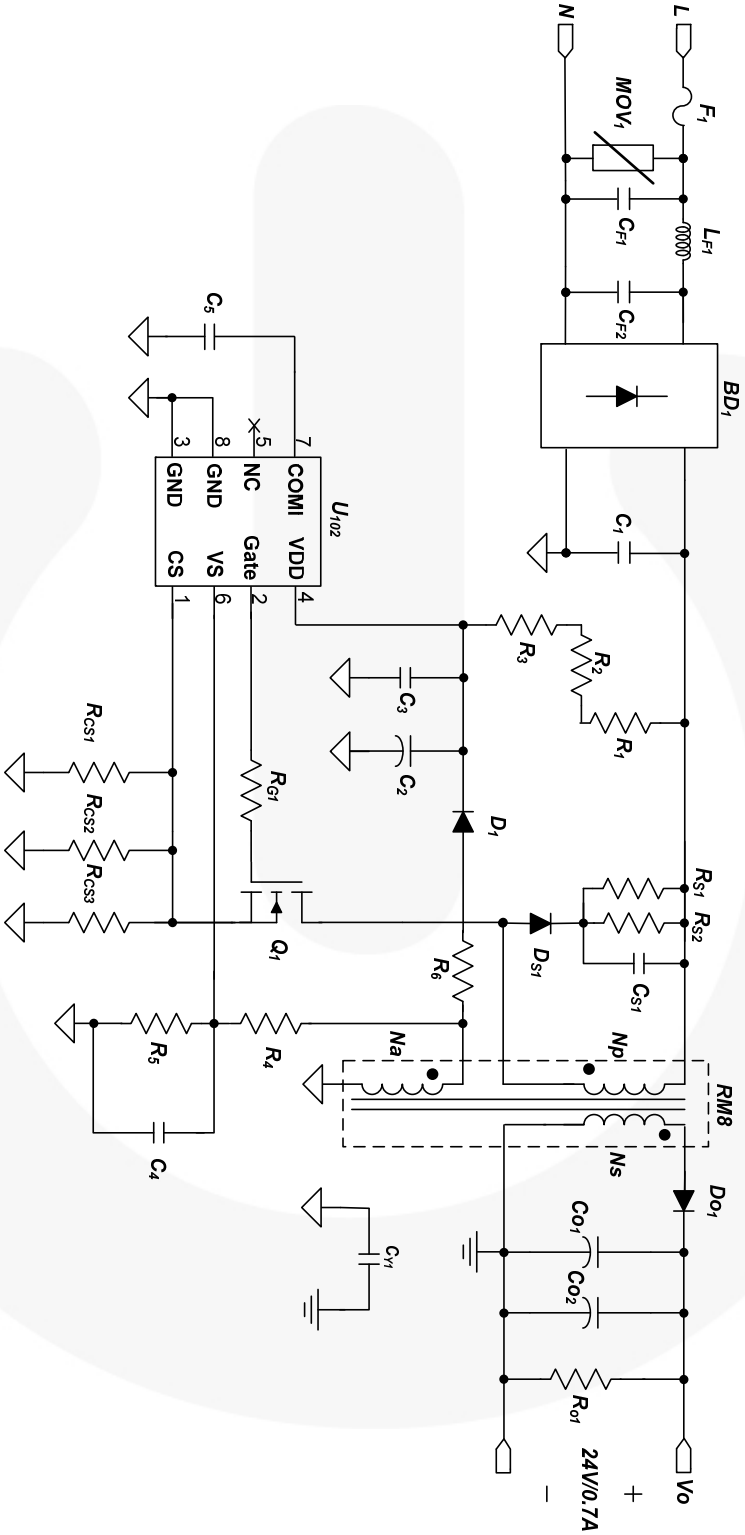

Figure 6. Schematic

6. 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	MPX AC275V 104 K	1	0.1 µF / 275 V_{AC} X-Capacitor	Carli
3	CF2	MPX AC275V 473 K	1	47 nF / 275 V_{AC} X-Capacitor	Carli
4	CS1	C1206C103KDRACTU	1	10 nF / 1 kV SMD Capacitor 3216	Kemet
5	CY1	SCFz2E472M10BW	1	4.7 nF / 250 V Y-Capacitor	Samwha
6	Co1, Co2	KMG 470 µF/35V	2	470 µF / 35 V Electrolytic Capacitor	Samyoung
7	C1	MPE 630V104K 14S	1	0.1 µF / 630 V MPE Film Capacitor	Sungho
8	C2	KMG 22 µF/50 V	1	22 µF / 35 V Electrolytic Capacitor	Samyoung
9	C3	C0805C104K5RACTU	1	0.1 µF / 50 V SMD Capacitor 2012	Kemet
10	C4	C0805C200J5GACTU	1	10 pF / 50 V SMD Capacitor 2012	Kemet
11	C5	C0805C225Z3VACTU	1	2.2 µF / 25 V SMD Capacitor 2012	Kemet
12	DS1	RS1M	1	1000 V / 1 A Ultra-Fast Recovery Diode	Fairchild Semiconductor
13	Do1	ES3D	1	200 V / 3 A, Fast Rectifier	Fairchild Semiconductor
14	D1	1N4003	1	200 V / 1 A, General Purpose Rectifier	Fairchild Semiconductor
15	F1	SS-5-1A	1	250 V / 1A Fuse	Bussmann
16	LF1	R10402KT00	1	4 mH Inductor, 10Ø	Bosung
17	MOV1	SVC 471 D-07A	1	Metal Oxide Varistor	Samwha
18	Q1	FDD5N60NZ	1	600 V / 4 A, N-Channel MOSFET	Fairchild Semiconductor
19	RG1, R6	RC1206JR-0710L	2	10 Ω SMD Resistor 3216	Yageo
20	RS1, RS2	RC1206JR-07100KL	2	100 kΩ SMD Resistor 3216	Yageo
21	Rcs1, Rcs2	RC1206JR-071RL	2	1 Ω SMD Resistor 3216	Yageo
22	Rcs3	RC1206JR-072R4L	1	2.4 Ω SMD Resistor 3216	Yageo
23	Ro1	RC1206JR-0720KL	1	20 kΩ SMD Resistor 3216	Yageo
24	R4	RC1206JR-07150KL	1	150 kΩ SMD Resistor 3216	Yageo
25	R1, R2, R3	RC1206JR-0768KL	3	68 kΩ SMD Resistor 3216	Yageo
26	R5	RC1206JR-0724KL	1	24 kΩ SMD Resistor 3216	Yageo
27	T1	RM8 Core	1	12-Pin, Transformer	TDK
28	U102	FL7732M_F116	1	Main PSR Controller	Fairchild Semiconductor

7. Transformer Design

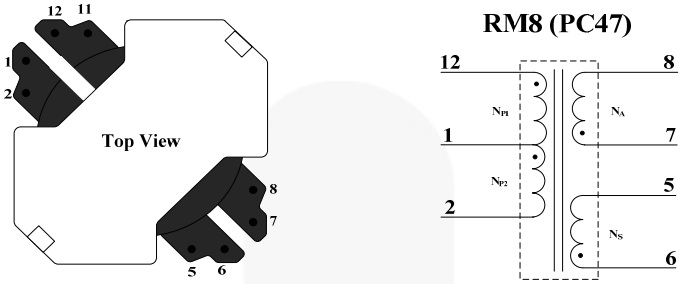

Figure 7. Transformer Bobbin Structure and Pin Configuration

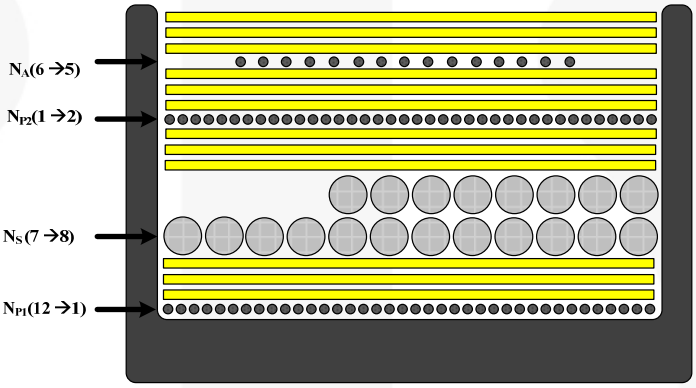

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	12 → 1	0.25φ	30 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	N_S	7 → 8	0.5φ (TIW)	20 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	N_{P2}	1 → 2	0.25φ	30 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
7	N_A	6 → 5	0.25φ	15 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specifications	Remark
Inductance	12–2	750 µH ±10%	60 kHz, 1 V
Leakage	12–2	6 µH	60 kHz, 1 V 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: 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-P03 (3W) by Everlight

8.1. Startup

Startup time is 890 ms (V_{IN} = 90 V_{AC}) ~ 362 ms (V_{IN} = 265 V_{AC}). The results were measured by using 7-LED load. Startup Time at 7-LED (24 V / 700 mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

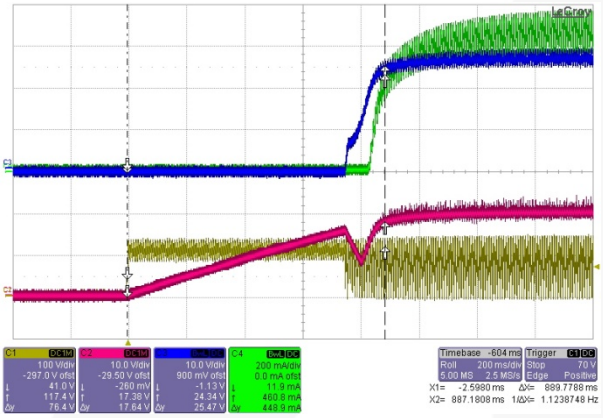

Figure 9. V_{IN} = 90 V_{AC} / 60 Hz

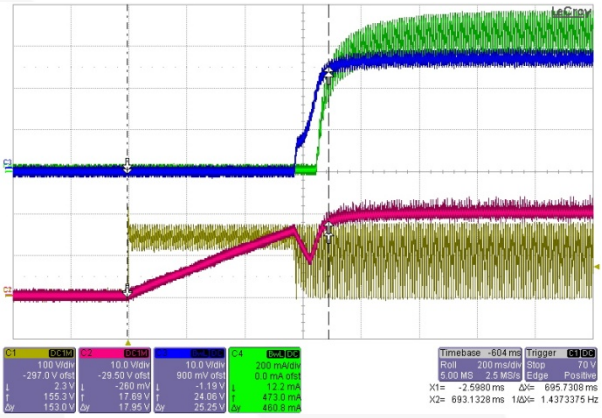

Figure 10. V_{IN} = 115 V_{AC} / 60 Hz

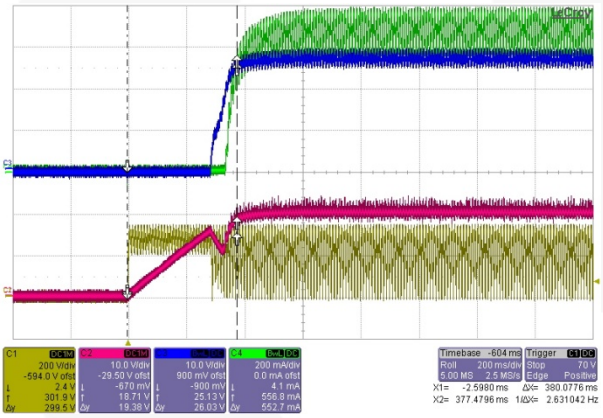

Figure 11. V_{IN} = 230 V_{AC} / 50 Hz

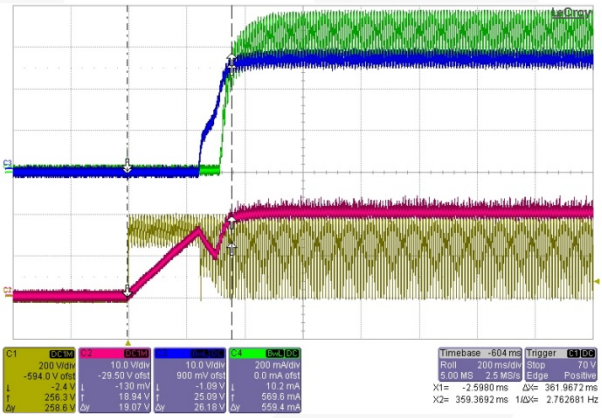

Figure 12. V_{IN} = 265 V_{AC} / 50 Hz

8.2. Operation Waveforms

Output current ripple is under 250 mAp-p with a rated output current of 700 mA. Operation Waveforms at 7-LED (24 V / 700 mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

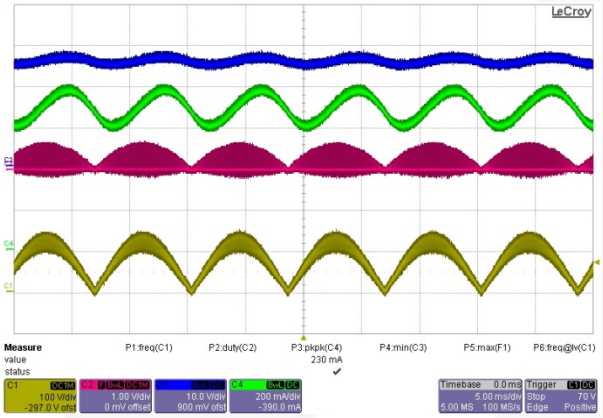

Figure 13. V_{IN} = 90 V_{AC} / 60 Hz

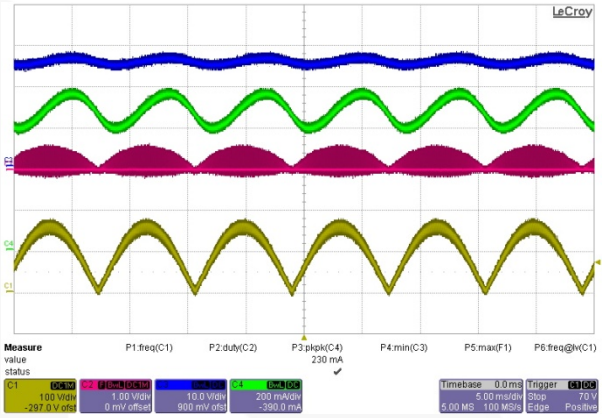

Figure 14. V_{IN} = 115 V_{AC} / 60 Hz

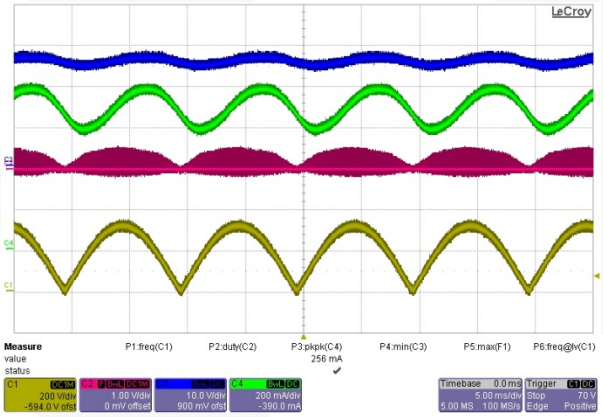

Figure 15. V_{IN} = 230 V_{AC} / 50 Hz

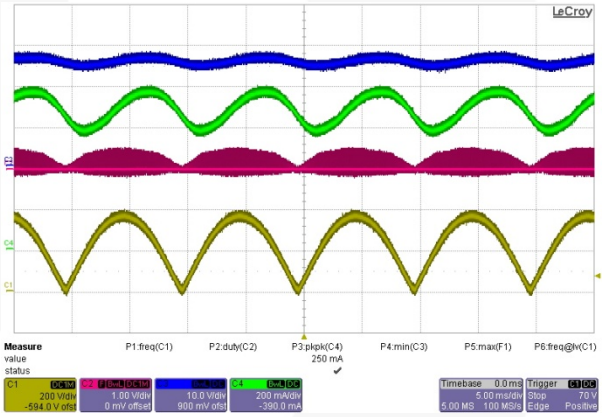

Figure 16. V_{IN} = 265 V_{AC} / 50 Hz

8.3. Constant-Current Regulation

Constant current deviation in the wide output voltage range from 11 V to 28 V is less than 2.88% at each line input voltage. Line regulation at the rated output voltage (24 V) is less than 2.80%. The results were measured with E-load [CR Mode].

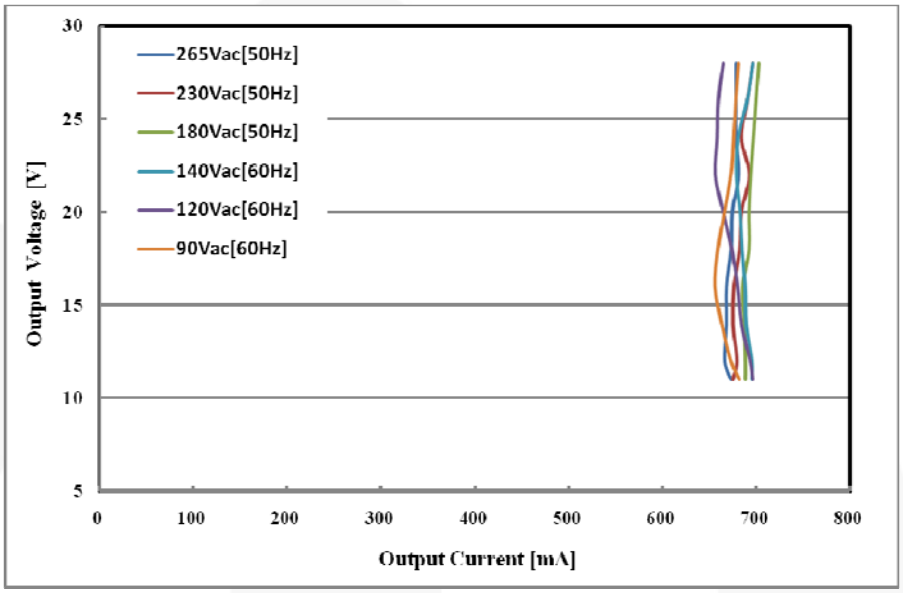

Figure 17. Constant-Current Regulation, Measured by E-Load [CR Mode]

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

Input Voltage	Min. Current [mA]	Max. Current [mA]	Tolerance
90 V_{AC} [60 Hz]	656	682	±1.94%
120 V_{AC} [60 Hz]	657	696	±2.88%
140 V_{AC} [60 Hz]	679	696	±1.24%
180 V_{AC} [50 Hz]	685	703	±1.30%
230 V_{AC} [50 Hz]	675	696	±1.53%
265 V_{AC} [50 Hz]	666	681	±1.11%

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
26 V	678 mA	660 mA	681 mA	700 mA	690 mA	678 mA	±2.94%
24 V	676 mA	659 mA	679 mA	697 mA	684 mA	678 mA	±2.80%
22 V	673 mA	657 mA	683 mA	694 mA	692 mA	681 mA	±2.74%

8.4. Short / Open-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 with actual rated LED loads. Short-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

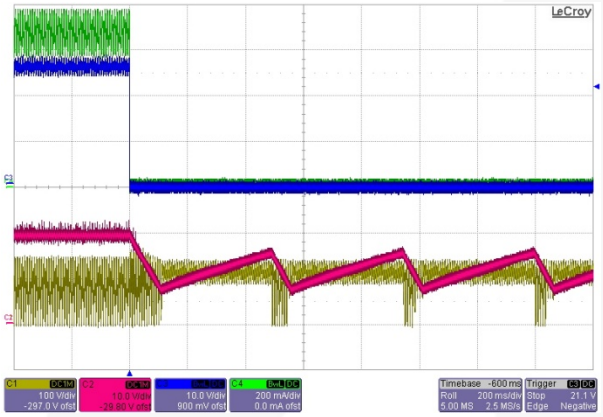

Figure 18. V_{IN} = 90 V_{AC} / 60 Hz

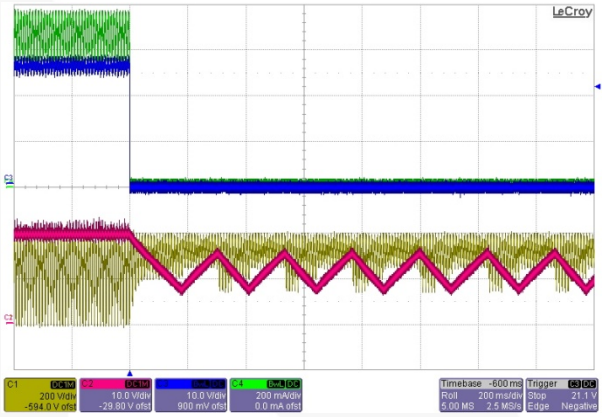

Figure 19. V_{IN} = 265 V_{AC} / 50 Hz

In open-LED condition, output voltage is limited ~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}].

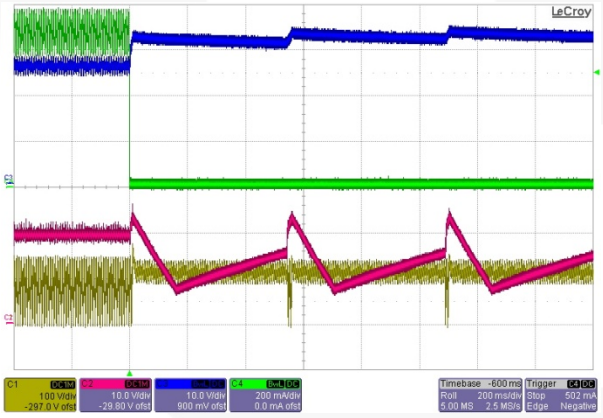

Figure 20. V_{IN} = 90 V_{AC} / 60 Hz

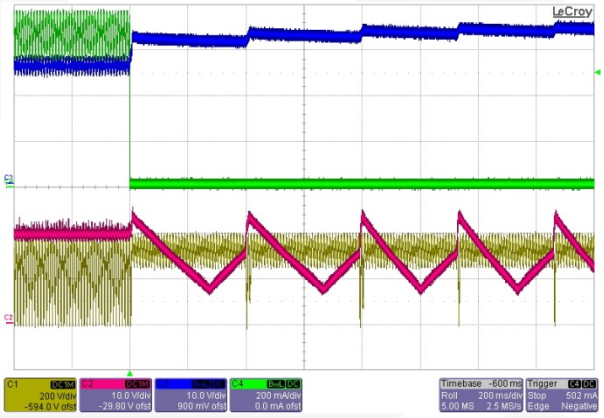

Figure 21. V_{IN} = 265 V_{AC} / 50 Hz

8.5. Efficiency

System efficiency is 86.45% ~ 89.03% in 90 ~ 265 V_{AC} input voltage range. The results were measured with actual rated LED loads at 30 minutes after startup.

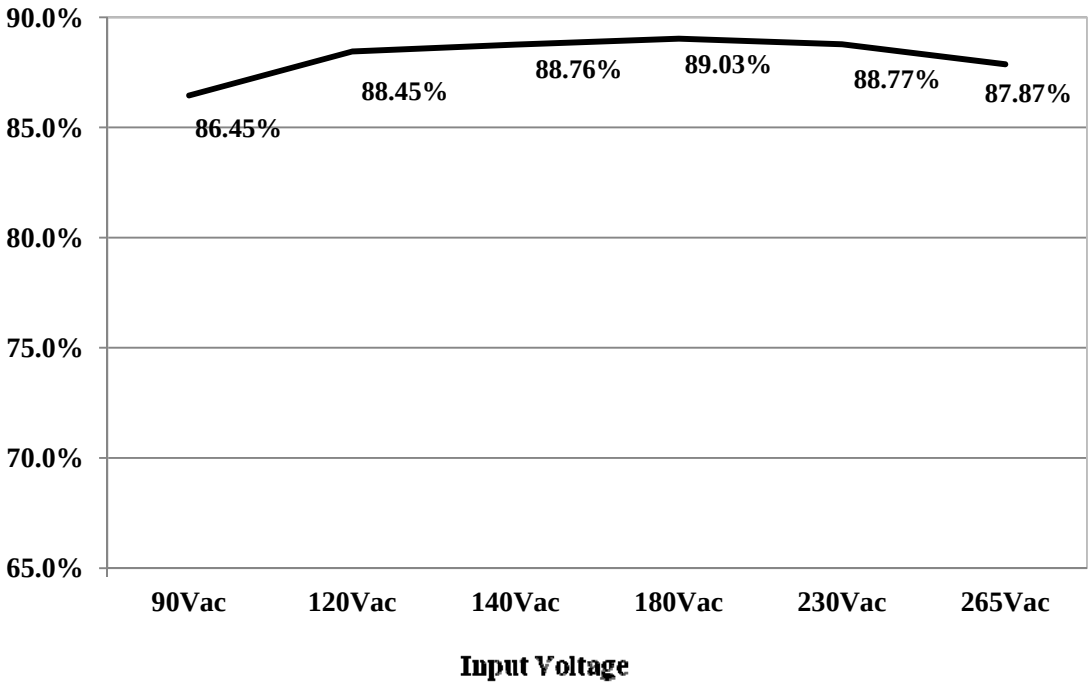

Figure 22. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90 V_{AC} [60 Hz]	18.91	0.678	24.10	16.35	86.45%
120 V_{AC} [60 Hz]	18.02	0.663	24.04	15.94	88.45%
140 V_{AC} [60 Hz]	18.78	0.687	24.27	16.67	88.76%
180 V_{AC} [50 Hz]	19.31	0.704	24.43	17.19	89.03%
220 V_{AC} [50 Hz]	18.99	0.693	24.34	16.86	88.77%
265 V_{AC} [50 Hz]	19.05	0.689	24.28	16.74	87.87%

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

FL7732 shows excellent THD performance. THD is much less than 30% specification. The results were measured with actual rated LED loads at 30 minutes after startup.

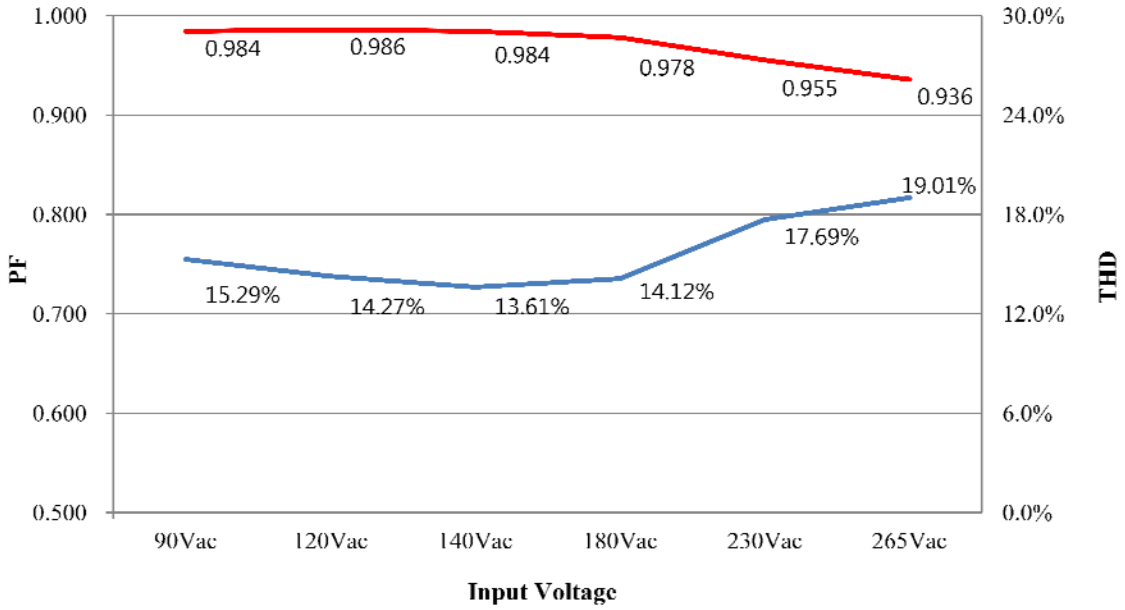

Figure 23. Power Factor & Total Harmonic Distortion

Table 8. Power Factor & Total Harmonic Distortion

Input Voltage	Output Current	Output Voltage	Power Factor	THD
90 V_{AC} [60 Hz]	0.678 A	24.10 V	0.98	15.29%
120 V_{AC} [60 Hz]	0.663 A	24.04 V	0.99	14.27%
140 V_{AC} [60 Hz]	0.687 A	24.27 V	0.98	13.61%
180 V_{AC} [50 Hz]	0.704 A	24.43 V	0.98	14.12%
220 V_{AC} [50 Hz]	0.693 A	24.34 V	0.96	17.69%
265 V_{AC} [50 Hz]	0.689 A	24.28 V	0.94	19.01%

8.7. Operating Temperature

Temperature of the all components on this board is less than 71 ºC.
The results were measured with actual rated LED loads at 30 minutes after startup.

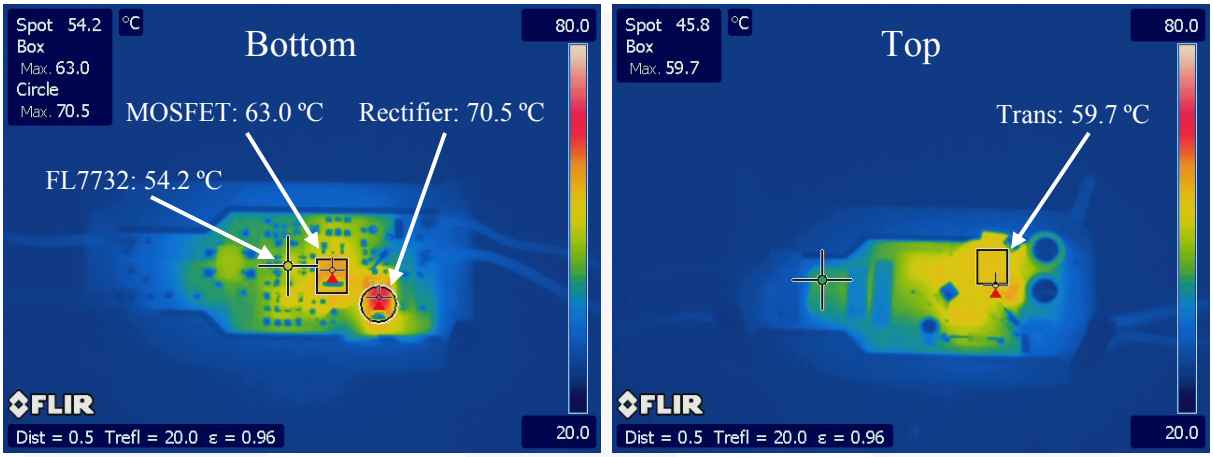

Figure 24. Board Temperature - V_{IN}[90 V_{AC}]

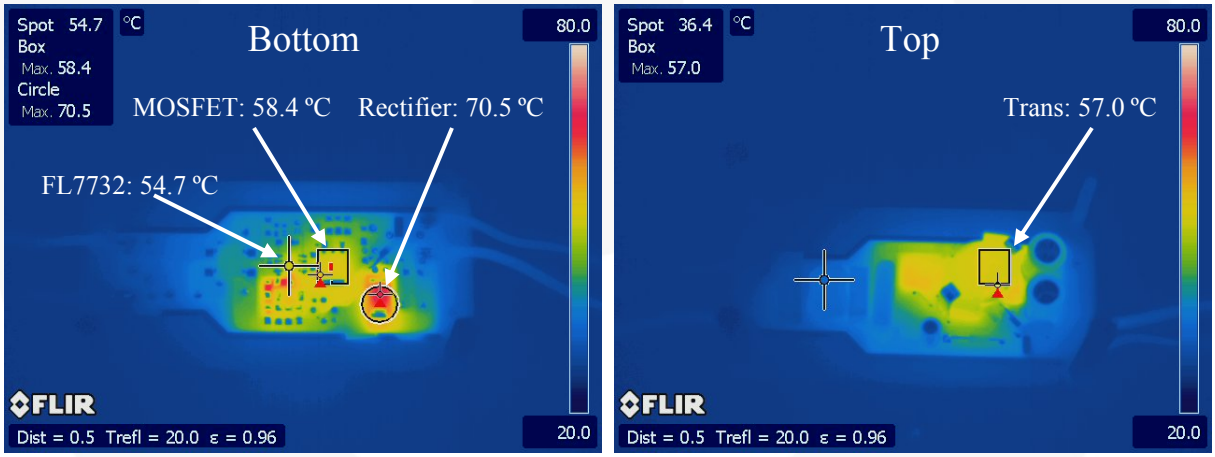

Figure 25. Board Temperature - V_{IN}[265 V_{AC}]

8.8. Electromagnetic Interference (EMI)

The all measurement was conducted in observance of EN55022 criteria.
The results were measured with actual rated LED loads at 30 minutes after startup.

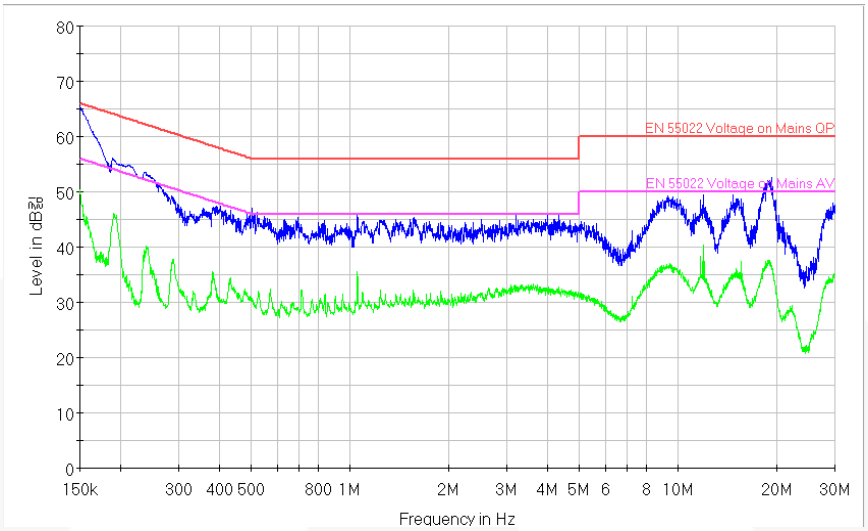

Figure 26. V_{IN} [110 V_{AC}, LIVE]

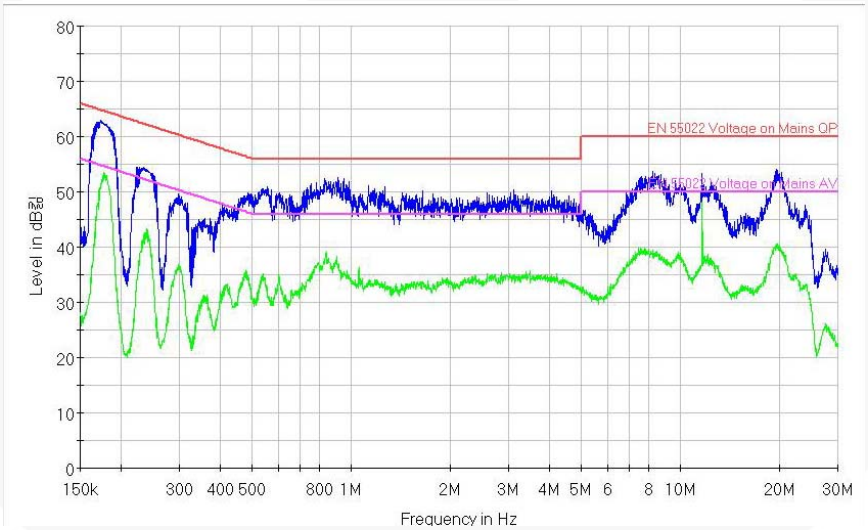

Figure 27. V_{IN} [220 V_{AC}, LIVE]

9. Revision History

Rev.	Date	Description
1.0.0	Apr. 2012	Initial Release
1.1.0	Jun. 2012	Manufacturer & Part number are added in BOM FL7732 is changed to FL7732MY_F116 (no frequency hopping) PF/THD at 50 Hz is added EMI test result is updated
1.1.1	Sep. 2012	Modified, edited, formatted document. Changed User Guide number from FEB-L026 to FEBFL7732_L26U017B
1.1.2	Apr. 2013	Changed the title (8.5 section)
1.1.3	Jun. 2013	Updated.

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