User Guide for

FEB-L026 Evaluation Board

Universal Line Voltage LED Ballast

Featured Fairchild Product: FL7732

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

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 ballast using the FL7732 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 700mA at $24V_{MAX}$. 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 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: 20µA
- Low Operating Current: 5mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8

1.3. Internal Block Diagram

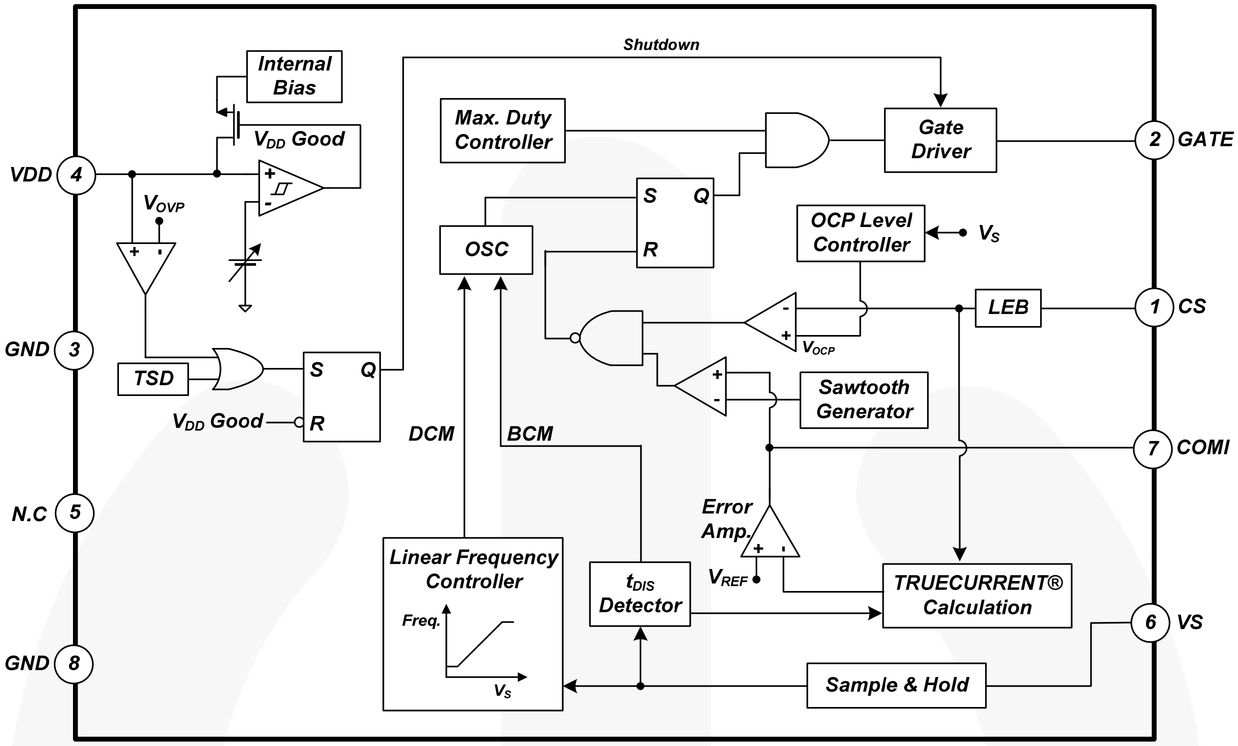

Figure 1. Block Diagram of FL7732

2. Specifications for Evaluation Board

Table 1. Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	Voltage	$V_{IN.MIN}$	90V	Minimum Input Voltage
		$V_{IN.MAX}$	265V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110V/220V	Nominal Input Voltage
	Frequency	f_{IN}	60Hz/50Hz	Line Frequency
Output	Voltage	$V_{OUT.MIN}$	11V	Minimum Output Voltage
		$V_{OUT.MAX}$	28V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	24V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	700mA	Nominal Output Current
		CC Deviation	< ±2.94%	Line Input Voltage Change: 90~265V_{AC}
			< ±2.88%	Output Voltage Change: 11~28V
Efficiency		Eff_{90VAC}	86.45%	Efficiency at 90V_{AC} Line Input Voltage
		Eff_{120VAC}	88.45%	Efficiency at 120V_{AC} Line Input Voltage
		Eff_{140VAC}	88.76%	Efficiency at 140V_{AC} Line Input Voltage
		Eff_{180VAC}	89.03%	Efficiency at 180V_{AC} Line Input Voltage
		Eff_{220VAC}	88.77%	Efficiency at 220V_{AC} Line Input Voltage
		Eff_{265VAC}	87.87%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.984/15.29%	PF/THD at 90V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.986/14.27%	PF/THD at 120V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.984/13.61%	PF/THD at 140V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.978/14.12%	PF/THD at 180V_{AC} Line Input Voltage
		PF/THD_{230VAC}	0.955/17.69%	PF/THD at 230V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.936/19.91%	PF/THD at 265V_{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.

2.1. Evaluation Board

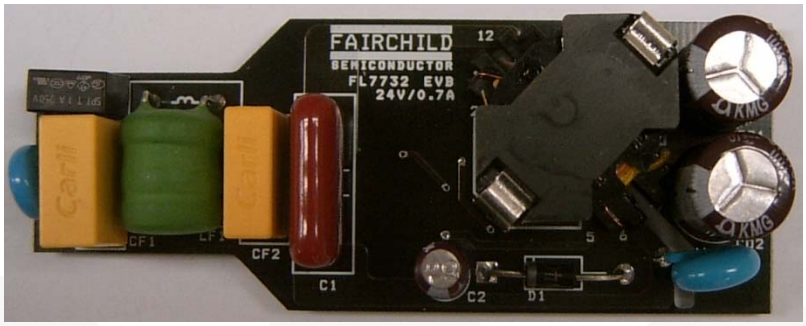

Figure 2. Top View (Dimensions:79mm (L) x 30mm (W) x 20mm (H))

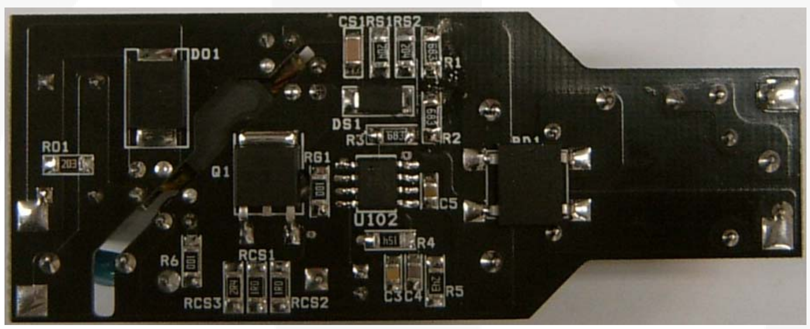

Figure 3. Bottom Views (Dimensions:79mm (L) x 30mm (W) x 20mm (H))

2.2. Printed Circuit Board

Dimension: mm

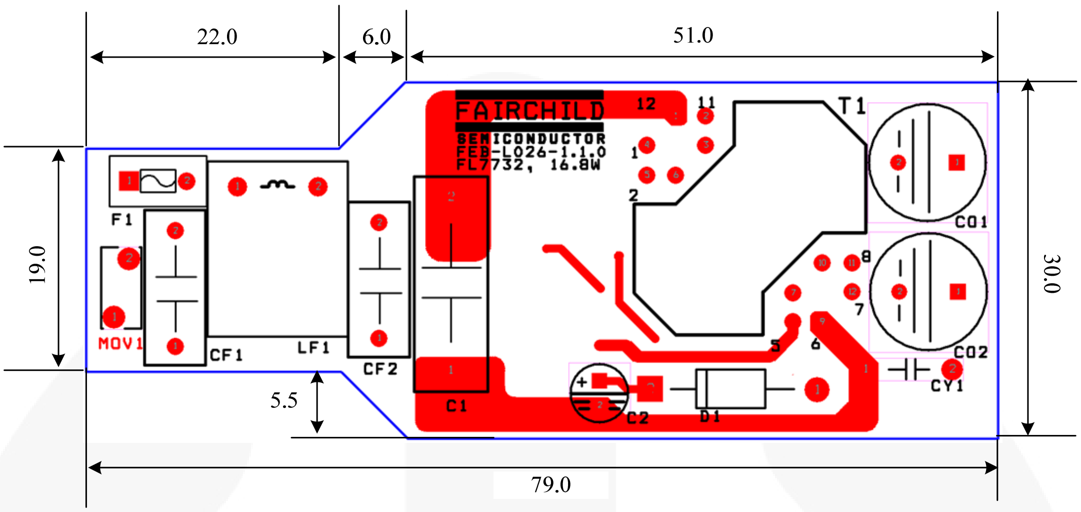

Figure 4. Top Pattern

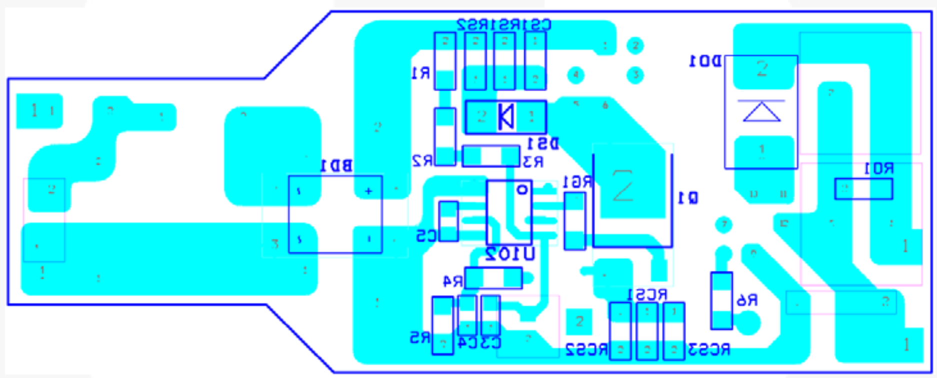

Figure 5. Bottom Pattern

2.3. Schematic of the Evaluation Board

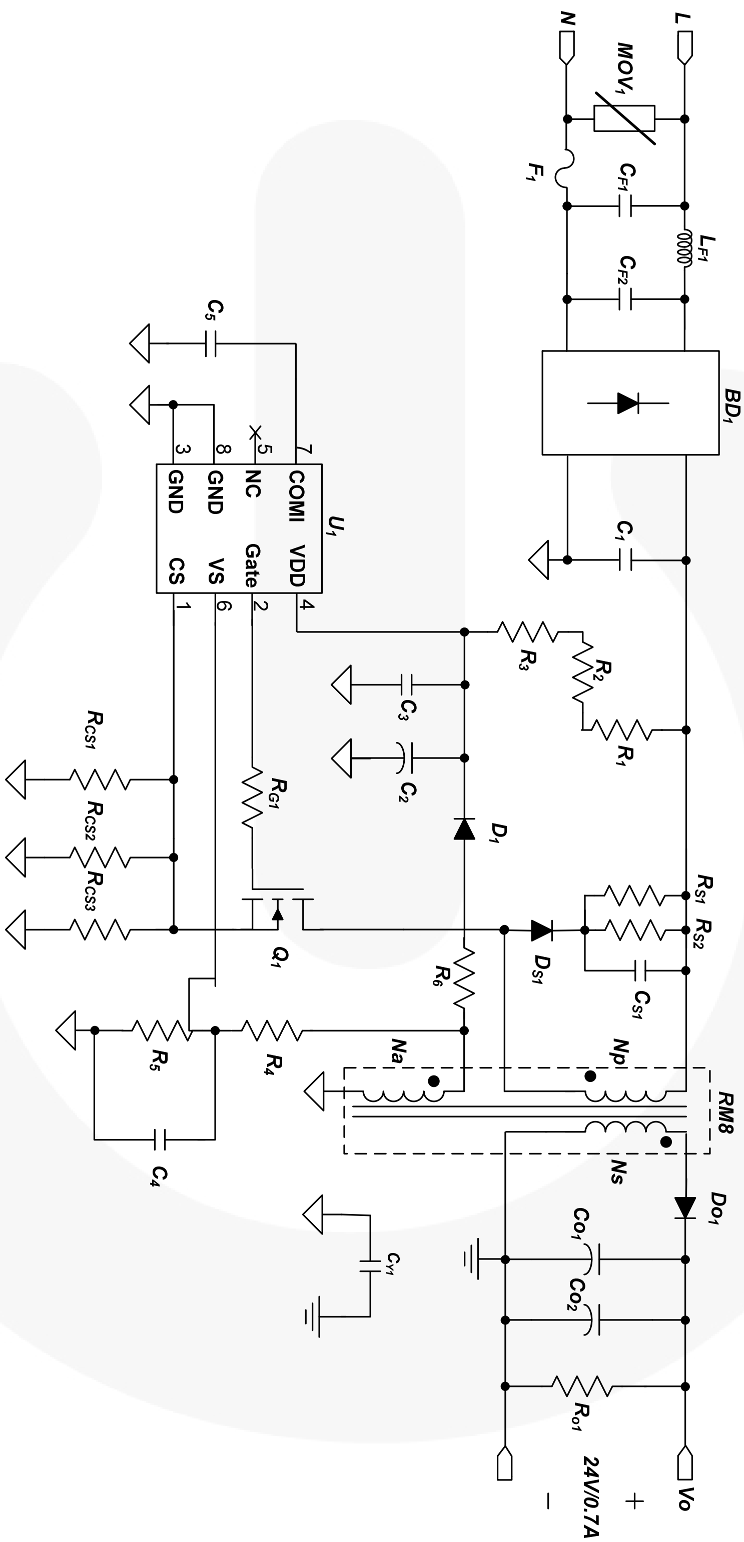

Figure 6. Schematic

2.4. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	BD1	DF06S	1	1.5A/600V Bridge Diode	Fairchild Semiconductor
2	CF1	MPX AC275V 104K	1	104/AC275V X-Capacitor	Carli
3	CF2	MPX AC275V 473K	1	473/AC275V X-Capacitor	Carli
4	CS1	C1206C103KDRACTU	1	103/1kV SMD Capacitor 3216	Kemet
5	CY1	SCFz2E472M10BW	1	472/250V Y-Capacitor	Samwha
6	Co1, Co2	KMG 470µF/35V	2	470µF/35V Electrolytic Capacitor	Samyoung
7	C1	MPE 630V104K 14S	1	104/630V MPE Film Capacitor	Sungho
8	C2	KMG 22µF/50V	1	22µF/35V Electrolytic Capacitor	Samyoung
9	C3	C0805C104K5RACTU	1	104/50V SMD Capacitor 2012	Kemet
10	C4	C0805C200J5GACTU	1	200/50V SMD Capacitor 2012	Kemet
11	C5	C0805C225Z3VACTU	1	225/25V SMD Capacitor 2012	Kemet
12	DS1	RS1M	1	1000V/1A Ultra-Fast Recovery Diode	Fairchild Semiconductor
13	Do1	ES3D	1	200V/3A, Fast Rectifier	Fairchild Semiconductor
14	D1	1N4003	1	200V/1A, General Purpose Rectifier	Fairchild Semiconductor
15	F1	SS-5-1A	1	250V/1A Fuse	Bussmann
16	LF1	R10402KT00	1	4mH Inductor, 10Ø	Bosung
17	MOV1	SVC 471 D-07A	1	Metal Oxide Varistor	Samwha
18	Q1	FDD5N60NZ	1	600V/4A, N-Channel MOSFET	Fairchild Semiconductor
19	RG1, R6	RC1206JR-0710L	2	10Ω SMD Resistor 3216	Yageo
20	RS1, RS2	RC1206JR-07100KL	2	100kΩ SMD Resistor 3216	Yageo
21	Rcs1, Rcs2	RC1206JR-071RL	2	1Ω SMD Resistor 3216	Yageo
22	Rcs3	RC1206JR-072R4L	1	2.4Ω SMD Resistor 3216	Yageo
23	Ro1	RC1206JR-0720KL	1	20KΩ SMD Resistor 3216	Yageo
24	R4	RC1206JR-07150KL	1	150KΩ SMD Resistor 3216	Yageo
25	R1, R2, R3	RC1206JR-0768KL	3	68KΩ SMD Resistor 3216	Yageo
26	R5	RC1206JR-0724KL	1	24KΩ SMD Resistor 3216	Yageo
27	T1	RM8 Core	1	12-Pin, Transformer	TDK
28	U1	FL7732M_F116	1	Main PSR Controller	Fairchild Semiconductor

2.5. Transformer Design

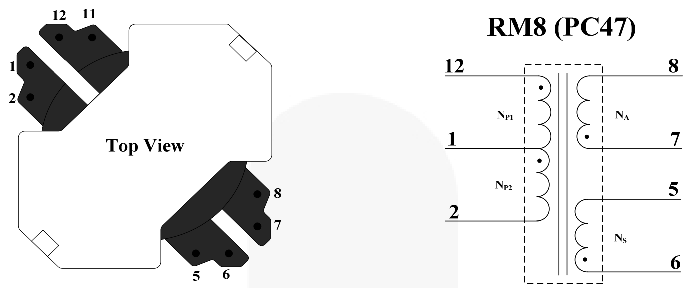

Figure 7. Transformer Bobbin Structure and Pin Configuration

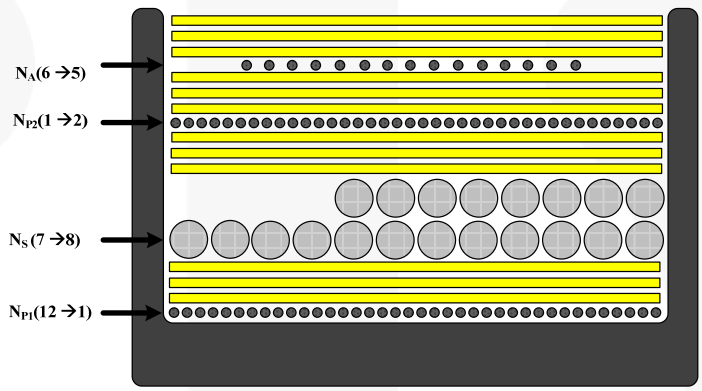

Figure 8. Transformer Winding Structure

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 = 0.025mm, 3-Layer				
3	N_S	7 → 8	0.5φ (TIW)	20 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
5	N_{P2}	1 → 2	0.25φ	30 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
7	N_A	6 → 5	0.25φ	15 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specifications	Remark
Inductance	12–2	750µH ±10%	60kHz, 1V
Leakage	12–2	6µH	60kHz, 1V Short All Output Pins

3. 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

3.1. Startup

Startup time is 890ms (V_{IN} = $90V_{AC}$) ~ 362ms (V_{IN} = $265V_{AC}$). The results were measured by using 7-LED load. Startup Time at 7-LED (25V/700mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

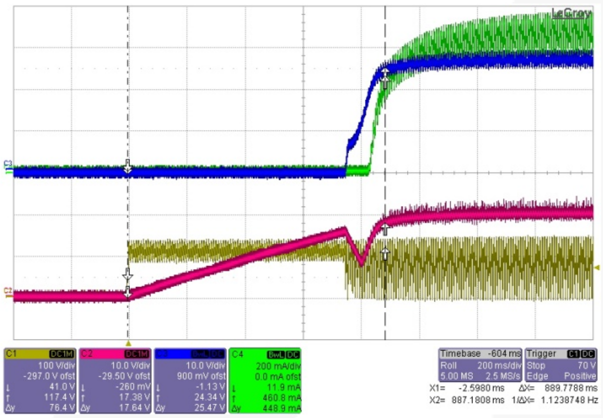

Figure 9. V_{IN} = $90V_{AC}$ / 60Hz

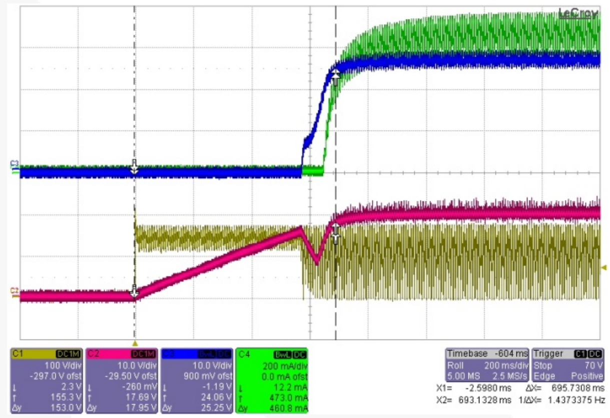

Figure 10. V_{IN} = $115V_{AC}$ / 60Hz

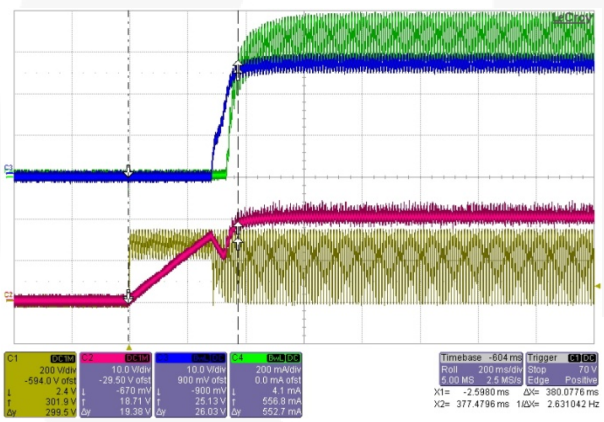

Figure 11. V_{IN} = $230V_{AC}$ / 50Hz

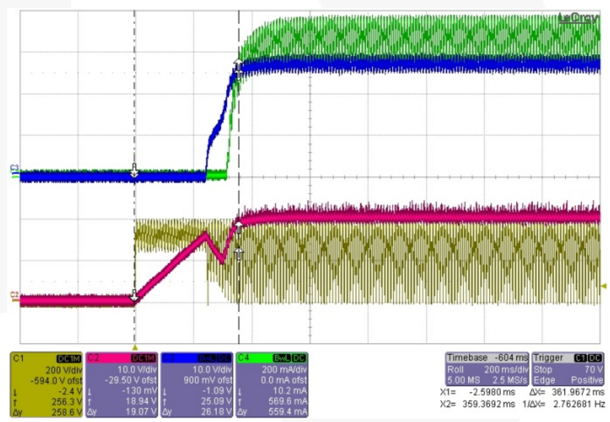

Figure 12. V_{IN} = $265V_{AC}$ / 50Hz

3.2. Operation Waveforms

Output current ripple is under 250mAp-p with a rated output current of 700mA. Operation Waveforms at 7-LED (25V/700mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

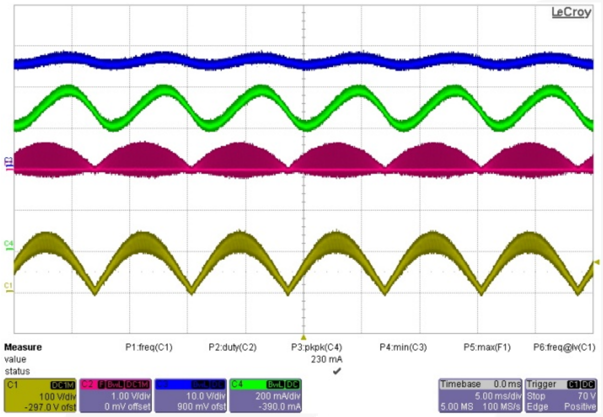

Figure 13. V_{IN} = 90V_{AC} / 60Hz

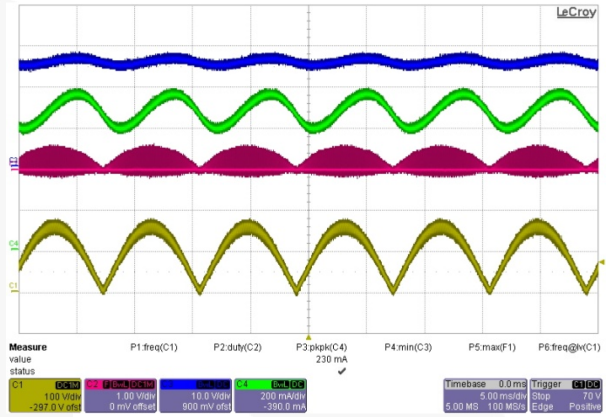

Figure 14. V_{IN} = 115V_{AC} / 60Hz

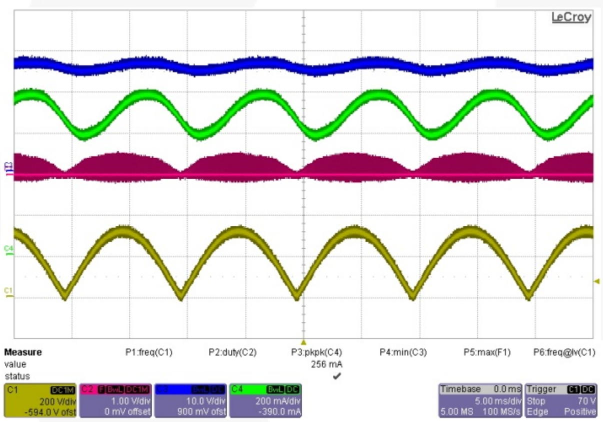

Figure 15. V_{IN} = 230V_{AC} / 50Hz

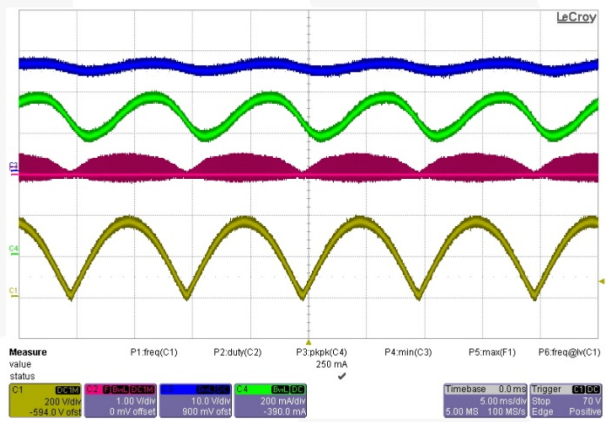

Figure 16. V_{IN} = 265V_{AC} / 50Hz

3.3. Constant-Current Regulation

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

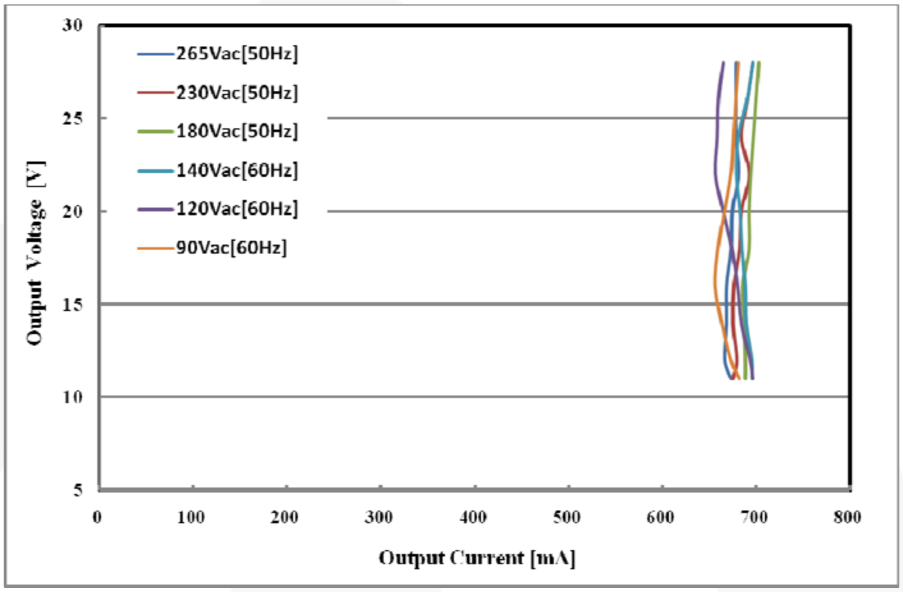

Figure 17. Constant-Current Regulation, Measured by E-Load [CR Mode]

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

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

Table 6. Constant-Current Regulation by Line Voltage Change (90~265V_{AC})

Output Voltage	$90V_{AC}$ [60Hz]	$120V_{AC}$ [60Hz]	$140V_{AC}$ [60Hz]	$180V_{AC}$ [50Hz]	$220V_{AC}$ [50Hz]	$265V_{AC}$ [50Hz]	Tolerance
26V	678mA	660mA	681mA	700mA	690mA	678mA	±2.94%
24V	676mA	659mA	679mA	697mA	684mA	678mA	±2.80%
22V	673mA	657mA	683mA	694mA	692mA	681mA	±2.74%

3.4. Short- / Open-LED Protections

In short-LED condition, OCP level is reduced from 0.7V to 0.2V because FL7732 lowers OCP level when V_S voltage is less than 0.4V 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}].

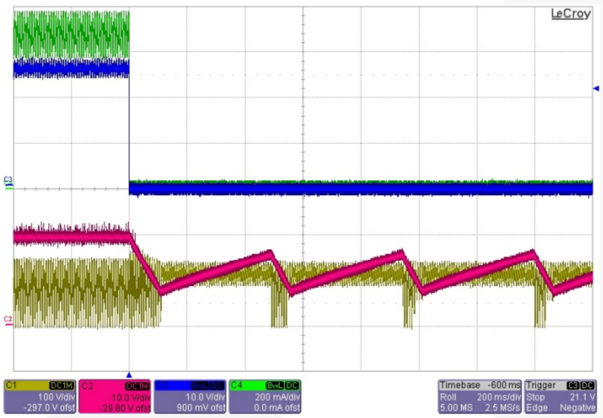

Figure 18. V_{IN} = 90V_{AC} / 60Hz

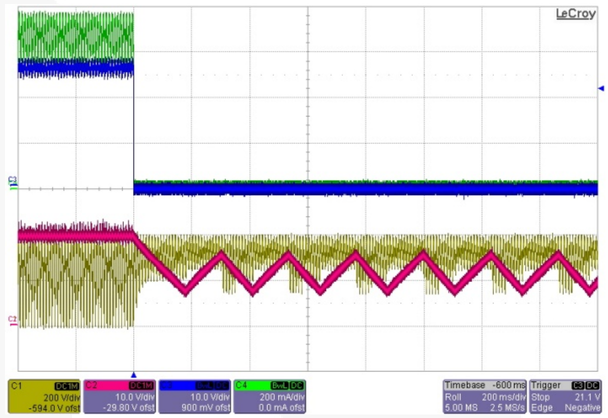

Figure 19. V_{IN} = 265V_{AC} / 50Hz

In open-LED condition, output voltage is limited ~30V 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}].

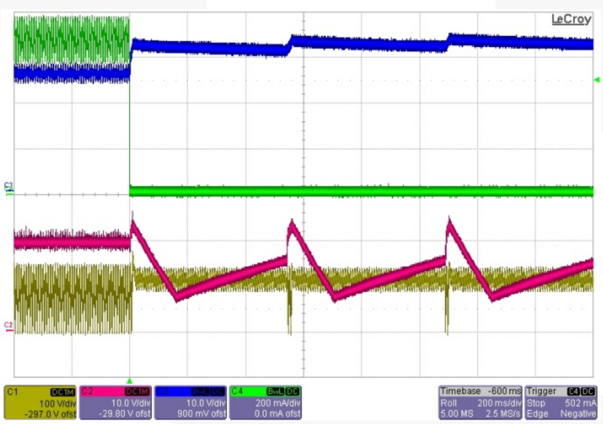

Figure 20. V_{IN} = 90V_{AC} / 60Hz

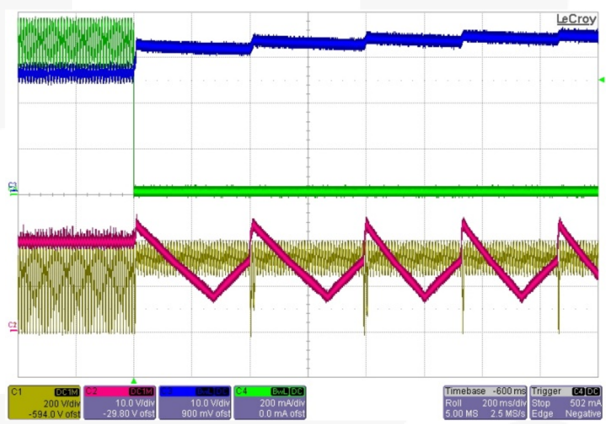

Figure 21. V_{IN} = 265V_{AC} / 50Hz

3.5. Power Factor

System efficiency is 86.45% ~ 89.03% in 90 ~ 265V_{AC} input voltage range. The results were measured at 30 minutes after startup by using 7-LED.

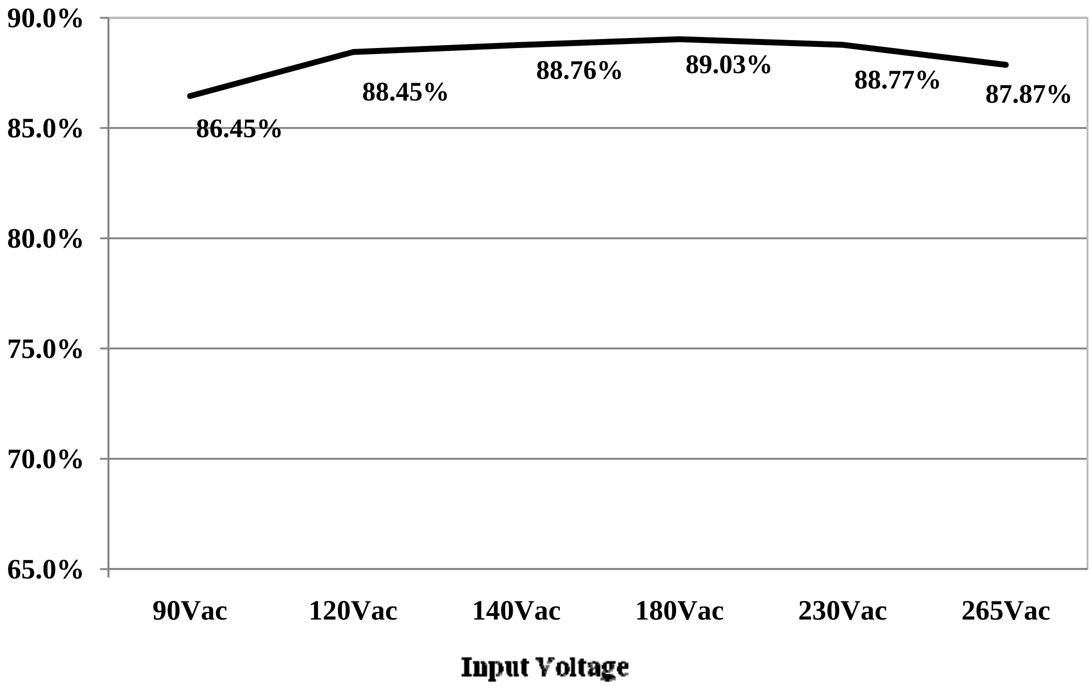

Figure 22. System Efficiency

Table 7. System Efficiency

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

3.6. PF & THD

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

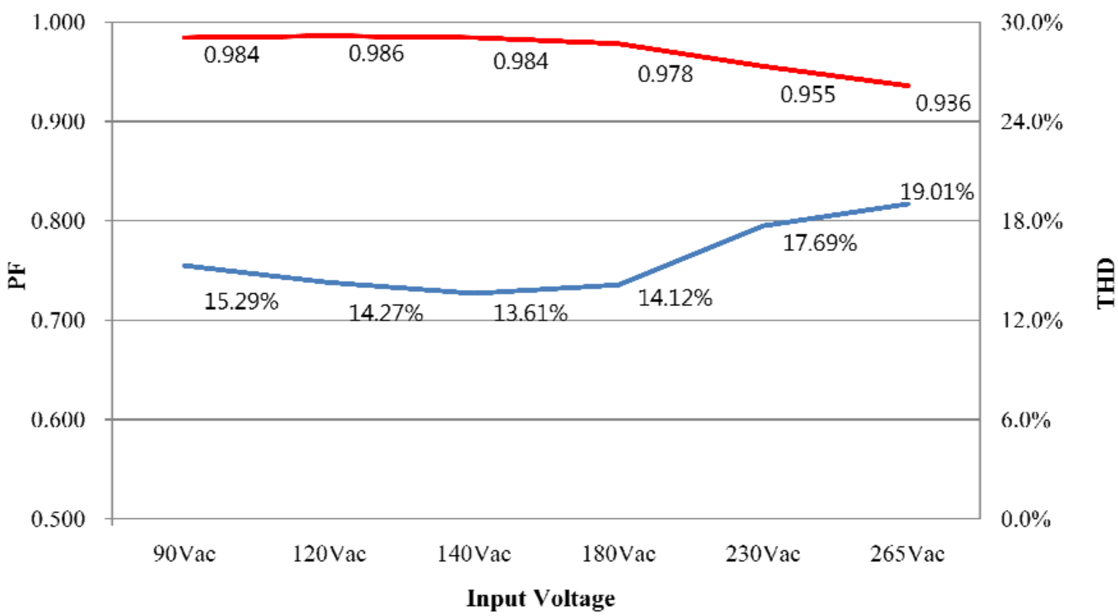

Figure 23. Power Factor & Total Harmonic Distortion

Table 8. PF & THD

Input Voltage	Output Current	Output Voltage	Power Factor	THD
$90V_{AC}$ [60Hz]	0.678A	24.10V	0.98	15.29%
$120V_{AC}$ [60Hz]	0.663A	24.04V	0.99	14.27%
$140V_{AC}$ [60Hz]	0.687A	24.27V	0.98	13.61%
$180V_{AC}$ [50Hz]	0.704A	24.43V	0.98	14.12%
$230V_{AC}$ [50Hz]	0.693A	24.34V	0.96	17.69%
$265V_{AC}$ [50Hz]	0.689A	24.28V	0.94	19.01%

3.7. Operating Temperature

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

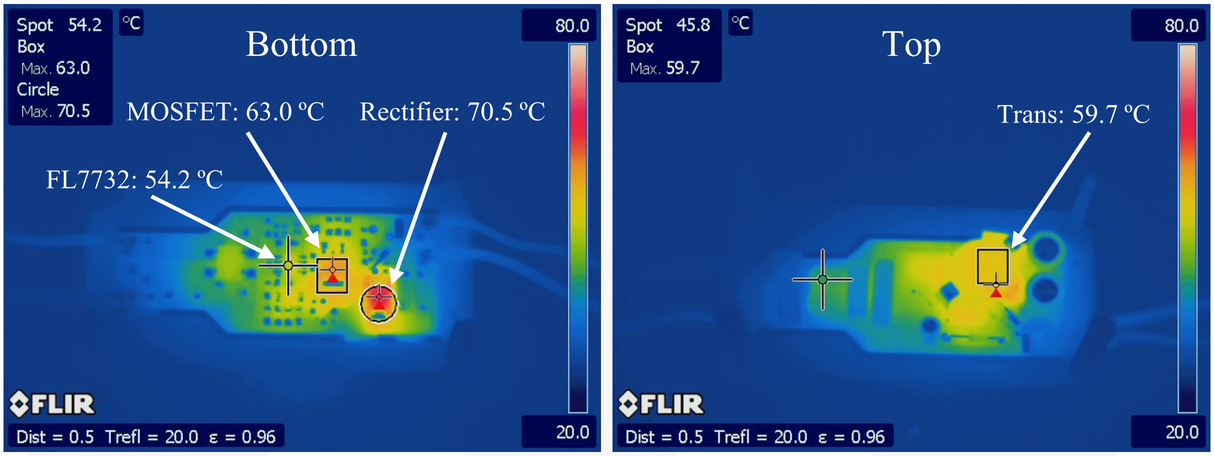

Figure 24. Board Temperature - V_{IN}[90V_{AC}], I_{OUT}[700mA]

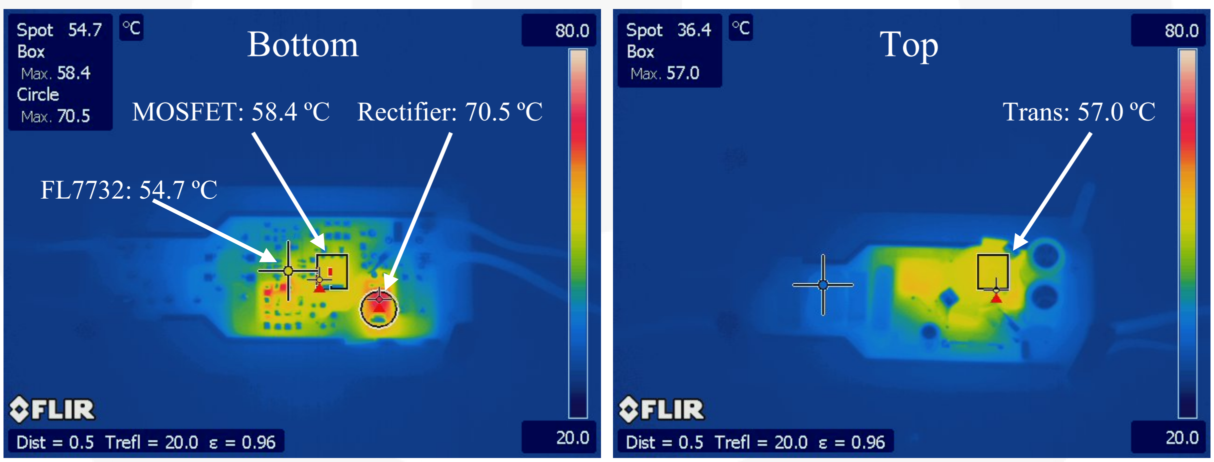

Figure 25. Board Temperature - V_{IN}[265V_{AC}], I_{OUT}[700mA]

3.8. EMI

The all measurement was conducted in observance of EN55022 criteria.
The results were measured at 30 minutes after startup by using actual LED load.

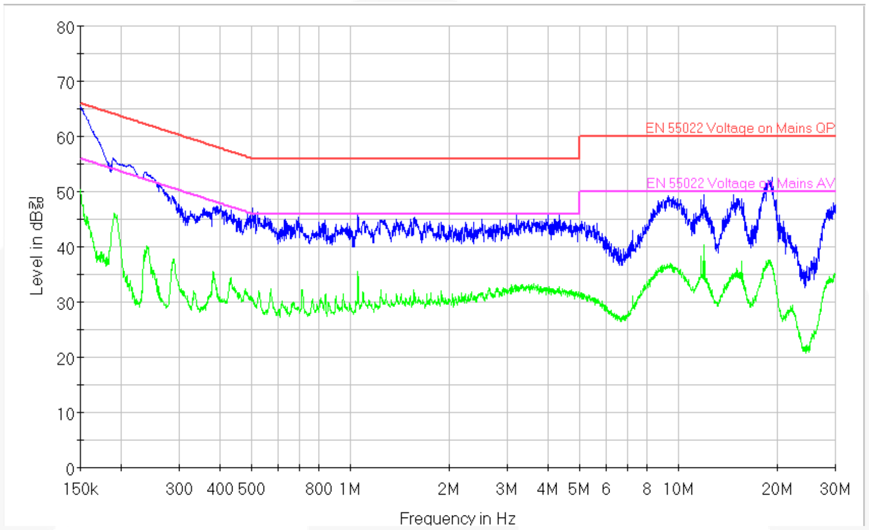

Figure 26. EMI, V_{IN} = 110V_{AC}

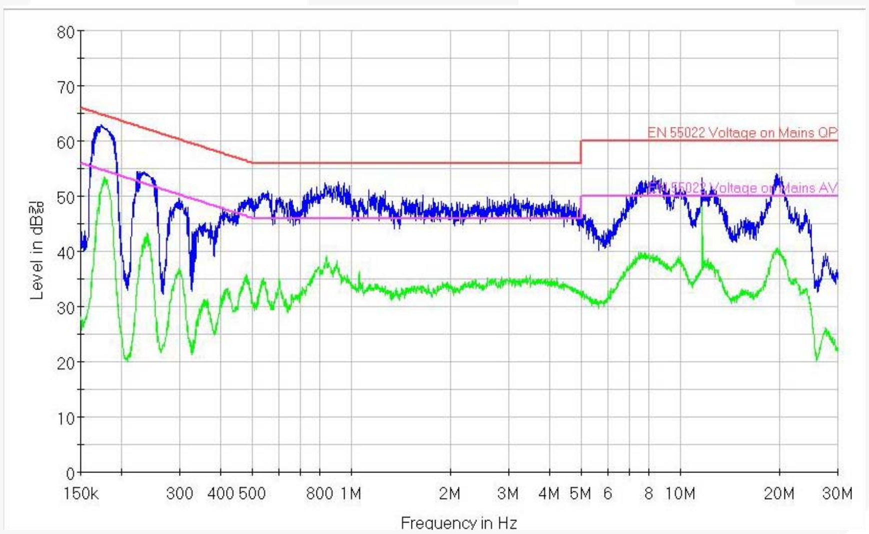

Figure 27. EMI, V_{OUT} [24V], I_{OUT} [700mA], EMI, V_{IN} = 220V_{AC}

4. 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