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User Guide for

FEBFL7730_L21L017A

Dimmable LED Bulb at Low Line

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FL7730

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Table of Contents

This user guide supports the evaluation kit for the FL7730. It should be used in conjunction with the FL7730 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 low line voltage LED ballast using the FL7730 Primary Side Regulator (PSR) single-stage controller. The input voltage range is 90 V_{RMS} – 140 V_{RMS} and there is one DC output with a constant current of 700 mA at 24 V_{OUT}. This document contains a general description of the FL7730, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description

The FL7730 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Dimming control with no flicker is implemented by the analog sensing method. 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 Discontinuous Conduction Mode (DCM) operation with high efficiency and simple design. FL7730 provides open-LED, short-LED, and over-temperature protections.

1.2. Features Compatible with Traditional TRIAC Control

- Compatible with Traditional TRIAC Control
- Cost-Effective Solution: No Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (CC) Control
- Line Voltage Compensation for CC Control
- 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 Package

1.3. Internal Block Diagram

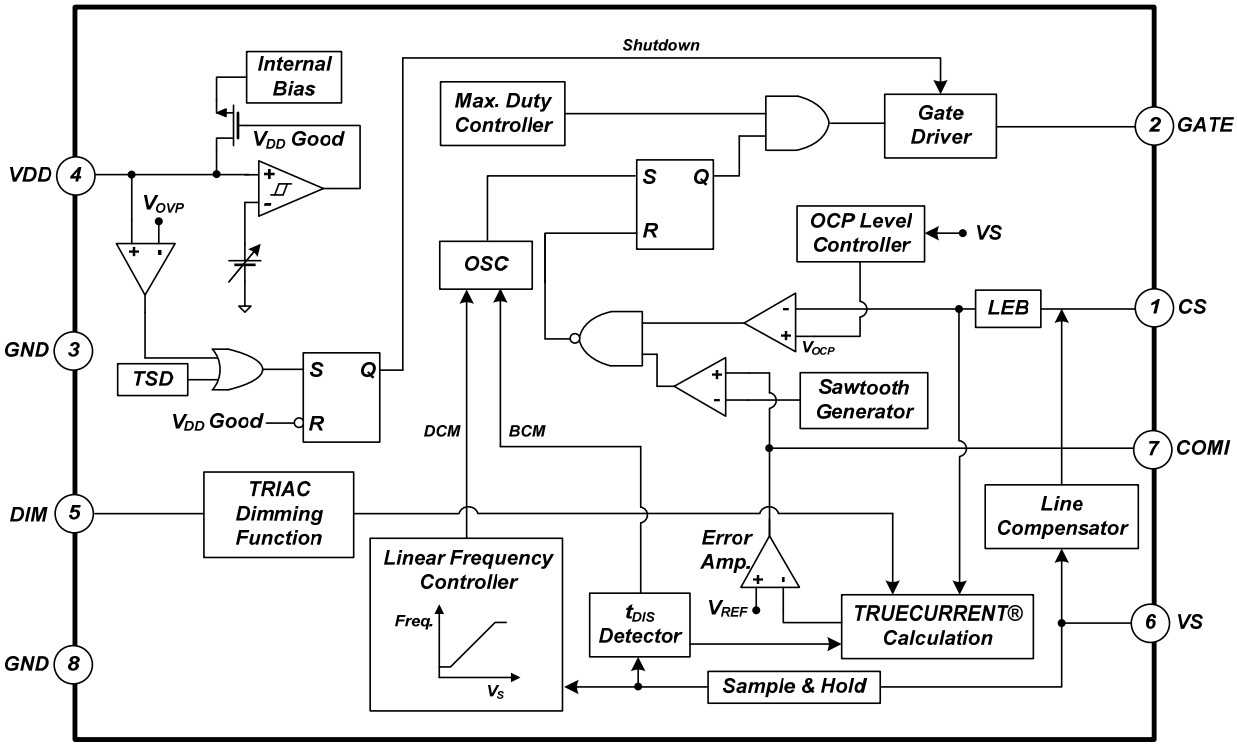

Figure 1. Block Diagram

2. General Specifications for Evaluation Board

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

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Description	Symbol	Value	Comments
Fairchild Device		FL7730	Control IC of Single-Stage PSR TRIAC Dimming
Input			
Voltage	$V_{IN.MIN}$	90 V	Minimum Input Voltage
	$V_{IN.MAX}$	140 V	Maximum Input Voltage
	$V_{IN.NOMINAL}$	110~120 V	Nominal Input Voltage
Frequency	f_{IN}	60 Hz	Line Frequency
Output			
Voltage	$V_{OUT.MIN}$	11 V	Minimum Output Voltage
	$V_{OUT.MAX}$	26 V	Maximum Output Voltage
	$V_{OUT.NOMINAL}$	24 V	Nominal Output Voltage
Current	$I_{OUT.NOMINAL}$	700 mA	Nominal Output Current
	$I_{OUT.RIPPLE}$	±130 mA	Output Current Ripple
	CC Deviation	< ±5%	Line Input Voltage Change: 90~140 V_{AC}
		< ±5%	Output Voltage Change: 11~26 V
Efficiency			No Dimmer Connected
	Eff_{90VAC}	82.67%	Efficiency at 90 V_{AC} Line Input Voltage
	Eff_{110VAC}	84.74%	Efficiency at 110 V_{AC} Line Input Voltage
	Eff_{120VAC}	85.25%	Efficiency at 120 V_{AC} Line Input Voltage
	Eff_{140VAC}	86.05%	Efficiency at 140 V_{AC} Line Input Voltage
PF / THD			No Dimmer Connected
	PF / THD_{90VAC}	0.994 / 9.62%	PF / THD at 90 V_{AC} / 60 Hz Line Input Voltage
	PF / THD_{110VAC}	0.990 / 8.77%	PF / THD at 110 V_{AC} / 60 Hz Line Input Voltage
	PF / THD_{120VAC}	0.987 / 8.58%	PF / THD at 120 V_{AC} / 60 Hz Line Input Voltage
	PF / THD_{140VAC}	0.976 / 10.18%	PF / THD at 140 V_{AC} / 60 Hz Line Input Voltage
Temperature			Open-Frame Condition (T_A=25ºC)
FL7730	T_{FL7730}	57.6ºC	FL7730 Temperature
Primary MOSFET	T_{MOSFET}	66.8ºC	Primary MOSFET Temperature
Secondary Diode	T_{DIODE}	55.9ºC	Secondary Diode Temperature
Transformer	$T_{TRNASFORMER}$	54.2ºC	Transformer Temperature
Damper Resistor	$T_{DAMPER, RESISTOR}$	66.1ºC	Active Damper Resistor Temperature
Damper MOSFET	$T_{DAMPER, MOSFET}$	64.0ºC	Active Damper MOSFET Temperature

3. Photographs

Figure 2. Top View (Dimensions: 34.5 mm (W) x 75 mm (L) x 20 mm (H)

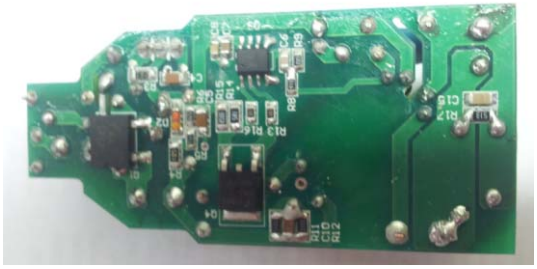

Figure 3. Bottom View Dimensions: 34.5 mm (W) x 75 mm (L) x 20 mm (H)

4. Printed Circuit Board

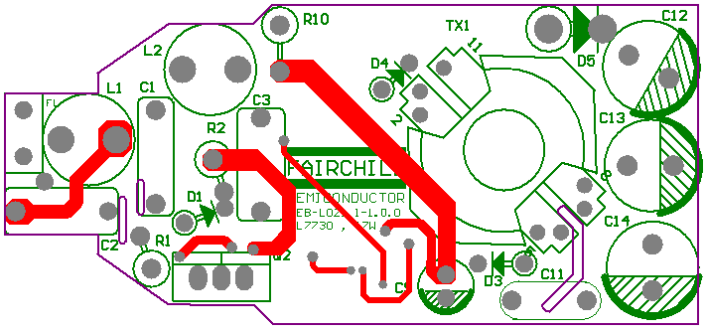

Figure 4. Top Pattern

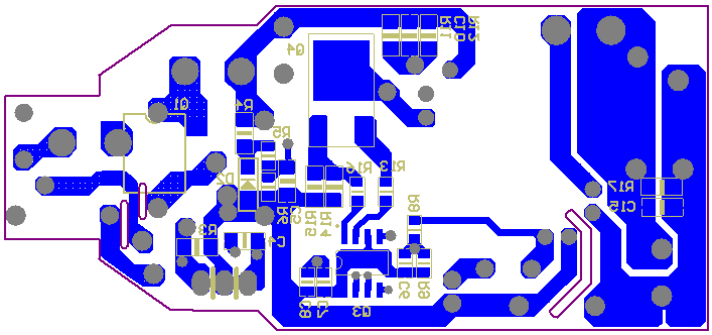

Figure 5. Bottom Pattern

5. Schematic

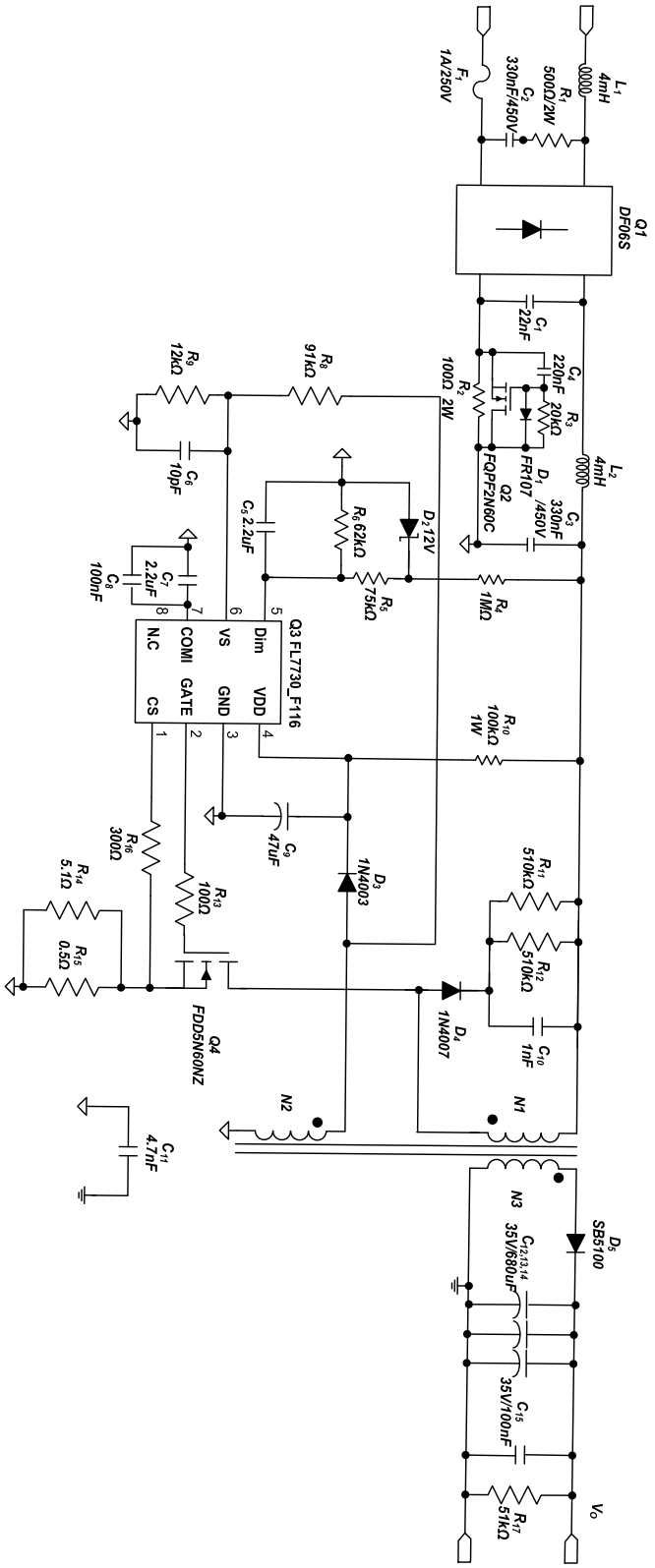

Figure 6. Schematic of Evalutation Board

6. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	Q1	DF06S	1	Bridge Diode	Fairchild Semiconductor
2	Q2	FQPF2N60C	1	2 A / 600 V Active Damper MOSFET	Fairchild Semiconductor
3	Q3	FL7730_F116	1	Main Controller	Fairchild Semiconductor
4	Q4	FDD5N60NZ	1	4 A / 600 V Main Switch	Fairchild Semiconductor
5	F1	Fuse	1	1 A / 250 V Fuse	SLEEK
6	L1, L2	R10402KT00	2	4 mH Filter Inductor	Bosung
7	D1	FR107DITR-ND	1	1 A / 1000 V Diode	CP
8	D2	12 V/ 0.5 W	1	12 V Zener Diode	RENESAS
9	D3	1N4003	1	1 A / 200 V General Purpose Rectifiers	Fairchild Semiconductor
10	D4	1N4007	1	1 A / 1000 V Diode	Fairchild Semiconductor
11	D5	SB5100	1	5 A / 100 V Fast Rectifier	Fairchild Semiconductor
12	C1	223K/275VACP	1	22 nF / 275 V_{AC} X Capacitor	CARL
13	C2, C3	MTF 334J450V	2	330 nF / 450 V Film Capacitor	CARL
14	C4	CC1206KRX7R8BB224	1	220 nF / 25 V SMD Capacitor 3216	Yageo
15	C5	1206F225Z250CT	1	2.2 µF / 25 V SMD Capacitor 3216	WALSIN
16	C6	0805N100J500NT	1	10 pF / 50 V SMD Capacitor 2012	Yageo
17	C7	C2012Y5V1H225Z	1	2.2 µF / 50 V SMD Capacitor 2012	TDK Corporation
18	C8	C0805X104K050T	1	100 nF / 50 V SMD Capacitor 2012	HEC
19	C9	SK-47UF/50V	1	47 µF / 50 V Electrolytic Capacitor	Su'scon
20	C10	C1206C102KDRAC	1	1 nF / 1 kV SMD Capacitor 3216	KEMET
21	C11	DE2E3KH472M	1	4.7 nF Y Capacitor	Murata
22	C12, C13, C14	UHE1V681MPD	3	680 µF / 35 V Electrolytic Capacitor	Nichicon
23	C15	CC1206MRY5V9BB104	1	100 nF / 35 V SMD Capacitor 3216	Yageo
24	R1	RMCF1206JG1K10-ND	1	500 Ω / 2 W Metal Resistor	Stackpole
25	R2	MCP200JR-100R	1	100 Ω / 2 W Metal Resistor	Yageo
26	R3	RMCF1206FG20K0	1	20 kΩ SMD Resistor 3216	ELCODIS
27	R4	RC1206JR-071ML	1	1 MΩ SMD Resistor 3216	Yageo
28	R5	CRCW080575K0JNEAHP	1	100 kΩ SMD Resistor 2012	Vishay
29	R6	RT0805WRB0762KL	1	82 kΩ SMD Resistor 2012	Yageo
30	R8	9C08052A9102JLHFT	1	91 kΩ SMD Resistor 2012	Yageo
31	R9	CRCW080512K0JNEA	1	12 kΩ SMD Resistor 2012	Vishay
32	R10	RSF100JB-100K	1	100 kΩ / 1W Metal Resistor	Yageo
33	R11, R12	RT1206CRD07510KL	2	510 kΩ SMD Resistor 3216	Yageo,
34	R13	MCR10EZPJ101	1	100 Ω SMD Resistor 2012	Rohm
35	R14	MCR18EZHJ5R1	1	5.1 Ω SMD Resistor 3216	Rohm
36	R15	RMCF1206JTR500	1	0.5 Ω SMD Resistor 3216	Stackpole
37	R16	ERJ-6GEYJ301V	1	300 Ω SMD Resistor 2012	Panasonic
38	R17	CRCW120651K0JNEA	1	51 kΩ SMD Resistor 3216	Vishay

7. Transformer Design

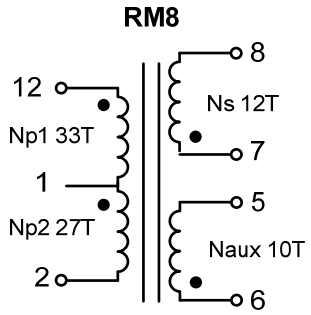

Figure 7. Transformer Pin Configuration

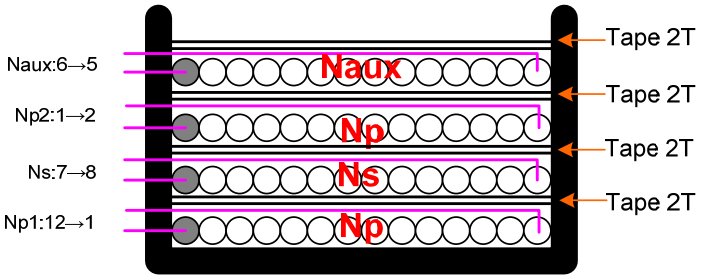

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np1	12 → 1	0.25Ø	33Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
3	Ns	7 → 8	0.35Ø X2	12Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
5	Np	1 → 2	0.25Ø	27Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
7	Naux	6 → 5	0.2Ø	10Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
9	Copper-Foil (Shielding), Closed Loop				
10	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	2 – 12	0.9 mH ±10%	50 kHz, 1 V
Leakage	2 – 12	< 10 μH	50 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: 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 0.87s. There is no overshoot at output current and voltage in startup sequence. Refer I_{OUT} and V_{DD} waveform. V_{DD} indicates a reflected output voltage. C1 [I_{OUT}], C2 [V_{IN}], C3 [V_{DD}], and C4 [V_{CS}].

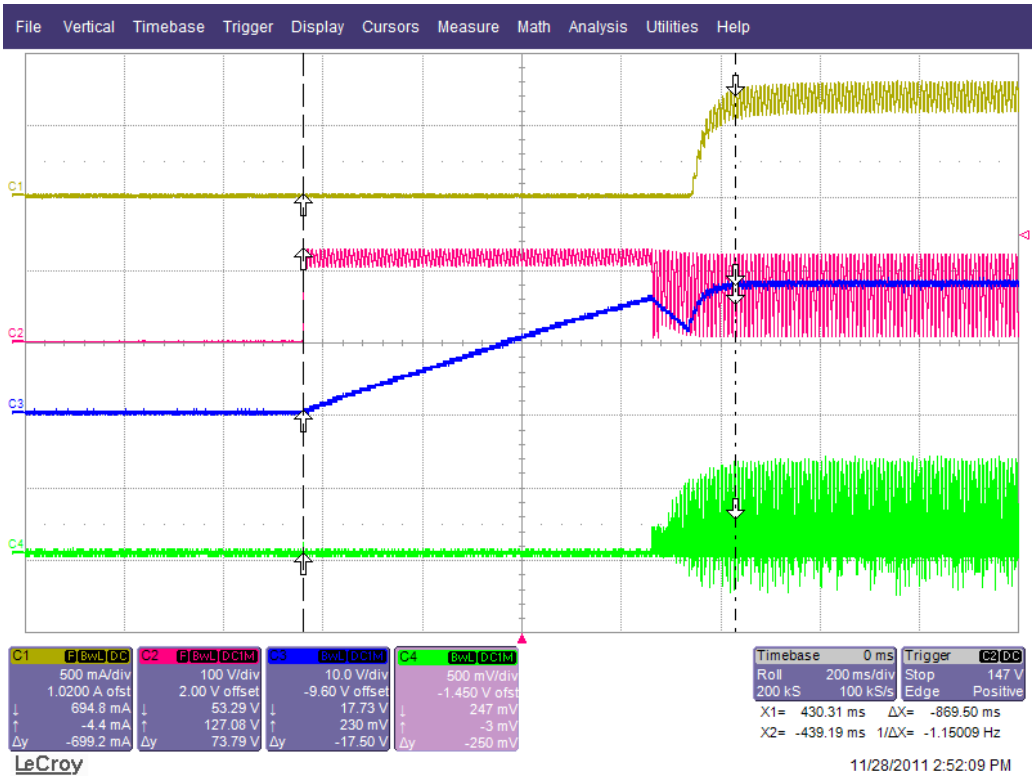

Figure 9. Startup – V_{IN} [90 V_{AC}]; No Dimmer, V_O [24 V], I_O [700 mA]

8.2. Operation Waveforms

In steady state, line compensation regulates output current regardless of input voltage variations. Output current ripple is ±130 mA with a rated output current of 700 mA. C1 [I_{OUT}], C3 [V_{IN}], and C4 [V_{CS}].

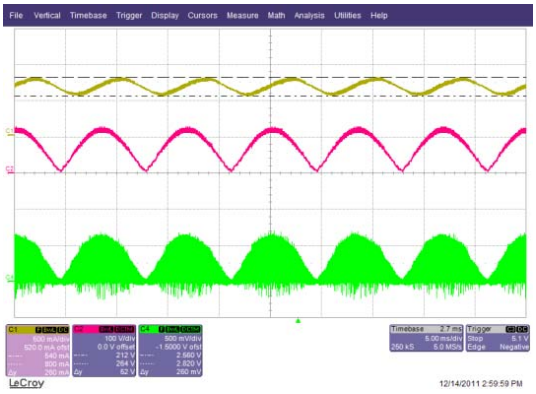

Figure 10. V_{IN} = 90 V_{AC}

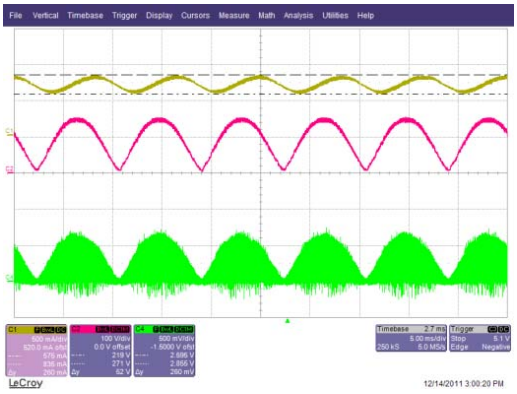

Figure 11. V_{IN} = 110 V_{AC}

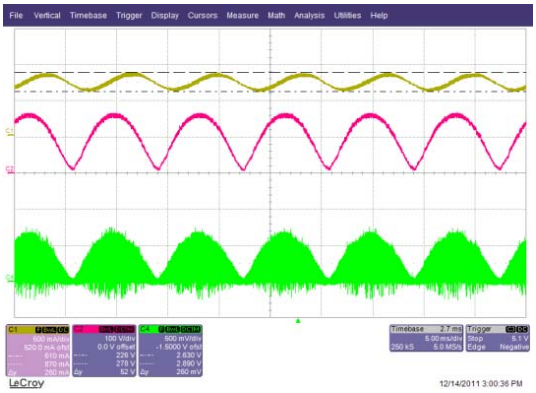

Figure 12. V_{IN} = 120 V_{AC}

Figure 13. V_{IN} = 140 V_{AC}

8.3. Constant Current Regulation

Constant current deviation in the output voltage range from 11 V to 26 V is less than ±5% at each line input voltage. Line regulation at the rated output voltage is less than 5%.

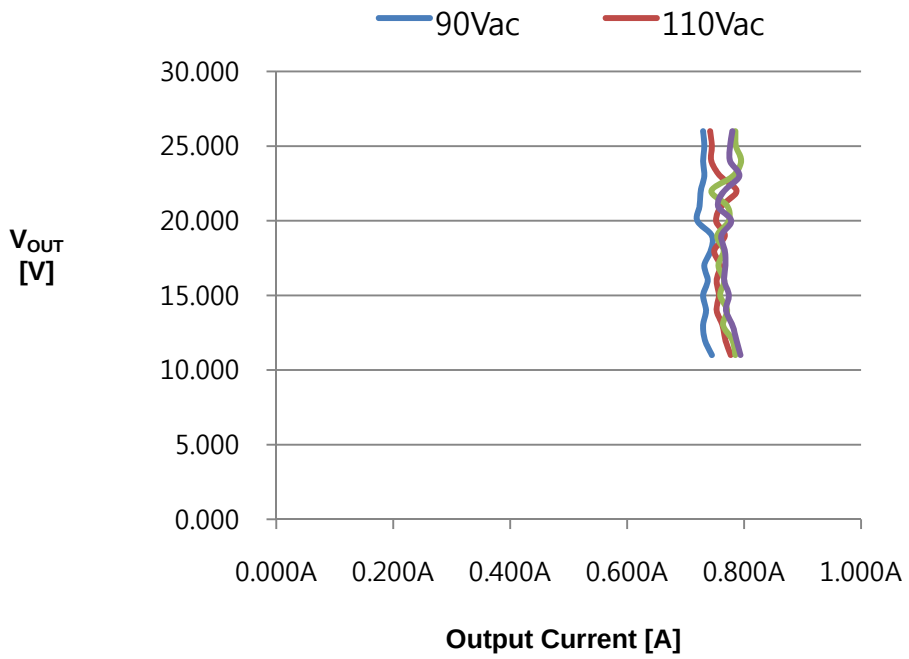

Figure 14. Constant Current Regulation – Measured by E LOAD [CR Mode]

Table 5. Constant Current Regulation by Output Voltage Change (11~26 V)

Input Voltage	Min. Current	Max. Current	Tolerance
90 V_{AC} / 60 Hz	720 mA	745 mA	±1.7%
110 V_{AC} / 60 Hz	742 mA	787 mA	±2.9%
120 V_{AC} / 60 Hz	744 mA	795 mA	±3.3%
140 V_{AC} / 60 Hz	755 mA	794 mA	±2.5%

Table 6. Constant Current Regulation by Line Voltage Change (90~140 V_{AC})

Output Voltage	90 V_{AC}	110 V_{AC}	120 V_{AC}	140 V_{AC}	Tolerance
20 V	720 mA	752 mA	774 mA	778 mA	±3.9%
22 V	726 mA	787 mA	744 mA	766 mA	±4.0%
24 V	730 mA	744 mA	795 mA	776 mA	±4.3%

8.4. Open-LED and Short-LED Protections

In short-LED condition, the Over-Current Protection (OCP) level is reduced from 0.7 V to 0.2 V because FL7730 lowers the OCP level when V_S voltage is less than 0.4 V during output diode conduction time. The output current in the short-LED condition is less than 2 A, which doesn't damage external components. C1 [V_{IN}], C2 [I_{OUT}], C3 [V_{DD}], and C4 [V_{CS}].

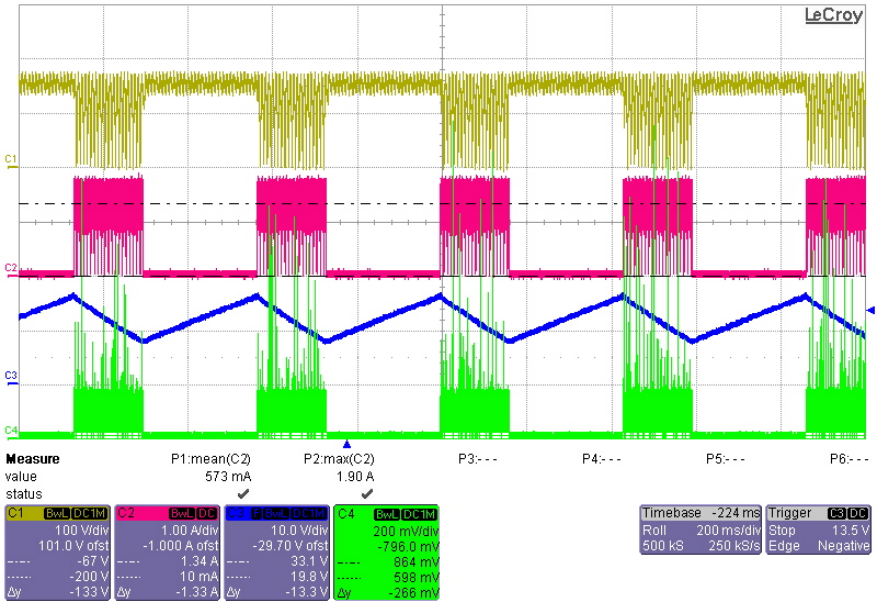

Figure 15. Short-LED Condition – V_{IN}, [120 V_{AC}]

In open-LED condition, output voltage is limited around 32 V by OVP in V_{DD}. Output over-voltage protection level can be controlled by the turn ratio of auxiliary and secondary windings. C1 [V_{OUT}], C2 [V_{IN}], C3 [V_{DD}], and C4 [V_{CS}].

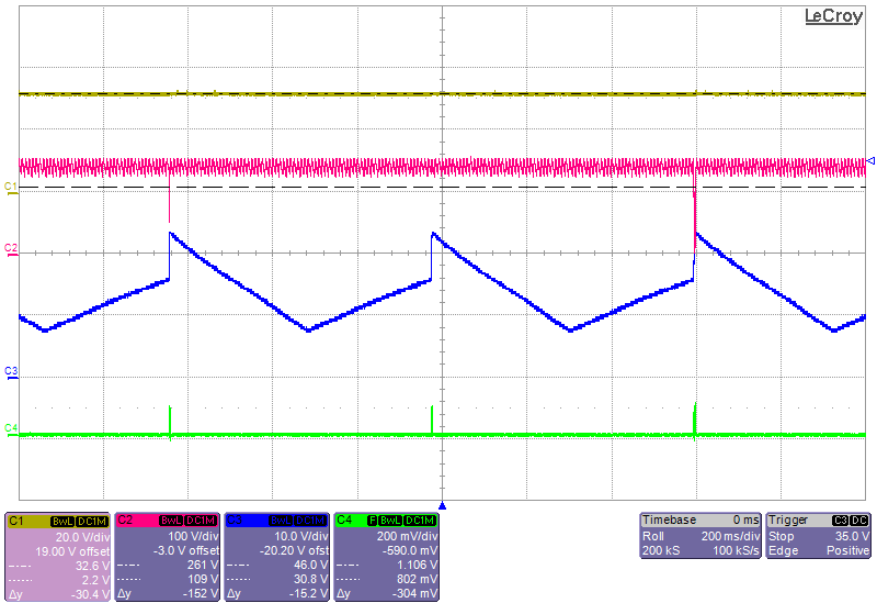

Figure 16. Open-LED Condition – V_{IN} [110 V_{AC}]

8.5. Dimming Operation

Dimming operation waveforms are shown in Figure 17 - Figure 20. Active damper, RC bleeder, and dimming control implement flicker-free dimming oepration. Spike current at dimmer firing is less than 1.5 A. C1 [V_{IN}], C2 [V_{CS}], and C4 [I_{IN}].

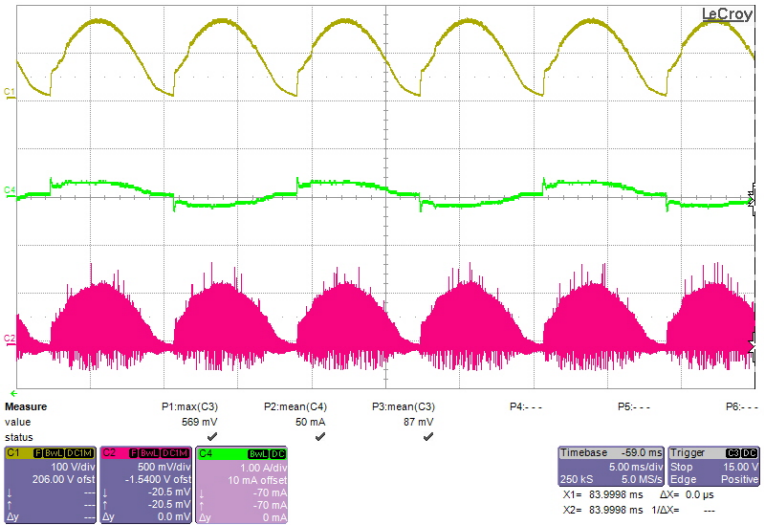

Figure 17. Dimming Operation Waveforms – Maximum Dimming Angle, V_{IN} [120 V_{AC}]

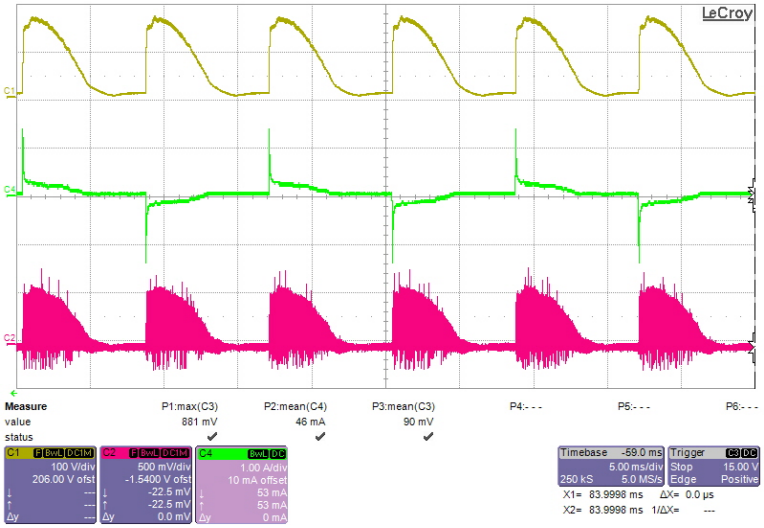

Figure 18. Dimming Operation Waveforms – 90º Dimming Angle, V_{IN} [120 V_{AC}]

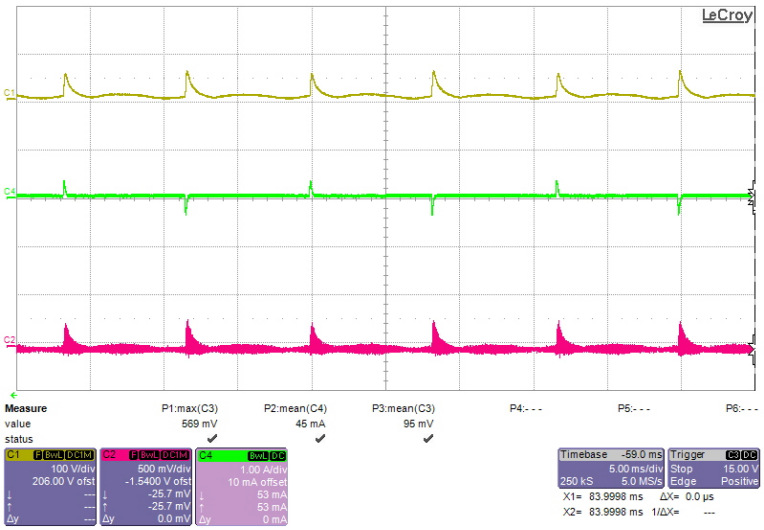

Figure 19. Dimming Operation Waveforms – Minimum Dimming Angle, V_{IN} [120 V_{AC}]

Output current is controlled by the dimming function when the rotating dimmer switch as below dimming curve. The dimming control block smoothly changes regulated output current by detecting dimming angle.

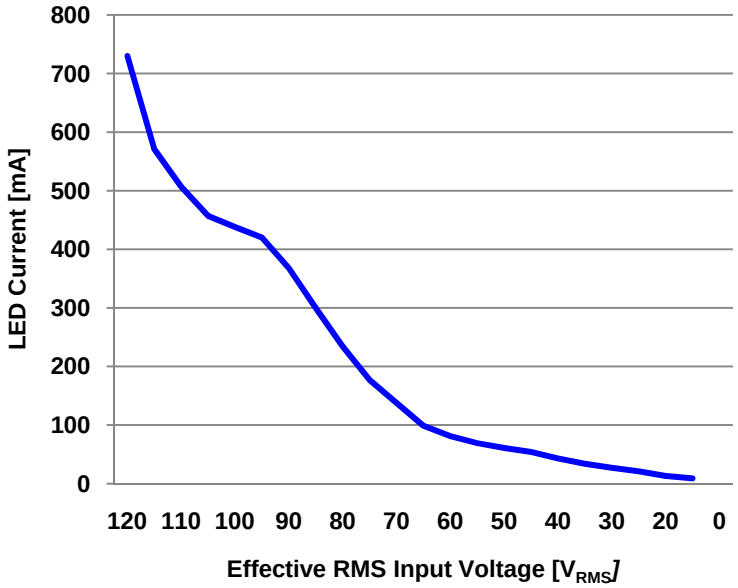

Figure 20. Dimming Curve (Input Voltage vs. Output Current) – V_{IN} [120 V_{AC}]

Table 7. TRIAC Dimmer Compatibility

Manufacturer	Dimmer	Condition	Max. Current	Min. Current	Flicker
LEVITON	6633	120 V / 60 Hz	742 mA	2 mA (0.3%)	No
LUTRON	AY-600P	120 V / 60 Hz	604 mA	19 mA (3.1%)	No
LUTRON	S-600	120 V / 60 Hz	690 mA	11 mA (1.6%)	No
LUTRON	DV-600P	120 V / 60 Hz	614 mA	9 mA (1.4%)	No
LUTRON	TG-603PG	120 V / 60 Hz	466 mA	11 mA (2.4%)	No
LUTRON	S-600P	120 V / 60 Hz	629 mA	7 mA (1.1%)	No
LUTRON	CN-600PHW	120 V / 60 Hz	616 mA	20 mA (3.2%)	No
LUTRON	GL-600H	120 V / 60 Hz	729 mA	10 mA (1.4%)	No

The FL7730 low-line evaluation board shows good dimmer compatibility without flicker. Minimum LED current is less than 5%.

8.6. System Efficiency

Power efficiency is 82.67 ~ 86.05% in 90 ~ 140 V_{AC} input voltage range.

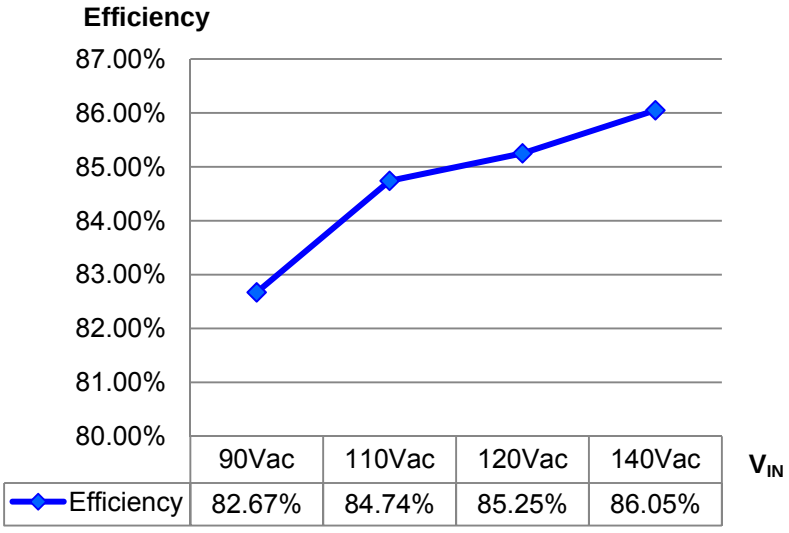

Figure 21. System Effiiciency (Input Voltage vs. Efficiency)

Table 8. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90 V_{AC}	21.73 W	735 mA	24.44 V	17.96 W	82.67%
110 V_{AC}	22.14 W	763 mA	24.59 V	18.76 W	84.74%
120 V_{AC}	23.05 W	794 mA	24.75 V	19.65 W	85.25%
140 V_{AC}	22.43 W	783 mA	24.65 V	19.30 W	86.05%

8.7. Power Factor and Total Harmonic Distortion

The FL7730 shows excellent power factor and total harmonic distortion performance. Power factor is very high with enough margins from the 0.9 specification. THD is much less than the 30% of the specification.

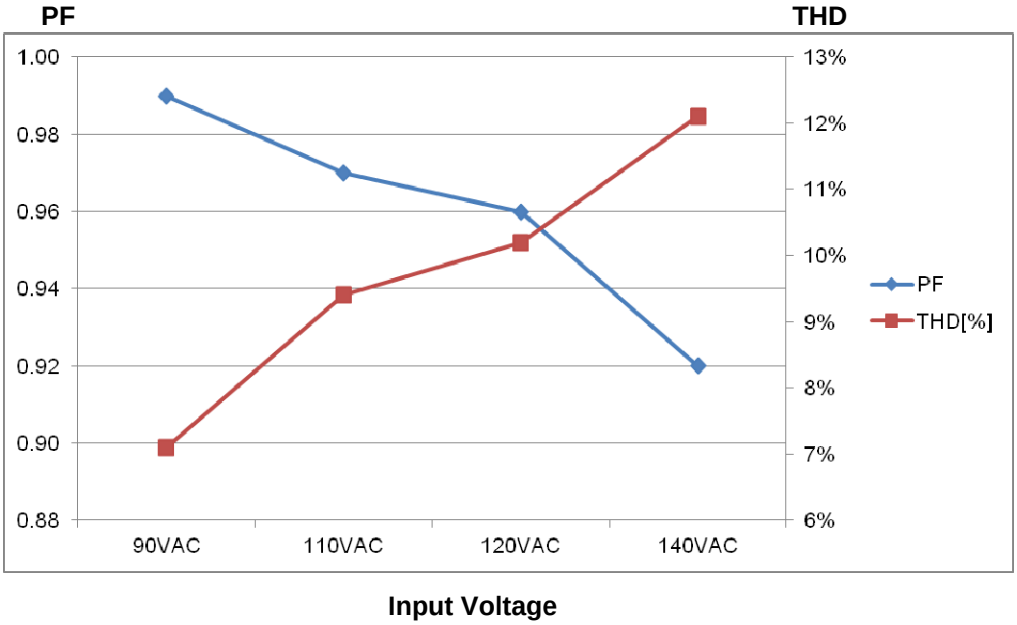

Figure 22. Power Factor & Total Harmonic Distortion (60 Hz)

Table 9. Power Factor and Total Harmonic Distortion (60 Hz)

Input Voltage	Output Current	Output Voltage	PF	THD
90 V_{AC} / 60 Hz	729 mA	23.91 V	0.994	9.62%
110 V_{AC} / 60 Hz	752 mA	24.05 V	0.990	8.77%
120 V_{AC} / 60 Hz	799 mA	24.25 V	0.987	8.58%
140 V_{AC} / 60 Hz	777 mA	24.14 V	0.976	10.18%

Table 10. Power Factor and Total Harmonic Distortion (50 Hz)

Input Voltage	Output Current	Output Voltage	PF	THD
90 V_{AC} / 50 Hz	726 mA	24.20 V	0.994	8.79%
110 V_{AC} / 50 Hz	745 mA	24.28 V	0.991	8.28%
120 V_{AC} / 50 Hz	787 mA	24.52 V	0.988	8.02%
140 V_{AC} / 50 Hz	774 mA	24.43 V	0.977	9.66%

8.8. Operating Temperature

Temperature of the components on this board is less than 70ºC.

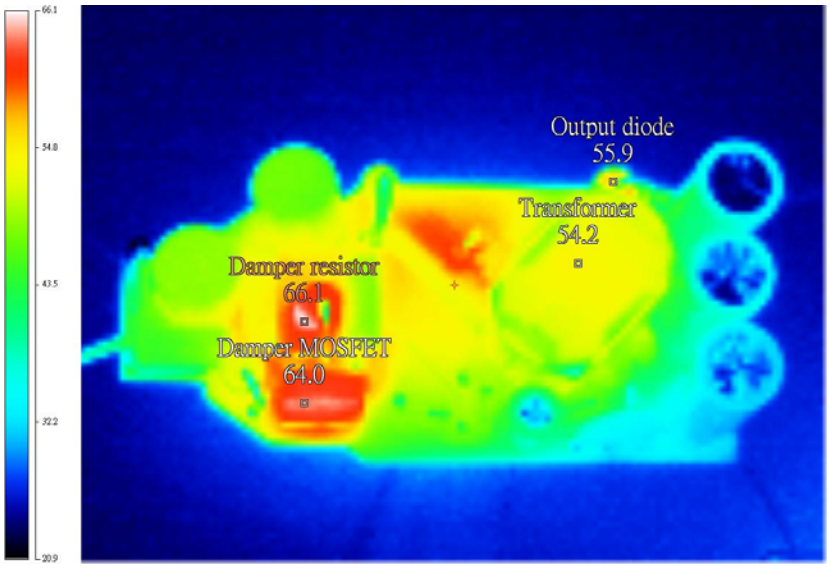

Figure 23. Board Temperature, Top View, V_{IN} [120 V_{AC}]

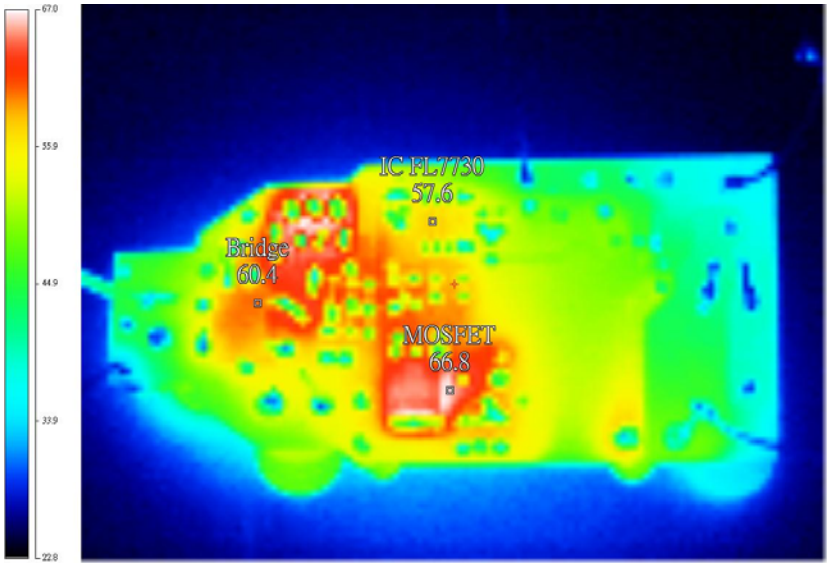

Figure 24. Board Temperature, Bottom View, V_{IN} [120 V_{AC}]

8.9. Electromagnetic Interference (EMI)

A measurement was conducted in observance of CISPR22 criteria.

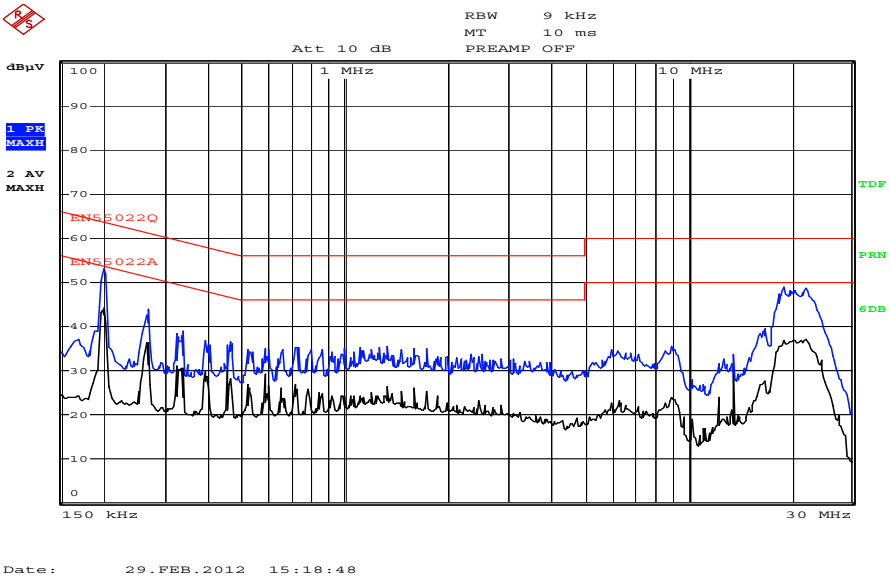

Figure 25. EMI Results – V_{IN} [110 V], V_{OUT} [24 V], I_{OUT} [780 mA]

9. Revision History

Rev.	Date	Description
1.0.0	July 2012	Initial Release
1.0.1	Sep. 2012	Modified, edited, formatted document. Changed User Guide number from FEB-L021-1 to FEBFL7730_L21L017A

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