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User Guide for

FEBFL7730_L21H017A

Dimmable LED Bulb at High 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 high line voltage LED ballast using the FL7730 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is 180 V_{RMS} – 265 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 of FL7730

- 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

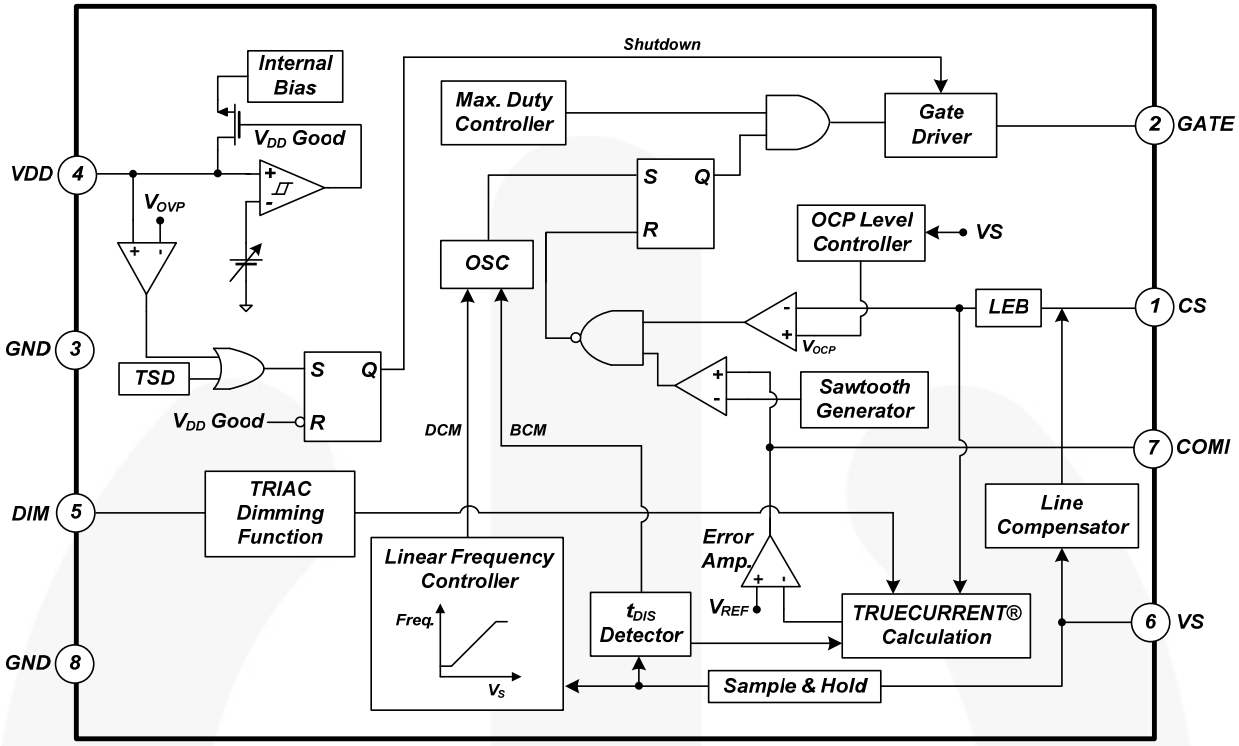

Figure 1. Block Diagram

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	$V_{IN.MIN}$	180 V	Minimum Input Voltage
	$V_{IN.MAX}$	265 V	Maximum Input Voltage
	$V_{IN.NOMINAL}$	220~230 V	Nominal Input Voltage
Frequency	f_N	50~60 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
	$I_{OUT.RIPPLE}$	±83 mA	Output Current Ripple
	CC Deviation	< ±3%	Line Input Voltage Change: 180~265 V_{AC}
		< ±5%	Output Voltage Change: 11~26 V
Efficiency			No Dimmer Connected
	Eff_{180VAC}	86.19%	Efficiency at 180 V_{AC} Line Input Voltage
	Eff_{220VAC}	86.70%	Efficiency at 220 V_{AC} Line Input Voltage
	Eff_{230VAC}	86.87%	Efficiency at 230 V_{AC} Line Input Voltage
	Eff_{265VAC}	86.69%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD			No Dimmer Connected
	PF / THD_{180VAC}	0.992 / 9.77%	PF / THD at 180 V_{AC} / 50 Hz Line Input Voltage
	PF / THD_{220VAC}	0.984 / 10.97%	PF / THD at 220 V_{AC} / 50 Hz Line Input Voltage
	PF / THD_{230VAC}	0.982 / 11.45%	PF / THD at 230 V_{AC} / 50 Hz Line Input Voltage
	PF / THD_{265VAC}	0.967 / 14.03%	PF / THD at 265 V_{AC} / 50 Hz Line Input Voltage
Temperature			Open-Frame Condition (T_A=25ºC)
FL7730	T_{FL7730}	54.4ºC	FL7730 Temperature
Primary MOSFET	T_{MOSFET}	65.2ºC	Primary MOSFET Temperature
Secondary Diode	T_{DIODE}	62.6ºC	Secondary Diode Temperature
Transformer	$T_{TRNASFORMER}$	54.6ºC	Transformer Temperature
Active Damper	T_{DAMPER}	60.9ºC	Active Damper MOSFET Temperature
Active Damper	T_{DAMPER}	59.3ºC	Active Damper Resistor 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

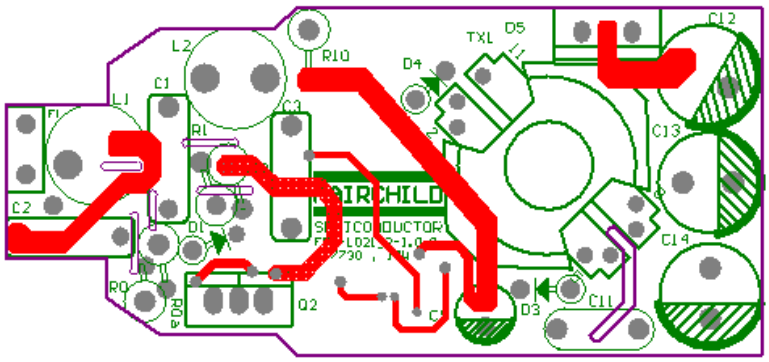

Figure 4. Top Pattern

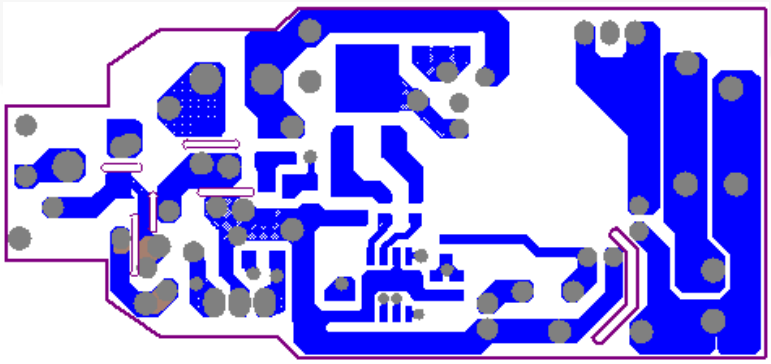

Figure 5. Bottom Pattern

5. Schematic

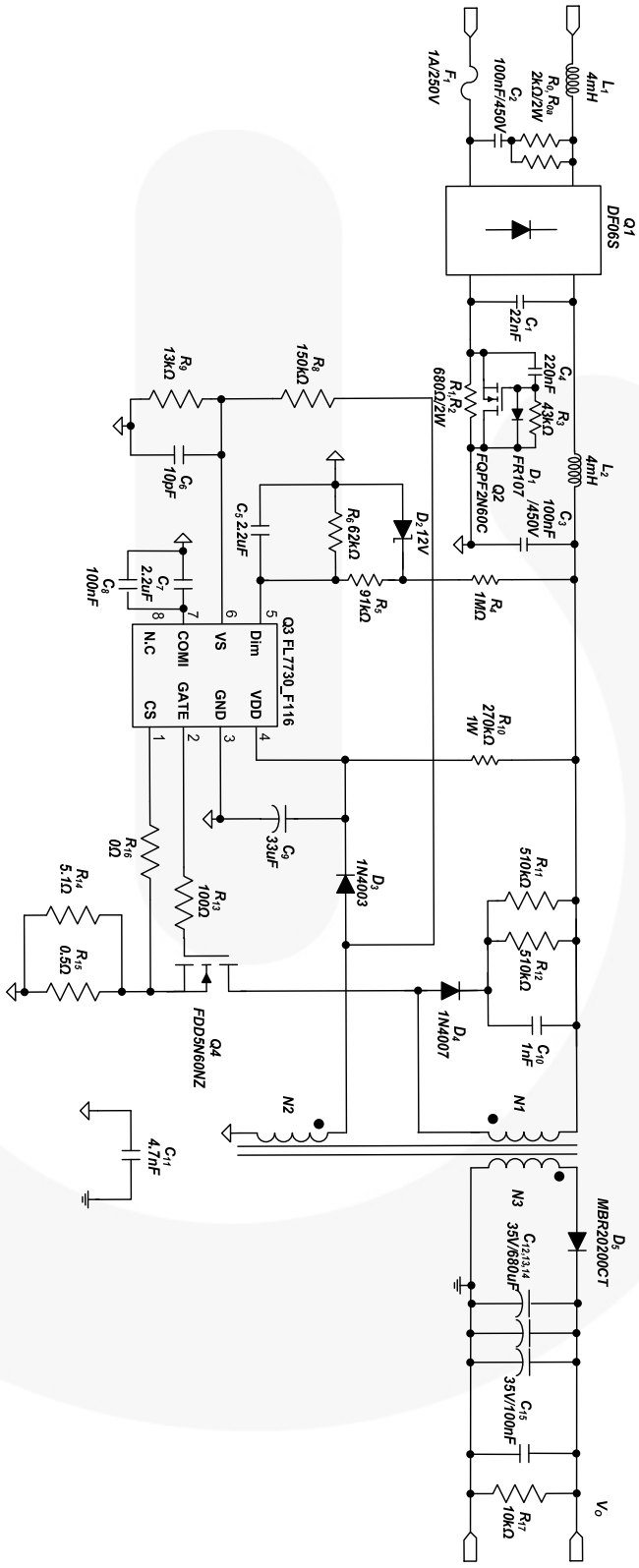

Figure 6. Schematic of Evaluation Board

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
10	D4	1N4007	1	1 A / 1000 V Diode	Fairchild Semiconductor
11	D5	MBR20200CT	1	20 A / 200 V Fast Rectifier	Fairchild Semiconductor
12	C1	223 K/275VACP	1	22 nF / 275 V_{AC} X Capacitor	CARL
13	C2, C3	ECW-F2W104JAQ	2	100 nF / 450 V Film Capacitor	Panasonic
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
18	C8	C0805X104K050T	1	100 nF / 50 V SMD Capacitor 2012	HEC
19	C9	SK-3 µF /5 V	1	33 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	R0, R0a	MCMF02WJJ0202A10	2	2 kΩ / 2 W Metal Resistor	MULTICOMP
25	R1, R2	RO2W680EJT	2	680 Ω / 2 W Metal Resistor	KEMET
26	R3	MCR18EZPJ433	1	43 kΩ SMD Resistor 3216	Rohm
27	R4	RC1206JR-071ML	1	1 MΩ SMD Resistor 3216	Yageo
28	R5	ERJ-6GEYJ913V	1	91 kΩ SMD Resistor 2012	Panasonic
29	R6	RT0805WRB0762KL	1	62 kΩ SMD Resistor 2012	Yageo
30	R8	MCR10EZHF1503	1	150 kΩ SMD Resistor 2012	Rohm
31	R9	ERA-6AEB133V	1	13 kΩ SMD Resistor 2012	Panasonic
32	R10	FMP100JR-52-270K	1	270 kΩ / 1W Metal Resistor	Yageo
33	R11, R12	RT1206CRD07510KL	2	510 kΩ SMD Resistor 3216	Yageo,
32	R13	MCR10EZPJ101	1	100 Ω SMD Resistor 2012	Rohm
33	R14	MCR18EZHJ5R1	1	5.1 Ω SMD Resistor 3216	Rohm
34	R15	RMCF1206JTR500	1	0.5 Ω SMD Resistor 3216	Stackpole
35	R16	ERJ-6GEY0R00V	1	0 Ω SMD Resistor 2012	Panasonic
36	R17	KTR18EZPJ103	1	10 kΩ SMD Resistor 3216	Rohm

7. Transformer Design

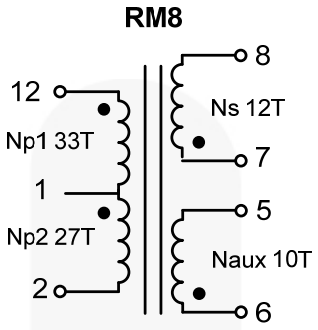

Figure 7. Transformer Pin Configuration

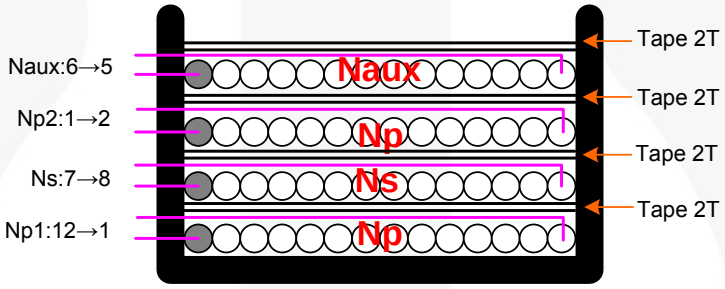

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

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

8.1. Startup

Startup time is 0.86 s. 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 [V_{IN}], C4 [V_{CS}], C3 [V_{DD}], and C4 [I_{OUT}].

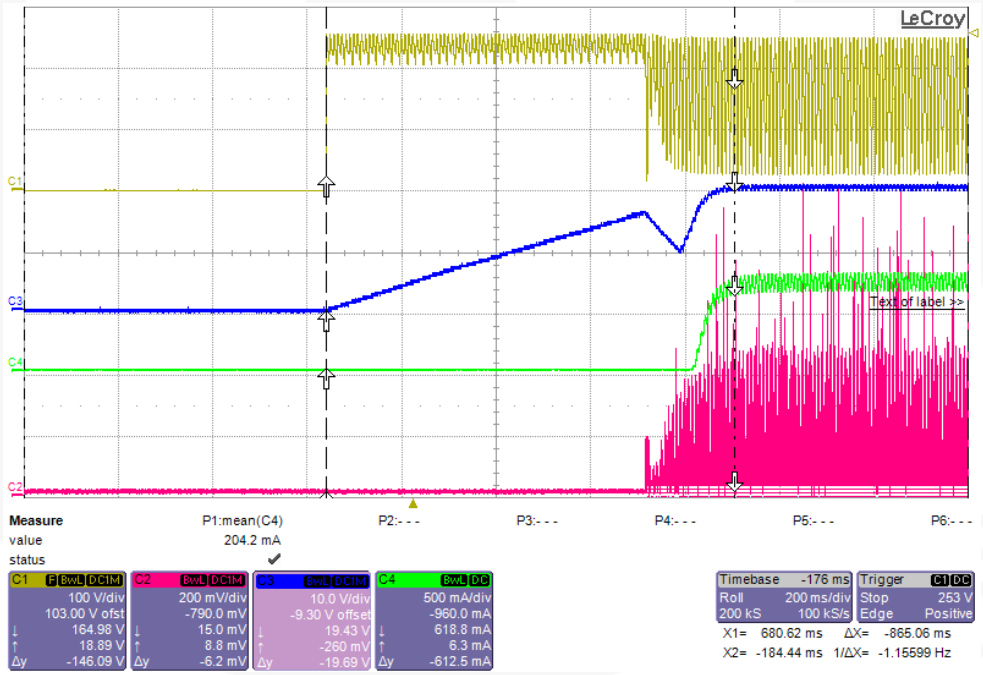

Figure 9. Startup – V_{IN} [180 V_{AC}]; No Dimmer, V_O [24 V], I_O [700 mA]

8.2. Operation Waveforms

In steady state, line compensation regulates output current regardless of input voltage variations. Output current ripple is ±83 mA with a rated output current of 700 mA. C1[V_{IN}], C2[V_{CS}], and C4[I_{OUT}].

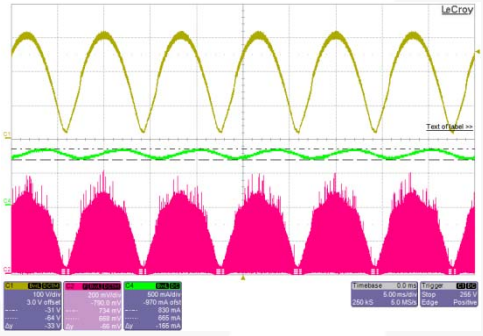

Figure 10. V_{IN} = 180 V_{AC}

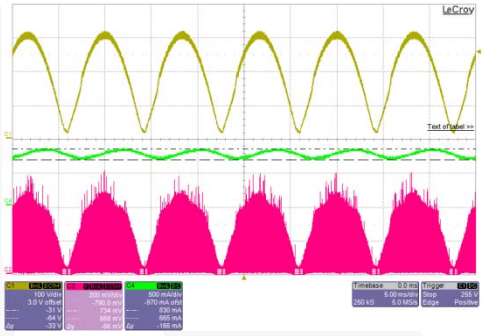

Figure 11. V_{IN} = 220 V_{AC}

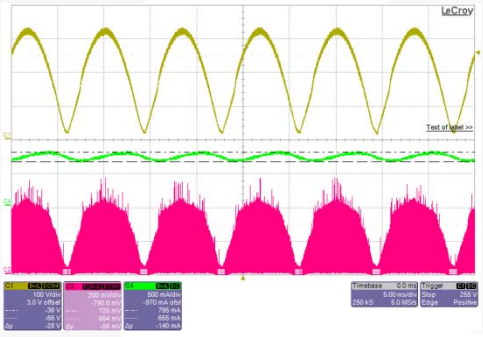

Figure 12. V_{IN} = 230 V_{AC}

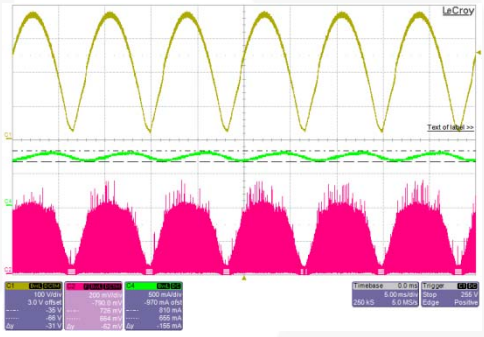

Figure 13. V_{IN} = 265 V_{AC}

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 ±3%.

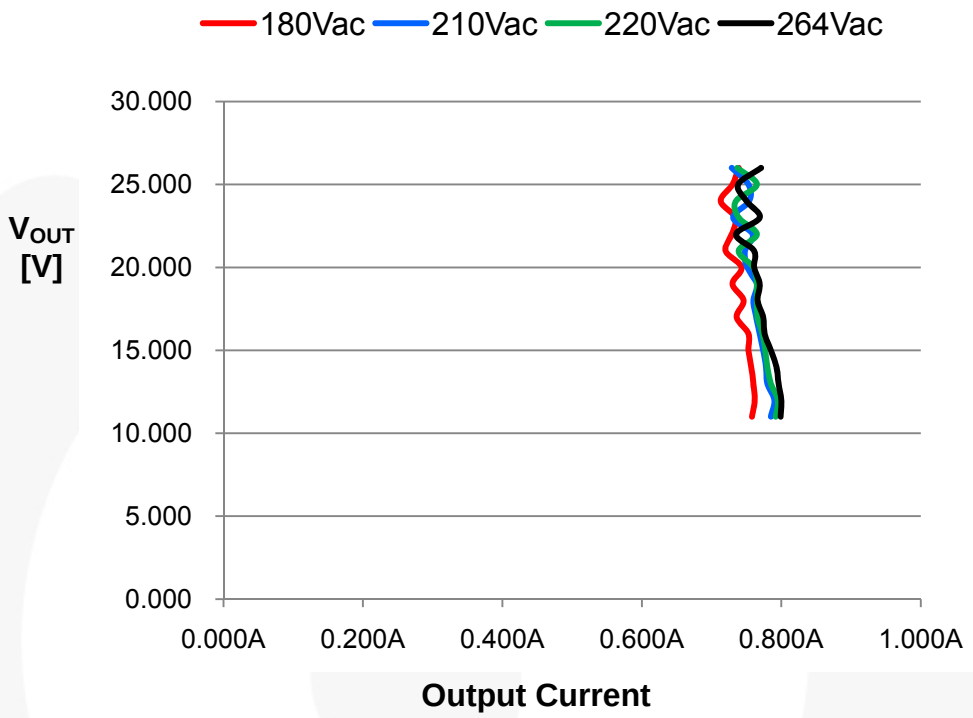

Figure 14. Constant Current Regulation – Measured by E LOAD [CR Mode]

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

Input Voltage	Min. Current	Max. Current	Tolerance
180 V_{AC} / 60 Hz	713 mA	762 mA	±3.3%
220 V_{AC} / 60 Hz	729 mA	790 mA	±4.0%
230 V_{AC} / 60 Hz	735 mA	795 mA	±3.9%
265 V_{AC} / 60 Hz	735 mA	800 mA	±4.2%

Table 6. Constant Current Regulation by Line Voltage Change (180~265 V_{AC})

Output Voltage	180 V_{AC}	220 V_{AC}	230 V_{AC}	265 V_{AC}	Tolerance
20 V	743 mA	751 mA	760 mA	761 mA	±1.2%
22 V	729 mA	759 mA	765 mA	735 mA	±2.4%
24 V	713 mA	754 mA	735 mA	750 mA	±2.8%

8.4. Open-LED and Short-LED Protections

In short-LED condition, the Over-Current Protect (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 short-LED condition is less than 5 A, which doesn't damage external components. C1 [V_{IN}], C2 [V_{CS}], C3 [V_{DD}], and C4 [I_{OUT}].

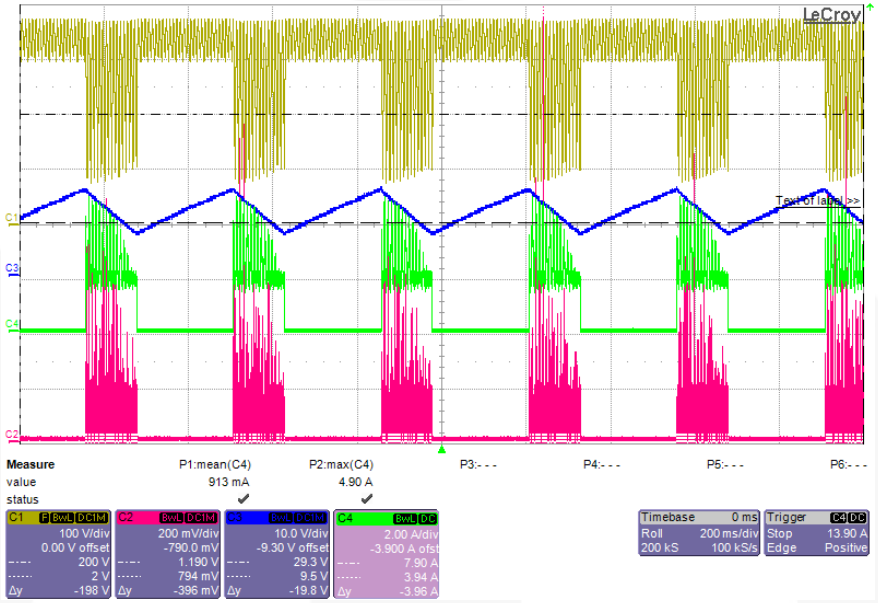

Figure 15. Short-LED Condition – V_{IN}, [265 V_{AC}]

In open-LED condition, output voltage is limited around 28 V by Over-Voltage Protection (OVP) in V_{DD}. The output OVP level can be controlled by the turn ratio of auxiliary and secondary windings. C1 [V_{IN}], C2 [V_{CS}], C3 [V_{DD}], and C4 [I_{OUT}].

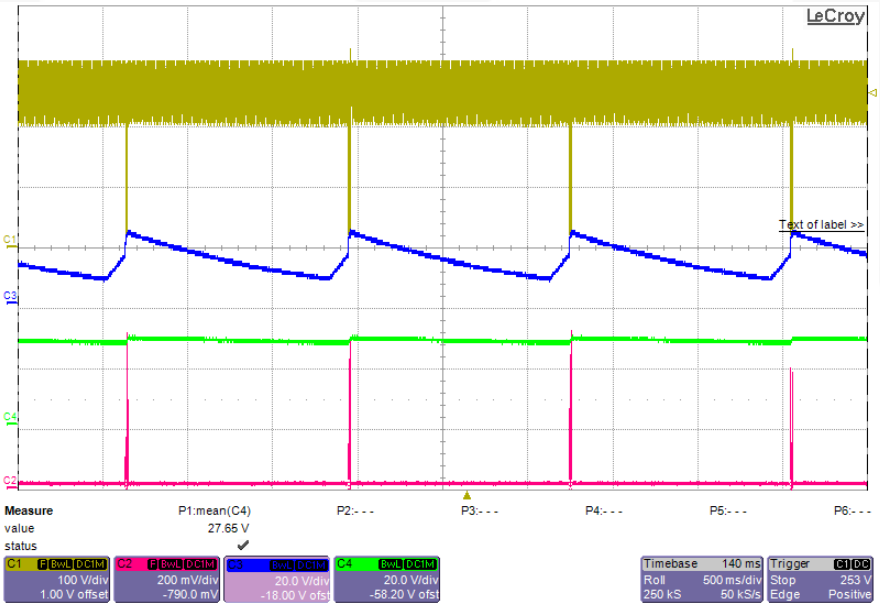

Figure 16. Open-LED Condition – V_{IN} [220 V_{AC}]

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 2 A. C1 [V_{IN}], C2 [V_{CS}], and C4 [I_{IN}].

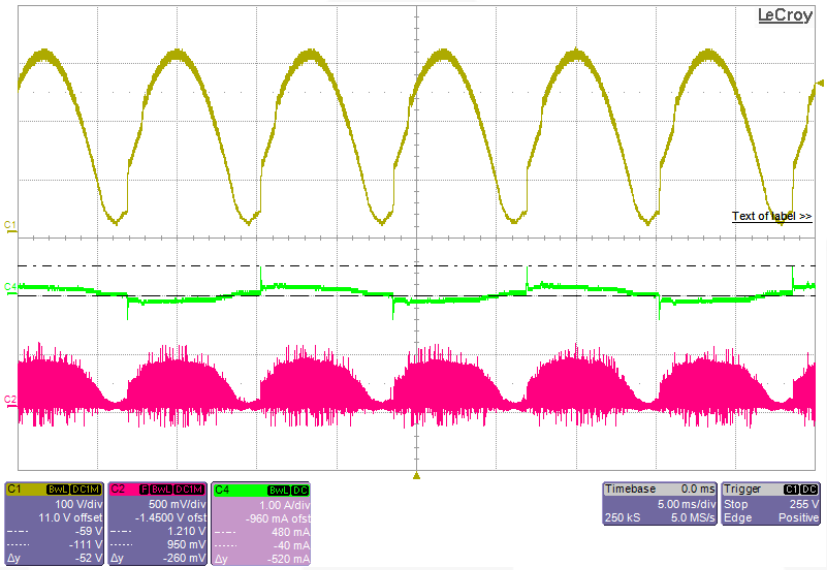

Figure 17. Dimming Operation Waveforms – Maximum Dimming Angle, V_{IN} [220 V_{AC}]

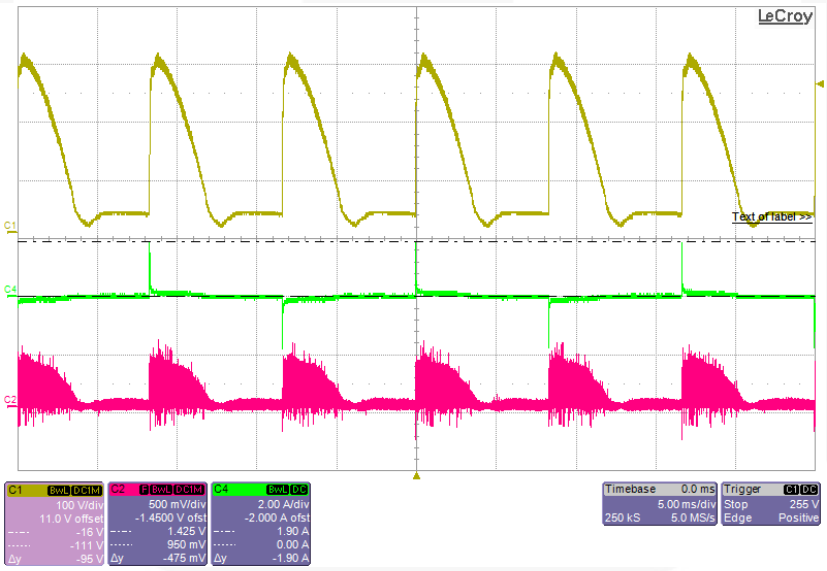

Figure 18. Dimming Operation Waveforms – 90º Dimming Angle, V_{IN} [220 V_{AC}]

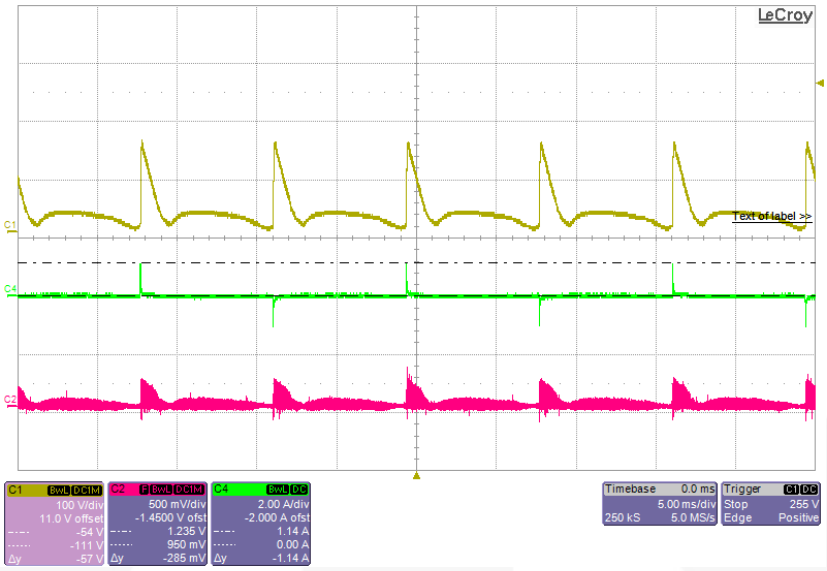

Figure 19. Dimming Operation Waveforms – Minimum Dimming Angle, V_{IN} [220 V_{AC}]

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

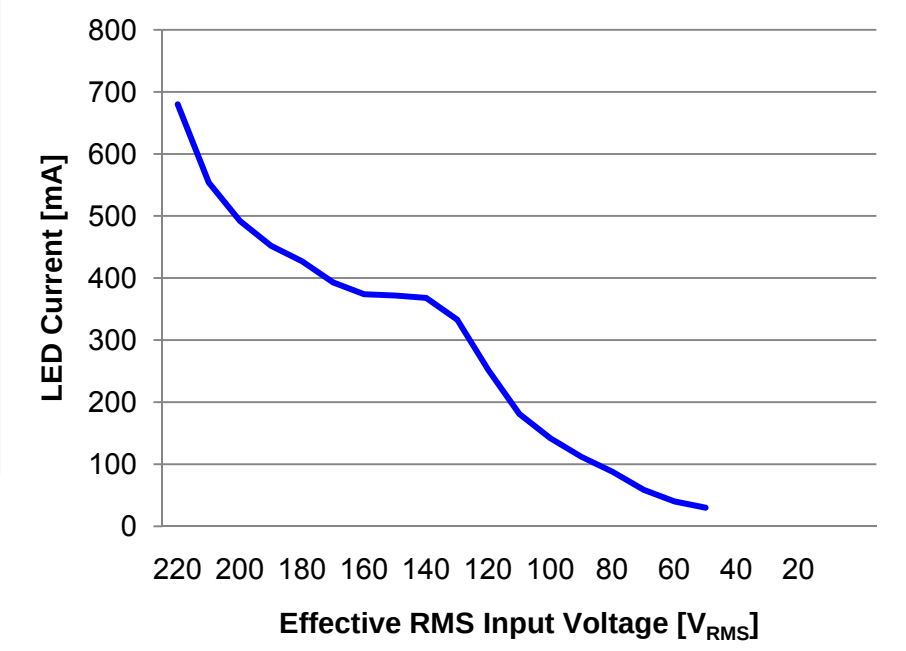

Figure 20. Dimming Curve (Effective RMS Input Voltage vs. Output Current) – Line Voltage[220 V_{AC}]

Table 7. Dimmer Compatibility

Manufacturer	Model	Input	Min. Current [mA]	Max. Current [mA]	Min.[%]	Flicker
GIRA	226200	230 V / 50 Hz	34	644	5.2795	No
JUNG	225NVDE	230 V / 50 Hz	37	644	5.74534	No
JUNG	266GDE	230 V / 50 Hz	47	667	7.04648	No
KOPP	8033		52	607	8.56672	No
BUSCH	2200	230 V / 50 Hz	60	674	8.90208	No
BUSCH	2247U	230 V / 50 Hz	62	647	9.58269	No
MERTEN	5721	230 V / 50 Hz	29	711	4.07876	No
BUSCH	2250	230 V / 50 Hz	38	672	5.65476	No
PEHA	436	230 V / 50 Hz	95	584	16.2671	No
EVERFLORISH	EF700DC [Trailing]	230 V / 50 Hz	162	609	26.601	No
MERTEN	577129 [Trailing]	230 V / 50 Hz	162	603	26.8657	No
BUSCH	6513 [Trailing]	230 V / 50 Hz	143	670	21.3433	No
NANO	SKD-500	220 V / 60 Hz	18	694	2.59366	No
JIN HEUNG	SA04003	220 V / 60 Hz	35	695	5.03597	No
DAESUNG	SKD-500	220 V / 60 Hz	5	696	0.71839	No
SHINSUNG	SSD-500	220 V / 60 Hz	23	716	3.21229	No
ANAM	D-500	220 V / 60 Hz	37	683	5.41728	No

The FL7730 high-line board shows good dimmer compatibility without flicker.

To reduce the minimum LED current, follow the below design guide:

- Reduce DIM resistors (R5 and R6) to decrease minimum DIM voltage. (DIM offset voltage by DIM internal current source (7.5 μA) is reduced by smaller R6.)
- Increase the bleeder capacitor (C1). (When reducing minimum LED current, bleeder current should be larger to stabilize input current without flicker. However, increasing C1 reducees PF. This is always trade-off of “flicker-free design vs. PF” in RC bleeder structure.)

8.6. System Efficiency

Power efficiency is 86.19~ 86.87% in 180 ~ 265 V_{AC} input voltage range.

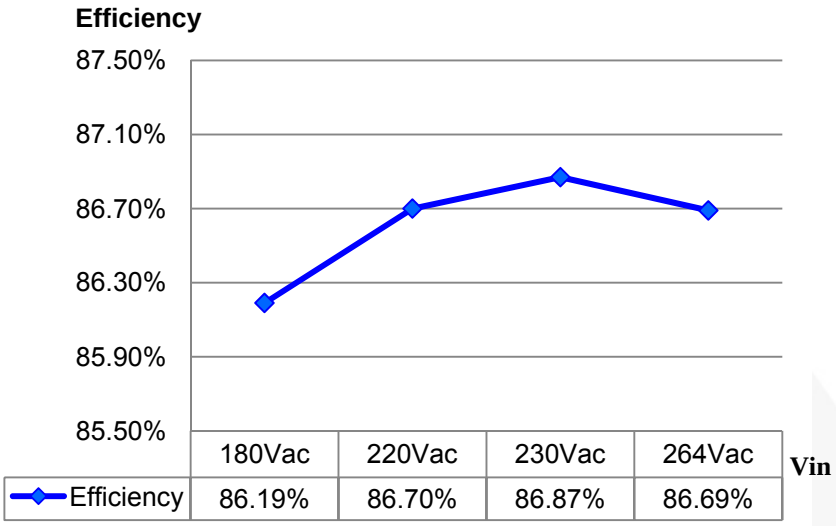

Figure 21. Power Efficiency (Input Voltage vs. Efficiency)

Table 8. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
180 V_{AC}	19.97 W	713 mA	24.14 V	17.21 W	86.19%
220 V_{AC}	21.23 W	755 mA	24.38 V	18.81 W	86.70%
230 V_{AC}	21.31 W	759 mA	24.39 V	18.20 W	86.87%
264 V_{AC}	20.47 W	733 mA	24.21 V	17.52 W	86.69%

8.7. Power Factor and Total Harmonic Distortion

FL7730 shows excellent power factor and total harmonic distortion performance. Power factor is over 0.9 at 180~265 V_{AC}. THD is less than 30% of the specification.

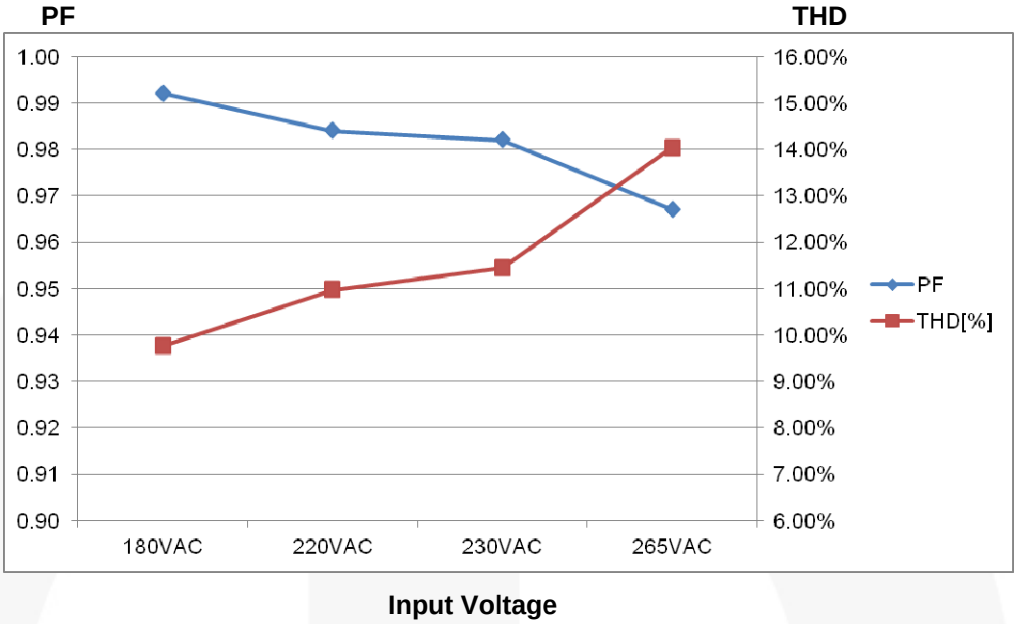

Figure 22. Power Factor & Total Harmonic Distortion (50 Hz)

Table 9. Power Factor and Total Harmonic Distortion (50 Hz)

Input Voltage	Output Current	Output Voltage	PF	THD
180 V_{AC} / 50 Hz	731 mA	24.02 V	0.992	9.77%
220 V_{AC} / 50 Hz	753 mA	24.23 V	0.984	10.97%
230 V_{AC} / 50 Hz	760 mA	24.20 V	0. 982	11.45%
264 V_{AC} / 50 Hz	732 mA	24.05 V	0.967	14.03%

Table 10. Power Factor and Total Harmonic Distortion (60 Hz)

Input Voltage	Output Current	Output Voltage	PF	THD
180 V_{AC} / 60 Hz	731 mA	24.05 V	0.991	9.85%
220 V_{AC} / 60 Hz	749 mA	24.17 V	0.981	10.75%
230 V_{AC} / 60 Hz	757 mA	24.21 V	0. 978	11.29%
264 V_{AC} / 60 Hz	729 mA	24.04 V	0.958	14.16%

8.8. Operating Temperature

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

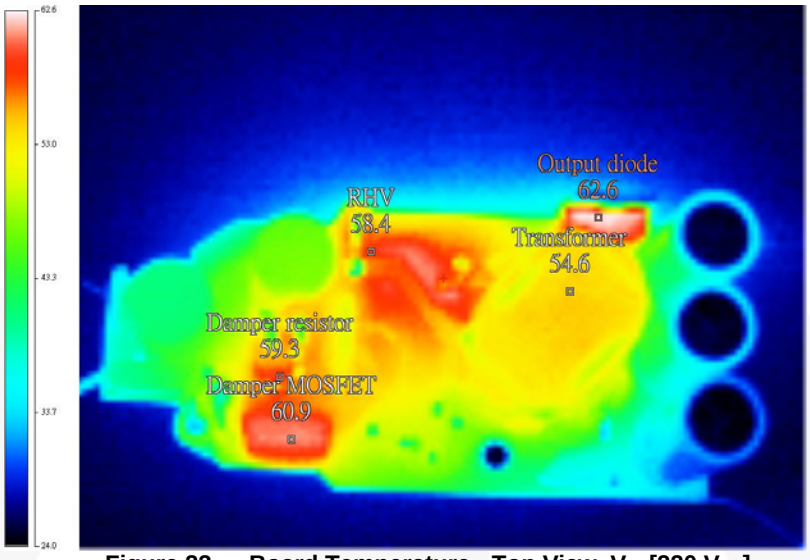

Figure 23. Board Temperature - Top View, V_{IN} [220 V_{AC}]

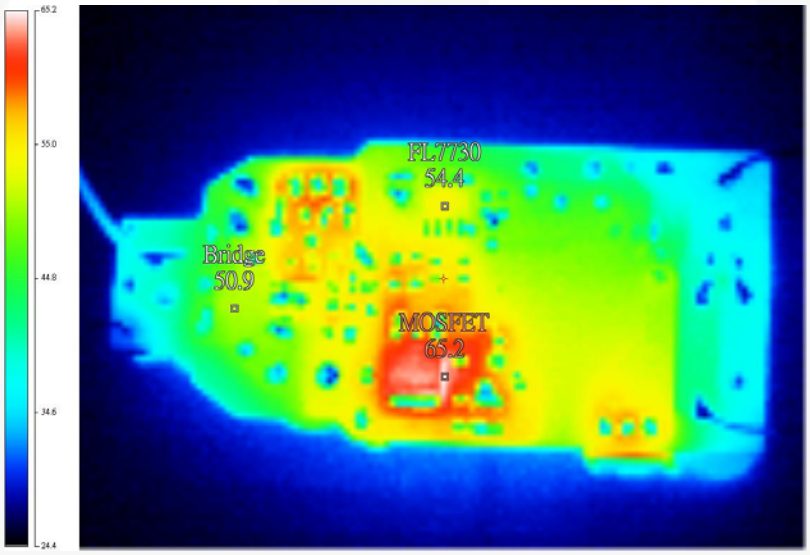

Figure 24. Board Temperature - Bottom View, V_{IN} [220 V_{AC}]

8.9. Electromagnetic Interference (EMI)

All measurement was conducted in observance of CISPR22 criteria.

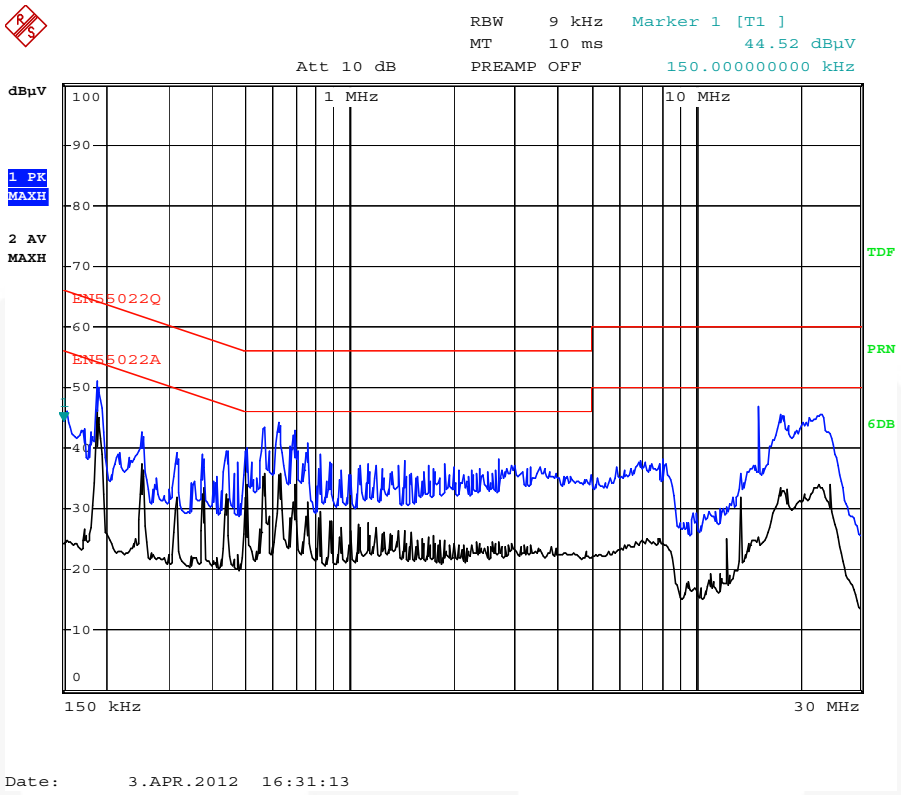

Figure 25. EMI Results – V_{IN} [220 V], V_{OUT} [24 V], I_{OUT} [754 mA]

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-L021-2 to FEBFL7730_L21H017A

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