User Guide for

FEBFL7730_L20H008A

8.4W LED Bulb Using FL7730

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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 PSR single-stage controller. The input voltage range is $180V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 380mA at $22V_{MAX}$. This document contains general description of FL7730, the power supply specification, schematic, bill of materials, and the 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 an 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 good power factor and Total Harmonic Distortion (THD), constant on-time control is utilized with 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 higher efficiency. FL7730 provides protections such as open-LED, short-LED, and over-temperature protection.

1.2. Features

- Compatible with Traditional TRIAC Control
- Cost-Effective Solution without Input Bulk Capacitor and Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (CC) Control
- Line Voltage Compensation for CC Control
- Linear Frequency Control for Better Efficiency and Simpler 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
- Frequency Hopping for EMI
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package Available

1.3. Internal Block Diagram

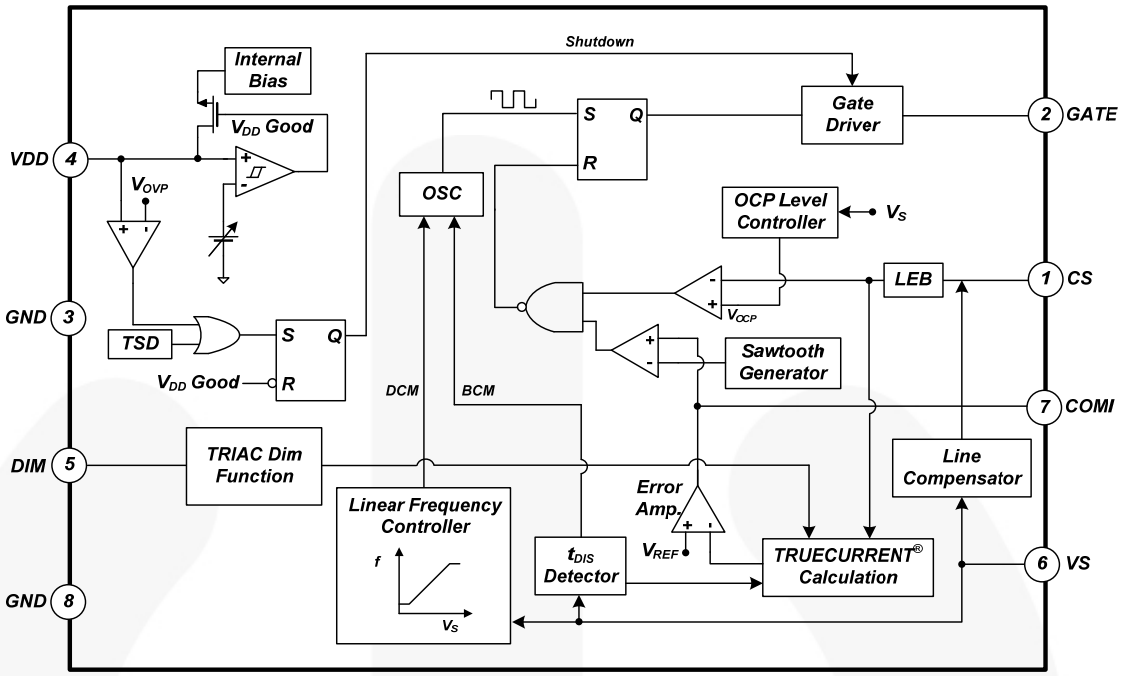

Figure 1. Internal Block Diagram

2. General Specifications

All data in Table 1 was measured at an ambient temperature of 25°C.

Table 1. Summary of Features and Performance for LED Lighting Bulb

Description	Symbol	Value	Comments
Input Voltage	$V_{IN,MIN}$	180V	Minimum Input Voltage
	$V_{IN,MAX}$	265V	Maximum Input Voltage
	$V_{IN,NOMINAL}$	220~230V	Nominal Input Voltage
Input Frequency	f_{IN}	60Hz	Line Frequency
Output Voltage Current	$V_{OUT,MIN}$	10V	Minimum Output Voltage
	$V_{OUT,MAX}$	28V	Maximum Output Voltage
	$V_{OUT,NOMINAL}$	22V	Nominal Output Voltage
	$I_{OUT,NOMINAL}$	380mA	Nominal Output Current
	$I_{OUT,RIPPLE}$	±65mA	Output Current Ripple
	CC Deviation	<±1.9%	Line Input Voltage Change: 180~265V_{AC}
		<±3.1%	Output Voltage Change: 10~28V
Efficiency	Note: No Dimmer Connected		
	Eff_{180VAC}	84.5%	Efficiency at 180V_{AC} Line Input Voltage
	Eff_{220VAC}	84.4%	Efficiency at 220V_{AC} Line Input Voltage
	Eff_{230VAC}	84.4%	Efficiency at 230V_{AC} Line Input Voltage
	Eff_{265VAC}	83.8%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD	Note: No Dimmer Connected		
	PF/THD_{180VAC}	0.97/13.7%	PF/THD at 180V_{AC} Line Input Voltage
	PF/THD_{220VAC}	0.93/16.6%	PF/THD at 220V_{AC} Line Input Voltage
	PF/THD_{230VAC}	0.92/17.3%	PF/THD at 230V_{AC} Line Input Voltage
	PF/THD_{265VAC}	0.87/19.7%	PF/THD at 265V_{AC} Line Input Voltage
Temperature	Note: Open-Frame Condition (T_A=25ºC)		
	T_{FL7730}	46ºC	FL7730 Temperature
	T_{MOSFET}	53ºC	Primary MOSFET Temperature
	T_{DIODE}	45ºC	Secondary Diode Temperature
	$T_{TRANSFORMER}$	48ºC	Transformer Temperature
	T_{DAMPER}	49ºC	Active Damper Temperature
	$T_{STR.RESISTOR}$	55ºC	Startup Resistor Temperature

3. Photographs

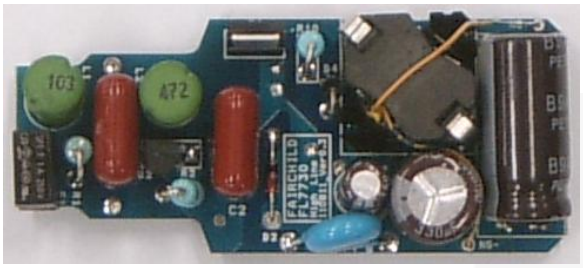

Figure 2. Top View of Evaluation Board

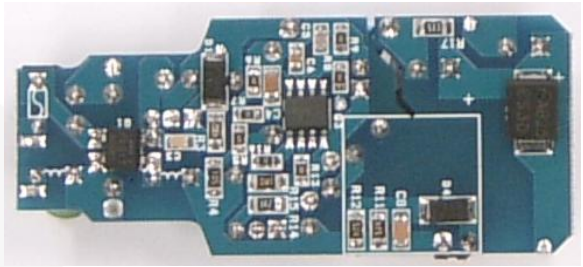

Figure 3. Bottom View of Evaluation Board

Dimensions: 62.5mm (L) × 26.8mm (W) × 12.0 (H)

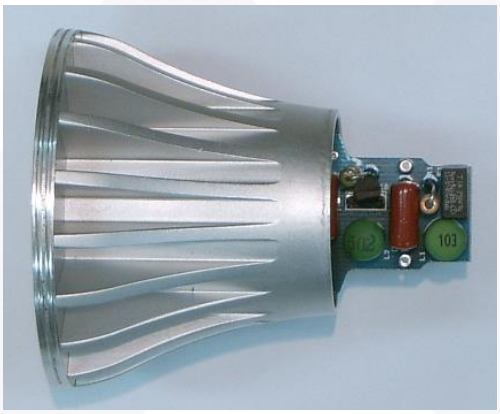

Figure 4. Side View in Bulb Case Type 1

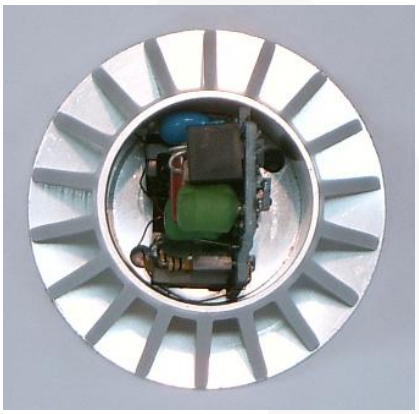

Figure 5. Bottom View in Bulb Case Type 1

Bulb Case Type 1 : 32mm (Case Diameter) × 40mm (Case Depth)

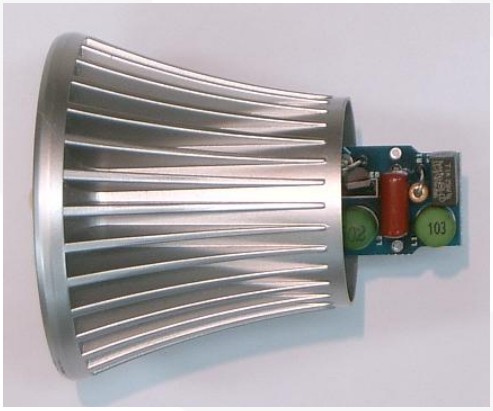

Figure 6. Side View in Bulb Case Type 2

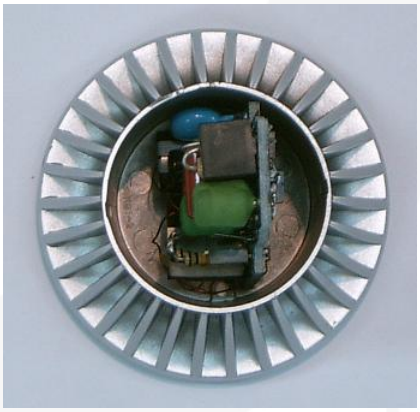

Figure 7. Bottom View in Bulb Case Type 2

Bulb Case Type 2 : 34mm (Case Diameter) × 44mm (Case Depth)

4. Printed Circuit Board

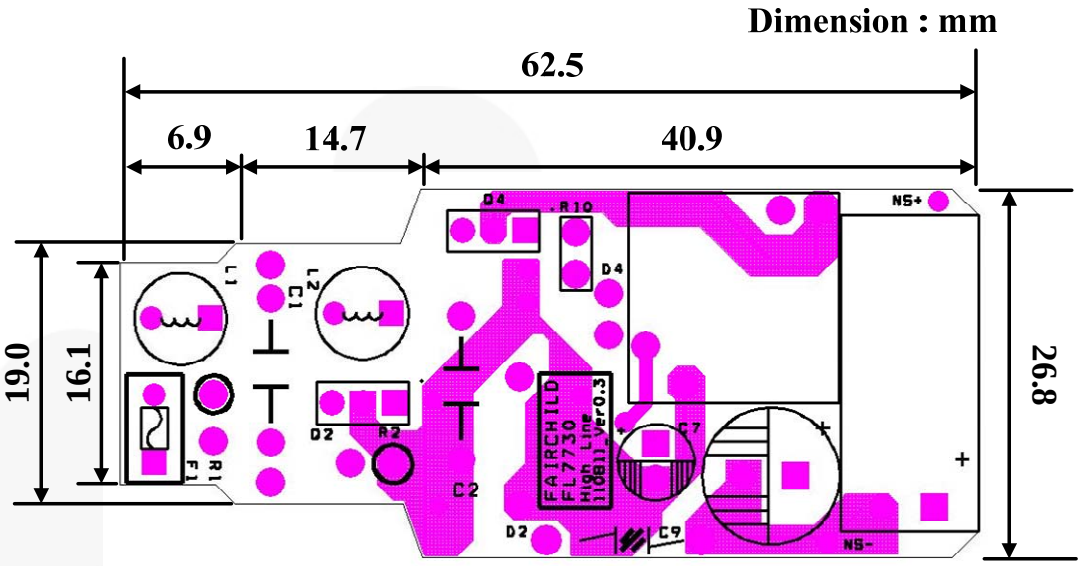

Figure 8. Printed PCB, Top Side

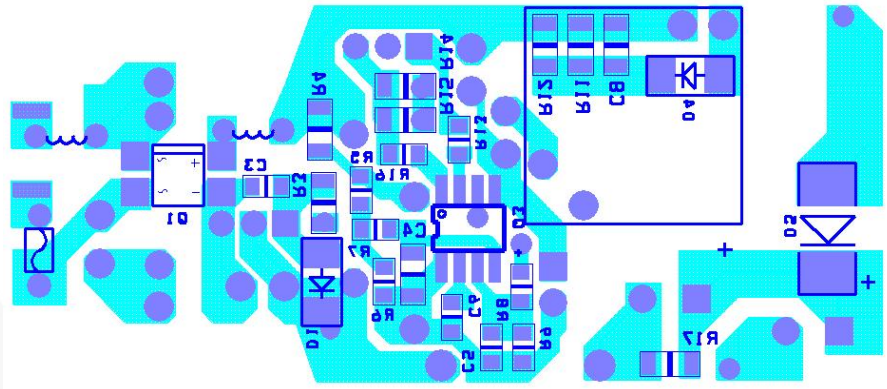

Figure 9. Printed PCB, Bottom Side

5. Schematic

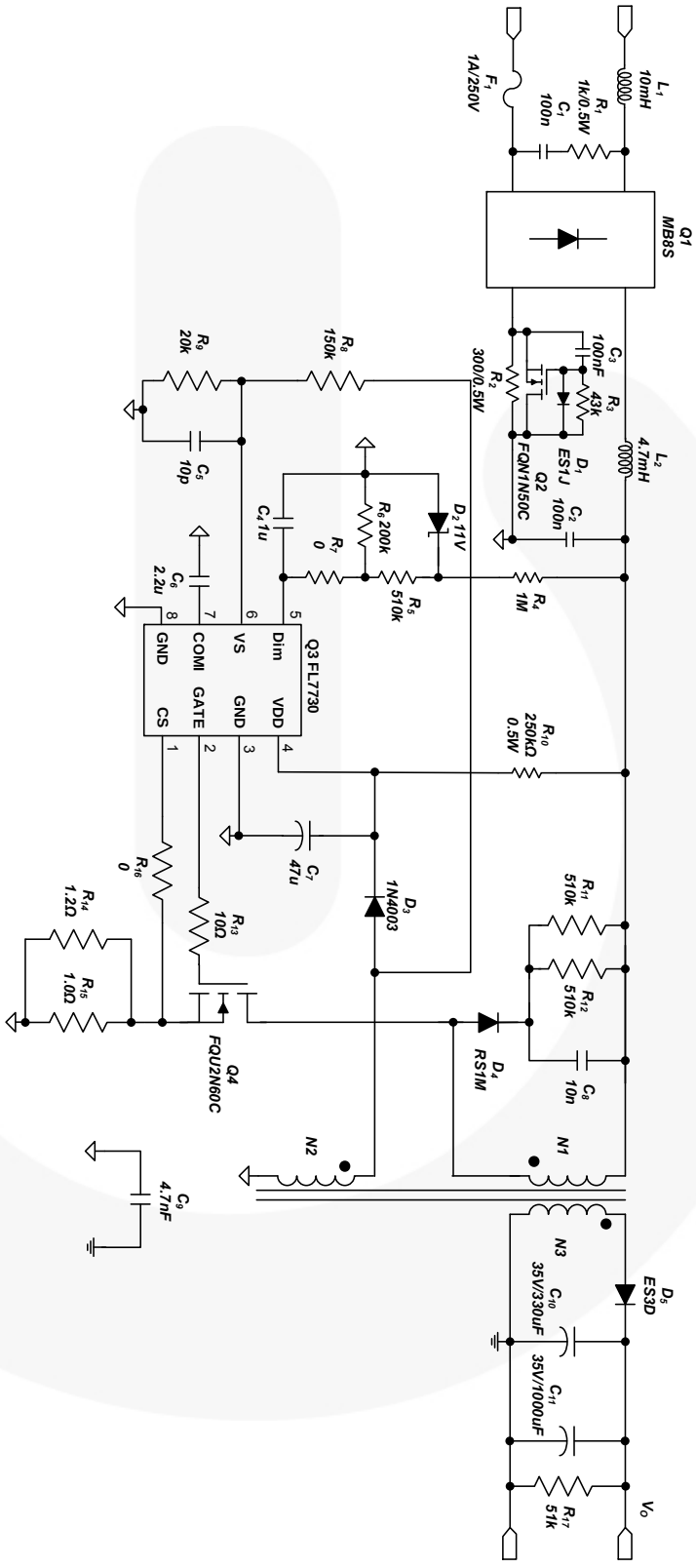

Figure 10. Schematic of Evaluation Board

2.1 Bill of Materials

No.	Part	Part number	Qty	Description	Manufacturer
1	Q1	MB8S	1	Bridge Diode	Fairchild
2	Q2	FQN1N50C	1	1A/500V Active Damper MOSFET	Fairchild
3	Q3	FL7730	1	Main Controller	Fairchild
4	Q4	FQU2N60C	1	5A/600V Main Switch	Fairchild
5	F1	SS-5-1A	1	1A/250V Fuse	Bussmann
6	L1	R06103KT00	1	10mH Filter Inductor	Bosung
7	L2	R06472KT00	1	4.7mH Filter Inductor	Bosung
8	D1	ES1J	1	1A/600V Diode	Fairchild
9	D2	1N5241	1	11V Zener Diode	Fairchild
10	D3	1N4003	1	1A/200V Diode	Fairchild
11	D4	RS1M	1	1A/1000V Diode	Fairchild
12	D5	ES3D	1	3A/200V Fast Rectifier	Fairchild
13	C1	MPE 400V104K 14S	1	104/400V Film Capacitor	Sungho
14	C2	MPE 400V104K 14S	1	104/400V Film Capacitor	Sungho
15	C3	C0805C104K3RACTU	1	104/25V SMD Capacitor 2012	Kemet
16	C4	C1206C105K3PACTU	1	105/25V SMD Capacitor 3216	Kemet
17	C5	C0805C100M3GACTU	1	10/25V SMD Capacitor 2012	Kemet
18	C6	C2012Y5V1E225Z	1	225/25V SMD Capacitor 2012	TDK
19	C7	KMG 47μF/35V	1	47μF/35V Electrolytic Capacitor	Samyoung
20	C8	C1206C103KDRACTU	1	103/1kV SMD Capacitor 3216	Kemet
21	C9	SCFz2E472M10BW	1	472/250V Y-Capacitor	Samwha
22	C10	KMG 330μF/35V	1	330μF/35V Electrolytic Capacitor	Samyoung
23	C11	RM 1000μF/35V	1	1000μF/35V Electrolytic Capacitor	Samwha
24	R1	SFR2500001001FR500	1	1kΩ/0.5W Metal Resistor	Vishay
25	R2	RNF12JTD300R	1	300Ω/0.5W Metal Resistor	Stackpole Elec.
26	R3	RC1206JR-0720KL	1	20kΩ SMD Resistor 3216	Yageo
27	R4	RC1206JR-071ML	1	1MΩ SMD Resistor 3216	Yageo
28	R5	RC0805JR-07510KL	1	510kΩ SMD Resistor 2012	Yageo
29	R6	RC0805JR-07200KL	1	200kΩ SMD Resistor 2012	Yageo
30	R7	0	1		
31	R8	RC0805JR-07150KL	1	150kΩ SMD Resistor 2012	Yageo
32	R9	RC0805JR-0720KL	1	20kΩ SMD Resistor 2012	Yageo
33	R10	RNF12GTD250K	1	250kΩ/0.5W Metal Resistor	Stackpole Elec.
34	R11, R12	RC1206JR-07510KL	2	510kΩ SMD Resistor 3216	Yageo
35	R13	RC0805JR-0710RL	1	10Ω SMD Resistor 2012	Yageo
36	R14	RC1206JR-071R2L	1	1.2Ω SMD Resistor 3216	Yageo
37	R15	RC1206FR-071RL	1	1.0Ω SMD Resistor 3216	Yageo
38	R16	RC0805JR-070RL	1	0Ω SMD Resistor 2012	Yageo
39	R17	RC1206JR-0751KL	1	51kΩ SMD Resistor 3216	Yageo

2.2 Transformer and Winding Specifications

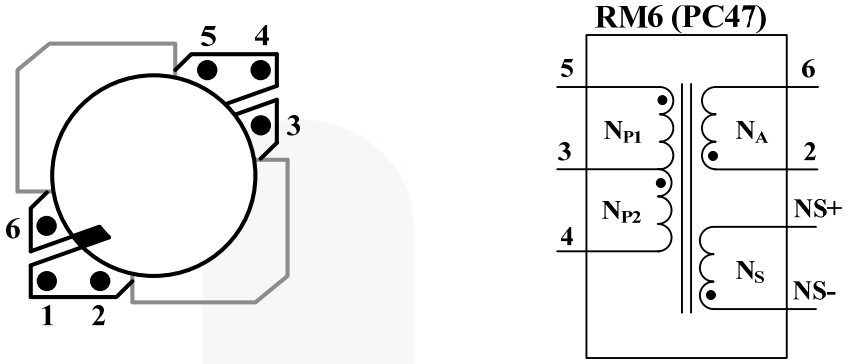

Figure 11. Transformer Specifications & Construction

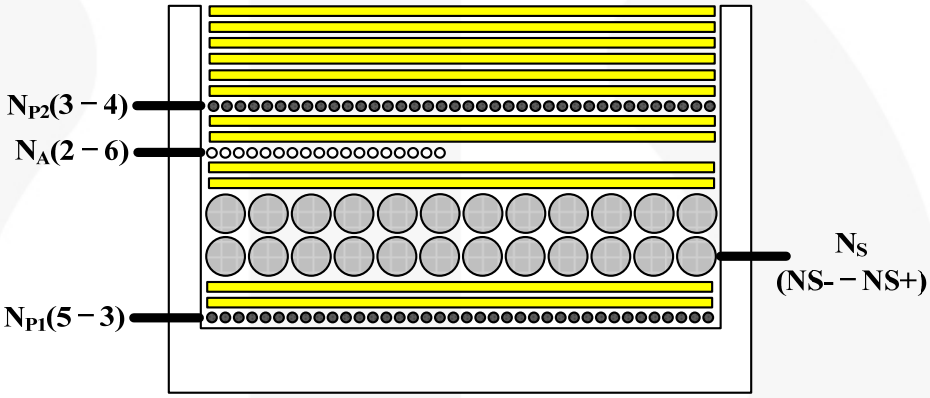

Figure 12. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	5 → 3	0.13φ	38 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025mm, 2 Layer				
3	N_S	NS- → NS+	0.3φ (TIW)	24 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 2 Layer				
5	N_A	2 → 6	0.13φ	18 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025mm, 2 Layer				
7	N_{P2}	3 → 4	0.13φ	38 Ts	Solenoid Winding
8	Insulation : Polyester Tape t = 0.025mm, 6 Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	1– 2	1mH ±10%	50kHz, 1V
Leakage	1– 2	8μH	50kHz, 1V Short All Output Pins

6. Performance of Evaluation Board

6.1. Startup

Startup time is 0.7s. 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*).

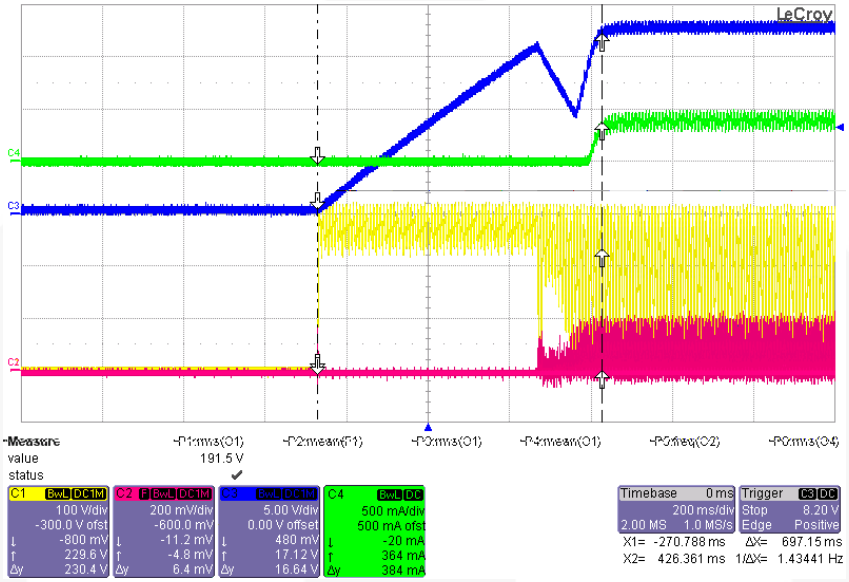

Figure 13. Startup – V_{IN} [220V_{AC}], C1 [V_{IN}], C2 [V_{CS}] C3 [V_{DD}], C4,[I_{OUT}], (No Dimmer Connected)

6.2. Operation Waveforms

In steady state, line compensation regulates output current regardless of input voltage variations. Output current ripple is ±65mA with a rated output current of 380mA.

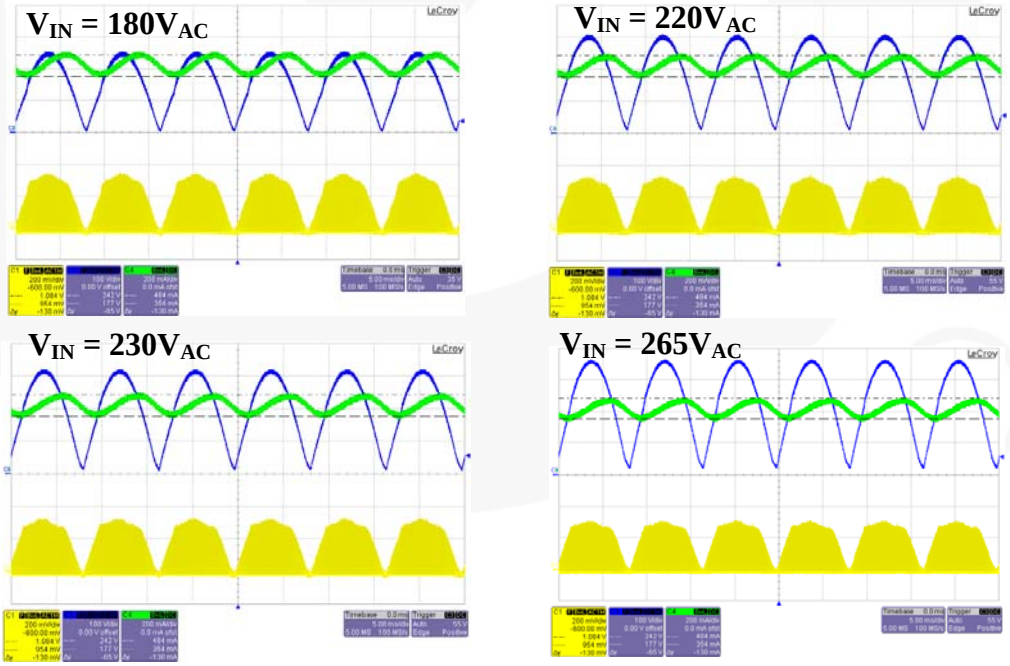

Figure 14. Operation Waveforms – V_O [22V], I_O [380mA], C1 [V_{CS}], C3, [V_{IN}], C4 [I_{OUT}]

6.3. Constant Current Regulation

Constant current deviation in the output voltage range from 10V to 28V is less than 3.1% at each line input voltage. Line regulation at the rated output voltage (22V) is less than 1.7%.

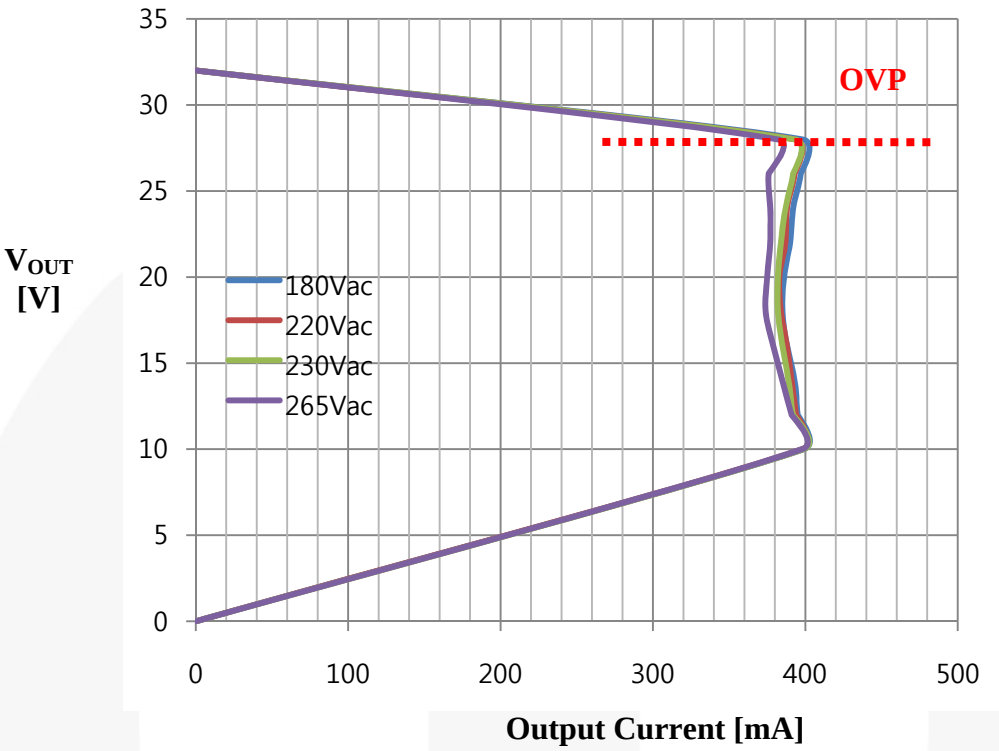

Figure 15. Constant Current Regulation – Measured by E-Load [CR Mode]

Table 4. Constant Current Regulation by Output Voltage Change (10~28V)

Input Voltage	Min. Current	Max. Current	Tolerance
180V_{AC} / 60Hz	385mA	399mA	±1.8%
220V_{AC} / 60Hz	383mA	398mA	±1.9%
230V_{AC} / 60Hz	382mA	399mA	±2.2%
265V_{AC} / 60Hz	374mA	398mA	±3.1%

Table 5. Constant Current Regulation by Line Voltage Change (90~140V_{AC})

Output Voltage	180V_{AC}	220V_{AC}	230V_{AC}	265V_{AC}	Tolerance
20V	392mA	388mA	387mA	377mA	±1.9%
22V	390mA	387mA	384mA	377mA	±1.7%
24V	386mA	383mA	382mA	375mA	±1.4%

6.4. Open/Short-LED Protections

In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because the FL7730 lowers the OCP level when V_S voltage is less than 0.4V during output diode conduction time. The output current in the short-LED condition is less than 1.5A, which doesn't damage any external components.

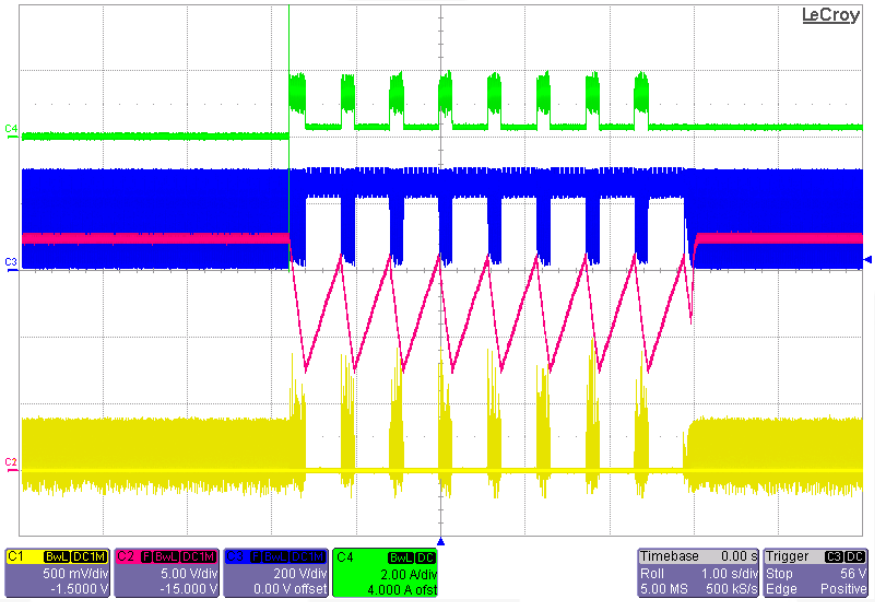

Figure 16. Short-LED Condition – V_{IN} [220V_{AC}], C1 [V_{CS}], C2 [V_{DD}], C3 [V_{IN}], C4 [I_{OUT}]

In open-LED condition, output voltage is limited around 32V by OVP in V_{DD}. The output over-voltage protection level can be controlled by turn ratio of auxiliary and secondary windings.

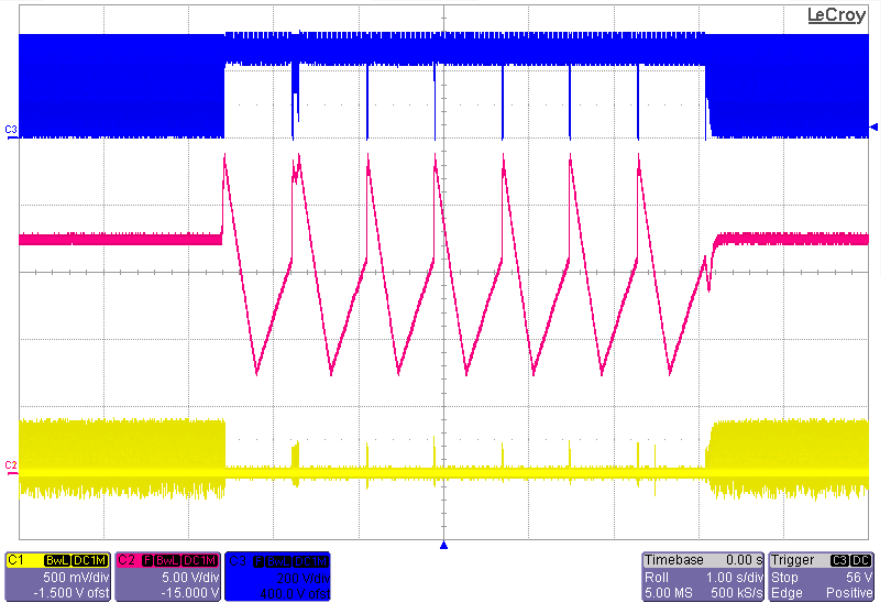

Figure 17. Open-LED Condition – V_{IN} [220V_{AC}], C1 [V_{CS}], C2 [V_{DD}], C3 [V_{IN}]

6.5. Dimming Operation

Dimming operation waveforms are shown in Figures 18-20. Active damper, RC bleeder, and dimming control in FL7730 implement flicker-free dimming operation. Spike current at dimmer firing is less than 1A.

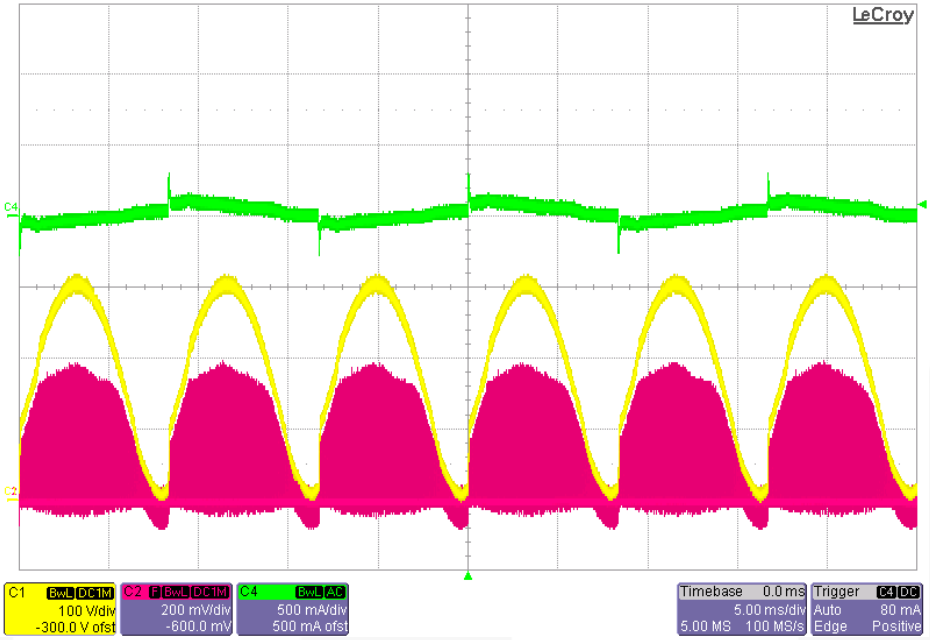

Figure 18. Dimming Operation Waveforms – Max. Dimming Angle, V_{IN} [220V_{AC}], C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

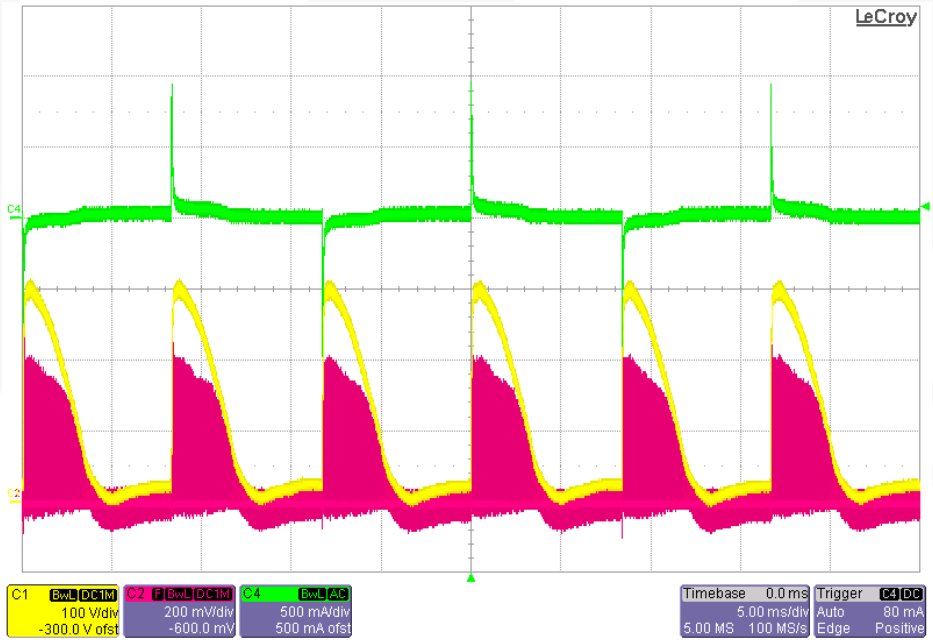

Figure 19. Dimming Operation Waveforms – 90° Dimming Angle, V_{IN} [220V_{AC}] ,C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

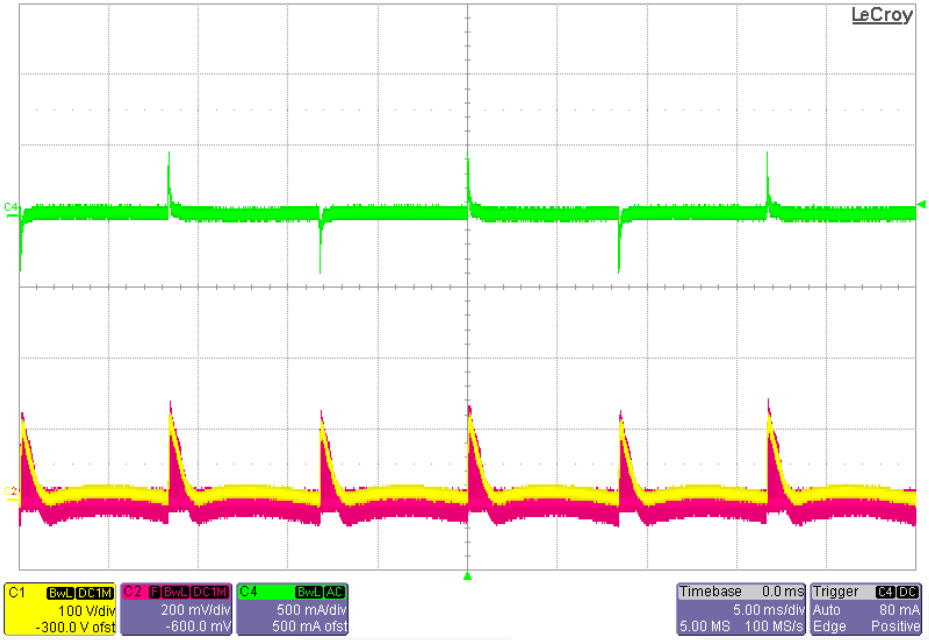

Figure 20. Dimming Operation Waveforms – Min. Dimming Angle, V_{IN} [220V_{AC}], C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

Output current is controlled by dimming function when rotating dimmer switch as in the dimming curve in Figure 21. The dimming control block in FL7730 smoothly changes regulated output current by detecting dimming angle.

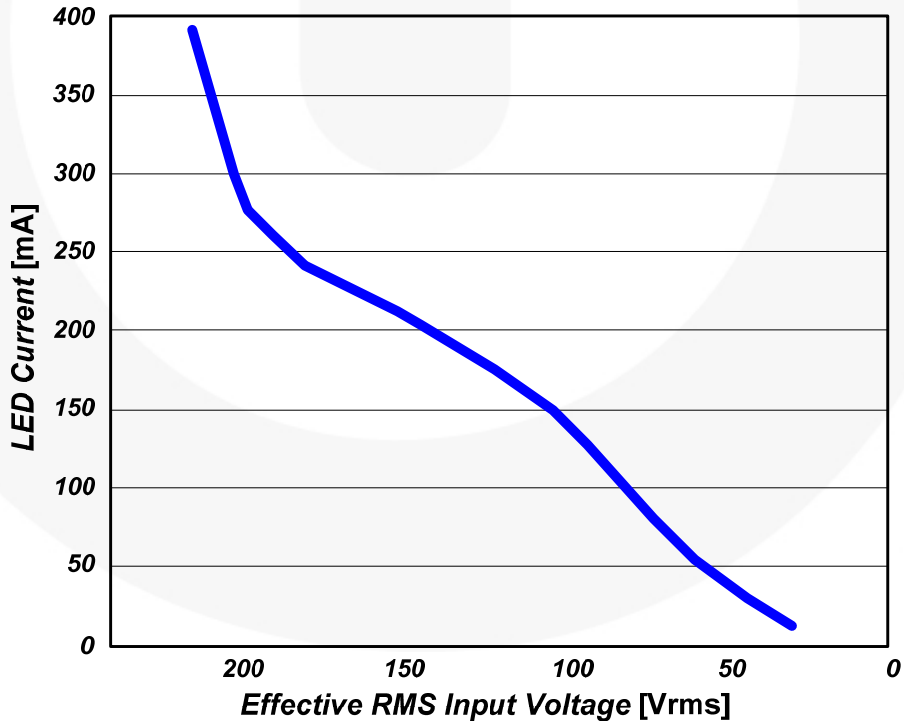

Figure 21. Dimming Curve (Effective RMS Input Voltage vs. Output Current) – Line Voltage [220V_{AC}]

Table 6. TRIAC Dimmer Compatibility

Manufacturer	Dimmer	Condition	Maximum Current	Minimum Current	Flicker
NANO	SKD-500	220V / 60Hz	365mA	24mA (7%)	No
JIN HEUNG	SA04003	220V / 60Hz	364mA	53mA (15%)	No
ANAM	D-500	220V / 60Hz	350mA	58mA (17%)	No
OPPLE	P068102	220V / 60Hz	378mA	6mA (2%)	No
DAESUNG	SKD-500	220V/ 60Hz	366mA	6mA (2%)	No

6.6. System Efficiency

Power efficiency is 83.8 ~ 84.5% in 180 ~ 365V_{AC} input voltage range.

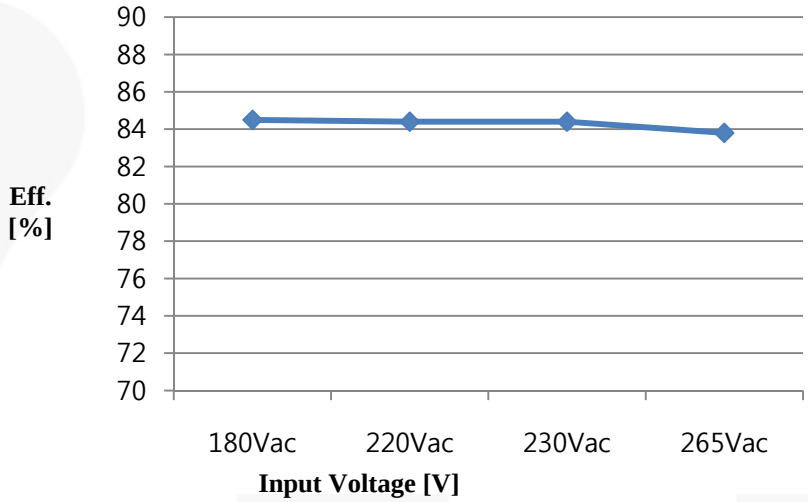

Figure 22. Power Efficiency (Input Voltage vs. Efficiency)

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
180V_{AC}	10.13W	392mA	21.84V	8.56W	84.5%
220V_{AC}	9.97W	386mA	21.80V	8.41W	84.4%
230V_{AC}	9.94W	385mA	21.79V	8.39W	84.4%
265V_{AC}	9.76W	376mA	21.75V	8.18W	83.8%

6.7. Power Factor and THD

FL7730 shows excellent power factor and THD performance. Power factor is over 0.9 at 180~230V_{AC}. THD is less than 30% specification.

Table 8. Power Factor and THD

Input Voltage	Output Current	Output Voltage	PF	THD
180V_{AC}	392mA	21.84V	0.97	13.7%
220V_{AC}	386mA	21.80V	0.93	16.6%
230V_{AC}	385mA	21.79V	0.92	17.3%
265V_{AC}	376mA	21.75V	0.87	19.7%

6.8. Operating Temperature

Temperature of the all components on this board is less than 55°C.

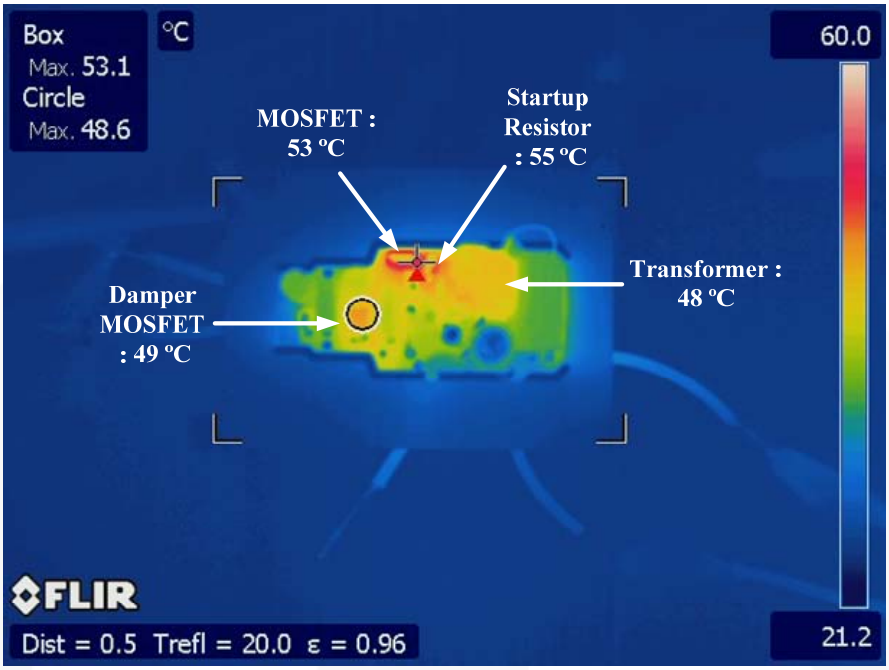

Figure 23. Board Temperature - Top View, V_{IN} [220V_{AC}], I_O [380mA]

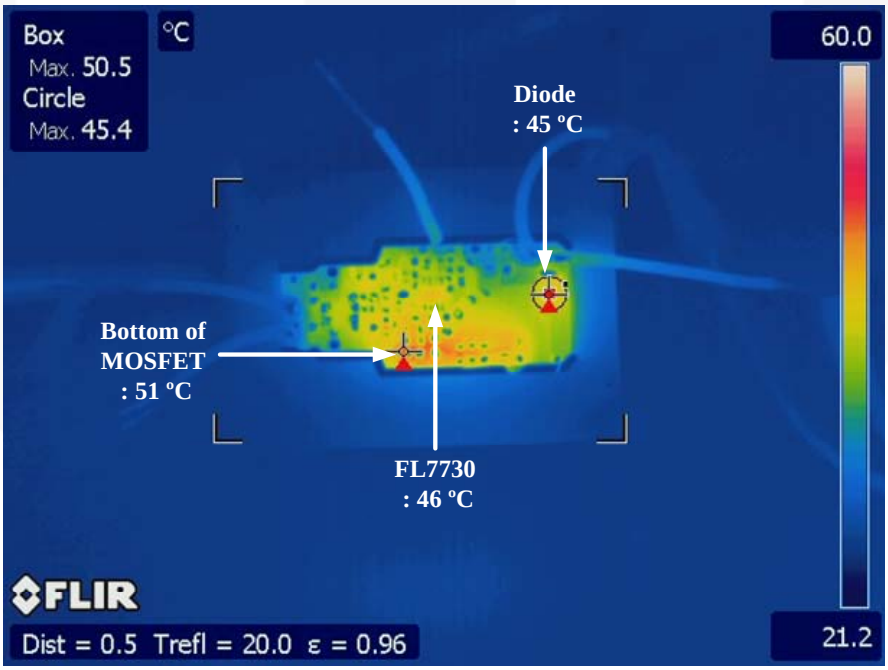

Figure 24. Board Temperature - Bottom View, V_{IN} [220V_{AC}], I_O [380mA]

6.9. EMI

The all measurement was conducted in observance of CISPR22 criteria.

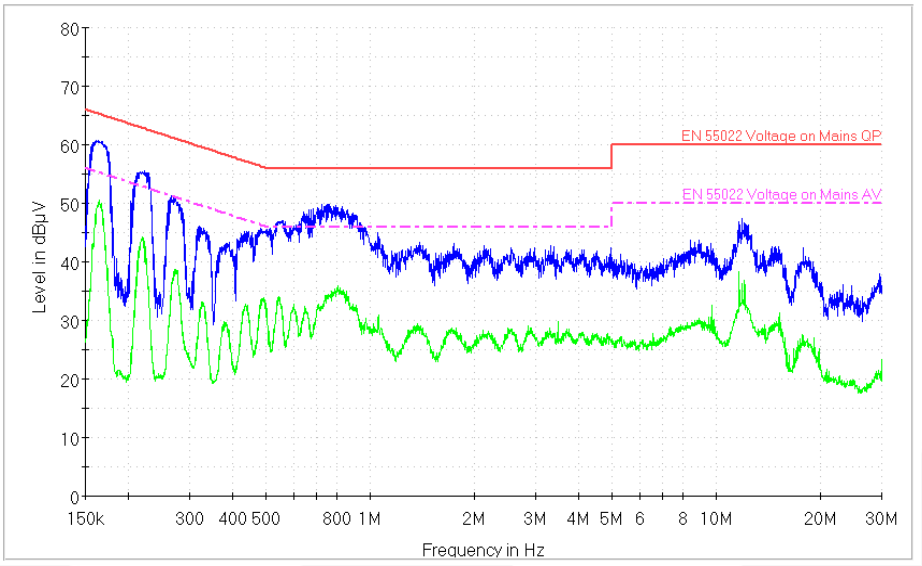

Figure 25. EMI Results – V_{IN} [220V], V_{OUT} [22V], I_{OUT} [380mA]

7. Revision History

Rev.	Date	Description
0.0.1	2/22/12	Initial edit/format pass
0.0.2	3/07/12	BOM revision and minor error correction

WARNING AND DISCLAIMER

Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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