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User Guide for

# FEBFL7730_L20H008B

## Dimmable LED Bulb at High Line

## Featured Fairchild Product:

## FL7730

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

*Fairchild Semiconductor.com*

# Table of Contents

This FEBFL7730_L20H008B Evalution Board can be identified by the silkscreen marking FL7730 High Line on the top side of the pcb. This user guide supports the evaluation board for the FL7730, FEBFL7730_L20H008B. This kit supersedes the FEBFL7730_L20H008A. The revised kit incorporates the next generation FL7730, which is redesigned for improved dimming performance. 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 or the evaluation board page http://www.fairchildsemi.com/products/evaluationboards/.

# 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 180 $V_{RMS}$ – 265 $V_{RMS}$ and there is one DC output with a constant current of 380 mA at 22 $V_{out}$. This document contains general description of FL7730, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

## 1.1. General Description of FL7730

The FL7730 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Dimming control with no flicker is implemented by analog sensing method. Primary-side regulation and single-stage topology minimize cost and reduce external components, such as input bulk capacitor and feedback circuitry. To improve power factor and THD, constant on-time control is utilized with internal error amplifier and 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 and simpler designs. FL7730 provides protections such as open-LED, short-LED, and over-temperature protection.

## 1.2. Features of FL7730

- 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 18 V
- SOP-8 Package Available

## 1.3. Block Diagram

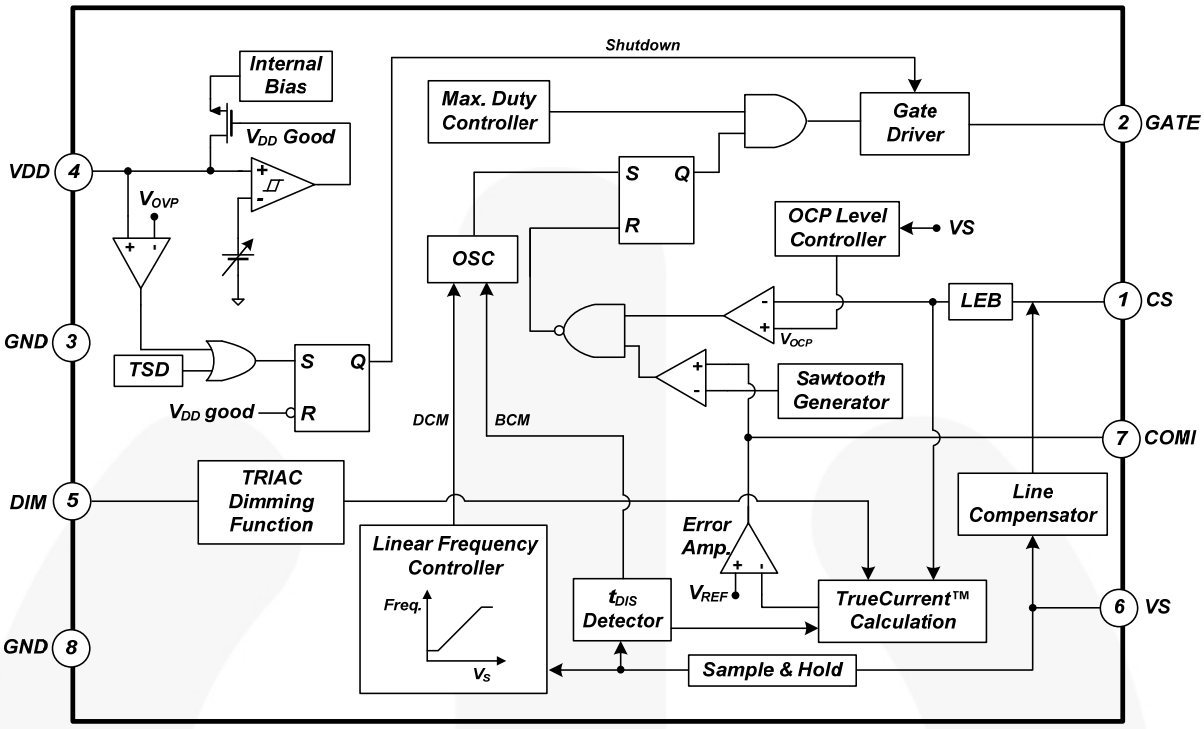



**Figure 1. Internal Block Diagram of FL7730**

# 2. General Specifications for Evaluation Board

All data was measured with the board was enclosed in a case and external temperature of approximately 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 | $F_{IN}$ | 50~60 Hz | Line frequency |
| **Output** | | | |
| Voltage | $V_{OUT.MIN}$ | 10 V | Minimum output voltage |
| | $V_{OUT.MAX}$ | 28 V | Maximum output voltage |
| | $V_{OUT.NOMINAL}$ | 22 V | Nominal output voltage |
| Current | $I_{OUT.NOMINAL}$ | 380 mA | Nominal output current |
| | $I_{OUT.RIPPLE}$ | ±65 mA | Output current ripple |
| | CC deviation | < ±1.9% | Line input voltage change: 180~265 $V_{AC}$ |
| | | < ±3.1% | Output voltage change: 10~28 V |
| **Efficiency** | | | No dimmer connected |
| | $Eff_{180VAC}$ | 84.5% | Efficiency at 180 $V_{AC}$ line input voltage |
| | $Eff_{220VAC}$ | 84.4% | Efficiency at 220 $V_{AC}$ line input voltage |
| | $Eff_{230VAC}$ | 84.4% | Efficiency at 230 $V_{AC}$ line input voltage |
| | $Eff_{265VAC}$ | 83.8% | Efficiency at 265 $V_{AC}$ line input voltage |
| **PF/THD** | | | No dimmer connected |
| | $PF/THD_{180VAC}$ | 0.97 / 13.7% | PF/THD at 180 $V_{AC}$ line input voltage |
| | $PF/THD_{220VAC}$ | 0.93 / 16.6% | PF/THD at 220 $V_{AC}$ line input voltage |
| | $PF/THD_{230VAC}$ | 0.92 / 17.3% | PF/THD at 230 $V_{AC}$ line input voltage |
| | $PF/THD_{265VAC}$ | 0.87 / 19.7% | PF/THD at 265 $V_{AC}$ line input voltage |
| **Temperature** | | | Open frame condition (Room temp. = 25ºC) |
| FL7730 | $T_{FL7730}$ | 46ºC | FL7730 temperature |
| Primary MOSFET | $T_{MOSFET}$ | 53ºC | Primary MOSFET temperature |
| Secondary Diode | $T_{DIODE}$ | 45ºC | Secondary diode temperature |
| Transformer | $T_{TRNASFORMER}$ | 48ºC | Transformer temperature |
| Active Damper | $T_{DAMPER}$ | 49ºC | Active damper temperature |
| Startup Resistor | $T_{STR.RESISTOR}$ | 55ºC | Startup resistor temperature |

# 3. Photographs

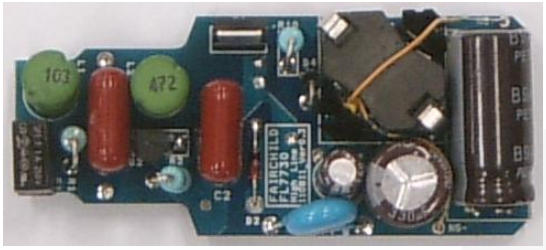


**Figure 2. Top View of Board**

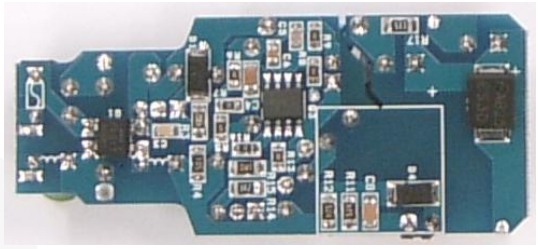


**Figure 3. Bottom View of Board**

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

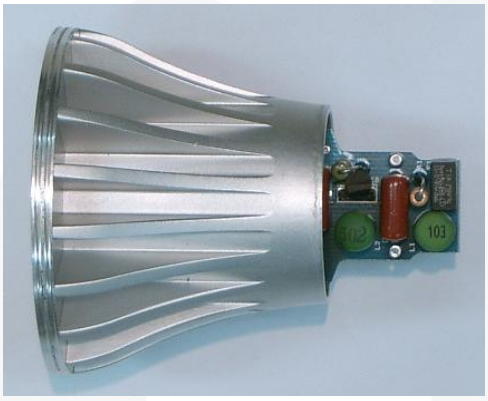


**Figure 4. Side View in Bulb Case Type 1**

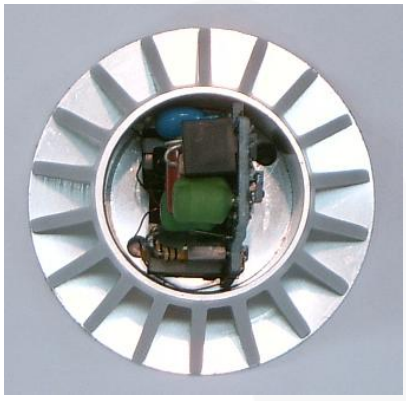


**Figure 5. Bottom View in Bulb Case Type 1**

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

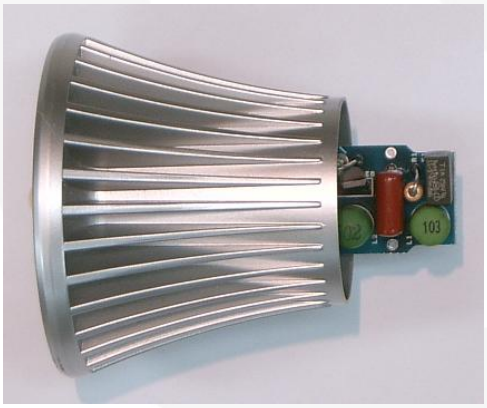


**Figure 6. Side View in Bulb Case Type 2**

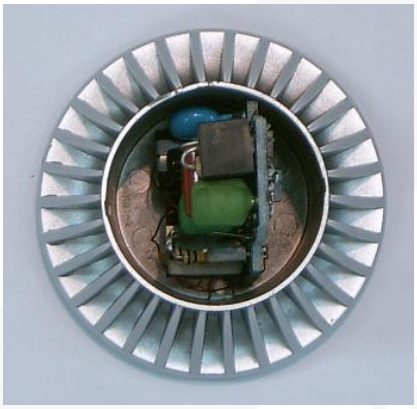


**Figure 7. Bottom View in Bulb Case Type 2**

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

# 4. Printed Circuit Board

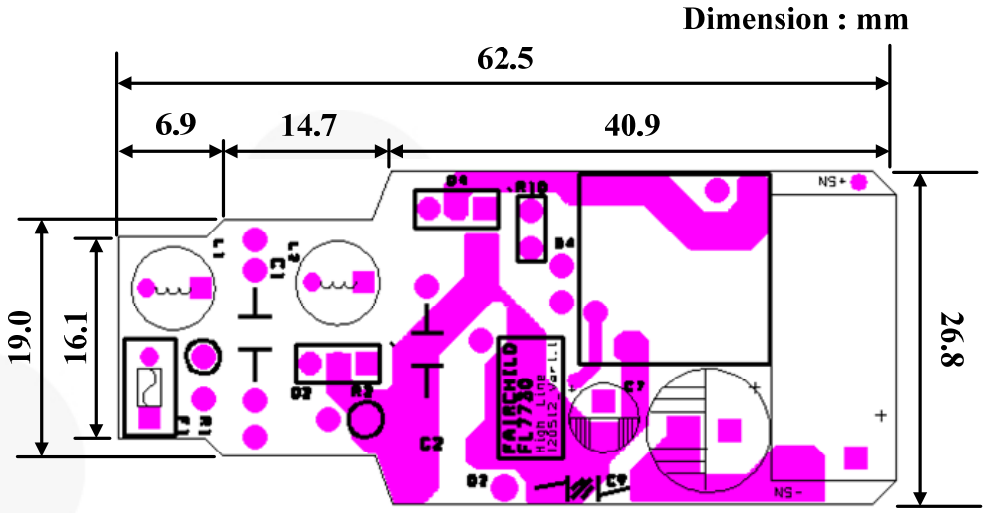



**Figure 8. Top Pattern of Board**

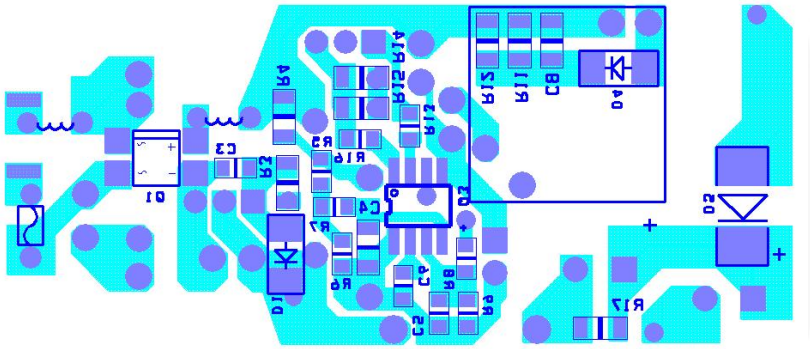


**Figure 9. Bottom Pattern of Board**

# 5. Schematic of the Evaluation Board

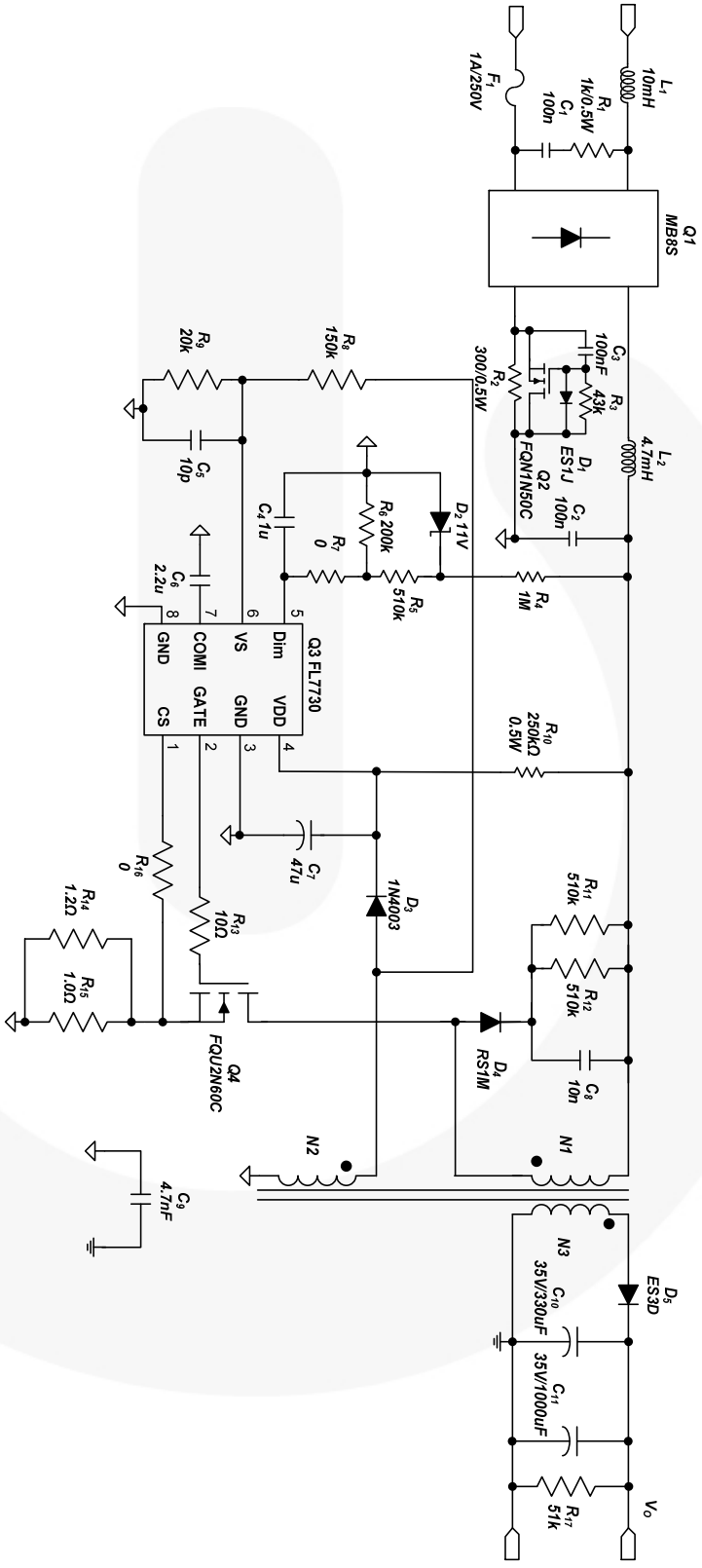



**Figure 10. FL7730 Schematic**

# 6. Bill of Materials

| Item No. | Part Reference | Part Number | Qty. | Description | Manufacturer |
|---|---|---|---|---|---|
| 1 | Q1 | MB8S | 1 | Bridge Diode | Fairchild Semiconductor |
| 2 | Q2 | FQN1N50C | 1 | 1 A / 500 V Active Damper MOSFET | Fairchild Semiconductor |
| 3 | Q3 | FL7730MY_F116 | 1 | Main Controller | Fairchild Semiconductor |
| 4 | Q4 | FQU2N60C | 1 | 2 A / 600 V Main Switch | Fairchild Semiconductor |
| 5 | F1 | SS-5-1A | 1 | 1 A / 250 V Fuse | Bussmann |
| 6 | L1 | R06103KT00 | 2 | 10 mH Filter Inductor | Bosung |
| 7 | L2 | R06472KT00 | 2 | 4.7 mH Filter Inductor | Bosung |
| 8 | D1 | ES1J | 1 | 1 A / 600 V Diode | Fairchild Semiconductor |
| 9 | D2 | 1N5241 | 1 | 11 V Zener Diode | Fairchild Semiconductor |
| 10 | D3 | 1N4003 | 1 | 1 A / 200 V Diode | Fairchild Semiconductor |
| 11 | D4 | RS1M | 1 | 1 A / 1000 V Diode | Fairchild Semiconductor |
| 12 | D5 | ES3D | 1 | 3 A / 200 V Fast Rectifier | Fairchild Semiconductor |
| 13 | C1, C2 | MPE 400V104K 14S | 1 | 100 nF / 400 V Film Capacitor | Sungho |
| 14 | C3 | C0805C104K3RACTU | 1 | 100 nF / 25 V SMD Capacitor 2012 | Kemet |
| 15 | C4 | C1206C105K3PACTU | 1 | 1 µF / 25 V SMD Capacitor 3216 | Kemet |
| 16 | C5 | C0805C100M3GACTU | 1 | 10 pF / 25 V SMD Capacitor 2012 | Kemet |
| 17 | C6 | C2012Y5V1E225Z | 1 | 2.2 µF / 25 V SMD Capacitor 2012 | TDK |
| 18 | C7 | KMG 47 µF / 35 V | 1 | 47 µF / 35 V Electrolytic Capacitor | Samyoung |
| 19 | C8 | C1206C103KDRACTU | 1 | 10 nF / 1 kV SMD Capacitor 3216 | Kemet |
| 20 | C9 | SCFz2E472M10BW | 1 | 4.7 nF / 250 V Y-Capacitor | Samwha |
| 21 | C10 | KMG 330 µF / 35 V | 1 | 330 µF / 35 V Electrolytic Capacitor | Samyoung |
| 22 | C11 | RM 1000 µF / 35 V | 1 | 1000 µF / 35 V Electrolytic Capacitor | Samwha |
| 23 | R1 | SFR2500001001FR500 | 1 | 1k Ω / 0.5 W Metal Resistor | Vishay |
| 24 | R2 | RNF12JTD300R | 1 | 300 Ω / 0.5 W Metal Resistor | Stackpole Electrical |
| 25 | R3 | RC1206JR-0743KL | 1 | 43 kΩ SMD Resistor 3216 | Yageo |
| 26 | R4 | RC1206JR-071ML | 1 | 1 MΩ SMD Resistor 3216 | Yageo |
| 27 | R5 | RC0805JR-07510KL | 1 | 510 kΩ SMD Resistor 2012 | Yageo |
| 28 | R6 | RC0805JR-07200KL | 1 | 200 kΩ SMD Resistor 2012 | Yageo |
| 29 | R7 | RC0805JR-070R0L | 1 | 0 Ω SMD Resistor 2012 | Yageo |
| 30 | R8 | RC0805JR-07150KL | 1 | 150 kΩ SMD Resistor 2012 | Yageo |
| 31 | R9 | RC0805JR-0720KL | 1 | 20 kΩ SMD Resistor 2012 | Yageo |
| 32 | R10 | RNF12GTD250K | 1 | 250 kΩ / 0.5W Metal Resistor | Stackpole Electrical |
| 33 | R11, R12 | RC1206JR-07510KL | 2 | 510 kΩ SMD Resistor 3216 | Yageo |
| 34 | R13 | RC0805JR-0710RL | 1 | 10 Ω SMD Resistor 2012 | Yageo |

## Bill of Materials (Continued)

| Item No. | Part Reference | Part Number | Qty. | Description | Manufacturer |
|---|---|---|---|---|---|
| 35 | R14 | RC1206JR-071R2L | 1 | 1.2 Ω SMD Resistor 3216 | Yageo |
| 36 | R15 | RC1206FR-071RL | 1 | 1.0 Ω SMD Resistor 3216 | Yageo |
| 37 | R16 | RC0805JR-070RL | 1 | 0 Ω SMD Resistor 2012 | Yageo |
| 38 | R17 | RC1206JR-0751KL | 1 | 51 kΩ SMD Resistor 3216 | Yageo |

# 7. Transformer Design

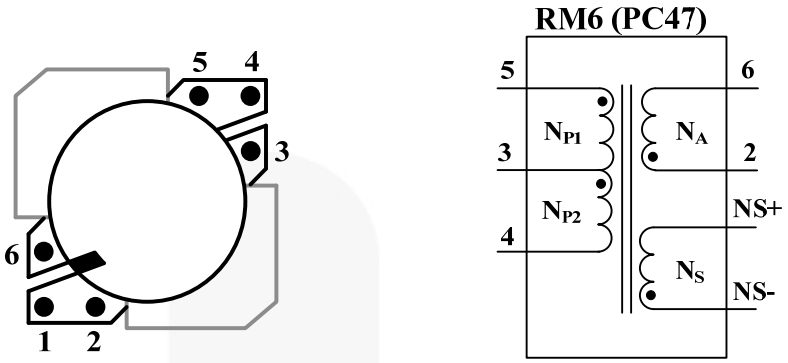



**Figure 11. Transformer Bobbin Structure and Pin Configuration**

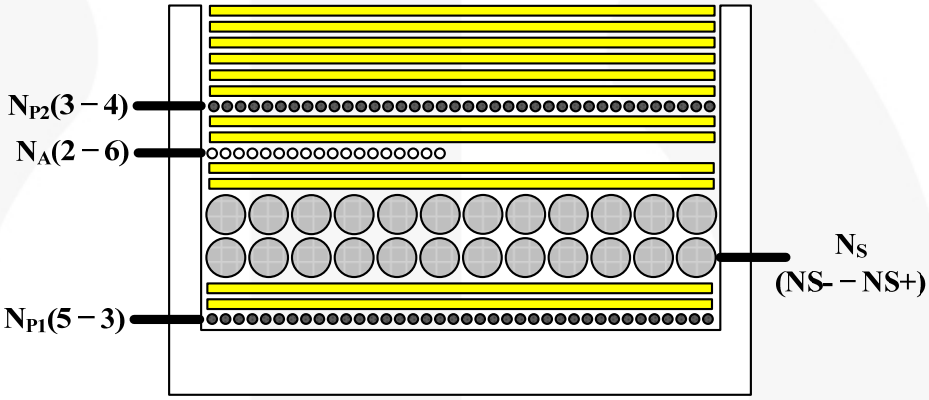



**Figure 12. Transformer Winding Structure**

**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 = 0.025 mm, 2 Layers | | | | |
| 3 | $N_S$ | NS- → NS+ | 0.3φ (TIW) | 24 Ts | Solenoid Winding |
| 4 | Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | |
| 5 | $N_A$ | 2 → 6 | 0.13φ | 18 Ts | Solenoid Winding |
| 6 | Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | |
| 7 | $N_{P2}$ | 3 → 4 | 0.13φ | 38 Ts | Solenoid Winding |
| 8 | Insulation: Polyester Tape t = 0.025 mm, 6 Layers | | | | |

**Table 3. Electrical Characteristics**

| | Pin | Specification | Remark |
|---|---|---|---|
| Inductance | 1– 2 | 1 mH ±10% | 50 kHz, 1 V |
| Leakage | 1– 2 | 8 μH | 50 kHz, 1 V Short all output pins |

# 8. Performance of Evaluation Board

## 8.1. Startup

Startup time is 0.7 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.)

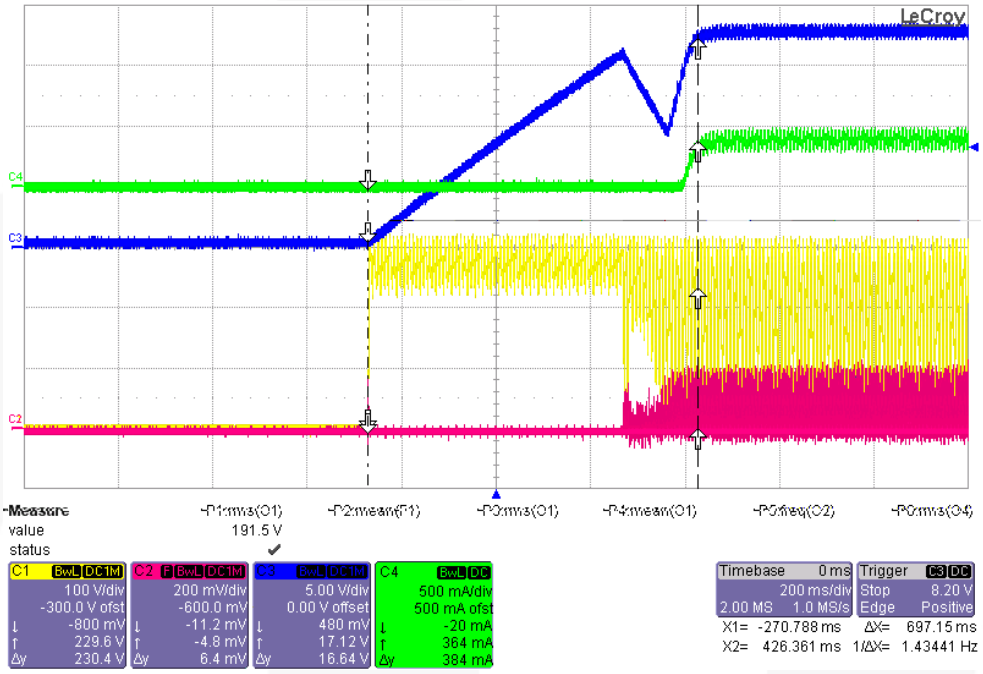
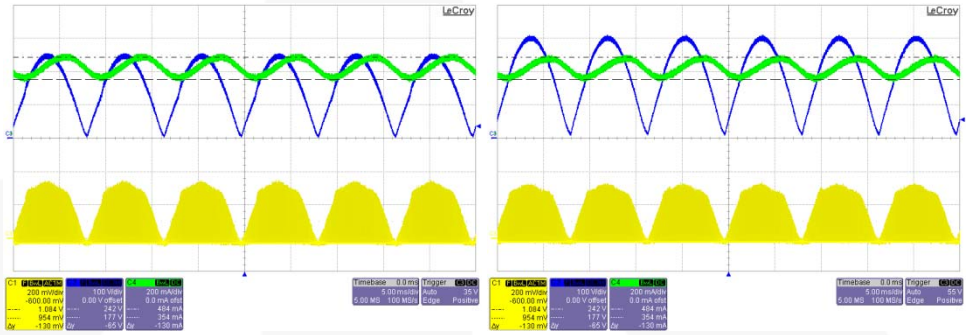



**Figure 13. Startup – $V_{IN}$[220$V_{AC}$] C1[$V_{IN}$] C2[$V_{CS}$] C3[$V_{DD}$] C4[$I_{OUT}$] (No Dimmer Connected)**

## 8.2. Operation Waveforms

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

$V_{IN}$ = 180 $V_{AC}$ $V_{IN}$ = 220 $V_{AC}$



$V_{IN}$ = 230 $V_{AC}$ $V_{IN}$ = 265 $V_{AC}$

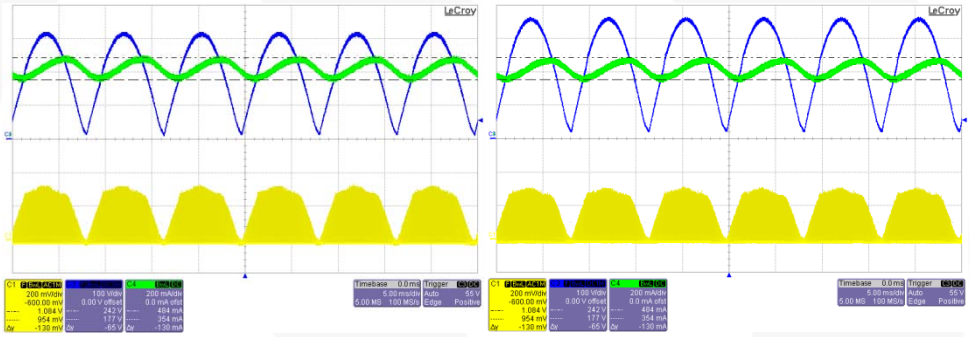


**Figure 14. Operation Waveforms – $V_O$[22V] $I_O$[380mA] C1[$V_{CS}$] C3[$V_{IN}$] C4[$I_{OUT}$]**

## 8.3. Constant Current Regulation

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

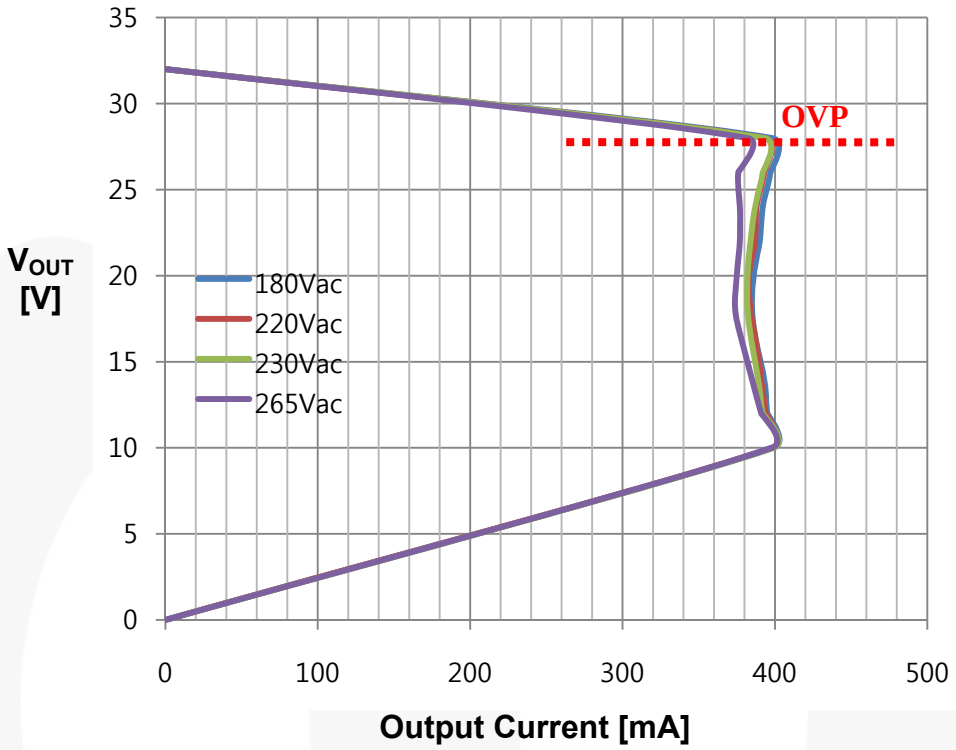



**Figure 15. Constant Current Regulation – Measured by E-Load [CR Mode]**

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

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

**Table 5. 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 | 392 mA | 388 mA | 387 mA | 377 mA | ±1.9% |
| 22 V | 390 mA | 387 mA | 384 mA | 377 mA | ±1.7% |
| 24 V | 386 mA | 383 mA | 382 mA | 375 mA | ±1.4% |

## 8.4. Open-LED and Short-LED Protections

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

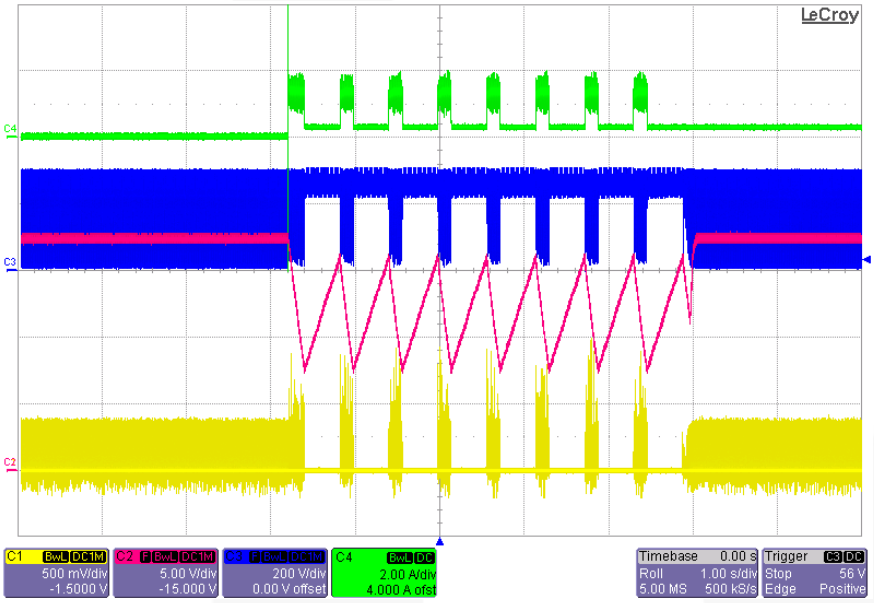



**Figure 16. Short-LED Condition – $V_{IN}$[220 $V_{AC}$] C1[$V_{CS}$] C2[$V_{DD}$] C3[$V_{IN}$] C4[$I_{OUT}$]**

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

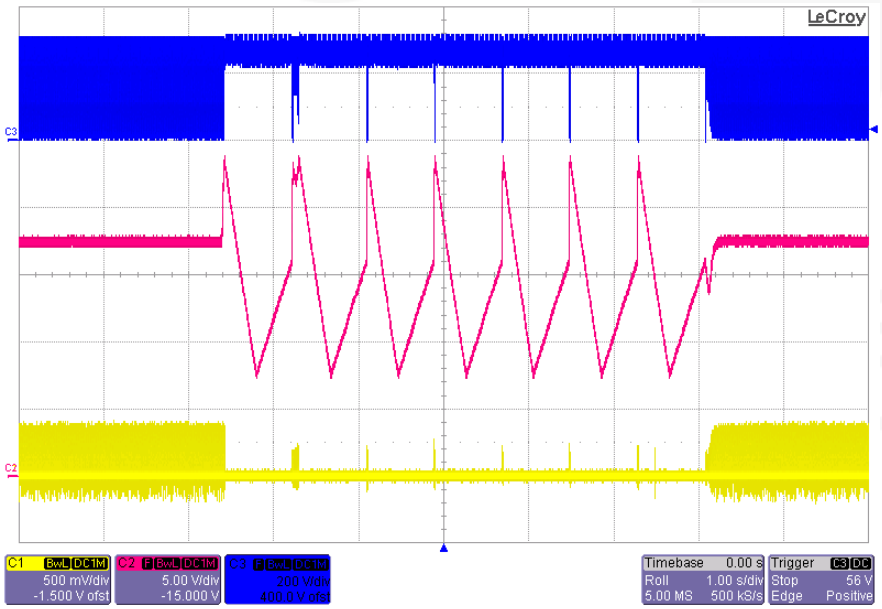



**Figure 17. Open-LED Condition – $V_{IN}$[220 $V_{AC}$] C1[$V_{CS}$] C2[$V_{DD}$] C3[$V_{IN}$]**

## 8.5. Dimming Operation

Dimming operation waveforms are shown in Figure 18 through Figure 21. Active damper, RC bleeder, and dimming control in FL7730 implement flicker-free dimming oepration. Spike current at dimmer firing is less than 1 A.

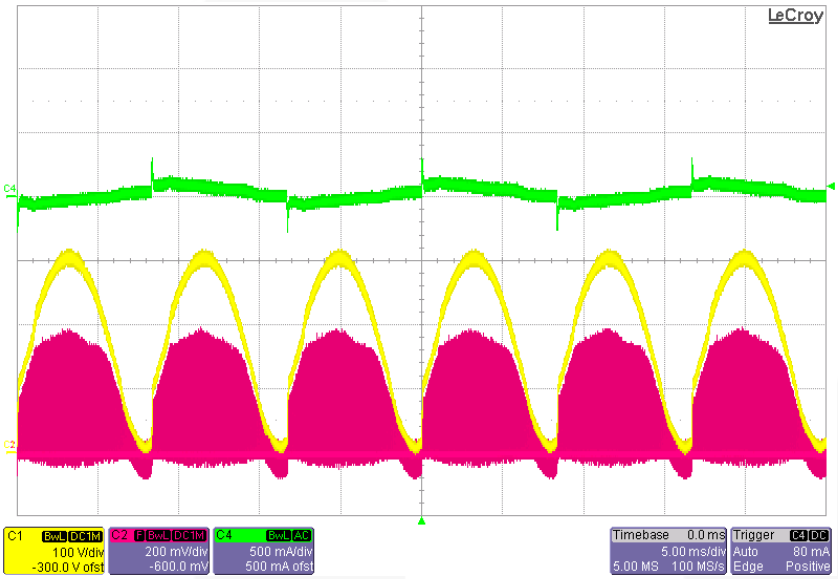



**Figure 18. Dimming Operation Waveforms – Max. Dimming Angle, $V_{IN}$[220 $V_{AC}$] C1[$V_{IN}$] C2[$V_{CS}$] C4[$I_{IN}$]**

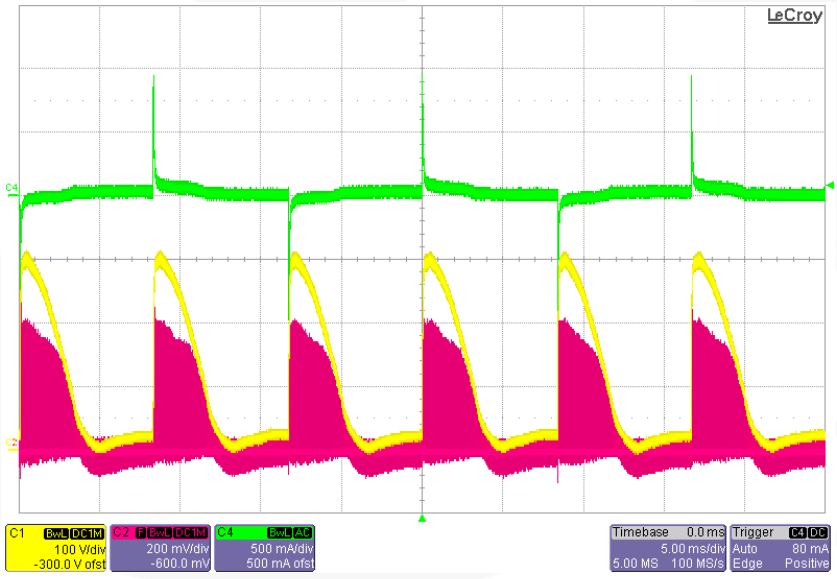



**Figure 19. Dimming Operation Waveforms – 90º Dimming Angle, $V_{IN}$[220 $V_{AC}$] C1[$V_{IN}$] C2[$V_{CS}$] C4[$I_{IN}$]**

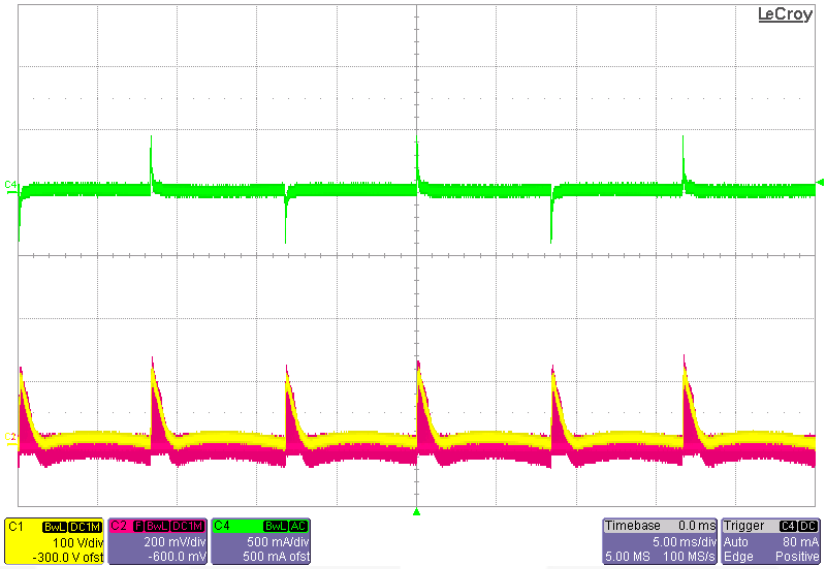



**Figure 20. Dimming Operation Waveforms – Min. Dimming Angle, $V_{IN}$[220 $V_{AC}$] C1[$V_{IN}$] C2[$V_{CS}$] C4[$I_{IN}$]**

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

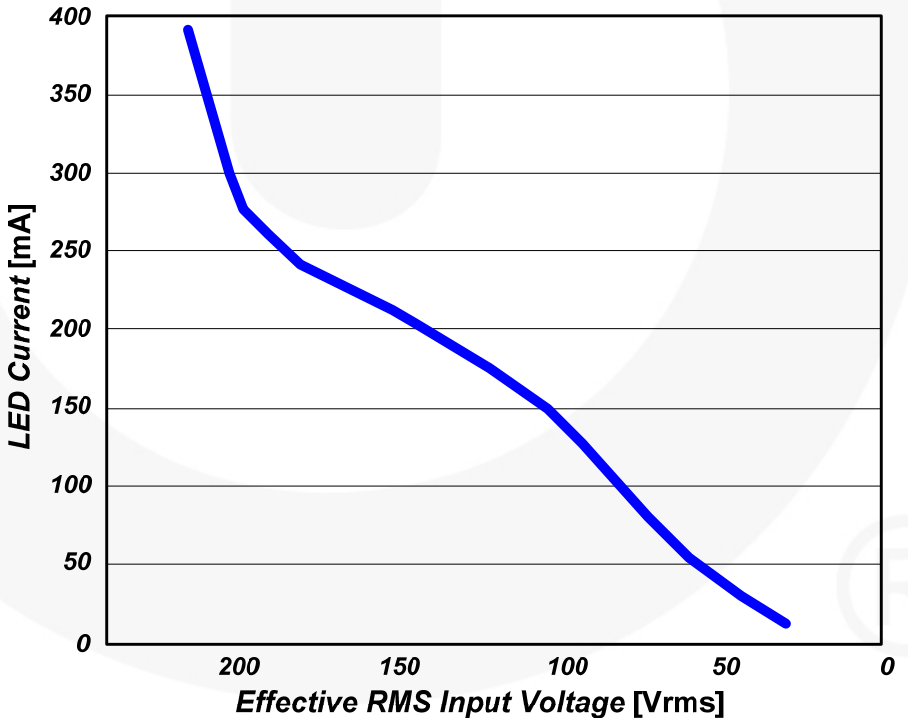



**Figure 21. Dimming Curve (Effective RMS Input Voltage vs. Output Current) – Line Voltage[220 $V_{AC}$]**

**Table 6. Dimmer Compatibility**

| Manufacturer | Dimmer | Condition | Max Current | Min Current | Flicker |
|---|---|---|---|---|---|
| NANO | SKD-500 | 220 V / 60Hz | 365 mA | 24 mA (7%) | No |
| JIN HEUNG | SA04003 | 220 V / 60Hz | 364 mA | 53 mA (15%) | No |
| ANAM | D-500 | 220 V / 60Hz | 350 mA | 58 mA (17%) | No |
| OPPLE | P068102 | 220 V / 60Hz | 378 mA | 6 mA (2%) | No |
| DAESUNG | SKD-500 | 220 V / 60Hz | 366 mA | 6 mA (2%) | No |
| GIRA | 226200 | 230 V / 50Hz | 319 mA | 64 mA (20%) | No |
| GIRA | 30000 | 230 V / 50Hz | 335 mA | 80 mA (24%) | No |
| JUNG | 225NVDE | 230 V / 50Hz | 320 mA | 70 mA (22%) | No |
| JUNG | ST550 | 230 V / 50Hz | 325 mA | 100 mA (31%) | No |
| JUNG | 266GDE | 230 V / 50Hz | 332 mA | 61 mA (18%) | No |
| KOPP | 8033 | 230 V / 50Hz | 300 mA | 100 mA (33%) | No |
| BUSCH | 2200 | 230 V / 50Hz | 338 mA | 66 mA (20%) | No |
| BUSCH | 2247U | 230 V / 50Hz | 323 mA | 108 mA (33%) | No |
| BUSCH | 2250 | 230 V / 50Hz | 335 mA | 60 mA (18%) | No |
| MERTEN | 5721 | 230 V / 50Hz | 365 mA | 30 mA (8%) | No |
| PEHA | 436 | 230 V / 50Hz | 306 mA | 120 mA (40%) | No |
| EVERFLORISH | EF700DC [Trailing] | 230 V / 50Hz | 327 mA | 154 mA (47%) | No |
| MERTEN | 577129 [Trailing] | 230 V / 50Hz | 330 mA | 147 mA (44%) | No |
| BUSCH | 6513 [Trailing] | 230 V / 50Hz | 353 mA | 145 mA (41%) | 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 83.8 ~ 84.5% in 180 ~ 265 $V_{AC}$ input voltage range.

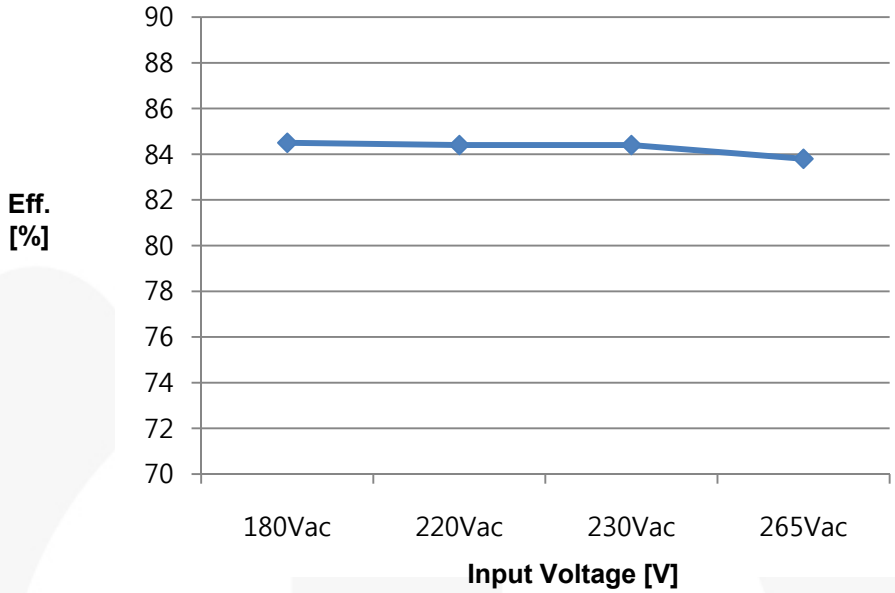



**Figure 22. Power Efficiency (Input voltage vs. Efficiency)**

**Table 7. System Efficiency**

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

## 8.7. Power Factor and Total Harmonic Distortion (THD)

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

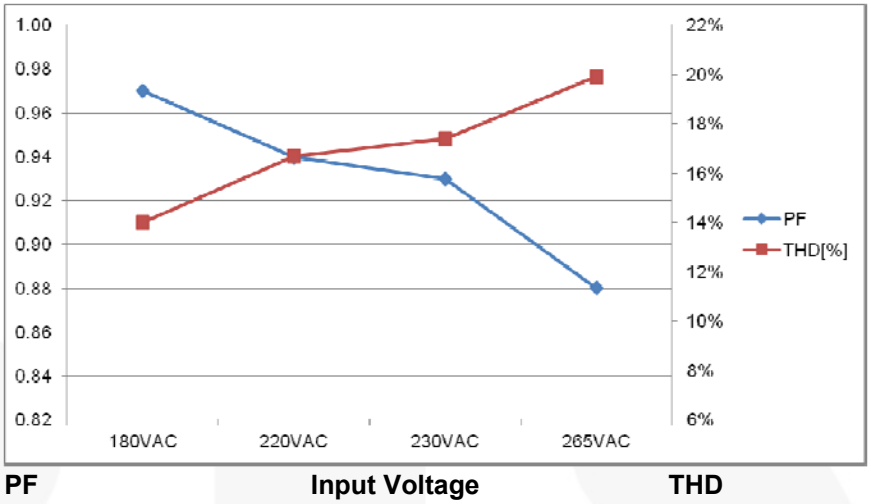



**Figure 23. PF & THD (50 Hz)**

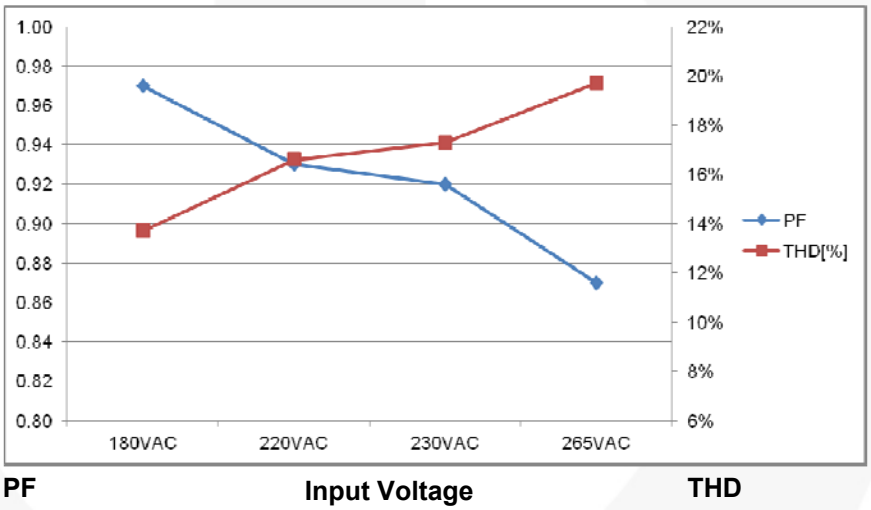



**Figure 24. PF & THD (60 Hz)**

**Table 8. Power Factor and THD**

| Input Voltage | Output Current | Output Voltage | Frequency | PF | THD |
|---|---|---|---|---|---|
| 180 $V_{AC}$ | 392 mA | 21.84 V | 50 Hz | 0.97 | 14.0% |
| | | | 60 Hz | 0.97 | 13.7% |
| 220 $V_{AC}$ | 386 mA | 21.80 V | 50 Hz | 0.94 | 16.7% |
| | | | 60 Hz | 0.93 | 16.6% |
| 230 $V_{AC}$ | 385 mA | 21.79 V | 50 Hz | 0.93 | 17.4% |
| | | | 60 Hz | 0.92 | 17.3% |
| 265 $V_{AC}$ | 376 mA | 21.75 V | 50 Hz | 0.88 | 19.9% |
| | | | 60 Hz | 0.87 | 19.7% |

## 8.8. Operating Temperature

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

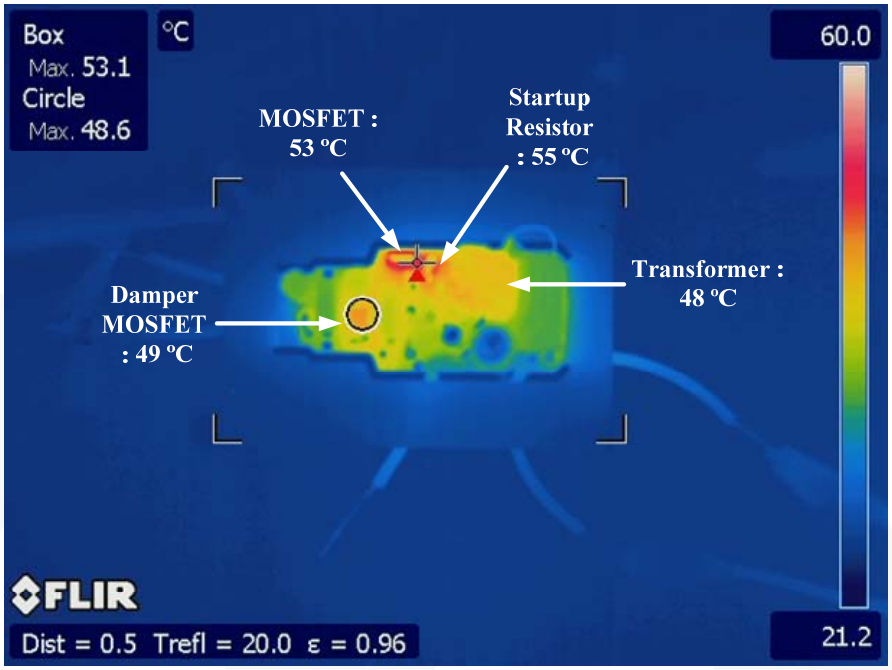



**Figure 25. Board Temperature - Top View, $V_{IN}$[220 $V_{AC}$] $I_O$[380 mA]**

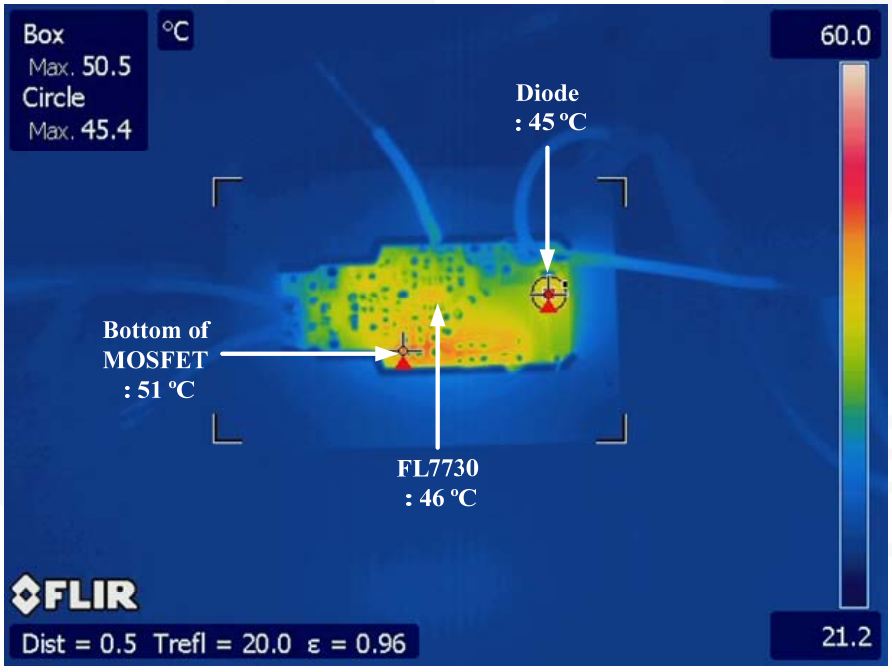



**Figure 26. Board Temperature - Bottom View, $V_{IN}$[220 $V_{AC}$] $I_O$[380 mA]**

## 8.9. EMI

The all measurement was conducted in observance of CISPR22 criteria.

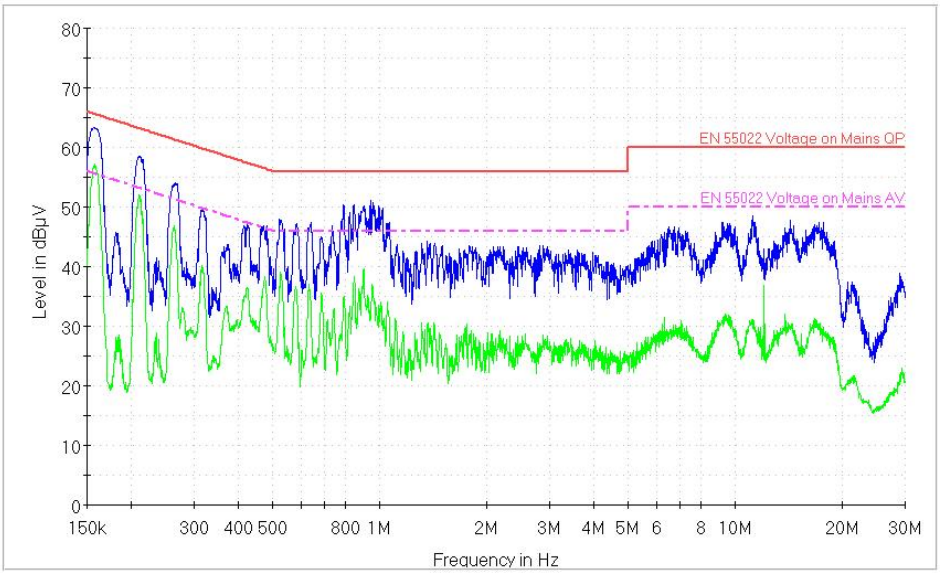



**Figure 27. EMI Results – $V_{IN}$[220 $V_{AC}$] $V_{OUT}$[22 V], $I_{OUT}$[380 mA]**

# 9. Revision History

| Rev. | Date | Description |
|---|---|---|
| 1.0.0. | Oct. 2011. | Initial Release |
| 1.1.0 | Aug. 2012. | Manufacturer & Part number are added in BOM<br>FL7730 is changed to FL7730MY_F116 (no frequency hopping)<br>Dimmer compatibility table is updated<br>PF/THD at 50Hz is added<br>EMI test result is updated<br>Updating to match new naming conventions |

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