FEB-L025 Reference Design Report

Using FL7732

Title	Reference Design Report for a 8.4W LED Bulb Using FL7732
Specification	V_{IN} = 90V_{AC} ~ 265V_{AC}, 60 Hz/50Hz V_O = 24V @ I_O = 0.35A Output Power : 8.4W
Application	LED Bulb
Author	System & Application Engineer Group
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Summary and Features

- Superior performance and end user experience
  - ➔ Constant current regulation vs output voltage change (11~28V) : < +/- 2.5%
  - ➔ Constant current regulation vs line voltage change (90~265Vac) : <+/- 3.5%
  - ➔ Output open & short circuit protection with auto restart
  - ➔ System efficiency up to 85%
  - ➔ PF and THD at nominal voltages (90~265Vac): PF(>0.9), THD(<25%)
  - ➔ All components' temperature (at room temp.): less than 60℃

Direct questions or comments about this Evaluation Board to:
"Worldwide Direct Support"

Fairchild Semiconductor.com

Table of Contents

The following user guide supports the demonstration 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 PSR single stage controller. The input voltage range is 90VRMS – 265VRMS and there is one DC output with a constant current of 350mA @ 24Vmax. 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 and minimize cost such as input bulk capacitor and feedback circuitry. To improve good 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 on input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee DCM operation with higher efficiency and simple design. FL7732 provides strong protections such as open LED, short LED and over temperature protection.

1.2. Features of FL7732

- Cost effective solution without input bulk capacitor and feedback circuitry
- Power Factor Correction
- Accurate constant-current (CC) Control
- Line voltage compensation for CC control
- Linear frequency control for better efficiency and easy design
- Open LED protection
- Short LED protection
- Cycle-by-Cycle current limiting
- Over Temperature Protection with Auto Restart
- Low start-up 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 of FL7732

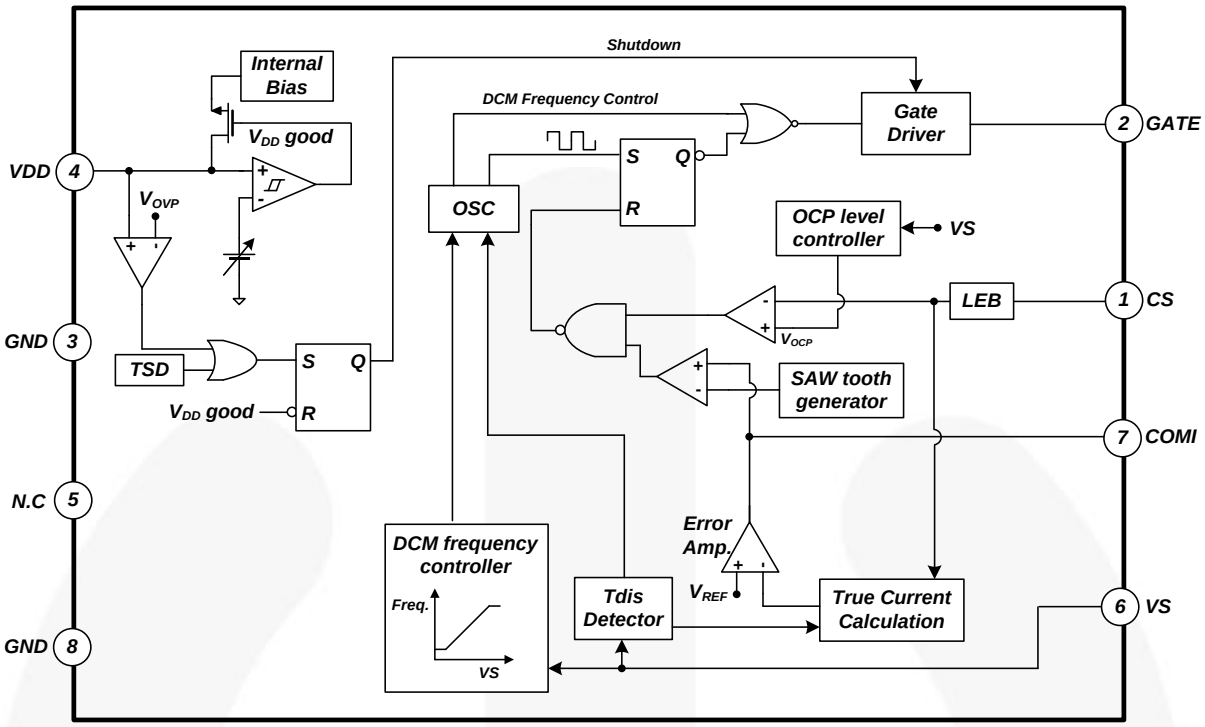


Figure 1. **Internal Block Diagram of FL7732**

2. General Specifications for Evaluation Board

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Description	Symbol	Value	Comments
Fairchild Device		FL7732	Control IC of single stage PSR TRIAC dimming
Input			
Voltage	$V_{IN.MIN}$	90V	Minimum input voltage
	$V_{IN.MAX}$	265V	Maximum input voltage
	$V_{IN.NOMINAL}$	110 V / 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	$I_{OUT.NOMINAL}$	350mA	Nominal output current
	CC deviation	< +/-3.5%	Line input voltage change : 90~265Vac
		< +/-2.5%	Output voltage change : 11~28V
Efficiency	Eff_{90Vac}	85.5%	Efficiency at 90Vac line input voltage
	Eff_{110Vac}	86.6%	Efficiency at 110Vac line input voltage
	Eff_{140Vac}	87.4%	Efficiency at 140Vac line input voltage
	Eff_{180Vac}	87.4%	Efficiency at 180Vac line input voltage
	Eff_{220Vac}	87.2%	Efficiency at 220Vac line input voltage
	Eff_{264Vac}	86.7%	Efficiency at 264Vac line input voltage
PF/THD	PF/THD $_{90Vac}$	0.992/10.57%	PF/THD at 90Vac line input voltage
	PF/THD $_{110Vac}$	0.990/ 9.44%	PF/THD at 110Vac line input voltage
	PF/THD $_{140Vac}$	0.981/12.26%	PF/THD at 140Vac line input voltage
	PF/THD $_{180Vac}$	0.965/16.24%	PF/THD at 180Vac line input voltage
	PF/THD $_{220Vac}$	0.941/19.43%	PF/THD at 220Vac line input voltage
	PF/THD $_{264Vac}$	0.902/23.23%	PF/THD at 264Vac line input voltage
Temperature			Open frame condition (Room temp. = 25ºC)
FL7732	T_{FL7732}	50.8ºC	FL7732 temperature
Primary MOSFET	T_{MOSFET}	57.3ºC	Primary MOSFET temperature
Secondary Diode	T_{DIODE}	56.2ºC	Secondary diode temperature
Transformer	$T_{TRNASFORMER}$	52.3ºC	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℃.

2.1. A Photograph of the Evaluation Board

- Dimensions: 58 (L) × 26.5 (W) × 18.0 (H) [mm]

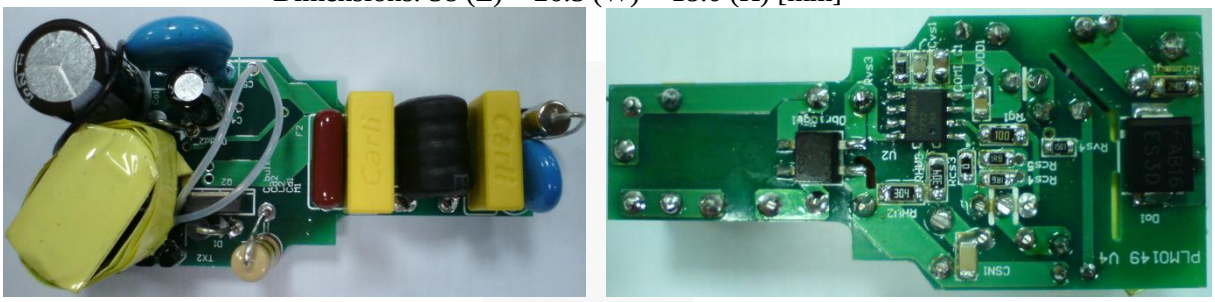


Figure 2. **Top/Bottom View of Evaluation Board**

- Bulb case type 1 : 31 (Case Diameter) × 35 (Case Depth) [mm]

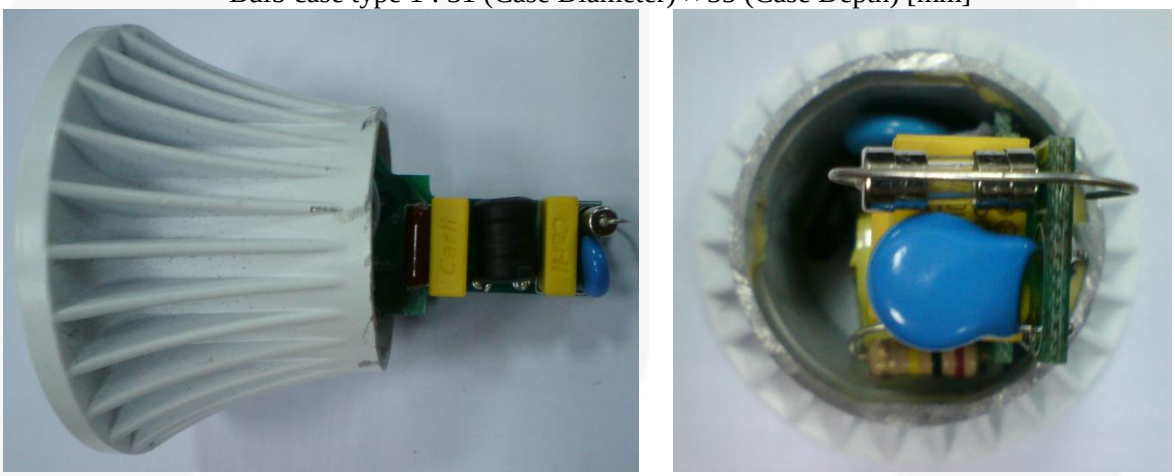


Figure 3. **Side/Bottom View in Bulb Case Type 1**

2.2. Printed Circuit Board

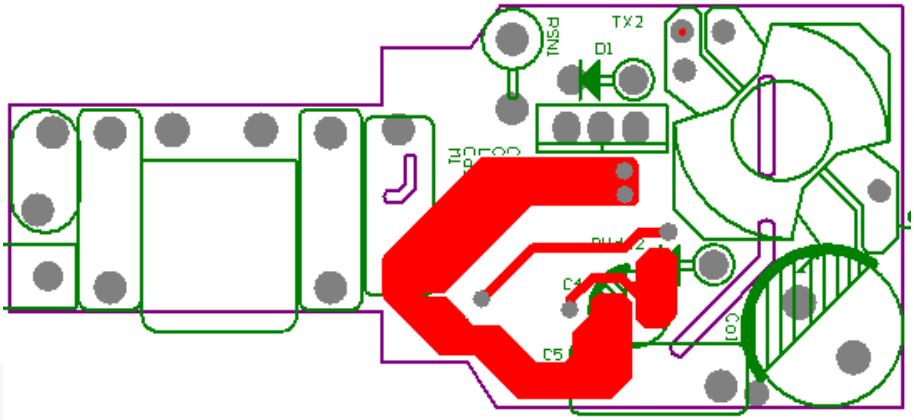


Figure 4. **PCB(Printed Circuit Board) Top pattern of reference board**

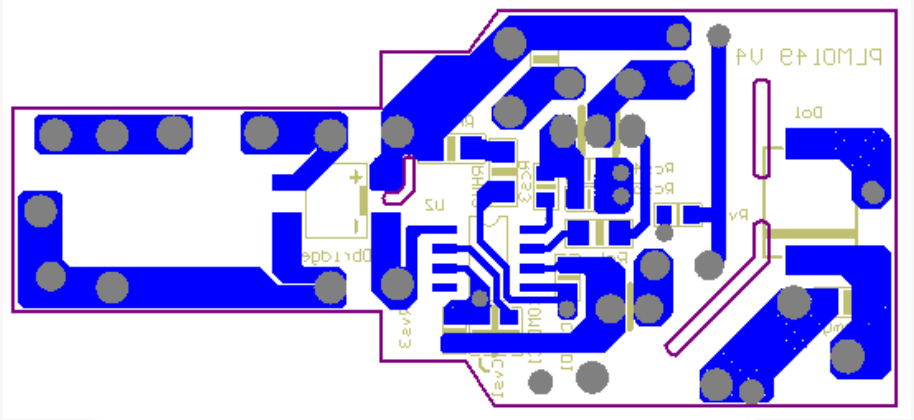


Figure 5. **PCB(Printed Circuit Board) Bottom pattern of reference board**

2.3. Schematic of the Evaluation Board

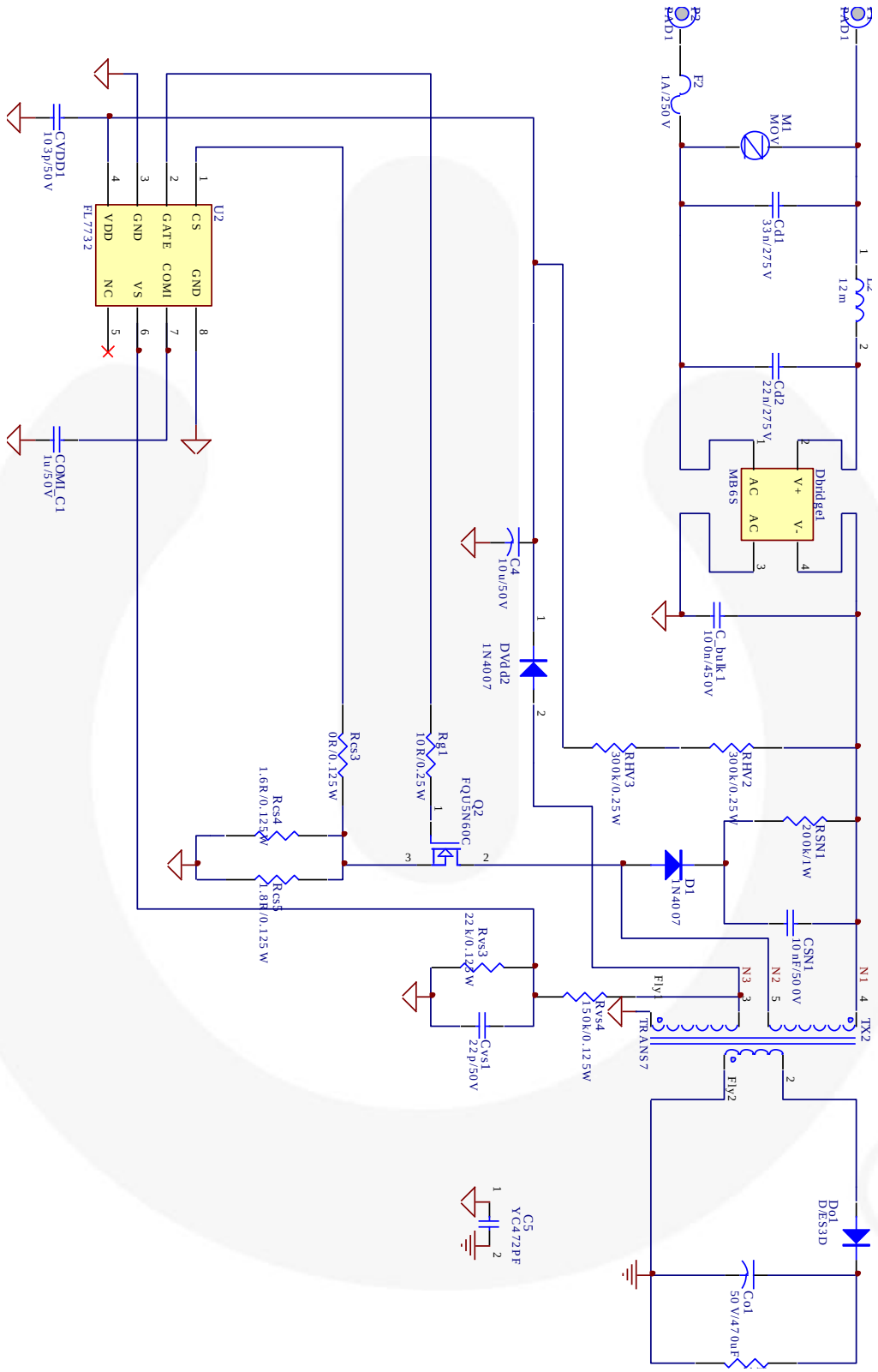


Figure 6. **FL7732 Schematic**

2.4. Bill of Material

Item No.	Part Reference	Value	Qty	Description (Manufacturer)
1	Dbridge1	MB6S	1	Bridge Diode (Fairchild Product)
2	Q2	FQU5N60CTU	1	2.8A/600V Main switch (Fairchild Product)
3	U2	FL7732	1	Main controller (Fairchild Product)
4	F2	1A/250V	1	Fuse
5	M1	7ψ 470V	1	Metal Oxide Varistors
6	L2	12mH	2	Filter inductor
7	Dvdd2, D1	1N4007	2	1A/1000V Diode (Fairchild Product)
8	Do1	ES3D	1	3A/200V Fast Rectifier (Fairchild Product)
9	RSN1	200K / 1W	1	Metal Oxide Film Resistor
10	C5	472P / 250V	1	Y2 Capacitor
11	Cd1	0.022u / 275V	1	X2 Capacitor
12	Cd2	0.033u / 275V	1	X2 Capacitor
13	C_bulk1	104/450V	1	Film Capacitor
14	CSN1	103/500V	1	SMD Capacitor 1206
15	Cvs1	22P/50V	1	SMD Capacitor 0805
16	COMI_C1	105/25V	1	SMD Capacitor 0805
17	CVDD1	103/50V	1	SMD Capacitor 0805
18	RHV2, RHV3	300KΩ	2	SMD Resistor 1206
19	Rdummy1	24KΩ	1	SMD Resistor 1206
20	Rg1	10Ω	1	SMD Resistor 1206
21	Co1	470uF/35V	1	Electrolytic Capacitor
22	C4	10uF/50V	1	Electrolytic Capacitor
23	Rvs3	22KΩ	1	SMD Resistor 0805
24	Rcs4	1Ω6	1	SMD Resistor 0805
25	Rss5	1Ω8	1	SMD Resistor 0805
26	Rvs4	150KΩ	1	SMD Resistor 0805
27	Rcs3	0Ω	1	SMD Resistor 0805
28	TX2	1mH	1	RM6 Transformer

2.5. Transformer Design

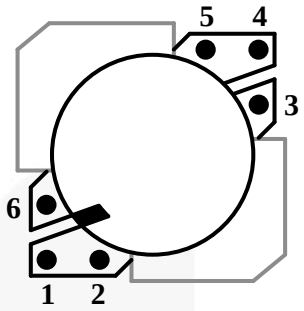


Figure 7. **Transformer Bobbin Structure**

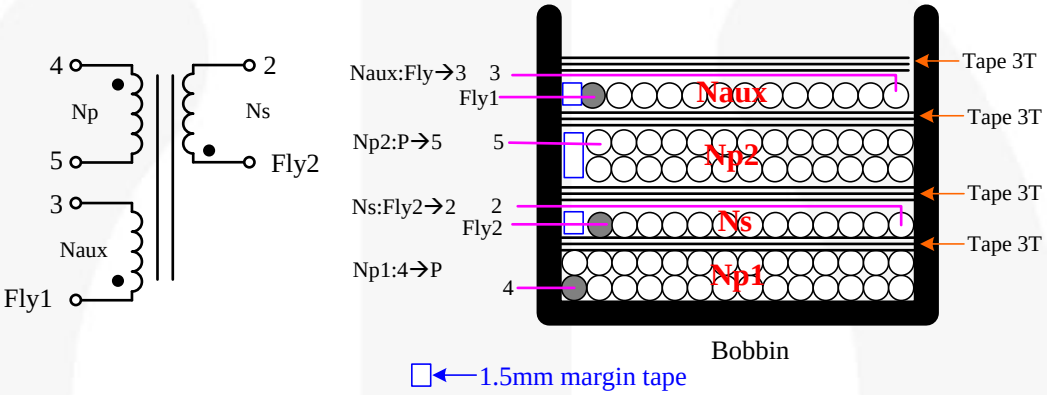


Figure 8. **Pin Configuration and Transformer Winding Structure**

Table 2. Winding specifications.

No	Winding	Pin(S → F)	Wire	Turns	Winding Method
1	N_{P1}	4 → P	0.2φ	36 Ts	Solenoid winding
2	Insulation : Polyester Tape t = 0.025mm, 3Layers				
3	N_S	Fly2 → 2	0.32φ	24 Ts	Solenoid winding
4	Insulation : Polyester Tape t = 0.025mm, 3Layers				
5	N_{P2}	P → 5	0.2φ	36 Ts	Solenoid winding
6	Insulation : Polyester Tape t = 0.025mm, 3Layers				
7	N_A	Fly1 → 3	0.12φ	18 Ts	Solenoid winding
8	Insulation : Polyester Tape t = 0.025mm, 3Layers				

Table 3. Electrical Characteristics.

	Pin	Spec.	Remark
Inductance	4– 5	1 mH ± 10%	50kHz, 1V
Leakage	4– 5	13uH	50kHz, 1V Short all output pins

3. Performance of Evaluation Board

3.1. Start Up

Startup time is 0.96s at Vin=90Vac.

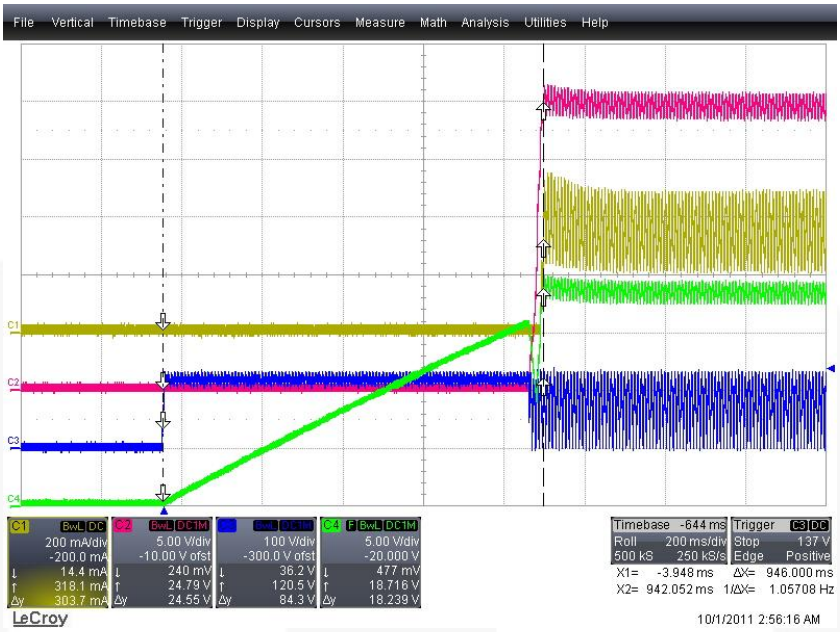
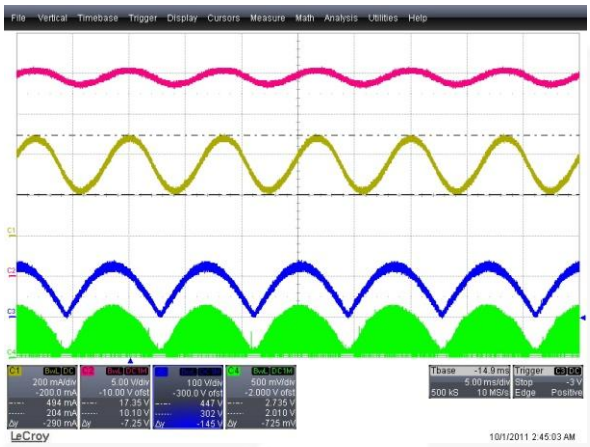


Figure 9. **Start Up – Vin[90Vac] C1[Io] C2[Vo] C3[Vin] C4[Vdd]**

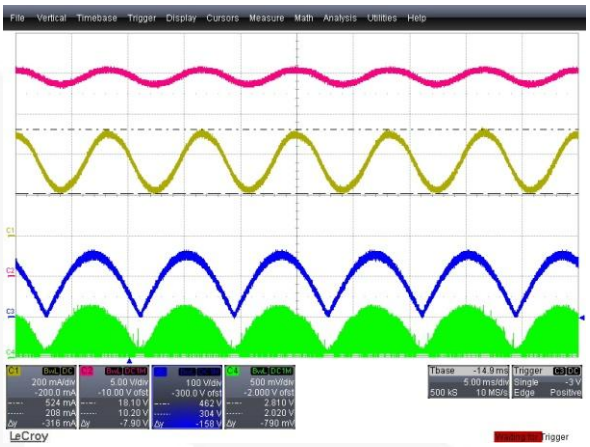
3.2. Operation Waveforms

Output current ripple is under +/- 160mA with a rated output current of 350mA.

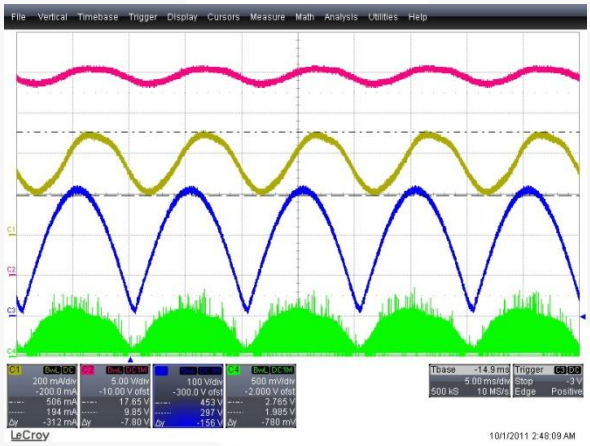
Vin=90Vac / 60Hz



Vin=110Vac / 60Hz



Vin=220Vac / 50Hz



Vin=265Vac / 50Hz

Figure 10. **Operation Waveforms – Vo[24V] Io[350mA] C1[Iout] C2[Vo] C3[Vin] C4[Vcs]**

3.3. Constant Current Regulation

Constant current deviation in the wide output voltage range from 11V to 28V is less than 2.1% at each line input voltage. Line regulation at the rated output voltage (24V) is less than 2.1%

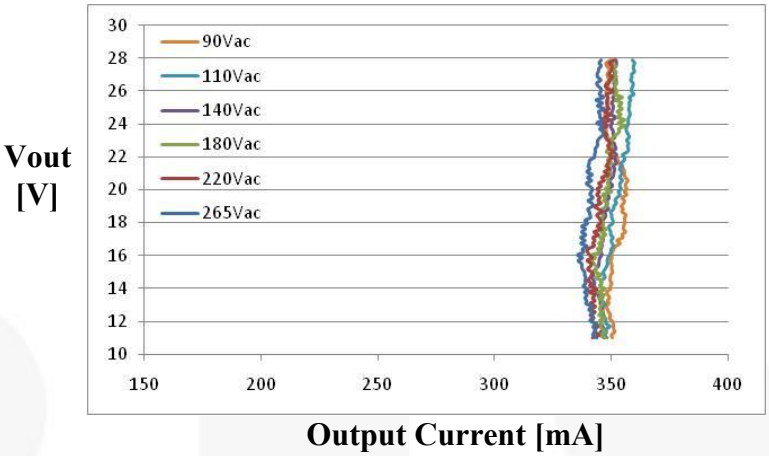


Figure 11. **Constant Current Regulation – Measured by E-load [LED mode]**

Table 4. Constant Current Regulation by Output Voltage Change (11~28V)

Input Voltage	Min Current	Max Current	Tolerance
$90V_{AC}$ /60Hz	347mA	357mA	+/- 1.5%
$110V_{AC}$ /60Hz	345mA	360mA	+/- 2.1%
$140V_{AC}$ /60Hz	342mA	352mA	+/- 1.5%
$180V_{AC}$ /50Hz	342mA	356mA	+/- 2.0%
$220V_{AC}$ /50Hz	340mA	351mA	+/- 1.7%
$265V_{AC}$ /50Hz	336mA	347mA	+/- 1.7%

Table 5. Constant Current Regulation by Line Voltage Change (90~265Vac)

Output Voltage	90Vac	110Vac	140Vac	180Vac	220Vac	265Vac	Tolerance
20V	347mA	357mA	350mA	353mA	346mA	344mA	+/- 1.9%
22V	350mA	355mA	352mA	350mA	349mA	343mA	+/- 1.7%
24V	357mA	354mA	349mA	347mA	344mA	342mA	+/- 2.1%

3.4. Open/Short LED Protections

In short LED condition, OCP level is reduced from 0.7V to 0.2V because FL7732 lowers OCP level when VS voltage is less than 0.4V during output diode conduction time.

Figure 12. **Short LED condition – Vin[110Vac] C1[Iout] C2[Vin] C3[Vdd] C4[Vcs]**

In open LED condition, output voltage is limited around 32V by OVP in VDD. Output over voltage protection level can be controlled by turn ratio of auxiliary and secondary windings.

Figure 13. **Open LED condition – Vin[110 Vac] C1[Iout] C2[Vin] C3[Vdd] C4[Vcs]**

3.5. System Efficiency

Power efficiency is 85.6 ~ 87.6% in 90 ~ 265Vac input voltage range.

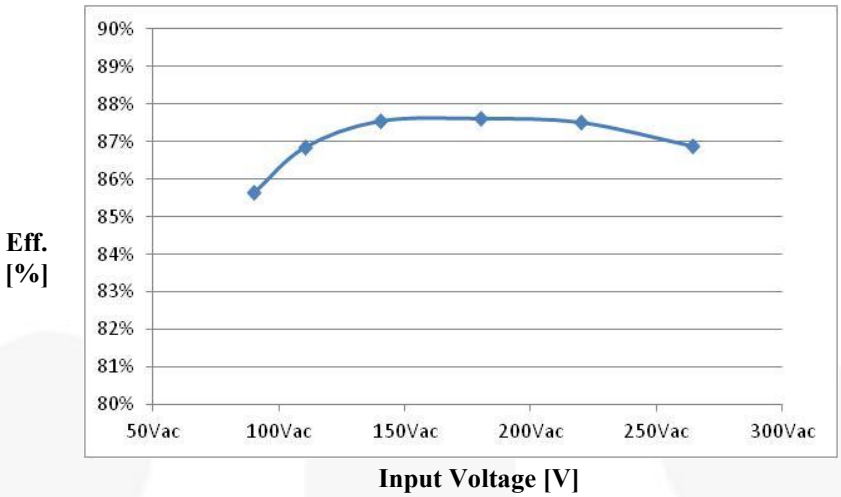


Figure 14. **Power Effiiciency (Input voltage vs. Efficiency)**

Table 1. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90Vac	9.623W	343mA	24.03V	8.24W	85.65%
110Vac	9.613W	347mA	24.06V	8.35W	86.85%
140Vac	9.473W	345mA	24.04V	8.29W	87.55%
180Vac	9.560W	348mA	24.07V	8.38W	87.62%
220Vac	9.328 W	340mA	24.01V	8.16W	87.52%
265Vac	9.182 W	333mA	23.96V	7.98W	86.89%

3.6. Power Factor and THD

FL7732 shows excellent power factor and THD performance. Power factor is very high with enough margins from 0.9. THD is much less than 30% specification.

Table 2. Power Factor and THD

Input Voltage	Output Current	Output Voltage	PF	THD
90Vac	343mA	24.03V	0.993	10.63%
110Vac	347mA	24.06V	0.991	9.53%
140Vac	345mA	24.04V	0.983	12.02%
180Vac	348mA	24.07V	0.969	15.47%
220Vac	340mA	24.01V	0.945	18.99%
265Vac	333mA	23.96V	0.906	22.95%

3.7. Operating Temperature

Temperature of the all components on this board is less than 60 ºC.

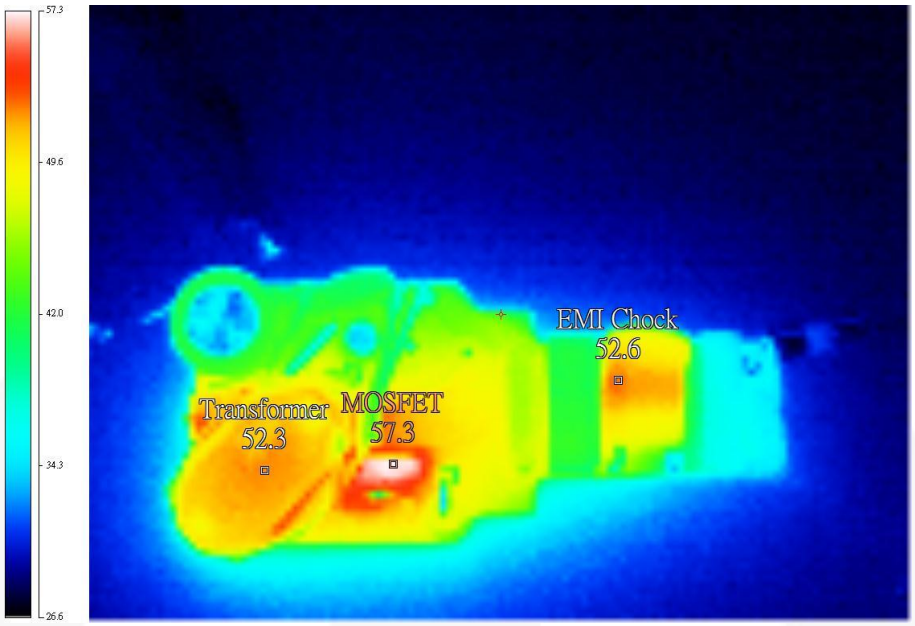


Figure 15. **Board Temperature - Top View, Vin[90Vac] Io[350mA]**

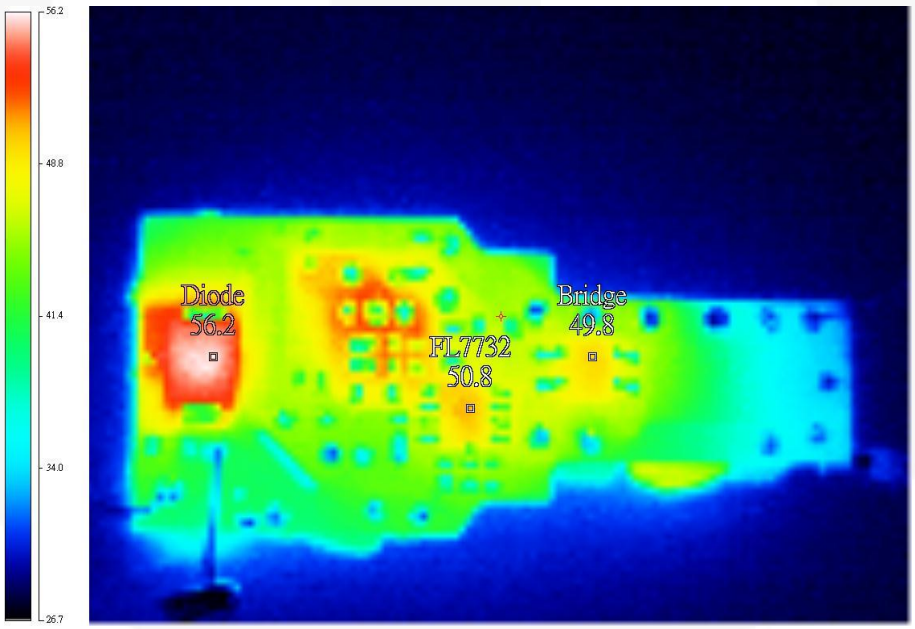
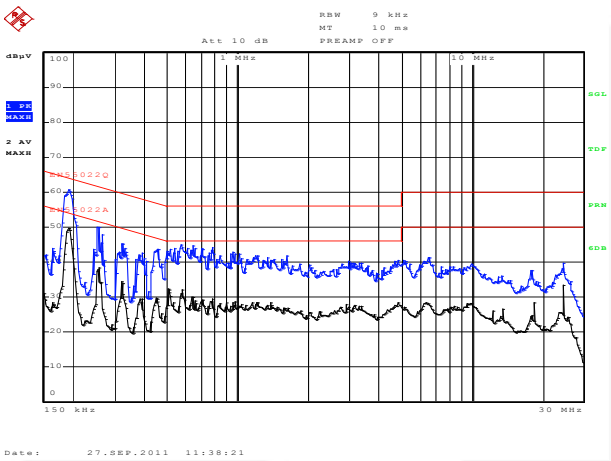


Figure 16. **Board Temperature - Bottom View, Vin[90Vac] Io[350mA]**

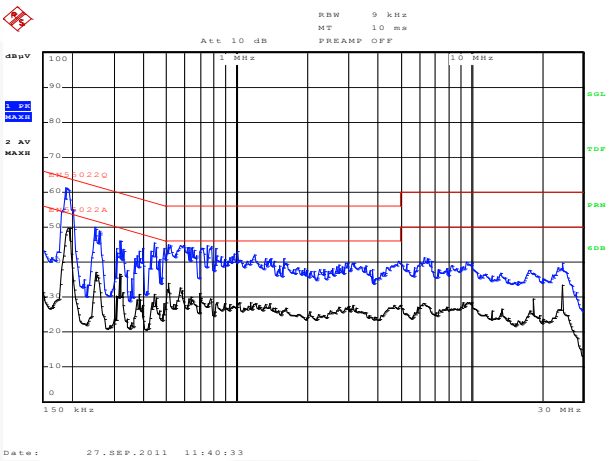
3.8. EMI

The all measurement was conducted in observance of EN55022 criteria.

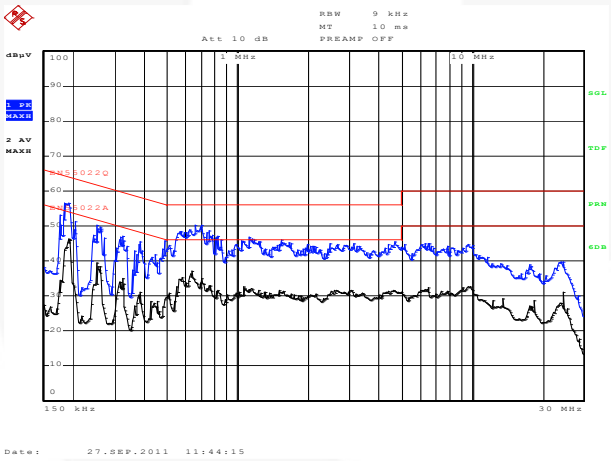
LIVE - Vin=115Vac



LIVE - Vin=115Vac



NEUTRAL - Vin=230Vac



NEUTRAL - Vin=230Vac

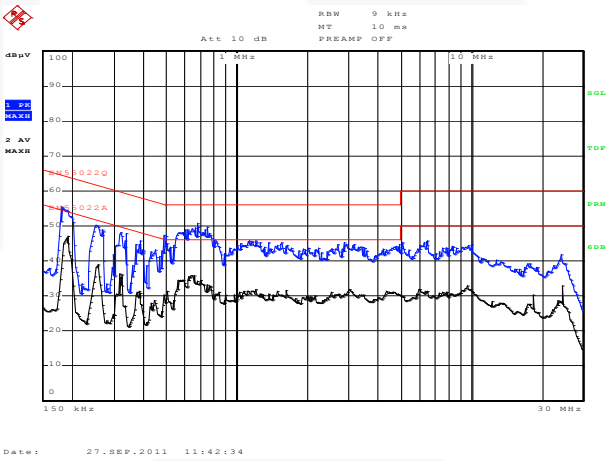


Figure 17. **EMI Results –Vout[24V], Iout[350mA]**

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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