User Guide for

FEB-L027

Evaluation Board

Reference Design Report for a 17.5W T8 LED Lamp Using FL7732

Featured Fairchild Product:

FL7732

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

Fairchild Semiconductor.com

Table of Contents

The following user guide supports the evaluation 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 a universal line voltage T8 LED lamp using the FL7732 Primary Side Regulator (PSR) single-stage controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$. There is one DC output with a constant current of 500mA at $35V_{MAX}$. This document contains general description of FL7732, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. General Description

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, such as input bulk capacitor and feedback circuitry, and minimize cost. To improve power factor and Total Harmonic Discharge (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 DCM operation with high efficiency and simple design. FL7732 provides open-LED, short-LED, and over-temperature protections.

1.2. Features

- Cost-Effective Solution: No Input Bulk Capacitor and Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (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 (OTP) with Auto Restart
- Low Startup Current: 20μA
- Low Operating Current: 5mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package

1.3. Internal Block Diagram

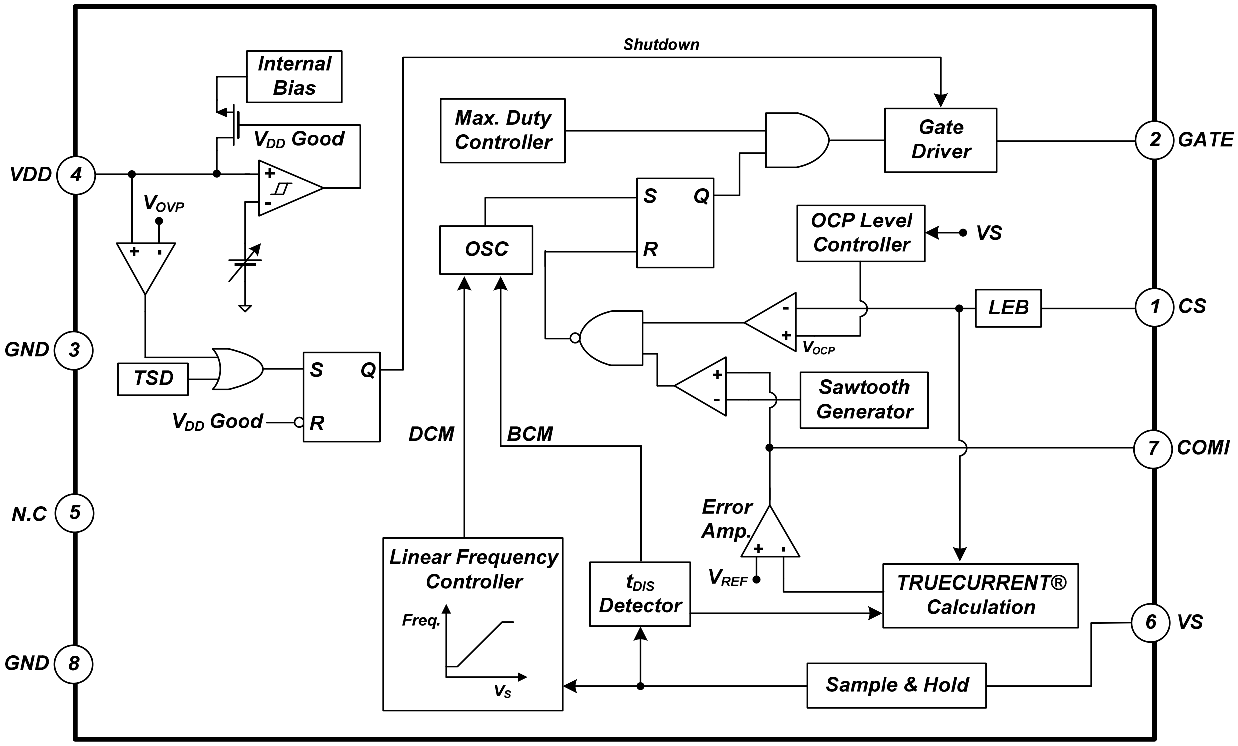


Figure 1. Block Diagram of FL7732

2. General Specifications for Evaluation Board

Table 1. Evaluation Board Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90V	Minimum Input Voltage
		$V_{IN.MAX}$	265V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110V / 220V	Nominal Input Voltage
	Frequency	f_{IN}	60Hz / 50Hz	Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	17.5V	Minimum Output Voltage
		$V_{OUT.MAX}$	37V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	35V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	500mA	Nominal Output Current
		CC Deviation	< ±2.59%	Line Input Voltage Change: 90~265V_{AC}
			< ±1.82%	Output Voltage Change: 17.5~35V
Efficiency		Eff_{90VAC}	87.02%	Efficiency at 90V_{AC} Line Input Voltage
		Eff_{120VAC}	88.67%	Efficiency at 120V_{AC} Line Input Voltage
		Eff_{140VAC}	89.22%	Efficiency at 140V_{AC} Line Input Voltage
		Eff_{180VAC}	89.60%	Efficiency at 180V_{AC} Line Input Voltage
		Eff_{220VAC}	89.54%	Efficiency at 220V_{AC} Line Input Voltage
		Eff_{265VAC}	89.14%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD		PF / THD_{90VAC}	0.999 / 7.38%	PF / THD at 90V_{AC} Line Input Voltage
		PF / THD_{120VAC}	0.997 / 8.98%	PF / THD at 120V_{AC} Line Input Voltage
		PF / THD_{140VAC}	0.995 / 11.02%	PF / THD at 140V_{AC} Line Input Voltage
		PF / THD_{180VAC}	0.990 / 13.87%	PF / THD at 180V_{AC} Line Input Voltage
		PF / THD_{220VAC}	0.978 / 16.63%	PF / THD at 220V_{AC} Line Input Voltage
		PF / THD_{265VAC}	0.959 / 18.75%	PF / THD at 265V_{AC} Line Input Voltage
Temperature	**FL7732**	T_{FL7732}	44.8ºC	Open-Frame Condition (T_A = 25ºC) Temperature
	Primary MOSFET	T_{MOSFET}	59.6ºC	Primary MOSFET Temperature
	Secondary Diode	T_{DIODE}	66.6ºC	Secondary Diode Temperature
	Transformer	$T_{TRANSFORMER}$	64.5ºC	Transformer Temperature

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

3. Evaluation Board

Dimensions: 297.81 (L) × 17.14 (W) × 11.00 (H) [mm]

Figure 2. Top / Bottom of Evaluation Board

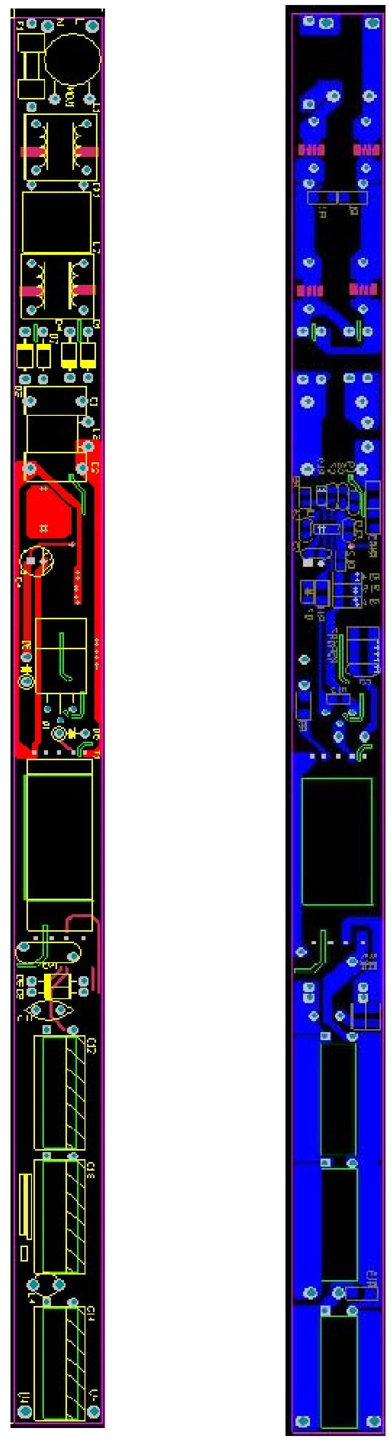


Figure 3. PCB Pattern Top / Bottom of Evaluation Board

4. Schematic

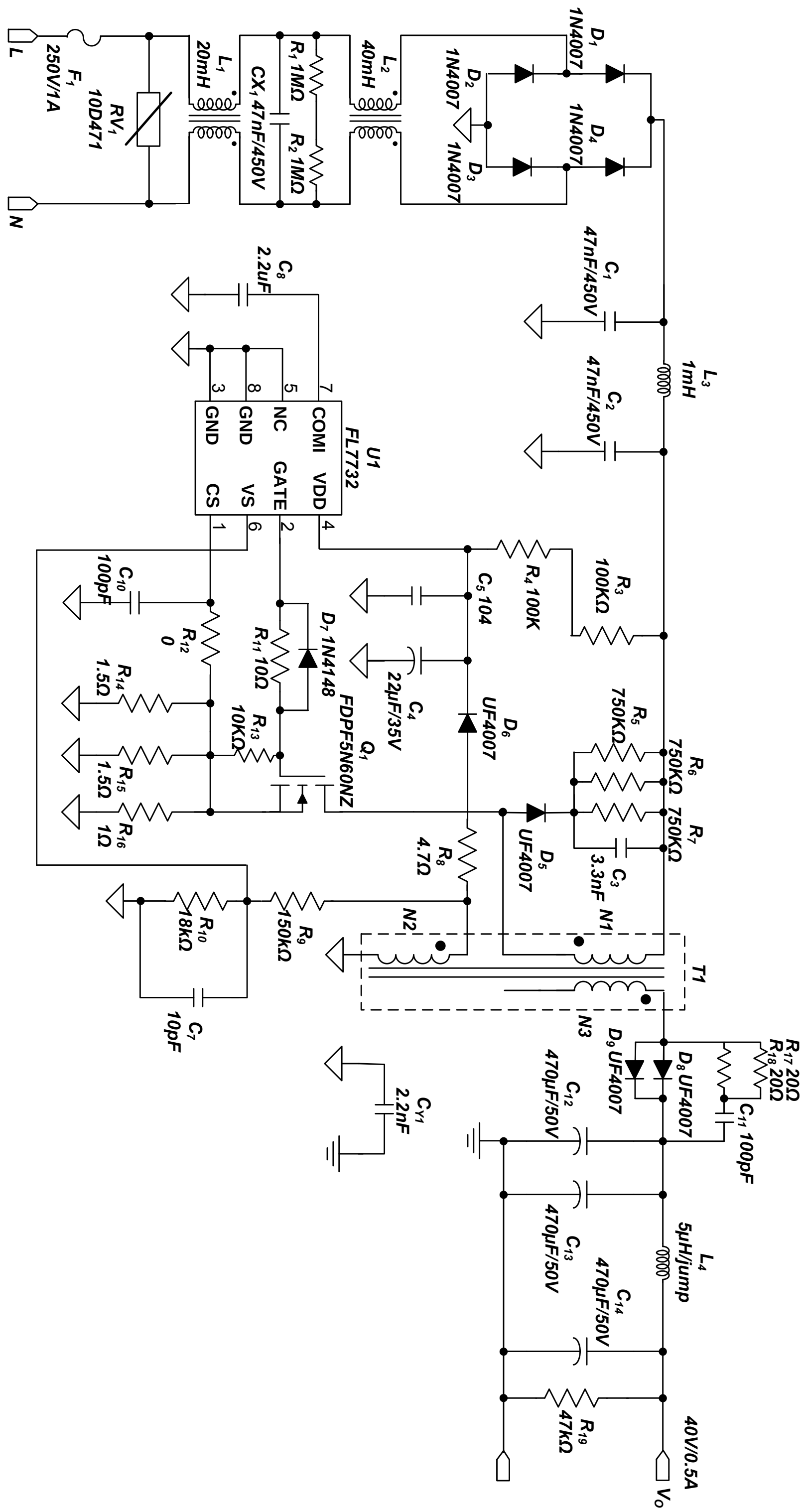


Figure 4. Evaluation Board Schematic

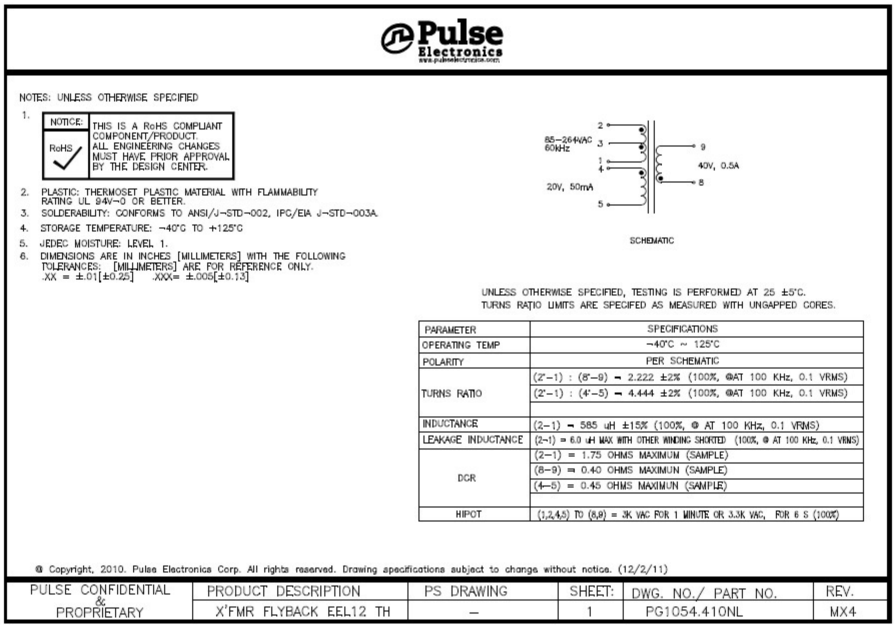
5. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	C1, C2	MPE 400V473K 14S	2	47nF / 400V MPE Film Capacitor	Sungho
3	C3	C1206C332KDRACTU	1	3.3nF / 1kV SMD Capacitor 3216	Kemet
4	C4	KMG 22µF / 35V	1	22µF / 35V Electrolytic Capacitor	Samyoung
5	C5	C0805C104K5RACTU	1	100nF / 50V SMD Capacitor 2012	Kemet
7	C7	C0805C100J5GACTU	1	10pF / 50V SMD Capacitor 2012	Kemet
8	C8	C0805C225Z3VACTU	1	2.2µF / 25V SMD Capacitor 2012	Kemet
10	C10	C0805C101J5GACTU	1	100pF / 50V SMD Capacitor 2012	Kemet
11	C11	DEBB33A101KC1B	1	100pF / 1kV Ceramic Capacitor	Murata
12	C12, C13, C14	KMG 470µF / 50V	3	470µF / 50V Electrolytic Capacitor	Samyoung
15	CX1	MPX AC275V 473K	1	47nF / AC275V X-Capacitor	Carli
16	CY1	SCFz2E222M10BW	1	2.2nF / 250V Y-Capacitor	Samwha
17	D1, D2, D3, D4	IN4007	4	1000V / 1A General-Purpose Rectifier	Fairchild Semiconductor
18	D5, D6, D8, D9	UF4007	4	1000V / 1A Fast Rectifier	Fairchild Semiconductor
19	D7	1N4148	1	100V / 1A Small Signal Rectifier	Fairchild Semiconductor
21	F1	0672001.MXE	1	1A / 250V_{AC} Fuse	Littelfuse
22	L1	20mH	1	20mH	SPI Electronic
23	L2	40mH	1	40mH	SPI Electronic
24	L3	R08102KT00	2	1mH Filter Inductor, 8Φ	Bosung
25	L4	Jumper	1	5µH / Jump	
26	Q1	FDPF5N60NZ	1	4.5A / 600V Main MOSFET	Fairchild Semiconductor
27	R1, R2	RC1206JR-071ML	2	1MΩ SMD Resistor 3216	Yageo
28	R3, R4	RC1206JR-07100KL	2	100KΩ SMD Resistor 3216	Yageo
29	R5, R6, R7	RC1206JR-07750KL	3	750KΩ SMD Resistor 3216	Yageo
30	R8	RC1206JR-074R7L	1	4.7Ω SMD Resistor 3216	Yageo
31	R9	RC0805FR-07150KL	1	150KΩ SMD Resistor 2012	Yageo
32	R10	RC0805JR-0718KL	1	18KΩ SMD Resistor 2012	Yageo
33	R11	RC1206JR-0710RL	1	10Ω SMD Resistor 3216	Yageo
34	R12	RC0805JR-070RL	1	0Ω SMD Resistor 2012	Yageo
35	R13	RC0805JR-0710KL	1	10KΩ SMD Resistor 2012	Yageo
36	R14, R15	RC1206JR-071R5L	2	1.5Ω SMD Resistor 3216	Yageo
37	R16	RC1206FR-071RL	1	1.0Ω SMD Resistor 3216	Yageo
38	R17, R18	RC1206JR-0720RL	2	20Ω SMD Resistor 3216	Yageo
39	R19	RC1206JR-0747KL	1	47kΩ SMD Resistor 3216	Yageo
41	RV1	SVC 471 D-10A	1	Metal Oxide Varistor	Samwha
42	T1	PG1054.410NL (1150-CDC-MX4)	1	Transformer, 585µH	Pulse Electronics

Bill of Materials (Continued)

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
43	U1	FL7732_F116	1	Main Controller	Fairchild Semiconductor

6. Transformer Design



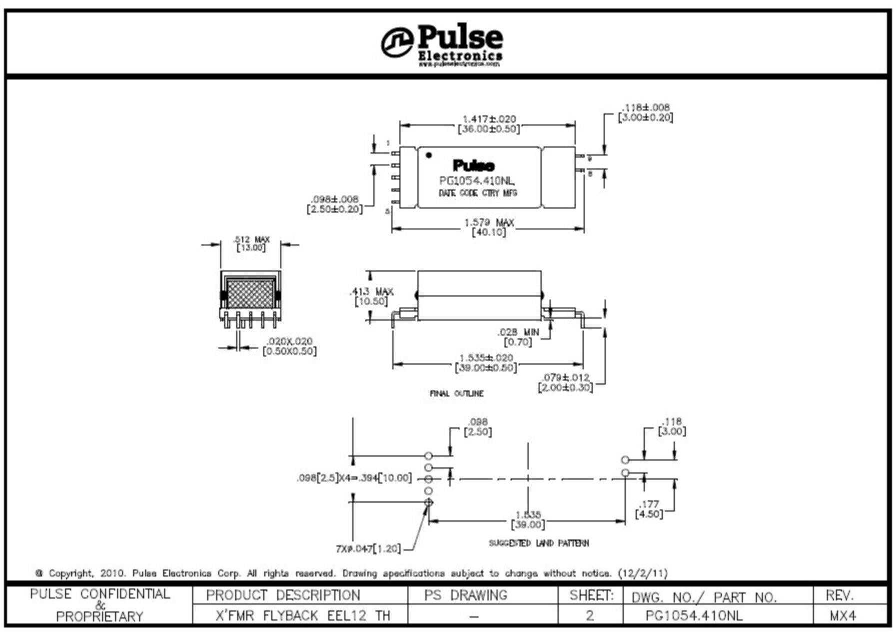


Figure 5. Transformer Bobbin Structure and Pin Configuration

Table 2. Electrical Characteristics

	Pin	Specifications	Remark
Inductance	2 – 1	585μH ± 10%	100kHz, 0.1V
Leakage	2 – 1	6μH	100kHz, 0.1V Short All Output Pins

7. Electromagnetic Interference (EMI) Inductor (L1 & L2) Design

PIN LOCATION (BOTTOM VIEW)

CONNECTION (• POLARITY)

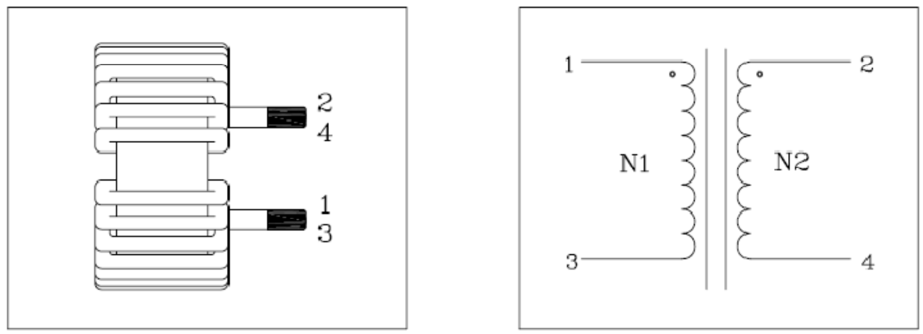


FIGURE-1

FIGURE-2

Figure 6. Transformer Bobbin Structure and Pin Configuration

Table 3. Winding Specifications

Part Ref.	Winding	Pin (S → F)	Wire	Turns	Inductance
L1	N1	1 → 3	0.25 Φ (2UEW)	68.5	22mH Min.
	N2	2 → 4	0.25 Φ (2UEW)	68.5	22mH Min.
L2	N1	1 → 3	0.25 Φ (2UEW)	74.5	50mH Min.
	N2	2 → 4	0.25 Φ (2UEW)	74.5	50mH Min.

Table 4. Material List

No.	Item	Material	Manufacturer	UL No.
1	PCB	CEM1	CHANG CHUN PLASTICS	E80513(S)
2	Core	R8K	VAKOS INDUSTRIES	
3	Wire	TYPU-130	TA YA ELECTRIC WIRE & CABLE	E84201(S)
		TYA1-130	TA YA ELECTRIC WIRE & CABLE	E84201(S)
		UEW-U	SIAM PACIFIC ELECTRIC WIRE & CABLE	E196993
4	Varnish	468-2(+)	RIPLEY RESIN ENGINEERING	E81777
5	Epoxy	H907	DONG GUAN HUA CHUANG CHEMICALINDUSTRY	
		G-9008	GUDAK CHEMISTRY TECH	

8. Performance of Evaluation Board

8.1. 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: Therma CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03(3W) by Everlight

8.2. Startup

Startup time is 1.3s (V_{IN} = 90V_{AC}) ~ 330ms (V_{IN} = 265V_{AC})

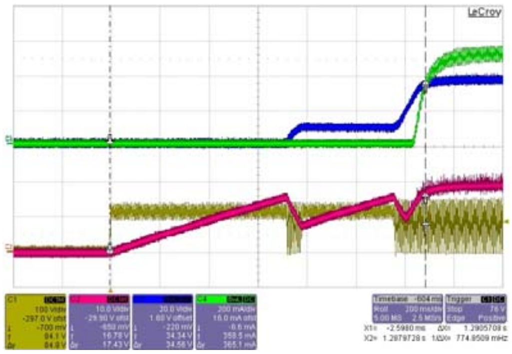


Figure 7. V_{IN} = 90V_{AC} / 60Hz, Startup Time at 10-LED (35V/500mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

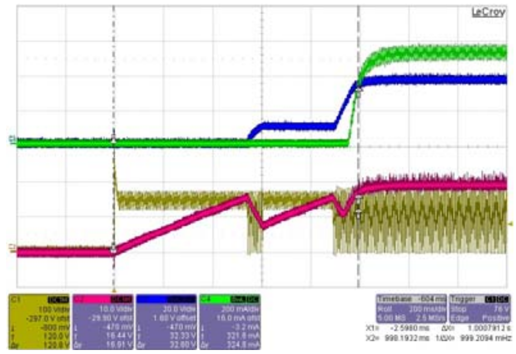


Figure 8. V_{IN} = 115V_{AC} / 60Hz Startup Time at 10-LED (35V/500mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}],

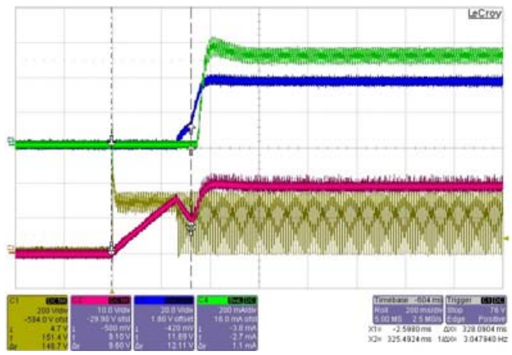


Figure 9. V_{IN} = 230V_{AC} / 50Hz, Startup Time at 10-LED (35V/500mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

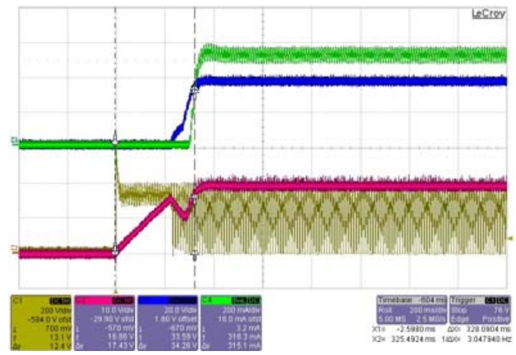


Figure 10. V_{IN} = 265V_{AC} / 50Hz, Startup Time at 10-LED (35V/500mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

8.3. Operation Waveforms

Output current ripple is under 115mAp-p with a rated output current of 500mA.

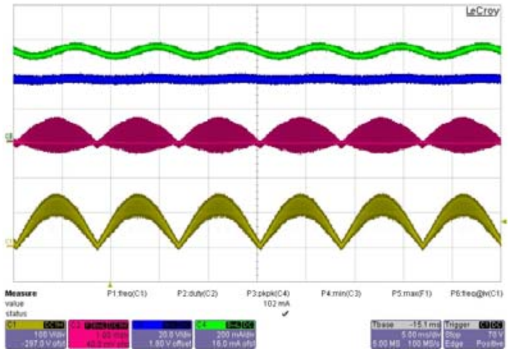


Figure 11. V_{IN}= 90V_{AC} / 60Hz, Operation Waveforms at 10-LED (35V/500mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

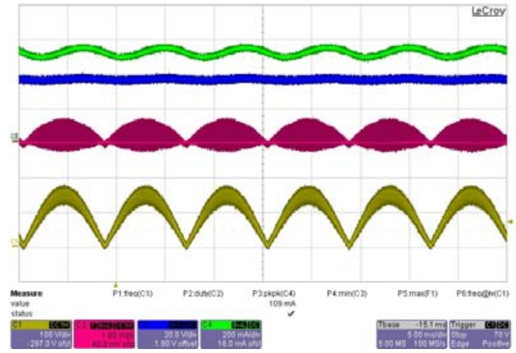


Figure 12. V_{IN} = 115V_{AC} / 60Hz Operation Waveforms at 10-LED (35V/500mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

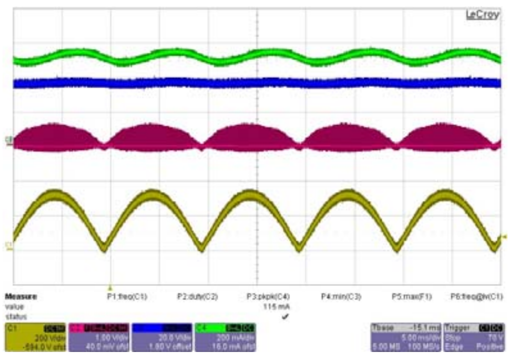


Figure 13. V_{IN} = 220V_{AC} / 50Hz, Operation Waveforms at 10-LED (35V/500mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

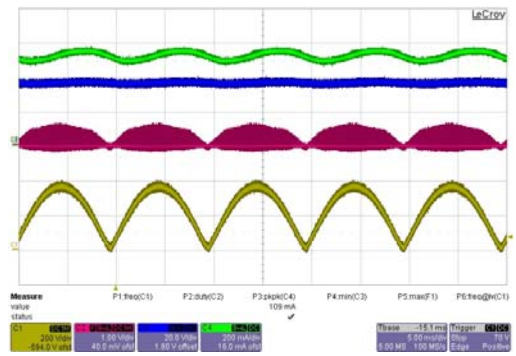


Figure 14. V_{IN} = 265V_{AC} / 50Hz, Operation Waveforms at 10-LED (35V/500mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

8.4. Constant-Current Regulation

Constant-current deviation in the wide output voltage range from 5-LED (17.5V) to 10-LED (35V) is less than ±1.82% at each line input voltage. Line regulation is less than ±2.59%. The results were measured using LED load.

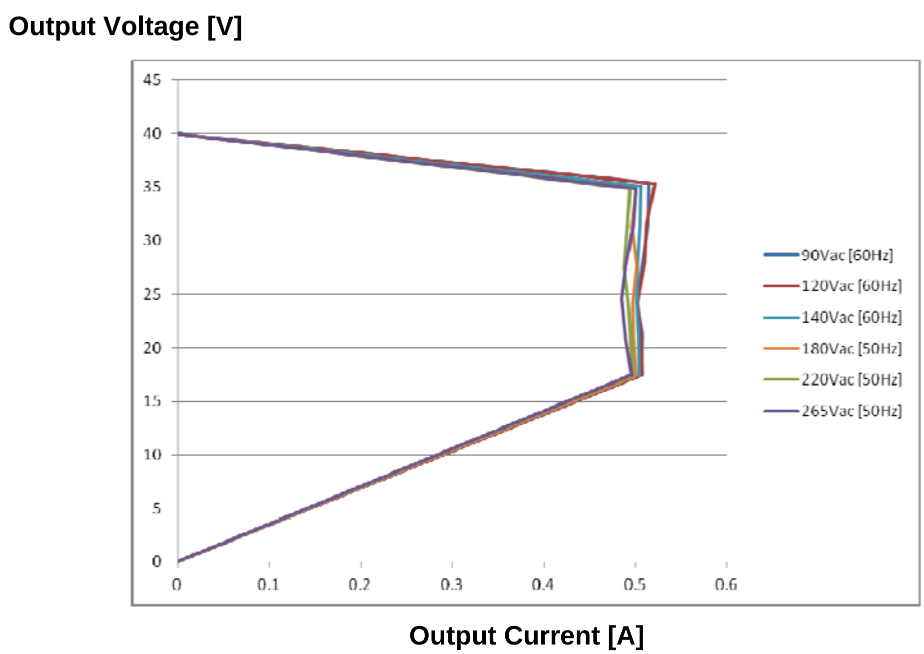


Figure 15. Constant-Current Regulation – Measured by LED Load

Table 5. Constant-Current Regulation by Output Voltage Change (17.5V ~ 35V)

Input Voltage	Min. Current [A]	Max. Current [A]	Tolerance
$90V_{AC}$ [60Hz]	0.501	0.515	±1.36%
$120V_{AC}$ [60Hz]	0.502	0.521	±1.82%
$140V_{AC}$ [60Hz]	0.501	0.506	±0.49%
$180V_{AC}$ [50Hz]	0.496	0.501	±0.50%
$220V_{AC}$ [50Hz]	0.488	0.497	±0.91%
$265V_{AC}$ [50Hz]	0.485	0.5	±1.50%

Table 6. Constant-Current Regulation by Line Voltage Change (90 ~ $265V_{AC}$)

Output Voltage	$90V_{AC}$	$120V_{AC}$	$140V_{AC}$	$180V_{AC}$	$220V_{AC}$	$265V_{AC}$	Tolerance
35V	0.515A	0.521A	0.506A	0.50A	0.494A	0.50A	±2.59%
31.5V	0.514A	0.512A	0.505A	0.496A	0.491A	0.498A	±2.24%
28V	0.509A	0.510A	0.502A	0.501A	0.488A	0.490A	±2.16%

8.5. Short-LED/ Open-LED Protections

In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because the FL7732 lowers the OCP level when the V_S voltage is less than 0.4V during output diode conduction time. The results are measured using actual LED load.

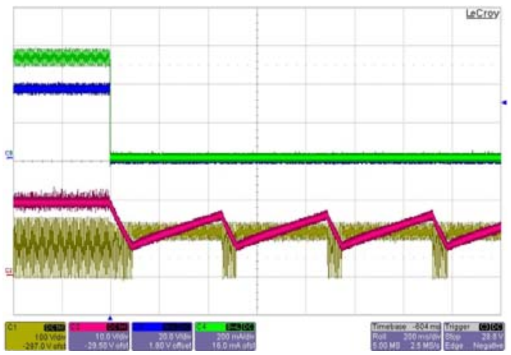


Figure 16. V_{IN} = 90V_{AC} / 60Hz, Short-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

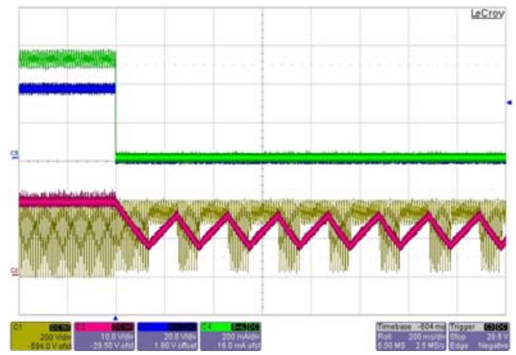


Figure 17. V_{IN} = 265V_{AC} / 50Hz, Short-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

In open-LED condition, output voltage is limited around 30V by OVP in V_{DD}. Output over-voltage protection level can be controlled by the turn ratio of the auxiliary and secondary windings.

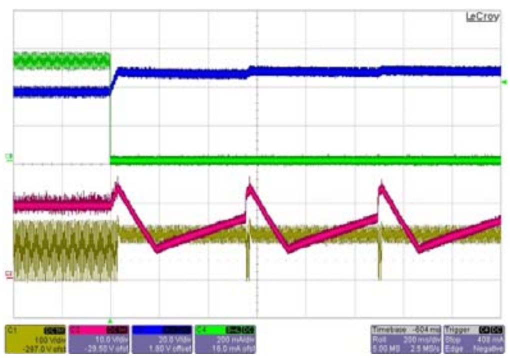


Figure 18. V_{IN} = 90V_{AC} / 60Hz, Open-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

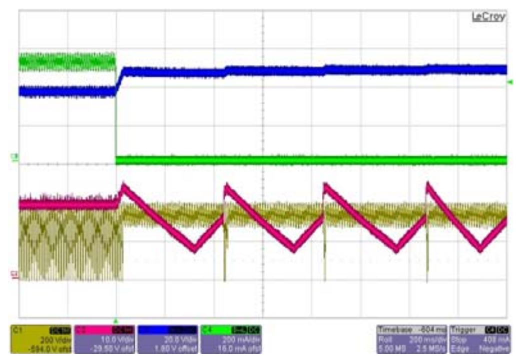


Figure 19. V_{IN} = 265V_{AC} / 60Hz, Open-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}]

8.6. System Efficiency

System efficiency is 87.02% ~ 89.6% in 90 ~ 265V_{AC} input voltage range. The results were measured after 30 minutes since startup by using LED load.

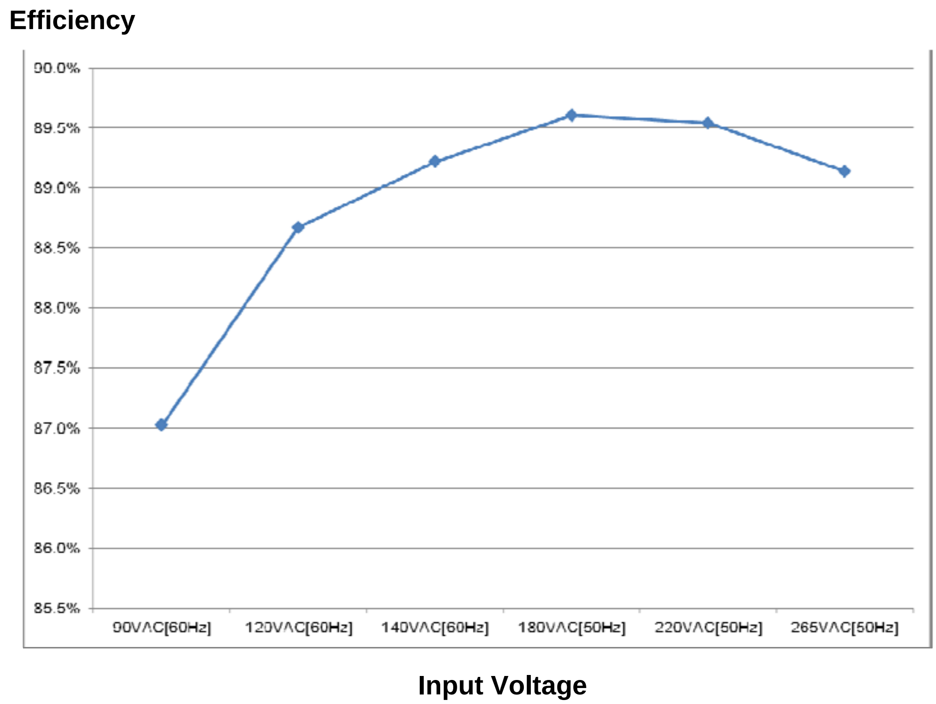


Figure 20. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90V_{AC} [60Hz]	20.380	0.509	34.83	17.735	87.02%
120V_{AC} [60Hz]	20.219	0.514	34.88	17.928	88.67%
140V_{AC} [60Hz]	19.825	0.508	34.79	17.687	89.22%
180V_{AC} [50Hz]	19.453	0.503	34.68	17.430	89.60%
220V_{AC} [50Hz]	19.065	0.494	34.55	17.071	89.54%
265V_{AC} [50Hz]	19.198	0.495	34.55	17.113	89.14%

8.7. Power Factor & Total Harmonic Distortion

FL7732 shows excellent THD performance. THD is much less than 30% of the specification. Power factor is very high with enough margin from 0.9. The results were measured 30 minutes after startup.

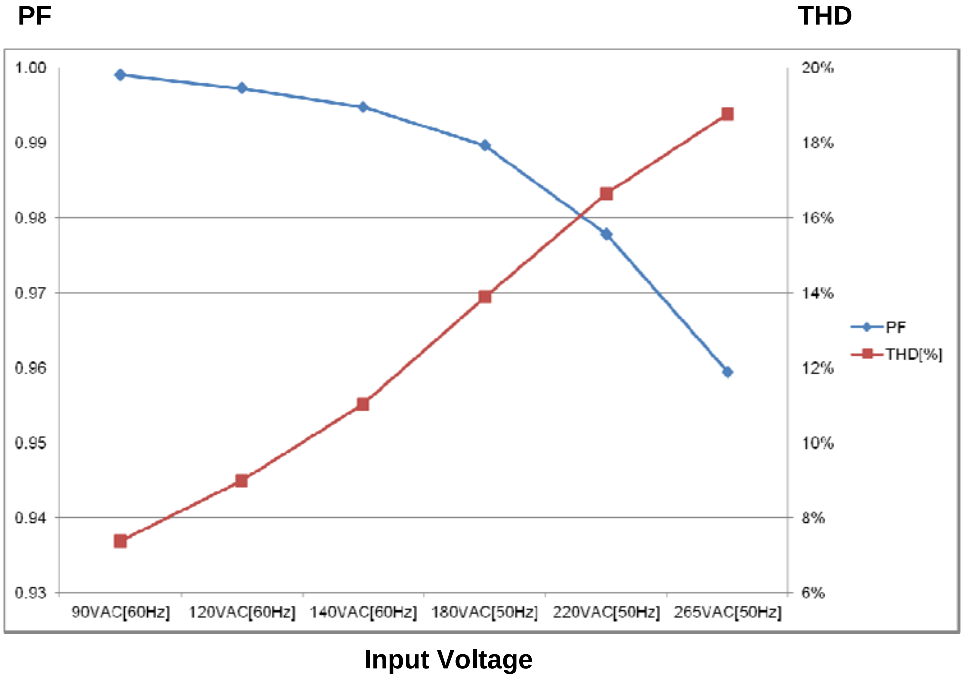


Figure 21. Power Factor & Total Harmonic Distortion

Table 8. Power Factor & Total Harmonic Distortion

Input Voltage	PF	THD
$90V_{AC}$ [60Hz]	0.999	7.38%
$120V_{AC}$ [60Hz]	0.997	8.98%
$140V_{AC}$ [60Hz]	0.995	11.02%
$180V_{AC}$ [50Hz]	0.990	13.87%
$220V_{AC}$ [50Hz]	0.978	16.63%
$265V_{AC}$ [50Hz]	0.959	18.75%

8.8. Operating Temperature

Temperature of the all components on this board is less than 67ºC.

The results were measured 60 minutes after startup.

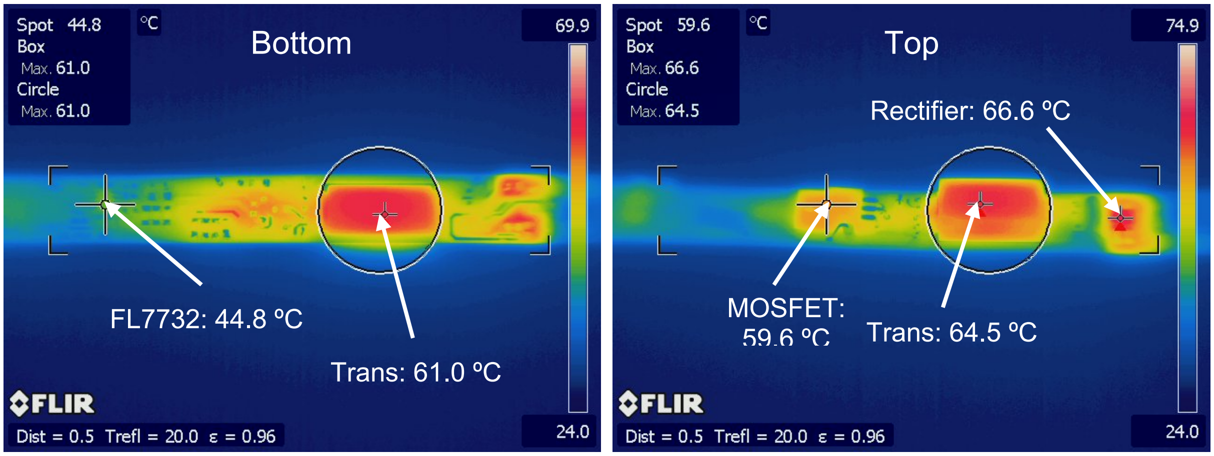


Figure 22. Board Temperature – V_{IN} [90V_{AC} / 60Hz], 10-LED (35V / 500mA)

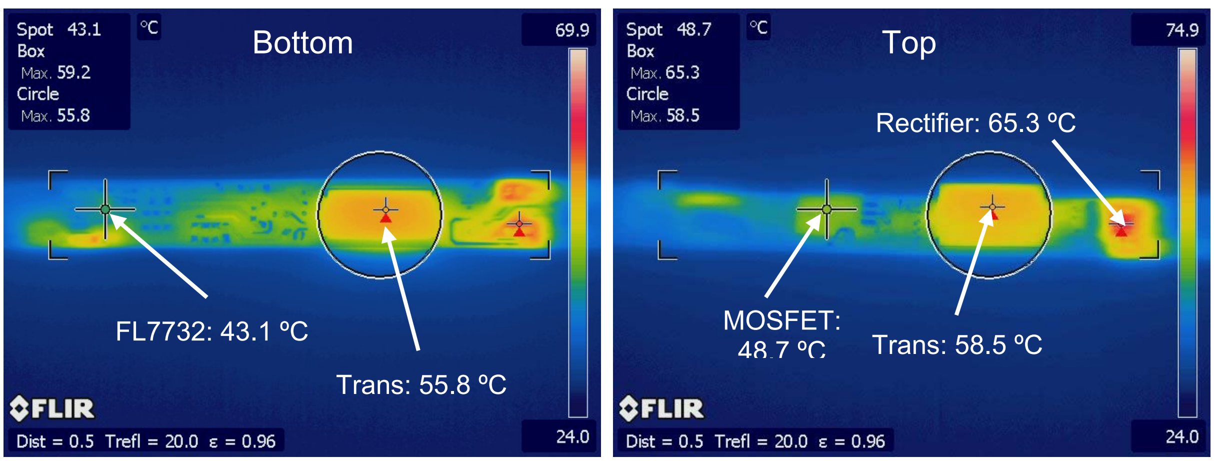


Figure 23. Board Temperature – V_{IN} [265V_{AC} / 50Hz], 10-LED (35V / 500mA)

8.9. Electromagnetic Interference (EMI)

All measurements were conducted in observance of EN55022 criteria.

The results were measured 30 minutes after startup.

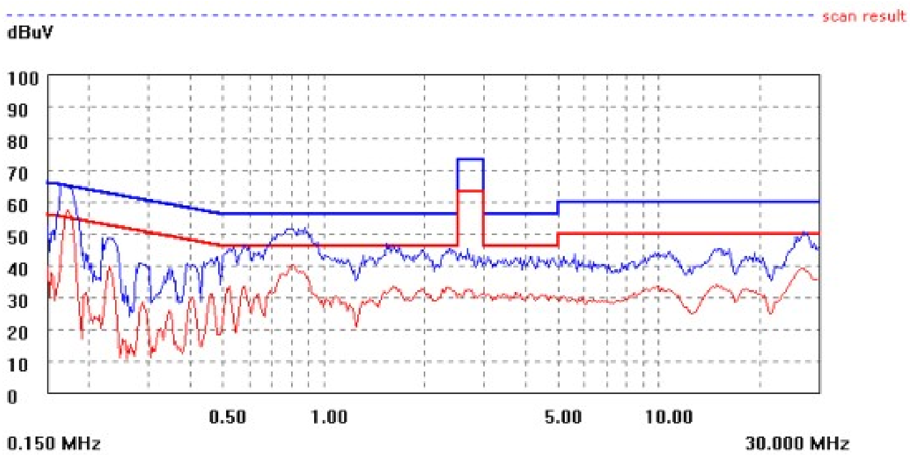


Figure 24. EMI Results – 10-LED (35V/500mA), Conduction Line; V_{IN} = 220V_{AC}

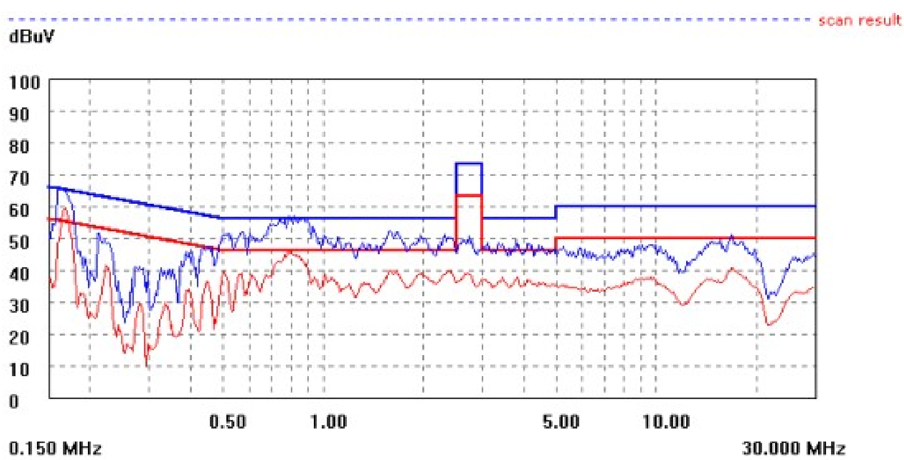


Figure 25. EMI Results – 10-LED (35V/500mA), Conduction Neutral; V_{IN} = 220V_{AC}

9. Revision History

Rev.	Date	Description
1.0.0	July 2011	Initial Release