User Guide for

FEB-L032 Evaluation Board

2.7W LED Ballast Using FLS0116

Featured Fairchild Product:

FLS0116

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

Fairchild Semiconductor.com

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This user guide supports the evaluation kit for the FLS0116. It should be used in conjunction with the FLS0116 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 an universal input, 2.7W LED ballast using the FLS0116. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 97mA at $28V_{MAX}$. This document contains general description of FLS0116, the power supply specification, schematic, bill of materials and the typical operating characteristics.

1.1. General Description

The FLS0116 LED lamp driver is a simple IC with PFC function and integrated switching MOSFET. The special "adopted digital" technique automatically detects input voltage condition and sends an internal reference signal, resulting in high power factor (PF). When AC input voltage is applied to the IC, PFC function is automatically enabled. When DC input voltage is applied to the IC, PFC function is automatically disabled. The FLS0116 does not require a bulk capacitor (electrolytic capacitor) for supply rail stability, which can significantly improve LED reliability.

1.2. Key Features

- Built-in MOSFET (1A/550V)
- Digitally Implemented Active PFC Function (No Additional Circuit Necessary for High PF)
- Built-in HV Supplying Circuit: Self Biasing
- AOCP Function with Auto-Restart Mode
- Built-in Over-Temperature Protection (OTP)
- Cycle-by-Cycle Current Limit
- Low Operating Current: 0.85mA (Typical)
- Under-Voltage Lockout with 5V Hysteresis
- Programmable Oscillation Frequency
- Programmable LED Current
- Analog Dimming Function
- Soft-Start Function
- Precise Internal Reference: ±3%

1.3. Internal Block Diagram

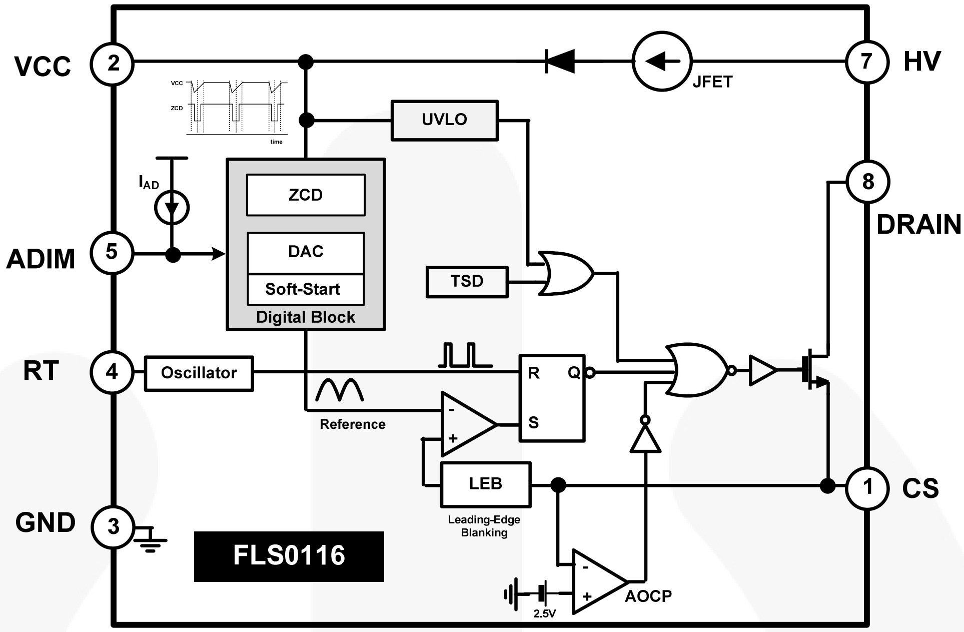


Figure 1. Internal Block Diagram

Pin No.	Symbol	Description
1	CS	**Current Sense**. Limits output current, depending on the sensing resistor voltage. The CS pin is also used to set the LED current regulation.
2	VCC	**VCC**. Supply pin for stable IC operation ZCD signal detection used for accurate PFC function.
3	GND	**GROUND**. Ground for the IC.
4	RT	**RT**. Programmable operating frequency using an external resistor. The IC has a fixed frequency when this pin is open or floating.
5	ADIM	**Analog Dimming**. Connects to the internal current source and can change the output current using an external resistor. If ADIM is not used, connect a 0.1µF bypass capacitor between ADIM and GND.
6	NC	No Connection.
7	HV	**High Voltage**. Connects to the high-voltage line and supplies current to the IC.
8	DRAIN	**High Voltage**. Internal switching FET drain pin.

2. General Specifications for Evaluation Board

All data for this table was measured at an ambient temperature of 25°C.

Table 1. Summary of Features and Performance

Description	Symbol	Value	Comments
Input Voltage Range	$V_{IN.MIN}$	90V	Minimum Input Voltage
	$V_{IN.NORMAL}$	110V / 220V	Normal Input Voltage
	$V_{IN.MAX}$	265V	Maximum Input Voltage
AC Input Frequency	$Freq_{IN.MIN}$	47Hz	Minimum Input Frequency
	$Freq_{IN.MAX}$	64Hz	Maximum Input Frequency
Output Voltage	$V_{OUT,MAX}$	30V	Maximum Output Voltage
	$V_{OUT,NORMAL}$	28V	Normal Output Voltage
	$V_{OUT,MIN}$	26V	Minimum Output Voltage
Output Current(1)	$I_{OUT.NORMAL}$	97mA	Normal Output Current
	CC Deviation	< ±1.3%	Line Input Voltage Change: 90~265V_{AC}
Output Power(2)	Output Power	2.7W	
Efficiency		>78%	At Full Load
Temperature	$T_{FLS0116}$	< 73°C	At Full Load (all at open-frame, room temperature / still air)
	$T_{DM\ filter}$	< 44°C	
	$T_{FRD,UF4007}$	< 47°C	
	$T_{CS\ resistor}$	< 59°C	
	$T_{inductor}$	< 66°C	
PCB Size			20mm (width) x 30mm (length)x 18mm (height)
Initial Application			LED Bulb

Notes:

1. The output current has I_{LEDPK} ripple. To reduce ripple current, use a large electrolytic capacitor in parallel with the LED. Ensure the capacitor voltage rating is high enough to withstand an open-LED condition or use a Zener diode for protection.
2. The output power is not equal to the apparent power due to the slight phase shift between the output voltage and current.

2.1. Photographs of Evaluation Board

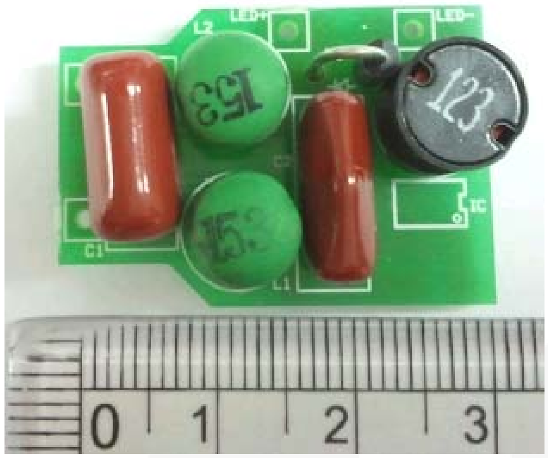


Figure 2. Top View (20mm x 30mm)

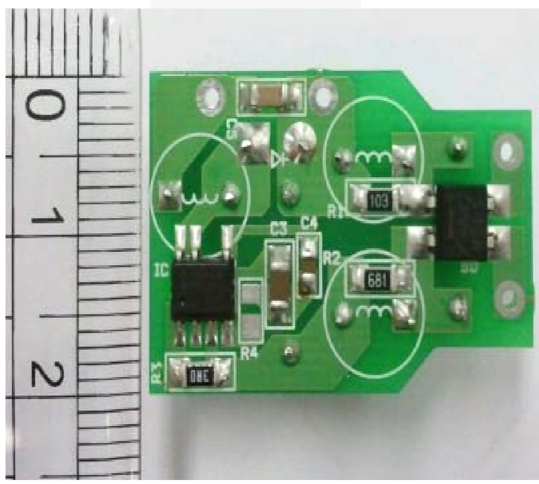


Figure 3. Bottom View (20mm x 30mm)

Figure 4. Side View (18mm)

2.2. Printed Circuit Board

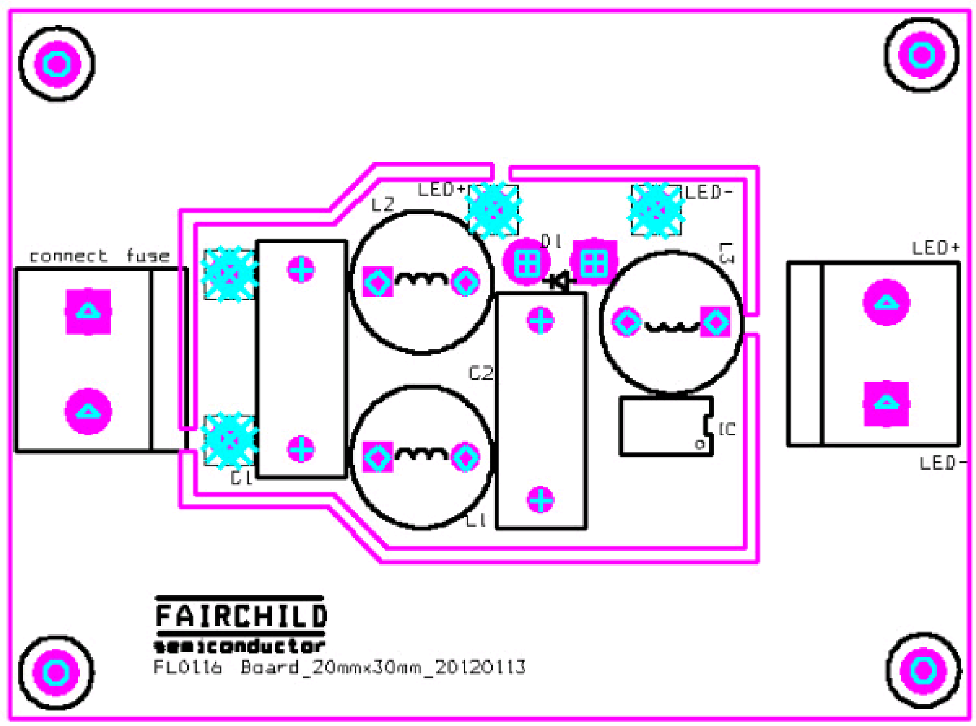


Figure 5. Top Side

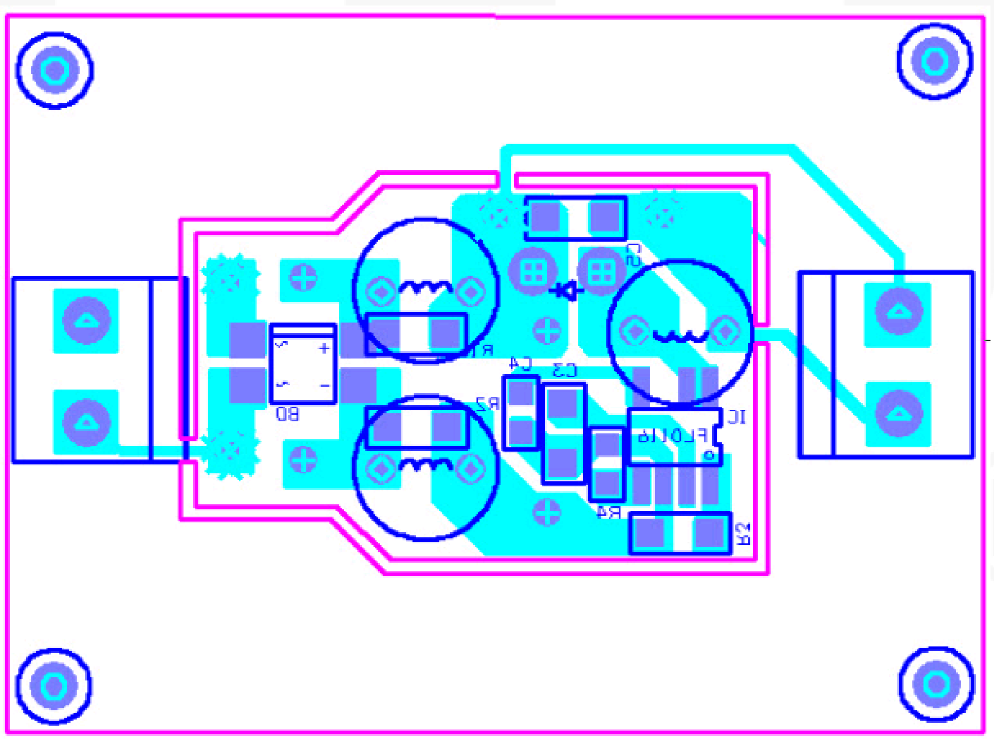


Figure 6. Bottom Side

2.3. Schematic

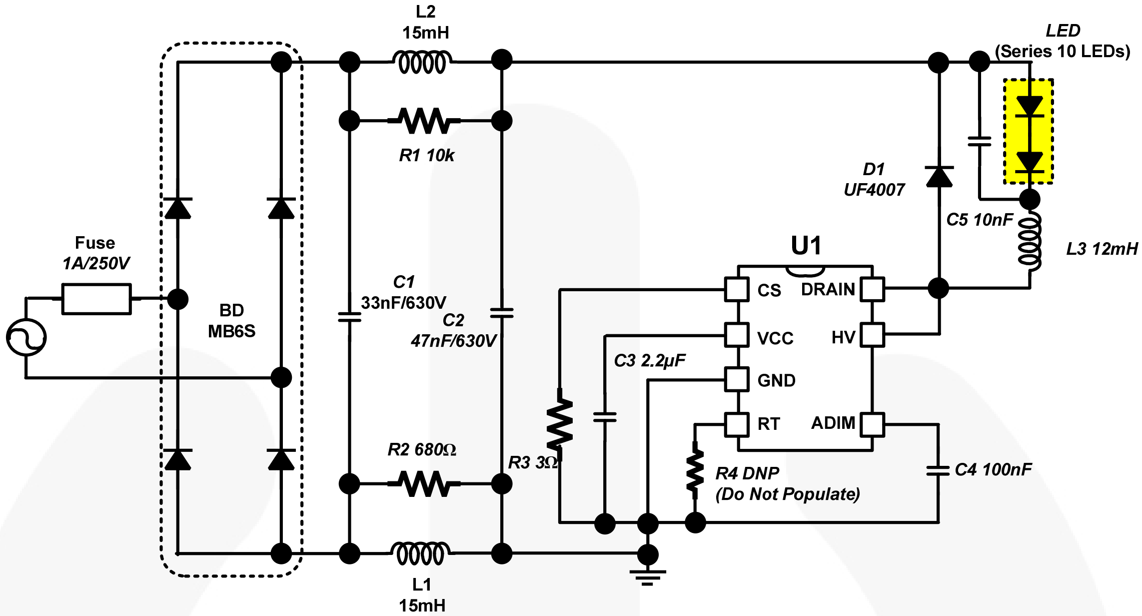


Figure 7. Evaluation Board Schematic

2.4. Bill Of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	U1	FLS0116M	1	Controller	Fairchild Semiconductor
2	BD	MB6S	1	0.5A/600V, Bridge Diode	Fairchild Semiconductor
3	C1	MPE 630V333K	1	333/630V_{AC}, Film Capacitor	Sungho
4	C2	MPE 630V473K	1	473/630V_{AC}, Film Capacitor	Sungho
5	C3	C1206C225K3PACTU	1	225/25V SMD Capacitor 3216	Kemet
6	C4	C0805C104K3RACTU	1	104/25V SMD Capacitor 2012	Kemet
7	C5	C1206C103KDRACTU	1	103/630V SMD Capacitor 3216	Kemet
8	D1	UF4007	1	1A/1000V, Ultra-Fast Recovery	Fairchild Semiconductor
9	L1,L2	R06153KT00	2	15mH, Filter Inductor	Bosung
10	L3	RFB0810-123L	1	12mH, Inductor	Coil Craft
11	R1	RC1206JR-07103RL	1	10kΩ, SMD Resistor 3216	Yageo
12	R2	RC1206JR-07680RL	1	680Ω, SMD Resistor 3216	Yageo
13	R3	RC1206JR-073RL	1	3Ω, SMD Resistor 3216	Yageo
-	R4	-	0	Open	

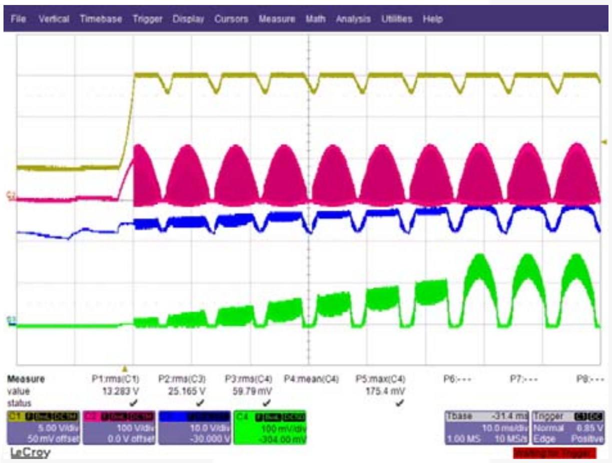
3. Performance of Evaluation Board

Table 2. Test Condition & Equipments

Test Temperature	T_A = 25°C
Test Equipment	AC Source : PCR500L by Kikusui Power Meter : PZ4000 by Yokogawa Oscilloscope : Waverunner 64Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer : CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03 (3W) by Everlight

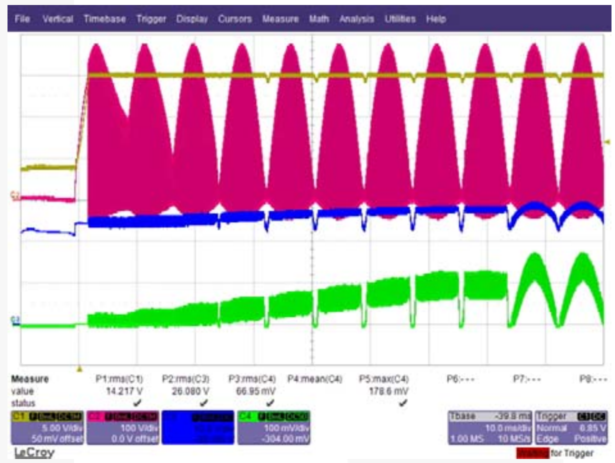
3.1. Typical Waveforms: Startup

Figure 8 through Figure 11 show the typical startup performance at different input voltage conditions. When AC input voltage is applied to the system, the FLS0116 automatically operates in AC Mode after finishing an internally fixed, seven-cycle, soft-start period. Figure 10 and Figure 11 show the soft-start characteristics when a DC input voltage is applied.



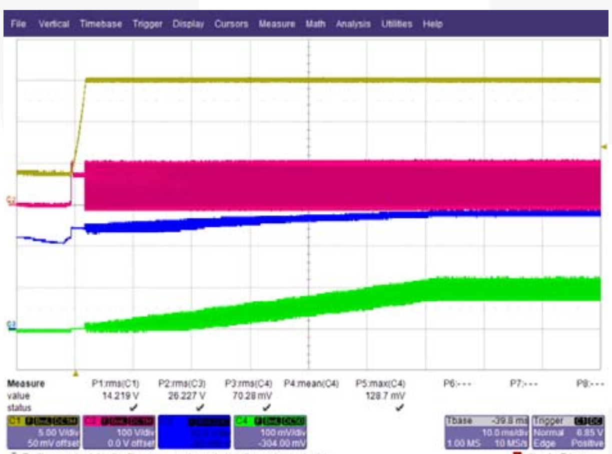
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 8. Soft-Start, AC Mode, 90V_{AC}



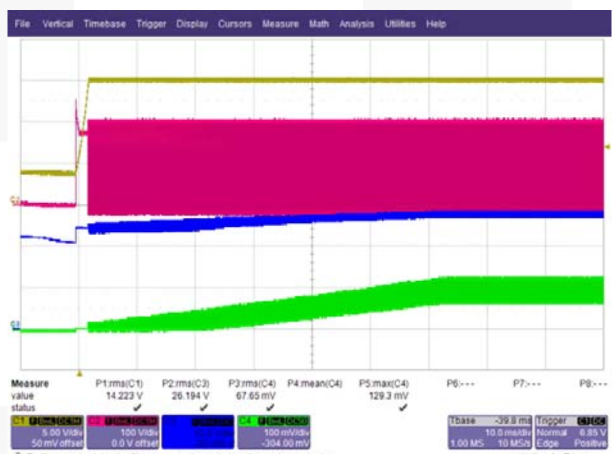
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 9. Soft-Start, AC Mode, 265V_{AC}



CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 10. Soft-Start, DC Mode, 100V_{DC}

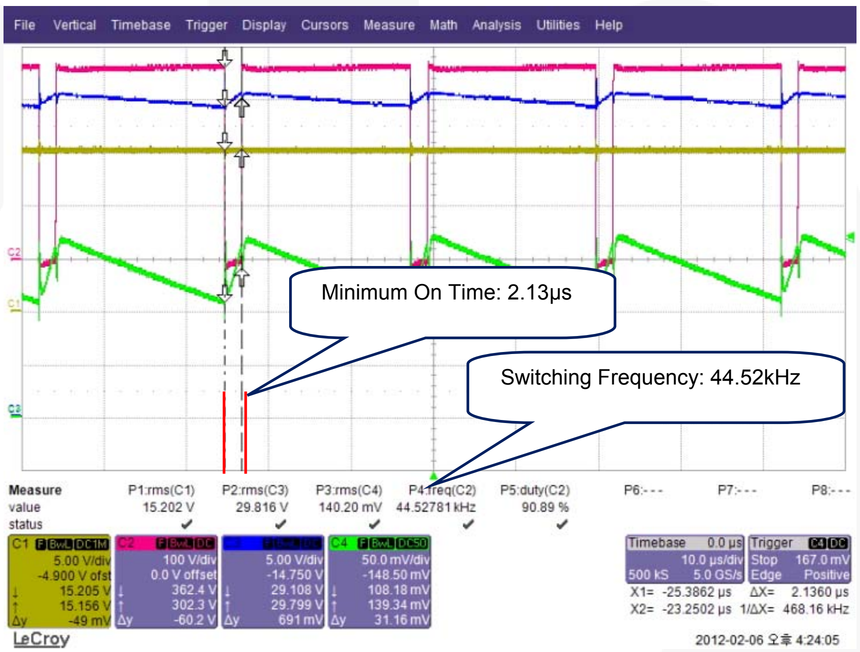


CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 11. Soft-Start, DC Mode, 200V_{DC}

3.2. Operating Frequency & Minimum Duty

The programmable switching frequency is between 20kHz ~ 250kHz, determined by selecting the RT resistor value. If no RT resistor is used (RT pin OPEN), the FLS0116 default switching frequency is set to 45kHz. The maximum duty ratio is fixed below 50% and has a fixed minimum typical on-time of 400ns. There are two crucial points to design properly. The first is consideration of the minimum duty ratio at minimum input voltage because the FLS0116 is limited to 50% duty ratio. The second consideration is minimum on-time at maximum input voltage condition. The FLS0116 cannot control output power when the operating conditions are such that the required on-time is less than the 400ns minimum on-time.

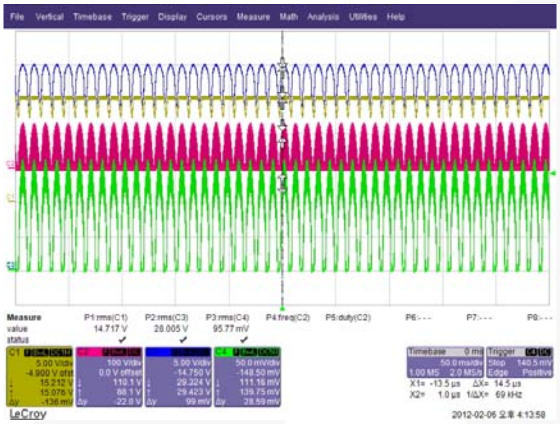


CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 12. Operating Frequency & Minimum Duty Ratio

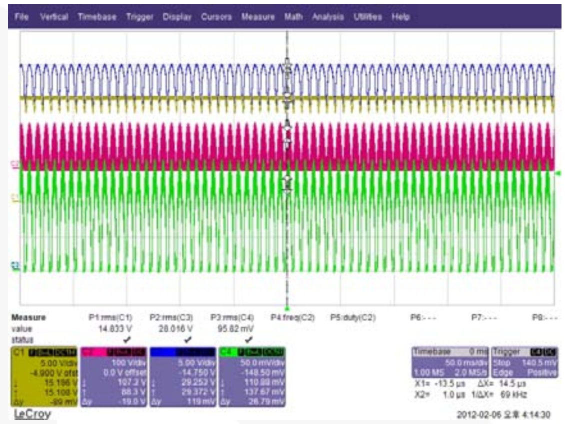
3.3. Typical Waveforms: Steady State

Figure 13 through Figure 22 show the normal operation waveform by input voltage and input frequency. The output voltage and current maintains a certain output level with 120Hz ripple, as shown in the test results in Table 2.



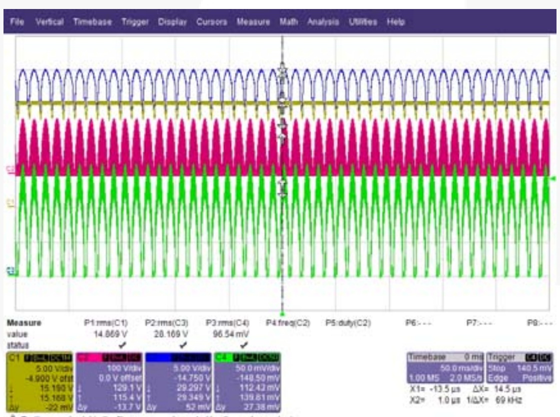
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 13. Input Voltage: 90V_{AC}, Input Frequency: 47Hz



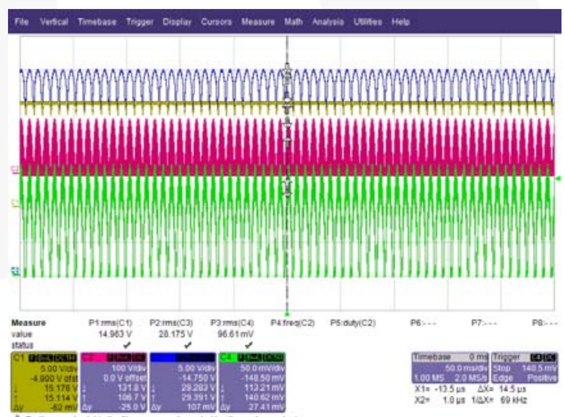
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 14. Input Voltage: 90V_{AC}, Input Frequency: 64Hz



H1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

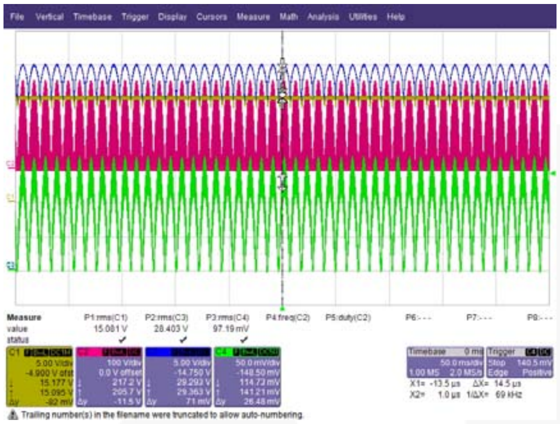
Figure 15. Input Voltage: 110V_{AC}, Input Frequency: 47Hz



H1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 16. Input Voltage: 110V_{AC}, Input Frequency: 64Hz

3.4. Typical Operating Waveforms: Output Characteristics

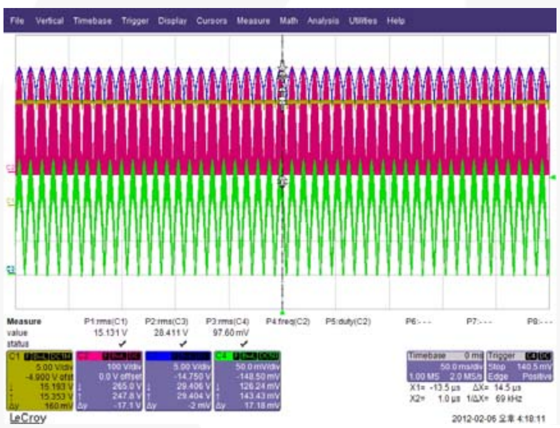


CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 17. Input Voltage: 180V_{AC}, Input Frequency: 47Hz

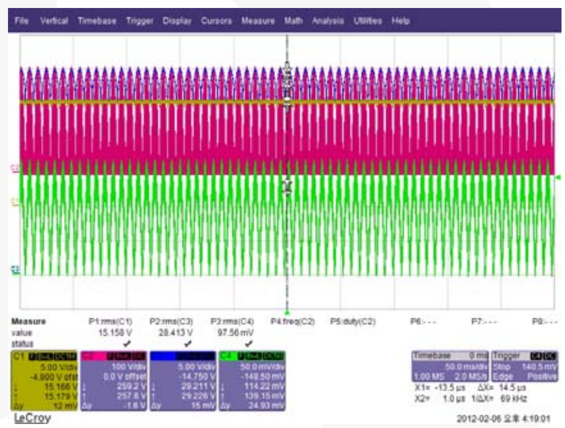
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 18. Input Voltage: 180V_{AC}, Input Frequency: 64Hz



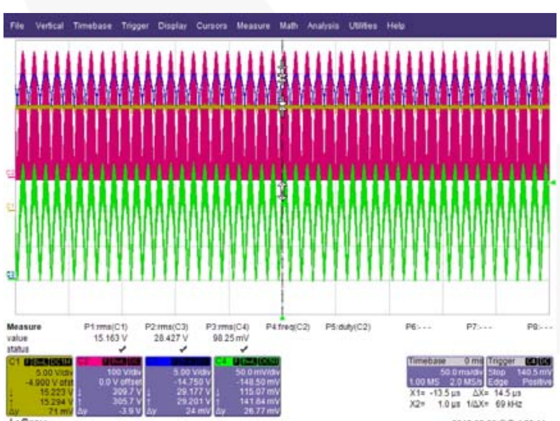
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 19. Input Voltage: 220V_{AC}, Input Frequency: 47Hz



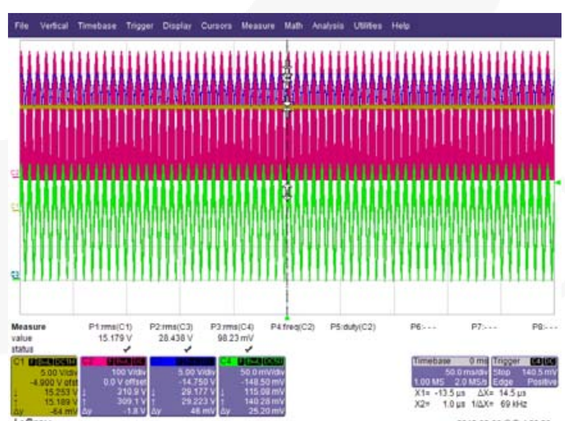
CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 20. Input Voltage: 220V_{AC}, Input Frequency: 64Hz



H1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 21. Input Voltage: 265V_{AC}, Input Frequency: 47Hz



H1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 22. Input Voltage: 265V_{AC}, Input Frequency: 64Hz

Table 3. Output Characteristics by Input Voltage and Frequency

	47Hz		64Hz	
	$V_{LED(RMS)}$	$I_{LED(RMS)}$	$V_{LED(RMS)}$	$I_{LED(RMS)}$
$90V_{AC}$	28.01V	95.77mA	28.02V	95.82mA
$110V_{AC}$	28.17V	96.54mA	28.17V	96.61mA
$180V_{AC}$	28.40V	97.19mA	28.37V	97.11mA
$220V_{AC}$	28.41V	97.60mA	28.41V	97.56mA
$265V_{AC}$	28.43V	98.25mA	28.43V	98.23mA

3.5. Typical Waveforms: Abnormal Mode (LED Open)

Figure 23 and Figure 24 show the open-load condition test method and result. When the LED disconnects from the system, the IC cannot operate because the HV pin is disconnected.

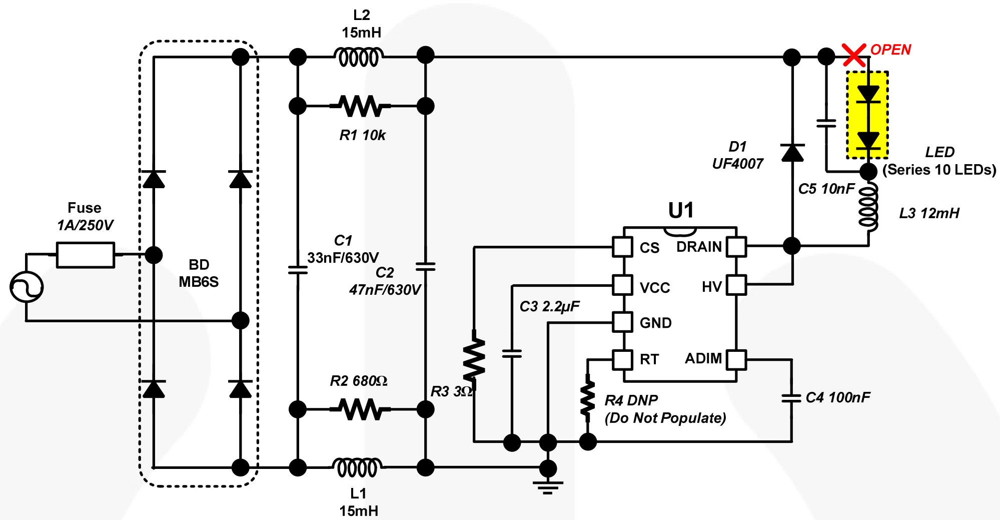
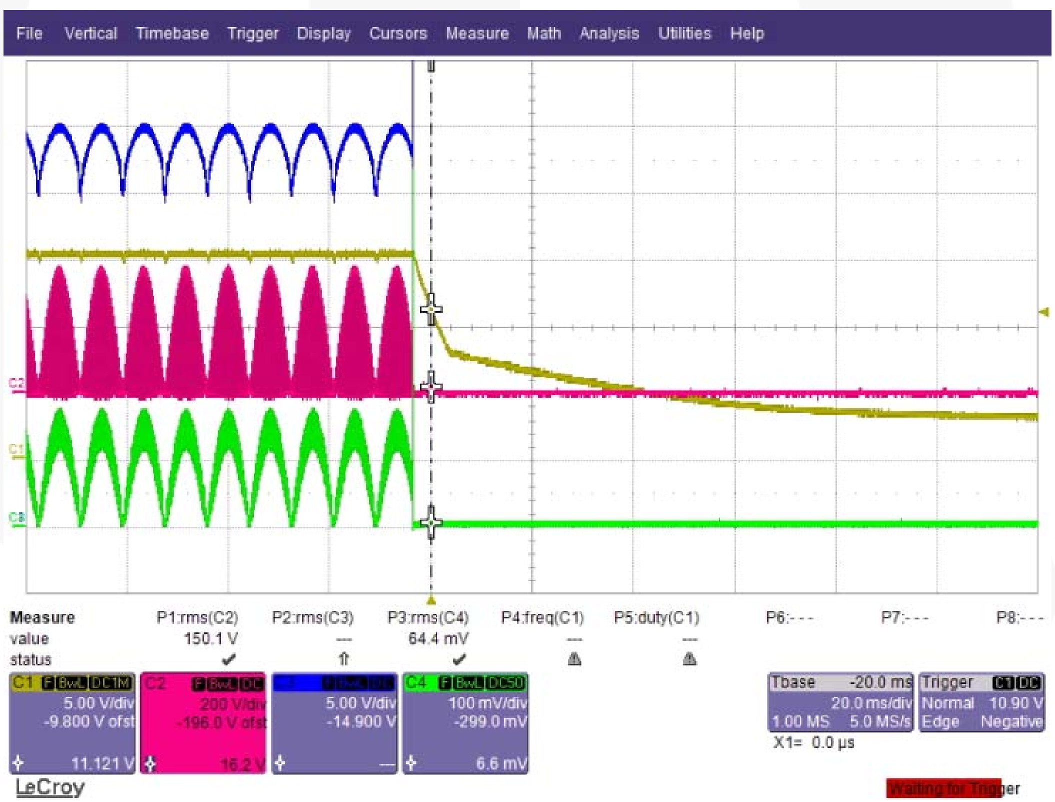


Figure 23. Open-Load Condition Test



CH1: V_{CC}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 24. Test Results of Open-Load Condition

3.6. Typical Waveforms: Abnormal Mode (Inductor Short)

Figure 25 and Figure 26 show the test method and result of an inductor short. The FLS0116 uses an abnormal over-current protection (AOCP) function, limiting the current on RCS in the event of an inductor short.

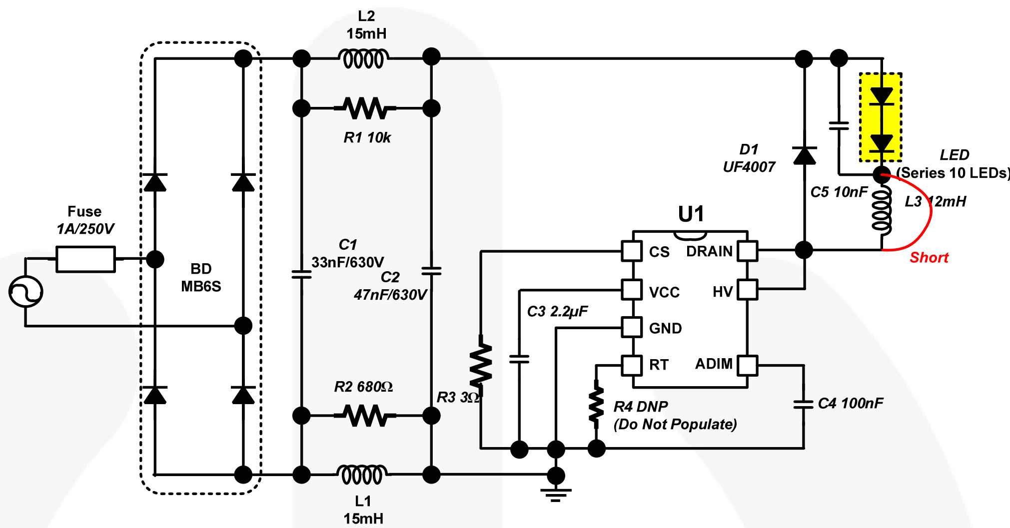
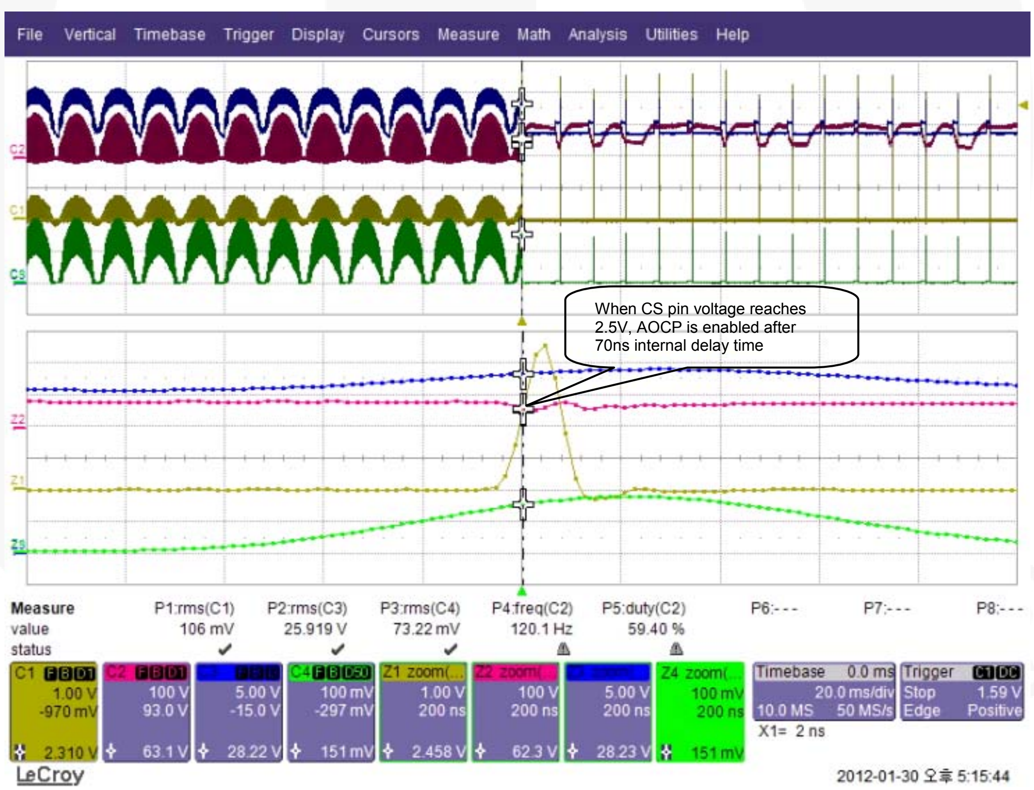


Figure 25. Inductor-Short Condition



CH1: V_{CS}, CH2: V_{DRAIN}, CH3: V_{LED}, CH4: I_{LED}

Figure 26. Test Results of Inductor Short Condition

3.7. System Efficiency

Figure 27 shows system efficiency results for different AC input voltage frequency conditions. As shown, the input frequency has negligible effect on system efficiency.

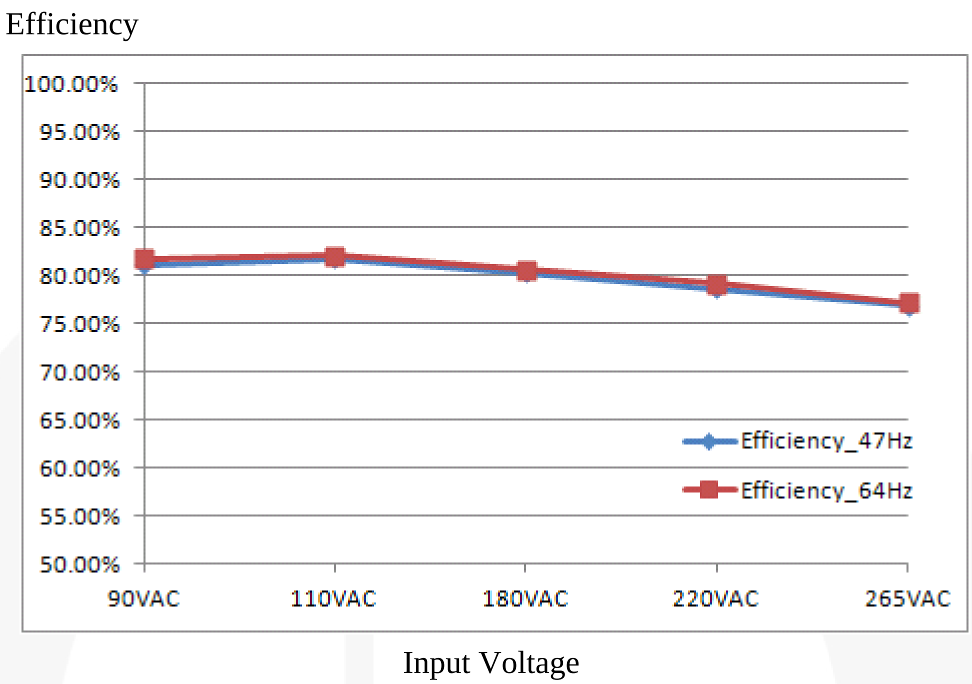


Figure 27. System Efficiency

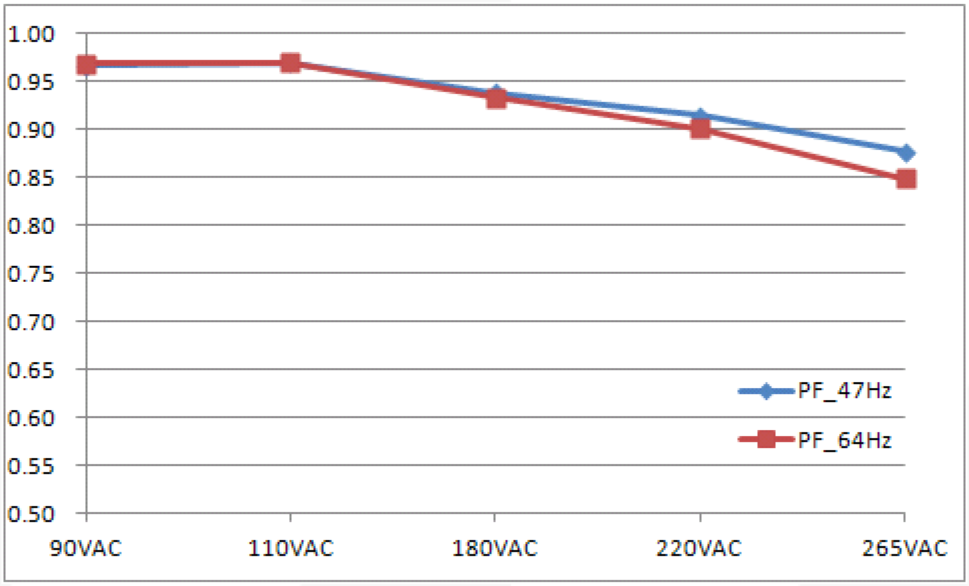
Table 4. Efficiency Test Results

Input Voltage (V_{AC})	Frequency (Hz)	Efficiency (%)
$90V_{AC}$	47Hz	81.12
	64Hz	81.73
$110V_{AC}$	47Hz	81.72
	64Hz	82.08
$180V_{AC}$	47Hz	80.26
	64Hz	82.57
$220V_{AC}$	47Hz	78.64
	64Hz	79.12
$265V_{AC}$	47Hz	76.84
	64Hz	77.14

3.8. Power Factor at Rated Load Condition

Figure 28 shows the system Power Factor (PF) performance for the entire input voltage range (90V_{AC} to 265V_{AC}) at different input frequency conditions (47Hz, 64Hz). The PF changes slightly according to the input frequency, but can achieve over 0.85 at 265V_{AC} condition.

PF



Input Voltage

Figure 28. Power Factor

Table 5. PF Test Results

Input Voltage		Power Factor
90V_{AC}	47Hz	0.97
	64Hz	0.97
110V_{AC}	47Hz	0.97
	64Hz	0.97
180V_{AC}	47Hz	0.94
	64Hz	0.94
220V_{AC}	47Hz	0.91
	64Hz	0.90
265V_{AC}	47Hz	0.88
	64Hz	0.85

3.9. Total Harmonic Distortion

Figure 29 shows the Total Harmonic Distortion (THD) performance at different input frequencies. Test results are quite similar, except the $90V_{AC}$ condition, but meet international regulations (under 30%).

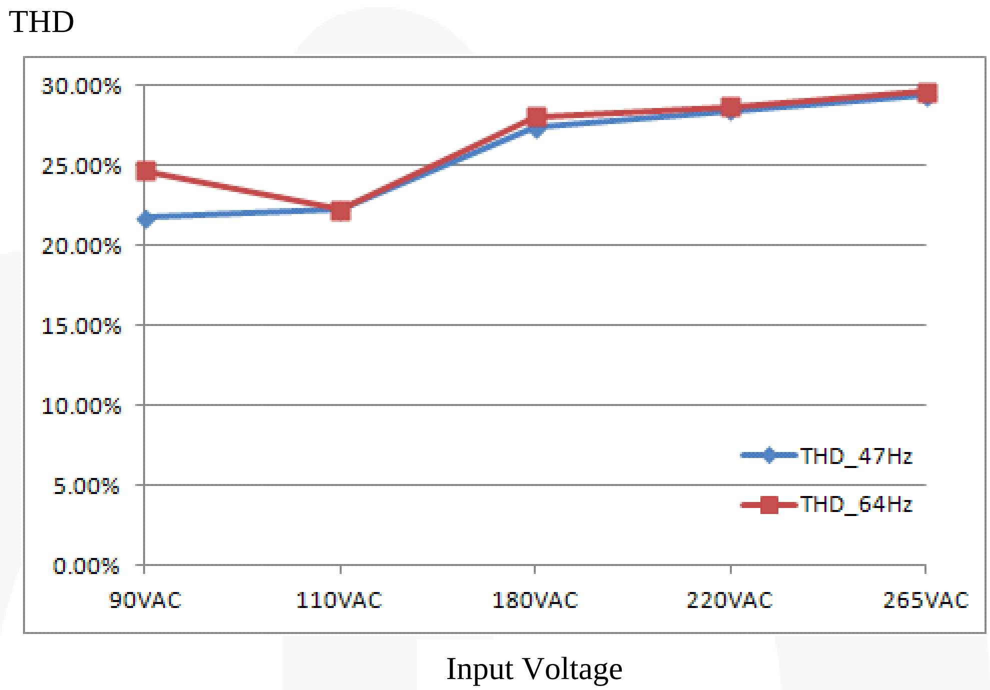


Figure 29. THD Performance

Table 6. THD Test Results

Input Voltage (V_{AC})	Frequency (Hz)	THD (%)
$90V_{AC}$	47Hz	21.74
	64Hz	24.70
$110V_{AC}$	47Hz	22.24
	64Hz	22.23
$180V_{AC}$	47Hz	27.38
	64Hz	28.09
$220V_{AC}$	47Hz	28.46
	64Hz	28.72
$265V_{AC}$	47Hz	29.37
	64Hz	29.64

3.10. Thermal Performance

Figure 30 through Figure 37 show the steady-state thermal test results with different input voltage conditions. Inductor L3 has the highest temperature on the top side of the PCB due to copper resistance. The FLS0116 has the highest temperature on the bottom side of the PCB due to power loss associated with the high-voltage device. The IC temperature is 67.1°C for the 220V_{AC} input condition.

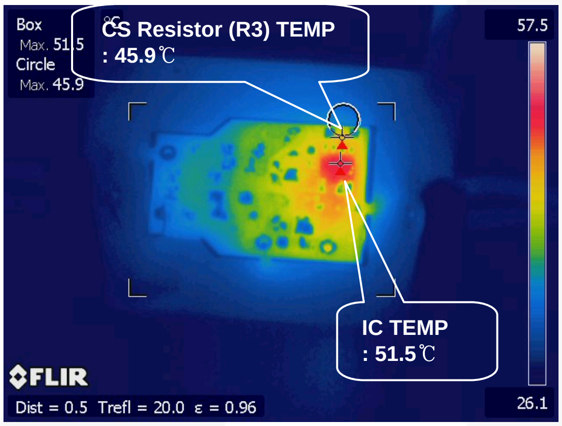


Figure 30. Bottom-Side Temperature at 90V_{AC} Condition (IC)

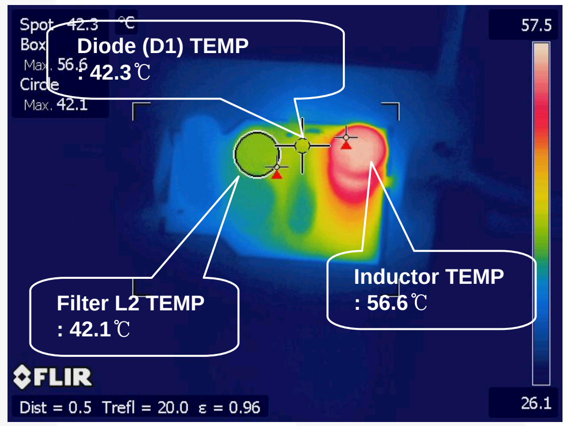


Figure 31. Top-Side Temperature at 90V_{AC} Condition (Inductor)

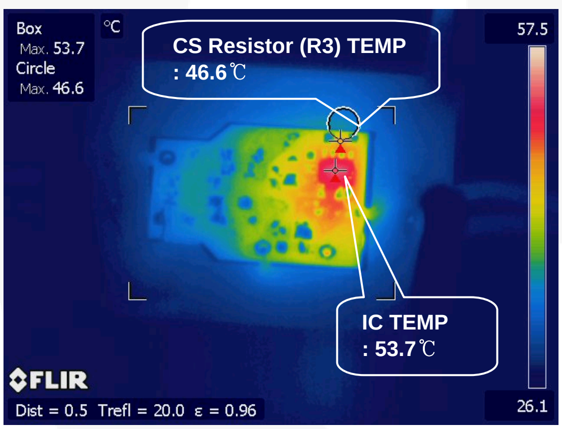


Figure 32. Bottom-Side Temperature at 110V_{AC} Condition (IC)

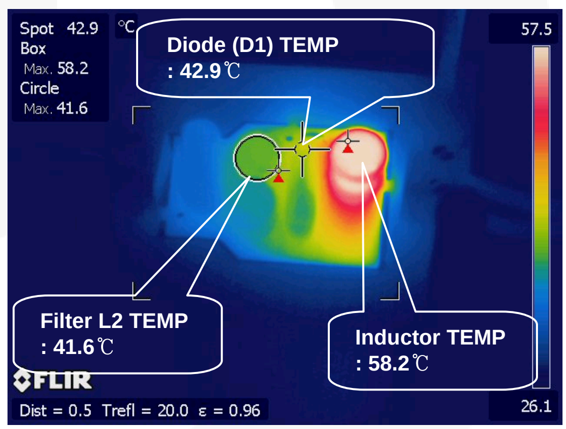


Figure 33. Top-Side Temperature at 110V_{AC} Condition (Inductor)

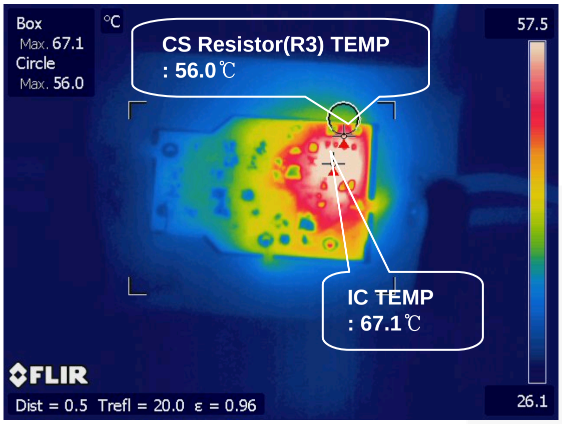


Figure 34. Bottom-Side Temperature at 220V_{AC} Condition (IC)

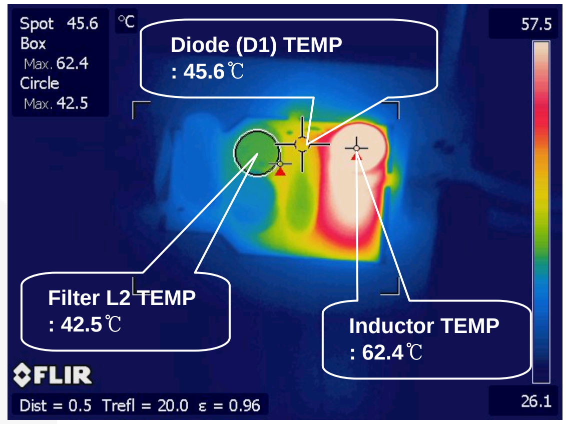


Figure 35. Top-Side Temperature at 220V_{AC} Condition (Inductor)

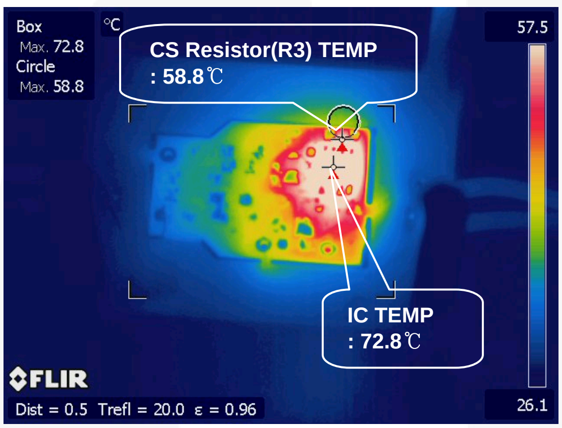


Figure 36. Bottom-Side Temperature at 264V_{AC} Condition (IC)

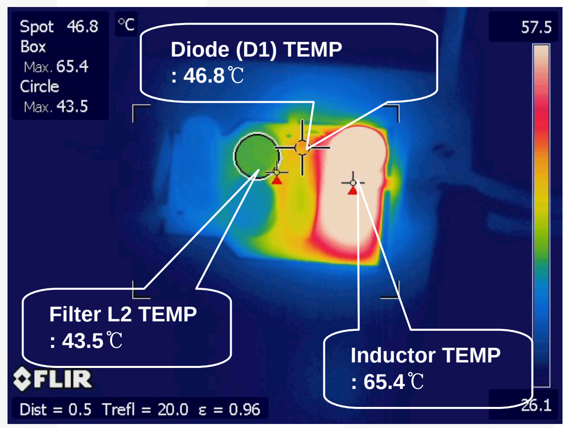


Figure 37. Top-Side Temperature at 264V_{AC} Condition (Inductor)

Table 7. Temperature Performance by Input Voltage

Input Voltage (V_{AC})	T_{IC}	$T_{INDUCTOR}$
90V_{AC}	51.5°C	56.6°C
110V_{AC}	53.7°C	58.2°C
220V_{AC}	67.1°C	62.4°C
265V_{AC}	72.8°C	65.4°C

3.11. EMI Test Results

EMI test measurements were conducted in observance of CISPR22 criteria, which has stricter limits than CISPR15 for lighting applications.

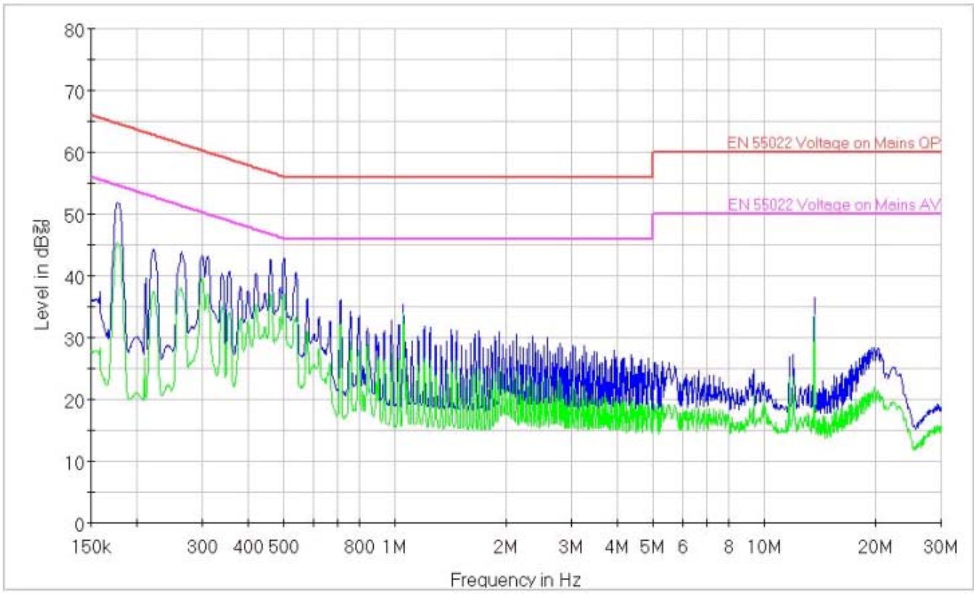


Figure 38. Conducted Emission-Line at 110V$_{AC}$ Input Condition, Full Load (10-LED Series)

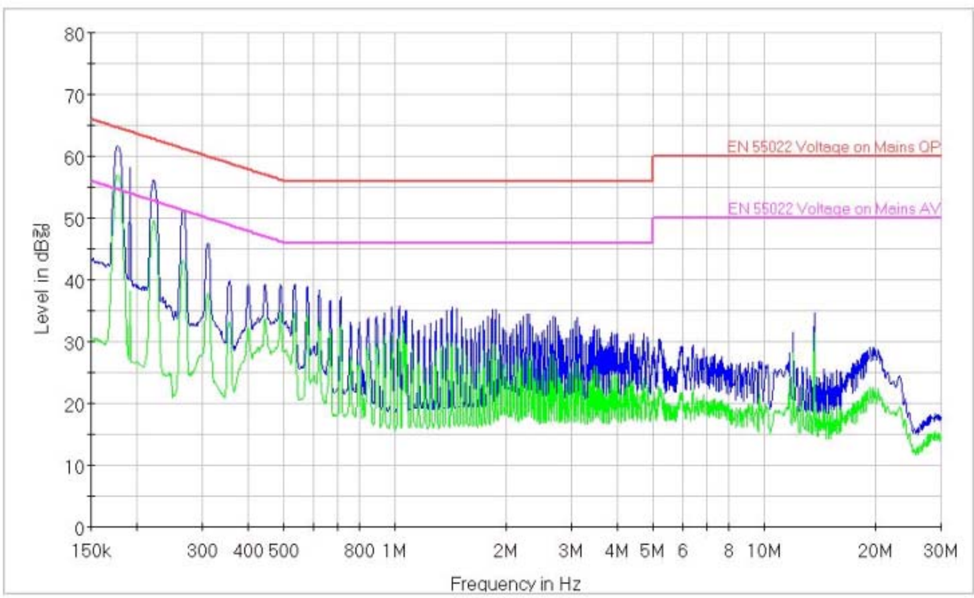


Figure 39. Conducted Emission-Line at 220V$_{AC}$ Input Condition, Full Load (10-LED Series)

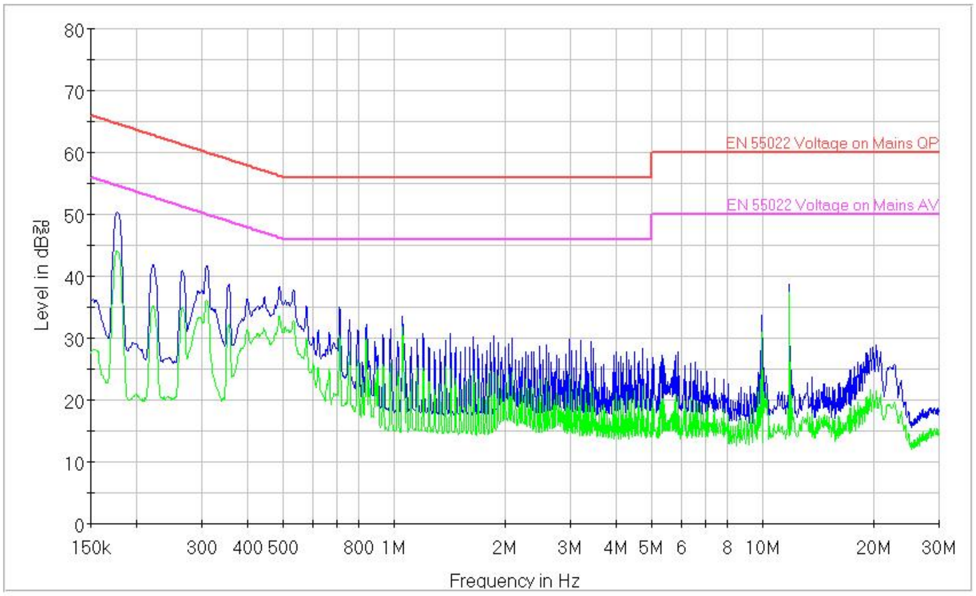


Figure 40. Conducted Emission-Line at 110V_{AC} Input Condition, Full Load (10-LED Series)

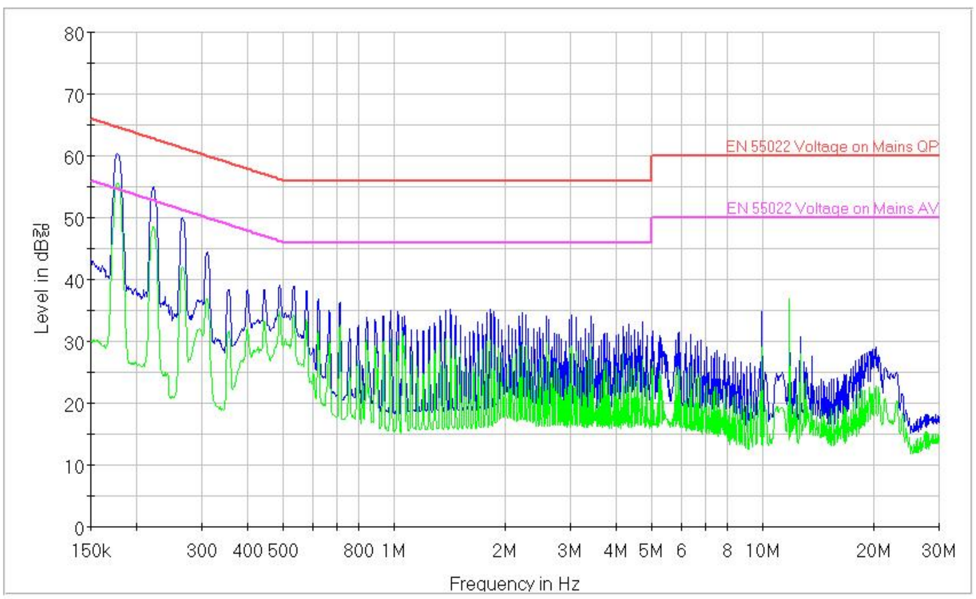


Figure 41. Conducted Emission-Neutral at 220V_{AC} Input Condition, Full Load (10-LED Series)

4. Revision History

Rev.	Date	Description
1.0.0	May 2012	First Release
1.0.1	June 2012	Changing Power Rating Changing Form