ON Semiconductor

Is Now

To learn more about onsemi™, please visit our website at
www.onsemi.com

Is Now Part of

ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

User Guide for

FEBFLS1800XS4CH_L11U100A

100 W LED Driver at Universal Line

Featured Fairchild Products:

FL7930B, FLS1800XS, FAN7346

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

Fairchild Semiconductor.com

Table of Contents

This user guide supports the evaluation kit for the FL7930B, FLS1800XS, and FAN7346 (orderable as FEBFLS1800XS4CH_L11U100A). It should be used in conjunction with the FL7930B, FLS1800XS, and FAN7346 datasheets 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 a proposed solution for an 100 W LED ballast, which is consists of a boost converter for power factor correction (PFC), a DC-DC converter with LLC resonant converter, and LED-current and voltage-regulation circuitry. The input voltage range is 90 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 1.0 A at 100 V_{MAX}. The power supply mainly utilizes Fairchild Semiconductor components: FL7930B CRM PFC controller, FLS1800XS half-bridge LLC controller with power MOSFET, FAN7346 4-channel current balance controller, FDPF12N60NZ UniFET™ technology N-channel MOSFET, and FFPF08H60S "Hyperfast" 2 rectifier. This document contains important information (e.g. schematic, bill of materials, printed circuit layout, and transformer design documentation) and the typical operating characteristics.

1.1. General Description of FL7930B

The FL7930B is an active Power Factor Correction (PFC) controller for low and high-power lumens applications that operate in Critical Conduction Mode (CRM). It uses a Voltage-mode PWM that compares an internal ramp signal with the error amplifier output to generate a MOSFET turn-off signal. Because the Voltage-Mode CRM PFC controller does not need rectified AC line voltage information, it saves the power loss of an input voltage-sensing network necessary for a Current-Mode CRM PFC controller. FL7930B provides over-voltage, open-feedback, over-current, input-voltage-absent detection, and under-voltage lockout protections. The FL7930B can be disabled if the INV pin voltage is lower than 0.45 V and the operating current decreases to a very low level. Using a new variable on-time control method, Total Harmonic Discharge is lower than the conventional CRM boost PFC ICs. The FL7930B provides an additional OVP pin that can be used to shutdown the boost power stage when output voltage exceeds OVP level due to damaged resistors connected at the INV pin.

1.2. Features

- Low Total Harmonic Distortion (THD)
- Precise Adjustable Output Over-Voltage Protection (OVP)
- Open-Feedback Protection and Disable Function
- Zero Current Detector
- 150 µs Internal Startup Timer
- MOSFET Over-Current Protection (OLP)
- Under-Voltage Lockout with 3.5 V Hysteresis (UVLO)
- Low Startup (40 µA) and Operating Current (1.5 mA)
- Totem-Pole Output with High-State Clamp
- +500 / -800 mA Peak Gate Drive Current
- SOP-8 Packaging

1.3. Internal Block Diagram

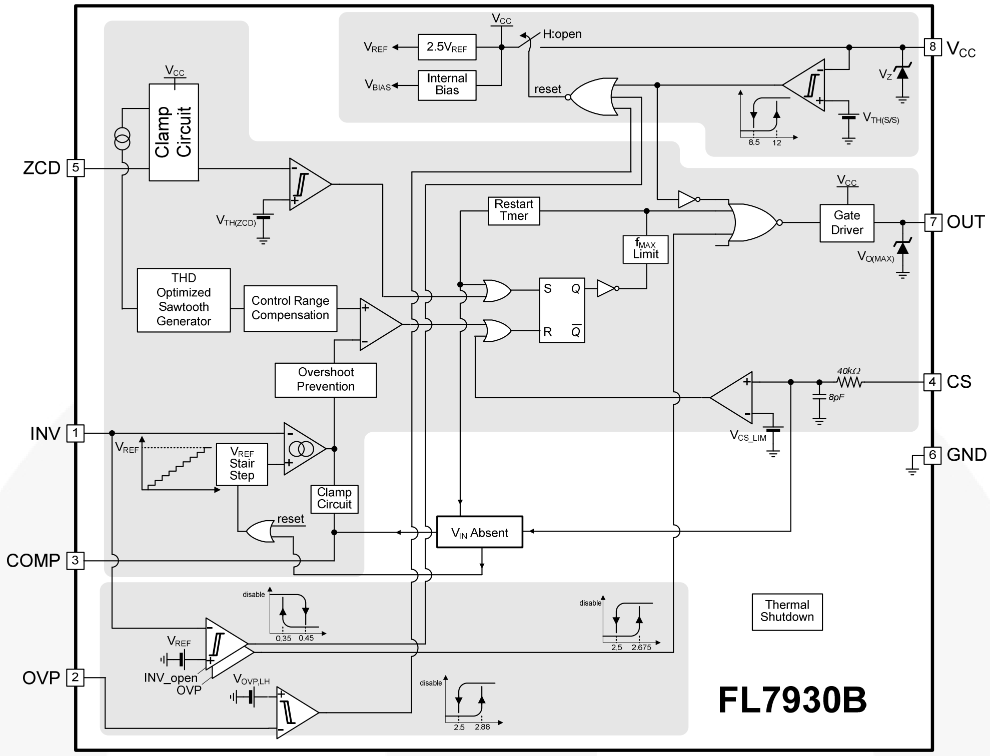

Figure 1. Block Diagram of FL7930B

1.4. General Description of FLS1800XS

The FLS1800XS power controller includes highly integrated power switches for medium- to high-power lumens applications. Offering everything necessary to build a reliable and robust half-bridge resonant converter, the FLS1800XS simplifies designs, improves productivity, and improves performance. The FLS1800XS series combines power MOSFETs with fast-recovery type body diodes, a high-side gate-drive circuit, an accurate current-controlled oscillator, frequency-limit circuit, soft-start, and built-in protection functions. The high-side gate-drive circuit has common-mode noise cancellation capability, which guarantees stable operation with excellent noise immunity. The fast-recovery body diode of the MOSFETs improves reliability against abnormal operation conditions, while minimizing the effects of reverse recovery. Using zero voltage switching (ZVS) dramatically reduces the switching losses and significantly improves efficiency. ZVS also reduces switching noise noticeably, which enables use of a small-sized Electromagnetic Interference (EMI) filter. The FLS1800XS can be applied to resonant converter topologies such as series resonant, parallel resonant, and LLC resonant converters.

1.5. Features

- Variable Frequency Control with 50% Duty Cycle for Half-Bridge Resonant Converter Topology
- High Efficiency through Zero Voltage Switching (ZVS)
- Internal UniFET™ (0.95 Ω) with Fast-Recovery Body Diode
- Fixed Dead Time (350 ns) Optimized for MOSFETs
- Up to 300 kHz Operating Frequency
- Auto-Restart Operation for All Protections with External LVCC
- Protections: Over-Voltage Protection (OVP), Over-Current Protection (OCP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown (TSD)

1.6. Internal Block Diagram

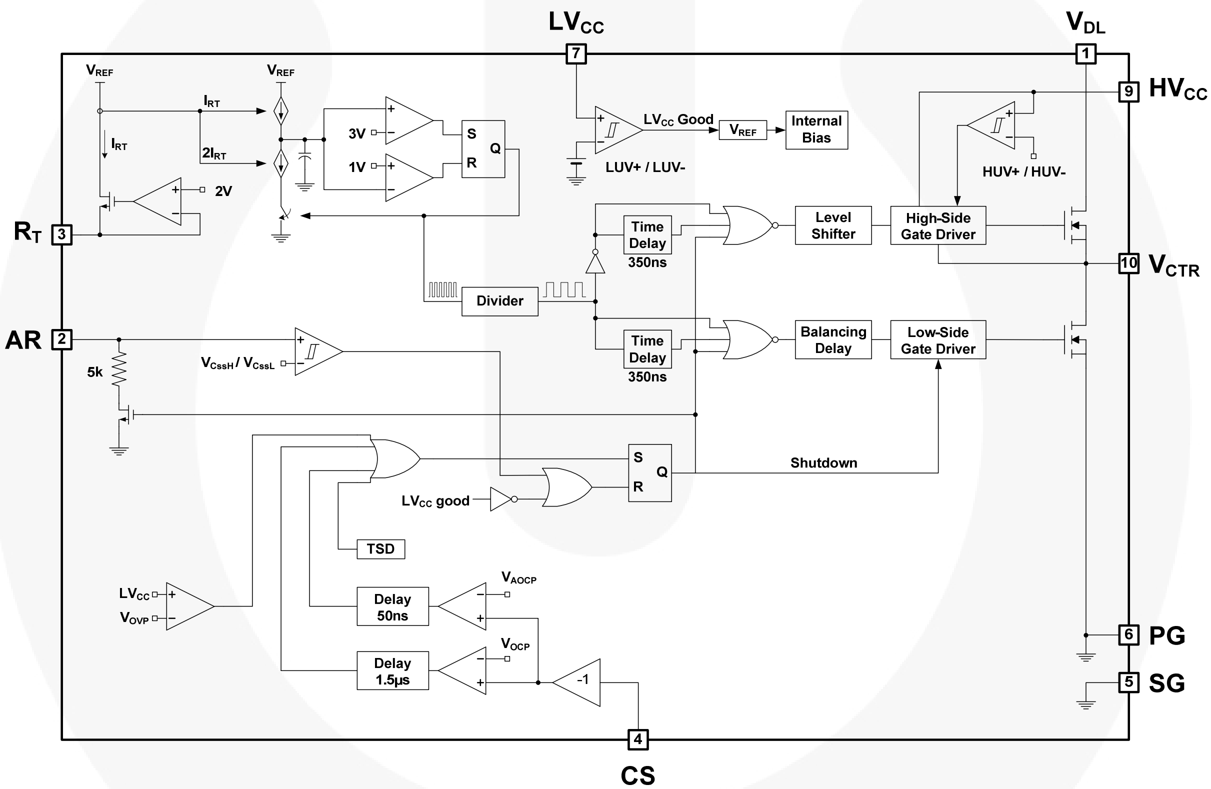

Figure 2. Block Diagram of FLS1800XS

1.7. General Description of FAN7346

The FAN7346 is an LED current-balance controller for 4-LED arrays to maintain equal LED current. The FAN7346 has a high withstanding voltage, so is suitable for edge-type LED BLU and LED Lighting. To minimize components between primary and secondary, the FAN7346 generates a new integrated feedback signal. The FAN7346 provides various protections; such as over-voltage regulation, open-LED protection, thermal protection, and drain-to-source voltage protection of the regulating switch (the FAN7346 monitors all LED arrays drain-to-source voltage for protection). To increase system reliability, FAN7346 applies individual string protection. Because FAN7346 integrates so many functions, it reduces overall BOM costs. LED brightness can be linearly varied up to LED current by applying an external Pulse Width Modulated (PWM) signal to the PWM pin.

1.8. Features

- Linear Balance Control for 4-Channel LED Arrays
- Wide LED String Voltage Range: 100 V
- Wide V_{CC} Voltage: 10.5 V to 35 V
- External Linear Regulation Switch: MOSFET or BJT
- Internal Voltage Regulator for Feedback
- Monitoring Drain-to-Source Voltage of External Switch
- Precision Current Accuracy Trimmed to 1.5%
- Supports External PWM Dimming - Positive
- Supports Wide Dimming Ratio: 0.5%~100%
- Adaptive Linear Regulation Method
- Generate Integrated Feedback Signal for Primary Controller (Current Feedback + PWM Dimming)
- High Efficiency by Primary-Side Direct Feedback
- Thermal Shutdown (Auto-Recovery)
- Over-Voltage Regulation
- Channel Individual Open-LED Protection
- Channel Individual Short-LED Protection
- Channel Individual Over-Current Protection
- Error Flag Output
- 28-Pin SOIC Packaging

1.9. Internal Block Diagram

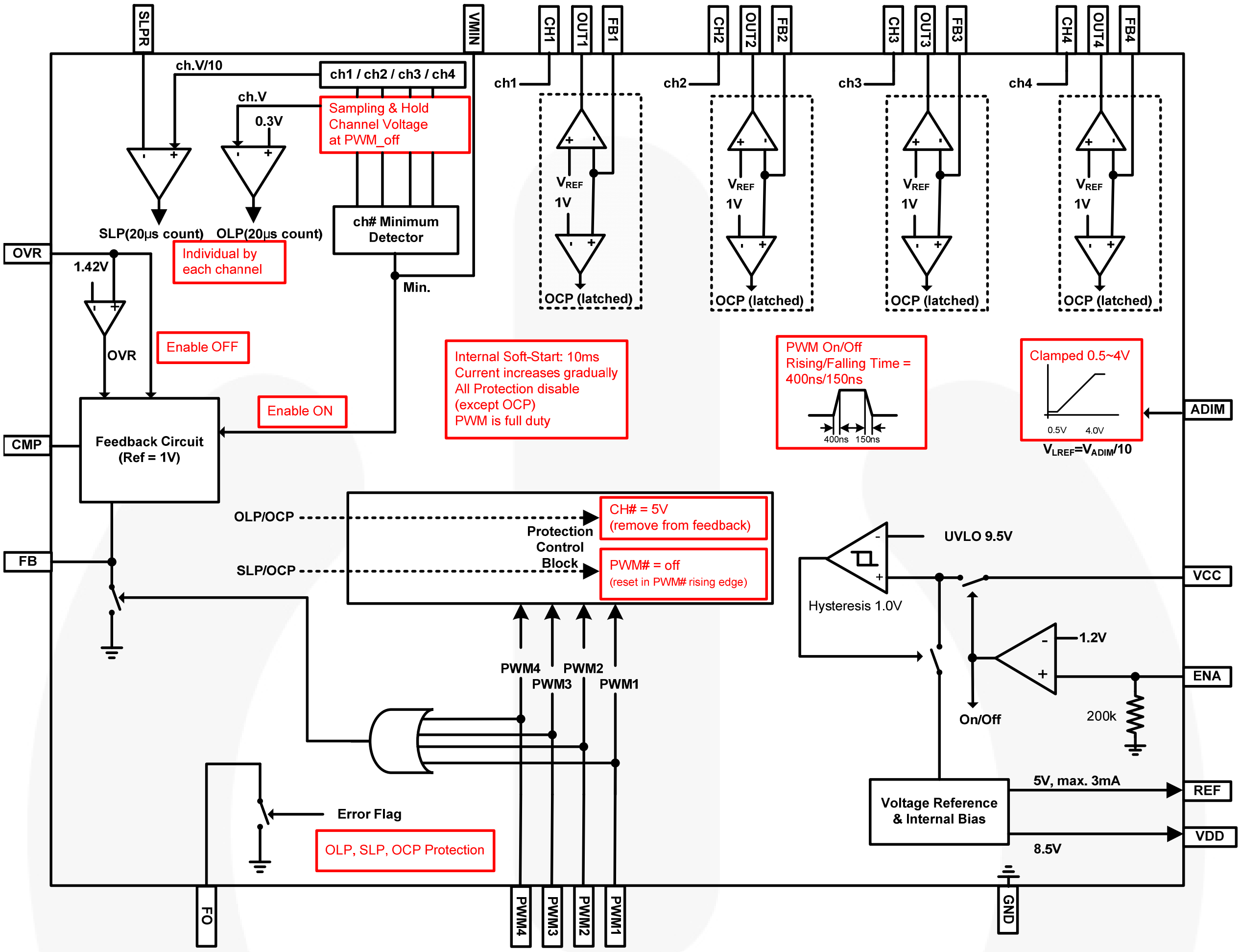

Figure 3. Block Diagram of FAN7346

2. Specifications for Evaluation Board

Table 1. Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90 V	Minimum Input Voltage
		$V_{IN.MAX}$	265 V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110 V / 220 V	Nominal Input Voltage
	Frequency	f_{IN}	60 Hz / 50 Hz	Line Frequency
Output	**Voltage**	V_{OUT}	100 V	Nominal Output Voltage
	Current	I_{OUT}	250 mA	Each Channels
		CC Deviation	< 0.79%	Line & Load Regulation, Based on 1-CH
Efficiency		Eff_{85VAC}	91.73%	Efficiency at 85 V_{AC} Line Input Voltage
		Eff_{115VAC}	92.55%	Efficiency at 115 V_{AC} Line Input Voltage
		Eff_{235VAC}	95.01%	Efficiency at 235 V_{AC} Line Input Voltage
		Eff_{265VAC}	95.11%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF / THD_{85VAC}	0.986 / 12.56%	PF / THD at 85 V_{AC} Line Input Voltage
		PF / THD_{115VAC}	0.989 / 12.01%	PF / THD at 115 V_{AC} Line Input Voltage
		PF / THD_{235VAC}	0.930 / 9.8%	PF / THD at 235 V_{AC} Line Input Voltage
		PF / THD_{265VAC}	0.891 / 15.47%	PF / THD at 265 V_{AC} Line Input Voltage

All data for the evaluation board as measured with the board enclosed in a case and external temperature of around 25°C.

3. Photographs

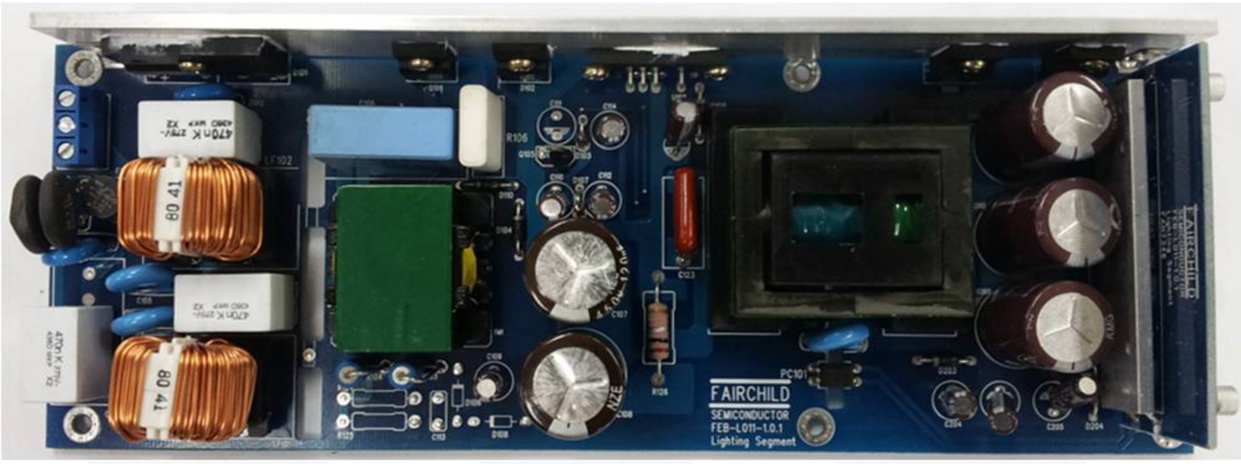

Figure 4. Top View (Dimensions:225 mm (L) x 80 mm (W) x 43 mm (H))

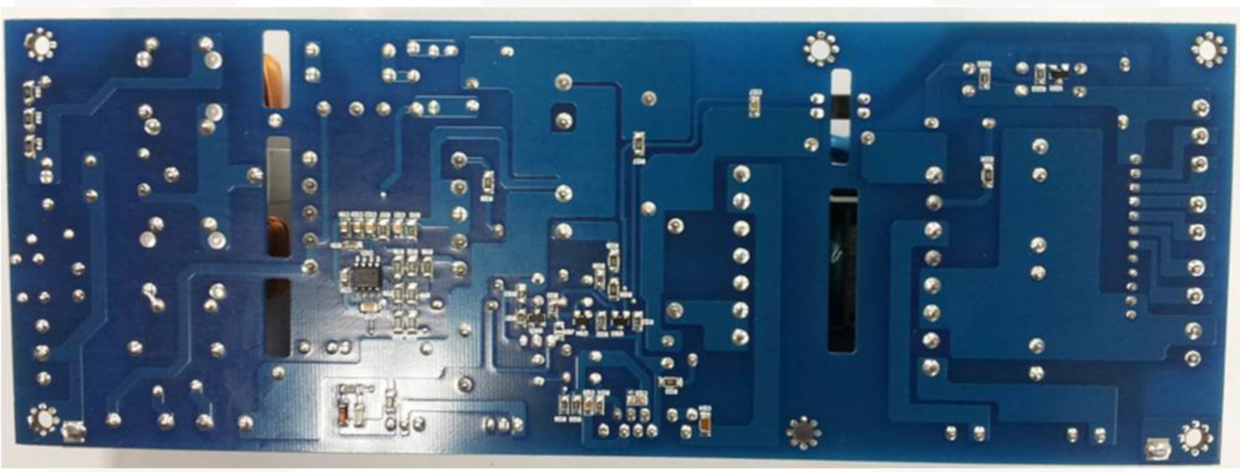

Figure 5. Bottom Views (Dimensions:225 mm (L) x 80 mm (W) x 43 mm (H))

4. Printed Circuit Board

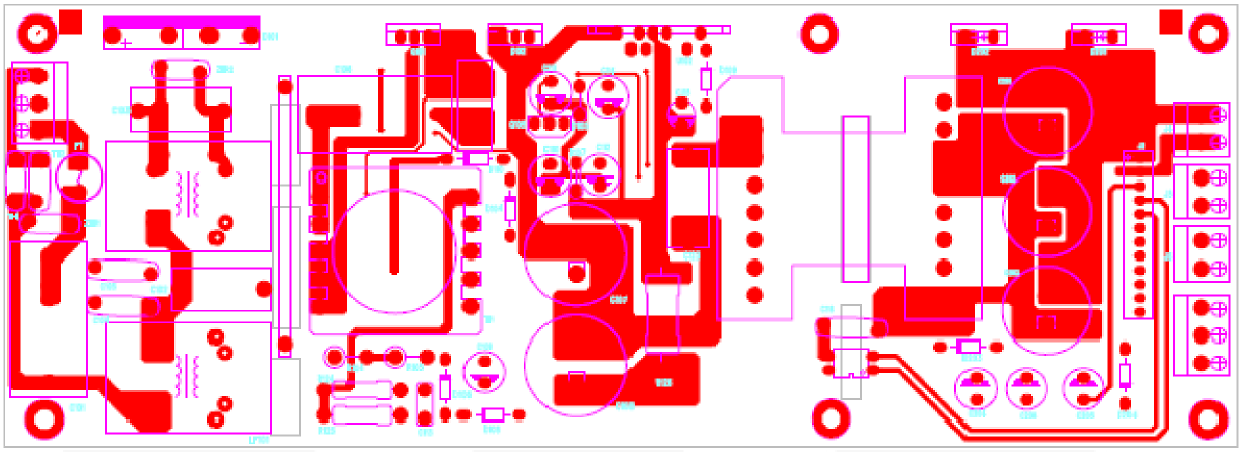

Figure 6. Top Pattern

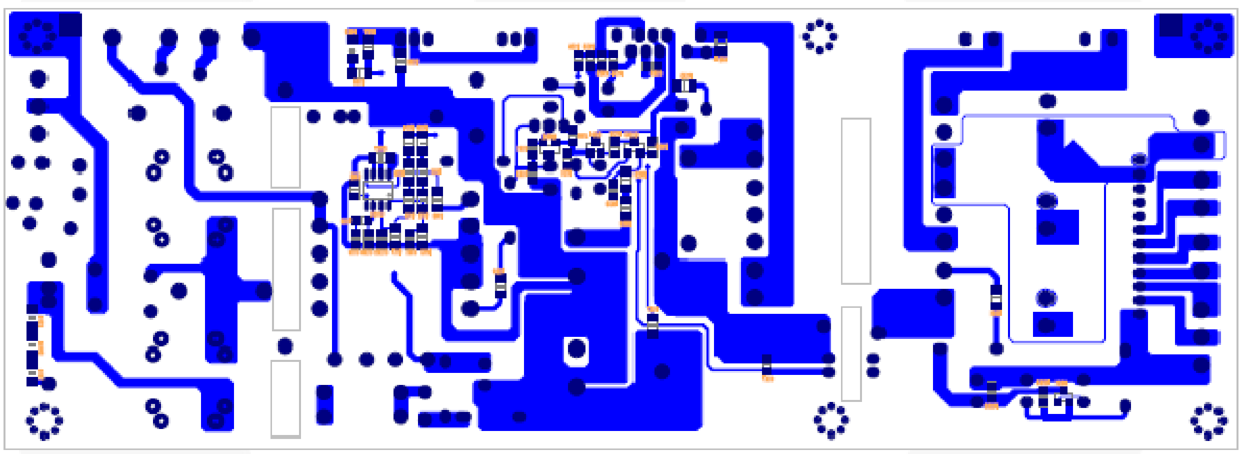

Figure 7. Bottom Pattern

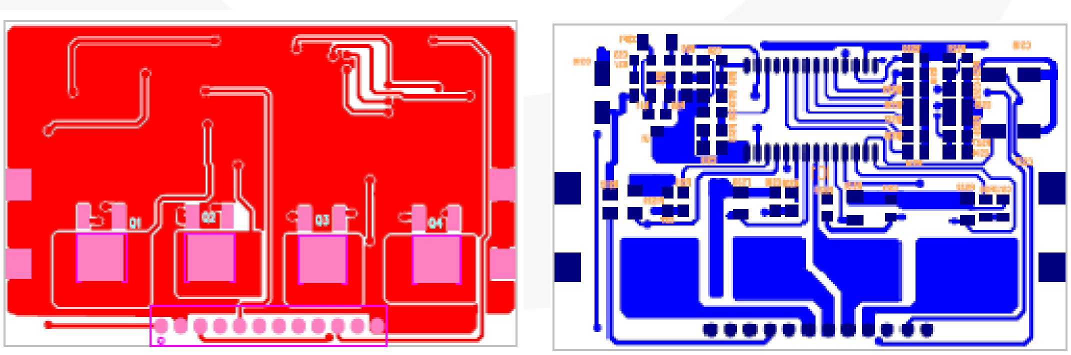

Figure 8. Top / Bottom Sub Board (for Current Balacing Part) Pattern

5. Schematic

5.1. Power Factor Correction (PFC)

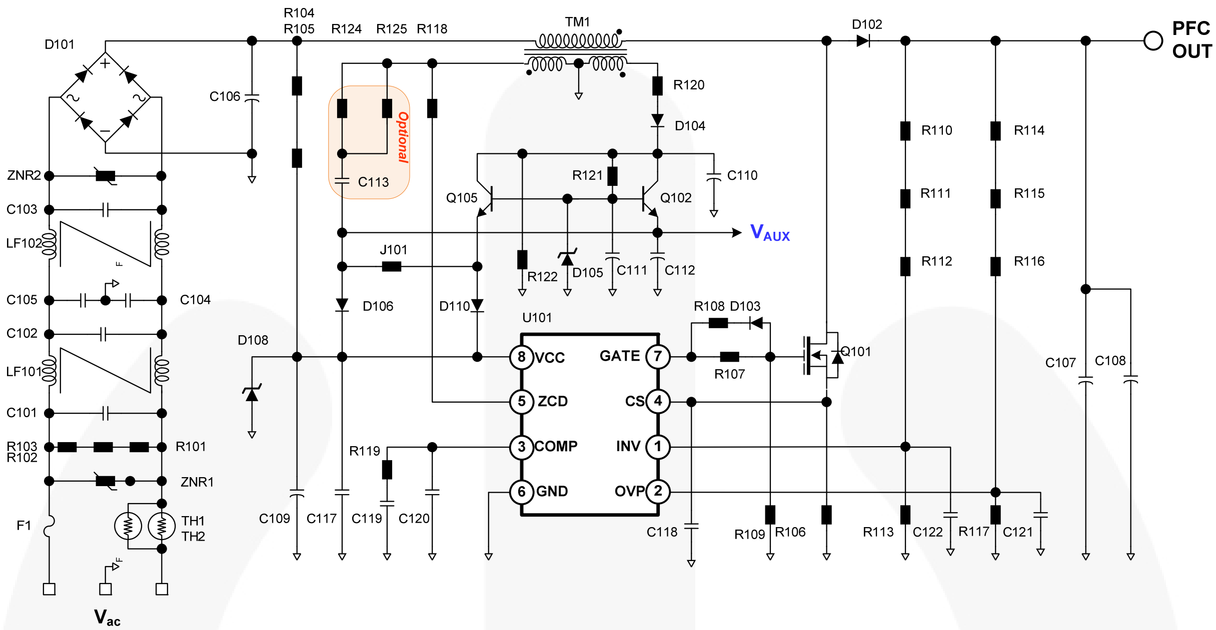

Figure 9. Schematic for PFC Part

5.2. DC-to-DC Converter and Current Balancing

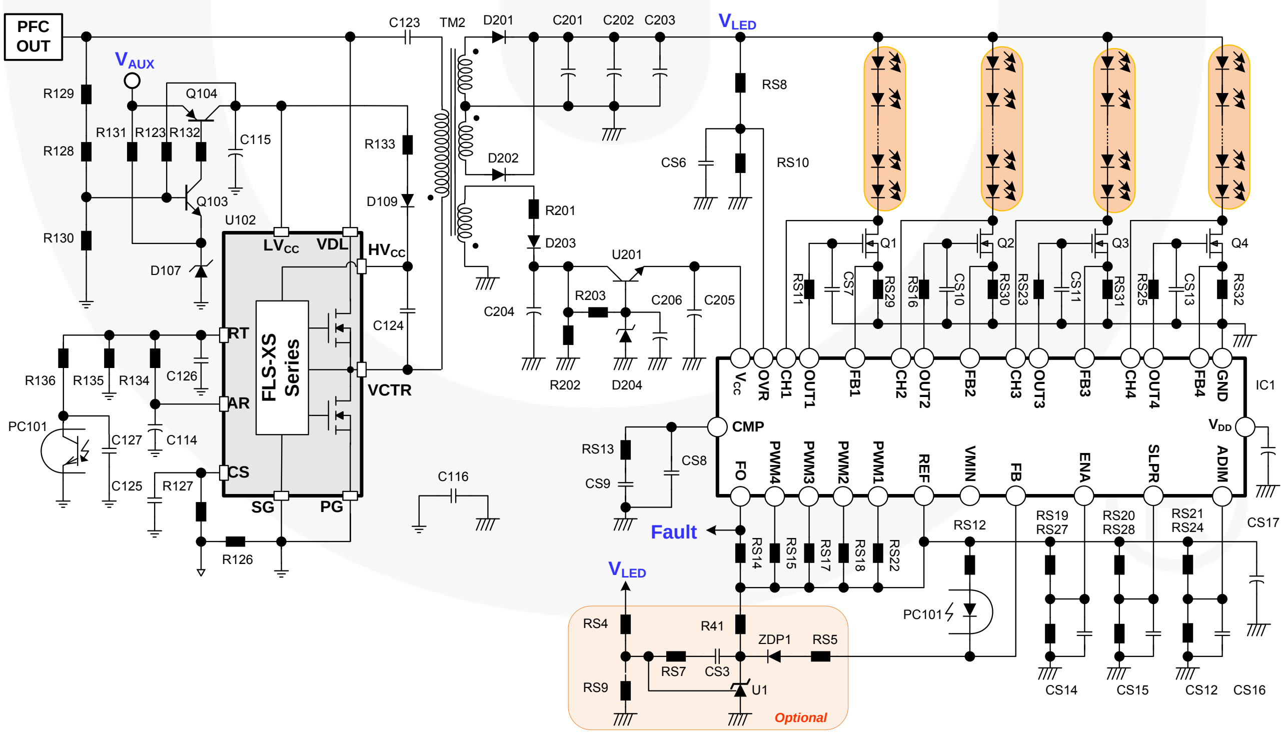

Figure 10. Schematic for DC-to-DC Converter and Current Balancing Part

6. Bill of Materials

6.1. Main Board (PFC and DC-to-DC Converter)

Item No.	Part Reference	Value	Quantity	Description
1	U101	FL7930B	1	8-SOP, Fairchild Semiconductor
2	U102	FLS1800XS	1	9-SIP, Fairchild Semiconductor
3	PC101	PC817	1	Opto-Coupler, Fairchild Semiconductor
4	C101, C102, C103	0.47 µF	3	X - Capacitor
5	C104, C105	4700 pF	2	Y - Capacitor
6	C106	0.68 µF / 630 V_{AC}	1	Film Capacitor
7	C107, C108	120 µF / 450 V	2	Electrolytic Capacitor
8	C109	22 µF / 50 V	1	Electrolytic Capacitor
9	C110, C112 C204, C205, C206	33 µF / 50 V	5	Electrolytic Capacitor
10	C111, C113	NC		No Connection
11	C114	10 µF / 16 V	1	Electrolytic Capacitor
12	C115	0.33 µF / 25 V	1	Electrolytic Capacitor
13	C116	3.3 nF	1	AC Ceramic Capacitor
14	C117	0.1 µF / 50 V	1	Chip Capacitor
15	C118	470 pF	1	Chip Capacitor
16	C119, C124	0.22 µF	2	Chip Capacitor
17	C120	47 nF	1	Chip Capacitor
18	C121, C122	1 nF	2	Chip Capacitor
19	C123	15 nF / 630 V	1	Film Capacitor
20	C125	100 pF	1	Chip Capacitor
21	C126	680 pF	1	Chip Capacitor
22	C127	12 nF	1	Chip Capacitor
23	C201, C202, C203	100 µF / 200 V	3	Electrolytic Capacitor
24	D101	D15XB60	1	Shindengen/Bridge Diode
25	D102, D201, D202	FFPF08H60S	3	Fairchild Semiconductor
26	D103	1N4148	1	LL-34, Fairchild Semiconductor
27	D104, D109, D110, D203	UF4007	4	Fairchild Semiconductor
28	D105, D204	1N4745	2	Fairchild Semiconductor
29	D107	1N4736	1	Fairchild Semiconductor
30	D106, D108	NC		No Connection
31	Q101	FDPF12N60NZ	1	Fairchild Semiconductor
33	Q102, Q103, U201	Q2N2222A	3	SOT-23, Fairchild Semiconductor
34	Q105	2N2222A	1	TO-92, Fairchild Semiconductor
35	Q104	2N2907	1	SOT-23, Fairchild Semiconductor

Main Board (PFC and DC-to-DC Converter) (Continued)

Item No.	Part Reference	Value	Quantity	Description
36	R101, R102, R103, R128, R129	1 MΩ-J	5	SMD Resistor, 3216
37	R104, R105	69 kΩ	2	2W
38	R106	0.1 Ω	1	5W
39	R107	47 Ω-J	1	SMD Resistor, 3216
40	R108	4.7 Ω -J	1	SMD Resistor, 3216
41	R109, R119, R131, R132, R203	10 kΩ-J	5	SMD Resistor, 3216
42	R110, R111, R112, R114, R115, R116	3.9 MΩ-J	6	SMD Resistor, 3216
43	R113	75 kΩ-J	1	SMD Resistor, 3216
44	R117	68 kΩ-J	1	SMD Resistor, 3216
45	R118	24 kΩ-J	1	SMD Resistor, 3216
46	R120, R133, R201	5.1 Ω-J	3	SMD Resistor, 3216
47	R121	33 kΩ-J	1	SMD Resistor, 2012
48	R122, R202	100 kΩ-J	2	SMD Resistor, 2012
49	R123	390 kΩ-J	1	SMD Resistor, 2012
50	R124, R125	NC		Optional
51	R126	0.1 Ω	1	1W
52	R127	1 kΩ-J	1	SMD Resistor, 2012
53	R130	47 kΩ-J	1	SMD Resistor, 2012
54	R134	2.7 Ω-J	1	SMD Resistor, 2012
55	R135	5.6 kΩ-J	1	SMD Resistor, 2012
56	R136	2 kΩ-J	1	SMD Resistor, 2012
57	TH1, TH2	5D15	2	NTC
58	ZNR1, ZNR2	10D471	2	Varistor
59	TM1	280 µH	1	EER3019N-10
60	TM2	Lp = 850 µH Lr = 170 µH	1	EER3543-16
61	LF101, LF102	40 mH	2	Line Filter
62	F1	250 V / 5 A	1	Fuse
63	J101	NC		Optional

6.2. Sub Board for Current Balancing

Item No.	Part Reference	Value	Quantity	Description
1	IC1	FAN7346	1	SOP28, Fairchild Semiconductor
2	U1	NC		Optional
3	Q1, Q2, Q3, Q4	FQT4N25	4	Fairchild Semiconductor
4	ZDP1	NC		Optional
5	RS4	NC		Optional
6	RS5	NC		Optional
7	RS6	NC		Optional
8	RS7	NC		Optional
9	RS8	1 MΩ-J	1	SMD Resistor, 2012
10	RS9	NC	1	Optional
11	RS10	13 kΩ-J	1	SMD Resistor, 2012
12	RS12	1 kΩ-J	1	SMD Resistor, 2012
13	RS11, RS16, RS23, RS25	0 Ω-J	4	SMD Resistor, 2012
14	RS15, RS17, RS18, RS22	100 Ω-J	4	SMD Resistor, 2012
15	RS14,RS19, RS20, RS21, RS27, RS28	10 kΩ-J	6	SMD Resistor, 2012
16	RS29, RS30, RS31, RS32	1.5 Ω-J	4	SMD Resistor, 3216
17	CS3, CS7, CS10, CS11, CS13, CS8	NC	6	
18	CS6, CS9, CS12, CS14	10 nF	4	Chip Capacitor
19	CS16, CS17, CS18	22 µF / 25 V	3	Electrolytic Capacitor

7. Transformer Design

7.1. PFC Transformer (TM1)

- Core: EER3019N (SAMHWA PL-7)
- Bobbin: 10 pin

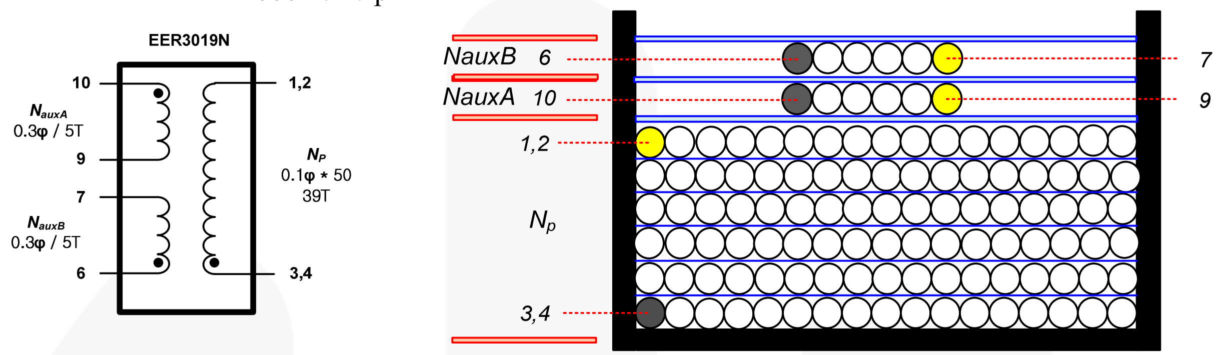

Figure 11. Transformer Specifications & Construction

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np	3, 4 → 1, 2	0.1φ × 50	39 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	NauxA	10 → 9	0.3φ	5 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	NauxB	6→ 7	0.3φ	5 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specifications	Remark
Inductance	3, 4 – 1, 2	280 μH ±5%	100 kHz, 1 V

7.2. LLC Resonant Converter Transformer (TM2)

- Core: EER3543
- Bobbin: 16 pin

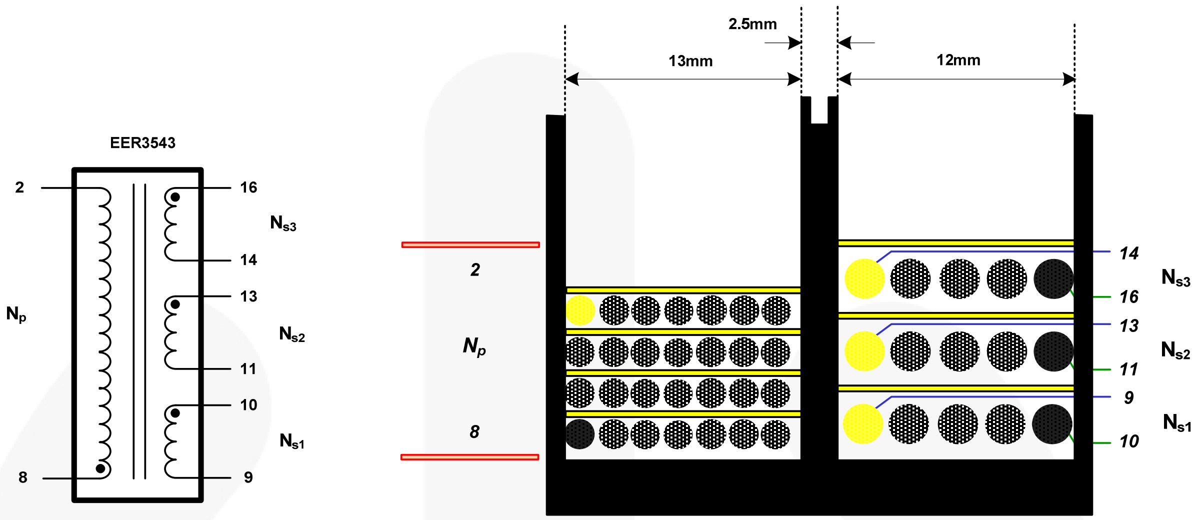

Figure 12. Transformer Specifications & Construction

Table 4. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np	8 → 2	0.1φ × 20	38 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	Ns1	10 → 9	0.3φ	2 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	Ns2	13 → 11	0.1φ×20	17 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
7	Ns3	16 → 14	0.1φ×10	17 Ts	Center Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				

Table 5. Electrical Characteristics

	Pin	Specification	Remark
Primary-Side Inductance (Lp)	2 – 8	850 µH ±5%	100 KHz, 1 V
Primary-Side Effective Leakage (LR)	2 – 8	Maximum 170 µH	Short One of the Secondary Windings

8. Performance of Evaluation Board

Table 6. Test Condition & Equipments

Ambient Temperature	**T_A = 25°C**
Test Equipment	AC Source: ES2000S by NF Electronic Load: EML-05B by Fujitsu Power Meter: PM6000 by Voltech Oscilloscope: Wave-runner 104Xi by LeCroy

8.1. Overall System Efficiency

Figure 13 shows 91% overall system efficiency is achievable with universal input condition at the rated output LED load.

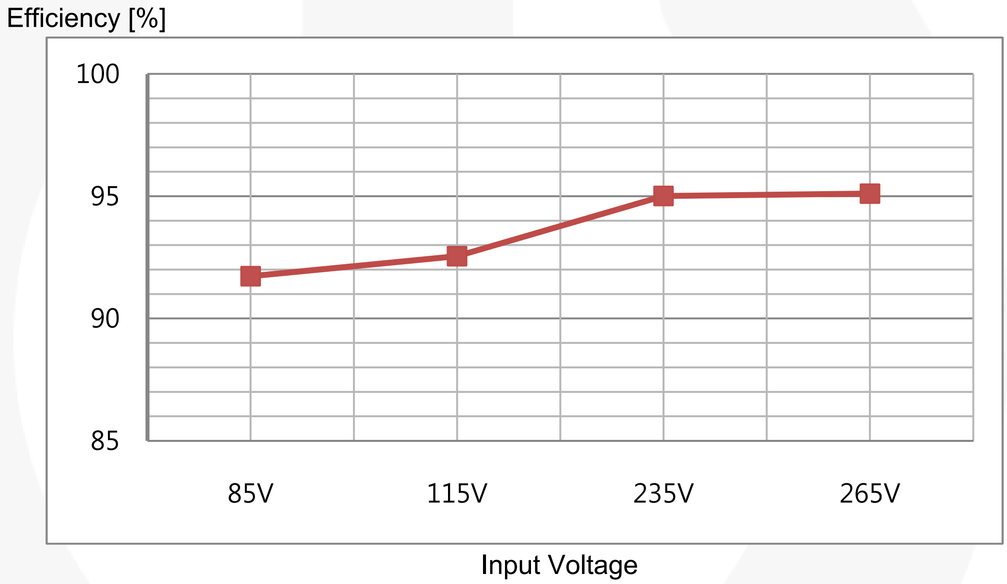

Figure 13. System Efficiency Curve

Table 7. System Efficiency

Input Voltage	**85 V_{AC}**	**115 V_{AC}**	**235 V_{AC}**	**265 V_{AC}**
Input Power [W]	112.04	111.18	108.46	108.47
Output Power [W]	102.77	102.89	103.05	103.16
Efficiency [%]	91.73	92.55	95.01	95.11

8.2. Power Factor (PF)

Figure 14 shows at least 89% power factor (PF) is achievable with universal input condition at the rated output LED load.

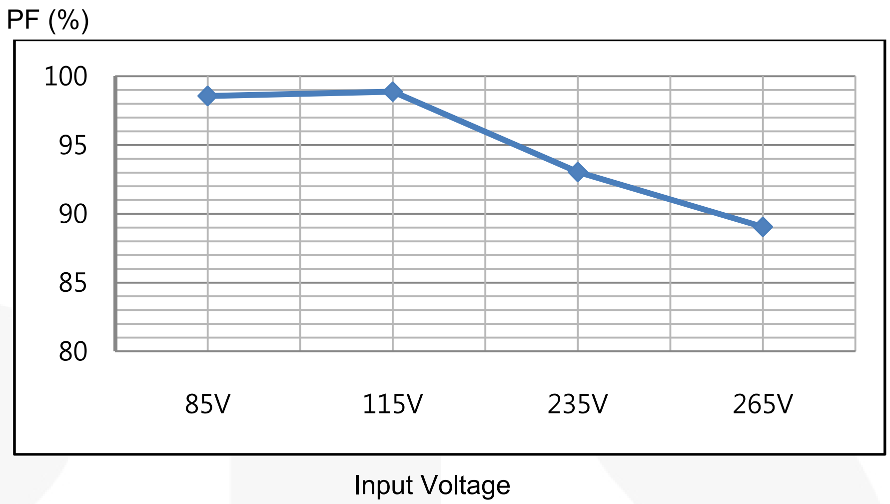

Figure 14. Power Factor Curve

Table 8. Power Factor

Input Voltage	85 V_{AC}	115 V_{AC}	235 V_{AC}	265V_{AC}
Power Factor [%]	98.57	98.88	93.04	89.05
THD [%]	12.56	12.01	9.80	15.47

Figure 15 shows the current harmonic result at the rated output power of100 W and input voltage of 230 V_{AC} and 50 Hz condition based on IEC61000-3 class-C for lighting application. This meets the international regulations.

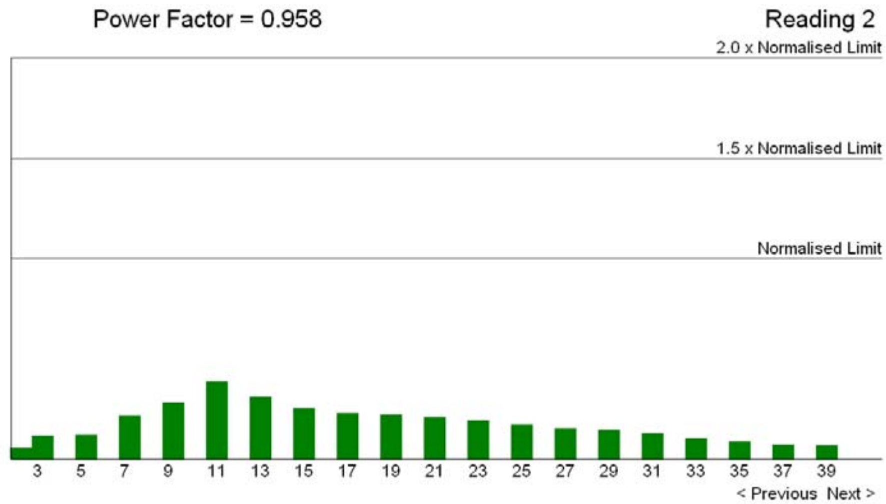

Figure 15. Total Harmonic Distortion (THD)

8.3. Constant Voltage and Current Regulation

Figure 16, Table 9, and Table 10 show the typical CC / CV performance on the board, displaying very stable CC performance over a wide input range.

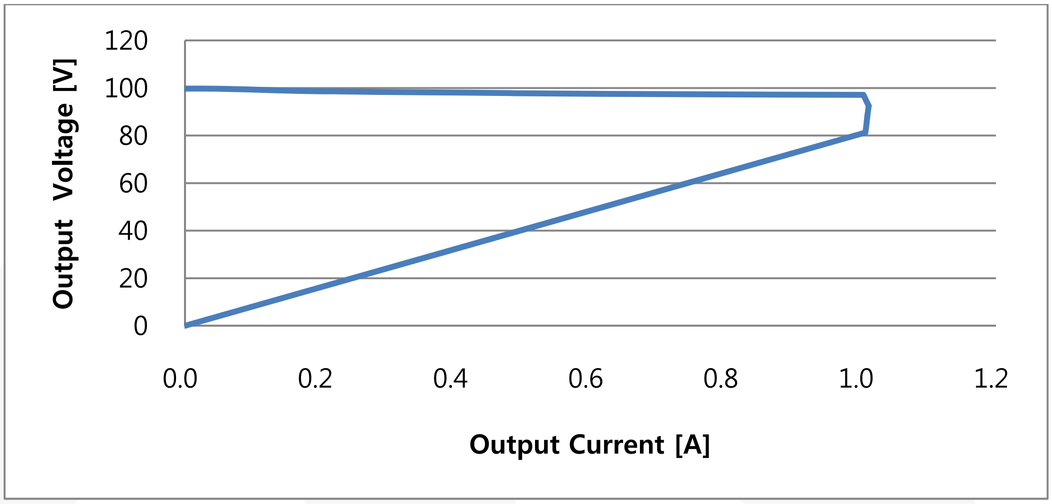

Figure 16. Constant Voltage and Current Regulation, Measured by E-Load [CR Mode]

Table 9. Output Voltage Regulation Performance

Output Voltage [V]	99.300	98.678	98.348	98.135	97.819	97.604	97.460
Output Current [mA]	100	201	300	400	500	600	700
Output Voltage [V]	97.346	97.228	97.132	92.469	88.555	83.579	81.279
Output Current [mA]	798	903	1004	1012.5	1009.9	1008.1	1006.8

Table 10. Output Voltage and Current Regulation Performance in CV/CC Region

	Mode	CV Mode	CC Mode
CC / CV	**Maximum Output**	99.30 V	1.01 A
	Minimum Output	97.23 V	1.00 A
	Difference	2.07 V	0.01 A
	Average	98.72 V	1.01 A
	Deviation	2.10 %	0.79 %

8.4. Overall Startup Performance

Figure 17 and Figure 18 show the overall startup performance; including boost converter, LLC resonant converter, and CV / CC circuitry. The output load current starts flowing after about 357 ms and 139 ms for input voltage of 90 V_{AC} and 265 V_{AC} when the AC input power switch is turned on; CH1: V_{CC_PFC} (10 V / div), CH2: V_{CC_LLC} (10 V / div), CH3: $V_{CC\_CC/CV}$ (10 V / div), CH4: I_{LOAD} (1 A / div), time scale: 100ms / div.

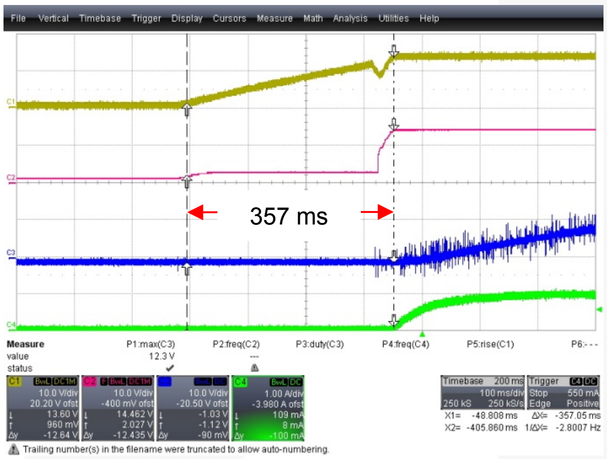

Figure 17. V_{IN} = 95 V_{AC}

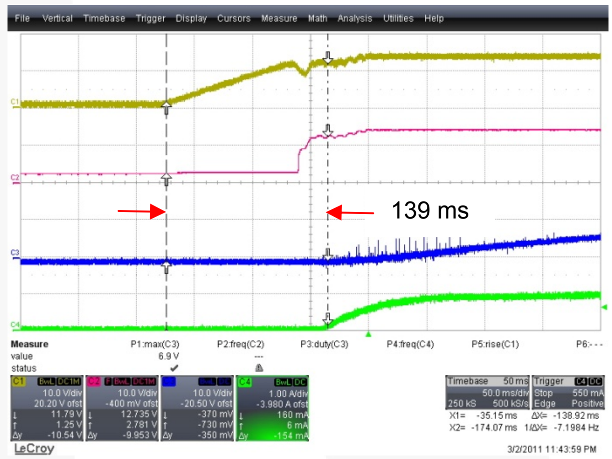

Figure 18. V_{IN} = 265 V_{AC}

8.5. Startup Performance of PFC

Figure 19 and Figure 20 show the typical startup performance on PFC converter. It is possible to have a long startup time at 95 V_{AC} condition rather than 265 V_{AC} condition and this time depends on starting resistor and capacitor on board.; CH1: V_{CC_PFC} (5 V / div), CH3: V_{PFC} (200 V / div), time scale: 100 ms / div.

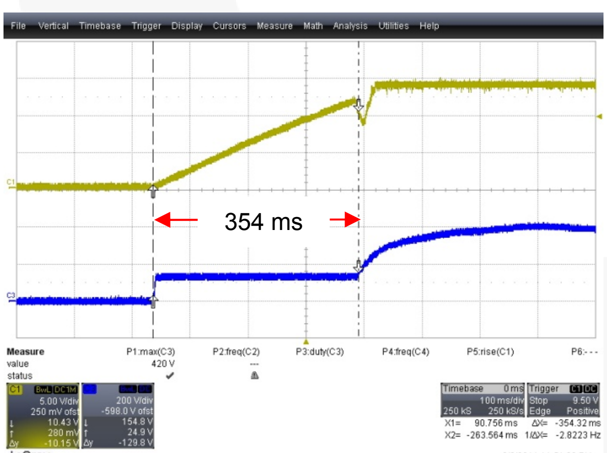

Figure 19. V_{IN} = 95 V_{AC}

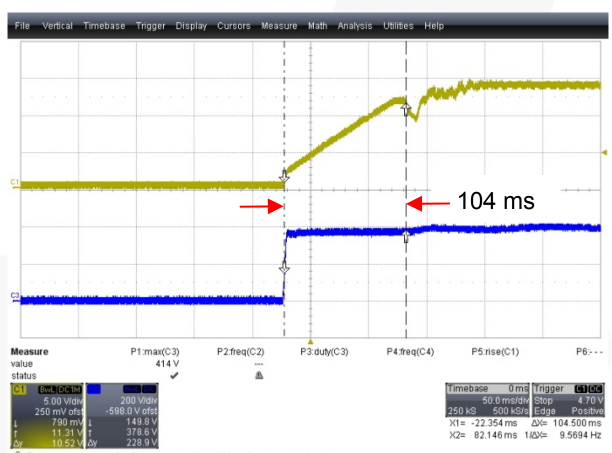

Figure 20. V_{IN} = 265 V_{AC}

8.6. Soft-Start Performance of PFC

Figure 21 through Figure 24 show the soft-start performance at output power at 100 W. Measured PFC output voltage reaches from 398 V to 401 V at input voltage 95 V_{AC} and 265 V_{AC} conditions; CH1: V_{CC_PFC} (10 V / div), CH3: V_{PFC} (20 V / div), time scale: 200 ms / div.

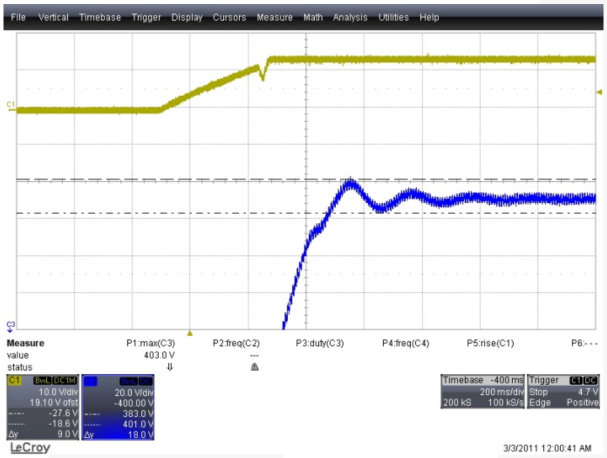

Figure 21. V_{IN} = 95 V_{AC}

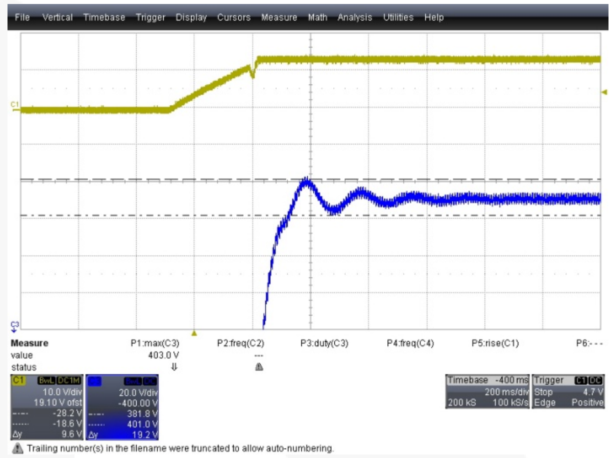

Figure 22. V_{IN} = 115 V_{AC}

Figure 23. V_{IN} = 235 V_{AC}

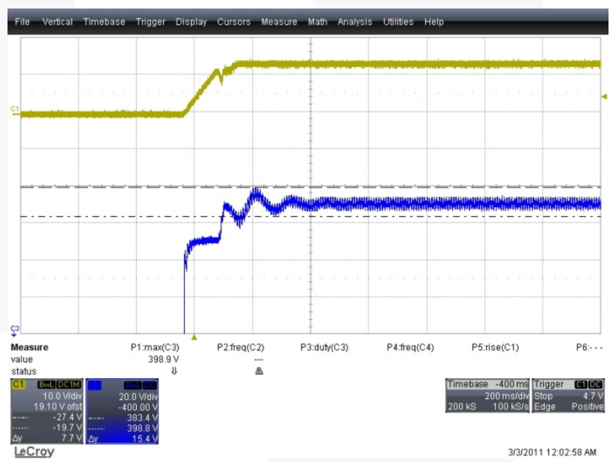

Figure 24. V_{IN} = 265 V_{AC}

8.7. Power On / Off Performance of DC-to-DC Converter

Figure 25 and Figure 26 show the soft-start waveforms at full-load and light-load conditions, respectively, for nominal input voltage condition; CH2: V_{PFC} (50 V / div), CH4: I_{LLC} (2 A / div), time scale: 50 ms / div.

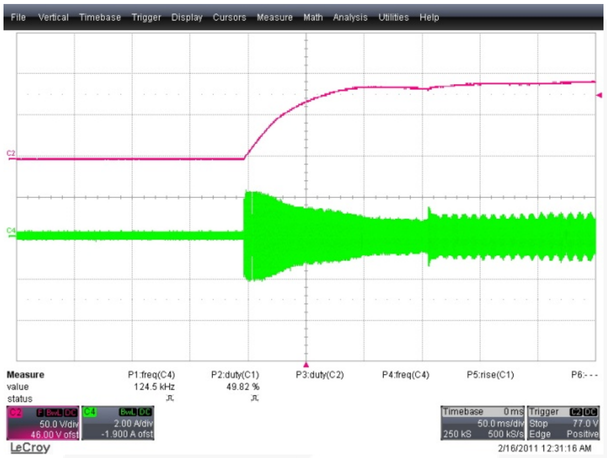

Figure 25. V_{PFC} = 400 V, P_O = 100 W

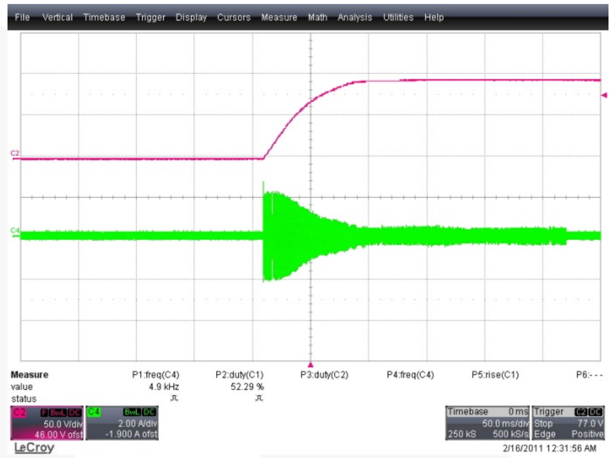

Figure 26. V_{PFC} = 400 V, P_O = 10 W

Figure 27 shows the startup waveforms when the input voltage source is supplied first, then the V_{CC} of 16 V is applied from the auxiliary winding of the PFC transformer.

Figure 28 shows the shutdown waveforms when input voltage source is turned off. When the DC bus voltage reaches about 260 V, the external brownout circuit disconnects V_{CC} from FLS1800XS, so it stops operation; CH1: V_{CC_LLC} (10 V / div), CH2: V_{PFC} (200 V / div), CH4: I_{LLC} (2 A / div).

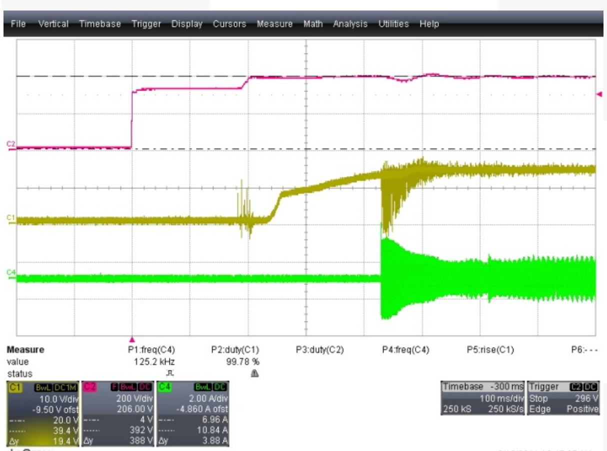

Figure 27. V_{PFC} = 400 V, P_O = 100 W; Startup Time Scale: 100 ms / div

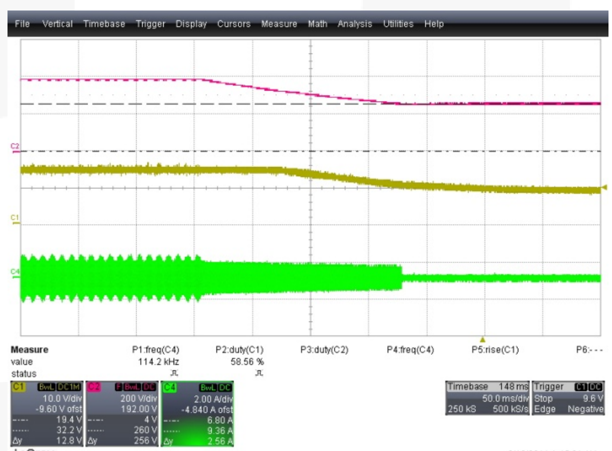

Figure 28. V_{PFC} = 400 V, P_O = 10 W; Shutdown Time Scale: 50 ms / div

8.8. AC Input Current

Figure 29 through Figure 32 show the AC input current waveforms at the rated output power 100 W and input voltage 95 V_{AC} and 265 V_{AC}; CH4: I_{AC} (500 mA / div), time scale: 10ms / div.

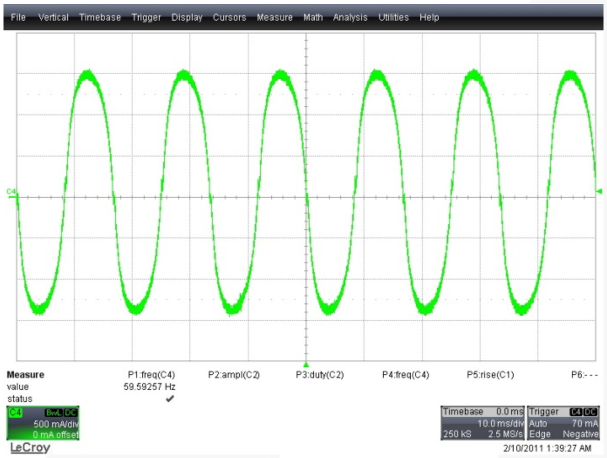

Figure 29. V_{IN} = 95 V_{AC}

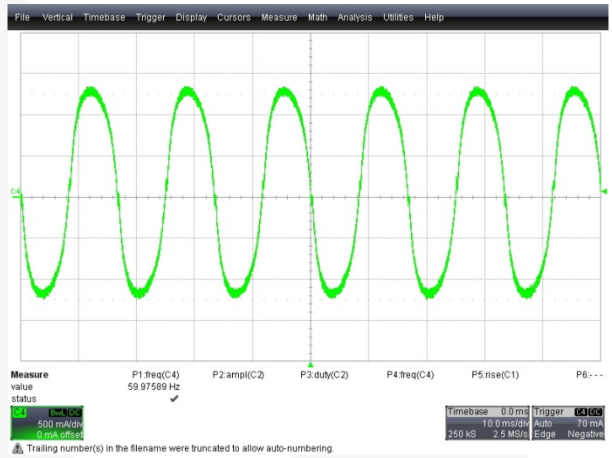

Figure 30. V_{IN} = 115 V_{AC}

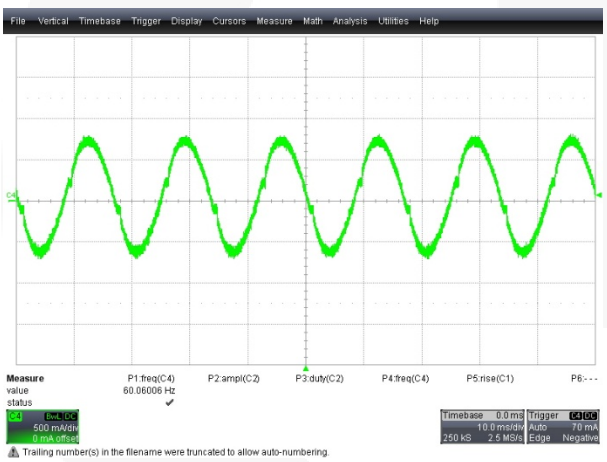

Figure 31. V_{IN} = 235 V_{AC}

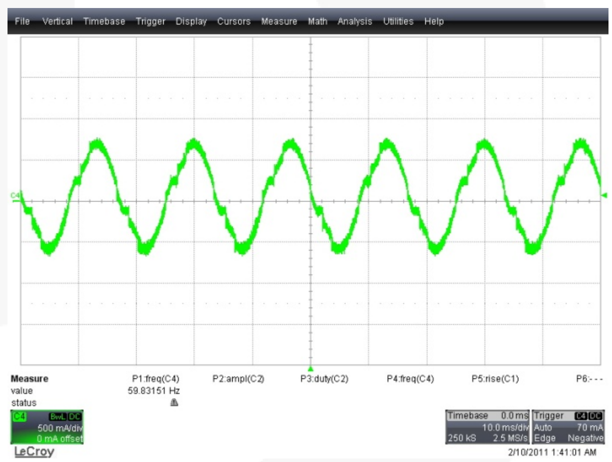

Figure 32. V_{IN} = 265 V_{AC}

8.9. Normal Operation of PFC

Figure 33 through Figure 36 show the AC input and MOSFET drain current waveforms at the rated output power of 100 W and input voltage 95 V_{AC}, and 265 V_{AC}; CH3: I_{D_PFC} (500 mA / div), CH4: I_{AC} (1 A / div), time scale: 5 ms / div.

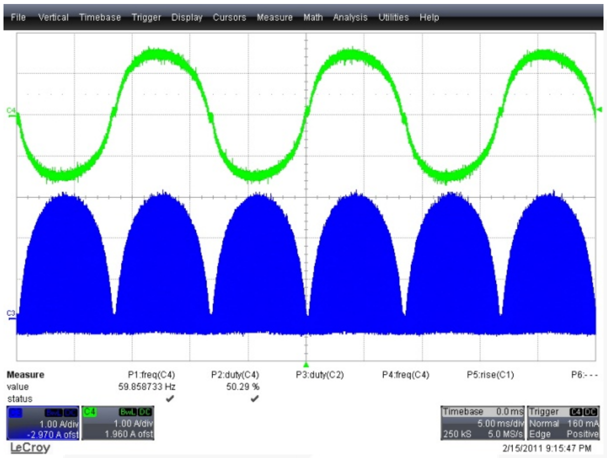

Figure 33. V_{IN} = 95 V_{AC}

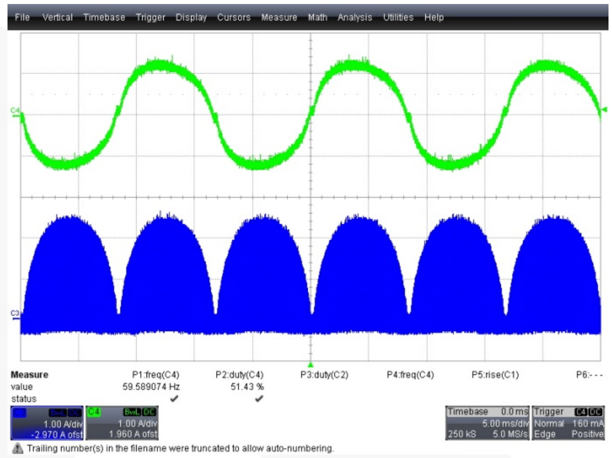

Figure 34. V_{IN} = 115 V_{AC}

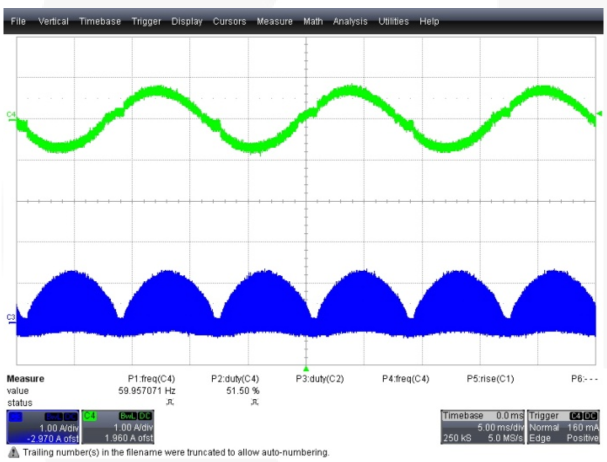

Figure 35. V_{IN} = 235 V_{AC}

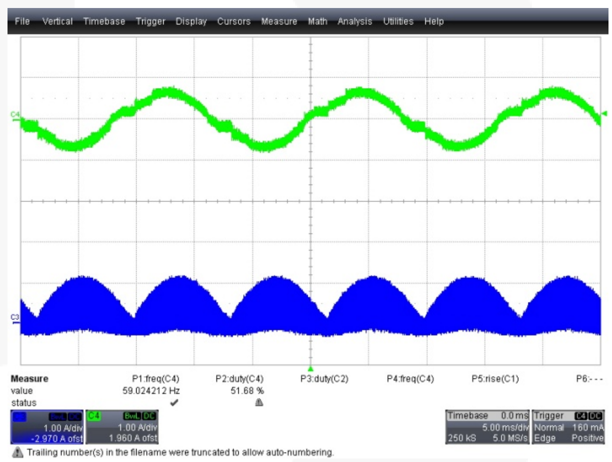

Figure 36. V_{IN} = 265 V_{AC}

8.10. Dynamic Performance of PFC

Figure 37 and Figure 38 show the PFC output voltage changes under about 40 V when input voltage changes from 115 V_{AC} to 235 V_{AC} and from 235 V_{AC} to 115 V_{AC} at the rated output power 100 W; CH1:V_{PFC} (20 V / div), CH4: I_{AC} (1 A / div), time scale: 200 ms / div.

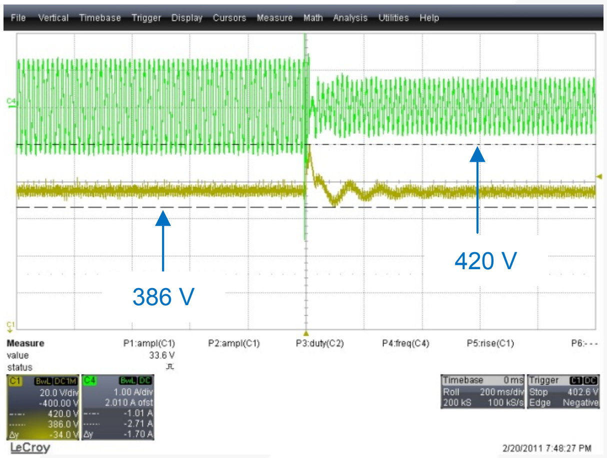

Figure 37. V_{IN} = 115 V_{AC} → 235 V_{AC}

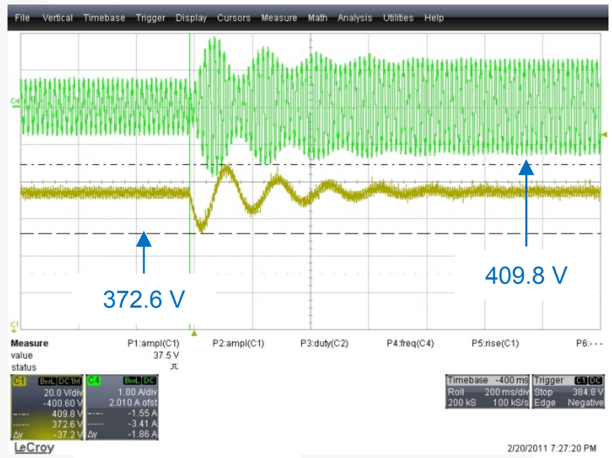

Figure 38. V_{IN} = 235 V_{AC} → 115 V_{AC}

Figure 39 and Figure 40 show the PFC output voltage changes about 32 V when output power changes from 14 W to 100 W and from 100 W to 14 W at input voltage is 235 V_{AC}; CH1: V_{PFC} (20 V / div), CH4: I_{AC} (1 A / div), time scale: 100 ms / div.

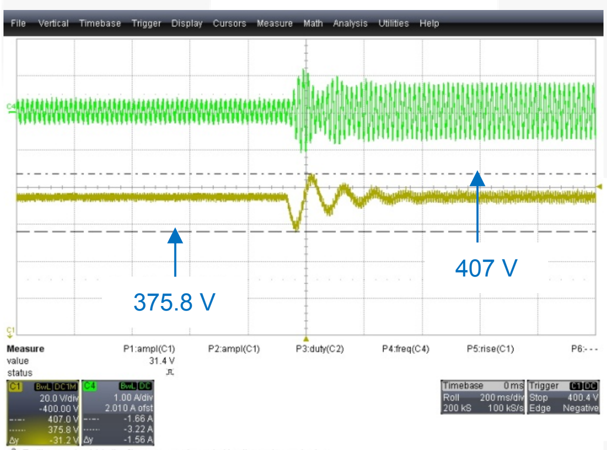

Figure 39. V_{IN} = 235 V_{AC}, P_O = 14 W → 100 W

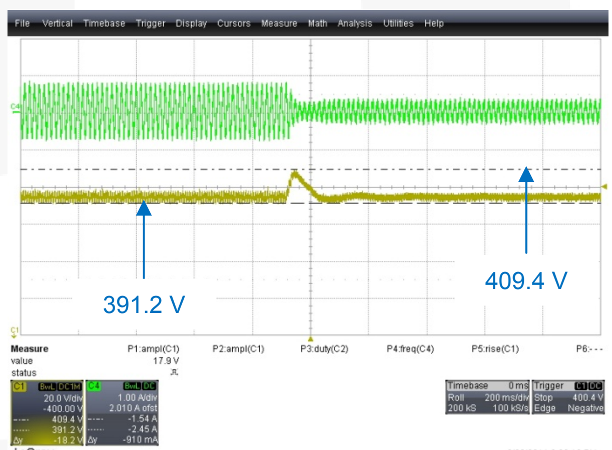

Figure 40. V_{IN} = 235 V_{AC}, P_O = 100 W → 14 W

8.11. Dynamic Performance of DC-to-DC Converter Part

Figure 41 shows the output voltage ripple with pulse load at nominal input voltage; CH1: V_{OUT} (5 V_{AC} / div), CH3: I_{LOAD} (1 A / div), CH4: I_{LLC} (1 A / div), time scale: 100 ms / div.

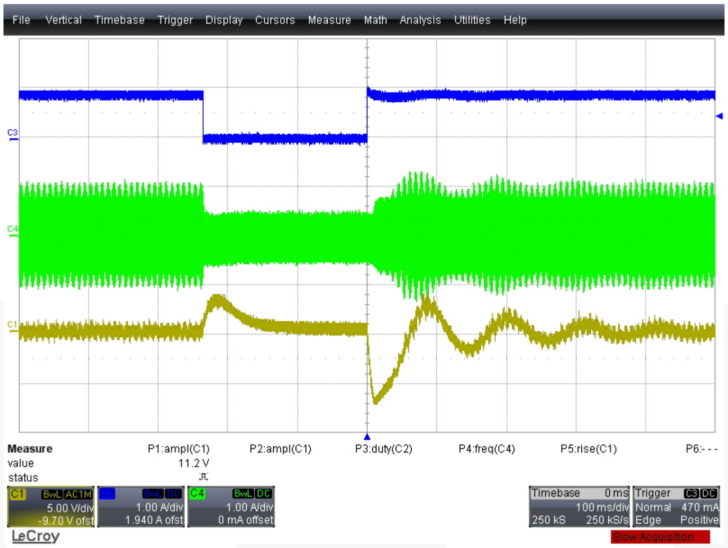

Figure 41. V_{PFC} = 400 V, I_O = 1A → 0.1 A → 1 A

8.12. Open-LED Protection of Current Balancing

Figure 42 shows the operation waveform when LED load is in open and restored condition. The OLP (Open-LED Protection) is auto-recovery protection when feedback drain voltage is higher than 0.3 V; CH1: V_{LED} (100 V / div), CH2: V_{DS_OPEN} (500 mV / div), CH3: V_{DS_NOR} (500 mV / div), CH4: I_{LED_OPEN} (200 mA / div), time scale: 500 ms / div.

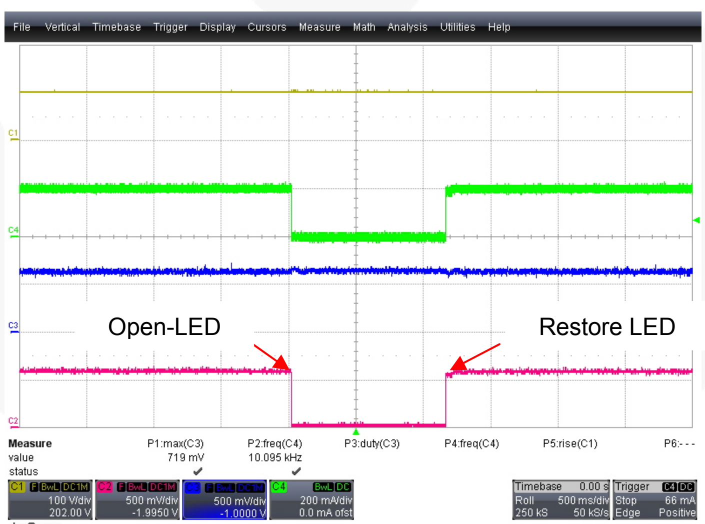

Figure 42. Open-LED Protection

8.13. Dimming Characteristics of Current Balancing

Figure 43 shows the FAN7346 analog dimming characteristic curves for estimate and real measurement values.

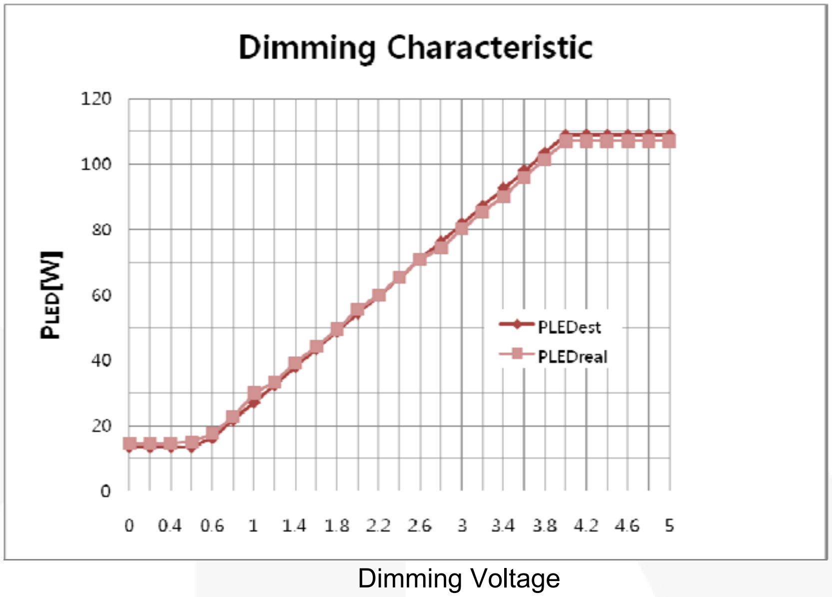

Figure 43. Analog Dimming Characteristics

8.14. Hold-Up Time Test of DC-to-DC Converter

Figure 44 shows the hold-up time performance when the AC power source is disconnected. The output voltage is slowly decreased until FLS1800XS stops operation for about 188 ms, when the power source is disconnected; CH1: V_{OUT} (50 V / div), CH2: V_{PFC} (200 V / div), CH4: I_{LLC} (1 A / div), time scale: 100 ms / div.

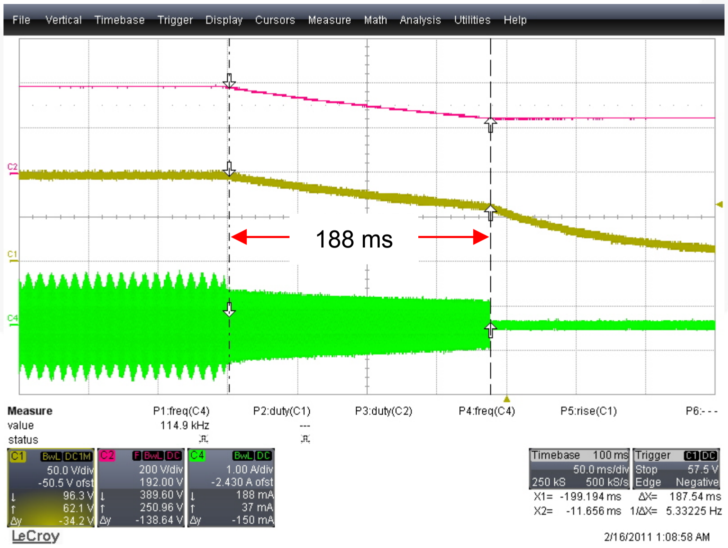

Figure 44. V_{PFC} = 400 V, P_O = 100 W

8.15. MOSFET Voltage and Current of DC-to-DC Converter

Figure 45 and Figure 46 show the resonant inductor current, low-side MOSFET current, and low-side MOSFET voltage waveforms in primary-side at full-load and no-load; CH2: V_{DS_LOW} (200 V / div), CH3: I_{LLC} (1 A / div), CH4: I_{D_LOW} (1 A / div), time scale: 5 µs/ div.

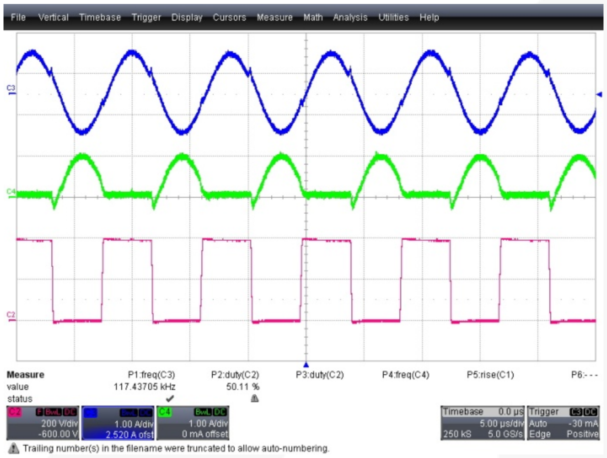

Figure 45. V_{PFC} = 400 V, P_O = 100 W

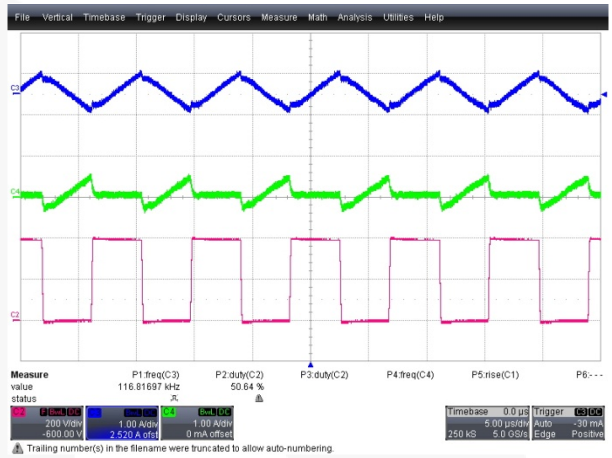

Figure 46. V_{PFC} = 400 V, P_O = 0 W

8.16. Secondary-Side Rectifier Diode Voltage and Current

Figure 47 and Figure 48 show the resonant inductor current in primary-side, rectifier diode current, and rectifier diode voltage waveforms in secondary-side at full load. It shows the soft commutation of the rectifier diodes in the secondary side due to below resonant operation. Below resonance operation is preferred for high-output-voltage applications, such as street LED lighting systems where the reverse recovery loss in the rectifier diode is severe; time scale: 5µs / div.

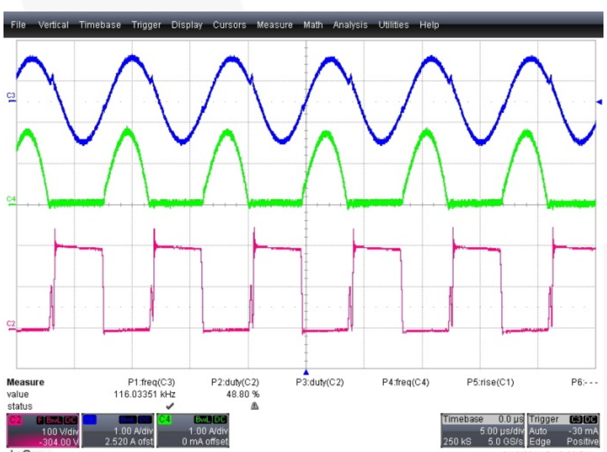

Figure 47. V_{PFC} = 400 V, P_O = 100 W; CH2: V_{D201} (100 V / div), CH3: I_{LLC} (1 A / div), CH4: I_{D201} (1 A / div)

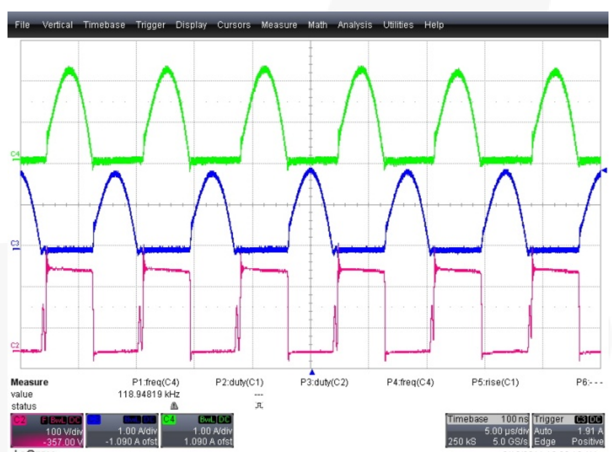

Figure 48. V_{PFC} = 400 V, P_O = 100 W; CH2: V_{D201} (100 V / div), CH3: I_{D201} (1 A / div), CH4: I_{D202} (1 A / div)

8.17. Operating Temperature

Figure 49 and Figure 50 show the temperature-checking results on the board in minimum and maximum input voltage condition at the rated LED load condition.

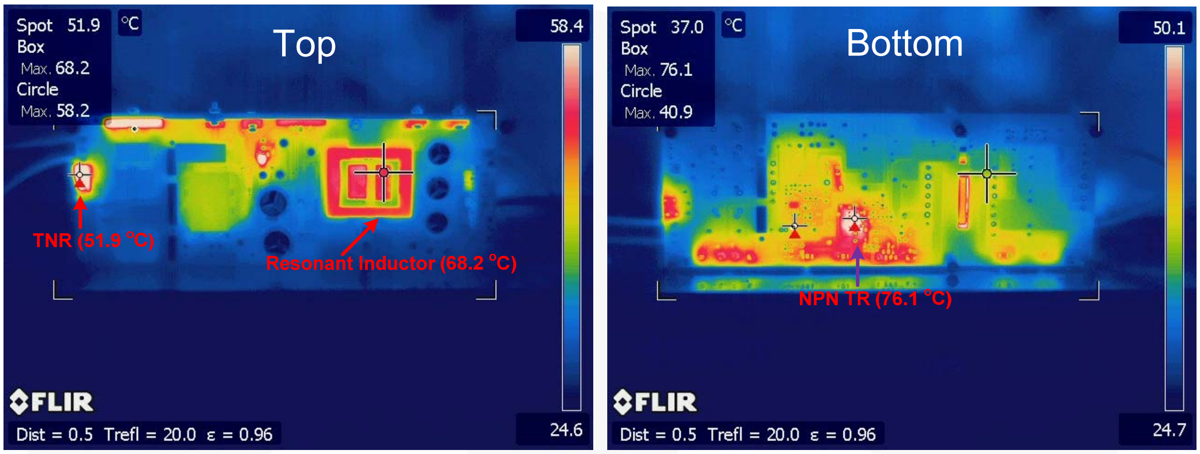

Figure 49. Board Temperature - V_{IN} = 90 V_{AC}

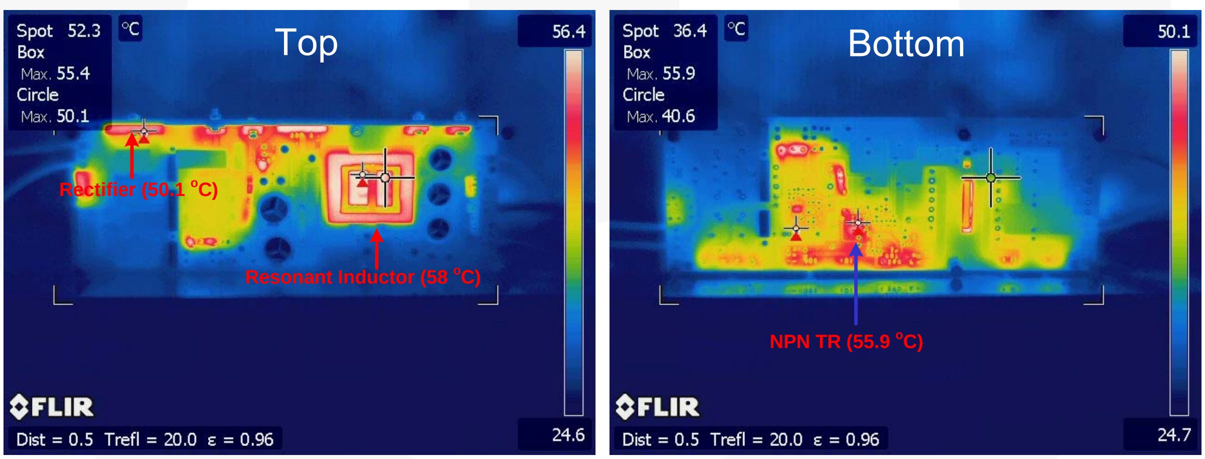

Figure 50. Board Temperature - V_{IN} = 265 V_{AC}

9. Revision History

Rev.	Date	Description
1.0.0	Nov. 2012	Initial Release
1.0.1	Mar. 2013	Updated pin name of FAN7346 in schematic

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative