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User Guide for

FEBFLS2100XS4CH_L12U160A

160 W LED Driver at Universal Line

Featured Fairchild Products:

FL7930B, FLS2100XS, FAN7346

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Table of Contents

This user guide supports the evaluation kit for the FL7930B, FLS2100XS, and FAN7346; orderable as FEBFLS2100XS4CH_L12U160A. It should be used in conjunction with the product 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 the proposed solution for an 160 W LED ballast, which consists of a boost converter for Power-Factor-Correction (PFC), DC-DC converter with LLC resonant converter, and current balancing for LED current regulation. The input voltage range is 90 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 1.4 A at 115 V_{MAX}. The power supply mainly utilizes Fairchild Semiconductor components: FL7930B CRM PFC controller, FLS2100XS Half-Bridge LLC controller, FAN7346 4-channel current-balance controller, FDP22N50N UniFET™ technology N-channel MOSFET, and FFPF08H60S "hyperfast" 2 rectifier. This document contains schematic, bill of materials, printed circuit layout, transformer design documentation and typical operating characteristics.

1.1. General Description of FL7730B

The FL7930B is an active Power Factor Correction (PFC) controller for low- to 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. 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 (THD) is lower than 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 (ZDC)
- 150 µs Internal Startup Timer
- MOSFET Over-Current Protection (OCP)
- 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 Package

1.3. Internal Block Diagram

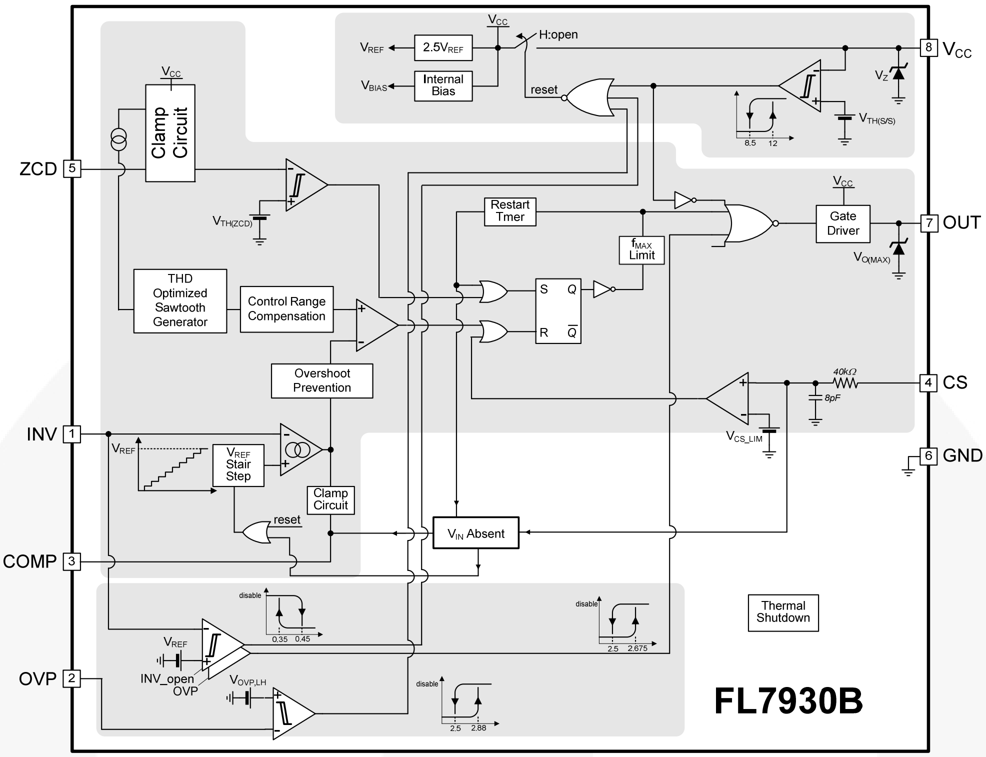


Figure 1. Block Diagram of FL7930B

1.4. General Description of FLS2100XS

The FLS2100XS lighting 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 FLS2100XS simplifies designs and improves productivity and performance. The FLS2100XS combines power MOSFETs with fast-recovery type body diodes, a high-side gate-drive circuit, an accurate current-controlled oscillator, a 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 effect of reverse recovery. Using Zero Voltage Switching (ZVS) dramatically reduces the switching losses and significantly improves efficiency. ZVS also reduces switching noise noticeably, which allows a small-sized Electromagnetic Interference (EMI) filter. The FLS2100XS 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™ (0.51 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
- Protection: Over-Voltage Protection (OVP), Over-Current Protection (OCP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown (TSD)

1.6. Internal Block Diagram

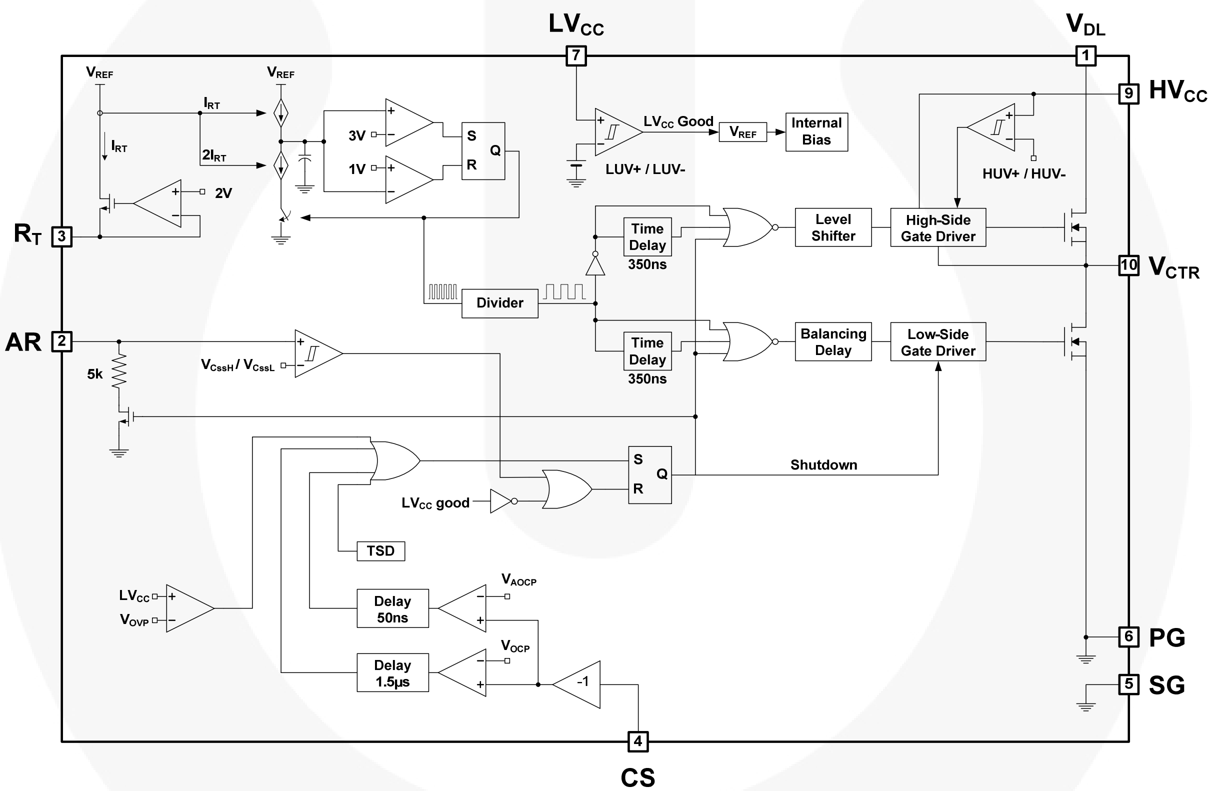


Figure 2. Block Diagram of FLS2100XS

1.7. General Description of FAN7346

The FAN7346 is an LED current-balance controller that controls four-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 an integrated feedback signal. The FAN7346 provides various protections: over-voltage regulation, open-LED protection, thermal protection, and drain-source voltage protection of the regulating switch (the FAN7346 monitors all LED arrays' drain-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 Bipolar Junction Transistor (BJT)
- Internal Voltage Regulator for Feedback
- Monitoring Drain-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 (OLP)
- Channel Individual Short-LED Protection
- Channel Individual Over-Current Protection (OCP)
- Error Flag Output
- 28-Pin SOIC Package

1.9. Internal Block Diagram

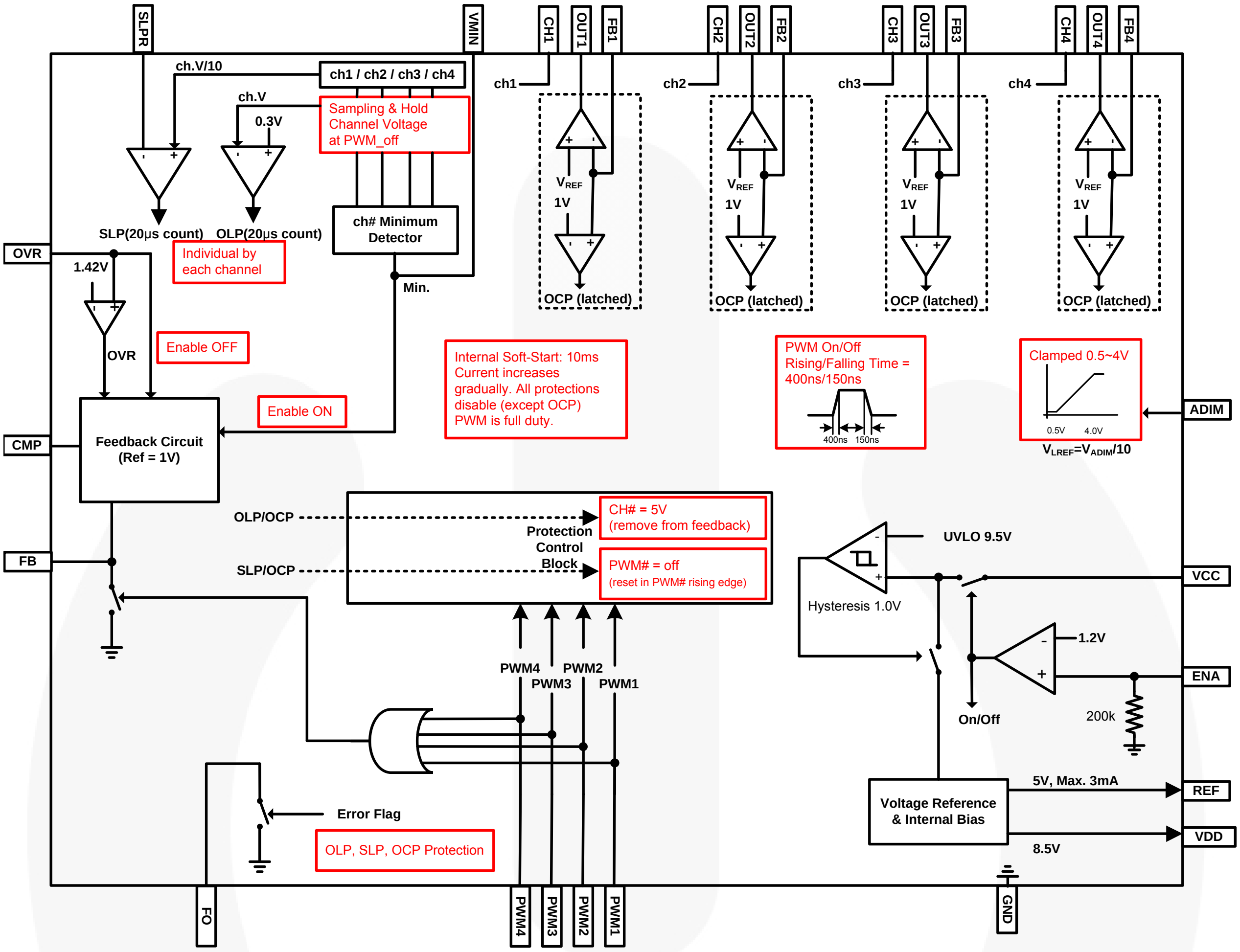


Figure 3. Block Diagram of FAN7346

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}	115 V	Nominal Output Voltage
	Current	I_{OUT}	350 mA	Each Channels
		CC Deviation	< 0.64%	Line & Load Regulation, Based on 1-CH
Efficiency		Eff_{85VAC}	88.34%	Efficiency at 85 V_{AC} Line Input Voltage
		Eff_{115VAC}	90.98%	Efficiency at 115 V_{AC} Line Input Voltage
		Eff_{235VAC}	94.73%	Efficiency at 235 V_{AC} Line Input Voltage
		Eff_{265VAC}	95.12%	Efficiency at 265 V_{AC} Line Input Voltage
PF/THD		PF / THD_{85VAC}	0.989 / 14.15%	PF / THD at 85 V_{AC} Line Input Voltage
		PF / THD_{115VAC}	0.988 / 14.6%	PF / THD at 115 V_{AC} Line Input Voltage
		PF / THD_{235VAC}	0.968 / 5.94%	PF / THD at 235 V_{AC} Line Input Voltage
		PF / THD_{265VAC}	0.952 / 6.26%	PF / THD at 265 V_{AC} Line Input Voltage

All data of the evaluation board was measured with the board enclosed in a case and external temperature 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

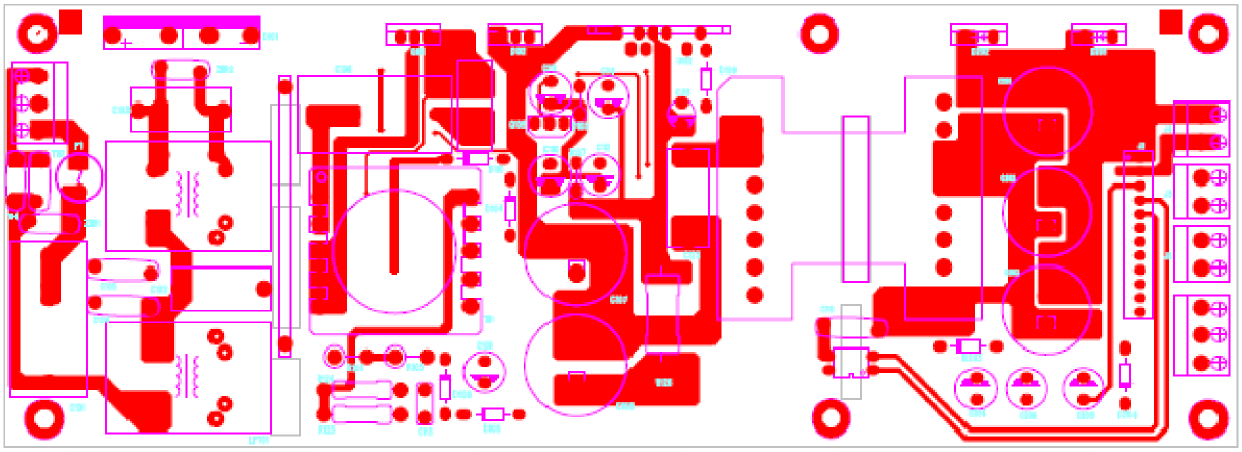


Figure 6. Top Pattern

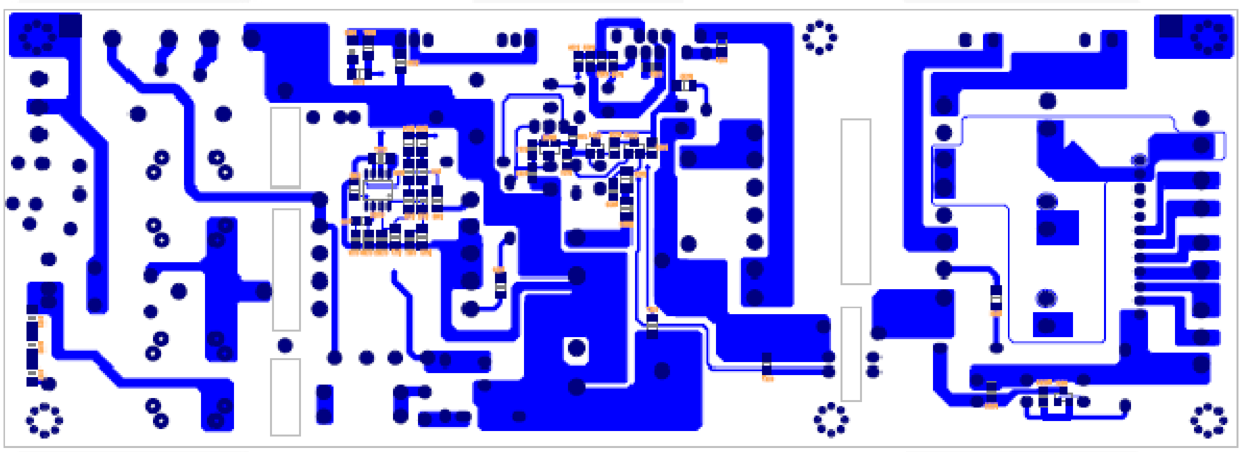


Figure 7. Bottom Pattern

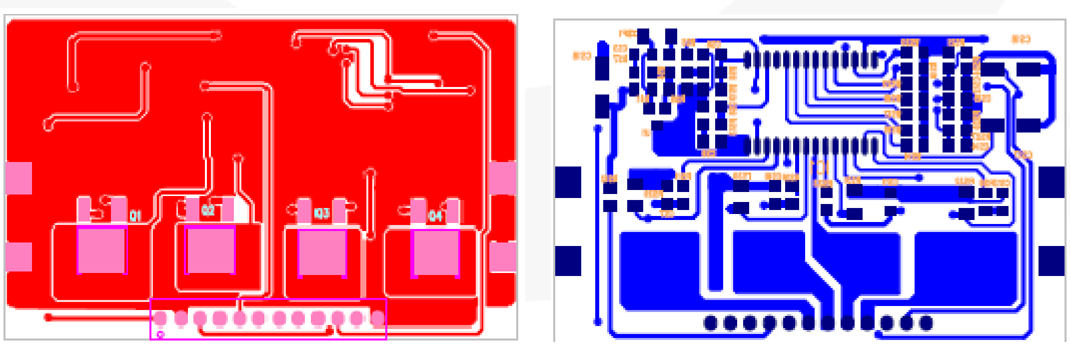


Figure 8. Top / Bottom Sub Board (Current-Balacing Part) Pattern

5. Schematic

5.1. Power Factor Correction (PFC)

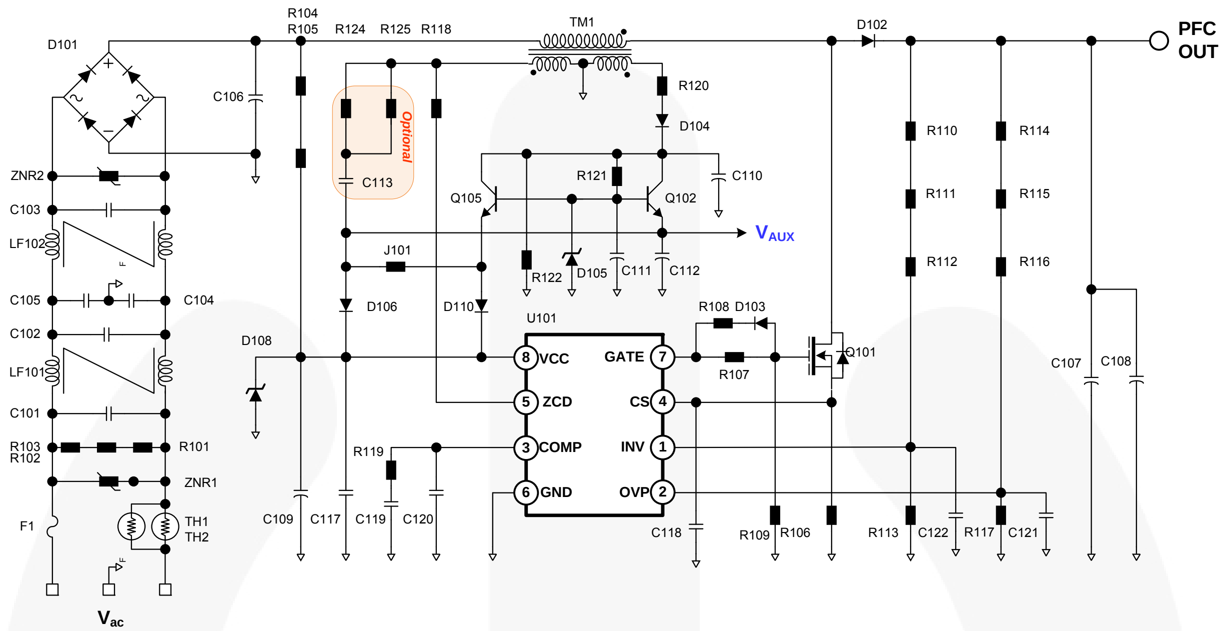


Figure 9. Schematic for PFC Part

5.2. DC-to-DC Converter and Current Balancing

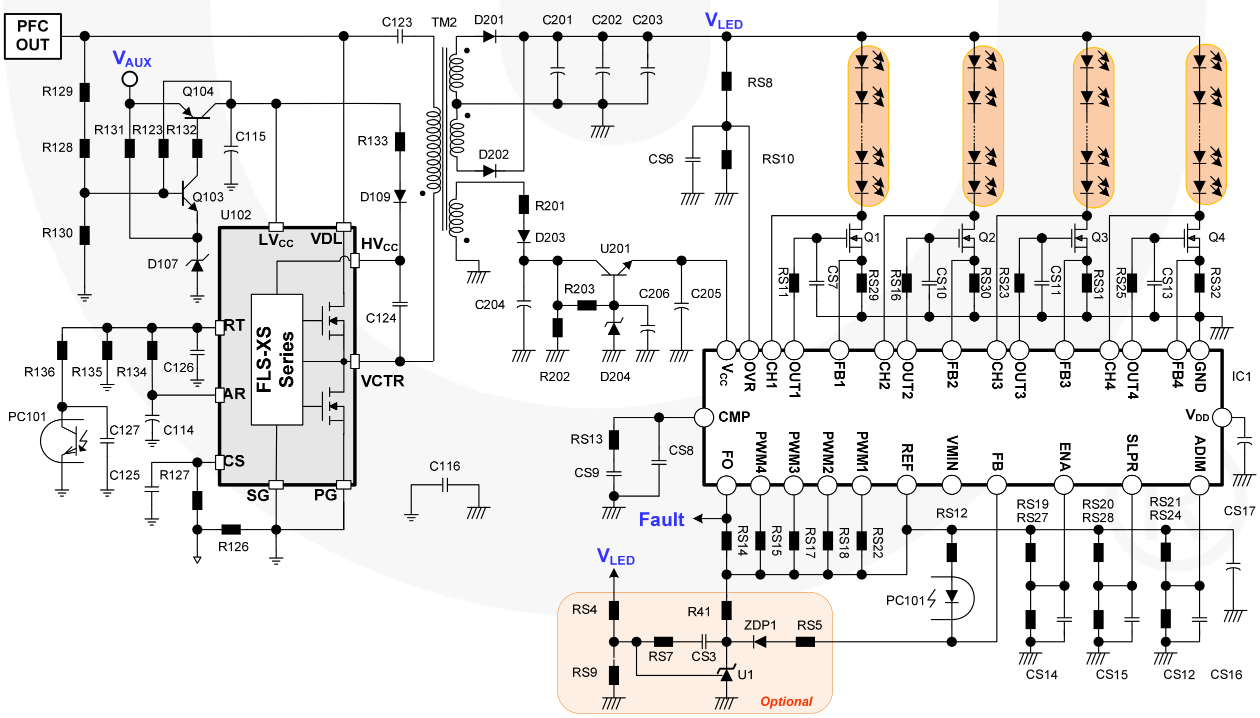


Figure 10. Schematic for DC-to-DC Converter and Current-Balancing Part

6. Bill of Materials

6.1. Main Board (PFC + DC-to-DC Converter Part)

Item No.	Part Reference	Value	Qty.	Description
1	U101	FL7930B	1	8-SOP, Fairchild Semiconductor
2	U102	FLS2100XS	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 / 2 5 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	FDP22N50N	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 + DC-to-DC Converter Part) (Continued)

Item No.	Part Reference	Value	Qty.	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		No Connection
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 kΩ-J	1	SMD Resistor, 2012
55	R135	7.5 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		No Connection

6.2. Sub Board for Current Balancing Part

Item No.	Part Reference	Value	Qty.	Description
1	IC1	FAN7346	1	SOP-28, 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		Optional
11	RS10	13 kΩ-J	1	SMD Resistor, 2012
12	RS12	15 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	1.2 Ω-J	4	SMD Resistor, 3216
17	CS3, CS7, CS10, CS11, CS13, CS8	NC		No Connection
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

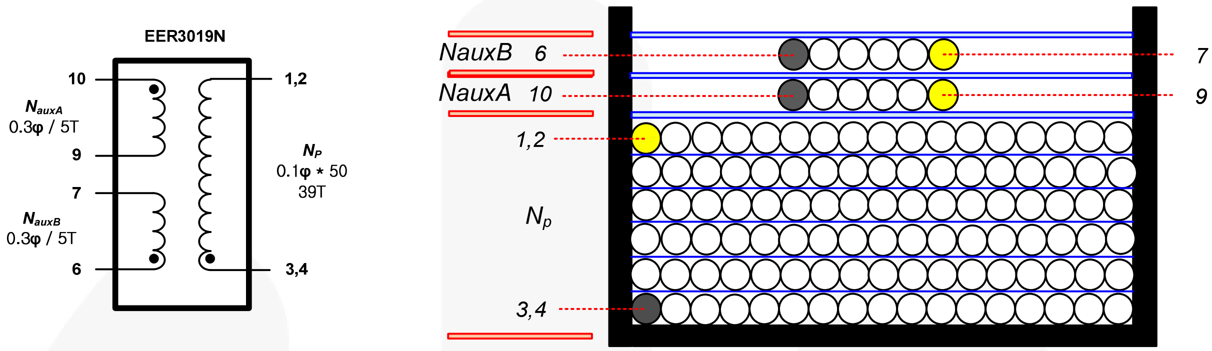


Figure 11. Transformer Specifications & Construction

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	194 μH ±5%	100 kHz, 1 V

7.2. LLC Resonant Converter Transformer (TM2)

- Core: EER3543
- Bobbin: 16 Pin

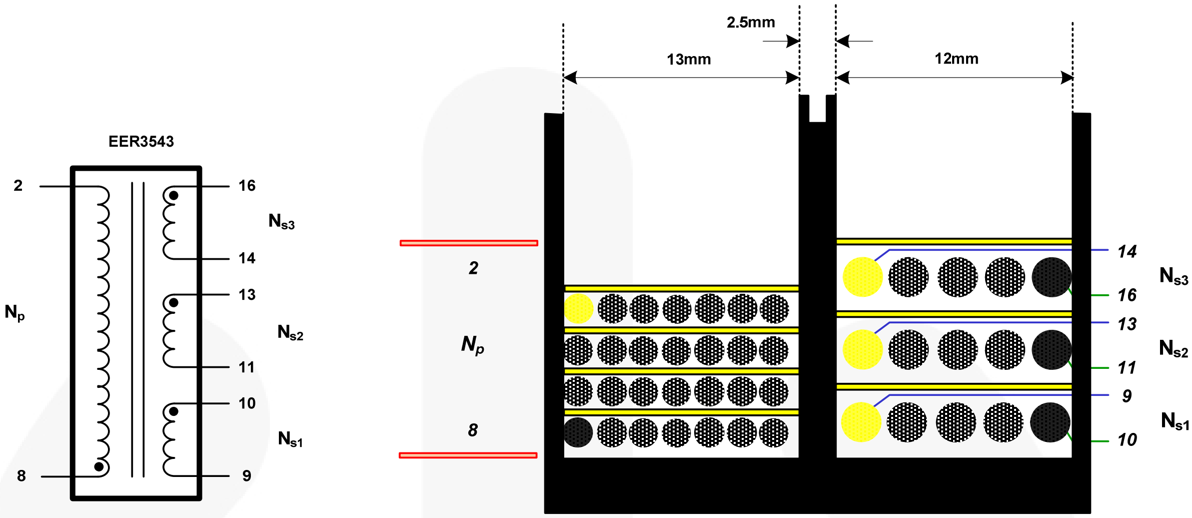


Figure 12. Transformer Specifications & Construction

Table 4. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np	8 → 2	0.1φ × 20	36 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	Ns1	10 → 9	0.3φ	3 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	Ns2	13 → 11	0.1φ×20	19 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
7	Ns3	16 → 14	0.1φ×10	19 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	630 μH ±5%	100 kHz, 1 V
Primary-Side Effective Leakage (Lr)	2 – 8	Maximum 135 μH	Short One of the Secondary Windings

8. Performance of Evaluation Board

Table 6. Test Conditions & Equipment

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 we can get at least 88% overall system efficiency with universal input condition at rated output LED load.

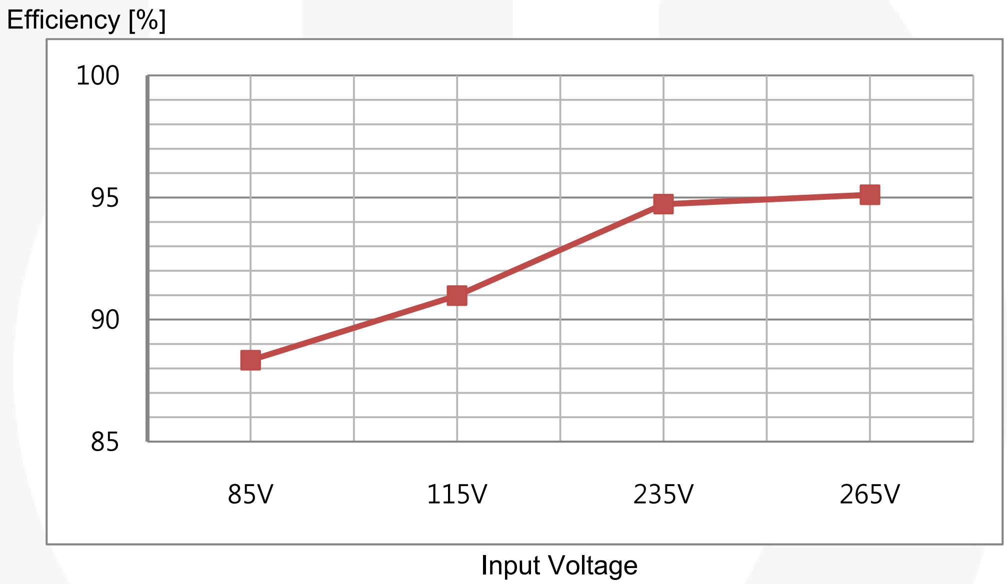


Figure 13. System Efficiency Curve

Table 7. System Efficiency

Input Voltage	**85 V_{AC}**	**115 V_{AC}**	**235 V_{AC}**	**265 V_{AC}**
Input Power [W]	183.16	177.90	170.75	170.06
Output Power [W]	161.80	161.86	161.75	161.75
Efficiency [%]	88.34	90.98	94.73	95.12

8.2. Power Factor (PF)

Figure 14 shows at least 95% power factor (PF) with universal input condition at rated output LED load.

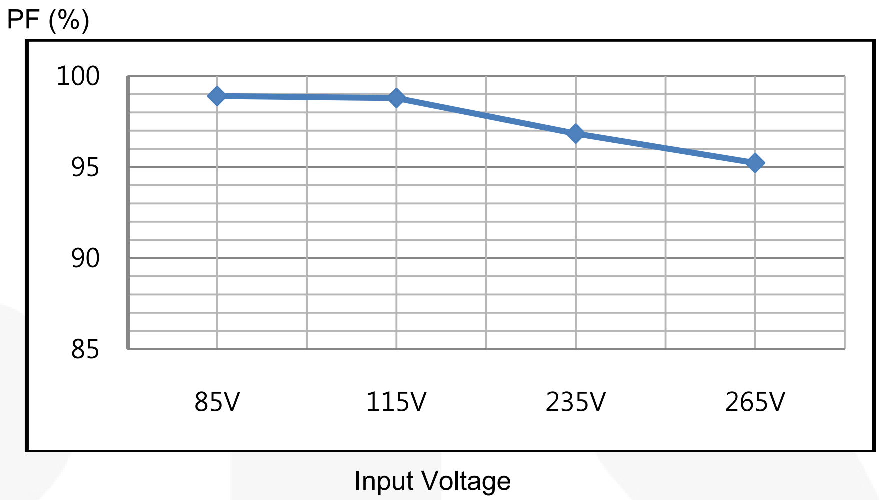


Figure 14. Power Factor Curve

Table 8. Power Factor

Input Voltage	85 V_{AC}	115 V_{AC}	235 V_{AC}	265 V_{AC}
Power Factor [%]	98.90	98.79	96.84	95.23
ATHD [%]	14.15	14.60	5.94	6.26

Figure 15 shows the current harmonic result at rated output power 160 W and input voltage 230 V_{AC} and 50 Hz condition based on IEC61000-3 Class-C for lighting applications. This meets the international regulations.

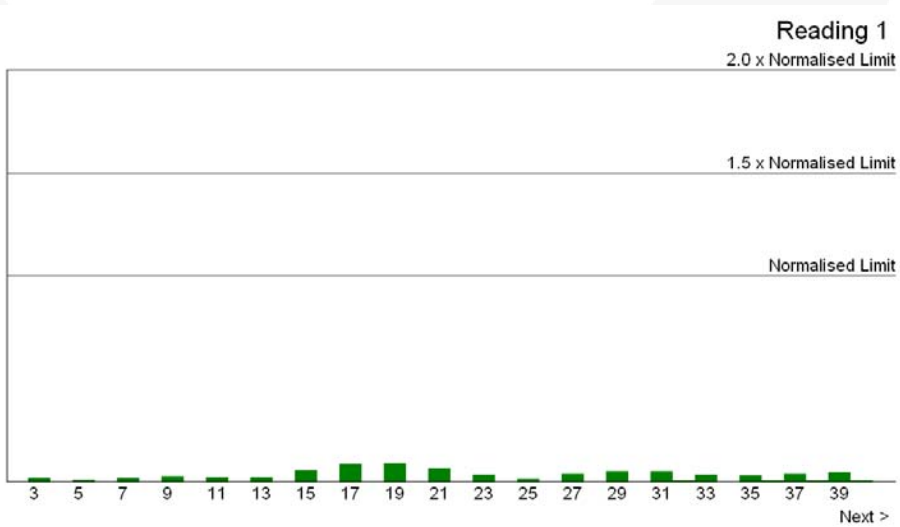


Figure 15. Total Harmonic Distortion (THD)

8.3. Constant Voltage and Current Regulation

Figure 16, Table 9, and Table 10 show the typical CC / CV performance on the board; showing very stable CC performance over a wide input range. Measured at 1-CH (1.4 A).

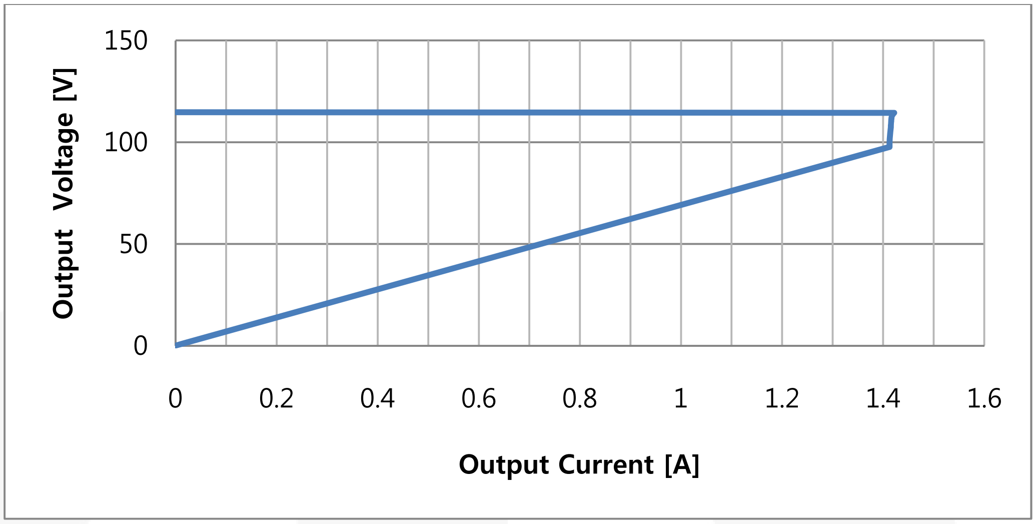


Figure 16. Constant Voltage and Current Regulation, Measured by E-Load [CR Mode]

Table 9. Output Voltage Regulation Performance

Output Voltage [V]	114.70	114.68	114.65	114.62	114.60	114.55	114.53
Output Current [mA]	115	211	311	419	511	707	803
Output Voltage [V]	114.48	114.47	114.43	112.37	106.63	101.48	97.65
Output Current [mA]	1015	1117	1313	1417	1415	1413	1413

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

	Mode	**CV Mode**	**CC Mode**
CC/CV	Max. Output	114.68 V	1.42 A
	Min. Output	114.43 V	1.41 A
	Difference	0.25 V	0.01 A
	Average	114.56 V	1.42 A
	Deviation	0.22%	0.64%

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 655 ms and 176 ms for input voltage 95 V_{AC} and 265 V_{AC} condition when the AC input power switch turns 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: 100 ms / div.

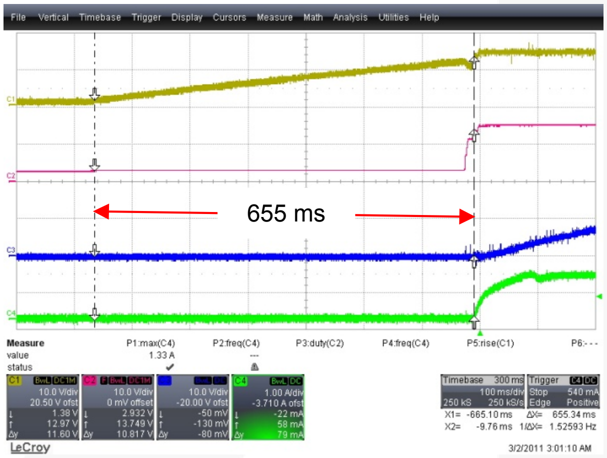


Figure 17. V_{IN} = 95 V_{AC}

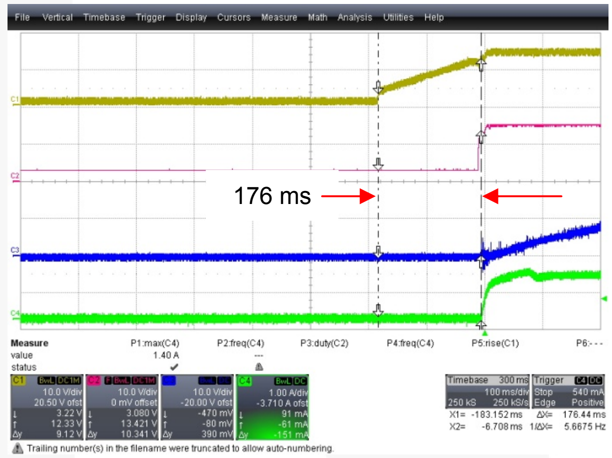


Figure 18. V_{IN} = 265 V_{AC}

8.5. Startup Performance of PFC Part

Figure 19 and Figure 20 show the typical startup performance on PFC converter. A long startup time is possible at 95 V_{AC} condition rather than 265 V_{AC} condition. This time normally depends on starting resistor and capacitor on board; CH1: V_{CC_PFC} (10 V / div), CH2: V_{PFC} (100 V / div), Time Scale: 200 ms / div.

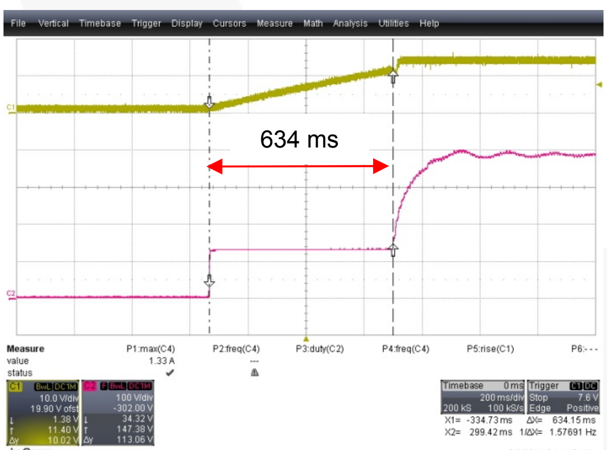


Figure 19. V_{IN} = 95 V_{AC}

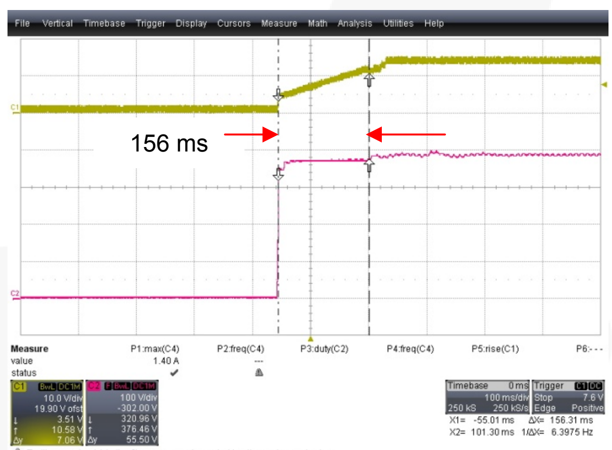


Figure 20. V_{IN} = 265 V_{AC}

8.6. Soft-Start Performance of PFC Part

Figure 21 through Figure 24 show the soft-start performance at output power 160 W. Measured PFC output voltage reaches 396.8 V and 402.2 V at input voltage 95 V_{AC} and 265 V_{AC} conditions; CH2: V_{PFC} (20 V / div), Time Scale: 100 ms / div.

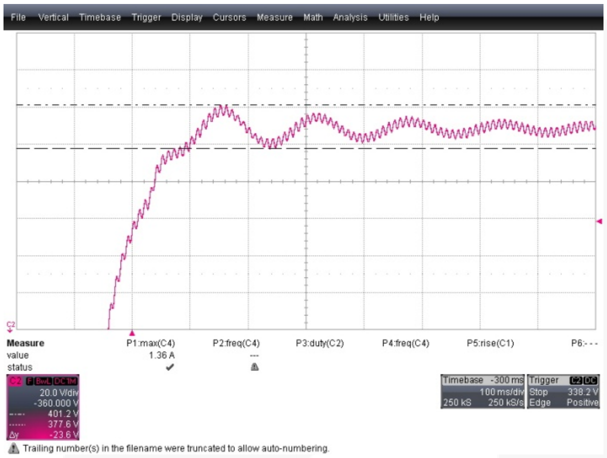


Figure 21. V_{IN} = 95 V_{AC}

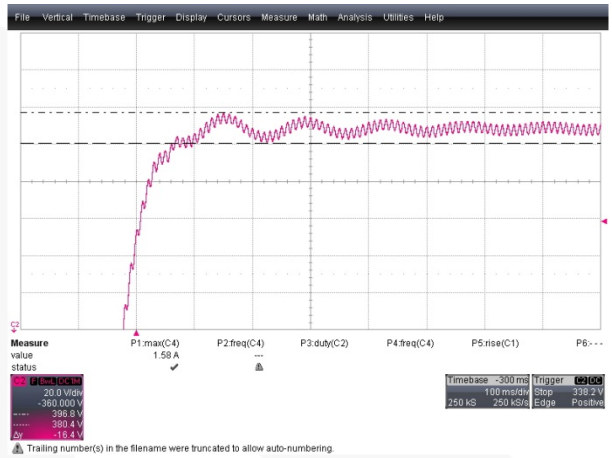


Figure 22. V_{IN} = 115 V_{AC}

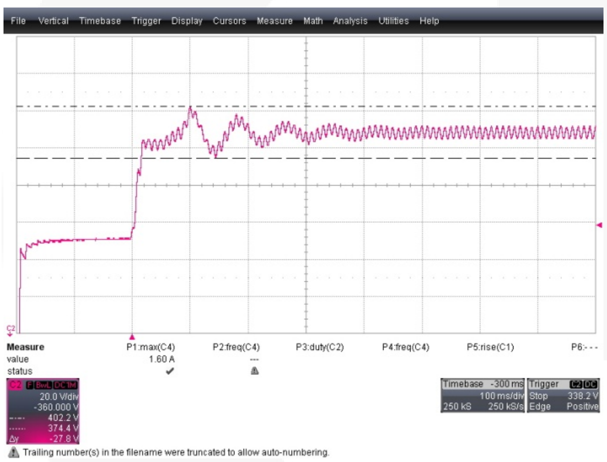


Figure 23. V_{IN} = 235 V_{AC}

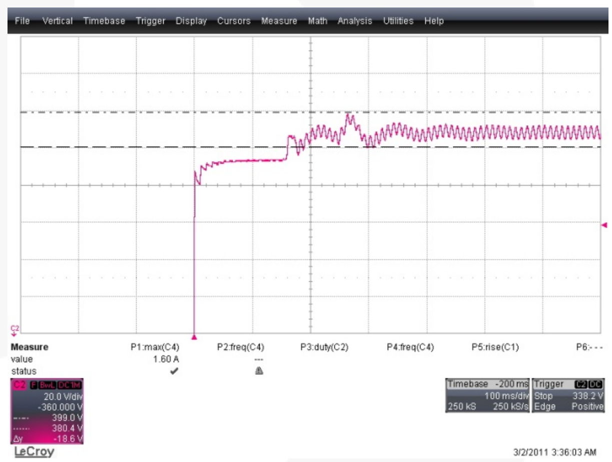


Figure 24. V_{IN} = 265 V_{AC}

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

Figure 25 through Figure 28 show the startup waveforms when input voltage source is supplied first, then the V_{CC_LLC} of 16 V is applied from auxiliary winding of PFC transformer; CH1: V_{PFC} (200 V / div), CH3: V_{CC_LLC} (10 V / div), CH4: I_{LLC} (2 A / div), Time Scale: 50 ms / div.

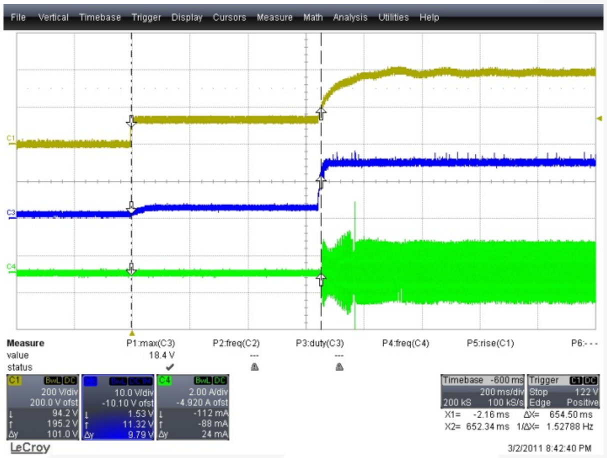


Figure 25. V_{PFC} = 400 V, P_O = 160 W

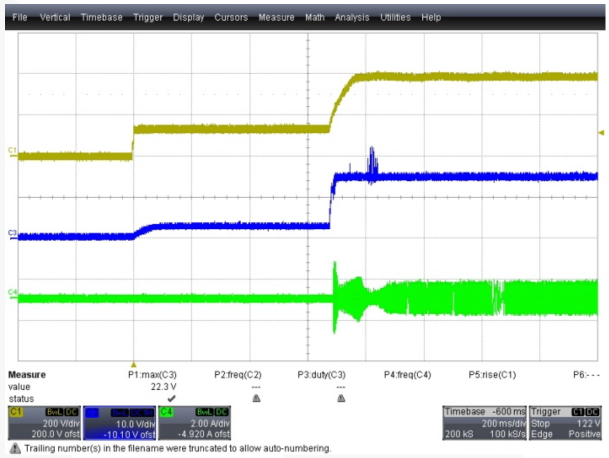


Figure 26. V_{PFC} = 400 V, P_O = 7 W

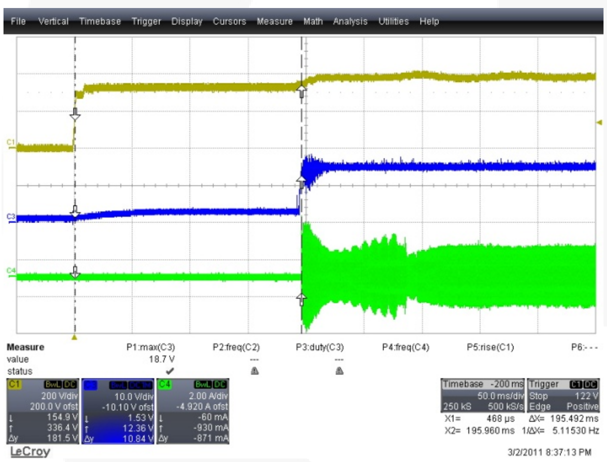


Figure 27. V_{PFC} = 400 V, P_O = 160 W

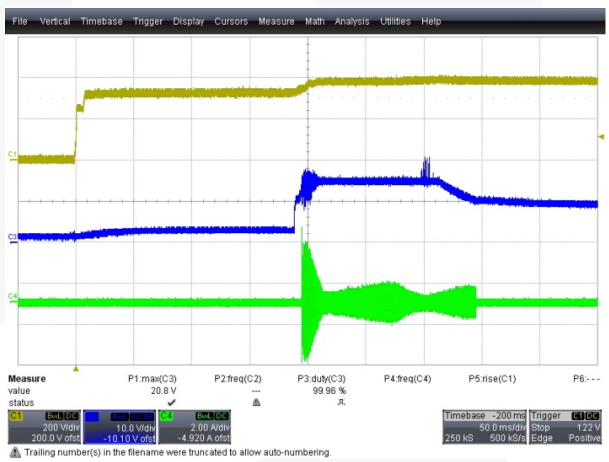


Figure 28. V_{PFC} = 400 V, P_O = 7 W

Figure 29 and Figure 30 show 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_LLC} from FLS2100XS, so it stops operation; CH1: V_{PFC} (200 V / div), CH3: $V_{CC\ LLC}$ (10 V / div), CH4: I_{LLC} (2 A / div), Time Scale: 100 ms / div.

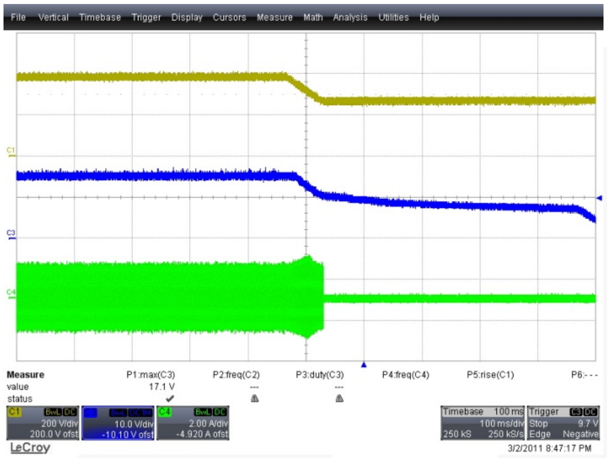


Figure 29. V_{PFC} = 400 V, P_O = 160 W

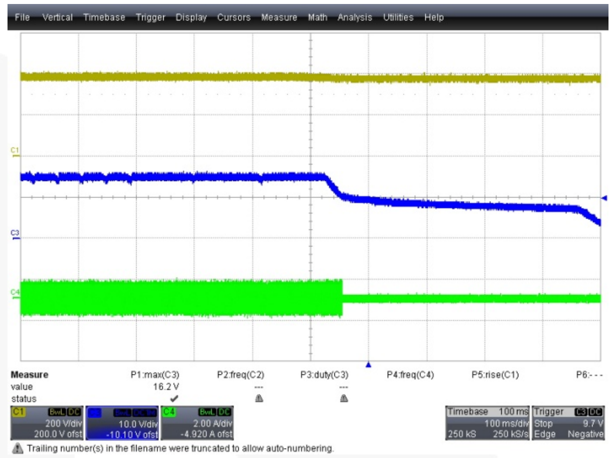


Figure 30. V_{PFC} = 400 V, P_O = 7 W

8.8. AC Input Current

Figure 31 through Figure 34 show the AC input current waveforms at the rated output power 160 W, input voltage 95 V_{AC}, and 265 V_{AC} condition; CH4: I_{AC} (1 A / div), Time Scale: 10 ms / div.

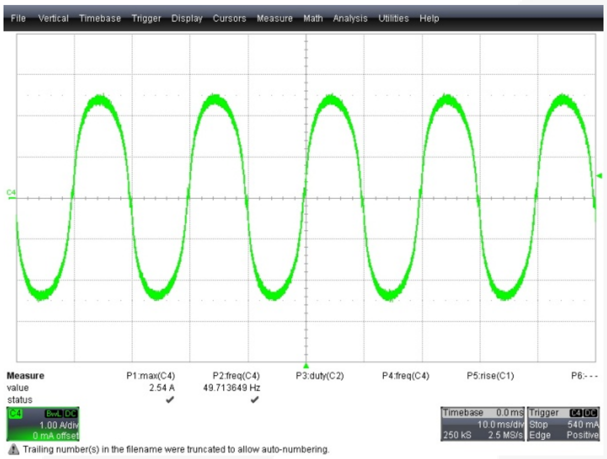


Figure 31. V_{IN} = 95 V_{AC}

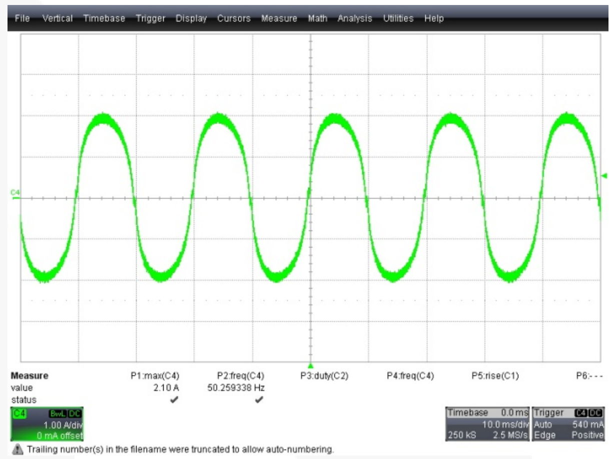


Figure 32. V_{IN} = 115 V_{AC}

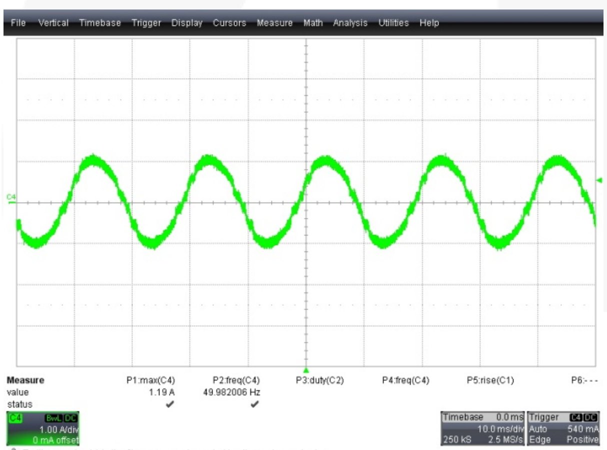


Figure 33. V_{IN} = 235 V_{AC}

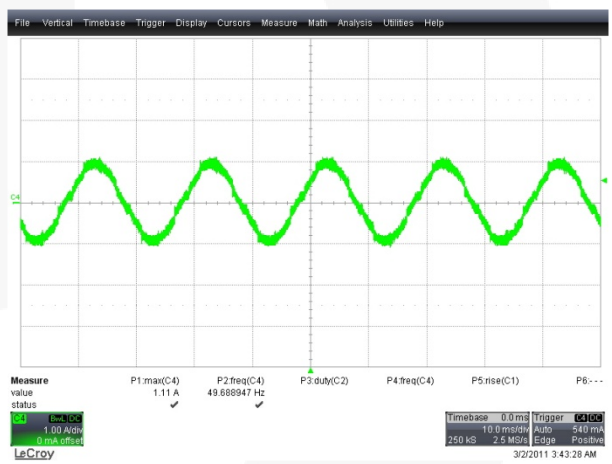


Figure 34. V_{IN} = 265 V_{AC}

8.9. Normal Operation of PFC Part

Figure 35 through Figure 38 show the AC input and MOSFET drain current waveforms at the rated output power for 160 W, input voltage 95 V_{AC}, and 265 V_{AC} condition; CH2: I_{AC} (2 A / div), CH4: I_D (500 mA / div), Time Scale: 5 ms / div.

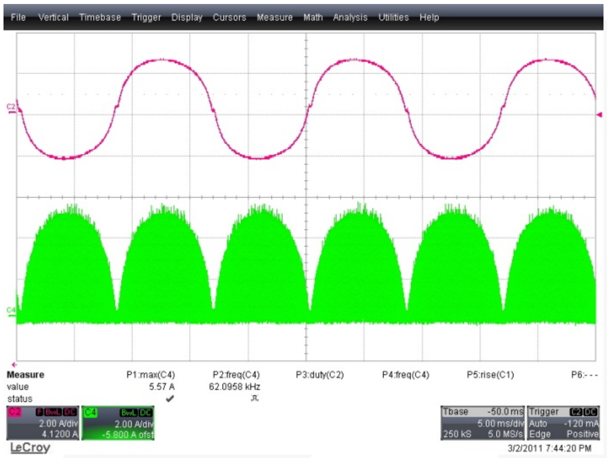


Figure 35. V_{IN} = 95 V_{AC}

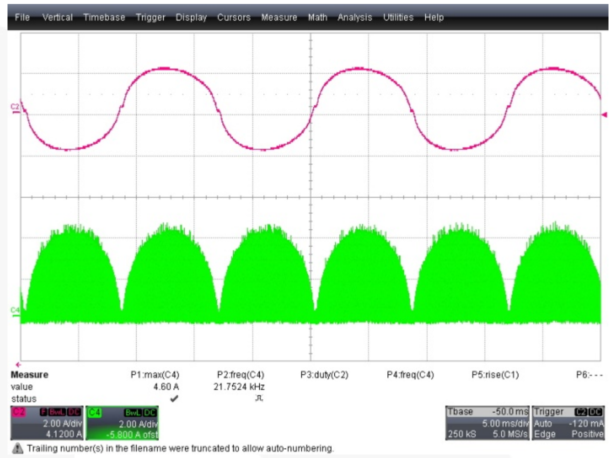


Figure 36. V_{IN} = 115 V_{AC}

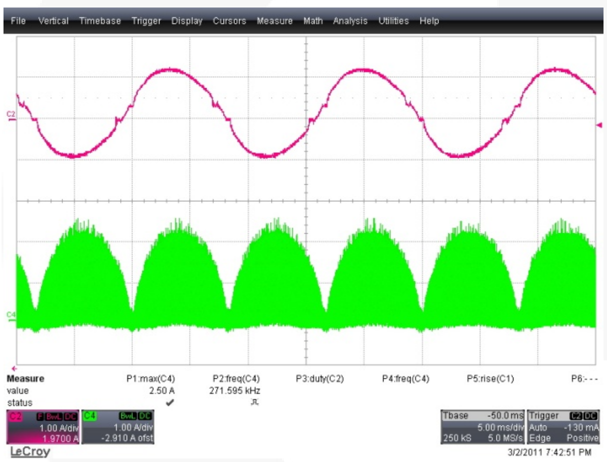


Figure 37. V_{IN} = 235 V_{AC}

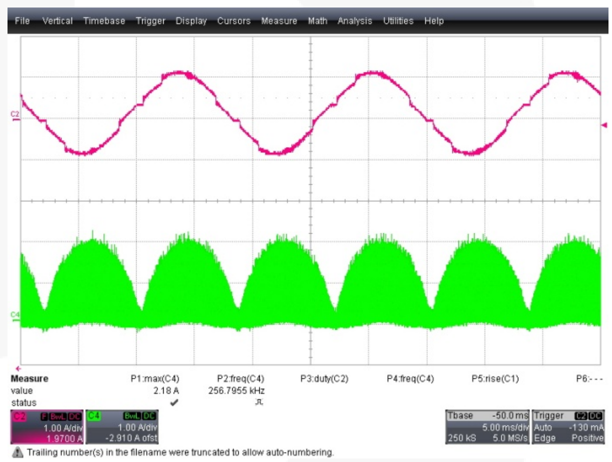


Figure 38. V_{IN} = 265 V_{AC}

8.10. Dynamic Performance of PFC Part

Figure 39 and Figure 40 show the PFC output voltage change under about 50 V when input voltage changes from 115 V_{AC} to 235 V_{AC} and from 235 V_{AC} to 115 V_{AC} at rated output power 160 W; CH1:V_{COMP} (5 V / div), CH2: V_{PFC} (20 V / div), CH4: I_{AC} (2 A / div), Time Scale: 100 ms / div.

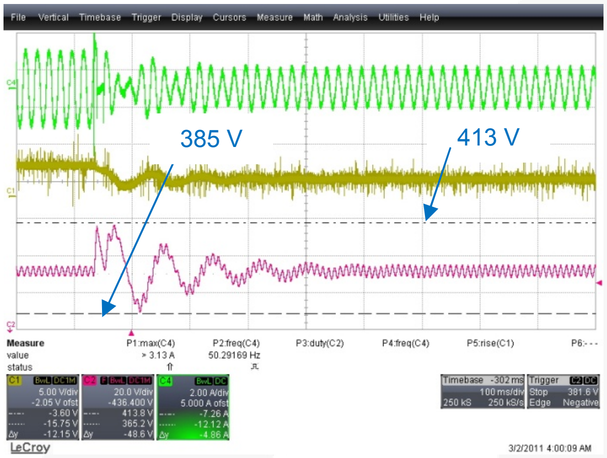


Figure 39. V_{IN} = 115 V_{AC} → 235 V_{AC}

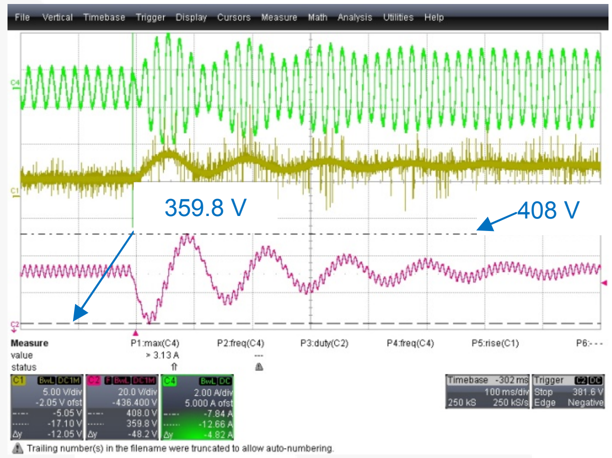


Figure 40. V_{IN} = 235 V_{AC} → 115 V_{AC}

Figure 41 and Figure 42 show the PFC output voltage change about 50 V when output power changies from 30 W to 160 W and from 160 W to 30 W at input voltage is 115 V_{AC}; CH1: V_{COMP} (5 V / div), CH2: V_{PFC} (20 V / div), CH4: I_{AC} (2 A / div), Time Scale: 100 ms / div.

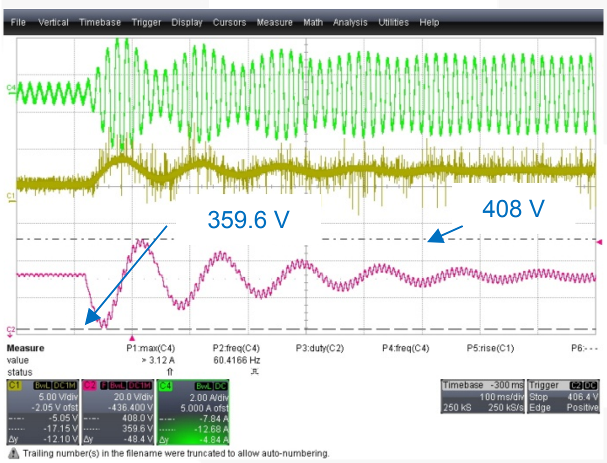


Figure 41. V_{IN} = 115 V_{AC}, P_O = 30 W → 160 W

Figure 42. V_{IN} = 115 V_{AC}, P_O = 160 W → 30 W

Figure 43 and Figure 44 show the PFC output voltage change about 40 V when output power changes from 30 W to 160 W and from 160 W to 30 W at input voltage is 235 V_{AC}; CH1: V_{COMP} (5 V / div), CH2: V_{PFC} (20 V / div), CH4: I_{AC} (2 A / div), Time Scale: 100 ms / div.

Figure 43. V_{IN} = 235 V_{AC}, P_O = 30 W → 160 W

Figure 44. V_{IN} = 235 V_{AC}, P_O = 160 W → 30 W

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

Figure 45 shows the load transient waveform at nominal input voltage; CH2: I_{LOAD} (1 A / div), CH3: V_{OUT} (1 V_{AC} / div), CH4: I_{LLC} (2 A / div), Time Scale: 100 ms / div.

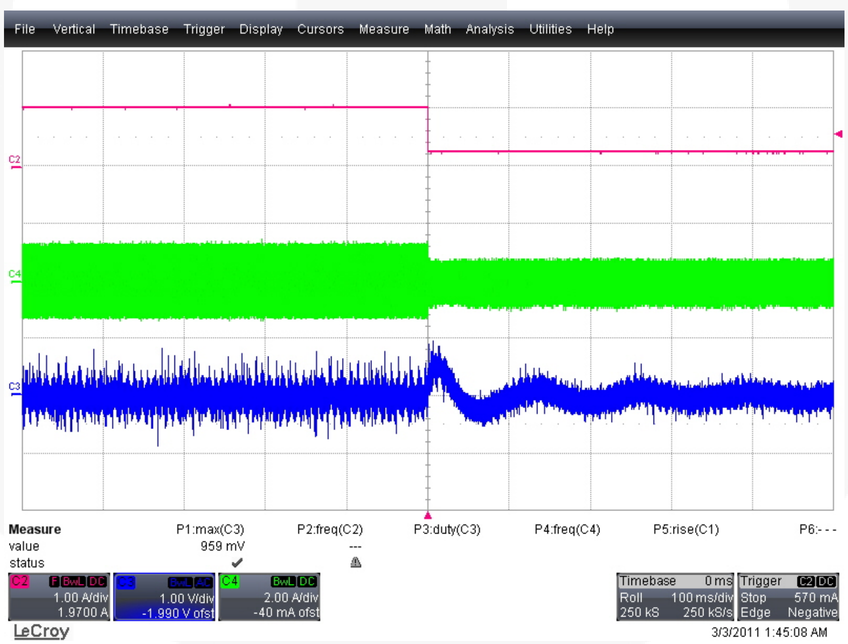


Figure 45. V_{IN} = 95 V_{AC}, P_O = 160 W → 50 W

8.12. Open-LED Protection of Current-Balancing Part

Figure 46 shows the operation waveforms when LED load is open at t0 and restored at t1. The FAN7346 can detect open-LED condition. The Open-LED Protection (OLP) is auto-recovery protection when feedback drain voltage is higher than 0.3 V; CH1: V_{LED} (100 V / div), CH2: V_{DS_NOR} (500 mV / div), CH3: V_{DS_OPEN} (500 mV / div), CH4: I_{LED_OPEN} (200 mA / div), Time Scale: 500 ms / div.

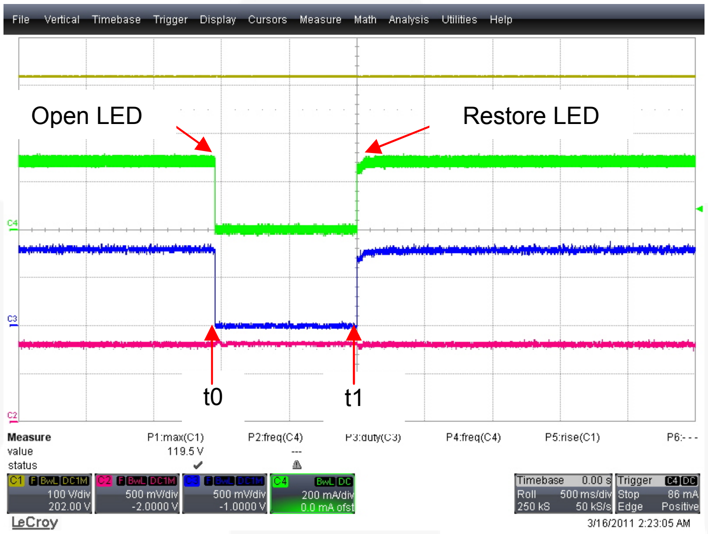
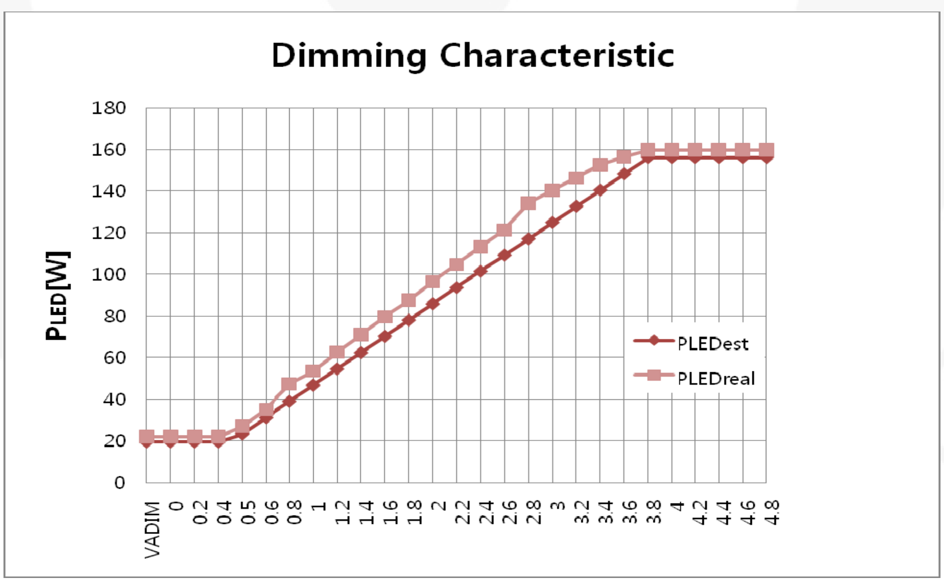


Figure 46. Open-LED Protection

8.13. Dimming Characteristics of Current-Balancing Part

Figure 47 shows the FAN7346 analog dimming characteristic curves for estimated and real measurement values.



Dimming Voltage

Figure 47. Analog Dimming Characteristics

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

Figure 48 shows the hold-up time performance when the AC power source is disconnected. Output voltage is maintained for about 34 ms and slowly decreased until FLS2100 stops operation for about 60 ms, when the power source is disconnected; CH1: V_{PFC} (200 V / div), CH3: V_{OUT} (50 V / div), CH4: I_{LLC} (2 A / div), Time Scale: 20 ms / div.

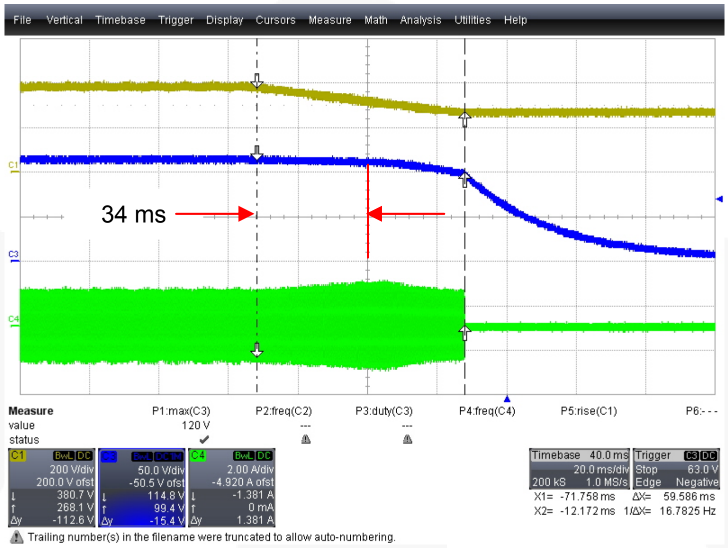


Figure 48. V_{PFC} = 400 V, P_O = 160 W

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

Figure 49 and Figure 50 show the resonant inductor current, low-side MOSFET current, and low-side MOSFET voltage waveforms in primary-side at full-load and light-load; CH2: I_{LLC} (2 A / div), CH3: V_{DS_LOW} (200 V / div), CH4: I_{D_LOW} (1 A / div), Time Scale: 5 µs / div.

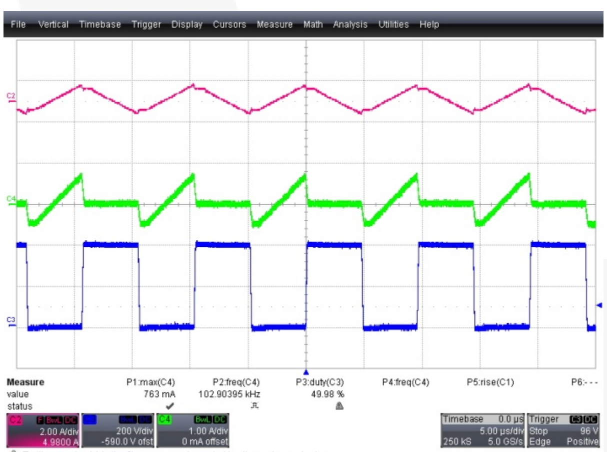


Figure 49. V_{PFC} = 400 V, P_O = 3 W

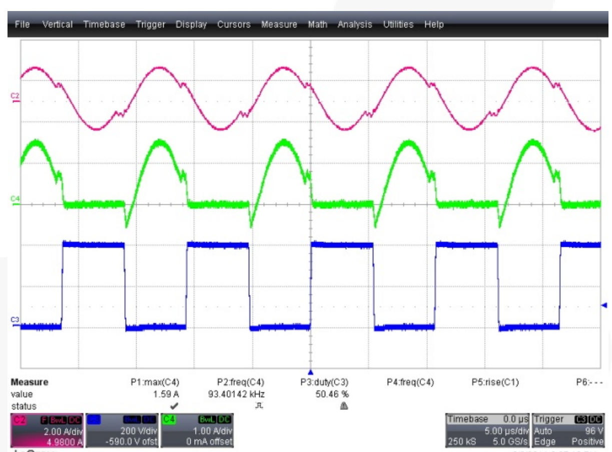


Figure 50. V_{PFC} = 400 V, P_O = 160 W

8.16. Secondary-Side Rectifier Diode Voltage and Current

Figure 51 and Figure 52 show the resonant inductor current in the primary side, rectifier diode current, and the rectifier diode voltage waveforms in the 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 lighting LED systems where the reverse-recovery loss in the rectifier diode is severe; Time Scale: 5 µs / div.

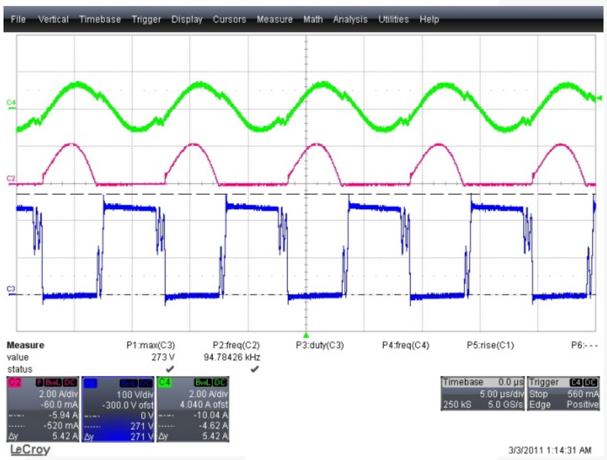


Figure 51. V_{PFC} = 400 V, P_O = 160 W; CH2: I_{LLC} (1 AV / div), CH3: V_{D201} (200 V / div), CH4: I_{D201} (2 A / div)

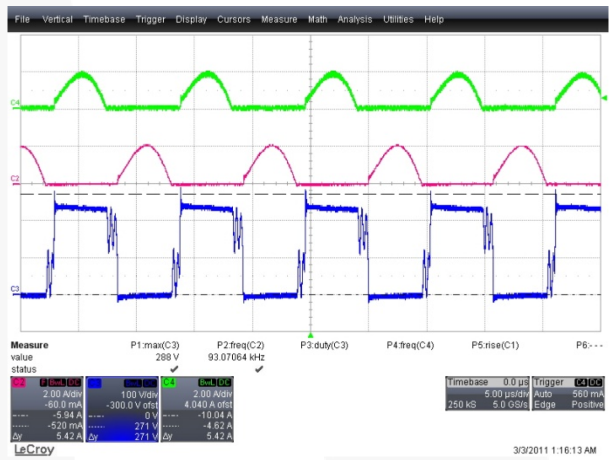


Figure 52. V_{PFC} = 400 V, P_O = 160 W; CH2: I_{D202} (2 A / div), CH3: V_{D201} (200 V / div), CH4: I_{D201} (2 A / div)

8.17. Operating Temperature

Figure 53 and Figure 54 show the temperature-checking results on the board in minimum and maximum input voltage condition at the rated LED load condition.

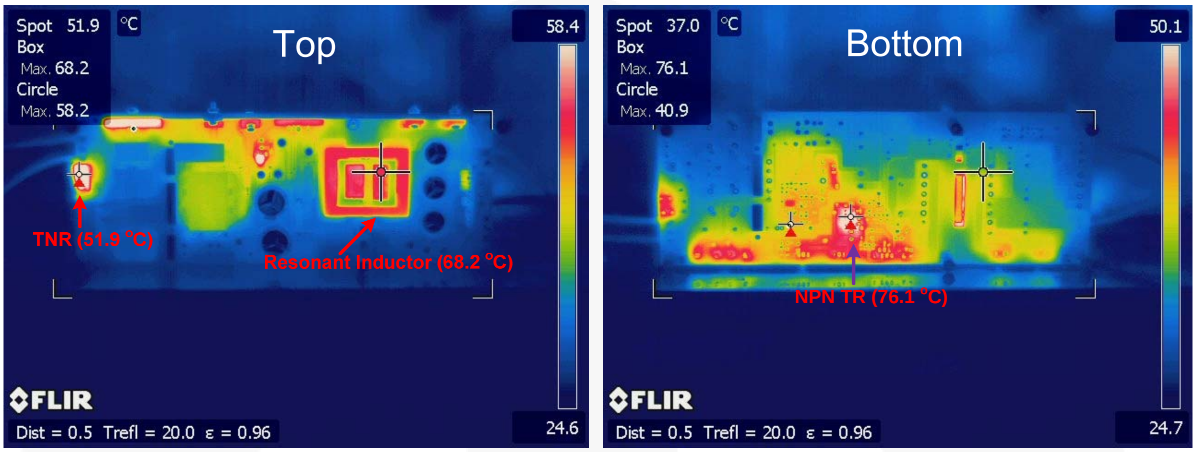


Figure 53. Board Temperature, V_{IN} = 90 V_{AC}

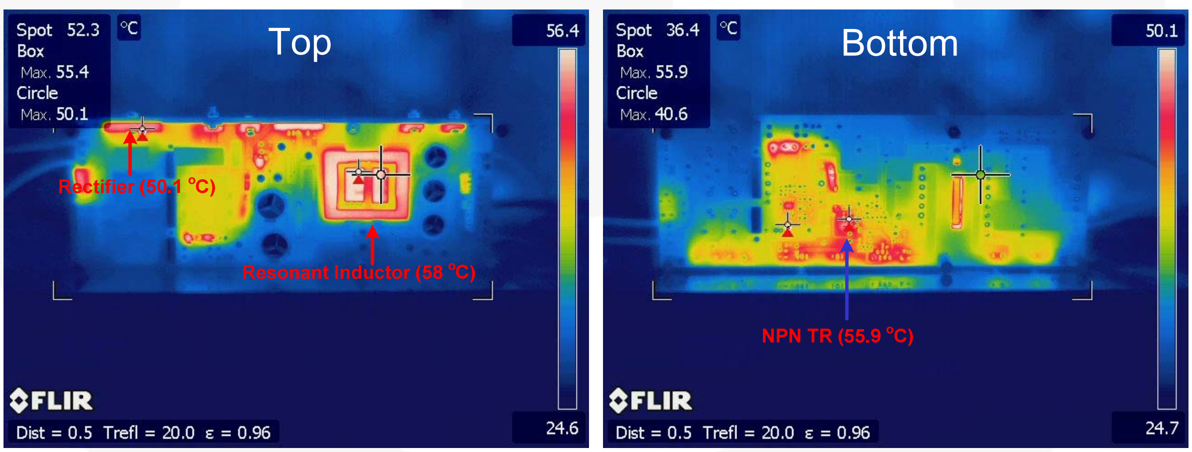


Figure 54. Board Temperature, V_{IN} = 265 V_{AC}

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

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