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User Guide for

FEBFLS2100XS1CH_L12U160A

160 W LED Driver at Universal Line

Featured Fairchild Products:
FL7930B, FLS2100XS

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

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Table of Contents

This user guide supports the evaluation kit for the FL7930B and FLS2100XS, orderable as FEBFLS2100XS1CH_L12U160A. It should be used in conjunction with the FL7930B and FLS2100XS 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 160 W LED ballast, which consists of a boost converter for Power-Factor-Correction (PFC), 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 1.4 A at 115 V_{MAX}. The power supply mainly utilizes Fairchild semiconductor components: FL7930B CRM PFC controller, FLS2100XS half-bridge LLC controller, LM2904 op-amplifier for LED current and voltage control, FDP22N50N 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 Pulse Width Modulator (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 Distortion (THD) 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 (ZCD)
- 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 Packaging

1.3. Internal Block Diagram

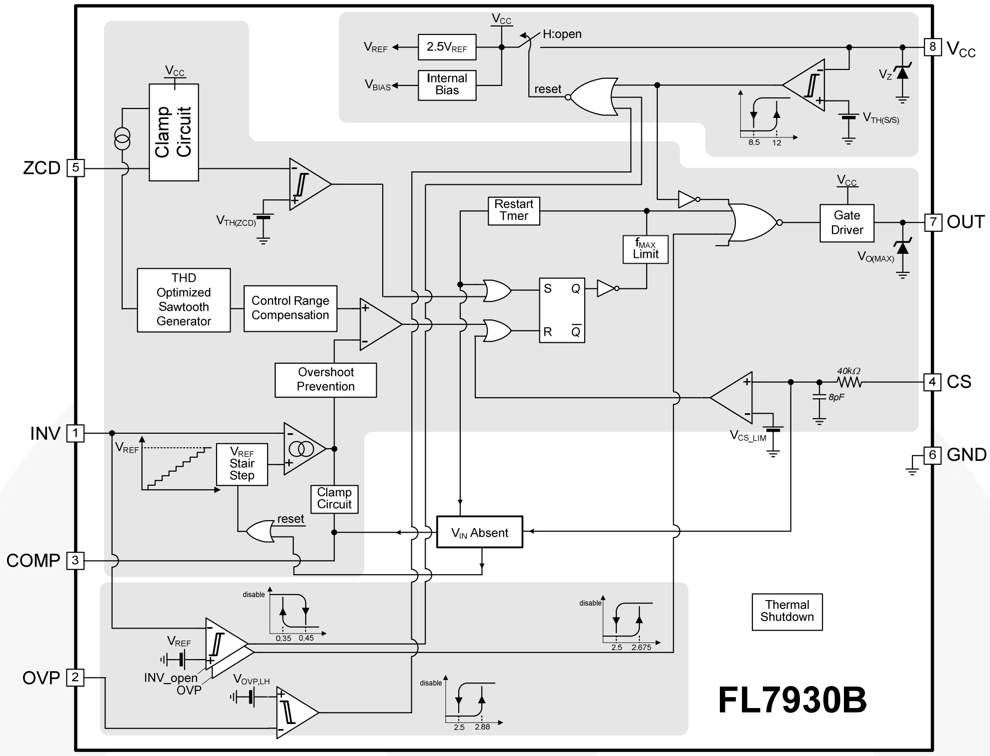

Figure 1. Block Diagram of FL7930B

1.4. General Description of FLS2100XS

The FLS2100XS 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, improves productivity, and improves performance. The FLS2100XS 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 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
- Protections: Over-Voltage Protection (OVP), Over-Current Protection (OCP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown (TSD)

1.6. Internal Block Diagram

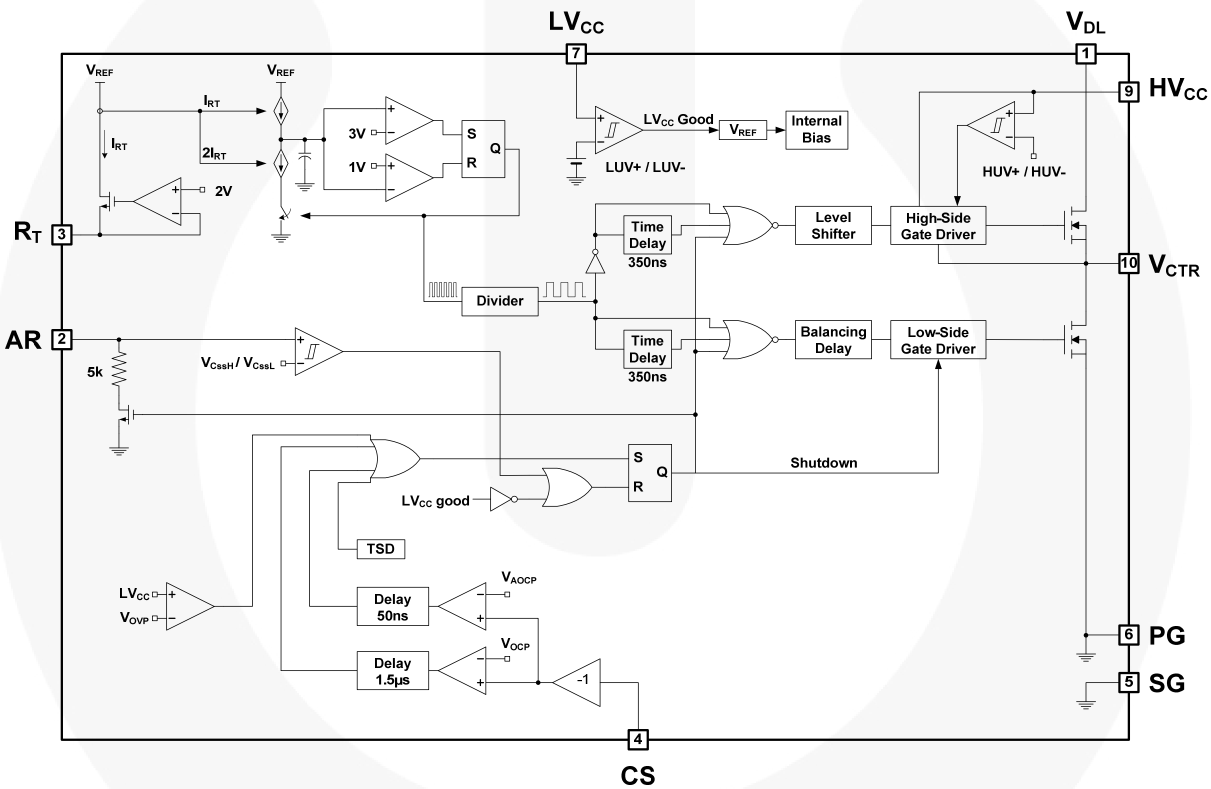

Figure 2. Block Diagram of FLS2100XS

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}	1.4 A	Nominal Output Current
		CC Deviation	< 0.64%	Line & Load Regulation
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 were measured under a condition where the board was enclosed in a case and external temperature was around 25°C.

3. Photographs

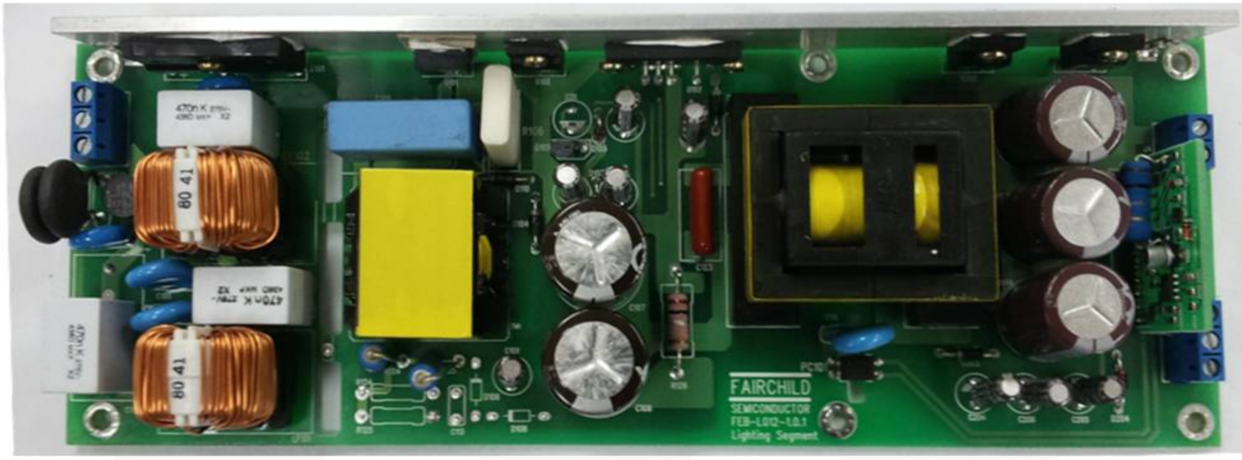

Figure 3. Top View (Dimensions: 225 mm (L) x 80 mm (W) x 30 mm (H))

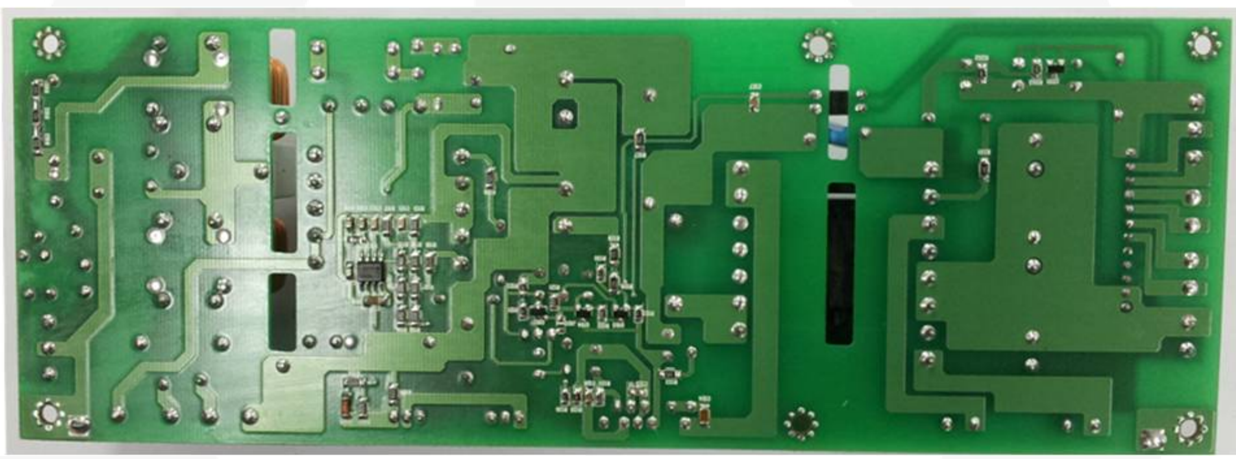

Figure 4. Bottom Views (Dimensions: 225 mm (L) x 80 mm (W) x 30 mm (H))

4. Printed Circuit Board

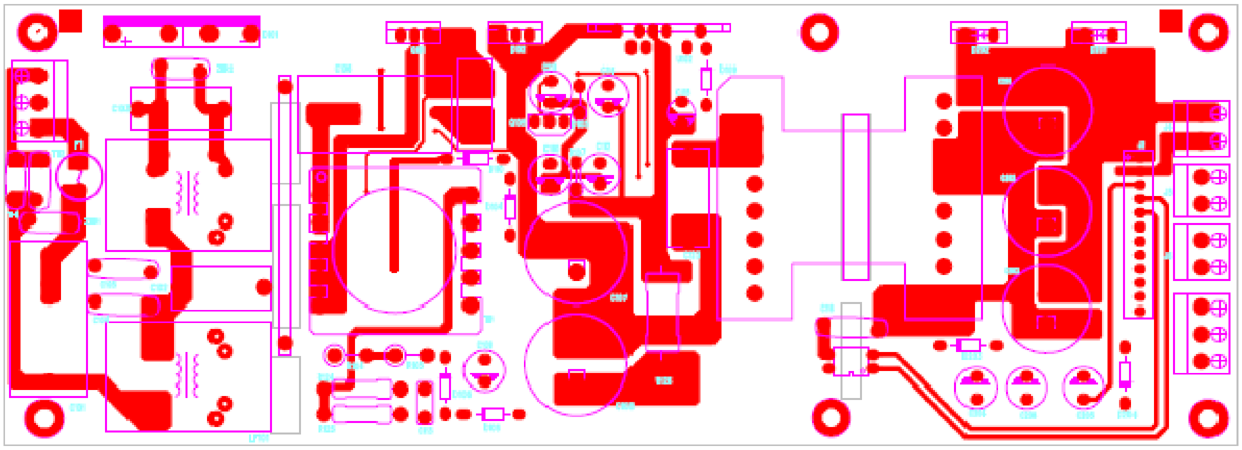

Figure 5. Top Pattern

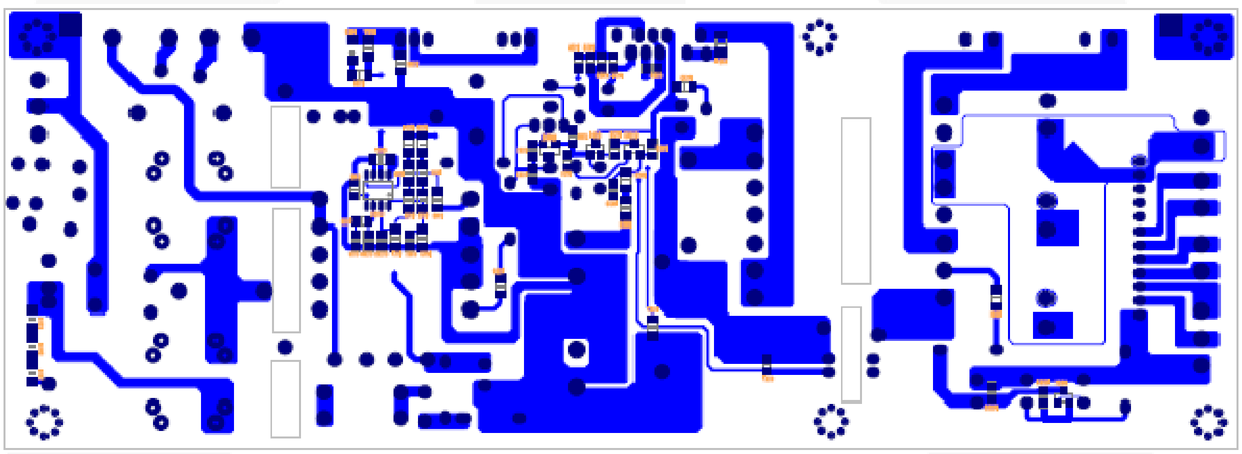

Figure 6. Bottom Pattern

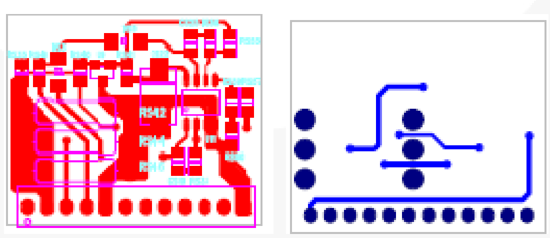

Figure 7. Top / Bottom Sub Board (CC / CV Contol Part) Pattern

5. Schematic

5.1. Power Factor Controller (PFC)

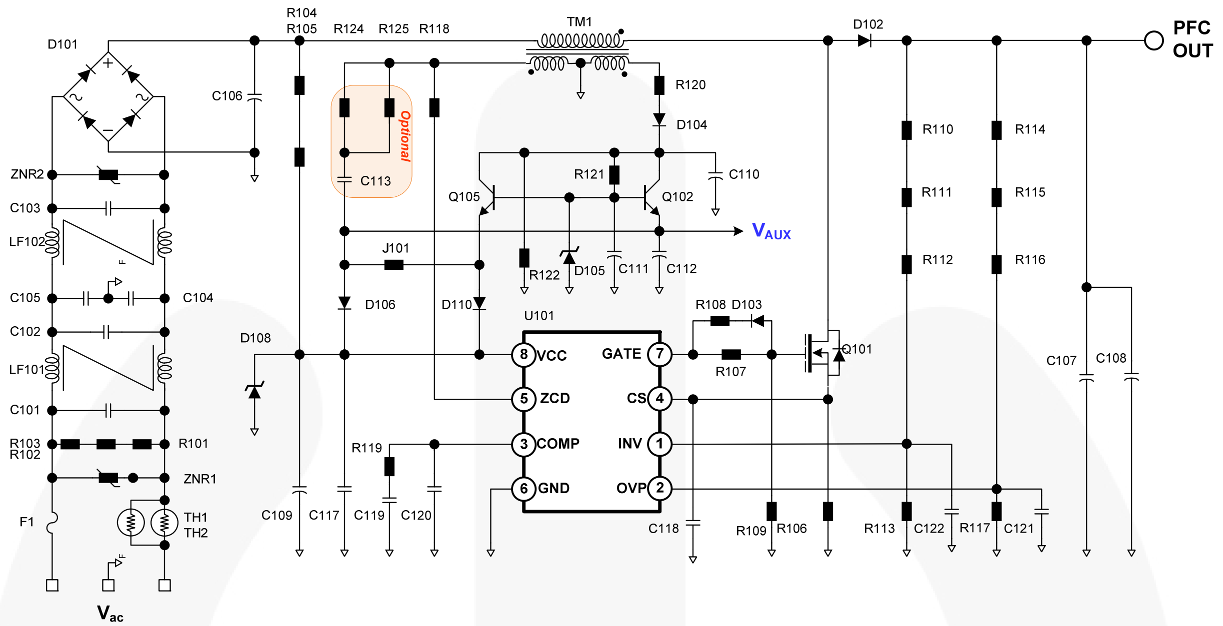

Figure 8. Schematic for PFC

5.2. DC-to-DC Converter and CC / CV Control

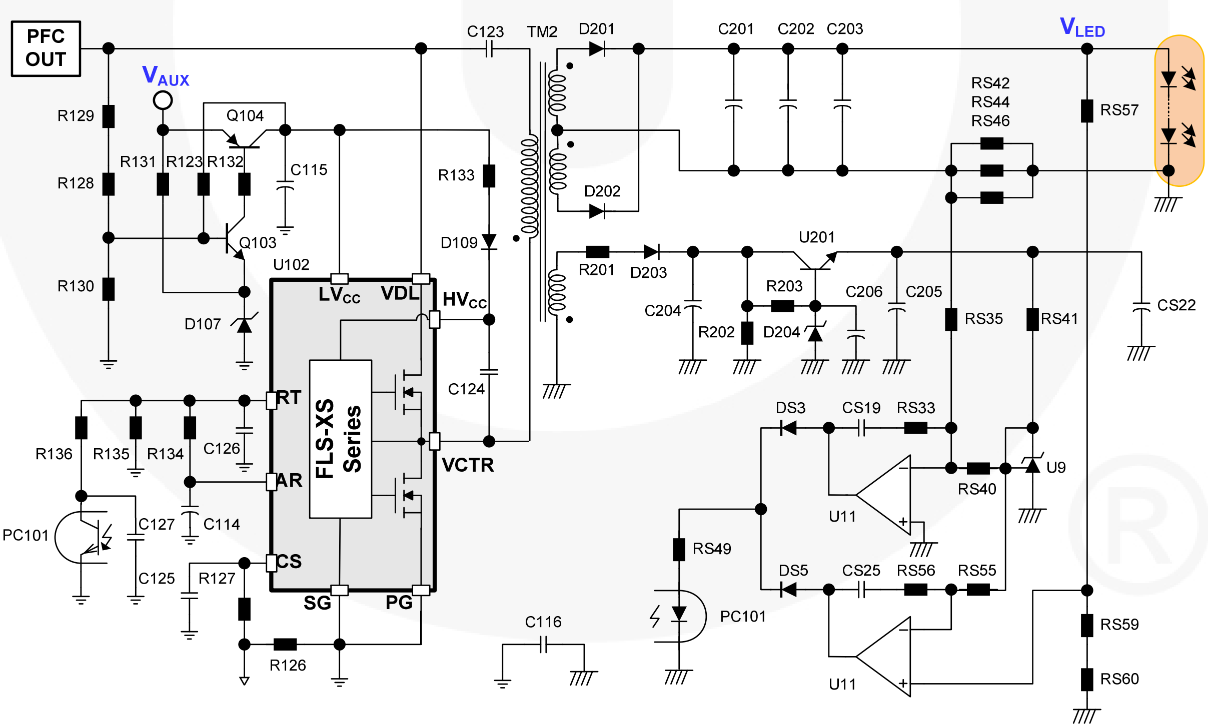

Figure 9. Schematic for DC-to-DC Converter and CC / CV Control

6. Bill of Materials

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

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 / 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	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
36	R101, R102, R103, R128, R129	1 MΩ-J	5	SMD Resistor, 3216
37	R104, R105	69 kΩ	2	2 W

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

Item No.	Part Reference	Value	Qty.	Description
38	R106	0.1 Ω	1	5 W
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	1 W
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 CC / CV Control

Item No.	Part Reference	Value	Qty.	Description
1	U9	KA431SLMF	1	SOT-23, Fairchild Semiconductor
2	U11	LM2904	1	8-SOP
3	RS33	47 kΩ-J	1	SMD Resistor, 3216
4	RS35	18 kΩ-J	1	SMD Resistor, 3216
5	RS40	100 kΩ-J	1	SMD Resistor, 3216
6	RS41	4.7 kΩ-J	1	SMD Resistor, 3216
7	RS49	1 kΩ-J	1	SMD Resistor, 3216
8	RS55	120 kΩ-J	1	SMD Resistor, 3216
9	RS56	47 kΩ-J	1	SMD Resistor, 3216
10	RS57	330 kΩ-J	1	SMD Resistor, 3216
11	RS59	6.8 kΩ-J	1	SMD Resistor, 3216
12	RS60	510 Ω-J	1	SMD Resistor, 2012
13	CS19	220 nF	1	Chip Capacitor
14	CS25	220 nF	1	Chip Capacitor
15	CS22	10 µF / 25 V	1	Electrolytic Capacitor
16	DS3,DS5	1N4148	2	LL-34, Fairchild Semiconductor
17	RS42	NC		No Connection
18	RS44	0.1 Ω	1	2 W
19	RS46	NC		No Connection

7. Transformer Design

7.1. PFC Transformer (TM1)

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

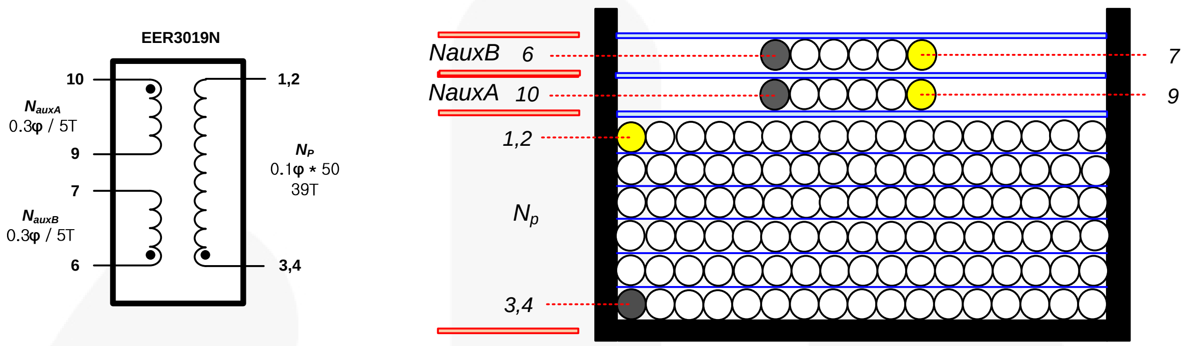

Figure 10. Transformer Specifications & Construction

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	Specification	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

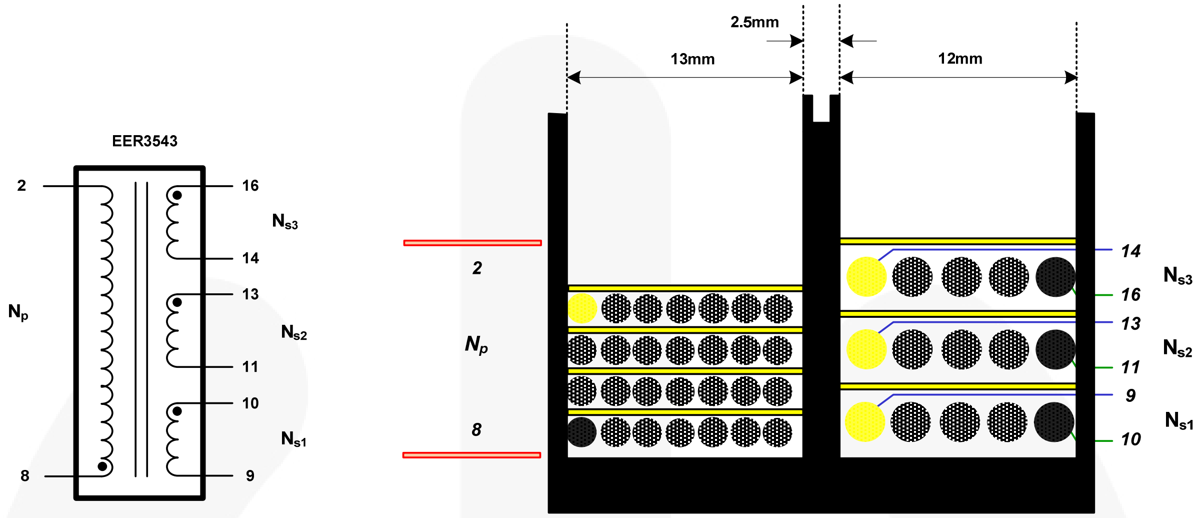

Figure 11. Transformer Specifications & Construction

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	19Ts	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 (L_R)	2 – 8	Maximum 135 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 12 shows at least 88% overall system efficiency is achievable with universal input condition at rated output LED load.

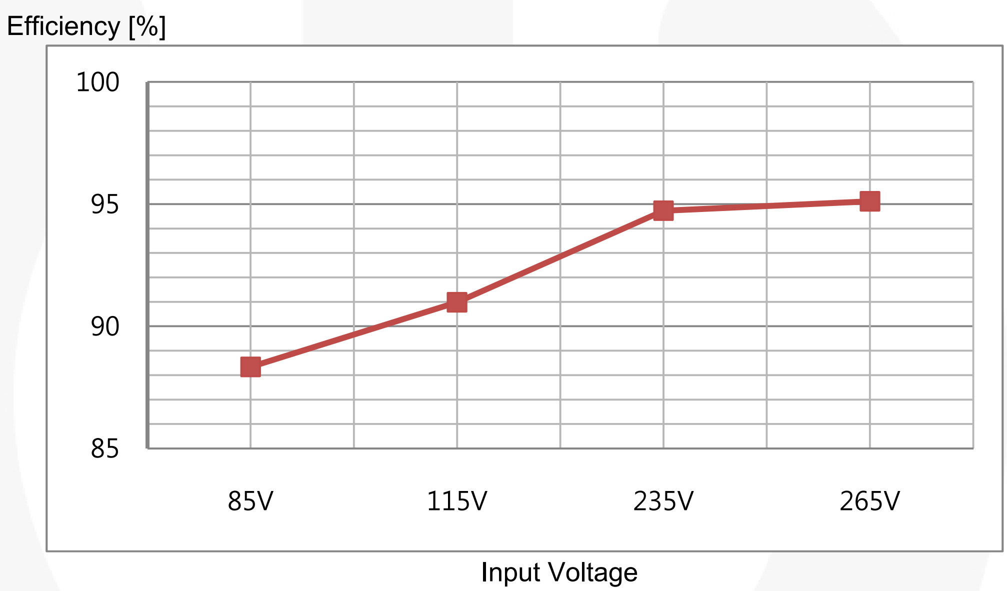

Figure 12. System Efficiency Curve

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 13 shows at least 95% power factor (PF) is achievable with universal input condition at rated output LED load.

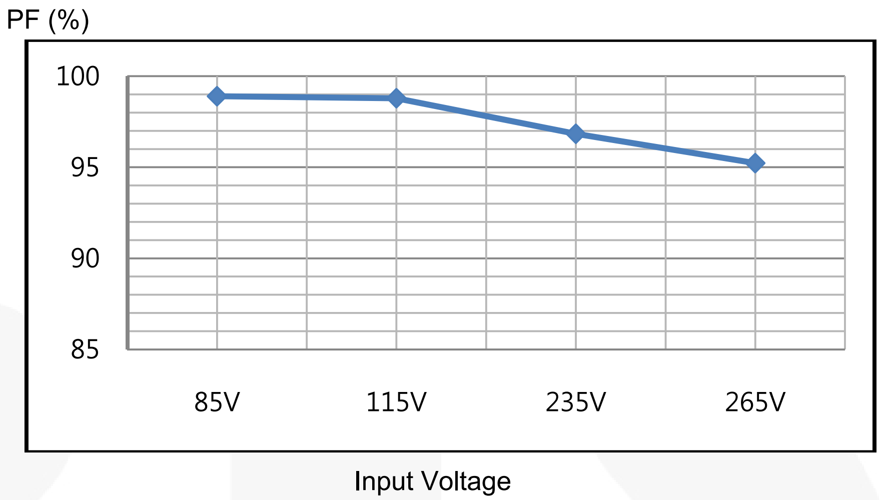

Figure 13. Power Factor Curve

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
THD [%]	14.15	14.60	5.94	6.26

Figure 14 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 application. This can meet the international regulation.

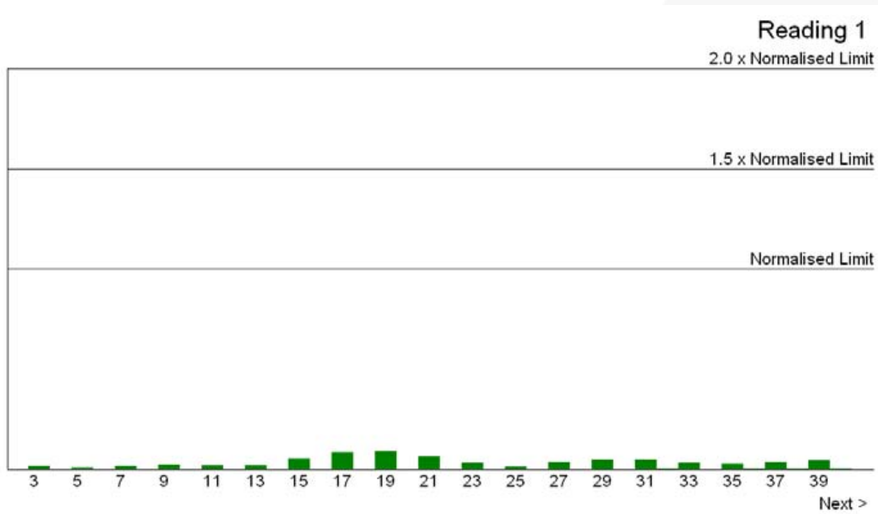

Figure 14. Total Harmonic Distortion (THD)

8.3. Constant Voltage and Current Regulation

Figure 15, Table 9, and Table 10 show the typical CC / CV performance on board; displaying very stable CC performance in wide input range.

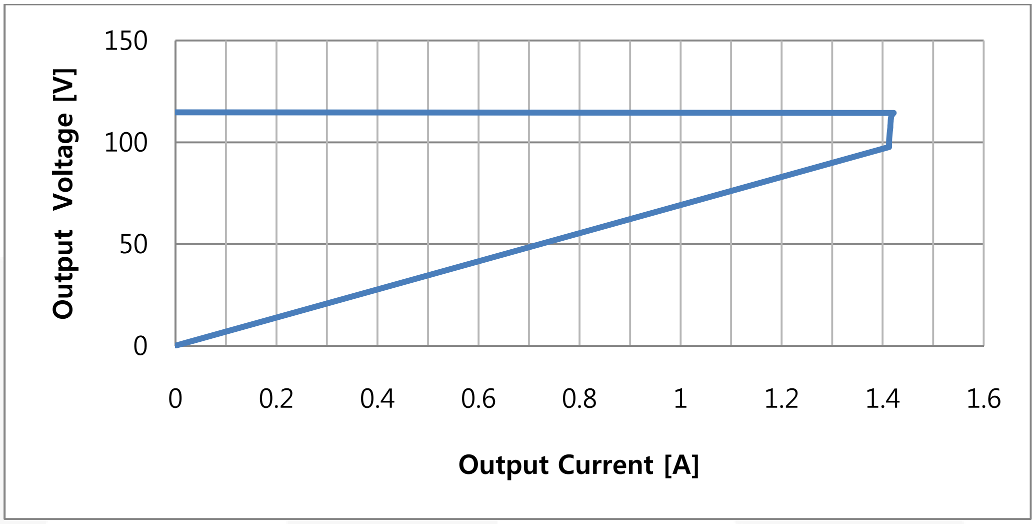

Figure 15. Constant Voltage and Current Regulation, Measured by E-Load [CR Mode]

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	**Maximum Output**	114.68 V	1.42 A
	Minimum 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 16 and Figure 17 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 90 V_{AC} and 265 V_{AC} condition when the AC input power switch is in turn-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.

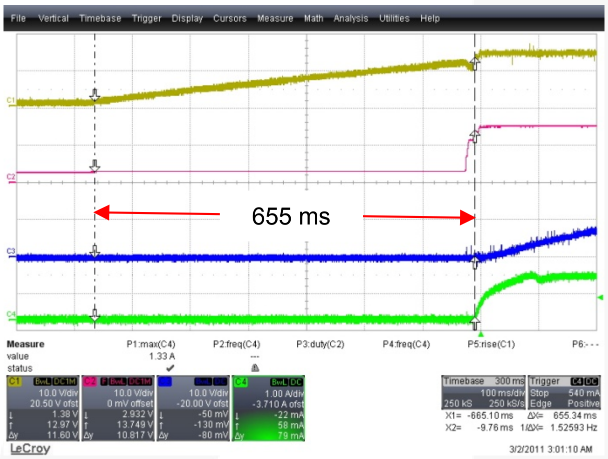

Figure 16. V_{IN} = 95 V_{AC}

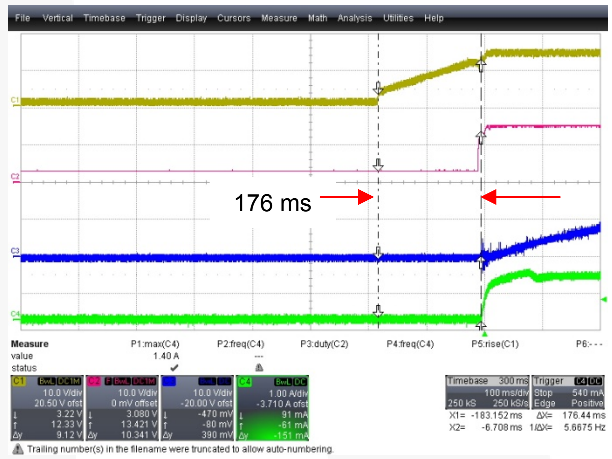

Figure 17. V_{IN} = 265 V_{AC}

8.5. Startup Performance of PFC

Figure 18 and Figure 19 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} (10 V / div), CH2: V_{PFC} (100 V / div), time scale: 200 ms / div.

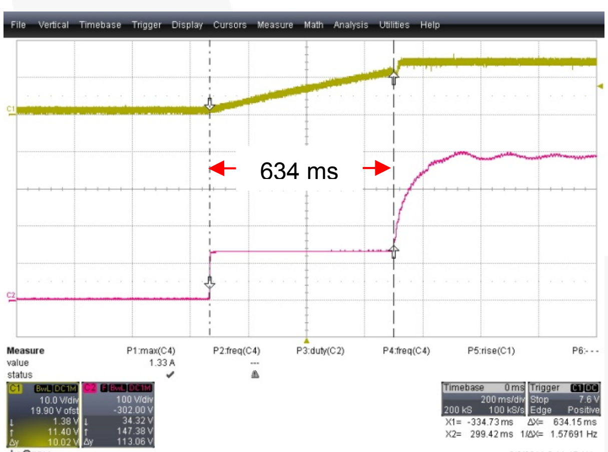

Figure 18. V_{IN} = 95 V_{AC}

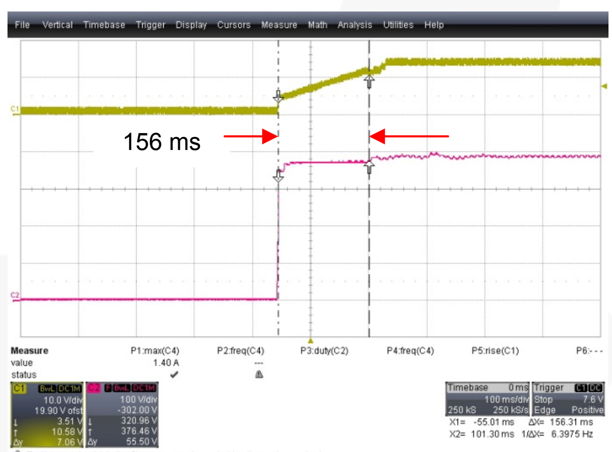

Figure 19. V_{IN} = 265 V_{AC}

8.6. Soft-Start Performance of PFC

Figure 20 through Figure 23 show the soft-start performance with output power at 160 W. Measured PFC output voltage reaches from 396.8 V to 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.

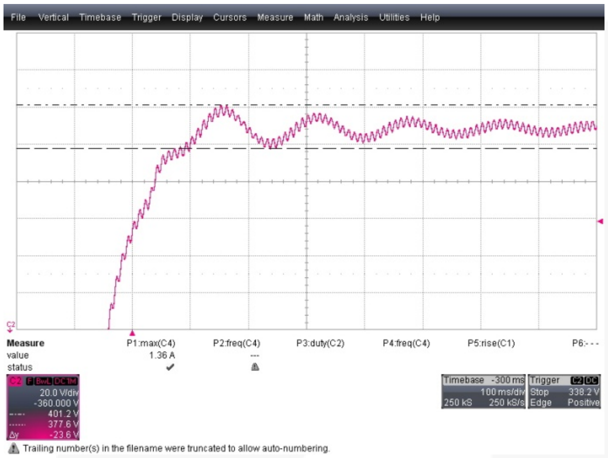

Figure 20. V_{IN} = 95 V_{AC}

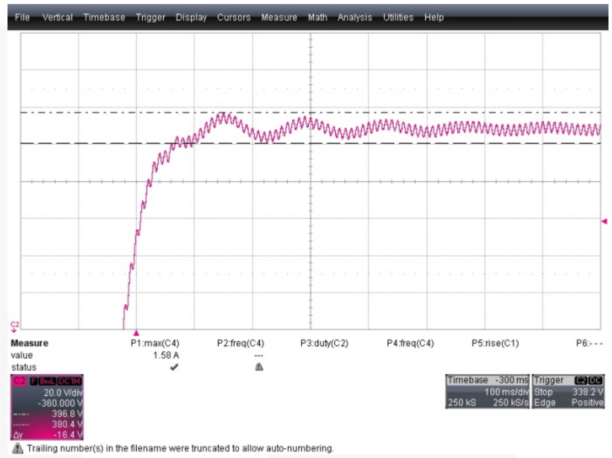

Figure 21. V_{IN} = 115 V_{AC}

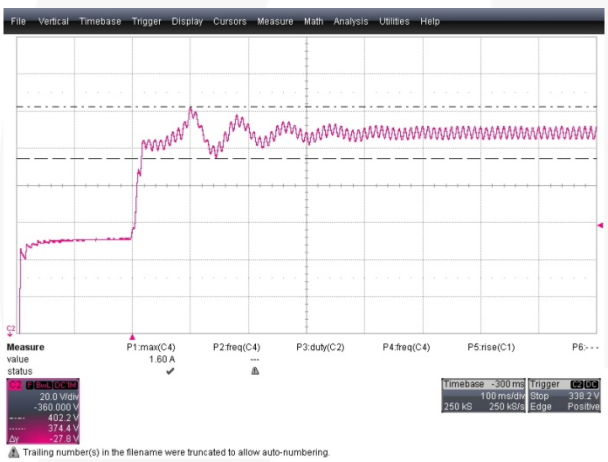

Figure 22. V_{IN} = 235 V_{AC}

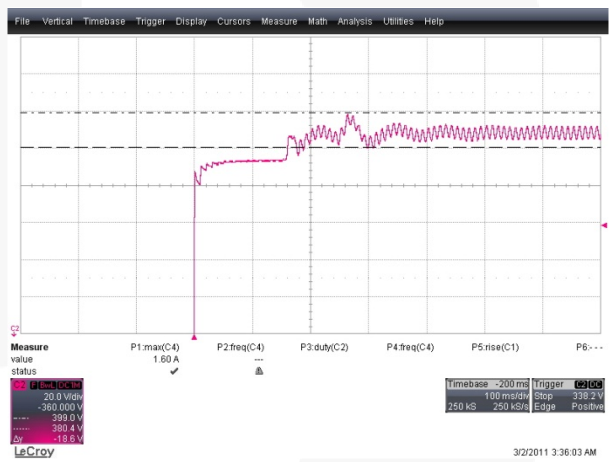

Figure 23. V_{IN} = 265 V_{AC}

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

Figure 24 through Figure 27 show the startup waveforms when input voltage source supplied first, then the V_{CC_LLC} of 16 V is applied from the auxiliary winding of the 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.

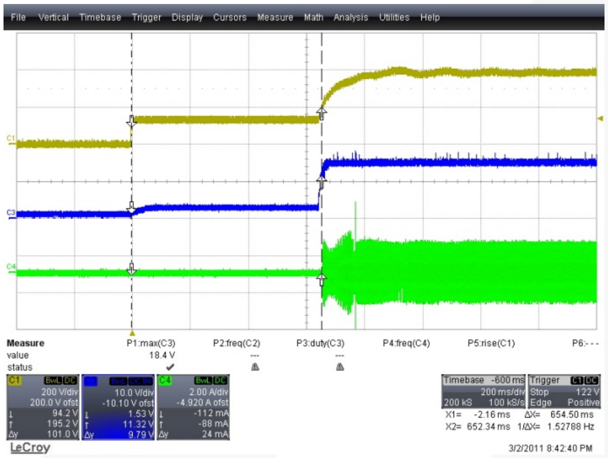

Figure 24. V_{PFC} = 400 V, P_O = 160 W

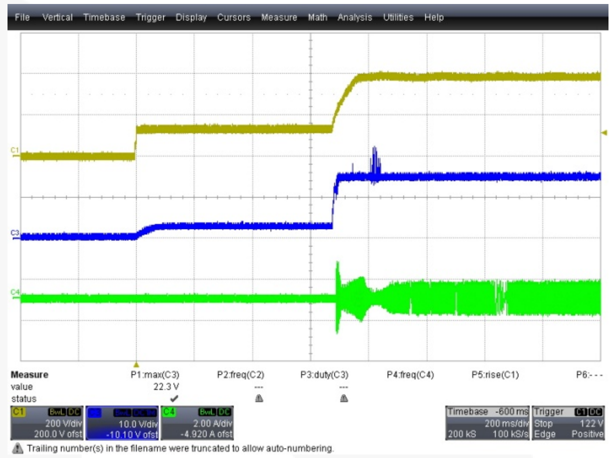

Figure 25. V_{PFC} = 400 V, P_O = 7 W

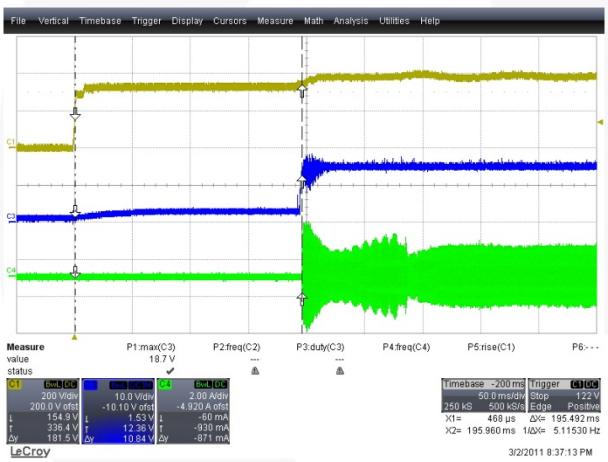

Figure 26. V_{PFC} = 400 V, P_O = 160 W

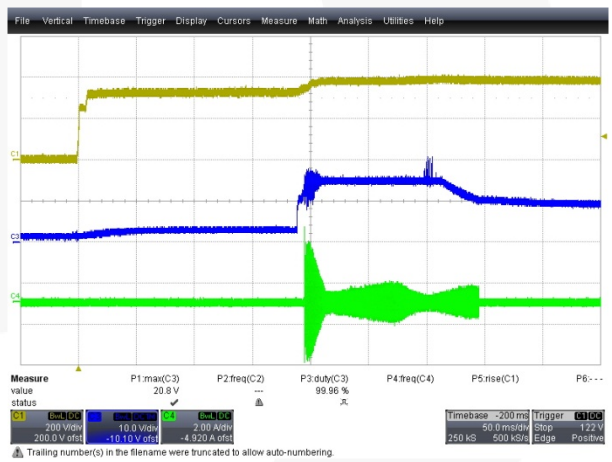

Figure 27. V_{PFC} = 400 V, P_O = 7 W

Figure 28 and Figure 29 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.

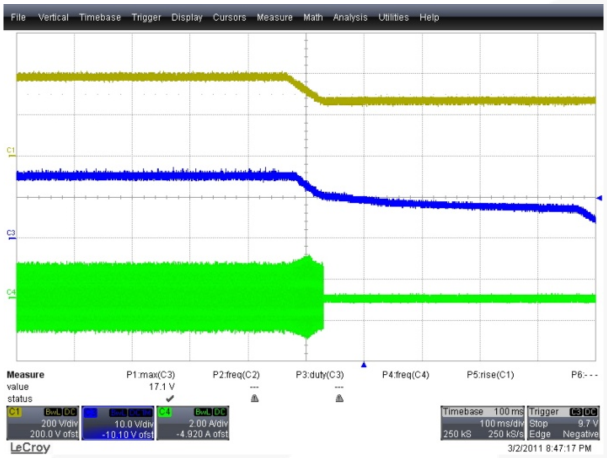

Figure 28. V_{PFC} = 400 V, P_O = 160 W

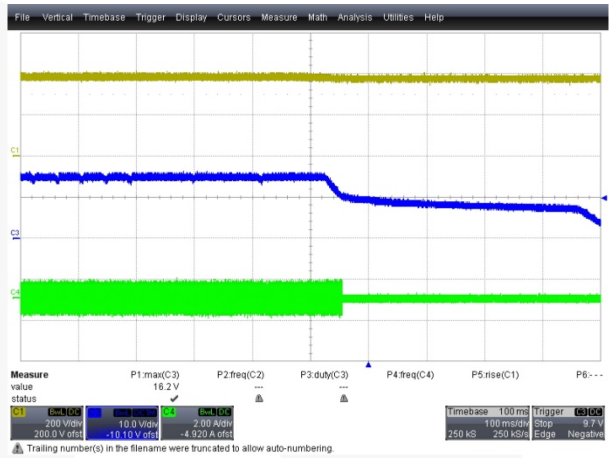

Figure 29. V_{PFC} = 400 V, P_O = 10 W

8.8. AC Input Current

Figure 30 through Figure 33 show the AC input current waveforms at the rated output power of 160 W and input voltage 95 V_{AC}, and 265 V_{AC}; CH4: I_{AC} (1 A / div), time scale: 10 ms / div.

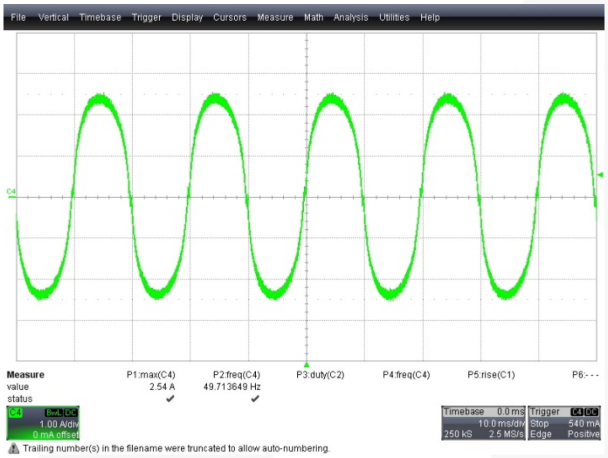

Figure 30. V_{IN} = 95 V_{AC}

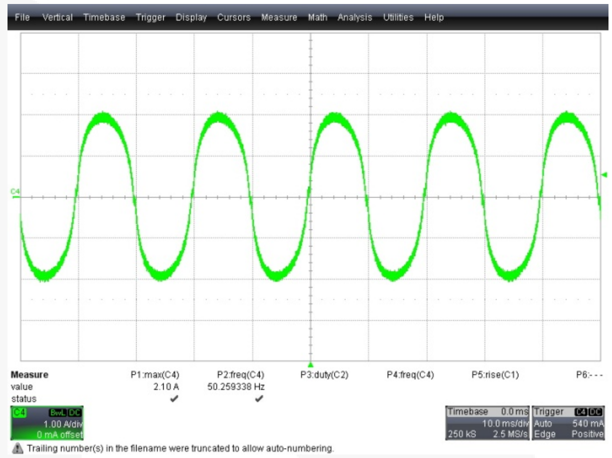

Figure 31. V_{IN} = 115 V_{AC}

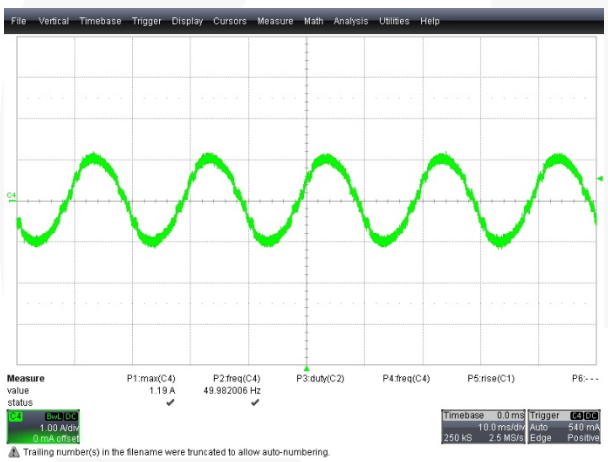

Figure 32. V_{IN} = 235 V_{AC}

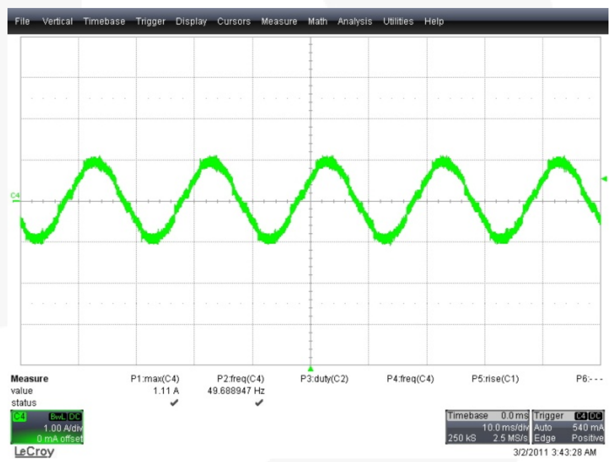

Figure 33. V_{IN} = 265 V_{AC}

8.9. Normal Operation of PFC

Figure 34 through Figure 37 show the AC input and MOSFET drain current waveforms at the rated output power of 160 W and input voltage of 95 V_{AC}, and 265 V_{AC}; CH2: I_{AC} (2 A / div), CH4: I_D (500 mA / div), time scale: 5 ms / div.

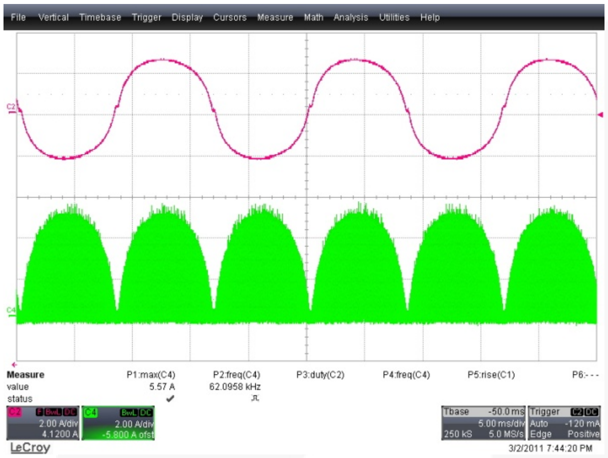

Figure 34. V_{IN} = 95 V_{AC}

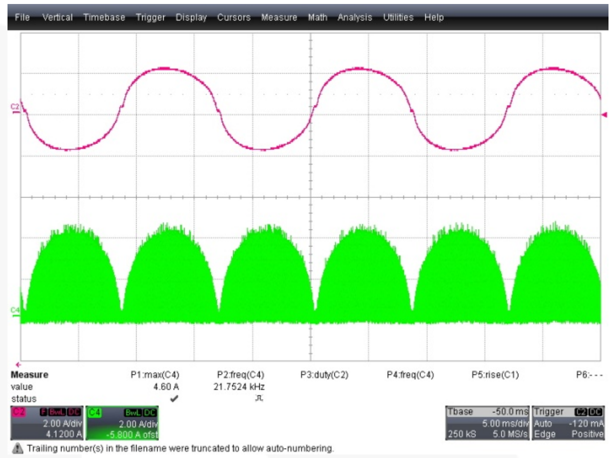

Figure 35. V_{IN} = 115 V_{AC}

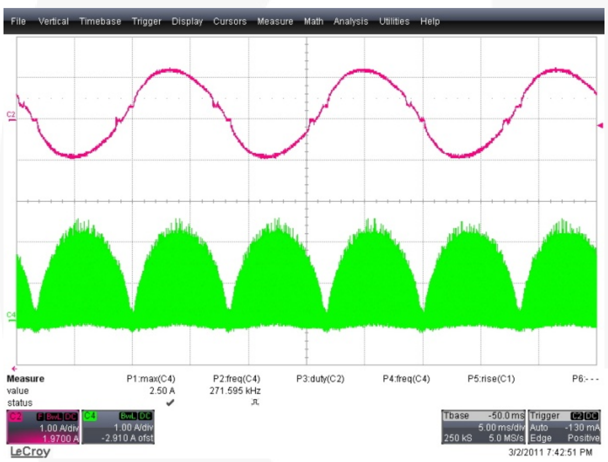

Figure 36. V_{IN} = 235 V_{AC}

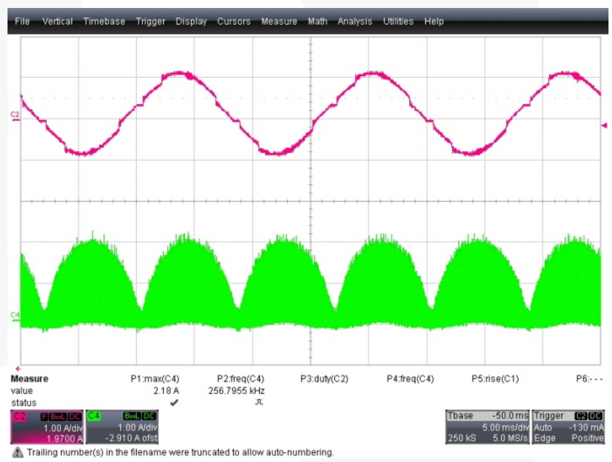

Figure 37. V_{IN} = 265 V_{AC}

8.10. Dynamic Performance of PFC

Figure 38 and Figure 39 show the PFC output voltage changed 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 the 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.

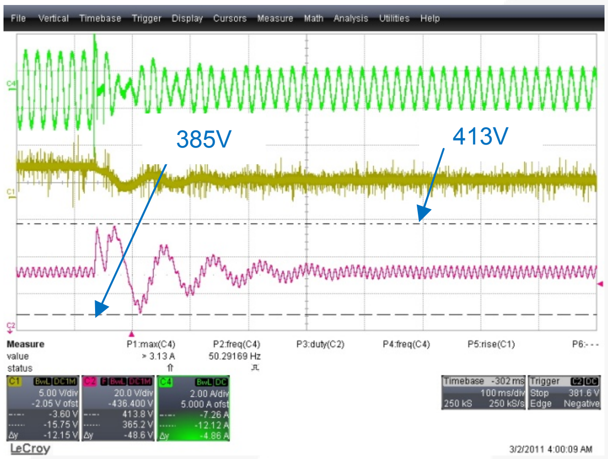

Figure 38. V_{IN} = 115 V_{AC} → 235 V_{AC}

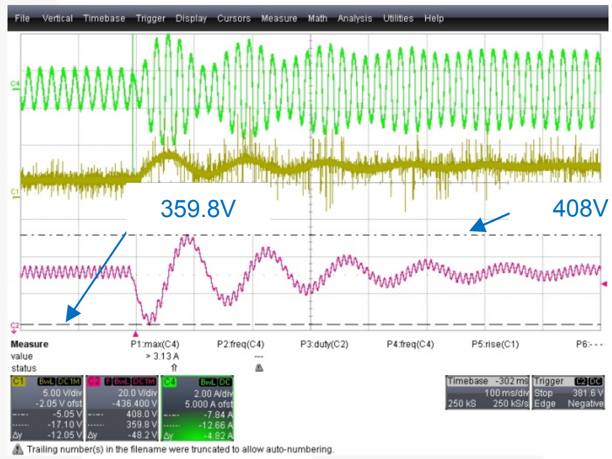

Figure 39. V_{IN} = 235 V_{AC} → 115 V_{AC}

Figure 40 and Figure 41 show the PFC output voltage changed about 50 V when output power changes from 30 W to 160 W and from 160 W to 30 W at input voltage 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.

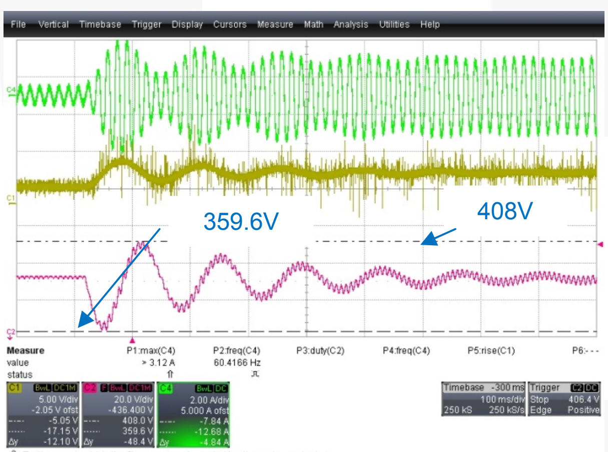

Figure 40. V_{IN} = 115 V_{AC}, P_O = 30 W → 160 W

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

Figure 42 and Figure 43 show the PFC output voltage changed about 40 V when output power changes from 30 W to 160 W and from 160 W to 30 W at input voltage 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.

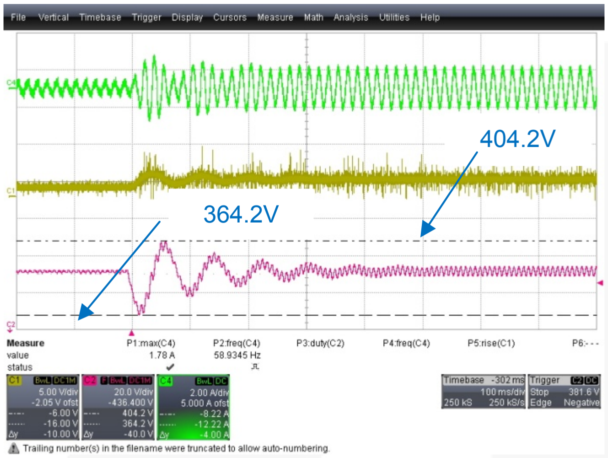

Figure 42. V_{IN} = 235 V_{AC}, P_O = 30 W → 160 W

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

8.11. Dynamic Performance of DC-to-DC Converter

Figure 44 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.

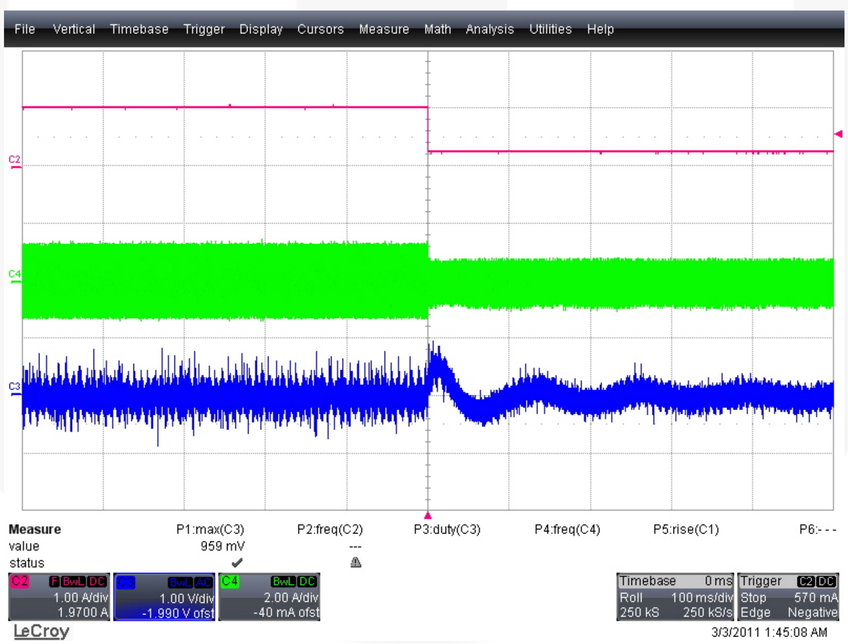

Figure 44. V_{IN} = 95 V_{AC}, P_O = 160 W → 50 W

8.12. Dynamic Performance of CC / CV Control

Figure 45 shows the output load current and output voltage of CC op-amp waveforms when output load is step changed; CH1:V_{OPAMP_CC} (2 V / div), CH2: I_{LOAD} (500 mA / div), time scale: 500 ms / div.

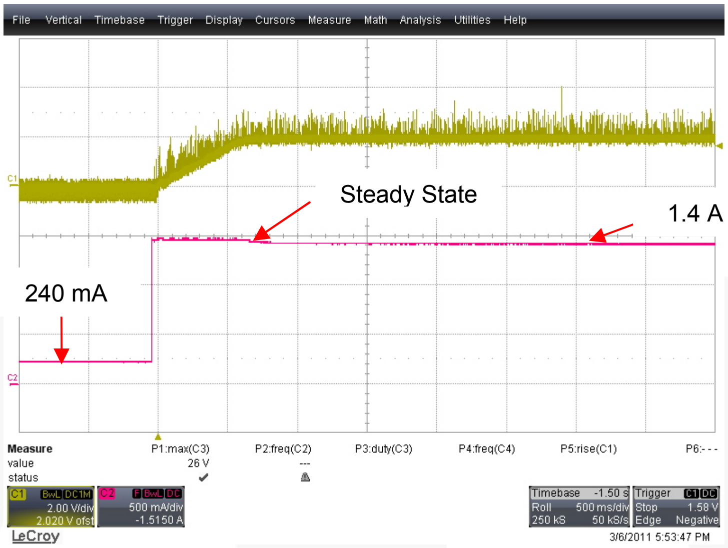

Figure 45. V_{IN} = 235 V_{AC}, I_O = 0.24 A → 1.4 A

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

Figure 46 shows the hold-up time performance, when the AC power source is disconnected. The output voltage is maintained for about 34 ms and slowly decreased until FLS2100XS 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.

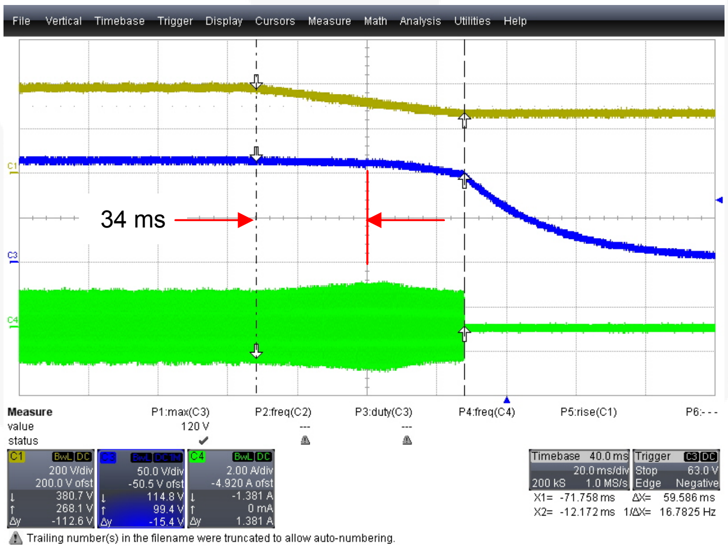

Figure 46. V_{PFC} = 400 V, P_O = 160 W

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

Figure 47 and Figure 48 show the resonant inductor current, low-side MOSFET current, and low-side MOSFET voltage waveforms in the 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.

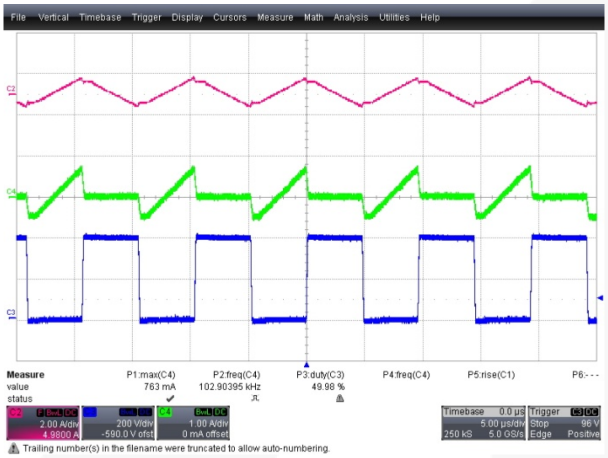

Figure 47. V_{PFC} = 400 V, P_O = 3 W

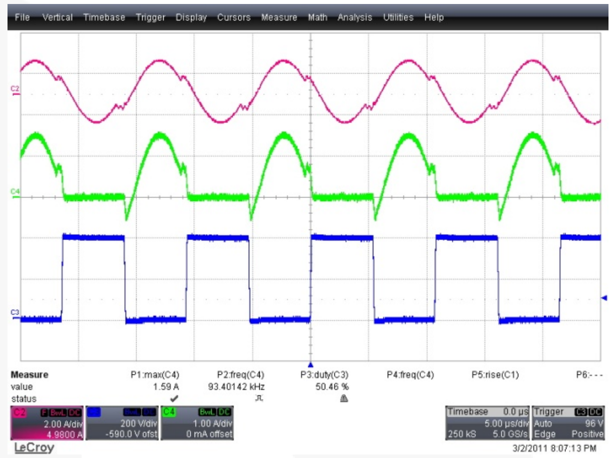

Figure 48. V_{PFC} = 400 V, P_O = 160 W

8.15. Secondary-Side Rectifier Diode Voltage and Current

Figure 49 and Figure 50 show the resonant inductor current in the primary-side, rectifier diode current, and rectifier diode voltage waveforms in secondary-side at full-load and light-load; time scale: 5µs / div.

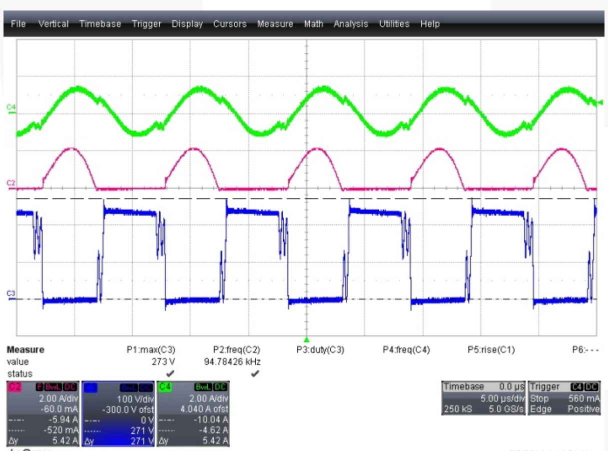

Figure 49. V_{PFC} = 400 V, P_O = 160 W ; CH2: I_{LLC} (1A V / div), CH3: V_{D201} (200 V / div), CH4: I_{D201} (2 A / div)

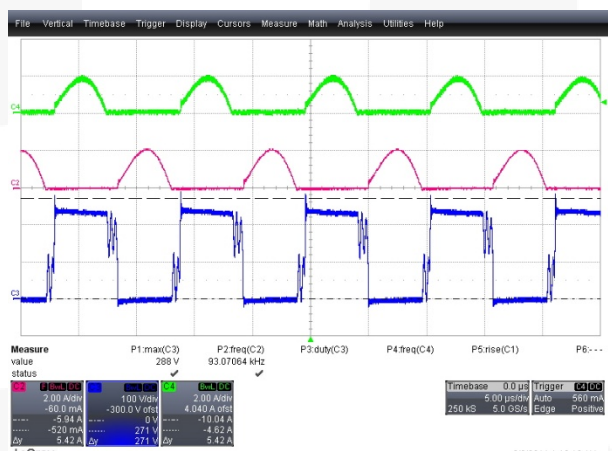

Figure 50. V_{PFC} = 400 V, P_O = 160 W ; CH2: I_{D202} (2 A / div), CH3: V_{D201} (200 V / div), CH4: I_{D201} (2 A / div)

8.16. Operating Temperature

Figure 51 and Figure 52 show the temperature-checking results on the board in minimum and maximum input voltage conditions at the rated LED load condition.

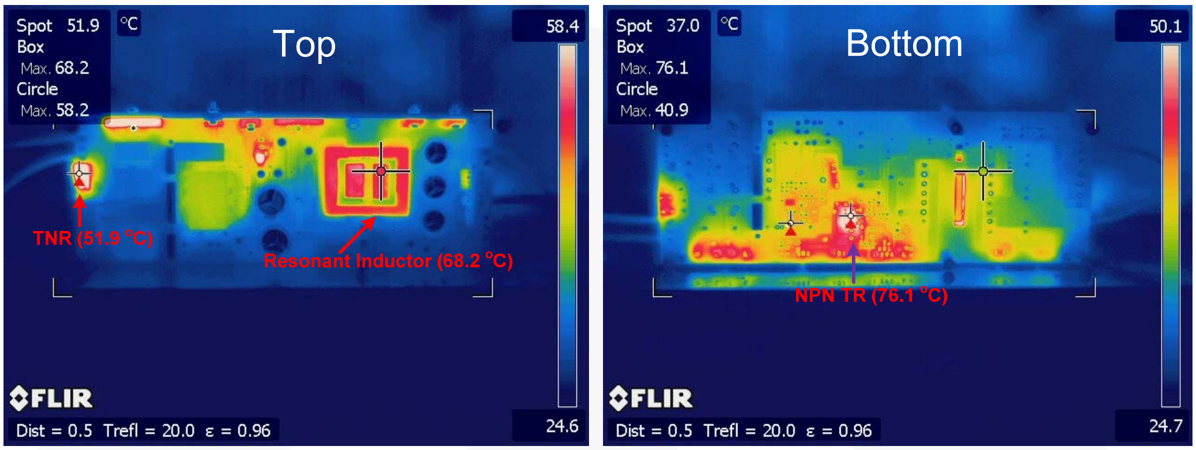

Figure 51. Board Temperature, V_{IN} = 90 V_{AC}

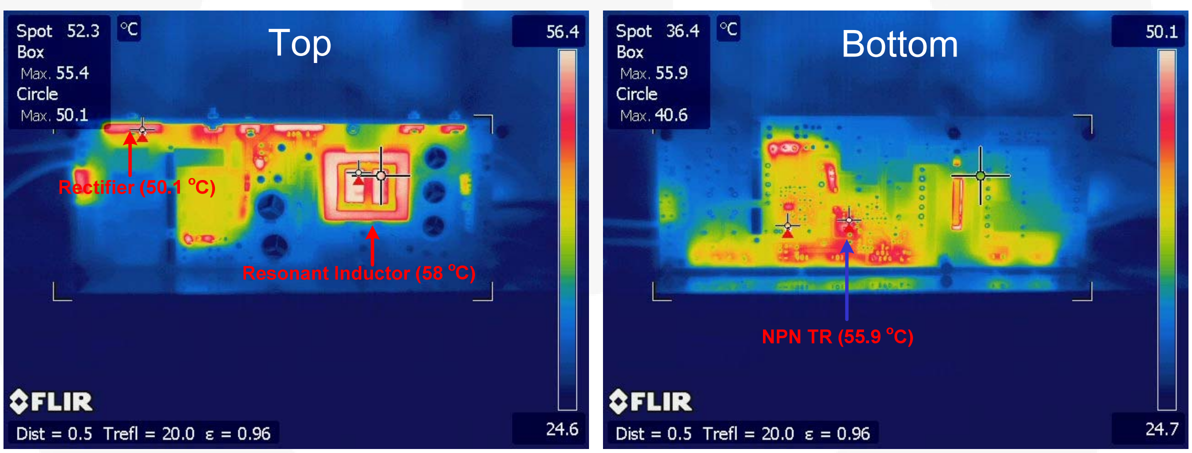

Figure 52. Board Temperature, V_{IN} = 265 V_{AC}

9. Revision History

Rev.	Date	Description
1.0.0	Nov. 2012	Initial Release

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