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TND6255/D

50 W Constant Voltage Output Driver

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REFERENCE DESIGN

Introduction

This document describes a high Power factor CV regulation solution with fast dynamic response. The input voltage range of the reference design is 90 V_{RMS} ~ 305 V_{RMS} and 50 V is regulated for secondary stage and 3.3 V is regulated for MCU power source at output terminal. Also in this document is a general description of the FL7740, the power supply solution specification, schematic, bill of materials, and typical operating characteristics.

Table 1.

Description		Symbol	Value	Comments
Input Voltage		$V_{IN.MIN}$	90 V_{AC}	Minimum AC Input Voltage
		$V_{IN.MAX}$	305 V_{AC}	Maximum AC Input Voltage
Output	Current	$I_{OUT.MIN}$	0 mA	Minimum Output Current
		$I_{OUT.NOMINAL}$	1000 mA	Nominal Output Current
	Voltage	$V_{OUT.NOMINAL}$	50 V	Nominal Output voltage
		CV Deviation Without PFO	< ±3.1%	Line Input Voltage Change: 90~305 V_{AC}
			< ±3%	Output Current Change: 0~1000 mA
		CV Deviation With PFO	< ±2.7%	Line Input Voltage Change: 90~305 V_{AC}
			< ±2.9%	Output Current Change: 0~1000 mA
Efficiency		120 VAC	89.0%	120 V_{AC} Input Voltage With 100 % load condition
		277 VAC	90.8%	277 V_{AC} Input Voltage With 100 % load condition
PF/THD		120 VAC	0.99 / 6.53%	120 V_{AC} Input Voltage With **25 % load condition**
		277 VAC	0.96 / 15.4%	277 V_{AC} Input Voltage With **50 % load condition**
Standby Power		120 VAC	270 mW	120 V_{AC} Input Voltage With 3.3 V/10 mA MCU winding load
		277 VAC	300 mW	120 V_{AC} Input Voltage With 3.3 V/10 mA MCU winding load

Key Features

High Performance

- Wide Universal Input Range (90 ~ 305 V_{AC})
- Precise CV Regulation in the Steady State : < ±3%
- CV Regulation in the Load Transient: < ±10%
- Overshoot−less Fast HV Start Up Time (< 0.3 sec)
- Standby Power < 300 mW with 10 mW Load Condition at MCU Winding
- PF Higher than 0.9 at High−line and Half Load by PF Optimizer
- Pulse−by−pulse Current Limit
- Output Short Protection
- Output Over Voltage Protection
- Output Diode Short Protection
- Sensing Resistor Short & Open Protection
- Over Load Protection

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SCHEMATIC

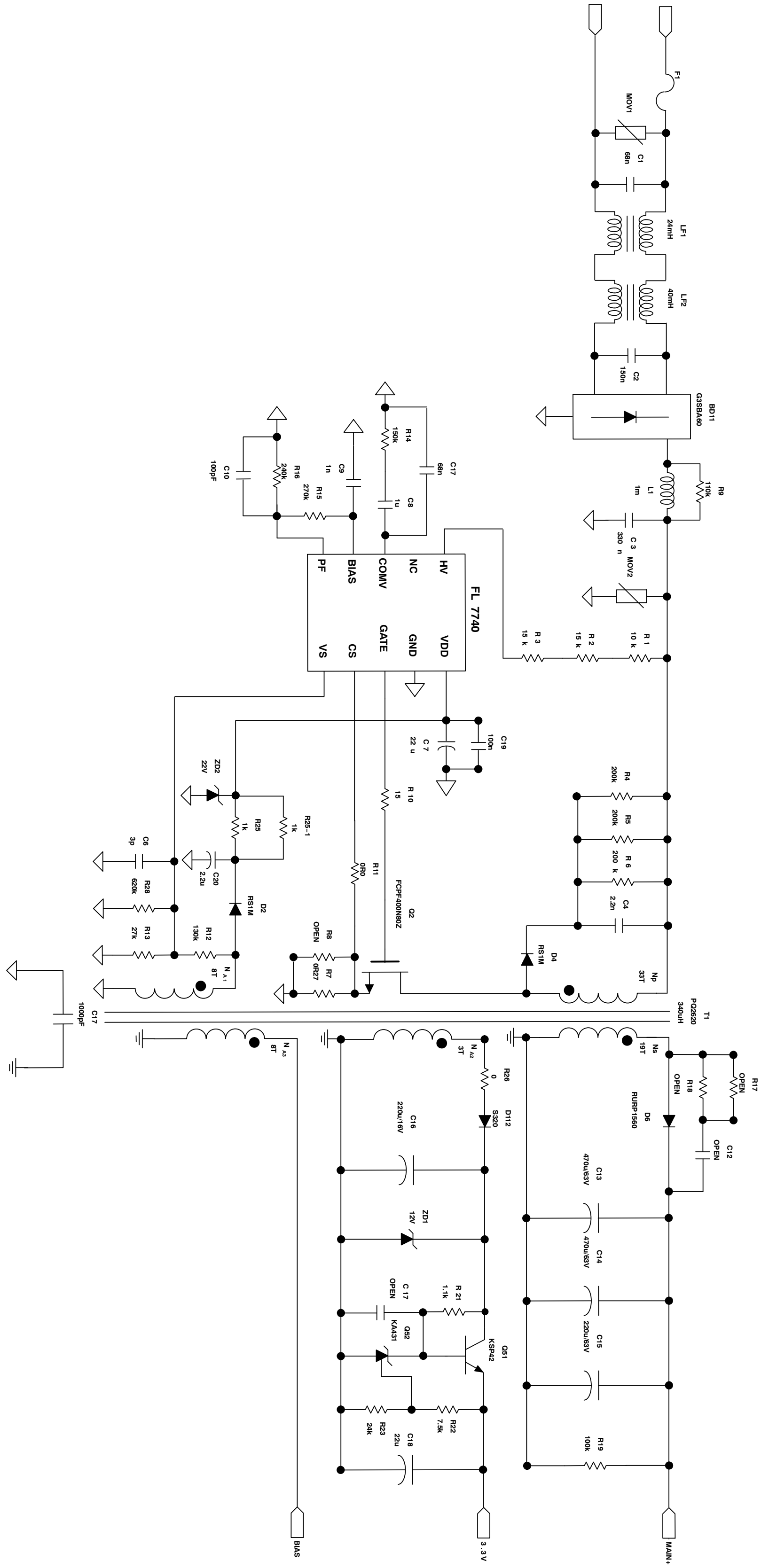

Figure 1. Schematic

Table 2. BILL OF MATERIAL (BOM)

Item No.	Part Reference	Part Number	Description	Manufacturer
1	F1	SS−5−2A	2 A/250 V Fuse	Bussmann
2	MOV1	SVC471D−10A	10D471 Metal Oxide Varistor	Samwha
3	MOV2	SVC471D−7A	7D471 Metal Oxide Varistor	Samwha
4	BD1	G3SBA60	4 A / 600 V, Bridge Diode	Vishay
5	R1	RC1206 JR−07103RL	10 kΩ SMD Resistor 3216 F 1/4W	Yageo
6	R2,R3	RC1206 JR−07153RL	15 kΩ SMD Resistor 3216 F 1/4W	Yageo
7	R4,R5,R6	RC1206 JR−07204RL	200 kΩ SMD Resistor 3216 F 1/4W	Yageo
8	R7	MOR 1W TC R27	Metal Oxide Film Resistor RSD Type F 0.27 Ω/1W R−Forming	ABC
9	R9	RC1206 JR−07114RL	110 kΩ SMD Resistor 3216 F 1/4W	Yageo
10	R10	RC0805 JR−0715RL	15 Ω SMD Resistor 2012 F 1/4W	Yageo
11	R11	RC0805 JR−070R0RL	0R0 Ω SMD Resistor 2012 F 1/4W	Yageo
12	R12	RC0805 JR−07134RL	130 kΩ SMD Resistor 2012 F 1/4W	Yageo
13	R13	RC0805 JR−07273RL	27 kΩ SMD Resistor 2012 F 1/4W	Yageo
14	R14	RC0805 JR−07154RL	150 kΩ SMD Resistor 2012 F 1/4W	Yageo
15	R15	RC0805 JR−07274RL	270 kΩ SMD Resistor 2012 F 1/4W	Yageo
16	R16	RC0805 JR−07244RL	240 kΩ SMD Resistor 2012 F 1/4W	Yageo
17	R19	RC1206 JR−07104RL	100 kΩ SMD Resistor 3216 F 1/4W	Yageo
18	R21	RC1206 JR−07112RL	1.1 kΩ SMD Resistor 3216 F 1/4W	Yageo
19	R22	RC0805 JR−07752RL	7.5 kΩ SMD Resistor 2012 F 1/4W	Yageo
20	R23	RC0805 JR−07243RL	24 kΩ SMD Resistor 2012 F 1/4W	Yageo
21	R25	MOR 1W TC R511	Metal Oxide Film Resistor RSD Type F 1kΩ/1W R−Forming	Yageo
22	R25−1	MOR 1W TC R511	Metal Oxide Film Resistor RSD Type F 1kΩ/1W R−Forming	Yageo
23	R26	RC0805 JR−070R0RL	0 Ω SMD Resistor 2012 F 1/4W	Yageo
24	R28	RC0805 JR−07624RL	620 kΩ SMD Resistor 2012 F 1/4W	Yageo
25	C1	MPE 400V683	MPE 68 nF/400 V	Sungho Electronics
26	C2	MPE 400V104	MPE 100 nF/400 V	Sungho Electronics
27	C3	TF334*2*10B	MTF 330 nF/400 V	CARLI
28	C4		222J 630 V	
29	C6	C0603C030K8GACTU	3 pF/16 V SMD Capacitor 2012 NP0	Murata
30	C7	NXH 22uF50V	NXH series 22 μF/50 V Electrolytic Capacitor	Samyoung
31	C8	GRM185D71A105KE36#	1 uF/16 V SMD Capacitor 2012	Murata
32	C9	GRM1881X1E102JA01#	1 nF/16 V SMD Capacitor 2012	Murata
33	C10	C0603C101K8GACTU	100 pF/16 V SMD Capacitor 2012	Murata
34	C11	SCF2E102M14DW7	Y cap 1000pF	SAMWHA Capacitor
35	C13,C14	KMG 470 μF / 63 V	470 μF / 63 V, Electrolytic Capacitor	Samyoung
36	C15	KMG 220 μF / 63 V	220 μF / 63 V, Electrolytic Capacitor	Samyoung
37	C16	NXH 220 μF / 16 V	220 μF / 16 V, Electrolytic Capacitor	Samyoung
38	C17	GRM1881X1E683JA01#	68 nF/16 V SMD Capacitor 2012	Murata
39	C18	NXH 22uF50V	NXH series 22 μF/50 V Electrolytic Capacitor	Samyoung
40	C19	GRM1881X1E104JA01#	100 nF/50 V SMD Capacitor 3216	Murata
41	C20	NXH 2.2uF50V	NXH series 2.2 μF/50 V Electrolytic Capacitor	Samyoung

Table 2. BILL OF MATERIAL (BOM) (continued)

Item No.	Part Reference	Part Number	Description	Manufacturer
42	LF1	CV613240H	24 mH Common mode inductor	TNC
43	LF2	B82733F	40 mH Common Inductor	EPCOS
44	D2	S320	200 V / 3 A Schottky Rectifier	ON Semiconductor
45	D4	RS1M	1000 V / 1.0 A SMA package fast recovery diode	ON Semiconductor
46	D6	RURP1560	600 V / 15 A, Ultrafast Rectifier	ON Semiconductor
47	D112	S320	200 V / 3 A Schottky Rectifier	ON Semiconductor
48	Q2	FCPF400N80Z	800 V, 14 A, 400 mΩ N−channel	ON Semiconductor
49	ZD1	MM3Z12VB	12 V, SOD−323	ON Semiconductor
50	ZD2	1N4748	22 V, DO−41	ON Semiconductor
51	Q51	KSP42	NPN Epitaxial Silicon Transistor VCEO 300 V	ON Semiconductor
52	Q52	KA431	Programmable shunt regulator	ON Semiconductor
53	U1	FL7740	Constant Voltage Primary−Side−Regulation PWM controller for Power factor Correction	ON Semiconductor

TRANSFORMER DESIGN

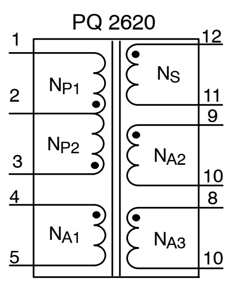

Figure 2. Pin Configuration

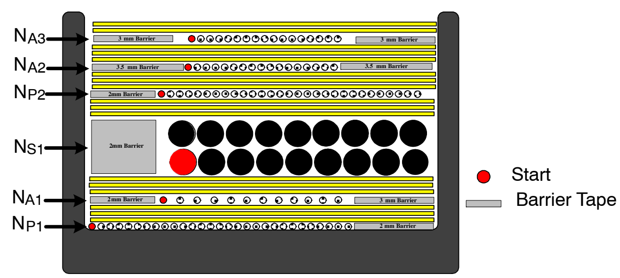

Figure 3. Transformer Winding Structure

Table 3. WINDING SPECIFICATIONS

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	3 → 2	0.33φ	19 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				
3	N_{A1}	4 → 5	0.2φ	8 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				
5	N_S	12 → 11	0.4φ (TIW)	19 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				
7	N_{P2}	2 → 1	0.33φ	14 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				
9	N_{A2}	9 → 10	0.2φ	3 Ts	Solenoid winding
10	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				
11	N_{A3}	9 → 10	0.2φ	8 Ts	Solenoid winding
12	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				

Table 4. ELECTRICAL CHARACTERISTICS

	Pins	Specifications	Remark
Inductance	1 – 3	340 uH ±10%	60 kHz, 1 V
Leakage	1 – 3	7 μH	60 kHz, 1 V, Short All Output Pins

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

PERFORMANCE

Table 5. TEST CONDITION & EQUIPMENT LIST

Ambient Temperature	T_A = 25°C
Test Equipment	AC Power Source: PCR500L by Kikusui Power Analyzer: PZ4000000 by Yokogawa Electronic Load: PLZ303WH by KIKUSUI Multi Meter: 2002 by KEITHLEY, 45 by FLUKE Oscilloscope: 104Xi by LeCroy Thermometer: Thermal CAM SC640 by FLIR SYSTEMS

Startup

Figure 8 through Figure 9 shows the overall startup performance at full load and no load condition. The output voltage is increased up to 90% of rated output voltage at least 0.28 s after the AC input power switch turns on for input voltage 90 V_{AC} condition. Once output voltage reaches close to the regulation level, gain control is smoothly changed to integration gain without output voltage overshoot and undershoot at the input voltage range from 90 to 305 V_{AC}. CH1: V_{IN} (100 V / div), CH2: COMV (1 V / div), CH3: VDD (10 V / div), CH4: V_{OUT} (10 V / div), Time Scale: (100 ms / div), Load: Electrical CC load.

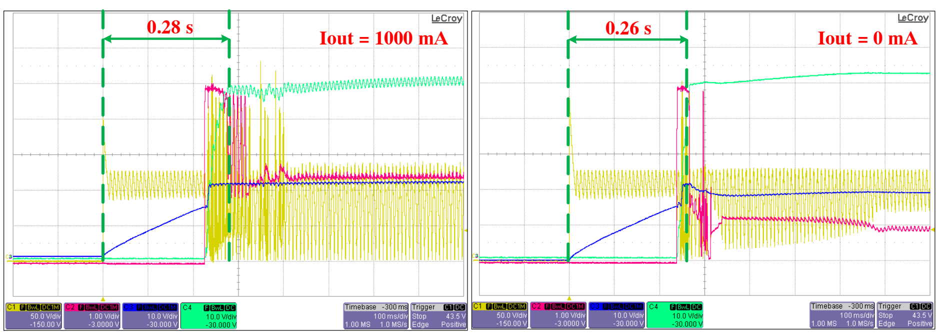

Figure 4. V_{IN} = 90 V_{AC} / 60 Hz

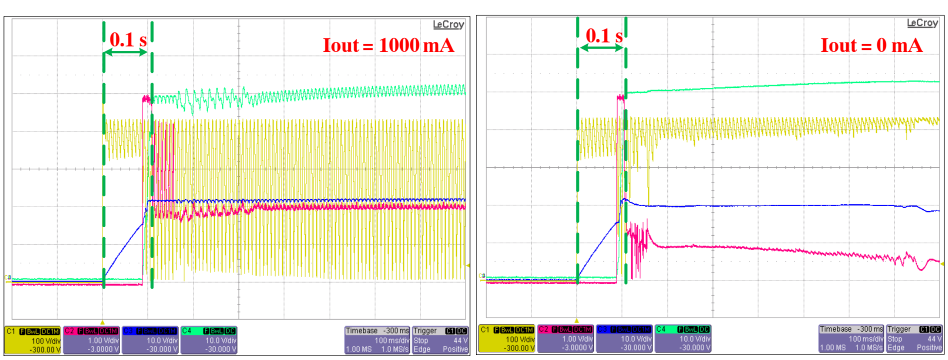

Figure 5. V_{IN} = 305 V_{AC} / 60 Hz

Fast Transient Response

Figure 10 through Figure 11 shows fast load transient performance. When output load is changed from full to no load, output voltage is managed less than + 10% of rated output voltage and when output load is changed from no to full load, output voltage is controlled higher than −10% of output voltage at the input voltage range from 90 to 305 V_{AC} with dynamic control function.

CH1: GATE (10 V / div), CH2: V_{IN} (100 V / div), CH3: V_{OUT} (10 V / div), CH4: I_{OUT} (500 mA / div), Time Scale: (50 ms / div), Load: Electrical load.

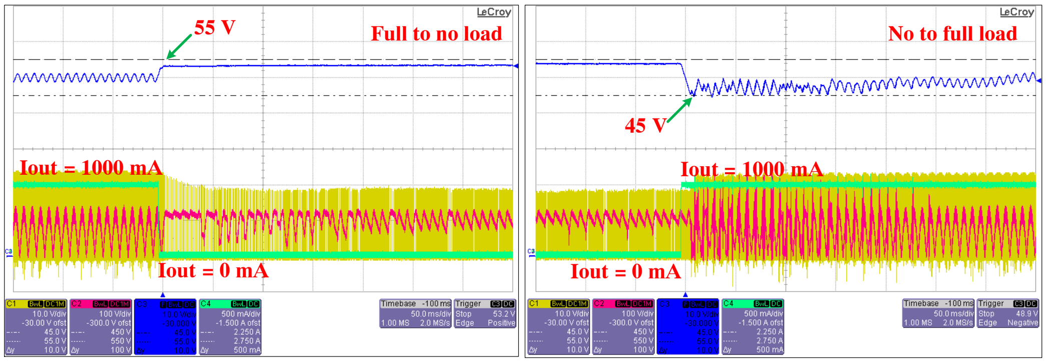

Figure 6. V_{IN} = 90 V_{AC} / 60 Hz

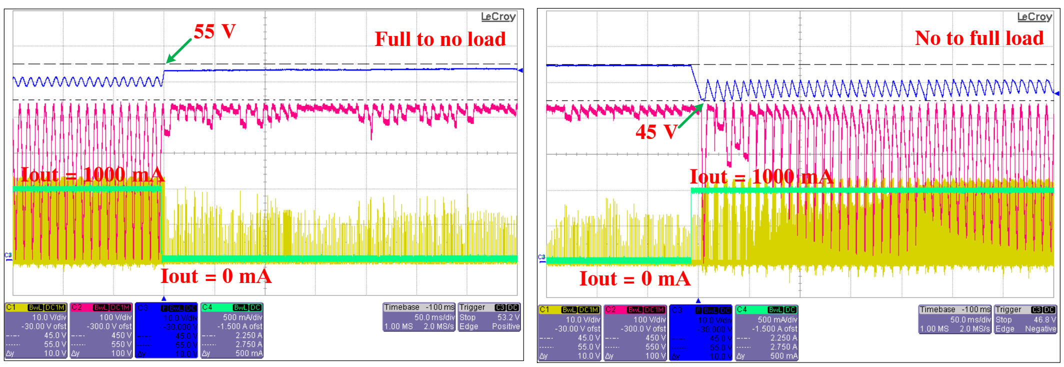

Figure 7. V_{IN} = 305 V_{AC} / 60 Hz

Figure 12 shows line transient performance. When input voltage is changed from 120 to 230 V_{AC} abruptly, output voltage is controlled lower than + 10% of rated output voltage. And when input voltage is changed from 230 to 120 VAC abruptly, output voltage is managed higher than −10% of rated output voltage. CH1: V_{IN} (100 V / div), CH2: COMV (1 V / div), CH3: GATE (10 V / div), CH4: V_{OUT} (10 V / div), Time Scale: (20 ms / div), Load: Electrical load

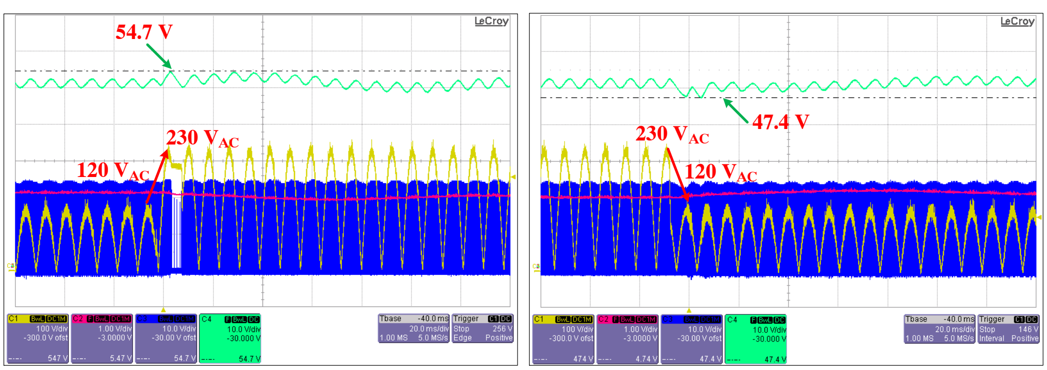

Figure 8. I_{OUT} = 1000 mA

Power Factor Optimizer Function

Figure 13 shows power factor and THD comparison data between without PF optimizer and with PF optimizer. Without PF optimizer function, power factor is lower than 0.84 at 230 VAC input voltage with 25% load condition. With PF optimizer function, power factor is significantly improved up to 0.93. While power factor is improved, it shows excellent THD performance, less than 20% even at 25% load condition at 230 VAC input voltage with PF optimizer function. In order to activate PF optimizer function, PF pin should be set higher than 1.5 V by adjusting PF resistors value to meet user's target as explained in datasheet

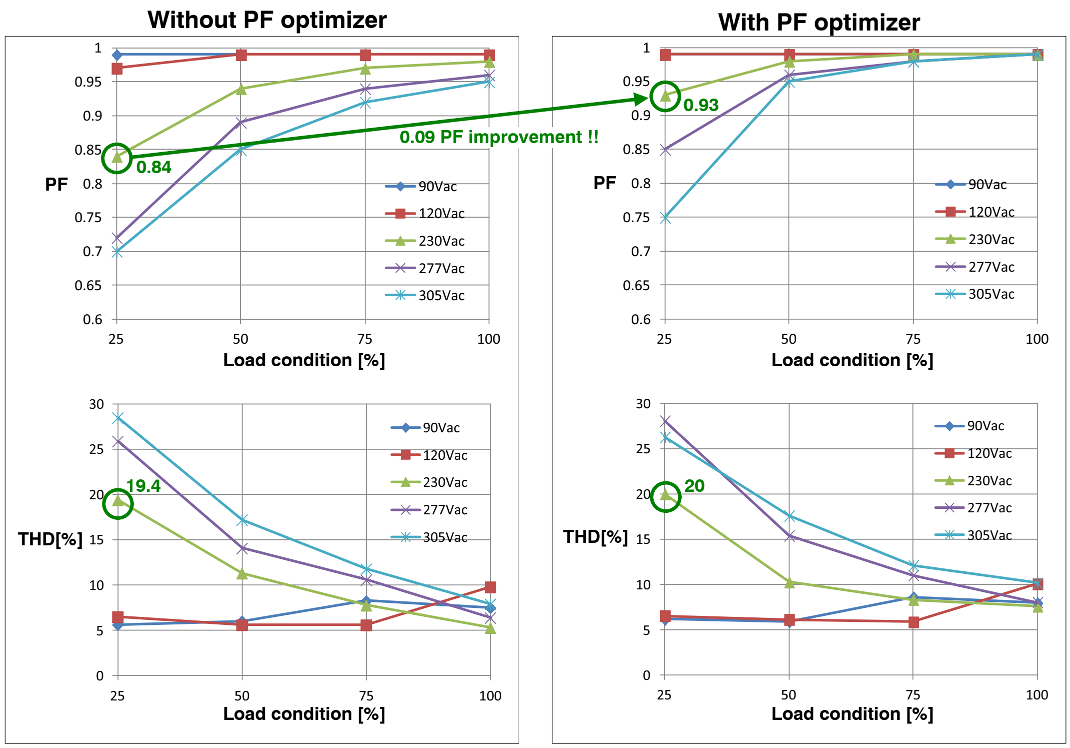

Figure 9. Power Factor & Total Harmonic Distortion Comparison

Constant Voltage Regulation Performance

Figure 14 shows excellent constant output voltage regulation result from no to full load with 3.3 V/ 20 mA load for MCU at secondary auxiliary winding. Even at no load condition with MCU power consumption, CV deviation is less than ± 3.1% regardless of PF optimizer function.

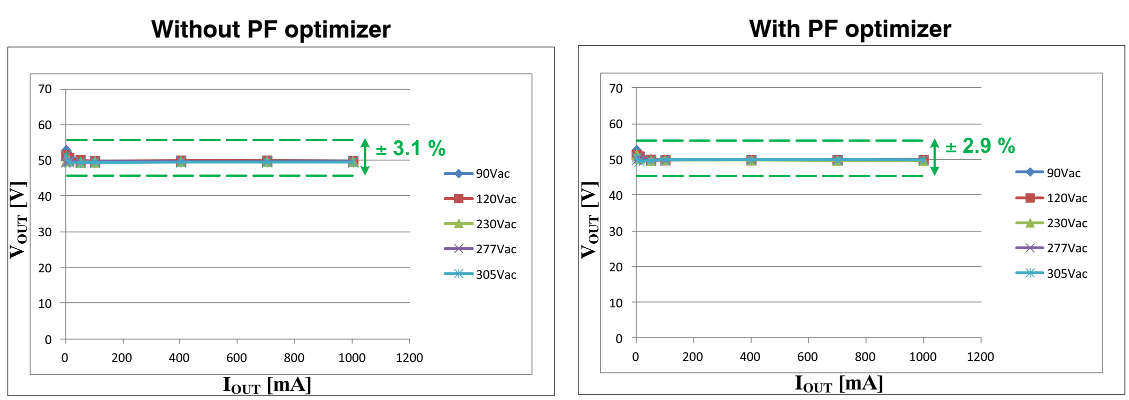

Figure 10. V_{IN} = 230 V_{AC} / 50 Hz

Table 6. CONSTANT VOLTAGE REGULATION BY LOAD CHANGE (90 ~ 305 V_{AC}) WITH PFO

Input Voltage	Output current [mA]							Tolerance
	1000	750	500	250	100	10	0	
90 V_{AC} [60 Hz]	49.7 V	49.9 V	49.9 V	49.9 V	49.9 V	51.6 V	52.7 V	± 2.9 %
120 V_{AC} [60 Hz]	49.9 V	49.9 V	49.9 V	49.9 V	49.9 V	50.9 V	51.3 V	± 1.4 %
230 V_{AC} [60 Hz]	49.8 V	49.8 V	49.9 V	49.9 V	49.9 V	50.3 V	51.5 V	± 1.7 %
277 V_{AC} [60 Hz]	49.9 V	49.9 V	49.9 V	49.9 V	49.9 V	50.6 V	49.9 V	± 0.9 %
305 V_{AC} [60 Hz]	49.9 V	50.0 V	50.0 V	50.0 V	50.0 V	49.6 V	50.6 V	± 1.0 %

Table 7. CONSTANT VOLTAGE REGULATION BY LINE CHANGE (0 ~ 1000 mA) WITH PFO

Output Current	Input Voltage [V_{AC}]					Tolerance
	90	120	230	277	305	
1000 mA	49.7 V	49.9 V	49.8 V	49.9 V	49.9 V	± 0.2 %
750 mA	49.9 V	49.9 V	49.8 V	49.9 V	50.0 V	± 0.2 %
500 mA	49.9 V	49.9 V	49.9 V	49.9 V	50.0 V	± 0.1 %
250 mA	49.9 V	49.9 V	49.9 V	49.9 V	50.0 V	± 0.2 %
100 mA	49.9 V	49.9 V	49.9 V	49.9 V	50.0 V	± 0.5 %
10 mA	51.6 V	50.9 V	50.3 V	50.6 V	49.6 V	± 2.0 %
0 mA	52.7 V	51.3 V	51.5 V	49.9 V	50.6 V	± 2.7 %

Efficiency

Figure 15 shows efficiency data at the input voltage range from 90 to 305 V_{AC} from 25 to 100% load condition. System efficiency is over 89% from 120 ~ 305 V_{AC} with 100% load condition. And efficiency is over 89% from 120 ~ 305 V_{AC} over half load condition as well.

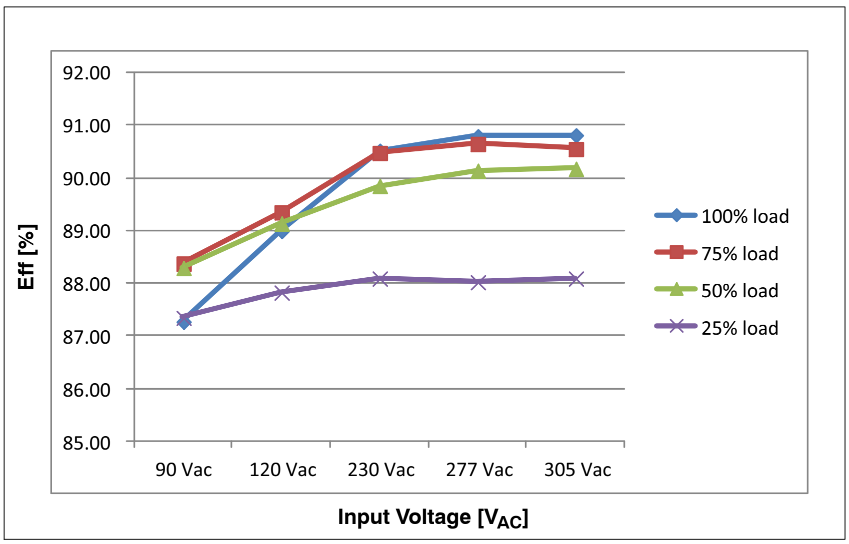

Figure 11. Efficiency by Line Voltage & Load Condition Change

Table 8. EFFICIENCY BY LOAD CHANGE WITH INPUT VOLTAGE VARIANCE

Load Condition	Input Voltage [V_{AC}]				
	90	120	230	277	305
1000 mA	87.3 %	89.0 %	90.5 %	90.8 %	90.8 %
750 mA	88.4 %	89.4 %	90.5 %	90.7 %	90.6 %
500 mA	88.3 %	89.1 %	89.9 %	90.1 %	90.2 %
250 mA	87.4 %	87.8 %	88.1 %	88.0 %	88.1 %

Standby Power

Figure 16 shows standby power performance with no load condition at different MCU load cases. With no load condition at MCU winding output, standby power is lower than 150 mW at the input range from 90 to 305 VAC. With 20 mA load condition at MCU winding output, standby power is lower than 410 mW

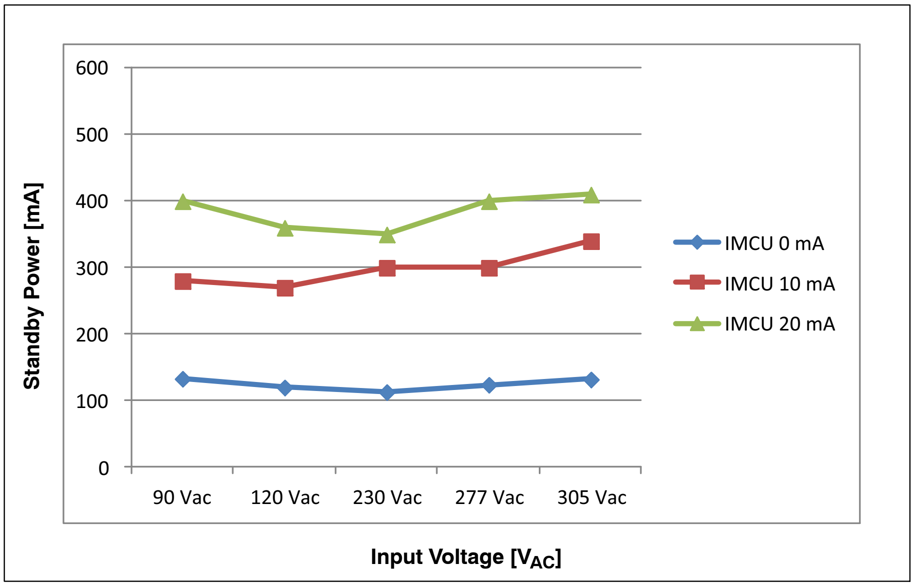

Figure 12. System Efficiency

Table 9. STANDBY POWER WITH DIFFERENT MCU WINDING LOAD

Input Voltage	MCU Winding Current		
	0 mA	**10 mA**	**20 mA**
90 V_{AC} [60 Hz]	133 mW	280 mW	400 mW
120 V_{AC} [60 Hz]	120 mW	270 mW	360 mW
230 V_{AC} [60 Hz]	113 mW	300 mW	350 mW
277 V_{AC} [60 Hz]	124 mW	300 mW	400 mW
305 V_{AC} [60 Hz]	132 mW	340 mW	410 mW

Output Short Protection (OSP)

Figure 17 shows waveforms for the protection and AR operation when main load terminal is shorted. When the main load terminal short occurs and then VS voltage reaches lower than 0.7 V for 35 ms, OSP is triggered and the controller then shuts down the switching MOSFET. After 3 s, the Startup sequence reinitiates. This behavior lasts until the fault condition is removed. Systems can restart automatically when normal condition resumes at least 3 seconds. CH1: GATE (10 V / div), CH2: V_{IN} (100 V / div), CH3: VDD (5 V / div), CH4: V_{OUT} (10 V / div), Time Scale: (1 s / div), Load: Electrical load

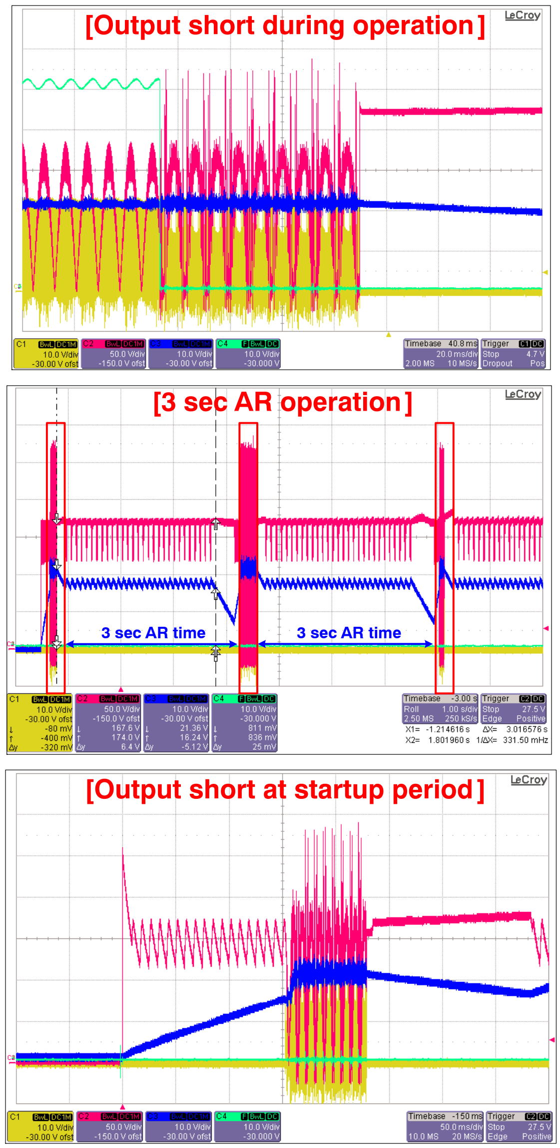

Figure 13. Output Short Protection

Over Load Protection

Figure 18 shows waveforms for the protection and AR operation when output is over loaded. When pulse−by−pulse current limit event is happened for 60 half line cycles consecutively, OLP is triggered and the controller then shuts down the switching MOSFET. After 3 s, the Startup sequence reinitiates. This behavior lasts until the fault condition is removed. Systems can restart automatically when normal condition resumes at least 3 seconds. CH1: VDD (10 V / div), CH2: V_{CS} (500 mV / div), CH3: GATE (10 V / div), CH4: I_{OUT} (10 V / div), Time Scale: (100 ms / div), Load: Electrical load

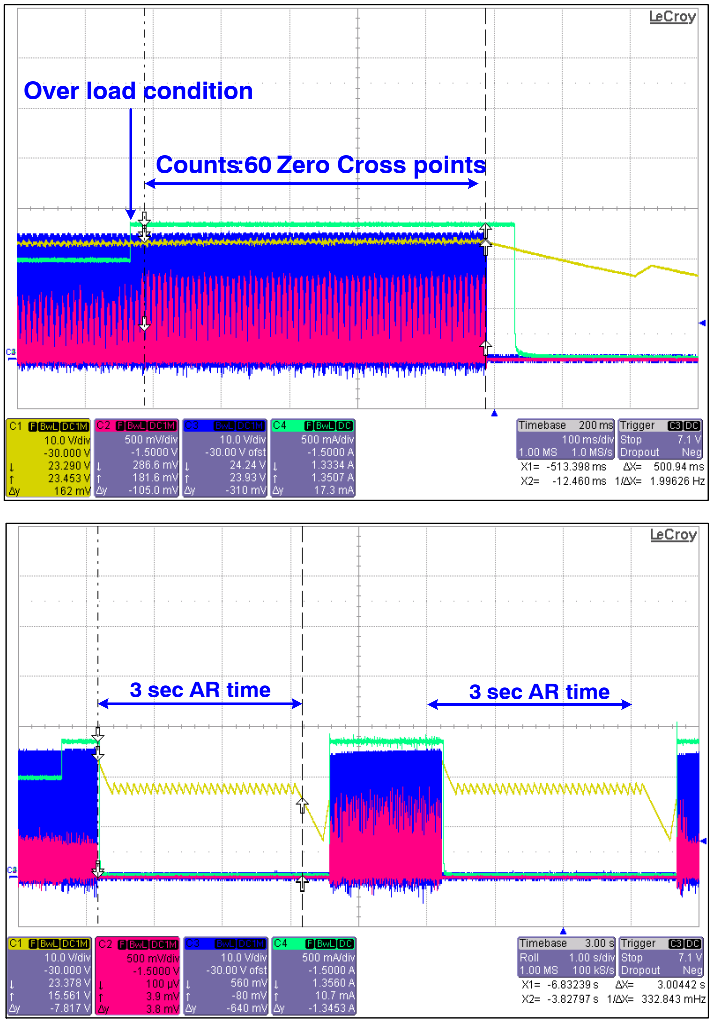

Figure 14. Over Load Protection

Sensing Resistor Short Protection

Figure 19 through Figure 20 shows waveforms for the protection when sensing resistor is shorted. If V_{CS} doesn’t reach over $V_{CS-SRSP}$ (0.075 V) at the initial first switching operations during the Startup period, SRSP is triggered and the controller then shuts down the switching MOSFET. After 3 s, the Startup sequence reinitiates. This behavior lasts until the fault condition is removed. Systems can restart automatically when normal condition resumes at least 3 seconds. CH1: V_{IN} (100 V / div), CH2: V_{CS} (500 mV / div), CH3: V_{GATE} (10 V / div), Time Scale: (10 ms / div), Load: Electrical load

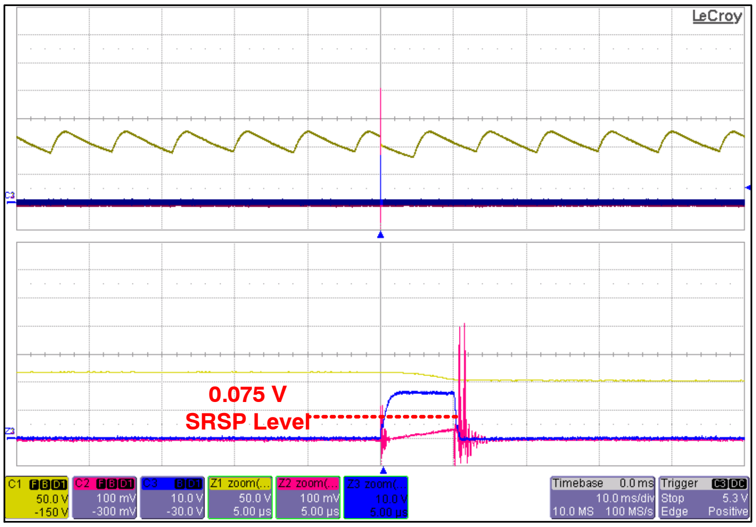

Figure 15. V_{IN} = 90 V_{AC} / 60 Hz

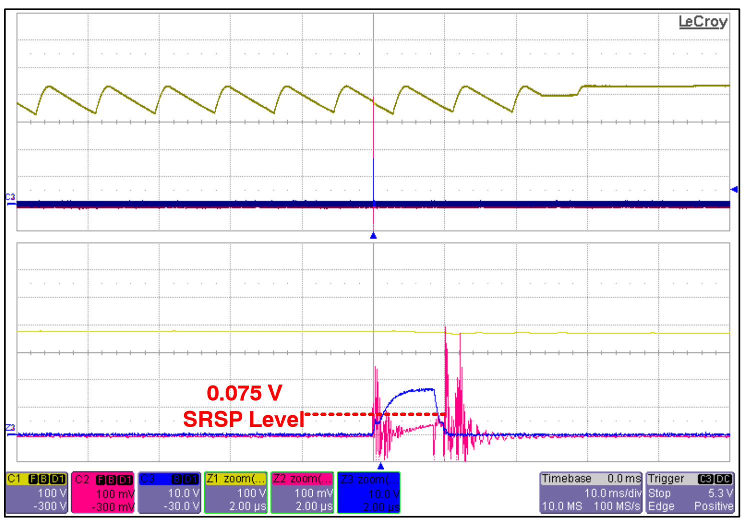

Figure 16. V_{IN} = 305 V_{AC} / 60 Hz

Output Diode Short Protection

Figure 21 shows a waveform for the protection operation when the secondary diode is shorted. V_{CS} is monitored during the gate turn−on time to detect over−current except for LEB time. Once V_{CS} goes higher than V_{CS-OCP} (1.8 V) after the LEB time, OCP is triggered and the controller then shuts down the switching MOSFET. I_{peak} amplitude can be adjusted by using different magnetizing inductance and input voltage condition. CH1: GATE (5 V / div), CH2: V_{CS} (500 mV / div), CH3: VDD (10 V / div), Time Scale: (100 ms / div), Load: Electrical load

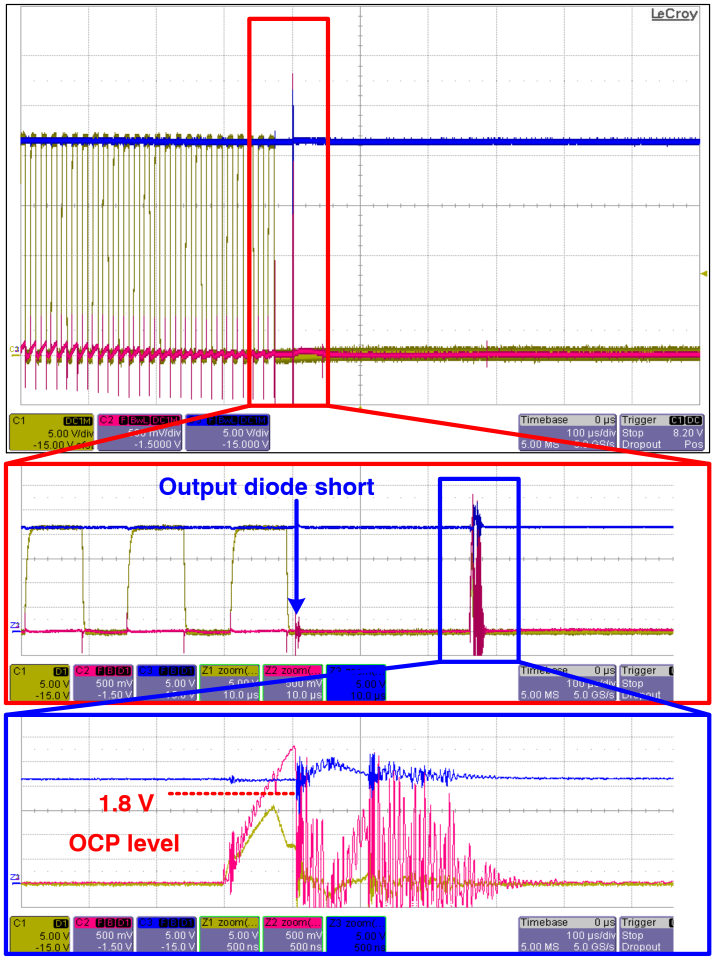

Figure 17. Output Diode Short Protection

Operating Temperature

The results were measured using the full load conditions after 30 minutes burn−in.

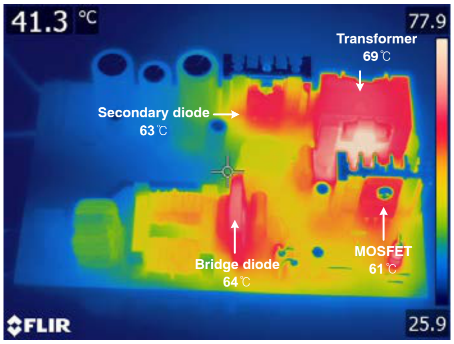

Figure 18. V_{IN} = 90 V_{AC}

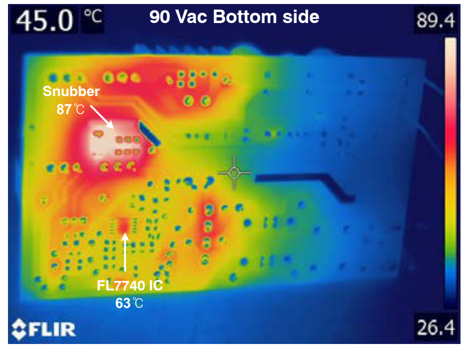

Figure 19. V_{IN} = 90 V_{AC}

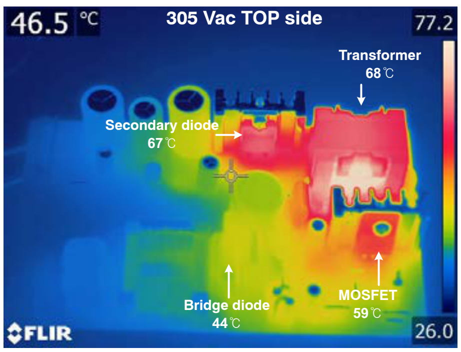

Figure 20. V_{IN} = 305 V_{AC}

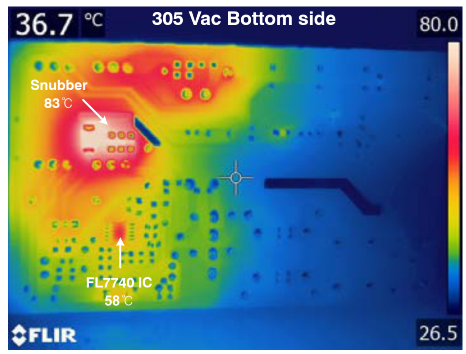

Figure 21. V_{IN} = 305 V_{AC}

Table 10. Surge Test

Condition	Surge	Note	Remark
Original EVB	3.4 kV	Only fuse is damaged	No issue at IC operation
Changed Fuse rating from 2 A to 3.15 A	5.4 kV	Only fuse is damaged	No issue at IC operation
Changed Fuse rating from 2 A to 10 A & Added 26 V TVS diode at GATE pin	7.8 kV	Fuse and MOV1 is damaged	No issue at IC operation

Electromagnetic Interference (EMI)

All measurements were conducted in observance of EN55022 criteria. The results were measured with FL7760 evaluation board using rated LED loads at output terminal after 10 minutes burn−in. If it needs to be checked for only FL7740 evalutaion board's EMI performance, C17 (Y−cap) should be changed from 1000 to 4700 pF.

[120Vac Live] **[120Vac Neutral]**

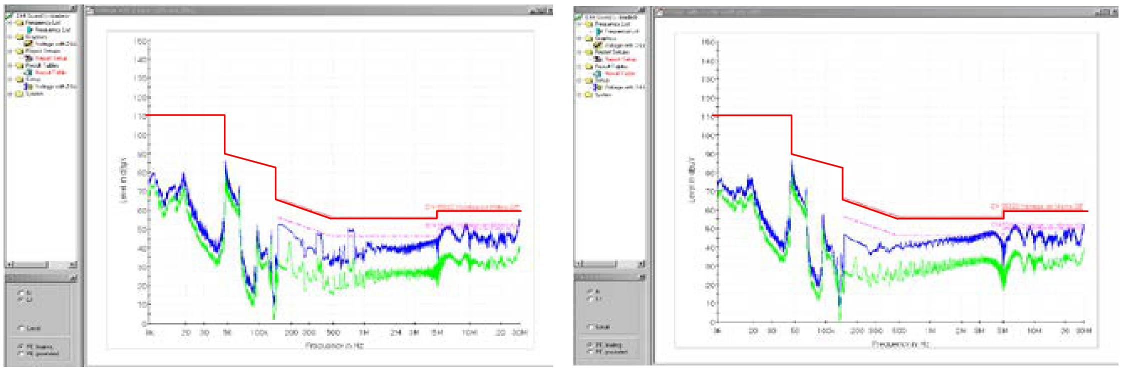

Figure 22. V_{IN} [120 V_{AC}, Live]

[230Vac Live] **[230Vac Neutral]**

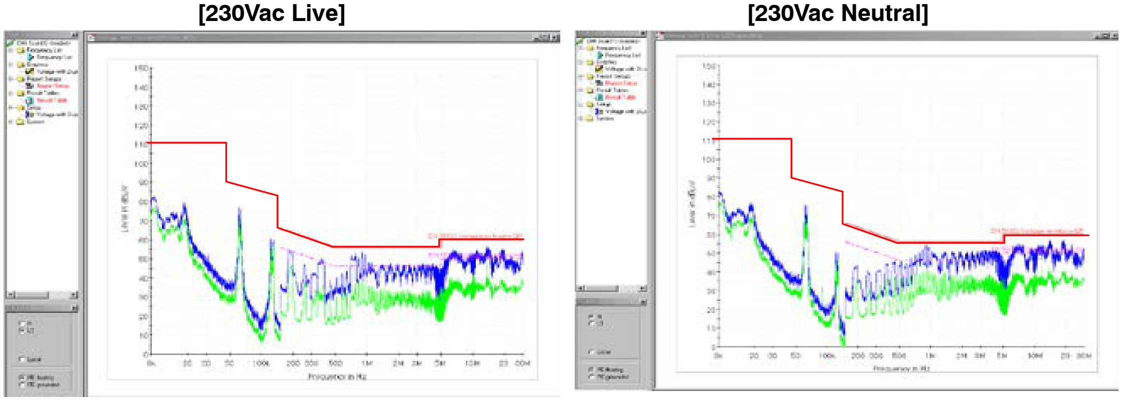

Figure 23. V_{IN} [230 V_{AC}, Live]

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