User Guide for

FEBFAN104WMX_T06U005A Evaluation Board

Fairchild PSR Smart Phone Battery Charger

Featured Fairchild Products: FAN104WMX

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[Fairchild Semiconductor.com](http://www.fairchildsemi.com)

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This user guide supports the evaluation kit for the FAN104WMX. It should be used in conjunction with the FAN104WMX datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

The FAN104WMX has several functions to achieve standby power consumption lower than 30 mW at 230 V_{AC}. Proprietary Burst Mode with lower operation current under light-load conditions and a built-in HV startup circuit to reduce startup resistor power loss both improve performance. By using the FAN104WMX, a smart phone charger can be implemented with few external components and minimized cost.

This document is an engineering report describing a 5 W power supply using the FAN104WMX. This power supply targets the smart phone battery charger market with a <30 mW solution and high efficiency.

1.1. Description

This highly integrated PWM controller, FAN104WMX, provides several features to enhance the performance of low-power flyback converters. The proprietary topology enables simplified circuit design for battery-charger applications. The result is a lower-cost, smaller and lighter charger compared to a conventional design or a linear transformer. To minimize standby power consumption, a proprietary Green-Mode function provides off-time modulation to linearly decrease PWM frequency under light-load conditions. Green Mode assists the power supply in meeting power conservation requirements.

1.2. Features

- Achieves < 30 mW; Energy Star's 5-Star Level
- Proprietary 500 V High-Voltage JFET Startup Reduces Startup Resistor Loss
- Low Operating Current in the Burst Mode: 600 µA
- Constant-Voltage (CV) and Constant-Current (CC) Control without Secondary-Side Feedback Circuitry
- Green Mode: PWM Frequency Linearly-Decreasing
- PWM Frequency at 85 kHz with Frequency Hopping to Solve EMI Problem
- Boundary-Conduction-Mode (BCM) Operation at Lower AC Input Voltage
- Cable Compensation in CV Mode
- V_{DD} Under-Voltage Lockout (UVLO) Available
- Built-in Protections:
- Output Short-Circuit Protection
- Output Over-Voltage-Protection (V_S OVP) with Latch Mode
- V_{DD} Over-Voltage-Protection (V_{DD} OVP)
- CS Pin Single-Fault Protection
- VS Pin Single-Fault Protection
- Over-Temperature-Protection (OTP) with Latch Mode

2. Evaluation Board Specifications

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

Table 1. Summary of Features and Performance

Description	Symbol	Value	Comments
Input Voltage	$V_{IN.\,MIN}$	90 V_{AC}	Minimum Input Voltage
	$V_{IN.MAX}$	264 V_{AC}	Maximum Input Voltage
	$V_{IN.NOMINAL}$	110 V_{AC} / 220 V_{AC}	Nominal Input Voltage
Input Frequency	f_{IN}	60 Hz / 50 Hz	Input Line Frequency
Output Voltage	$V_{OUT.MIN}$	4.75 V	CV: ± 3% Regulation CC: ± 3% Regulation
	$V_{OUT.MAX}$	5.25 V	
	$V_{OUT.NOMINAL}$	5 V	
Output Current	$I_{OUT.NOMINAL}$	1.2 A	
Output Power	$P_{OUT.NOMINAL}$	6 W	
Output Power	$P_{OUT.MAX}$	6.3 W	
Ripple	V_{RIPPLE}	< 150 mV	Measured: < 95 mV
Efficiency	$Eff._{MIN}$	74.85%	Meets DoE. Standard at Full Load (73.37%)
	$Eff._{NOMINAL}$	77.92%	
Temperature	T_{FAN104}	< 41°C	At Full Load (Open-Frame)
	T_{MOSFET}	< 66°C	
	T_{SD1}	< 75°C	
	T_{D2}	< 32°C	
	$T_{transformer}$	< 62°C	
Transformer	Core	EPC-13	The core volume of the low-profile EPC-13 is 66% lower than the* conventional type of transformer core. The height of the low-profile EPC-13 core is 57% less than the * conventional type of transformer core. *EPCxxx, (*refer to page 9*)

3. Photographs

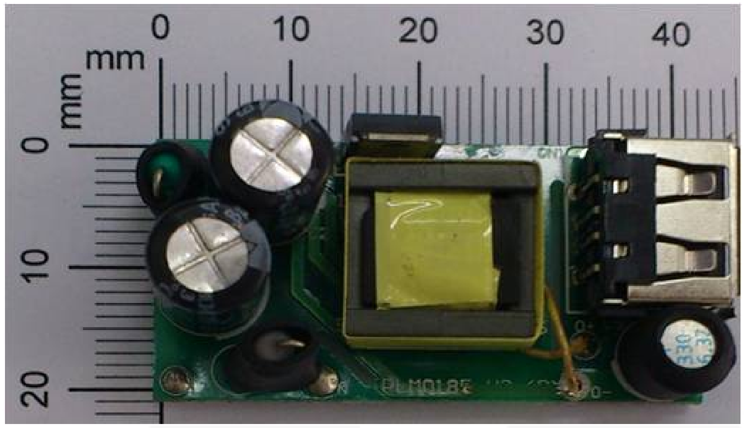

Figure 1. Photograph (32.4x 26 mm^2) Top-View

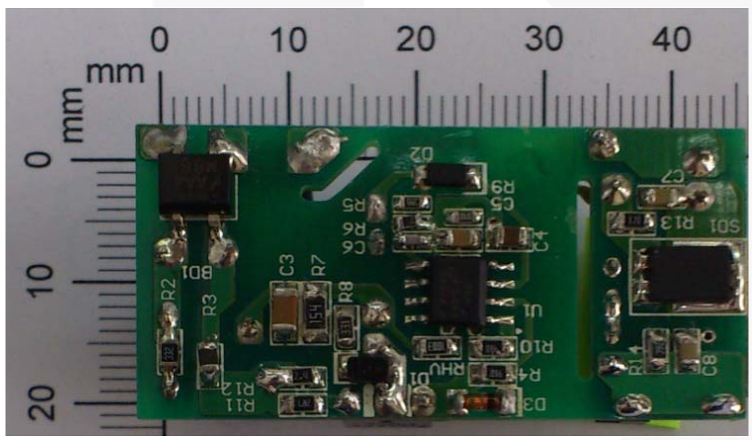

Figure 2. Photograph (32.4 (H) x 26 mm^2(W)) Bottom-View

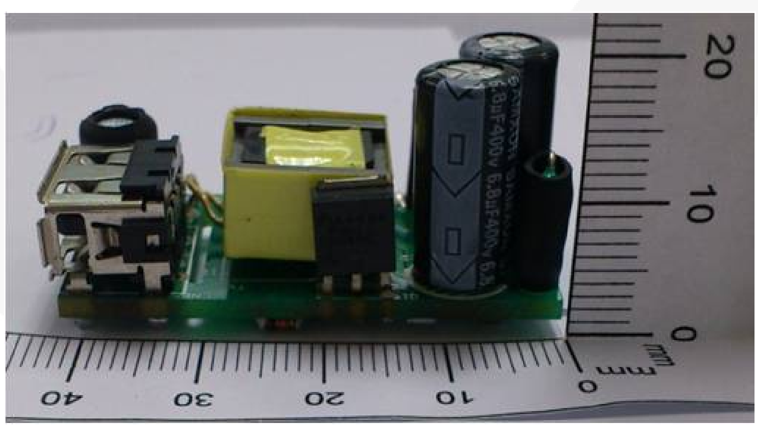

Figure 3. Photograph (32.4 (L) x 21 mm^2 (H)) Side-View

4. Printed Circuit Board

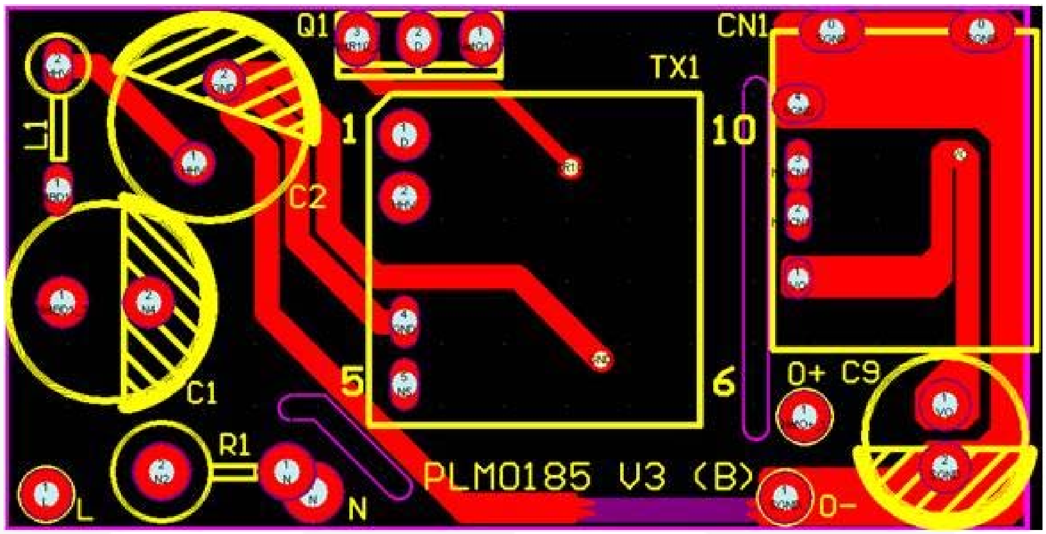

Figure 4. Top-Side

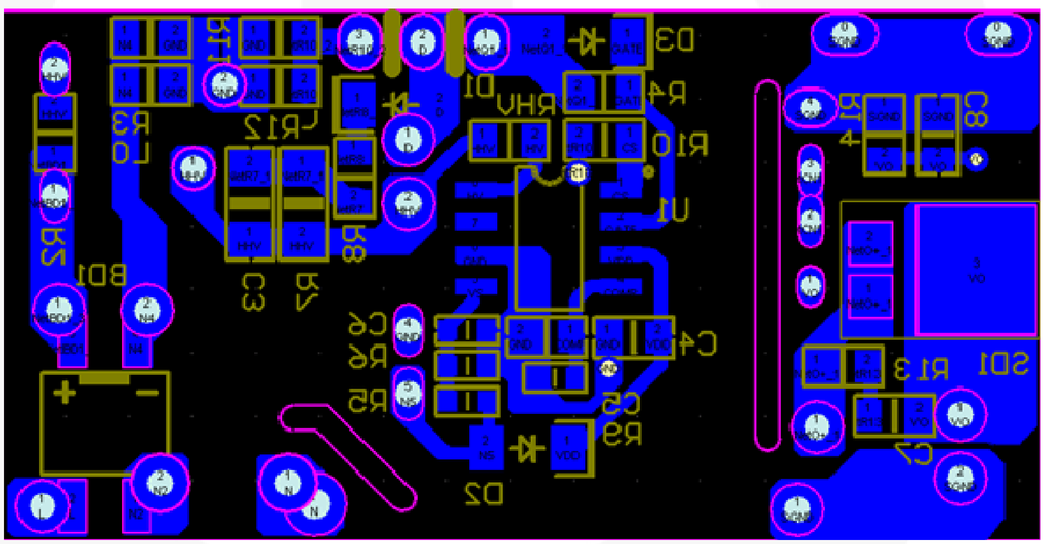

Figure 5. Bottom-Side

5. Schematic

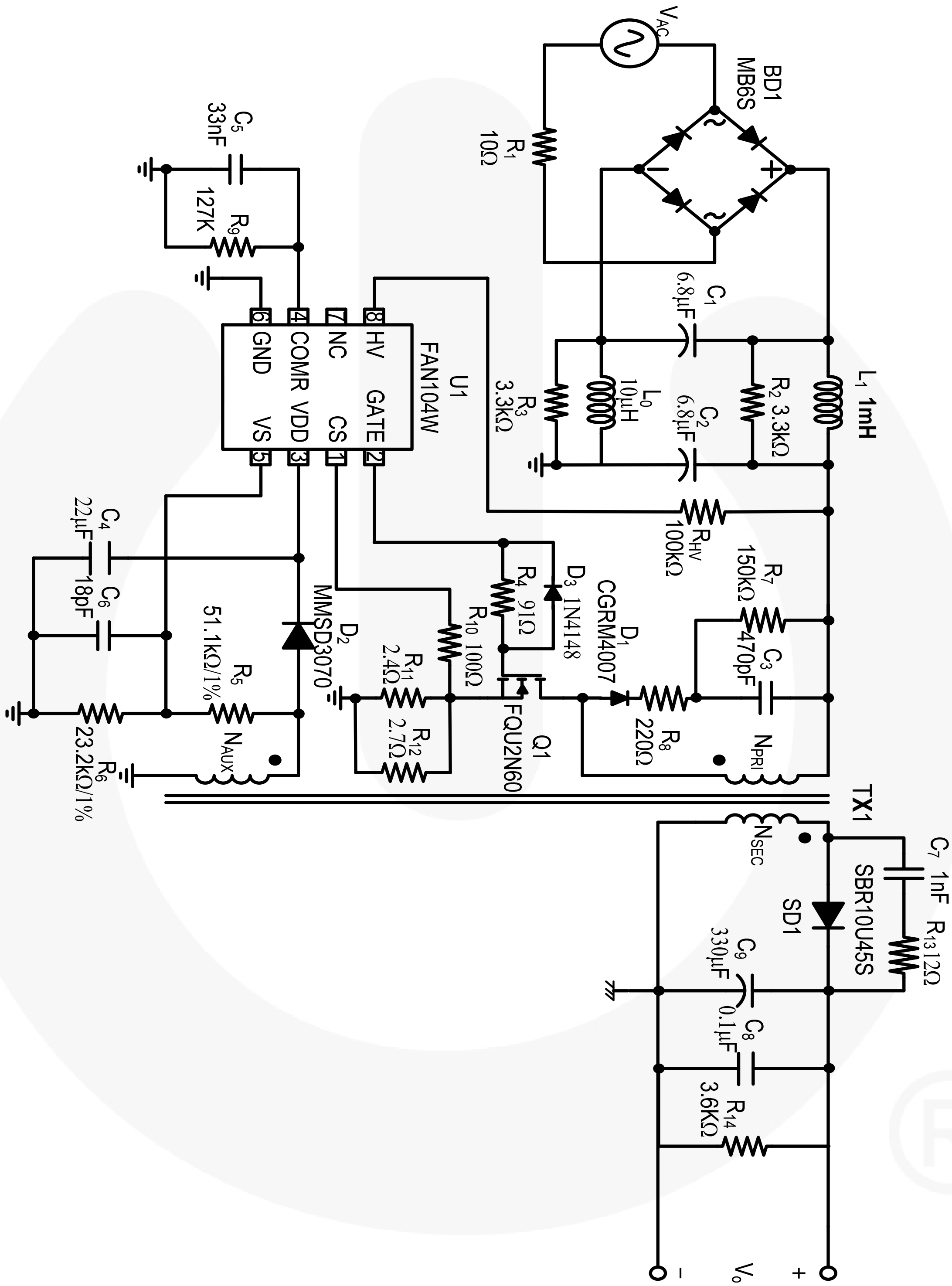

Figure 6. Evaluation Board Schematic

6. Bill of Materials

Component Series	Part Name	Specification	Qty	Part No.
02-3510005-10	DIP Res. 1 W-S 10 Ω ±5%	TAPING	1	R1
02-5112731-00	SMD Res. 0603 127 kΩ ±1%	REEL	1	R9
02-5123221-00	SMD Res. 0603 23.2 kΩ ±1%	REEL	1	R6
02-5151121-00	SMD Res. 0603 51.1 kΩ ±1%	REEL	1	R5
02-5210105-00	SMD Res. 0805 100 Ω ±5%	REEL	1	R10
02-5210405-00	SMD Res. 0805 100 kΩ ±5%	REEL	1	RHV
02-5212005-00	SMD Res. 0805 12 Ω ±5%	REEL	1	R13
02-5222105-00	SMD Res. 0805 220 Ω ±5%	REEL	1	R8
02-5224A05-00	SMD Res. 0805 2.4 Ω ±5%	REEL	1	R11
02-5227A05-00	SMD Res. 0805 2.7 Ω ±5%	REEL	1	R12
02-5233205-00	SMD Res. 0805 3.3 kΩ ±5%	REEL	2	R2, R3
02-5236011-00	SMD Res. 0805 3.6 kΩ ±1%	REEL	1	R14
02-52910A5-00	SMD Res. 0805 91 Ω ±5%	REEL	1	R4
02-5315405-00	SMD Res. 1206 150 kΩ ±5%	REEL	1	R7
03-3218031-00	SMD NPO 0603 18 P 50 V ±10%	REEL	1	C6
03-3310239-00	0805 X7R ±10% 102 P 50 V	REEL	1	C7
03-3310439-00	0805 X7R ±10% 104 P 50 V	REEL	1	C8
03-332201A-00	0805 X5R ±20% 22 µF 25 V	No: GRM21BR61E226ME44	1	C4
03-3339339-00	0805 X7R ±10% 393 P 50 V	REEL	1	C5
03-3447179-00	1206 X7R ±10% 471 P 1 kV	REEL	1	C3
03-5068AC1-01	Electrolytic Cap. 6 µ8 400 V 105°C	8*16 RADIAL KM Unpackaged	2	C1, C2
03-7033101-01	OCVZ Cap. 330 µ 6.3 V 105°C	OVZ331M0JTR-0606,6.3*5.9 mm	1	C9
04-1000328-00	SMD Inductor TRN0328(10 µH ±20%0805)	No:LQM21FN100M80L, Supertrade	1	L0
04-1136102-00	DIP Inductor 1 mH ±10%	EC36-102 K	1	L1
04-2000329-00	Transformer TRN0329	EPC13, Horizontal, Lm=1.3 mH	1	TX1
07-03070F1-00	SMD Diode MMSD3070	Fairchild Semiconductor	1	D2
07-0L41481-00	SMD Diode LL4148	1 A/100 V SOD80	1	D3
07-0400711-00	SMD Diode CGRM4007-HF	1 A/1000 V,SOD-123,COMCHIP	1	D1
07-110U450-11	SMD Schottky Diode SBR10U45SP5	10 A SBR, PowerDIR5	1	SD1
07-1MB6S0F-11	SMD Bridge Rectifier MB6S	Fairchild Semiconductor	1	BD1
09-12N600F-00	MOSFET FQU2N60CTU	Fairchild Semiconductor	1	Q1
11-EN104WF-11	SMD IC FAN104WMX	Fairchild Semiconductor	1	U1
38-0000002-00	CANADA Silicone ES2482W 333 ml		0	
42-J100432-10	USB JC0010 4411-02004L	Short Type 10*13 mm	1	CN1
54-1020653-00	MCH0653	Heat-Shrinkable Tube 6ψ10 mm	3	L1, R1, C9
70-PLM0185-03	PCB PLM0185(B) REV 3.	For FAN104 5 W 1*5 Connected	1	

7. Transformer and Winding Specifications

- Core: EPC-13 (PC-40)
- Bobbin: 10 pins

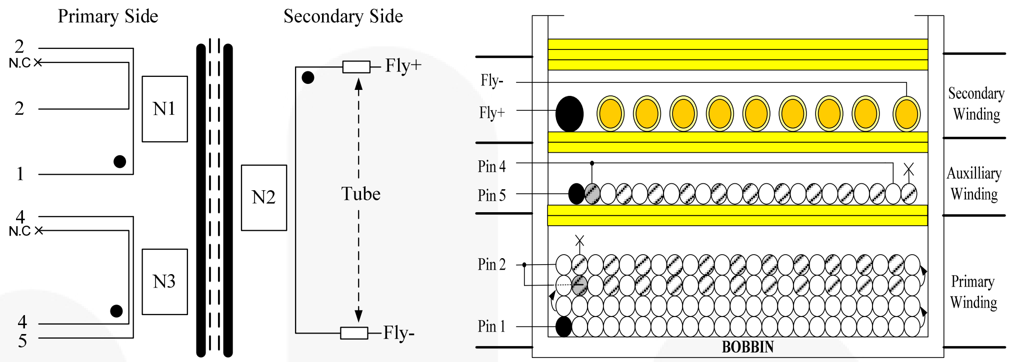

Figure 7. Transformer Specifications & Construction

Table 2. Winding Specifications

No.	Pin (S → F)	Wire	Turns	Isolation Tape Turns	Notes
W1	1 → 2	2UEW 0.12φ*1	132	2	Layer-1: 48 Turns Layer-2: 47 Turns Layer-3: 23 + 23 Turns (Parallel) Layer-4: 14 + 14 Turns (Parallel)
	2 → NC		37		
W2	5 → 4	2UEW 0.18φ*1	16	2	2 Line Parallel
	4 →NC				
W4	Fly+ → Fly-	TEX-E 0.45φ*1	10	2	
		Core Rounding Tape		3	
Core Shielding		Cooper Sheet	1	2	Cooper shielding should be close with core

Table 3. Electrical Characteristics

Item	Pin	Specification	Remark
Inductance	1 - 2	1.3 mH ±10%	1 kHz, 1 V

8. Test Conditions & Test Equipment

Table 4. Test Conditions & Test Equipment

Evaluation Board #	FEBFAN104WMX_TU06005A
Test Date	2012-08-15
Test Temperature	25°C
Test Equipment	AC Power Source: 6801 by EXTECH ELECTRONICS Power Analyzer: WT210 by YOKOGAWA Electronic Load: 63030 by CHROMA Automatic Power Tester: 6312A & 63102A by CHROMA Multi Meter: BM817a by BRYMEN Oscilloscope: 24MXs-B by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Thermometer: Therma CAM SC640 by FLIR SYSTEMS

9. Performance of Evaluation Board

9.1. Input Current

Test Conditions

Measure the AC input current at maximum loading.

Table 5. Test Results

Input Voltage	Input Current
90 V_{AC} / 60 Hz	122.2 mA
264 V_{AC} / 50 Hz	61.1 mA

9.2. Input Wattage at No-Load Condition

Test Conditions

Measure the input wattage and output voltage at no load.

Table 6. Test Results

Input Voltage	Input wattage	Output Voltage	Specification
90 V_{AC} / 60 Hz	25.1 mW	5.15 V	< 30 mW
115 V_{AC} / 60 Hz	25.4 mW	5.19 V	
230 V_{AC} / 50 Hz	26.7 mW	5.11 V	
264 V_{AC} / 50 Hz	28.6 mW	5.13 V	

Measured Waveforms

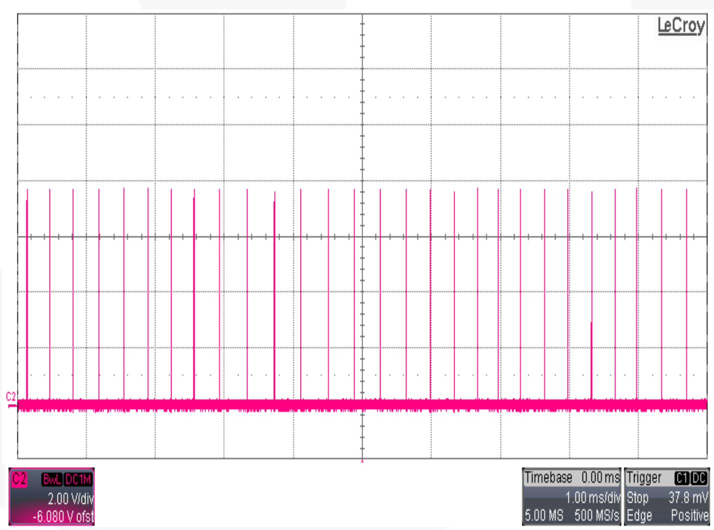

Figure 8. 90 V_{AC} / 60 Hz, C2 [V_{GS}] at No Load

Measured Waveforms

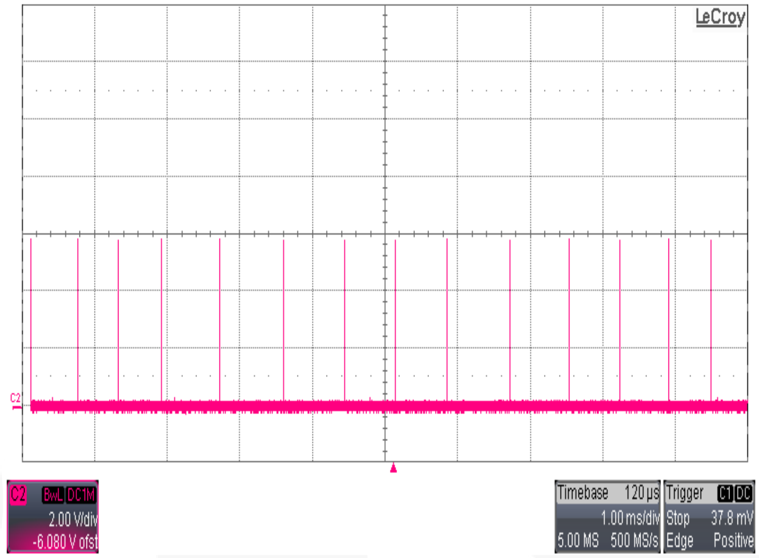

Figure 9. 264 V_{AC} / 50 Hz, C2 [V_{GS}] at No Load

9.3. Startup Time

Test Conditions

Set the output at maximum loading. Measure the time interval between the AC line on condition and a stable output condition.

Table 7. Test Results

Input Voltage	Startup Time	Specification
90 V_{AC} / 60 Hz	150 ms	< 3 s
264 V_{AC} / 50 Hz	73 ms	

Measured Waveforms

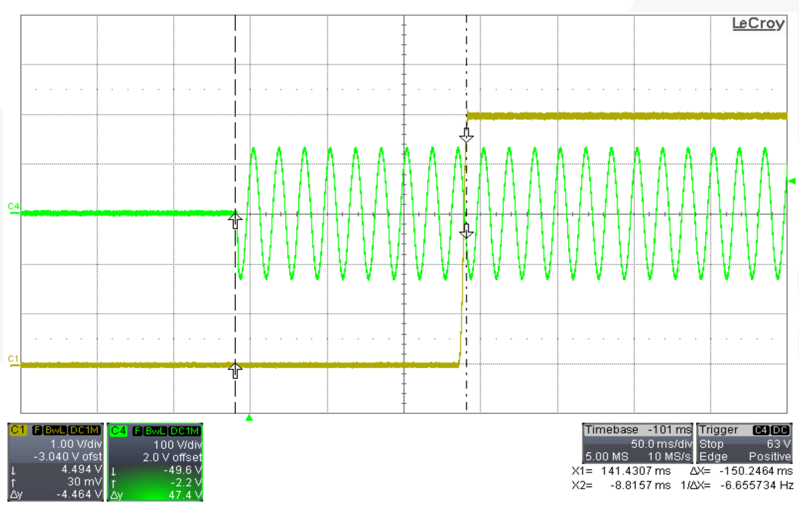

Figure 10. 90 V_{AC} / 60 Hz, C1 [V_O], C4 [V_{AC}] at Maximum Load

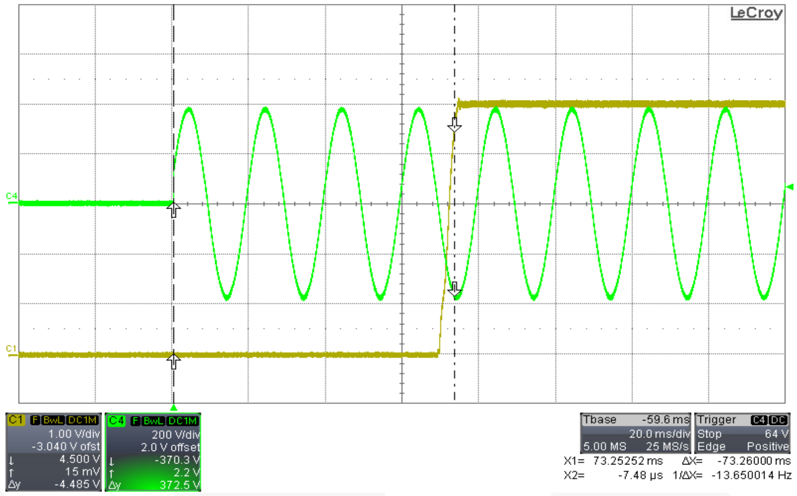

Figure 11. 264 V_{AC} / 50 Hz, C1 [V_O], C4 [V_{AC}] at Maximum Load

9.4. DC Output Rising Time

Test Conditions

Set the output at maximum load and no load. Measure the time interval between 10% and 90% output during startup.

Table 8. Test Results

Input Voltage	No Load	Maximum Load	Specification
90 V_{AC} / 60 Hz	2.88 ms	3.50 ms	< 20 ms
264 V_{AC} / 50 Hz	2.64 ms	3.59 ms	

Measured Waveforms

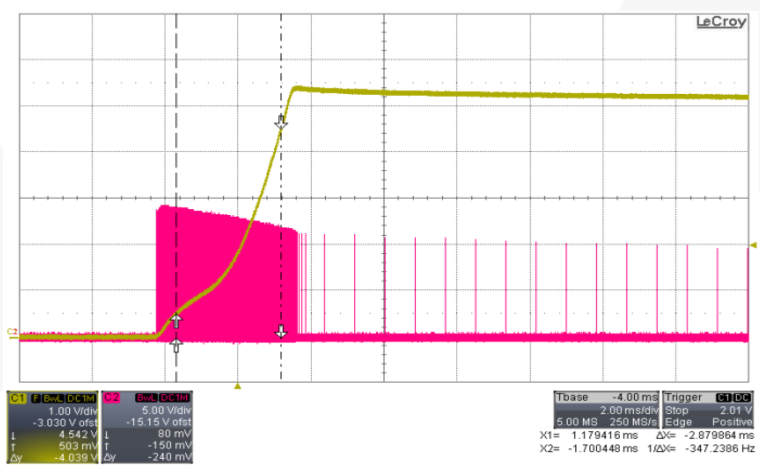

Figure 12. 90 V_{AC} / 60 Hz, C1 [V_O], C2 [V_{GS}] at No Load

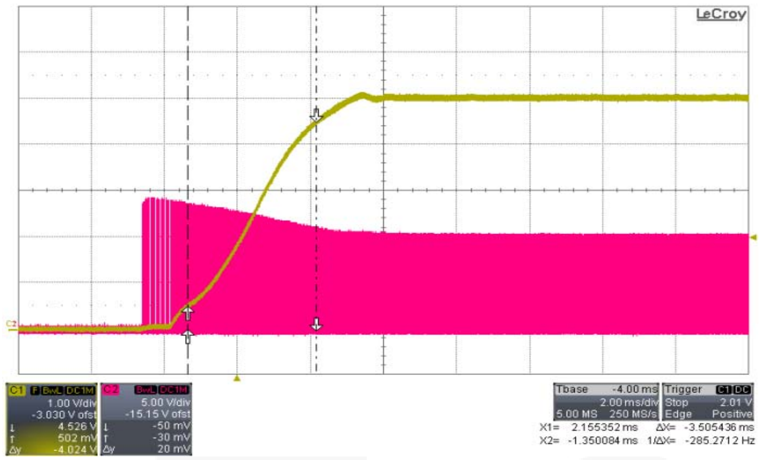

Figure 13. 90 V_{AC} / 60 Hz, C1 [V_O], C2 [V_{GS}] at Maximum Load

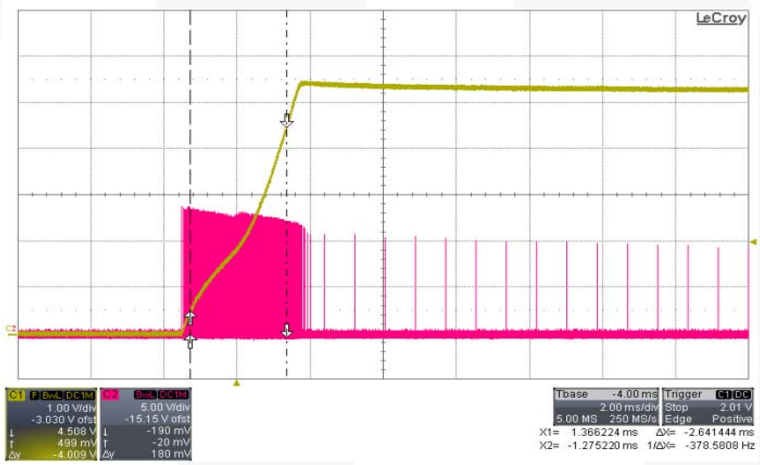

Figure 14. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}] at No Load

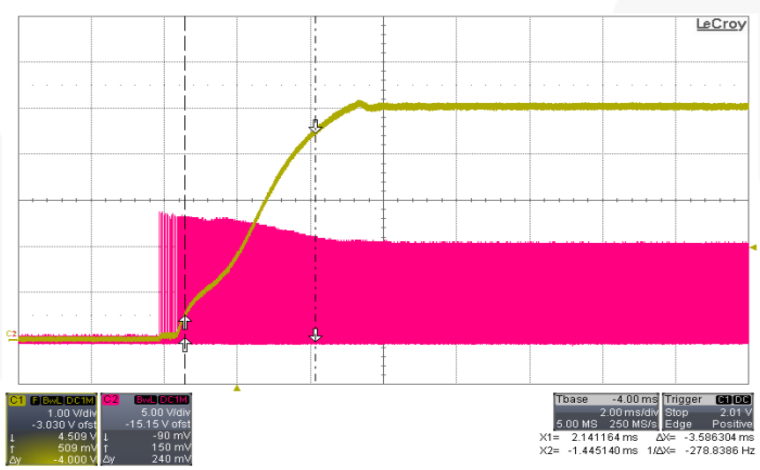

Figure 15. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}] at Maximum Load

9.5. Conversion Efficiency

Test Conditions

Measure the input power and output power at maximum loading.

Table 9. Test Results

Input Voltage	Input Power	Output Power	Efficiency	Specification
90 V_{AC} / 60 Hz	6.428 W	5.02 W	78.09%	> 73.37%
115 V_{AC} / 60 Hz	6.454 W	5.10 W	79.02%	
230 V_{AC} / 50 Hz	6.620 W	5.09 W	76.97%	
264 V_{AC} / 50 Hz	6.585 W	5.11 W	77.60%	

Table 10. Average Efficiency Test Results

Input Voltage	Efficiency					Specification
	25% Load	50% Load	75% Load	100% Load	Avg.	
115 V_{AC} / 60 Hz	75.40%	79.50%	78.69%	79.02%	78.15%	> 73.37%
230 V_{AC} / 50 Hz	70.00%	76.44%	76.08%	76.87%	74.85%	

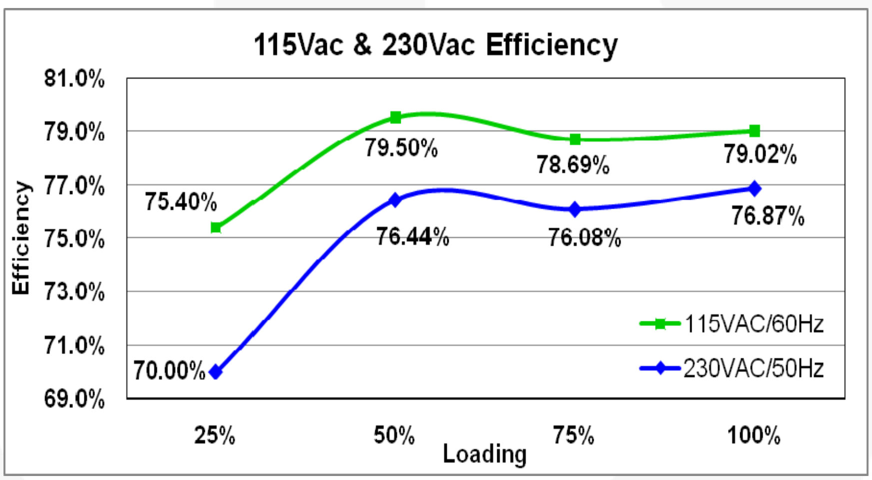

Figure 16. Average Efficiency Test Results

9.6. Output Ripple & Noise

Test Condition

Ripple and noise are measured by using a 20 MHz bandwidth-limited oscilloscope with a 10 µF capacitor paralleled with a high-frequency 0.1 µF capacitor across each output.

Table 11. Test Results

Input Voltage	Output Ripple at No Load	Output Ripple at Maximum Load	Specification
90 V_{AC} / 60 Hz	18.6 mV	81.4 mV	< 150 mV
115 V_{AC} / 60 Hz	21.2 mV	83.2 mV	
230 V_{AC} / 50 Hz	26.7 mV	90.3 mV	
264 V_{AC} / 50 Hz	27.2 mV	95.0 mV	

Measured Waveforms

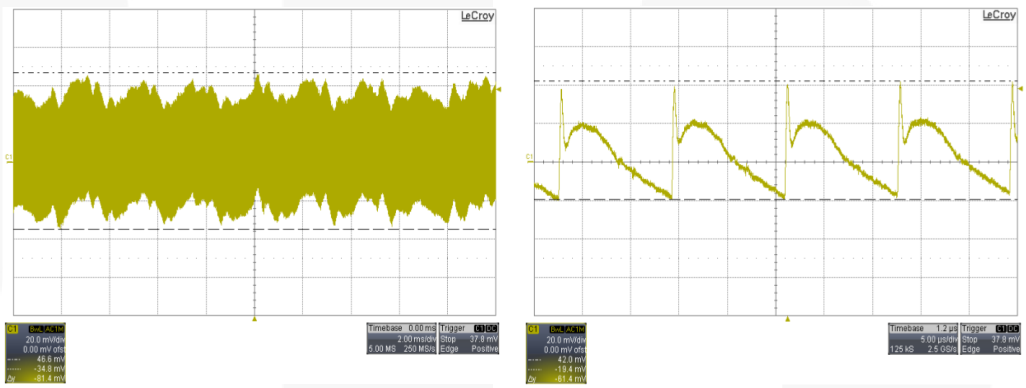

Figure 17. 90 V_{AC} / 60 Hz, C1 [V_O] at Maximum Load

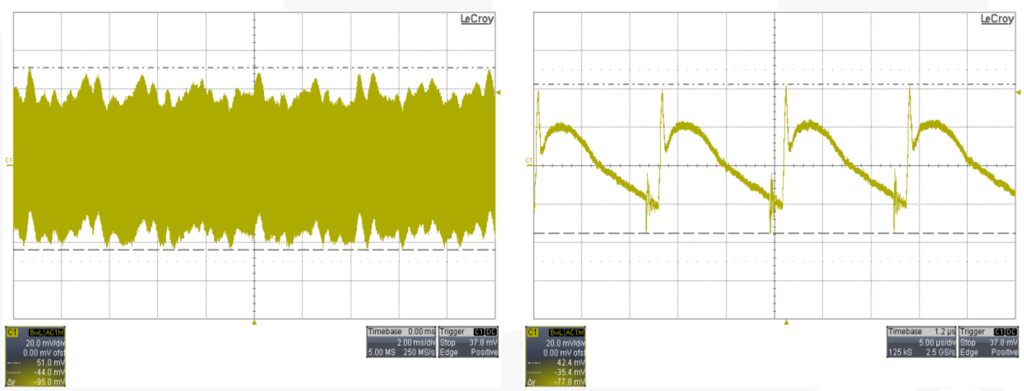

Figure 18. 264 V_{AC} / 50 Hz, C1 [V_O] at Maximum Load

9.7. Dynamic Response

Test Conditions

Dynamic loading (0 %~50 %) of the full load, 5 ms duty cycle, 2.5 A/μs rise/fall time.

Table 12. Test Results

Input Voltage	Overshoot	Undershoot
90 V_{AC} / 60 Hz	5.218 V	4.034 V
264 V_{AC} / 50 Hz	5.206 V	4.028 V

Measured Waveforms

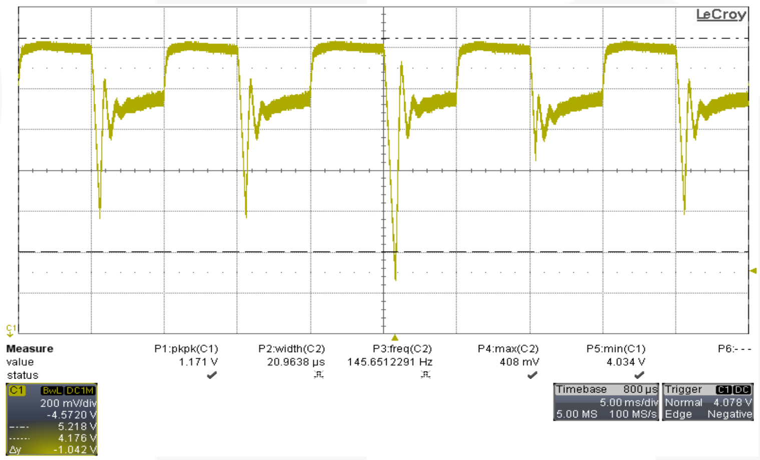

Figure 19. 90 V_{AC} / 60 Hz, C1 [V_O] at Dynamic Response

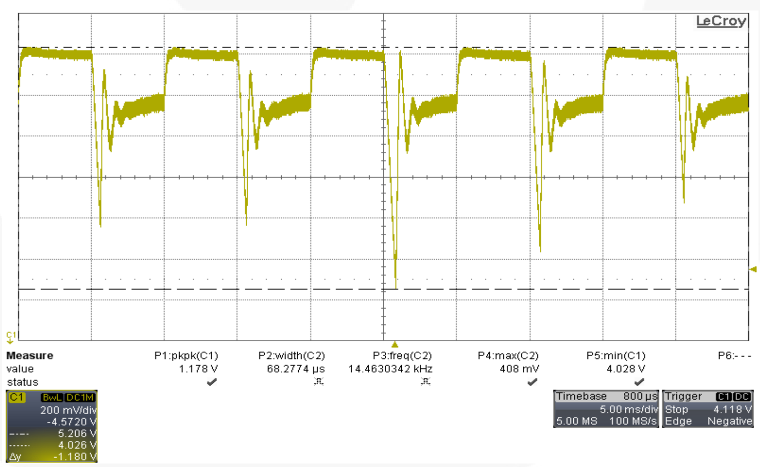

Figure 20. 264 V_{AC} / 50 Hz, C1 [V_O] at Dynamic Response

9.8. Over-Power Protection

Test Conditions

Increase the output loading gradually. Measure the output power.

Table 13. Test Results

Input Voltage	Output Power
90 V_{AC} / 60 Hz	5.82 W
115 V_{AC} / 60 Hz	5.85 W
230 V_{AC} / 50 Hz	5.92 W
264 V_{AC} / 50 Hz	5.94 W

9.9. Hold-up Time

Test Conditions

Set the output at maximum loading. Measure the time interval between AC line off condition and the output voltage falling to the lower limit of rated value. The AC waveform should be off at zero degrees.

Table 14. Test Results

Input Voltage	Hold-up Time
90 V_{AC} / 60 Hz	10.9 ms
264 V_{AC} / 50 Hz	133 ms

Measured Waveforms

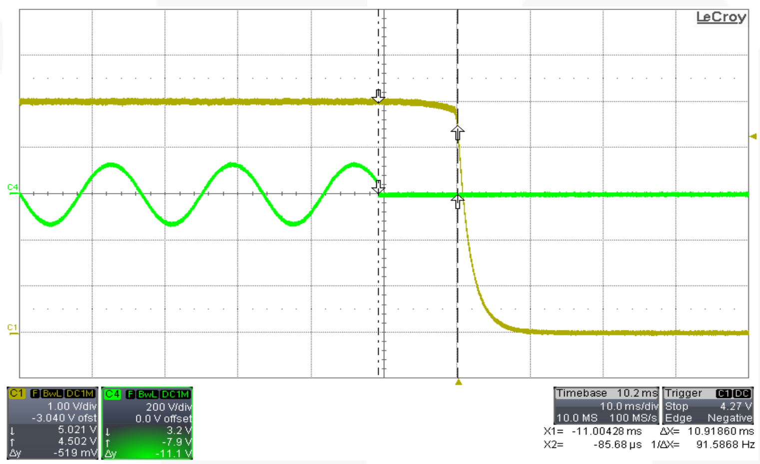

Figure 21. 90 V_{AC} / 60 Hz, C1 [V_O], C4 [V_{AC}] at Maximum Load

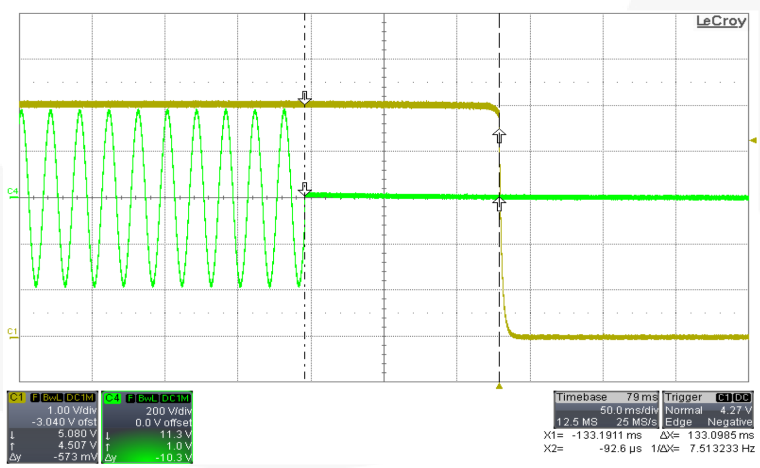

Figure 22. 264 V_{AC} / 50 Hz, C1 [V_O], C4 [V_{AC}] at Maximum Load

9.10. Short-Circuit Protection

Test Conditions

Short the output of the power supply. The power supply should enter Hiccup Mode protection. Input power should be less than 2 W.

Table 15. Test Results

Input Voltage	Input Power at Maximum Load	Input Power at Minimum Load	Specification
90 V_{AC} / 60 Hz	0.361 W	0.372 W	<2 W
264 V_{AC} / 50 Hz	0.969 W	0.991 W	

Measured Waveforms

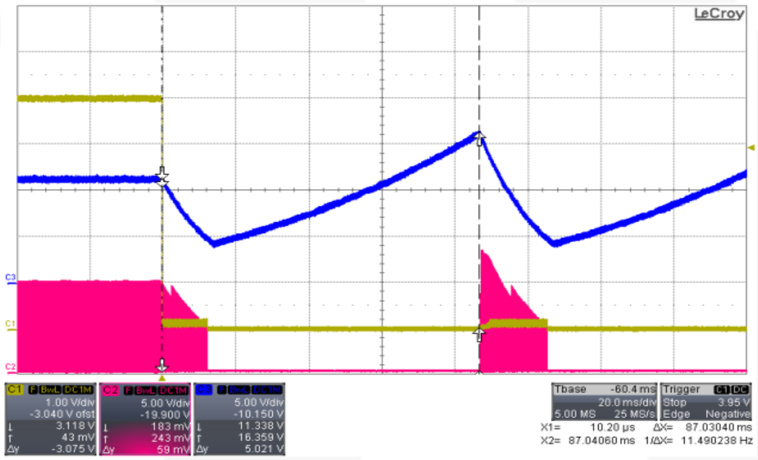

Figure 23. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at No Load Output Short

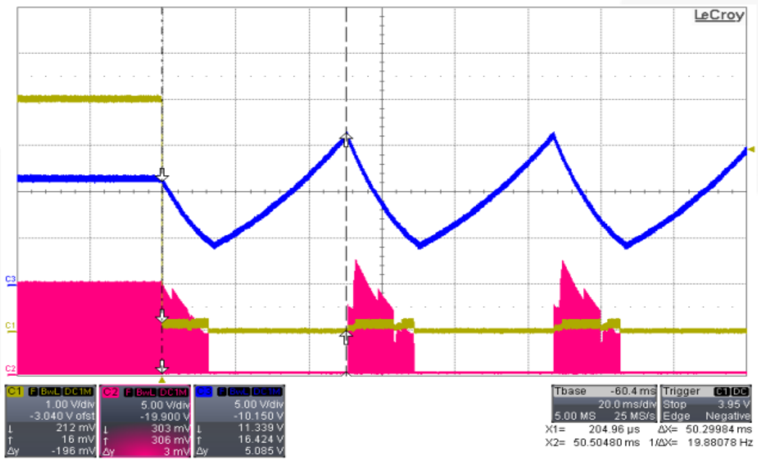

Figure 24. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Maximum Load Output Short

9.11. Brownout Test

Test Conditions

Input Voltage	Input Wattage	Output Voltage
90 V_{AC} / 60 Hz	6.832 W	5.164 V
85 V_{AC} / 60 Hz	6.841 W	5.160 V
80 V_{AC} / 60 Hz	6.860 W	5.154 V
75 V_{AC} / 60 Hz	6.903 W	5.140 V
70 V_{AC} / 60 Hz	6.97 W	5.124 V
65 V_{AC} / 60 Hz	7.08 W	5.096 V
63 V_{AC} / 60 Hz	Brownout	Brownout

Table 16. Test Results

Recovery Voltage	Input Power	Output Voltage
64 V_{AC} / 60 Hz	7.12 W	5.09 V

9.12. V_{DD} Voltage Level

Table 17. Test Results

Input	V_{DD} Level at No Load	V_{DD} Level at Max. Load	V_{DD} Level at OPP	Max. V_{DD} Level at Output Short	Specification
90 V_{AC} / 60 Hz	7.5 V	11.4 V	11.9 V	16.4 V	< 24 V
264 V_{AC} / 50 Hz	7.4 V	11.8 V	12.1 V	16.4 V	

Measured Waveforms

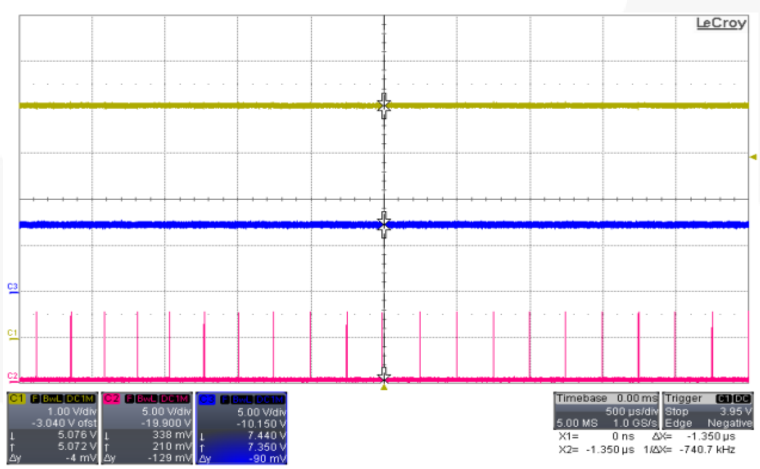

Figure 25. 90 V_{AC} / 60 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at No Load

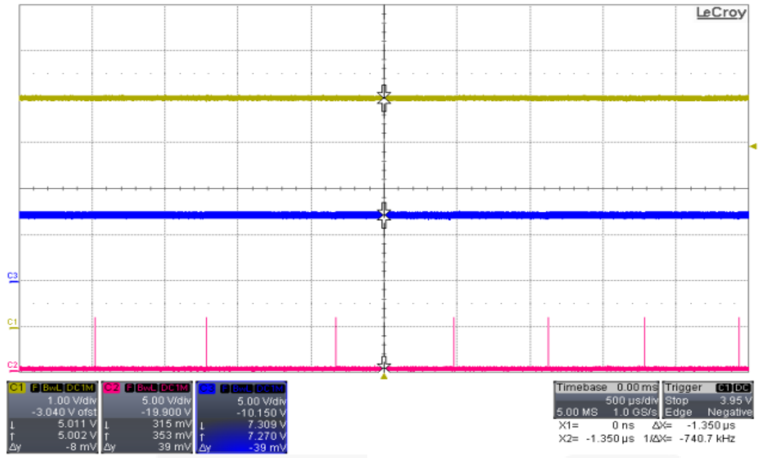

Figure 26. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at No Load

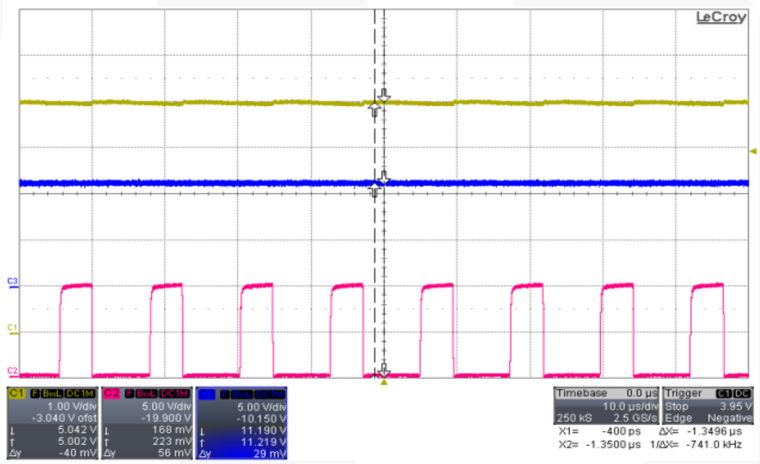

Figure 27. 90 V_{AC} / 60 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Maximum Load

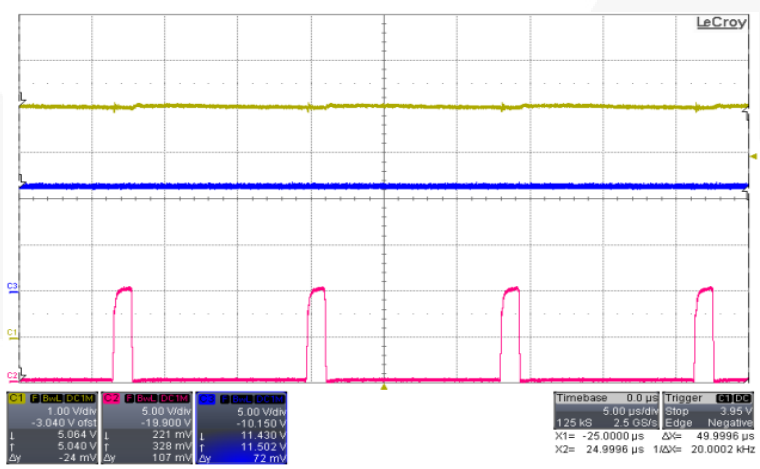

Figure 28. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Maximum Load

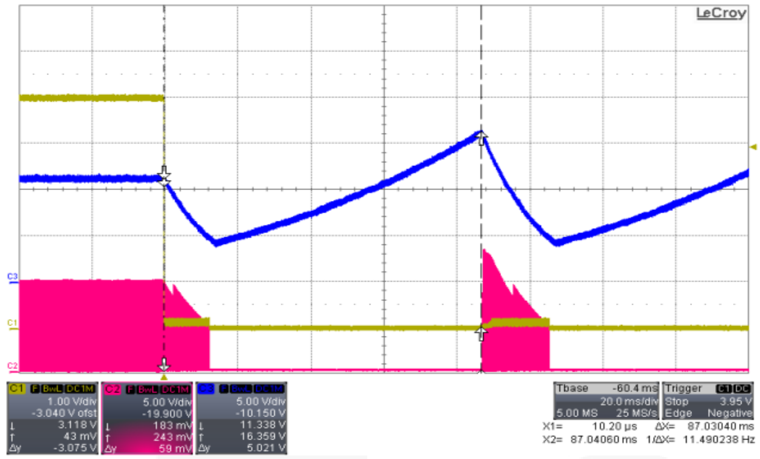

Figure 29. 90 V_{AC} /60 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Output Short

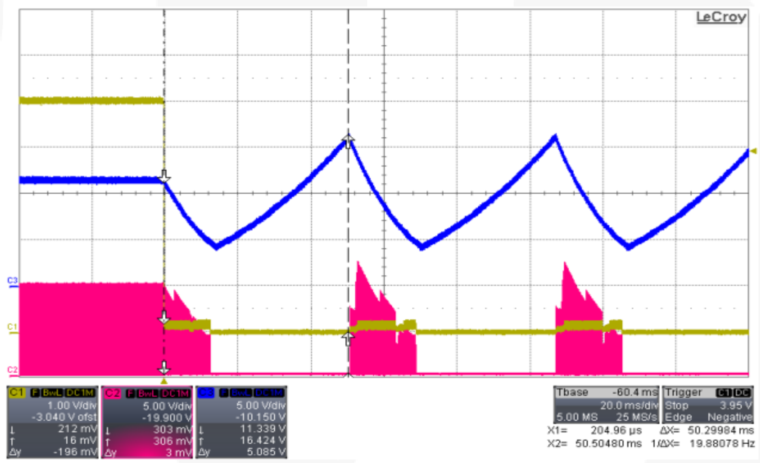

Figure 30. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Output Short

9.13. Voltage Stress on MOSFET & Rectifier

Test Conditions

Measure the voltage stress on the MOSFET and the secondary rectifier under the below specified conditions.

Table 18. Test Results

Input Voltage	Stress On MOSFET	Rating	Stress On Output Rectifier	Rating
90 V_{AC} / 60 Hz at Maximum Load	295 V		19.7 V	
90 V_{AC} / 60 Hz at Maximum Load, Startup	296 V		19.7 V	
90 V_{AC} / 60 Hz at Maximum Load, Output Short	302 V		20.4 V	
264 V_{AC} / 50 Hz at Maximum Load	554 V	600V	42.4 V	45 V
264 V_{AC} / 50 Hz at Maximum Load, Startup	554 V		42.4 V	
264 V_{AC} / 50 Hz at Maximum Load, Output Short	564 V		45 V	
264 V_{AC} / 50 Hz at Maximum Load, Turn Off	564 V		45 V	

Measured Waveforms

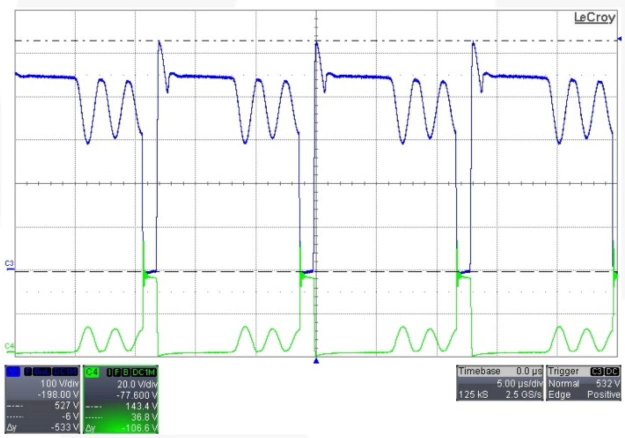

Figure 31. 264 V_{AC} / 50 Hz, C3 [V_{DS}], C4 [V_{DIODE}] at Maximum Load

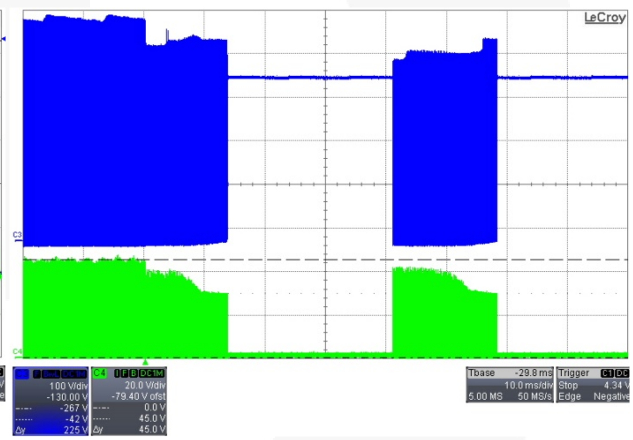

Figure 32. 264 V_{AC}/50 Hz, C3 [V_{DS}], C4 [V_{DIODE}] at Output Short

9.14. Constant-Voltage (CV) and Constant-Current (CC) Curves

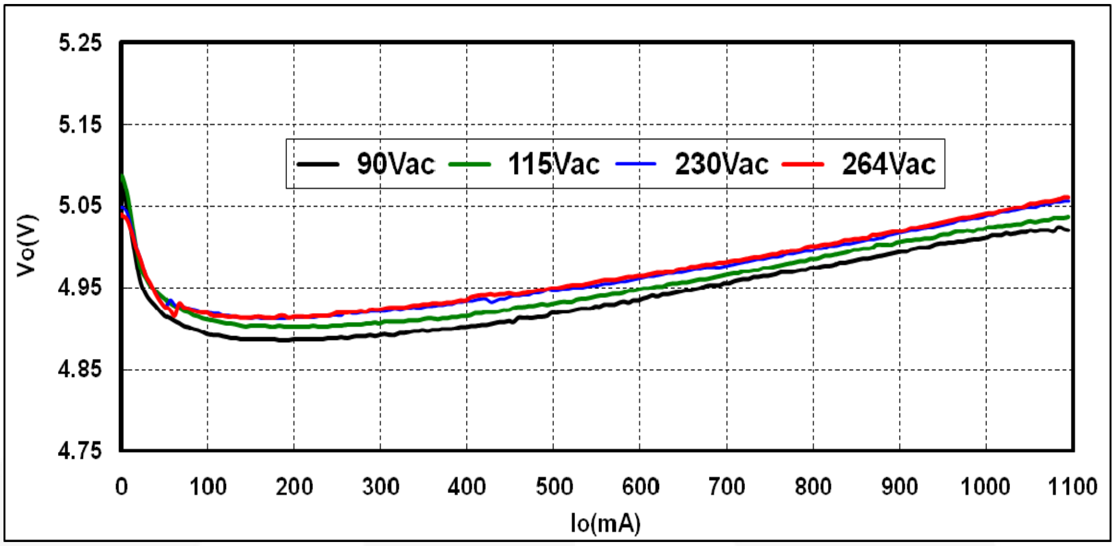

Figure 33. Constant – Voltage (CV) Curves

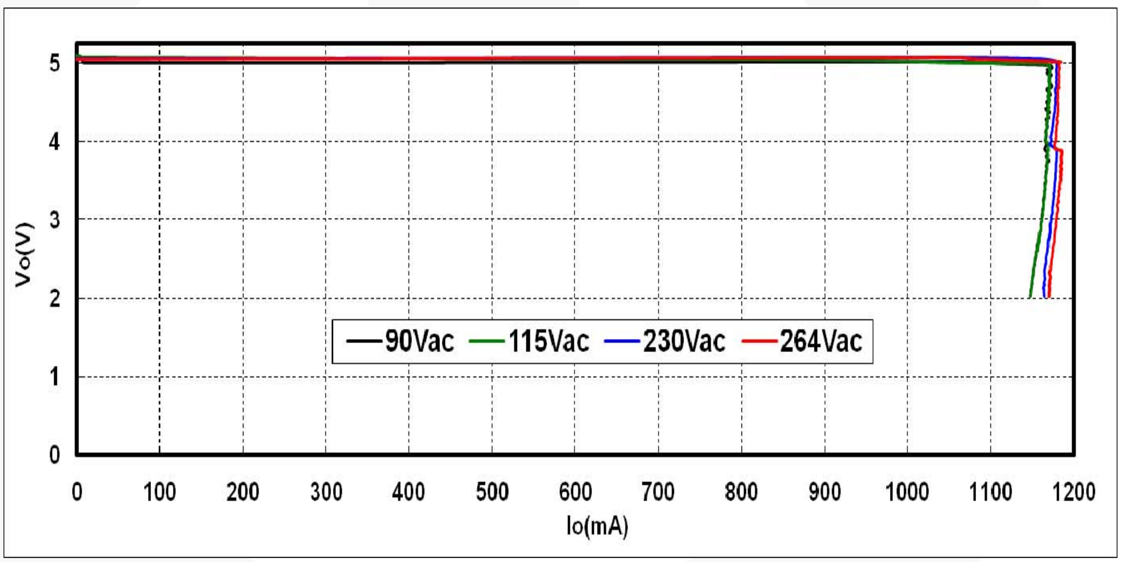

Figure 34. Constant – Current (CC) Curves

9.15. V_S Over-Voltage Protection Test

Test Conditions

Measure the maximum output voltage when the auxiliary feedback signal is disabled (Vs pin low-side resistor opened).

Table 19. Test Results

Input Voltage	Maximum Output at No Load	Maximum Output at Maximum Load
90 V_{AC} / 60 Hz	6.8 V	0 V
264 V_{AC} / 50 Hz	6.8 V	0 V

9.16. Over-Temperature Protection Test (OTP)

Test Conditions

Measure the output voltage and the MOSFET gate voltage when the IC temperature increases above 140°C.

Measured Waveforms

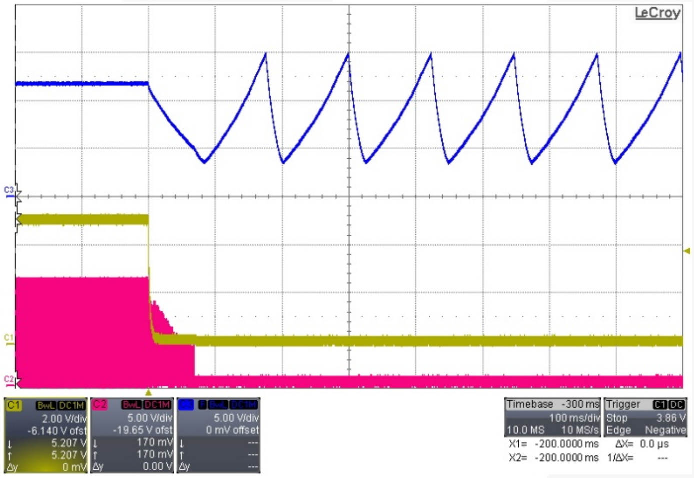

Figure 35. 90 V_{AC} / 6 0Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Maximum Load

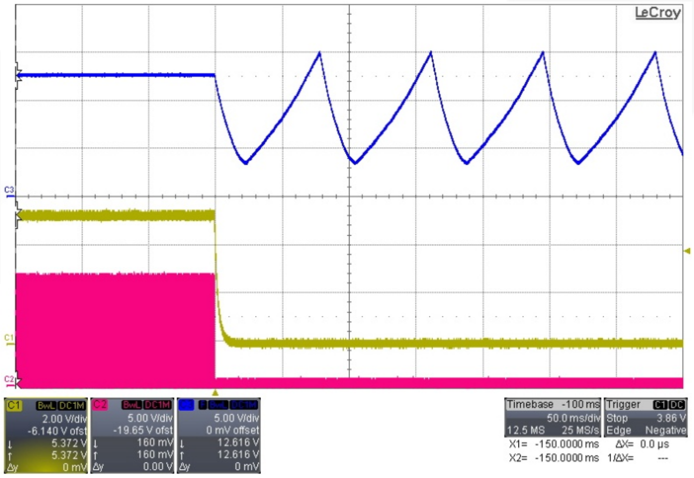

Figure 36. 264 V_{AC} / 50 Hz, C1 [V_O], C2 [V_{GS}], C3 [V_{DD}] at Maximum Load

9.17. Electromagnetic Interference (EMI) Tests

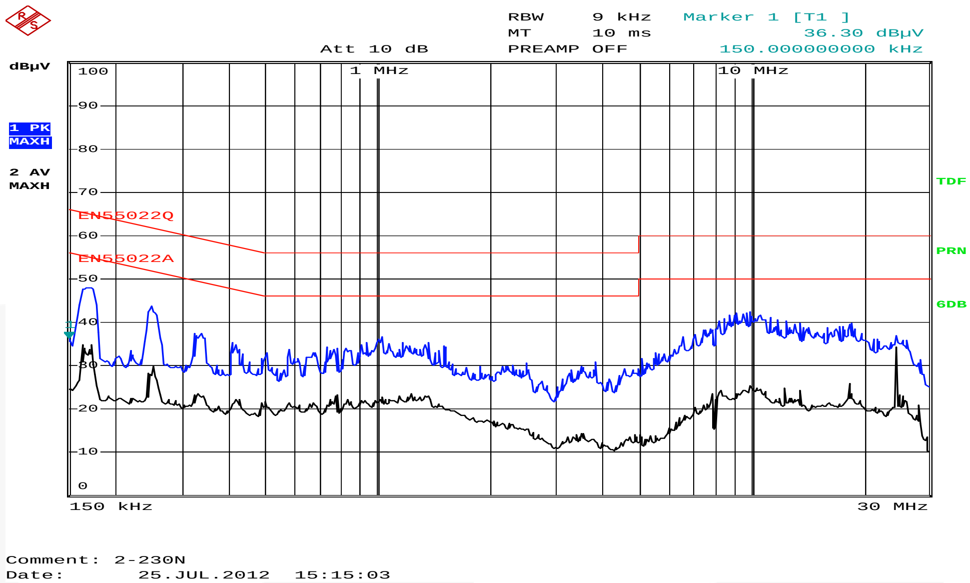

Figure 37. Line at 115 V_{AC}

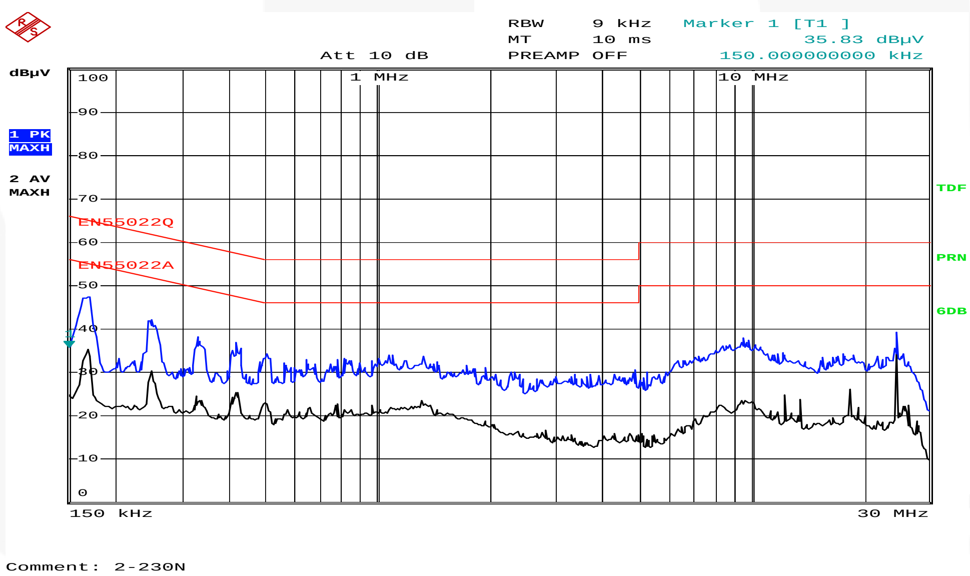

Figure 38. Neutral at 115 V_{AC}

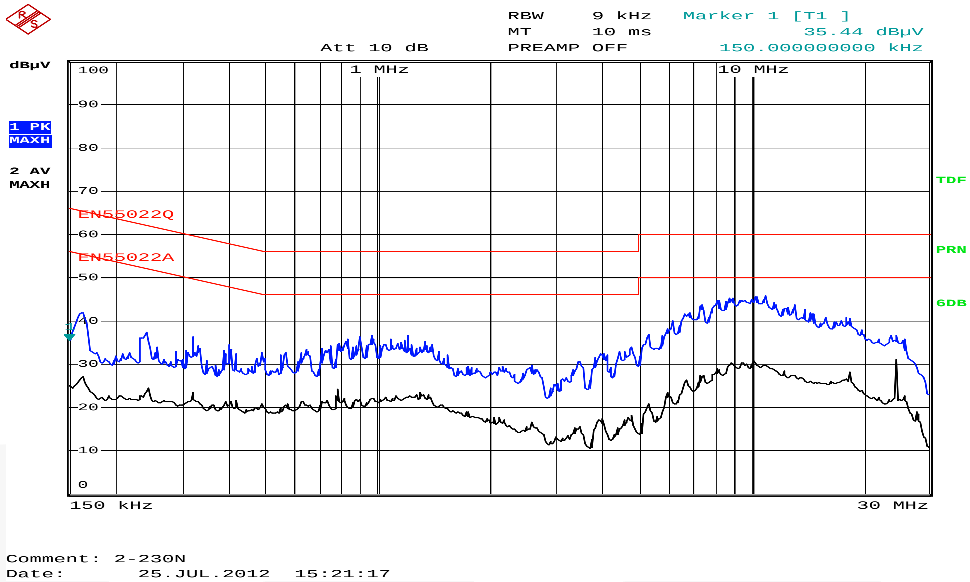

Figure 39. Line at 230 V_{AC}

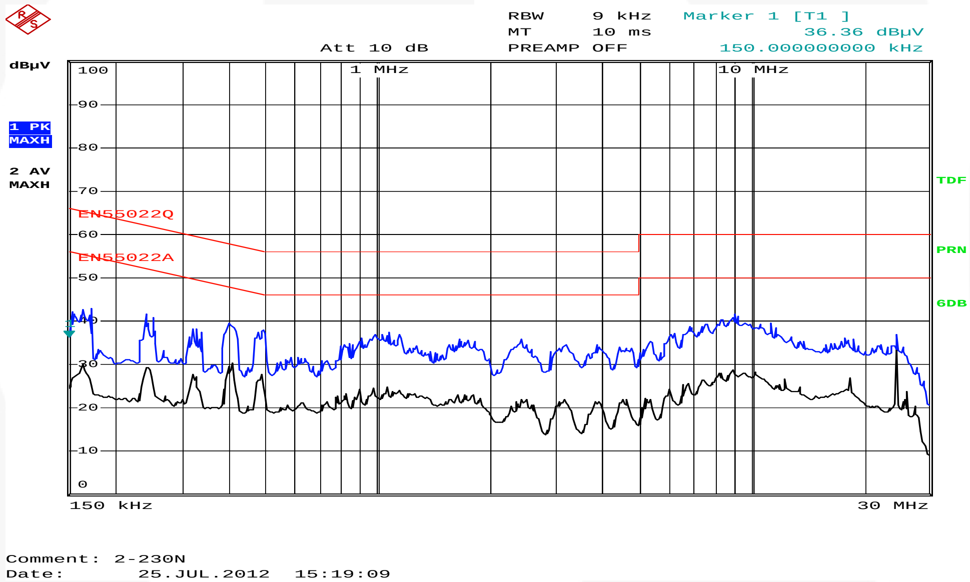

Figure 40. Neutral at 230 V_{AC}

9.18. Surge Test

Table 20. Test Results

Mode	Polarity	Phase	Voltage	Condition
L-N	±	0°	2.2 kV	PASS
	±	90°		PASS
	±	180°		PASS
	±	270°		PASS
L-PE	±	0°	4.4 kV	PASS
	±	90°		PASS
	±	180◦		PASS
	±	270°		PASS
N-PE	±	0°	4.4 kV	PASS
	±	90°		PASS
	±	180°		PASS
	±	270°		PASS

9.19. Electrostatic Discharge Capability (ESD) Test

Table 21. Test Results

Mode	Polarity	Voltage	Condition
Air	±	16.5 kV	PASS
Contact	±	8.8 kV	PASS

10. Revision History

Rev.	Date	Description
1.0.0	October 2012	Initial Release