EVBUM2650/D

14.5 W Auxiliary Power for White Goods and Industrial Equipment with FSL538HPG

ON Semiconductor®

www.onsemi.com

EVAL BOARD USER'S MANUAL

Table 1. GENERAL SPECIFICATIONS

Devices	Applications	Input Voltage	Output Power	Topology	Board Size
FSL538HPG	White Goods and Industrial Power Supplies	85–265 Vac	14.5 W	Non−Isolated Flyback	88 × 45 × 22 mm 2.73 W/inch^3
Output Spec.	**Turn on Time**	**Efficiency**	**Operating Temperature**	**Cooling**	**Standby Power**
12 V/1 A & 5 V/0.5 A	< 200 ms	Above 85% @ Full Load	0–50°C	Convection Open Frame	< 50 mW @ 230 Vac

Description

This user manual provides elementary information about a Non−isolated dual output flyback with FSL538HPG, it performs high efficiency and smaller than 50 mW no−load power consumption. FSL538HPG is an integrated pulse width modulation (PWM) and 800 V power switch with SENSEFET®, it can help to save external MOSFET and sense resistor, increase power density and reliability. This application is targeting auxiliary power supply for white goods and industrial equipment, such as refrigerator, E−metering or similar types of equipment.

The PWM controller includes an integrated variable frequency oscillator, Under−Voltage Lockout (UVLO), Leading Edge Blanking (LEB), optimized gate driver, internal soft−start, and built−in error amplifier for feedback connection directly and self−protection circuitry. This design focuses mainly on the FSL538HPG current−mode PWM controller. Please refer to FSL538HPG's materials to get more information about this device.

The FSL538HPG is a current−mode PWM controller, it can have better response to handle dynamic operation. Controller combines line detection and burst−mode adjustment in one pin. It's easy to achieve these functionalities just need voltage divider and one Zener diode. Line detection includes brown−in, brown−out and line OVP, burst−mode adjustment is for fine tune audible noise and light load efficiency. Of course, it also provides frequency reduction with loading decreasing for gaining more design margin to improve light load efficiency.

Key Features

- Integrated Rugged 800 V Super Junction MOSFET with SENSEFET Technology
- Built−in HV Current Source for Start−up
- Peak−Current−Mode Control with Slope Compensation
- Line Compensation for Maximum Over−Power Limiting
- Advanced Soft−start for Low Electrical Stress
- Pulse−by−pulse Current Limit
- Line Brown−in, Brown−out, and Over−Voltage Protection (LOVP)
- Adjustable Burst−mode Operation
- Frequency Hopping for Better EMI
- Various Protections:
  - Auto Restart Mode: Brown−out, OLP, OVP, AOCP and TSD
  - Recovery Immediately by Triggering Level: LOVP

DETAIL DEMO−BOARD SCHEMATIC DESCRIPTION

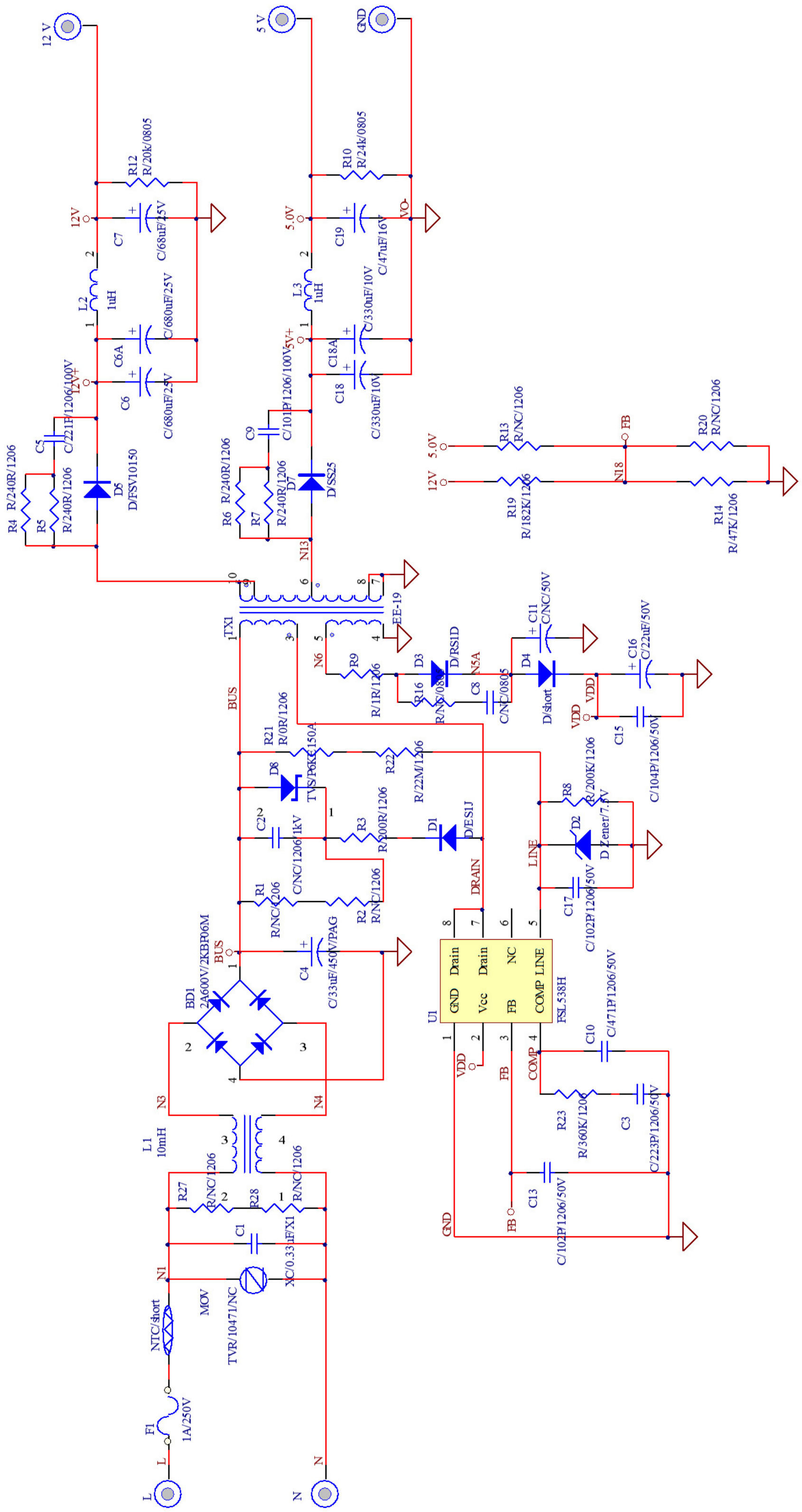


Figure 1. FSL538HFLYGEVB Demo−Board – Main Board Schematic

The input EMI filter is formed by components L1 and C1. Bleeder for X−cap, R27 and R28, are left not connected.

The primary side of flyback converter is composed of these devices; power transformer TX1, dc−link capacitor, TVS snubber, the integrated switcher U1(FSL538HPG) and related components. Meanwhile, the integrated switcher has a peak current mode PWM controller and 800 V super junction MOSFET. D1, R3 and D8 form TVS snubber to protect instant voltage spike produced by leakage inductance. R19 (or R13) and R14 (or R20) are a voltage divider to sense the output voltage, which needs a capacitor C13 optionally to avoid switching noise interference and stabilize FB pin voltage. COMP pin is the output of the internal error amplifier, where a compensation network, for example R23, C3 and C10 are connected and it generates a control voltage for PWM controller. LINE pin of U1 connects voltage divider from bulk capacitor to detect input voltage for some protections of brown−in, brown−out and LOVP. Besides, there is parallel−connected D2 on LINE pin to adjust burst threshold to fine tune audible noise and light load efficiency. C17 is used to avoid larger switching noise interference, which is usually recommended around 1 nF~3.3 nF. Auxiliary winding shares same ground reference with U1. That is, reference ground is negative terminal of output of bridge rectifier BD1. Transformer winding is also used for providing VCC voltage in normal operation. R9 and D3 provide path to delivery energy when PWM is turned off. C16 can keep enough voltage if PWM is turned off for a while, and C15 is for better stability.

The secondary−side output is composed of two outputs. One is 12 V output terminal in which there are D5, C6 and C6A. The other is 5 V output terminal that composed of D7, C18 and C18A. When the MOSFET integrated in the switcher turns off, energy stored in the coupled inductor is transferred to the secondary side. At the time, there is switching noise on the output voltage, which can be, however, reduced by a LC filter on each output terminal formed by L2 and C7 (L3 and C19). R12 and R10 are used as dummy load to avoid V_{CC} self supply operation for better no load power consumption. The ground is same to reference ground of primary side.

CIRCUIT LAYOUT

The PCB consists of a double layer FR4 board with 2 oz. copper cladding.

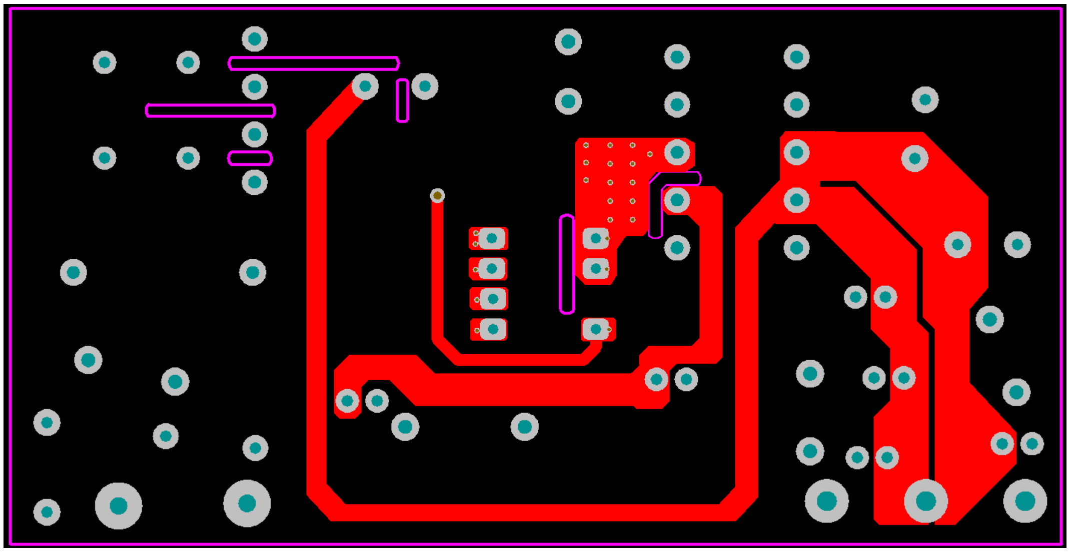


Figure 2. Main Board Top Layer

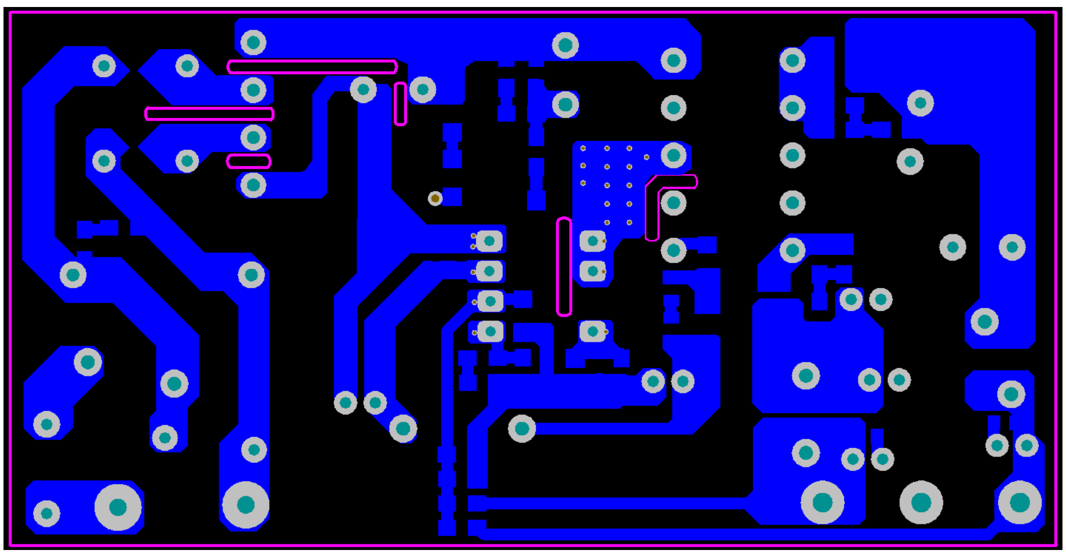


Figure 3. Main Board Bottom Layer

CIRCUIT LAYOUT (Continued)

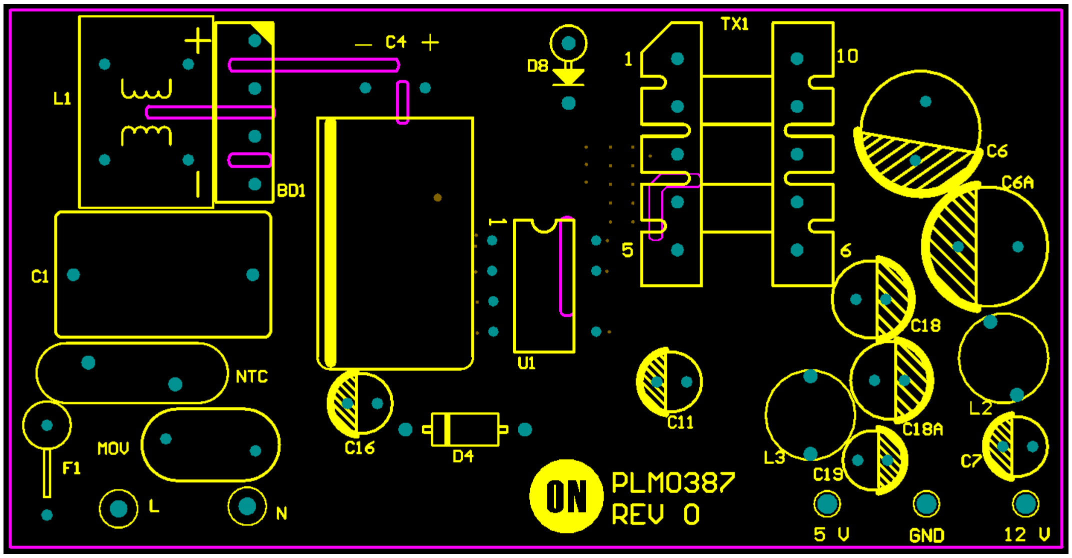


Figure 4. Main Board Top Side Components

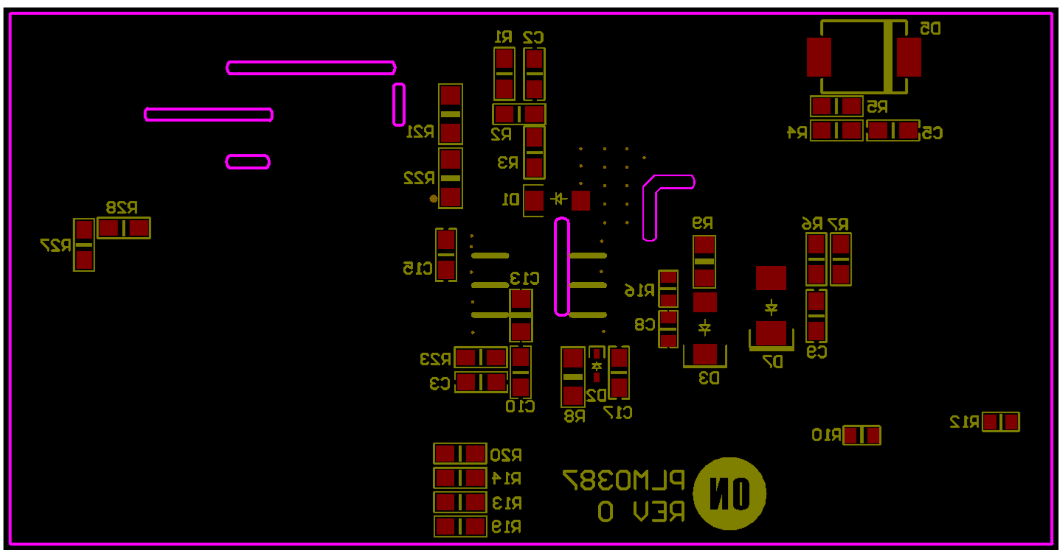


Figure 5. Main Board Bottom Side Components

BOARD PICTURES

Figure 6. Main Board Photo − Top Side

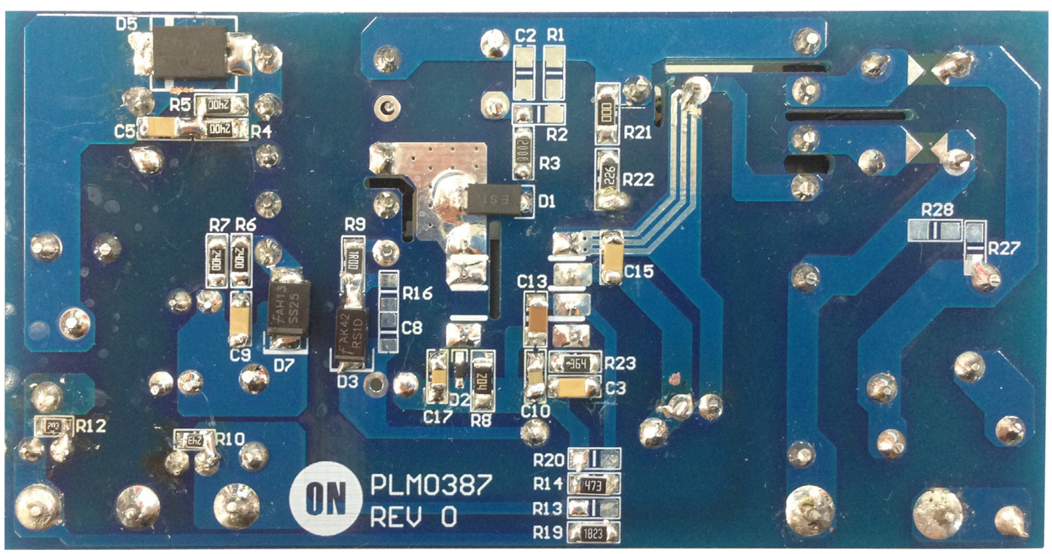
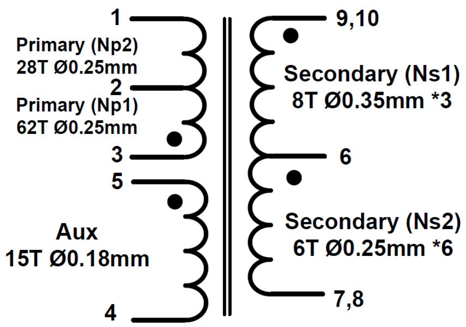


Figure 7. Main Board Photo − Bottom Side

TRANSFORMER DATA

Bobbin & Core : EE-19



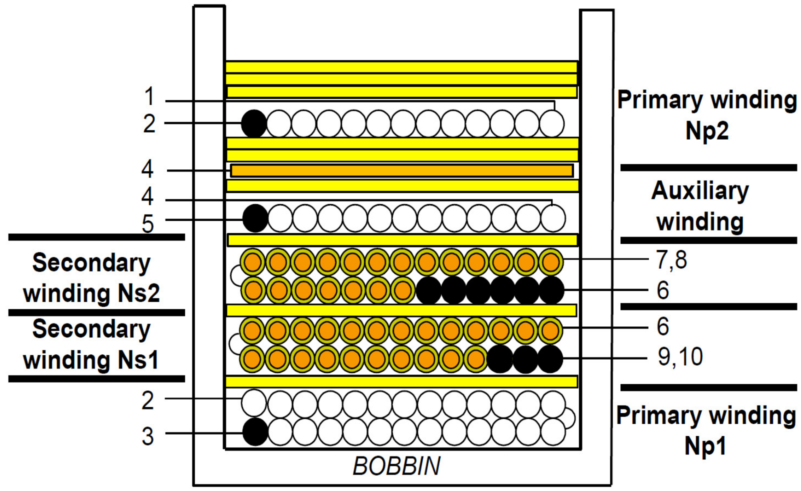


Table 2.

	Pin	Specification	Remark
Primary–Side Inductance	Drain – B+	960 μH (Typ.)	100 kHz, 1 V

Table 3.

Layer	TERMINAL		WIRE	Turns	Isolation Layer
	Start Pin	End Pin			Turns
Primary Winding (Np1)	3	2	2UEW 0.25 * 1	62	1
Secondary (Ns1)	9,10	6	0.35 * 3	8	1
Secondary (Ns2)	6	7,8	0.25 * 6	6	1
AUX Winding	5	4	2UEW0.18 * 1	15	1
Copper Shield	4	–		1.2	1
Primary Winding (Np2)	2	1	2UEW 0.25 * 1	28	2

*Copper shield is open loop and connect to ground.

TEST DATA

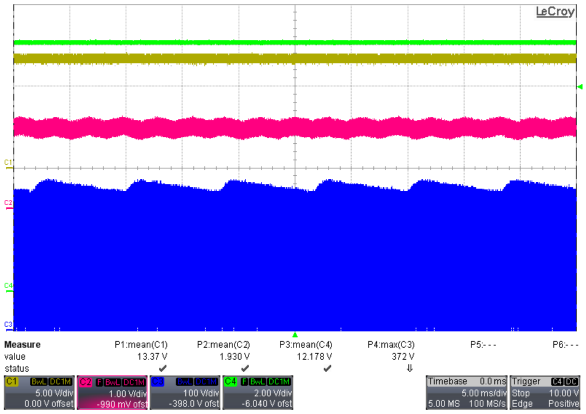


Figure 8. Operation, Full Load, 115 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

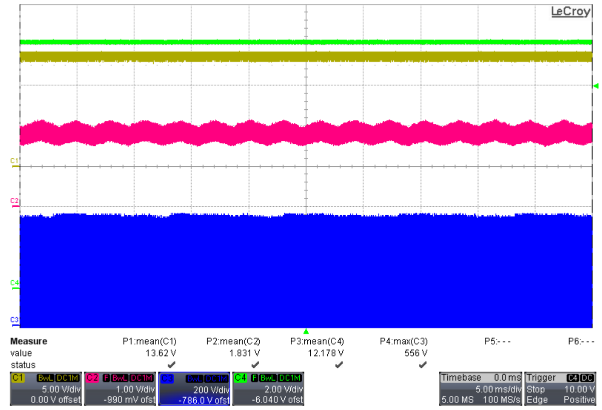


Figure 9. Operation, Full Load, 230 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

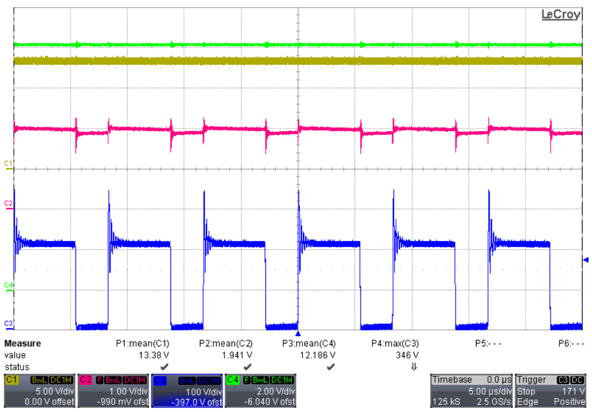


Figure 10. Zoom in Operation, Full Load, 115 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

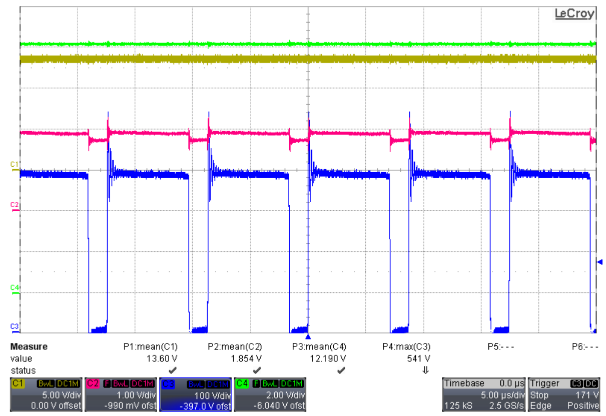


Figure 11. Zoom in Operation, Full Load, 230 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

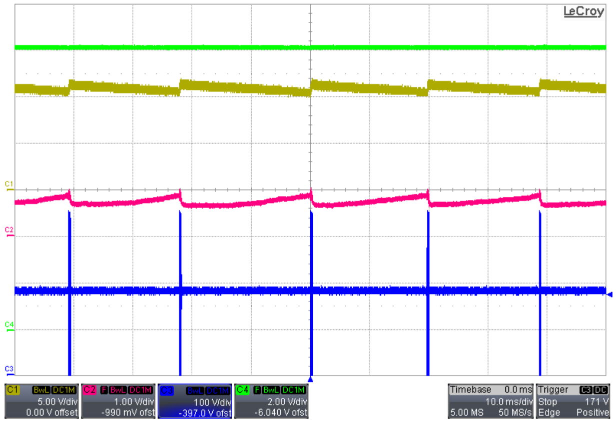


Figure 12. Operation, No Load, 115 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

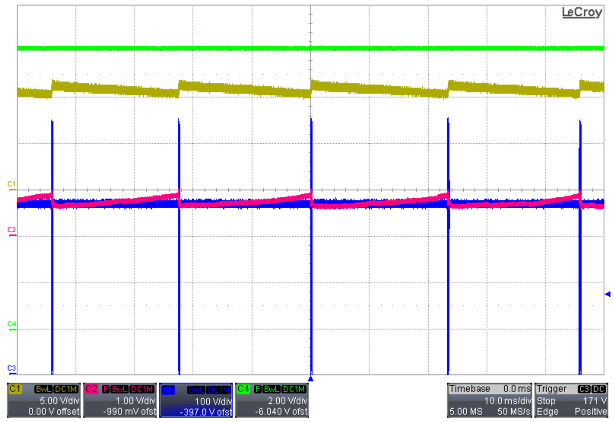


Figure 13. Operation, No Load, 230 Vac
(Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

TEST DATA (Continued)

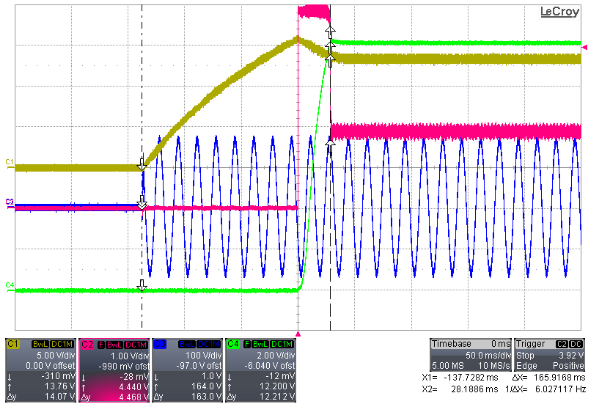


Figure 14. Ton On time, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Vac, Ch4: Vo)

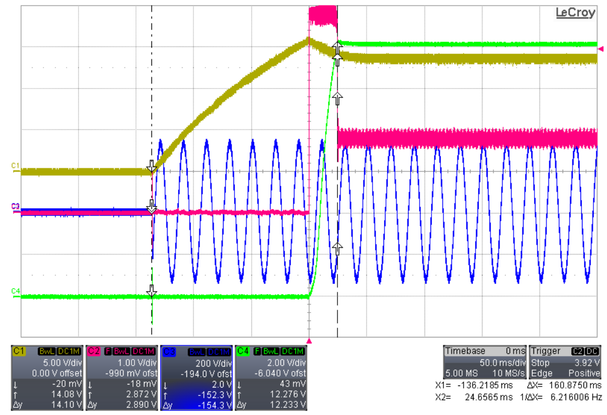


Figure 15. Ton on time, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Vac, Ch4: Vo)

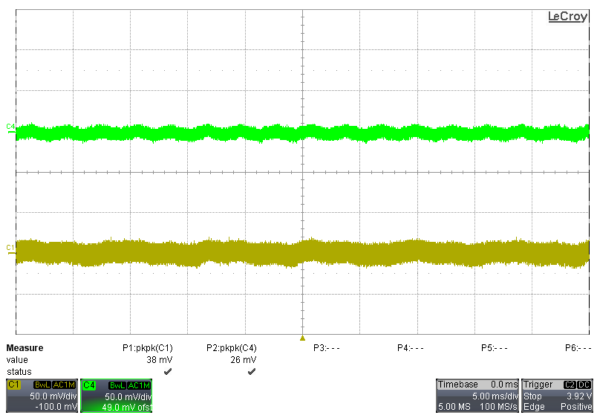


Figure 16. Output Ripple, Full Load, 115 Vac (Ch1: Vo−5 V (AC), Ch4: Vo−12 V (AC))

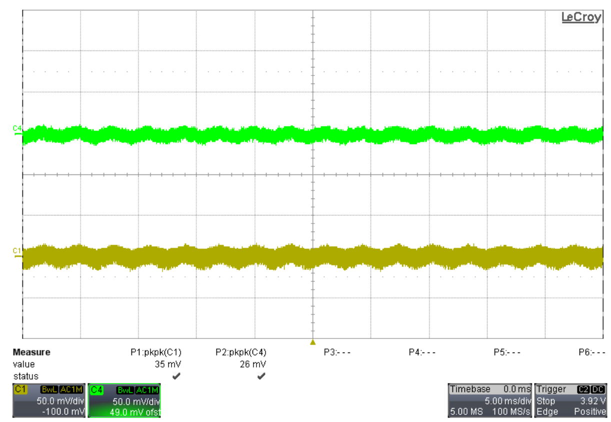


Figure 17. Output Ripple, Full Load, 230 Vac (Ch1: Vo−5 V (AC), Ch4: Vo−12 V (AC))

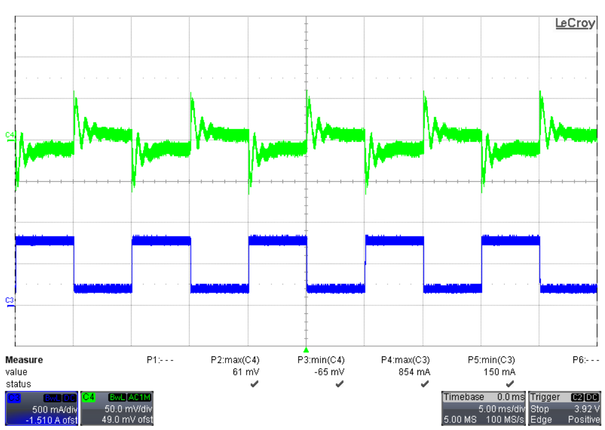


Figure 18. Dynamic operation (20%~80% of the Full Load for 12 V Output, 5 ms Duty Cycle, 2.5 A/μs Rise/Fall Time), 115 Vac (Ch3: Io, Ch4: Vo(AC))

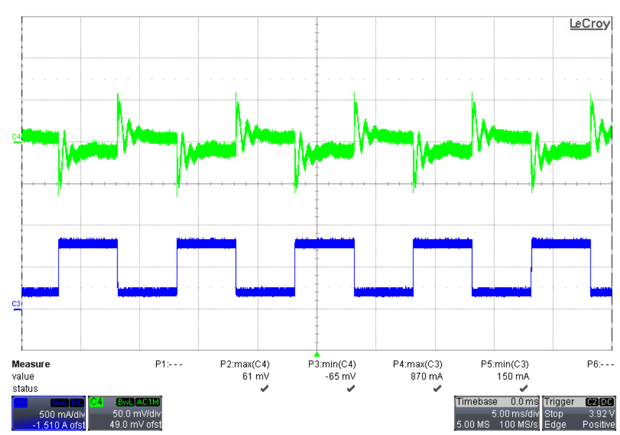


Figure 19. Dynamic Operation (20%~80% of the Full Load for 12 V Output, 5 ms Duty Cycle, 2.5 A/μs Rise/Fall Time), 230 Vac (Ch3: Io, Ch4: Vo(AC))

TEST DATA (Continued)

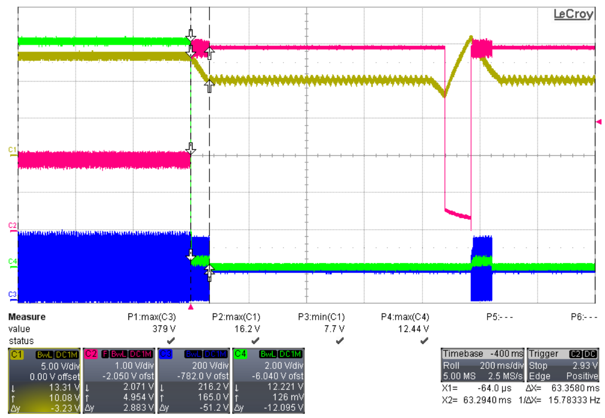


Figure 20. Output Short Triggers OLP, Full Load, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

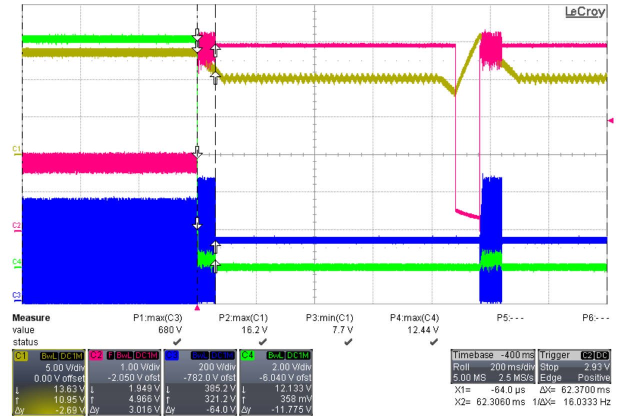


Figure 21. Output Short Triggers OLP, Full Load, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

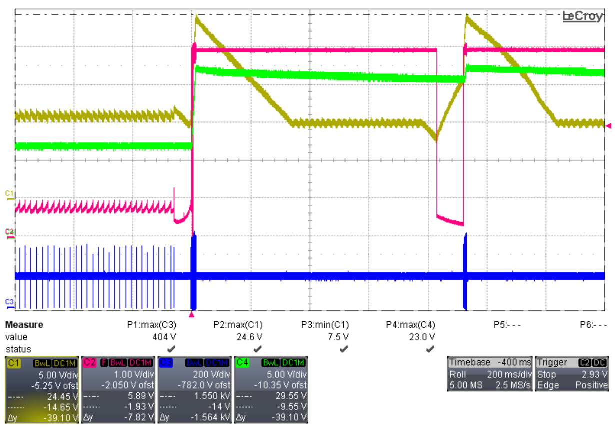


Figure 22. Short R14 to Trigger VCC OVP, No Load, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

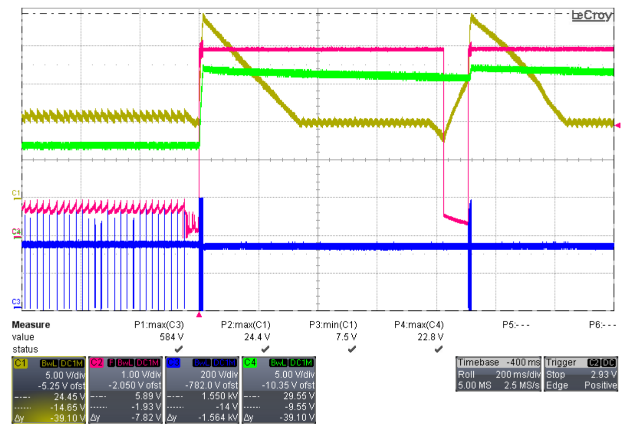


Figure 23. Short R14 to Trigger VCC OVP, No Load, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo

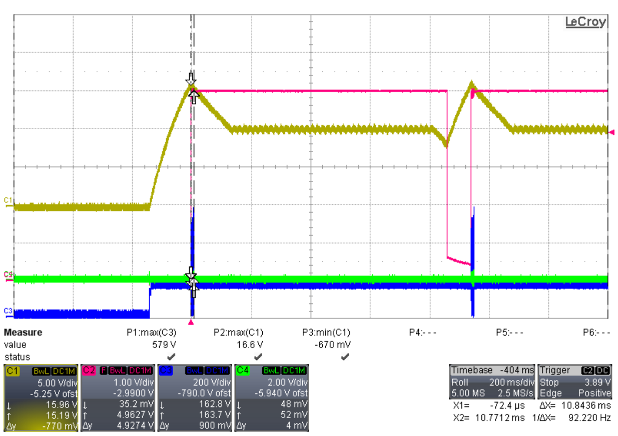


Figure 24. Short Output Schottky Diode to Trigger AOCP, Full Load, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

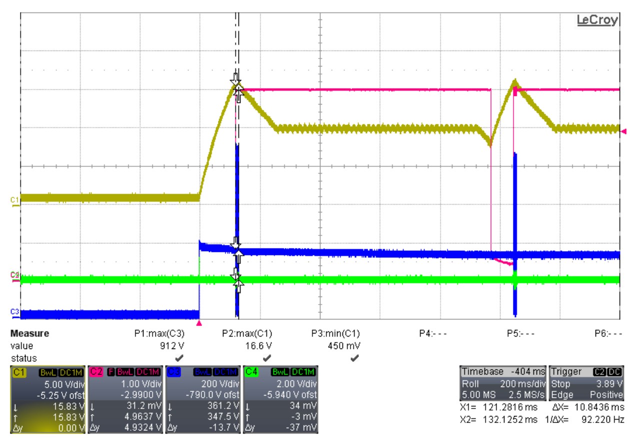


Figure 25. Short Output Schottky Diode to Trigger AOCP, Full Load, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

TEST DATA (Continued)

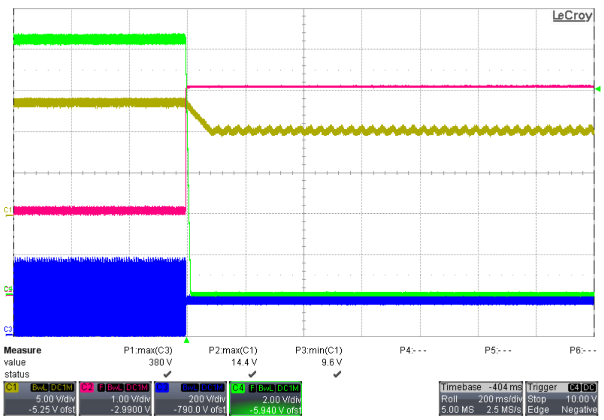


Figure 26. Heating on IC's Case to Trigger TSD, Full Load, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

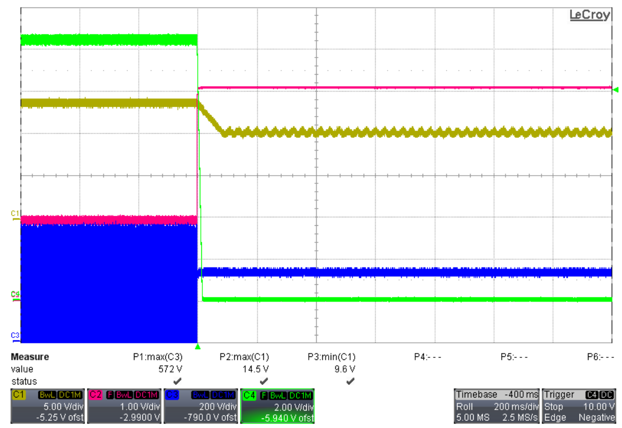


Figure 27. Heating on IC's Case to Trigger TSD, Full Load, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

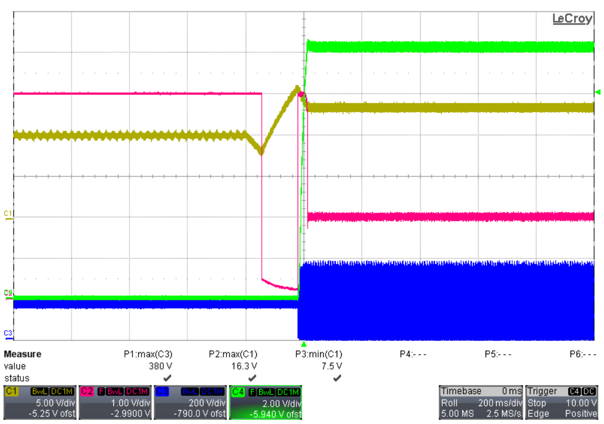


Figure 28. Remove Heating from IC's Case to Recover TSD Protection, Full Load, 115 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

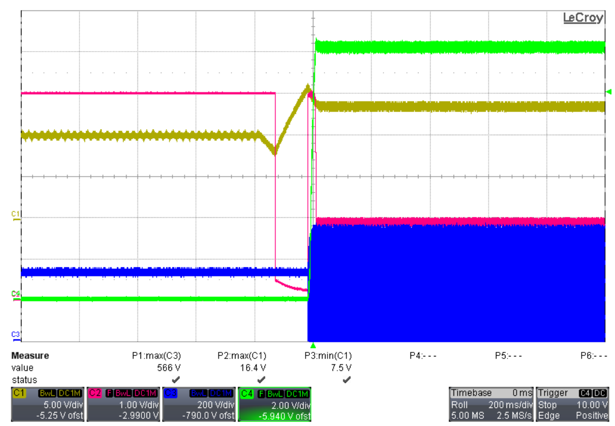


Figure 29. Remove Heating from IC's Case to Recover TSD Protection, Full Load, 230 Vac (Ch1: V_{CC}, Ch2: COMP, Ch3: Drain, Ch4: Vo)

Table 4. BROWN IN/OUT

Behavior	Vin (Vrms)
Brown In	77
Brown Out	64

NOTE: Test condition is full load.
Gradually increase/decrease input AC by 1 V/step.

Table 5. NO−LOAD INPUT POWER CONSUMPTION

Input Voltage [Vac]	Power Consumption [mW]
115 Vac	24.2
230 Vac	28.05

NOTE: Test condition: Outputs are connected to electronic load, but loading is not applied. Input power is integrated over three minutes.

Table 6. EFFICIENCY

Input Voltage [Vac]	25% Load	50% Load	75% Load	100% Load	Avg.
115 Vac	85.61%	86.12%	85.28%	84.98%	85.50%
230 Vac	81.99%	84.46%	84.94%	84.84%	84.06%

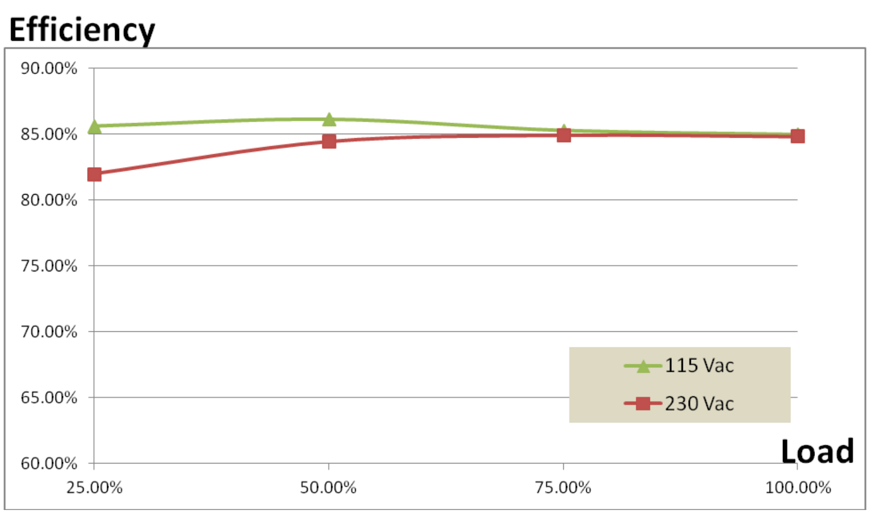


Figure 30. Board Efficiency

Table 7. LINE/LOAD REGULATION

Input Voltage [Vac]	85 Vac		115 Vac		230 Vac		265 Vac		Line Regulation (±)	
Load	V_{O1} (V)	V_{O2}(V)	V_{O1} (V)	V_{O2}(V)	V_{O1} (V)	$V_{O\,2}$(V)	V_{O1} (V)	V_{O2}(V)	V_{O1} (V)	V_{O2}(V)
0 W	12.205	5.0955	12.2165	5.0955	12.211	5.0945	12.217	5.0915	0.05%	0.04%
0.25 W	12.203	5.076	12.208	5.0765	12.206	5.071	12.211	5.07	0.03%	0.06%
0.5 W	12.202	5.0795	12.204	5.08	12.205	5.075	12.208	5.073	0.02%	0.07%
25%	12.1975	5.056	12.1995	5.059	12.203	5.058	12.205	5.059	0.03%	0.03%
50%	12.196	5.0445	12.1955	5.045	12.2	5.059	12.2045	5.0505	0.04%	0.14%
75%	12.195	5.0295	12.194	5.033	12.201	5.0405	12.2025	5.043	0.03%	0.13%
100%	12.1955	5	12.194	5.0125	12.197	5.026	12.206	5.031	0.05%	0.31%
Load Regulation (±)	0.04%	0.94%	0.09%	0.82%	0.06%	0.68%	0.06%	0.60%		

NOTE: Equation of line/load regulation is ±(max − min) / (max + min).
Measured within load range shown in specification.

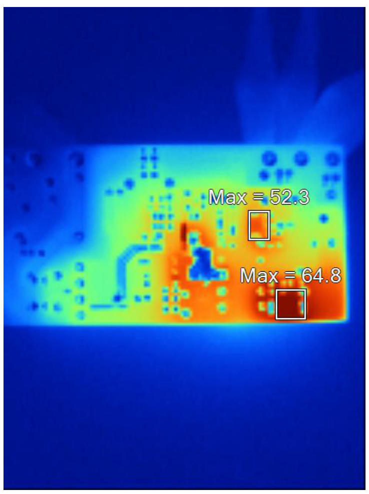


Figure 31. Temperature Checking on Bottom Side, Full Load, 115 Vac

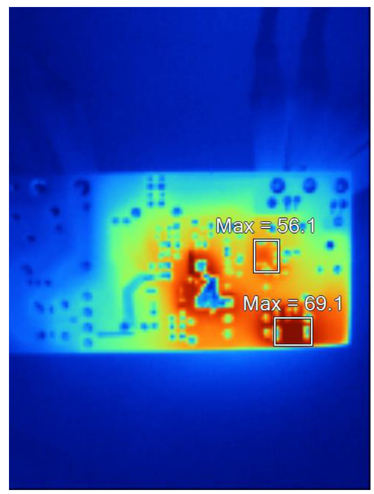


Figure 32. Temperature Checking on Bottom Side, Full Load, 230 Vac

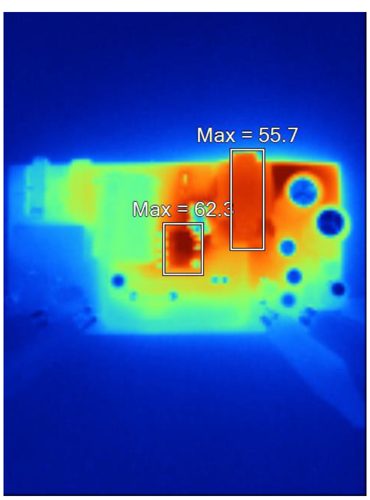


Figure 33. Temperature Checking on Top Side, Full Load, 115 Vac

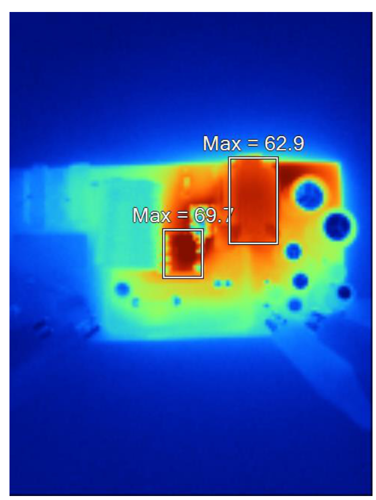


Figure 34. Temperature Checking on Top Side, Full Load, 230 Vac

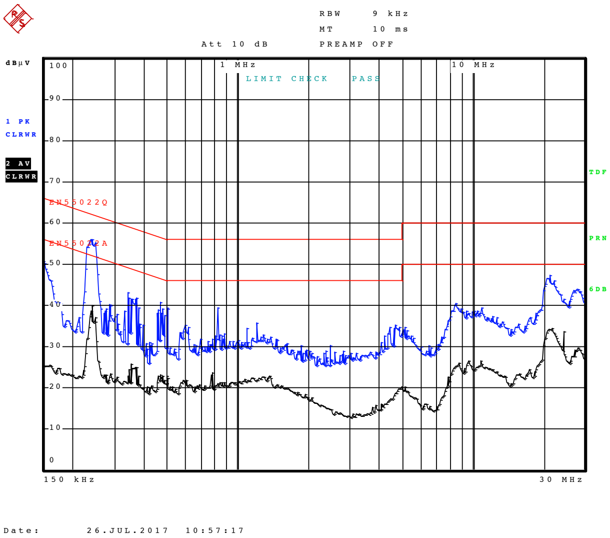


Figure 35. Conducted EMI, 115 Vac, LINE

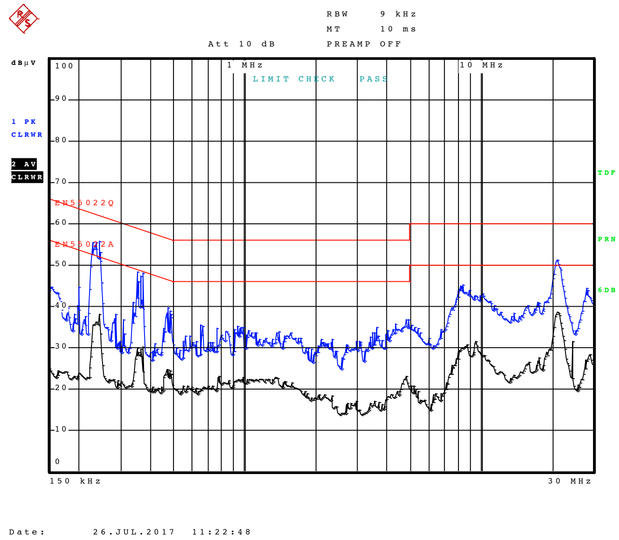


Figure 36. Conducted EMI, 230 Vac, LINE

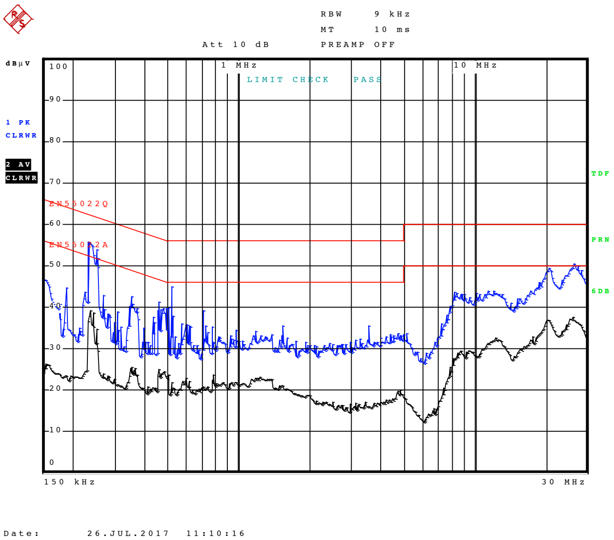


Figure 37. Conducted EMI, 115 Vac, Neutral

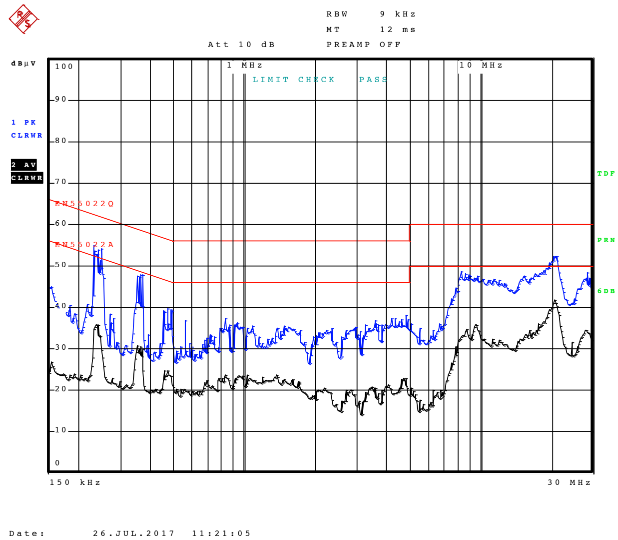


Figure 38. Conducted EMI, 230 Vac, Neutral

BILL OF MATERIALS

Table 8. BILL OF MATERIALS

Parts	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Pb−Free
C1	1	X2 Capacitor	0.33 μF/275 V	±10%	17 × 7.5 × 15.5 mm Pitch = 15 mm	CARLI	PX334K3ID1	Yes	Yes
C3	1	MLCC X7R Capacitor	223 pF/100 V	±10%	1206	Taiwan−Resister	CP223K100XRC	Yes	Yes
C4	1	Electrolytic Capacitor	33 μF/450 V	±10%	18 × 21 mm	SAMYOUNG	NHA	Yes	Yes
C5	1	MLCC X7R Capacitor	221 pF/100 V	±10%	1206	Taiwan−Resister	CP221K100XRC	Yes	Yes
C6, C6A	2	Electrolytic Capacitor	680 μF/25 V		10 × 20 mm	SAMYOUNG	SHL	Yes	Yes
C7	1	Electrolytic Capacitor	68 μF/25 V		5 × 11 mm	SAMYOUNG	KMG	Yes	Yes
C9	1	MLCC X7R Capacitor	101 pF/100 V	±10%	1206	Taiwan−Resister	CP101K100XRC	Yes	Yes
C10	2	MLCC X7R Capacitor	471 pF/50 V	±10%	0805	Taiwan−Resister	CP471K050XRB	Yes	Yes
C13, C17	1	MLCC X7R Capacitor	102 pF/50 V	±10%	0805	Taiwan−Resister	CP102K050XRB	Yes	Yes
C15	1	MLCC X7R Capacitor	104 pF/50 V	±10%	0805	Taiwan−Resister	CP104K050XRB	Yes	Yes
C16	1	Electrolytic Capacitor	22 μF/50 V		5 × 11 mm	SAMYOUNG	KMG	Yes	Yes
C18, C18A	2	Electrolytic Capacitor	330 μF/10 V		6.3 × 11mm	SAMYOUNG	KMG	Yes	Yes
C19	1	Electrolytic Capacitor	47 μF/16 V		5 × 11 mm	SAMYOUNG	KMG	Yes	Yes
R3	1	Resistor SMD	200 Ω	±5%	1206	Taiwan−Resister	RP12200RJR	Yes	Yes
R4, R5, R6, R7	4	Resistor SMD	240 Ω	±5%	1206	Taiwan−Resister	RP12240RJR	Yes	Yes
R8	1	Resistor SMD	200 kΩ	±5%	1206	Taiwan−Resister	RP12200KJR	Yes	Yes
R9	1	Resistor SMD	1 Ω	±5%	1206	Taiwan−Resister	RP1201ROJR	Yes	Yes
R10	1	Resistor SMD	24 kΩ	±5%	0805	Taiwan−Resister	RP0824KOJR	Yes	Yes
R12	1	Resistor SMD	20 kΩ	±5%	0805	Taiwan−Resister	RP0820KOJR	Yes	Yes
R14	1	Resistor SMD	47 kΩ	±5%	1206	Taiwan−Resister	RP1247KOJR	Yes	Yes
R19	1	Resistor SMD	182 kΩ	±5%	1206	Taiwan−Resister	RP12182KJR	Yes	Yes
R21	1	Resistor SMD	0 Ω	±5%	1206	Taiwan−Resister	RP12000JR	Yes	Yes
R22	1	Resistor SMD	22 MΩ	±5%	1206	Taiwan−Resister	RP1222MOJR	Yes	Yes
R23	1	Resistor SMD	360 kΩ	±5%	1206	Taiwan−Resister	RP12360KJR	Yes	Yes
D1	1	Fast Rectifier	600 V, 1 A		DO−214AC	ON Semiconductor	ES1J	Yes	Yes
D2	1	Zener Diode	7.5 V, 0.2 W		SOD−523F	ON Semiconductor	MM5Z7V5	Yes	Yes
D3	1	Fast Rectifier	200 V, 1 A		DO−214AC	ON Semiconductor	RS1D	Yes	Yes
D4	1	Jumper Wire	short					Yes	Yes
D5	1	Schottky Rectifier	150 V, 10 A		TO−277	ON Semiconductor	FSV10150V	Yes	Yes
D7	1	Schottky Rectifier	50 V, 2 A		DO−214AA	ON Semiconductor	SS25	Yes	Yes
D8	1	TVS	150 V, 600 W		DO−15	ON Semiconductor	P6KE150A	Yes	Yes
5 V, 12 V, GND, L, N	5	TEST PIN	Pin Ψ2.2 × 18.2 m m OEM−10		2.2 × 18.2 mm	KANG YANG	SG004−05 Pin	Yes	Yes
F1	1	Fuse	FUSE CERAMIC 1 A/ 250 V SLOW		3.6 × 10 mm		37SG	Yes	Yes
MOV	1	MOV	470 V	±10%		THINKING	MOV−471KD10SBNL	Yes	Yes
NTC	1	Jumper wire	Short					Yes	Yes

Table 8. BILL OF MATERIALS (continued)

Parts	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Pb−Free
BD1	1	Bridge Rectifier	600 V, 2 A		KBPM	ON Semiconductor	2KBP06M	Yes	Yes
L1	1	Common−mode Choke	10 mH		UU9.8	SEN HUEI	TRN0356	Yes	Yes
L2, L3	2	Inductor, Ferrite Core	1 μH		DR 6 × 8	WURTH	744772010	Yes	Yes
TX1	1	Transformer	960 μH	±10%	EE−19	SEN HUEI		No	Yes
U1	1	PWM with Power SENSEFET			7DIP	ON Semiconductor	FSL538HPG	No	Yes
	1	PCB					PLM0387V0	No	Yes
NTC, D4, F1, C4, D8	5	Teflon Tube	17L × 305 m					Yes	Yes

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Email Requests to: orderlit@onsemi.com

onsemi Website: www.onsemi.com

TECHNICAL SUPPORT
North American Technical Support:
Voice Mail: 1 800−282−9855 Toll Free USA/Canada
Phone: 011 421 33 790 2910

Europe, Middle East and Africa Technical Support:
Phone: 00421 33 790 2910
For additional information, please contact your local Sales Representative

◊