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User Guide for

FEBFSL306LRN_CS01U02A

Evaluation Board

Integrated Controller

FSL306LR

2.05 W Auxiliary Power Supply

Featured Fairchild Product:

FSL306LR

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

Fairchild Semiconductor.com

Table of Contents

This user guide supports the evaluation kit for the FSL306LR. It should be used in conjunction with the FSL306LR datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document is an engineering report describing measured performance of the FSL306LR evaluation board.

1.1. General Description

The FSL306LR integrated Pulse Width Modulator (PWM) and SenseFET is specifically designed for high-performance offline buck, buck-boost, and non-isolation flyback Switched Mode Power Supplies (SMPS) with minimal external components. This device integrates a high-voltage power regulator that enables operation without auxiliary bias winding. An internal transconductance amplifier reduces external components for the feedback compensation circuit.

The integrated PWM controller includes: 10 V regulator for no external bias circuit, Under-Voltage Lockout (UVLO), Leading-Edge Blanking (LEB), an optimized gate turn-on / turn-off driver, EMI attenuator, Thermal Shutdown (TSD), temperature-compensated precision current sources for loop compensation, and fault-protection circuitry. Protections include: Overload Protection (OLP), Over-Voltage Protection (OVP), Feedback Open-Loop Protection (FB_OLP), and Abnormal Over-Current Protection (AOCP). FSL306LR offers good soft-start performance during startup.

The internal high-voltage startup switch and the Burst-Mode operation with very low operating current reduce the power loss in Standby Mode. As the result, it is possible to reach power loss of 120 mW without external bias and 25 mW with external bias when input voltage is 230 V_{AC}.

1.2. Features

- Built-in Avalanche-Rugged SenseFET: 650 V
- Fixed Operating Frequency: 50 kHz
- No-Load Power Consumption: <25 mW at 230 V_{AC} with External Bias; <120 mW at 230 V_{AC} without External Bias
- No Need for Auxiliary Bias Winding
- Frequency Modulation for Attenuating EMI
- Pulse-by-Pulse Current Limiting
- Ultra-Low Operating Current: 250 µA
- Built-in Soft-Start and Startup Circuit
- Adjustable Peak Current Limit
- Built-in Transconductance (Error) Amplifier
- Various Protections: Overload Protection (OLP), Over-Voltage Protection (OVP), Feedback Open Loop Protection (FB_OLP), AOCP (Abnormal Over-Current Protection), Thermal Shutdown (TSD)
- Fixed 650 ms Restart Time for Safe Auto-Restart Mode of All Protections

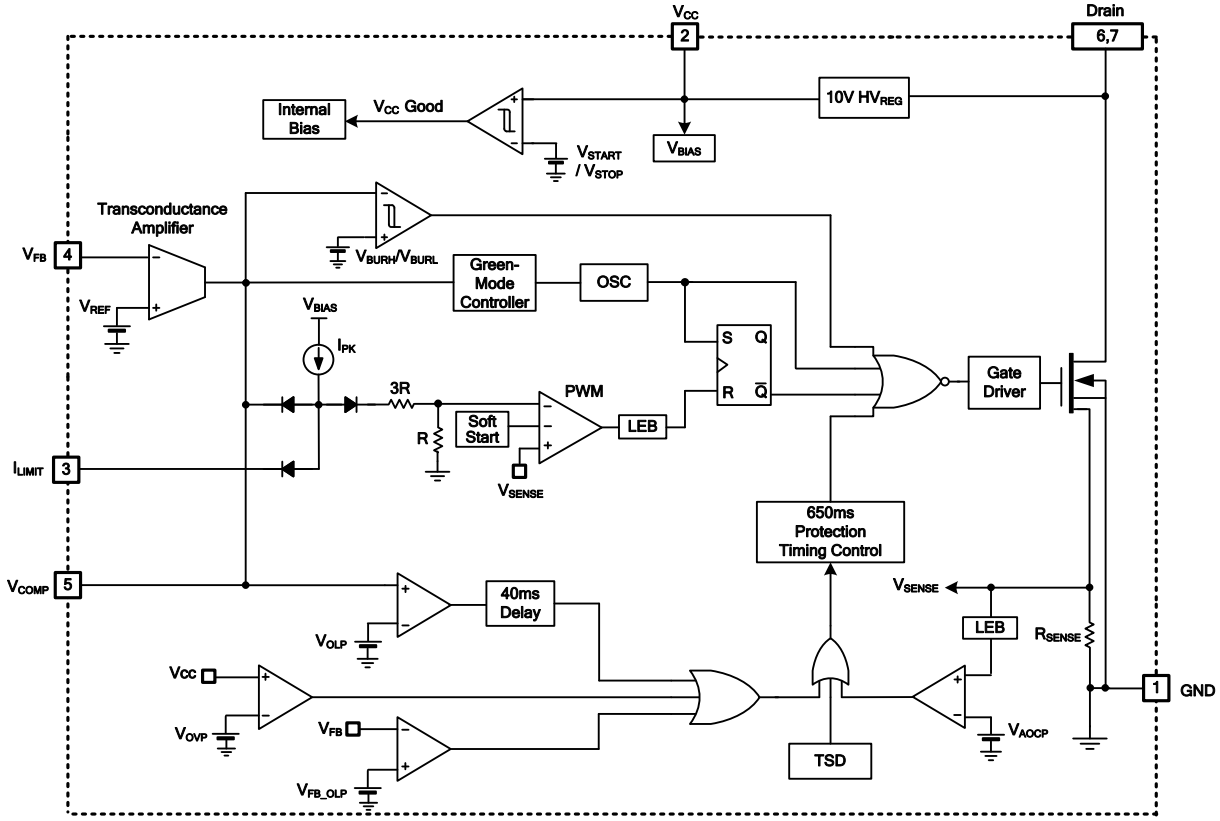


Figure 1. Internal Block Diagram

2. Specifications

Table 1. Evaluation Board Specifications

Fairchild Device	FSL306LR
Input Voltage Range	85 ~ 300 V_{AC}
Frequency	60 Hz
Maximum Output Power	2.05 W
Output Full-Load Condition	12 V / 0.15 A, 5 V / 0.05 A

3. Photographs

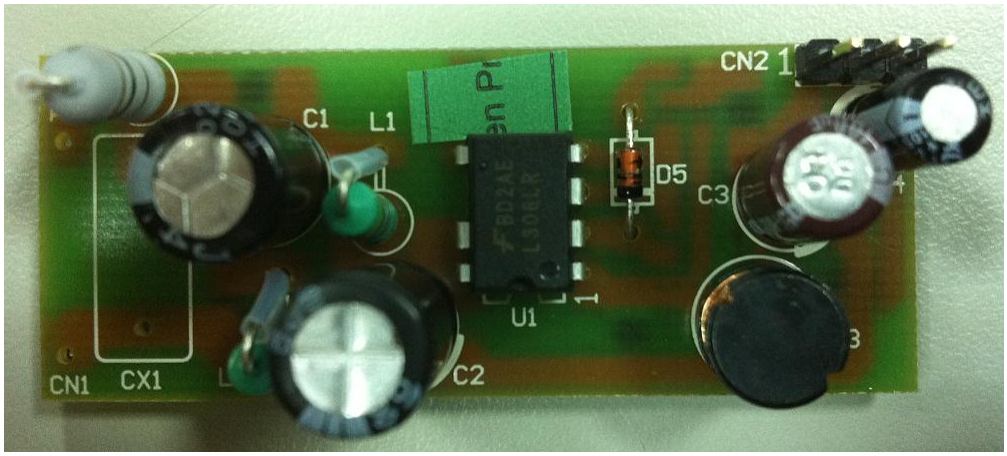


Figure 2. Top View (Dimension 64 x 33 [mm^2])

Figure 3. Bottom View (Dimension 64 x 33 [mm^2])

4. PCB Layout

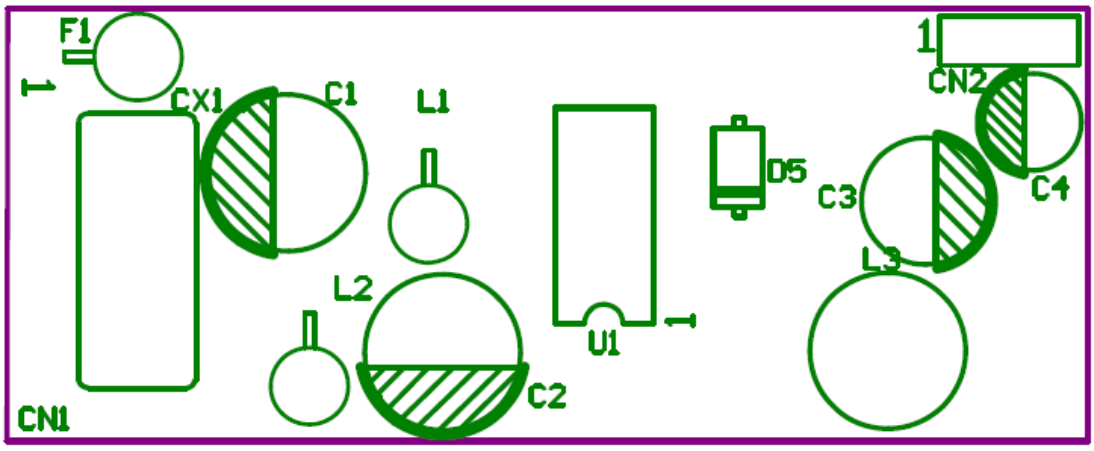


Figure 4. Top Overlay

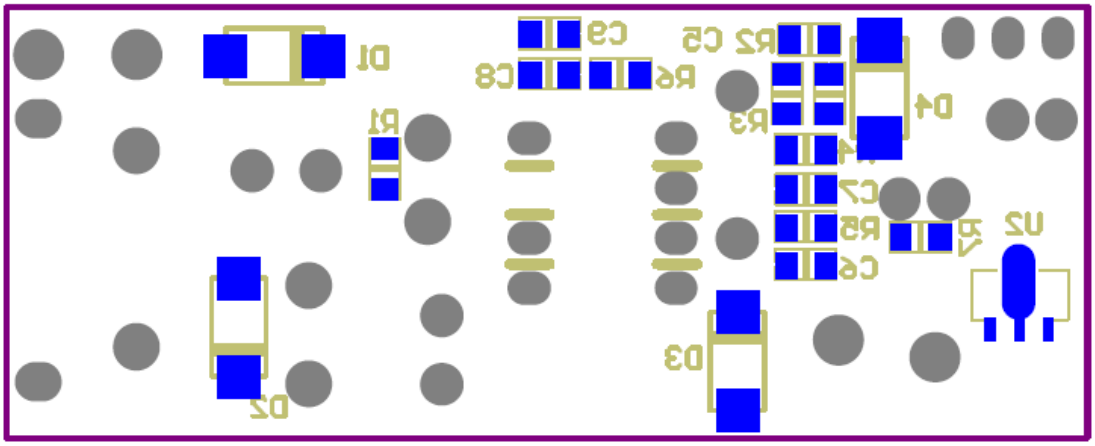


Figure 5. Bottom Overlay

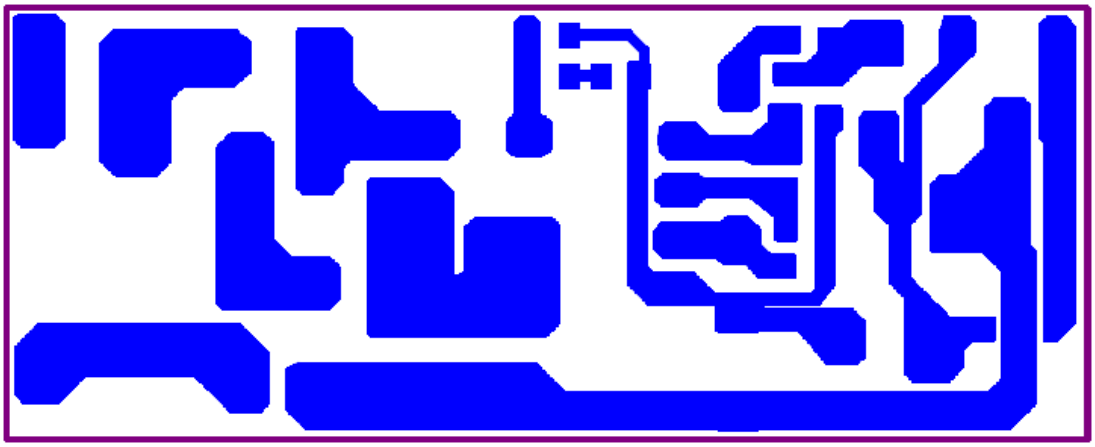


Figure 6. Bottom Layer

5. Test Conditions

Evaluation Board #	FEBFSL306LRN_CS01U02A
Test Date	April 17, 2013
Test Equipment	AC Source: 6800 Series Electronic Load: Chroma 63030 Oscilloscope: LeCroy 24Xs-A Power Meter: Yokogawa WT210
Test Items	1. Startup Performance 2. Normal Operation 3. Voltage Stress of Drain and Freewheeling Diode 4. Output Ripple and Noise 5. Step Load Response 6. Output Short Protections 7. Output Line & Load Regulation 8. Temperature Measurement 9. Efficiency Test Result 10. Standby Power Consumption 11. Conducted EMI Measurement

6. Performance of Evaluation Board

6.1. Startup Performance

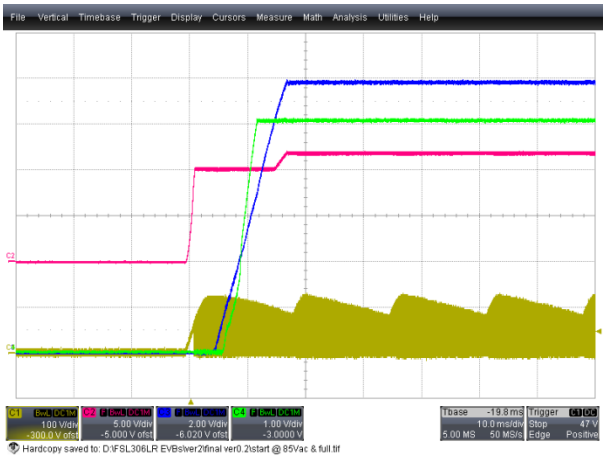


Figure 7. Startup Time = 18 ms, 85 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2V/div), CH4: 5 V_{OUT} (1 V/div), Time: 10 ms/div)

Figure 8. Startup Time = 14 ms, 300 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 10 ms/div)

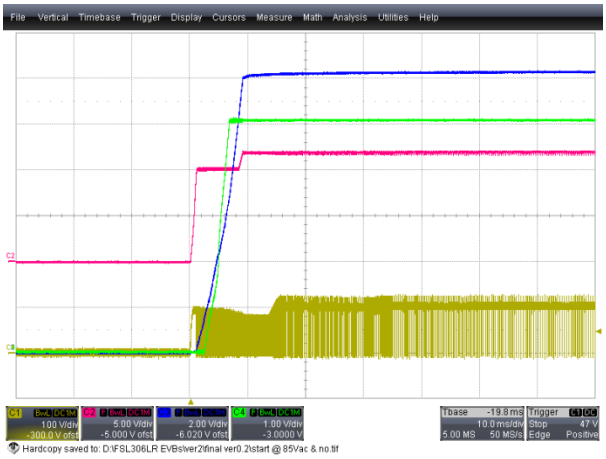


Figure 9. Startup Time = 10 ms, 85 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 10 ms/div)

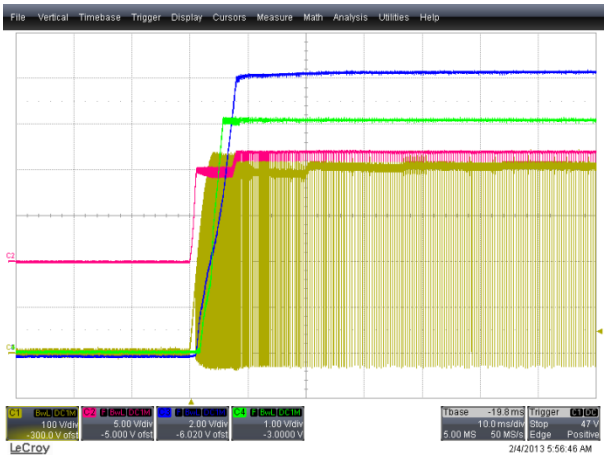


Figure 10. Startup Time = 9 ms, 300 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 10 ms/div)

6.2. Normal Operation

Figure 11. Full-Load Condition, 85 V_{AC}, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 10 µs/div)

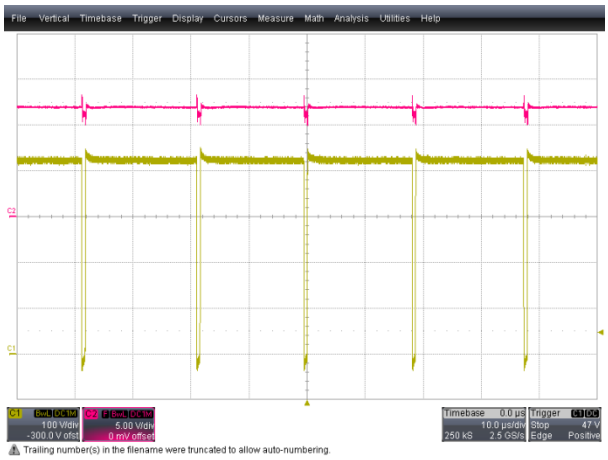


Figure 12. Full-Load Condition, 300 V_{AC}, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 10 µs/div)

Figure 13. No-Load Condition, 85 V_{AC}, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 200 µs/div)

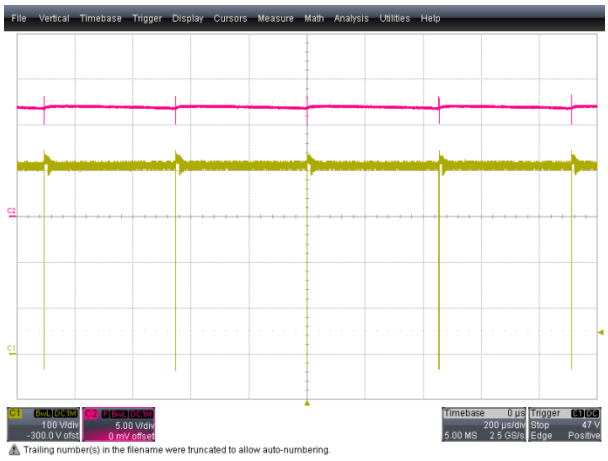


Figure 14. No-Load Condition, 300 V_{AC}, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 200 µs/div)

6.3. Voltage Stress of Drain and Freewheeling Diode

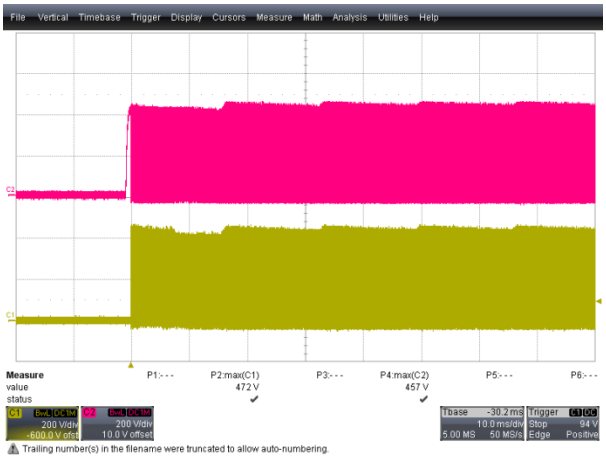


Figure 15. V_{DS}=457 V, V_{DIODE}=472 V, Startup Condition, Full-Load Condition, 300 V_{AC}, (CH1: V_{DIODE} (200 V/div), CH2: V_{DS} (200 V/div), Time: 10 ms/div)

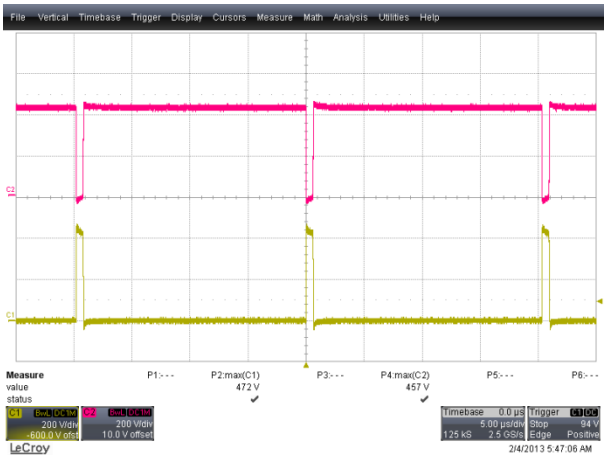


Figure 16. V_{DS}=457 V, V_{DIODE}=472 V, Steady-State, Full-Load Condition, 300 V_{AC}, (CH1: V_{DIODE} (200 V/div), CH2: V_{DS} (200 V/div), Time: 5 µs/div)

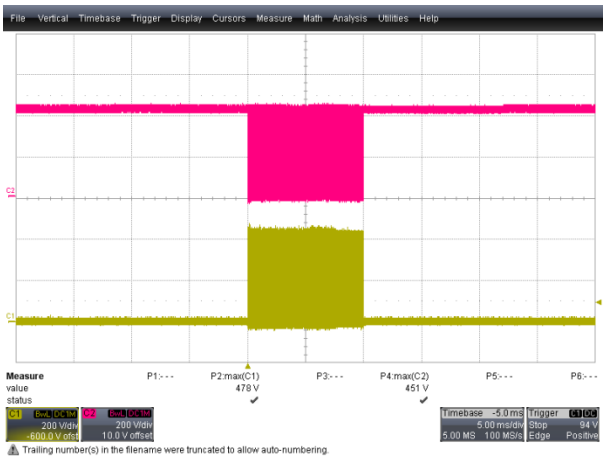


Figure 17. V_{DS}=451 V & V_{DIODE}=478 V, 12 V Output Short Condition, Full-Load Condition, 300 V_{AC}, (CH1: V_{DIODE} (200 V/div), CH2: V_{DS} (200 V/div), Time: 5 ms/div)

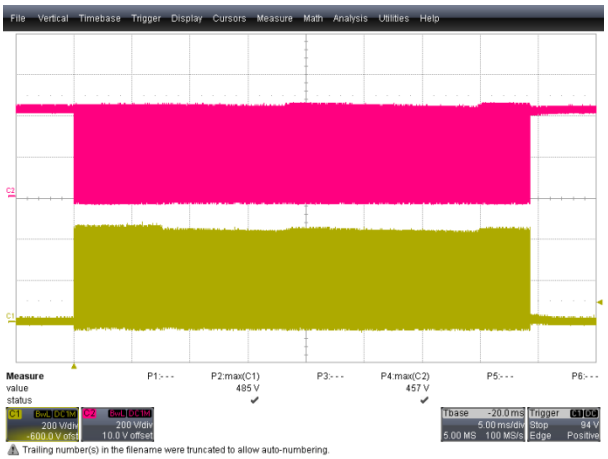


Figure 18. V_{DS}=457 V & V_{DIODE}=485 V, 5 V Output Short Condition, Full-Load Condition, 300 V_{AC}, (CH1: V_{DIODE} (200 V/div), CH2: V_{DS} (200 V/div), Time: 5 ms/div)

6.4. Output Ripple and Noise

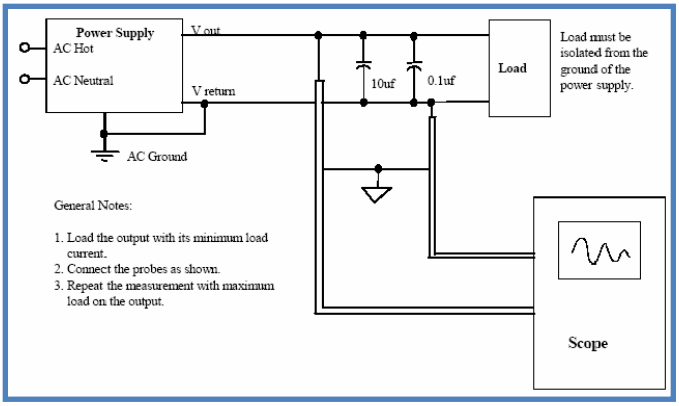


Figure 19. Recommended Test Setup

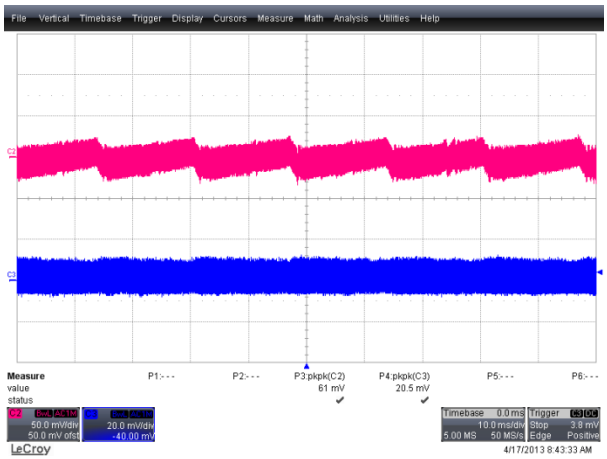


Figure 20. 12 V_{OUT_RIPPLE} = 61 mV, 5 V_{OUT_RIPPLE} = 21 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 12 V_{OUT} (50 mV/div), CH3: 5 V_{OUT} (20 mV/div), Time: 10 ms/div

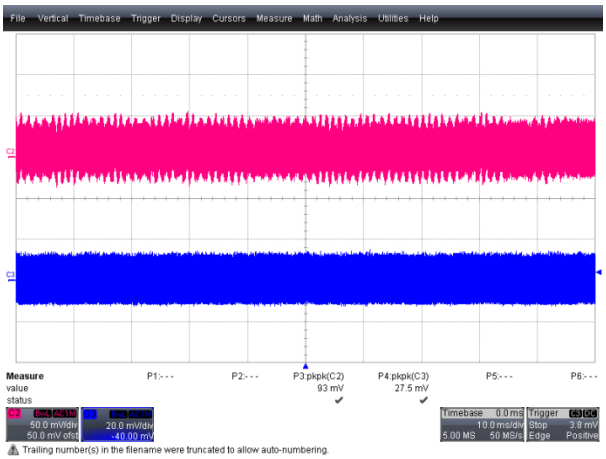


Figure 21. 12 V_{OUT_RIPPLE} = 93 mV, 5 V_{OUT_RIPPLE} = 28 mV, Output with 300 V_{AC} and Full-Load Condition, CH2: 12 V_{OUT} (50 mV/div), CH3: 5V_{OUT} (20 mV/div), Time: 10 ms/div

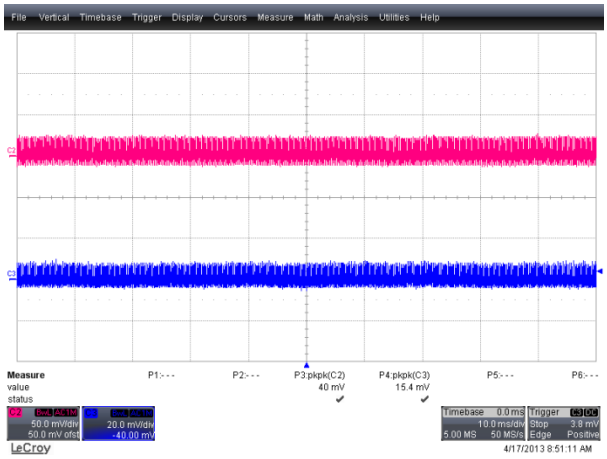


Figure 22. 12 V_{OUT_RIPPLE} = 40 mV, 5 V_{OUT_RIPPLE} = 16mV, Output with 85 V_{AC} and No-Load Condition, CH2: 12 V_{OUT} (50 mV/div), CH3: 5 V_{OUT} (20 mV/div), Time: 10 ms/div

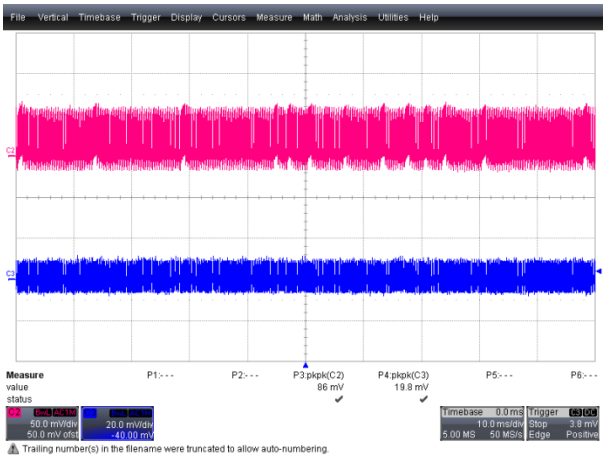


Figure 23. 12 V_{OUT_RIPPLE} = 86 mV, 5 V_{OUT_RIPPLE} = 20 mV, Output with 300 V_{AC} and No-Load Condition, CH2: 12 V_{OUT} (50 mV/div), CH3: 5 V_{OUT} (20 mV/div), Time: 10 ms/div

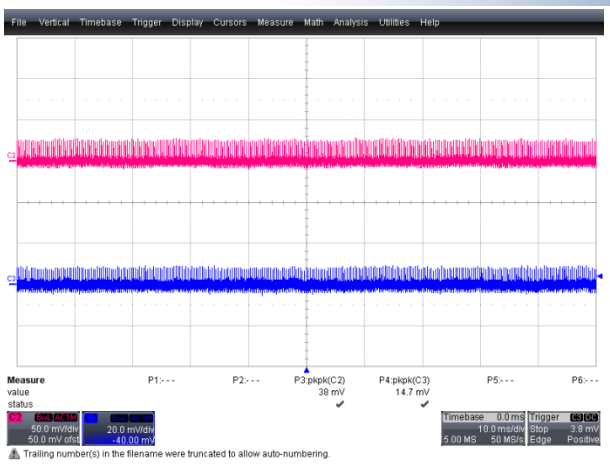


Figure 24. 12 V_{OUT_RIPPLE} = 38 mV, 5 V_{OUT_RIPPLE} = 15 mV, Output with 85 V_{AC} and Burst-Mode Entry Power, CH2: 12 V_{OUT} (50 mV/div), CH3: 5 V_{OUT} (20 mV/div), Time: 10 ms/div

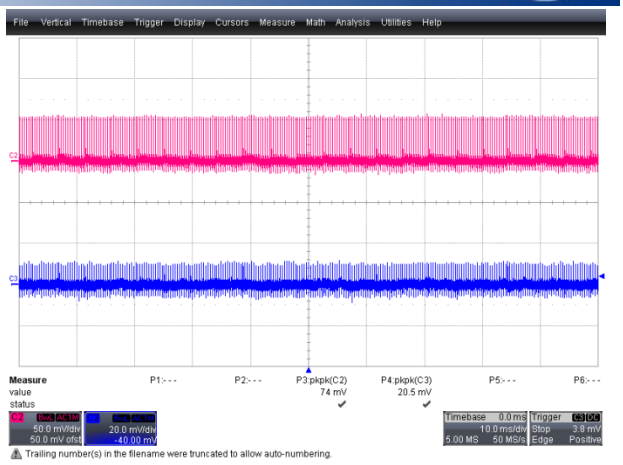
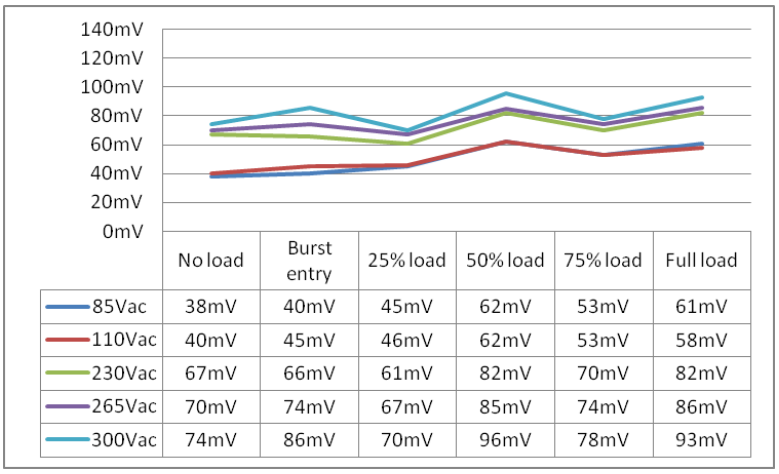
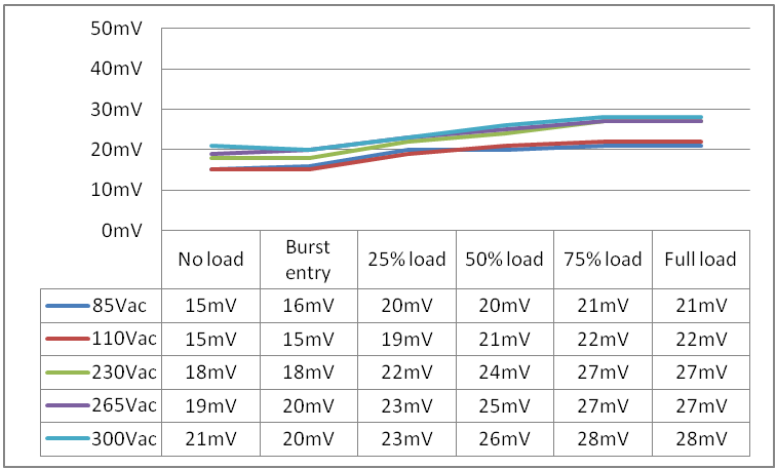


Figure 25. 12 V_{OUT_RIPPLE} = 74 mV, 5 V_{OUT_RIPPLE} = 21 mV, Output with 300 V_{AC} and Burst-Mode Entry Power, CH2: 12 V_{OUT} (50 mV/div), CH3: 5 V_{OUT} (20 mV/div), Time: 10 ms/div



	No load	Burst entry	25% load	50% load	75% load	Full load
85Vac	38mV	40mV	45mV	62mV	53mV	61mV
110Vac	40mV	45mV	46mV	62mV	53mV	58mV
230Vac	67mV	66mV	61mV	82mV	70mV	82mV
265Vac	70mV	74mV	67mV	85mV	74mV	86mV
300Vac	74mV	86mV	70mV	96mV	78mV	93mV

Figure 26. 12 V Output Ripple



	No load	Burst entry	25% load	50% load	75% load	Full load
85Vac	15mV	16mV	20mV	20mV	21mV	21mV
110Vac	15mV	15mV	19mV	21mV	22mV	22mV
230Vac	18mV	18mV	22mV	24mV	27mV	27mV
265Vac	19mV	20mV	23mV	25mV	27mV	27mV
300Vac	21mV	20mV	23mV	26mV	28mV	28mV

Figure 27. 5 V Output Ripple

6.5. Step Load Response

Test Slew Rate (250 mA/µs)

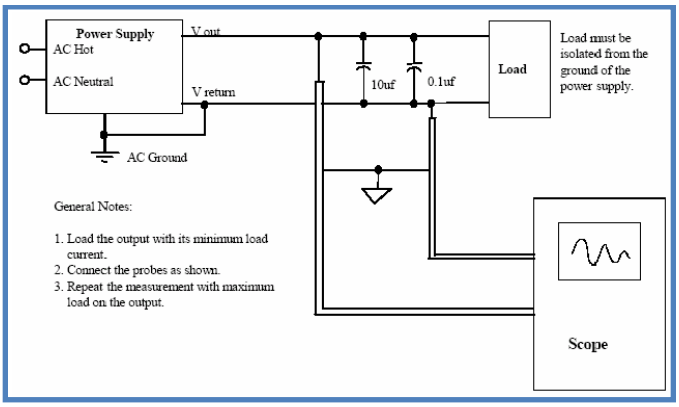


Figure 28. Recommended Test Setup

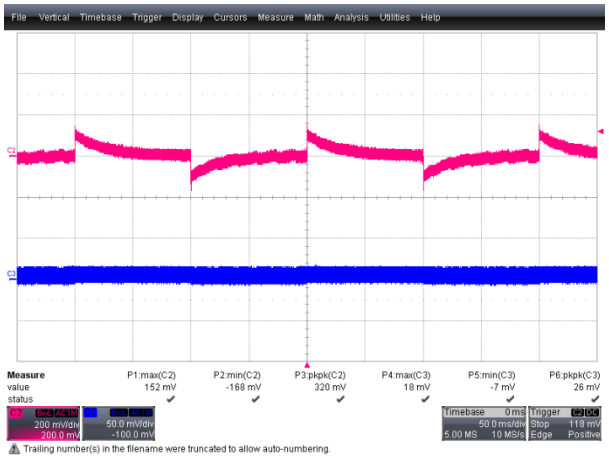


Figure 29. 12 V Output Step Load with 85 V_{AC}, 80% Load ↔ 20% Load (CH2: 12 V_{OUT} (200 mV/div), CH3: 5 V_{OUT} (50 mV/div), Time: 50 ms/div)

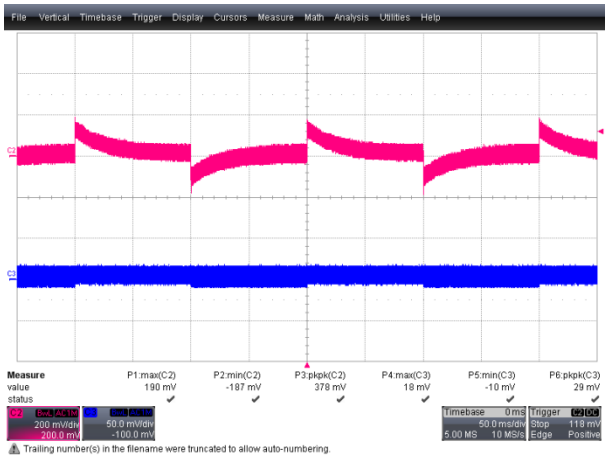


Figure 30. 12 V Output Step Load with 300 V_{AC}, 80% Load ↔ 20% load (CH2: 12 V_{OUT} (200 mV/div), CH3: 5 V_{OUT} (50 mV/div), Time: 50 ms/div)

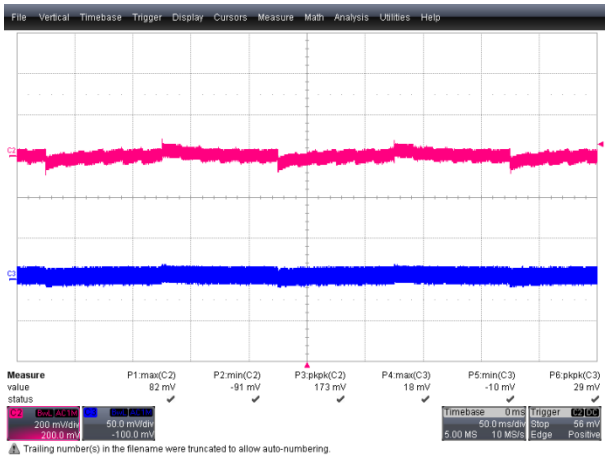


Figure 31. 5 V Output Step Load with 85 V_{AC}, 80% Load ↔ 20% Load (CH2: 12 V_{OUT} (200 mV/div), CH3: 5 V_{OUT} (50 mV/div), Time: 50 ms/div)

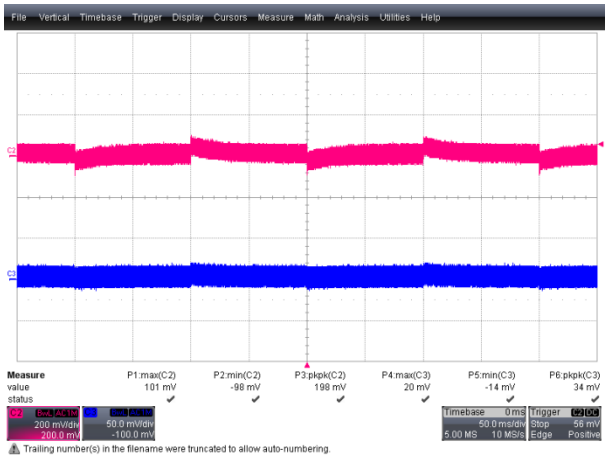


Figure 32. 5 V Output Step Load with 300 V_{AC}, 80% Load ↔ 20% load (CH2: 12 V_{OUT} (200 mV/div), CH3: 5 V_{OUT} (50m V/div), Time: 50 ms/div)

Table 2. 12 V Output Step Load Response (5 V Output Full Load Condition)

12 V Output Step Load (80% ↔ 20%)		85 V_{AC}		110 V_{AC}		230 V_{AC}		300 V_{AC}		300 V_{AC}	
		12 V	5 V	12 V	5 V	12 V	5 V	12 V	5 V	12 V	5 V
5 V Full Load	Overshoot	152 mV	18 mV	158 mV	18 mV	178 mV	20 mV	184 mV	20 mV	190 mV	18 mV
	Undershoot	168 mV	7 mV	168 mV	9 mV	187 mV	10 mV	187 mV	10 mV	187 mV	10 mV
	Peak-Peak	320 mV	26 mV	326 mV	27 mV	365 mV	30 mV	371 mV	30 mV	378 mV	29 mV

Table 3. 5 V Output Step Load Response (12 V Output Full Load Condition)

5V **O**utput **S**tep **L**oad (80% ↔ 20%)		85 V_{AC}		110 V_{AC}		230 V_{AC}		300 V_{AC}		300 V_{AC}	
		12 V	5 V	12 V	5 V	12 V	5 V	12 V	5 V	12 V	5 V
12 V Full Load	Overshoot	82 mV	18 mV	82 mV	20 mV	101 mV	20 mV	101 mV	22 mV	101 mV	20 mV
	Undershoot	91 mV	10 mV	91 mV	10 mV	91 mV	12 mV	91 mV	12 mV	98 mV	14 mV
	Peak-Peak	173 mV	29 mV	173 mV	30 mV	192 mV	32 mV	192 mV	34 mV	198 mV	34 mV

6.6. Output Short Protection

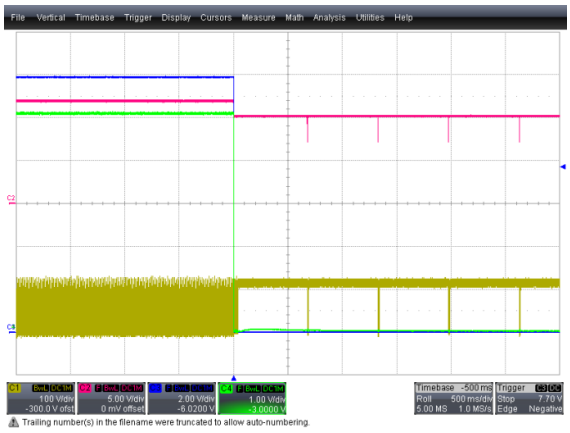


Figure 33. OLP Triggered, 12 V Output Short with 85 V_{AC}, Full-Load, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 500 ms/div)

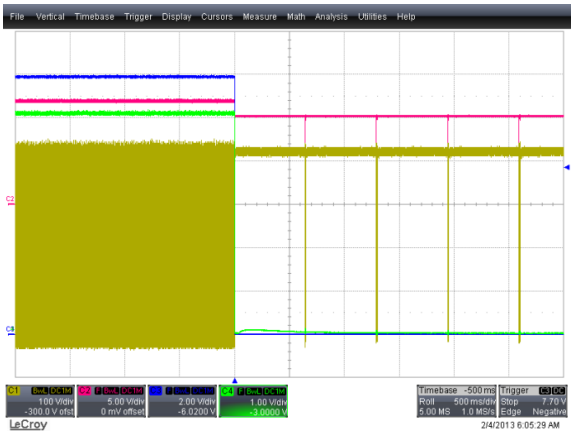


Figure 34. AOCP Triggered, 12 V Output Short with 300 V_{AC}, Full-Load, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2V/div), CH4: 5 V_{OUT} (1 V/div), Time: 500 ms/div)

Figure 35. OLP Triggered, 5 V Output Short with 85V $_{AC}$, Full-Load, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 500 ms/div))

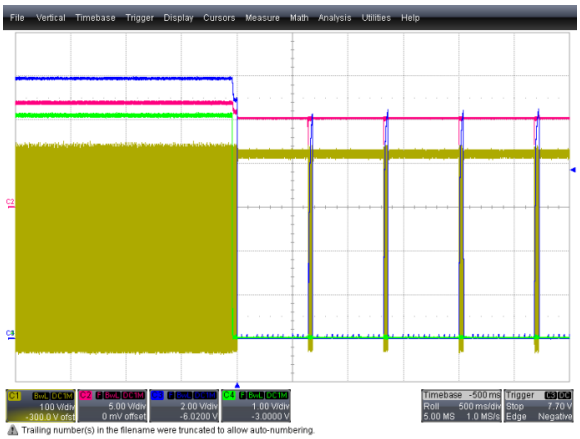
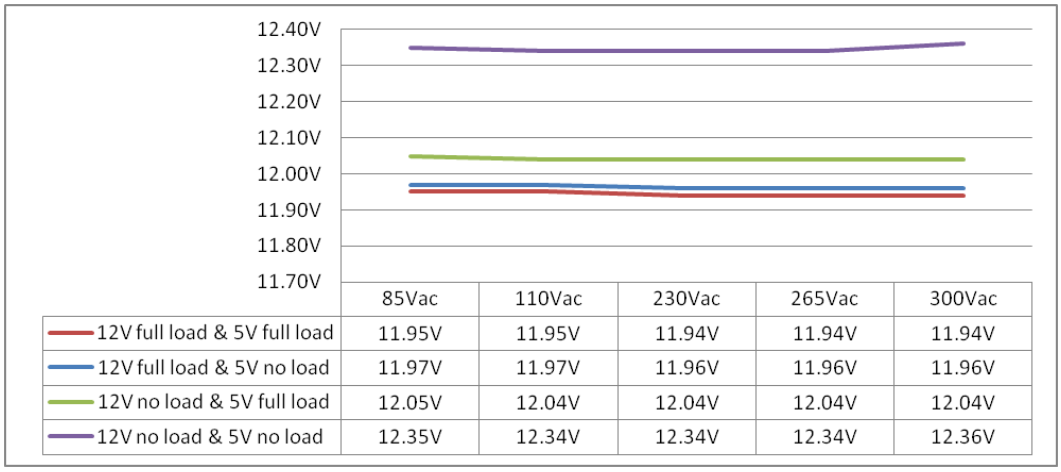


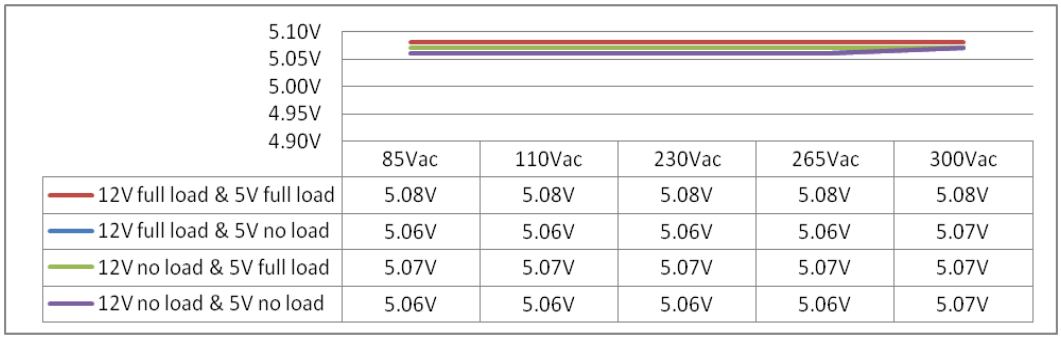
Figure 36. OLP Triggered, 5 V Output Short with 300 V_{AC}, Full-Load, (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 12 V_{OUT} (2 V/div), CH4: 5 V_{OUT} (1 V/div), Time: 500 ms/div)

6.7. Output Line & Load Regulation



	85Vac	110Vac	230Vac	265Vac	300Vac
12V full load & 5V full load	11.95V	11.95V	11.94V	11.94V	11.94V
12V full load & 5V no load	11.97V	11.97V	11.96V	11.96V	11.96V
12V no load & 5V full load	12.05V	12.04V	12.04V	12.04V	12.04V
12V no load & 5V no load	12.35V	12.34V	12.34V	12.34V	12.36V

Figure 37. 12 V Output Line & Load Regulation



	85Vac	110Vac	230Vac	265Vac	300Vac
12V full load & 5V full load	5.08V	5.08V	5.08V	5.08V	5.08V
12V full load & 5V no load	5.06V	5.06V	5.06V	5.06V	5.07V
12V no load & 5V full load	5.07V	5.07V	5.07V	5.07V	5.07V
12V no load & 5V no load	5.06V	5.06V	5.06V	5.06V	5.07V

Figure 38. 5 V Output Line & Load Regulation

6.8. Temperature Measurement

Table 4. Temperature Test Result

Input Voltage		85 V_{AC}	110 V_{AC}	230 V_{AC}	265 V_{AC}	300 V_{AC}
Temperature	IC **(FSL306LR)**	48.0°C	47.0°C	49.0°C	51.0°C	54.0°C
	Freewheeling Diode **(ES1J)**	57.0°C	58.0°C	61.0°C	62.0°C	63.0°C
	Inductor **(PKS0807-681K-TF)**	58.0°C	60.0°C	65.0°C	68.0°C	70.0°C
	5 V LDO **(KA78L05AI)**	67.0°C	69.0°C	71.0°C	71.0°C	72.0°C
Room Temperature		25°C				

6.9. Efficiency Test Result

- Test Method:
  - Test after 15 minutes aging

Test from heavy load to light load

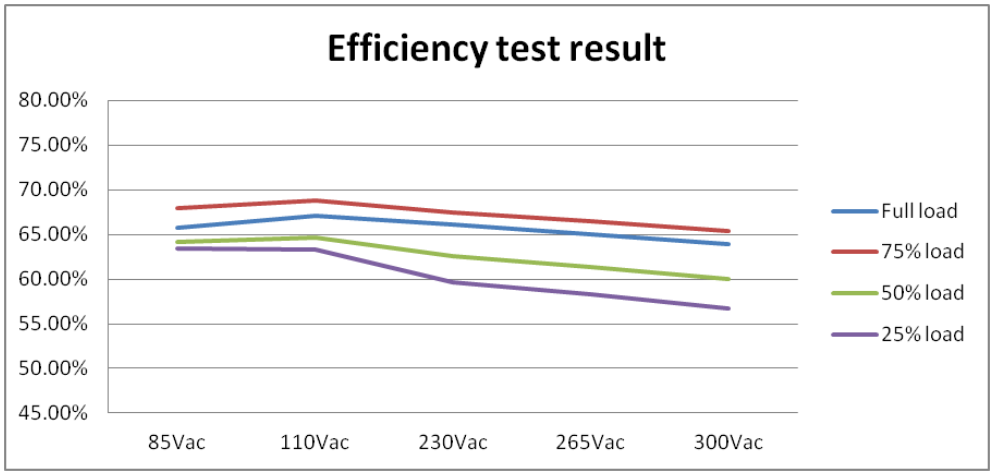


Figure 39. Efficiency vs. Output Load and Input Voltage

Table 5. Efficiency Test Result

		85 V_{AC}		110 V_{AC}		230 V_{AC}		265 V_{AC}		300 V_{AC}	
Full Load	**Output 1**	11.95 V	0.15 A	11.95 V	0.15 A	11.94 V	0.15 A	11.94 V	0.15 A	11.94 V	0.15 A
	Output 2	5.08 V	0.050 A	5.08 V	0.050 A	5.08 V	0.050 A	5.08 V	0.050 A	5.08 V	0.050 A
	Pin	3.112 W		3.049 W		3.095 W		3.144 W		3.202 W	
	Efficiency	65.76%		67.12%		66.07%		65.04%		63.87%	
75% Load	**Output 1**	11.98 V	0.11 A	11.97 V	0.11 A	11.97 V	0.11 A	11.97 V	0.11 A	11.96 V	0.11 A
	Output 2	5.07 V	0.038 A	5.07 V	0.038 A	5.07 V	0.038 A	5.07 V	0.038 A	5.07 V	0.038 A
	Pin	2.265 W		2.235 W		2.280 W		2.310 W		2.351 W	
	Efficiency	67.90%		68.76%		67.40%		66.53%		65.32%	
50% Load	**Output 1**	11.99 V	0.08 A	11.99 V	0.08 A	11.99 V	0.08 A	11.99 V	0.08 A	11.99 V	0.08 A
	Output 2	5.07 V	0.025 A	5.07 V	0.025 A	5.07 V	0.025 A	5.07 V	0.025 A	5.07 V	0.025 A
	Pin	1.600 W		1.587 W		1.640 W		1.671 W		1.711 W	
	Efficiency	64.13%		64.65%		62.56%		61.40%		59.96%	
25% Load	**Output 1**	12.04 V	0.04 A	12.03 V	0.04 A	12.03 V	0.04 A	12.03 V	0.04 A	12.03 V	0.04 A
	Output 2	5.07 V	0.013 A	5.06 V	0.013 A	5.06 V	0.013 A	5.06 V	0.013 A	5.06 V	0.013 A
	Pin	0.812 W		0.813 W		0.863 W		0.882 W		0.907 W	
	Efficiency	63.41%		63.27%		59.60%		58.32%		56.71%	

6.10. Standby Power Consumption

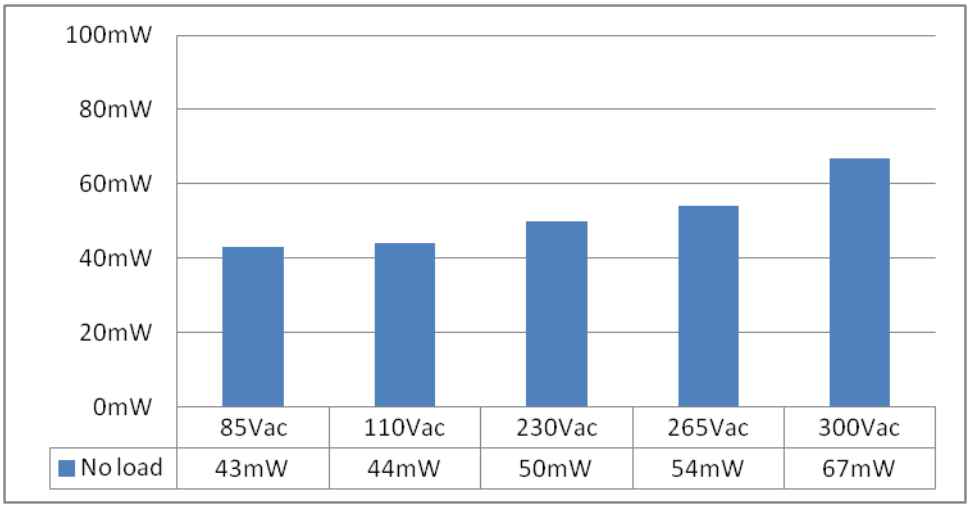


Figure 40. Standby Power Consumption at No Load Condition (Including 5 V Regulator Power Loss)

6.11. Conducted EMI Measurement

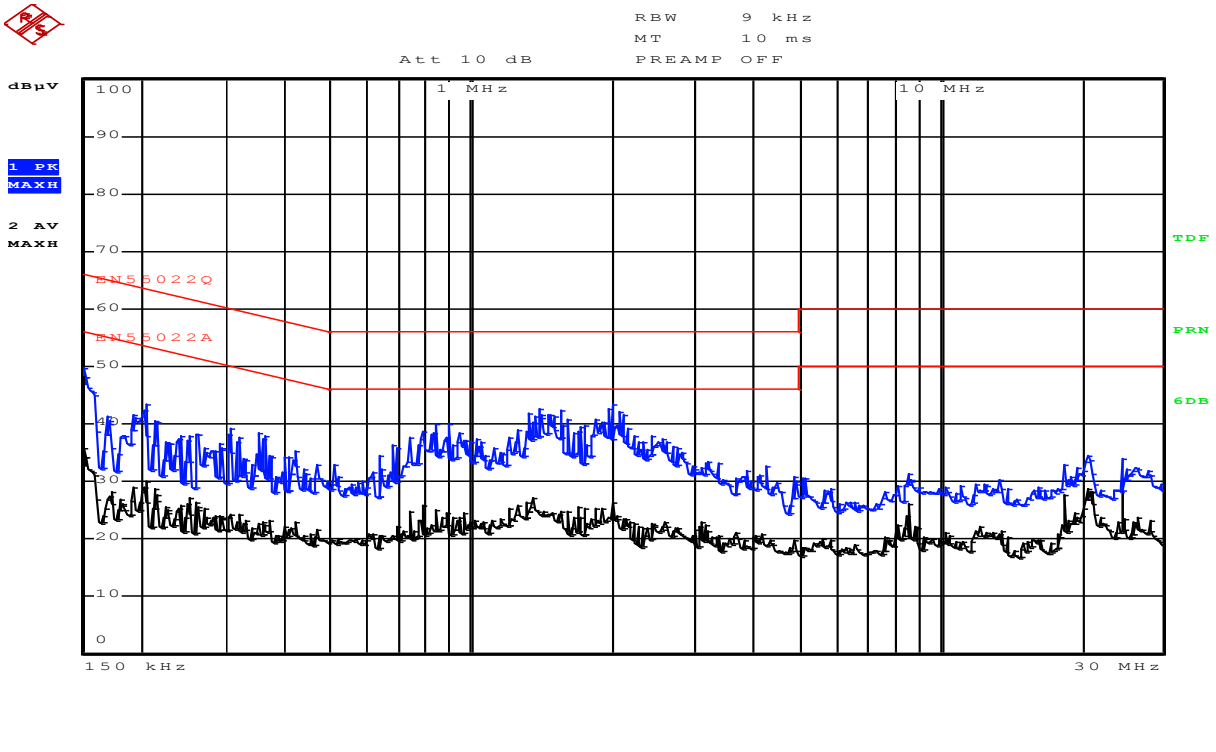


Figure 41. L at 110 V_{AC}

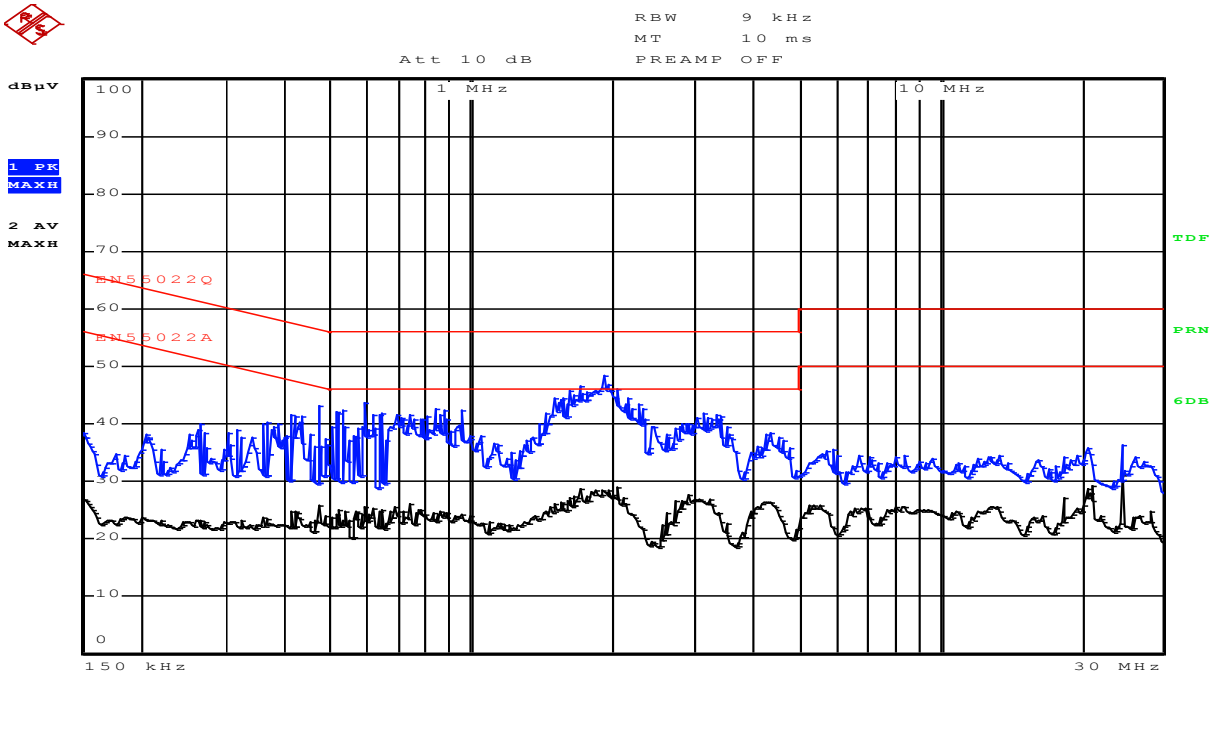


Figure 42. L at 230 V_{AC}

7. Schematic

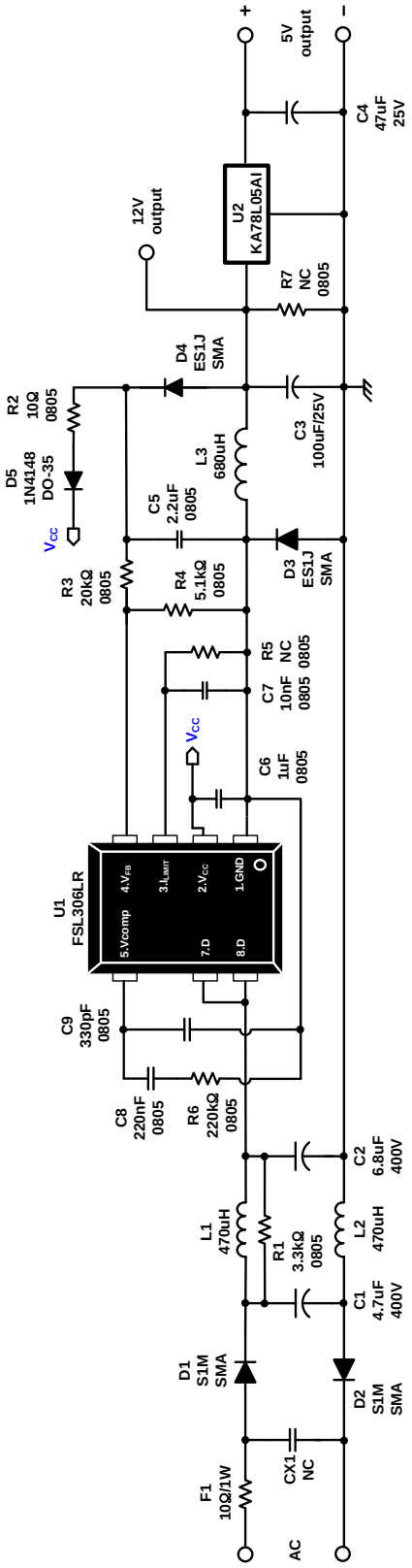


Figure 43. Schematic

8. Bill of Materials

Component	Qty.	Part No.	Manufacturer	Reference
Chip Resistor 0805 10 Ω ±5%	1			R2
Chip Resistor 0805 3.3 kΩ ±5%	1			R1
Chip Resistor 0805 5.1 kΩ ±1%	1			R4
Chip Resistor 0805 20 kΩ ±1%	1			R3
Chip Resistor 0805 220 kΩ ±5%	1			R6
0805 MLCC X7R ±10% 331P (330 pF) 50 V	1			C9
0805 MLCC X7R ±10% 103P (10 nF) 50 V	1			C7
0805 MLCC X7R ±10% 224P (220 nF) 50 V	1			C8
0805 MLCC X7R ±10% 105P (1 µF) 50 V	1			C6
0805 MLCC X7R ±10% 225P (2.2 µF) 50 V	1			C5
Electrolytic Capacitor 4.7 µF 400 V 105°C	1	LHK General Purpose	JACKCON	C1
Electrolytic Capacitor 6.8 µF 400 V 105°C	1	KM(M)	SAMXON	C2
Electrolytic Capacitor 47 µF 25 V 105°C	1	LHK General Purpose	JACKCON	C4
Electrolytic Capacitor 100 µF 25 V 105°C	1	KY		C3
Fixed Inductor 470 µH ±10%	2	EC36-471K	SYNTON	L1, L2
Inductor DR8X7 680 µH	1	PKS0807-681K-TF	3L Electronic	L3
General Diode 1 A / 1000 V SMA	2	S1M	Fairchild Semiconductor	D1, D2
Super Fast Diode 1 A / 600 V SMA	2	ES1J	Fairchild Semiconductor	D3, D4
Diode DO-35 300 mA / 100 V	1	1N4148	Fairchild Semiconductor	D5
IC Positive Voltage Regulator	1	KA78L05AIMTF	Fairchild Semiconductor	U2
IC SMPS Power Switch	1	FSL306LR	Fairchild Semiconductor	U1
Wire Wound Resistor 1 W 10R ±5%	1			F1

9. Revision History

Rev.	Date	Description
1.0.0	4/2013	Initial release

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