User Guide for

FEBFSL336LRN_CS04U07A

Evaluation Board

Fairchild Multi-Output Buck Converter

Featured Fairchild Product:

FSL336LRN

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

Fairchild Semiconductor.com

Table of Contents

The following reference design supports inclusion of FSL336LRN. It should be used in conjunction with the FSL336LRN datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at http://www.fairchildsemi.com.

1. Introduction

The FSL336LRN integrated Pulse-Width Modulator (PWM) and SenseFET are 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), and Feedback Open-Loop Protection (FB_OLP). FSL336LRN 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}.

Key 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
- Protections: Overload Protection (OLP), Over-Voltage Protection (OVP), Feedback Open Loop Protection (FB_OLP), Thermal Shutdown (TSD)
- Fixed 650 ms Restart Time for Safe Auto-Restart Mode of All Protections

2. Evaluation Board Specifications

The data for Table 1 was measured with 85 V_{AC}~265 V_{AC} line input at an ambient temperature of 25°C.

Table 1. Summary of Features and Performance

Specification	Min.	Max.	Unit
Input Voltage	85	265	V_{AC}
Input Frequency	47	63	Hz

Description	Design Spec.	Test Results	Comments
Output Voltage	13.5 ~ 16.5 V	±6.4%	
	3.15 ~ 3.45 V	±0.15%	
Input Power	< 120 mW	99 mW	265 V_{AC}
Ripple	< 350 mVp-p	298 mVp-p (Max.)	Measured at PCB End
Startup Time	< 20 mS	11.7 mS	Full Load
Dynamic	> 13.5 V	14.15 V	Measure at PCB End
Voltage Stress	600 V	416 V	265 V_{AC}
	600 V	434 V	
Efficiency	Efficiency > 75%	78.35 % at 110 V_{AC} 77.68 % at 230 V_{AC}	Full Load
Conducted EMI	Under 6 dB	3 dB Margin	Meets CISPER22B/EN55022B/IEC950/UL1950 Class II

3. Photographs

Figure 1. Photograph (W x L: 76 x 42 mm^2) Top View

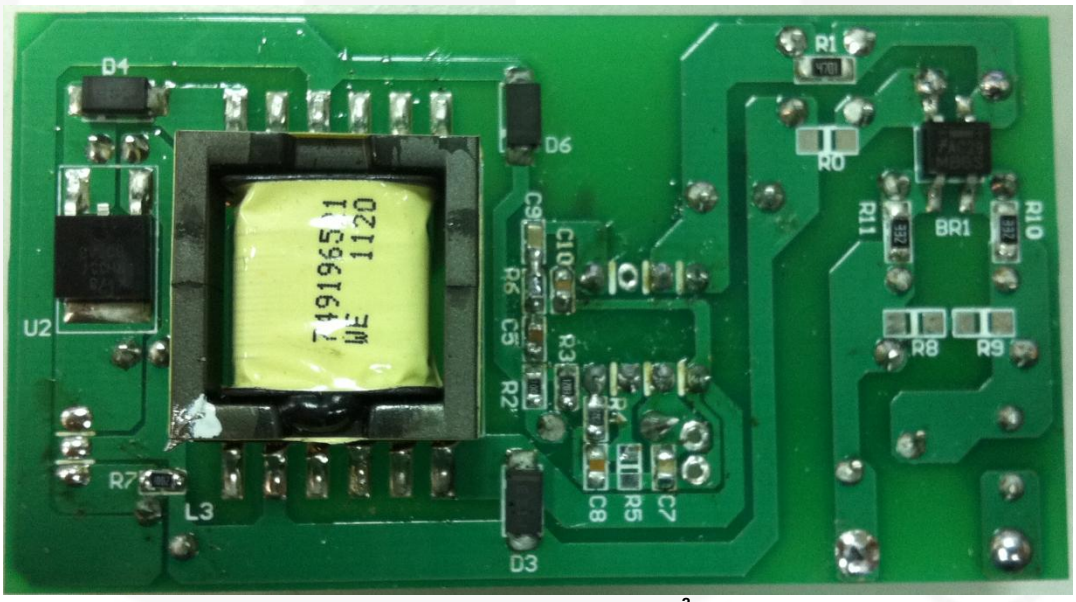


Figure 2. Photograph (W x L: 76 x 42 mm^2) Bottom View

4. Printed Circuit Board

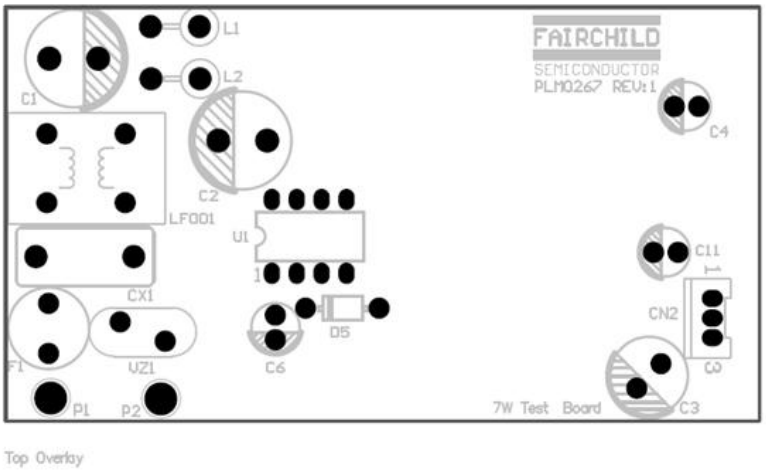


Figure 3. Top View

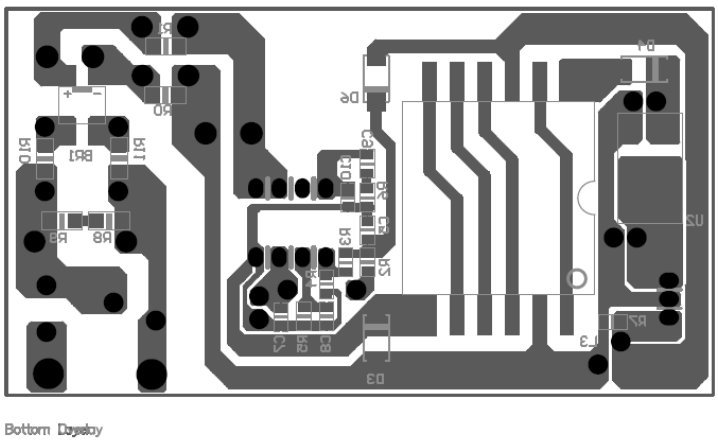


Figure 4. Bottom View

5. Schematic

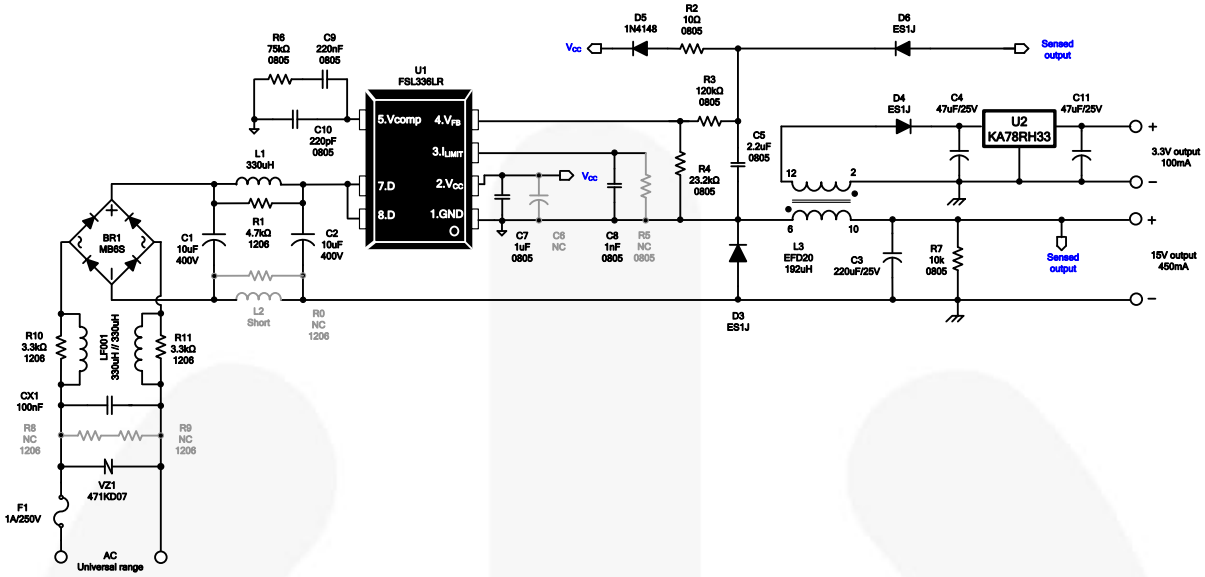


Figure 5. Evaluation Board Schematic

6. Bill of Materials

Part Specification	Part No.	Manufacture	Qty.	Reference
Chip Resistor 0805 10 Ω ±5%			1	R2
Chip Resistor 1206 3.3 kΩ ±5%			2	R10, R11
Chip Resistor 1206 4.7 kΩ ±1%			1	R1
Chip Resistor 0805 10 kΩ ±5%			1	R7
Chip Resistor 0805 23.2 kΩ ±1%			1	R4
Chip Resistor 0805 75 kΩ ±5%			1	R6
Chip Resistor 0805 120 kΩ ±1%			1	R3
0805 MLCC X7R ±10% 221P (220 pF) 50 V			1	C10
0805 MLCC X7R ±10% 102P (1 nF) 50 V			1	C8
0805 MLCC X7R ±10% 224P (220 nF) 50 V			1	C9
0805 MLCC X7R ±10% 105P (1 µF) 50 V			1	C7
0805 MLCC X7R ±10% 225P (2.2 µF) 50 V			1	C5
Electrolytic Capacitor 10 µF 400 V 105°C			2	C1, C2
Electrolytic Capacitor 47 µF 25 V 105°C			2	C4, C11
Electrolytic Capacitor 220 µF 25 V 105°C			1	C3
X-cap 0.1 µF 250 V_{AC}			1	CX1
Fixed Inductor 330 µH ±10%			3	LF001, L1
Flexible Transformer EFD20	749196521	Wurth	1	L3
Bridge Rectifier 0.5 A / 600 V SMA	MB6S	Fairchild Semiconductor	2	BR1
Super Fast Diode 1 A / 600 V SMA	ES1J	Fairchild Semiconductor	3	D3, D4, D6
Diode DO-35 300 mA / 100 V	1N4148	Fairchild Semiconductor	1	D5
IC Positive Voltage Regulator	KA78RH33	Fairchild Semiconductor	1	U2
IC SMPS Power Switch	FSL336LRN	Fairchild Semiconductor	1	U1
Varistor 7Φ 470 V	471KD07		1	VZ1
Radial Type 1 A / 250 V			1	F1

7. Transformer and Winding Specifications

Kunde / customer :
Artikelnummer / part number : 749196521 LF

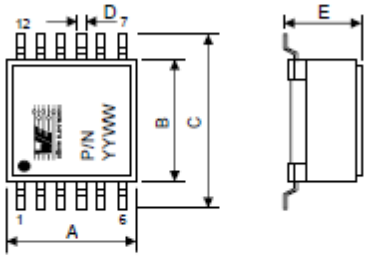
Bezeichnung : FLEX-ÜBERTRAGER WE-FLEX
description : FLEX-TRANSFORMER WE-FLEX

compliant RoHS

WÜRTH ELEKTRONIK

DATUM / DATE : 2006-08-01

A Mechanische Abmessungen / dimensions :



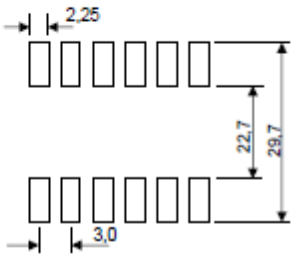
● = Marking Pin 1

	EFD20	
A	21,0 max	mm
B	21,0 typ.	mm
C	29,5 max	mm
D	0,7 ± 0,1	mm
E	10,8 max	mm

B Elektrische Eigenschaften / electrical properties :

Eigenschaften / properties	Testbedingungen / test conditions		Wert / value	Einheit / unit	tol.
Induktivität / inductance	10 kHz / 1 V	L_{base}	12,0	µH	±20%
Sättigungsstrom / saturation current	|ΔL/L|<10%	$I_{sat\ base}$	1,73	A	typ.
Nennstrom / rated current	ΔT=40 K	$I_{rms\ base}$	1,70	A	typ.
DC-Widerstand / DC-resistance	@ 20°C	$R_{DC\ base}$	71,1	mΩ	max.
Spannungs-Zeit-Fläche / Voltage-µsecond		∫Udt	98,4	µVs	max.
Speicherenergie / storage energy		$E_{peak\ base}$	16,07	µJ	typ.
Streuinduktivität / leakage inductance	10 kHz / 1V	$L_{s\ base}$	0,24	µH	typ.
Hochspannungstest / Hipot test	3mA / 1sec	HV	500	V_{DC}	

C Lötpad / soldering spec. :



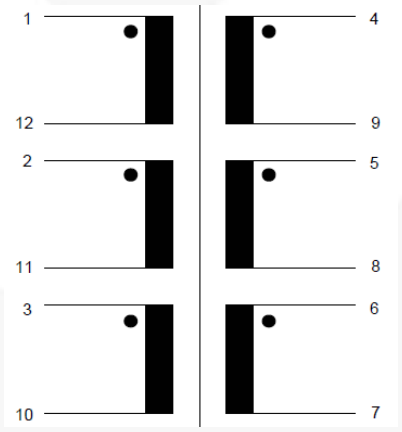


Figure 6. Transformer Specifications & Construction

8. Test Conditions & Test Equipment

Table 2. Test Conditions & Test Equipment

Evaluation Board #	FEBFSL336LRN_CS04U07A
Test Date	2013-12-5
Test Temperature	25℃
Test Equipments	AC Power Source: 6800 AC POWER SOURCE Electronic Load: Chroma 63030 Power Meter: WT210 Oscilloscope: LeCory 24Xs-A

9. Performance of Evaluation Board

9.1. Startup Performance

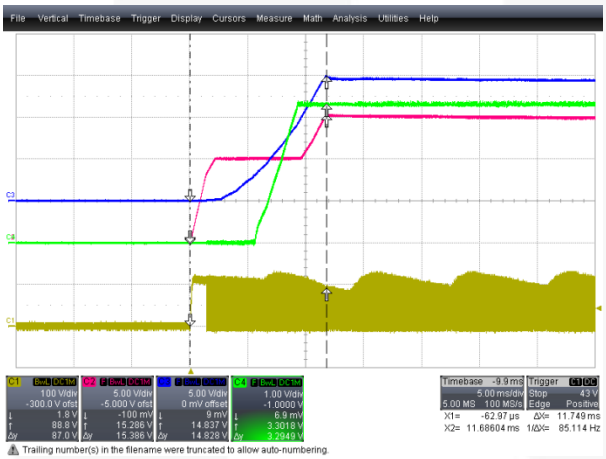


Figure 7. Startup Time=11.7 ms, 85 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

Figure 8. Startup Time=10.6 ms, 265 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

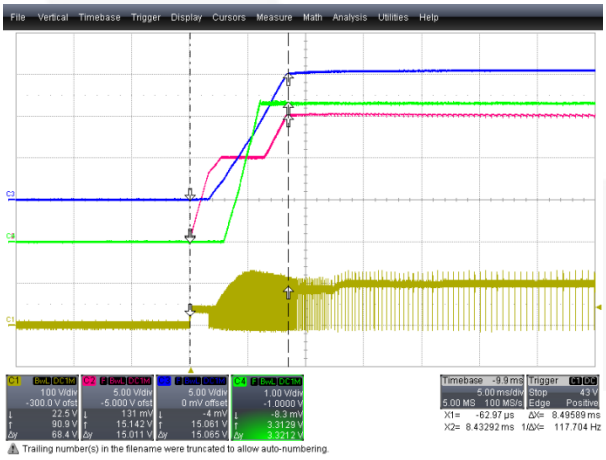


Figure 9. Startup Time=8.5 ms, 85 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

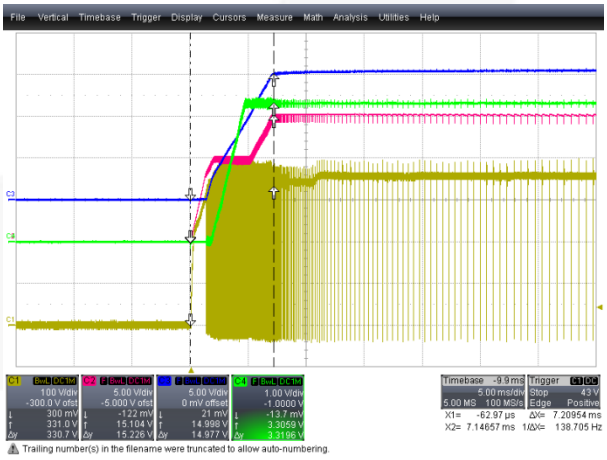


Figure 10. Startup Time=7.2 ms, 265 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

9.2. 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)

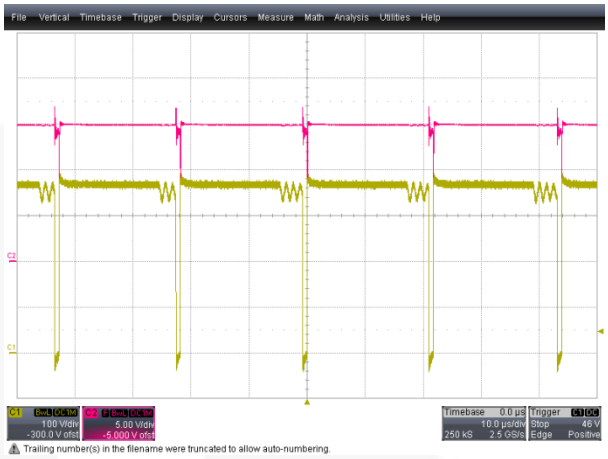


Figure 12. Full-Load Condition, 265 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 10 µs/div)

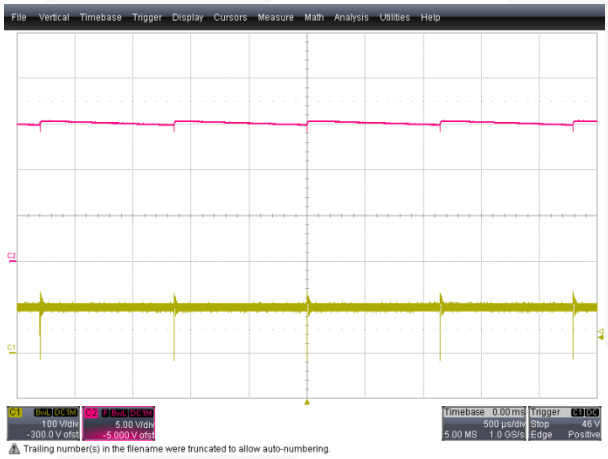


Figure 13. No-Load Condition, 85 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 µs/div)

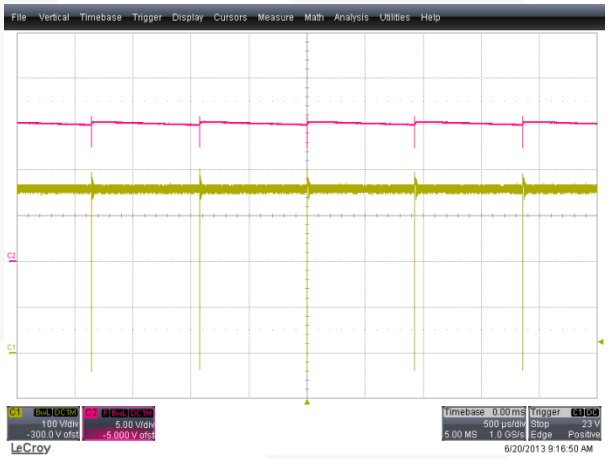


Figure 14. No-Load Condition, 265 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 µs/div)

9.3. Voltage Stress of Drain and Freewheeling Diode

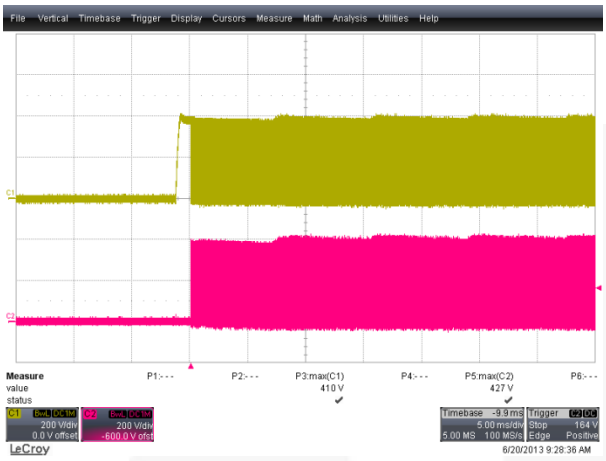


Figure 15. V_{DS}=410 V, V_{DIODE}=427 V, Startup Condition, Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 5 ms/div)

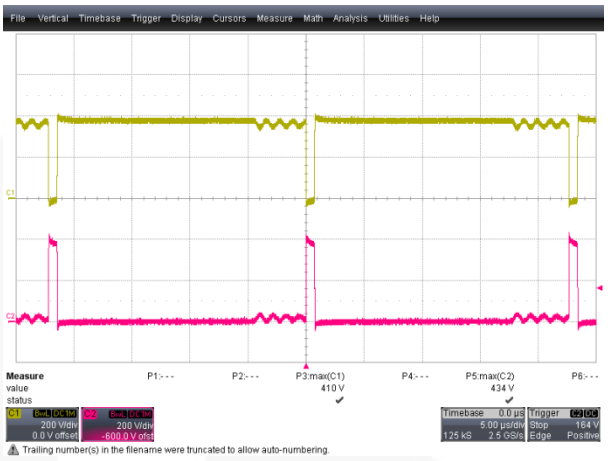


Figure 16. V_{DS}=410 V, V_{DIODE}=434 V, Steady-State, Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 5 µs/div)

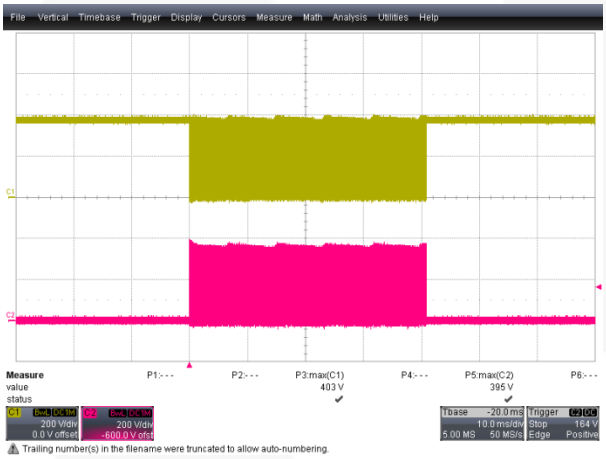


Figure 17. V_{DS}=403 V & V_{DIODE}=395 V, 15 V Output Short Condition, 3.3 V Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 10 ms/div)

Figure 18. V_{DS}=416 V & V_{DIODE}=434 V, 3.3 V Output Short Condition, 15 V Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 10 ms/div)

9.4. Output Ripple and Noise

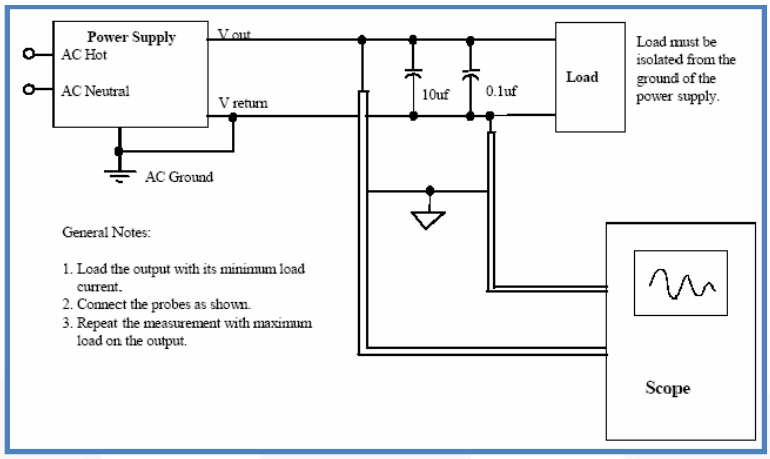


Figure 19. Recommended Test Setup

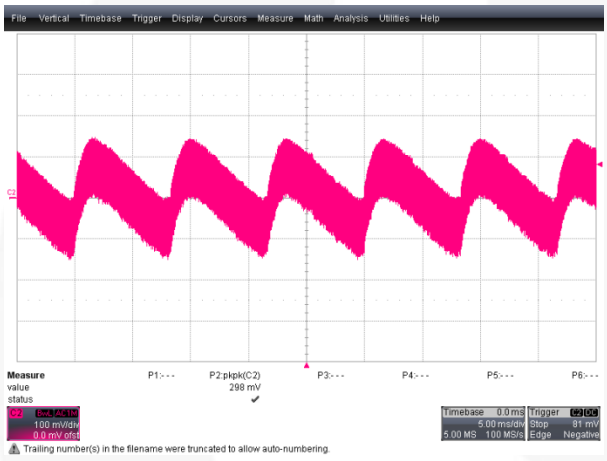


Figure 20. 15 V_{OUT_RIPPLE}=298 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

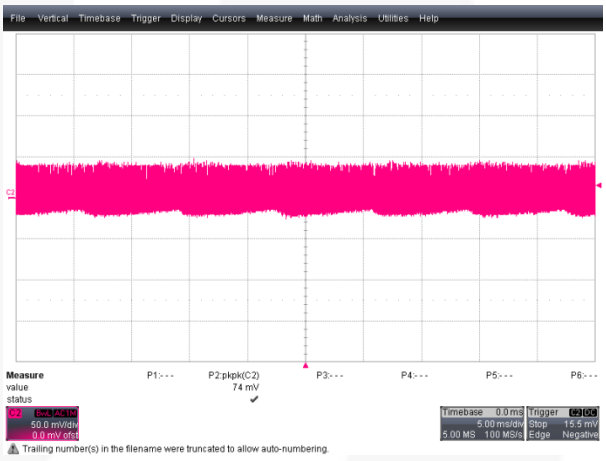


Figure 21. 3.3 V_{OUT_RIPPLE}=74 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

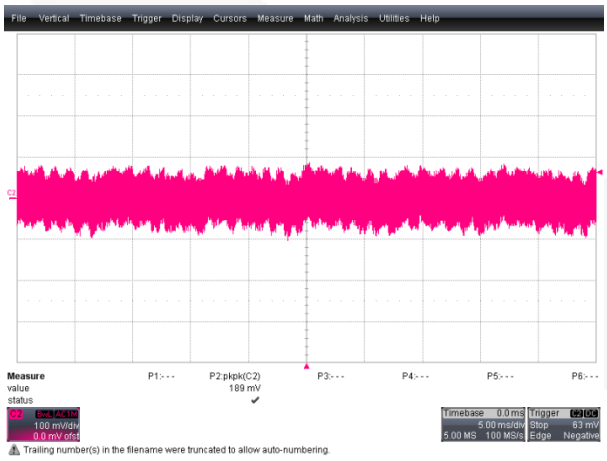


Figure 22. 15 V_{OUT_RIPPLE}=189 mV, Output with 265 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

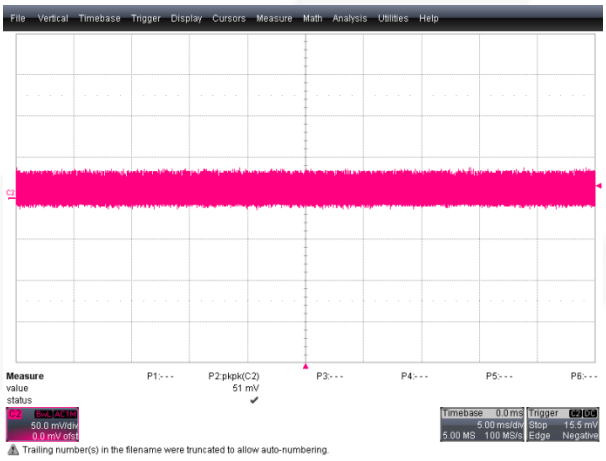


Figure 23. 3.3 V_{OUT_RIPPLE}=51 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

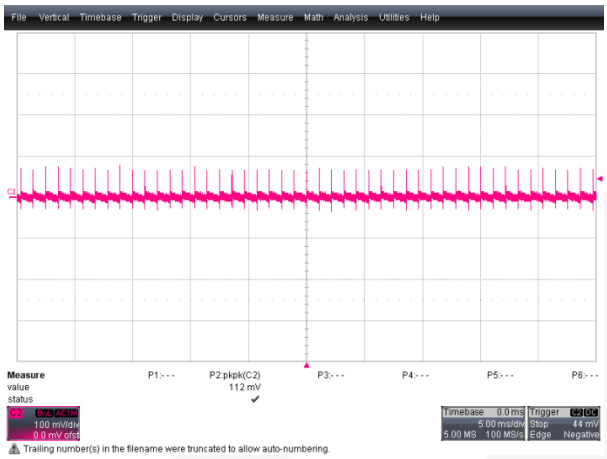


Figure 24. 15 V_{OUT_RIPPLE}=112 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

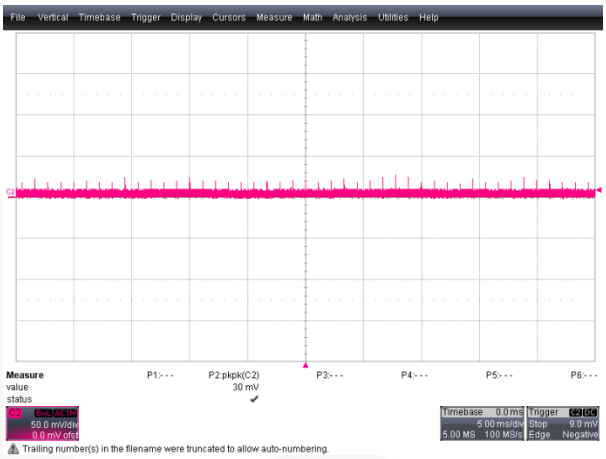


Figure 25. 3.3 V_{OUT_RIPPLE}=30 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

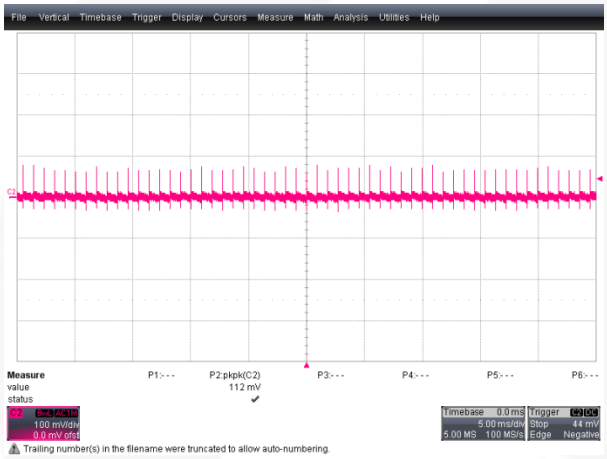


Figure 26. 15 V_{OUT_RIPPLE}=112 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

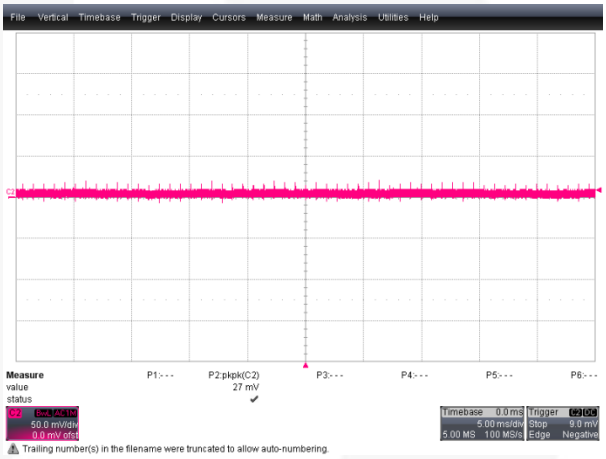
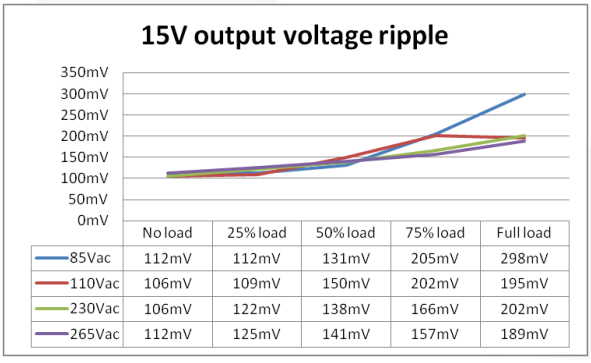
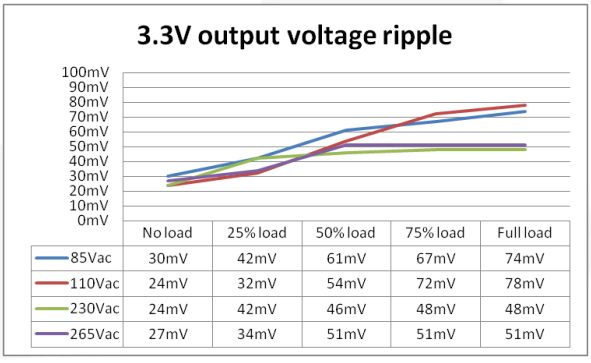


Figure 27. 3.3 V_{OUT_RIPPLE}=27 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div



	No load	25% load	50% load	75% load	Full load
85Vac	112mV	112mV	131mV	205mV	298mV
110Vac	106mV	109mV	150mV	202mV	195mV
230Vac	106mV	122mV	138mV	166mV	202mV
265Vac	112mV	125mV	141mV	157mV	189mV

Figure 28. 12 Output Ripple



	No load	25% load	50% load	75% load	Full load
85Vac	30mV	42mV	61mV	67mV	74mV
110Vac	24mV	32mV	54mV	72mV	78mV
230Vac	24mV	42mV	46mV	48mV	48mV
265Vac	27mV	34mV	51mV	51mV	51mV

Figure 29. 5 V Output Ripple

9.5. Step Load Response

Test Condition:

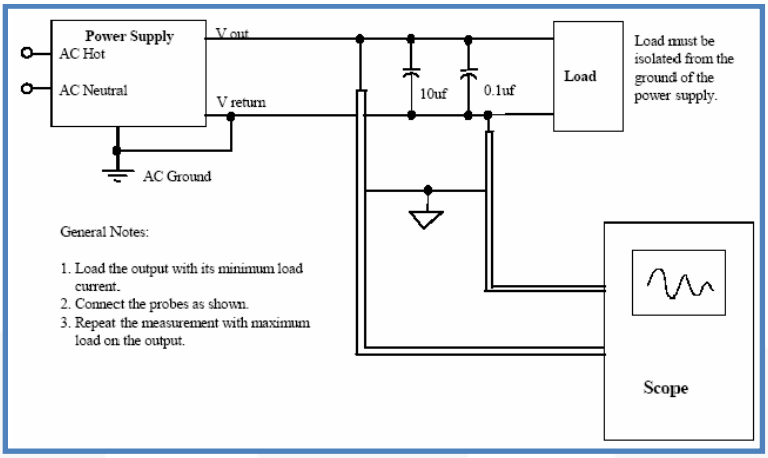


Figure 30. Recommended Test Setup

Table 3. 15 V Output Step Load Response (3.3 V Output Full Load Condition)

15 V Output Step Load (80% ↔ 20%)	85 V_{AC}		110 V_{AC}		230 V_{AC}		265 V_{AC}	
	15 V	3.3 V	15 V	3.3 V	15 V	3.3 V	15 V	3.3 V
Peak-Peak Voltage	992 mV	72 mV	870 mV	82 mV	1210 mV	53 mV	973 mV	56 mV

Table 4. 3.3 V Output Step Load Response (15 V Output Full Load Condition)

3.3 V Output Step Load (80% ↔ 20%)	85 V_{AC}		110 V_{AC}		230 V_{AC}		265 V_{AC}	
	15 V	3.3 V	15 V	3.3 V	15 V	3.3 V	15 V	3.3 V
Peak-Peak Voltage	333 mV	74 mV	211 mV	82 mV	230 mV	53 mV	211 mV	56 mV

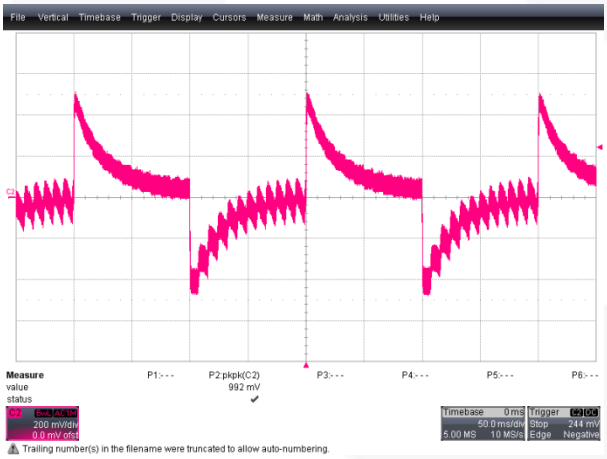


Figure 31. 15 V Output with 85 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

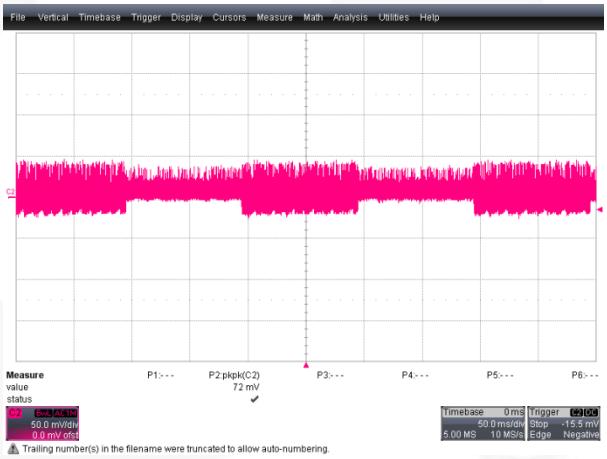


Figure 32. 3.3 V Output with 85 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

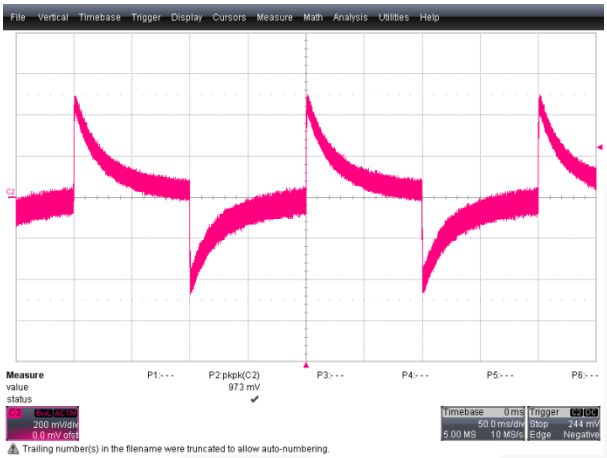


Figure 33. 15 V Output with 265 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

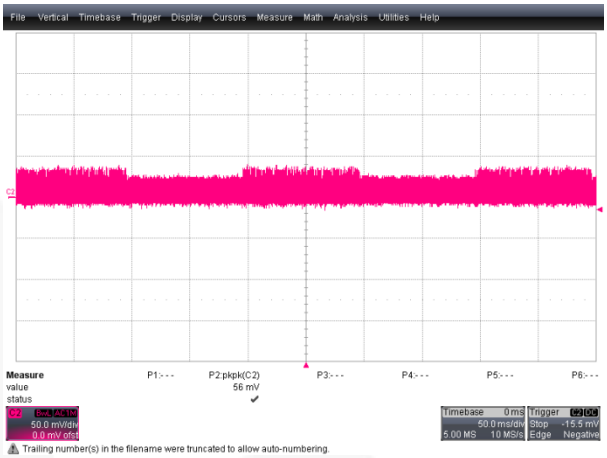
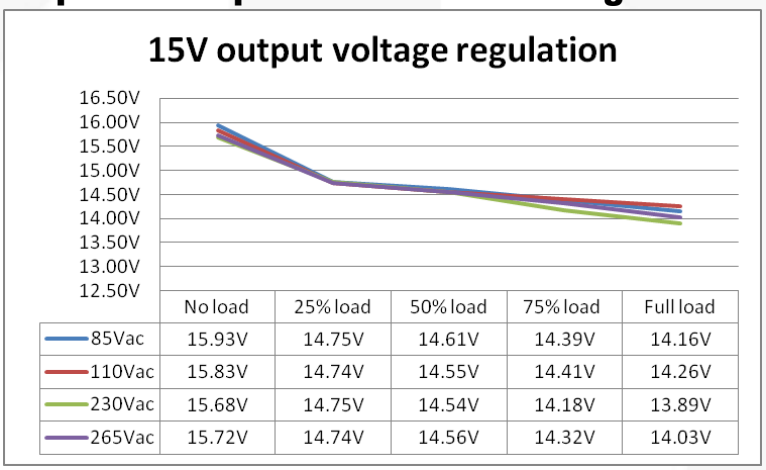


Figure 34. 3.3 V Output with 265 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

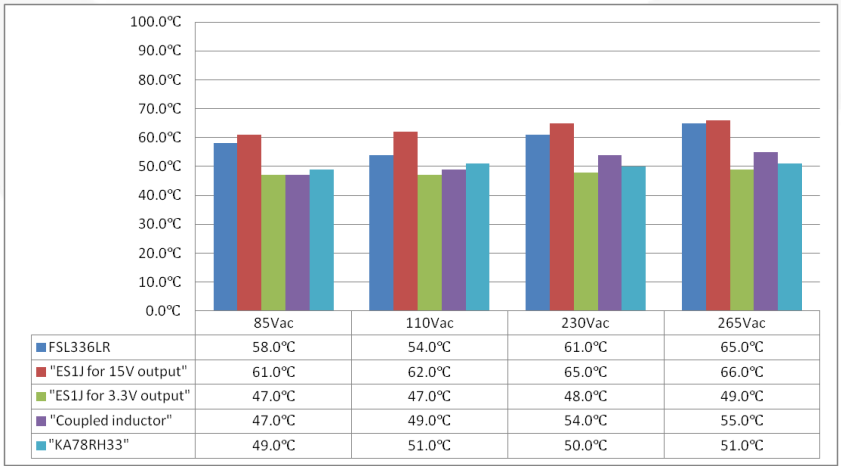
9.6. Dynamic Response Output Line and Load Regulation



	No load	25% load	50% load	75% load	Full load
85Vac	15.93V	14.75V	14.61V	14.39V	14.16V
110Vac	15.83V	14.74V	14.55V	14.41V	14.26V
230Vac	15.68V	14.75V	14.54V	14.18V	13.89V
265Vac	15.72V	14.74V	14.56V	14.32V	14.03V

Figure 35. 15 V Output Line & Load Regulation

9.7. Temperature Measurement



	85Vac	110Vac	230Vac	265Vac
FSL336LR	58.0℃	54.0℃	61.0℃	65.0℃
"ES1J for 15V output"	61.0℃	62.0℃	65.0℃	66.0℃
"ES1J for 3.3V output"	47.0℃	47.0℃	48.0℃	49.0℃
"Coupled inductor"	47.0℃	49.0℃	54.0℃	55.0℃
"KA78RH33"	49.0℃	51.0℃	50.0℃	51.0℃

Figure 36. Total Temperature Test Result

9.8. Efficiency Test Result

Test Condition

- Test after 30 minutes aging
- Test from heavy load to light-load

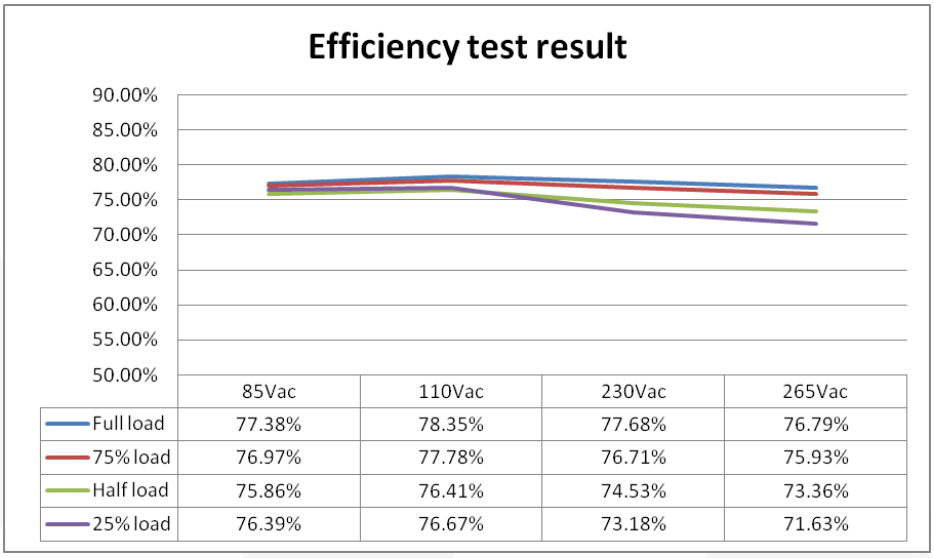


Figure 37. Efficiency vs. Output Load and Input Voltage

Table 5. Efficiency Test Results

		85 V_{AC}		110 V_{AC}		230 V_{AC}		265 V_{AC}	
Full Load	Output 1	14.16 V	0.45 A	14.26 V	0.45 A	13.89 V	0.45 A	14.03 V	0.45 A
	Output 2	3.29 V	0.10 A	3.29 V	0.10 A	3.29 V	0.10 A	3.29 V	0.10 A
	Input Power	8.66 W		8.61 W		8.47 W		8.65 W	
	Efficiency	77.38%		78.35%		77.68%		76.79%	
75% Load	Output 1	14.39 V	0.34 A	14.41 V	0.34 A	14.18 V	0.34 A	14.32 V	0.34 A
	Output 2	3.29 V	0.08 A	3.29 V	0.08 A	3.29 V	0.08 A	3.29 V	0.08 A
	Input Power	6.63 W		6.57 W		6.56 W		6.69 W	
	Efficiency	76.97%		77.78%		76.71%		75.93%	
Half Load	Output 1	14.61 V	0.23 A	14.55 V	0.23 A	14.54 V	0.23 A	14.56 V	0.23 A
	Output 2	3.29 V	0.05 A	3.29 V	0.05 A	3.29 V	0.05 A	3.29 V	0.05 A
	Input Power	4.55 W		4.50 W		4.61 W		4.69 W	
	Efficiency	75.86%		76.41%		74.53%		73.36%	
25% Load	Output 1	14.75 V	0.11 A	14.74 V	0.11 A	14.75 V	0.11 A	14.74 V	0.11 A
	Output 2	3.29 V	0.03 A	3.29 V	0.03 A	3.29 V	0.03 A	3.29 V	0.03 A
	Input Power	2.28 W		2.27 W		2.38 W		2.43 W	
	Efficiency	76.39%		76.67%		73.18%		71.63%	

9.9. Standby Power Consumption

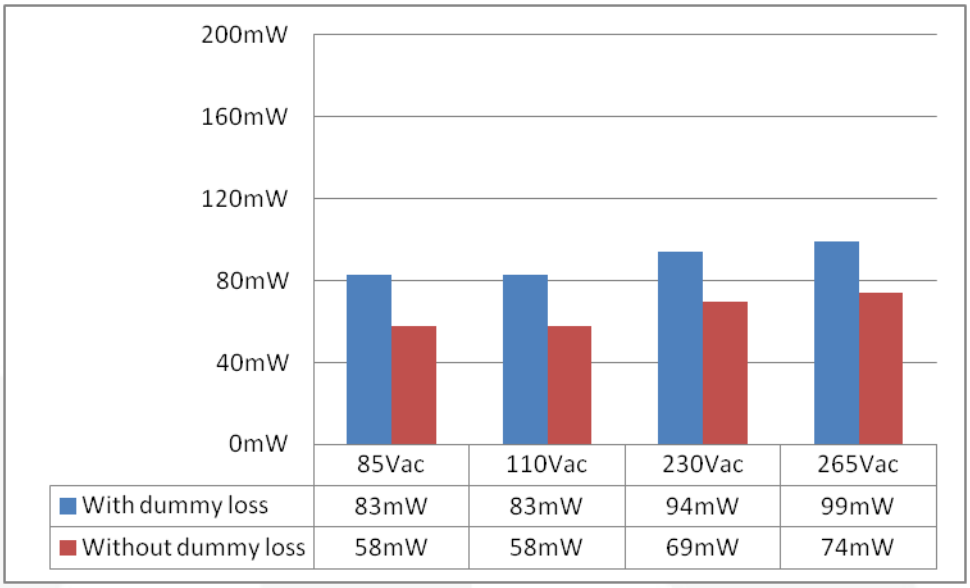


Figure 38. Standby Power Consumption at No Load Condition (Including 3.3 V Regulator Power Loss)

9.10. Conducted Electromagnetic Interference (EMI)

Test Condition

- Frequency Range: 150 kHz – 30 MHz, Probe: 2-Line-LISN ENV216
- Signal Path: Receiver-2-Line-LISN ENV216, Detectors: Average

Test Results:

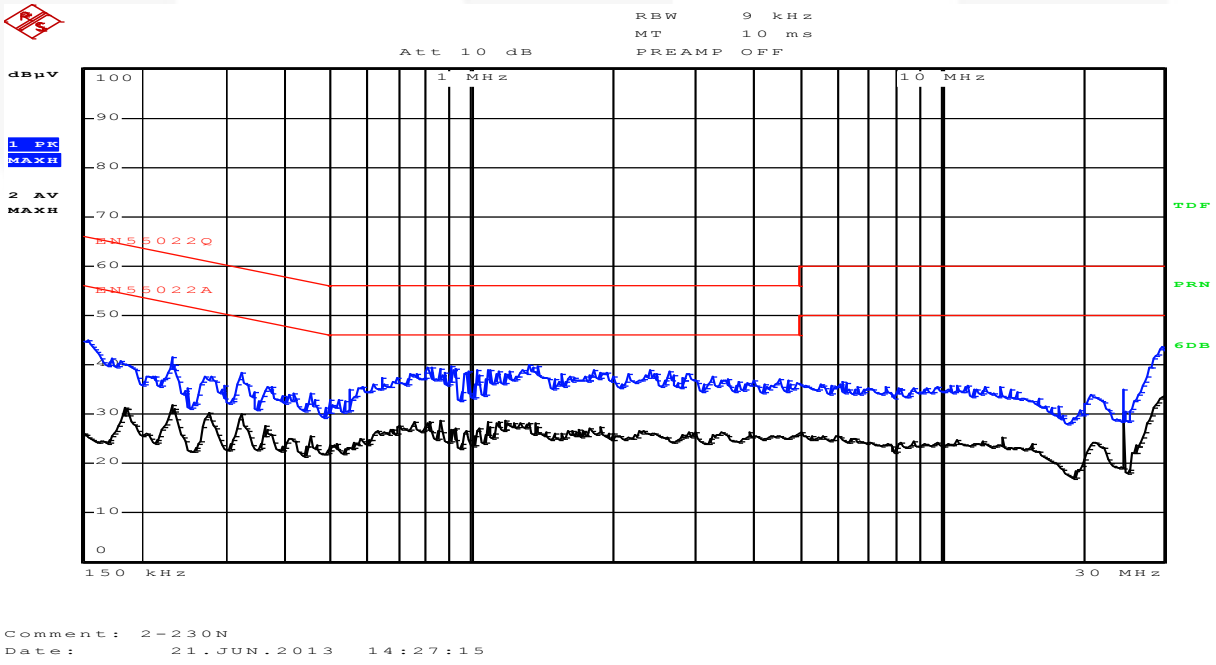


Figure 39. L at 110 V_{AC}

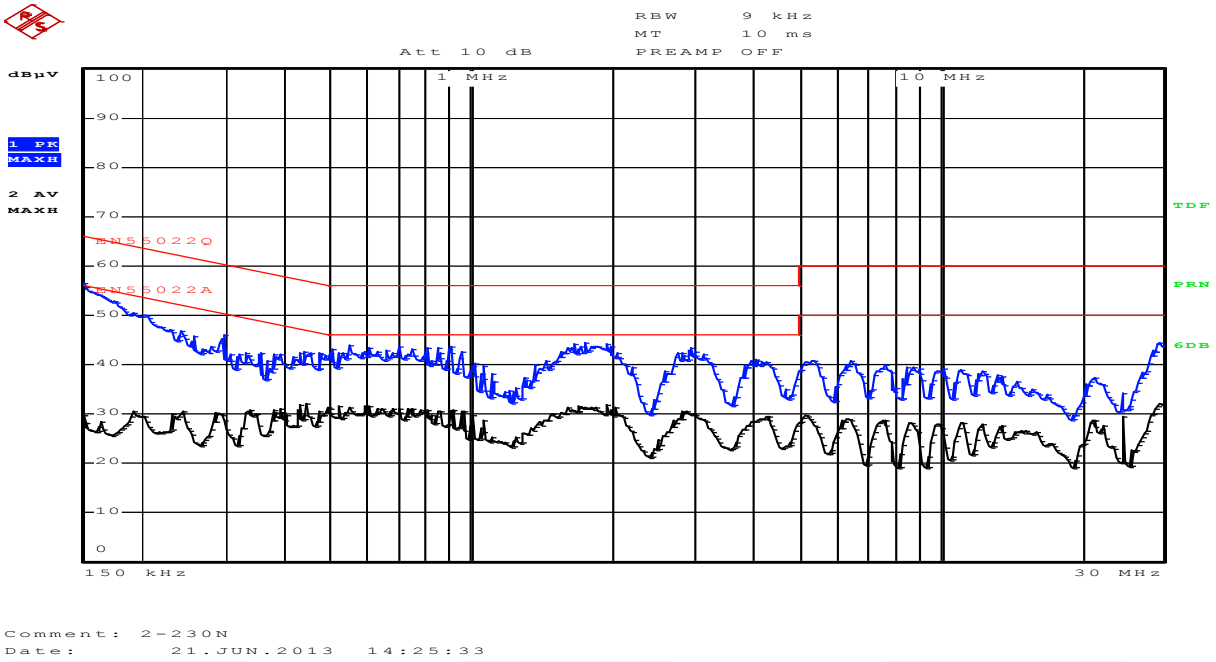


Figure 40. L at 230 V_{AC}

10. Revision History

Rev.	Date	Description
1.0	July 2016	Initial Release

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Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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