Fairchild Reference Design

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.

Application	Fairchild Device	Input Voltage Range	Maximum Output Power	Output Full-Load Condition
Multi-Output Buck Converter	FSL336LRN	85-265 V_{AC}	7.08 W	15 V (0.45 A) 3.3 V (0.1 A)

General Description

The FSL336LRN 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), 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

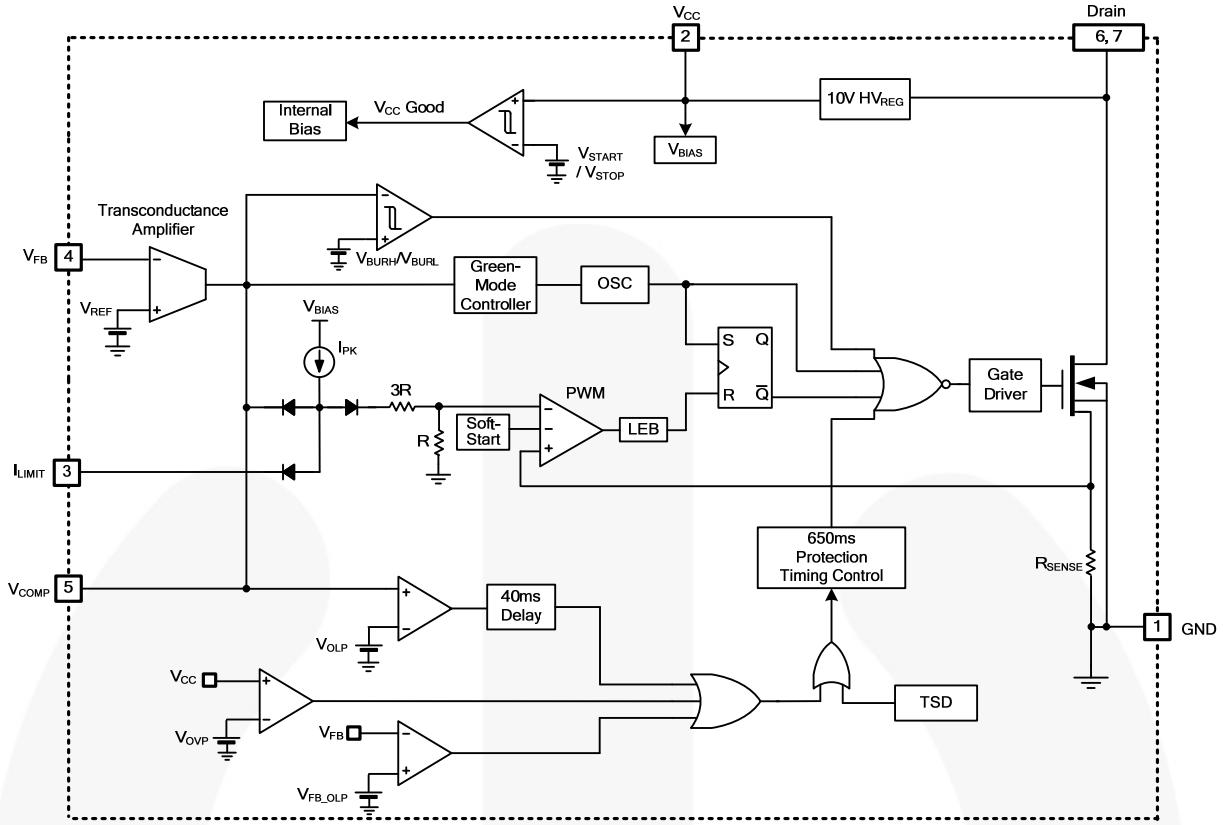


Figure 1. Internal Block Diagram

1. Photographs

Figure 2. Top View (Dimension 76 x 42 [mm^2])

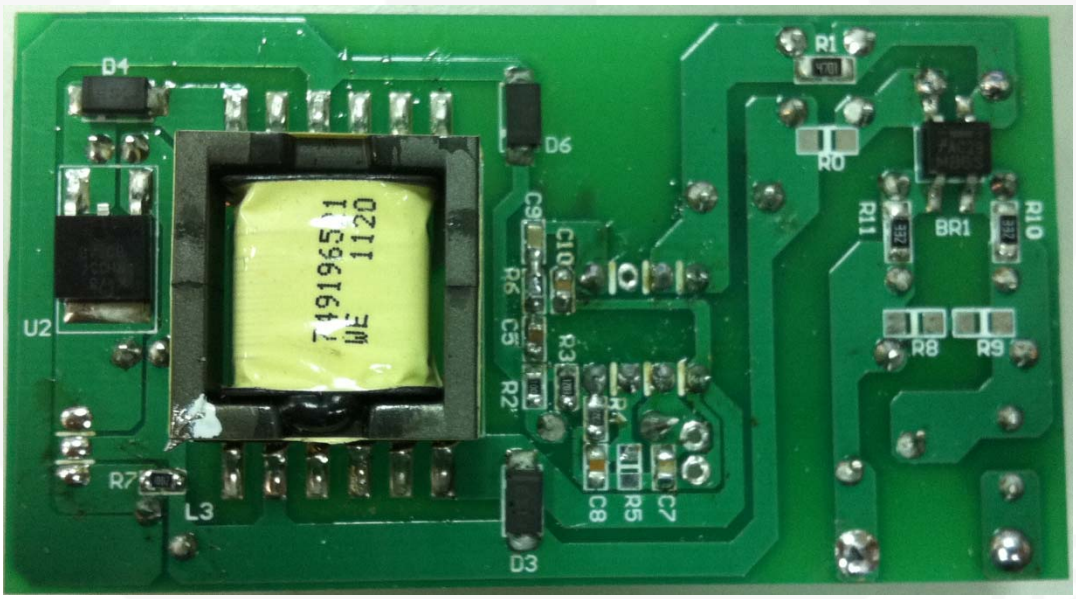


Figure 3. Bottom View (Dimension 76 x 42 [mm^2])

2. Print Circuit Board (PCB) Layout

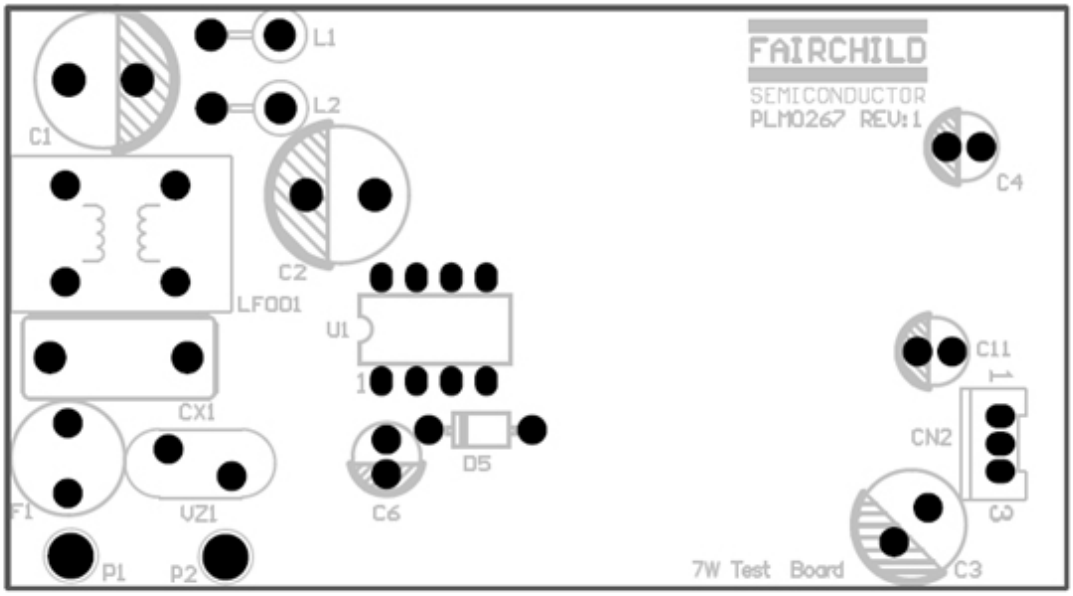


Figure 4. Top Side

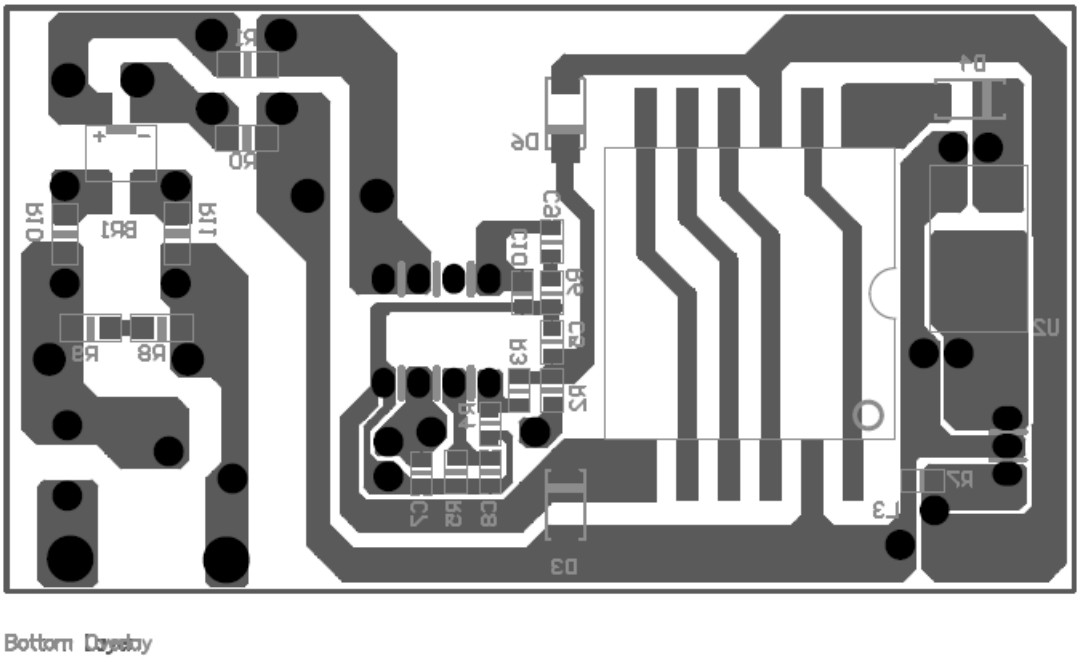


Figure 5. Bottom Side

3. Test Conditions

Evaluation Board #	FEBFSL336LRN_CS04U07A
Test Date	December 5, 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 Line & Load Regulation 7. Temperature Measurement 8. Efficiency Test Result 9. Standby Power Consumption 10. Conducted EMI Measurement

4. Performance of Evaluation Board

4.1. Startup Performance

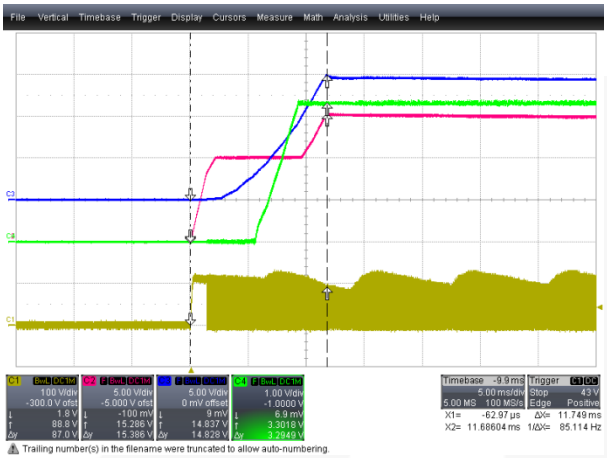


Figure 6. Startup Time=11.7 ms, 85 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

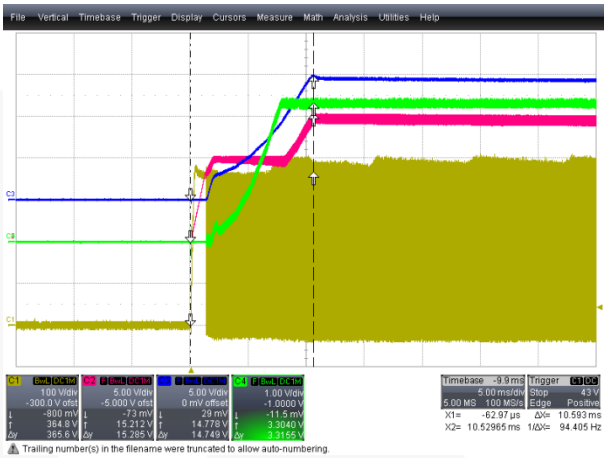


Figure 7. Startup Time=10.6 ms, 265 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

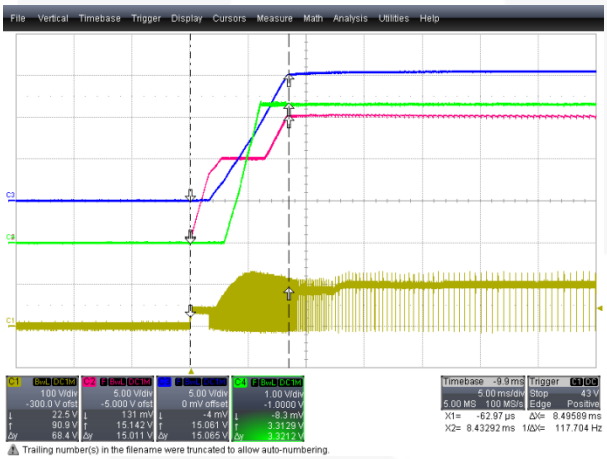


Figure 8. Startup Time=8.5 ms, 85 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

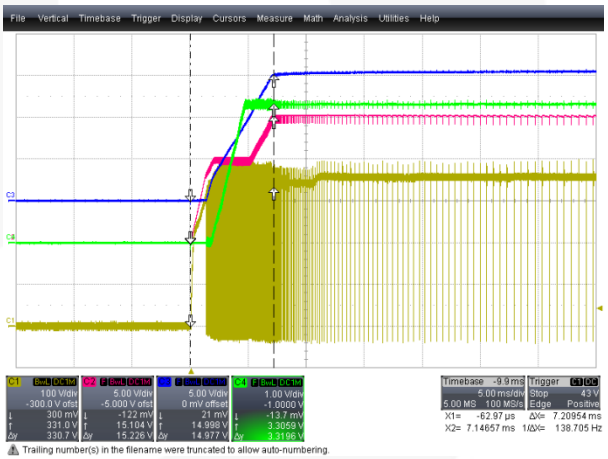


Figure 9. Startup Time=7.2 ms, 265 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

4.2. Normal Operation

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

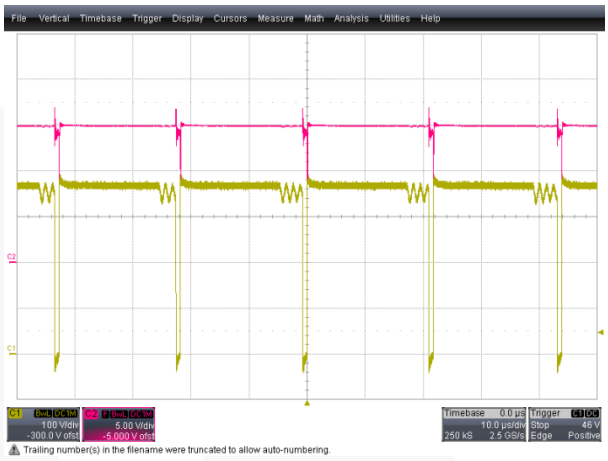


Figure 11. Full-Load Condition, 265 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 10 µs/div)

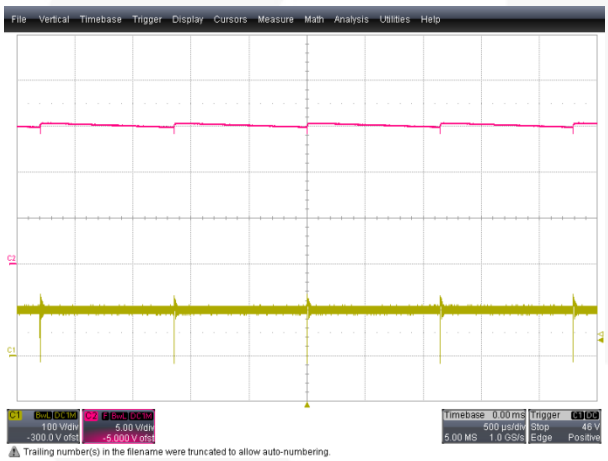


Figure 12. No-Load Condition, 85 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 µs/div)

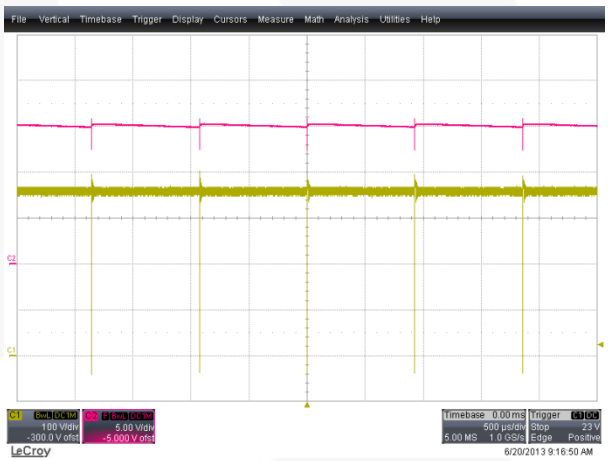


Figure 13. No-Load Condition, 265 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 µs/div)

4.3. Voltage Stress of Drain and Freewheeling Diode

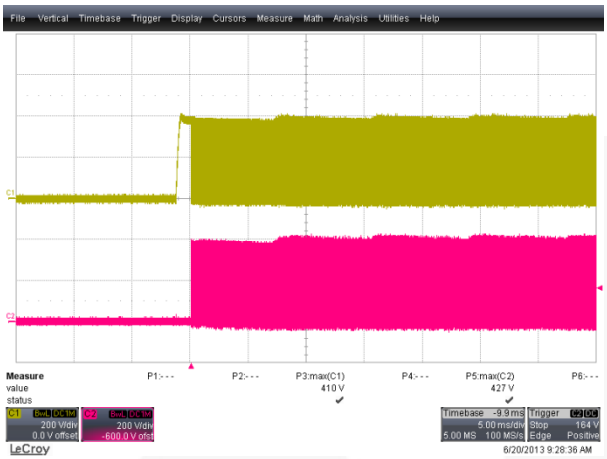


Figure 14. V_{DS}=410 V, V_{DIODE}=427 V, Startup Condition, Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 5 ms/div)

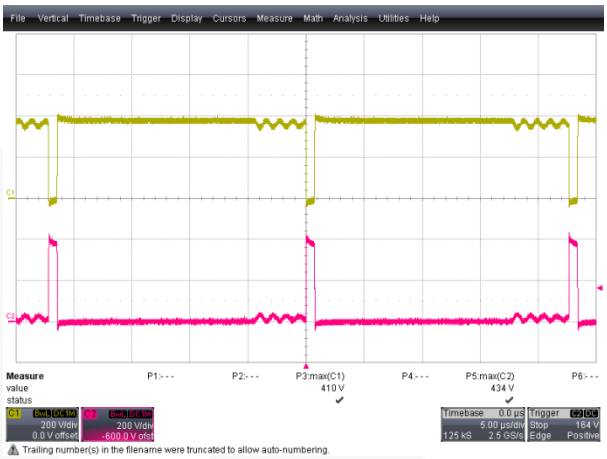


Figure 15. V_{DS}=410 V, V_{DIODE}=434 V, Steady-State, Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 5 µs/div)

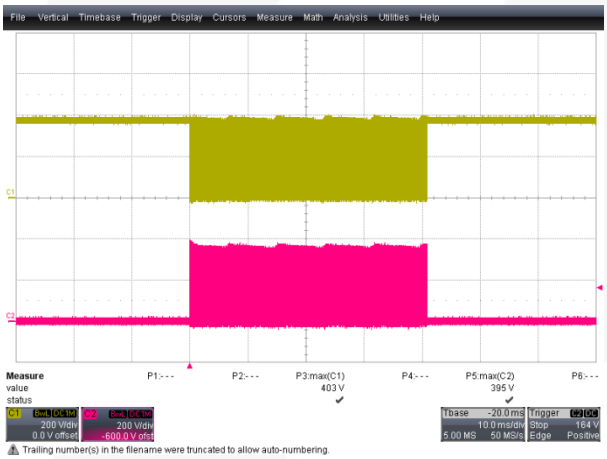


Figure 16. V_{DS}=403 V & V_{DIODE}=395 V, 15 V Output Short Condition, 3.3 V Full-Load Condition, 265 V_{AC}, (CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div), Time: 10 ms/div)

Figure 17. 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)

4.4. Output Ripple and Noise

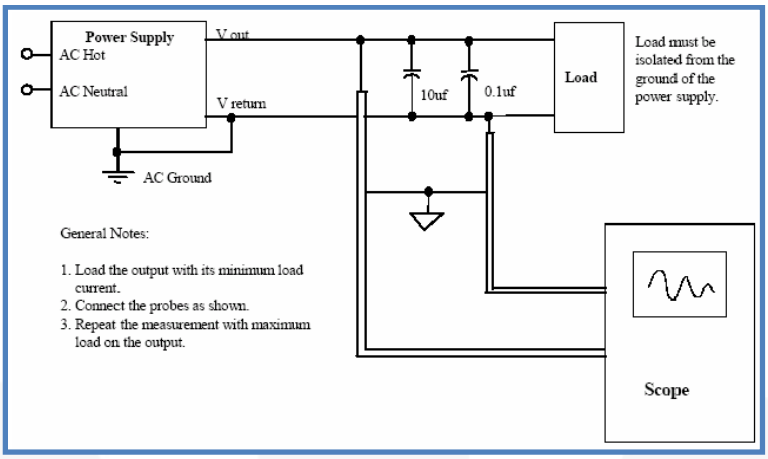


Figure 18. Recommended Test Setup

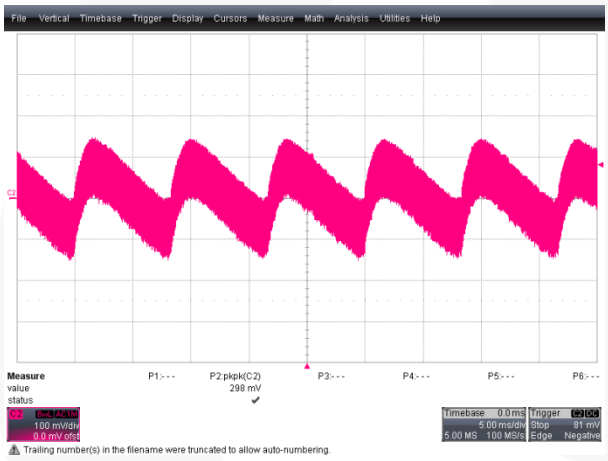


Figure 19. 15 V_{OUT_RIPPLE}=298 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

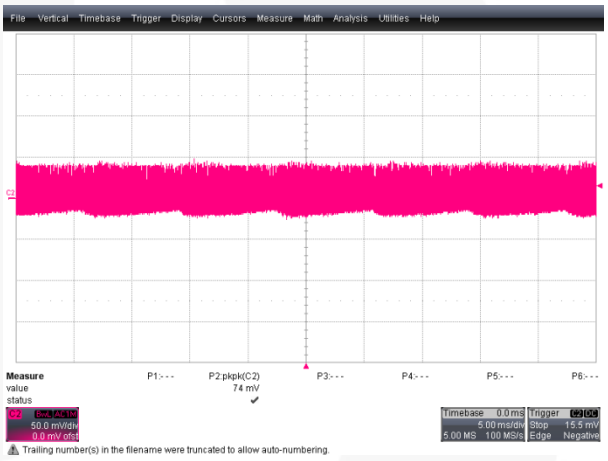


Figure 20. 3.3 V_{OUT_RIPPLE}=74 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

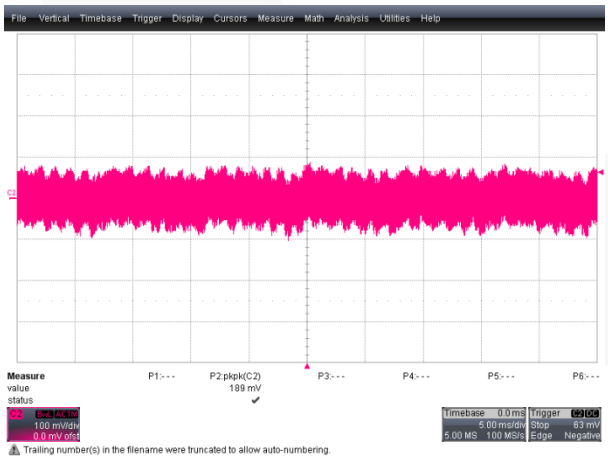


Figure 21. 15 V_{OUT_RIPPLE}=189 mV, Output with 265 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

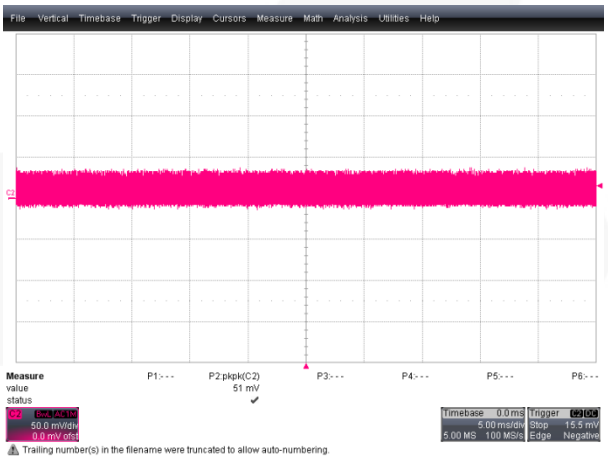


Figure 22. 3.3 V_{OUT_RIPPLE}=51 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

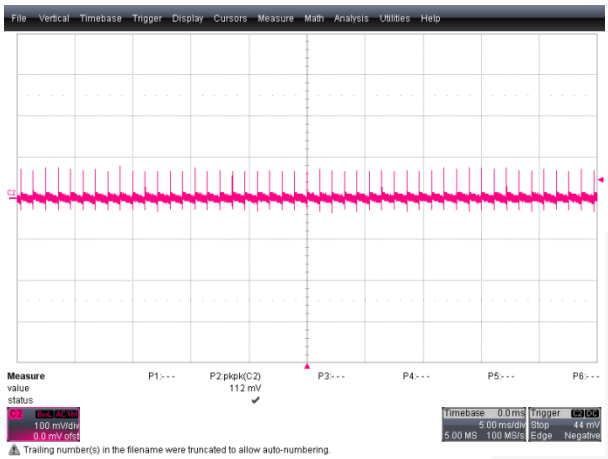


Figure 23. 15 V_{OUT_RIPPLE}=112 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

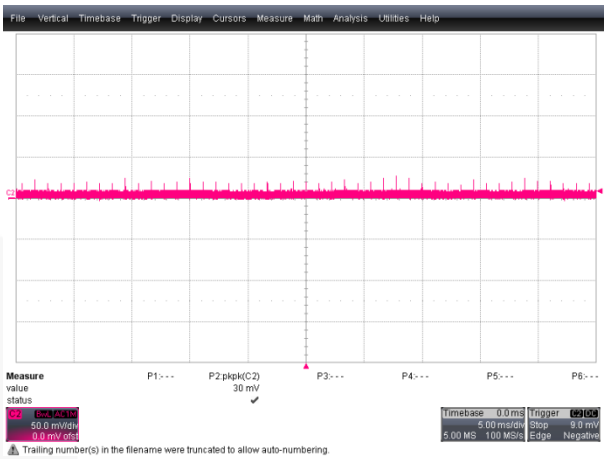


Figure 24. 3.3 V_{OUT_RIPPLE}=30 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

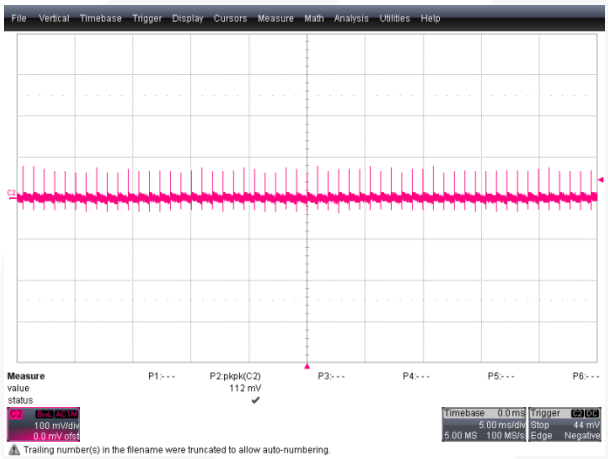


Figure 25. 15 V_{OUT_RIPPLE}=112 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

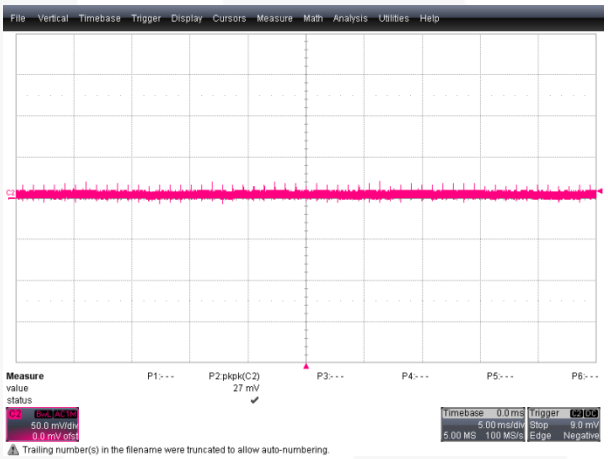
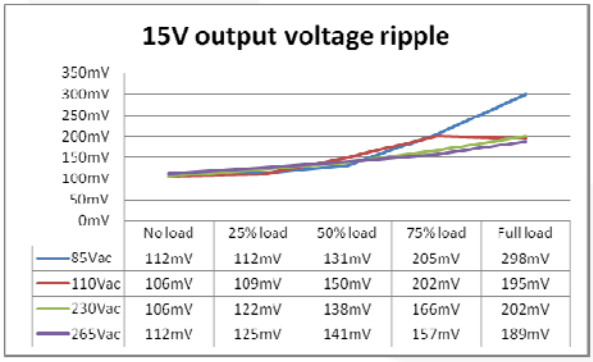
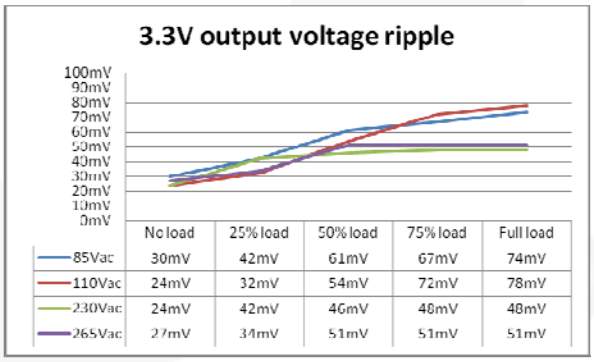


Figure 26. 3.3 V_{OUT_RIPPLE}=27 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div



	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 27. 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 28. 5 V Output Ripple

4.5. Step Load Response

Test Slew Rate (250 mA/µs)

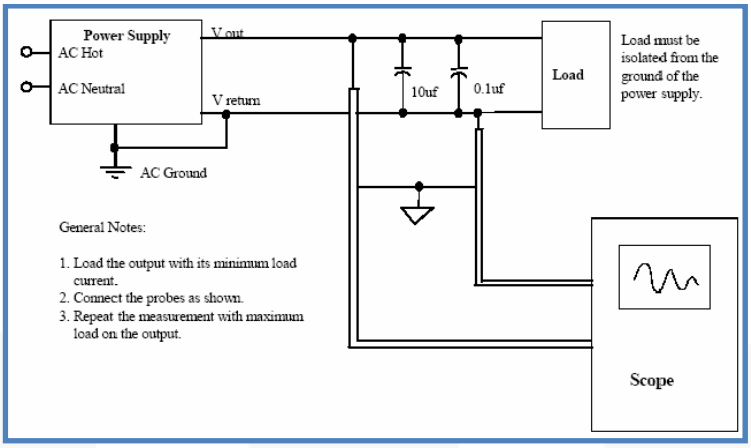


Figure 29. Recommended Test Setup

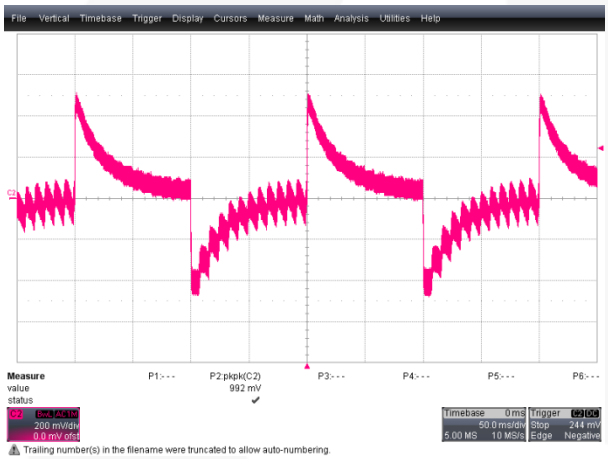


Figure 30. 15 V Output with 85 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

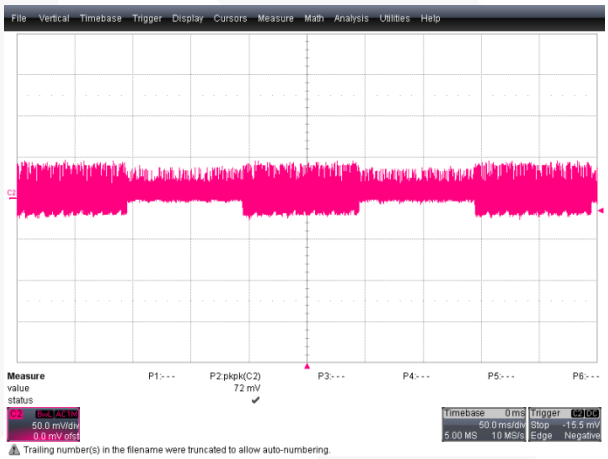


Figure 31. 3.3 V Output with 85 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

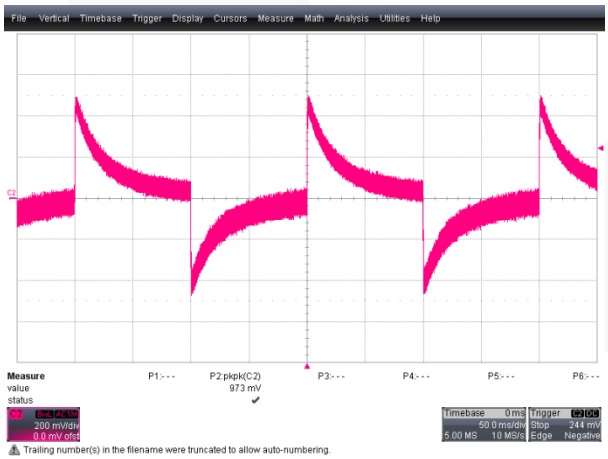


Figure 32. 15 V Output with 265 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

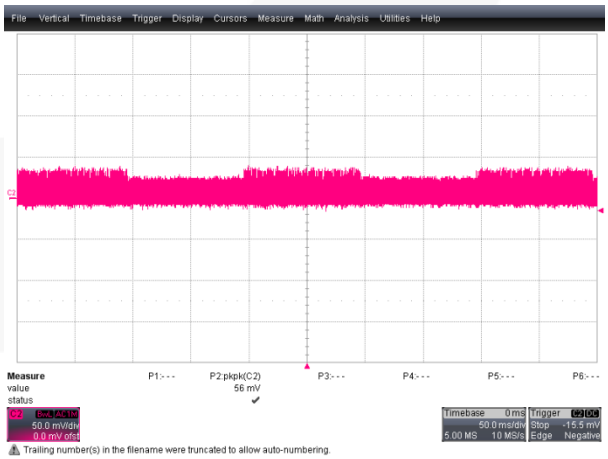


Figure 33. 3.3 V Output with 265 V_{AC}, 80% Load ↔ 20% Load of 15 V Output (CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

Table 1. 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 2. 3.3 V Output Step Load Response (5 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

4.6. Output Line & Load Regulation

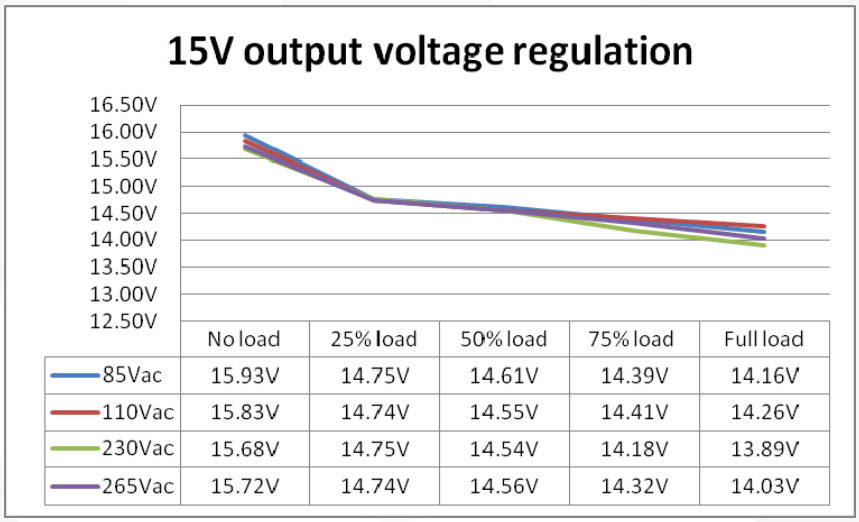


Figure 34. 15 V Output Line & Load Regulation

4.7. Temperature Measurement

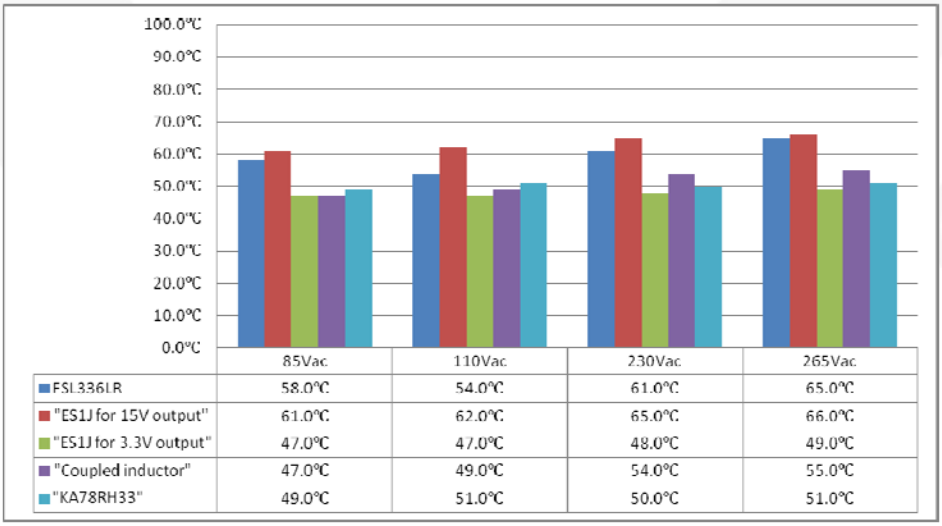


Figure 35. Total Temperature Test Result

4.8. Efficiency Test Result

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

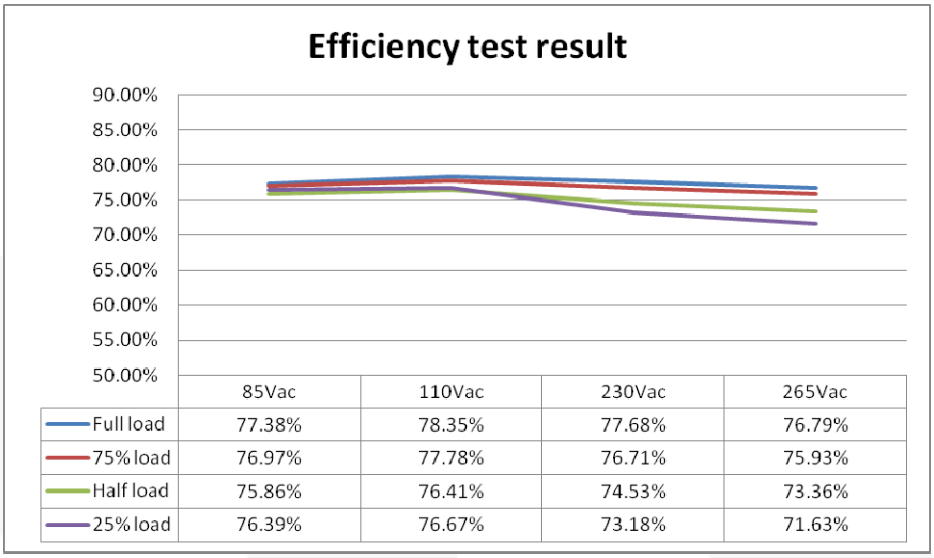
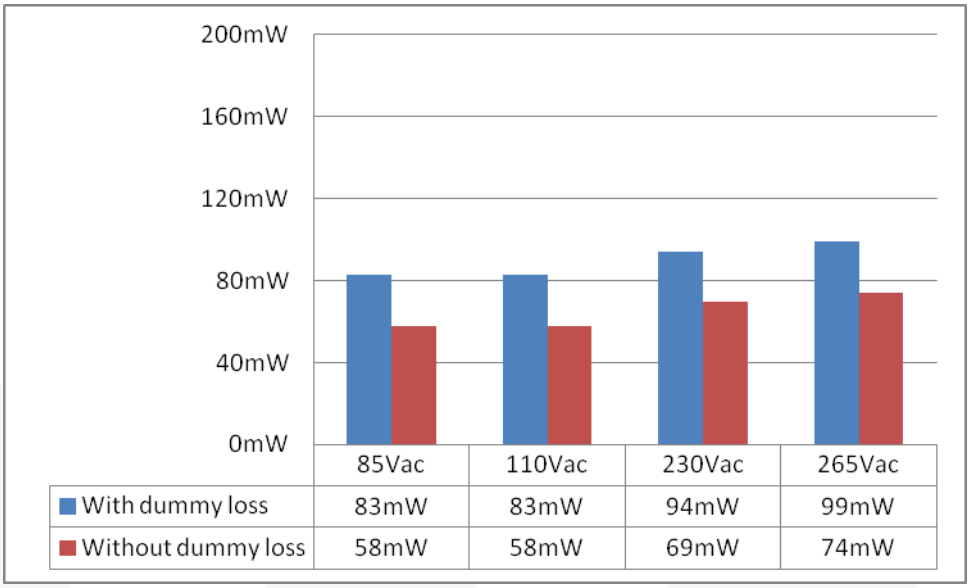


Figure 36. Efficiency vs. Output Load and Input Voltage

Table 3. Efficiency Test Result

		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%	

4.9. Standby Power Consumption



	85Vac	110Vac	230Vac	265Vac
With dummy loss	83mW	83mW	94mW	99mW
Without dummy loss	58mW	58mW	69mW	74mW

Figure 37. Standby Power Consumption at No Load Condition (Including 3.3 V Regulator Power Loss)

4.10. Conducted Electromagnetic Interference (EMI) Measurement

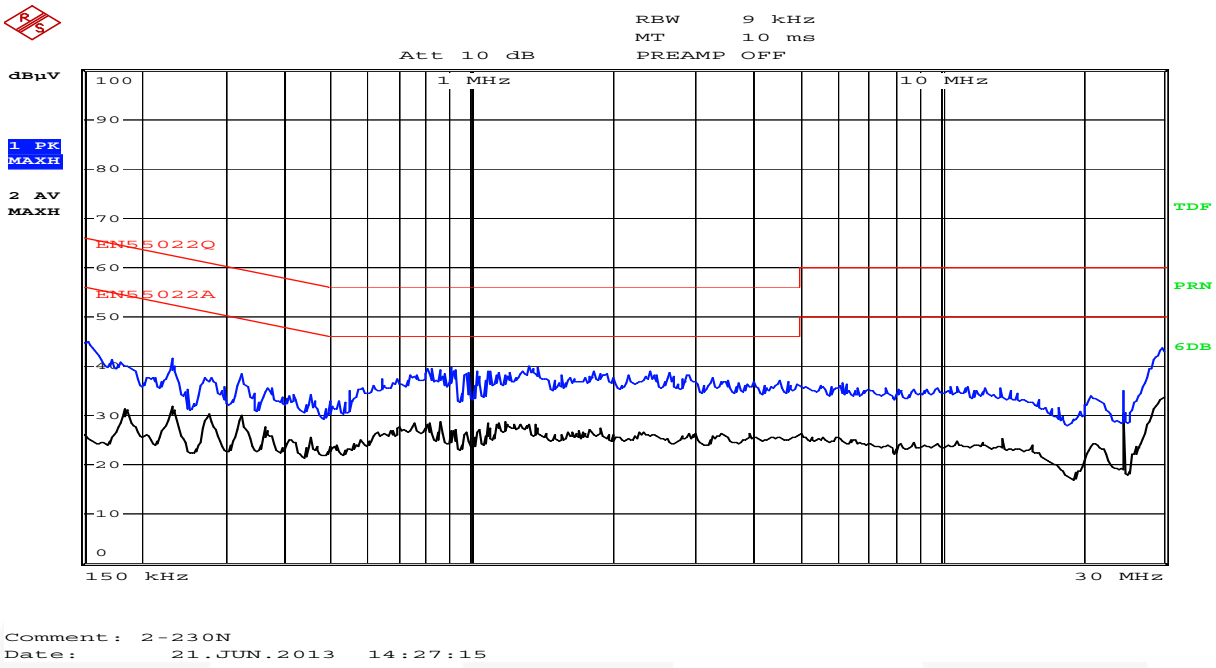


Figure 38. L at 110 V_{AC}

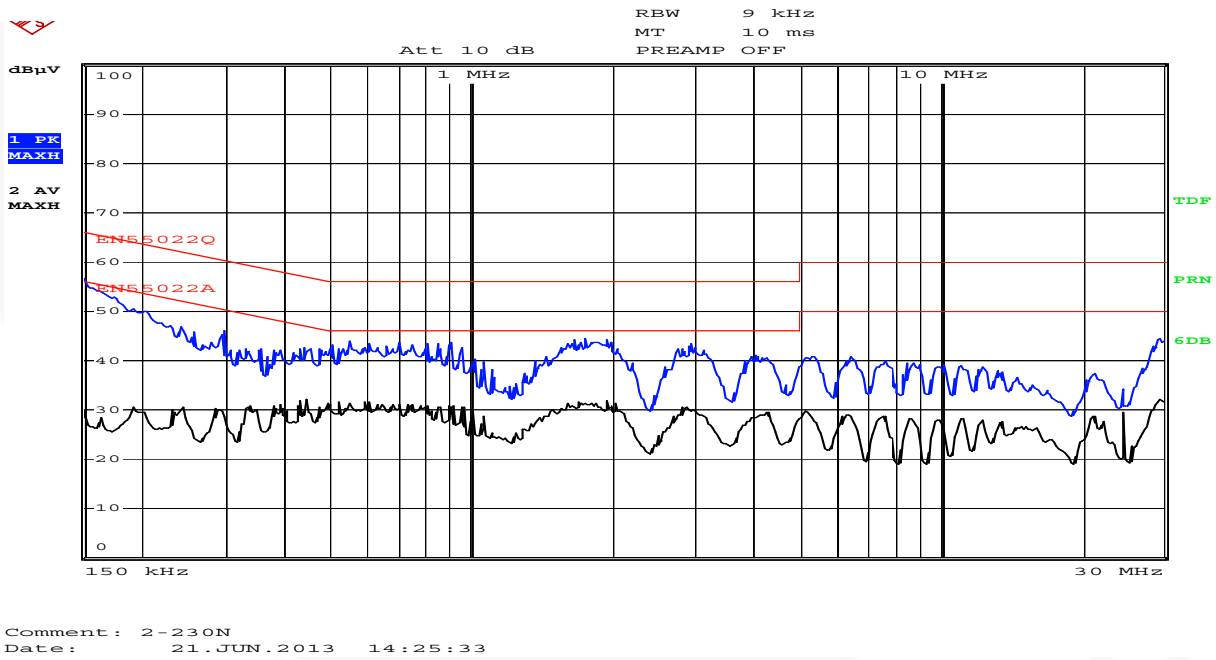


Figure 39. L at 230 V_{AC}

5. Schematics

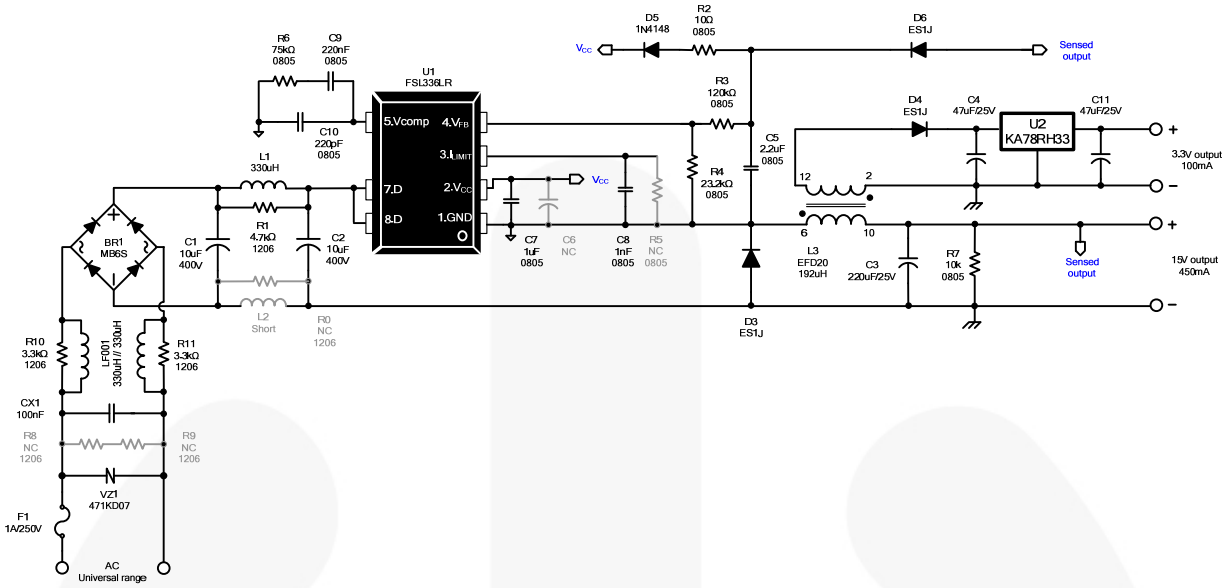


Figure 40. Schematic

6. Transformer

6.1. Specification of Flexible Transformer

Kunde / customer :
Artikelnummer / part number : 749196521 LF

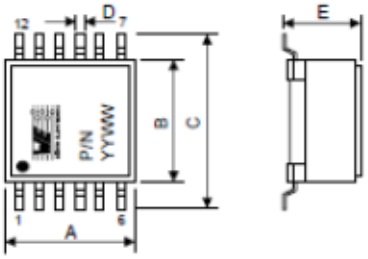
Bezeichnung : FLEX-ÜBERTRAGER WE-FLEX
description : FLEX-TRANSFORMER WE-FLEX

compliant RoHS

WÜRTH ELEKTRONIK

DATUM / DATE : 2006-08-01

A Mechanische Abmessungen / dimensions :



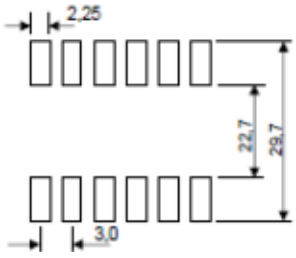
● = Marking Pin 1

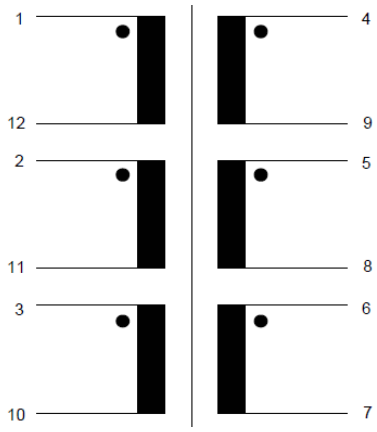
	EFD20	
A	21,0 max	mm
B	21,0 typ.	mm
C	29,5 max	mm
D	0,7 ± 0,1	mm
E	10,8 max	mm

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. :





7. Bill of Materials

Component	Qty.	Part No.	Manufacturer	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	1	749196521	3L Electronic	L3
Bridge Rectifier 0.5 A / 600 V SMA	2	MB6S	Fairchild Semiconductor	BR1
Super Fast Diode 1 A / 600 V SMA	3	ES1J	Fairchild Semiconductor	D3, D4, D6
Diode DO-35 300 mA / 100 V	1	1N4148	Fairchild Semiconductor	D5
IC Positive Voltage Regulator	1	KA78RH33	Fairchild Semiconductor	U2
IC SMPS Power Switch	1	FSL336LRN	Fairchild Semiconductor	U1
Varistor 7Φ 470 V	1	471KD07		VZ1
Radial Type 1 A / 250 V	1			F1

8. Related Resources

FSL336RN — Green Mode Fairchild Buck Switch

http://www.fairchildsemi.com/referencedesign/