

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

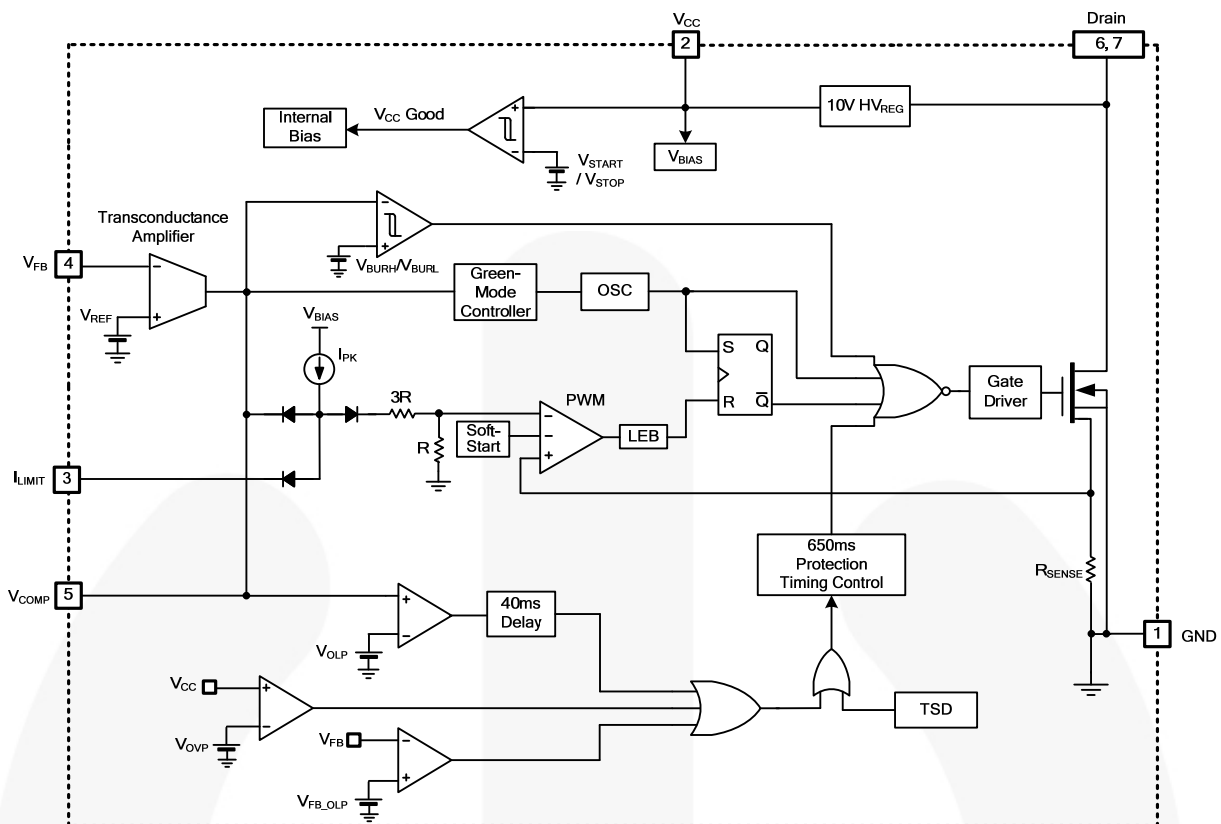


Figure 1. Internal Block Diagram

1. Photographs



Figure 2. Top View (Dimension 76 x 42 [mm²])

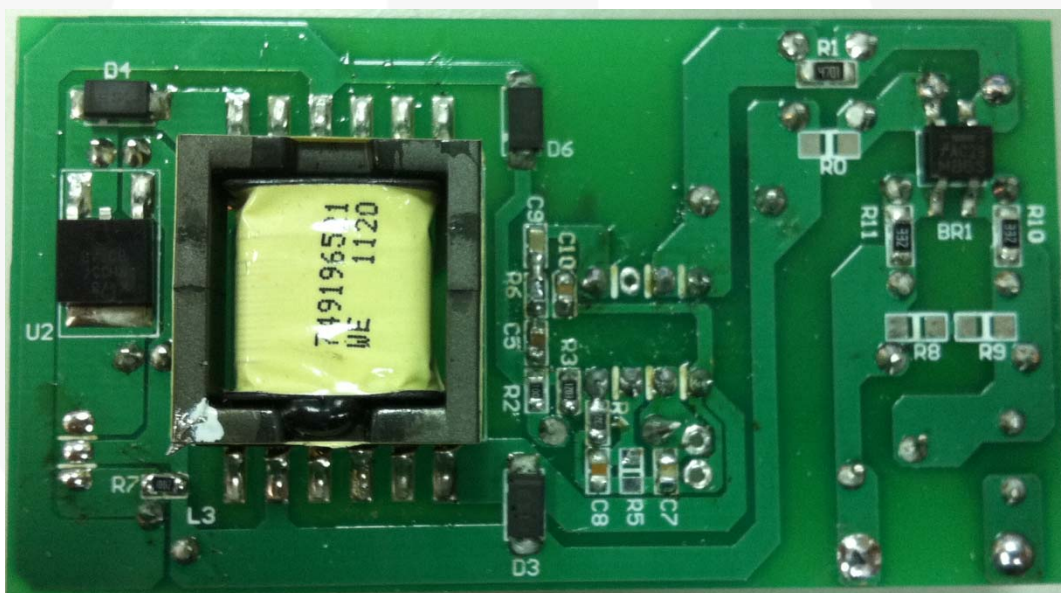
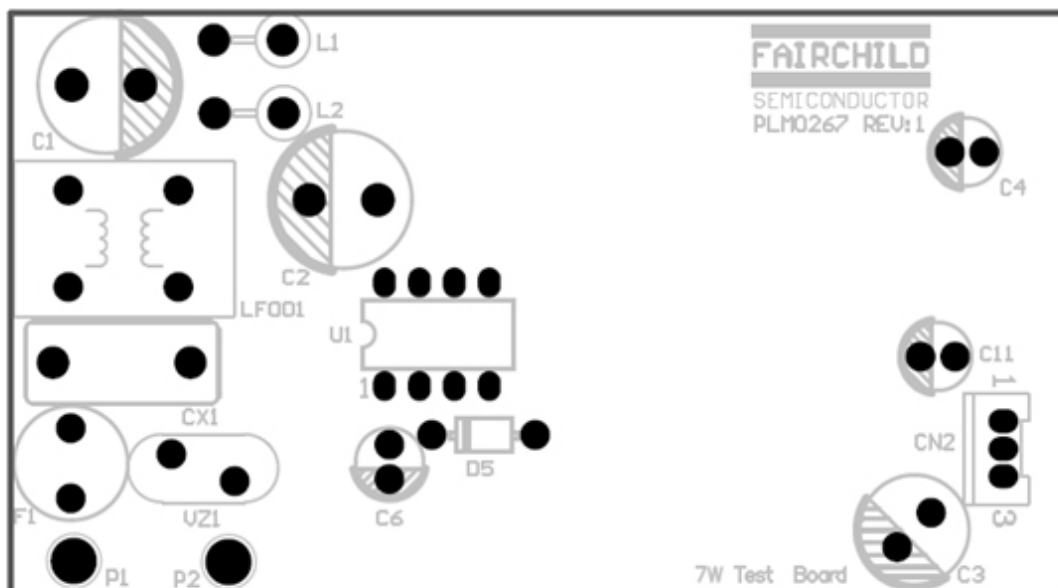


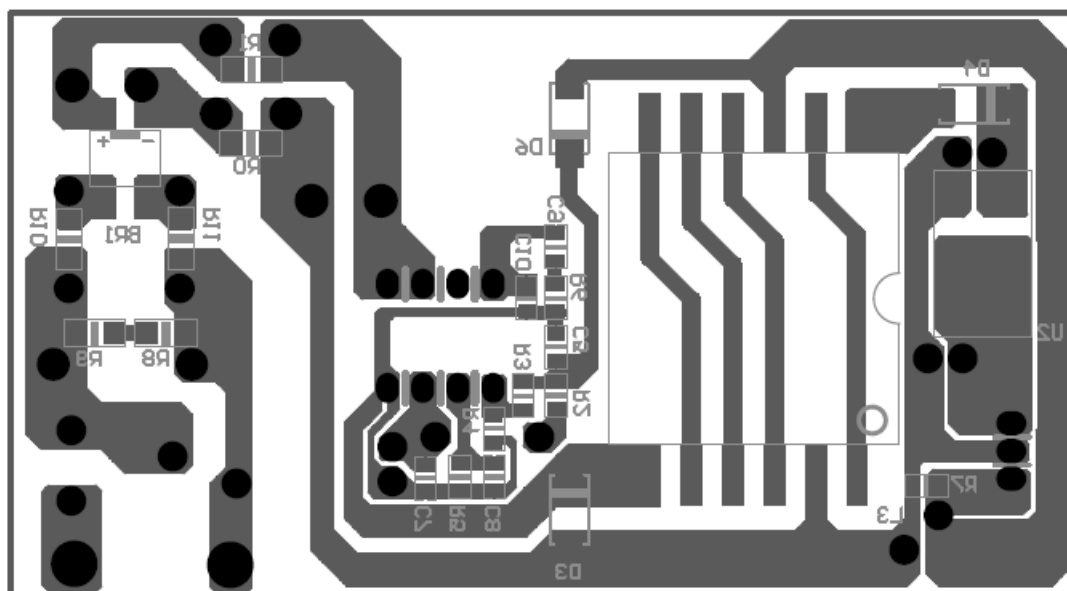
Figure 3. Bottom View (Dimension 76 x 42 [mm²])

2. Print Circuit Board (PCB) Layout



Top Overlay

Figure 4. Top 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)

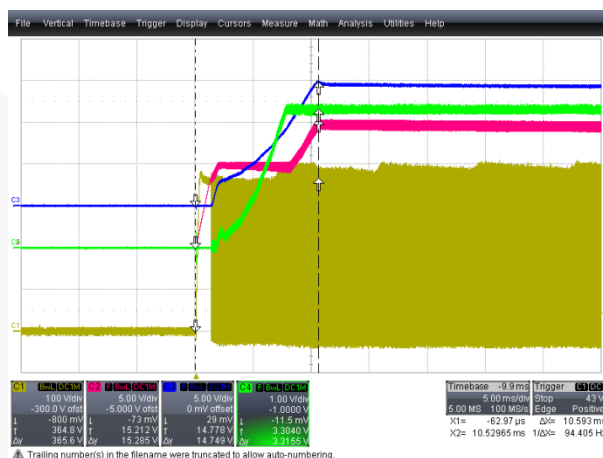


Figure 7. Startup Time=10.6 ms, 265 V_{AC}, Full-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

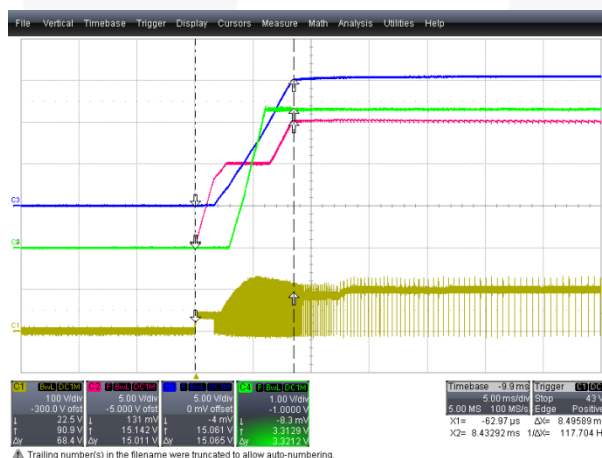


Figure 8. Startup Time=8.5 ms, 85 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

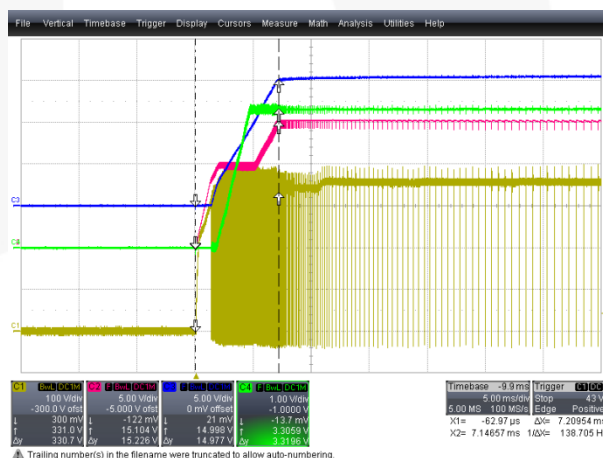


Figure 9. Startup Time=7.2 ms, 265 V_{AC}, No-Load Condition (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), CH3: 15 V_{OUT} (5V/div), CH4: 3.3 V_{OUT} (1 V/div), Time: 5 ms/div)

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)

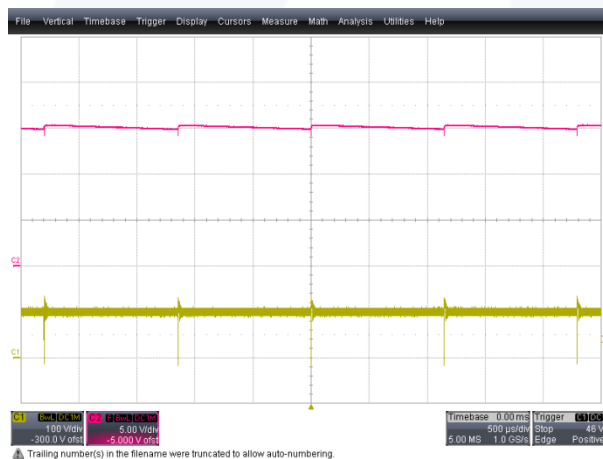


Figure 12. No-Load Condition, 85 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 μs/div)

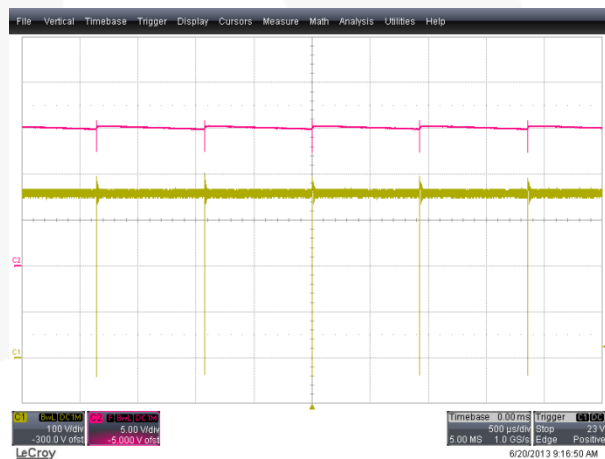


Figure 13. No-Load Condition, 265 V_{AC} (CH1: V_{DS} (100 V/div), CH2: V_{CC} (5 V/div), Time: 500 μs/div)

4.3. Voltage Stress of Drain and Freewheeling Diode

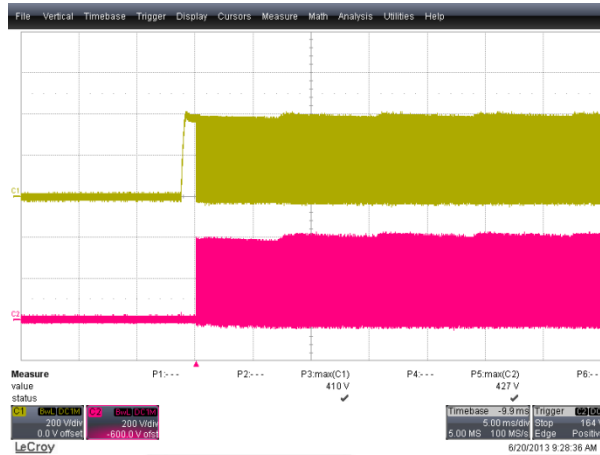


Figure 14. $V_{DS}=410 V$, $V_{DIODE}=427 V$,
Startup Condition, Full-Load Condition, 265 V_{AC} ,
(CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div),
Time: 5 ms/div)

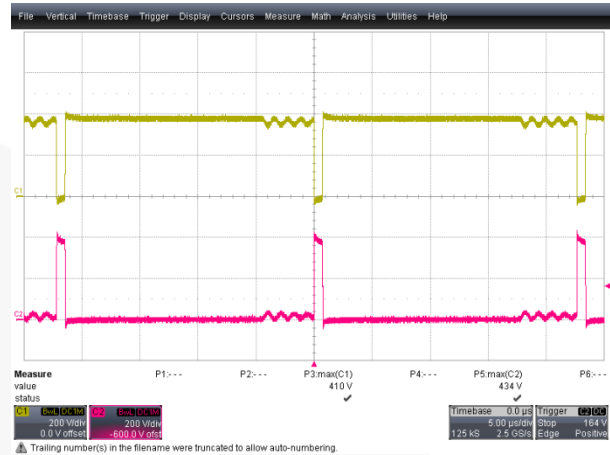


Figure 15. $V_{DS}=410 V$, $V_{DIODE}=434 V$, Steady-State,
Full-Load Condition, 265 V_{AC} , (CH1: V_{DS} (200 V/div),
CH2: V_{DIODE} (200 V/div), Time: 5 μs /div)

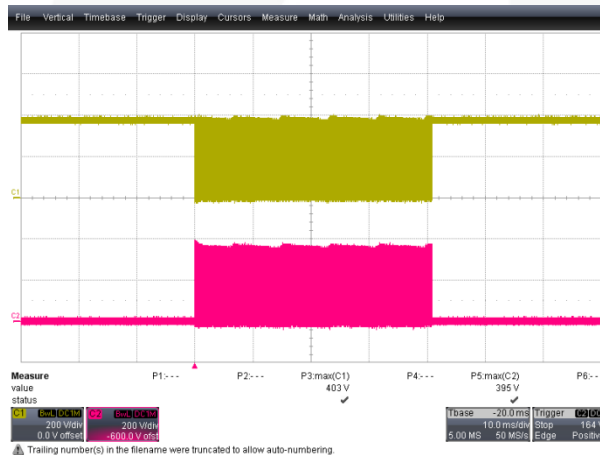


Figure 16. $V_{DS}=403 V$ & $V_{DIODE}=395 V$, 15 V Output
Short Condition, 3.3 V Full-Load Condition, 265 V_{AC} ,
(CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div),
Time: 10 ms/div)

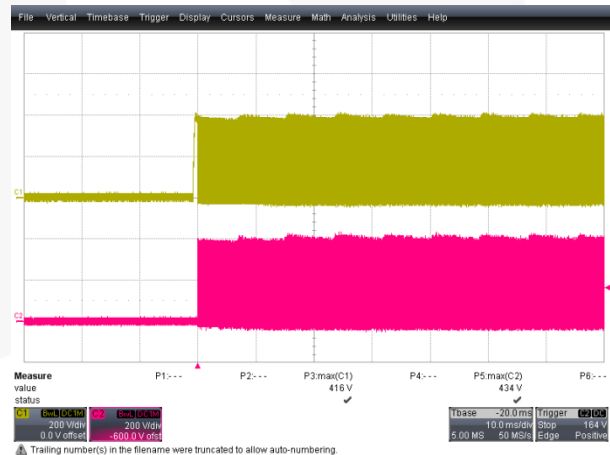


Figure 17. $V_{DS}=416 V$ & $V_{DIODE}=434 V$, 3.3 V Output
Short Condition, 15 V Full-Load Condition, 265 V_{AC} ,
(CH1: V_{DS} (200 V/div), CH2: V_{DIODE} (200 V/div),
Time: 10 ms/div)

4.4. Output Ripple and Noise

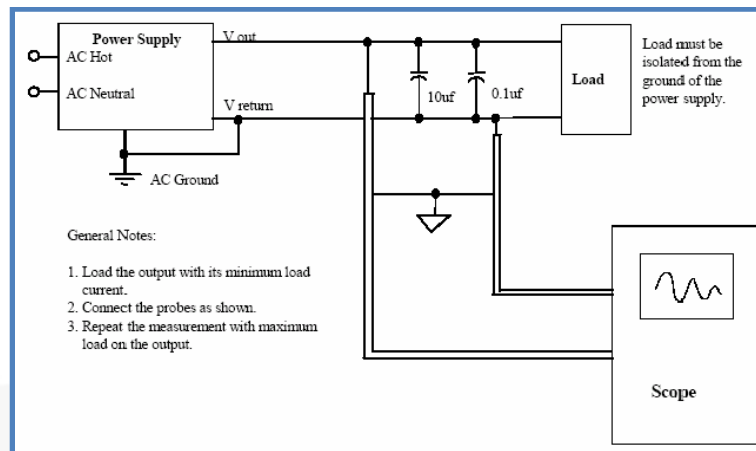


Figure 18. Recommended Test Setup

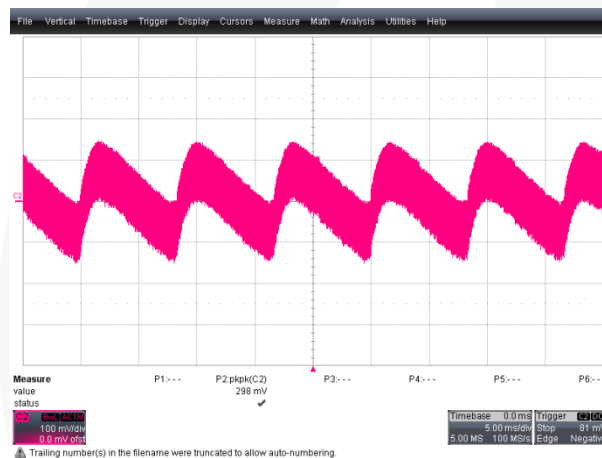


Figure 19. 15 V_{OUT_RIPPLE}=298 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

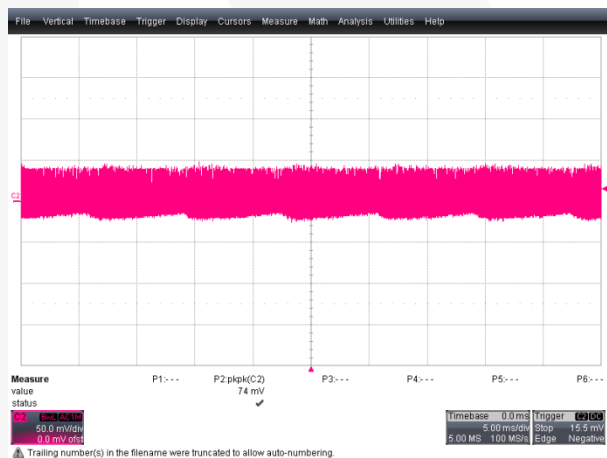


Figure 20. 3.3 V_{OUT_RIPPLE}=74 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

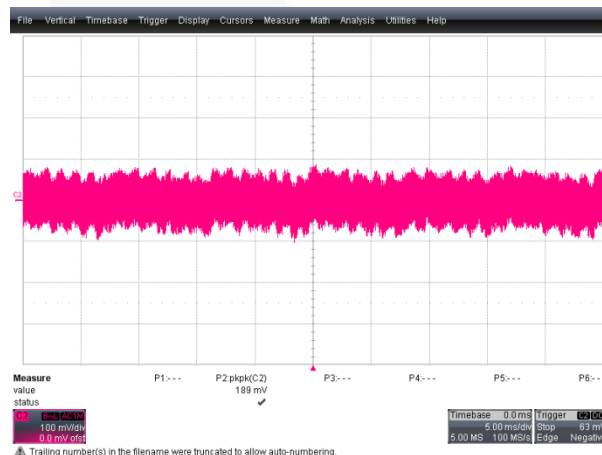


Figure 21. 15 V_{OUT_RIPPLE}=189 mV, Output with 265 V_{AC} and Full-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

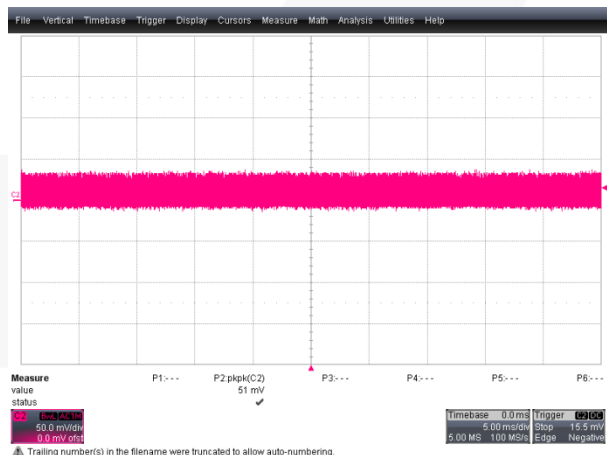


Figure 22. 3.3 V_{OUT_RIPPLE}=51 mV, Output with 85 V_{AC} and Full-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

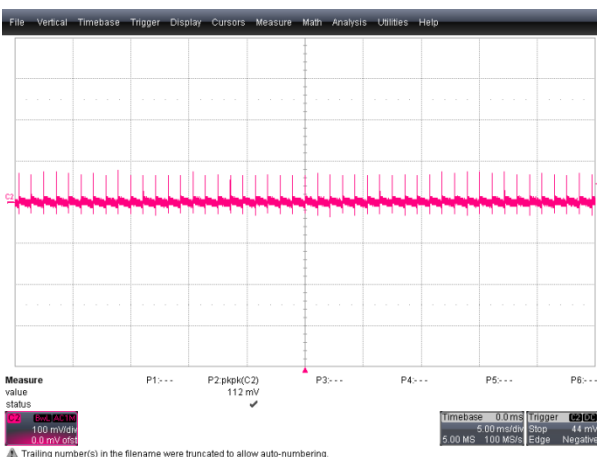


Figure 23. 15 V_{OUT_RIPPLE} =112 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

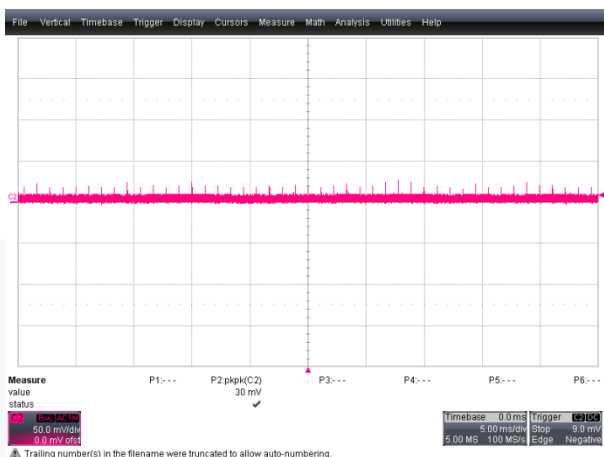


Figure 24. 3.3 V_{OUT_RIPPLE} =30 mV, Output with 85 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

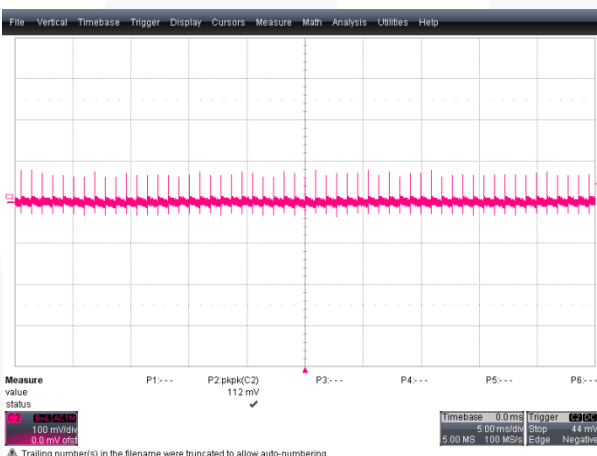


Figure 25. 15 V_{OUT_RIPPLE} =112 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 15 V_{OUT} (100 mV/div), Time: 5 ms/div

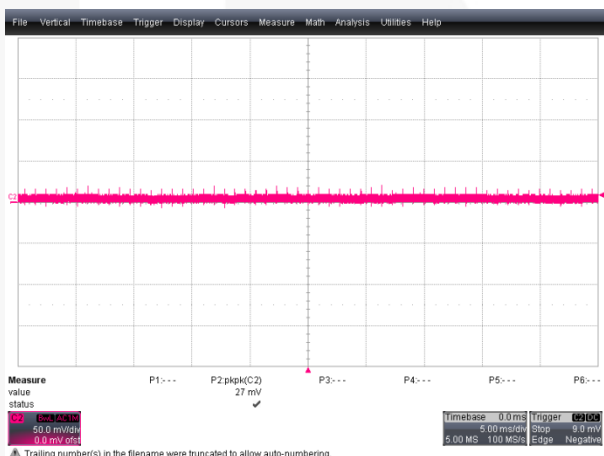


Figure 26. 3.3 V_{OUT_RIPPLE} =27 mV, Output with 265 V_{AC} and No-Load Condition, CH2: 3.3 V_{OUT} (50 mV/div), Time: 5 ms/div

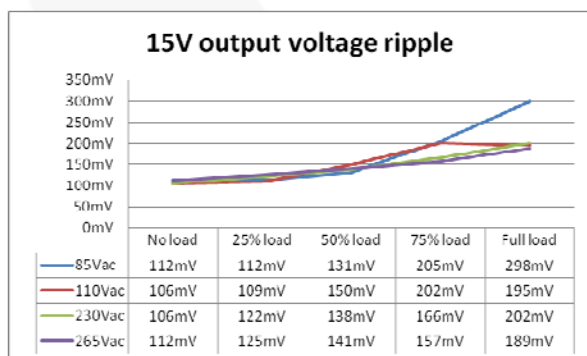


Figure 27. 12 Output Ripple

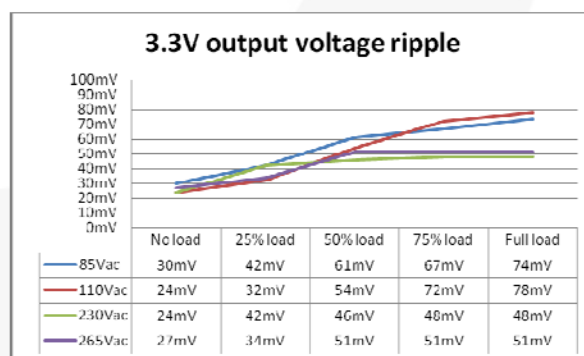


Figure 28. 5 V Output Ripple

4.5. Step Load Response

Test Slew Rate (250 mA/ μ s)

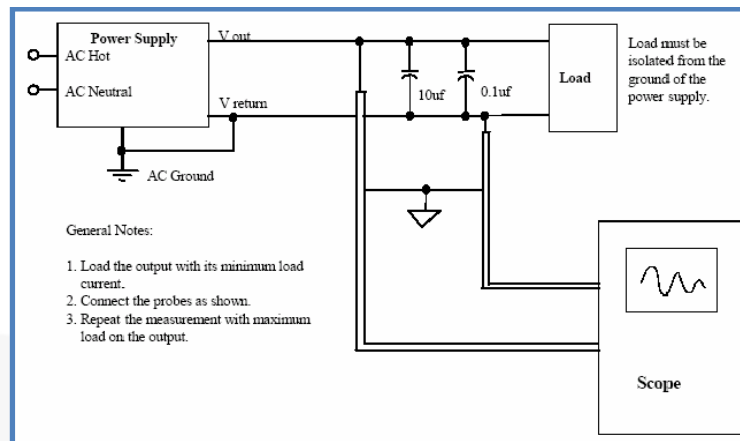


Figure 29. Recommended Test Setup

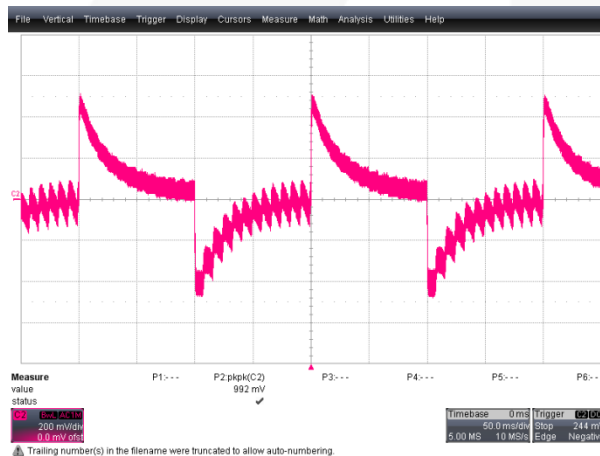


Figure 30. 15 V Output with 85 V_{AC},
80% Load ↔ 20% Load of 15 V Output
(CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

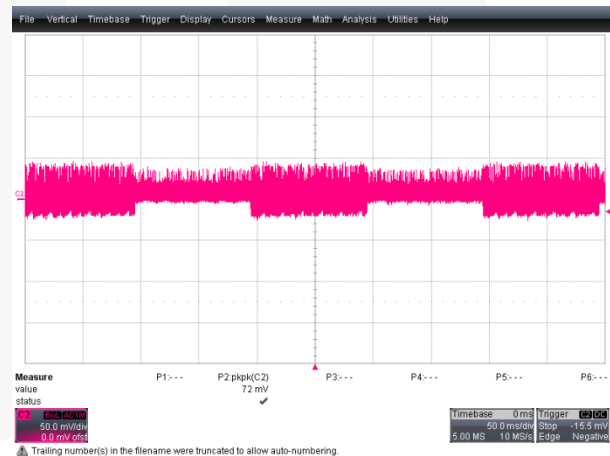


Figure 31. 3.3 V Output with 85 V_{AC},
80% Load ↔ 20% Load of 15 V Output
(CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

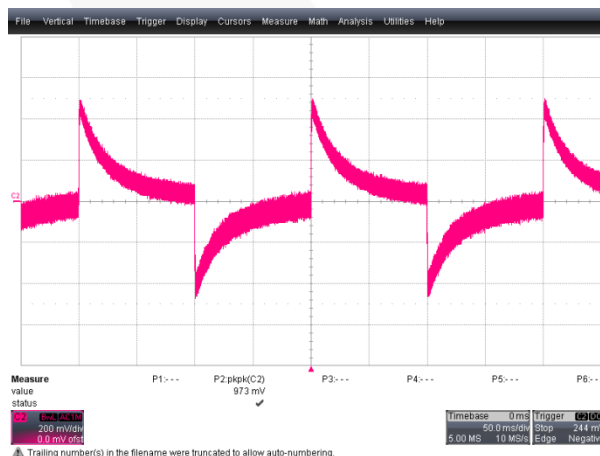


Figure 32. 15 V Output with 265 V_{AC},
80% Load ↔ 20% Load of 15 V Output
(CH2: 15 V_{OUT} (200 mV/div), Time: 50 ms/div)

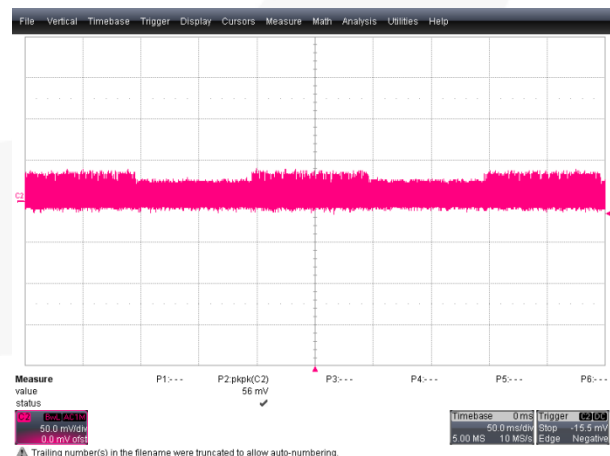


Figure 33. 3.3 V Output with 265 V_{AC},
80% Load ↔ 20% Load of 15 V Output
(CH2: 3.3 V_{OUT} (50 mV/div), Time: 50 ms/div)

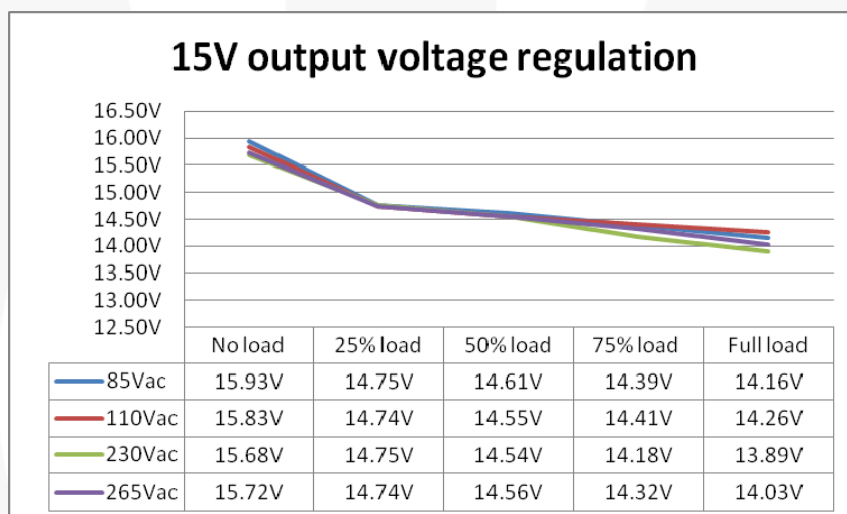
Table 1. 15 V Output Step Load Response (3.3 V Output Full Load Condition)

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

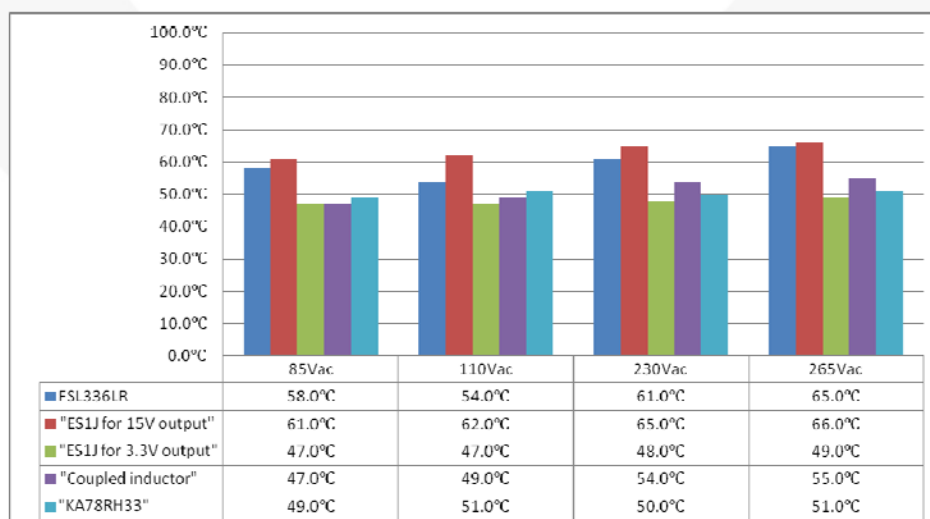
Table 2. 3.3 V Output Step Load Response (5 V Output Full Load Condition)

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

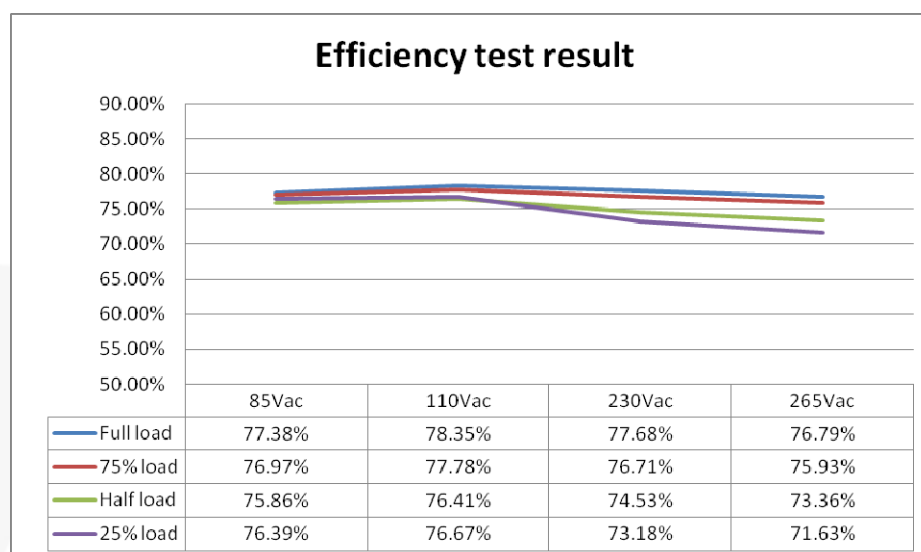


Figure 36. Efficiency vs. Output Load and Input Voltage

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

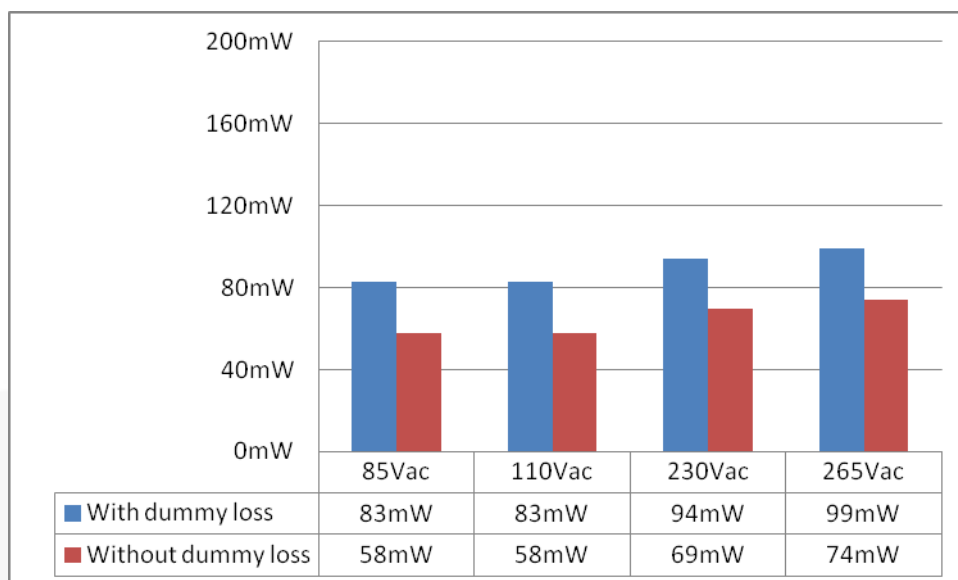
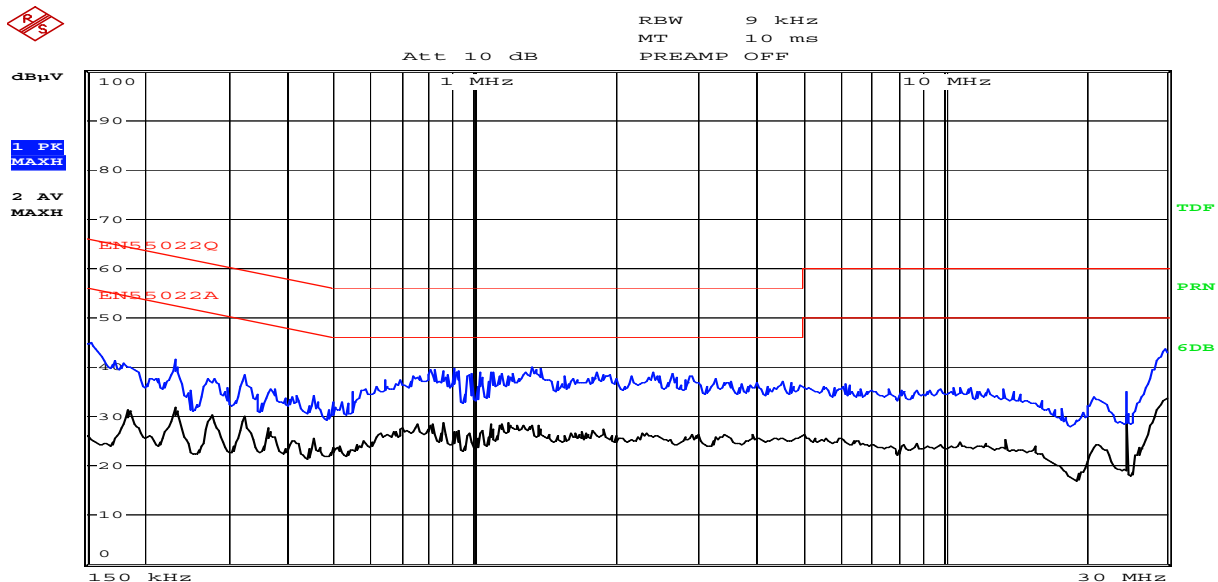


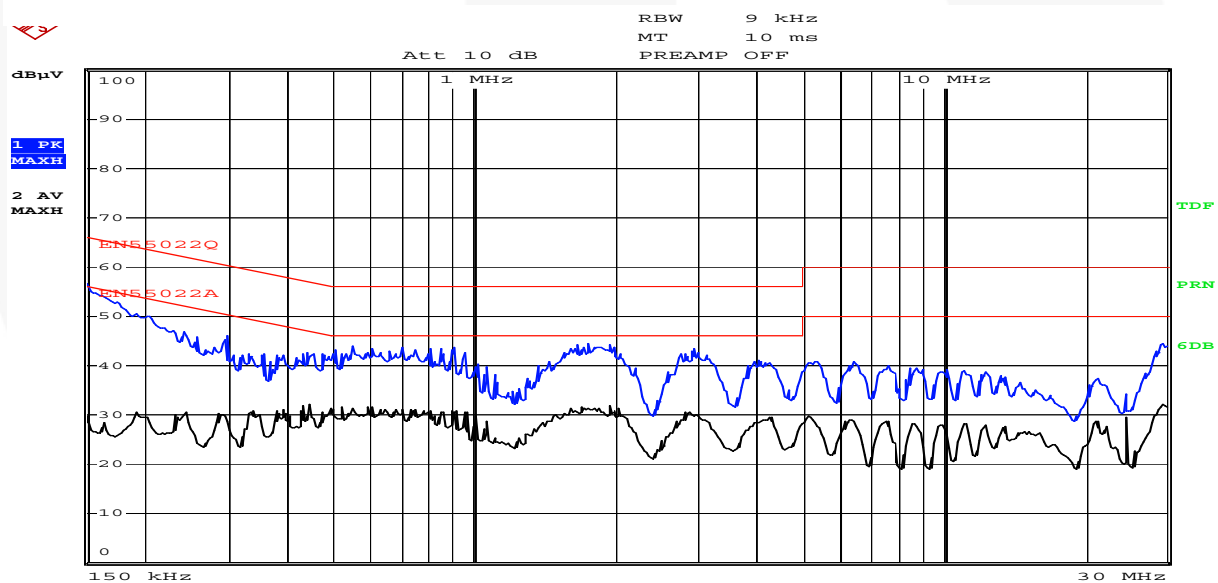
Figure 37. Standby Power Consumption at No Load Condition (Including 3.3 V Regulator Power Loss)

4.10. Conducted Electromagnetic Interference (EMI) Measurement



Comment: 2-230N
Date: 21.JUN.2013 14:27:15

Figure 38. L at 110 V_{AC}



Comment: 2-230N
Date: 21.JUN.2013 14:25:33

Figure 39. L at 230 V_{AC}

5. Schematics

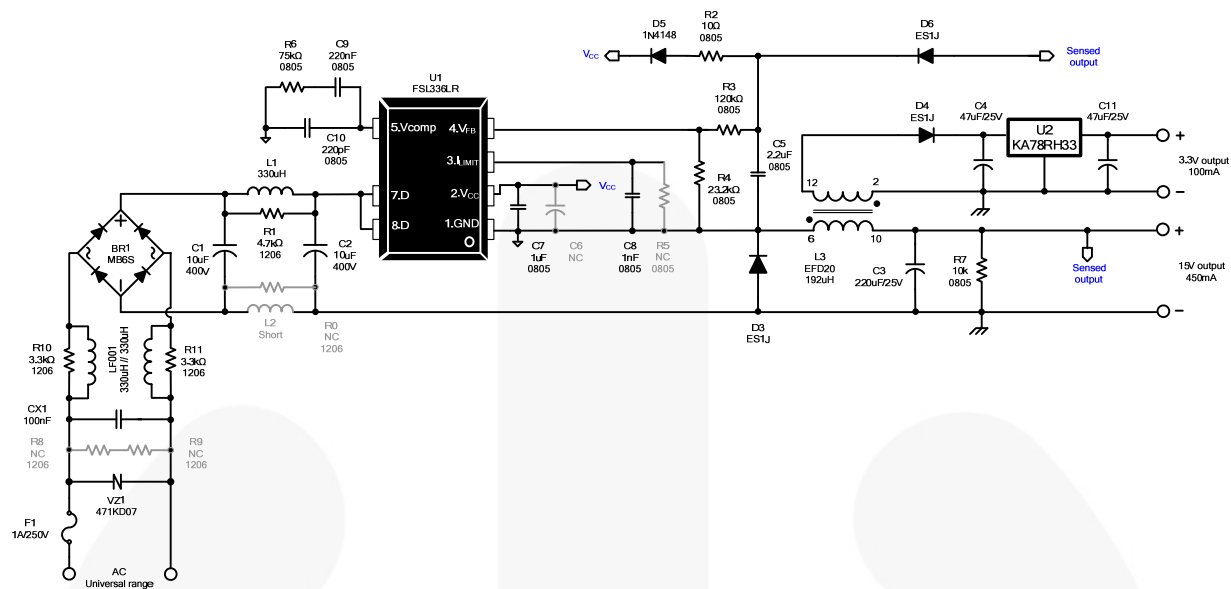


Figure 40. Schematic

6. Transformer

6.1. Specification of Flexible Transformer

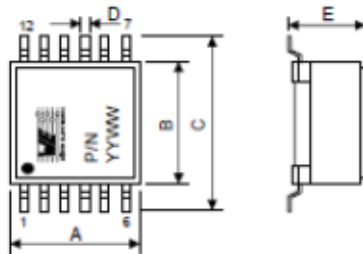
Kunde / customer :
 Artikelnummer / part number : 749196521
 Bezeichnung : FLEX-ÜBERTRAGER WE-FLEX
 description : FLEX-TRANSFORMER WE-FLEX

LF



DATUM / DATE : 2006-08-01

A Mechanische Abmessungen / dimensions :



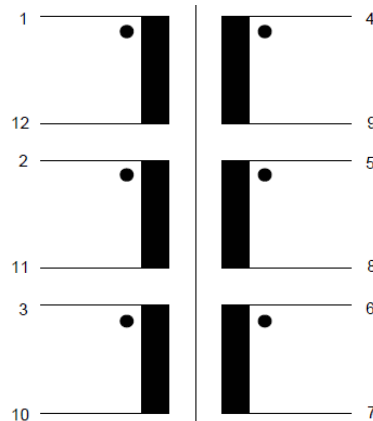
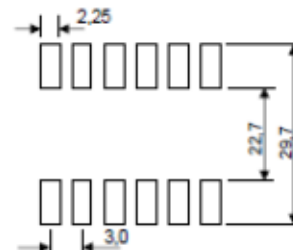
● = Marking Pin 1

	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 $\pm 5\%$	1			R2
Chip Resistor 1206 3.3 k Ω $\pm 5\%$	2			R10, R11
Chip Resistor 1206 4.7 k Ω $\pm 1\%$	1			R1
Chip Resistor 0805 10 k Ω $\pm 5\%$	1			R7
Chip Resistor 0805 23.2 k Ω $\pm 1\%$	1			R4
Chip Resistor 0805 75 k Ω $\pm 5\%$	1			R6
Chip Resistor 0805 120 k Ω $\pm 1\%$	1			R3
0805 MLCC X7R $\pm 10\%$ 221P (220 pF) 50 V	1			C10
0805 MLCC X7R $\pm 10\%$ 102P (1 nF) 50 V	1			C8
0805 MLCC X7R $\pm 10\%$ 224P (220 nF) 50 V	1			C9
0805 MLCC X7R $\pm 10\%$ 105P (1 μ F) 50 V	1			C7
0805 MLCC X7R $\pm 10\%$ 225P (2.2 μ F) 50 V	1			C5
Electrolytic Capacitor 10 μ F 400 V 105°C	2			C1, C2
Electrolytic Capacitor 47 μ F 25 V 105°C	2			C4, C11
Electrolytic Capacitor 220 μ F 25 V 105°C	1			C3
X-cap 0.1 μ F 250 V _{AC}	1			CX1
Fixed Inductor 330 μ H $\pm 10\%$	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 7 Φ 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/*](http://www.fairchildsemi.com/referencedesign/)

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