

FSL117MRIN Evaluation Board User's Manual

GENERAL BOARD DESCRIPTION

FSL117MRIN Power Switch which is utilized in the evaluation board can be applied for home appliance applications. FSL117MRIN is an integrated Pulse-Width Modulation (PWM) controller and SENSEFET[®] specifically designed for high performance off-line SMPS. In order to minimize the power consumption in stand-by mode, the start up current source supplied by JFET is turned off during normal operation and the burst operation. Furthermore, A soft burst operation reduces audible noise during stand-by mode.

The board is designed to minimize the power consumption in stand-by mode and to have high efficiency in normal mode. The power stage has single output. It is a 12 V_{OUT}.

Features of FSL117MRIN

- Advanced Burst Mode Operation for Low Stand-by Power
- Random Frequency Fluctuation for Low EMI
- Pulse-by-Pulse Current Limit
- Various Protection Functions: Overload Protection (OLP), Over-Voltage Protection (OVP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown (TSD) with Hysteresis, Output-Short Protection (OSP), Line Over-Voltage Protection (LOVP), and Under-Voltage Lock Out (UVLO) with Hysteresis
- Auto-Restart Mode
- Internal Start-up Circuit
- Internal High-Voltage SENSEFET (700 V)
- Built-in Soft Start: 15 ms



ON Semiconductor[®]

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EVAL BOARD USER'S MANUAL

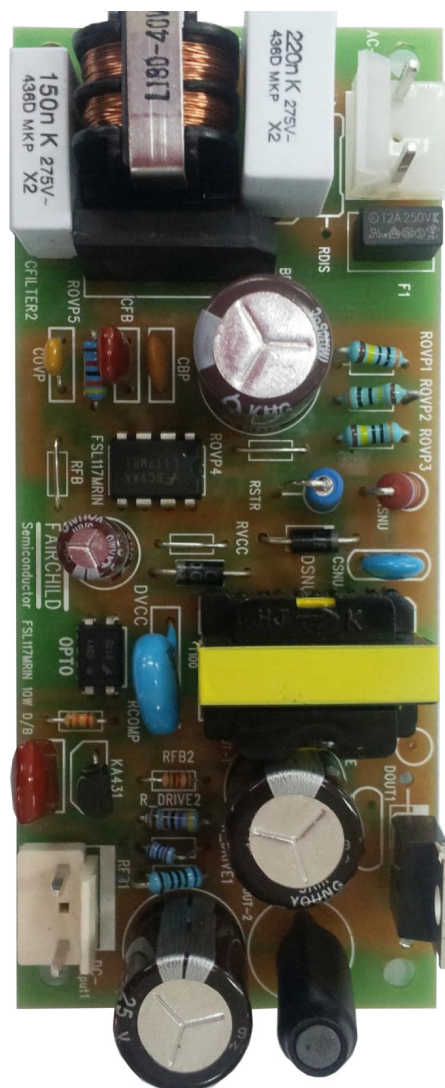


Figure 1. FSL117MRIN Evaluation Board

Block Diagram of FSL117MRIN

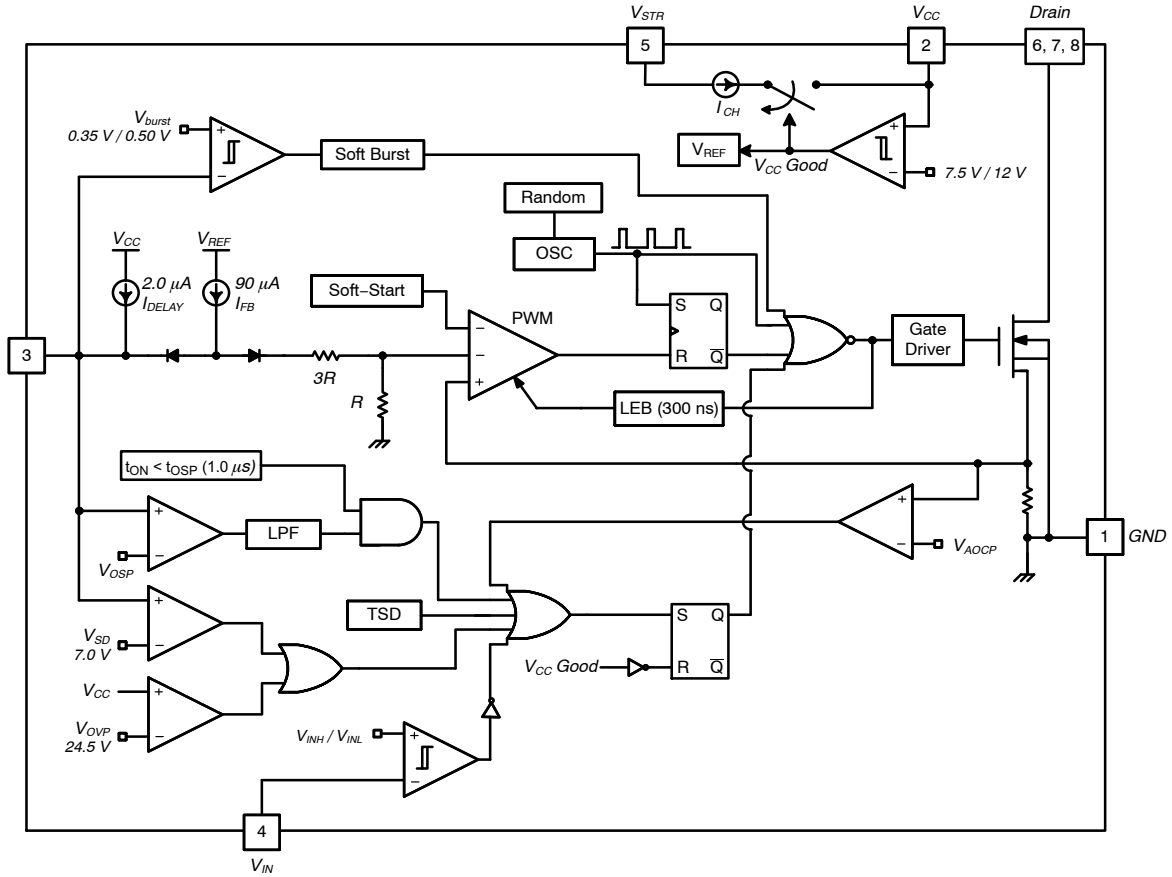


Figure 2. Block Diagram of FSL117MRIN

Input-Output Specifications of the Evaluation Board

Table 1. INPUT-OUTPUT SPECIFICATIONS

Description	Voltage	Current	Max Power
Input Voltage (V _{IN})	85~265 Vac 50~60 Hz	–	–
Output Voltage 1 (V _{OUT1})	12 Vdc	0.83 A	9.96 W (100%)
Total Output Power	–	–	9.96 W (100%)

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Summary of Performance

Table 2. SUMMARY OF PERFORMANCE

Symbol	Description	Value	Comments
$P_{IN,@0.000W}$ $P_{IN,@0.120W}$ $P_{IN,@0.240W}$ $P_{IN,@0.360W}$ $P_{IN,@0.480W}$	Stand-by Power (without discharge resistor / FSL117MRIN)	0.053 W 0.231 W 0.397 W 0.540 W 0.701 W	230 Vac input, P_{IN} was averaged for 10 minutes
η_{85Vac} η_{115Vac} η_{230Vac} η_{264Vac}	Efficiency (η) $P_{OUT} = 23.0$ W	Avg. 82.87% Avg. 84.38% Avg. 84.25% Avg. 83.53%	Average of 25, 50, 75 and 100% load (open frame, room temperature / still air)
$T_{PKG,85Vac}$ $T_{PKG,115Vac}$ $T_{PKG,230Vac}$ $T_{PKG,264Vac}$	Temperature (FSD156MRBN)	69.0°C 57.9°C 52.3°C 54.7°C	Around Drain PIN of package surface of the IC @ full load (enclosed rectangular box)

Schematic of the Evaluation Board

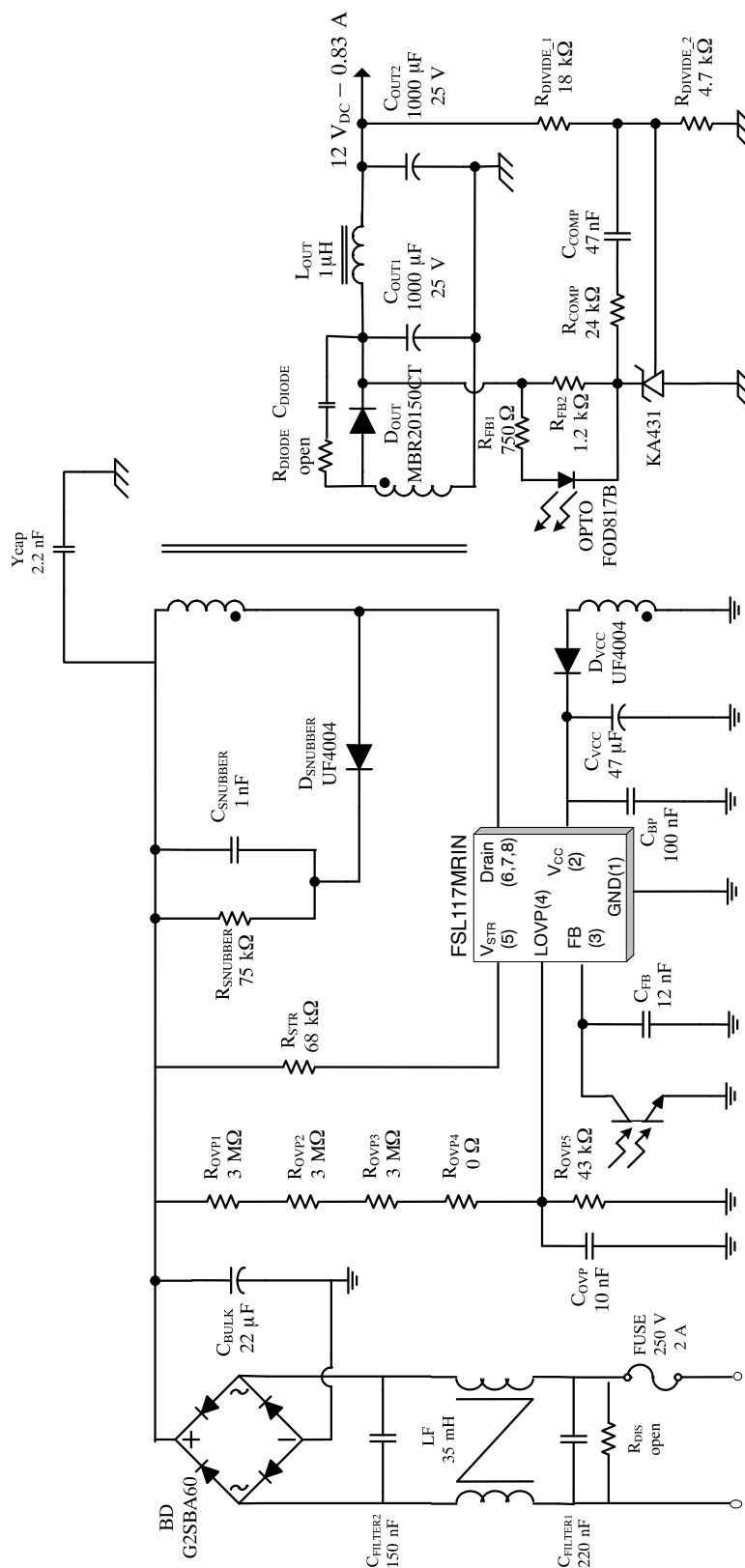


Figure 3. Schematic of the Evaluation Board

Photographs of Evaluation Board

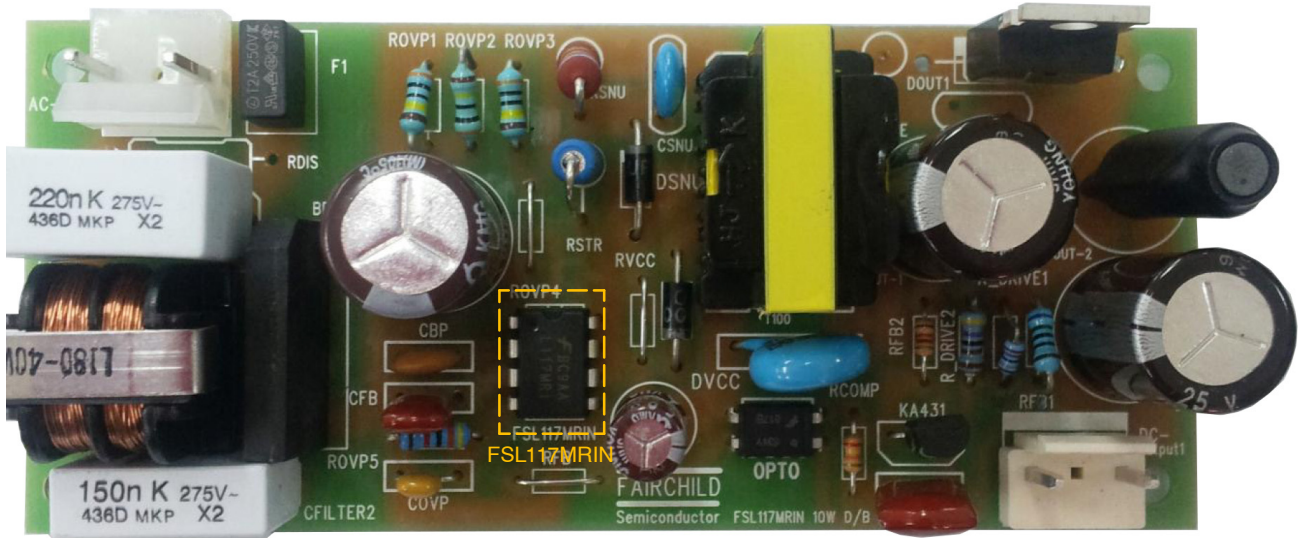


Figure 4. Top Side Photograph of the Evaluation Board

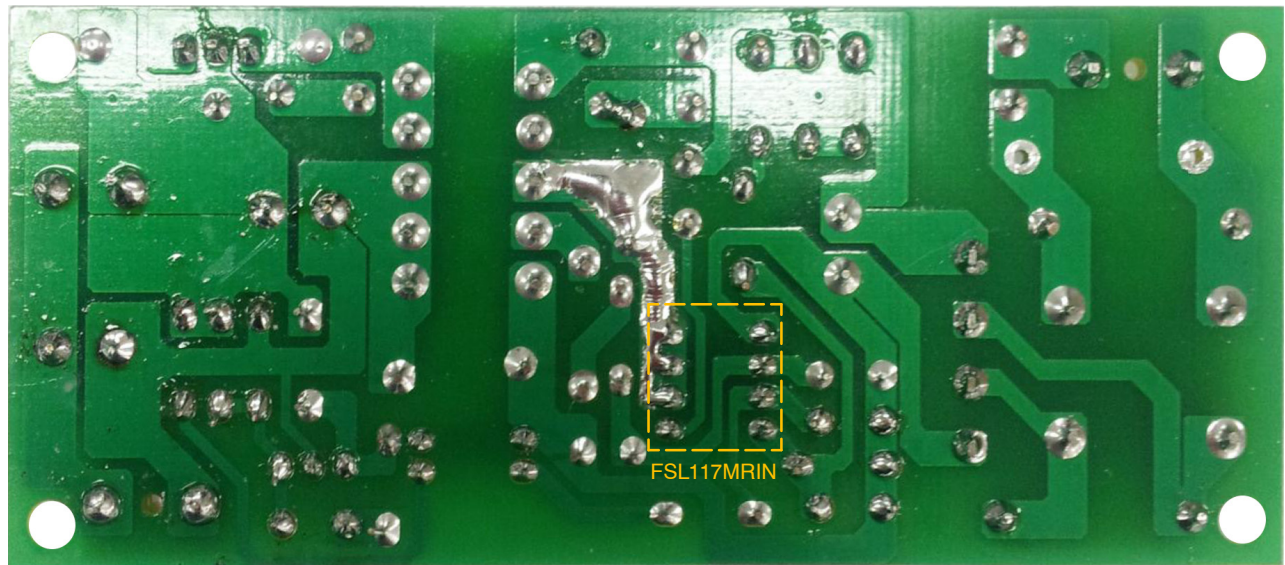


Figure 5. Bottom Side Photograph of the Evaluation Board

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Bill of Materials

The selected components for the evaluation board are shown in Table 3.

Table 3. BILL OF MATERIALS FOR EVALUATION BOARD

Part #	Value	Note	Part #	Value	Note
Fuse			Capacitor		
FUSE	250 V 2 A		CFILTER1	220 nF / 275 V	Box (Pilkor)
Resistor			CFILTER2	150 nF / 275 V	Box (Pilkor)
RDIS	open		CBULK	22 μ F / 400 V	Electrolytic (SamYoung)
ROVP1	3 M Ω	1%, 1/4 W	CSNUBBER	1 nF / 1 kV	film (sewha)
ROVP2	3 M Ω	1%, 1/4 W	CVCC	47 μ F / 50 V	Electrolytic (KMG)
ROVP3	3 M Ω	1%, 1/4 W	CFB	12 nF / 100 V	film (sewha)
ROVP4	0 Ω	Jumper	CBP	100 nF	film (sewha)
ROVP5	43 k Ω	1%, 1/4 W	COVP	10 nF	film (sewha)
RSTR	68 k Ω	1 W	COUT1	1000 μ F / 25 V	Electrolytic (SamYoung)
RSNUBBER	75 k Ω	1 W	COUT2	1000 μ F / 25 V	Electrolytic (SamYoung)
RVCC	0 Ω	Jumper	CDIODE	open	
RFB	0 Ω	Jumper	CCOMP	47 nF	film (sewha)
RDIODE	open		YCAP	2.2 nF	film (sewha)
RFB1	750 Ω	1/4 W			
RFB2	1.2 k Ω	1/4 W	Inductor		
RCOMP	24 k Ω	1/4 W	LOUT	1 μ H	
RDIVIDE1	18 k Ω	1%, 1/4 W	LF	35 mH	
RDIVIDE2	4 k Ω	1%, 1/4 W	Transformer		
IC			T101	1 mH	EE2219
SMPS	FSL117MRIN	ON Semiconductor			
SHUNT	KA431LZ	ON Semiconductor			
OPTO	FOD817B	ON Semiconductor			
Diode					
DSNUBBER	UF4004	Vishay			
DVCC	UF4004	Vishay			
DOUT	MBR20150CT	ON Semiconductor			
BD	G2SBA60	Vishay			

Transformer Specification

- Core: EE2219 ($A_e = 40.1 \text{ mm}^2$)
- Bobbin: EE2219

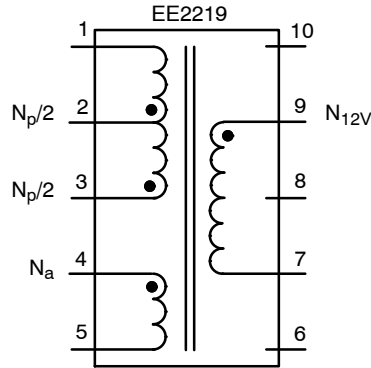


Figure 6. Transformer Specification

Table 4. WINDING SPECIFICATION

	Pin(S → F)	Wire	Turns	Winding Method	Barrier Tape		
					TOP	BOT	Ts
$N_p/2$ (BOT)	3 → 2	0.25φ x 1	34	Solenoid winding	–	–	
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							
N_{12V}	9 → 7	0.4φ x 2 (TIW)	12	Solenoid winding	–	–	
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							
N_a	4 → 5	0.2φ x 1	14	Solenoid winding		–	
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							
$N_p/2$ (TOP)	2 → 1	0.25φ x 1	33	Solenoid winding	–	–	
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							

Electrical Characteristics

Table 5. ELECTRICAL CHARACTERISTICS

	Pin	Spec	Remark
Inductance	3 → 1	1.0 mH $\pm 6\%$	67 kHz, 1 V

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PERFORMANCE DATA

Stand-by Power without AC Discharge Resistor

Table 6.

Test Condition	12 V _{OUT}
Load	0.000 A~0.040 A
Output Power	0.000 W~0.480 W

Table 7. STAND-BY POWER

FSL117MRIN			Pin (W)			
Vo (V)	Io (A)	Po (W)	85 Vac	115 Vac	230 Vac	265 Vac
12	0.000	0.000	0.037	0.039	0.053	0.059
12	0.005	0.060	0.141	0.143	0.164	0.172
12	0.010	0.120	0.205	0.207	0.231	0.239
12	0.015	0.180	0.284	0.287	0.316	0.326
12	0.020	0.240	0.362	0.365	0.397	0.410
12	0.025	0.300	0.438	0.443	0.477	0.491
12	0.030	0.360	0.497	0.503	0.540	0.555
12	0.035	0.420	0.575	0.581	0.622	0.638
12	0.040	0.480	0.650	0.657	0.701	0.719

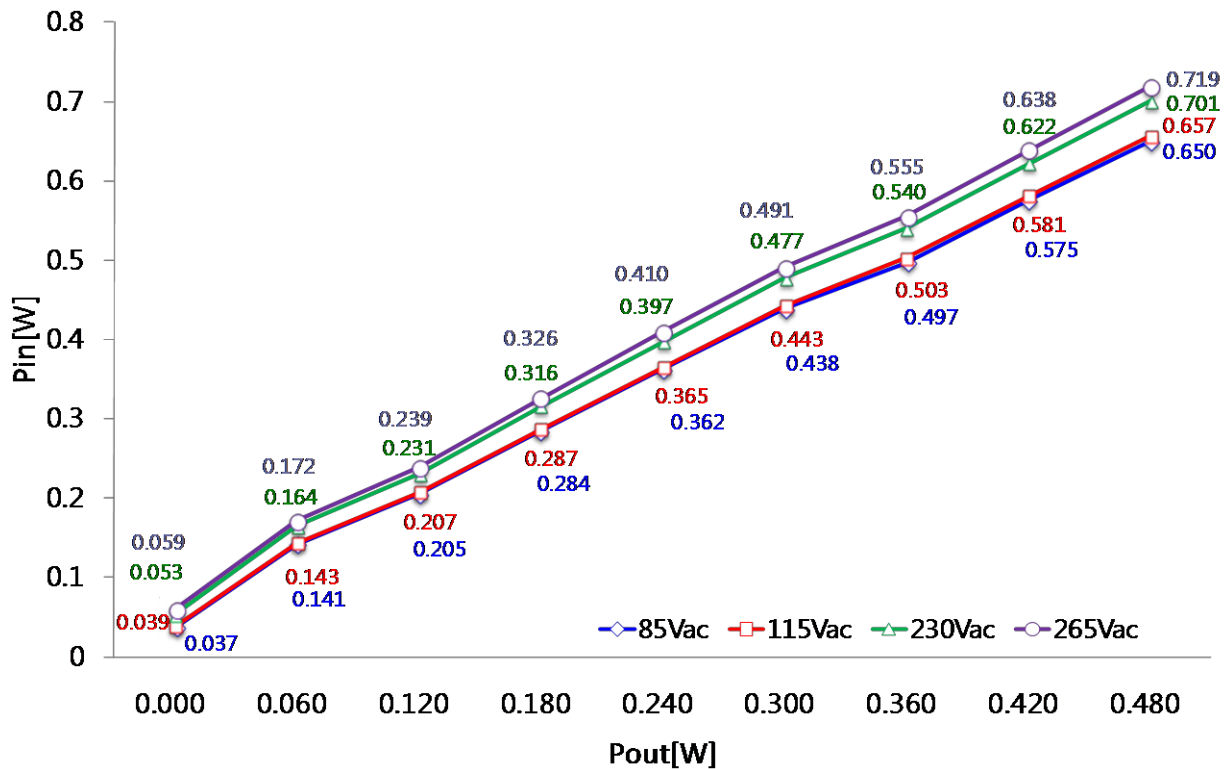


Figure 7. Graph of Standby Power

NOTE: Test results (P_{IN}) were averaged for 10 minutes at each load

Efficiency

Table 8.

Test Condition	12 V _{OUT}
Load	0.083 A~0.83 A
Output Power	0.99 W~9.96 W

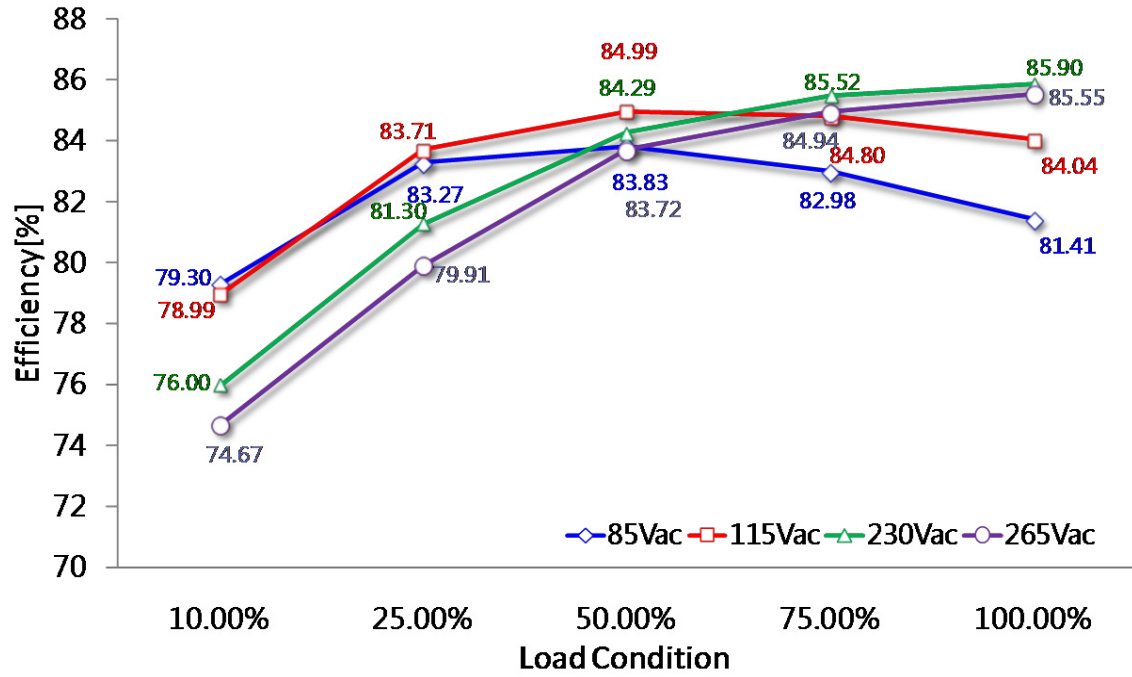


Figure 8. Graph of Efficiency

Table 9. EFFICIENCY OF THE EVALUATION BOARD

Vin	12.0 V		Pout [W]	Pin [W]	Efficiency [%]	Load
	Iout [A]	Vout [V]				
85 Vac	0.083	12.010	1.00	1.26	79.30	10.00%
	0.209	12.010	2.51	3.01	83.27	25.00%
	0.414	12.000	4.97	5.93	83.83	50.00%
	0.620	12.000	7.44	8.97	82.98	75.00%
	0.827	11.990	9.92	12.18	81.41	100.00%
Average (25, 50, 75, 100%)					82.87	
115 Vac	0.083	12.010	1.00	1.26	78.99	10.00%
	0.209	12.010	2.51	3.00	83.71	25.00%
	0.414	12.000	4.97	5.85	84.99	50.00%
	0.620	12.000	7.44	8.77	84.80	75.00%
	0.827	11.990	9.92	11.80	84.04	100.00%
Average (25, 50, 75, 100%)					84.38	
230 Vac	0.083	12.010	1.00	1.31	76.00	10.00%
	0.209	12.010	2.51	3.09	81.30	25.00%
	0.414	12.000	4.97	5.89	84.29	50.00%
	0.620	12.000	7.44	8.70	85.52	75.00%
	0.827	11.990	9.92	11.54	85.90	100.00%
Average (25, 50, 75, 100%)					84.25	
265 Vac	0.083	12.010	1.00	1.34	74.67	10.00%
	0.209	12.010	2.51	3.14	79.91	25.00%
	0.414	12.000	4.97	5.93	83.72	50.00%
	0.620	11.990	7.43	8.75	84.94	75.00%
	0.827	11.990	9.92	11.59	85.55	100.00%
Average (25, 50, 75, 100%)					83.53	

EMI Test Result

EMI Test Result at $V_{IN} = 220\text{ Vac}$

Table 10.

Test Condition	12 V _{OUT}
Load	0.8 A
Output Power	9.6 W

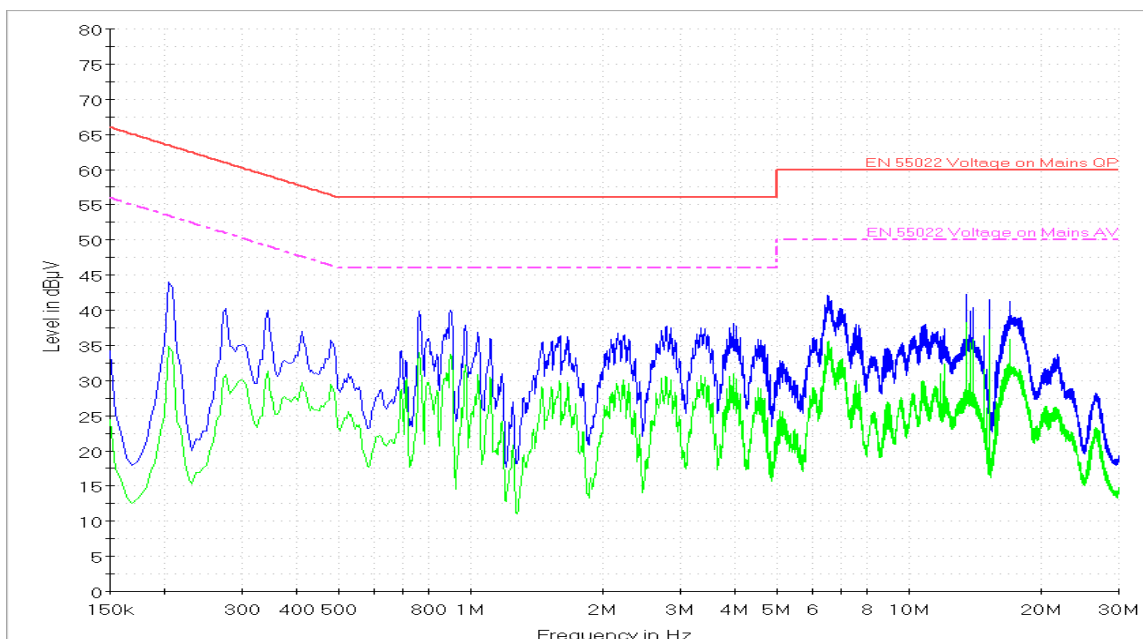


Figure 9. EMI Test Result @ $V_{IN} = 220\text{ Vac}$ & Full Load

EMI Test Result at $V_{IN} = 110\text{ Vac}$

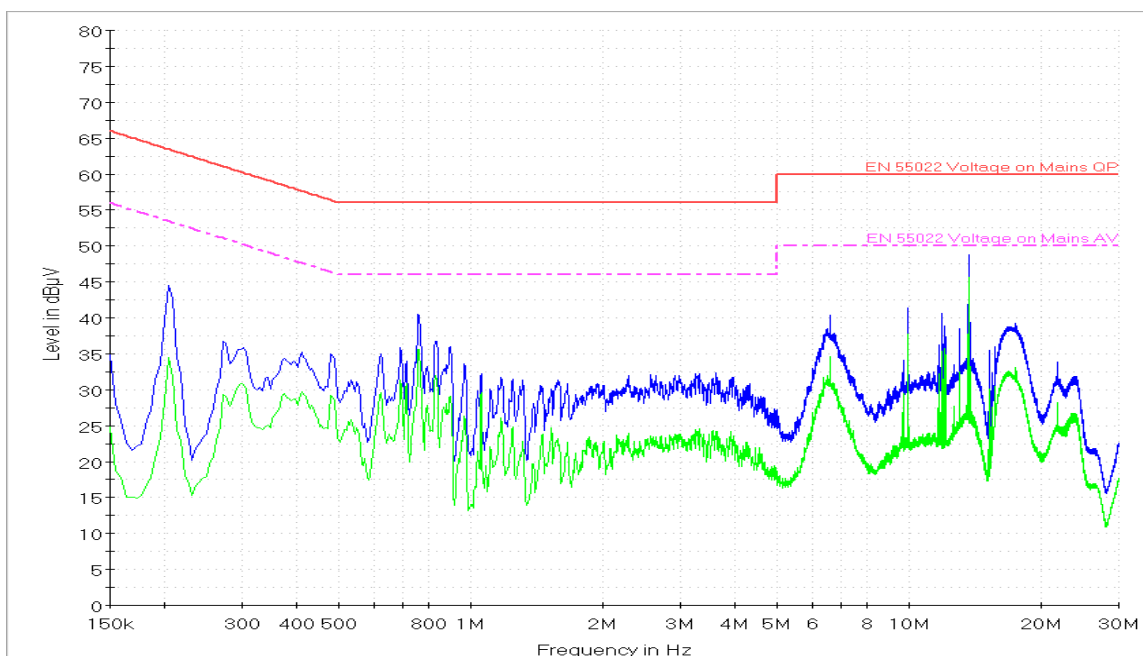


Figure 10. EMI Test Result @ $V_{IN} = 110\text{ Vac}$ & Full Load

Thermal Characteristics

Table 11.

Test Condition	12 V _{OUT}
Load	0.83 A
Output Power	9.96 W

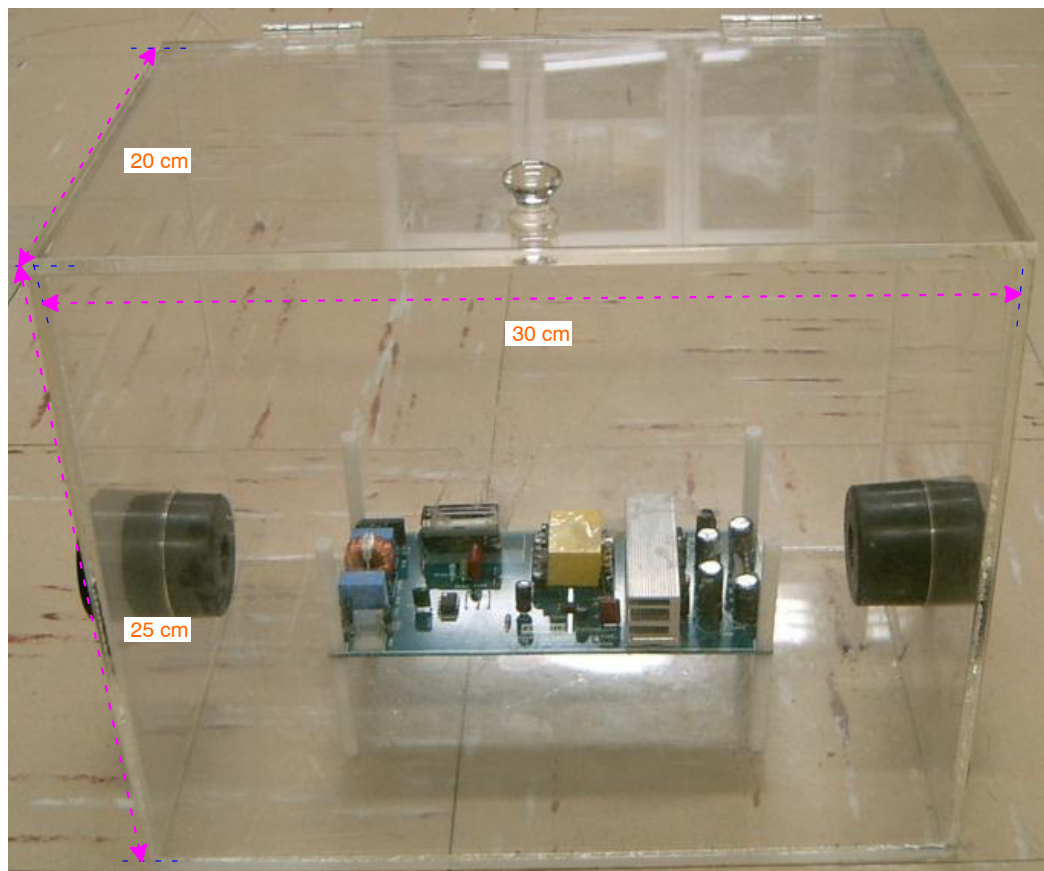


Figure 11. Rectangular Box

NOTE: Temperature of each component was measured in the rectangular box (Fig. 11)

Temperature Measurement

Table 12. THERMAL CHARACTERISTICS OF THE EVALUATION BOARD

Input Voltage	IC	Transformer	12 V Diode
85 Vac	69.0°C	44.5°C	55.1°C
115 Vac	57.9°C	44.7°C	55.4°C
230 Vac	52.3°C	46.2°C	55.7°C
265 Vac	54.7°C	47.1°C	55.5°C

Thermal Cam at $V_{IN} = 265$ Vac, Full Load

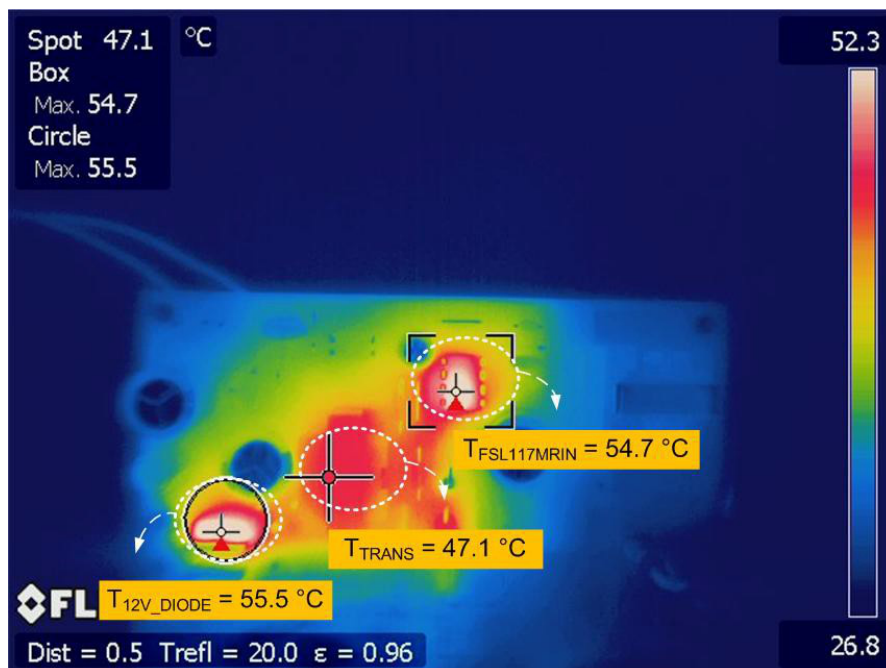


Figure 12. Thermal Cam @ $V_{IN} = 265$ Vac & Full Load

Thermal Cam at $V_{IN} = 230$ Vac, Full Load

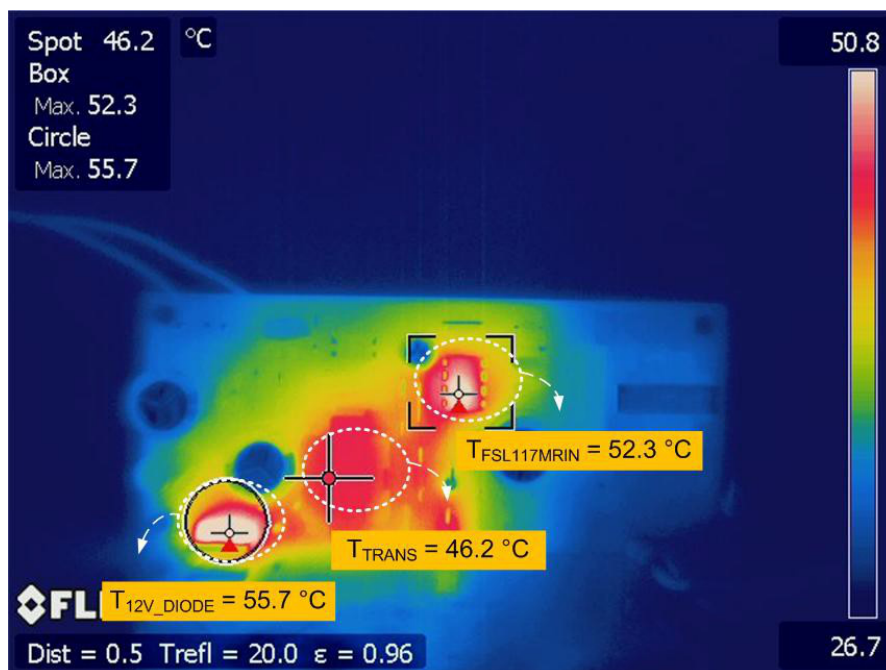


Figure 13. Thermal Cam @ $V_{IN} = 230$ Vac & Full Load

Thermal Cam at $V_{IN} = 115$ Vac, Full Load

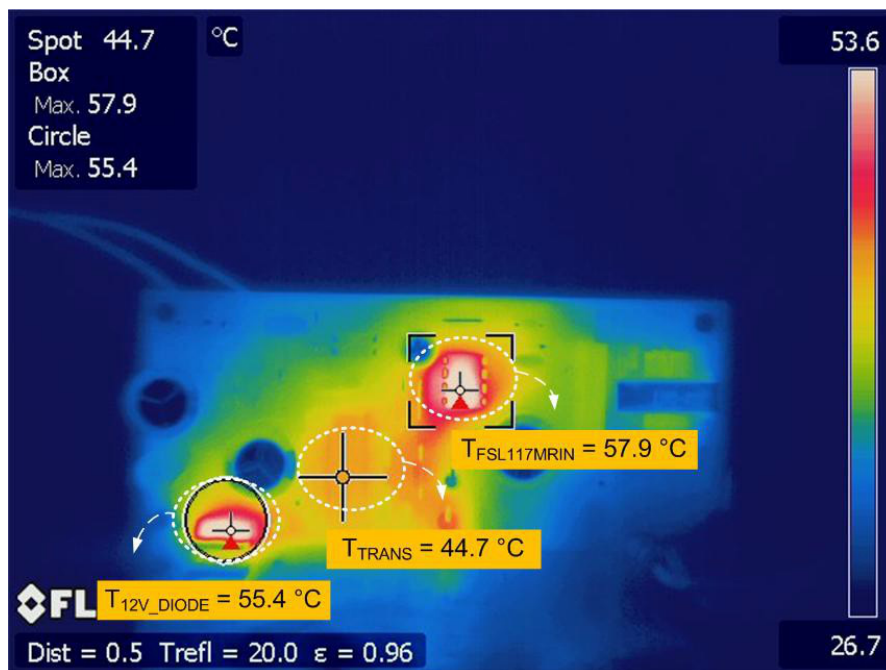


Figure 14. Thermal Cam @ $V_{IN} = 115$ Vac & Full Load

Thermal Cam at $V_{IN} = 85$ Vac, Full Load

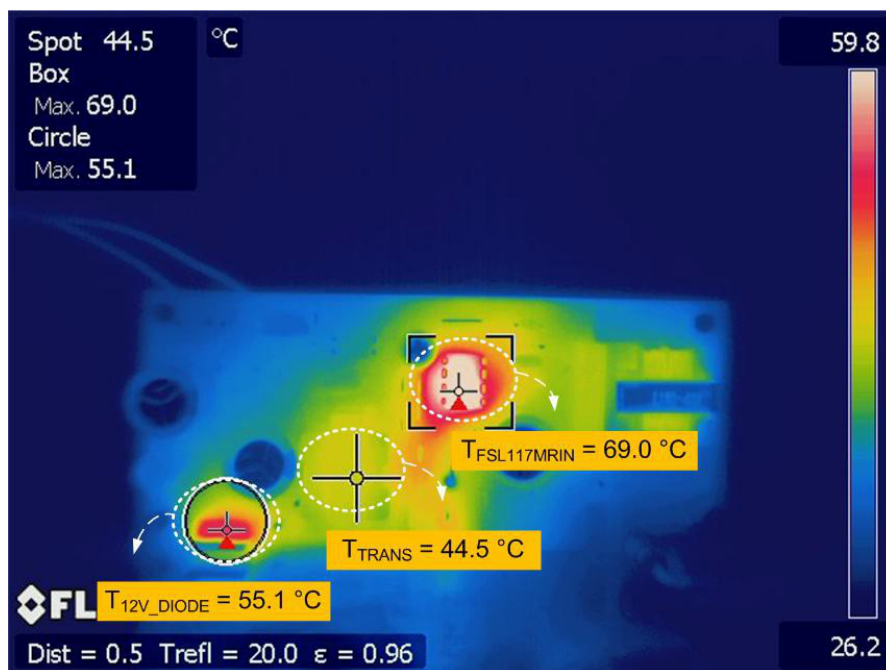


Figure 15. Thermal Cam @ $V_{IN} = 85$ Vac & Full Load

WAVEFORMS

Soft-Start

Table 13.

Test Condition	12 V _{OUT}
Load	0.83 A
Output Power	9.96 W

Soft-Start at $V_{IN} = 85$ Vac, Full Load

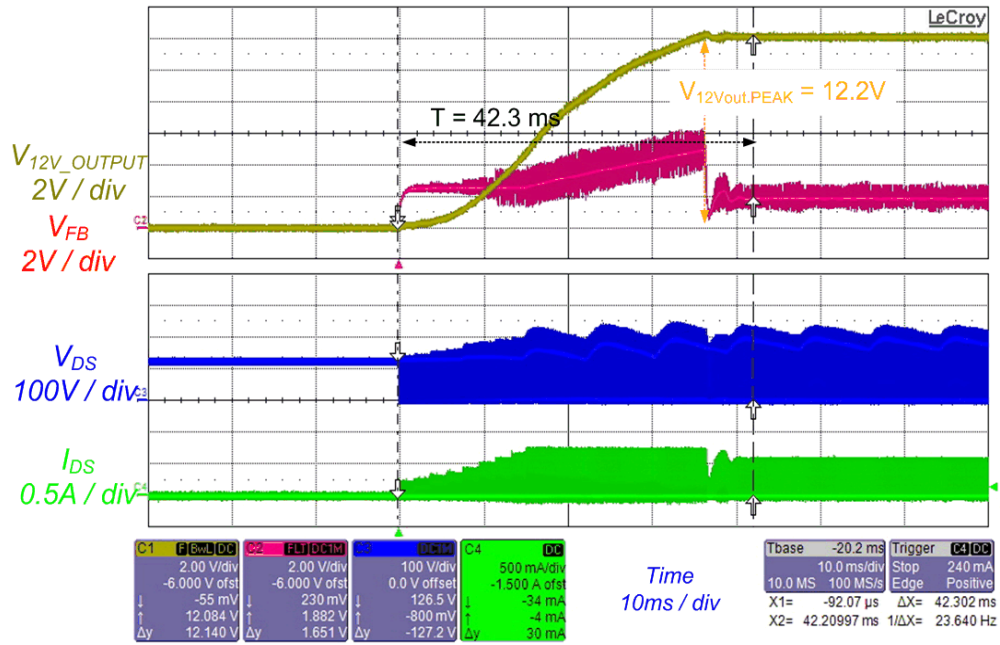


Figure 16. Soft-Start Waveforms @ $V_{IN} = 85$ Vac & Full Load

Soft-Start at $V_{IN} = 90$ Vac, No Load

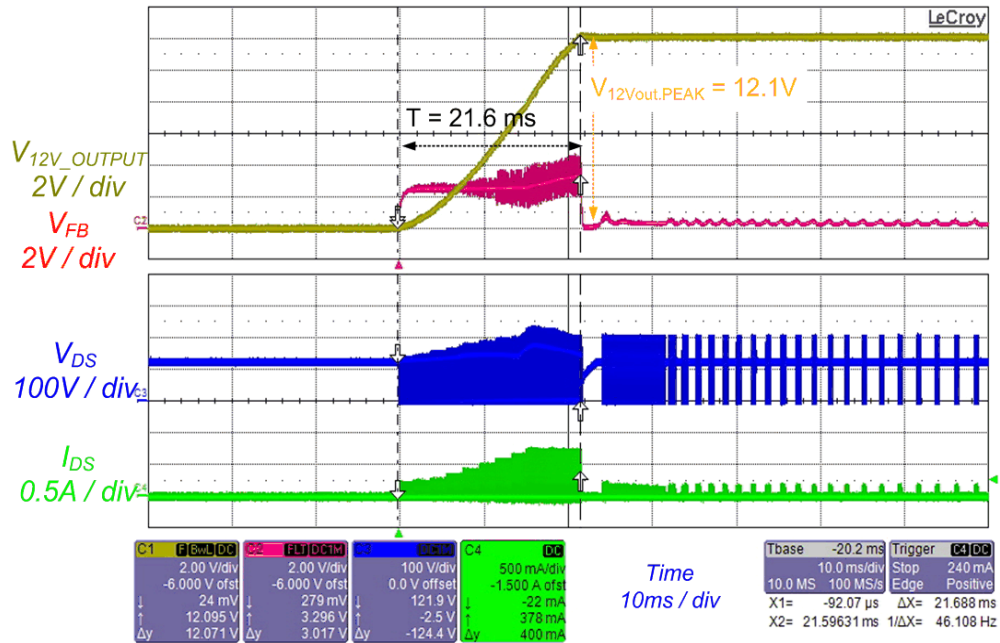


Figure 17. Soft-Start Waveforms @ $V_{IN} = 85$ Vac & No Load

Soft-Start at $V_{IN} = 265 \text{ Vac}$, Full Load

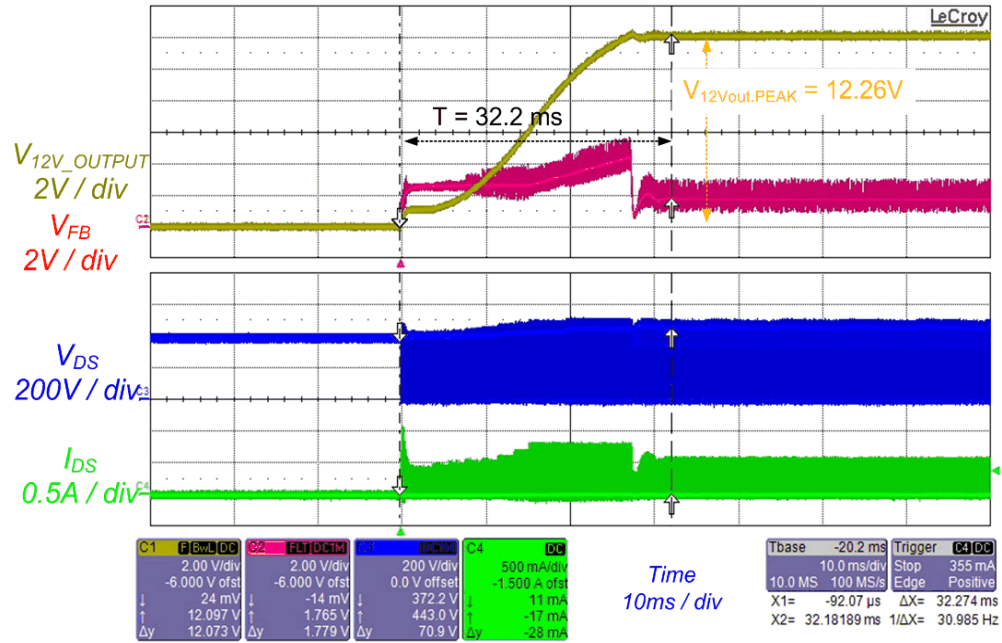


Figure 18. Soft-Start Waveforms @ $V_{IN} = 265 \text{ Vac}$ & Full Load

Soft-Start at $V_{IN} = 265 \text{ Vac}$, No Load

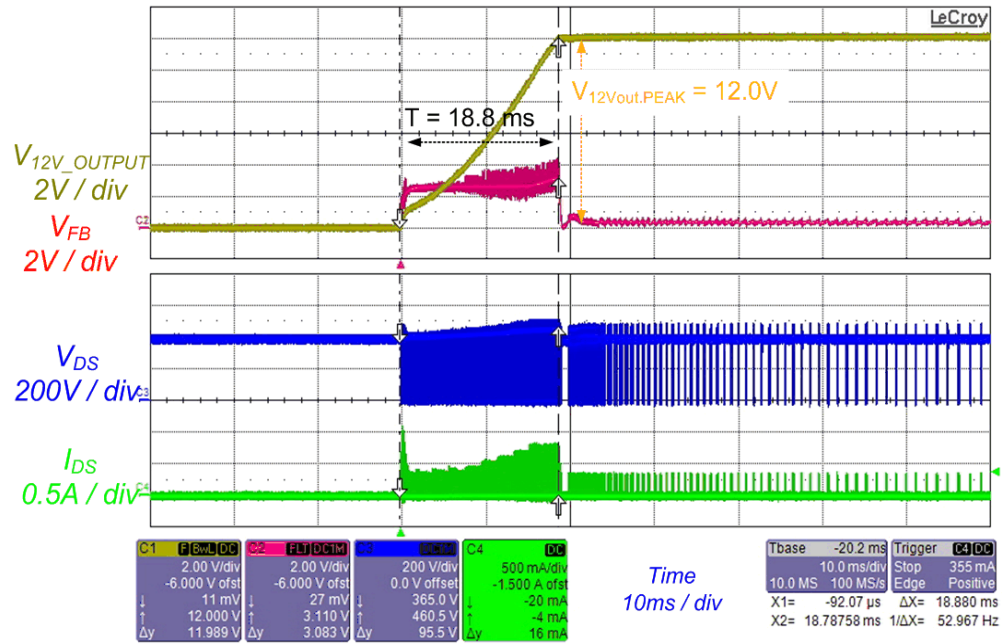


Figure 19. Soft-Start Waveforms @ $V_{IN} = 265 \text{ Vac}$ & No Load

Start-up

Table 14.

Test Condition	12 V _{OUT}
Load	0.83 A
Output Power	9.96 W

Start-up at $V_{IN} = 85$ Vac, Full Load

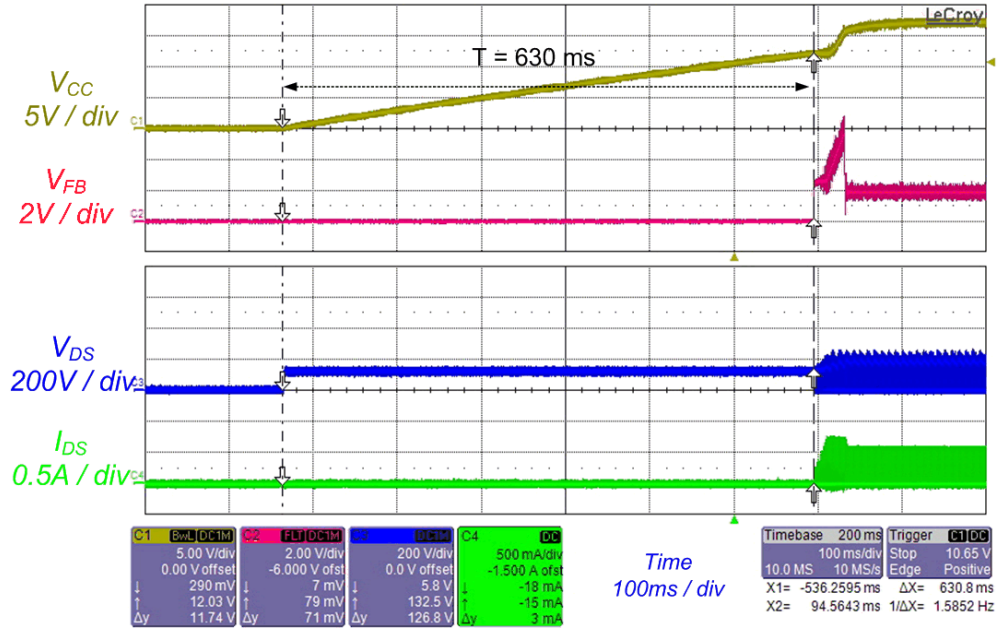


Figure 20. Start-up Waveforms @ $V_{IN} = 85$ Vac & Full Load

Start-up at $V_{IN} = 85$ Vac, No Load

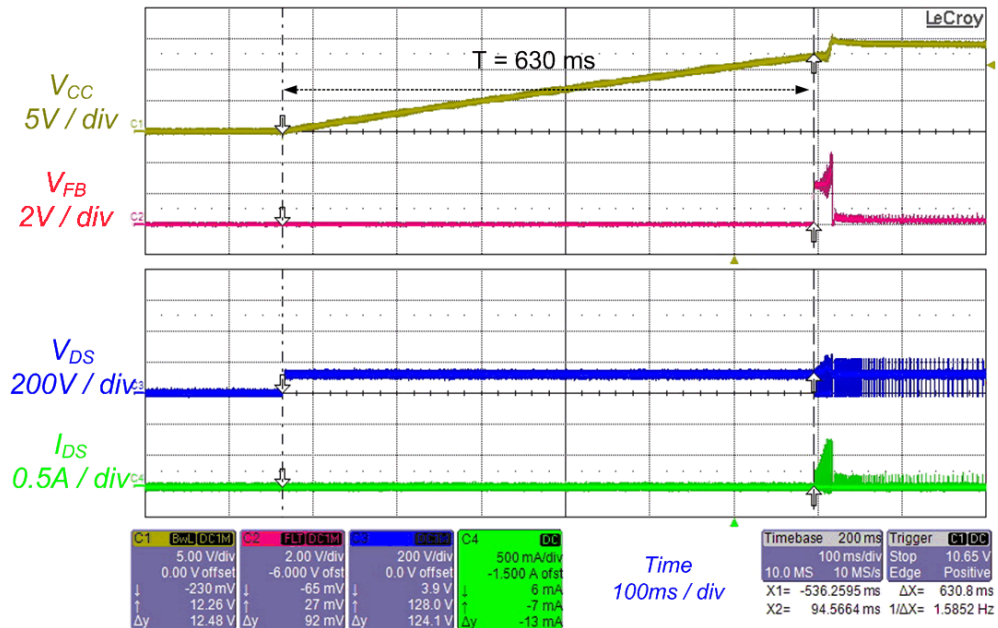


Figure 21. Start-up Waveforms @ $V_{IN} = 85$ Vac & No Load

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Start-up at $V_{IN} = 265 \text{ Vac}$, Full Load

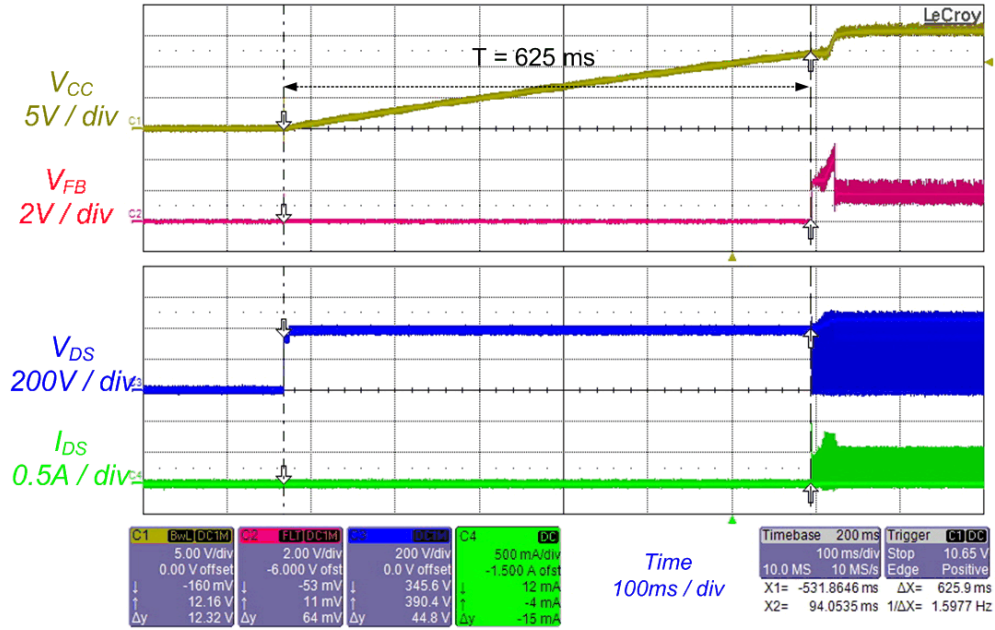


Figure 22. Start-up Waveforms @ $V_{IN} = 265 \text{ Vac}$ & Full Load

Start-up at $V_{IN} = 265 \text{ Vac}$, No Load

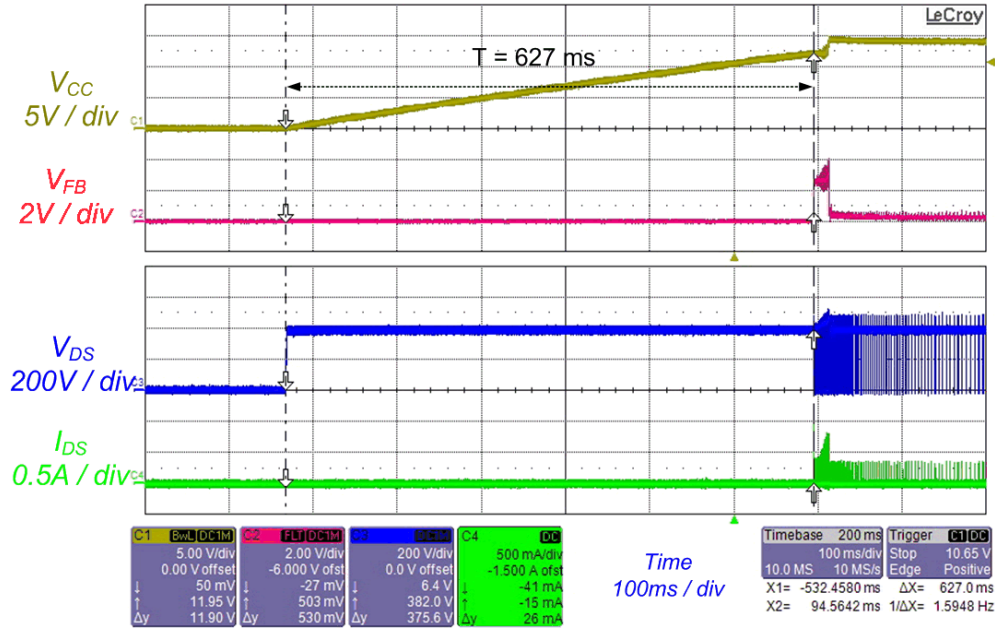


Figure 23. Start-up Waveforms @ $V_{IN} = 265 \text{ Vac}$ & No Load

Normal Operation

Table 15.

Test Condition	12 V _{OUT}
Load	0.83 A
Output Power	9.96 W

Normal Operation at $V_{IN} = 85 \text{ Vac}$

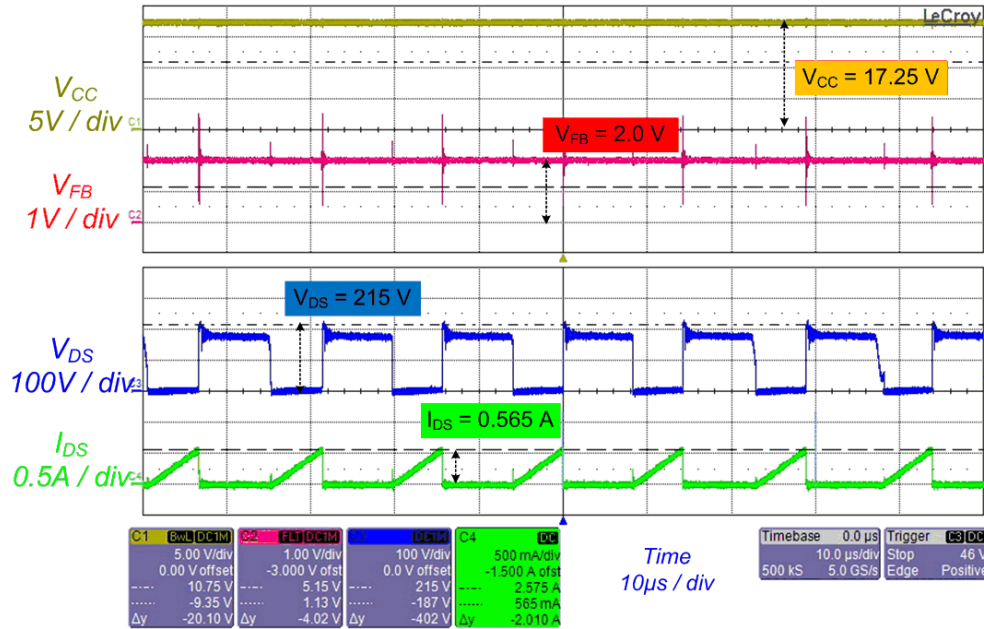


Figure 24. Normal Operation @ $V_{IN} = 85 \text{ Vac}$ & Full Load

Normal Operation at $V_{IN} = 265 \text{ Vac}$

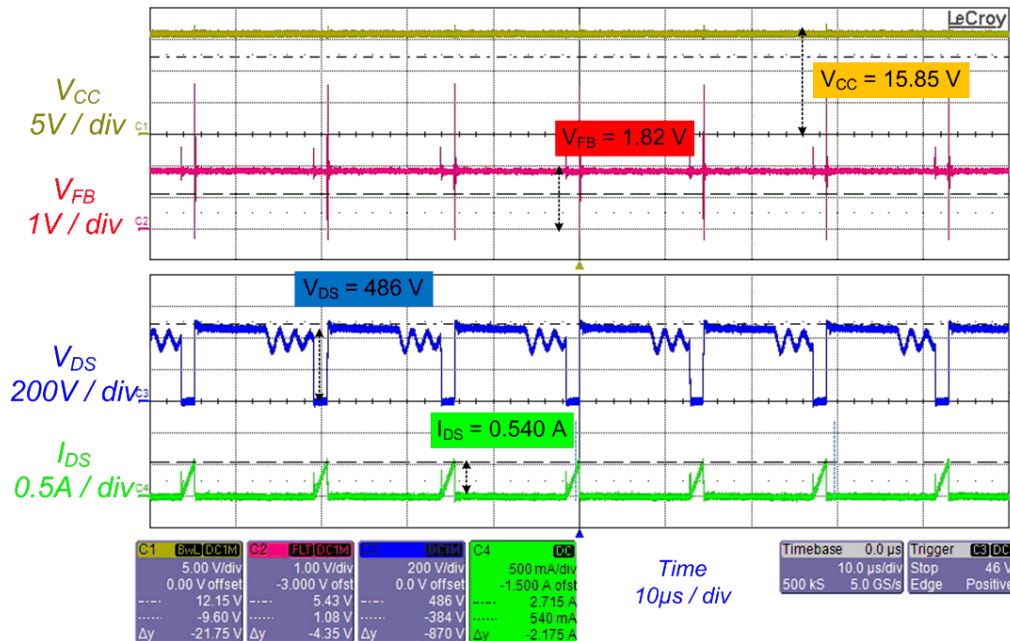


Figure 25. Normal Operation @ $V_{IN} = 85 \text{ Vac}$ & No Load

Burst Operation

Table 16.

Test Condition	12 V _{OUT}
Load	No Load
Output Power	0 W

Burst Operation at $V_{IN} = 85 \text{ Vac}$

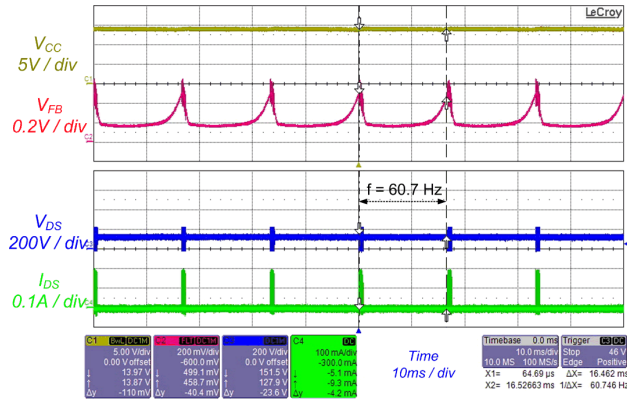


Figure 26. Burst Operation @ $V_{IN} = 85 \text{ Vac}$, No Load

Burst Operation at $V_{IN} = 85 \text{ Vac}$

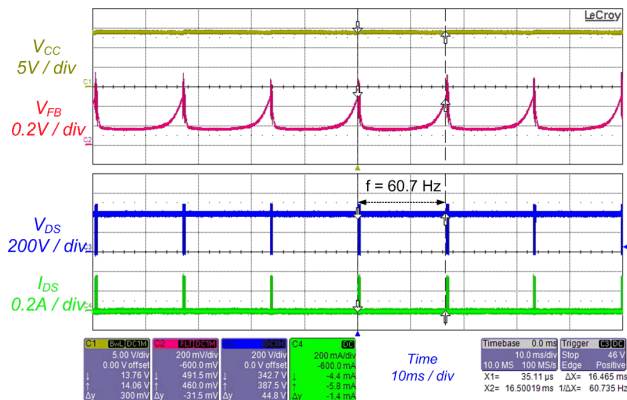


Figure 27. Burst Operation @ $V_{IN} = 265 \text{ Vac}$, No Load

Output Voltage Ripple

Table 17.

Test Condition	12 V _{OUT}
100% load	0.83 A
75% load	0.62 A
50% load	0.41 A
25% load	0.20 A
0% load	0 A

12 V Output Voltage Ripple at $V_{IN} = 85 \text{ Vac}$

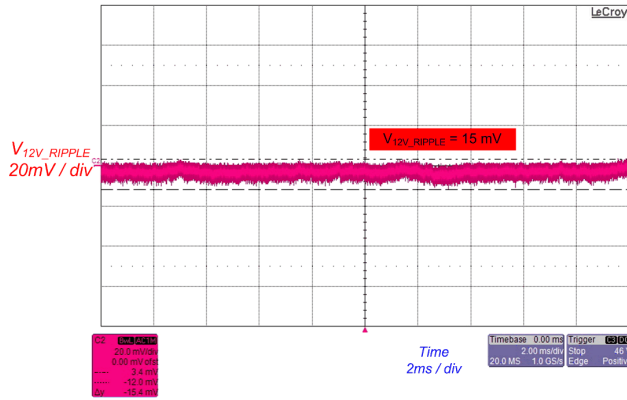


Figure 28. 12 V Ripple @ $V_{IN} = 85 \text{ Vac}$, 100% Load

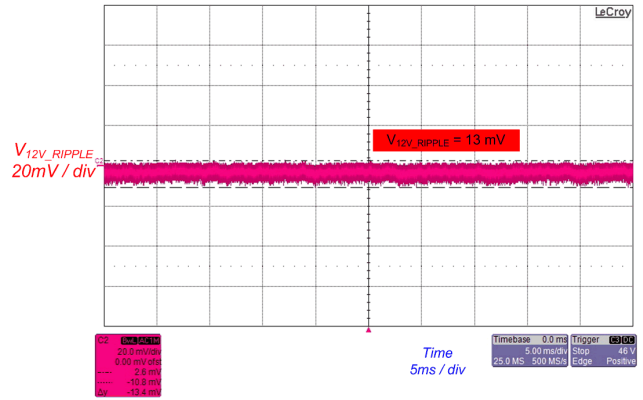


Figure 29. 12 V Ripple @ $V_{IN} = 85 \text{ Vac}$, 75% Load

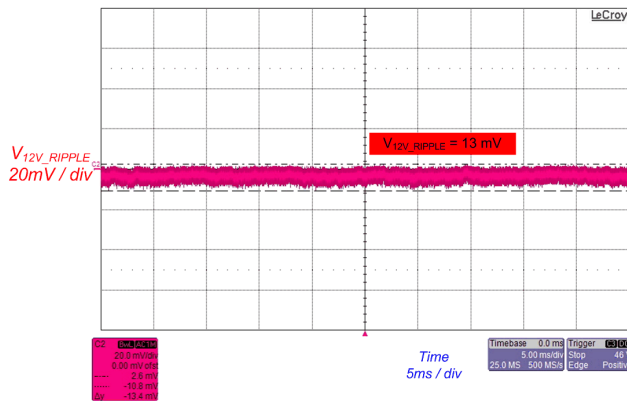


Figure 30. 12 V Ripple @ $V_{IN} = 85 \text{ Vac}$, 50% Load

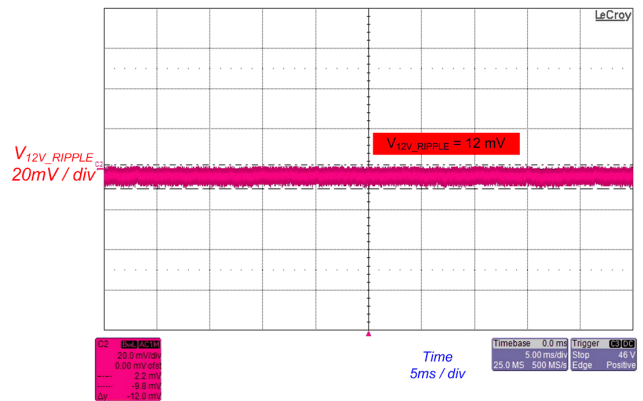


Figure 31. 12 V Ripple @ $V_{IN} = 85 \text{ Vac}$, 25% Load

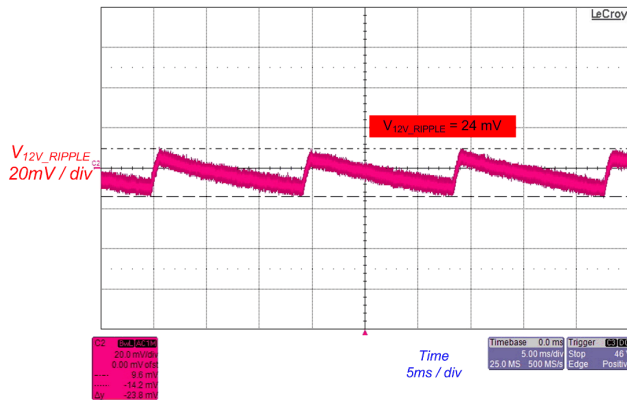


Figure 32. 12 V Ripple @ $V_{IN} = 85 \text{ Vac}$, 0% Load

12 V Output Voltage Ripple at $V_{IN} = 115$ Vac

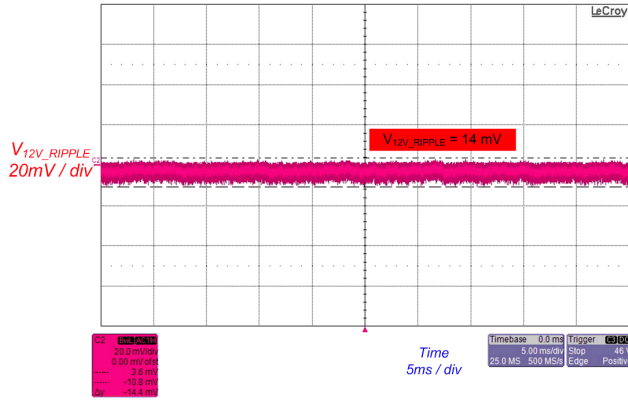


Figure 33. 12 V Ripple @ $V_{IN} = 115$ Vac, 100% Load

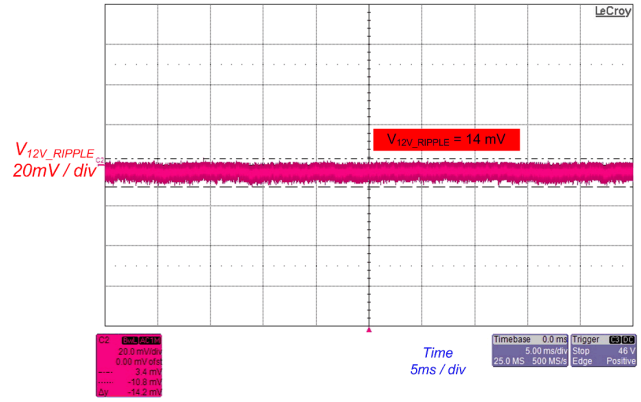


Figure 34. 12 V Ripple @ $V_{IN} = 115$ Vac, 75% Load

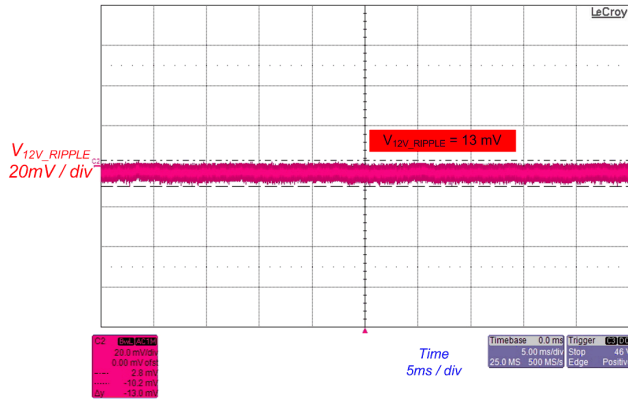


Figure 35. 12 V Ripple @ $V_{IN} = 115$ Vac, 50% Load

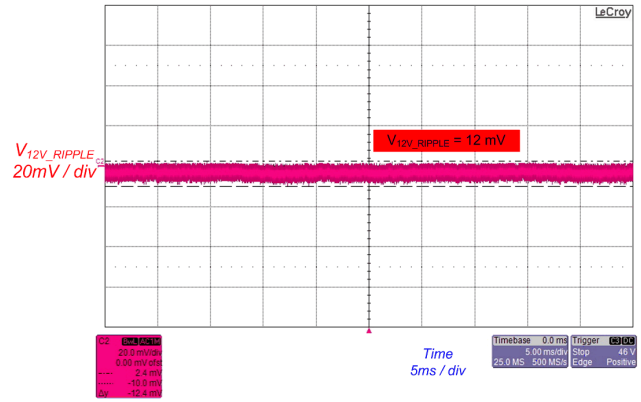


Figure 36. 12 V Ripple @ $V_{IN} = 115$ Vac, 25% Load

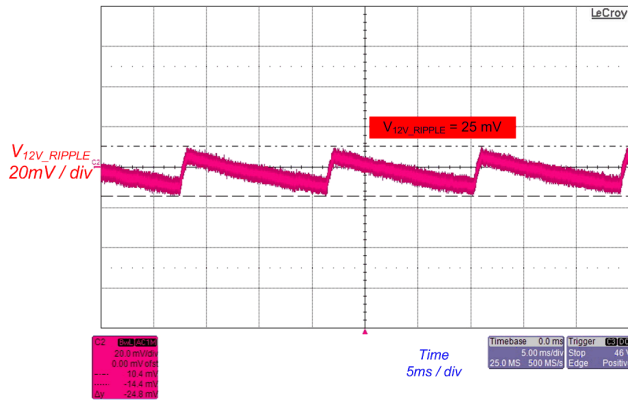


Figure 37. 12 V Ripple @ $V_{IN} = 115$ Vac, 0% Load

12 V Output Voltage Ripple at $V_{IN} = 230 \text{ Vac}$

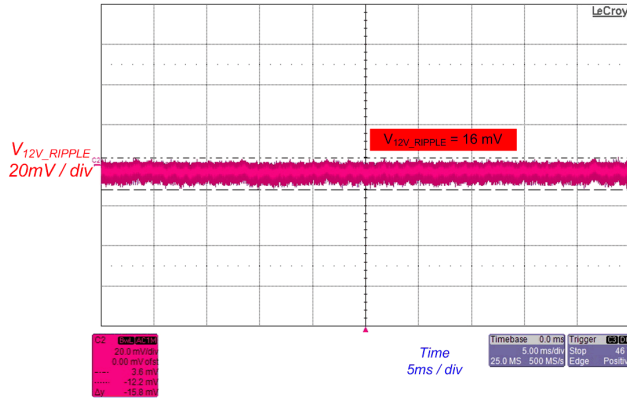


Figure 38. 12 V Ripple @ $V_{IN} = 230 \text{ Vac}$, 100% Load

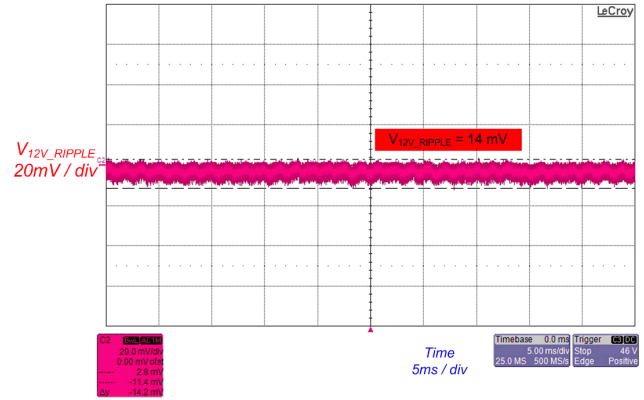


Figure 39. 12 V Ripple @ $V_{IN} = 230 \text{ Vac}$, 75% Load

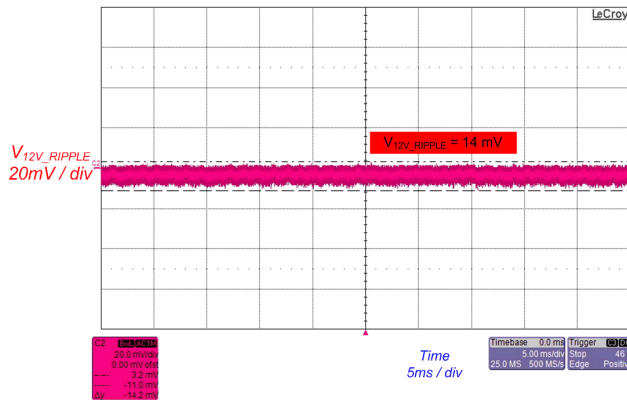


Figure 40. 12 V Ripple @ $V_{IN} = 230 \text{ Vac}$, 50% Load

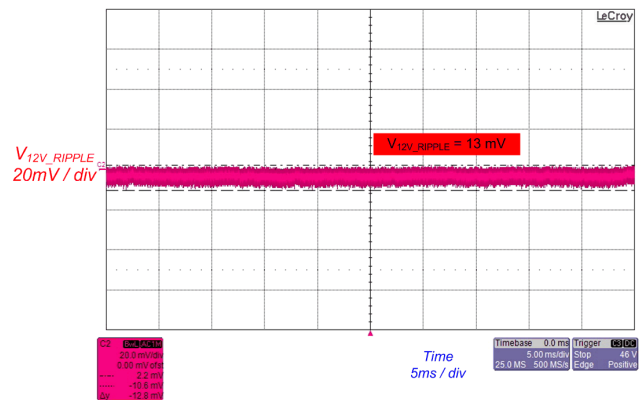


Figure 41. 12 V Ripple @ $V_{IN} = 230 \text{ Vac}$, 25% Load

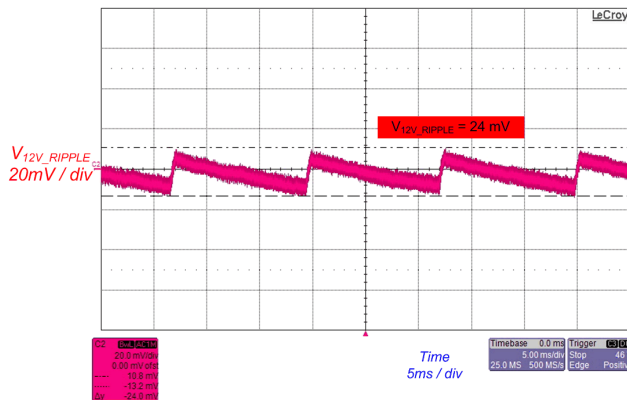


Figure 42. 12 V Ripple @ $V_{IN} = 230 \text{ Vac}$, 0% Load

12 V Output Voltage Ripple at $V_{IN} = 265 \text{ Vac}$

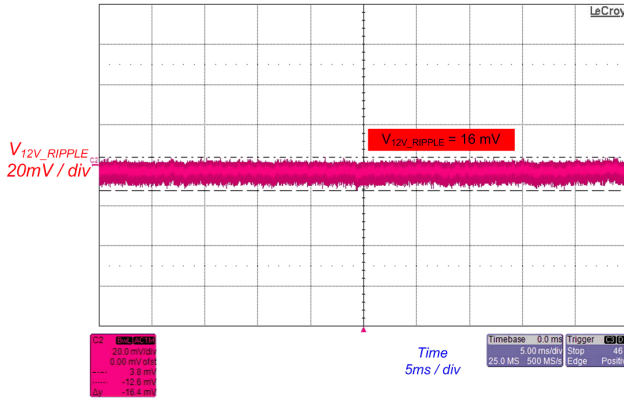


Figure 43. 12 V Ripple @ $V_{IN} = 265 \text{ Vac}$, 100% Load

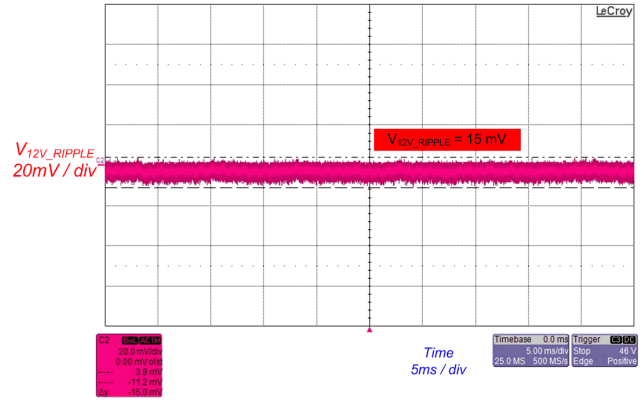


Figure 44. 12 V Ripple @ $V_{IN} = 265 \text{ Vac}$, 75% Load

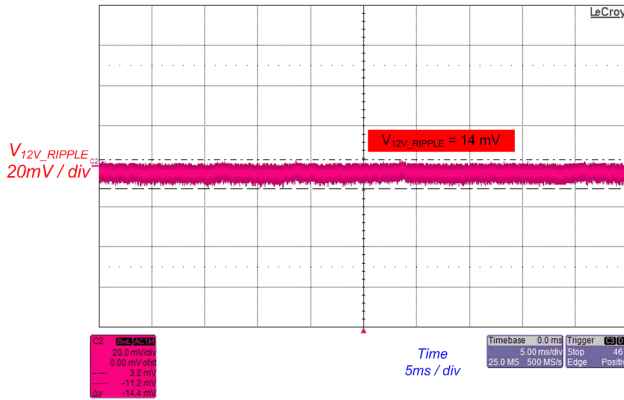


Figure 45. 12 V Ripple @ $V_{IN} = 265 \text{ Vac}$, 50% Load

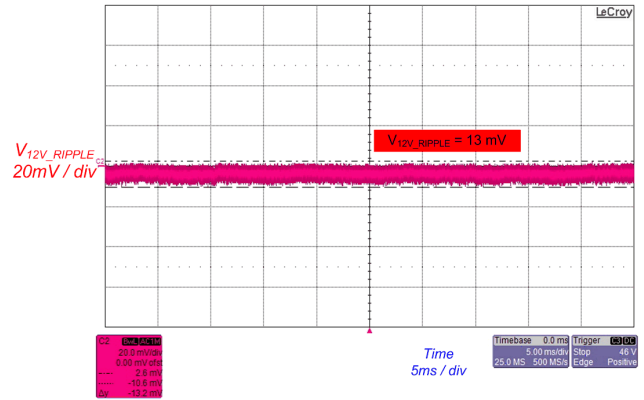


Figure 46. 12 V Ripple @ $V_{IN} = 265 \text{ Vac}$, 25% Load

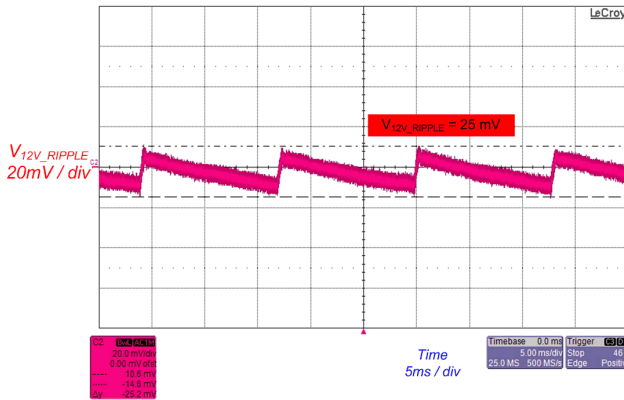
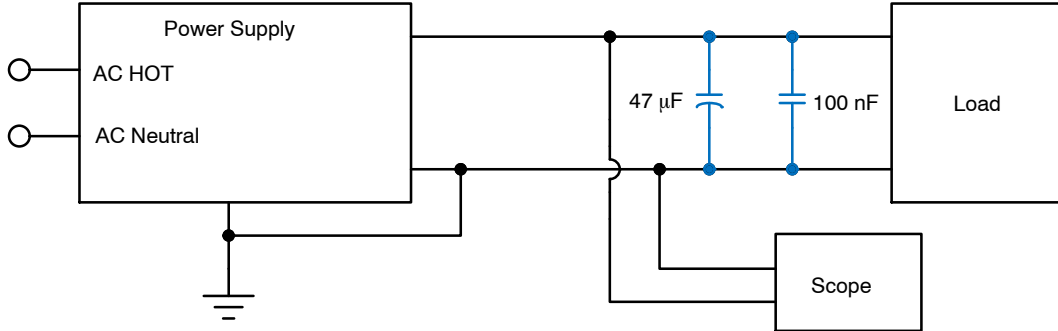


Figure 47. 12 V Ripple @ $V_{IN} = 265 \text{ Vac}$, 0% Load

- Measure with additional capacitors (47 μF electrolytic and 100 nF mono) on 5 V_{OUT} PCB
- Oscilloscope bandwidth: 20 MHz

Table 18. OUTPUT RIPPLE VOLTAGE

Load	85 Vac	110 Vac	230 Vac	265 Vac	Unit
	12 V Ripple	12 V Ripple	12 V Ripple	12 V Ripple	
100%	15	14	16	16	mV
75%	13	14	14	15	
50%	13	13	14	14	
25%	12	12	13	13	
0%	24	25	24	25	



NOTES:

1. Load the output with its maximum load current
2. Connect the probes as shown
3. Repeat the measurement with standby load on the output

Figure 48.

Output Voltage Regulation

Table 19. OUTPUT VOLTAGE REGULATION

VIN	VOUT	Load				
		100%	75%	50%	25%	No Load
265 Vac	12 V _{OUT}	-0.08%	0.00%	0.08%	0.17%	0.17%
230 Vac		-0.08%	0.00%	0.08%	0.17%	0.17%
115 Vac		0.00%	0.00%	0.08%	0.17%	0.17%
85 Vac		0.00%	0.00%	0.08%	0.17%	0.17%

Short Test

12 V Output Overload at $V_{IN} = 85 \text{ Vac}$

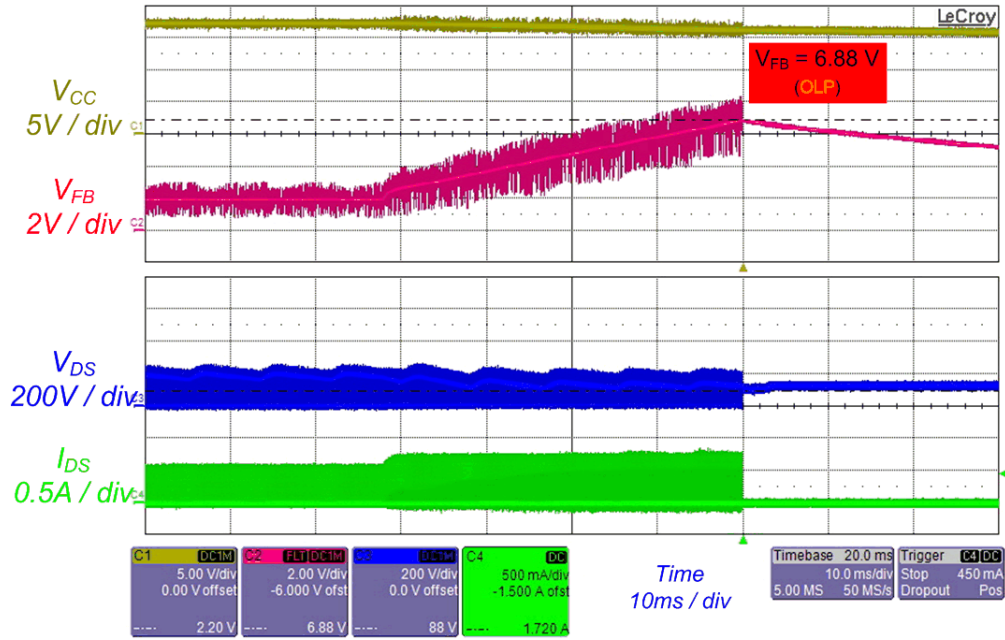


Figure 49. 12 V Output Overload @ $V_{IN} = 85 \text{ Vac}$, Full Load

12 V Output Voltage Short at $V_{IN} = 85 \text{ Vac}$

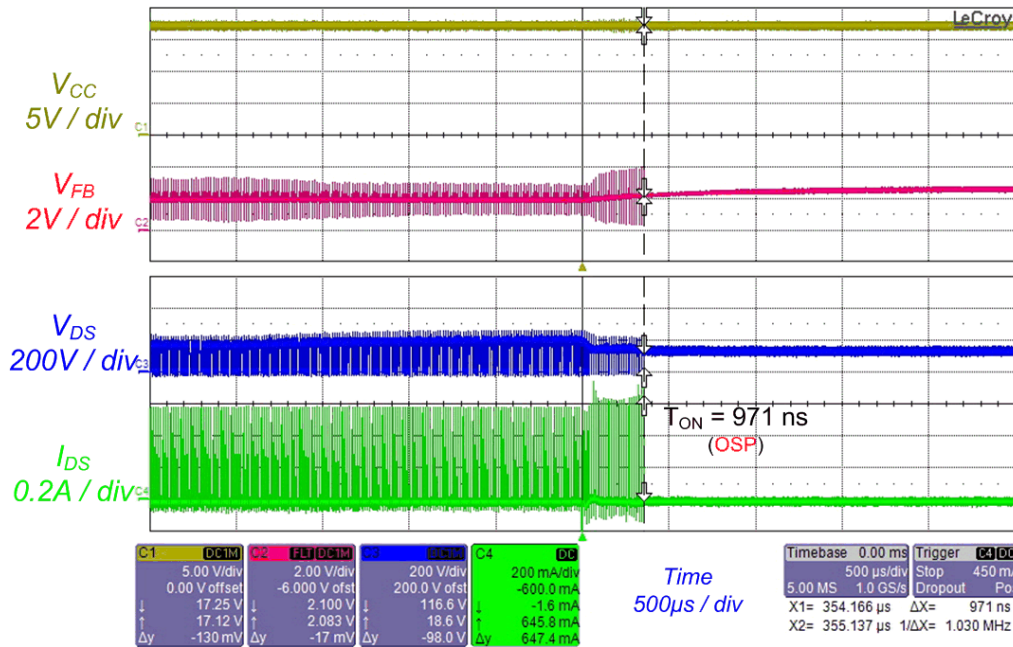


Figure 50. 12 V Output Voltage Short @ $V_{IN} = 85 \text{ Vac}$, Full Load

12 V Output Voltage Short at $V_{IN} = 265 \text{ Vac}$

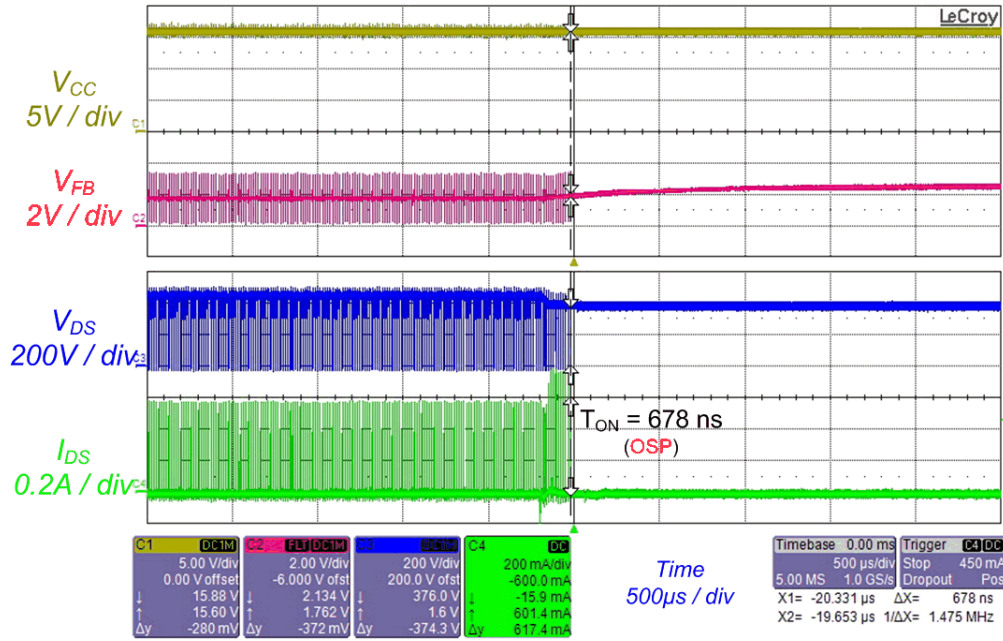


Figure 51. 12 V Output Voltage Short @ $V_{IN} = 265 \text{ Vac}$, Full Load

12 V Output Diode Short at $V_{IN} = 85 \text{ Vac}$

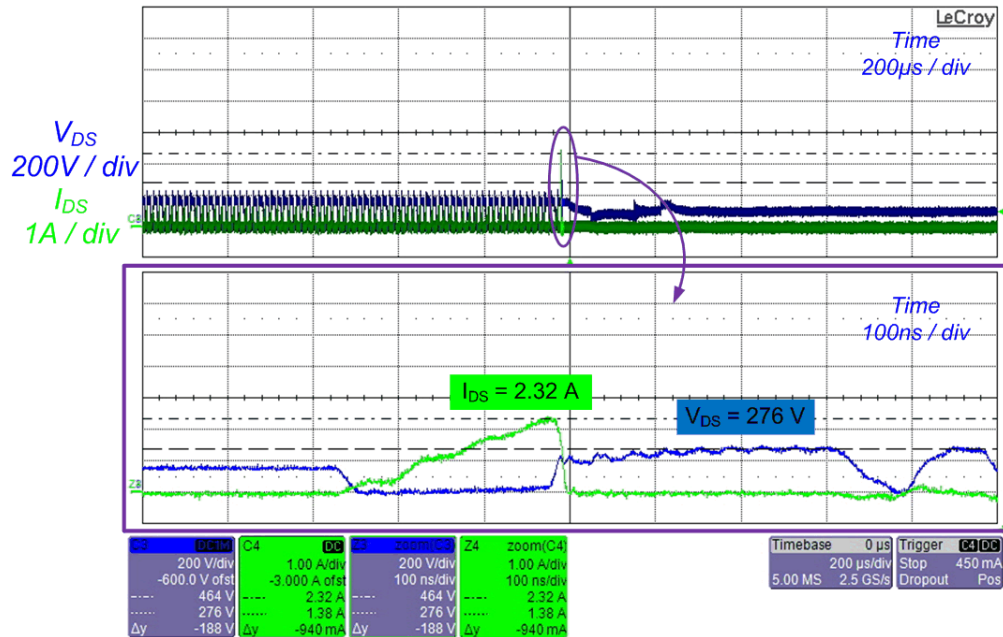


Figure 52. 12 V Output Diode Short @ $V_{IN} = 85 \text{ Vac}$, Full Load

12 V Output Diode Short at $V_{IN} = 265 \text{ Vac}$

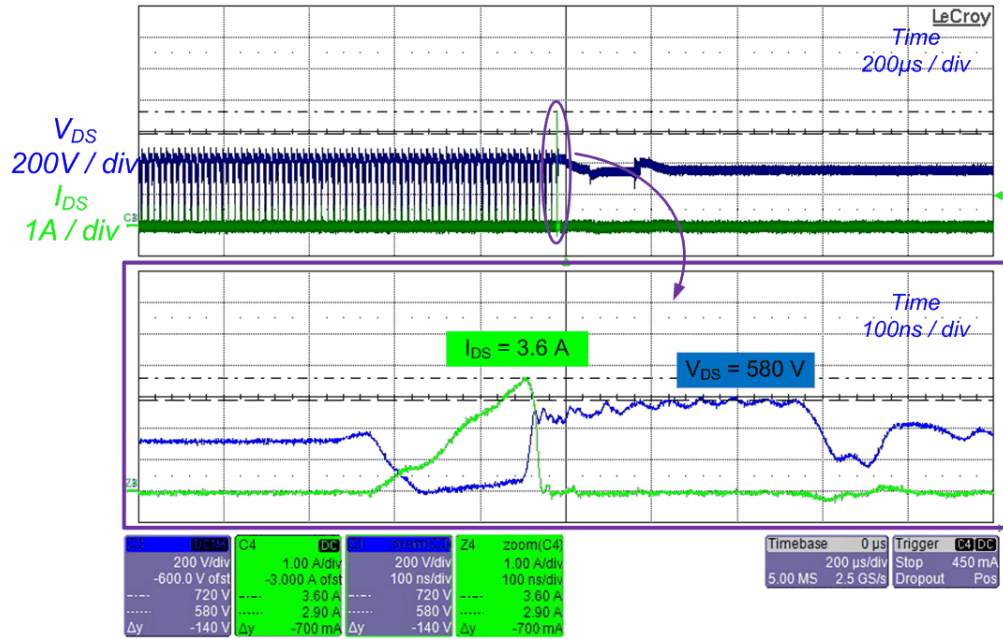


Figure 53. 12 V Output Diode Short @ $V_{IN} = 265 \text{ Vac}$, Full Load

2nd Opto-coupler Short at $V_{IN} = 85 \text{ Vac}$

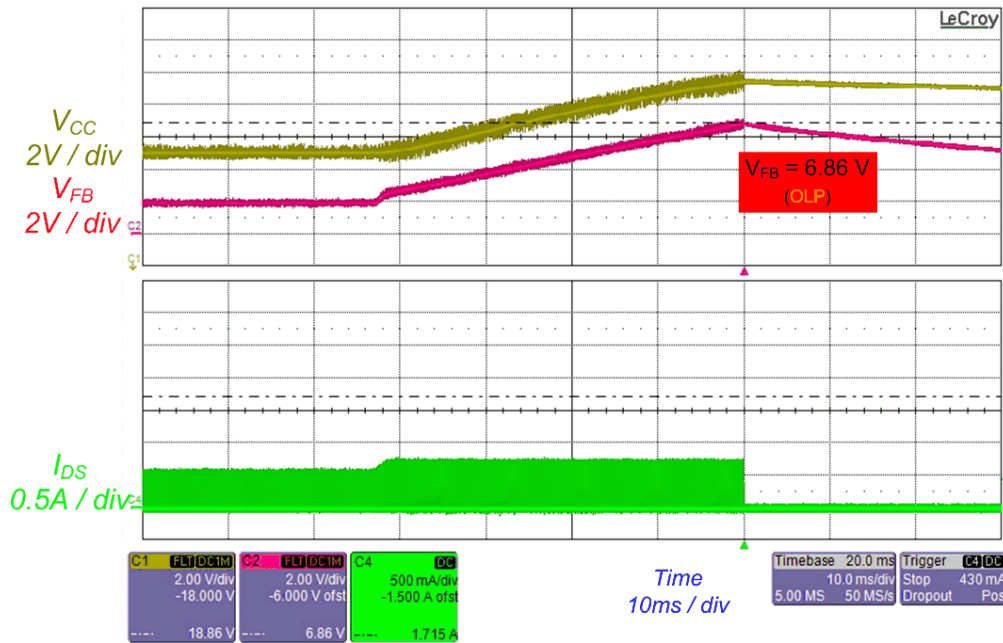


Figure 54. 2nd Opto Short @ $V_{IN} = 85 \text{ Vac}$, Full Load

2nd Opto-coupler Short at $V_{IN} = 265 \text{ Vac}$

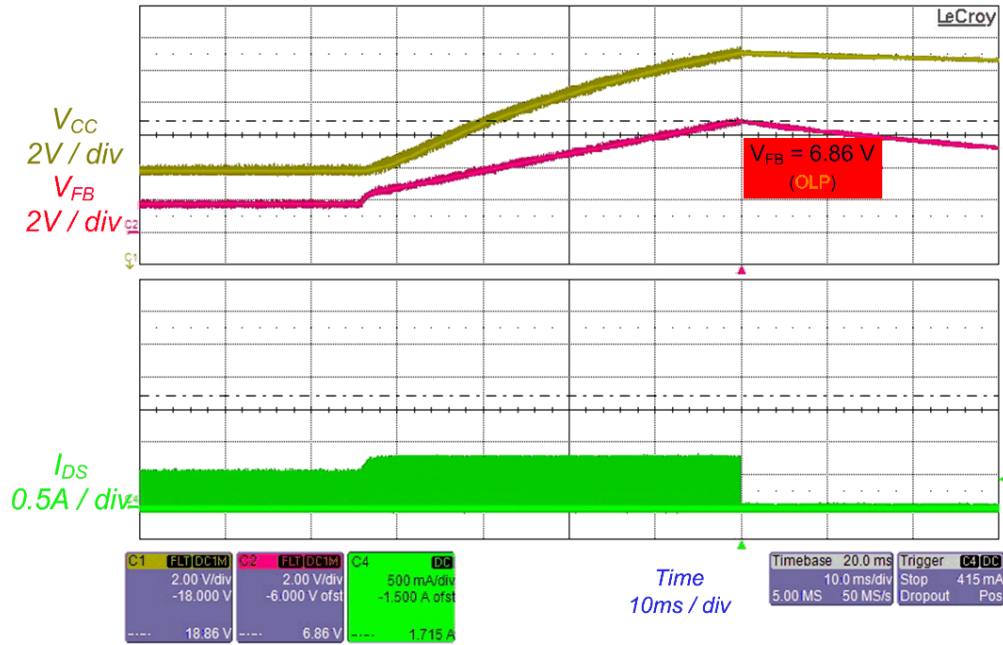


Figure 55. 2nd Opto Short @ $V_{IN} = 265 \text{ Vac}$, Full Load

LOVP (Line Over Voltage Protection) Test

LOVP at $V_{IN} = 265 \text{ Vac} \rightarrow V_{IN} = 300 \text{ Vac}$

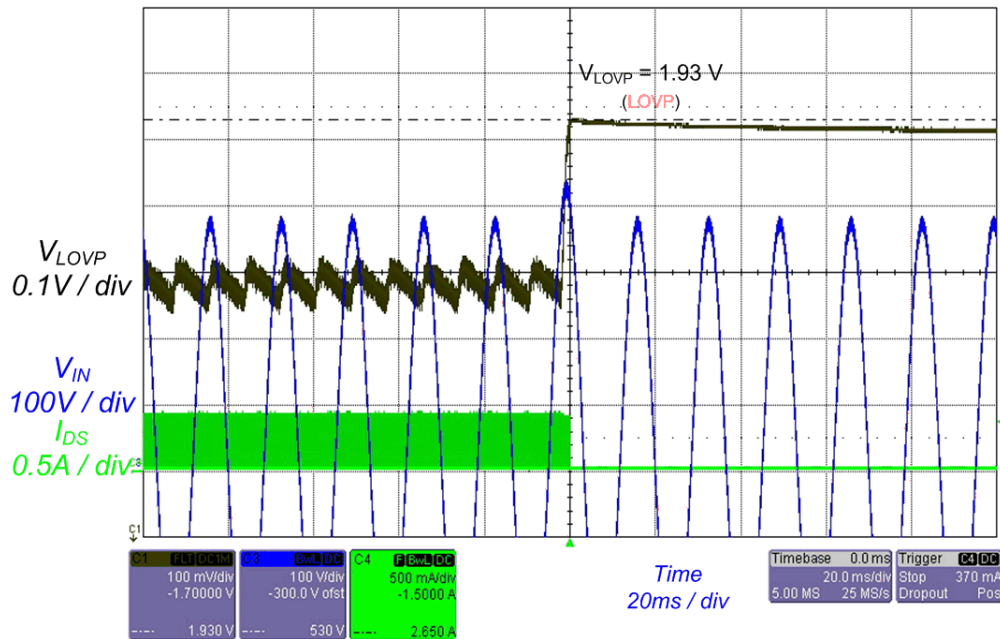


Figure 56. LOVP @ $V_{IN} = 265 \text{ Vac} \rightarrow V_{IN} = 300 \text{ Vac}$

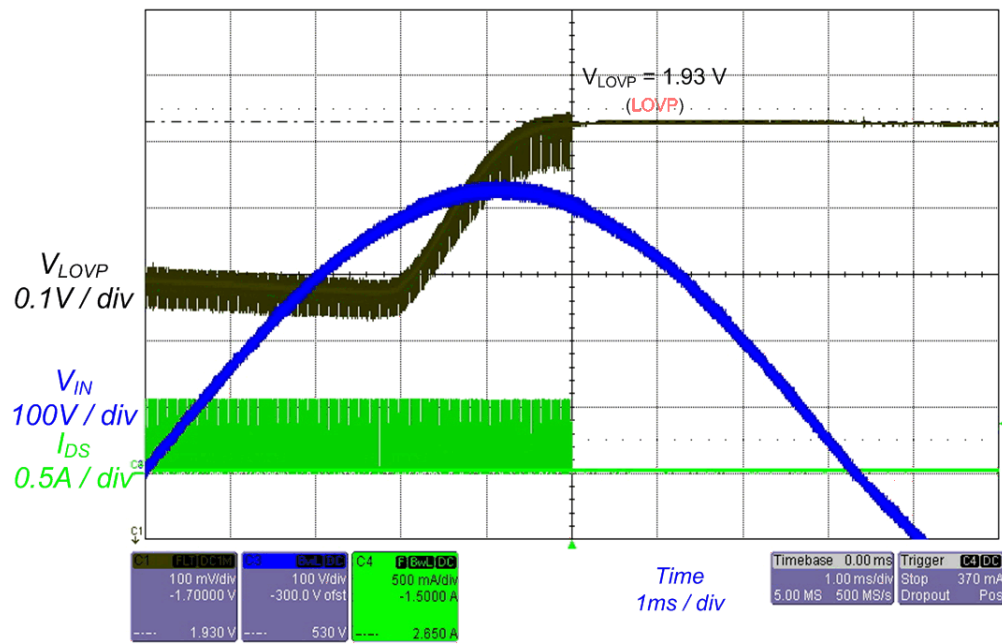


Figure 57. LOVP @ $V_{IN} = 265\text{ Vac} \rightarrow V_{IN} = 300\text{ Vac}$, Enlarge

Voltage Stress of Secondary Diode and Drain

Voltage Stress of Drain at $V_{IN} = 265\text{ Vac}$, Full Load

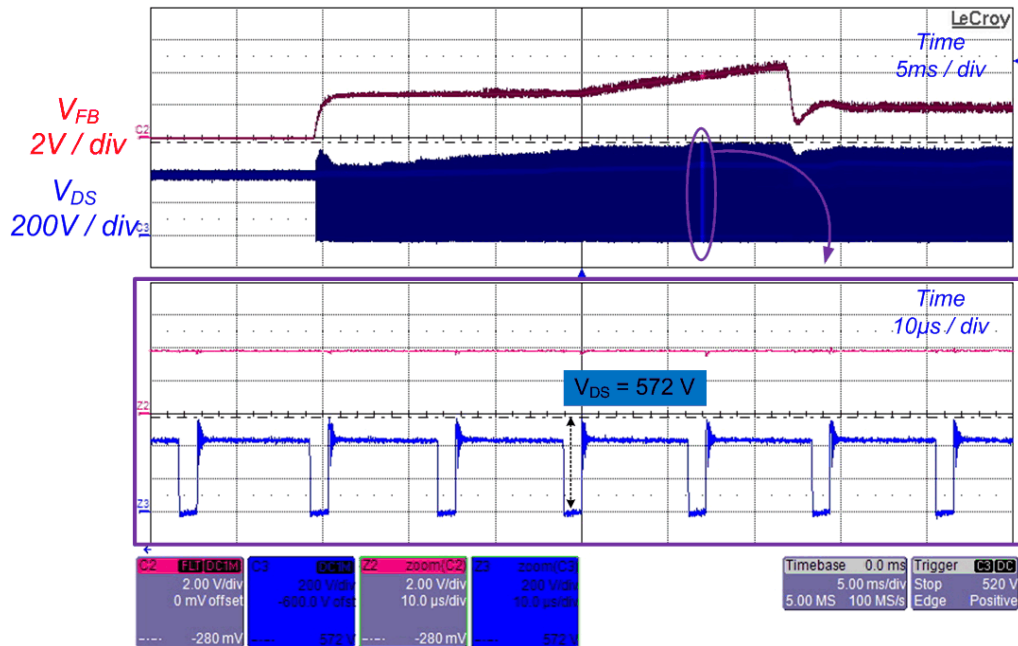


Figure 58. Drain Voltage @ $V_{IN} = 265\text{ Vac}$, Full Load

Voltage Stress of 2nd Diode at $V_{IN} = 265 \text{ Vac}$, Full Load

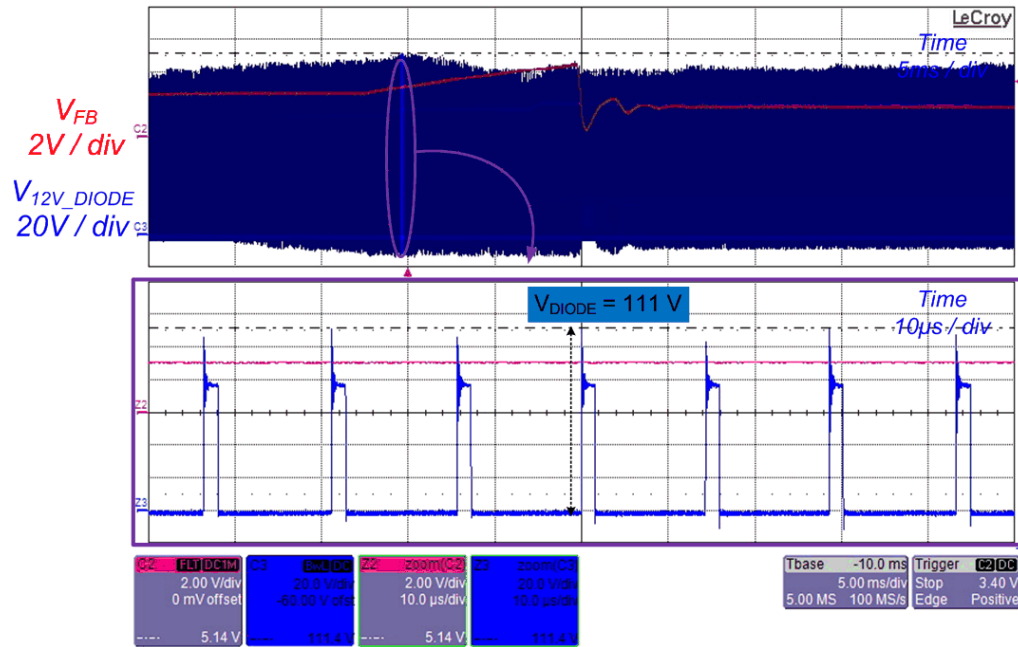


Figure 59. Diode Voltage @ $V_{IN} = 265 \text{ Vac}$, Full Load

TRANSFORMER DESIGN USING DESIGN TOOL

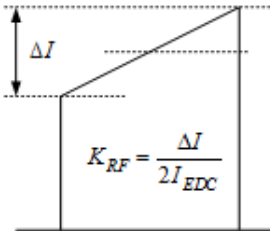
1. Define the system specifications							
Minimum Line voltage (V_{line}^{min})	85	V,rms					
Maximum Line voltage (V_{line}^{max})	280	V,rms					
Line frequency (f_L)	60	Hz					
	$V_{o(n)}$		$I_{o(n)}$		$P_{o(n)}$		$K_L(n)$
1st output for feedback	12 V	0.80 A	10 W	W	100		
2nd output	0 V	0.00 A	0 W	W	0		
3rd output	0 V	0.00 A	0 W	W	0		
4th output	0 V	0.00 A	0 W	W	0		
5th output	0 V	0.00 A	0 W	W	0		
6th output	V	A	0 W	W	0		
Maximum output power (P_o) =	9.6	W					
Estimated efficiency ($E_{\#}$)	80	%					
Maximum input power (P_{in}) =	12.0	W					
2. Determine DC link capacitor and DC link voltage range							
DC link capacitor (C_{DO})	22	μF					
Minimum DC link voltage (V_{DC}^{min}) =	85	V					
Maximum DC link voltage (V_{DC}^{max})=	396	V					
3. Determine Maximum duty ratio (Dmax)							
Maximum duty ratio (D_{max})	0.45						
Max nominal MOSFET voltage (V_{ds}^{nom}) =	465	V					
Output voltage reflected to primary (V_{RO})=	69	V					
4. Determine transformer primary inductance (L_m)							
Switching frequency of FPS (f_s)	66	kHz					
Ripple factor (K_{RF})	0.91						
Primary side inductance (L_m) =	1008	μH					
Maximum peak drain current (I_{ds}^{peak}) =	0.60	A					
RMS drain current (I_{ds}^{rms}) =	0.24	A					
Maximum DC link voltage in CCM (V_{DC}^{CCM})	94	V					
			<div>$K_{RF}=1$ (DCM) $K_{RF}<1$ (CCM)</div>  <div>$K_{RF} = \frac{\Delta I}{2I_{EDC}}$</div>				
5. Choose the proper FPS considering the input power and current limit							
Typical current limit of FPS (I_{over})	0.80	A					
Minimum I_{over} considering tolerance of 12%	0.70	A	>	0.60	A		
	→O.K.						

Figure 60.

6. Determine the proper core and the minimum primary turns									
Saturation flux density (B_{sat})	0.32	T							
Cross sectional area of core (A_g)	40.1	mm ²							
Minimum primary turns (N_p^{min})=	62.9	T							
7. Determine the number of turns for each output									
	$V_{o(n)}$		$V_{F(n)}$					# of turns	
Vcc (Use Vcc start voltage)	14	V	0.5	V	13.9	=>		14	
1st output for feedback	12	V	0.5	V	12	=>		12	
2nd output	0	V	0	V	0.0	=>		0	
3rd output	0	V	0	V	0.0	=>		0	
4th output	0	V	0	V	0.0	=>		0	
5th output	0	V	0	V	0.0	=>		0	
6th output	0	V	0	V	0.0	=>		0	
VF : Forward voltage drop of rectifier diode			Primary turns (N_p)=		67				
			---->enough turns						
Ungapped AL value (AL)	840	nH/T ²		n	=			5,545	
Gap length (G) : center pole gap =	0.1612	mm							
8. Determine the wire diameter for each winding									
	Diameter		Parallel		$I_{D(n)}^{rms}$			(A/mm ²)	
Primary winding	0.25	mm	1	T	0.2	A		4.9	
Vcc winding	0.2	mm	1	T	0.7	A		22.3	
1st output winding (12V)	0.4	mm	2	T	1.5	A		5.8	
2nd output winding (0V)	0	mm	0	T	#####	A		#####	
3rd output winding (0V)	0	mm	0	T	#####	A		#####	
4th output winding (0V)	0	mm	0	T	#####	A		#####	
5th output winding (0V)	0	mm	0	T	#####	A		#####	
6th output winding (V)		mm		T	#####	A		#####	
Copper area (A_c) =	6.72	mm ²							
Fill factor (K_F)	0.15								
Required window area (A_{wr})	44.79	mm ²							
9. Choose the rectifier diode in the secondary side									
	$V_{D(n)}$				$I_{D(n)}^{rms}$				
Vcc diode	97	V			0.10	A			
Rectifier diode for 1st output (12V)	83	V			1.46	A			
Rectifier diode for 2nd output (0V)	0	V			#####	A			
Rectifier diode for 3rd output (0V)	0	V			#####	A			
Rectifier diode for 4th output (0V)	0	V			#####	A			
Rectifier diode for 5th output (0V)	0	V			#####	A			
Rectifier diode for 6th output (V)	0	V			#####	A			

Figure 61.

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