Test Report
Aug 2016

PMP15002 Test Results

Note that this reference design is not an orderable device from TI, but shows the performance of a UCC28704/UCC24636 in a constant voltage/ constant current controller in a typical 15-W USB adapter application.

Contents

1 Photos

The photographs below show the PMP15002 prototype assembly.

Top View

Bottom View

2 Design Features

- **Designed using UCC28704, a simple and low cost CC-CV primary side regulated Flyback controller eliminating Optical Coupler**
- **Quasi-resonant/DCM Flyback with Synchronous Rectification**
- **<75mW No-load power consumption**
- **high efficiency over entire operating range: DOE VI and CoC V5 tier 2 Compliant at 150 mΩ cable end**
- **Fully tested and passed EN55022 Class B Conducted & Radiated EMI**

3 Electrical Characteristics

3.1 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	NOM	MAX	UNITS
Input Characteristics					
Voltage range, V_{IN}		85	115/230	265	V_{RMS}
Line frequency		47	60/50	63	H_Z
No-load power consumption				75	mW
Output Characteristics (Output voltage was measured at 100 mΩ cable end)					
Output voltage, Vout	$V_{INmin} \le V_{IN} \le V_{INmax}$, $0A \le I_{OUT} \le I_{OUTmax}$	4.85	5	5.15	V
Output load current, CV mode, I_{OUTMAX}	$V_{INmin} \le V_{IN} \le V_{INmax}$	3.2	3.3	3.4	A
Output voltage regulation	Line Regulation: $V_{INmin} \le V_{IN} \le V_{INmax}$, $I_{OUT} = I_{OUTmax}$			3	%
	Load Regulation: $0A \le I_{OUT} \le I_{OUTmax}$			3	%
Output voltage ripple	$V_{INmin} \le V_{IN} \le V_{INmax}$, $0A \le I_{OUT} \le I_{OUTmax}$			150	mV
Output over current, I_{OCC}	$V_{INmin} \le V_{IN} \le V_{INmax}$	3.3		3.5	A
Minimum output	$V_{INmin} \le V_{IN} \le V_{INmax}$, $I_{OUT} = I_{OCC}$	2.45	2.6	2.75	V

voltage, CC mode					
Brown-out protections	$I_{OUT} = I_{OUTmax}$		66		V_{RMS}
Transient response undershoot	I_{OUT} = 0 A to 0.5A load transient	4.7			V
System Characteristics					
Switching frequency, fsw		1.2		55	kHz
Average efficiency	25%， 50%， 75%， 100% load average at nominal input voltages; Output voltage was measured at board end		88		%
Operating temperature			25		℃
Conducted EMI	Output floating	EN 55022 B and FCC PART 15 B			
Radiated EMI	Output floating	EN 55022 B and FCC PART 15 B			

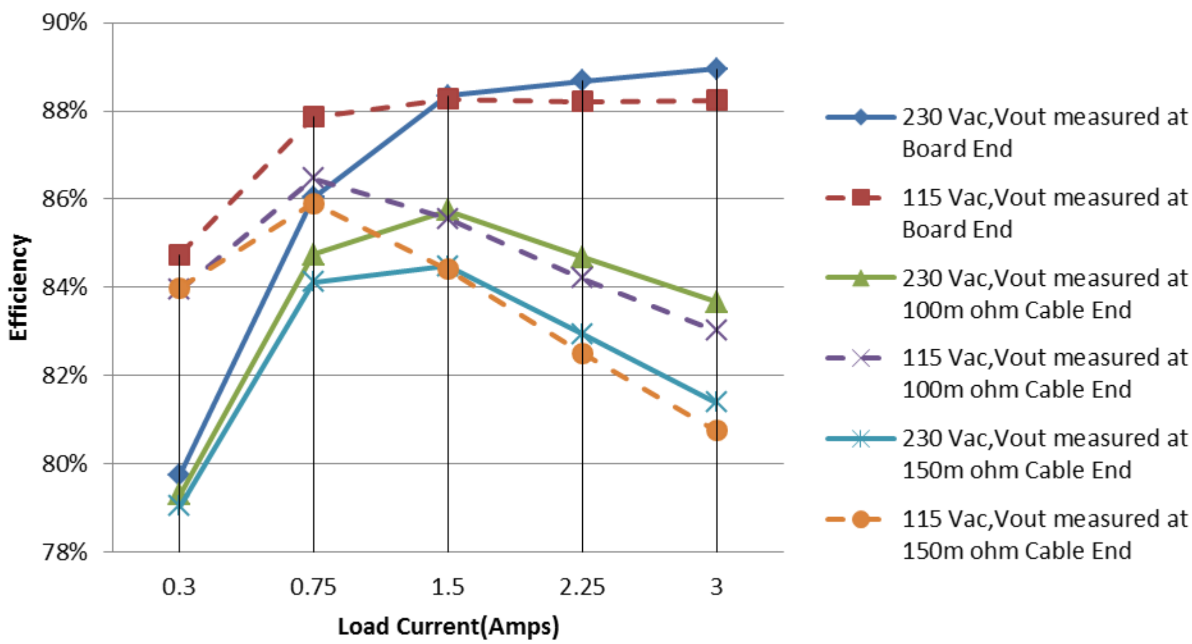
3.2 Efficiency & No-Load Power Consumption

Both the U.S. Department of Energy Level VI and European Union code of conduct (CoC) Version 5.0 Tier 2 went into effect in 2016, and set higher efficiency standards for power supplies than ever before.
The efficiency of this PMP15002 design can meet COC Tier2 and DOE VI even with 150mΩ cable.

3.2.1 Remark:

The nominal output of PMP15002 at 150 mΩ cable end is 5V/3A
COC Version 5.0 Tier 2 Compliance for 5V/3A:
Average efficiency: ≥ 0.0834*ln(5*3)-0.0011*(5*3)+0.609=81.84%
Efficiency at 10% load: ≥ 0.0834*ln(5*3)-0.00127*(5*3)+0.518=72.48%
No-Load Power Consumption: ≤ 75mW
DOE Level VI Compliance for 5V/3A:
Average efficiency: ≥ 0.0834*ln(5*3)-0.0014*(5*3)+0.609=81.39%
*Average efficiency is the simple arithmetic average of efficiency measurements made at 25%, 50%, 75%, 100% of full rated output current in active mode

3.2.2 Chart



3.2.3 No-Load Power Consumption

Vin (Vac)	Input Power (mW)
90	40.7
115	42.4
132	43.8
180	48.5
230	56.9
265	70

3.2.4 Efficiency Data

Vout was measured at board end.

Vin	PIN (W)	Vout (V)	Iout (A)	Load(%)	EFFICIENCY	Avg. Eff.	COC V5 Tier2
230 Vac, 50 Hz	1.869	4.982	0.299	10%	79.75%		72.48%
	4.391	5.044	0.749	25%	86.04%	88.00%	81.84%
	8.709	5.134	1.499	50%	88.35%		
	13.233	5.218	2.249	75%	88.68%		
	17.848	5.294	2.998	100%	88.95%		
115 Vac, 60 Hz	1.759	4.983	0.299	10%	84.75%		72.48%

	4.309	5.054	0.749	25%	87.86%	88.15%	81.84%
	8.719	5.135	1.499	50%	88.27%		
	13.3	5.217	2.249	75%	88.21%		
	18.0	5.294	2.998	100%	88.24%		

Vout was measured at 100 mΩ cable end

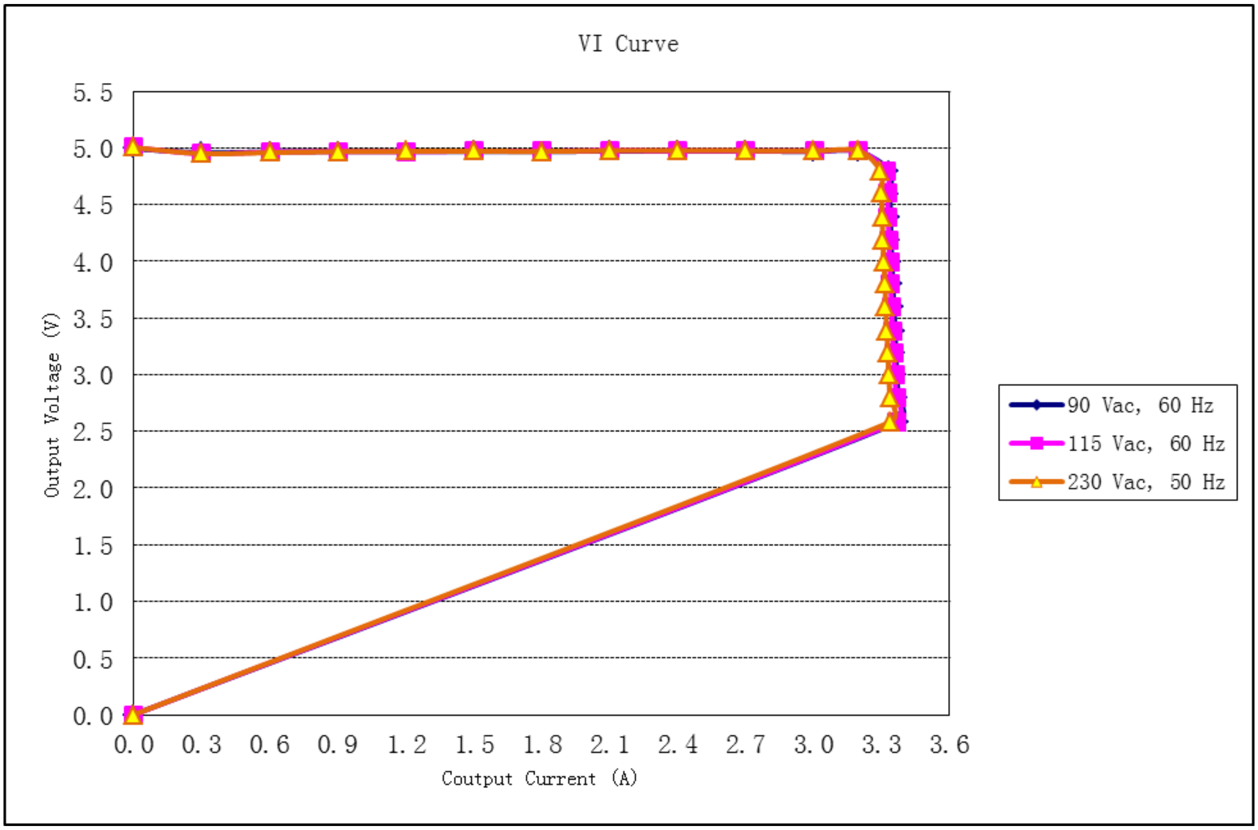
Vin	PIN (W)	Vout (V)	Iout (A)	Load(%)	EFFICIENCY	Avg. Eff.	COC V5 Tier2
230 Vac, 50 Hz	1.869	4.954	0.299	10%	79.30%		72.48%
	4.391	4.968	0.749	25%	84.74%	84.71%	81.84%
	8.703	4.980	1.499	50%	85.75%		
	13.238	4.986	2.249	75%	84.68%		
	17.853	4.982	2.998	100%	83.66%		
115 Vac, 60 Hz	1.766	4.953	0.299	10%	83.95%		72.48%
	4.311	4.977	0.749	25%	86.47%	84.81%	81.84%
	8.721	4.979	1.499	50%	85.55%		
	13.303	4.982	2.249	75%	84.21%		
	17.982	4.979	2.998	100%	83.02%		

Vout was measured at 150 mΩ cable end

Vin	PIN (W)	Vout (V)	Iout (A)	Load(%)	EFFICIENCY	Avg. Eff.	COC V5 Tier2
230 Vac, 50 Hz	1.869	4.938	0.299	10%	79.03%		72.48%
	4.391	4.932	0.749	25%	84.12%	83.23%	81.84%
	8.709	4.910	1.499	50%	84.48%		
	13.233	4.881	2.249	75%	82.95%		
	17.848	4.845	2.998	100%	81.39%		
115 Vac, 60 Hz	1.759	4.938	0.299	10%	83.99%		72.48%
	4.309	4.942	0.749	25%	85.91%	83.39%	81.84%
	8.719	4.911	1.499	50%	84.41%		
	13.3	4.880	2.249	75%	82.51%		
	18.0	4.845	2.998	100%	80.75%		

3.3 V-I Curve

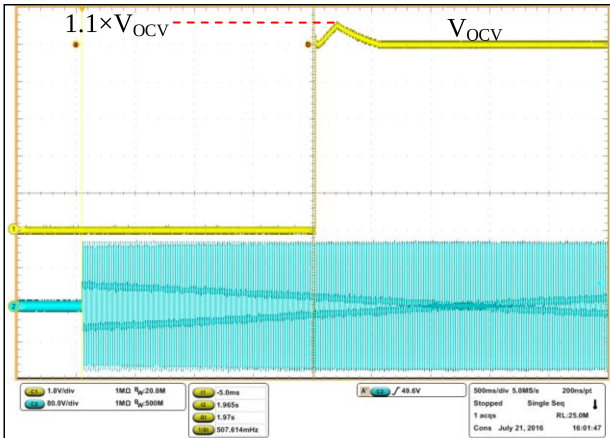
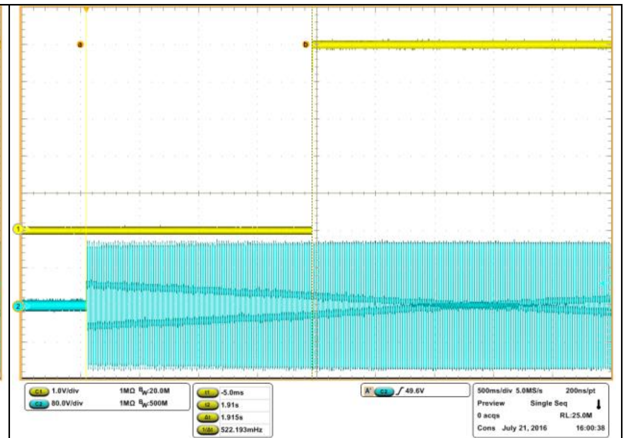
Vout was measured at 100 mΩ cable end



3.4 Turn-on Delay Time

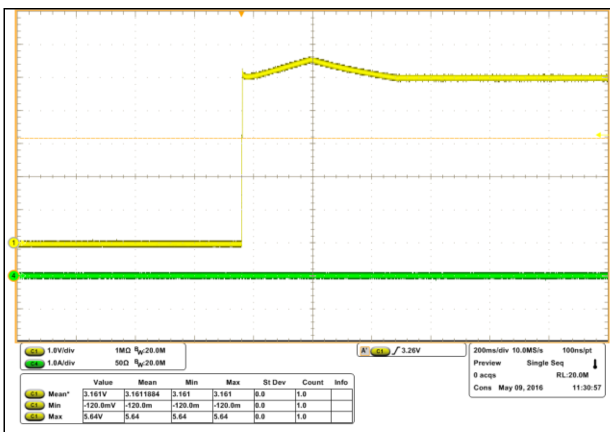
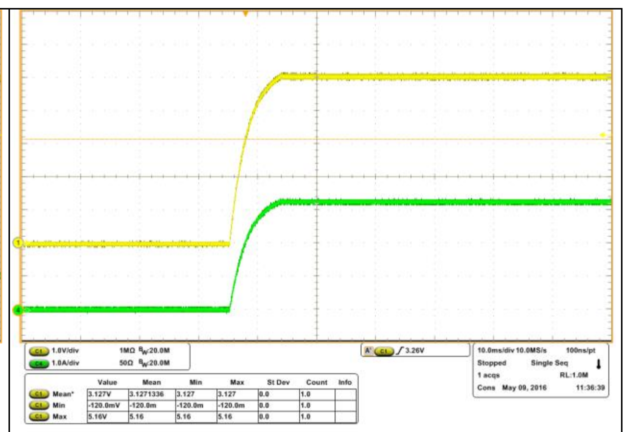
Input voltage	Output current	Turn on delay time
90 Vac, 47 Hz	0 A	**1.97 s**
90 Vac, 47 Hz	3 A	**1.92 s**

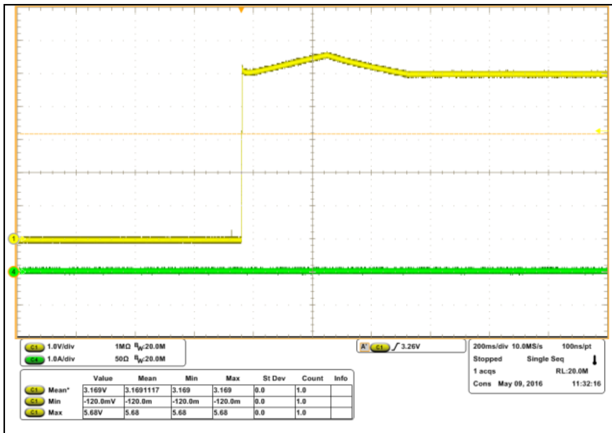
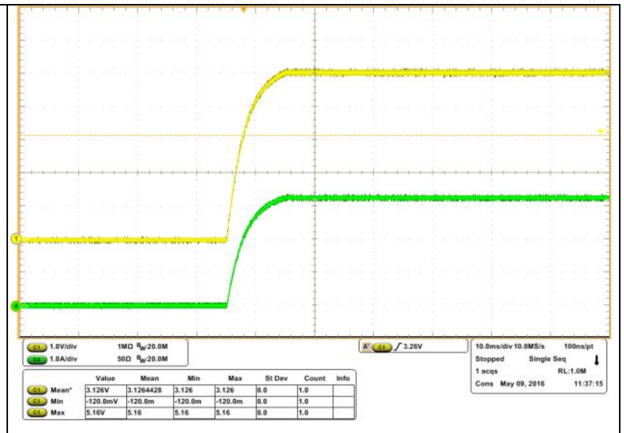
*Output Voltage experience a 10% overshoot during a no-load start up. This overshoot is a by-product of enhanced load transient scheme of UCC28704 which enable a better response of load transient. Refer to section 8.2.3 of UCC28704 datasheet for the detail explanation. V_{OCV} is the regulated output voltage.

	
Vin: 90 Vac Io: 0 A Ch1: Output voltage, 1 V/div Ch2: AC INPUT, 80 V/div	Vin: 90 Vac Io: 3 A Ch1: Output voltage, 1 V/div Ch2: AC INPUT, 80 V/div

3.5 Startup Waveforms

*Output Voltage experience a 10% overshoot during a no-load start up. This overshoot is a by-product of enhanced load transient scheme of UCC28704 which enable a better response of load transient. Refer to section 8.2.3 of UCC28704 datasheet for the detail explanation.

	
Vin:115 Vac Output current: 0 A Ch1: Output voltage, 1 V/div Ch4: Load current, 1 A/ div	Vin:115 Vac 1.67 Ω Load Ch1: Output voltage, 1V/div Ch4: Load current, 1 A/ div

	
Vin: 230 Vac Output current: 0A Ch1: Output voltage, 1V/div Ch4: Load current, 1 A/ div	Vin: 230 Vac 1.67 Ω Load Ch1: Output voltage, 1V/div Ch4: Load current, 1 A/ div

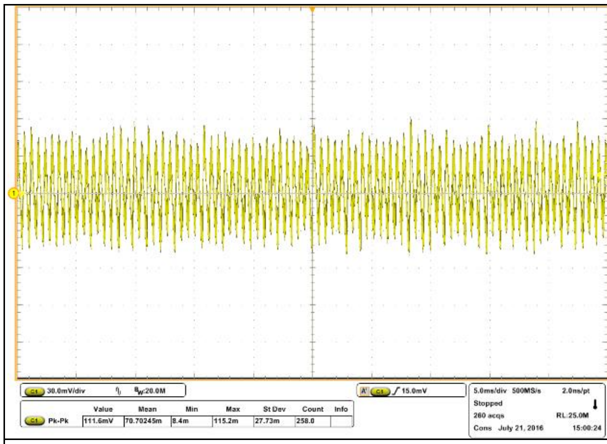
3.6 Ripple and Noise

Measured results taken at the end of a 100 mΩ cable with a 10 µF Aluminum electrolytic capacitor in parallel with a 0.1 µF ceramic capacitor.

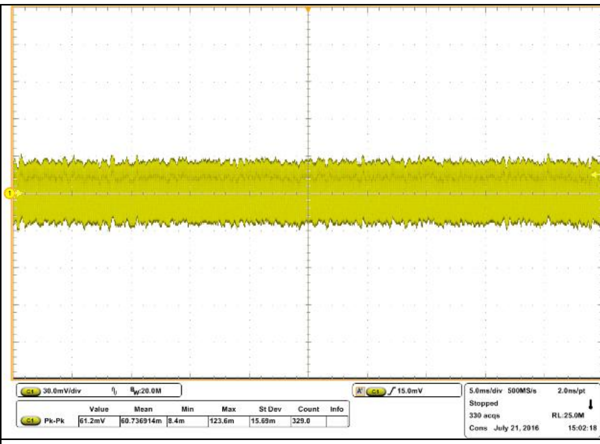
The ripple and noise voltage should be less than 150mV at full input range and load range.

Io(A)	Ripple and Noise (mV)			
	265 Vac, 50 Hz	230Vac, 50Hz	115 Vac, 60 Hz	85 Vac, 50 Hz
0.0	14.4	19.2	18	18
0.1	16.8	19.2	19.2	19.2
0.2	26.4	36	63.6	76.8
0.3	26.4	27.6	72	91.2
0.4	55.2	74.4	93.6	105.6
0.5	70.8	88.8	118.8	110.4
0.6	78	104.4	117.6	45.6
0.7	96	135.6	54	50.4
0.8	40.8	111.6	46.8	45.6
0.9	40.8	58.8	50.4	45.6
1.0	46.8	57.6	55.2	55.2
1.1	44.4	51.6	50.4	56.4
1.2	50.4	54	54	54
1.3	49.2	58.8	61.2	57.6
1.4	51.6	57.6	62.4	60
1.5	54	61.2	62.4	61.2
1.6	58.8	61.2	63.6	63.6
1.7	60	66	64.8	63.6
1.8	62.4	69.6	64.8	68.4

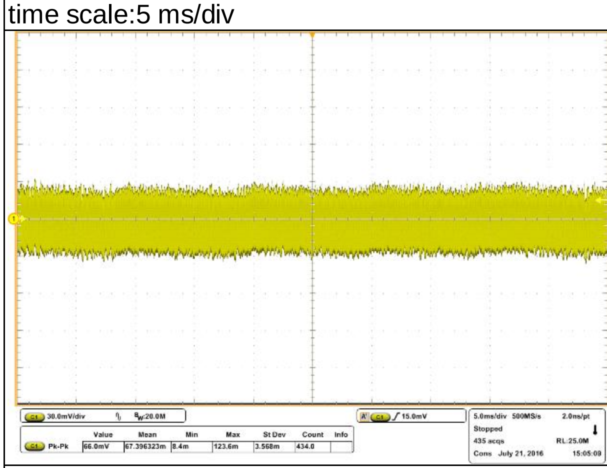
1.9	62.4	67.2	70.8	68.4
2.0	63.6	68.4	67.2	68.4
2.1	60	68.4	67.2	67.2
2.2	61.2	68.4	66	69.6
2.3	57.6	67.2	67.2	73.2
2.4	63.6	66	67.2	67.2
2.5	60	66	67.2	69.6
2.6	62.4	64.8	68.4	69.6
2.7	56.4	66	66	68.4
2.8	61.2	66	64.8	66
2.9	58.8	66	66	67.2
3.0	61.2	68.4	66	69.6



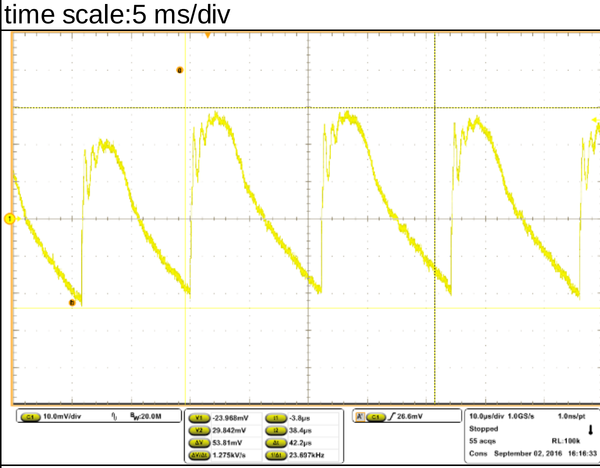
Vin:115 Vac Io: 0.5 A;
Ch1: output ripple voltage, 30mV/div
time scale:5 ms/div



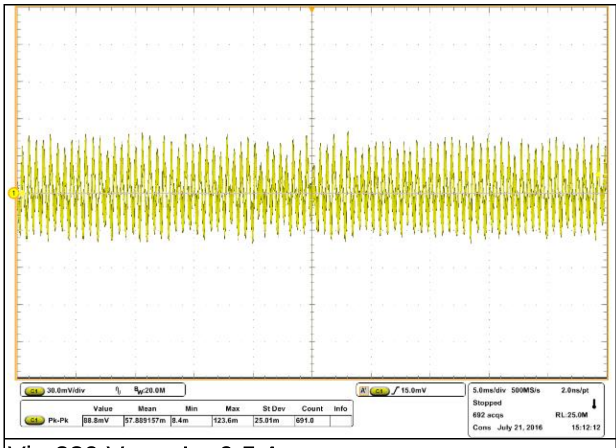
Vin:115 Vac Io: 1.5 A;
Ch1: output ripple voltage, 30mV/div
time scale:5 ms/div



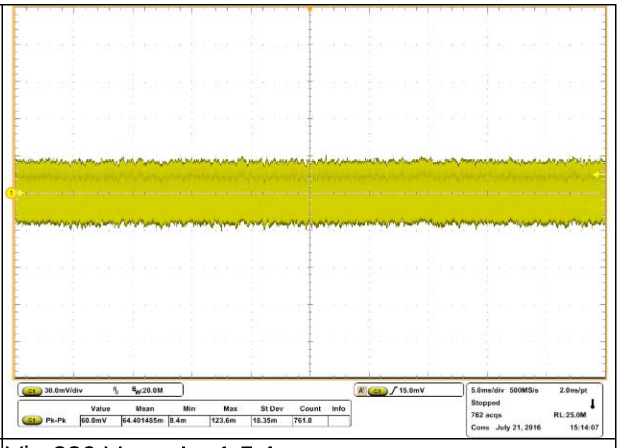
Vin:115 Vac Io: 3 A;
Ch1: output ripple voltage, 30 mV/div
Time scale:5 ms/div



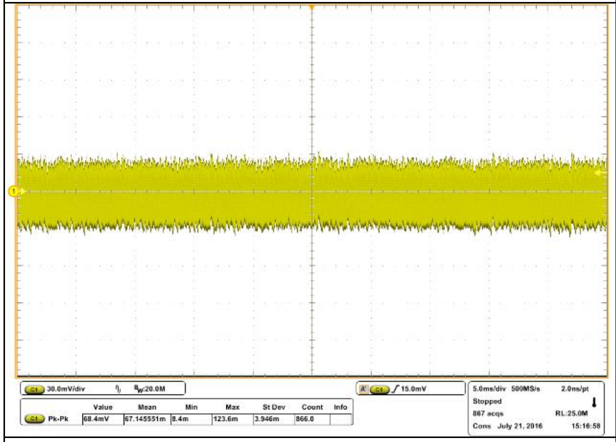
Vin:115 Vac Io: 3 A;
Ch1: output ripple voltage, 10mV/div;
Zoomed waveform, time scale:10 us/div



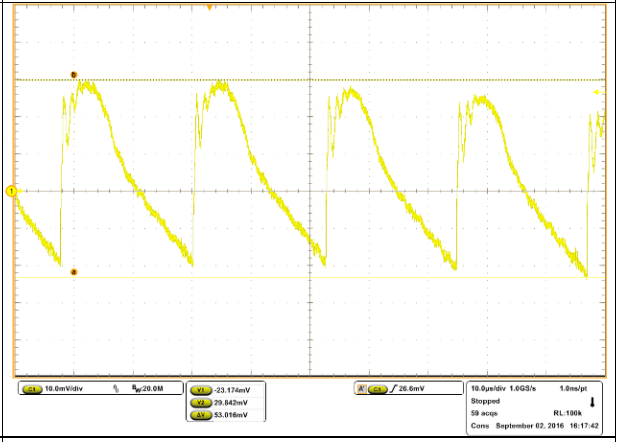
Vin:230 Vac Io: 0.5 A;
Ch1: output ripple voltage, 30 mV/div
Time scale: 5 ms/div



Vin:230 Vac Io: 1.5 A;
Ch1: output ripple voltage, 30 mV/div
Time scale: 5 ms/div



Vin:230 Vac Io: 3A;
Ch1: output ripple voltage, 30mV/div
Time scale:5 ms/div

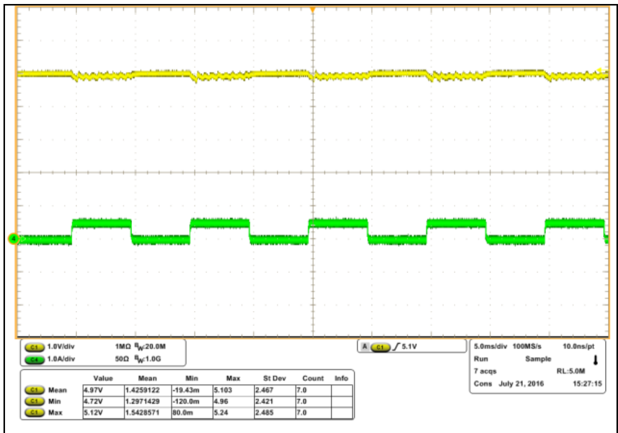


Vin:230 Vac Io: 3 A;
Ch1: output ripple voltage, 10mV/div
Zoomed waveform, time scale:10 us/div

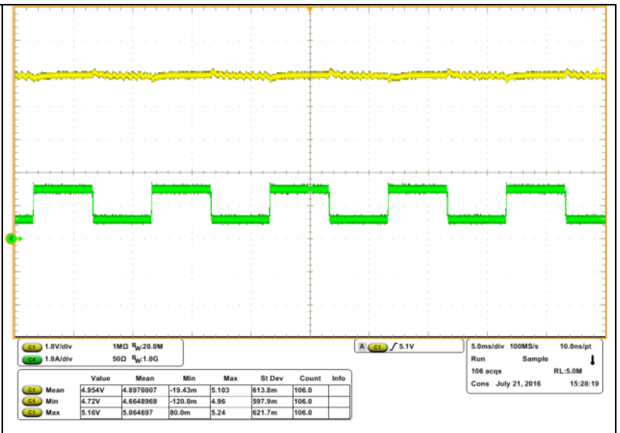
3.7 Dynamic Response

Output voltage was measured at 100mΩ cable end

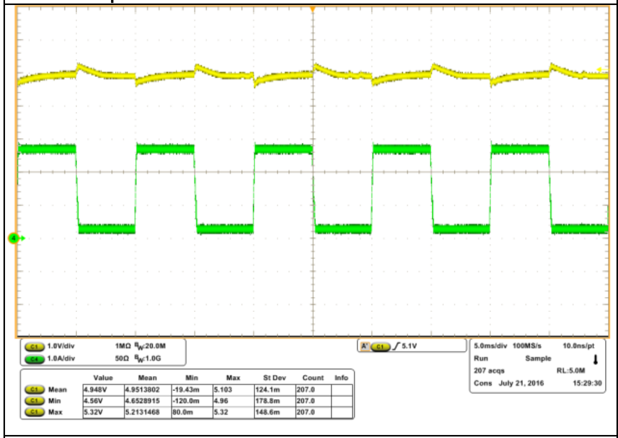
Input voltage	Output current	Min voltage (V)	Max voltage (V)	Mean (V)
115 Vac, 60 Hz	0~500 mA	**4.72**	**5.12**	**4.97**
115 Vac, 60 Hz	20%-50% of full load	**4.72**	**5.16**	**4.954**
115 Vac, 60 Hz	10%-90% of full load	**4.56**	**5.32**	**4.948**
230 Vac, 50 Hz	0~500 mA	**4.72**	**5.12**	**4.973**
230 Vac, 50 Hz	20%-50% of full load	**4.72**	**5.16**	**4.953**
230 Vac, 50 Hz	10%-90% of full load	**4.56**	**5.36**	**4.952**



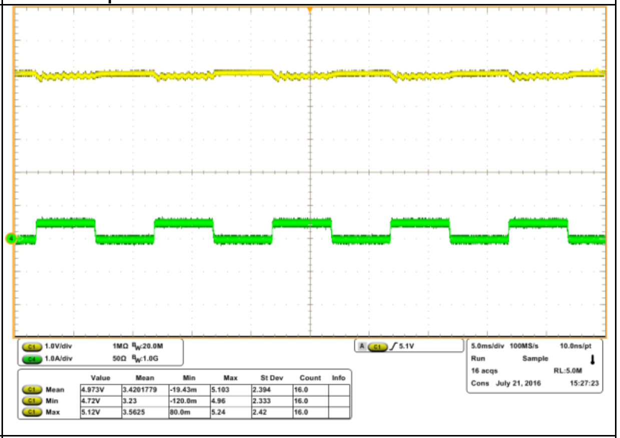
Vin:115 Vac test condition: 0-500mA, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current



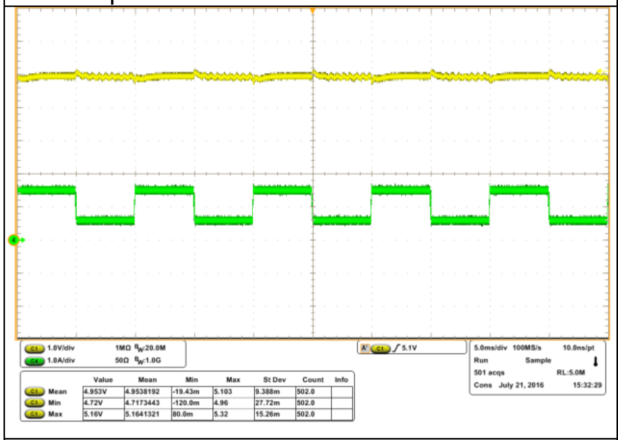
Vin:115 Vac test condition: 20%-50% of full load, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current



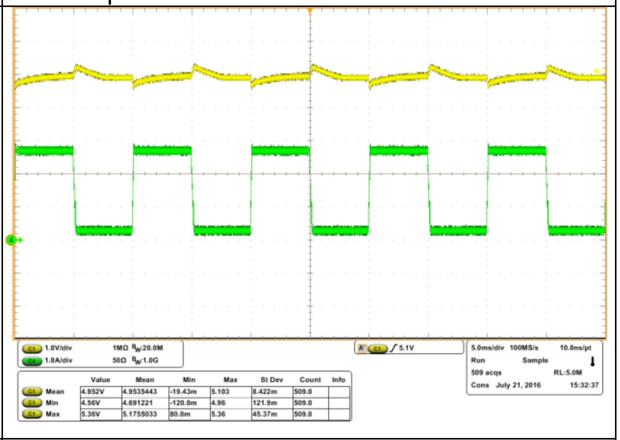
Vin:115 Vac test condition: 10%-90% of full load, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current



Vin:230 Vac test condition: 0-500mA, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current



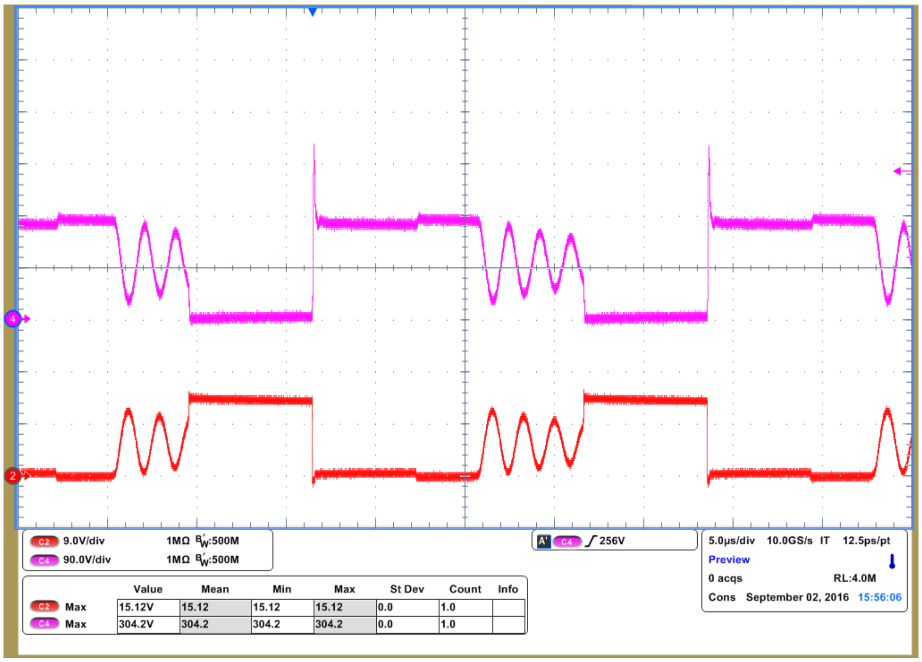
Vin:230 Vac test condition: 20%-50% of full load, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current



Vin:230 Vac test condition: 10%-90% of full load, 1A/us, 10ms cycle
Ch1: output voltage
Ch4: output current

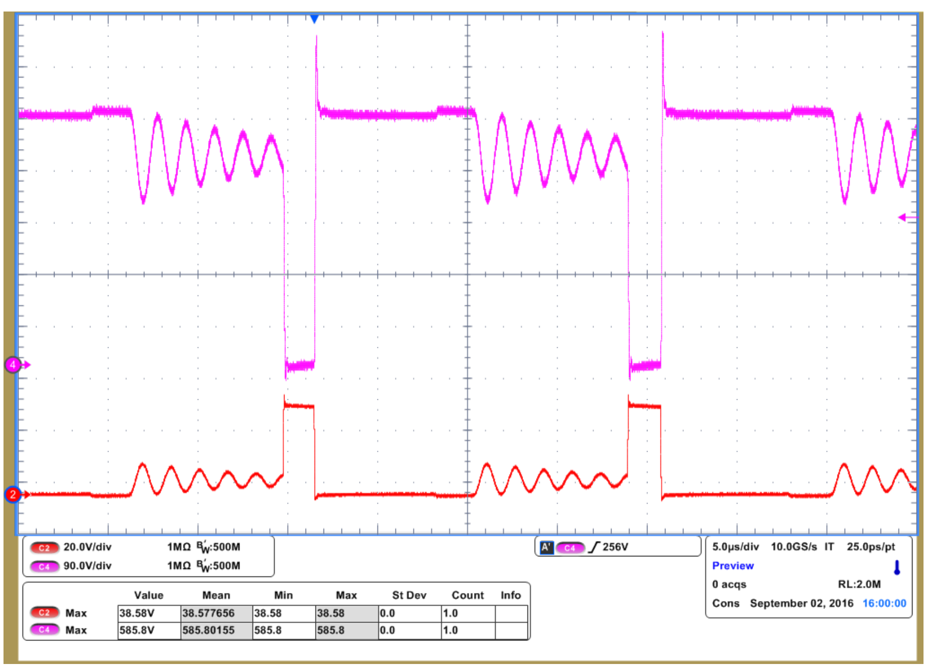
3.8 Switching Node Waveforms

3.8.1 85 Vac, 60 Hz Input, 3 A output



Ch2: Output Rectifier MOSFET drain to source; Ch4: Primary MOSFET drain to source

3.8.2 265 Vac, 60 Hz Input, 3 A output

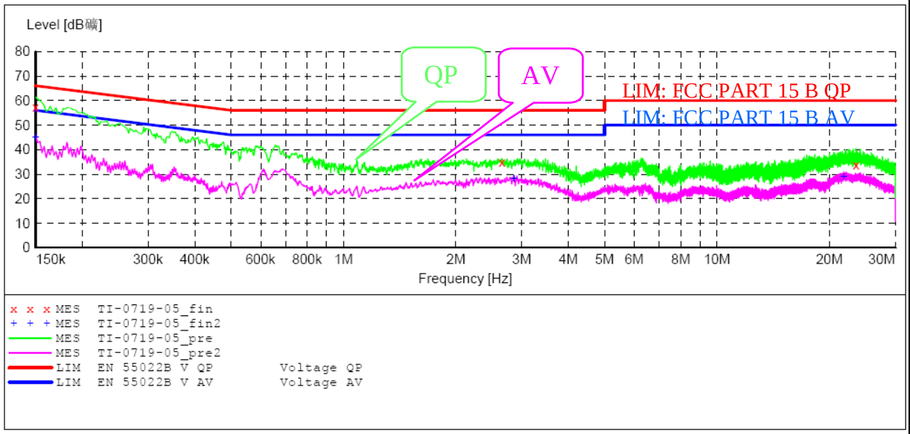


Ch2: Output Rectifier MOSFET drain to source; Ch4: Primary MOSFET drain to source

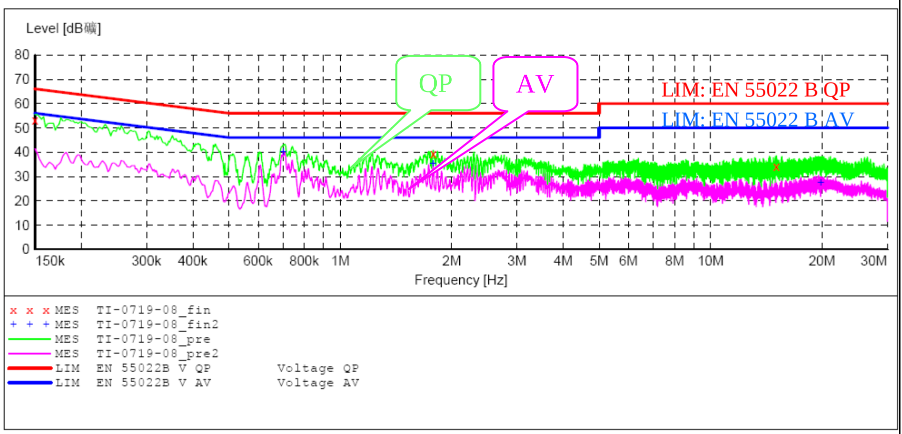
4 EMI Test

4.1 Conducted EMI

Note: 1.67 Ω resistive load, floating output



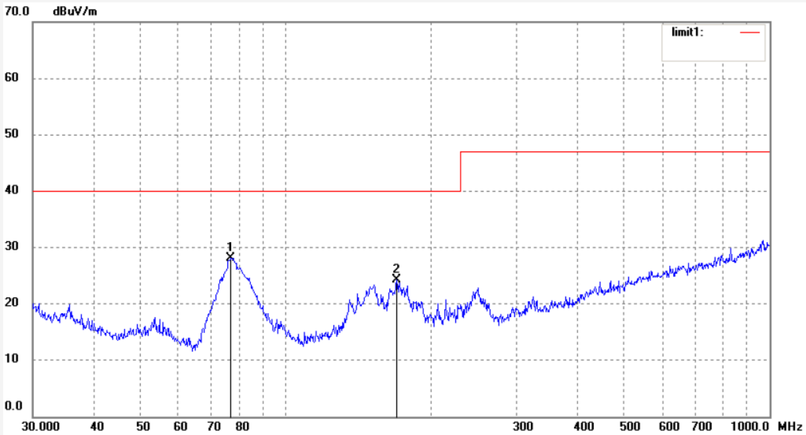
Vin: 120 Vac, 60 Hz



Vin: 230 Vac, 60 Hz

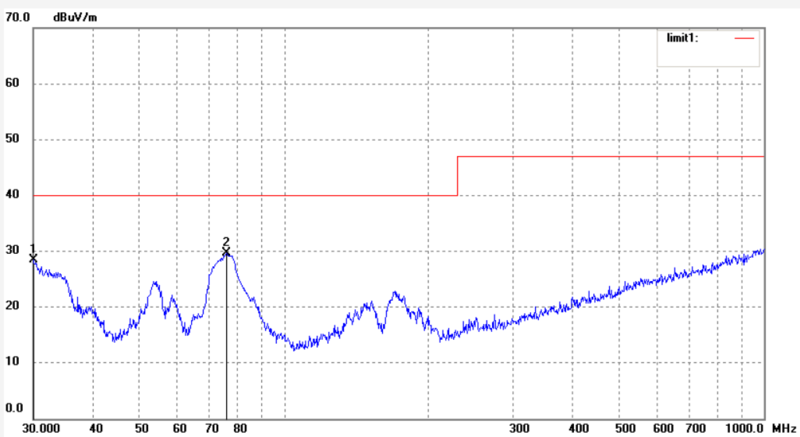
4.2 Radiated EMI

Note: 1.67 Ω resistive load, floating output



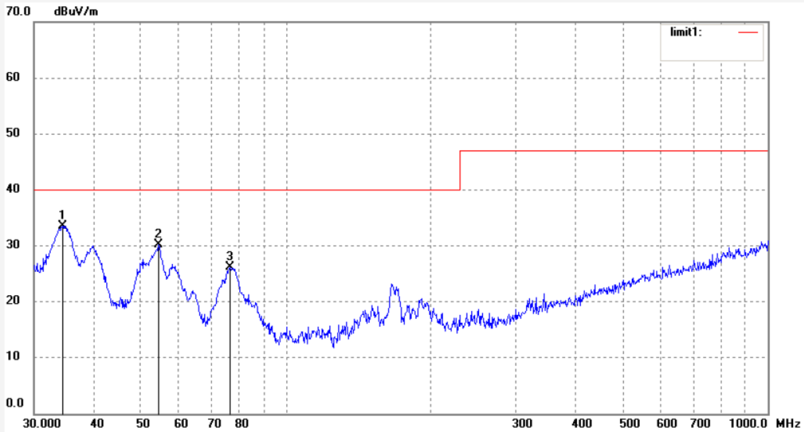
No.	Freq. (MHz)	Reading (dBuV/m)	Factor (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Height (cm)	Degree (deg.)	Remark
1	77.0505	44.81	-16.66	28.15	40.00	-11.85	peak			
2	169.5990	37.94	-13.74	24.20	40.00	-15.80	peak			

Vin: 120 Vac, 60 Hz; Polarization: Horizontal



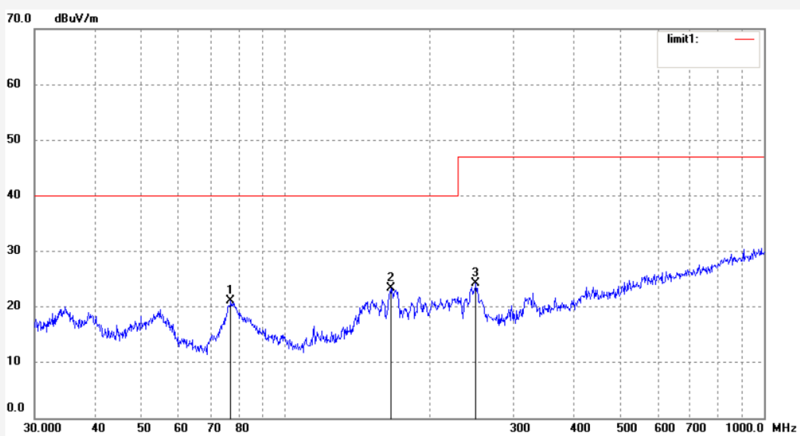
No.	Freq. (MHz)	Reading (dBuV/m)	Factor (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Height (cm)	Degree (deg.)	Remark
1	30.0000	37.32	-8.93	28.39	40.00	-11.61	peak			
2	75.7114	46.42	-16.72	29.70	40.00	-10.30	peak			

Vin: 120 Vac, 60 Hz; Polarization: Vertical



No.	Freq. (MHz)	Reading (dBuV/m)	Factor (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Height (cm)	Degree (deg.)	Remark
1	34.3964	43.69	-10.24	33.45	40.00	-6.55	peak			
2	54.4516	43.06	-12.94	30.12	40.00	-9.88	peak			
3	76.5121	42.77	-16.69	26.08	40.00	-13.92	peak			

Vin: 230 Vac, 50 Hz; Polarization: Horizontal

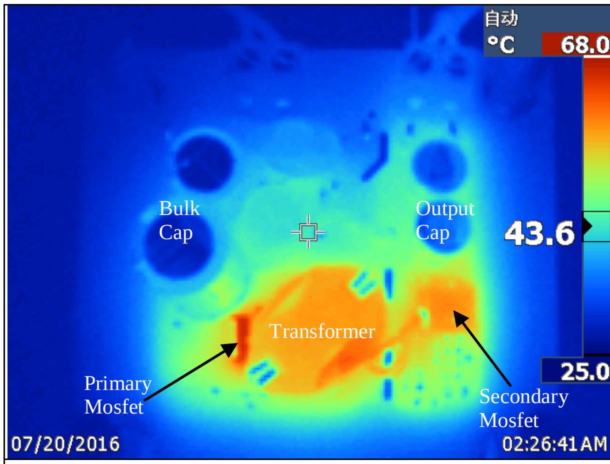


No.	Freq. (MHz)	Reading (dBuV/m)	Factor (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Height (cm)	Degree (deg.)	Remark
1	77.0505	37.76	-16.66	21.10	40.00	-18.90	peak			
2	166.6514	37.60	-14.21	23.39	40.00	-16.61	peak			
3	250.3012	35.06	-10.77	24.29	47.00	-22.71	peak			

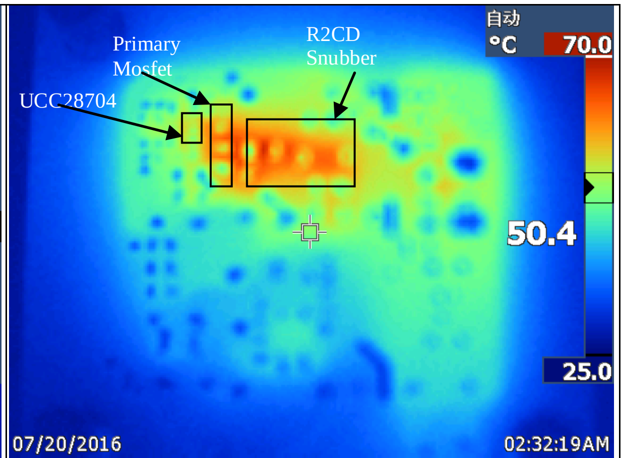
Vin: 230 Vac, 50 Hz; Polarization: Vertical

5 Thermal Test

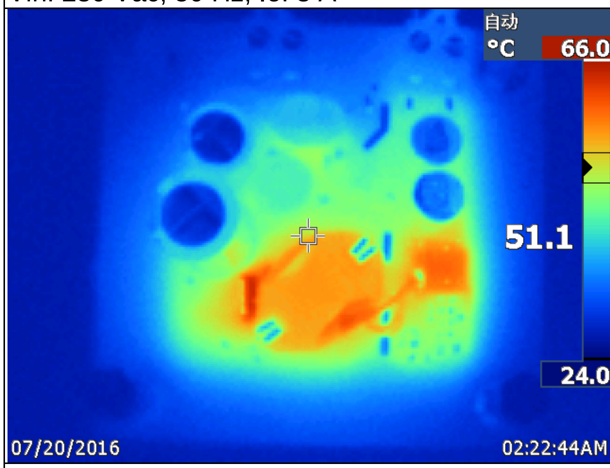
Open frame, ambient temperature 25℃， No air flow



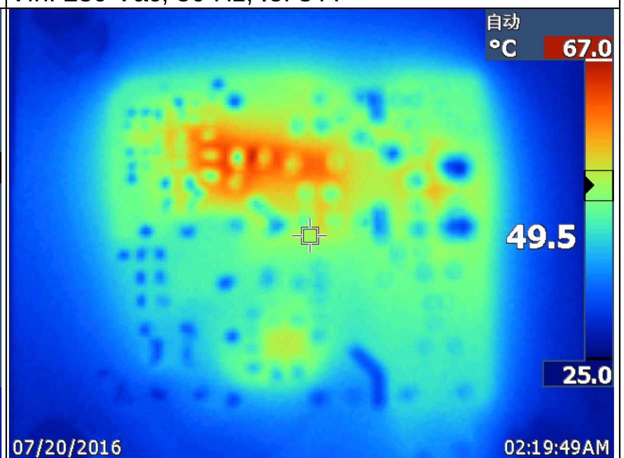
Top View
Vin: 230 Vac, 50 Hz; Io: 3 A



Bottom View
Vin: 230 Vac, 50 Hz; Io: 3 A

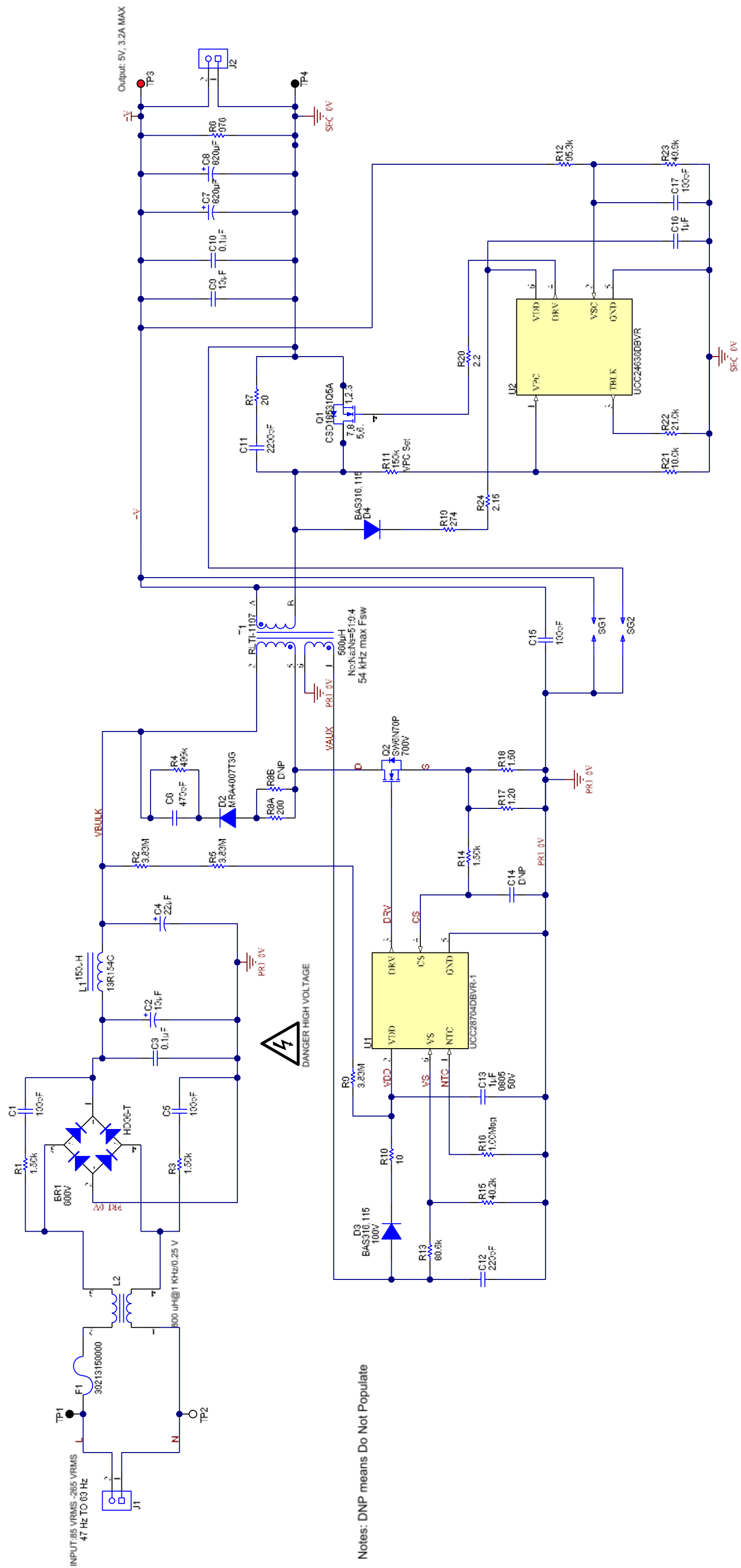


Top View
Vin: 115 Vac, 60 Hz; Io: 3A



Bottom View
Vin: 115 Vac, 60 Hz; Io: 3A

6 Schematic


Output: 5V, 3.2A MAX
UCC24636DBVR
UCC28704DBVR-1
DANGER HIGH VOLTAGE
INPUT:85 VRMS -265 VRMS
47 Hz TO 63 Hz
Notes: DNP means Do Not Populate

7 Key Design Notes

7.1 Design Goal Parameters

Input Voltage:	85 Vac to 265 Vac
Output Voltage:	5 V
Load Current:	3 A
Output Power	15 W
Constant Current:	3.3 A
Desired Switching frequency:	52k Hz (at full load)
Ripple and Noise:	≤150mV
Target efficiency:	88%
EMI target:	EN55022B/FCC PART 15 Class B with maximum 100p Y cap

7.2 Design Tips

UCC28704 is TI's latest highly integrated, 6-pin primary-side regulated PWM controller for designing high efficiency AC-to-DC power supplies with low standby power consumption to comply with global efficiency standards.
UCC24636 is a compact, 6-pin secondary-side synchronous rectifier MOSFET controller and driver for high efficiency flyback converts operating in Discontinuous (DCM) and Transition mode (TM).
Transformer used is RM7, with 3C94 material. The turn ratio Np:Na:Ns = 51:9:4, Primary Inductance Lp= 560uH

7.2.1 Tips to achieve high efficiency

- Synchronization rectification using UCC24636
- Lower the turns of auxiliary winding
- Sandwich winding method for transformer
- Use standard recovery diode MRA4007 for D2 in primary R2CD snubber. Refer to application note snva744.

7.2.2 Tips to improve EMI performance

- Adjust the turns and directions of inside two cancelling windings of transformer
- Connect core of transformer to primary GND
- Use RC (R1,C1,R3,C5) to improve the 4 MHz-10 MHz band
- Use the Si MOSFET SW6N70P instead of CoolMOS or similar
- Use RC snubber (C11, R7) on secondary side to damping the ringing
- Use R2CD snubber with standard recovery diode MRA4007 in primary side
- Use different differential mode choke and common mode choke
- Put small capacitor (C12) across the auxiliary winding
- Keep distance between common mode choke and the noise source such as MOSFET and transformer
- Layout carefully. Refer to the section 10.2 in UCC28704 datasheet for the layout example

7.2.3 Design considerations in Using with synchronous Rectifiers

- To avoid stable issue, special design considerations need to be observed. The key parameters to be considered carefully are t_{BW}, t_{DMAG} and working frequency. Where t_{BW} is the SR bump width, t_{DMAG} is the secondary rectifier conduction time. Refer to section 8.2.2.9 of UCC28704 datasheet for the detail explanation.

7.2.4 Other considerations

- Bias UCC24636 by Drain of Q1 through D4 and R19. This way could guarantee UCC24636 still work even Vout goes down to 2.5V.
- The NTC function is not used in this design. So a 1 Meg resistor is used to make sure the voltage on NTC pin exceed the NTC shut-down threshold. Customer could use NTC function by using NTC (Negative temperature coefficient) resistor.

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