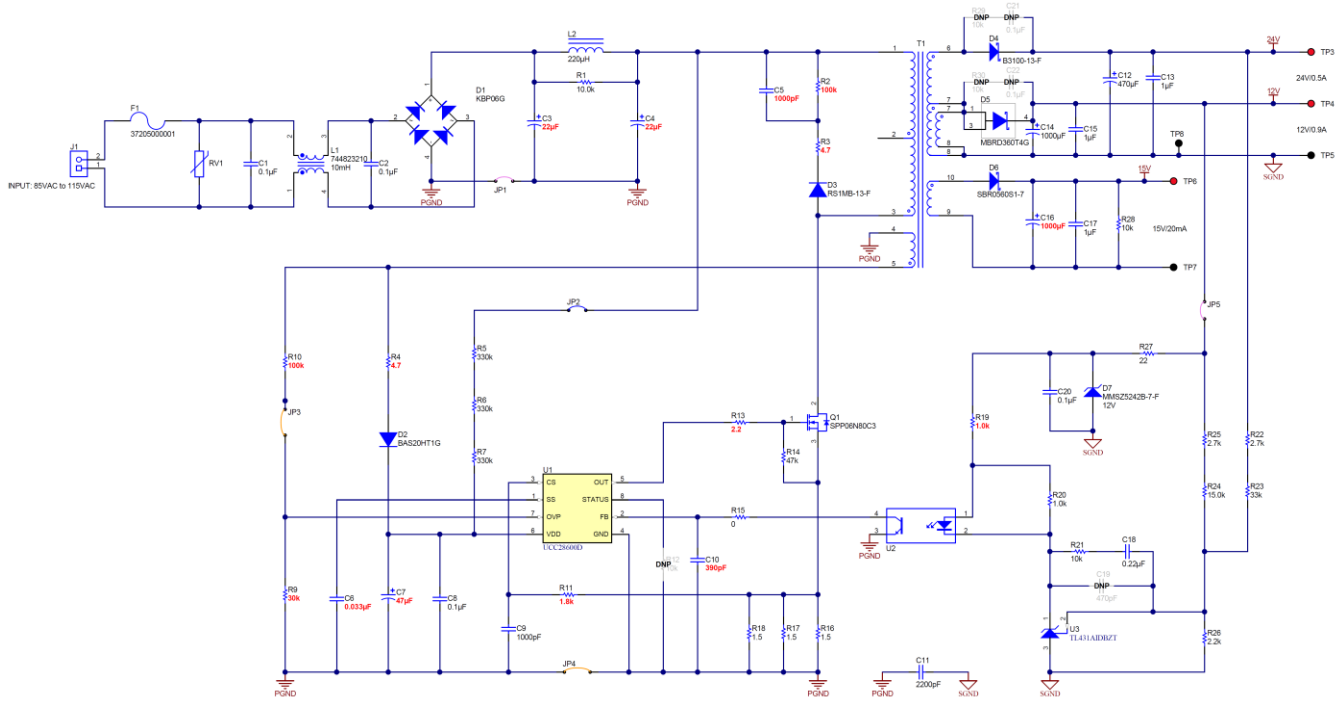
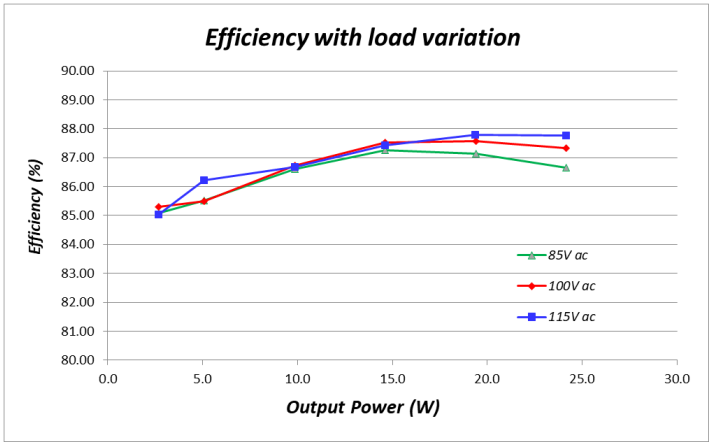
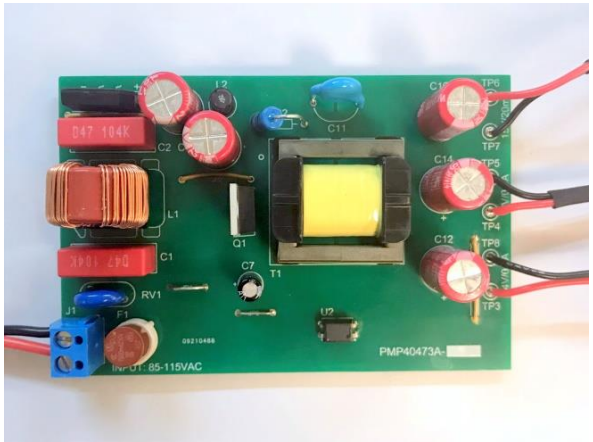
Test Report: PMP40473
85 - 115-Vac input to isolated three-output flyback reference design for washing machines

Description

This is a quasi-resonance(QR) flyback reference design for industrial applications, which illustrates how to convert AC input voltage 85-115 VAC to isolated multiple outputs - 24V/0.5A, 12V/1.0A and 15V/20mA using the UCC28600 Controller. The quasi-resonant switching of the UCC28600 allows this design to achieve peak efficiency up to 87.5%, while the no load losses are less than 82mW.







1 Test Prerequisites

1.1 System Specification

Table 1. System Specification

PARAMETER	SYMBOL	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS					
AC Input voltage	V_{AC}	85	100	115	V
Frequency	F_{AC}	47	-	63	Hz
OUTPUT CHARACTERISTICS					
Output voltage	V_{O1}	-	24	-	V
Output current	I_{O1}		0.5		A
Output voltage	V_{O2}	-	12	-	V
Output current	I_{O2}		1.0		A
Output voltage	V_{O3}	-	15	-	V
Output current	I_{O3}		0.02		A
Output power	P_{OUT}	-	25		W
Output voltage ripple	V_{OUT_RIPPLE}	-	-	520	mV
SYSTEM CHARACTERISTICS					
Switching frequency	f_{SW}	40		130	kHz
Peak efficiency	η_{PEAK}	-	-	87.5	%

1.2 Required Equipment

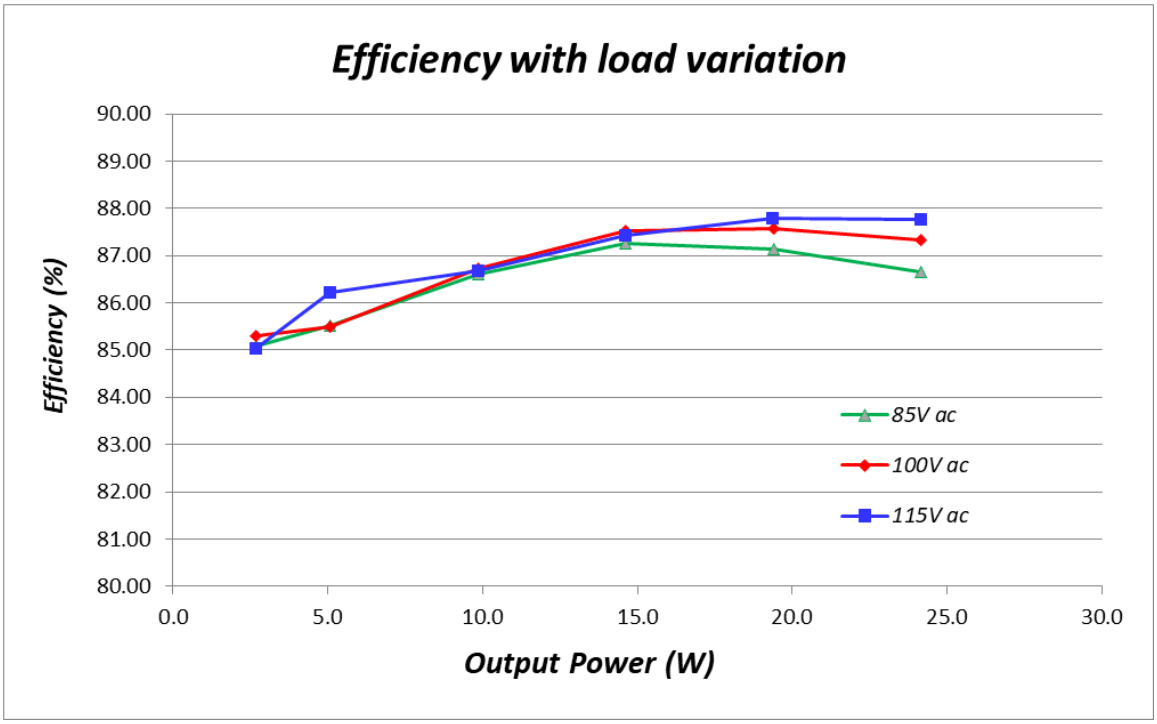
- **AC Voltage Source:** capable of single-phase output AC voltage 85 VAC to 264 VAC, 47 Hz to 63 Hz, adjustable with minimum power rating 300 W. The AC voltage source to be used should meet IEC60950 reinforced insulation requirement.
- **DC Digital Multimeter:** One unit capable of 0-VDC to 450-VDC input range, four digit display preferred;
- **Output Load:** DC load capable of receiving 0 VDC to 20 VDC, 0 A to 15 A, and 0 W to 200 W or greater, with the capability to display things such as load current and load power.
- **Oscilloscope:** capable of 500-MHz full bandwidth, digital or analog, if digital, 5 Gs/s or better.
- **Recommended Wire Gauge:** capable of 5 A, or better than #16 AWG, with the total length of wire less than 8 feet (4 feet input and 4 feet return).

1.3 Considerations

High voltage may still be present after turning off the AC source. Check bulk capacitors (C3, C4) and output terminals with a voltage meter, and make sure the bulk capacitors and output capacitors have completely discharged before handling the PMP40473 board.

2 Testing and Results

2.1 Efficiency Graphs

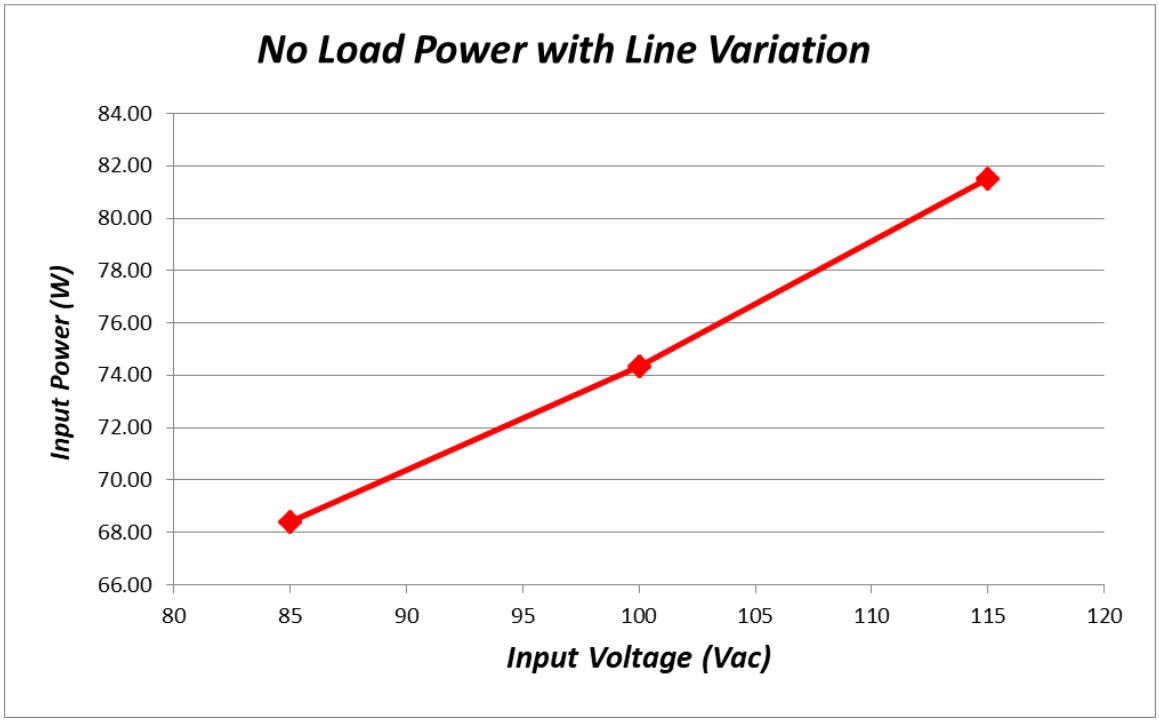


2.2 Efficiency Data

V_{INAC} (V)	I_{INAC} (mA)	P_{IN} (W)	V_{O1} (V)	I_{O1} (A)	V_{O2} (V)	I_{O2}(A)	V_{O3} (V)	I_{O3}(A)	P_{OUT} (W)	Eff(%)
85	74	3.15	24.12	0.05	11.80	0.10	14.74	0.02	2.7	85.08
85	136	5.93	24.07	0.10	11.79	0.20	15.28	0.02	5.1	85.51
85	239	11.37	24.06	0.20	11.78	0.40	16.19	0.02	9.8	86.62
85	337	16.76	24.06	0.30	11.77	0.60	17.24	0.02	14.6	87.25
85	432	22.25	24.07	0.40	11.75	0.80	18.15	0.02	19.4	87.15
85	528	27.87	24.08	0.50	11.73	1.00	19.12	0.02	24.2	86.65
V_{INAC} (V)	I_{INAC} (mA)	P_{IN} (W)	V_{O1} (V)	I_{O1} (A)	V_{O2} (V)	I_{O2}(A)	V_{O3} (V)	I_{O3}(A)	P_{OUT} (W)	Eff(%)
100	63	3.14	24.12	0.05	11.78	0.10	14.73	0.02	2.7	85.31
100	117	5.93	24.07	0.10	11.79	0.20	15.27	0.02	5.1	85.49
100	212	11.35	24.06	0.20	11.77	0.40	16.19	0.02	9.8	86.72
100	295	16.70	24.06	0.30	11.76	0.60	17.22	0.02	14.6	87.51
100	380	22.13	24.06	0.40	11.74	0.80	18.14	0.02	19.4	87.57
100	461	27.63	24.07	0.50	11.71	1.00	19.07	0.02	24.1	87.33
V_{INAC} (V)	I_{INAC} (mA)	P_{IN} (W)	V_{O1} (V)	I_{O1} (A)	V_{O2} (V)	I_{O2}(A)	V_{O3} (V)	I_{O3}(A)	P_{OUT} (W)	Eff(%)
115	55	3.15	24.13	0.05	11.78	0.10	14.73	0.02	2.7	85.04
115	102	5.88	24.13	0.10	11.77	0.20	15.20	0.02	5.1	86.23
115	192	11.35	24.05	0.20	11.76	0.40	16.17	0.02	9.8	86.68
115	267	16.71	24.05	0.30	11.75	0.60	17.08	0.02	14.6	87.42
115	339	22.07	24.06	0.40	11.74	0.80	18.13	0.02	19.4	87.79
115	412	27.49	24.06	0.50	11.72	1.00	18.99	0.02	24.1	87.78

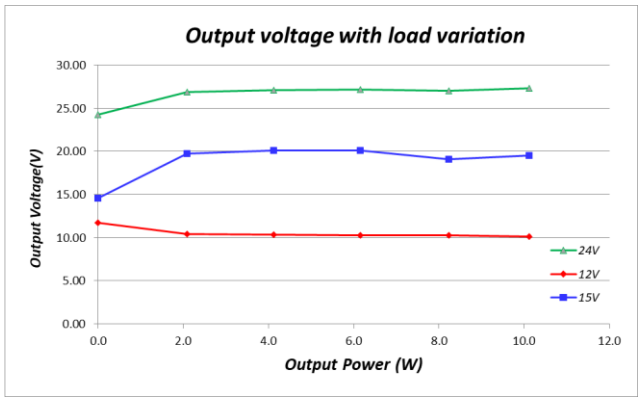
2.3 Standby Power

V_{INAC} (V)	I_{INAC} (mA)	P_{IN} (mW)	V_{O1} (V)	V_{O2} (V)	V_{O3} (V)	P_O (mW)	No Load Power(mW)
85	6.62	68.42	24.23	11.74	14.58	0.00	68.42
100	7.66	74.33	24.23	11.73	14.58	0.00	74.33
115	8.74	81.53	24.00	12.00	15.00	0.00	81.53

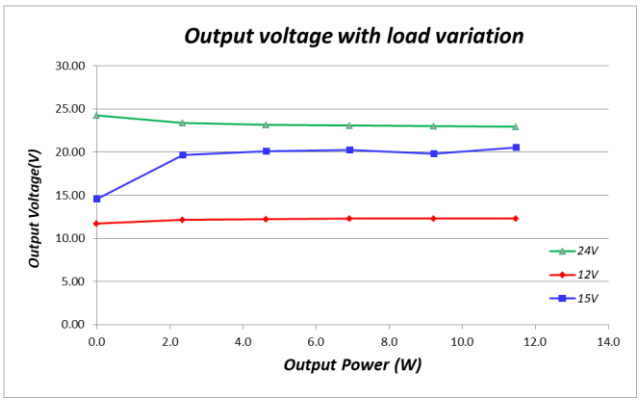


2.4 Cross Regulation

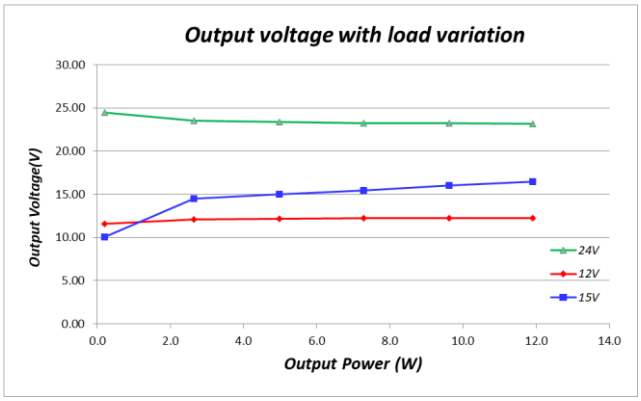
V_{INAC} (V)	I_{O1} (A)	I_{O2}(A)	I_{O3}(A)	V_{O1} (V)	V_{O2} (V)	V_{O3} (V)	P_{OUT} (W)	V_{O1} Regulation(%)	V_{O2} Regulation(%)	V_{O3} Regulation(%)
100	0.00	0.00	0.00	24.22	11.74	14.56	0.0	0.9%	-2.1%	-41.8%
	0.10			23.40	12.15	19.66	2.3	-2.5%	1.2%	-21.4%
	0.20			23.19	12.25	20.11	4.6	-3.4%	2.1%	-19.6%
	0.30			23.06	12.31	20.25	6.9	-3.9%	2.6%	-19.0%
	0.40			23.04	12.31	19.80	9.2	-4.0%	2.6%	-20.8%
	0.50			22.96	12.34	20.54	11.5	-4.3%	2.8%	-17.9%
100	0.00	0.00	0.00	24.22	11.74	14.56	0.0	0.9%	-2.2%	-41.8%
		0.20		26.87	10.42	19.74	2.1	12.0%	-13.2%	-21.0%
		0.40		27.07	10.31	20.13	4.1	12.8%	-14.1%	-19.5%
		0.60		27.17	10.24	20.07	6.1	13.2%	-14.6%	-19.7%
		0.80		27.05	10.28	19.04	8.2	12.7%	-14.3%	-23.8%
		1.00		27.34	10.12	19.49	10.1	13.9%	-15.7%	-22.0%
100	0.00	0.00	0.02	24.49	11.61	10.07	0.2	2.1%	-3.3%	-59.7%
	0.10			23.52	12.09	14.51	2.4	-2.0%	0.7%	-42.0%
	0.20			23.38	12.15	15.00	4.7	-2.6%	1.3%	-40.0%
	0.30			23.26	12.21	15.46	7.0	-3.1%	1.7%	-38.2%
	0.40			23.24	12.21	16.00	9.3	-3.2%	1.8%	-36.0%
	0.50			23.16	12.24	16.44	11.6	-3.5%	2.0%	-34.2%
100	0.00	0.00	0.02	24.49	11.61	10.07	0.2	2.1%	-3.3%	-59.7%
		0.20		26.40	10.65	13.78	2.1	10.0%	-11.2%	-44.9%
		0.40		26.71	10.48	14.31	4.2	11.3%	-12.7%	-42.8%
		0.60		26.84	10.40	14.87	6.2	11.8%	-13.3%	-40.5%
		0.80		26.84	10.38	15.39	8.3	11.8%	-13.5%	-38.4%
		1.00		27.15	10.22	15.69	10.2	13.1%	-14.9%	-37.2%



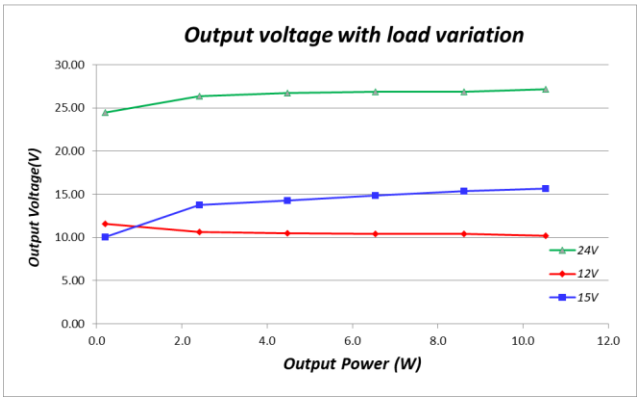
Output voltages variation with I_{O2} = 0A, I_{O3} = 0A



Output voltages variation with I_{O1} =0A, I_{O3} = 0A



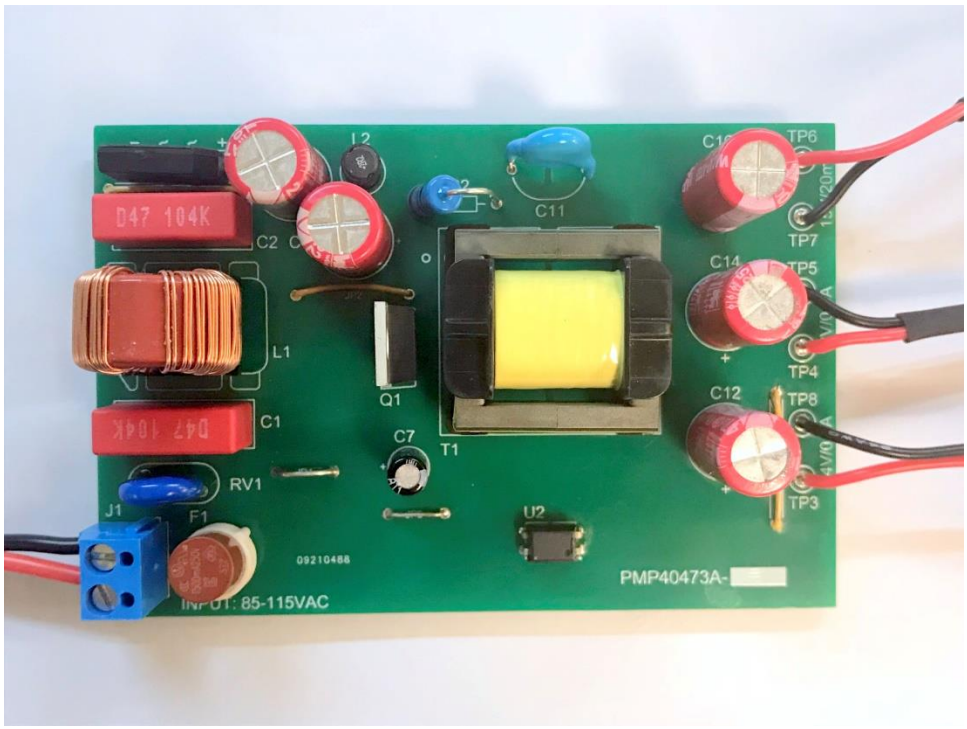
Output voltages variation with I_{O1} = 0A, I_{O3} = 20mA



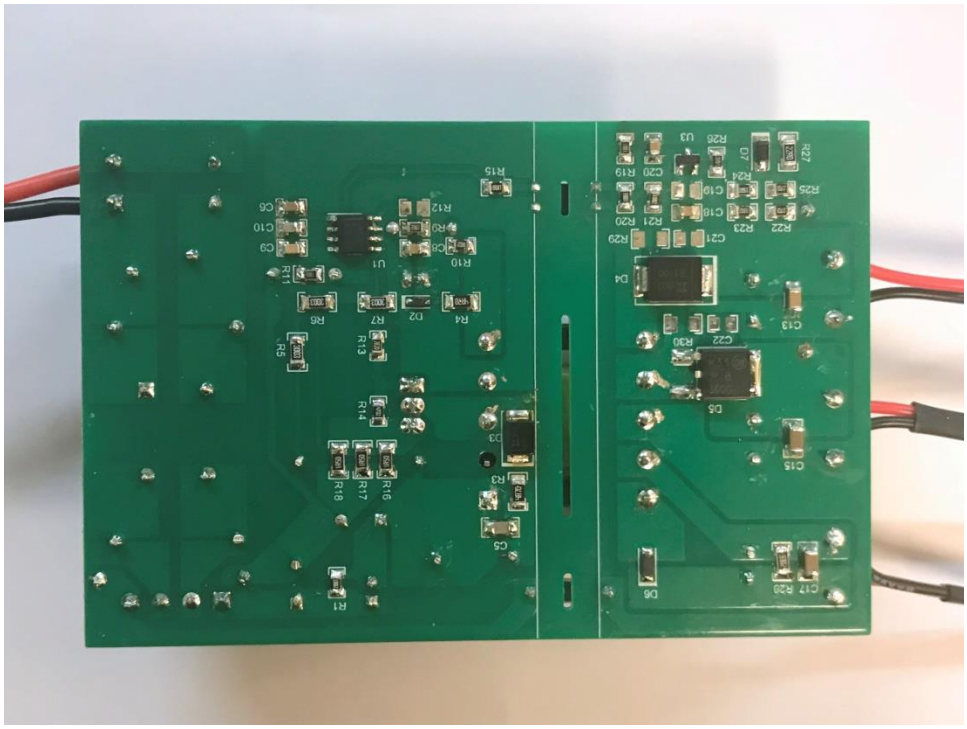
Output voltages variation with I_{O2} = 0A, I_{O3} = 20mA

2.5 Dimensions

The photos below show the top and bottom view of the PMP40473 board. Board dimension is 100mm x 66mm.



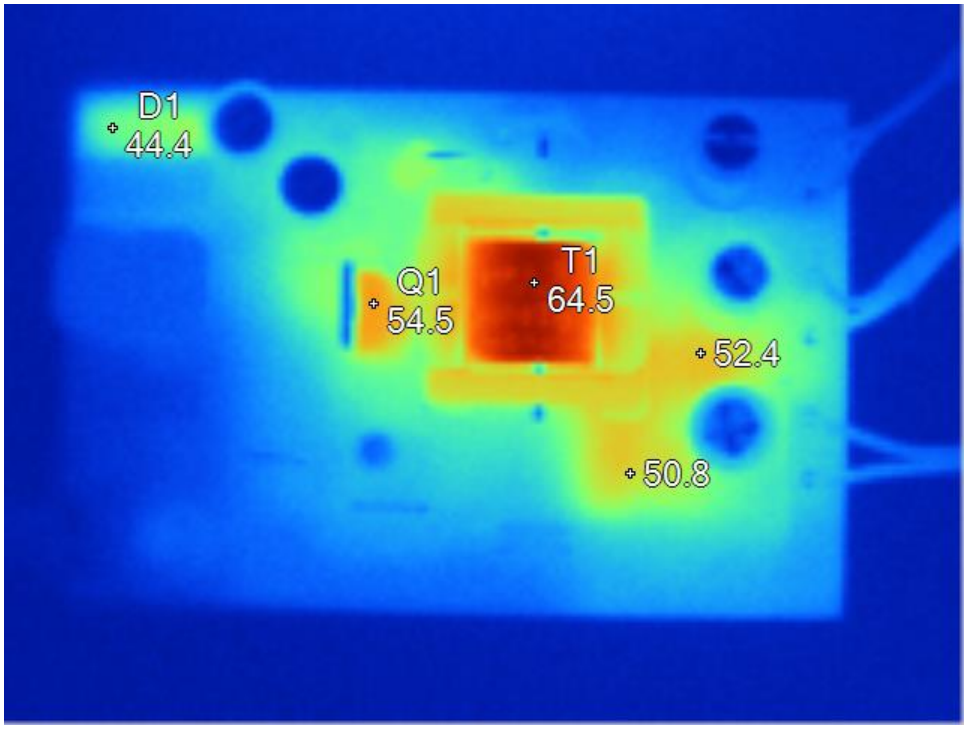
Top side



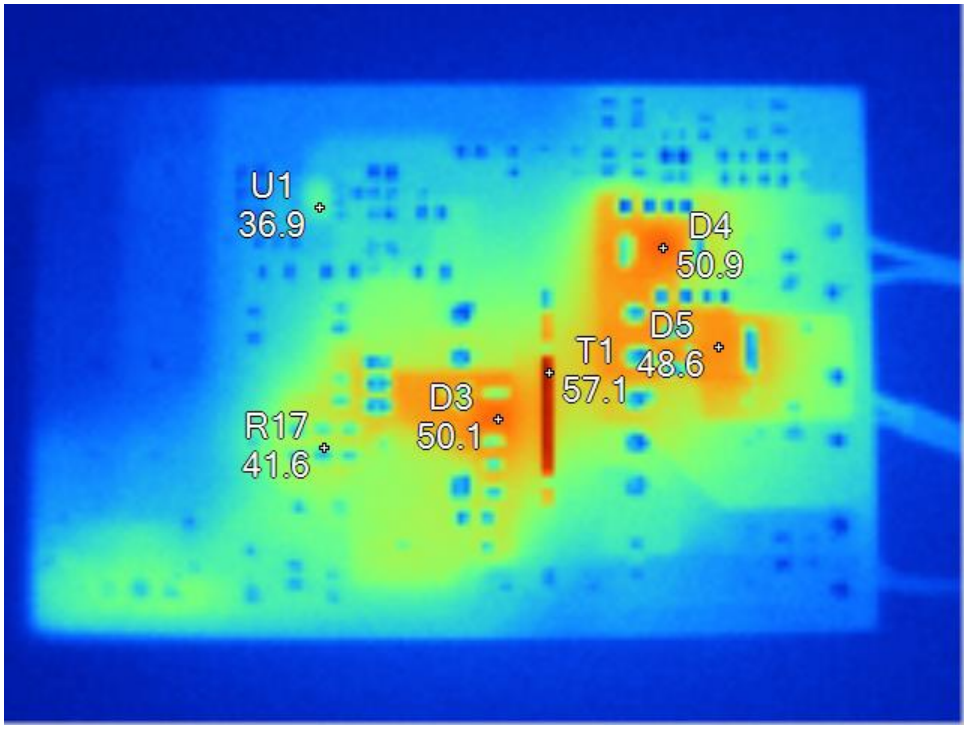
Bottom side

2.6 Thermal Images

The thermal images below show a top view and bottom view of the board. The ambient temperature was 25ºC with no forced air flow. The input voltage was 100Vac/60Hz and the outputs were loaded with 24V/0.5A, 12V/1.0A and 15V/0.02A.



Top side

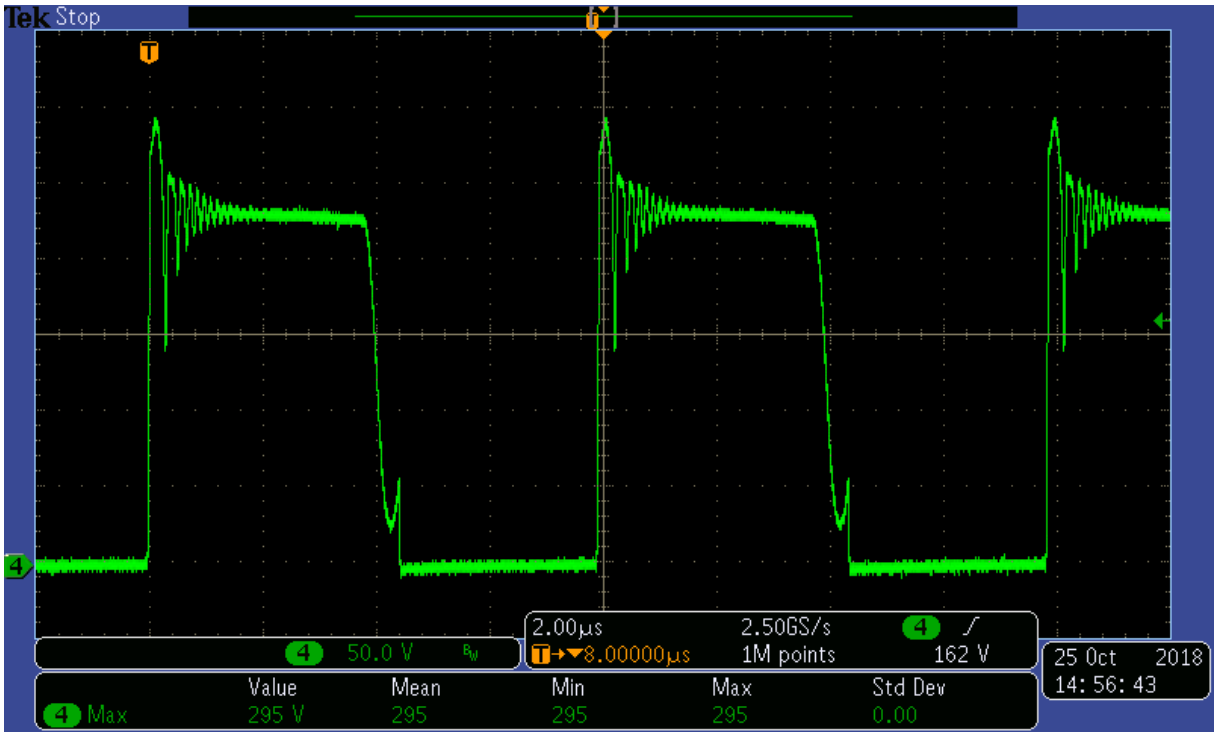


Bottom side

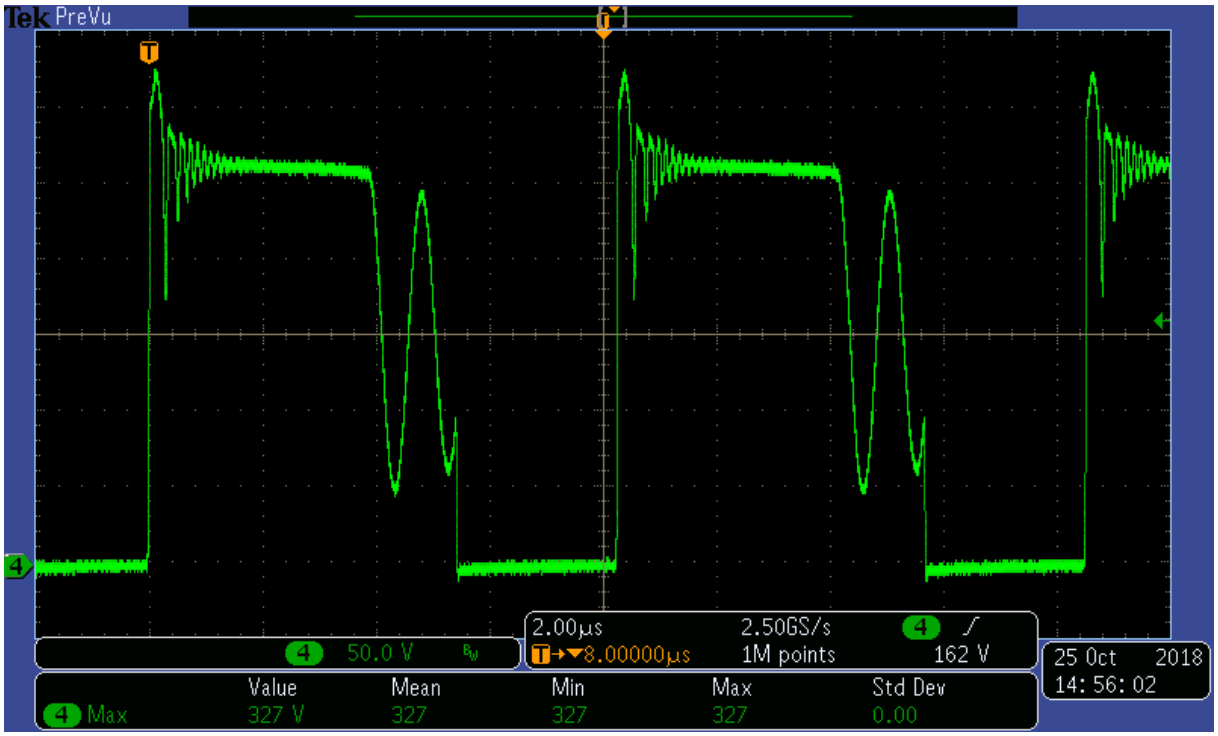
3 Waveforms

3.1 Switch Node

The photo below shows the switch node voltage (Q1 Vds). The input is 85VAC and the outputs are full loaded.

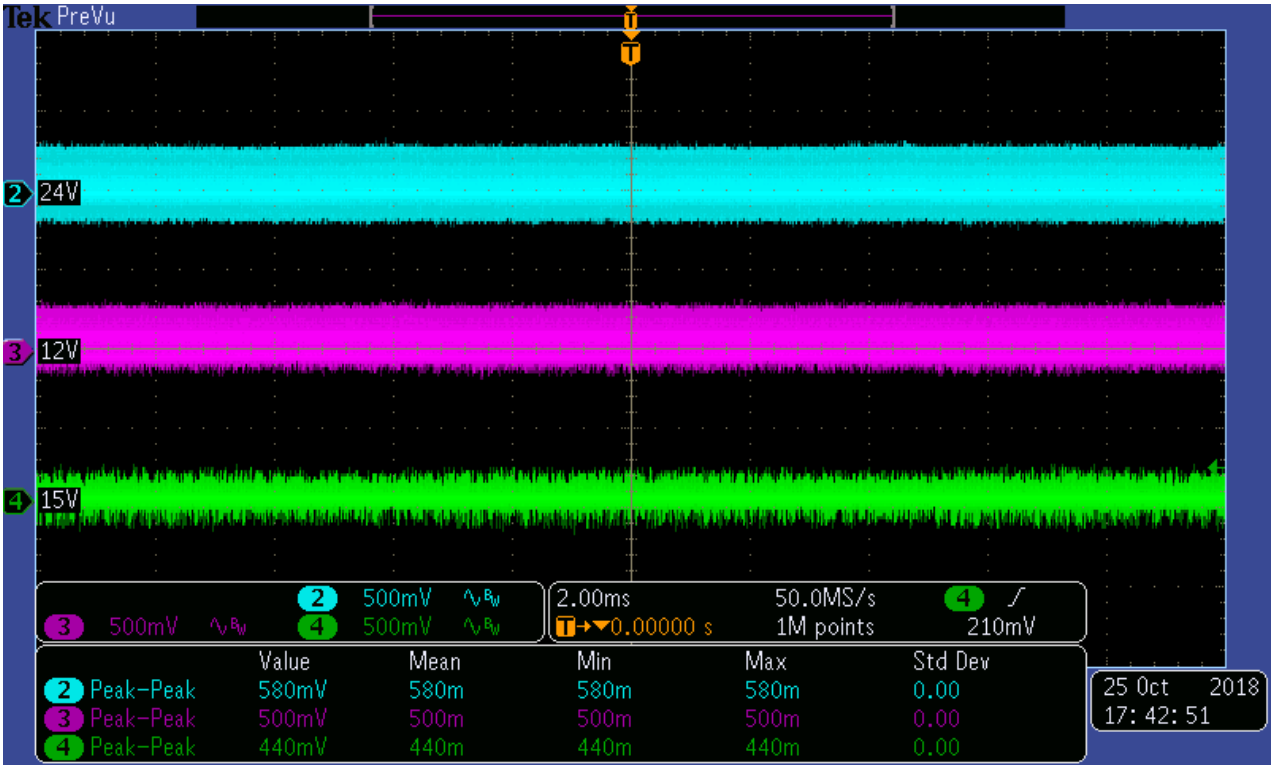


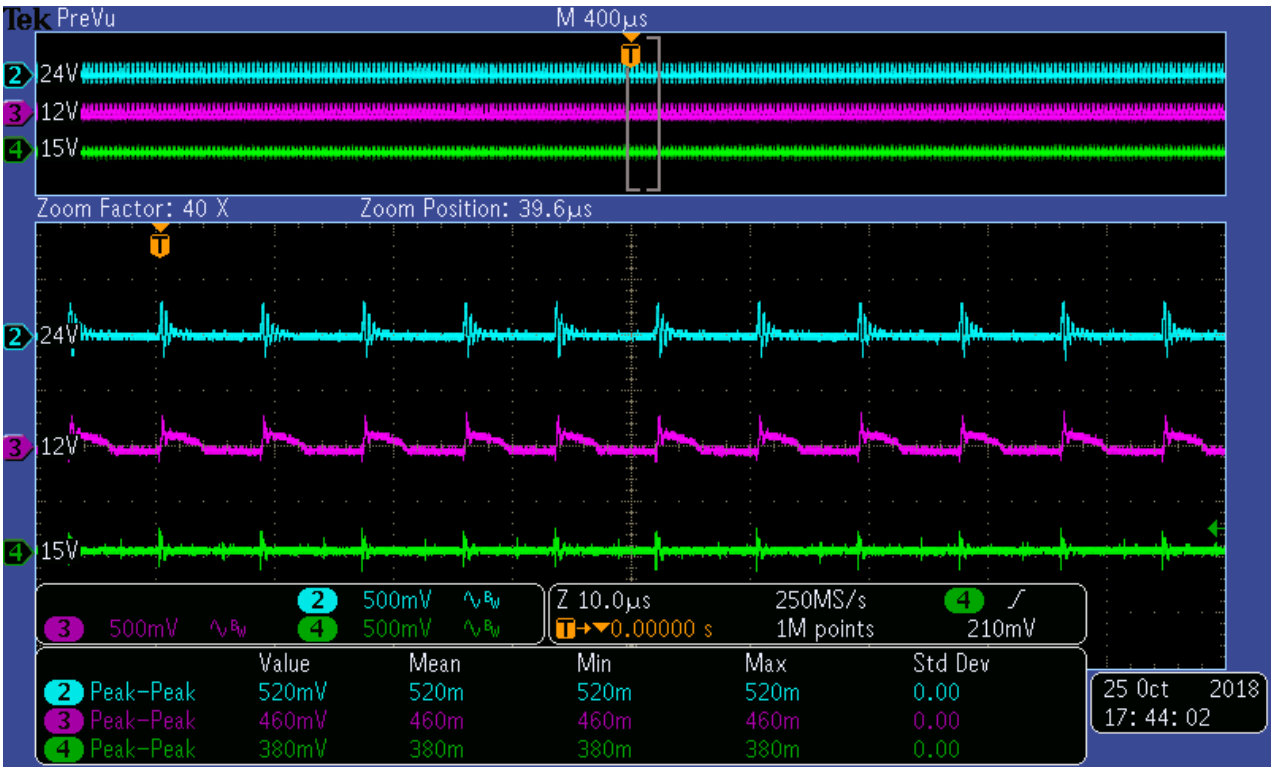
The photo below shows the switch node voltage (Q1 Vds). The input is 115VAC and the outputs are full loaded.



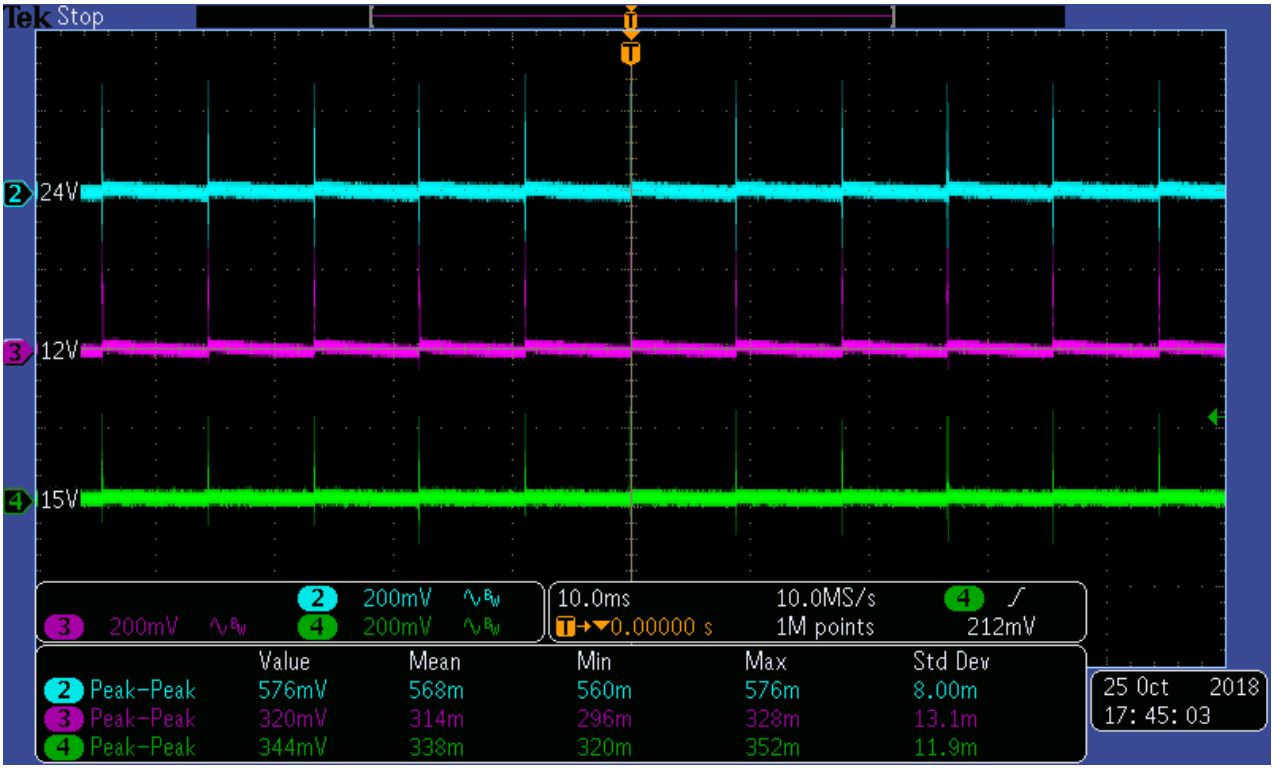
3.2 Output Voltage Ripple

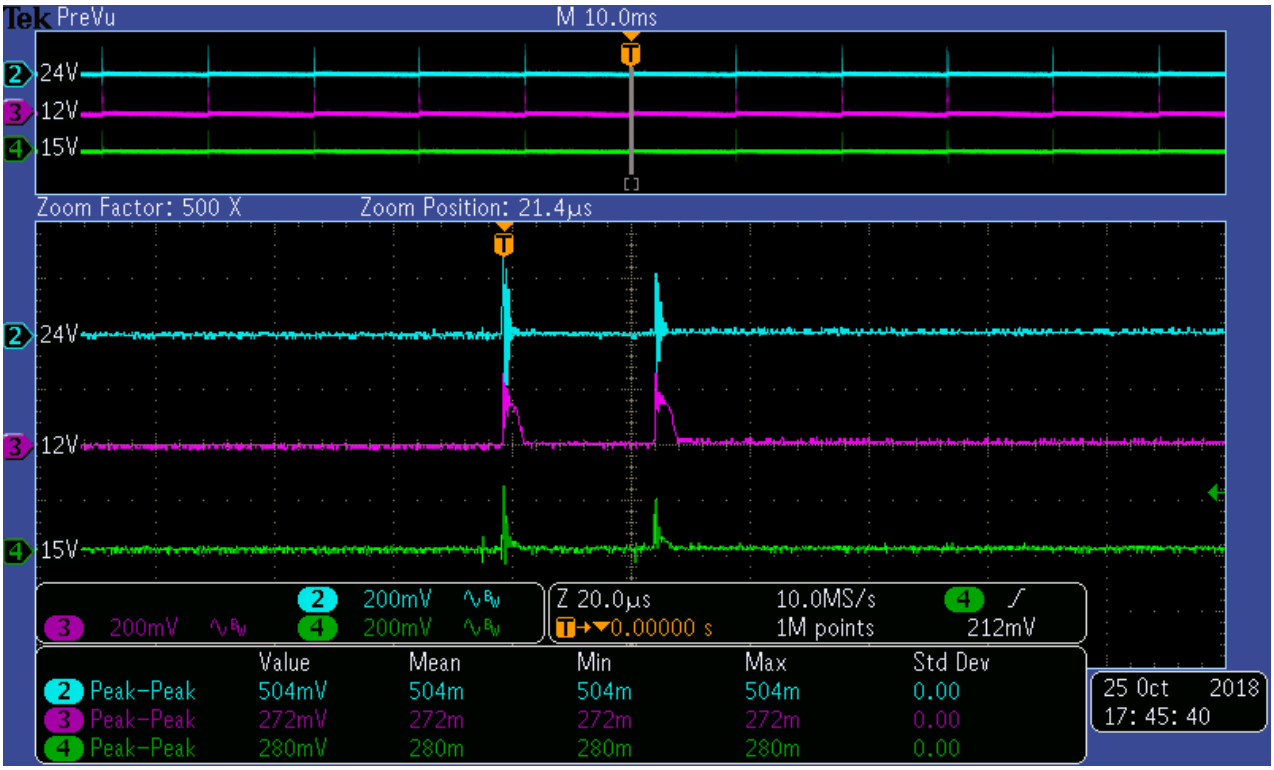
The output ripple voltage waveform (in AC coupling) is shown in the image below. The image was taken with output full loaded and the input voltage set to 100VAC/60Hz. (CH2: 24V output voltage, CH3: 12V output voltage, CH4: 15V output voltage).





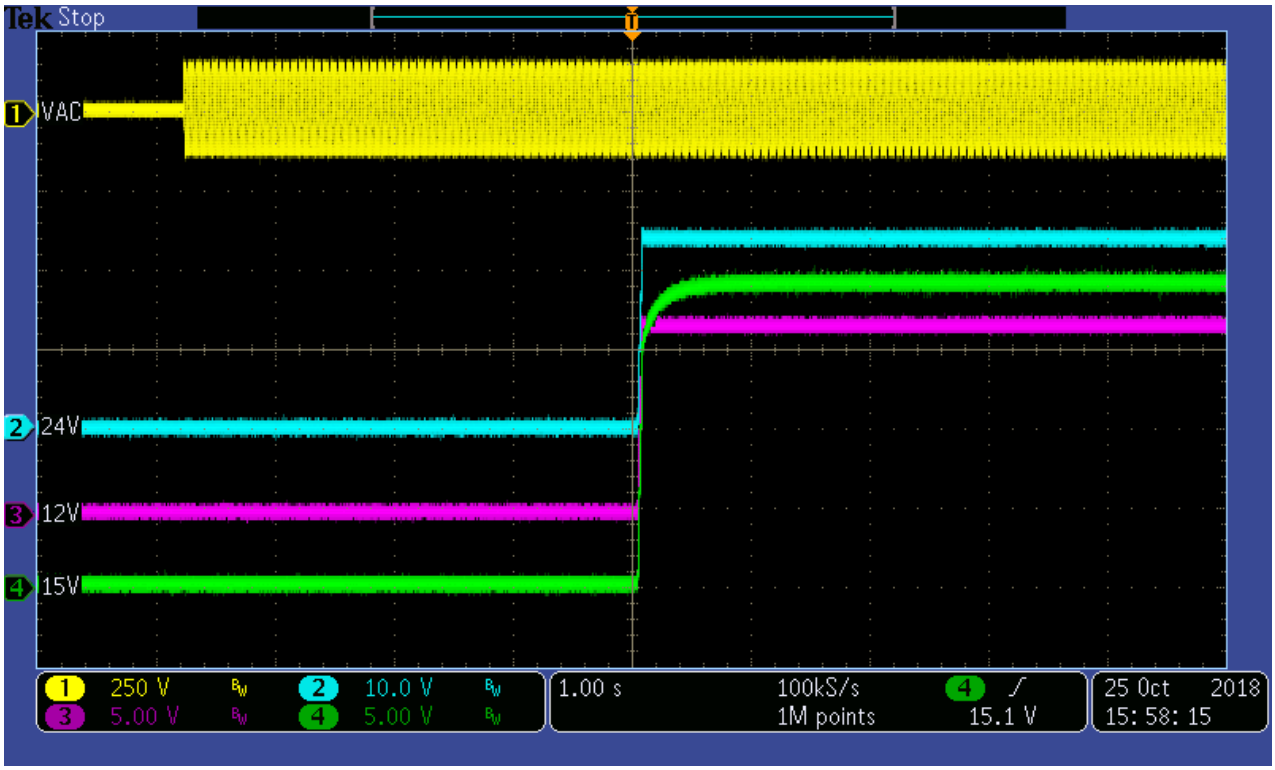
The output ripple voltage is shown in the figure below. The image was taken with no load output and the input voltage set to 100VAC/60Hz. (CH2: 24V output voltage, CH3: 12V output voltage, CH4: 15V output voltage).



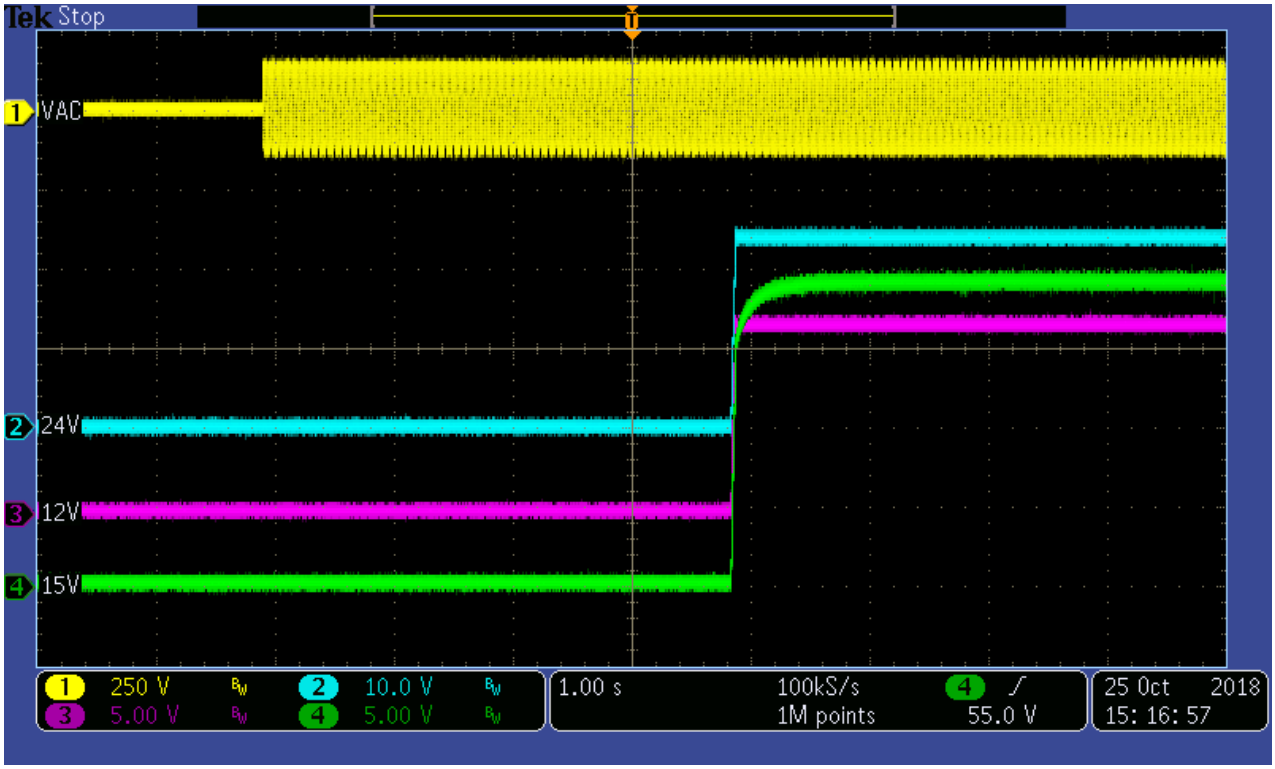


3.3 Start-up Sequence

The photo below shows the output voltage startup waveform after the application of 100VAC/60Hz and all outputs loaded to 0A. (CH1: Input Voltage, CH2: 24V output voltage, CH3: 12V output voltage, CH4: 15V output voltage)



The photo below shows the output voltage startup waveform after the application of 100VAC/60Hz and output full loaded. (CH1: Input Voltage, CH2: 24V output voltage, CH3: 12V output voltage, CH4: 15V output voltage)



3.4 Shutdown

The photo below shows the input voltage waveform after the input voltage disconnects at full load conditions. (CH1: Input Voltage, CH2: 24V output voltage, CH3: 12V output voltage, CH4: 15V output voltage)

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