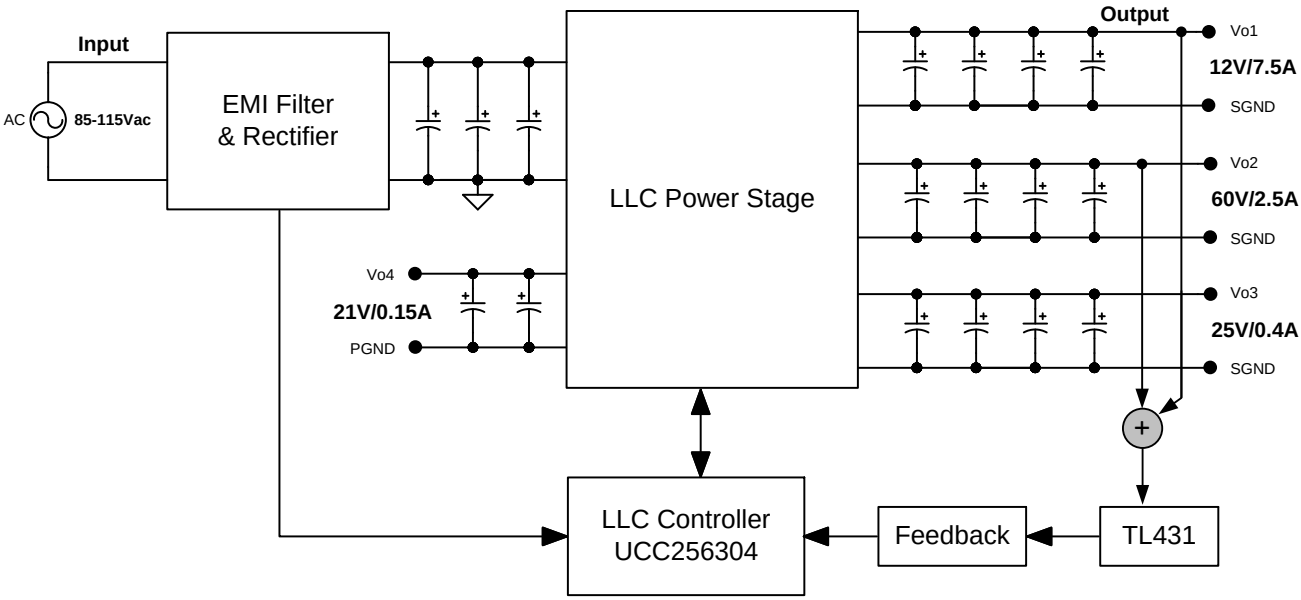
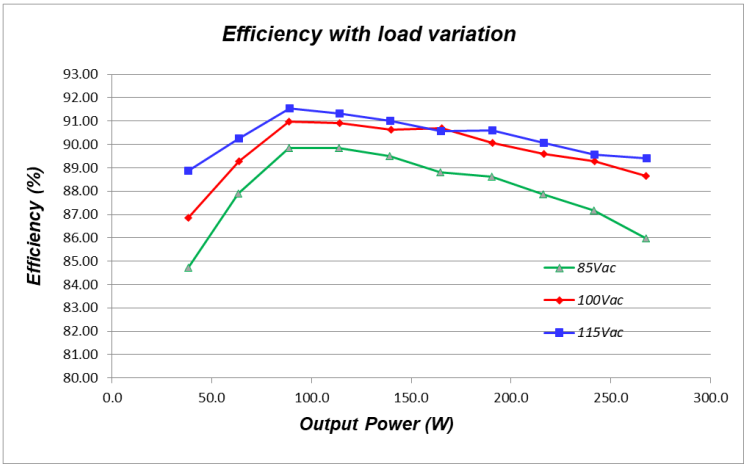
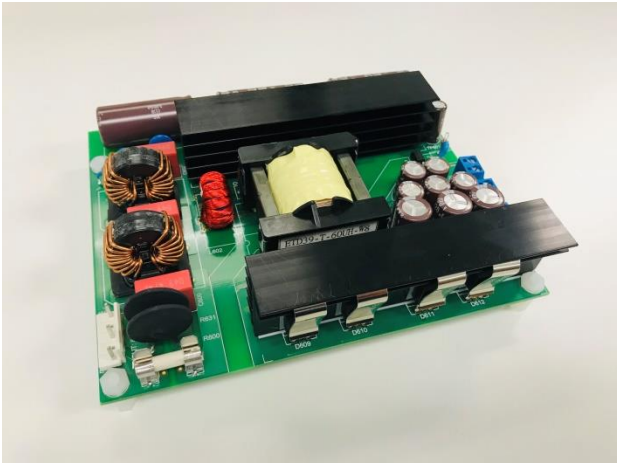
Test Report: PMP40482
250-W Single Stage LLC Converter With Multiple Outputs Reference Design

Description

This is a single-stage reference design converting AC input voltage 85-115 V to three isolated outputs - 12 V/7.5 A, 60 V/2.5 A, 25 V/0.4 A with one non-isolated output 21 V/0.15 A using the UCC256304 resonant controller. The design is for industrial applications and the bill of materials (BOM) cost is highly optimized with the single-stage structure and the use of the resonant controller. The high voltage startup, integrated driver and burst operation of UCC256304 allows minimum use of discrete components and eliminates the need for an auxiliary supply.







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}		60		Hz
OUTPUT CHARACTERISTICS					
Output Voltage - 1 (Secondary)	V_{OUT1}	12	12.6	13.6	V
Output Current - 1	I_{OUT1}		4.7	7.5	A
Output Voltage - 2 (Secondary)	V_{OUT2}	53	60	70	V
Output Current - 2	I_{OUT2}		1.8	2.5	A
Output Voltage - 3 (Secondary)	V_{OUT3}	22	25	33	V
Output Current - 4	I_{OUT3}		0.24	0.4	A
Output Voltage - 4 (Primary)	V_{OUT4}	20	22	27	V
Output Current - 4	I_{OUT4}		0.15		A
Output Power	P_{OUT}	-	180	250	W
Standby Power	P_{SB}	-	-	0.5	W
SYSTEM CHARACTERISTICS					
Switching frequency	f_{SW}	53	100	160	kHz
Peak efficiency	η_{PEAK}	-	-	92	%

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; and one unit capable of 0-VDC to 20-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.
- **Current Meter**: DC, optional in case the load has no display, one unit, capable of 0 A to 15 A. If you want to measure standby power, the current meter needs to have a time averaging function.
- **Oscilloscope:** capable of 500-MHz full bandwidth, digital or analog, if digital, 5 Gs/s or better.
- **Recommended Wire Gauge:** capable of 15 A, or better than #14 AWG, with the total length of wire less than 8 feet (4 feet input and 4 feet return).

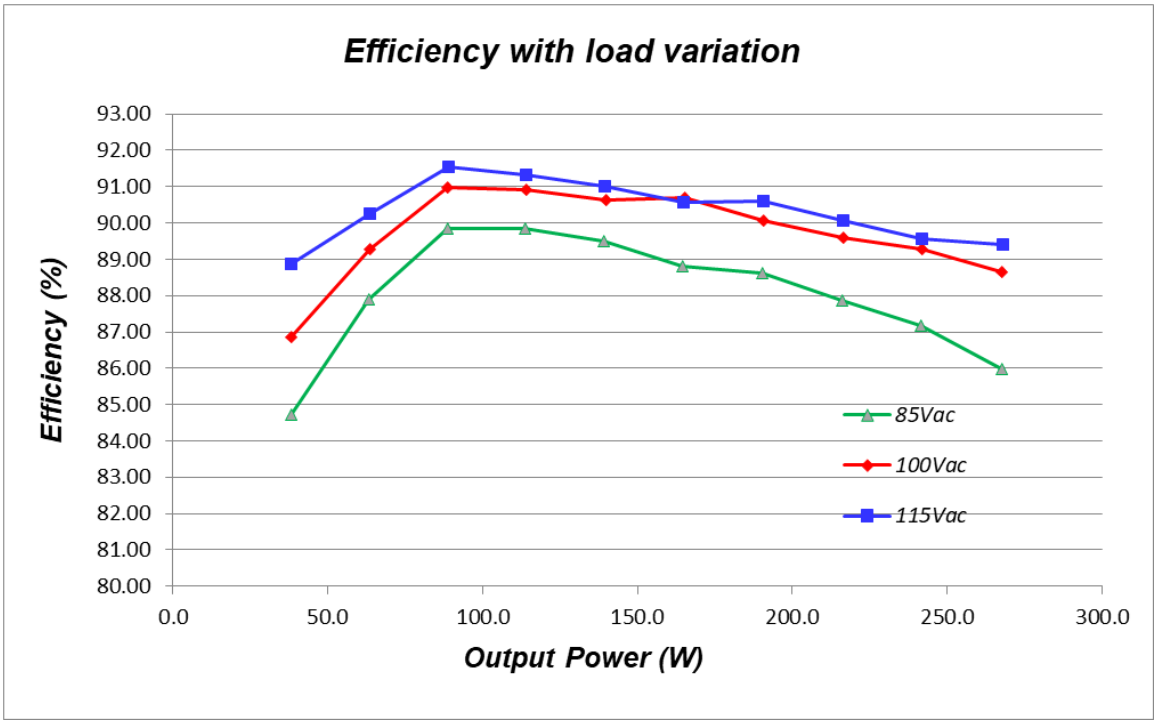
1.3 Considerations

High voltage may still be present after turning off the AC source. Check bulk capacitors and output terminals with a voltage meter, and make sure the bulk capacitors (C605-C607) and output capacitors have completely discharged before handling the PMP40482A board.

2 Testing and Results

2.1 Efficiency Graphs

The converter efficiency is shown in the figures below for 85VAC-115VAC input with load variation.



2.2 Efficiency Data

Below is the efficiency data for 85VAC-115VAC input with load conditions as below

Condition	Load			
	Vo1 = 12V	Vo2 = 60V	Vo3 = 25V	Vo4 = 21V
1. Maximum	7.5A	2.5A	0.4A	0.15A
2. Stationary Operation	6.0A	1.76A	0.4A	0.1A
3. Burst Mode	0.7A	No load	No load	No load
4. Standby Mode	0.04A	No load	No load	No load

V_{INAC} (V)	P_{IN} (W)	V_{O1} (V)	I_{O1} (A)	V_{O2} (V)	I_{O2}(A)	V_{O3} (V)	I_{O3}(A)	V_{O4} (V)	I_{O4}(A)	P_{OUT} (W)	P_{LOSS} (W)	Eff(%)
85	4.84	12.50	0.04	64.74	0.00	26.31	0.00	21.45	0.00	0.5	4.3	10.33
85	14.16	12.48	0.70	64.85	0.00	26.33	0.00	21.85	0.00	8.7	5.4	61.69
85	223.60	12.42	6.00	63.68	1.76	25.73	0.40	21.06	0.10	199.0	24.6	88.98
85	307.96	12.27	7.50	64.34	2.50	26.05	0.40	21.20	0.15	266.4	41.5	86.52
100	2.24	12.54	0.04	65.06	0.00	26.42	0.00	21.82	0.00	0.5	1.7	22.40
100	14.06	12.39	0.70	66.21	0.00	26.61	0.00	22.29	0.00	8.7	5.4	61.69
100	220.40	12.52	6.00	63.48	1.76	25.71	0.40	21.05	0.10	199.3	21.1	90.41
100	300.60	12.44	7.50	64.00	2.50	21.16	0.40	25.99	0.15	265.6	35.0	88.37
115	1.27	12.64	0.04	64.51	0.00	26.40	0.00	21.66	0.00	0.5	0.8	39.92
115	12.67	12.34	0.70	67.25	0.00	26.88	0.00	22.96	0.00	8.6	4.0	68.17
115	220.35	12.61	6.00	63.40	1.76	25.70	0.40	21.07	0.10	199.6	20.8	90.58
115	299.00	12.57	7.50	63.76	2.50	25.95	0.40	21.18	0.15	267.3	31.7	89.38

2.3 Standby Efficiency Data

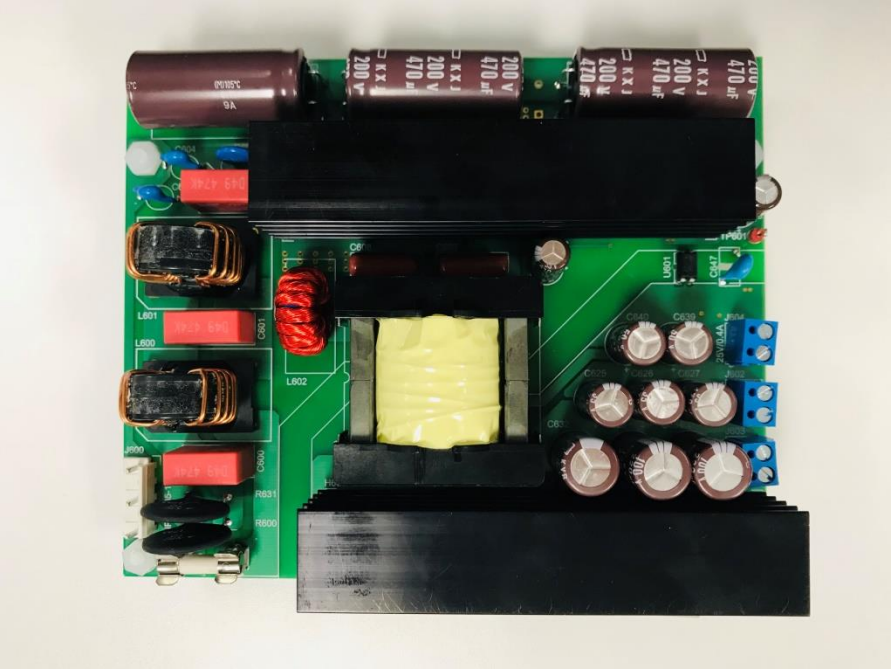
V_{INAC} (V)	I_{INAC} (mA)	P_{IN} (mW)	V_{O1} (V)	I_{O1} (mA)	V_{O2} (V)	V_{O3} (V)	V_{O4} (V)	P_O (mW)	Power Losses(mW)
85	46.87	461.30	12.65	0.00	64.01	26.45	19.98	0.00	461.30
100	54.00	273.00	12.68	0.00	64.00	26.46	20.54	0.00	273.00
115	63.00	588.00	12.72	0.00	63.83	26.43	20.62	0.00	588.00
85	71.21	4803.00	12.48	40.00	65.11	26.50	21.53	499.12	4303.88
100	69.05	2246.00	12.54	40.00	65.23	26.03	26.53	501.52	1744.48
115	66.67	1529.00	12.64	40.00	64.54	26.45	21.77	505.76	1023.24

2.4 Cross Regulation

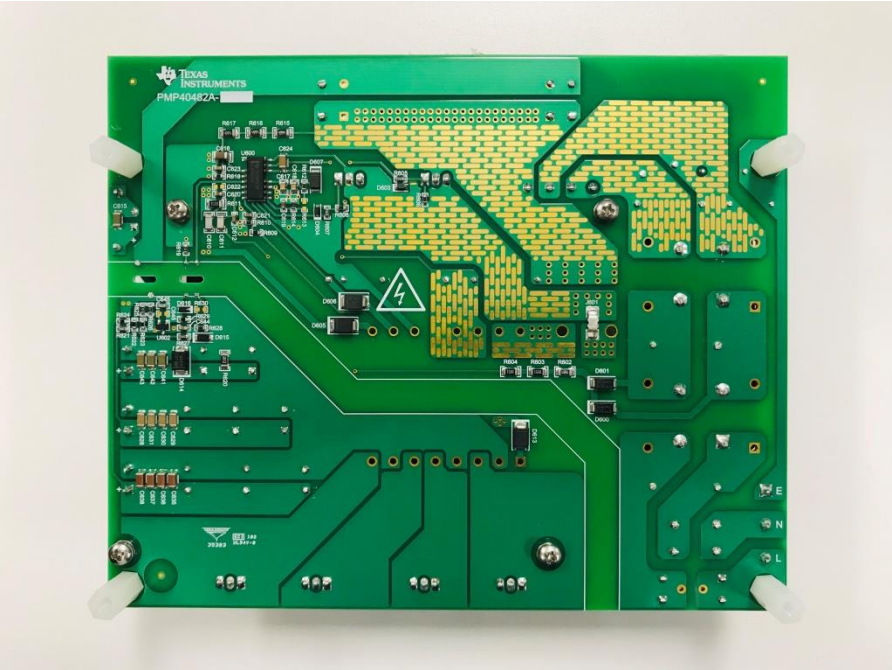
V_{INAC} (V)	I_{O1} (A)	I_{O2} (A)	I_{O3} (A)	I_{O4} (A)	V_{O1} (V)	V_{O2} (V)	V_{O3} (V)	V_{O4} (V)	V_{CC} (V)
85	0.00	0.00	0.00	0.00	12.83	62.67	26.65	19.28	14.10
	3.80				12.68	63.58	26.91	21.66	16.00
	7.50				12.56	64.37	27.45	21.99	16.20
	0.00	2.50	0.40	0.00	13.30	56.50	24.82	21.80	15.70
	3.80				12.97	60.10	26.30	22.40	16.40
	7.50				12.64	62.05	26.92	22.44	16.40
	0.10	0.50	0.00	0.00	13.17	58.91	26.59	21.93	16.00
	3.80				12.67	63.13	27.57	22.49	16.40
	7.50				12.92	61.04	26.93	22.32	16.20
	0.10	2.50			13.24	57.44	26.63	22.39	16.10
	3.80				12.94	59.95	26.98	22.49	16.30
	7.50				12.66	62.00	27.70	22.63	16.50
	0.10	0.50	0.40	0.15	13.17	58.99	25.46	20.65	15.70
	3.80				12.92	61.20	26.28	21.04	16.00
	7.50				12.67	63.33	26.95	21.19	16.10
	0.10	2.50			13.25	57.38	25.20	20.64	15.70
	3.80				12.93	60.06	26.23	21.16	16.10
	7.50				12.65	62.16	26.99	21.38	16.30
100	0.00	0.00	0.00	0.00	12.90	62.92	26.68	20.32	15.00
	3.80				12.67	64.71	26.99	21.86	15.90
	7.50				12.50	66.45	27.45	22.74	16.00
	0.00	2.50	0.40	0.00	13.43	56.60	24.82	22.24	15.70
	3.80				13.02	60.14	26.29	22.71	16.30
	7.50				12.80	61.94	26.94	22.86	16.50
	0.10	0.50	0.00	0.00	13.23	59.25	26.73	22.22	16.00
	3.80				12.98	61.32	27.02	22.78	16.30
	7.50				12.77	63.10	27.60	22.60	16.40
	0.10	2.50			13.29	57.87	26.80	22.93	16.20
	3.80				13.03	60.16	27.00	22.84	16.40
	7.50				12.80	61.90	27.60	23.00	16.50
	0.10	0.50	0.40	0.15	13.22	59.28	25.60	20.77	15.80
	3.80				12.98	61.42	26.38	21.12	16.10
	7.50				12.77	63.32	26.98	21.28	16.20
	0.10	2.50			13.30	57.87	25.38	20.76	15.80
	3.80				13.02	60.22	26.29	21.25	16.20
	7.50				12.80	62.02	26.94	21.45	16.30
115	0.00	0.00	0.00	0.00	12.95	62.95	26.77	20.87	15.50
	3.80				12.61	66.00	27.40	23.55	15.80
	7.50				12.66	65.17	27.50	25.34	16.20
	0.00	2.50	0.40	0.00	13.73	54.40	23.97	22.19	15.20
	3.80				13.10	60.20	26.36	23.90	16.40
	7.50				12.92	61.81	26.93	24.23	16.50
	0.10	0.50	0.00	0.00	13.27	59.48	26.89	22.94	16.10
	3.80				13.03	61.60	27.16	24.33	16.30
	7.50				12.85	63.12	27.65	25.34	16.50
	0.10	2.50			13.38	57.92	26.91	22.89	16.20
	3.80				13.10	60.22	27.06	23.97	16.40
	7.50				12.92	61.70	27.57	24.42	16.50
	0.10	0.50	0.40	0.15	13.26	59.45	25.65	20.79	15.80
	3.80				13.03	61.58	26.46	21.19	16.10
	7.50				12.85	63.18	27.02	21.37	16.30
	0.10	2.50			13.37	57.97	25.40	20.79	15.80
	3.80				13.10	60.33	26.36	21.33	16.20
	7.50				12.91	61.99	26.93	21.51	16.40

2.5 Dimensions

The photos below show the top and bottom view of the PMP40482A board. Board dimension is 160mm x 130mm.



Top side

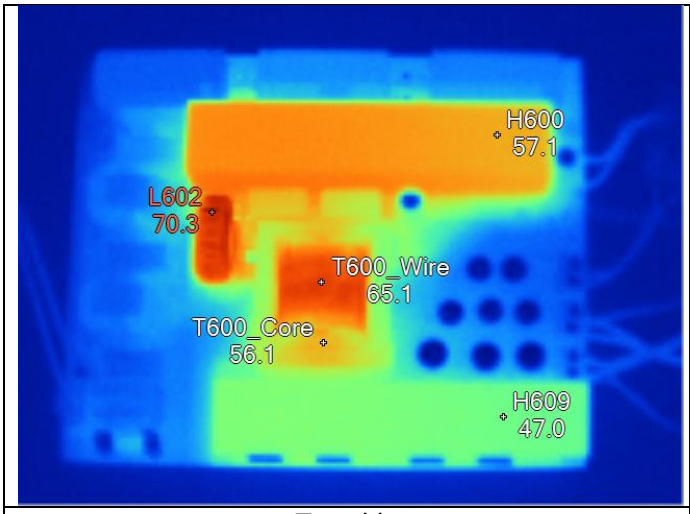


Bottom side

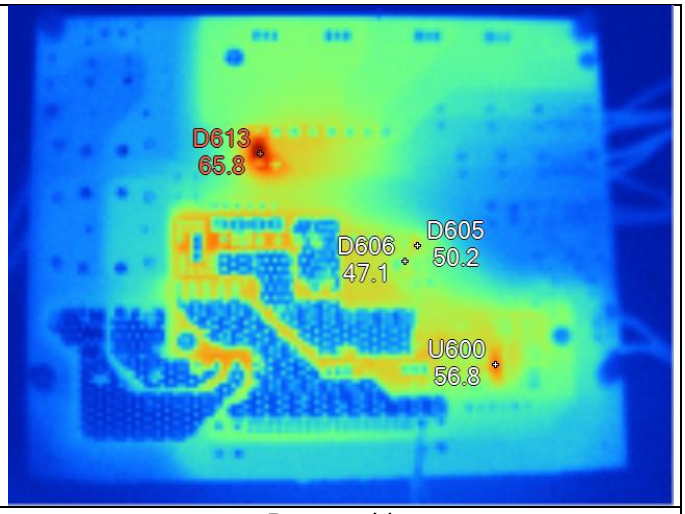
2.6 Thermal Images

The thermal images below show the top and bottom view of the board. The ambient temperature was 25ºC with no air flow. The input voltage is 100Vac/60Hz and load condition is shown as below.

Condition	Load			
	Vo1 = 12V	Vo2 = 60V	Vo3 = 25V	Vo4 = 21V
1. Stationary Operation	3.9A	1.76A	0.4A	0.15A



Top side

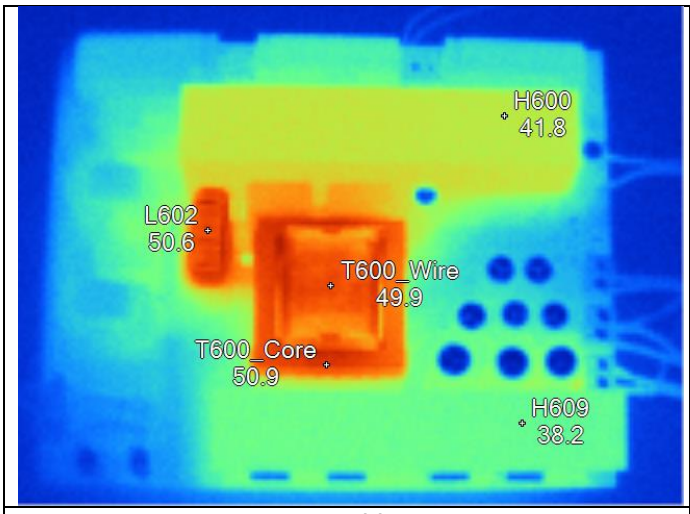


Bottom side

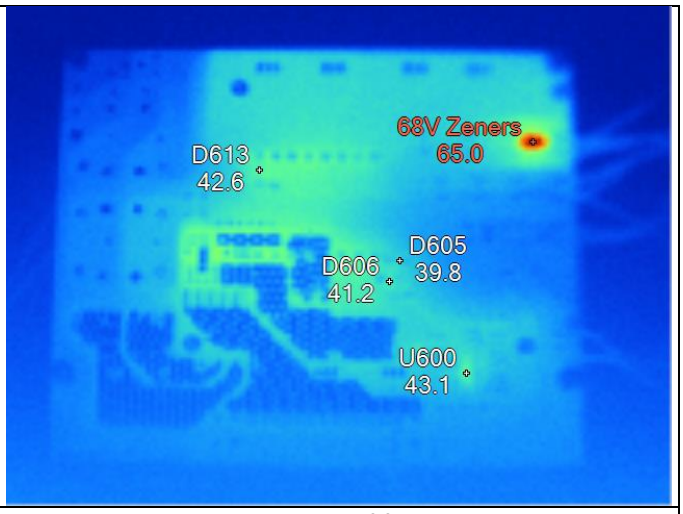
U600	56.8	ºC
Q600	64.6	ºC
Q601	63.4	ºC
D602	67.3	ºC
D605	50.2	ºC
D606	47.1	ºC
D609	51.6	ºC
D610	51.5	ºC
D611	49.9	ºC
D612	49.9	ºC
D613	65.8	ºC
L602	70.3	ºC
Core of transformer	56.1	ºC
Wire of transformer	65.1	ºC

The thermal images below show the top and bottom view of the board. The ambient temperature was 25ºC with no air flow. The input voltage is 100Vac/60Hz and load condition is shown as below.

Condition	Load			
	Vo1 = 12V	Vo2 = 60V	Vo3 = 25V	Vo4 = 21V
2. Burst Mode	0.7A	No load	No load	No load



Top side



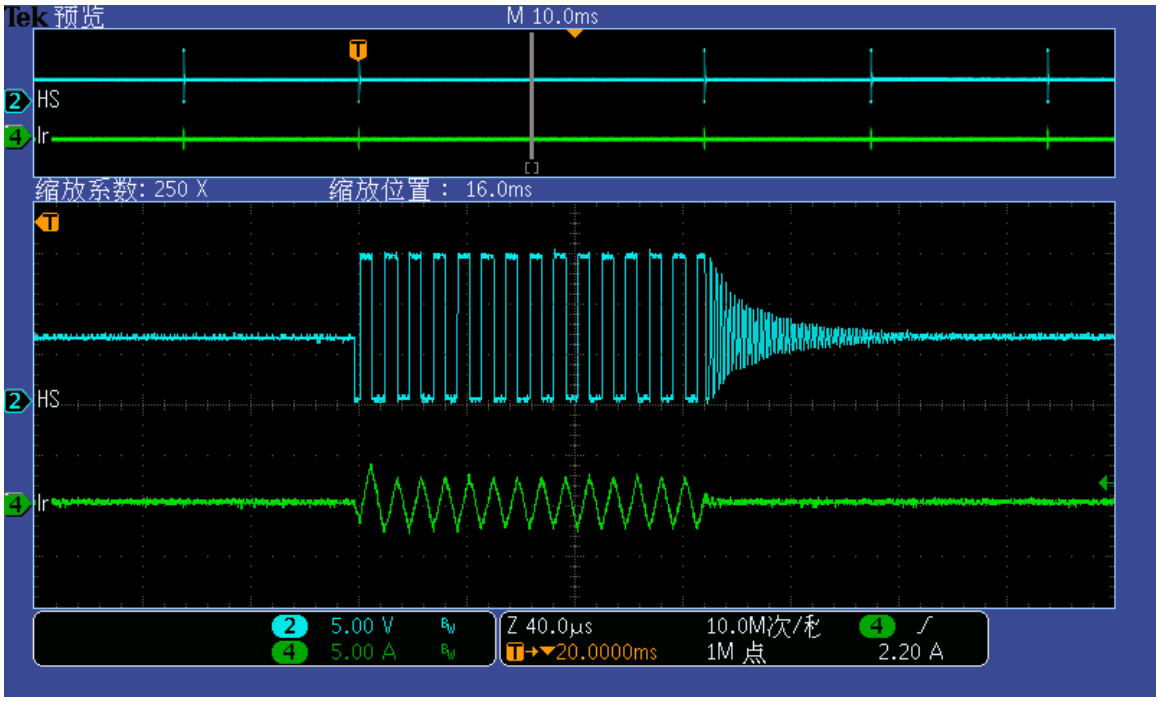
Bottom side

U600	43.1	ºC
Q600	43.0	ºC
Q601	43.0	ºC
D602	42.1	ºC
D605	39.8	ºC
D606	41.2	ºC
D609	38.8	ºC
D610	38.8	ºC
D611	38.5	ºC
D612	38.3	ºC
D613	42.6	ºC
L602	50.6	ºC
Core of transformer	50.9	ºC
Wire of transformer	49.9	ºC

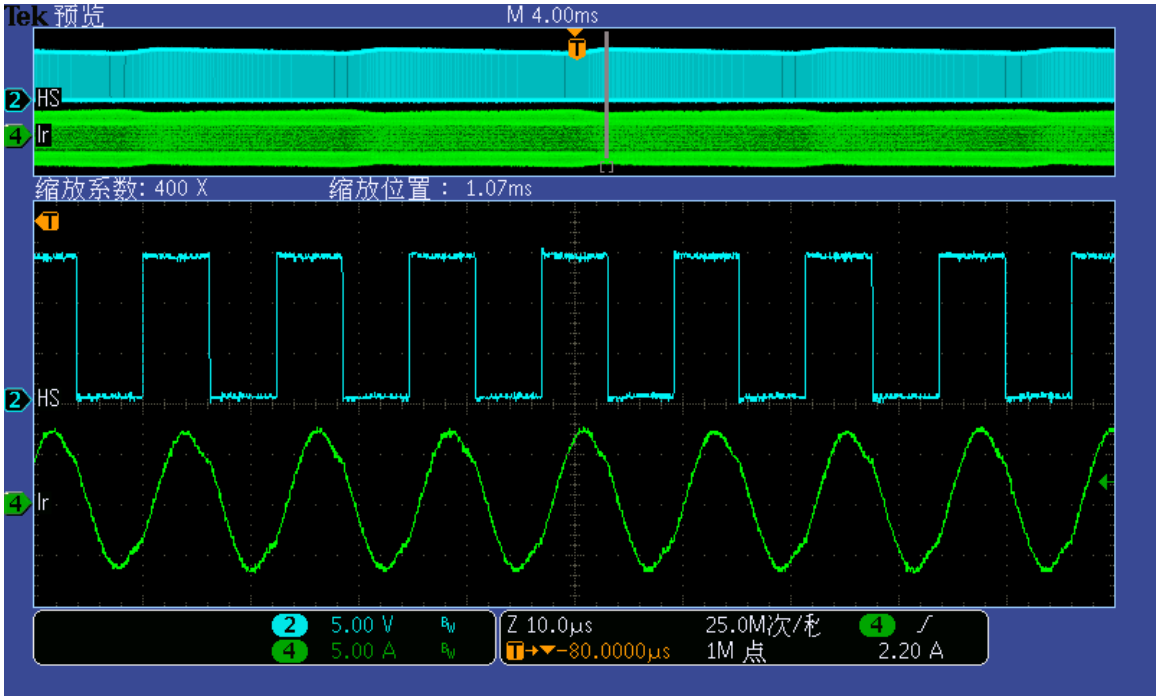
3 Waveforms

3.1 Switching

The photo below shows the switch node voltage (Q601 Vds) and resonant current waveforms at no load condition. The input voltage is 100VAC/60Hz. (CH2: Q601Vds, CH4: resonant current)

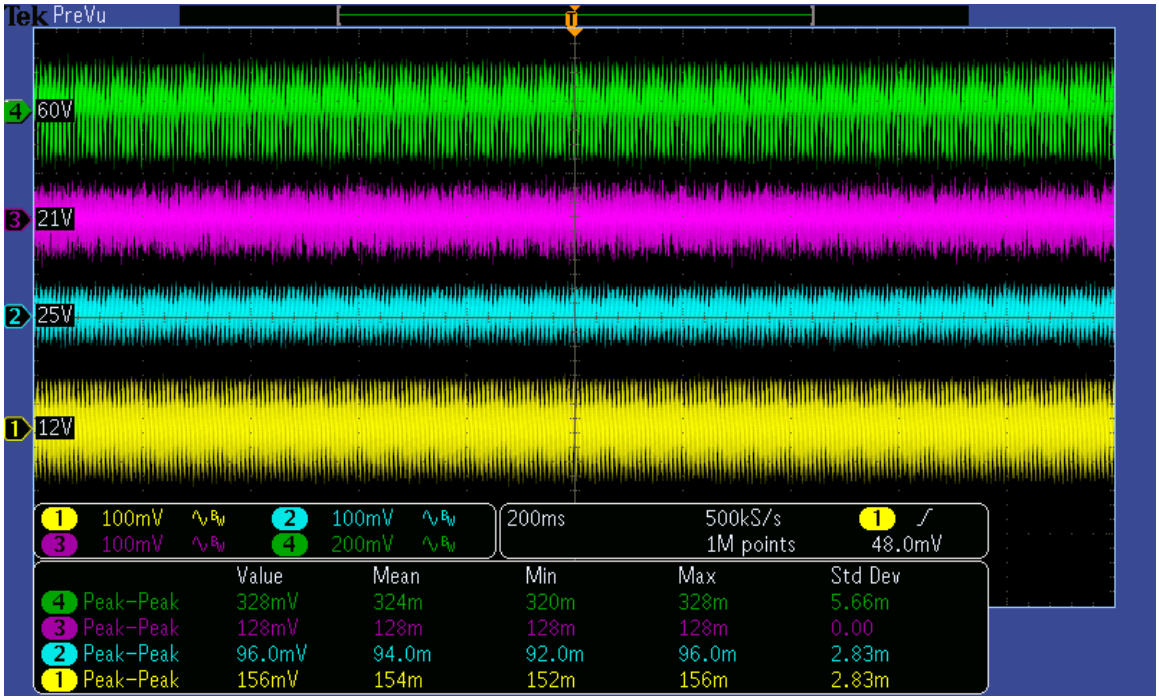


The photo below shows the switch node voltage (Q601 Vds) and resonant current waveforms at full load condition. The input voltage is 100VAC/60Hz. (CH2: Q601Vds, CH4: resonant current)

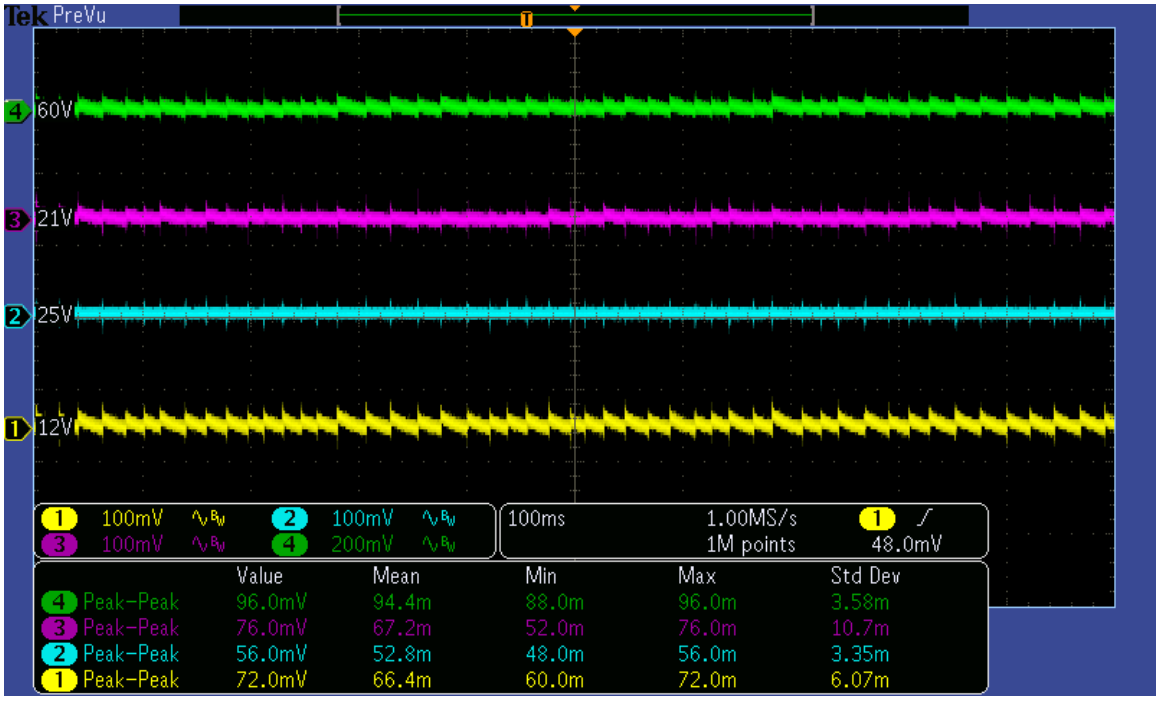


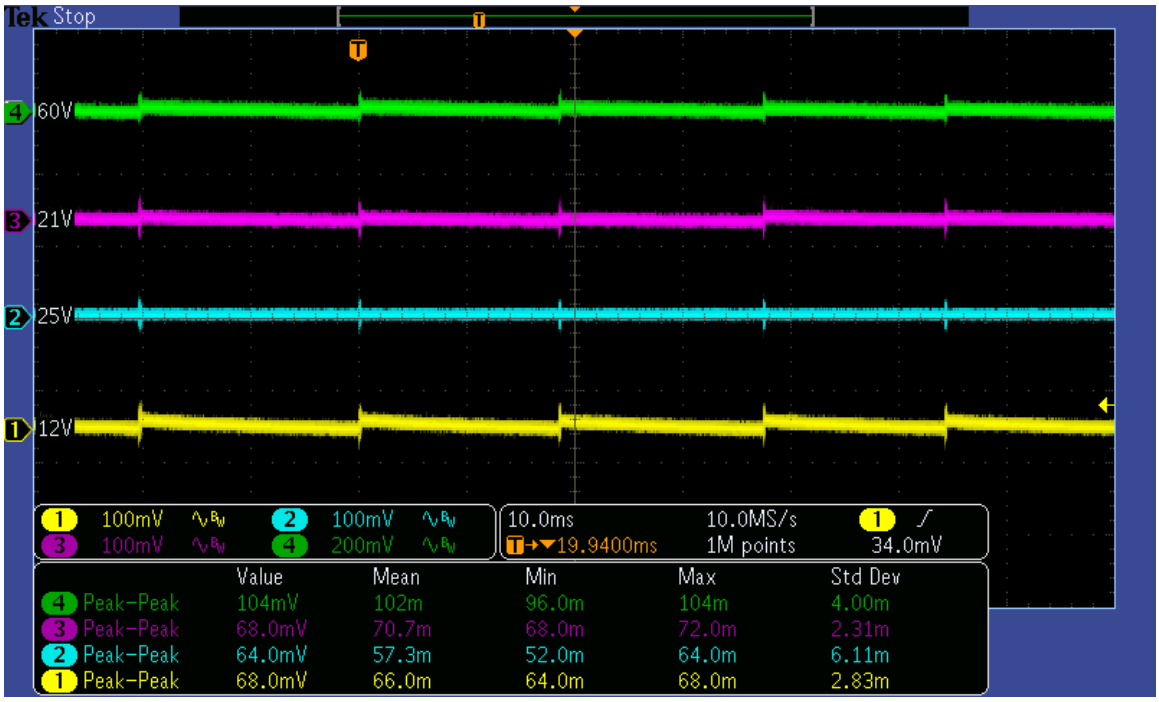
3.2 Output Voltage Ripple

The output voltage ripple is shown in the figure below. The image was taken with output full load and the input voltage set to 100VAC/60Hz. (CH1: 12V output voltage, CH2: 25V output voltage, CH3: 21V output voltage, CH4: 60V output voltage, all in AC coupling)



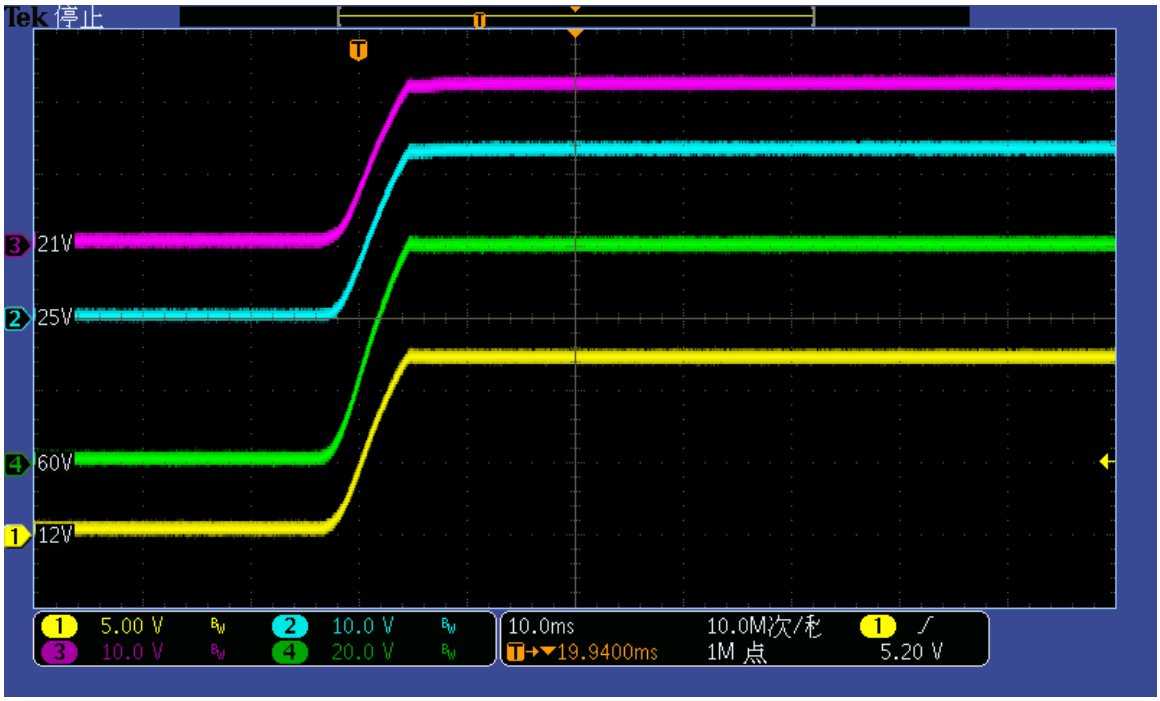
The output voltage ripple is shown in the figure below. The image was taken with output no load and the input voltage set to 100VAC/60Hz. (CH1: 12V output voltage, CH2: 25V output voltage, CH3: 21V output voltage, CH4: 60V output voltage, all in AC coupling)



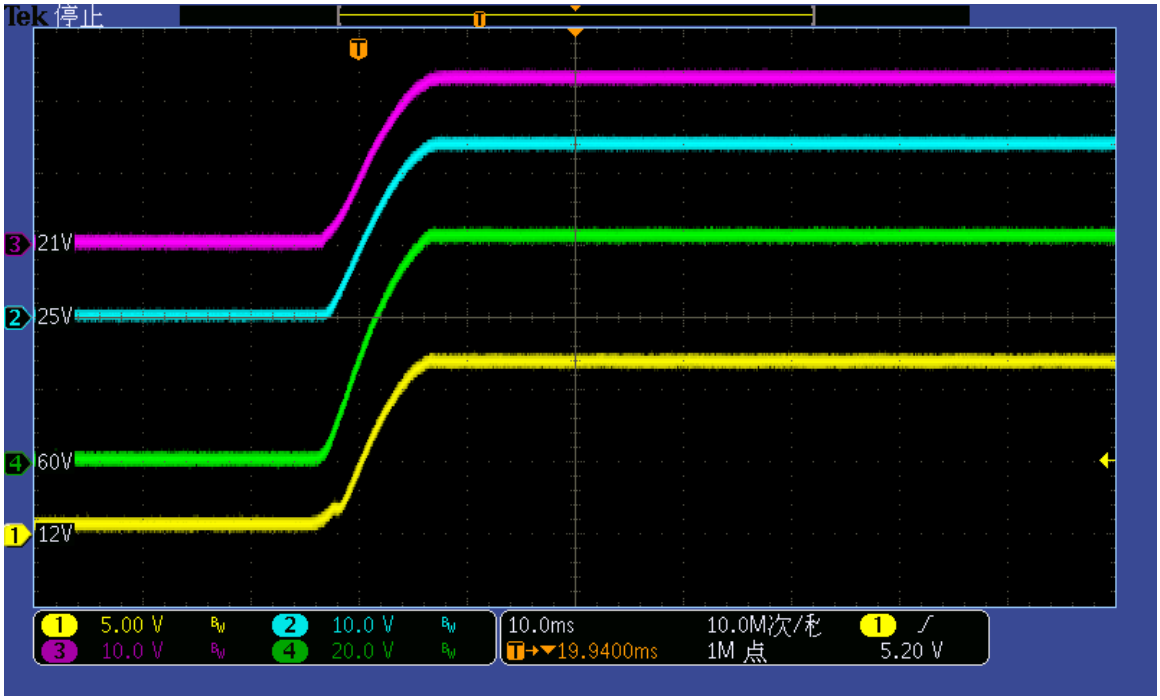


3.3 Start-up

The photo below shows the output voltage startup waveforms at no load condition after the application of 100Vac. (CH1: 12V output voltage, CH2: 25V output voltage, CH3: 21V output voltage, CH4: 60V output voltage)



The photo below shows the output voltage startup waveforms at full load condition after the application of 100Vac. (CH1: 12V output voltage, CH2: 25V output voltage, CH3: 21V output voltage, CH4: 60V output voltage)



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