

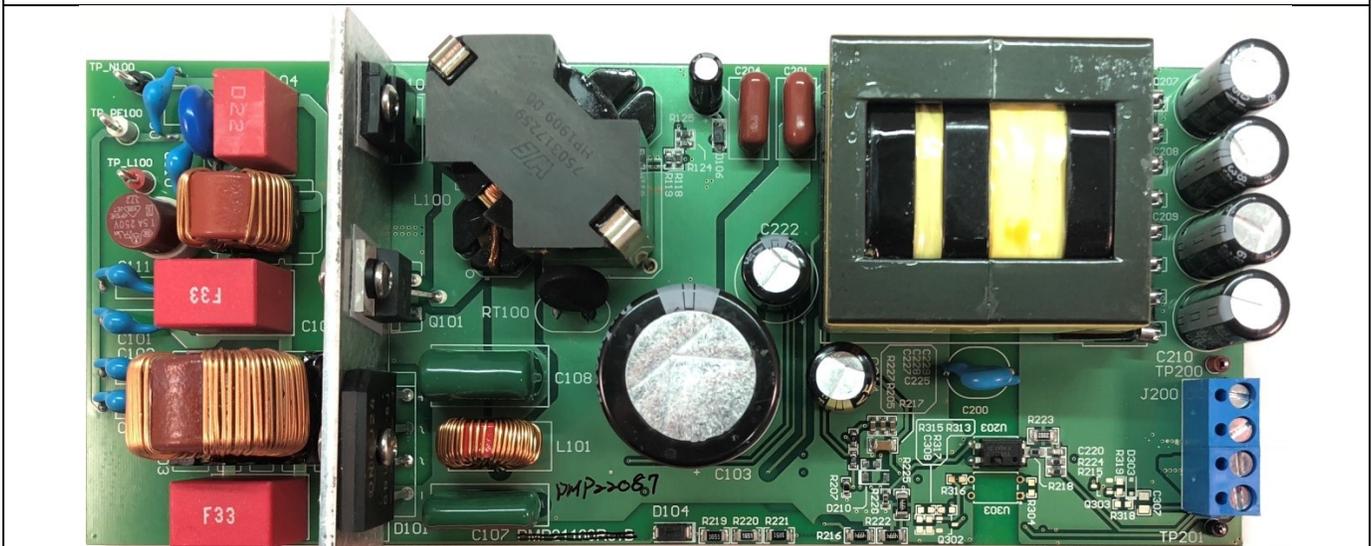
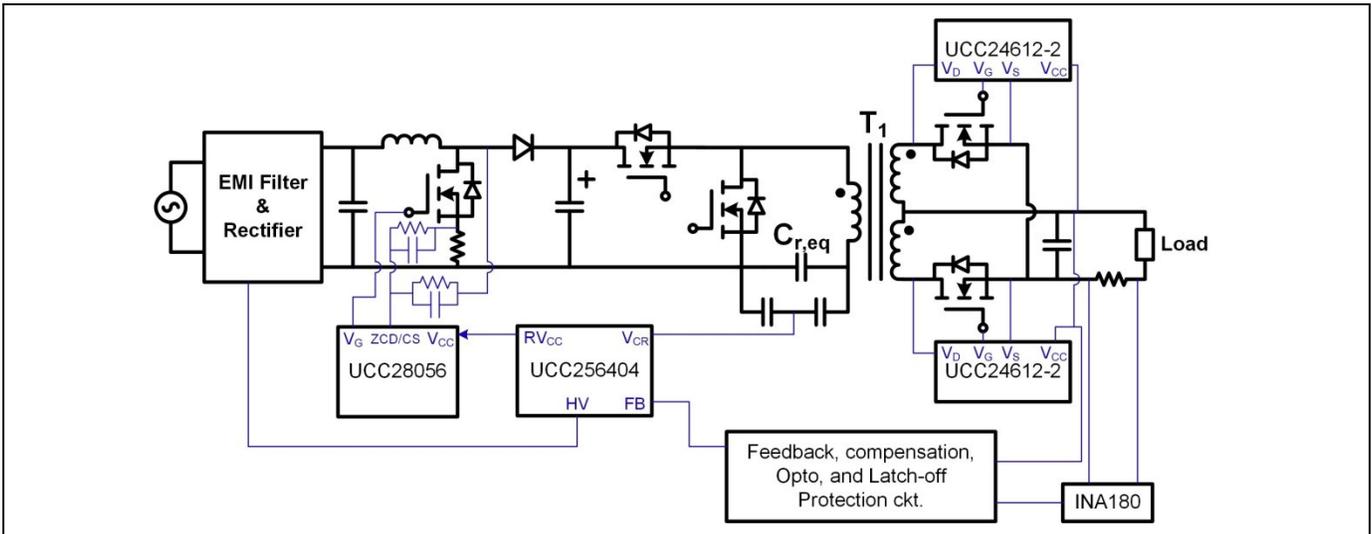
Test Report: PMP22087

336-W Auxless AC/DC Power Supply Reference Design With 80 PLUS Platinum Compatible Performance



Description

This reference design is an AC to DC power supply design with critical conduction mode (CRM) PFC and half-bridge LLC series resonant converter that provides 24V, 240W continuous, 336W peak output from universal input AC voltage (90VAC to 264VAC). This design uses UCC28056 CRM/DCM PFC controller, UCC256404 enhanced LLC controller, and UCC24612-2 synchronous rectifier controller with burst mode enabled for low standby power losses. 87mW @ 115VAC and 124mW @ 230VAC is achieved in this design. Moreover, 93.4% peak efficiency at 115-Vac input and 95.3% peak efficiency at 230-Vac input are achieved in this design. The efficiency and power factor numbers also meet both 115-V and 230-V internal 80 PLUS Platinum specifications and DoE level VI requirement.



An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Specification

1.1 Board Dimension:

75mm x 180mm x 30mm.

1.2 Input Characteristics

1.2.1 AC Input Voltage and Frequency Limitations:

Minimum	Nominal	Maximum	
90	100~240	265	VAC
47	50~60	63	Hz

1.2.2 AC Input Current:

- 4A Max. at 100VAC.
- 2A Max. at 200VAC.
- Current total harmonic distortion should be less than 20% from 5A to 10A load.

1.2.3 Power Factor:

Power factor should be greater than 0.95 at 50% load with either 115VAC/60Hz or 230VAC/50Hz input.

1.2.4 Inrush Current:

- Cold start: <50A at both 100VAC and 230VAC input and 25degC ambient temperature.
- Hot start: no component damage.

1.3 Output Characteristics

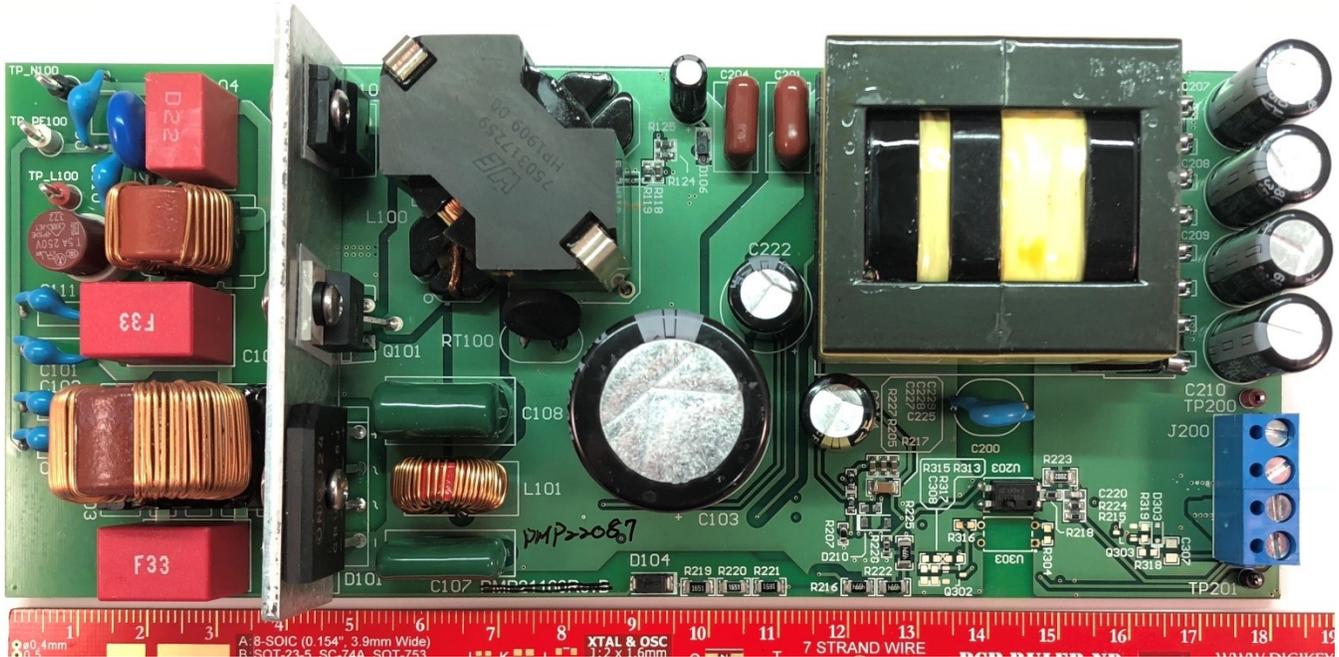
The power supply unit should be able to supply 24V+/-5%, 240W output power continuously and 24V+/-5%, 336W peak power for 20second with 10% duty cycle.

2 Testing and Results

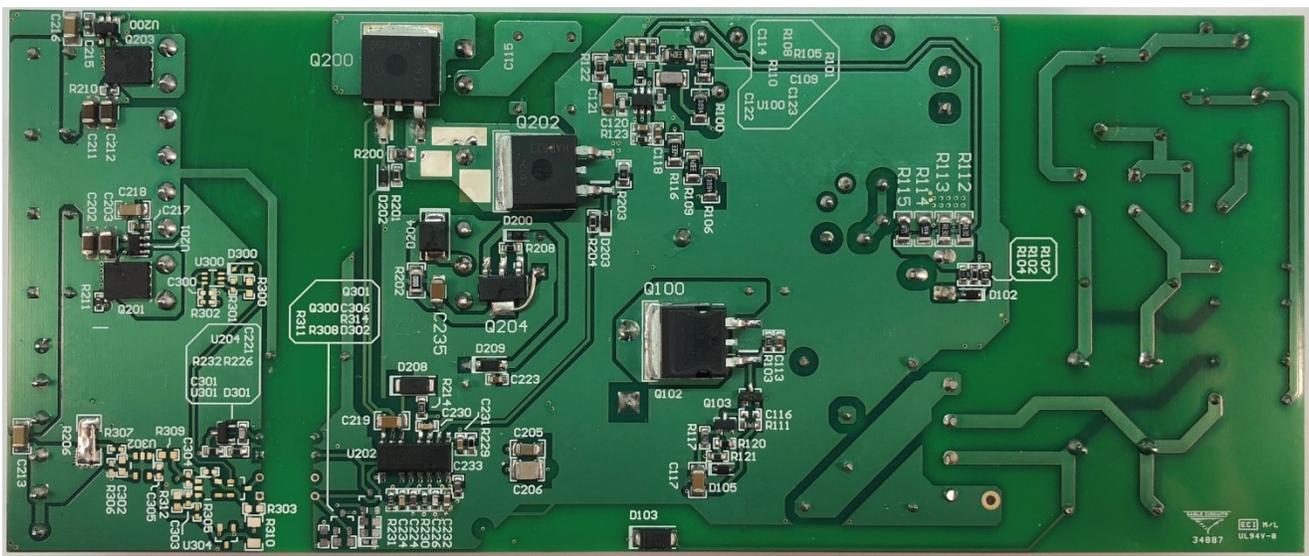
2.1 Board Photos

The photographs below show the top and bottom view of the PMP22087Rev A board. PMP22087Rev A circuit is built on PMP21160Rev B PCB board.

2.1.1 Top Side

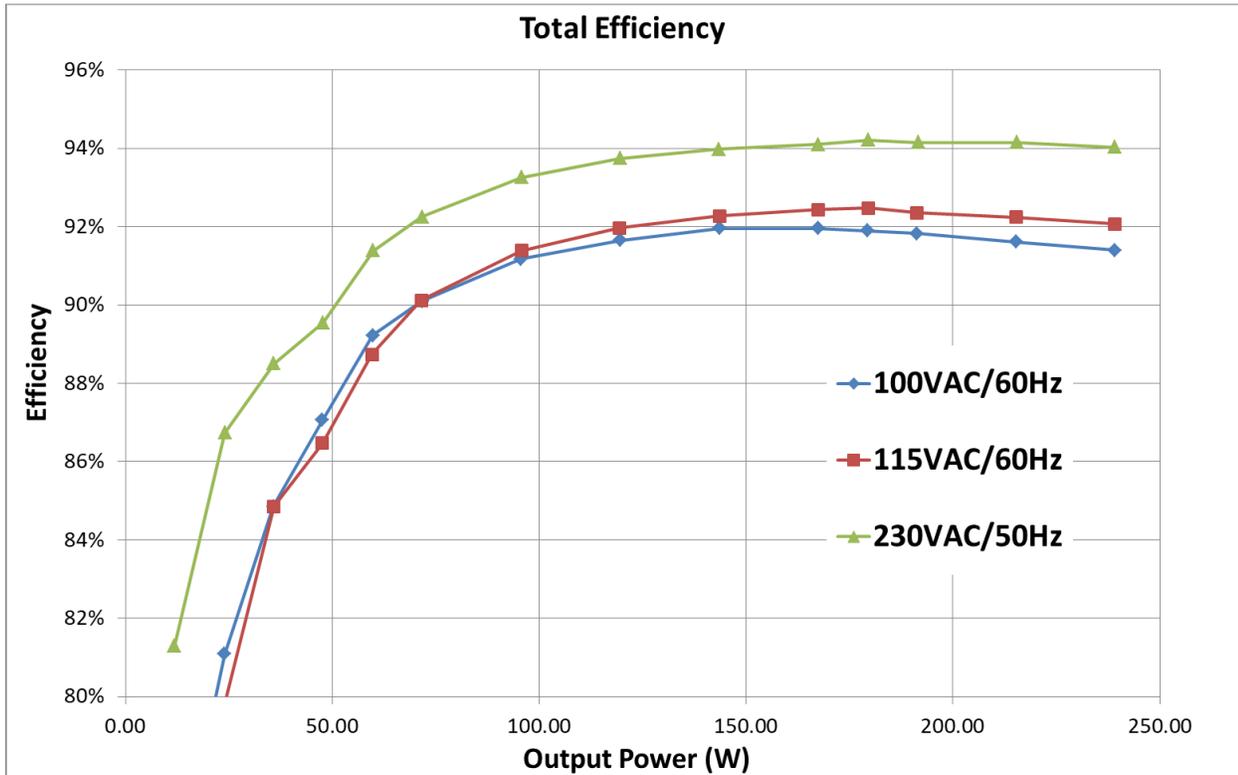


2.1.2 Bottom Side



2.2 Efficiency Data

4-point average efficiency: 92.38% @ 115VAC/60Hz and 94.16% @ 230VAC/50Hz



2.2.1 100VAC/60Hz Efficiency Measurement

Vin (V)	Iin (A)	Pin (W)	P.F.	THD (%)	Vout (V)	Iout (A)	Pout(W)	Efficiency (%)
100.09	0.288	15.71	0.546	19.31	23.92	0.493	11.79	75.07%
100.06	0.391	29.56	0.754	18.01	23.92	1.002	23.97	81.08%
100.05	0.439	42.17	0.961	8.26	23.92	1.496	35.78	84.86%
100.02	0.561	54.65	0.974	9.36	23.92	1.989	47.58	87.06%
100.11	0.682	66.94	0.981	9.02	23.92	2.497	59.73	89.23%
100.18	0.806	79.59	0.985	8.04	23.92	2.998	71.71	90.10%
100.14	1.059	104.86	0.989	7.47	23.92	3.997	95.61	91.18%
100.10	1.315	130.57	0.992	6.26	23.92	5.003	119.67	91.65%
100.07	1.581	156.13	0.987	14.73	23.92	6.002	143.57	91.95%
100.02	1.839	182.08	0.990	13.39	23.92	7.000	167.44	91.96%
100.01	1.971	195.22	0.990	12.86	23.92	7.500	179.40	91.90%
100.18	2.099	208.40	0.991	12.36	23.92	8.000	191.36	91.82%
100.13	2.364	235.00	0.992	11.47	23.92	9.000	215.28	91.61%
100.10	2.633	261.70	0.993	10.83	23.92	10.000	239.20	91.40%

2.2.2 115VAC/60Hz Efficiency Measurement

Vin (V)	Iin (A)	Pin (W)	P.F.	THD (%)	Vout (V)	Iout (A)	Pout(W)	Efficiency (%)
115.10	0.254	16.02	0.550	26.86	23.92	0.497	11.89	74.21%
115.07	0.394	29.91	0.640	32.60	23.92	0.997	23.85	79.73%
115.06	0.471	42.20	0.775	18.11	23.92	1.497	35.81	84.85%
115.04	0.497	55.02	0.962	6.74	23.92	1.989	47.58	86.47%
115.03	0.599	67.12	0.973	7.48	23.92	2.490	59.56	88.74%
115.01	0.705	79.36	0.979	8.30	23.92	2.990	71.52	90.12%
115.08	0.923	104.72	0.985	8.73	23.92	4.001	95.70	91.39%
115.14	1.140	129.86	0.989	6.97	23.92	4.993	119.43	91.97%
115.11	1.364	155.60	0.991	6.89	23.92	6.002	143.57	92.27%
115.07	1.595	181.14	0.987	14.31	23.92	7.000	167.44	92.44%
115.07	1.709	194.26	0.988	13.81	23.92	7.510	179.64	92.47%
115.04	1.821	207.20	0.989	13.22	23.92	8.000	191.36	92.36%
115.01	2.049	233.40	0.991	12.30	23.92	9.000	215.28	92.24%
114.97	2.278	259.80	0.992	11.59	23.92	10.000	239.20	92.07%

2.2.3 230VAC/50Hz Efficiency Measurement

Vin (V)	Iin (A)	Pin (W)	P.F.	THD (%)	Vout (V)	Iout (A)	Pout(W)	Efficiency (%)
230.50	0.195	14.60	0.322	22.98	23.93	0.496	11.87	81.30%
230.40	0.246	27.70	0.505	36.95	23.93	1.004	24.03	86.74%
230.50	0.292	40.56	0.608	35.24	23.93	1.500	35.90	88.50%
230.40	0.329	53.31	0.705	14.09	23.93	1.995	47.74	89.55%
230.40	0.358	65.46	0.794	11.56	23.92	2.501	59.82	91.39%
230.40	0.391	77.68	0.862	10.03	23.92	2.996	71.66	92.26%
230.40	0.491	102.68	0.909	8.14	23.92	4.003	95.75	93.25%
230.40	0.587	127.51	0.942	7.60	23.92	4.997	119.53	93.74%
230.40	0.692	152.66	0.957	7.09	23.92	5.998	143.47	93.98%
230.40	0.799	177.94	0.967	6.57	23.92	7.000	167.44	94.10%
230.40	0.853	190.67	0.970	6.52	23.92	7.510	179.64	94.21%
230.30	0.907	203.50	0.973	6.61	23.92	8.010	191.60	94.15%
230.30	1.016	228.90	0.978	7.61	23.92	9.010	215.52	94.15%
230.30	1.127	254.40	0.981	7.07	23.92	10.000	239.20	94.03%

2.3 No Load Power Consumption

No load power consumption was measured with Voltech PM1000+ power meter using **5-minute-average** and Chroma 61605 AC source.

2.3.1 No Part Change (Test as is):

115VAC/60Hz: $P_{in}=113mW$.

230VAC/50Hz: $P_{in}=157mW$.

2.3.2 Test With Following Parts Change: Disconnect Vout to SR controllers (U200, U201), short RT100 and remove C117 and R121.

115VAC/60Hz: $P_{in}=80mW$.

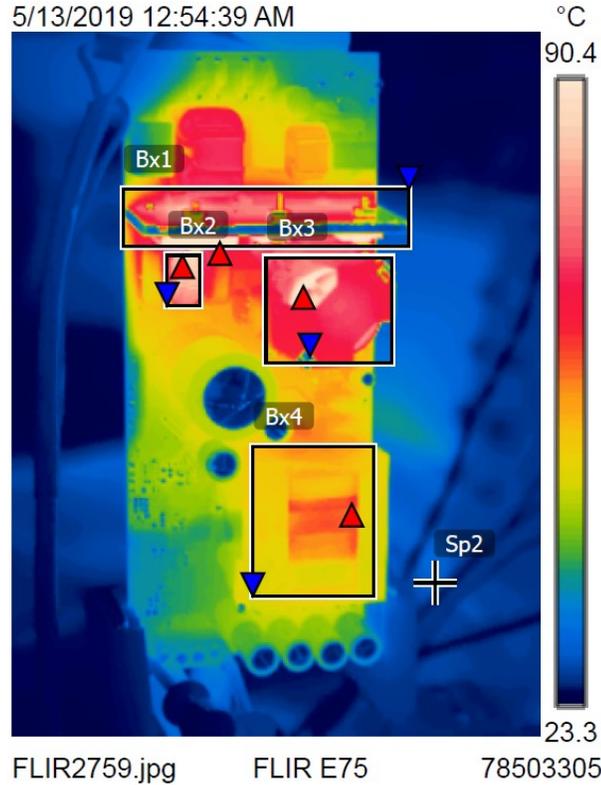
230VAC/50Hz: $P_{in}=121mW$.

2.4 Thermal Images

The thermal images below show a top view and bottom view of the board. The board is placed vertically during the test. The ambient temperature was 25°C with no air flow. The output was loaded with 24V/10A.

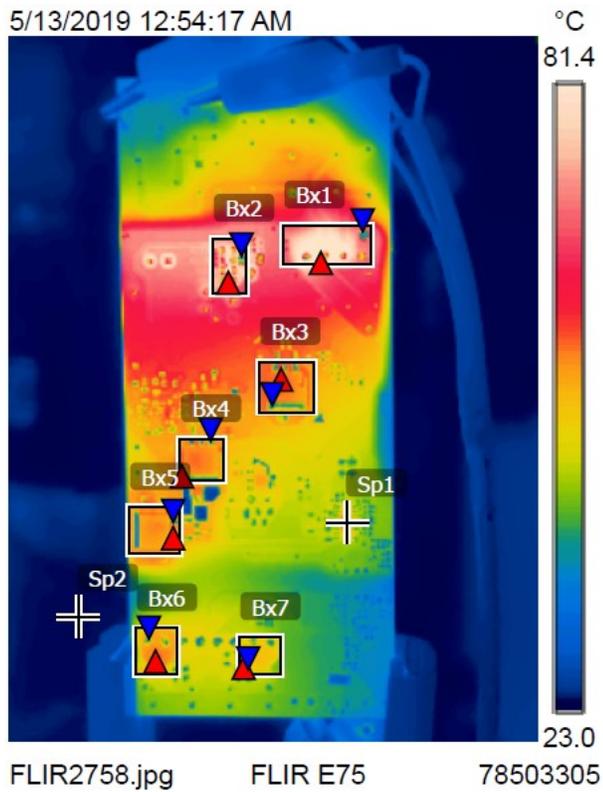
2.4.1 100V_{AC}/60Hz, Top Side

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Bx1	Max	101.2 °C
	Min	25.5 °C
	Average	62.4 °C
Bx2	Max	89.1 °C
	Min	58.1 °C
	Average	79.9 °C
Bx3	Max	91.3 °C
	Min	29.1 °C
	Average	69.6 °C
Bx4	Max	66.7 °C
	Min	50.4 °C
	Average	56.6 °C
Sp2		30.2 °C

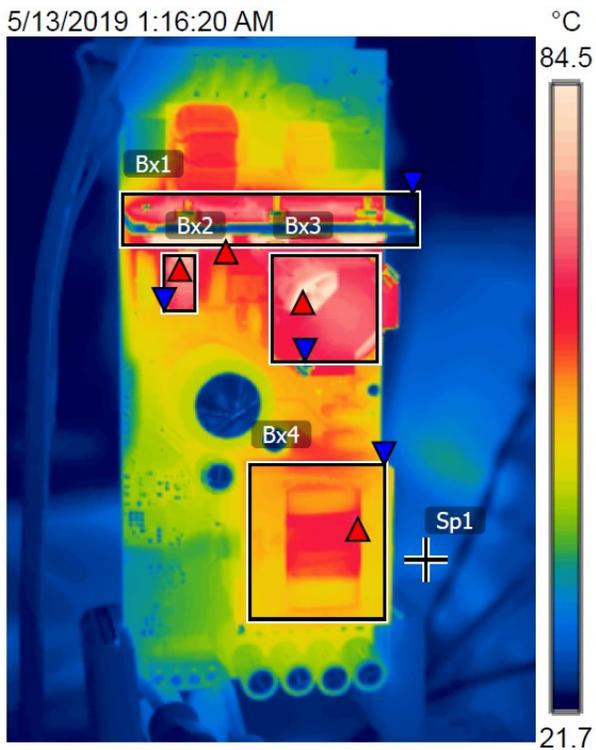
2.4.2 100V_{AC}/60Hz, Bottom Side



Bx1	Max	90.2 °C
	Min	33.7 °C
	Average	75.7 °C
Bx2	Max	89.7 °C
	Min	32.7 °C
	Average	72.2 °C
Bx3	Max	62.2 °C
	Min	37.8 °C
	Average	57.1 °C
Bx4	Max	61.5 °C
	Min	34.0 °C
	Average	55.9 °C
Bx5	Max	61.5 °C
	Min	33.9 °C
	Average	55.9 °C
Bx6	Max	59.8 °C
	Min	38.7 °C
	Average	54.3 °C
Bx7	Max	59.3 °C
	Min	33.9 °C
	Average	51.2 °C
Sp1		61.0 °C
Sp2		24.0 °C

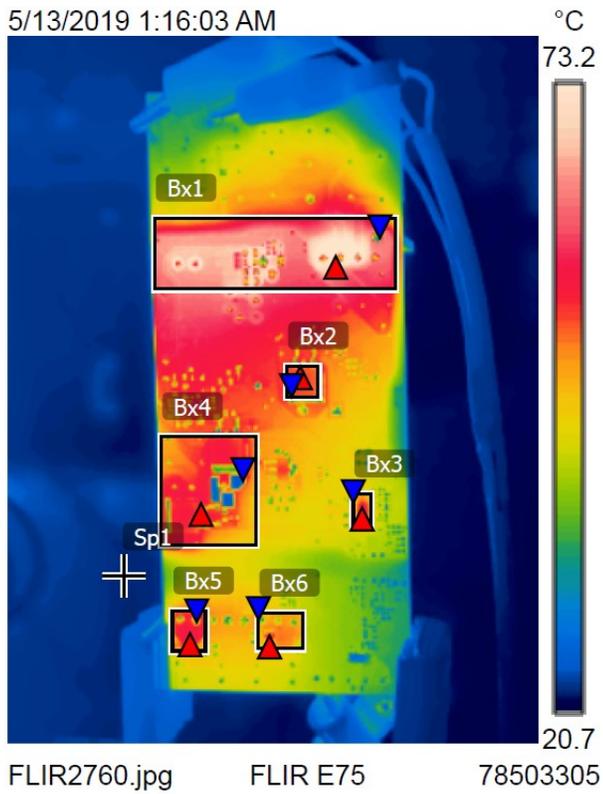
2.4.3 115V_{AC}/60Hz, Top Side

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Bx1	Max	91.9 °C
	Min	23.1 °C
	Average	57.2 °C
Bx2	Max	78.5 °C
	Min	54.6 °C
	Average	70.8 °C
Bx3	Max	86.0 °C
	Min	29.9 °C
	Average	70.5 °C
Bx4	Max	68.0 °C
	Min	50.5 °C
	Average	57.3 °C
Sp1		32.4 °C

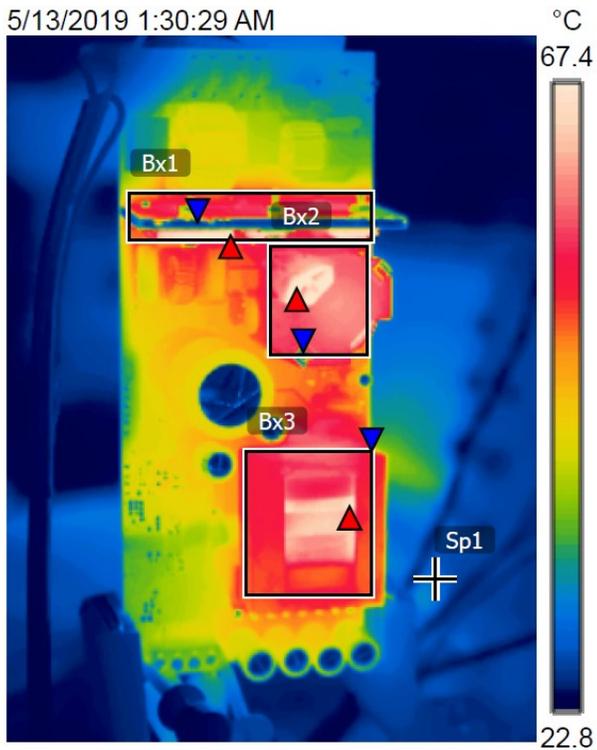
2.4.4 115V_{AC}/60Hz, Bottom Side



Bx1	Max	81.9 °C
	Min	28.2 °C
	Average	65.1 °C
Bx2	Max	58.1 °C
	Min	39.9 °C
	Average	54.6 °C
Bx3	Max	60.1 °C
	Min	41.2 °C
	Average	51.5 °C
Bx4	Max	60.7 °C
	Min	24.8 °C
	Average	53.1 °C
Bx5	Max	59.5 °C
	Min	37.3 °C
	Average	55.0 °C
Bx6	Max	58.6 °C
	Min	32.0 °C
	Average	50.4 °C
Sp1		22.5 °C

2.4.5 230V_{AC}/50Hz, Top Side

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FLIR2763.jpg

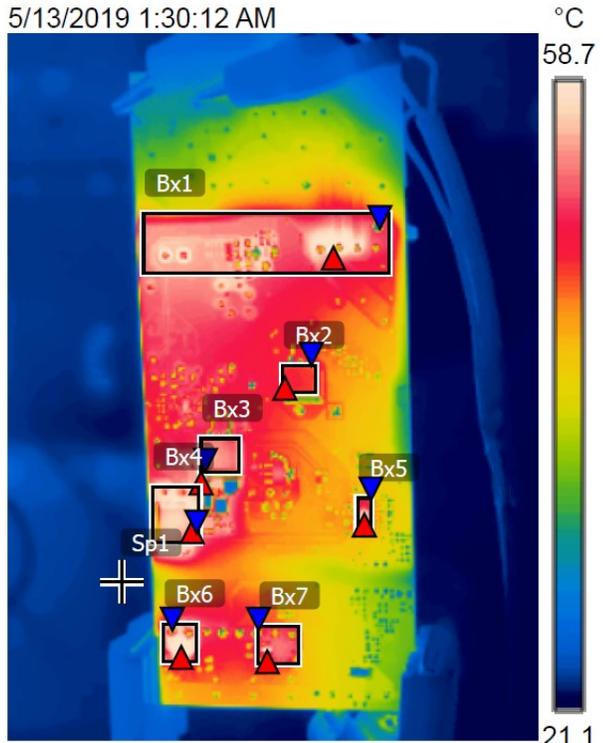
FLIR E75

78503305

Bx1	Max	69.5 °C
	Min	24.9 °C
	Average	49.4 °C
Bx2	Max	70.7 °C
	Min	27.7 °C
	Average	60.3 °C
Bx3	Max	67.3 °C
	Min	50.0 °C
	Average	57.1 °C
Sp1		29.3 °C

2.4.6 230V_{AC}/50Hz, Bottom Side

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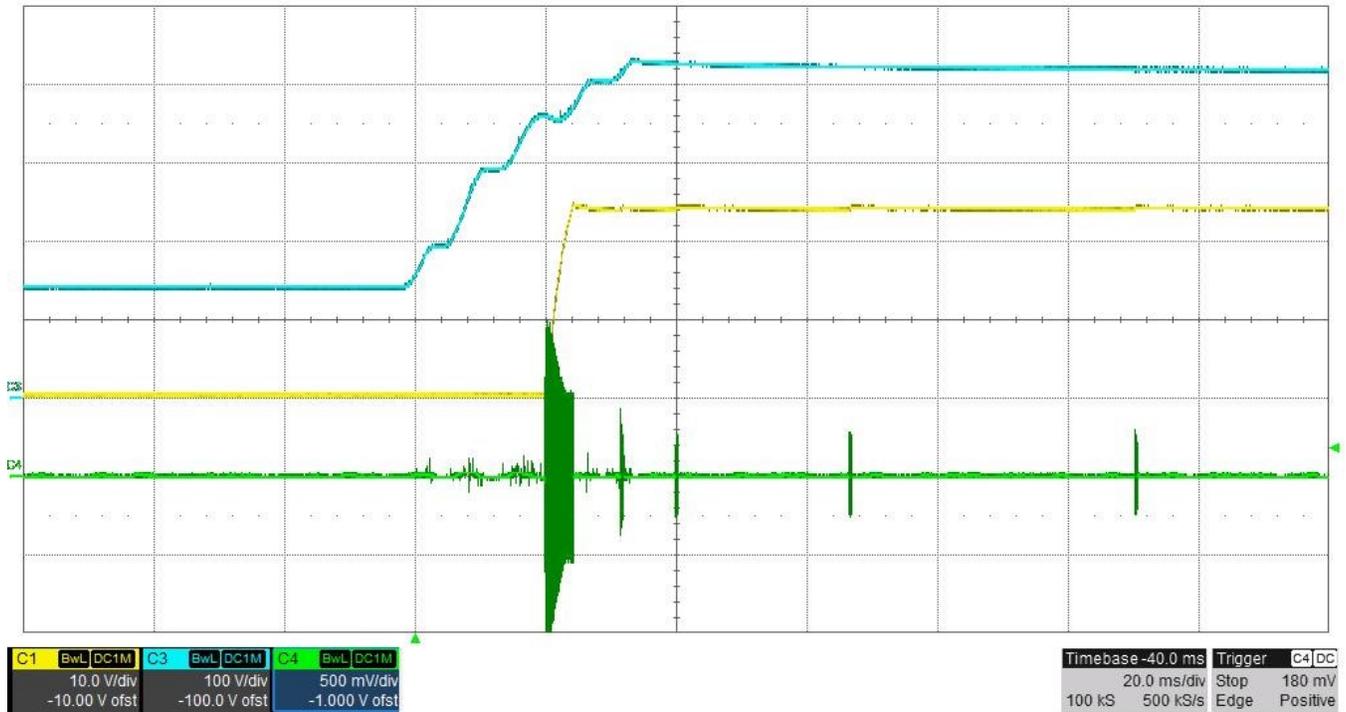
FLIR2762.jpg FLIR E75 78503305

Bx1	Max	61.5 °C
	Min	28.1 °C
	Average	53.5 °C
Bx2	Max	50.4 °C
	Min	43.5 °C
	Average	48.7 °C
Bx3	Max	56.5 °C
	Min	37.7 °C
	Average	53.5 °C
Bx4	Max	60.0 °C
	Min	34.3 °C
	Average	55.3 °C
Bx5	Max	58.0 °C
	Min	44.3 °C
	Average	51.5 °C
Bx6	Max	59.1 °C
	Min	35.9 °C
	Average	55.2 °C
Bx7	Max	58.8 °C
	Min	33.1 °C
	Average	50.6 °C
Sp1		22.5 °C

2.5 Startup

The voltages at startup are shown in the images below, where Channel 1 is output voltage, Channel 3 is HV to GND, and Channel 4 is T200 Primary winding current (200mV/A).

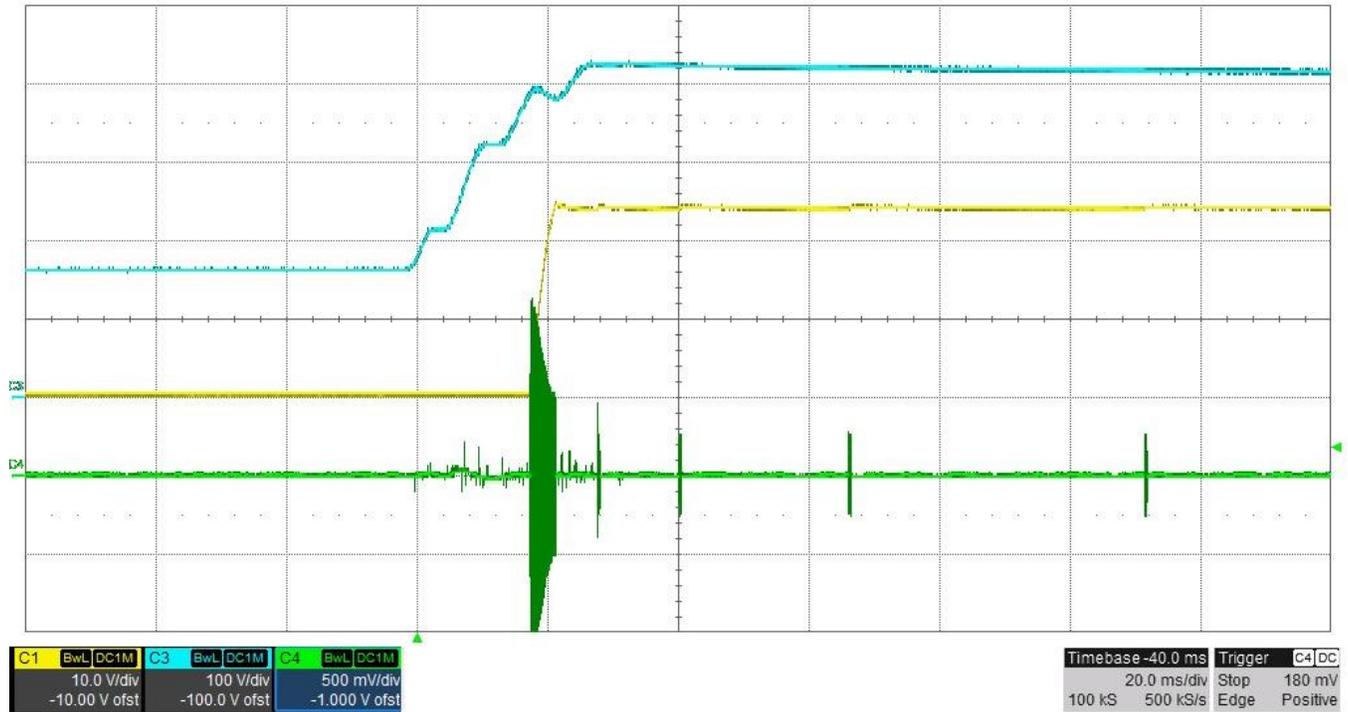
2.5.1 100V_{AC}/60Hz – No Load



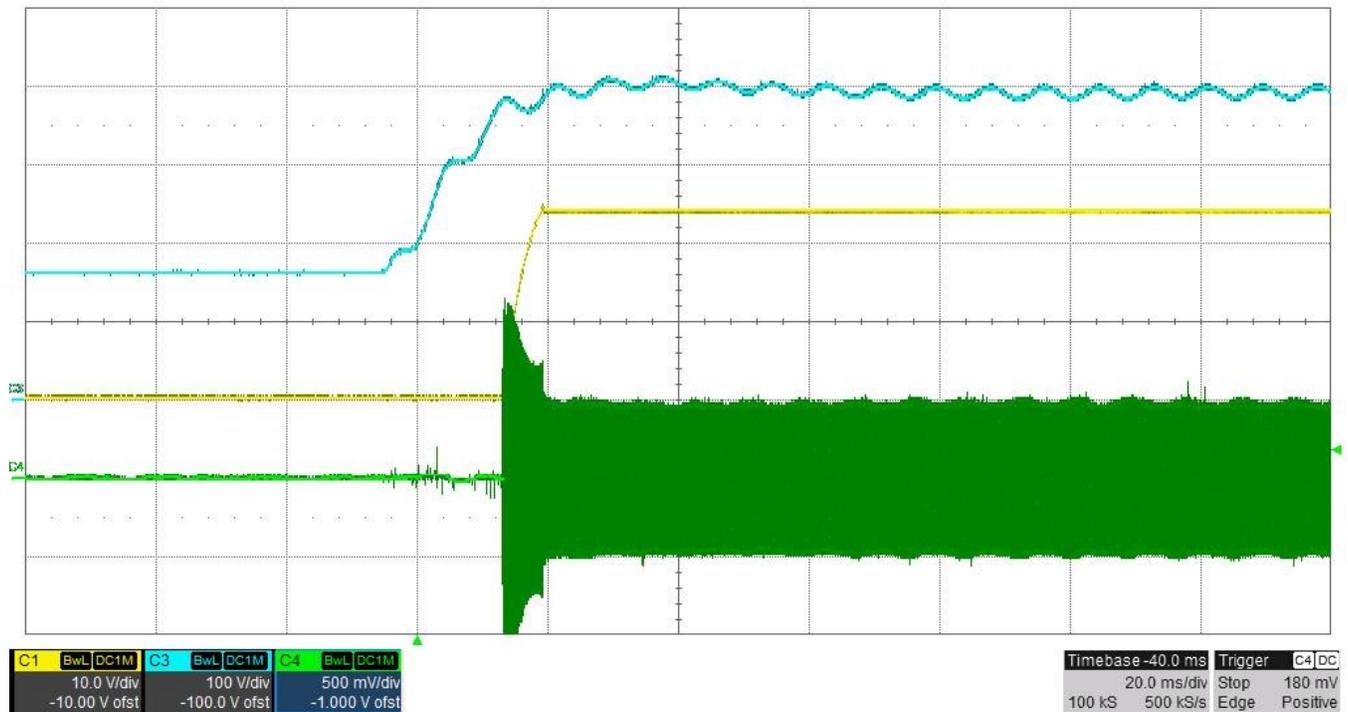
2.5.2 100V_{AC}/60Hz –24V/10A



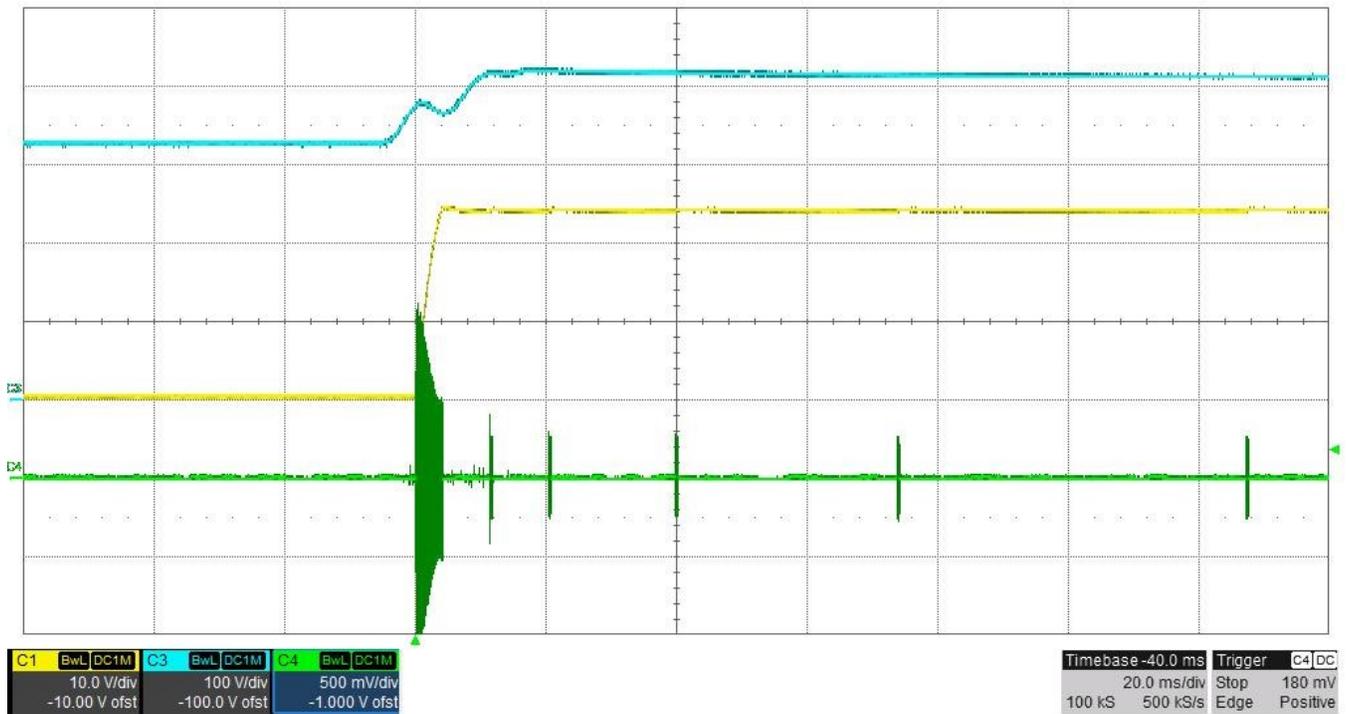
2.5.3 115V_{AC}/60Hz – No Load



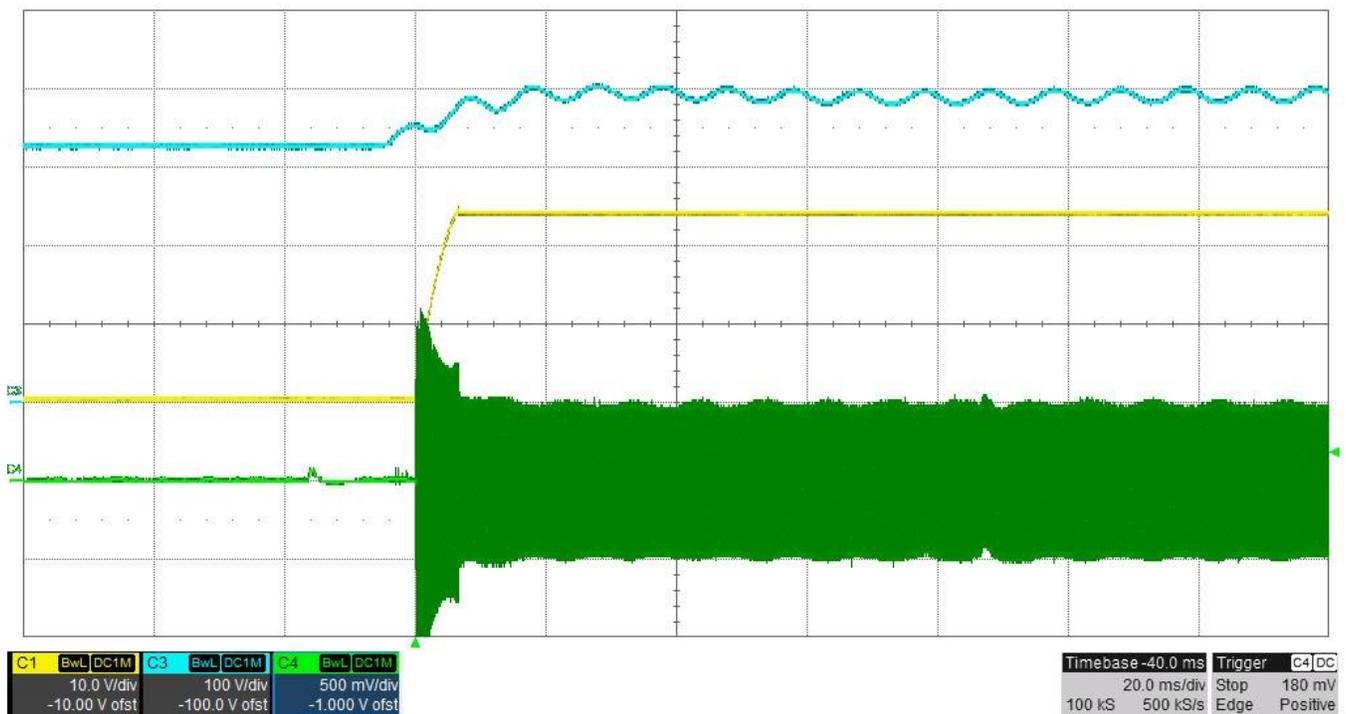
2.5.4 115V_{AC}/60Hz –24V/10A



2.5.5 230V_{AC}/50Hz – No Load



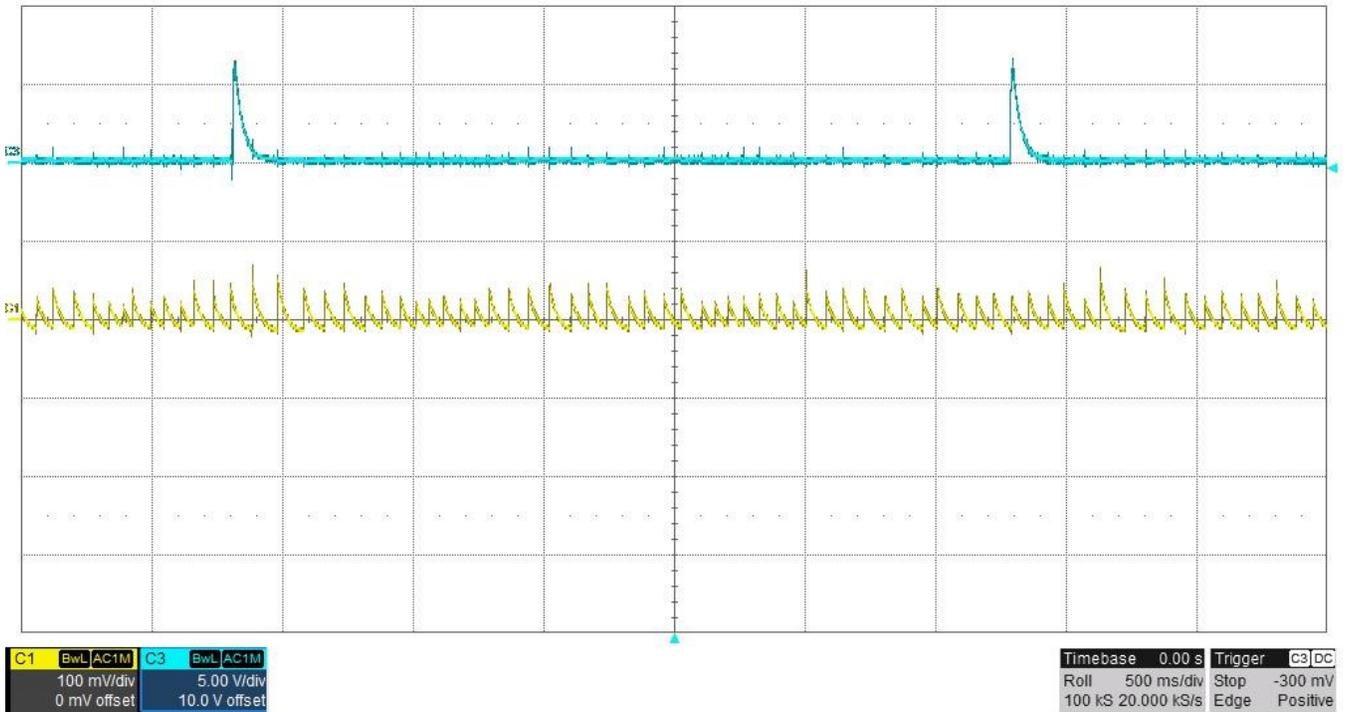
2.5.6 230V_{AC}/50Hz – 24V/10A



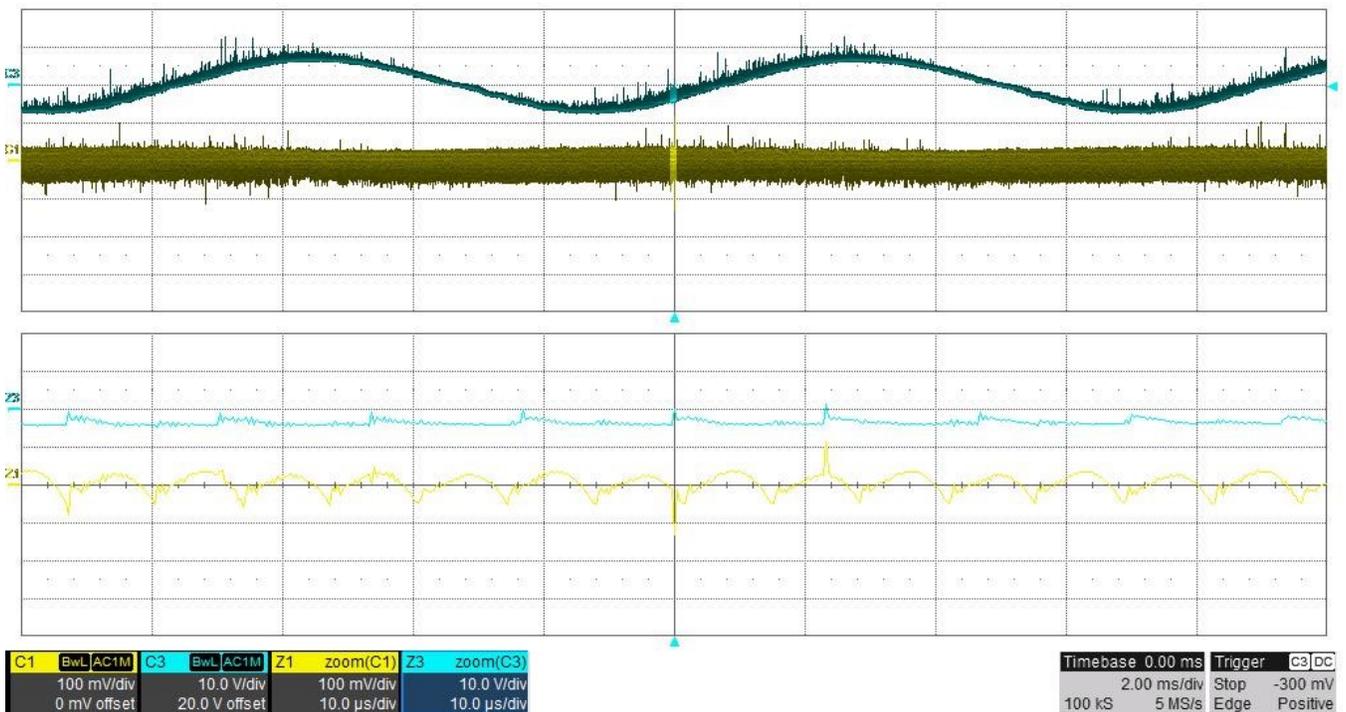
2.6 Ripple Voltages

Ripple voltages are shown in the images below, where Channel 1 is V_{out} to GND voltage in AC level and Channel 3 is HV to GND voltage in AC level.

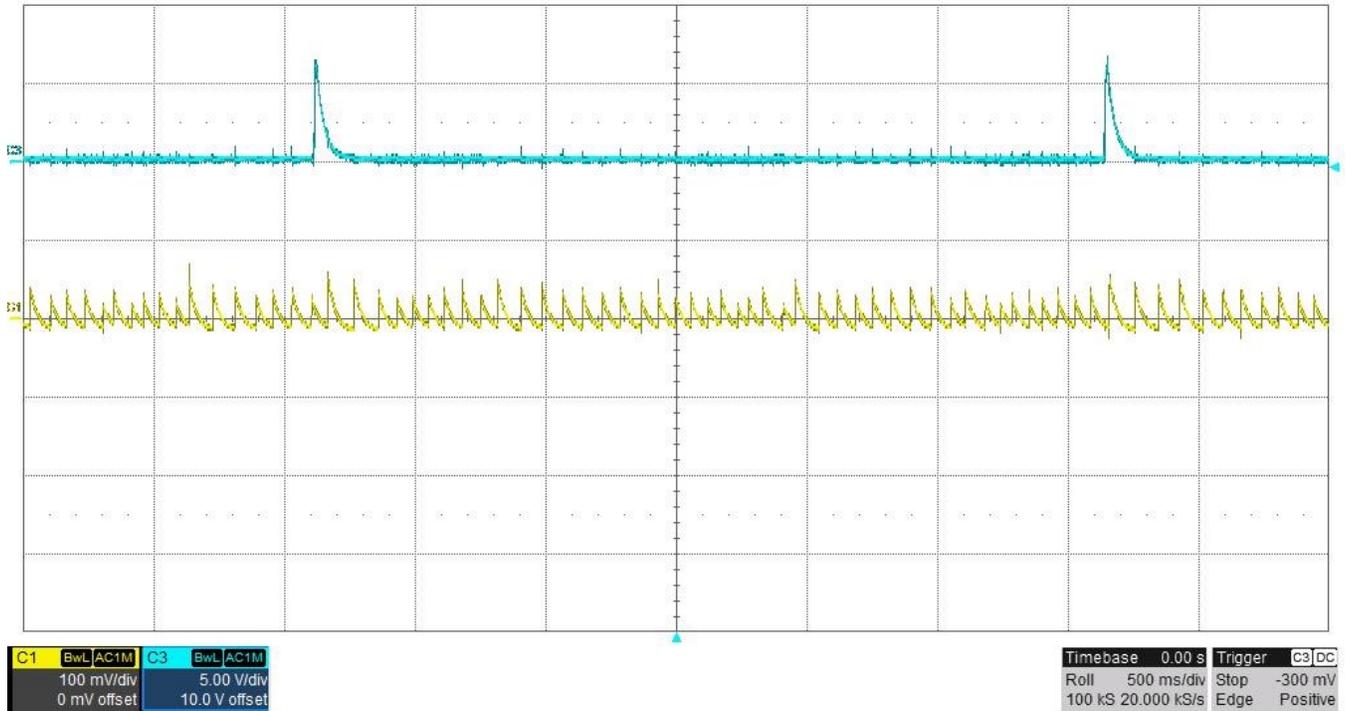
2.6.1 100V_{AC}/60Hz – 24V/0A



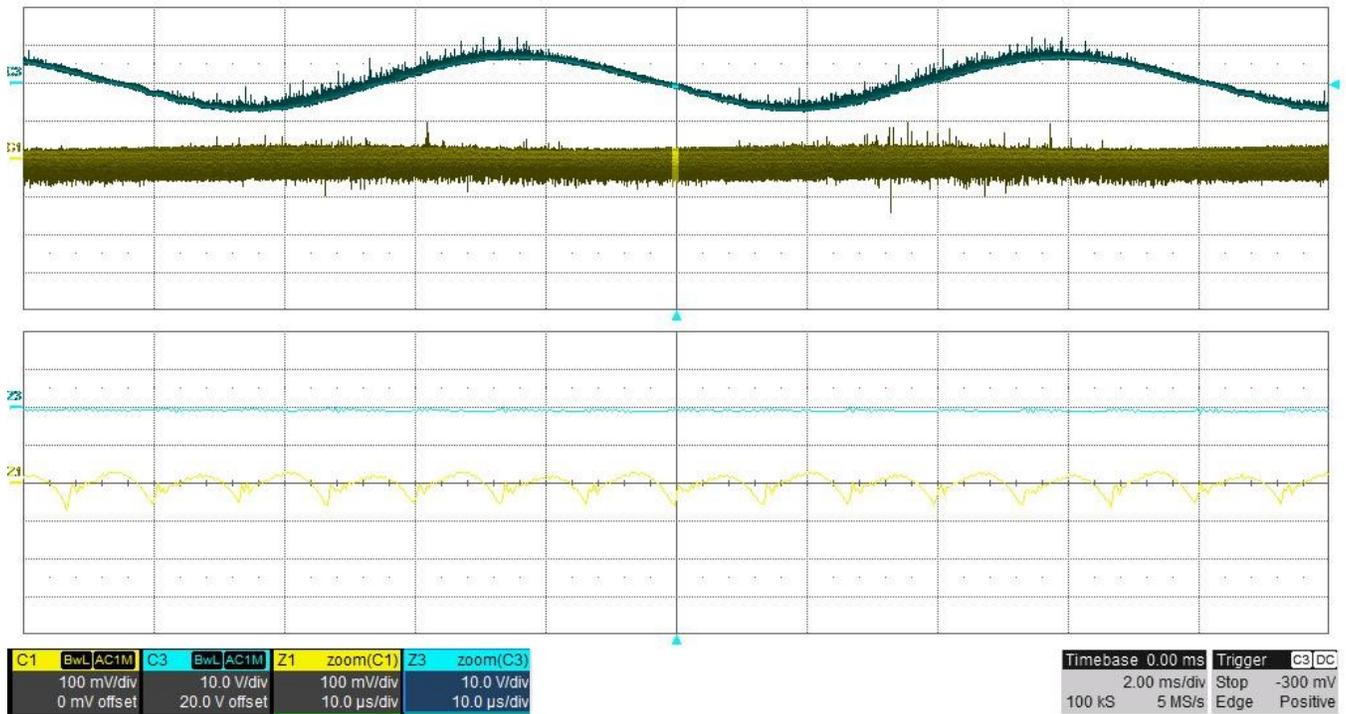
2.6.2 100V_{AC}/60Hz – 24V/10A



2.6.3 115V_{AC}/60Hz – 24V/0A

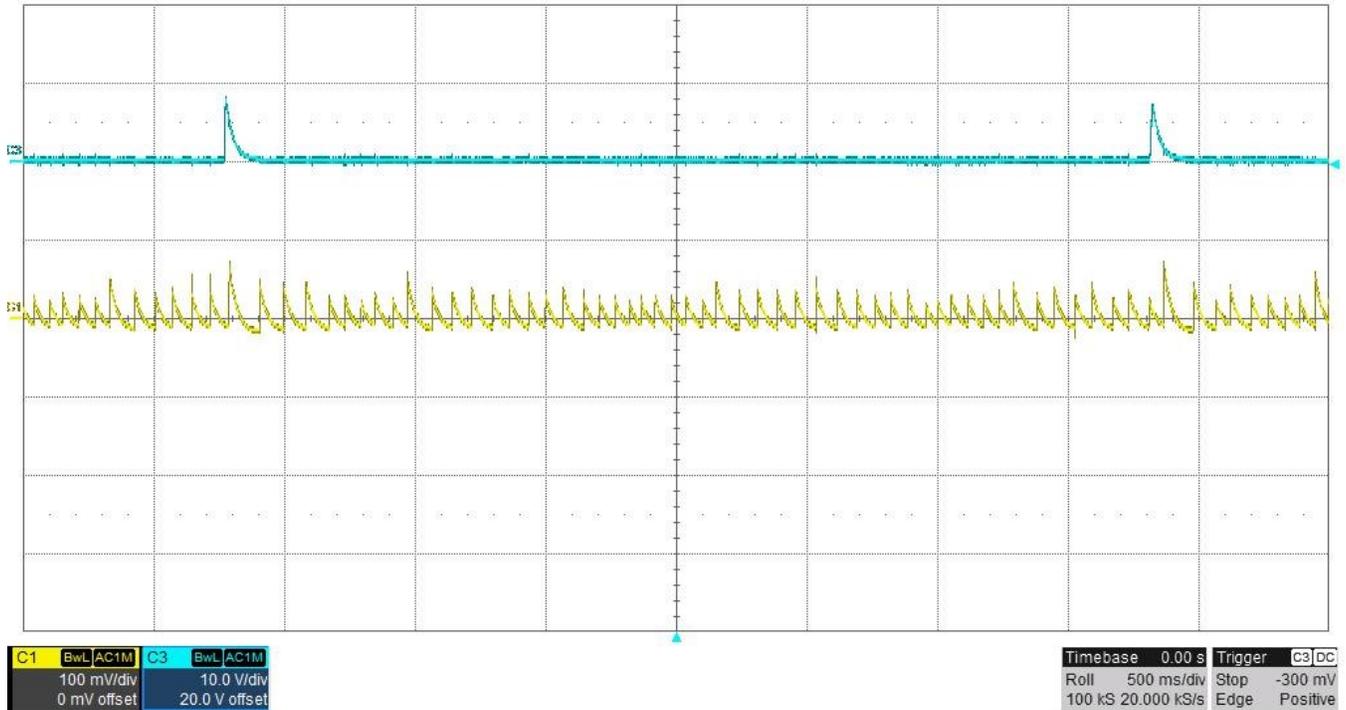


2.6.4 115V_{AC}/60Hz – 24V/10A

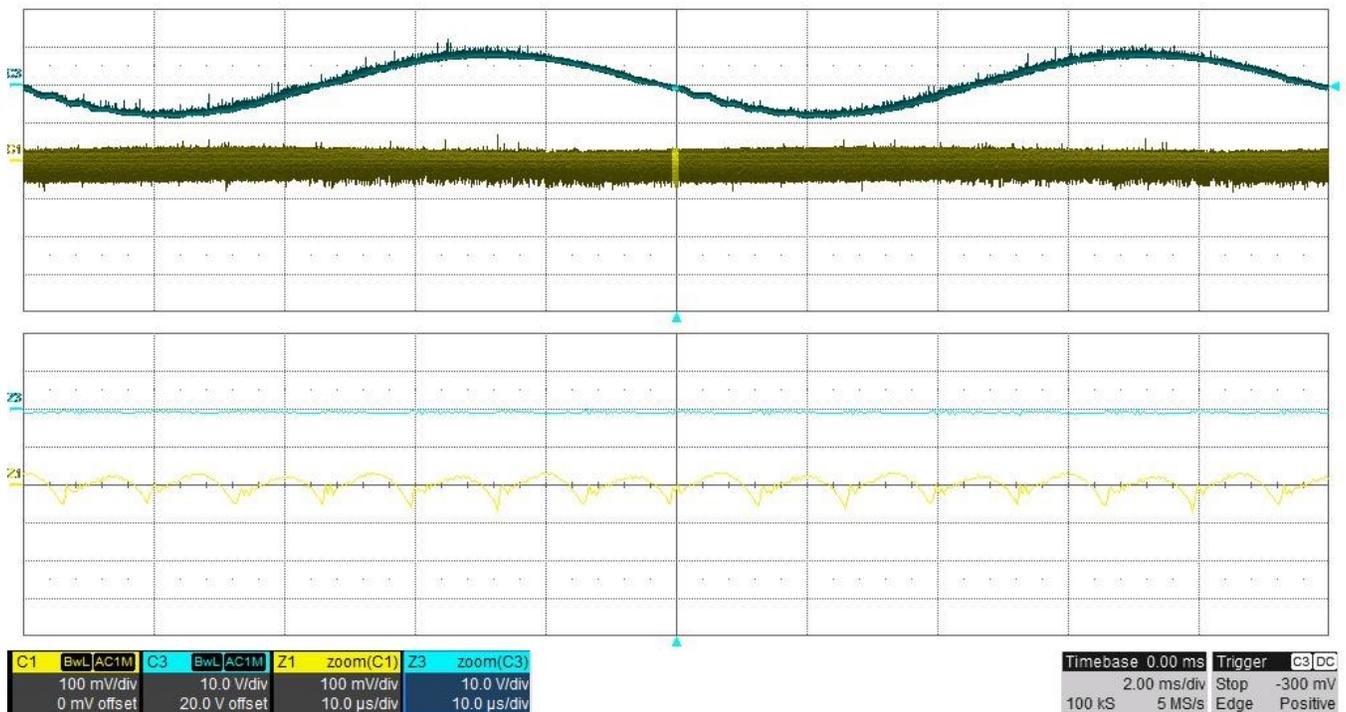


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2.6.5 230V_{AC}/50Hz – 24V/0A



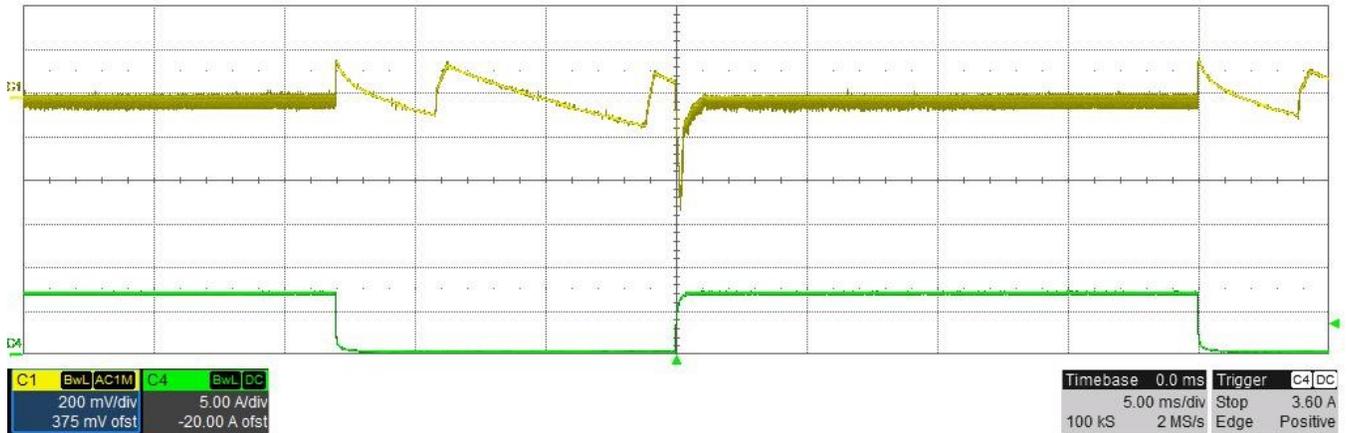
2.6.6 230V_{AC}/50Hz – 24V/10A



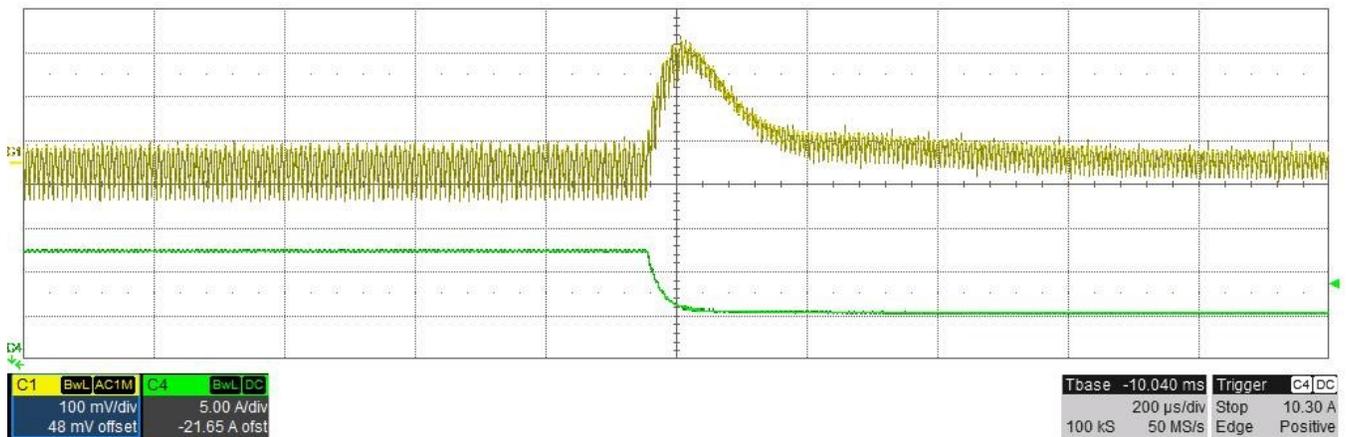
2.7 Load Response

Load response is tested at 230V_{AC}/50Hz input, where Channel 3 is the output voltage in AC level and Channel 4 is output current.

2.7.1 Load step from 0.1A to 7A:

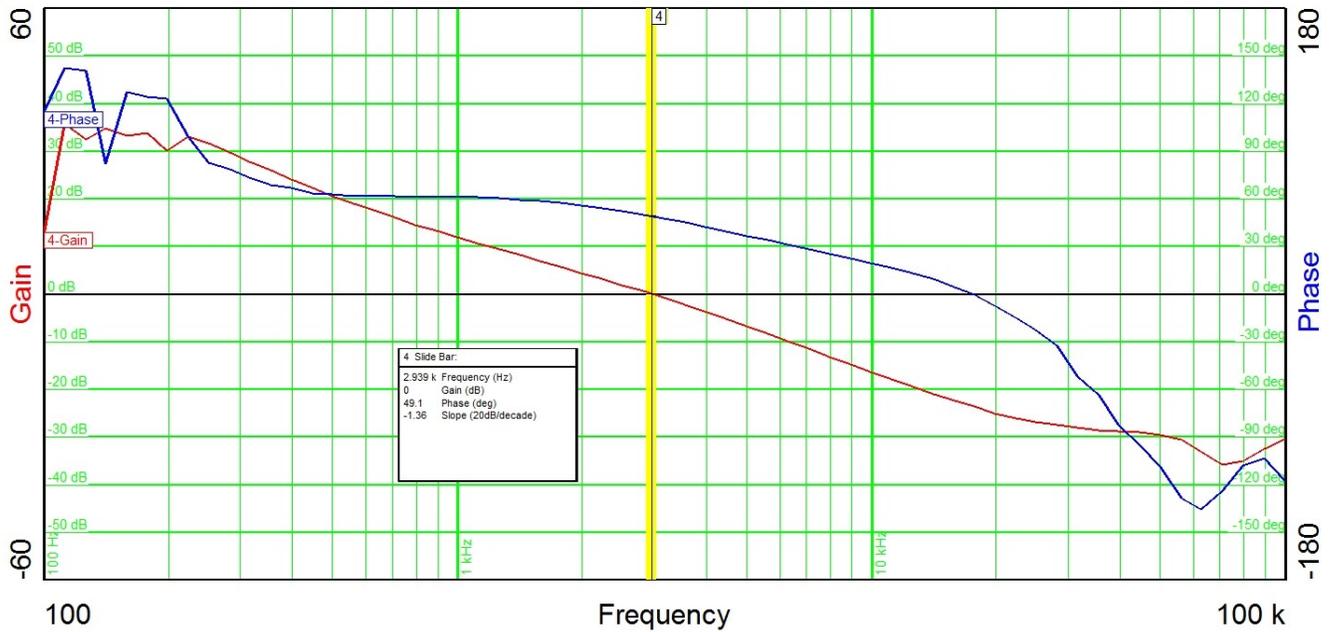


2.7.2 Load step from 7A to 14A:



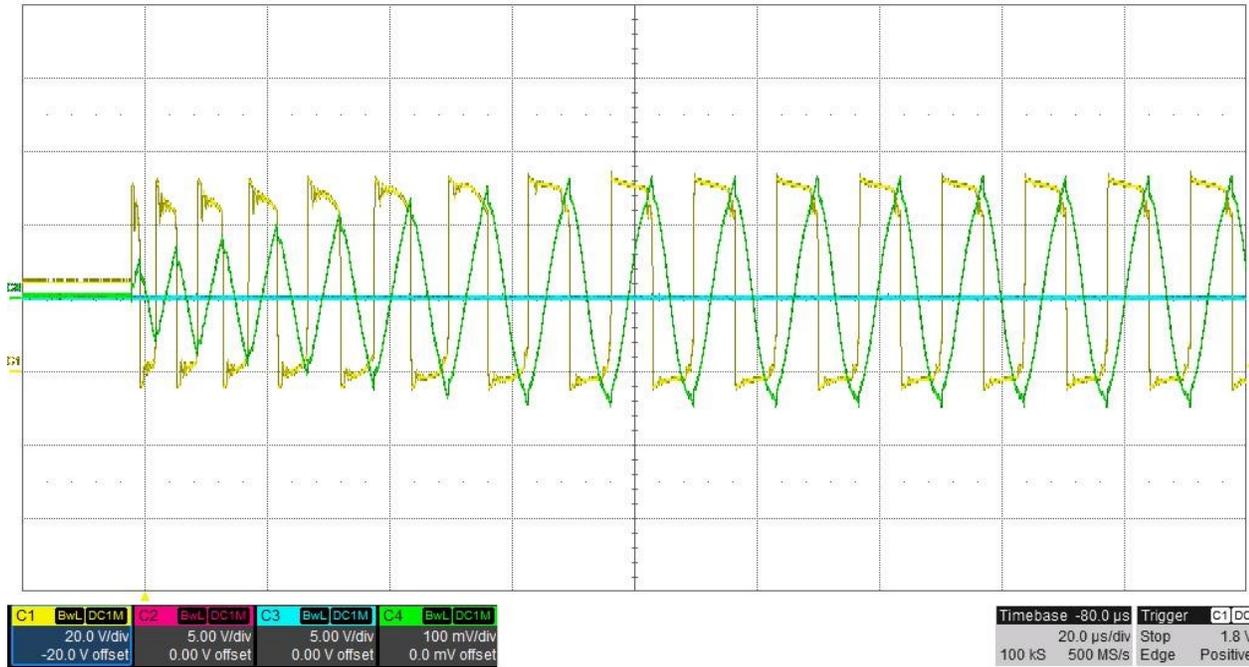
2.8 Frequency Response

Frequency response of the LLC-SRC stage is tested with 230V_{AC}/50Hz input at 10A load. Signal was injected on R215.

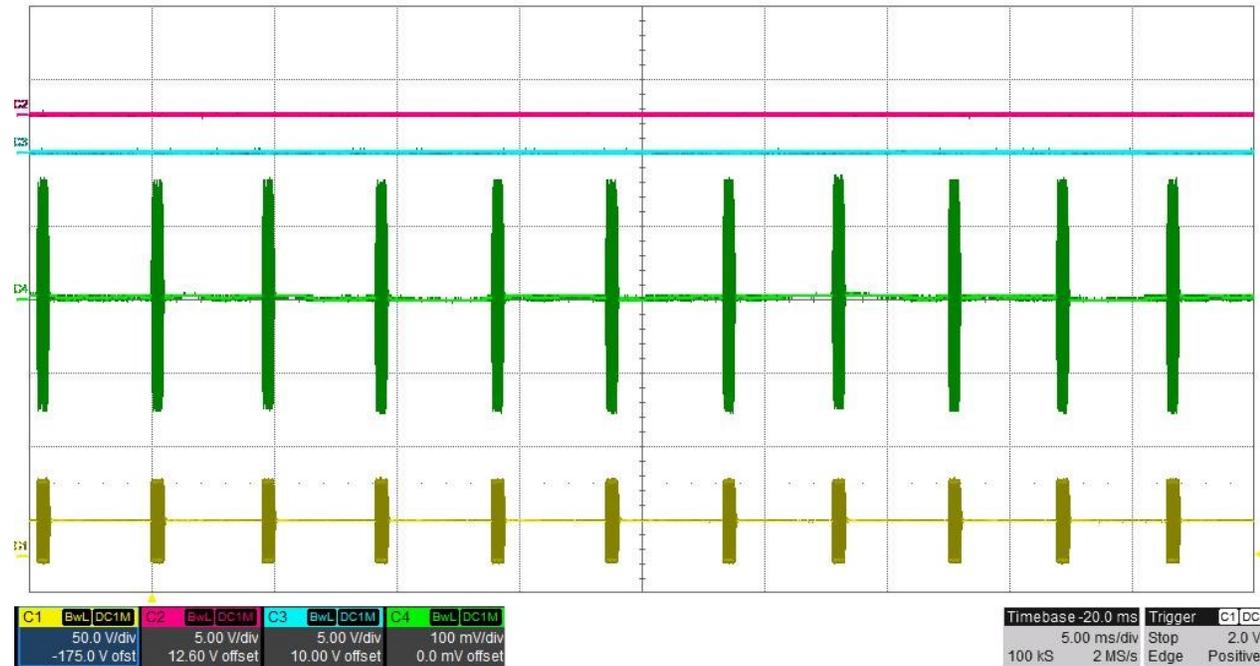


2.9 Key Waveforms

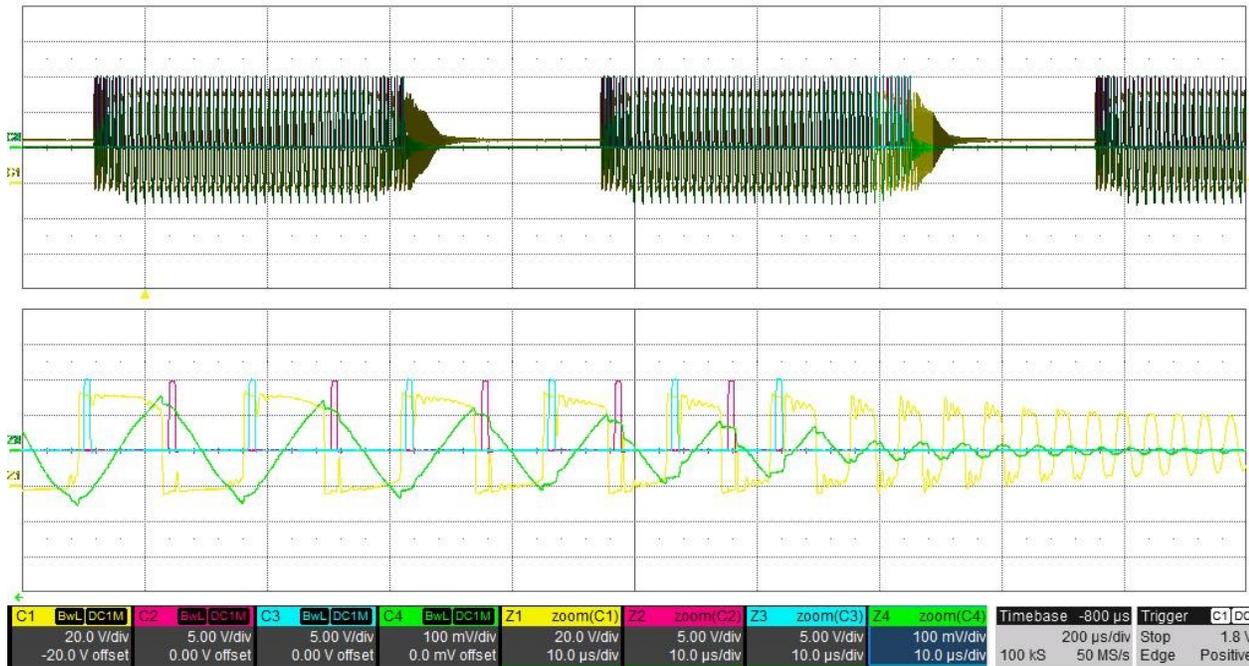
2.9.1 SR FET conduction at 100VAC/60Hz input, 24V/0A output: C1: Q203 V_{DS}, C2: Q201 V_{GS}, C3: Q203 V_{GS}, C4: I_{PRI}



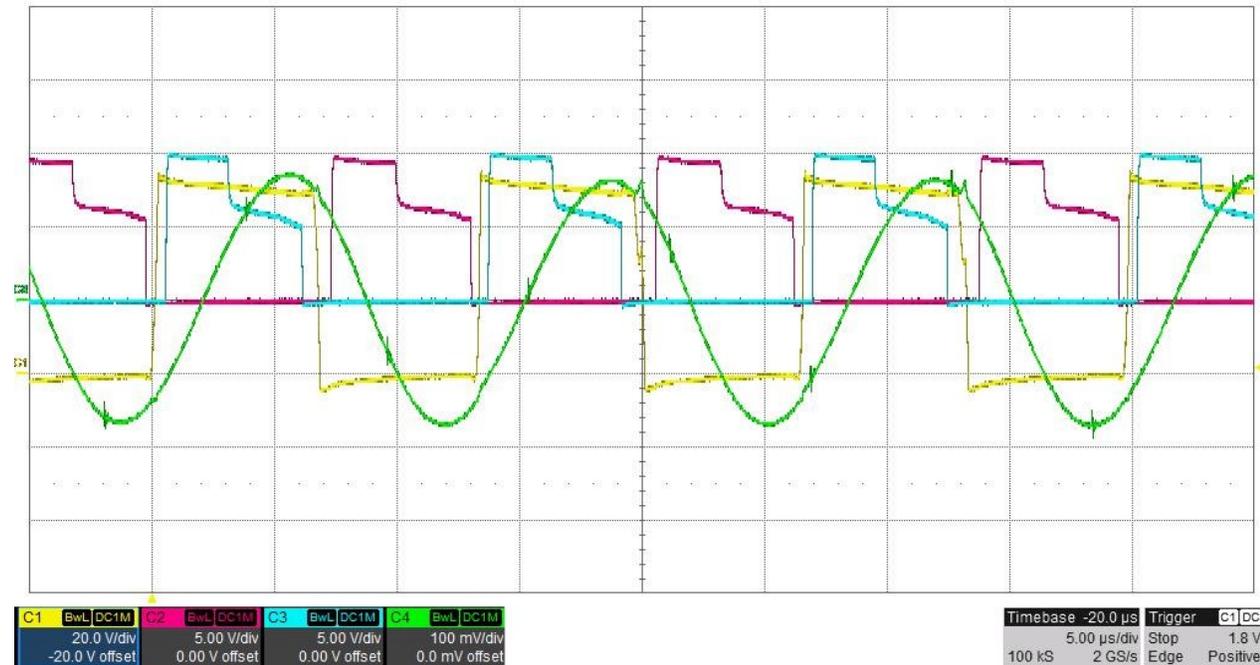
2.9.2 SR FET conduction at 100VAC/60Hz input, 24V/0.1A output: C1: Q203 V_{DS}, C2: Q201 V_{GS}, C3: Q203 V_{GS}, C4: I_{PRI}



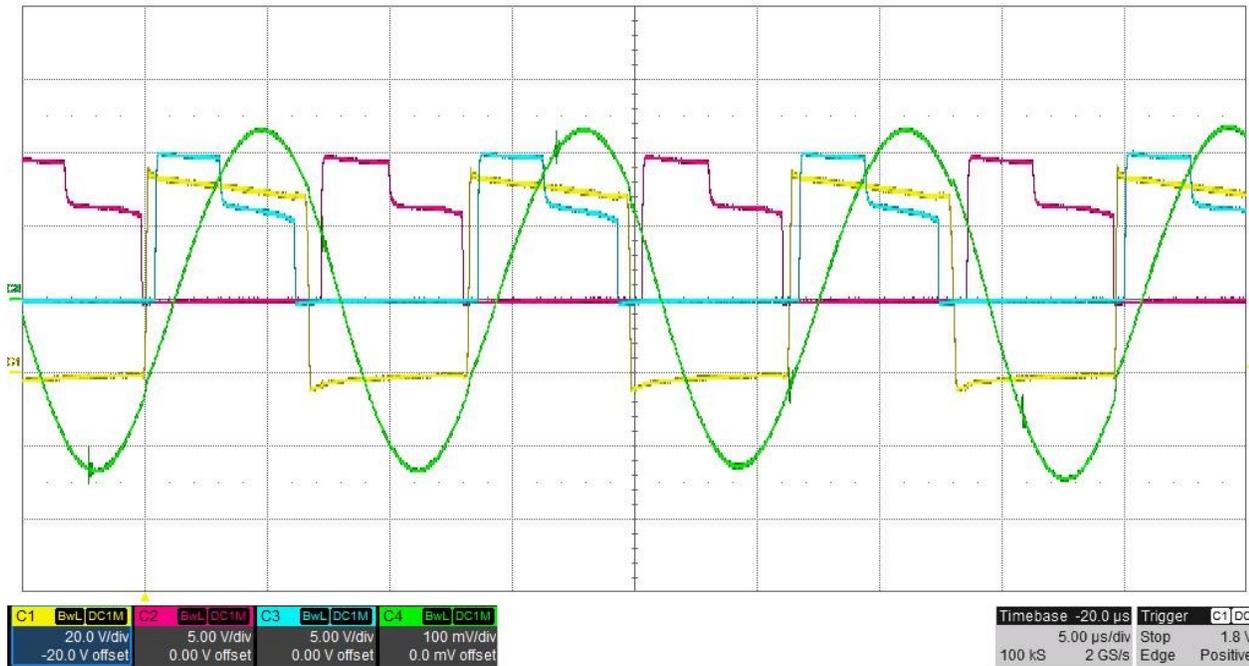
2.9.3 SR FET conduction at 100VAC/60Hz input, 24V/0.5A output: C1: Q203 V_{DS}, C2: Q201 V_{GS}, C3: Q203 V_{GS}, C4: I_{PR1}



2.9.4 SR FET conduction at 100VAC/60Hz input, 24V/5A output: C1: Q203 V_{DS}, C2: Q201 V_{GS}, C3: Q203 V_{GS}, C4: I_{PR1}



2.9.5 SR FET conduction at 100VAC/60Hz input, 24V/10A output: C1: Q203 V_{DS}, C2: Q201 V_{GS}, C3: Q203 V_{GS}, C4: I_{PRI}



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