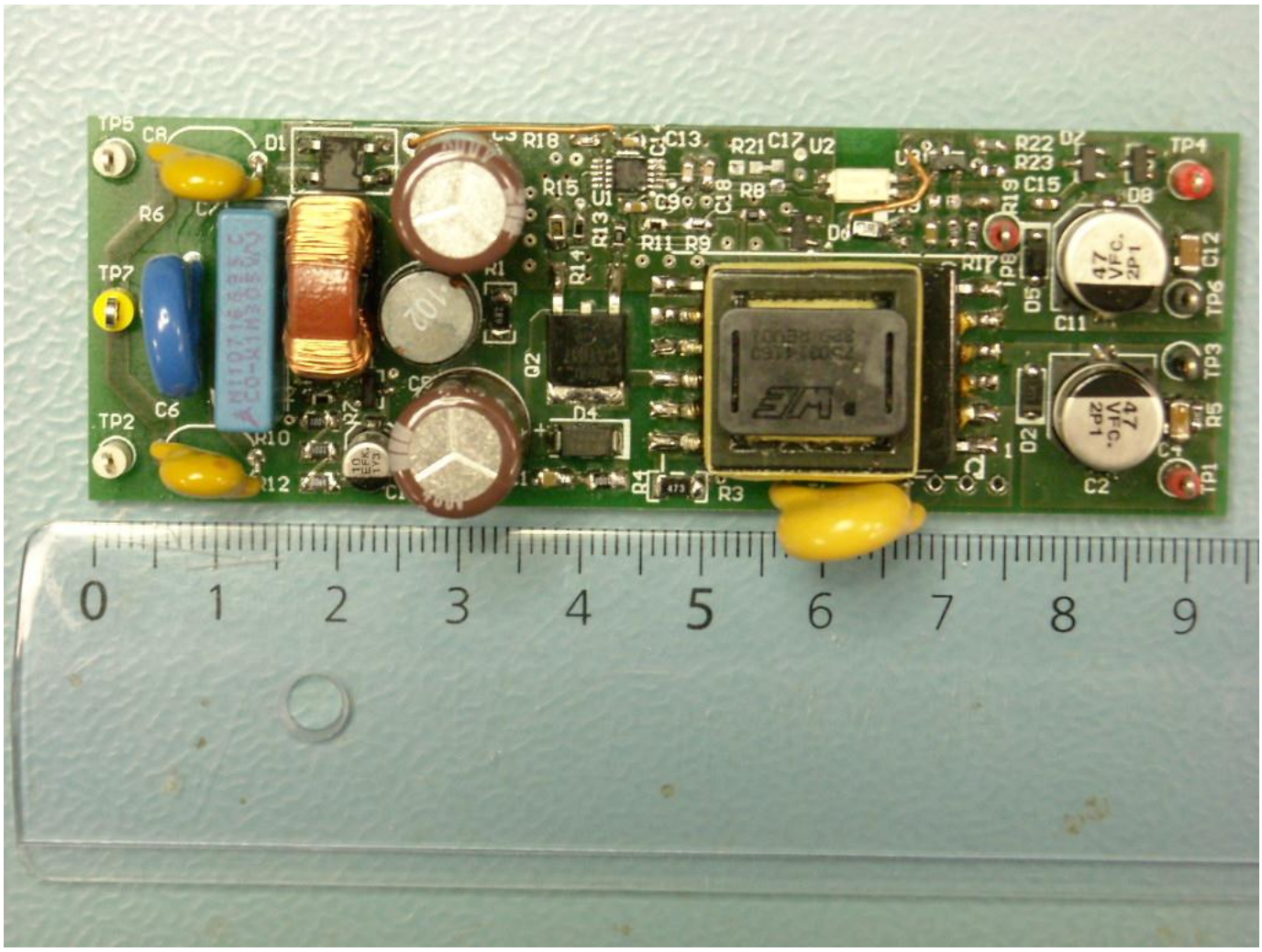
PICTURE OF THE BOARD:

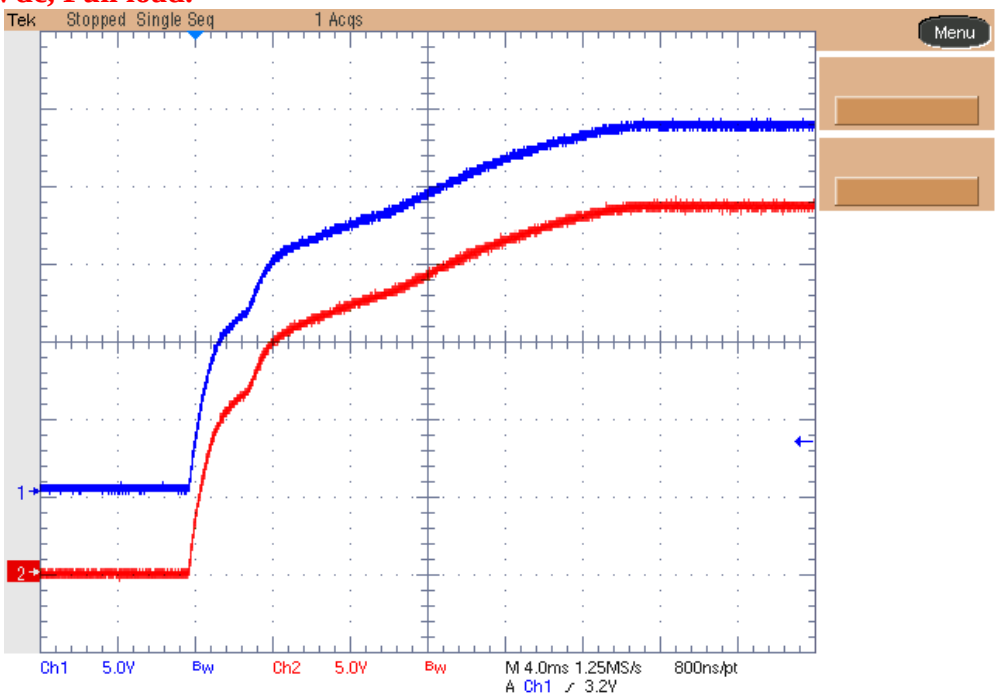


1 Startup

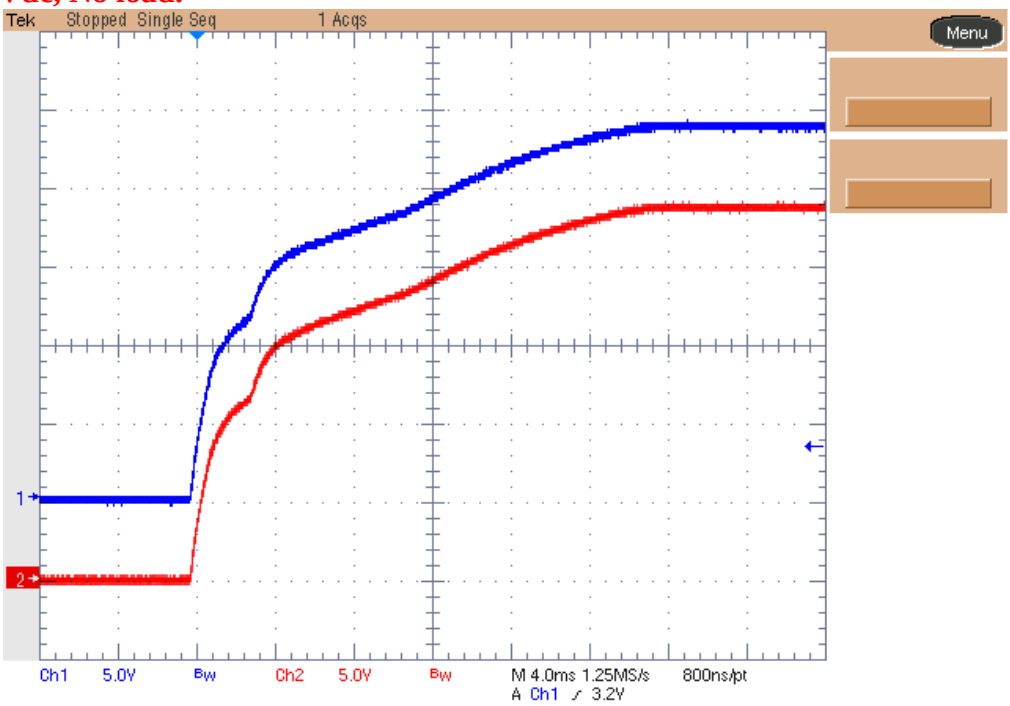
The output voltage behavior at startup is shown in the images below. Four cases have been analyzed at 24Vdc, 320Vdc, full and no-load.

Ch.1: Vout-1 (5V/div, 4ms/div, DC coupling, 20MHz BWL), Ch.2: Vout-2 (5V/div)

Vin = 24Vdc, Full load.

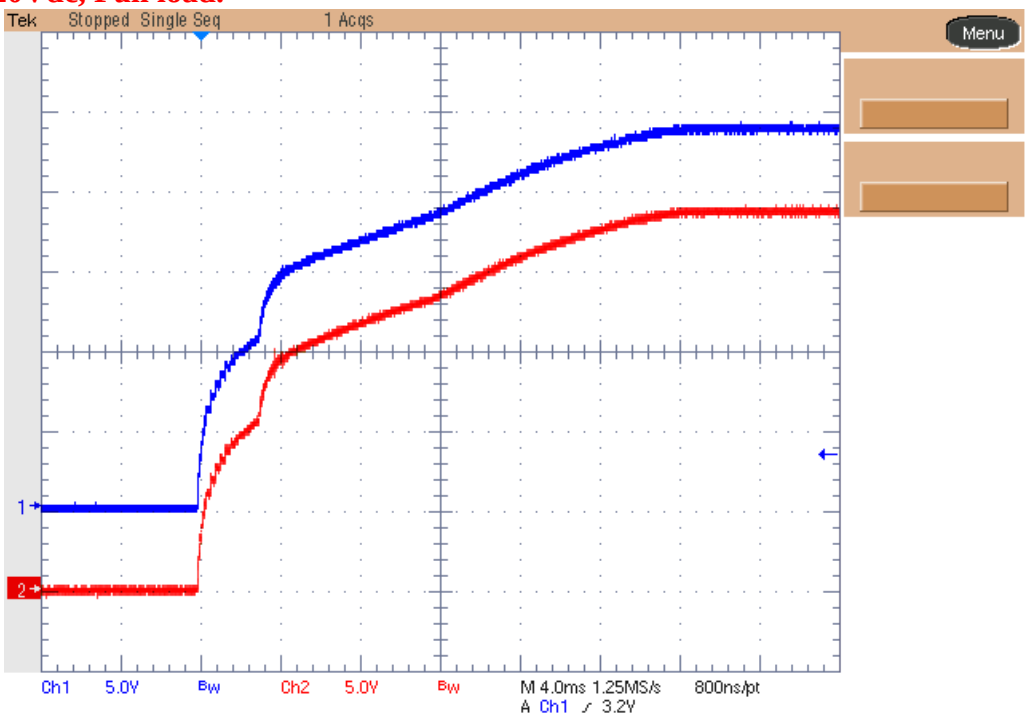


Vin = 24Vdc, No load.

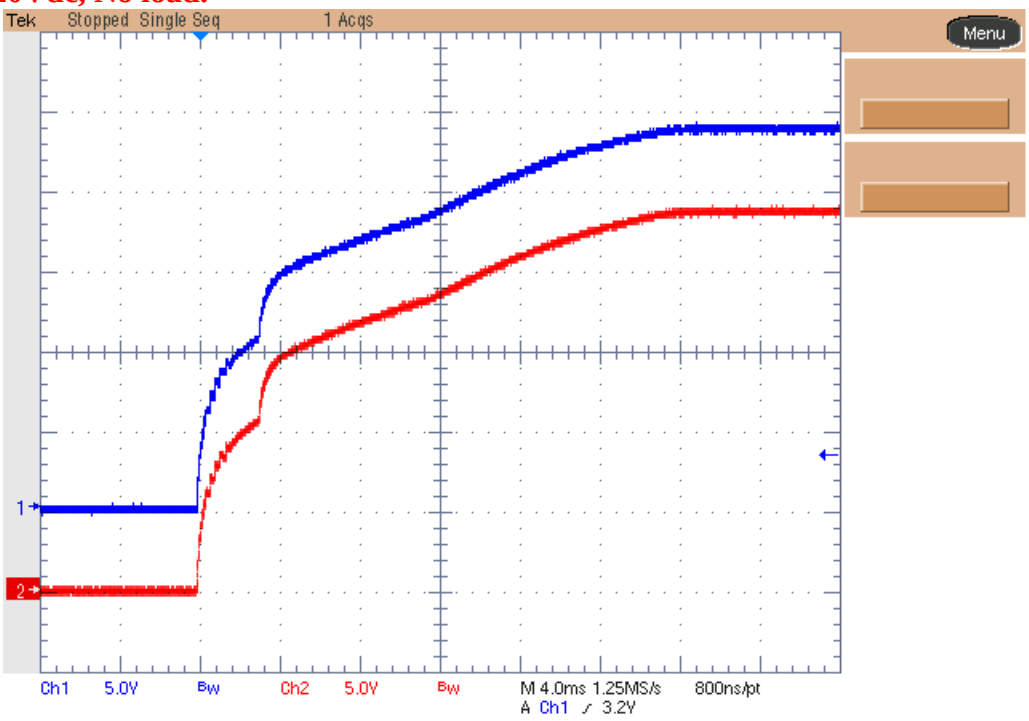


Ch.1: Vout-1 (5V/div, 4ms/div, DC coupling, 20MHz BWL), Ch.2: Vout-2 (5V/div)

Vin = 320Vdc, Full load.



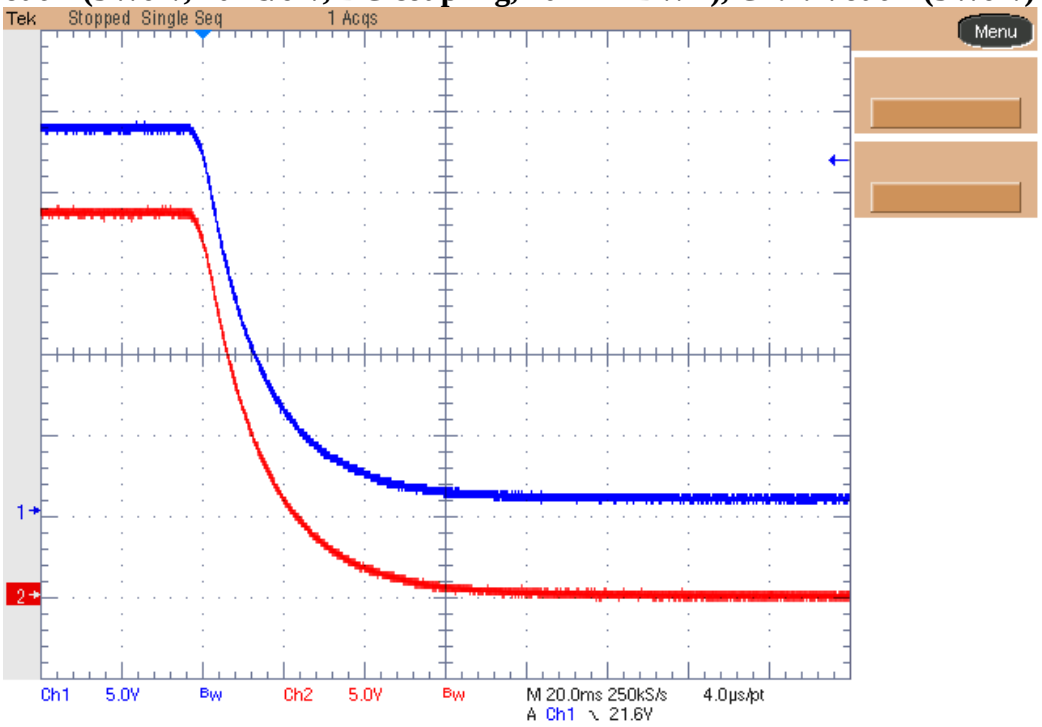
Vin = 320Vdc, No load.



2 Shut down

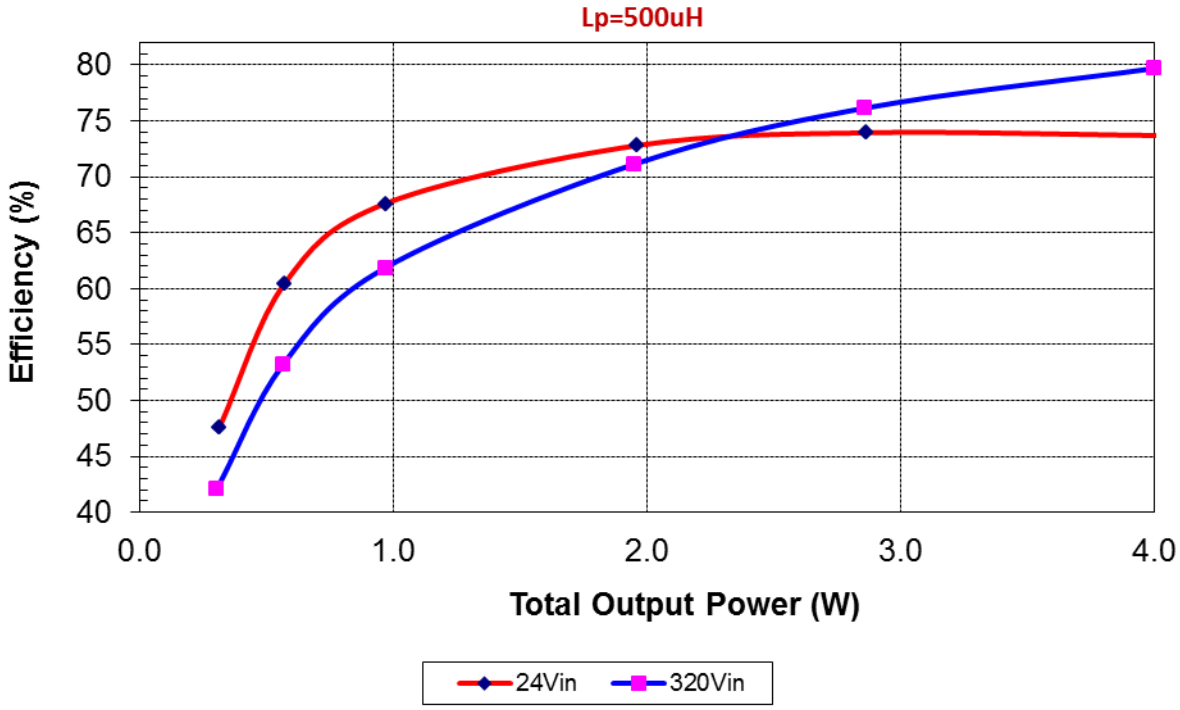
The output voltage behavior during shut down is shown in the image below. The input voltage has been set to 320Vdc and the outputs loaded with resistors at full load.

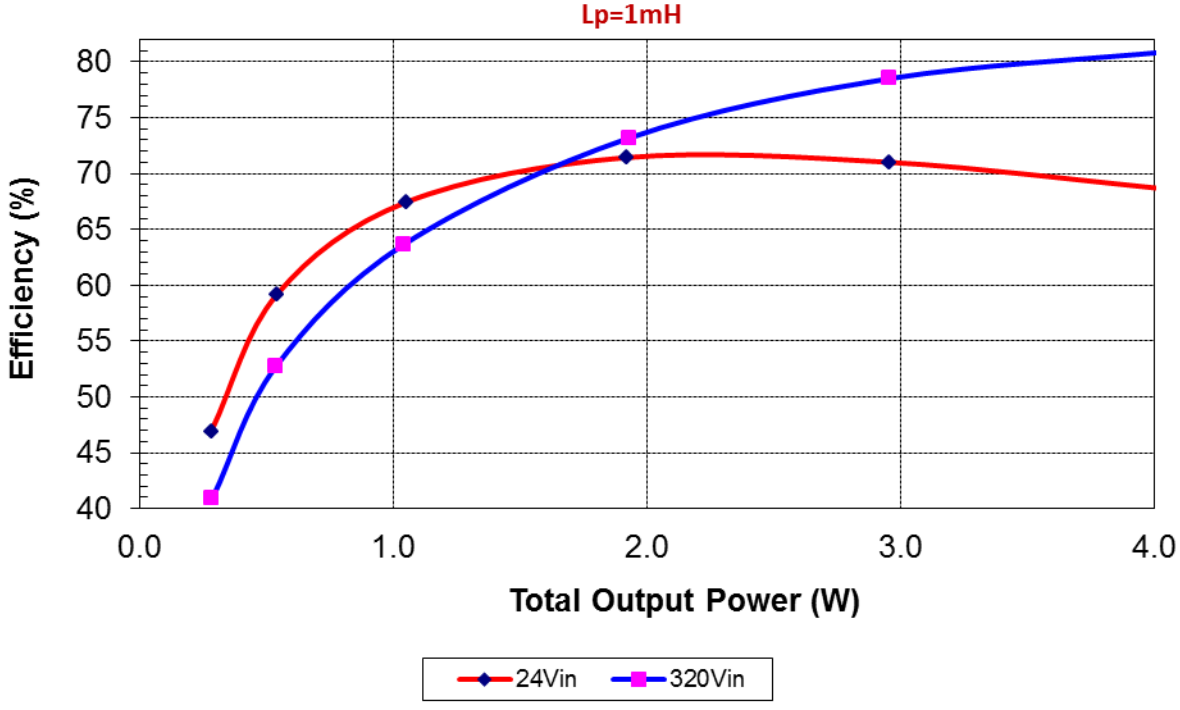
Ch.1: Vout-1 (5V/div, 20ms/div, DC coupling, 20MHz BWL), Ch.2: Vout-2 (5V/div)



3 Efficiency

The efficiency data are shown in the tables and graph below. A DC voltage source has been set to the maximum and minimum input voltage (24Vdc and 320Vdc). Two different transformers have been used: the first one with Lp=500uH and the second one with 1mH. The turn ratios were the same for both transformers. The 500uH value has been chosen for the final design.





Lp=500uH, 24Vin									
Iout-1 (mA)	Vout-1 (V)	Iout-2 (mA)	Vout-2 (V)	Pout (W)	Iin (mA)	Vin (Vdc)	Pin (W)	Ploss (W)	Eff (%)
0	23.72	0	23.69	0.000	11.98	24.05	0.288	0.2881	0.00
6.5	23.71	6.7	23.69	0.313	27.35	24.04	0.657	0.3447	47.58
12.1	23.70	12.0	23.69	0.571	39.3	24.02	0.944	0.3729	60.49
20.7	23.69	20.1	23.69	0.967	59.6	23.99	1.430	0.4633	67.60
40.6	23.69	42.1	23.69	1.959	112.5	23.92	2.691	0.7318	72.80
60.3	23.68	60.7	23.68	2.865	162.4	23.86	3.875	1.0096	73.95
86.2	23.65	84.5	23.68	4.040	228.3	24.01	5.481	1.4419	73.70

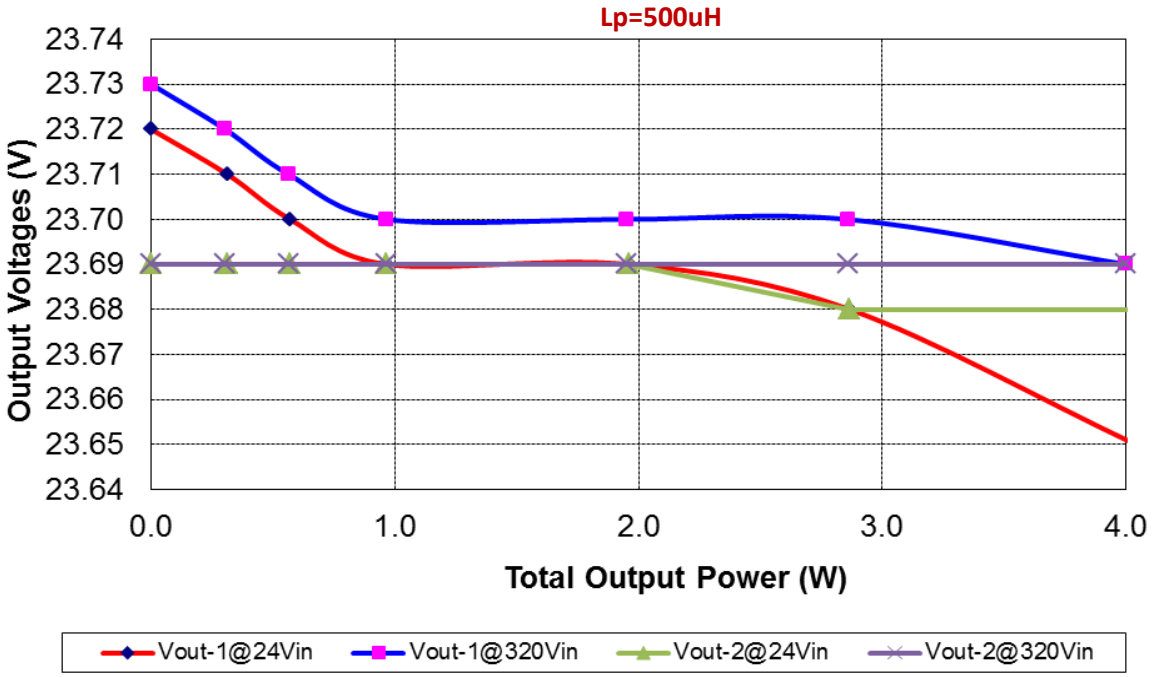
Lp=500uH, 320Vin									
Iout-1 (mA)	Vout-1 (V)	Iout-2 (mA)	Vout-2 (V)	Pout (W)	Iin (mA)	Vin (Vdc)	Pin (W)	Ploss (W)	Eff (%)
0	23.73	0	23.69	0.000	1.025	320.2	0.328	0.3282	0.00
6.2	23.72	6.6	23.69	0.303	2.25	320.2	0.720	0.4170	42.12
11.8	23.71	12.0	23.69	0.564	3.31	320.2	1.060	0.4958	53.22
20.7	23.70	20.1	23.69	0.967	4.88	320.2	1.563	0.5958	61.87
40.7	23.70	41.6	23.69	1.950	8.56	320.2	2.741	0.7908	71.15
60.5	23.70	60.1	23.69	2.858	11.72	320.2	3.753	0.8951	76.15
84.5	23.69	84.3	23.69	3.999	15.67	320.2	5.018	1.0187	79.70

Lp=1mH, 24Vin									
Iout-1 (mA)	Vout-1 (V)	Iout-2 (mA)	Vout-2 (V)	Pout (W)	Iin (mA)	Vin (Vdc)	Pin (W)	Ploss (W)	Eff (%)
0	23.69	0	23.69	0.000	11.02	24.08	0.265	0.2654	0.00
6.1	23.68	5.7	23.69	0.279	24.77	24.07	0.596	0.3167	46.88
11.7	23.67	11.1	23.69	0.540	37.91	24.06	0.912	0.3722	59.19
22.5	23.67	21.9	23.68	1.051	64.9	24.01	1.558	0.5071	67.46
40.3	23.67	40.7	23.68	1.918	110.7	24.25	2.684	0.7668	71.44
62.8	23.65	62.1	23.68	2.956	172.2	24.17	4.162	1.2063	71.02
86.2	23.64	86.3	23.68	4.081	247.3	24.08	5.955	1.8736	68.54

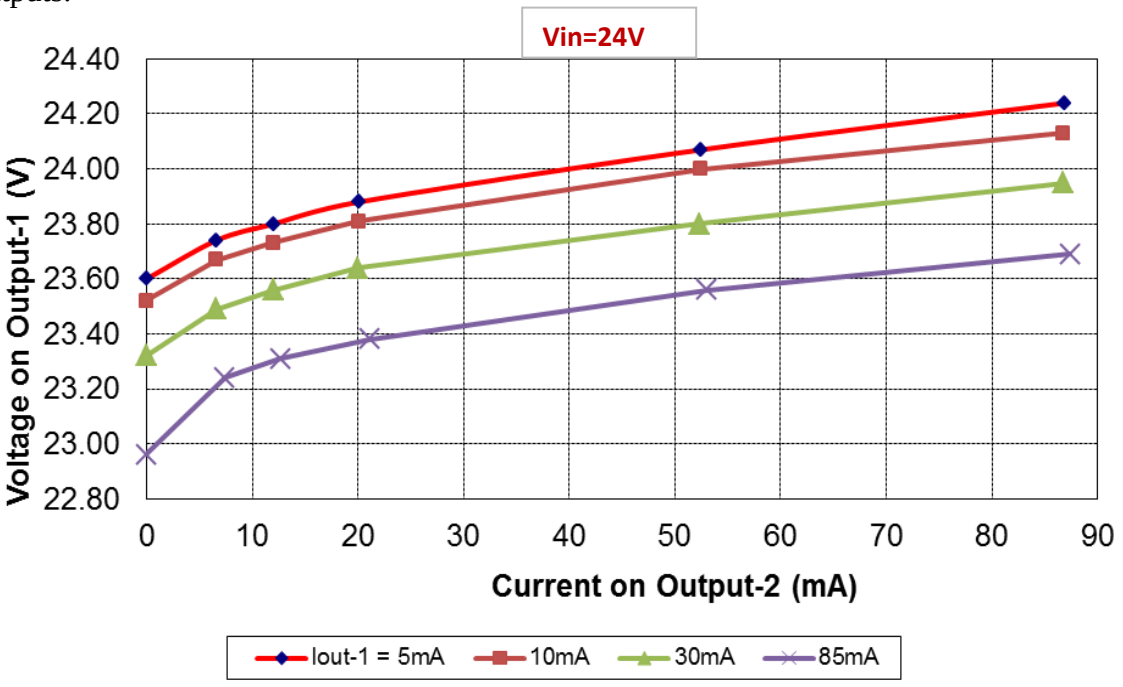
Lp=1mH, 320Vin									
Iout-1 (mA)	Vout-1 (V)	Iout-2 (mA)	Vout-2 (V)	Pout (W)	Iin (mA)	Vin (Vdc)	Pin (W)	Ploss (W)	Eff (%)
0	23.71	0	23.69	0.000	1.026	320.3	0.329	0.3286	0.00
6.2	23.68	5.8	23.68	0.284	2.17	320.3	0.695	0.4109	40.88
11.5	23.68	11.1	23.68	0.535	3.17	320.3	1.015	0.4802	52.71
22.0	23.68	21.9	23.68	1.040	5.10	320.3	1.634	0.5940	63.64
40.8	23.67	40.7	23.68	1.930	8.23	320.3	2.636	0.7066	73.20
62.8	23.67	62.0	23.68	2.955	11.75	320.3	3.764	0.8089	78.51
86.1	23.67	86.1	23.68	4.077	15.72	320.3	5.035	0.9583	80.97

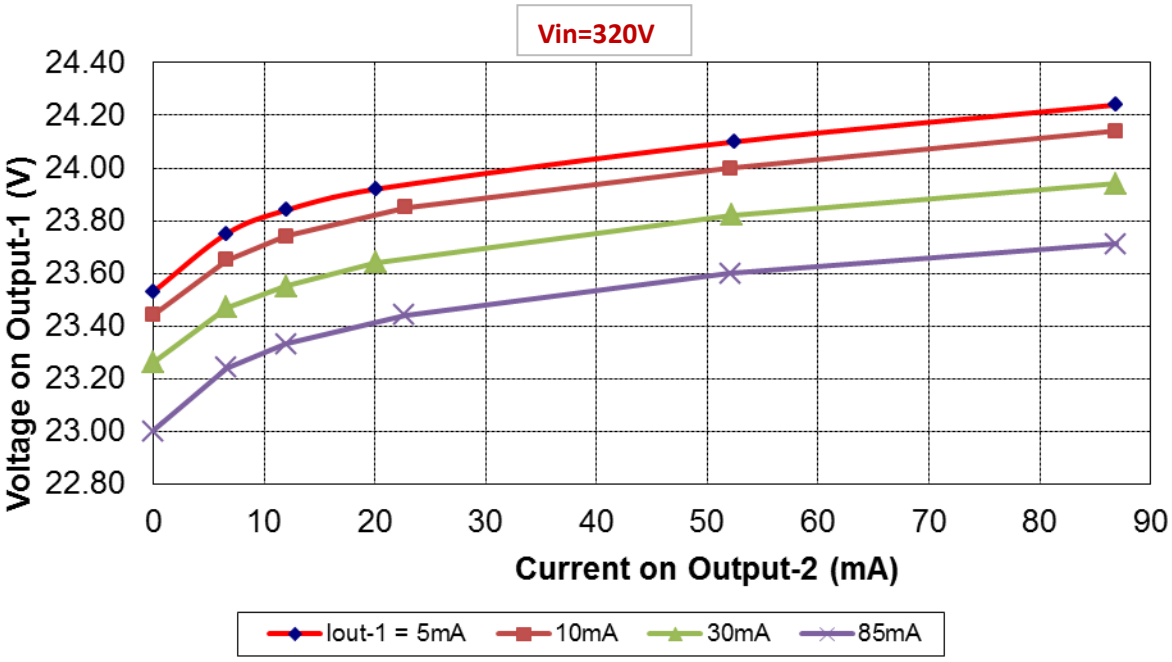
4 Output Voltage Regulation

The output voltage variation as function of load and input voltage is shown below. The two output loads have been varied proportionally. From now and beyond, the primary inductance of the transformer was 500uH.



A further measurement has been performed in order to measure the cross regulation between outputs.

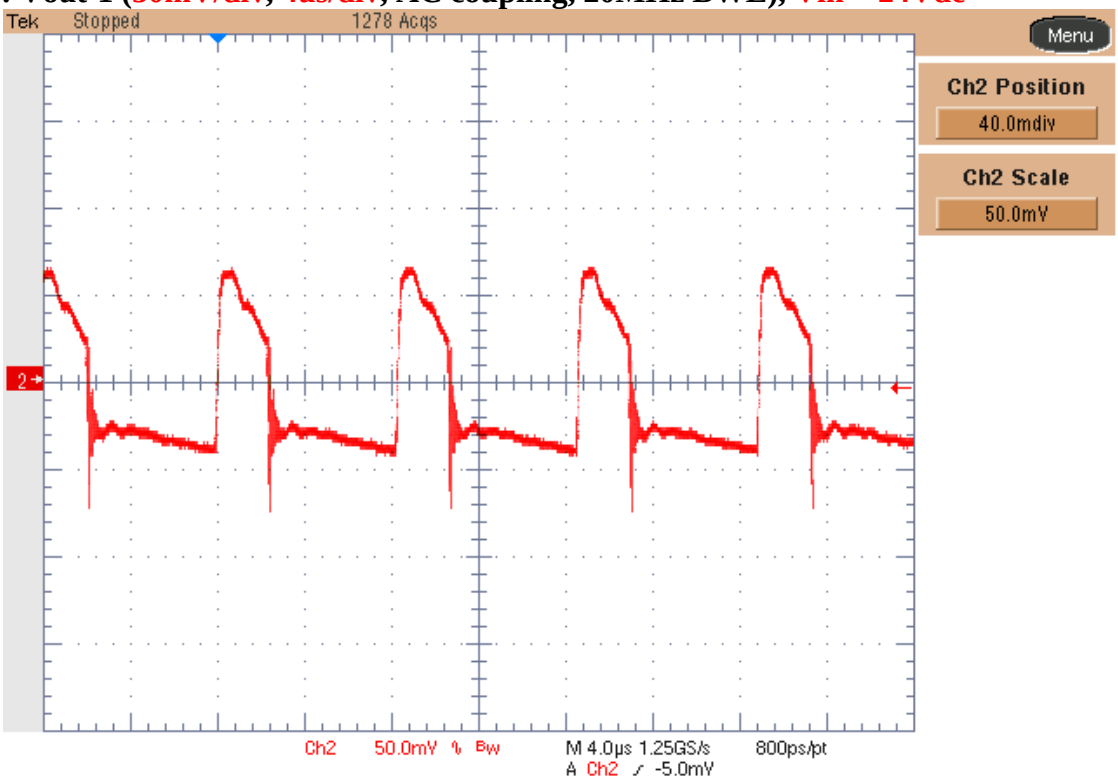




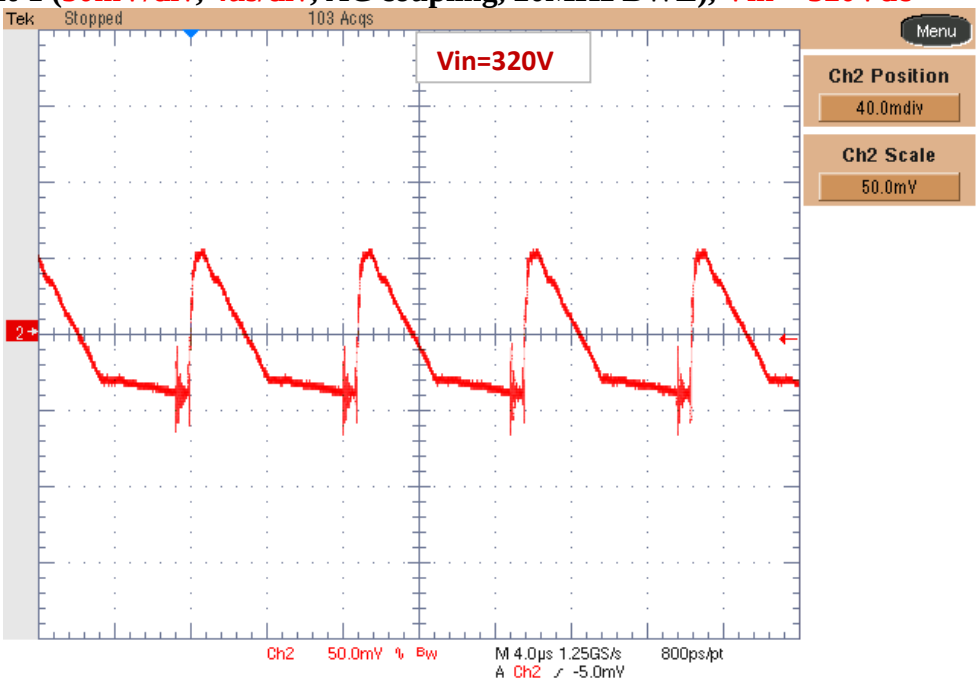
5 Output Ripple Voltage

The output ripple voltage (the same for both outputs) is shown in the plots below. The input was set to 24Vdc and 320Vdc while the output was fully loaded.

Ch.2: Vout-1 (50mV/div, 4us/div, AC coupling, 20MHz BWL), Vin = 24Vdc



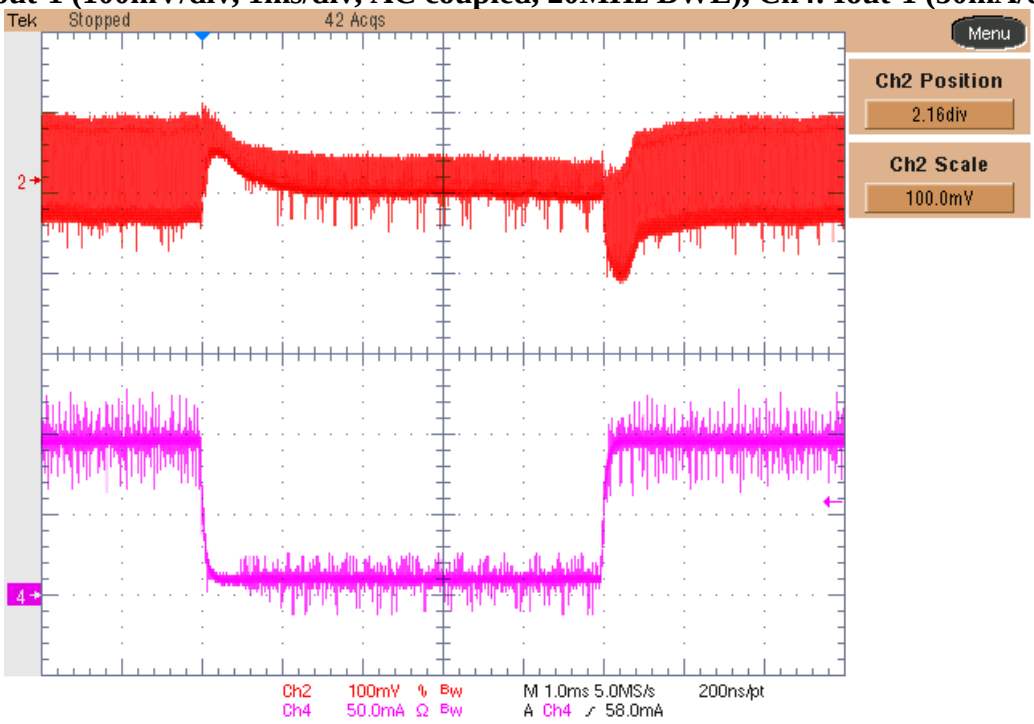
Ch.2: Vout-1 (50mV/div, 4us/div, AC coupling, 20MHz BWL), Vin = 320Vdc



6 Transient response

The image below shows the transient response on the output-1 voltage when its load has been switched between 10mA and 100mA while the load on output-2 has been kept constant to 85mA. The input voltage was 24Vdc.

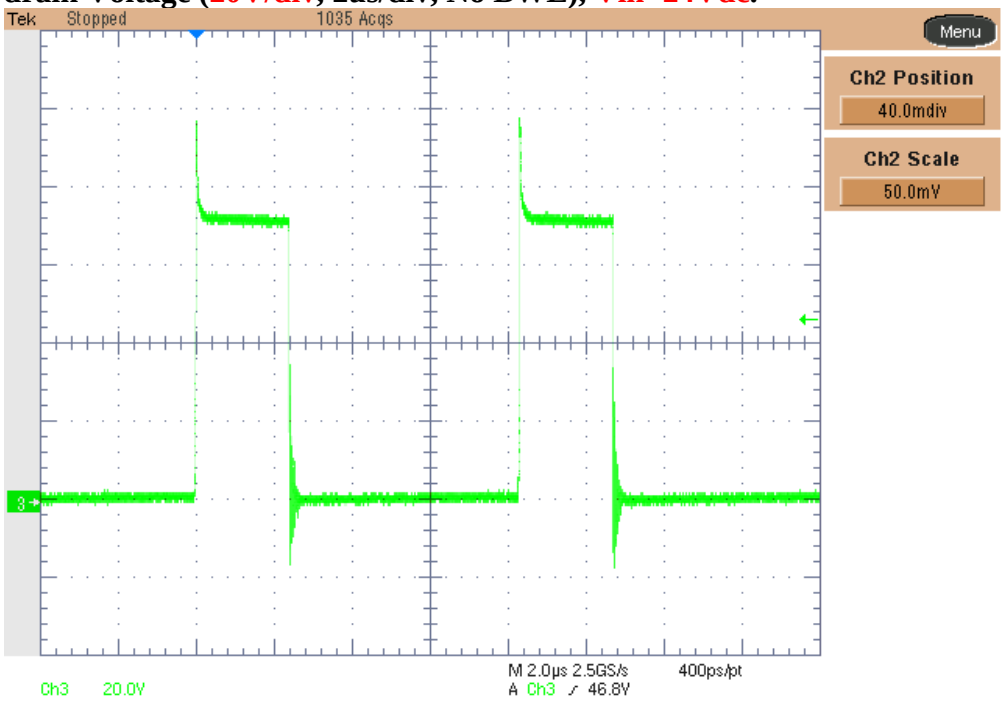
Ch2: Vout-1 (100mV/div, 1ms/div, AC coupled, 20MHz BWL), Ch4: Iout-1 (50mA/div)



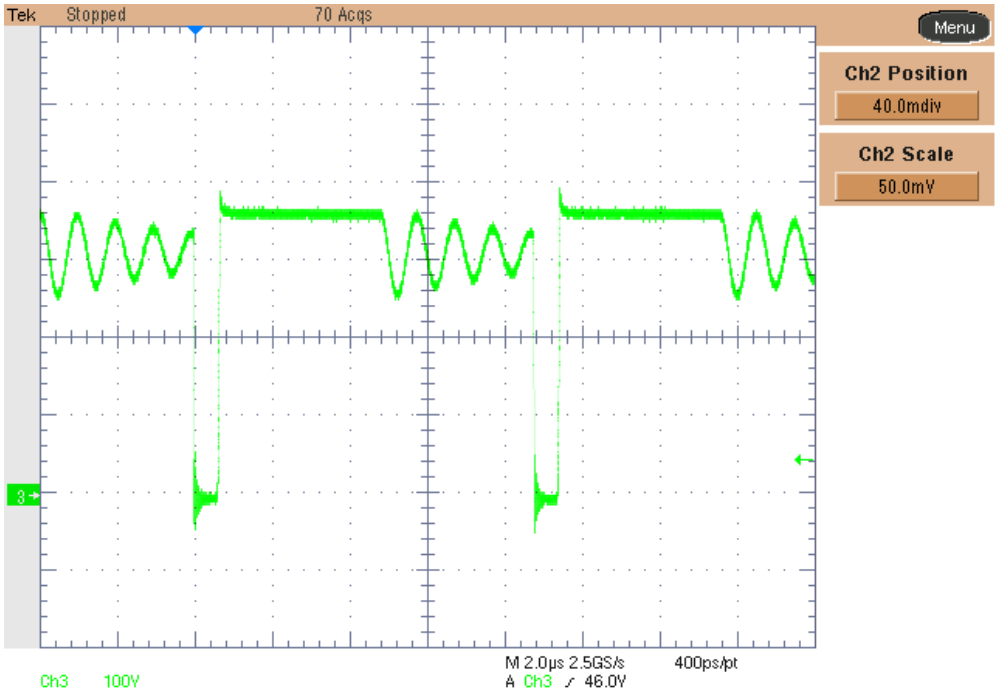
7 Switching Node Waveform

The image below shows the peak voltage on drain of Q2 at 24Vdc and 320Vdc input voltage in full load conditions.

Ch3: Q2 drain Voltage (20V/div, 2us/div, No BWL), Vin=24Vdc.

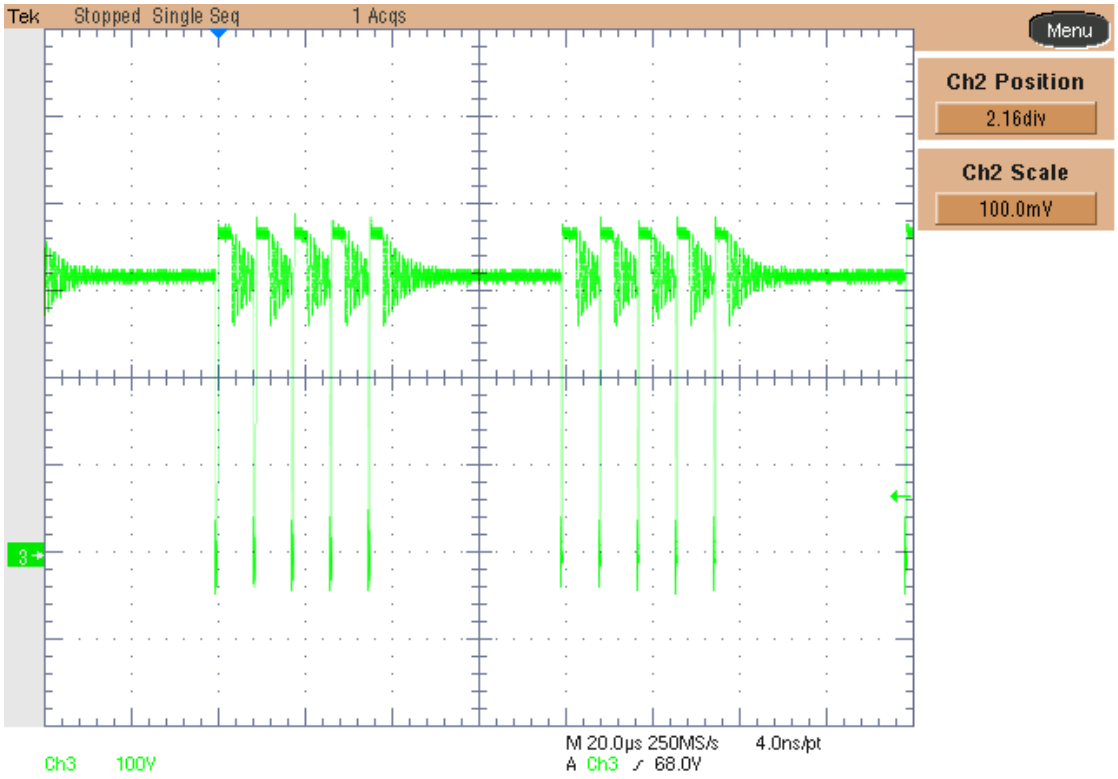


Ch3: Q2 drain Voltage (100V/div, 2us/div, No BWL), Vin=24Vdc.



The load has been reduced down to 15mA for each output. The image below shows that the converter works in burst mode. The input voltage was 320Vdc.

Ch3: Q2 drain Voltage (100V/div, 20us/div, No BWL), Vin=320Vdc.



8 Thermal Analysis

The thermal analysis of the converter shows the temperatures for each component, in the graphs below. The converter has been placed horizontally on the bench without any forced convection. The input voltage was 24Vdc for the first scan and 320Vdc for the second one. Both outputs have been fully loaded. The ambient temperature was 25C.

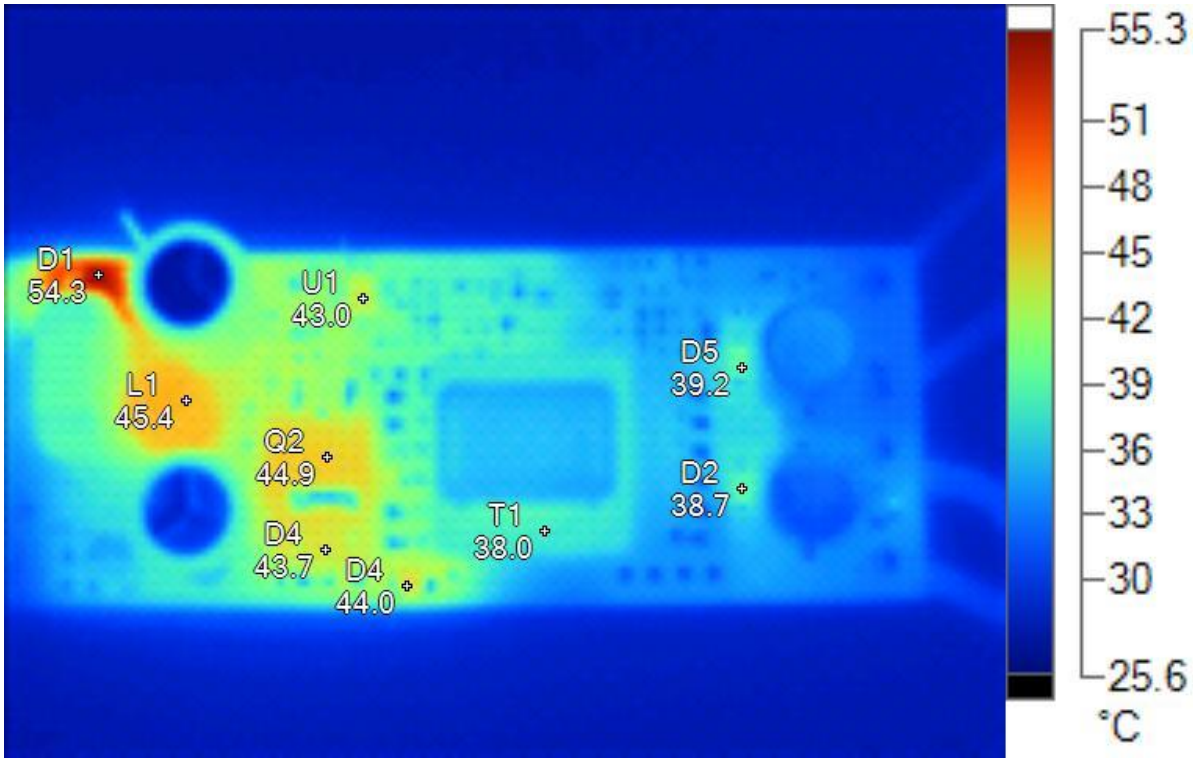


Image Info

Background temperature	25.0°C
Average Temperature	31.9°C
Image Range	26.8°C to 54.3°C
Camera Model	Ti40FT
Camera Manufacturer	Fluke
Image Time	7/29/2013 2:41:22 PM

Main Image Markers

Name	Temperature
D1	54.3°C
L1	45.4°C
Q2	44.9°C
D4	43.7°C
U1	43.0°C
T1	38.0°C
D5	39.2°C
D2	38.7°C
D4	44.0°C

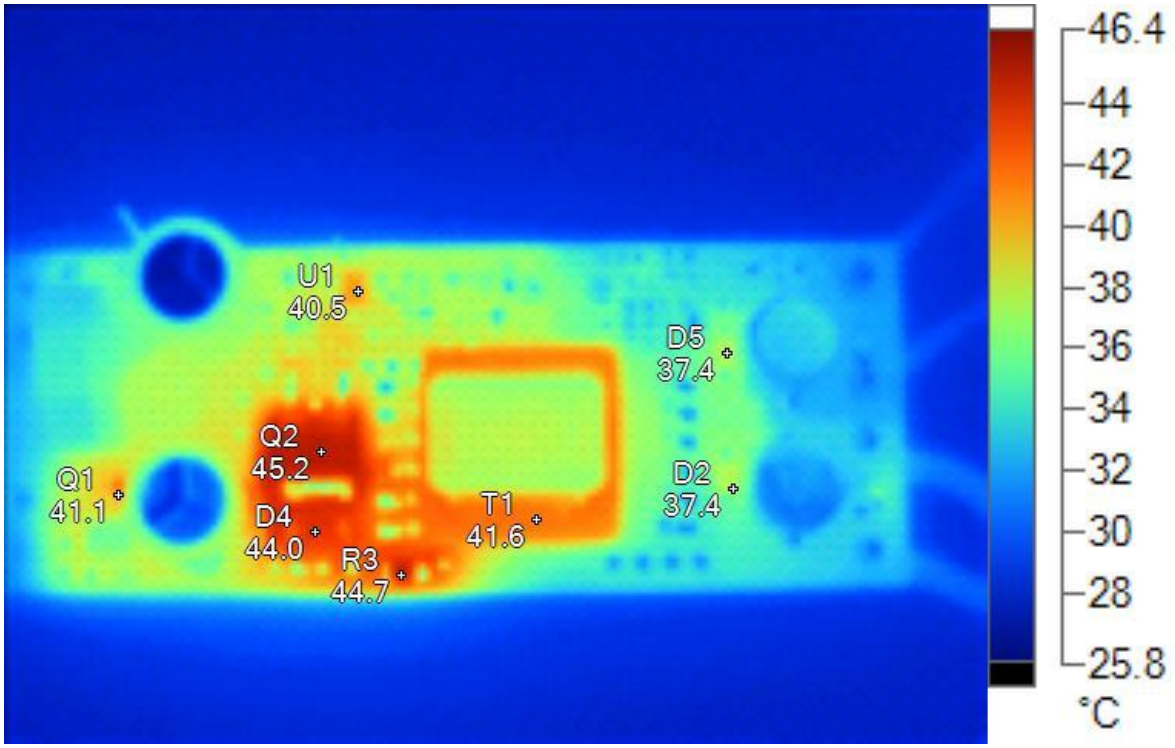


Image Info

Background temperature	25.0°C
Average Temperature	31.6°C
Image Range	26.8°C to 45.4°C
Camera Model	Ti40FT
Camera Manufacturer	Fluke
Image Time	7/29/2013 2:45:12 PM

Main Image Markers

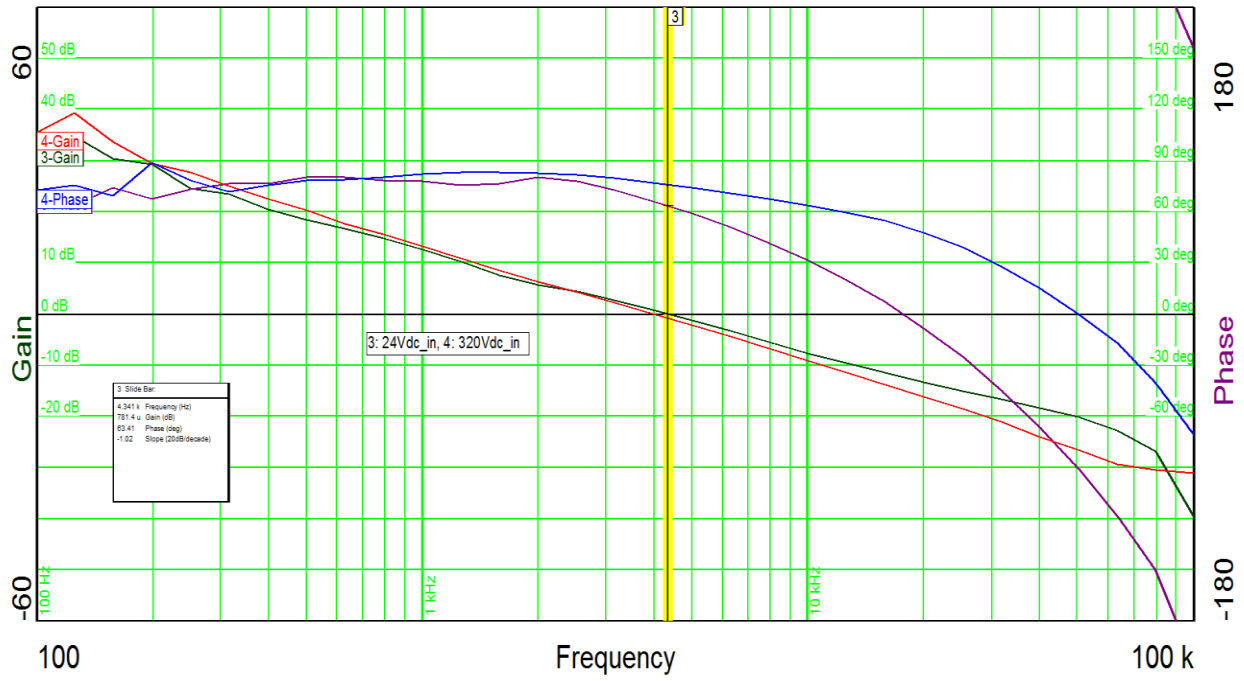
Name	Temperature
Q1	41.1°C
Q2	45.2°C
R3	44.7°C
D4	44.0°C
U1	40.5°C
D5	37.4°C
D2	37.4°C
T1	41.6°C

9 Loop Analysis

The loop analysis on the converter shows results regarding phase margin and gain margin, as well as crossover frequency. The converter has been supplied @ 24Vdc and 320Vdc input voltage while fully loaded.

The graph below shows the worst case gain and phase margin, measured when the input voltage was 24Vdc and therefore the converter was running in CCM:

1) Phase margin = 63.41 deg.
2) Gain margin = 12.34 dB
3) Crossover frequency = 4.341 KHz



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