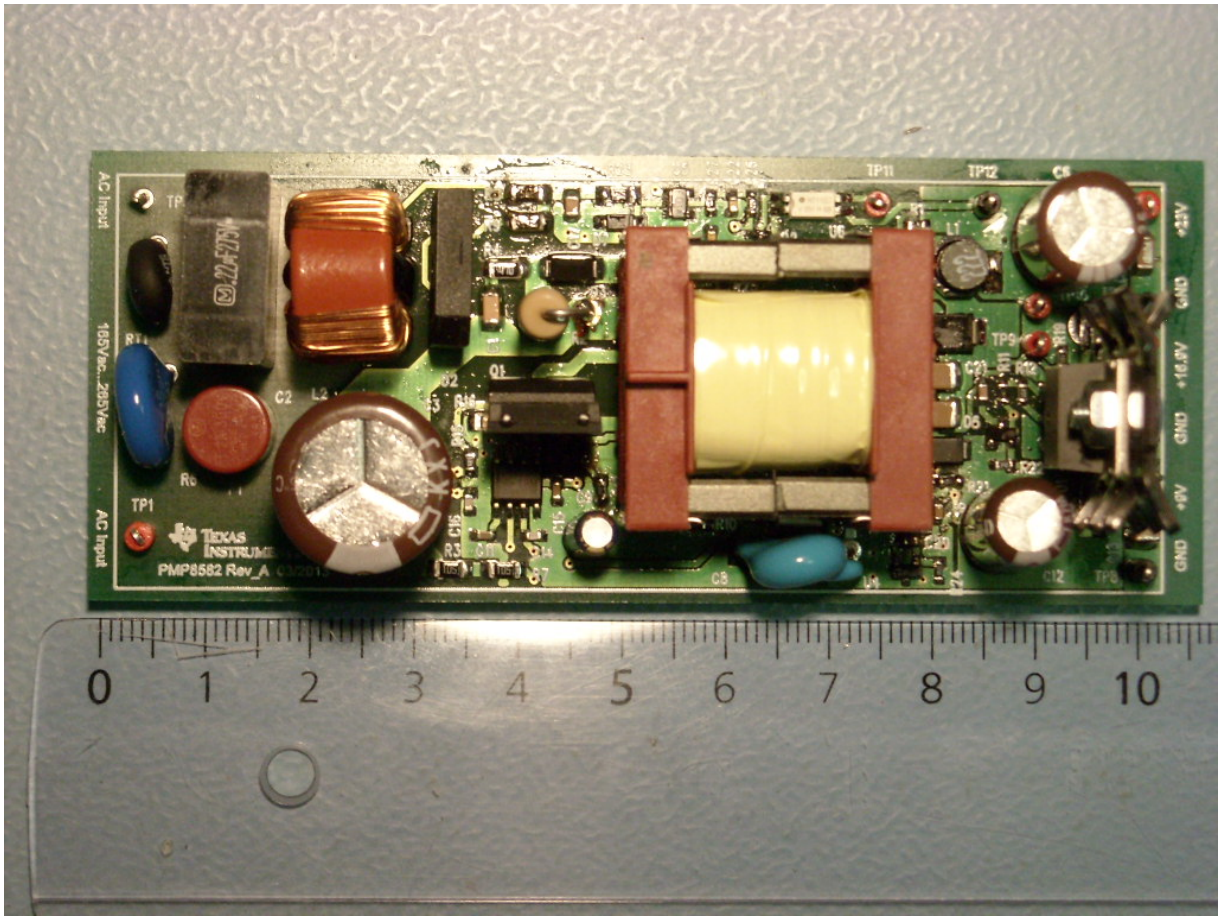
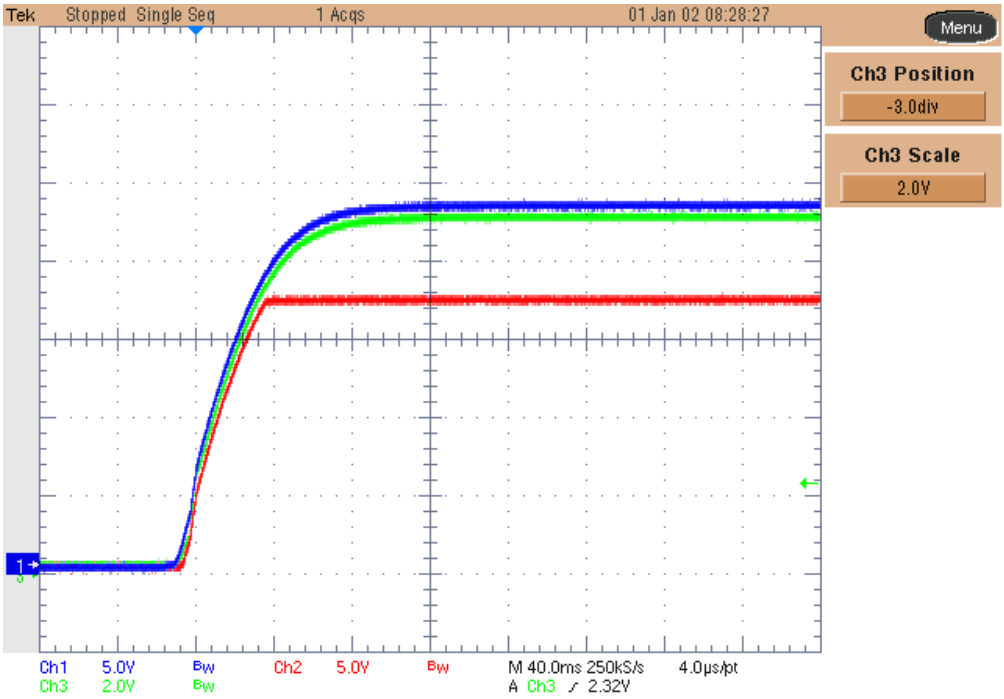
PHOTO OF THE PROTOTYPE:



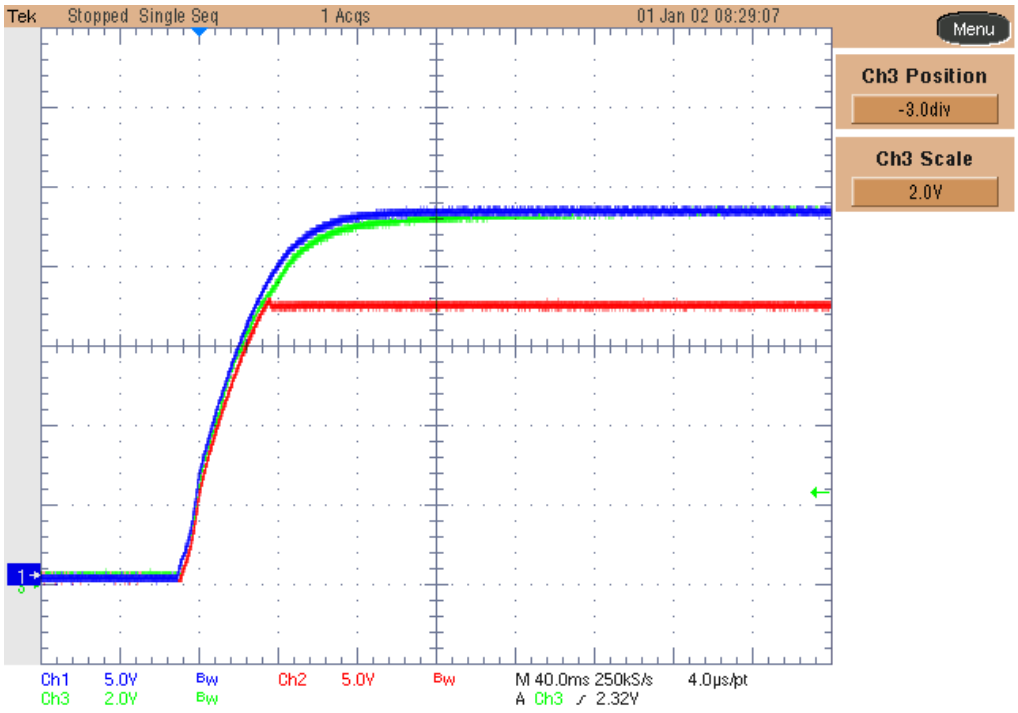
1. Startup

The output voltage behavior at startup is shown in the images below. The input voltage was set to 230Vac, 50Hz. All outputs fully loaded in the upper picture and unloaded for the bottom one.
Ch1: 23Vout (5V/div, 40ms/div), Ch2: 17Vout (5V/div), Ch3: 9Vout (2V/div)
Bandwidth limit for all channels: 20MHz

Full Load:

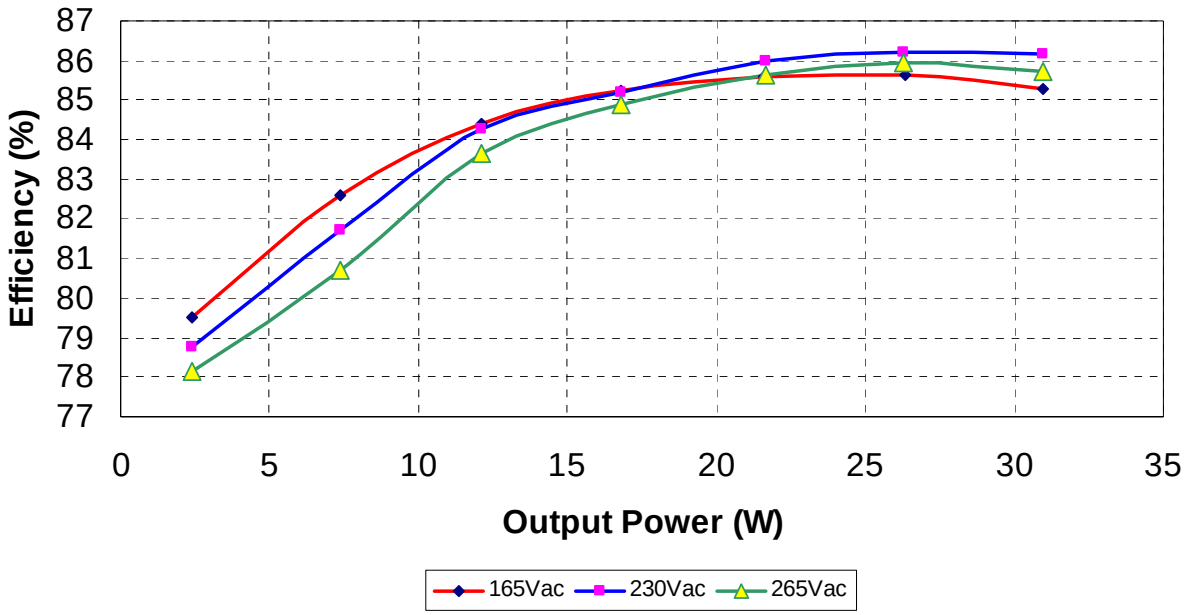


No Load



2. Efficiency

The efficiency data are shown in the tables and graph below. A digital power meter Yokogawa WT210 has been used and the input AC voltage set to 165, 230 and 265Vrms, 50Hz.
All loads have been increased at the same time from 0% to 100% of its nominal value.



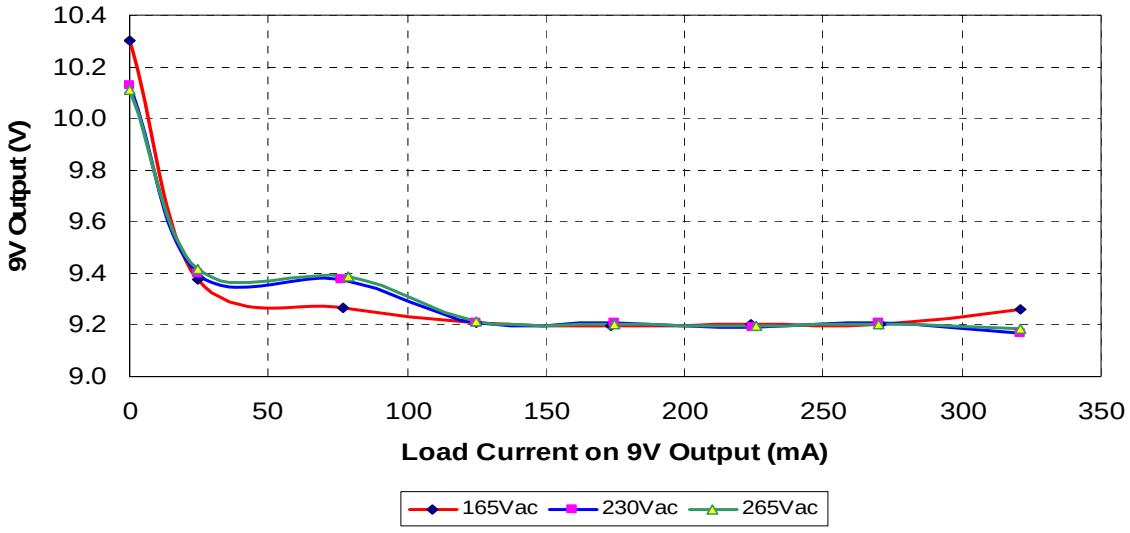
Vin = 165Vac, Vout in V and Iout in mA									
I_9V	I_17V	I_23V	V_9V	V_17V	V_23V	Pout (W)	Pin (W)	Ploss (W)	Eff (%)
0	0	0	10.30	17.05	22.60	0.00	0.13	0.130	0.00
24.6	16.4	83.3	9.376	17.03	22.99	2.43	3.05	0.625	79.51
76.8	49.9	251.7	9.265	17.03	23.04	7.36	8.91	1.549	82.61
124.6	83.1	414.6	9.207	17.03	23.05	12.12	14.36	2.241	84.39
173.2	115.0	575.6	9.197	17.03	23.05	16.82	19.73	2.911	85.25
223.9	147.5	738.7	9.202	17.03	23.03	21.58	25.22	3.635	85.58
270.8	180.4	901.7	9.201	17.03	23.02	26.32	30.73	4.409	85.65
321.3	213.1	1059.4	9.263	17.03	22.98	30.95	36.30	5.350	85.26

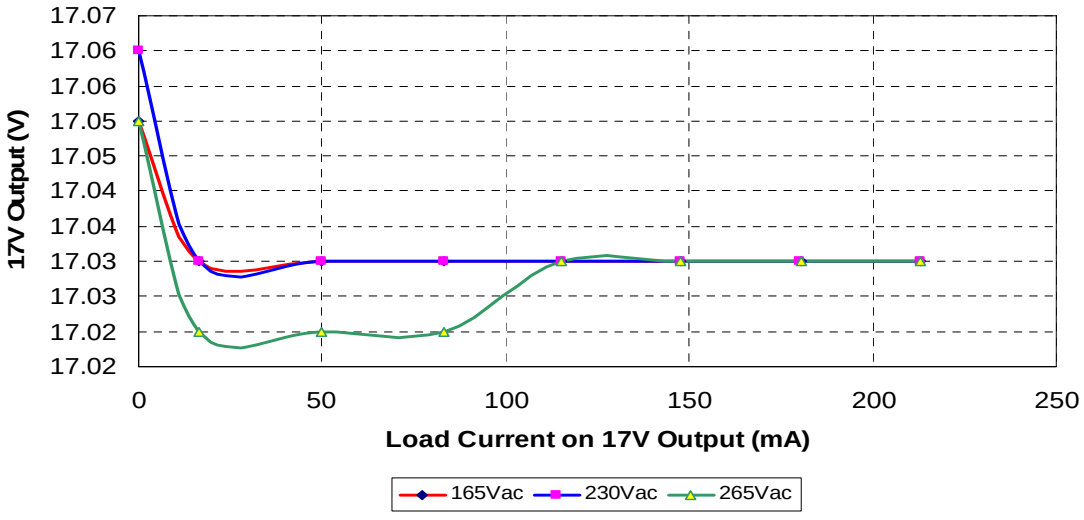
Vin = 230Vac, Vout in V and Iout in mA									
I_9V	I_17V	I_23V	V_9V	V_17V	V_23V	Pout (W)	Pin (W)	Ploss (W)	Eff (%)
0	0	0	10.13	17.06	22.56	0.00	0.16	0.160	0.00
24.8	16.4	83.3	9.400	17.03	22.97	2.43	3.08	0.654	78.76
76.2	49.9	251.6	9.374	17.03	22.98	7.35	8.99	1.644	81.71
124.9	83.0	414.7	9.211	17.03	23.04	12.12	14.38	2.261	84.27
174.5	115.0	575.6	9.207	17.03	23.03	16.82	19.74	2.919	85.21
224.6	147.4	741.3	9.190	17.03	23.03	21.65	25.17	3.524	86.00
270.0	180.3	901.7	9.211	17.03	23.01	26.31	30.51	4.204	86.22
321.1	213.1	1059.4	9.170	17.03	23.01	30.95	35.92	4.970	86.16

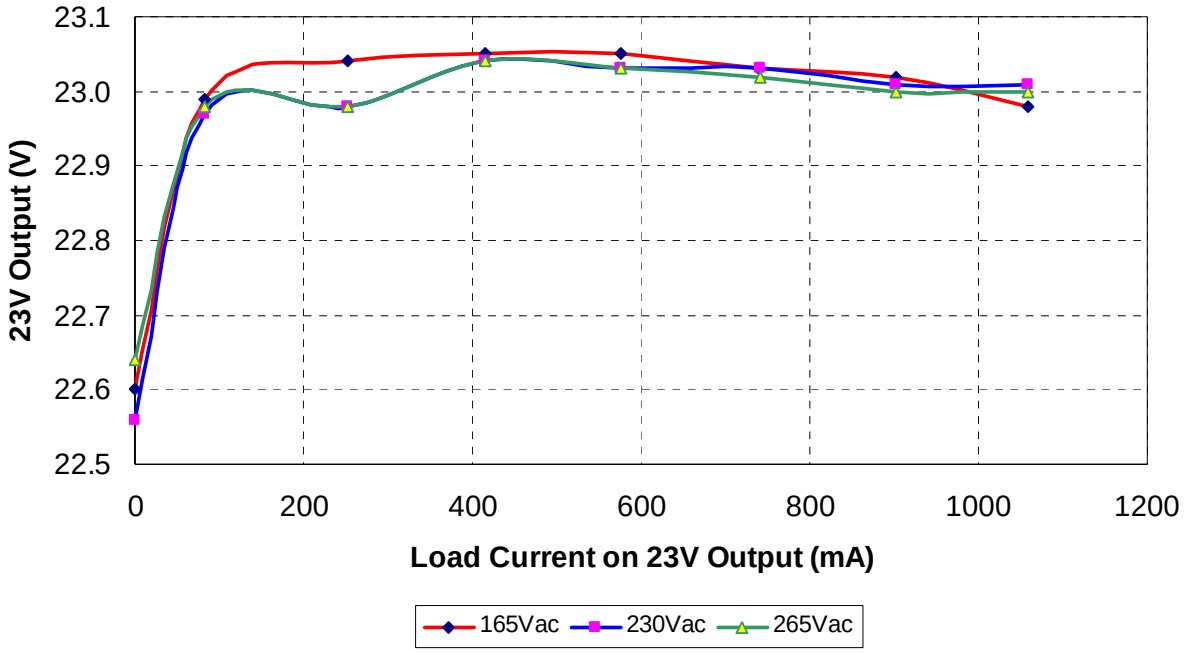
Vin = 265Vac, Vout in V and Iout in mA									
I_9V	I_17V	I_23V	V_9V	V_17V	V_23V	Pout (W)	Pin (W)	Ploss (W)	Eff (%)
0	0	0	10.11	17.05	22.64	0.00	0.18	0.180	0.00
24.3	16.4	83.3	9.418	17.02	22.98	2.42	3.10	0.678	78.14
78.7	49.9	251.6	9.385	17.02	22.98	7.37	9.13	1.760	80.72
124.9	83.0	414.7	9.213	17.02	23.04	12.12	14.49	2.372	83.63
174.5	115.0	575.6	9.203	17.03	23.03	16.82	19.82	3.000	84.87
225.5	147.5	741.4	9.196	17.03	23.02	21.65	25.28	3.627	85.65
270.1	180.4	901.7	9.203	17.03	23.00	26.30	30.60	4.303	85.94
320.7	213.1	1059.5	9.185	17.03	23.00	30.94	36.10	5.157	85.72

1 Output Voltage Regulation

The output voltage variation for each output is shown in the graphs below.



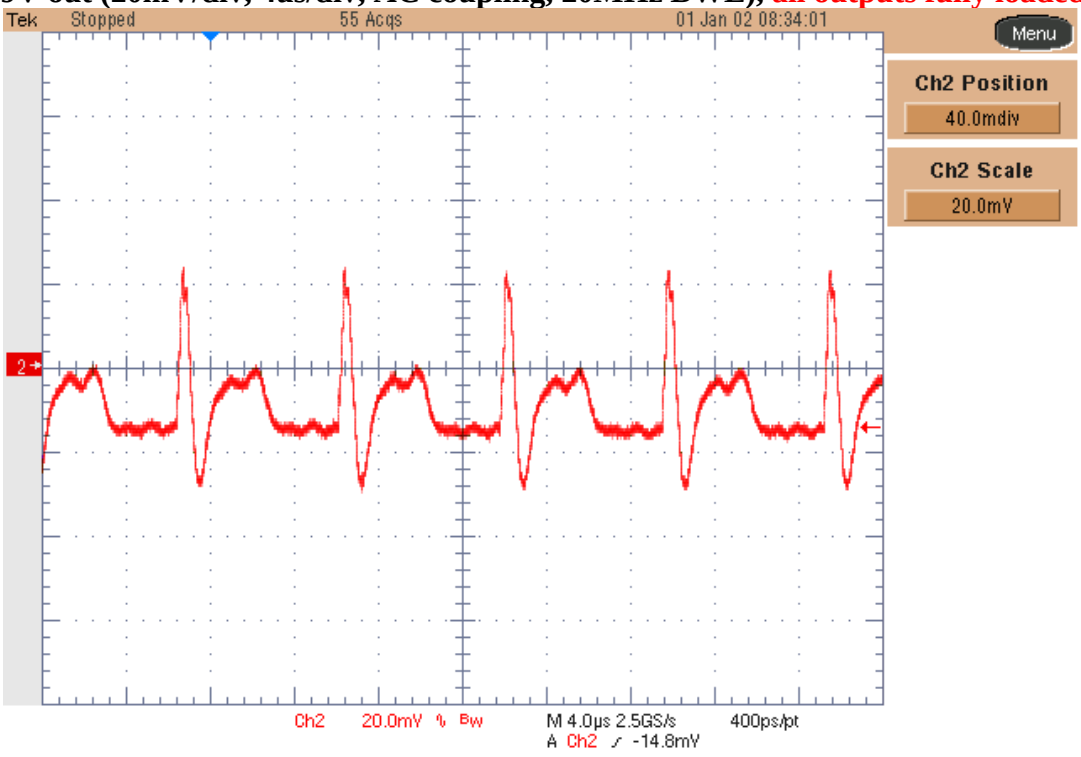




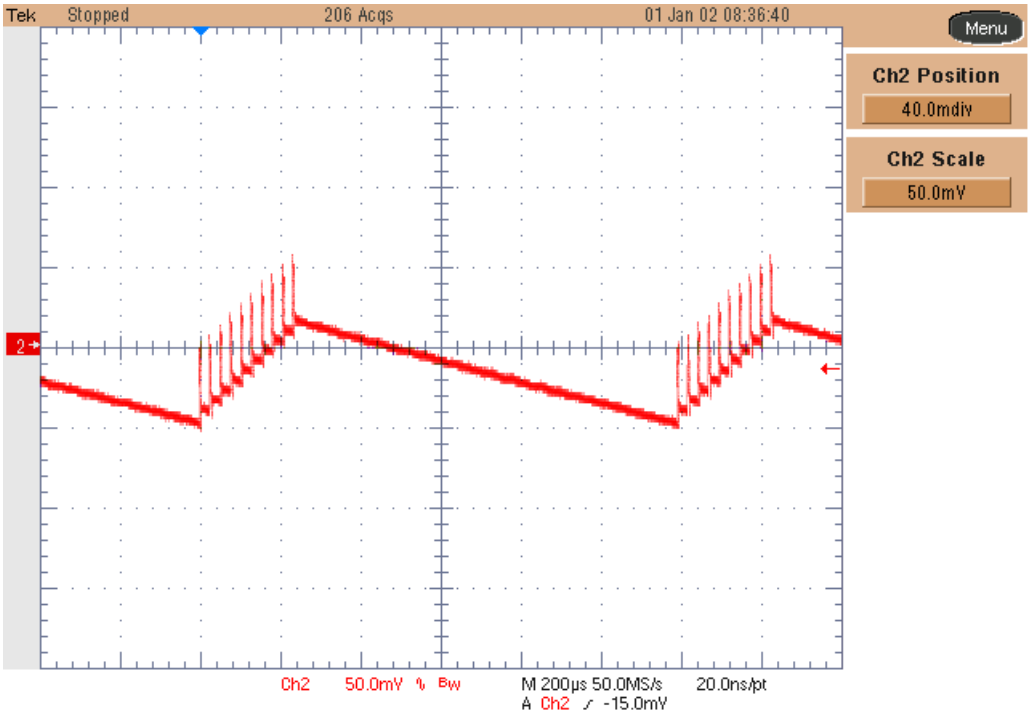
3. Output Ripple Voltage

The output ripple voltages for each output and in several load conditions are shown in the plots below. The input was set to 230Vac.

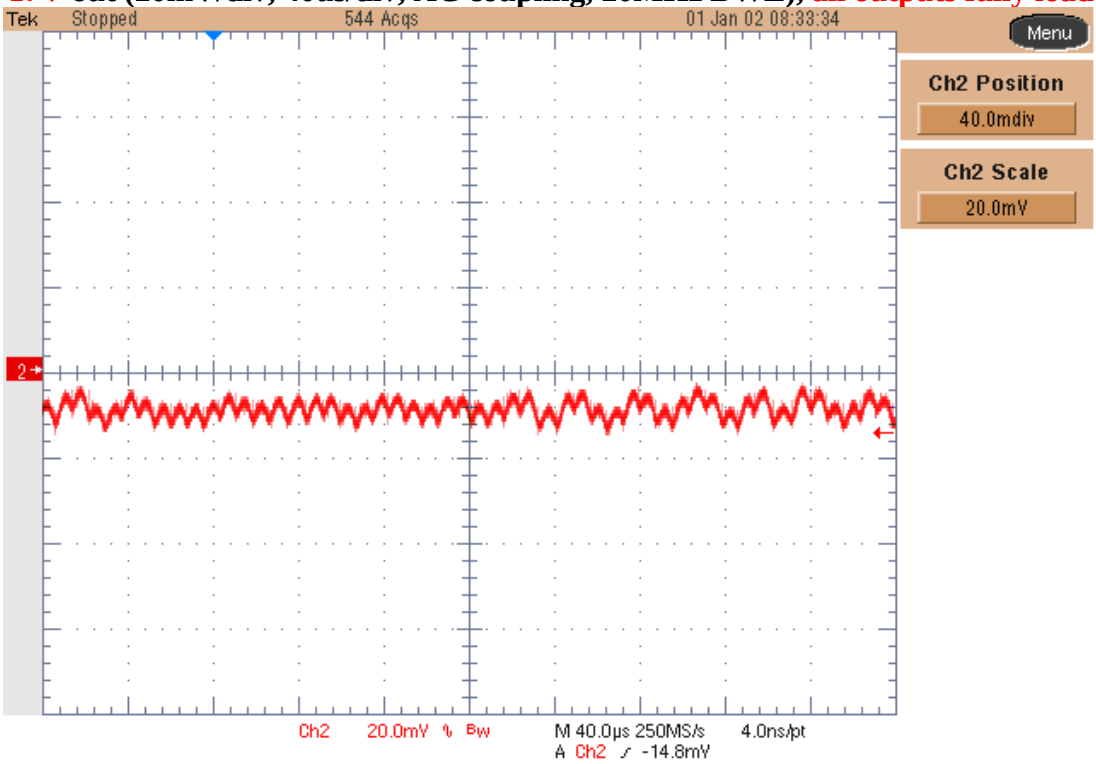
Ch.2: 9V out (20mV/div, 4us/div, AC coupling, 20MHz BWL), all outputs fully loaded



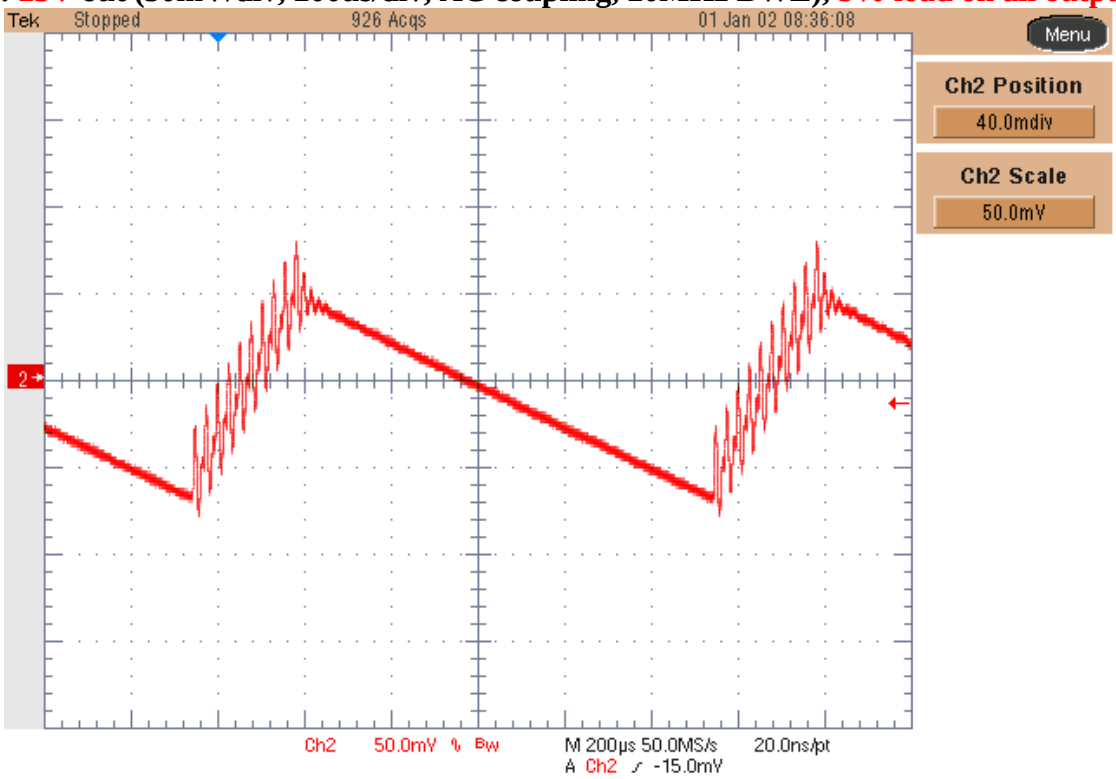
Ch.2: 9V out (50mV/div, 200us/div, AC coupling, 20MHz BWL), 5% load on all outputs



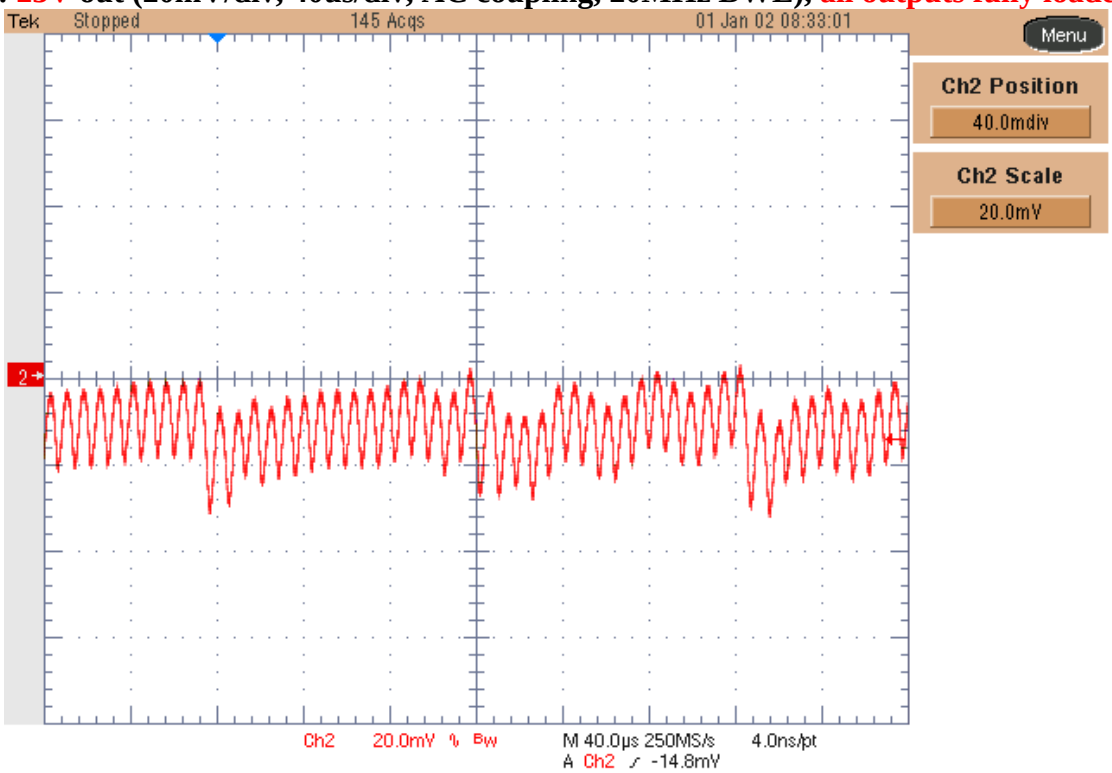
Ch.2: 17V out (20mV/div, 40us/div, AC coupling, 20MHz BWL), all outputs fully loaded



Ch.2: 23V out (50mV/div, 200us/div, AC coupling, 20MHz BWL), 5% load on all outputs



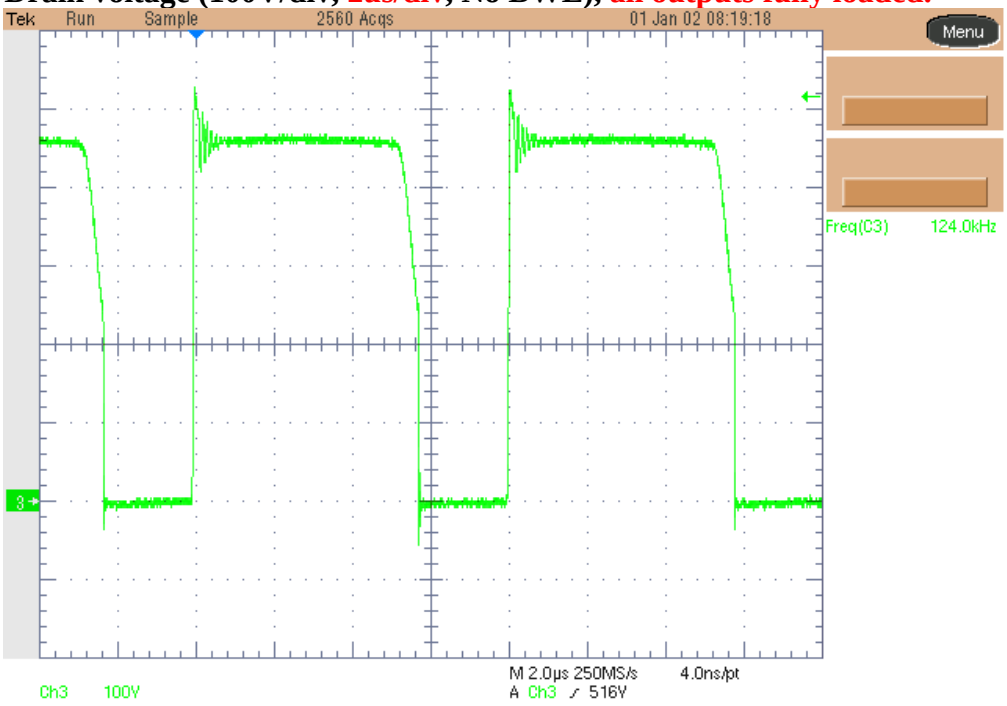
Ch.2: 23V out (20mV/div, 40us/div, AC coupling, 20MHz BWL), all outputs fully loaded



2 Switching Node Waveform

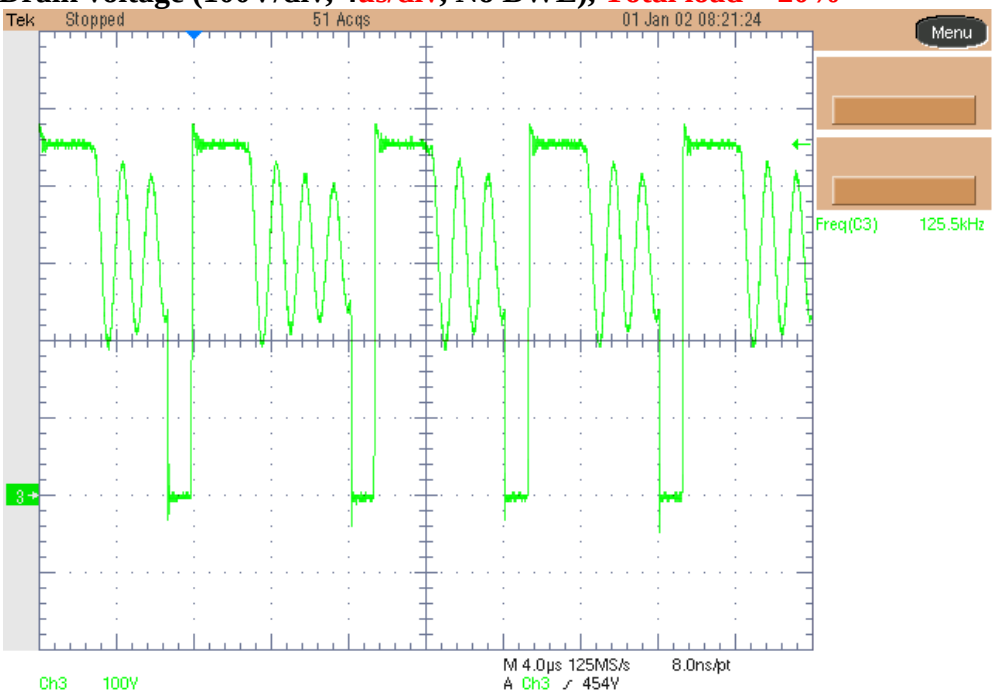
The images below show the peak voltage on the drain of the Mosfet Q1 with a 230Vac input at different loads.

Ch3: Q1 Drain voltage (100V/div, 2us/div, No BWL), all outputs fully loaded.



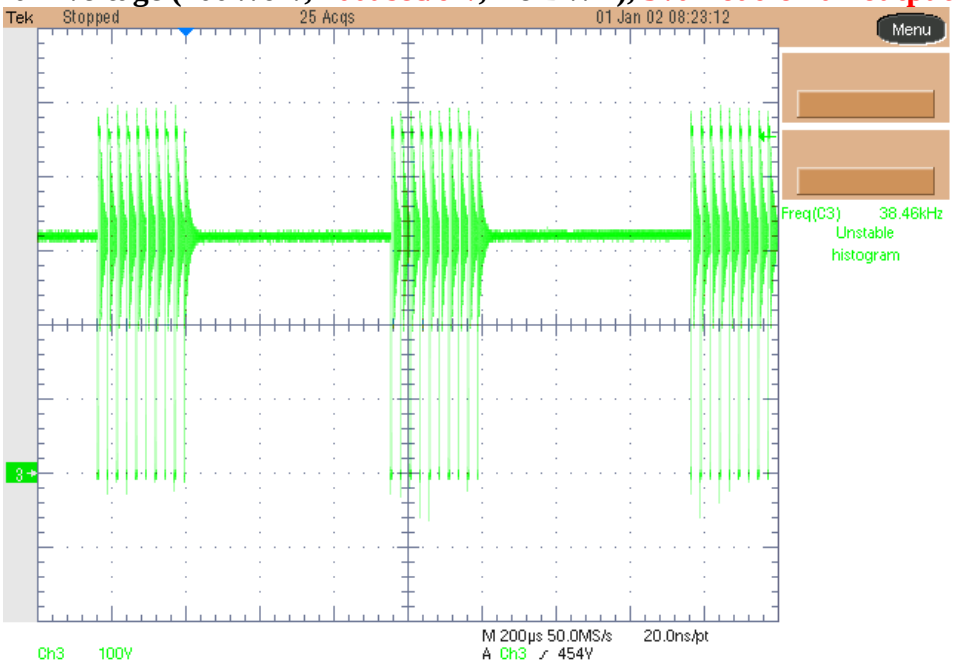
At light load, the converter reduces the switching frequency as shown in the picture below.

Ch3: Q1 Drain voltage (100V/div, 4us/div, No BWL), Total load = 20%



At 5% load on each output the converter enters burst mode:

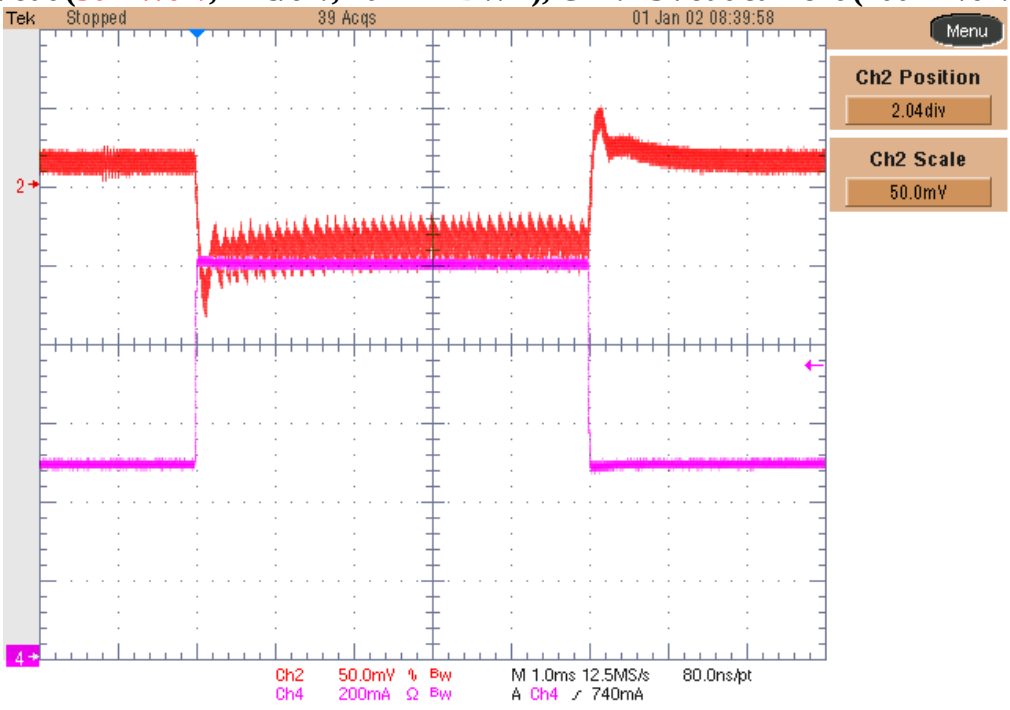
Ch3: Q1 Drain voltage (100V/div, 200usec/div, No BWL), 5% Load on all outputs



3 Transient Response

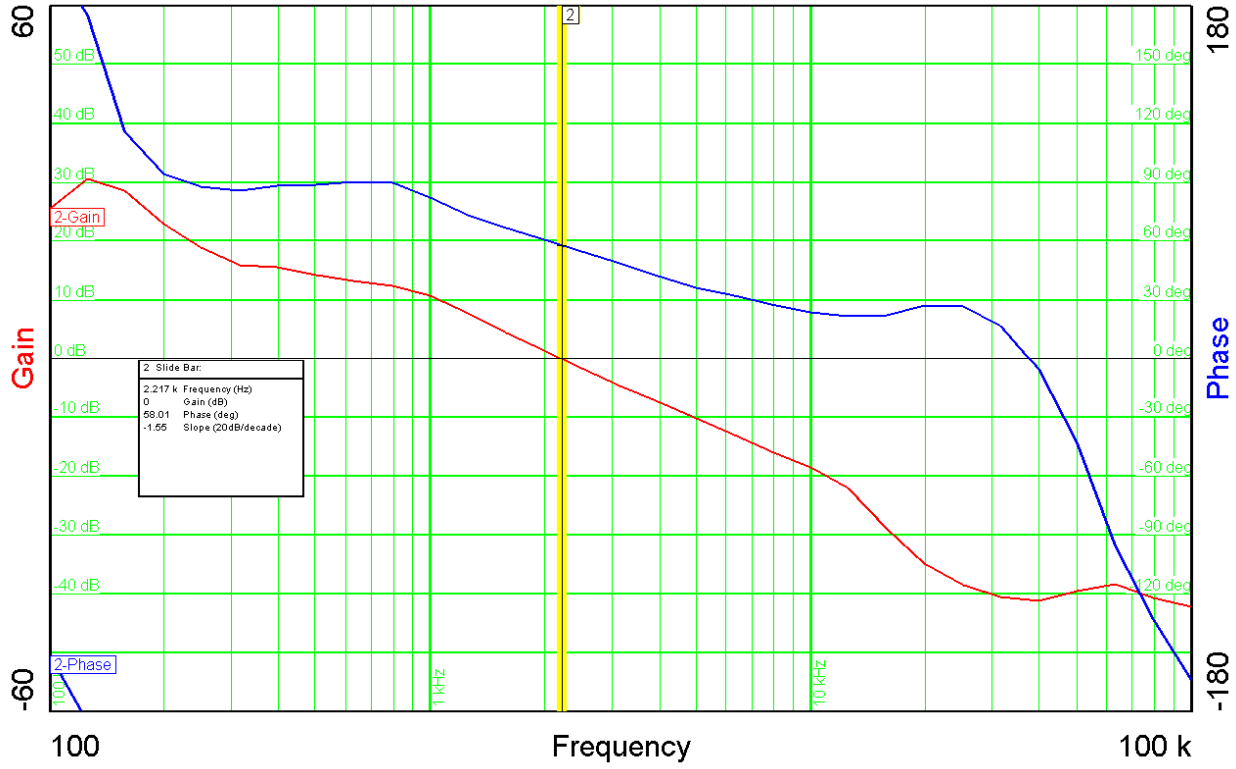
The image below show the transient response on the 23V out when the load on this output has been switched between 50% and 100% of its nominal value and the 9V out was fully loaded. The 17V out was unloaded. The input voltage was set to 230Vac.

Ch2: 23Vout (50mV/div, 1ms/div, 20MHz BWL), Ch4: 23Vout current (200mA/div).



4 Loop Analysis

The image below show the bode diagram of the converter supplied with 320Vdc and loaded @ 1A on 23Vout, 200mA on 9Vout and 200mA on 17Vout.
The crossover frequency was 2.2KHz, the phase margin 58deg and the gain margin 41dB.



5 Notes on the voltage regulation

1) Condition: 23Vout unloaded, 9Vout @ 280mA, 17Vout unloaded
Measure: 23Vout = 23.9V, 17Vout = 17V, 9Vout = 7.588V

2) Needed minimum 40mA on 23Vout in order to keep the 9Vout >= 8.5V, when this output is fully loaded

3) Needed minimum 26mA on 9Vout in order to keep it < 12V when the 23Vout is fully loaded

3) The 17V is always stable; any load on this output will be considered the same load on the 23Vout.

6 Thermal Analysis

The image below show the thermal picture taken with the prototype fully loaded on all outputs, without any forced convection and placed horizontally on the bench. The input voltage has been set to 230Vac, 50Hz.

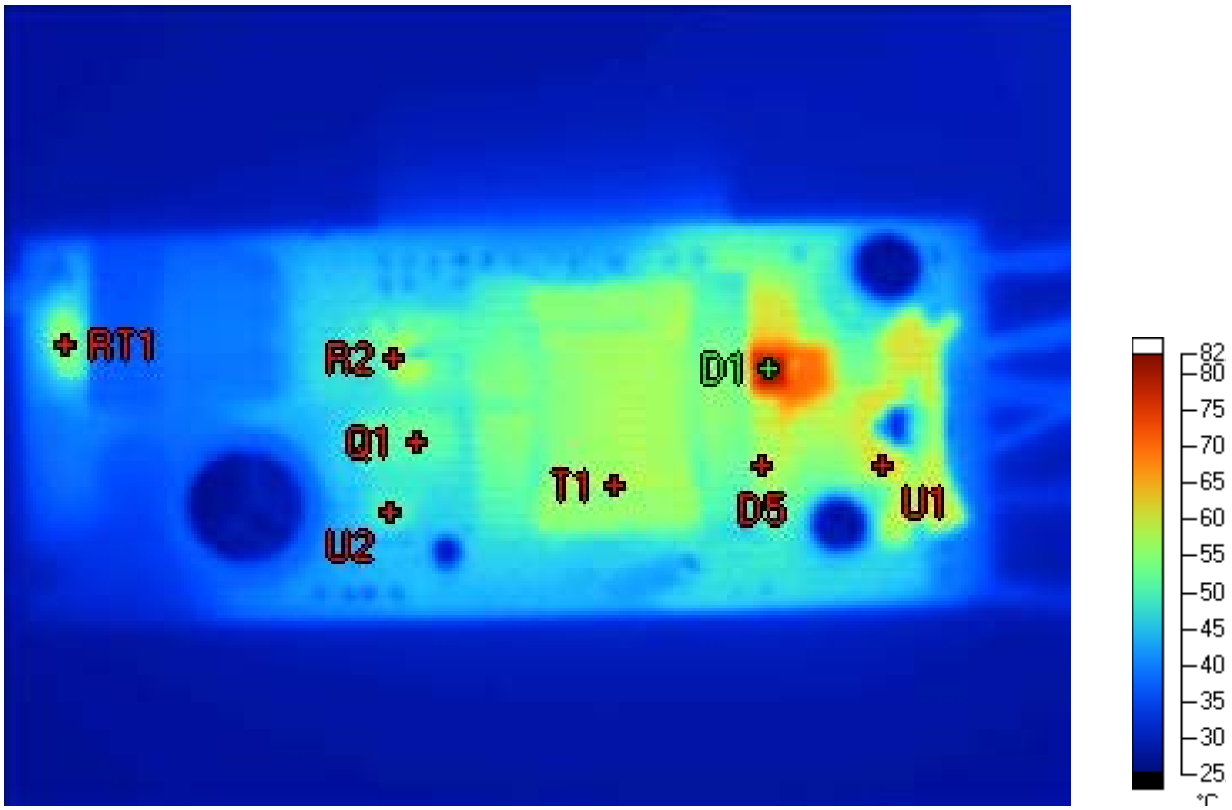


Image Info

Background	20.0 °C
Average Temperature	36.1 °C
Calibration Range	-20.0 °C to 350.0 °C
Camera Model	Ti40FT
Manufacturer	Fluke
Camera Serial Number	Ti40FT-070263

Markers

Label	Temperature	Emissivity	Background
RT1	55.6 °C	0.95	20.0 °C
U2	50.0 °C	0.95	20.0 °C
Q1	51.4 °C	0.95	20.0 °C
T1	58.0 °C	0.95	20.0 °C
D5	58.1 °C	0.95	20.0 °C
D1	81.7 °C	0.95	20.0 °C
U1	61.1 °C	0.95	20.0 °C
R2	57.1 °C	0.95	20.0 °C

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