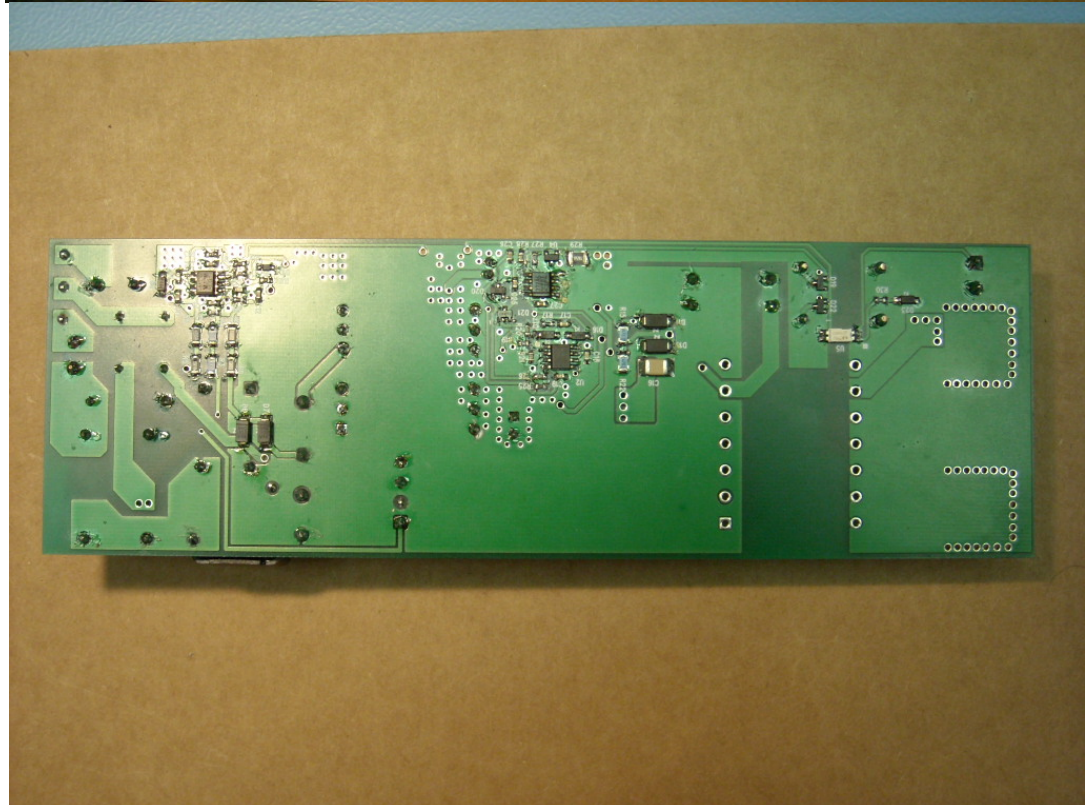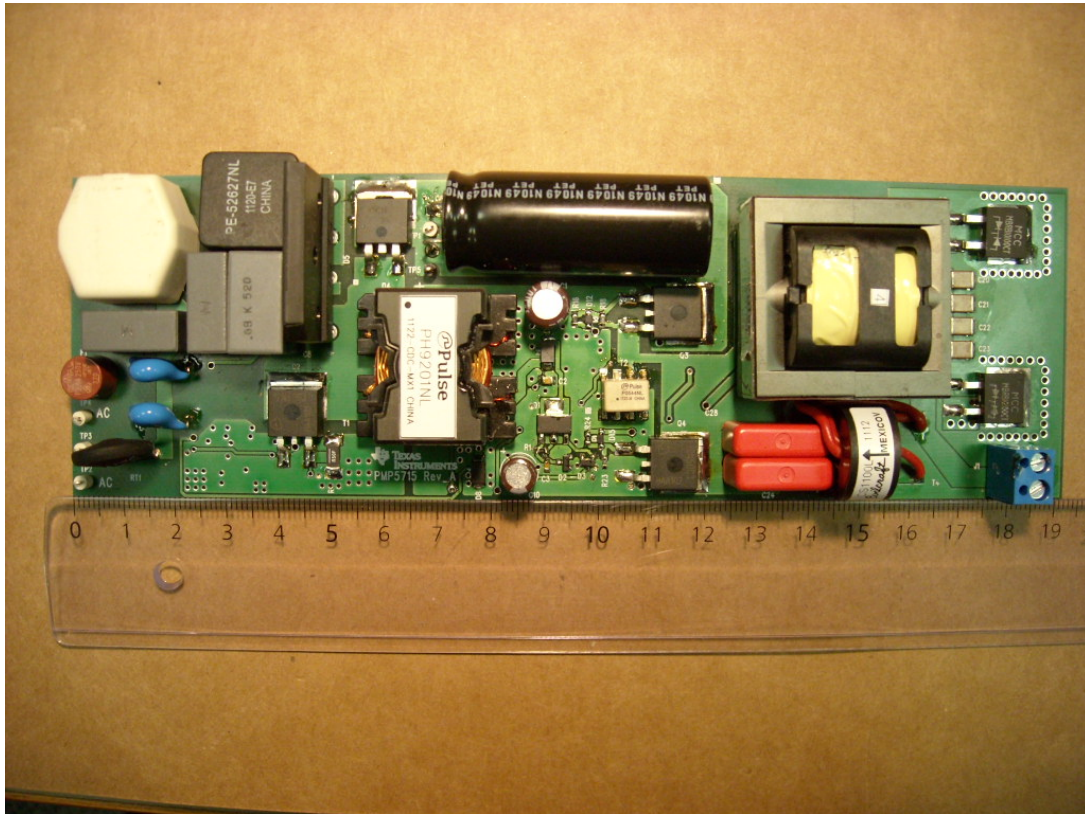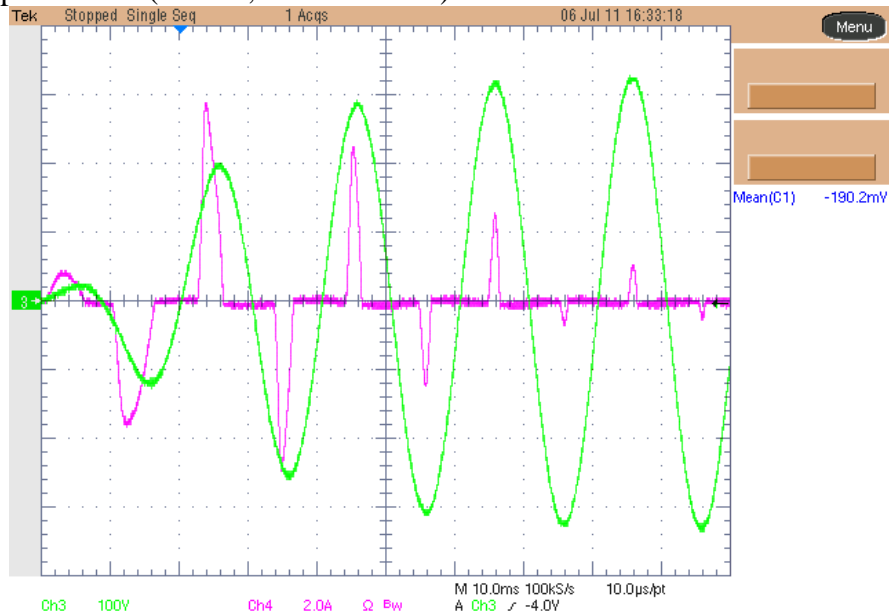**TEXAS INSTRUMENTS**

PHOTO OF THE PROTOTYPE:

1 Startup and inrush current

The input and output voltage, and current, waveforms at startup are shown in the images below. The input voltage has been set to 230Vac. The output was loaded with a LED panel, 24Vnom, 4Anom.
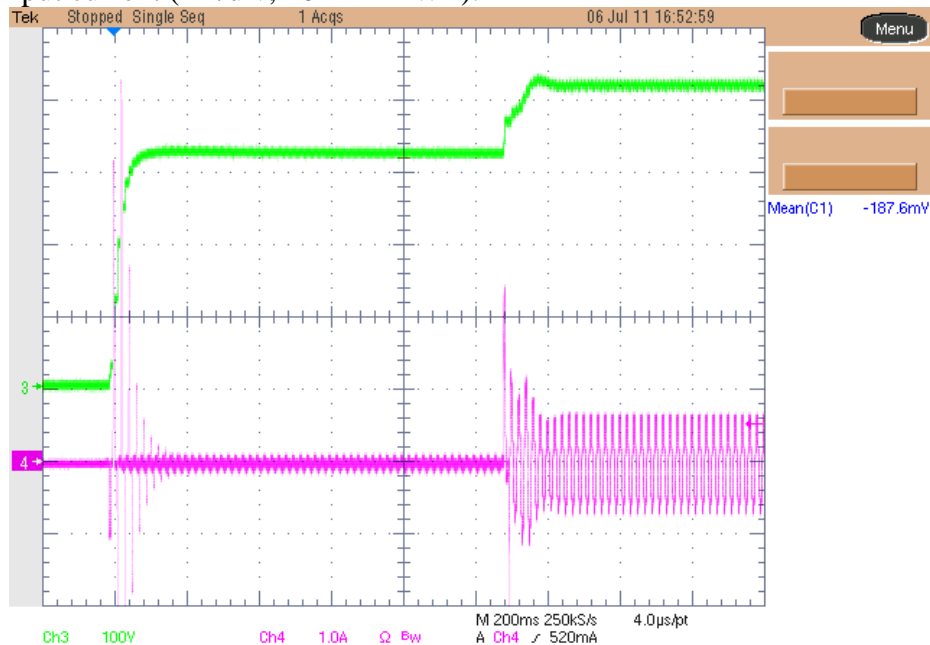Channel 3: Input voltage (100 V/div, 10ms/div, No BWL).
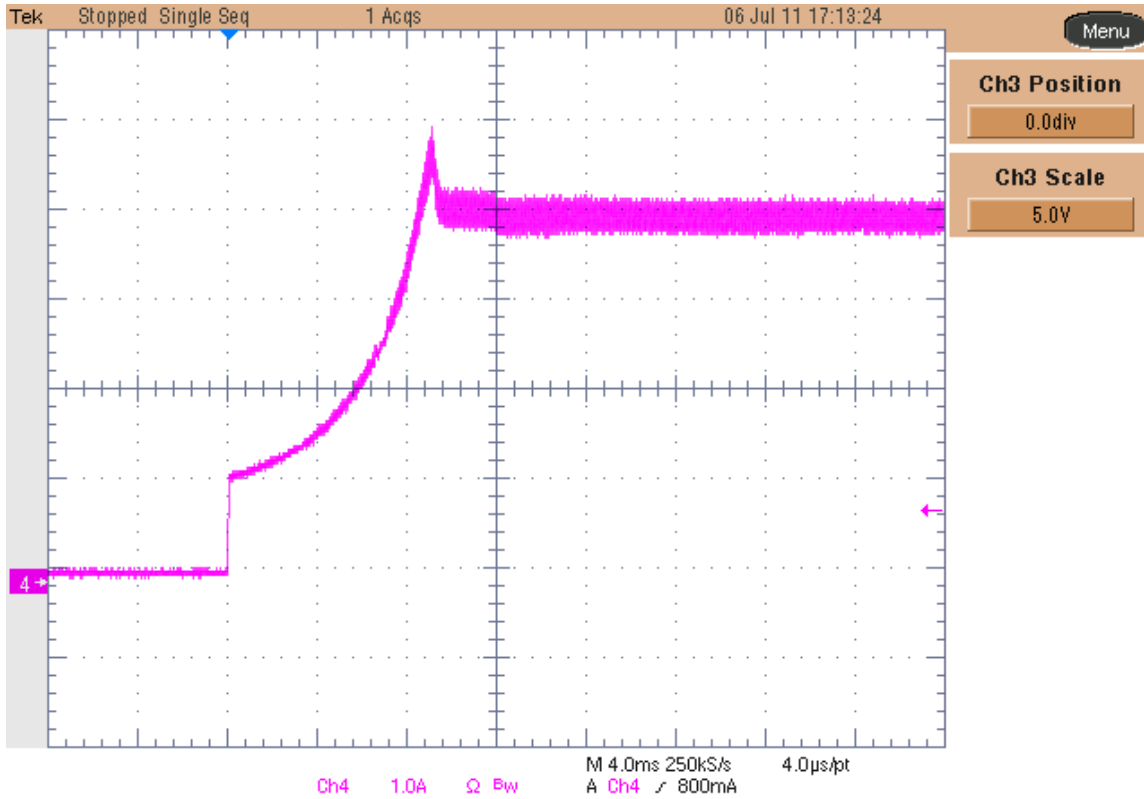Channel 4: Input current (2A/div, 20MHz BWL).

Channel 3: Vbulk Voltage (100 V/div, 200ms/div, No BWL).
Channel 4: Input current (1A/div, 20MHz BWL).

2 Startup on the output current

Channel 4: Output current (1A/div, 4ms/div, 20MHz BWL).

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3 Efficiency

The efficiency data (total converter) versus output voltage is shown in the tables and graph below. The input power consumption, power factor and harmonic content has been measured by a Yokogawa power meter WT210, while a California Instruments 2100 was used as AC source.
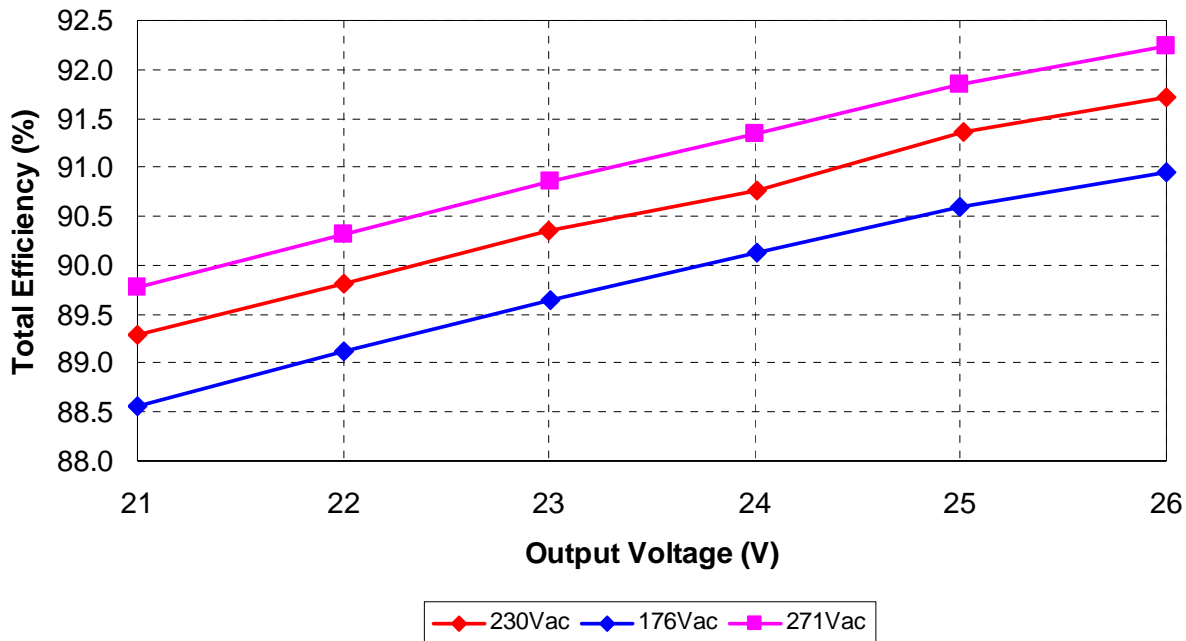

Power Factor (%)	Iout (A)	Vout (Vdc)	Pout (W)	Vin (Vac)	Pin (W)	Ploss (W)	Eff (%)
98.02	4.021	21.00	84.44	230	94.57	10.13	89.3
98.17	4.022	22.00	88.48	230	98.52	10.04	89.8
98.29	4.023	23.00	92.53	230	102.40	9.87	90.4
98.41	4.023	24.01	96.59	230	106.42	9.83	90.8
98.50	4.023	25.01	100.62	230	110.13	9.51	91.4
98.59	4.023	26.00	104.60	230	114.05	9.45	91.7

Power Factor (%)	Iout (A)	Vout (Vdc)	Pout (W)	Vin (Vac)	Pin (W)	Ploss (W)	Eff (%)
99.30	4.027	21.00	84.57	176	95.49	10.92	88.6
99.35	4.028	22.00	88.62	176	99.44	10.82	89.1
99.40	4.029	23.01	92.71	176	103.42	10.71	89.6
99.44	4.029	24.01	96.74	176	107.34	10.60	90.1
99.47	4.029	25.00	100.73	176	111.19	10.47	90.6
99.50	4.029	26.00	104.75	176	115.18	10.43	90.9

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| Power Factor (%)	Iout (A)	Vout (Vdc)	Pout (W)	Vin (Vac)	Pin (W)	Ploss (W)	Eff (%)
96.29	4.032	21.00	84.67	271	94.31	9.64	89.8
96.53	4.030	22.00	88.66	271	98.16	9.50	90.3
96.74	4.030	23.01	92.73	271	102.06	9.33	90.9
96.93	4.029	24.00	96.70	271	105.86	9.16	91.3
97.11	4.029	25.00	100.73	271	109.67	8.95	91.8
97.28	4.028	26.00	104.73	271	113.53	8.80	92.2

4 Output Current Regulation

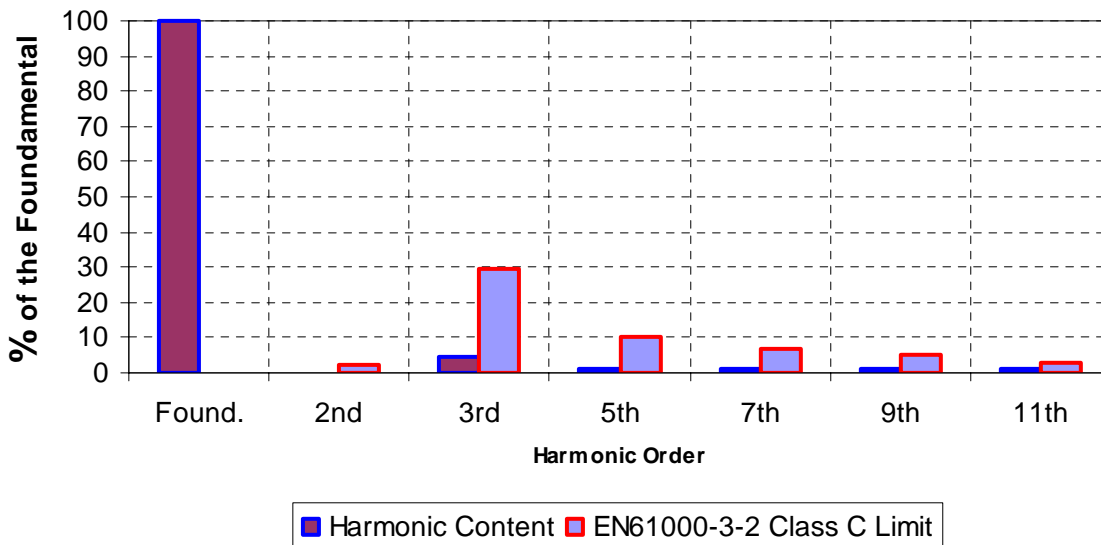The output current versus output voltage is plotted below.
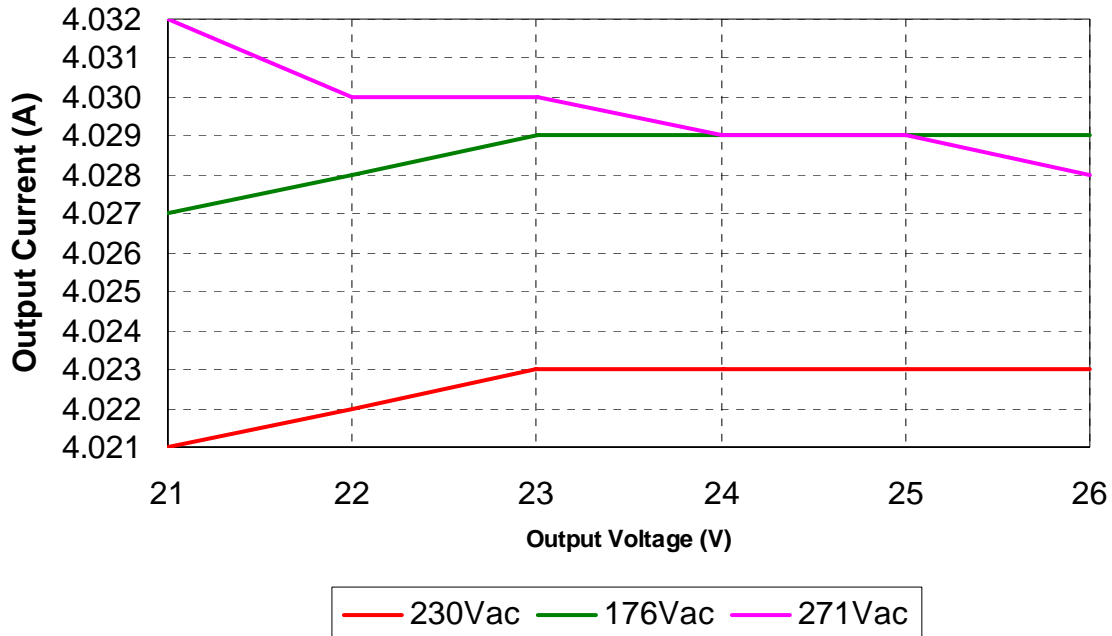
5 Power Factor

The Power Factor graph for the three input voltages and versus output voltage is shown below:
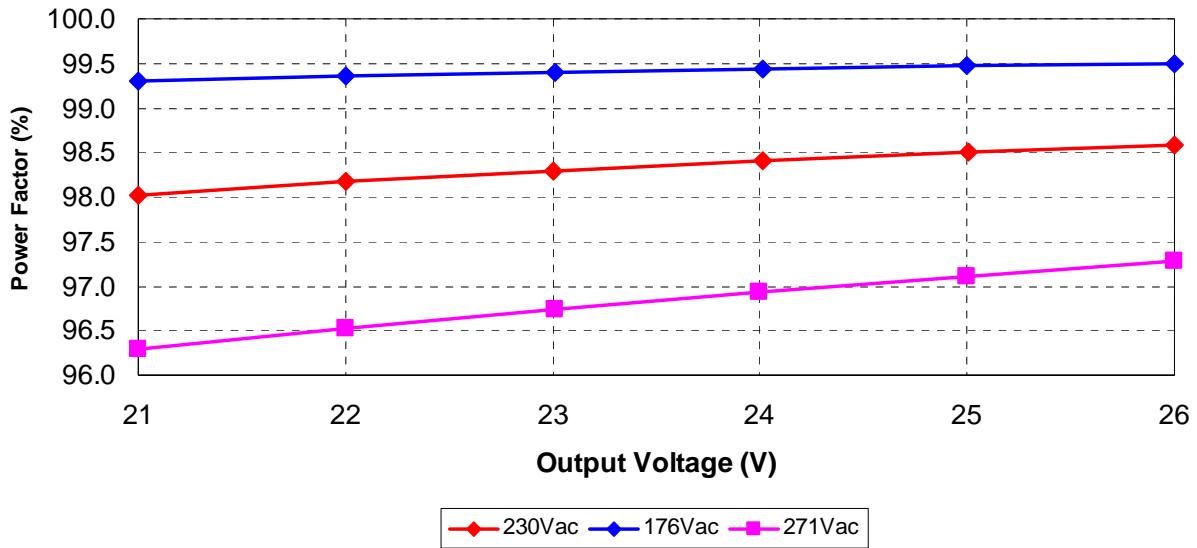
6 Harmonic Content

The harmonic content and the EN61000-3-2 Class C (lighting equipments) Limits are shown below; the input voltage was set to 230Vac, and the output loaded with the LED panel (24V, 4A).

**The measured THD was 5.33%;** below are shown the harmonic current contents:

Harmonic Order	%	EN61000-3-2 Class C Limit
Found.	100.0	//
2nd	0.00	2.0
3rd	4.45	29.4
5th	1.18	10.0
7th	1.12	7.0
9th	0.96	5.0
11th	0.86	3.0
13th	0.65	3.0
15th	0.51	3.0

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7 Output Ripple Current and Vbulk ripple

The output ripple current is shown in the plot below. The input was set at 230Vac and the converter loaded the LED panel (full load).
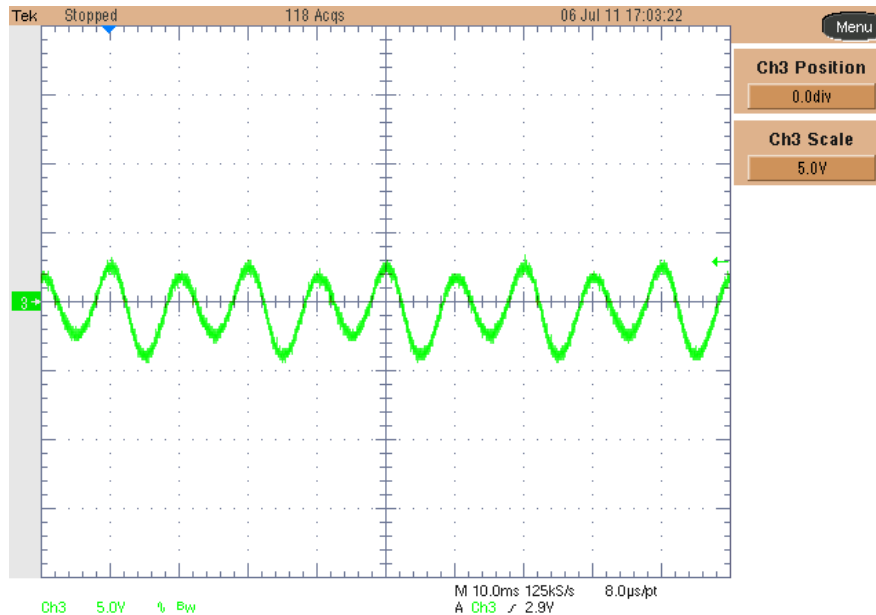
Output ripple current:
Channel 4: Output current (500mA/div, 4us/div, 20MHz BWL, DC coupling).
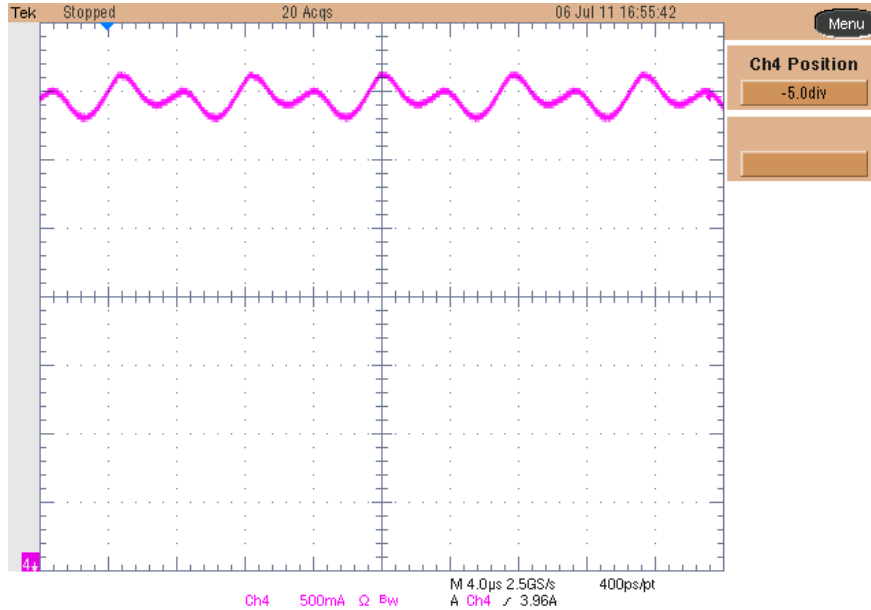
Voltage ripple:
Channel 3: 410V Vbulk ripple voltage (5V/div, 10ms/div, 20MHz BWL, AC coupling).
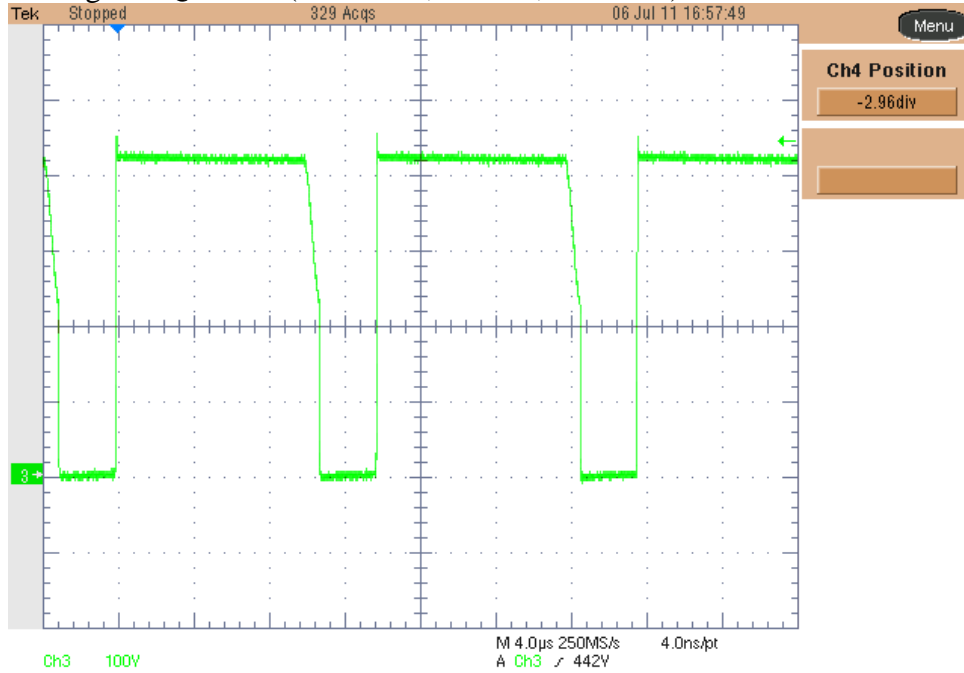
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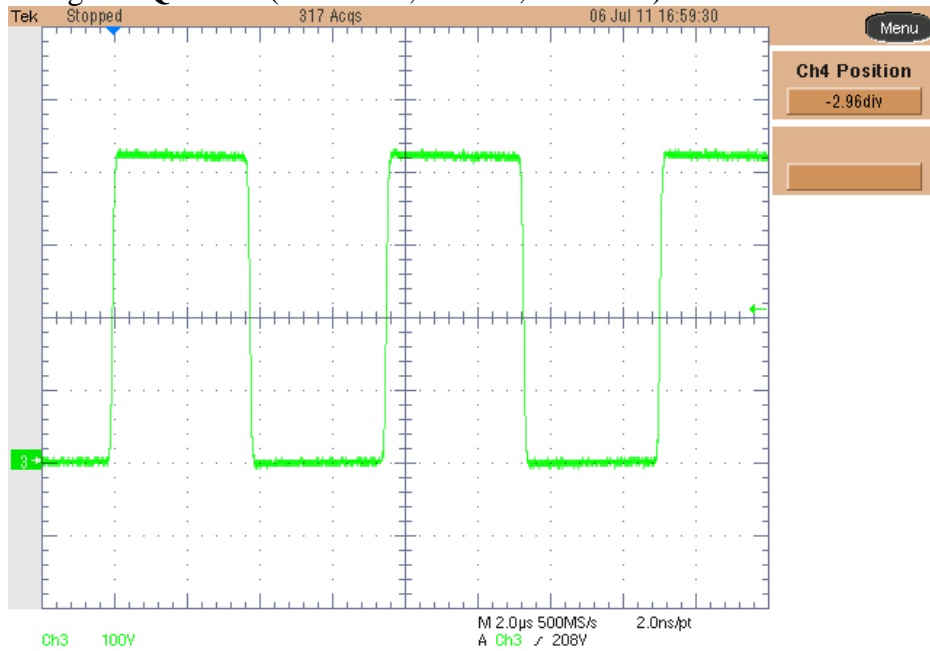
8 Switching Node Waveform

The images below show the voltage on the drain of the Boost's switching node (Q2) (upper picture) and Q4 drain (switch node of the LLC), with a 230Vac input, and full load.

Channel 3: Voltage on **Q2** drain (100 V/div, 4us/div, No BWL).

Channel 3: Voltage on **Q4** drain (100 V/div, 2us/div, No BWL).

9 Input Voltage and Current Waveforms

The images below show the input waveforms of input voltage and current; the output was fully loaded and the input respectively set to 230Vac, 176Vac and 271Vac (limit of the AC generator), 50Hz.

Vin = 230Vac
Channel 3: Input voltage (100 V/div, 4ms/div, No BWL).
Channel 4: Input current (200mA/div, 20MHz BWL).

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TEXAS INSTRUMENTS
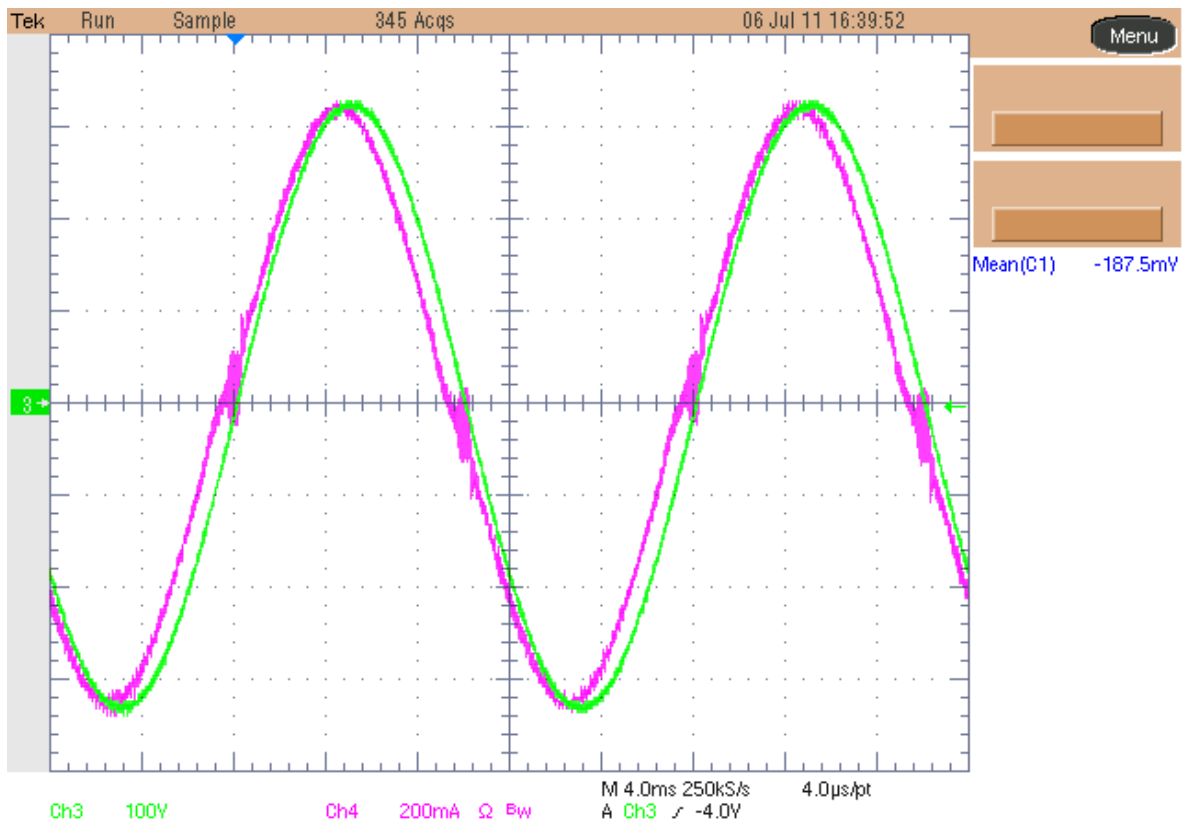
Vin = 176Vac
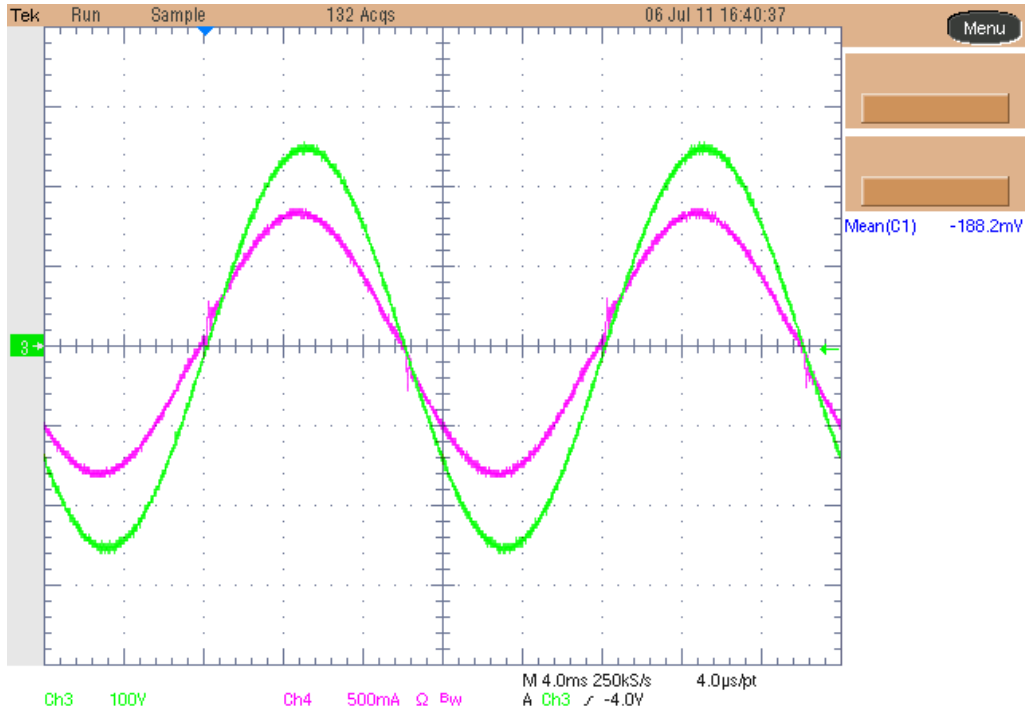Channel 3: Input voltage (100 V/div, 4ms/div, No BWL).
Channel 4: Input current (500mA/div, 20MHz BWL).

Vin = 271Vac
Channel 3: Input voltage (100 V/div, 4ms/div, No BWL).
Channel 4: Input current (200mA/div, 20MHz BWL).

Power Management Solutions
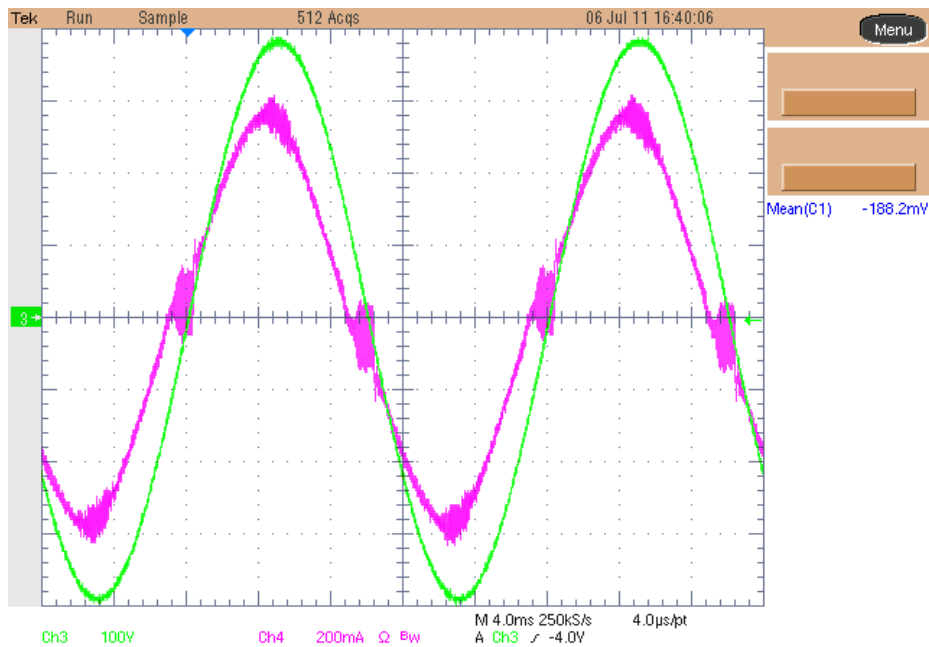
10 Loop Response

The image below shows the current loop response of the LLC converter measured with a 410Vdc input, while connected to the LED panel. The phase margin was 86.96 deg., the gain margin 19.19dB and the crossover frequency 2.046 KHz.
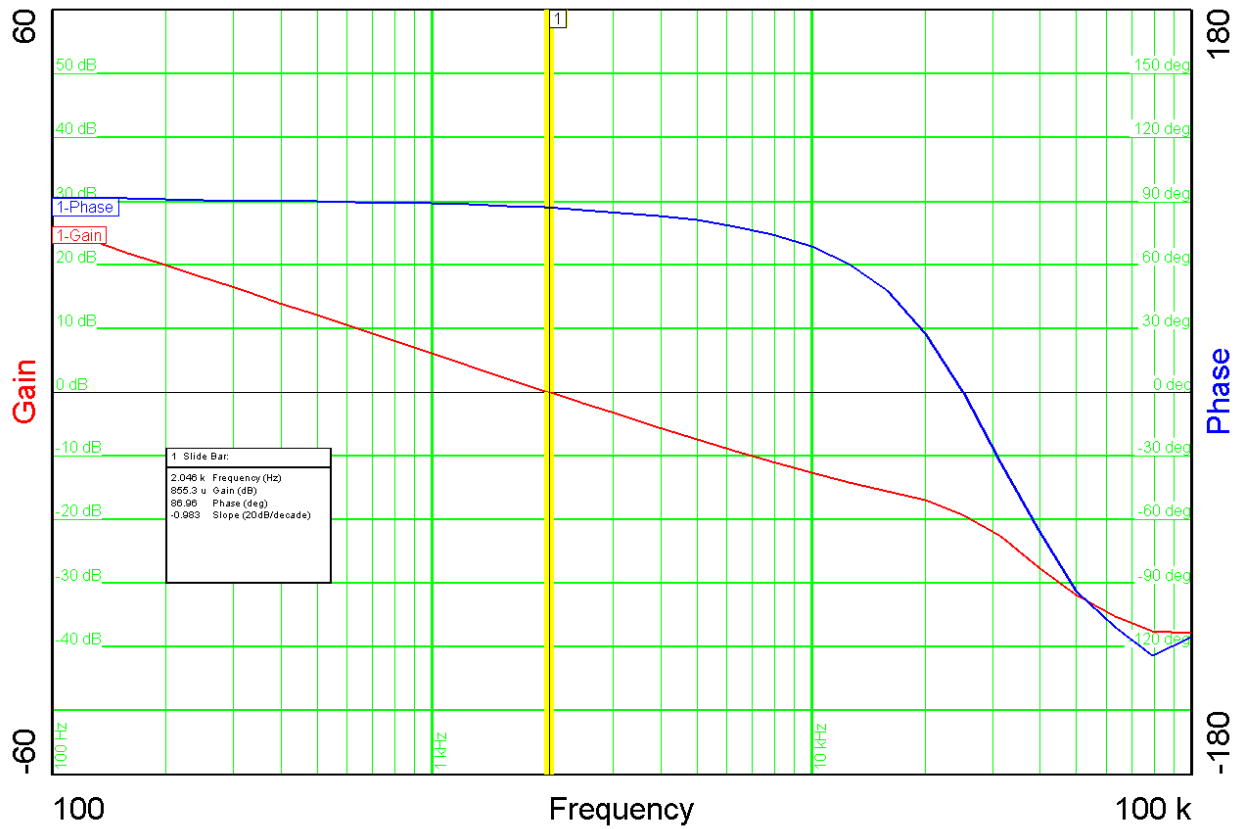
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