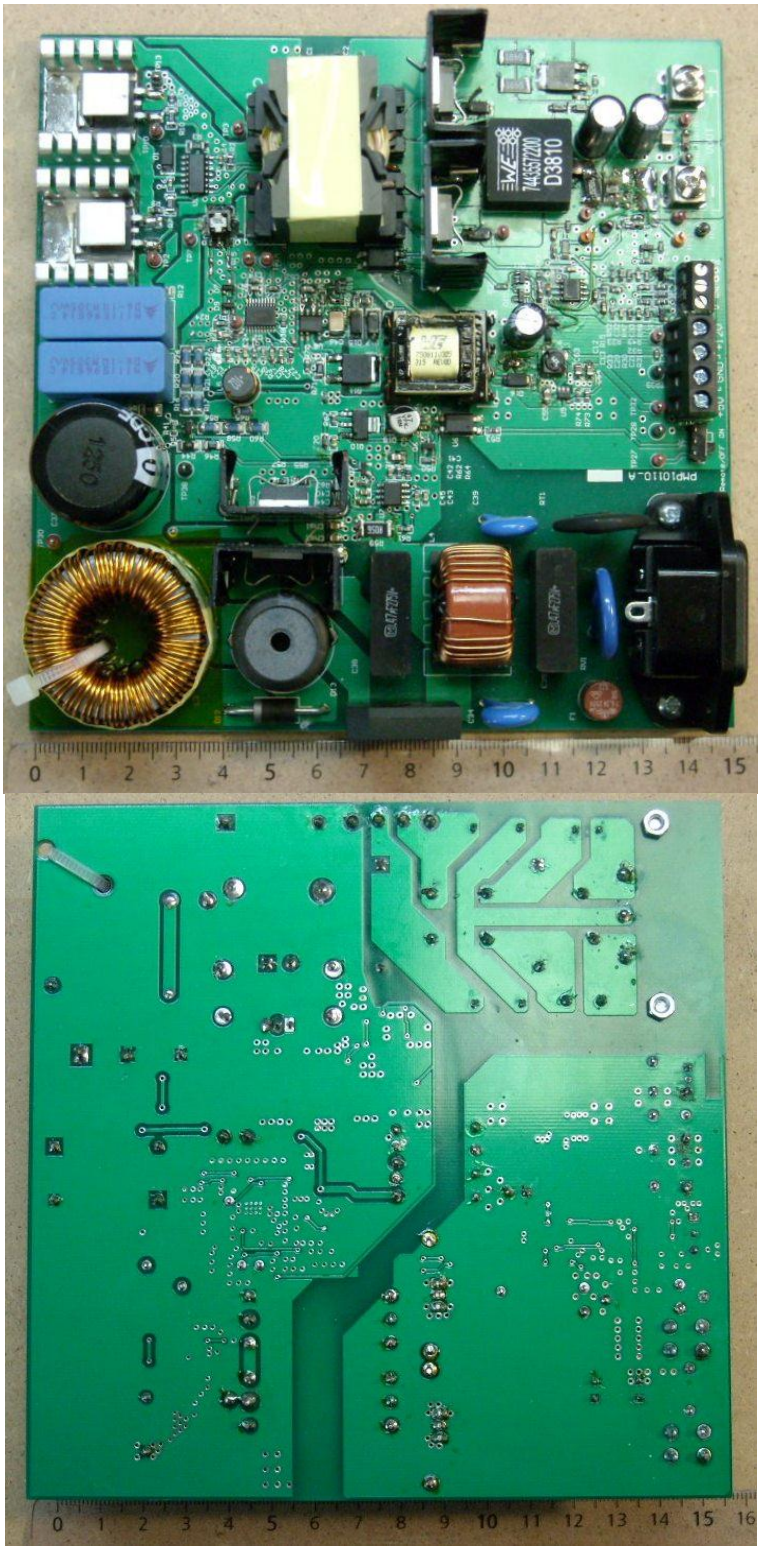
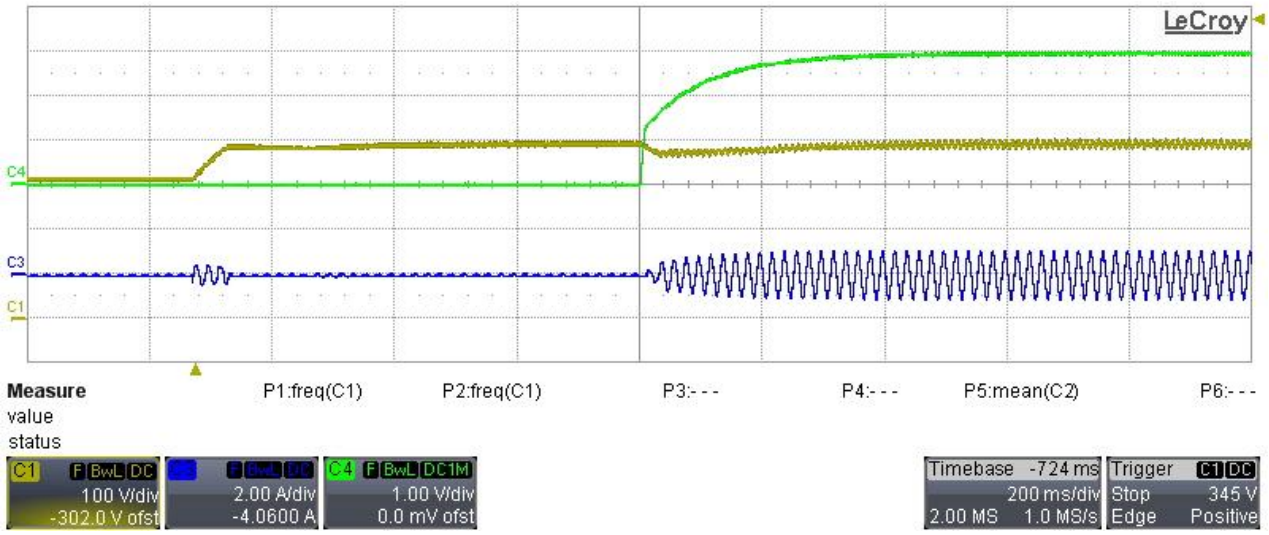
PHOTO OF THE PROTOTYPE



1 Startup behavior on Vbulk (400V) and Iout

The behavior of the converter at startup is shown in the images below. The input voltage was set to 230Vac, 50Hz and the main output loaded at 6A and set to 24V, with the 5V and 12V outputs left open.
The AC voltage has been applied and then the switch S1 has been set to ON.

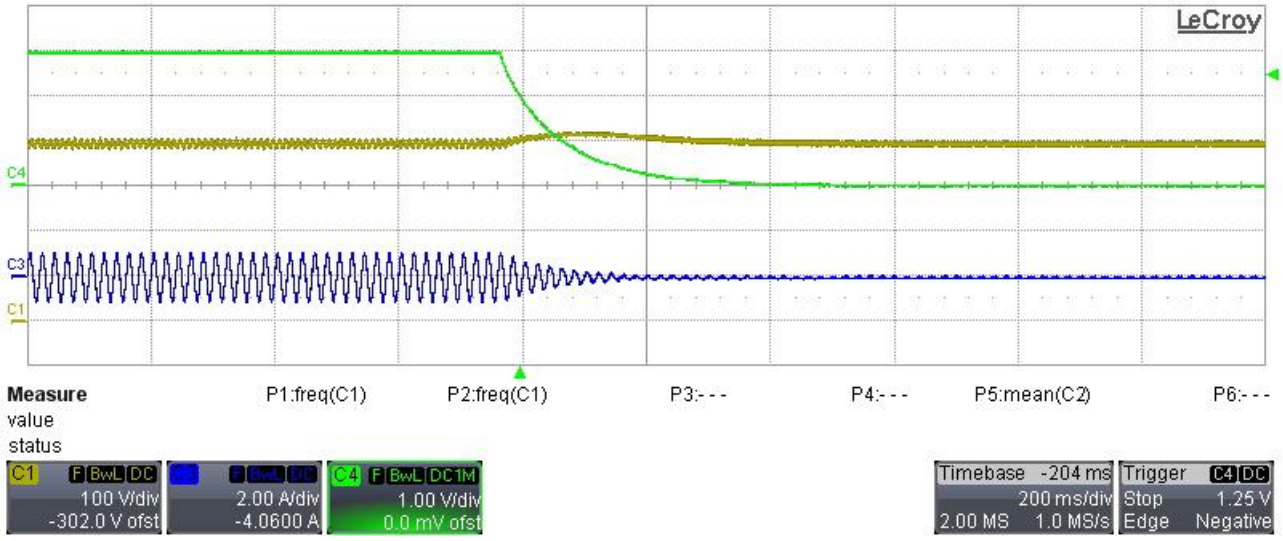
Ch1: PFC output voltage (100V/div, 200ms/div), 20MHz BWL for all waveforms.
Ch3: Input AC current (2A/div)
Ch4: Output current monitor (pin 1 of U100), (1V/div = 2A/div)

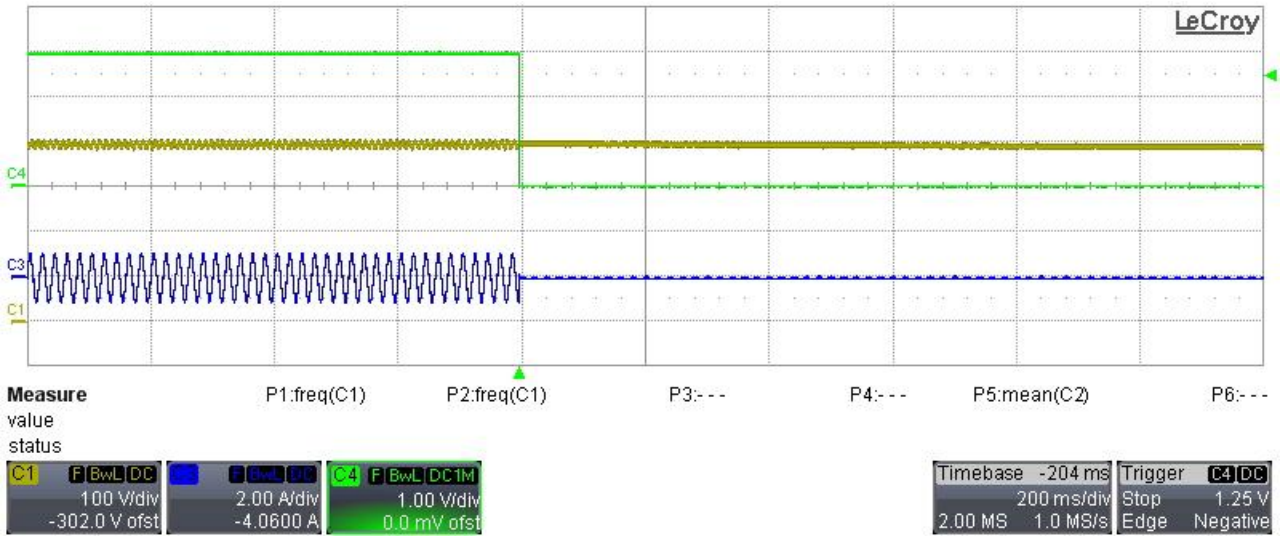


2 Shut down behavior on Vbulk and Iout

The same waveforms were taken during shut down of the converter. The input voltage was again 230Vac, 50Hz and all outputs loaded in the same way like the startup phase.
The AC voltage source was always ON; the PWM (Iref) signal has been switched OFF for the upper picture (with the switch S1 always ON), while S1 has been switched to OFF position (with the PWM signal always ON) for the bottom one.

Ch1: PFC output voltage (100V/div, 200ms/div). All waveforms have 20MHz BWL.
Ch3: Input AC current (2A/div)
Ch4: Output current monitor (pin 1 of U100), (1V/div = 3A/div)

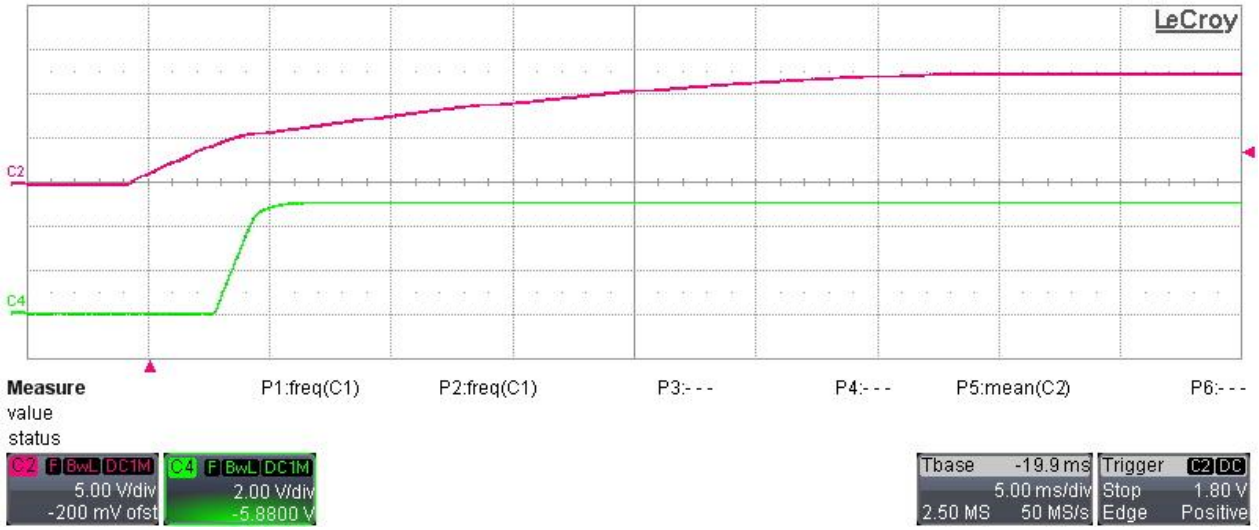




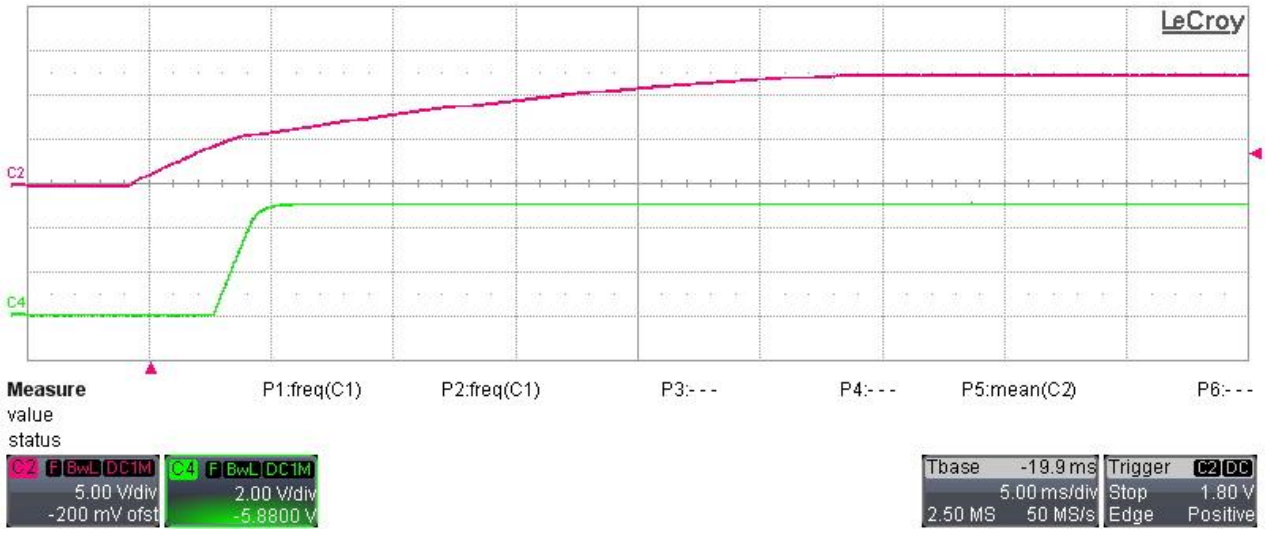
3 Startup on 12Vout and 5Vout from auxiliary PSU

The auxiliary power supply has been tested by connecting two resistors on both outputs, to deliver full load. The screen shots below show the behavior at startup.

Ch2: 12Vout (5V/div, 5ms/div, 20MHz BWL)
Ch4: 5Vout (2V/div., 20MHz BWL)
Vin = 85Vac, 60Hz, full load on both outputs



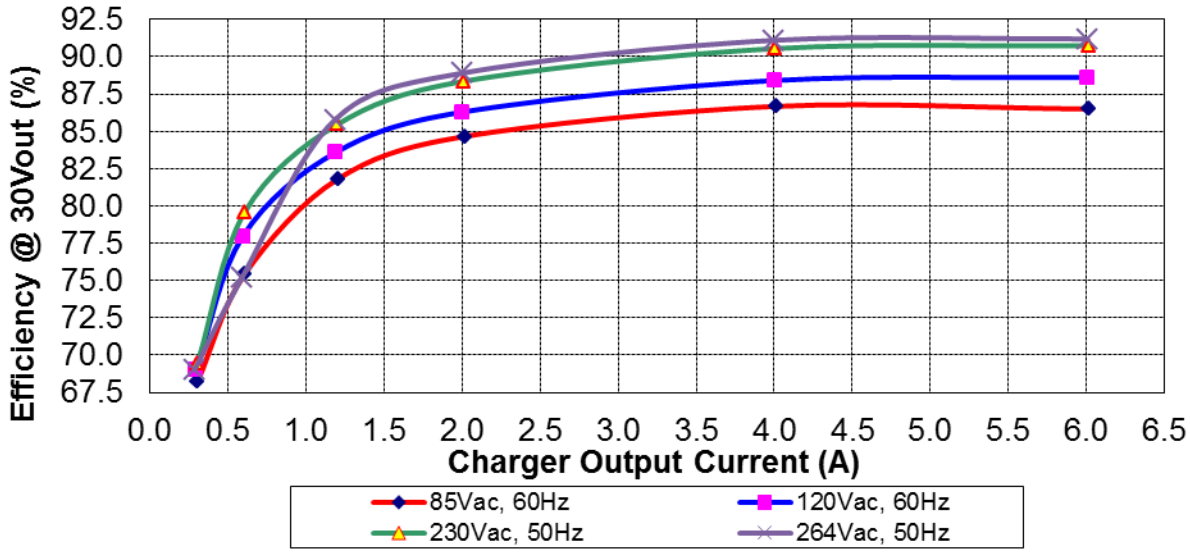
Ch2: 12Vout (5V/div, 5ms/div, 20MHz BWL)
Ch4: 5Vout (2V/div., 20MHz BWL)
Vin = 264Vac, 50Hz, full load on both outputs



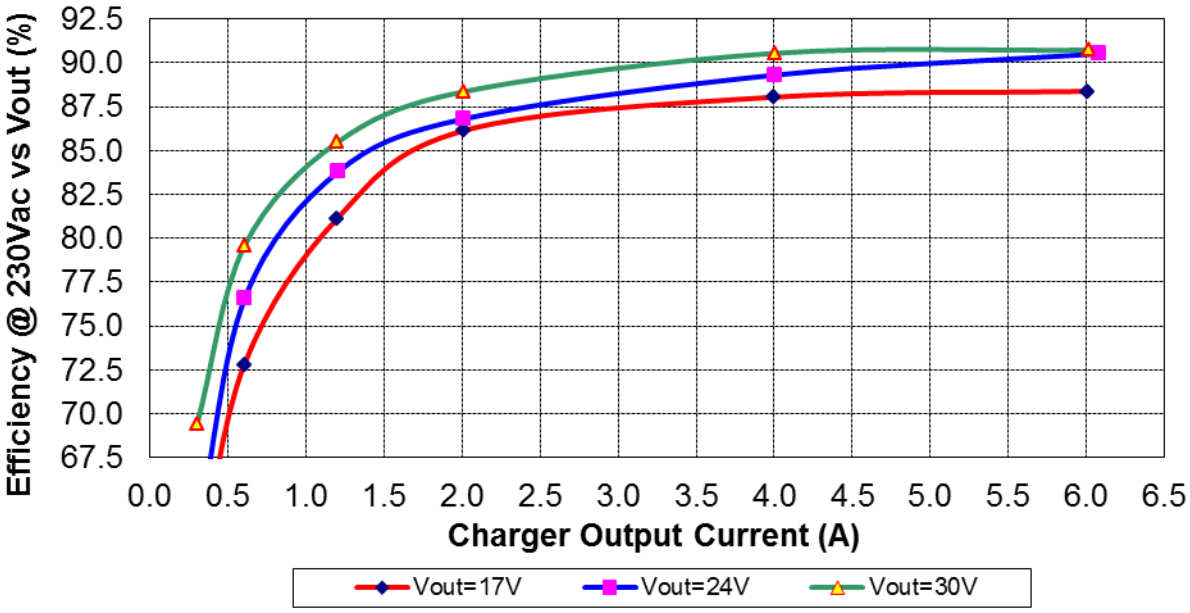
4 Efficiency

The efficiency data are shown in the tables and graphs below. The data show the plug-to-plug efficiency where the load on the 5Vout was 300mA (fixed) and for the 12V and 30V outputs it has been varied accordingly.

Efficiency of the converter (plug-to-plug) versus Vac & Output current @ constant Vout = 30V.



Efficiency of the converter (plug-to-plug) versus Vac & Output current with different Vout:



The converter has been switched OFF by S1 and the stand-by losses measured (5Vout and 12Vout are always ON, but unloaded); here is the result:

Vin (RMS)	85V, 60Hz	120V, 60Hz	175V, 50Hz	230V, 50Hz	264V, 50Hz
Pin (mW)	199	207	242	298	319

PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.3041	30.02	0	12.5	300	5.0	10.63	15.58	85	4.951	98.42	68.22
90.4	0.6053	30.02	100	12.5	300	5.0	20.92	27.74	85	6.819	99.48	75.42
80.2	1.203	30.03	200	12.5	300	5.0	40.13	49.05	85	8.924	99.79	81.81
66.4	2.014	30.00	300	12.5	300	5.0	65.67	77.57	85	11.900	99.89	84.66
33.0	4.009	30.01	300	12.5	300	5.0	125.6	144.86	85	19.300	99.88	86.68
0.0	6.015	30.00	400	12.5	300	5.0	187.0	216.14	85	29.190	99.86	86.49

PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.2910	30.01	0	12.5	300	5.0	10.23	14.83	120	4.597	95.62	69.00
90.4	0.5937	30.01	100	12.5	300	5.0	20.57	26.38	120	5.813	97.77	77.96
80.2	1.192	30.01	200	12.5	300	5.0	39.77	47.57	120	7.798	99.30	83.61
66.4	2.005	30.00	300	12.5	300	5.0	65.40	75.78	120	10.380	99.66	86.30
33.0	4.001	30.00	300	12.5	300	5.0	125.3	141.70	120	16.420	99.84	88.41
0.0	6.009	30.00	400	12.5	300	5.0	186.8	210.76	120	23.990	99.86	88.62

PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.3019	30.05	0	12.5	300	5.0	10.57	15.23	230	4.658	77.64	69.42
90.4	0.6035	30.00	100	12.5	300	5.0	20.86	26.22	230	5.365	89.75	79.54
80.2	1.201	30.01	200	12.5	300	5.0	40.04	46.85	230	6.808	94.14	85.47
66.4	2.012	30.00	300	12.5	300	5.0	65.61	74.25	230	8.640	97.16	88.36
33.0	4.007	30.00	300	12.5	300	5.0	125.5	138.55	230	13.090	99.18	90.55
0.0	6.014	30.00	400	12.5	300	5.0	186.9	206.02	230	19.100	99.39	90.73

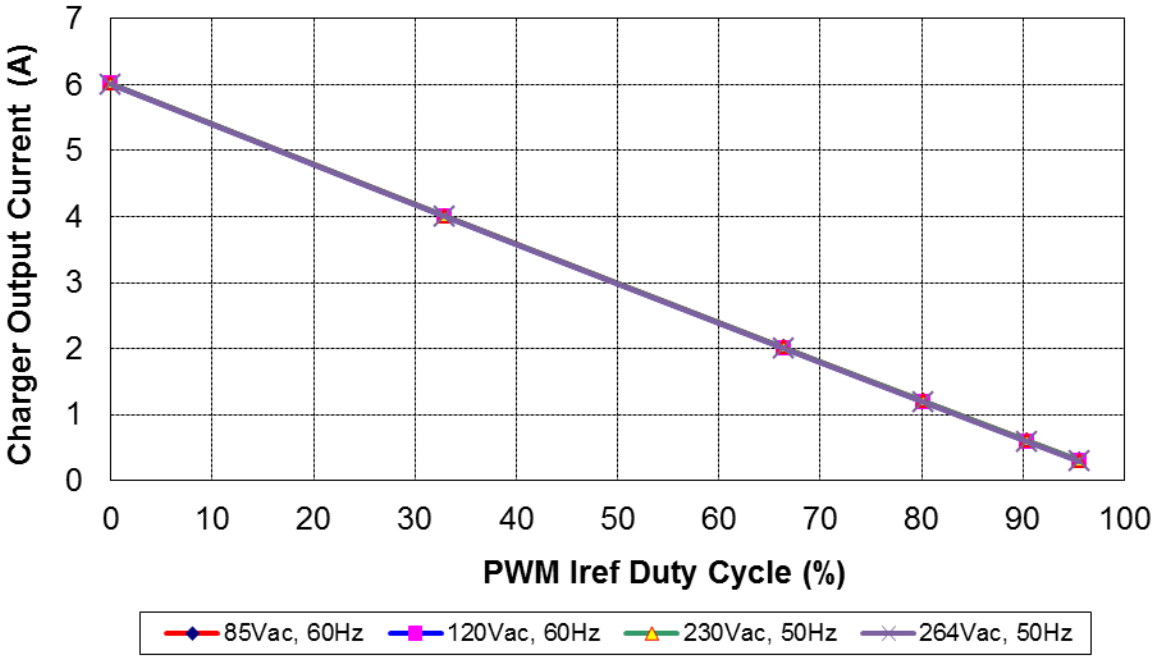
PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.2848	30.02	0	12.5	300	5.0	10.05	14.56	264	4.510	68.86	69.02
90.4	0.5880	30.00	100	12.5	300	5.0	20.39	27.12	264	6.730	84.77	75.18
80.2	1.186	30.00	200	12.5	300	5.0	39.57	46.13	264	6.556	91.82	85.79
66.4	2.001	30.01	300	12.5	300	5.0	65.30	73.45	264	8.150	95.78	88.90
33.0	3.998	30.02	300	12.5	300	5.0	125.3	137.50	264	12.230	98.75	91.11
0.0	6.006	30.00	400	12.5	300	5.0	186.7	204.70	264	18.020	99.16	91.20

PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.3011	17.00	0	12.5	300	5.0	6.62	10.92	230	4.301	69.40	60.61
90.4	0.6042	17.03	100	12.5	300	5.0	13.04	17.91	230	4.870	81.04	72.81
80.2	1.200	17.05	200	12.5	300	5.0	24.46	30.15	230	5.690	91.63	81.13
66.4	2.006	17.03	300	12.5	300	5.0	39.41	45.76	230	6.348	93.94	86.13
33.0	3.998	17.01	300	12.5	300	5.0	73.3	83.20	230	9.944	97.74	88.05
0.0	6.005	17.01	400	12.5	300	5.0	108.6	122.93	230	14.285	99.10	88.38

PWM Iref (%)	Iout (A)	Vout (V)	I_12 (mA)	V_12 (V)	I_5 (mA)	V_5 (V)	Pout (W)	Pin (W)	Vin (Vac)	Ploss (W)	Power Factor (%)	Eff (%)
95.6	0.3072	24.06	0	12.5	300	5.0	8.89	14.04	230	5.149	69.40	63.33
90.4	0.6071	24.04	100	12.5	300	5.0	17.34	22.65	230	5.305	81.04	76.58
80.2	1.204	24.01	200	12.5	300	5.0	32.91	39.28	230	6.372	91.63	83.78
66.4	2.011	24.04	300	12.5	300	5.0	53.59	61.74	230	8.146	93.94	86.81
33.0	4.004	24.00	300	12.5	300	5.0	101.3	113.48	230	12.134	97.74	89.31
0.0	6.080	24.00	400	12.5	300	5.0	152.4	168.39	230	15.970	99.10	90.52

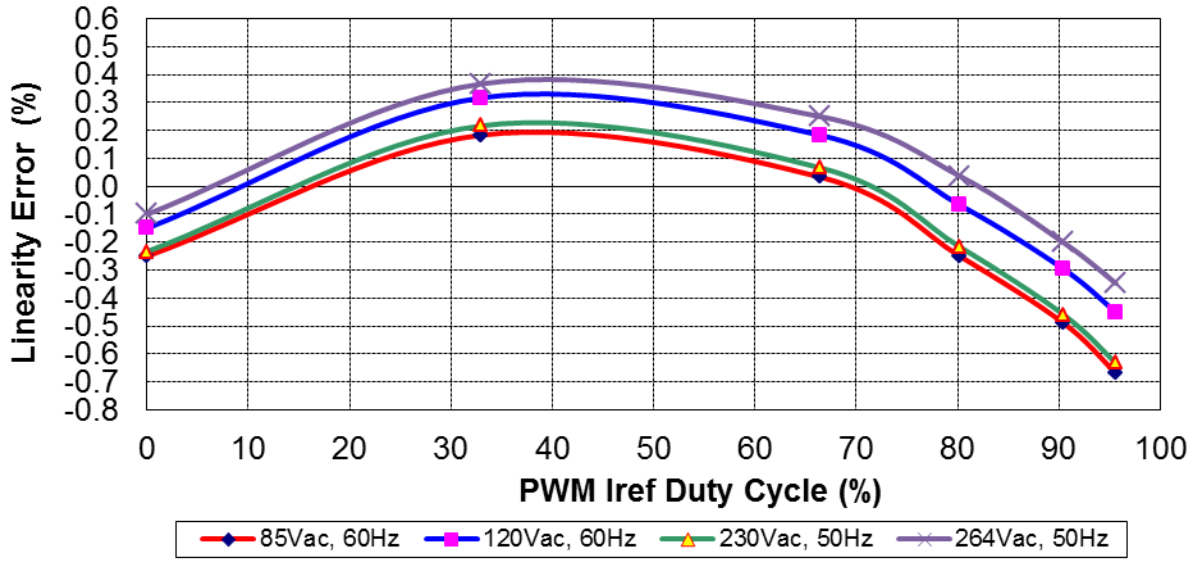
5 Output current regulation

The graph below shows the relationship between main output current and PWM Iref applied on TP26. The frequency of the PWM was 5KHz.



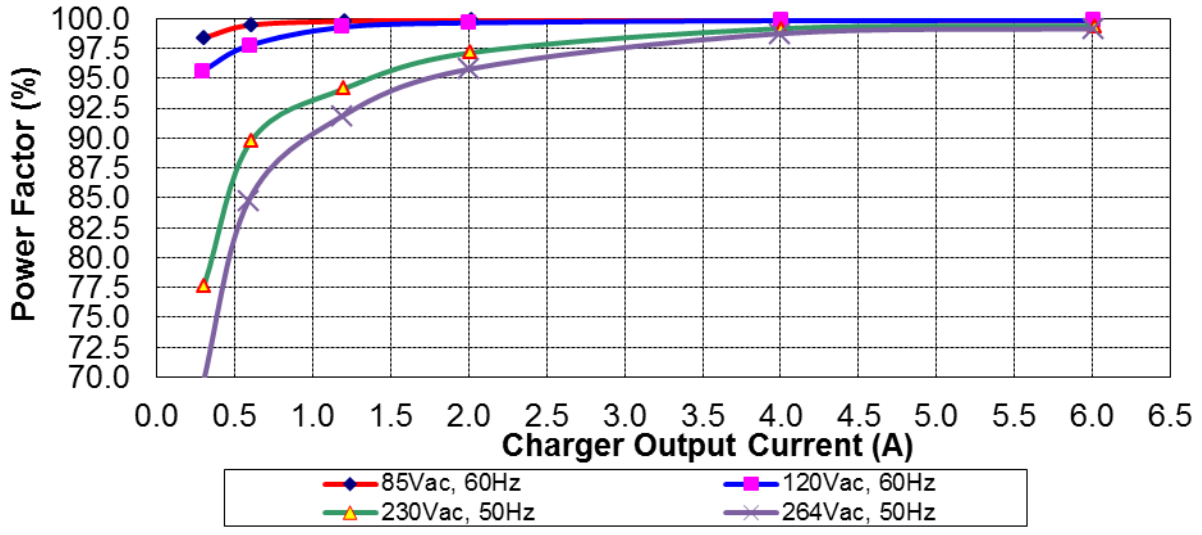
6 Linearity on PWM Iref versus output current

The graph below shows the linearity error between the PWM Iref and the programmed output current (weighted to full scale 6A).



7 Power Factor

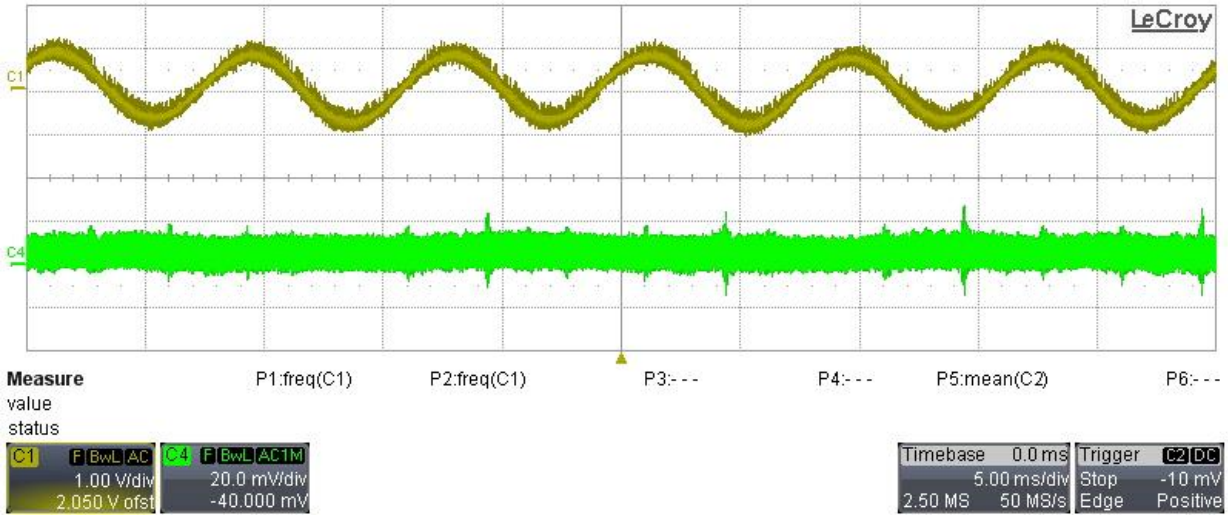
The Power Factor graph versus Vin and main output current is shown below (same loads condition of the efficiency tables) :



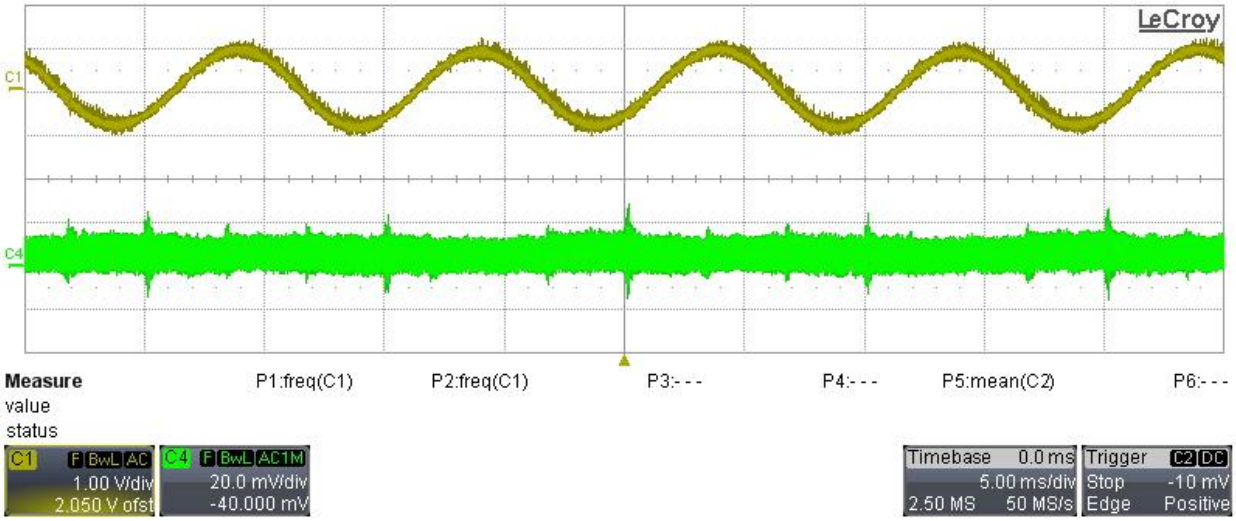
8 Output ripple voltage

The output ripple voltage for the main output and the 400V is shown in the plot below. The input was set at 85Vac, 60Hz and 264Vac, 50Hz respectively. The main output voltage was set to 27V and the current 6A, while 12Vout and 5Vout were fully loaded.

Ch1: 400V output (1V/div, 5ms/div, AC coupling, 20MHz BWL)
Ch4: Main output voltage (20mV/div, AC coupling, 20MHz BWL)
Vin = 85Vac, 60Hz

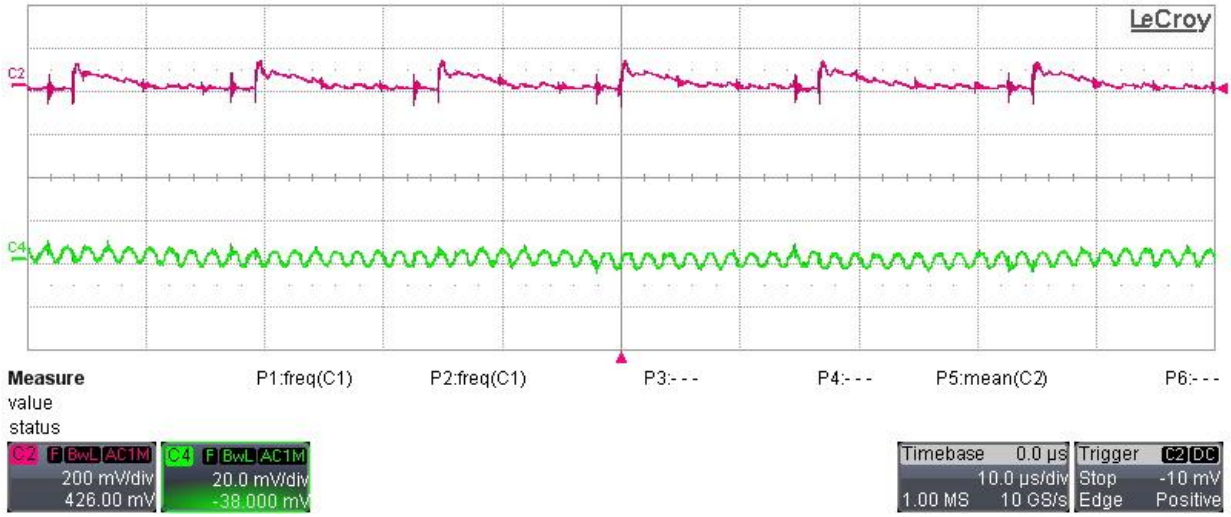


Vin = 264Vac, 50Hz



This picture below shows the ripple voltage on 5Vout and 12Vout, both fully loaded, while the main output was off (S1 switch was OFF); the input voltage was 230Vac.

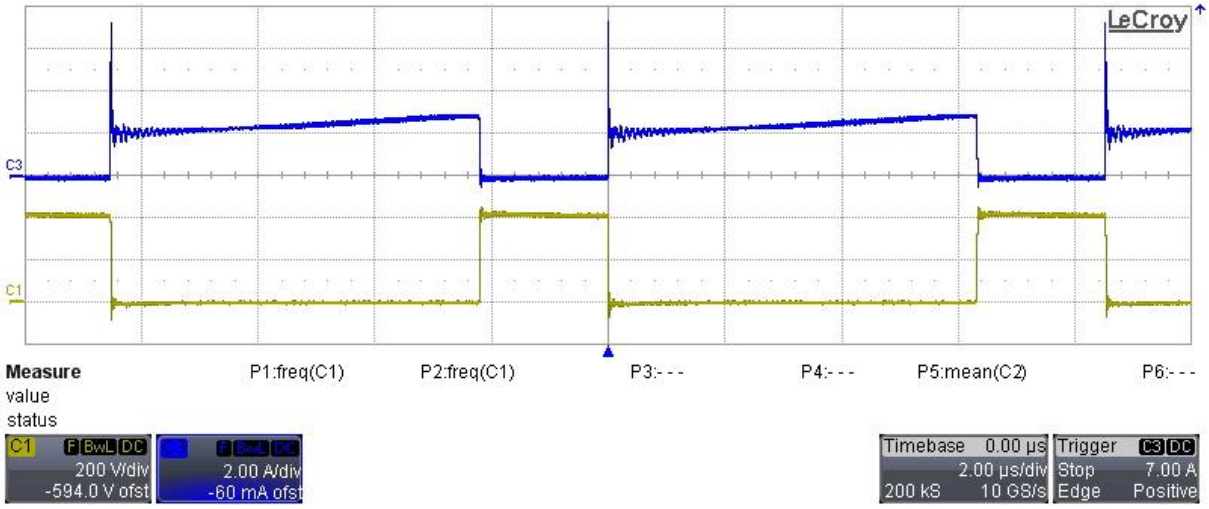
Ch2: 12Vout (200mV/div, 10us/div, AC coupling, 20MHz BWL)
Ch4: 5Vout (20mV/div, AC coupling, 20MHz BWL)



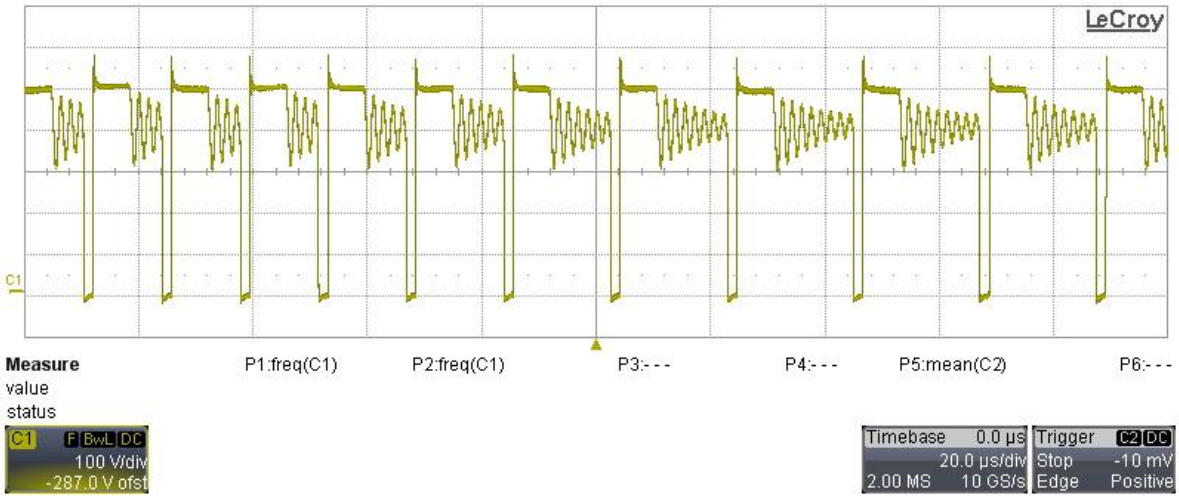
9 Switching Node Waveforms

The images below show respectively the voltage and the current on the drain of the FET Q9, the switch-node on Q11 and the DC/DC switching waveforms taken on TP3 and TP5 in different input voltage and output current conditions, and always with auxiliary PSU fully loaded.

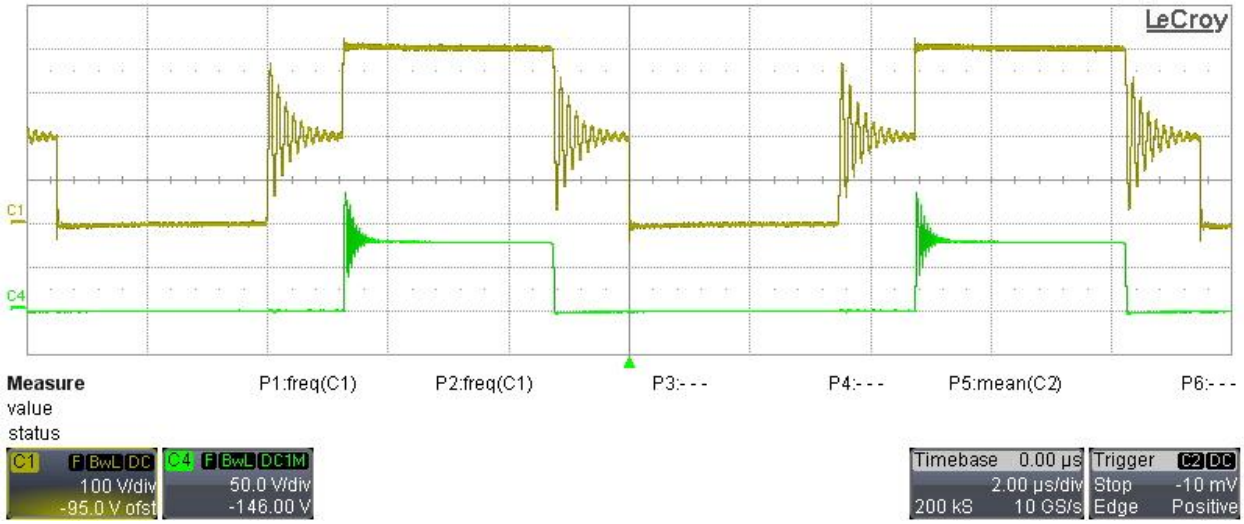
Ch1: Q9 Drain voltage (200V/div, 2us/div, 200MHz BWL)
Ch3: Q9 Drain current (2A/div, 200MHz BWL)
Vin = 85Vac, Vout = 26V, Iout = 6A



Ch1: Q11 Drain voltage (100V/div, 20us/div, 200MHz BWL)
Vin = 230Vac, Vout = 27V, Iout = 6A



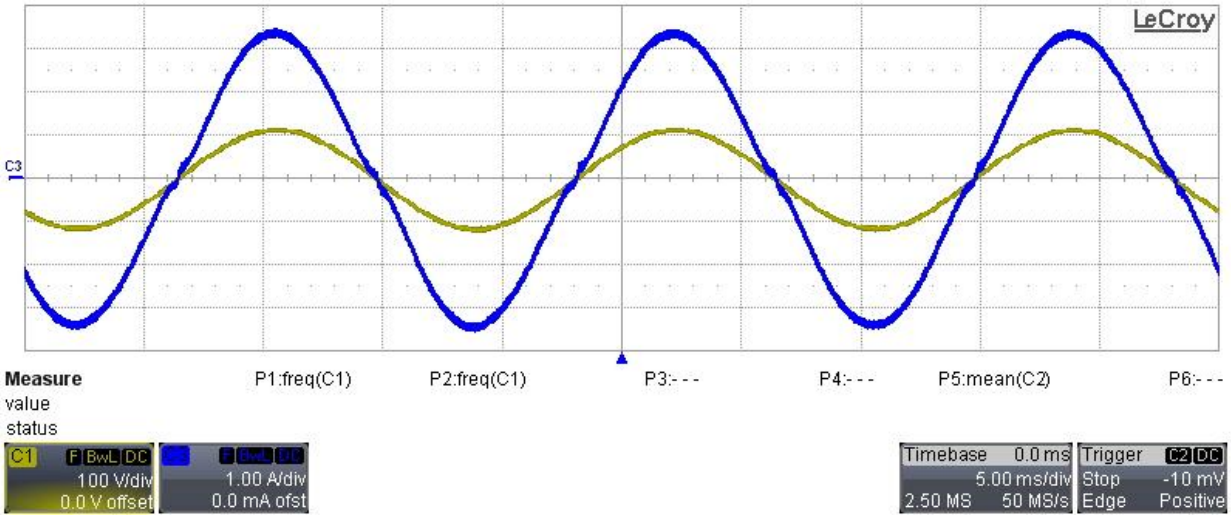
Ch1: TP3 switch node (100V/div, 2us/div, 200MHz BWL)
Ch4: TP5 switch node (50V/div, 200MHz BWL)
Vin = 230Vac, Vout = 27V, Iout = 6A



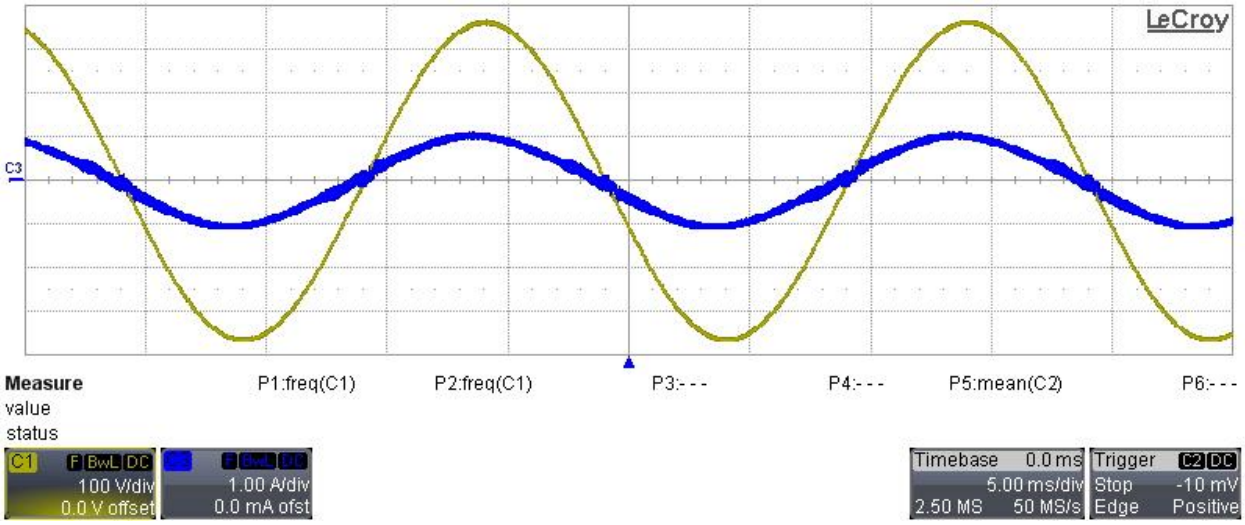
10 Input voltage and current waveforms

The images below show the input voltage and current waveforms while the source was set respectively to 85Vac, 60Hz and 264Vac, 50Hz. The main output voltage was 27V and all outputs fully loaded.

Ch1: Input Voltage (100V/div, 5ms/div, 20MHz BWL)
Ch3: Input Current (1A/div, 20MHz BWL)
Vin = 85Vac, 60Hz



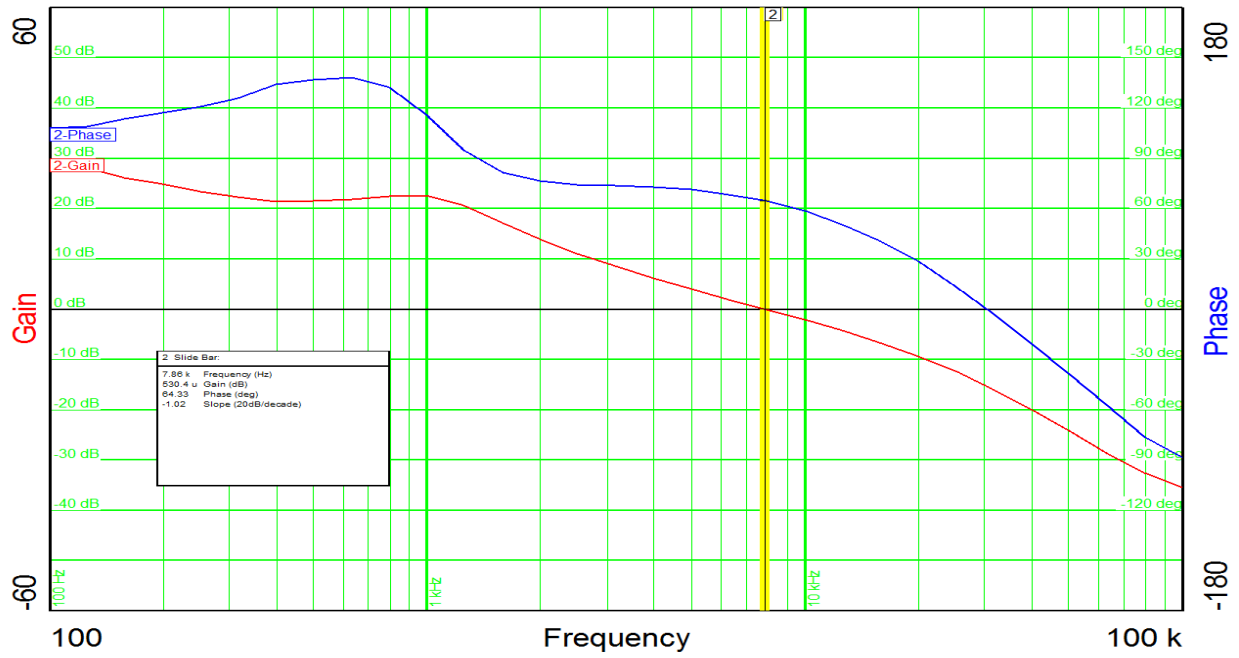
Ch1: Input Voltage (100V/div, 5ms/div, 20MHz BWL)
Ch3: Input Current (1A/div, 20MHz BWL)
Vin = 264Vac, 50Hz



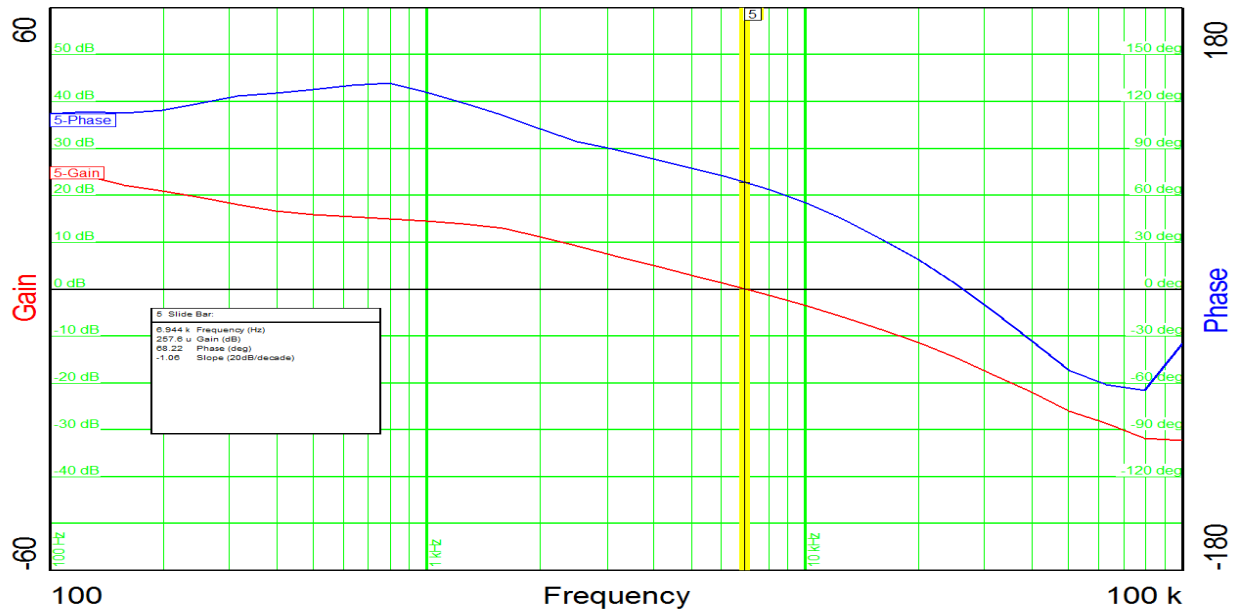
11 Loop Response

The graphs below show the two responses of the converter's loop, respectively during constant voltage and constant current regulation, measured at 300Vdc input, while the output voltage was set to 20V and the load 5A.

Voltage loop (TP18, TP19, TP20): Fco = 7.86KHz, PM = 64.33 deg, GM = 15.5dB.

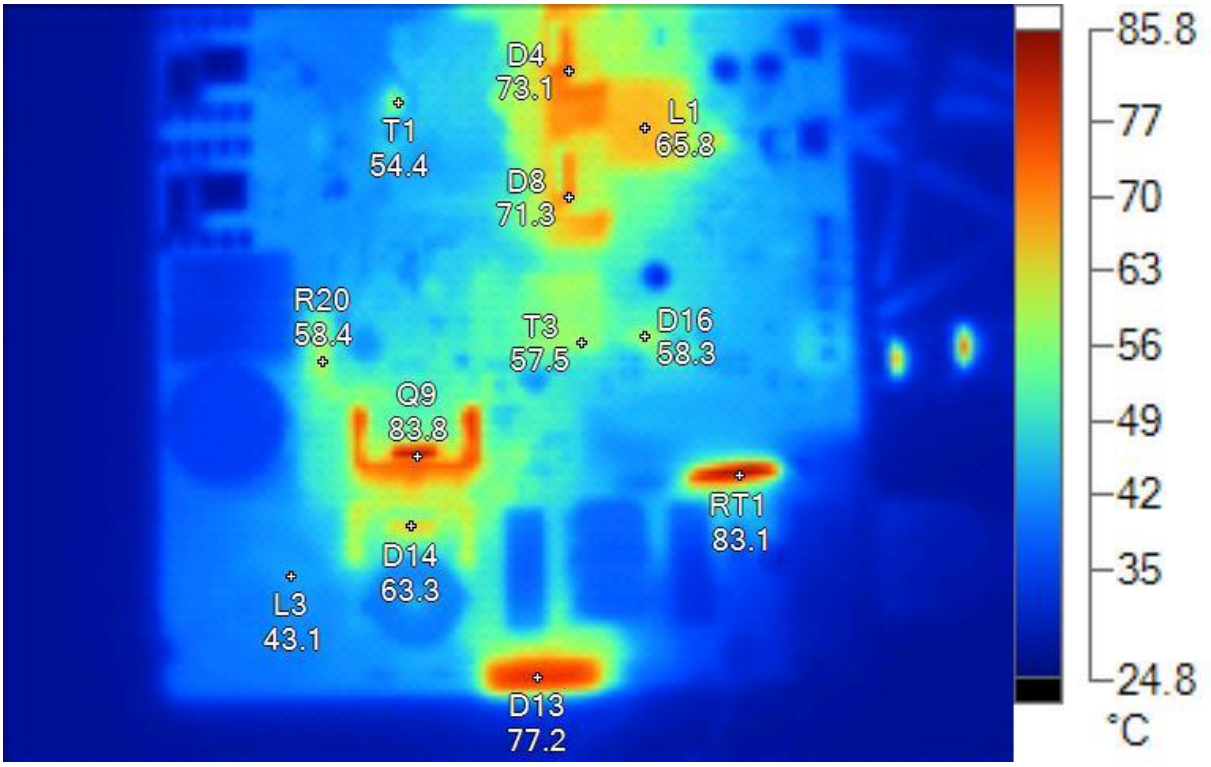


Current loop (TP23, TP24, TP25): Fco = 6.944KHz, PM = 68.22 deg, GM = 15.41dB.



12 Thermal analysis

The thermal image has been taken in steady state condition and when the board was placed horizontally on the bench without any forced convection. The ambient temperature was 25C and the converter fully loaded (30Vout@6A, 12V@400mA, 5V@300mA), **Vin = 115Vac**

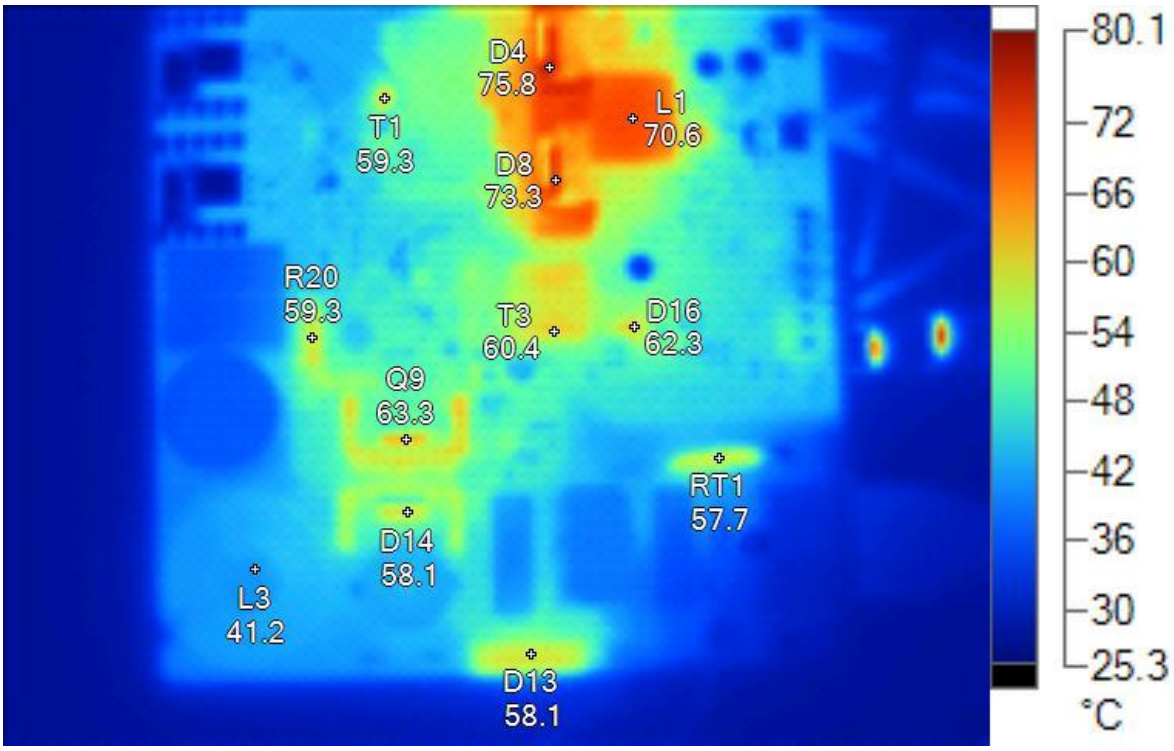


Background temperature	25.0°C
Image Range	25.8°C to 83.9°C
Camera Model	Ti40FT
Camera Manufacturer	Fluke
Image Time	5/26/2015 4:43:37 PM

Main Image Markers

Name	Temperature
D13	77.2°C
RT1	83.1°C
Q9	83.8°C
L1	65.8°C
D14	63.3°C
D4	73.1°C
D8	71.3°C
T3	57.5°C
R20	58.4°C
L3	43.1°C
T1	54.4°C
D16	58.3°C

Vin =230Vac



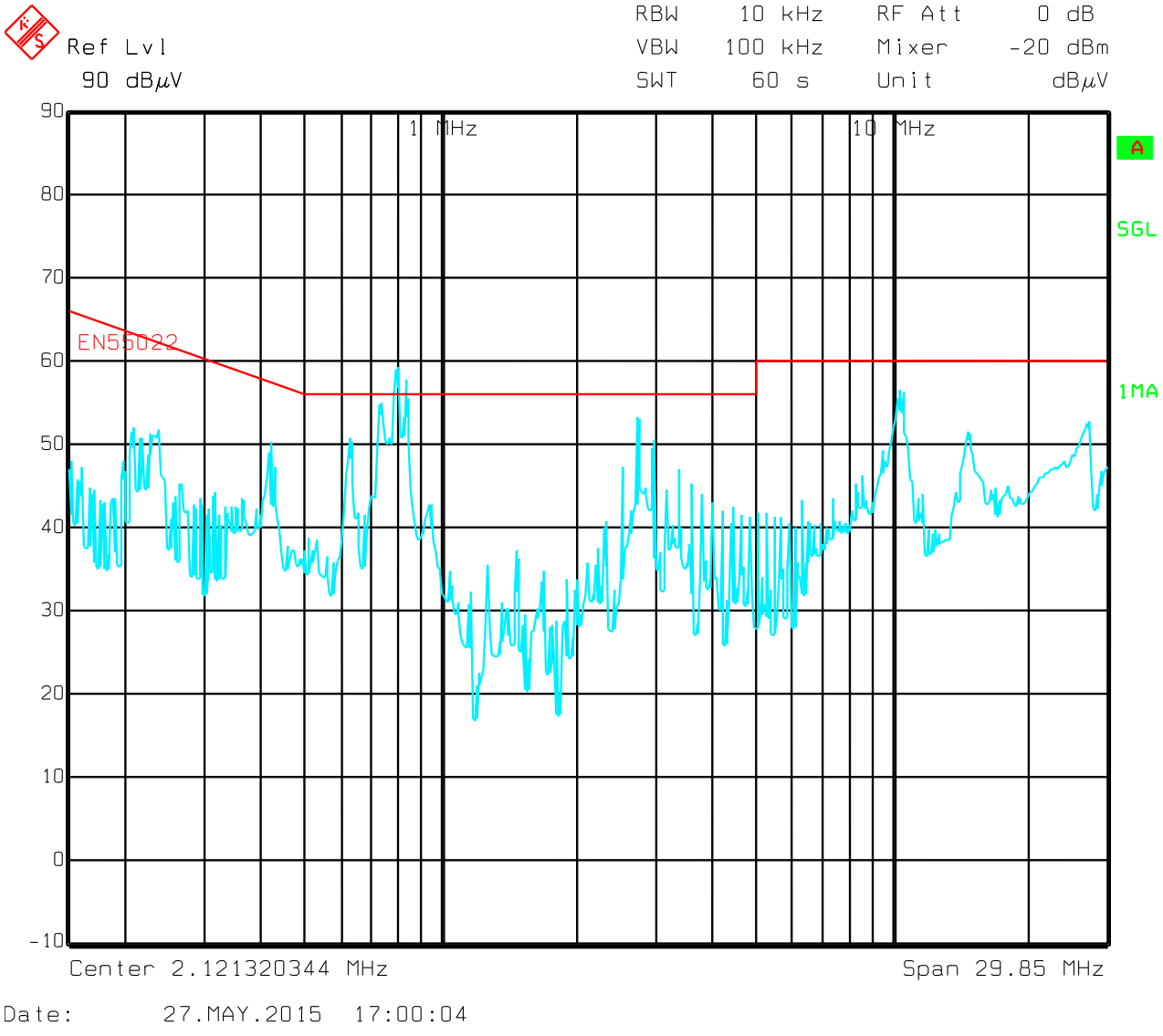
Background temperature	25.0°C
Average Temperature	39.3°C
Image Range	26.3°C to 78.0°C
Camera Model	Ti40FT
Camera Manufacturer	Fluke
Image Time	5/26/2015 4:48:17 PM

Main Image Markers

Name	Temperature
D13	58.1°C
D14	58.1°C
L3	41.2°C
Q9	63.3°C
R20	59.3°C
RT1	57.7°C
D16	62.3°C
T3	60.4°C
L1	70.6°C
D4	75.8°C
D8	73.3°C
T1	59.3°C

13 EMI measurement

The graph below shows the EMI measurement of the converter connected to an isolation transformer plus a Hameg HM6050-2 LISN. The supply voltage was 230Vac.
The converter has been loaded with a passive resistor set to deliver full load on all outputs.
The output negative terminal of the converter has been connected to the ground of the LISN.
The detector of the receiver was set to “quasi-peak” and the limit is the equivalent EN65022 grade B.



EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMER

For Feasibility Evaluation Only, in Laboratory/Development Environments. The EVM is not a complete product. It is intended solely for use for preliminary feasibility evaluation in laboratory / development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical / mechanical components, systems and subsystems. It should not be used as all or part of a production unit.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

Certain Instructions. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output ranges are maintained at nominal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be indentified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of this agreement. This obligation shall apply whether Claims arise under the law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate TI components for possible use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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