AN5797

Application note

1 kW bridgeless CCM-PFC pre-regulator based on L4986A

Introduction

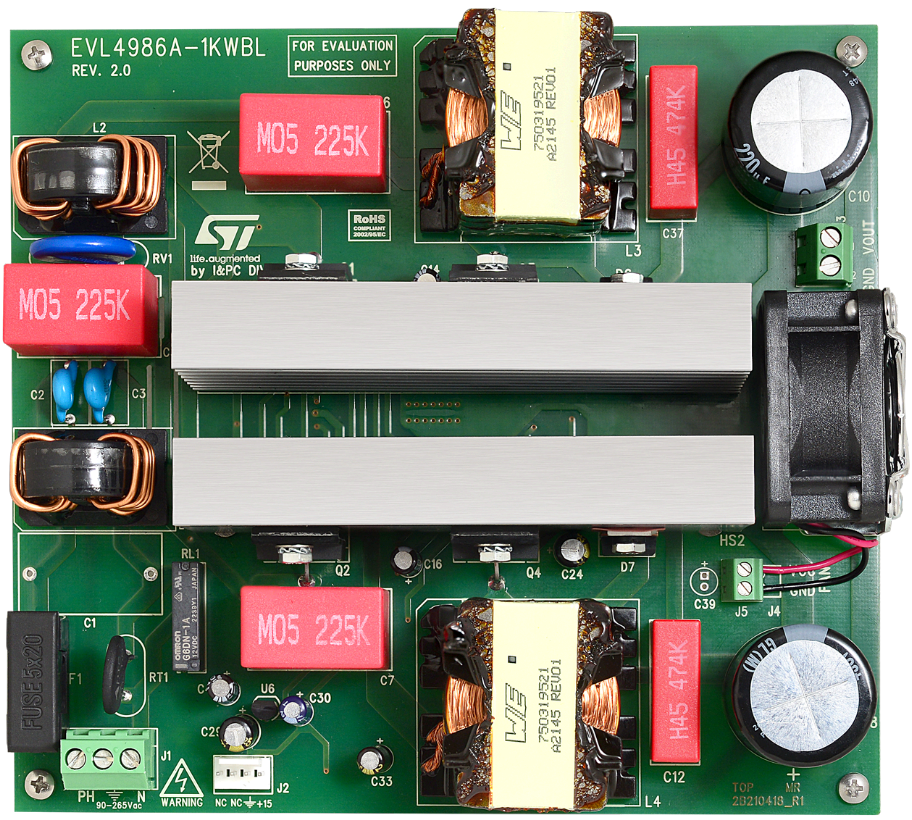
The EVL4986A-1KWBL demonstration board is bridgeless PFC pre-regulator in double-boost topology, featuring 1 kW output power (400 Vdc) and wide input voltage range (90–265 Vac), based on the new L4986A peak current mode CCM power factor controller.

It is intended as a front-end converter up to 1 kW, able to comply with IEC61000-3-2 and JEITA-MITI.

The demo is designed on the double-boost (Barbi) topology using two branches, each with a boost stage managing half mains cycle. Each section works at almost fixed frequency (65 kHz).

Thanks to the bridgeless approach and the L4986A control IC, the board has high efficiency and low input current THD on whole the ac input voltage range. It also features lower schematic complexity and part count than similar bridgeless solutions.

Figure 1. EVL4986A-1KWBL bridgeless PFC demonstration board



1 Description

This section describes the main characteristics and architecture of the converter, including details regarding the L4986A PFC controller (see Section 1.6).

1.1 Main characteristics

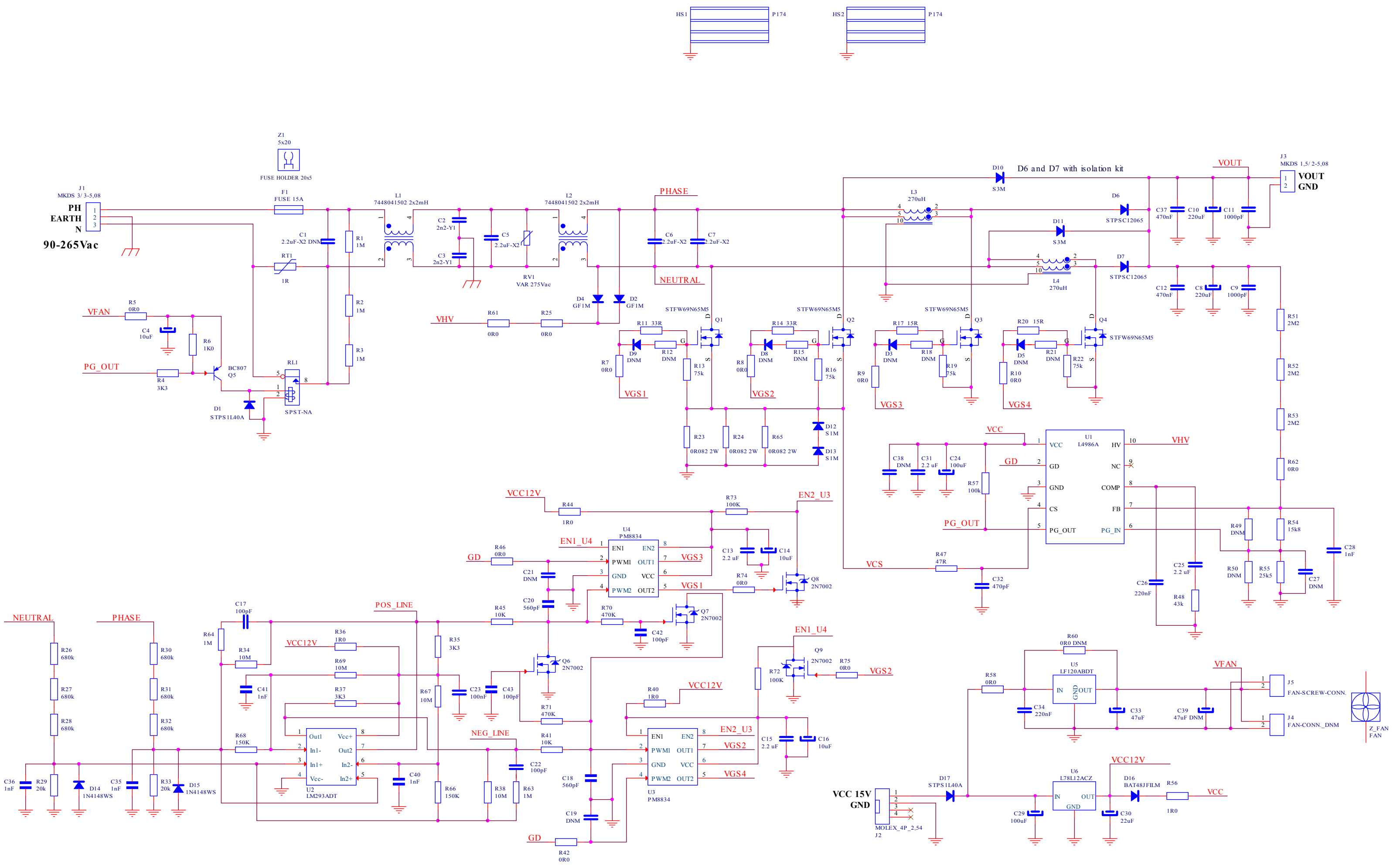
The main features of EVL4986A-1KWBL are listed below:

Table 1. **EVL498A-1KWBL main characteristics**

Parameter	Value
Input Mains Range	90 to 265 Vac–Frequency 45 to 65 Hz
Output Voltage/Load	400 V/2.5 A
Efficiency	> 98% at 230 Vac–full load > 95.5% at 115 Vac–full load > 94% between 10% and 100% of full load
No load mains consumption	< 250 mW at 230 Vac
Mains Harmonics according to	EN61000-3-2 Class-A and JEITA-MITI
EMI	According to EN55022 Class-B
THD	<10% between 10% and 100% of full load
Safety	According to EN62368
Dimensions	145 x 160 mm, component height = 35 mm
PCB	Double side, 70 µm, FR-4, mixed PTH/SMT

1.2 Schematic

Figure 2. EVL4986A-1KWBL schematic

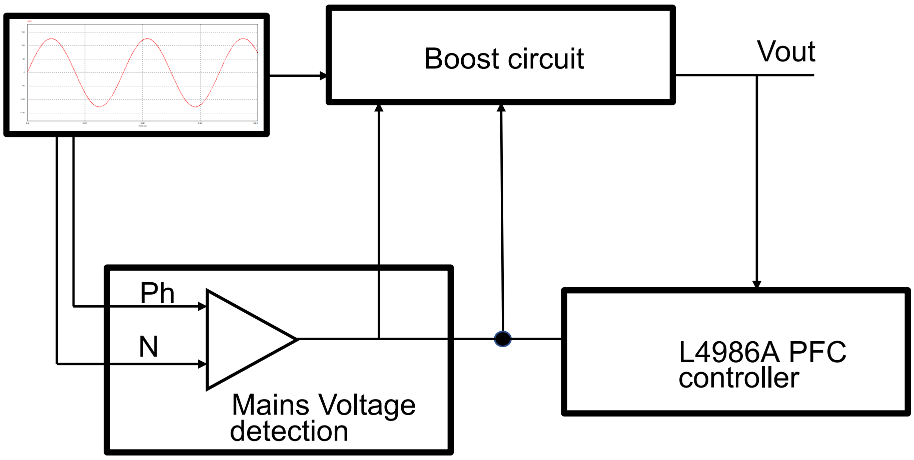


1.3 Schematic description

Figure 3 shows the top-level block diagram of EVL4986A-1KWBL, highlighting the following main blocks:

1. boost converter circuit
2. input mains voltage detection circuit
3. controller circuit managed by L4986A working in CCM peak current mode

Figure 3. **EVL4986A-1KWBL schematic block**



1.4 The boost converter circuit

The PFC double boost topology used for this demo board is based on two alternating boost sections. Both sections are directly connected to phase and neutral lines. One section works when the phase wire is positive and the other section when the neutral wire is positive. In both cases, the return wire is the opposite to the one in operation.

This solution allows the PFC circuit to work without the conventional mains bridge rectifier and corresponding power dissipation, especially at low input mains voltage. The bridge heatsink cost can also be eliminated, rendering the entire solution very attractive for its very high efficiency and low cost. Circuit complexity is also relatively low because the current sensing and the MOSFET drivers are all referred to ground, so complex MOSFET driving and isolated current sensing solutions are not required.

Figure 4. **EVL4986A-1KWBL boost schematic**

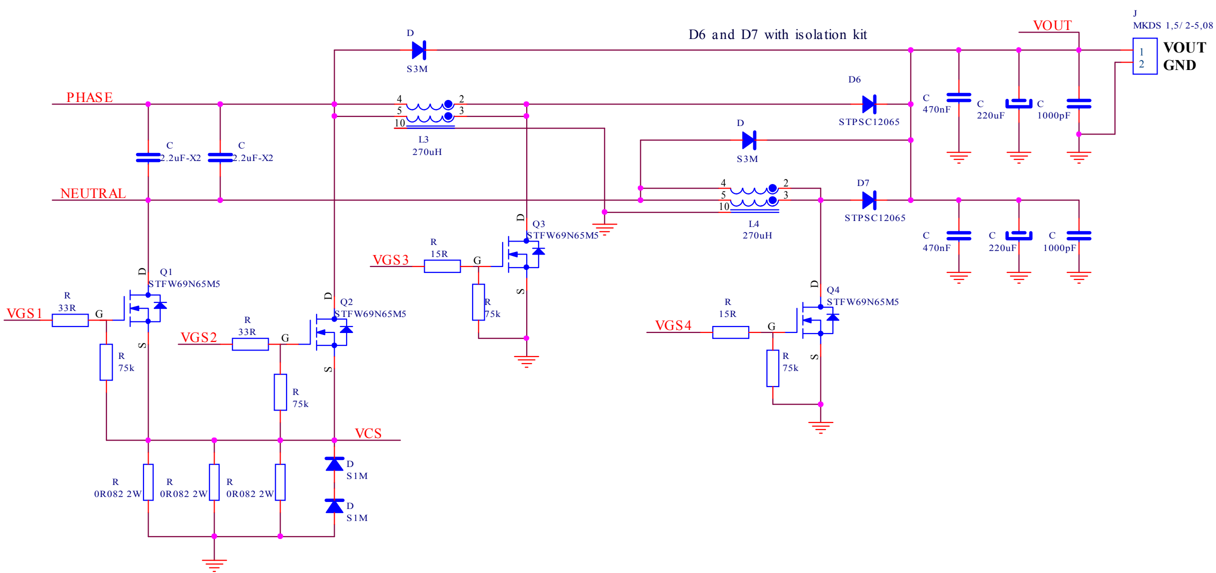


Figure 5 and Figure 6 show the equivalent boost schematic for each branch working on the positive and negative input voltage lines. The current paths are highlighted for both.

Figure 5. EVL4986A-1KWBL power boost bridgeless circuit positive line (Phase)

In green, the forward path from AC mains to the output
In red, the return path from AC mains to the output

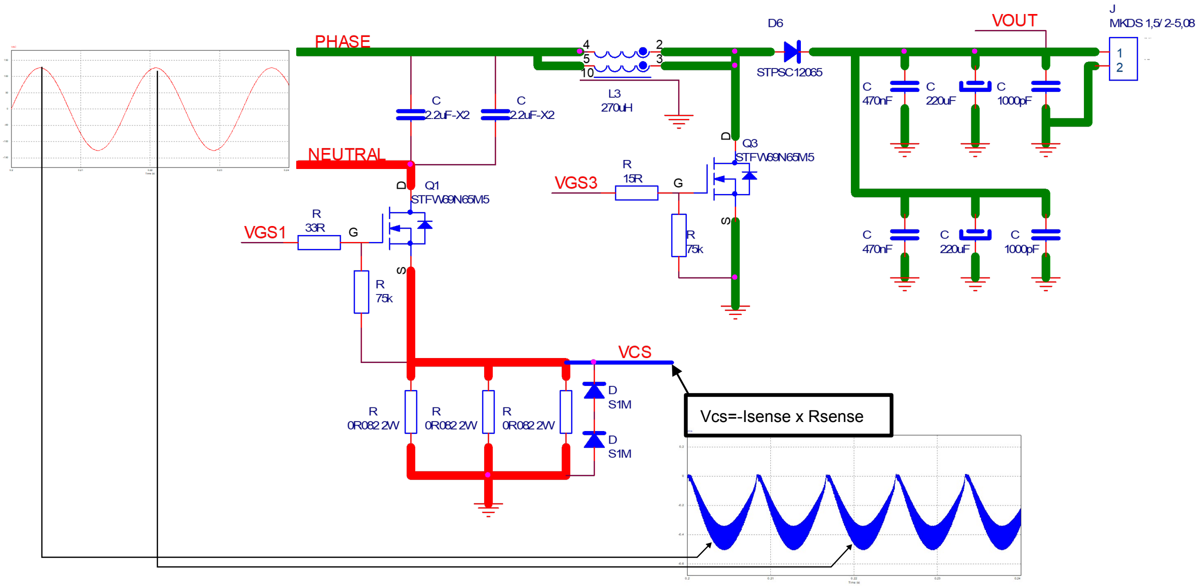
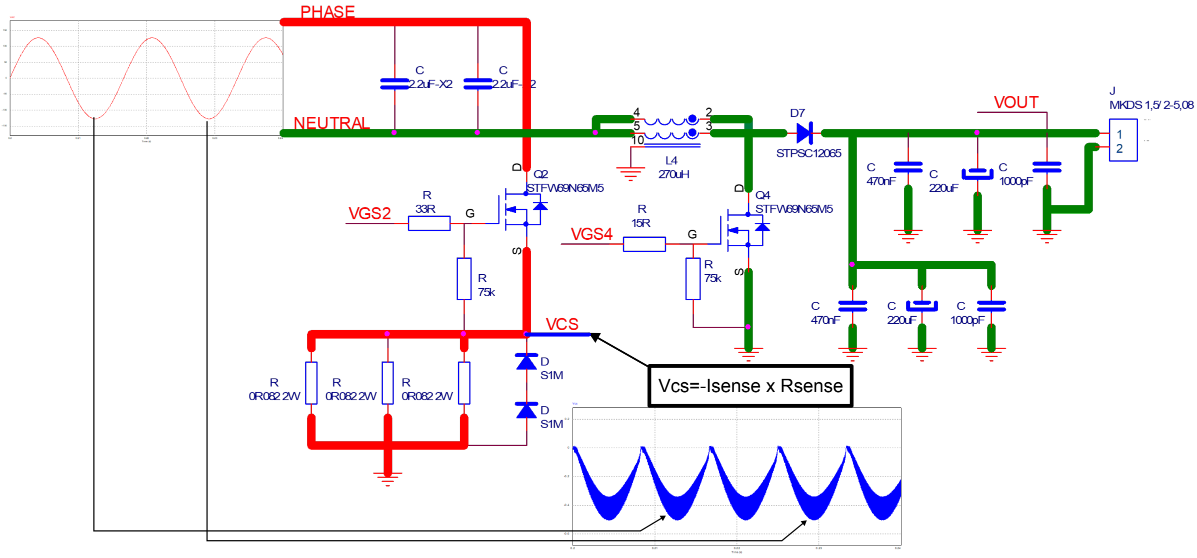


Figure 6. EVL4986A-1KWBL power boost bridgeless circuit negative line (Neutral)

In green, the forward path from AC mains to the output
In red, the return path from AC mains to the output



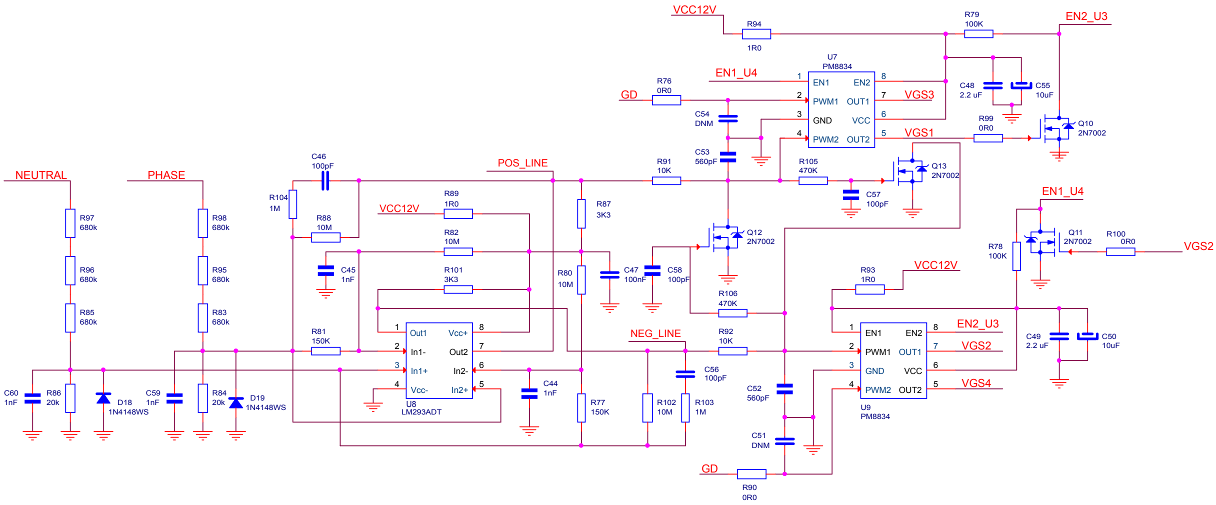
The boost circuit (Barbi topology) highlighted above deliver the following main advantages:

1. The input voltage rectification is obtained without using the diode bridge.
2. Input current flows through Power MOSFETs Q1 and Q2 instead of the typical diodes used in this topology, therefore reducing power dissipation and boosting efficiency.

1.5 Positive and negative input voltage detection circuit

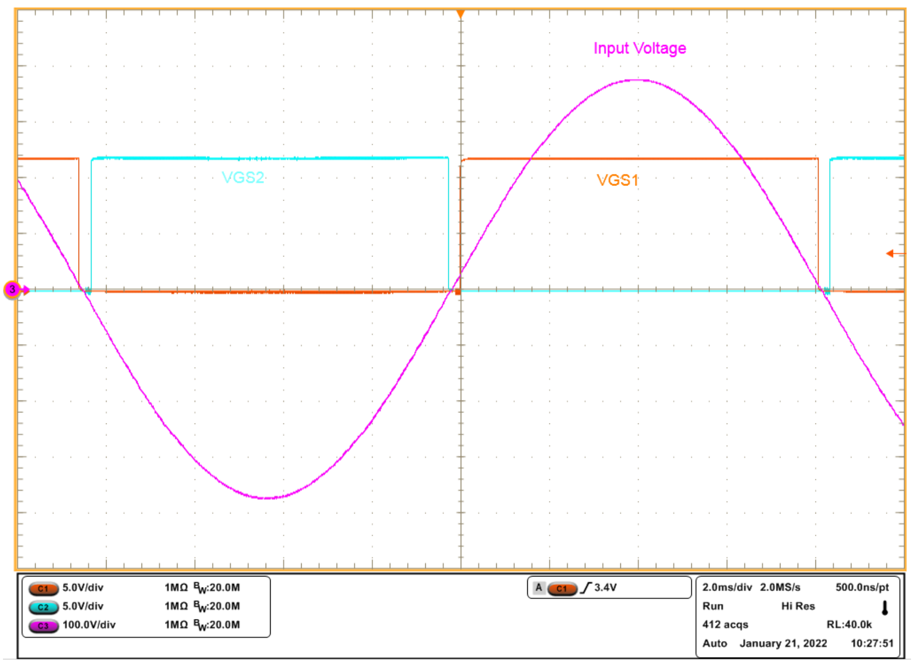
The following circuit has been designed to drive the circuitry during the positive and negative phases of the input sinewave.

Figure 7. **EVL4986A-1KWBL positive and negative input voltage detection circuit**



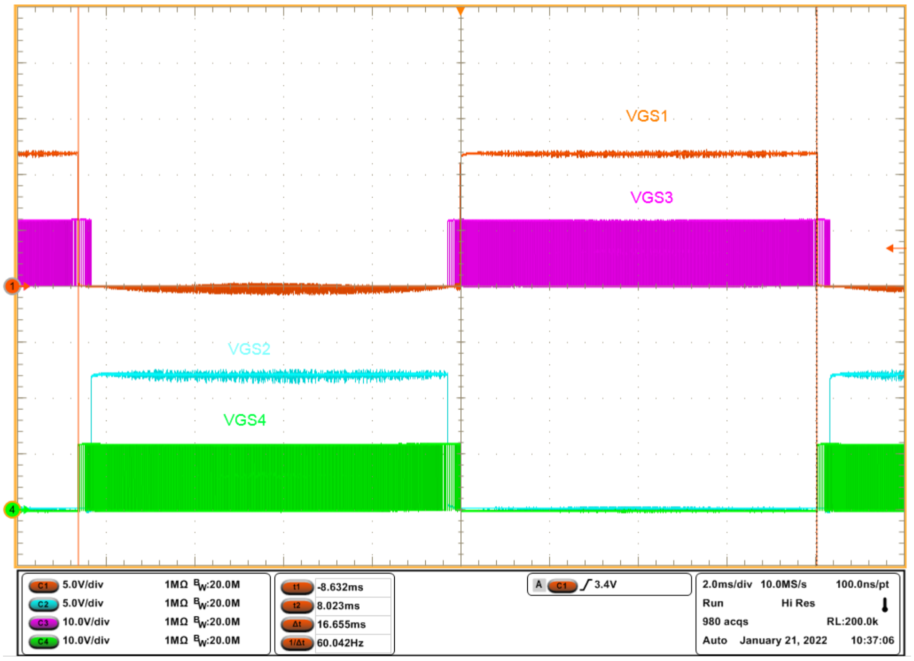
By sensing the input voltage via comparators, two complementary signals are generated and used to enable the relevant boost section. The signals are Positive and Negative Line, or VGS1 and VGS2 highlighted in Figure 8 below.

Figure 8. **EVL4986A-1KWBL positive and negative signals vs. AC input voltage mains**



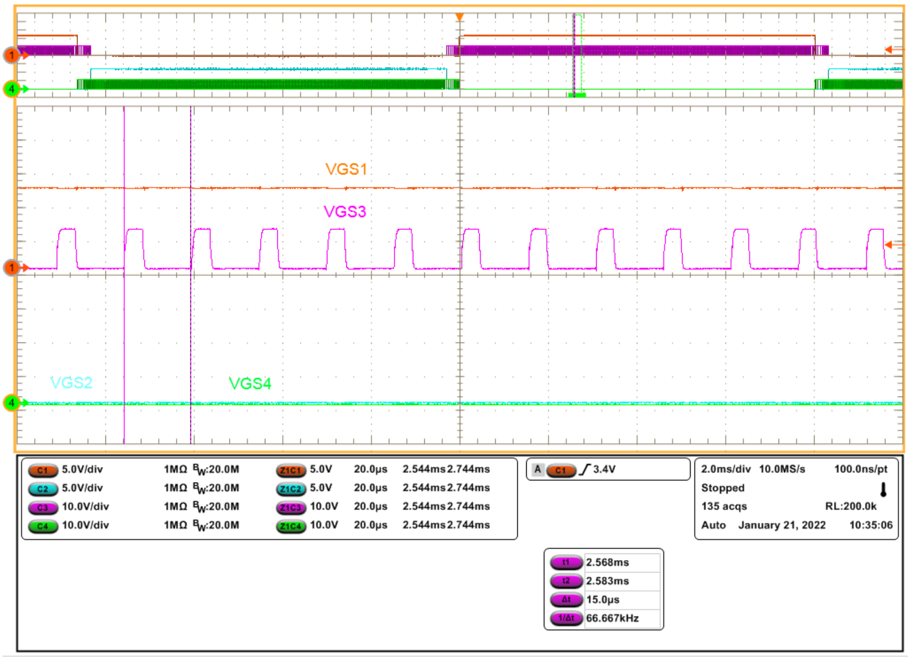
The POS LINE and NEG LINE signals are used to control the EN pins of drivers U3 and U4 (PM8834), which are used to drive the power MOSFETs Q1, Q2, Q3, and Q4, as shown in Figure 9 below.

Figure 9. **EVL4986A-1KWBL boost switching MOSFET VGS**



The figure below details VGS3 during positive half cycle working at around 65 kHz.

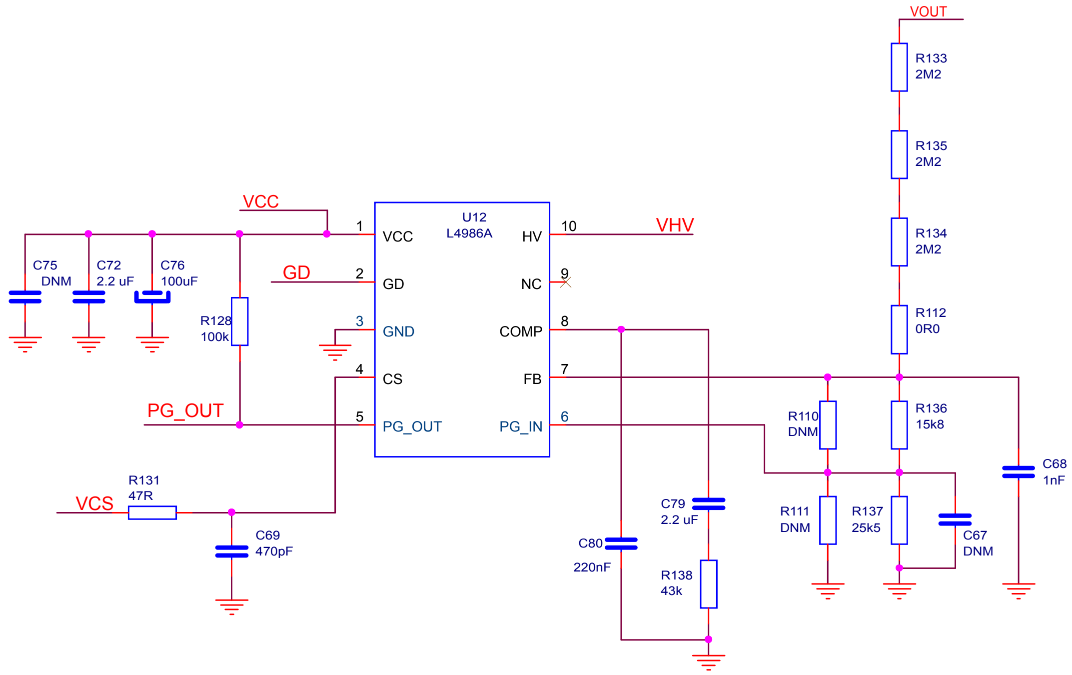
Figure 10. **EVL4986A-1KWBL Power MOSFET VGS detail**



1.6 The L4986A PFC controller circuit

Figure 11 shows the circuitry around the L4986A PFC control IC.

Figure 11. EVL4986A-1KWBL L4986A PFC controller circuit



The L4986A is a peak current-mode PFC controller for boost converters with a proprietary multiplier 'emulator', which in addition to the innovative THD optimizers, guarantees very low Total Harmonic Distortion performance in all operating conditions. The IC, using a proprietary off-time modulator, operates in quasi-fixed frequency (65 kHz) in all operating conditions.

It is equipped with an 800 V integrated High Voltage startup block managing the IC startup. It also includes circuitry to discharge the X-capacitors of the EMI filter to a safe level once the mains is disconnected, meeting safety regulations such as IEC 61010-1 or IEC 62368-1 without using the traditional discharge resistor in parallel to the X-capacitors. This feature significantly helps achieve very small input power at no load. The pin HV also helps manage brown-in and brown-out by preventing operation if the input mains voltage is too low.

The L4986A also integrates overvoltage protection to keep the output voltage under control during transient conditions. The output voltage is monitored via the divider R51, R52, R53, R62, R54, and R55 connected to pin FB. Protections against feedback loop failures or erroneous settings and boost inductor saturation are also embedded.

The output divider is also used by the PG_IN pin, which has a comparator connected on this pin to monitor the PFC output voltage and provide a logic signal (PG_OUT) that can be used to activate the relay RL1 after the PFC has started up. The relay is used to bypass the NTC RT1, limiting the inrush current at mains plug in.

An external Vcc must be supplied to start up the board because the PFC is not self-supplied. It is intended to form part of a more complex system with an additional converter providing the Vcc.

2 Efficiency measurements

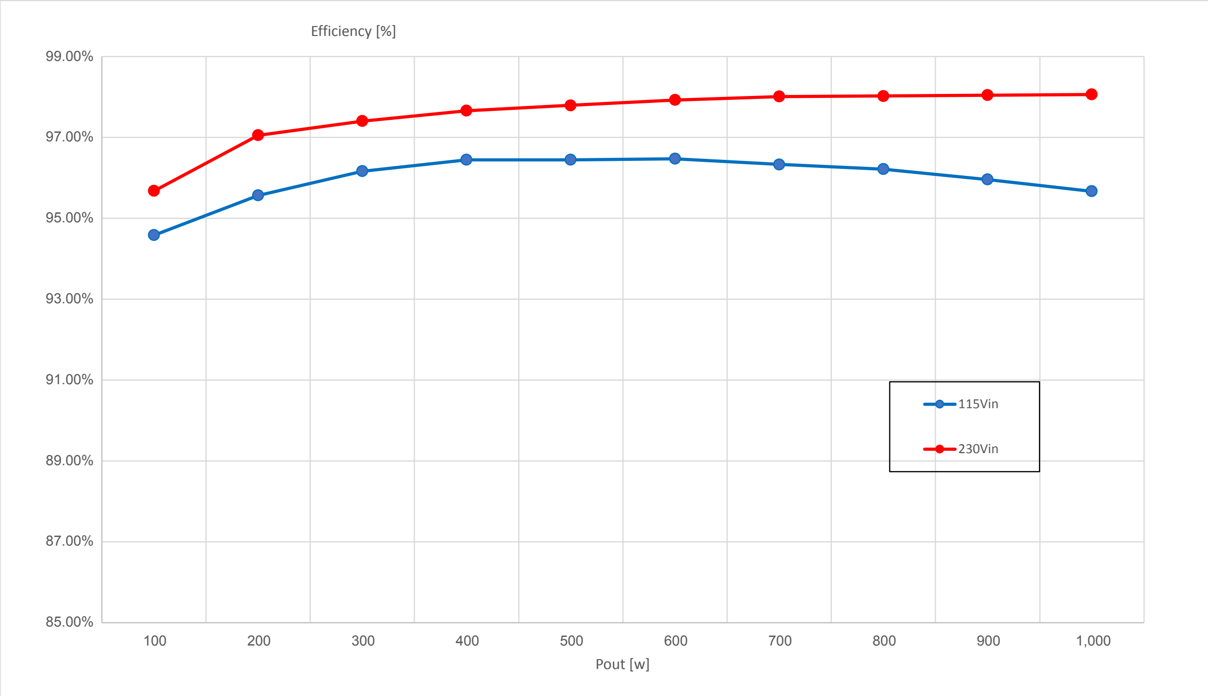
2.1 Full load measurement

The following table shows the overall efficiency of the EVL4986A-1KWBL demo board after a warmup time of about 1 hour, measured at different loads and nominal mains voltages (115 Vac and 230 Vac).

Table 2. **EVL4986A-1KWBL efficiency**

Output load	230 Vac–50 Hz					115 Vac–60 Hz				
	Vout [V]	Iout [A]	Pout [W]	Pin [W]	η	Vout [V]	Iout [A]	Pout [W]	Pin [W]	η
10%	399.41	0.2550	101.84	106.45	95.68%	399.22	0.2528	100.92	106.7	94.59%
20%	399.39	0.5000	199.69	205.75	97.06%	399.2	0.5078	202.71	212.12	95.57%
30%	399.37	0.7547	301.40	309.43	97.41%	399.19	0.7519	300.15	312.11	96.17%
40%	399.35	1.0047	401.69	410.84	97.66%	399.18	1.0016	399.81	414.56	96.44%
50%	399.33	1.2544	500.91	512.22	97.79%	399.17	1.2509	499.32	517.71	96.45%
60%	399.31	1.5094	602.71	615.5	97.92%	399.16	1.5012	599.21	621.1	96.48%
70%	399.28	1.7588	702.25	716.5	98.01%	399.16	1.755	700.52	727.2	96.33%
80%	399.19	2.0072	801.25	817.4	98.02%	399.15	2.0038	799.81	831.3	96.21%
90%	399.1	2.2563	900.48	918.4	98.05%	399.14	2.2519	898.82	936.7	95.96%
100%	399.06	2.5050	999.64	1019.4	98.06%	399.13	2.4997	997.70	1042.9	95.67%

Figure 12. **EVL4986A-1KWBL efficiency**



Thanks to the topology and solutions implemented, the efficiency is always very high and remains stable across the entire measured load range.

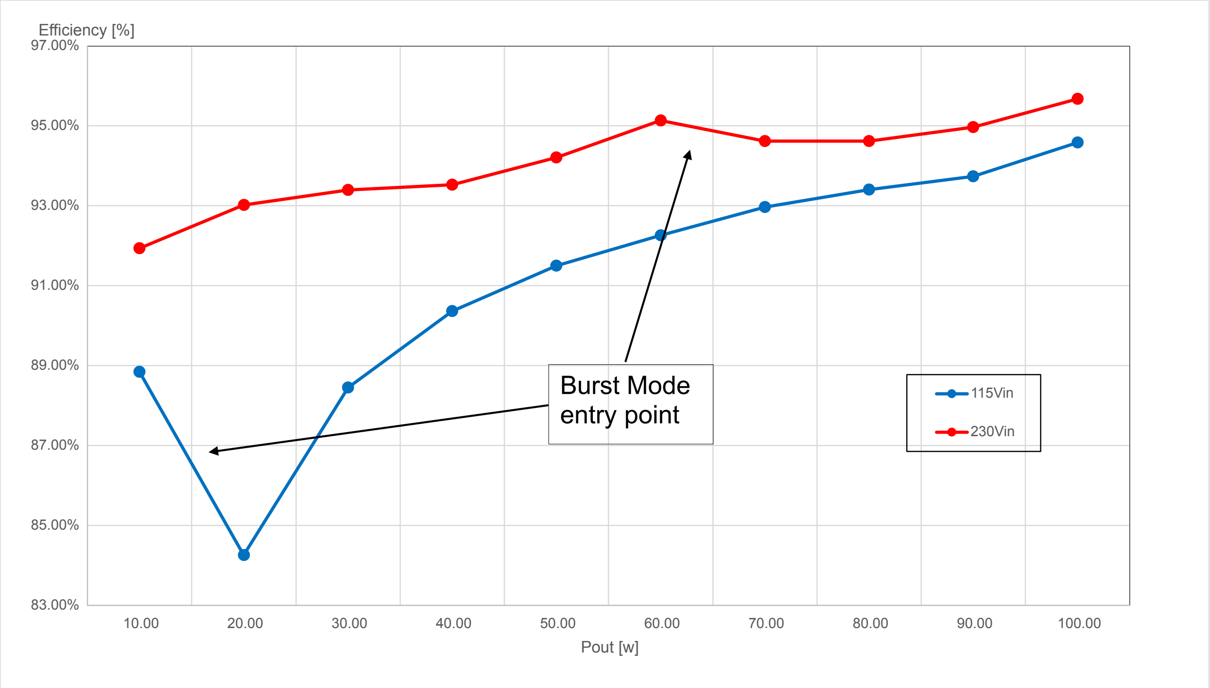
2.2 Efficiency measures at light and no loads

As there are several applications requiring high efficiency over a broad load range, the efficiency details from 10% down to 0 are provided. The following table and figure report the data measured at both input nominal mains voltages.

Table 3. **EVL4986A-1KWBL light load efficiency measurements**

Output load	230Vac–50Hz					115Vac–60Hz				
	Vout [V]	Iout [A]	Pout [W]	Pin [W]	η	Vout [V]	Iout [A]	Pout [W]	Pin [W]	η
No	400.62			0.238		400.43			0.173	
1%	399.7	0.0247	9.872	10.73	91.94%	399.75	0.0249	9.95	11.19	88.85%
2%	399.65	0.0484	19.34	20.79	93.02%	399.41	0.0487	19.45	23.07	84.26%
3%	399.58	0.0769	30.72	32.90	93.39%	399.38	0.0773	30.87	34.90	88.45%
4%	399.55	0.103	41.15	44.00	93.53%	399.35	0.1037	41.41	45.82	90.36%
5%	399.51	0.1248	49.85	52.92	94.21%	399.29	0.1251	49.95	54.59	91.50%
6%	399.48	0.154	61.51	64.665	95.14%	399.26	0.1517	60.56	65.65	92.26%
7%	399.45	0.1778	71.02	75.06	94.62%	399.25	0.1783	71.18	76.57	92.97%
8%	399.44	0.204	81.48	86.12	94.62%	399.25	0.2048	81.76	87.53	93.41%
9%	399.43	0.2252	89.95	94.72	94.97%	399.23	0.22618	90.29	96.33	93.74%
10%	399.41	0.255	101.84	106.45	95.68%	399.22	0.2528	100.92	106.7	94.59%

Figure 13. **EVL4986A-1KWBL light load efficiency**



The L4986A control circuitry implements burst mode on the PFC stage during light load operation to prevent unwanted rising of the PFC output voltage and minimize input power consumption.

Figure 13 shows the burst mode load entry point at both mains input voltages. The measured data demonstrates that the design is suitable for meeting highly stringent efficiency regulations requested by the consumer and industrial markets.

2.3 Harmonic content, THD and PF

Among the main purposes of a PFC pre-conditioner is to shape the input current and decrease the harmonic contents below relevant regulation limits. The board has been tested according to European EN61000-3-2 Class-A and Japanese JEITA-MITI Class-A standards at full load and 70 W output power for both nominal input voltage mains.

The following figures demonstrate that the circuit can maintain harmonics well below both regulation limits, from full load down to light load. An output power of 70 W was chosen because it is near the lower power limit at which the harmonics must be limited according to the mentioned rules.

The board has been tested according to the European EN61000-3-2 Class-A and Japanese JEITA-MITI Class-A standards, at the nominal input voltage mains (50Hz).

Figure 14. EN61000-3-2 compliance at full load

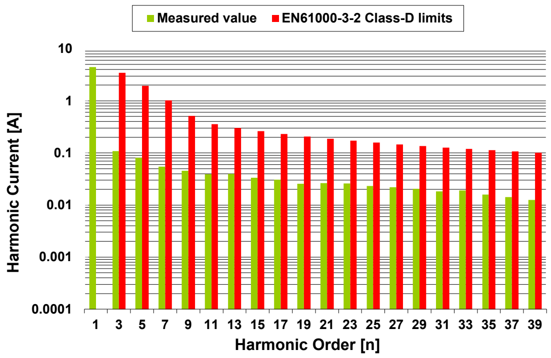


Figure 15. JEITA-MITI compliance at full load

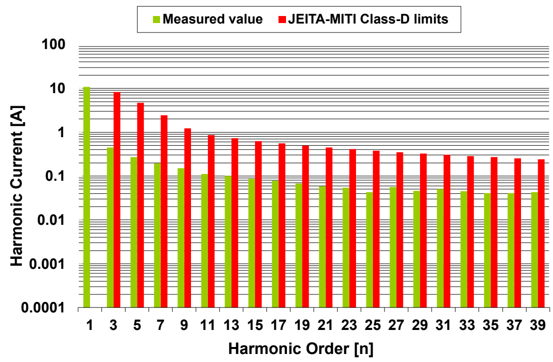


Figure 16. EN61000-3-2 compliance at 70W

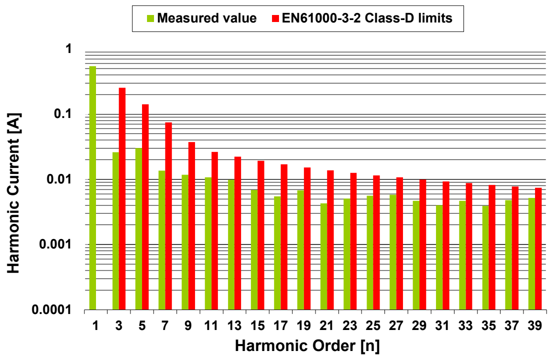


Figure 17. JEITA-MITI compliance at 70W

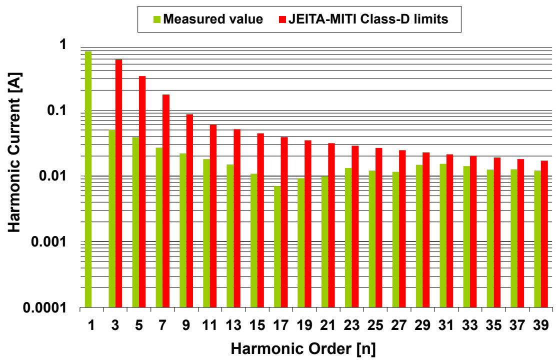


Figure 18. EVL4986A-1KWBL Total Harmonic Distortion

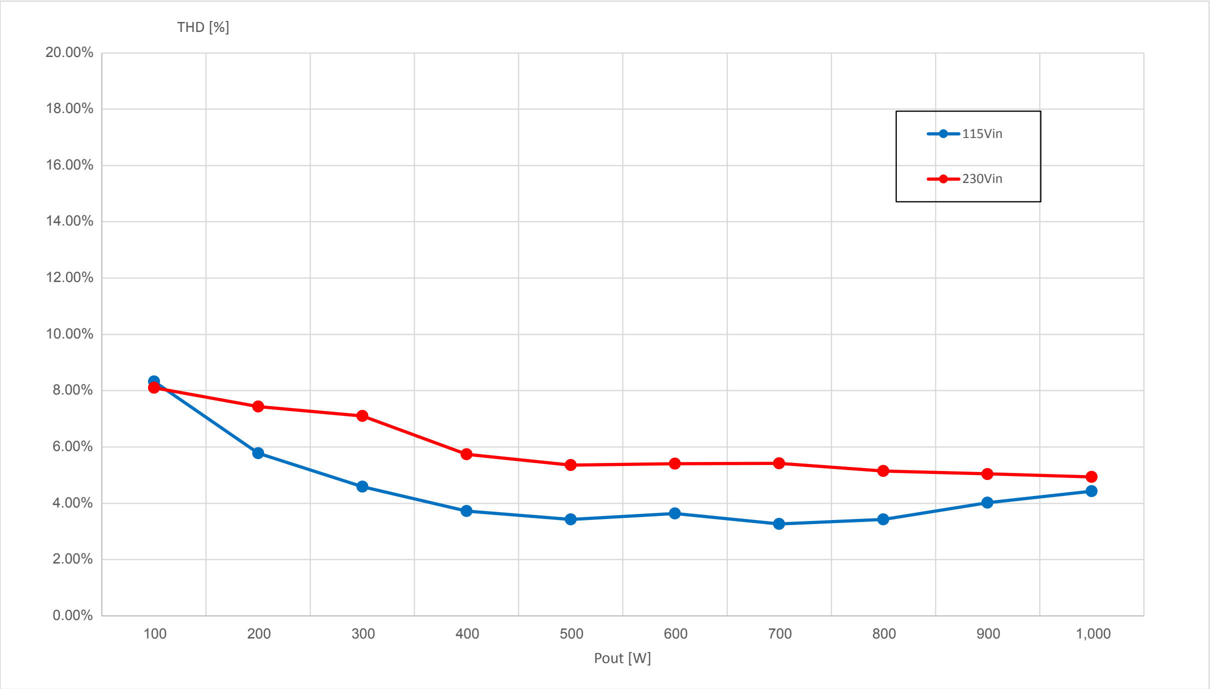
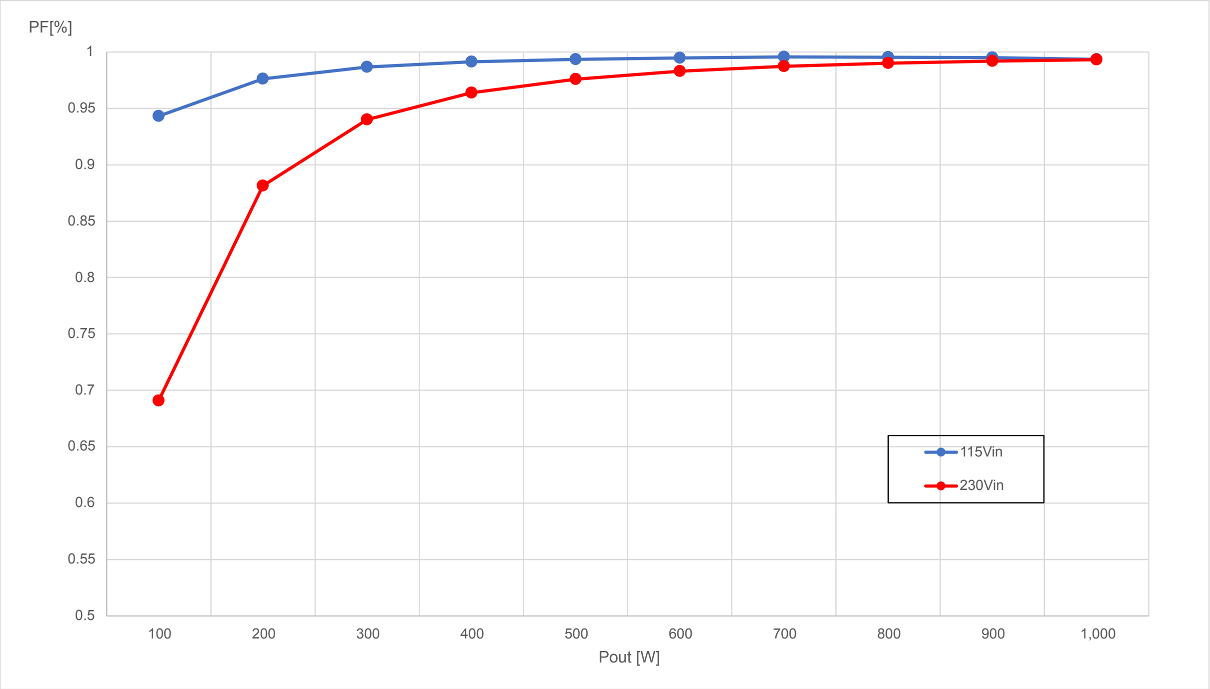


Figure 19. EVL4986A-1KWBL Power Factor



2.4 Full load input current

The L4986A is equipped with an innovative THD optimizer that can shape the input current with a very low Total Harmonic Distortion (THD). The previous Figure 18 shows that the THD is well below 10% from full load down to 10%. Figure 20 and Figure 21 highlight the operations of the THD optimizer of the L4986A in terms of input current vs input voltage at full load.

Figure 20. **Steady state input current at 115 Vac 1 kW**

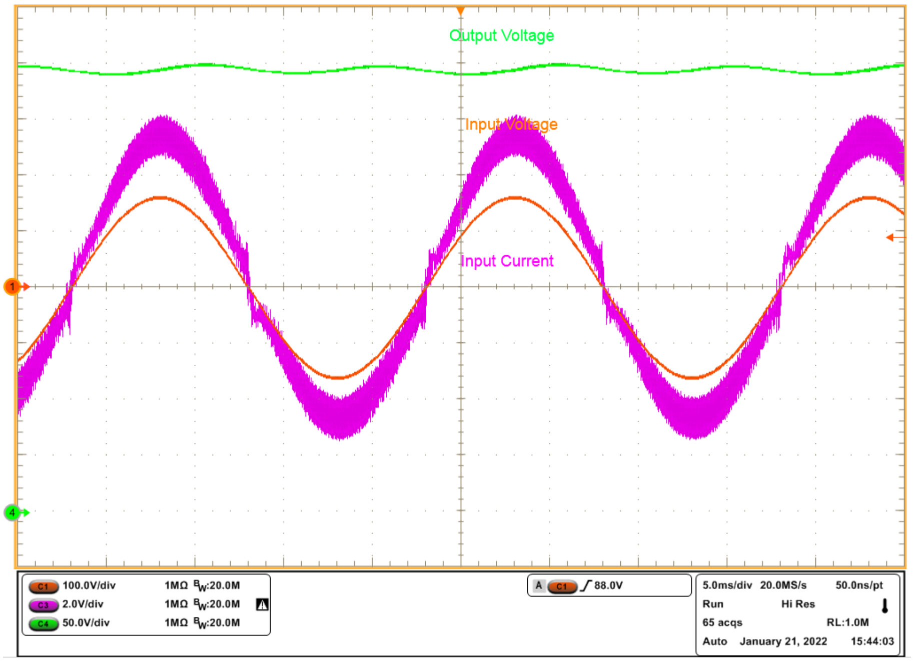
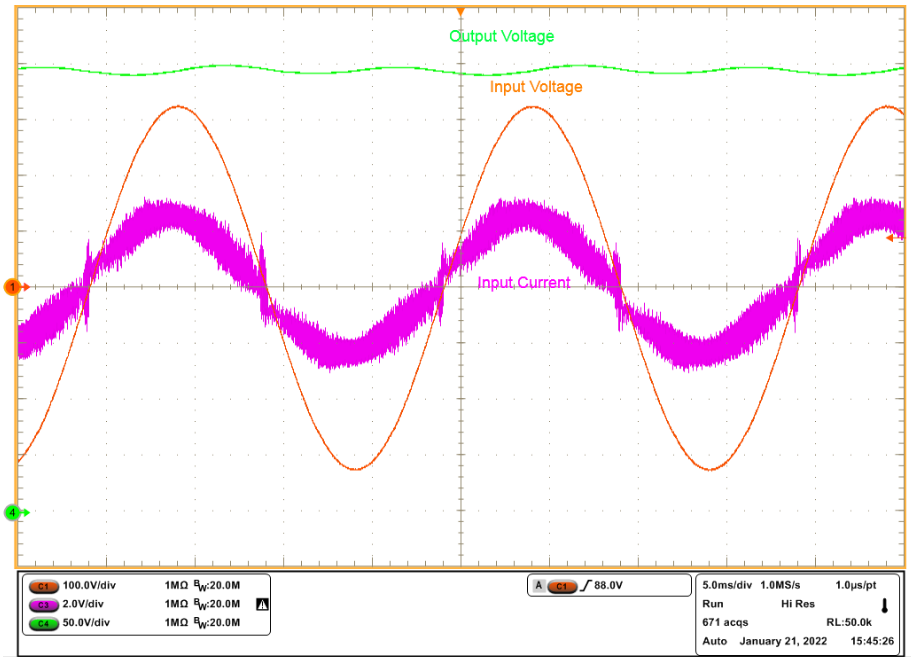


Figure 21. **Steady state input current at 230 Vac 1 kW**



3 Functional check

3.1 Start up

The Startup signals are shown in Figure 22 and Figure 23. The waveforms were captured with an external Vcc voltage already present before connecting the ac input to the mains. There are no significant differences, and the board can still power up if we invert the sequence by applying Vac before the auxiliary Vcc.

In steady state condition, the auxiliary Vcc must always be connected to the board to supply the L4986A (Vcc), the fan, and the other circuitry, otherwise the L4986A will attempt to startup periodically because of the internal HV startup, as shown in Figure 25. Figure 22 shows the L4986A startup attempts as Vcc is charged up to the startup threshold (VCC_ON) and discharged by the consumption of the IC. As the external Vcc is already available, the PFC starts up.

There are no dangerous situations when the L4986A tries startup with no external Vcc because the gate drivers and the rest of the circuitry is unpowered. Figure 24 shows how the PG_OUT signal goes low to activate the relays shorting the NTC after the L4986A turns on.

Figure 22 shows Vcc rising above the Vcc_on threshold due to the HVSU, and the expected increases in output voltage and output current, and the activation of L4986A GD signal.

Figure 22. Startup at 230Vin full load

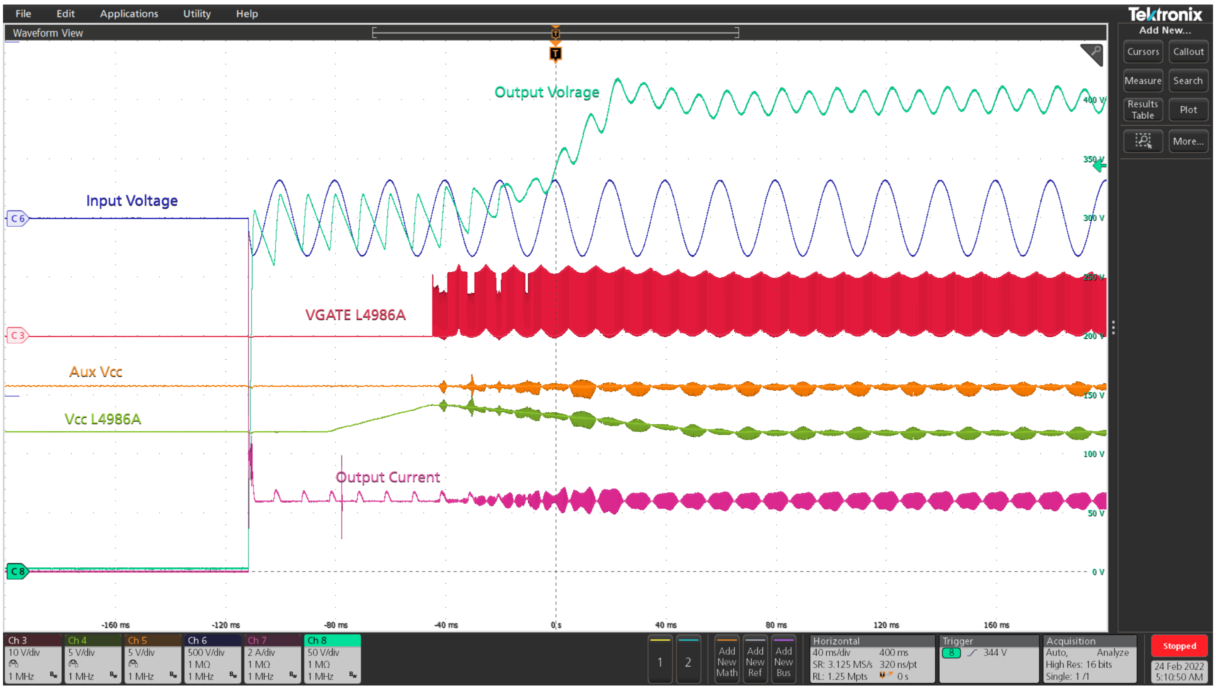


Figure 23 shows the startup at 115 Vac. Also in this case, the Vcc is applied before and the ac mains voltage.

Figure 23. Startup at 115Vin full load

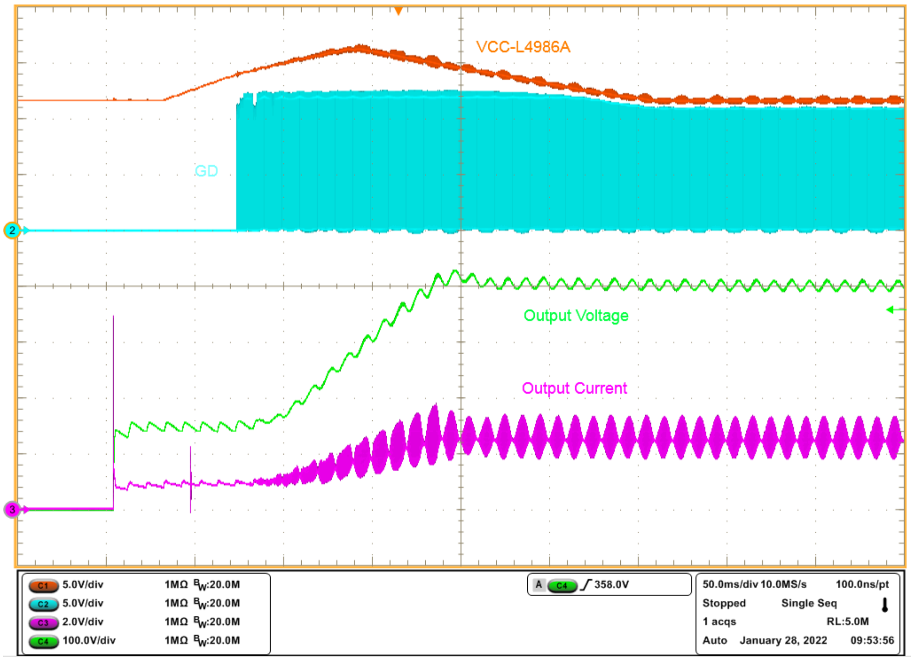


Figure 24 and Figure 25 compare the startup between the auxiliary Vcc being available before AC mains voltage increases (Figure 24) and the auxiliary Vcc voltage supplied after the AC mains voltage is available (Figure 25). In both cases Vac is 230V at full load (2.5A). In both cases, the board can power itself up and the PG_OUT and VRT1 signals are highlighted to show the relay activations needed to decrease the consumption, triggered as soon as PG_OUT falls to zero voltage. VRT1 monitored on RT1 became 0V due to the relay activation, considering that the relay and RT1 are in parallel.

Figure 24. Startup 230Vin at full load with auxiliary Vcc + Vinac

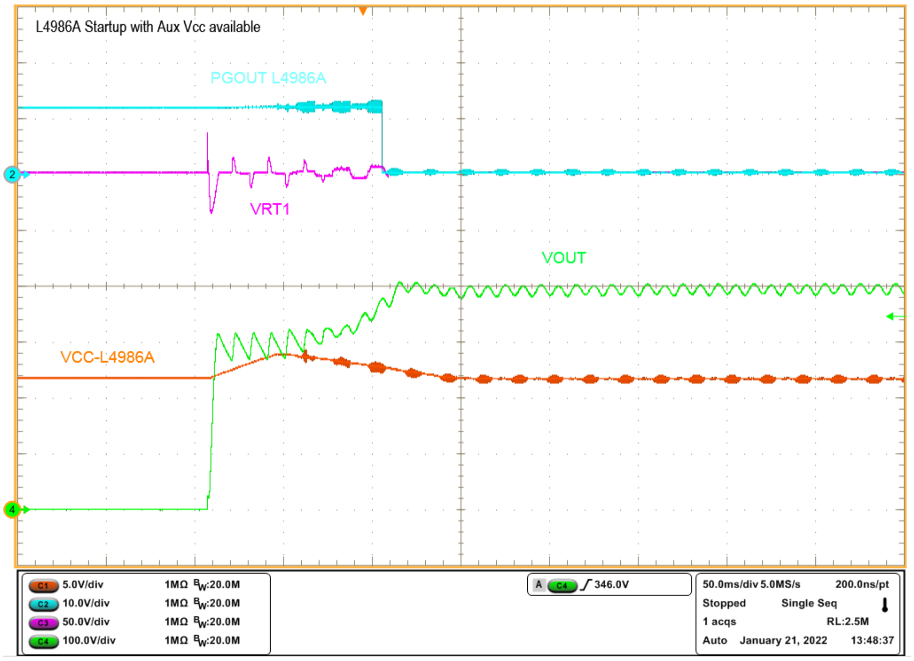
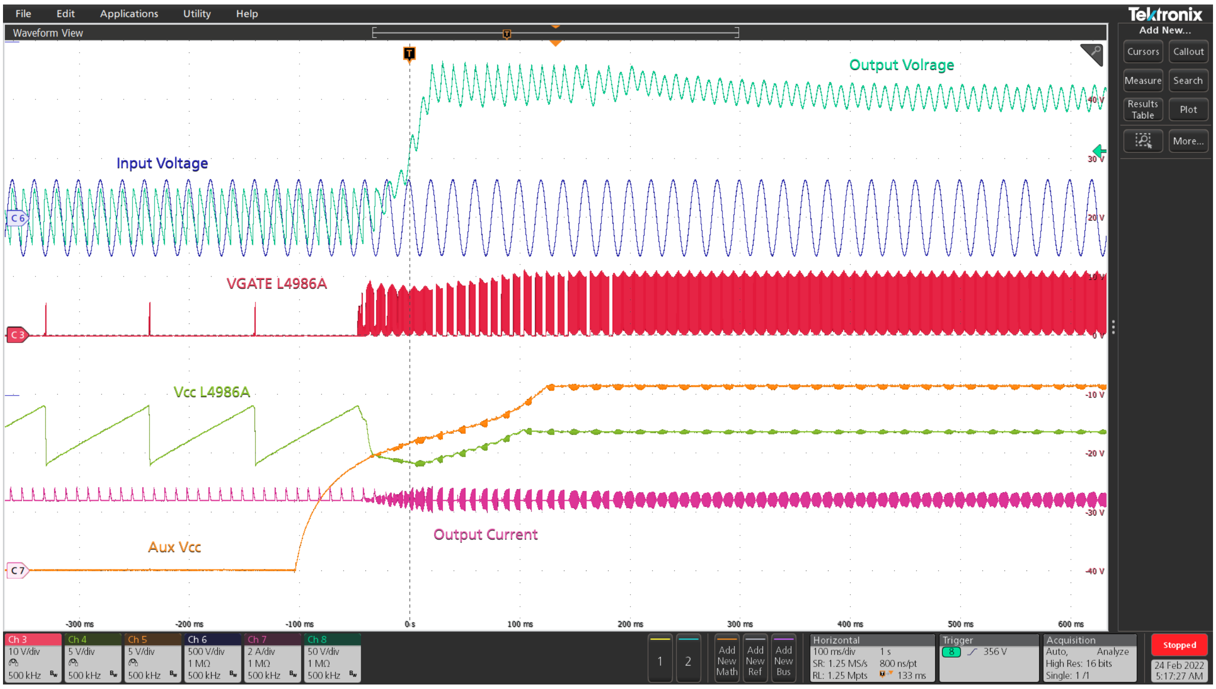


Figure 25 shows the Vcc voltage applied after AC mains. The L4986A attempts controller turn-on several times before the auxiliary Vcc is sufficient to support L4986A starting operation.

Figure 25. **Startup 230Vin at full load with Vinac + auxiliary Vcc**



3.2 Steady state waveforms

The L4986A needs to sense the current of all the switching, during on and off times. The sensing resistors are therefore connected on the return path of both boost sections, and the current sensing signal connected to the Vcs via an RC filter is consequently a negative voltage. Figure 26 and Figure 27 show the detail of Vcs shape at mains frequency and detail at switching frequency. The same figures show waveforms captured at both nominal AC mains voltages and full load conditions.

Figure 26. **Steady state Vcs 115Vin full load**

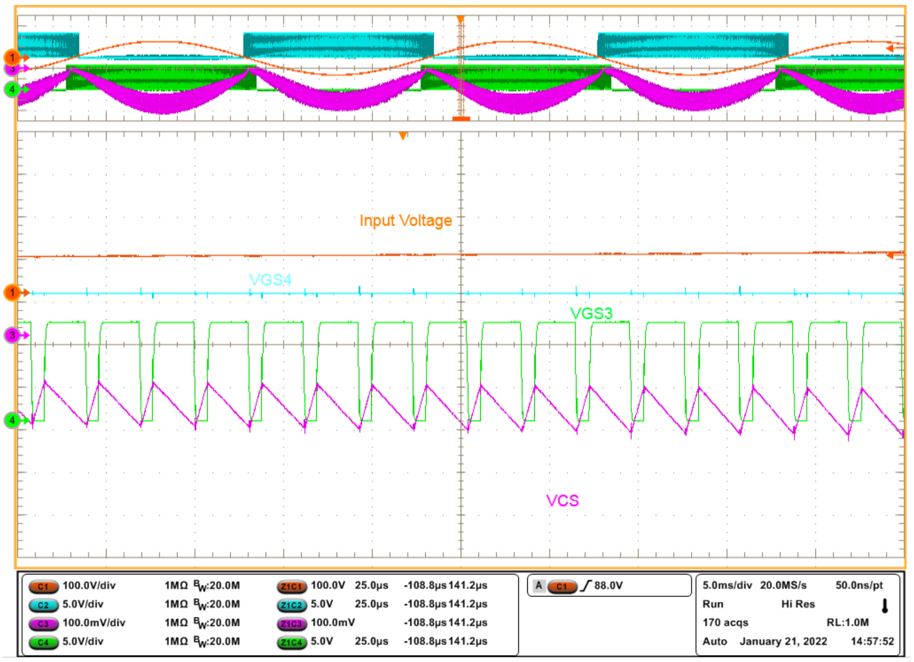
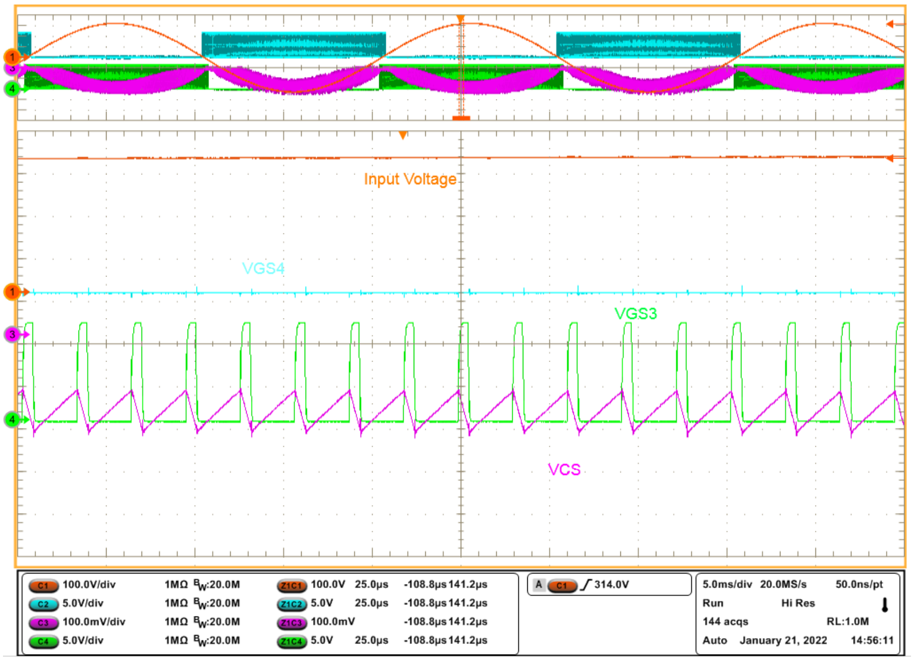


Figure 27. **Steady state Vcs 230Vin full load**



3.3 Steady state waveforms: boost inductance current

Figure 28 shows the current flowing in L3 and L4 (boost inductors).

Figure 28. **Steady state IL3 and IL4 90Vin full load**

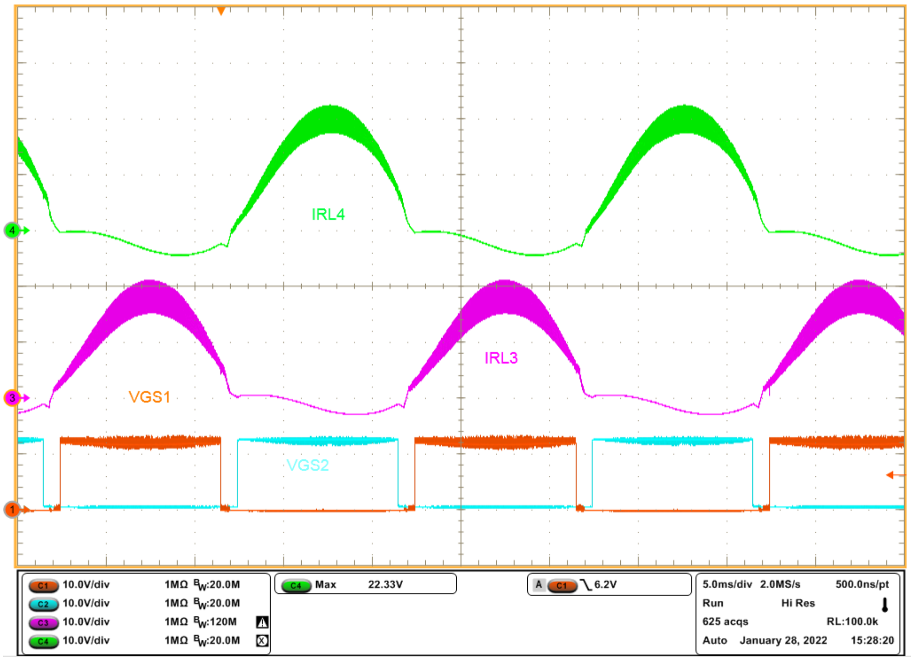


Figure 29 and Figure 30 detail the IRL3 and IRL4 behaviors and the captured VGS3 and VGS4 signals that drive the boosted Q3 and Q4 MOSFETs.

Figure 29. **Steady state 90Vin full load IRL3 detail**

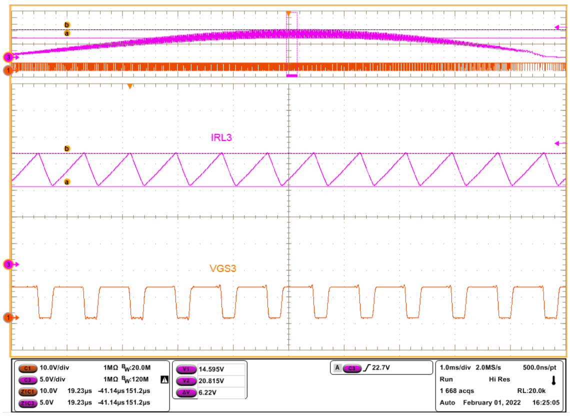
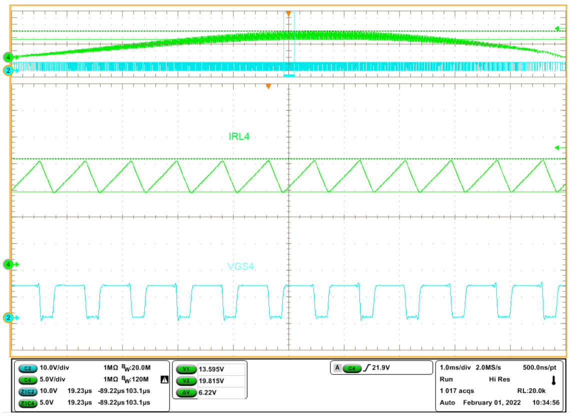


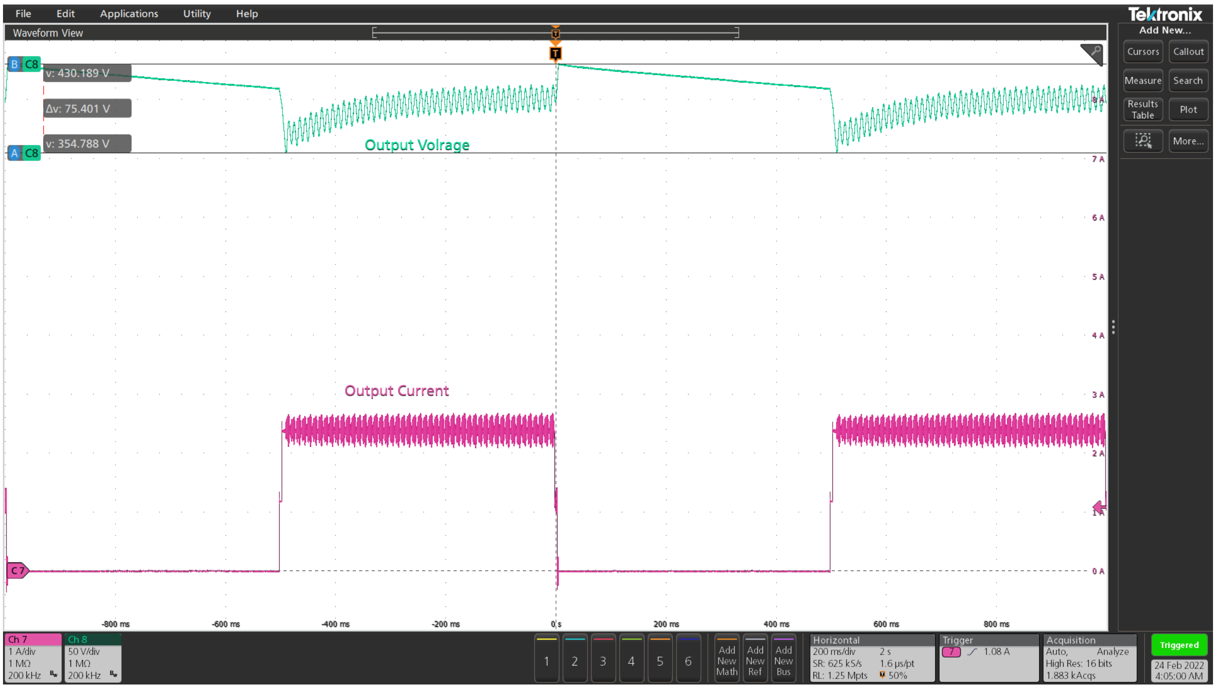
Figure 30. **Steady state 90Vin full load IRL4 detail**



3.4 Dynamic load transient

We tested the EVL4986A-1KWBL for output voltage variation in case of load transients. Figure 31 shows that despite the significant load step, the voltage variation is limited and the response is clean and monotonic thanks to the regulation loop margin phase.

Figure 31. **Load step no load to full load at 230Vac**



3.5 Line transition at full load

We tested the EVL4986A-1KWBL with input mains voltage transitions during operation at low mains and high mains, in both directions, during full load operation. The results demonstrate very limited output voltage variation.

Figure 32. AC line transient 90V to 140V to 90Vac at full load

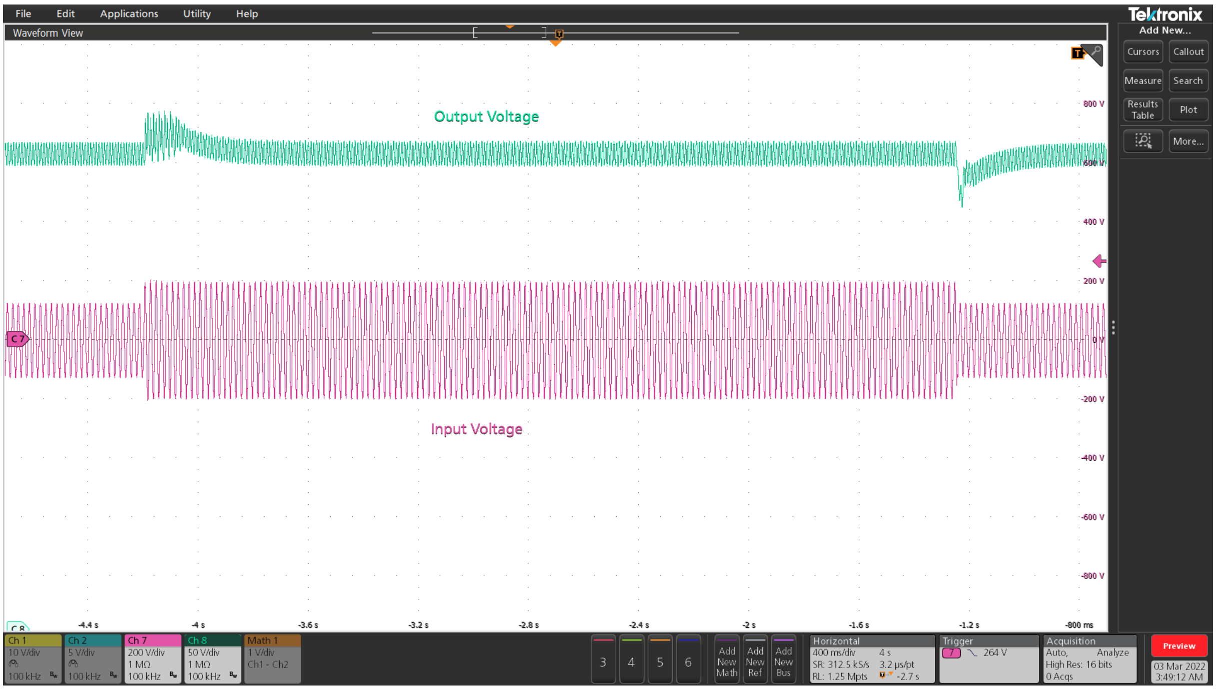
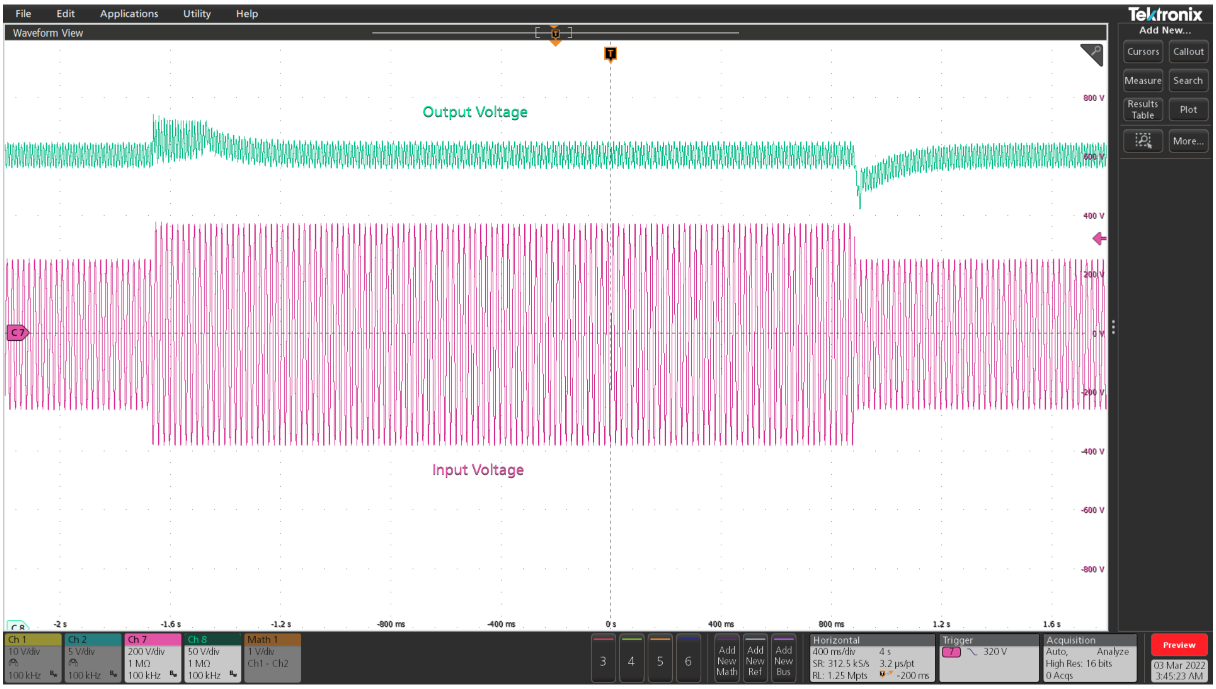


Figure 33. AC line transient 180V to 265V to 180Vac at full load



4 Thermal map

A thermal mapping with an IR camera was performed to assess design reliability. The following figure shows the thermal maps of the PTH component side of the EVL4986A-1KWBL after 2 hours operation at 90Vac–1kW. The temperature measurements of the power components are provided in the table. The ambient temperature was around 20 °C.

Figure 34. Thermal map 90Vac full load

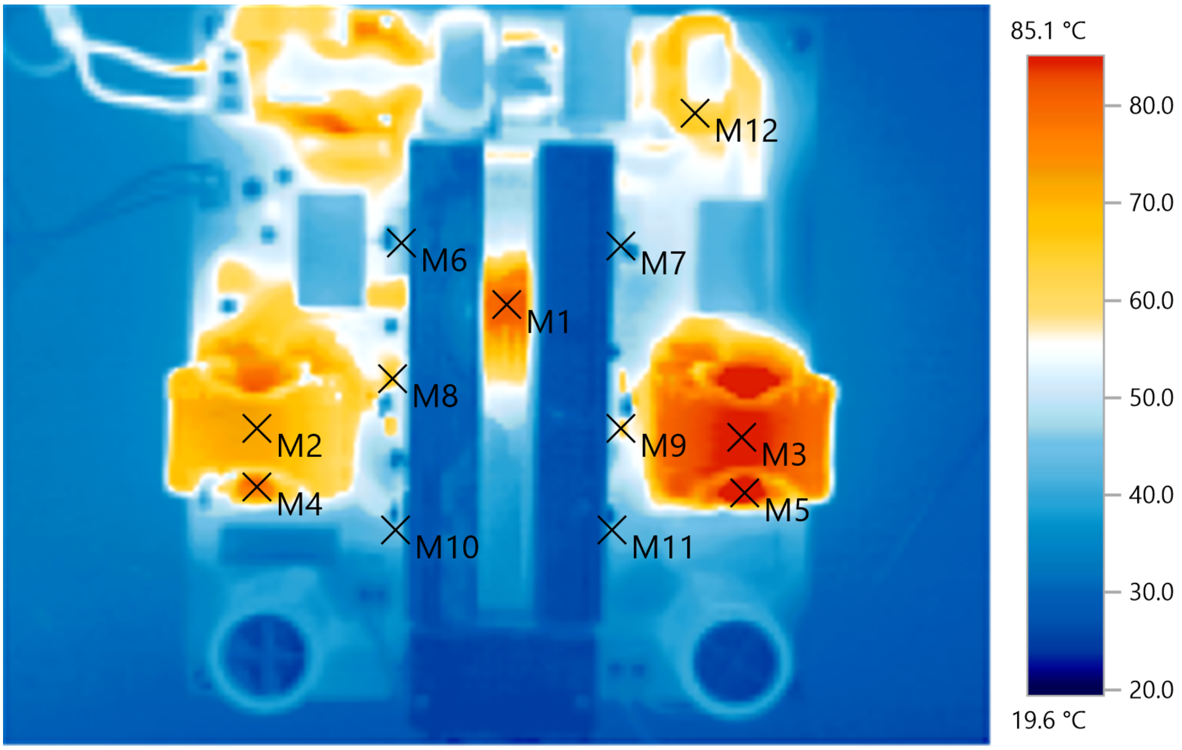


Table 4. EVL4986A-1KWBL 90Vin FL

Point	Sch. Ref.	Description	T [°C] @90Vac/1KW	T [°C] @115Vac/1KW	T [°C] @230Vac/1KW
M1	R23, R24, R65 bottom	Rsense	81.3	61.2	36.7
M2	L4	Boost Inductance Case	72.1	51.1	44.5
M3	L3	Boost Inductance Case	80.1	60.1	50.4
M4	L4	Boost Inductance Wire	78.2	51.3	42.9
M5	L3	Boost Inductance Wire	86.9	60.2	49.9
M6	Q2	Freewheeling MOSFET	46.6	38.1	30.8
M7	Q1	Freewheeling MOSFET	41.5	35.7	29.9
M8	Q4	Boost MOSFET	63.6	45.3	34.5
M9	Q3	Boost MOSFET	62.7	39.6	30.5
M10	D7	Boost Rectifier	43.8	38.1	30.9
M11	D6	Boost Rectifier	42.6	37.0	31,6
M12	L2	common mode choke	62.8	43.0	30.9

5 PCB layout

The layout of any converter is a very important phase in the design process. Here below the PCB layout and PCB tracks:

Figure 35. EVL4986A-1KWBL PCB layout–top side

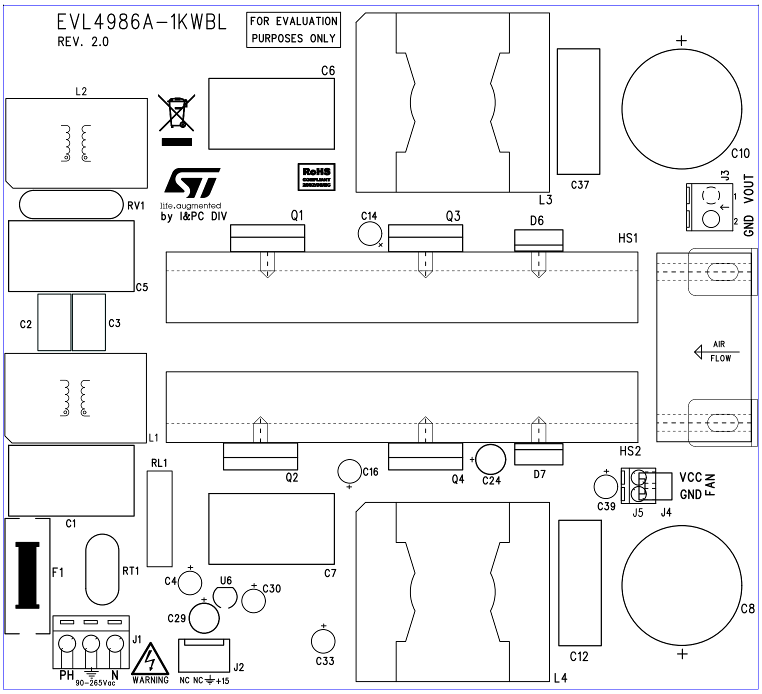


Figure 36. EVL4986A-1KWBL PCB layout–bottom side

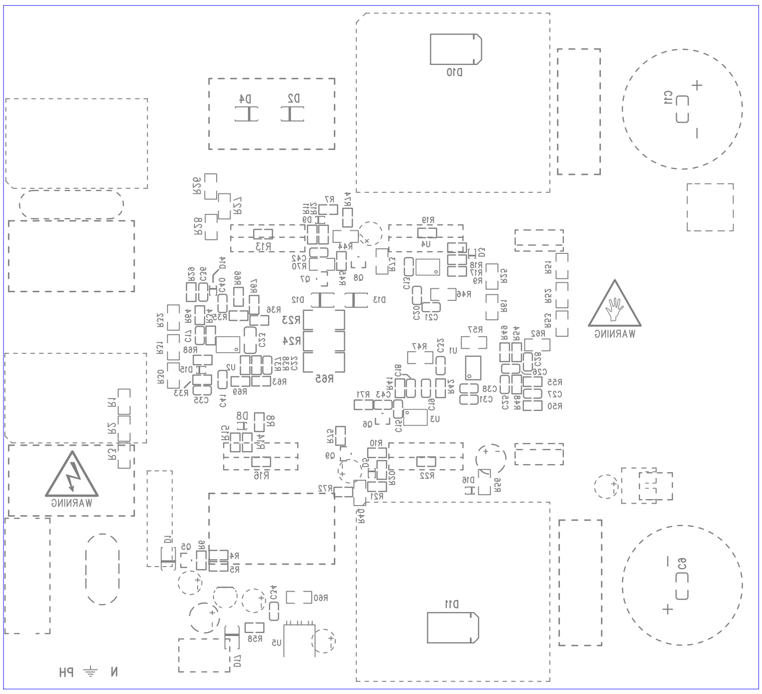


Figure 37. EVL4986A-1KWBL PCB tracks–top side

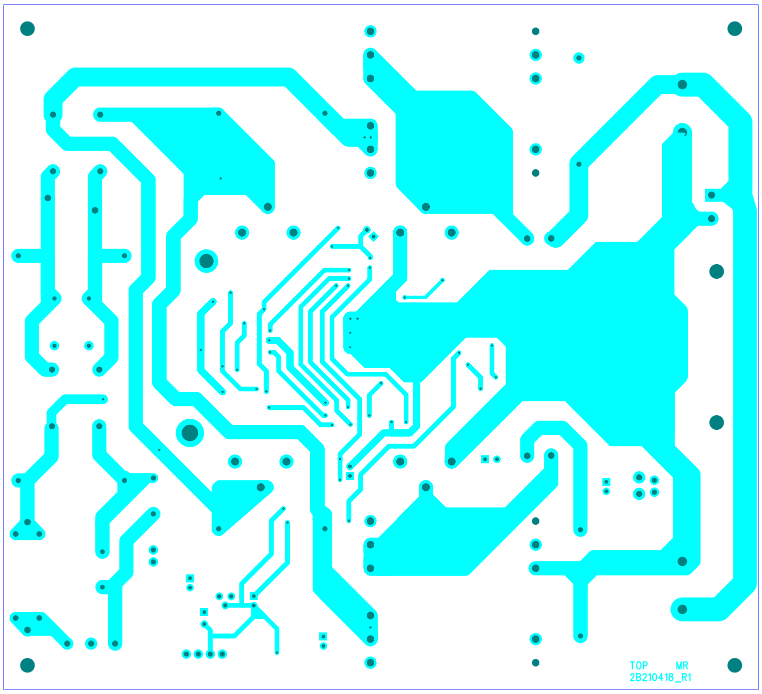
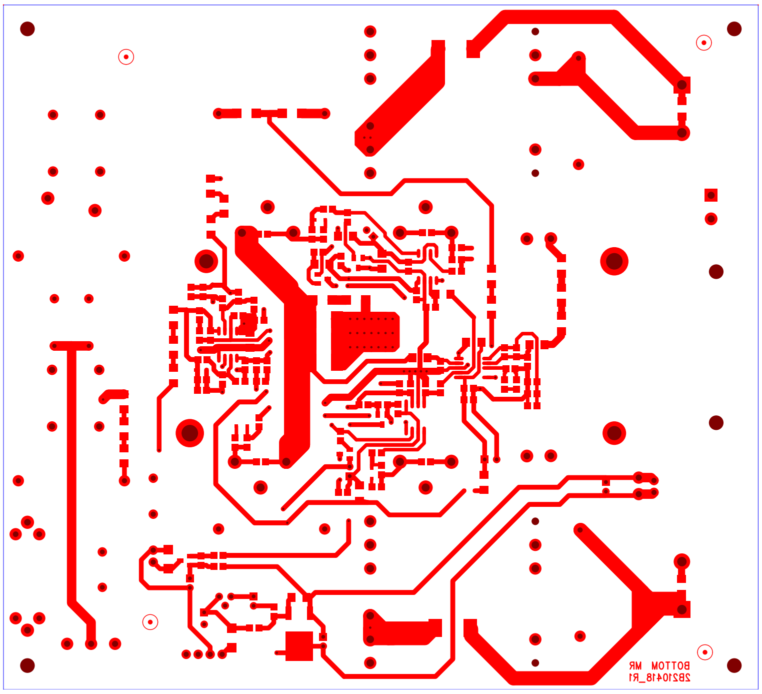


Figure 38. EVL4986A-1KWBL PCB tracks–bottom side



6 Conducted emission pre-compliance test

The following figures show the peak measurement of the conducted noise at full load and nominal mains voltages. The limits shown in the diagrams relate to EN55022 Class-B, the most common norm for domestic equipment using a two-wire mains connection.

As shown, the measured values are well within the limits in all test conditions. All EMI measurements were performed with average filtering.

Figure 39. CE 115 Vac - 60Hz - full load

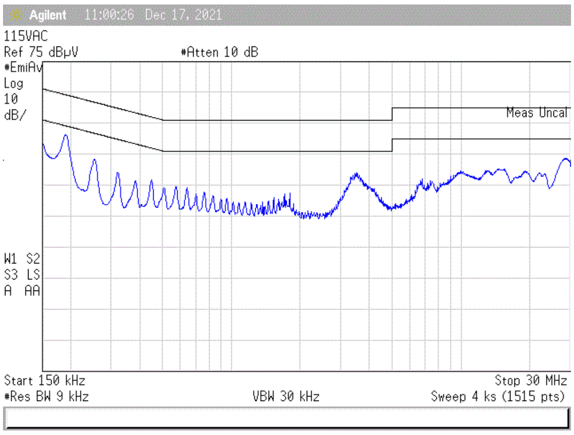
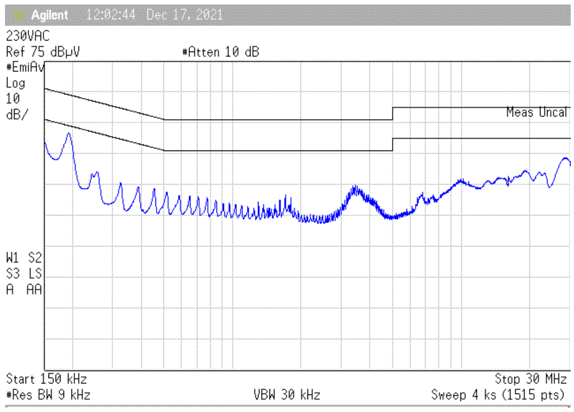


Figure 40. CE 230 Vac - 50Hz – full load



7 Bill of material

Table 5. EVL4986A-1KWBL BOM

Reference	Value	Description	PCB Footprint	Supplier
C2	2n2-Y1	DE1E3KX222MN4AP01F	CAPP-12X7-P10	MURATA
C3	2n2-Y1	DE1E3KX222MN4AP01F	CAPP-12X7-P10	MURATA
C4	10µF	Elcap	CE5X11_P2	Panasonic
C5	2.2µF-X2	WE 890324026034	CP26.5X15_P22.5	Wurth Elektronik
C6	2.2µF-X2	WE 890324026034	CP26.5X15_P22.5	Wurth Elektronik
C7	2.2µF-X2	WE 890324026034	CP26.5X15_P22.5	Wurth Elektronik
C8	220µF	Radial Electrolytic Cap. SNAP-IN	CE25_SNAP-IN	Nichicon
C9	1000pF	Ceramic Capacitor	1206-CAP	MURATA
C10	220uF	Radial Electrolytic Cap. SNAP-IN	CE25_SNAP-IN	Nichicon
C11	1000pF	Ceramic Capacitor	1206-CAP	MURATA
C12	470nF	890303426008CS	CP26.5X9_P22.5	Wurth Elektronik
C13	2.2µF	Capacitor	0805-CAP	Several
C14	10µF	Elcap	CE5X11_P2	Panasonic
C15	2.2µF	Capacitor	0805-CAP	Several
C16	10µF	Elcap	CE5X11_P2	Panasonic
C17	100pF	Capacitor	0805-CAP	Several
C18	560pF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C20	560pF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C22	100pF	Capacitor	0805-CAP	Several
C23	100nF	Capacitor	1206-CAP	KEMET
C24	100µF	Elcap	CE06	Panasonic
C25	2.2µF	MLCC - 25V - X7R - 10%	0805-CAP	Several
C26	220nF	MLCC - 25V - X7R - 10%	0805-CAP	Samsung
C28	1nF	Capacitor	0805-CAP	KEMET
C29	100µF	Elcap	CE06	Panasonic
C30	22µF	Elcap	CE5X11_P2	Panasonic
C31	2.2µF	Capacitor	0805-CAP	Several
C32	470pF	Ceramic Capacitor	0805-CAP	Several
C33	47µF	Elcap	CE5X11_P2	Panasonic
C34	220nF	Capacitor	0805-CAP	Several
C35	1nF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C36	1nF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C37	470nF	890303426008CS	CP26.5X9_P22.5	Wurth Elektronik
C40	1nF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C41	1nF	SMD Multilayer Ceramic Cap.	0805-CAP	Several
C42	100pF	SMD Multilayer Ceramic Cap.	0805-CAP	Walsin
C43	100pF	SMD Multilayer Ceramic Cap.	0805-CAP	Walsin
D1	STPS1L40A	Schottky Diode	SMA	STMicroelectronics

Reference	Value	Description	PCB Footprint	Supplier
D2	GF1M	GENERAL PURPOSE RECTIFIER, SMT	SMA	Vishay
D4	GF1M	GENERAL PURPOSE RECTIFIER, SMT	SMA	Vishay
D6	STPSC12065	Diode Schottky silicon carbide	TO220_V_D	STMicroelectronics
D7	STPSC12065	Diode Schottky silicon carbide	TO220_V_D	STMicroelectronics
D10	S3M	Diode	SMC	Vishay
D11	S3M	Diode	SMC	Vishay
D12	S1M	Diode	SMA	Vishay
D13	S1M	Diode	SMA	Vishay
D14	1N4148WS	Diode	SOD-323	Several
D15	1N4148WS	Diode	SOD-323	Several
D16	BAT48JFILM	Diode	SOD-323	STMicroelectronics
D17	STPS1L40A	Schottky Diode	SMA	STMicroelectronics
F1	FUSE 15A	FUSE 250V - 15A	FUSE5X20	LITTLEFUSE
HS1	P174	Heatsink A	DISS_2B-MEC-0203	ELLEDIESSE
HS2	P174	Heatsink B	DISS_2B-MEC-0202	ELLEDIESSE
J1	MKDS 3/ 3-5,08	PCB TERM. BLOCK, SCREW CONN., PITCH 5.08mm 3W.	MORS3V1P5.08_11.2MM	PHOENIX CONTACT
J2	MOLEX_4P_2,54	Molex Male Connector 2,54mm pitch	CONN_MOLEX_6410-04	PHOENIX CONTACT
J3	MKDS 1,5/ 2-5,08	PCB TERM. BLOCK, SCREW CONN., PITCH 5.0mm 3W.	MKDS1.5/2	PHOENIX CONTACT
J5	FAN-SCREW-CONN.	Screw connecting terminal, single row, 3.5mm pitch, Green	MKDS1/2-3.5	Molex
L1	7448041502 2x2mH	Inductor Common Mode	WURTH-7448041502	Wurth Elektronik
L2	7448041502 2x2mH	Inductor Common Mode	WURTH-7448041502	Wurth Elektronik
L3	270µH	Inductor	WURTH-750319521	Wurth Elektronik
L4	270µH	Inductor	WURTH-750319521	Wurth Elektronik
Q1	STFW69N65M5	Power Mosfet	TO-3PF_GDS_V_T	STMicroelectronics
Q2	STFW69N65M5	Power Mosfet	TO-3PF_GDS_V_T	STMicroelectronics
Q3	STFW69N65M5	Power Mosfet	TO-3PF_GDS_V_T	STMicroelectronics
Q4	STFW69N65M5	Power Mosfet	TO-3PF_GDS_V_T	STMicroelectronics
Q5	BC807	Transistor	SOT23_BEC_T	Onsemi
Q6	2N7002	Mosfet N channel	SOT23	Several
Q7	2N7002	Mosfet N channel	SOT23	Several
Q8	2N7002	Mosfet N channel	SOT23	Several
Q9	2N7002	Mosfet N channel	SOT23	Several
RL1	SPST-NA	Relay	OMRON-G6DN-1A	Omron
RT1	1R	NTC	VAR_15X7	TDK EPCOS
RV1	VAR 275Vac	Varistor	VAR_21.5X5.8_10.0	TDK EPCOS
R1	1M	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several

Reference	Value	Description	PCB Footprint	Supplier
R2	1M	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R3	1M	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R4	3K3	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R5	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R6	1K0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R7	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R8	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R9	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R10	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R11	33R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	YAGEO
R13	75k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R14	33R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	YAGEO
R16	75k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R17	15R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R19	75k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R20	15R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R22	75k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R23	0R082 2W	SMD Resistor	2512-RES	TE CONNECTIVITY
R24	0R082 2W	SMD Resistor	2512-RES	TE CONNECTIVITY
R25	0R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R26	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R27	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R28	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R29	20k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R30	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R31	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several

Reference	Value	Description	PCB Footprint	Supplier
R32	680k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R33	20k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R34	10M	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R35	3K3	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	YAGEO
R36	1R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R37	3K3	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	YAGEO
R38	10M	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R40	1R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R41	10K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	YAGEO
R42	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R44	1R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R45	10K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	YAGEO
R46	0R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R47	47R	SMD STANDARD FILM RES - 1/4W - 1% - 200ppm/°C	1206-RES	TE CONNECTIVITY
R48	43k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R51	2M2	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R52	2M2	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R53	2M2	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R54	15k8	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R55	25k5	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R56	1R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R57	100k	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R58	0R0	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	0805-RES	Several
R61	0R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R62	0R0	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several

Reference	Value	Description	PCB Footprint	Supplier
R63	1M	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R64	1M	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R65	0R082 2W	SMD Resistor	2512-RES	TE CONNECTIVITY
R66	150K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R67	10M	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R68	150K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R69	10M	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R70	470K	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	1206-RES	Several
R71	470K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R72	100K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	0805-RES	Several
R73	100K	SMD STANDARD FILM RES - 1/4W - 5% - 200ppm/°C	1206-RES	Several
R74	0R0	SMD Resistor	0805-RES	Several
R75	0R0	SMD Resistor	0805-RES	Several
U1	L4986A	Controller	10SSOP	STMicroelectronics
U2	LM293ADT	Op Amp	SO8NB	STMicroelectronics
U3	PM8834	Dual Driver	SO8NB	STMicroelectronics
U4	PM8834	Dual Driver	SO8NB	STMicroelectronics
U5	LF120ABDT	Voltage Regulator	DPAK_IGO_H_VR	STMicroelectronics
U6	L78L12ACZ	Voltage Regulator	TO92_OGI_VR	STMicroelectronics
Z_FAN	FAN	12Vdc 40x40x20mm	FAN_40X20	RS PRO
Z1	5x20	Fuse Holder 5x20		RS Pro
Z2	2B210418_R1	PCB 2L FR4 1.6mm		

8 PFC coil specification

Table 6. Inductor general characteristics

Characteristic	Value
Manufacturer	Wurth Elektronik
Inductor P/N	750319521
Application type	Consumer, home appliances
Transformer type	Open
Coil former	Vertical type, 11 pins
Max. Operating ambient temp.	-40°C to +125°C including temp rise
Mains insulation	N.A.
Unit finishing	Vacuum Varnished

Table 7. Inductor electrical characteristics

Characteristic	Value
Converter topology	Boost, Transition mode
Core type	PQ35/35
Min. Operating frequency	50 KHz
Typical operating freq	65 KHz
Primary inductance	270 µH ±10% @10KHz – 0.1V(1)
Peak primary current	19 Apk
Rms primary current	11.8 Arms

1. *Measured between pins #2,3 & #4,5*

Table 8. Inductor winding characteristics

Pins	Winding	RMS current	DC resistance	Saturation current
1	Primary [1]	11.88 Arms	0.048Ω	19A

Table 9. Inductor mechanical aspects and pin numbering

Characteristic	Value
Maximum height from PCB	39.37 mm
Coil former type	Vertical, 11 pins
Pin distance	See mechanical drawing
Row distance	See mechanical drawing
Pin 9	Remove for insertion polarity key
Ferrite grounding	Grounded by soldered shield fixed pin 10 and soldered to PCB

Figure 41. Inductor electrical diagram

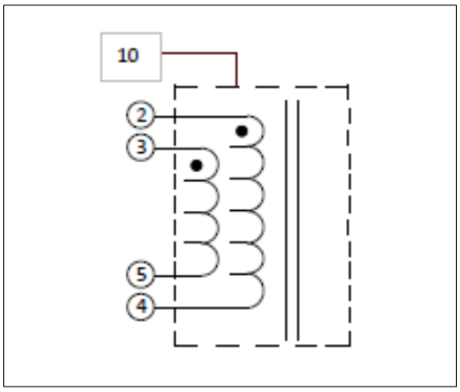


Figure 42. Inductor mechanical drawing

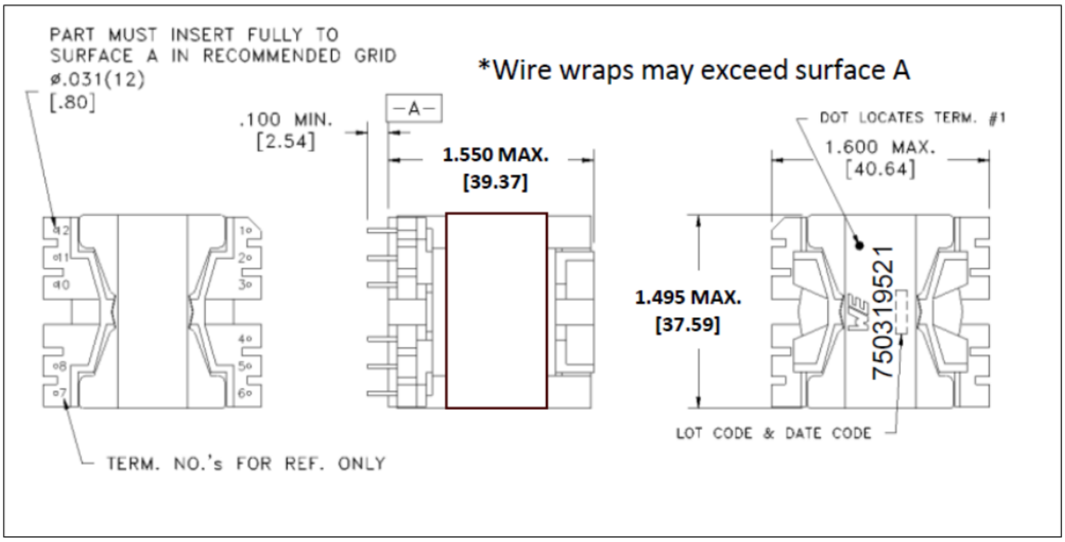
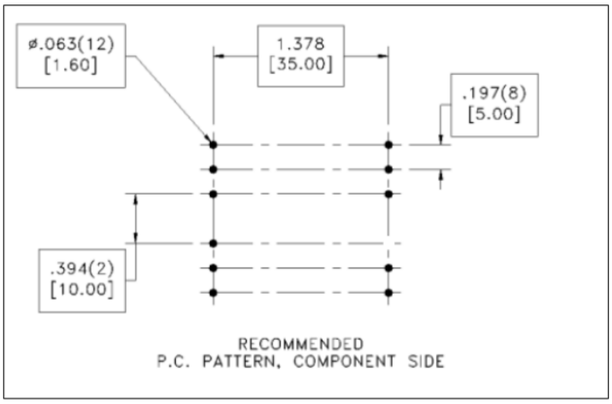


Figure 43. Inductor dot locations



Revision history

Table 10. **Document revision history**

Date	Version	Changes
13-Jun-2022	1	Initial release.

Contents

List of figures

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