AN5824

Application note

12 V - 400 W adapter based on L4985A, L6699 and SRK2001

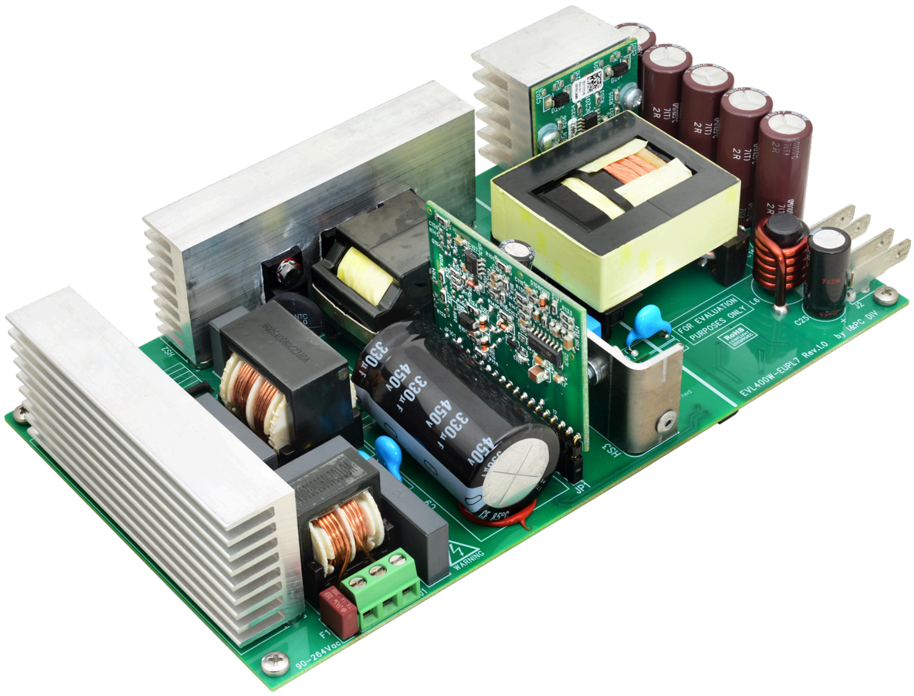
Introduction

This application note describes the main characteristics of the EVL400W-80PL 400W, wide input range, power-factor corrected demonstration board for adapters and ATX power supplies with very low power consumption during light load operation without standby supply.

Table 1. **EVL400W-80PL main components**

Part	Description
L4985A	CCM PFC controller
L6699D	Enhanced high-voltage resonant controller
SRK2001	Synchronous rectifier smart driver for LLC resonant converters

Figure 1. **EVL400W-80PL demonstration board**



1 Specification

- Wide input voltage range: 90Vac to 264 Vac (45 to 65 Hz)
- Output voltage: 12 V ±2% at 33 A continuous operation
- Overall efficiency at full load: above 89% according to ENERGY STAR® 6.1 for computers and compliant with 80Plus PLATINUM level.
- Avg. efficiency: >89%, according to European CoC ver. 5 Tier 2 for external power supplies
- No load mains consumption: <150 mW at 230 Vac, according to European CoC ver. 5 Tier 2 for external power supplies
- Light load efficiency: European CoC ver. 5 Tier 2 requirements for external power supplies and EuP Lot 6 Tier 2 for office equipment (Pin <500 mW for Pout = 250 mW @ 115 Vac and 230 Vac)
- Mains Harmonics: According to EN61000-3-2 Class-D or JEITA-MITI Class-D
- EMI: According to EN55022 Class-B

2 Circuit description

The application architecture is designed for supplying ATX or similar applications required to meet the most stringent efficiency and standby regulations.

The board is divided into a motherboard that mounts the high voltage power devices, a primary control board that mounts the L4985A and L6699 IC controllers, and a secondary control board dedicated to the synchronous rectification of the output current.

The L4985A controller of the front-end PFC pre-regulator is a peak current-mode PFC controller for boost converter with a proprietary multiplier “emulator” which, in addition to the innovative THD optimizers, guarantees very low Total Harmonic Distortion (THD) performance in all operating conditions.

The device operates in quasi-fixed frequency in all operating conditions, thanks to a proprietary off-time modulator, and includes the high voltage start-up block with the circuitry to discharge the X-capacitors of the EMI filter. This level of integration reduces the solution component count for boost PFC pre-regulators and can help applications satisfy the strictest energy saving specifications.

The PFC 400 V DC output voltage supplies the downstream LLC resonant half-bridge converter designed around the L6699, which provides the 12V regulated output voltage that is obtained by modulating the operating frequency.

The main focus of this demonstration board is the light-load efficiency, achieved through the burst mode function of both PFC and LLC controllers and the self-adaptive deadtime of the L6699 that is modulated by the internal logic according to the half-bride node transition times, which allows maximization of the transformer magnetizing inductance and reduction of the primary current at light load operation.

The SRK2001 synchronous rectification controller mounted on the secondary control board ensures very high rectification efficiency and a reduction in the required heatsink size.

2.1 Schematic diagrams

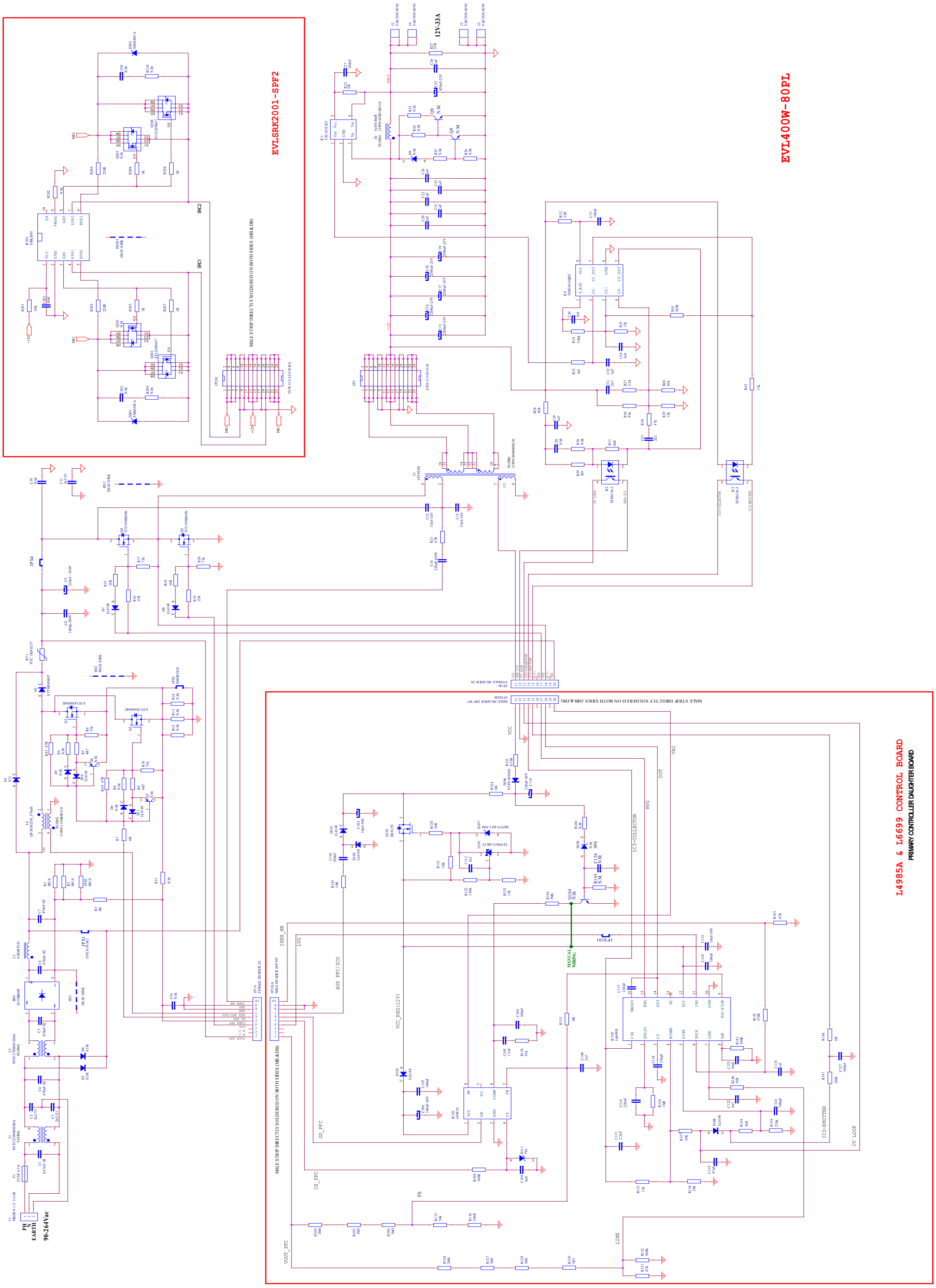


Figure 2. EVL400W-80PL electrical diagram

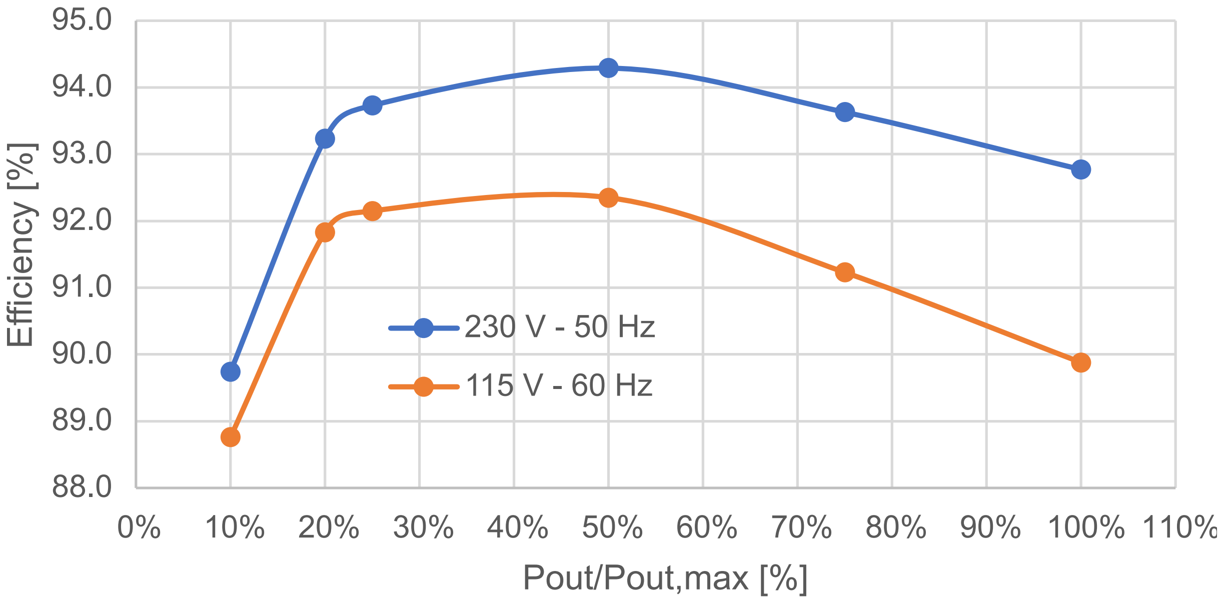
3 Efficiency and no-load consumption measurements

Table 2 shows the overall efficiency measurements at the nominal mains voltages. At 115 Vac, the full load efficiency is 89.88% and at 230Vac it is 92.77%.

Table 2. **Overall efficiency measurements**

Test	230 V-50 Hz					115 V-60 Hz				
	Vout [V]	Iout [A]	Pout [W]	Pin [W]	Eff. [%]	Vout [V]	Iout [A]	Pout [W]	Pin [W]	Eff. [%]
No load	12.17	0.00	0.00	0.1321	-----------	12.16	0.00	0.00	0.109	-----------
100mW Load	12.18	0.0085	0.1034	0.2651	39.01	12.18	0.0085	0.1035	0.289	35.80
250mW Load	12.18	0.0212	0.2583	0.4350	59.38	12.18	0.0212	0.2583	0.473	54.61
10% load eff.	12.16	3.288	40.00	44.57	89.74	12.16	3.290	40.01	45.07	88.76
20% load eff.	12.17	6.573	79.98	85.78	93.23	12.17	6.577	80.03	87.15	91.83
25% load eff.	12.17	8.213	99.97	106.7	93.73	12.17	8.213	99.95	108.5	92.15
50% load eff.	12.21	16.38	200.0	212.1	94.29	12.21	16.38	200.0	216.6	92.35
75% load eff.	12.25	24.48	300.0	320.4	93.63	12.25	24.49	300.0	328.8	91.23
100% load eff.	12.38	32.31	400.0	431.2	92.77	12.38	32.32	400.0	445.1	89.88
Avg. Eff. 25%, 50%, 75%, 100%					93.6					91.4

Figure 3. **EVL400W-80PL efficiency measurements**



At 100mW load the efficiency is 35.80% at 115 Vac and 39.01% at 230 Vac.

No load consumption at 115 V is around 109 mW and around 132 mW at 230 V.

At 250 mW load, the efficiency is 54.61% at 115Vac and 59.38% at 230 Vac.

Also at no load, the board performance is superior for a 400 W power supply: no load consumption at nominal mains voltage is lower than 150 mW.

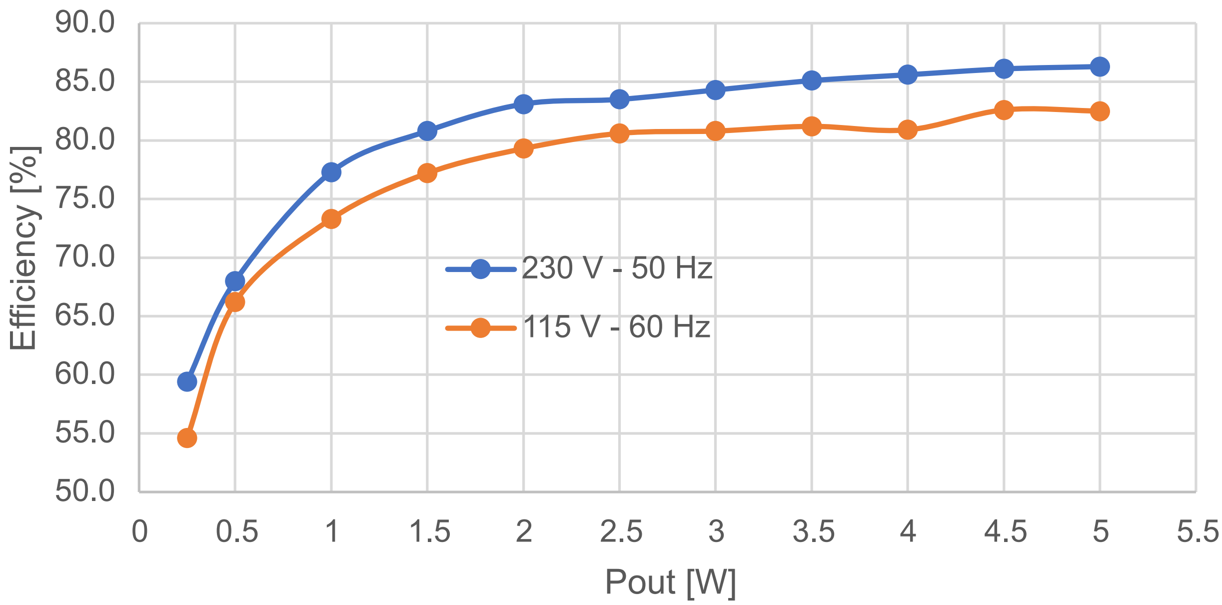
3.1 Light load operation efficiency

Measurements results at light load are reported in Table 3 and plotted in Figure 4. Efficiency is better than 50%, even for 250 mW output power.

Table 3. Light load efficiency

Test	230 V - 50 Hz					115 V - 60 Hz				
	Vout [V]	Iout [mA]	Pout [W]	Pin [W]	Eff. [%]	Vout [V]	Iout [mA]	Pout [W]	Pin [W]	Eff. [%]
0.25 W	12.18	21.2	0.258	0.435	59.4	12.18	21.2	0.258	0.473	54.6
0.5 W	12.18	41.0	0.499	0.730	68.0	12.18	43.0	0.524	0.791	66.2
1.0 W	12.18	81.0	0.987	1.28	77.3	12.18	81.0	0.987	1.35	73.3
1.5 W	12.19	123	1.50	1.86	80.8	12.18	123	1.50	1.94	77.2
2.0 W	12.18	161	1.96	2.36	83.1	12.18	166	2.02	2.55	79.3
2.5 W	12.18	202	2.46	2.95	83.5	12.18	208	2.53	3.14	80.6
3.0W	12.18	246	3.00	3.56	84.3	12.18	245	2.98	3.69	80.8
3.5 W	12.18	287	3.50	4.11	85.1	12.18	287	3.49	4.30	81.2
4.0 W	12.18	330	4.02	4.69	85.6	12.17	330	4.02	4.96	80.9
4.5 W	12.18	368	4.48	5.20	86.1	12.18	368	4.48	5.42	82.6
5.0 W	12.18	410	4.99	5.79	86.3	12.17	410	4.99	6.05	82.5

Figure 4. Light load efficiency diagram



The following measurements were performed according to the following considerations:

1. As the current flowing through the circuit under measurement is relatively small, the current measurement circuit is connected to the demonstration board side and the voltage measurement input is connected to the AC source side. In this way the current absorbed by the voltage circuit is not considered in the measured consumption amount.
2. During any efficiency measurement, all oscilloscope probes are disconnected from the board.
3. For any load measurement, we apply a warmup time of 20 minutes for each load. Loads were applied by increasing the output power from minimum to maximum.

4. Because of the input current shape during light load condition, the input power measurement may be critical or unreliable using a power meter in the normal way. To overcome this, all light measurements are performed by measuring the active energy consumption of the demo board under test and then calculating the power as the energy divided by the integration time. The integration time was set 108 seconds for no-load, 100 mW and 250 mW and 36 seconds for the other loads as a compromise between reliable measurement and reasonable measurement time. The Yokogawa WT210 Power Meter was used to perform measurements.

3.2 Verification of power supply Ecodesign requirements

The following tables compare the regulation requirements for Ecodesign and the EVL400W-80PL test results.

The design meets all requirements with ample margin.

Table 4. ENERGY STAR® requirements for computers ver. 6.1

ENERGY STAR® requirements for computers ver. 6.1:	Test results		Limits	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz		
Efficiency at 20% load	91.8%	93.2%	>82%	Pass
Efficiency at 50% load	92.3%	94.3%	>85%	
Efficiency at 100% load	89.9%	92.8%	>82%	
Power factor at 100% load	0.99	0.99	>0.9	

Table 5. EuP Lot 6 Tier 2 requirements for household and office equipment

EuP Lot 6 Tier2 requirements:	Test results		Limits	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz		
Avg. Efficiency measured at 25%, 50%, 75%, 100%	91.4%	93.6%	>87%	Pass
Efficiency at 250 mW load	54.6%	59.4%	>50%	
Efficiency at 100 mW load	35.8%	39.0%	>33%	

Table 6. European CoC ver. 5 Tier 2 requirements for External Power Supplies

European CoC ver. 5 Tier-2 requirements for External Power Supplies:	Test results		Limits	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz		
Avg. Efficiency measured at 25%, 50%, 75%, 100%	91.4%	93.6%	>89%	Pass
Efficiency at 10% load	88.8%	89.7%	>79%	
No load input power [W]	0.109 W	0.132 W	<0.15 W	

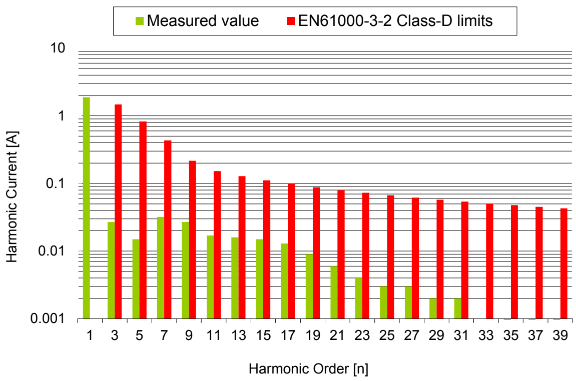
Table 7. 80Plus-PLATINUM level

80Plus-PLATINUM	Test results		Limits internal non redundant at 115Vac	Limits internal redundant at 230Vac	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz			
Efficiency at 20% load	91.8%	93.2%	>90%	>90%	Pass
Efficiency at 50% load	92.4%	94.3%	>92%	>92%	
Efficiency at 100% load	89.9%	92.8%	>89%	>89%	
Power Factor at 50%Load	0.99	0.99	>0.90	>0.90	

3.3 Harmonics content measurement

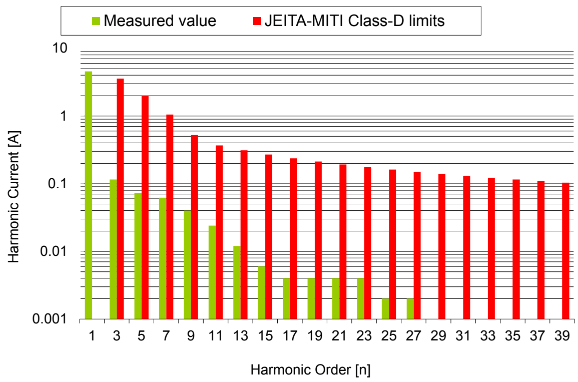
The board was tested according to the European Standard EN61000-3-2 Class-D and Japanese standard JEITA-MITI Class-D, at both the nominal input voltage mains. Figure 5 and Figure 6 show that the circuit is able to reduce the harmonics well below the limits of both regulations. The total harmonic distortion and power factor measurements are also given. The values in all conditions clearly demonstrate the correct functionality of the PFC.

Figure 5. European Standard EN61000-3-2 Class D at 230Vac – 50 Hz, full load



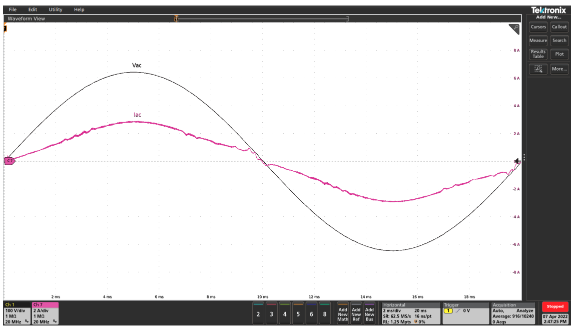
THD = 3.32% – PF = 0.9985

Figure 6. Japanese standard JEITA-MITI at 100Vac – 50 Hz, full load



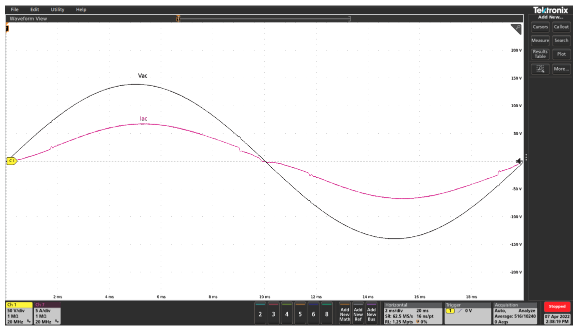
THD = 3.43% – PF = 0.9972

Figure 7. Main voltage and current waveforms at 230 V – 50 Hz, full load



CH1: Vac, CH7: Iac

Figure 8. Main voltage and current at waveforms 100 V – 50 Hz, full load



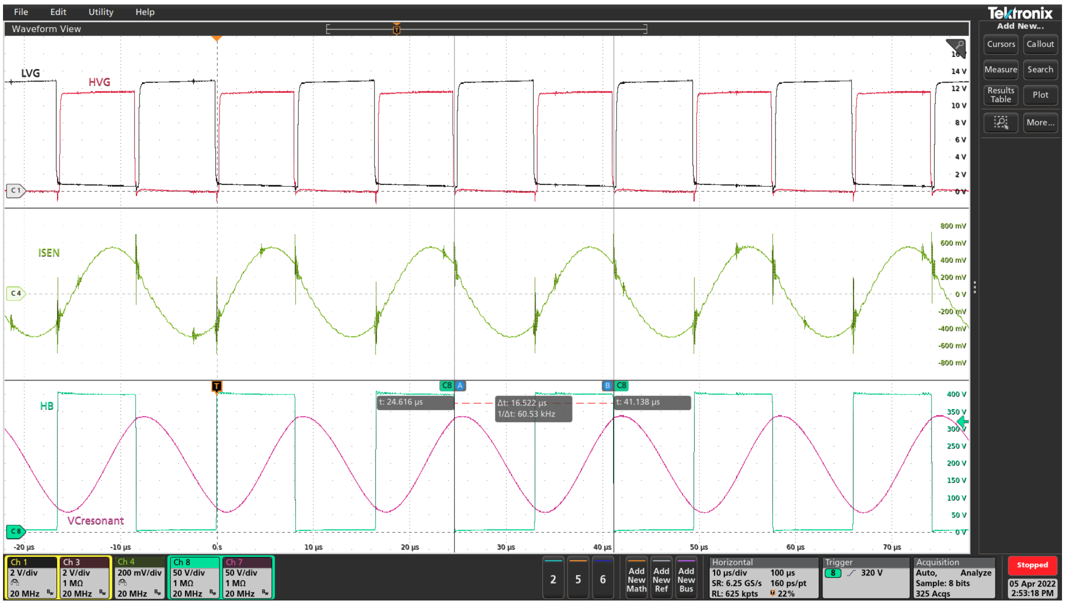
CH1: Vac, CH7: Iac

4 Functional check

4.1 Resonant stage waveforms

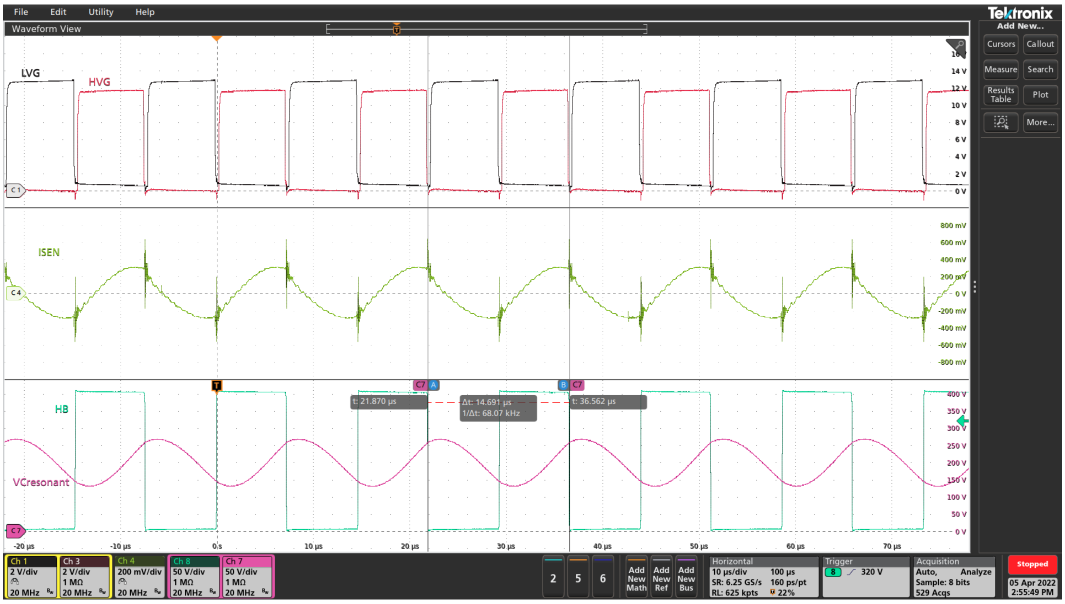
Figure 9 and Figure 10 show the main waveforms of the resonant tank during steady state operation at full load and half load, respectively. The switching frequency in nominal conditions (Vin = 400V and Iout = 33A) is about 60 kHz: here, the converter operates slightly above the resonance frequency.

Figure 9. 115 Vac – 60 Hz, full load, voltage on the resonant cap



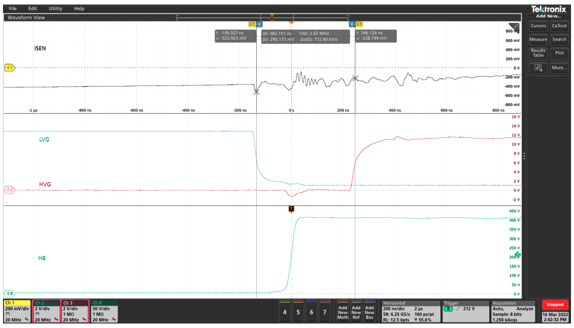
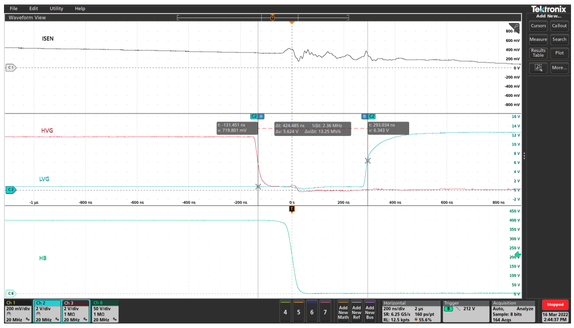
CH1: LVG, CH3: HVG, CH4: ISEN, CH7: VCresonant, CH8: HB

Figure 10. 115 Vac – 60 Hz, half load, voltage on the resonant cap



CH1: LVG, CH3: HVG, CH4: ISEN, CH7: VCresonant, CH8: HB

Figure 11 and Figure 12 shows the waveforms during full load operation. It is possible to note the measurement of the edges and the relevant deadtime.

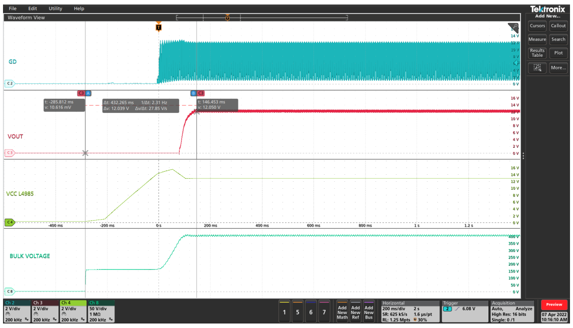
Figure 11. HB transition at full load – rising edge	Figure 12. HB transition at full load – falling edge
	
CH1: ISEN, CH2: LVG, CH3: HVG, CH8: HB	CH1: ISEN, CH2: LVG, CH3: HVG, CH8: HB

4.2 Startup

The waveforms relevant to the board startup at 115 Vac and full load were captured with focus on the PFC startup in and on the LLC startup in.

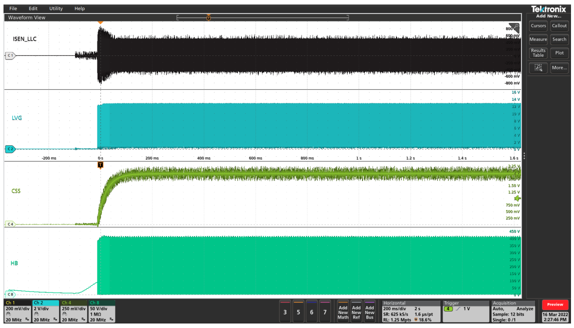
Note: The output voltage reaches the nominal value approximately 430 ms after plug-in.

Figure 13. PFC startup at 115 Vac – full load



CH2: GD L4985A, CH3: VOUT(+12V), CH4: VCC L4985A, CH8: BULK VOLTAGE

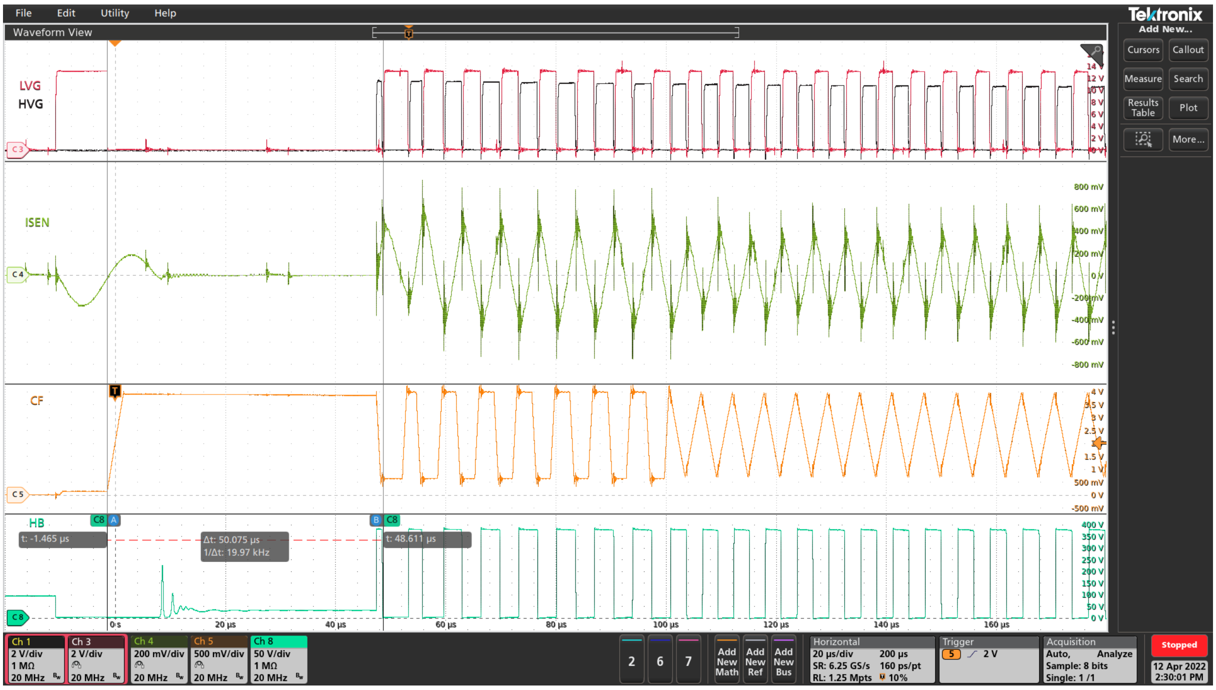
Figure 14. LLC startup at 115 Vac – full load



CH1: ISEN, CH2: LVG, CH4: CSS, CH8: HB

In Figure 15, the device goes to normal operation after approximately 50 µs from the first switching cycle to avoid hard switching.

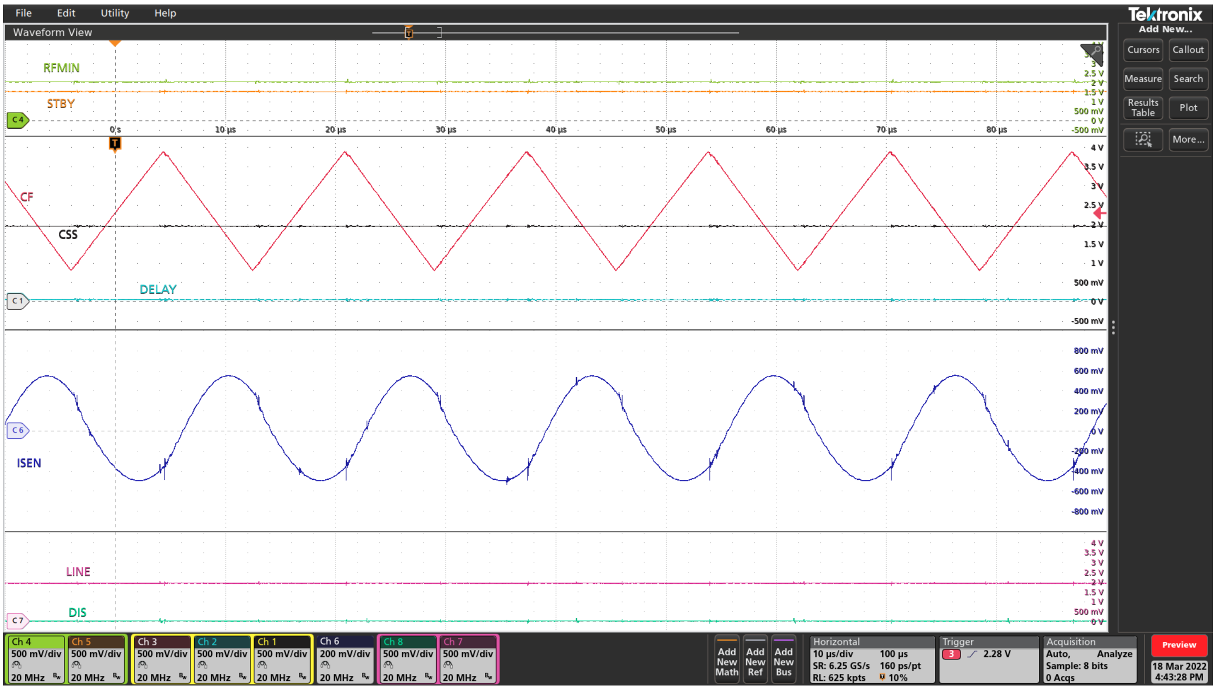
Figure 15. Safe-start at 115Vac, 60Hz – full load, Fsmooth start = 175 kHz



CH1: HVG, CH3: LVG, CH4: ISEN, CH5: CF, CH8: HB

In Figure 16, the main L6699 pin signal was measured during normal operation at full load.

Figure 16. L6699 pin signals



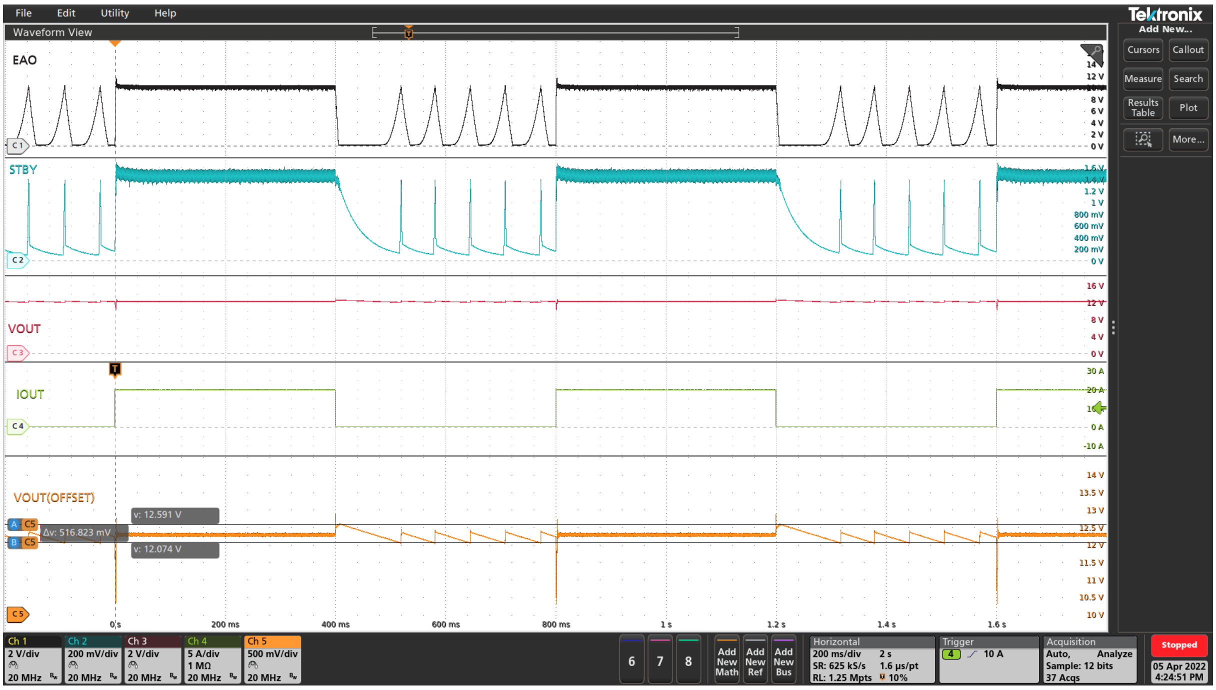
CH1: CSS, CH2: DELAY (it is at GND), CH3: CF, CH4: RFMIN, CH5: STBY, CH6: ISEN, CH7: LINE, CH8: DIS (it is at GND)

- ISEN pin (#6) matches the instantaneous current flowing in the transformer primary side. The L6699 integrates the anti-capacitive mode protection on pin #6, therefore it needs to sense the instantaneous value of the current to check the correct phase between the voltage and current in the resonant tank.
- LINE pin (#7) divider is dimensioned to start up the L6699 once the PFC output voltage has reached the rated value, to have correct converter sequencing, with PFC starting first and LLC starting later in order to optimize the design of the LLC converter and prevent capacitive mode operation that may occur because of operation at too low input voltage.
- DELAY pin (#2) is zero during normal operation because it works during overcurrent protection operation.
- DIS pin (#8) is used for open loop protection and its voltage is also at ground level.
- RFmin pin (#4) is a 2 V (typ.) reference voltage of the oscillator; the switching frequency is proportional to the current flowing out from the pin.
- CSS pin (#1) voltage is the same value as pin #4 because it is connected to the latter via a resistor (R133), determining the soft-start frequency. A capacitor (C115) is also connected between the CSS pin and ground, to set the soft-start time. At the beginning of L6699 operation the voltage on the CSS pin is at ground level because C115 is discharged, then the CSS pin (#1) voltage increases according to the time constant till the RFmin voltage level is reached.
- STBY pin (#5) senses the optocoupler voltage; once the voltage decreases below 1.26 V, both gate drivers stop switching and the circuit works in burst mode.
- CF pin (#3) is the controller oscillator; its ramp speed is proportional to the current flowing out from the RFmin pin (#4). The CF signal must be clean and undistorted to obtain correct symmetry by the half bridge current, and therefore care must be taken in the layout of the PCB.

4.3 Dynamic load response

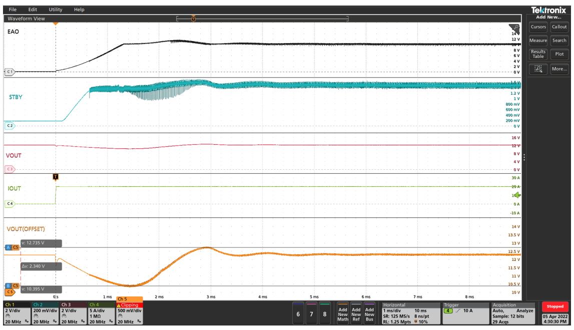
EVL400W-80PL was connected to a dynamic load to measure the output voltage variations. The load changed every 400 ms from open load to 20 A and vice versa, at 800 mA/µs. The response of output voltage is shown with a ripple of about 500 mV pkpk at 115 Vac-60 Hz.

Figure 17. Dynamic load response – open load to 20 A and vice versa, 115 Vac-60 Hz



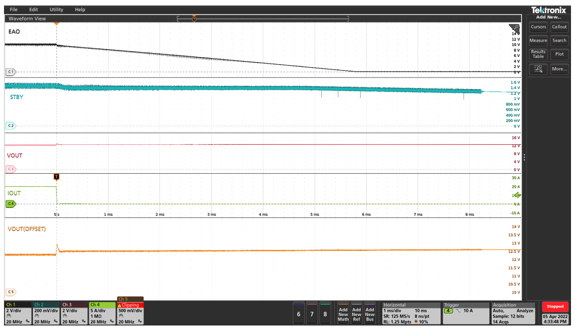
CH1: EAO, CH2: STBY, CH3: VOUT, CH4: IOUT, CH5: VOUT(OFFSET)

Figure 18. Detail-open load to 20A load



CH1: EAO, CH2: STBY, CH3: VOUT, CH4: IOUT, CH5: VOUT(OFFSET)

Figure 19. Detail-20A load to open load

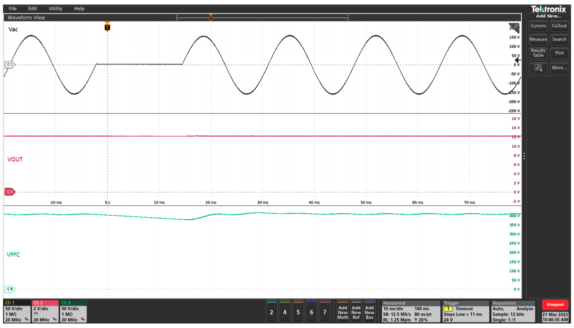


CH1: STBY, CH2: EAO, CH3: VOUT, CH4: IOUT, CH5: VOUT(OFFSET)

4.4 Mains dips at half load

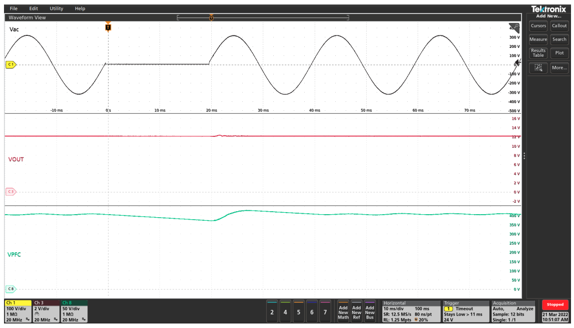
The EVL400W-80PL was tested against a 0% mains dip (single line cycle, according to IEC61000-4-11) at both nominal voltages while operating at half load (16.5 A). The output voltages of the board and of the PFC are shown.

Figure 20. Single cycle 100% mains dip at 115 Vac-60 Hz – half load (16.5 A)



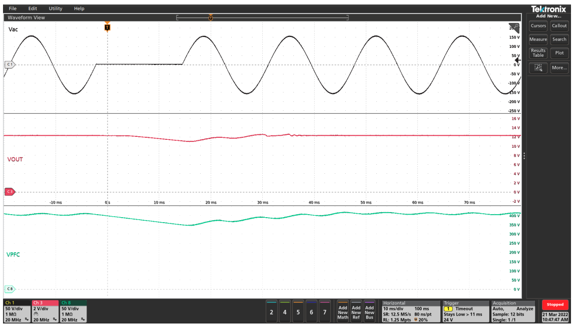
CH1: Vac, CH3: VOUT, CH8: VPFC

Figure 21. Single cycle 100% mains dip at 230 Vac-50 Hz – half load (16.5 A)



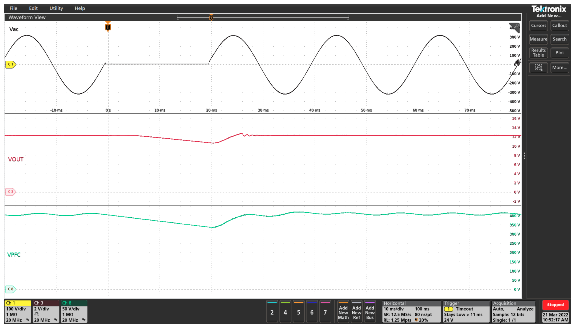
CH1: Vac, CH3: VOUT, CH8: VPFC

Figure 22. Single cycle 100 % mains dip at 115 Vac-60 Hz – full load (33 A)



CH1: GD, CH2: FB = PFC_STOP

Figure 23. Single cycle 100 % mains dip at 230 Vac-50 Hz – full load (33 A)



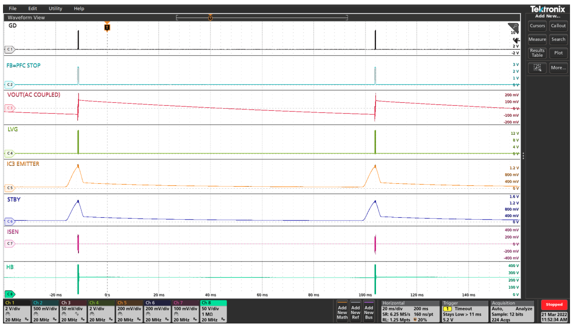
CH1: GD, CH2: FB = PFC_STOP

4.5 Burst mode operation at light load

Figure 24 shows some burst mode pulses captured during 250 mW load operation. The burst pulses are very narrow and their period is quite long, resulting in a very low equivalent switching frequency and therefore high efficiency. The resulting output voltage ripple during burst mode operation is about 200 mV peak-to-peak.

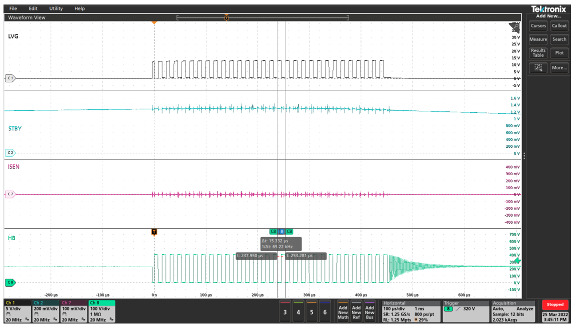
Figure 25 shows the detail of the burst. The first initial pulse is shorter than the following ones to avoid the typical high current peak at half-bridge operation restart due to the recharging or the resonant capacitor. The operating frequency of the half bridge during burst mode is around 65 kHz.

Figure 24. Pout = 250 mW, burst mode operation



CH1: GD, CH2: FB = PFC_STOP, CH3: VOUT(AC_COUPLED), CH4: LVG, CH5: IC3 EMITTER, CH6: STBY, CH7: ISEN, CH8: HB

Figure 25. Detail of the burst mode pulse



CH1: LVG, CH2: STBY, CH7: ISEN, CH8: HB

Figure 25 shows the detail of the burst. The first initial pulse is shorter than the following ones to avoid the typical high current peak at half-bridge operation restart due to the recharging or the resonant capacitor. The operating frequency of the half bridge during burst mode is around 65 kHz.

4.6 Overcurrent and short-circuit protection

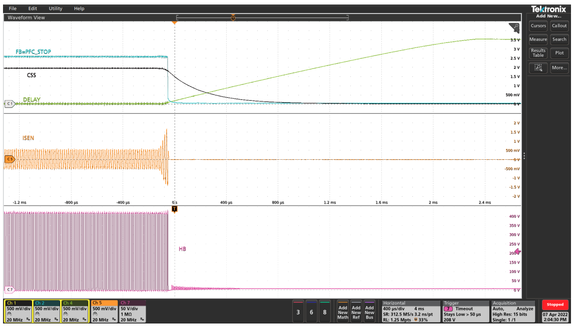
The L6699 is equipped with a current sensing input (pin 6, ISEN) and a dedicated overcurrent management system. In the case of overload, the voltage on the pin surpasses an internal threshold (0.8 V) that triggers a protection sequence. An internal switch is turned on for 5 µs and discharges the soft-start capacitor. This quickly increases the oscillator frequency and thereby limits energy transfer. Under output short-circuit conditions, this operation results in a peak primary current that periodically oscillates below the maximum value allowed by the sense resistor.

The converter runs under this condition for a time set by the capacitor on pin DELAY (pin 2). During this condition, the DELAY capacitor is charged by a 350 µA current for 50 µs from pin DELAY, generated by an internal current generator, and is slowly discharged by the external parallel resistor. If overload persists, the voltage on the pin rises and, when it reaches 2 V, the switch that discharges the soft-start capacitor is continuously turned on, so that the switching frequency is pushed to its maximum value and the 350 µA current source is forced continuously on. As the voltage on the pin exceeds 3.5 V, the IC stops switching and the internal generator is turned off, so that the voltage on the pin decays because of the external resistor. The IC undergoes soft restart when the voltage drops below 0.3 V. In this way, under short-circuit conditions, the converter works intermittently with very low input average power.

This procedure allows the converter to handle overload conditions lasting less than a set amount of time, avoiding IC shutdown in case of short overload or peak power transients. In the case of dead short, however, a second comparator referenced to 1.5 V immediately disables switching and activates a restart procedure.

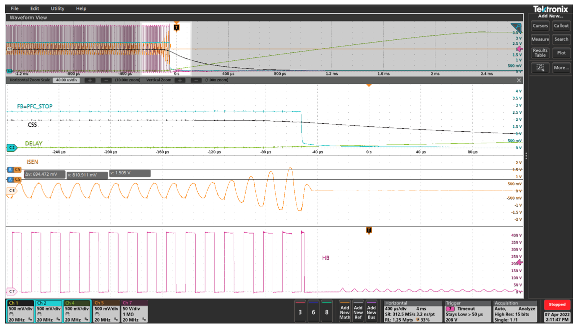
Figure 26 shows a dead short-circuit event. In this case, the overcurrent protection is triggered by the second comparator referenced at 1.5 V, which stops switching by the L6699 and discharging of the soft-start capacitor. At the same time, the capacitor connected to the DELAY pin (#2) begins charging up to 3.5 V (typ.). Once the voltage on the DELAY pin reaches 3.5 V, the L6699 stops charging the delay capacitor and the L6699 operation is resumed once the DELAY pin (#2) voltage decays to 0.3 V (typ.) by the parallel resistor, via a soft-start cycle. Figure 27 shows the peak current detail during short-circuit.

Figure 26. Short-circuit at 115Vac, 60Hz – full load



CH1: CSS, CH2: FB = PFC_STOP, CH4: DELAY, CH5: ISEN, CH7: HB

Figure 27. Zoom of Figure 26

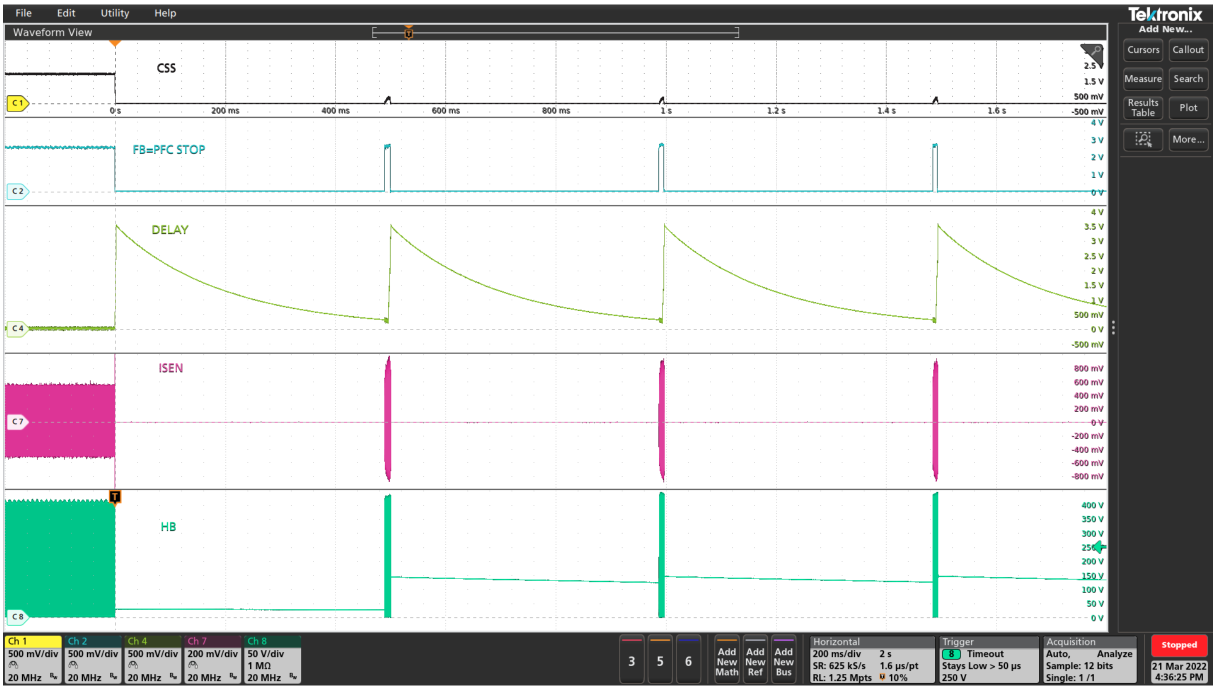


CH1: CSS, CH2: FB = PFC_STOP, CH4: DELAY, CH5: ISEN, CH7: HB

Figure 26 shows a dead short-circuit event. In this case, the overcurrent protection is triggered by the second comparator referenced at 1.5 V, which stops switching by the L6699 and discharging of the soft-start capacitor. At the same time, the capacitor connected to the DELAY pin (#2) begins charging up to 3.5 V (typ.). Once the voltage on the DELAY pin reaches 3.5 V, the L6699 stops charging the delay capacitor and the L6699 operation is resumed once the DELAY pin (#2) voltage decays to 0.3 V (typ.) by the parallel resistor, via a soft-start cycle. Figure 27 shows the peak current detail during short-circuit.

If the short-circuit condition is removed, the converter restarts operation. If the short persists, the converter operation becomes intermittent (hiccup mode) with a narrow operating duty cycle of the converter to prevent overheating of power components, as shown in Figure 28.

Figure 28. Short circuit at 115Vac, 60Hz – full load, hiccup mode



CH1: CSS, CH2: FB = PFC_STOP, CH4: DELAY, CH7: ISEN, CH8: HB

5 Thermal map

In order to check the design reliability, a thermal mapping by means of an IR camera was performed. Below, the thermal measurements of the board, component side, at nominal input voltage are shown. Some pointers have been placed across key components or components showing high temperature. The ambient temperature during both measurements was 23 °C. The thermal mapping was taken with a natural convective cooling of the board.

To maintain lower temperatures, a cooling fan is necessary. With a cooling fan of 7 cm of diameter placed at about 3.5 cm from the edge of the board and with an air flow of about 4 m/s at 15 cm away in central position, the highest temperature can be kept below 60 °C.

Figure 29. **Thermal map at 90 Vac, 60 Hz – full load**

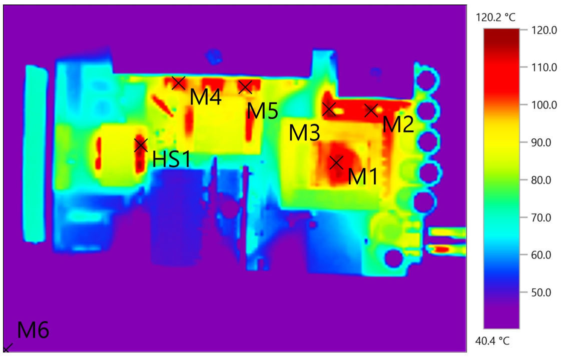


Figure 30. **Thermal map at 230 Vac, 50 Hz – full load**

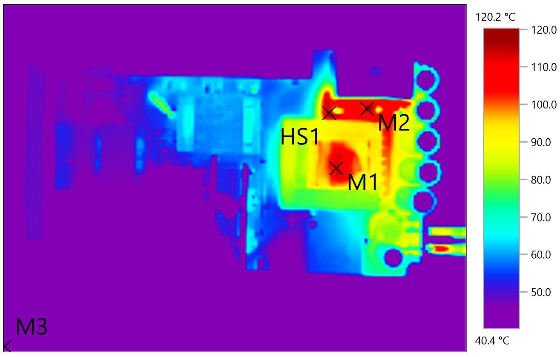


Table 8. **Thermal map reference points at 90 Vac – 60 Hz, full load**

Point	Ref.	Description	Temp. (°C)
M1	T1	Resonant transf. – secondary	114°C
M2	SRK2001	Synchronous rectifier board	116°C
M3	SRK2001	Synchronous rectifier board	114°C
M4	D2	PFC diode	103°C
M5	Q3	PFC MOSFET	105°C
M6		Ambient temperature	23°C
HS1	L2	Common mode choke	122°C

Table 9. **Thermal map reference points at 230 Vac – 50 Hz, full load**

Point	Ref.	Description	Temp. (°C)
M1	T1	Resonant transf. – secondary	113 °C
M2	SRK2001	Synchronous rectifier board	117 °C
M3		Ambient temperature	23 °C
HS1	SRK2001	Synchronous rectifier board	118 °C

6 Conducted emission precompliance test

A precompliance test (testing environment not compliant) on conducted emission was performed. The following figures represent the average measurements of conducted emission at full load and at the nominal mains voltages. The measurements were taken with the ground AC input and the negative pole output of the board grounded and compared with the EN55022-ClassB limits. The converter is fed by AC line through an isolation transformer and the LISN.

Figure 31. **EMI at 115Vac, 60 Hz – full load**

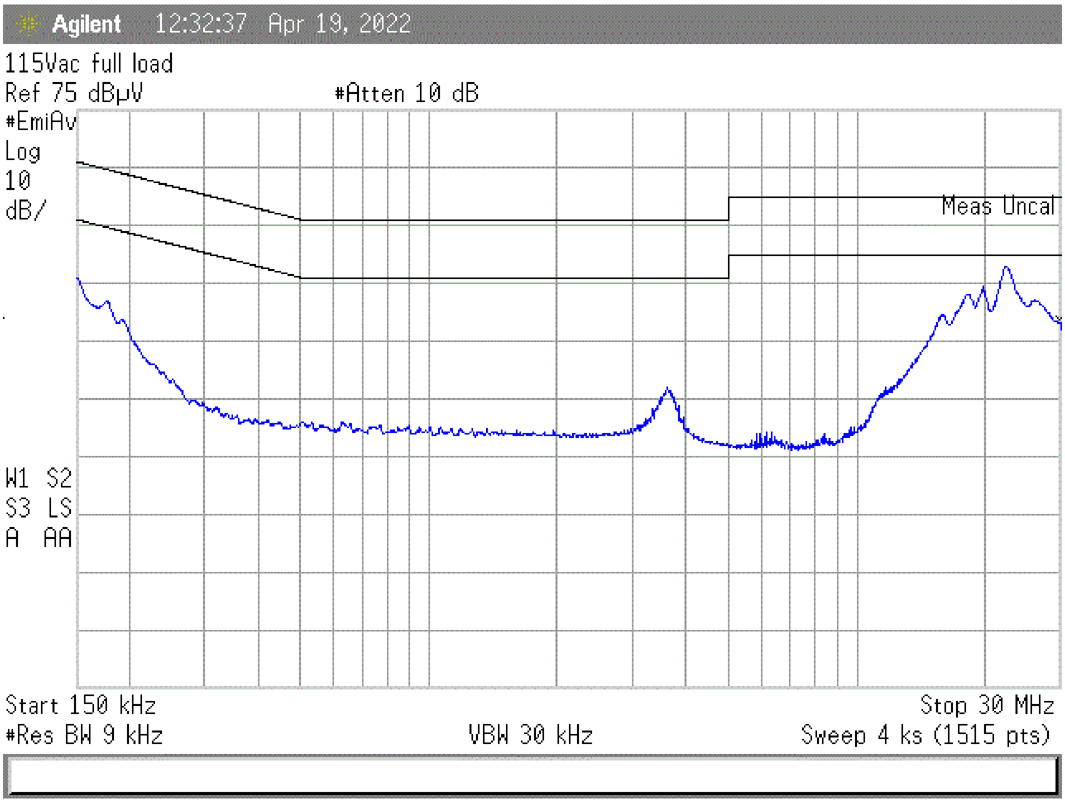
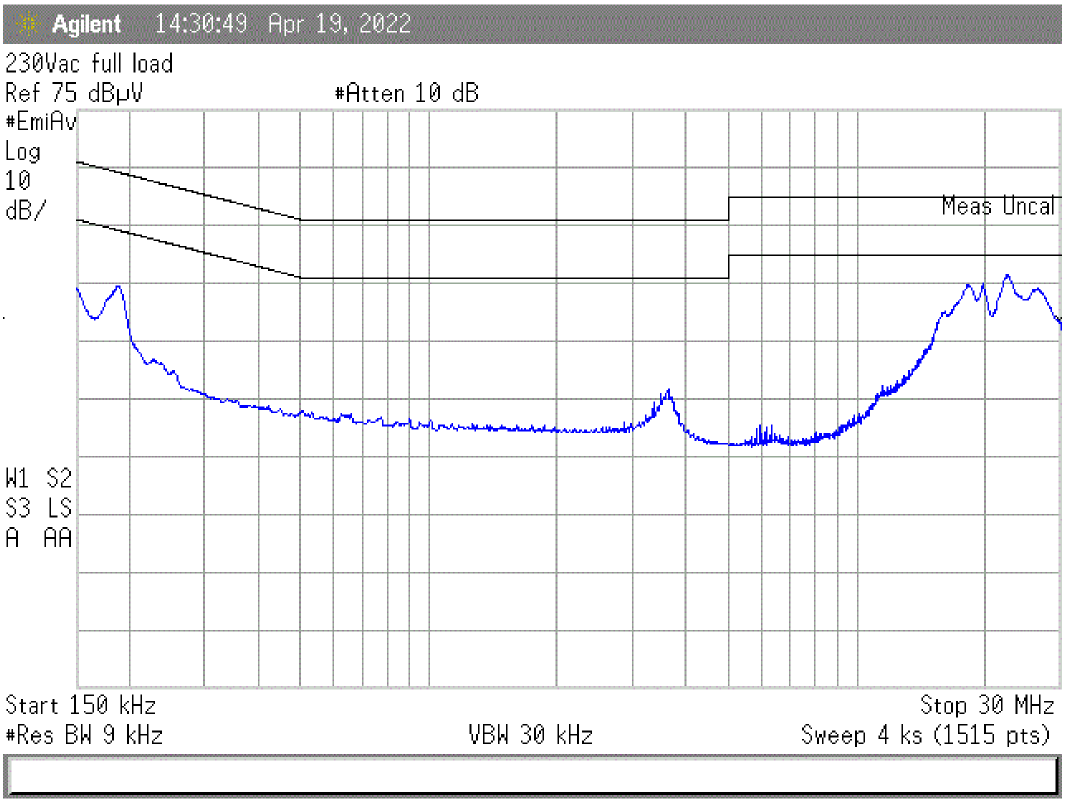


Figure 32. **EMI at 230Vac, 50 Hz – full load**



7 PFC coil specification

Electrical characteristics:

- Converter Topology: Boost, Continuous Conduction Mode
- Core Type: QP3038-25H, MB4 or equivalent
- Min. Operating Frequency: 40kHz
- Typical Operating Frequency: 70kHz
- Primary Inductance: 370μH ±10% at 1kHz – 0.25V
- Supplier: YUJING TECHNOLOGY, PN: 11999-115H4001D/C

Figure 33. Transformer pin-out

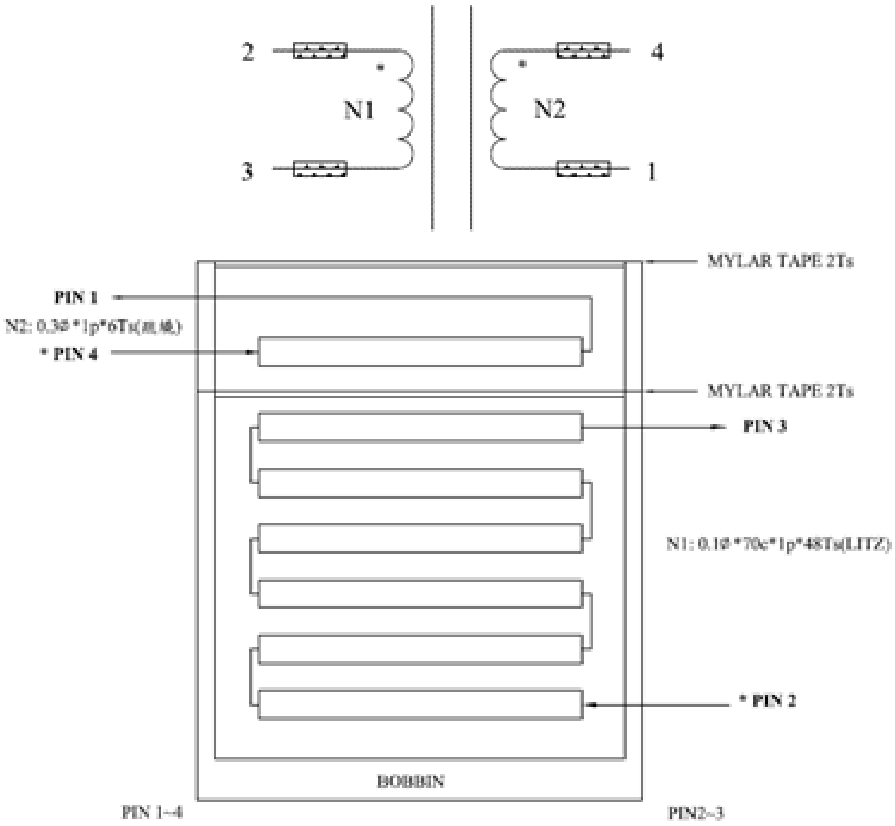
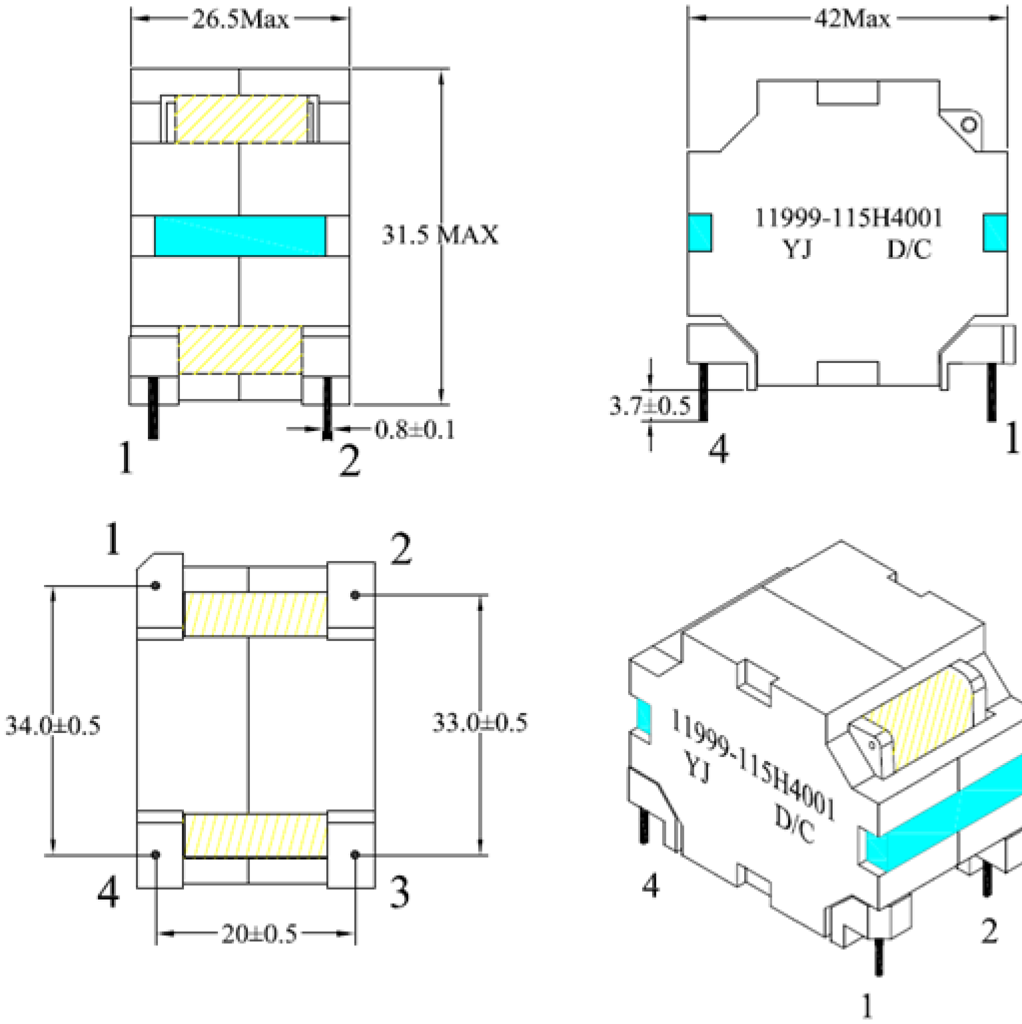


Table 10. PFC coil winding data

No.	Start	Finish	Wire	Color	Turns	Inductance	DCR (mΩ)
L1	2	3	0.1Ø*70c*1p (LITZ)	Y	48 ±0.5	370 μH ±10%	160 Max
L2	1	4	0.3Ø*1p	Y	6 ±0.5	-	-

Figure 34. PFC coil mechanical aspect



8 Transformer specification

Electrical characteristics:

- Converter Topology: Half Bridge, LLC resonant
- Core Type: LP3925H-3C94 or equivalent
- Min. Operating Frequency: 65kHz
- Typical Operating Frequency: 70kHz
- Primary Inductance: 720 μH ±10% at 1kHz-0.25V
- Leakage inductance: 95 μH ±10% at 1kHz-0.25V
- Supplier YUJING TECHNOLOGY
- Transformer P/N: 1999-204H4002D/C

Figure 35. Transformer pin-out

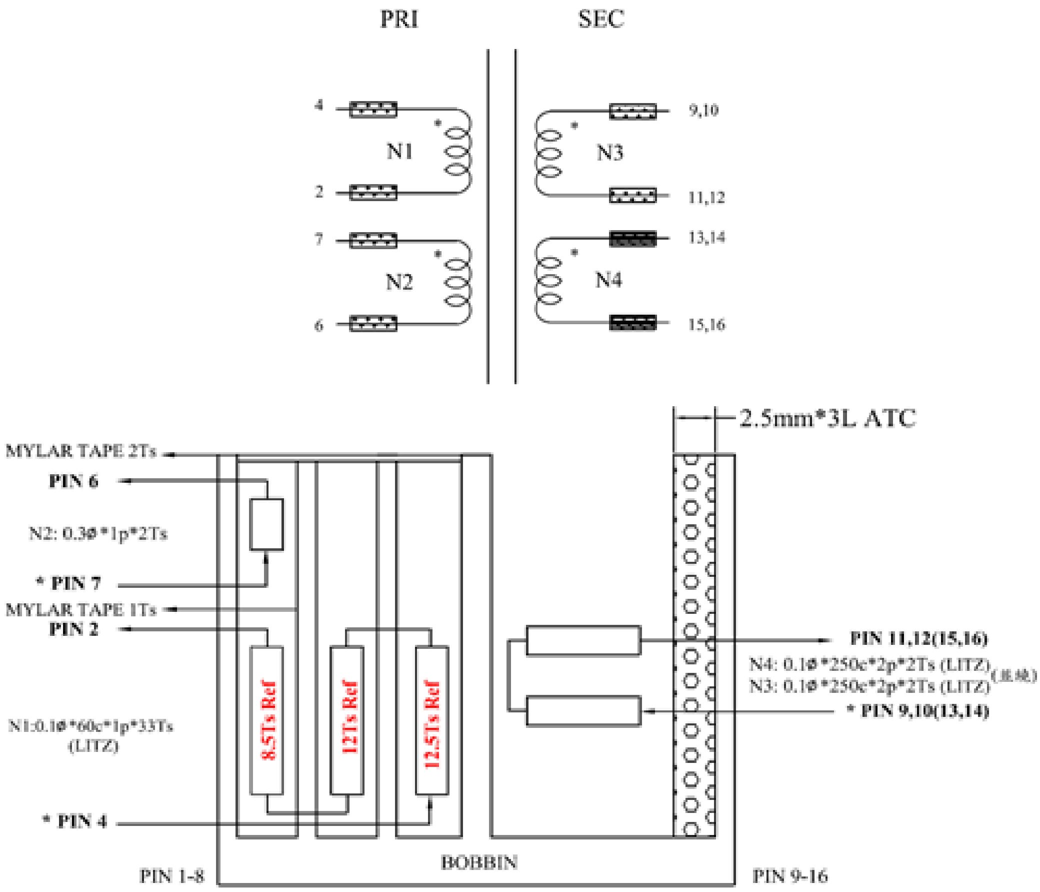
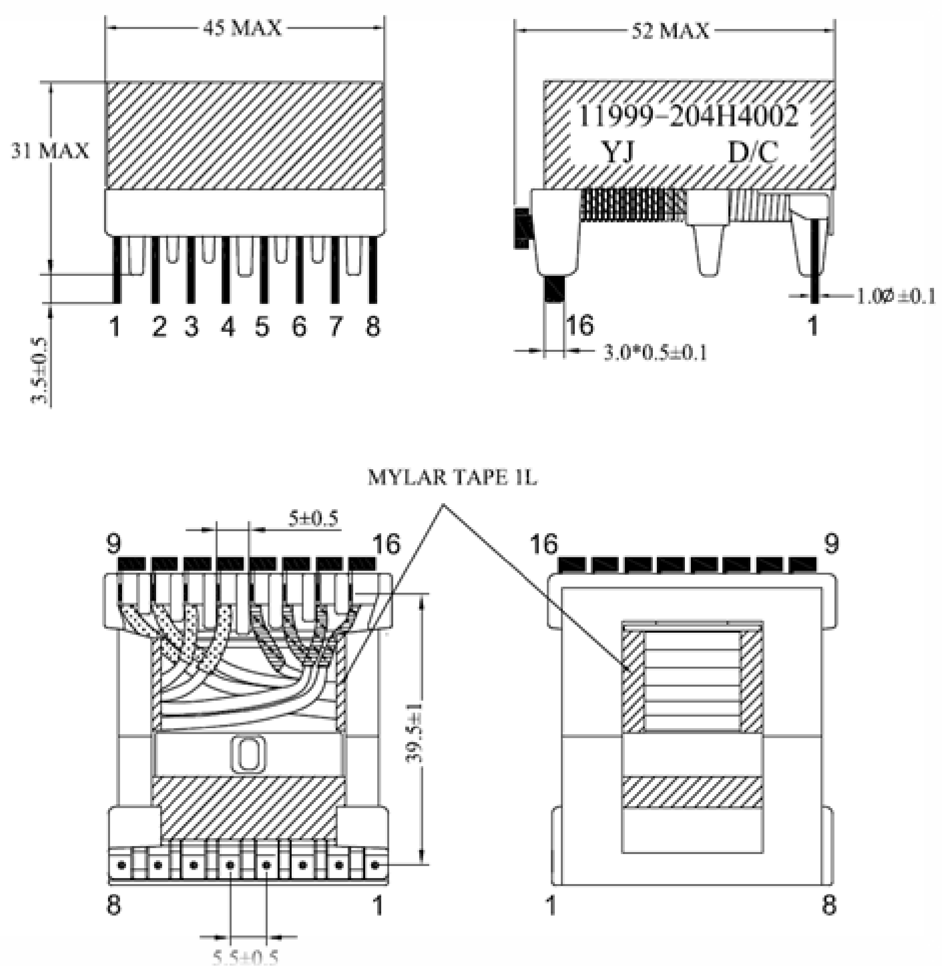


Table 11. PFC coil winding data

No.	Start	Finish	Wire	Color	Turns	Inductance	DCR (mΩ)
L1	4	2	0.1Ø*60c*1p (LITZ)	Y	33 ±0.5	720 µH ±10%	110 Max
L2	7	6	0.3Ø*1p	Y	2 ±0.5	-	-
L3	9, 10	11, 12	0.1Ø*250c*2p (LITZ)	Y	2 ±0.5	-	-
L4	13, 14	15, 16	0.1Ø*250c*2p (LITZ)	Y	2 ±0.5	-	-
LK	4	2	0.1Ø*60c*1p (LITZ)	Y	33 ±0.5	95 µH ±10% @ Secondary short	

Figure 36. Transformer mechanical drawing



9 Motherboard and daughter board layout

Figure 37. Motherboard – top view

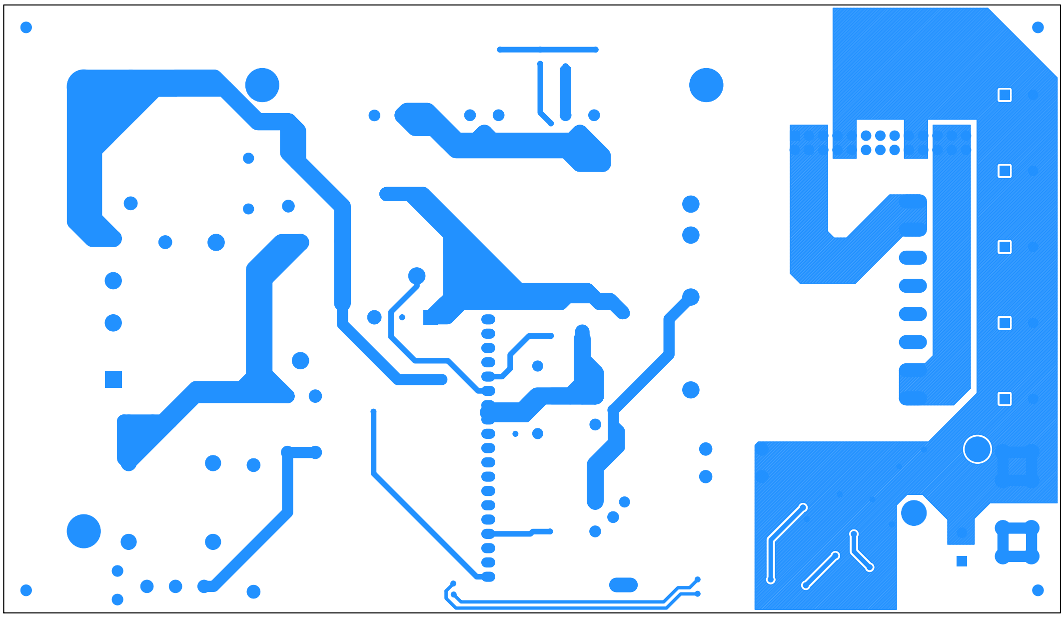


Figure 38. Motherboard – bottom view

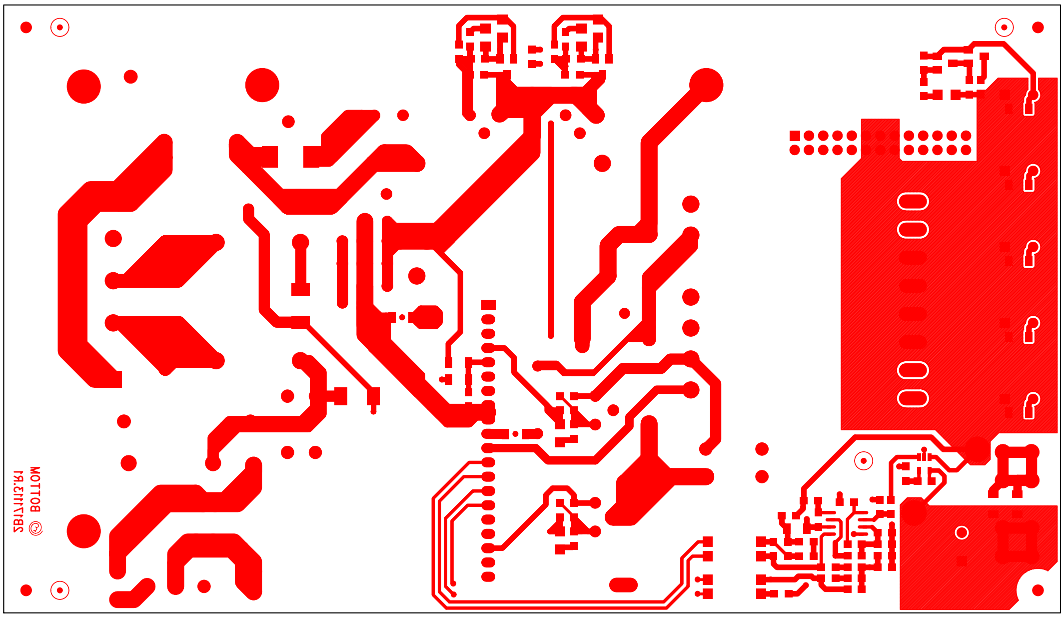


Figure 39. Control board – top view

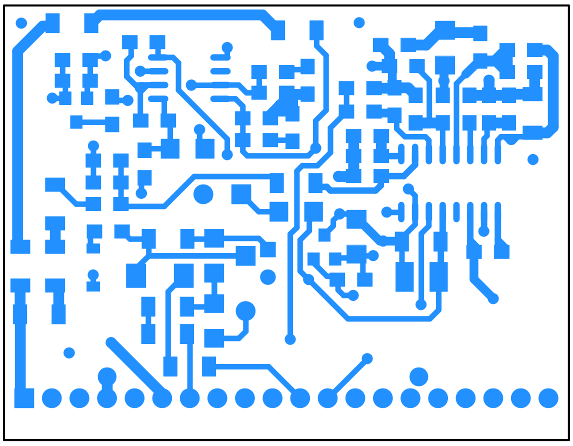


Figure 40. Control board – bottom view

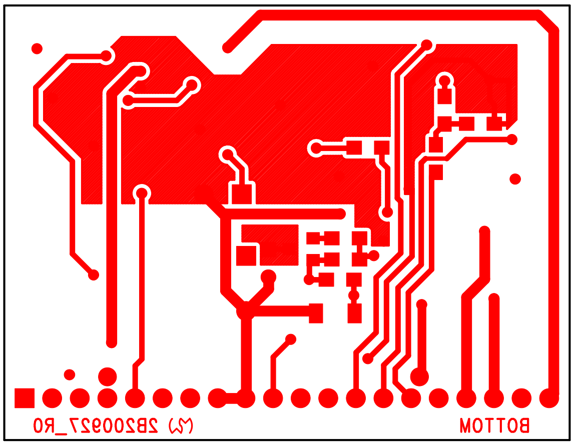


Figure 41. Synchronous rectification board – top view

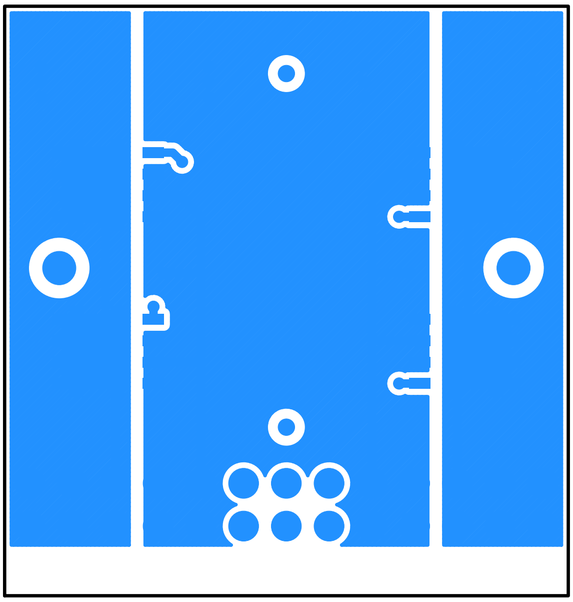
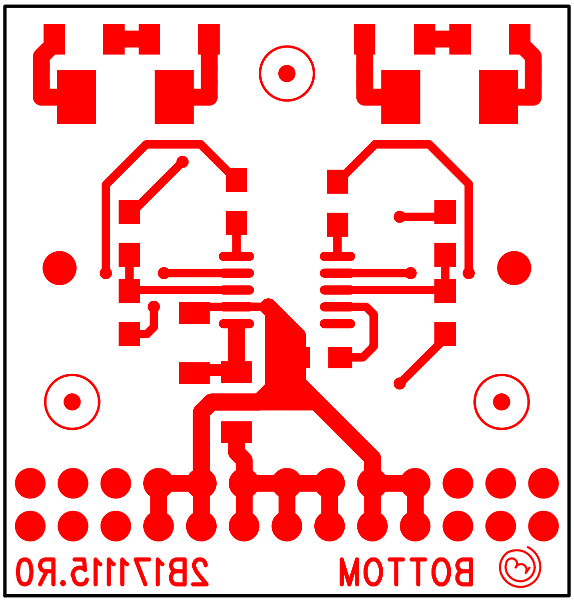


Figure 42. Synchronous rectification board – bottom view



10 Bill of materials

Table 12. EVL400W-80PL motherboard BOM

Reference	Value	Description	Manufacturer
BD1	D15XB60H	SINGLE PHASE BRIDGE RECTIFIER	SHINDENGEN
C1	0.47uF-X2	X2 - FILM CAP - R46 Series, Class X2, 275 Vac, 110ºC	KEMET
C2, C3, C11	2n2-Y1	Y1 SAFETY CAP. DE1E3KX222M	MURATA
C4, C5, C6	470nF-X2	X2 - FILM CAP - R46 Series, Class X2, 310 Vac, 110ºC	KEMET
C7	470nF-X2	X2 - FILM CAP - R46 Series, Class X2, 275 VAC, 110ºC	KEMET
C8	1000p-500V	500Vac CERCAP - 1206	VISHAY
C9	330uF - 450V	ALUMINIUM ELCAP - 330uF-450V 20% - LLG2W331MELA45	NICHICON
C10	N.M.	Y1 SAFETY CAP. DE1E3KX222M	MURATA
C12, C13	33nF-1kV	1kVdc Cap. - B32652A6333	EPCOS
C14	220pF-630V	630V CERCAP - GRM31A7U2J221JW31	MURATA
C15, C16, C17, C18, C19	2200uF-25V	ELCAP KZE series-EKZE250ELL222MK35S	NIPPON CHEMI-CON
C20, C21, C22, C23, C24, C26, C29	1uF	50V CERCAP - X7R - 10%	TDK
C25	820uF-25V	25V ALUMINIUM CAP - EEUTP1E821	PANASONIC
C27, C33	100nF	50V CERCAP - GENERAL PURPOSE	AVX
C36	N.M.	50V CERCAP - GENERAL PURPOSE	AVX
C28	N.M.	50V CERCAP - GENERAL PURPOSE	AVX
C30, C34	1n0	50V CERCAP - GENERAL PURPOSE	AVX
C31	2n7	50V CERCAP - GENERAL PURPOSE	AVX
C32	1uF	50V CERCAP - GENERAL PURPOSE	AVX
C35	2n2	50V CERCAP - C0G - 10%	AVX
D1	S3J	GENERAL PURPOSE RECTIFIER 600V 3A	ON SEMI
D2	STTH8S06FP	ULTRAFAST HIGH VOLTAGE RECTIFIER	STMICROELECTRONICS
D3, D4	S1M	GENERAL PURPOSE RECTIFIER, SMT	FAIRCHILD
D5, D6	N.M.	HIGH SPEED SIGNAL DIODE	VISHAY
D7, D8, D10, D11	LL4148	HIGH SPEED SIGNAL DIODE	VISHAY
D9	N.M.	High junction temperature Transil™	STMICROELECTRONICS
F1	FUSE 6.3A	FUSE TR5/TE5 250V - 6.3A	LITTLEFUSE
HS1	HEAT-SINK	HEAT SINK FOR BD1	-
HS2	HEAT-SINK	HEAT SINK FOR Q2,Q3,D2	-
HS3	HEAT-SINK	HEAT SINK FOR Q4, Q5	-
IC1	TSC101CILT	HIGH SIDE CURRENT SENSE AMPLIFIER	STMICROELECTRONICS
IC2, IC3	SFH6156-3	Optocoupler, Phototransistor Output, High Reliability, 5300 VRMS	VISHAY
IC4	TSM1014AIDT	LOW CONSUMPTION CV/CC CONTROLLER	STMICROELECTRONICS
JPX1	OPEN (N.M.)	WIRE JUMPER	-

Reference	Value	Description	Manufacturer
JPX2 (R211 su schema)	0R18	RSMF1TB - METAL FILM RES - 1W - 2% - 250ppm/°C	AKANEOHM
JPX3	SHORTED	WIRE JUMPER (See Mech Parts)	-
JPX4	SHORTED	WIRE JUMPER (See Mech Parts)	-
JP1	FEMALE HEADER 20	FEMALE HEADER p.2,54mm PRECI-DIP	-
JP2	SSQ-113-02-G-D	13x2p Straight Female Receptacle SSQ Series	SAMTEC
J1	MKDSN 1,5/ 3-5,08	PCB TERM. BLOCK, SCREW CONN., PITCH 5.08mm - 3 W.	PHOENIX CONTACT
J2, J3, J4, J5	FASTON M 90	FASTON - CONNECTOR	TE Connectivity
L1	VOTC2109000200A	INPUT EMI FILTER 2mHx2 - 4.7A	YUJING
L2	VOTC2708001500A	INPUT EMI FILTER 15mHx2 - 3.7A	YUJING
L3	SHORTED	WIRE JUMPER (See Mech Parts)	-
L4	QP303825H_370uH	PFC INDUCTOR QP3038-25H-370uH-40-70kHz	YUJING
L6	1uH-0.8mR	Output ripple filter inductor	YUJING
Q2, Q3	STF18N60M2	N-CHANNEL POWER MOSFET	STMICROELECTRONICS
Q4, Q5	STF19NM50N	N-CHANNEL POWER MOSFET	STMICROELECTRONICS
Q6, Q7	N.M.	PNP GENERAL PURPOSE AMPLIFIER	FAIRCHILD
Q8, Q9	N.M.	NPN SMALL SIGNAL BJT	VISHAY
RT1	NTC 1R0-S237	NTC RESISTOR P/N B57237S0109M000	EPCOS
R1, R2	0R18	RSMF1TB - METAL FILM RES - 1W - 2% - 250ppm/°C	AKANEOHM
R3	0R	SMD STANDARD FILM RES - 1/4W - 5% - 250ppm/°C	VISHAY
R4, R8, R23, R24, R25, R26	N.M.	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R5, R9	4R7	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R6, R10, R17, R20	75k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R7	0R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R11	N.M.	SMD STANDARD FILM RES - 1/4W - 5% - 250ppm/°C	VISHAY
R12, R13, R14	N.M.	RSMF1TB - METAL FILM RES - 1W - 2% - 250ppm/°C	AKANEOHM
R15, R18	10R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R16, R19	15R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R21	47R	PTH STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R22	0R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R27	51K	SMD STANDARD FILM RES - 1/4W - 5% - 250ppm/°C	VISHAY
R28	56R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R29	3k9	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R30	N.M.	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R31	6k8	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R32	22R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R33	1k0	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R34	330k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R35, R42	15k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R36	91k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY

Reference	Value	Description	Manufacturer
R37	2.2k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R38	47k	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R39	12k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R40	82k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R41	820k	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R43, R44	47R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
T1	LP3925H	RESONANT POWER TRANSFORMER - LP3925H	YUJING

Table 13. **EVL400W-80PL primary control board BOM**

Reference	Value	Description	Manufacturer
C101	100nF	100V CERCAP - GENERAL PURPOSE	AVX
C102	10uF-50V	ALUMINIUM ELCAP - YXF SERIES - 105°C	RUBYCON
C104, C107, C127	100nF	50V CERCAP - GENERAL PURPOSE	AVX
C105	1.5uF	50V CERCAP - GENERAL PURPOSE	AVX
C106	100uF-50V	ALUMINIUM ELCAP - YXF SERIES - 105°C	RUBYCON
C108	2n7	50V CERCAP - GENERAL PURPOSE	AVX
C122	4n7	50V CERCAP - GENERAL PURPOSE	AVX
C109	6n8	50V CERCAP - GENERAL PURPOSE	AVX
C113	2n2	50V CERCAP - C0G - 10%	AVX
C114	330uF-50V	ALUMINUM ELCAP - 105°C	PANASONIC
C115	2.2uF	25V CERCAP - GENERAL PURPOSE	AVX
C116, C117	220nF	25V CERCAP - GENERAL PURPOSE	AVX
C118	330pF	50V CERCAP - GENERAL PURPOSE	AVX
C119	47nF	50V CERCAP - GENERAL PURPOSE	AVX
C120	100nF	50V CERCAP - GENERAL PURPOSE	AVX
C121	10uF-50V	50V CERCAP - GENERAL PURPOSE	TDK
C123	10nF	50V CERCAP - GENERAL PURPOSE	AVX
C124	560pF	50V CERCAP - GENERAL PURPOSE	AVX
C125	1n5	50V CERCAP - GENERAL PURPOSE	AVX
C126	N.M.	50V CERCAP - X7R - 10%	AVX
D101, D102, D105, D108	LL4148	HIGH SPEED SIGNAL DIODE	VISHAY
D106	STPS1H100A	POWER SCHOTTKY DIODE	STMICROELECTRONICS
D107	BZV55-B11-NM	ZENER DIODE	VISHAY
D109	N.M.	ZENER DIODE	DIODES
D111	7V5	ZENER DIODE	VISHAY
IC101	L4985A	LOW CONSUMPTION CV/CC CONTROLLER	STMICROELECTRONICS
IC102	L6699D	IMPROVED HV RESONANT CONTROLLER	STMICROELECTRONICS
JPX101	SHORTED	WIRE JUMPER (See Mech Parts)	-
JP101	MALE HEADER 20P 90°	MALE HEADER p.2,54mm 90°	-

Reference	Value	Description	Manufacturer
Q103	BSS159	N-CH DEPLETION MOSFET	INFINEON
Q104	N.M.	NPN SMALL SIGNAL BJT	VISHAY
R101, R140	10R	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R104, R126	2M4	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R105, R106, R127, R128	3M3	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R108, R141	100R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R115	56k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R116	560R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R118	91k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R120	10R	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R121	16K	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R122	150K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R123	15k	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R124	0R	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R125	0.33R	SMD STANDARD FILM RES - 1/4W - 5% - 250ppm/°C	VISHAY
R130	1K5	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R131	47K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R132	560K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R133	15k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R134	20k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R135, R148	0R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R136	1M0	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R137	10K	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R138	56R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R139	270k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R142	270R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R143	47R	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
R144	5M6	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R145, R146	N.M.	SMD STANDARD FILM RES - 1/8W - 5% - 200ppm/°C	VISHAY
R147	100k	SMD STANDARD FILM RES - 1/8W - 1% - 100ppm/°C	VISHAY
U101	TLVH431AIL3T	1.24V PROGRAMMABLE SHUNT VOLTAGE REFERENCE	STMICROELECTRONICS

Table 14. EVL400W-80PL EVLSRK2001-SPF BOM

Reference	Value	Description	Manufacturer
C201	10uF	35V CERCAP X5R - GENERAL PURPOSE	TDK
C202, C203	N.M.	100V CERCAP - X7R - 10%	TDK
D201, D202	SMAJ40CA	High junction temperature Transil	STMICROELECTRONICS
HS201	HEAT-SINK	HEAT SINK FOR Q201,Q202,Q203,Q204	-
IC201	SRK2001	SRK2001 SR CONTROLLER	STMICROELECTRONICS

Reference	Value	Description	Manufacturer
JP201	TSW-113-22-F-D-RA	13x2p Right Angle Male Header TSW Series	SAMTEC
Q201, Q203	N.M.	N-CHANNEL POWER MOSFET	STMICROELECTRONICS
Q202,Q204	STL220N6F7	N-CHANNEL POWER MOSFET	STMICROELECTRONICS
R201	10R	SMD STANDARD FILM RES - 1/4W - 1% - 100ppm/°C	VISHAY
R202	N.M.	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R203, R204	220R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R205, R206, R207, R208	1R	SMD STANDARD FILM RES - 1/8W - 5% - 250ppm/°C	VISHAY
R209, R210	N.M.	SMD STANDARD FILM RES - 1/4W -5% - 250ppm/°C	VISHAY

11 References and resources

- L4985A datasheet: *CCM PFC controller with high voltage startup*
- L6699 datasheet: *Enhanced high-voltage resonant controller*
- SRK2001 datasheet: *Synchronous rectifier smart driver for LLC resonant converters*
- TSC888CILT datasheet: *Low cost high-side current sense amplifier*
- TSM1014AID datasheet: *Low Consumption Voltage and Current Controller for Battery Chargers and Adaptors*
- STF19NM50N datasheet: *N-channel 500 V, 0.2 Ohm, 14 A MDmesh™ II Power MOSFET in TO-220FP*
- STF18N60M2 datasheet: *N-channel 600 V, 0.2 Ohm, 16 A MDmesh™ II Power MOSFET in TO-220FP*
- STL220N6F7 datasheet N-channel 60 V, 0.0012 Ω, 120 A, STripFET™ F7 Power MOSFET
- STTH8S06FP datasheet: *Turbo 2 ultrafast high voltage rectifier*
- STPS1H100 datasheet: *100 V, 1 A power Schottky rectifier*
- AN4027: *112 V - 150 W resonant converter with synchronous rectification using the L6563H, L6699 and SRK2000A*
- AN4149: *Designing a CCM PFC pre-regulator based on the L4984D*
- AN4163: *EVL4984-350W: 350 W CCM PFC pre-regulator with the L4984D*
- YUJING Technology Co .Ltd

Revision history

Table 15. Document revision history

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

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