AN5264
Application note

EVL400W-EUPL7 400W SMPS demonstration board

Main components	
L4984D	Continuous conduction mode PFC controller
L6699D	Enhanced high-voltage resonant controller
SRK2001	Synchronous rectifier smart driver for LLC resonant converters

Introduction

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

Specifications

- Wide input voltage range: 90 Vac to 264 Vac (45 ÷ 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
- Certified as **80Plus PLATINUM level at 115 Vac and GOLD level at 230 Vac** in the CLEAResult Plug Load Solutions website[a]
- 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

a. CLEAResult Plug Load Solutions site is owned and maintained by CLEAResult - the largest provider of energy efficiency programs and services in North America: https://www.plugloadsolutions.com/80PlusPowerSuppliesDetail.aspx?id=238&type=4

Contents

1 Circuit description

The application architecture is made up of two stages: a front-end PFC pre-regulator based on a CCM (continuous conduction mode) boost PFC controller, using the L4984, and a downstream LLC resonant half-bridge converter, designed around the L6699, providing a 12 V regulated output voltage, dedicated to supplying ATX or similar applications requiring to meet the most stringent efficiency and standby regulations.

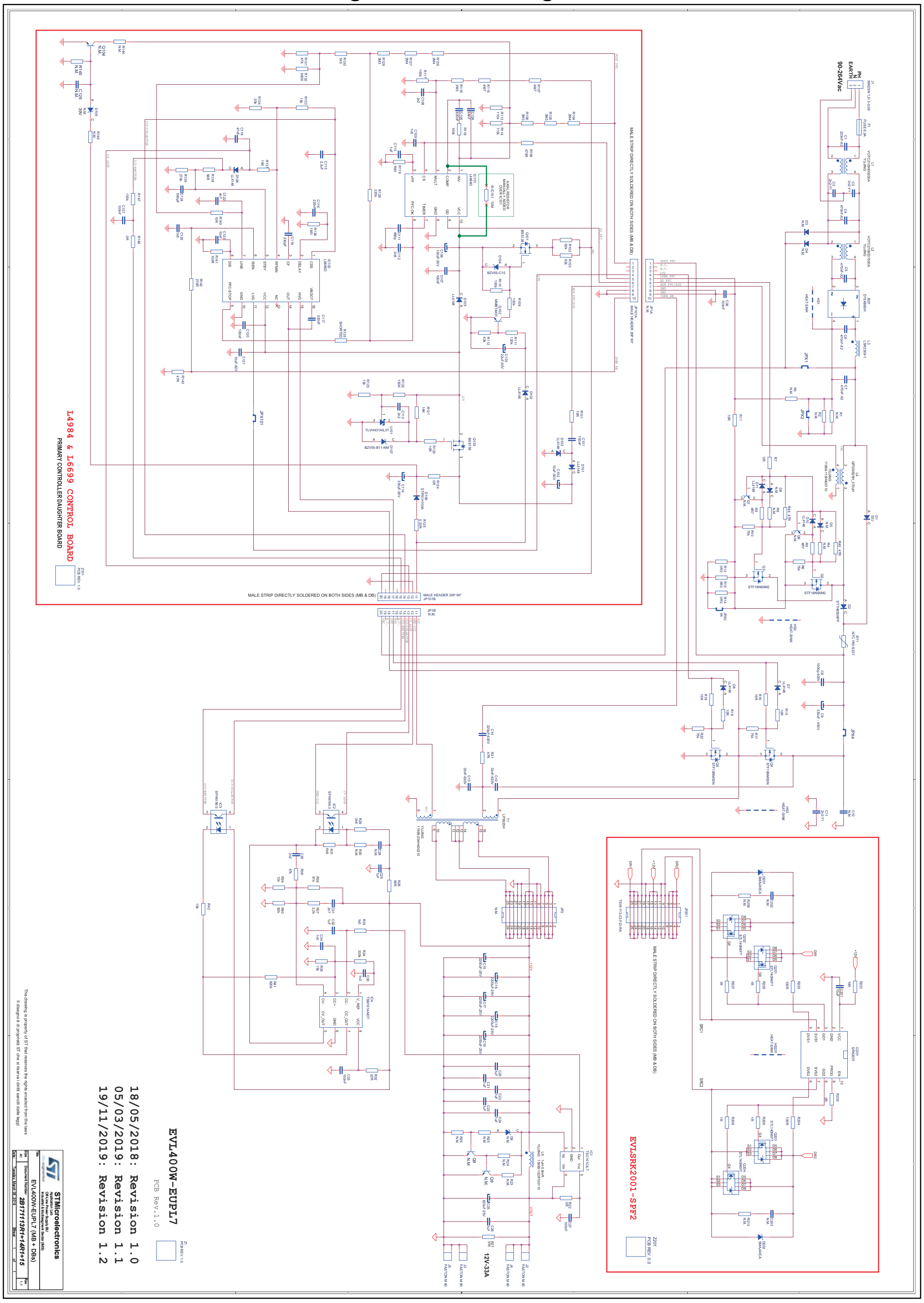
The main focus of this demonstration board is the light-load efficiency, achieved through the burst mode function of both PFC and LLC controllers and the self-adaptive deadtime of the L6699, modulated by the internal logic according to the half-bridge node transition times, which allows the maximization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

An active high voltage start-up circuitry based on a depletion MOSFET provides a very fast start-up time and minimizes the residual consumption during normal operation to a negligible level.

The very high efficiency during normal load operation and the very small Heat Sink used at secondary side is obtained by using synchronous rectification, based on the SRK2001.

Figure 1. EVL400W-EUPL7: 400W SMPS demonstration board

Figure 2. Circuit diagram



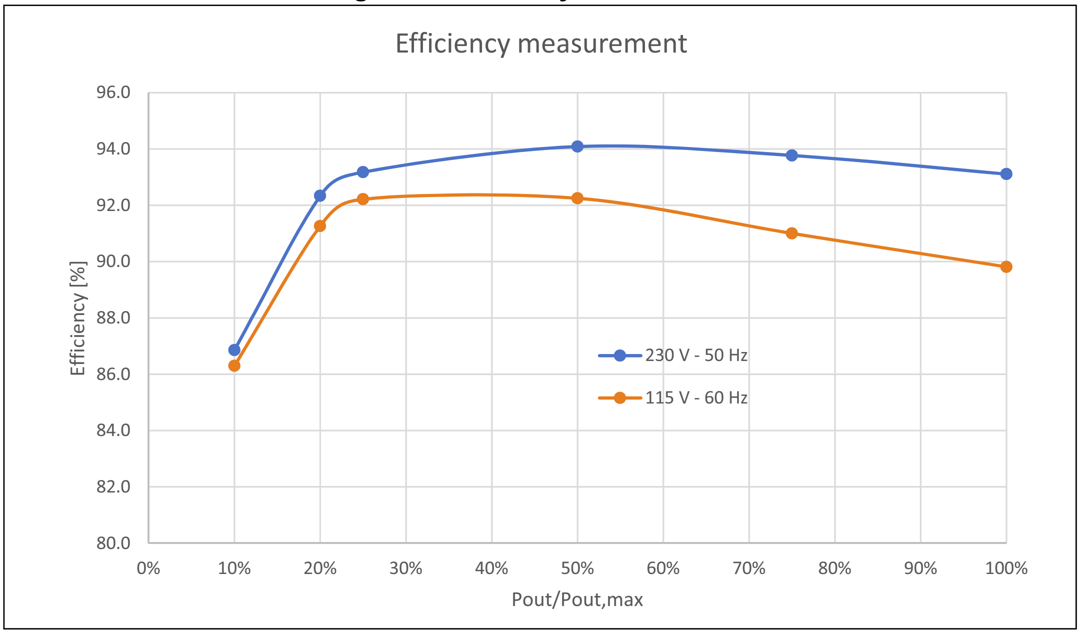
2 Efficiency and no load consumption measurements

Table 1 shows the overall efficiency measurements at the nominal mains voltages. At 115 Vac the full load efficiency is 89.8% and at 230 Vac it is 93.1%.

Table 1. 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	12.09	0.00	0.00	**0.136**	--------	12.09	0.00	0.00	**0.121**	--------
100mW Load	12.10	0.0085	0.103	0.272	37.8	12.09	0.0085	0.103	0.280	36.7
250mW Load	12.10	0.0211	0.255	0.455	56.1	12.09	0.0211	0.256	0.466	54.8
10% load eff.	12.09	3.33	40.26	46.35	86.9	12.09	3.33	40.26	46.65	86.3
20% load eff	12.09	6.66	80.52	87.20	92.3	12.09	6.66	80.52	88.23	91.3
25% load eff.	12.10	8.33	100.82	108.20	93.2	12.10	8.33	100.79	109.30	92.2
50% load eff.	12.14	16.50	200.31	212.90	94.1	12.14	16.55	200.92	217.80	92.2
75% load eff.	12.22	25.00	305.50	325.80	93.8	12.22	25.00	305.50	335.70	91.0
100% load eff.	12.31	33.00	406.23	436.30	93.1	12.31	33.00	406.23	452.30	89.8
Avg. eff. 25%, 50%, 75%, 100%					**93.5**					**91.3**

Figure 3. Efficiency measurement



At 100 mW load the efficiency is 36.7% at 115 Vac and 37.8% at 230 Vac. No load consumption at 115 V is around 121 mW and around 136 mW at 230 V. At 250 mW load the efficiency is 54.8% at 115 Vac and 56.1% 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.

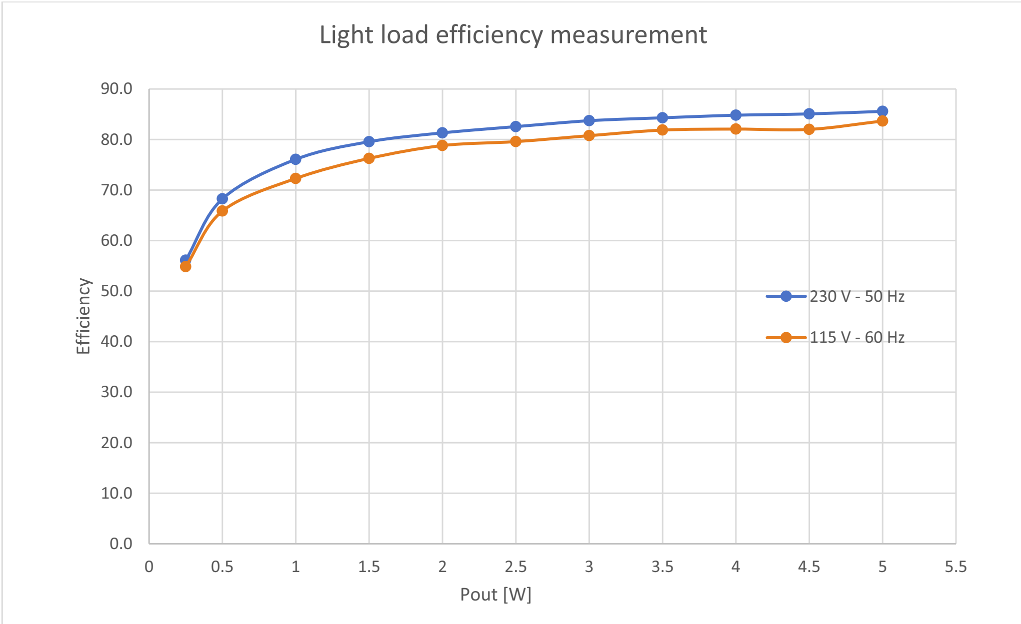
Measurement results at light load are reported in *Table 2* and plotted in *Figure 4*. Efficiency is better than 50% even with 250 mW output power.

It should be highlighted that the measurements do not take into account the power dissipation on the Cx discharge resistor, as it is not present here since different solutions can be adopted to discharge Cx capacitors: a single resistor or a device enabling/disabling the connection of the discharge resistor. In the case of a single resistor an additional power loss due to the resistor should be considered.

Table 2. 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. [%]
0.25W	12.10	21.1	0.255	0.455	**56.1**	12.09	21.1	0.256	0.466	**54.8**
0.5W	12.10	41.8	0.506	0.741	**68.3**	12.10	41.9	0.507	0.770	**65.8**
1.0W	12.11	82.8	1.003	1.318	**76.1**	12.10	82.9	1.003	1.388	**72.3**
1.5W	12.11	124.7	1.510	1.898	**79.6**	12.10	124.8	1.510	1.980	**76.3**
2.0W	12.11	166.6	2.018	2.481	**81.3**	12.10	167.0	2.021	2.564	**78.8**
2.5W	12.12	207.0	2.509	3.039	**82.6**	12.11	207.6	2.514	3.159	**79.6**
3.0W	12.11	250.0	3.028	3.616	**83.7**	12.10	249.8	3.023	3.743	**80.8**
3.5W	12.12	292.0	3.539	4.198	**84.3**	12.10	290.8	3.519	4.298	**81.9**
4.0W	12.12	331.0	4.012	4.730	**84.8**	12.10	333.0	4.029	4.910	**82.1**
4.5W	12.11	374.8	4.539	5.335	**85.1**	12.11	373.8	4.527	5.520	**82.0**
5.0W	12.12	416.2	5.044	5.895	**85.6**	12.10	416.5	5.040	6.024	**83.7**

Figure 4. Light load efficiency diagram



The measurements reported here following have been done according to the recommendation of this measurement procedure:

1. Because 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 remove any oscilloscope probe from the board.
3. For any load measurement we apply a warm time of 20 minutes by each different load. Loads have been applied increasing the output power from minimum to maximum.
4. Because of the input current shape during light load condition, the input power measurement could be critical or not reliable using a power meter in the usual way. To overcome the issues, all light measurements have been done by measuring the active energy consumption of the demonstration board under test and then calculating the power as the energy divided by the integration time. The integration time has been set as 36 seconds, as a compromise between a reliable measurement and a reasonable time measurement time. The energy is measured in mWh, then the result in mW is simply calculated by dividing the instrument reading (in mWh) by 100. The instrument used was Yokogawa, WT210 Power Meter.

3 Eco design requirement verification power supplies

In the following tables the comparison between the regulation requirements for Eco design and the EVL400W-EUPL7 test results are reported: note that the design overcomes the requirements with margin.

Table 3. 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 @ 20 % load	91.3	92.3	>82%	Pass
Efficiency @ 50 % load	92.2	94.1	>85%	
Efficiency @ 100 % load	89.8	93.1	>82%	
Power factor	0.99	0.97	>0.9	

Table 4. EuP Lot 6 tier 2 requirements for household and office equipment

EuP Lot 6 Tier 2 requirements:	Test results		Limits	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz		
Avg. efficiency measured at 25%, 50%, 75%, 100%	91.3	93.5	>87%	Pass
Efficiency @ 250 mW load	54.8	56.1	>50%	
Efficiency @ 100 mW load	36.7	37.8	>33%	

Table 5. 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%	91.3	93.5	>89%	Pass
Efficiency @ 10% load	86.3	86.9	>79%	
No load input power [W]	0.121	0.136	<0.15 W	

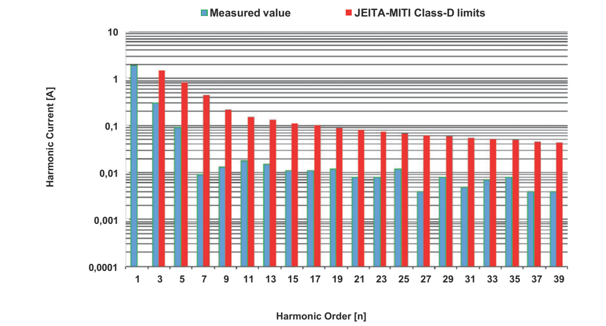
Table 6. 80Plus-Efficiency level

80Plus-PLATINUM	Test results		Limits internal non redundant @ 115Vac PLATINUM	Limits internal non redundant @ 230Vac GOLD	Status
	115 Vac - 60 Hz	230 Vac - 50 Hz			
Efficiency @ 20% load	90.41%	91.33%	>90%	>90%	Pass
Efficiency @ 50% load	92.02%	94.08%	>92%	>92%	
Efficiency @ 100% load	89.41%	93.52%	>89%	>89%	
Power factor @ 50%Load	0.98	0.96	>0.95	>0.9	

4 Harmonics content measurement

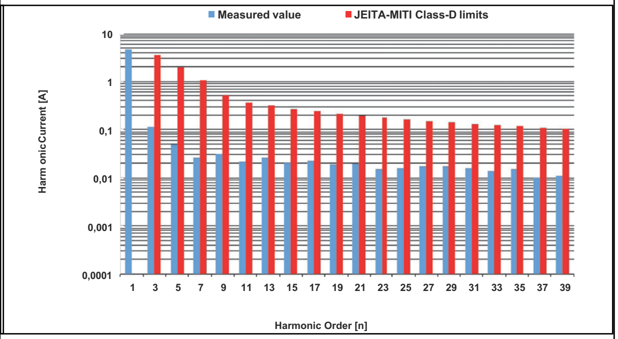
The board has been tested according to the European Standard EN61000-3-2 Class-D and Japanese standard JEITA-MITI Class-D, at both the nominal input voltage mains. As reported in the following *Figure 5* and *Figure 6*, the circuit is able to reduce the harmonics well below the limits of both regulations. On the bottom side of the diagrams the total harmonic distortion and power factor have been measured too. The values in all conditions give a clear idea about the correct functionality of the PFC.

Figure 5. European Standard EN61000-3-2 Class-D



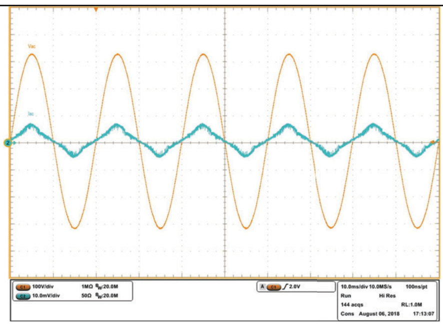
THD = 16.8% - PF = 0.9987

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



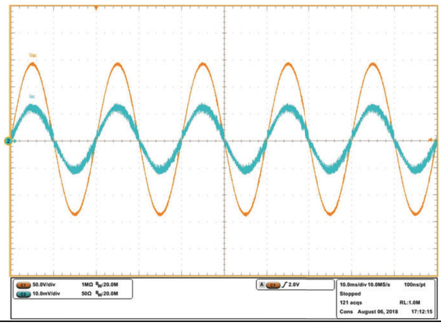
THD = 3.38% - PF = 0.9994

Figure 7. Mains voltage and current waveforms at 230 V - 50 Hz - full load



THD = 17.1% - PF = 0.9988

Figure 8. Mains voltage and current waveforms at 100 V - 50 Hz - full load

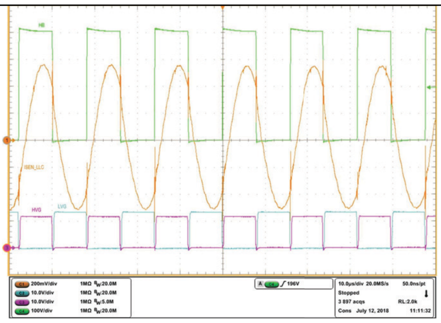


THD = 4.01% - PF = 0.9995

5 Functional check

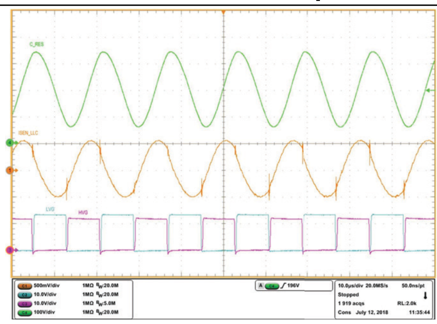
5.1 Resonant stage waveforms

Figure 9. 115 Vac -60 Hz - full load



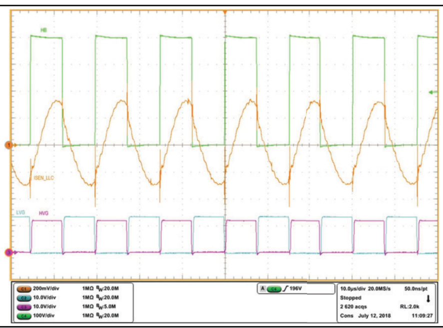
CH1: ISEN_LLC
CH2: LVG
CH3: HVG
CH4: HB

Figure 10. 115 Vac - 60 Hz - full load - voltage on the resonant cap



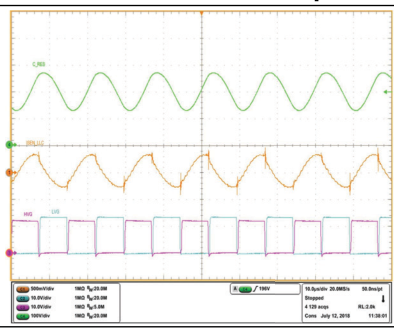
CH1:ISEN_LLC
CH2: LVG
CH3: HVG
CH4: C_RES

Figure 11. 115 Vac - 60 Hz - half load



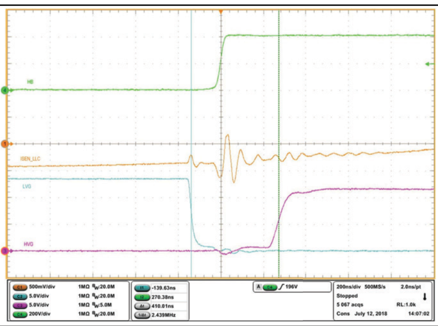
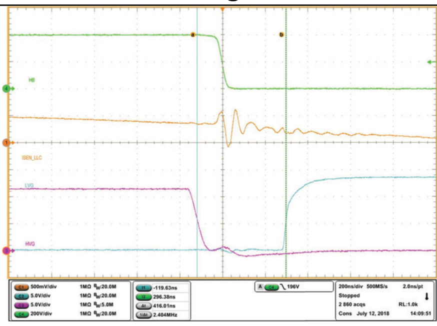
CH1: ISEN_LLC
CH2: LVG
CH3: HVG
CH4: HB

Figure 12. 115 Vac - 60 Hz - half load - voltage on the resonant cap



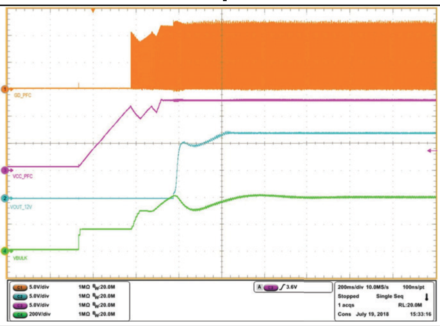
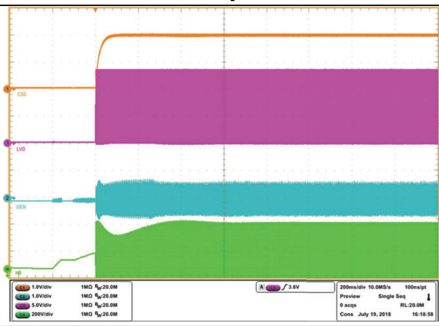
CH1:ISEN_LLC
CH2: LVG
CH3: HVG
CH4: C_RES

Figure 13 and *Figure 14* show the waveforms during full load operation. It is possible to note the measurement of the edges and the relevant deadtime.

Figure 13. HB transition at full load - rising edge	Figure 14. HB transition at full load - falling edge
	
CH1: ISEN_LLC	CH1: ISEN_LLC
CH2: LVG	CH2: LVG
CH3: HVG	CH3: HVG
CH4: HB	CH4: HB

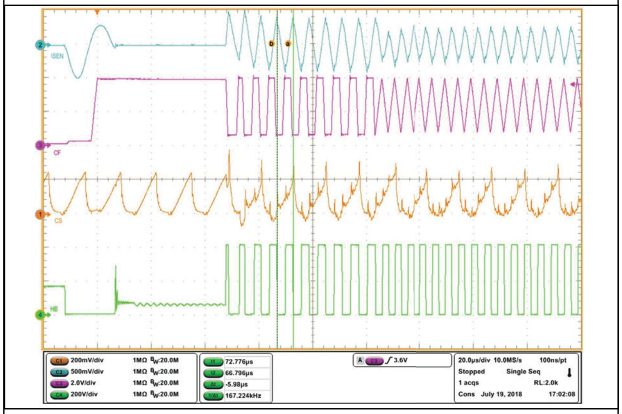
5.2 Startup

The waveforms relevant to the board startup at 115 Vac and full load have been captured focusing in *Figure 15* on the PFC startup and in *Figure 16* on the LLC startup. Note that the output voltage reaches the nominal value approximately 700 msec after plug-in.

Figure 15. PFC startup at 115 Vac full load	Figure 16. LLC startup at 115 Vac full load
	
CH1: GD L4984	CH1: CSS
CH2: VOUT+12V	CH2: ISEN
CH3: VCC L4984	CH3: LVG
CH4: BULK VOLTAGE	CH4: HB

Note in *Figure 17* that the start-up frequency has been set close to the smooth start frequency during the initial 50 us.

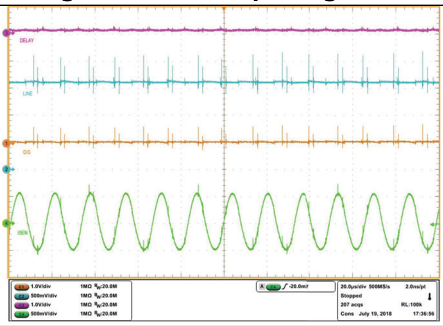
Figure 17. Safe-start at 115 Vac/60 Hz - full load Fsmooth start = 167 kHz



CH1: CF; CH2: ISEN; CH4: HB

In *Figure 18* and *Figure 19*, the main L6699 pin signal has been measured during normal operation at full load. Referring to *Figure 18* we can note the signals:

Figure 18. L6699 pin signals - 1

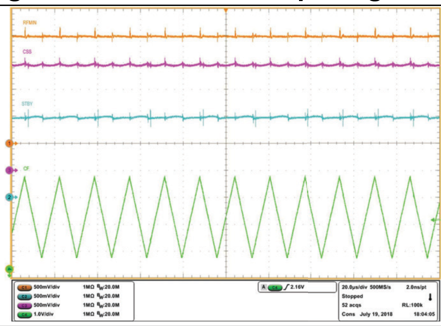


CH1: DIS (it is at GND); CH2: LINE

CH3: DELAY (it is at GND);

CH4: ISEN

Figure 19. L6699 control pin signals - 2



CH1: RFMIN; CH2: STBY

CH3: CSS; CH4: CF

- 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 has been dimensioned to start up the L6699 once the PFC output voltage has reached the rated value, in order 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, as it must be during normal operation, because it works during the overcurrent protection operation.
- DIS pin (#8) is used for open loop protection and therefore, even in this case, its voltage is at ground level.

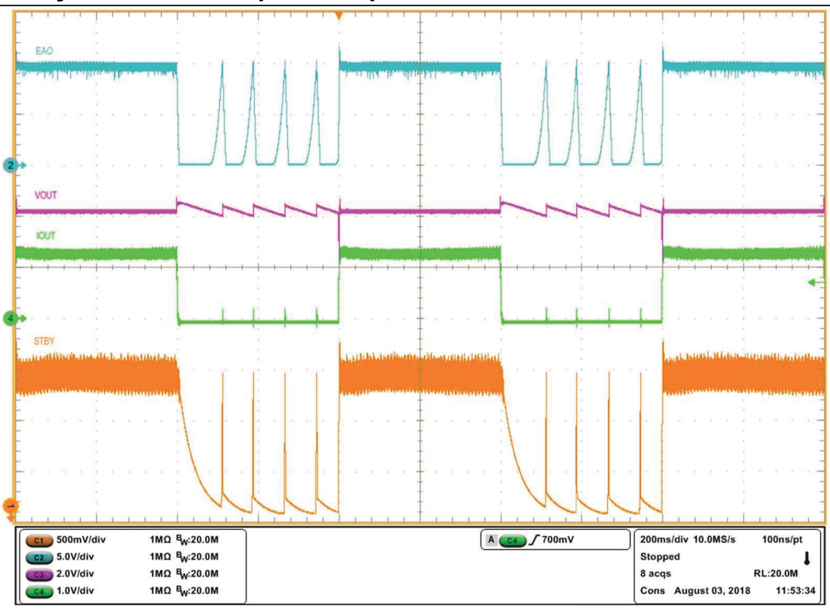
In *Figure 19* the pins dedicated to the control part of the L6699 are reported:

- 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 (R37), determining the soft-start frequency. A capacitor (C24) 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 C18 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 to 1.25 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.

5.3 Dynamic load response

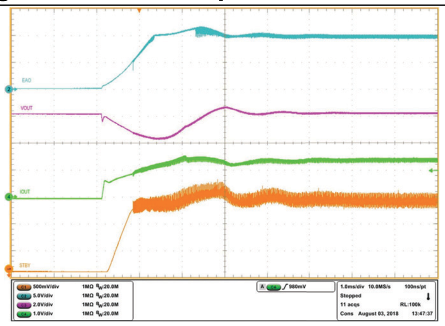
The EVL400W-EUPL7 has been connected to a dynamic load to measure the output voltage variations. The load changed every 400 ms from open load to 20 A load and vice versa, at 800 ma/µs. The response of the output voltage is shown with a ripple of about 600 mV pkpk at 115 Vac-60 Hz.

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



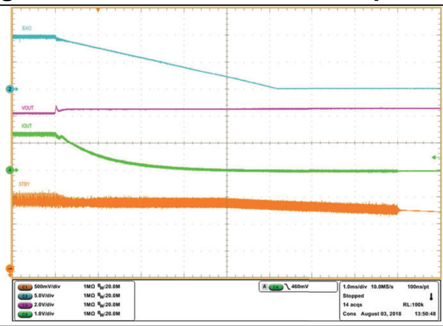
CH1: STBY; CH2: EAO; CH3: VOUT; CH4: IOUT

Figure 21. Detail - open load to 20A load



CH1: STBY; CH2: EAO; CH3: VOUT; CH4: IOUT

Figure 22. Detail - 20A load to open load

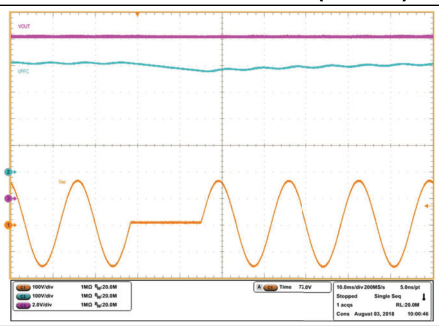


CH1: STBY; CH2: EAO; CH3: VOUT; CH4: IOUT

5.4 Mains dips at half load

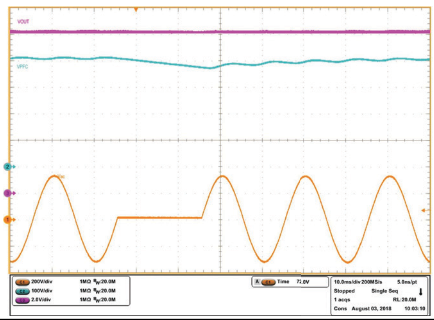
In this test the EVL400W-EUPL7 has been checked against a 0 % mains dip (single line cycle, according to IEC61000-4-11) at both nominal voltages while operating at half load (16.5 A). The output voltages of the board and of the PFC are shown.

Figure 23. Single cycle 100% mains dip at 115 Vac - 60 Hz - half load (16.5 A)



CH1: Vac; CH2: VPFC; CH3: VOUT

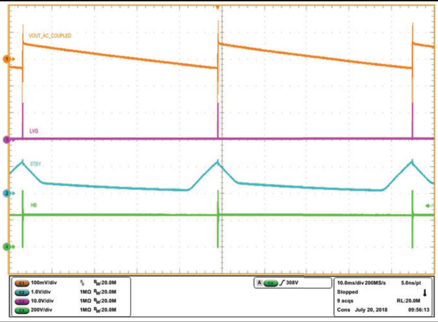
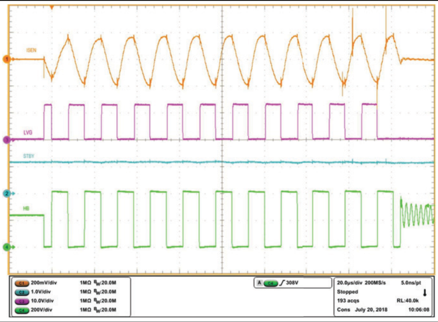
Figure 24. Single cycle 100% mains dip at 230 Vac - 50 Hz - half load (16.5 A)



CH1: Vac; CH2: VPFC; CH3: VOUT

5.5 Burst mode operation at light load

In *Figure 25* some burst mode pulses are captured during 250 mW load operation. The burst pulses are very narrow and their period is quite long, therefore the resulting equivalent switching frequency is very low, ensuring high efficiency. The resulting output voltage ripple during burst mode operation is about 100 mV peak-to-peak.

Figure 25. Pout = 250 mW, BM operation	Figure 26. Detail of the BM pulse
	
CH1: VOUT (AC COUPLED)	CH1: ISEN; CH2: STBY
CH2: STBY; CH3: LVG; CH4: HB	CH3: LVG; CH4: HB

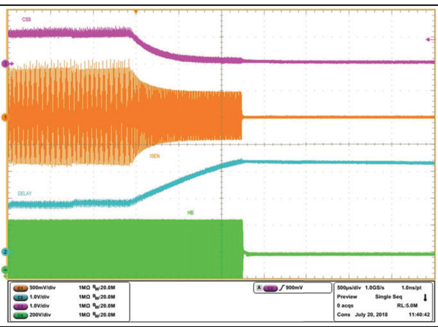
In *Figure 26* the detail of the burst is reported: the first initial pulse is shorter than the following ones avoiding the typical high current peak at half-bridge operation restarting, due to the recharging or the resonant capacitor. The operating frequency of the half-bridge during burst mode is around 62 kHz.

5.6 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 from pin DELAY, generated by an internal current generator, and is slowly discharged by the external parallel resistor. If overload lasts, the voltage on the pin rises and when it reaches 2 V the soft-start capacitor is completely discharged, 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 is soft-restarted as 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 an overload condition for a time lasting less than a set value, avoiding IC shutdown in the case of short overload or peak power transients. On the other hand, in the case of dead short, a second comparator referenced to 1.5 V immediately disables switching and activates a restart procedure.

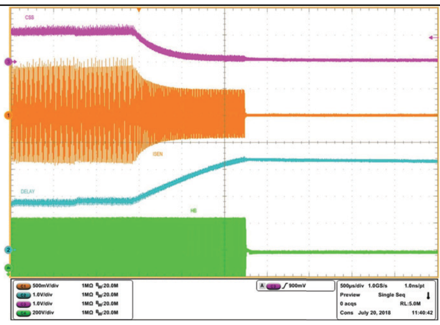
Figure 27. Short-circuit at 115 Vac/60 Hz - full load



CH1: ISEN; CH2: DELAY

CH3: CSS; CH4: HB

Figure 28. Short-circuit - zoom at 115 Vac/60Hz - full load



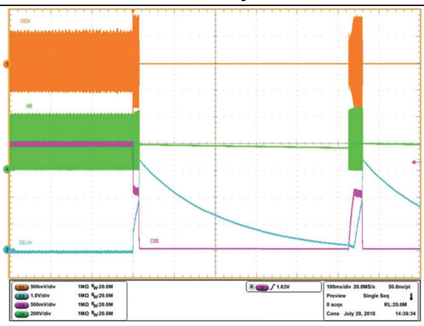
CH1: ISEN; CH2: DELAY

CH3: CSS; CH4: HB

In *Figure 27* a dead short-circuit event has been captured. 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. In *Figure 28* details of peak current with short-circuit occurring is shown.

If the short-circuit condition is removed, the converter restarts operation, otherwise, if the short is still there, the converter operation results in an intermittent operation (Hiccup mode) with a narrow operating duty cycle of the converter, in order to prevent overheating of power components, as can be noted in *Figure 29*.

Figure 29. Short-circuit at 115 Vac/60 Hz - full load Hiccup mode



CH1: ISEN; CH2: DELAY

CH3: CSS; CH4: HB

6 Thermal map

In order to check the design reliability, a thermal mapping by means of an IR camera was done. Below, the thermal measurements of the board, component side, at nominal input voltage are shown. Some pointers, visible on the images, have been placed across key components or components showing high temperature. The ambient temperature during both measurements was 25 °C; a 7 cm diameter cooling fan was used during thermal measurement. It was placed at about 5 cm from the edge of the board below with respect to the images. The air flow produced by the fan was 1,2 m/s at 15 cm away in central position.

Figure 30. Thermal map at 90 Vac - 60 Hz - full load

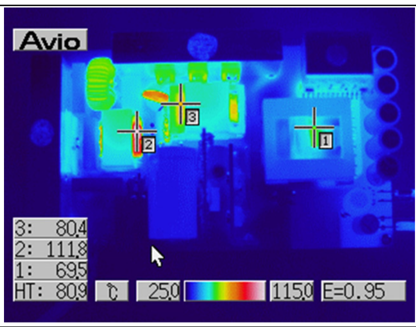


Figure 31. Thermal map at 230 Vac - 50 Hz - full load

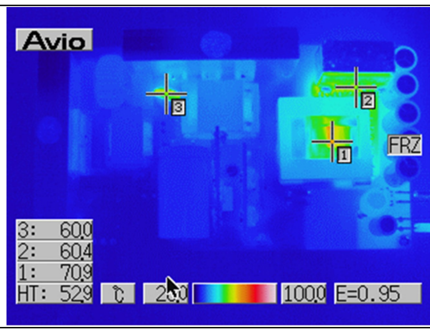


Table 7. Thermal maps reference points fig. 30 at 90 Vac - 60 Hz - full load

Point	Ref.	Description	Temp. (°C)
1	L2	Resonant transf. - secondary	69.5 ºC
2	T1	Common mode choke	111.8 ºC
3	L4	PFC inductor	80.4 ºC

Table 8. Thermal maps reference points fig. 31 at 230 Vac - 50 Hz - full load

Point	Ref.	Description	Temp. (°C)
1	T1	Resonant transf. - secondary	70.9 ºC
2	SRK2001	Synchronous rectifier board	60.4 ºC
3	R3	NTC 1R0-S237	60.0 ºC

7 Conducted emission pre-compliance test

A pre-compliance test (testing environment not compliant) on conducted emission has been performed. The following images are the average and the quasi peak measurements of conducted emission at full load and at the nominal mains voltages. The measurements have been 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. see *Figure 33*.

Figure 32. EMI at 115 Vac - 60 Hz - full load

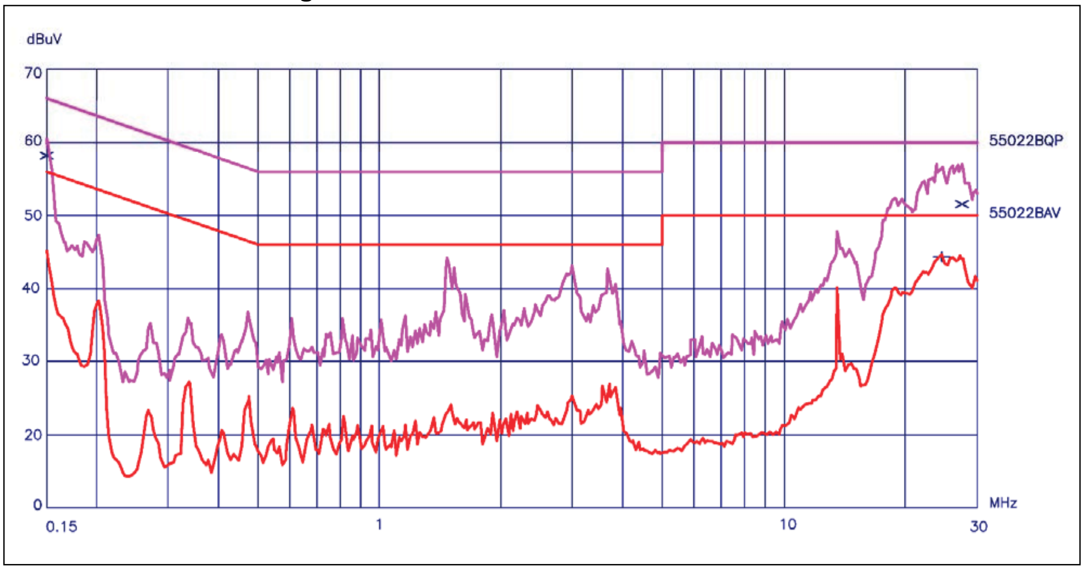
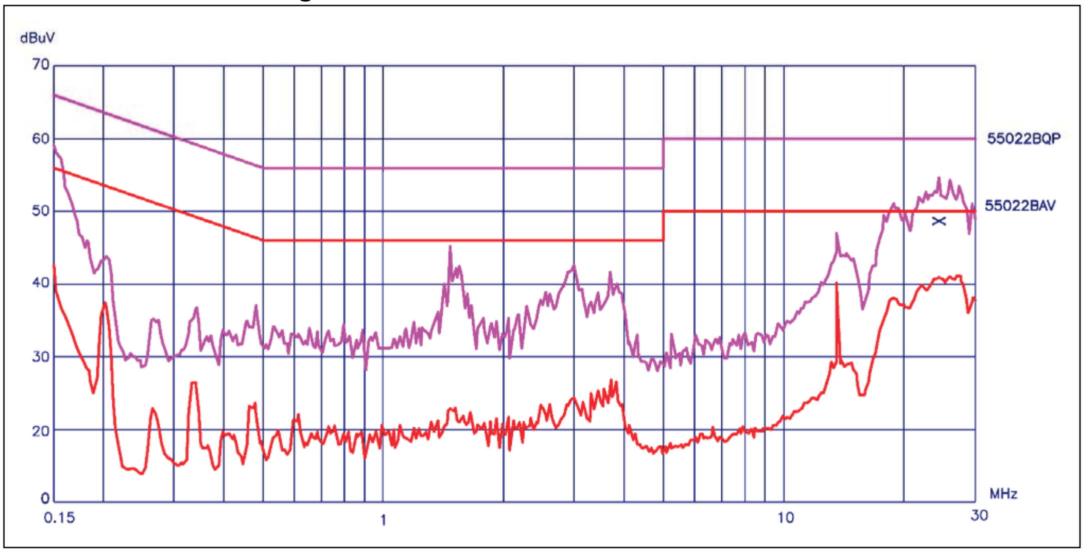


Figure 33. EMI at 230 Vac - 50 Hz - full load



8 PFC coil specification

8.1 Electrical characteristics

- Converter topology: Boost, Continuous Conduction Mode
- Core type: QP3038-25H, MB4 or equivalent
- Min. operating frequency: 40 kHz
- Typical operating frequency: 70 kHz
- Primary inductance: 370 µH±10% at 1 kHz-0.25 V
- Supplier: YUJING TECHNOLOGY, PN: 11999-115H4001D/C

Figure 34. Transformer pin-out

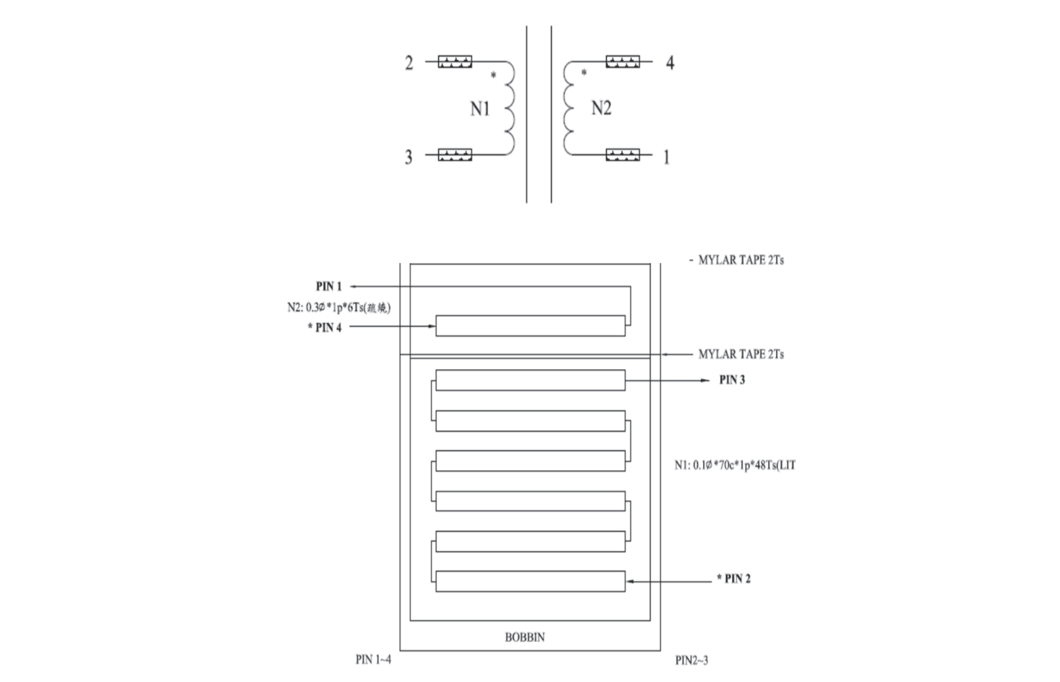
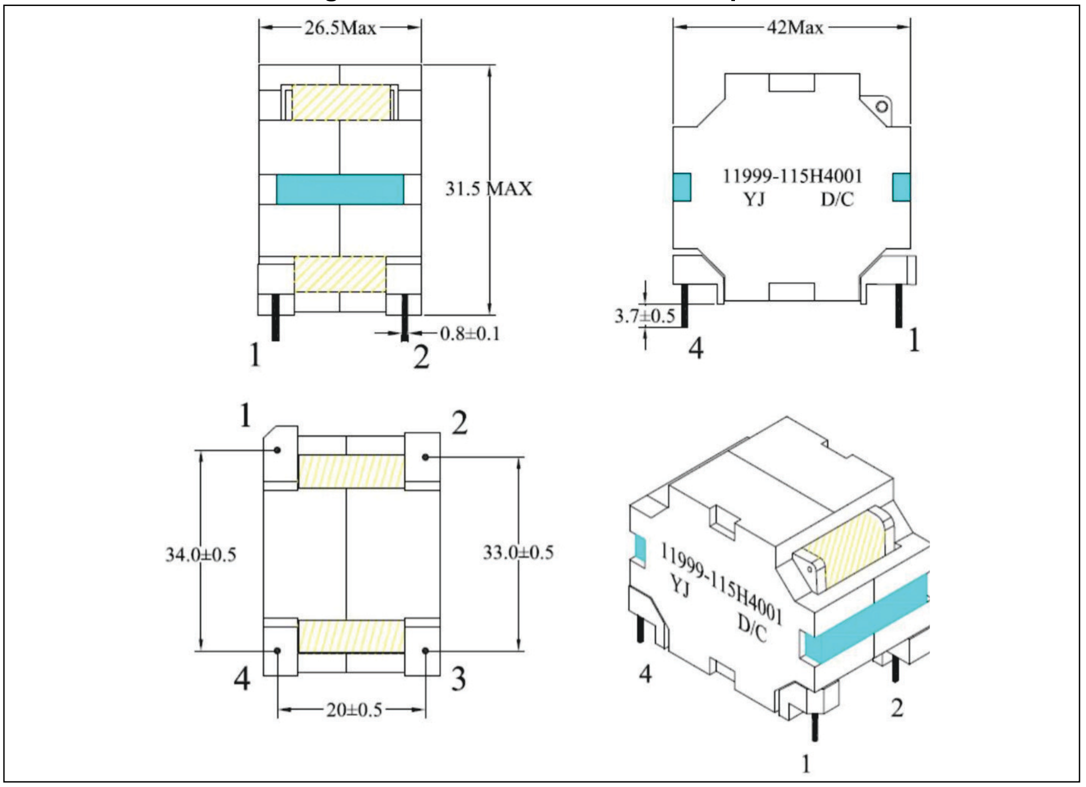


Table 9. PFC coil winding data

ZENTECH: WK5235, 502A, F = 20KHz V = 1.0V AT 25ºC							
No.	**Start**	**Finish**	**Wire**	**Color**	**Turns**	**Inductance**	**DCR (mΩ)**
L1	2	3	0.1Ø*70c*1p(LITZ)	Y	48±0.5	370 uH±10%	160 max.
L2	4	1	0.3Ø*1p		6±0.5	-	-

Figure 35. PFC coil mechanical aspect



Manufacturer

- YUJING TECHNOLOGY
- Inductor P/N: 1999-115H4001D/C

9 Transformer specification

9.1 Electrical characteristics

- Converter topology: half-bridge, LLC resonant
- Core type: LP3925H-3C94 or equivalent
- Min. operating frequency: 65 kHz
- Typical operating frequency: 70 kHz
- Primary inductance: 720 µH ±10% at 1 kHz-0.25 V
- Leakage inductance: 95 µH ±10% at 1 kHz-0.25 V

Figure 36. Transformer pin-out

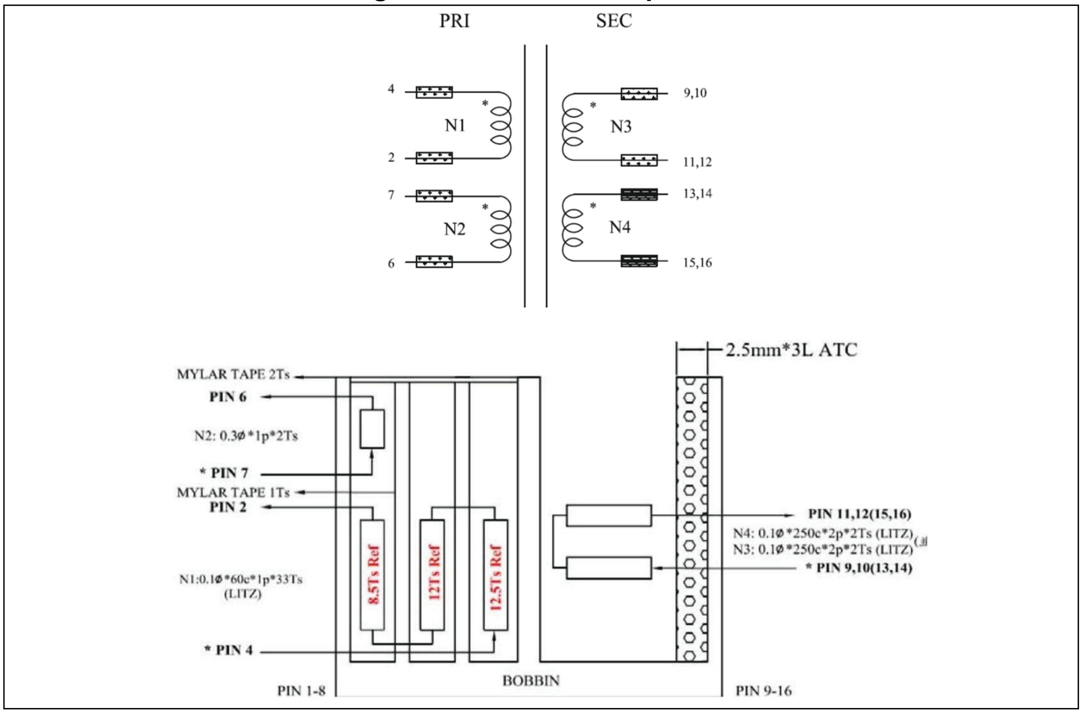
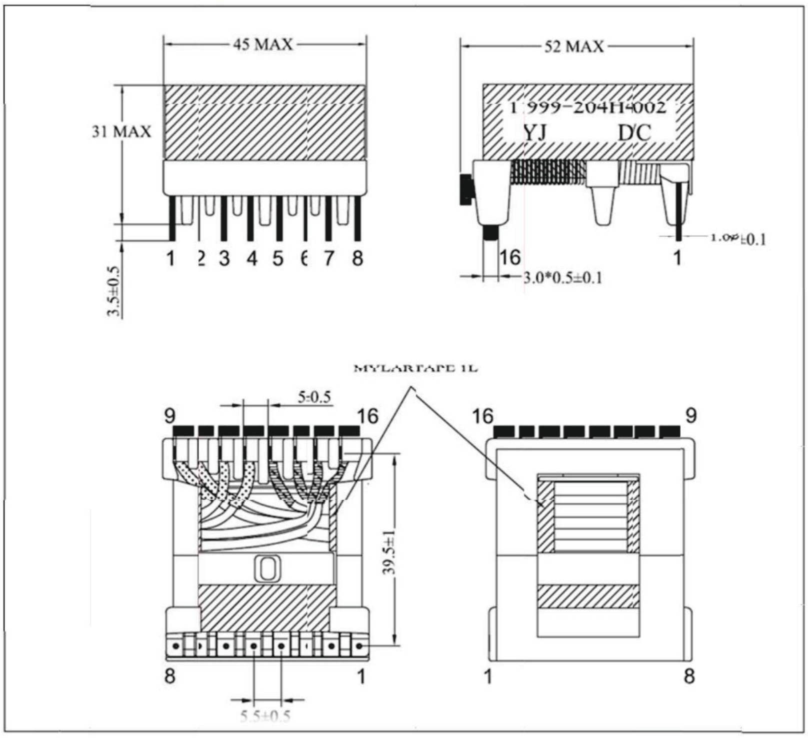


Table 10. Transformer winding data

ZENTECH: WK5235, 502A, F = 100KHz V = 1.0 V AT 25ºC							
No.	**Start**	**Finish**	**Wire**	**Color**	**Turns**	**Inductance**	**DCR (mΩ)**
L1	4	2	0.1Ø*60c*1p(LITZ)	Y	33±0.5	720uH±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	95uH±10% @ Secondary Short	

Figure 37. Transformer overall drawing



Manufacturer

- YUJING TECHNOLOGY
- Transformer P/N: 1999-204H4002D/C

10 Motherboard and daughterboard layout

Figure 38. Motherboard top and bottom view

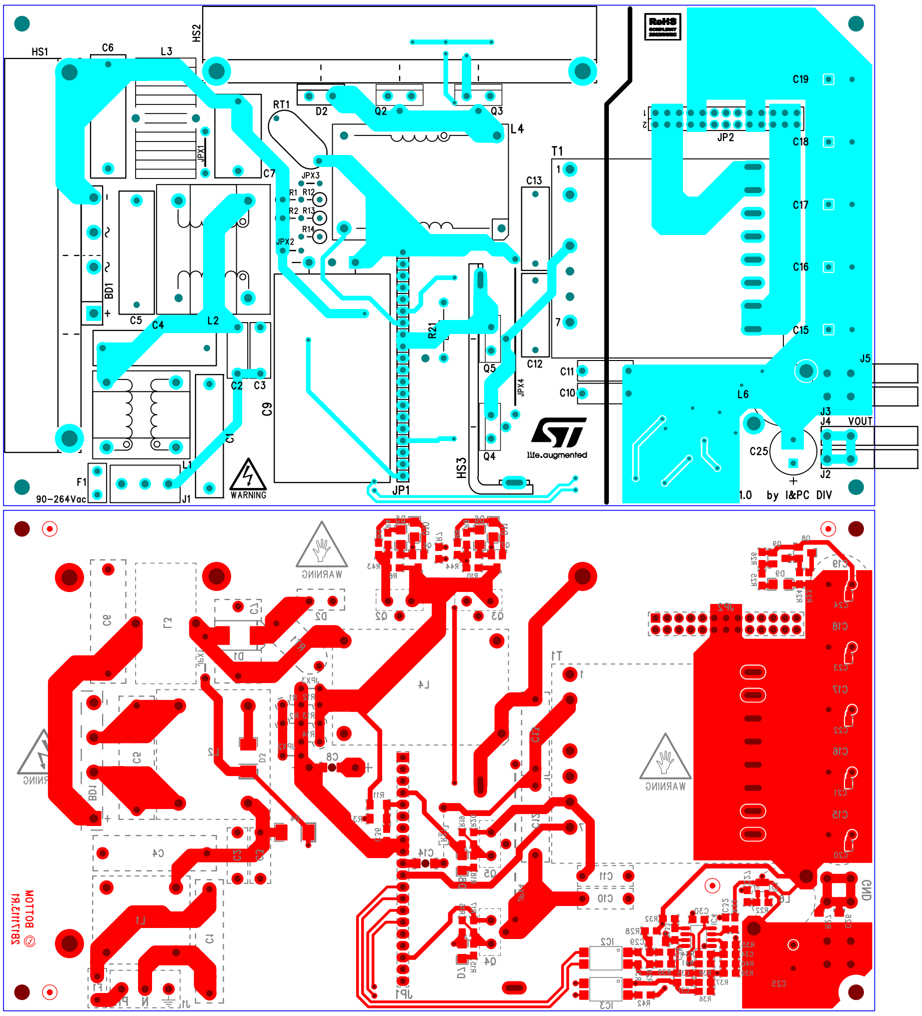


Figure 39. Control daughterboard top and bottom view

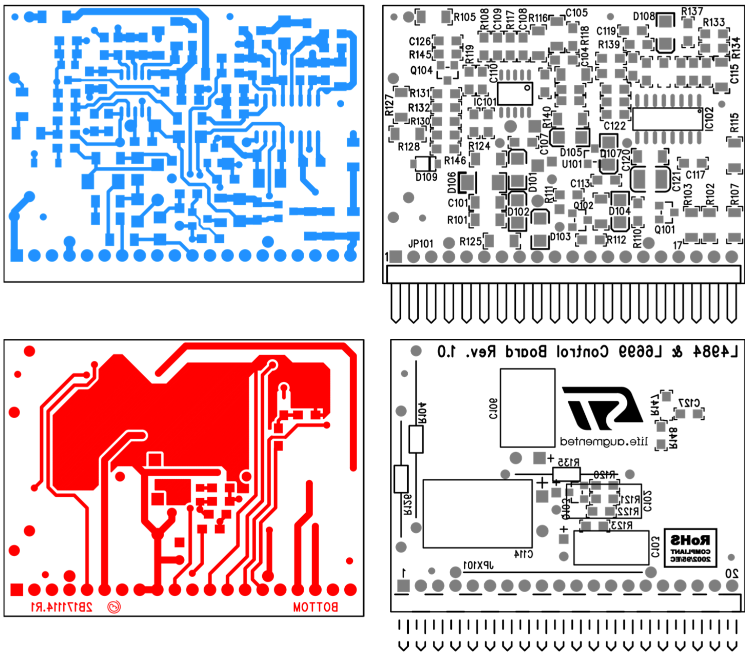


Figure 40. SR board top and bottom view

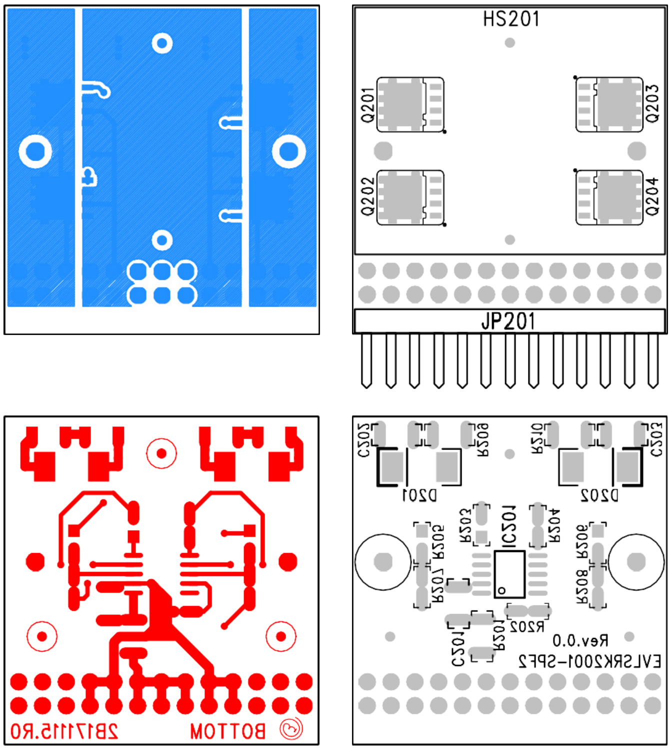


Table 11. Bill of material - motherboard

Reference	Value	Description	Manufacturer
BD1	D15XB60H	Single phase bridge rectifier	SHINDENGEN
C1	220nF-X2	X2 - film cap - R46 series, class X2, 310 Vac, 110ºC	KEMET
C2, C3, C11	2n2-Y1	Y1 safety cap. DE1E3KX222M	MURATA
C10	N.M.		
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	500 Vac CERCAP - 1206	VISHAY
C9	330uF - 450V	Aluminum ELCAP - 330uF - 450V 20% - LLG2W331MELA45	NICHICON
C12, C13	33nF-630V	630Vdc 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 aluminum cap - EEUTP1E821	PANASONIC
C27, C33, C36	100nF	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	N.M.	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	

Table 11. Bill of material - motherboard (continued)

Reference	Value	Description	Manufacturer
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, JPX2, JPX4	Shorted	Wire jumper (see Mech Parts)	
JPX3	1R	RSMF1TB - metal film res - 1W - 2% - 250ppm/°C	AKANEOHM
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	VOTC2109000 200A	Input EMI filter 2mHx2 - 4.7A	YUJING
L2	VOTC2708001 500A	Input EMI filter 15mHx2 - 3.7A	YUJING
L3	LSR2306-1	51uH-6A DM inductor	DELTA
L4	QP303825H_3 70uH	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	N.M.	Not mounted	
R3	N.M.	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	10R	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R12, R13, R14	0R3	RSMF1TB - metal film res - 1W - 2% - 250ppm/°C	AKANEOHM
R15, R18	10R	SMD standard film res - 1/8W - 5% - 250ppm/°C	VISHAY

Table 11. Bill of material - motherboard (continued)

Reference	Value	Description	Manufacturer
R43, R44	47R	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
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
T1	LP3925H	Resonant power transformer - LP3925H	YUJING

Table 12. Bill of material - control board

Reference	Value	Description	Manufacturer
C101	100nF	100V CERCAP - general purpose	AVX
C102	10uF-50V	Aluminum ELCAP - YXF series - 105°C	RUBYCON
C103	22uF-50V	50V-ELCAP SK type tol 20%	YAGEO
C104	68nF	50V CERCAP - general purpose	AVX
C105	820nF	25V CERCAP - general purpose	AVX
C106	100uF-50V	Aluminum ELCAP - YXF series - 105°C	RUBYCON
C107, C127	100nF	50V CERCAP - general purpose	AVX
C108, C113	2n2	50V CERCAP - C0G - 10%	AVX
C109, C125	1n5	50V CERCAP - general purpose	AVX
C110	1uF	CERCAP - 25V - X7R - 10%	AVX
C111	680p	50V CERCAP - general purpose	AVX

Table 12. Bill of material - control board (continued)

Reference	Value	Description	Manufacturer
C112	3n9	50V CERCAP - general purpose	AVX
C114	330uF-50V	Aluminum ELCAP - YXF series - 105°C	TREC
C115	2.2uF	25V CERCAP - general purpose	AVX
C116, C117	220nF	25V CERCAP - general purpose	AVX
C118	330pF	25V CERCAP - general purpose	AVX
C119	47nF	25V CERCAP - general purpose	AVX
C120	100nF	25V CERCAP - general purpose	AVX
C121	10uF-50V	25V CERCAP - general purpose	TDK
C122	4n7	25V CERCAP - general purpose	AVX
C123	10nF	25V CERCAP - general purpose	AVX
C124	560pF	25V CERCAP - general purpose	AVX
C126	N.M.	50V CERCAP - X7R - 10%	AVX
D101, D102, D103, D105, D108	LL4148	High speed signal diode	VISHAY
D104	BZV55-C15	ZENER diode	VISHAY
D106	STPS1H100A	Power Schottky diode	STMicroelectronics
D107	BZV55-B11-NM	ZENER diode	VISHAY
D109	N.M.	ZENER diode	DIODES
IC101	L4984D	CCM PFC 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°	
Q101	BSS126	N-CH Depletion MOSFET	INFINEON
Q102	MMBT4401	NPN small signal BJT	VISHAY
Q103	BSS159	N-CH Depletion MOSFET	INFINEON
Q104	N.M.	NPN small signal BJT	VISHAY
R101	10R	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R102, R103	62k	SMD standard film res - 1/4W - 1% - 100ppm/°C	VISHAY
R104, R126	2M4	Standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R105, R106, R116, R128	3M3	SMD standard film res - 1/4W - 1% - 100ppm/°C	VISHAY
R127	2M4	SMD standard film res - 1/4W - 1% - 100ppm/°C	VISHAY
R107, R115	4M7	SMD standard film res - 1/4W - 1% - 100ppm/°C	VISHAY
R108	470R	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY

Table 12. Bill of material - control board (continued)

Reference	Value	Description	Manufacturer
R109	100k	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R110, R117, R147	100k	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R111	120k	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R112	43k	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R113, R114	110k	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R118	100K	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R119, R136	1M0	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 - 1/8W - 1% - 100ppm/°C	VISHAY
R124	0R	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R125	0.33R	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R129	220k	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R130	1.5k	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	Shorted	Wire jumper (see Mech Part)	
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
R140	10R	SMD standard film res - 1/4W - 1% - 100ppm/°C	VISHAY
R141	100R	SMD standard film res - 1/8W - 5% - 200ppm/°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, R145, R146	N.M.	SMD standard film res - 1/8W - 5% - 200ppm/°C	VISHAY
R148	Shorted	SMD standard film res - 1/8W - 1% - 100ppm/°C	VISHAY
R149	10 M	SMD standard film res - 1/8W - 5% - 200ppm/°C	VISHAY
U101	TLVH431AIL3T	1.24V programmable shunt voltage reference	STMicroelectronics

Table 13. Bill of Material - EVLSRK2001-SPF2

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
JP201	TSW-113-22-F-D-RA	13x2p right angle male header TSW series	SAMTEC
Q201, Q202, Q203, Q204	STL140N6F7	N-channel Power MOSFET	STMicroelectronics
R201	10R	SMD standard film res - 1/4W - 5% - 250ppm/°C	VISHAY
R202	0R	SMD standard film res - 1/8W - 5% - 250ppm/°C	VISHAY
R203, R204	100R	SMD standard film res - 1/8W - 5% - 250ppm/°C	VISHAY
R205, R206, R207, R208	1R0	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 Support material

Table 14. Support material documentation

Documentation
Datasheet L4984, CCM PFC controller
Datasheet L6699, Enhanced high-voltage resonant controller
SRK2000A datasheet, Adaptive synchronous rectification controller for LLC resonant converter
TSC888CILT datasheet, 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(TM) II Power MOSFET in TO-220FP
STF22NM60N datasheet , N-channel 600 V, 0.2 Ohm, 16 A MDmesh(TM) II Power MOSFET in TO-220FP
STL140N4LLF5 datasheet, N-channel 40 V, 0.00275 Ω, 32 A, PowerFLAT™ 5x6 STripFET™ V Power MOSFET
STTH8S06FP datasheet, Turbo 2 ultrafast high voltage rectifier
STPS1H100A datasheet, HIGH VOLTAGE POWER SCHOTTKY RECTIFIER
AN4027: "12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6699 and SRK2000"
AN4149: "Designing a CCM PFC pre-regulator based on the L4984D"
AN4163: "EVL4984-350W: 350 W CCM PFC pre-regulator with the L4984D"
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12 Revision history

Table 15. Document revision history

Date	Revision	Changes
04-Jun-2019	1	Initial release.
16-Dec-2019	2	Updated Specifications *on page 1*. Changed R127 from 3.3 MΩ to 2.4 MΩ on the Schematic (*Figure 2. on page 4*) and on the BOM (*Table 12. on page 28*). Modified *Table 6. on page 9*.