AN3233
Application note

12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6599A, and SRK2000

Introduction

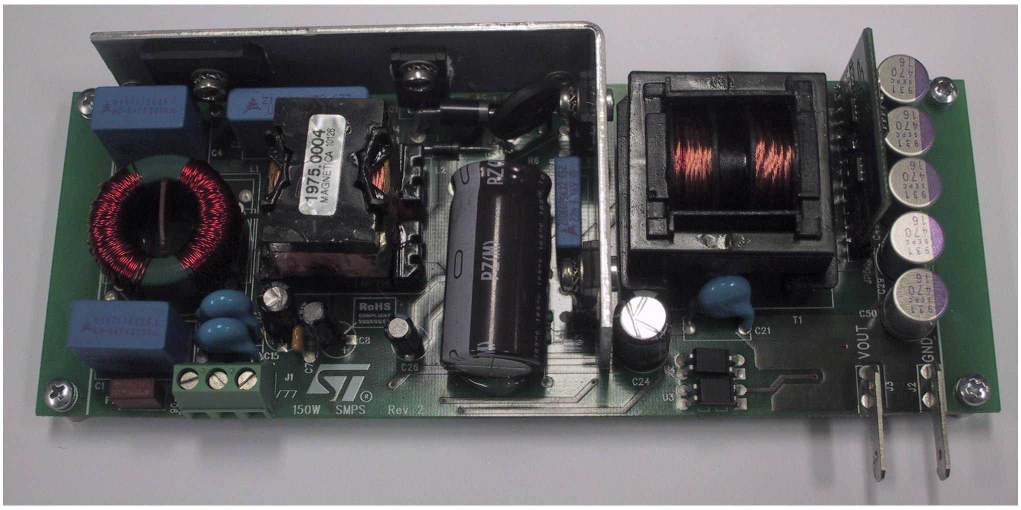
This application note describes the characteristics and features of a 150 W SMPS demonstration board (EVL150W-ADP-SR), tailored to all-in-one computer power supply (PS) specifications.

The characteristics of this design are the very high efficiency and low consumption at light load which make it a viable solution for applications compliant with ENERGY STAR® eligibility criteria (EPA rev. 5.0 computer and EPA rev. 2.0 EPS). One of the key factors to achieving high efficiency at heavy load is the SRK2000. This synchronous rectification (SR) driver for LLC resonant converters allows a significant decrease in secondary side losses.

Standby consumption is very low thanks to the sleep function embedded in the SRK2000 and the high voltage start-up circuit integrated in the L6563H. The possibility of driving the PFC burst mode via the L6599A PFC_STOP pin dramatically boosts light load efficiency.

Additionally, a secondary sensing circuit, dedicated to driving the primary controller into burst mode, reduces deviation of light load efficiency against resonant circuit parameter spread, improving the repeatability of design in production volumes.

Figure 1. EVL150W-ADP-SR: 150 W SMPS demonstration board



Contents

List of figures

List of tables

1 Main characteristics and circuit description

The main features of the SMPS are:

- Input mains range: 90 ÷ 264 Vac - frequency 45 ÷ 65 Hz
- Output voltage: 12 V at 12.5 A continuous operation
- Mains harmonics: Acc. to EN61000-3-2 Class-D or JEITA-MITI Class-D
- Standby mains consumption: <0.2 W at 230 Vac
- Efficiency at nominal load: > 91 % at 115 Vac
- EMI: according to EN55022-Class-B
- Safety: according to EN60950
- Dimensions: 65x154 mm, 28 mm component maximum height
- PCB: double side, 70 µm, FR-4, mixed PTH/SMT.

The circuit is composed of two stages: a front-end PFC using the L6563H and an LLC resonant converter based on the L6599A and the SRK2000, controlling the SR MOSFETs on the secondary side. The SR driver and the rectifier MOSFETs are mounted on a daughterboard.

The L6563H is a current mode PFC controller operating in transition mode and implements a high voltage start-up source to power on the converter.

The L6599A integrates all the functions necessary to properly control the resonant converter with a 50 % fixed duty cycle and working with variable frequency.

The output rectification is managed by the SRK2000, an SR driver dedicated to LLC resonant topology.

The PFC stage works as the pre-regulator and powers the resonant stage with a constant voltage of 400 V. The downstream converter operates only if the PFC is on and regulating. In this way, the resonant stage can be optimized for a narrow input voltage range.

The L6599A's LINE pin (pin 7) is dedicated to this function. It is used to prevent the resonant converter from working with an input voltage that is too low which can cause incorrect capacitive mode operation. If the bulk voltage (PFC output) is below 380 V, the resonant start-up is not allowed. The L6599A LINE pin internal comparator has a hysteresis allowing to set the turn-on and turn-off voltage independently. The turn-off threshold has been set to 300 V in order to avoid capacitive mode operation but allow the resonant stage to operate even in the case of mains sag and consequent PFC output dip.

The transformer uses the integrated magnetic approach, incorporating the resonant series inductance. Therefore, no external, additional coil is needed for the resonance. The transformer configuration chosen for the secondary winding is center-tap.

On the secondary side, the SRK2000 core function is to switch on each synchronous rectifier MOSFET whenever the corresponding transformer half-winding starts conducting (i.e. when the MOSFET body diode starts conducting) and then switching it off when the flowing current approaches zero. For this purpose, the IC is provided with two pins (DVS1 and DVS2) sensing the MOSFET drain voltage level.

One of the SRK2000’s main characteristics is the ability to automatically detect light load operation and enter sleep mode, disabling MOSFET driving and decreasing its consumption. This function allows great power saving at light load with respect to benchmark SR solutions.

In order to decrease the output capacitors size, aluminium solid capacitors with very low ESR were preferred to standard electrolytic ones. Therefore, high frequency output voltage ripple is limited and output LC filter is not required. This choice allows a saving of output inductor power dissipation which can be significant in the case of high output current applications like this.

Start-up sequence

The PFC acts as master and the resonant stage can operate only if the PFC output is delivering the nominal output voltage. Therefore, the PFC starts first and then the downstream converter turns on. At the beginning, the L6563H is supplied by the integrated high voltage start-up circuit; as soon as the PFC starts switching, a charging pump connected to the PFC inductor supplies both PFC and resonant controllers and the HV internal current source is disabled. Once both stages have been activated, the controllers are supplied also by the auxiliary winding of the resonant transformer, assuring correct supply voltage even during standby operation.

As the L6563H integrated HV start-up circuit is turned off, and therefore is not dissipative during the normal operation, it gives a significant contribution to power consumption reduction when the power supply operates at light load, in accordance with worldwide standby standards currently required.

Standby power saving

The board has a burst mode function implemented which allows power saving during light load operation.

The L6599A's STBY pin (pin 5) senses the optocoupler's collector voltage (U3), which is related to the feedback control. This signal is compared to an internal reference (1.24 V). If the voltage on the pin is lower than the reference, the IC enters an idle state and its quiescent current is reduced. When the voltage exceeds the reference by 50 mV, the controller restarts the switching.

The burst mode operation load threshold can be programmed by properly choosing the resistor connecting the optocoupler to pin RFMIN (R34). Basically, R34 sets the switching frequency at which the controller enters burst mode.

As the power at which the converter enters burst mode operation heavily influences converter efficiency at light load, it must be properly set. Anyhow, despite this threshold being well set, if its tolerance is too wide, the light load efficiency of mass production converters has a considerable spread.

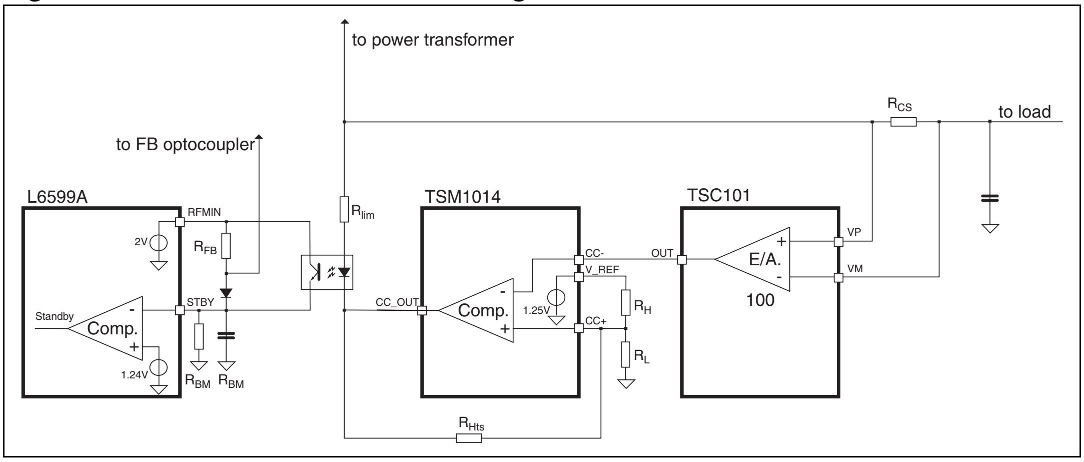
The main factors affecting the burst mode threshold tolerance are the control circuitry tolerances and, even more influential, the tolerances of resonant inductance and the resonant capacitor. Slight changes of resonance frequency can affect the switching frequency and, consequently, notably change the burst mode threshold.

Typical production spread of these parameters, which fits the requirements of many applications, are no longer acceptable if very low power consumption in standby must be guaranteed.

As reducing production tolerance of resonant components causes cost increases, a new cost-effective solution is required.

The key point of the proposed solution is to directly sense the output load to set the burst mode threshold. In this way the resonant elements parameters no longer affect this threshold. The implemented circuit block diagram is shown in *Figure 2*.

Figure 2. Burst mode circuit block diagram



The output current is sensed by a resistor (R_{CS}); the voltage drop across this resistor is amplified by TSC101, a dedicated high side current sense amplifier; its output is compared to a set reference by the TSM1014; if the output load is high, the signal fed into the CC- pin is above the reference voltage, CC_OUT stays down and the optocoupler transistor pulls up the L6599A's STBY pin to the RFMIN voltage (2 V), setting continuous switching operation (no burst mode); if load decreases, the voltage on CC- falls below the set threshold, CC_OUT goes high opening the connection between RFMIN and STBY and so allowing burst mode operation by the L6599A.

R_{CS} is dimensioned considering two constraints. The first is the maximum power dissipation allowed, based on the efficiency goal. The second limitation is imposed by the necessity to feed a reasonable voltage signal into the TSM1014A inverting input. In fact, signals which are too small would affect system accuracy.

On this board, the maximum acceptable power dissipation has been set to $P_{loss,MAX}$ = 500 mW. R_{CS} maximum value is calculated as follows:

$$R_{CS,MAX} = \frac{P_{loss,MAX}}{I^2_{out,MAX}} = 3.2\text{m}\Omega$$

The burst mode threshold is set at 5 W corresponding to C_{BM} = 417 mA output current at 12 V.

Choosing $V_{CC+,min}$ = 50 mV as the minimum reference of TSM1014A, which allows a good signal-to-noise ratio, the R_{CS} minimum value is calculated as follows:

$$R_{CS,min} = \frac{V_{CC+,min}}{100 \cdot C_{BM}} = 1.2\text{m}\Omega$$

The actual value of the mounted resistor is 2 mΩ, corresponding to P_{loss} = 312 mW power losses at full load. The actual resistor value at burst mode threshold current provides an output voltage by TSC101 of 83 mV. The reference voltage of TSM1014 V_{CC+} must be set at this level. The resistor divider setting the TSM1014 threshold R_H and R_L should be in the range of kilo-ohms to minimize dissipation. By selecting R_L = 22 kΩ, the right RH value is obtained as follows:

$$R_H = \frac{R_L(1.25V - V_{BM})}{V_{BM}} = 309k\Omega$$

The value of the mounted resistor is 330 kΩ.

R_{Hts} sets a small de-bouncing hysteresis and is in the range of mega-ohms. R_{lim} is in the range of tens of kilo-ohms and limits the current flowing through the optocoupler's diode.

Both L6599A and L6563H implement their own burst mode function but, in order to improve the overall power supply efficiency, at light load the L6599A drives the L6563H via the PFC_STOP pin and enables the PFC burst mode: as soon as the L6599A stops switching due to load drops, its PFC_STOP pin pulls down the L6563H's PFC_OK pin disabling PFC switching. Thanks to this simple circuit, the PFC is forced into idle state when the resonant stage is not switching and rapidly wakes up when the downstream converter restarts switching.

Fast voltage feed forward

The voltage on the L6563H VFF pin (pin 5) is the peak value of the voltage on the MULT pin (pin 3). The RC network (R15+R26, C12) connected to VFF completes a peak-holding circuit. This signal is necessary to derive information of the RMS input voltage to compensate the loop gain that is mains voltage dependent.

Generally speaking, if the time constant is too small, the voltage generated is affected by a considerable amount of ripple at twice the mains frequency causing distortion of the current reference (resulting in higher THD and lower PF). If the time constant is too large, there is a considerable delay in setting the right amount of feed-forward, resulting in excessive overshoot or undershoot of the pre-regulator's output voltage in response to large line voltage changes.

To overcome this issue, the L6563H implements the fast voltage feed forward function. As soon as the voltage on the VFF pin decreases by a set threshold (40 mV typically), a mains dip is assumed and an internal switch rapidly discharges the VFF capacitor via a 10 kΩ resistor. Thanks to this feature, it is possible to set an RC circuit with a long time constant, assuring a low THD, keeping a fast response to mains dip.

Brownout protection

Brownout protection prevents the circuit from working with abnormal mains levels. It is easily achieved using the RUN pin (pin 12) of the L6563H: this pin is connected through a resistor divider to the VFF pin (pin 5), which provides the information of the mains voltage peak value. An internal comparator enables the IC operations if the mains level is correct, within the nominal limits. At startup, if the input voltage is below 90 Vac (typ.), circuit operations are inhibited.

Output voltage feedback loop

The feedback loop is implemented by means of a typical circuit using the dedicated operational amplifier of TSM1014A modulating the current in the optocoupler's diode. The second comparator embedded in the TSM1014A - usually dedicated to constant current regulation - is here utilized for burst mode as previously described.

On the primary side, R34 and D17 connect the RFMIN pin (pin 4) to the optocoupler's phototransistor closing the feedback loop. R31, which connects the same pin to ground, sets the minimum switching frequency. The R-C series R44 and C18 sets both soft-start maximum frequency and duration.

L6599A overload and short-circuit protection

The current into the primary winding is sensed by the loss-less circuit R41, C27, D11, D10, R39, and C25 and it is fed into the ISEN pin (pin 6). In the case of overcurrent, the voltage on the pin overpasses an internal threshold (0.8 V) that triggers a protection sequence. The capacitor (C45) connected to the DELAY pin (pin 2) is charged by an internal 150 µA current generator and is slowly discharged by the external resistor (R24). If the voltage on the pin reaches 2 V, the soft-start capacitor is completely discharged so that the switching frequency is pushed to its maximum value. 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.

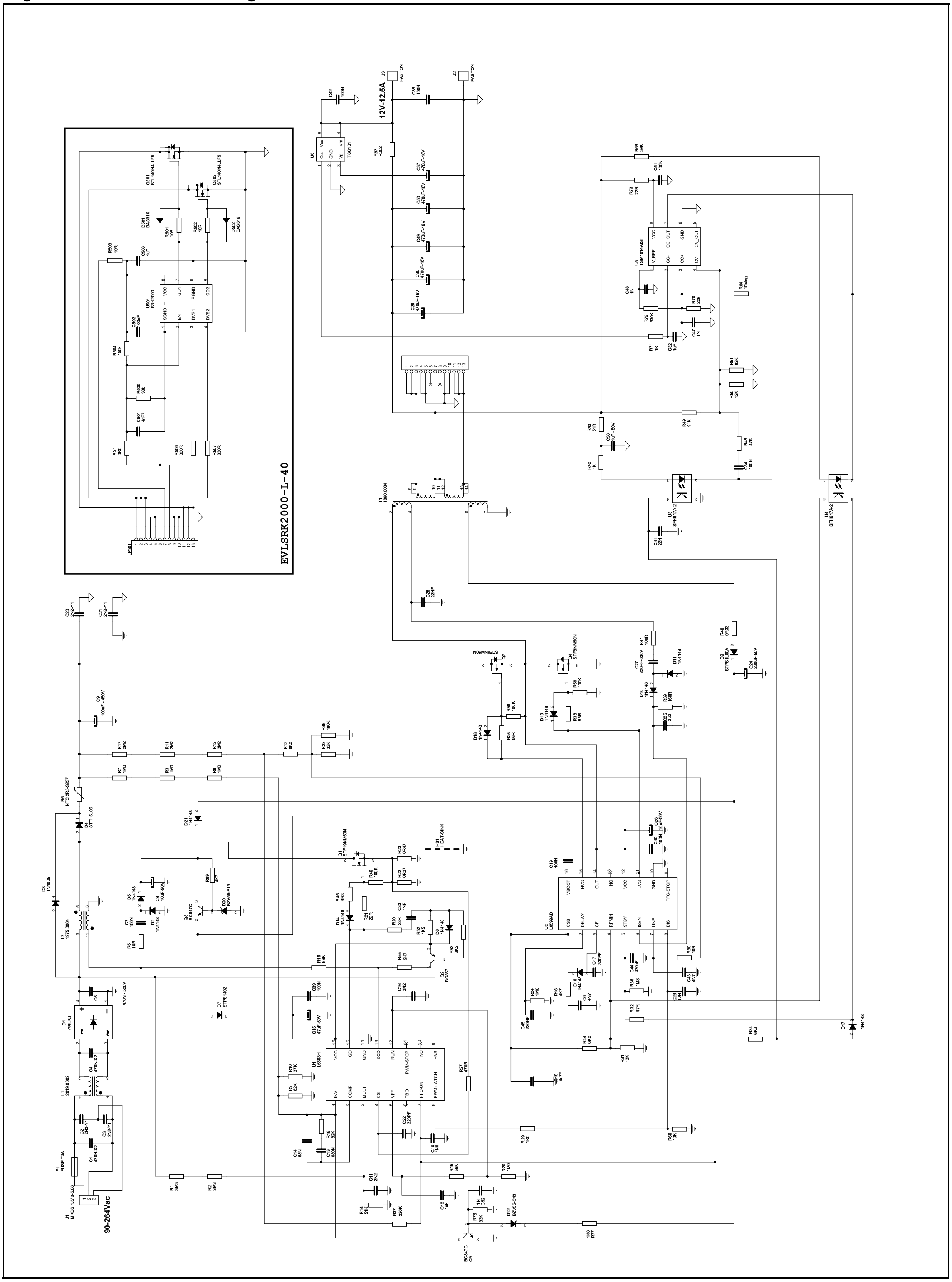
Open loop protection

Both circuit stages, PFC and resonant, are equipped with their own overvoltage protections.

The PFC controller L6563H monitors its output voltage via the resistor divider connected to a dedicated pin (PFC_OK, pin 7) protecting the circuit in case of loop failures or disconnection. If a fault condition is detected, the internal circuitry latches the L6563H operations and, by means of the PWM_LATCH pin (pin 8), it also latches the L6599A via the DIS pin (pin 8). The converter is kept latched by the L6563H internal HV start-up circuit that supplies the IC by charging the Vcc capacitor periodically. To resume converter operation, a mains restart is necessary.

The output voltage is monitored by sensing the Vcc voltage. If Vcc voltage overrides the D12 breakdown voltage, Q9 pulls down the L6563H INV pin latching the converter.

Figure 3. Electrical diagram



2 Efficiency measurement

EPA rev. 2.0 external power supply compliance verification

Table 1 shows the no-load consumption and the overall efficiency, measured at the nominal mains voltages. At 115 Vac the average efficiency is 90.6 %, while at 230 Vac it is 91.8 %. Both values are much higher than the 87 % required by EPA rev 2.0 external power supply (EPS) limits.

The efficiency at nominal load, 230 Vac, is 94 %, which is a very high efficiency for a double stage converter and confirms the benefit of implemented SR.

Also at no load the board performances are superior: maximum no-load consumption at nominal mains voltage is 200 mW; this value is significantly lower than the limit imposed by the ENERGY STAR program which is 500 mW.

Table 1. Overall efficiency

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	12.10	0.00	0.00	0.20	-----------	12.10	0.00	0.00	0.20	-----------
25 % load eff.	12.14	3.10	37.63	43.15	87.2 %	12.13	3.10	37.60	43.08	87.3 %
50 % load eff.	12.14	6.19	75.15	81.30	92.4 %	12.12	6.19	75.02	82.34	91.1 %
75 % load eff.	12.08	9.37	113.19	120.81	93.7 %	12.07	9.38	113.22	123.00	92.0 %
100 % load eff.	12.04	12.47	150.14	159.79	94.0 %	12.04	12.50	150.50	163.90	91.8 %
Average eff.					91.8 %					90.6 %

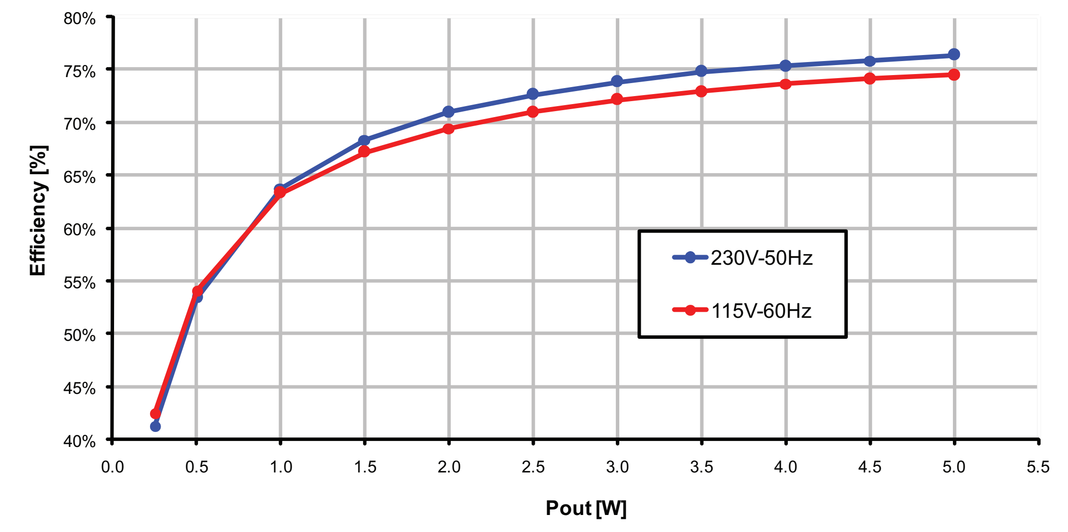
Light load operation efficiency

Measurement results are reported in *Table 2* and plotted in *Figure 4*. As can be seen, efficiency is better than 50 % even for very light loads such as 500 mW.

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. [%]
0.25 W	12.12	20.84	0.253	0.581	43.5 %	12.12	20.84	0.253	0.565	44.7 %
0.5 W	12.12	41.34	0.501	0.931	53.8 %	12.12	41.34	0.501	0.912	55.0 %
1.0 W	12.12	82.65	1.002	1.553	64.5 %	12.12	82.65	1.002	1.552	64.5 %
1.5 W	12.12	123.93	1.502	2.203	68.2 %	12.12	123.93	1.502	2.211	67.9 %
2.0 W	12.12	164.93	1.999	2.797	71.5 %	12.12	164.93	1.999	2.828	70.7 %
2.5 W	12.12	206.75	2.506	3.392	73.9 %	12.12	206.75	2.506	3.439	72.9 %
3.0 W	12.11	248.00	3.003	3.979	75.5 %	12.11	248.00	3.003	4.040	74.3 %
3.5 W	12.11	288.25	3.491	4.560	76.6 %	12.11	288.25	3.491	4.644	75.2 %
4.0 W	12.11	330.06	3.997	5.155	77.5 %	12.11	330.06	3.997	5.258	76.0 %
4.5 W	12.11	372.31	4.509	5.748	78.4 %	12.11	372.31	4.509	5.874	76.8 %
5.0 W	12.11	413.34	5.006	6.327	79.1 %	12.11	413.34	5.006	6.474	77.3 %

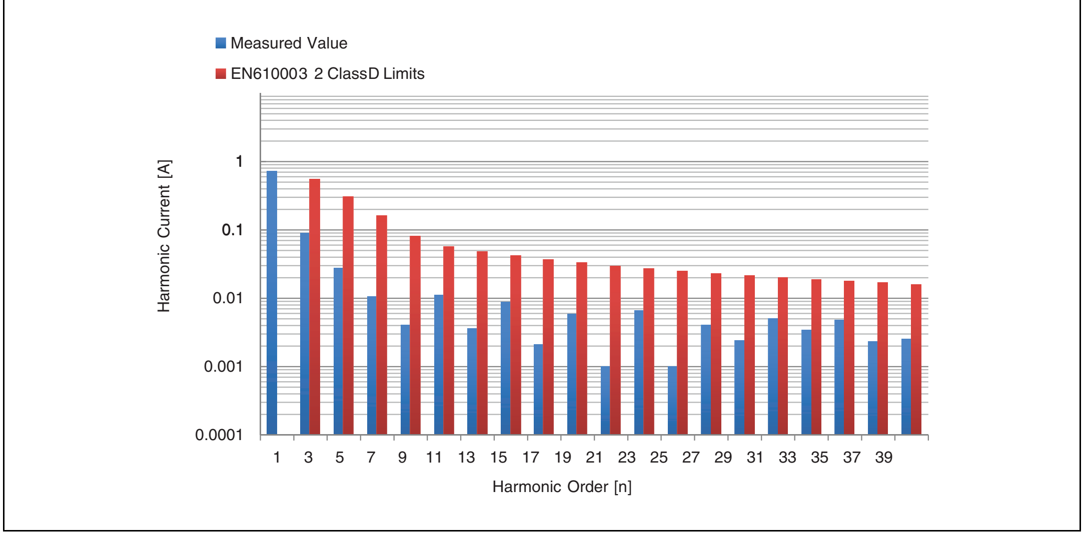
Figure 4. Light load efficiency diagram



3 Harmonic content measurement

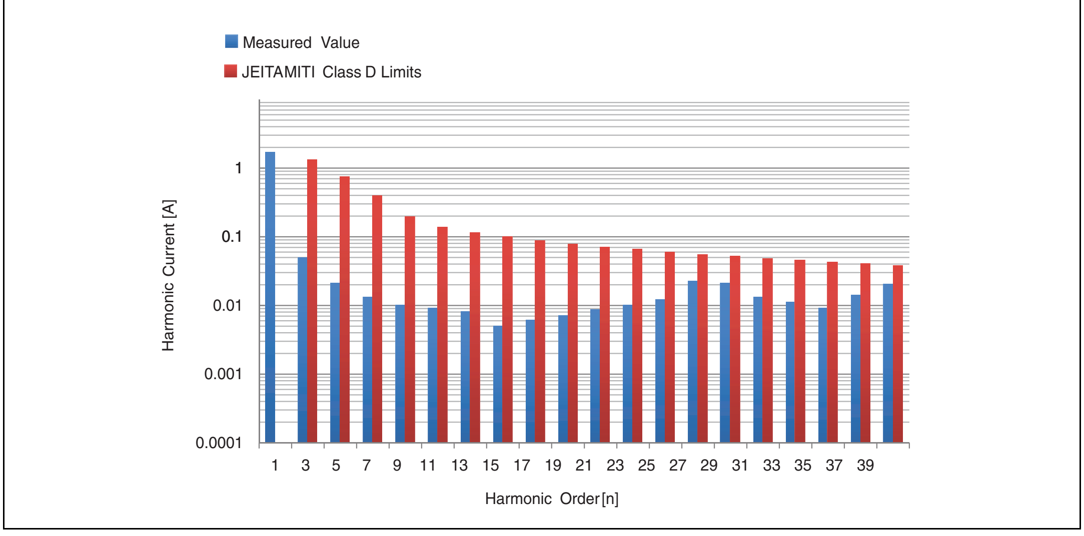
The board has been tested according to the European standard EN61000-3-2 Class-D and the Japanese standard JEITA-MITI Class-D, at both the nominal input voltage mains. As shown in the following images, the circuit is able to reduce the harmonics well below the limits of both regulations.

Figure 5. Compliance with EN61000-3-2 at 230 Vac – 50 Hz, full load



THD = 14.70 % - PF = 0.978

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



THD = 5.20 % - PF = 0.995

On the bottom side of the diagrams the total harmonic distortion (THD) and power factor (PF) have been measured too. The values in all conditions give a clear idea regarding the correct functioning of the PFC.

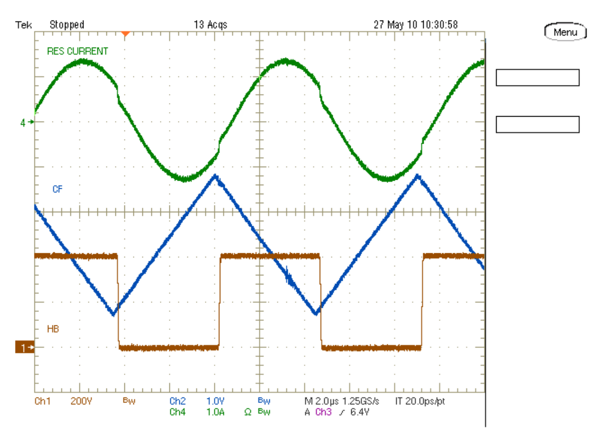
4 Functional check

Steady-state operation

In *Figure 7* some waveforms relevant to the resonant stage during steady-state operation are given. The selected switching frequency is about 120 kHz, in order to have a good trade off between transformer losses and dimensions. The converter operates slightly above the resonance frequency.

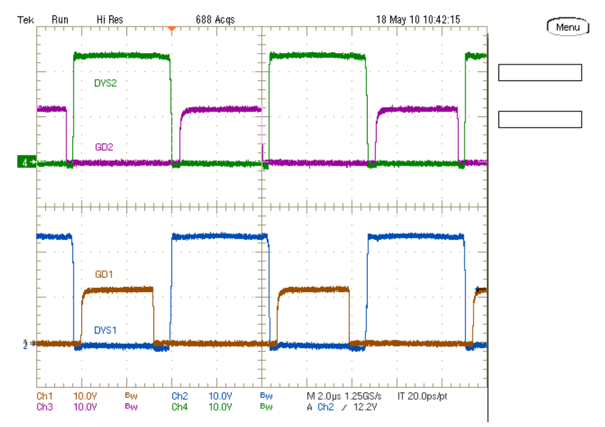
Figure 8 shows the key signals of SRK2000: each rectifier MOSFET is switched on and off according to its drain-source voltage which, during conduction time, is the voltage image of the current flowing through the MOSFET.

Figure 7. Resonant stage waveforms at 115 V – 60 Hz – full load



CH1: HB voltage
CH2: CF pin voltage
CH4: Res. tank current

Figure 8. SRK2000 key signals at 115 V – 60 Hz – full load

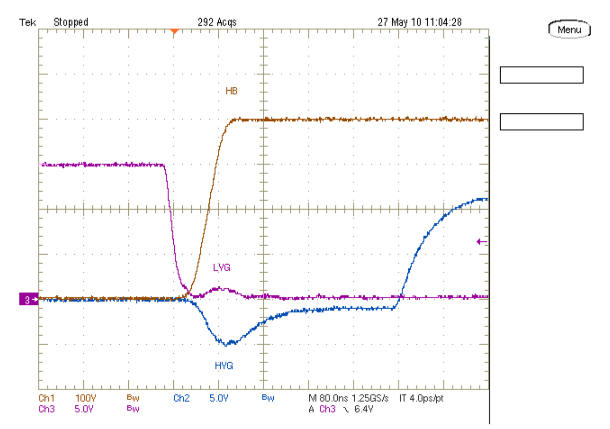


CH1: GD1 pin voltage
CH2: DVS1 pin
CH3: GD2 pin voltage
CH4: DVS2 pin

Zero voltage switching

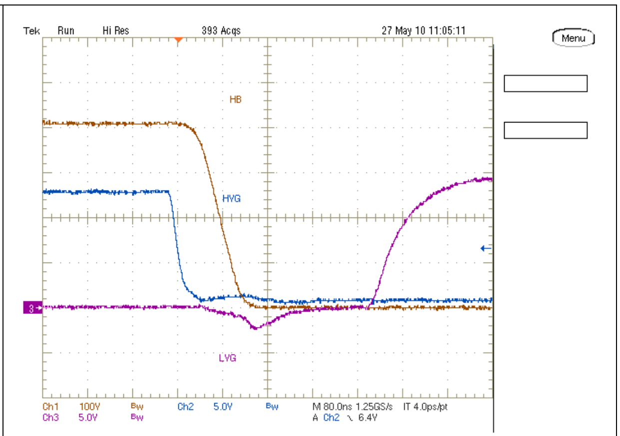
Figure 9 and *10* show details of ZVS operation. Both MOSFETs turn on when current is flowing through their body diodes and drain-source voltage is zero.

Figure 9. High-side MOSFET ZV turn-on at 115 V – 60 Hz – full load



CH1: HB voltage CH2: HVG pin voltage
CH3: LVG pin voltage

Figure 10. Low-side MOSFET ZV turn-on at 115 V – 60 Hz – full load

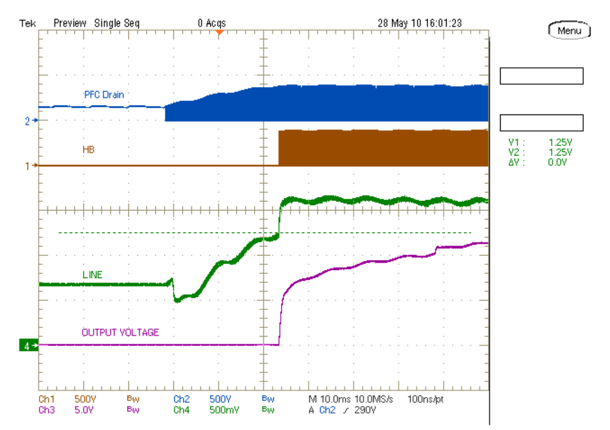


CH1: HB voltage CH2: HVG pin voltage
CH3: LVG pin voltage

Startup and shutdown

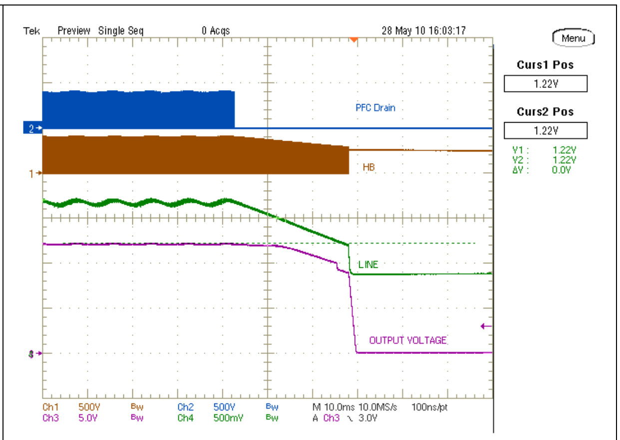
Figure 11 and *12* show the start-up and shut-down sequence of the two converter stages: The PFC starts first and the LLC only starts after the PFC achieves regulation. In the same way the PFC stops first and the LLC shuts down as its input voltage falls below the allowed voltage.

Figure 11. Converter startup at 115 Vac full load



CH1: Half-bridge node CH2: PFC drain
CH3: Output voltage CH4: LINE pin

Figure 12. Converter shutdown at 115 Vac full load



CH1: Half-bridge node CH2: PFC drain
CH3: Output voltage CH4: LINE pin

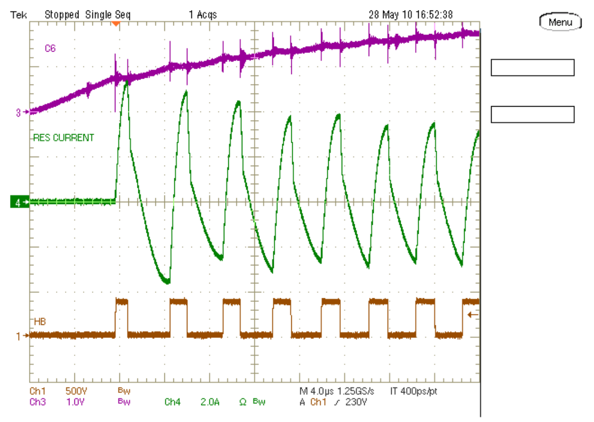
Figure 13 and *14* again show startup and shutdown but highlighting the current flowing through the resonant tank.

In *Figure 13* it can be noted that the resonant current at turn-on has some oscillations due to the charging of the resonant elements. However, current zero-crossing always lags the HB commutations and, consequently, MOSFETs are soft switched.

Figure 14 shows the resonance current at shutdown. Due to input voltage dip, the LLC stage operates below resonance, but current still lags the HB voltage.

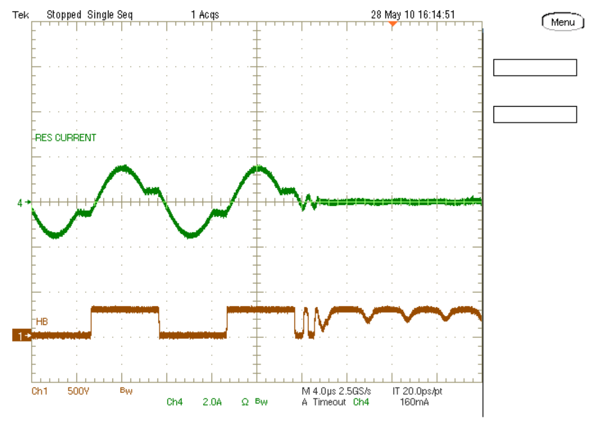
Avoiding hard switching also during transitions like startup and shutdown is a must for a reliable design, because some hard switching commutations could also damage the converter.

Figure 13. Startup resonant current



CH1: Half-bridge
CH3 C6 voltage
CH4: Res. tank current

Figure 14. Shutdown resonant current

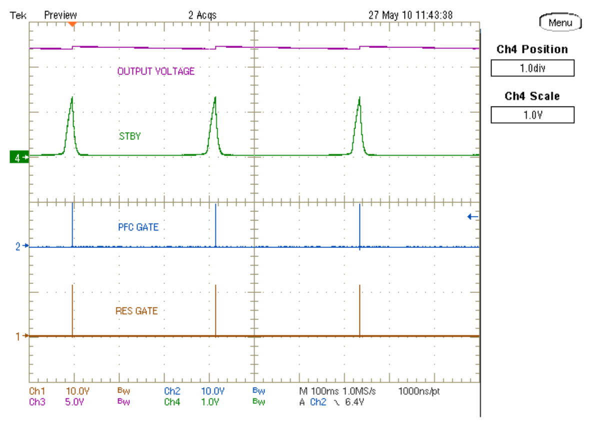


CH1: Half-bridge
CH4: Res. tank current

No-load operation

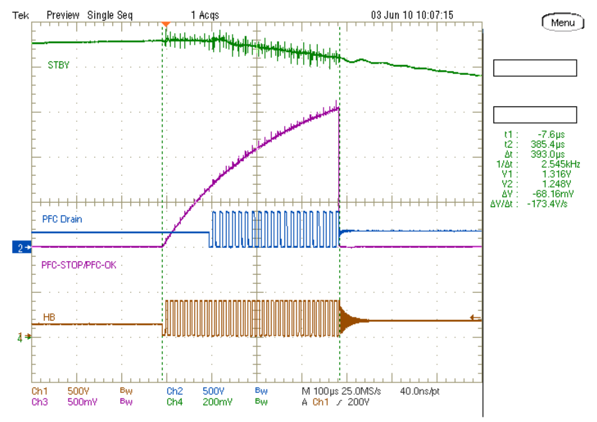
In *Figure 15* and *16*, some burst mode waveforms are captured. As seen, both L6599A and L6563H operate in burst mode. In *Figure 16*, it is possible to see that PFC and LLC bursts are synchronized.

Figure 15. No-load operation



CH1: LVG pin
CH2: PFC gate
CH3: Output voltage
CH4: STBY pin

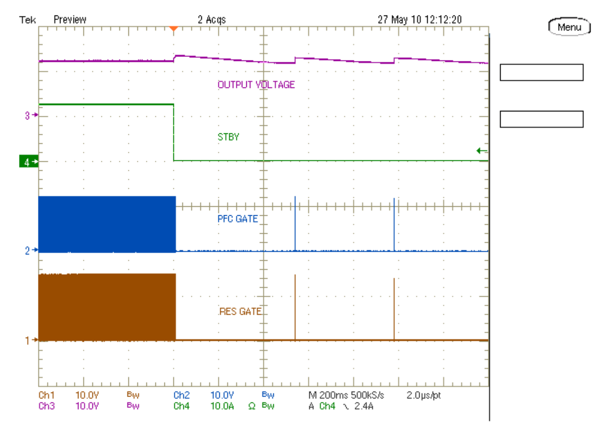
Figure 16. No-load operation – detail



CH1: Half-bridge
CH2: PFC Drain
CH3: PFC-STOP pin
CH4: STBY pin

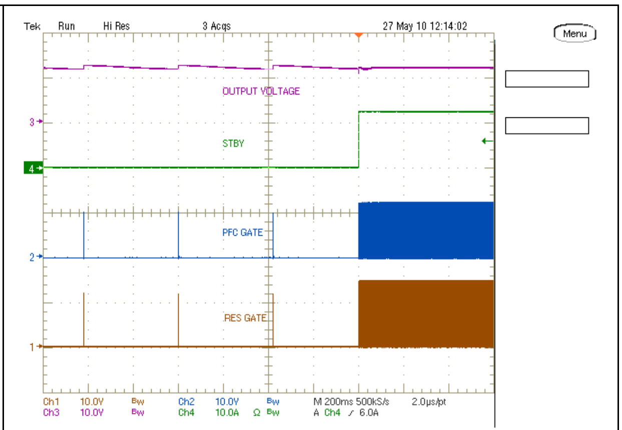
In *Figure 17* and *18* the transitions from full load to no load and vice versa have been checked. As seen in the images, both transitions are clean and there isn't any output voltage dip.

Figure 17. Transition full load to no load at 115 Vac – 60 Hz



CH1: LVG pin CH2: PFC gate
CH3: Output voltage CH4: Output current

Figure 18. Transition no load to full load at 115 Vac – 60 Hz



CH1: LVG pin CH2: PFC gate
CH3: Output voltage CH4: Output current

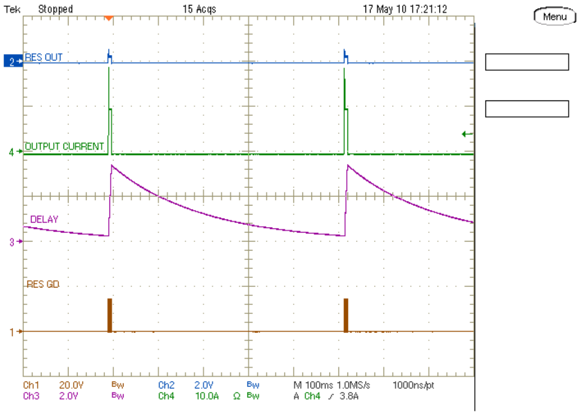
Overcurrent and short-circuit protection

The L6599A is equipped with a current sensing input (pin 6, ISEN) and a dedicated overcurrent management system. The current flowing in the resonant tank is detected and the signal is fed into the ISEN pin. It is internally connected to a first comparator, referenced to 0.8 V, and to a second comparator referenced to 1.5 V. If the voltage externally applied to the pin exceeds 0.8 V, the first comparator is tripped causing an internal switch to be turned on and the soft-start capacitor CSS to be discharged.

Under output short-circuit, this operation results in an almost constant peak primary current.

With the L6599A, the board designer can externally program the maximum time that the converter is allowed to run overloaded or under short-circuit conditions. Overloads or short-circuits lasting less than the set time do not cause any other action, therefore providing the system with immunity to short duration phenomena. If, instead, the overload condition continues, a protection procedure is activated that shuts down the L6599A and, in case of continuous overload/short-circuit, results in continuous intermittent operation with a user defined duty cycle. This function is realized with the DELAY pin (pin 2), by means of a capacitor C45 and the parallel resistor R24 connected to ground. As the voltage on the ISEN pin exceeds 0.8 V, the first OCP comparator, in addition to discharging CSS, turns on an internal 150 µA current generator that, via the DELAY pin, charges C45. As the voltage on C45 is 3.5 V, the L6599A stops switching and the PFC_STOP pin is pulled low. Also the internal generator is turned off, so that C45 is now slowly discharged by R24. The IC restarts when the voltage on C45 is less than 0.3 V. Additionally, if the voltage on the ISEN pin reaches 1.5 V for any reason (e.g. transformer saturation), the second comparator is triggered, the L6599A shuts down and the operation is resumed after an off-on cycle. *Figure 19* shows intermittent operations caused by an output short-circuit: average output current is limited, preventing the converter from overheating and consequent failure.

Figure 19. Short-circuit at full load and 115 Vac – 60 Hz



CH1: LVG pin
CH2: Output voltage
CH3: DELAY pin
CH4: Output current

5 Thermal map

In order to check the design reliability, a thermal mapping by means of an IR camera was done. In *Figure 20* and *21* the thermal measurements of the board, component side, at nominal input voltage, are shown. Some pointers, visible in the images, have been placed across key components or components showing high temperature. The ambient temperature during both measurements was 27 °C.

Figure 20. Thermal map at 115 Vac – 60 Hz - full load

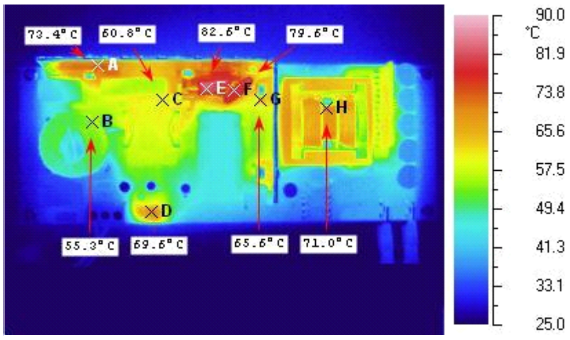


Figure 21. Thermal map at 230 Vac – 50 Hz - full load

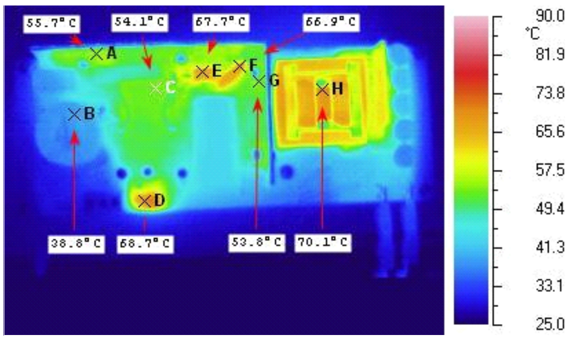


Table 3. Thermal maps reference points

Point	Reference	Description
A	D1	Bridge rectifier
B	L1	EMI filtering inductor
C	L2	PFC inductor
D	Q8	ICs supply regulator
E	D4	PFC output diode
F	R6	Inrush limiting NTC resistor
G	Q4	Resonant low side MOSFET
H	T1	Resonant power transformer

To directly check the efficiency of the SR stage, a thermal map of the SR daughterboard has also been taken. As seen, the temperature of both rectifier MOSFETs is below 70 °C, confirming that heatsinking is not required and confirming that the SR solution implemented allows a significant secondary side board dimension squeezing.

Figure 22. Thermal map SR daughterboard - full load

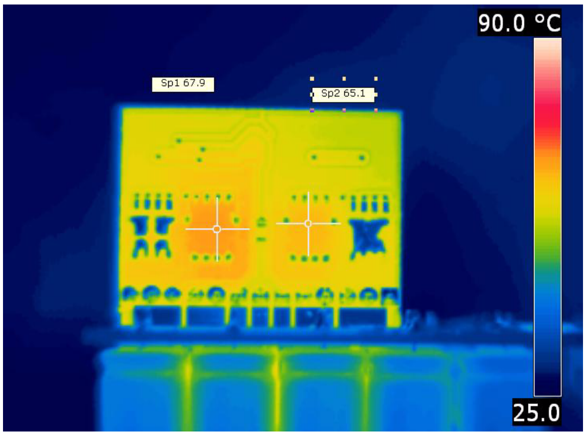


Table 4. Daughterboard thermal map reference points

Point	Reference	Description
SP1	Q501	SR MOSFET
SP2	Q502	SR MOSFET

6 Conducted emission pre-compliance test

Figure 23 and *24* represent the average measurement of the conducted emission at full load and nominal mains voltages. The limit indicated in red on the diagrams is relevant to average measurements and is the EN55022 Class-B one, which has more severe limits compared to Class-A, dedicated to IT technology equipment. As can be seen, in all test conditions the measurements are significantly below the limits.

Figure 23. CE average measurement at 115 Vac and full load

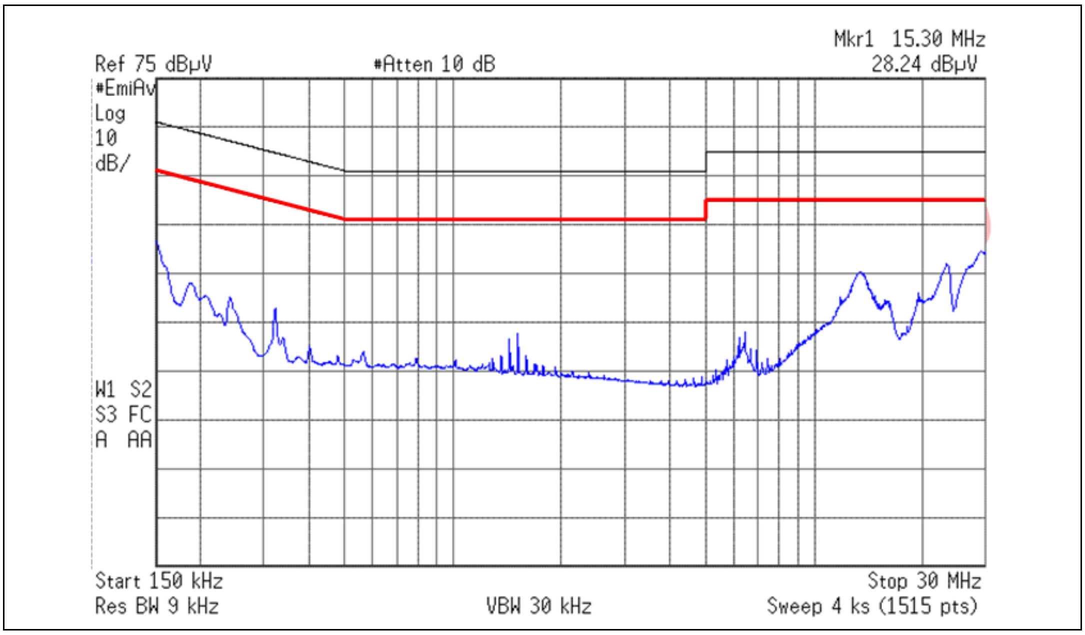
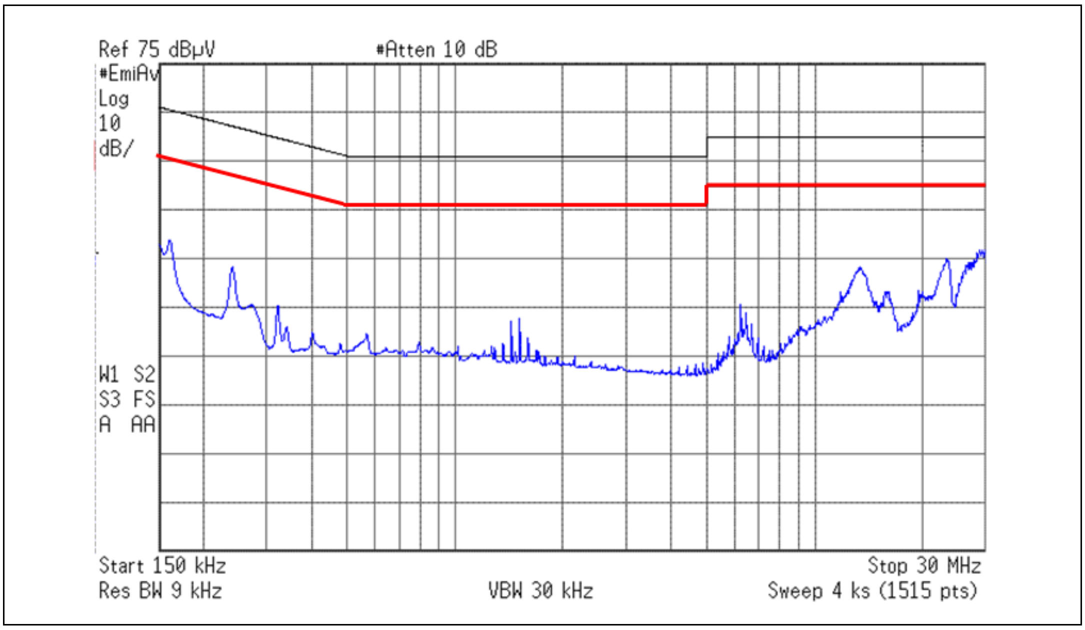


Figure 24. CE average measurement at 230 Vac and full load



7 Bill of material

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials

Des.	Part type/ part value	Description	Supplier	Case
C1	470N	X2 - film cap - B32922C3474K	EPCOS	9.0 x 18.0 p15 mm
C2	2N2	Y1 safety cap. DE1E3KX222M	MURATA	p10 mm
C3	2N2	Y1 safety cap. DE1E3KX222M	MURATA	p10 mm
C4	470N	X2 - film cap - B32922C3474K	EPCOS	9.0 x 18.0 p15 mm
C5	470N	520 V - film cap - B32673Z5474K	EPCOS	7.0 x 26.5 p22.5 mm
C6	4N7	50 V cercap - general purpose	AVX	0805
C7	100N	100 V cercap - general purpose	AVX	PTH
C8	10 uF - 50 V	Aluminium elcap - YXF series - 105 °C	RUBYCON	DIA 5.0 x 11 p2 mm
C9	100 uF - 450 V	Aluminium elcap - UPZ2W101MHD	NICHICON	DIA 18 x 32 mm
C10	1N0	50 V cercap - general purpose	AVX	0805
C11	2N2	50 V cercap - general purpose	AVX	0805
C12	1 uF	25 V cercap - general purpose	AVX	0805
C13	680N	25 V cercap - general purpose	AVX	1206
C14	68N	50 V cercap - general purpose	AVX	0805
C15	47 uF - 50 V	Aluminium elcap - YXF series - 105 °C	RUBYCON	DIA 6.3 x 11p2.5 mm
C16	2N2	50 V cercap - general purpose	AVX	1206
C17	330PF	50 V - 5 % - C0G - cercap	AVX	0805
C18	4u7F	25 V cercap - general purpose	MURATA	1206
C19	100N	50 V cercap - general purpose	AVX	1206
C20	2N2	Y1 safety cap. DE1E3KX222M	MURATA	p10 mm
C21	2N2	Y1 safety cap. DE1E3KX222M	MURATA	p10 mm

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
C22	220PF	50 V cercap - general purpose	AVX	0805
C23	10N	50 V cercap - general purpose	AVX	0805
C24	220 uF - 50 V	Aluminium elcap - YXF series - 105 °C	RUBYCON	DIA10 x 16 p5 mm
C25	2u2	50 V cercap - general purpose	AVX	0805
C26	10 uF - 50 V	Aluminium elcap - YXF series - 105 °C	RUBYCON	DIA 5.0 x 11 p2 mm
C27	220 pF - 630 V	630 V cercap - GRM31A7U2J220JW31	MURATA	1206
C28	22NF	1 KV - film cap - B32652A223K	EPCOS	5.0 x 18.0 p15 mm
C29	470 uF - 16 V	16 V aluminium solid capacitor	SANYO	DIA 10 X 13 p5 mm
C30	470 uF - 16 V	16 V aluminium solid capacitor	SANYO	DIA 10 x 13 p5 mm
C32	1 uF	50 V cercap - general purpose	AVX	0805
C33	1NF	50 V cercap - general purpose	AVX	0805
C34	100N	50 V cercap - general purpose	AVX	0805
C36	1 uF - 350 V	50 V cercap - general purpose	AVX	1206
C37	470 uF - 16 V	16 V aluminium solid capacitor	SANYO	DIA 10 x 13 p5 mm
C38	100N	50 V cercap - general purpose	AVX	0805
C39	100N	50 V cercap - general purpose	AVX	0805
C40	100N	50 V cercap - general purpose	AVX	1206
C41	22N	50 V cercap - general purpose	AVX	0805
C42	100N	50 V cercap - general purpose	AVX	0805
C43	4N7	50 V cercap - general purpose	AVX	0805
C44	3N3	50 V cercap - general purpose	AVX	0805
C45	220NF	25 V cercap - general purpose	AVX	0805
C47	1N	50 V cercap - general purpose	AVX	0805
C48	1N	50 V cercap - general purpose	AVX	0805

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
C49	470 uF	16 V aluminium solid capacitor	SANYO	DIA 10 x 13 p5 mm
C50	470 uF	16 V aluminium solid capacitor	SANYO	DIA 10 x 13 p5 mm
C51	100N	50 V cercap - general purpose	AVX	0805
C52	1N	25 V cercap - general purpose	AVX	0805
D1	GBU8J	Single phase bridge rectifier	VISHAY	STYLE GBU
D2	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D3	1N4005	General purpose rectifier	VISHAY	DO-41 DO - 41
D4	STTH5L06	Ultrafast high voltage rectifier	STMicroelectronics	DO-201
D5	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D6	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D7	STPS140Z	Power Schottky rectifier	STMicroelectronics	SOD-123
D9	STPS1L60A	Power schottky diode	STMicroelectronics	SMA
D10	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D11	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D12	BZV55-C43	Zener diode	VISHAY	Minimelf SOD-80
D14	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D16	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D17	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D18	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D19	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
D20	BZV55-B15	Zener diode	VISHAY	Minimelf SOD-80
D21	LL4148	High speed signal diode	VISHAY	Minimelf SOD-80
F1	FUSE T4A	Fuse 4A - time lag - 3921400	LITTLEFUSE	8.5x4 p.5.08 mm
HS1	HEAT-SINK	Heat sink for D1, Q1, Q3, Q4		DWG

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
J1	MKDS 1,5/ 3-5,08	PCB term. block, screw conn., pitch 5 mm - 3 W	PHOENIX CONTACT	DWG
J2	FASTON	Faston - connector		DWG
J3	FASTON	Faston - connector		DWG
L1	2019.0002	Common mode choke - EMI filter	MAGNETICA	DWG
L2	1975.0004	PFC inductor - 0.31 mH - PQ26/25	MAGNETICA	DWG
Q1	STF19NM50N	N-channel power MOSFET	STMicroelectronics	TO-220FP
Q2	BC857	PNP small signal BJT	VISHAY	SOT-23
Q3	STF8NM50N	N-channel power MOSFET	STMicroelectronics	TO-220FP
Q4	STF8NM50N	N-channel power MOSFET	STMicroelectronics	TO-220FP
Q8	BC847C	NPN small signal BJT	VISHAY	SOT-23
Q9	BC847C	NPN small signal BJT	VISHAY	SOT-23
R1	3M3	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R2	3M3	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R3	1M0	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R5	10R	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R6	NTC 2R5-S237	NTC resistor P/N B57237S0259M000	EPCOS	DWG
R7	1M0	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R8	1M0	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R9	62K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R10	27K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R11	2M2	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R12	2M2	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R13	8K2	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R14	51K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
R15	56K	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R16	4K7	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R17	2M2	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R18	82K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R19	56K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R20	33R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R21	22R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R22	0R27	SFR25 axial stand. film res - 0.4 W - 5 % - 250 ppm/°C	VISHAY	PTH
R23	0R47	SFR25 axial stand. film res - 0.4 W - 5 % - 250 ppm/°C	VISHAY	PTH
R24	1M0	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R25	56R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R26	1M0	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R27	470R	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R28	33K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R29	1K0	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R30	10R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R31	12K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R32	47R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R34	27K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R35	180K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R36	1M8	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R37	220K	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R38	56R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R39	160R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
R40	R33	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R41	100R	SFR25 axial stand. film res - 0.4 W - 5 % - 250 ppm/°C	VISHAY	PTH
R42	1K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R43	51R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R44	6K2	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R45	3R3	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R46	100K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R48	47K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R49	91K	SMD film res - 1/4 W - 1 % - 100 ppm/°C	VISHAY	1206
R50	12K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R51	82K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R52	1K5	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R53	2K2	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R54	0R0	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R55	2K7	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R57	R002	SMD shunt resistor - RL3264-9V-R002-FNH-11	CYNTEC	2512
R58	100K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R59	100K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R60	10K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R63	0R0	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R64	10Meg	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R68	39K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R69	4K7	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R70	22k	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805

Table 5. EVL150W-ADP-SR demonstration board: motherboard bill of materials (continued)

Des.	Part type/ part value	Description	Supplier	Case
R71	1K	SMD film res - 1/4 W - 5 % - 250 ppm/°C	VISHAY	1206
R72	330K	SMD film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R73	22R	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R75	0R0	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R76	33K	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R77	1K0	SMD film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
T1	1860.0034	Resonant power transformer	MAGNETICA	ETD34
U1	L6563H	High voltage start-up TM PFC controller	STMicroelectronics	SO-16
U2	L6599AD	Improved HV resonant controller	STMicroelectronics	SO-16
U3	SFH617A-2	Optocoupler	INFINEON	DIP-4 - 10.16 mm
U4	SFH617A-2	Optocoupler	INFINEON	DIP-4 - 10.16 mm
U5	TSM1014AIST	Low consumption CV/CC controller	STMicroelectronics	MINI SO-8
U6	TSC101C	High side current sense amplifier	STMicroelectronics	SOT23-5

Table 6. EVL150W-ADP-SR evaluation board: daughter board bill of material

Des.	Part type/ part value	Description	Supplier	Case
C501	4nF7	50 V cercap - general purpose	VISHAY	0805
C502	100 nF	50 V cercap - general purpose	VISHAY	0805
C503	1 uF	50 V cercap - general purpose	VISHAY	0805
D501	BAS316	Fast switching signal diode	STMicroelectronics	SOD-123
D502	BAS316	Fast switching signal diode	STMicroelectronics	SOD-123
JP501	HEADER 13	13-pin connector		
Q501	STL140N4LLF5	N-channel power MOSFET	STMicroelectronics	POWER FLAT
Q502	STL140N4LLF5	N-channel power MOSFET	STMicroelectronics	POWER FLAT
R501	10R	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R502	10R	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R503	10R	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R504	150k	SMD standard film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R505	33k	SMD standard film res - 1/8 W - 1 % - 100 ppm/°C	VISHAY	0805
R506	330R	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
R507	330R	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
RX1	0R0	SMD standard film res - 1/8 W - 5 % - 250 ppm/°C	VISHAY	0805
U501	SRK2000	SR smart driver for LLC resonant converter	STMicroelectronics	SO8

8 PFC coil specification

General description and characteristics

- Application type: consumer, home appliance
- Transformer type: open
- Coil former: vertical type, 6+6 pins
- Max. temp. rise: 45 ºC
- Max. operating ambient temperature: 60 ºC
- Mains insulation: n.a.
- Unit finishing: varnished.

Electrical characteristics

- Converter topology: boost, transition mode
- Core type: PQ26/25-PC44 or equivalent
- Min. operating frequency: 40 kHz
- Typical operating frequency: 120 kHz
- Primary inductance: 310 µH±10 % at 1 kHz-0.25 V[a]
- Peak current: 5.6 Apk.

Electrical diagram and winding characteristics

Figure 25. PFC coil electrical diagram

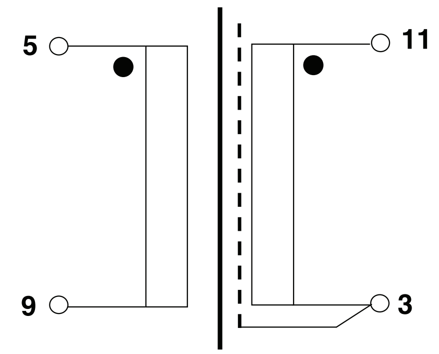


Table 7. PFC coil winding data

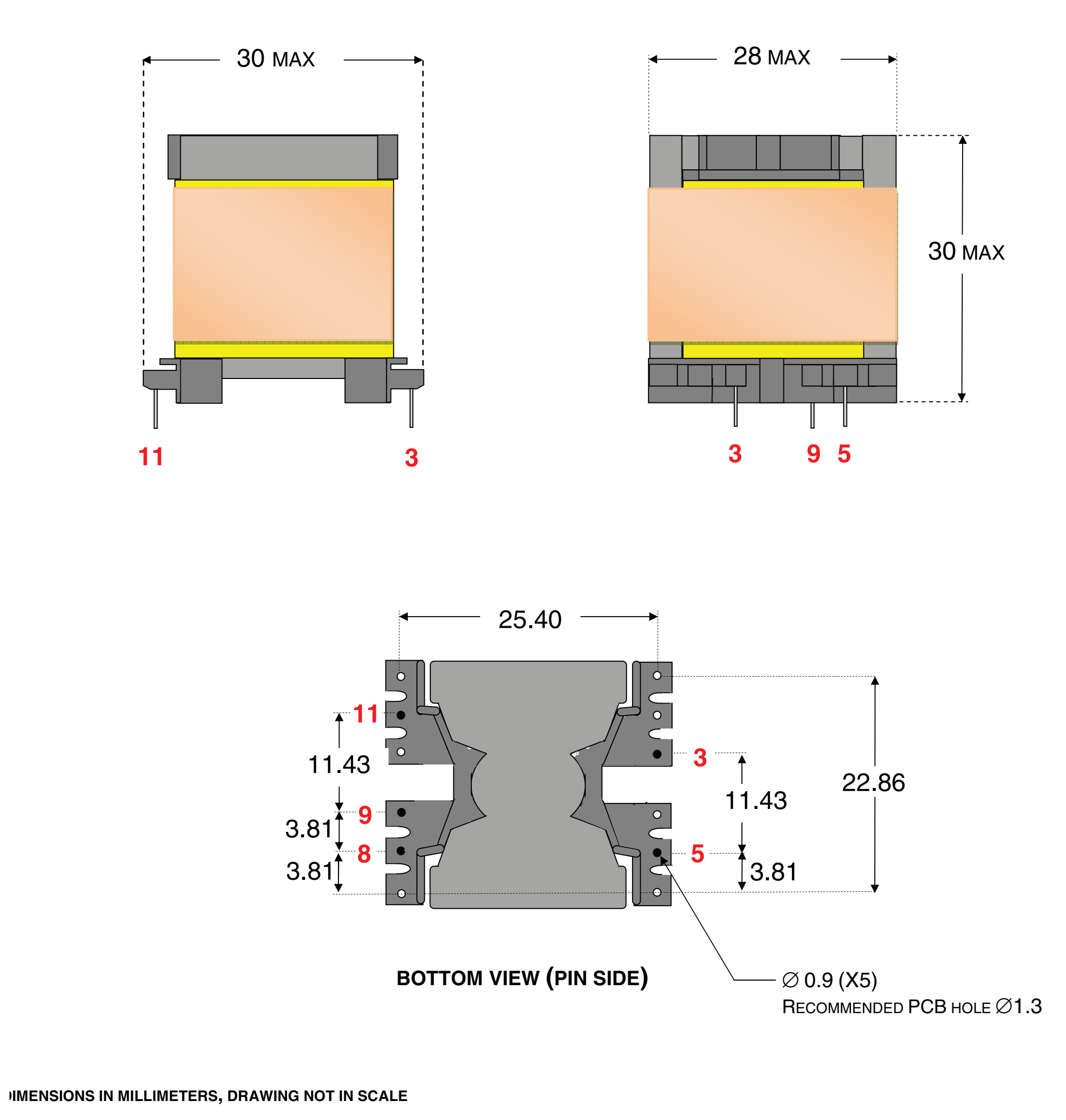
Pins	Windings	RMS current	Number of turns	Wire type
11 - 3	AUX	0.05 A_{RMS}	5	ϕ 0.28 mm – G2
5 - 9	PRIMARY	2.3 A_{RMS}	50	50xϕ 0.1 mm – G1

a. Measured between pins #5 and #9

Mechanical aspects and pin numbering

- Maximum height from PCB: 30 mm
- Coil former type: vertical, 6+6 pins (Pins 1, 2, 4, 6, 7, 10, 12 are removed)
- Pin distance: 3.81 mm
- Row distance: 25.4 mm
- External copper shield: not insulated, wound around the ferrite core and including the coil former. Height is 8 mm. Connected to pin #3 by a soldered solid wire.

Figure 26. PFC coil mechanical aspect



Manufacturer

- Magnetica - Italy
- Inductor P/N: 1975.0004

9 Transformer specifications

General description and characteristics

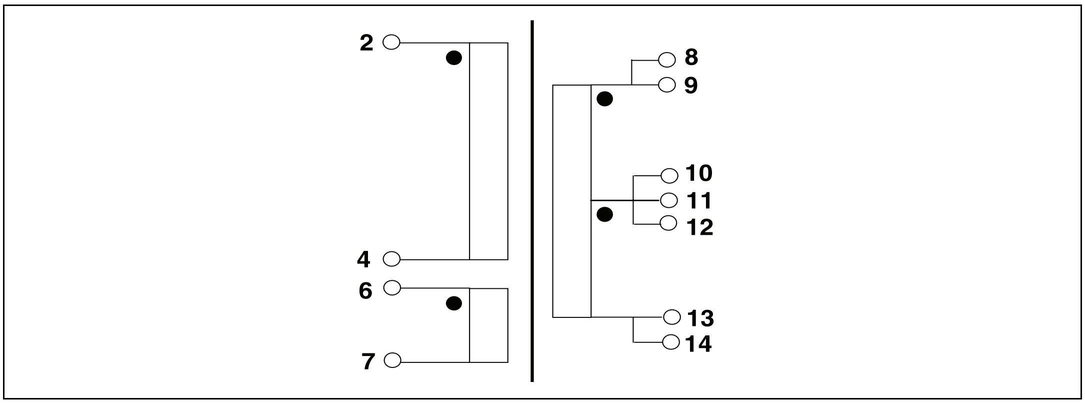
- Application type: consumer, home appliance
- Transformer type: open
- Coil former: horizontal type, 7+7 pins, two slots
- Max. temp. rise: 45 ºC
- Max. operating ambient temperature: 60 ºC
- Mains insulation: Acc. With EN60065.

Electrical characteristics

- Converter topology: half bridge, resonant
- Core type: ETD34-PC44 or equivalent
- Min. operating frequency: 60 kHz
- Typical operating frequency: 100 kHz
- Primary inductance: 800 µH ±10 % at 1 kHz-0.25 V[b]
- Leakage inductance: 100 µH ±10 % at 100 kHz-0.25 V[c].

Electrical diagram and winding characteristics

Figure 27. Transformer electrical diagram



b. Measured between pins 2-4

c. Measured between pins 2-4 with only half secondary winding shorted at time

Table 8. Transformer winding data

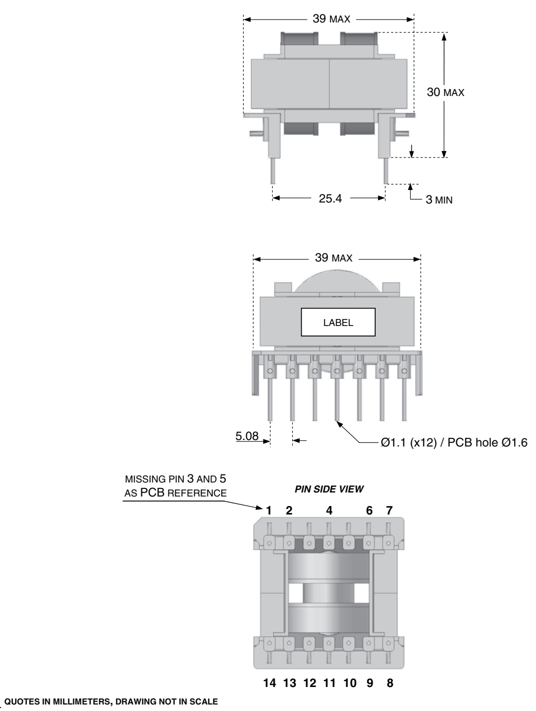
Pins	Winding	RMS current	Number of turns	Wire type
2 - 4	PRIMARY	1.2 A_{RMS}	34	30 x ϕ 0.1 mm – G1
8 - 11	SEC-1A[4]	5 A_{RMS}	2	90 x ϕ 0.1 mm – G1
9 -10	SEC-1B[4]	5 A_{RMS}	2	90 x ϕ 0.1 mm – G1
10 - 13	SEC-2A[(1)]	5 A_{RMS}	2	90 x ϕ 0.1 mm – G1
12 - 14	SEC-2B[4]	5 A_{RMS}	2	90 x ϕ 0.1 mm – G1
6 - 7	AUX[(2)]	0.05 A_{RMS}	3	ϕ 0.28 mm– G2

1. Secondary windings A and B are in parallel
2. Aux winding is wound on top of primary winding

Mechanical aspect and pin numbering

- Maximum height from PCB: 30 mm
- Coil former type: horizontal, 7+7 pins (pins #3 and #5 are removed)
- Pin distance: 5.08 mm
- Row distance: 25.4 mm.

Figure 28. Transformer overall drawing



Manufacturer

- Magnetica - Italy
- Transformer P/N: 1860.0034

10 Revision history

Table 9. Document revision history

Date	Revision	Changes
13-Jan-2011	1	Initial release