AN5106
Application note

150 V – 150 W LED driver using the STCMB1 transition mode PFC and HBR resonant tank combo controller

Introduction

The growing popularity of LEDs, thanks to their high efficiency and longer lifetime, are greatly contributing to the reduction of energy consumption for internal and external lighting. Street lighting applications require a power supply specifically designed to power an LED lamp having high efficiency and a long lifetime in order to guarantee maintenance-free operation during the lifetime of the LED.

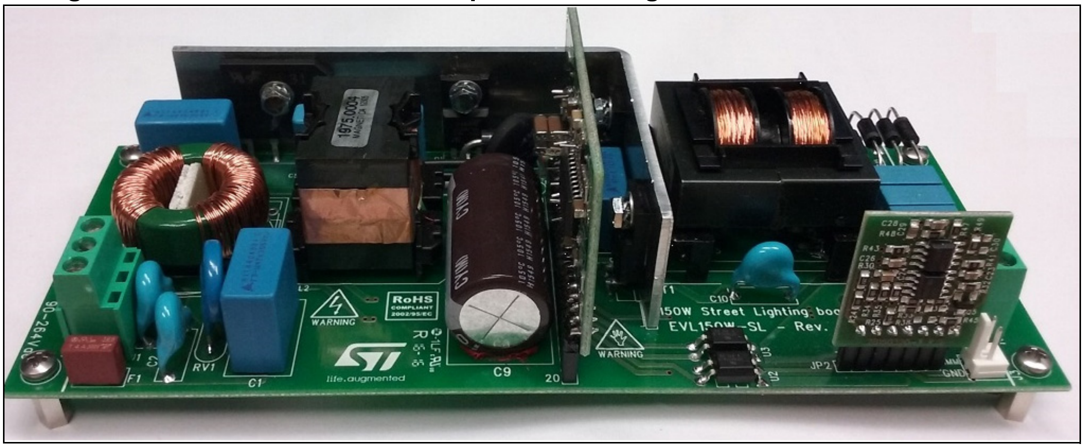
This application note describes the performance of a 150 W, wide input mains range, power-factor-corrected, LED driver board. Its electrical specification is tailored to a typical high-power street lighting application.

The architecture is based on a two-stage approach: a front-end PFC pre-regulator and a downstream resonant half-bridge converter: both are using the new STCMB1 embedded in the same device; a PFC and a resonant controller. Thanks to the STCMB1, the main features of this design are high efficiency, very low no-load input power consumption, reduced harmonics compliant with the EN61000-3-2 Class-C, and EMI within the relevant EN55022 limits.

Another noticeable feature of this LED driver is the extremely wide dimming capability; actually the board can regulate the current from the maximum level down to less than 10% with analog dimming and to 1% in PWM dimming. The PWM dimming is perfectly flicker free, because even in the case of a very low current it is kept continuous (DC) in the LED and thus independent of the frequency of the PWM dimming signal.

The board also has protection features in the case of an overload, short-circuit, and open loop by each section. For this particular application, all protections in the case of intervention have an auto-restart functionality.

Figure 1. EVL150W-HVSL: wide input mains range 150 V - 1 A LED driver board



Contents

List of tables

List of figures

1 Main characteristics and circuit description

The main features of this LED driver demonstration board are listed here below:

- Universal input mains range: 90 ÷ 264 Vac - frequency 45 ÷ 65 Hz
- Half-bridge topology: **LCC**
- Max. output voltage and current: 150 V at 1 A continuous operation
- Mains harmonics: EN61000-3-2 Class-C and JEITA-MITI Class-C
- No-load mains consumption: < 0.5 W
- THD: < 10% at 230 Vac from 30 to 100% of the full load
- No need of Auxiliary SMPS (Viper or equivalent)
- Efficiency: >91 % at full load
- Conducted EMC: within EN55022-Class-B limits
- Safety: meets EN60950
- Dimensions: 69 x 157mm, 28 mm components maximum height
- PCB: double side, 70 µm, FR-4, mixed PTH/SMT
- Dimming: analog, resistive, PWM (open collector)
- Feedback loops: constant current and constant voltage
- Protections: LED short-circuit, LED string open, regulation loop failure

The circuit is composed of two stages: a front-end PFC and a resonant converter featuring the STCMB1. It embodies a transition mode (TM) PFC, a high voltage double-ended controller for the resonant half-bridge, an 800 V-rated high voltage section and the glue logic that supervises the operation of these three blocks.

The half-bridge (HB) section provides two complementary outputs that drive the high-side and low-side MOSFET 180° out-of-phase. The deadtime inserted between the turn-off of either switch and the turn-on of the other is automatically adjusted to ensure zero voltage switching and higher efficiency from the low to full load. A proprietary control method, time-shift control - TSC, improves dynamic behavior and input ripple rejection.

1.1 PFC power stage

The PFC stage works as a pre-regulator and powers the resonant stage with a constant of 400 V. The PFC section uses a proprietary constant on-time control methodology that does not require a sinusoidal input reference, thereby reducing the system cost and external component count. It includes also a complete set of protections: a cycle-by-cycle overcurrent (OCP), an output overvoltage (OVP), a feedback failure (FFP, latch-mode), an AC brownout, boost inductor saturation and inrush current detection both at the start-up and after mains sags or missing cycles.

1.2 Resonant power stage

The STCMB1 embeds an advanced double-ended controller specific to the resonant half-bridge topology. Normally, in this converter the MOSFETs of the half-bridge leg are alternately switched on and off (180° out-of-phase) for exactly the same time with a deadtime TD inserted between the turn-off of either MOSFET and the turn-on of the other one, where both MOSFETs are off. This deadtime is essential in order for the converter to work correctly: it enables soft-switching and, then, the high frequency operation with high efficiency and low EMI emissions.

The transformer uses the integrated magnetic approach, incorporating the resonant series inductance. Thus, no additional external coil is needed for the resonance.

The transformer secondary winding configuration is full bridge, and makes use of four rectifiers p/n STTH3R02Q. A small LC filter has been added on the output to reduce the high frequency ripple current through the LEDs. The output capacitors are film type, to increase the system lifetime.

1.3 LCC topology

For the resonant tank, the LCC topology has been selected: different reasons led to this choice. First, it looks like a current source because when the frequency is changed, the output current is almost not dependent on the load. Second, at given resonant inductance and capacitance, considering the voltage gain, the peak is higher and the slope is steeper than in an LLC topology, giving wider voltage at both input and output of the resonant tank.

On one hand, the input voltage range is not so relevant in this case, because of the PFC pre-regulator stage; however, on the other hand, a wide output voltage range is a key feature in LED driving application because it allows to accommodate larger LED string values. Third, if the switching frequency tends to ∞, then the voltage gain quickly tends to 0, not depending on the load: this behavior allows to regulate down to very light loads without the need of burst mode operation of the resonant converter that would impact the light emission by the LED string.

Of course, the continuous switching operation down to very light loads brings to not minimized light load consumption. Last but not least, there is no need of precise transformer integration, because there is no leakage inductance, and, furthermore, it is a capacitor ratio that has to be set, rather than an inductance ratio, and this usually simplify the design.

1.4 Dimming and feedback loops

The EVL150W-HVSL implements two different feedback loops: one is controlling the output voltage, the second one is dedicated to regulating the LED current and can work alternatively.

The voltage feedback loop components are located on the motherboard. It is implemented by means of a typical circuit using the TLVH431, sensing the output voltage by a divider and modulating the current in the optocoupler U3.

On the primary side, R121 - connecting the RFMIN pin (#4) to the optocoupler's phototransistor - closes the feedback loop and its value sets the maximum switching frequency at about 300 kHz. Then, to limit the switching losses at no-load operation, the voltage feedback loop implements burst-mode via the STCMB1 (U101) STBY pin, sensing the photocoupler voltage. This signal is compared to an internal reference (1.24 V); if the load decreases and the voltage on the STBY photocoupler pin becomes lower than the reference, the IC enters an idle state and its quiescent current is reduced. Once the voltage exceeds the reference by 30 mV, the controller restarts switching. The burst-mode operation threshold is programmed by properly choosing the resistor connecting the photocoupler to the RFMIN pin (R121).

In such a way, if the output voltage rises for any reason above the setpoint value (155 V), the voltage loop keeps the output voltage regulated, for example, if the LED string fails to open, which could result in a very high and dangerous potential on the secondary side that would bring the board to catastrophic failures and safety issues.

During normal operation an LED driver is required to regulate the current flowing in the LED string according to the dimming voltage. This is achieved by this second, current control loop. It is mainly located on the smaller daughterboard, at the secondary side. The dimming signal applied to the J3 connector is filtered and then inserted as the reference signal in the CC error amplifier, comparing this signal with the signal coming from the sensing resistors. The output of the CC error amplifier drives the optocoupler U2, which modulates the current through the resistor R120, and thus the resonant converter frequency. In this case, to prevent flickering in the case of deep dimming, burst-mode is not implemented by the CC loop but it can only work with the continuous switching operation.

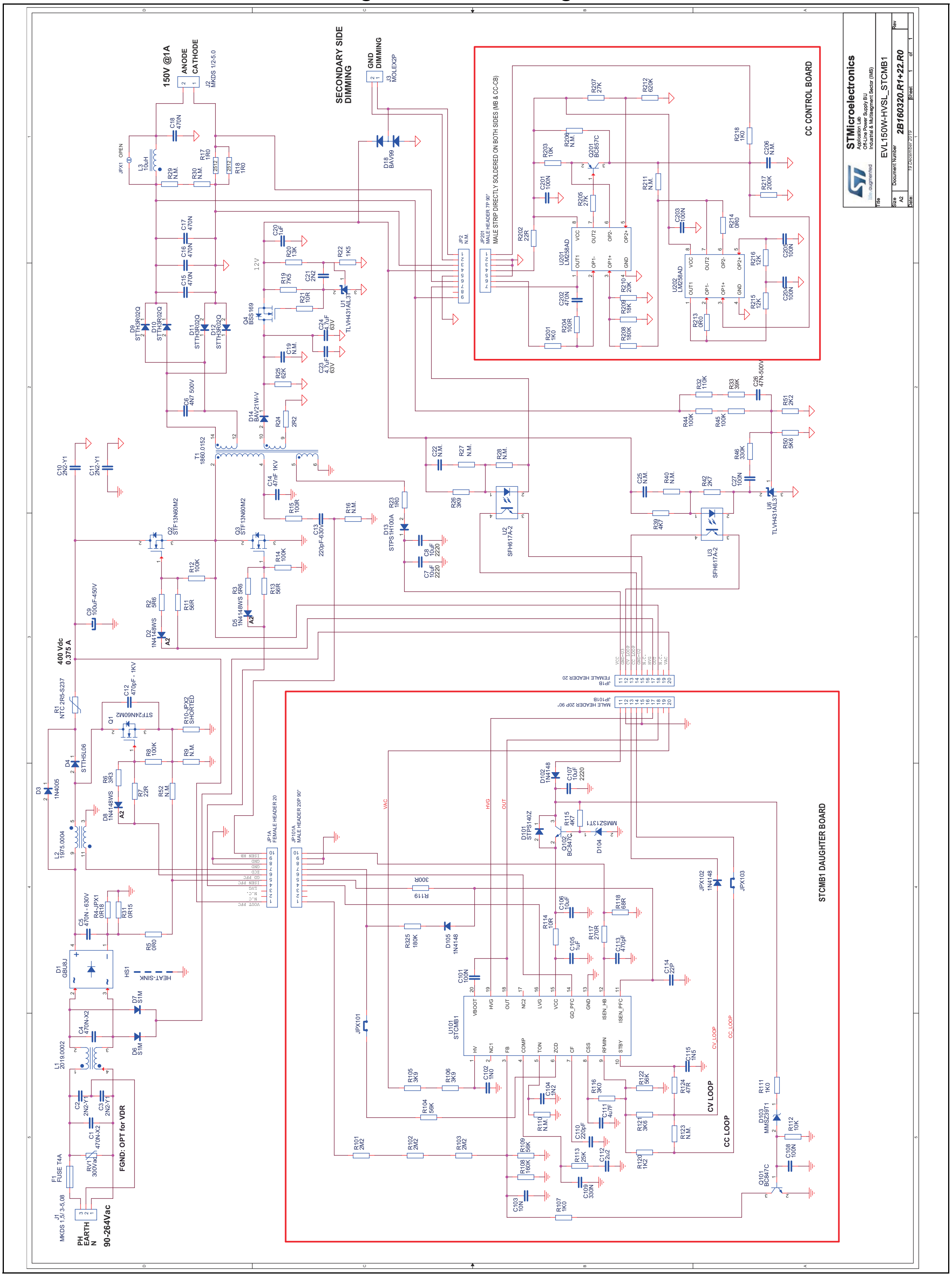
1.5 Protections and secondary auxiliary voltage regulator

If the CC loop fails with the LED string connected, the voltage loop can not operate because the output voltage is clamped by the LED string, but the output current would be uncontrolled. To protect the system against additional failures, the primary side overcurrent protection (OCP) integrated in the STCMB protects the board by working in hiccup mode.

An additional open loop protection is implemented at the primary side on the STCMB1 daughterboard, by Q1. The Zener diode D103 senses the voltage from the transformer T1 auxiliary winding; in case the auxiliary voltage gets too high the transistor Q1 stops the operation by pulling low pin 3# (FB) of the STCMB1 thus triggering PFC open loop latch protection.

To power the control circuitry at the secondary side an auxiliary voltage is derived from an additional secondary winding of the transformer, and then regulated by the MOSFET Q4, driven by the shunt regulator U1.

Figure 2. Electrical diagram



2 Efficiency and open load input power

2.1 Normal operation efficiency measurement

Table 1 shows the overall efficiency measured at the nominal mains voltages, powering an LED string as the load. At 115 Vac the full load efficiency is 91.35%, and at 230 Vac it is 93.27%. Measurements of efficiency versus output power are also reported in *Figure 3*.

Table 1. Overall efficiency at nominal mains input voltage

Vin [Vac]	Pin [W]	V_{LED} [V]	I_{LED} [A]	Pout [W]	Efficiency %
230 V - 50 Hz	175,20	153,00	1,068	163,40	**93,27%**
230 V - 50 Hz	162,94	151,10	1,002	151,40	92,92%
230 V - 50 Hz	145,12	149,50	0,900	134,55	92,72%
230 V - 50 Hz	128,30	147,90	0,800	118,32	92,22%
230 V - 50 Hz	111,35	146,30	0,700	102,41	91,97%
230 V - 50 Hz	95,53	144,00	0,600	86,40	90,44%
230 V - 50 Hz	79,80	142,60	0,500	71,30	89,35%
230 V - 50 Hz	50,10	139,00	0,300	41,70	83,23%
230 V - 50 Hz	33,39	134,70	0,200	26,94	80,68%
230 V - 50 Hz	18,32	130,00	0,100	13,01	70,96%
230 V - 50 Hz	12,39	127,00	0,060	7,62	61,50%
115 V - 60 Hz	173,02	148,40	1,065	158,05	**91,35%**
115 V - 60 Hz	160,80	147,20	1,001	147,35	91,63%
115 V - 60 Hz	143,40	145,50	0,900	131,01	91,36%
115 V - 60 Hz	126,40	143,99	0,800	115,19	91,13%
115 V - 60 Hz	110,00	142,50	0,700	99,76	90,69%
115 V - 60 Hz	93,41	140,70	0,600	84,38	90,33%
115 V - 60 Hz	77,56	138,70	0,500	69,38	89,45%
115 V - 60 Hz	62,30	136,90	0,400	54,81	87,99%
115 V - 60 Hz	47,20	134,60	0,300	40,41	85,61%
115 V - 60 Hz	32,44	131,40	0,200	26,31	81,09%
115 V - 60 Hz	18,33	127,14	0,100	12,69	69,22%

In *Figure 4* the efficiency is reported at different input mains voltage values: we can see that even in this case the efficiency measured is very high at the full load and it still remains at very high levels even when decreasing the load down to ~8% of the nominal one.

Figure 3. Efficiency vs. output power

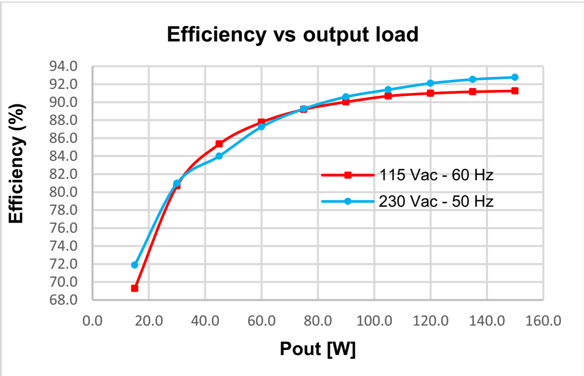
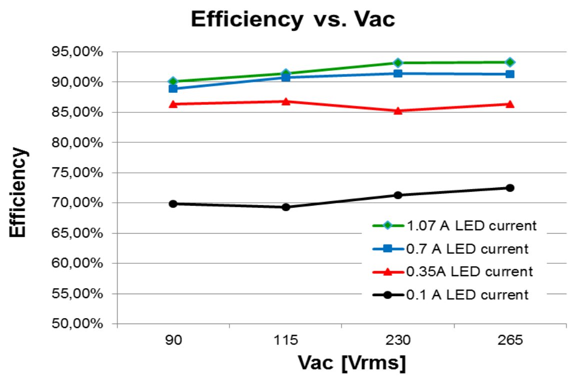


Figure 4. Efficiency vs. Vac

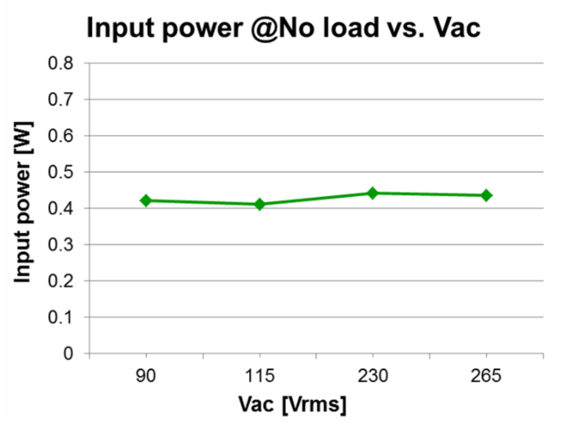


2.2 Open load input power consumption

Measurements during the open load operation have been measured and reported in *Figure 5*. As can be seen, input power is below 500 mW at any input mains voltage.

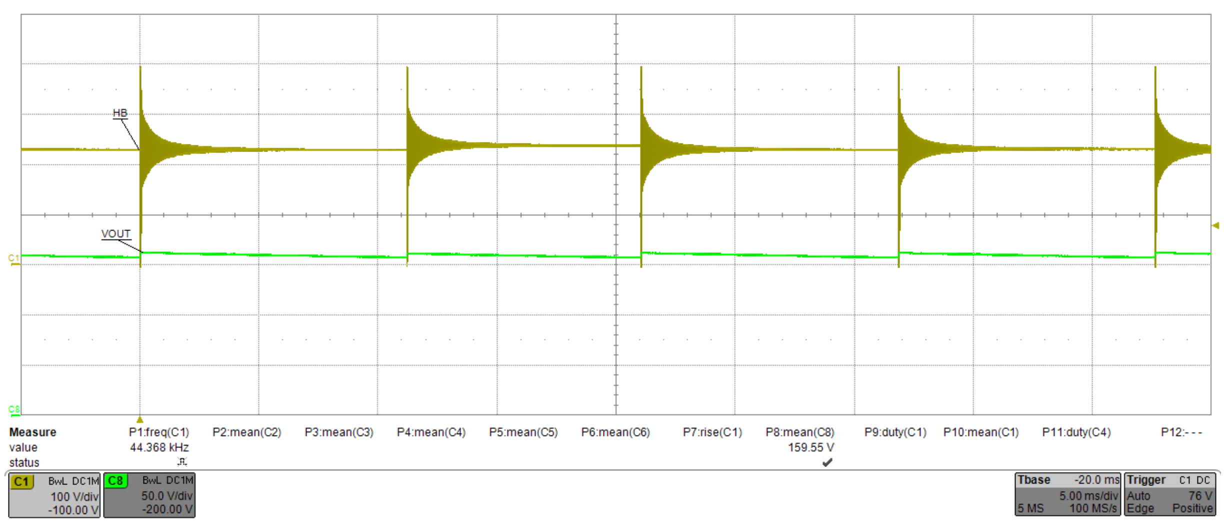
Measurements have been done disconnecting the LED string from the board and measuring the input power by power meter integration. Input power doesn't change if the dimming circuitry is driven by an external dimming signal or the dimming input connector is open too.

Figure 5. Open load input power vs. Vac



Waveforms of the operation during burst-mode are reported here following. In *Figure 6* it is possible to see the short operating time by the HB and we can also note that the o/p voltage is kept stable. During the no-load operation (LED string disconnected) the o/p voltage is kept regulated by the voltage loop at 158 V, slightly above the maximum LED voltage.

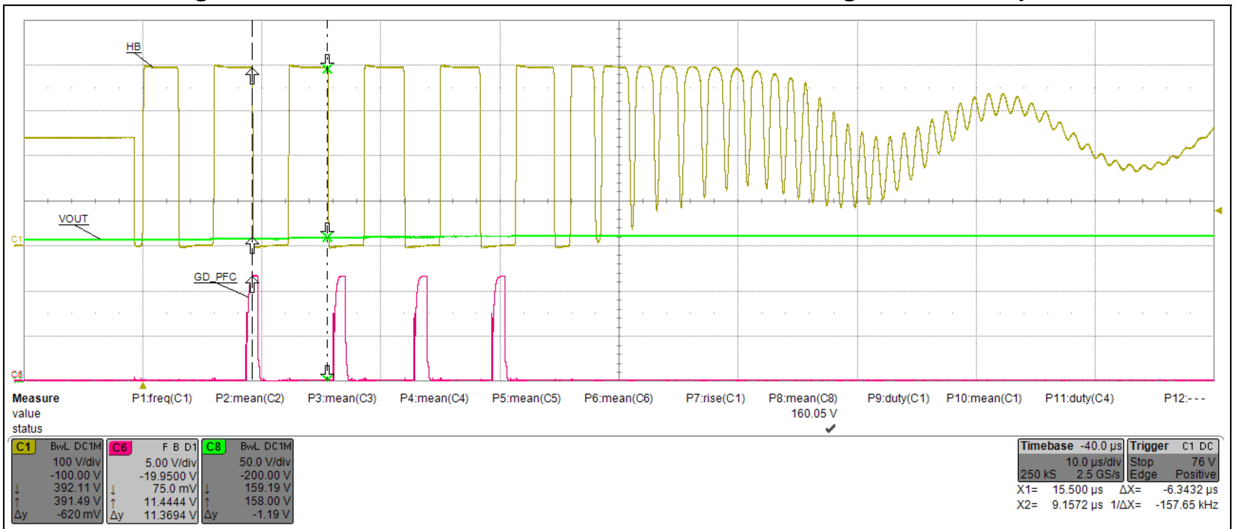
Figure 6. Burst-mode at 230 Vac - no-load



CH1: HB voltage CH8: LED voltage

Detail of waveforms during the burst are shown in *Figure 7*. As shown, we can note that both the half-bridge and the PFC are performing just a few switching cycles. The HB frequency inside the bursts is around 160 kHz.

Figure 7. Detail of burst at 230 Vac - no-load - dimming connector open



CH1: HB voltage CH6: GD_PFC CH8: LED voltage

3 Mains current harmonic content and power-factor

The board has been tested in accordance with the European norm EN61000-3-2 Class-C and Japanese norm JEITA-MITI Class-C compliance, at both the nominal input voltage mains. As reported in *Figure 8* to *Figure 11*, the circuit is able to reduce the harmonics well below the limits of both regulations.

Figure 8. Compliance to EN61000-3-2 at 230 Vac - 50 Hz, full load

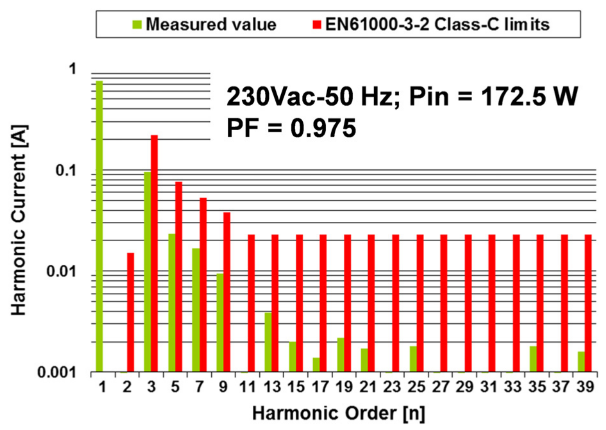


Figure 9. Compliance to JEITA-MITI at 100 Vac - 60 Hz, full load

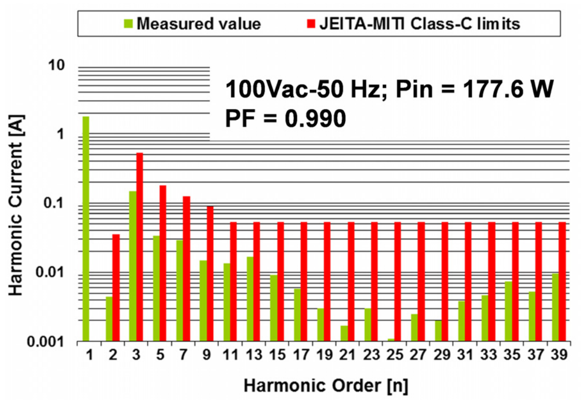


Figure 10. Compliance to EN61000-3-2 at 230 Vac - 50 Hz, Pin = 75.0 W

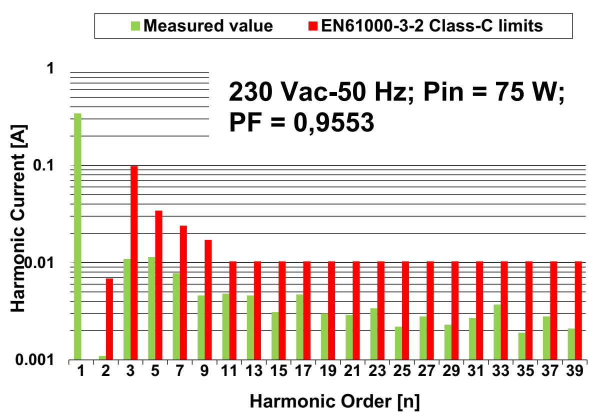
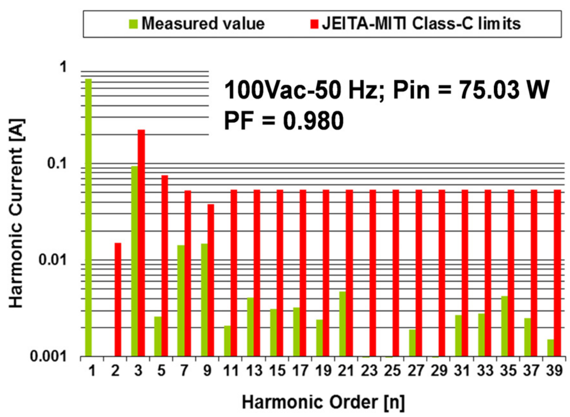


Figure 11. Compliance to JEITA-MITI at 100 Vac - 60 Hz, Pin = 75.0 W



From *Figure 8* to *Figure 11* the harmonics of the input mains current at both nominal mains input voltage, European and Japanese, have been reported at the full load and 50% load, all harmonics are within the limits specified by both regulations.

Further decreasing the load, we can observe an increase of the input harmonics as reported in *Figure 12* and *Figure 13* . In these figures we can observe that the harmonics are slightly overriding the limiting values because the PFC stage is working in burst-mode and in that condition it is not possible to have good shaping of the input current.

Figure 12. Compliance to EN61000-3-2 at 230 Vac - 50 Hz; Pin = 25 W

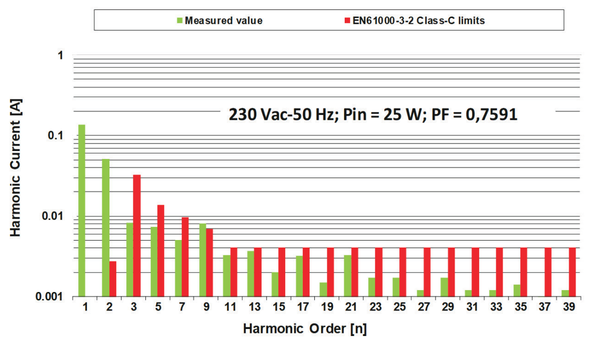
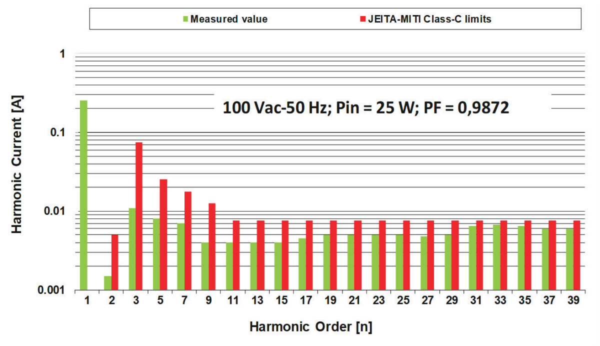


Figure 13. Compliance to JEITA-MITI at 100 Vac - 60 Hz; Pin = 25 W



In *Figure 14* and *Figure 15* the power-factor measurements are reported, as a function of the output LED current and input mains voltage. The power-factor is high as expected; it tends to decrease when the power-factor stage begins working in burst-mode.

Figure 14. Power-factor vs. input power

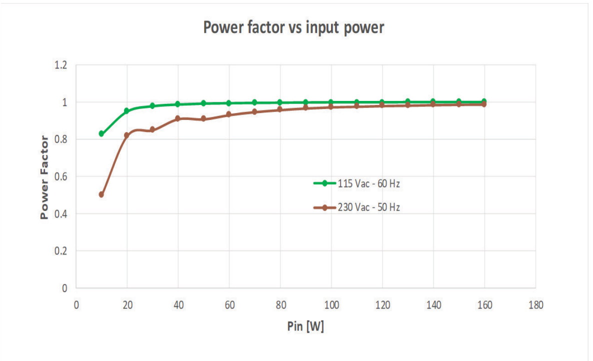


Figure 15. Power-factor vs. Vac and LED current

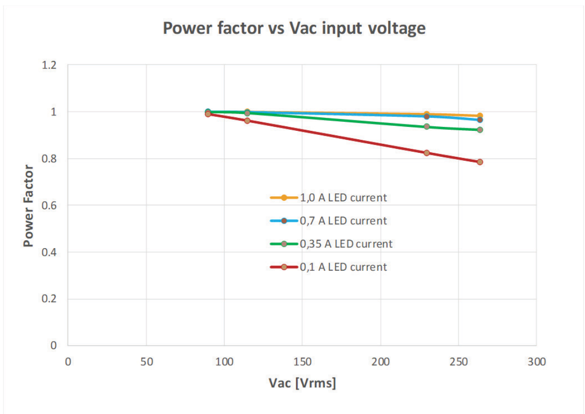
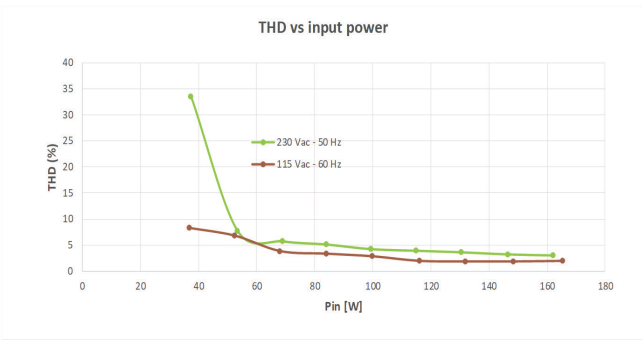


Figure 16. THD vs. input power



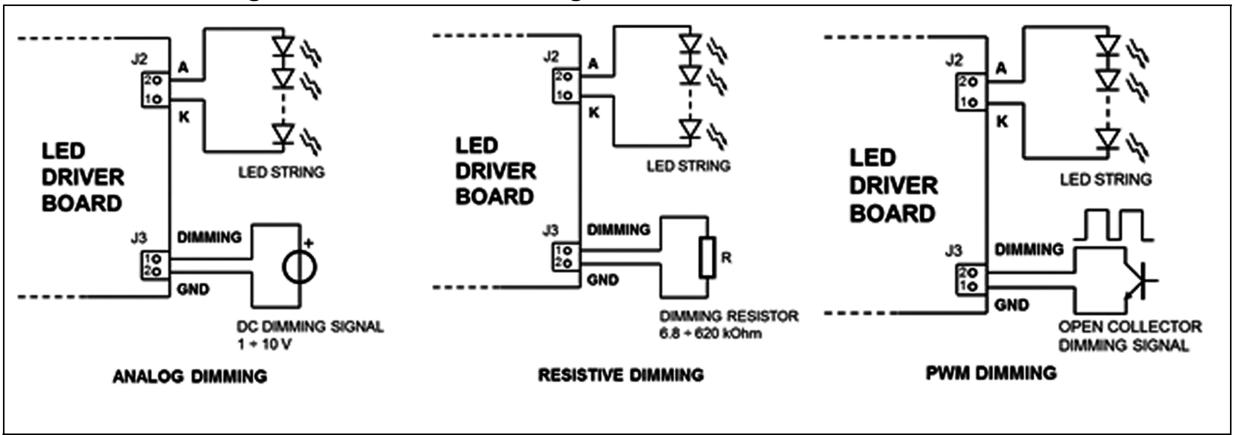
In *Figure 16* the THD measurements versus the input power at nominal mains are reported.

4 LED current dimming

The board accepts different dimming signals for controlling the current flowing in the LED: analog, resistive and PWM. The board provides a dedicated connector (J3) for all dimming types; dimming signals have to be supplied referring to the secondary ground. There is no insulation between the dimming input connector and the secondary ground.

Connections of different dimming types to the boards are indicated in *Figure 17*.

Figure 17. Different dimming connections at board connectors



Where no dimming signal is provided to the board connector, the maximum current is delivered to LEDs by the power supply board, a small percentage higher than the nominal current value.

The features of different dimming types which can be used to drive by the board are:

- **Analog dimming**

The board accepts as the analog dimming signal a voltage in the range 1 ÷ 10 V, with an input impedance of 200 kΩ. The LED current changes proportionally with the dimming voltage, current variation is very linear with the dimming signal, as we can see in the diagram of *Figure 18*.

Applying 10 V at the dimming connector the maximum current is delivered (1 A), then the relationship between the dimming voltage and LED current is 0.1 A/V down to 1 V.

For LED voltage from 150 V to 50 V the current can be dimmed in the range 10 ÷ 100%; decreasing the LED voltage to 30 V, the minimum current decreases down to 0.16 A, as shown in *Figure 18*.

- **Resistive dimming**

The LED current can be changed also by connecting a suitable resistor to the pins of the connector J3. The current changes proportionally with the resistor value, as we can see in the diagram of *Figure 19*.

This dimming mode is used for low-cost applications needing a selectable, fixed preset of the LED current by the user.

A potentiometer could be used if a variable LED current is needed instead of a fixed resistor.

Figure 18. LED current vs. analog dimming signal at different VLED

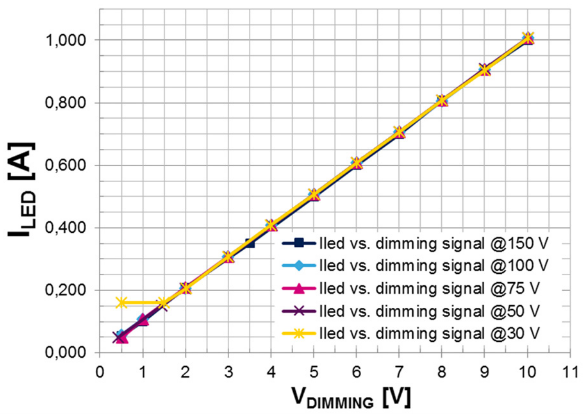
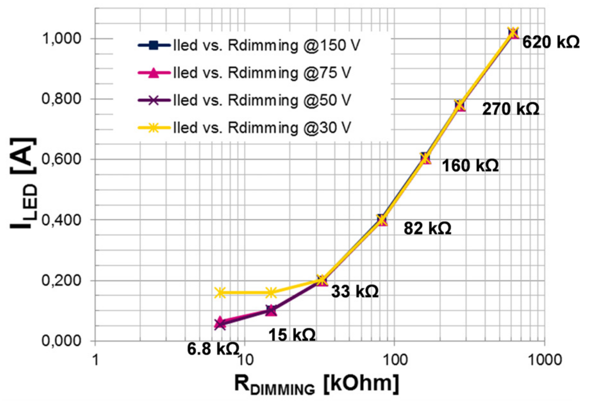


Figure 19. LED current vs. dimming resistor at different VLED



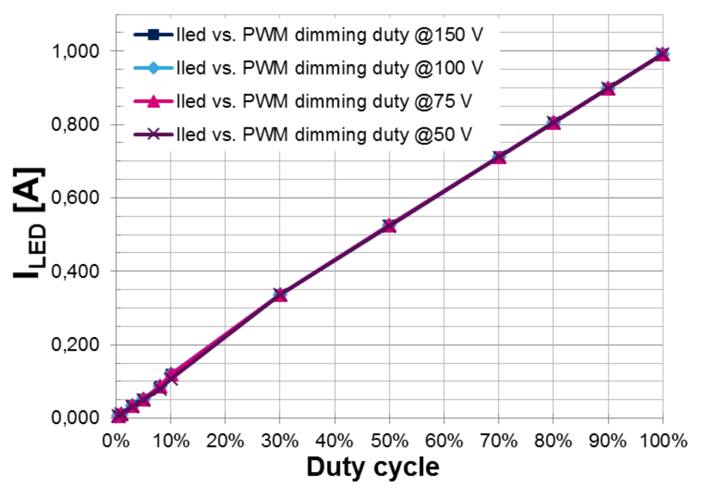
- **PWM dimming**

Another popular control signal for LED current is the so-called PWM dimming: the board accepts this kind of driving signal, still applied to the J3 connector by an open collector or open drain output. The open collector has to sustain a 12 V maximum voltage, and has to pull down a current of 0.1 mA.

The input dimming signal is averaged by the board circuitry; therefore any dimming frequency and duty cycle can be fed into the J3 connector and the board does not show any light flickering due to the PWM modulating signal because the current flowing in the LED string is a DC current, proportional to the average value of the PWM signal multiplied for the maximum (preset) current. In *Figure 20* the diagram shows the output current flowing into the LED string vs. the duty cycle of the PWM dimming signal, fed into the board by an open collector signal.

The PWM dimming circuit allows to regulate the LED current with good linearity even with duty cycles in the range of 1%, making this board also suitable not only for street lighting but also for applications like indoor lighting where the PWM duty is required.

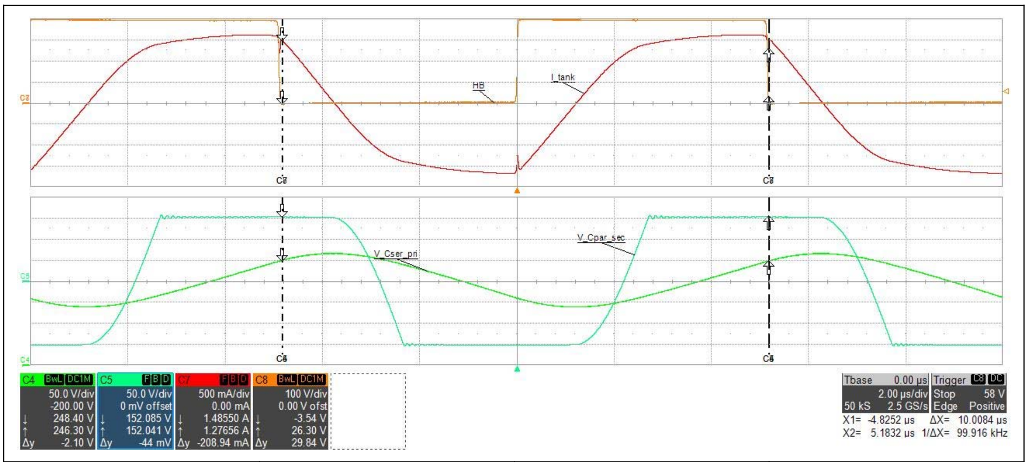
Figure 20. LED current vs. PWM dimming signal at different VLED



5 LCC topology: main waveforms of the tank

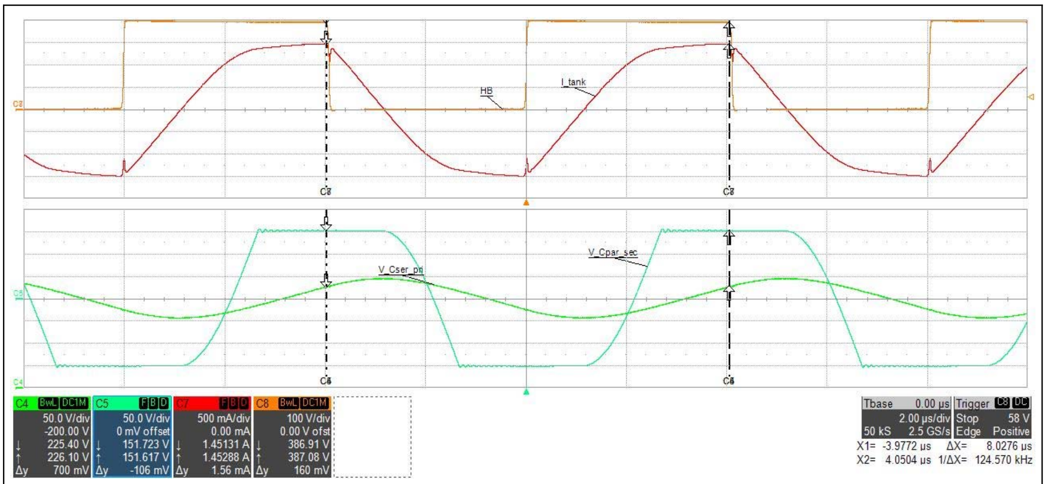
In this section, typical waveforms of the LCC resonant tank are shown. Referring to the schematic of the board, reported in Figure 2, the half bridge node, the series capacitor voltage at primary (C14), the parallel capacitor voltage at secondary (C6) and the primary current entering into the resonant tank have been captured at some steady state conditions at 230Vac / 50Hz (active load in CV set at 150V).

Figure 21. LCC typical waveforms, 150V - 1A (full load, 100% dimming)



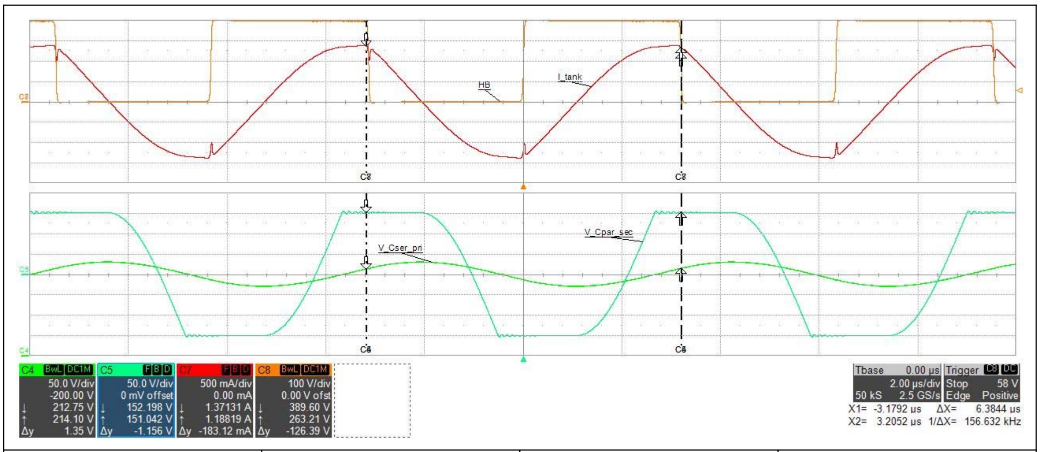
CH4: V_C14	CH5: V_C6 (diff)	CH7: I_tank	CH8: HB

Figure 22. LCC typical waveforms, 150V - 0.75A (75% dimming)



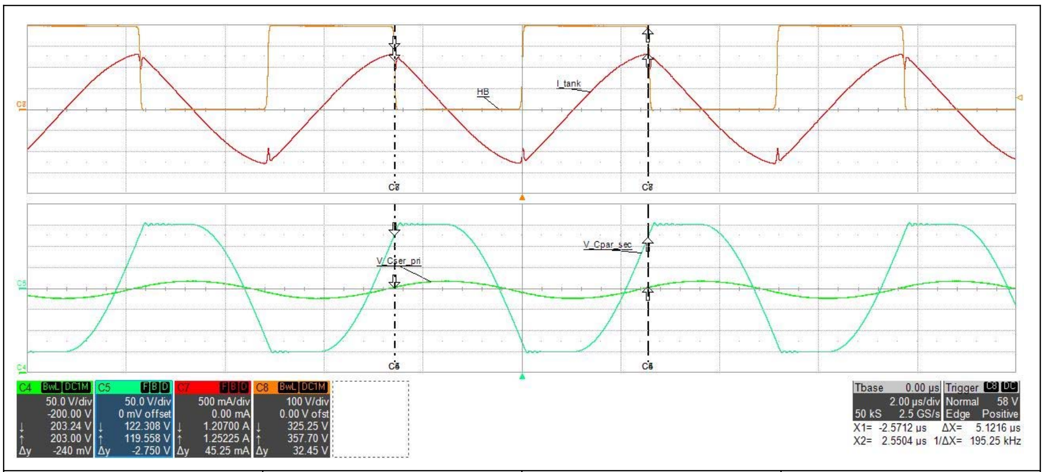
CH4: V_C14	CH5: V_C6 (diff)	CH7: I_tank	CH8: HB

Figure 23. LCC typical waveforms, 150V - 0.5A (half load, 50% dimming)



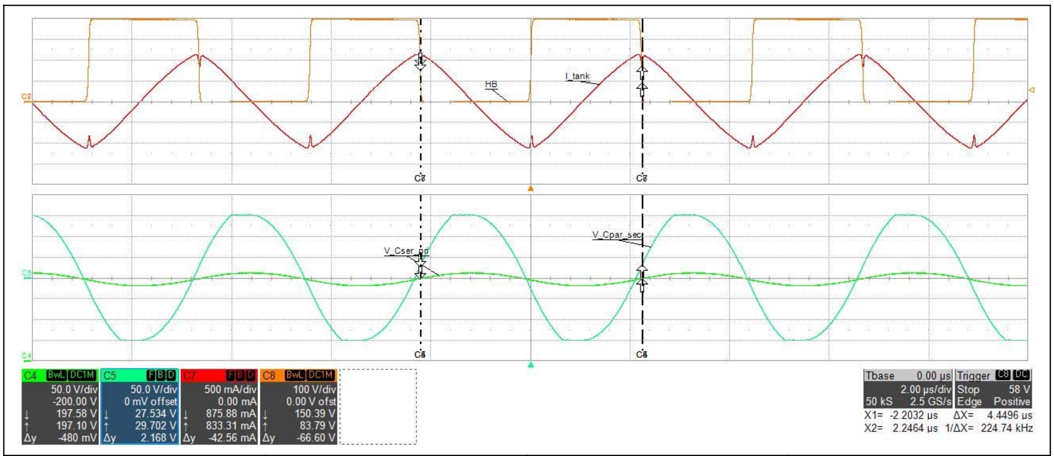
CH4: V_C14	CH5: V_C6 (diff)	CH7: I_tank	CH8: HB

Figure 24. LCC typical waveforms, 150V - 0.25A (25% dimming)



CH4: V_C14	CH5: V_C6 (diff)	CH7: I_tank	CH8: HB

Figure 25. LCC typical waveforms, 150V - 0.05A (min. dimming)



CH4: V_C14	CH5: V_C6 (diff)	CH7: I_tank	CH8: HB

6 Startup

The STCMB1 is equipped with internal HV start-up circuitry dedicated to supplying the IC during the initial start-up phase, before the self-supply winding is operating. The external capacitors connected to the VCC pin are charged by the HV start-up circuitry, connected to the HV pin.

As soon as the voltage on the HV pin is higher than $V_{HVstart}$ (20 V typ.), the HV start-up system turns on and the external V_{CC} capacitors are charged up to the turn-on threshold (V_{CCOn}, 16.5 V typ.), To then guarantee a reliable start-up of the STCMB1, the HV start-up system is turned off only after the half-bridge section starts up. In case of a fault that prevents the half-bridge section from starting up, the HV start-up system is automatically shut down after a timeout T_{TOUT} = 80 ms.

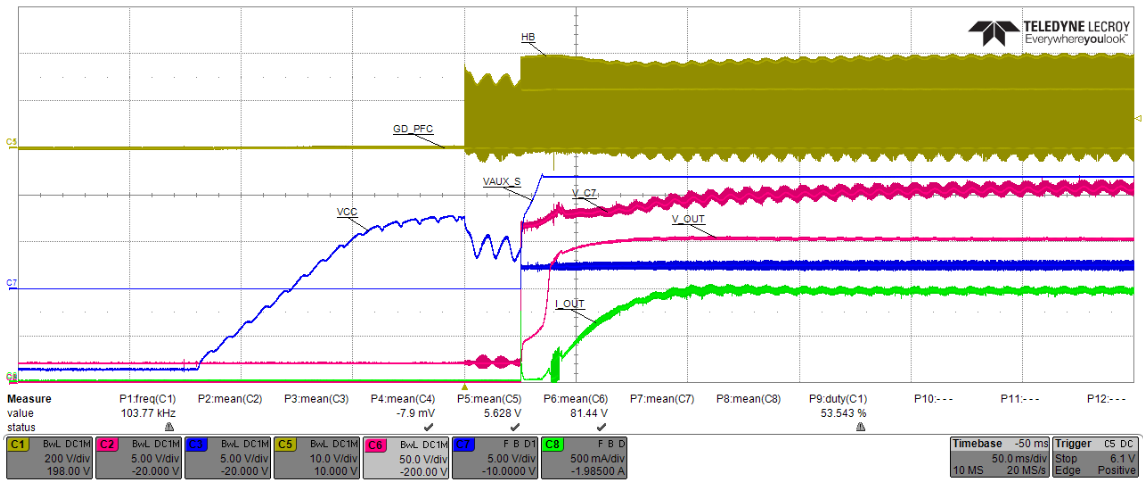
Once the V_{CCOn} is reached, the STCMB1 starts operating and the GD_PFC starts driving the PFC MOSFET, and the PFC voltage increases from the peak of the rectified mains voltage to the PFC nominal output voltage.

The resonant stage begins to operate once the PFC voltage reaches the DC brownout voltage level, thus ensuring that the resonant HB stage starts after the PFC has started up, and PFC output voltage is close to the nominal level.

The waveforms relevant to the startup have been captured in *Figure 26*. We can note that the startup is very fast, the LED output current reaches the nominal value 250 ms after power-up, signed by the beginning of V_{CC} increasing.

The STCMB1 has an embedded high voltage startup charging the V_{CC} capacitor ensuring a fast wake-up time in all conditions. Comparing *Figure 26* with *Figure 27*, the latter relevant to a startup at 265 Vac and dimming voltage at 10 V, we can note that in both conditions the LED current has no overshoot and its rise is smooth and monotonic.

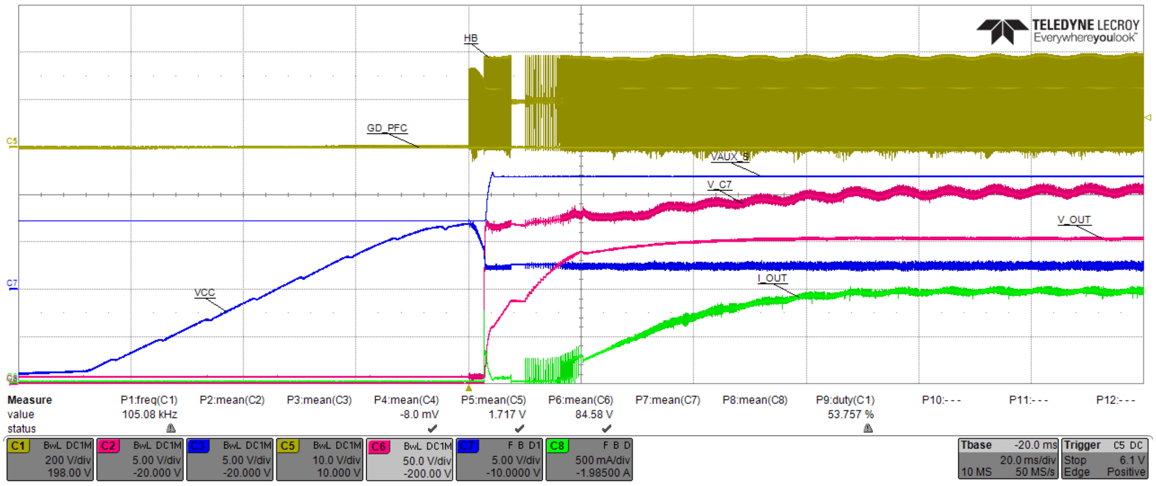
Figure 26. Startup at 90 Vac - full load - dimming connector open



CH1: HB voltage CH2: V_C7 CH3: VCC CH4: --

CH5: GD_PFC CH6: LED voltage CH7: V_C20 CH8: LED current

Figure 27. Startup at 265 Vac - full load - V_Dimming = 10 V



CH1: HB voltage CH2: V_C7 CH3: VCC CH4: --

CH5: GD_PFC CH6: LED voltage CH7: V_C20 CH8: LED current

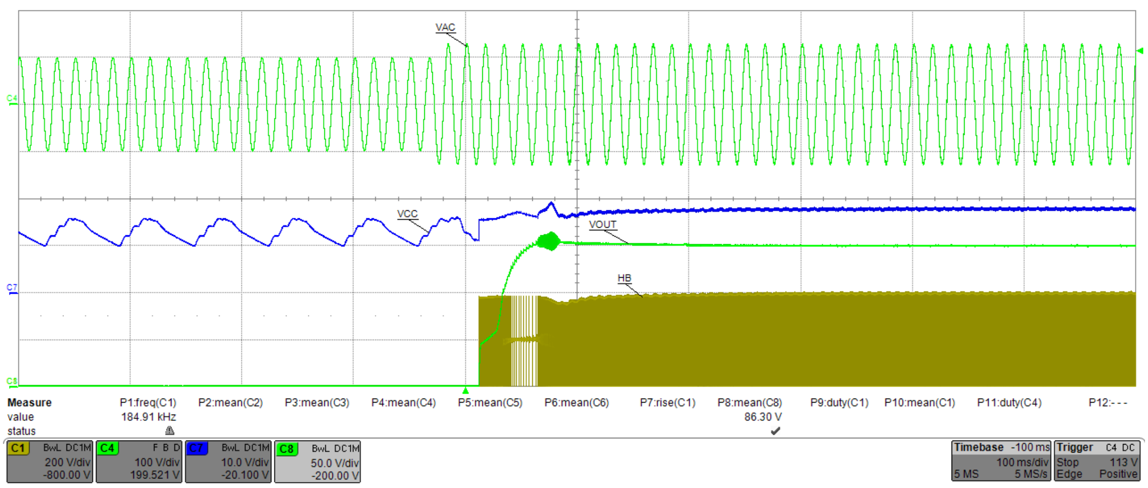
AC brownout

The STCMB1 is equipped with brown-in and brownout protection to prevent the operation at too low AC input voltage.

At the mains plug, if the AC voltage is below the brown-in threshold, the HV start-up generator charges the V_{CC} capacitors until the V_{CC} reaches the turn-on threshold but the operation of both converters is inhibited. Converter startup is enabled once the AC mains is higher than the brown-in threshold.

An example of the brown-in is reported here following: with AC mains voltage below the threshold we can see the HV start-up generator charging the V_{CC} periodically up to V_{CCon}, the converter startup is inhibited. Then, increasing the AC mains voltage, once it reaches the brown-in threshold the SMPS operation is allowed and it starts operating.

Figure 28. Brown-in - V_{LED} = 150 V - I_{LED} = 0.350 A



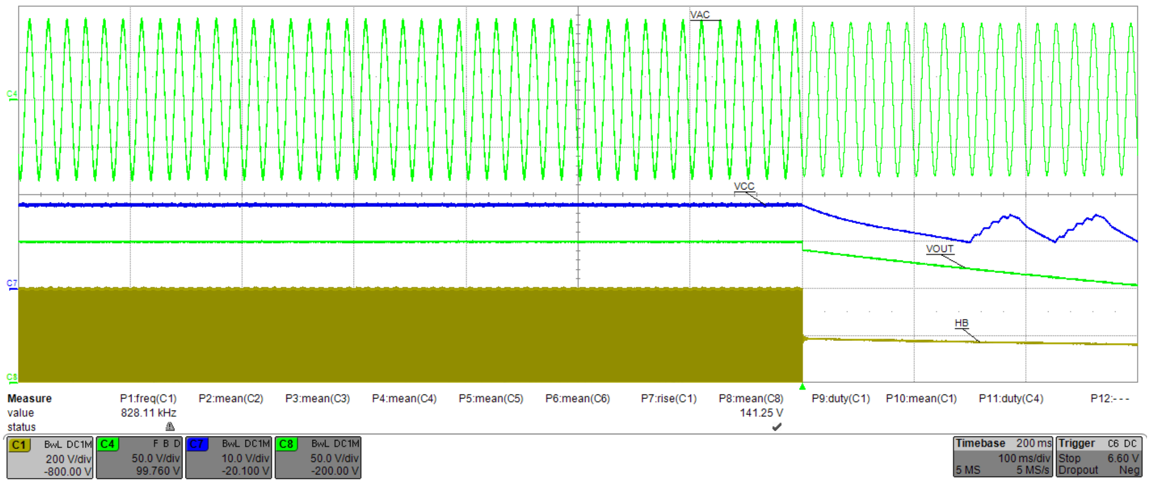
CH1: HB voltage CH4: Vac CH7: VCC CH8: LED voltage

If, during the operation, the AC mains voltage drops below the brownout threshold, the PFC and HB sections are turned off and the HV start-up is turned on until V_{CC} reaches the turn-on threshold V_{CCon}. When V_{CC} equals V_{CCon}, the HV generator is turned off, the switching activity does not start and V_{CC} falls again. This V_{CC} recycling operation continues as long as the abnormal AC mains condition lasts. This sequence takes place until the AC voltage comes back above the brown-in threshold.

In order to avoid unexpected intervention of this protection in the case of missing cycles or short dips of the AC mains, a 40 ms of debounce time is introduced; thus, during the operation, if a brownout condition is detected, the converter stops the operation after the debounce time is elapsed.

An example of the brownout operation by slowly decreasing the input mains voltage is reported in *Figure 29*.

Figure 29. Brownout - V_{LED} = 150 V - I_{LED} = 0.350 A

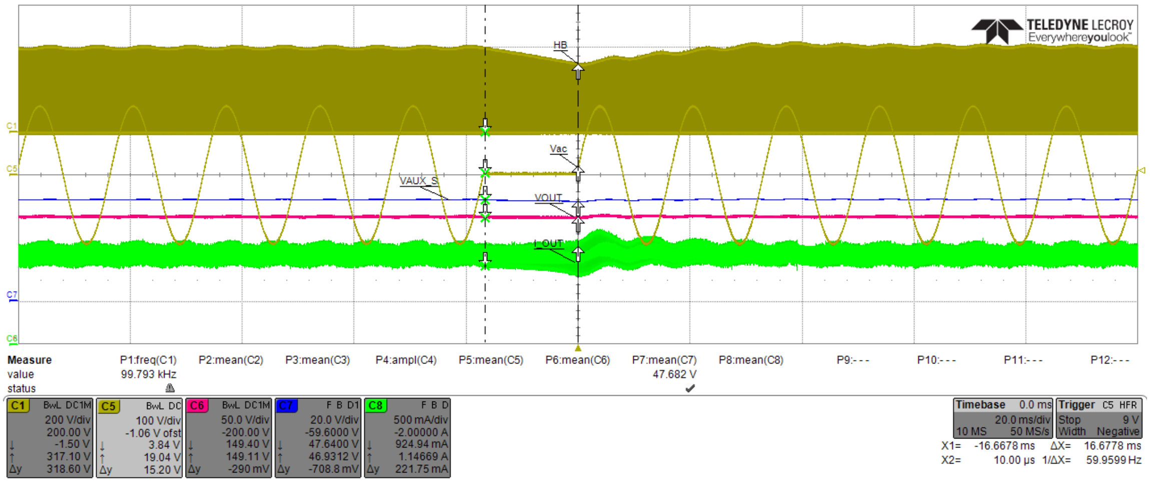


CH1: HB voltage CH4: Vac CH7: VCC CH8: LED voltage

7 Mains dips and short interruptions

In order to validate the design the board has been submitted to the test compliances in accordance with the EN 61000-4-11. The board has not shown anomalous condition at restarting or a missing restart. Here following some significant images during the tests.

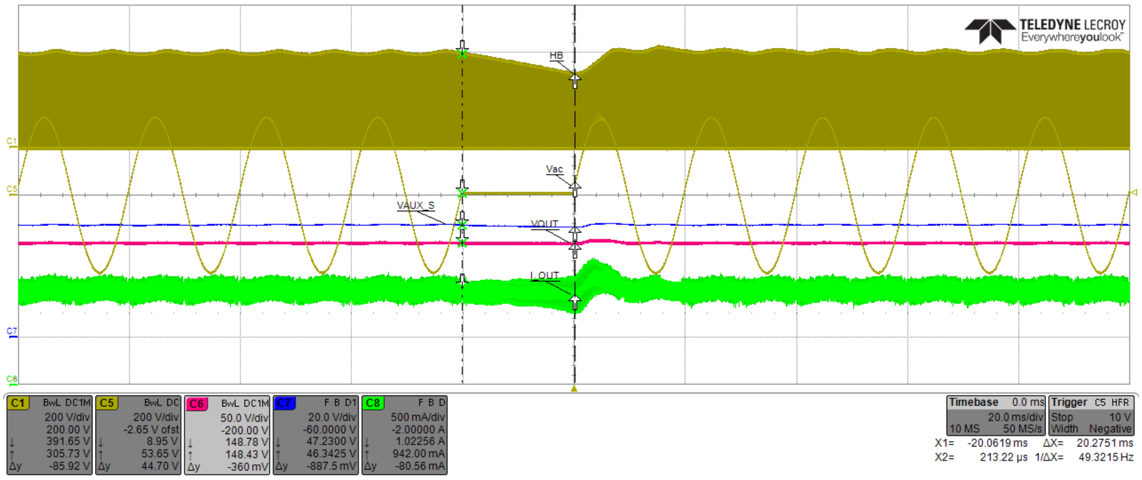
Figure 30. Mains dips 16.6 ms at 115 Vac - 60 Hz - V_{LED} = 150 V - I_{LED} = 1 A



CH1: HB voltage CH2: -- CH3: V-- CH4: --

CH5: Vac CH6: LED voltage CH7: Vaux_S CH8: LED current

Figure 31. Mains dips 20 ms at 230 Vac - 50 Hz - V_{LED} = 150 V - I_{LED} = 1 A



CH1: HB voltage CH2: -- CH3: V-- CH4: --

CH5: Vac CH6: LED voltage CH7: Vaux_S CH8: LED current

Figure 32. Mains dips 83.3 ms at 115 Vac - 60 Hz - V_{LED} = 150 V - I_{LED} = 1 A

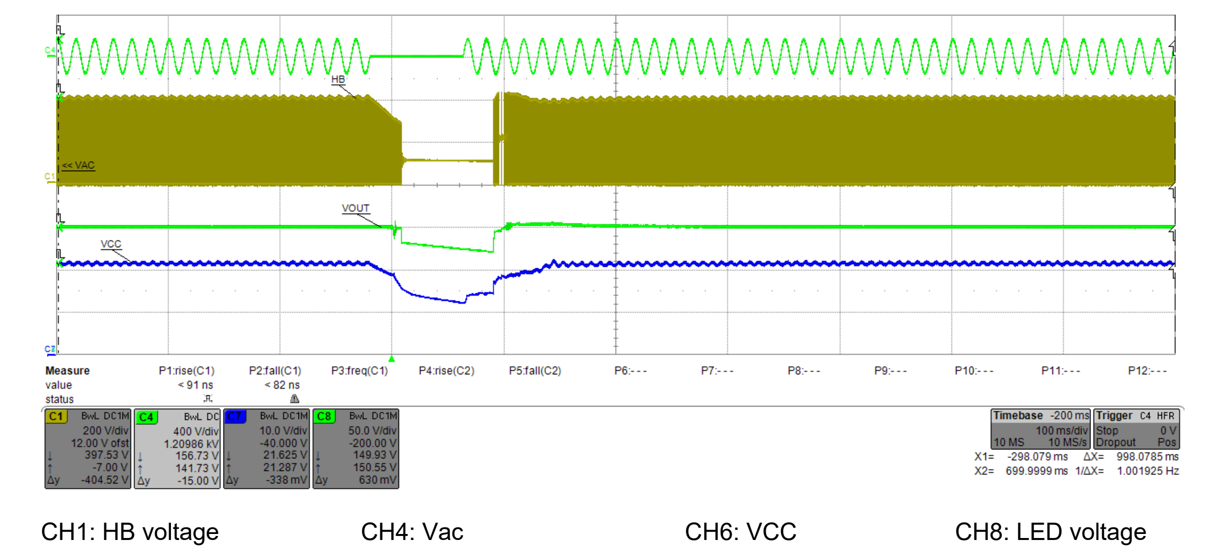


Figure 33. Mains dips 830 ms at 115 Vac - 60 Hz - V_{LED} = 150 V - I_{LED} = 1 A

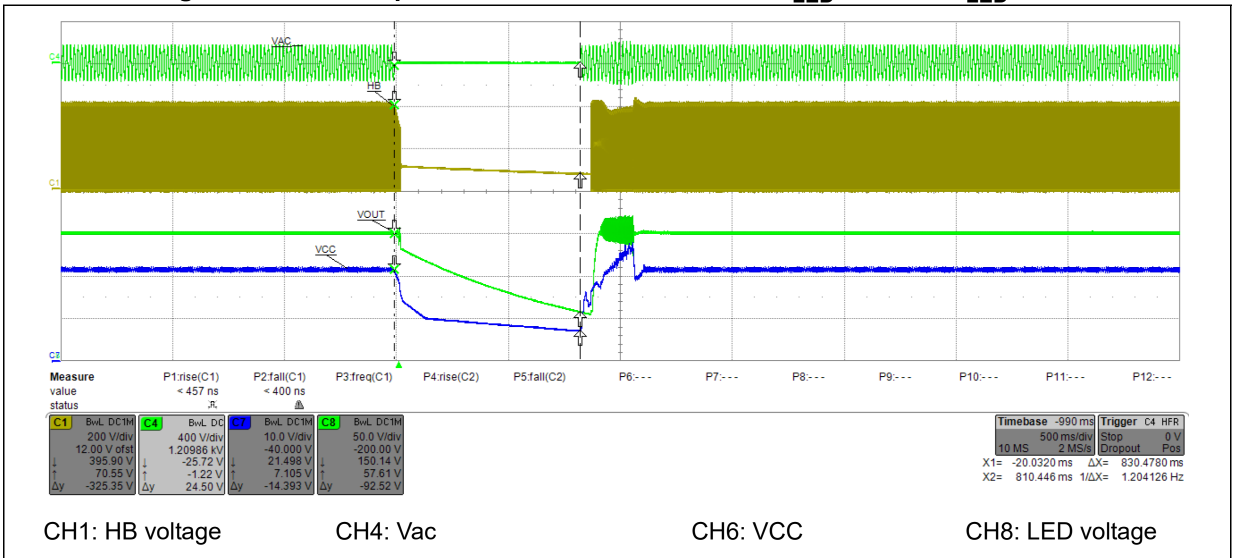
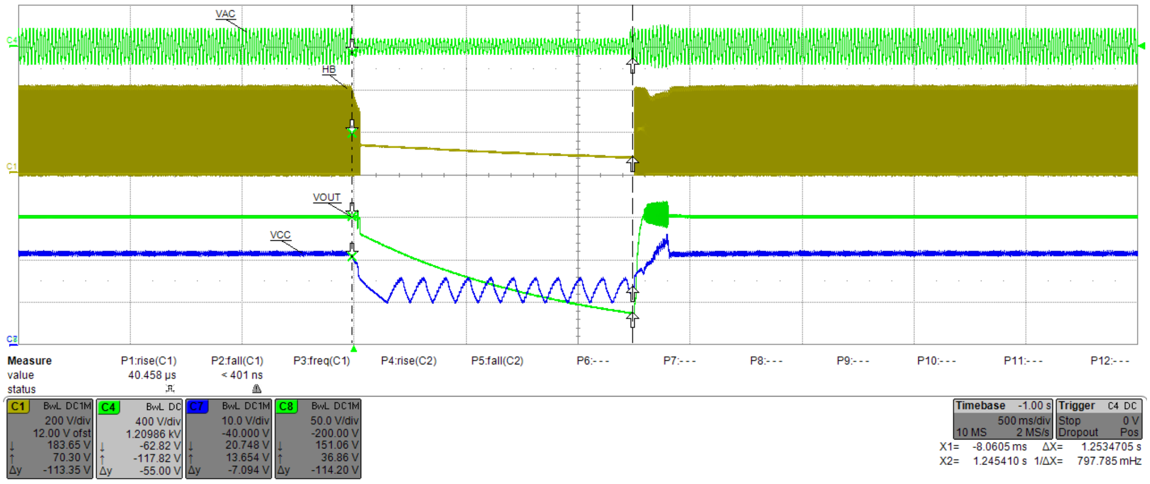


Figure 34. Mains sag 115 to 50 Vac - 60 Hz - 1.2 s - V_{LED} = 150 V - I_{LED} = 1 A



CH1: HB voltage CH4: Vac CH6: VCC CH8: LED voltage

8 Thermal map

In order to check the design reliability, a thermal mapping by means of an IR camera was done. Here below the thermal measures of the board, component side, at nominal input voltage are shown. Some pointers visible in the images have been placed across key components or showing high temperature. The ambient temperature during both measurements was 27 °C. All components are working within their operating temperature range with a margin.

Figure 35. Thermal map at 115 Vac - 60 Hz - full load

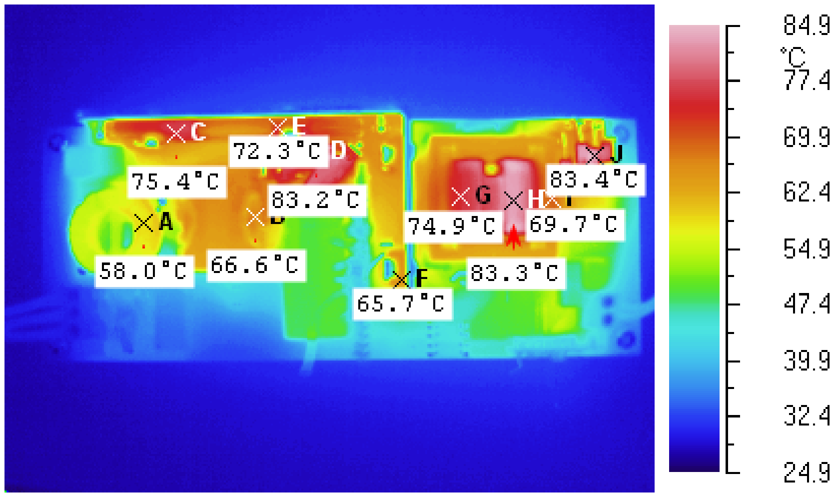


Figure 36. Thermal map at 230 Vac - 50 Hz - full load

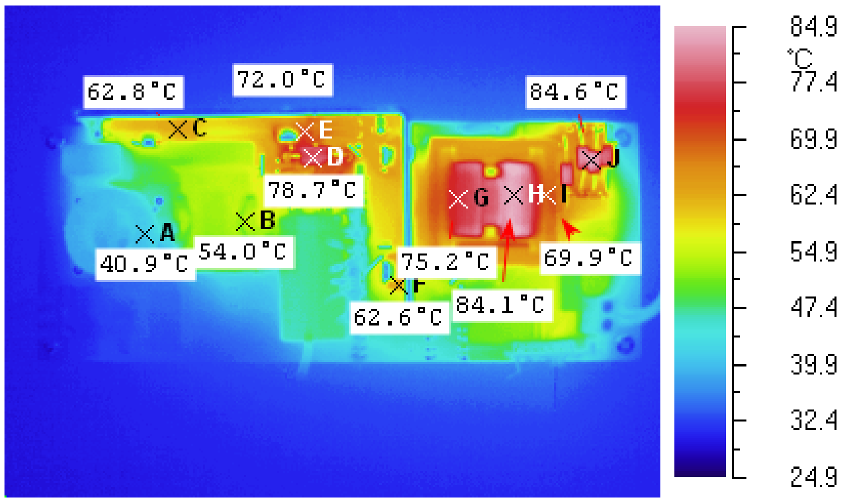


Table 2. Thermal maps reference points

Point	Reference	Description
A	L1	EMI filtering inductor
B	L2	PFC inductor - hottest point
C	D1	Bridge rectifier
D	D4	PFC output diode
E	Q1	PFC MOSFET
F	Q2	Resonant HB MOSFET
G - H - I	T1	Resonant power transformer
J	D10	Output rectifier (hottest one)

9 Conducted emission pre-compliance test

Figure 37 and *Figure 38* are measurements of the conducted noise in average detection, at the full load and nominal mains voltages. The limits shown in the diagrams are the EN55022 Class-B ones, which are the same as those ones relevant to the EN55015 for lighting equipment. As seen in the diagrams, in all test conditions the measures are well below the limits.

Figure 37. CE peak measurement at 115 Vac and full load

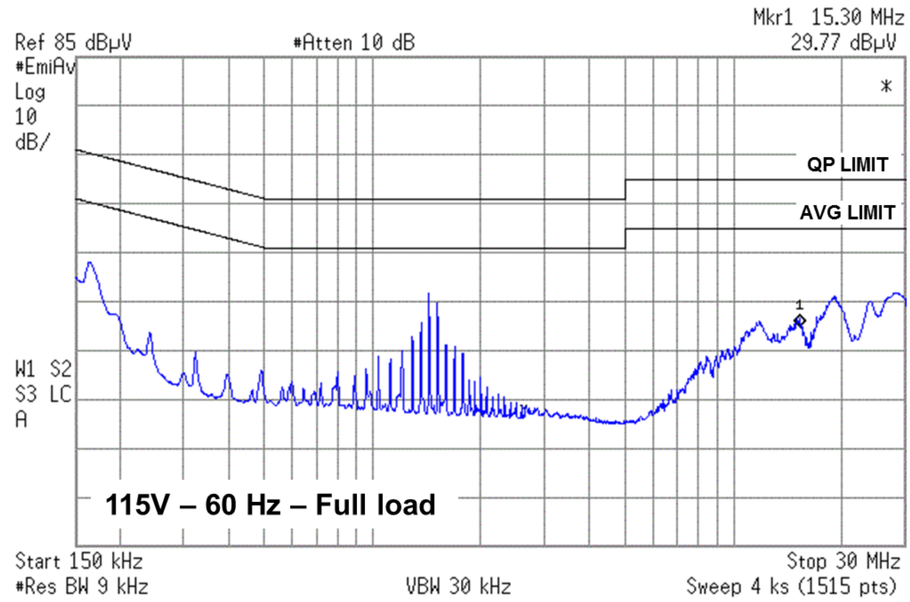
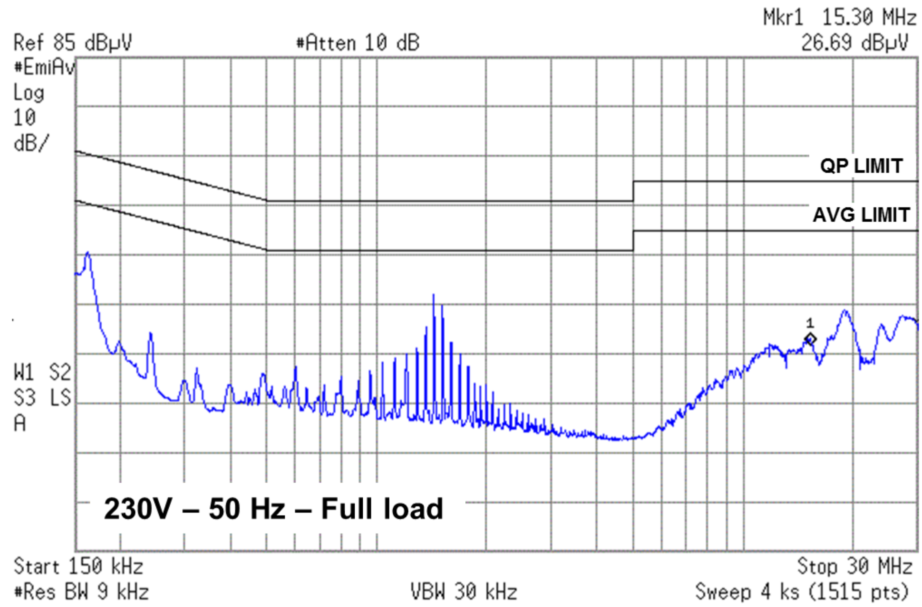


Figure 38. CE average measurement at 230 Vac and full load



10 Bill of material

Table 3. EVL150W-HVSL evaluation board: bill of material

Des.	Part type/ part value	Case style/ package	Description	Supplier
C1	470 nF - X2	9.0 × 18.0 p. 15 mm	X2 - film cap. - B32922C3474K	EPCOS
C2	2.2 nF - Y1	P. 10 mm	Y1 safety cap. DE1E3KX222M	MURATA
C3	2.2 nF - Y1	P. 10 mm	Y1 safety cap. DE1E3KX222M	MURATA
C4	470 nF - X2	9.0 × 18.0 p. 15 mm	X2 - film cap. - B32922C3474K	EPCOS
C5	470 nF - 630 V	8.5 x 26.5 p. 22.5 mm	630 V - film cap. - B32673Z6474K	EPCOS
C6	4.7 nF	5.0 x 13.0 p. 10 mm	450 VAC - film cap. - B32651A7472K	EPCOS
C7	10 µF	2220	CERCAP - 50 V - X7R - 20%	TDK
C8	10 µF	2220	CERCAP - 50 V - X7R - 20%	TDK
C9	100 µF - 450 V	Dia.18 x 35.5 mm	Aluminum ELCAP - CY series - 105 °C	NICHICON
C10	2.2 nF - Y1	p. 10 mm	Y1 safety cap. DE1E3KX222M	MURATA
C11	2.2 nF - Y1	p. 10 mm	Y1 safety cap. DE1E3KX222M	MURATA
C12	470 pF - 1 KV	1206	1 KV CERCAP - X7R - 10%	MURATA
C13	220 pF	1206	630 V CERCAP - GRM31A7 u2J220JW31	MURATA
C14	47 nF 1 KV	7.0 x 18.0 p. 15 mm	1 KV - film cap. - B32652A0473K	EPCOS
C15	470 nF	6.0 x 13 p. 10 mm	MKT film cap. - B32521C3474 m - 250 V - 20%	EPCOS
C16	470 nF	6.0 x 13 p. 10 mm	MKT film cap. - B32521C3474 m - 250 V - 20%	EPCOS
C17	470 nF	6.0 x 13 p. 10 mm	MKT film cap. - B32521C3474 m - 250 V - 20%	EPCOS
C18	470 nF	6.0 x 13 p. 10 mm	MKT film cap. - B32521C3474 m - 250 V - 20%	EPCOS
C19	N.M.	1210	CERCAP - 50 V - X7R - 20%	TDK
C20	1 µF	1206	CERCAP - 50 V - X7R - 20%	TDK
C21	2.2 nF	0805	50 V CERCAP - C0G - 10%	AVX
C22	N.M.	0805	Not mounted	-
C23	4.7 µF	8.5 x 7.2 p. 5 mm	MKS2 film cap. - MKS2C044701M00 - 63 V - 5%	WIMA
C24	4.7 µF	8.5 x 7.2 p. 5 mm	MKS2 film cap. - MKS2C044701M00 - 63 V - 5%	WIMA
C25	N. M.	0805	Not mounted	-

Table 3. EVL150W-HVSL evaluation board: bill of material (continued)

Des.	Part type/ part value	Case style/ package	Description	Supplier
C26	47 nF - 500 V	1206	CERCAP - 500 V - X7R - 10%	KEMET
C27	100 nF	0805	CERCAP - 50 V - X7R - 10%	KEMET
C101	100 N	1206	50 V CERCAP - general purpose - X7R - 10%	TDK
C102	1 N	1206	2 KV CERCAP - X7R - 10%	EPCOS
C103	10 N	0805	50 V CERCAP - general purpose - X7R - 10%	TDK
C104	1.2 nF	0805	50 V CERCAP - general purpose - X7R - 10%	EPCOS
C105	1 µF	1206	50 V CERCAP - general purpose - X7R - 10%	TDK
C106	10 µF	1206	CERCAP - 25 V - X7R - 20%	TDK
C107	10 µF	2220	CERCAP - 50 V - X7R - 20%	TDK
C108	100 nF	0805	CERCAP - 50 V - X7R - 10%	TDK
C109	330 nF	0805	50 V CERCAP - general purpose - X7R - 10%	TDK
C110	220 pF	0805	50 V CERCAP - general purpose - COG - 5%	EPCOS
C111	4.7 µF	1206	16 V CERCAP - general purpose - X7R - 10%	TDK
C112	2.2 µF	1206	16 V CERCAP - general purpose - X7R - 10%	TDK
C113	470 pF	0805	50 V CERCAP - general purpose - COG - 5%	EPCOS
C114	22 pF	0805	50 V CERCAP - general purpose - COG - 5%	EPCOS
C115	1.5 nF	0805	50 V CERCAP - general purpose - COG - 5%	EPCOS
C201	100 nF	0805	CERCAP - 50 V - X7R - 10%	KEMET
C202	470 nF	0805	CERCAP - 25 V - C0G - 10%	AVX
C203	100 nF	0805	CERCAP - 50 V - X7R - 10%	KEMET
C204	100 nF	0805	CERCAP - 50 V - X7R - 10%	KEMET
C205	100 nF	0805	CERCAP - 50 V - X7R - 10%	KEMET
C206	N. M.	0805	Not mounted	-
D1	GBU8J	STYLE GBU	Single phase bridge rectifier	VISHAY
D2	1N4148 WS	SOD-323	High speed signal diode	VISHAY
D3	1N4005	DO-41	General purpose rectifier	VISHAY
D4	STTH5L06	DO-201	Ultrafast high voltage rectifier	STMicroelectronics
D5	1N4148 WS	SOD-323	High speed signal diode	VISHAY
D6	S1M	DO214AC	General purpose rectifier, SMT	FAIRCHILD
D7	S1M	DO214AC	General purpose rectifier, SMT	FAIRCHILD
D8	1N4148 WS	SOD-323	High speed signal diode	VISHAY
D9	STTH3R02Q	DO-15	Ultra fast rectifier	STMicroelectronics
D10	STTH3R02Q	DO-15	Ultra fast rectifier	STMicroelectronics
D11	STTH3R02Q	DO-15	Ultra fast rectifier	STMicroelectronics
D12	STTH3R02Q	DO-15	Ultra fast rectifier	STMicroelectronics
D13	STPS1H100A	SMA	Power Schottky diode	STMicroelectronics

Table 3. EVL150W-HVSL evaluation board: bill of material (continued)

Des.	Part type/ part value	Case style/ package	Description	Supplier
D14	BAV21 W-V	SOD-123	Small signal diode high voltage	VISHAY
D18	BAV99	SOT-23	Dual small signal diode	VISHAY
D101	STPS140Z	SOD-123	Power Schottky diode	STMicroelectronics
D102	1N4148	DO-35	Fast switching diode	VISHAY
D103	MMSZ39T1	SOD-123	39 V Zener diode	ONSEMI
D104	MMSZ13T1	SOD-123	13 V Zener diode	ONSEMI
D105	1N4148	DO-35	Fast switching diode	VISHAY
F1	Fuse T4A	8.5 x 4 p. 5.08 mm	Fuse 4 A - time lag - 3921400	LITTLEFUSE
HS1	Heatsink	DWG	Heatsink for D1, Q1, Q2, Q3	-
J1	MKDS 1,5/ 3 - 5,08	DWG	PCB term. block, screw conn., pitch 5 MM - 3 W	PHOENIX CONTACT
J2	MKDS 1/2-5.0	DWG	PCB term. block, screw conn., pitch 5 MM - 2 W	PHOENIX CONTACT
J3	MOLEX2P	Header 2.54	Male header 2.54 mm - 2P	MOLEX
JP1A	Female header 20	DWG	Female header p. 2,54 mm PRECI-DIP	-
JP1B	Female header 20	DWG	Female header p. 2,54 mm PRECI-DIP	-
JP2	Female header 9	DWG	Female header p. 2,54 mm PRECI-DIP	-
JP. 101A	Male header 20P 90°	DWG	Male header p. 2,54 mm 90°	-
JP. 101B	Male header 20P 90°	DWG	Male header p. 2,54 mm 90°	-
JP201	Male header 7P 90°	DWG	Male header p. 2,54 mm 90°	-
JPX1	Jumper	Shorted	-	-
JPX101	Shorted	-	Wire jumper	-
JPX102	1N4148	DO-35	Fast switching diode	VISHAY
JPX103	Shorted	-	Wire jumper (see mech. part)	-
L1	2019.0002	DWG	Input EMI filter	MAGNETICA
L2	1975.0004	DWG	PFC inductor - 0.31 mH - PQ26/25	MAGNETICA
L3	10 µH	Dia. 8.8, p. 5 mm	Drum coil RFB0807-100	COILCRAFT
Q1	STF24N60M2	TO-220FP	N-channel power MOSFET	STMicroelectronics
Q2	STF13N60M2	TO-220FP	N-channel power MOSFET	STMicroelectronics
Q3	STF13N60M2	TO-220FP	N-channel power MOSFET	STMicroelectronics
Q4	BSS169	SOT-23	N-CH depletion MOSFET	INFINEON
Q101	BC847C	SOT-23	Small signal NPN BJT	VISHAY

Table 3. EVL150W-HVSL evaluation board: bill of material (continued)

Des.	Part type/ part value	Case style/ package	Description	Supplier
Q102	BC847C	SOT-23	Small signal NPN BJT	VISHAY
Q201	BC857C	SOT-23	PNP small signal BJT	VISHAY
R1	NTC 2R5-S237	DWG	NTC resistor P/N B57237S0259M000	EPCOS
R2	5.6 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R3	5.6 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R4-JPX1	0.18 Ω	PTH	RSMF1TB - metal film res. - 1 W - 2% - 200 ppm/°C	AKANEOHM
R5	0 Ω	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R6	3.3 RΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R7	22 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R8	100 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R9	N. M.	PTH	Not mounted	-
R10-JPX2	Shorted	PTH	Wire jumper	-
R11	56 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R12	100 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R13	56 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R14	100 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R15	100 Ω	1206	SMD standard film res. - 1/4 W - 1% - 100 ppm/°C	VISHAY
R16	N.M.	0805	Not mounted	-
R17	1 Ω	2512	SMD current sense resistor - 1 W - 1%	PANASONIC
R18	1 Ω	2512	SMD current sense resistor - 1 W - 1%	PANASONIC
R19	7.5 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R20	13 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R21	10 Ω	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R22	1.5 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R23	1 Ω	1206	SMD standard film res. - 1/4W - 1% - 100 ppm/°C	VISHAY
R24	2.2 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R25	62 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R26	3.3 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R27	N. M.	0805	Not mounted	-
R28	N. M.	0805	Not mounted	-
R29	N. M.	1206	Not mounted	-
R30	N. M.	1206	Not mounted	-
R31	0.15 Ω	PTH	RSMF1TB - metal film res. - 1 W - 2% - 200 ppm/°C	AKANEOHM
R32	110 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY

Table 3. EVL150W-HVSL evaluation board: bill of material (continued)

Des.	Part type/ part value	Case style/ package	Description	Supplier
R33	39 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R39	4.7 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R40	N. M.	0805	Not mounted	-
R42	2.7 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R44	100 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R45	100 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R46	330 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R50	5.6 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R51	2.2 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R52	N. M.	0805	Not mounted	-
R101	2.2 MΩ	1206	SMD standard film res. - 1/4 W - 1% - 100 ppm/°C	VISHAY
R102	2.2 MΩ	1206	SMD standard film res. - 1/4 W - 1% - 100 ppm/°C	VISHAY
R103	2.2 MΩ	1206	SMD standard film res. - 1/4 W - 1% - 100 ppm/°C	VISHAY
R104	56 KΩ	1/4 W	PTH standard film res. - 1/4 W - 5% - 250 ppm/°C	VISHAY
R105	3.9 KΩ	1206	SMD standard film res. - 1/4 W - 5% - 200 ppm/°C	VISHAY
R106	3.9 KΩ	1206	SMD standard film res. - 1/4 W - 5% - 200 ppm/°C	VISHAY
R107	1 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R108	160 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R109	56 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R110	N. M.	0805	Not mounted	-
R111	1 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R112	10 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R113	25 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R114	10 Ω	1206	SMD standard film res. - 1/4W - 5% - 250 ppm/°C	VISHAY
R115	4.7 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R116	3 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R117	270 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R118	68 Ω	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R119	300 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R120	1.2 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R121	3.6 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R122	56 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R123	N. M.	0805	Not mounted	-
R124	47 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R201	1 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R202	22 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY

Table 3. EVL150W-HVSL evaluation board: bill of material (continued)

Des.	Part type/ part value	Case style/ package	Description	Supplier
R203	10 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R204	100 Ω	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R205	27 KΩ	0805	SMD standard film res. - 1/8 W - 5% - 250 ppm/°C	VISHAY
R206	N. M.	0805	Not mounted	-
R207	27 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R208	180 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R209	18 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R210	20 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R211	N. M.	0805	Not mounted	-
R212	620 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R213	0 Ω	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R214	0 Ω	0805	SMD standard film res. - 1/8 W - 5% - 200 ppm/°C	VISHAY
R215	12 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R216	12 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R217	200 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R218	1 KΩ	0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C	VISHAY
R325	180 KΩ	1206	SMD standard film res. - 1/4 W - 5% - 250 ppm/°C	VISHAY
RV1	300 Vac	Dia.15 x 5 p. 7.5 mm	300 V metal oxide varistor- B72214S0301 K101	EPCOS
T1	1860.0152	DWG	Resonant transformer	MAGNETICA
U1	TLVH431AIL3T	SOT23-3L	1.24 V programmable shunt voltage reference	STMicroelectronics
U2	SFH617A-2	DIP-4 - 10.16 MM	Optocoupler	VISHAY
U3	SFH617A-2	DIP-4 - 10.16 MM	Optocoupler	VISHAY
U6	TLVH431AIL3T	SOT23-3L	1.24 V programmable shunt voltage reference	STMicroelectronics
U101	STCMB1	SO20W	TM PFC and LLC resonant combo controller	STMicroelectronics
U201	LM258AD	SO-8	Low power dual op amp	STMicroelectronics
U202	LM258AD	SO-8	Low power dual op amp	STMicroelectronics
Z1	PCB rev. 2.0	-	STCMB1 power board	-
Z101	PCB rev. 1.0	-	STCMB1 daughterboard	-
Z201	PCB rev. 1.0	-	CC control board	-

11 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 °C
- Max. operating ambient temperature: 60 °C
- 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 39. PFC coil electrical diagram

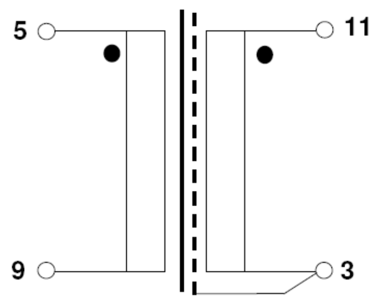


Table 4. PFC coil winding data

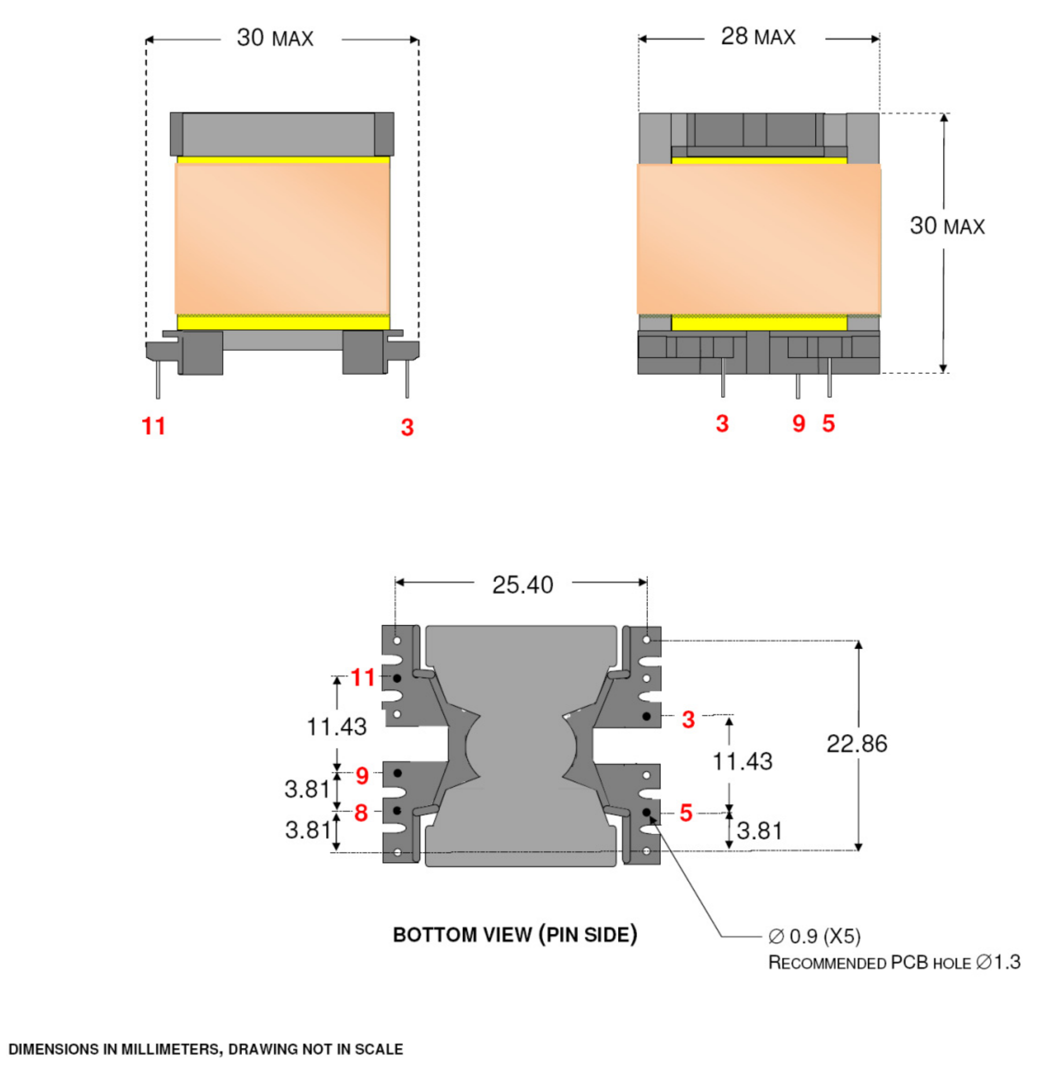
Pins	Windings	RMS current	Number of turns	Wire type
11 - 3	AUX	0.05 A_{RMS}	5	0.28 mm - G2
5 - 9	PRIMARY	2.3 A_{RMS}	50	50 x 0.1 mm - G1

a. Measured between pins #5 and #9.

Mechanical aspect 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 the pin #3 by a soldered solid wire.

Figure 40. PFC coil mechanical aspect



Manufacturer

- MAGNETICA di R. Volpini - Italy - www.magnetica.eu
- Inductor P/N: 1975.0004

12 Transformer specification

General description and characteristics

- Application type: industrial, lighting
- 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: in acc. with EN60950

Electrical characteristics

- Converter topology: half bridge, resonant
- Core type: ETD34-PC44 or equivalent
- Min. operating frequency: 56 kHz
- Typical operating frequency: 90 KHz
- Primary inductance: 3.00 mH ± 20% at 10 KHz - 0.25 V[b]
- Leakage inductance: 300 µH ± 10% at 100 KHz - 0.25 V[c]

Figure 41. Transformer electrical diagram

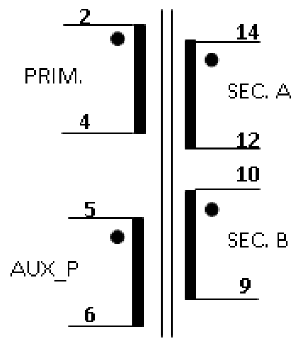


Table 5. Transformer winding data

Pins	Winding	DC resistance	Number of turns	Wire type
2 - 4	PRIMARY	1.6 A_{RMS}	60	TBD
5 - 6	AUX_P(1)	0.05 A_{RMS}	5	TBD
14 - 12	SEC. A	1.6 A_{RMS}	54	TBD
10 - 9	SEC. B(2)	0.05 A_{RMS}	17	TBD

1. The AUX winding primary side is wound on the top of primary winding, turns are close to each other, placed on the external side of the coil former.
2. Secondary B winding on the secondary side is wound on the top of the SECONDARY A winding, turns are spaced on the whole coil former secondary side slot.

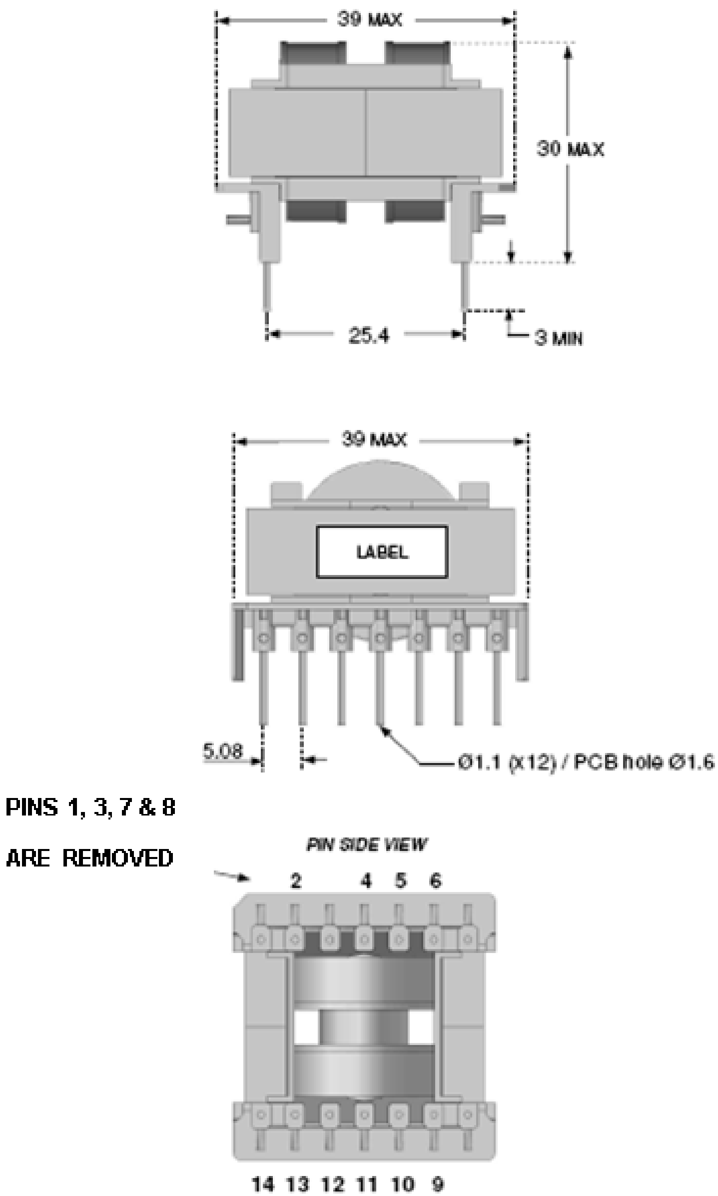
b. Measured between pins 2 - 4.

c. Measured between pins 2 - 4 with all secondary windings shorted.

Mechanical aspect and pin numbering

- Maximum height from PCB: 30 mm
- Coil former type: horizontal, 7 + 7 pins (pins #1, 3, 7 and 8 are removed)
- Pin distance: 5.08 mm
- Row distance: 25.4 mm

Figure 42. Transformer overall drawing



Manufacturer

- MAGNETICA di R. Volpini - Italy - www.magnetica.eu
- Transformer P/N: 1860.0152

Appendix A EVL150W-HVSL with extended range 85 -300 Vac

Sometimes, in order to keep the maximum commonality among the designs or to be compliant with mains in some countries where the mains voltage has huge variations, it is required that the PFC can work not only within the typical universal input mains range from 90 to 264 Vac but with an extended mains range, such as 85 to 300 Vac.

The EVL150W-HVSL board proposed in this document can support also the operation of the extended mains range, it just requires a few minor modifications optimizing the PFC circuit for the new specification. The resonant stage does not need any revision.

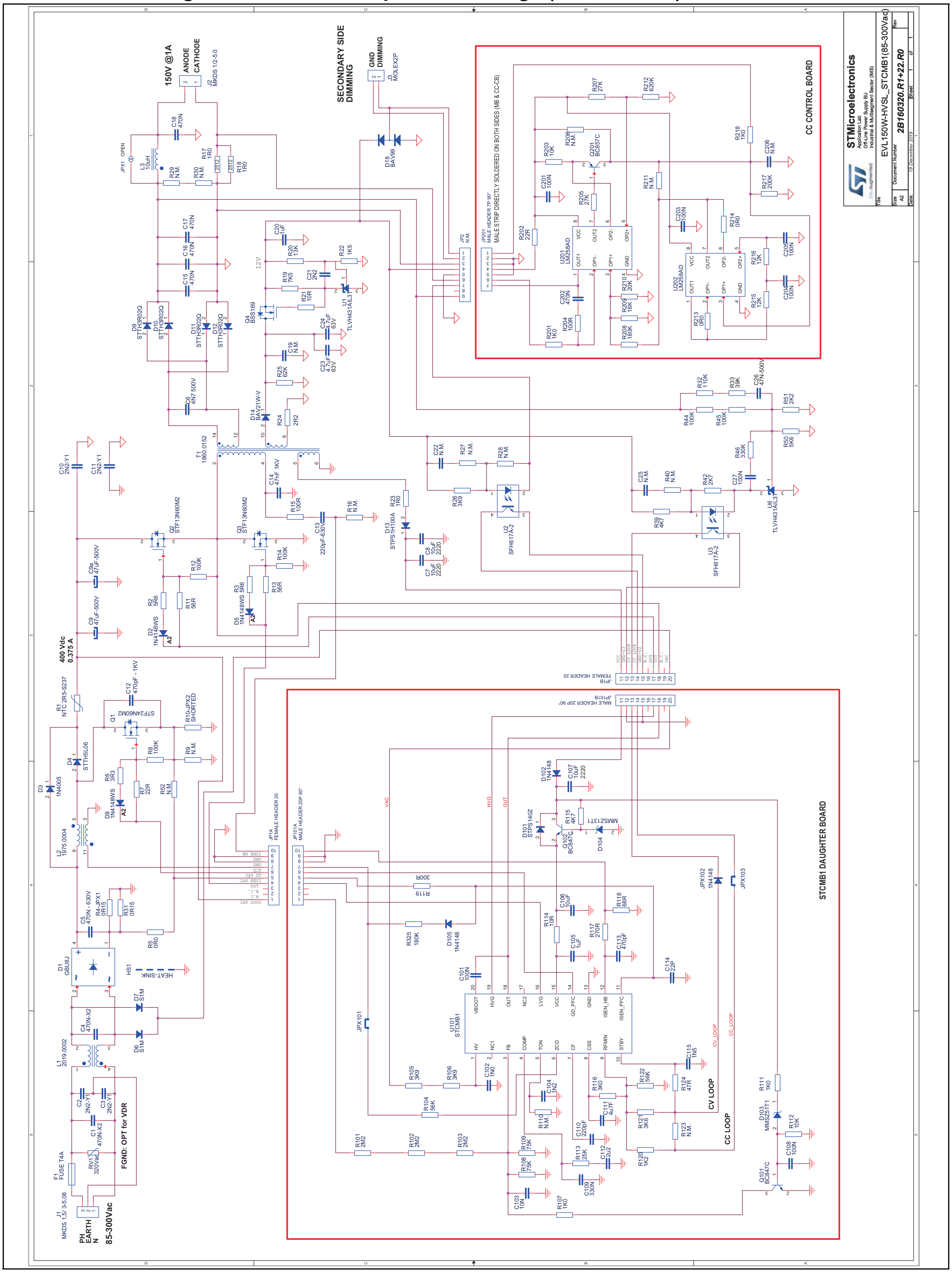
In more detail, circuit modifications involve the PFC feedback divider because it has to deliver a slightly higher voltage, the PFC current sensing resistor, in order to deliver the higher input current at 85 Vac, and the open loop protection on the STCMB1 daughterboard. Modifications are listed in *Table 6*.

Table 6. EVL150W-HVSL evaluation board: modifications for extended mains range

Des.	ORIGINAL part value	NEW part value	Description / MFR	Purpose
C2	2N2-Y1 DE1E3KX222MxxxN01F	2N2-Y1 DE1E3KX222MxxxP01F	Y1 safety cap. DE1E3KX222M / MURATA	Replaced with similar one having higher voltage rating
C3	2N2-Y1 DE1E3KX222MxxxN01F	2N2-Y1 DE1E3KX222MxxxP01F	Y1 safety cap. DE1E3KX222M / MURATA	Replaced with similar one having higher voltage rating
C9	100 µF - 450 V CY SERIES	2 x 47 µF - 500 V in parallel CY SERIES	Aluminium ELCAP - 105 °C / NICHICON	Replaced with 2 ELCAP in parallel having higher voltage rating
D103	39 V - 0.5 W Zener MMSZ39T1	51 V - 0.5 W Zener MMSZ51T1	Zener diode / ONSEMI	Changed value because of higher Vac max.
R4-JPX1	0R18 - RSMF1T	0R15 - RSMF1T	Metal film res. - 1 W - 2% - 200 ppm/°C / AKANEOHM	Changed value because of higher input current at 85 Vac
R108	160 K - 0805	75 K - 0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C / VISHAY	Changed value to obtain higher PFC voltage (440 V)
R109	56 K - 0805	75 K - 0805	SMD standard film res. - 1/8 W - 1% - 100 ppm/°C / VISHAY	Changed value to obtain higher PFC voltage (440 V)
RV1	300 Vac varistor B72214S0301 K101	320 Vac varistor B72214S0321 K101	Metal oxide varistor/ EPCOS	Replaced with similar with higher voltage rating

In *Figure 43*, the schematic with modifications is reported. The test results are very similar and differences are not significant with respect to the standard EVL150W-HVSL board, in order to keep this document brief, they are not here reported.

Figure 43. Extended input mains range (85 ÷ 300 Vac) schematic



Appendix B PFC for single mains range only

As well as countries requiring an extended input mains range of the input voltage, there are also countries with a rather stable mains voltage. In this case, the BOM cost and the size of some components can be optimized by designing the board to work in a single mains range.

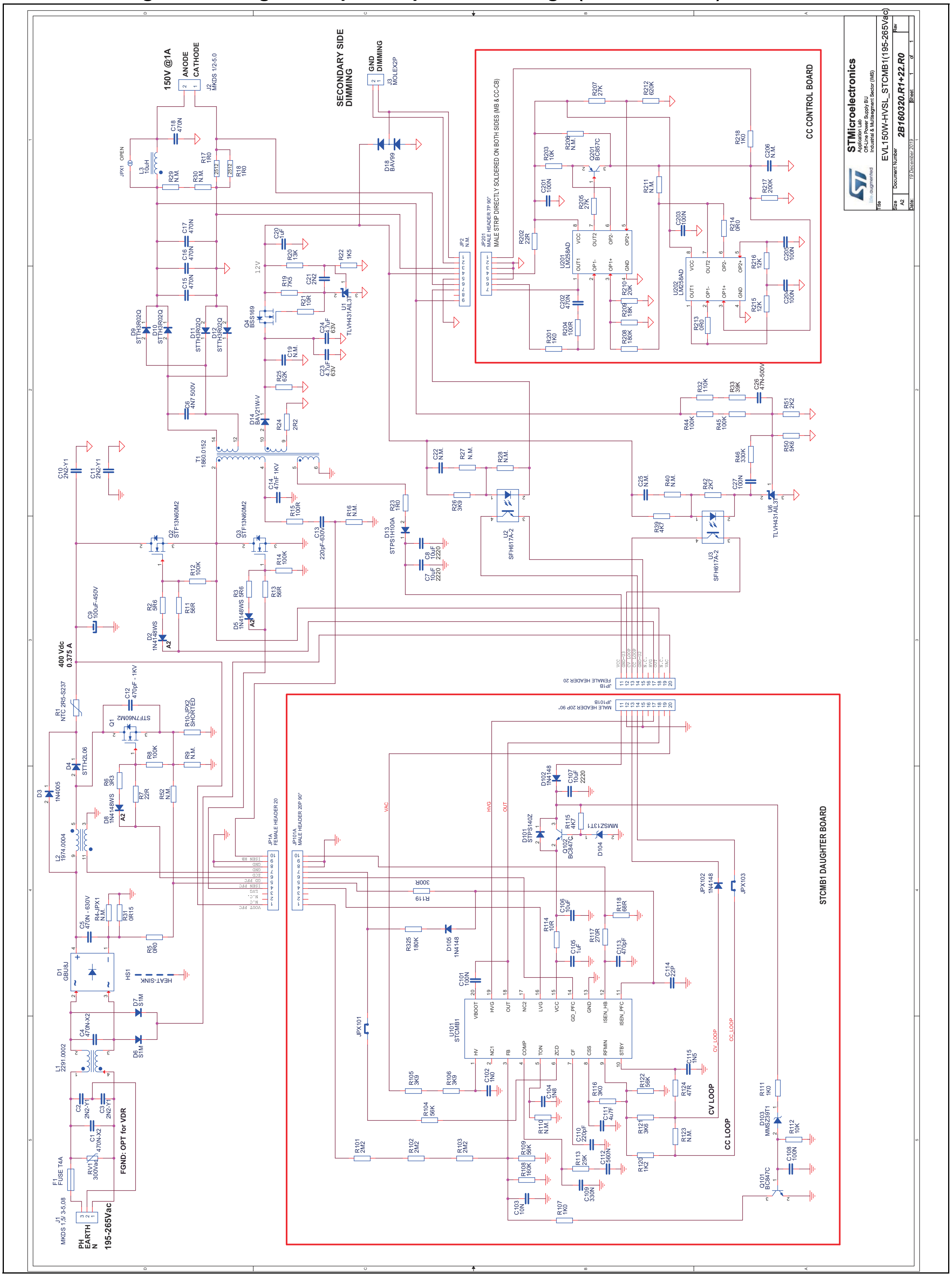
If the input range is the US or Japanese one the input voltage range is typically 90 to 135 Vac, so the board can be used as it is. This is because a wide range PFC is mainly calculated considering the minimum input mains voltage and thus, if it has to work at 100 Vac or 115 Vac, it can work properly. In that case it would also be possible to decrease the PFC output voltage to 200 VDC but a complete redesign of the downstream converter would be needed, therefore we've not considered this option in this application note.

If, instead, the range is the European one (230 Vac) the board can be modified as indicated in *Table 7*, involving the PFC part. In this case the PFC can be optimized because, for the effect of the higher input voltage, the peak and RMS current in its inductor, MOSFET and boost diode is lower and this allows to decrease their size with cost benefits too. Also the EMI filter can be downsized because of the lower AC RMS current and the heatsink can be removed too. Few modification are needed by the control part after the modifications of the PFC power components.

Table 7. EVL150W-HVSL evaluation board: modifications for European mains range

Des.	Original part value	New part value	Description / MFR	Purpose
L1	2019.0002	2291.0002	Input EMI filter / MAGNETICA	Replaced with similar one, smaller
L2	1975.0004	1974.0002	PFC inductor - 520 µH / MAGNETICA	Replaced with similar one, smaller
R4	0R18	Not mounted	Removed	Not needed
D4	STTH5L06	STTH2L06	UF high voltage rectifier / STMicroelectronics	Replaced with similar one, smaller
Q1	STF24N60M2	STF7 n60 m2	N-channel power MOSFET / STMicroelectronics	Replaced with similar one, smaller
C104	1N2 - 0805	1N8 - 0805	50 V CERCAP - C0G - 10% / EPCOS	Ton proper setting
C112	2u2 - 1206	560 N - 1206	16 V CERCAP - X7R - 10% / TDK	PFC loop compensation

Figure 44. Single European input mains range (195 ÷ 265 Vac) schematic



The board, with all modifications indicated above, has been tested, here following the salient test results for the PFC stage.

Figure 45. Compliance to EN61000-3-2 at 230 Vac - 50 Hz, full load

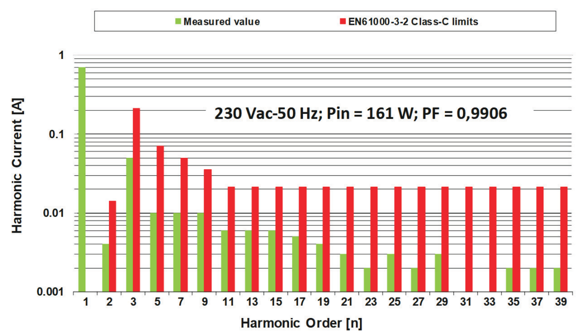


Figure 46. Compliance to EN61000-3-2 at 230 Vac - 50 Hz, Pin = 75 W

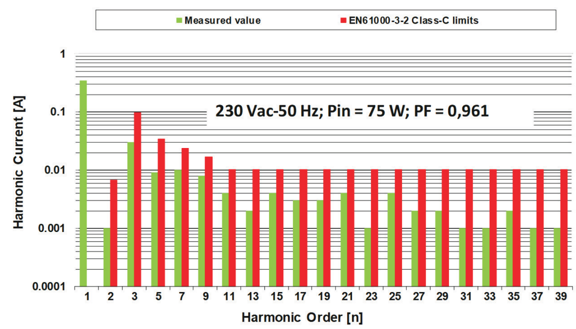
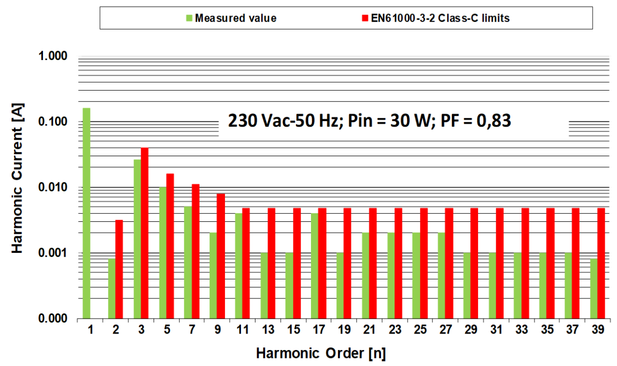


Figure 47. Compliance to EN61000-3-2 at 230 Vac - 50 Hz, Pin = 30 W



In *Figure 45* and *Figure 46* the harmonics of the input mains current at 230 Vac at the full load and 75 W input power have been reported; all harmonics are within the limits specified by the EN61000-3-2 Class-C.

The THD versus the input power is reported in *Figure 48*.

The power-factor measurement versus the load is reported in *Figure 49*. The power-factor is high as expected; it tends to decrease approaching light load conditions.

Figure 48. THD vs. input power

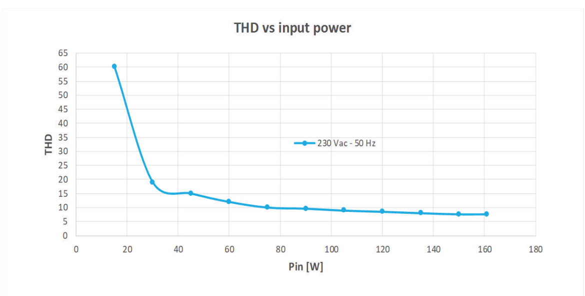
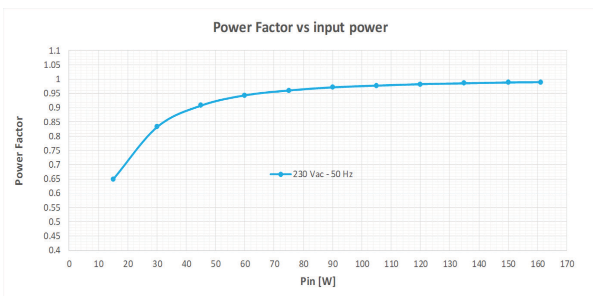


Figure 49. Power-factor vs. output power



The efficiency measurements are reported in *Figure 50*. The efficiency at the maximum load is aligned as the original board, but in this case the PFC power components are cheaper and smaller in size.

In *Figure 51* the input power at no-load is reported too.

Figure 50. Efficiency vs. output load

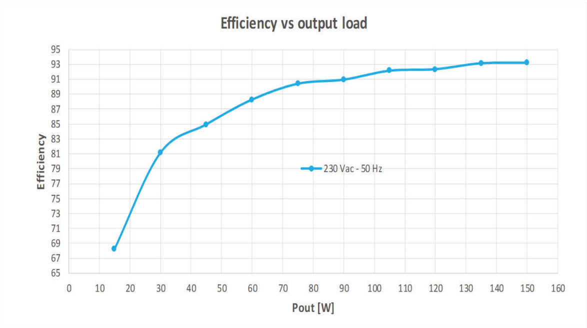
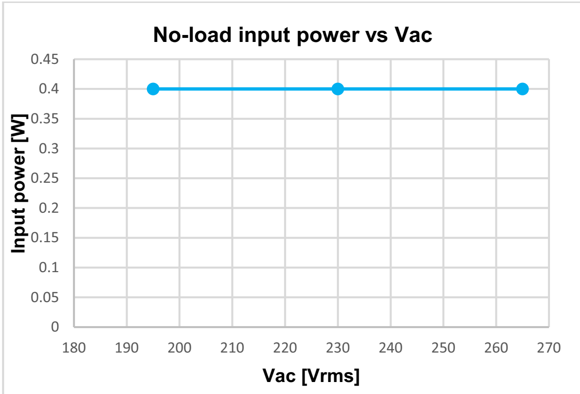


Figure 51. No-load input power vs. Vac



Appendix C Low cost schematic, with single optocoupler

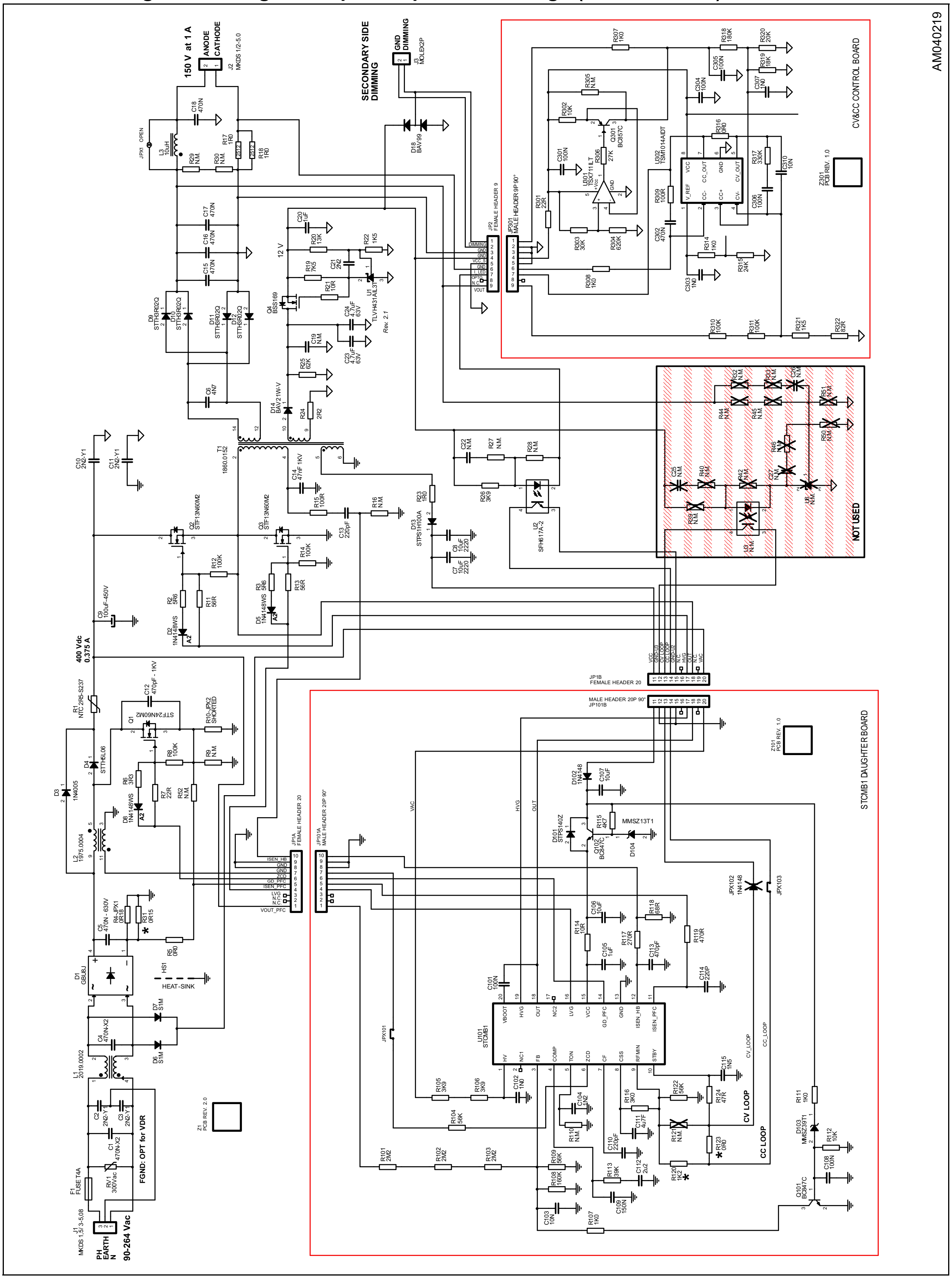
A critical situation that can happen to an LED lamp is the opening of the LED string: in that case the output voltage would rise uncontrolled if not properly limited. The EVL150W-HVSL schematic has dedicated protection against this failure: actually, in the case of open load condition the output voltage is kept perfectly regulated under control by means of the shunt regulator U6, the optocoupler U3 and the relevant circuitry. Some applications are required to be as simple as possible or very economical, or they are molded into resin. In these cases it might be a viable solution to simplify the schematic by removing the shunt regulator U6, the optocoupler U3 and their surrounding components. In this way, the board, in the case of failures, has less protections but it has a lower cost and complexity. Additionally, if we consider a molded unit as an outdoor application, in the case of failures the unit has no way to be repaired, thus it makes sense to remove some protections. It should be noted that in this case the unit is no longer protected against the open load condition, therefore pay close attention during testing or measuring the board to avoid the unintentional generation of any dangerous condition.

As a compromise to the complete removal of the CV circuitry, we propose in *Figure 52* a schematic implementing a CV control loop but using a single optocoupler: by slightly modifying the control daughterboard we can implement a CC/CV controller as the TSM1014 or a similar one, achieving both the control loops. In order to keep the solution as simple as possible we've also removed the PWM dimming option; thus the LED current of the board using the proposed schematic is set only by analog or resistive dimming. All modifications can be easily implemented on the EVL150W-HVSL to make trials as indicated by the schematic in *Figure 52*.

Note: The schematic of Figure 52, using the feedback of the half-bridge modified with a single optocoupler, implements the wide range version of the PFC (90 ÷ 264 Vac) as the standard board.

It is absolutely possible to implement this single optocoupler schematic with a different PFC solution, using one of those proposed in this document obtaining the features required by the user‘s specifications.

Figure 52. Single European input mains range (195 ÷ 265 Vac) schematic



Revision history

Table 8. Document revision history

Date	Revision	Changes
26-Feb-2019	1	Initial release.
31-Aug-2019	2	Added on daughterboard: D105 and R325
03-Mar-2020	3	Changed R325, R119, R113, C109, C114 values