DESIGNS from our LABS

Performance of a 350W-Power Factor corrector operating in Transition Mode with L6564

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By Federico Levati

Main components	
L6564	10 pin transition-mode PFC controller
STTH8L06	Turbo 2 ultrafast high voltage rectifier
STF21N65M5	N-channel 650 V, 0150 Ω, 17 A MDmesh™ V Power MOSFET, TO-220FP
TM Boost inductor	L=160uH - with auxiliary winding

Introduction

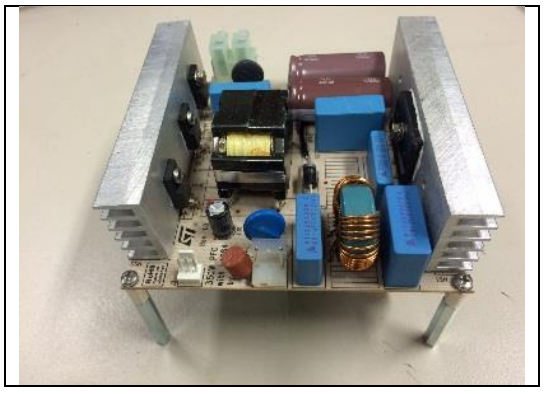
Transition mode operation in PFC pre-regulator is typically suggested in applications at low power level up to 250W, while CCM is recommended for high power level-starting from a power higher than 300W. In the middle power range is often difficult to decide which is the most performing solutions and which is the boundary between the two working mode. The aim of this note is to evaluate the performance of a PFC-preregulator working in TM up to 350W. The simple ST L6564 TM controller has been used to realize the prototype.

Specification

The demonstration board has the following characteristics:

- Line voltage range: 90 to 265 Vac
- Minimum line frequency (fL): 47 Hz
- Regulated output voltage: 400 V
- Rated output power: 350 W
- Transition Mode operation (TM)
- EMI: in accordance with EN55022 Class-B

Figure 1: 350W-TM PFC with L6564-first prototype



Circuit description

This design note describes a 350W PFC prototype board operating in **transition mode**. Starting from the PCB of EVL4984-350W (described in AN4163), changing the inductor, sense resistors and adapting a L6564 [1] instead of the L4984 [2], a 350W TM board has been obtained.

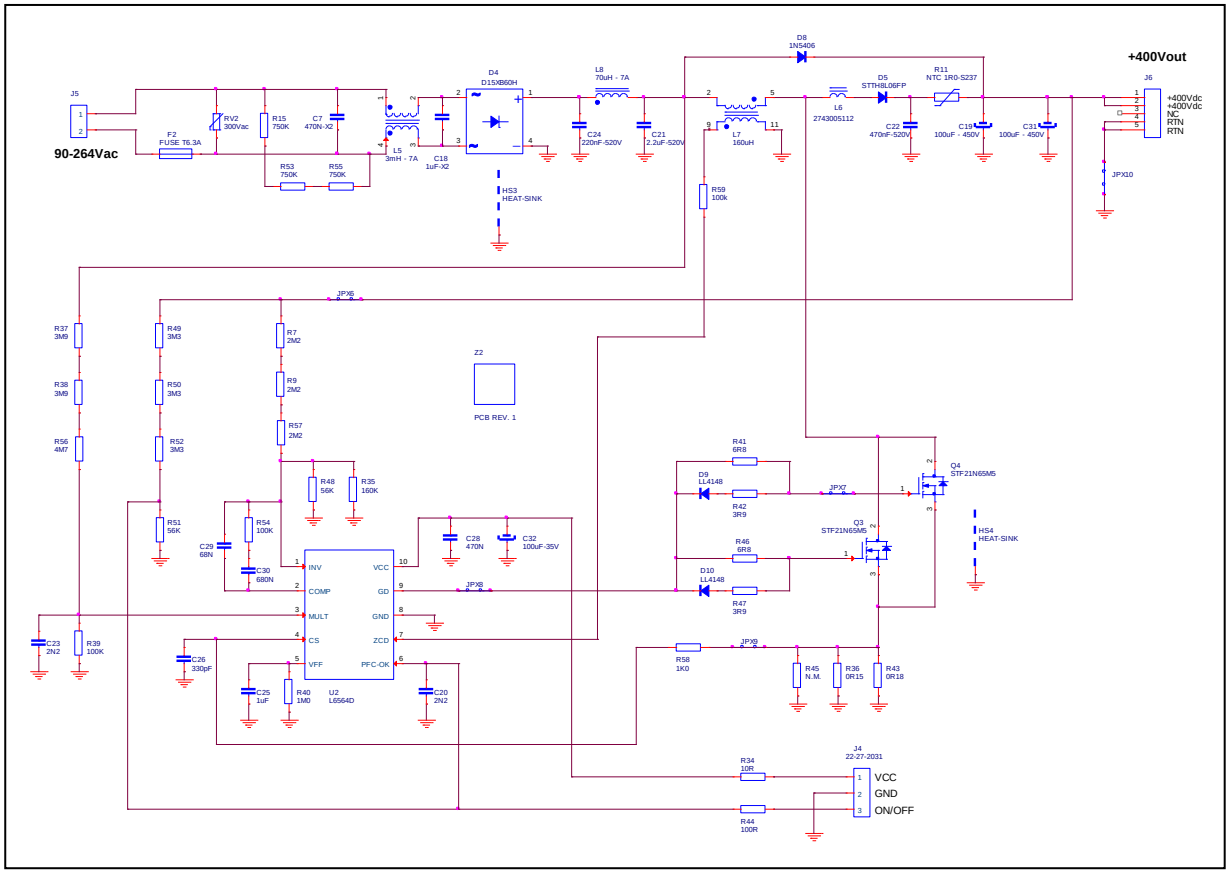
Except for pin 7, L6564 and L4984 are pin to pin compatible. The L6564- pin 7 (ZCD) has been connected through a 100k resistor to the auxiliary winding of the inductor sample.

Major changes to the EVL4984-350W [4] are listed below:

- L6564
- TM boost inductor 160uH.
- Rsense: 0.15Ω in parallel with 0.18Ω.
- Pin 7-ZCD connected to boost inductor auxiliary winding with a 100k.
- Added a 1uF X Cap on C2 input P-Filter of EMI stage.
- STTH8L06 [3] instead of fast recovery diode STTH8S06FP.

Note that only few modifications have been applied to the initial EMI filter. Schematics is shown in **Figure 2** and the test result are reported in the following paragraph:

Figure 2: 350W-TM PFC with L6564 schematics.

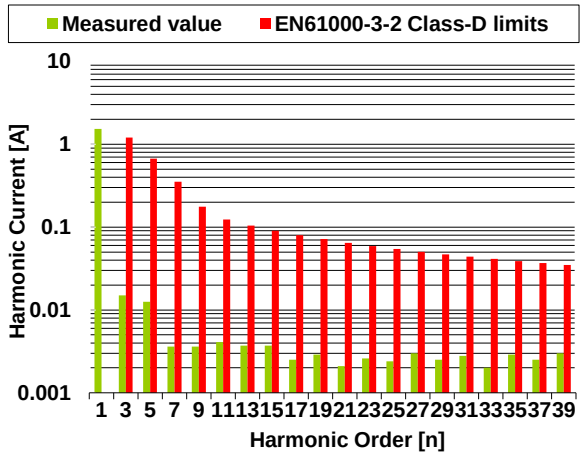


Test results and significant waveforms

Harmonic content measurement

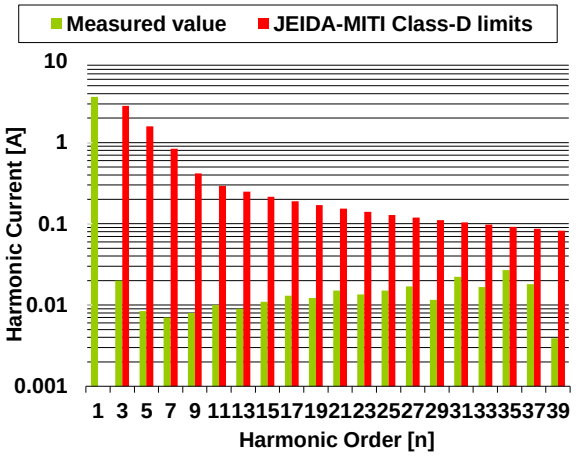
One of the main purposes of a PFC pre-conditioner is the correction of input current distortion, decreasing the harmonic contents below the limits of the relevant regulations. Therefore, this evaluation board has been tested according to the European rule EN61000-3-2 Class-D and Japanese rule JEITA-MITI Class-D, at full load at both the nominal input voltage mains.

Figure 3: L6564-350W-TM PFC Evaluation board: Compliance to EN61000-3-2 standard



Vin = 230 Vac - 50 Hz, Pout = 350 W
THD = 1.45 %, PF = 0.9910

Figure 4: L6564-350W-TM PFC Evaluation board: Compliance to JEITA-MITI standard

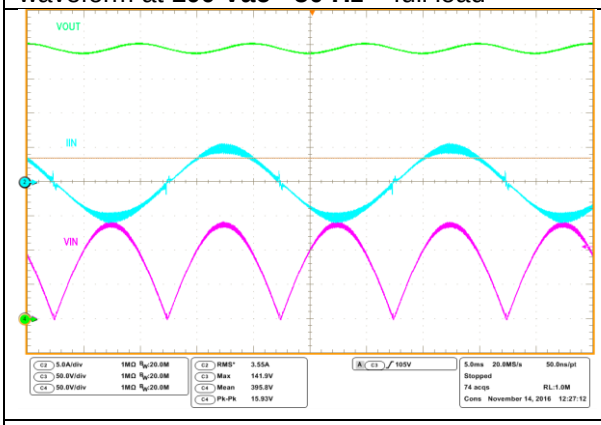


Vin = 100 Vac - 50 Hz, Pout = 350 W
THD = 2.5 %, PF = 0.9967

The circuit is able to reduce the harmonics well below the limits of both regulations from full load (measurements are reported in **Figure 3** and **Figure 4**) down to light load. Please note that all measures and waveforms have been done using a Pi-filter for filtering the noise coming from the circuit, using a 70uH inductor and two X2 filter capacitors (C24=220nF, C21=2.2uF-see **Figure 2**).

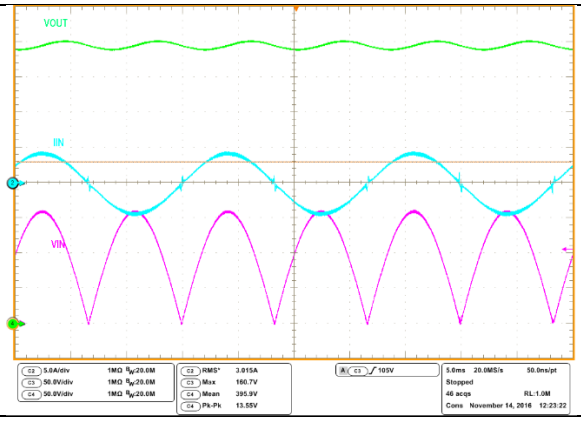
For user reference, waveforms of the input current and voltage at the nominal input voltage mains and different load conditions are reported here following in **Figure 5**, **Figure 6**, **Figure 7** and **Figure 8**.

Figure 5: 350W TM PFC input current waveform at **100 Vac - 50 Hz** – full load



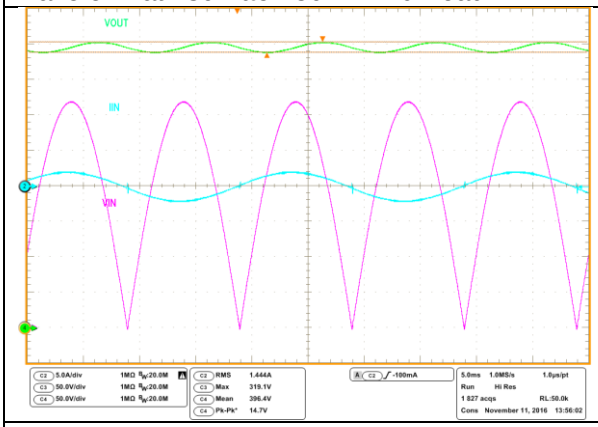
CH1: Input Current
CH2: Input voltage
Ch3: Output voltage
PF=0.9967, THD=2.5%

Figure 6: 350W TM PFC input current Waveform at **115 Vac - 60 Hz** – full load



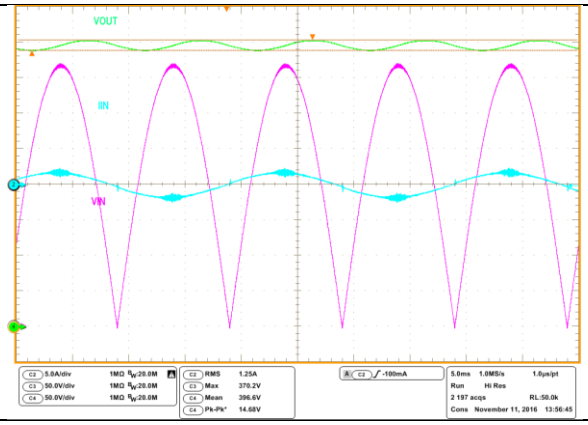
CH1: Input Current
CH2: Input voltage
Ch3: Output voltage
PF=0.9985, THD=3%

Figure 7: 350W TM PFC input current waveform at **230 Vac - 50 Hz** – full load



CH1: Input Current
CH2: Input voltage
Ch3: Output voltage
PF=0.9910, THD=1.45%

Figure 8: 350W TM PFC input current waveform at **265 Vac - 50 Hz** – full load



CH1: Input Current
CH2: Input voltage
Ch3: Output voltage
PF=0.9813, THD=2.40%

The Power Factor (PF) and the Total Harmonic Distortion (THD) have been measured too and the results are reported in **Figure 9** and **Figure 10**. As visible, the PF remains close to unity throughout the input voltage mains at full load and the Total Harmonic Distortion is very low till 75% load.

Figure 9: Power Factor vs Vin @different loads

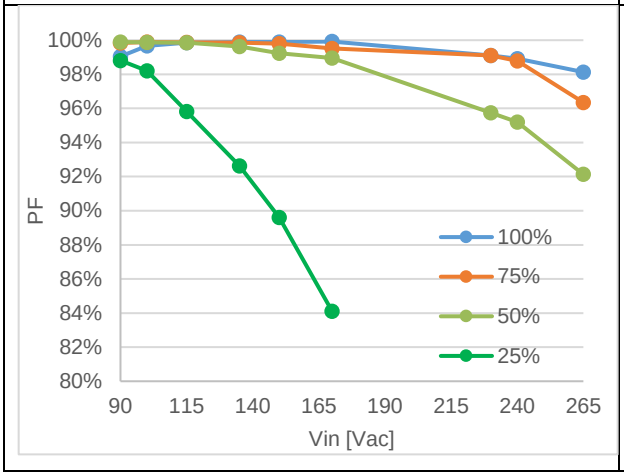
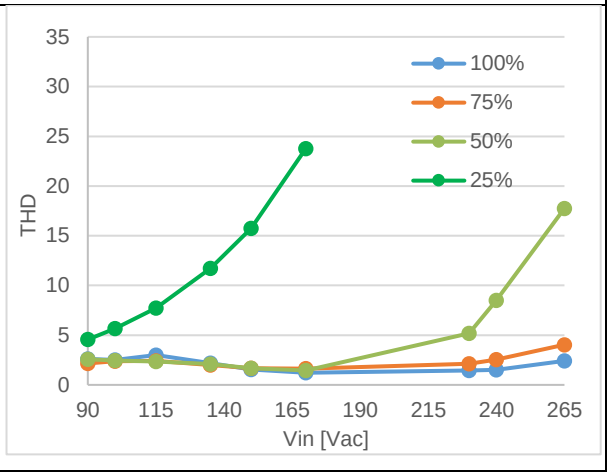


Figure 10: THD vs Vin @different loads



Efficiency measurements

The measured efficiency is shown in **Figure 11**: it is very good at all load and line conditions. At full load it is always higher than 96%, making this design suitable for high efficiency power supply.

Figure 11: Efficiency vs Vin @different loads

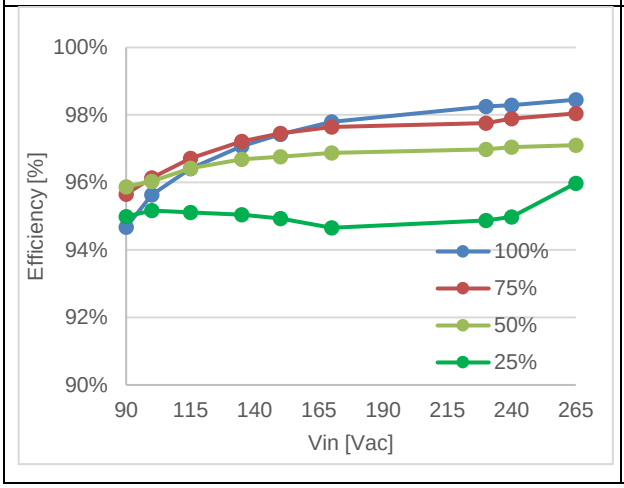


Figure 12: Light Load Efficiency vs Vin

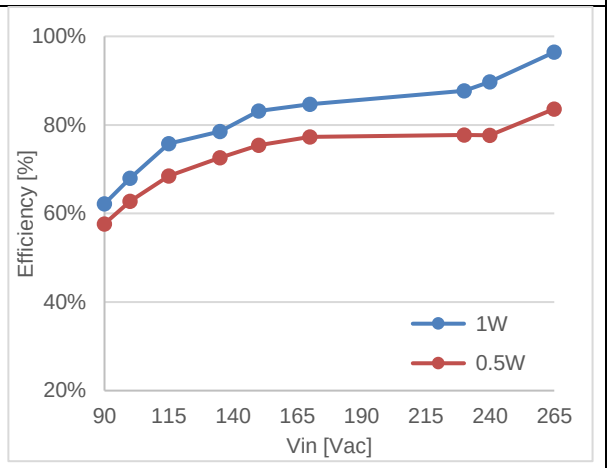


Figure 12 show the efficiency versus line when a 1W or 0.5W load is applied.

The consumption at no load and the efficiency at very light load (0.5-1W) are reported in the following table:

Table 1: light load (0.5-1W) efficiency and no load consumption with R15, R53, R55 disconnected

	350W-L6564 TM PFC			
Vin [Vac]	**Vout [V]**	**Load [W]**	**Pin [W]**	**Efficiency [%]**
115Vac/60Hz	395.4	0	0.128	-
230Vac/50Hz	395.4	0	0.136	-
115Vac/60Hz	395.4	0.50	0.730	68.49%
230Vac/50Hz	395.4	0.50	0.643	77.76%
115Vac/60Hz	394.4	1.00	1.320	75.75%
230Vac/50Hz	395.4	1.00	1.140	87.71%
ICC [mA]	[1.8-2.5]mA during BM			

Conducted emission pre-compliance test

The following figures **Figure 13**, **Figure 14**, **Figure 15** and **Figure 16** are the average measurement of the conducted noise at full load (0.875A) and nominal input mains voltages in order to check the EMC behavior at every working frequency.

Figure 13: 115Vac-60Hz-full load-**L**

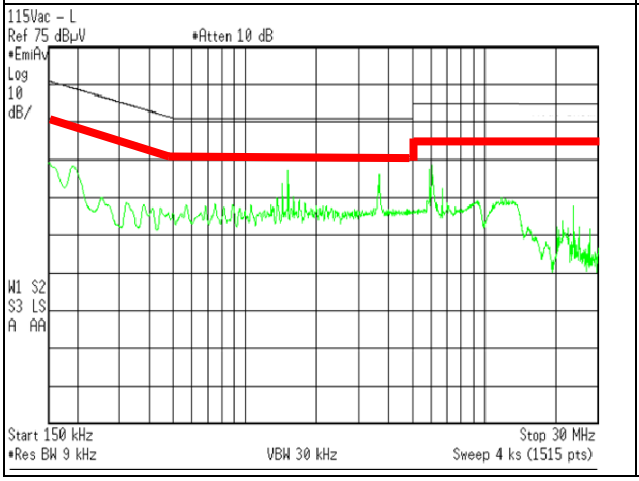


Figure 14: 115Vac-60Hz-full load-**N**

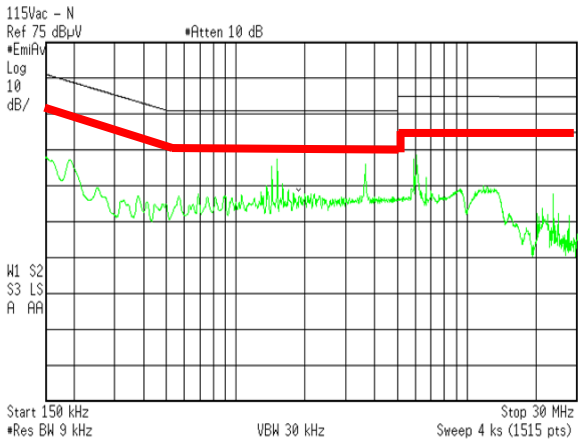


Figure 15: 230Vac-50Hz-full load-**L**

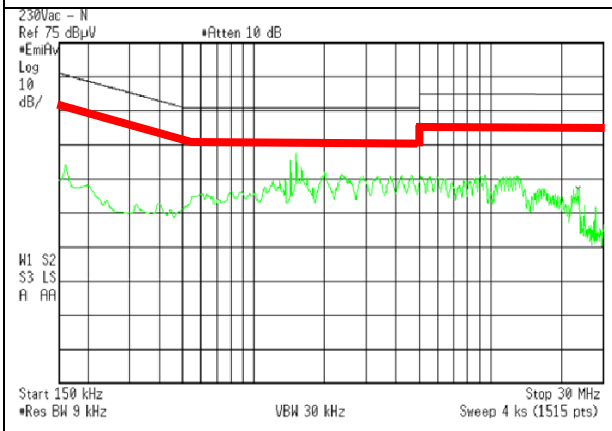
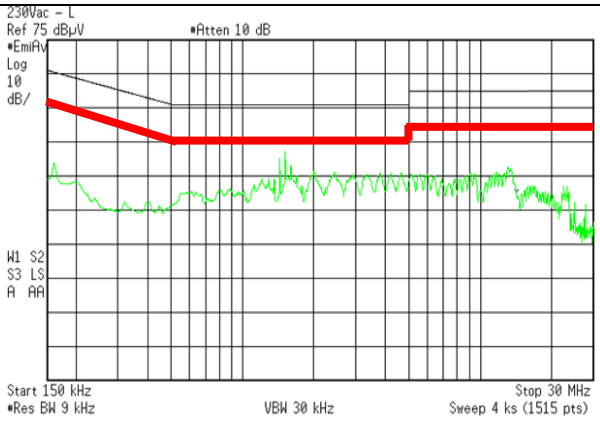


Figure 16: 230Vac-50Hz-full load-**N**



A safe margin is observed.

Thermal map

In order to check the design reliability, a thermal mapping by means of an IR Camera has been done. The ambient temperature during both measurements was 25 °C.

Figure 17: 115Vac-60Hz-full load

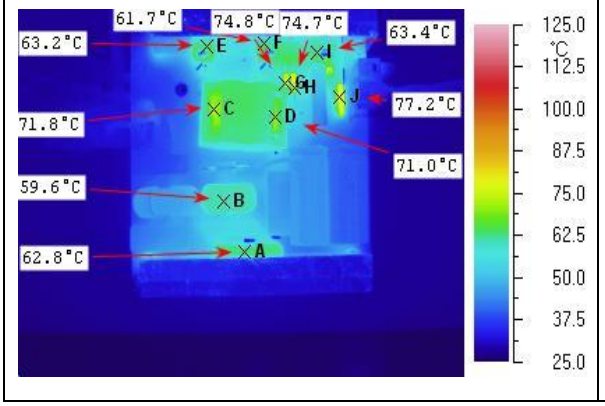
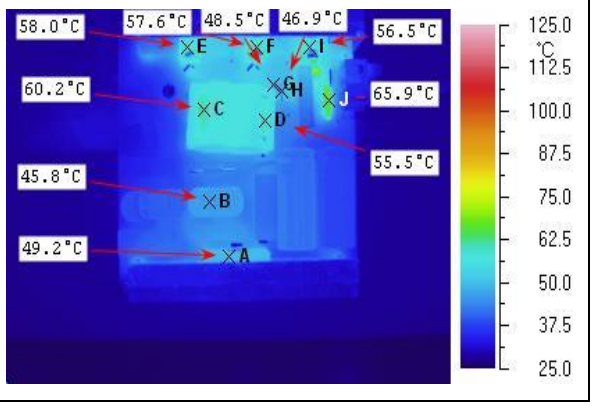


Figure 18: 230Vac-50Hz-full load



Point	Component	T@115Vac [°C]	T@230Vac [°C]
A	**Bridge**	62.8	49.2
B	**Filter**	59.6	45.8
C	**Boost inductor**	71.8	60.2
D	**Boost inductor**	71.0	55.5
E	**MOSFET Q1**	63.2	58.0
F	**MOSFET Q2**	61.7	57.6
G	**R sense**	74.8	48.5
H	**R sense**	74.7	46.9
I	**D3 diode**	63.4	56.5
J	**R2 NTC**	77.2	65.9

Conclusions

Even if, in a so high power throughput, TM operation involves higher peak currents as compared to CCM and a cost-performance trade off needs to be done on a case-by-case basis, this note demonstrates that a PFC can work easily in transition mode till 350W using the ST L6564.
At this boundary power level, the performance is solid in terms of efficiency and THD from full load till the boundary with the burst mode. A considerable power saving is noted at light load and during standby mode.
Harmonic contents are well below the limits of the actual regulations European and Japanese and the prototype is Compliant with EN55022 class-B at nominal input voltage.
Also the design reliability is guarantee by the thermal evaluations.

Support material

Documentation
[1] L6564 Datasheet
[2] L4984 Datasheet
[3] STTH8L06 Datasheet
[4] AN4163, EVL4984-350W: 350 W CCM PFC pre-regulator with the L4984D

Revision history

Date	Version	Changes
14-Mar-2017	1	Initial release