800 W PFC demoboard system solution

High power density 800 W 130 kHz platinum server design EVAL_800W_130PFC_C7

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**Description:**

The “**EVAL_800W_130PFC_C7**“ - evaluation board shows how to design an high power density 800 W 130 kHz platinum server supply with Power Factor Correction (PFC) Boost Converter working in Continuous Conduction Mode (CCM). On this purpose the latest CoolMOS™ technology **IPP60R180C7** 600 V power MOSFET, **IDH06G65C5** 650 V thinQ!™ SiC Schottky Diode Generation 5, **ICE3PCS01G** PFC Controller, low-side Non Isolated Gate Driver **2EDN7524F** EiceDRIVER™, **XMC 1300** Microcontroller and Quasi Resonant CoolSET™ **ICE2QR4780Z** have been applied.

**Summary of features:**

- Output voltage: 380 V$_{DC}$
- Output current: 2.1 A
- Efficiency: >96% @ 20% load, $V_{in} = 230$ V$_{DC}$
- Switching Frequency: 130 kHz

The following variant is available:

- 800 W 130 kHz PFC version with CoolMOS™ C7, **IPP60R180C7**, **EVAL_800W_130PFC_C7**
Infineon high power density 800 W 130 kHz platinum server design

- **PWM Controller**
  - CoolSET™ ICE2QR4780Z

- **Silicon Carbide Diode**
  - 5th G. thinQ!™ IDH06G65C5

- **Power MOSFETs**
  - CoolMOS™ IPP60R180C7

- **Microcontroller**
  - XMC 1300 DIGITAL XMC1302-T038X0200 AB

- **PFC CCM Controller**
  - ANALOG ICE3PCS01G

- **EiceDRIVER™**
  - 2EDN7524F
Main power board schematic

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Bias board schematic
Digital control board schematic
PFC control schematic
Temperature monitoring and inrush relay control schematic
PCB layout

Top layer

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# Requirements

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<td>$90 , V_{\text{AC}} - 265 , V_{\text{AC}}$</td>
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<tr>
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<td>$230 , V_{\text{AC}}$</td>
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<td>$47 - 64 , \text{Hz}$</td>
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<td>Max peak input current, $I_{\text{in_max}}$</td>
<td>$10 , A_{\text{RMS}} @ V_{\text{in}} = 90 , V_{\text{AC}} , \ P_{\text{out_max}} = 800 , \text{W} , \ \text{Max load}$</td>
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<tr>
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<td>$80 , V_{\text{AC}} - 87 , V_{\text{AC}} , \ \text{Ramping up}$</td>
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<tr>
<td>Power Factor Correction (PFC)</td>
<td>Shall be greater than 0.95 from 20% rated load and above</td>
</tr>
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<tr>
<td>Maximum output power, $P_{\text{out}}$</td>
<td>$800 , \text{W}$</td>
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<tr>
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<tr>
<td>Output OV threshold minimum</td>
<td>$420 , V_{\text{DC}}$</td>
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High Line and Low Line efficiency with:

2x IPP60R180C7 @ $f_s = 130$ kHz, $R_{gate(on)} = 39 \, \Omega$, $R_{gate(off)} = 14 \, \Omega$
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Power Factor Correction (PFC)

Power Factor Correction (PFC) shapes the input current of the power supply to be in synchronization with the mains voltage, in order to maximize the real power drawn from the mains. In a perfect PFC circuit, the input current follows the input voltage as a pure resistor, without any input current harmonics.

This document is to demonstrate the design and practical results of an 800 W 130 kHz platinum server PFC demo board based on Infineon Technologies devices in terms of power semiconductors, non-isolated Gate Drivers, analog and digital controllers for the PFC converter as well as Flyback controller for the auxiliary supply.
Although active PFC can be achieved by several topologies, the boost converter is the most popular topology used in Server PFC applications, for the following reasons:

- The line voltage varies from zero to some peak value typically 375 V; hence a step up converter is needed to output a DC bus voltage of 380 V or more. For that reason the buck converter is eliminated, and the buck-boost converter has high switch voltage stress ($V_{in} + V_{o}$), therefore it is also not the popular one.
- The boost converter has the filter inductor on the input side, which provides a smooth continuous input current waveform as opposed to the discontinuous input current of the buck or buck-boost topology. The continuous input current is much easier to filter, which is a major advantage of this design because any additional filtering needed on the converter input will increase the cost and reduces the power factor due to capacitive loading of the line.

Structure and key waveforms of a boost converter
The boost converter can operate in three modes: Continuous Conduction Mode (CCM), Discontinuous Conduction Mode (DCM), and Critical Conduction Mode (CrCM). Figure 2 shows modeled waveforms to illustrate the inductor and input currents in the three operating modes, for the same exact voltage and power conditions. By comparing DCM among the others, DCM operation seems simpler than CrCM, since it may operate in constant frequency operation; however DCM has the disadvantage that it has the highest peak current compared to CrCM and also to CCM, without any performance advantage compared to CrCM. For that reason, CrCM is a more common practice design than DCM, therefore, this document will exclude the DCM design.

PFC inductor and input line current waveforms in the three different operating modes
The EMI filter implemented is as a two-stage filter, which provides sufficient attenuation for both Differential Mode (DM) and Common Mode (CM) noise.

The two high current common mode chokes $L_{cm}$ are based on high permeability toroid ferrite cores.
1. 2 x 26 Turns/ 2 x 4.76 mH
2. 2 x 28 Turns/ 2 x 5.7 mH

The relatively high number of turns causes a considerable amount of stray inductance, which ensures sufficient DM attenuation.
Rectifier bridge

The rectifier bridge is designed for the worst case: maximum output power and minimum input voltage. To calculate the input current, an efficiency of 94% (at $V_{in} = 90$ V) is applied.

Maximum rms value of the input current:

$$I_{INrms} = \frac{P_{OUTmax}}{\eta V_{INrms}} = \frac{800\,W}{0,94 \cdot 90\,V} = 9,46\,A$$

Maximum rms value of the diode current:

$$I_{Drms} = \frac{I_{INrms}}{2} = 4,73\,A$$

Maximum average value of the diode current:

$$I_{Davg} = \frac{\sqrt{2}I_{INrms}}{\pi} = 4,26\,A$$

Conduction losses of a rectifier diode:

$$P_D = I_{Davg} \cdot V_D + (I_{Drms})^2 \cdot r_D = 4,26\,A \cdot 0,5\,V + (4,73\,A)^2 \cdot 0,016\,\Omega = 2,49\,W$$

Total losses of the rectifier:

$$P_{REC} = 4P_D = 4 \cdot 2,49\,W = 9,96\,W$$
The PFC choke design is based on a toroid high performance powder core. Toroid chokes allow well balanced and minimized core and winding losses, having a homogeneous heat distribution w/o hot spots and a large surface area. Hence they are predestined for systems which are targeting highest power density with forced air convection. Thereby very small choke sizes are feasible.

The core material was chosen to be a 60µ Chang Sung Corporation’s (CSC) HIGH FLUX, which has an excellent DC bias and good core loss behavior. The outer diameter of the magnetic powder toroidal core is 27 mm. The winding was implemented using enameled copper wire AWG 16 (1,25 mm diameter).
Support slides
800 W 130 kHz platinum server design

Evaluation board page
- Technical description
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Product family pages
- Product brief
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- EVAL_800W_130PFC_C7
- IPP60R180C7
- IDH06G65C5
- ICE3PCS01G
- 2EDN7524F
- XMC_1300
- ICE2QR4780Z
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