Application Note:

TDPS250E2D2 All-in-One Power Supply Evaluation Board

1. Introduction

Transphorm has designed a complete 250 W power supply evaluation board specifically to meet the requirements for an all-in-one computer. The Power Supply combines a PFC input stage with an LLC DC-DC converter, using ON Semiconductor control ICs (NCP4810, NCP1654, NCP1397, NCP432) together with three Transphorm 600 V GaN high electron mobility transistors (HEMTs).

The compact-size board showcases GaN devices' advantage in delivering both small size and high efficiency not possible with existing silicon solutions. It is designed to switch at 200 kHz in order to shrink the size and maintain high efficiency. With universal AC input, the All-in-One Power Supply Evaluation Board can deliver up to 20 A from the 12 V output with a peak efficiency of 95.4% from a 230 V ac line. The evaluation board is shown in Fig. 1.

Fig. 1. All-in-One Power Supply Evaluation Board

2. TDPS250E2D2 Input/output Specifications:

- Universal AC Input: 90-265Vac;
- Output: 12Vdc at 20A;
- PFC PWM Frequency: 200kHz;
- LLC Switching Frequency: 170kHz to 250 kHz ;

3. Circuit Description for the All-in-One Power Supply

Figure 2 illustrates the topology of the power supply. Three basic functions are shown: an input EMI filter, a boost-mode PFC circuit, and an LLC DC-DC converter. Not shown is a 12V DC regulator which provides power to the PFC and LLC controllers. The link between the PFC and LLC is a 390V DC voltage, identifiable in the schematic as the voltage across capacitor C1.

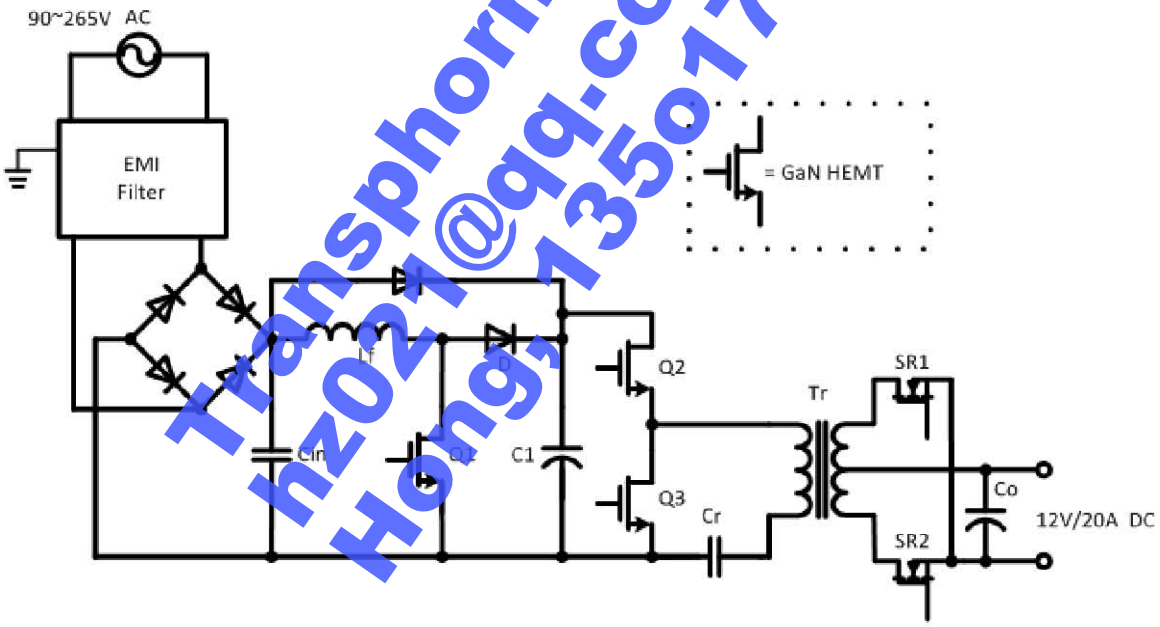

Figure 2: Simplified schematic for the complete power supply

The detailed schematic is included in pdf form with the kit documentation. The bill of materials is provided in Table I.

5 Circuit Descriptions for the LLC DC-DC Converter

Figure 4 illustrates the topology of the LLC DC-DC converter portion of the evaluation board, which is based on the NCP1397 and NCP4304 controllers. The series capacitor forms the series-parallel resonant tank with leakage and magnetic inductances in the primary side of the transformer. From this configuration, the resonant tank and the load on the secondary side, act as a voltage divider. By changing the frequency of input voltage, the impedance of resonant tank will change; this impedance will divide the input voltage with load. The primary-side switches, M1 and M2, are the GaN HEMTs. Transistors S1 and S2 on the secondary side are synchronous rectifiers to improve the performance and efficiency. As may be seen in Fig. 4, there is no need for special gate drivers for the GaN HEMTs. Further information and discussion on the fundamental circuit schematics and the characteristics of LLC DC-DC converters are provided in [3]-[5].

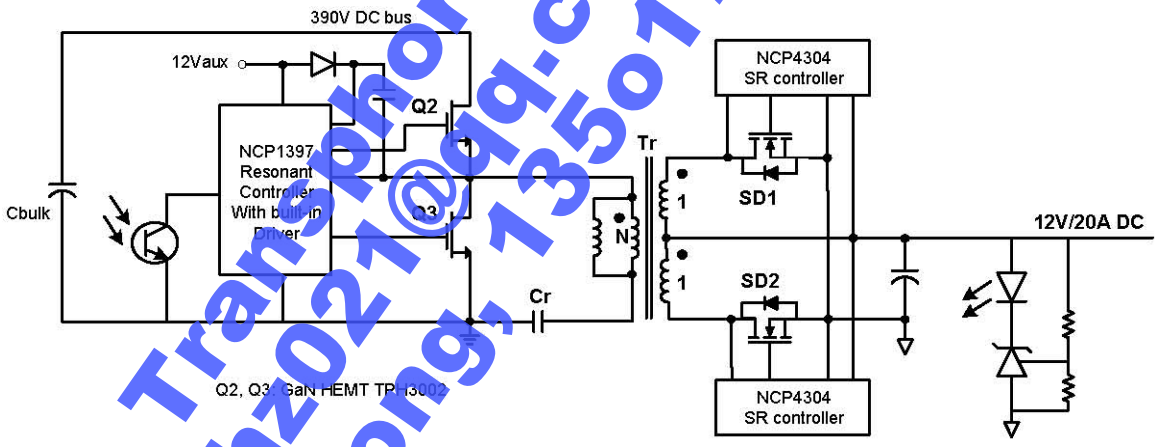

Fig .4. Circuit topology for LLC DC-DC converter using silicon MOSFETs for line rectification

Although the LLC is a resonant topology, characterized by soft switching, hard switching does nevertheless occur during start up. During this phase, the large reverse recovery charge (Qrr) of typical silicon MOSFETs causes problematic overshoot, ringing, and loss. Transphorm's TPH3002PS 1st-generation GaN power devices show a low on-resistance of 0.29 ohm typical and

are capable of reverse conduction during dead time with a low Qrr of 29nC, more than 20 times lower than state-of-the-art Si counterpart as seen in Figure 5. These features can remarkably improve the performance and efficiency of hard-switch circuits, and are also important for hard starting in resonant circuits such as the LLC topology.

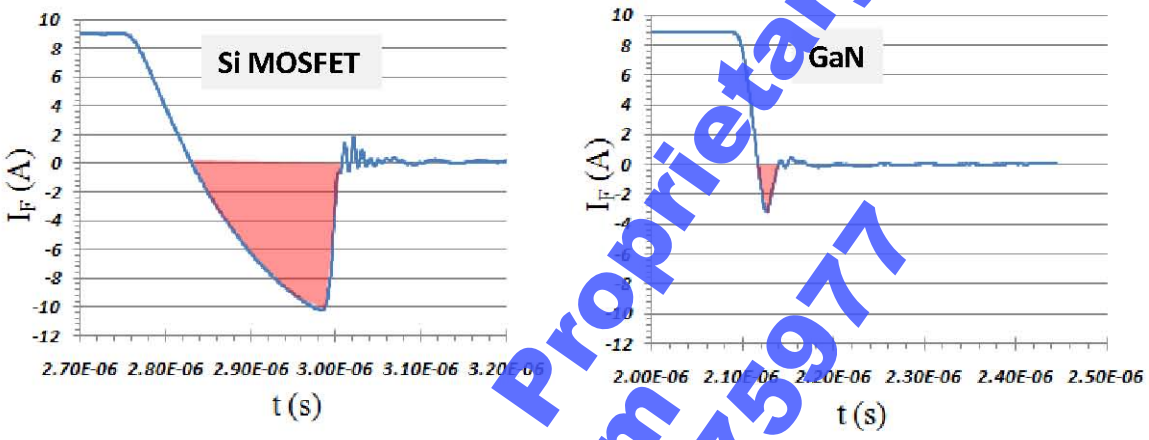

Fig.5 Reverse recovery charge test result for a Si MOSFET and a GaN HEMT with similar on resistance, showing a 20x reduction of Qrr for GaN.

Table IV gives a comparison of CoolMOS and GaN HEMT. The low Qrr will help reducing excessive spikes during start-up process in a LLC dc-dc converter.

Table IV: Comparison of GaN HEMT with equivalent CoolMOS IPP60R380C6

Parameter	TPH3002PS	IPP60R380C6
ID	9A (continuous)	10.6A (for D=0.75)
Ron	290mΩ	340mΩ
Qg	6.2nC	32nC
Eoss(400V)	3.1µJ	2.8µJ
Qrr	29nC	3.3µC

Startup sequence:

1) Connect a load; The load should be resistive, and maximum of 240watt at 12Vdc;
2) Connect an AC power source, set to the desired voltage higher than 90V.

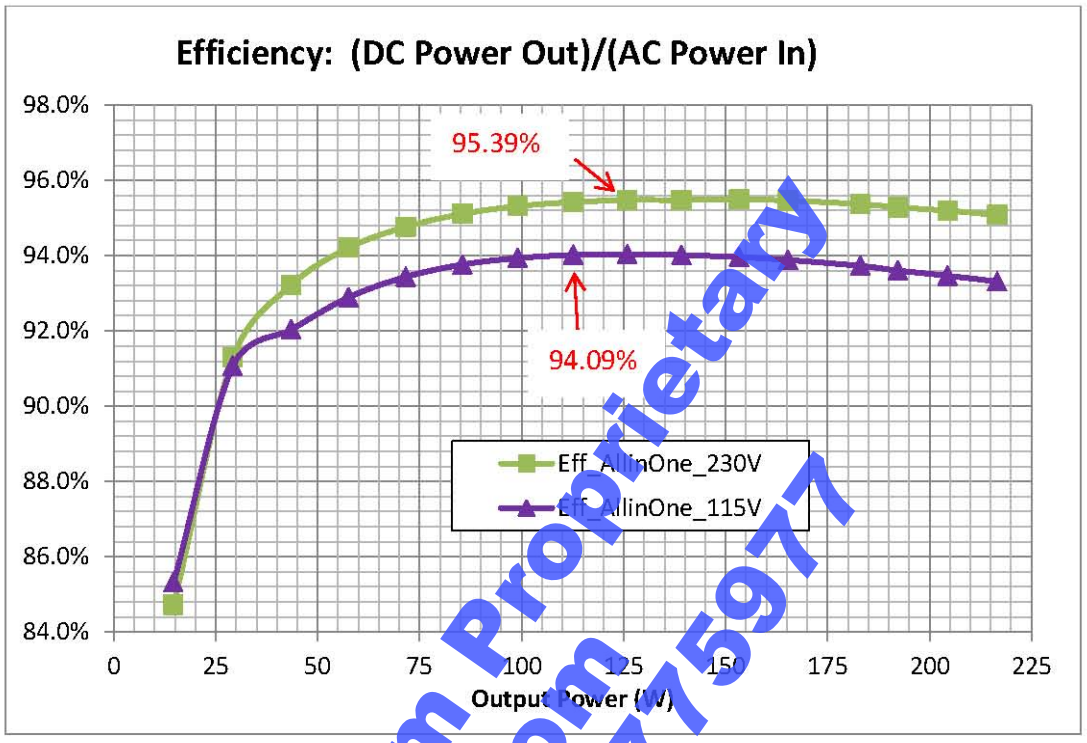

Figure 7. Efficiency for the power supply at 115V and 230V input

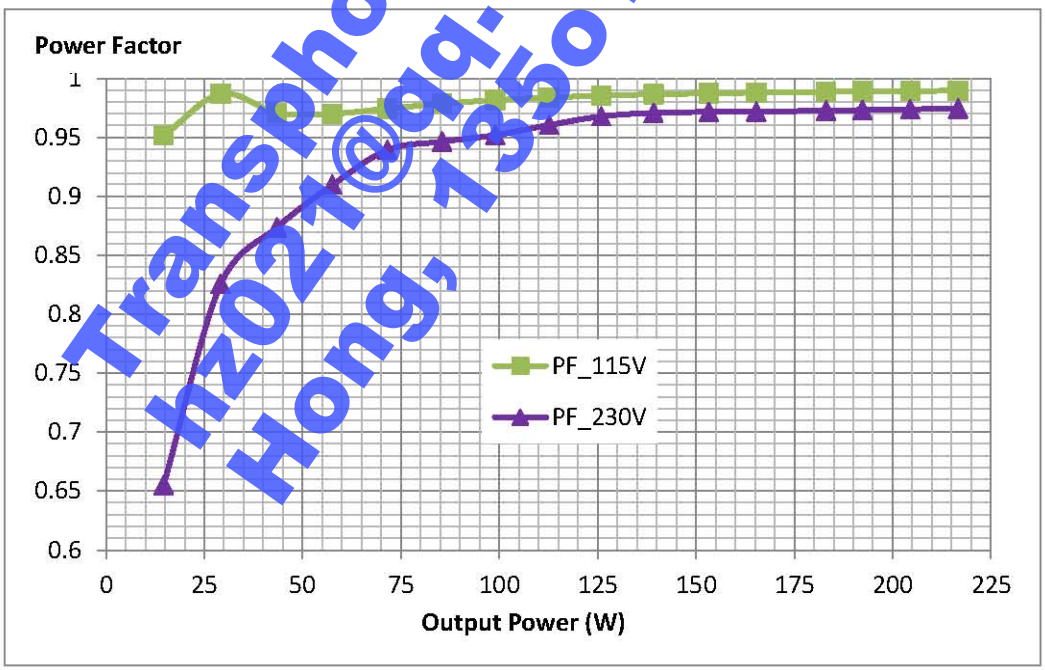

Figure 8. Power Factor vs. Output Power at 115V and 230V input

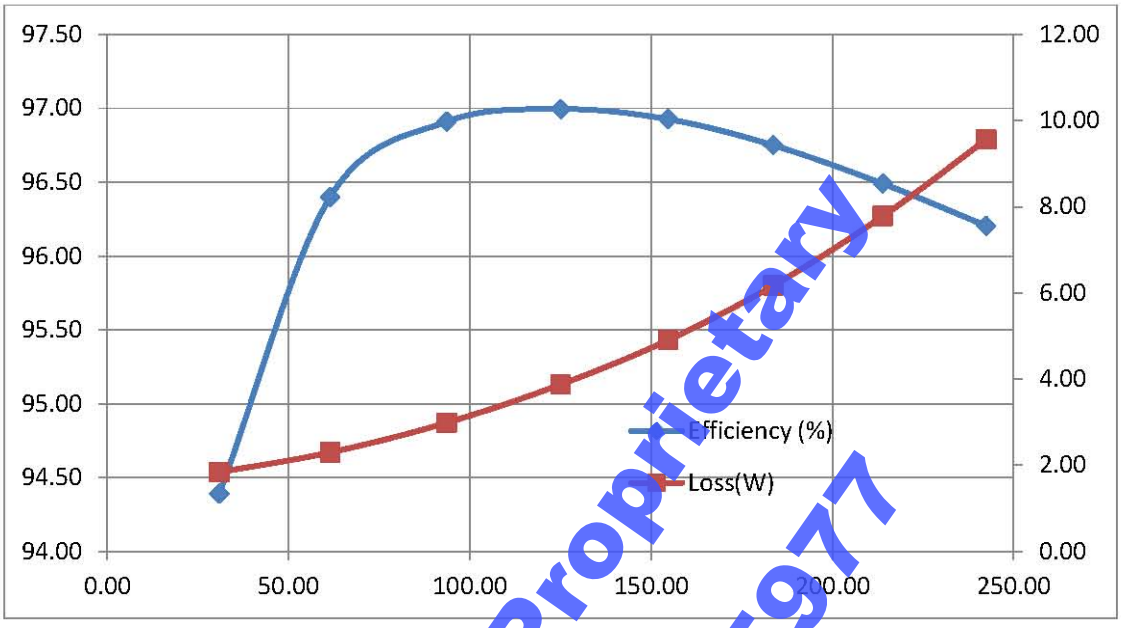

Figure 9. The efficiency result for the LLC DC/DC Converter circuit at 390Vdc input to 12Vdc output

Conducted emissions have also been measured for this board using a LIN-115A LISN by Com-Power. The results compared to EN55022B limits are shown in figure 10.

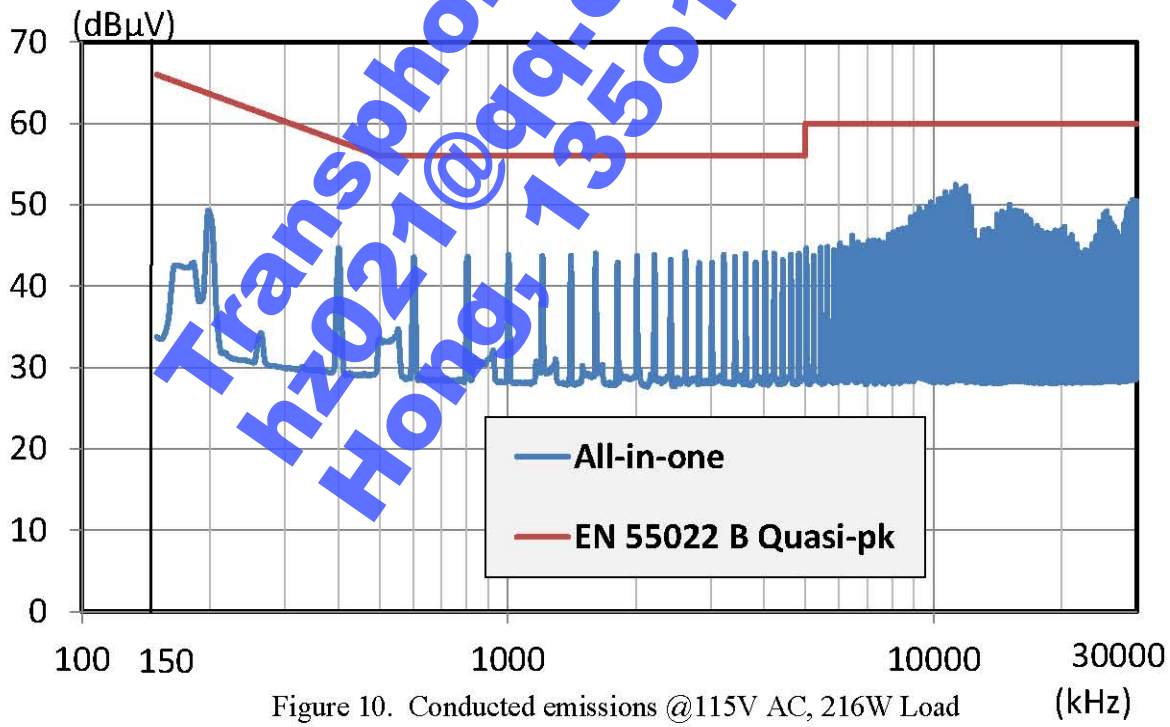

Figure 10. Conducted emissions @115V AC, 216W Load