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High Frequenzy (MHz) Resonant Converters using GaN HEMTs and Novel Planar Transformar Technology

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Abstract:

The increased power consumption and power density demands of modern technologies have increased the technical requirements of DC/DC and AC/DC power supplies. In this regard, the primary objective of the power supply researcher/engineer is to build energy efficient, high power density converters by reducing the losses and increasing the switching frequency of converters respectively. Operating the converter circuits at higher switching frequencies reduces the size of the passive components such as transformers, inductors, and capacitors, which results in a compact size, weight, and increased power density of the converter. Therefore, the thesis work is focussed on the design, analysis and evaluation of isolated converters operating in the 1 - 5MHz frequency region with the assistance of the latest semi conductor devices, both coreless and core based planar power transformers designed in Mid Sweden University and which are suitable for consumer applications of varying power levels ranging from 1 – 60W.

In high frequency converter circuits, since the MOSFET gate driver plays a prominent role, different commercially available MOSFET gate drivers were evaluated in the frequency range of 1 - 5MHz in terms of gate drive power consumption, rise/fall times and electromagnetic interference (EMI) and a suitable driver was proposed.

Initially, the research was focused on the design and evaluation of a quasi resonant flyback converter using a multilayered coreless PCB step down transformer in the frequency range of 2.7 – 4MHz up to the power level of 10W. The energy efficiency of this converter is found to be 72 - 84% under zero voltage switching conditions (ZVS). In order to further improve the energy efficiency of the converter in the MHz frequency region, the new material device GaN HEMT was considered. The comparisons were made on a 45 - 15V quasi resonant flyback DC-DC converter using both the Si and GaN technology and it was found that an energy efficiency improvement of 8 – 10% was obtained with the GaN device in the frequency range of 3.2 – 5MHz. In order to minimize the gate drive power consumption, switching losses and to increase the frequency of the converter in some applications such as laptop adapters, set top box etc., a cascode flyback converter using a low voltage GaN HEMT and a high voltage Si MOSFET was designed and evaluated using a multi-layered coreless PCB transformer in the MHz frequency region. Both the simulation and experimental results have shown that, with the assistance of the cascode flyback converter, the switching speeds of the converter can be increased with the benefit of obtaining a significant improvement in the energy efficiency as compared to that for the single switch flyback converter.

In order to further maximize the utilization of the transformer, to reduce the voltage stress on MOSFETs and to obtain the maximum power density from the converter circuit, double ended topologies were considered. Due to the lack of high voltage high side gate drivers in the MHz frequency region, a gate drive circuitry utilising the multi-layered coreless PCB signal transformer was designed and evaluated in both a half-bridge and series resonant converter (SRC).