Title of thesis:

High Speed (MHz) Switch Mode Power Supplies (SMPS) using Coreless PCB Transformer Technology

Abstract:

The most essential unit required for all the electronic devices is the Power Supply Unit (PSU). The main objective of power supply designers is to reduce the size, cost and weight, and to increase the power density of the converter. There is also a requirement to have a lower loss in the circuit which leads an improved energy efficiency of the converter circuit. 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 for the converter. At present the switching frequency of the converter circuit is limited due to the increased switching losses in the existing semiconductor devices and in the magnetic area, because of increased hysteresis and eddy current loss in the core based transformer. Based on continuous efforts to improve new semi conductor materials such as GaN/SiC and with recently developed high frequency multi-layered coreless PCB step down power transformers, it is now feasible to design ultra-low profile, high power density isolated DC/DC and AC/DC power converters. This thesis is focussed on the design, analysis and evaluation of the converters operating in the MHz frequency region with the latest semi conductor devices and multi-layered coreless PCB step-down power and signal transformers.

An isolated flyback DC-DC converter operated in the MHz Frequency with multi-layered coreless PCB step down 2:1 power transformer has been designed and evaluated. Soft switching techniques have been incorporated in order to reduce the switching loss of the circuit. The flyback converter has been successfully tested up to a power level of 10W, in the switching frequency range of 2.7-4 MHz. The energy efficiency of the quasi resonant flyback converter was found to be approximately 72-84% under zero voltage switching conditions (ZVS). The output voltage of the converter was regulated by implementing the constant off-time frequency modulation technique.

Because of the theoretical limitations of the Si material MOSFETs, new materials such as GaN and SiC are being introduced into the market and these are showing promising results in the converter circuits as described in this thesis. Comparative parameters of the semi conductor materials such the energy band gap, field strengths and the figure of merit have been discussed. In this case, the comparison of an existing Si MOSFET with that of a GaN MOSFET has been evaluated using a multi-layered coreless PCB step-down power transformer for the given input/output specifications of the flyback converter circuit. It has been determined that the energy efficiency of the 45-15V regulated converter using GaN MOSFET was improved by 8-10% compared to the converter using the Si MOSFET due to

the gate drive power consumption, lower conduction losses and improved rise/fall times of the switch.

For some of the AC/DC and DC/DC applications such as laptop adapters, set top box, and telecom applications, high voltage power MOSFETs used in converter circuits possess higher gate charges as compared to that of the low voltage rating MOSFETs. In addition, by operating them at higher switching frequencies, the gate drive power consumption, which is a function of frequency, increases. The switching speeds are also reduced due to the increased capacitance. In order to minimize this gate drive power consumption and to increase the switching frequency of the converter, a cascode flyback converter was built up using a multi-layered coreless PCB transformer and this was then evaluated. Both simulation and experimental results have shown that with the assistance of the cascode flyback converter the switching speeds of the converter were increased, the improvement in the energy efficiency in comparison 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 power converter, double ended topologies were chosen. For this purpose, a gate drive circuitry utilising the multi-layered coreless PCB gate drive transformer was designed and evaluated in both a half-bridge and a series resonant converter. It was found that the gate drive power consumption using this transformer was less than 0.8W for the frequency range of 1.5-3.5MHz. In addition, by using this gate drive circuitry, the maximum energy efficiency of the series resonant converter was found to be 86.5% with an output power of 36.5W.

Subject

Electronics

Name of institution

Mid Sweden University

Date, time and place for the seminar

27th May 2011, 10.00 AM, M102, Sundsvall