Very High Frequency Switch-Mode Power Supplies. - DTU Orbit (30/12/2018)

Very High Frequency Switch-Mode Power Supplies.: Miniaturization of Power Electronics.

The importance of technology and electronics in our daily life is constantly increasing. At the same time portability and energy efficiency are currently some of the hottest topics. This creates a huge need for power converters in a compact form factor and with high efficiency, which can supply these electronic devices. This calls for new technologies in order to miniaturize the power electronics of today. One way to do this is by increasing the switching frequency dramatically and develop very high frequency switch mode power supplies. If these converters can be designed to operate efficiently, a huge size, weight and cost reduction can be achieved due to the smaller energy storing elements needed at these frequencies. The research presented in this thesis focuses on exactly this. First various technologies for miniaturization of power supplies are studied, e.g. piezo electric transformers, wide band gap semiconductors and integrated power supplies. Afterwards a wide range of topologies suited for operation at very high frequencies is investigated and the most promising ones are tested experimentally. Through a comparison of these topologies the class DE inverter is found to be superior to the other alternatives, at least for converters with hundreds of volts as input and a few tens of watts output power. A class DE inverter does however require a high side gate drive, which have never been presented before for these frequencies and voltages. This thesis presents the worlds first high side gate drive capable of operating at these frequencies and voltage levels. With this gate drive the worlds first class DE inverter operating at very high frequencies with more than 100 V input is also developed and presented. These achievements are considered huge breakthroughs in the development of technologies for very high frequency switch mode power supplies. At these highly elevated frequencies normal bulky magnetics with heavy cores consisting of rare earth materials, can be replaced by air core inductors embedded in the printed circuit board. This is investigated thoroughly and both spirals, solenoids and toroids are considered, both for use as inductors and transformers. Two control methods are also investigated, namely burst mode control and outphasing. It is shown that a very flat efficiency curve can be achieved with burst mode. A 89.5% efficient converter is implemented and the efficiency only drops 5% at 10% load. This is one of the highest efficiencies presented for converters operating at these frequencies. Burst mode control does however have two major drawbacks, iii/xv introductions of low frequency harmonics and decreased control bandwidth. Outphasing is therefore investigated as an alternative, which does not introduce these drawbacks. In the last chapter the conducted and radiated electromagnetic interference from two prototypes are investigated, one running with constant output and one with burst mode control implemented. By the end of the thesis it is shown, that a size reduction of 70%, weight reduction of 81%, cost reduction of 56% and efficiency gain of 4.5%-points can be achieved with a very high frequency class DE converter, compared to a commercial product.

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