HIGH FREQUENCY, HIGH EFFICIENCY, FULLY INTEGRATED DC-DC CONVERTER SYSTEM

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ABSTRACT

For System-On-Chip (SOC) solutions, switch mode supply regulators usually have the highest efficiency compared to linear and hybrid regulators. Operating switch mode supply regulators at high switching speeds in the hundreds of MHz and above will reduce the size of passive components as well as the overall module size and weight through the integration of various functional blocks in a single platform. However, such high operation frequency tends to cause the increase in switching loss in power devices and reduction in regulator efficiency. This thesis addresses the integration and high speed operation of switch mode DC-DC converters. Issues associated with circuit techniques for high speed integrated switch-mode DC-DC converters are illustrated through two design examples in mainstream GaAs and CMOS technologies. Appropriate architectures and passive design methodologies are presented to achieve high efficiency and small output current ripple in a small form-factor module.

A 150 MHz two-phase interleaved DC-DC converter with negatively coupled integrated inductors in 0.5 μm Gallium Arsenide p-HEMT technology is introduced for RF power amplifiers embedded in a polar modulation system. Polar modulators improve the efficiency of radio frequency transmitters by allowing the power amplifier core to operate in saturation mode with high efficiency while having envelope modulation transfer to the PA through the supply modulator. The designed DC-DC converter reaches 84 % efficiency at 3.3 W output power which is among the best results published to date.

Given the technical challenges of controlling the operation of DC-DC converters at high switching frequency, hysteresis controller is proposed due to its immediate response to load transients. Delay locked loop for synchronizing multiple phases operation is investigated. The close loop circuit with adaptive deadtime control circuit is implemented in 0.25 μm CMOS technology with both 2.5 V and 6.5 V devices. It consume 71 mW power loss which is less than 1 % of overall DC-DC converter input power and the linear gain for tracking mode application can reach up to 10

MHz.

One of the fundamental challenges of DC-DC converters is the drop in efficiency at light load conditions. A novel resonant gate driver structure is proposed to reduce the gate driver loss by introducing an energy storage component to the gate of power switches. A new multi-phase output inductor network with both positively coupled inductors and negatively coupled inductors is also discussed for phase shedding/segmentation applications. A 100 MHz two-phase, four-segment CMOS DC-DC converter with resonant gate driver and the new inductor network is implemented employing hysteresis controller and an open loop delay chain with automatic duty ratio corrector. Complete close loop measurement results show 77.8 % peak efficiency at 4 V/3 V conversion and 5 % efficiency improvement using resonant gate drivers is achieved at 1 V output. The output efficiency follows the peak value when load current changes from 0.1 A to 2 A with phase shedding/segmentation technique.

Overall, the current studies presented in this dissertation show promising results for high speed fully integrated DC-DC converters with advanced techniques for light load efficiency improvement. Proper integration adoption, novel converter structures, advanced passive devices design and fast and robust control circuit techniques allow significant improvement in the performance of high frequency DC-DC converters.