ABSTRACT

Design and Implementation of Switching Voltage Integrated Circuits Based on Sliding Mode Control

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The need for high performance circuits in systems with low-voltage and low-power requirements has exponentially increased during the few last years due to the sophistication and miniaturization of electronic components. Most of these circuits are required to have a very good efficiency behavior in order to extend the battery life of the device. This dissertation addresses two important topics concerning very high efficiency circuits with very high performance specifications. The first topic is the design and implementation of class D audio power amplifiers, keeping their inherent high efficiency characteristic while improving their linearity performance, reducing their quiescent power consumption, and minimizing the silicon area. The second topic is the design and implementation of switching voltage regulators and their controllers, to provide a low-cost, compact, high efficient and reliable power conversion for integrated circuits. The first part of this dissertation includes a short, although deep, analysis on class D amplifiers, their history, principles of operation, architectures, performance metrics, practical design considerations, and their present and future market distribution. Moreover, the harmonic distortion of open-loop class D amplifiers based on pulse-width modulation (PWM) is analyzed by applying the duty cycle variation technique for the most popular carrier waveforms giving an easy and practical analytic method to evaluate the class D amplifier distortion and determine its specifications for a given linearity requirement. Additionally, three class D amplifiers, with an architecture based on sliding mode control, are proposed, designed, fabricated and tested. The amplifiers make use of a hysteretic controller to avoid the need of complex overhead circuitry typically needed in other architectures to compensate non-idealities of practical implementations. The design of the amplifiers based on this technique is compact, small, reliable, and provides a performance comparable to the state-of-the-art class D amplifiers, but consumes only one tenth of quiescent power. This characteristic gives to the proposed amplifiers an advantage for applications with minimal power consumption and very high performance requirements. The second part of this dissertation presents the design, implementation, and testing of switching voltage regulators. It starts with a description and brief analysis on the power converters architectures. It outlines the advantages and drawbacks of the main topologies, discusses practical design considerations, and compares their current and future market distribution. Then, two different buck converters are proposed to overcome the most critical issue in switching voltage regulators: to provide a stable voltage supply for electronic devices, with good regulation

voltage, high efficiency performance, and, most important, a minimum number of components. The first buck converter, which has been designed, fabricated and tested, is an integrated dual-output voltage regulator based on sliding mode control that provides a power efficiency comparable to the conventional solutions, but potentially saves silicon area and input filter components. The design is based on the idea of stacking traditional buck converters to provide multiple output voltages with the minimum number of switches. Finally, a fully integrated buck converter based on sliding mode control is proposed. The architecture integrates the external passive components to deliver a complete monolithic solution with minimal silicon area. The buck converter employs a poly-phase structure to minimize the output current ripple and a hysteretic controller to avoid the generation of an additional high frequency carrier waveform needed in conventional solutions. The simulated results are comparable to the state-of-the-art works even with no additional post-fabrication process to improve the converter performance.