Digital Control of a Multi-Megahertz Variable-Frequency Boost Converter for Dynamic LiDAR (AGSR_51)

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The LiDAR(Light Detection and Ranging) sensor is widely used as the “eyes” of autonomous ground and airborne vehicles because of its high accuracy in long-range detection and low sensitivity to ambient interference. The system efficiency and thermal dissipation of LiDAR can be significantly improved by dynamically adjusting parameters such as the number of active laser diodes and repetition rate with the vehicle speed and environmental conditions. A boost converter is usually used for creating a high voltage to the LiDAR transmitter. To support the rapidly fluctuating voltage level and power consumption demand of the dynamic LiDAR transmitter, the boost converter needs a fast dynamic response and large control bandwidth over a wide output voltage and load range. The dynamics of power converters vary with operating point and real-time tuning can be easily realized on a digital controller to ensure consistently good dynamic performance, in contrast to a single analog compensation network.

A boost converter with multi-megahertz variable switching frequency is a good candidate for dynamic voltage scaling (DVS) in dynamic LiDAR. However, the digital controller design strategies have been especially limited in this type of power converters. Either a high-cost ADC (analog-to-digital converter) or architecturally intensive control methods are required. In previous paper, we published a high-speed digital control framework with high accuracy and low sampling and computational burden. This control framework relies on the switching-synchronized sampled-state space (5S) that includes a series of non-periodic sampling and control actions, which are triggered by events instead of clocks.

In this paper, we theoretically verify the effectiveness of using this 5S based controller design method for a current-mode boost converter with constant off-time. We demonstrate a converter prototype in Fig. 1(a) that operates in CCM (Continuous Conduction Mode) with a peak switching frequency of 3.3 MHz. It can deliver 16 W of power from a 12 V vehicle battery to a 40 V LiDAR transmitter array. The experimental waveform corresponds to theory. A dynamic voltage scaling sequence of 20 V → 25 V → 30 V → 35 V → 40 V shown in the Fig.1(b) demonstrates stability of the closed-loop system over a wide operating range. The converter illustrates a fast rise time of approximately 5 μs with small overshoot in each voltage step.

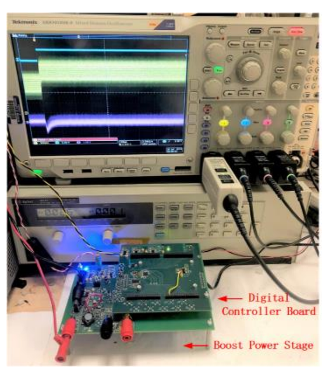

Fig. 1 (a)

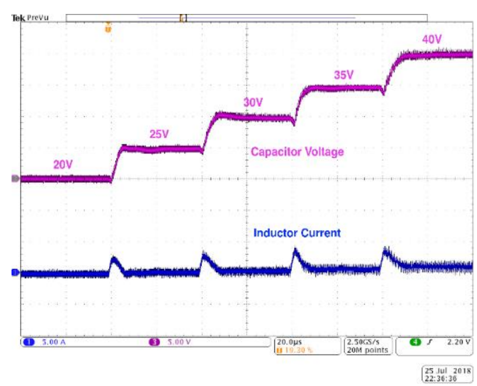

Fig. 1 (b)