ABSTRACT

Modern-day vehicles require advanced driver assistance systems to enhance passenger safety and a comfortable driving experience, along with entertainment units, navigation systems and wireless technologies, leading to the explosion of automotive cockpit electronics over the past decade. This has led to the development of point-of-load buck regulators powered from a car battery that nominally operates at 13.5 V with a full range of 3.8 V to 36 V to deliver higher current power supply regulation at lower voltages in an automotive power management unit. This thesis presents the design and implementation of an integrated high voltage buck converter circuit for automotive applications, supporting a wide input (3.8-36 V) to output (3.3 V) step-down ratio with a full load requirement of 3.3 A. The major contributions of this work are (i) the design and implementation of an on-chip bias generator to generate a regulated low voltage supply, (ii) a high voltage level shifter to communicate signals between the high voltage power stage and the low voltage controller, (iii) a voltage-emulated peak current sensing method and (iv) an adaptive switching frequency controller with a re-configurable compensation.

The proposed adaptively biased low dropout regulator generates a 5 V regulated voltage from 5.5-36 V input with 5 μA standby quiescent current for supplying 10 μA-20 mA load current. With a 0-20 mA load step and 1 μF output capacitor, undershoot of 40 mV and overshoot of 55 mV are achieved experimentally. The proposed high voltage level shifter has a strengthened pull-up path during transients, which enables it to overcome the limited speed of operation and a high switching power loss due to a large crowbar current in the conventional designs. The voltage-emulated peak current sensing method adopted in this work is faster and more accurate compared to conventional schemes that are limited in sensing speed by the bandwidth of the Op-Amp based feedback mechanisms. The error voltage emulates the inductor peak current for current comparison and dynamically adjusts its value with the load current. The efficacy of the proposed scheme is extended to implement over-current protection for the converter with an in-built maximum current limiter which restricts the maximum sense-FET current. A dual switching frequency (2.1 MHz, 1.05 MHz) controller, determined by the input voltage level, is presented in this work to meet the stringent requirement of the minimum on/off time over a wide input supply range for the buck convertor. A re-configurable compensation achieved by tuning the feedback resistances, optimizes the transient response, in contrast to the conventional fixed compensator circuit where the loop bandwidth of the converter is optimized mainly at the lowest switching frequency.

The proposed wide input voltage automotive buck converter design is implemented in a high voltage 0.18 μm Bipolar-CMOS-DMOS technology and validated with post-layout simulation results. A settling time of ~70 μs is observed for a load transient of 3.3 A-1 mA with an undershoot and overshoot of 81 mV and 75 mV respectively using off-chip filter components of L = 1.1 μH and C = 47 μF. The converter shows the load and line regulations of 24.54 mV/A and 0.97 mV/V respectively. The peak power efficiency is 88.6% at 3.3 A at 13.5 V supply.

Keywords: High voltage buck converter, Double diffused MOS (DMOS), VDD domain, V_{BOOT} domain, Floating N-well, On-chip bias generator, High voltage level shifter, Peak current control, Voltage-emulated peak current sensor, Maximum current limiter, Adaptive switching frequency, Minimum on-time, Minimum off-time, Re-configurable compensation