A Novel Soft-Switching Buck Converter with a Non-Dissipative Resonant Loop for Wide-Input-Voltage Applications

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Introduction

Auxiliary and gate-driver supply in electrified vehicles require high efficiency and reliability under wide input variation. Prior ZVS/ZVT/ZCT approaches often increase device voltage stress, circulating energy, or circuit complexity. We present a buck converter with a single, **non-dissipative resonant loop** that achieves near-zero-current (ZC) turn-on and zero-voltage-transition (ZVT) turn-off of the main switch without auxiliary active switches.

Experimental Procedures

The converter employs a single quasi-resonant tank (Ls–Cs1–Cs2) added to a buck stage to realize near-ZC turn-on and ZVT turn-off of the high-side switch without auxiliary active switches. From the mode analysis, the peak voltages of Cs1/Cs2 — and thus the main switch — do not exceed the source voltage (Vs), preventing over-voltage stress. The control is hysteretic with maximum on-time / minimum off-time constraints, enabling fast line/load transients while guaranteeing start-up/stability across the full operating range. The resonant frequency is designed < 500 kHz to avoid interference with in-vehicle audio bands.

Prototype specifications: Input 60–600 V, regulated output 15 V / 30–300 mA (gate-driver supply use-case in HEV/EV powertrains).

Results and Discussion

Soft-switching (near-ZC turn-on and ZVT turn-off) was experimentally observed at full load for both Vs = 60 V and Vs = 600 V, confirming that resonance-assisted transitions are maintained across the entire input range. The resonant frequency remained within 410–498 kHz over operating conditions, while the switching frequency varied between 363 Hz and 10.2 kHz as the source voltage changed from 60 V to 600 V. Switching-loss evaluation using measured VDS and IDS showed reductions versus the conventional buck at 600 V / 300 mA: −49% (turn-on) and −84% (turn-off). The overall converter efficiency improved by 18%, and the maximum measured efficiency reached 87% at 600 V, 15 V / 300 mA. In addition, the maximum VDS of the main switch equals the input voltage (Vs), indicating no over-voltage penalty. (For completeness: simulation-based acoustic analysis indicates ≤ 43 dB over load, consistent with the designed resonance band being outside human audibility.)

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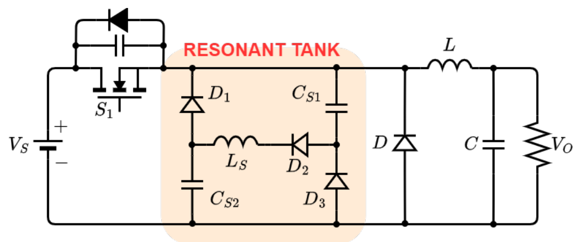

Figure 1 Circuit schematic of proposed novel zero-current zero-voltage transition DC-DC converter.

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