Novel Solutions to Mitigate the Switching Noise in Power Circuit Applications

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As power electronics is becoming even more pervasive in every-day life, the use of fast and reliable power switches is of primary concern. In this context, the driving strategy of power transistor plays a key role, as it determines the switching performance of the power circuit, thus directly affecting the reliability and the delivered Electro-Magnetic Interference (EMI) of the overall system. The research reported in this thesis investigates novel solutions to drive power switches, with the aim of achieving the best trade-off between switching losses and delivered EMI. After a brief introduction on the switching phenomena taking place in a half-leg, the impact of switching waveforms on the conducted emissions is discussed. Then, traditional solutions to control overshoots and oscillations are discussed, more precisely, RC snubbers, ferrite beads and gate resistance, have been analyzed and standard design procedures are reported as well.

To overcome the limitations of such solutions, Active Gate Drivers (AGDs) have been recently introduced to control the switching trajectories of power transistors. Indeed, by modifying the driver strength during the transients, fast and non-oscillating switching waveforms can be achieved. The focus was lately moved on the tuning of open-loop AGDs, as only qualitative indications on how to modify the driver strength were provided in the literature. Such an issue is of the utmost importance, as a non-optimal modulation profile of AGDs can cause a sub-optimal trade-off between switching losses and overshoots, or, even worsen, to degrade significantly the switching performance of the power switch. To this purpose, a method to get the optimal switching waveforms and to tune a current-modulation AGD was proposed and verified through simulations. More precisely, by exploiting the Miller's plateau, the drain-source voltage of the AGD-driven power transistors can be shaped, which in turn affects the remaining switching waveforms.

The proposed method was experimentally verified on a Buck converter, whose power transistor is driven by a discrete-level AGD purposely designed. By exploiting the proposed method and a resistance-modulating AGD, the optimal switching waveforms expected from simulations can be attained, thus assessing the validity of what presented. By comparing the proposed solution with traditional solutions, i.e., gate resistance and RC snubbers, it was verified the out-performance of properly tuned AGDs, both in terms of conversion efficiency and reduction of frequency spectra magnitude. Then, the proposed method was verified under variable operating conditions of the power circuit, resulting in a degradation of the switching performance. As far as load current variations are concerned, a solution to mitigate such an issue is proposed, which is based on the tuning of the timing parameters on the basis of the actual load current. To overcome definitely such issues, a brief discussion on how to implement a closed-loop adaptive AGD is reported.

Besides the investigations carried out on AGDs, this thesis also proposed a simpler and less-expensive solution to achieve results similar to those obtained by AGDs. Indeed, the source inductance, i.e., the portion of parasitic inductance shared between the power loop and the gate loop, can be exploited to slow down a power transistor during its turn-on commutation, thus avoiding unwanted oscillations from being triggered. Such a solution was investigated by simulations, and on a real case 48 V-12 V converter, resulting in a significant reduction of the common-mode and differential-mode conducted emissions, indeed. The source inductance solution can reduce EMI at lower cost with respect to AGDs, and it represents an alternative solution with respect to traditional damping techniques before AGDs gain a foothold.