Abstract

Today's portable devices (viz., laptops, cell phones, PDAs and hand-held electronic gadgets) are moving towards miniaturization. Consequently, the power management units (PMU) of these devices operating from single supply source (primarily a battery) demand compactness, better efficiency (minimum power loss), regulated dc outputs and finally, extended battery life. To meet all these requirements a Single-Inductor Multiple-Output (SIMO) dc-dc converters serves as a better alternative to multiple switching converters (buck and/or boost and/or buck-boost) operating in parallel to deliver the various supply levels needed. SIMO topologies avoid the mutual coupling amongst inductors, reduce the number of power switches and its associated losses and bring down the size of the passives. However, with the above mentioned advantages, SIMO converters are affected by some significant drawbacks. The outputs being coupled, these converters suffer from cross-regulation amongst the outputs. This leads to system instability and all the outputs are affected drastically during load transient in any one or all of them. Lastly, the inductor does not have any path to discharge if all the output switches are turned OFF at the same instant of time. If the dead time amongst the switches is not chosen and designed carefully then it can lead to a short circuit between the outputs or breakdown of the power switches. Thus, designing an appropriate control mechanism is a fundamental challenge and hence the system dynamics should be analyzed and predicted accurately.

Switch averaged modeling approach used to model buck or boost converters assumes the ripple in the inductor current to be small and averages the current over an entire cycle. Thus it does not hold good for SIMO topologies as they are driven by the ripple and the sequence of switching of the inductor current. Consequently, an inductor current ripple based state space modeling has been proposed here to analyze the system properly. The model averages the inductor current over each and every mode in one switching cycle. Subsequently, it has been inferred that unlike single output switching converters, the steady state output voltages in SIMO converters are dependent on the load applied at the corresponding outputs, the size of the inductor and the switching frequency.

SIMO topologies, which exist in literature, are capable of generating only positive buck and boost outputs. However, the developed model helps us explore the operating range of a SIMO configuration and enables it to generate buck, boost and inverted outputs simultaneously (SIBBI), the first of its kind. The same has been validated in simulation and hardware. This would be of immense use if applied in portable devices that require bipolar supplies (viz., devices with LCD panels).

Finally, a cross derivative feedback control scheme has been proposed and applied to SIMO converters that ensures stable operation, perfect regulation at the outputs and most importantly, significantly reduces cross regulation amongst the outputs. Simulation results show cross regulation effect to be negligible and tight regulation at the outputs. A prototype, using discrete components and operated at 100 kHz, has been built in house to validate all the proposed concepts.