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Design and performance investigation of a canonical circuit model for power converters

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A "Switched Mode Power Supply (SMPS)" is an electronic device that involves switching regulation for efficient power conversion. They take power from an AC or a DC input, and produce a processed current/voltage output of DC power. The major advantage of a SMPS over linear supplies is the higher efficiency. Since the control elements of them are continuously swung between their low dissipation, full-ON/full-OFF states, only allowing them to be in high dissipation modes and consume power during only a small amount of time, thereby reducing the energy wastage. This ideally converts power with 100% efficiency. In this study, an attempt was made to design a "Canonical Circuit Topology" that automatically switches between Buck (output voltage is less than the input), Boost (output voltage is greater than the input) or Buck-Boost (in the margin of both buck & boost modes, alternating between both) mode by continuously monitoring the input and output voltages, and operating in the user-set parameters. Fundamentals SMPS's such as Buck, Boost & Buck-Boost were studied theoretically using MATLAB Simulink modelling and they were compared with physical implementation. It was seen that real behavior of them is very much deviating from ideal behavior due to inherent issues of common MOSFETs and inductor coils. The Conventional Buck converter performs well in terms of conversion ratio and efficiency (71% maximum) for very small loads of few ohms, with inherent input noise issues. The Conventional Boost converter performs well in terms of conversion ratio for large loads of few kilo ohms, but efficiency was inappreciable, with inherent output noise issues. Different candidates for a Canonical Circuit Topology were identified, and the 4-switch buck-boost converter was selected as the most plausible, due to its power range of operation, efficiency (up to 96% maximum), simplicity & cost effectiveness. MATLAB Simulink model simulations revealed the input noise problems in both modes, yet the output was smooth. The physically implemented model showed that the circuit behavior is slightly deviating from ideal behavior, with an average efficiency of 70% in buck mode. It provided a linear correlation among conversion ratios with respect to the duty cycle of the control signal. Further, in order to improve the behavior in terms of conversion ratio and noise, super capacitors were introduced and it brought about significant results, raising the conversion ratio from 0.82 to 0.947 for 100% duty cycle in buck mode.

Keywords: Canonical circuit model, conversion ratio, switched mode power supply