ABSTRACT

Switched-mode dc-dc converters are widely employed in low-power portable applications because of their high power-efficiency. The Pulse Width Modulation (PWM) scheme is usually employed in switched-mode dc-dc converters to generate switching output pulses. The PWM scheme is simple to realize, but it results in harmonics at multiples of the switching-frequency. The high harmonic power will undesirably translate to high conducted Electromagnetic Interference (EMI) at the input current of the dc-dc converter. The prevalent method to mitigate the harmonics is to replace the conventional PWM with the spread-spectrum modulation schemes. These modulation schemes spread the power of the switching-frequency harmonics over the frequency spectrum such that the peak spectral power of the harmonics is reduced as compared to that of the PWM. One such a scheme is the Randomized Wrapped-Around Pulse Position Modulation scheme (RWAPPM). It features a simple algorithm and is able to highly attenuate the harmonic power in its output voltage. Nonetheless, it has a drawback of a higher ripple noise at low-frequencies compared to that of the PWM. Therefore, it is desirable that there is a modulation scheme that can collectively address both the switching-frequency harmonics and the low-frequency noise for applications in low-harmonics low-noise switched-mode dc-dc converters.

We propose a novel low-harmonics low-noise modulation scheme for switched-mode dc-dc converters. The proposed scheme is a hybrid of a randomized modulation scheme, namely the RWAPPM, and a noise-shaper. The RWAPPM mitigates the switching-frequency harmonics in the input current, whereas the noise-shaper mitigates the low-frequency noise therein. We derive an analytical expression for the input current spectrum of the hybrid scheme. We benchmark the hybrid scheme against the conventional Pulse Width Modulation scheme (PWM) and the RWAPPM without the noise-shaper. At 0.5 duty cycle, 3.3 V input voltage, 100 kHz average switching frequency, and with a 2^{nd}-order noise-shaper, the peak spectral power in the input current spectrum of the hybrid scheme is 18.1 dB lower than the PWM. Other randomized and spread-spectrum modulation schemes, in general, have undesirably higher input noise current than that of the PWM. However, the input noise current of the proposed hybrid scheme, obtained at ~73mA rms (integrated over a 200 kHz bandwidth without an input filter), is comparable to that of the PWM, and is lower by ~16 mA rms compared to that of the RWAPPM without the noise-shaper. We also benchmark the hybrid scheme against other well-known randomized and spread-spectrum modulation schemes. We further propose a novel pulse generator structure that embodies the hybrid scheme. We realize a dc-dc converter employing the pulse generator, and measure the converter to verify the derived expression and the characteristics of the hybrid scheme. We also measure the output voltage spectrum, the transient-response, and the operating range of the converter.