Improvement of power supply EMC by chaos

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Abstract

We demonstrate the feasibility of using chaos to depress the spectral peaks of the interference from a switched mode power supply. A boost converter is used to show experimentally that the spectrum of the input current is spread, its peaks are reduced and EMC is improved, compared to the case when the circuit is operating periodically.

1. Introduction

Switched mode power supplies generate electromagnetic interference, generally consisting of the switching frequency and many harmonics. Such interference poses significant EMC problems, particularly in the face of new regulations. Although it may be possible to reduce the interference at source, it is generally necessary to employ filtering to reduce conducted interference and screening to reduce radiated interference.

However, since the regulations set an upper bound on the spectral content, various methods of amelioration have been proposed based on spread spectrum techniques. These include periodic or pseudo-random modulation of pulse width or switching frequency: see [1]–[3] and references therein.

Implementing any of the above requires extra circuitry, adding to size and cost.

In conventional power supplies, all the waveforms are periodic and hence most of the energy is concentrated in narrow spikes at the clock frequency and its harmonics. With modulation, however, the energy is spread over a wider range of frequencies. The advantage is that the height of the spikes is now reduced, thereby making it easier to meet the EMC regulations.

Switched mode power supplies are now known to be capable of chaotic behaviour (*i.e.* deterministic, aperiodic behaviour that exhibits broadband spectral characteristics) [4], [5]. We therefore propose a novel technique: by deliberately designing a power supply to work in the chaotic region the spectrum of interference can be spread without extra circuitry.

In order to demonstrate the viability of the technique, we concentrate on the boost converter, operating at a low switching frequency (2.5kHz). The boost converter is particularly relevant, not only because it is relatively easy to model its chaotic behaviour [4], but also because it is widely used in power factor correction schemes [6]; these in turn are becoming mandatory in order to meet harmonic regulations.

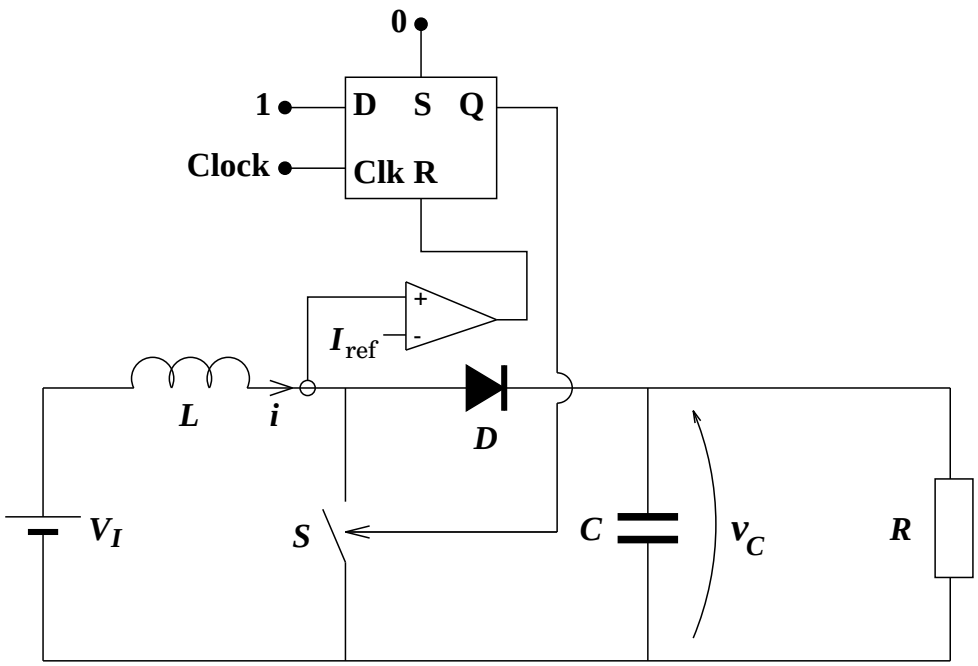

Figure 1: The boost converter studied in this paper.

2. Experimental results

A peak current controlled boost converter circuit is described in [4], and is shown in figure 1. This was built with $R = 250\Omega$, $L = 100$mH, $C = 220\mu$F, $V_I = 10$V, reference current $I_{\text{ref}} = 0.5$A and clock frequency $f_s = 2.5$kHz. With the feedback loop connected the circuit behaved chaotically — that is, the input current $i(t)$ was aperiodic — and the output voltage was approximately 29V with a small chaotic ripple. A spectrum of $i(t)$ was measured using an audio frequency spectrum analyser. The feedback loop was then disconnected and a pulse generator used instead to drive switch S periodically with a duty factor chosen so that the output voltage was again 29V. The current spectrum was again measured. The two spectra obtained are shown superimposed in figure 2.

The peaks in the spectrum occur at multiples of f_s and the table below shows the amount by which chaos reduces them.

Frequency	f_s	$2f_s$	$3f_s$	$4f_s$	$5f_s$	$6f_s$	$7f_s$	$8f_s$	$9f_s$	$10f_s$
Reduction (dB)	7	11	7	0	7	6	−2	5	8	4

$11f_s$	$12f_s$	$13f_s$	$14f_s$	$15f_s$	$16f_s$	$17f_s$	$18f_s$	$19f_s$	$20f_s$
−5	4	5	0	0	5	3	0	2	4

Although some peaks are greatly reduced (*e.g.* by 11dB at $2f_s$), others are emphasised (*e.g.* by 5dB at $11f_s$). The average reduction of 3.6dB represents a useful improvement, and this is without any attempt at optimisation.

Figure 2: Experimental spectra from the circuit of figure 1. The sweep rate was 5 sec/kHz and the resolution bandwidth was 100Hz. The comb-like spectrum was obtained for periodic behaviour and the broadband spectrum for chaos.

3. Conclusion

A useful spreading of the spectrum of the input current can be obtained simply by letting a boost converter operate chaotically. Despite the fact that no attempt was made to optimise the effect, the chaos-induced decrease in the spectral peaks is comparable with that obtained by 'artificially' spreading the spectrum, the latter requiring extra circuitry. In [2] a decrease of more than 10dB is claimed and in [3], up to 9dB.

Although the measurements have been done at low frequency, the results should scale to higher frequencies. Moreover, since the switching process also causes radiated interference, chaos is expected to reduce it by a similar amount.

Further work is needed to determine the best mode of chaotic operation and to apply the technique to practical power supplies.

References

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