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Experimental study of dynamic behaviors and routes to chaos in DC–DC boost converters

D. Cafagna *, G. Grassi

Dipartimento di Ingegneria dell'Innovazione, Università degli Studi di Lecce, via Monteroni, 73100 Lecce, Italy

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Abstract

This paper illustrates an experimental study of a current-programmed DC–DC boost converter, with the aim of investigating possible pathways through which the converter may enter chaos. In particular, based on experimental measurements, it is shown that variations of input voltage and reference current can generate periodic, subharmonic, quasi-periodic and chaotic behaviors.

1. Introduction

In nonlinear circuits and systems a great variety of strange phenomena has been observed, including subharmonics, quasi-periodic oscillations, chaotic behaviors, intermingled basins of attraction, synchronization properties and multi-scroll attractors [1–6]. These behaviors have been intensively studied in the cross-disciplinary science of chaos. In particular, it has been recently observed that a large number of power electronic circuits can exhibit deterministic chaos [7–9]. Referring to power DC–DC converters, some investigations have shown that buck, boost and buck-boost converters are prone to subharmonic behavior and chaos [10–13]. Even though most of the approaches proposed until now are very interesting, they mainly present theoretical or simulated results. As a consequence, there is a lack of experimental analysis on the parameter domains for which chaotic behavior may occur. Therefore, this paper aims to bridge this gap by presenting an experimental study of some dynamic phenomena that can occur in current-programmed boost converters. In particular, the paper illustrates a novel hardware implementation able to show some pathways through which the boost converter may enter chaos. The manuscript is organized as follows. In Section 2 the state equations of the boost converter are briefly summarized. Moreover, the circuit implementation of the proposed current-programmed converter is illustrated in detail. In Section 3 it is experimentally shown that variations of the reference current can lead to interesting routes to chaos. Analogously, the experimental study carried out in Section 4 highlights that the implemented converter may enter chaos by considering the input voltage as a bifurcation parameter.

* Corresponding author.
E-mail addresses: donato.cafagna@unile.it (D. Cafagna), giuseppe.grassi@unile.it (G. Grassi).

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2. Hardware implementation

This section describes the hardware implementation of the proposed current-programmed boost converter, which is constituted by a *power stage* and a *control circuit* (Fig. 1). The proposed power stage includes an inductor L, a diode D, a DC source V_{in}, a switch S, a load resistance R, a capacitor C and resistors R_1, R_2, R_5. The converter is assumed to operate in continuous conduction mode, that is, the inductor current $i(t)$ never falls to zero [14]. Hence, there are two switch states:

(i) switch S ON and diode D OFF; (ii) switch S OFF and diode D ON.

The two states toggle periodically, that is, the boost takes state (i) for $nT \leqslant t < (n+d)T$ and state (ii) for $(n+d)T \leqslant t < (n+1)T$, where T is the switching period, d is the duty cycle and n is an integer. Therefore, the state equations of the converter are

$$\begin{bmatrix} \frac{dv(t)}{dt} \\ \frac{di(t)}{dt} \end{bmatrix} = \begin{bmatrix} -1/RC & 0 \\ 0 & -(R_1+R_2+R_5)/L \end{bmatrix} \begin{bmatrix} v(t) \\ i(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1/L \end{bmatrix} V_{in} \quad \text{for } nT \leqslant t < (n+d)T; \tag{1}$$

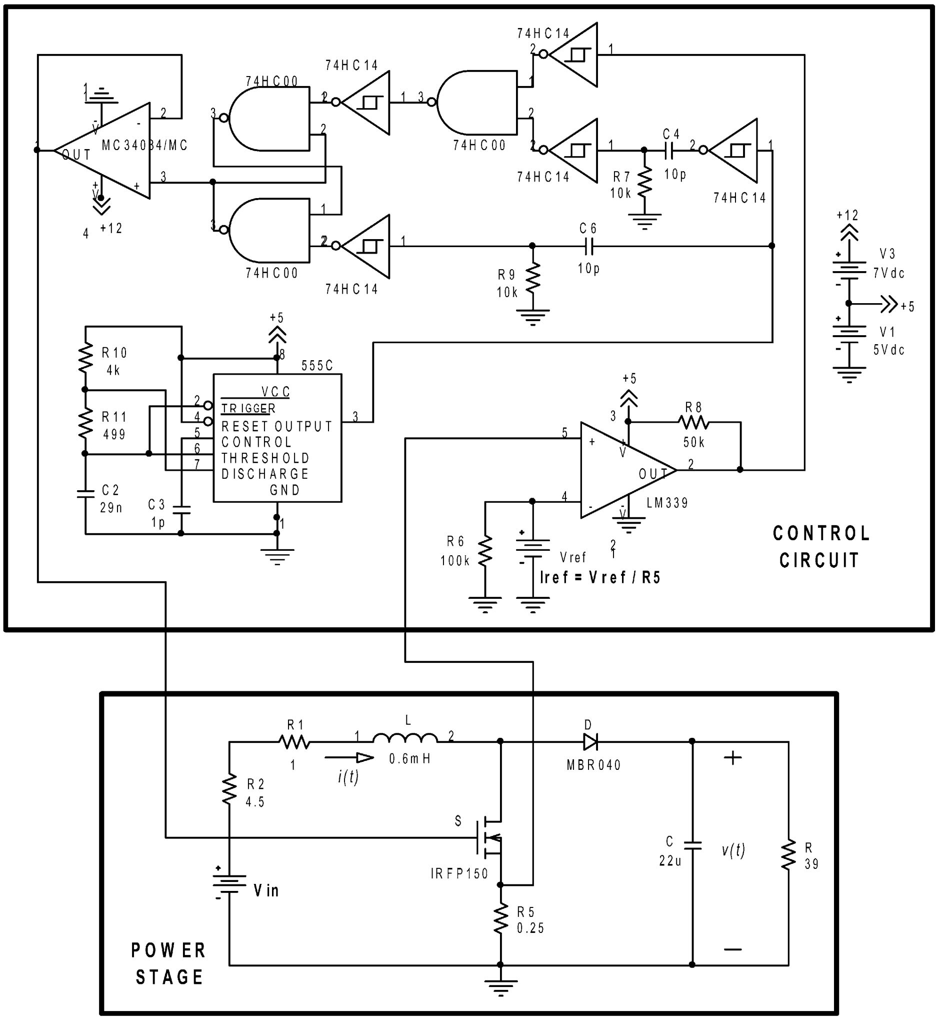

Fig. 1. Experimental current-programmed boost converter.