International Journal of Innovative
Computing, Information and Control
Volume **7**, Number **7(A)**, July **2011**

ICIC International ©2011 ISSN 1349-4198
pp. **3739–3750**

A STEP-DOWN SWITCHED-CAPACITOR AC-DC CONVERTER FOR ENERGY HARVESTING SYSTEM USING VIBRATION-BASED ENERGY

Kei Eguchi[1], Sawai Pongswatd[2], Kitti Tirasesth[2], Kuniaki Fujimoto[3]
Hirofumi Sasaki[3] and Takahiro Inoue[4]

[1]Department of Technology Education
Shizuoka University
No. 836, Ohya, Suruga-ku, Shizuoka 422-8529, Japan
ekeguch@ipc.shizuoka.ac.jp

[2]Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Ladkrabang, Bangkok 10520, Thailand
{ klsawai; ktkitti }@kmitl.ac.th

[3]School of Industrial Engineering
Tokai University
9-1-1 Toroku, Kumamoto-shi, Kumamoto 862-8652, Japan
{ kfuji; hsasaki }@ktmail.tokai-u.jp

[4]Department of Electrical and Computer Engineering
Kumamoto University
2-40-1 Kurokami, Kumamoto 860-8555, Japan
pt-inoue@cs.kumamoto-u.ac.jp

Received April 2010; revised August 2010

Abstract. *To realize battery-free operation employing energy harvesting, a step-down switched-capacitor-based converter has been used as a vibration-to-electricity converter. In this paper, to improve power efficiency, an AC-DC converter realizing* $1/N\times$ $(N = 2, 3, \ldots)$ *step-down is designed by using switched-capacitor techniques. Although conventional converters offer a DC output by regulating the stored energy in a big capacitor, the proposed converter generates a DC output by realizing AC-DC conversion. Thus, the proposed converter can improve power efficiency. To clarify effectiveness of the proposed converter, theoretical analysis is performed concerning power efficiency and equivalent circuit. When the AC input is a rectangular-wave voltage, the theoretical results obtained by the theoretical analysis are consistent with SPICE simulated results. Furthermore, SPICE simulation results show that the proposed converter can improve power efficiency about 32 % from the conventional converter when* $R_L = 100\Omega$. *Next, the validity of the circuit design is confirmed by experiments. The experiments show that the proposed converter can offer stepped-down DC voltage from sinusoidal voltage.*

Keywords: AC-DC converters, Power converters, Step-down converters, Switched capacitor circuits, Energy harvesting, Vibration-based energy

1. **Introduction.** In the field of WSN (Wireless Sensor Network), energy harvesting attracts many researchers' attention. Although the WSN is composed of a large number of wireless sensor nodes, battery-free operation can be realized by using energy harvesting. As a power source for the energy harvesting system, there are many ambient energy sources such as solar power, vibration-based power and thermoelectric power. Among others, a piezoelectric (PZT) element for scavenging vibration-based power is one of the most popular elements as an energy source of the energy harvesting system. To supply