

Comments on "Compact, Energy-Efficient High-Frequency Switched Capacitor Neural Stimulator With Active Charge Balancing" (vol 11, pg 878, 2017)

Comments on 'Compact, energy-efficient high-frequency switched capacitor neural stimulator with active charge balancing (IEEE Transactions on Biomedical Circuits and Systems (2017) 11:4 (878–888) DOI: 10.1109/TBCAS.2017.2694144)

Urso, Alessandro; Giagka, Vasso; Serdijn, Wouter A.

DOI

[10.1109/TBCAS.2019.2898555](https://doi.org/10.1109/TBCAS.2019.2898555)

Publication date

2019

Document Version

Accepted author manuscript

Published in

IEEE Transactions on Biomedical Circuits and Systems

Citation (APA)

Urso, A., Giagka, V., & Serdijn, W. A. (2019). Comments on "Compact, Energy-Efficient High-Frequency Switched Capacitor Neural Stimulator With Active Charge Balancing" (vol 11, pg 878, 2017): Comments on 'Compact, energy-efficient high-frequency switched capacitor neural stimulator with active charge balancing (IEEE Transactions on Biomedical Circuits and Systems (2017) 11:4 (878–888) DOI: 10.1109/TBCAS.2017.2694144). *IEEE Transactions on Biomedical Circuits and Systems*, 13(2), 480-480. Article 8638545. Advance online publication. <https://doi.org/10.1109/TBCAS.2019.2898555>

Important note

To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

Comments on “Compact, Energy-Efficient High-Frequency Switched Capacitor Neural Stimulator With Active Charge Balancing”

Alessandro Urso, *Student Member, IEEE*, Vasiliki Giagka, *Member, IEEE*, and Wouter A. Serdijn, *Fellow, IEEE*

Abstract—This manuscript points out some mistakes in the Introduction and in the table of comparison of a paper already published in this journal by Hsu and Schmid [1]. Although the main claim of [1] is still preserved, we believe the paper needs to be rectified for scientific correctness of the work.

Index Terms—High-frequency stimulation, power efficiency.

I. COMMENTS AND CORRECTIONS

In [1], the first High Frequency Switched-Capacitor (HFSC) stimulator is presented. The stimulation voltage is derived from the main supply by using an 1 : 1 switched-capacitor DC-DC converter. This particular topology of DC-DC converter operates as a resistor [2]. The further away the output voltage is from the input voltage, the lower the power efficiency is. As a result, the output voltage of the DC-DC converter, and therefore the total charge delivered to the tissue, can only be regulated at the expense of the power efficiency.

Section I of [1], provides an overview of the most recently published works in the field of electrical stimulation. Based on the stimulation mode, Hsu and Schmid classify the papers into three categories, named voltage-mode stimulation (VMS), current-mode stimulation (CMS) and switched-capacitor stimulation (SCS).

In [1], the work presented in [3] has been classified as SCS. However, [3] proposes CMS which adapts the voltage supply of the neurostimulator to the voltage across the electrodes.

In [1], the work presented in [4] has been classified as VMS. However, [4] proposes a CMS. In fact, an inductor-based DC-DC converter without the output capacitance is used to deliver the charge to the tissue.

Section V of [1] provides a table of comparison, in which the performances of the stimulator circuit are compared with some relevant contributions found in literature. Several errors have been found in the comparison table. The entries in **bold characters** and red colour of Table I below corrects the table of comparison presented in [1].

II. CONCLUSION

The aim of this comment is two-fold. Firstly, it corrects a classification of the most recent works, which was presented in the Introduction of a paper previously published in this

journal [1]. Secondly, it corrects some mistakes in its table of comparison. Although errors have been found, the main claim of [1], and hence its scientific contribution, are still preserved.

REFERENCES

- [1] W. Y. Hsu and A. Schmid, “Compact, Energy-Efficient High-Frequency Switched Capacitor Neural Stimulator with Active Charge Balancing,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 11, no. 4, pp. 878–888, 2017.
- [2] T. V. Breussegeem and M. Steyaert, *CMOS Integrated Capacitive DCDC Converters*. Springer, New York, 2013.
- [3] S. K. Kelly and J. L. Wyatt, “A power-efficient neural tissue stimulator with energy recovery,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 5, no. 1, pp. 20–29, 2011.
- [4] M. N. van Dongen and W. A. Serdijn, “A Power-Efficient Multichannel Neural Stimulator Using High-Frequency Pulsed Excitation From an Unfiltered Dynamic Supply,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 10, no. 1, pp. 61–71, 2016.
- [5] H. M. Lee, H. Park, and M. Ghovanloo, “A power-efficient wireless system with adaptive supply control for deep brain stimulation,” *IEEE Journal of Solid-State Circuits*, vol. 48, no. 9, pp. 2203–2216, 2013.
- [6] H. M. Lee, K. Y. Kwon, W. Li, and M. Ghovanloo, “A power-efficient switched-capacitor stimulating system for electrical/optical deep brain stimulation,” *IEEE Journal of Solid-State Circuits*, vol. 50, no. 1, pp. 360–374, 2015.
- [7] I. Williams and T. G. Constandinou, “An energy efficient dynamic voltage scaling neural stimulator for a proprioceptive prosthesis,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 7, no. 2, pp. 129–139, 2013.
- [8] S. K. Arfin and R. Sarpeshkar, “An energy-efficient, adiabatic electrode stimulator with inductive energy recycling and feedback current regulation,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 6, no. 1, pp. 1–14, 2012.

A. Urso and W. A. Serdijn are with Delft University of Technology, Delft, The Netherlands. V. Giagka is with Delft University of Technology, Delft, The Netherlands and with Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany.

TABLE I

	[5]	[6]	[7]	[8]	[4]	[3]	[1]
Process	0.5 μm	0.35 μm	0.18 μmHV	0.35 μm	0.18 μmHV	1.5 μm	0.18 μmHV
Supply voltage (V)	2.5 – 4.6	± 2	6	3.3	20	± 1.75	5
Power source	Inductive Link	Inductive Link	Battery	Battery	Battery	Inductive Link	Battery
Stimulus type	CMS	SCS	CMS	VMS	CMS	CMS	HFSC
Stimulation charge variation over electrode	Lowest	Low	Lowest	Low	N.A.	Low	Low
Peak Efficiency	68 %	80.4%	80%*	50%	50%	N.A.	49%
Dedicated power management	Y	Y	Y	Y	Y	Y	N
Area per channel (mm^2)	0.23	0.37	0.35	0.58	0.21	0.317	0.035
Maximum charge (nC)	> 992	> 840	50.4	450	1280	678	190
# external components	0	2	0	2	1	N.A	0

* DC-DC converter only.