

Yifei PU, Bo YU, Qiuyan HE, Xiao YUAN, 2021, Fractional-order memristive neural synaptic weighting achieved by pulse-based fracmemristor bridge circuit. *Frontiers of Information Technology & Electronic Engineering*, 22(6):862-876.
<https://doi.org/10.1631/FITEE.2000085>

Fractional-order memristive neural synaptic weighting achieved by pulse-based fracmemristor bridge circuit

Key words: Fractional calculus; Fracmemristor; Fracmemristance; Fractional-order memristor; Fractional-order memristive synapses

Corresponding authors: Qiuyan HE and Xiao YUAN

E-mail: heqiuyan789@163.com and yuanxiao@scu.edu.cn

 ORCID: <https://orcid.org/0000-0002-4983-778X>;

<https://orcid.org/0000-0003-3003-0326>

Motivation

1. The changes occurring in synaptic weight are well known as synaptic plasticity, which is the cellular mechanism that underlies learning and memory. The synaptic simulation is a hot area of research. However, due to the lack of a proper device to implement the synapses, research in this area has only had limited success practically.
2. The existing memristor bridge synapses were of the integer-order memristive neural synaptic weightings. While the concept of memristor has been generalized preliminarily from the classical integer-order memristor to the fractional-order memristor, a challenging theoretical problem would be whether the fracmemristor can be applied to achieve the fractional-order memristive synapses or not.

Main idea

1. To implement the fractional-order memristive neural synaptic weighting, the pulse-based fracmemristor bridge circuit should be firstly designed.
 2. By applying a pulse-based fracmemristor bridge circuit, the fracmemristor bridge synaptic circuit can be achieved.
 3. By applying the fracmemristor bridge synaptic circuit, the fracmemristor bridge neuron circuit can be implemented.
- Furthermore, the architecture of the fractional-order memristive neural networks circuit can be obtained.

Method

The pulse-based fracmemristor bridge circuit can be obtained by two ν -order oppositely incremental capacitive fracmemristors (FM_1^1 and FM_2^1) with the same circuit parameters (Fig. 1).

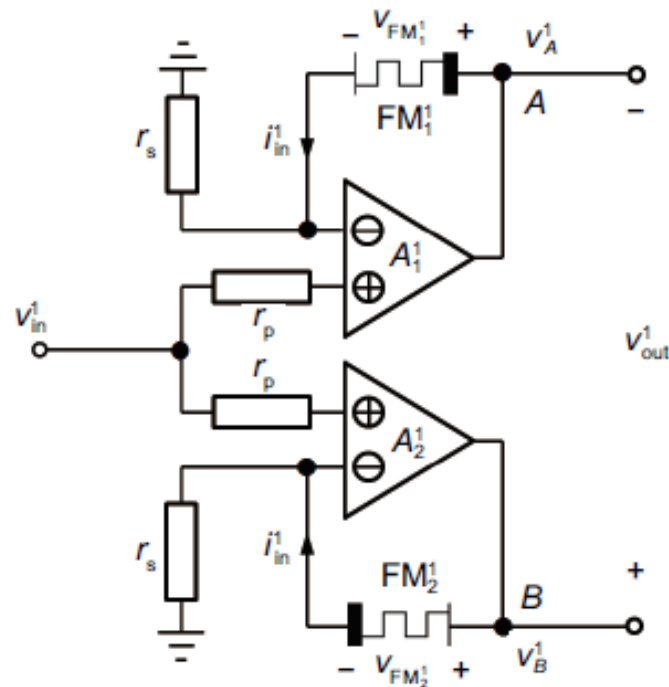


Fig. 1 Pulse-based fracmemristor bridge circuit

Major results

Comparison of electrical characteristics between the pulse-based fracmemristor and memristor bridge circuits

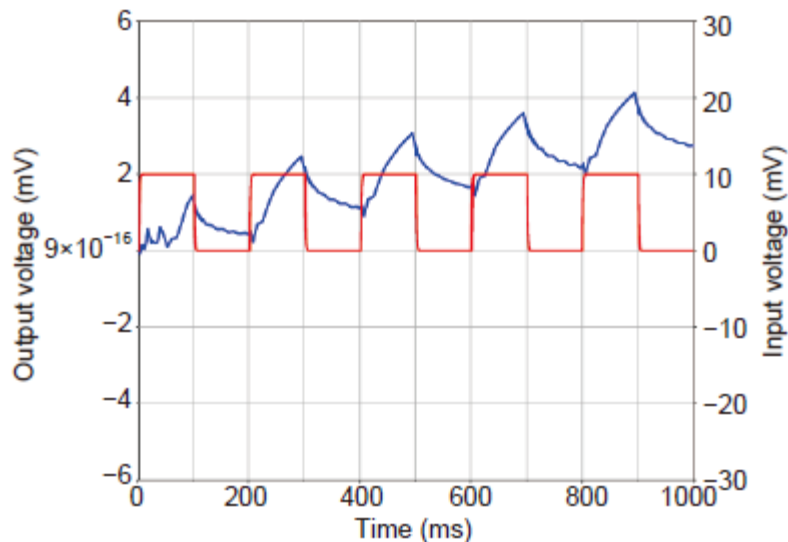


Fig. 9 Output voltage of a pulse-based fracmemristor bridge circuit with $v_{in}^1(t) = 10$ mV, $r_p = 1000 \Omega$, and $r_s = 1000 \Omega$. Red corresponds to the right vertical axis and blue corresponds to the left vertical axis

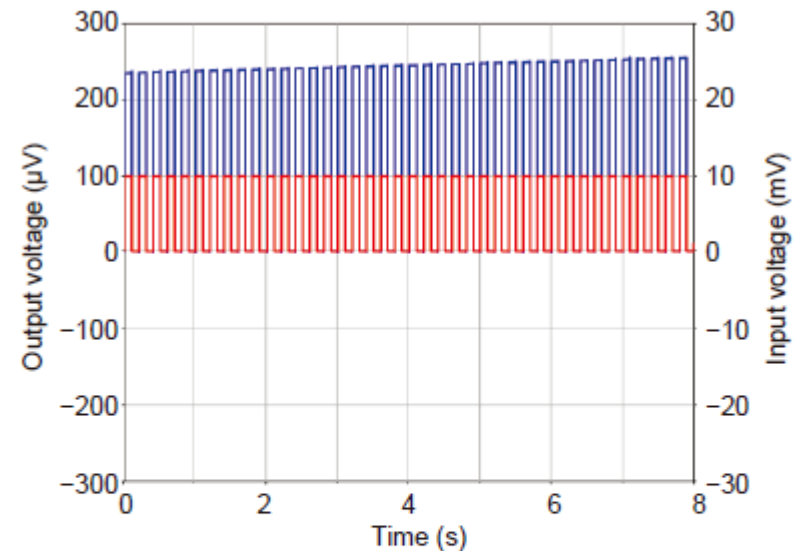


Fig. 10 Output voltage of a pulse-based memristor bridge circuit with $v_{in}^1(t) = 10$ mV, $r_p = 1000 \Omega$, and $r_s = 1000 \Omega$. Red corresponds to the right vertical axis and blue corresponds to the left vertical axis

Major results (Cont'd)

Simulation of LTP and LTD

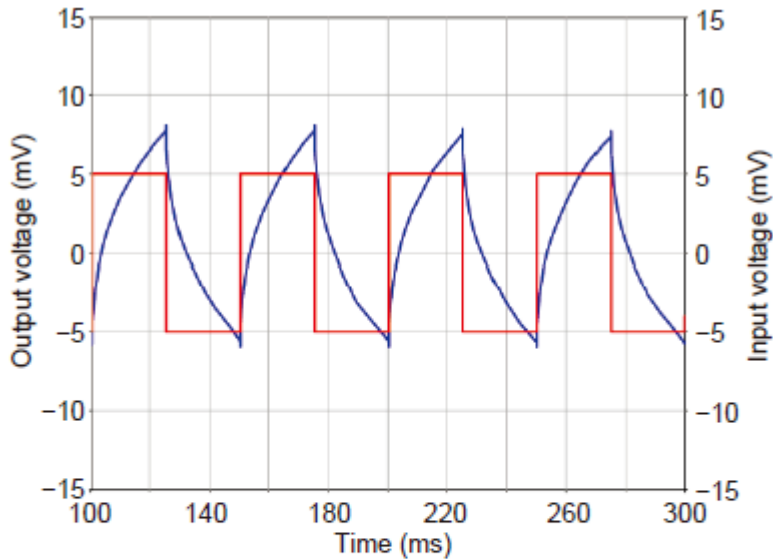


Fig. 13 Output voltage of a pulse-based fracmemristor bridge circuit with the duty cycle of the input voltage pulse equal to 50%. Red corresponds to the right vertical axis and blue corresponds to the left vertical axis.

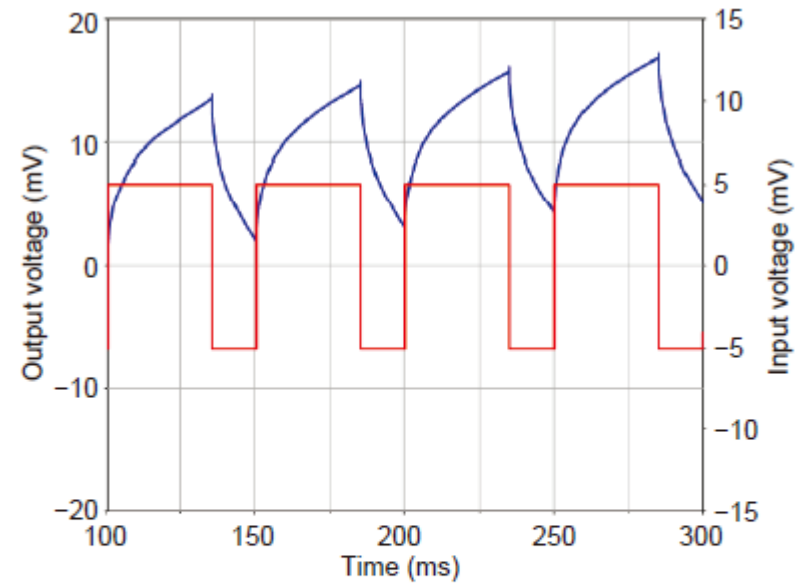


Fig. 14 Output voltage of a pulse-based fracmemristor bridge circuit with the duty cycle of the input voltage pulse equal to 70%. Red corresponds to the right vertical axis and blue corresponds to the left vertical axis

Conclusions

1. The pulse-based memristor bridge circuit realizes linear weighting on the input signal, whereas the pulse-based fracmemristor bridge circuit yields nonlinear weighting operation, which is more appropriate for explaining the neural synaptic weighting.
2. Electrical characteristics of a pulse-based fracmemristor bridge circuit can be used to explain the cellular mechanisms that underlie learning and memory such as LTP, LTD, habituation, and sensitization.



蒲亦非，四川大学计算机学院（软件学院）教授、博士生导师。研究领域：分数阶微积分理论及应用、分数阶数字图像处理、分数阶机器学习、分忆抗（分数阶忆阻）、分数阶信号处理、计算法学（人工智能+法学）。发表SCI论文40余篇，其中以第一作者在*IEEE Trans Image Process*, *IEEE Trans Neur Netw Learn Syst*, *IEEE Trans Circ Syst I Regul Pap*, *Int J Neur Syst*, *IEEE Intell Transp Syst Mag*, *IEEE Int Things J*, *Sci China Inform Sci* 等期刊发表SCI论文20余篇；以第一发明人身份获授权专利14项；出版学术专著5部。以第一作者身份发表的论文“Fractional Differential Approach to Detecting Textural Features of Digital Image and Its Fractional Differential Filter Implementation”获得*Sci China Inform Sci* 2018年十年持续影响力论文奖。担任中国自动化学会分数阶系统与控制专业委员会副主任委员、中国自动化学会自适应动态规划与强化学习专业委员会委员、国际学术期刊*Metaheuristics*（启发式演算，Springer-Nature Press）编委。