# A Novel Hardware-Aware Bursting Neuron for Local Spiking Online Learning

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Bursts, together with spikes and silences, form the triad of neural communication [1]. These high-frequency trains of spikes are related to plasticity and learning [2], and signal association [3]. Nevertheless, contrary to spikes and silences, the implementation of bursting on Spiking Neural Networks (SNNs) has been scarce. In this work, we introduce a novel hardware-aware multi-compartment neuron model to replicate the basic bursting properties of rodent cortical layer V pyramidal neurons. Its conjunctive bursting properties are illustrated in Figure 1. Adding a simple local learning rule based on pattern-firing-dependent plasticity, our model can work as the basic unit of an SNN. The model is then implemented in a novel analog neuromorphic CMOS circuit, based on a combination of existing and simple circuits, allowing for its straightforward implementation in ultra-low-power hardware.

In an emergent fashion, our neuron shows 1) output burst and single spike mixtures without random number generators, 2) an output single spike frequency directly proportional to the basal input, 3) an output bursting frequency directly proportional to the apical input, and 4) a follower behavior suited for target learning. Paired with Short-Term Plasticity (STP) synapses, the bursting and single spikes can be demultiplexed [4]. This can be used to recover the apical and basal inputs and serve as the base for multi-layer SNNs. Tested on an online supervised binary classification task, a single-layer SNN of our neurons achieves perfect accuracy with as few as 2 learning examples. In a novel approach, we use the STP synapses to dynamically change network properties between learning and test phases. This modification increased robustness to device mismatch and opens the door for better dynamics normalization and tuning in SNNs.

With the generalized use of automated systems in a wide range of contexts, new solutions capable of continuously learning to adapt and react to ever-changing environments in real time are needed. Our system provides a base for the design of SNNs that meet these requirements in hardware-constrained applications.

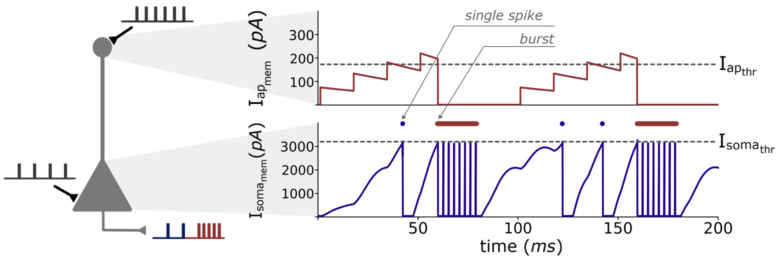


Figure 1: Behavior of our novel neuron model. Apical and basal inputs are integrated into the compartments $I_{ap_{mem}}$ and $I_{soma_{mem}}$, respectively. If $I_{soma_{mem}}$ exceeds a threshold $I_{soma_{thr}}$, when $I_{ap_{mem}}$ is below $I_{ap_{thr}}$, a single spike is generated. On the contrary, if $I_{soma_{mem}}$ crosses $I_{soma_{thr}}$ when $I_{ap_{mem}}$ is above $I_{ap_{thr}}$, a burst is generated.

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[4] R. Naud, H. Sprekeler., Proc Natl Acad Sci U S A., 115(27), E6329-E6338, 2018