

Revisiting mismatch in neuromorphic neurons through input dynamics

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Reliable event timing is essential for neuromorphic systems performing sensory processing and motor control with low-power analog hardware subject to device mismatch. Under constant inputs, excitable silicon neurons operate as autonomous oscillators whose limit-cycle dynamics are sensitive to parametric variations. In these conditions, device mismatch induces variability in firing rates and phases, resulting in unreliable event timing across neurons. In this work, inspired by previous biological and computational findings [1, 2], we demonstrate experimentally that time-varying inputs provide a practical mechanism to recover reliable event timing in heterogeneous silicon neurons without calibration or coupling.

Using a 16-neuron array of mixed-feedback analog silicon neurons capable of spiking and bursting, and exhibiting significant transistor mismatch, we compare responses to constant (DC) stimulation and various repeated time-varying inputs. Timing reliability is derived from SPIKE-distance metrics [3], across repeated and throughout the neuron population. While DC inputs produce autonomous oscillations with trial-to-trial variability and no inter-neuron coherence, fluctuating inputs drive neurons into an input-triggered excitable regime. In this regime, events are triggered by shared input fluctuations, resulting in highly reproducible timing across trials, and improved alignment across mismatched neurons, despite remaining heterogeneity in firing rates and waveform details. Thus, time-varying inputs reduce the mismatch-induced variability in event timing at the population level without requiring calibration, coupling, or network interactions. We further show that timing reliability depends on input bandwidth, revealing distinct optimal timescales for spiking and bursting neurons. This supports a trigger-based mechanism in which input fluctuations must match the intrinsic dynamics of the excitable system, while faster fluctuations will interfere with event formation. These results demonstrate that appropriate input design can transform heterogeneous neuromorphic neurons from unreliable autonomous oscillators into robust event-driven computational elements. More broadly, they highlight an alternative to calibration, mismatch compensation and rate-based synchronization, by exploiting input-driven excitable dynamics to achieve reliable event-based computation under hardware variability.

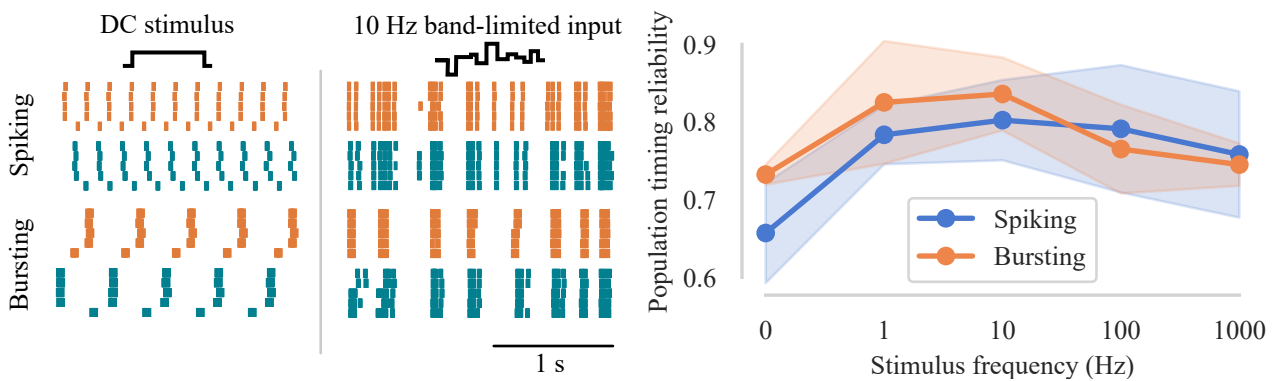


Fig. 1: Timing reliability in mismatched neurons increases with time-varying stimulation and shows different ideal input bandwidths for spiking and bursting. Left: raster plots for two neurons. Right: population reliability $R = 1 - \overline{D}_{i \neq j}$ with $D_{i,j}$ the SPIKE-distance averaged across trials of neurons i, j .

[1] Z. Mainen & T. Sejnowski, Science, 268 (5216), pp. 1503–1506, 1995.

[2] T. Kirby et al., arXiv:2112.14134, 2021.

[3] T. Kreuz et al., Jour. Neur. Meth., 195 (1), pp. 92–106, 2011