Electrical-Coupling-Induced Synchronization in Thermally Separated VO_2 Oscillators

Ke Li, Zhuoqun Fang, Zhuoying Chen, Lionel Aigouy, Alexandre Zimmers

Laboratoire de Physique et d'Etude des Matériaux (LPEM) ESPCI Paris, PSL Research University, Sorbonne Université, CNRS, 10 Rue Vauquelin, Paris, France

Oscillatory neural hardware has emerged as a promising paradigm for energy-efficient neuromorphic computing. In closely spaced VO_2 oscillator systems, however, the relative contributions of intentional electrical coupling and unintended thermal cross-talk can be difficult to disentangle. Here, we suppress direct inter-device thermal coupling by placing two oscillators on separate chips and coupling them only through external resistive or capacitive pathways. Under these conditions, we observe stable synchronization together with rational (p:q) frequency locking and Arnold-tongue-like locking regions, indicating that, apart from thermal coupling [1,2], electrical inter-oscillator coupling alone is sufficient to sustain higher-order synchronization in this two-oscillator VO_2 system. We further find that resistive and capacitive coupling produce distinct dynamical signatures, including different locking ranges, frequency-pulling behavior, and phase relations. These results clarify the role of electrical coupling in VO_2 oscillator synchronization and provide a controlled basis for designing more predictable phase-transition-oscillator circuits.

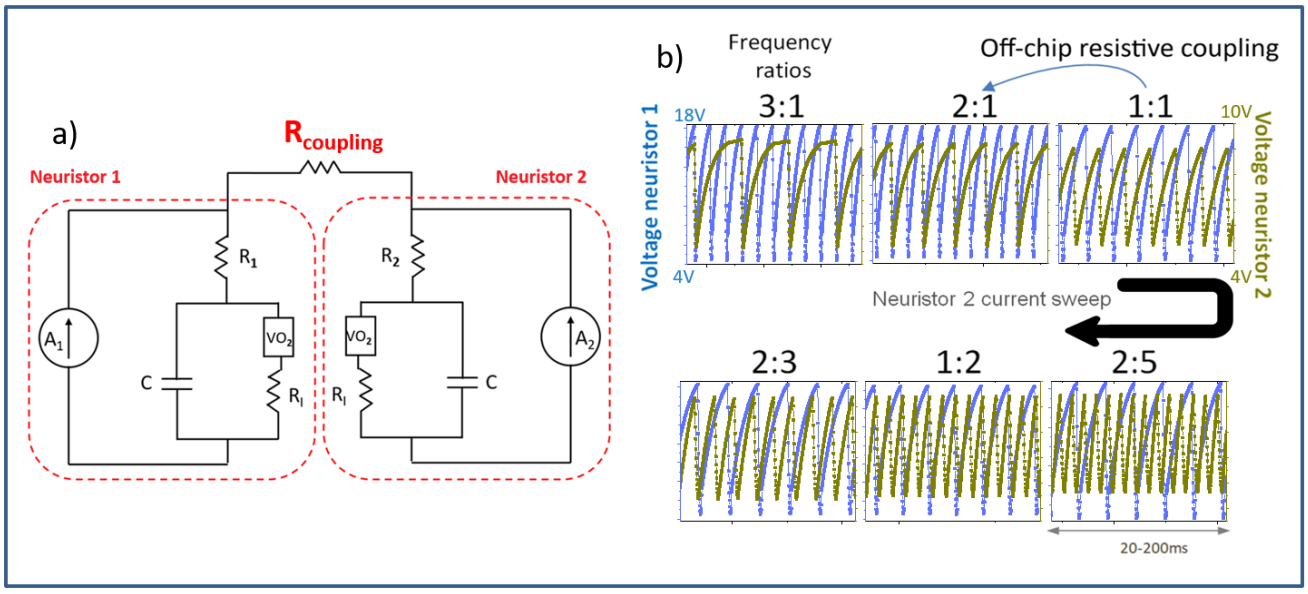

Figure 1: a) Electrical circuit of two VO_2 oscillators coupled by a resistance $R_{coupling}$. b) Spiking behavior of both neuristors as the current in neuristor 1 is kept fixed while the current in neuristor 2 is swept upward. Frequency-locked ratios of **3:1, 2:1, 1:1, 3:2, 1:2,** and **2:5** are observed. At fixed input currents, switching between the **1:1** and **1:2** states can also be achieved by varying the off-chip resistive coupling between 10 and 20 kΩ.

[1] E. Qiu et al., Proc. Natl. Acad. Sci. U.S.A., 120(38), e2303765120, 2023.

[2] Li et al., Nat. Commun., 15, 5820, 2024.