Synchronization of bursting oscillators by a common noise source

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Neuron synchronization plays a fundamental role in many complex brain functions (memory, control, thought, etc.) Its study might help understand e.g. why (and how) do neurons use either single spikes or bursts to transmit, encode and process information. Since a single neuron typically receives random inputs from nearly 10^4 others, the neurocomputational paradigm finally arising will necessarily have noise as a central ingredient. Previous theoretical studies[1,2] have shown that—against common sense—*noise may improve neuron synchronization.* We are not aware of such paradoxical noise effect having been reported in any physical device that emulates the spiking *and bursting* neuron electrical activity.

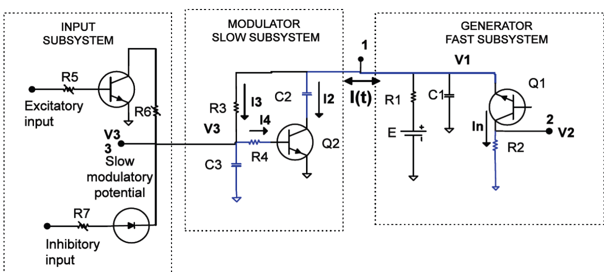

FIG. 1. Non-identical weakly coupled bursting electronic model of a neuron.

Our analog electronic circuit[3] (Fig. 1) is based on the *same operating principles* (conductance change) as neurons (analogues for potentials, currents and conductances can be easily identified) and exhibits the *same bifurcation scenarios* and essentially the same bursting behavior as the Hodgkin–Huxley model. Through a single parameter (a conductance) our circuit can be set into different self-oscillating regimes: *single spikes at nonregular interspike intervals*, and *two- and three-spike bursts interspersed with single spikes.*

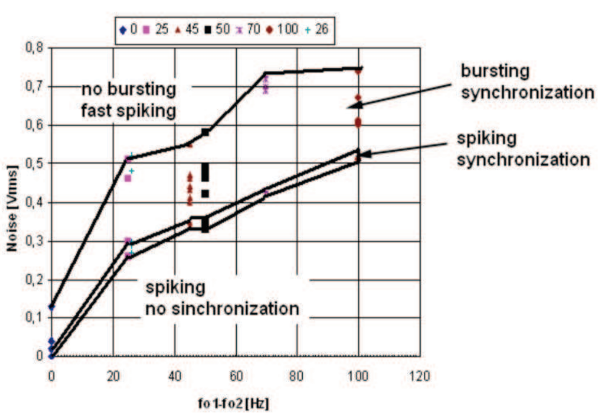

FIG. 2. Synchronization regimes.

The circuits are naturally nonidentical due to their components' value dispersion, and unavoidably coupled—even if not deliberately done—when using a common noise source. By applying to two such circuits a common noise of increasing intensity, their initially very different instantaneous frequencies increase and match, and the system's self-oscillation becomes periodic. We show that this effect is noise-mediated rather than due to the (very) weak coupling. The histograms, frequency spectra, correlation and recurrence plots show the measured activation and excursion times as the frequencies of both oscillators become equal for a definite noise intensity. Moreover, the plots for different noise intensities of the spike-sequence phase differences between the two circuits as time goes on show plateaux with different duration, indicating phase synchronization induced by the common noise. Complete synchronization has never been observed. When the circuits undergo saddle–homoclinic bifurcation, phase synchronization of spikes, spikes-bursts, and bursts occurs for definite noise intensities. The experimental results confirm the theoretical assertion that for noise mediated synchronization of two nonidentical oscillators, a stable and an unstable manifolds are necessary. When the circuits undergo a saddle–node bifurcation on invariant circle, no synchronization is detected in our experimental setup.

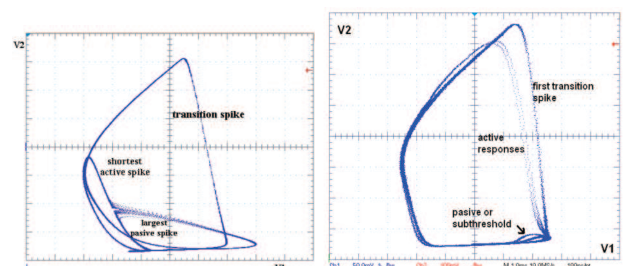

FIG. 3. a) saddle–homoclinic bifurcation; b) saddle–node bifurcation on invariant circle.

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[3] G. V. Savino and C. M. Formigli, BioSystems **97**, 9-14 (2009).