Oscillations by symmetry breaking in homogeneous networks with electrical coupling

By Loewenstein
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By Loewenstein February 3, 2011


Abstract:

In many biological systems, the electrical coupling of nonoscillating cells generates synchronized membrane potential oscillations. This work describes a dynamical mechanism in which the electrical coupling of identical nonoscillating cells destabilizes the homogeneous fixed point and leads to network oscillations via a Hopf bifurcation. Each cell is described by a passive membrane potential and additional internal variables. The dynamics of the internal variables, in isolation, is oscillatory, but their interaction with the membrane potential damps the oscillations and therefore constructs nonoscillatory cells. The electrical coupling reveals the oscillatory nature of the internal variables and generates network oscillations. This mechanism is analyzed near the bifurcation point, where the spatial structure of the membrane potential oscillations is determined by the network architecture and in the limit of strong coupling, where the membrane potentials of all cells oscillate in-phase and multiple cluster states dominate the dynamics. In particular, we have derived an asymptotic behavior for the spatial fluctuations in the limit of strong coupling in fully connected networks and in a one-dimensional lattice architecture.

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