

LIF voltage traces and a recurrent network raster

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A single leaky integrate-and-fire (LIF) neuron driven by a steady supra-threshold current should fire periodically; wire 200 of them together with sparse excitation and noisy per-neuron bias and the population should sustain ongoing, irregular firing rather than fall silent or lock into synchrony. We ran both (one neuron, then the network) and report the voltage trace, the raster, and the measured firing rates.

Methods

The LIF membrane voltage decays toward a resting potential and is pushed around by injected current; a threshold crossing emits a spike and resets the voltage.

- **Subthreshold dynamics.** Integrate the leaky-membrane ODE

$$\tau_m \frac{dV}{dt} = -(V - V_{\text{rest}}) + R_m I,$$

with V the membrane potential, τ_m the membrane time constant, V_{rest} the resting potential, R_m the input resistance, and I the injected current.

- **Spike-and-reset.** When $V(t) \geq V_{\text{th}}$, record a spike at t and set $V \leftarrow V_{\text{reset}}$, with V_{th} the threshold and V_{reset} the reset potential.
- **Integration.** Forward Euler at timestep Δt ,

$$V \leftarrow V + \frac{\Delta t}{\tau_m} [-(V - V_{\text{rest}}) + R_m I].$$

- **Single-neuron run.** Drive one neuron with a constant supra-threshold tonic current.
- **Network run.** Wire 200 neurons with sparse, all-excitatory recurrence. Each neuron i takes total current $I_i(t) = I_i^{\text{bias}} + s_i(t)$, with noisy bias $I_i^{\text{bias}} \sim \mathcal{N}(\mu, \sigma^2)$ and synaptic current s_i that decays between spikes and is kicked by incoming ones,

$$s_i \leftarrow s_i e^{-\Delta t / \tau_{\text{syn}}} + \sum_{j \in \text{spiked}} W_{ij},$$

where τ_{syn} is the synaptic time constant and $W_{ij} = w C_{ij}$ with connectivity $C_{ij} \sim \text{Bernoulli}(p)$, weight w , and no self-connections. Each neuron is held at V_{reset} for a refractory period after spiking.

Parameter values are tabulated below.

Results

With a steady tonic input above threshold, the single neuron fires periodically at 90 Hz. Each upward sweep is the membrane charging through its RC time constant; each vertical line is a reset after a spike.

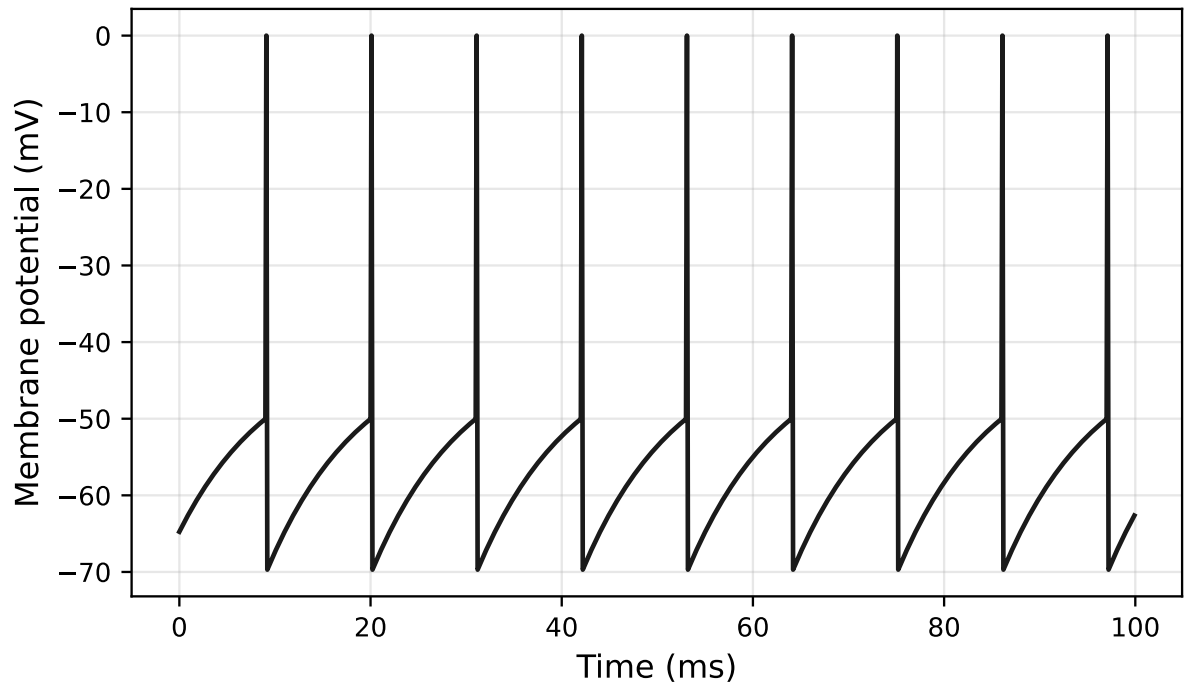


Figure 1: Single LIF neuron under tonic input: membrane potential (mV) against time (ms). The membrane charges toward its steady state and resets at each threshold crossing, giving periodic firing at 90 Hz.

The network sustains ongoing irregular firing: a population mean of 104 Hz, spanning 56–148 Hz across neurons, no silence, no runaway synchrony. The raster shows every spike from every neuron over half a second; the panel beneath tracks the network's mean total input current.

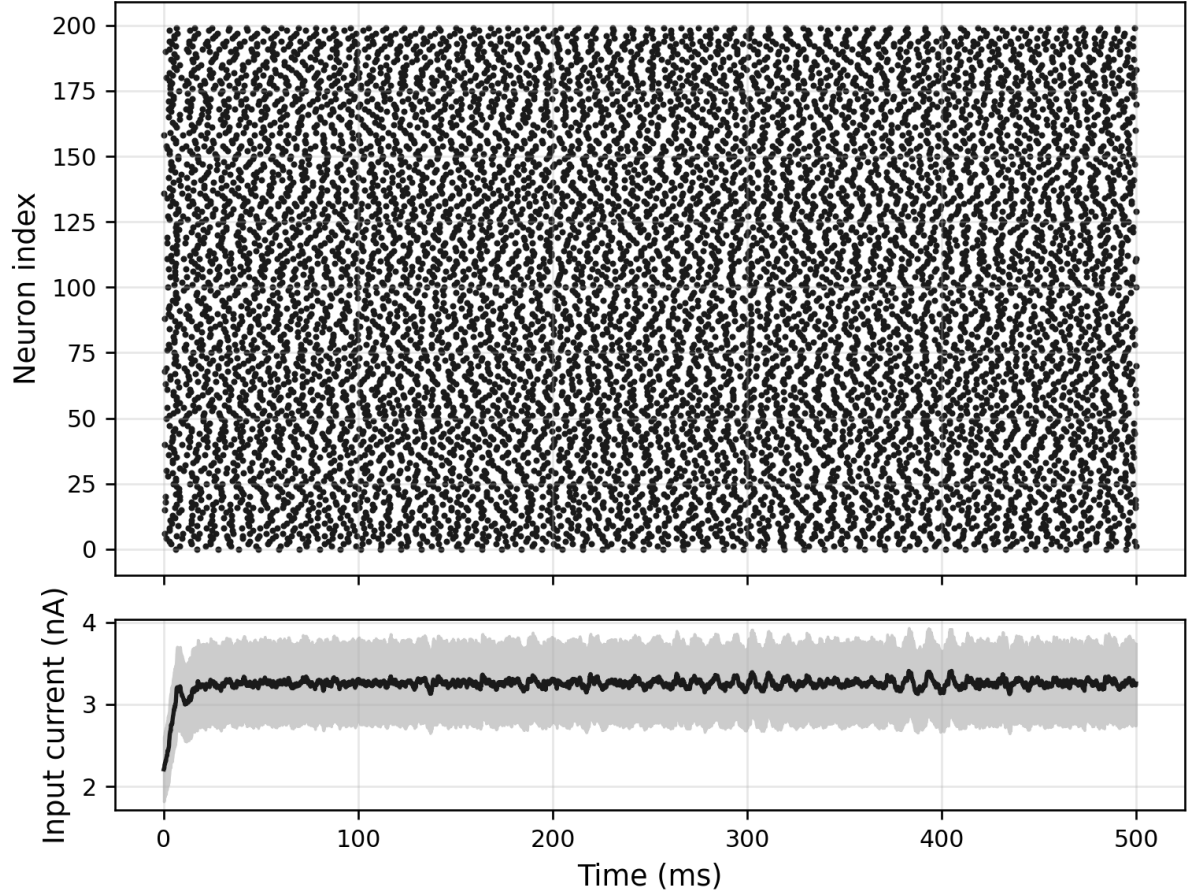


Figure 2: Network raster (top: spike time vs neuron index) and mean input current (bottom, nA vs ms) across 200 recurrently coupled LIF neurons over 500 ms. Mean firing rate 104 Hz; the shaded band is ± 1 s.d. of the per-neuron total current across the population.

LIF run parameters

Parameter	Value
current	2.5
duration	100
dt	0.1
tau_m	10
r_m	10
v_rest	-65
v_reset	-70
v_thresh	-50
firing_rate_hz	90

Network run parameters

Parameter	Value
n	200
duration	500
dt	0.1
seed	0
mean_firing_rate_hz	104.2
min_firing_rate_hz	56
max_firing_rate_hz	148

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