

EIF voltage traces and a recurrent network raster

exp001 · 13 May 2026

The exponential integrate-and-fire (EIF) neuron replaces LIF’s hard threshold with an explicit exponential term that models the upswing of a spike. Under the same tonic drive as exp000 it should fire at a different rate than LIF (the exponential accelerates spike initiation, but the upswing itself takes time) while a network of them should behave much like the LIF network with a softened spike onset. We ran the single neuron and the network and compare against exp000.

Methods

The EIF neuron keeps LIF’s one-variable spirit but grows an exponential term, so the threshold becomes a soft inflection point rather than a discontinuity.

- **Subthreshold dynamics.** Integrate

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

with V the membrane potential, τ_m the membrane time constant, V_{rest} the resting potential, R_m the input resistance, I the injected current, V_T the soft threshold, and Δ_T the slope factor.

- **Peak-and-reset.** When $V(t) \geq V_{\text{peak}}$, record a spike at t and set $V \leftarrow V_{\text{reset}}$, with V_{peak} the peak cutoff and V_{reset} the reset potential.
- **Threshold behaviour.** V_T is no longer a discontinuity: it is the point at which the exponential term takes over and the voltage blows up on its own. Small Δ_T approximates LIF; larger Δ_T smooths spike initiation.
- **Integration.** Forward Euler at timestep Δt ,

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

- **Single-neuron run.** Drive one neuron with a constant tonic current.
- **Network run.** Structurally identical to exp000: 200 all-excitatory neurons, sparse p random connectivity, weight w , exponentially-decaying synaptic input with time constant τ_{syn} , noisy per-neuron bias $I_i^{\text{bias}} \sim \mathcal{N}(\mu, \sigma^2)$, and a refractory period, with every neuron now obeying the EIF dynamics above.

Parameter values are tabulated below.

Results

Under the same tonic input, the EIF neuron fires at 60 Hz, against 90 Hz for the LIF neuron in exp000: the exponential term accelerates spike initiation, but the upswing takes time, so the inter-spike period shifts.

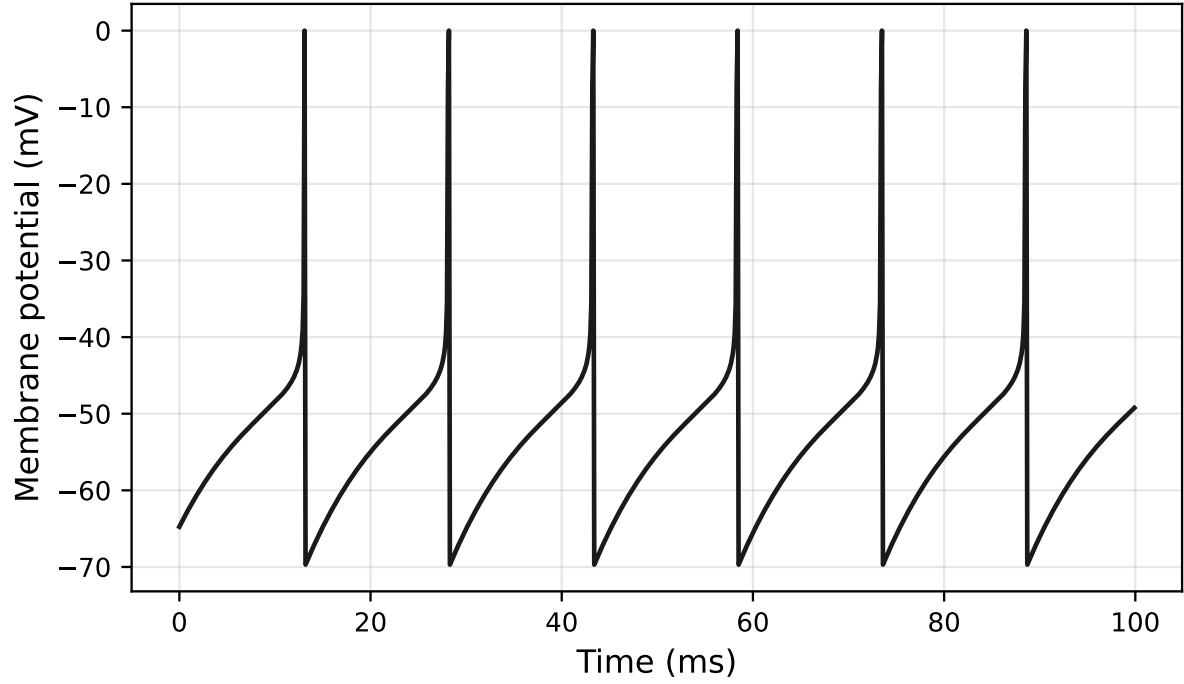


Figure 1: Single EIF neuron under tonic input: membrane potential (mV) against time (ms). The soft exponential threshold produces a curved spike upswing rather than LIF's hard reset, and periodic firing at 60 Hz.

The EIF network sustains irregular firing at a population mean of 69 Hz, spanning 32–98 Hz across neurons, the same asynchronous-irregular regime as the LIF network, shifted in rate.

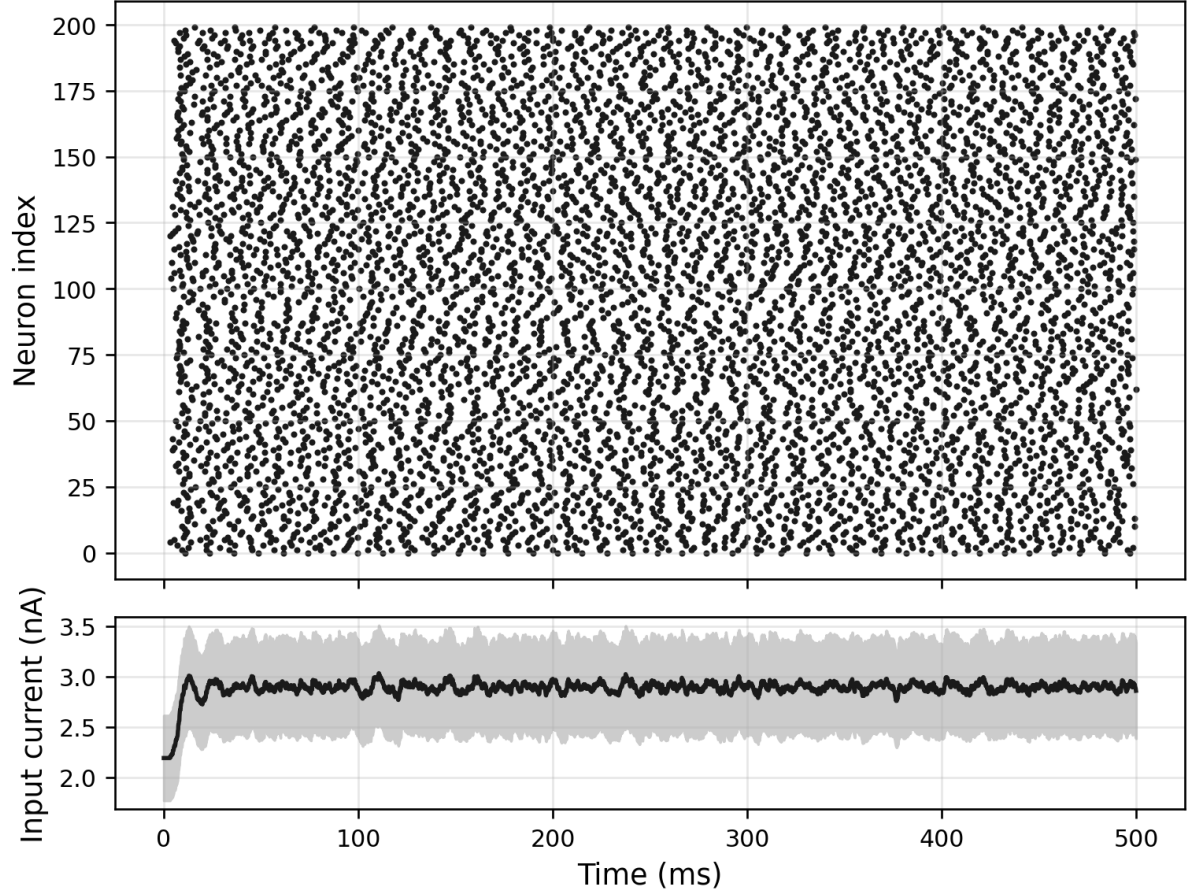


Figure 2: EIF network raster (top: spike time vs neuron index) and mean input current (bottom, nA vs ms) across 200 neurons over 500 ms. Mean firing rate 69 Hz; the shaded band is ± 1 s.d. of the per-neuron total current.

EIF 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_t	-50
delta_t	2
v_peak	0
firing_rate_hz	60

EIF network run parameters

Parameter	Value
n	200
duration	500
dt	0.1
seed	0
mean_firing_rate_hz	69.11
min_firing_rate_hz	32
max_firing_rate_hz	98

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