

Paper: Time-Dependent Nanoparticle Networks

1. Introduction & Literature Review

- **Background on Time-Independent Nanoparticle Networks:** Recap of equilibrated studies and static nonlinearity.
- **Neuromorphic-Computing Context:** Dynamical response, memory, fading-memory, kernel richness; examples from reservoir computing and spiking networks.
- **Gap & Objectives:** Need for quantitative dynamical characterization under time-varying drive; role of two-type disorder in tuning time scale, nonlinearity, and memory.

2. Model & Simulation Tool

2.1. Network Geometry & Disorder

- 2D lattice with fixed inter-particle spacing.
- Two NP types: Diameter of a NP defined as $d_i = N(\mu_{d_i}, \sigma_{d_i}^2)$, with $\mu_{d_i} \in \{d_1, d_2\}$ and $\sigma_{d_i} = 0$ by default.
- Two Junction types: Resistance of a junction defined as $R_i = N(\mu_{R_i}, \sigma_{R_i}^2)$, with $\mu_{R_i} \in \{R_1, R_2\}$ and $\sigma_{R_i} = 0$ by default.

2.2. KMC with Floating Output & Time-Dependent Boundaries

- Original KMC summary and modifications:
 - Floating output node.
 - Time-stepped boundary voltages for input and optional controls.
- Event rates and charge updates under time-dependent boundaries.

3. System Characterization

3.1. Transient (Step) Response & Tunable Time Scales

- **Protocol:** Single voltage step, record NP and Output potentials.
- **Large Output Capacitance Study:**
 - Vary $C_{ext} > C_{NP}$ to shift τ into ms regime.
- **Metrics:** Exponential fits to extract τ ; plots of τ vs. C_{ext} and NP/junction types.

3.2. Frequency Response & Hammerstein Approximation

- **Protocol:** Sinusoidal sweep f_0 from f_{min} to f_{max} .
- **Metrics:** Gain $|H(f)|$, phase $\phi(f)$, quasi-static plateau and roll-off.
- **Modeling:** Fit to Hammerstein block model (static nonlinearity + linear filter).

3.3. Nonlinearity & Total Harmonic Distortion

- **Protocol:** Sinusoidal sweep f_0 from f_{min} to f_{max} .
- **Metrics:** THD vs. frequency, and NP/junction configuration.

3.4. Memory Effects

- **Multi-Pulse Protocol:** Two step pulses separated by Δt ; quantify second-response attenuation.
- **Optional Noise Protocol:** White-noise drive; compute short-term memory kernel or autocorrelation decay.
- **Figure:** Memory metric vs. Δt and NP/junction configuration.

4. Parametric Control via Additional Electrodes

- **8-Electrode Extension:** 1 input, 1 floating output, 6 fixed-bias controls.
- **Protocol:** At given f_0 random control voltages or just varying two representative controls for heatmaps.
- **Studies:**
 - Control-bias effects on τ .
 - Control-bias effects on THD/nonlinearity.

5. Conclusions & Outlook

- Summary, Applications, Neuromorphic Computing context
- Key takeaways and directions for future work.

Supplementary

- **RC-Ladder Analogy:**
 - 1D NP string vs. classical RC ladder.
 - τ and $|H(f)|$ comparisons.
- **Raw output traces and model-fit residuals.**