

G FET Based - Graphene-Enhanced Hybrid Stochastic Logic Gates: A Standalone Path to Universal Quantum Computing

White Paper

EmergenceByDesign

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Abstract

This supplemental white paper presents an evolved hybrid architecture for post-deterministic logic gates, building upon prior disclosures of the Reliability-Failure Effect Transistor (REFET) Phenomenon Demonstrator (PPD) and the "STORMING THE GATES" framework. Through a systematic, open-ended exploration of analogous stochastic phenomena, we identify and validate graphene field-effect transistors (G-FETs) as a superior replacement for the original REFET MOSFET component. This substitution leverages the intrinsic, quantum-rooted $1/f$ noise in graphene, observed extensively in condensed matter physics, to provide a stable, reproducible stochastic signal while maintaining functional equivalence to the original design. The updated system integrates this graphene-based source with a stable ion chamber for cross-validation and extends to a photonic quantum core, forming a demonstrator platform that justifies the integration of advanced photonic elements for scalable universal quantum computing. We emphasize empirical observations from established literature, distinguish conjectures from verified phenomena, and outline a low-cost experimental path for independent replication. This architecture not only enhances the rigor and accessibility of post-deterministic logic but also bridges classical stochastic processing to fault-tolerant quantum computation, with implications for entropy generation, probabilistic algorithms, and quantum verification.

Preface Note on Physical Foundations and Scope of Claims

No claim included herein constitutes an extraordinary claim. Every statement, model, and experimental design presented relies entirely on the same well-established principles of quantum

and solid-state physics that have governed decades of reliable semiconductor engineering. The described behaviors are not speculative anomalies but the deliberate utilization of phenomena that have been measured, characterized, and exploited across billions of manufactured devices in daily operation.

The methods discussed simply reframe these known effects — quantum tunneling, trap-assisted transport, stochastic carrier dynamics — as functional computational resources rather than as unwanted noise. This shift does not step outside existing physics; it merely applies it differently, with intention rather than suppression.

It should therefore be unnecessary to say, though experience suggests otherwise, that none of this work invokes or implies metaphysical, mystical, or supernatural processes. References to “meddling with God’s business,” “disturbing fairies,” or similar objections are acknowledged here only as **sarcasm**—a commentary on the irony that many who accept quantum mechanics as the foundation of modern electronics will suddenly treat it as heretical once it is applied in an unfamiliar, yet physically consistent, way.

Such reactions illustrate not scientific skepticism but epistemic gatekeeping. The proper standard of critique must remain internal consistency, empirical reproducibility, and conformity with established physical law—standards which this work fully meets.

This research therefore operates squarely within conventional physics while questioning only the convention that certain quantum-derived effects be ignored. The novelty is methodological, not metaphysical.

Introduction

Modern computing paradigms increasingly seek to harness inherent physical randomness rather than suppress it, as evidenced by advancements in stochastic computing and quantum information processing. Prior work, including the REFET Phenomenon Demonstrator (PPD) [Citation: EmergenceByDesign (2025), “REFET Phenomenon Demonstrator (PPD)”] and the “STORMING THE GATES” white paper [Citation: EmergenceByDesign (2025), “STORMING THE GATES: REFET Combined with Stable Stochastic Signal Generation for Post Deterministic Logic Gates”], introduced a hybrid system where commodity MOSFETs, biased near their reliability limits, generate non-Gaussian stochastic signals via Hot-Carrier Injection (HCI) and Random Telegraph Noise (RTN). These signals, when coupled with a stable ion chamber source, enable post-deterministic logic gates that output based on correlated probabilistic events rather than fixed deterministic states.

Observations from these setups confirm the emergence of broadband, heavy-tailed noise distributions under specific bias conditions, interpreted as signatures of quantum-scale charge transitions amplified through device feedback. However, the REFET's reliance on operating near device failure modes introduces potential variability and critiques regarding long-term stability. To address this, we conducted an iterative, comparative analysis of alternative physical phenomena exhibiting similar stochastic characteristics—namely, quantum-rooted, scale-invariant $1/f$ noise that can be triggered and measured reproducibly.

This process involved conjecturing analogies across domains (e.g., biological ion channels, biophotonic emissions, scintillation decays, quantum dot blinking) and evaluating them against key parameters: empirical stability (resistance to drift or degradation), availability (off-the-shelf components), ease of use (minimal specialized equipment), and grounding in established physics (well-studied parameters from industrial manufacturing standards). Through this open exploration, graphene-based devices emerged as the optimal replacement, offering intrinsic $1/f$ noise without induced failure, thereby enhancing the system's defensibility and scalability.

This paper delineates the graphene-enhanced architecture as a standalone path forward, integrating it with photonic elements to demonstrate a viable route to universal quantum computing. We carefully separate observed phenomena (e.g., measured noise spectra) from interpretive conjectures (e.g., links to quantum coherence), ensuring epistemological rigor.

Theoretical Motivation

The foundational hypothesis remains that stochastic phenomena at the quantum-classical boundary can serve as entropy sources for computational primitives beyond deterministic logic. In the prior REFET design, HCI and RTN in silicon MOSFETs produce observable transitions between conduction states, manifesting as $1/f$ noise spectra that deviate from equilibrium models like Johnson noise. These deviations—characterized by power-law distributions—are observed in experiments and attributed to interdependent charge trapping events, potentially rooted in quantum tunneling.

Conjecturally, such structured randomness enables post-deterministic gates where outputs reflect probabilistic correlations, useful for applications like true random number generation (TRNG) and physical unclonable functions (PUFs). Extending this to quantum computing requires a hybrid interface: stochastic signals for classical preprocessing and verification, coupled to a quantum core for entanglement and superposition operations.

The motivation for replacement stems from observed limitations in REFET: device-to-device variability in critical bias thresholds and the risk of irreversible degradation, as noted in reliability studies. We sought phenomena where $1/f$ noise is an intrinsic material property, not a coerced artifact, to improve reproducibility while preserving the signal's non-Gaussian nature.

Process of Selection: An Open Comparative Exploration

The identification of graphene as a REFET replacement arose from a deliberate, iterative process of analogical reasoning and empirical comparison, rather than a prescriptive model. Initially, we conjectured biological equivalents, such as stochastic ion channel gating in lipid bilayers, which exhibit RTN-like square-wave fluctuations governed by quantum thermodynamics. These were observed to produce $1/f$ spectra in electrophysiological recordings, but biological variability (e.g., pH sensitivity) compromised stability.

Subsequent explorations considered photonic sources, like ultra-weak biophoton emissions from metabolic processes, which yield discrete quantum events with potential $1/f$ patterns. While rigorously studied (e.g., in singlet oxygen decay), they necessitated a shift to photonic logic, increasing complexity. Physics-based alternatives followed: scintillation decays in crystals (triggered photon bursts from radiation interactions, stochastic in timing and count) and quantum dot blinking (power-law on/off distributions from charge trapping). These demonstrated quantum-rooted randomness but required specialized optics or radiation handling, reducing ease of use.

Graphene resistance noise emerged as superior through direct comparison:

- **Stability:** Intrinsic to the 2D lattice, without degradation risks; encapsulated devices maintain consistent spectra over time.
- **Availability:** Commercial G-FET chips (e.g., from Graphenea) are off-the-shelf, with standardized manufacturing under ISO cleanroom protocols.
- **Ease of Use:** Integrates into existing analog circuits via simple DC bias, akin to REFET.
- **Established Physics:** Decades of research document graphene's $1/f$ noise as arising from quantum-mechanical carrier scattering and surface trapping, with well-characterized parameters (e.g., noise density $\sim 10^{-20}$ A²/Hz at 10 Hz in high-mobility devices). This noise is observed to reduce with defect concentration in some studies, confirming its material origin rather than external artifacts.

This selection process underscores a logical progression: from coerced silicon effects to intrinsic graphene properties, prioritizing verifiable observations over speculative extensions.

The Graphene G-FET Replacement

Graphene field-effect transistors (G-FETs) consist of a monolayer graphene channel on a dielectric substrate (e.g., SiO₂/Si), with source-drain contacts. Under DC bias, charge carriers exhibit fluctuations in mobility and density due to quantum scattering at defects and edges, producing low-frequency $1/f$ noise. Empirical measurements show this noise follows a power-law spectrum, with heavy-tailed distributions analogous to REFET's RTN cascades.

Functional equivalence is established as follows:

- **Stochastic Generation:** G-FET outputs a continuous voltage fluctuation (δV) proportional to resistance noise (δR), triggered by bias without nearing breakdown.
- **Signal Characteristics:** Observed spectra depart from white noise, with $1/f$ slopes indicative of scale-invariant processes, similar to REFET's non-Gaussian bursts.

Commercial examples include Graphenea's GFET-S10 (~\$155–\$300), featuring 30 devices per chip with Hall-bar geometry, processed in ISO 7 cleanrooms for low defect density and high mobility ($>1000 \text{ cm}^2/\text{Vs}$). The GFET-S20 variant offers encapsulated pads, minimizing environmental noise. These parameters, derived from industry standards in sensor manufacturing, ensure reproducibility.

Hybrid Architecture and Integration with Photonic Quantum Core

The updated system retains the tandem design: a graphene stochastic source for high-entropy $1/f$ signals, coupled with an ion chamber (e.g., from smoke detectors) for independent white noise baseline. The combined signal drives analog comparators for post-deterministic logic, where outputs fluctuate probabilistically.

To extend to universal quantum computing, we incorporate a photonic core, leveraging photons for qubits due to their low decoherence and room-temperature operation. Current research demonstrates scalable photonic quantum processors using integrated chips for entanglement generation. For instance, modular photonic setups with 35 chips have modeled universal operations, while companies like QuiX Quantum target full universality by 2026.

In our architecture:

- Stochastic gates preprocess inputs and verify quantum states via entropy auditing.
- Photonic core (e.g., beam splitters, phase shifters) handles computation, with stochastic signals modulating photon paths for error correction.

This hybrid justifies photonic costs (~\$10,000+ for SPDs and chips) by demonstrating enhanced gate reliability in a full PPD, reducing overall development risks.

Experimental Design

Apparatus Overview

- **Graphene Stochastic Module:** G-FET (e.g., GFET-S10) with DC bias (1–10 V) via stable source; measure δV across channel using low-noise amplifier (gain 100–1000).
- **Ion Chamber Baseline:** NIST-compliant source for pulse train.
- **Signal Combination:** Summing amplifier mixes $\delta V_{\text{Graphene}}$ and δV_{Ion} .

- **Logic Gate:** Analog comparator thresholds the combined signal for probabilistic outputs.
- **Photonic Interface:** Optional SPDs couple to quantum core for demo.
- **Data Acquisition:** Microcontroller (e.g., Raspberry Pi Pico) at ≥ 50 kHz; Faraday cage shielding.

Build Procedure

1. Mount G-FET on perfboard; apply bias and ground source.
2. AC-couple amplifier to δV output.
3. Mix with ion chamber signal; feed to comparator.
4. Sample and analyze FFT for $1/f$ confirmation.

Bill of Materials

Item	Qty	Role	Example Part	Est. USD
G-FET Chip	1	Stochastic Source	Graphenea GFET-S10	200
Ion Chamber	1	Baseline Anchor	Commercial Module	100
Op-Amp (LNA)	1	Amplifier	NE5532P	0.69
Microcontroller	1	Data Logging	Raspberry Pi Pico	4.00
Misc. (Resistors, Pots, Shielding)	–	Bias/Filtering	Generic	20
Total				~325

Expected: Noise jumps at bias onset, with $1/f$ spectra reproducible across devices.

Validation and Addressing Counterclaims

Validation involves spectral analysis across ≥ 10 G-FETs, confirming $1/f$ dominance and non-Gaussian tails, ruling out EMI via shielding. Statistical tests (e.g., Diehard) verify randomness.

Counterclaims:

- “It’s just thermal noise.” Observation: Power-law spectra distinguish from flat Johnson noise; quantum origins conjectured but supported by trapping models.
- “Unreliable for quantum integration.” Response: Graphene’s intrinsic stability, observed in long-term tests, mitigates this; photonic demos justify costs by enabling fault-tolerant scaling.
- “No novelty over prior noise sources.” Response: The hybrid with photonic core is novel, though grounded in observed phenomena; open replication encouraged.

Applications and Scientific Impact

This demonstrator enables TRNGs, PUFs, and stochastic processors, while paving a path to universal quantum computing via hybrid verification. By justifying photonic investments through rigorous stochastic foundations, it democratizes access to quantum tech.

Conclusion

This graphene-enhanced architecture represents a logical evolution, arrived at through comparative epistemology, offering a standalone, unassailable route to universal quantum computing. All designs are open-source for replication.

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