REFET Phenomenon Demonstrator (PPD)

Revision 1.1

Coaxed Quantum Effects in Classical Silicon
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Abstract

This white paper introduces the **REFET (Reliability-Failure Effect Transistor) Phenomenon Demonstrator (PPD)**: a compact, low-cost laboratory platform designed to reveal and characterize coherent, non-Gaussian stochastic phenomena that emerge spontaneously in standard MOSFETs biased near their reliability limit.

The demonstration shows that, under precise sub-breakdown bias conditions, minute structural noise within the silicon lattice and oxide interface can induce self-organized electronic behavior that mimics—or in some interpretations, crosses into—quantum-coherent dynamics.

The PPD provides reproducible, measurable evidence that stochastic, nonlinear, and quantum-rooted coherence can arise in ordinary, mass-produced semiconductors without cryogenic or exotic preparation. This has direct implications for entropy generation, physical random number generation, unclonable signatures, stochastic analog processing, and post-classical probabilistic computation.

The project is open-source by design: all circuitry, code, and analysis procedures are released for immediate replication by independent labs.

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1. Introduction

Modern electronics treat *noise* as a nuisance—an artifact to be minimized, filtered, or averaged away. Yet noise arises from physical interactions that are fundamentally quantum-mechanical: shot noise, 1/f fluctuations, tunneling currents, and hot-carrier scattering. In classical digital design, extensive error correction hides these fluctuations, enforcing determinism by suppressing spontaneous micro-events that encode high-dimensional physical information.

The REFET project begins with the inversion of this assumption. Instead of eliminating noise, it amplifies and stabilizes it—creating a device where stochastic interactions become *the signal*.

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2. Theoretical Motivation

The guiding hypothesis is that the boundary between "classical thermal noise" and "quantum stochastic resonance" is not abrupt but continuous. In a MOSFET, this continuum can be accessed by operating just below the threshold where **Hot-Carrier Injection (HCI)** and **Random Telegraph Noise (RTN)** begin to dominate transistor aging behavior.

At these limits, charge carriers occasionally gain sufficient energy to cross local potential barriers, becoming trapped in the oxide. These events alter the electrostatic environment, modifying the current through a feedback loop that can produce bursts of aperiodic, broadband noise.

Key insight: the device's internal feedback network forms a microscopic chaotic oscillator driven by quantum-scale noise sources. Properly biased, this oscillator exhibits signatures of spontaneous coherence—structured oscillations emerging from apparent randomness—suggesting a bridge between quantum statistics and classical dynamics.

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3. The REFET-PPD Concept

The PPD circuit isolates and excites this regime using minimal hardware:

- One N-channel power MOSFET (e.g., IRF540ZPBF)
- A controlled bias network allowing VGS and VDS to be tuned independently
- A high-impedance amplifier to detect drain current fluctuations
- A microcontroller-based data acquisition system

Under correct bias (VDS ≈ 8–10 V, VGS ≈ 0.5·VDS), the MOSFET enters a metastable state where stochastic fluctuations in oxide charge produce spontaneous, reversible transitions between multiple conduction states.

Spectral analysis reveals broadband, heavy-tailed distributions inconsistent with Johnson noise. Reproducible spectral plateaus and pseudo-periodic bursts suggest underlying coherence modulated by microscopic state coupling.

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4. Relation to Standard Noise Models

Traditional semiconductor noise models—Johnson, shot, flicker (1/f), avalanche—assume stationary, linear behavior around equilibrium. The REFET effect occurs beyond that domain: at the boundary where aging and instability mechanisms couple dynamically.

From a modeling standpoint, this behavior can be treated as a **dynamic renormalization** of local trap states, akin to self-organized criticality. Each fluctuation perturbs the local potential, momentarily lowering the barrier for neighboring traps, producing cascades.

Physically, this regime represents **feedback-sustained stochastic amplification** of quantum-scale charge transitions.

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5. Experimental Design

Apparatus Overview

- Drain bias: 12 V DC through 1 MΩ resistor
- Gate bias: adjustable (PWM or DAC output, fine-tuned via 10 kΩ potentiometer)
- Source grounded
- LNA (op-amp) AC-coupled to drain via large capacitor
- Microcontroller (e.g., Raspberry Pi Pico) for bias control and ADC sampling

Build Procedure

Stage 1 – Bias setup

1. Connect drain → 12 V rail through 1 MΩ resistor
2. Source → ground
3. Gate → PWM output via 10 kΩ trim pot
4. Sweep VGS until ID = 10 pA at VDS = 5 V → define VTH
5. Lock VGS; gradually raise VDS toward 10 V

Stage 2 – Noise coupling and amplification
6. Place 1000 µF capacitor between drain node and LNA input
7. Configure NE5532P op-amp, gain = 100–1000
8. Power LNA from isolated 9 V battery
9. Enclose MOSFET + amp in grounded foil box

Stage 3 – Data capture
10. LNA output → Pico ADC
11. Sample ≥ 50 kHz, stream 12-bit data to PC
12. Plot variance and FFT in real time

Expected result: Noise power remains low until VDS ≈ 8–10 V, then jumps 10×–100×, becoming broadband and non-Gaussian. Lowering VDS quenches the effect instantly.

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6. Bill of Materials

Item	Qty	Role	Example Part	Est. USD
MOSFET (REFET core)	1	Instability engine	IRF540ZPBF	0.77
Microcontroller/ADC	1	Bias + data logging	Raspberry Pi Pico	4.00
Op-Amp (LNA)	1	AC-coupled amplifier	NE5532P	0.69
Coupling Capacitor	1	Blocks DC bias	1000 µF, 16 V	0.50
Drain Resistor	1	Converts ID → V	1 MΩ	0.05
Bias Potentiometer	1	VGS fine-tune	10 kΩ trim pot	2.05
Breadboard/Perfboard	1	Assembly platform	Generic	5.00
12 V DC supply	1	VDS stress	Wall adapter	10.00
Misc. passives, foil	–	Filtering & shielding	–	3.00

Total Estimated Cost: $28–$45

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7. Analysis and Validation

- Repeat across ≥10 MOSFETs: critical voltage varies slightly but effect recurs
- Noise only appears inside Faraday cage at critical bias → rules out EMI
- Breakdown voltage >> operating voltage → not avalanche noise
- Spectrum departs from 1/f → signature of nonlinear HCI cascade

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8. Related Work and Novelty Positioning

The REFET PPD concept—deliberately biasing commodity MOSFETs near their reliability limits to elicit reproducible, non-Gaussian stochastic signals—shares physical mechanisms with prior work on RTN and metastability-based TRNGs. However, it was independently conceived from observing MOSFET error correction behavior and recognizing the discarded error states as quantum-rooted stochastic signatures.

Key distinctions:

- Prior works focus on digital integration, cryptographic post-processing, or nanoscale simulation
- PPD emphasizes analog coherence, open-source reproducibility, and low-cost empirical demonstration
- No known prior art packages HCI/RTN behavior into a single-device, coherence-focused demonstrator with educational and defensive publication intent

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9. Applications

- **True Random Number Generator (TRNG):** High-entropy, high-throughput source
- **Physical Unclonable Function (PUF):** Each device has unique VDScrit signature
- **Stochastic Analog Processor:** Arrays provide native entropy for probabilistic computation
- **Low-Power Analog Memory:** Exploit non-volatile trapped-charge shifts
- **Ultra-Sensitive Sensors:** Hypercritical bias amplifies single-event responses

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10. Expected Scientific Outcome

- Establish controlled, reversible HCI chaos in standard MOSFETs
- Provide time-series and spectral data demonstrating transition from deterministic conduction to broadband stochastic oscillation
- Supply open scripts and hardware details for replication and pre-registration
- Support theoretical linkage to Lambda-Irreducibility and TUFT/SEAL models as a verified physical substrate

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11. Addressing Skeptical Counterclaims

- **"It's just thermal noise."**
  Response: Spectral plateaus, heavy-tailed distributions, and reproducible bias-dependent transitions distinguish REFET signals from Johnson noise. The presence of Hot-Carrier Injection (HCI) tunneling confirms quantum roots, even if the

output is classically amplified.

- **“RTN TRNGs already exist.”**
  Response: True, but the REFET PPD is not a derivative of those designs. It was independently conceived from observing MOSFET error correction behavior and recognizing the discarded error states as quantum-rooted stochastic signatures. The novelty lies in its open-source, coherence-focused, low-cost demonstrator — not in cryptographic integration.

- **“It’s unreliable or destructive.”**
  Response: The calibration protocol defines a safe operating zone — the Edge of Phenomena (P_E) — between the Threshold of Tidy (T_T) and the Burnout Threshold (B_T). Empirical 24-hour tests confirm stability and repeatability across devices. The system is designed to operate within a controlled instability zone, not at the point of failure.

- **“There’s no killer app.”**
  Response: The REFET PPD enables multiple applications: TRNGs, PUFs, analog memory, and stochastic sensors. Its coherence metrics open new directions in probabilistic computing and physical entropy harvesting. The demonstrator is not a commercial product — it’s a platform for exploring overlooked utility in quantum-rooted noise.

Authorship and License

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