IDEC Chip Design Contest

Oscillatory Transistor Devices and Circuit Design for Versatile Applications

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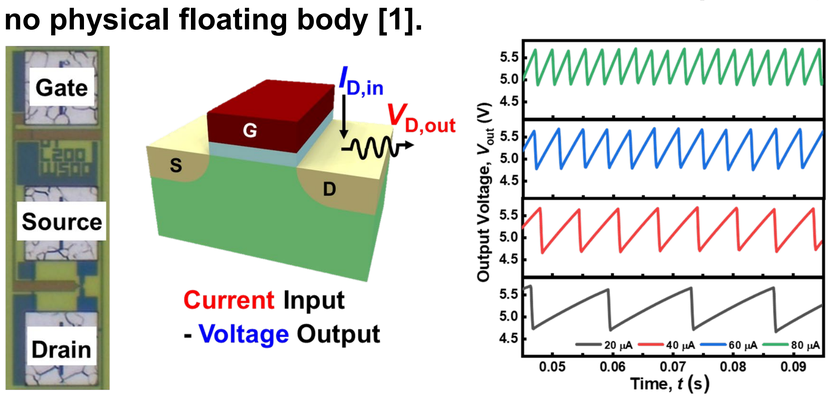
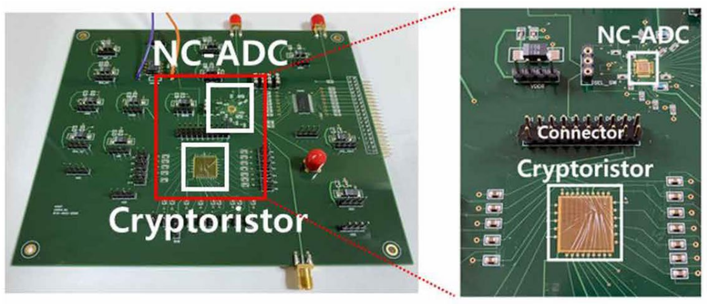
Introduction

- Recently, single transistor latch (STL) was occurred at a MOSFET on a bulk-Si wafer, which was fabricated with TSMC 180 nm process, although there is no physical floating body [1].

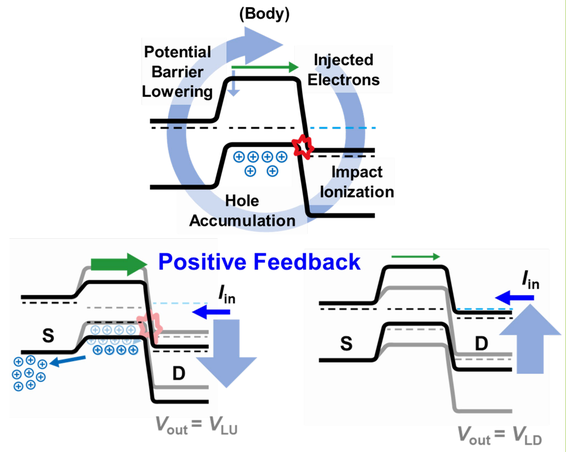




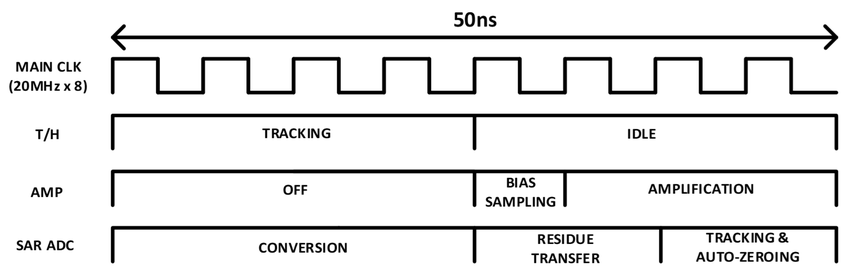
- This MOSFET is applicable to an artificial neuron, a single transistor based oscillator, and a true random number generator.

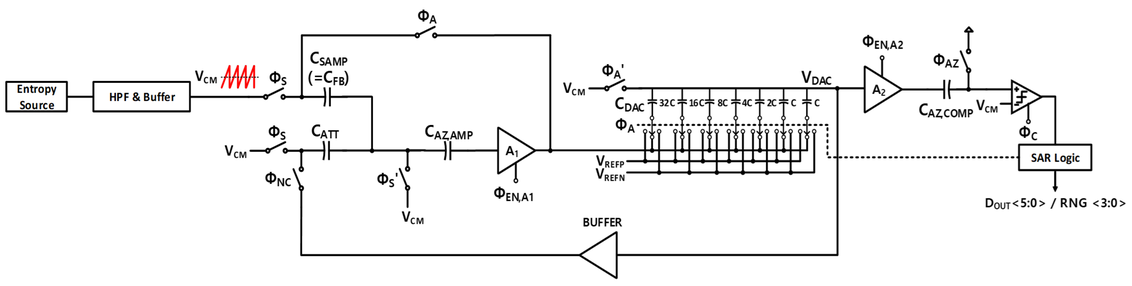
Underlying Mechanism

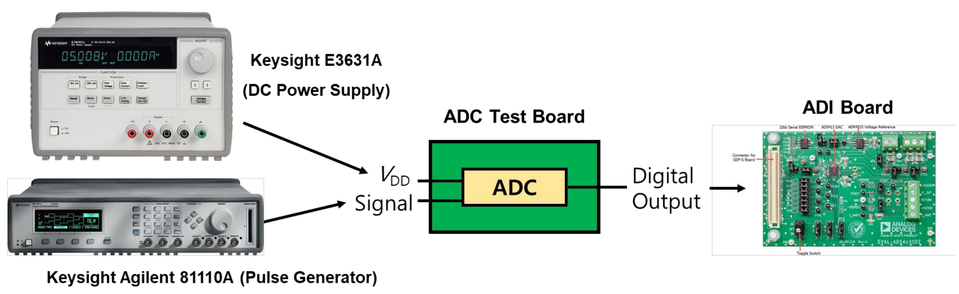
- The charging and discharging process makes a positive feedback loop and continues repeating the oscillations as long as input current (I_{in}) is supplied.
- Energy band along the 'n⁺ source (S) - p-type channel - n⁺ drain (D)' is periodically deformed and flattened for the gradual charging and abrupt discharging, respectively.



Chip Designs, Fabrication and Measurements

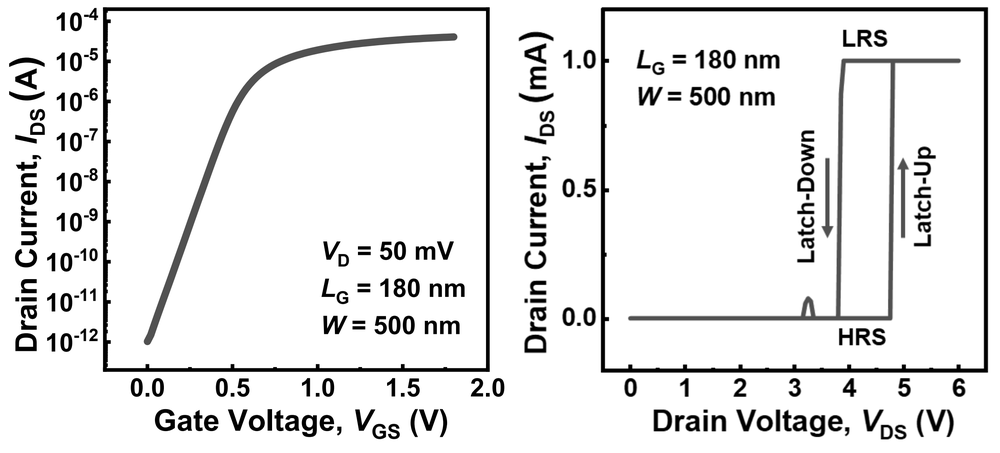






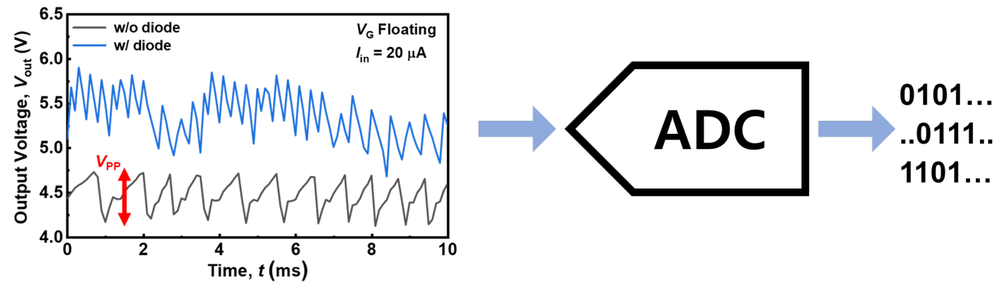
- Random Number Generator Outputs Characterization with a ADI Board.

Transfer Characteristics and Single Transistor Latch



- The I_{DS}-V_{GS} characteristics with a single MOSFET without the ADC, a hysteresis associated with STL is evident in the I_{DS}-V_{DS} characteristics.

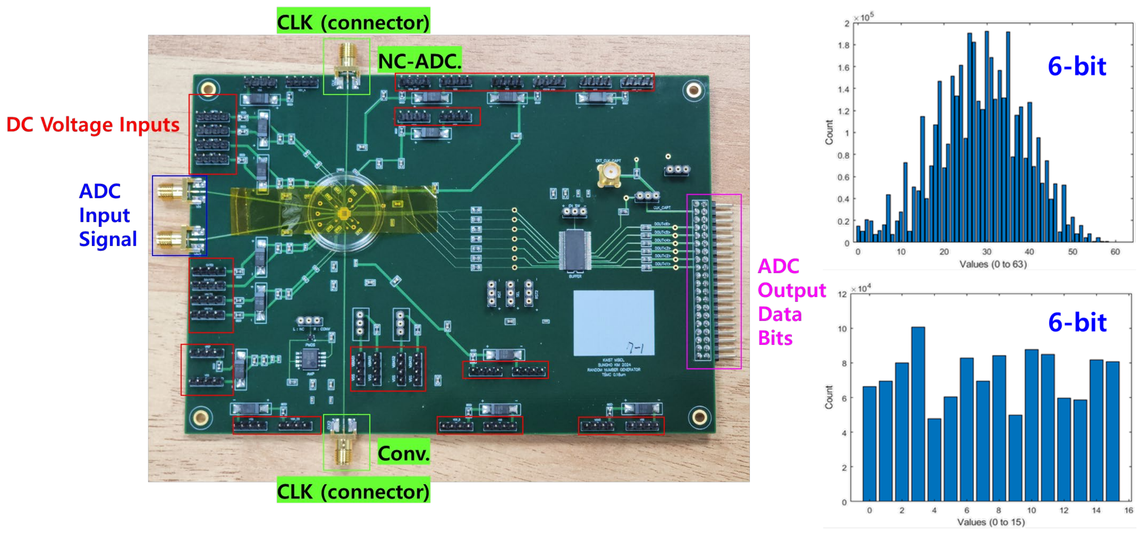
True Random Number Generator



- This irregular oscillation acts as a true random number generator.
- When I_{in} is applied to the drain, the drain output voltage is oscillated.

Printed Circuit Board (PCB)

- The NC-ADC circuit was realized on a PCB, integrating the necessary components for functional testing and evaluation.



- The results of testing the NC-ADC input using a function generator prior to verifying the integrated operation with the 1T-O_{bulk} is shown.

Conclusions

- Single-transistor latch (STL) and its oscillation characteristics were achieved from a bulk-Si MOSFET fabricated.
- This MOSFET, which showed irregular oscillations utilized as an entropy source, is applied for a true random number generator to secure a chip.
- This proposal is expected to address the mass production and compatibility limitations of existing TRNGs and neuromorphic hardware, enhancing their practicality for widespread adoption.

Reference

[1] H.-Y. Kim, S.-I. Kim, J.-K. Han, J.-W. Jung and Y.-K. Choi. "A Single MOSFET-Based Oscillator on a Bulk-Silicon Wafer", *IEEE Electron Device Letters*, vol. 45, no. 1, pp. 8-11, Jan. 2024.
[2] S.-I. Kim, H.-J. You, M.-S. Kim, U.-S. An, M.-S. Kim, D.-H. Lee, S.-T. Ryu, Y.-K. Choi, "Cryptographic transistor for true random number generator with low power consumption," *Sci. Adv.*, vol. 10, no. 8, pp. 1–10, Feb. 2024.

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