Technology trends in Physically Unclonable Functions from the PUFdb (*http://www.green-ic.org/pufdb* - National University of Singapore)

Massimo Alioto, Anastacia Alvarez

The PUFdb database collects thorough and up-to-date information on publicly available Physically Unclonable Functions (PUFs) and related performance figures. We hope this will be useful to our community, help keep track of the continuous advances in PUFs and acknowledge the fine work of our colleagues who push the boundaries in the field.

Feel free to visit our GREEN IC group website (http://www.green-ic.org) to know more about us, our vision and what we do in the area of integrated circuit design.

PUFdb spreadsheet

For use in publications and presentations please cite this data collection as follows:

M. Alioto, A. Alvarez, "Physically Unclonable Function database," [Online]. Available: *http://www.green-ic.org/pufdb*.

For authors of new PUFs and papers with experimental validation

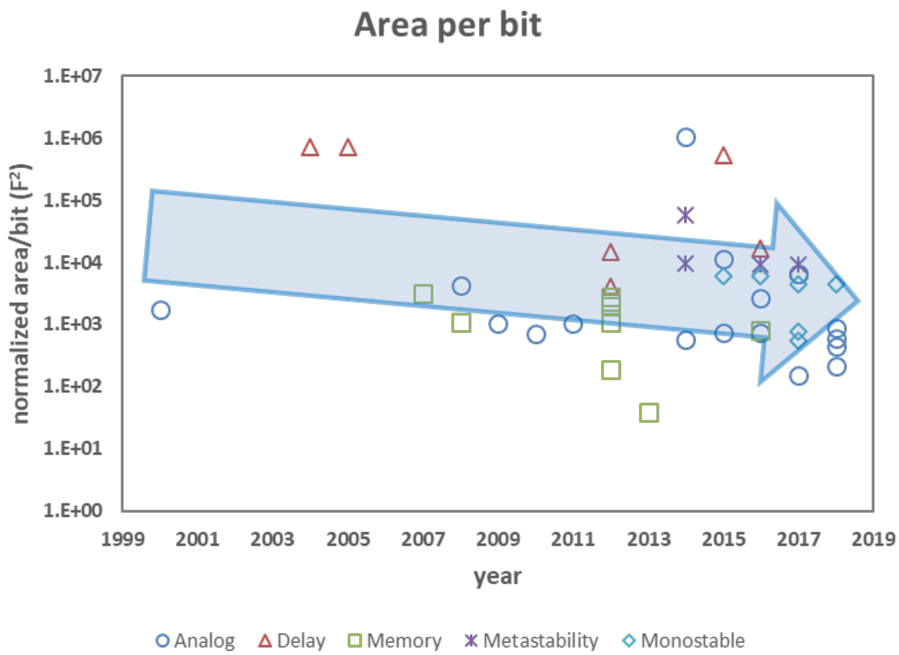
Authors of new PUFs who wish their PUF to be included in the future revisions of this database can send an email to Prof. Alioto (malioto@ieee.org) and attach the following pieces of information:

- reference of the publication presenting the PUF
- PUF performance and numerical data based on the figures of merit used in the above spreadsheet.

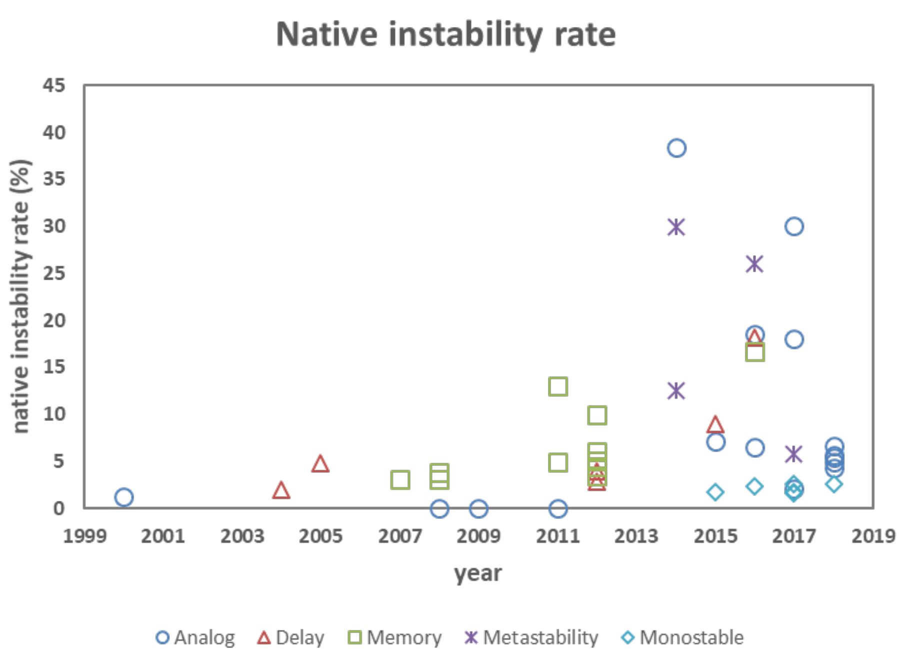
Any comment/suggestion on how to improve this page and the spreadsheet is welcome.

Technology trends in PUFs

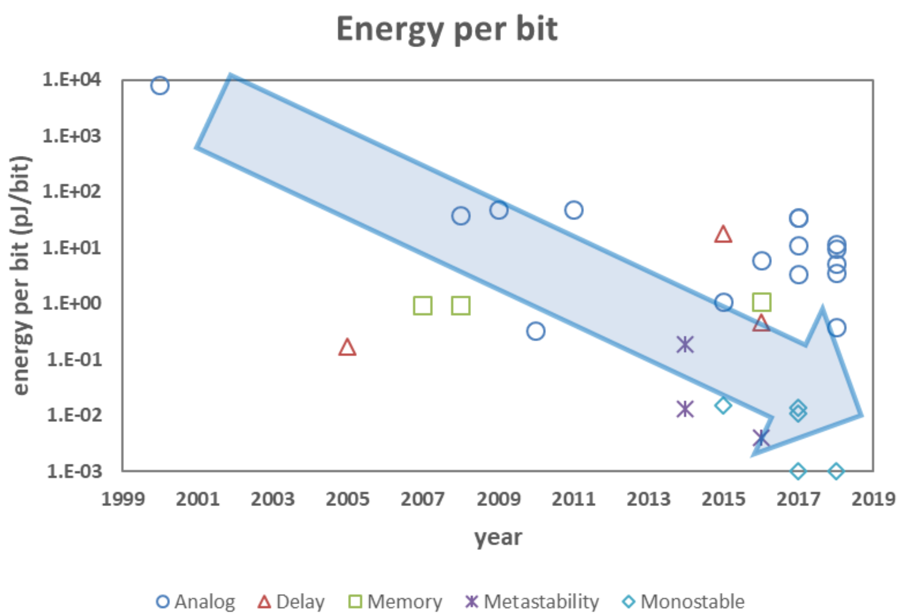
From the PUFdb data collection, trends in ASIC implementation of PUFs are identified and described in terms of density (area per bit), native instability rate, and energy efficiency (energy per bit). The related figures and comments below are also reported in the PUFdb spreadsheet, to facilitate their usage in other publications (see above for how to cite the data collection).



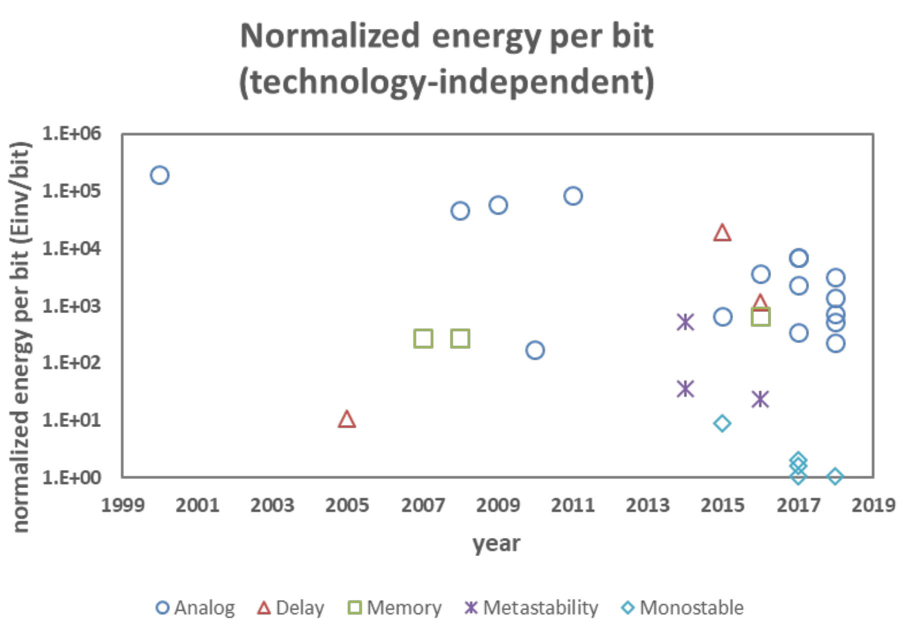
The area per bit is highest for delay-based PUFs (the area is normalized to F^2, being F the minimum feature size of the process). In general, the area efficiency of PUF bitcells has improved over time, especially due to the adoption of more digital approaches that offer better density than analog ones (especially for more recent technologies). Analog PUF bitcells have an opposite trend, as their area tends to increase over time, when area is normalized to the square of the minimum feature size of the technology. This is mostly because of their analog nature, which does not really enable shrinking with finer technologies.



Metastability-based PUFs have the worst native instability rate, while the monostable PUFs exhibit the best native instability rate. The high native instability rate in metastability-based PUFs is reduced through post-processing and other stability enhancement techniques, at the cost of increased energy, area and/or testing time. For the other PUFs, the native instability rate has slightly increased over the years.



Energy per bit is improving, thanks to the adoption of more energy-aware PUFs. Delay-based PUFs are an exception, as they tend to have larger energy per bit over the years, due to the need for a larger number of ring oscillators or oscillations to maintain acceptable stability.



Same trend is shown in the normalized energy per bit, showing that the circuit improvements in terms of energy definitely dominate the benefits of mere technology scaling (energy is normalized to the energy consumed by a minimum-sized inverter gate).