

## A Ring Oscillator Based Physical Unclonable Function with Enhanced Challenge Response Pairs to Improve the Security of Internet of Things Devices

Marco Grossi, Martin Omaña, Cecilia Metra, Andrea Acquaviva

Department of Electrical Energy and Information Engineering, University of Bologna, Bologna, Italy

### INTRODUCTION & AIM

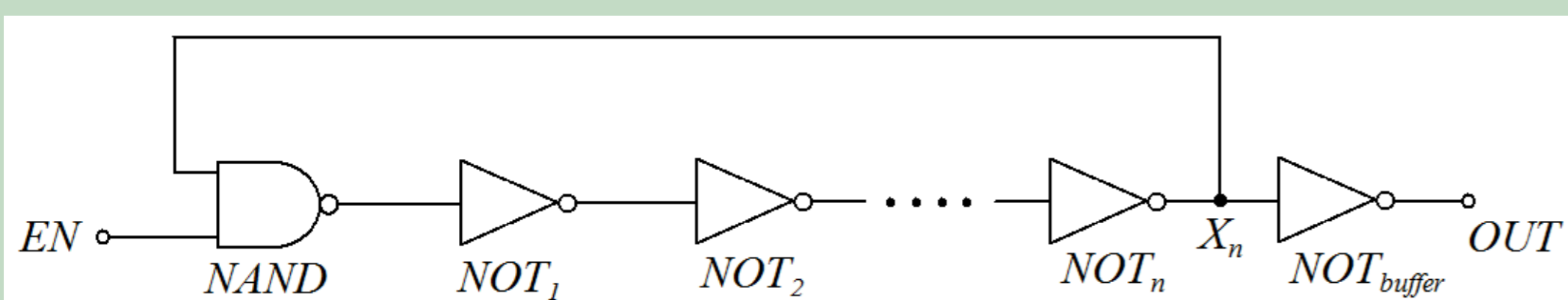
Internet of Things (IoT) devices have attracted much attention in the recent years. The interconnection of devices has led to a sharp increase in information sharing but also in the frequency of cyber-attacks.

Physical unclonable functions (PUFs) exploit inherent randomness introduced during the production to create an unclonable, unique fingerprint. Among the different PUF structures, ring oscillator (RO) based PUFs are very popular, since they feature a simple structure and can be easily implemented on FPGAs.

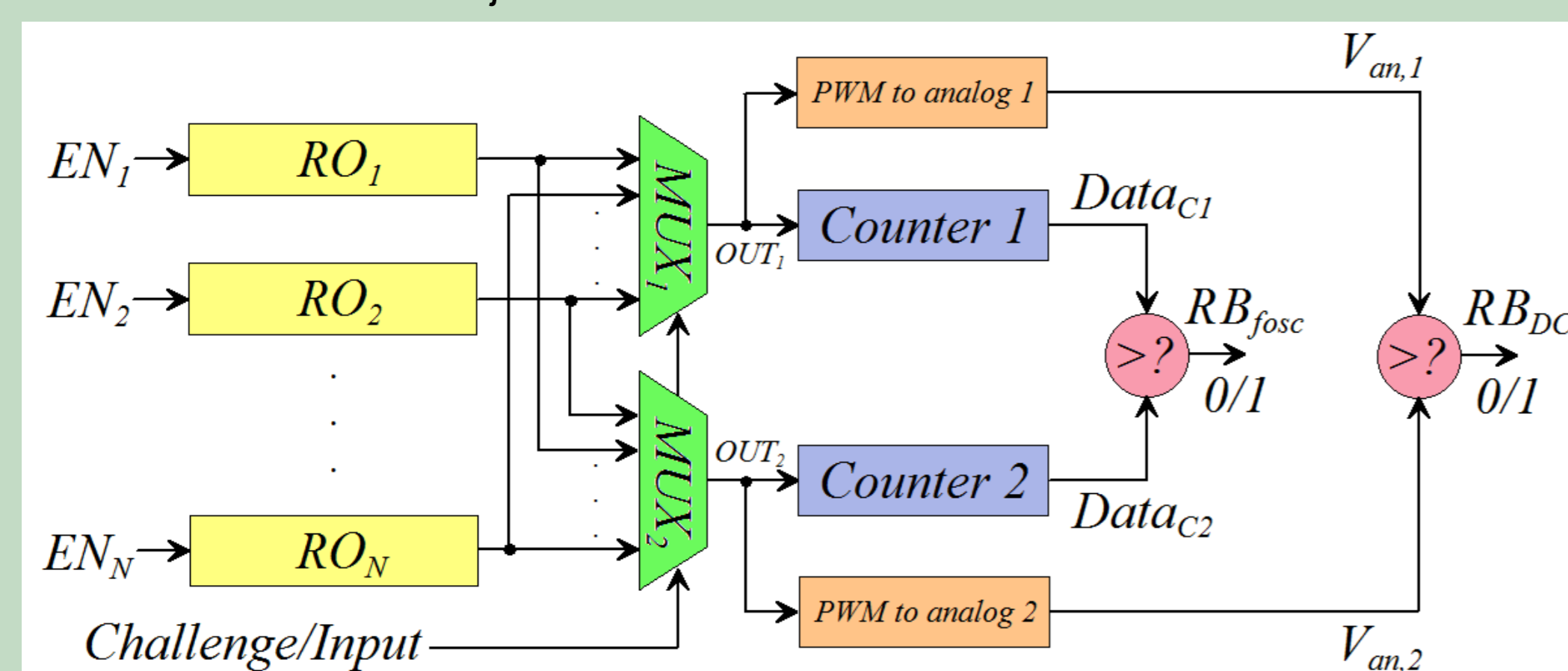
The aim of this work is to investigate the feasibility to increase the number of challenge-response pairs (CRPs) of a RO PUF by the measurement of two different parameters: the oscillation frequency and duty-cycle.

### METHOD

The structure of a RO circuit implemented in CMOS technology consists of an odd number of inverting stages and an output buffer.

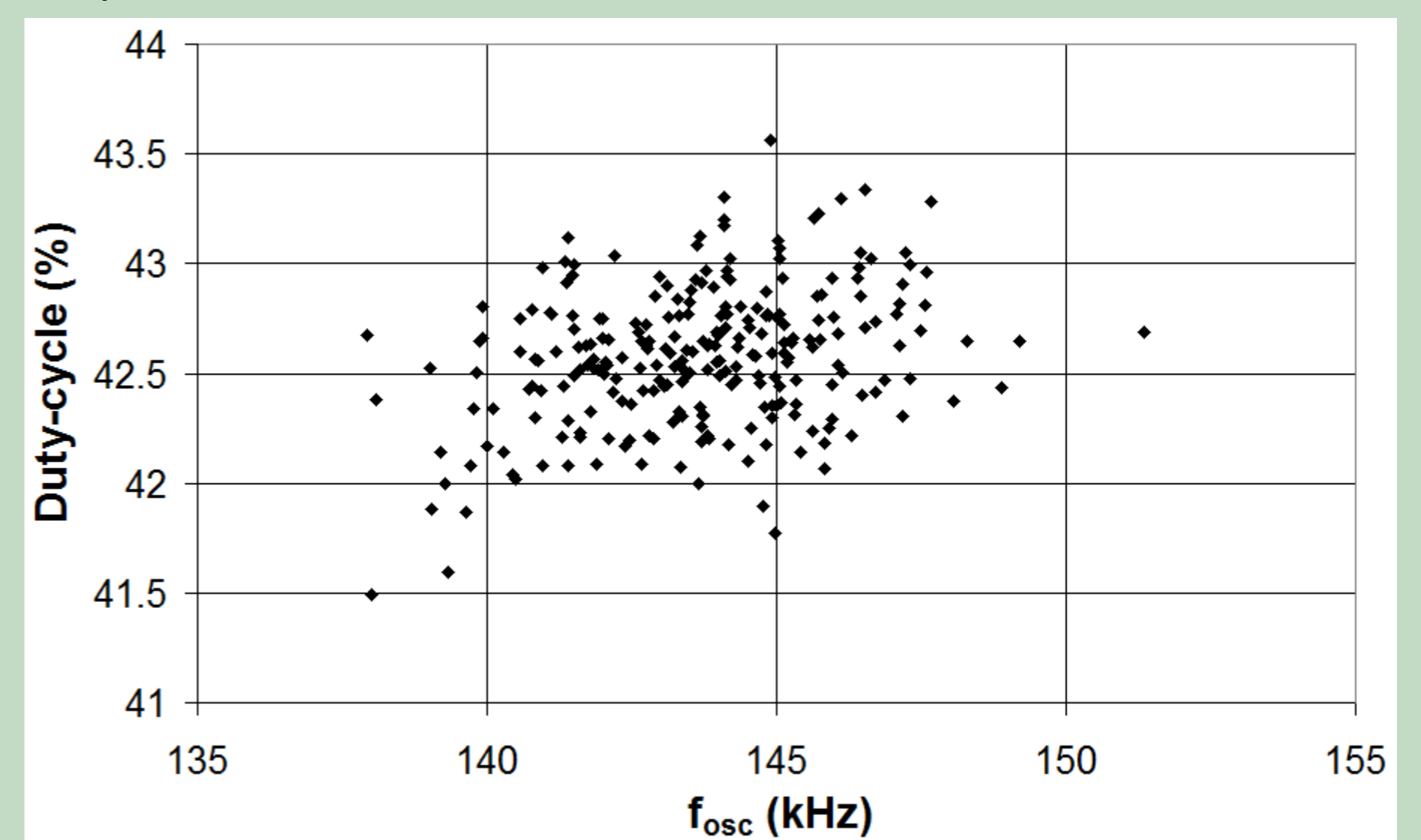


The proposed RO PUF consists of  $N$  different copies of the RO circuit ( $RO_1, RO_2, \dots, RO_N$ ). The input challenge selects  $n$  different couples of RO circuits. For each couple of RO circuits ( $RO_i$  and  $RO_j$ ) the response bit (RB) is set as 1 if the monitored parameter, either oscillation frequency ( $f_{osc}$ ) or duty-cycle (DC), for  $RO_i$  is higher than the monitored parameter of  $RO_j$ , or 0 otherwise.

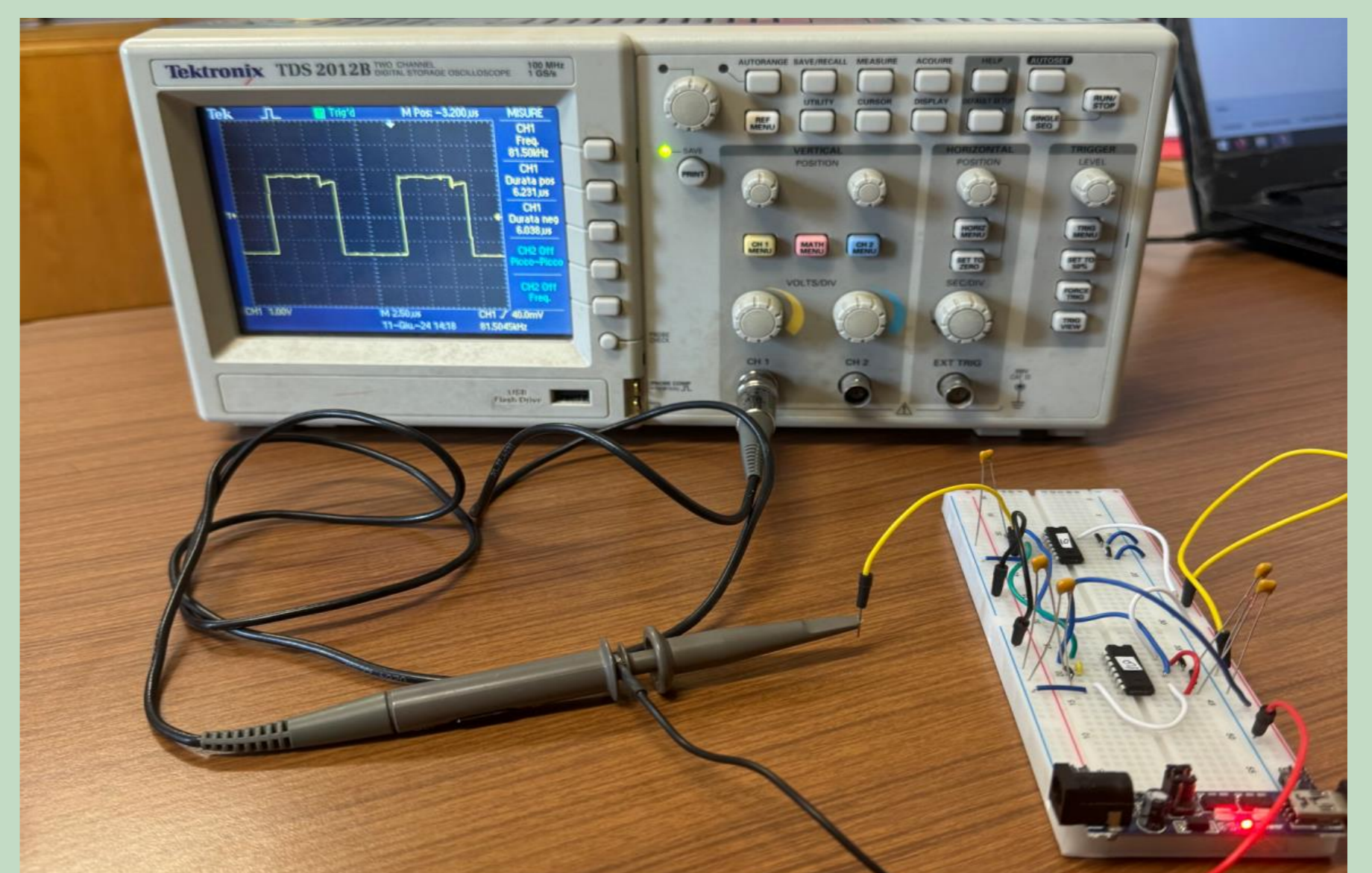


### RESULTS & DISCUSSION

Monte Carlo simulations were carried out using LTSpice for a 180nm CMOS technology, 10% tolerance on the transistor parameters, and RO circuits with five inverting stages. The RO PUF was simulated with 256 RO circuits. The results have shown that the correlation between  $f_{osc}$  and the duty-cycle is low ( $R^2 = 0.098$ ).



Experimental measurements were carried out to validate the simulation results. A RO PUF was built with 45 RO circuits using the SN74HC00N chip. The experimental results confirmed the low correlation between  $f_{osc}$  and the duty-cycle ( $R^2 = 0.112$ ).



### CONCLUSION

The results of circuitual simulations and experimental measurements confirmed that the oscillation frequency and duty-cycle of a RO circuit feature a weak correlation and can be used to increase the number of CRPs in a RO PUF, thus improving its security.