PHYSICALLY UNCLONABLE FUNCTIONS (PUFs) and CAMPUFs: Utilizing CMOS Technology for Hardware-Based Security

Group 08

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1 Introduction

In this era where digital security is very important, hardware-based security is on the rise because provide very complex and reliable solutions. Physically Unclonable Functions (PUFs) have emerged as a promising approach to address the challenges of hardware authentication, secure key generation, and anti-counterfeiting measures. Among the various PUF implementations, Complementary Metal-Oxide-Semiconductor Arbiter PUFs (CAMPUFs) stand out as a powerful hardware security primitive based on CMOS technology.

CAMPUFs leverage the unique physical variations inherent in CMOS integrated circuits to generate unpredictable and practically unclonable responses. The foundation of CMOS technology, with its low power consumption and high integration capabilities, makes it an ideal platform for building complex digital circuits and implementing PUFs.

This documentation will present and underly principles of PUFs, explain the workings of CAMPUFs.

2 General characteristics

Physically unclonable functions (PUFs) are a technique in hardware security that exploits inherent device variations to produce an unclonable, unique device response to a given input.

2.1 Purposes

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Key Generation: PUFs can generate cryptographic keys directly from the unique physical responses of the ICs. These keys can be used for secure communication, encryption, and data protection.

Challenge-Response Mechanism: PUFs operate on a challenge-response mechanism, where a unique challenge is provided to the device, and the corresponding response is generated based on the unique physical characteristics of that particular IC.

Randomness and Entropy Generation: PUFs can serve as a high-quality source of randomness and entropy, critical for cryptographic protocols and secure communication.

Authentication: PUF responses can be used for secure device authentication, verifying the identity and integrity of hardware components in various applications, such as secure booting and secure firmware updates.

Uniqueness and Unpredictability: PUFs generate device-specific responses based on the inherent physical variations during manufacturing. As a result, each instance of the IC exhibits a unique response, making it practically impossible to clone or replicate the device.

Anti-Counterfeiting Measures: PUFs play a crucial role in preventing counterfeiting and unauthorized duplication of hardware components, as the uniqueness of the responses ensures the authenticity of genuine devices.

2.2 Security Properties and Applications of PUFs

Key Security Properties of PUFs

Unpredictability: The inherent randomness linked to PUF responses, even when given the same challenge multiple times. This property makes stonger the security of PUF-based authentication and key generation.

Uniqueness and Unclonability: PUFs depend on the uniqueness of their physical microstructure. This microstructure depends on random physical factors introduced during manufacturing that gives unique reponses. These factors are unpredictable and uncontrollable, which makes it virtually impossible to duplicate or clone the structure.

Resistance to Physical Attacks: PUFs are resilient against various physical attacks, including invasive attacks like reverse engineering and probing, as well as non-invasive attacks like side-channel analysis.

Practical Applications of PUFs

Secure Key Generation: PUF responses can be utilized to generate cryptographic keys without the need for additional storage of secret keys, enhancing the security of cryptographic protocols.

Hardware Authentication: PUFs can be employed for secure device authentication, ensuring the legitimacy of hardware components and protecting against unauthorized access.

Anti-Counterfeiting Measures: PUFs serve as a powerful tool for detecting counterfeit devices, as the unique responses enable the verification of genuine products.

Secure Communication: PUF-based keys are valuable for securing communication channels, enabling secure and authenticated data transmission.

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1.2.1 Intrinsic PUFs Characteristics of Intrinsic PUFs

Intrinsic PUFs are characterized by their reliance on the inherent physical variations present within a single chip during the semiconductor manufacturing process. These variations arise due to manufacturing imperfections, process fluctuations, and random dopant fluctuations. The unique characteristics of each individual chip create a fingerprint-like response, making Intrinsic PUFs ideal for hardware authentication and identification purposes.

Common Implementations of Intrinsic PUFs

Delay PUFs: Delay PUFs exploit the differences in signal propagation delay along various paths within the circuit. By measuring these delays, a set of unique challenge-response pairs can be generated, forming the basis for secure authentication.

Ring Oscillator PUFs: Ring oscillator PUFs use the frequency differences in ring oscillators, circuits comprising an odd number of inverters. The varying delays in these oscillators result in distinctive response patterns, enabling the generation of cryptographic keys and unique device identifiers.

Butterfly PUFs: Butterfly PUFs combine two Ring Oscillator PUFs to enhance the quality and randomness of the responses. By introducing a feedback mechanism, they offer improved robustness against environmental variations.

1.2.2 Extrinsic PUFs Concept of Extrinsic PUFs

Extrinsic PUFs differ from Intrinsic PUFs as they derive their responses from external environmental factors that influence the behavior of the chip. These external factors may include temperature variations, light levels, power supply fluctuations, and electromagnetic interference. The responses generated by Extrinsic PUFs can change under different operating conditions, leading to additional sources of randomness.

Examples of Extrinsic PUFs

Ambient Light PUFs: Ambient light PUFs utilize the incident light level on the chip's surface to create distinct response patterns. Variations in light intensity cause corresponding variations in the generated responses, enabling unique identification.

Temperature PUFs: Temperature PUFs exploit temperature-induced changes in the electrical characteristics of the chip. Different temperature levels result in varied responses, contributing to the unclonable behavior of the device.