Physical Unclonable Functions In Theory And Practice

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in physical unclonable functions in theory and practice the authors present an in depth overview of various topics concerning pufs providing theoretical background and application details this book concentrates on the practical issues of puf hardware design focusing on dedicated microelectronic puf circuits additionally the authors discuss the whole process of circuit design layout and chip verification the book also offers coverage of different published approaches focusing on dedicated microelectronic puf circuits specification of puf circuits general design issues minimizing error rate from the circuit s perspective transistor modeling issues of montecarlo mismatch simulation and solutions examples of puf circuits including an accurate description of the circuits and testing measurement results different error rate reducing pre selection techniques this monograph gives insight into pufs in general and provides knowledge in the field of puf circuit design and implementation it could be of interest for all circuit designers confronted with puf design and also for professionals and students being introduced to the topic

physically unclonable functions pufs are innovative physical security primitives that produce

unclonable and inherent instance specific measurements of physical objects in many ways they are the inanimate equivalent of biometrics for human beings since they are able to securely generate and store secrets they allow us to bootstrap the physical implementation of an information security system in this book the author discusses pufs in all their facets the multitude of their physical constructions the algorithmic and physical properties which describe them and the techniques required to deploy them in security applications the author first presents an extensive overview and classification of puf constructions with a focus on so called intrinsic pufs he identifies subclasses implementation properties and design techniques used to amplify submicroscopic physical distinctions into observable digital response vectors he lists the useful qualities attributed to pufs and captures them in descriptive definitions identifying the truly puf defining properties in the process and he also presents the details of a formal framework for deploying pufs and similar physical primitives in cryptographic reductions the author then describes a silicon test platform carrying different intrinsic puf structures which was used to objectively compare their reliability uniqueness and unpredictability based on experimental data in the final chapters the author explains techniques for puf based entity identification entity authentication and secure key generation he proposes practical schemes that implement these techniques and derives and calculates measures for assessing different puf constructions in these applications based on the quality of their response statistics finally he presents a fully functional prototype implementation of a puf based cryptographic key generator demonstrating the full benefit of using pufs and the efficiency of the processing techniques described this is a suitable introduction and reference for security researchers and engineers and graduate students in information security and cryptography

this book discusses the design principles of physically unclonable functions pufs and how these can be employed in hardware based security applications in particular the book provides readers with a comprehensive overview of security threats and existing countermeasures this book has many features that make it a unique source for students engineers and educators including more than 80 problems and worked exercises in addition to approximately 200 references which give extensive direction for further reading

this book features high quality peer reviewed papers from the fourth international conference on recent advancements in computer communication and computational sciences racccs 2021 held at aryabhatta college of engineering and research center ajmer india on august 20 21 2021 presenting the latest developments and technical solutions in computational sciences it covers a variety of topics such as intelligent hardware and software design advanced communications intelligent computing technologies advanced software engineering the web and informatics and intelligent image processing as such it helps those in the computer industry and academia to use the advances in next generation communication and computational technology to shape real world applications

this book is about security in embedded systems and it provides an authoritative reference to all aspects of security in system on chip soc designs the authors discuss issues ranging from security requirements in soc designs definition of architectures and design choices to enforce and validate security policies and trade offs and conflicts involving security functionality and debug requirements coverage also includes case studies from the trenches of current industrial practice in design implementation and validation of security critical embedded systems provides an authoritative reference and summary of the current state of the art in security for embedded systems hardware ips and soc designs takes a cross cutting view of security that interacts with different design and validation components such as architecture implementation verification and debug each enforcing unique trade offs includes high level overview detailed analysis on implementation and relevant case studies on design verification debug issues related to ip soc security

today embedded systems are used in many security critical applications from access control electronic tickets sensors and smart devices e g wearables to automotive applications and critical

infrastructures these systems are increasingly used to produce and process both security critical and privacy sensitive data which bear many security and privacy risks establishing trust in the underlying devices and making them resistant to software and hardware attacks is a fundamental requirement in many applications and a challenging yet unsolved task solutions solely based on software can never ensure their own integrity and trustworthiness while resource constraints and economic factors often prevent the integration of sophisticated security hardware and cryptographic co processors in this context physically unclonable functions pufs are an emerging and promising technology to establish trust in embedded systems with minimal hardware requirements this book explores the design of trusted embedded systems based on pufs specifically it focuses on the integration of pufs into secure and efficient cryptographic protocols that are suitable for a variety of embedded systems it exemplarily discusses how pufs can be integrated into lightweight device authentication and attestation schemes which are popular and highly relevant applications of pufs in practice for the integration of pufs into secure cryptographic systems it is essential to have a clear view of their properties this book gives an overview of different approaches to evaluate the properties of puf implementations and presents the results of a large scale security analysis of different puf types implemented in application specific integrated circuits asics to analyze the security of puf based schemes as is common in modern cryptography it is necessary to have a security framework for pufs and puf based systems in this book we give a flavor of the formal modeling of pufs that is in its beginning and that is still undergoing further refinement in current research the objective of this book is to provide a comprehensive overview of the current state of secure puf based cryptographic system design and the related challenges and limitations table of contents preface introduction basics of physically unclonable functions attacks on pufs and puf based systems advanced puf concepts puf implementations and evaluation puf based cryptographic protocols security model for puf based systems conclusion terms and abbreviations bibliography authors biographies

this book investigates the susceptibility of intrinsic physically unclonable function puf implementations on reconfigurable hardware to optical semi invasive attacks from the chip backside it explores different classes of optical attacks particularly photonic emission analysis laser fault injection and optical contactless probing by applying these techniques the book demonstrates that the secrets generated by a puf can be predicted manipulated or directly probed without affecting the behavior of the puf it subsequently discusses the cost and feasibility of launching such attacks against the very latest hardware technologies in a real scenario the author discusses why pufs are not tamper evident in their current configuration and therefore pufs alone cannot raise the security level of key storage the author then reviews the potential and already implemented countermeasures which can remedy pufs security related shortcomings and make them resistant to optical side channel and optical fault attacks lastly by making selected modifications to the functionality of an existing puf architecture the book presents a prototype tamper evident sensor for detecting optical contactless probing attempts

this book addresses the issue of machine learning ml attacks on integrated circuits through physical unclonable functions pufs it provides the mathematical proofs of the vulnerability of various puf families including arbiter xor arbiter ring oscillator and bistable ring pufs to ml attacks to achieve this goal it develops a generic framework for the assessment of these pufs based on two main approaches first with regard to the inherent physical characteristics it establishes fit for purpose mathematical representations of the pufs mentioned above which adequately reflect the physical behavior of these primitives to this end notions and formalizations that are already familiar to the ml theory world are reintroduced in order to give a better understanding of why how and to what extent ml attacks against pufs can be feasible in practice second the book explores polynomial time ml algorithms which can learn the pufs under the appropriate representation more importantly in contrast to previous ml approaches the framework presented here ensures not only the accuracy of the model mimicking the behavior of the puf but also the delivery of such a model besides off the shelf ml algorithms the book applies a set of algorithms hailing from the field of property testing

which can help to evaluate the security of pufs they serve as a toolbox from which puf designers and manufacturers can choose the indicators most relevant for their requirements last but not least on the basis of learning theory concepts the book explicitly states that the puf families cannot be considered as an ultimate solution to the problem of insecure ics as such it provides essential insights into both academic research on and the design and manufacturing of pufs

with the ever increasing demand for security in embedded systems and wireless sensor networks we require integrating security primitives for authentication in these devices one such primitive is known as a physically unclonable function this entity can be used to provide security at a low cost as the key or digital signature can be generated by dedicating a small part of the silicon die to these primitives which produces a fingerprint unique to each device this fingerprint produced by a puf is called its response the response of pufs depends upon the process variation that occurs during the manufacturing process in embedded systems and especially wireless sensor networks there is a need to secure the data the collected from the sensors to tackle this problem we propose the use of sram based pufs to detect the temperature of the system this is done by taking the puf response to generate temperature based keys the key would act as proofs of the temperature of the system in sram pufs it is experimentally determined that at varying temperatures there is a shift in the response of the cells from zero to one and vice versa this variation can be exploited to generate random but repeatable keys at different temperatures to evaluate our approach we first analyze the key metrics of a puf namely reliability and uniqueness in order to test the idea of using the puf as a temperature based key generator we collect data from a total of ten sram chips at fixed temperatures steps we first calculate the reliability which is related to bit error rate an important parameter with respect to error correction at various temperatures to verify the stability of the responses we then identify the temperature of the system by using a temperature sensor and then encode the key offset by puf response at that temperature using bch codes this key temperature pair can then be used to establish secure communication between the nodes thus this scheme helps in establishing secure keys as the generation has an extra variable to produce confusion we developed a novel puf for xilinx fpgas and evaluated its quality metrics it is very compact and has high uniqueness and reliability we also implement 2 different puf configurations to allow per device selection of best pufs to reduce the area and power required for key generation we also evaluate the temperature response of this puf and show improvement in the response by using per device selection

physically unclonable functions pufs translate unavoidable variations in certain parameters of materials waves or devices into random and unique signals they have found many applications in the internet of things iot authentication systems fpga industry several other areas in communications and related technologies and many commercial products statistical trend analysis of physically unclonable functions first presents a review on cryptographic hardware and hardware assisted cryptography the review highlights puf as a mega trend in research on cryptographic hardware design afterwards the authors present a combined survey and research work on pufs using a systematic approach as part of the survey aspect a state of the art analysis is presented as well as a taxonomy on pufs a life cycle and an established ecosystem for the technology in another part of the survey the evolutionary history of pufs is examined and strategies for further research in this area are suggested in the research side this book presents a novel approach for trend analysis that can be applied to any technology or research area in this method a text mining tool is used which extracts 1020 keywords from the titles of the sample papers then a classifying tool classifies the keywords into 295 meaningful research topics the popularity of each topic is then numerically measured and analyzed over the course of time through a statistical analysis on the number of research papers related to the topic as well as the number of their citations the authors identify the most popular topics in four different domains over the history of pufs during the recent years in top conferences and in top journals the results are used to present an evolution study as well as a trend analysis and develop a roadmap for future research in this area this method gives an automatic popularity based statistical trend analysis which eliminates the need for passing personal judgments

about the direction of trends and provides concrete evidence to the future direction of research on pufs another advantage of this method is the possibility of studying a whole lot of existing research works more than 700 in this book this book will appeal to researchers in text mining cryptography hardware security and iot

physical unclonable functions pufs make use of the measurable intrinsic randomness of physical systems to establish signatures for those systems thus pufs provide a means to generate unique keys that don t need to be stored in nonvolatile memory and they offer exciting opportunities for new authentication and supply chain security technologies

duty cycle and frequency are important characteristics of periodic signals that are exploited to develop a variety of application circuits in ic design controlling the duty cycle and frequency provides a method to develop adaptable circuits for a variety of applications these applications range from stable on chip clock generation circuits on chip voltage regulation circuits and physical unclonable functions for hardware security applications ring oscillator circuits that are developed with cmos inverter circuits provide a simple versatile flexible method to generated periodic signals on an ic chip a digitally controlled ring oscillator circuit can be adapted to control its duty cycle and frequency this work describes a novel current starved ring oscillator with digitally controlled current source based headers and footers that is used to provide a versatile duty cycle and a precise frequency control using this novel circuit the duty cycle and frequency can be adapted to a wide range of values the proposed circuit achieves i a controlled duty cycle that can vary between 20 and 90 with a high granularity and ii a compensation circuit that guarantees a constant duty cycle under process voltage and temperature pvt variations a novel application of the proposed pwm circuit is the design and demonstration of a reliable and reconfigurable duty cycle based physical unclonable function puf the proposed pwm based puf circuit is demonstrated to work in a reliable and stable operation for a variety of process voltage and temperature conditions with circuit implementations using 22nm and 32nm cmos technologies a comparative presentation of the duty cycle based puf are provided using standard puf figures of merits

i present an algorithm for repeatably generating keys using entropy from a physical unclonable function puf pufs are logically identical devices with challenge response pairs unique to each device puf errors inhibit key repeatability my algorithm corrects puf errors enabling repeatable cryptographic key generation

physically unclonable functions pufs are now widely being used to uniquely identify integrated circuits ics in this work we propose a novel set reset sr flip flop based puf design for a nand gate based sr flip flop the input condition s set 1 and r reset 1 must be avoided as it is an inconsistent condition when s r 1 is applied followed by s r 0 then the outputs q and q undergo race condition and depending on the delays of the nand gates in the feedback path the output q can settle at either 0 or 1 because of process variations in an ic the nand delays are statistical in nature thus for a given sr ff based n bit register implemented in an ic when we apply s r 1 to all flip flops followed by s r 0 then we obtain an n bit string that can be interpreted as a signature of the chip due to process variations the signature is highly likely to be unique for an ic we validated the proposed idea by spice level simulations for 90nm 45nm and 32nm designs for both intra and inter chip variations to establish the robustness of the proposed puf experimental results for 16 32 64 and 128 bit registers based on monte carlo simulations demonstrate that the proposed puf is robust the main advantage of the proposed puf is that there is very little area overhead as we can reuse existing registers in the design

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