CNRS - Grenoble INP - UGA

CDSI team

Circuits, Devices and System Integration

Circuits, Devices and System Integration (CDSI team)

Keywords: Asynchronous circuits, design methods and tools, design for ultra-low power, FDSOI technology, MEMS, Smart sensors and actuators

The CDSI team

The team activity covers a broad spectrum of activities from MEMS to systems. Indeed, the team postulates high performances are achieved thanks to disruptive technologies, which are at the frontiers of different fields of applications. Nevertheless, the team is built on two key pillars, sensing and event processing.

Event-based techniques are key for enhancing integrated circuits and systems because they offer a unique opportunity to rethink circuit design, which does not take well into account most of the non-functional specifications, such as power, security, safety or electromagnetic emissions. This paves the way to ultra-low power systems, enhanced secured systems, proven design methods but also near sensor computing.

Sensing is the second key. Taking advantage of smart sensors and actuators requires globally envisioning systems, favors a smart sensing approach limiting useless information and pushes new experiments and usage.

Event-based technologies

Event-based approach

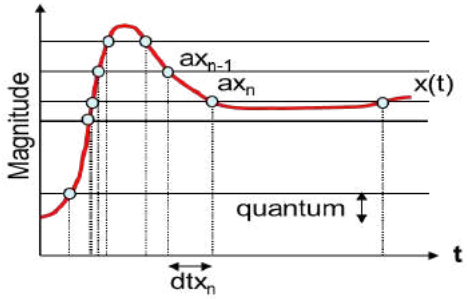

Figure 1: Level Crossing Sampling Scheme

Event-based is a quite simple idea, which suggests operating a circuit only when needed. Nevertheless, this is countercurrent when looking the semiconductor industry. Indeed, everything is clocked synchronized, analog-to-digital conversion is clock-sampled. In practice, clock is used as an event generator giving the pace of the circuits generating a large number of events and producing useless activity, computation, storage or communication. The event-based approach tends generating sparse events related to natural events such as a pressure variation or a heartbeat. Therefore, the team works on alternative analog-to-digital converters able to drastically reduce the number of samples and, hence, limit useless activity and energy consumption.

Asynchronous Circuits

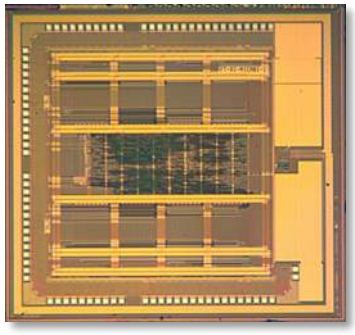

Figure 2: Asynchronous microcontroller with on-chip NFC antenna

Since more than 20 years, the team works on new synchronization paradigms, which are not based on a clock but on handshake signals. Such techniques reveal many opportunities for rethinking the circuit design process and opening new degrees of freedom. The first expected advantage is probably the reusability of existing blocks that can simply be connected together, making the assembly of a system a kind of LEGO build. Indeed, the timing assumptions are locally fulfilled guarantying an easy block association. Moreover, many other advantages are of interest such a lower power consumption, a better robustness, lower electromagnetic emissions, safer and more secured circuits…

Targeting Ultra-low power

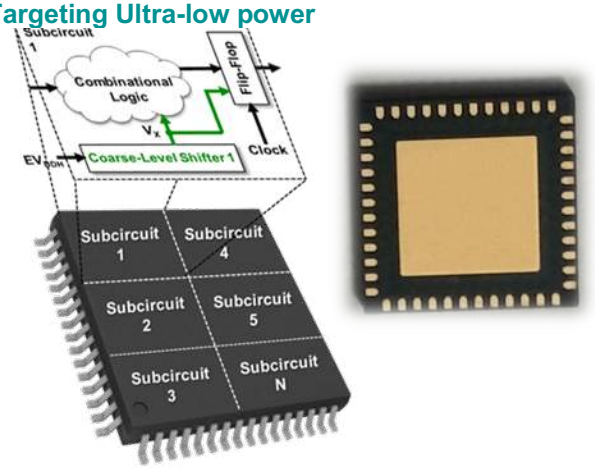

Figure 3: FDSOI 28 nm asynchronous testchip managing several local fine-grain body-bias domains

Today power is a main concern for chip design. The event-based strategy is probably the best technique for reducing power at least by one order of magnitude. Indeed, a sparse sampling scheme produces much less data, which are non-uniformly spaced in time. Each datum is no more than an event that can be sporadically processed by asynchronous circuits. Indeed, these latter are data-driven and consume energy only when computing. Moreover, the intrinsic robustness of asynchronous circuits favors their use at low-voltage, near- or subthreshold. Indeed, lowering the voltage is an efficient and well-known strategy to save power. Its main drawback is the decrease of the circuit speed. The Fully Depleted Silicon on Insulator (FDSOI) technology allows mitigating this speed drop thanks to forward body biasing.

As asynchronous circuits use communication protocols indicating circuit activity, the handshake signals are perfectly suited for controlling local body-bias domains ensuring low-energy expenses for body biasing and compensating the speed loss. All these mechanisms can be implemented for mitigating the energy and helping the adoption of energy harvesting in batteryless systems.

Security

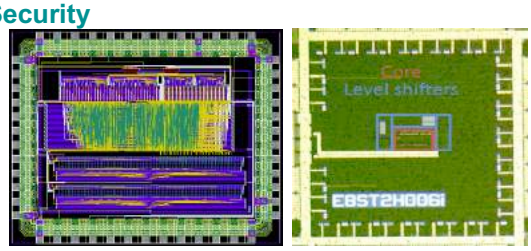

Figure 4: TRNG with entropy monitoring (left) and Ultra-low power TRNG (right) (30 pJ/bit@0.3 V)

Another opportunity offered by the asynchronous circuits is its ability to make more difficult the side-channel analysis and attacks in trusted devices. Indeed, the absence of clock synchronization, the specific encoding and the computation time control makes them of interest for developing trusted platforms. They also offer disruptive strategies for true random number generators (TRNG) and physically unclonable functions (PUF) while consuming a few energy.

Design flow and proven technology

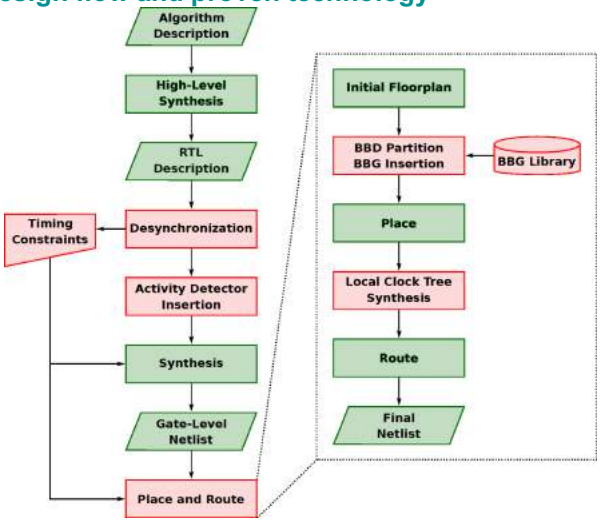

Figure 5: Asynchronous circuit HLS to layout design flow

Developing non-conventionally synchronized circuits is not obvious because of the lack of dedicated CAD tools. Although the first good idea is to implement such tools, there is some overcoming hurdles. The first one is clearly the quasi-absence of trained people with the know-how for designing efficient and performant asynchronous circuits. The second is the impact, the reliability and the engineer confidence into a new design flow. Therefore, for more than 10 years, the team is developing dedicated flows based on the standard commercial tools with a particular emphasis on a proven by construction synthesis.

Near-sensor computing

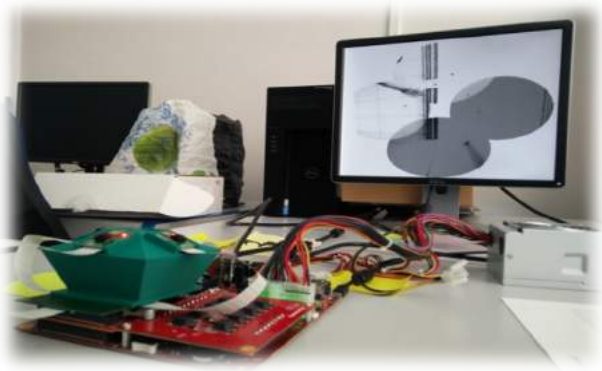

Figure 6: Panoptic camera for laparoscopy

With the dissemination of autonomous and connected objects, it appeared the need to limit the amount of transmitted raw data, especially in RF communications where the problem is more acute. Therefore, developing tiny sensor platforms able to preprocessed data before transmitting information is becoming a challenging topic. Indeed, enhancing the sensing techniques and immediately processing the raw data with a reduced energy budget is the grail in near-sensor computing. The team developed several strategies based on event-based techniques or improving the adequacy between the algorithms and the circuit architecture. This is typically the case for many image-processing applications such as panoptic camera for laparoscopy.

Smart-sensing technologies

In-sensor computing

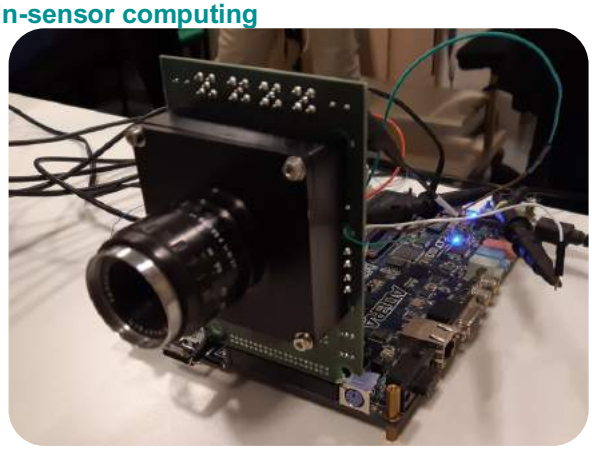

Figure 7: Event-based camera

As previously stated, smart sensing is a key for envisioning systems with advanced features such as detection, pattern recognition or low-power. Beyond the state of art of sensor technology, the enhancement can be obtained thanks to new architectures or in-sensor computing. One of the approach concerns image sensors, which usually permanently read the image. This is a waste of energy and time for acquiring an image. In order to reduce these issues, the image capture can be performed thanks to an event-based readout, which only samples a pixel when this latter fires. In this case, the firing pixel indicates that its value has to be changed in the image memory. Such a strategy is applied for reducing the power consumption and increasing the speed sensor thanks to a dedicated readout canceling the spatial and temporal redundancies.

Measuring time

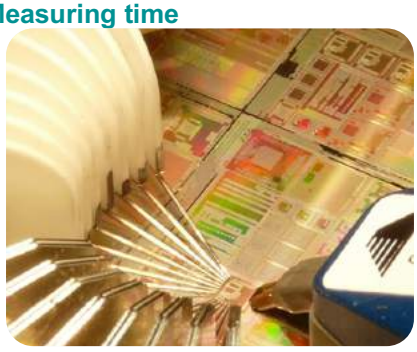

Figure 8: Asynchronous multiphase oscillator (under test) used in TDC

Using an event-based sensing implies a duality with the standard Nyquist analog-to-digital conversion because the quantization is no more applied to the amplitude but to the time elapsed between two successive events. Therefore, designing advanced Time-to-Digital Converters (TDC) is an important block for many sensors or even for some security primitives such as TRNG or PUF.

Harvesting for ultra-low power systems

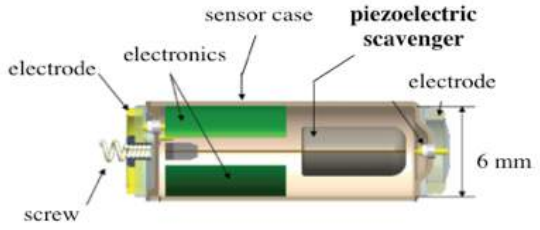

Figure 9: Piezoelectric scavenger for automous pacemaker (Vibration: 10 - 25 Hz, Size: L = 30 mm, Ø= 6 mm, energy: 5 - 10 µJ)

With the advent of the Internet of Things, the system requirements in term of power are extremely demanding, especially for smart sensing and actuating. A typical highlight targets the medical implant such as pacemakers. Indeed, they need today a battery, which lasts less than 10 years. Then the pacemaker has to be explanted because this is not a rechargeable battery. In order to overcome this issue, a strategy is to harvest the heart mechanic power thanks to a piezoelectric harvester. The MEMS are particularly well-suited for extracting energy from different sources (thermal, mechanical, electrical…) for small autonomous and smart objects.

Security (chaotic approach)

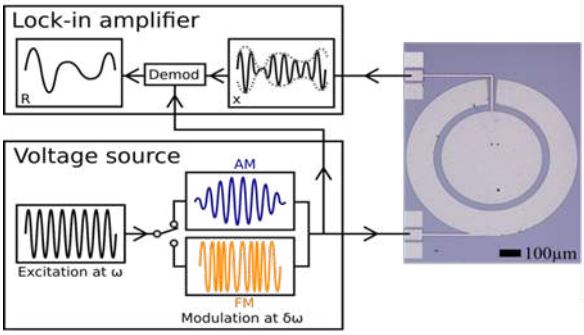

Figure 10: Experimental Setup and modulations in the Duffing's regime. The MEMS (photography) is driven by a voltage modulated voltage source (AM or FM). The Lock-in-Amplifier extracts the displacement magnitude of the MEMS to observe the chaos.

MEMS have opened the doors to intense researches covering most of the technology fields. It is not surprising that they can be of interest for security. They offer original solutions for designing chaotic generators using the dynamical bistability of a Duffing's microresonator. This approach is particularly relevant for generating true random numbers because MEMS already exist on various systems such as mobile phones and are useable for extracting chaos. Moreover, this could be employed for securing communications thanks to a couple of twin chaotic MEMS, using various transduction schemes such as electrical, acoustic or optical signals.

New Sensors and actuators

Figure 11: Haptic screen, the modulation of stationary waves gives different feeling when touching the surface

The team is also developing original micro-acoustic systems (Piezo Micromachined Ultrasonic Transducers) used as microphones, non-contact gesture recognitions, proximity sensors, fingerprint sensors or aeroacoustic measurements.

Piezo-MEMS devices have been developed in order to give a haptic rendering by friction modulation. They are key components for the future haptic touch screen, which will be used in many applications (automotive, smartphones, …).

Highlights of 2020 and of the recent years

- Asynchronous circuit High Level Synthesis for fine-grain body-biasing in FDSOI (tetschips in 65 nm and 28 nm from STMicroelectronics)
- New event-based image sensor cancelling spatial and temporal redundancies in FDSOI 28 nm from STMicroelectronics
- Physically Unclonable Function based on self-timed ring and TDC (testchip in 65 nm from STMicroelectronics)
- First DFT technique for asynchronous bundled-data circuits based on commercial tools
- Static Timing Analysis of asynchronous bundled-Data Circuits
- Local clock set methodology for implementing asynchronous circuits with commercial tools
- Event-based demodulation for NFC applications
- EM shaping with bundled-data circuits
- First demonstration of MEMS-based TRNG achieving NIST requirements
- Generation and reception of chaotic ultrasonic waves

Academic and research members

Skandar BASROUR

Position
Professor at UGA – POLYTECH school

Responsibilities
Deputy Director of TIMA Lab. since 01/2015
Co-leader of CDSI team
Researcher in CDSI team

Agnès BONVILAIN

Position
Associate Professor at UGA – POLYTECH school

Responsibilities
Researcher in CDSI team

Martial DEFOORT

Position
Researcher at CNRS

Responsibilities
Researcher in CDSI team

Sylvain ENGELS

Position
Associate Professor PAST at Grenoble INP - PHELMA school

Responsibilities
Researcher in CDSI team

Laurent FESQUET

Position
Associate Professor at Grenoble INP - PHELMA school

Responsibilities
Co-leader of CDSI team
Researcher in CDSI team

Stéphane MANCINI

Position
Associate Professor at Grenoble INP - ENSIMAG school

Responsibilities
Researcher in CDSI team

Katell MORIN-ALLORY

Position
Associate Professor at Grenoble INP - PHELMA school

Responsibilities
Researcher in CDSI team

Rodrigo POSSAMAI BASTOS

Position
Associate Professor at UGA - IM2AG school

Responsibilities
Researcher in CDSI team until 30/06/2020

CNRS (French National Center for Scientific Research)
ENSIMAG school (Ecole Nationale Supérieure d'Informatique et de Mathématiques Appliquées)
GRENOBLE INP (Grenoble Institute of Technology)
IM2AG school (Informatique, Mathématiques et Mathématiques Appliquées)
PHELMA school (Physique-Electronique-Matériaux)
UGA (Université Grenoble Alpes)

Ph. D. candidates

1. AKRARAI Mohamed
Title of thesis: **Smart Event-Based Image Sensor for wake-up applications**
Expected date of defense: **2022**
Previous degrees: Engineer - Institut National des Postes et Télécommunications de Rabat, Morocco (2018)

2. AQUINO GUAZZELLI Ricardo
Title of thesis: **Exploring a Non-conventional Testing Technique for Asynchronous Circuits**
Completed on: **December 3rd, 2020**
Previous degrees: Engineer – Pontifícia Universidade Católica do Rio Grande do Sul – Porto Alegre, Brazil (2017)

3. BELOT Jérémy
Title of thesis: **Towards robust, low power and adjustable accuracy Bayesian computers**
Expected date of defense: **2022**
Previous degrees: Engineer Grenoble INP – Phelma, France (2018)

4. CROZET Florent
Title of thesis: **Extreme Learning Machine for embedded neural networks**
Expected date of defense: **2024**
Previous degrees: Engineer (2019)

5. DECOUDU Yoan
Title of thesis: **An asynchronous Design Flow for Event-Based Processing in FDSOI Technologies**
Expected date of defense: **2021**
Previous degrees: Engineer – Grenoble INP – Phelma, France (2018)

6. DE GIOVANNI Adrien
Title of thesis: **Design of a piezoelectric micro-actuator with mechanical amplification for extra-auricular earphones**
Expected date of defense: **2023**
Previous degrees: Engineer (2020)

7. FERNANDEZ BRILLET Lucas
Title of thesis: **Convolutional Neural Networks for embedded vision**
Completed on: **September 28th, 2020**
Previous degrees: Engineer – ENSEIRB / MATMECA - Bordeaux INP, France (2016)

8. GARAY TRINDADE Matheus
Title of thesis: **Optimization and Qualification of Hardware Machine-Learning Systems under Radiation-Induced Effects**
Expected date of defense: **2021**
Previous degrees: Engineer – Universidade Federal de Santa Maria, Rio Grande do Sul, Brazil (2017)

9. GASSAB Marwa
Title of thesis: **New electroactive nanostructured materials for flexible sensors**
Expected date of defense: **2021**
Previous degrees: Engineer – Higher Institute of Applied Sciences and Technology of Sousse (2018)

10. GIMENEZ Grégoire
Title of thesis: **Design of secure and very low power circuits : an asynchronous alternative**
Completed on: **February, 12th, 2020**
Previous degrees: Engineer – Grenoble INP, France (2009)

11. HACHEMI Mohammed-Bilal
Title of thesis: **Study of HZO films for MEMS applications**
Expected date of defense: **2022**
Previous degrees: Engineer - ECole Polytechnique de Constantine – Algeria (2017)

12. IGA Rodrigo
Title of thesis: **EM compliant Low-Energy Sugnal Demodulation for NFC applications**
Expected date of defense: **2021**
Previous degrees: Engineer – Université Grenoble Alpes, France (2010)

13. LAUWERS Thomas

Title of thesis: **Resonant optical transduction for photoacoustic detection**
Completed on: **March 22nd, 2020**
Previous degrees: Engineer – Grenoble INP – Phelma, France (2016)

14. LECLAIRE Nicolas

Title of thesis: **Hardware and software architectures for deep learning acceleration on embedded multi-processor**
Expected date of defense: **2021**
Previous degrees: Engineer – Grenoble INP - Phelma, France (2017)

15. LIM Olivier

Title of thesis: **Real-Time unconventional adaptive cameras for multimodal acquisition**
Expected date of defense: **2023**
Previous degrees: Master (2020)

16. ROUX Julie

Title of thesis: **Safety Evaluation of Aircraft Systems using Virtual Platforms**
Expected date of defense: **2021**
Previous degrees: Engineer – Grenoble INP - Phelma, France (2017)

Other members

Post-doctoral position – Engineers – Experts – Teaching Assistants (ATER)

Name	Forename	Country	Duration
1. ABDALI	El Mehdi	MOROCCO	9 months 12 days
2. MARGOTAT	Nils	FRANCE	12 months
3. RICART	Thibault	FRANCE	3 months

Visitors

Name	Forename	Country	Duration
1. FRAGA GARIBOTTI	Rafael	BRAZIL	5 months
2. RUFER	Libor	CZECH REP.	12 months

Trainees

Name	Forename	Country	Duration
1. HAI	Joycelyn	MALAYSIA	1 month
2. HOLANDA BATISTA	Madson Ivens	BRAZIL	1 month
3. MAAMER	Bilel	TUNISIA	12 months
4. MALDANER	Liege	BRAZIL	1 month
5. MATIASSO PORTELLA	Kenedy	BRAZIL	12 days

Contracts

TIMA has a long tradition of international cooperation, both with industrial and academic partners in the context of multinational projects. This chapter provides a short abstract of the topics and objectives of the contracted partnerships that were active in 2020.

ANRT

CIFRE Jérémy BELOT
Responsable scientifique : FESQUET Laurent
Durée : 2020 - 2023

CIFRE Alexis Rodrigo IGA RADUE
Titre : "Démodulation NFC Basse Consommation et Respectueuse de la Compatibilité Electromagnétique"
Responsable scientifique : FESQUET Laurent
Durée : 2018 - 2021

CIFRE Nicolas LECLAIRE
Titre : "Architectures matérielles et logicielles pour l'accélération du "deep learning" sur multiprocesseur évolutif embarqué"
Responsable scientifique : MANCINI Stéphane
Durée : 2018 - 2021

CARNOT

EBIS
Titre : Event Based Image Sensor
Responsable scientifique : FESQUET Laurent
Durée : 2019 - 2020

CEC-NATIONAL

OCEAN 12
Programme : ECSEL
Titre : Opportunity to Carry European Autonomous driviNg further with FDSOI technology up to 12nm node
Responsable scientifique : FESQUET Laurent
Durée : 2018 - 2021

EPST

Chameleon
Programme : IRS (Initiative de Recherche Stratégique)
Responsable scientifique : BASROUR Skandar
Durée : 2020 - 2021

Cyber@Alpes
Programme : Grenoble Alpes CyberSecurity Institute
Responsable scientifique : MAISTRI Paolo
Co-partage d'équipes (AMfoRS, CDSI)
Durée : 2018 – 2021

INDUSTRIE

ICALPS - G.GIMENEZ
Titre : Conception de circuits d'identification sécurisé basse consommation
Responsable scientifique : FESQUET Laurent
Durée : 2018 - 2021

Thèse Grégoire GIMENEZ
Titre : "Etude et conception de puces sécurisées basse consommation pour plateforme IoT"
Responsable scientifique : FESQUET Laurent
Durée : 2016 - 2020

INTERNATIONAL

BRAFISAT
Programme : BRAFITEC
Responsable scientifique : POSSAMAI BASTOS Rodrigo
Durée : 2019 - 2022

MINISTERES-FUI

IMSPOC-UV
Programme : PIA Programme d'Investissemeent d'Avenir
Titre : Imaging Spectrometer On Chip
Responsable scientifique : BASROUR Skandar
Durée : 2018 – 2022

REGION

MucoPiezoRheo
Programme : PSPC
Responsable scientifique : BASROUR Skandar
Durée : 2020 - 2023

GRESAM
Programme : Pack Ambition International
Titre : Grenoble Sousse Autonomous Microsystems
Responsable scientifique : BASROUR Skandar
Durée : 2019 - 2021

FAIR
Programme : Pack Ambition Recherche
Titre : Conception et fabrication par Fabrication Additive de produits Intelligents
Responsable scientifique : BASROUR Skandar
Durée : 2018 - 2023

Convertisseur temps numérique
Programme : SCUSI
Titre : Dispositif microélectronique ultra-précis de mesure de temps basé sur l'oscillateur en anneau auto-séquencé
Responsable scientifique : FESQUET Laurent
Durée : 2017 - 2020

Organization and participation of international conferences, workshops, forums

13th International Conference on Advances in Circuits, Electronics and Micro-electronics (CENICS'2020)
November 21-25, 2020, Valencia, SPAIN
Rang : NC
technical program committee: FESQUET L.

6th International Conference on Event-Based Control, Communication, and Signal Processing (EBCCSP'2020)
June 3-5, 2020, Grenoble, FRANCE
Rang : NC
general chair: FESQUET L.

10èmes Journées Nationales sur la Récupération et le Stockage de l'Energie (reportées à 2021) (JNRSE'2020)
May 27-28, 2020, Grenoble, FRANCE
Rang : NC
technical program committee: BASROUR S.

5th International Conference on Advances in Signal, Image and Video Processing (SIGNAL'2020)
May 24-29, 2020, Venice, ITALY
Rang : NC
industry liaison: FESQUET L.
technical program committee: FESQUET L.

International Symposium on Asynchronous Circuits and Systems (ASYNC '2020)
May 17-20, 2020, Snowbird (Utah), USA
Rang : A+
technical program committee: FESQUET L.

21st IEEE Latin-American Test Symposium (LATS'2020)
March 30-April 2, 2020, Jatiúca (Maceió), BRAZIL
Rang : NC
technical program committee: POSSAMAI BASTOS R.

21st International Symposium on Quality Electronic Design (ISQED'2020)
March 25-26, 2020, Santa Clara, USA
Rang : A
track chair: RUFER L.

Design, Automation & Test in Europe (DATE'2020)
March 9-13, 2020, Grenoble, FRANCE
Rang : A+
technical program committee: MORIN-ALLORY K.

Responsibilities

Role	TIMA member	Starts	Ends	Comments
Faculties / Schools				
PHELMA school PHysique, ÉLectronique, Matériaux				
Manager of SEI branch	MORIN-ALLORY K.	01/09/2017		
UFR IM2AG Informatique, Mathématiques et Mathématiques Appliquées				
Manager of Office Automation and Informatics	POSSAMAI BASTOS R.	01/09/2017		Formation à tous les parcours du Département Licence Sciences et Technologies de l'UGA
Research structures				
CIME Nanotech Centre Interuniversitaire de MicroElectronique et Nanotechnologies				
Deputy Director	FESQUET L.	01/09/2017		
Manager of Communicating objects platform	MANCINI S.	01/09/2017		
Manager of Microsystems platform	BASROUR S.	01/10/2006		
PEM pole Physique, ingénierie, matériaux				
TIMA representative of PEM cluster	BASROUR S.	01/09/2016		
Parents institutions				
Grenoble INP				
Board of Directors member (elected member)	MANCINI M.	12/12/2019	01/01/2024	Strategy, jobs, promotion files, invited professors, teaching assistants

Scientific production

International journals

Possamai Bastos R., **Dutertre J.M.**, **Garay Trindade M.**, **Andreoni Camponogara Viera R.**, **Potin O.**, **Letiche M.**, **Cheymol B.**, **Beaucour J.**, Assessment of On-Chip Current Sensor for Detection of Thermal-Neutron Induced Transients, IEEE Transactions on Nuclear Science, Ed. IEEE, Vol. 67, No. 7, pp. 1404-1411, DOI: 10.1109/tns.2020.2975923, 2020

Hadj Salem K., **Jost V.**, **Kieffer Y.**, **Libralesso L.**, **Mancini S.**, Minimizing makespan under data prefetching constraints for embedded vision systems: a study of optimization methods and their performance, ORIJ - Operational Research - An International Journal, Ed. Springer , Vol. , 2020

Skaf A., **Ezzadeen M.**, **Benabdenbi M.**, **Fesquet L.**, Clocked and event-driven redundant adjustable precision computing, Microelectronics Reliability, Ed. Elsevier, Vol. 111, pp. 113729, DOI: 10.1016/j.microrel.2020.113729, août 2020

Sansa M., **Defoort M.**, **Brenac A.**, **Hermouet M.**, **Banniard L.**, **Fafin A.**, **Gely M.**, **Masselon C.D.**, **Favero I.**, **Jourdan G.**, **Hentz S.**, Optomechanical mass spectrometry, Nature Communications, Ed. Nature Publishing Group, Vol. 11, No. 1, pp. 3781, DOI: 10.1038/s41467-020-17592-9, juillet 2020

Popescu A., **Besancon G.**, **Voda A.**, **Basrour S.**, Observer-Based 3-D Control Enhancement for Topographic Imaging--Validation With an STM Prototype, IEEE Transactions on Control Systems Technology, Ed. IEEE, Vol. , pp. 1-12, DOI: 10.1109/TCST.2020.2991871, mai 2020

Aquino Guazzelli R., **Garay Trindade M.**, **Acunha Guimaraes L.**, **Ferreira De Paiva Leite T.**, **Fesquet L.**, **Possamai Bastos R.**, Trojan Detection Test for Clockless Circuits, Journal of Electronic Testing: Theory and Applications, Ed. Springer , Vol. , février 2020

Patents

Engels S., **Fesquet L.**, **Germain S.**, System and Method for Managing Requests in an Asynchronous Pipeline, No. US2020184110 (A1), 11 juin 2020

Fesquet L., **Cherkaoui A.**, **Frisch R.**, Circuit and Method for Protecting Asynchronous Circuits, No. WO/2020/008229, 9 janvier 2020

Invited conferences talks

Fesquet L., **Decoudu Y.**, **Iga R.**, **Ferreira De Paiva Leite T.**, **Rolloff O.**, **Diallo M.**, **Possamai Bastos R.**, **Morin-Allory K.**, **Engels S.**, Body-Bias Micro-Generators for Activity-Driven Power Management, Invited Talk, FDSOI workshop at DATE Conference 2020, Grenoble, FRANCE, 9 mars 2020

International conferences

Roux J., **Beroulle V.**, **Morin-Allory K.**, **Leveugle R.**, **Bossuet L.**, **Cezilly F.**, **Berthoz F.**, **Genevrier G.**, **Cerisier F.**, High Level Fault Injection Method for Evaluating Critical System Parameter Ranges, 27th IEEE International Conference on Electronics, Circuits and Systems (ICECS 2020), pp. 1-4, Glasgow, UNITED KINGDOM, DOI: 10.1109/ICECS49266.2020.9294821, 23 au 25 novembre 2020

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