MicroElectronics Group

Andrea Baschirotto
Department of Physics ‘G. Occhialini’
University of Milan-Bicocca
Milan – Italy

andrea.baschirotto@unimib.it

Group Composition

Andrea Baschirotto – Full Professor Director

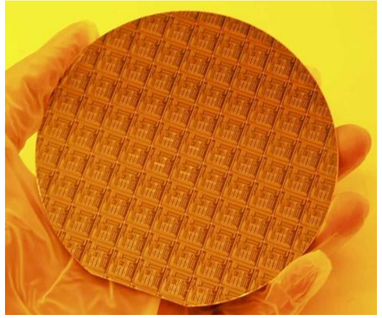
Marcello De Matteis – Associate Professor

Valeria Vadalà – Associate Professor

- 4 Researchers
- > 20 PhD Students
- Master Students

What is Microelectronics ??

- Microelettronica
  - Sviluppo di circuiti elettronici integrati
    - chips
  - Altissima tecnologia
    - Diametro capello = 70µm
    - Grandezza transistor minimo = 3nm
      - In un capello ci stanno >20.000 transistor



- Applicazioni futuristiche
  - Tempo di sviluppo di un chip 2-3 anni
  - si lavora sempre su circuiti che dovranno essere usati tra 3-4 annI
    - si lavora nel future
      - Huawei ha iniziato a sviluppare il 6G nel 2018 e sarà sul mercato nel 2030

Sandwich Seminars !!!

Short Seminars (30min)
about Microelectronics World

Expert Responsible from Indisutries and Research

Lunch break (h 13:00 - 13.30)

13 Gennaio 2026 – Aula U2/06

Microwave Electronics Bites

Renato Lombardi, Huawei Italia
(President of Milan Research Center)

20 Gennaio 2026 – Aula U2/05

Micro and Nano electronics
in High energy Physics at LHC

L. Pacher, Università di Torino (LHC CMS)

Sandwich Seminars !!!

Second Part !!

Second Semester !!

Short Seminars (30min)
about Microelectronics World

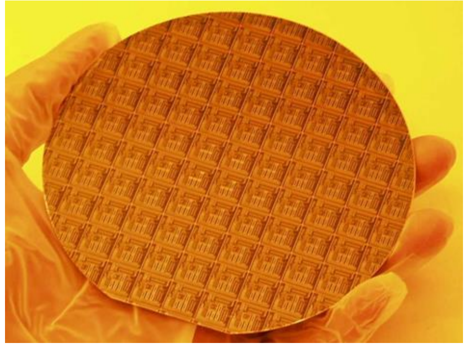
Young designers
from Industries & Research
reporting their experience

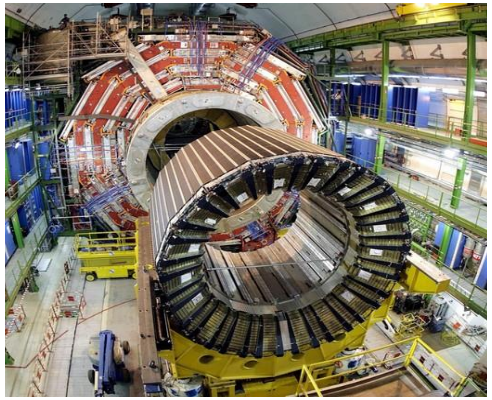
Lunch break(h 13:00 - 13.30)

Under Organization

Research Activities

- **Development of Microelectronics Integrated Circuits**
  - Applications
    - Research
      - Electronics for High Energhy Experiments
      - Biomedical (Brain interface)
      - Quantum Computing & Artificial Intelligence
    - Industry
      - Automotive / Electric Car (Power management)
      - Sensor interfaces (gas&microphone) for mobile phone
      - …..





Research Activities & Collaboration

- ME Group is active in several research projects within
  - **Government** funded projects (PRIN, PNRR, etc…)
  - **European** funded projects
  - Experiments funded by **National Institute for Nuclear Physics** (INFN)
  - Research collaboration with **Industries**

Courses

- **Bachelor courses**
  - Analog electronics basic (Elementi di Elettronica) *Analogica* - 6CFU
  - Electronic Lab (Laboratorio di Elettronica) Microcontroller - 8CFU
- **Master courses**
  - Microelectronics Lab I - 10CFU
  - Microelectronics Lab II - 6CFU
  - Electronics - 6CFU
  - Electronics Devices - 6CFU
  - Industrial Electronics (VHDL) - 6CFU
    - ➔ Same amount of Electronics Engineering Course (PoliMI, UniPavia, etc..)
  - Master thesis in partner companies

Semiconductor Physics + Technology + Design Know-how

Thesis Activity

- **Design a part of an IC device within one running project**
  - Participate to a complete device development
    - Acquire experience in working in a team
  - Develop an independent project
    - ➔ Acquire design experience
  - Acquire experience in using industrial ***most advanced HW&SW***
    - Cadence, Mentor, Synopsys, etc.…
    - Analog & Digital circuit design
    - Layout: design & verification
  - The activity could be carried out **in the Lab** or in **external sites**

“Path-to-job”

- ***Bachelor degree*** (3 years)
  - Thesis in ME lab with an activity that could continue during Master courses

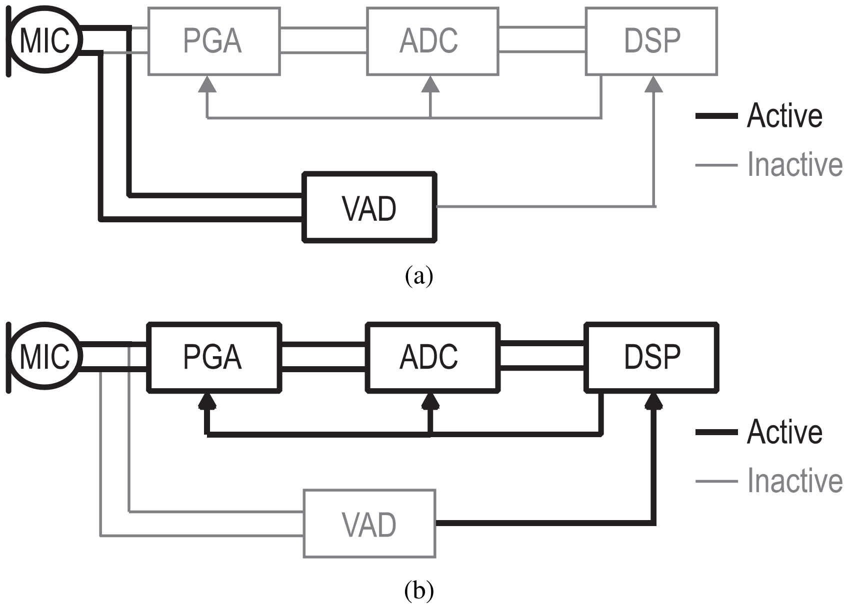
- ***Master degree*** (2 years)
  - Thesis in ME lab
  - Thesis in company (**$$$**)

- ***PhD*** (3 years + **$$$**)
  - Applied research in microelectronics (CERN, CEA-Lethi, etc…..)
  - In collaboration with Companies (Italy, Austria, France, Germany, California-USA)
    - 50% in University
    - 50% in Company

Education flow *Master + PhD*

It could be defined at the beginning of the Master course

nA Front-End for Voice Activity Detector (ALEXA)



IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 56, NO. 3, MARCH 2021

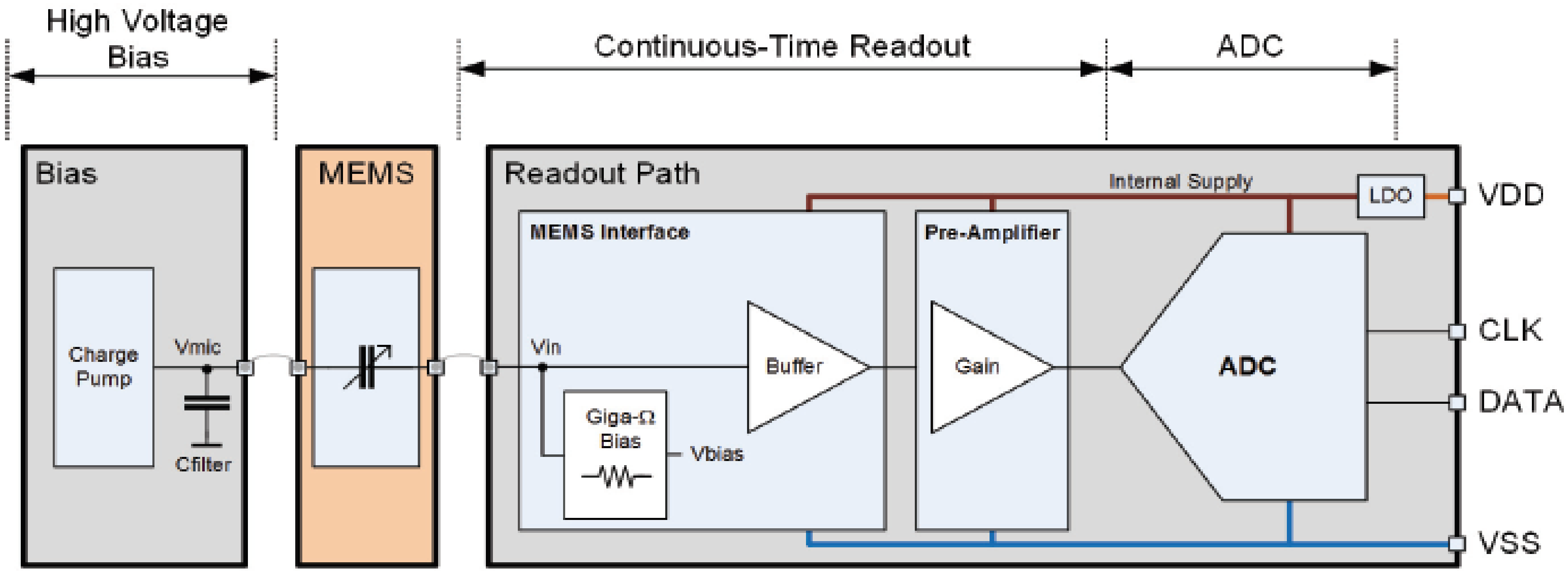
A 760-nW, 180-nm CMOS Fully Analog Voice Activity Detection System for Domestic Environment

IEEE-CICC2020 Best Paper Award
+ 1 US Patent

Parameter	This Work
Technology [nm]	180
Input Device	Passive Mic
Feature	Analog
Bandwidth [kHz]	0.3 – 6.8
Classifier	Analog SNR-Based Decision Rule
Power [μW]	0.76
Area [mm^2]	0.14
Rate [1/s]	31.25

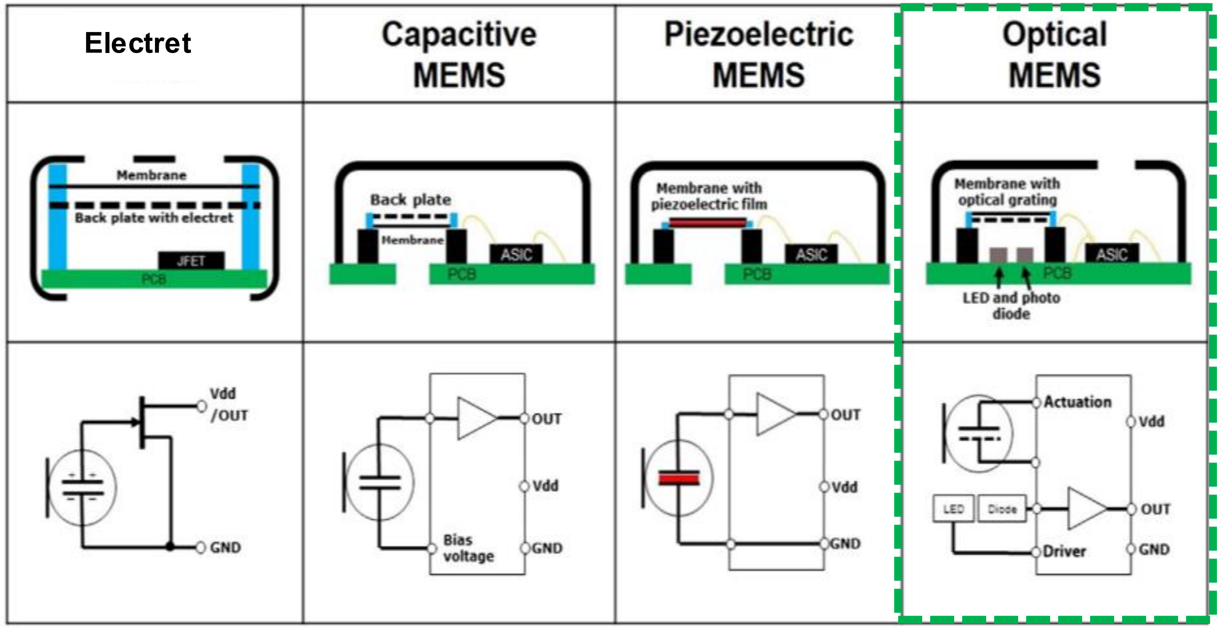
Silicon Microphone Interface

- ***Infineon holds 40% market of µPhone for cellphones***
  - *Advanced µPhone interfaces in 55nm technology*
  - *Bandgap, LDO, Charge-pump, Preamp, etc….*

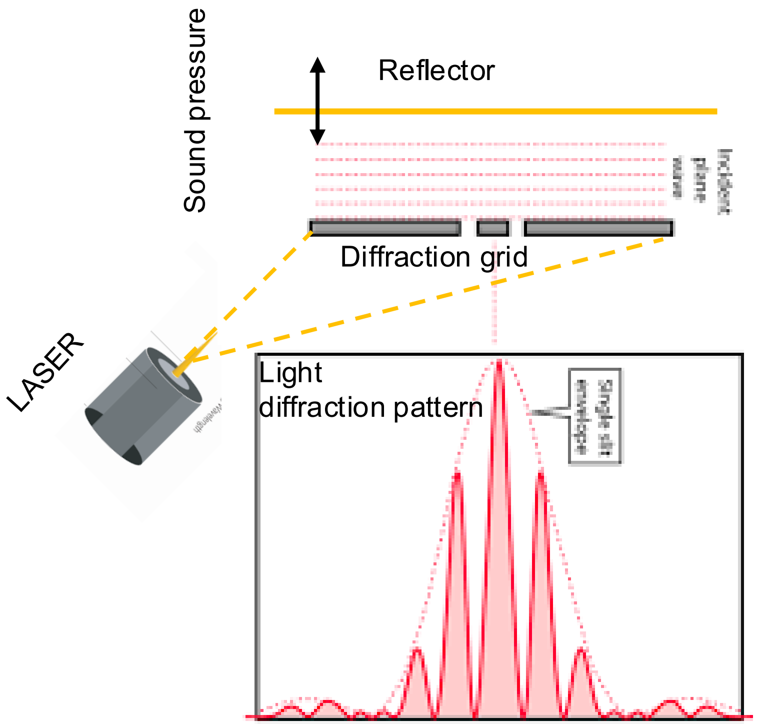


Future Optical Microphone Interface

- ***Microphone system better than present MEMS µPhone***
  - *>70dB SNR and package smaller than 5x4x2mm (state-of-art)*

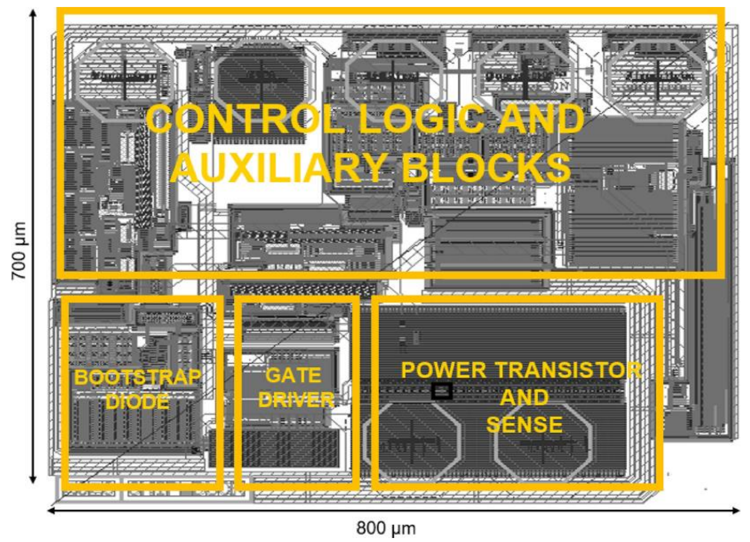


Transduction scheme



Power Management devices

- DC-DC Converters
  - Automatic Design of DC-DC Converters
    - Optimization and Efficient porting
  - High-Speed DC-DC Converters
    - Passive component reduction
  - High Efficiency DC-DC Converters
  - Advanced Architecture for DC-DC Converters
    - Multistage DC-DC Converters for Electric Cars



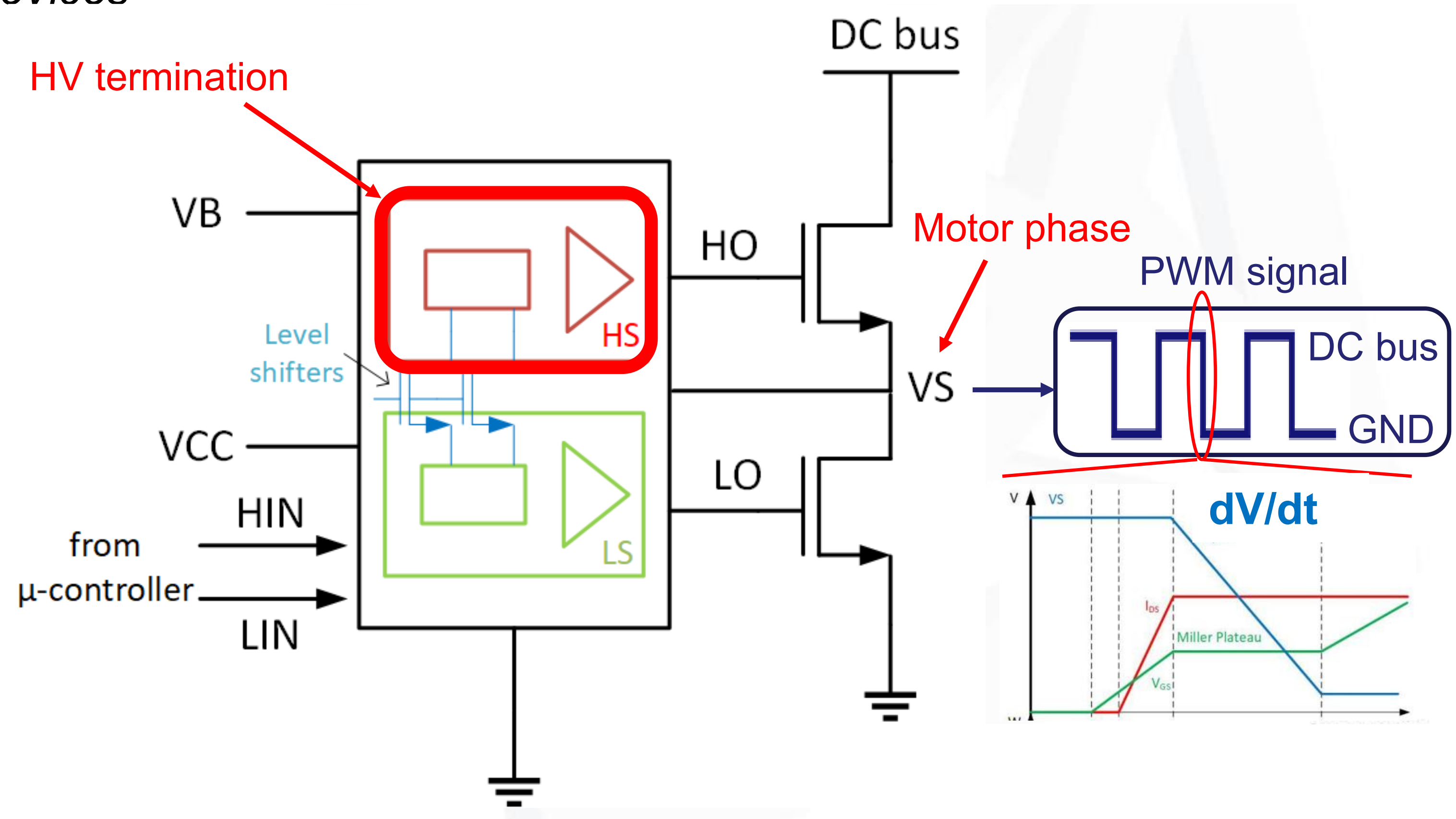
Ultra Low-Power for parked cars

- ***nA circuits in 10A technology***
  - *Issue about device modeling, temperature behaviour, etc…*

Master Student with 3 Patents

High-Voltage Circuits (>600V)

- ***Gate Driver architecture with dV/dt sensing structure***
  - *600V devices*

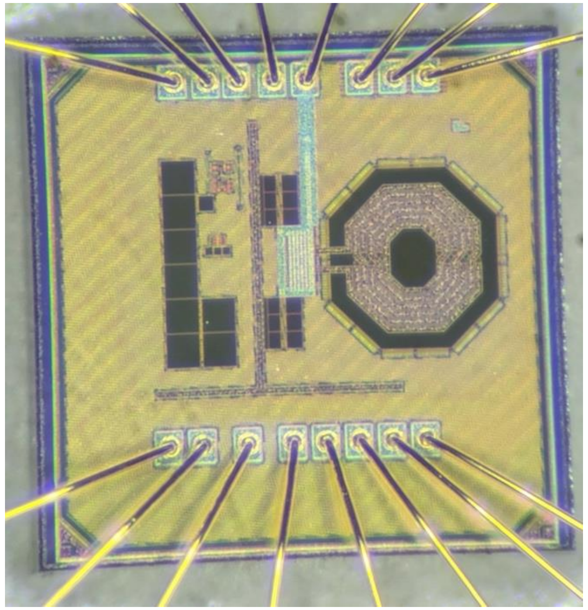


Advanced Istrumentation

- ***Automatic System for optical measurement alignment***

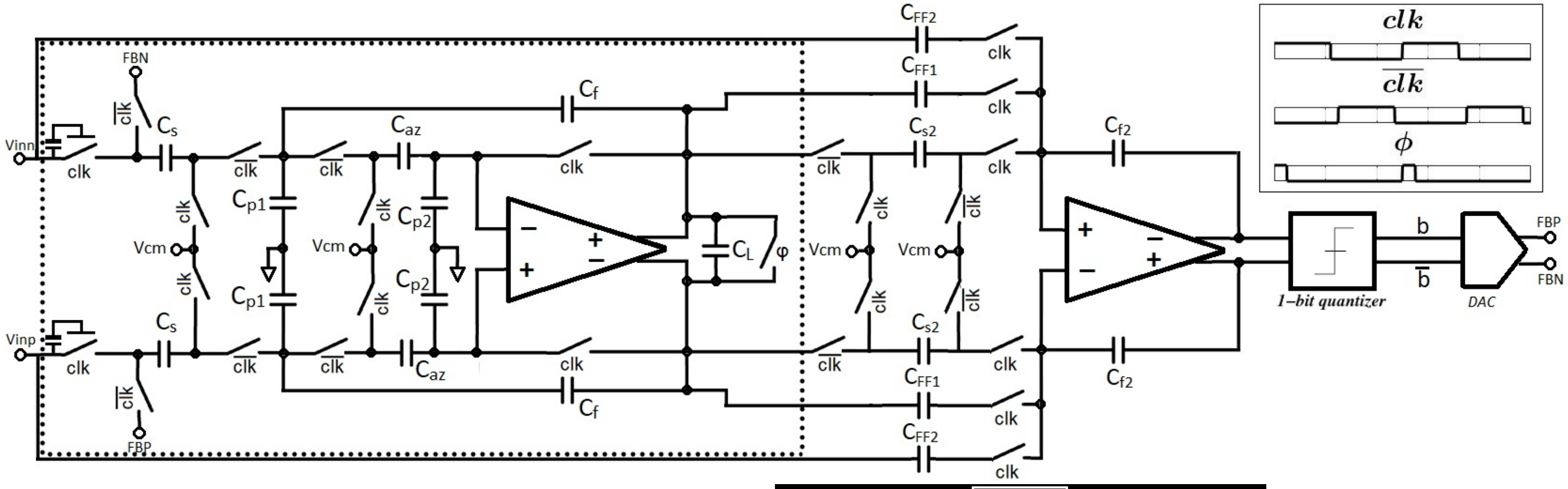
Internet-of-Thing Devices

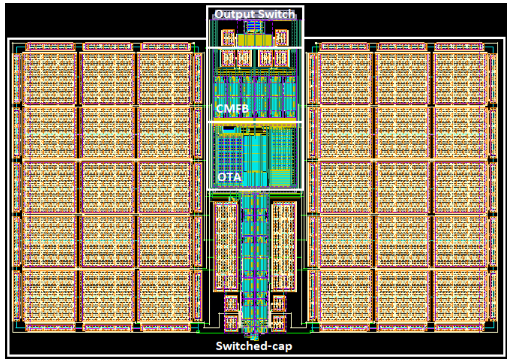
- ***Hyper-Low-Power low-date-rate transmitter***
  - ***Battery life is >10years***



Very-Large Dynamic Range Sensor interface

- *110dB-SNR in 1kHz-band with 200µW*
  - *Innovative solutions for SC implementation*





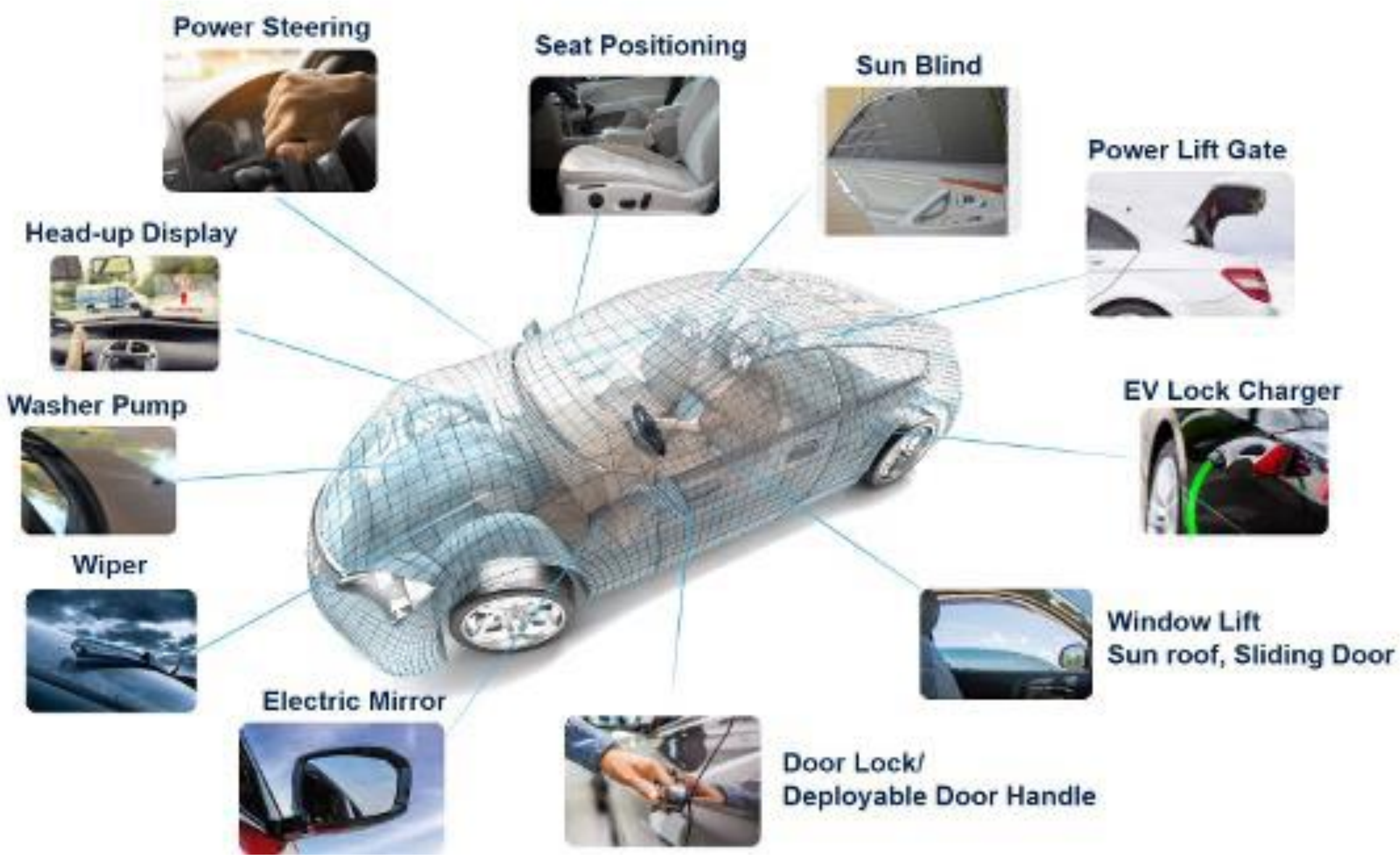
Booth C3-249

Munich fairground
Germany

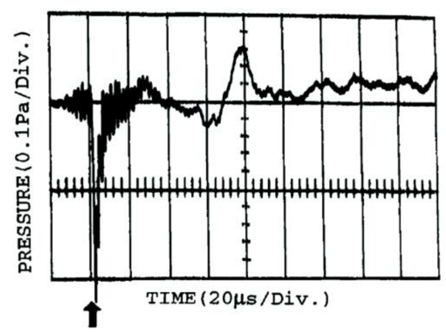
November 12-15, 2024

Future Optical Microphone Interface

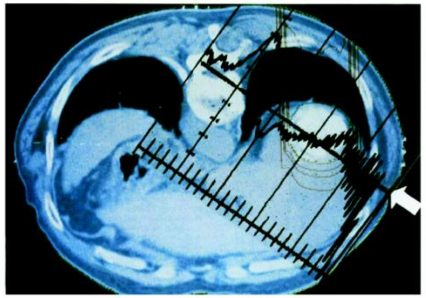
- *IC devices for transceiver on the power lines*



Proton Sound Detectors

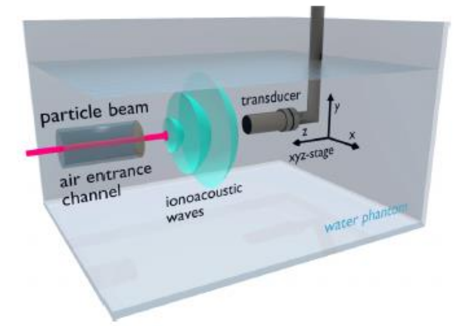


Acoustic pulse measured with a hydrophone

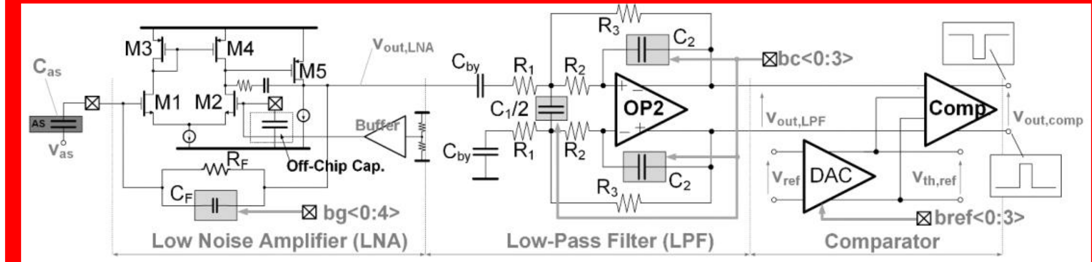


Treatment plan (hepatic cancer patient)

First evidences of **A CLEAR ACOUSTIC SIGNAL** generated in a patient (hepatic cancer) irradiated by a pulsed proton beam



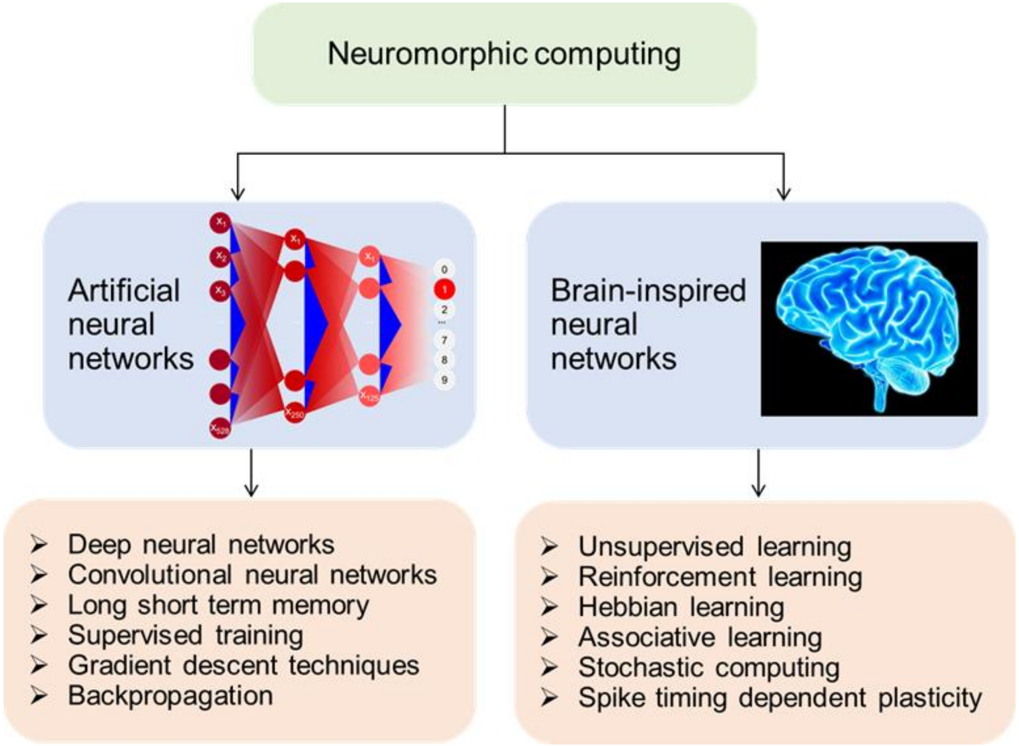
Proton Sound Detectors EXPERIMENTAL SETUP



Proton Sound Detectors ASIC (Application Specific Integrated Circuit) in 28 nm CMOS

Topic 1: Software Defined Acoustic Receiver for Proton Sound Detectors (System Level Model of the ASIC for Operation in 65/200 MeV Proton Energy)
Topic 2: Analog and Digital Circuits Design in 28 nm CMOS for Proton Sound Detectors
Topic 3: Analog and Digital **Denoising Techniques** for Proton Sound Detectors

Neuromorphic Artificial Neural Network in 7 & 16 nm-FinFET



- **ANNs** (Artificial Neural Network) excel on **static** images inference
- **SNNs** (Spiking Neural Network (are Brain-Inspired)) exhibit competitive energy efficiency on **temporal tasks**
  - Only case when fully on-chip learning is possible
  - Leverage **sparse firing** activity

Topic 1: Analog Design of **Izhikevich Neuron** in 7 nm FinFET
Topic 2: Design Equations of Analog Circuits Emulating Izhikevich Spiking Neuron based on **Sub-Threshold MOS Transitors**

28nm-Analog Design for High-Energy-Physics (HEP) Experiments

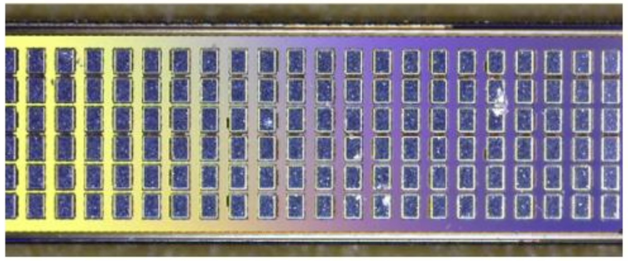


Fig. 1. Photo of single devices matrix.

Chip Photo of **Single MOST for RAD Test**

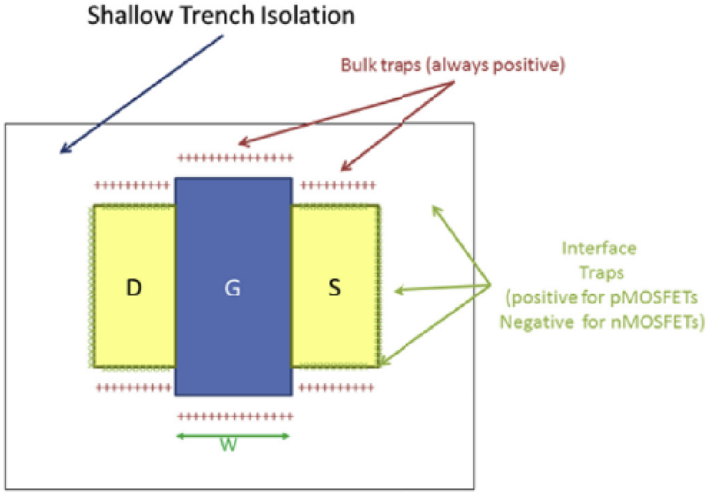


Fig. 5. Top view of a MOSFET structure, highlighting bulk and interface traps.

Top View of a MOST Layout with Bulk and Interface Traps due to RADIATION DAMAGES

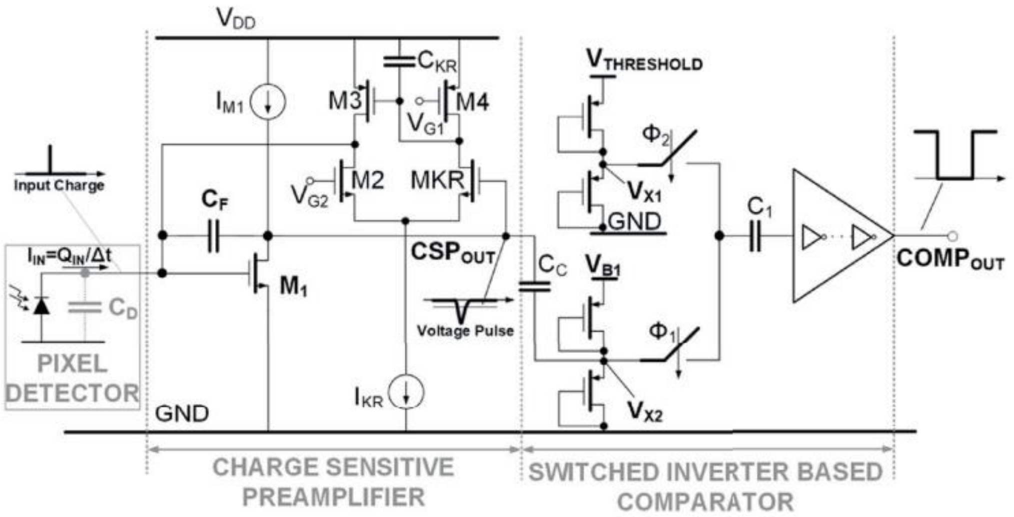


Fig. 13. IC-PIX28 simplified block scheme.

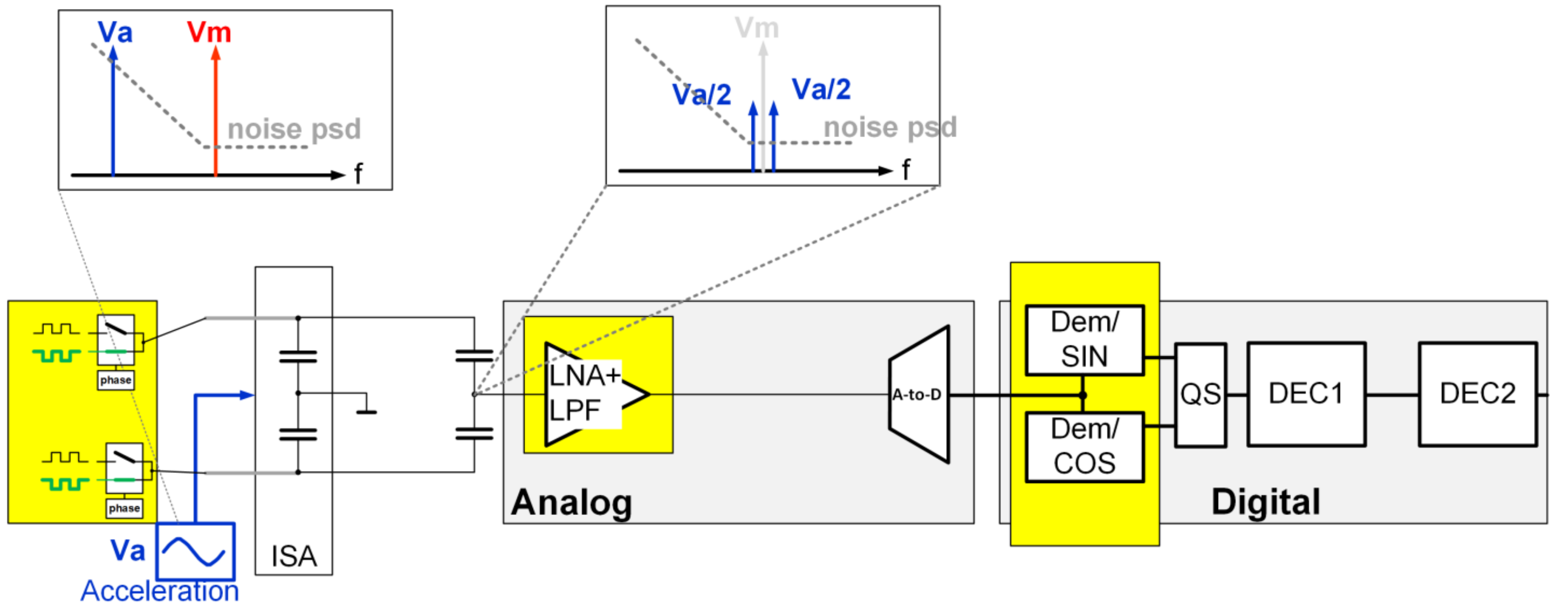
Charge Sensitive Preamplifier and Analog Front-End for HEP Experiments

Topic 1: 28 nm MOS Transistor SPICE BSIM Model based on Equivalent Gate Oxide Capacitance Supporting Electrical Effects of **1-Grad Total Ionizing Dose**

Topic 2: Rad-Hard Analog Design of **Charge Sensitive Preamplifier in 7 nm FinFET**

[1] Resta, F., et al. (2018). "1GigaRad TID impact on 28 nm HEP analog circuits". Integration, 63, 306–314.

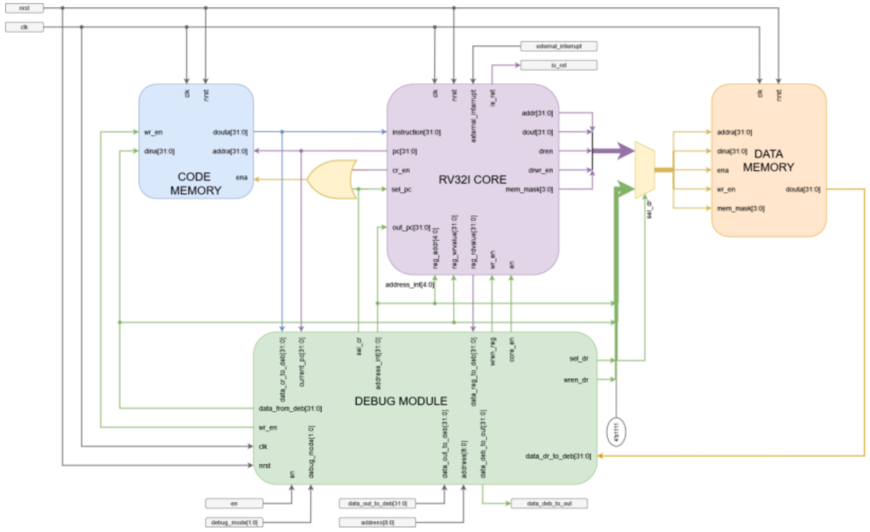
28nm-Analog Front-End for Microgravity Accelerometers



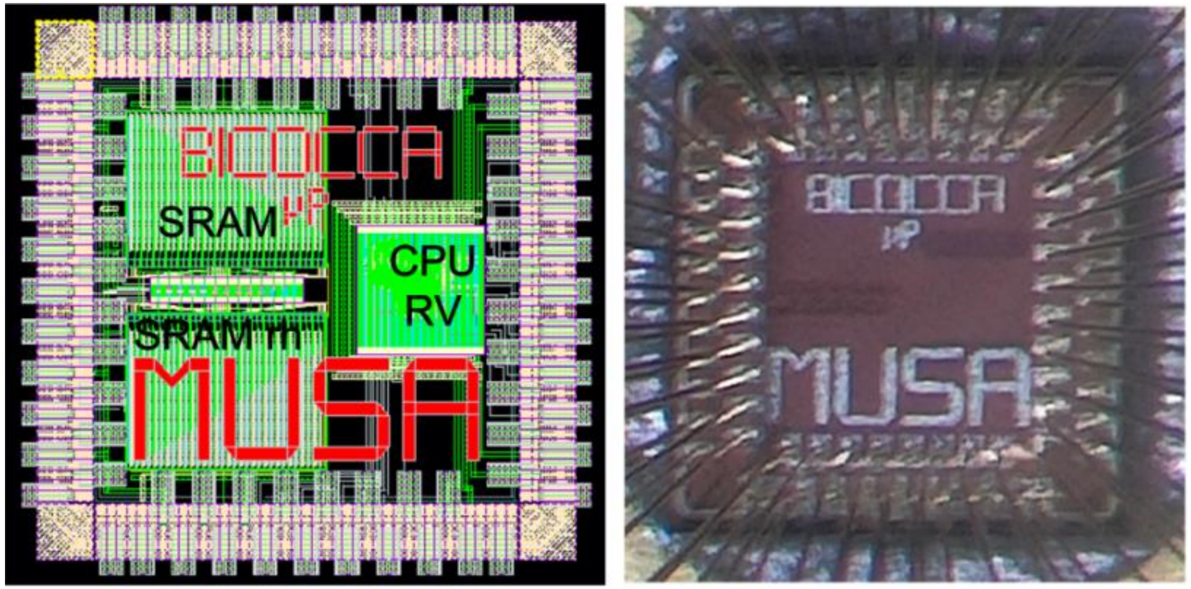
Analog Front-End for Microgravity Accelerometers in 28 nm CMOS

Topic 1: **<u>Low Noise Amplifier Modelling, Design and Layout</u>** for Microgravity Accelerometers Analog Front-end in 28 nm CMOS

7nm-FinFET Digital Design for Aerospace



Microprocessor Block Scheme



Microprocessor and SRAM Chip Layout and Photo

Topic 1: Laboratory **Experimental Measurements of a 28 nm CMOS RISCV** Microprocessor at 100 MHz clock Frequency

Topic 2: **Digital Design of RISCV** (Reduced Instruction Set Computer Version V) Microprocessors in 28 nm and 7 nm CMOS

MUSA Joint Labs

- Three Joint-Lab established within MUSA Project (PNRR funds)
  - Automatic Testing Lab (**ATLab**)
    - In collaboration with Infineon
  - Nanoelectronics Lab for Sensors and Space (**NANOLABS²**)
    - In collaboration with Thales
  - mm-Wave Electronics Lab (**WELab**)
    - In collaboration with Huawei

MUSA Joint Lab for Automatic Testing

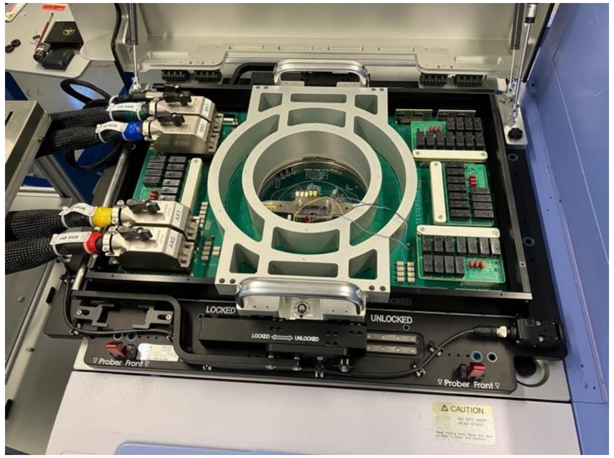
- **In the development of Integrated Circuits testing cost as a percentage of total production cost** is approximately:
  - **Simple / high-volume ICs (MCUs, mature ASICs)**
    👉 **5–10%** of the total manufacturing cost
  - **Complex digital ICs (SoCs, CPUs, GPUs)**
    👉 **10–20%** of the total manufacturing cost
  - **Analog, mixed-signal, RF ICs**
    👉 **15–30%** of the total manufacturing cost
    (analog testing is slower and requires more expensive instrumentation)
  - **High-reliability devices (automotive, aerospace, medical)**
    👉 **20–35%** of the total manufacturing cost
    (burn-in, environmental and screening tests)

MUSA Joint Lab for Automatic Testing

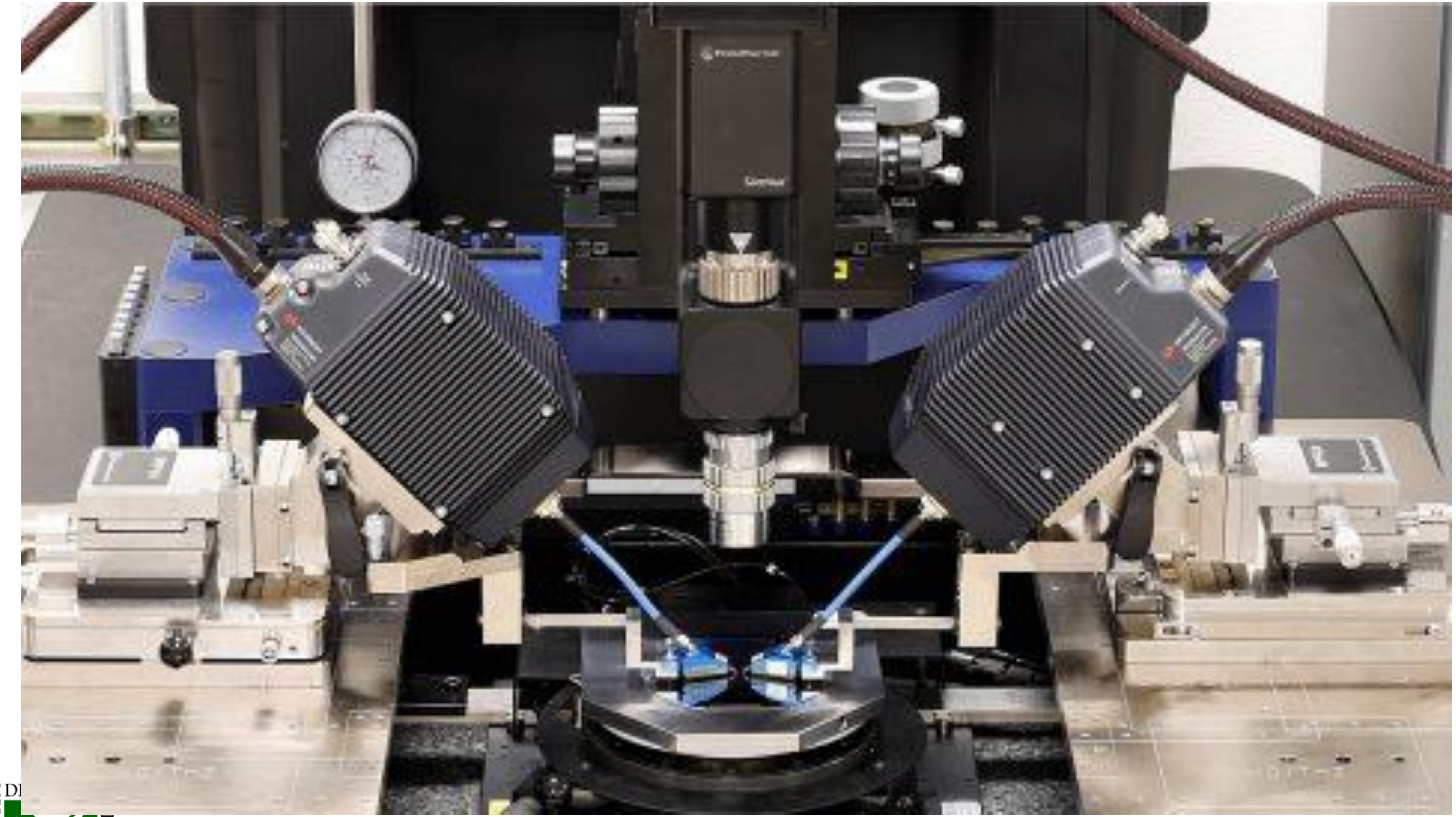
- **Why is testing so expensive?**
  - The main cost drivers are:
    - **Automatic Test Equipment (ATE)** systems cost **several million euros/dollars**
      - very high hourly operating cost
    - **Test time**
      - longer for complex or analog ICs
      - cost is almost proportional to test duration per chip
    - **Multiple test stages**
      - wafer probe test
      - final (package) test
      - burn-in / stress testing (when required)
    - **Yield and defect density**
      - advanced nodes → higher defect sensitivity → more sophisticated tests

MUSA Joint Lab for Automatic Testing

- **Same Industrial Instrumentation Equipment**
- **Development of testing procedures with cost reduction solutions**
  - System-C modelling for set-up development improvement
  - AI-based testing for testing speed-up

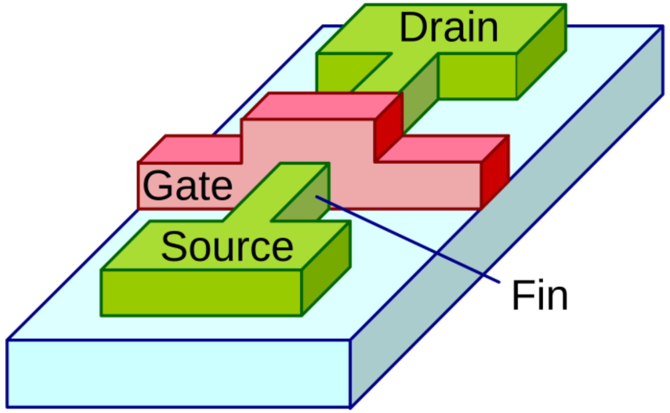


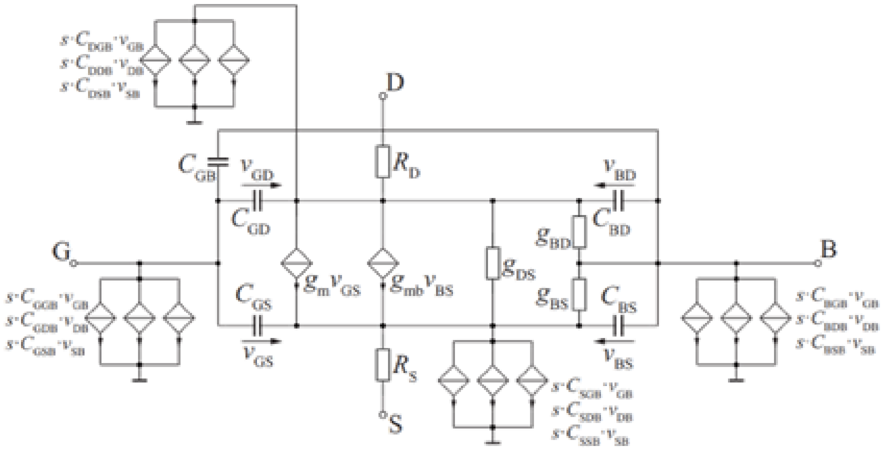
MUSA Joint Lab for High-Frequency Measurement



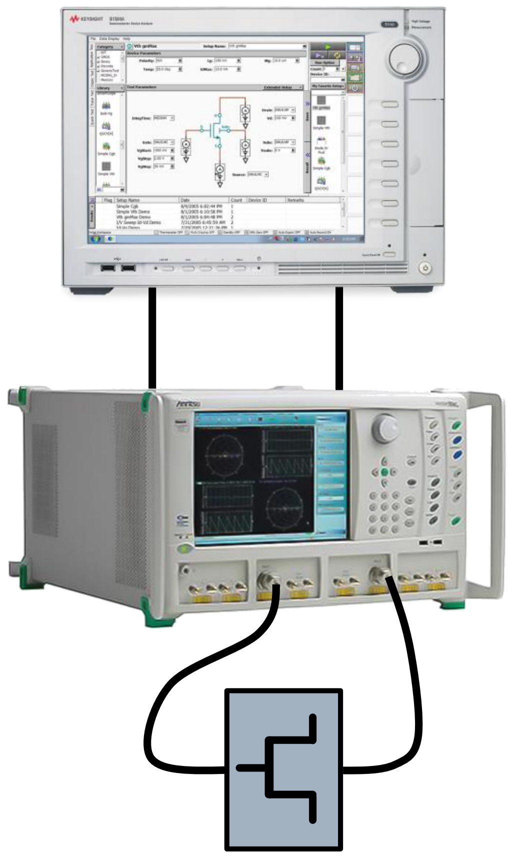
High-Frequency Microelectronics - Modeling of electronic devices

- ***Linear and nonlinear modelling of electronic devices for microwave applications***
  - *Neural-network behavioral models Vs equivalent circuit models*
  - *State-of-the-art technologies*
    - *Silicon FinFET for cryogenic quantum applications*
    - *GaAs pHEMT and GaN HEMT for RF front end design*





High-Frequency Microelectronics
Development of Microwave Measurement Setups



Device Under Test (DUT)

- *Microwave transistor characterization under DC operation using a semiconductor analyzer*
- *Small-signal characterization of on-wafer microwave devices (transistors, power amplifiers,…) using a 220-GHz vector-network analyzer (VNA)*
- *Time-domain oscilloscope-based characterization of microwave circuits*
- *VNA-based noise measurements: design and development of the setup*

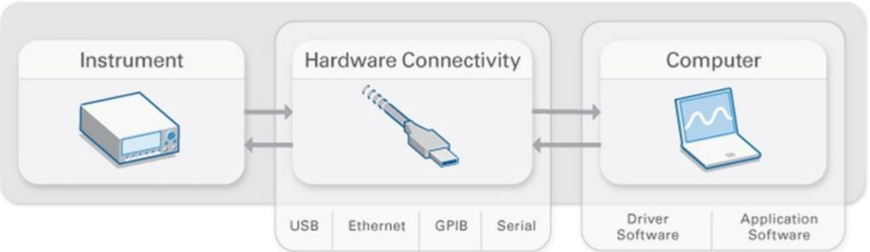
mm-Wave Electronics Laboratory
Milano Bicocca & Huawei Joint-Lab

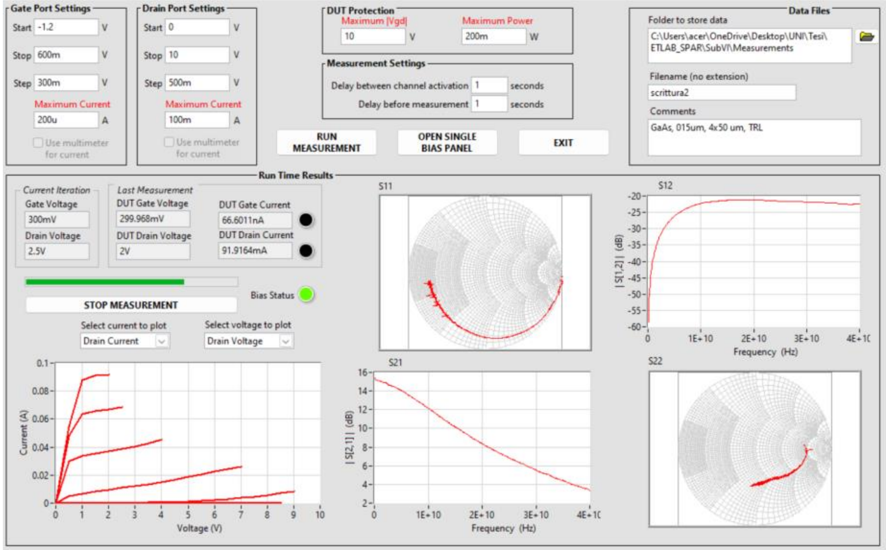
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

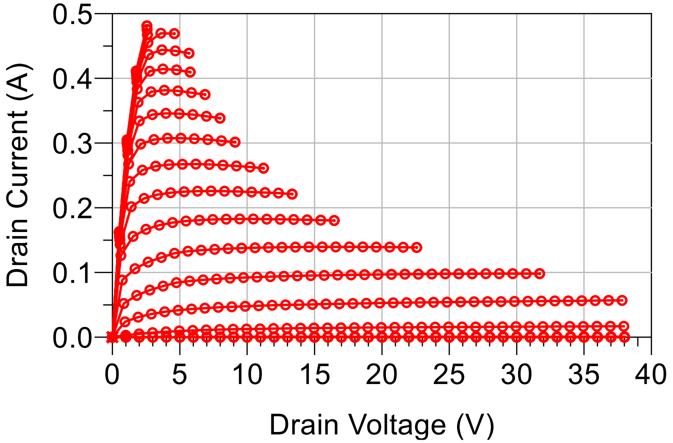
HUAWEI

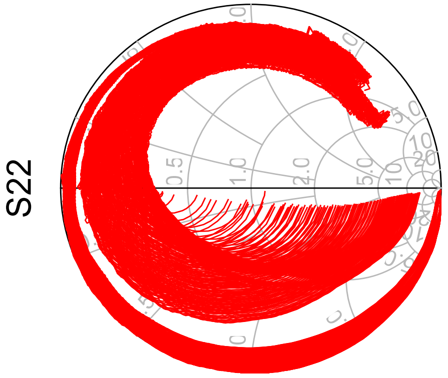
High-Frequency Microelectronics
Microwave Measurement Automation

- ***Development of software for remote control of the instruments, data acquisition and processing***
  - *DC characterization (Semiconductor analyzer, DC supply, multimeters,…)*
  - *S-parameter characterization (VNA)*









MUSA Joint Lab UniMIB-Thales

Nanoelectronics LAB for Sensors and Space (NANOLABS2)
Design and Characterization of advanced nanometer electronics for:

- Space Missions Satellites
- Deep Space Observation
- Radiation Hardness

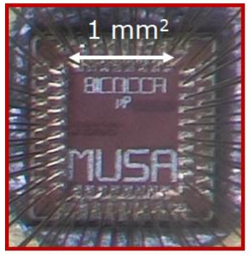
Some Examples:

- **ANALOG**: **µGravity** Accelerometer Analog Front-End
  - Possible Thesis Topics:
    - Low noise amplifier, filters, oscillators, a-to-d converters for space applications
- **DIGITAL**: **µProcessors** based on RISCV Architectures
  - Possible Thesis Topics:
    - Behavioral (HDL) µProcessors Design
    - Transistor-Level (CMOS) µProcessors Design
- **Mixed-Signal**: **Neuromorphic** Neural Network
  - Possible Thesis Topics:
    - Behavioral (HDL) and Transistor-Level Design

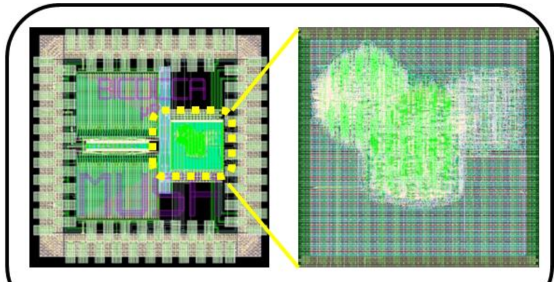
MUSA Joint Lab UniMIB-Thales

Nanoelectronics LAB for Sensors and Space
Design and Characterization of advanced nanometer electronics for:

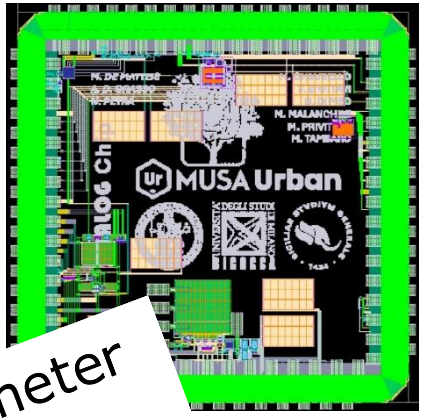
- Space Missions Satellites
- Deep Space Observation
- Radiation Hardness



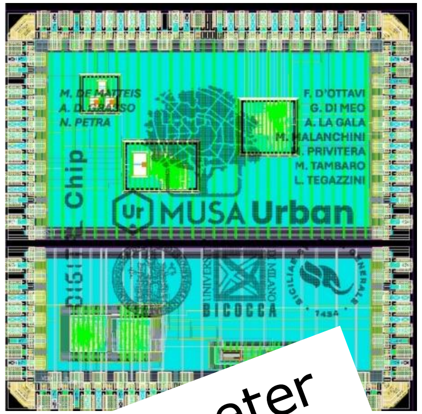
Chip Photo


Chip CAD Photo µP CAD Photo

µProcessors in 28 nm CMOS



µGravity Accelerometer (Analog)



µGravity Accelerometer (Digital)

MUSA Joint Lab UniMIB-Thales

Nanoelectronics LAB for Sensors and Space
Design and Characterization of advanced nanometer electronics for:

- Space Missions Satellites
- Deep Space Observation
- Radiation Hardness

More info at:

NASCE NANOLABSS, IL JOINT LAB CHE UNISCE UNIVERSITÀ E INDUSTRIA PER LA MICROELETTRONICA DEL FUTURO

https://musascarl.it/nasce-nanolabss-il-joint-lab-che-unisce-universita-e-industria-per-la-microelettronica-del-futuro/