FROM RESEARCH TO INDUSTRY
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Control activities for SOC (LIALP)

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En partenariat avec

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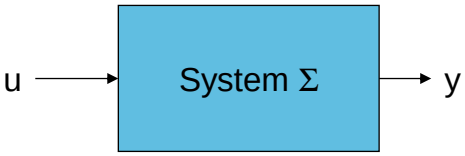
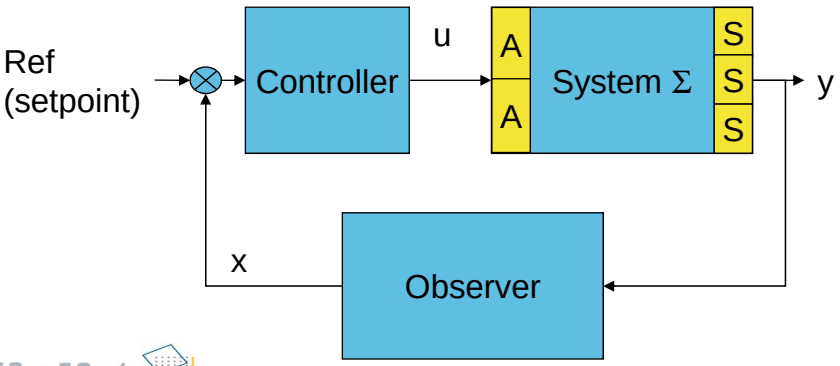
leti & list

Control in context: definitions

- System Σ
  - Inside / Outside (“boundary”)
  - Inputs u (→ actuation)
  - Output y (→ sensing)



- System Σ
  - Open loop
  - **Closed-loop with observer**

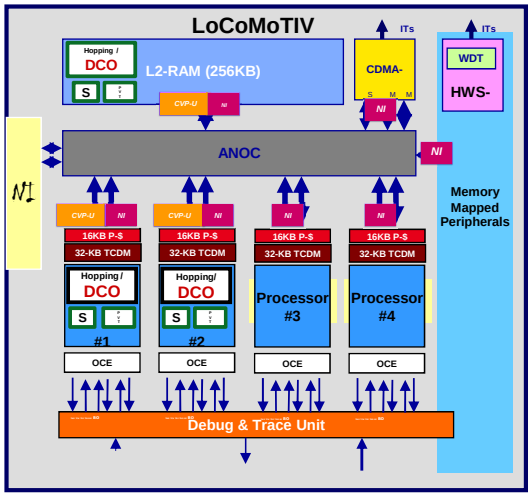


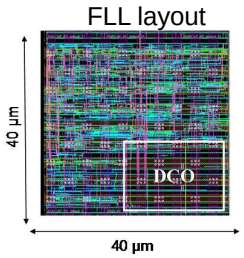
S: sensor
A: actuator

x: system state (not always fully measured)

Control for MPSoC: genesis

- Management of PW consumption
  - **Frequency Locked-Loop** FLL (collaboration LISAN)
    - (quasi-)Linear system
      « robust » approach
      (pole placement)
      32nm → 28 nm
      65 nm
      HW implementation of control law
    - Non linear control approach → **SW** saturations/ NL
    - Similar results





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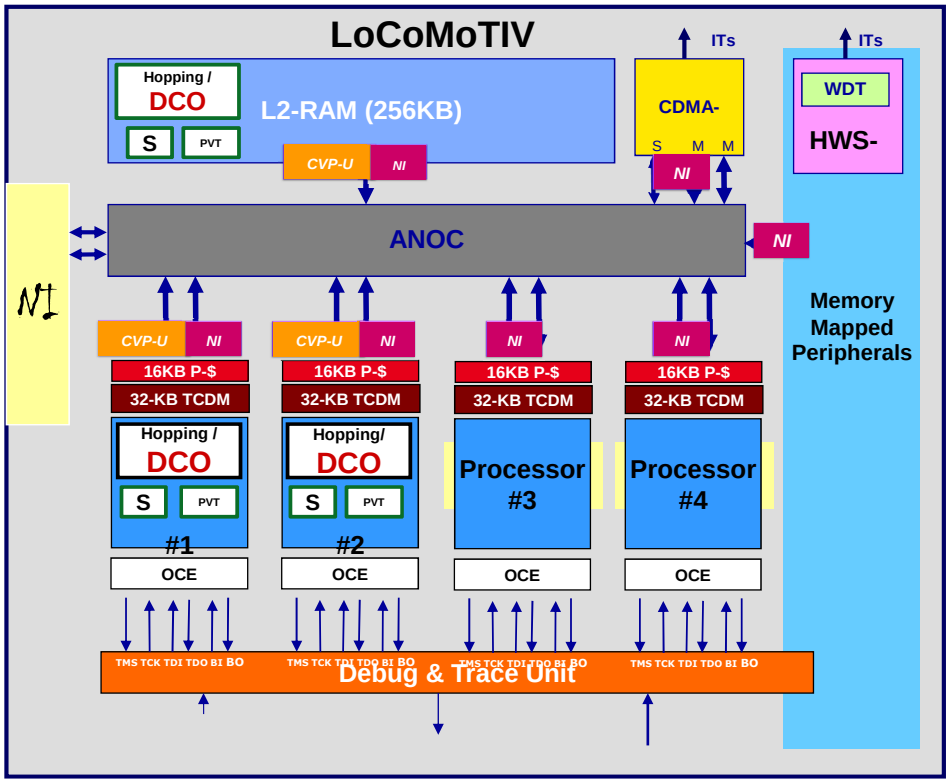
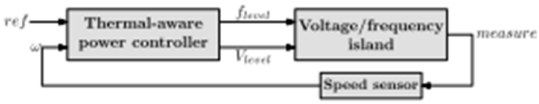
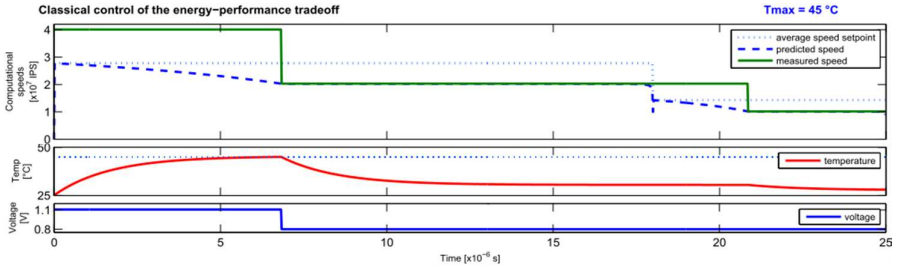


Control for MPSoC

- PW consumption management





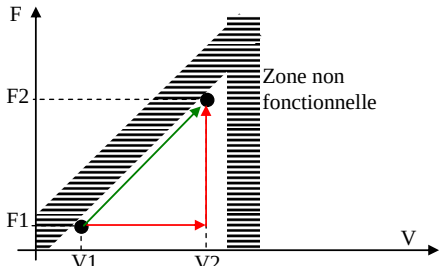
DVFS
[S. Durand, doctorat INPG, 2011]

- Collaboration CRI-INRIA (NeCS team)
  DVFS under thermal constraints

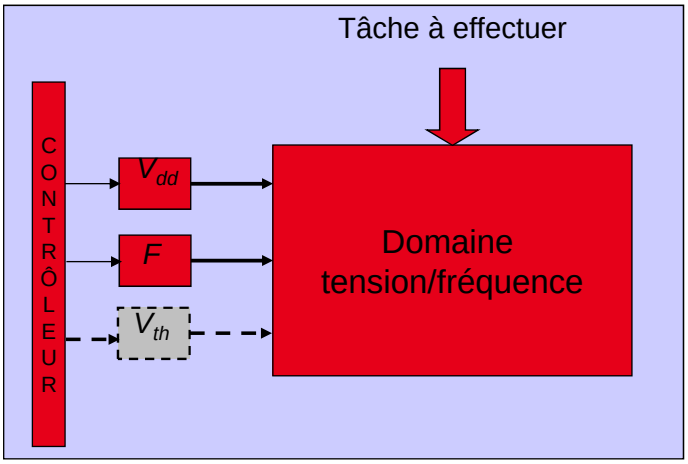
Several VFI → towards distributed control

Control for MPSoC

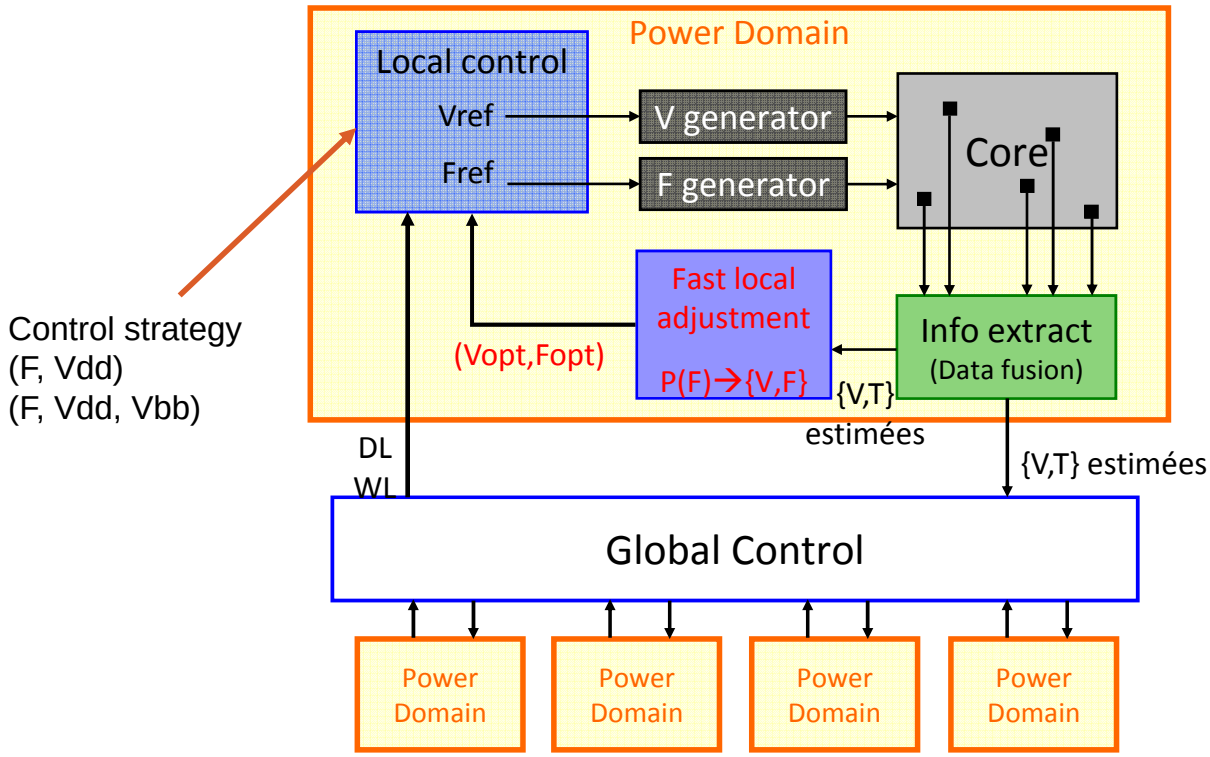
- PW consumption management
  - **Joint V/F control**



  - 3ème actuator (Vth) ??



Outline



Temperature and Fast Voltage On-Chip Monitoring using Low-Cost Digital Sensors

Travaux de Lionel Vincent

UNIVERSITÉ MONTPELLIER 2 SCIENCES ET TECHNIQUES

Laboratoire d'Informatique de Robotique et de Microélectronique de Montpellier
LIRMM

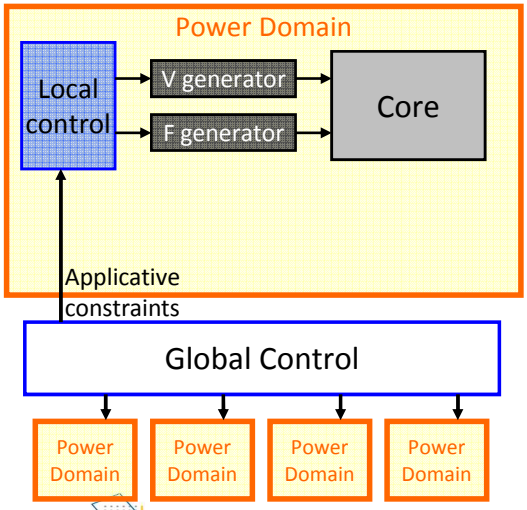
Embedded electronics

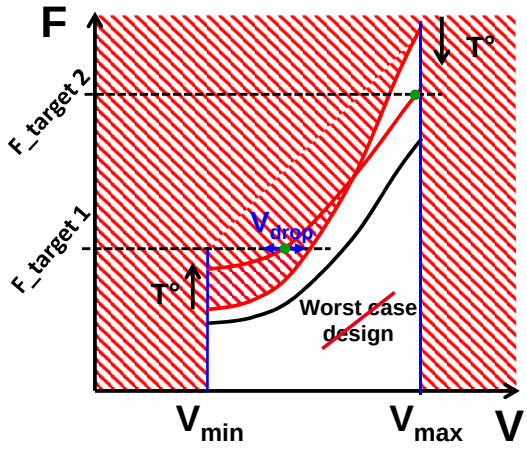
Performances

Low power Consumption

⇒ **Distributed Architectures and Management**

⇒ **Usually : DVFS in each resource**

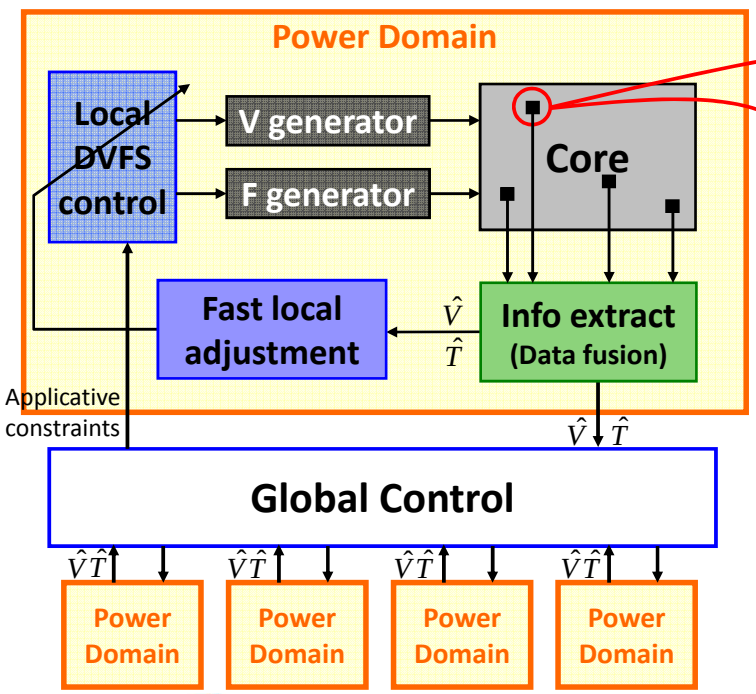


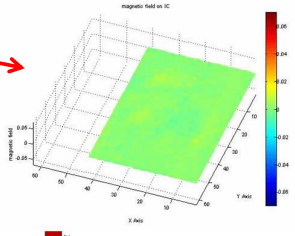


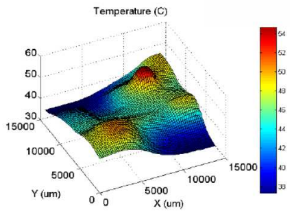
⇒ **Monitor the variability**

Adaptive architecture

⇒ AVFS : Adaptive Voltage and Frequency Scaling : Adaptive architecture to mitigate local but also dynamic PVT variations







⇒Reach the **most energy efficient** and safe operating point

Sensor for variability monitoring

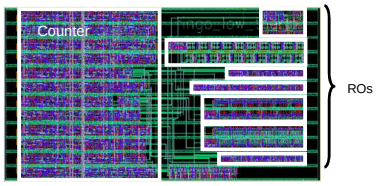
Ref: 2nd European Workshop on CMOS Variability **VARI 2011,** L. Vincent, et al., "A Fully Integrated 32nm Multiprobe for Dynamic PVT Measurements within Complex Digital SoC".

⇒ Proposed sensor : Multiprobe

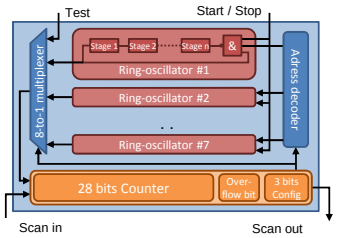
⇒ Standard library cell : **Easy to design**

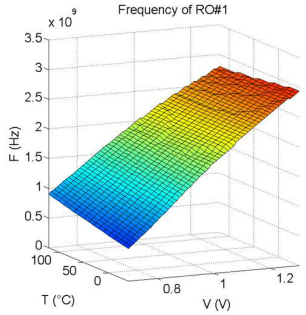
⇒ Small : **Easy to integrate** and **duplicate** many times in a core

⇒ Values of V and T **not directly readable**

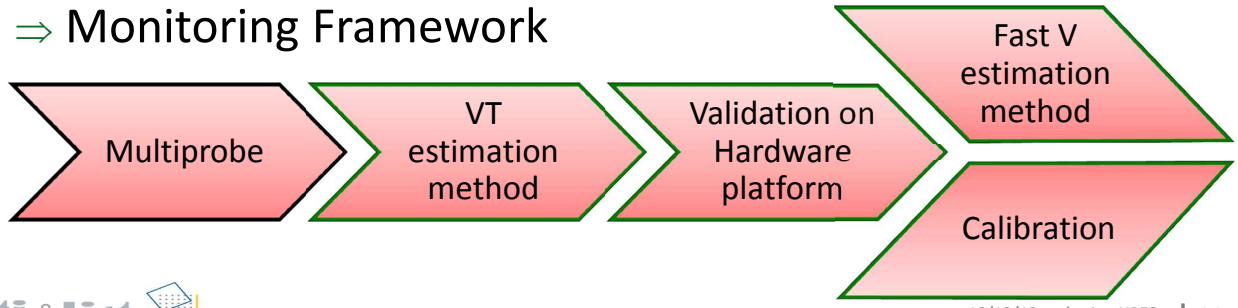


31µm x 14.4µm = 450 µm² in CMOS 32nm



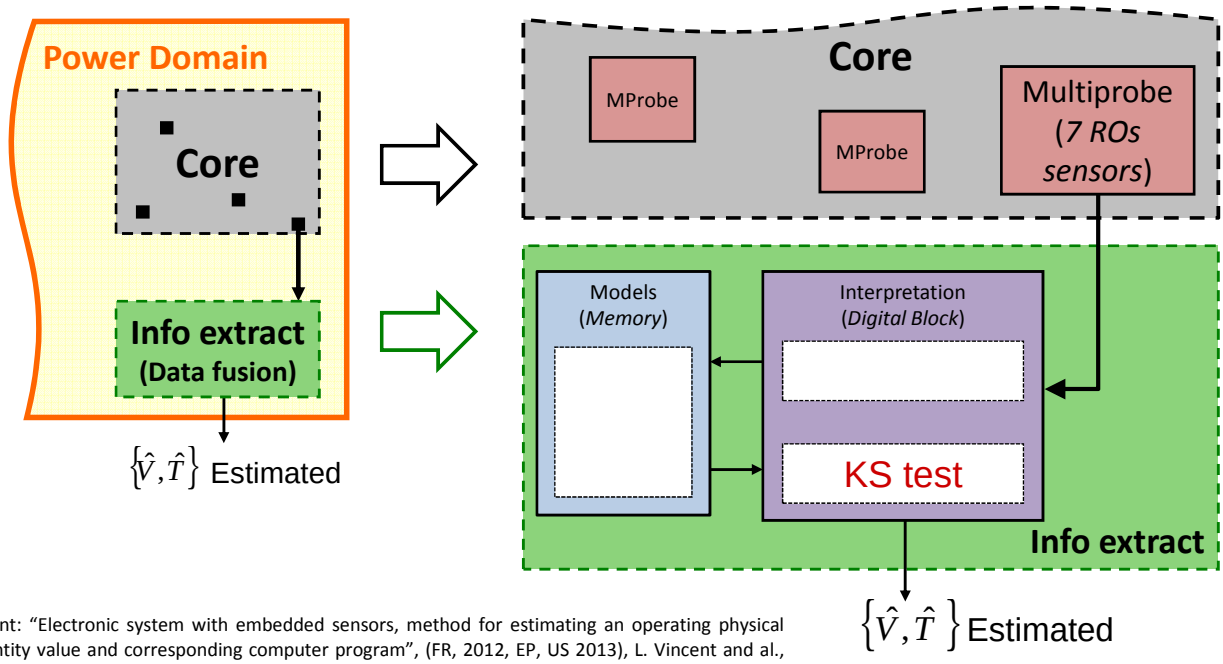


⇒ Monitoring Framework



Data fusion based on KS test in IC

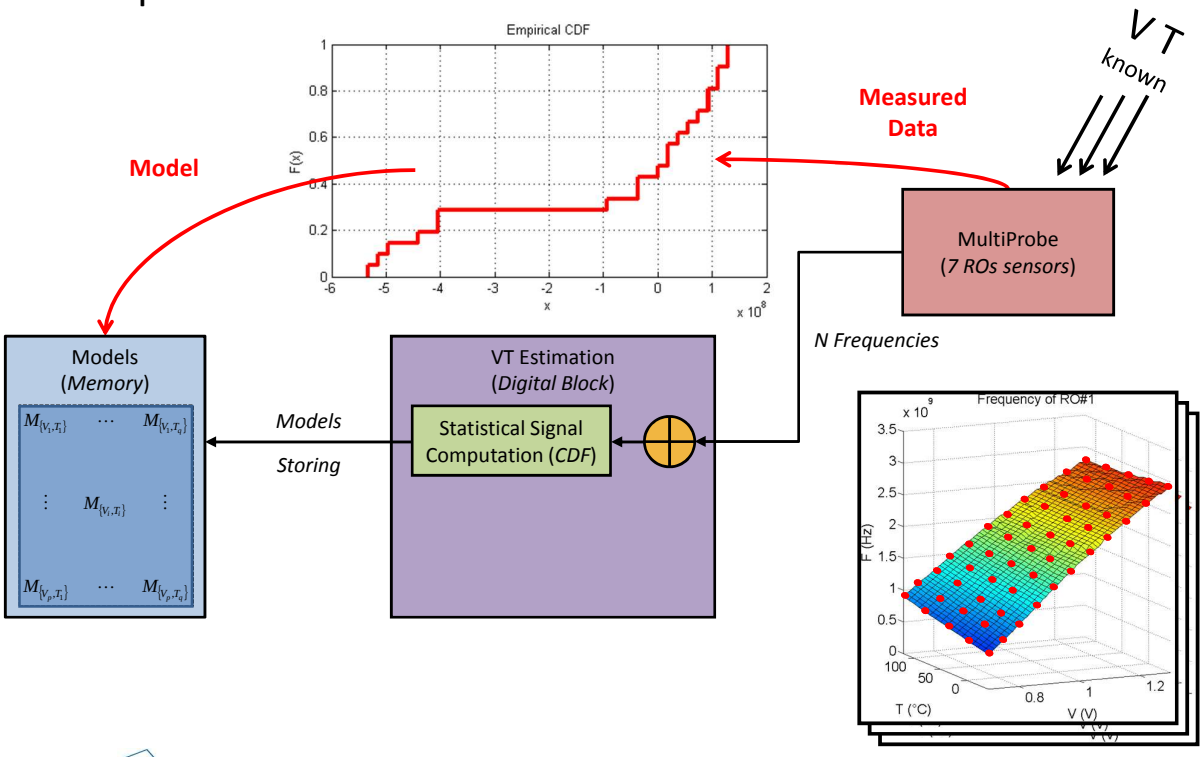
- **Comparison** between Measurements and Models using Kolmogorov-Smirnov test



Patent: "Electronic system with embedded sensors, method for estimating an operating physical quantity value and corresponding computer program", (FR, 2012, EP, US 2013), L. Vincent and al., N° E.N. : 12 54781, Date : 24/05/2012 In cooperation with LIRMM (P. Maurine)

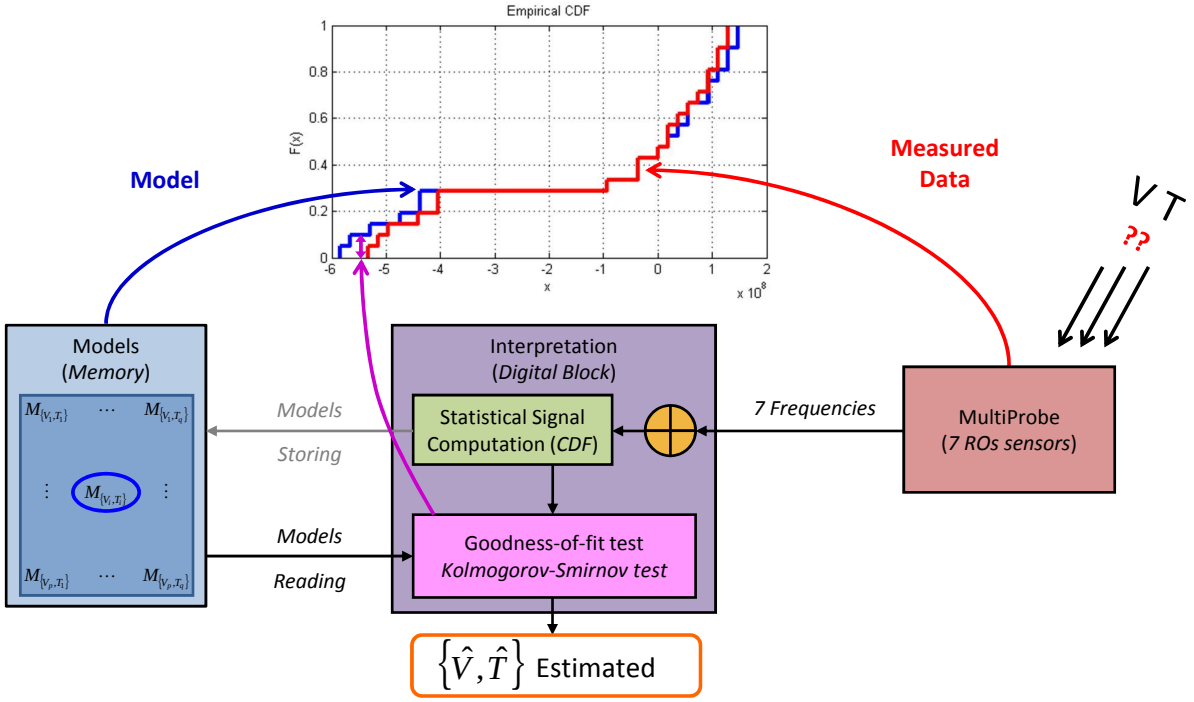
Ideal calibration phase

- Principle : Store some Measurements as Models

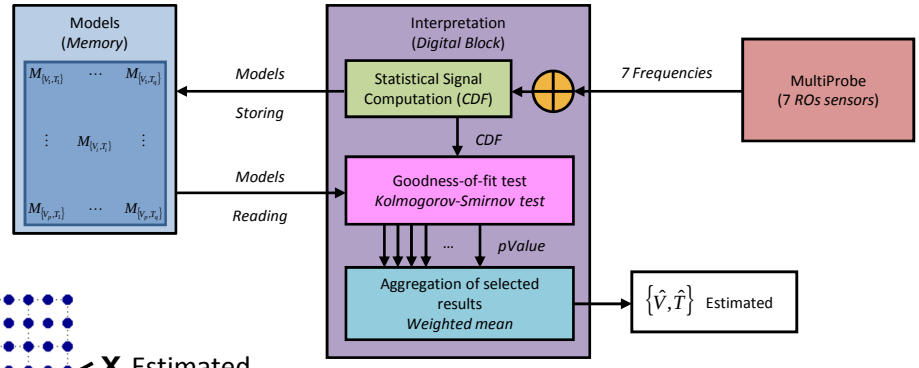


Running-time phase

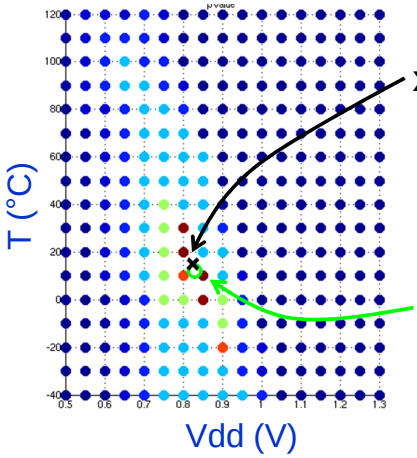
- Based on goodness-of-fit hypothesis test



Results: method validation



Dots = models M
- Discrepancy
- Similarity



X Estimated state
V = 0,831V
T = 11,66°C

O Conditions applied
V = 0,83V
T = 12°C

Ref: **DAC'12** "Embedding Statistical Tests for On-Chip Dynamic Voltage and Temperature Monitoring " L. Vincent et al.

Average estimation errors of **3.7mV** and **6.2°C**

⇒ Equivalent to timing margins in re-adaptation policy < **3%**

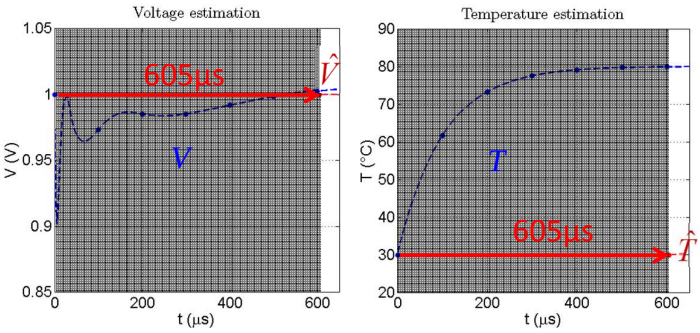
Dependent on:
- The number of models
- The statistical test choice
- The pre-treatment of the measurements

Performances on hardware platform

- Software implementation on SThorm platform
  - 2500 cycles by tested model

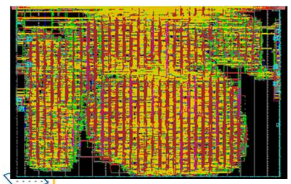
  ⇒605µs @ 500MHz

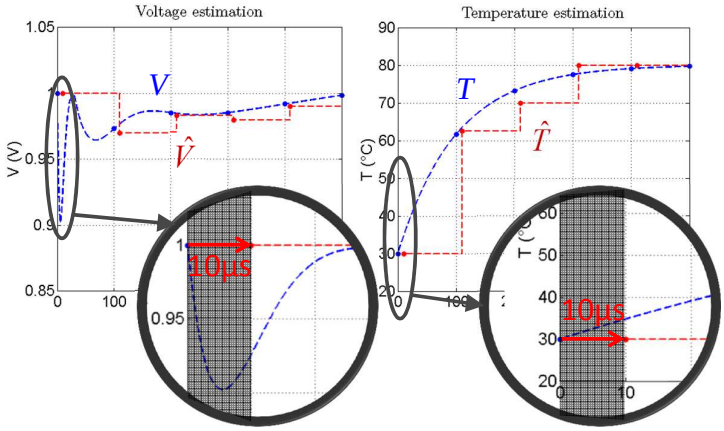
Ref : D. Melpignano and al. Platform 2012, a many-core computing accelerator for embedded SoCs : Performance evaluation of visual analytics applications. Design Automation Conference (DAC), 2012



- Hardware accelerator:
  - 42 cycles by tested model
  - 10kbits memory
  - 9kgates

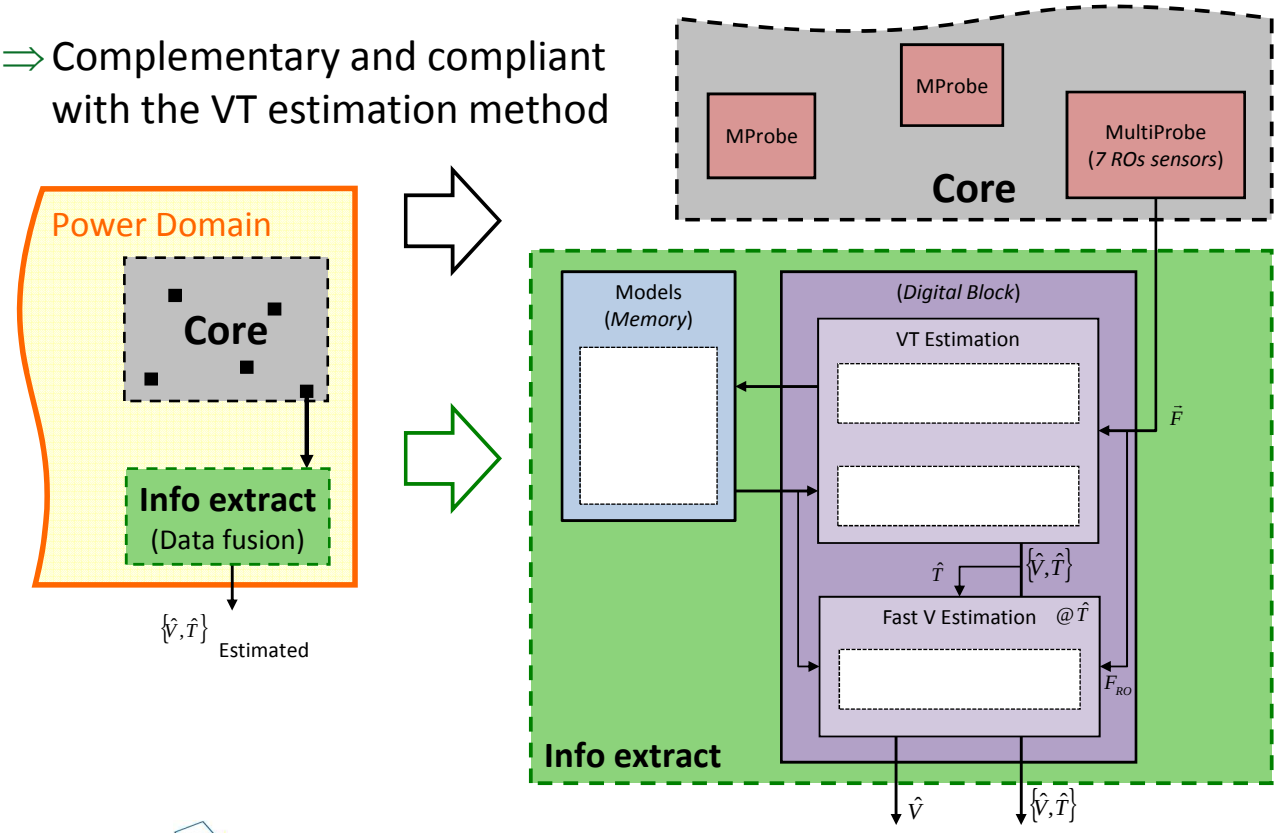
  ⇒10µs @ 500MHz





Need for a Fast Voltage monitoring

⇒ Complementary and compliant with the VT estimation method

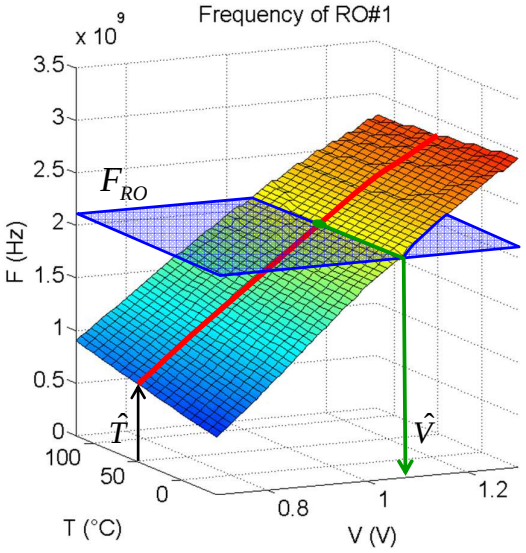


Fast Voltage monitoring method

⇒ Principle : Take advantage of the dynamics disparities

⇒ *Hypothesis : The temperature is constant during the measurement*

⇒ On SThorm : $t_m \approx 0.66\mu s << t_{T°}$ time constant (>10µs)



⇒ Influence of the chosen RO :

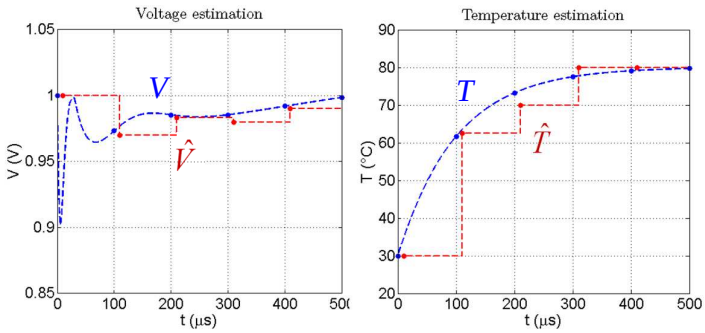
RO	Inverter	LowTherm	LongWire	Latches	Xor	Ncap	Pcap
μ_{ϵ_V} (mV)	3.24	2.31	2.84	2.56	2.90	3.43	3.80
σ_{ϵ_V} (mV)	3.94	4.94	3.56	3.30	3.64	4.14	4.60

Performances on hardware platform

- Hardware accelerator :
  - 2,3 cycles estimated by tested model

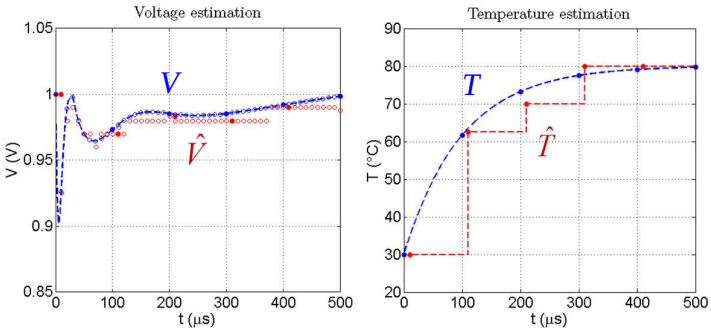
  ⇒0.28µs @ 500MHz

  ⇒Limited by measurements: 0.66µs



x18

- Monitoring using the two complementary methods



Summary

- A complete framework to monitor Voltage and Temperature variations on wide range of dynamics
  - Low-cost digital and general purpose sensor
  - VT estimation methods
    - VT conjoint data fusion method: Use of goodness-of-fit hypothesis tests
    - Fast voltage monitoring method
  - Calibration method
- Validated on SThorm hardware platform

- A complete framework to monitor Voltage and Temperature