Variation mapping for analog devices

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Analog Versus Digital (1)

- Digital
  - Gates (level, delay)
  - Few interactions
  - Binary output
  - Testability (DFT, SCAN, BIST)
  - Fault propagation (Functional test)
- Soft defects
  - Easy to manage (Dynamic Laser Stimulation: SDL, LADA, …)
- Hard defect
  - Sometimes tricky (opens, fault propagation, no leakage)

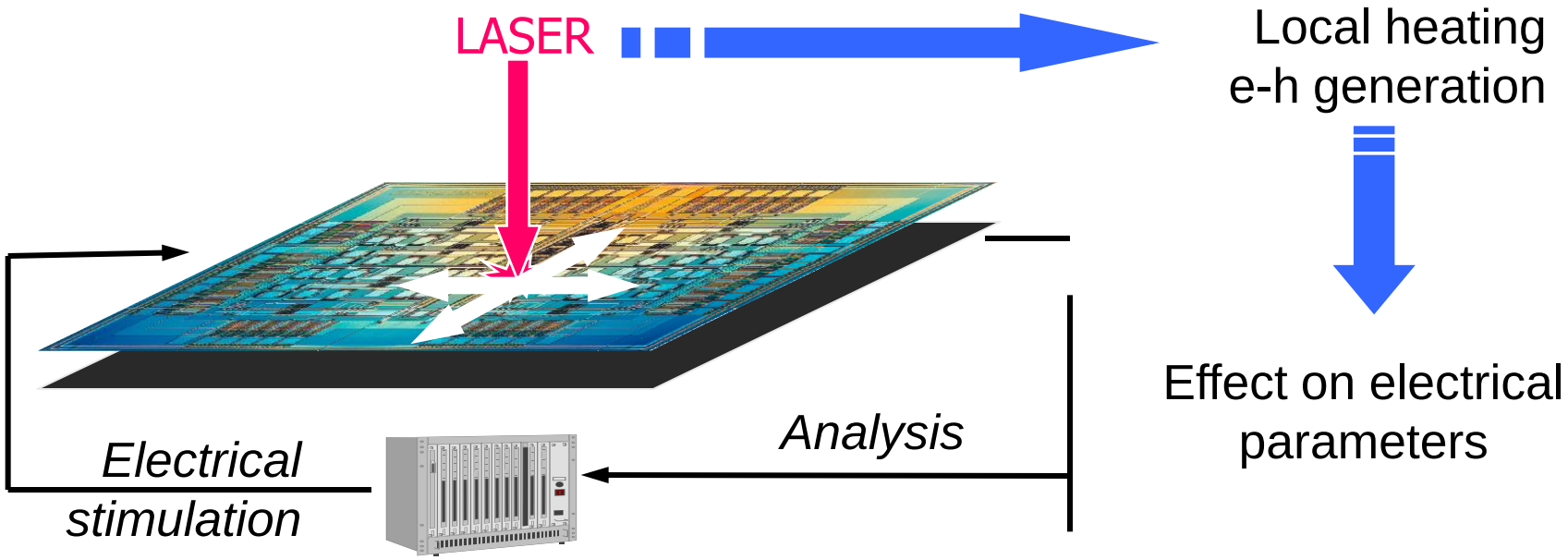
Analog Versus Digital (2)

- Analog
  - Full set of parameters
    - At transistor level
    - At device level
    - Analogue
  - Interactions between stages (backward coupling)
  - “Poor” testability
- Soft defects
  - Difficult (all the areas are laser sensitive) except some Mixed Mode ASIC (DLS)
- Hard defect
  - Easier? (no fault propagation)

Needs for analog device

- Measure the analogue parameters at the outputs of the IC
  - Continuous (no longer level / time)
  - Various (voltage, current, bandwidth, distortion, noise …)
- While few external inputs are available (poor testability)
- Establish the link between external analog measurements and abnormal device behavior
- Verify at elementary structure level (transitor probing)

Laser Stimulation Principle



- Local temperature increase:
  - Resistance change
  - μ, VT …
  - Thermal expansion
  - Thermoelectric generation
- Photo electric effect:
  - Current source

Why laser stimulation?

- Ability to activate internal node
  - All the nodes can be individually activated
  - The effect of the stimuli can be measured outside
- Ability to adjust stimulation
  - Thermal
  - Photoelectric
  - Continuous (analogue modulation)
- Direct measurement of the effects on the IC pins
- Drawback: understand the effect

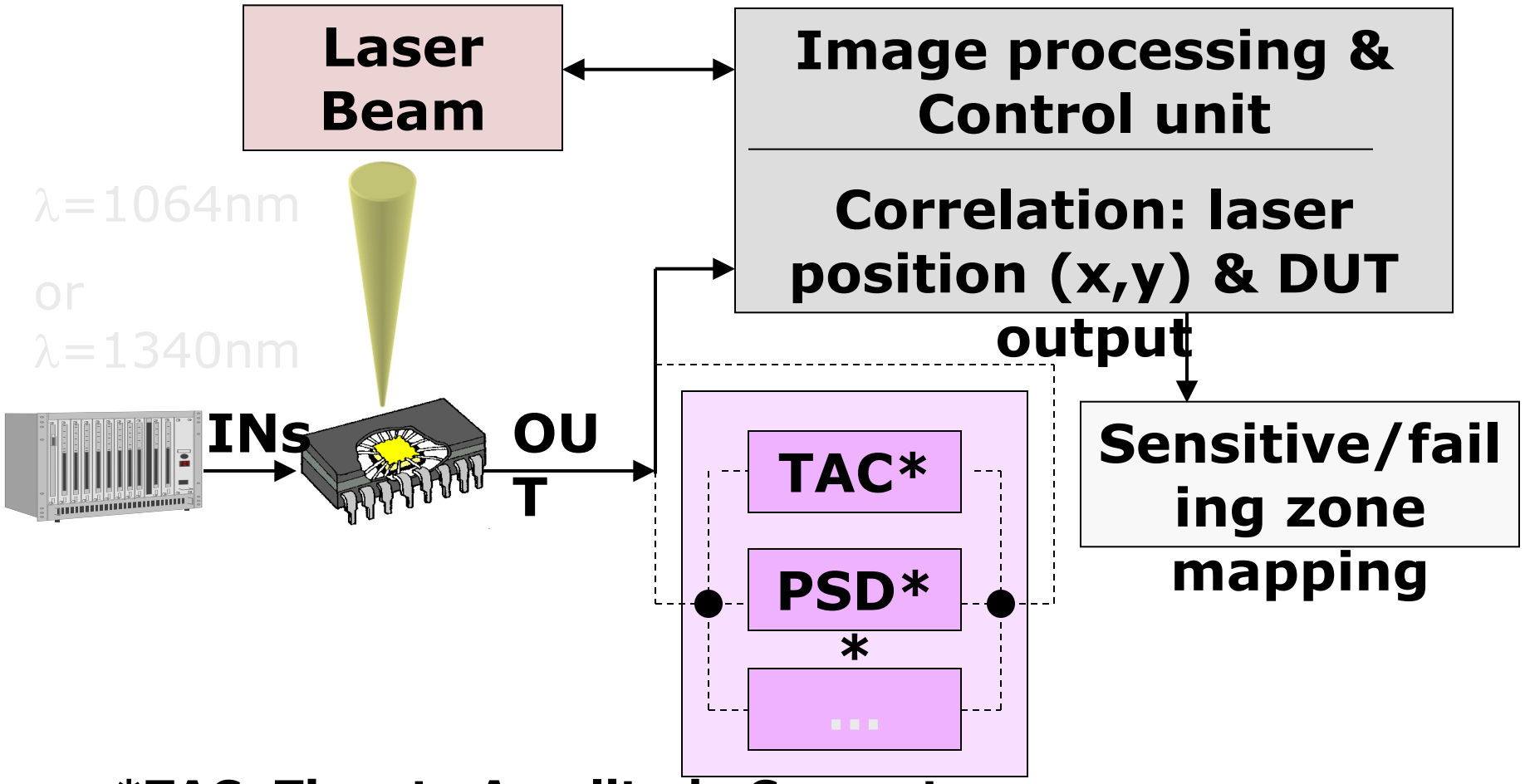
x Variation Mapping principle

- xVM= x Variation Mapping
- Laser induces slight electrical changes
- Analog approach (xVM)
  - Analog measurement of one or more electrical parameters relevant (or not) to the “defective” signature (delay, frequency, voltage,…)
  - Requires dedicated electronics
- Ex: Analog devices
  - OPA
  - Current mirror/ regulator
  - PWM
  - PLL
  - Comparators
  - Oscillators
  - …

Measurable parameters x:

- Output Voltage
- Current
- Noise
- Cut-off frequency
- Distortions
- Gain
- Offset
- Frequency
- Phase
- Delay
- Duty cycle
- Pulse width
- …

x Variation Mapping setup

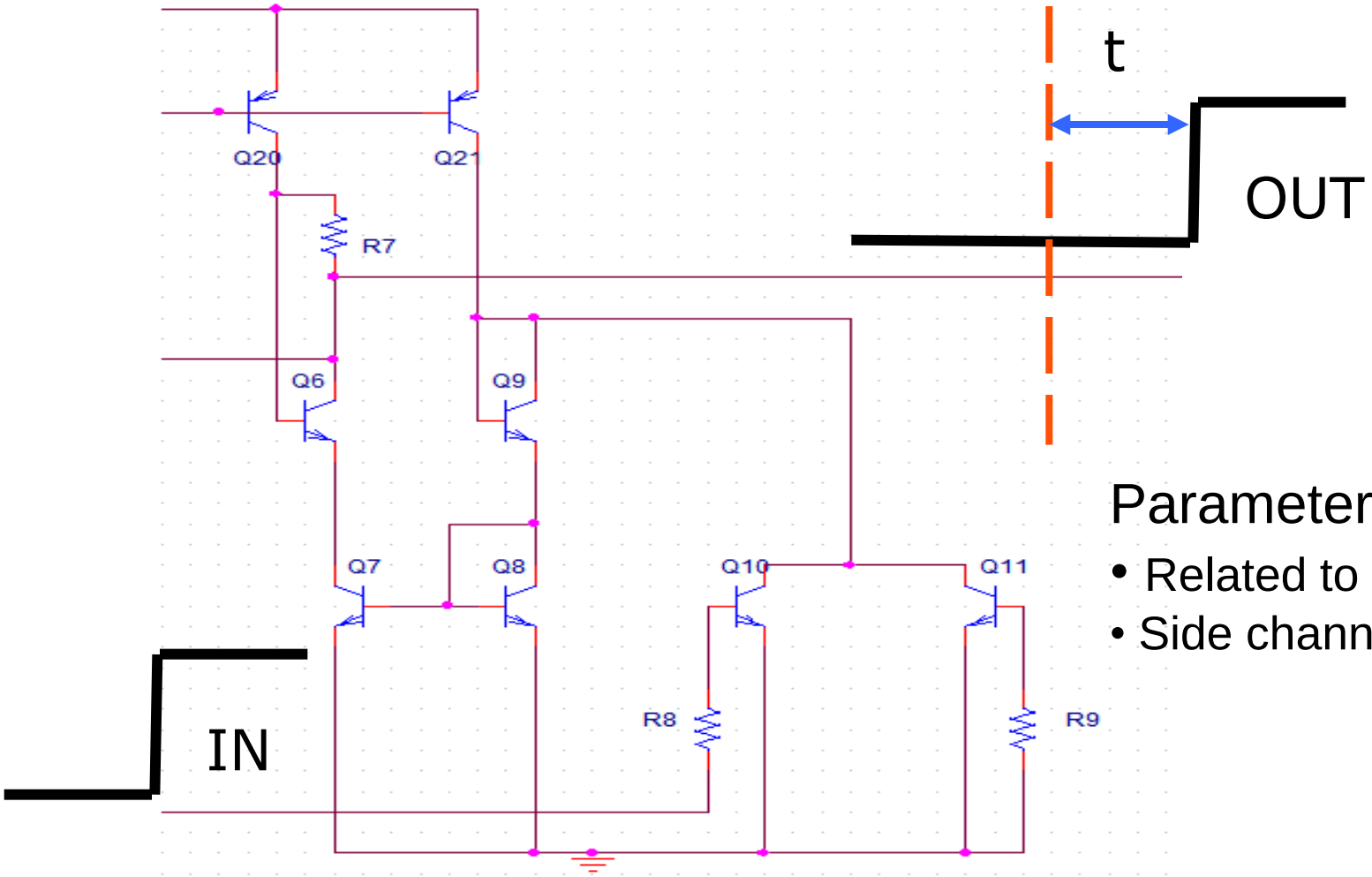


*TAC: Time to Amplitude Converter

**PSD: Phase Sensitive Detector

Example: DVM

- Power Amplifier driver block

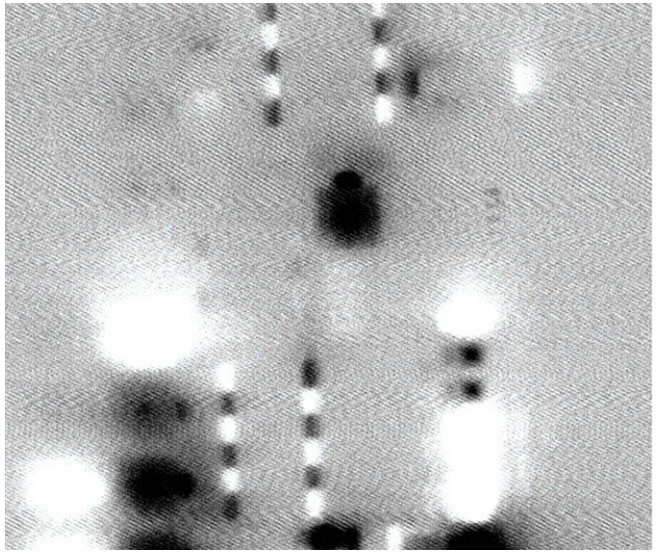


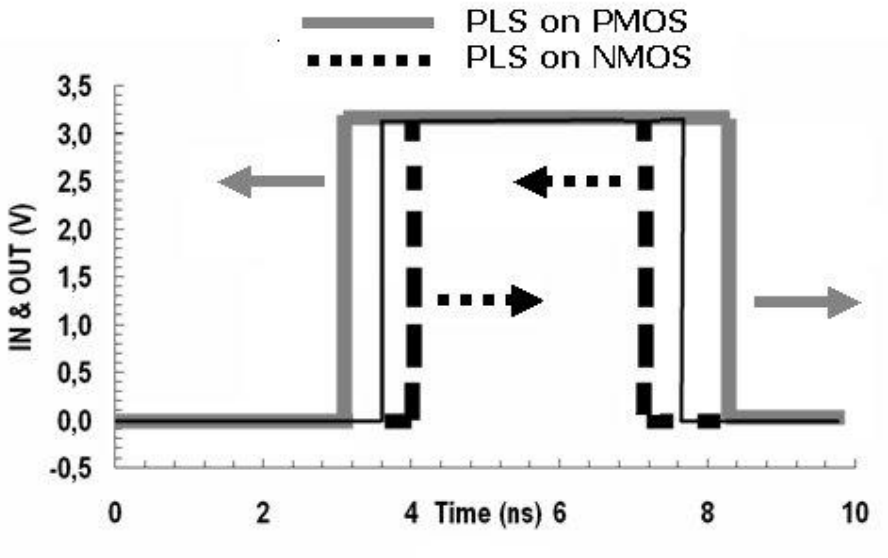
Parameter can be:

- Related to function
- Side channel

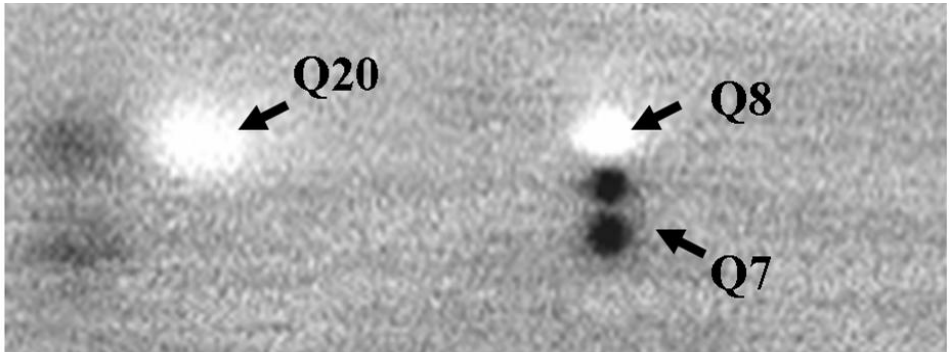
Understanding xVM images

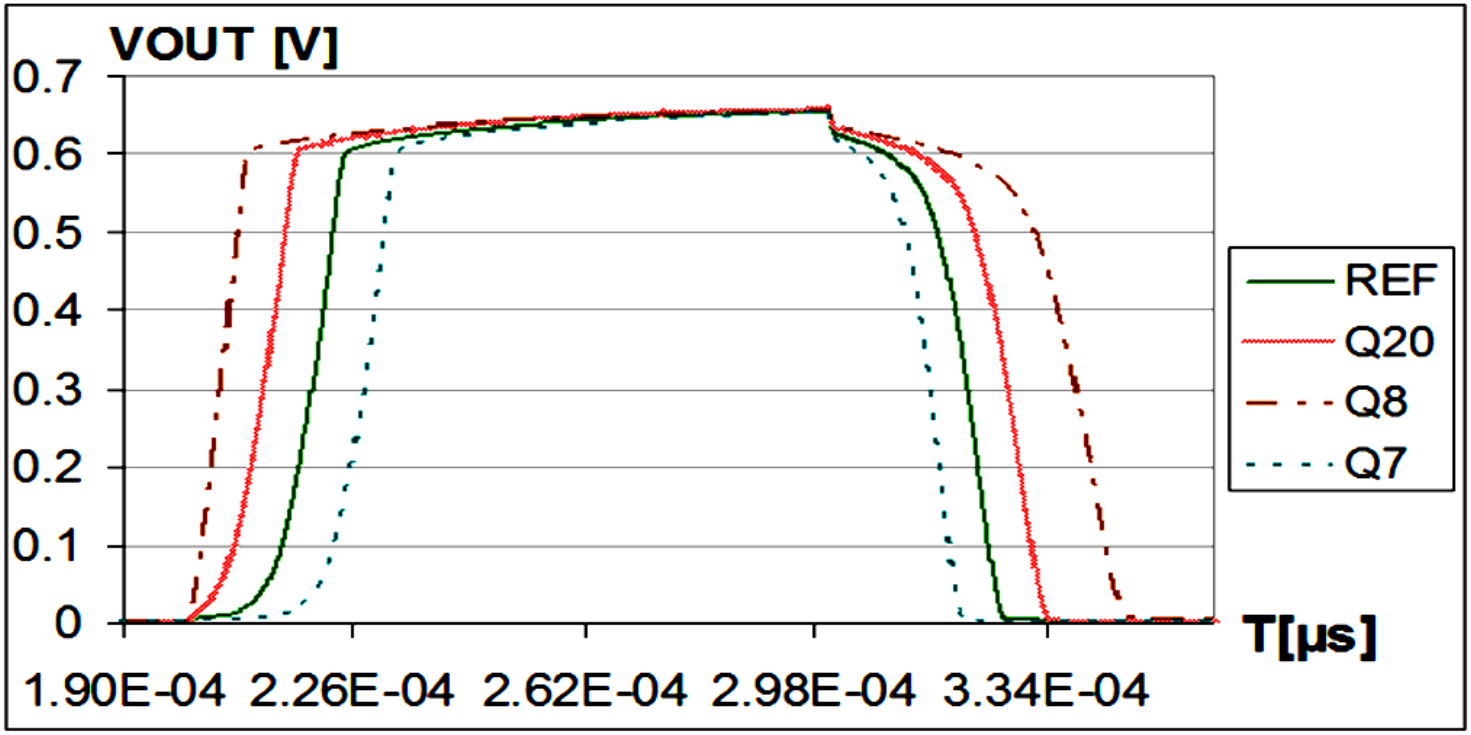
- Complex results
  - Even for good devices
  - All the sensitive areas are mapped
  - What is abnormal?
- Simulation approach
  - Understand the effect of laser stimulation on elementary structure
  - Understand how a defect modify it
  - Use these results at cell and full device level
- Can be reversely used (from signature to defect)



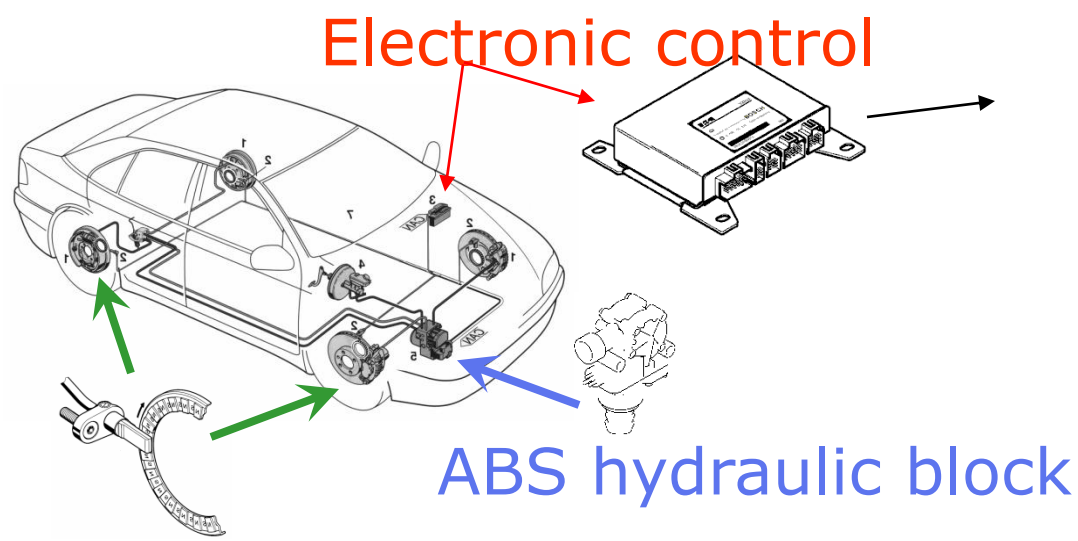


Simulation approach





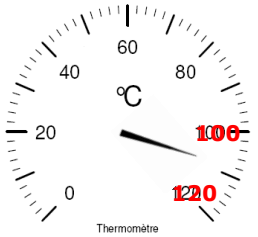
Soft defect failure analysis on MIXED mode Technology (1)



- **P**ower **C**ontrol **U**nit **A**nti Lock **B**rake **S**ystem
- TQFP100
- 4 metal layers
- Mixed mode IC

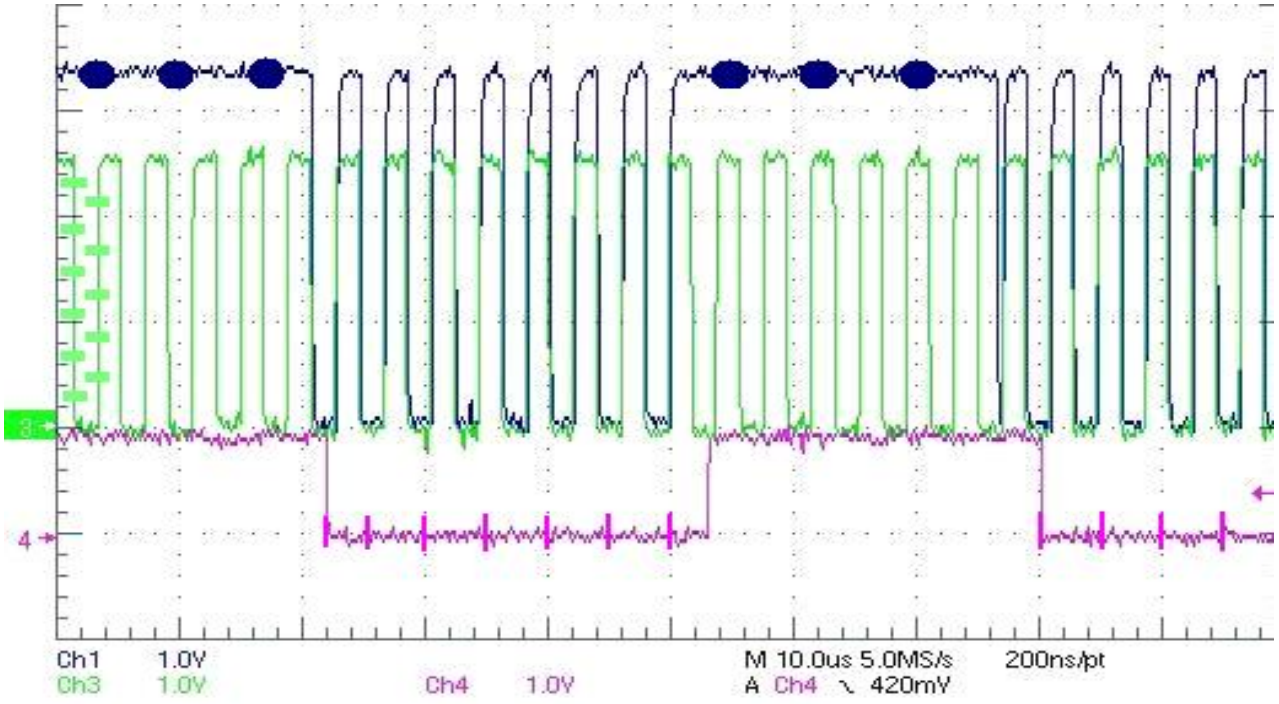
Functional failure conditions

The device fails when temperature is over 100°C



Soft defect failure analysis on MIXED mode Technology (2)

At high temperature, device becomes and stays fail
Electrical failure = No **Rx** signal = No data communication

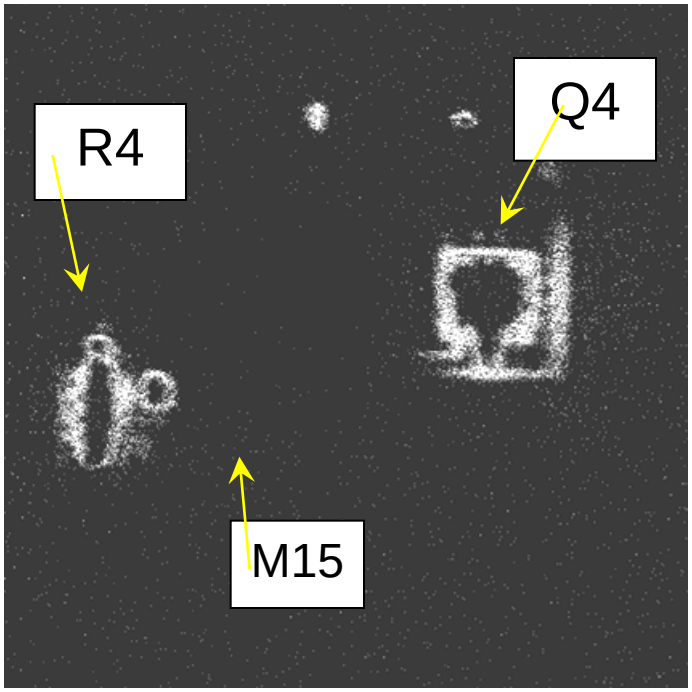


Tx

Rx

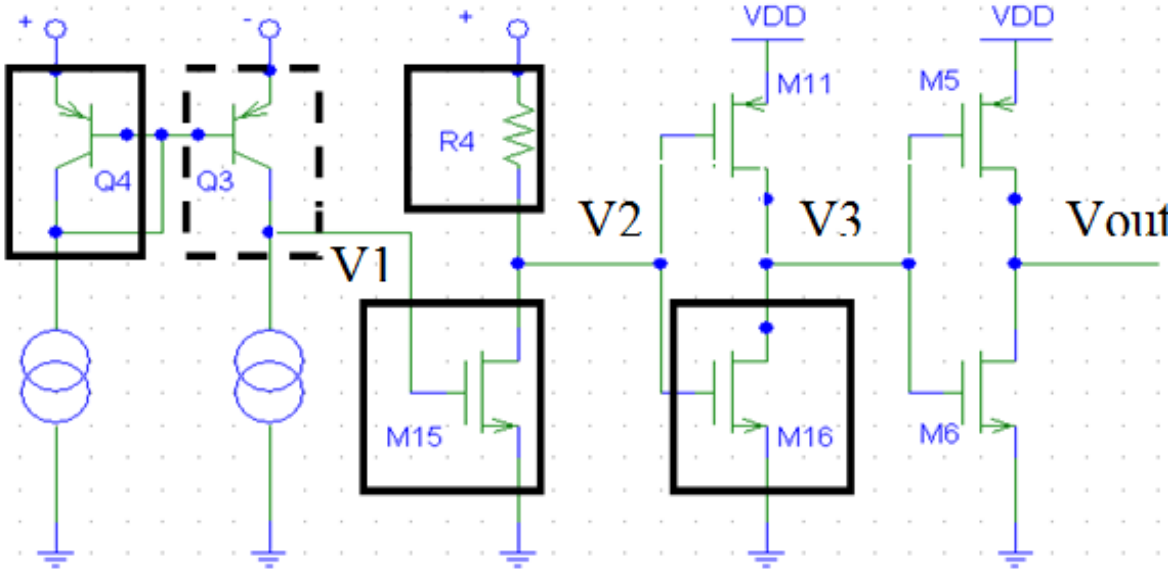
PASS/FAIL

Soft defect failure analysis on MIXED mode Technology (3)

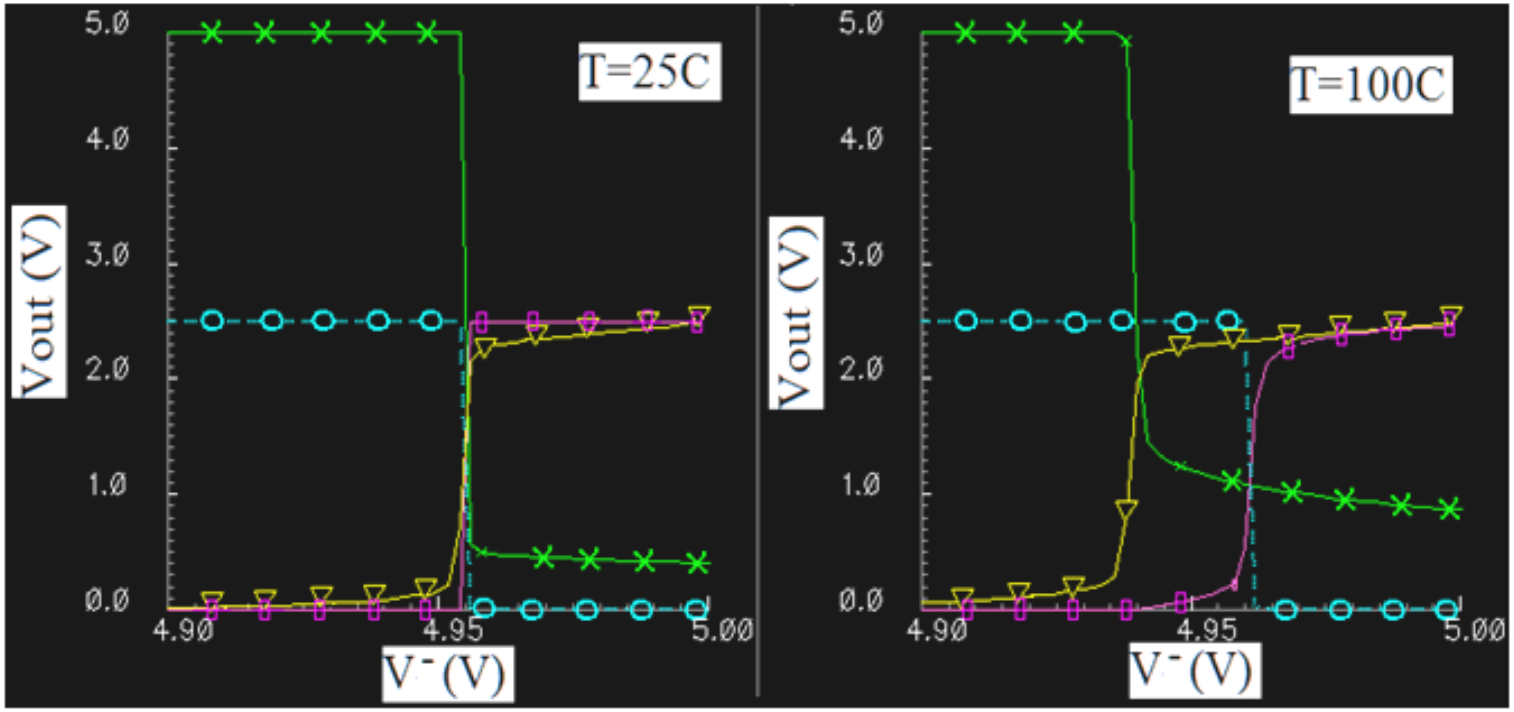


Backside DVM results: sensitive area under Thermal Laser Stimulation (TLS) for the temperature below 90°C (zoom: 80X).

Simplified electrical schematic of sub block highlighted by DTLS techniques and simulated in Cadence



Soft defect failure analysis on MIXED mode Technology (4)



a *b*

Electrical simulations: Plot of signal propagation in sub block highlighted by SDL at 25°C (a) and 100°C (b). V1: V, V2: X, V3: □, Vout: o.

R_{ds} of M15 is depends on T.

Undersized M15 (NMOS) transistor.

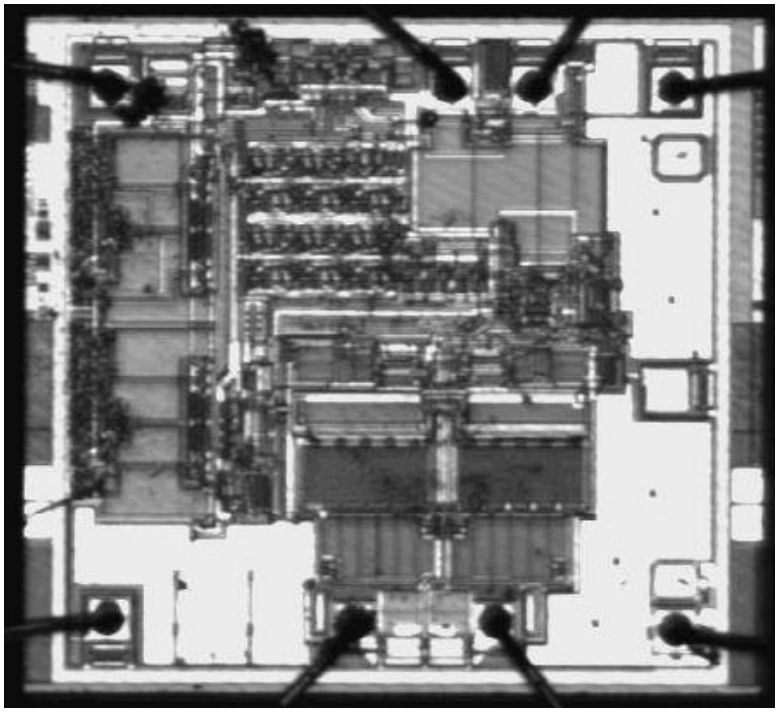
Example of design failure.

Multi xVM principle

- FA Purpose
  - One effect (delay, threshold …) can be the result of different causes
  - One defect can cause a lot of effects
  - Looking simultaneously at a lot of effect helps to find the unique cause
- Characterization purpose (need of multi channel)
- Margin analysis
- …
- Implementation
  - Real time map often limited to 1 channel
  - Multi channel acquisition performed at tester level
  - For all samples (multi channel, one pixel) x,y position recorded
  - Post processing of the data (could be quite real time with very slow scanning)

Multi xVM example

- Commercial, good device
- Operational amplifier set in a high gain configuration



- Bias condition: V+ = 1.5V, V- = -1.5V
- VIN = 50mVp-p sinusoidal signal at 1kHz

- Channel 1: I(t) + signal analysis
- Channel 2: V(t) + signal analysis