SystemC-AMS Modeling at Infineon Technologies Austria – AIM SC

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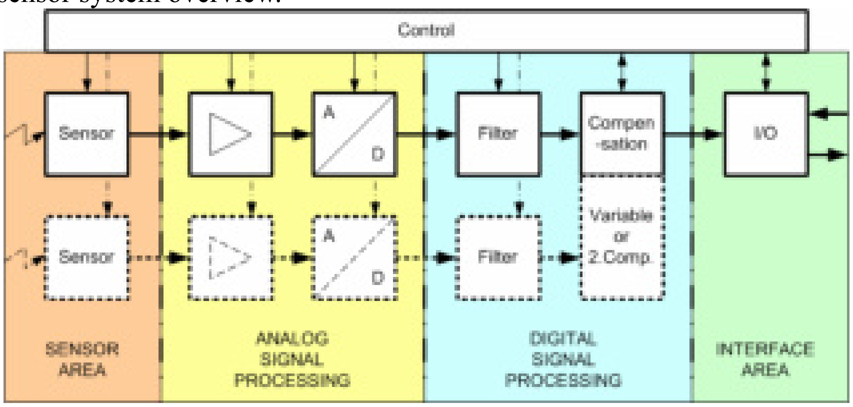
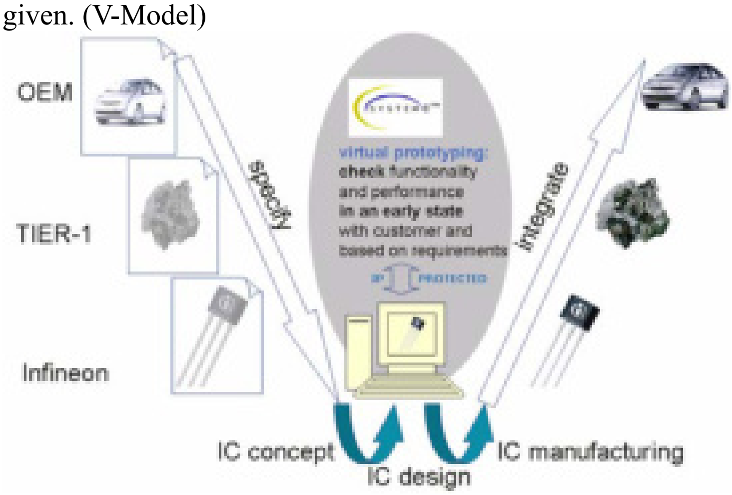
AUTOMOTIVE SENSOR SYSTEMS:
The requirements for modeling automotive sensors systems are shown on hand of a general automotive sensor system overview.



The requirements and solutions for modeling the physical behavior of capacitive/resistive/Hall/GMR or Inertia Sensor-cells are shown.
Modeling requirements of the analog signal path comprising ADCs and DACs of different conversion technologies like Switched Capacitor (SC) or Continuous Time (CT) with feedback loops are given.
Modeling of the digital signal processing for hardware-filters and for a configurable inhouse DSP called "Intelligent State Machine (ISM)" is presented as well as modeling of different interfaces used in Automotive Systems.

Also an overview of the information flow beginning at the customer down to the implementation will be given. (V-Model)



As summary all the requirements with their up to now used solutions and possible improvements will be given.

SystemC-AMS Modeling of Embedded Sensors for Automotive Applications

Infineon Technologies Austria AG
Automotive Industrial and Multimarket
Sense & Control

Wolfgang Scherr, Wolfgang Granig
26.June 2007

Never stop thinking

Who I am (Wolfgang Scherr)

- Diploma thesis "A Configurable Controller Core for Embedded-SoC Applications in Sensor-ASICs."

- Working since 1996 for the Siemens Design Center Villach
  - >6 years design experience (also before IFX with part-time jobs)
  - Responsibilities for Communication and Automotive groups:
    - M/S verification
    - M/S simulation methodology in Villach as overall project leader
    - SPICE and Modelsim expert; Author of in-house Modelsim+SPICE coupling
    - design expertise for m/s systems, including embedded processors

- Since 2001 working at Automotive Sense & Control
  - >5 years sensor system experience
  - Concept/System engineer of sensor products (magnetics/pressure)
  - Interests and responsibilities:
    - system modeling methods and prototyping within AIM (SC)
    - still interest in design methodology
    - sensor ASIPs and specific firmware development flows
    - embedded HW architectures, C compilers, HW-a/HW-d/SW partitioning
  - Head of concept engineering group at Sense & Control, Villach
  - Member of OSCI SystemC-AMS working group

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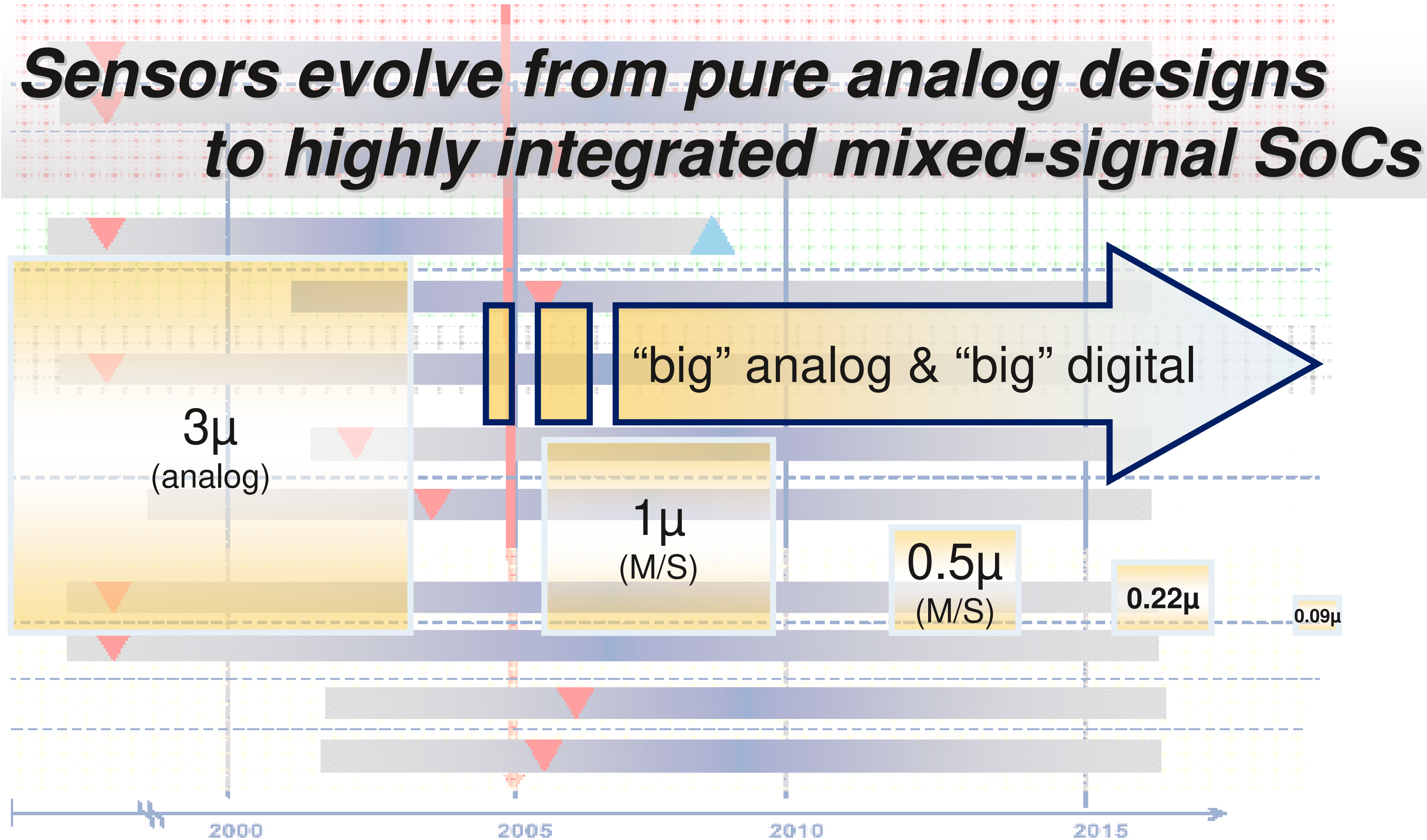
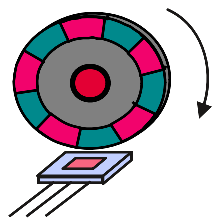
Technology Trend for Integrated Sensor Products

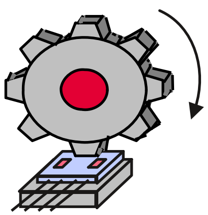


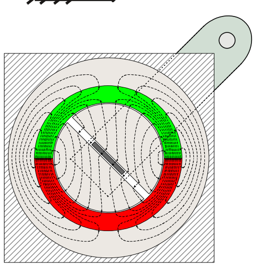
Sensor Products developed at IFX in Villach

Example 1

	Powertrain	Safety	Body and non automotive	
Integrated Pressure	MAP: KP110/115 BAP: KP120/125	Side Air Bag: KP100 KP105 KP107		Integrated Pressure
Differential Hall	Crank: TLE4925 Cam: TLE4980 Gear Tooth: TLE4923, TLE4921, TLE4953	Wheel Speed: TLE4941/42/47	TLE49x5 TLE49x6 Low Power: TLE4913/17	Hall Switches
Linear Hall	Pedal, Throttle Pos., Industrial, I-Sense: TLE4990, TLE4997, TLE4998	Angle sensor: TLE5010 TLE5011 Wheel speed: TLE5044		
		Integrated GMR		





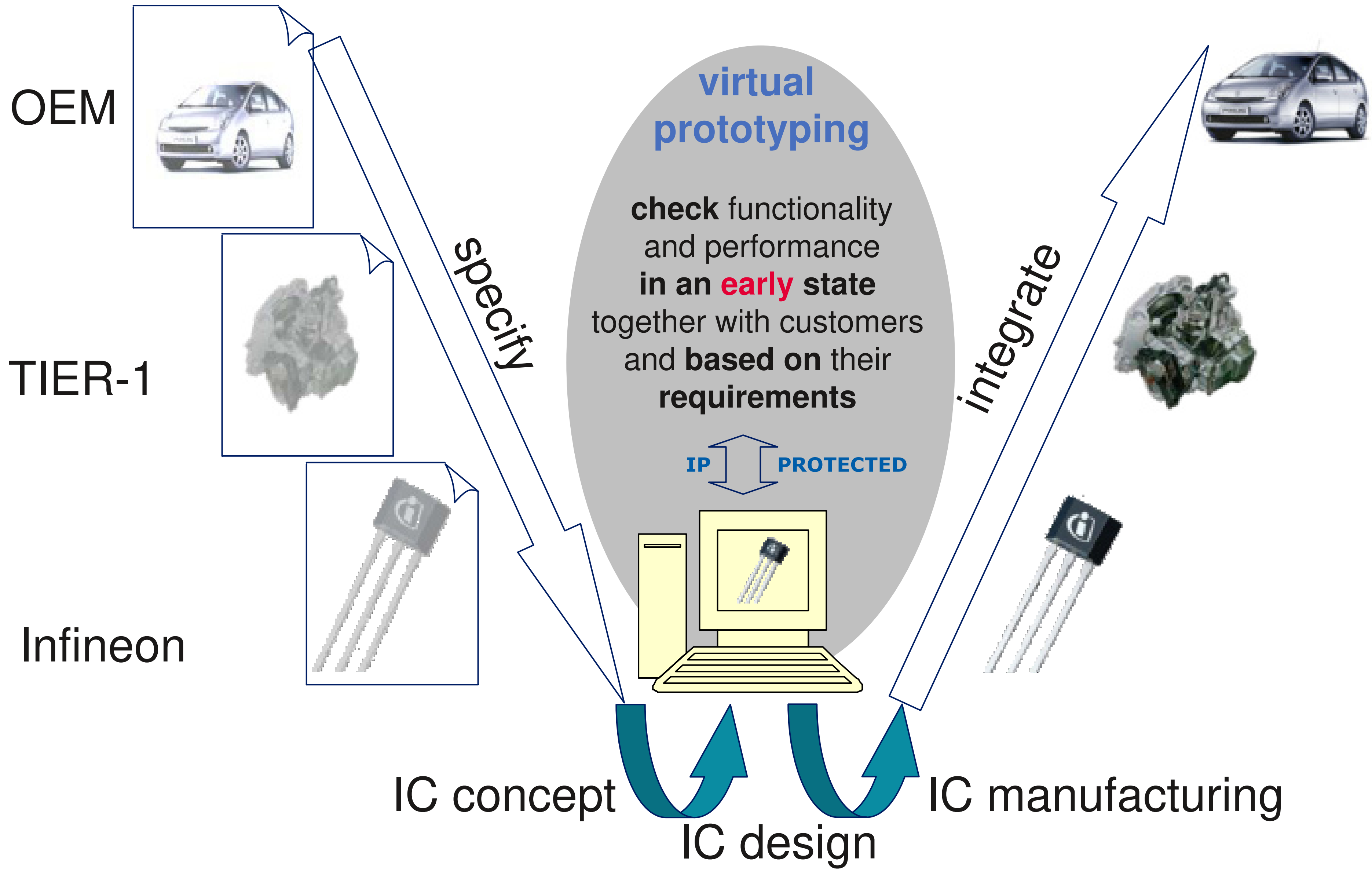


45 Degrees

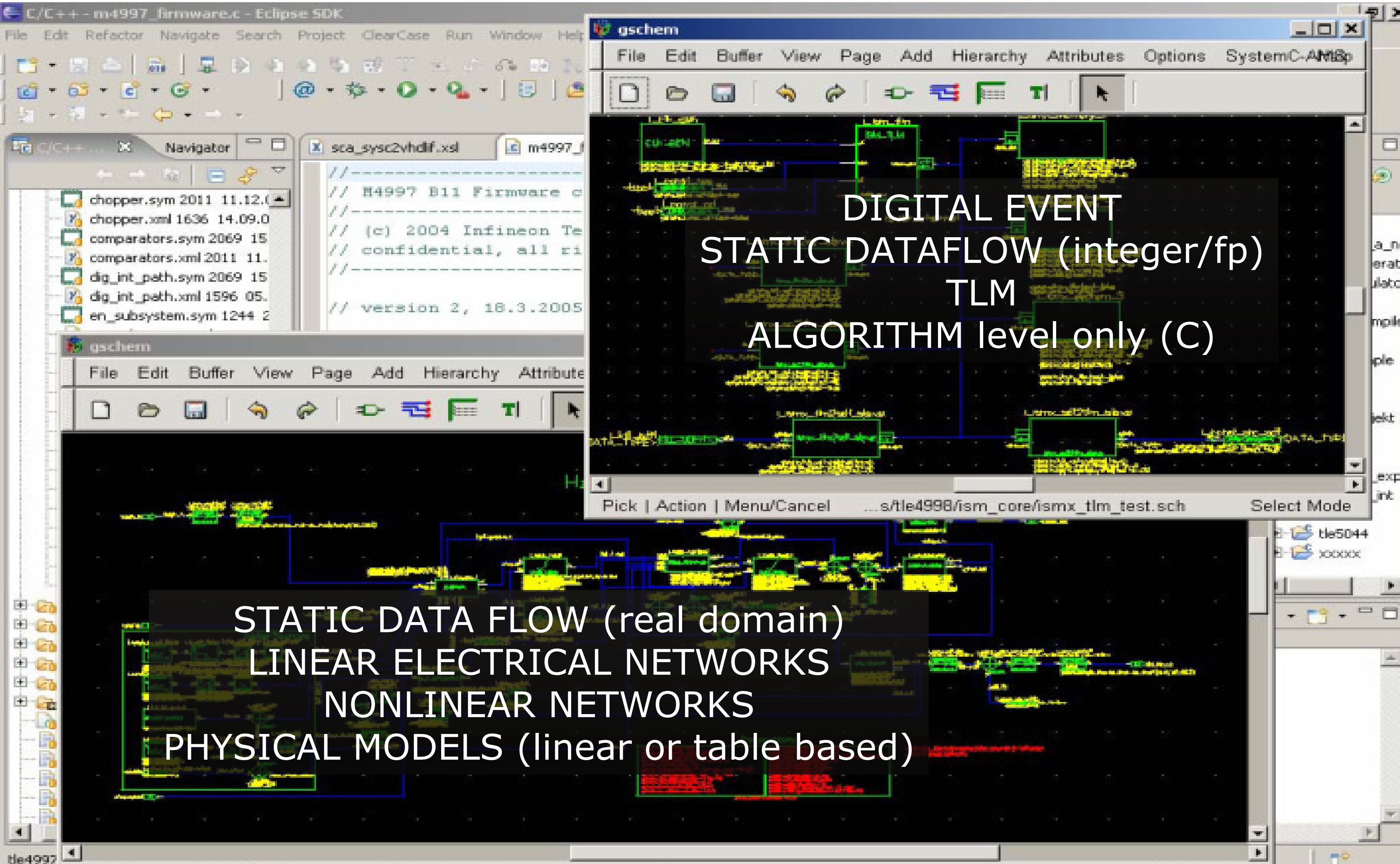
Example 2

Example 3

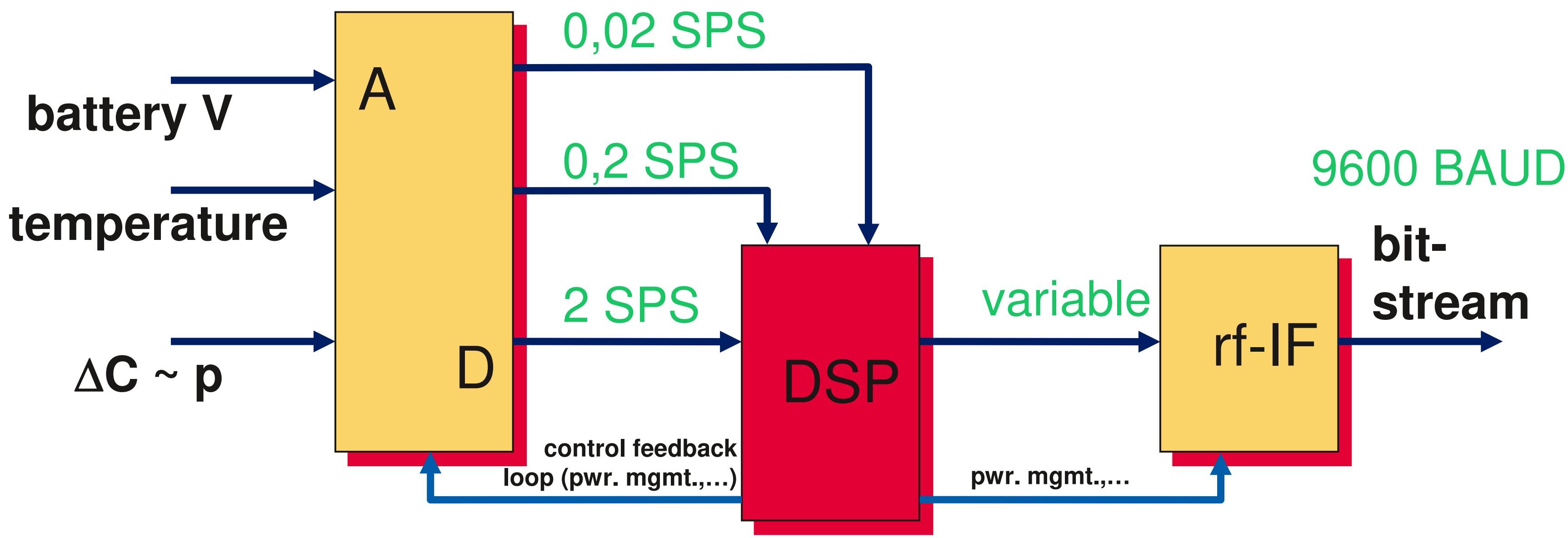
Driving a standard for virtual system modeling, get rid of long „loops" in the development cycle!



Sensor SoCs require mix of physical, electrical, SDF, TLM and software/algorithm models to one interacting model



Sensor applications and complexity in time domain shown on an example… 1/2



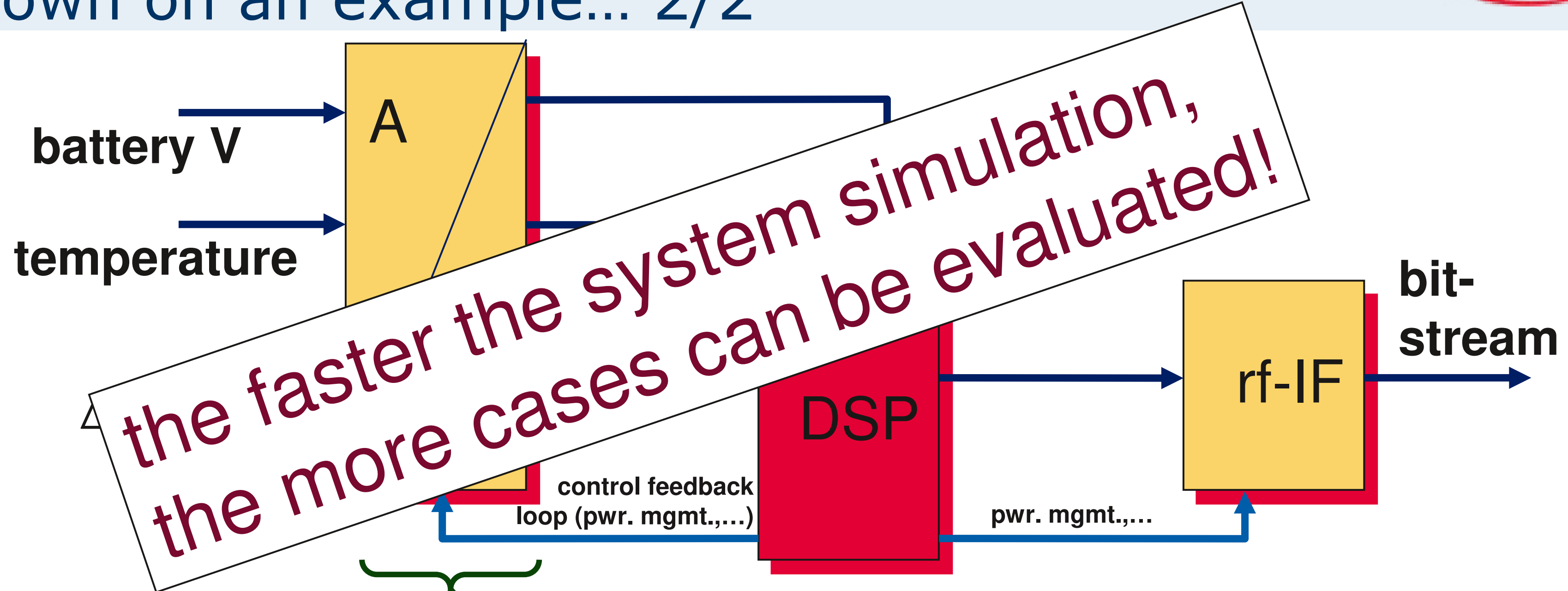
- **Temperature compensated TPMS sensor (MEMS)**
  - application (driving) 2 … s. (1/t ~ 250µHz)
  - battery voltag… te ~ 20mHz
  - temper… 200mHz
  - pr… (wakeup) ~ 2Hz
  - an… sing rate ~ 1MHz
  - digi… processing rate ~ 4Mhz

80
10
10
500000
4

speed factor: **$16*10^9$**

„transient domain“
complexity is high !

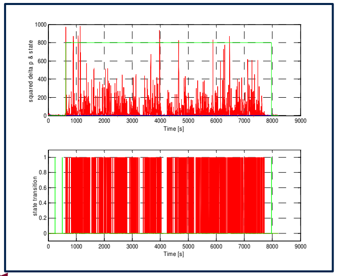
Sensor applications and complexity in time domain shown on an example… 2/2



the faster the system simulation, the more cases can be evaluated!

Simulate one conversion (ADC only)

One parking/driving case to verify data trans-mission behavior (a "6000 sec." simulation)



- Pure **analog** simulation: **approx. 25 min/conversion** **"not possible"**
- Pure **VHDL** simulation: **approx. 0.1s/conversion** **"real time"**
- Abstract **C**-model: **not noticeable…** **"minutes range"**

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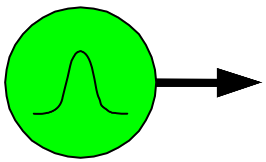
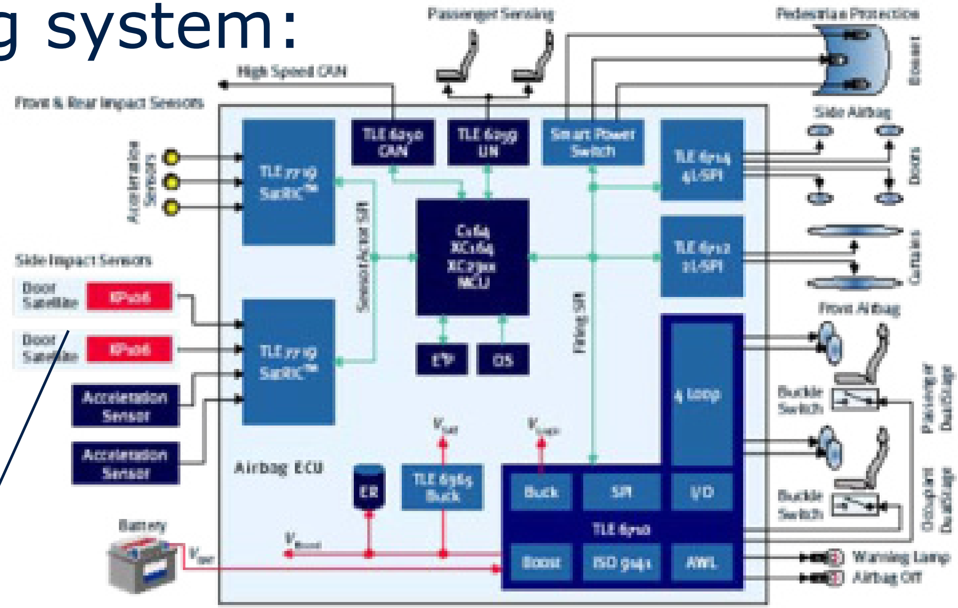
Example: Side-Airbag Sensor (pressure based) - the evolution steps of a pressure sensor

Airbag system:



pressure pulse

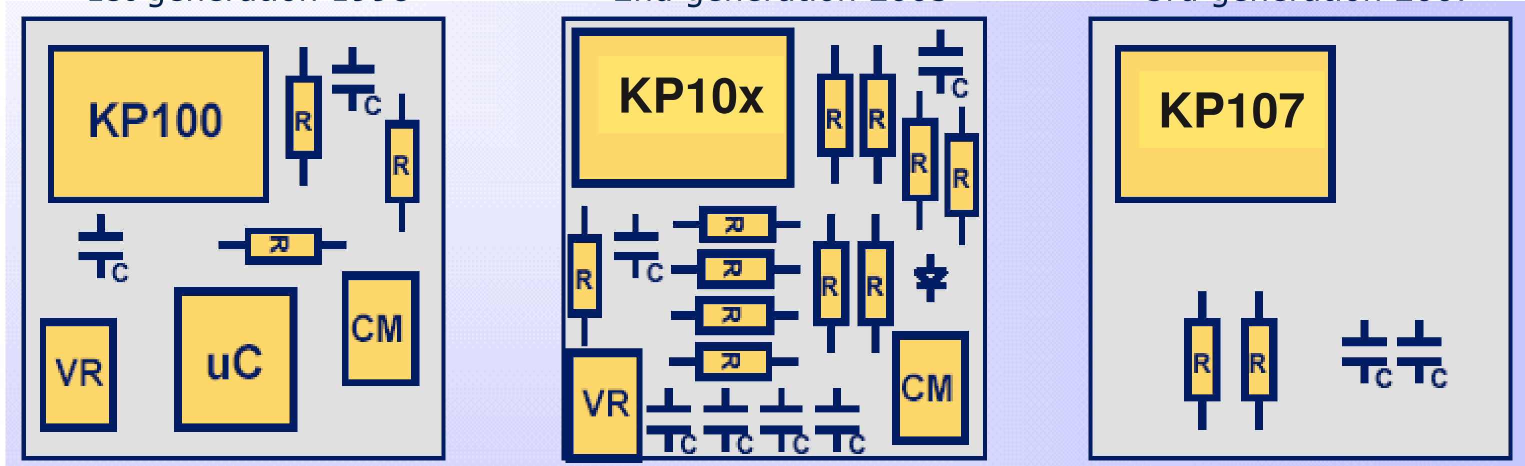


door satellite (PCB)

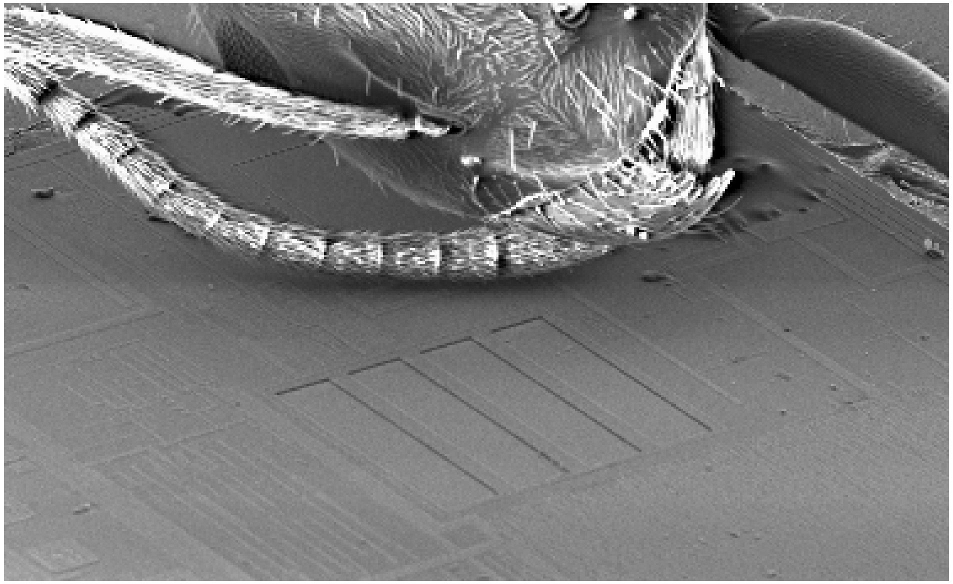
1st generation 1998

2nd generation 2003

3rd generation 2007



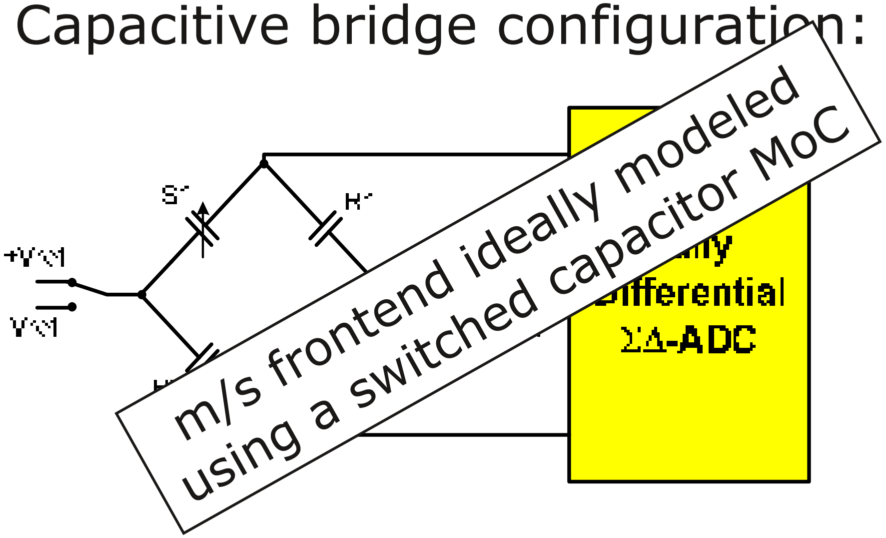
Sensor Cell Arrangement and Signal Processing



Sensor cells in size comparison with a head of an ant

Effects:
- mismatch effects
- non linearity
- T dependency

Capacitive bridge configuration:



(4 arrays)

$$Q = V_{ref} \cdot \left[\underbrace{(C_{S1} + C_{S2})}_{\text{pressure dependent}} - \underbrace{(C_{R1} + C_{R2})}_{\text{constant}} \right]$$

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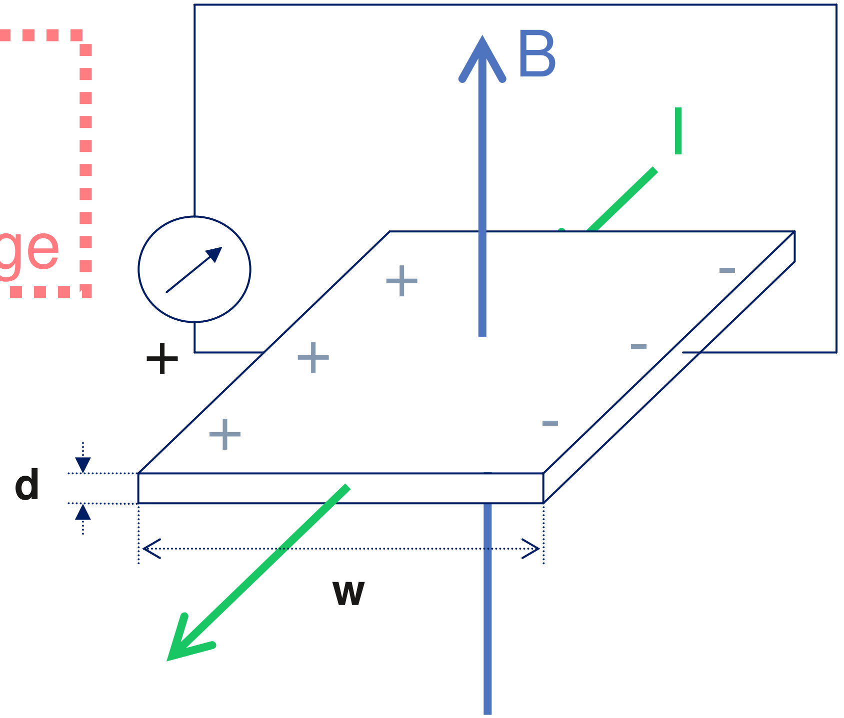
Hall probe modeling

- modeling and sensor compensation challenges

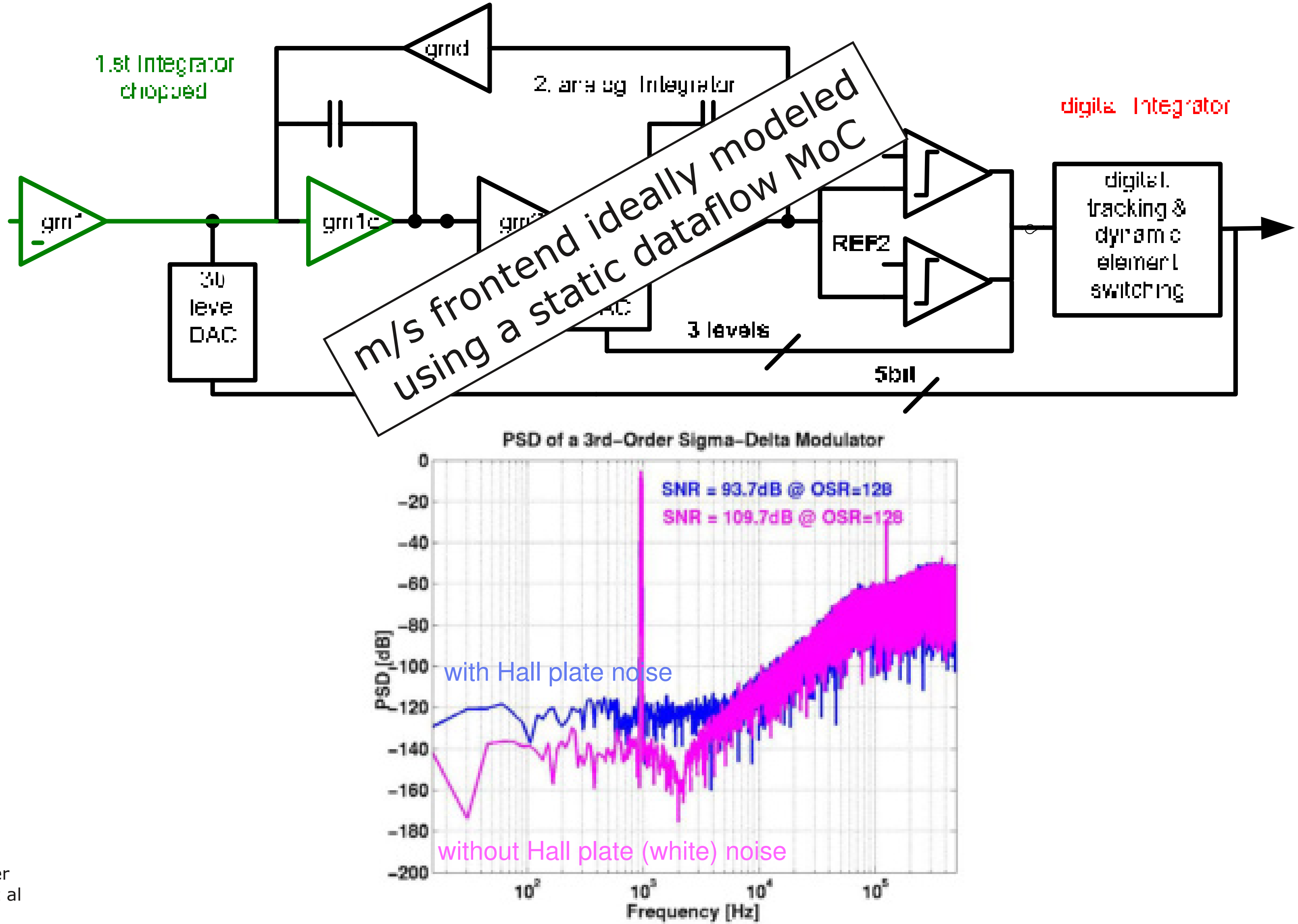
$$V_H = \frac{I\,B}{n\,e\,d}$$

Hall Voltage



- manufacturing tolerances of probe and bias current
- temperature dependency of probe and bias current
- on-chip stress effects, piezoelectric side effects
- noise

Simplified Structure of the Cont.-Time ADC



from IEEE sensors paper by M. Motz, et al

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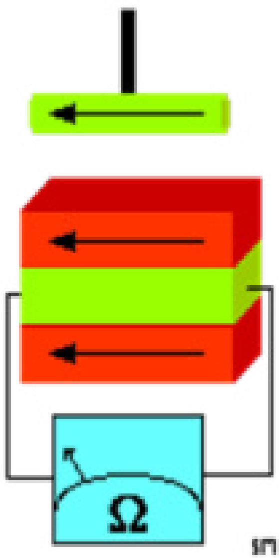
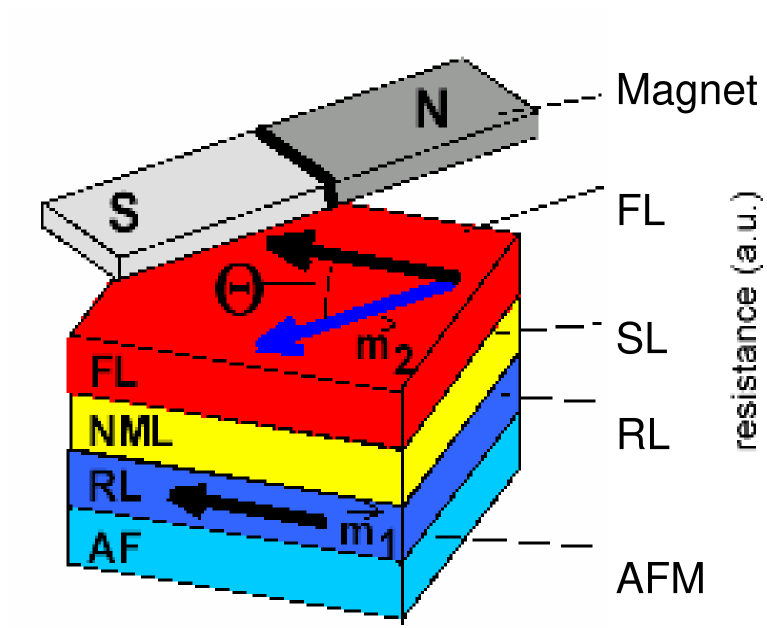
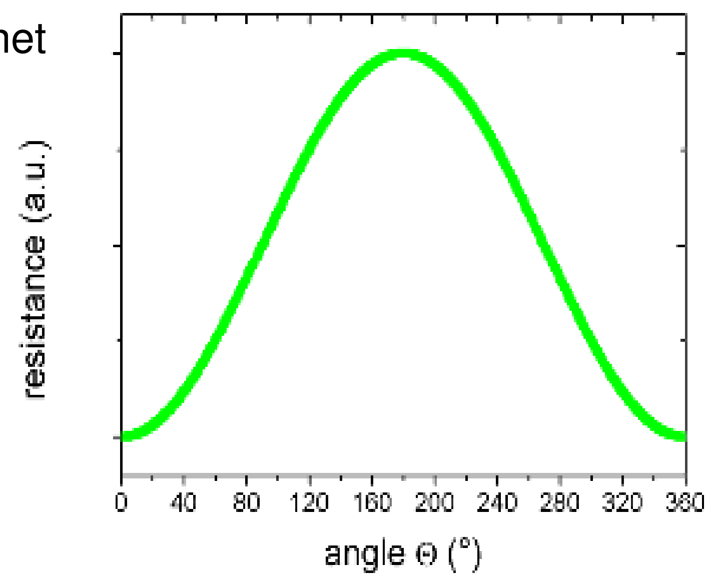
GMR angle sensor basics
Spin Valve

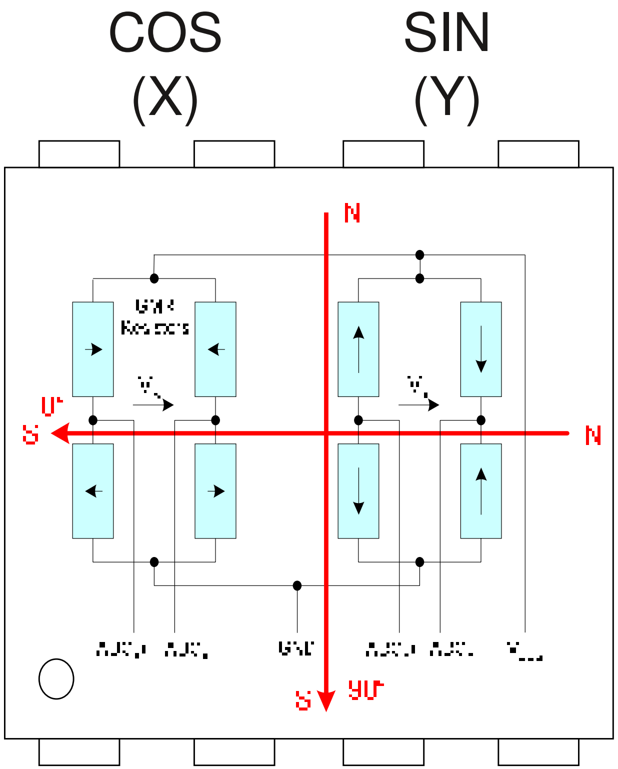
- Effect discovered 1988 (Dr. P. Grünberg)
- The **Resistance** of the spacer layer depends on the external magnetic **Field Direction**

$$\frac{\Delta R}{R}(\Theta_{m1m2}) = \left(\frac{\Delta R}{R}\right)_{GMR} \cdot \frac{(1-\cos\Theta_{m1m2})}{2}$$

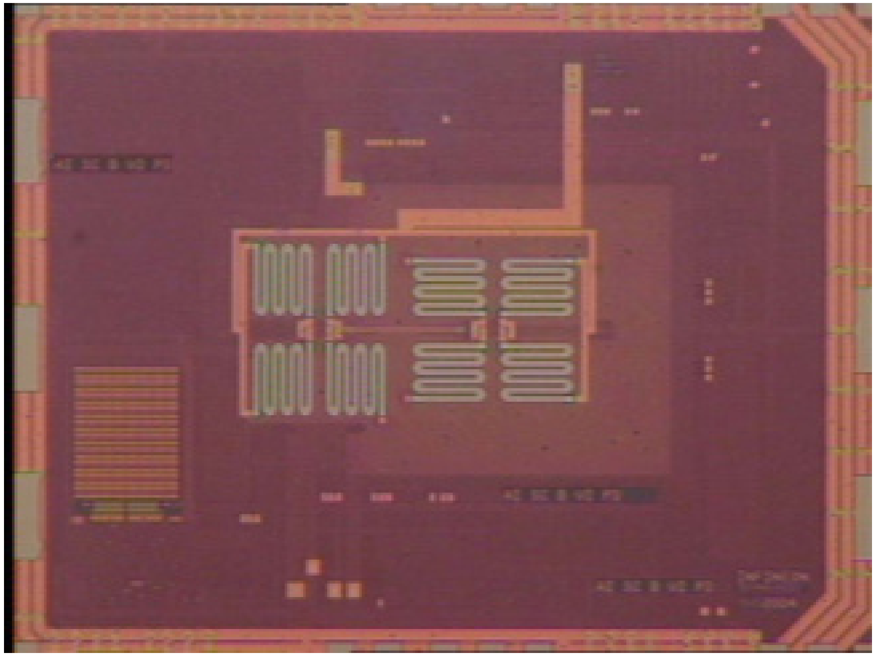








One GMR Wheatstone Sensor Bridge for each Orthogonal Direction



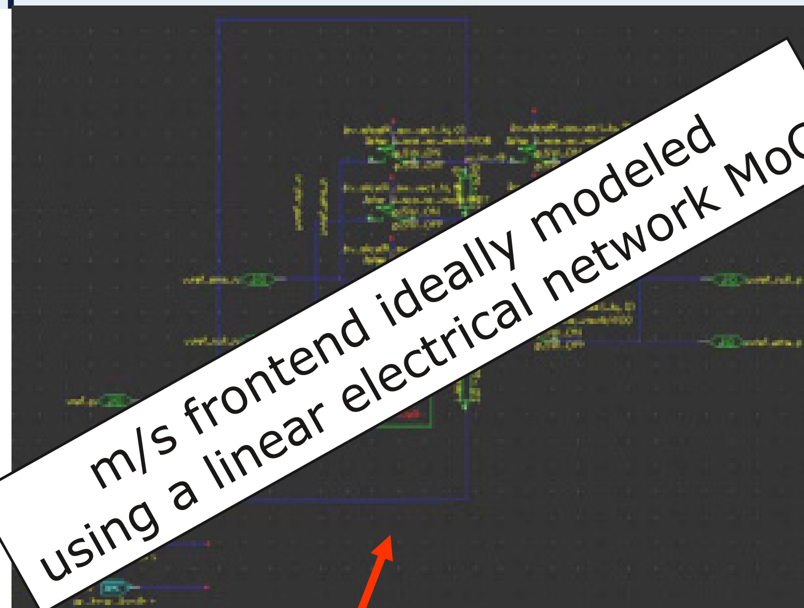
Wordwide First Mass-Productive Integrated GMR Angle Sensor

(On Top of Active Silicon Area)

GMR Angle Sensor SAR – an example for a typical sensor model

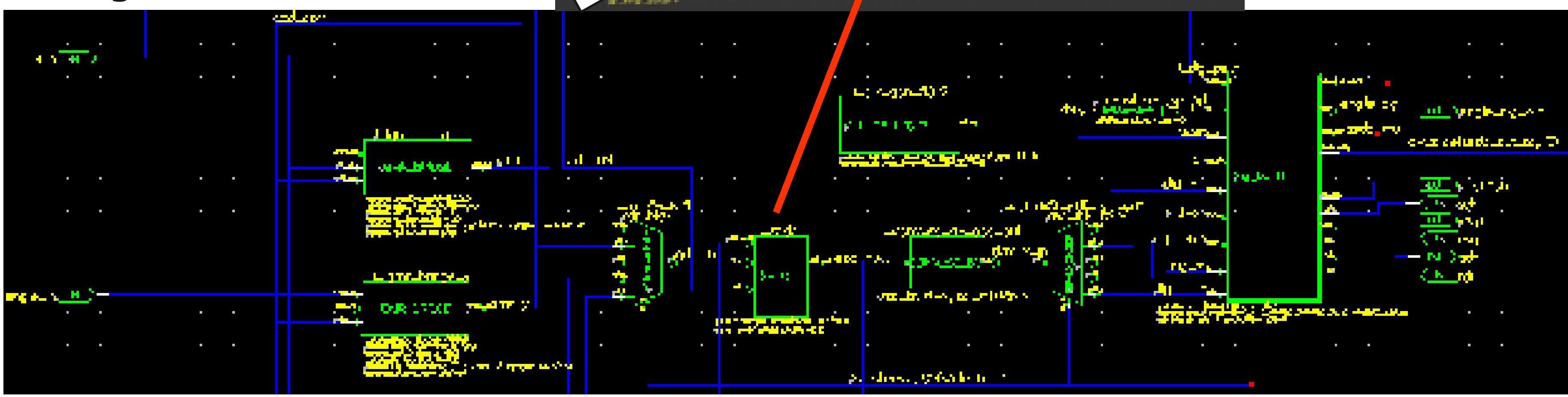
ADC

R-Ladder



m/s frontend ideally modeled using a linear electrical network MoC

Signal Path:



Physical Input

Sensor Model

ADC-Model

DSP Model

„Never stop thinking“