Mechanical mounting variation effects on magnetic speed sensor applications

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Agenda

- Introduction
- Methodology
- Results
- Conclusions

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Infineon Technologies AG, Villach

Automotive (ATV)

- Power Semi-conductors
- Power ICs
- Microcontrollers
- Sensors
- Electric Drivetrain

Industrial Power Control (IPC)

- IGBT Modules
- IGBT (Chips & Discretes)
- Driver ICs and boards
- Module Systems

Power Management & Multimarket (PMM)

- Power Discretes & Driver ICs
- Power ICs
- ASICs
- RF & Protection Devices
- Silicon MEMS-Microphones

Chip Card & Security (CCS)

- Payment
- Communication
- Transport, Access & Object ID
- Government ID
- Platform Security
- Entertainment

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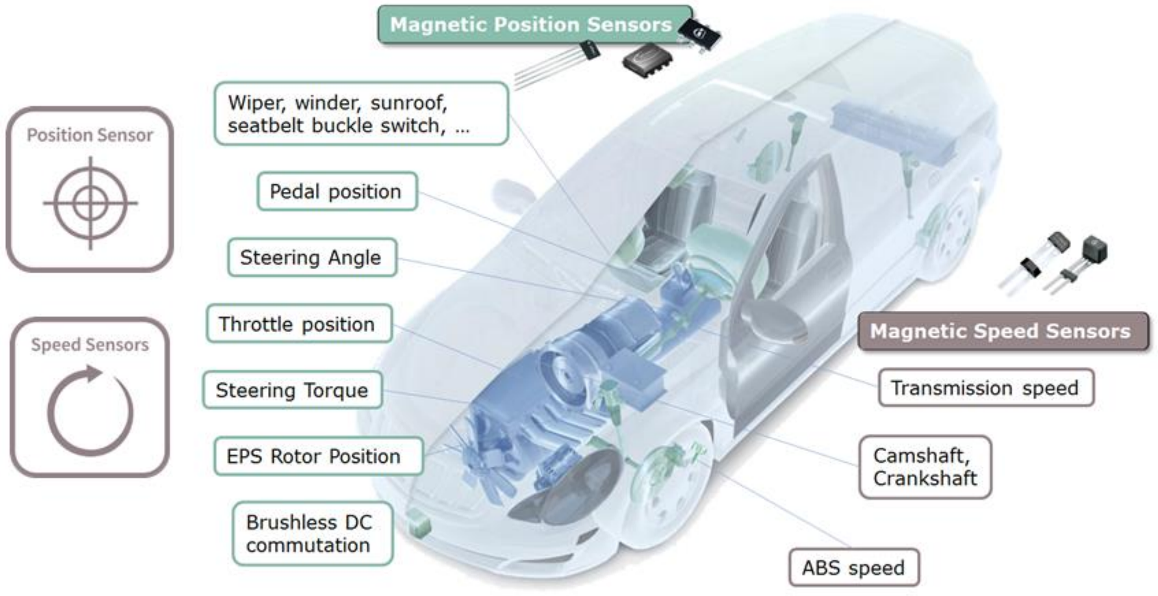
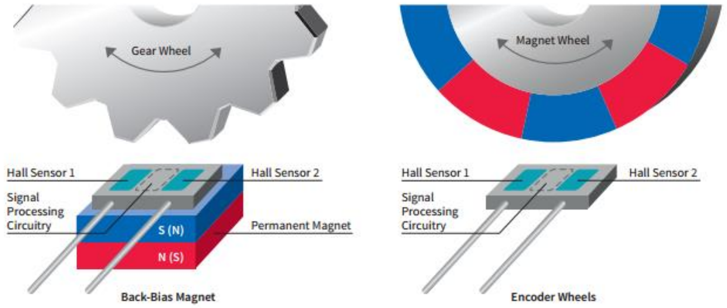
Magnetic sensors in automotive: benefits

- Application: contactless measurement of mechanical quantities

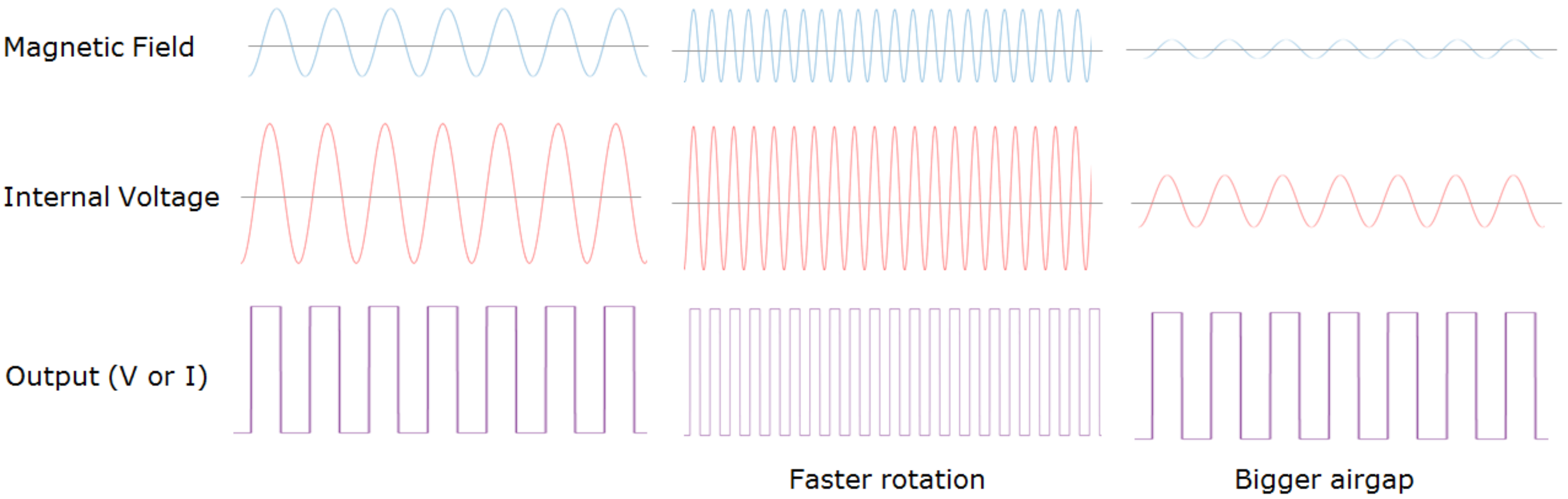


- Benefits
  – Wear free
  – Robust
  – Standard material housing
  – Low-cost

Magnetic sensors: working principle

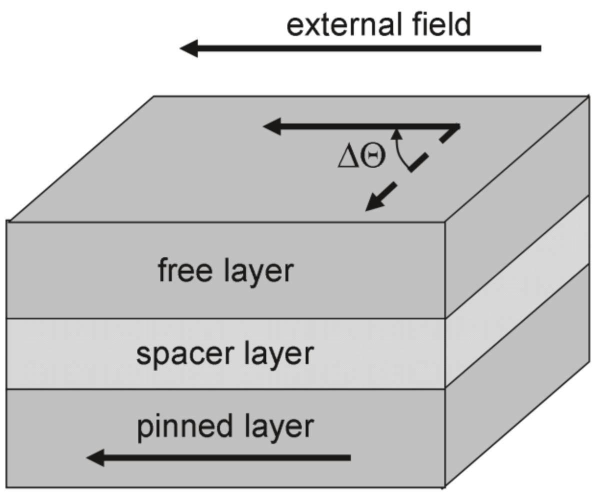


Quantity to measure	Magnetic Field	Sensing Element	Signal Processing	Output to ECU
Angle Position Speed Current	Magnet Pole wheel Back-bias	Hall GMR/AMR/TMR	Analog Analog & Digital	PWM AK SPI



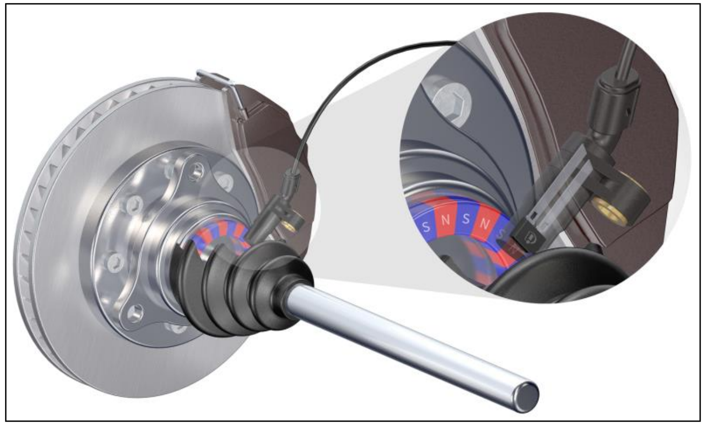
From Hall to GMR

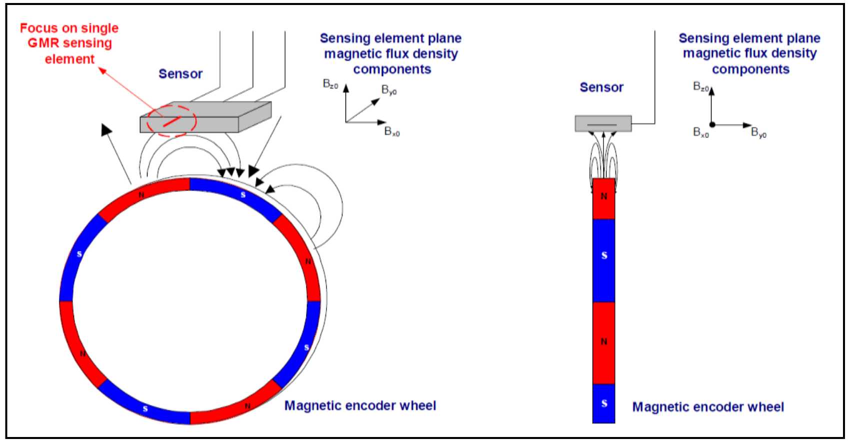
- GMR sensors
  - Higher sensitivity
  - Better jitter performance
  - Bigger operating area
  - Better performance/cost ratio
  - New phenomena to be understood



ABS wheel speed sensors

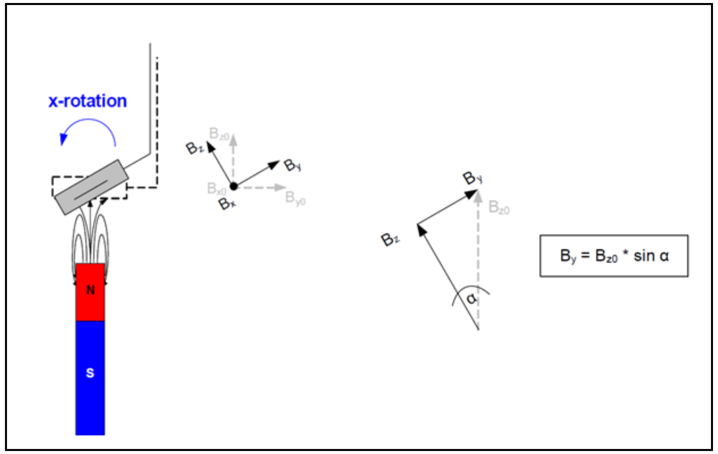
- TLE5046iC: Infineon ABS new gen.
  - Speed and direction information
  - AK & PWM protocols
  - Low jitter 0.02%
  - Stable duty cycle
  - Outstanding airgap performance
  - Immunity against y-displacement
  - Immunity against tilting

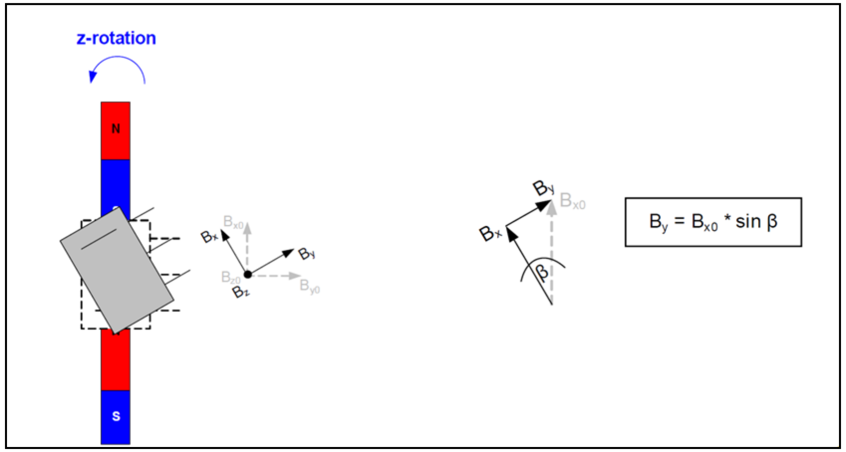




Mounting tolerances effects

- Duty cycle and jitter performance of GMR based sensors may be degraded if By component of the encoder wheel field is too big





- Useful to investigate and predict such phenomena via measurements and simulations (faster, cheaper, more flexible)

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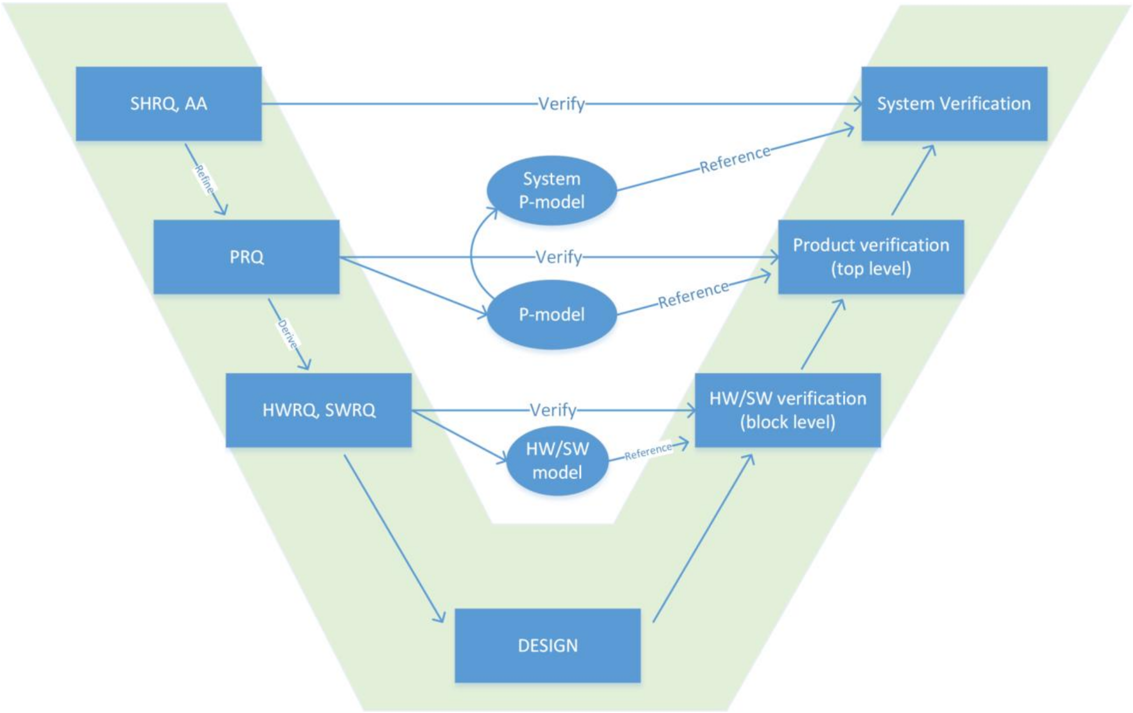
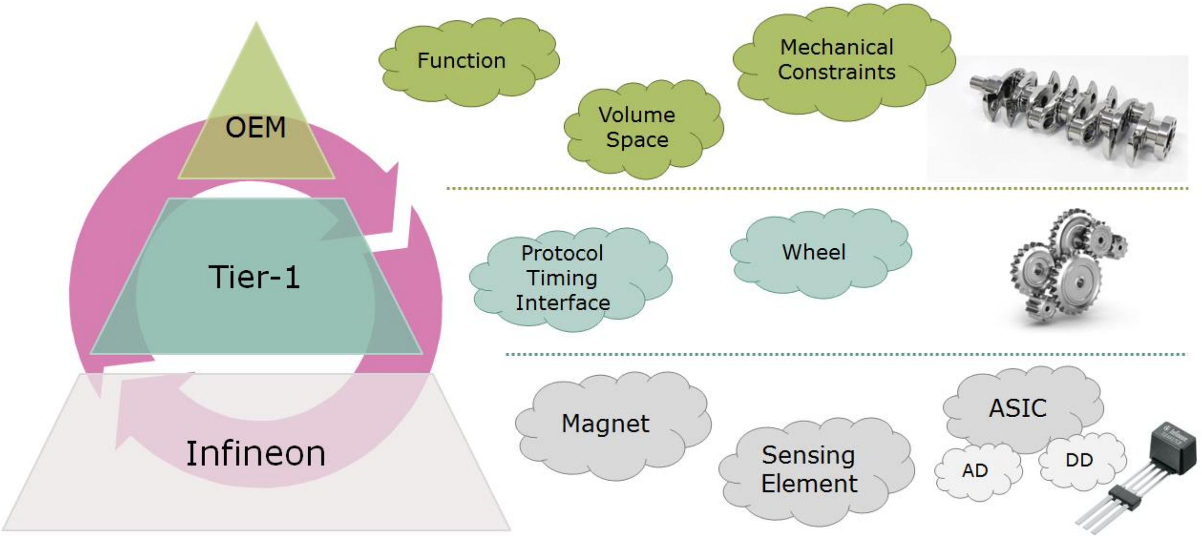
Two simulations domains

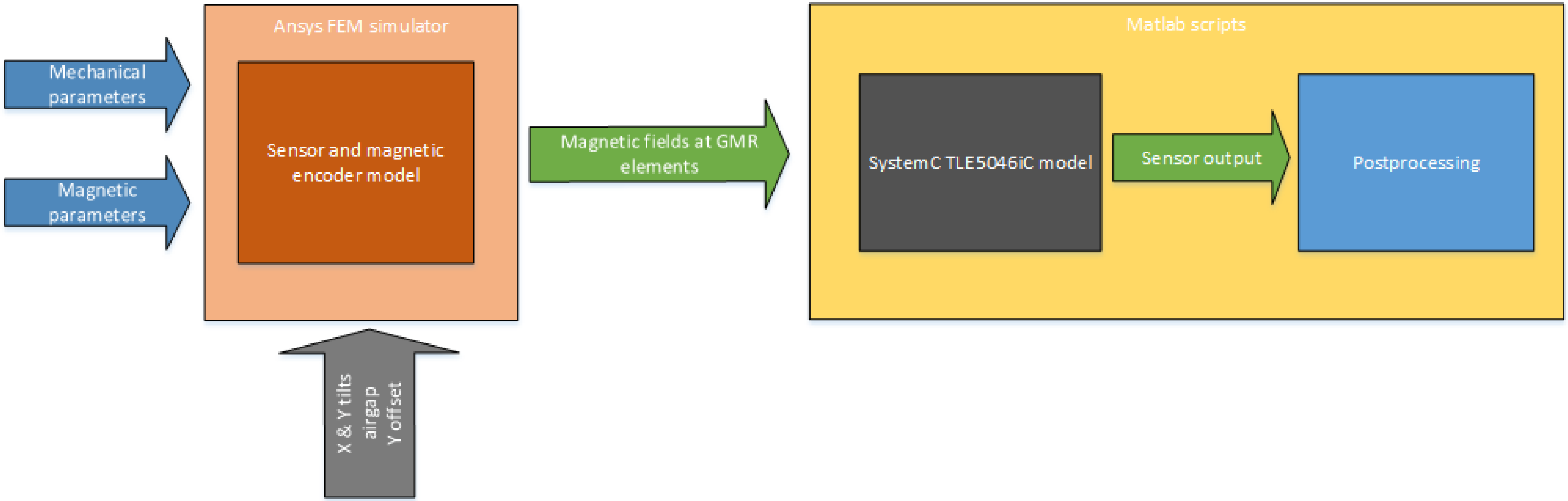
SystemC sensor model



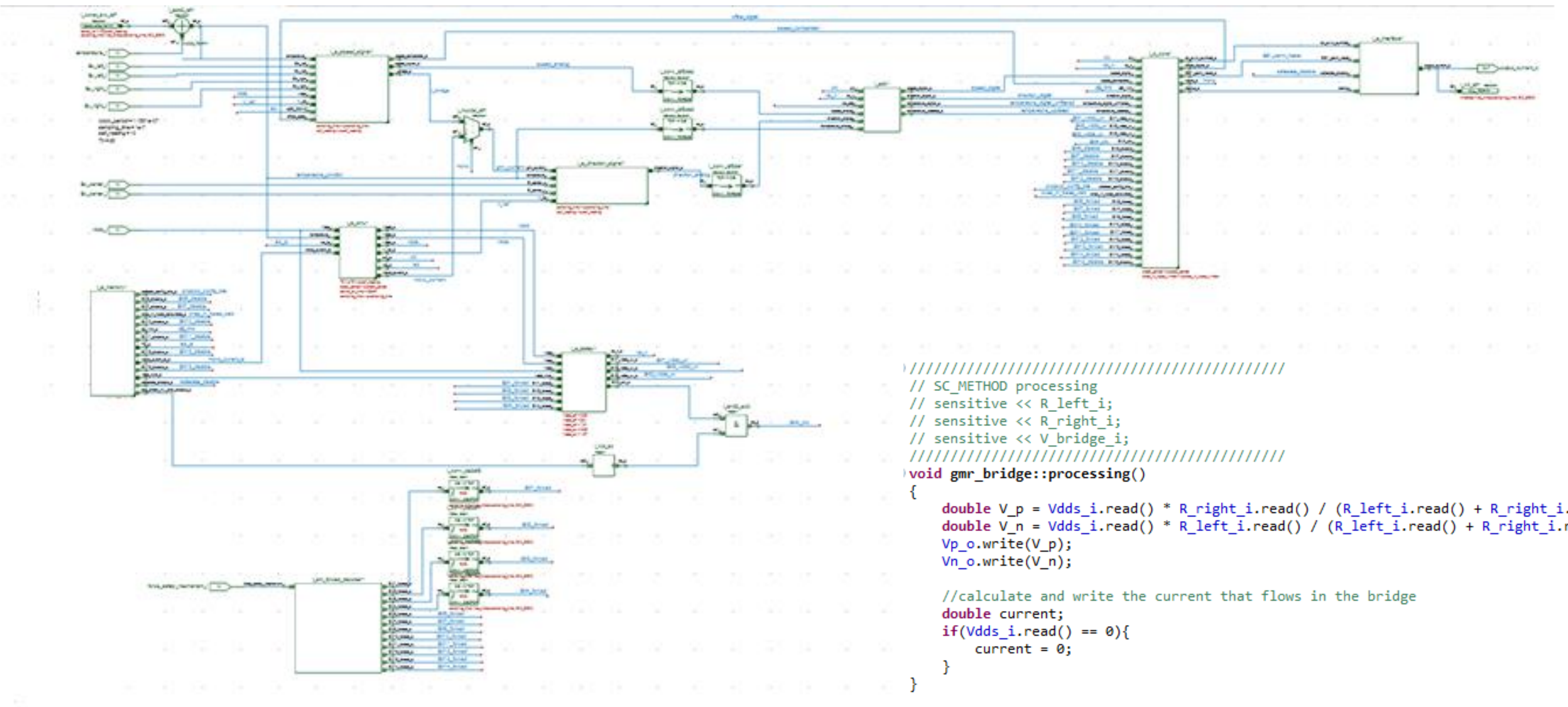
Finite Element Method simulations



Simulation flow



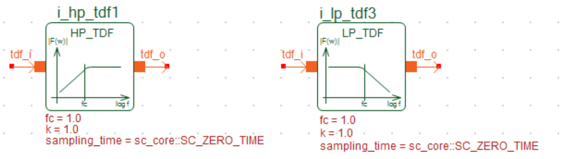
SystemC sensor model (1/2)



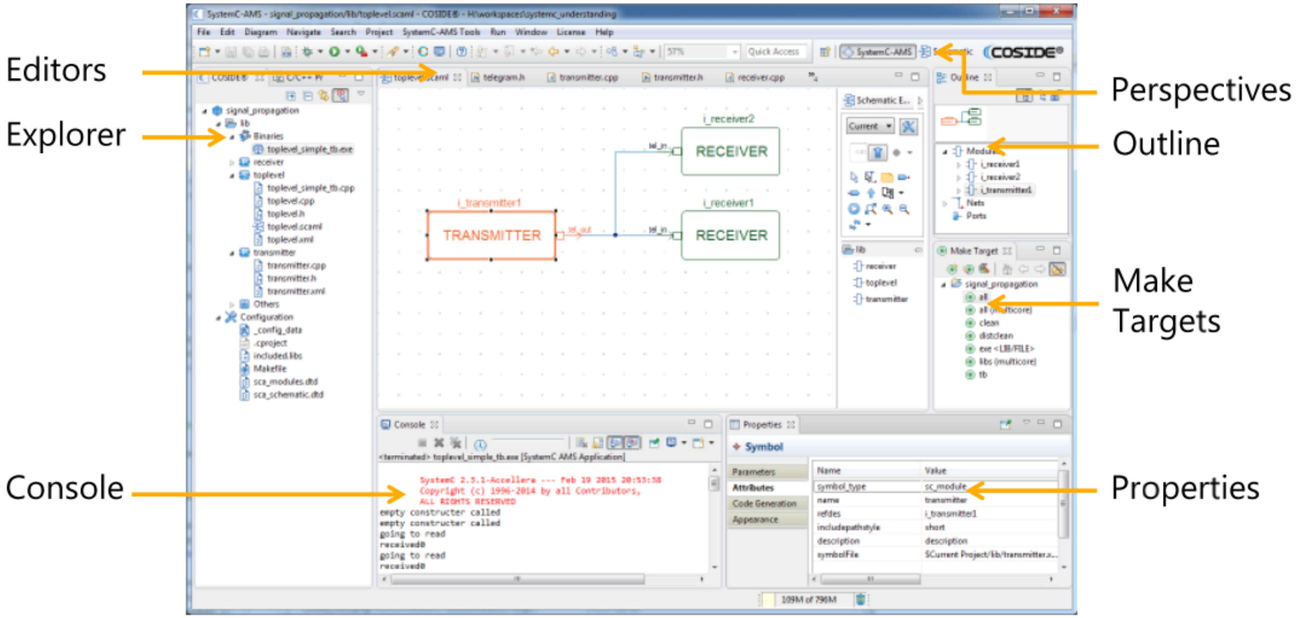
```
////////////////////////////////////////////
// SC_METHOD processing
// sensitive << R_left_i;
// sensitive << R_right_i;
// sensitive << V_bridge_i;
////////////////////////////////////////////
void gmr_bridge::processing()
{
    double V_p = Vdds_i.read() * R_right_i.read() / (R_left_i.read() + R_right_i.read());
    double V_n = Vdds_i.read() * R_left_i.read() / (R_left_i.read() + R_right_i.read());
    Vp_o.write(V_p);
    Vn_o.write(V_n);

    //calculate and write the current that flows in the bridge
    double current;
    if(Vdds_i.read() == 0){
        current = 0;
    }
}
```

SystemC sensor model (2/2)

- IDE: Coside 2.3
- Sensor model
  - Digital: SystemC
  - Analog: SystemC AMS

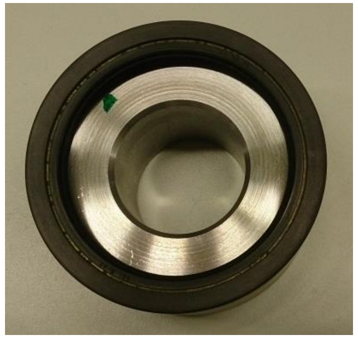


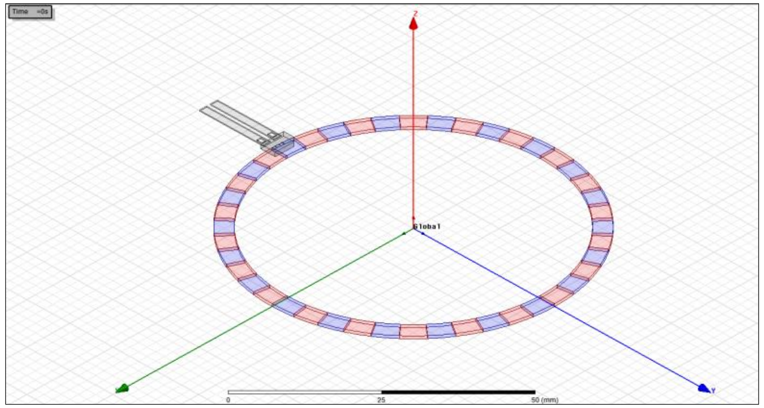
- Methodology
  - Develop model in Coside
  - First block-level validation in Coside
  - Iterative simulations from Matlab

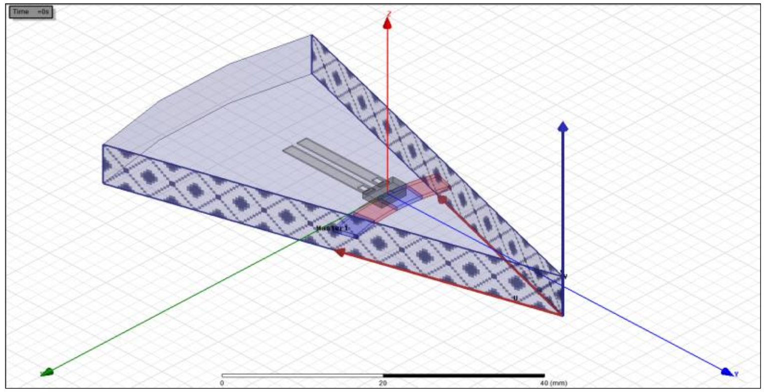


Source: Coside documentation slides

FEM setup

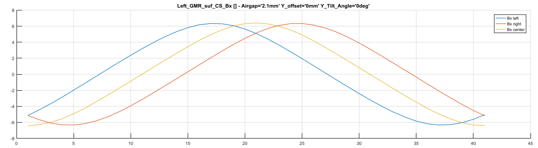


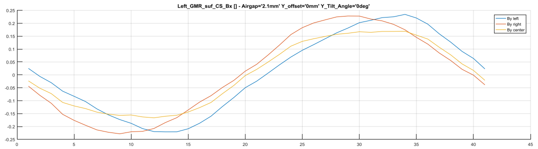




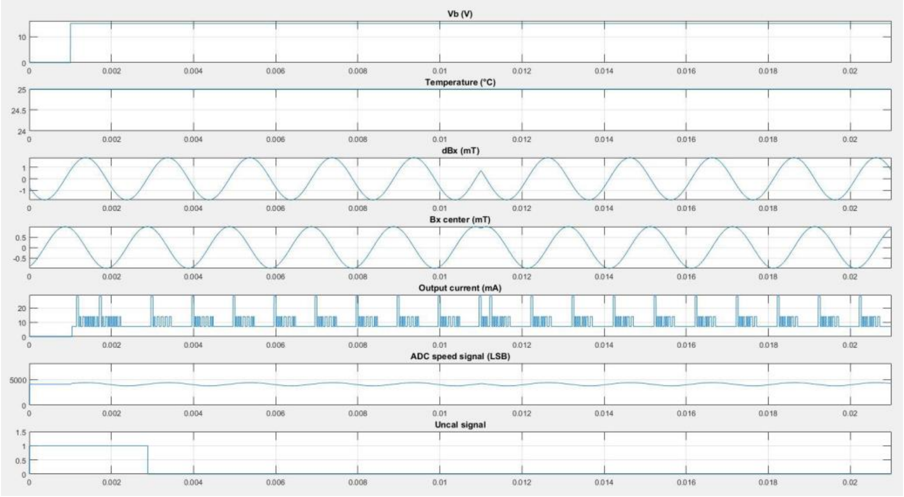
- Ansys
- Magnetic parameters
  - 44 pole pairs
  - Axial magnetization (Z-axis direction)
  - Coercivity and remanence to fit measurements
- Geometric parameters
  - Inner radius of the magnetic encoder = 29.5 mm
  - Outer radius of the magnetic encoder = 32.9 mm
  - Height of the magnetic encoder = 0.6 mm

Matlab scripts





- Repeat in a loop:
  1. Read the results from Ansys FEM simulations
  2. Post-process the results in a SystemC friendly format
  3. Run the SystemC simulation
  4. Perform automatic pass/fail tests on the simulation output
     - Number of output protocols
     - Duty cycle of the output protocols



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Performed simulations

- Use case coming from Korean customer
- Most difficult assembly parameter to control is tilt along Y axis

- Airgap: 1.1mm, 2.1mm (distance between the magnet and the package)
- Tilt along X axis: 0°
- Tilt along Y axis: -15°, -7.5°, 0, 7.5°, 15°
- Offset along Y axis: -2mm, 0, 2mm
- Total: 30 simulations

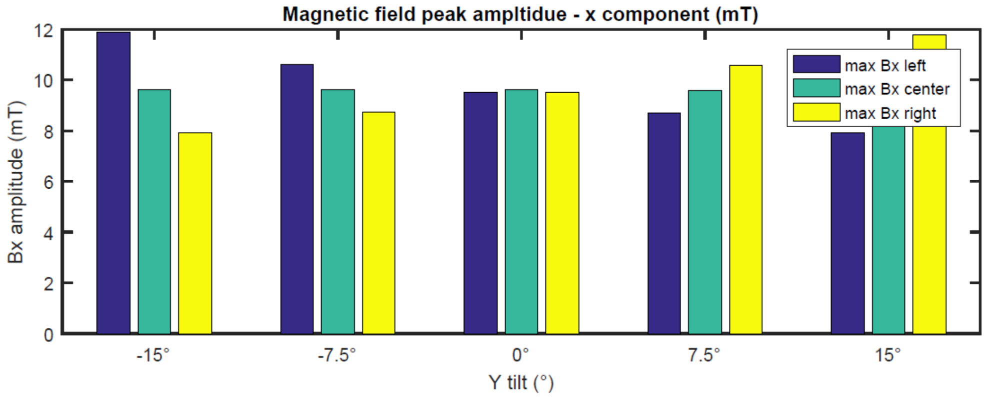
Effects of airgap variation on the magnetic field

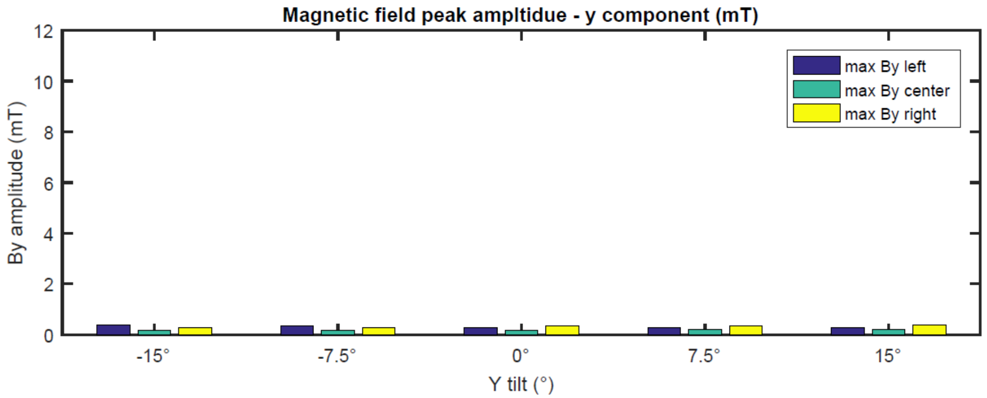
- Increasing the airgap: the amplitude of the magnetic field at all the three GMR elements decreases.
- Decreasing the airgap: the amplitude of the magnetic field at all the three GMR elements increases.

- Useful analysis to find max. airgap given a wheel and a sensor

Effects of tilt around Y axis on the magnetic field

airgap = 1.1mm, Y offset = 0



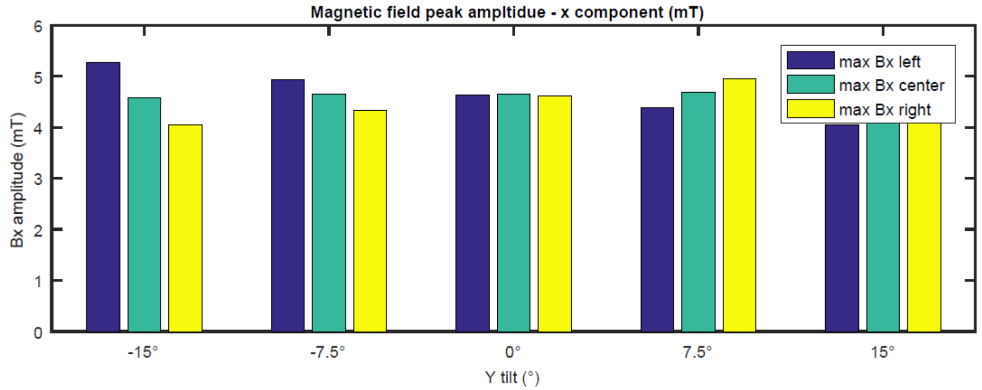


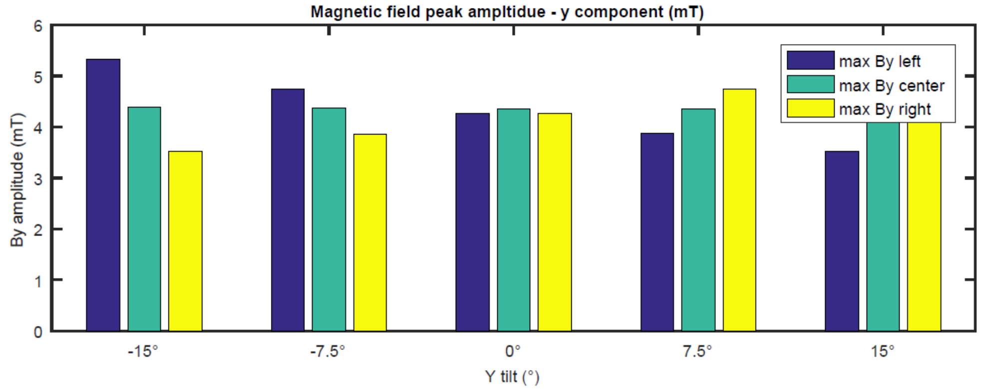
Effects

	Positive tilt	Negative tilt
B @ right GMR	↑	↓
B @ left GMR	↓	↑

Effects of offset along Y axis on the magnetic field

airgap = 1.1mm, Y offset = 2mm





Effects

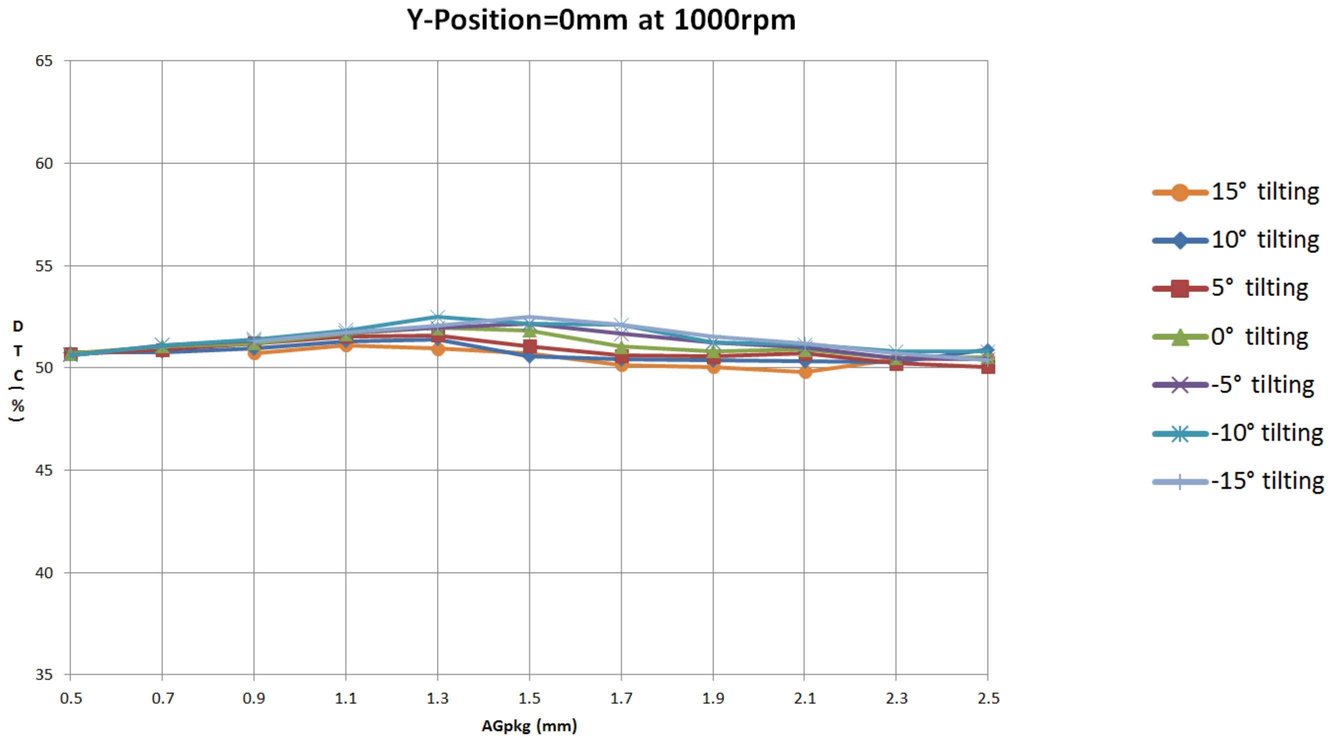
	Positive offset	Negative offset
Bx	↓	↓
By	↑	↑
Wheel pitch seen by the sensor	↑	↓

Effects on the sensor performance

- All pulses are sent out correctly
  - Number of output protocols = number of magnetic encoder periods
- Duty cycle degradation as expected, due to combination of Bx/By fields
  - Max values comparable to measurements
  - Different trend due to
    - Wheel description leading to different Bx/By configuration
    - GMR Stoner–Wohlfarth model
- Jitter cannot be evaluated from simulations (stochastic phenomenon)
  - We prefer to have repeatability in simulations

Duty cycle trend from measurements

- Duty cycle always within specs up to +-15° (as shown in simulations)
- Duty cycle variations depends on airgap, Y position and tilt



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Conclusions

- Combined simulation approach useful for a P2S systematic approach
  - Magnetic field from FEM
  - Sensor behavior from SystemC
- Simulations can be used to test the robustness of a sensor
  - Faster
  - Cheaper
  - More flexible
- Simulation results can give a first good figure about sensor robustness
- To obtain exact answers measurements should always be performed

Questions & Answers

Any questions?