Usage of SystemC-AMS MDVP for virtual prototyping of a MEMS application

Fabio CENNI

Central CAD/Physical IPs and mixed-signal Design Solutions
STMicrolectronics, Grenoble, France

e-mail: fabio.cenni@st.com

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Outline

- Virtual Prototyping: the Objective
- Application description
- The MEMS sensors : modeling and MoCs
- Coherent Stimuli: the challenge
- MoC considerations & Conclusions

Objective

- SystemC AMS and Multi-Domain Virtual Prototyping (MDVP) **virtual platforms** will allow **costs** and **time-to-market reduction**
- The architect perspective:
  - HW/SW partitioning
  - HW resources specification
- The SW developer perspective
  - **Early development/debug of the embedded SW before prototypes** (with analog and mechanical parts)
  - **Embedded SW validation for families of object movements and corners** (Temperature)
  - **Power efficient control/readout of MEMS** (HW resources optimization)
- Virtual platform used as **demonstrator** for customers

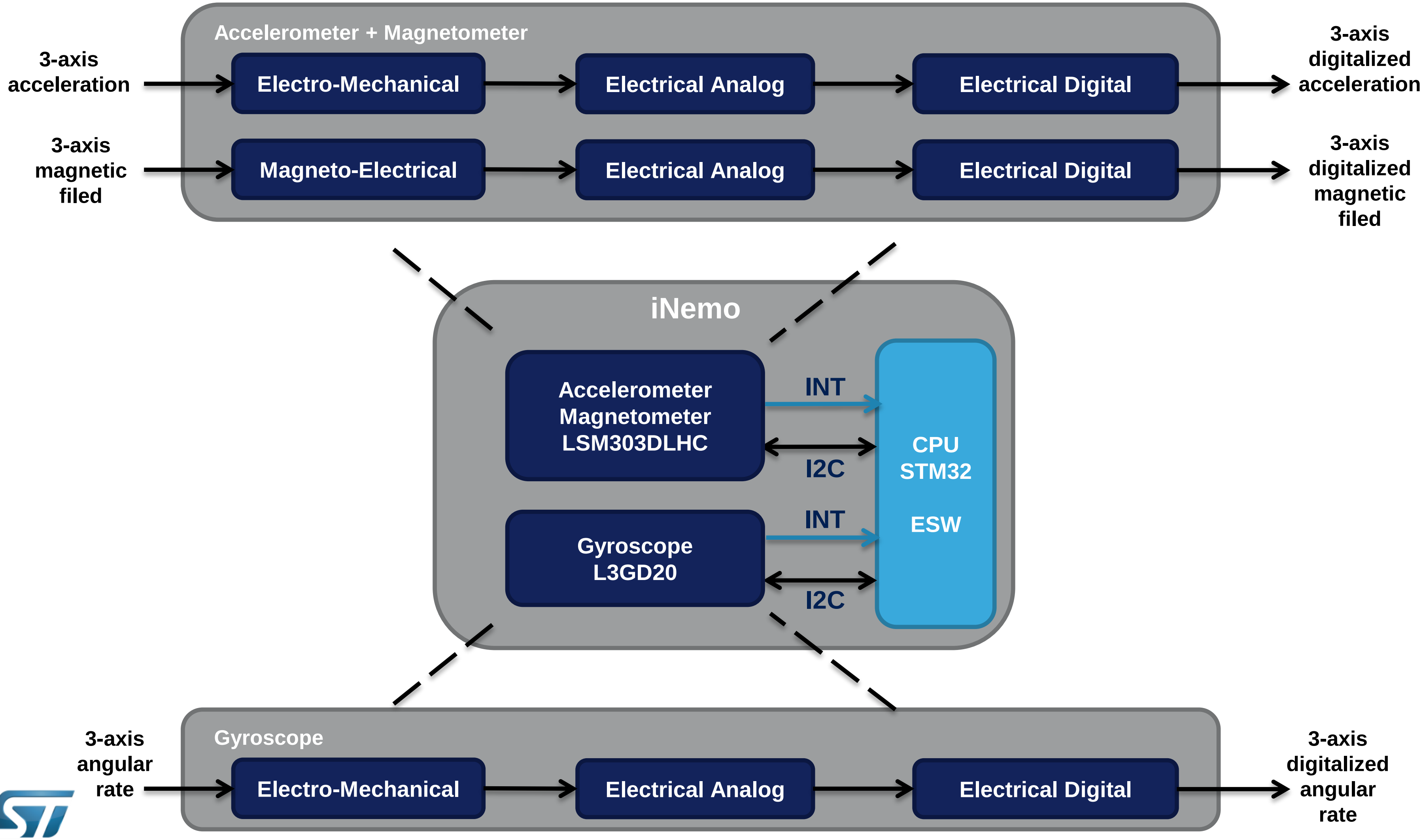
Application description

- iNemo board embedding:
  - Accelerometer/Magnetometer
  - Gyroscope
- Motion detection for:
  - Gesture recognition
  - Motion tracking
  - Fall detection
- Through:
  - Sensor fusion algorithms

Motion detection

LEGEND:

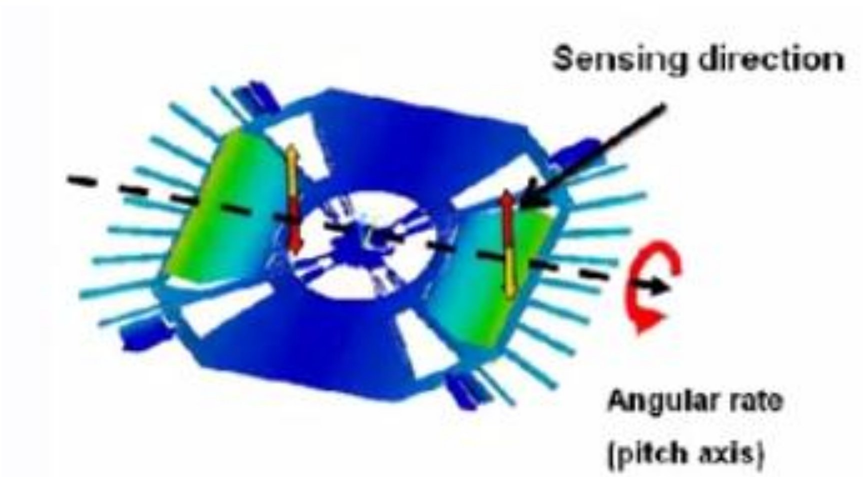
- SystemC AMS+TLM
- C Embedded SW

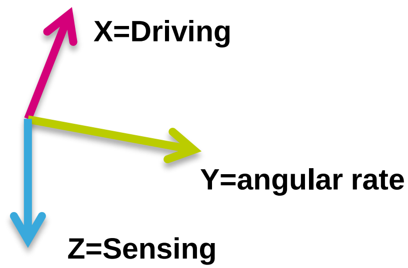


MEMS sensor: Gyroscope example

- Sensor functioning overview
- TDF MoC model
- Bond-Graph MoC model proposal
- Non-linear refined model from FEA
- Digital on-chip processing

Gyroscope functioning overview





Coriolis force: $$\boldsymbol{F}_C = -2\,m\,\boldsymbol{\Omega} \times \boldsymbol{v}$$

Where: $$\boldsymbol{\Omega} \times \boldsymbol{v} = \begin{vmatrix} \boldsymbol{i} & \boldsymbol{j} & \boldsymbol{k} \\ \Omega_x & \Omega_y & \Omega_z \\ v_x & v_y & v_z \end{vmatrix} = \begin{pmatrix} \Omega_y v_z - \Omega_z v_y \\ \Omega_z v_x - \Omega_x v_z \\ \Omega_x v_y - \Omega_y v_x \end{pmatrix}$$

— F_{CZ} on Sensing axis

$\Omega_x v_y$: Unwanted term

$\Omega_y v_x$: Desired term

source :http://youtu.be/A03AENwOVNY?t=8m1s

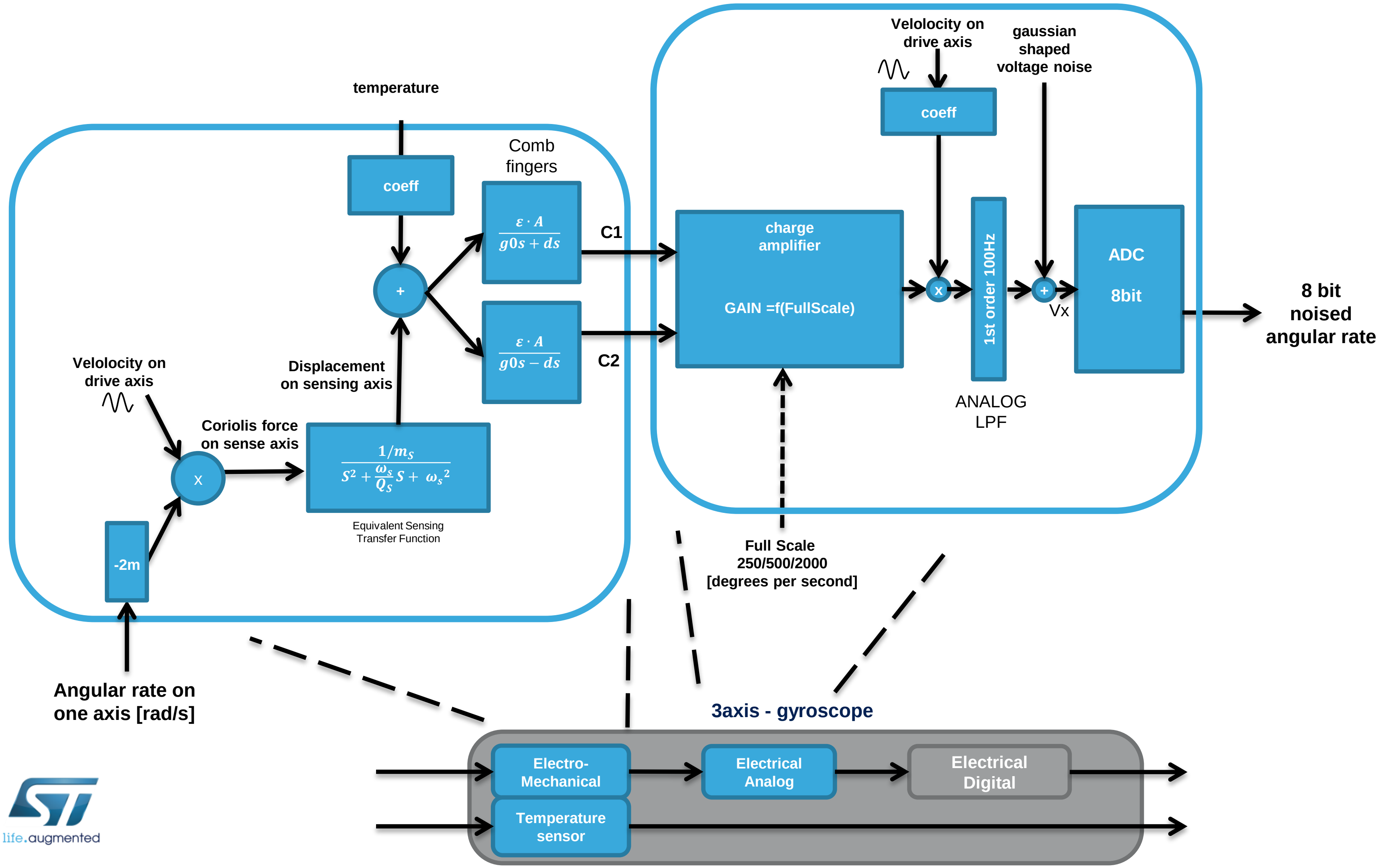
LEGEND:

SystemC TLM

SystemC AMS TDF

Gyroscope TDF model

- Time step to be specified by user based on his knowledge of the system and independently from signal dynamics

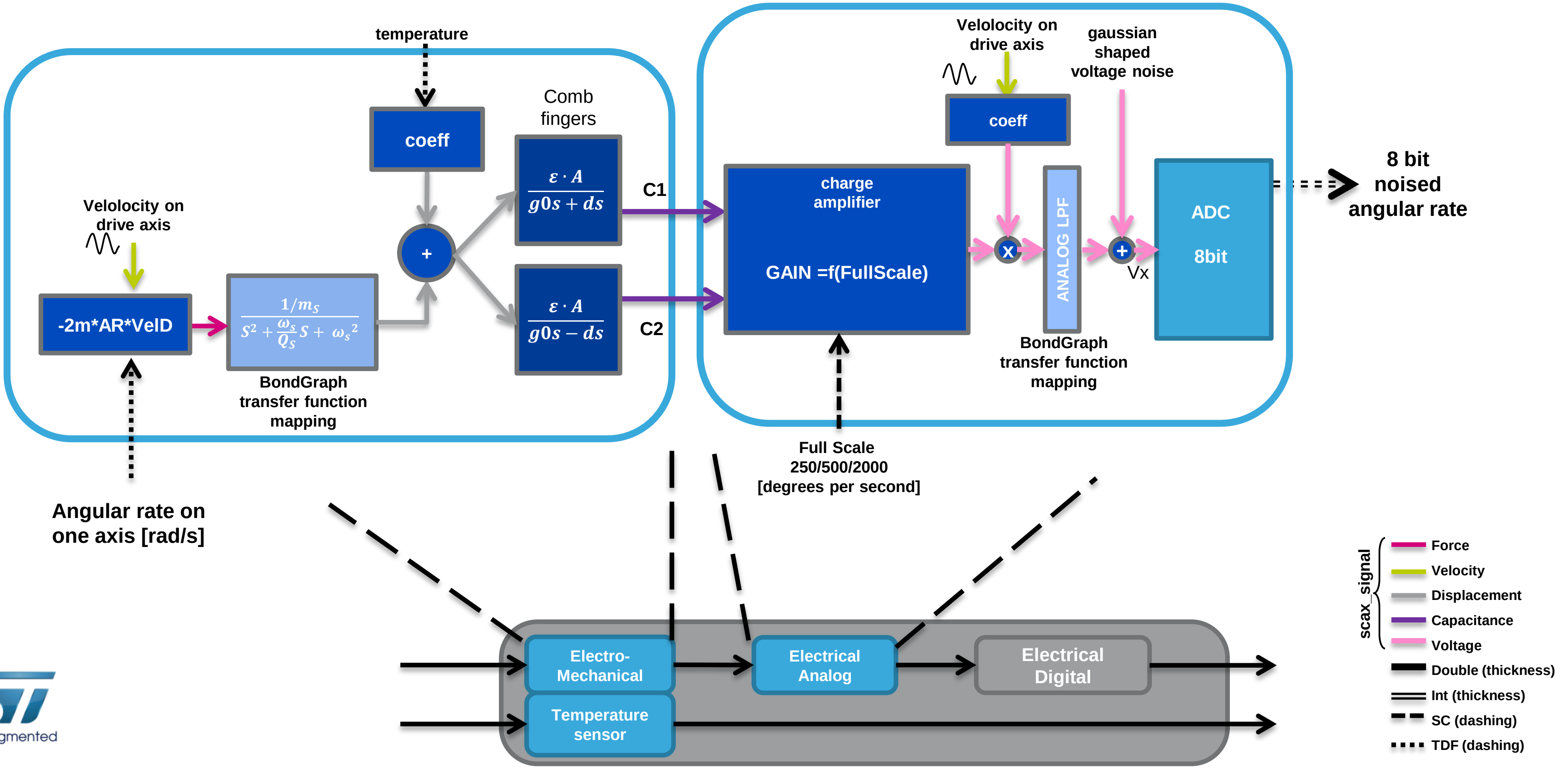


LEGEND:

SystemC MDVP BlockDiagram
SystemC MDVP BondGraph
SystemC AMS TDF

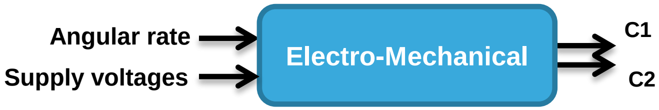
Bond-Graph MoC model proposal

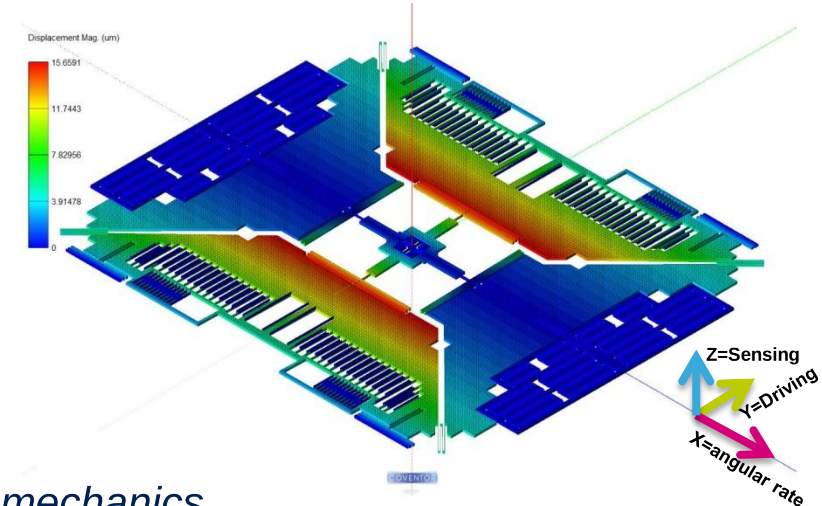
- Signal typing (connectivity check)
- Time step adapted to signal dynamics (time step max specified)



Non-linear refined model from FEA

Under development in MEMS+® by Coventor





- Component-based Finite Element Analysis (FEA)
- Coupling multiple physical domains *electrostatics, mechanics*…
- Based on state-space system *inherent to MEMS+® 3D model*
  - Model-Order Reduction thanks to state-number reduction
  - Non-linearity thanks to the interpolation of state-space linearizations
- Integration in SystemC-AMS
  - Custom TDF module with specific *processing()* method
  - Ongoing tests with Dynamic TDF (potential speed-up of the computation)

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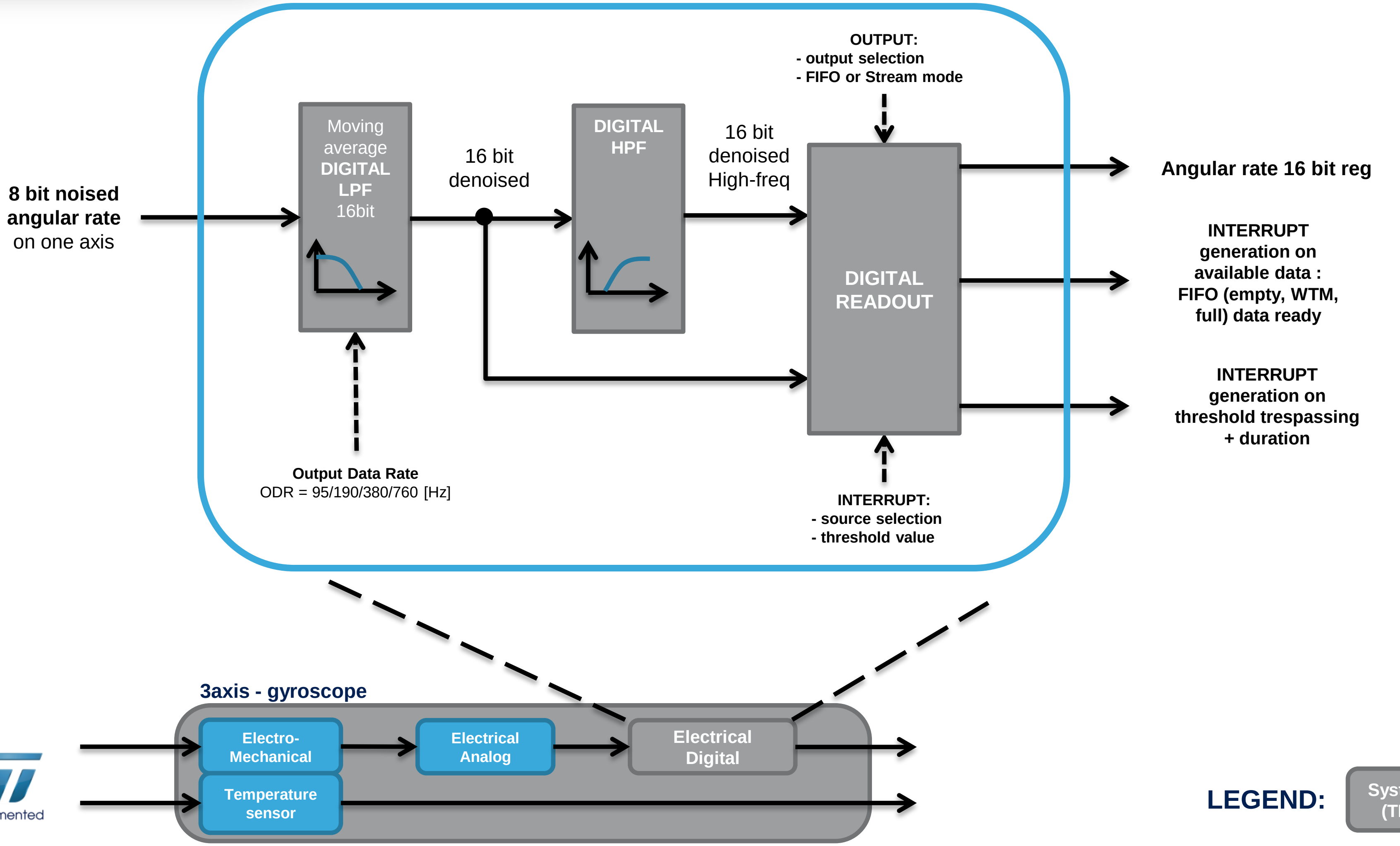
Digital on-chip processing

Register bank

Name	Slave address	Type	Register address		Default
			Hex	Binary	
Reserved (do not modify)	*Table 14*		00 - 1F	--	--
CTRL_REG1_A	*Table 14*	rw	20	010 0000	00000111
CTRL_REG2_A	*Table 14*	rw	21	010 0001	00000000
CTRL_REG3_A	*Table 14*	rw	22	010 0010	00000000
CTRL_REG4_A	*Table 14*	rw	23	010 0011	00000000
CTRL_REG5_A	*Table 14*	rw	24	010 0100	00000000
CTRL_REG6_A	*Table 14*	rw	25	010 0101	00000000
REFERENCE_A	*Table 14*	rw	26	010 0110	00000000
STATUS_REG_A	*Table 14*	r	27	010 0111	00000000

CONFIG registers



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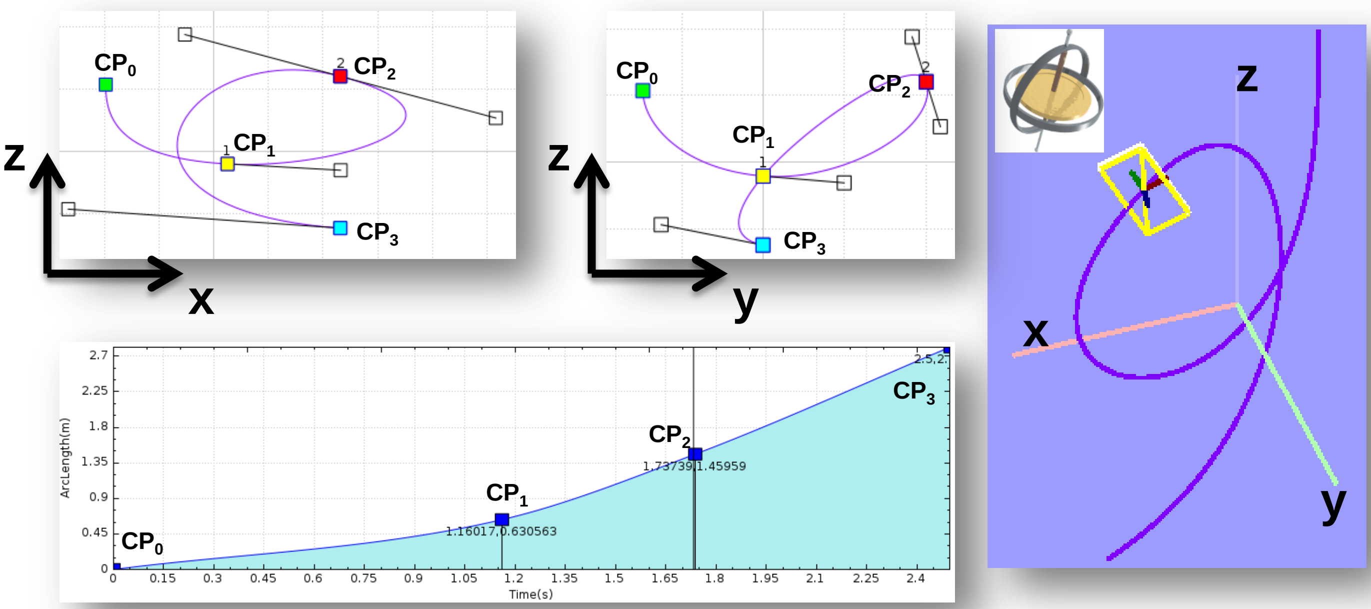
LEGEND: SystemC (TLM)

Coherent stimuli generation

- Internal tool for
  - Object trajectory definition (both 3D path+temporal aspect)
  - Object orientation evolution along the trajectory (through Control Points CP)
  - Generate xml file to provide the stimuli to SystemC MEMS simulation



<p>
<i>5</i>
<t>0.0020</t>
<tS>0.0004</tS>
<deltaPos> ... </deltaPos>
<deltaAngle>...</deltaAngle>
<absPos> ... </absPos>
<rotMat> ... </rotMat>
<gravity> ... </gravity>
<Quat> ... </Quat>
<temper>27</temper>
</p>

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MoC considerations

MoC	Time step	Advantages	Drawbacks
TDF	constant & user defined	Easy to code	time step - constant → non-optimal for analog behaviors and closed loops - user defined
Bond Graph	dynamic max limit to be specified	Dynamic time step →faster simulation Good accuracy on closed-loops (delay needed with TDF) Simulator accuracy tunable	Not trivial to code in current PoC
Refined model from FEA (TDF)	constan in current PoC & user defined	High accuracy from FEA (driving voltages + non-linearities) Automatic code generation	Code interpreteability time step - user defined

Bond Graph MoC and MEMS+ model are ongoing developments in the frame of CATRENE CA701 H-INCEPTION Project

Conclusions

- State-of-the-art for MEMS applications simulation
  - **Co-simulation**
    MEMS as FEM models + TLM VP on Linux : Too much compute-greedy
  - **Co-emulation**
    MEMS on daughter board + TLM VP on Linux : Too many boards, tough reproducibility

- SystemC AMS-TLM Virtual Platform assembled and validated

- Next steps
  - Exploit the methodology for new projects during their architecture definition phase
  - Reuse the methodology for new projects with
    Multi-physical domains + Analog + Digital + SW parts