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Neural network-based sensorless FOC of PMSM using AURIX™ TC4x PPU

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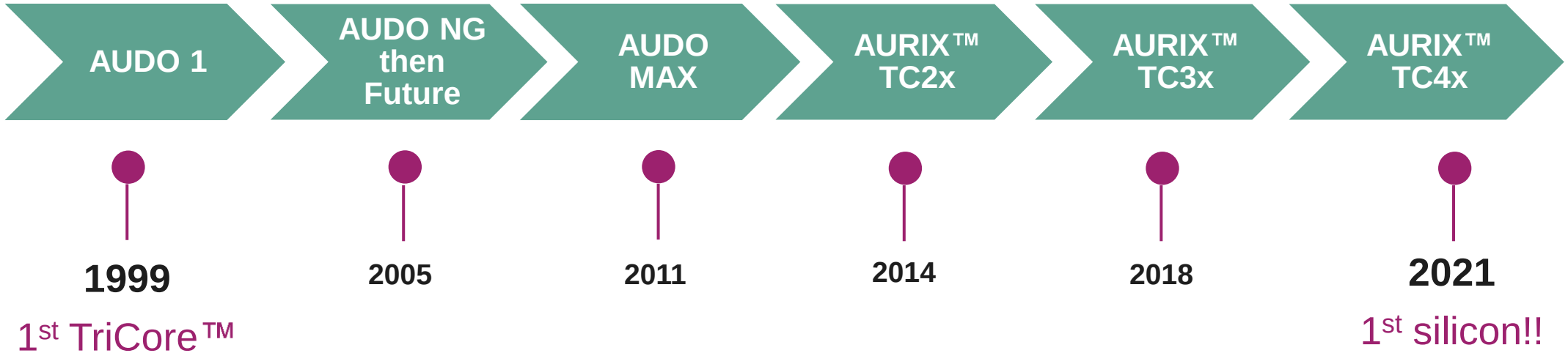
MATLAB EXPO

TriCore™ is the trusted choice for Automotive, with shipments exceeded 1 Billion units in 2022

The TriCore™ concept was born in 1999

TriCore™ integrates three functions: DSP, RISC & MCU

The success story started in Powertrain and spread to the entire automotive MCU market



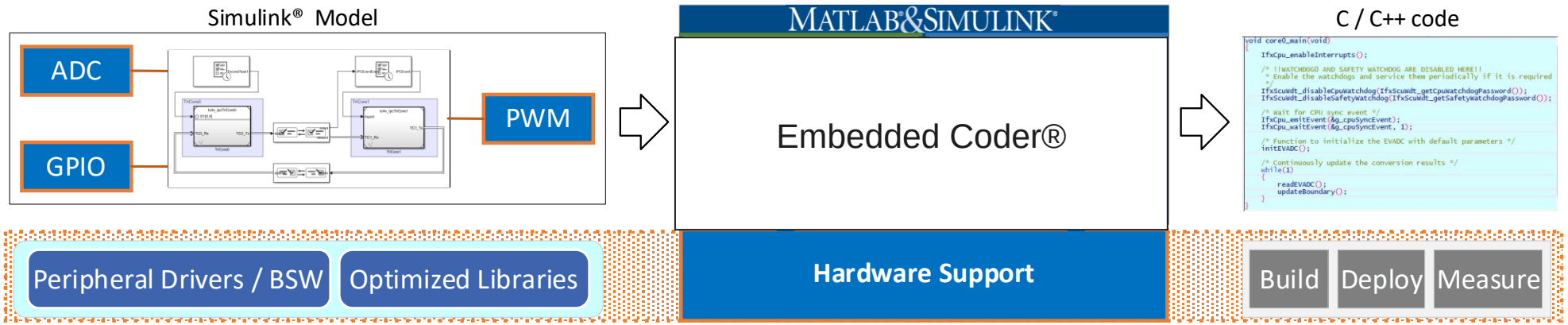
More than 1,000,000,000 TriCore™ shipped since 1999
with outstanding quality <<1ppm

The AURIX™ TC4x meets these future needs and more, providing the industries most extensive major upgrade path for auto MCUs

Whilst ensuring **dependability**

Headroom to grow	– Feature rich to offer applications headroom to grow – Scalable family HW and SW concept for platform reuse
High Performance with AI	– More processing power from TriCore™ v1.8 with virtualization support and new AURIX™ Accelerator Suite – Parallel Processing Unit (PPU) for affordable AI
New E/E architecture	– Optimized devices for Zone and Domain control, – Optimized devices for complex sensor and actuator control
Fully connected and secured	– Enhanced connectivity, new high-speed interfaces – Data Routing Engine for efficient communication – Cutting edge security features to protect with future post quantum cryptography → ISO/SAE 21434 certified
Fast Time to Market	– Seamless "Ease of Use" tool chain and software offering – Model based design for reduced R&D effort – Early development support based on virtual prototyping

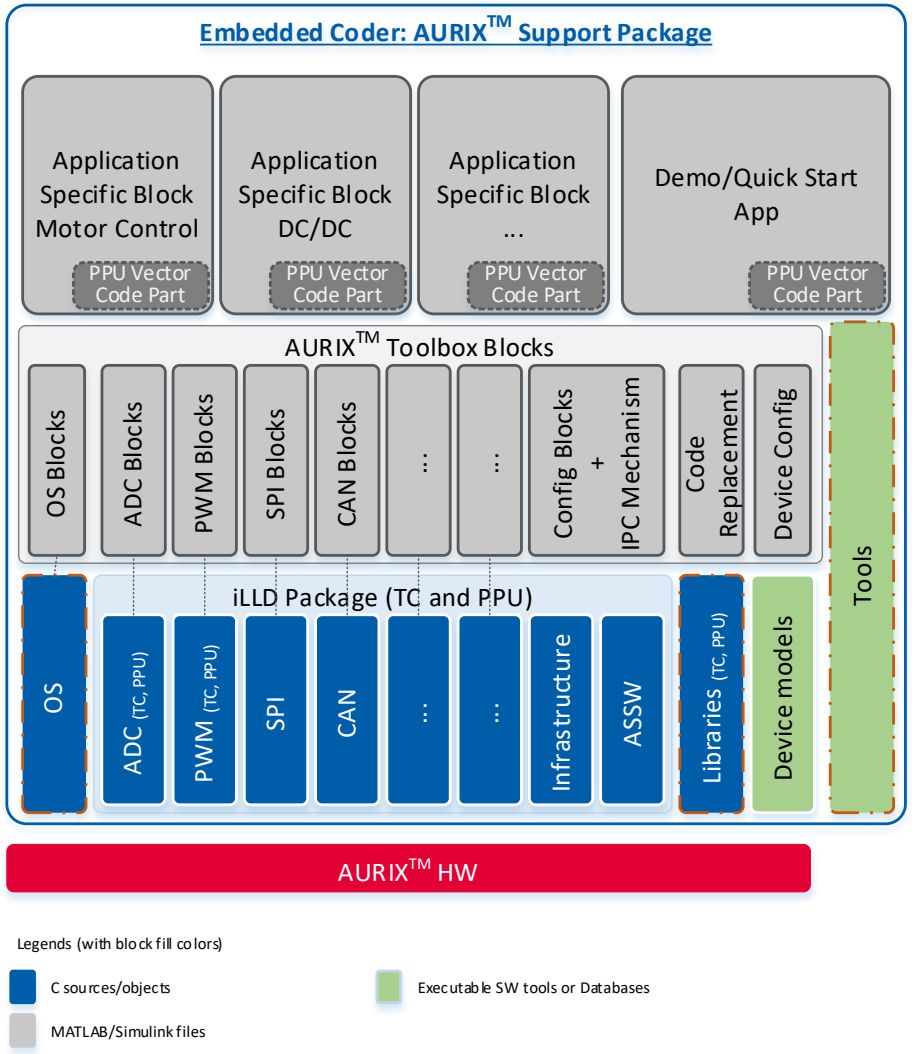
AURIX™ TC4x Hardware Support Package (HSP)

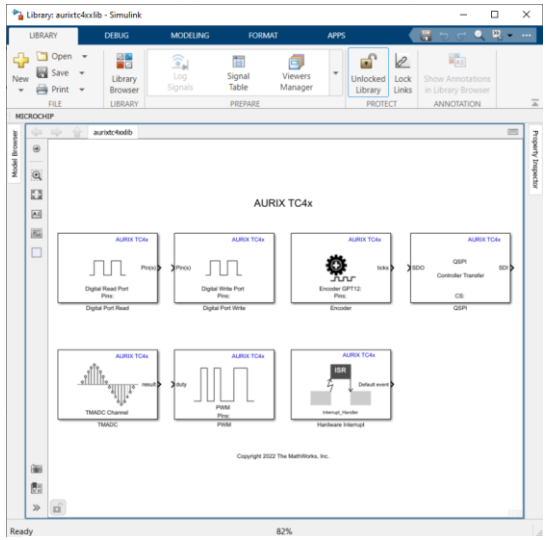


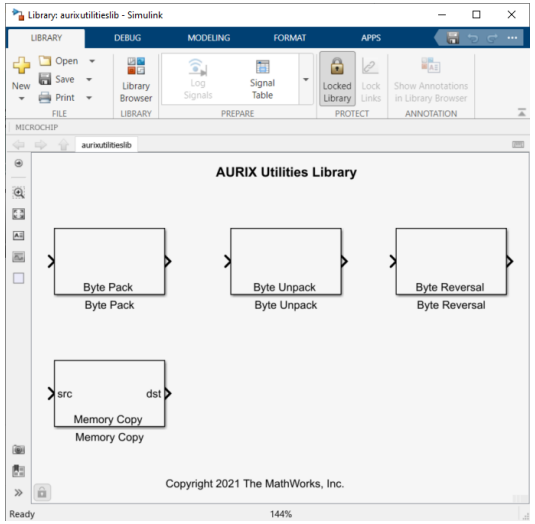
Hardware Support Package (HSP)

- **Is a plugin** to MathWorks Embedded Coder®
- Provides **simulation support with target (PIL)**
- Aids to generate **target specific optimized code**
- **Connects** application to the **peripherals** → calls to driver APIs
- Provides HW mapping → **Configuration Graphical User Interface (GUI)**

AURIX™ TC4x Hardware Support Package (HSP)

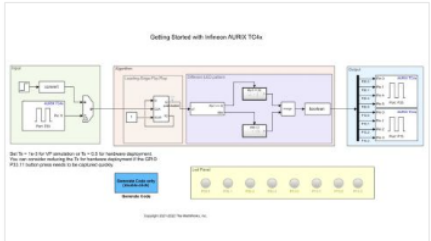




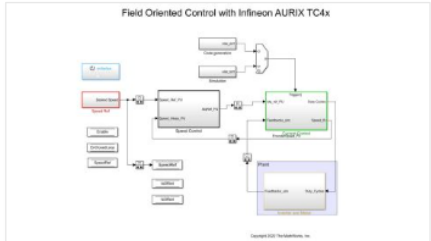


Starting from R2022a

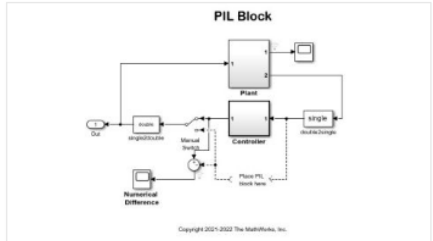
Reference Examples



Getting Started with Embedded Coder Support Package for Infineon AURIX TC4x Microcontrollers



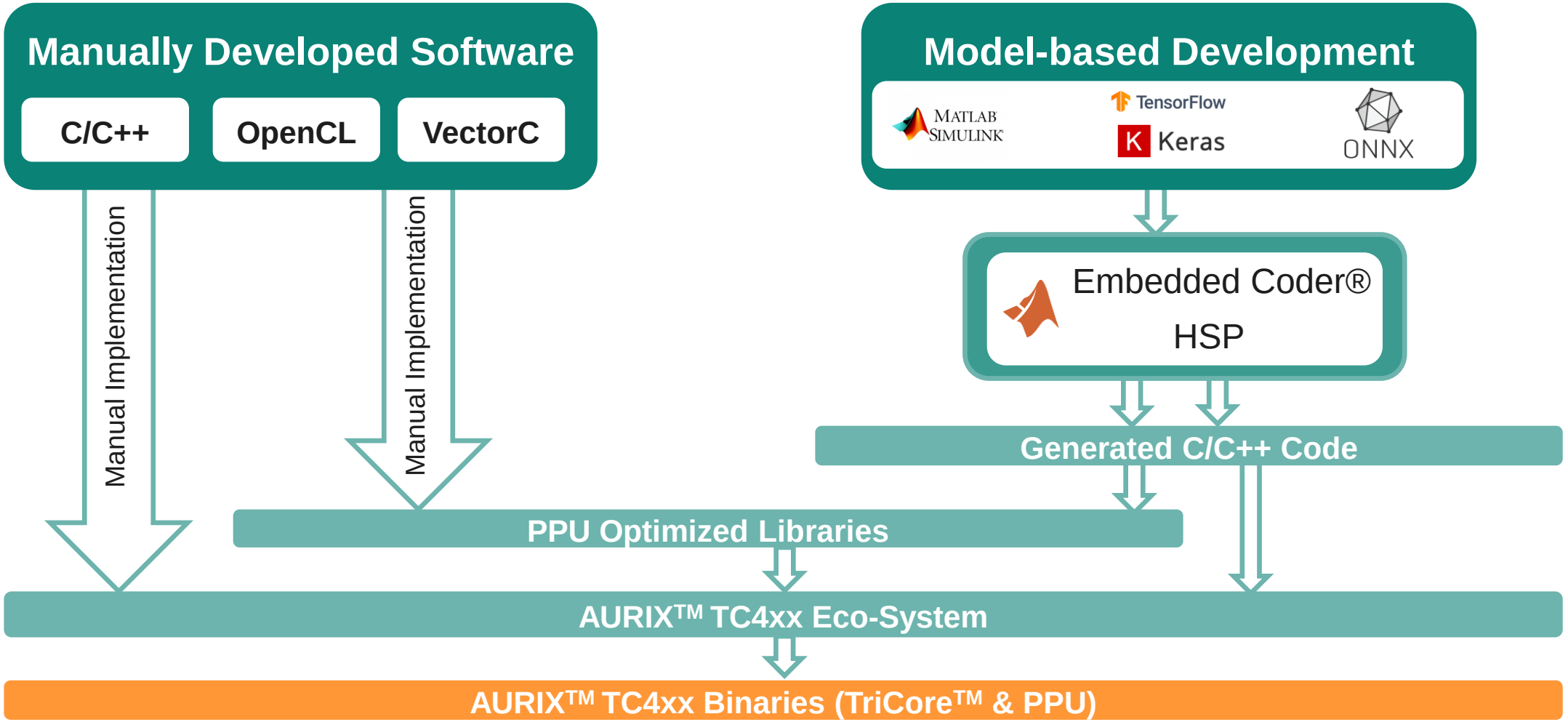
Field-Oriented Control of BLDC with Encoder Using Infineon AURIX Microcontrollers



Code Verification and Validation with PIL

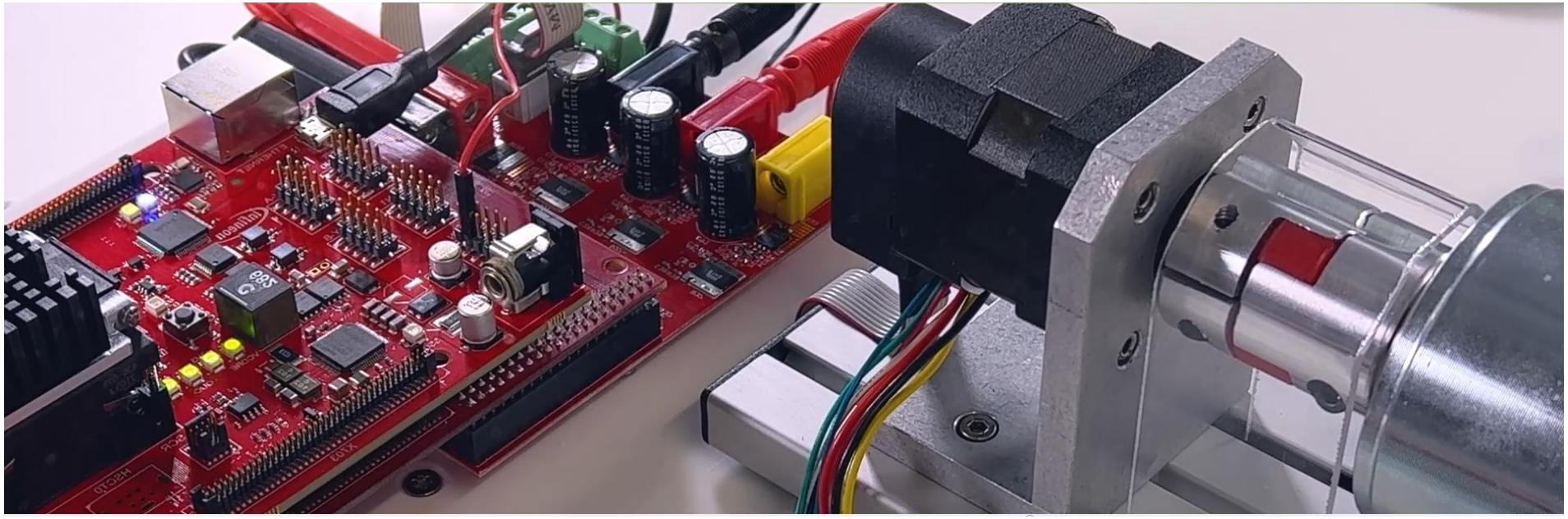
Source: http://www.mathworks.com/aurix

Embedded Software Development Landscape for AURIX™ TC4x

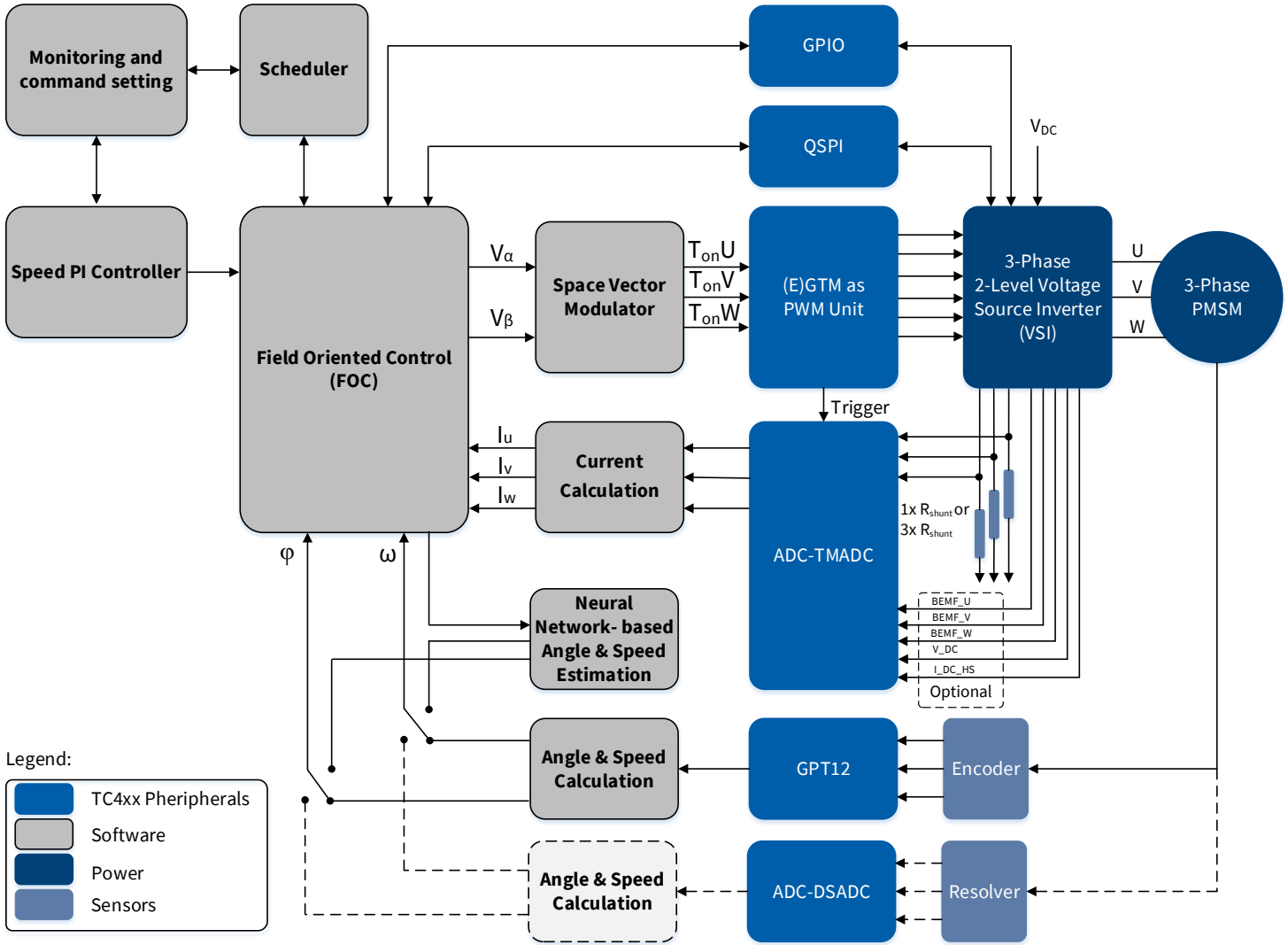


NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™ Description of the demonstrator

- Artificial Intelligence (AI) offers new use cases for advanced data processing:
  - to achieve an improved system performance, e.g. in terms of energy-efficiency
  - to achieve potential cost advantages through replacement of hardware by intelligent software
- In the domain of electrification, energy-efficiency and cost-efficiency are of highest interest
- This demonstrator shows an implementation of neural network-based sensorless Field Oriented Control (FOC) of a Permanent Magnet Synchronous Motor (PMSM)



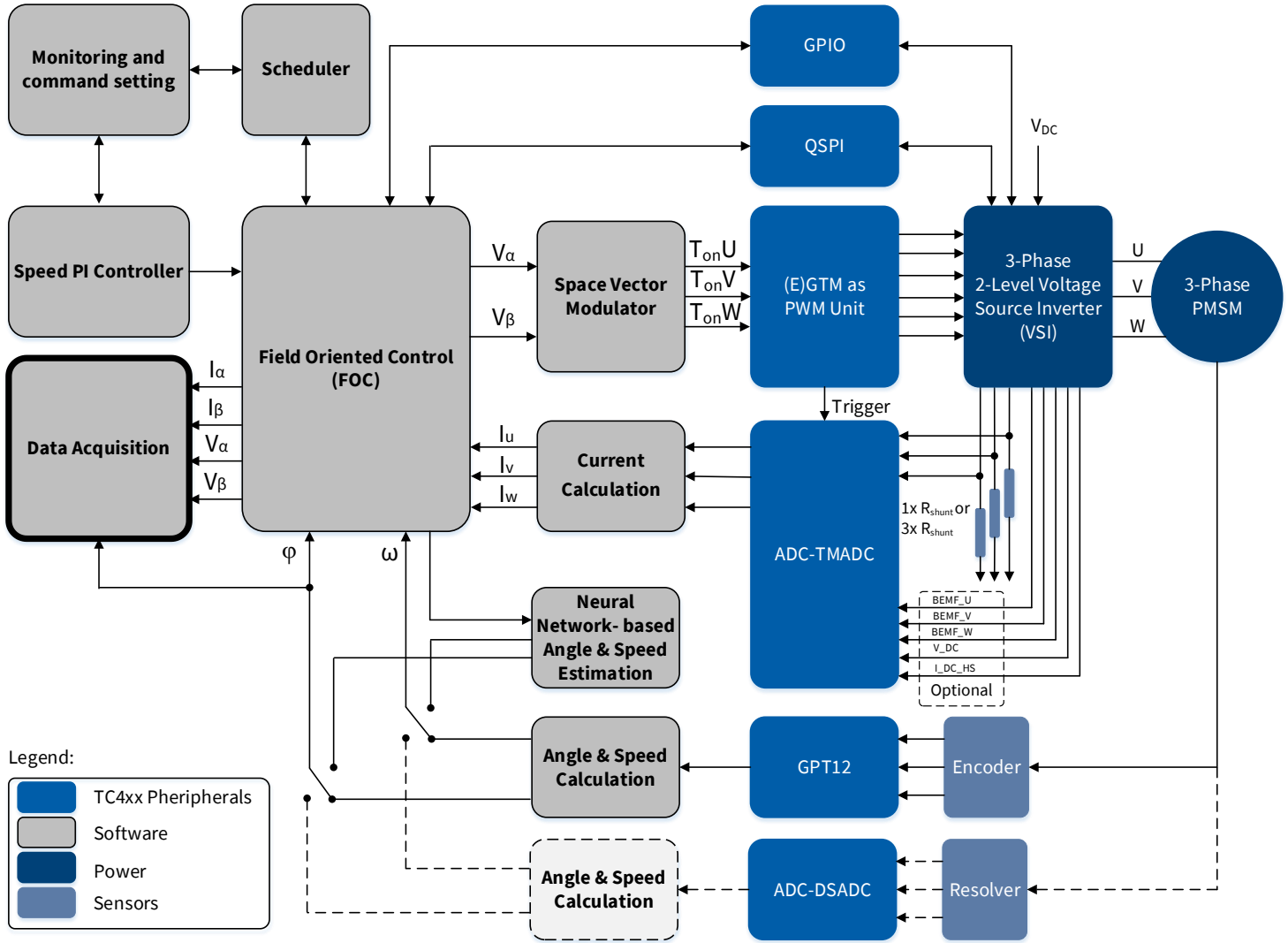
NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™
Simplified system block diagram



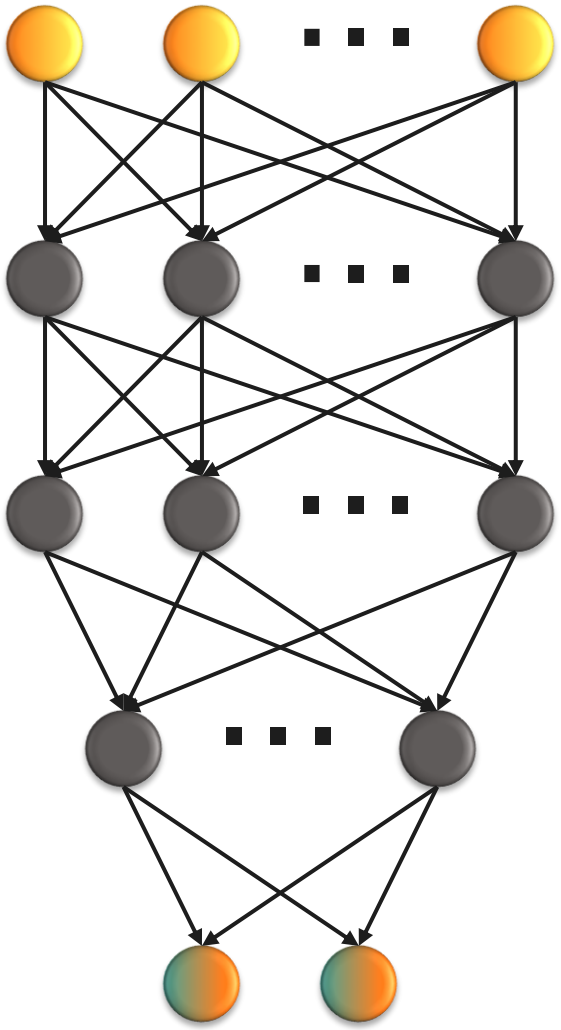
NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™ Development process: Data acquisition

Recorded data:

$I_\alpha, I_\beta, V_\alpha, V_\beta, \varphi$



NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™
Development process: Training of multilayer perceptron (MLP)



Model Selection

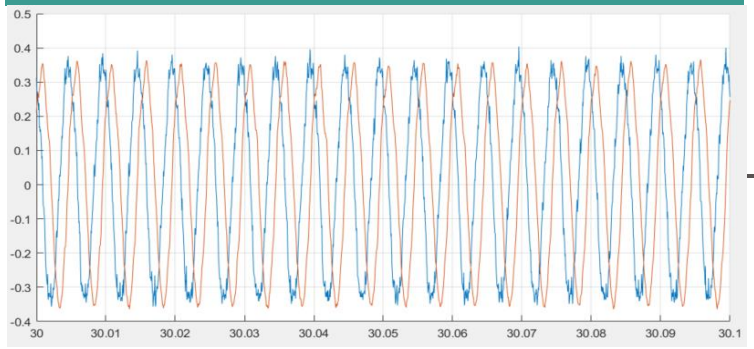
- Different input sizes
- Different layer sizes
- Different number of layers
- Different optmizers
- Different model types
- ...

MLP Scaling

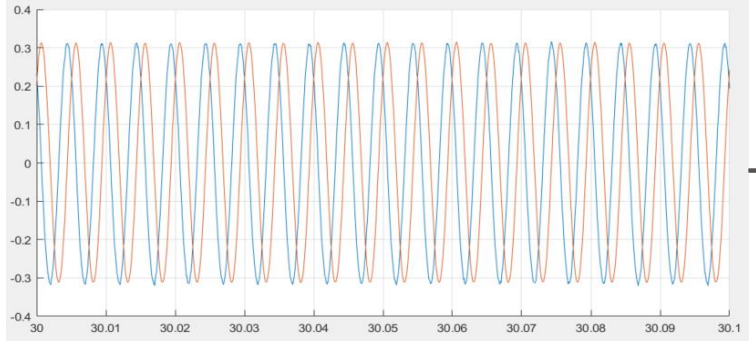
- Input layer size: $S_{\text{in}} = N * T_{in} = 4 * T_{in}$
- # Main layers: $2 + \max(0, ceil(T_{in}) - 2)$
- Size Main layers: S_{in}
- # Trans. layers: $\text{l}_\text{t} = \max(0, floor(\log(S_{in}, S_{out})) - 3)$
- Size ith Trans. layers: $2\text{^}(l_t + 2 - i)$
- Output layer size: $S_{out} = M * T_{out} = 2 * 1 = 2$

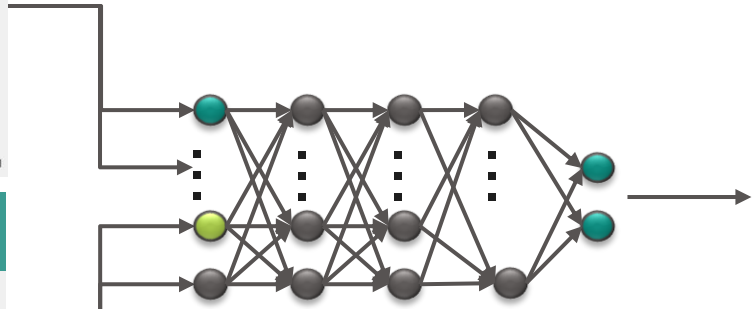
NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™
Development process: Evaluation of multilayer perceptron (MLP)

NN input: αβ current pair

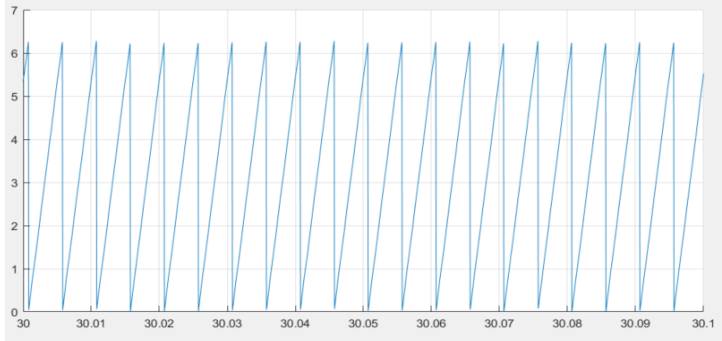


NN input: αβ control output pair



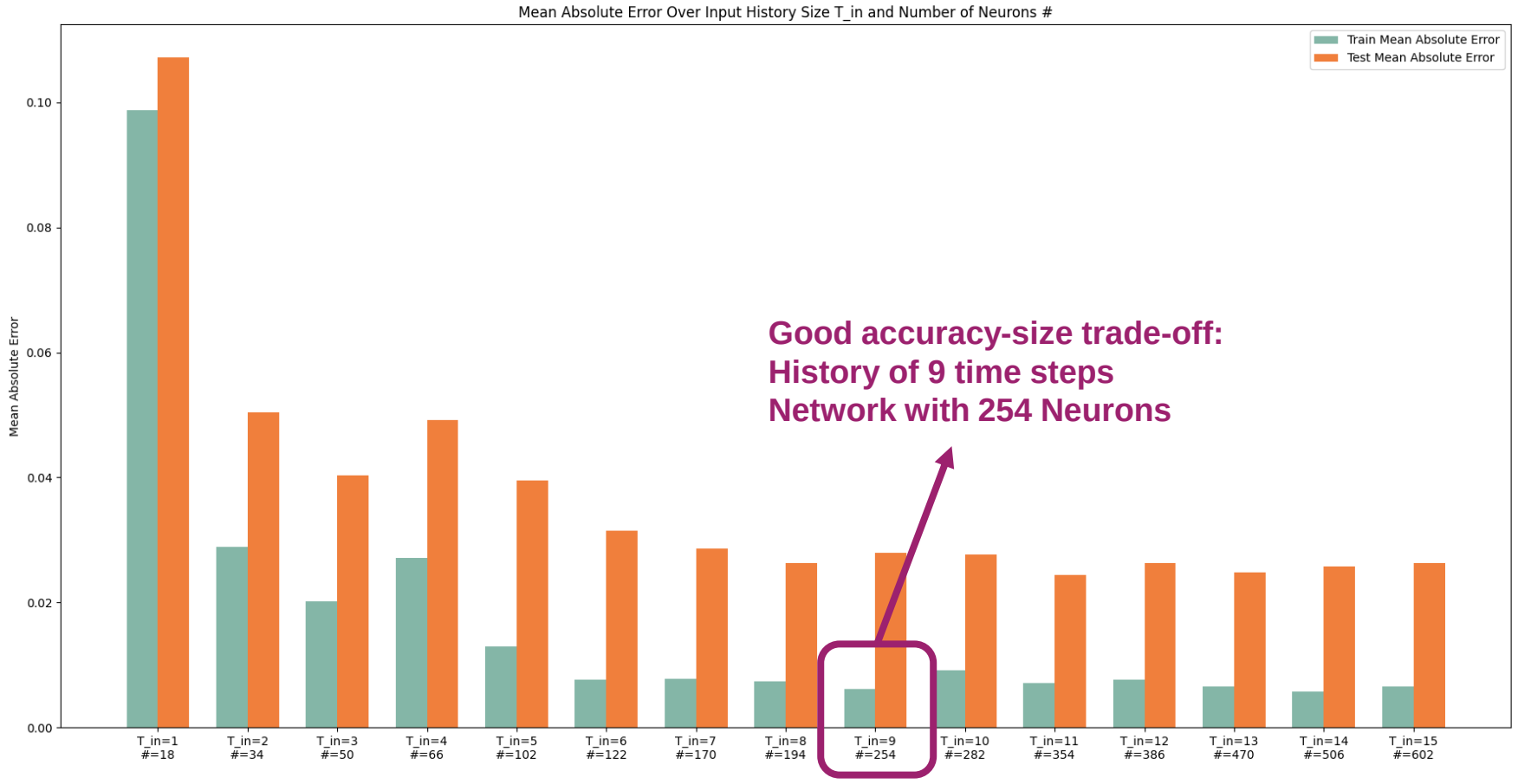


NN output: motor position

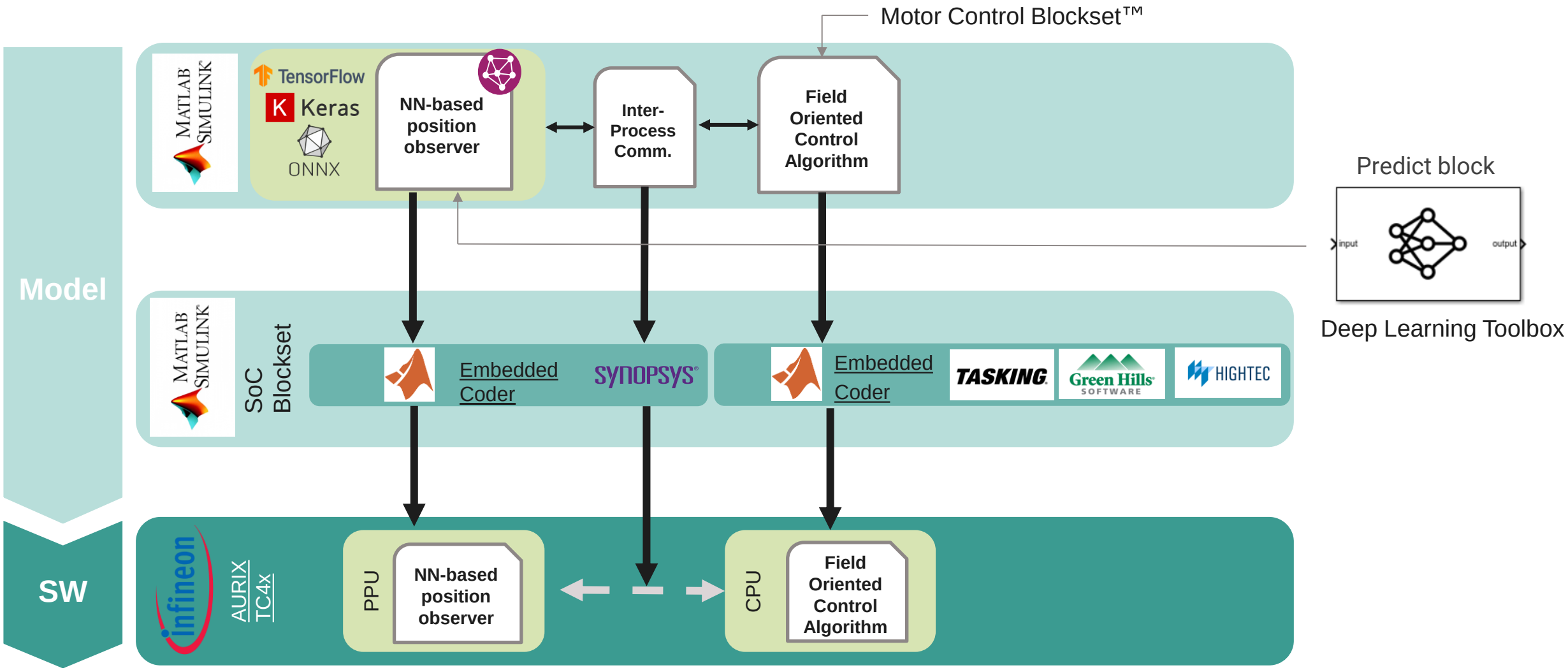


Input Layer: 36 = 4 signals x 9 time steps
6 Hidden Layers: 36 (+rectified linear unit)
Output Layer: 2 = sin and cos of motor position

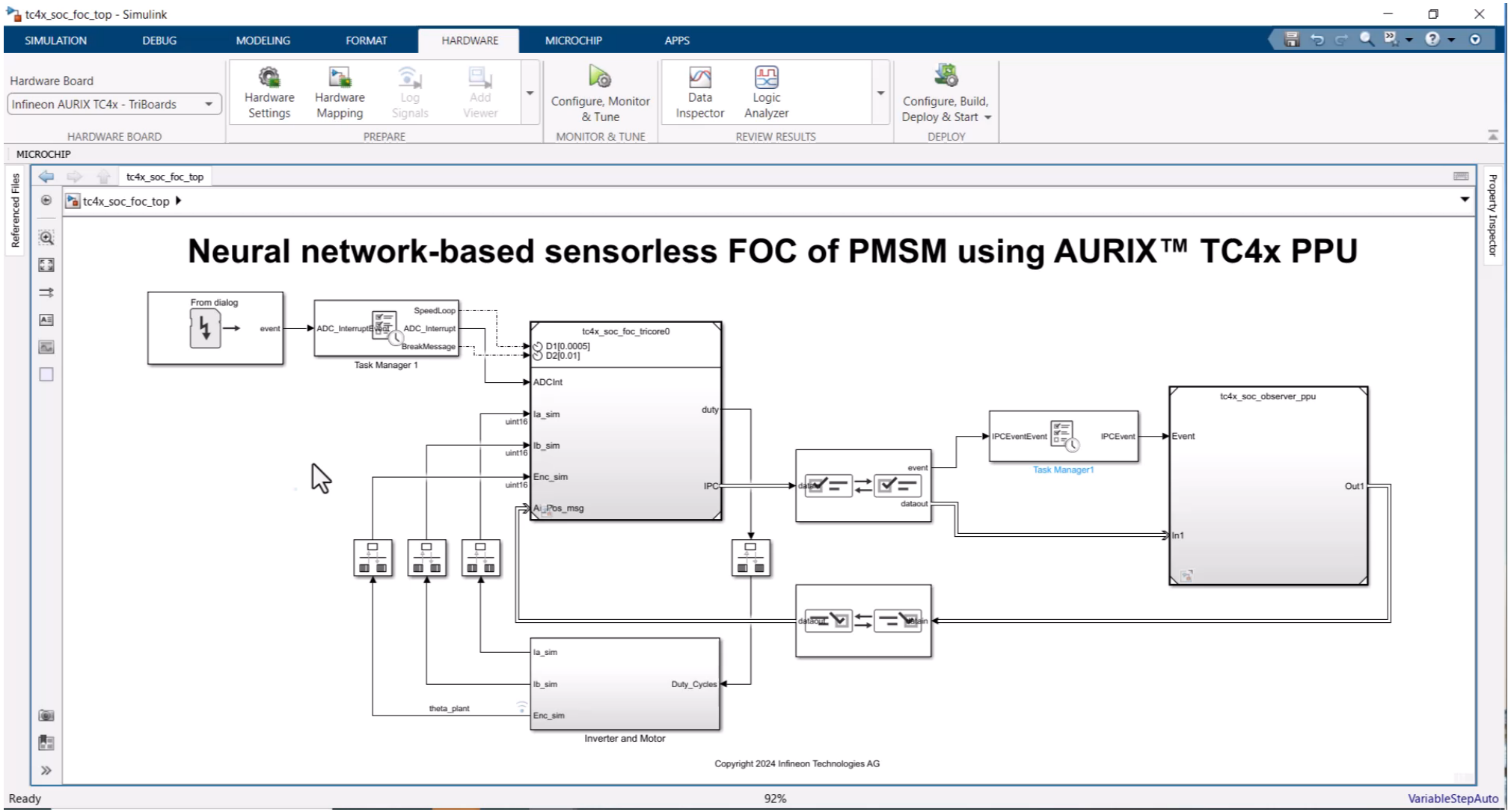
NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™
Development process: Evaluation of multilayer perceptron (MLP)



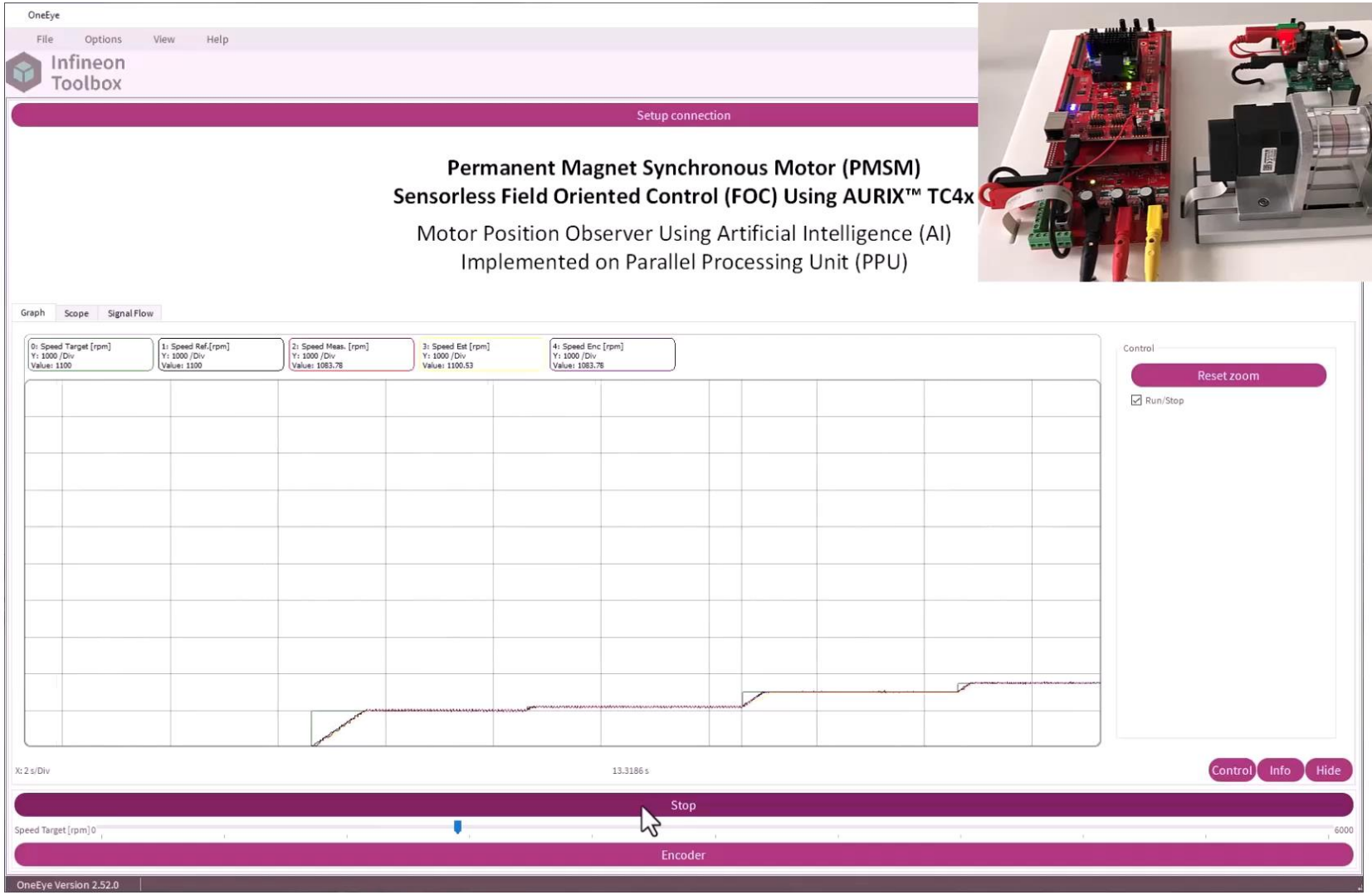
Partitioning of the motor control application using MathWorks Embedded Coder® support for AURIX™ TC4x



NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™ Development process: Deployment



NN-based sensorless FOC of PMSM using AURIX™ TC4x PPU™ Development process: Measure



Wrapping Up

- AI-based virtual position sensor can increase the quality of the electric motor position sensing. The AI can take the position sensing of a “cheap” physical sensor and – due to training with high-quality data – transform it into a high-quality position sensing
- AURIX™ TC4x hardware support package enables code generation and software built for multi-core applications including PPU
- Model driven development maximizes re-use of existing projects and decreases the engineering effort
- With MathWorks as a partner, Infineon Technologies AG offers complete ecosystem for model driven development and closed-loop validation on different abstraction levels

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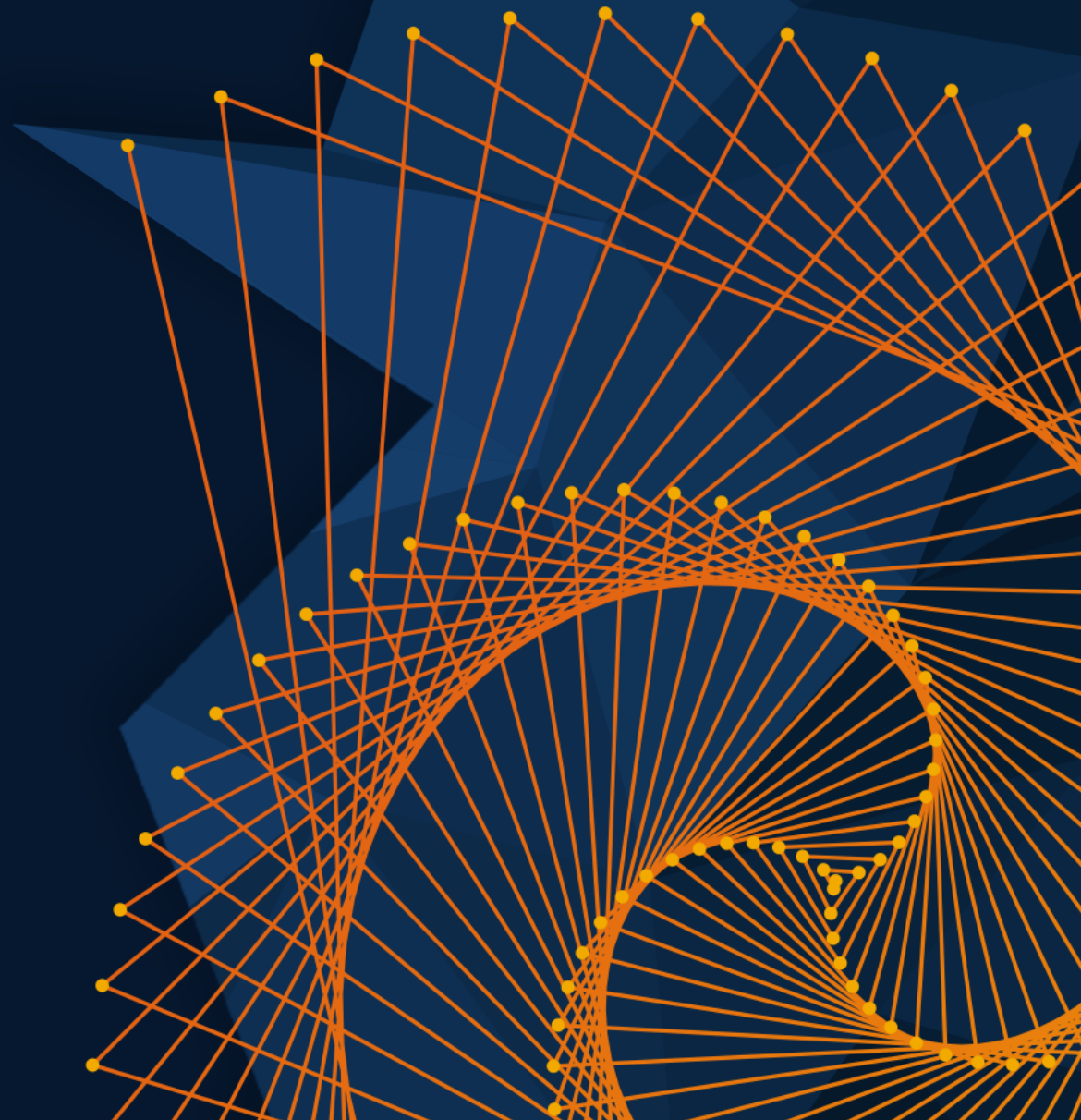

MathWorks®