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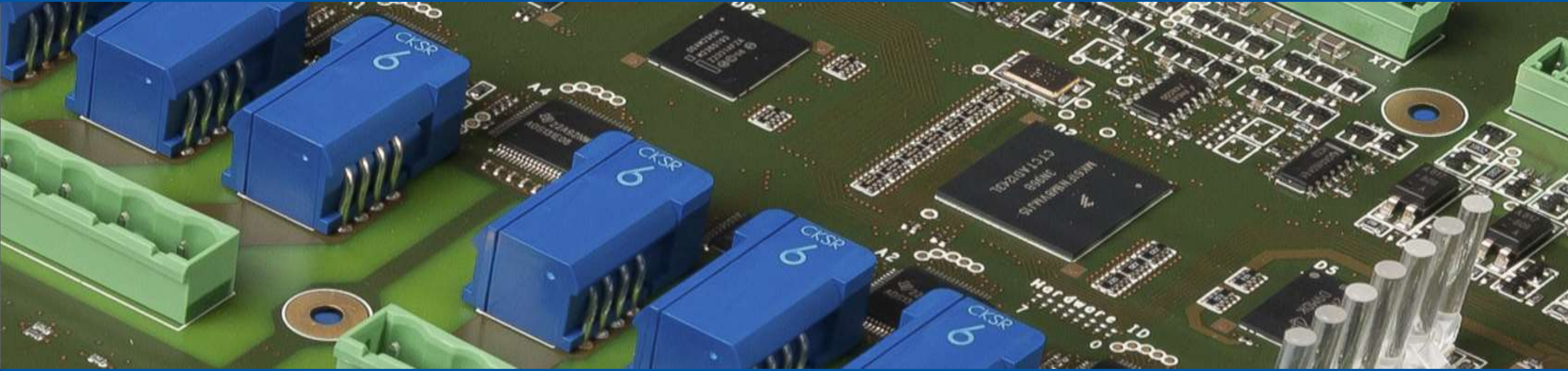
CO-DEVELOPMENT MANUFACTURING INNOVATION & SUPPORT



High-Performance Motion Control with the PEPPER/MINT System-on-Chip Platform

Ronald Grootelaar, Consulting Engineer

Agenda

- Introduction 3T
- Model-based Design
- Projects
- Platforms & building blocks
- Sensorless Field Oriented Control (FOC) for BLDC

Company profile

- Founded in 1982, 3T since 1994
- Co-development, manufacturing and support of *customer specific electronics*
- ISO 9001:2015 and EN ISO 13485:2016 certified
- 80 employees
- Offices in Enschede and Eindhoven
- Strong partner network

intel FPGA Design Solutions Network

MathWorks Partner

XILINX ALLIANCE PROGRAM CERTIFIED MEMBER — BASE

Microsemi

Systems are becoming more intelligent, more complex

- Model-Based Design is a way to deal with this

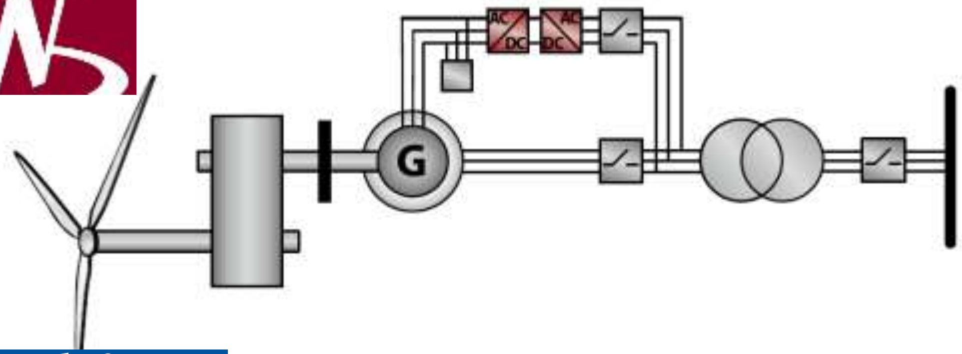
ASML

Wafer Handler robot

Tracking Radar

Sensys Gatso Group

SR E-drive system



Wind Turbine

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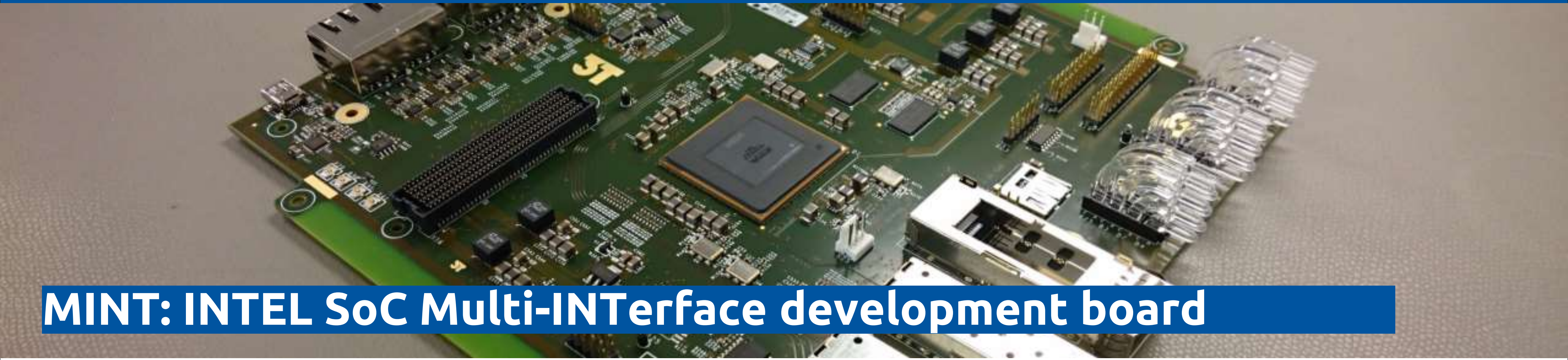
punch powertrain
Gear up for the future

Platforms & building blocks

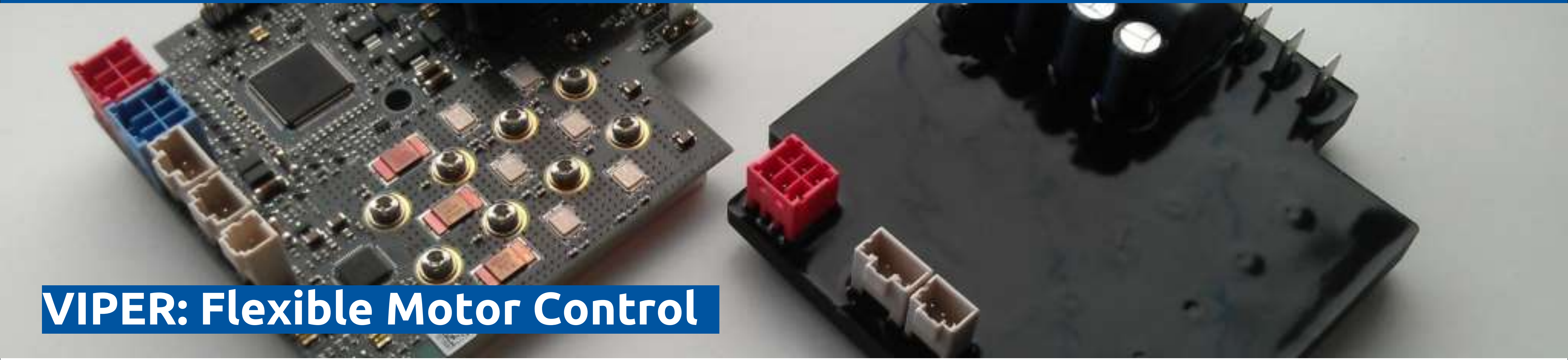
- Systems are becoming more intelligent and more complex
  - increasing use of advanced motor/power control
  - increasing use of System on Chip (SoC) devices
- Generic platforms & building blocks: *MINT, VIPER, PEPPER*
  - prove feasibility early in the design phase
  - reduce development risks, cost and time to market
  - kick-start customer projects



MINT: INTEL SoC Multi-INTerface development board

- INTEL SoC: FPGA and dual-core ARM Cortex-A9
- USB3, Ethernet, SFP+ and QSFP sockets, UART, SPI, i2C, GPIO, RS-485
- Linux
- Board Support Package (BSP) for Model-Based Design using MATLAB/Simulink
- FMC connector for extension boards e.g. PEPPER

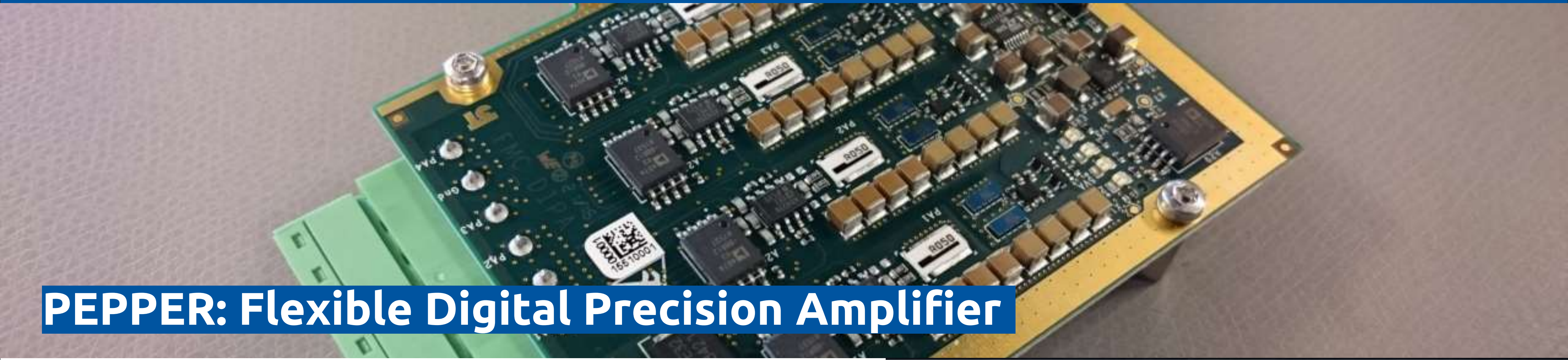
- See: http://3t.nl/mint/



VIPER: Flexible Motor Control

- Power up to 50V/60A (scalable)
- Support BLDC / PMSM / IPM / steppers (microstepping)
- Interface UART, CAN, Ethernet
- 3 phase sensorless sinus steering based upon FOC (Field Oriented Control)

- See: http://3t.nl/viper/



PEPPER: Flexible Digital Precision Amplifier

- Flexible 4-channel GaN FETs based power amplifier
- Output power 4 x 50V x 5A = 1kW (scalable)
- High efficiency, accuracy and bandwidth
- FMC (FPGA Mezzanine Card)
- Board Support Package (BSP)
  for Model-Based Design using MATLAB/Simulink
- See: http://3t.nl/pepper/

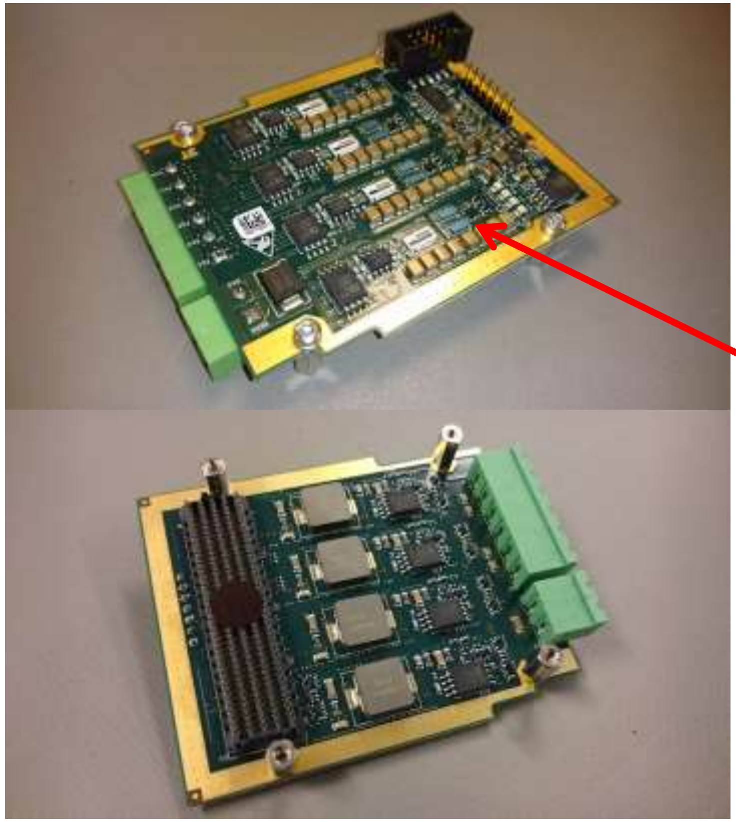
Power control application

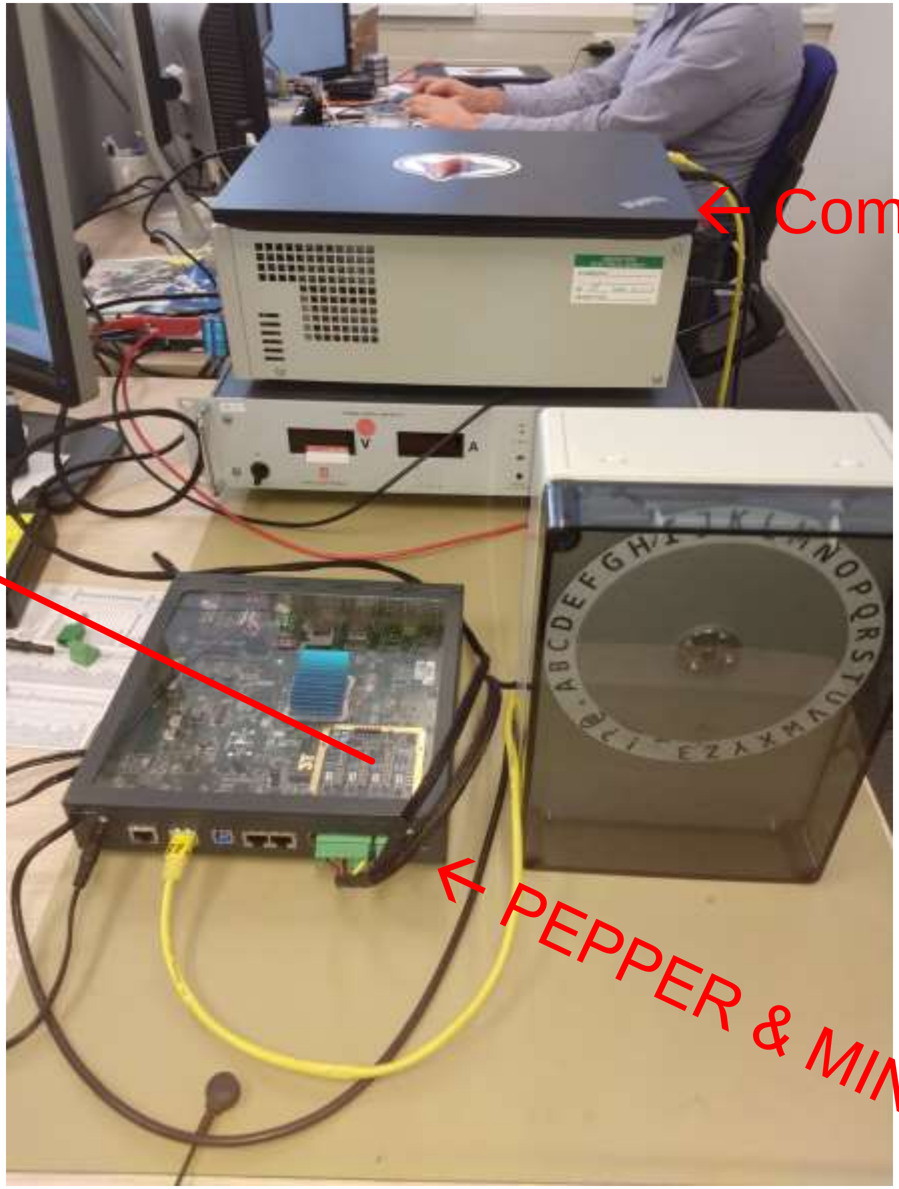
Sensorless Field Oriented Control (FOC) for Brushless DC (BLDC) Motors

Goal

- Develop sensorless FOC (Field Oriented Controller) for BLDC motor on MINT & PEPPER platform
- Design FOC, motor position estimator, path planner / motion control
- Realize demonstrator

The demonstration setup





← Computer running MATLAB

← Motor with letter wheel

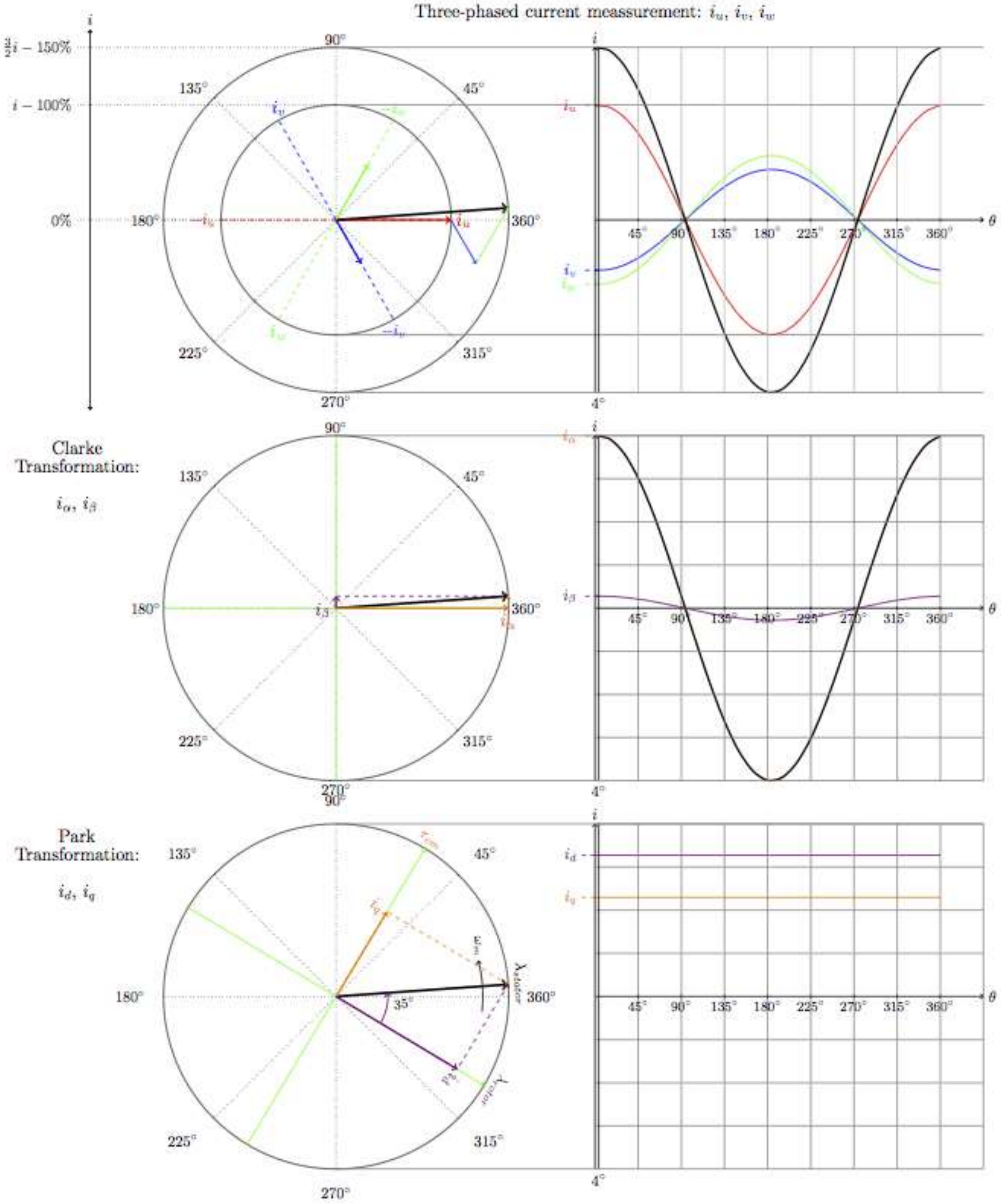
← PEPPER & MINT

Demonstration

Speed: 3000 rpm
Flash: 50Hz

Field Oriented Control (FOC)

- Geometric transformations
  3-phase AC to 2-phase DC
- Torque control
- No frequency dependency



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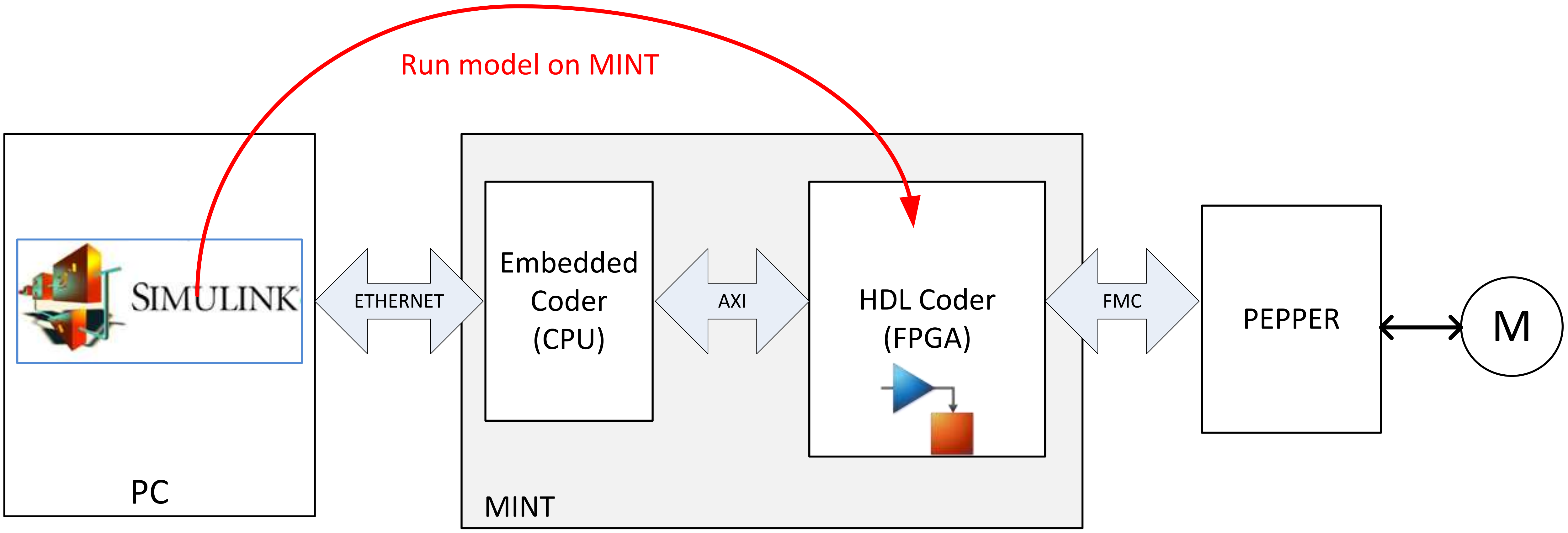
Source: https://www.switchcraft.org

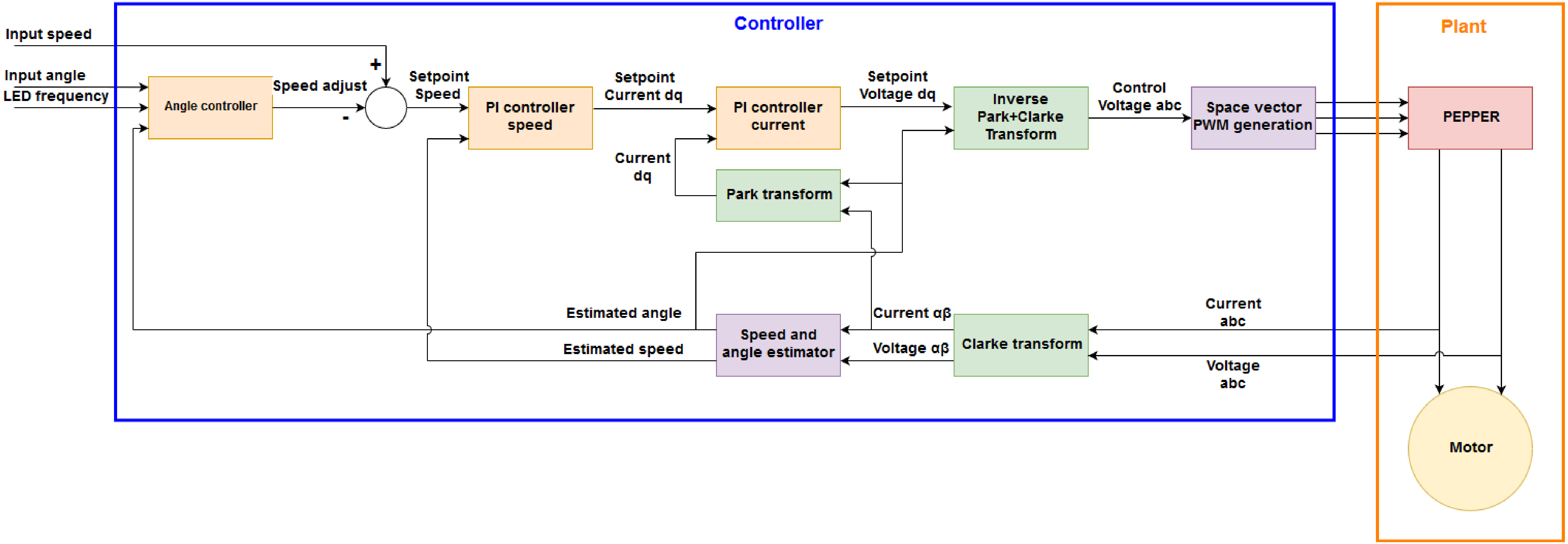
3T SoC/MINT Workflow



Model-Based Design steps

1. High level system model design
2. Plant model design
3. Controller model design
4. Deployment on hardware platform
5. Optimization
6. Hardware verification

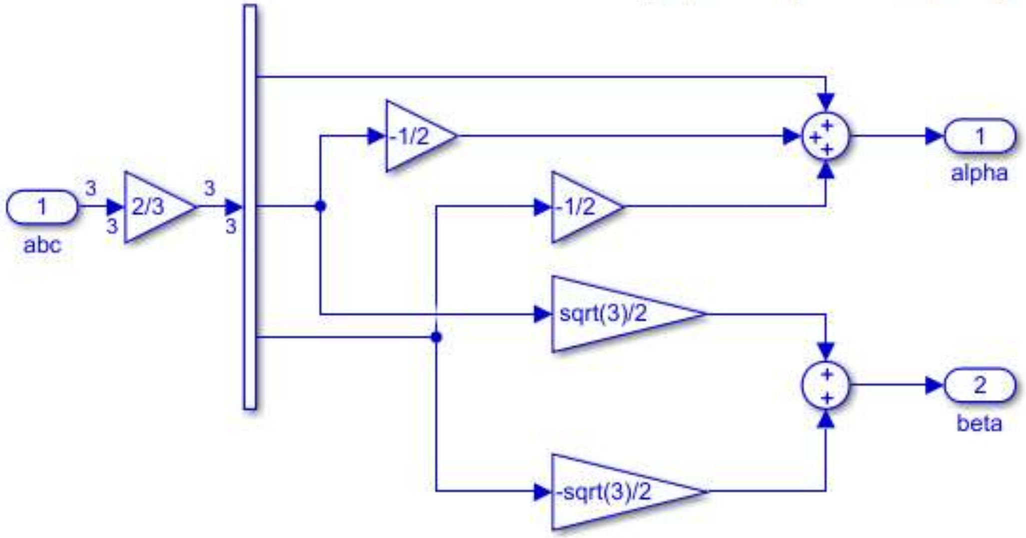
High level system model



Clarke transform

Clarke transform implementation in simulink

The 0 element is omitted
$$\begin{bmatrix}\alpha\\ \beta\\ 0\end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix}1 & -\frac{1}{2} & -\frac{1}{2}\\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2}\\ \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}}\end{bmatrix}\begin{bmatrix}a\\ b\\ c\end{bmatrix}$$

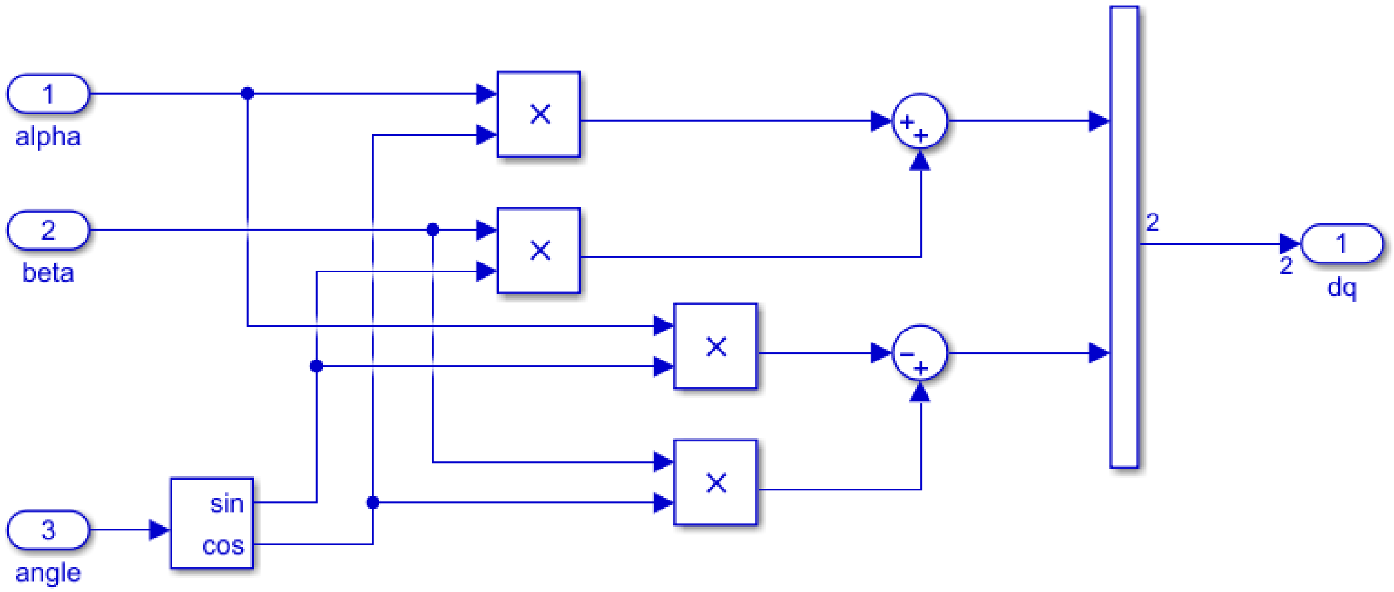


Park transform

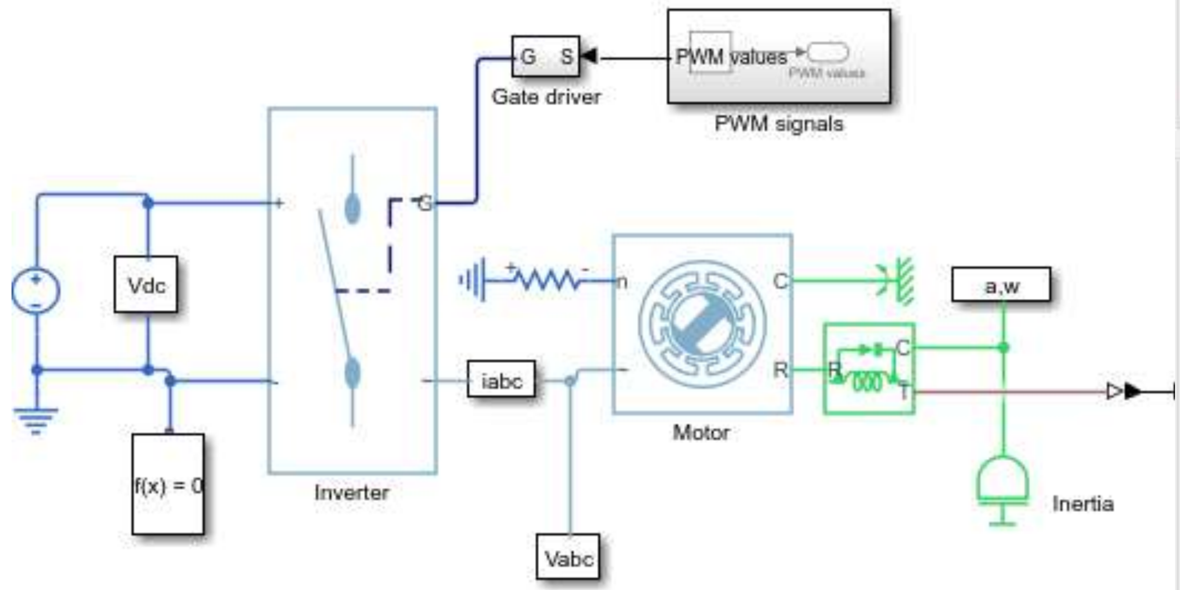
Clarke to park transform implementation in simulink

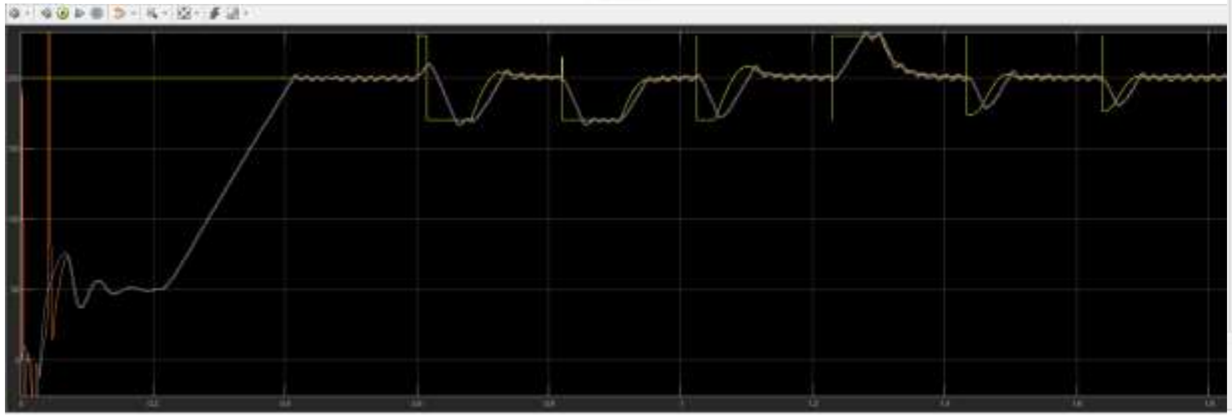
$$\begin{bmatrix} d \\ q \\ 0 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \\ 0 \end{bmatrix}$$

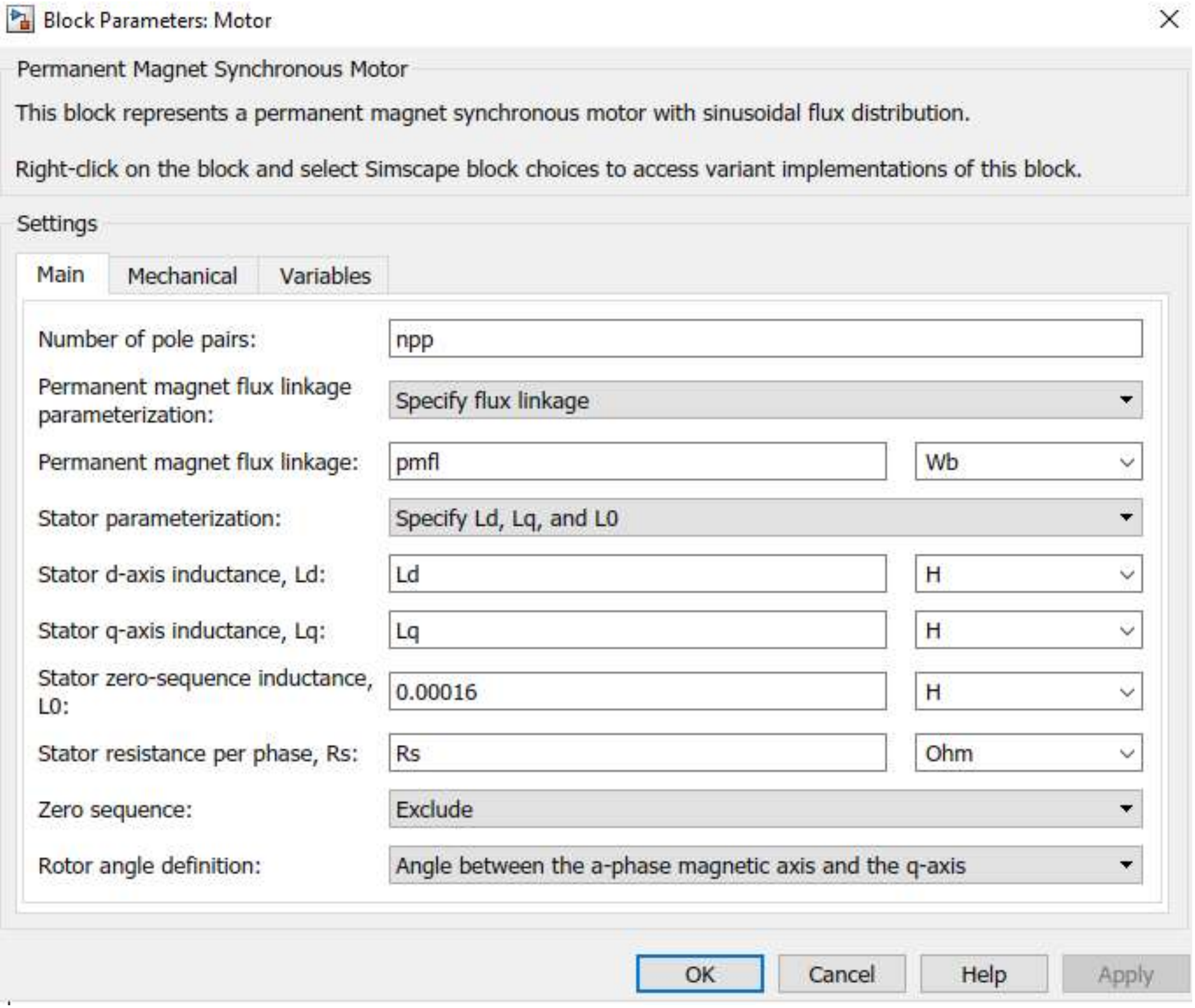
The 0 element is omitted



Plant







Block Parameters: Motor

Permanent Magnet Synchronous Motor

This block represents a permanent magnet synchronous motor with sinusoidal flux distribution.

Right-click on the block and select Simscape block choices to access variant implementations of this block.

Settings

Main | Mechanical | Variables

Number of pole pairs:	npp	
Permanent magnet flux linkage parameterization:	Specify flux linkage	
Permanent magnet flux linkage:	pmfl	Wb
Stator parameterization:	Specify Ld, Lq, and L0	
Stator d-axis inductance, Ld:	Ld	H
Stator q-axis inductance, Lq:	Lq	H
Stator zero-sequence inductance, L0:	0.00016	H
Stator resistance per phase, Rs:	Rs	Ohm
Zero sequence:	Exclude	
Rotor angle definition:	Angle between the a-phase magnetic axis and the q-axis	

OK | Cancel | Help | Apply

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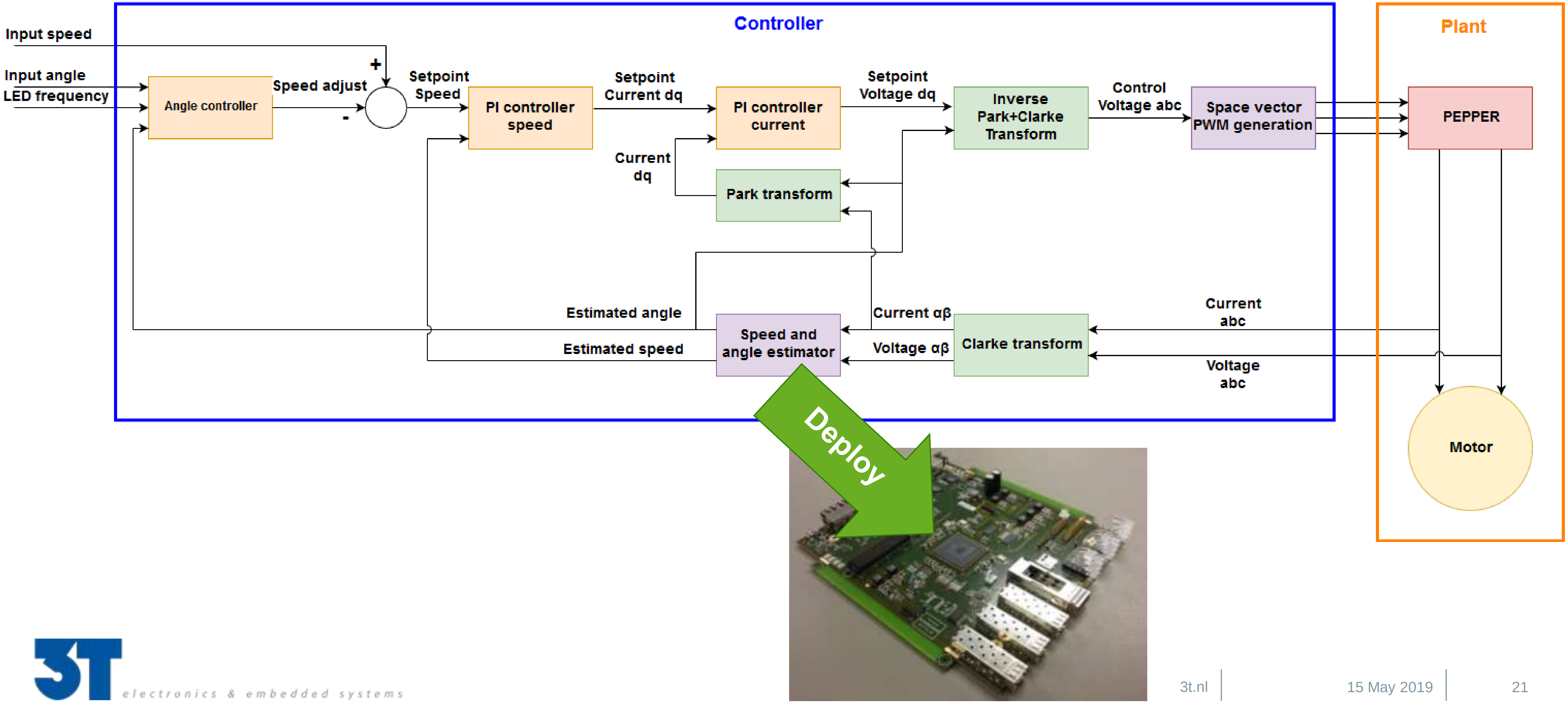
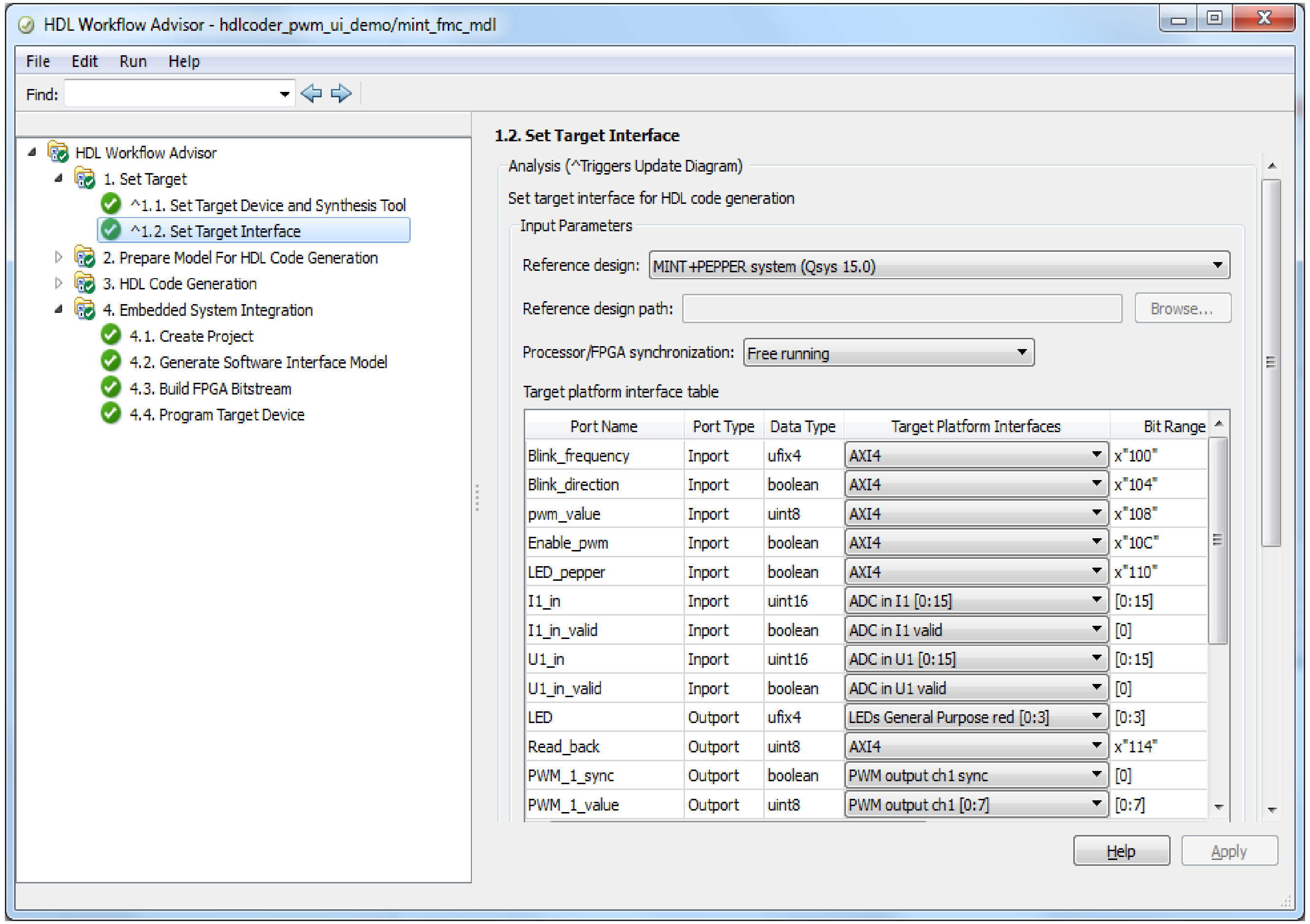
Controller | Deployment



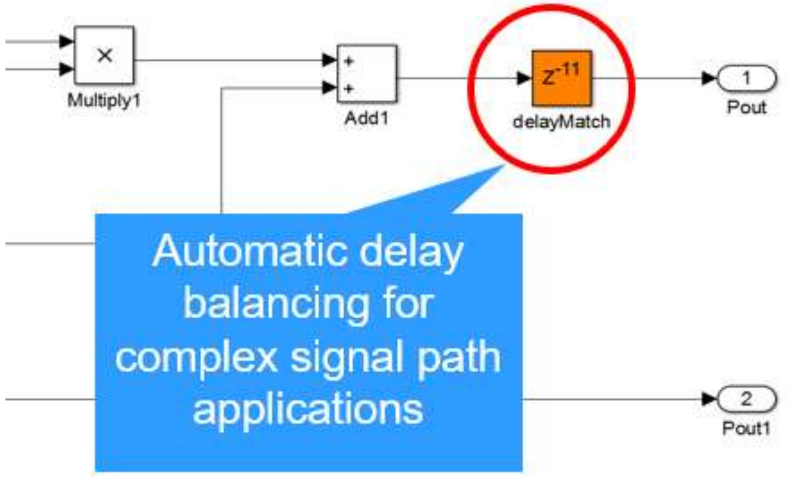
Deployment on hardware platform

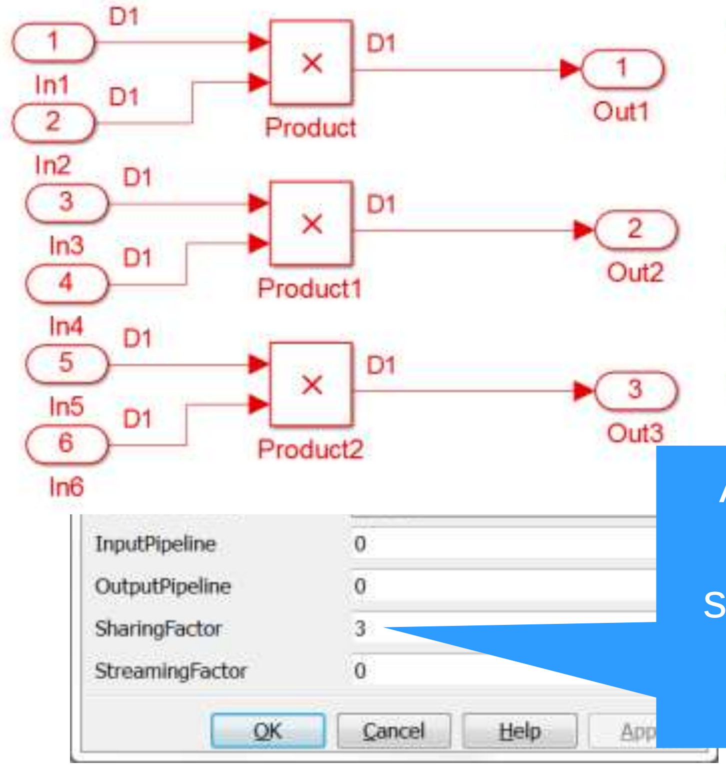
- Set Target
  MINT Board Support Package (BSP)
- Prepare Model for Code Generation
- HDL Code Generation
- Embedded System Integration

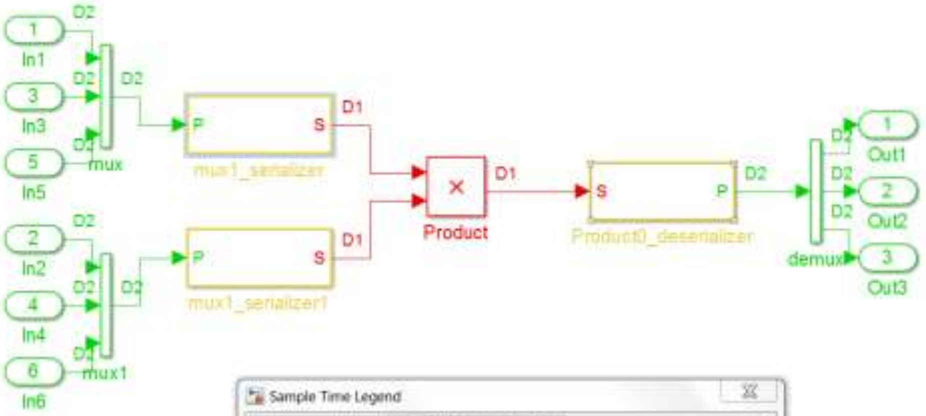


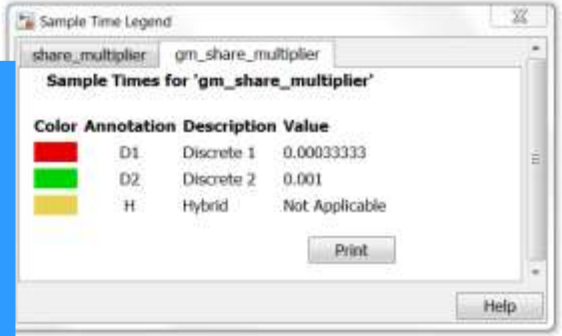
HDL Coder optimizations

- Fixed-point vs floating point
- Sample rate conversion
- Resource sharing
- Pipelining









Automatic resource sharing is a powerful feature.

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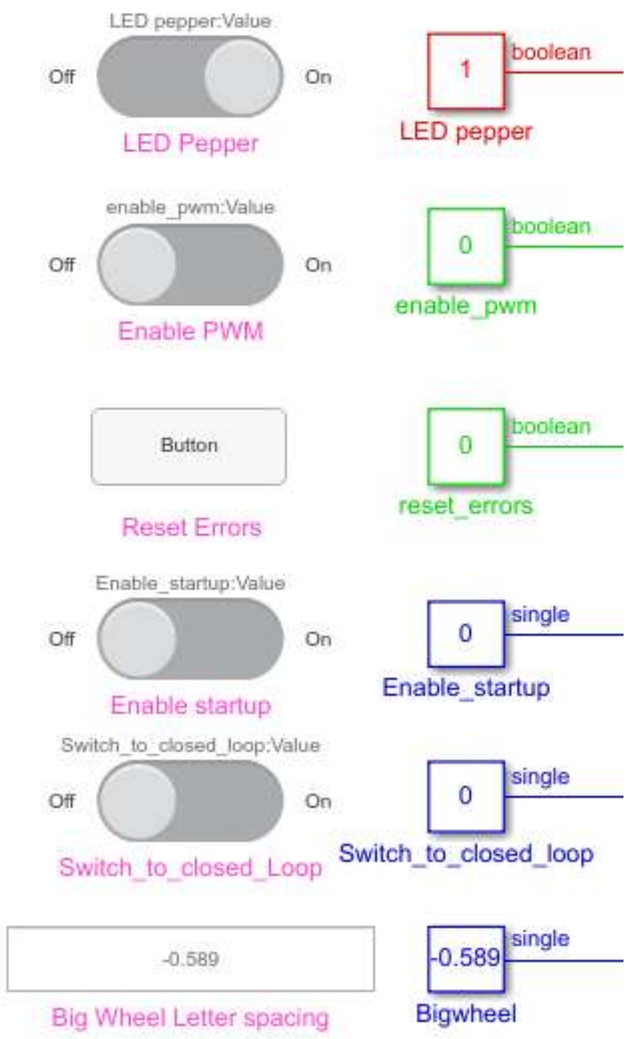
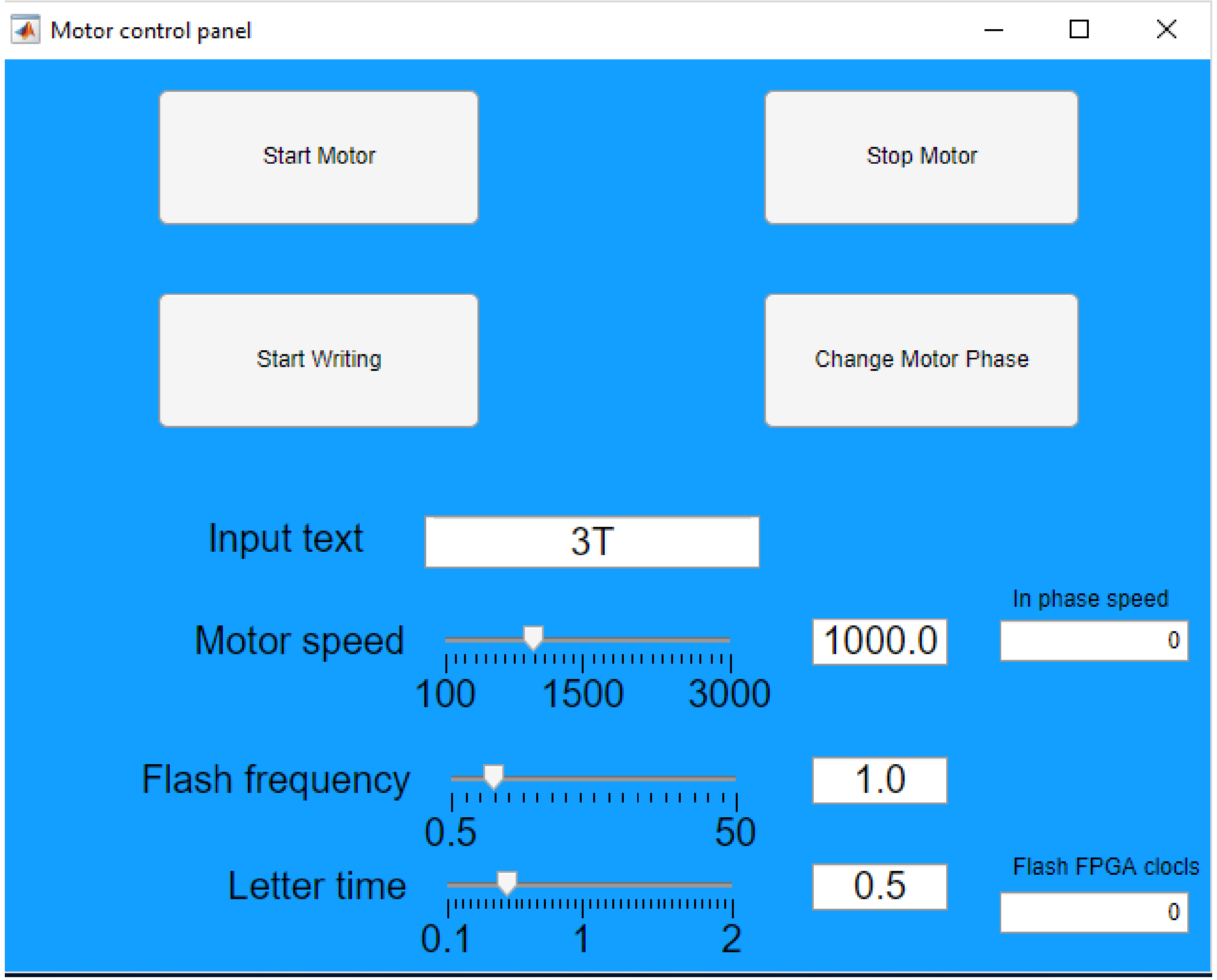
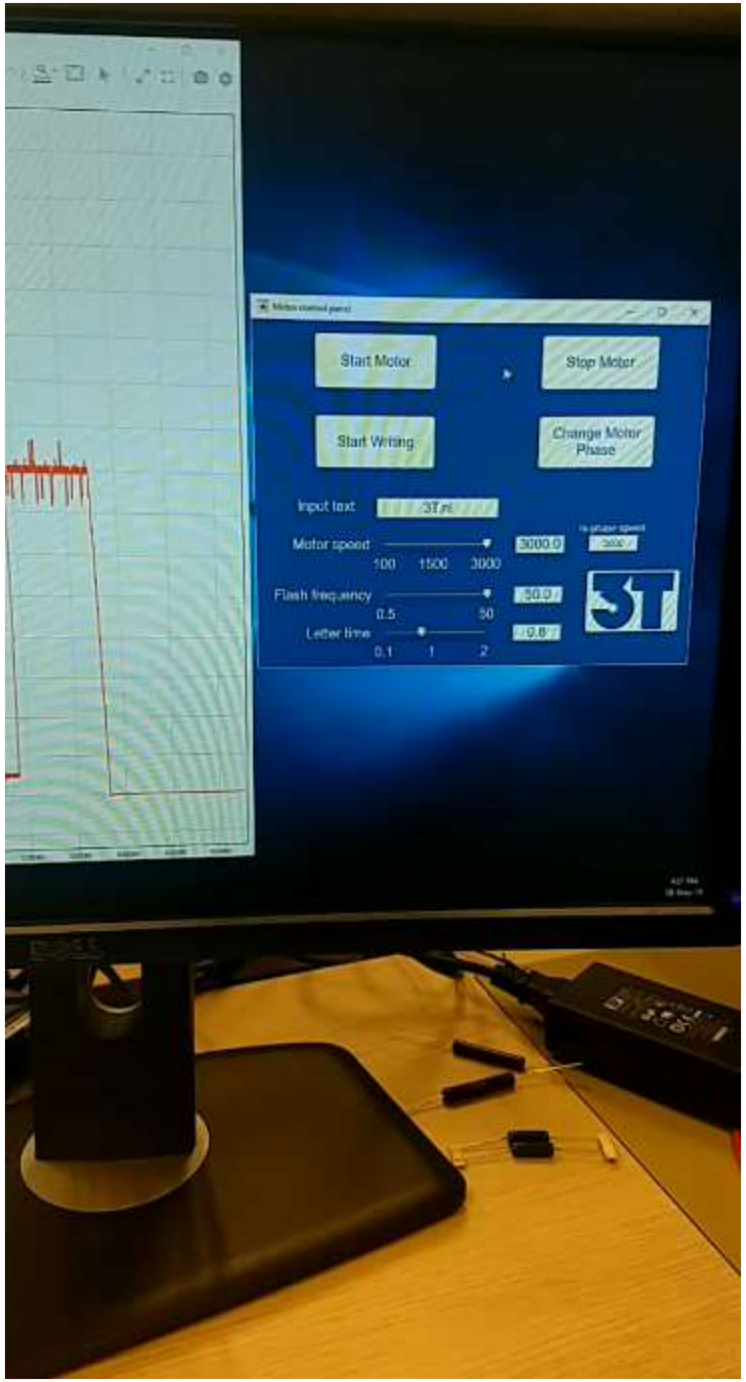
Hardware verification

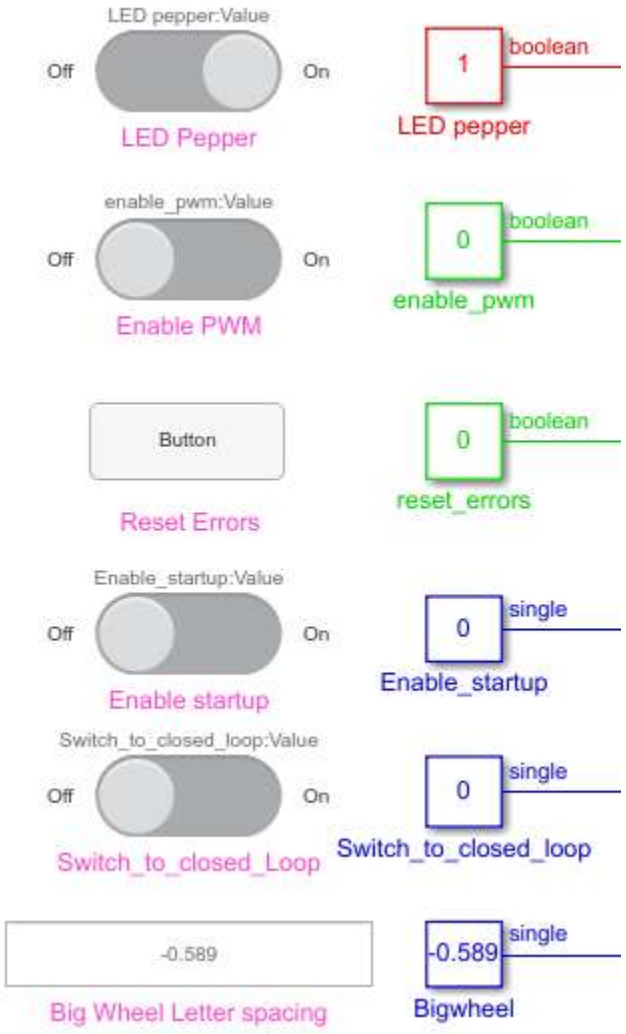
- Simulink in external mode to control deployed model





Simulink External mode





Runtime parameter tuning on target for phase calibration

Conclusions

- The project results show that Model-Based Design helps to:
  - Shortened lead time (letter wheel completed in 10 weeks, instead of planned 20 weeks)
  - Positive customer feedback

  - Assess feasibility through simulation
  - Improve collaboration between different disciplines
  - Respond quickly to changing requirements, hours instead of days

e l e c t r o n i c s & e m b e d d e d s y s t e m s

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