

# SyMSpace and X2C

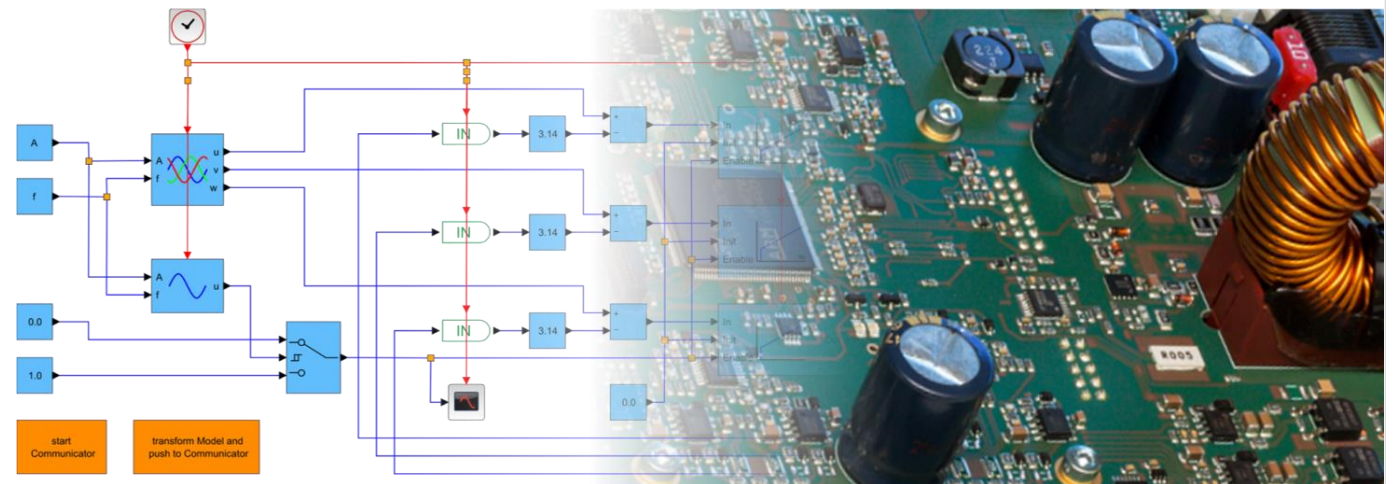
SyMSpace Days

September 18<sup>th</sup>, 2024

# X2C

## What is X2C?

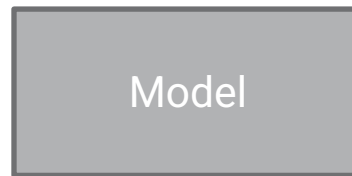
- Rapid control prototyping system
  - Model based design
  - Code generator for C
- Real-time control on microprocessors
  - Support of many various DSP/DSC families
    - Microchip dsPIC, PIC32
    - Texas Instruments C28xx, Tiva
    - STMicroelectronics ARMv6, ARMv7
    - Infineon XMC4xxx
    - ...
- Available for Matlab/Simulink and Scilab/Xcos



# X2C

## Structure

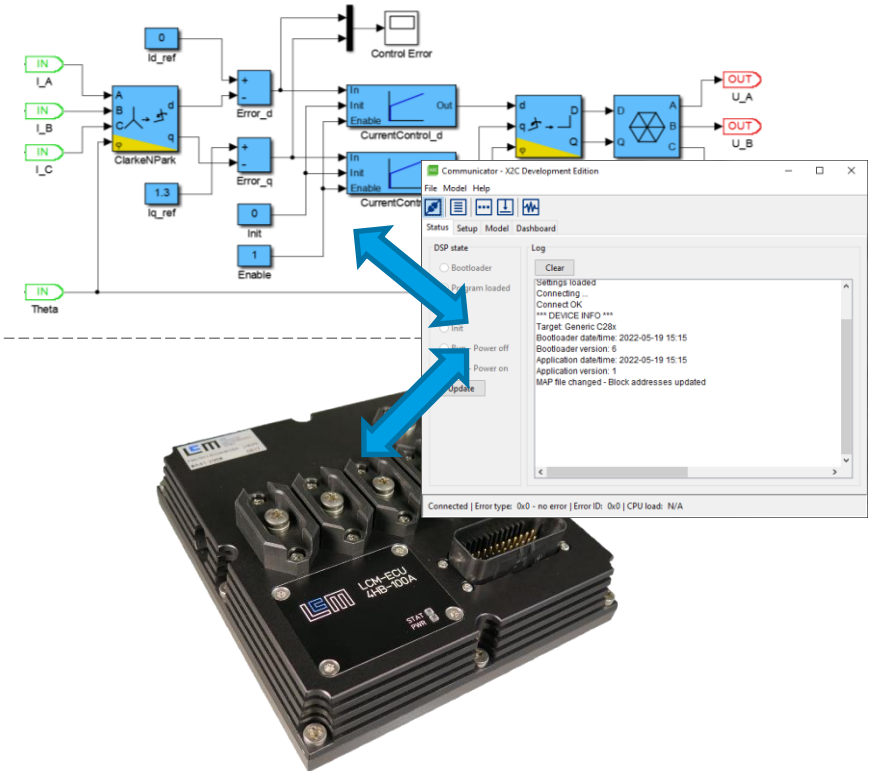
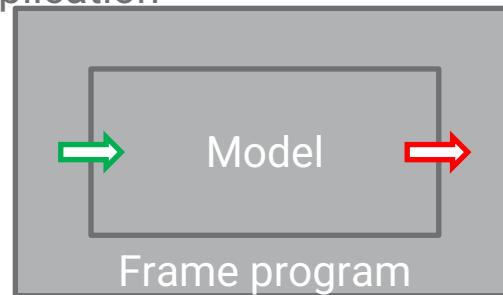
PC  
(Xcos/Simulink)



Java

Application

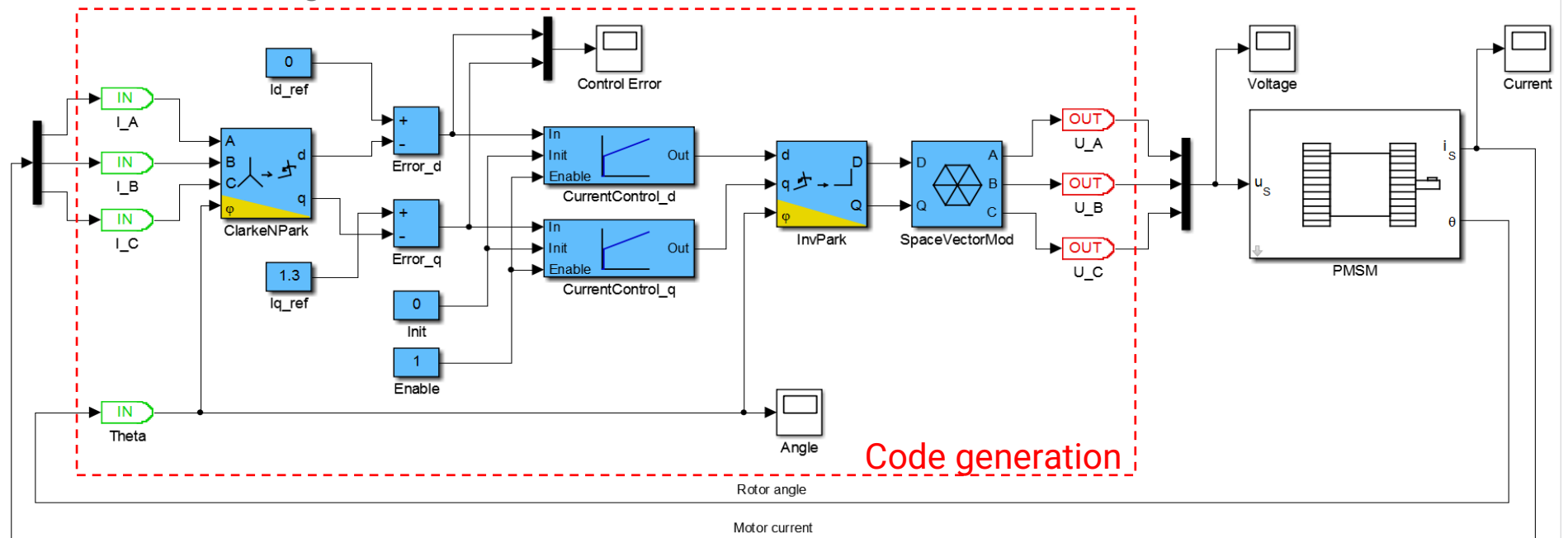
Target  
(ANSI C)



# X2C

## Code Generation & Simulation

- Simulation of target code in Simulink or Xcos
- One model for simulation and code generation



# X2C

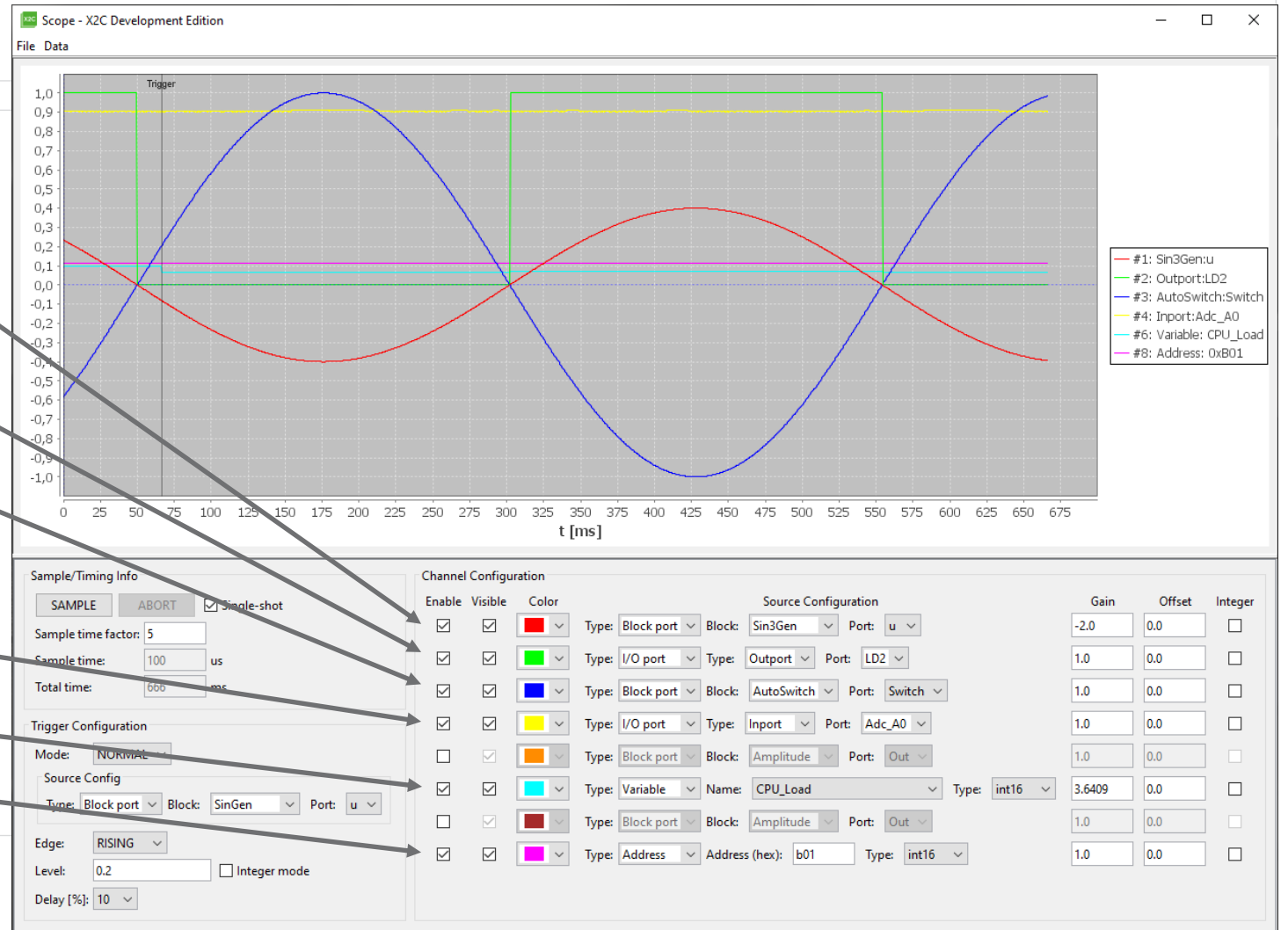
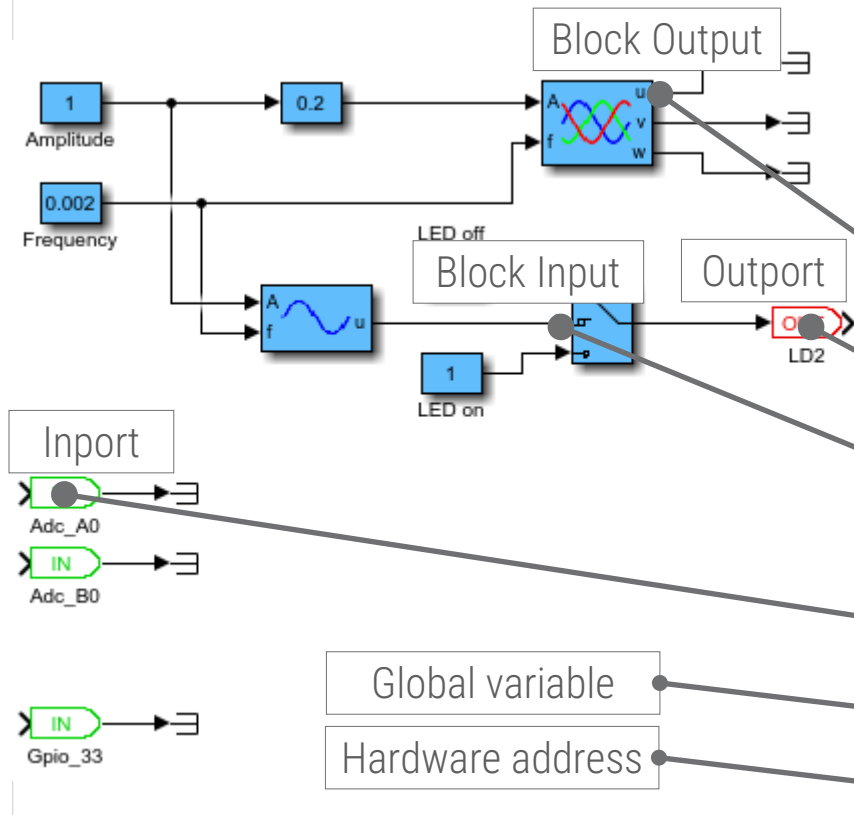
## Libraries

The image displays a collection of X2C libraries organized into several categories:

- General:** Includes blocks like **Peripheral** (Inport, Outport), **Source/Sink** (Constant, uConstant, Gain, uGain, SaveSignal, uSaveSignal, SinGen), **Limitation** (Limitation, RateLimiter, uRateLimiter, Sin2Limiter), **Routing** (AutoSwitch, ManualSwitch), and **Logic**.
- Control:** Includes **Controller**, **Filter**, and **Transfer Function**.
- Math:** Includes **Arithmetic**, **Trigonometric**, and **Spec**.
- MotorControl:** Includes **Transformation** (Clarke, Park, InvClarke, InvPark, ClarkeNPark, InvClarkeNPark) and **Modulation** (SinMod, SpaceVectorMod, SpaceVectorLimit, SpaceVectorAdjust).
- MotorSensorless:** Includes **BearinglessMotorControl** and **StateControl**.
- Angular Sensing:** Includes **States**, **Transitions**, and **Routing**.

# X2C

## Monitoring/Debugging



Global variable  
Hardware address

# X2C Workflow

## Start: Motor Project as Basis

Placeholder Expert Mode

MotorDemo\_2024-09-18

Wizard

Search

Component v1.0.8799 documentation » MotorControl X2C

### MotorControl X2C

This component is the base component for creating an X2C control model for a PMSM project.

### Parameter

List of Component parameters

Parameter	Description	Info
SimulationSettings.EnableSimulation	Flag whether the simulation of the motor control model should be possible.	input
SimulationSettings.ExecuteSimulation	Flag whether simulation should be run.	input
SimulationSettings.SimulationTime	Model simulation stop time.	input
CodeSettings.CompileCode	Flag whether generated X2C code should be compiled.	input
CodeSettings.DownloadCode	Flag whether compiled X2C code should be downloaded to target.	input
ModelFile	JSON file with information about the structure of the motor control model	output
ModelProp	User set properties of motor control model.	output

# X2C Workflow

## X2C MotorControl Main Component

The screenshot displays the X2C MotorControl software interface. The top bar shows the project name "MotorDemo\_2024-09-18" and various control icons. The left sidebar contains a tree view of the project components: "ProjectName Motor Interior", "Geometry Geometry PMSM Interior", "PMSM PMSM FEMM", and "MotorControl\_X2C X2C Motor Control". The "MotorControl\_X2C" component is highlighted with a red box and contains sub-components: "X2C Inverter", "X2C Controller", "Optional", "Simulation", and "Optional". The main area shows the "Parameters" section for "MotorControl\_X2C", which is divided into "SimulationSettings" and "CodeSettings".

Parameter	Value	Units
SimulationSettings.EnableSimulation	true	
SimulationSettings.ExecuteSimulation	true	
SimulationSettings.SimulationTime	1.0	s
CodeSettings.CompileCode	true	
CodeSettings.DownloadCode	true	

The "Filter" section on the right shows the following settings:

- Input:
- Results:
- Editable:



# X2C Workflow

## X2C Inverter Component - Selection

The screenshot displays the X2C software interface for a project named "MotorDemo\_2024-09-18". The interface is divided into a left sidebar and a main workspace.

**Left Sidebar (Component Tree):**

- Placeholder (checked) / Expert Mode (unchecked)
- ProjectName: Motor Interior
- Geometry: Geometry PMSM Interior
- PMSM: PMSM FEMM
- MotorControl\_X2C: X2C Motor Control (highlighted with a red box)
- X2C Inverter (highlighted with a red box)
- X2C Controller
- Optional
- Simulation
- Optional

**Main Workspace (Wizard):**

The main workspace is titled "Wizard" and features a "Free Search" bar. Below the search bar, a grid of component cards is displayed, each with an image, a name, a version number, and a "+" button for selection:

- LCM-ECU-10HB-10A-80V 1.1
- LCM-ECU-4HB-100A-75V 1.0
- Microchip MCLV-2 1.0
- Semikron SKAI 2 HV 1.1
- Texas Instruments BOOSTXL 1.0
- Wolfspeed CRD300DA12E-XM3 1.0

# X2C Workflow

## X2C Inverter Component - Configuration

The screenshot displays the X2C software interface for configuring an inverter component. The left sidebar shows a project tree with the following components: **ProjectName** (Motor Interior), **Geometry** (Geometry PMSM Interior), **PMSM** (PMSM FEMM), **MotorControl\_X2C** (X2C Motor Control), and **Inverter\_X2C** (Texas Instruments BOOSTXL). The **Inverter\_X2C** component is highlighted with a red box. Below the tree are several optional components: **Optional**, **X2C Controller**, **Optional**, **Simulation**, and **Optional**.

The main window shows the configuration for the **Inverter\_X2C** component. The title bar indicates the project is **MotorDemo\_2024-09-18**. The **Parameters** section is expanded, showing the following settings:

Parameter	Value	Units
ResetFromTemplate	false	
auto_link_imports	true	
log_level	'WARNING'	
CONTROL_TASK_FREQUENCY_DIVIDER	1.0	
PWM_FREQUENCY	20000.0	Hz
ENCODER	1000.0	ppr
MAX_CUR_MOTOR_SHORT	17.0	Apeak

Additional parameters are visible at the bottom of the list:

- Reset output files: false
- Automatically link fields to imports: true
- Set log level (DEBUG, INFO, WARNING, ERROR, CRITICAL): 'WARNING'
- Ratio between sample frequency and PWM frequency: 1.0
- PWM frequency of power stage [Hz]: 20000.0 Hz
- Pulses per revolution of the encoder - zero for digital hall effect sensors: 1000.0 ppr
- Maximum allowed motor current [Apeak]: 17.0 Apeak
- Flag to enable extended CAN messages: (checkbox)

# X2C Workflow

## X2C Controller Component

The screenshot displays the X2C software interface. On the left, a project tree shows the following components:

- ProjectName (Motor Interior)
- Geometry (Geometry PMSM Interior)
- PMSM (PMSM FEMM)
- MotorControl\_X2C (X2C Motor Control) - highlighted with a red box
- Inverter\_X2C (Texas Instruments BOOSTXL)
- X2C Controller - highlighted with a red box

Below the tree are three filter tags: "Optional", "Simulation", and "Optional".

The top right of the interface shows the project name "MotorDemo\_2024-09-18" and a toolbar with icons for save, a green indicator, play, menu, and refresh.

The main area is titled "Wizard" and "Free Search". A search bar contains the text "Search". Below the search bar, two controller options are displayed:

- Speed Controller X2C 1.0
- Torque Controller X2C 1.0

Each controller option includes a small schematic icon, a question mark icon, and a plus sign icon.

# X2C Workflow

## X2C ModelParameter Component

The screenshot displays the X2C software interface. On the left, a project tree shows the following components:

- ProjectName (Motor Interior)
- Geometry (Geometry PMSM Interior)
- PMSM (PMSM FEMM)
- MotorControl\_X2C (X2C Motor Control)
- Inverter\_X2C (Texas Instruments BOOSTXL)
- SpeedController\_X2C (Speed Controller X2C)
- TorqueController\_X2C (Torque Controller X2C) - highlighted in red
- X2C ModelParameter - highlighted with a red box
- PMSM MotorLUT

On the right, the search results panel shows the following components:

- PMSM LinearModel X2C RBF (1.0) -  $y=kx+d$
- PMSM NonLinearModel X2C RBF (0.1) -  $y=f(x)$

# X2C Workflow

## PMSM MotorLUT Component (optional)

The screenshot displays the X2C software interface. On the left, a project tree shows the following components:

- ProjectName (Motor Interior)
- Geometry (Geometry PMSM Interior)
- PMSM (PMSM FEMM)
- MotorControl\_X2C (X2C Motor Control)
- Inverter\_X2C (Texas Instruments BOOSTXL)
- SpeedController\_X2C (Speed Controller X2C)
- TorqueController\_X2C (Torque Controller X2C)
- LinearModel\_X2C\_RBF (PMSM LinearModel X2C RBF)

Below the project tree, an "Optional" label is present, and a red box highlights the "PMSM MotorLUT" component in the search results.

On the right, the "Wizard" search interface is shown for the project "MotorDemo\_2024-09-18". The search results include:

- PMSM MotorLUT Flux2D (RBF 1.0)
- PMSM MotorLUT Flux3D (RBF 1.0)
- PMSM MotorLUT MTPA (RBF 1.0)

# Execution

## Automatized X2C

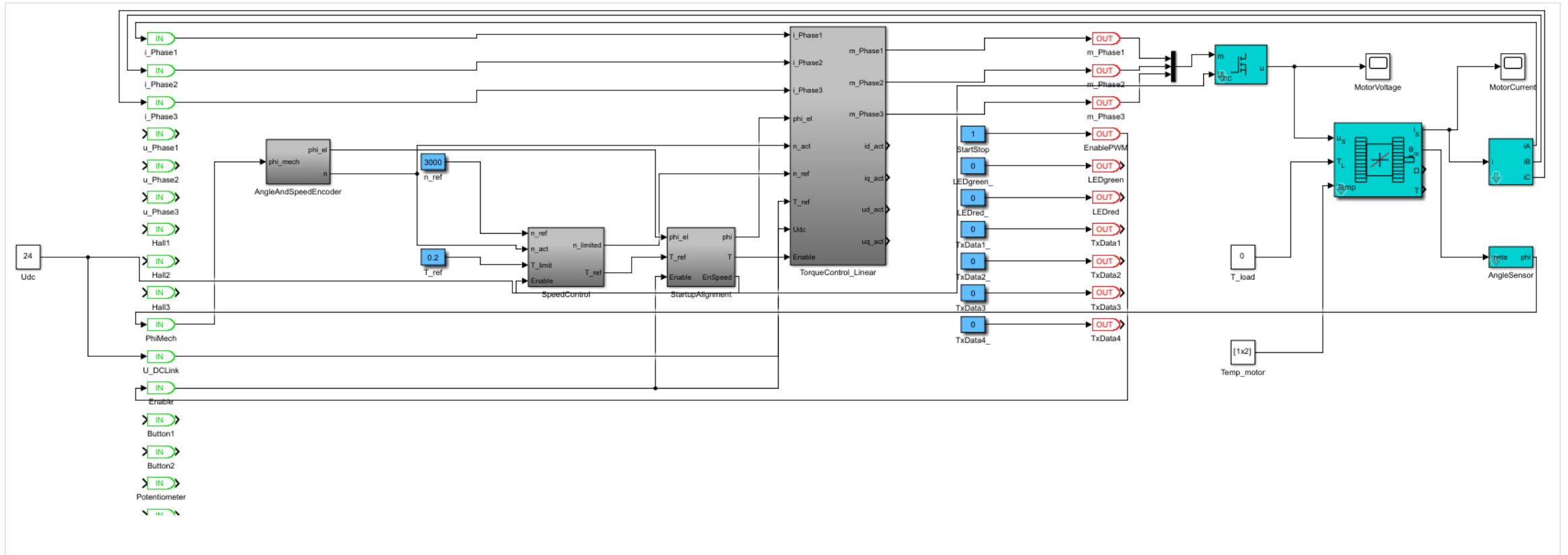
- Regenerate / Run Simulation command triggers:
  - Assembly of X2C control algorithm in Matlab/Simulink
  - Simulation of control loop in Simulink
  - X2C code generation
  - Compilation of code
  - Download of compiled code to inverter

```
Command Window
[INFO] Creating simulink model...
[INFO] Position control subsystem not available!
[INFO] Creating SpeedReference blocks...
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
[INFO] Creating blocks needed for X2C outports...
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
No 'Model' object found in 'Analyze' block
[INFO] Simulink model created!
[INFO] Running simulation...
[INFO] Simulation finished!
[INFO] Creating C-Code...

CCS headless build complete! 0 out of 1 projects have errors.
[INFO] Fetching binary application file to download...SUCCESS
[INFO] Checking port COM4 for target TM4C123GH6...FAILED
[INFO] Checking port COM6 for target TM4C123GH6...FOUND
[INFO] Downloading application to target...DONE
[INFO] Starting X2C Communicator...DONE
fx >> |
```

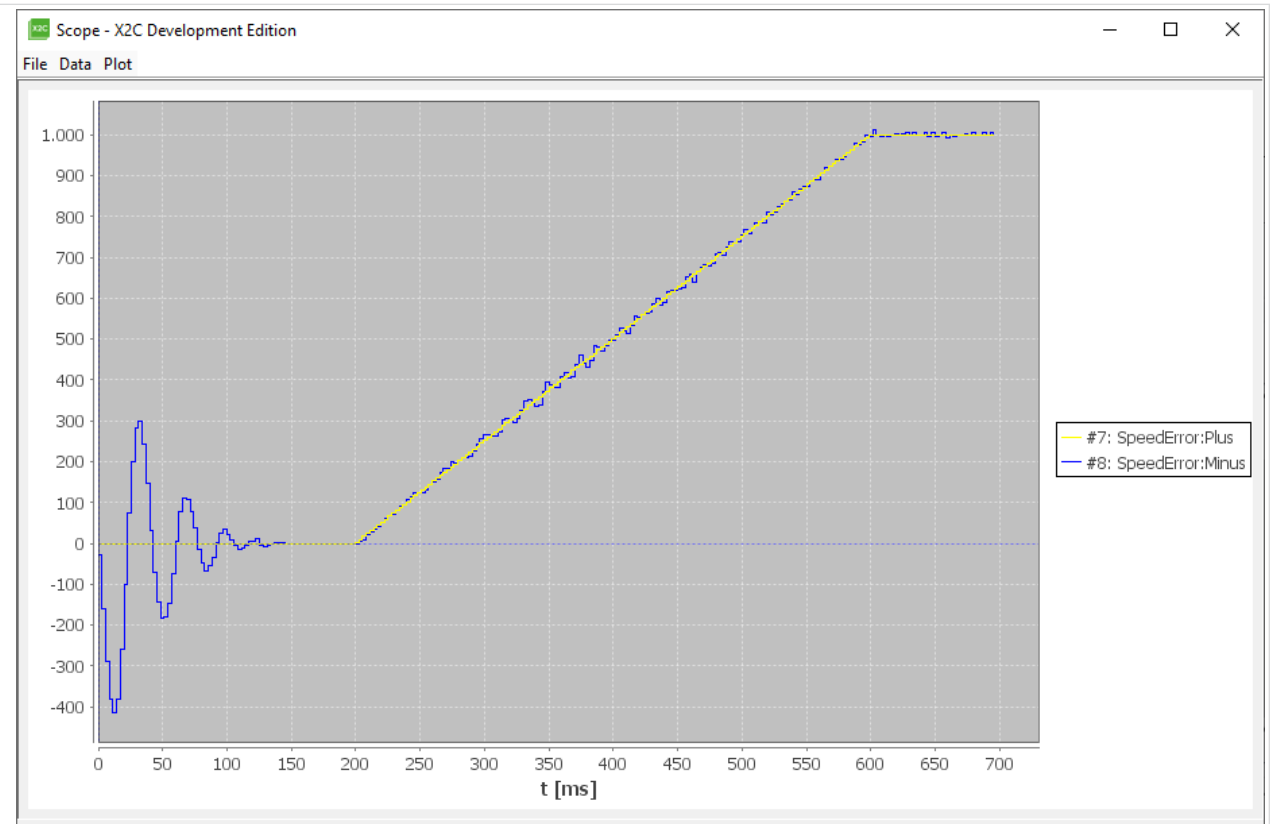
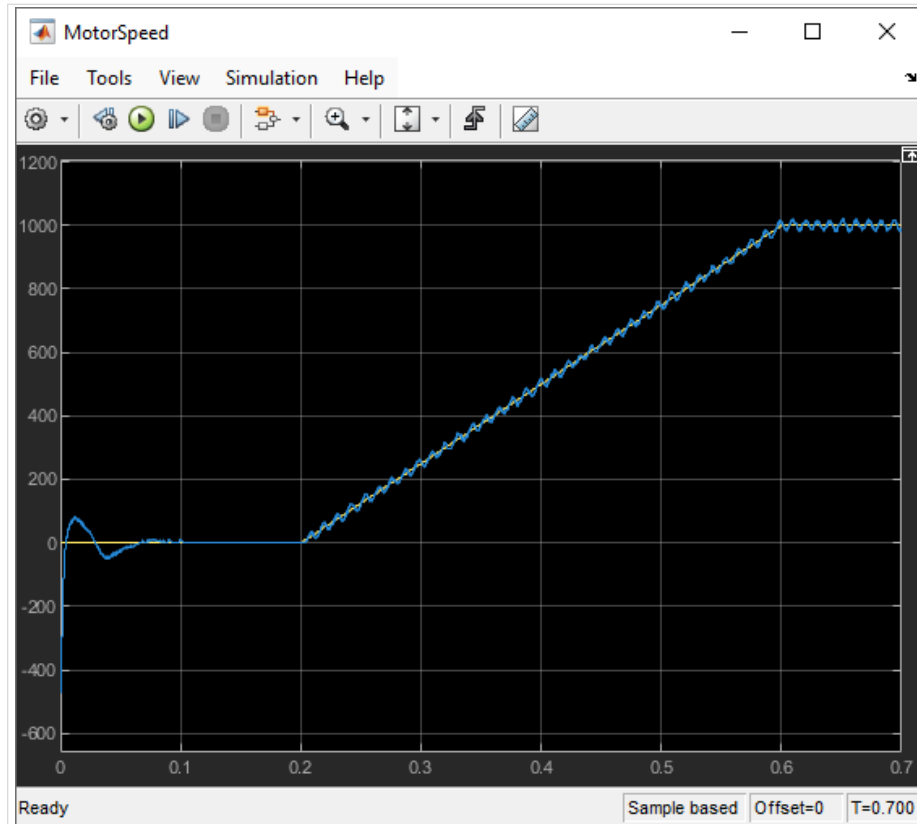
# Results

## Control Model



# Results

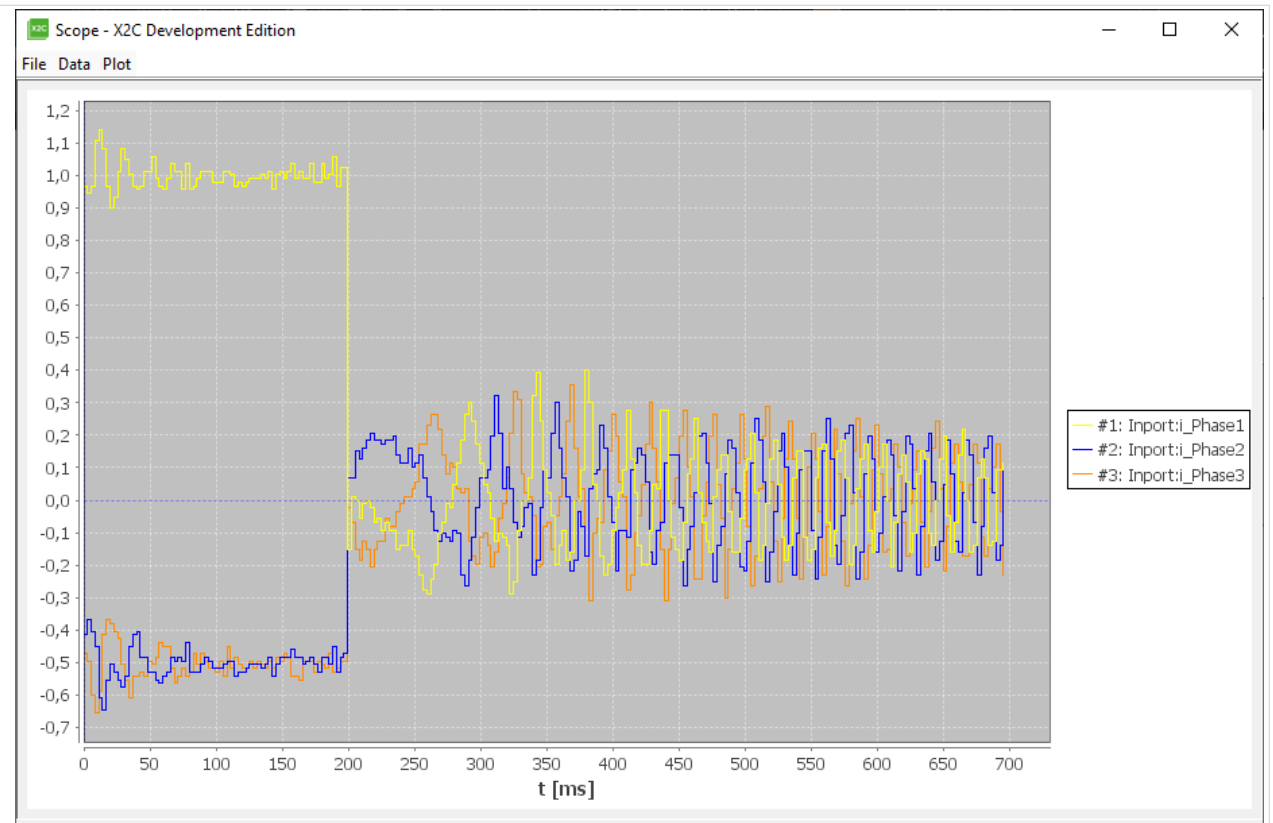
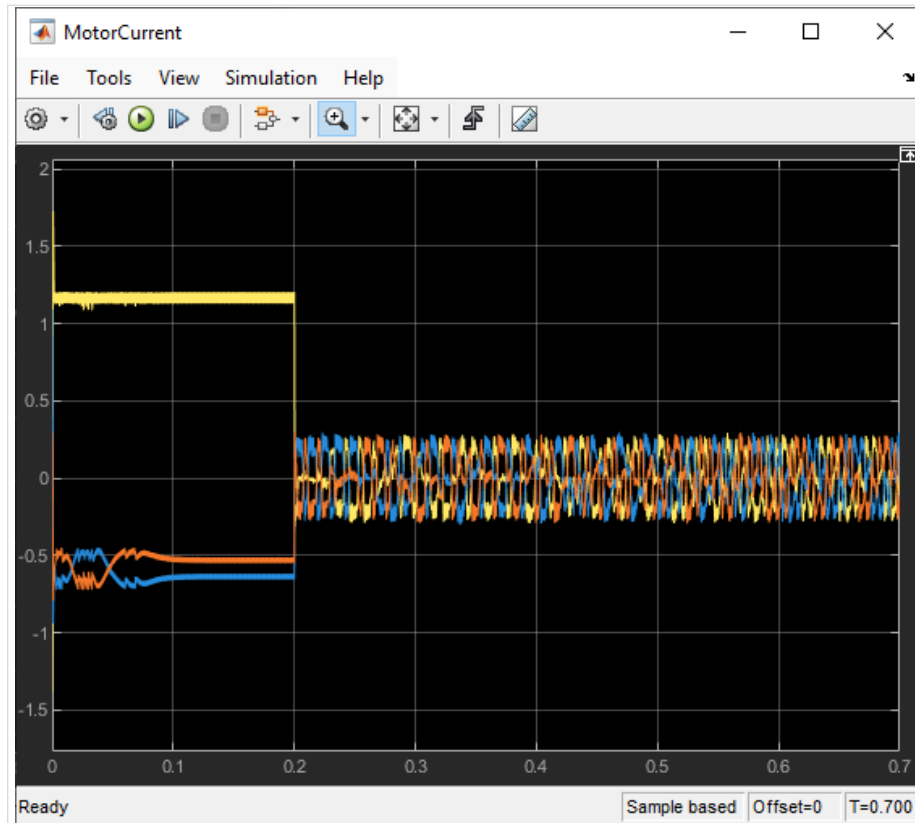
## Simulation in Simulink vs Measurement with X2C (Speed)





# X2C Results

## Simulation in Simulink vs Measurement with X2C (Current)



# Summary

## Benefits

- Full motor development workflow
  - Motor design, simulation and optimization
  - Motor control design
  - Code generation & compilation
  - Motor commissioning
- Motor control simulation
- Inverter is selectable and configurable
- No to little motor control design skills required
- No programming skills required

# Summary

## Outlook

- Finalizing & testing of non-linear motor models & controller
- Support of position control algorithm
- Support of sensorless speed control algorithm
- Support of motor optimization in respect to motor control simulation result(s)
- ...

Science becomes  
**reality**