SECURE CONNECTIONS
FOR A SMARTER WORLD

Motor Control: Rapid Design, Development and Deployment Using NXP MBDT

Joaquin Liao/廖乾坤, NXP Semiconductors

MATLAB EXPO

OVERVIEW

- NXP Corporate Overview
- NXP Automotive platforms: S32K1 & S32K3
- NXP Model-Based Design Toolbox: Overview
- NXP Motor Control solutions on MBDT
- Additional Resources

NXP Corporate Overview

MATLAB EXPO

NXP | SECURE CONNECTIONS FOR A SMARTER WORLD

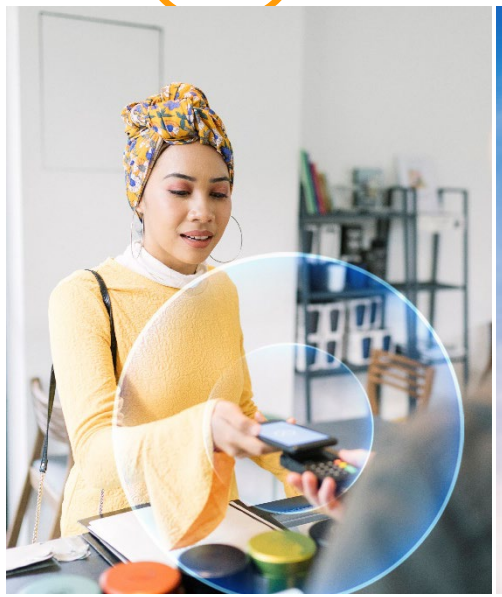
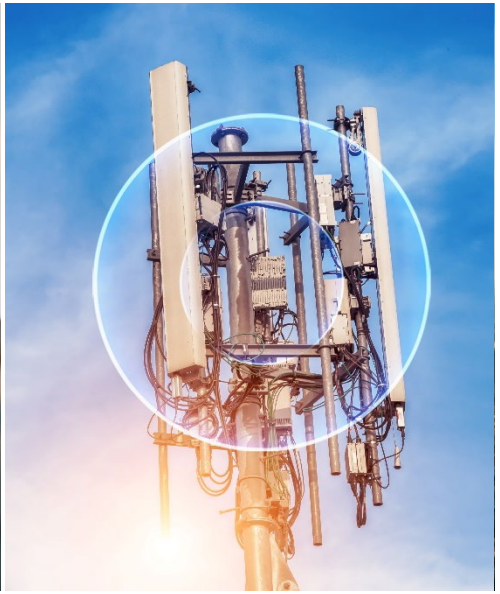
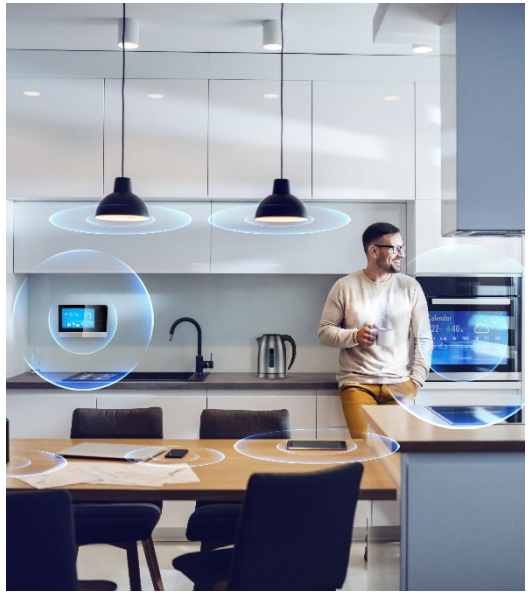
PUBLIC

NXP, THE NXP LOGO AND NXP SECURE CONNECTIONS FOR A SMARTER WORLD ARE TRADEMARKS OF NXP B.V.
ALL OTHER PRODUCT OR SERVICE NAMES ARE THE PROPERTY OF THEIR RESPECTIVE OWNERS. © 2023 NXP B.V.

SECURE CONNECTIONS FOR A SMARTER WORLD

OUR DIGITALLY ENHANCED WORLD IS EVOLVING TO ANTICIPATE AND AUTOMATE

NXP Semiconductors N.V. (NASDAQ: NXPI) enables a smarter, safer and more sustainable world through innovation. As the world leader in secure connectivity solutions for embedded applications, NXP is pushing boundaries in the automotive, industrial & IoT, mobile, and communication infrastructure markets.

AUTOMOTIVE MARKET POSITIONS

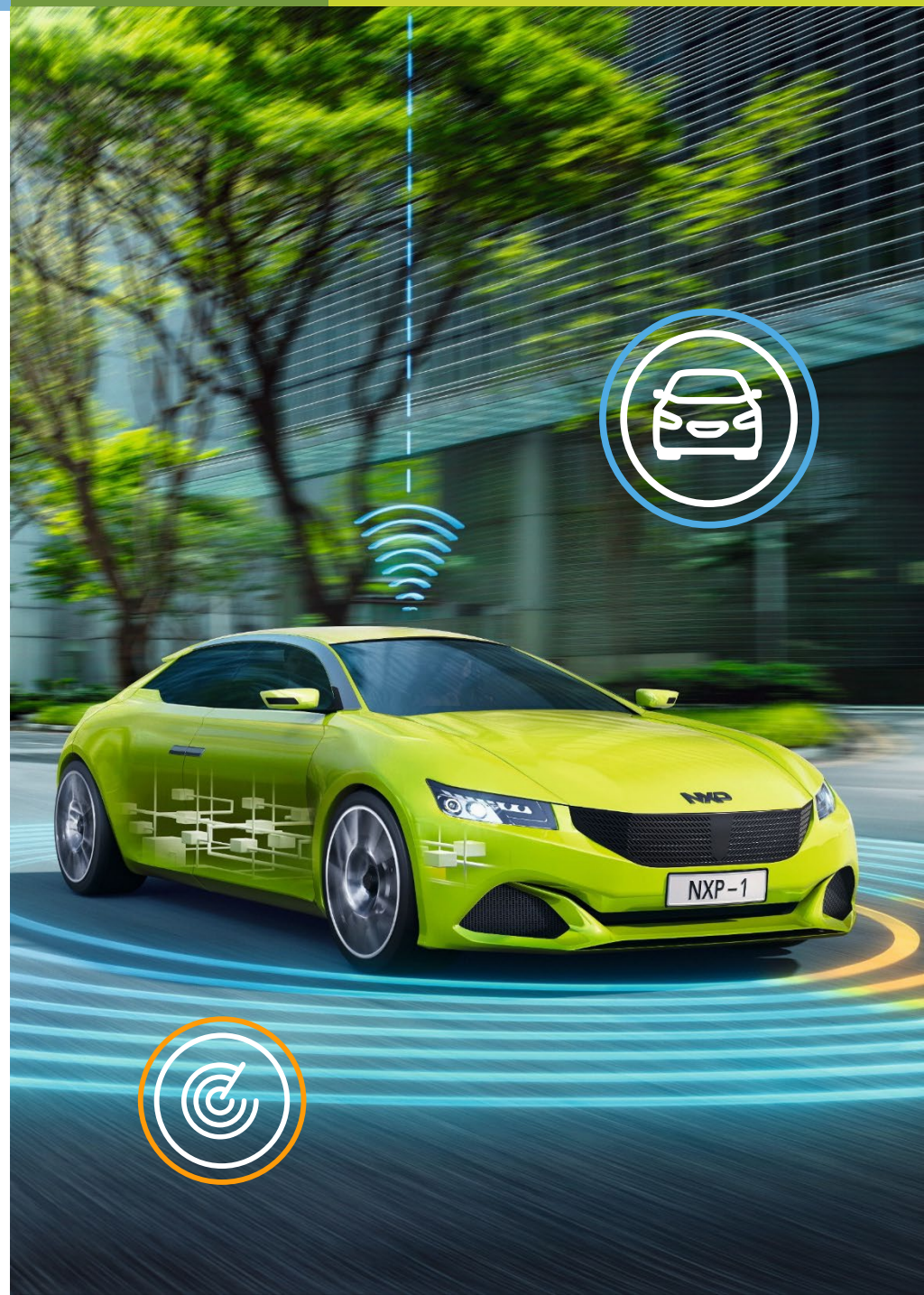
Technology Leadership

#1 Auto Processors
#1 Auto Application Processors
#1 Auto RF
#1 Auto DSPs
#1 Vehicle Network Processors
#2 Auto Analog
#2 Auto Microcontrollers

+

Applications Leadership

#1 Car Infotainment
#1 Digital Radio
#1 Secure Car Access*
#1 In-Vehicle Networking*
#1 Radar*
#2 Powertrain



*Excluding portions of the market not serviced by NXP products
Source: Strategy Analytics, IHS Markit, NXP. Based on 2021 Auto TAM

NXP Automotive platforms: S32K1 & S32K3

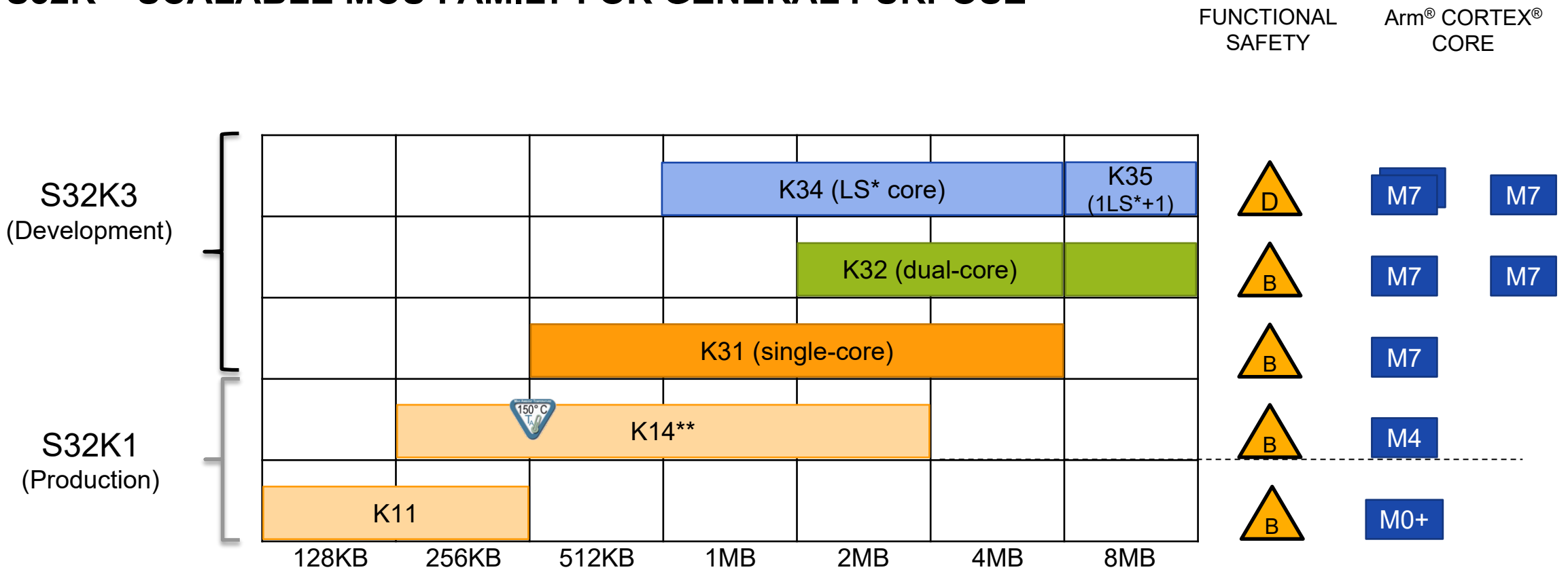
MATLAB EXPO

NXP | SECURE CONNECTIONS FOR A SMARTER WORLD

PUBLIC

NXP, THE NXP LOGO AND NXP SECURE CONNECTIONS FOR A SMARTER WORLD ARE TRADEMARKS OF NXP B.V.
ALL OTHER PRODUCT OR SERVICE NAMES ARE THE PROPERTY OF THEIR RESPECTIVE OWNERS. © 2023 NXP B.V.

S32K – SCALABLE MCU FAMILY FOR GENERAL PURPOSE



Product highlights:

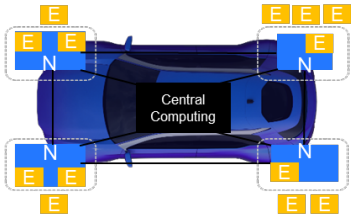
- ✓ Platform scalability and compatibility 平台可扩展性和兼容性
- ✓ Scalable performance 可扩展性能
- ✓ Functional safety 功能安全
- ✓ Advanced communication interface 先进的通讯接口
- ✓ Market-leading cyber security 市场领先的信息安全
- ✓ Over the air update ready 无线更新准备就绪
- ✓ Complete SW and tools eco-system 完整的软件和工具生态系统

* LS = lock step
**AEC-Q100 Grade 0 device K142W and K144W

S32K – BROAD RANGE OF TARGET APPLICATIONS

Body and Comfort

Door Module



Zone Control

Seat Control

HVAC

Motor Control

Traction Inverter

eCompressor

Pumps & eTurbo

Blowers / Fans

Trunk Opener

Window Lift

Lighting

Front Lighting

Rear Lighting

Interior Lighting

BMS

Battery Management System

HMI

Steering Wheel

Switch Panels

Touch

Gear Shift

Door Handle

IVI

Remote Amp

IO Controller

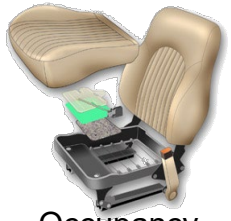
Safety

SB Pretensioner

Passive Entry

Acoustic Alert

Exhaust Sensor


Occupancy Detection

Rain Light Sensor

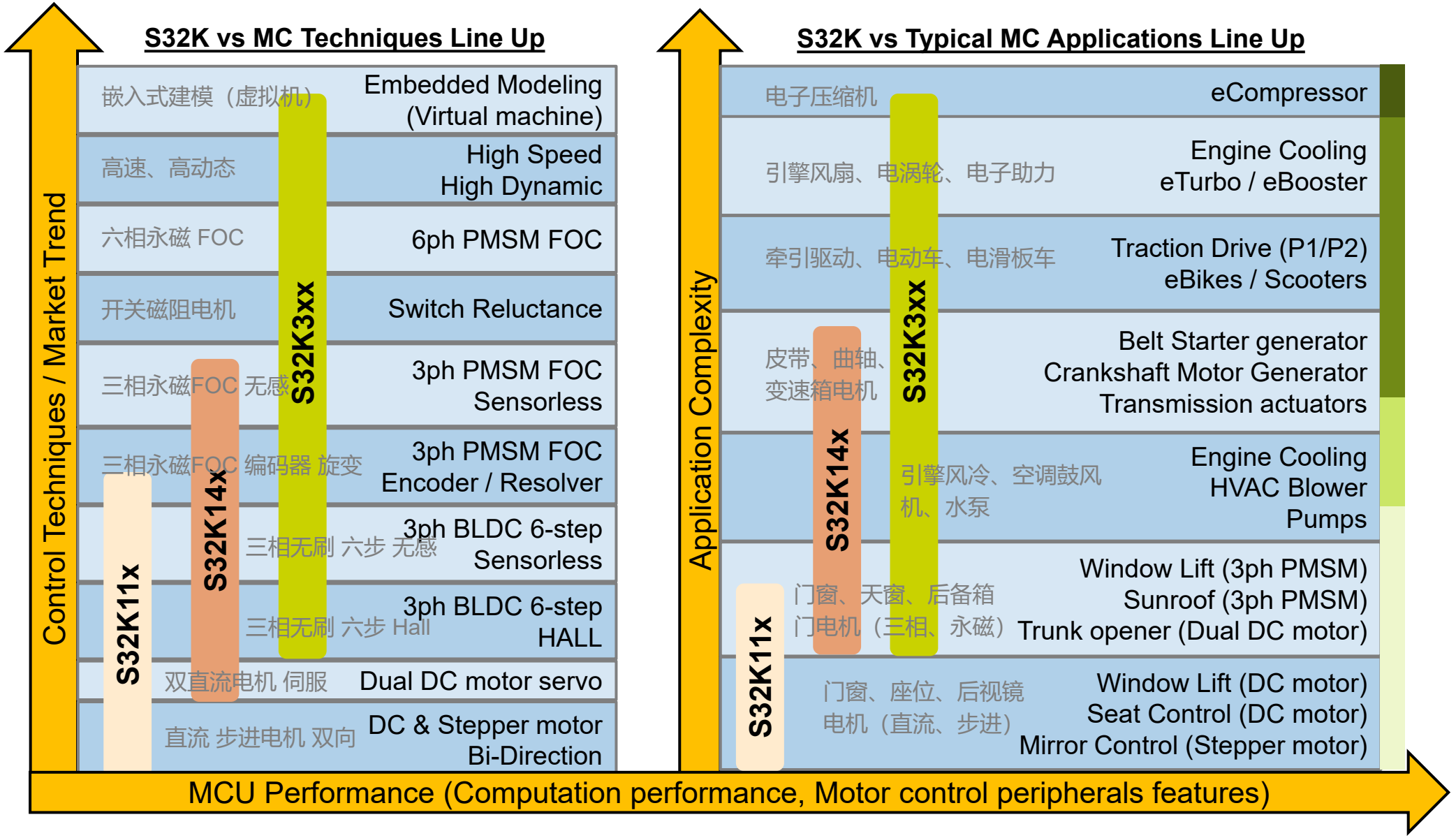
Power Conversion

DC-DC

EV Charging

Wireless Charge

S32K MOTOR CONTROL LINE-UP



Arm® Cortex®-M7

Arm® Cortex®-M4F

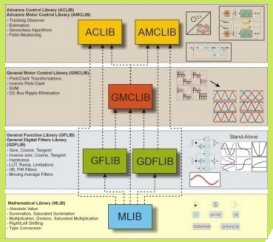
Arm® Cortex®-M0+

Power range	Power
Low power	12V, ~10A
Mid power	12V, ~70A
High power	48V, ~100A
High Voltage	> 200V

MOTOR CONTROL ECOSYSTEM CONCEPT S32K

Automotive Math and Motor Control Library Set

- **Precompiled software library** containing building blocks for a wide range of motor control applications
- Easy migration between platforms with minimized effort
- Production ready SW (SPICE Level 3, CMMI and ISO9001/TS16949)
- Control loop modeling with Matlab/Simulink® models



Motor Control Application Tuning Tool (MCAT)

Tune your drive:

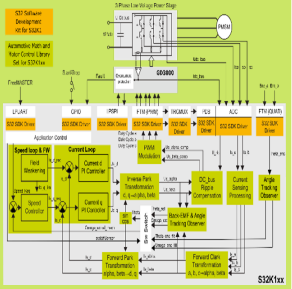
- Graphical User Interface, plugin to FreeMaster
- interfacing with the target MCU, modify software variables during runtime to tune your motor control algorithms to achieve control objectives (i.e. PI parameters)

Motor Control Reference SW

PMSM / BLDC

Reference SW:

- Sensorless / sensor based



Model Based Design Toolbox (MBDT)

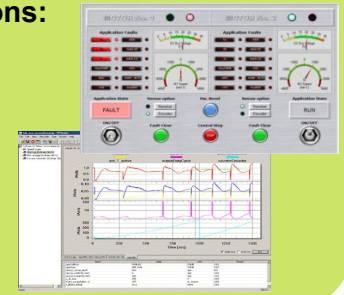
MATLAB Simulink integrated tool chain for configuring and generating software, and it can be used to execute motor control algorithms on NXP MCUs:

- Includes AMMCLib Library set
- plug in to MATLAB™/Simulink™ model-based design environment
- optimized for fast execution on our MCUs with bit-accurate results compared to Simulink® simulation

FreeMASTER (Lite)

Debugger for Real-time Applications:

- Graphical User Interface
- View & Modify variables run-time
- Real-time Monitor Tool
- Track & trace your variables
- Demonstration Platform
- Design your own dashboard

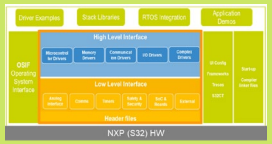


S32K1
arm M0+/M4F
CAN-FD
CSEC Security
ASIL B

S32K3
arm M0+/M4F
CAN-FD
CSEC Security
ASIL B

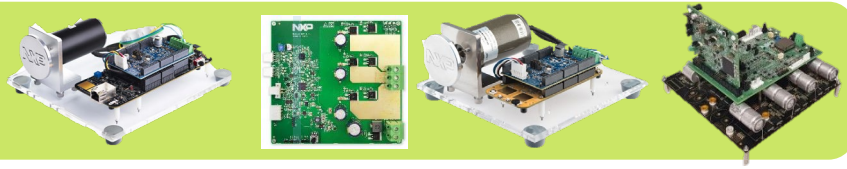
RTD Real Time Drivers

- Peripheral Driver including: **High Level Interface** AUTOSAR 4.4 & **Low Level Interface**
- ISO26262 Compliance for all SW layers



Motor Control Devkit

- 12V, 24V or 48V solutions
- 3phase or 6 phase Sensorless /sensor based
- Different power levels 6A, 25A, 2x80A



Model-Based Design Toolbox (MBDT): Overview

MATLAB EXPO

NXP | SECURE CONNECTIONS FOR A SMARTER WORLD

PUBLIC

NXP, THE NXP LOGO AND NXP SECURE CONNECTIONS FOR A SMARTER WORLD ARE TRADEMARKS OF NXP B.V.
ALL OTHER PRODUCT OR SERVICE NAMES ARE THE PROPERTY OF THEIR RESPECTIVE OWNERS. © 2023 NXP B.V.

MODEL BASED DESIGN TOOLBOX

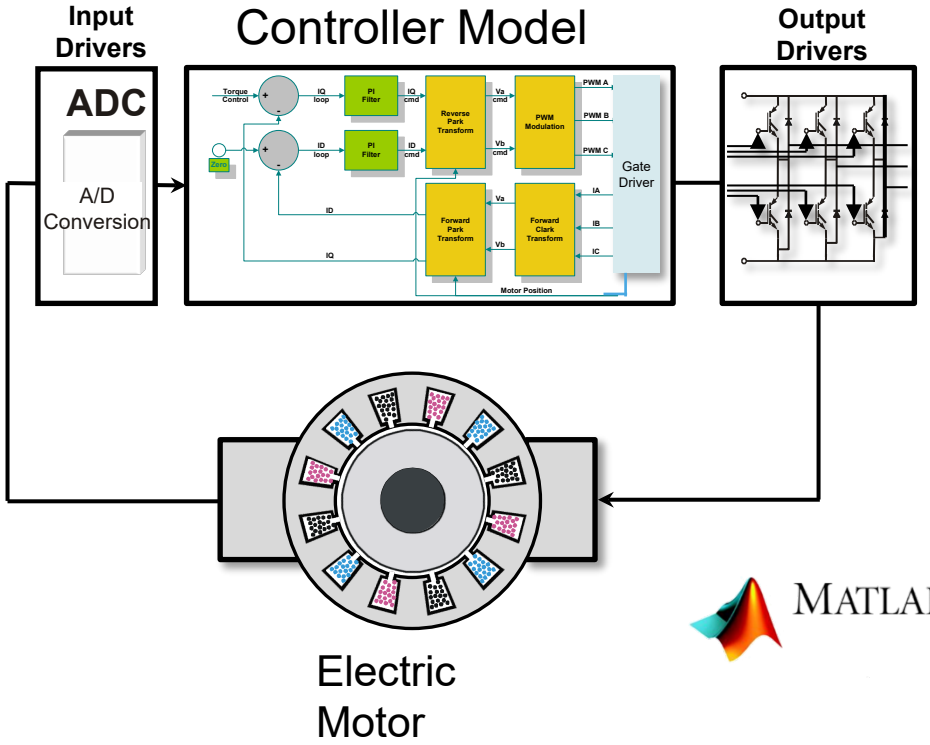
NXP Model-Based Design Toolbox (**MBDT**) is a comprehensive collection of tools that plug into the MATLAB™ and Simulink™ model-based design environment to support fast prototyping and verification.

NXP 基于模型的设计工具箱 (MBDT) 是一个全面的工具集合，可嵌入 MATLAB™ 和 Simulink™ 基于模型的设计环境以支持快速原型设计和验证。

- MCU configuration
- Code generation
- Deployment on NXP MCUs directly from Simulink™
- Software-in-the-Loop (SIL) and Processor-in-the-Loop (PIL)
- Automotive Math and Motor Control Library
- FreeMASTER for fine tuning and data visualization
- Online Community Support

- MCU配置
- 代码生成
- 直接从 Simulink™ 部署到 NXP MCU
- 软件在环 (SIL) 和处理器在环 (PIL)
- 汽车数学和电机控制库
- FreeMASTER 用于微调和数据可视化
- 在线社区支持

www.nxp.com/mbdt



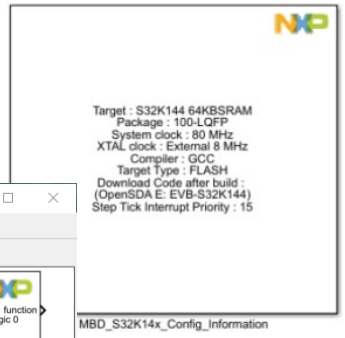
- ✓ **Reduce development & prototyping time** 减少开发和原型制作时间
- ✓ **Faster Time to Market** 更快的上市时间
- ✓ **Easy to use & reuse** 易于使用和重复使用
- ✓ **Hardware independent simulation** 硬件独立仿真

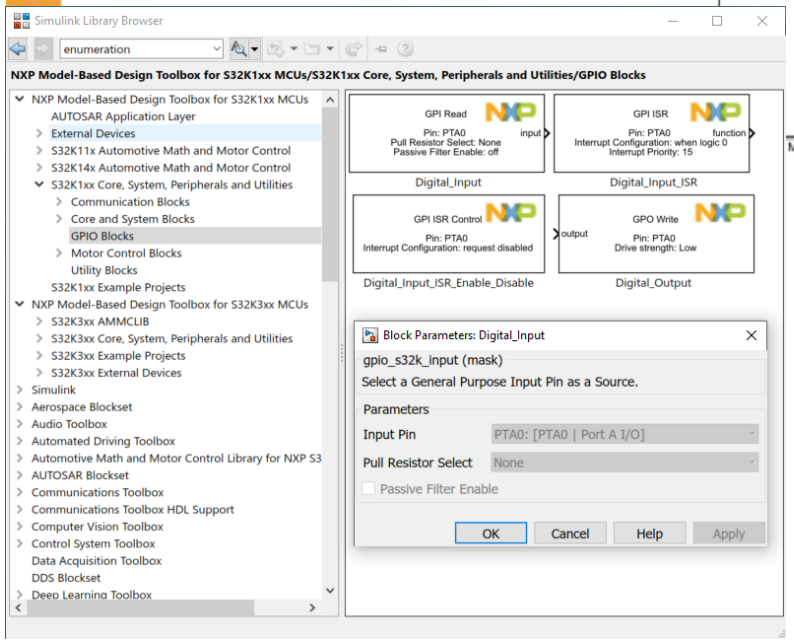
MODEL BASED DESIGN TOOLBOX

- MBDT fromS32K1 to S32K3: Workflow and framework **updates**
  - Using external configuration tools
  - Code generation based on RTD support (MCAL drivers)

MBDT从S32K1到S32K3：工作流和框架更新

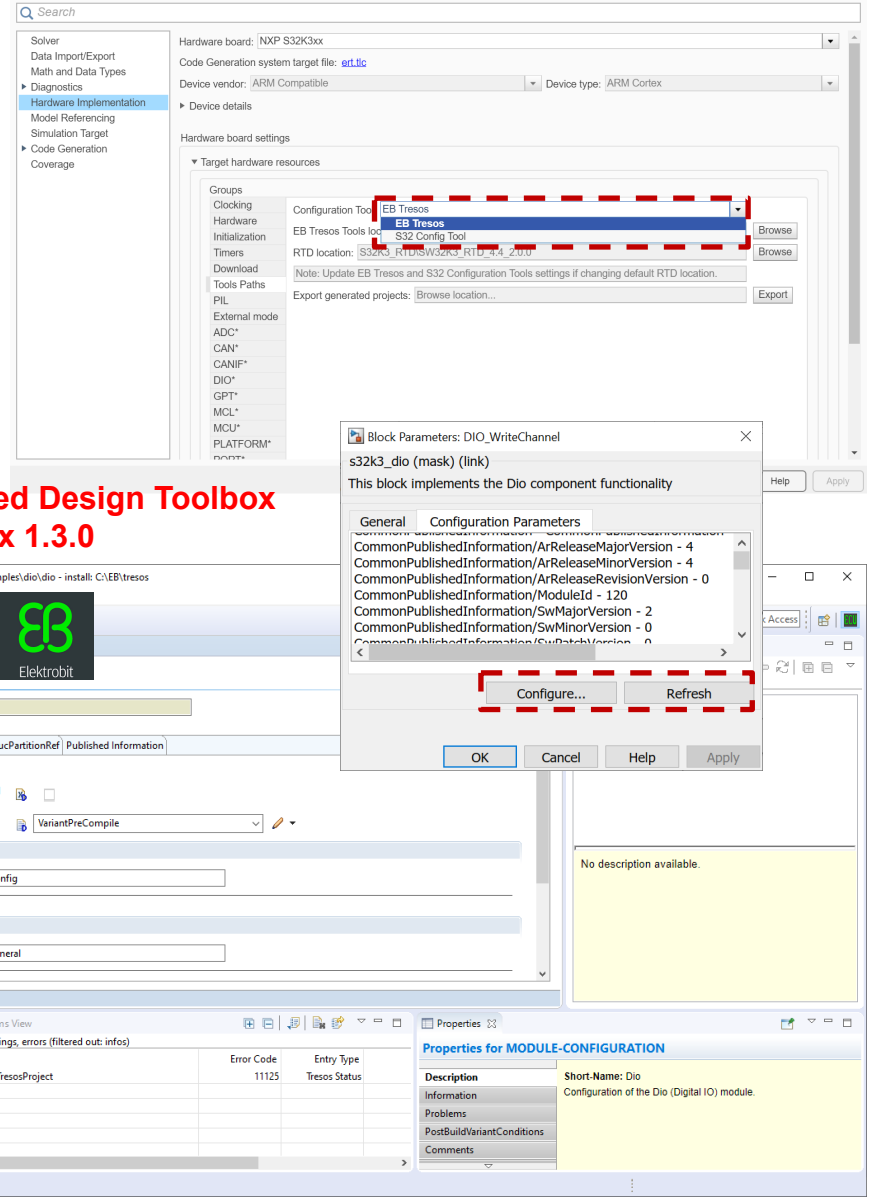
Model-Based Design Toolbox for S32K1xx 4.3.0



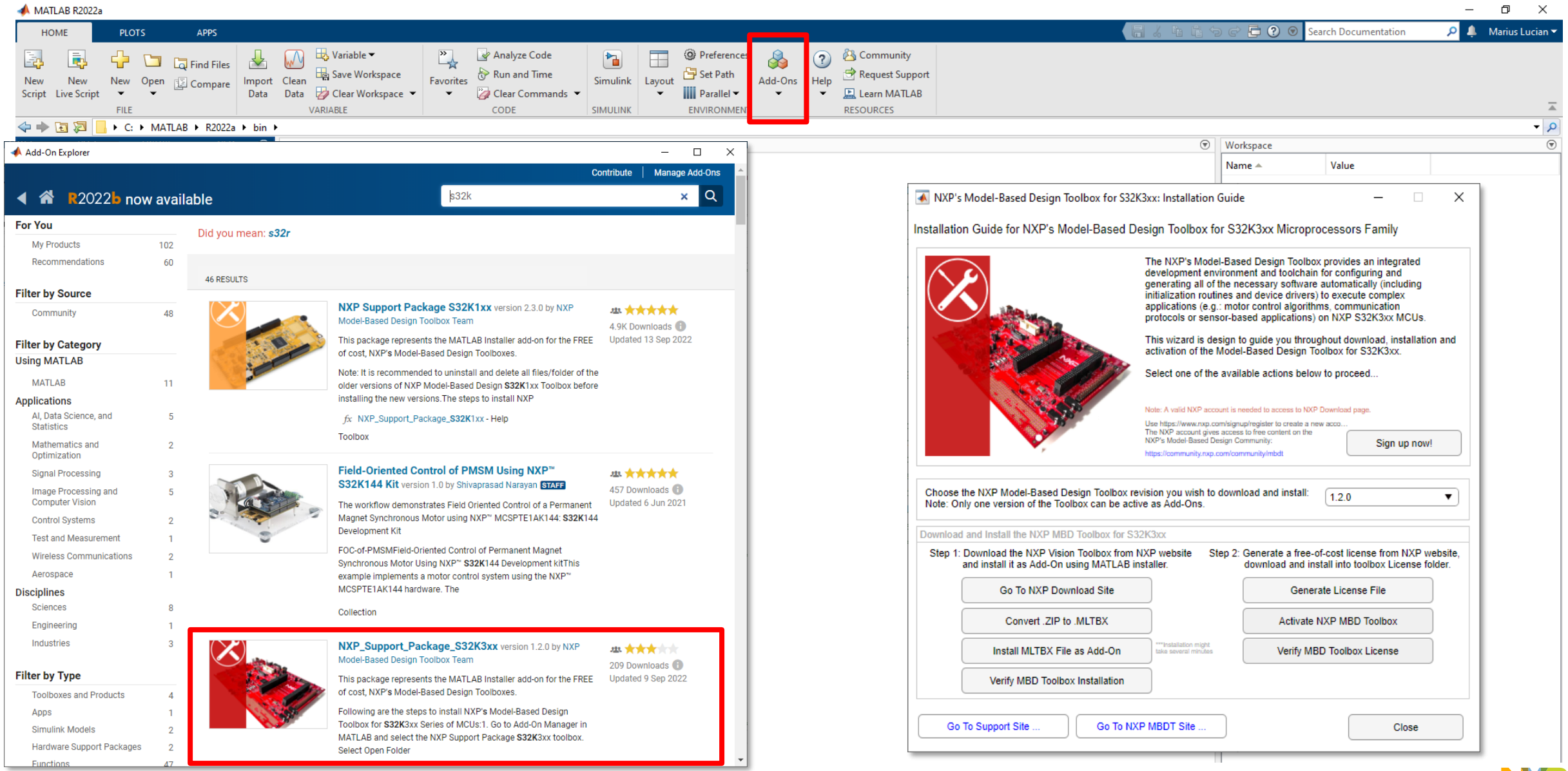


Update

Model-Based Design Toolbox for S32K3xx 1.3.0

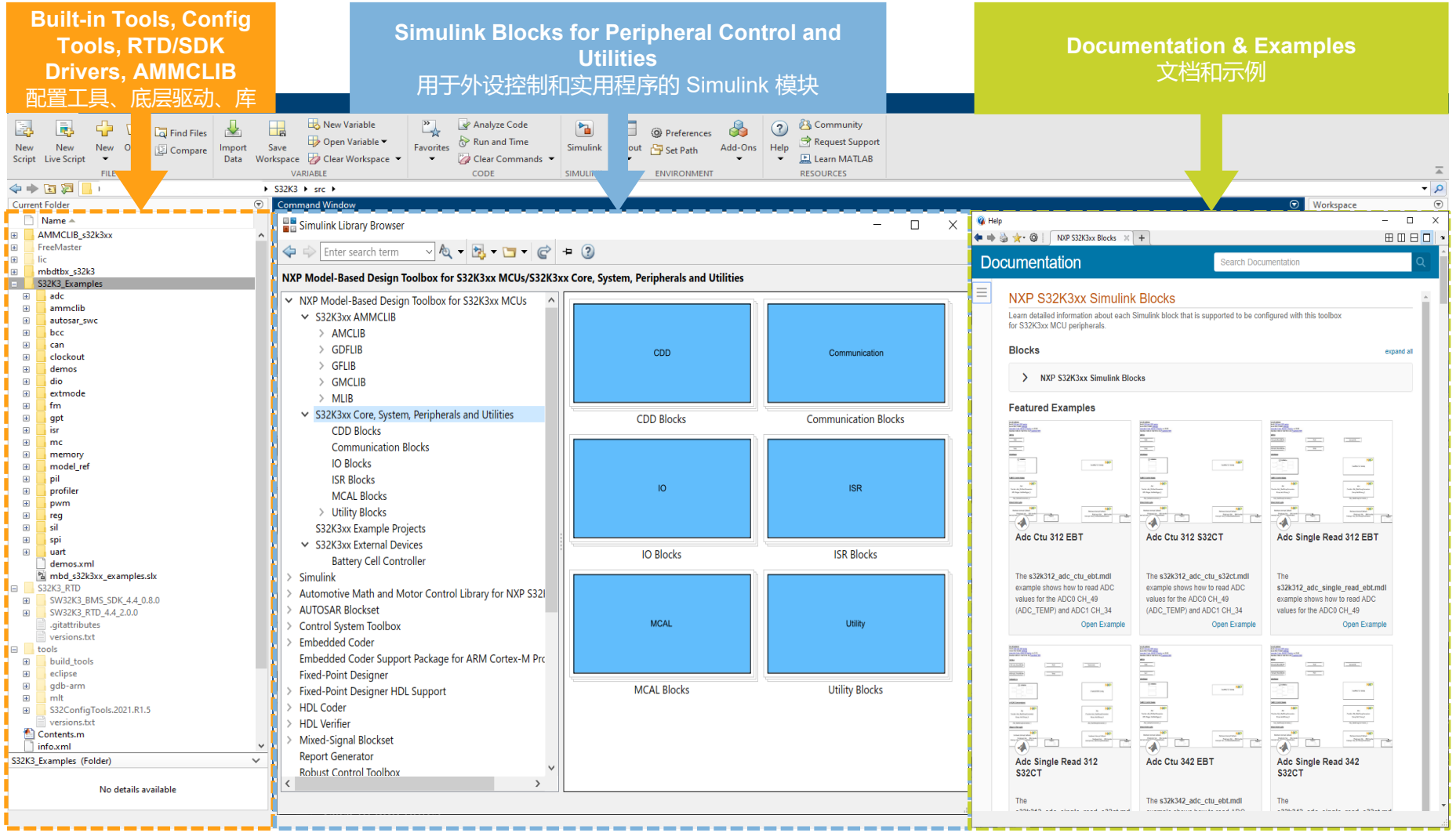


HOW TO INSTALL

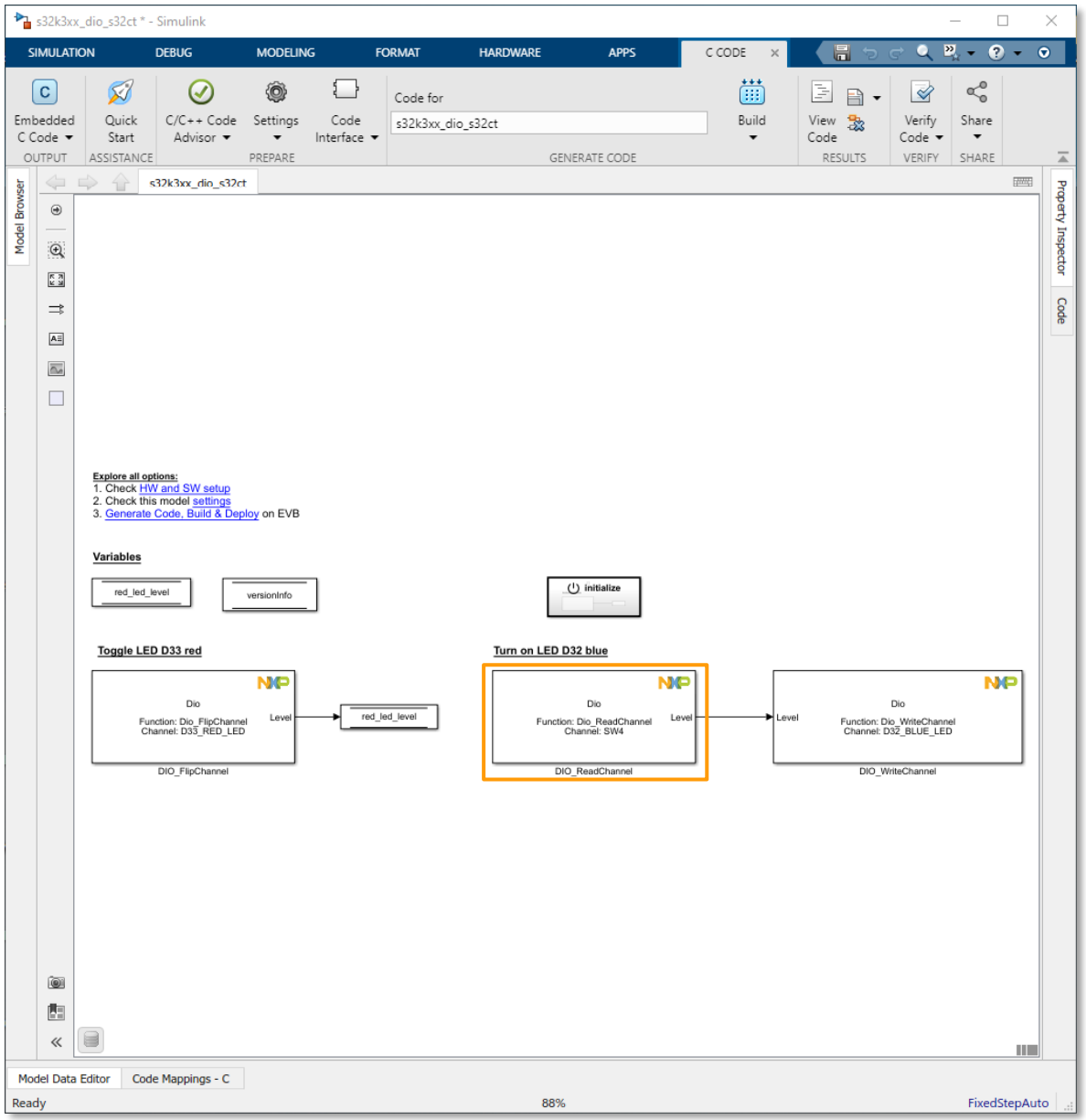


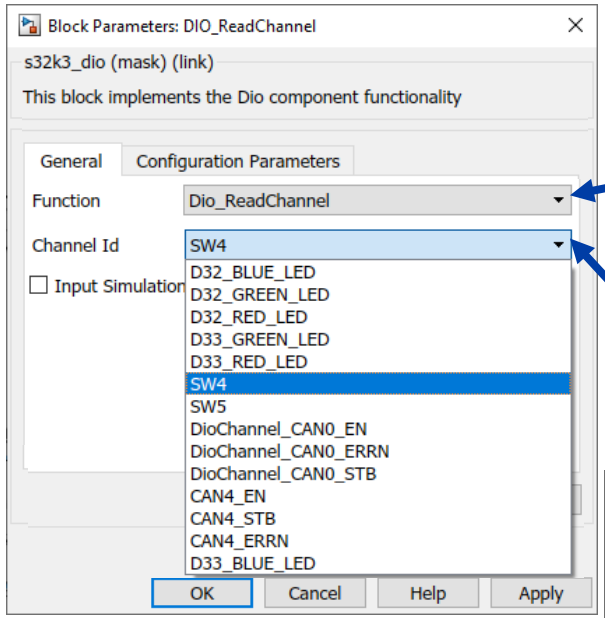
MBDT OVERVIEW

- Designed to assist customers with embedded systems design and deployment on NXP MCUs
  适用于NXP微控制芯片
- External Tools integration for peripherals, pins and clocks configuration
  外设、引脚和时钟配置的外部工具集成
  - True MBD with **UNLIMITED CONFIGURATION MODE**
    无任何限制的“真”MBD
- MCU Peripherals Configuration & Control using NXP’s Real-Time Drivers (RTD) for AUTOSAR® and non-AUTOSAR
  支持RTD，支持AUTOSAR和non-AUTOSAR



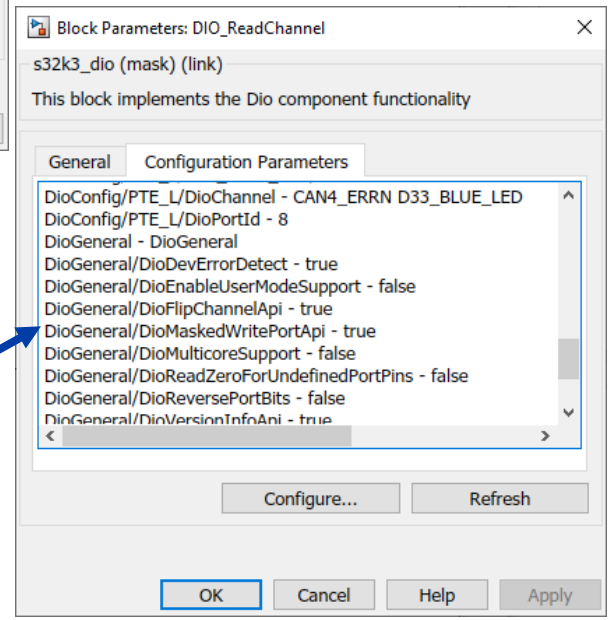
MBDT FOR S32K3 – DEFAULT CONFIGURATION MODE





Available AUTOSAR functionality for the selected MCAL Component
可选的MCAL组件函数

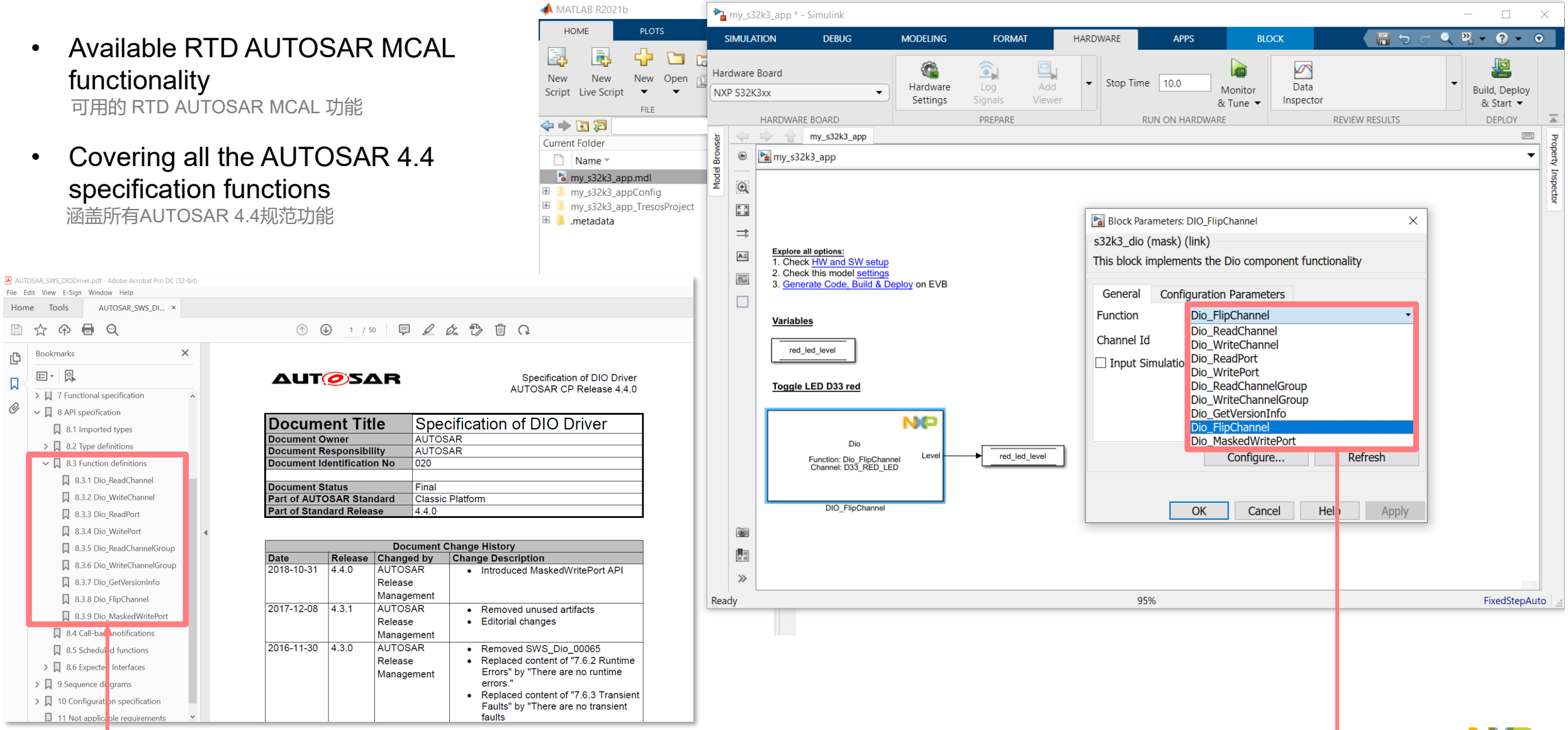
Options configured in the Default Project available for the selected Function
可选的函数参数



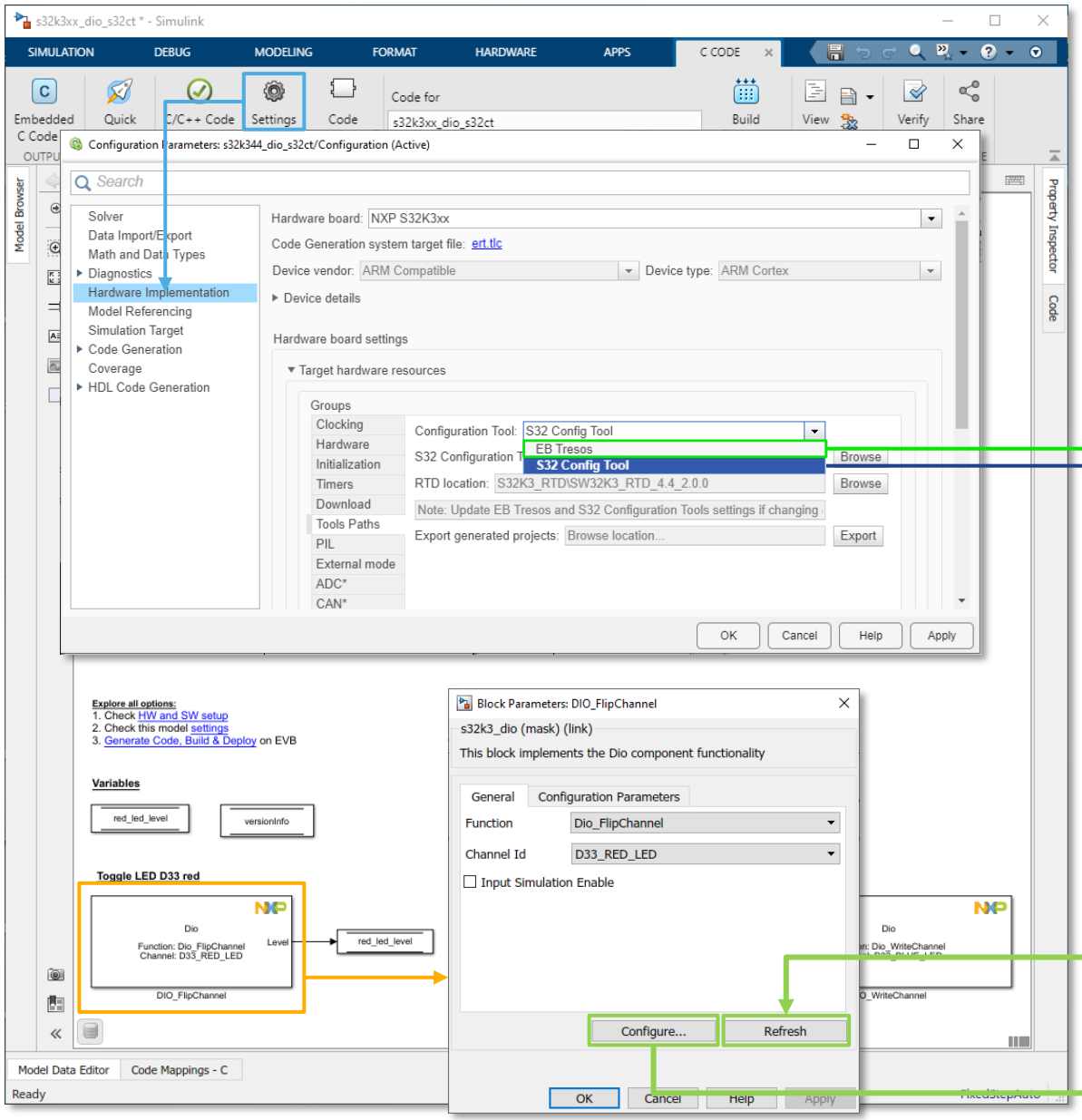
Default project configuration parameters for the selected MCAL Component
MCAL组件配置参数

MBDT FOR S32K3 – UNLIMITED CONFIGURATION MODE

- Available RTD AUTOSAR MCAL functionality
  可用的 RTD AUTOSAR MCAL 功能
- Covering all the AUTOSAR 4.4 specification functions
  涵盖所有AUTOSAR 4.4规范功能

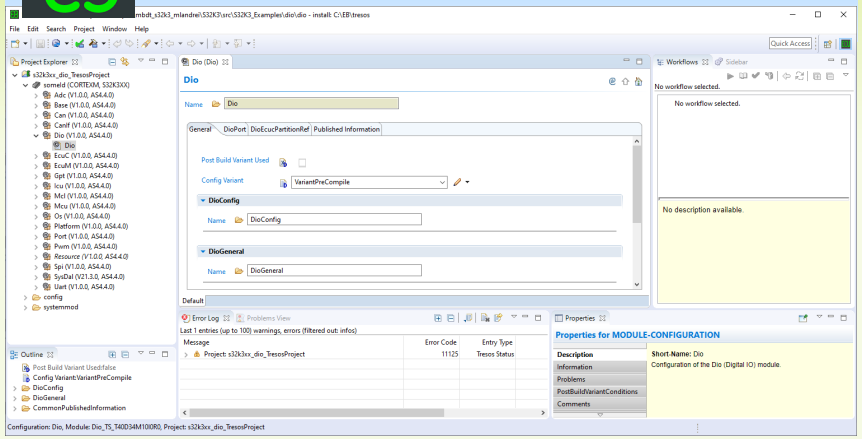


MBDT FOR S32K3 – UNLIMITED CONFIGURATION MODE

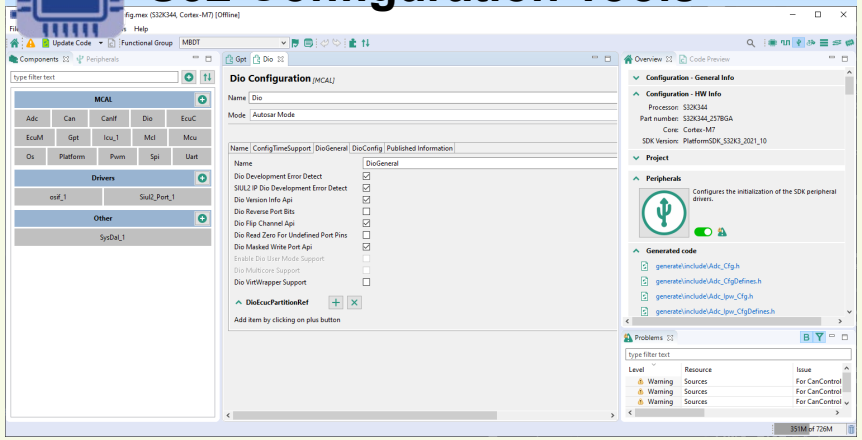


External Configuration Tools

EB tresos Studio

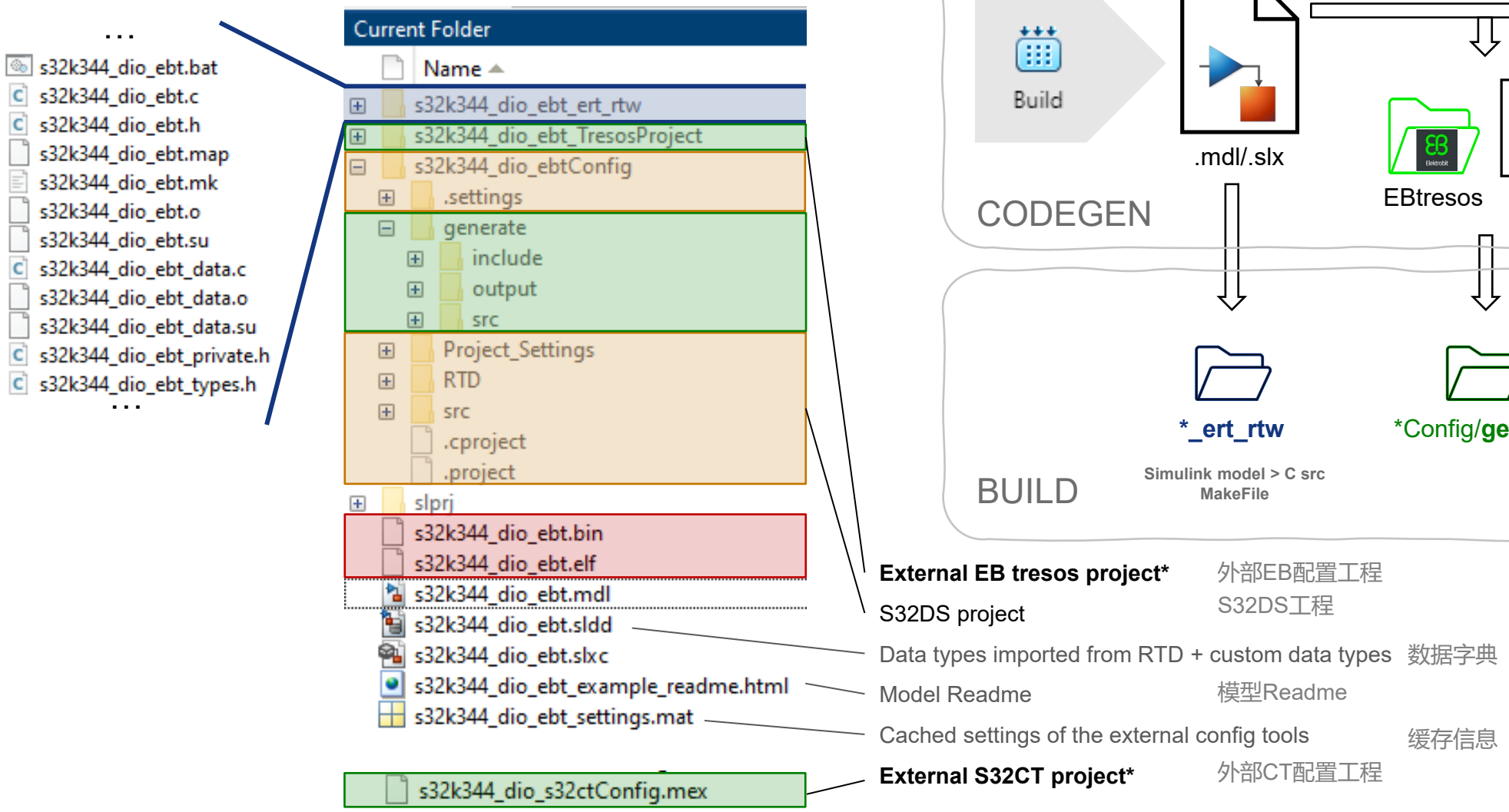


S32 Configuration Tools



MCAL Components Configuration (Pins, Clocks, Peripherals)

MBDT FOR S32K3 CODE GENERATION FLOW



** If deleted, the configuration will be reset to default settings*
** 如果删除，配置将重置为默认设置*

MODEL-BASED DESIGN TOOLS USE CASES

	+ MBDT	+ S32DS
Pins, MCU, Clock and Peripheral configuration	Configured and driven by MBDT (NXP hardware support package). True MBD with unlimited configuration mode (K3 only) 由 MBDT配置和驱动， 无任何配置限制，可以实现真正的MBD（仅K3）	Configured and driven by Processor Expert / Configuration Tools and SDK/RTD in S32DS 由 S32DS 中的PE/CT和 SDK/RTD 配置和驱动
Project files	Entire application built in Simulink™. The models include all SW and drivers needed in project 全部模型在Simulink中实现，项目中所有的软件算法和驱动程序均由模型/模块实现	Components of the application are built in Simulink™ and then integrated with configuration code and SDK/RTD drivers in IDE (S32DS) 部分代码由模型生成，然后在IDE（S32DS）中与配置代码和SDK/RTD驱动集成
Application development, build and deployment	Good for development and deployment, not perfect for build and debug 适合开发和部署，不适合编译和调试	Final integration, build and deployment done from S32DS, full function support for build and debug 从 S32DS 完成最终集成、构建和部署，构建和调试的全功能支持
Hardware awareness	MBDT Framework: Simulink™ model can be split into a hardware independent component (algorithm) and a hardware-aware component (MCU configs and inputs/outputs drivers) MBDT 框架：Simulink™ 模型可以分为硬件独立组件（算法模型）和硬件依赖组件（MCU配置、 输入/输出驱动程序）	Simulink™ model can be hardware independent (if only algorithm component is generated by the model) Simulink™ 模型可以是独立于硬件的（如果模型仅生成算法组件）

NXP MC solutions on MBDT

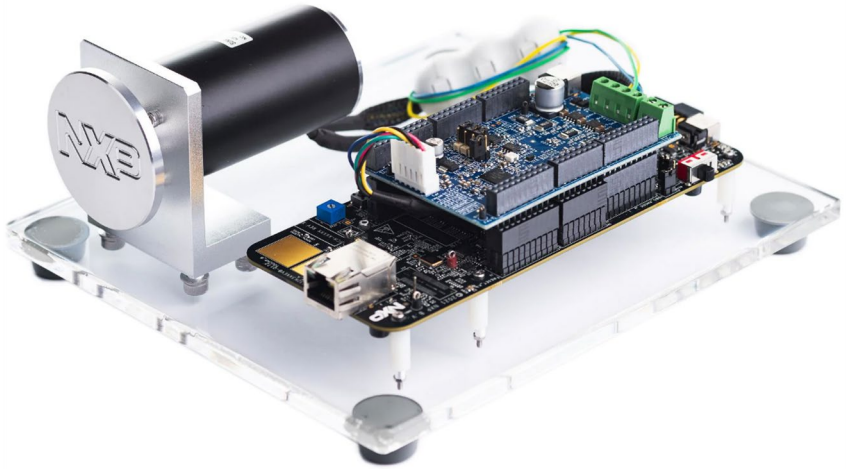
MATLAB EXPO

NXP | SECURE CONNECTIONS FOR A SMARTER WORLD

PUBLIC

NXP, THE NXP LOGO AND NXP SECURE CONNECTIONS FOR A SMARTER WORLD ARE TRADEMARKS OF NXP B.V.
ALL OTHER PRODUCT OR SERVICE NAMES ARE THE PROPERTY OF THEIR RESPECTIVE OWNERS. © 2023 NXP B.V.

S32K344 BLDC AND PMSM MOTOR CONTROL DEVELOPMENT KIT: MCSPTE1AK344



- Motor Control Capabilities
  - Low voltage 3-phase permanent magnet motor (BLDC or PMSM)
  - Current sensor: Single, dual and triple shunt current sensing
  - Position sensor: Hall/encoder/sensorless
- Software Features
  - Field-oriented control (FOC) with field weakening for sinusoidal motor type (PMSM)
  - Six-step commutation control for trapezoidal motor type (BLDC)
  - Examples built on RTD high-level API (AUTOSAR applications) or low-level API (non-AUTOSAR)

- 电机控制能力
  - 低压三相永磁电机（BLDC 或 PMSM）
  - 电流传感器：单路、双路和三路分流电流感应
  - 位置传感器：霍尔/编码器/无传感器
- 软件特色
  - 正弦电机类型 (PMSM) 的弱磁磁场定向控制 (FOC)
  - 梯形电机类型（BLDC）的六步换向控制
  - 基于 RTD 高级 API（AUTOSAR 应用程序）或低级 API（非 AUTOSAR）构建的示例

S32K3XX MC BLOCK DIAGRAM – BLDC

MCU, Motor, circuits

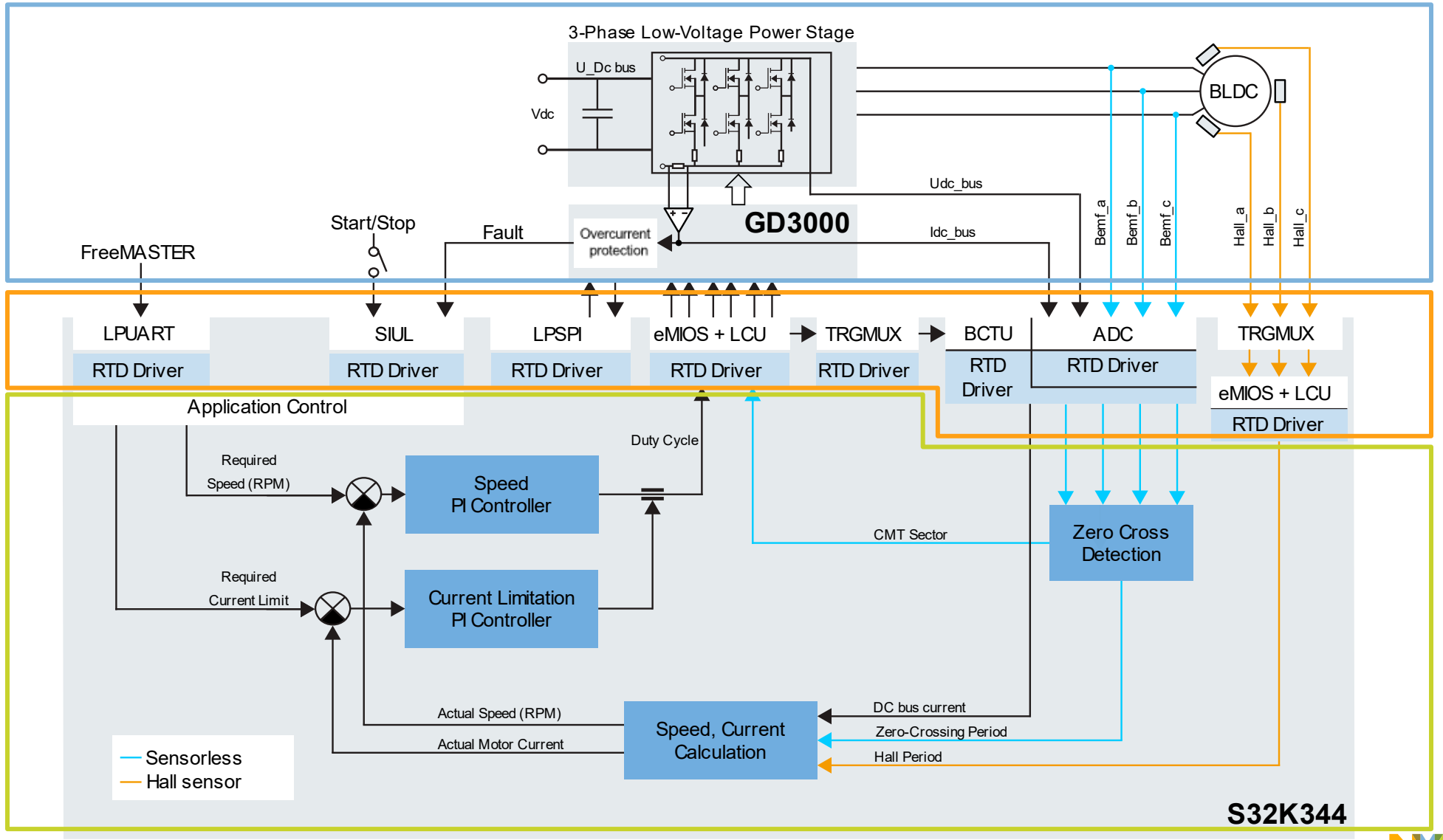
MBDT

Drivers, Configs, APIs

App, Algorithm, Data processing

Real-Time Drivers for S32K3

Automotive Math and Motor Control Library Set for S32K3



S32K3XX MC BLOCK DIAGRAM – PMSM

MCU, Motor, circuits

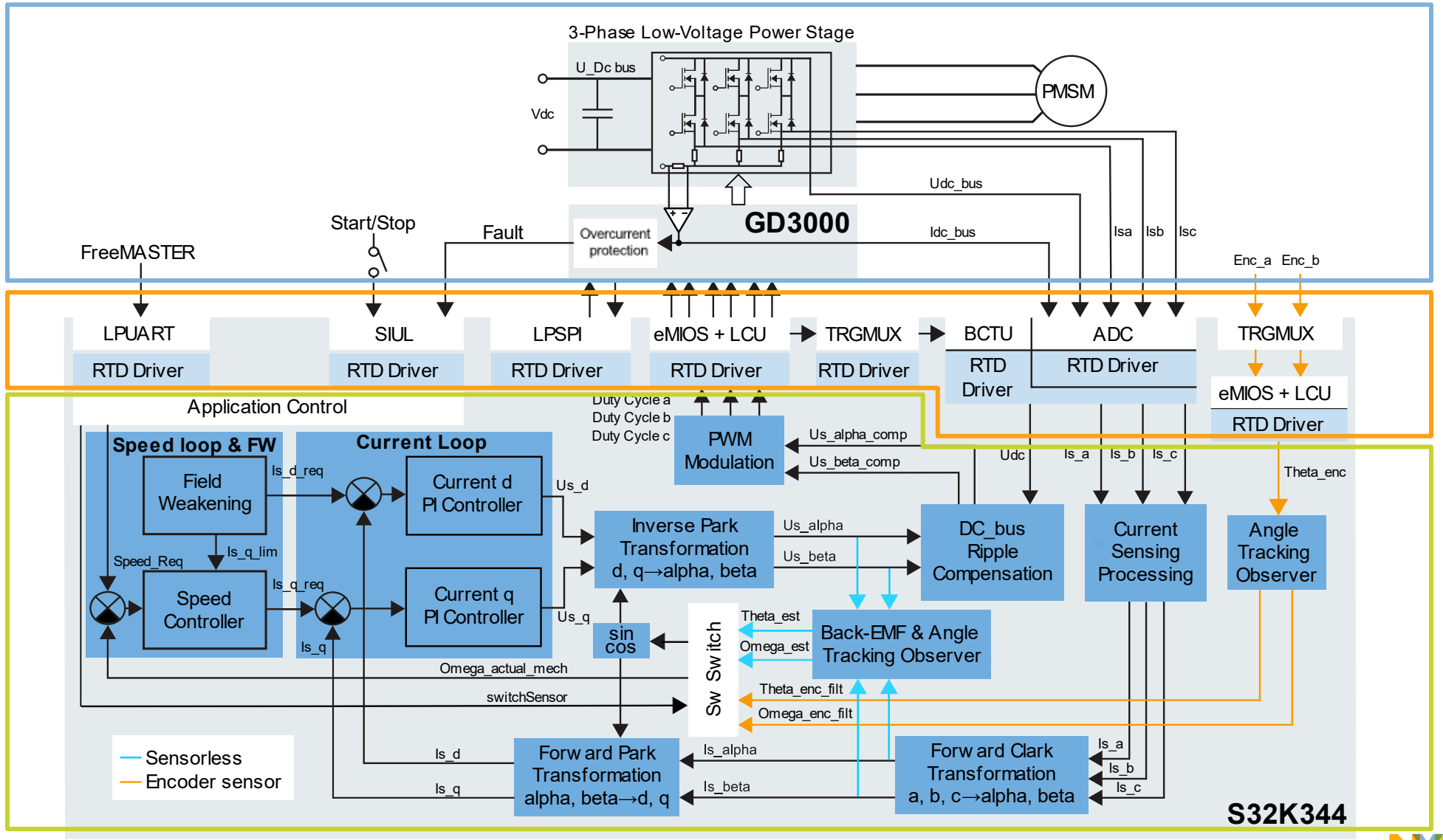
MBDT

Drivers, Configs, APIs

App, Algorithm, Data processing

Real-Time Drivers for S32K3

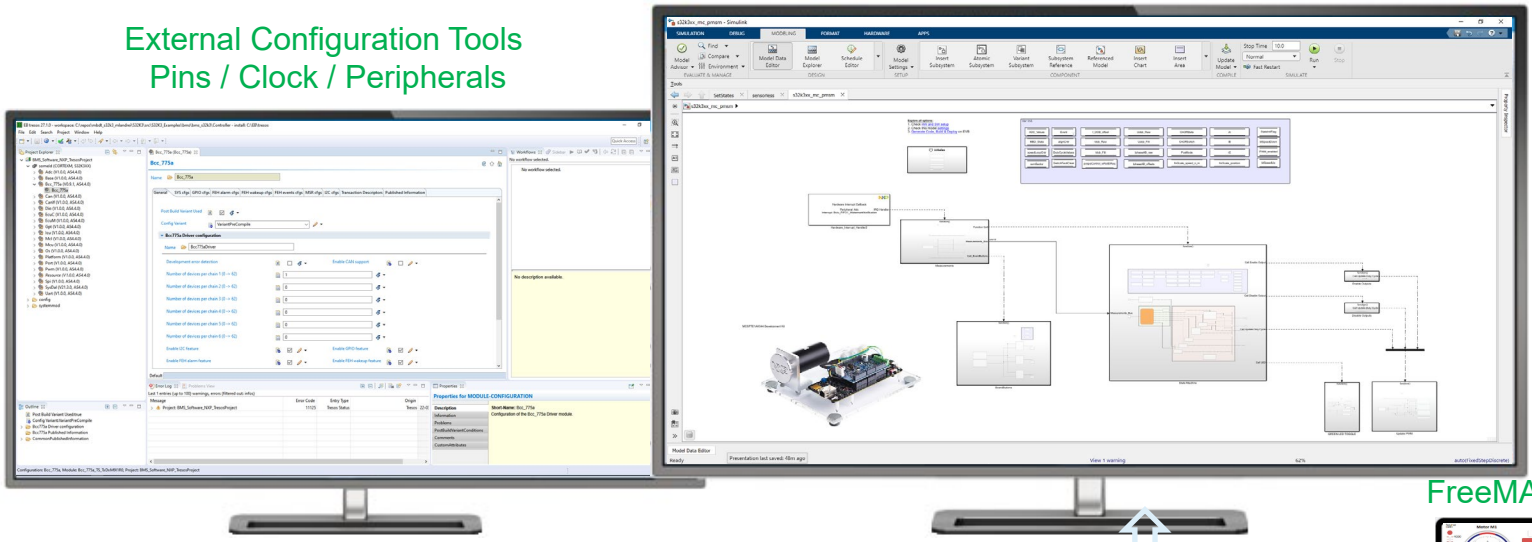
Automotive Math and Motor Control Library Set for S32K3

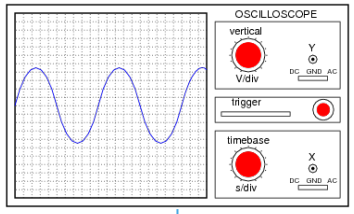


RAPID PROTOTYPING – MBDT ENVIRONMENT

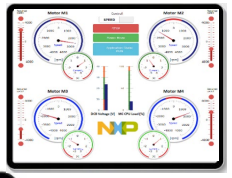
Model-Based Design Toolbox for Simulink

External Configuration Tools
Pins / Clock / Peripherals

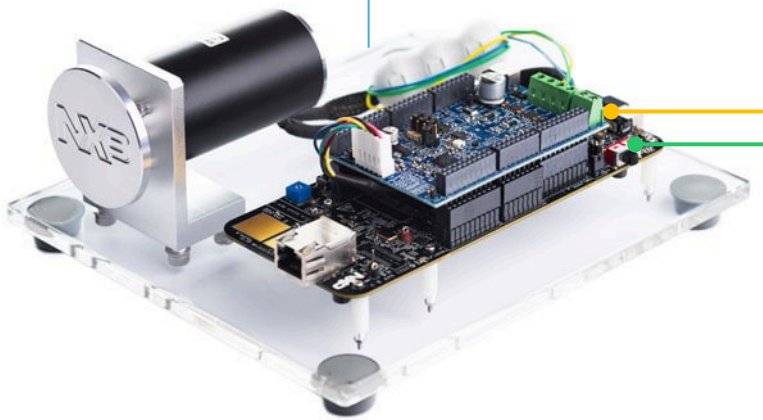




FreeMASTER Lite



FreeMaster



JTAG

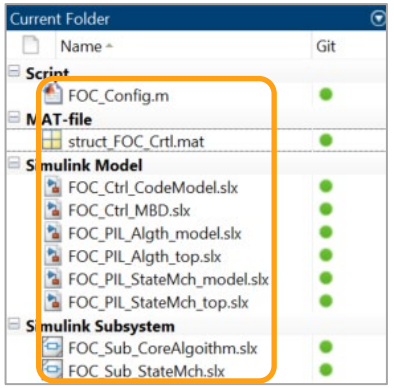
UART

Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.

MBD MOTOR CONTROL DEMO OVER MBDT – OVERVIEW

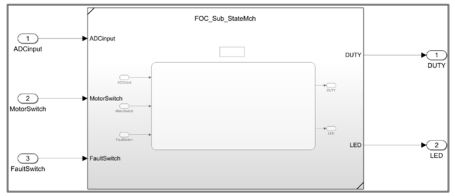
- Structure of MBD MC Frameworks - **Layered Model**

MBD电机控制框架：分层模型



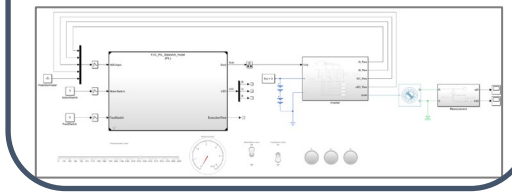
Combine with input and output ports to construct the top level MBD controller only model used to generate the code for integration.

结合输入和输出端口构建用于生成集成代码的顶层 MBD 控制器模型。



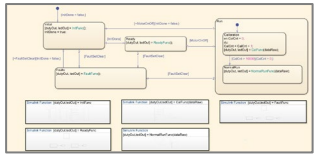
结合 Simscape 电机模型运行 MIL、SIL 或 PIL 进行有限状态机仿真和验证

Combine with Simscape motor model to run MIL, SIL or PIL for finite state machine simulation and verification

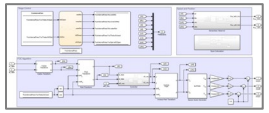


MIL/PIL/SIL

SW state machine



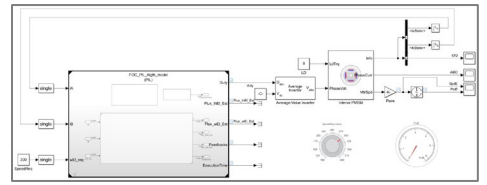
Core FOC Algorithm model



MIL/SIL/PIL

结合理想电机模型运行MIL、SIL或PIL进行算法仿真或验证

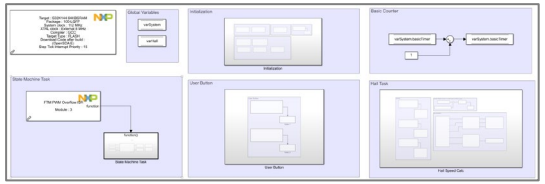
Combine with ideal motor model run MIL, SIL or PIL for algorithm simulation or verification



MBDT

结合 MBDT 块构建顶层 MBD MC 模型

Combine with MBDT blocks to construct the top level MBD MC model.



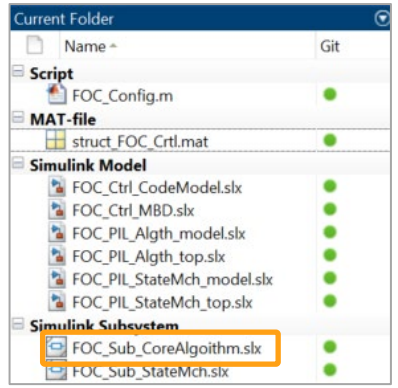
Simulink subsystem

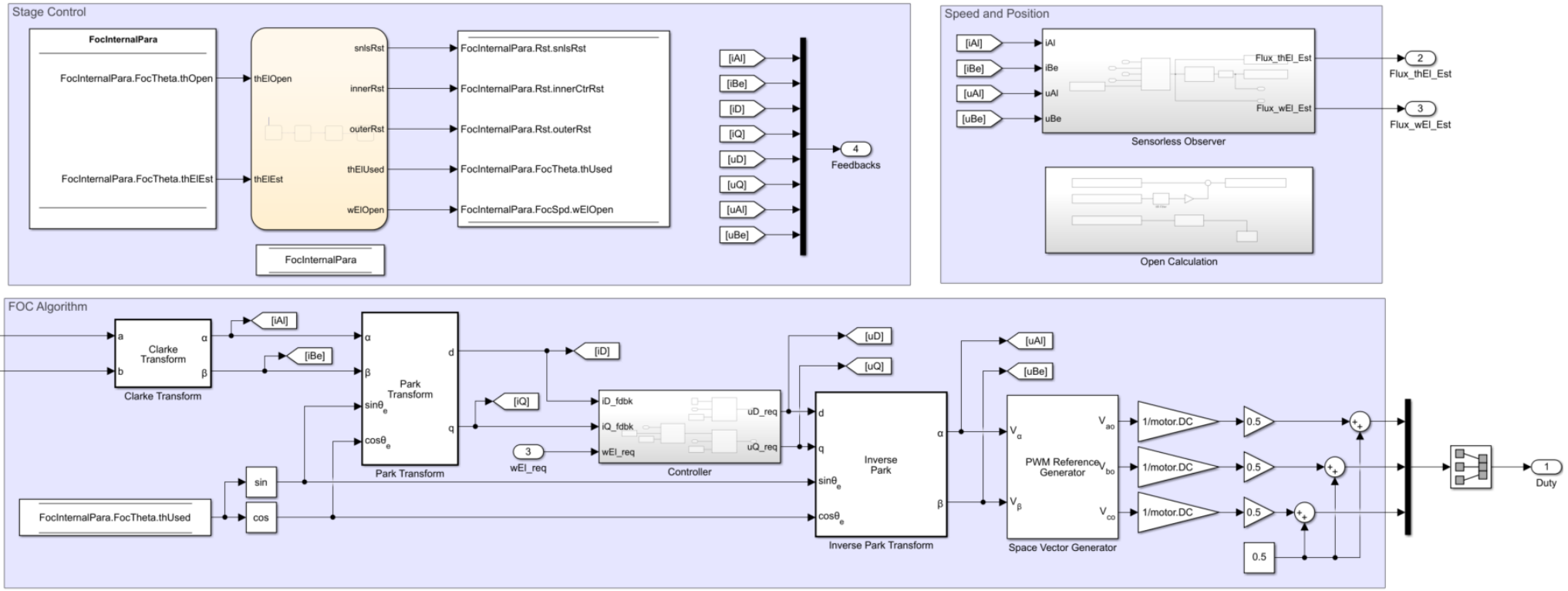
Simulink Model

MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

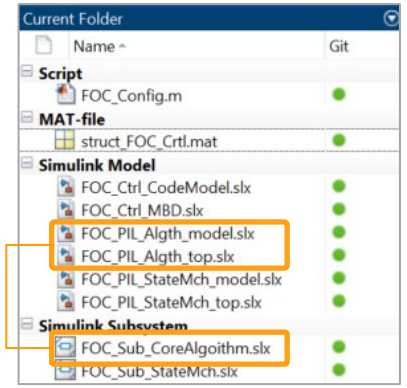
- Core FOC Algorithm model
  - HW independent

    FOC核心算法模型



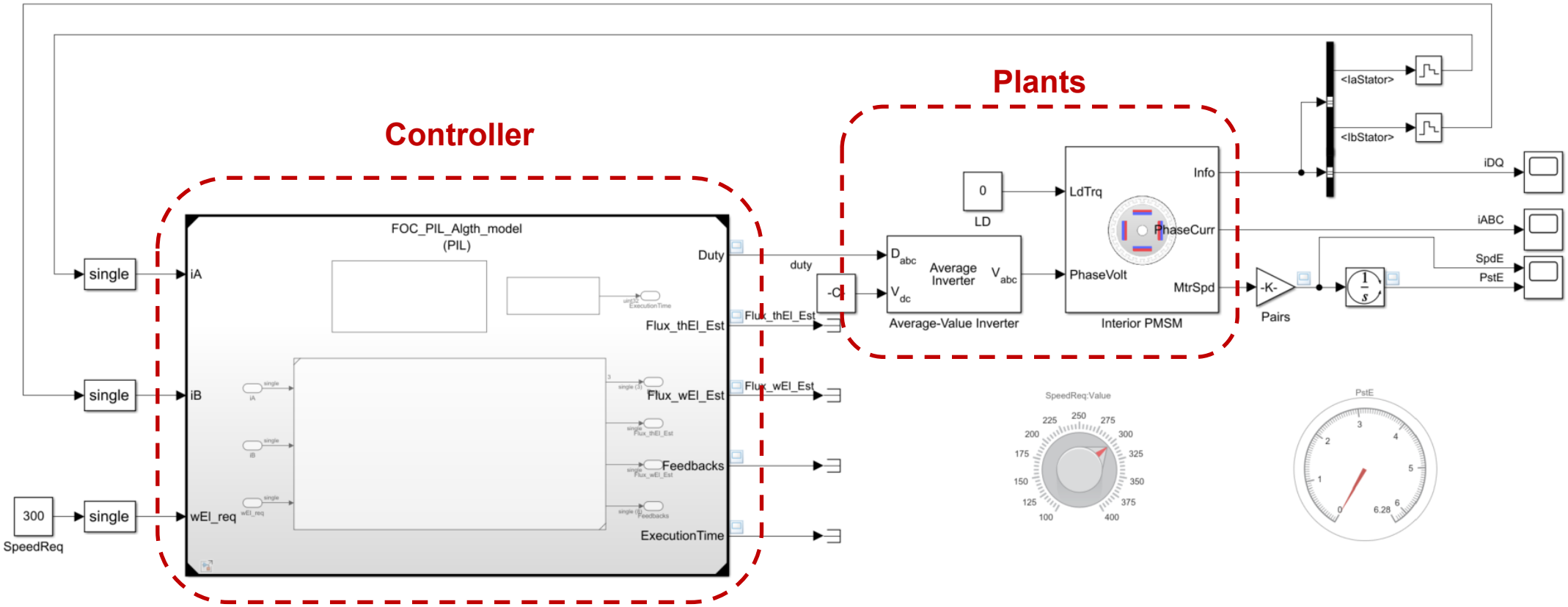


MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS



- SIL or PIL model for Core Field Oriented Control Algorithm model
  - It's easy to switch between SIL and PIL

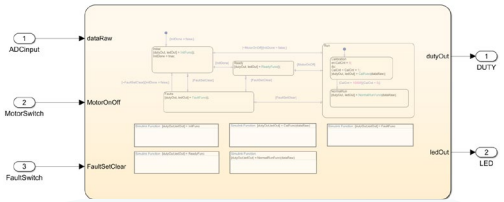
FOC核心算法模型及其SIL/PIL模型

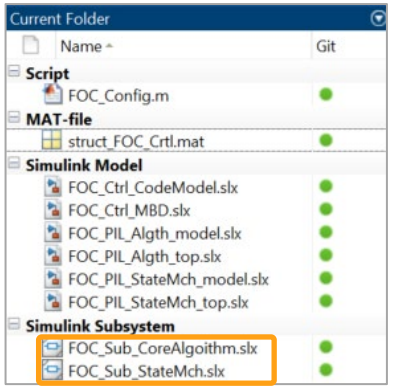


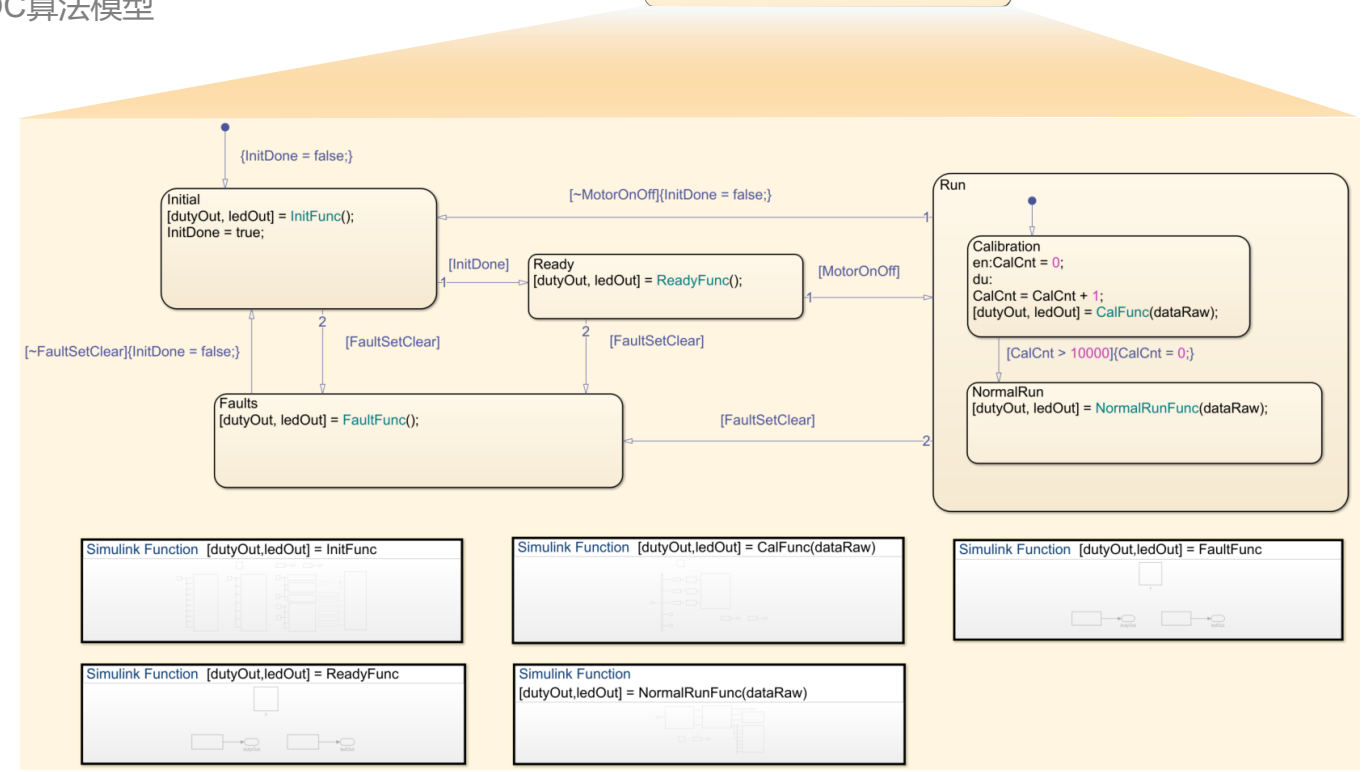
MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

- Finite state machine model
  - HW independent
  - Upper layer for Core FOC Algorithm model

有限状态机模型，下层结合FOC算法模型



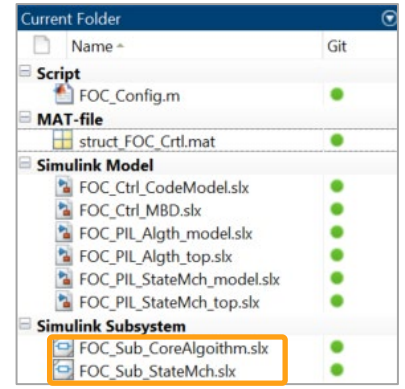


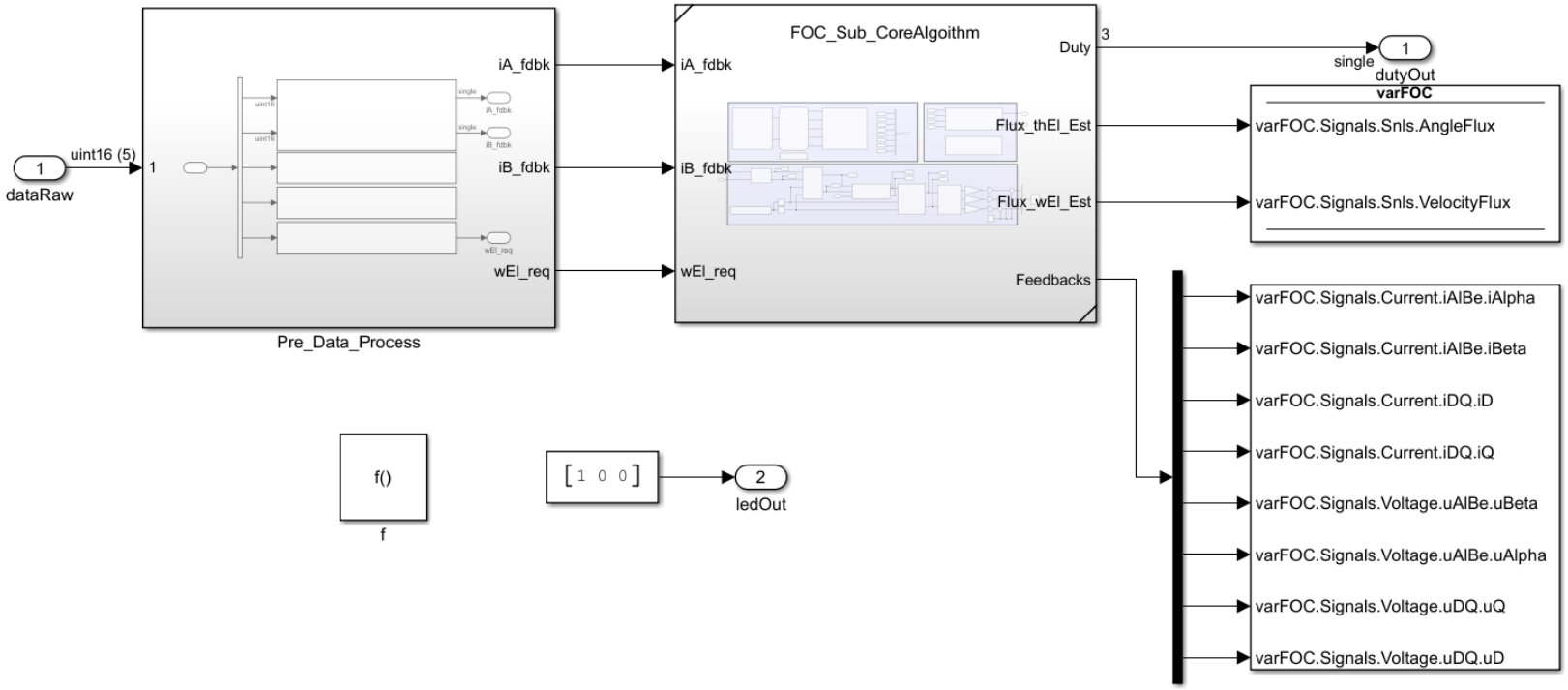


MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

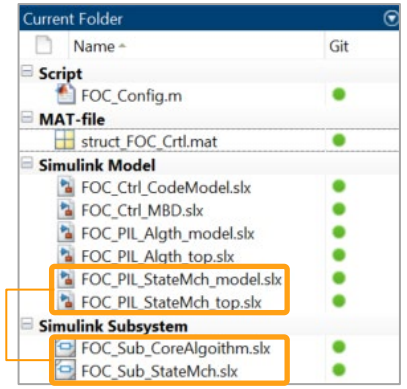
- Finite state machine model (continued)
  - Data preprocessing

    有限状态机模型，输入/输出的数据处理，以及分层模型结合方式



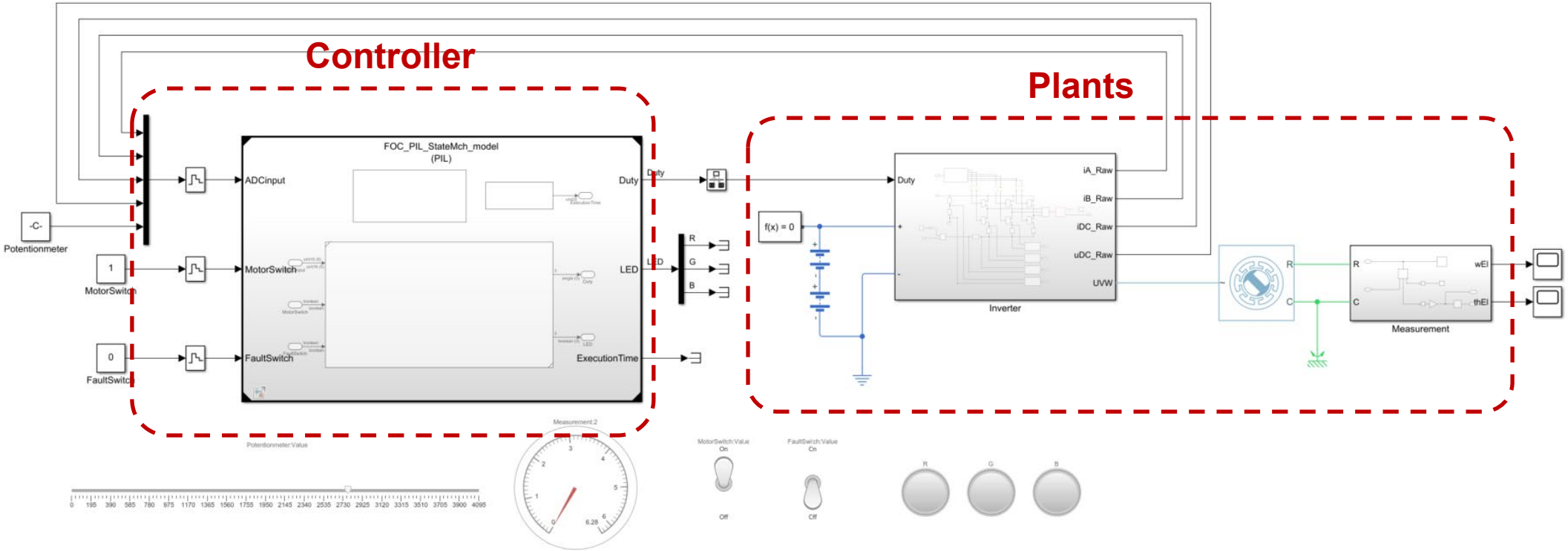


MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

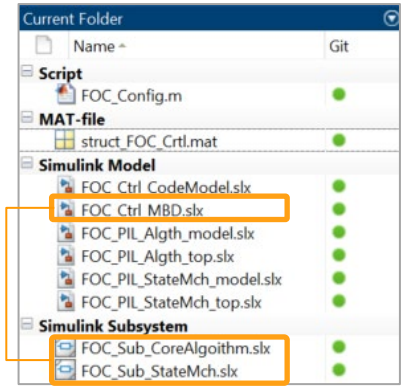


- SIL or PIL model for finite state machine
  - It's easy to switch between SIL and PIL

    有限状态机模型的SIL/PIL测试



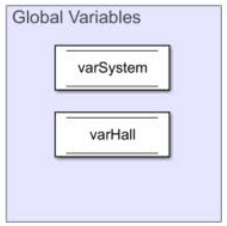
MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

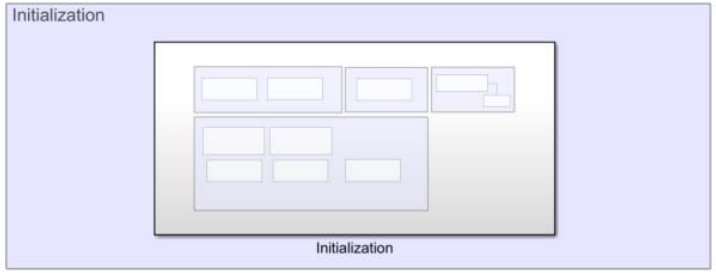


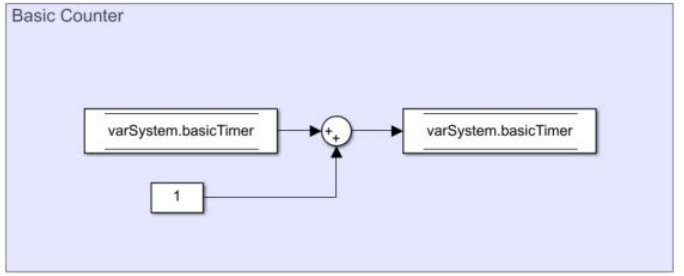
- The top level MBD MC Framework
  - Peripheral control done via MBDT
  - Five tasks: initialization, basic counter, user button, hall speed calculation and state machine

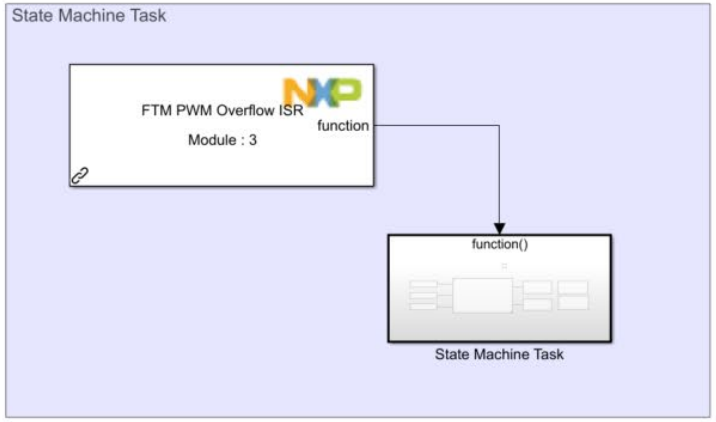
MBDT

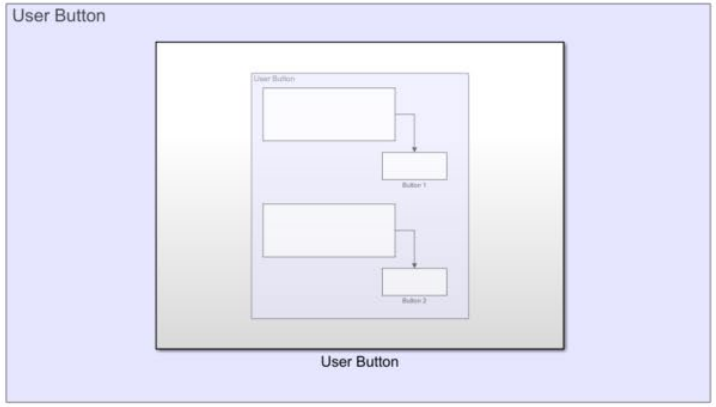
顶层电机控制框架模型：基于MBDT的外设、时钟配置，其他非FOC算法任务

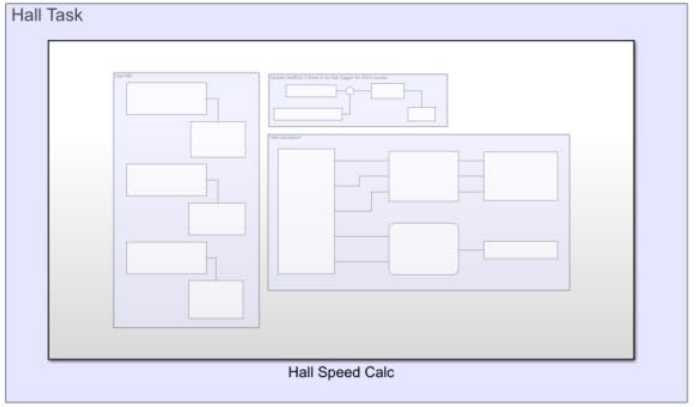










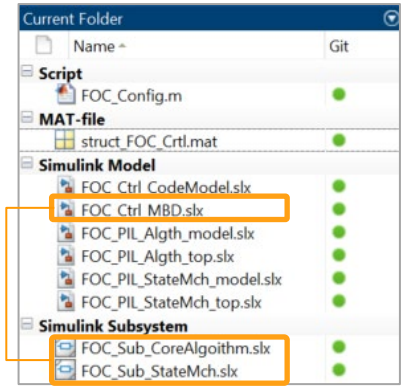


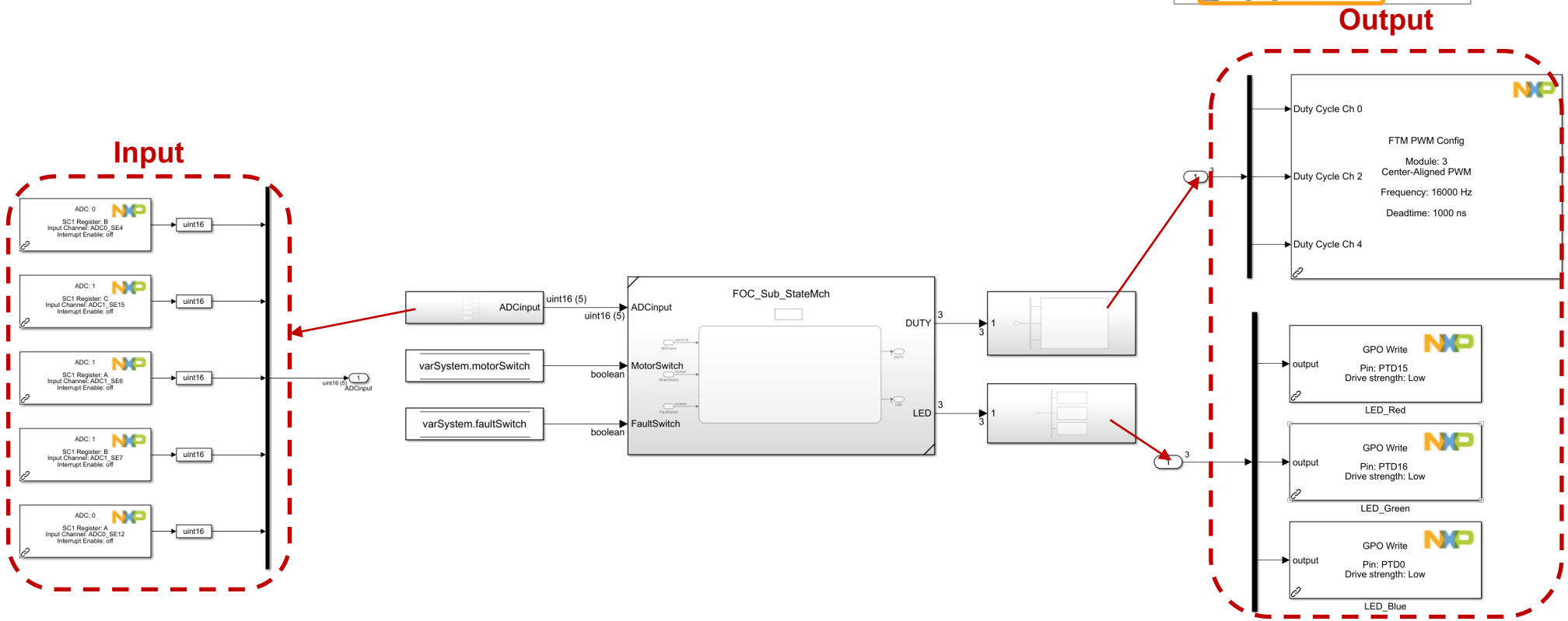
MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS

- The top level MBD MC model
  - The input interface and output interface through MBDT blocks

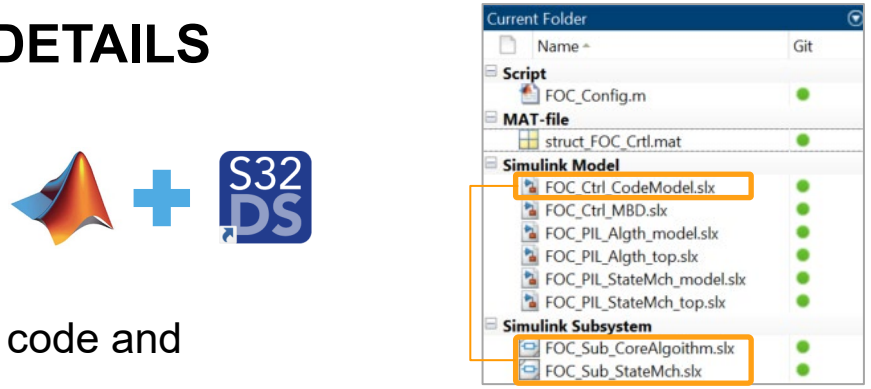
  顶层模型：状态机模型和MCU模块的结合方法

MBDT



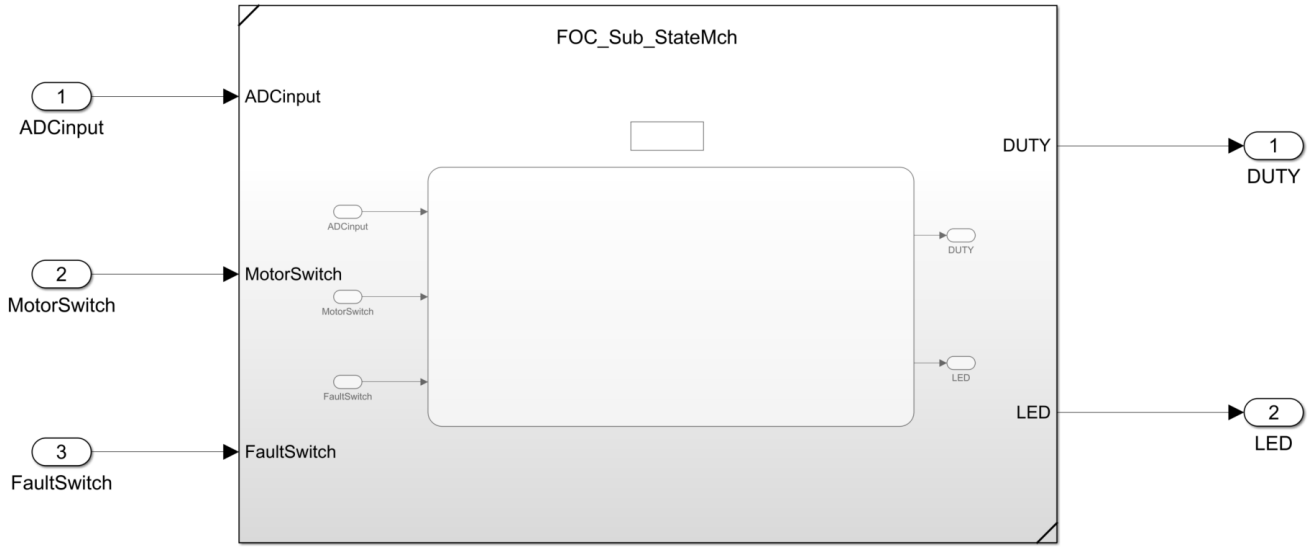


MBD MOTOR CONTROL DEMO OVER MBDT – DETAILS



- The top level MBD controller-only model
  - The model is only used to generate C code
  - Developer integrates the generated code with configuration code and SDK/RTD in IDE (S32DS)

顶层模型：通过S32DS集成开发，仅生成算法部分的代码，驱动由S32DS配置和实现



Additional resources

MATLAB EXPO

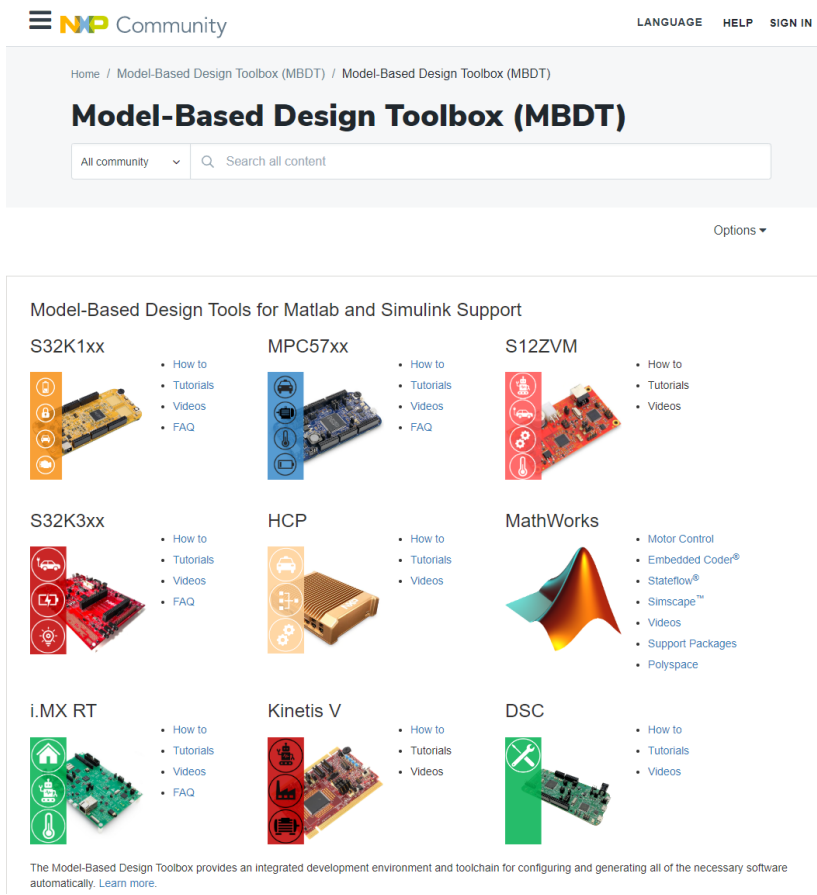
NXP | SECURE CONNECTIONS FOR A SMARTER WORLD

PUBLIC

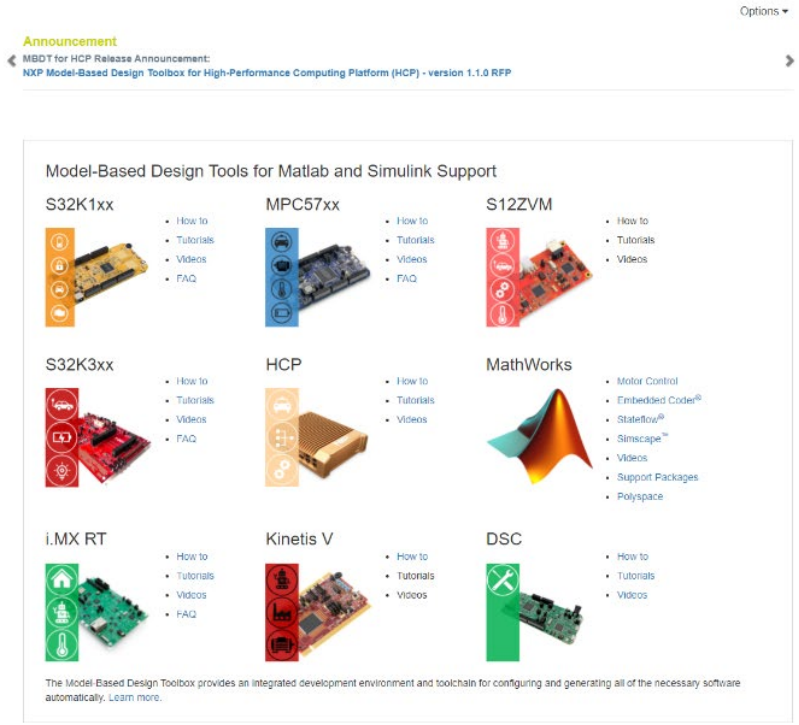
NXP, THE NXP LOGO AND NXP SECURE CONNECTIONS FOR A SMARTER WORLD ARE TRADEMARKS OF NXP B.V.
ALL OTHER PRODUCT OR SERVICE NAMES ARE THE PROPERTY OF THEIR RESPECTIVE OWNERS. © 2023 NXP B.V.

MBDT USEFUL LINKS AND SOURCES

- Hardware
  - S32K Automotive General-Purpose Microcontrollers
  - S32K344 Brushless Direct Current and Permanent Magnet Synchronous Motor Control Development Kit
  - HVBMS Reference Design Bundle using ETPL
- Software
  - Model-Based Design Toolbox (MBDT)
  - Automotive Math and Motor Control Library (AMMCLib)
  - Real-Time Drivers (RTD)
- Community
  - MBDT Community
  - WeChat public account: autoMBD



ADDITIONAL RESOURCES & SUPPORT



MBDT Beginner's Guide

W1: MBDT Introduction
W2: How-To SPI
W3: How-To CAN
W4: How-To PWM
W5: How-To LIN
W6: How-To PIL
W7: How-To Timers

Webinars

MW: Motor Control: S32K
MW: Motor Control: i.MX RT
Motor Control: BLDC/PMSM
Motor Control: Design Application
MW: Code Generation and Verification
MW: Speed Up Applications Development with MBDT
MW: Rapid Prototyping of Embedded Designs with MBDT
MW: AUTOSAR SW on S32K1/MPC
AUTOSAR SW on S32K3
MW: Deploying BMS algorithm on S32K1
MW: Deploying Deep Learning SOC algorithm on S32K3
MW: HIL Testing of Balance of Plant Controller of Fuel Cell System
MW: Vision
FreeMASTER
MW: Automotive DevOps for MBD with AWS
MW: Integrating AI-Based Virtual Sensors into Model-Based Design

PMSM Control Workshop

Course Main Page
M1: Environment Setup
M2: PMSM and FOC
M3: System Partitioning
M4: PWM Modulation
M5: V/f Scalar Control
M6: Current Sensing
M7: Torque Control
M8: Speed Control
M9: Position Observer
M10: Sensorless Speed Control

BLDC Control Workshop

Course Main Page
1. Introduction
2. Application Partitioning
3. Input Commands
4. BLDC Motor Theory
5. Hall Sensors
6. Commutation
7. Commutation Algorithm
8. Power Stage Config
9. Open Loop Control
10. Speed Estimator
11. Closed Loop Control
12. Motor Control System

MATLAB EXPO

Thank you

© 2023 The MathWorks, Inc. MATLAB and Simulink are registered trademarks of The MathWorks, Inc.
See *mathworks.com/trademarks* for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.