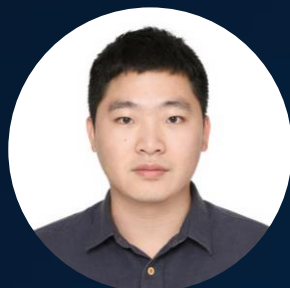


MATLAB EXPO

基于 STM32 的 MATLAB 电机控制方案

May 30, 2023 | 上海



赵耀, 意法半导体

樊朝祥, MathWorks



life.augmented

STM32 in Motor Control

赵耀

意法半导体 GPM市场经理

2023年5月30日





STM32: the leading 32-bit MCU in Industrial

ST market share: 25% - #1
of 2022 General Purpose MCU* TAM

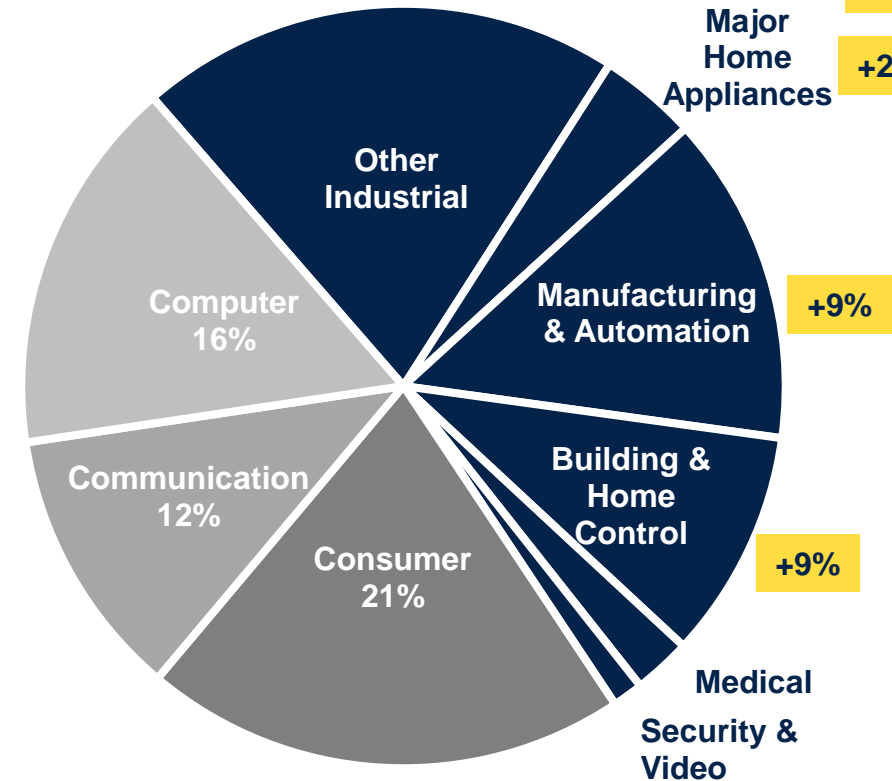
2017	2018-2020	2021-2022
	Competitor A	#1
B	#2	A
#3	Competitor B	

Organic growth driving ST market share gains

2021-2026 Industrial market growth drivers

- Home appliances - Energy efficiency & cloudification
- Factory automation - AI based predictive maintenance
- Power tools - Wireless connectivity
- Automotive electrification - Infrastructure development
- Building - Smarter, safer and more energy efficient

2022 32-bit GP MCU* TAM(\$M)



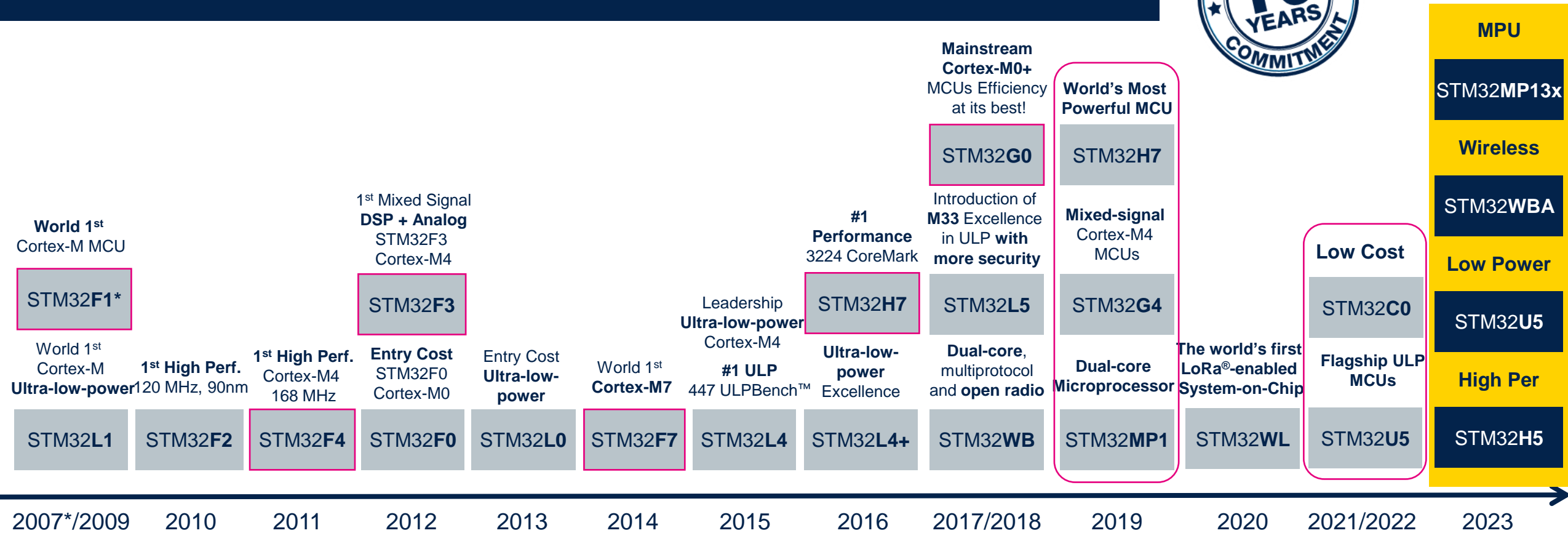
Industrial growing from 52% of TAM in 2022 to 65% in 2026



STM32 Innovation Over Years

Performance, Peripheral, Efficiency

Arm® Cortex® 32bit MCU & MPU Leader








Key product for Industrial Application





Wide STM32 Portfolio Refresh In 2023

 <p>MPU</p>					<p>STM32MP1 Up to 1 GHz Cortex®-A7 209 MHz Cortex®-M4</p>	
 <p>High Perf MCUs</p>			<p>STM32F2 Up to 398 CoreMark 120 MHz Cortex®-M3</p>	<p>STM32F4 Up to 608 CoreMark 180 MHz Cortex®-M4</p>	<p>STM32F7 1082 CoreMark 216 MHz Cortex-M7</p> <p>STM32H5 Up to 1023 CoreMark 250 MHz Cortex®-M33</p>	<p>STM32H7 Up to 3224 CoreMark Up to 550 MHz Cortex®-M7 240 MHz Cortex®-M4</p>
 <p>Mainstream MCUs</p>			<p>STM32F3 245 CoreMark 72 MHz Cortex®-M4</p>	<p>STM32G4 569 CoreMark 170 MHz Cortex®-M4</p>	<p><i>Mixed-signal MCUs</i></p>	
 <p>Ultra-low Power MCUs</p>	<p>STM32C0 114 CoreMark 48 MHz Cortex-M0+</p>	<p>STM32F0 106 CoreMark 48 MHz Cortex®-M0</p>	<p>STM32G0 142 CoreMark 64 MHz Cortex®-M0+</p>	<p>STM32F1 177 CoreMark 72 MHz Cortex®-M3</p>		
 <p>Wireless MCUs</p>			<p>STM32WL 162 CoreMark 48 MHz Cortex®-M4 48 MHz Cortex®-M0+</p>	<p>STM32WB 216 CoreMark 64 MHz Cortex®-M4 32 MHz Cortex®-M0+</p>	<p>STM32WBA 407 CoreMark 100 MHz Cortex®-M33</p>	<p>STM32U5 651 CoreMark 160 MHz Cortex®-M33</p>

Latest product generation

New Series Introduced in 2023





STM32 for motor control



MPU

STM32MP1
Up to 1 GHz Cortex®-A7
209 MHz Cortex®-M4

High Perf MCUs

STM32F2
Up to 398 CoreMark
120 MHz Cortex®-M3

STM32F4
Up to 608 CoreMark
180 MHz Cortex®-M4

STM32F7
1082 CoreMark
216 MHz Cortex-M7

STM32H5
Up to 1023 CoreMark
250 MHz Cortex®-M33

STM32H7
Up to 3224 CoreMark
Up to 550 MHz Cortex®-M7
240 MHz Cortex®-M4

Mainstream MCUs

STM32F3
245 CoreMark
72 MHz Cortex®-M4

STM32G4
569 CoreMark
170 MHz Cortex®-M4

Mixed-signal MCUs

STM32C0
114 CoreMark
48 MHz Cortex-M0+

STM32F0
106 CoreMark
48 MHz Cortex®-M0

STM32G0
142 CoreMark
64 MHz Cortex®-M0+

STM32F1
177 CoreMark
72 MHz Cortex®-M3

Ultra-low Power MCUs

STM32L0
75 CoreMark
32 MHz Cortex®-M0+

STM32L4
273 CoreMark
80 MHz Cortex®-M4

STM32L4+
409 CoreMark
120 MHz Cortex®-M4

STM32L5
443 CoreMark
110 MHz Cortex-M33

STM32U5
651 CoreMark
160 MHz Cortex®-M33

Wireless MCUs

STM32WL
162 CoreMark
48 MHz Cortex®-M4
48 MHz Cortex®-M0+

STM32WB
216 CoreMark
64 MHz Cortex®-M4
32 MHz Cortex®-M0+

STM32WBA
407 CoreMark
100 MHz Cortex®-M33

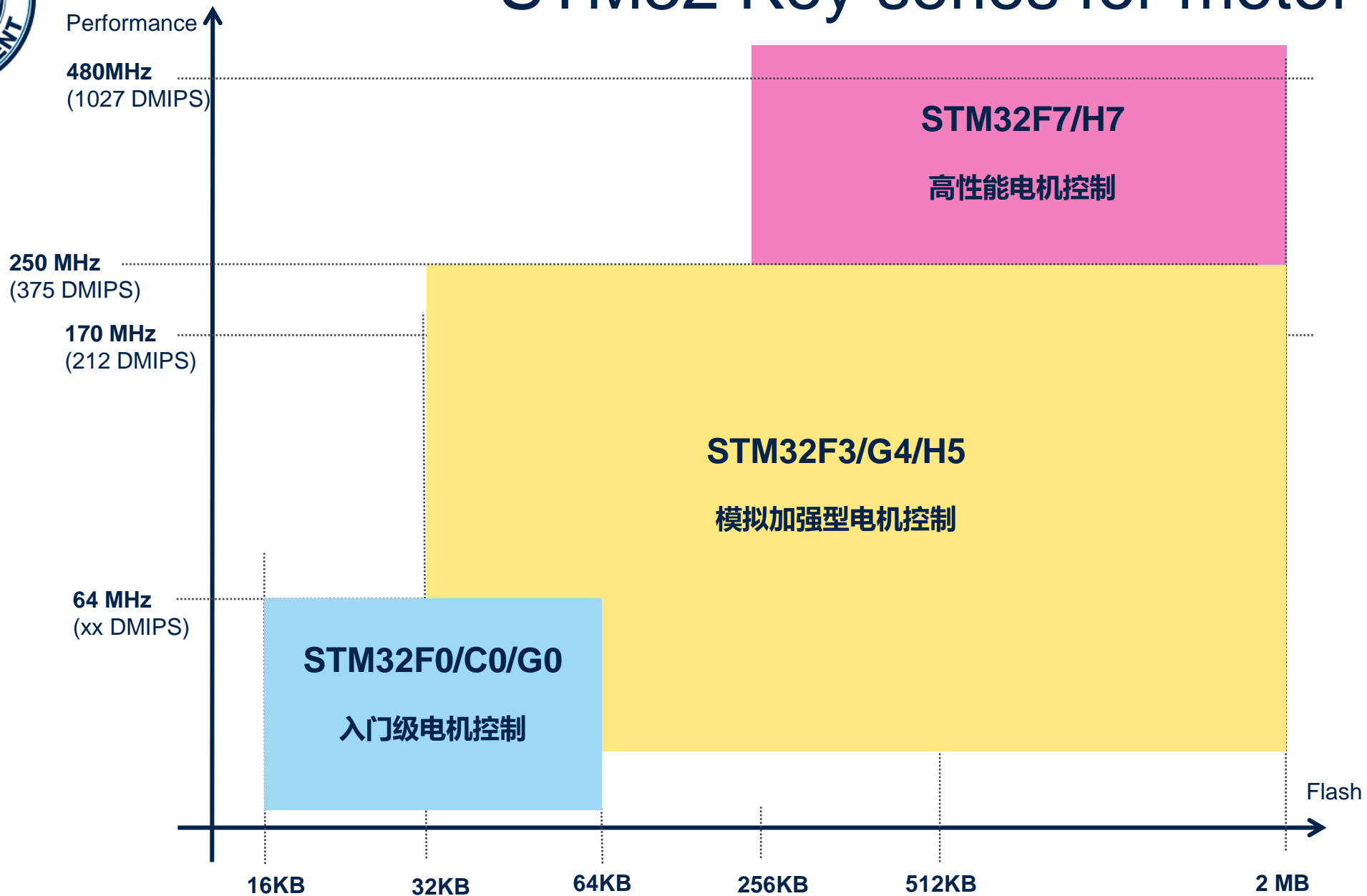
Latest product generation

New Series Introduced in 2023

- STM32 with advanced timer
- STM32 with advanced timer and MC-SDK support



STM32 Key series for motor control





More Than Silicon: Motor Control Solution STM32 + Ecosystem + Safety + Security + HMI + AI

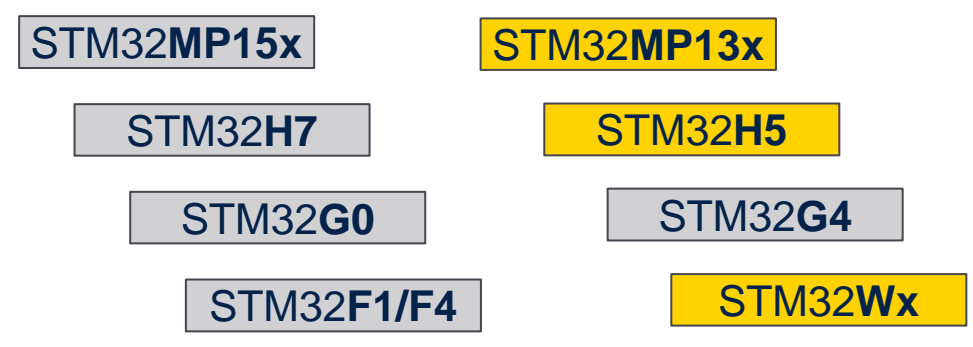
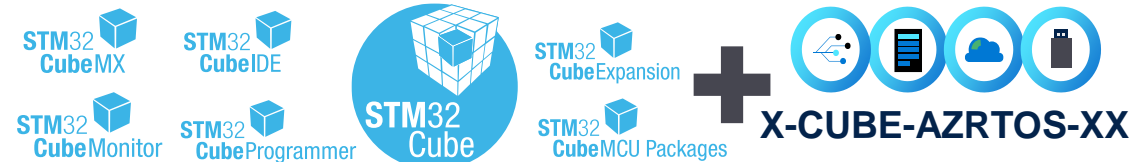
Microcontroller Requirements

Functional Safety Requirements

Security Requirements

Graphics / HMI Requirements

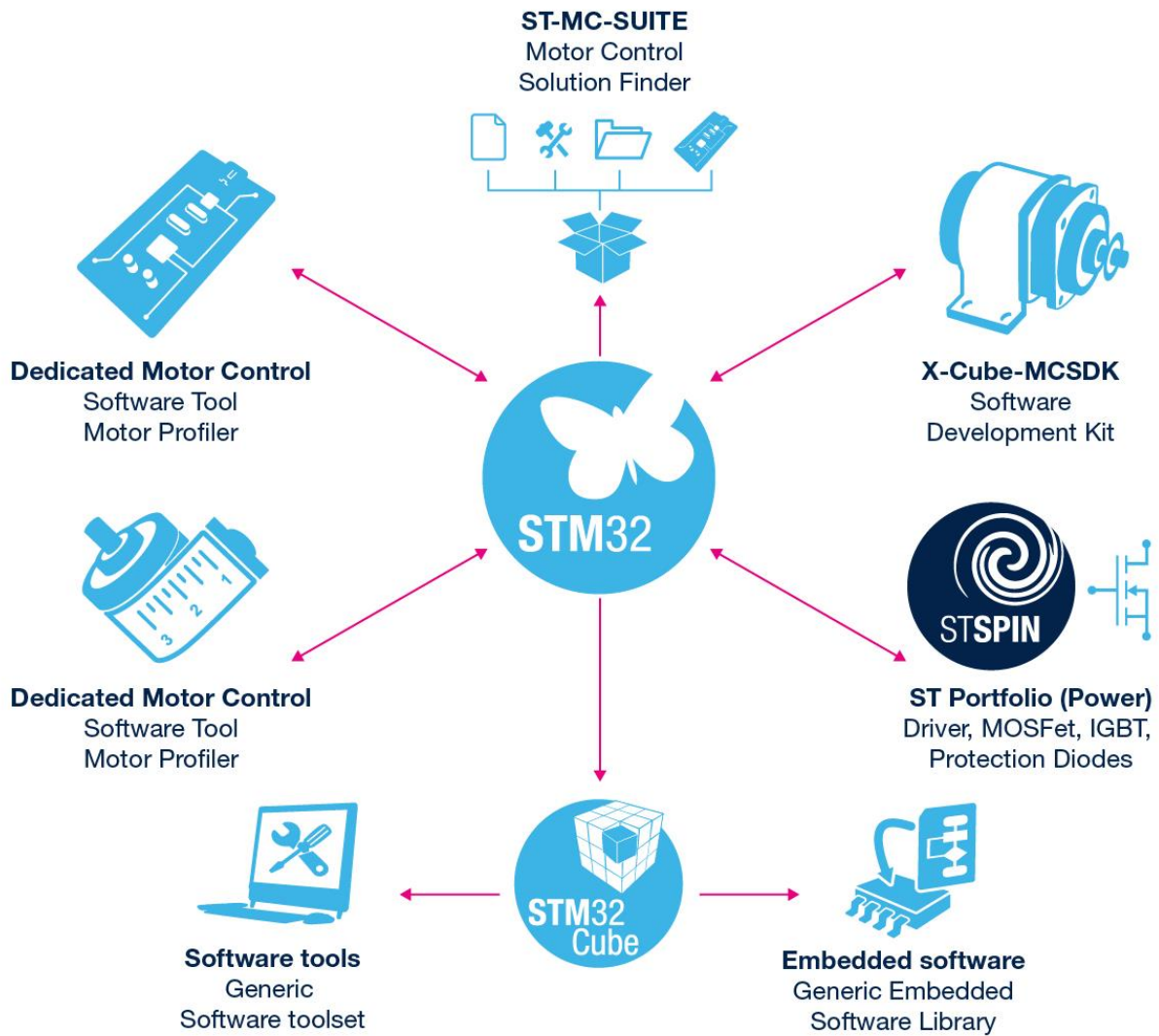
Artificial Intelligence Requirements



Customer benefits from **STM32 Wide Portfolio** + **More Than Silicon** ecosystem answers customers' challenges



STM32 motor control Ecosystem



- [X-CUBE-MCSDK](#)
- [STM32 Cube Ecosystem](#)
- [STM32电机控制Wiki](#)
- [ST-MC-SUITE](#)

STM32 电机套件方便客户快速评估

控制 + 电源

逆变器
(完整驱动器)

MC套装

评估STM32Nucleo + 电源/扩展

控制级



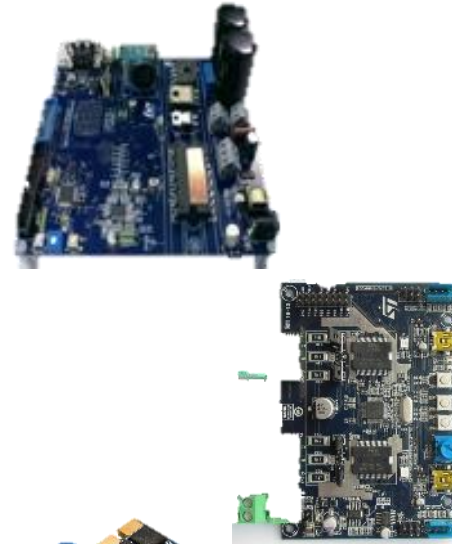
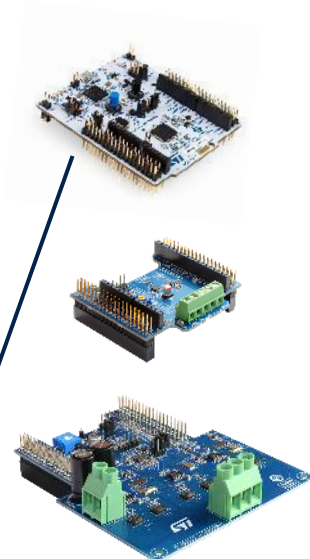
功率级



MC连接器
扁平电缆

NUCLEO-G431RB

X-NUCLEO-IHM16



B-G431B-ESC1



P-NUCLEO-IHM03

→ 使用ST-MC-SUITE在线工具选择您的硬件板

联合开发硬件平台--基于STM32硬件生态



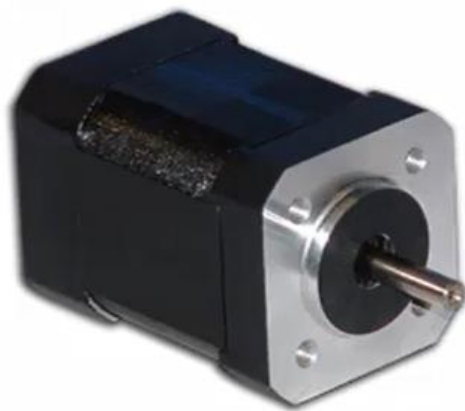
NUCLEO-G474RE



X-NUCLEO-IHM07M1



NUCLEO-G431RB



BLY172S-24V-4000 BLDC Motor

Our technology starts with You



Find out more at www.st.com

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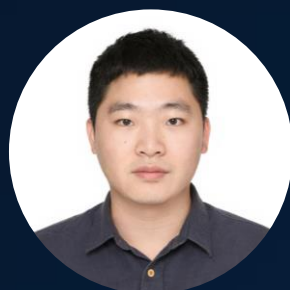


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MATLAB EXPO

基于 STM32 的 MATLAB 电机控制方案 2nd

May 30, 2023 | 上海



樊朝祥, MathWorks

MathWorks 解决方案 —— STM32 MCUs



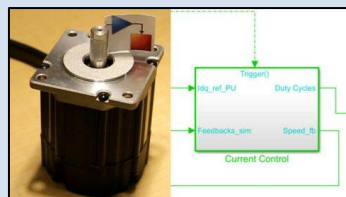
STM32 Processors (Embedded Coder) 代码生成硬件支持包

- ✓ 支持 STM32F4xx, STM32F7xx, STM32G4xx, STM32H7xx(单核), STM32L4xx, STM32L5xx, 和 STM32WBxx 系列开发板。
- ✓ 可与 STM32CubeMX 集成进行外设配置。
- ✓ 免费支持包，可用于快速原型和产品级代码生成。



STM32 Nucleo (Simulink Coder) 代码生成硬件支持包

- ✓ 支持 Nucleo-F031K6, F103RB, F302R8, F401RE, F411RE, F746ZG, F767ZI, H743ZI, H743ZI2, L053R8, L476RG 系列开发板。
- ✓ 免费支持包，用于快速原型算法验证。



Motor Control Blockset 电机控制算法工具箱

- ✓ FOC 控制算法调优与电机本体建模。
- ✓ 可生成代码的 Simulink 模块库：帕克和克拉克变换、无传感器观测器、弱磁、等.....。
- ✓ 闭环仿真验证控制算法。

传感器
在线标定

电机参数
在线估计

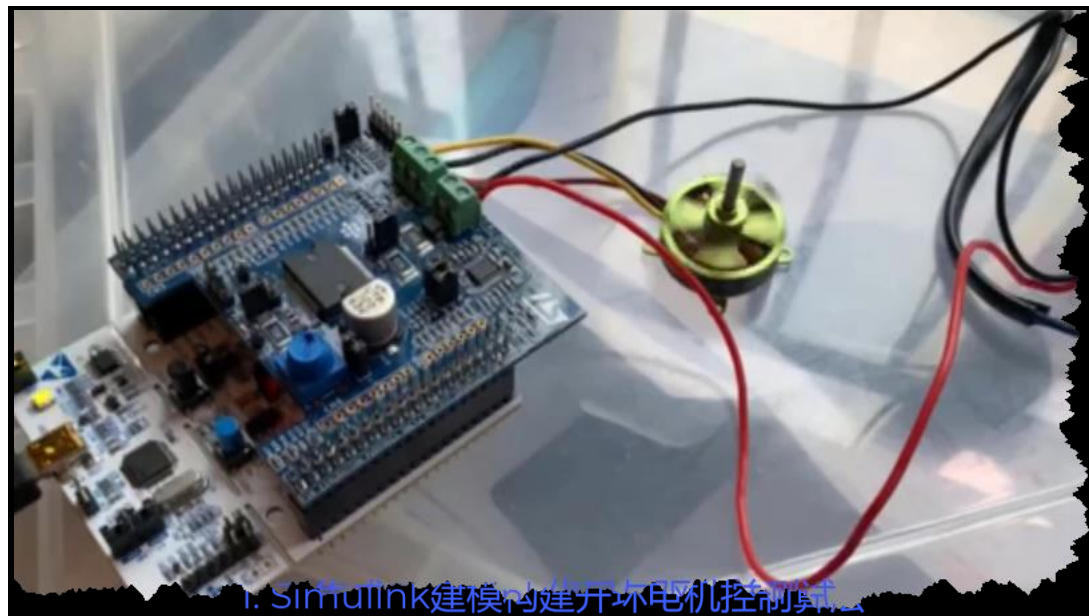
电力电子
系统建模

控制算
法开发

算法实现
和验证

算法导出 workflow —— stm32 电机控制示例

1. 建模构建开环电机控制算法
2. 使用STM32CubeMX为STM32F302R8配置驱动
3. 集成Simulink代码与驱动并测试
4. [算法导出 workflow 视频](#)
5. [Algorithm-Export Workflows for Custom Hardware 示例](#)



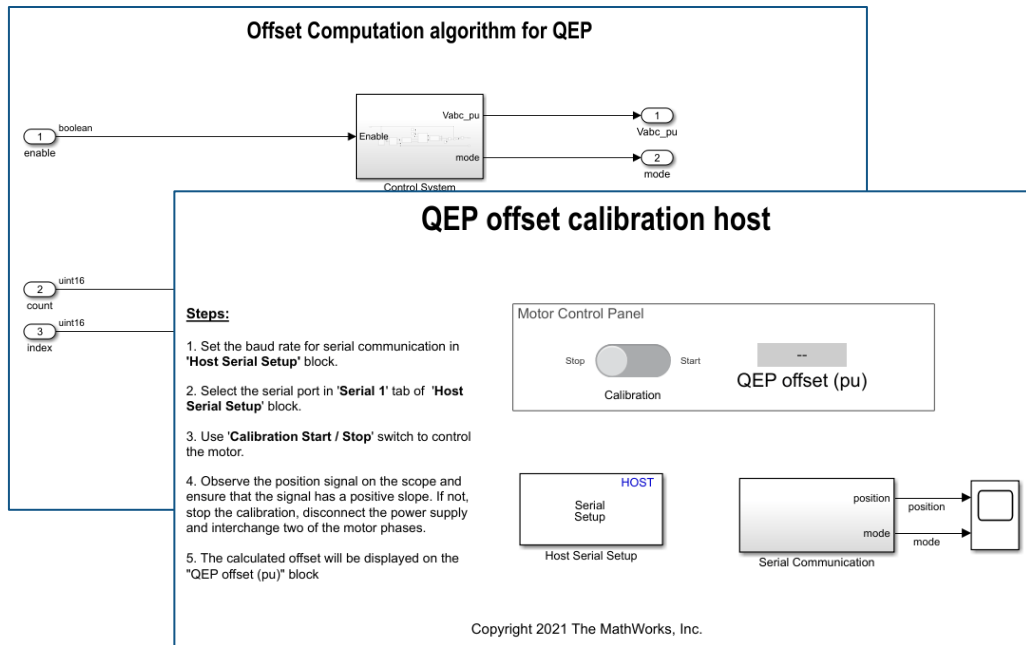
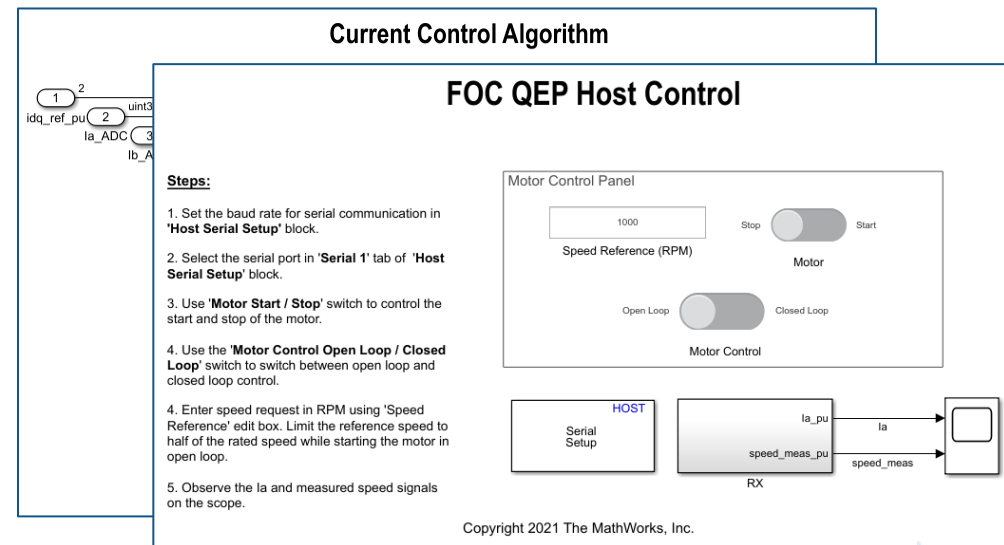
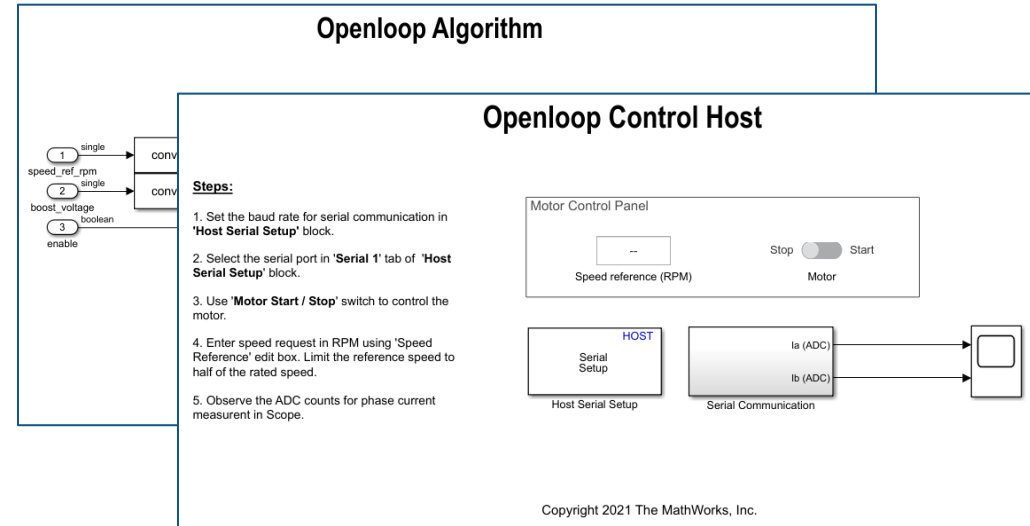
算法导出 workflow —— stm32 电机控制示例 (2)

1. [Open-Loop Control and ADC Offset Calibration](#)
2. [Quadrature Encoder Offset Calibration](#)
3. [Field-Oriented Control](#)

Controller: STMicroelectronics® STM32F302R8

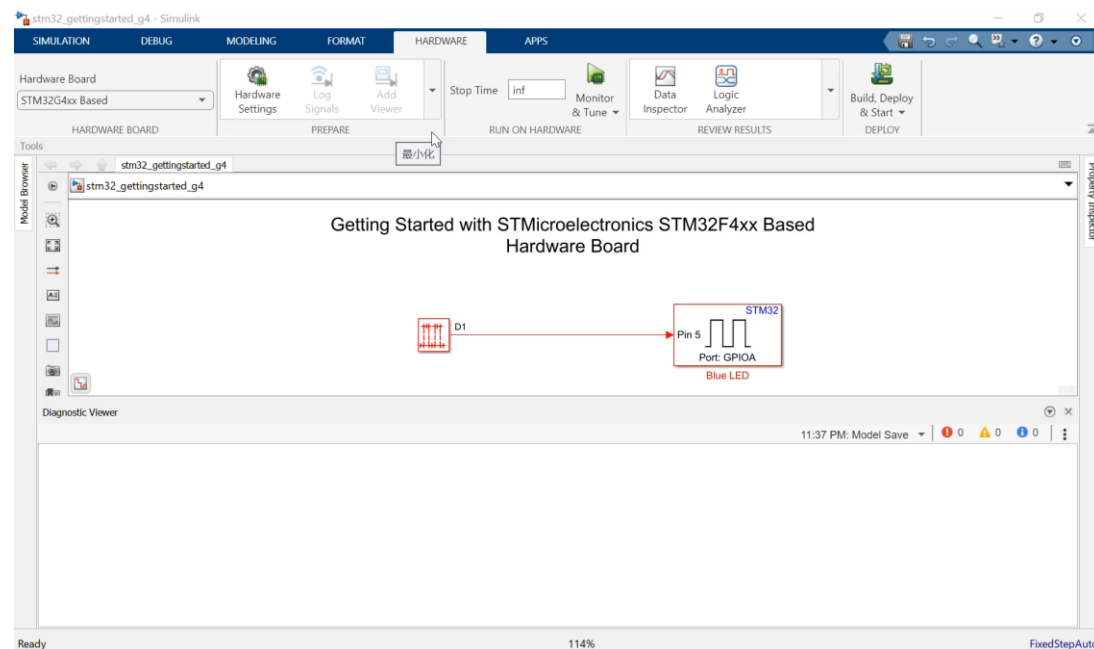
Inverter: STMicroelectronics® X-NUCLEO-IHM07M1

Motor: BLY171D (includes quadrature encoder sensor)

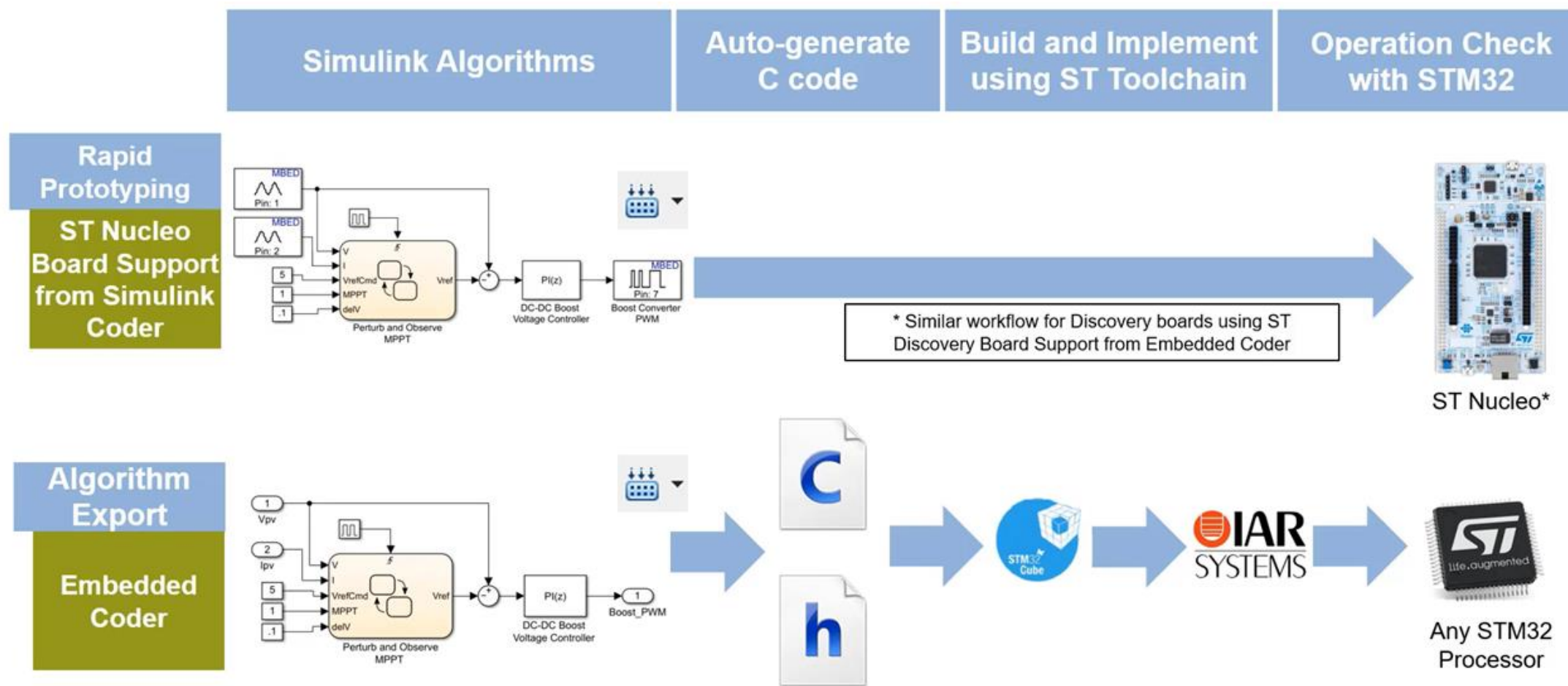


一键部署快速原型 —— 调节 STM32 开发板指示灯

- 安装 STM32 硬件支持包
- 硬件配置: STM32G474RE
- Simulink 外部模式 (External Mode) 参数调节
- 参考资料
 - [安装 Embedded Coder Support for STMicroelectronics STM32 Boards \(3:55\)](#)
 - [Getting Started with Embedded Coder Support Package for STMicroelectronics Discovery Boards](#)



算法导出与一键部署 workflows 比较 (1)



算法导出与一键部署 workflow 比较 (2)

	Rapid Prototyping	Algorithm Export
Typical User	Control/Systems Engineer	Systems/Software Engr
Purpose	Fast, one click deployment to test algorithms	Integration with larger existing code base in production
Output	Full Executable	Algorithm C code
Key attribute	Ease of use	Flexibility
Hardware Support Package shown	ST Nucleo Board Support for Simulink Coder	Embedded Coder (core functionality, no HSP)

Related features available (not shown in this video)

- Processor specific optimizations including CMSIS-DSP, CMSIS-RTX
- Processor-in-the-loop (PIL) testing (using hardware or QEMU)

Other Hardware Support Packages for ST Products

- ST Discovery Board Support from Embedded Coder
- ARM Cortex M Support from Embedded Coder

基于 STM32 的电机控制示例

■ 依赖硬件

- ✓ [NUCLEO-G474RE board](#)
- ✓ [X-NUCLEO-IHM07M1: Driver expansion board](#)
- ✓ [BLY172S-24V-4000 - Brushless DC Motor](#)

■ 文档示例

- [Open-Loop Control of 3-Phase AC Motors Using STM32 Processor-Based Boards](#)
- [Closed-Loop Sensorless Field-Oriented Control of PMSM Using STM32 Processor-Based Boards](#)



NUCLEO-G474RE



X-NUCLEO-IHM07M1



BLY172S-24V-4000 BLDC Motor

基于 STM32 processor 的应用开发流程

Configure MCU Peripherals with STM32CubeMX



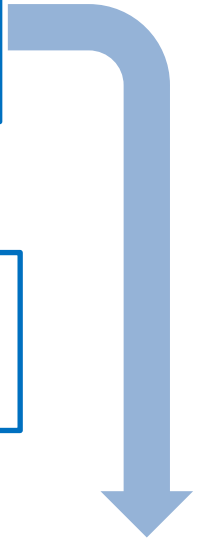
FOC Control Design with MCB Blocks
MCU peripheral access with EC Driver Blocks



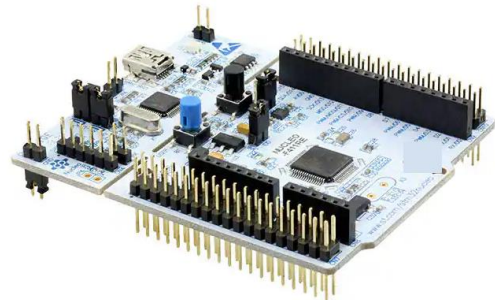
Generate Code, Create Executable From Simulink



Generates Code Using STM32CubeMX

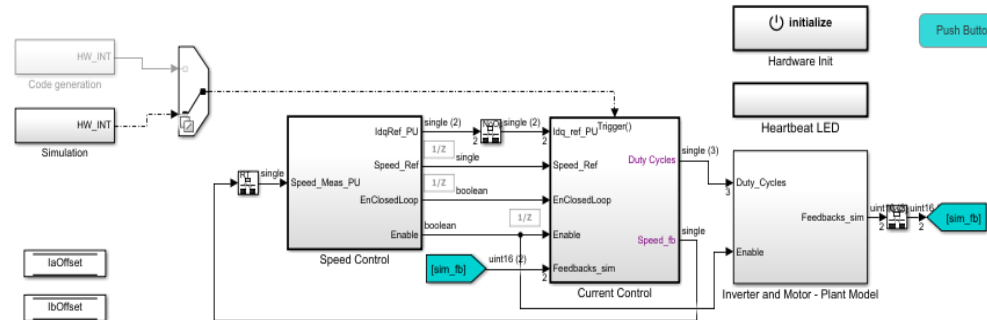


Download Application Using STM32CubeProgrammer



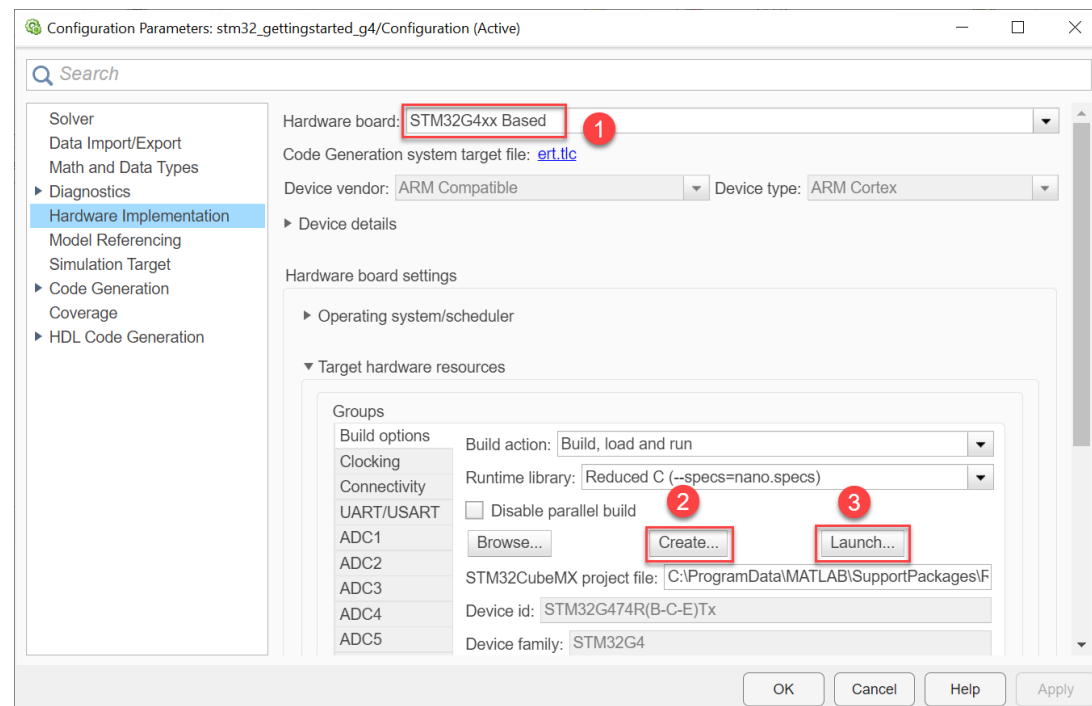
Permanent Magnet Synchronous Motor Field Oriented Control

Note: This example requires a NUCLEO-G474RE with a X-NUCLEO-IHM07M1 connected to a BLY172S-24V-4000 PMSM Motor



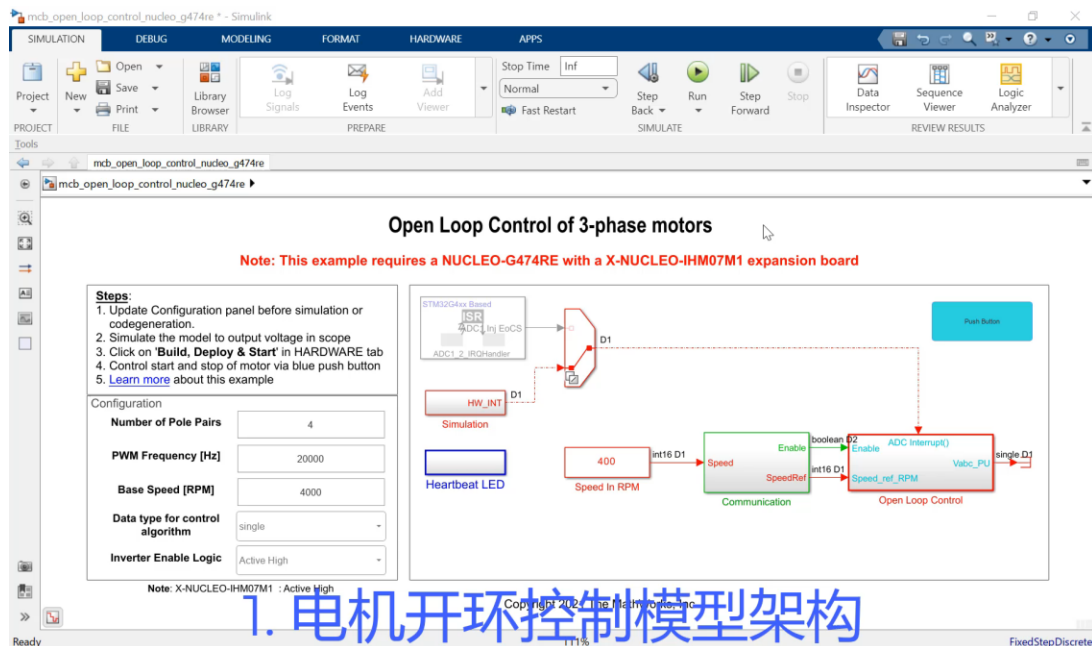
基于 STM32 processor 的应用开发流程 —— 集成 STM32CubeMX

1. GUI 界面配置系统和外设时钟
2. GUI 界面配置开发板上的其他外设
3. 基于配置生成外设的初始化代码
4. 管理并下载依赖的固件包
STM32Cube Firmware packages
5. 自动生成启动代码以及链接脚本用以构建可执行文件

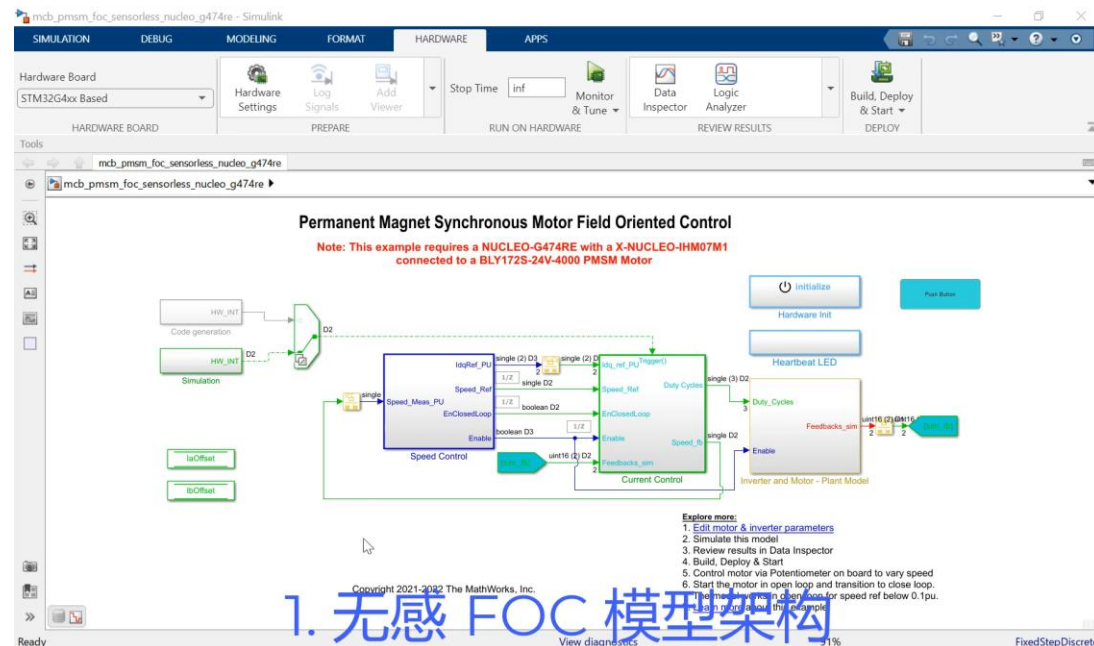


STM32 电机示例演示

Open-Loop Control of 3-Phase AC Motors Using STM32 Processor-Based Boards 电机开环控制



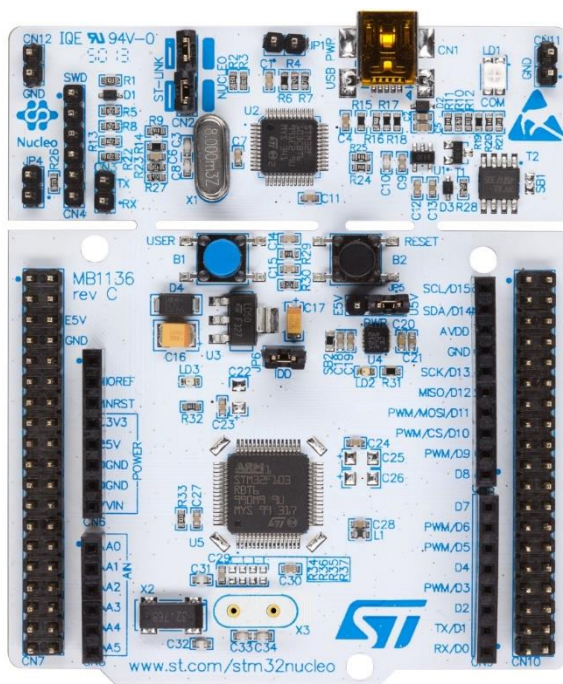
Closed-Loop Sensorless Field-Oriented Control of PMSM Using STM32 Processor-Based Boards 无感 FOC 闭环控制



电机培训 - 5天实战课程

课程交付内容

- Simulink电机本体建模
- Simulink电机控制器设计和优化-从算法到模型
- 电机控制算法代码生成和硬件部署-从模型到C/C++代码
- 控制算法的确认验证 (V&V)



Day 1

- Introduction
- Motors and Motor Control Algorithms
- DC Motor and Controls
- BLDC Plant Modeling
- PMSM Plant Modeling

Day 2

- Open-loop Control of PM
- Closed-loop Control of PM
- Sensors
- BLDC Controls
- PMSM Controls

Day 3

- Control Tuning
- Analyze and Evaluate Uncertainties
- Fault Diagnostics and Protection
- Sensorless Control
- Rapid Control Prototype
- Code Generation

Day 4

- Code Optimization
- Model-in-the-Loop Testing
- SIL and PIL Testing and Profiling
- Code Deployment

Day 5

- HIL Testing
- Standards Compliance
- Conclusions

Appendices

- Software Environment Setup
- Hardware Environment Setup
- Model Configuration Parameters
- Fixed-point Precision Control
- Speedgoat Target Machine Setup
- App Designer

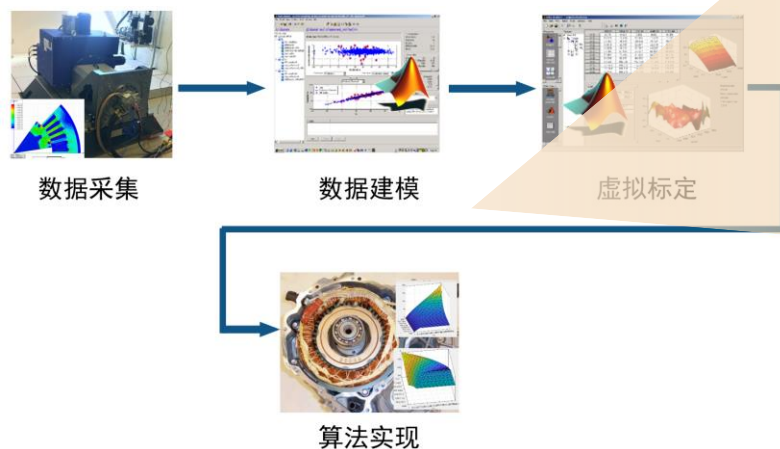
弱磁标定工程服务

工程支持

- 流程讨论
- 方法教学

标定工具

- 用户界面
- 按需定制



标定流程工具

Motor Calibration V1.0

Motor Parameters

Vsmax	<input type="text" value="0"/>	Ismax	<input type="text" value="0"/>
Torque Minimum	<input type="text" value="0"/>	Speed Maximum	<input type="text" value="0"/>
Torque Maximum	<input type="text" value="0"/>	Speed Minimum	<input type="text" value="0"/>

Data Process

Import Data

Test Data

X Axis: Option 1
Y Axis: Option 1
Z Axis: Option 1

Fit Models

Torque Tolerance:
Speed Tolerance:
RMSE:

Generate Calibration

Data Visualization Window

X-axis: Trq Y-axis: n Z-axis: Id

X-axis: Trq Y-axis: n Z-axis: Iq

数据可视化

MATLAB EXPO

Thank you



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