MATLAB EXPO

双电机控制算法开发与双核嵌入式处理器实现

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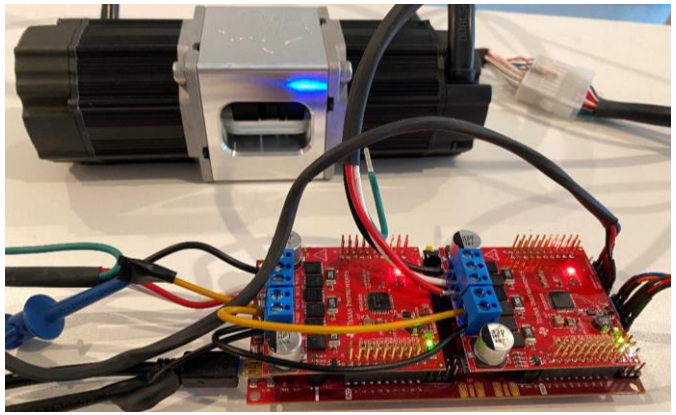
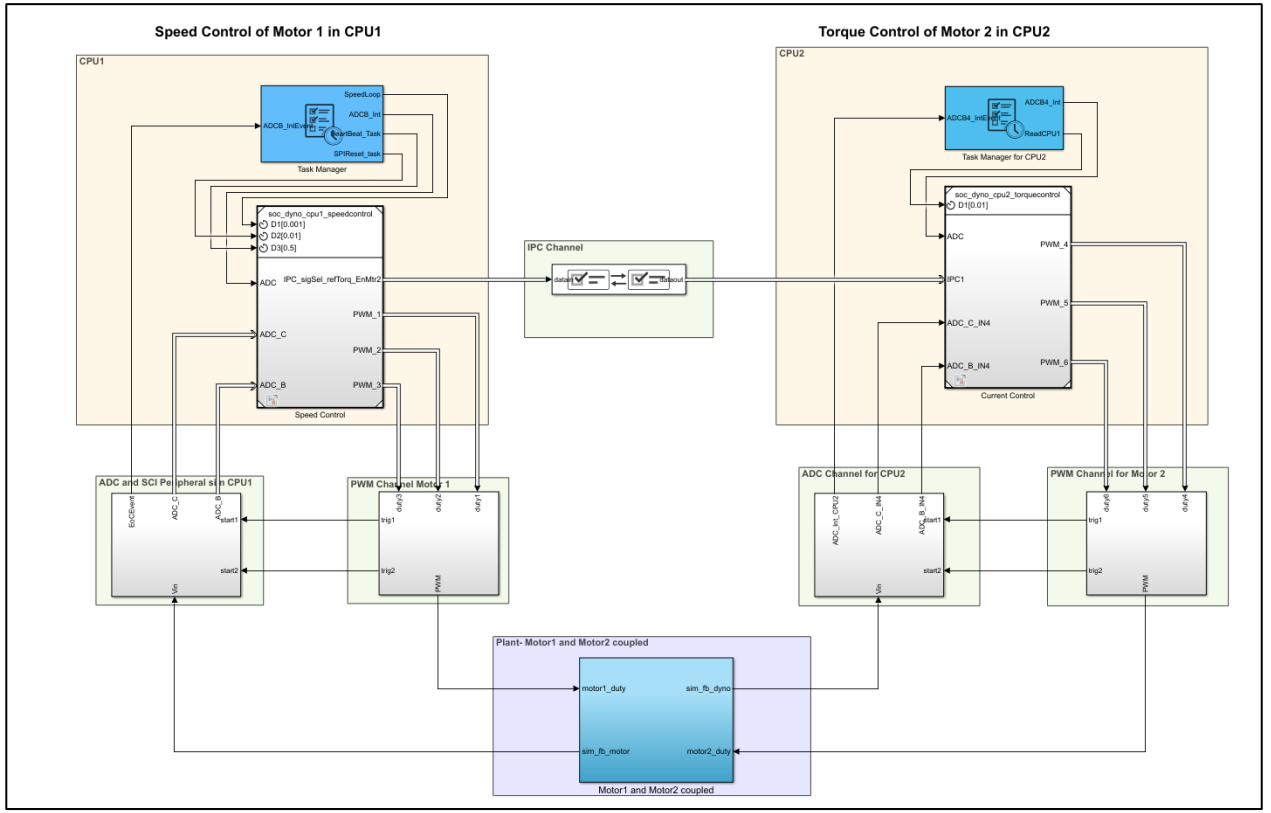
MathWorks

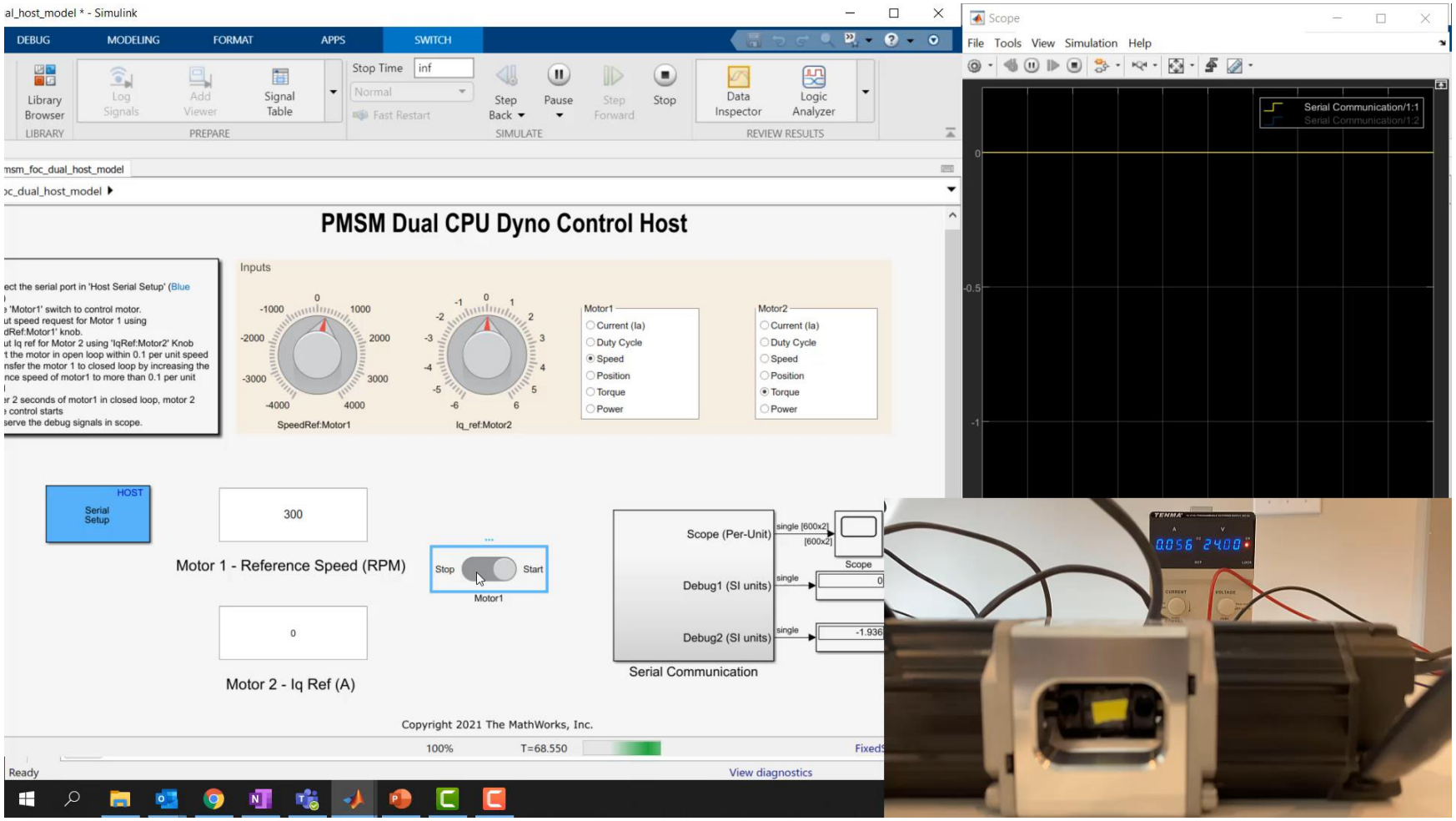
主要内容

- 在开发模式进行无传感器定向控制（FOC）仿真
- 面向多核微控制器的基于模型设计完成流程
- 硬件组件和设备驱动行为仿真
  - 片上性能评估

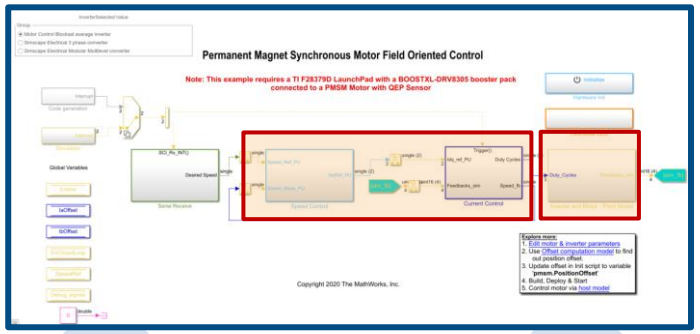




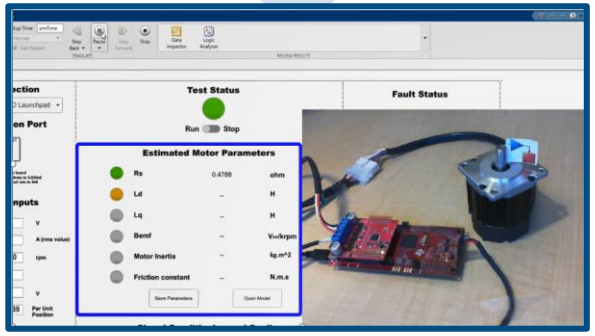
多处理器永磁同步电机（ PMSM ）开发模式测试



使用 Motor Control Blockset 进行 FOC 算法开发的工作流



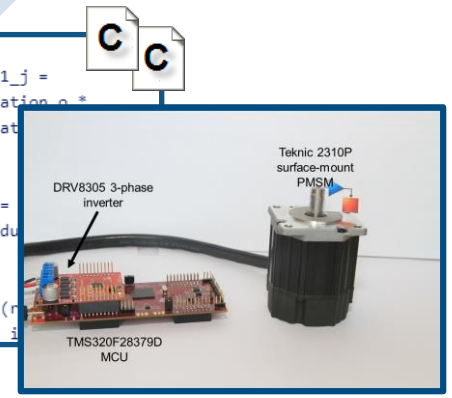
传感器标定 → 电机参数估计 → 电机和逆变器建模 → 控制算法设计 → 部署和验证



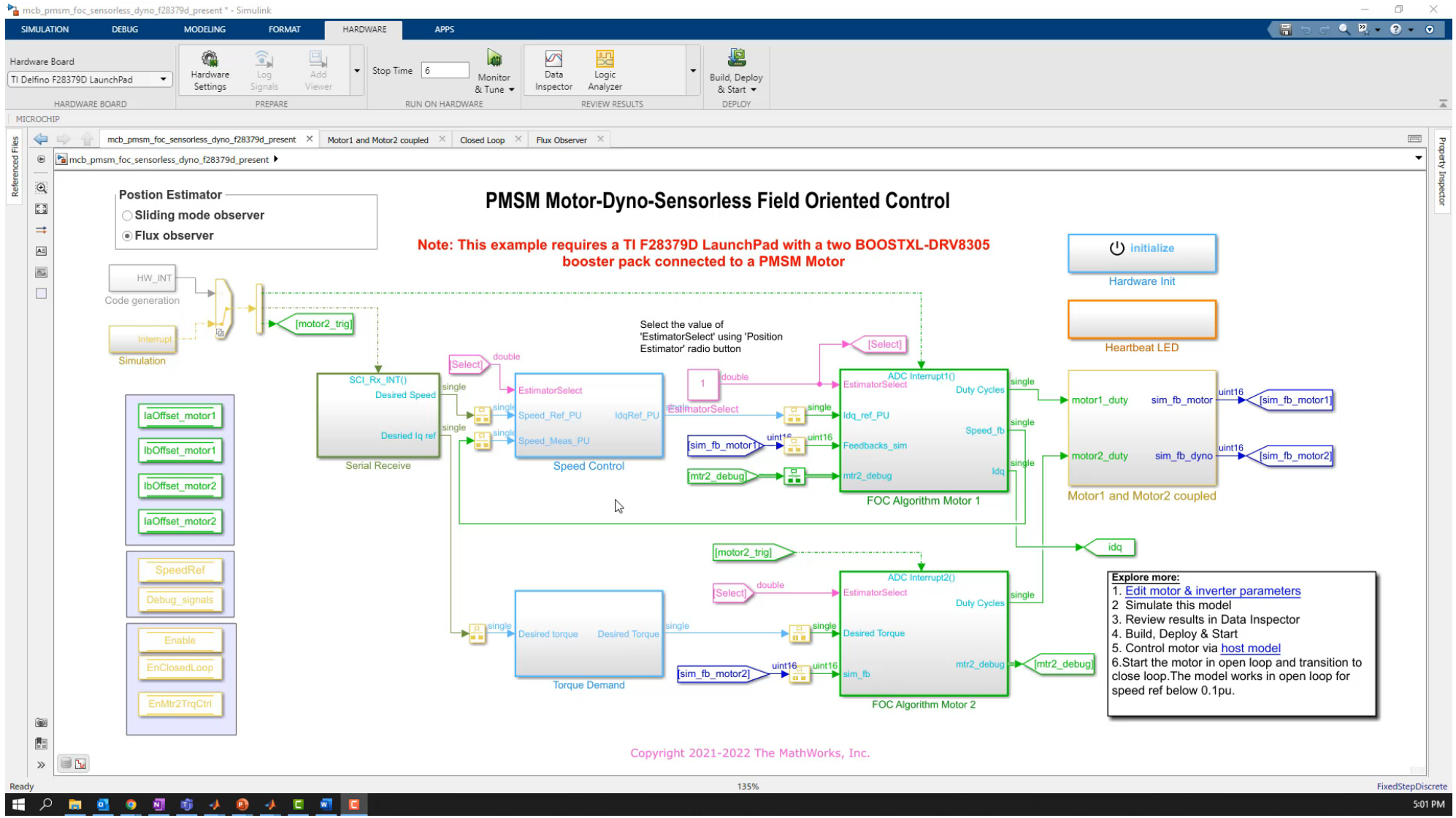

```
/* Product: '<S26>/Product1' */
mcb_pmsm_foc_hall_f28379d_B.Product1_j =
  mcb_pmsm_foc_hall_f28379d_B.Saturation_o *
  mcb_pmsm_foc_hall_f28379d_B.Saturat

/* Sum: '<S26>/Sum2' */
mcb_pmsm_foc_hall_f28379d_B.Sum2_i =
  + mcb_pmsm_foc_hall_f28379d_B.Produ

/* Sqrt: '<S26>/Sqrt' */
mcb_pmsm_foc_hall_f28379d_B.Sqrt = (r
  (mcb_pmsm_foc_hall_f28379d_B.Sum2_i
```



示例 – PMSMs Dyno Model in FOC Sensorless Control



在嵌入式系统部署的挑战

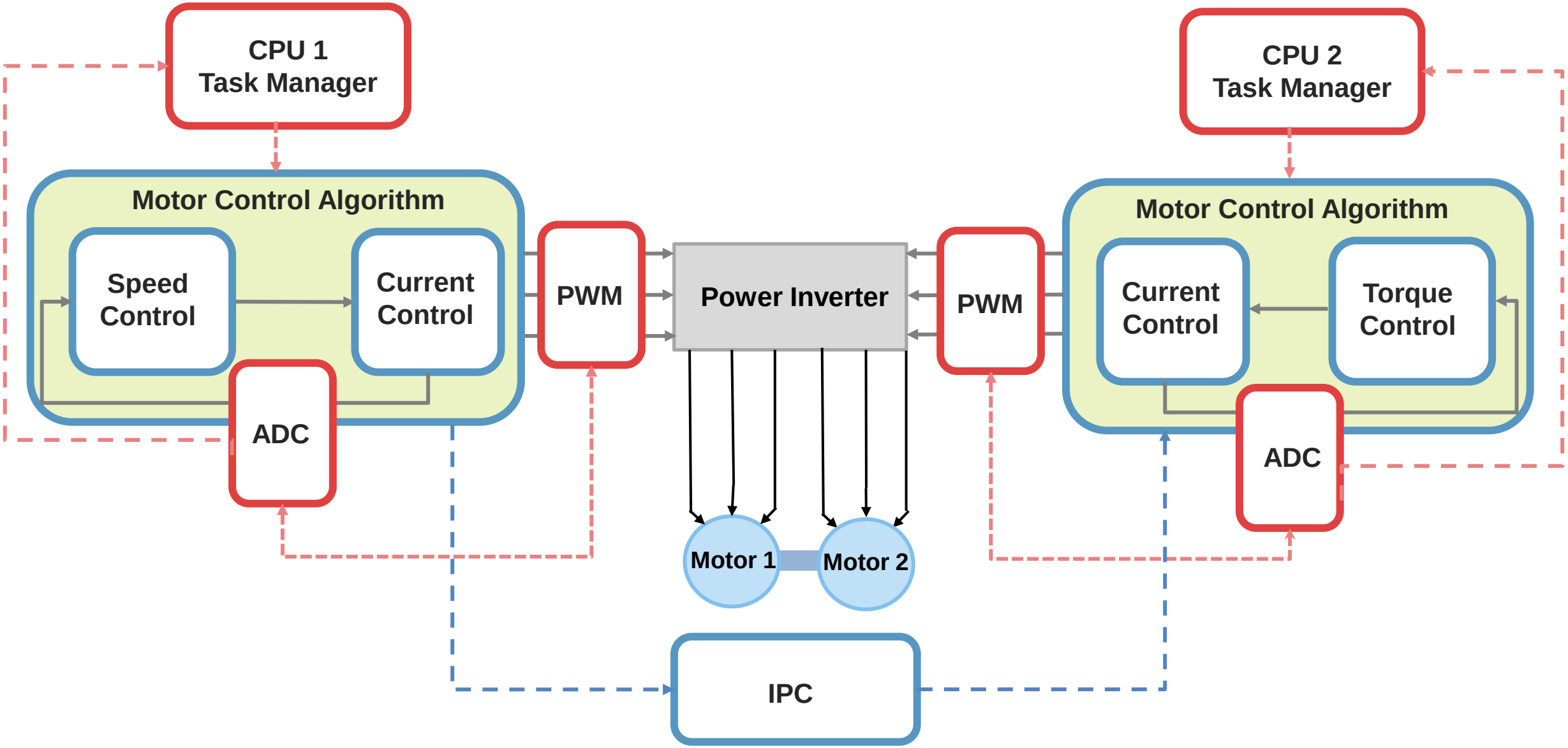
模型

- 系统需求
  - TI C2000多核处理器
- 控制器采样率 20kHz
  - FOC 控制
  - 无感控制
  - 双电机
- 无传感器延迟
- ADC-PWM 同步

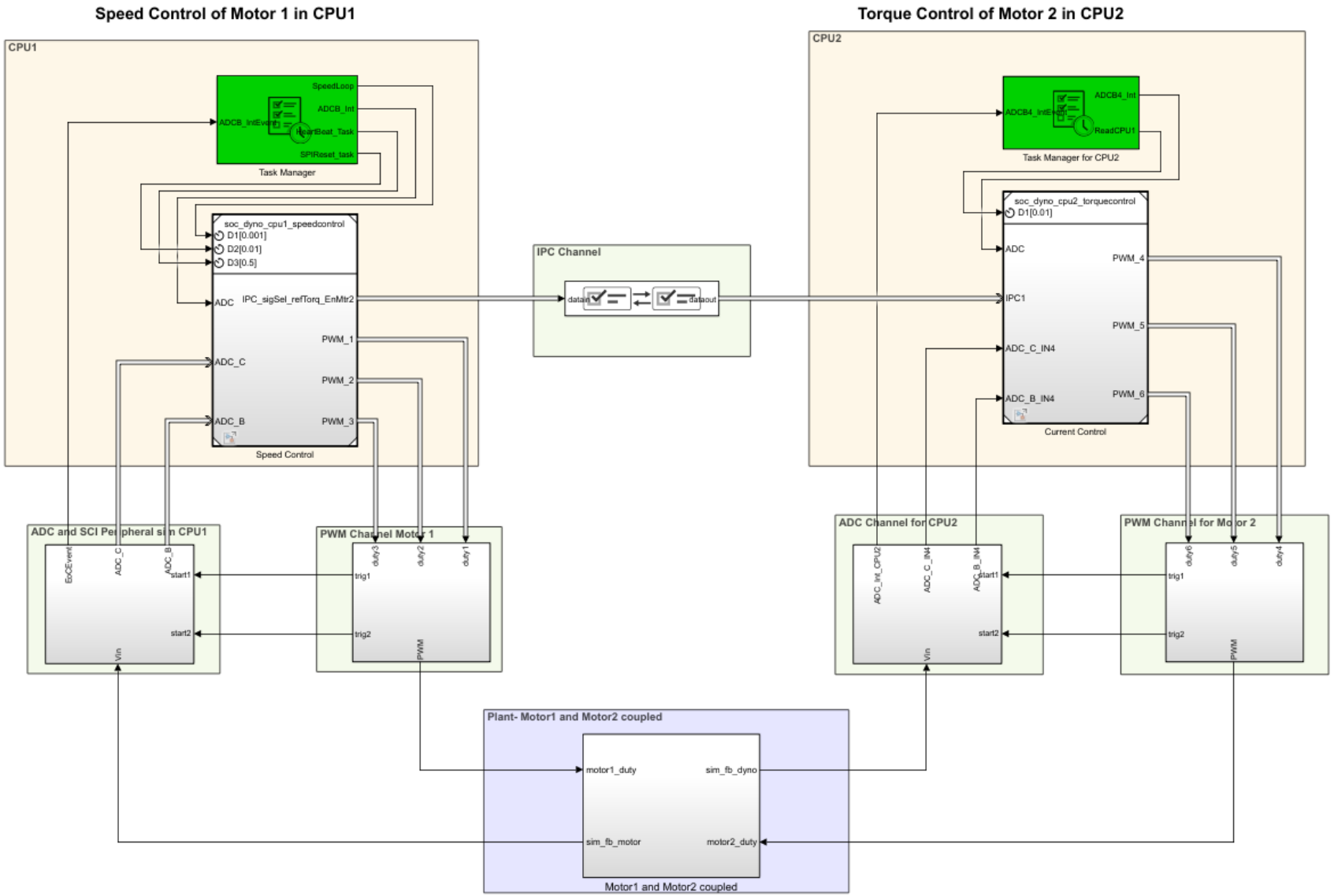
多核处理器的挑战

- 如何实现并将控制算法划分到两个独立的内核？
- 两个 CPU 之间如何通讯？
- 如何保证任务执行满足软件需求？

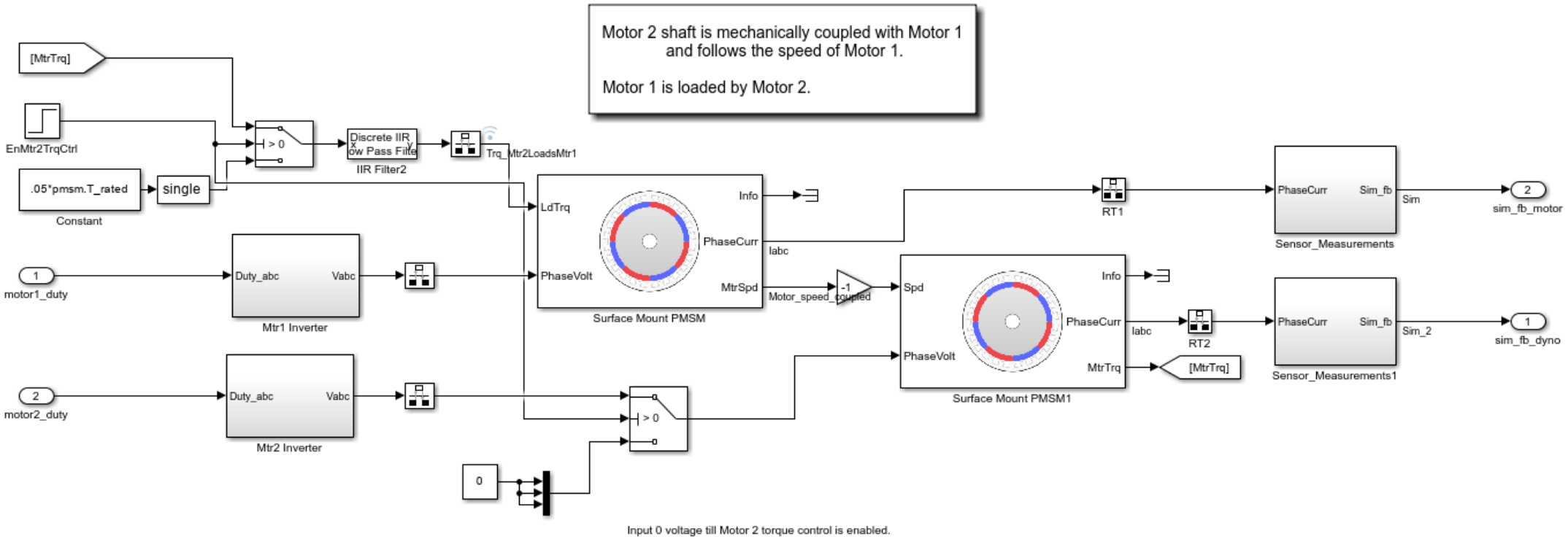
带外设和任务执行的电机控制系统仿真



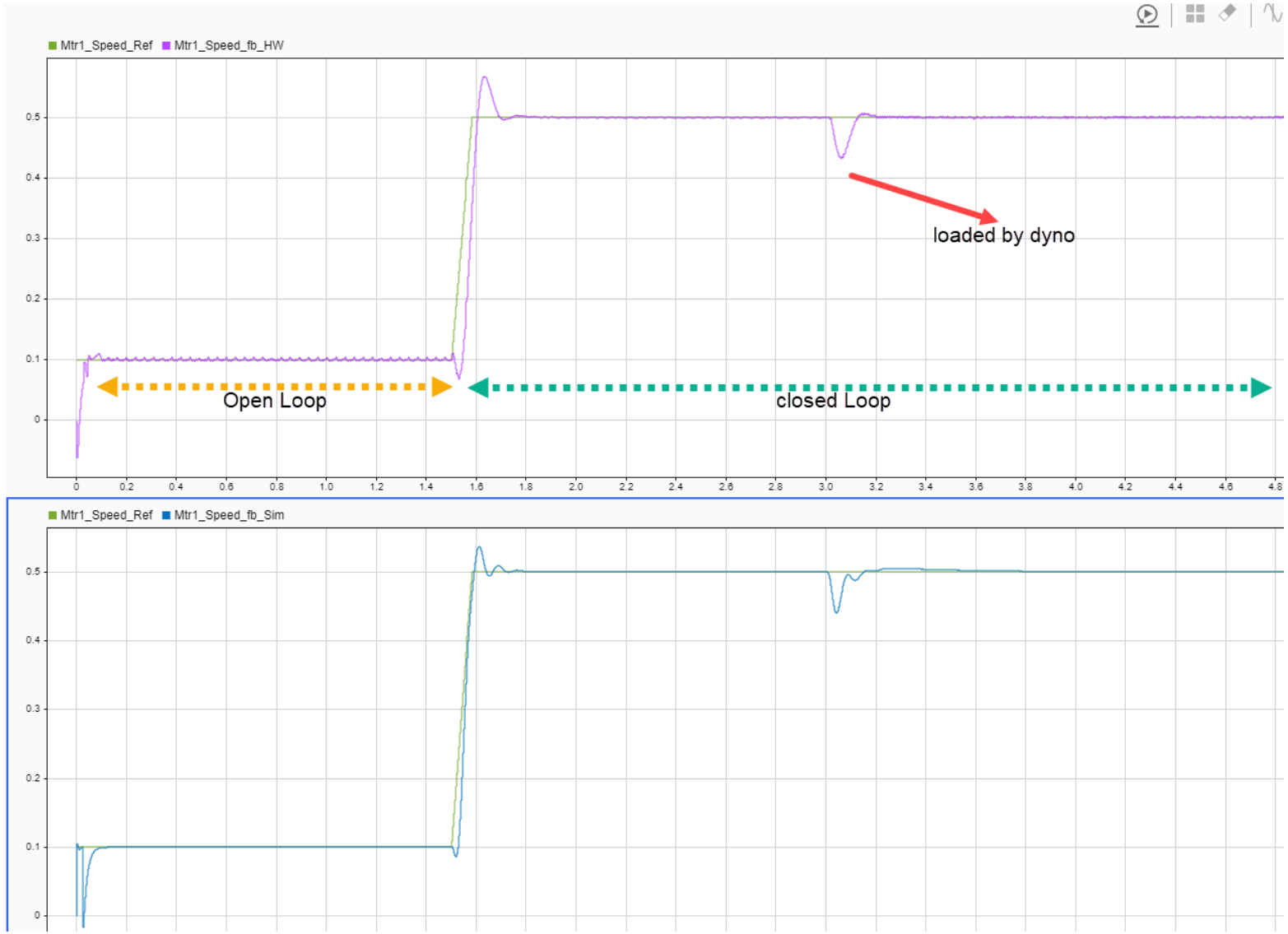
使用 SoC Blockset 进行多核应用建模



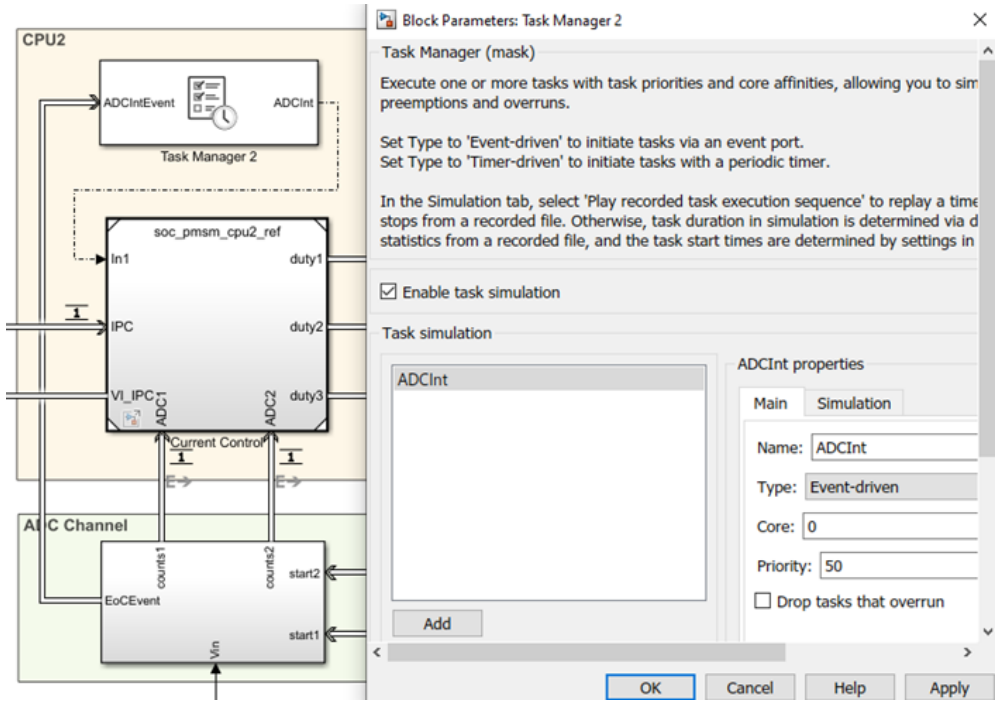
被控对象模型

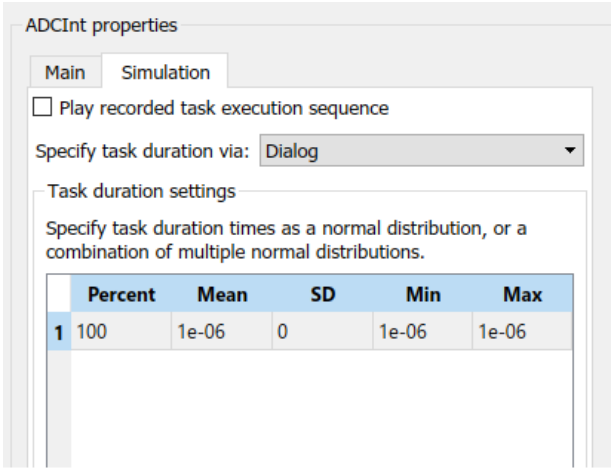

Motor 2 shaft is mechanically coupled with Motor 1 and follows the speed of Motor 1.
Motor 1 is loaded by Motor 2.
[MtrTrq]
EnMtr2TrqCtrl
> 0
Discrete IIR Low Pass Filter
IIR Filter2
Trq_Mtr2LoadsMtr1
.05*pmsm.T_rated
Constant
single
LdTrq
Info
PhaseCurr
PhaseVolt
MtrSpd
Surface Mount PMSM
Motor_speed_coupled
-1
RT1
PhaseCurr
Sim_fb
Sim
2
sim_fb_motor
Sensor_Measurements
1
motor1_duty
Duty_abc
Vabc
Mtr1 Inverter
Spd
Info
PhaseCurr
PhaseVolt
MtrTrq
Surface Mount PMSM1
labc
RT2
[MtrTrq]
Sim_2
1
sim_fb_dyno
Sensor_Measurements1
2
motor2_duty
Mtr2 Inverter
0
Input 0 voltage till Motor 2 torque control is enabled.

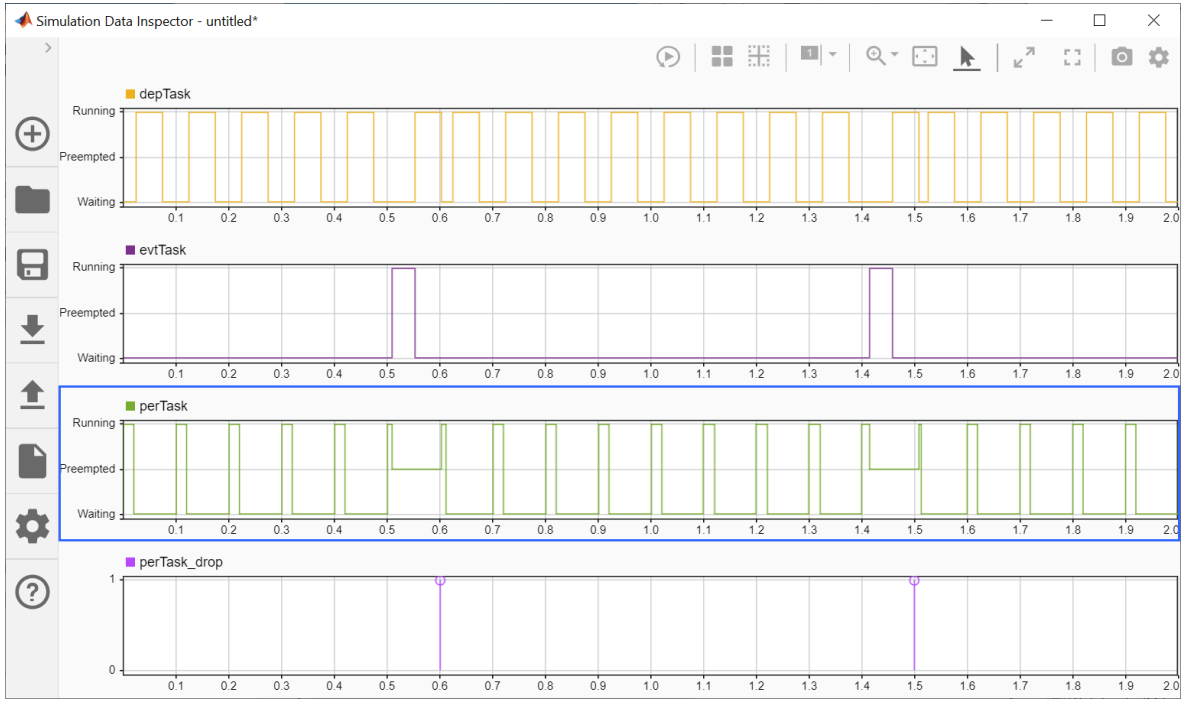
硬件测试结果 vs 仿真结果



任务管理模块



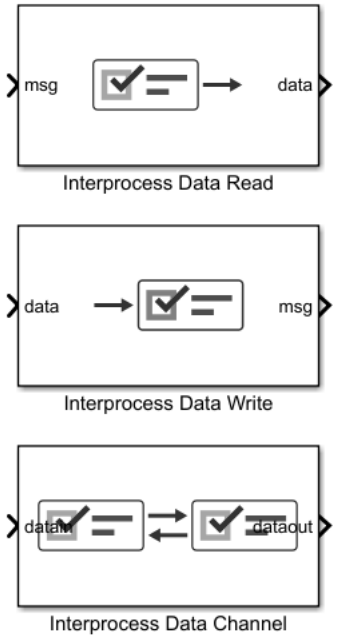


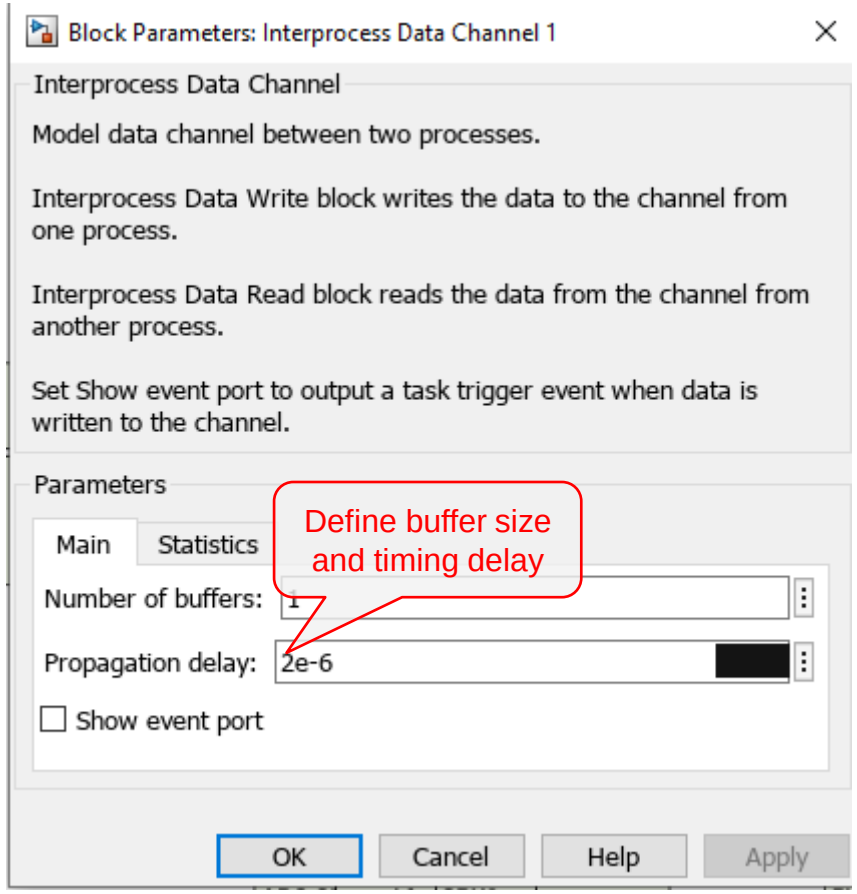


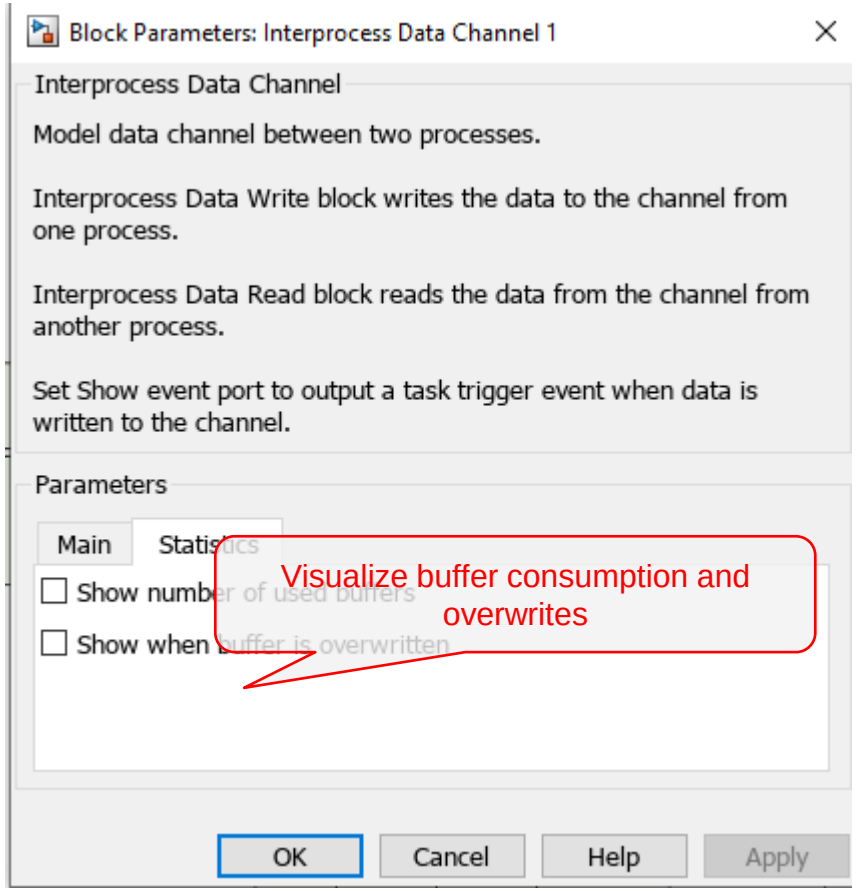
- 建模 / 仿真
  - 周期任务 / 异步任务
  - 任务优先级
  - CPU 潜伏期
  - 任务持续时间设置

使用 IPC 模块进行多核处理器内部通讯

- 通讯缓存和延迟的建模

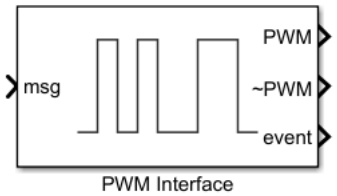


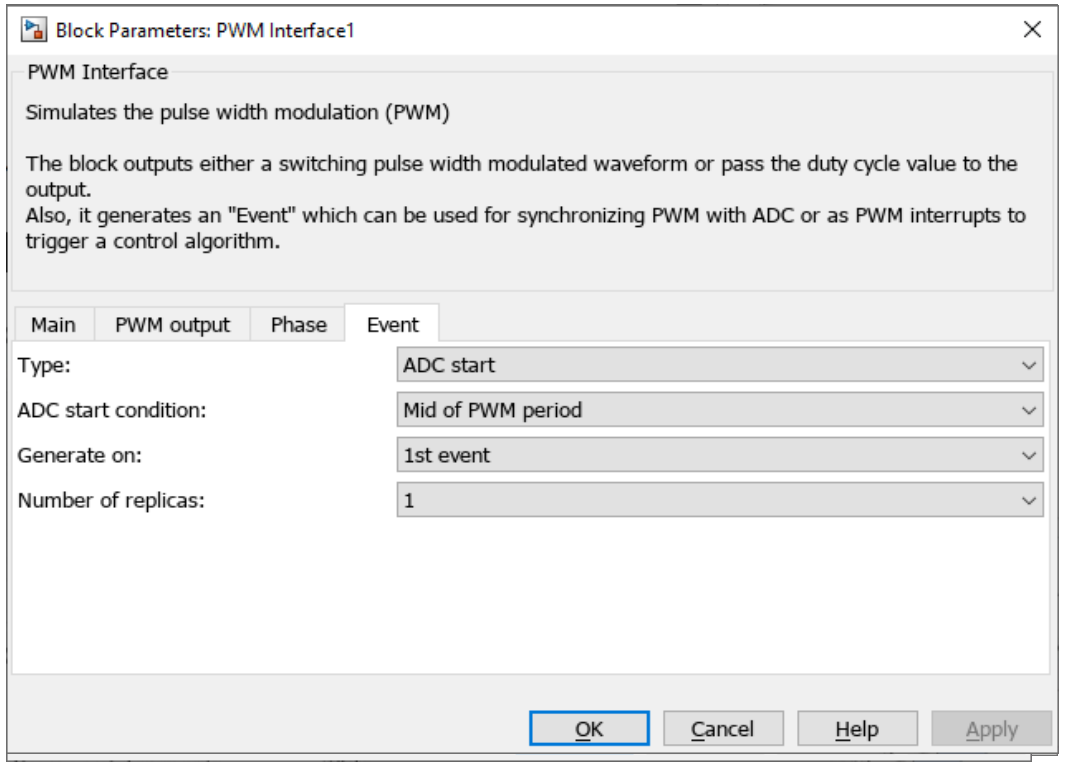


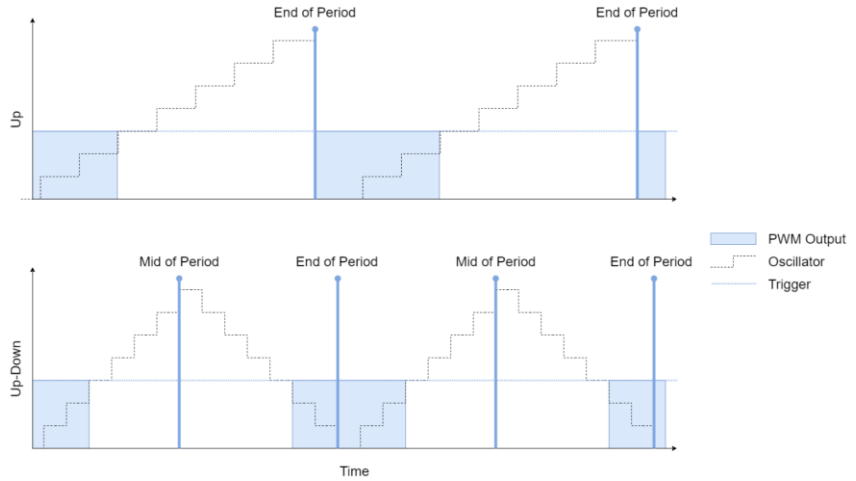


PWM 建模

- PWM 波形模拟
- 通过事件与 ADC 或者任务同步

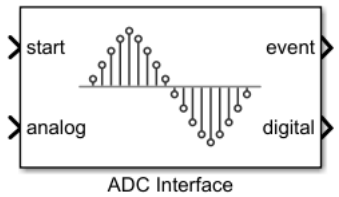


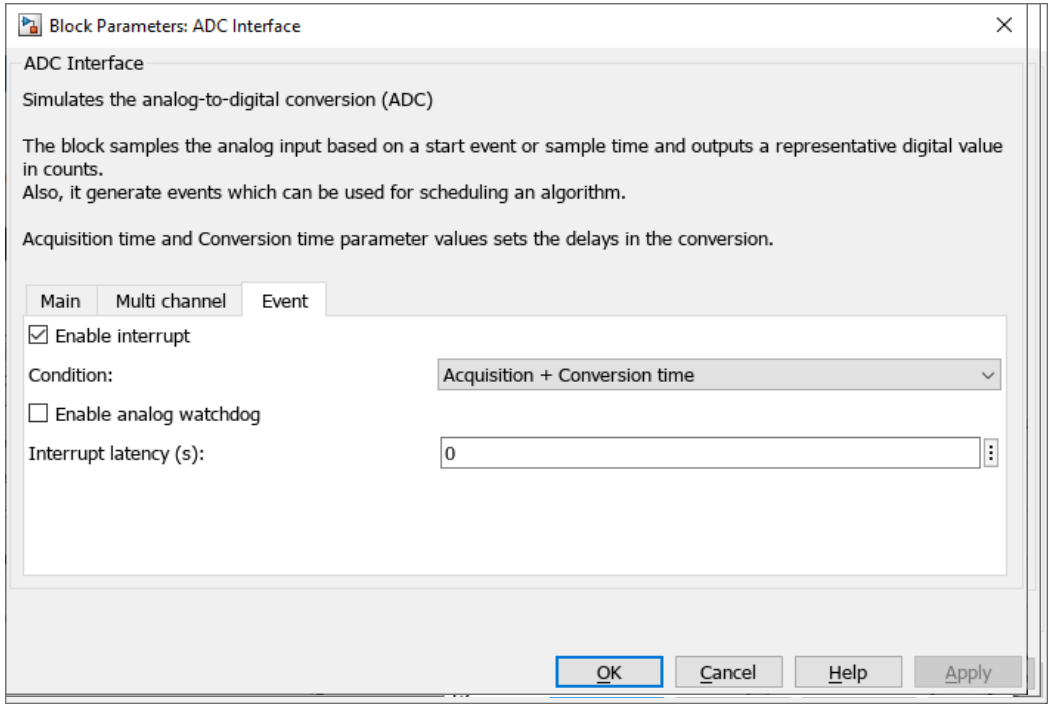


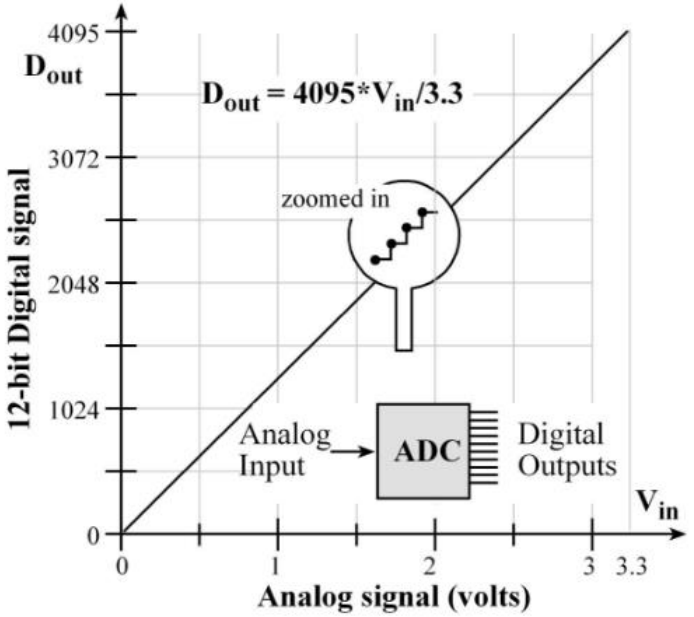


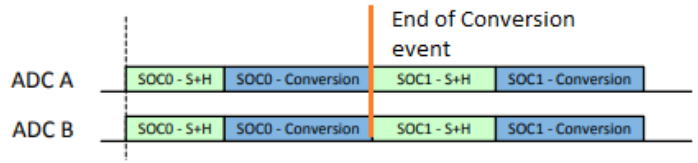
ADC 建模

- 将模拟信号转换为数字信号
- 分辨率 / 转换延迟和事件驱动建模

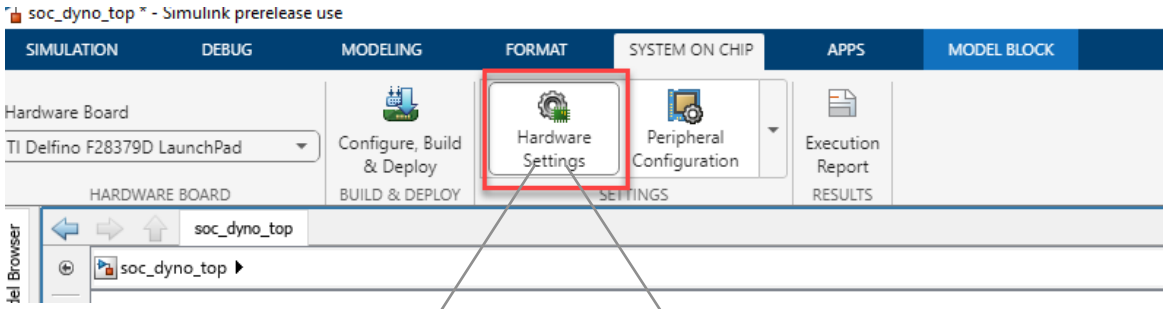


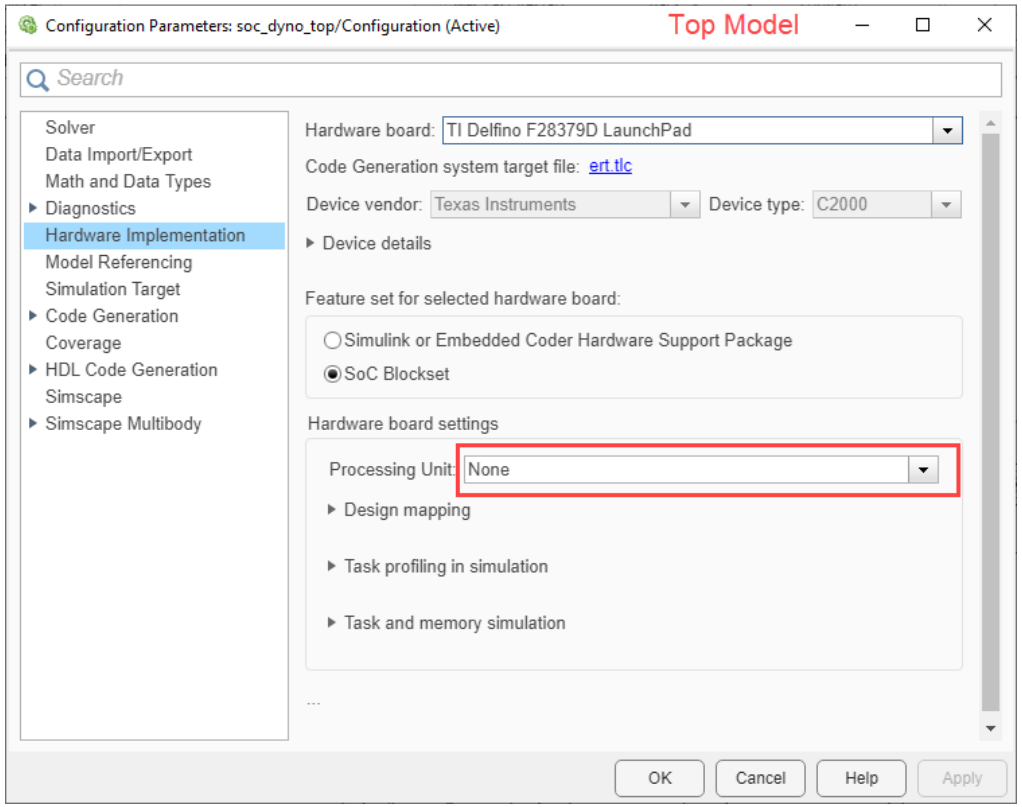


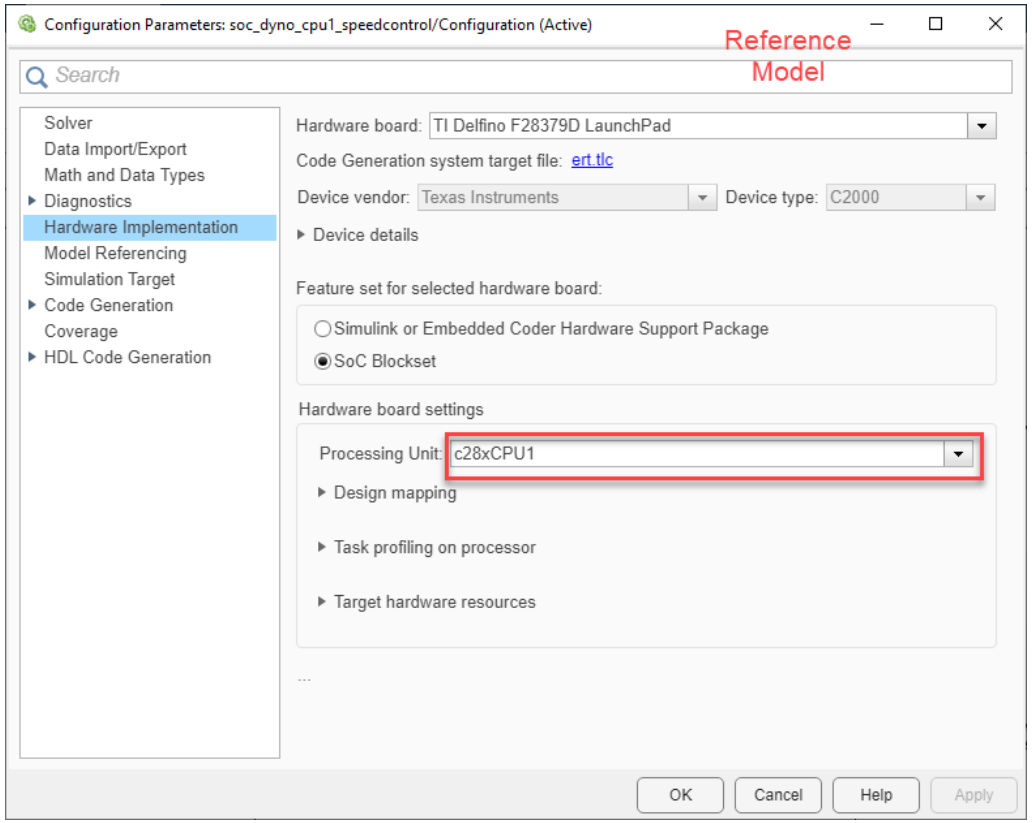




硬件配置

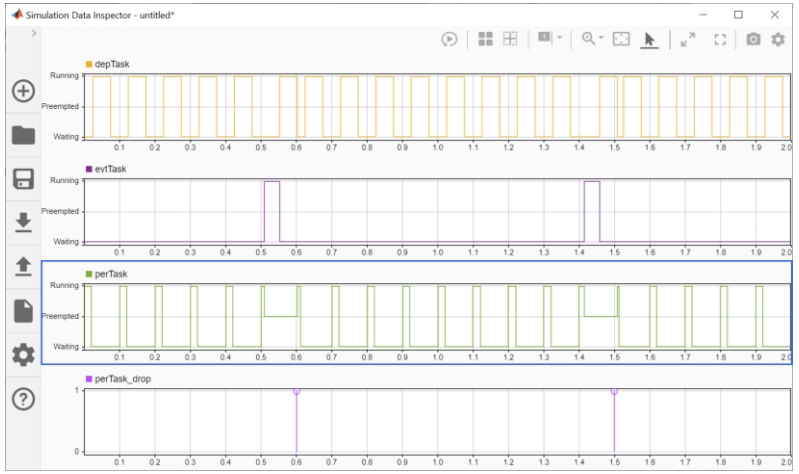

soc_dyno_top * - Simulink prerelease use
SIMULATION
DEBUG
MODELING
FORMAT
SYSTEM ON CHIP
APPS
MODEL BLOCK
Hardware Board
TI Delfino F28379D LaunchPad
HARDWARE BOARD
Configure, Build & Deploy
BUILD & DEPLOY
Hardware Settings
Peripheral Configuration
SETTINGS
Execution Report
RESULTS
soc_dyno_top
soc_dyno_top

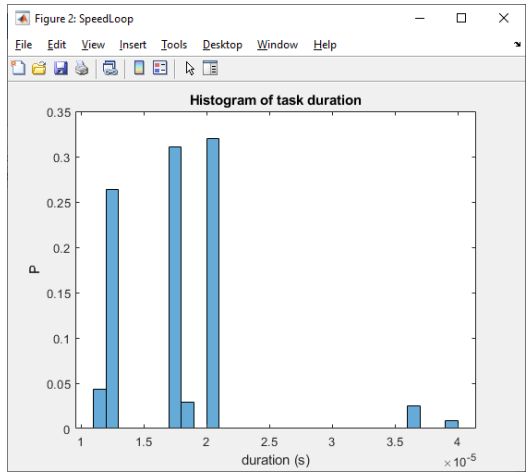

Configuration Parameters: soc_dyno_top/Configuration (Active)
Top Model
Search
Solver
Data Import/Export
Math and Data Types
Diagnostics
Hardware Implementation
Model Referencing
Simulation Target
Code Generation
Coverage
HDL Code Generation
Simscape
Simscape Multibody
Hardware board: TI Delfino F28379D LaunchPad
Code Generation system target file: ert.tlc
Device vendor: Texas Instruments
Device type: C2000
Device details
Feature set for selected hardware board:
Simulink or Embedded Coder Hardware Support Package
SoC Blockset
Hardware board settings
Processing Unit: None
Design mapping
Task profiling in simulation
Task and memory simulation
OK
Cancel
Help
Apply

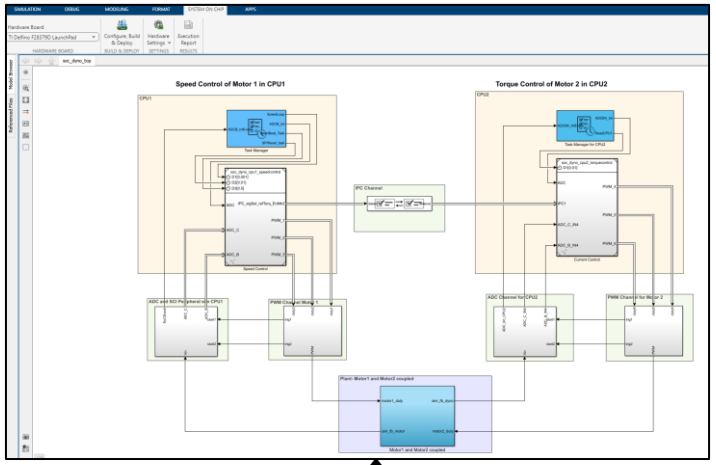

Configuration Parameters: soc_dyno_cpu1_speedcontrol/Configuration (Active)
Reference Model
Search
Solver
Data Import/Export
Math and Data Types
Diagnostics
Hardware Implementation
Model Referencing
Simulation Target
Code Generation
Coverage
HDL Code Generation
Hardware board: TI Delfino F28379D LaunchPad
Code Generation system target file: ert.tlc
Device vendor: Texas Instruments
Device type: C2000
Device details
Feature set for selected hardware board:
Simulink or Embedded Coder Hardware Support Package
SoC Blockset
Hardware board settings
Processing Unit: c28xCPU1
Design mapping
Task profiling on processor
Target hardware resources
OK
Cancel
Help
Apply

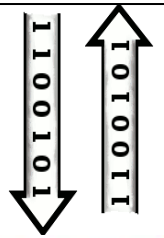
SoC Blockset 重要功能：片上性能评估

- 在硬件上的实时性能评估，包括：
  - 任务执行时间
  - CPU 使用率
  - 通讯缓存和延迟
  - 实时数据查看
  - 分析报告









内容总结

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- 面向多核微控制器的基于模型设计完成流程
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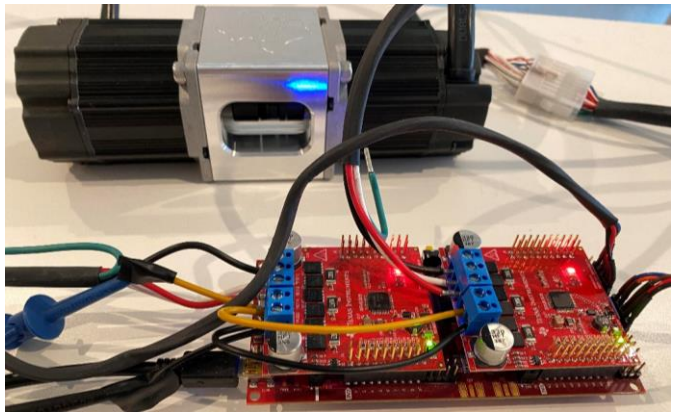
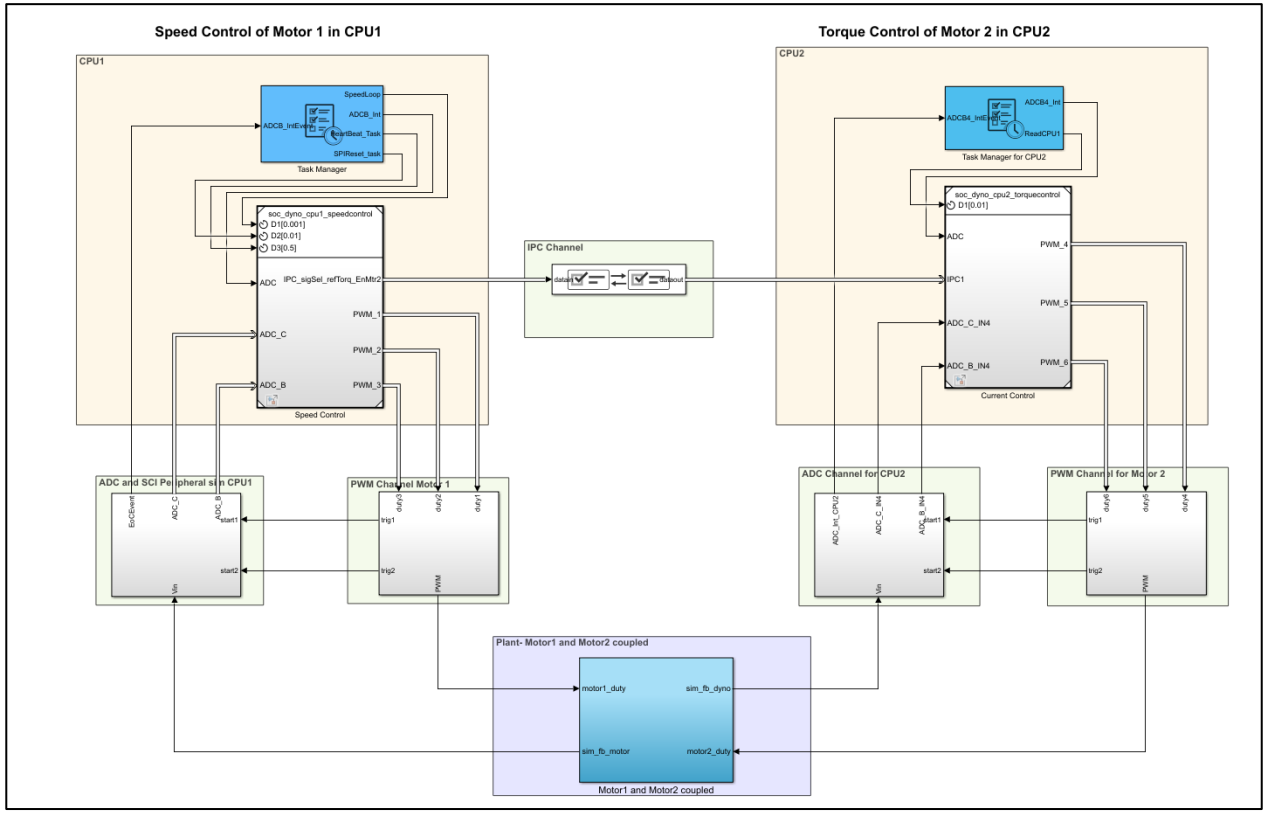
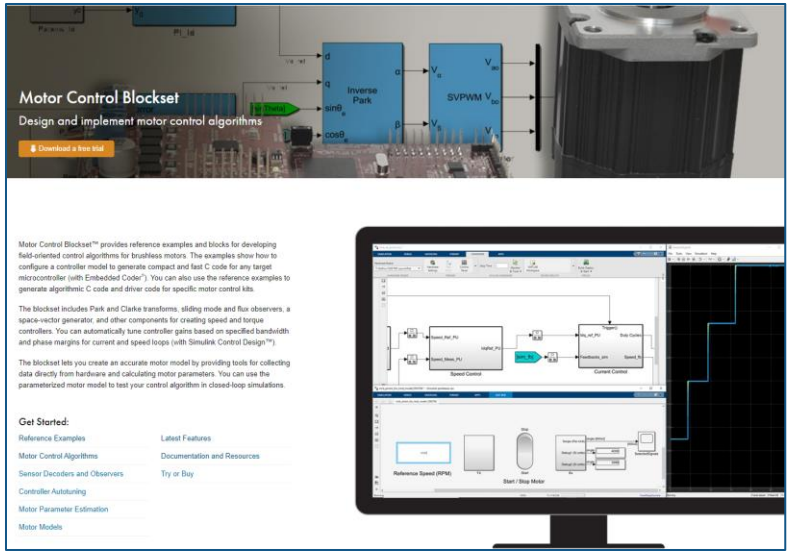




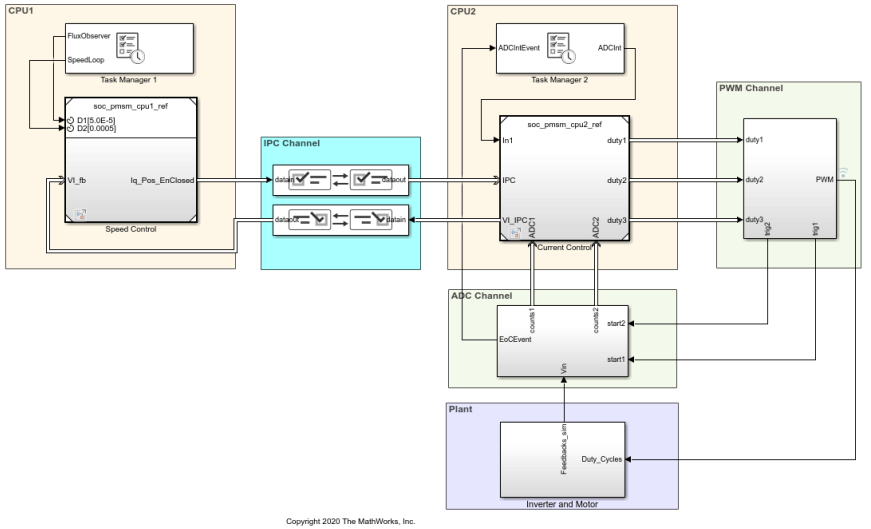
更多资料

- 研讨会
  - Field Oriented Control Made Easy
  - Motor Control with TI Multicore MCUs Using Simulink
  - Implementing Motor and Power Electronics Control on an FPGA-Based SoC

- 示例
  - Partition Motor Control for Multiprocessor MCUs
  - Control PMSM Loaded with Dual Motor (Dyno)
  - Integrate MCU Scheduling and Peripherals in Motor Control Application



Field-Oriented Control on Dual CPU Processor



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Thank you