MathWorks

MATLAB EXPO 2018

MATLAB/Simulink
在电机控制器开发中的应用

戴民

安捷励电控
AGILITY CONTROLS

安捷励电控

MATLAB/Simulink
在电机控制器开发中的应用

演讲人介绍

博士　　PhD

总经理　CEO

戴民

安捷励电控创始人

前美国通用汽车高级工程师(Vehicle Electrification)

沃蓝达(Volt) 、赛欧(Spark EV/Springo)电驱动团队核心成员(2007-2013)

俄亥俄州立大学博士

清华大学学士、硕士

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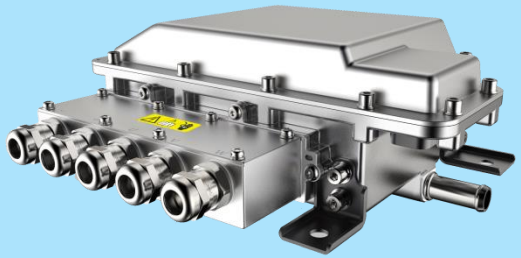
安捷励电控介绍

天津研发中心

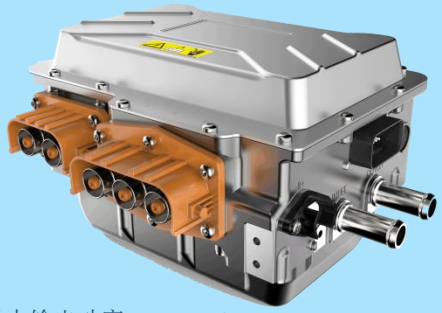
南京生产基地

安捷励电控产品介绍



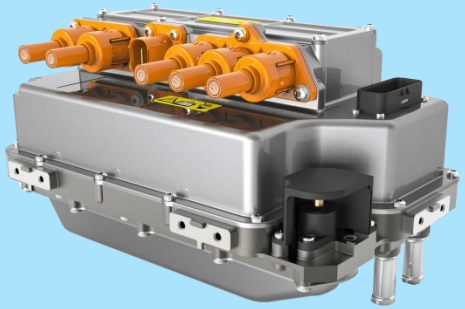
最大输出功率：45 ~ 60 kW@370VDC

功率密度: 10.7 kW/ kg ， 15.7 kW/ L



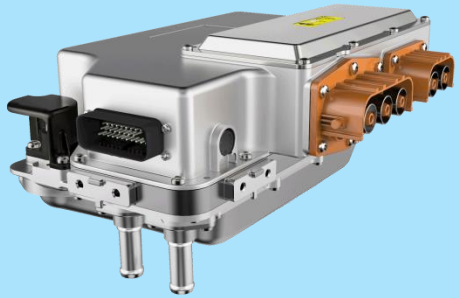
最大输出功率：60～80kW @370VDC，60kW@550VDC

功率密度:14.3kW/kg，20kW/L



最大输出功率：135kW

功率密度:12.8kW/kg，20.1kW/L



最大输出功率：80～135kW @370VDC，90 ～ 140kW@450VDC

功率密度:13.7kW/kg，22.9kW/L

最大输出功率：135kW

功率密度:15.3kW/kg，20.1kW/L

最大输出功率：135kW

功率密度:15.1 kW/ kg, 20.1 kW/ L

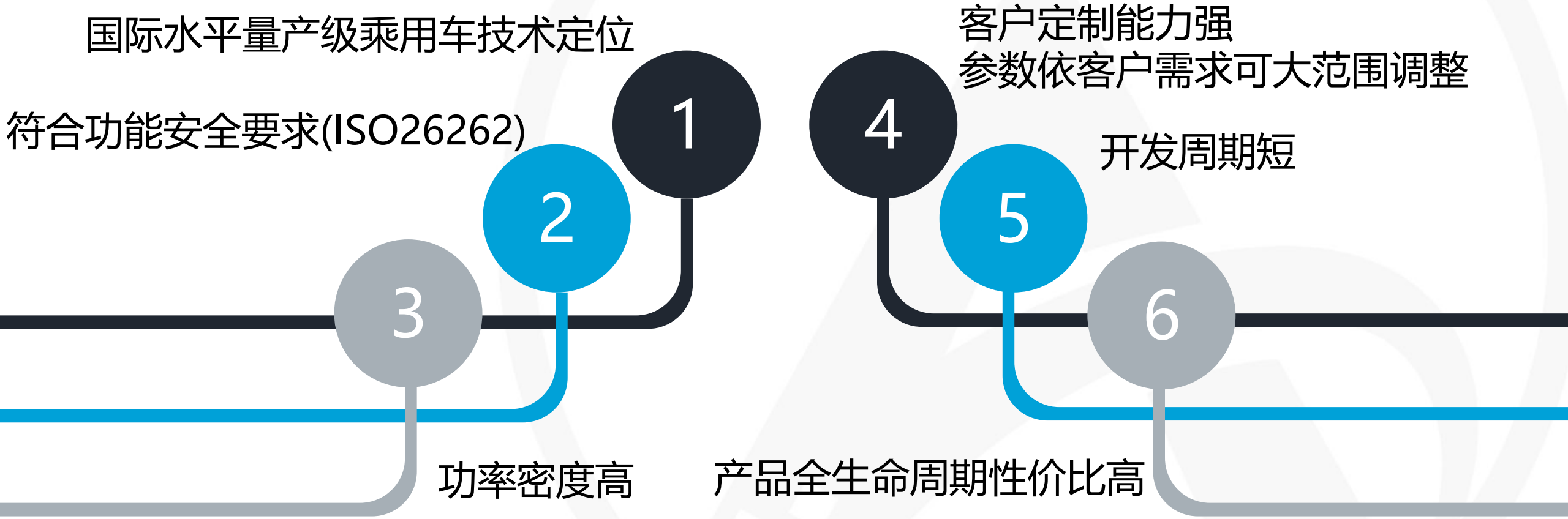
最大输出功率：135 ~ 180kW @370VDC，

功率密度:18kW/kg，21.7kW/L

最大输出功率：280kW

功率密度: 18.7kW/kg，21.1kW/L

技术能力综述


国际水平量产级乘用车技术定位
1
符合功能安全要求(ISO26262)
2
3
功率密度高
客户定制能力强
参数依客户需求可大范围调整
4
开发周期短
5
6
产品全生命周期性价比高

生产能力综述

采用制造信息化管理技术-MES系统
保证了产品制造的高效、准确及可追溯性

高度定制化生产设备

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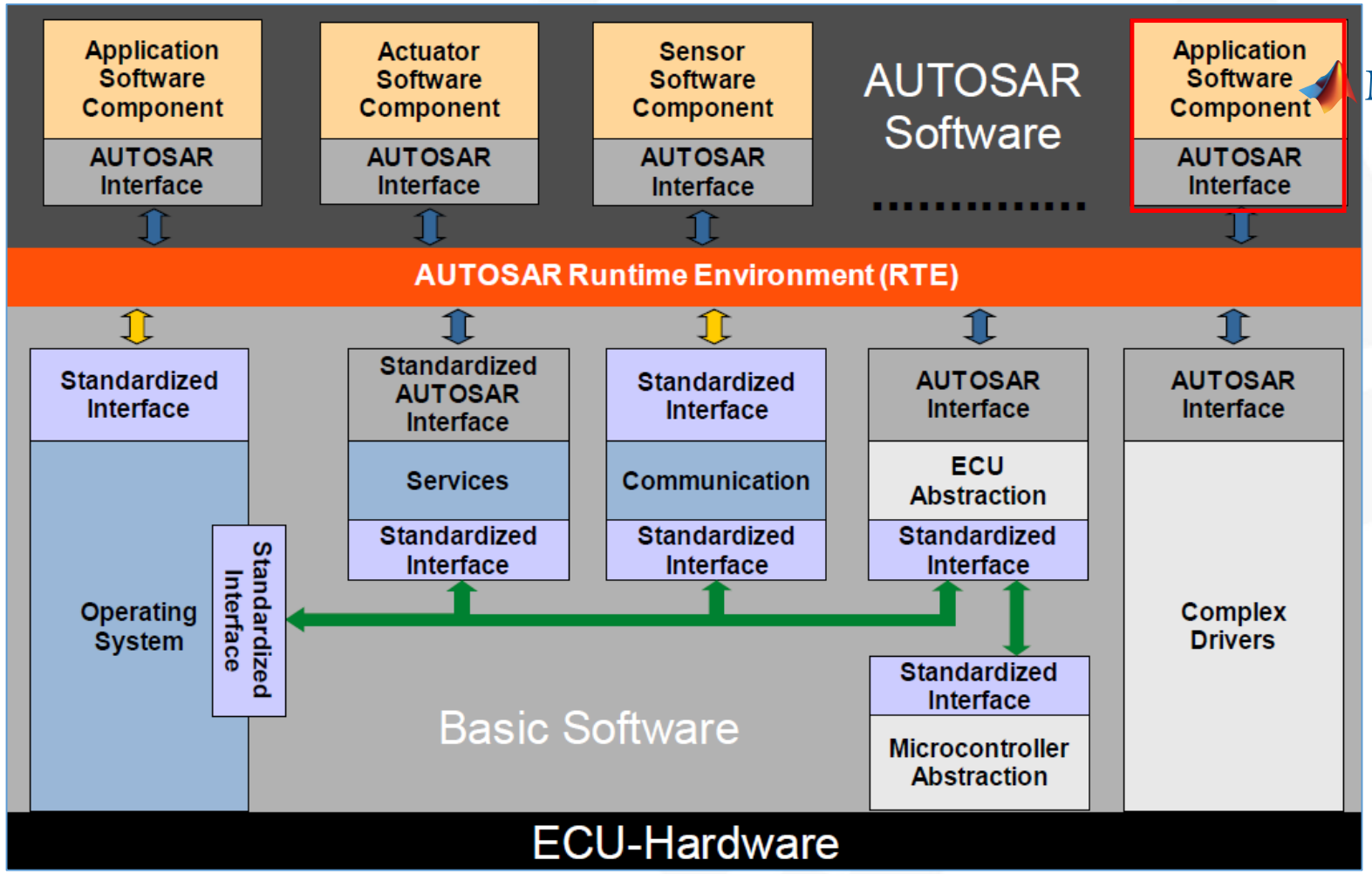
符合AUTOSAR标准的MBD开发模式

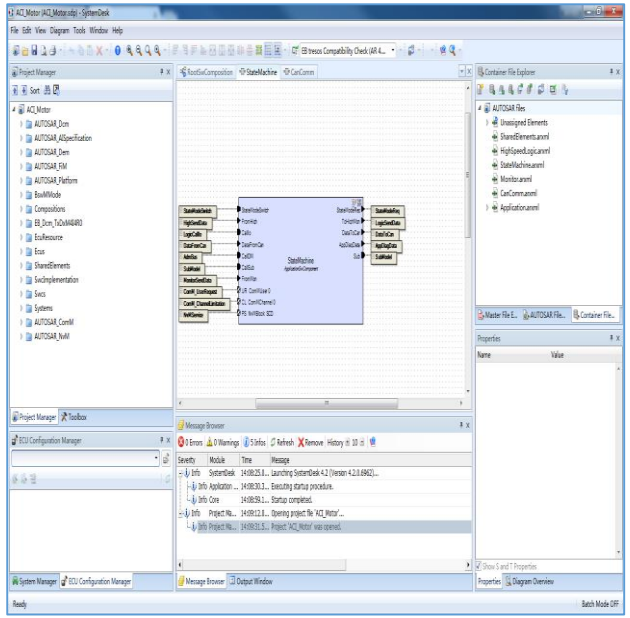
MATLAB提供了AUTOSAR标准的支持



MathWorks®

- 分层结构
- 模块化开发
- 极大的缩短了开发周期

模型生成采用自上而下的方法



AUTOSAR Authoring Tool (AAT)

导出SWC
的描述文件

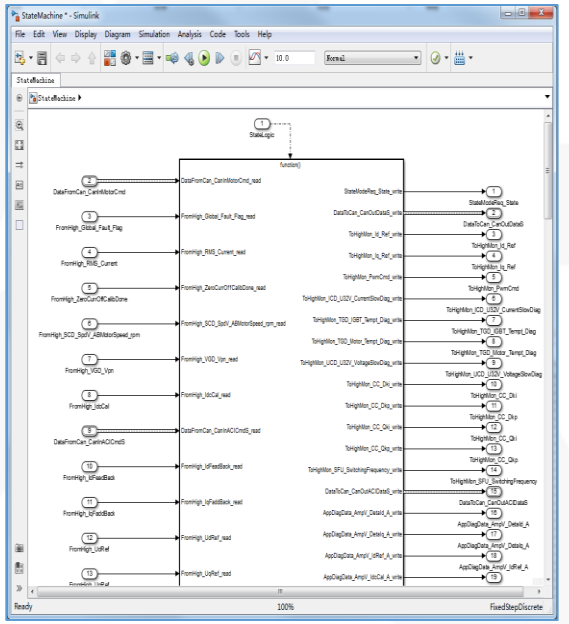
Export

定义了模块的输入输出及数据定义等内容

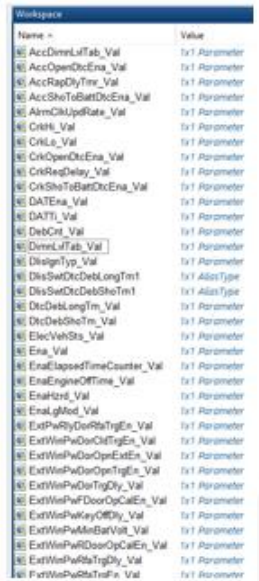
.arxml

Import

通过MATLAB命令
导入，创建模型
及数据定义



Simulink Model



数据定义

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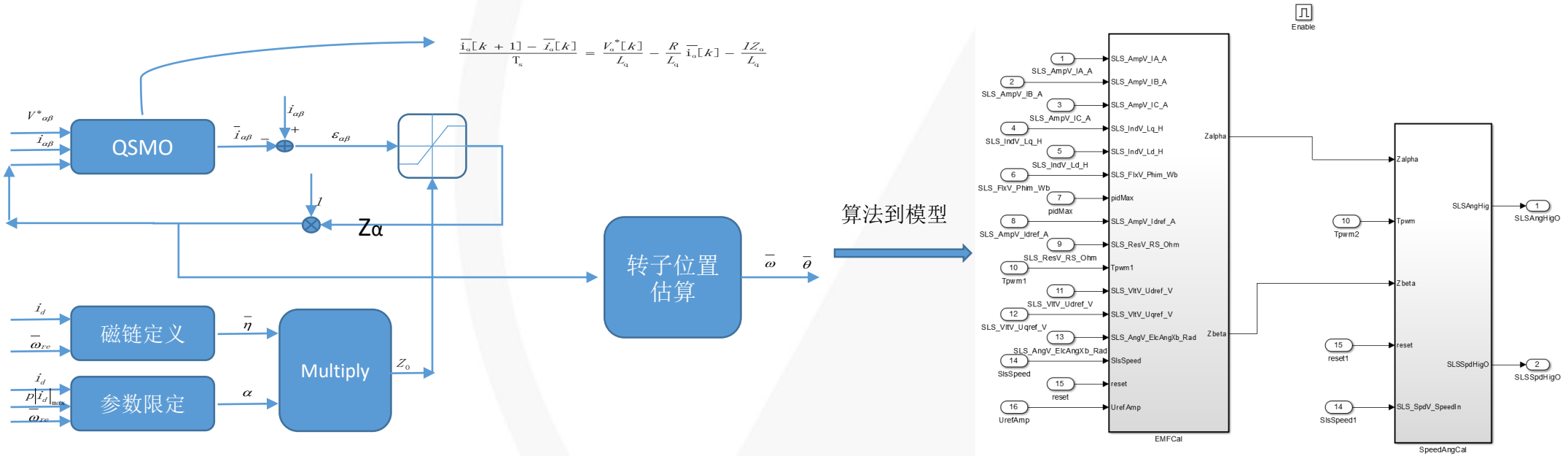
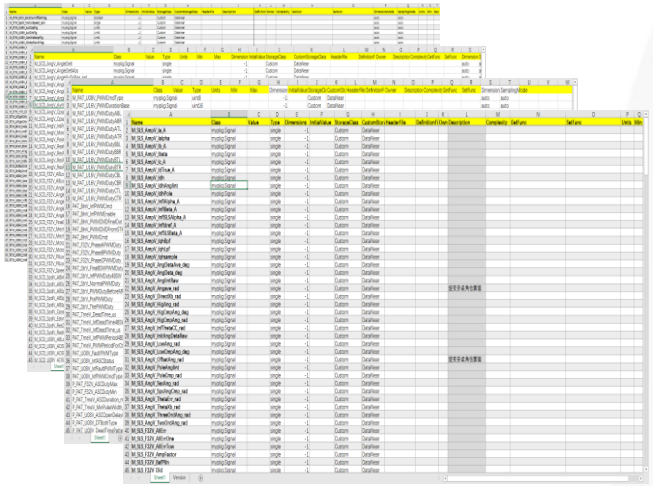
算法模型搭建

利用MATLAB/Simulink平台搭建算法模型



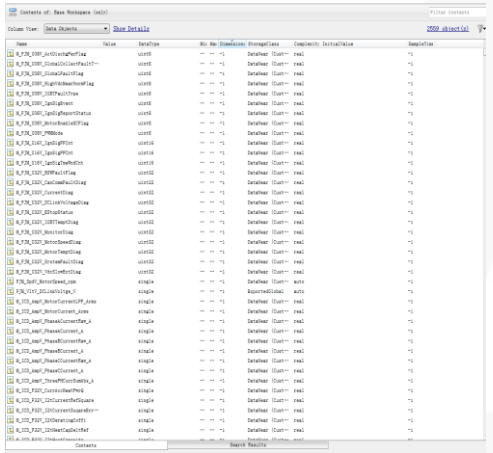
模型开发中的数据管理

利用MATLAB/EXCEL协同进行数据管理



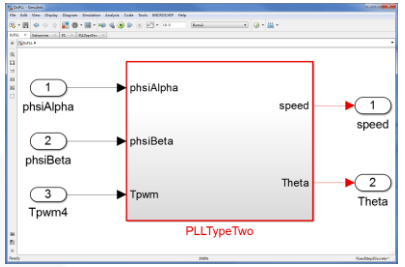
EXCEL文档

数据加载到
Base Workspace

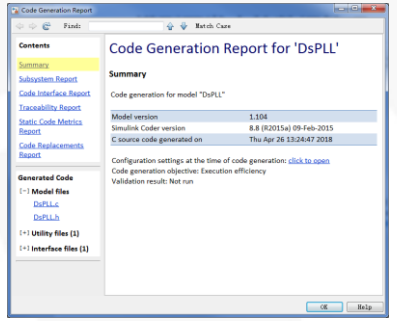


Base Workspace

数据应用



模型仿真

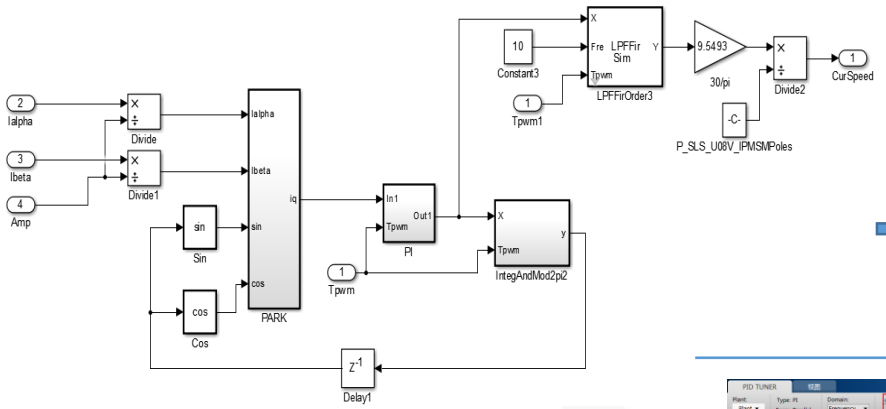


代码生成

添加修改数据

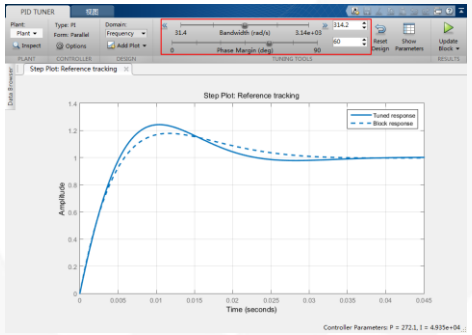
算法仿真测试

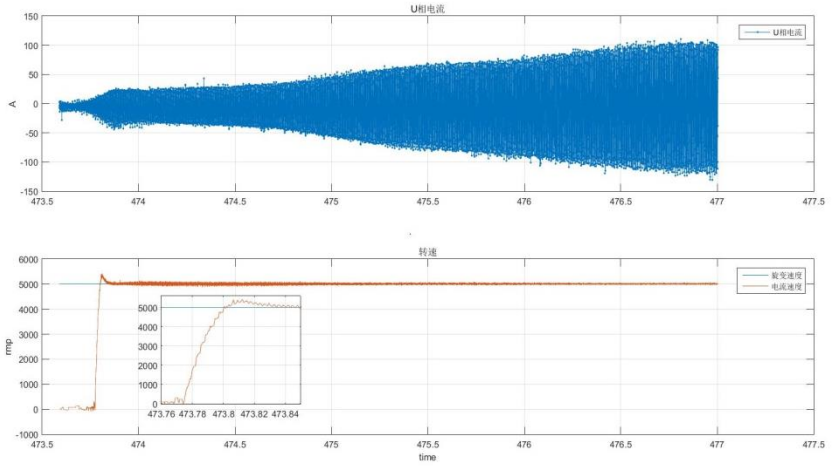
产品开发早期，利用MATLAB/Simulink验证算法的正确性及复杂工况可行性



算法仿真

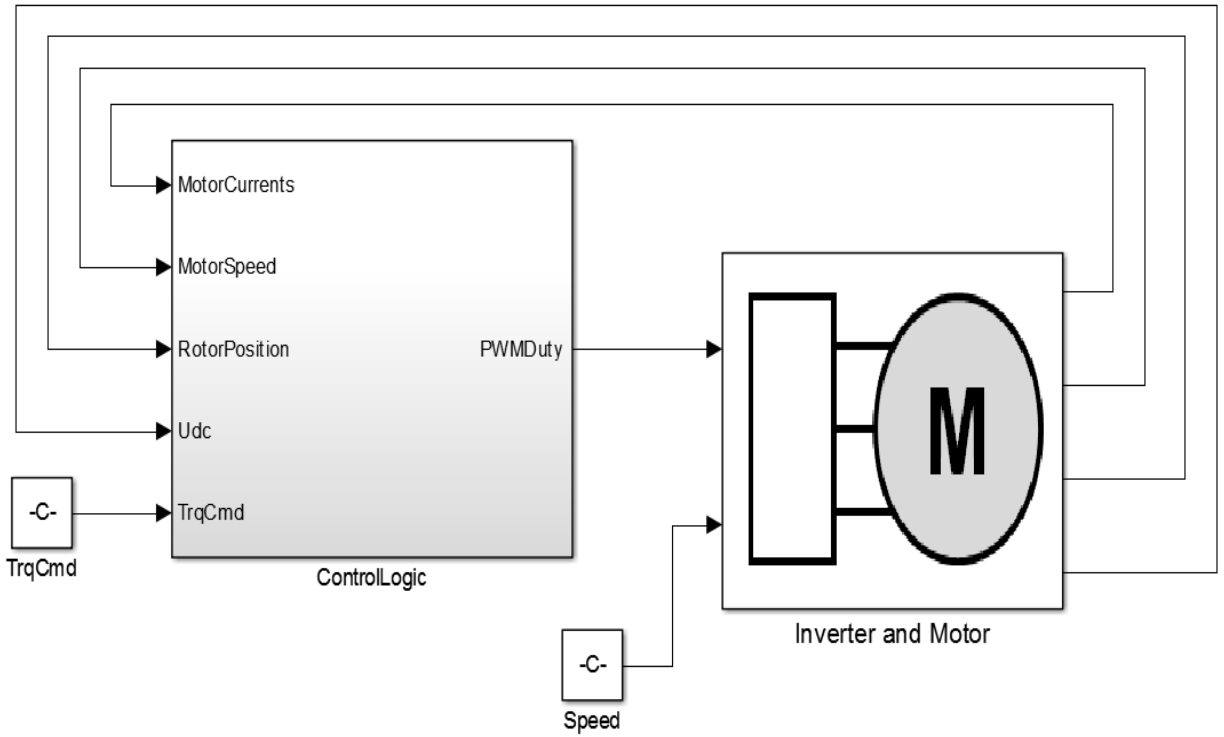
PID Tuner

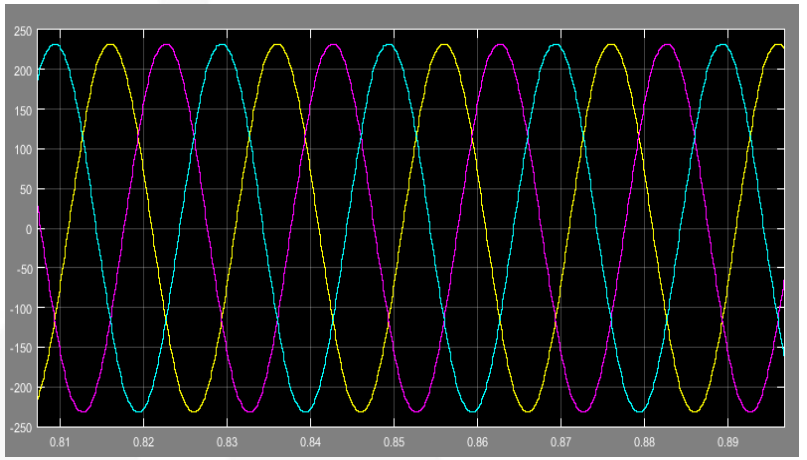


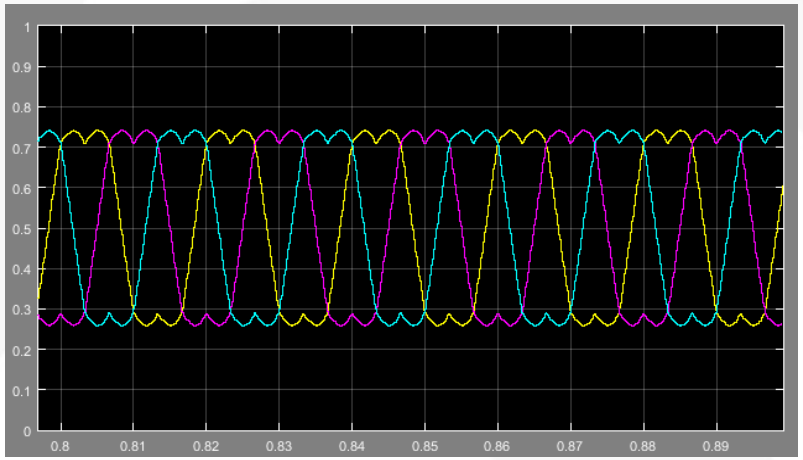


建模与仿真

利用MATLAB/Simulink对算法进行仿真验证

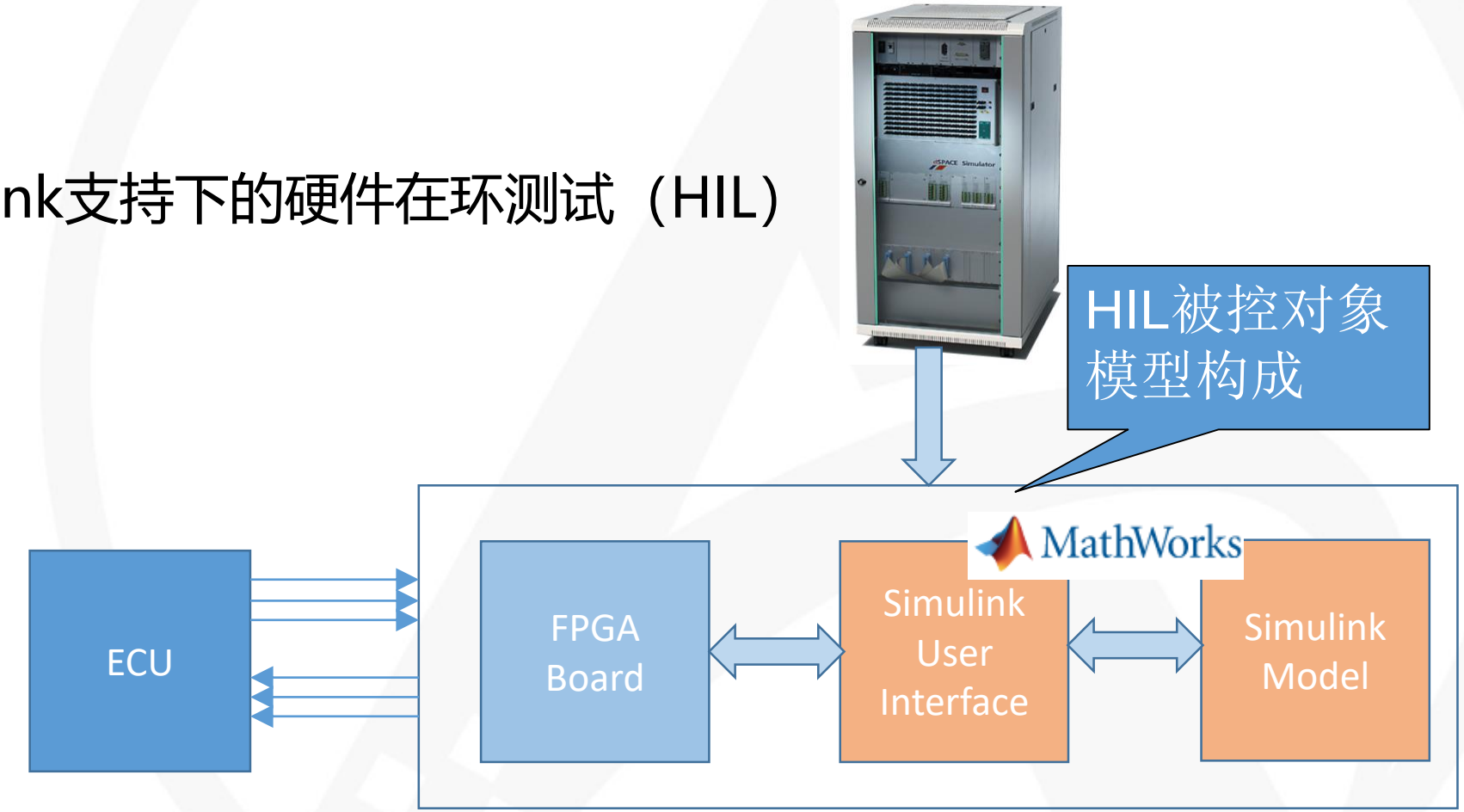




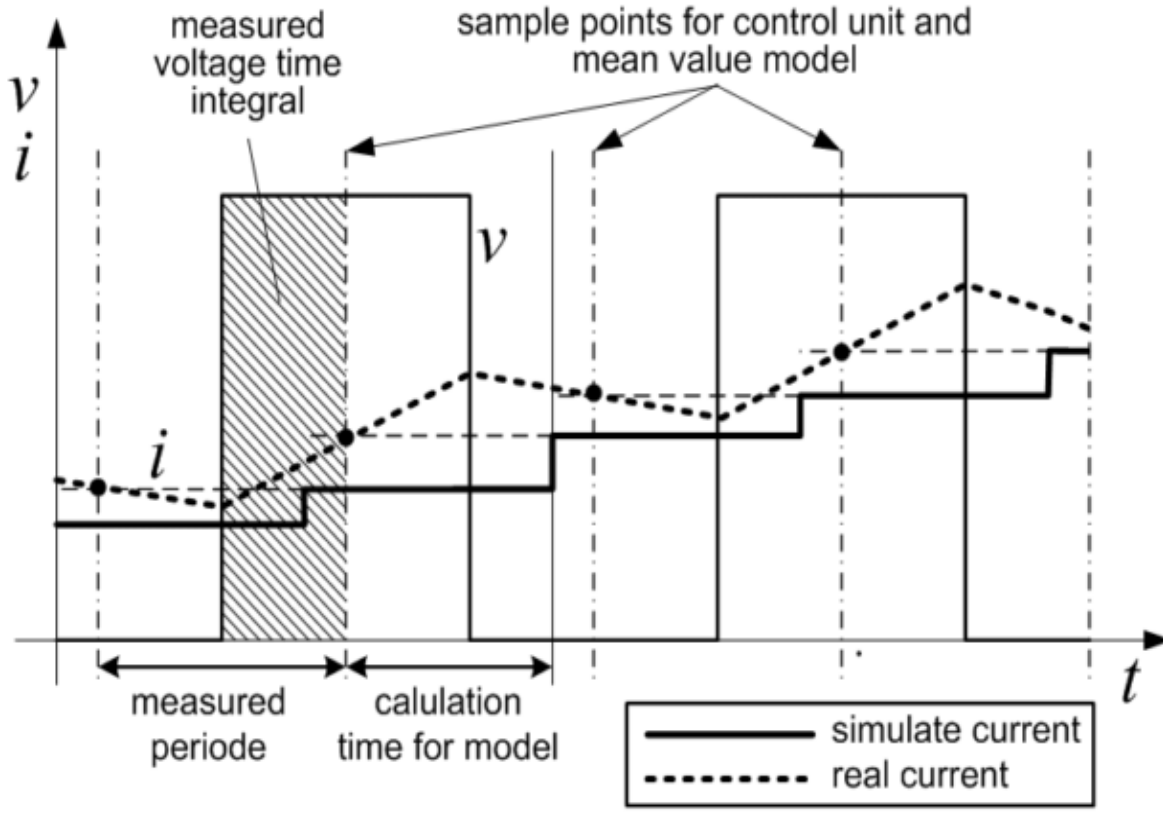


硬件在环测试

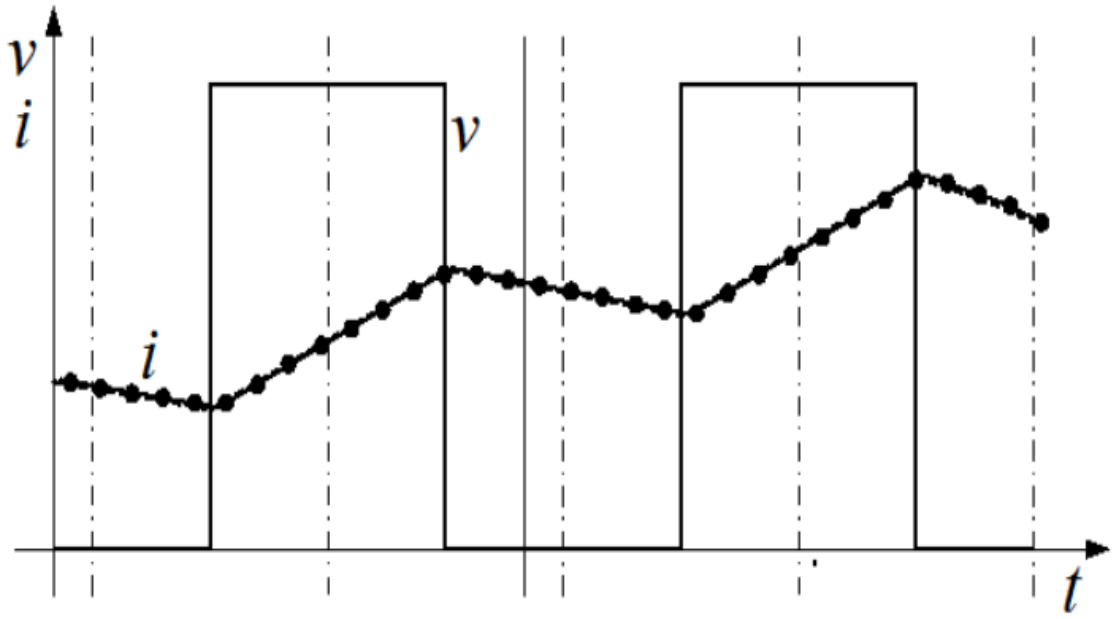
MATLAB/Simulink支持下的硬件在环测试（HIL）



案例：硬件在环测试优化

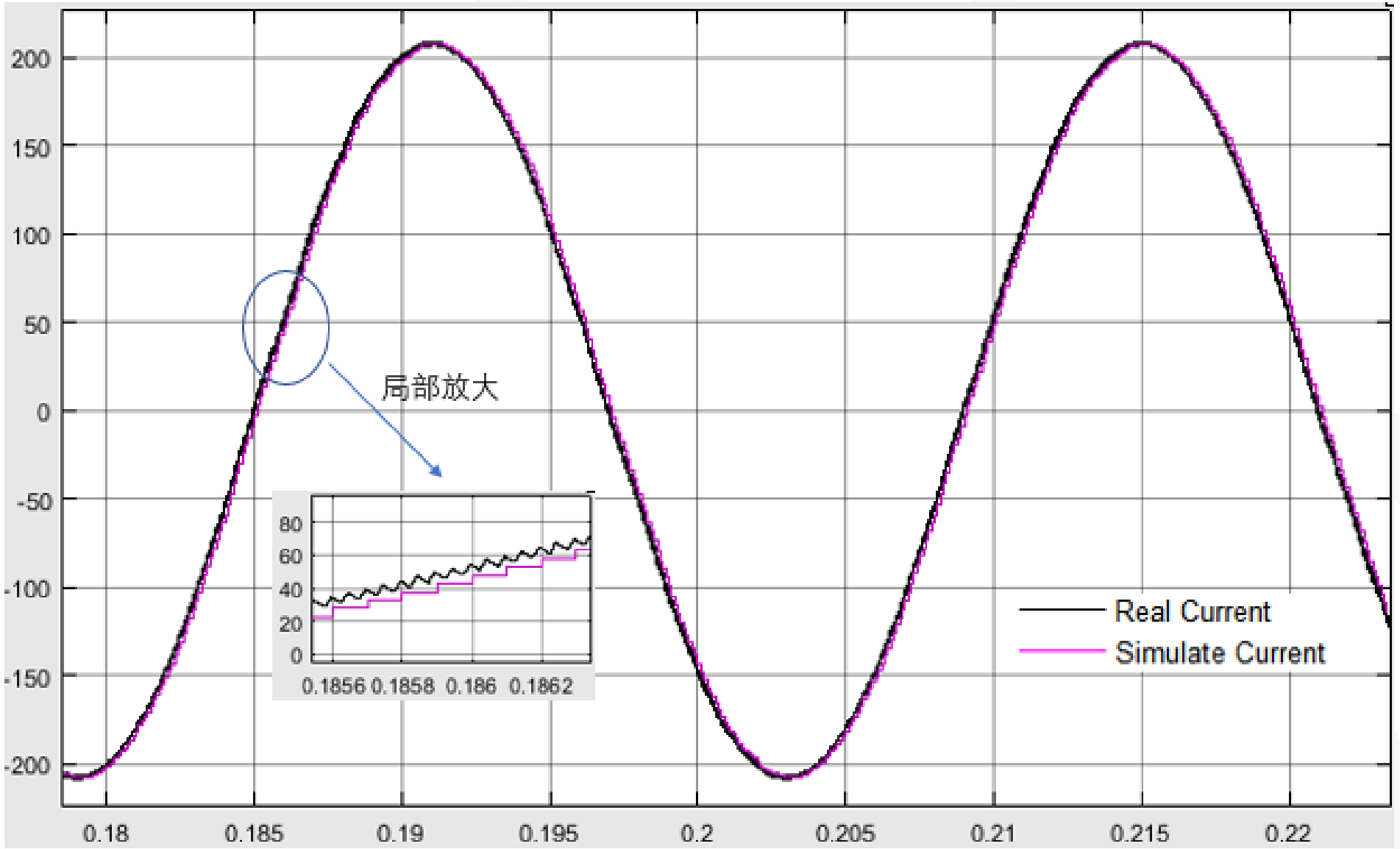


较慢仿真电机模型



快速仿真电机模型

案例：硬件在环测试优化


200
150
100
50
0
-50
-100
-150
-200
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
局部放大
80
60
40
20
0
0.1856 0.1858 0.186 0.1862
Real Current
Simulate Current

目录

代码自动生成

Embedded Coder

Simulink Coder

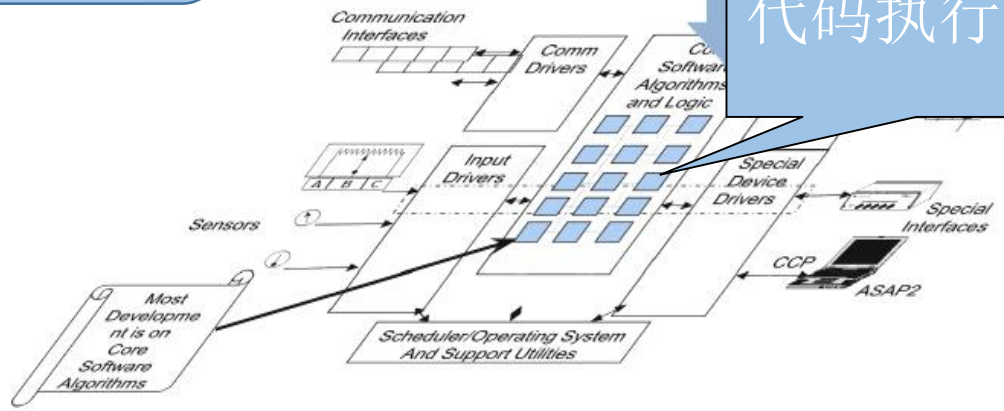
MATLAB Coder

我们会关注什么？

模型与代码的追溯关系

数据存储设计

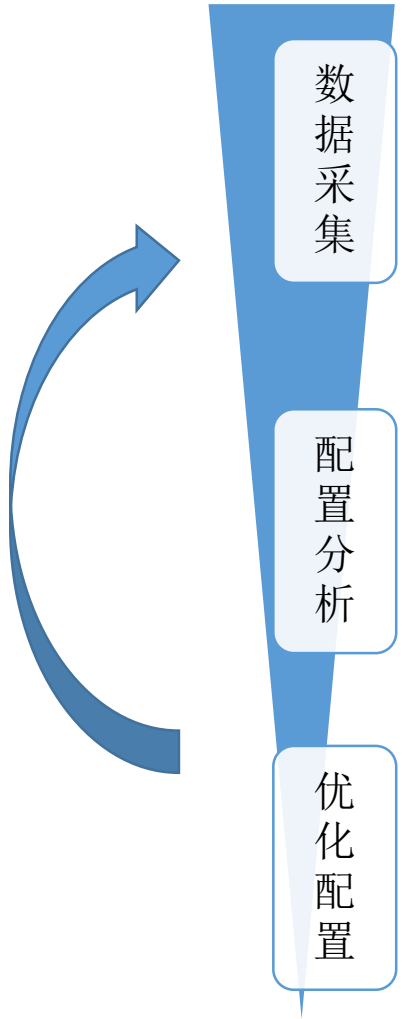
代码执行效率



模型和代码的版本追溯

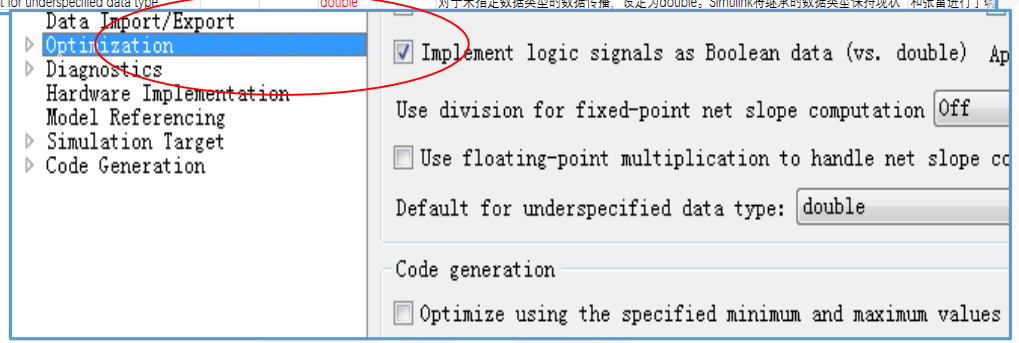

Software Requirement ID
Model Properties: PCA
Main
Callbacks
History
Description
Data
Model information
Created by: ZT140409
Last saved by: DF160922
Created on: Tue Mar 03 17:18:13 2015
Last saved on: Mon Aug 21 14:17:39 20
Read Only
Model version: 4.3.1
Model history:
Model Name :PCA
Description :
Version :4.3.0
Update :1.2017/08/15 Daif Update history1
2.
Main
Callbacks
History
Description
Data
Model callbacks
PreLoadFcn
PostLoadFcn
InitFcn
StartFcn
PauseFcn
ContinueFcn
StopFcn
PreSaveFcn
PostSaveFcn*
CloseFcn
Model post-save function
ref = get_param('ITE',
sm = get_param('StateMac
set_param('StateMachine'
Embedded coder
Summary
Subsystem Report
Code Interface Report
Traceability Report
Static Code Metrics Report
Code Replacements Report
Generated Code
[-] Main file
rt_main.c
CanComm_types.h
[-] Data files
FIM_Calib.h
TCD_Calib.h
[+] Utility files (1)
[+] Interface files (4)
[+] Other files (5)
/*
* Copyright(C), 20XX-20XX, Agility Controls Tech. Nanjing Co., Ltd.
* Project :C110
* File: CanComm.c
* Code generated for Simulink model 'CanComm'.
* Simulink Coder version : 8.8 (R2015a) 09-Feb-2015
* Model version : 1.57
* Model History :
*/
#include "CanComm.h"
#if (UCHAR_MAX != (0xFFU)) || (SCHAR_MAX !=
#error Code was generated for compiler with di
Consider adjusting Test hardware word size settings on the \
Hardware Implementation pane to match your compiler word sizes as \
defined in limits.h of the compiler. Alternatively, you can \
select the Test hardware is the same as production hardware option and \
select the Enable portable word sizes option on the Code Generation > \
Verification pane for ERT based targets, which will disable the \
preprocessor word size checks.
#endif
#if (USHRT_MAX != (0xFFFFU)) || (SHRT_MAX != (0x7FFF))
#error Code was generated for compiler with different sized ushort/short. \

优化配置来提高代码效率



tACIDataS	0.233us	0.117us	0.117us	0.117us	2.	0.006%
anOutDataS	0.489us	0.244us	0.244us	0.244us	2.	0.014%
eReq_State	5.211us	2.567us	2.644us	2.605us	2.	0.009%
tGrpStatus	6.428us	0.022us	1.628us	0.536us	12.	0.003%
tGrpStatus	5.317us	0.022us	1.211us	0.443us	12.	0.002%
te\SCD\SCD	120.717us	2.367us	3.528us	3.263us	37.	0.111%
)\SCD_Fast	112.345us	3.178us	3.444us	3.210us	35.	3.130%
st_Disable	0.400us	0.200us	0.200us	0.200us	2.	0.011%
)'SCD_STow	4.111us	2.017us	2.094us	2.056us	2.	0.114%
te\SLS\SLS	26.533us	0.756us	0.778us	0.758us	35.	0.769%
_LastPhase	16.900us	8.450us	8.450us	8.450us	2.	0.489%
StateLogic	232.828us	116.217us	116.611us	116.414us	2.	0.189%
e_SubModel	179.867us	89.789us	90.078us	89.933us	2.	0.007%
_Subsystem	0.278us	0.139us	0.139us	0.139us	2.	0.008%
Subsystem1	0.156us	0.078us	0.078us	0.078us	2.	0.004%

项目	可选项	选项分析	优化方式	详细分析 参考
Simulation and code generation				
Block reduction	ON	Simulink将削减删除无 效的数据类型转换模块，移除无用模块和信号。	保持现状	Simulink® softw
	OFF	Simulink不处理可优化的模块		
Conditional input branch execution	ON	只有当部件需要计算控制输入和数据输入时，才被执行。这个优化可以加速	保持现状	仅针对Switch模
	OFF	执行所有驱动Switch模块的输入信号		
Implement logic signals as Boolean data (vs. double)	ON	模块会输出一个boolean型逻辑信号	保持现状	当模型的输出是
	OFF	模块会输出一个double型逻辑信号		
Application lifespan (days)		1		
Use division for fixed-point net slope computation	ON	Performs net slope computation using a rational approximation of the net slo	保持现状	和张雷进行了确
	OFF	Performs net slope computation using integer multiplication followed by shifts		
	Use division for recipr	Performs net slope computation using division when the net slope can be represented by the reciprocal		
Use floating-point multiplication to handle net slope corrections	ON	Use floating-point multiplication to perform net slope correction for floating-	保持现状	和张雷进行了确
	OFF	Use division to perform net slope correction for floating-point to fixed-point casts		
Default for underspecified data type	double	对于未指定数据类型的数据传播，设定为double。Simulink将继承的数据类型	保持现状	和张雷进行了确



Step1
采集数据
确定对象

Step2
分析配置
确定项目

Step3
优化比对
采集验证

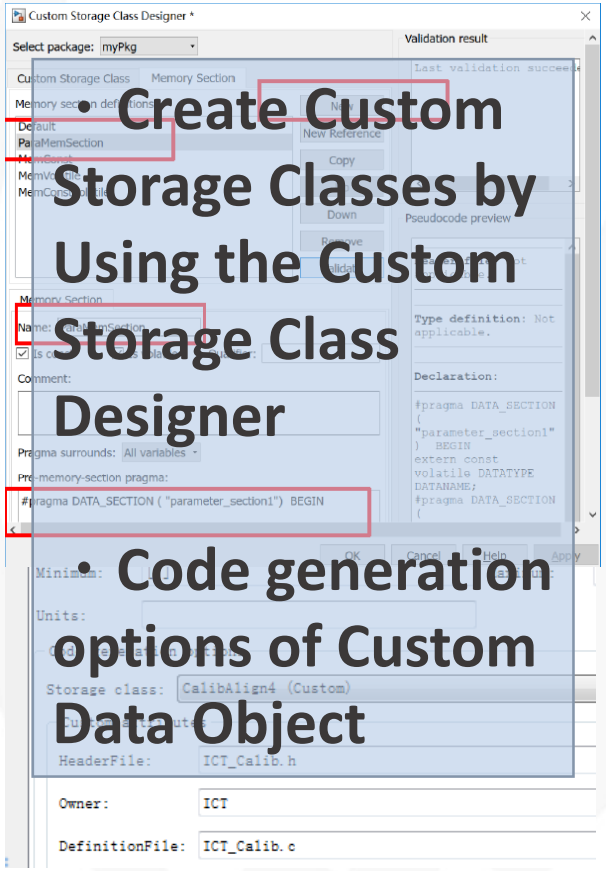
定制化数据应用

利用Embedded Coder的自定义数据包来实现定制化数据应用

Datasheet
Memory Map

Architecture
Design

Complier
Configuration



・基于需求和芯片存储特性的定制化数据应用

・数据对象和生成代码的双向追溯

案例：定制化数据优化提高函数执行效率

利用上述定制化数据方式将需要频繁存储的数据放在可快速存取的内存区域，从而提高函数执行效率，降低软件整体负载。

优化前

55.347

tree	total	min	max	avr	count
OS_ISR_OsIsr_AD_Current	3.427ms	57.183us	57.183us	57.119us	60.(1/0)
HighSpeedLogic_HighLogicCo..	17.050us	-	17.050us	17.050us	1.(1/0)
Rte_Write_HighSpeedLogic_D..	0.178us	0.178us	0.178us	0.178us	1.
Rte_Write_HighSpeedLogic_D..	0.217us	0.217us	0.217us	0.217us	1.
ETK_Distab13_Process_R01	10.123us	0.133us	0.172us	0.172us	59.
HighSpeedLogic_CycRun	3.265ms	54.767us	57.072us	55.347us	59.
HighSpeedLogic_HighLogic..	3.224ms	54.067us	56.344us	54.645us	59.
Rte_Read_HighSpeedLogi..	6.806us	0.111us	0.161us	0.115us	59.
IoAbstract_GetAD2S1210..	19.784us	0.294us	0.461us	0.335us	59.
IoAbstract_GetAD2S1210..	20.239us	0.322us	0.406us	0.343us	59.
IoAbstract_GetAD2S1210..	161.127us	2.650us	2.972us	2.731us	59.
IoAbstract_GetAdcFast	17.289us	0.272us	0.311us	0.293us	59.
IoAbstract_GetDriver15..	55.900us	0.944us	1.017us	0.947us	59.
IoAbstract_GetIGBTLvGp..	54.467us	0.922us	0.978us	0.923us	59.
IoAbstract_GetPwmCTR	17.794us	0.228us	0.306us	0.302us	59.
IoAbstract_GetPwmCheck..	6.395us	0.056us	0.117us	0.108us	59.
HighSpeedLogic_SubModel	2.152ms	36.044us	37.722us	36.479us	59.
IDQ	10.251us	0.161us	0.211us	0.174us	59.
ICD	107.989us	1.783us	1.972us	1.830us	59.
UCD	77.494us	1.256us	1.317us	1.313us	59.
SCD	207.850us	3.378us	3.722us	3.523us	59.
ICT	1.058ms	17.700us	18.528us	17.930us	59.
ICT_Fast	1.053ms	17.611us	18.439us	17.841us	59.
_floor_spf	33.595us	0.489us	0.733us	0.569us	59.
_modf_spf	16.366us	0.200us	0.422us	0.277us	59.
_copysign_spf	3.028us	0.039us	0.100us	0.051us	59.
_fmod_spf	19.911us	0.306us	0.450us	0.337us	59.
_fabs_spf	9.111us	0.017us	0.039us	0.035us	260.
ICT_DeadTimeComp	187.534us	3.156us	3.267us	3.179us	59.
ICT_ICT_VdVqOut	7.966us	0.133us	0.144us	0.135us	59.
PCA	406.444us	6.633us	7.556us	6.889us	59.

优化后

52.760

tree	total	min	max	avr	count
OS_ISR_OsIsr_AD_Current	3.012ms	53.750us	56.[illegible]us	54.767us	55.
ETK_Distab13_Process_R01	9.745us	0.139us	0.18[illegible]	0.177us	55.
HighSpeedLogic_CycRun	2.902ms	51.744us	54.606us	52.760us	55.
HighSpeedLogic_HighLogic..	2.868ms	51.122us	53.983us	52.138us	55.
Rte_Read_HighSpeedLogi..	7.328us	0.128us	0.178us	0.133us	55.
IoAbstract_GetAD2S1210..	17.516us	0.294us	0.406us	0.318us	55.
IoAbstract_GetAD2S1210..	18.144us	0.322us	0.411us	0.330us	55.
IoAbstract_GetAD2S1210..	159.761us	2.844us	3.028[illegible]	2.905us	55.
IoAbstract_GetAdcFast	14.511us	0.194us	0.2[illegible]	0.264us	55.
IoAbstract_GetDriver15..	50.156us	0.9[illegible]us	0[illegible]	0.912us	55.
IoAbstract_GetIGBTLvGp..	50.078us	0.[illegible]	[illegible]	0.9[illegible]us	55.
IoAbstract_GetPwmCTR	1[illegible]	[illegible]	[illegible]	[illegible]19us	55.
IoAbstract_GetPwmCheck..	[illegible]	[illegible]	[illegible]	[illegible]118us	55.
HighSpeedLogic_SubModel	1[illegible]	[illegible]	[illegible]	[illegible]	55.
IDQ	[illegible]	[illegible]	[illegible]	[illegible]	55.
ICD	[illegible]	[illegible]	[illegible]	[illegible]us	55.
ICD_Fast	[illegible]	[illegible]	[illegible]	[illegible]11us	55.
UCD	[illegible]	[illegible]	[illegible]	[illegible]	55.
UCD_Fast	[illegible]	[illegible]	[illegible]	[illegible]278us	55.
SCD	[illegible]	[illegible]	[illegible]	[illegible]518us	55.
SCD_Fast	[illegible]	[illegible]	[illegible]	[illegible]0us	55.
_fabs_spf	[illegible]	[illegible]	[illegible]	0.[illegible]	110.
ICT	[illegible]	[illegible]	[illegible]	17.369us	55.
ICT_Fast	[illegible]	[illegible]	18.044us	17.284us	55.
_floor_spf	[illegible]	[illegible]450us	[illegible]	0.622us	0.479us	55.
_modf_spf	1[illegible]	[illegible].233us	[illegible]	0.400us	0.270us	55.
_copysign_spf	[illegible]	[illegible]00us	0.039us	0.100us	0.040us	55.
_fmod_spf	1[illegible]	[illegible].134us	0.306us	0.406us	0.330us	55.
_fabs_spf	6.861us	0.033us	0.039us	0.034us	200.
ICT_DeadTimeComp	173.078us	3.128us	3.167us	3.147us	55.
ICT_ICT_VdVqOut	7.400us	0.133us	0.144us	0.135us	55.
PCA	354.528us	6.189us	6.994us	6.446us	55.

效率提升：
4.7%

目录

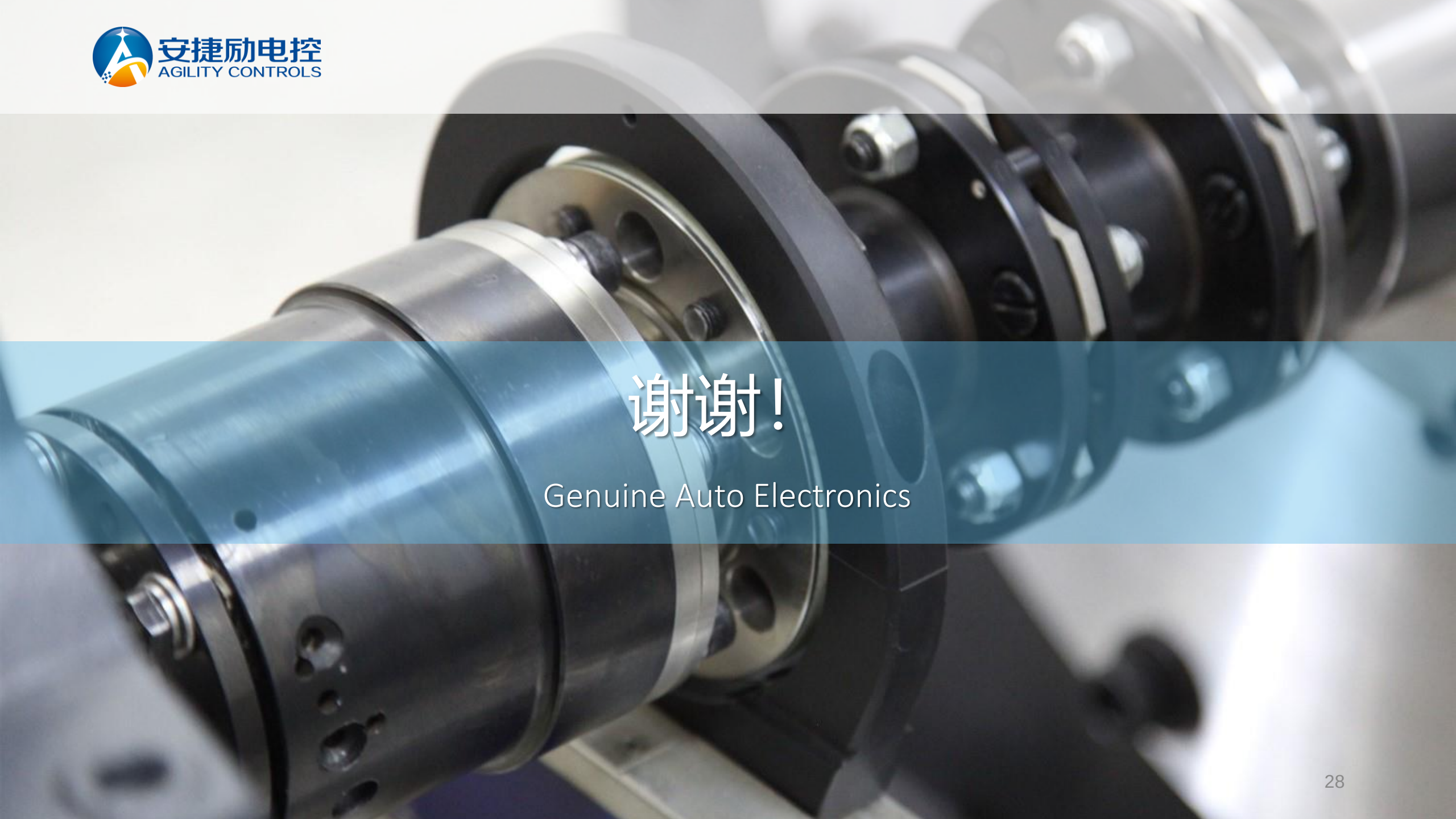
总结与展望

- 基于模型设计的AUTOSAR软件开发已经成为汽车行业广泛使用与认可的方法，其稳定高效、易集成的特点大大降低了像电机控制这种高复杂度系统的开发难度，节约了开发时间。

- MATLAB/Simulink强大的仿真工具使控制算法开发更为高效，大大减轻了基于硬件平台的逻辑算法验证工作。

- MATLAB/Simulink强大的代码生成工具，在安捷励控制器软件开发过程中起着非常重要的基础作用。

- 为快速完善开发测试流程、进一步优化模型测试验证过程，安捷励团队即将引入V&V、Simulink Test等工具。



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谢谢!

Genuine Auto Electronics