Webinar

MATLAB & Simulink Model-Based Design for C2000™ Real-Time Microcontrollers

Chen-Yu Chang

Product Marketing Engineer, Texas Instruments

Jayakarthigeyan Prabakar

Senior Product Marketing Manager, MathWorks

Agenda

- Overview on Model Based Design on ASM Devices
- ASM Portfolio & Model Based Support
- TIDM-02012 Reference Design Walkthrough
- MathWork Offering on Model Based Design

Overview on Model Based Design

Why?

- Ease-of-use
- Efficiency and performance of the generated code

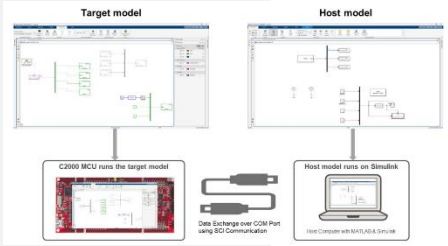
What is needed?

TI

- Code Composer Studio IDE
- C2000Ware Software Development Kit (SDK)

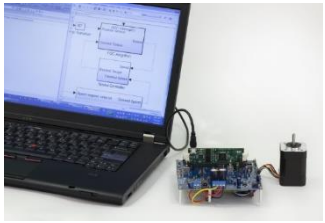
MathWorks

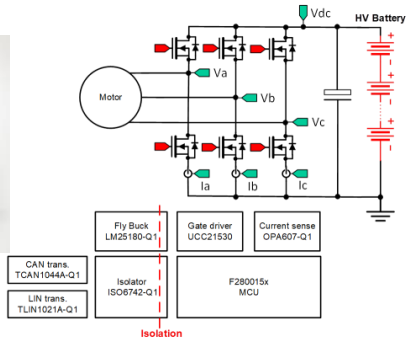
- MATLAB Simulink®
- MATLAB Coder
- Embedded Coder
- C2000 Microcontroller Blockset



eCompressor Reference Design

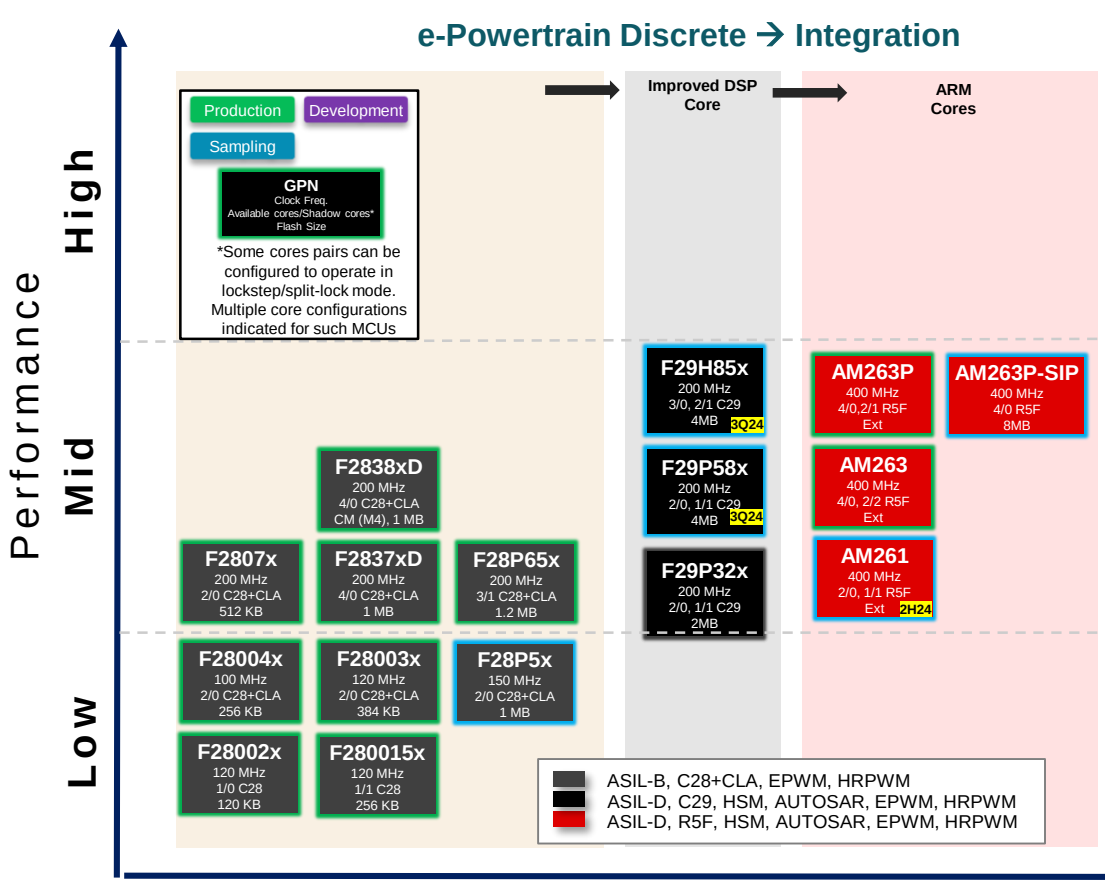
Demonstrates the control of eCompressor motor using field-oriented control (FOC) without a position sensor





Model Based Design App note for details: [MATLAB® Model-Based Design Using C2000™ Microcontrollers (ti.com)]

ASM's Scalable Automotive MCU Portfolio



More to expect

F28x MCUs (C2000) -> Proprietary core designed for Real-time Control

- Software compatible portfolio
- Broad packaging options
- High Precision Analog Sensing & Feature Rich PWMs
- TMU, FPU, & Control Law Accelerator (CLA) for More Performance
- CLB for Peripheral Customization
- DSP-Efficient CPU, Control Accelerators, & Parallel Multi-Core Processing
- Over 25 years of expertise in Real-Time Control Systems
- Extensive Library of Public Reference Designs

F29x MCUs (C2000) -> Proprietary core designed for Real-time Control

- 2x signal chain performance increase from F28x
- 4x Faster Interrupt Response & Reduced Latency from F28x
- ASIL-D capable with code isolation in hardware (Security & Safety Unit)
- Hardware Security Module (HSM) offers a wide range of cryptographic accelerators (AES, RSA, ECC, etc)
- Hardware interrupt prioritization requires no software overhead
- High Resolution PMW (HRPWM) resolution is 75ps (150ps on F28x)
- Increased memory (up to 4MB), ADC channels (up to 80), etc.

AM263x MCUs(Sitara) -> ARM based with real-time control IPs

- Same control IPs (EPWM, ADC, etc.) as C2000 devices
- Up to 4 ARM cores (R5F) with external flash
- AM263x -> AM263Px major changes include increased RAM, TMU, HW Resolver, more ECAP/CAN-FD/SPI, OSPI flash interface, and XIP support
- Flash in package option (AM263P-SIP), same specs as AM263Px
- AM261x has up to 2 R5F cores
- All contain programmable real-time unit (PRU) to support interfaces like SENT, UART, or redundant safety channels for PWM

Model based design (Matlab) Support

AM263x Key milestones :

Early Access Release

- Target/HSP definition (AM263x ControlCard)
- AM263x MATLAB/Simulink Embedded Coder package (Add on package)
- Subset peripherals + features

General Availability Release

- Extended set of peripheral + features

General Availability Release

- Code Optimizations , profiling …

F28 Devices has support available now!

AM263Px Key milestones :

Early Access Release

- Target/HSP definition (AM263Px ControlCard & LaunchPad)
- AM263Px support package (Add on package)
- Subset peripherals + features

General Availability Release

- Extended set of peripheral + features + Code Optimizations , profiling …

F29x Key milestones :

Early Access Release

- Target/HSP definition (F29x controlSOM)
- F29x support package (Add on package)
- Subset peripherals + features

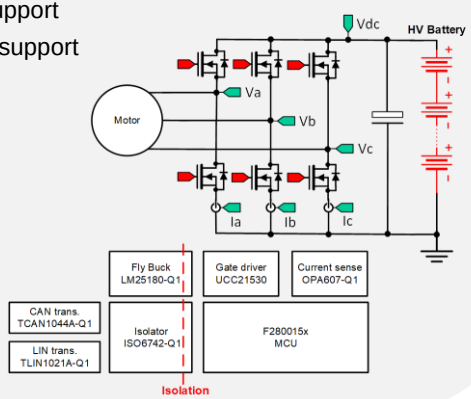
General Availability Release

- Extended set of peripheral + features + Code Optimizations , profiling …

TIDM-02012 HEV/EV Compressor Reference Design

Features

- Cost-optimized C2000 real time MCUs (F28003x, F280015x)
- Observer for sensorless-FOC: InstaSPIN FAST observer
- Motor over current protection with on-chip comparator
- Field weakening control, MTPA, Overmodulation
- Stall detection and recovery
- Lost phase detection/protection
- Startup failure detection and restart
- Torque ripple / vibration compensation
- Efficiency improvement algorithm for IPM type compressor
- CAN-FD and LIN interface support
- Multi-shunt and single-shunt support



Benefits

- Proven, highly integrated single MCU motor control design based on real HVAC systems
- Innovative algorithms for high efficiency, lowest/highest speed, low vibration and acoustics, robust start-up, wide adaptability
- Scalability across low-end and mid-end MCUs to cover wide range of application requirements
- Hardware-based ASIL B functional safety enablers
- Migration path to ASIL D / EVITA Full / high-end roadmap devices

Target Applications

- HEV/EV HVAC compressor

Release Timelines

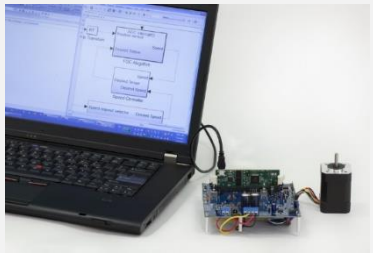
- RTM (F28003x): Done, TI.com
- RTM (F280015x): Done, TI.com

https://www.ti.com/tool/TIDM-02012

TIDM-02012 HEV/EV eCompressor Reference Design + added support of MathWorks model-based design

Features

- Cost-optimized C2000 real time MCUs (F28003x, F280015x)
- Observer for sensorless-FOC: InstaSPIN FAST observer
- Motor over current protection with on-chip comparator
- Startup failure detection and restart
- Torque ripple / vibration compensation
- Efficiency improvement algorithm for IPM type compressor
- CAN-FD and LIN interface support; Multi-shunt and single-shunt support\
- **Model-based approach enables faster development, fewer engineering resources required, no software expertise needed!**
- Decouples control algorithm development and firmware development.
- **Simulation capability enables offline development, tuning and validation of control algorithms.**
- Easy to port between C2000 MCU families



Benefits

- Innovative algorithms for high efficiency, lowest/highest speed, low vibration and acoustics, robust start-up, wide adaptability
- Scalability across low-end and mid-end MCUs to cover wide range of application requirements
- Hardware-based ASIL B functional safety enablers
- Migration path to ASIL D / EVITA Full / high-end roadmap devices
- Simulation capability to develop/validate control algorithm.

Target Applications

- HEV/EV eCompressor

Release Timelines

- RTM (F28003x): Done, TI.com
- RTM (F280015x): Done, TI.com

https://www.ti.com/tool/TIDM-02012

Agenda

- MathWorks overview
- Model-based design for Embedded Software Development using Automatic code generation
- MathWorks C2000 Microcontroller Blockset
- Model-based Simulink example for TIDM- 2012 eCompressor motor control reference design running on C2000 MCU

Headquarters
Natick, MA USA

North America
United States

Europe
Finland
France
Germany
Ireland
Italy
Netherlands
Spain
Sweden
Switzerland
UK

Asia
Australia
China
India
Japan
Korea
Singapore

MathWorks®

5 million+ users
in more than 180 countries

6500+ staff
in 34 offices around the world

Trusted partner
for companies across multiple industries

Privately held
and focus on long-term customer success

Customers in industry innovate with MathWorks software

Aerospace and Defense

Automotive

Communications

Software and Internet

Complex multi-domain systems, software-defined and autonomous, model-based and data-driven

Comms infrastructure, plus all types of connected systems across industries

Big Data, Agile, DevOps, integration with IT systems

Railway Systems

Energy Production

Electronics

Neuroscience

Biological Sciences

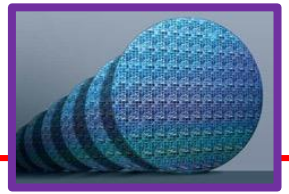
Modernization, often on legacy platforms, becoming data-centric for optimization and maintenance

Wide range of compute platforms, many kinds of HW/SW integration

Collaboration between science, engineering, and informatics

Process Industries

Industrial Machinery



Semiconductors

Medical Devices

Biotech and Pharmaceutical

MathWorks

MATLAB

Data Analysis

Signal Processing

Predictive Maintenance

Machine Learning

Algorithm Development

Algorithm Development

Mathematical Modeling

Test and Measurement

MathWorks

Simulink

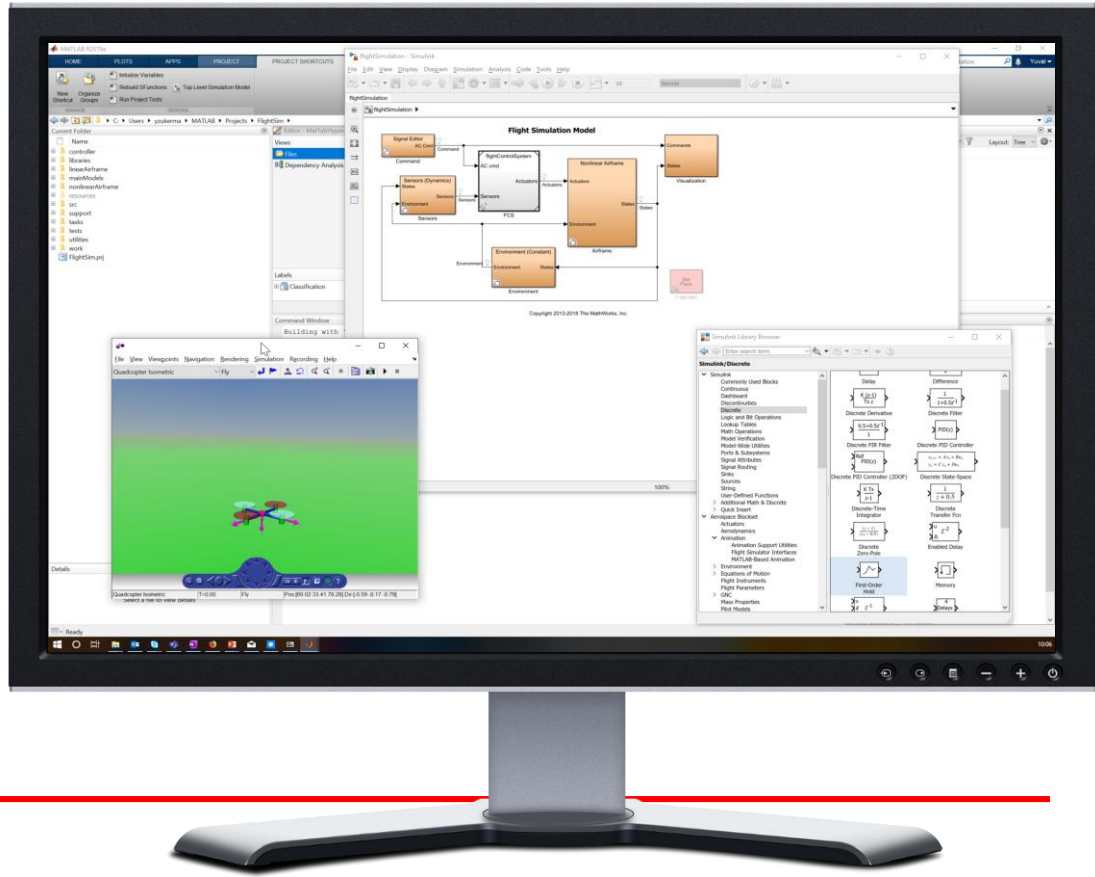
Industry-Specific Solutions

Code Generation

Embedded Systems

Model-Based Design

Real-Time Simulation & Testing



MathWorks

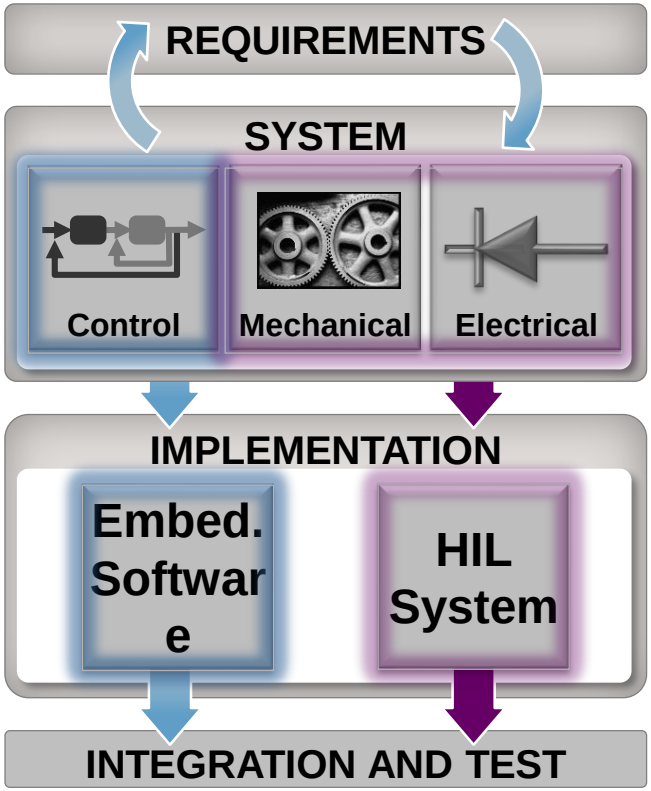
Application specific add-on products Simulink for Motor Control and Power Conversion

Simscape Electrical:

- Libraries of electrical components
  - Power electronics, sensors, actuators, passives, logic, …
  - Create custom models using MATLAB-based language
  - Nonlinearities, operational limits, faults, thermal effects
- SPICE netlist importer
- Simulation modes and analyses
  - Ideal switching, discretization, and phasor
  - Load flow, harmonic analysis
- Application-specific examples
  - AC and DC electric drives, smart grids, renewable energy
- Support for C-code generation

Motor Control Blockset:

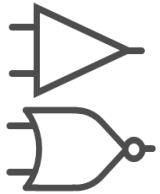
- Calibrate Sensors
- Estimate Motor Parameters
- Model Motor and Inverter
- Design Motor Control Algorithms like FOC



Simscape Electrical Component Models

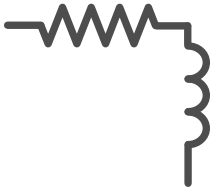
Semi-conductors

Motors, Actuators

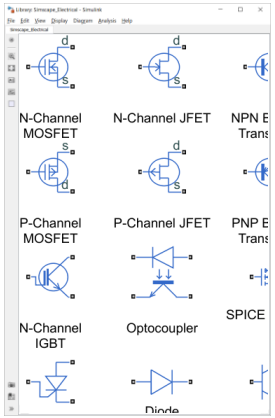


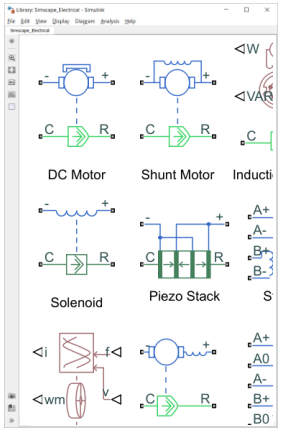
Op-Amps, Logic Gates

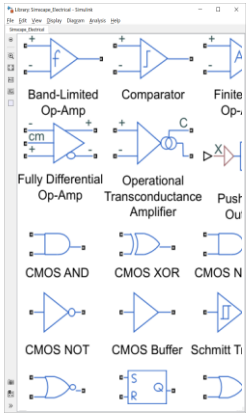
Sensors

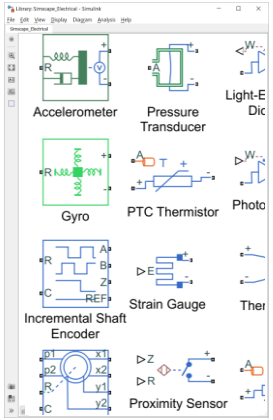


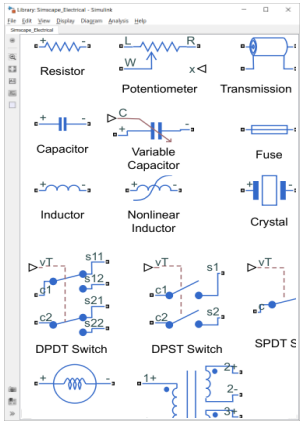
Passive Devices











C Coder Products

MATLAB Coder - Code from MATLAB

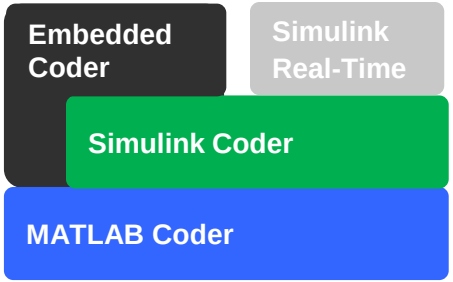
- Portable code for numerical algorithms
- Speed up MATLAB code (mex)

Simulink Coder - Code from Simulink

- Rapid prototyping or HIL applications
- Real-time machines (Simulink Real-Time)

Embedded Coder – Optimized Code and Tools for Production

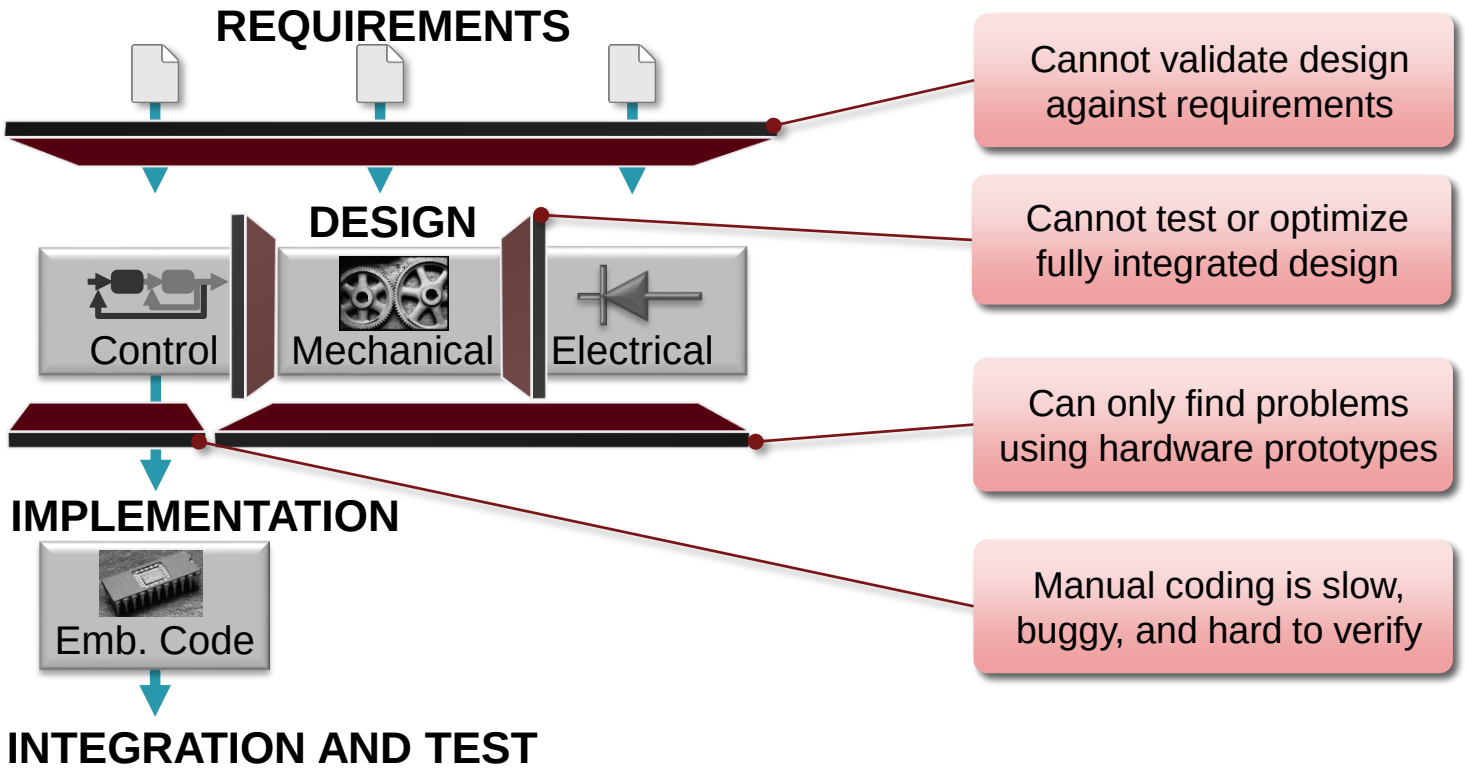
- Embedded applications
- MCU and DSP (fixed or float)
- Code verification (in-the-loop)
- Target-specific support (APIs and examples)



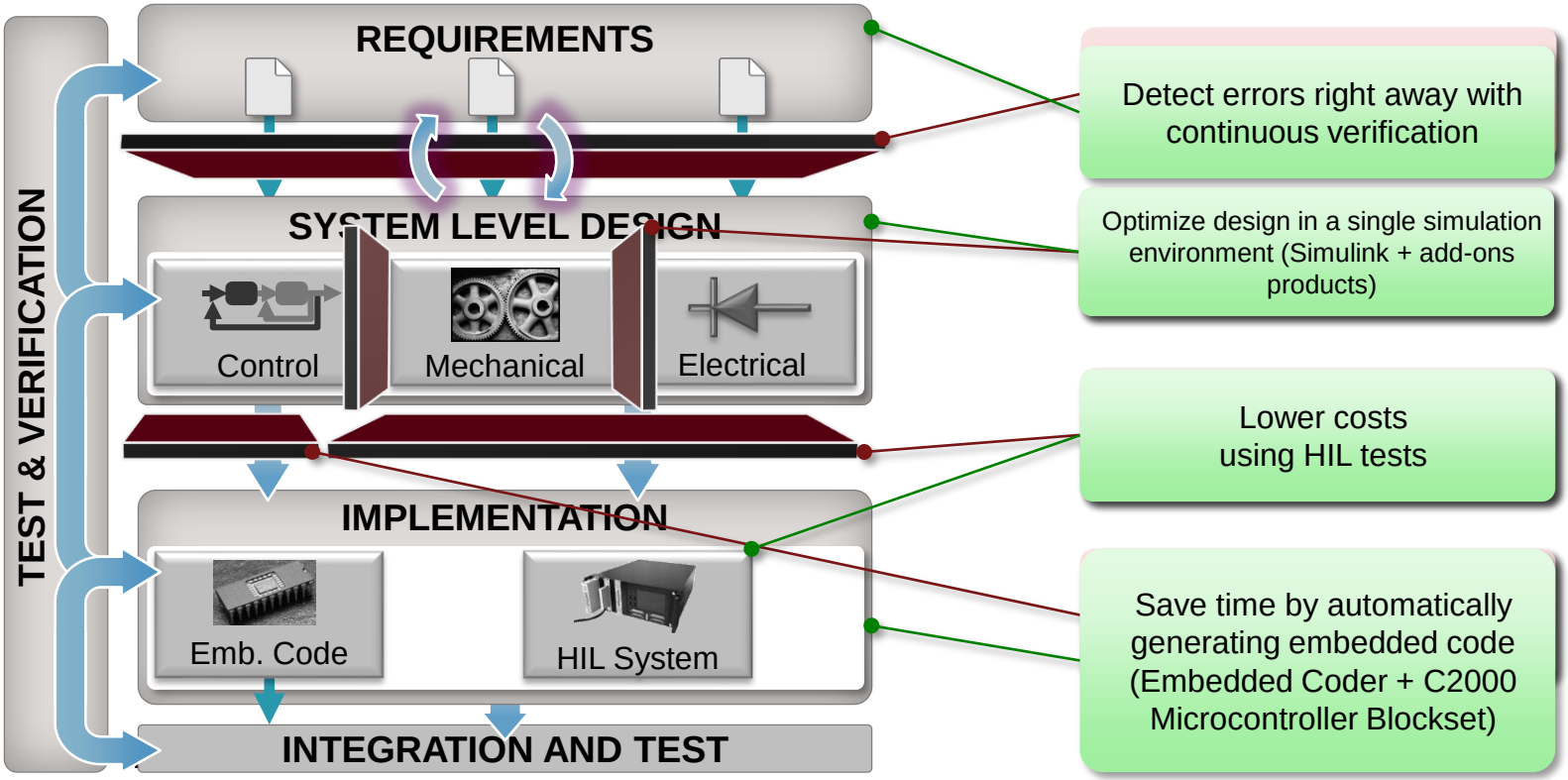
All coders generate portable code (ANSI/ISO C) by default.

Model-Based Design

Traditional Design Process

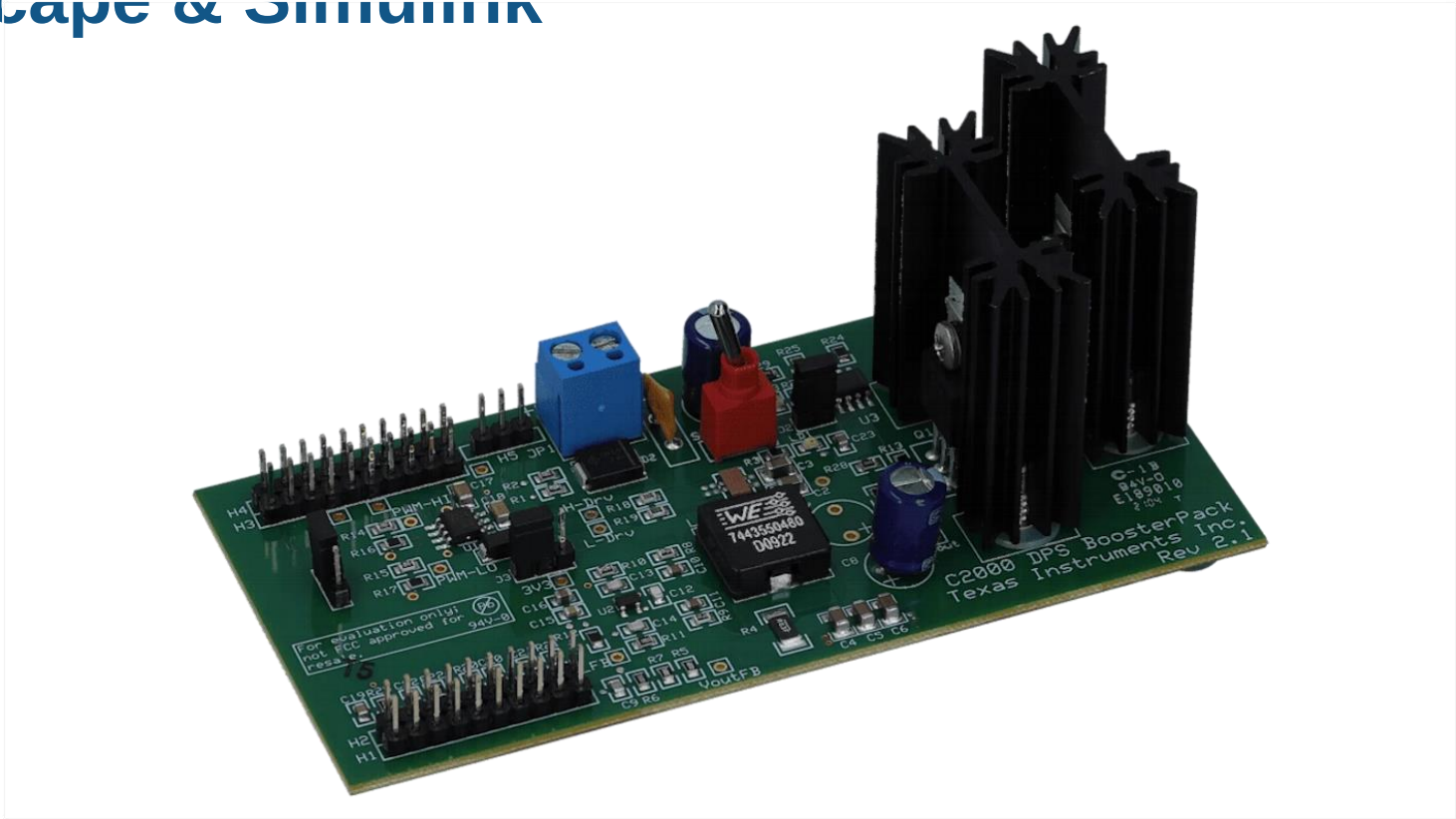


Model-Based Design

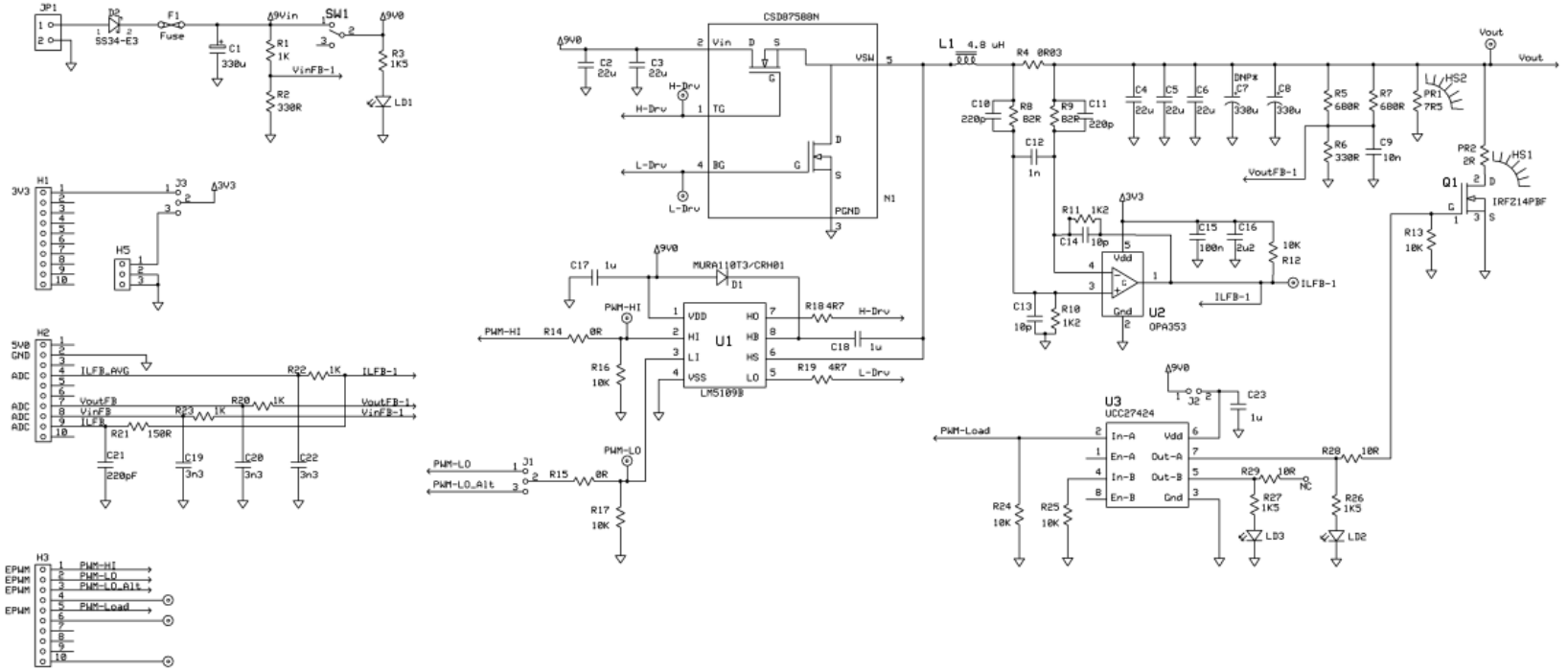


Embedded Control Software Development using Model Based Design

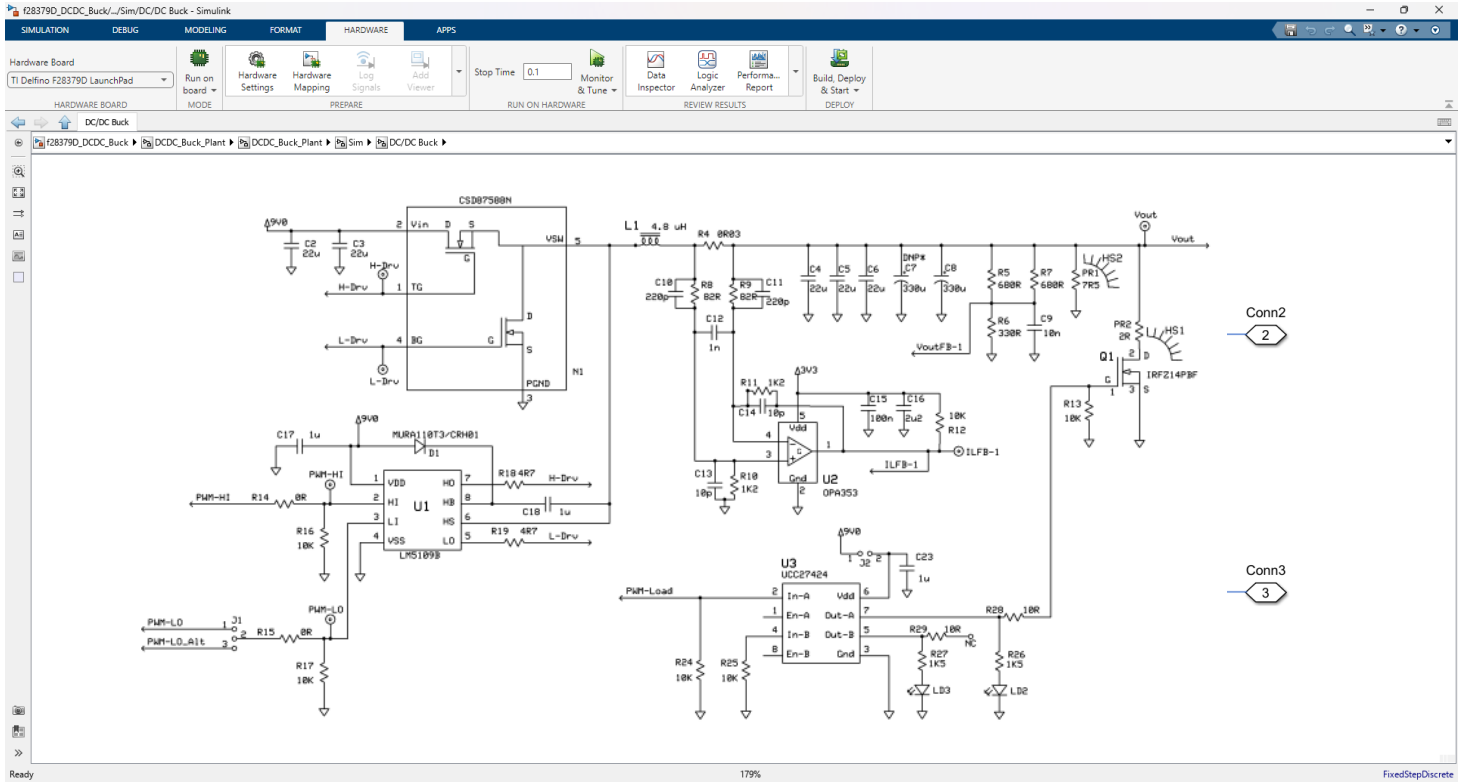
Step 1: Modeling Buck Converter Plant using Simscape & Simulink



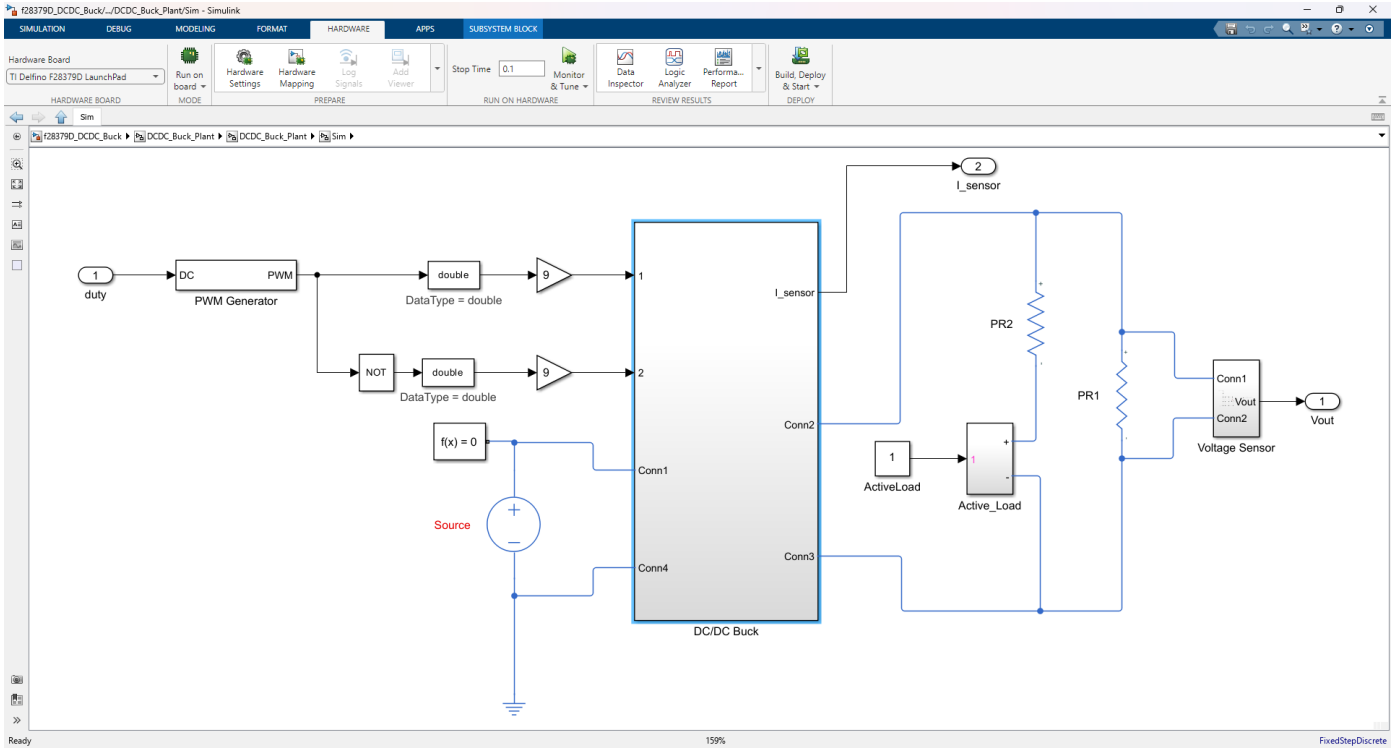
Step 1: Modeling Buck Converter Plant using Simscape & Simulink



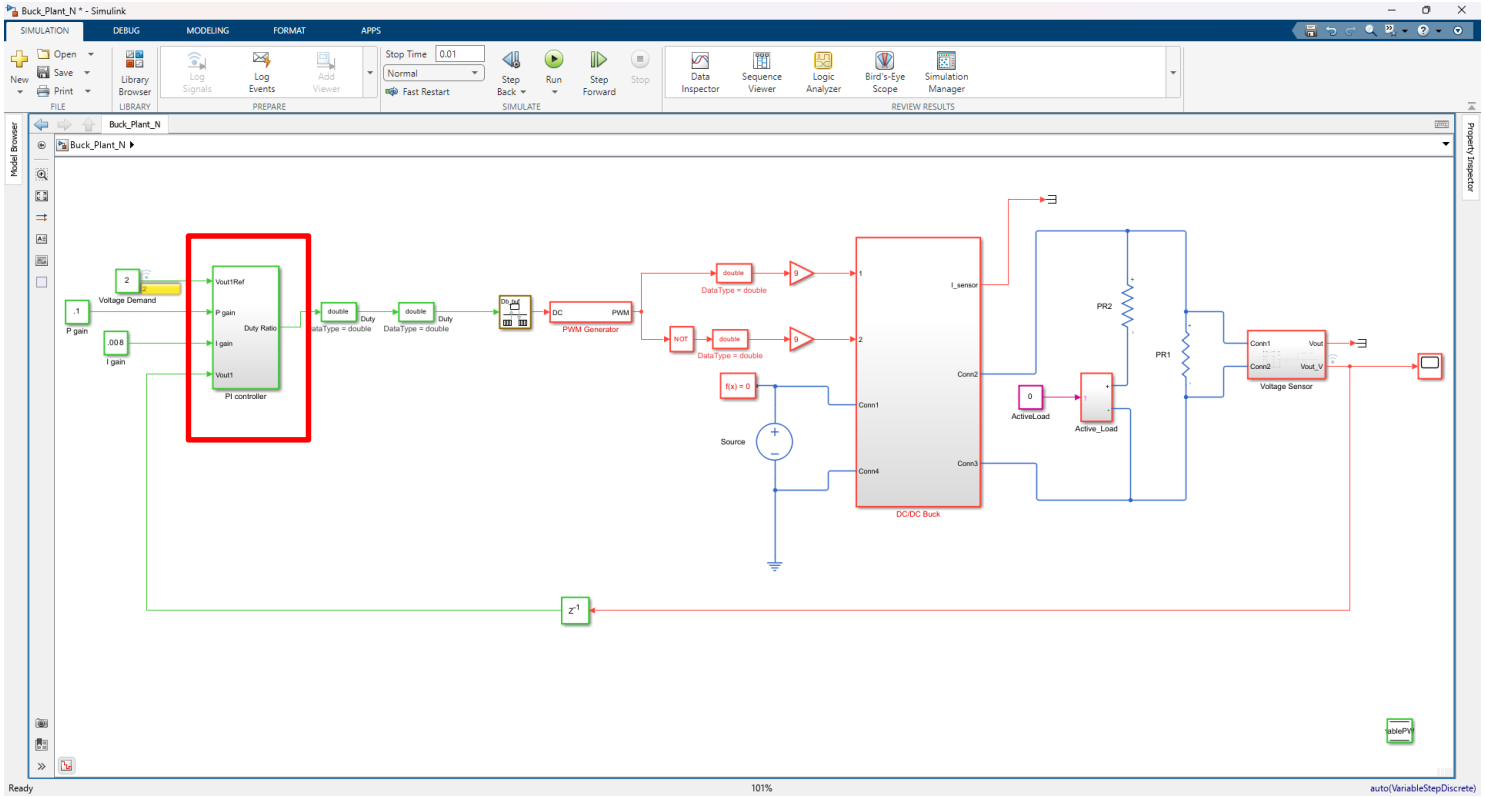
Step 1: Modeling Buck Converter using Simscape & Simulink



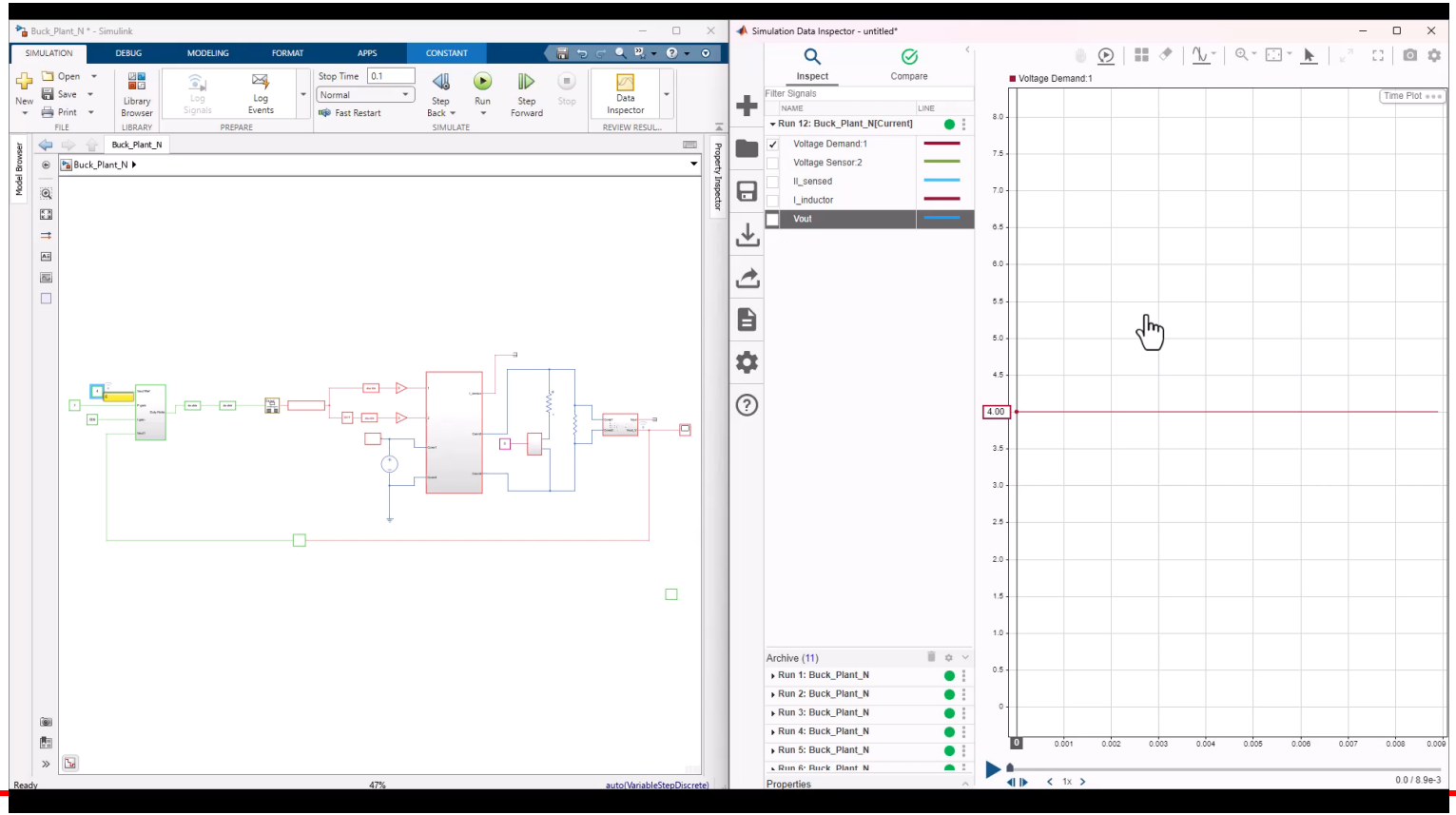
Step 1: Modeling Buck Converter Plant using Simscape & Simulink



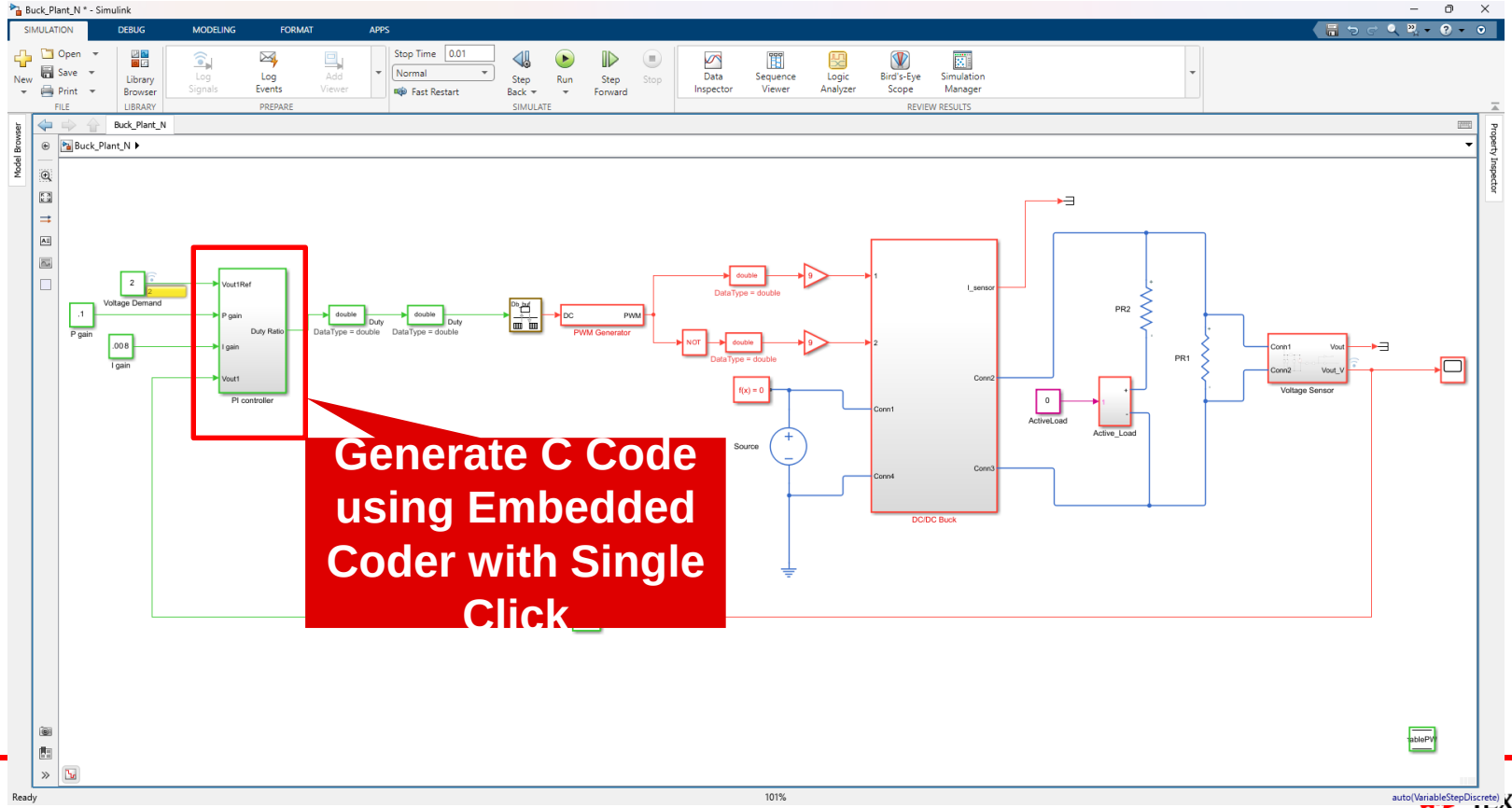
Step 2: Simulate Control Algorithm with Buck Plant model



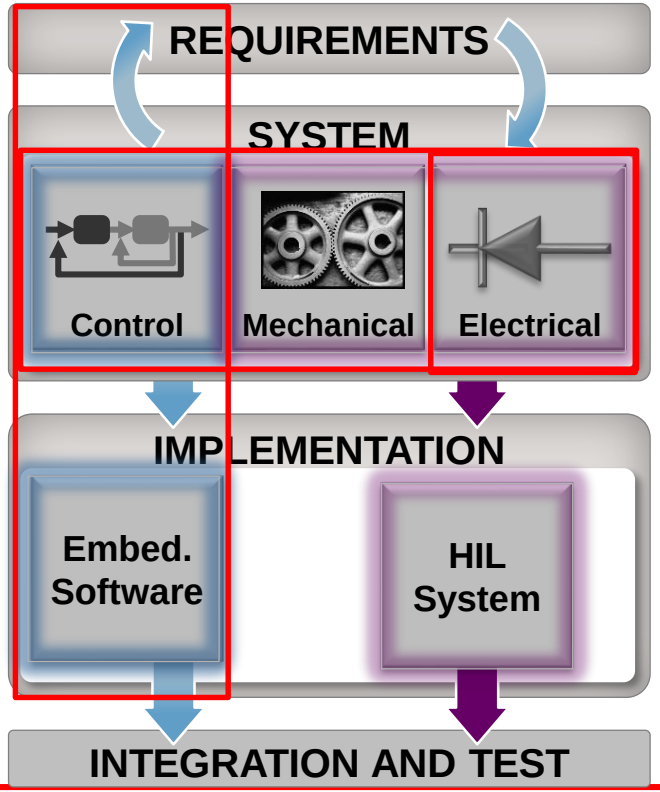
Step 3: Visualize simulation results



Step 4: Simulate Control Algorithm with Buck Plant model

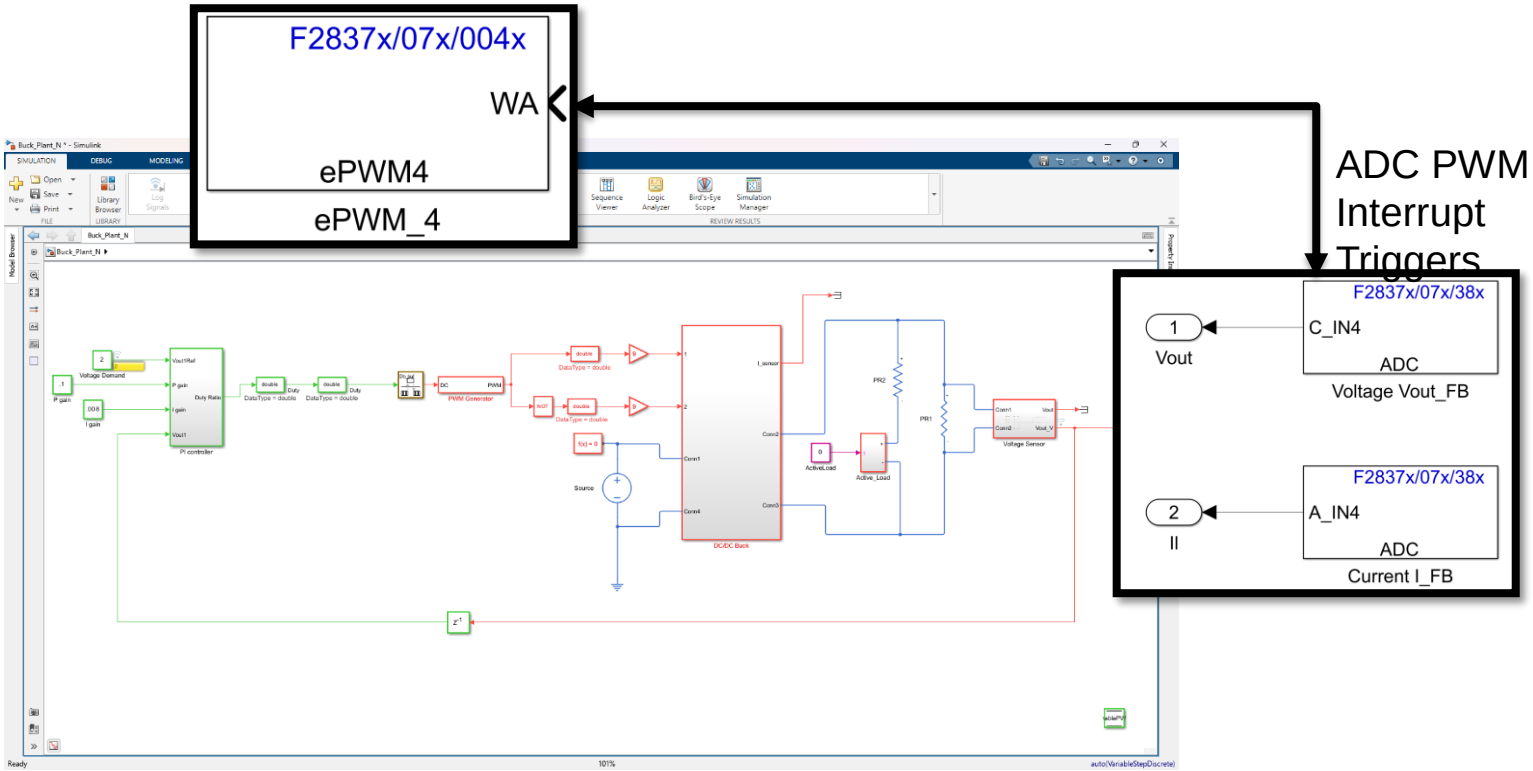


Model Based Design for Embedded Firmware Development

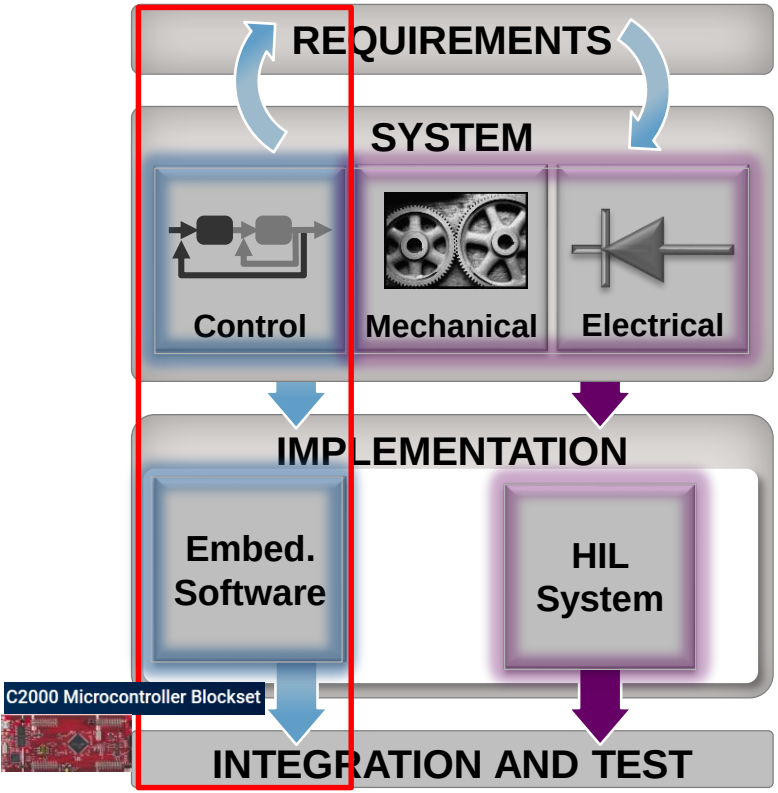


- Model & Simulate the **Plant (DC-DC Converter)**
- Model & Simulate the **Control Algorithm**
- Generate algorithm code for controller
- Integrate driver code manually

Step 4: Use MCU device driver blocks for code generation



Add hardware peripheral driver blocks from C2000 Microcontroller Blockset



- Model & Simulate the **Plant**
- Model & Simulate the **Control Algorithm**

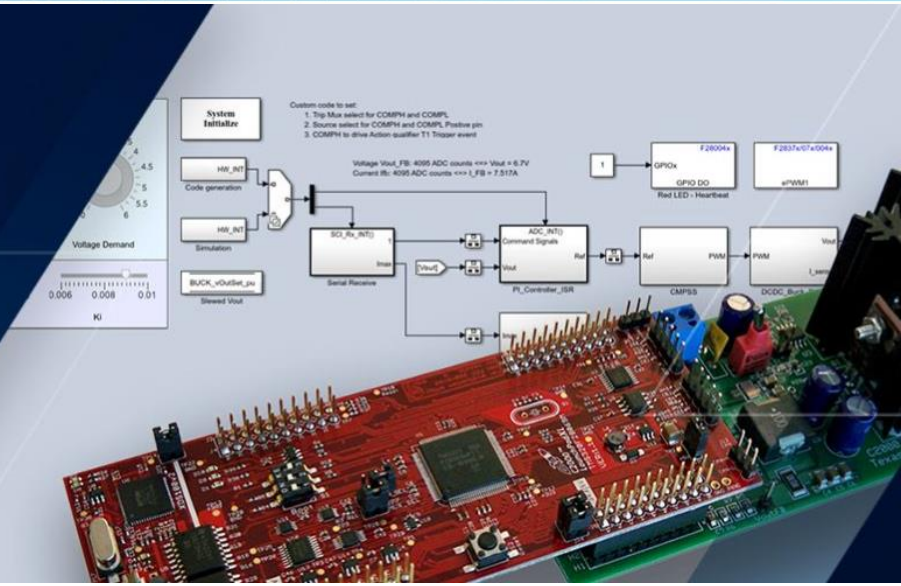
- **Add driver blocks from C2000 Blockset to the model**

- **Generate code with device drivers**

- **No Manual Code integration needed to test the code on hardware**

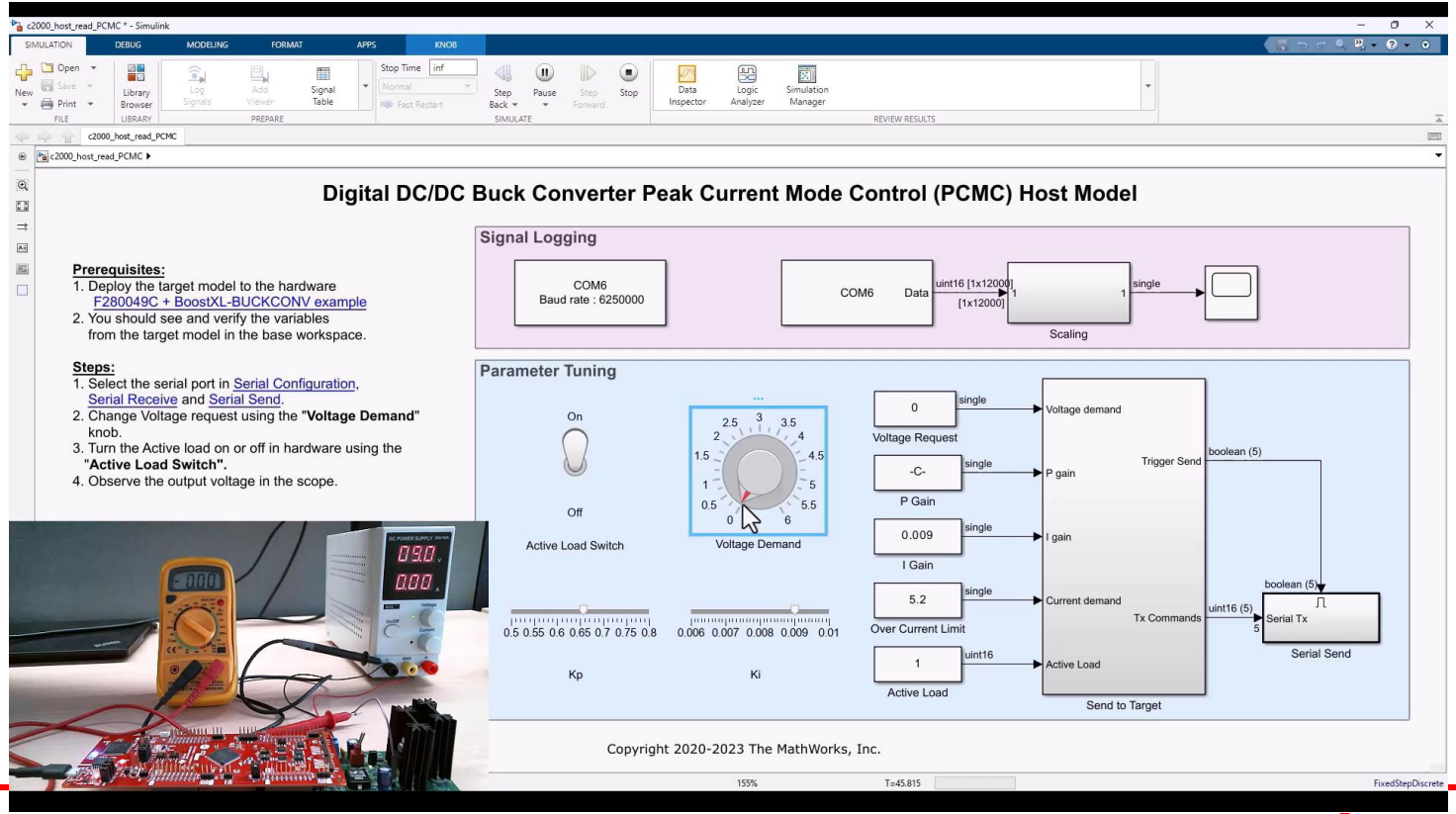
C2000 Microcontroller Blockset

Design, simulate, and implement applications for Texas Instruments C2000 microcontrollers



MathWorks

Controlling a DC-DC converter hardware using C2000 MCU from Simulink Model-based design



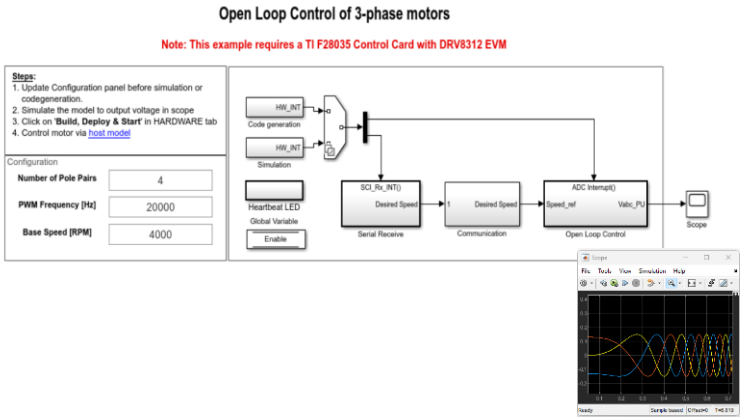
MathWorks

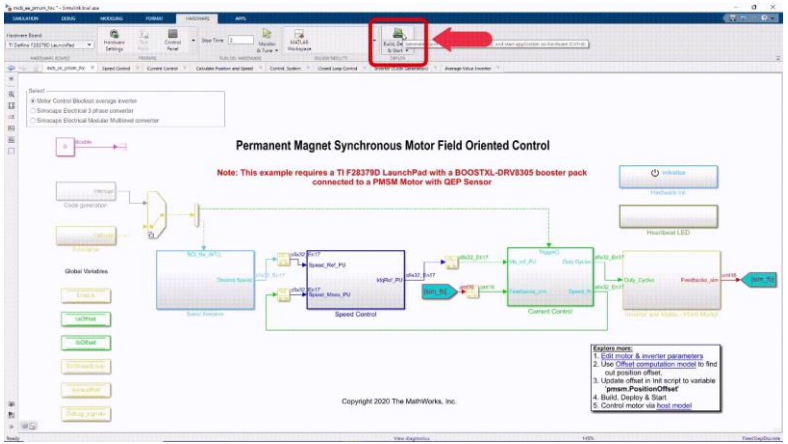
Texas Instruments

What is C2000 Microcontroller Blockset?

Design, simulate and implement applications for TI C2000 MCUs

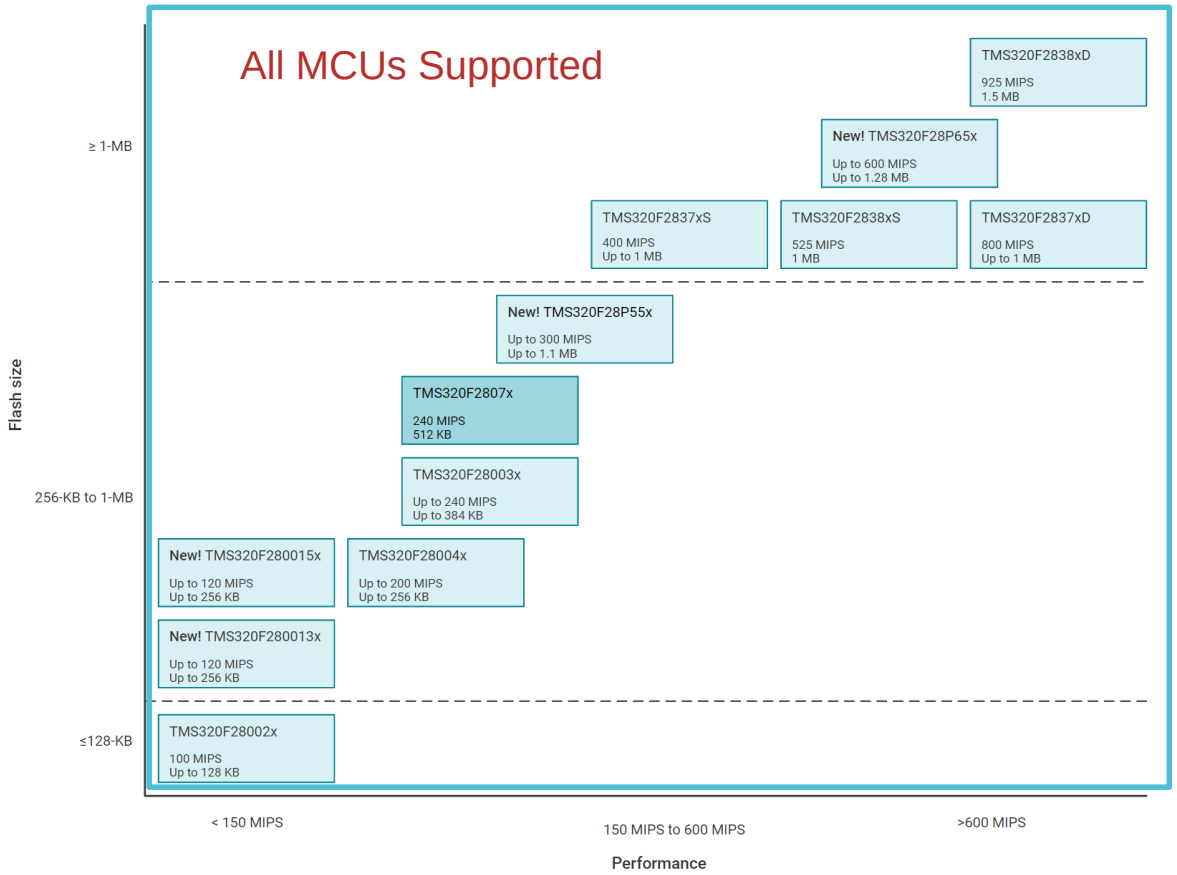
Design **Simulate** **Implement**





MathWorks

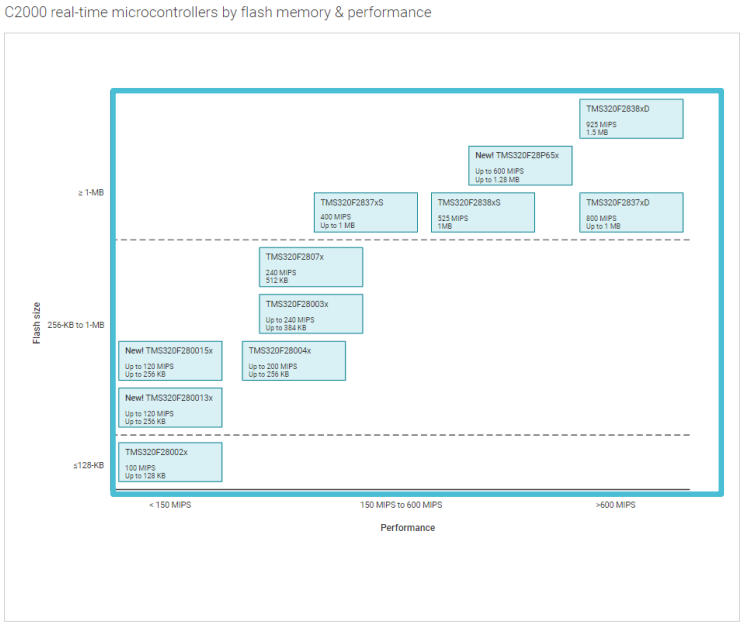
Texas Instruments

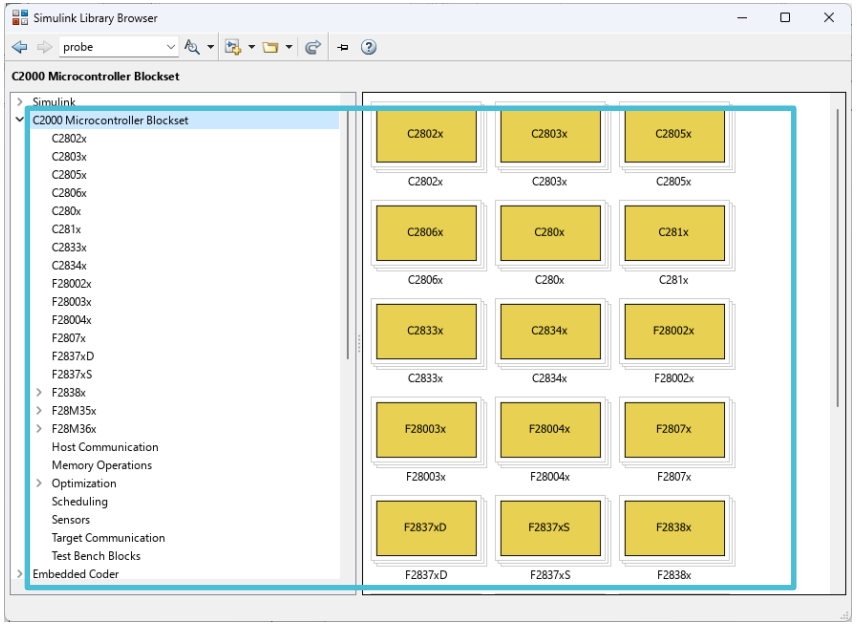


Legacy C2000 MCUs supported:

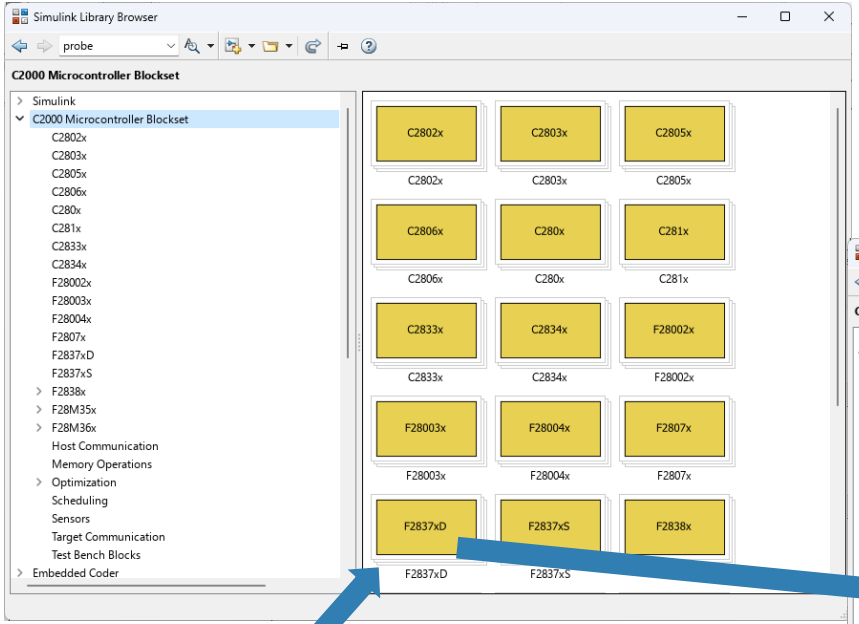
- TI C2000 Gen 2:
  - F2806x
  - F2805x
  - F2803x
  - F2833x
  - F281x
  - F280x
- TI C2000 Concerto:
  - F28M35x
  - F28M36x

C2000 Microcontroller Blockset





Hardware Block Libraries

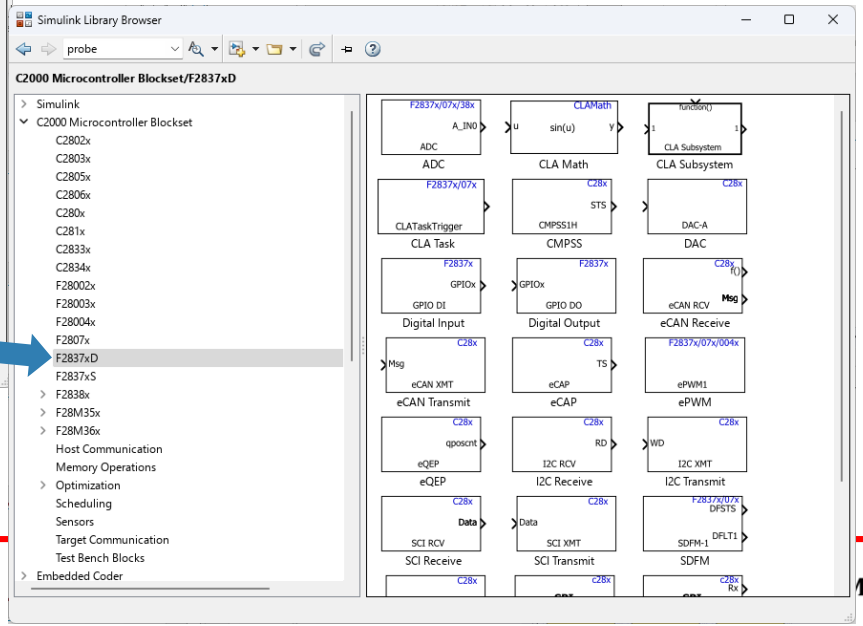


TMS320F2837xD

800 MIPS
Up to 1 MB

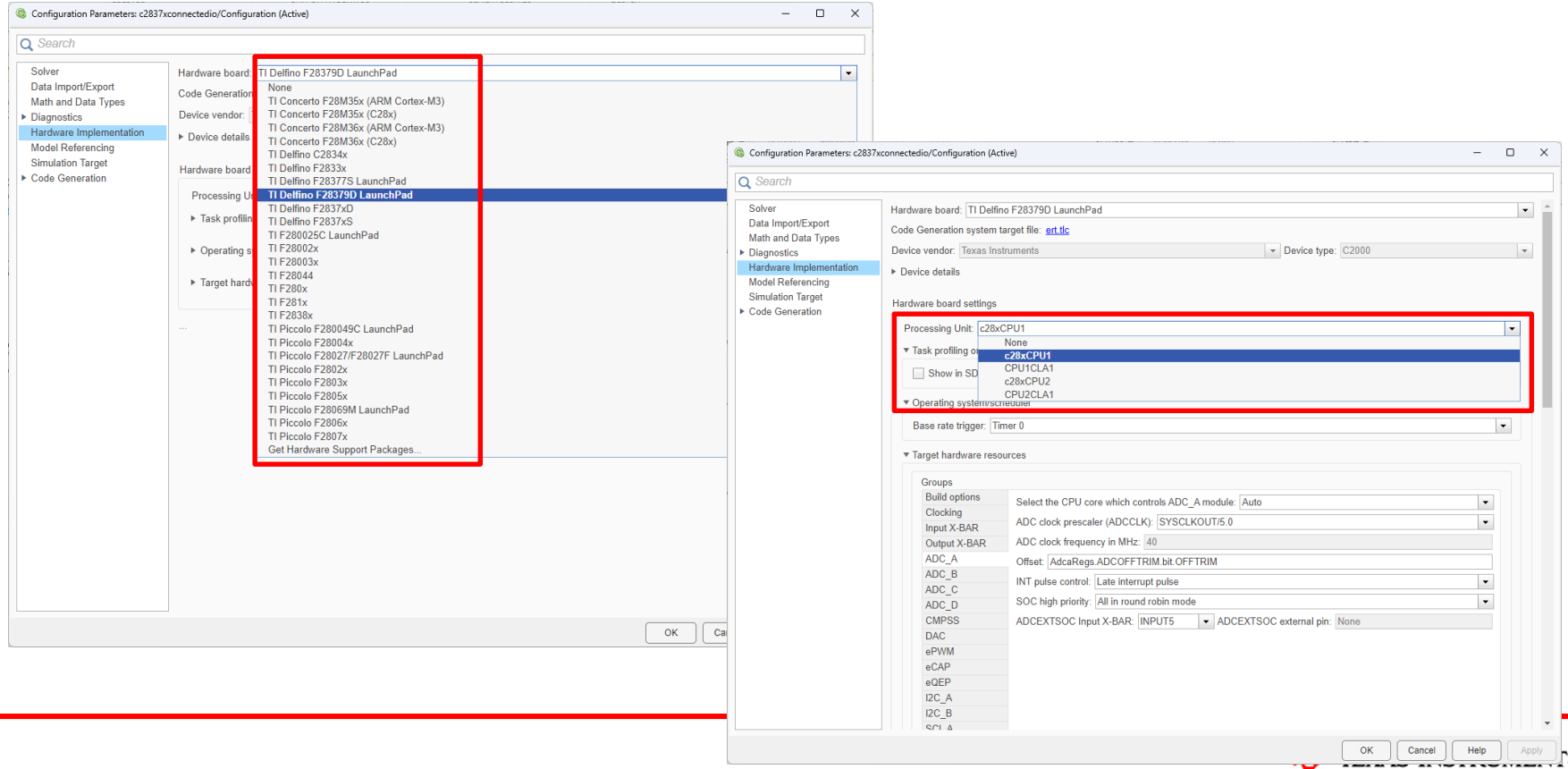
C2000 Microcontrollers

Microcontroller Specific Peripheral Blocks

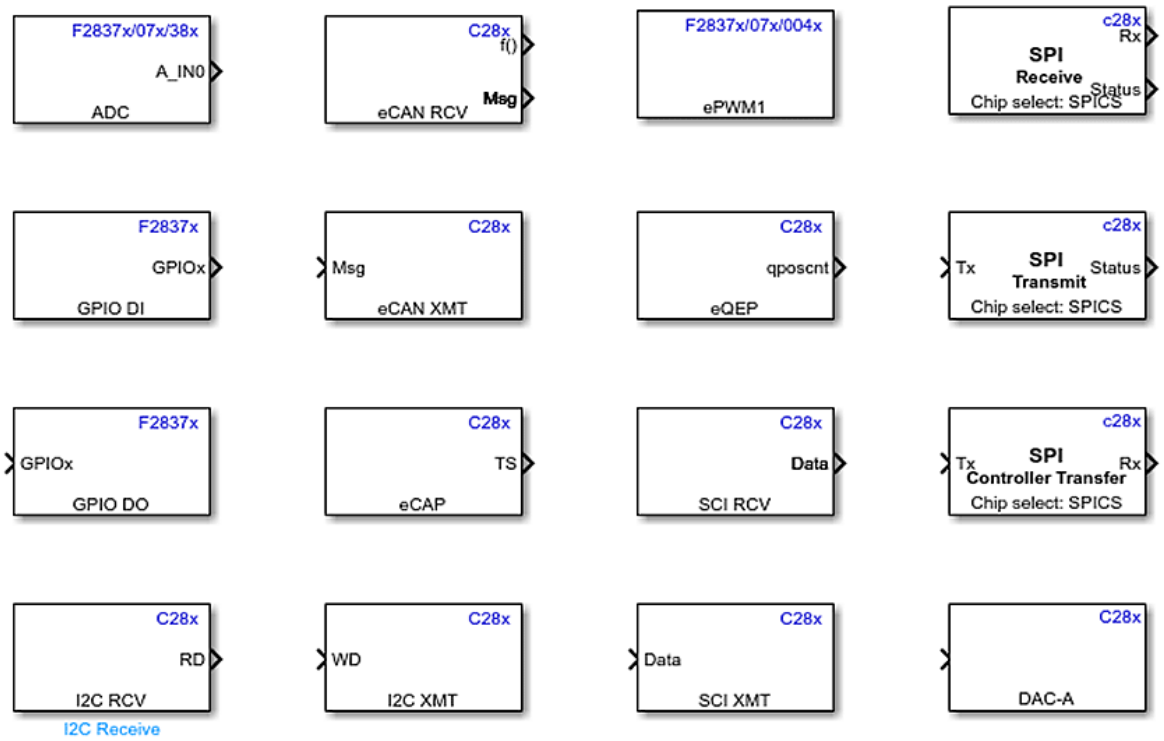


MathWorks

Target code generation to specific C2000 MCU and specific CPU

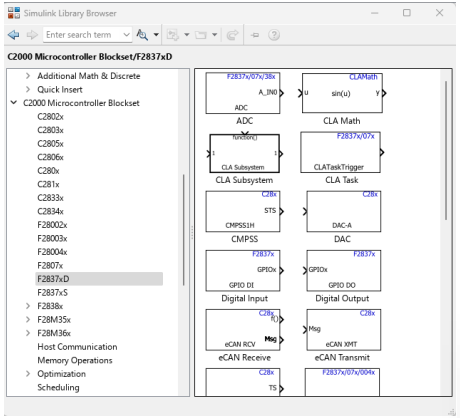


Extensive block library for TI C2000 Drivers

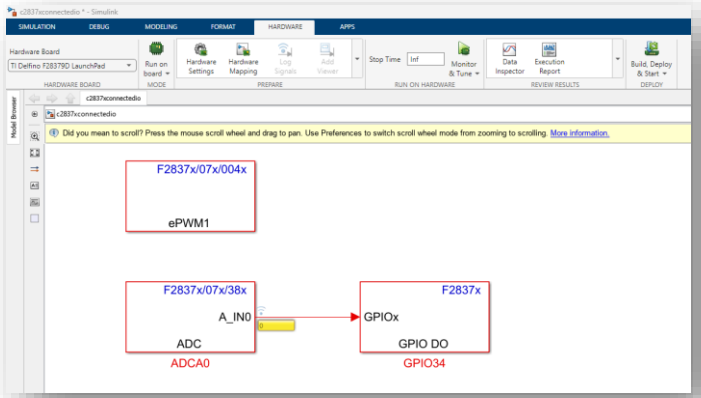


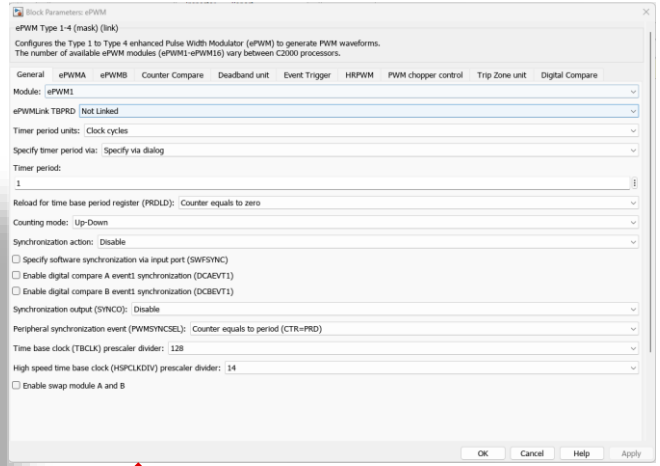
- ADC, Digital IO
- eCAP, ePWM, eQEP
- DAC, I2C, SCI, SPI, UART
- Watchdog, DMA
- eCAN, LIN
- Software and Hardware Interrupt
- CLA, CMPSS
- SDFM
- Memory Allocate & Copy
- Iqmath, Register Read & Write

Peripheral Block Library



Drag and drop Peripheral Blocks

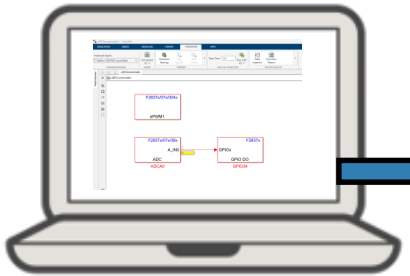




Configure Peripheral Blocks

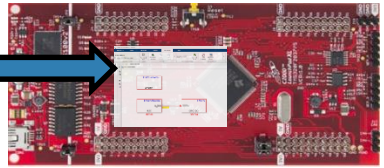
On-Target Prototyping helps reduce development time significantly

C2000 Microcontroller Blockset



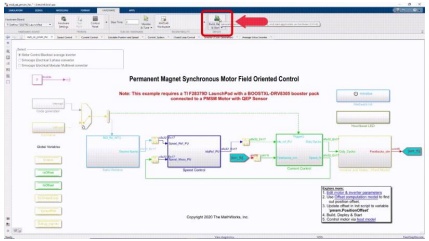
Enables you to model Embedded Control Applications using Hardware Peripheral Blocks

Target Hardware runs the model



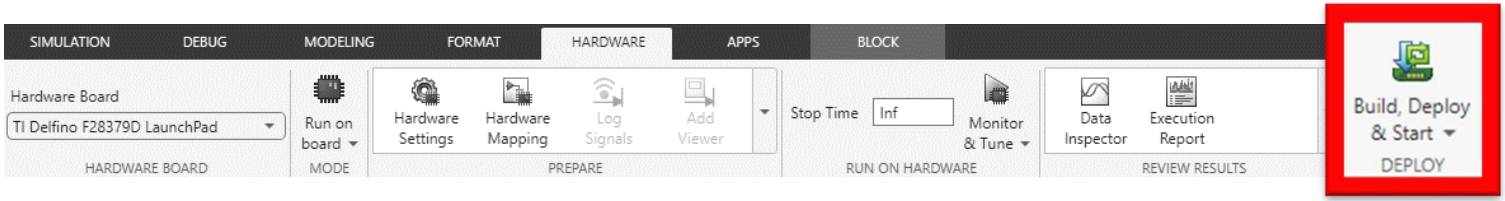
TI C2000 Launchpad

Embedded Applications



Embedded Developers can iterate significantly faster using the Blockset

Build, Deploy & Start

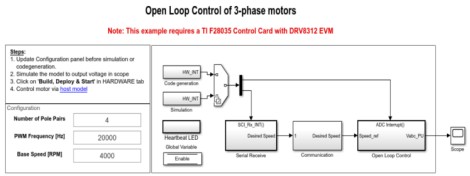


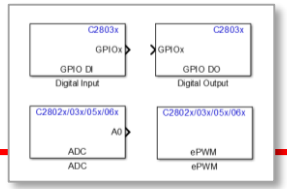
Simulink Model

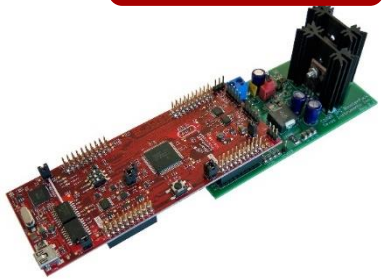
C2000 Blockset + Embedded Coder

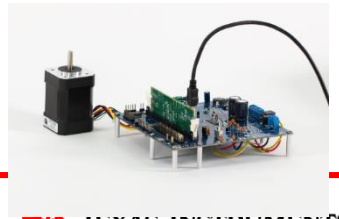
CCS Project

Run on C2000





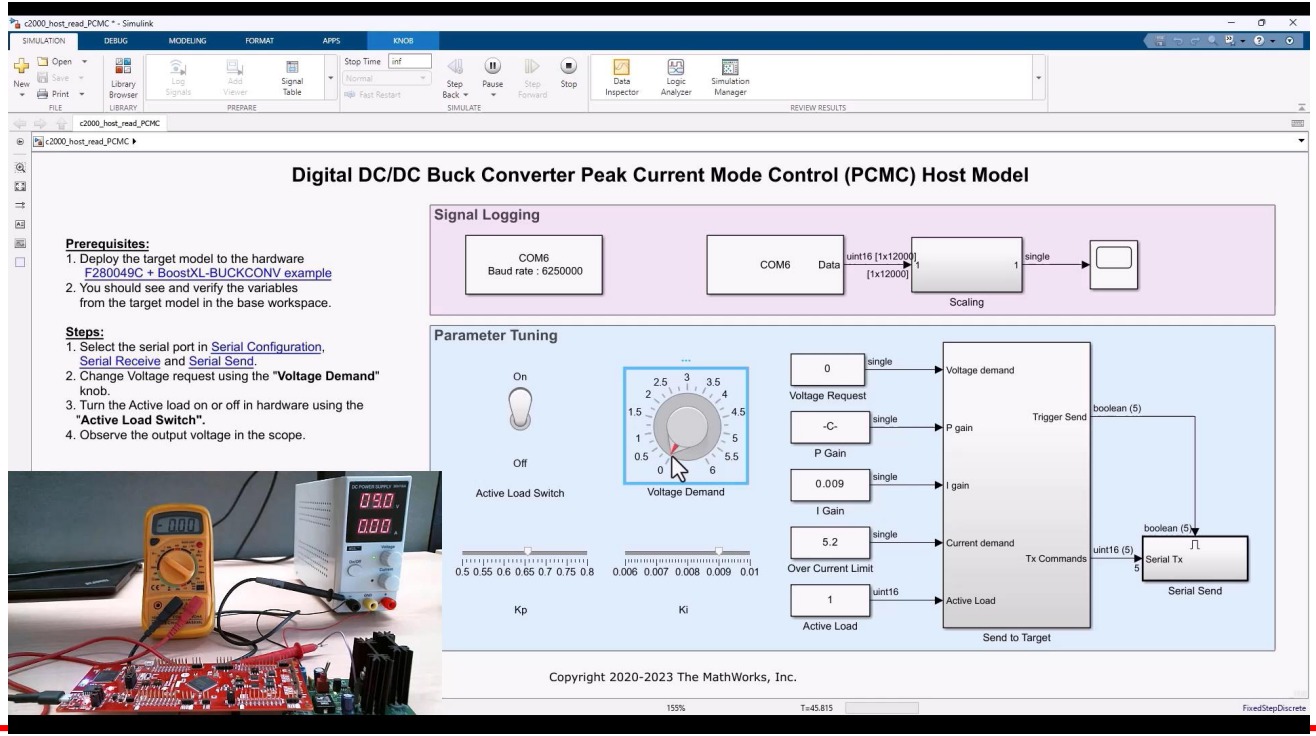




MathWorks

TEXAS INSTRUMENTS

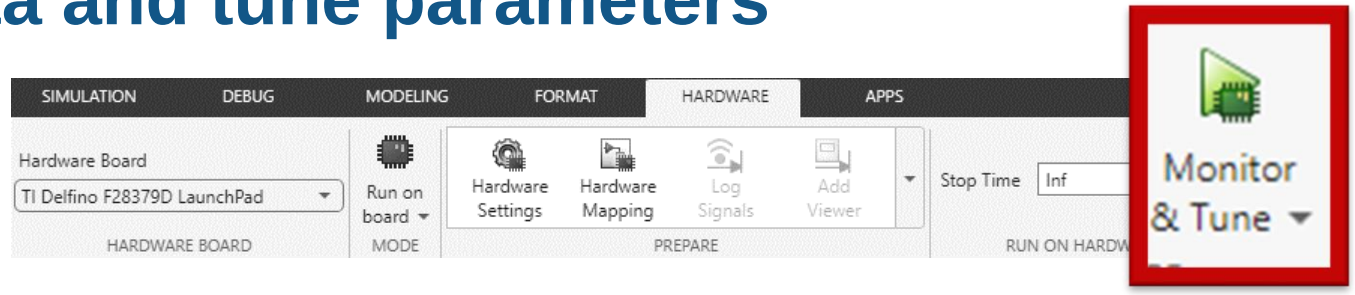
Controlling a buck converter hardware using C2000 MCU from Simulink Model-based design

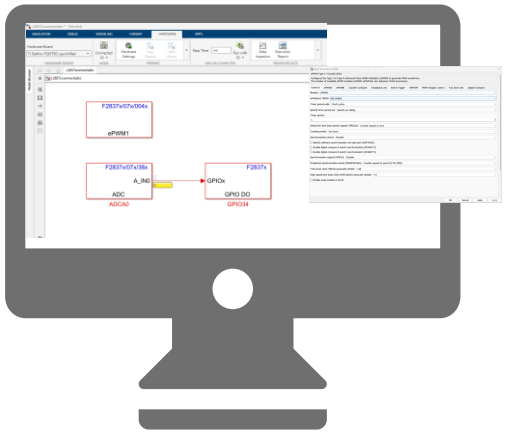


MathWorks

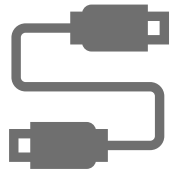
Texas Instruments

Debugging using Monitor and tune: Log signal data and tune parameters

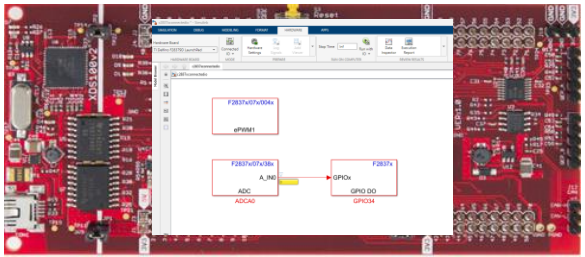




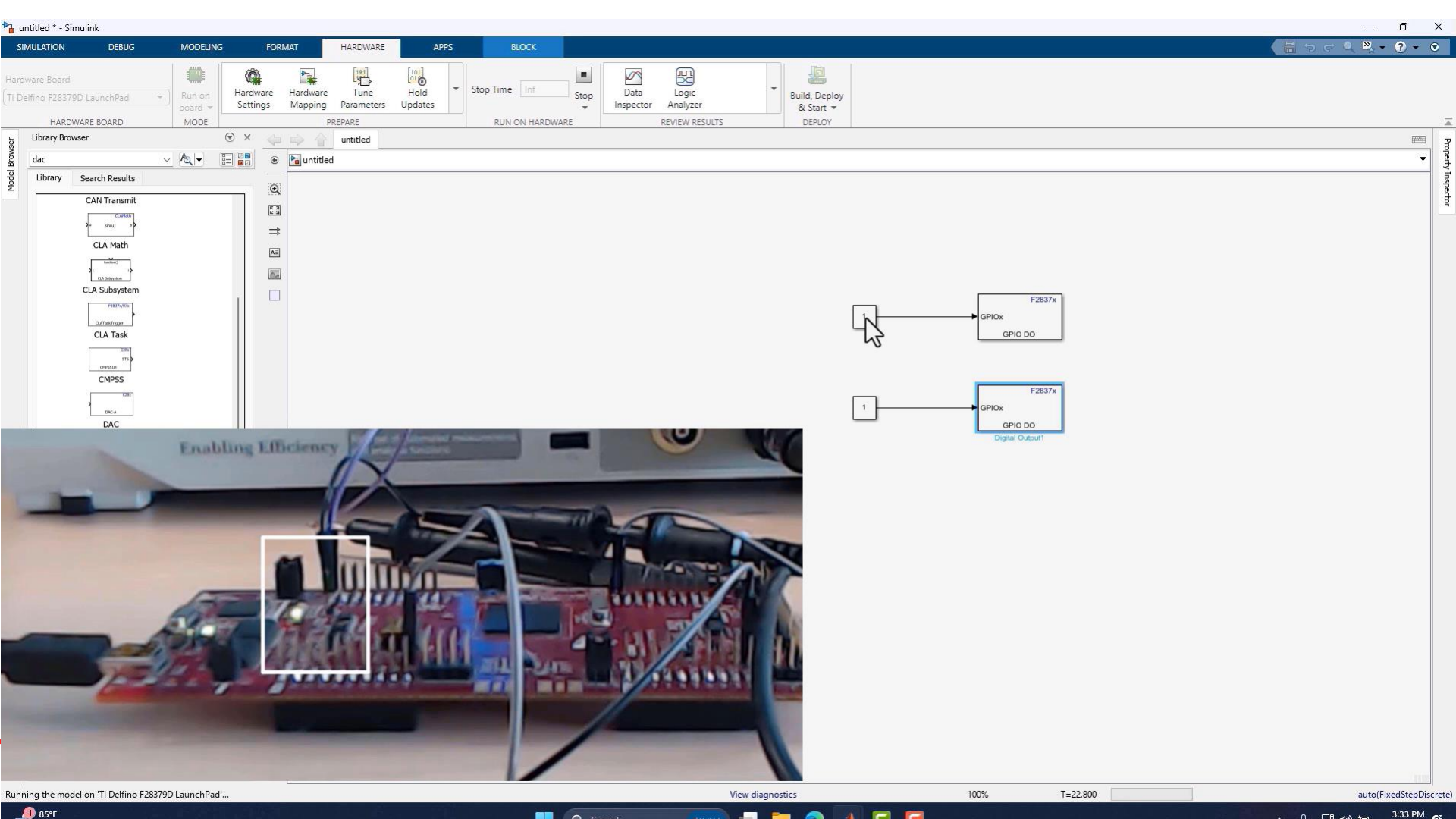
Simulink Model

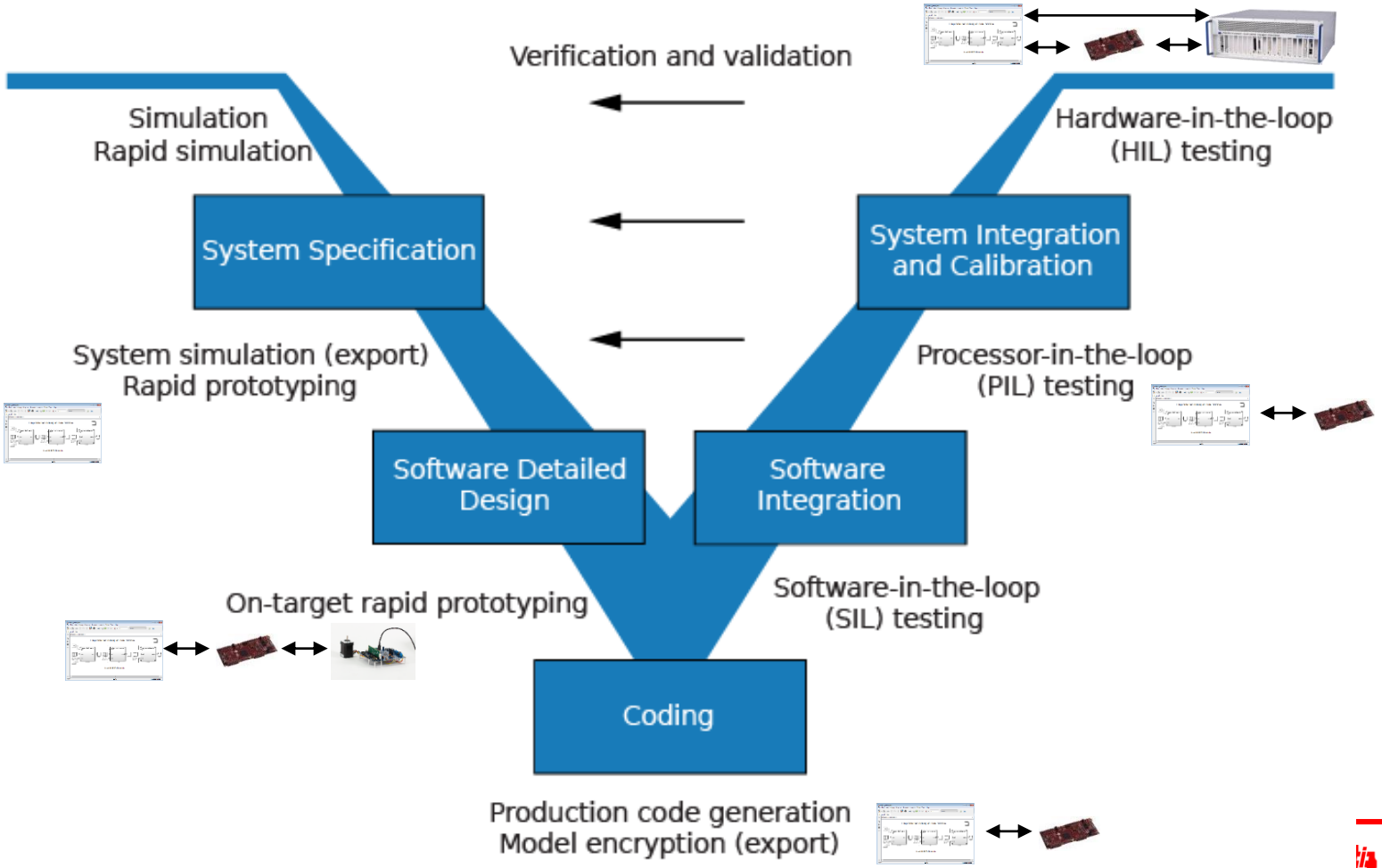


Data Exchange over
XCP over Serial,
TCP I/P and CAN



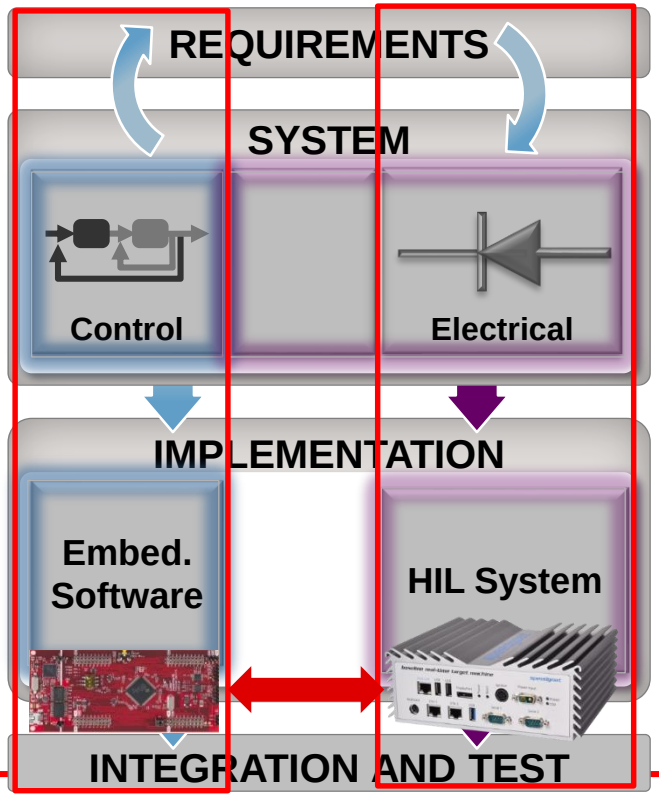
Model running on hardware with additional code


untitled * - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
HARDWARE
APPS
BLOCK
Hardware Board
TI Delfino F28379D LaunchPad
HARDWARE BOARD
Run on board
MODE
Hardware Settings
Hardware Mapping
Tune Parameters
Hold Updates
PREPARE
Stop Time
Inf
Stop
RUN ON HARDWARE
Data Inspector
Logic Analyzer
REVIEW RESULTS
Build, Deploy & Start
DEPLOY
Model Browser
Library Browser
dac
Library
Search Results
CAN Transmit
CLA Math
CLA Subsystem
CLA Task
CMPSS
DAC
untitled
F2837x
GPIOx
GPIO DO
Digital Output1
Property Inspector
Running the model on 'TI Delfino F28379D LaunchPad'...
View diagnostics
100%
T=22.800
auto(FixedStepDiscrete)
85°F
3:33 PM

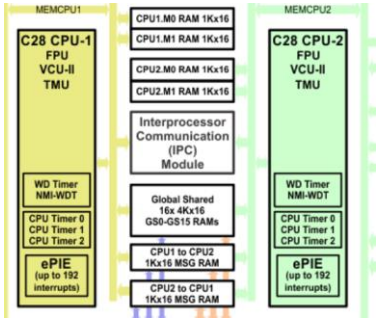

Verification and validation
Simulation
Rapid simulation
Hardware-in-the-loop
(HIL) testing
System Specification
System Integration
and Calibration
System simulation (export)
Rapid prototyping
Processor-in-the-loop
(PIL) testing
Software Detailed
Design
Software
Integration
On-target rapid prototyping
Software-in-the-loop
(SIL) testing
Coding
Production code generation
Model encryption (export)

Using Hardware in the loop simulation

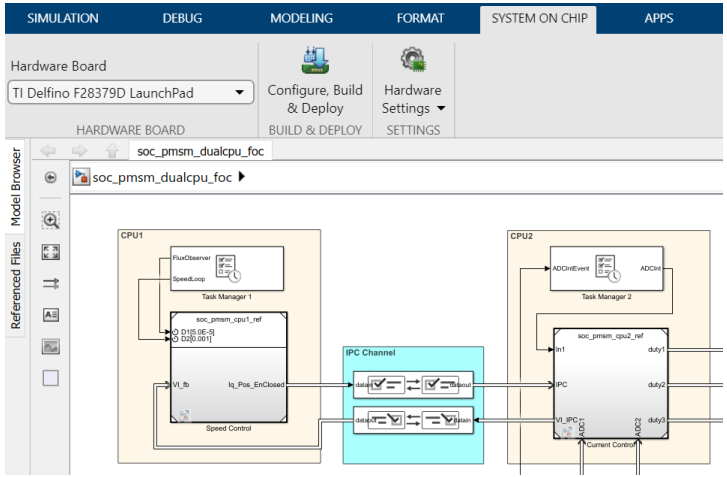
C2000 Control Card adaptors as to interact with Real-time hardware like SpeedGoat



Multi-Core Modeling using C2000 Microcontroller Blockset



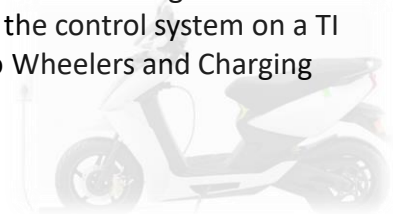
Dual-Core Architecture
(F28379D)



Dual-Core MCU
(F28379D)

Customer Success Stories

Ather Energy Developed used model-based design with Simulink to model, simulate, and implement the control system on a TI C2000 MCU to develop Electric Two Wheelers and Charging stations



Results

- **50% reduction** in testing time
- Design alternatives evaluated in **weeks**, not months
- Field issues rapidly resolved

Link to user story

Hutchinson improved C code performance for Anti-Vibration Control systems on **TI C2000 controller** using Processor In Loop **(PIL) tests**

Results

- **Reduced CPU load** by **46%**
- **Code Optimization** options tried out quickly
- Fast iterations of PIL testing

Link to user story

Customer Success Stories

ATB Technologies used model-based design with Simulink to model, simulate, and implement the control system on a TI C2000 MCU for a **permanent magnet synchronous motor**

Results

- **50% reduction** in development time
- Design reviews **simplified**
- Target verification and deployment **accelerated**

Link to user story

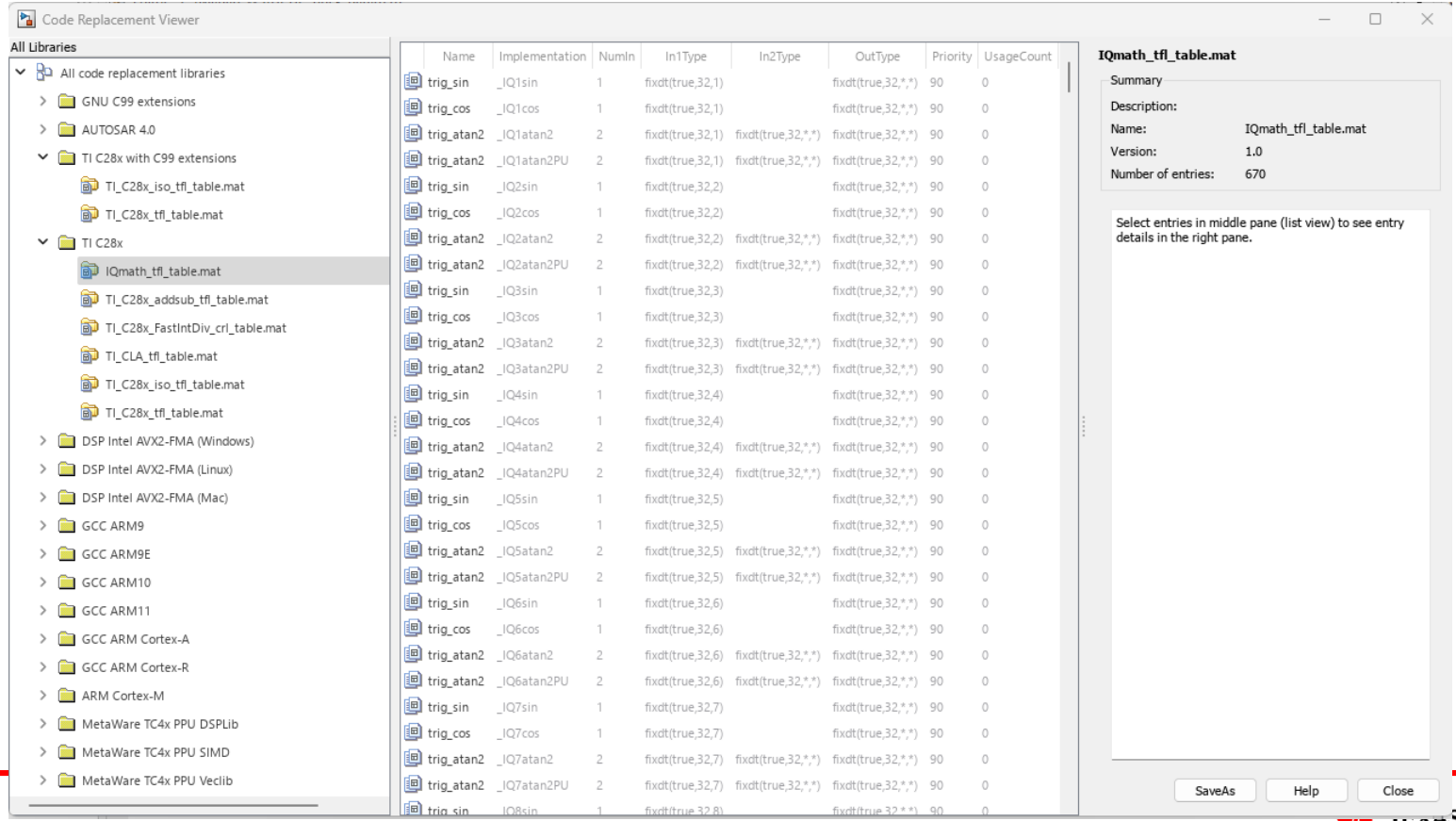
Murata used model-based design with Simulink to model the EMS **controller and power electronics**, run simulations, and generate production code implemented on Piccolo™ and Delfino™ 32-bit microcontrollers made by TI

Results

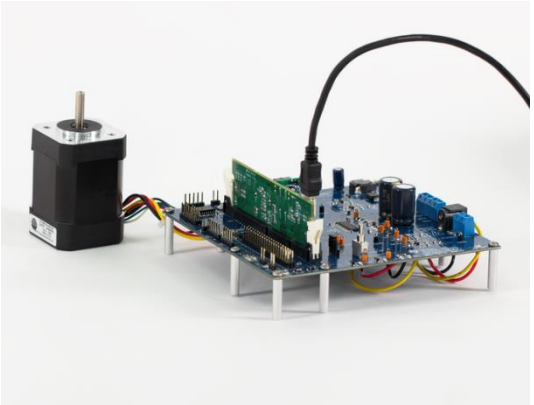
- Control software development **time reduced by more than 50%**
- **Defect-free** code generated
- Project ramp-up time shortened

Link to user story

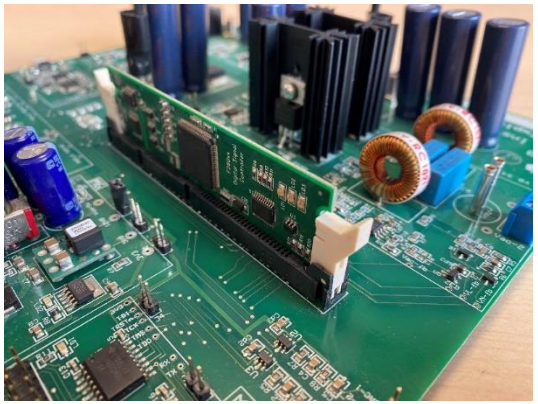
Generated code is optimized for C28x core with CRLs



Reference Example to get started with

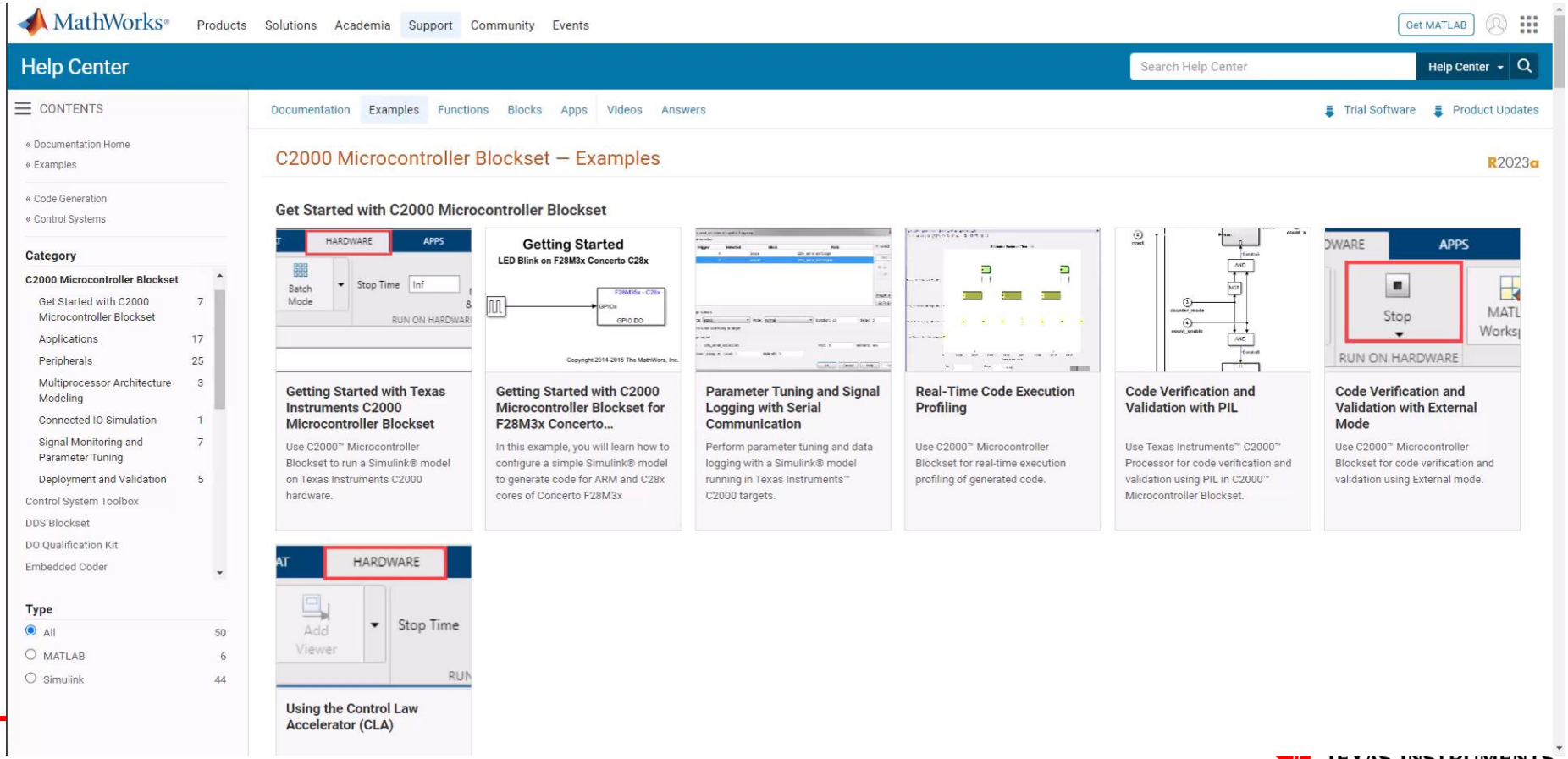


Motor Control
with Motor Control Blockset



Power Conversion
with Simscape Electrical

and more…

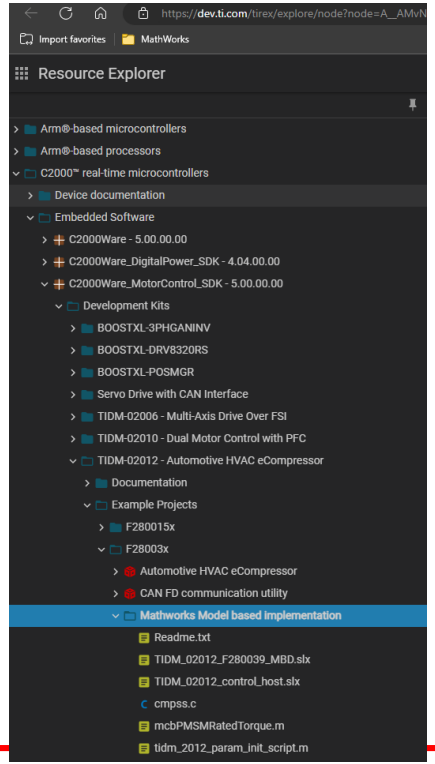

MathWorks
Products
Solutions
Academia
Support
Community
Events
Get MATLAB
Help Center
Search Help Center
Help Center
CONTENTS
« Documentation Home
« Examples
« Code Generation
« Control Systems
Category
C2000 Microcontroller Blockset
Get Started with C2000 Microcontroller Blockset 7
Applications 17
Peripherals 25
Multiprocessor Architecture Modeling 3
Connected IO Simulation 1
Signal Monitoring and Parameter Tuning 7
Deployment and Validation 5
Control System Toolbox
DDS Blockset
DO Qualification Kit
Embedded Coder
Type
All 50
MATLAB 6
Simulink 44
Documentation
Examples
Functions
Blocks
Apps
Videos
Answers
Trial Software
Product Updates
C2000 Microcontroller Blockset — Examples
R2023a
Get Started with C2000 Microcontroller Blockset
HARDWARE
APPS
Batch Mode
Stop Time
Inf
RUN ON HARDWARE
Getting Started with Texas Instruments C2000 Microcontroller Blockset
Use C2000™ Microcontroller Blockset to run a Simulink® model on Texas Instruments C2000 hardware.
Getting Started
LED Blink on F28M3x Concerto C28x
Copyright 2014-2015 The MathWorks, Inc.
Getting Started with C2000 Microcontroller Blockset for F28M3x Concerto...
In this example, you will learn how to configure a simple Simulink® model to generate code for ARM and C28x cores of Concerto F28M3x
Parameter Tuning and Signal Logging with Serial Communication
Perform parameter tuning and data logging with a Simulink® model running in Texas Instruments™ C2000 targets.
Real-Time Code Execution Profiling
Use C2000™ Microcontroller Blockset for real-time execution profiling of generated code.
Code Verification and Validation with PIL
Use Texas Instruments™ C2000™ Processor for code verification and validation using PIL in C2000™ Microcontroller Blockset.
APPS
Stop
RUN ON HARDWARE
Code Verification and Validation with External Mode
Use C2000™ Microcontroller Blockset for code verification and validation using External mode.
HARDWARE
Add Viewer
Stop Time
Using the Control Law Accelerator (CLA)

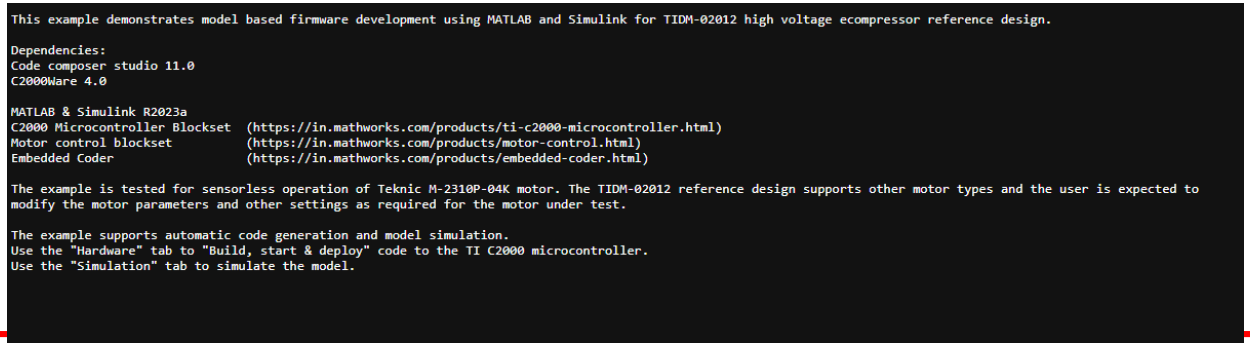
On-demand webinars available on MathWorks.com

Power Conversion Webinar

Motor Control Webinar

TI Reference Design in Simulink Models in C2000Ware_MotorControl_SDK





Ref Link: C2000WARE-MOTORCONTROL-SDK Software development kit (SDK) | TI.com

MathWorks

Texas Instruments

Summary

- Model based design overview
- Model based design for Embedded Software Development using Automatic code generation – (DC-DC Buck converter example)
- Using C2000 Microcontroller Blockset to deploy algorithms on the C2000 MCUs directly
- Model-based reference design example for eCompressor motor control running on C2000 MCU
- For more details:

  Contact:

  - Jayakarthigeyan Prabakar – Product Manager for C2000 Microcontroller Blockset
  - jprabaka@mathworks.com

Thank you

Q&A

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265