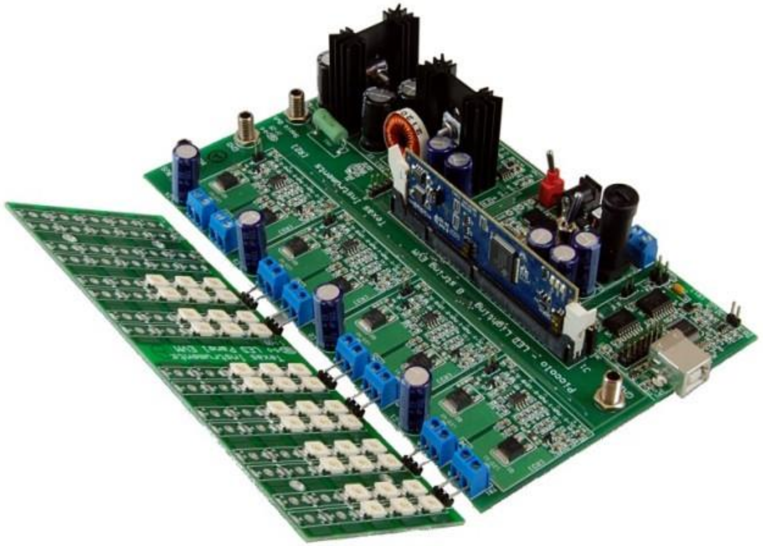
Developing DC-DC Converter Control with Simulink



Vasco Lenzi
Senior Application Engineer

Key Takeaways

- Graphical programming across our solutions is **intuitive** and **powerful**
- State-of-the-art technologies facilitate the **design** and **verification** of complex systems developed by **multidisciplinary teams**
- Find design errors **early** and cut down development **cost** while increasing delivered **quality**.

Our Project Today

DC/DC LED Developer's Kit

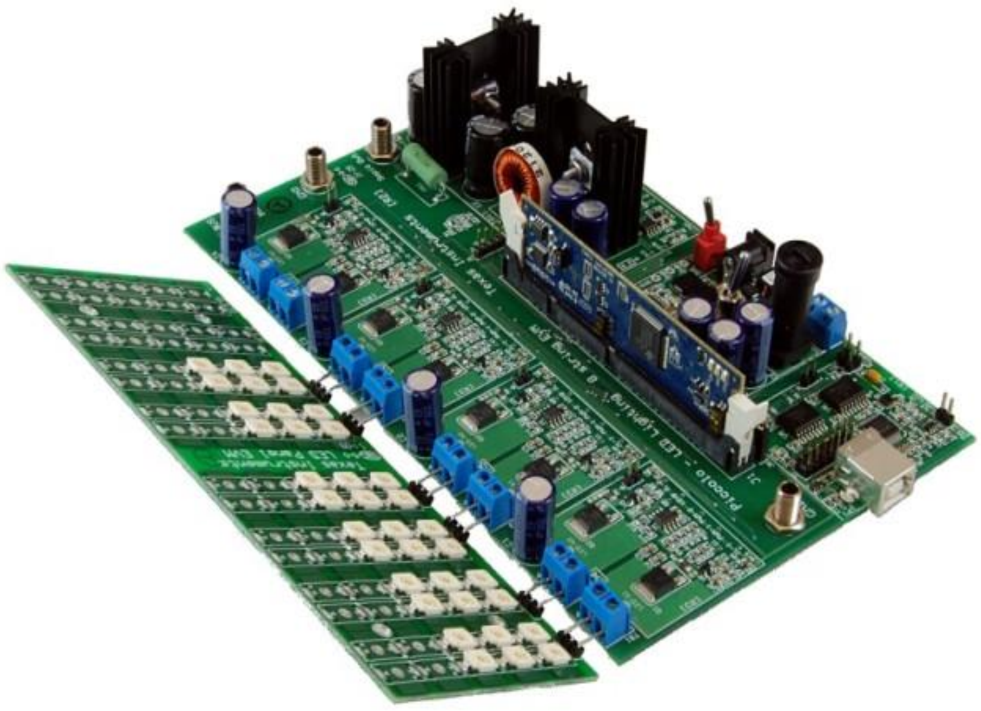


Fig 1: TMDSDCDCLEDKIT

LED Head Lamp

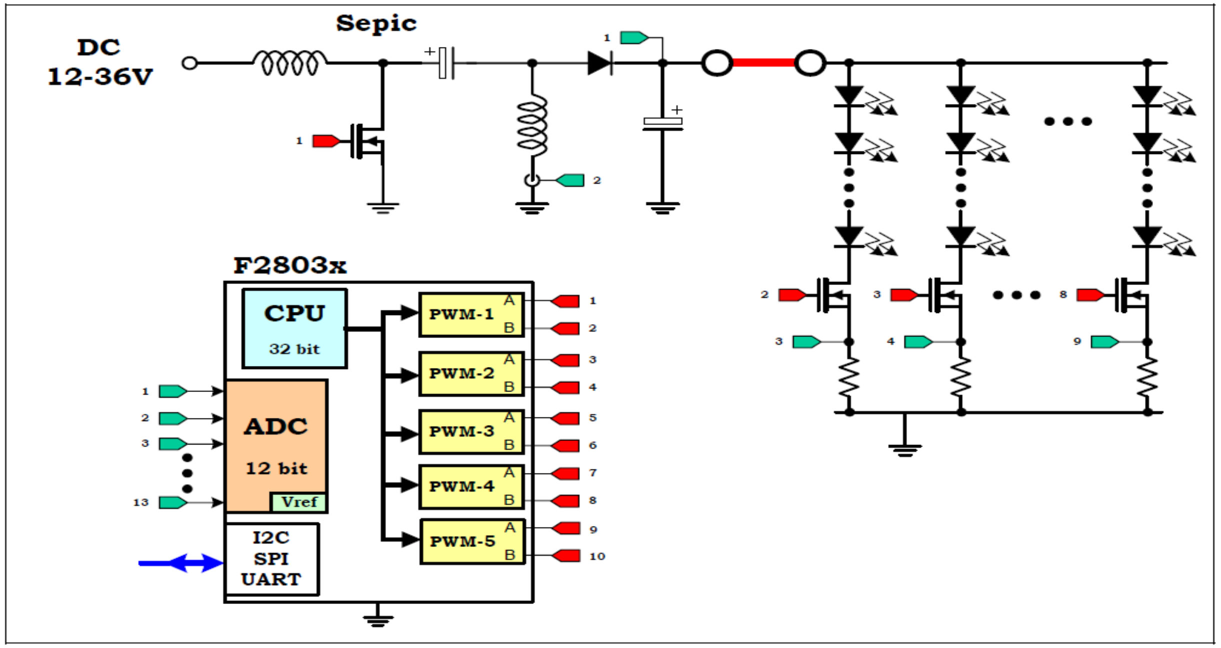


Fig4: DC/DC LED Lighting Board Block diagram with F28035

ZKW Lichtsysteme GmbH

Rapid Control Prototyping with Simulink Real-Time and Speedgoat:

- Design control algorithms for an innovative LED headlamp projection technology changing its illumination dynamically
- Seamless integration into MathWorks Tools
- Faster time to market

"Model-based design itself has proven to be very flexible, powerful and efficient for our purposes. Using the Mobile real-time target machine from Speedgoat, we were able to completely redesign a functional prototype based on a model and verify it during an afternoon session."

- Matthaeus Artmann, Manager Electronics Engineering Pre- and Module Development, ZKW Lichtsysteme GmbH

ZKW

[Official Speedgoat User Story](https://www.youtube.com/watch?v=wAk9e5w0dSg)

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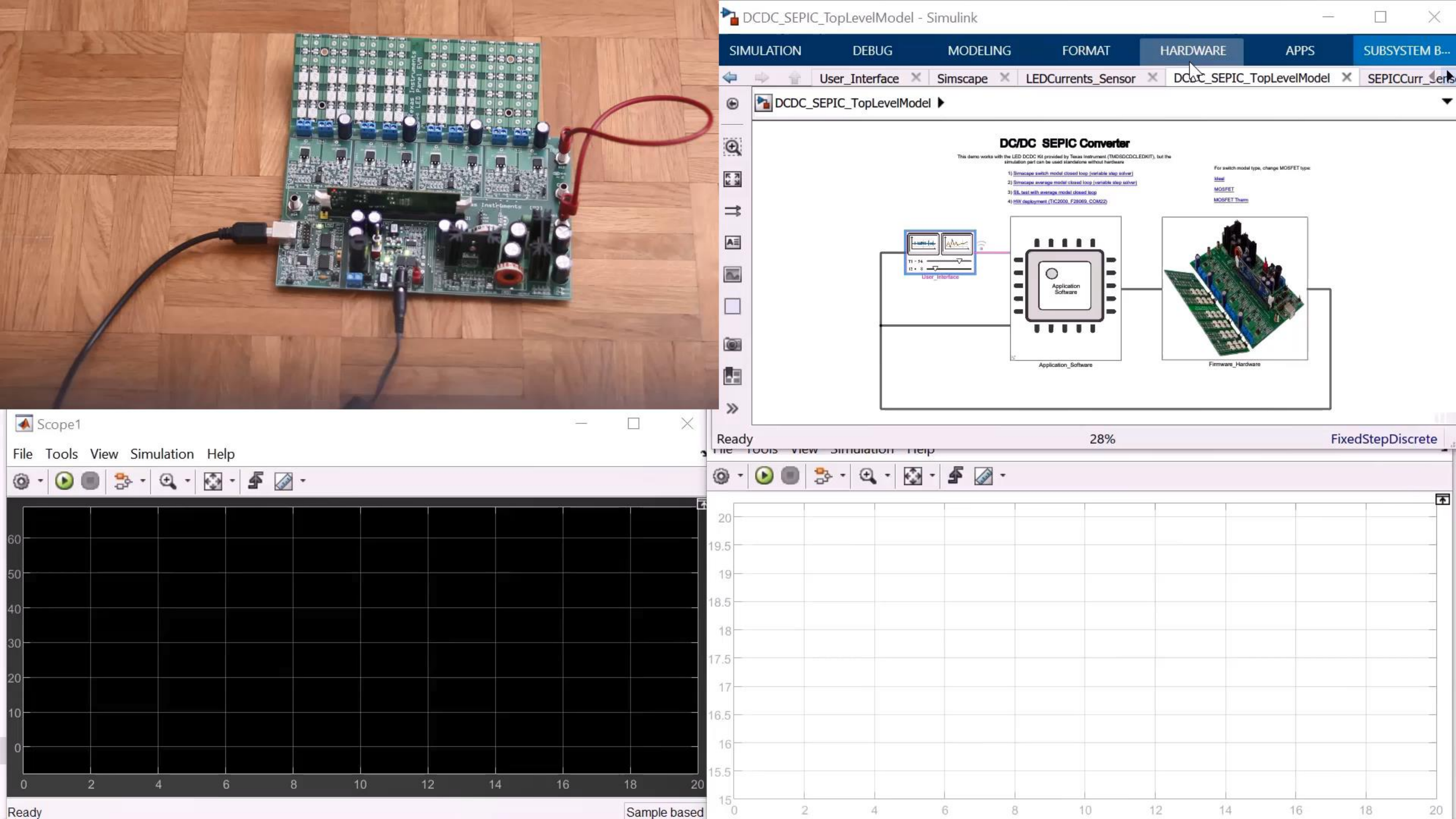
Developing DC-DC Converter Control with Simulink

- Model the converter and calculate the most efficient operating region
- Determine power losses and the thermal behaviour of the converter
- Design control algorithm based on time/frequency domain specification
- Design supervisory logic and implement unit testing
- Implement power electronic controls on an embedded platform


DCDC_SEPIC_TopLevelModel - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
HARDWARE
APPS
SUBSYSTEM B...
User_Interface
Simscape
LEDCurrents_Sensor
DCDC_SEPIC_TopLevelModel
DCDC_SEPIC_TopLevelModel
DC/DC SEPIC Converter
This demo works with the LED DCDC Kit provided by Texas Instrument (TMDSDCDCLEDKIT), but the simulation part can be used standalone without hardware
1) Simscape switch model closed loop (variable step solver)
2) Simscape average model closed loop (variable step solver)
3) SIL test with average model closed loop
4) HW deployment (TIC2000, F28069, COM22)
For switch model type, change MOSFET type:
Ideal
MOSFET
MOSFET Therm
User_Interface
Application Software
Application_Software
Firmware_Hardware
Ready
28%
FixedStepDiscrete
Scope1
File
Tools
View
Simulation
Help
Ready
Sample based

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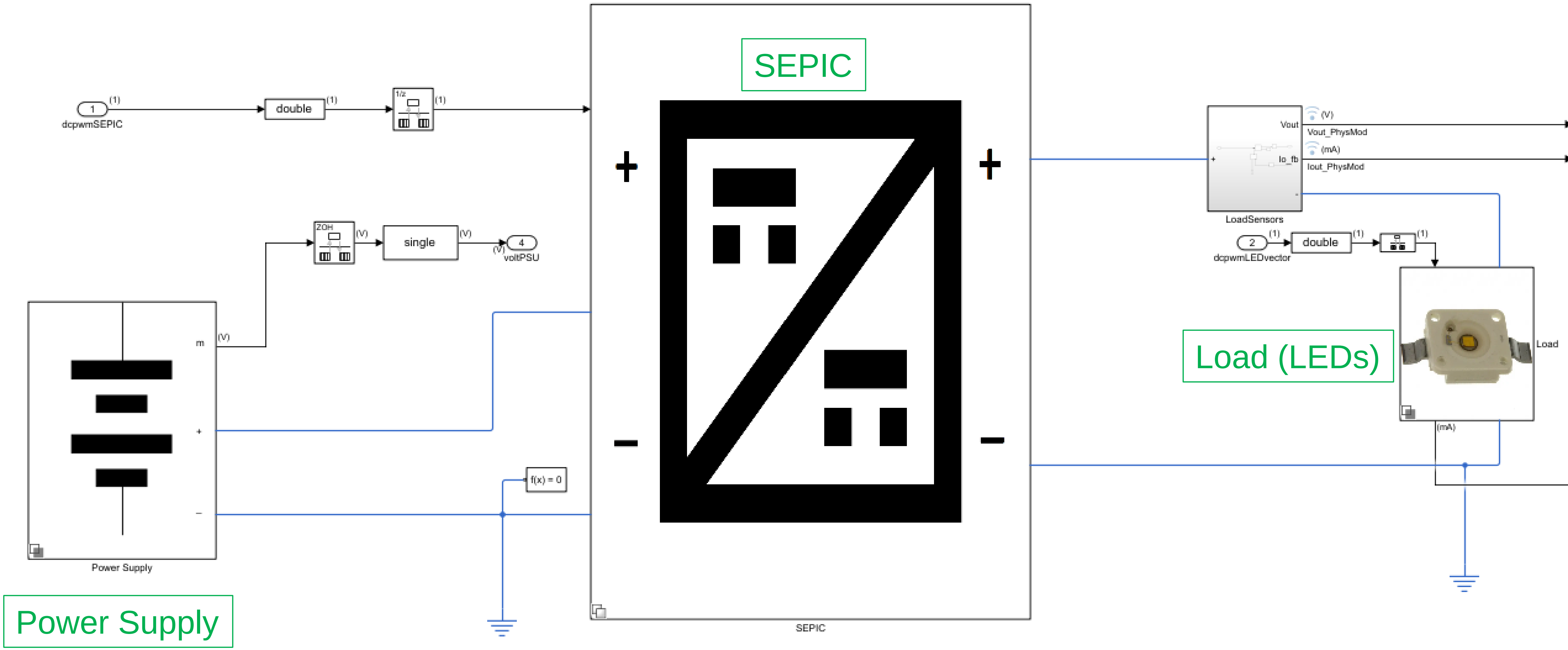
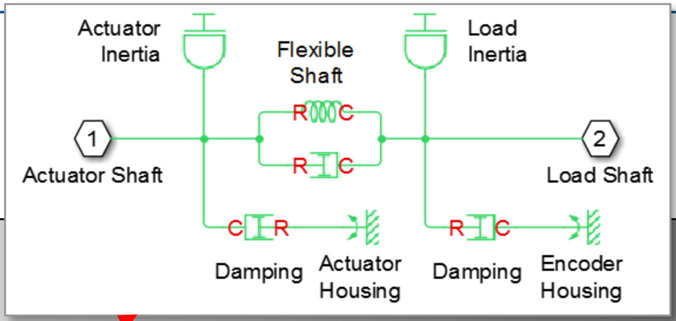
Modeling the converter



Modeling Approaches



First Principles

Data-Driven

Programming

Physical Networks

Statistical Methods

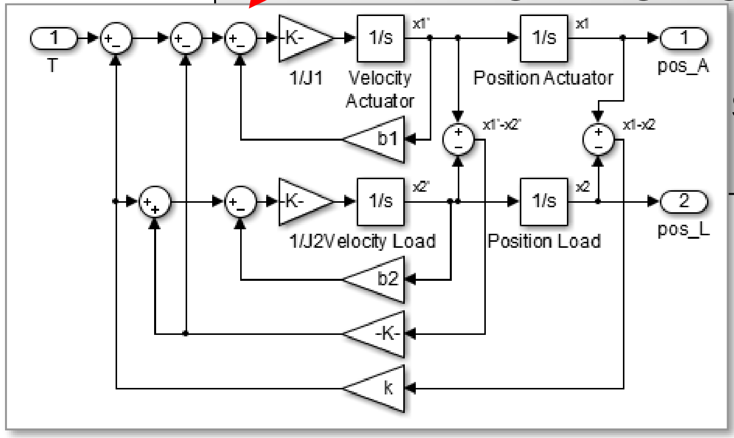
System Identification

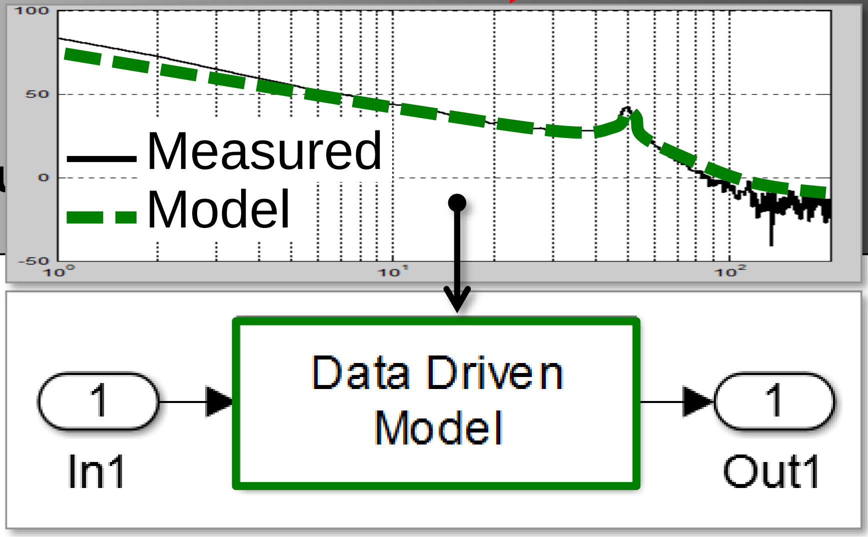
Block Diagram

Modeling Language

s

Parameter Tu



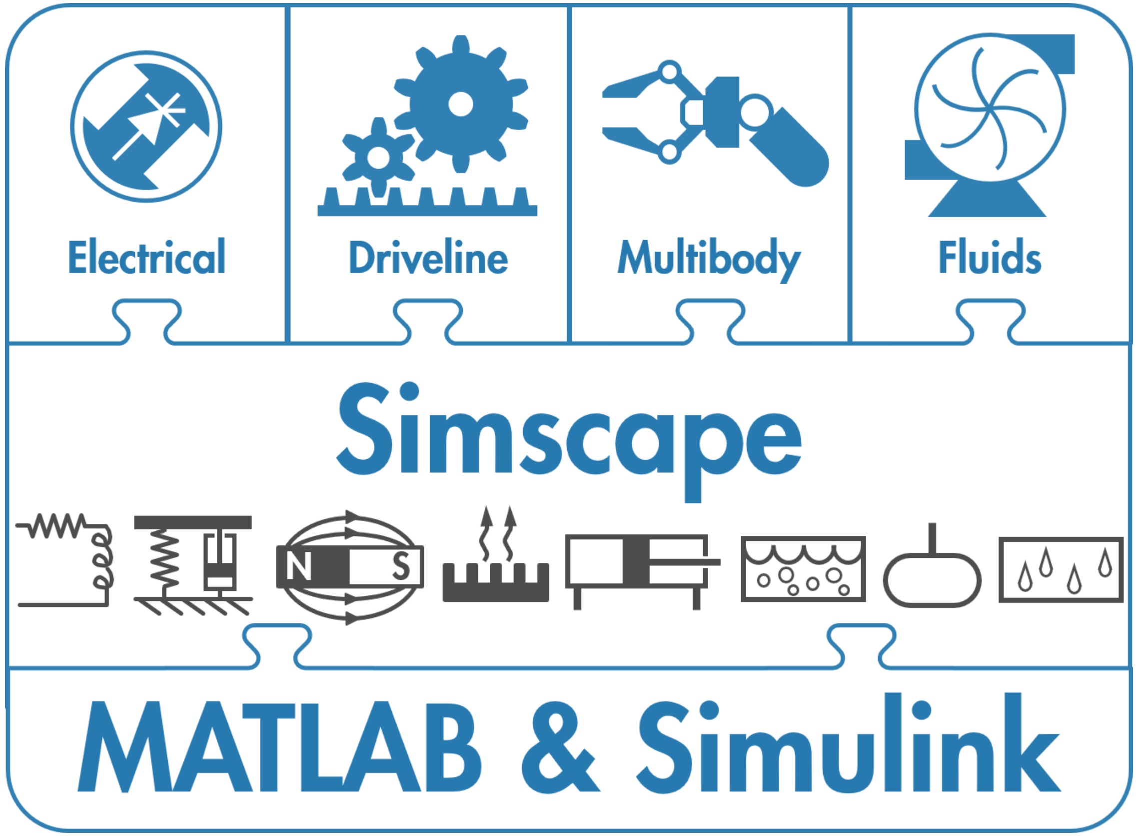


Simscape Products

- MATLAB and Simulink provide foundation for technical computing and algorithm development

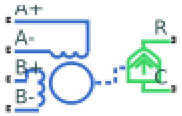
- Simscape platform
  - Simulation engine and custom diagnostics
  - Foundation libraries in many domains
  - Language for defining custom blocks

- Simscape add-on libraries



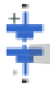
What’s new in Simscape Electrical

- Parametrized Stepper motor block

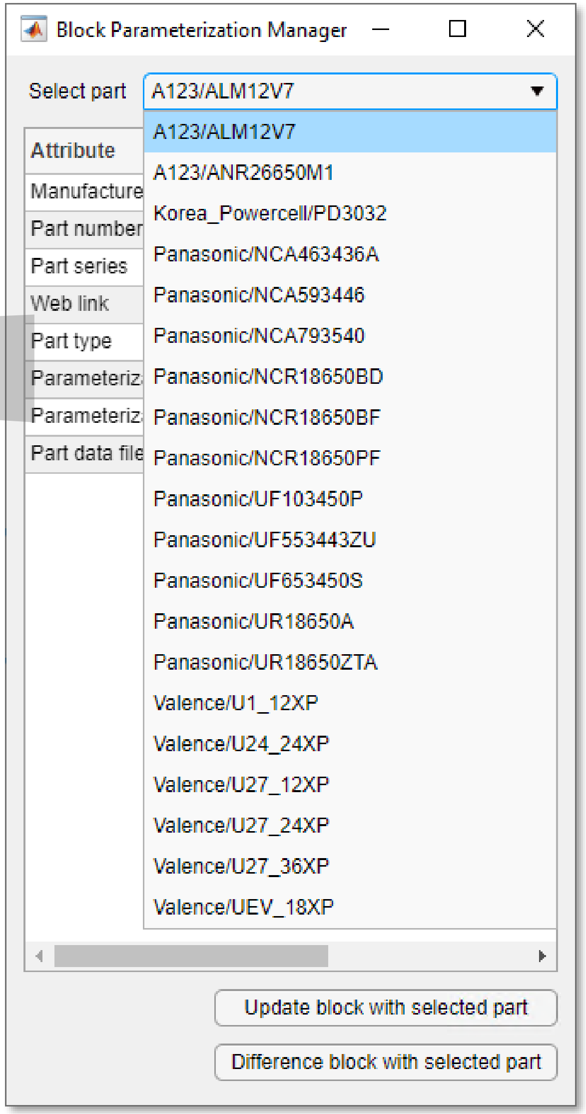


Stepper Motor

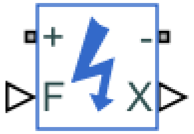
- Parametrized Battery block



Battery
(Table-Based)



- Faults
  - Dynamic Load from DC or AC supply
  - Constant Power Load
  - Delta-Connected Load, Wye-Connected Load



Fault

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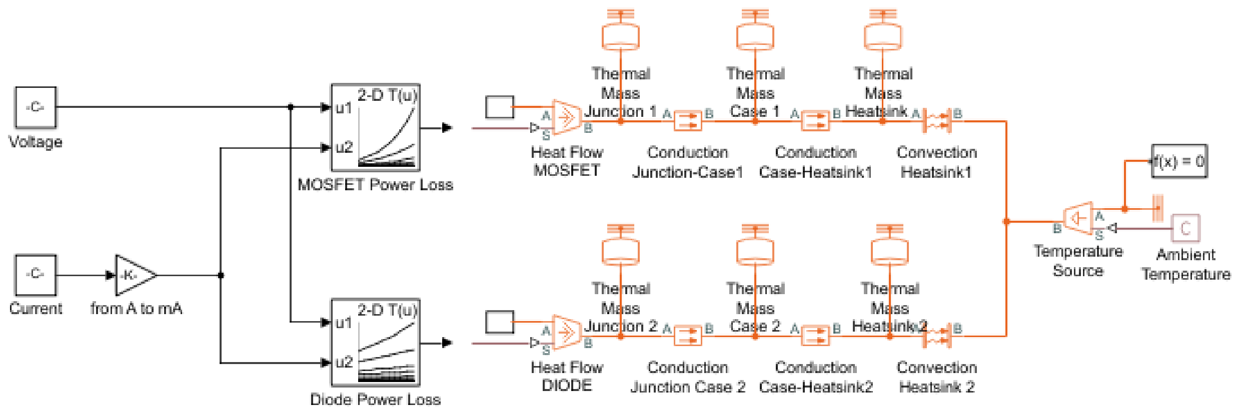
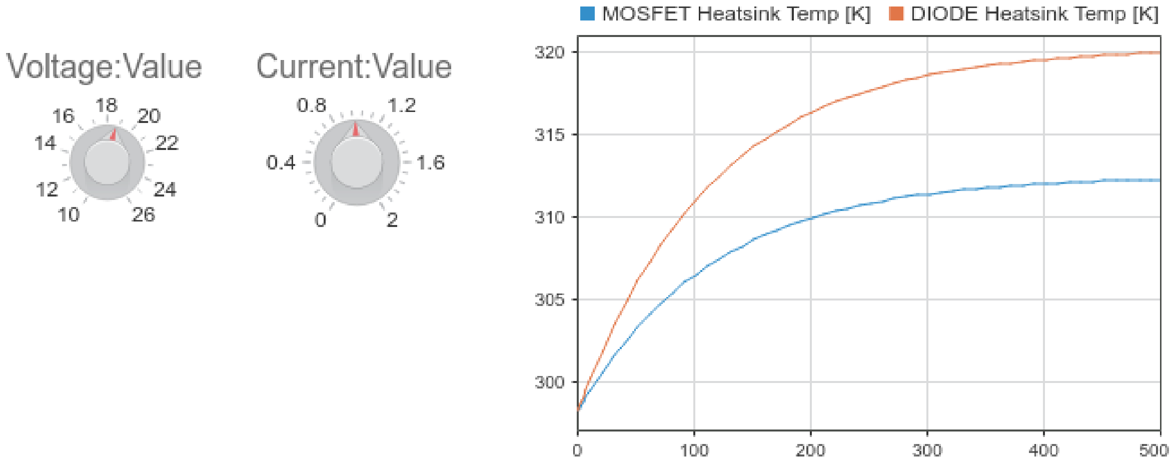
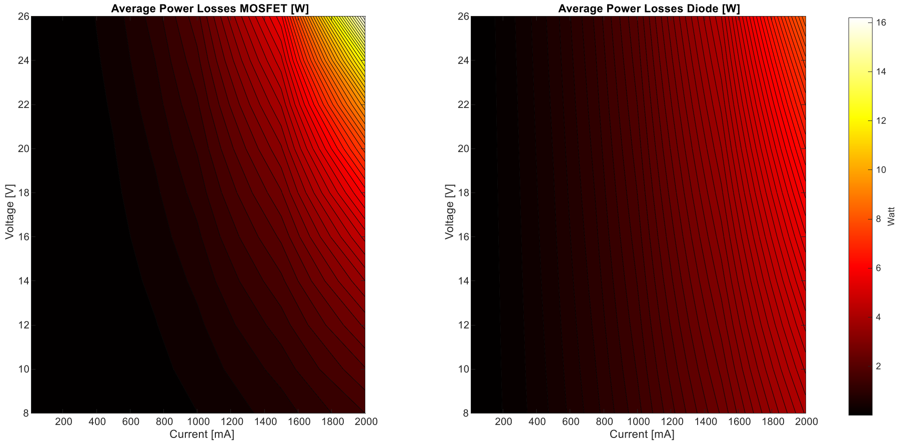
Recap: What have we seen?

ee_switching_power_supply_thermal

- Create heat maps
- Reuse it in extremely fast thermal-focused model for cooling sizing and control







ee_getpowerlossSummary

Convert SPICE models into Simscape components

Netlist

testMosfetNetlist.txt

```
.FUNC   Idiode(Usd,Tj,Iss)  {exp(min(lo
.FUNC   Idiod(Usd,Tj)        {a*Idiode(U

.FUNC   Pr(Vss0,Vssp)   {Vss0*Vss0/Rm+V

.FUNC J1(d,g,T,da,s,x)  {a*(s*(exp(mi

.FUNC QCds(x)  {Cds3*min(x,x1)+Cds0*ma
```

`subcircuit2ssc`

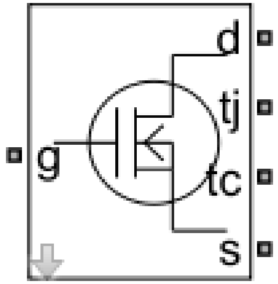
testMosfetNetlist.txt | ipt015n10n5_l1.ssc

```
components(ExternalAccess=observe)
    X1 = test.s5_100_f_var(a=act,rsp=r
        rs=rs,rp=rd,dc=dc,rm=rm);
    RG = elec.passive.instrumented_res
    LG = foundation.electrical.element
        i_L.priority=priority.none);
    RSA = elec.passive.instrumented_re
    LS = foundation.electrical.element
```

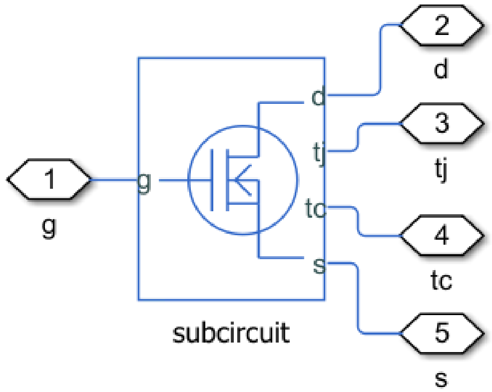
Simscape Electrical

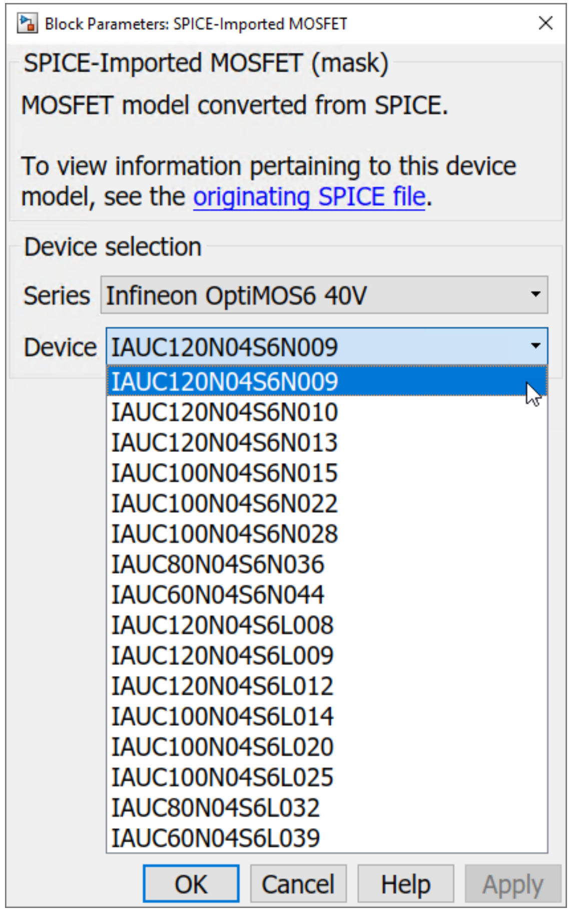
SPICE Models

- Manufacturer-specific MOSFETs
- Additional transistor capacitance models in SPICE NMOS and SPICE PMOS blocks
  - Meyer gate or charge conservation
- Conversion Assistant supports table SPICE function
- Validate MOSFET conversions by generating characteristics and comparing with LTspice



SPICE-Imported MOSFET





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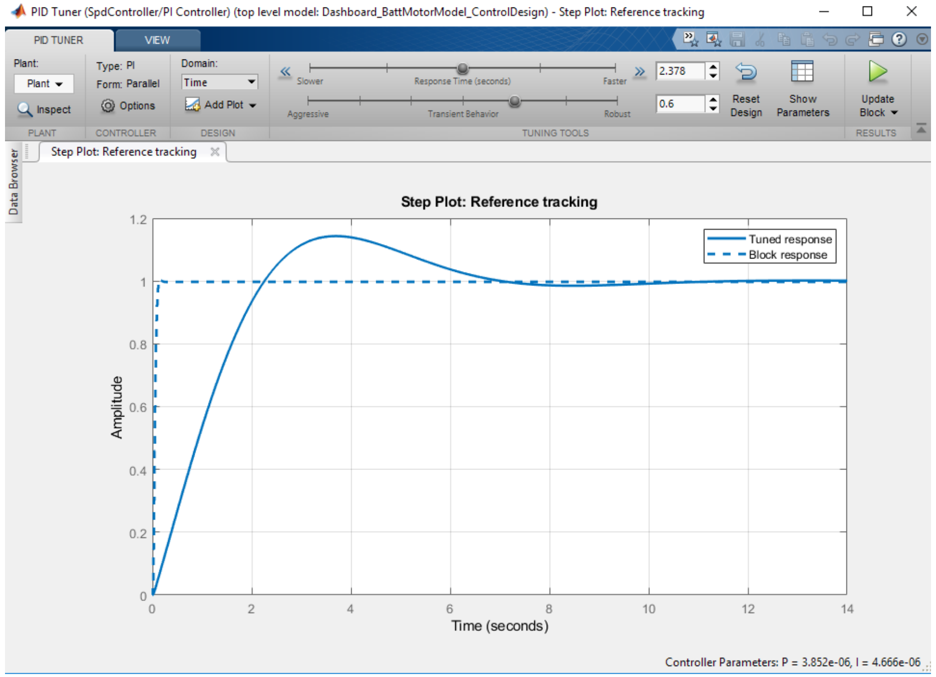
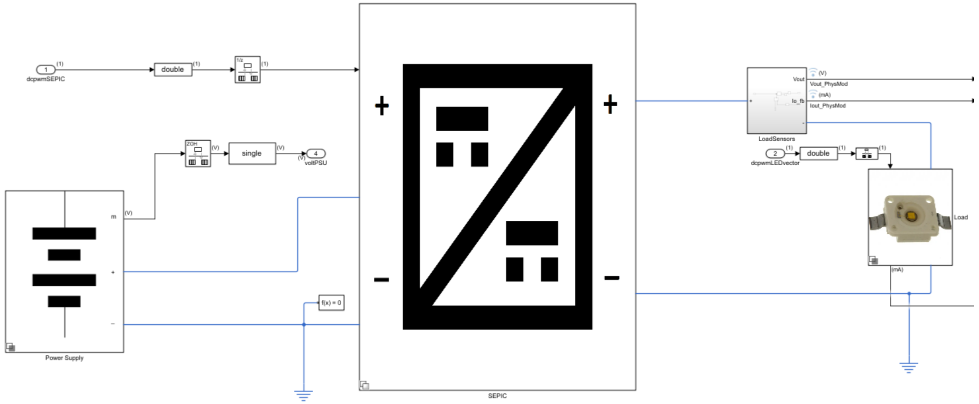
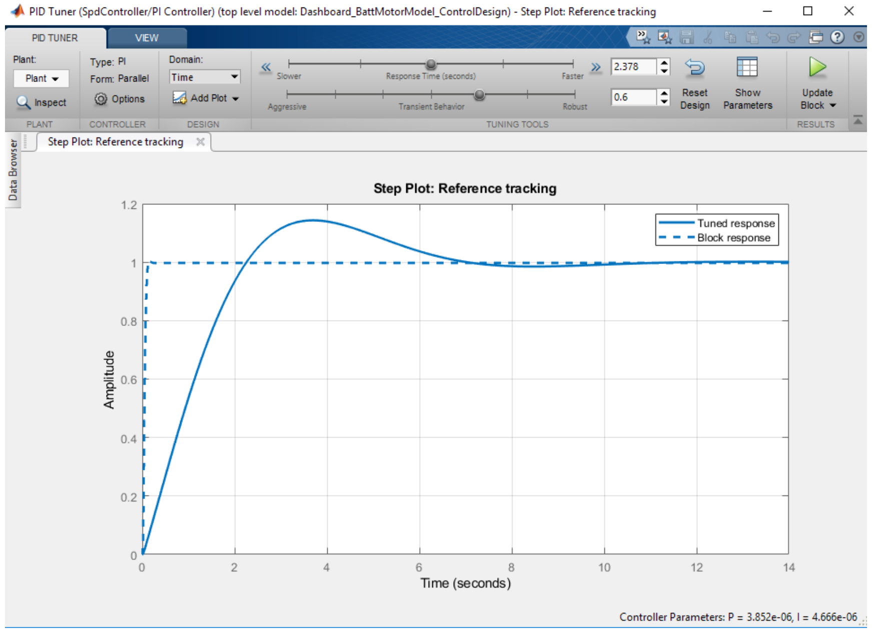
Voltage Controller Design

- Requirement
  - Implement voltage controller and tune it
- Approach
  - Create transfer function equivalent model
  - Tune controllers based on requirements



What have we seen?

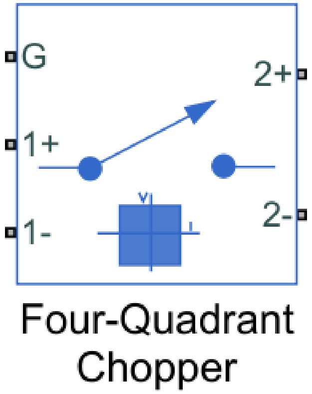


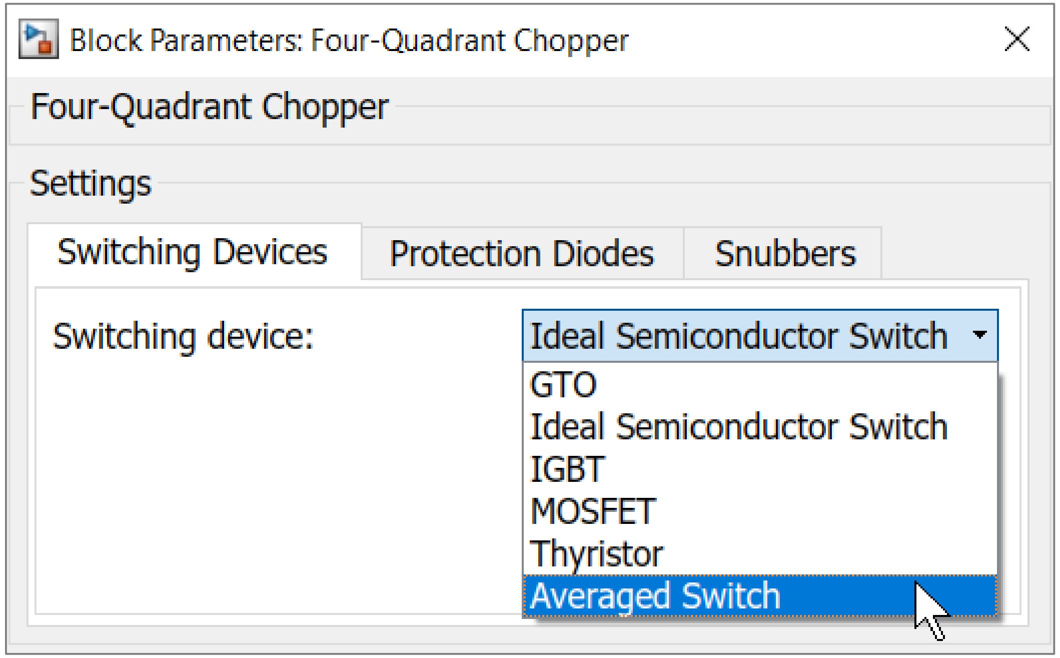


- Tuning based on System Identification
- Works with any topology

Average switch option for converters and choppers

- Faster simulation by using modulation signal or undersampling as gate signal
  - Bidirectional DC-DC Converter
  - Boost Converter
  - Buck Converter
  - Buck-Boost Converter
  - Converter (Three-Phase)
  - Four-Quadrant Chopper
  - One-Quadrant Chopper
  - Three-Level Converter (Three-Phase)
  - Two-Quadrant Chopper





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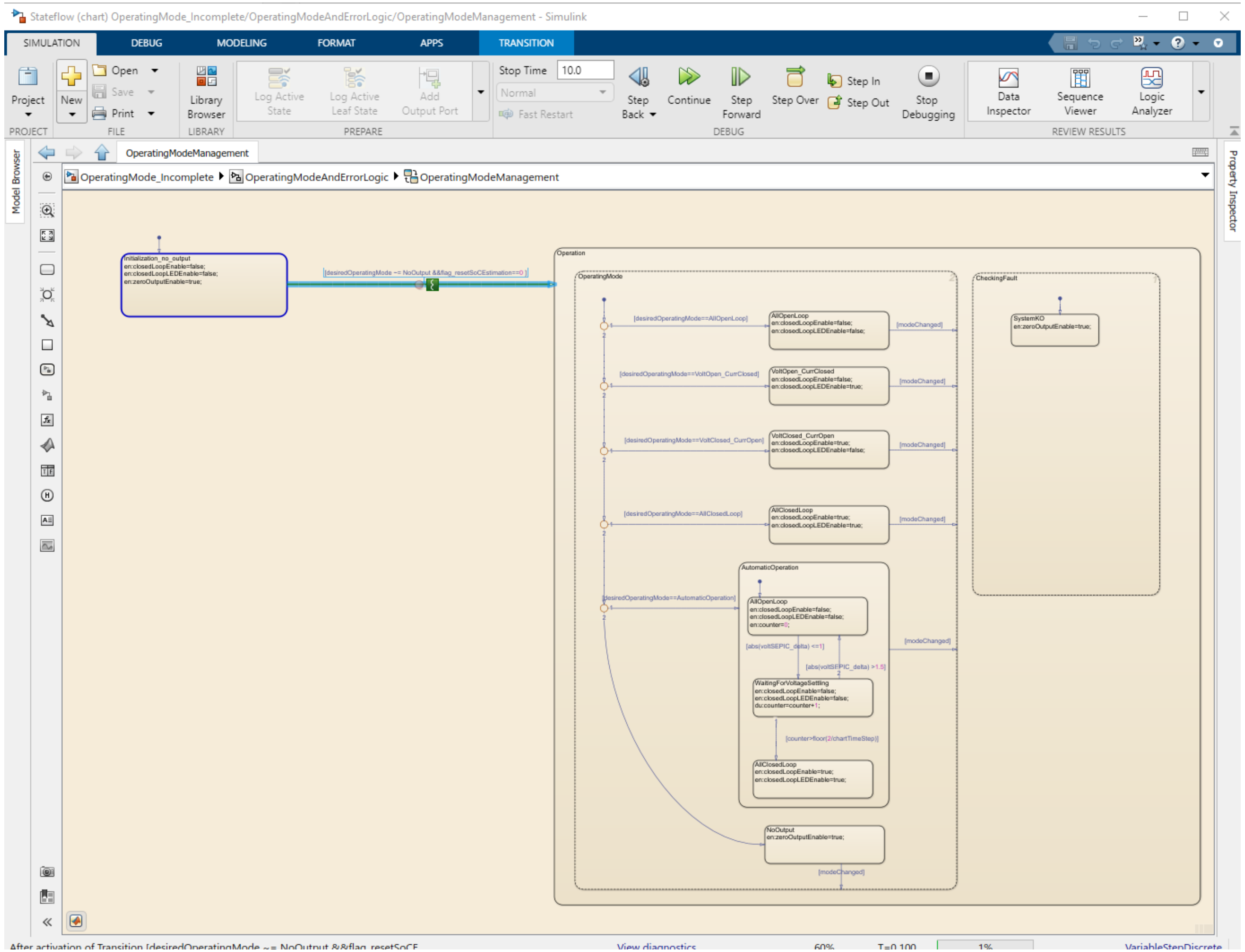
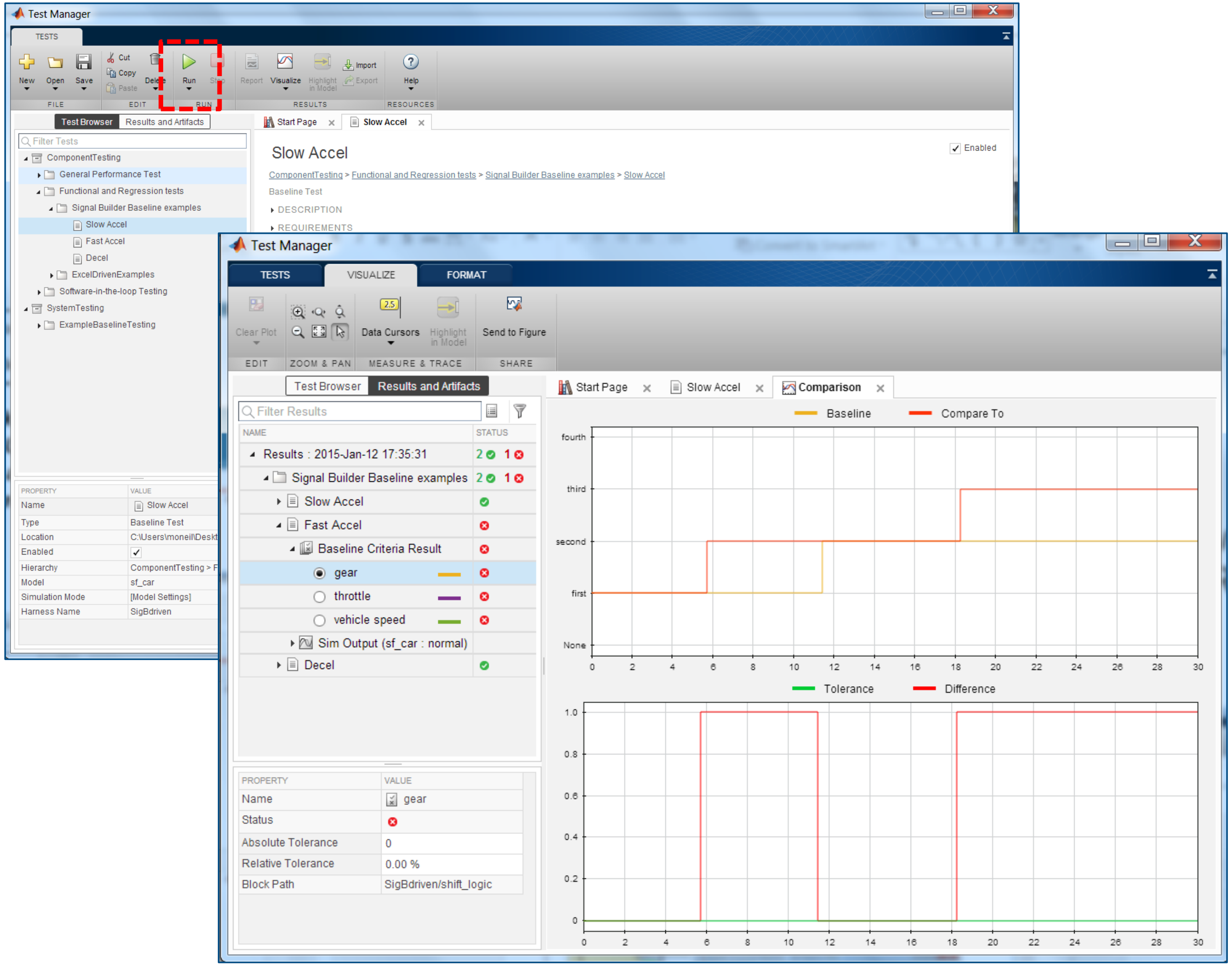
Stateflow



Recap: What have we seen?

Simulink Test

- ✓ Create test harnesses and test cases
- ✓ Group into suites and test files
- ✓ Execute individual or batch
- ✓ View result summary
- ✓ Analyze results
- ✓ Archive, export, report



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Automatic Code Generation

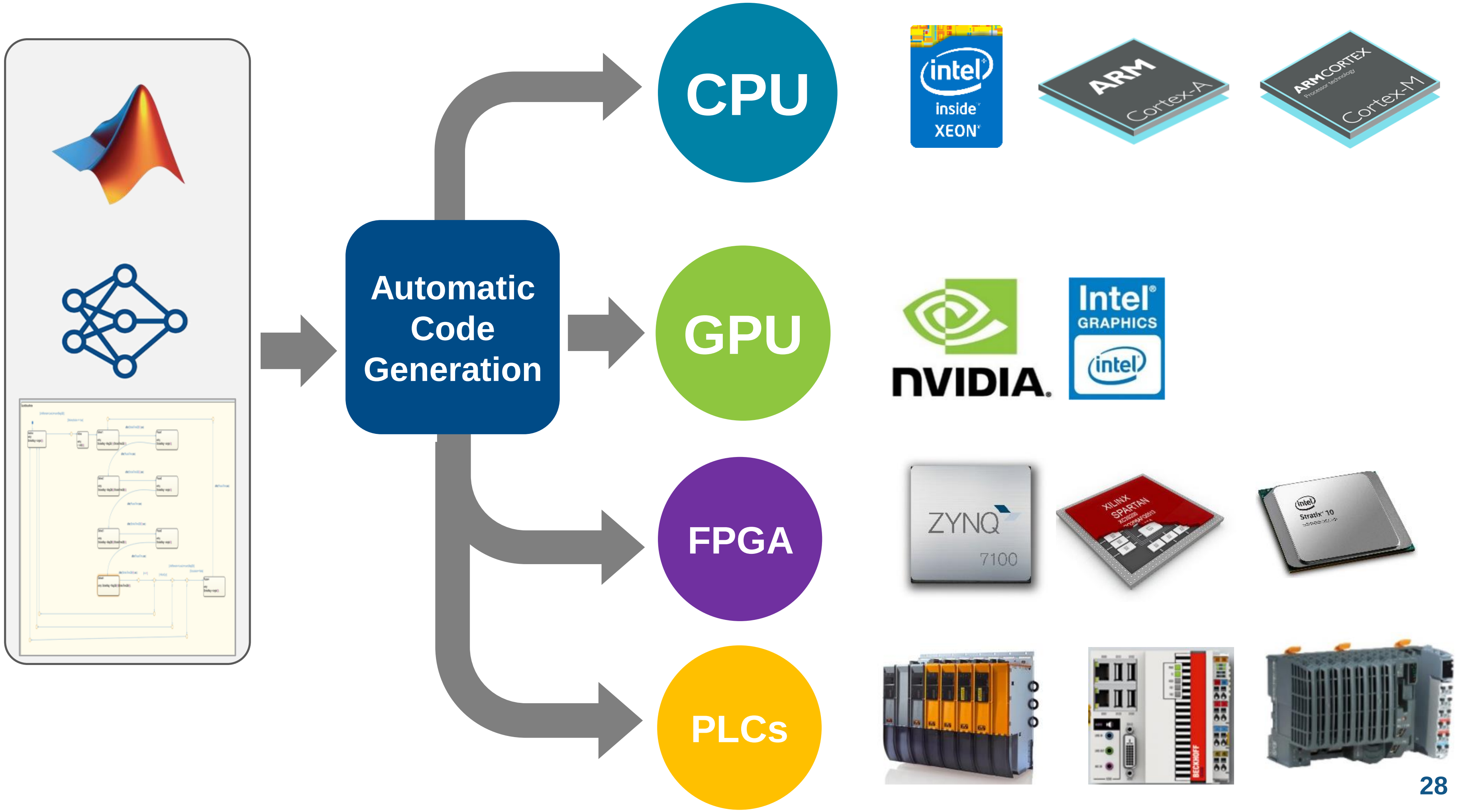
- Requirement
  - Generate target-aware, efficient C-code
- Approach
  - Model elaboration for C-code generation
  - Create a first configuration set with Embedded Coder Quick Start
  - Build the code, automatically generate reports

Deploy to Any Processor with Best-in-Class Performance

Models in MATLAB and Simulink can be deployed on embedded devices, edge devices, enterprise systems, the cloud, or the desktop.

Deployment

- Embedded devices
- Enterprise systems
- Edge, cloud, desktop

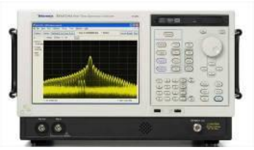


28

MATLAB Connects to Your Hardware Devices

Instrument Control

Oscilloscopes, Signal Generators,
Lab Instruments




Data Acquisition

Plug-in data acquisition devices, I/O boards and sound cards

Image and Video Acquisition

Industrial and scientific cameras





Digital Networks

OPC, CAN, J1939, and XCP protocol devices

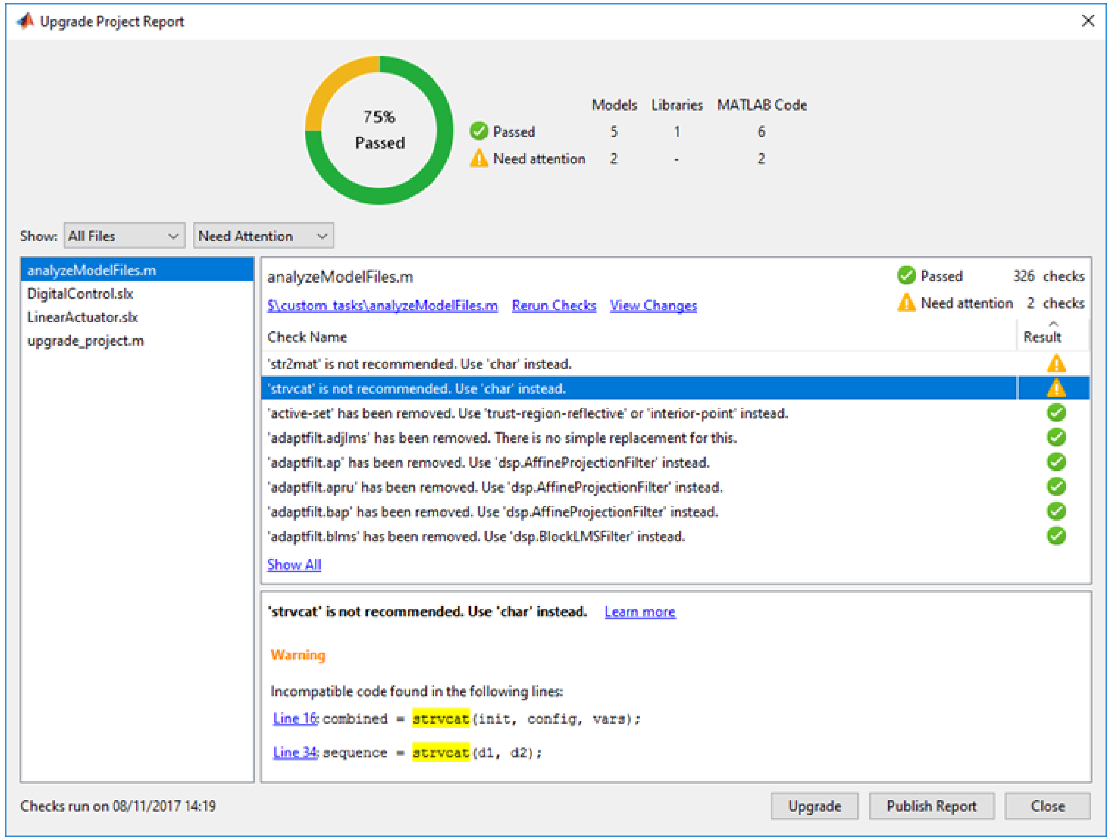
Hardware support packages

Built-in and downloadable support for a wide range of devices and development boards

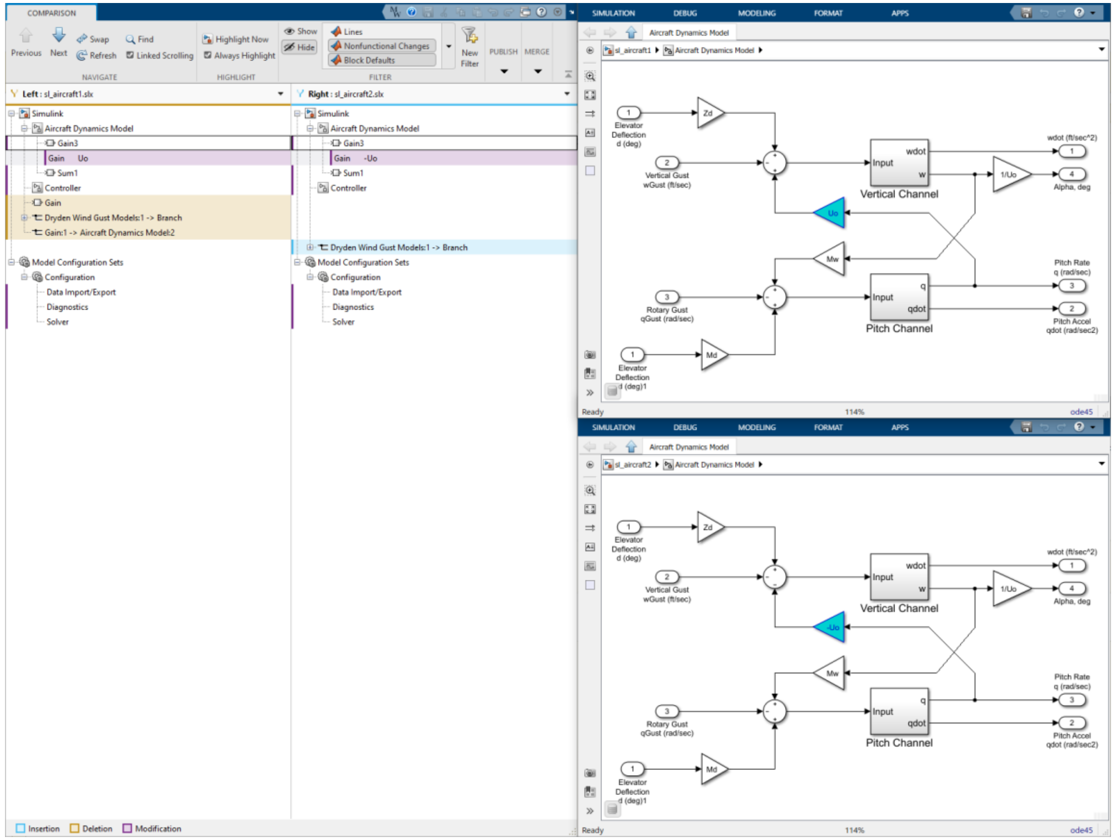
Project and File Management

Included in Simulink since 2017b!

Simulink Project Upgrade

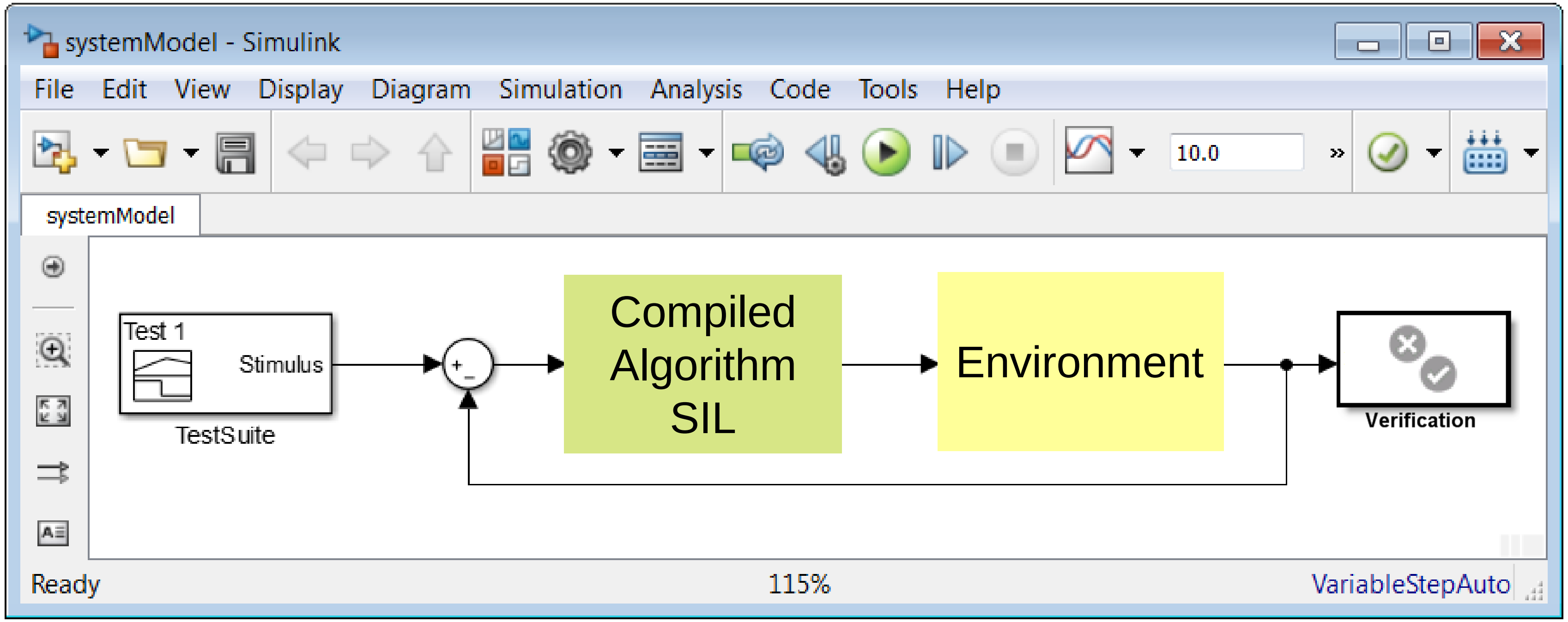


Simulink Graphical Model Comparison&Merge



In-the-Loop Verification Methodologies

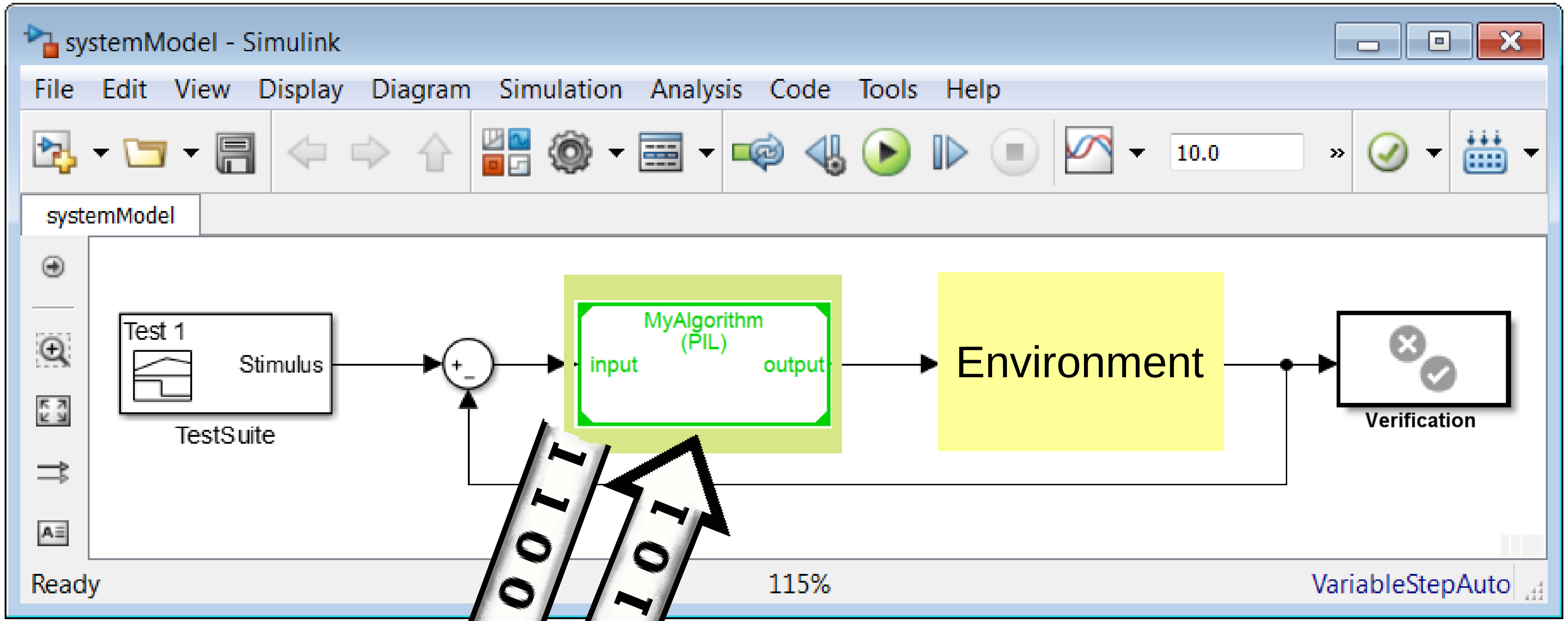
Software-in-the-Loop



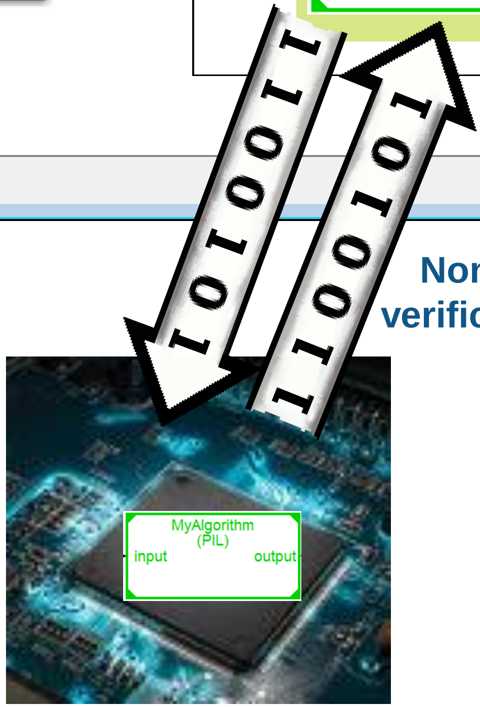
Is the generated code functionally equivalent to the model ?

In-the-Loop Verification Methodologies

Processor or FPGA-in-the-Loop



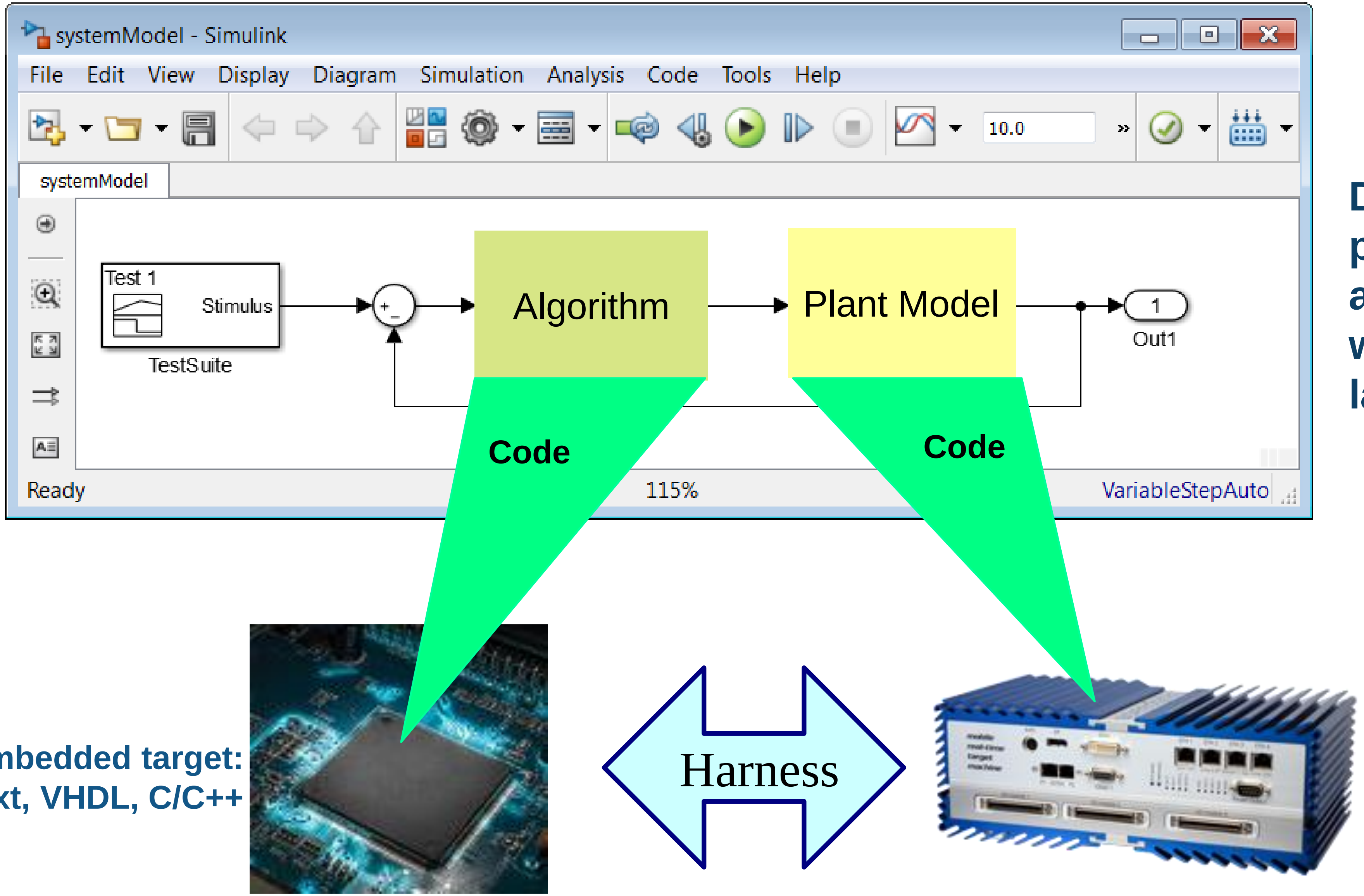
Is the generated code functionally equivalent to the model ?



Non-Real-Time functional verification of the algorithm component, C or HDL

In-the-loop verification methodologies

Hardware-in-the-Loop: “HIL”



Does algorithm perform well on actual device with true latencies?

Production embedded target: Structured Text, VHDL, C/C++

Real-Time Machine eg “Speedgoat”

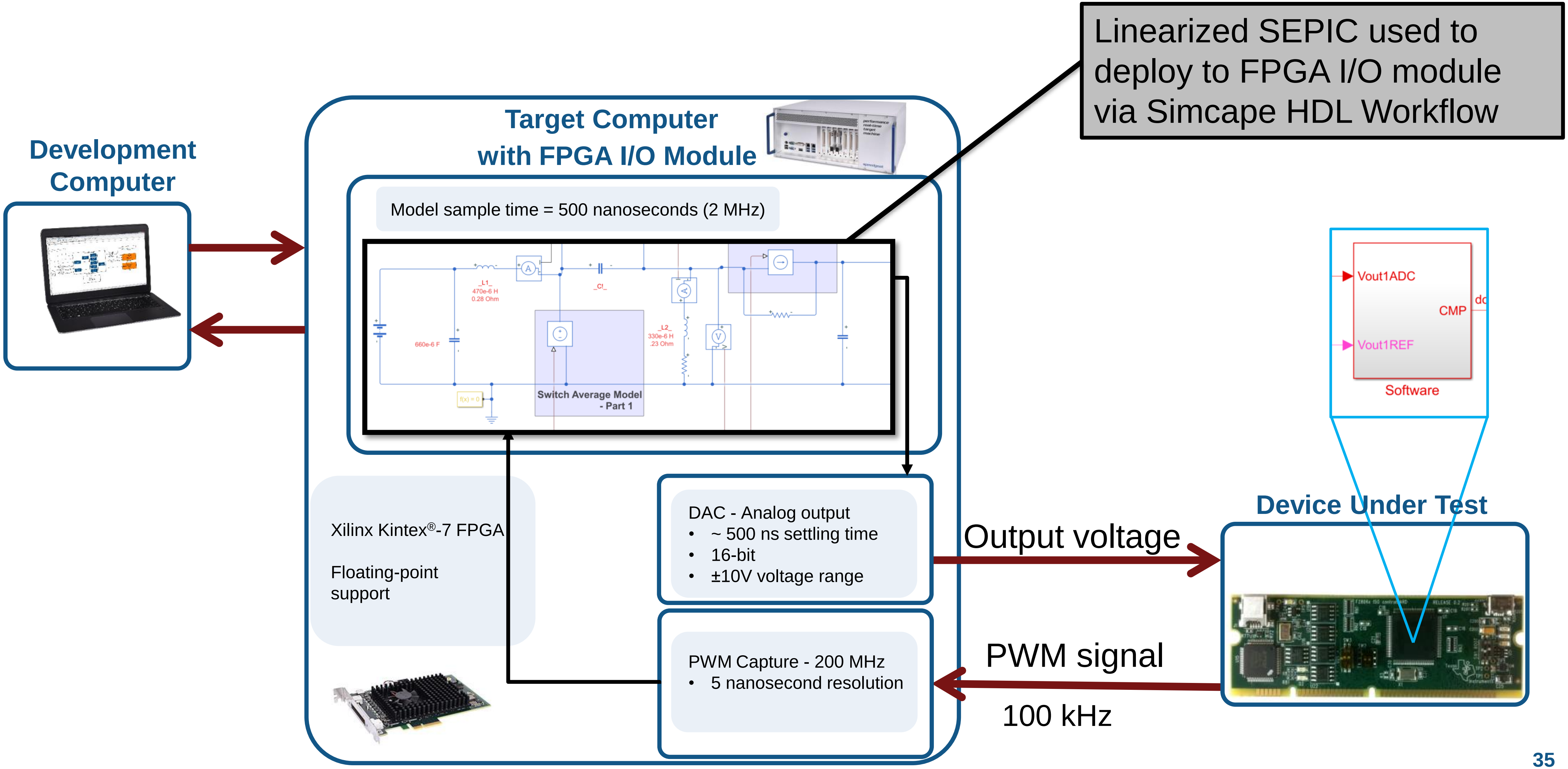
About Speedgoat

- A MathWorks associate company, incorporated in 2006 by former MathWorks employees. Headquarters in Switzerland, with subsidiaries in the USA and Germany

- Provider of real-time target computers, expressly designed for use with Simulink

- Real-time core team of around 200 people within MathWorks and Speedgoat. Closely working with the entire MathWorks organization employing around 5,000 people worldwide

Hardware-in-the-Loop Simulation of SEPIC Converter



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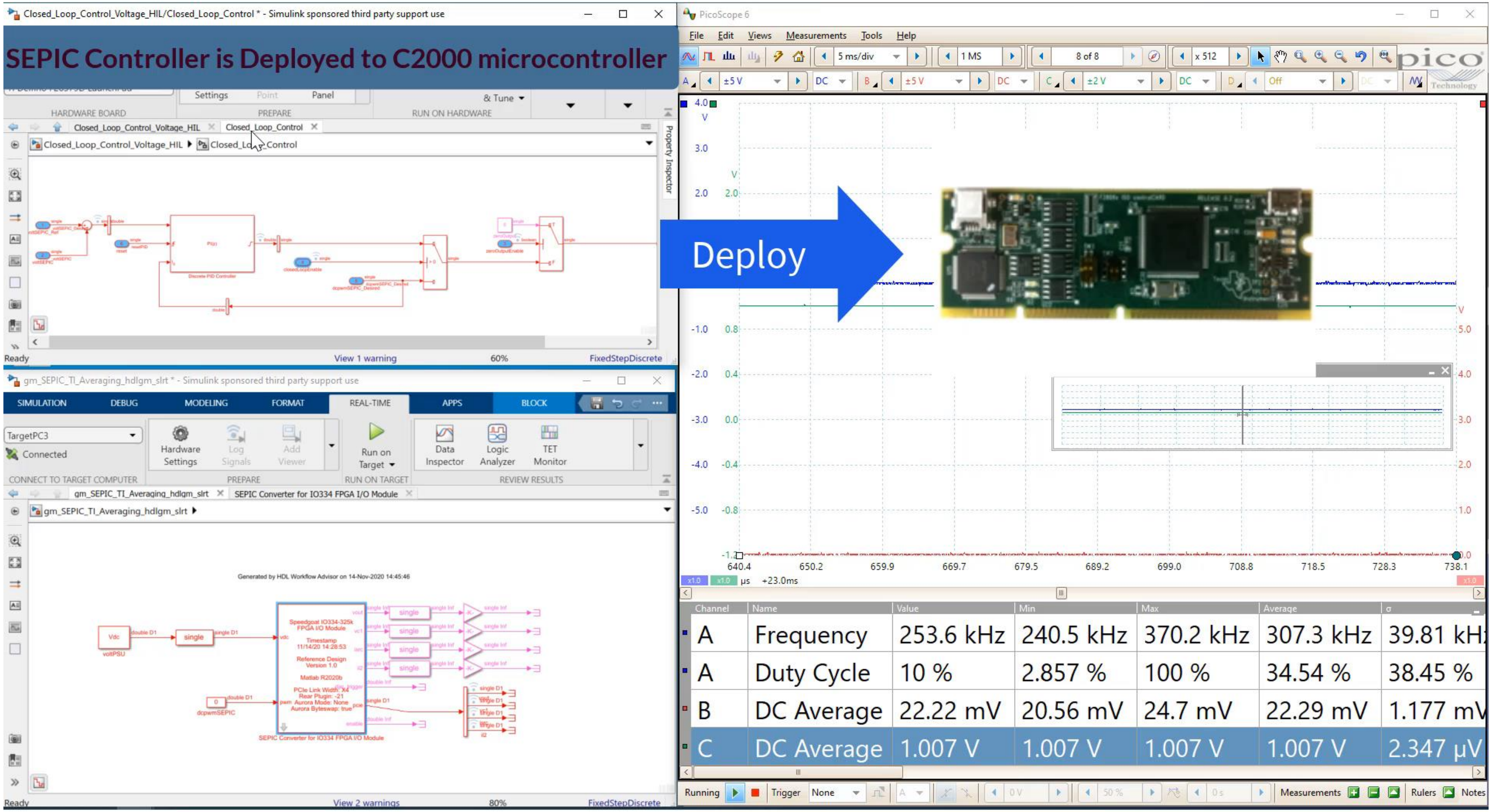

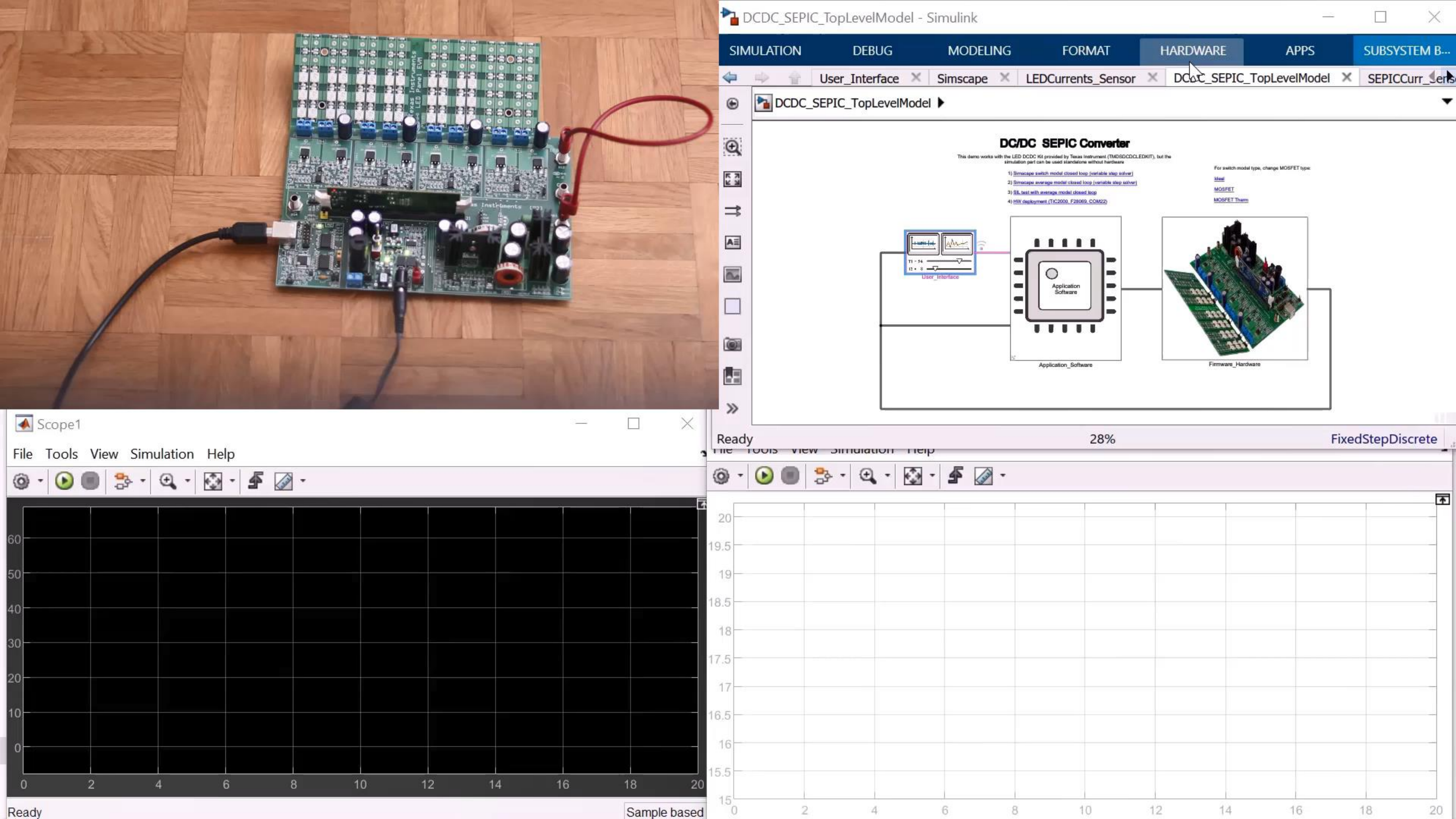
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File
Tools
View
Simulation
Help
Ready
Sample based

With Simulink and Model-Based Design

Use Simulation Models to Generate Production Ready Code

A cabinet of Power Electronic Building Blocks (PEBBs).

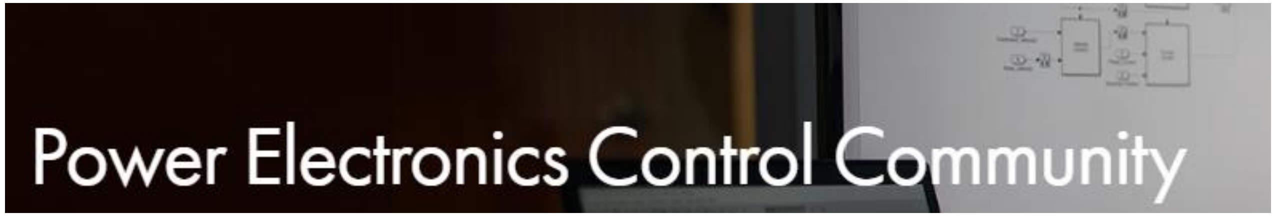
*"With Model-Based Design, our developer productivity is easily increased tenfold. **Simulation and code generation enable us to turn changes around quickly and eliminate human errors in coding**. Our algorithms typically work the first time, so we no longer waste a big part of our development cycle debugging code."*

Dr. Robert Turner, ABB link

Key Takeaways

- Graphical programming across our solutions is **intuitive** and **powerful**
- State-of-the-art technologies facilitate the **design** and **verification** of complex systems developed by **multidisciplinary teams**
- Find design errors **early** and cut down development **cost** while increasing delivered **quality**.

Visit the Power Electronics Control Community on MATLAB Central to find Models, Answers, and How-to Videos



https://www.mathworks.com/matlabcentral/topics/power-electronics-control.html

Q&A and Conclusion

- Questions: vlenzi@mathworks.com