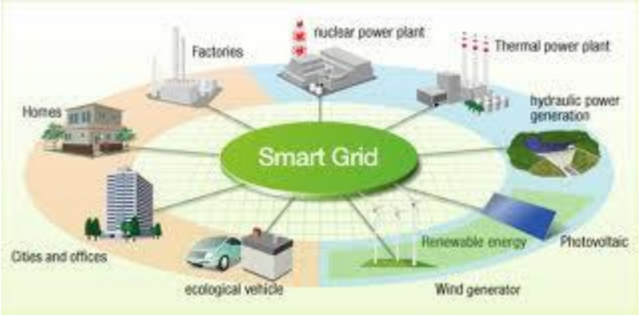
MATLAB EXPO 2018

Designing Efficient Power Electronics Systems Using Simulation

Vivek Raju & Naga Pemmaraju
Application Engineering
Control Design Automation

Power and Energy Applications

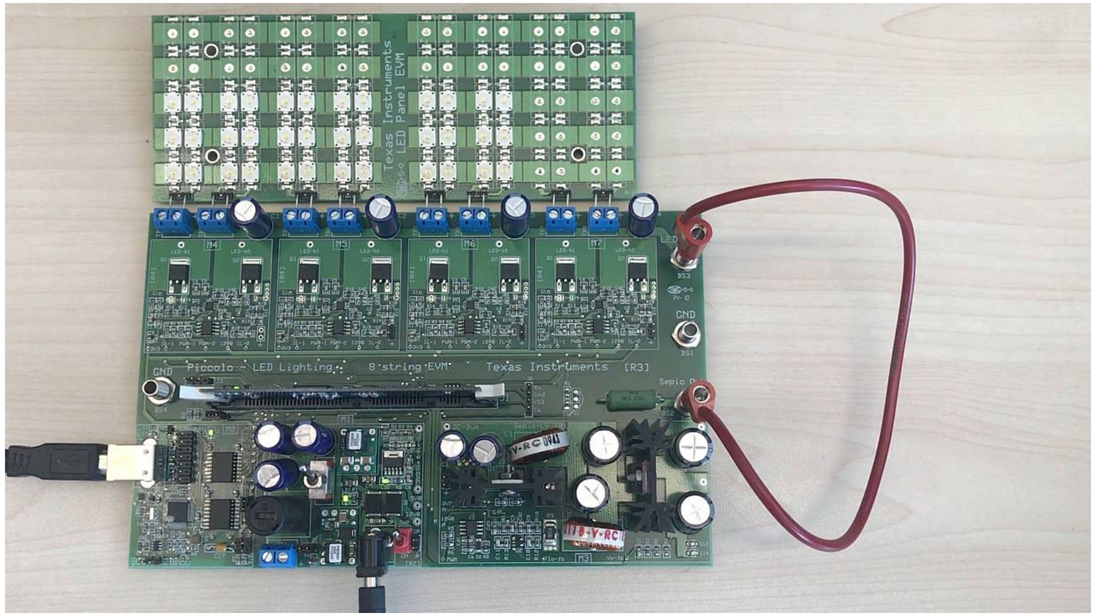


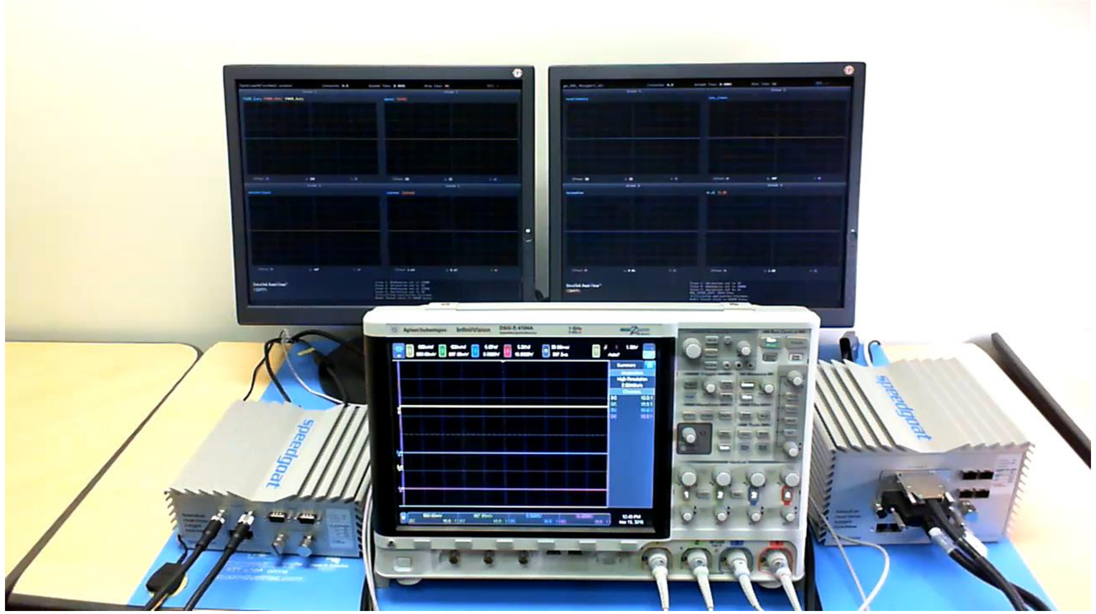
Switching Electronics

Challenges:

- How to size inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode?
- How to determine power losses and simulate the thermal behaviour of the converter?
- How to design control algorithm based on time domain specification(Rise time , Overshoot , Settling time)?
- How to run power electronics in HIL simulations at 1MHz frequency?

What are we doing today?





DC-DC Sepic Converter Implementation

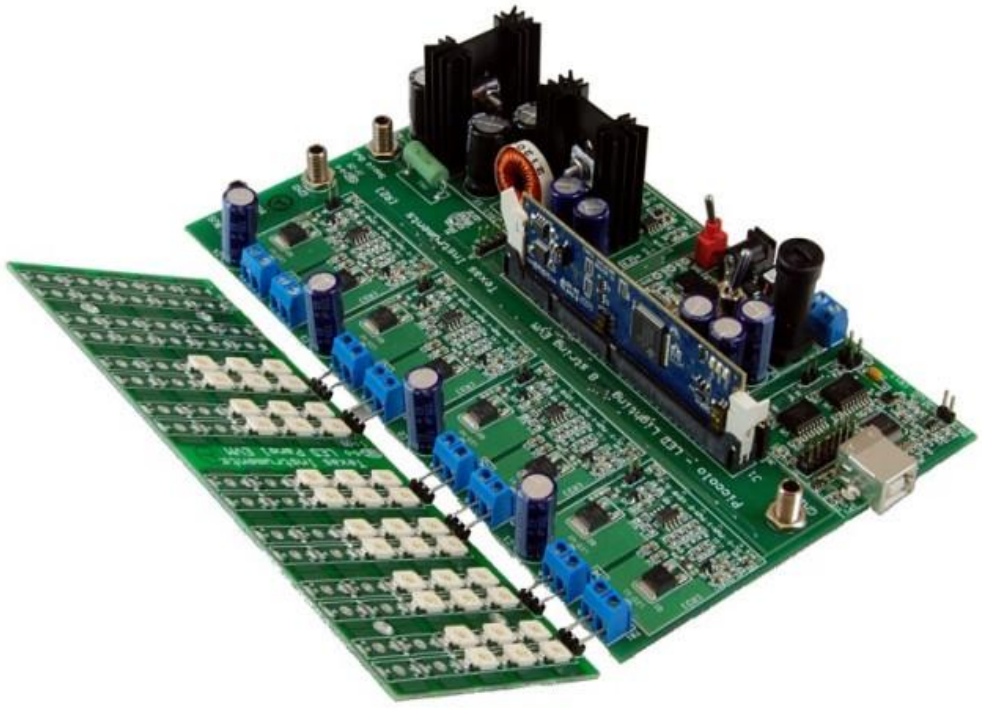


Fig 1: TMDSDCDCLEDKIT

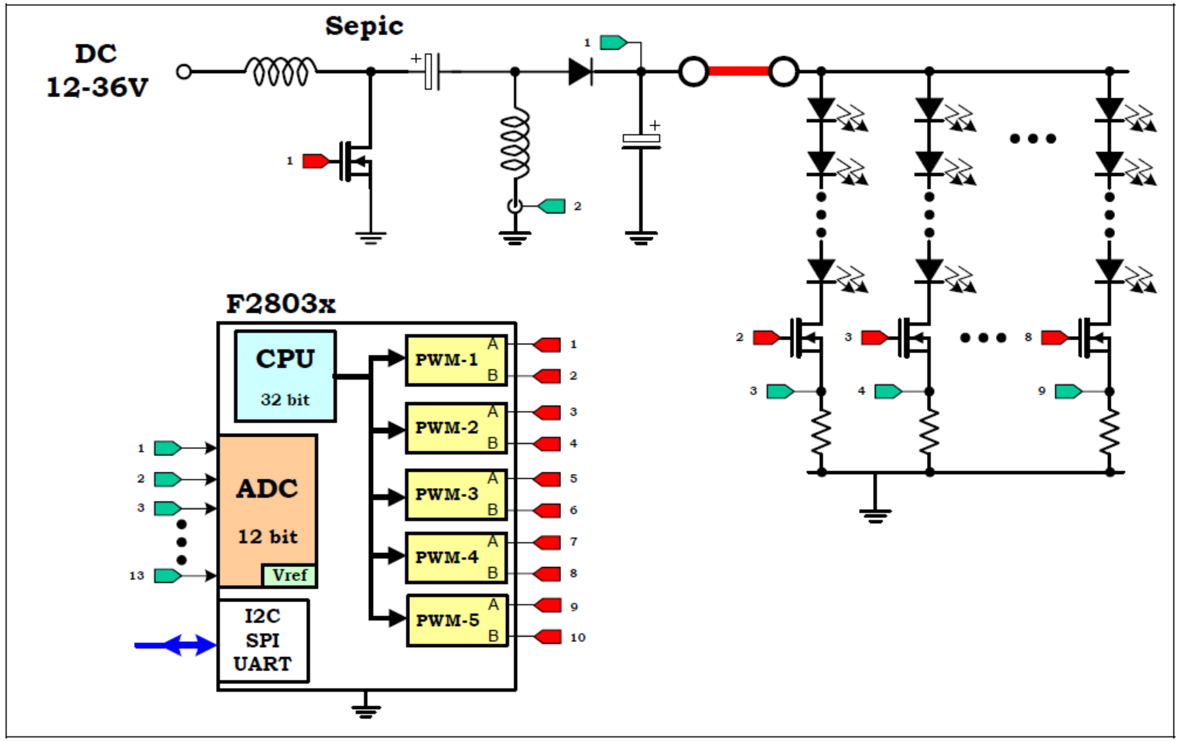


Fig4: DC/DC LED Lighting Board Block diagram with F28035

Lets explore interesting problem statements

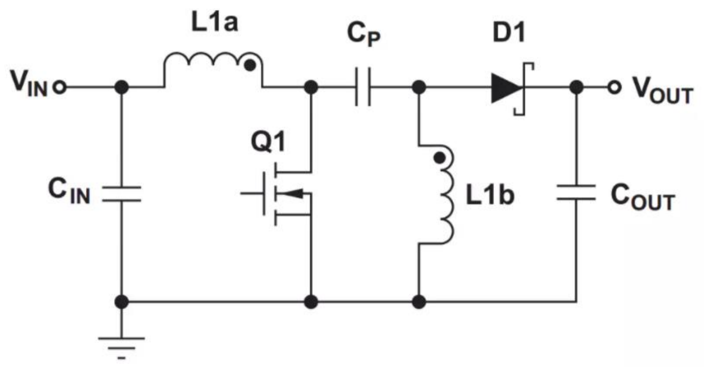
- **How to size inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode?**

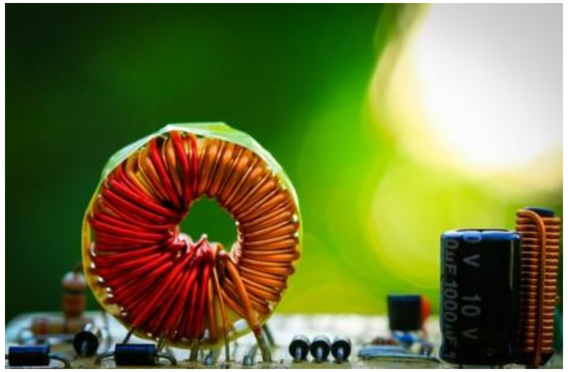
- How to determine power losses and simulate the thermal behaviour of the converter?

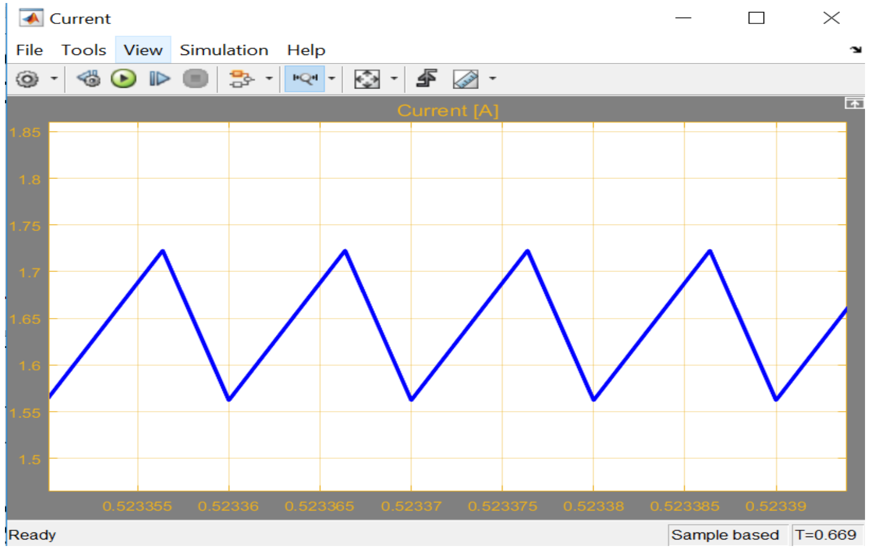
- How to design control algorithm based on time domain specification(Rise time , Overshoot , Settling time)?

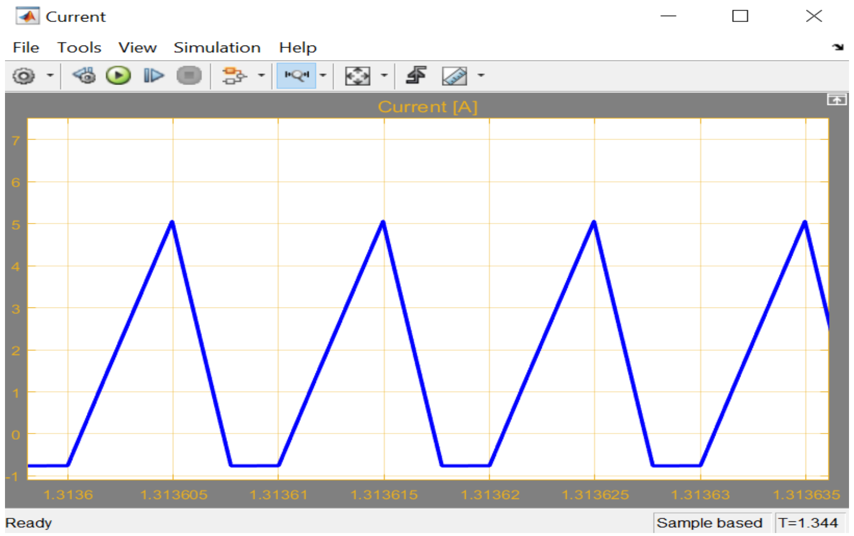
- How to run power electronics in HIL simulations at 1MHz frequency?

Sizing inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode.









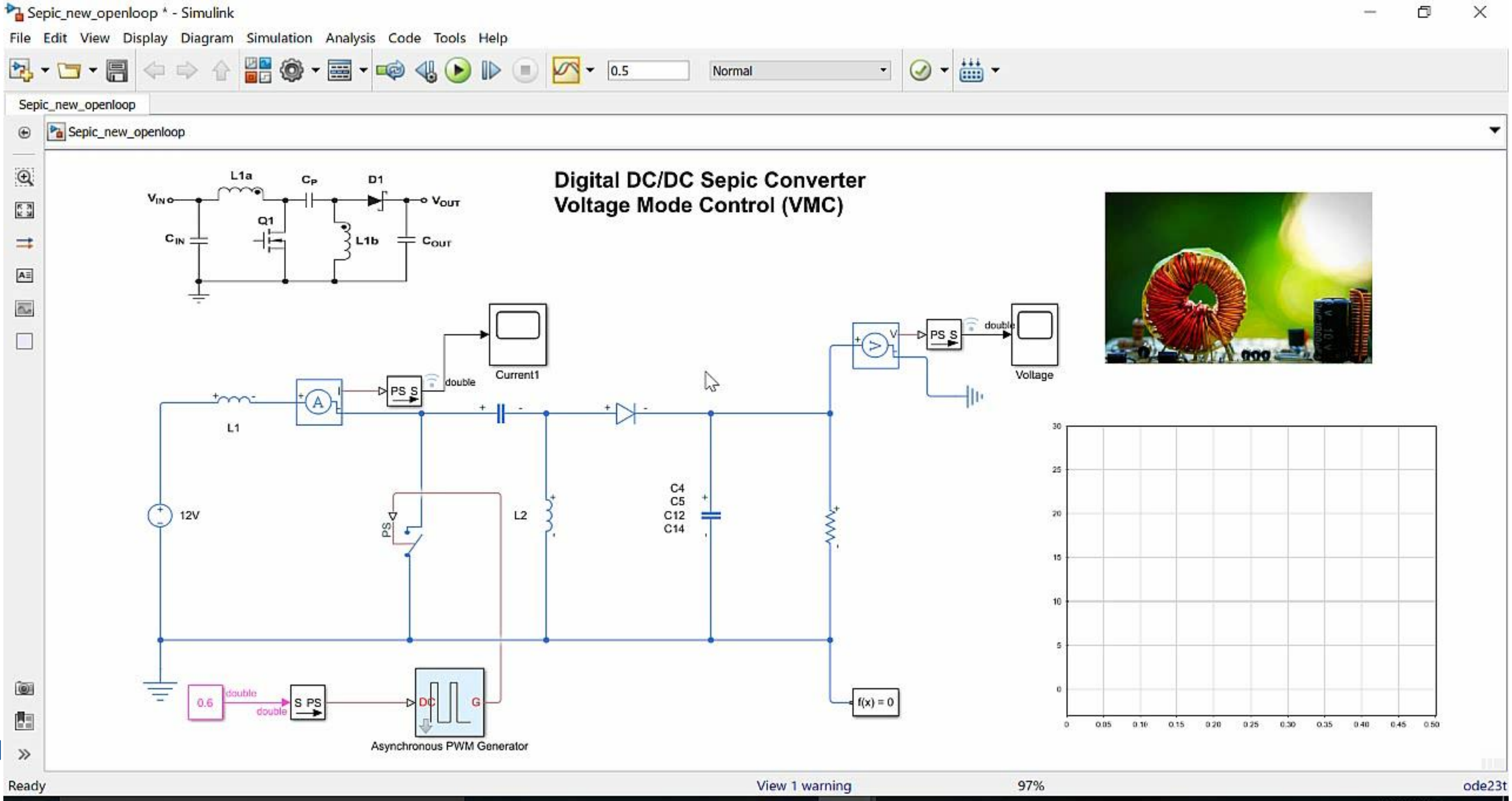
Challenge

- Need an efficient process for electrical component sizing that minimizes overall size of the DC to DC converters

Solution

- Usage of simulation to design DC to DC converters
- Optimize component sizing using Simulation driven analysis

Sizing components and understand the behaviour in Continuous and Discontinuous model.



Lets explore interesting problem statements

- How to size inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode?

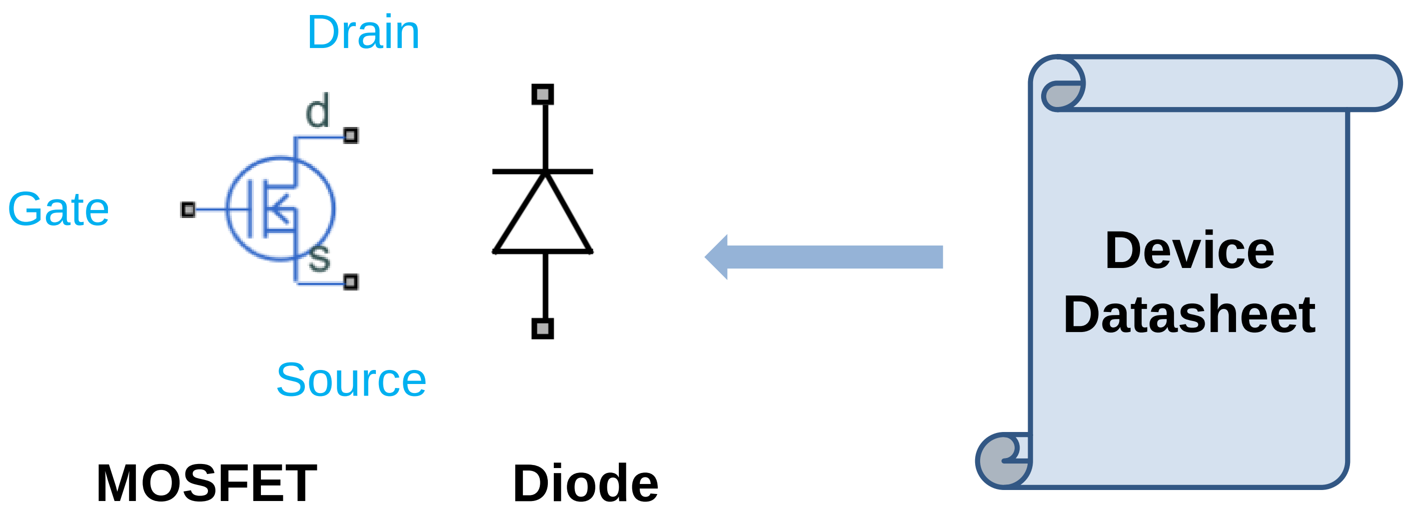
- **How to determine power losses and simulate the thermal behaviour of the converter?**

- How to design control algorithm based on time domain specification(Rise time , Overshoot , Settling time)?

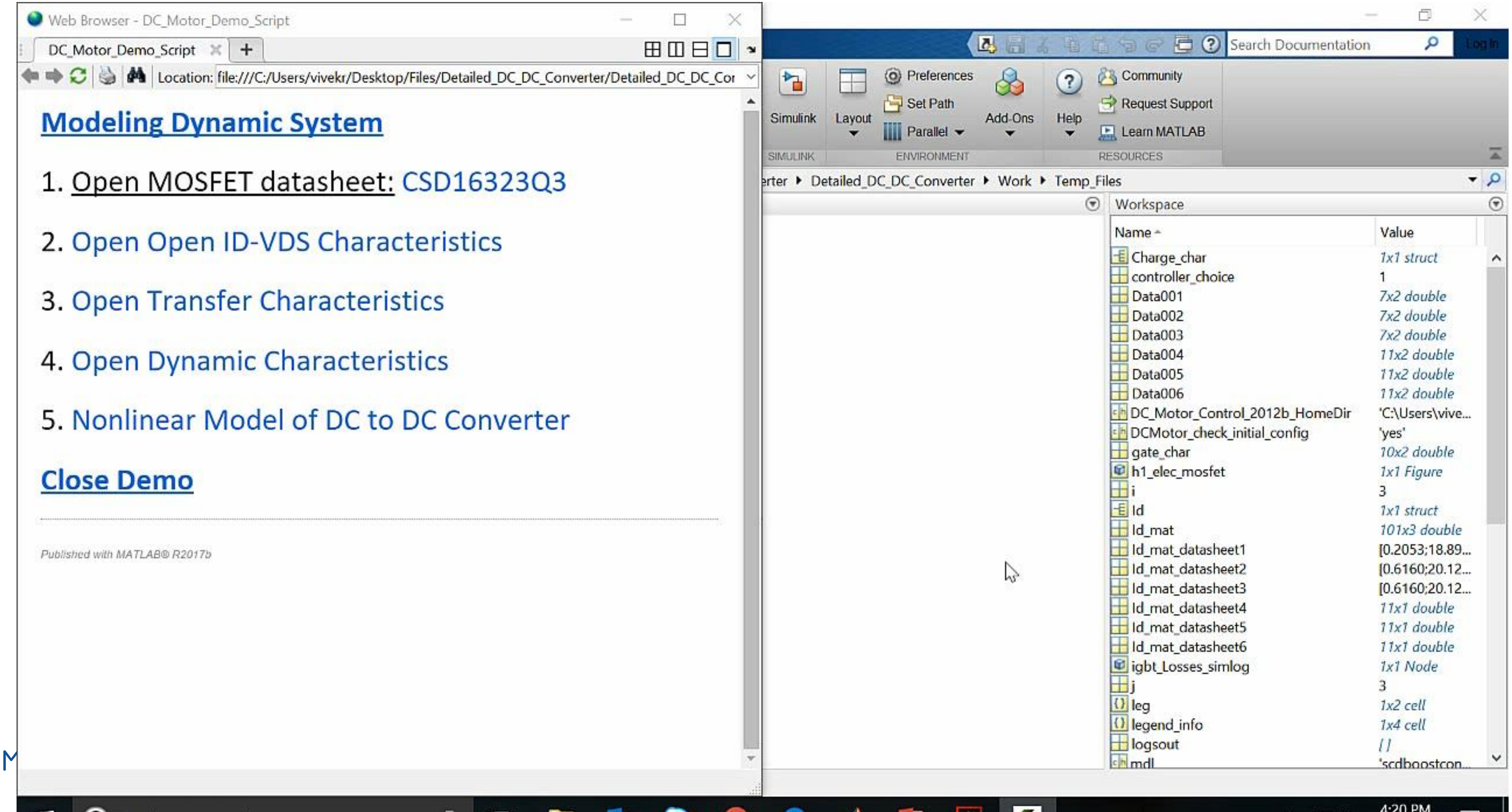
- How to run power electronics in HIL simulations at 1MHz frequency?

Parameterizing the MOSFET Switch from the datasheet

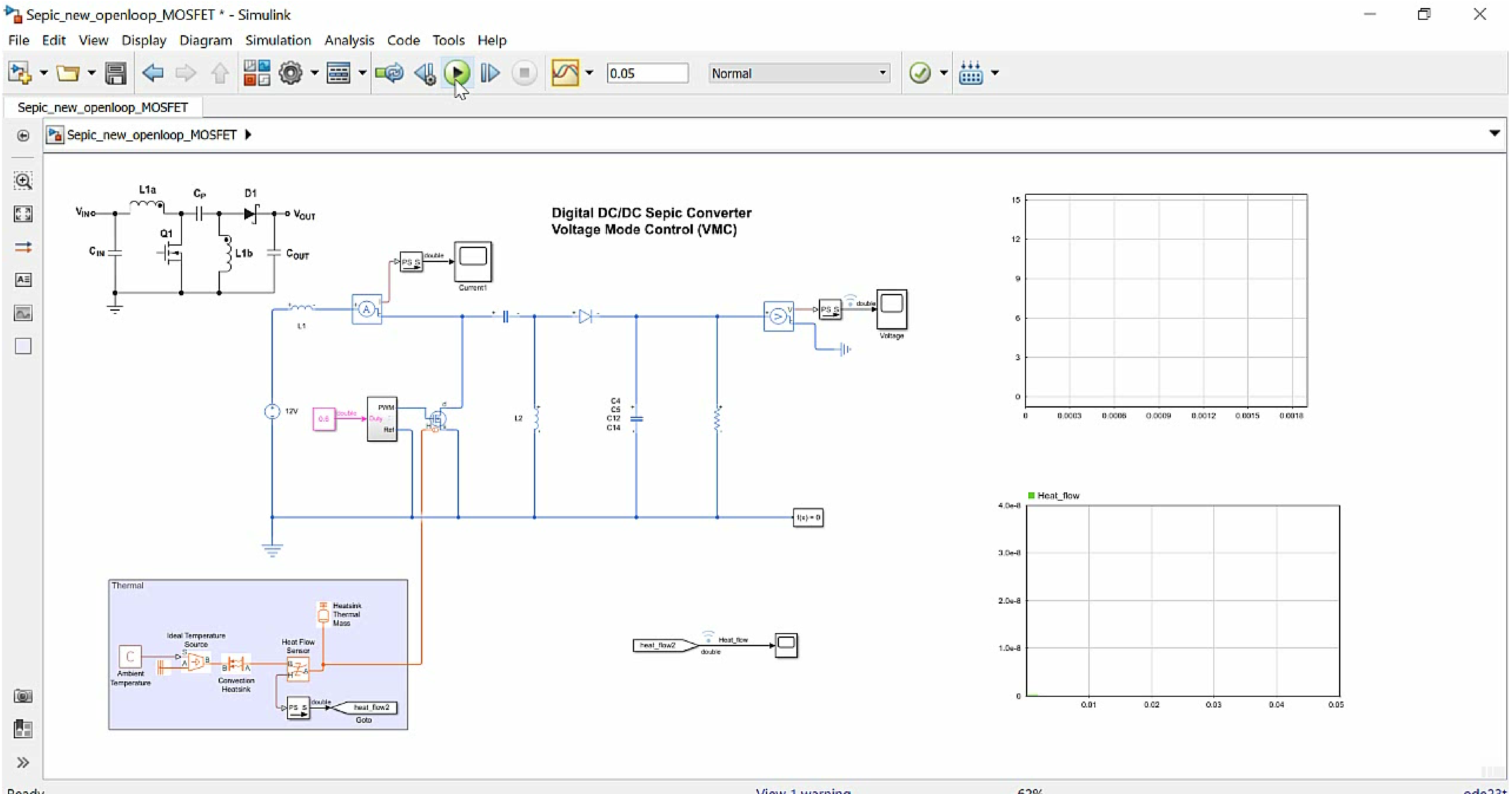
Device Blocks



Parameterizing the MOSFET Switch from the datasheet



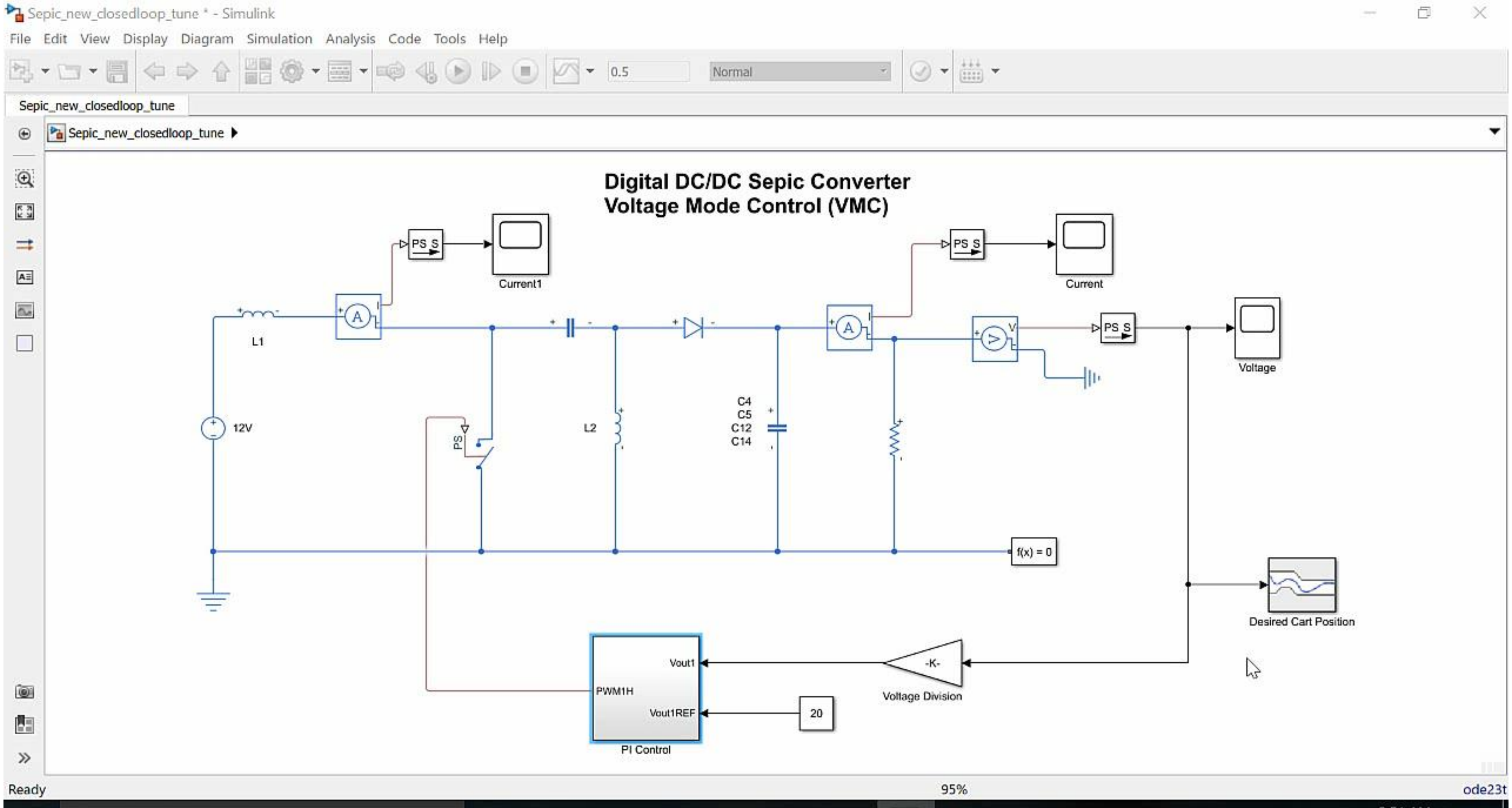
Determine power losses and simulate the thermal behaviour of the converter.



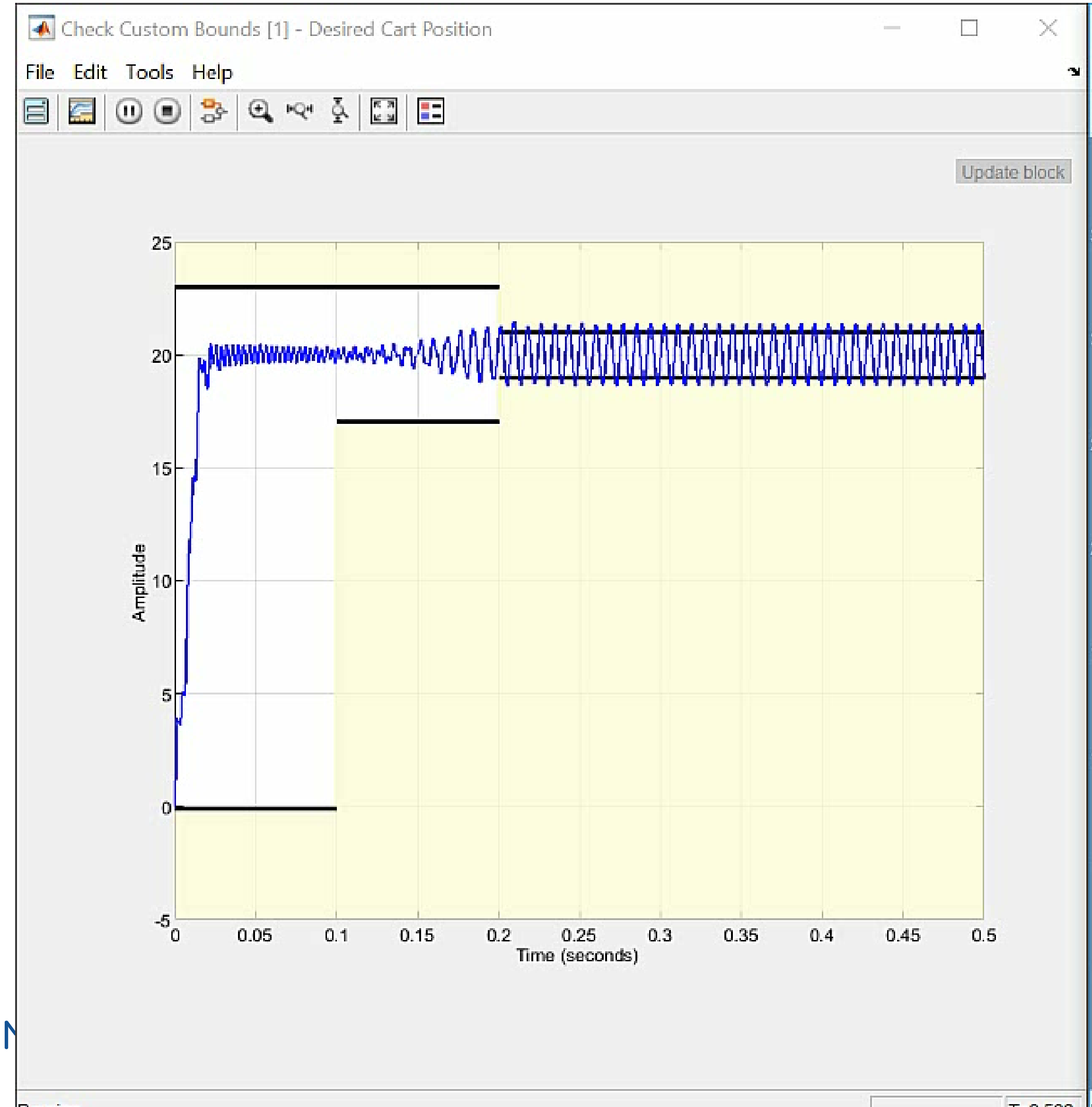
Lets explore interesting problem statements

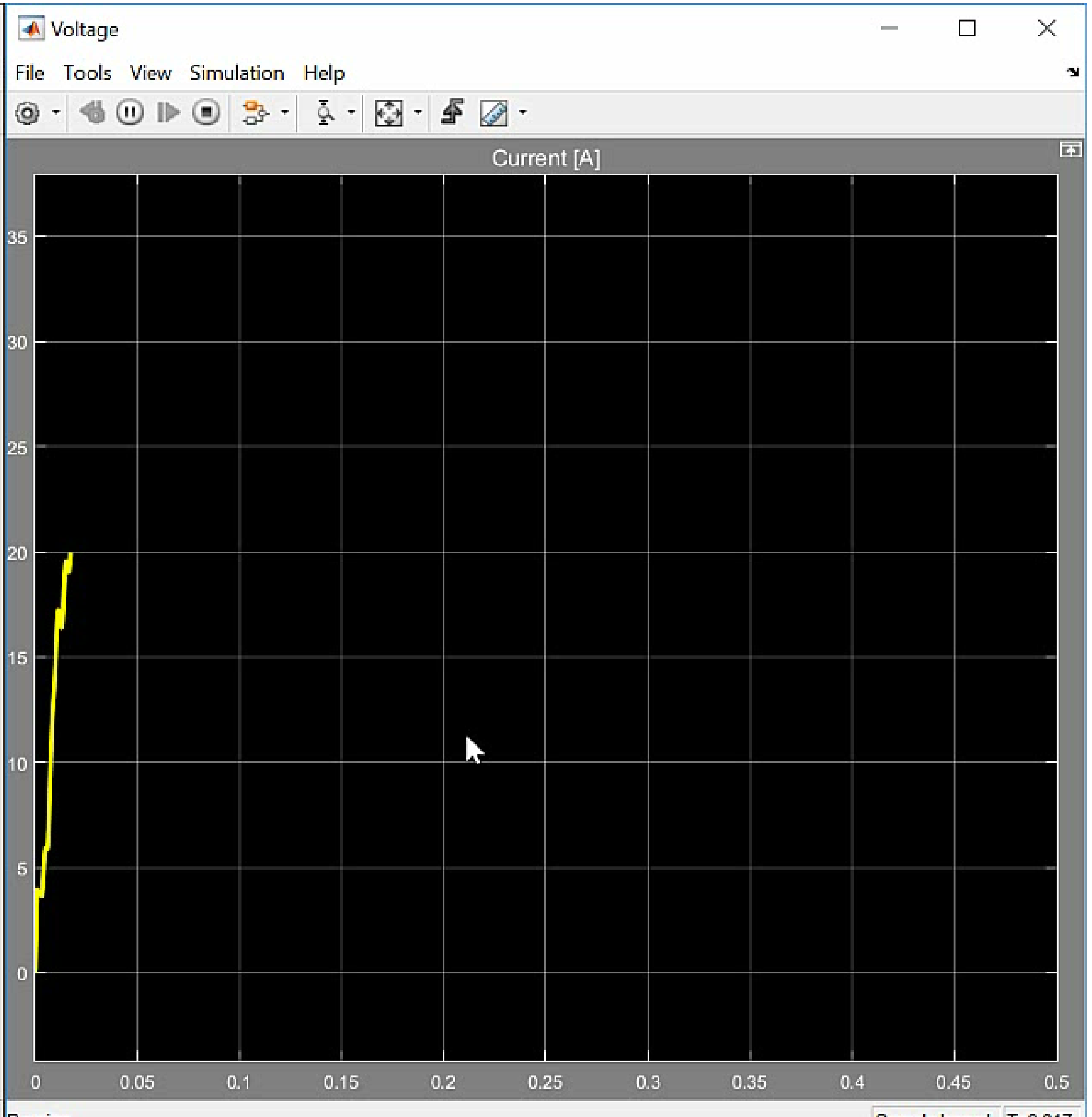
- How to size inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode?
- How to determine power losses and simulate the thermal behaviour of the converter?
- **How to design control algorithm based on time domain specification(Rise time , Overshoot , Settling time)?**
- How to run power electronics in HIL simulations at 1MHz frequency?

Design and tune the control logic for the power electronics converter.

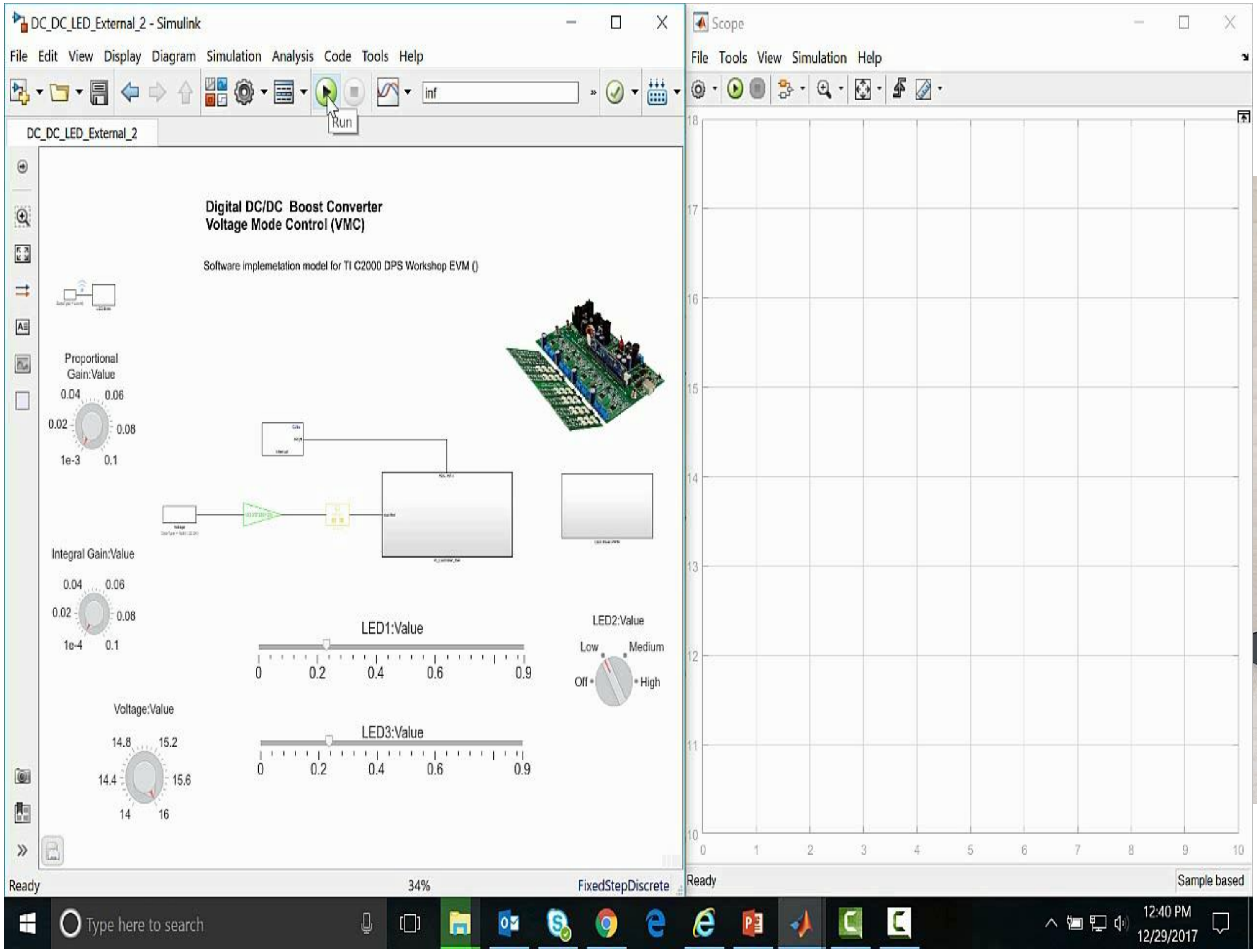


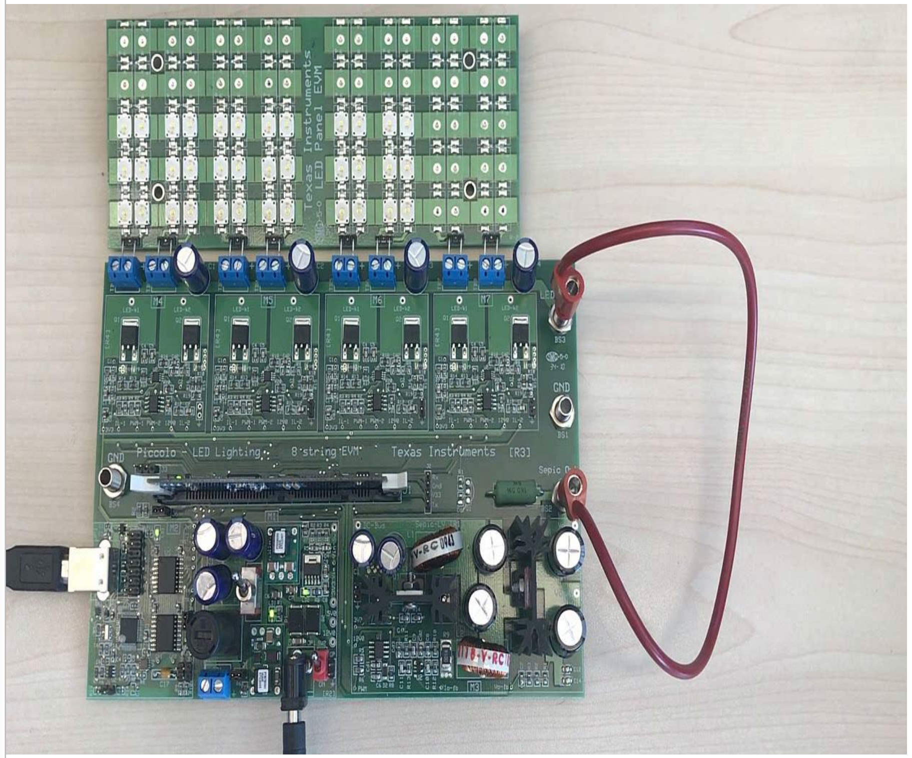
Design and tune the control logic for the power electronics converter.





Implementation of the power electronic controls on an Embedded Processor





Lets explore interesting problem statements

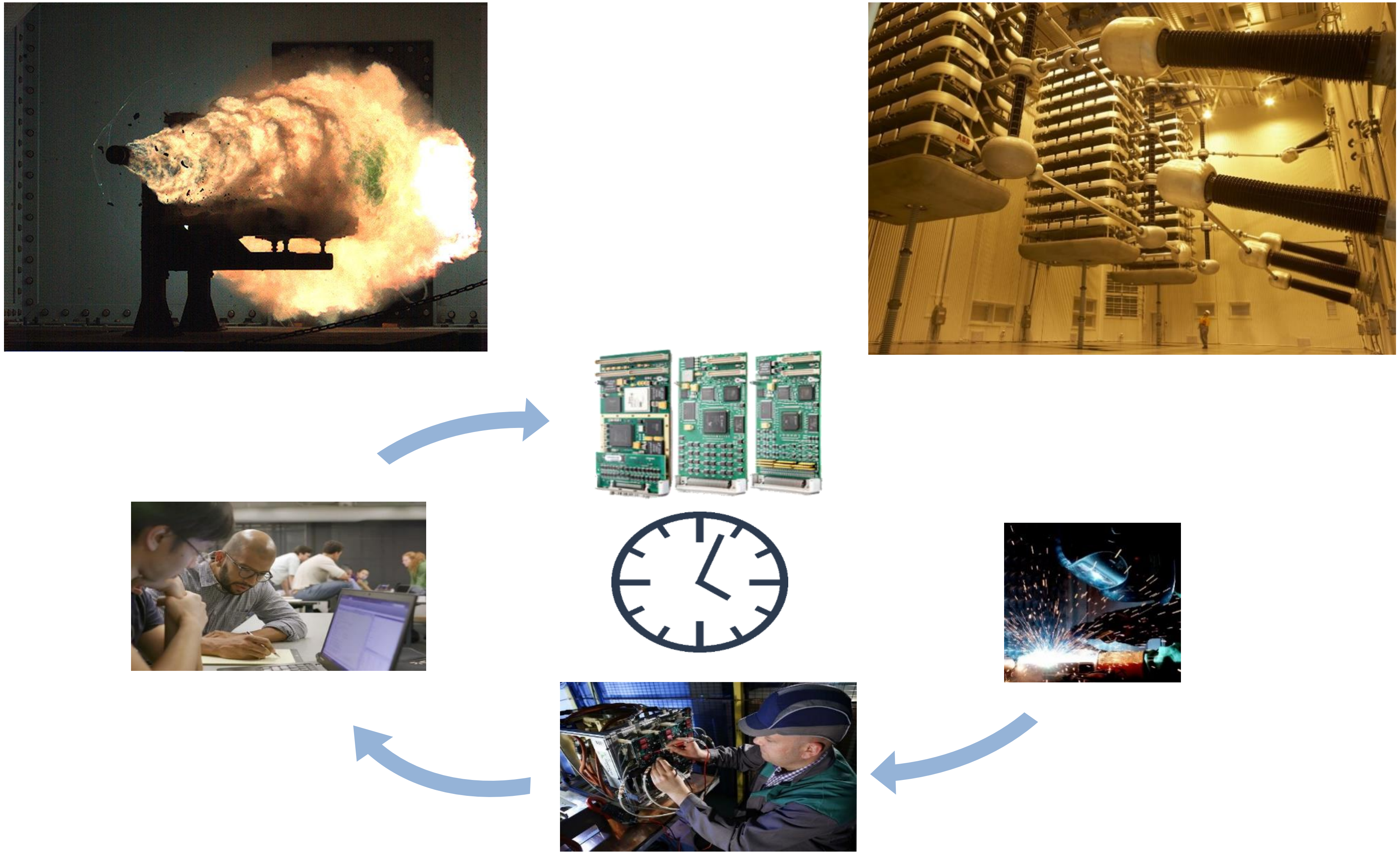
- How to size inductor, capacitor and understand the behaviour in Continuous and Discontinuous mode.

- How to determine power losses and simulate the thermal behaviour of the converter.

- How to design control algorithm based on time domain specification(Rise time , Overshoot , Settling time)

How to run power electronics in HIL simulations at 1MHz frequency?

Why Hardware-in-Loop Simulations (HIL)?

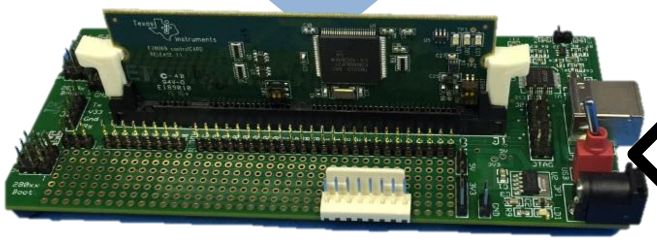


What is HIL

Algorithm Model

Controller

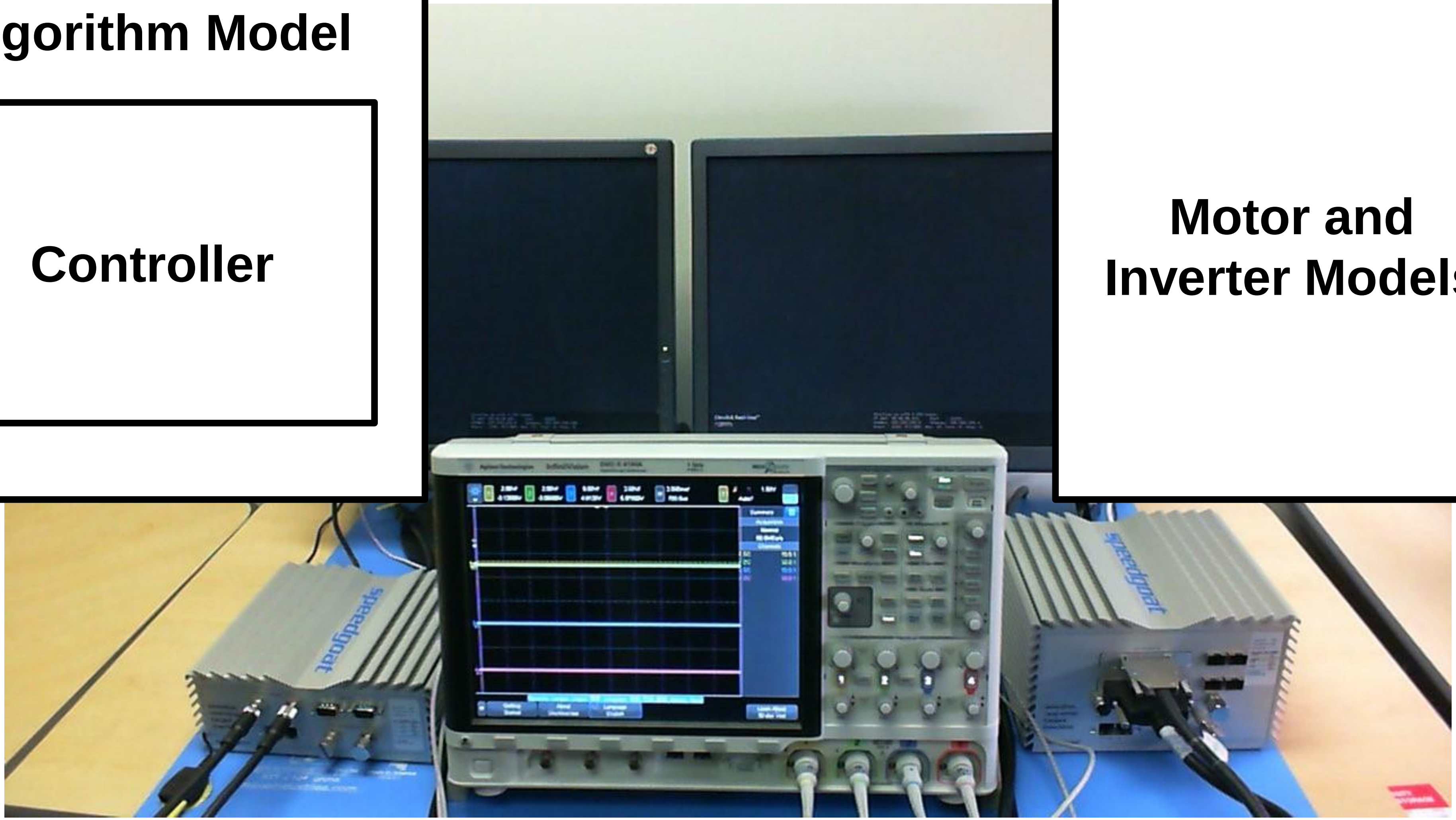
Motor and Inverter Models



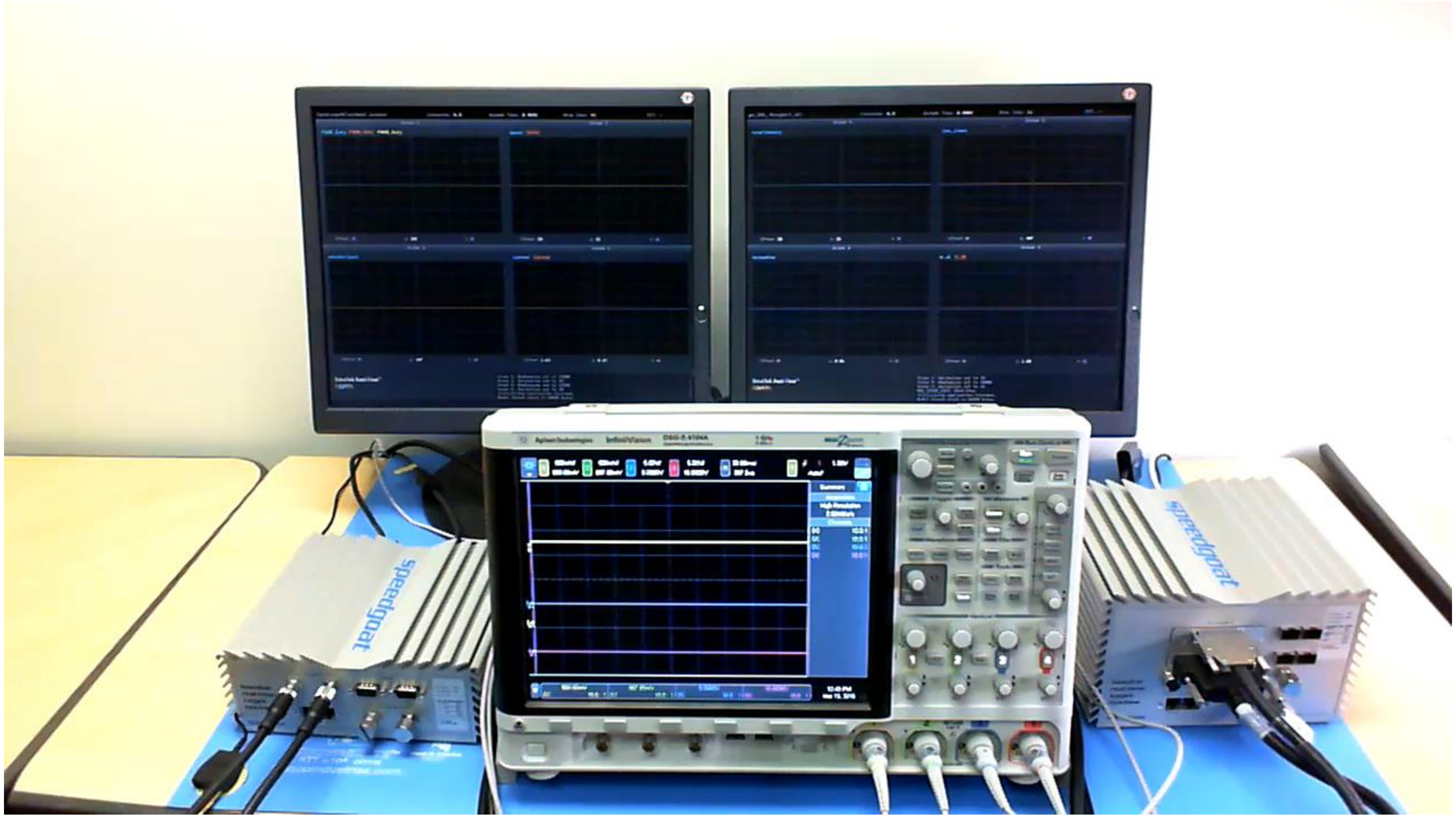
Algorithm Model

Controller

Motor and Inverter Models



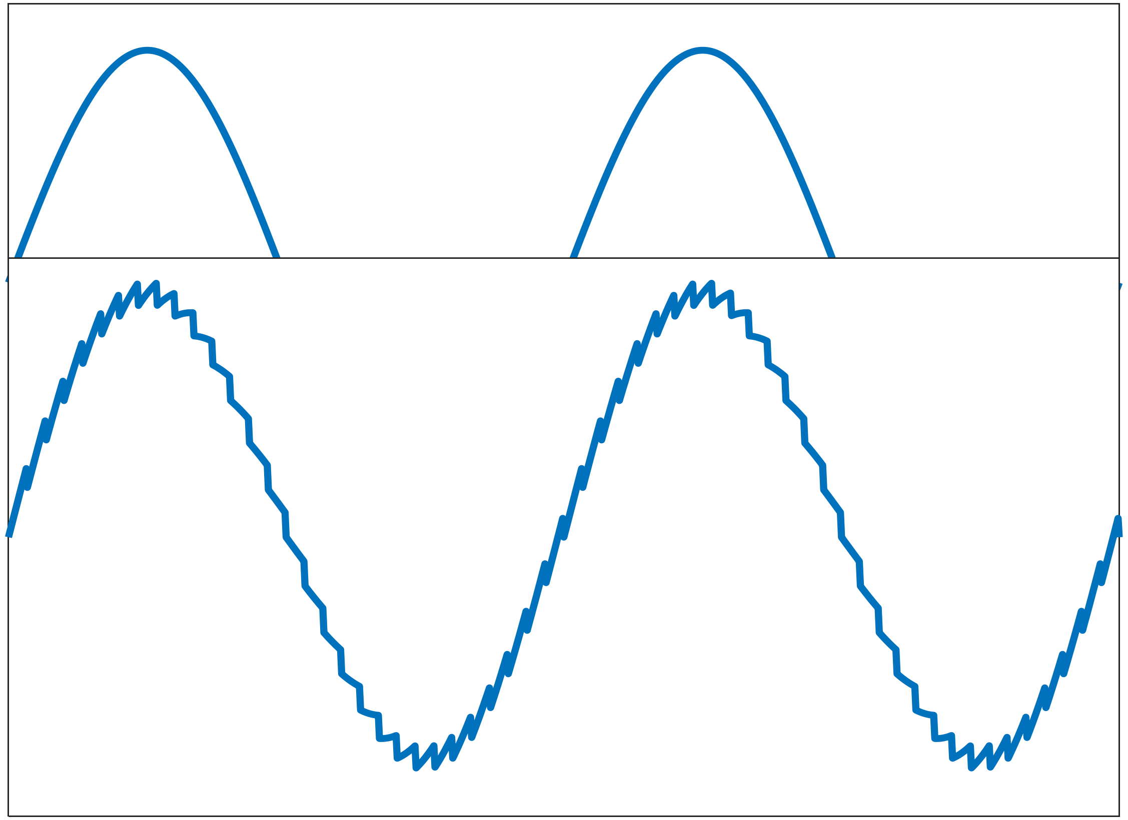
Demo



Power Electronics and Motor Control - Switching

2 Ways to simulate power electronics

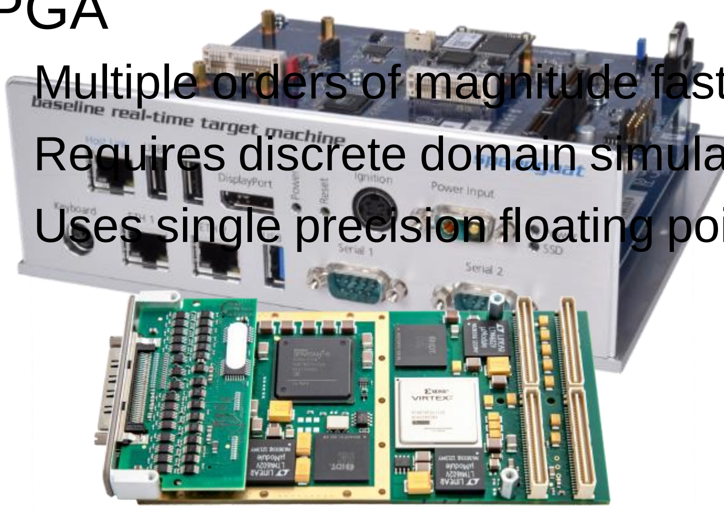
- Average
  - Easy to implement in real time
  - Ignores dynamics of switching devices
  - Good enough for some types of analysis
- Switching
  - Captures switching events
  - Requires simulation 100 times faster than switching frequency

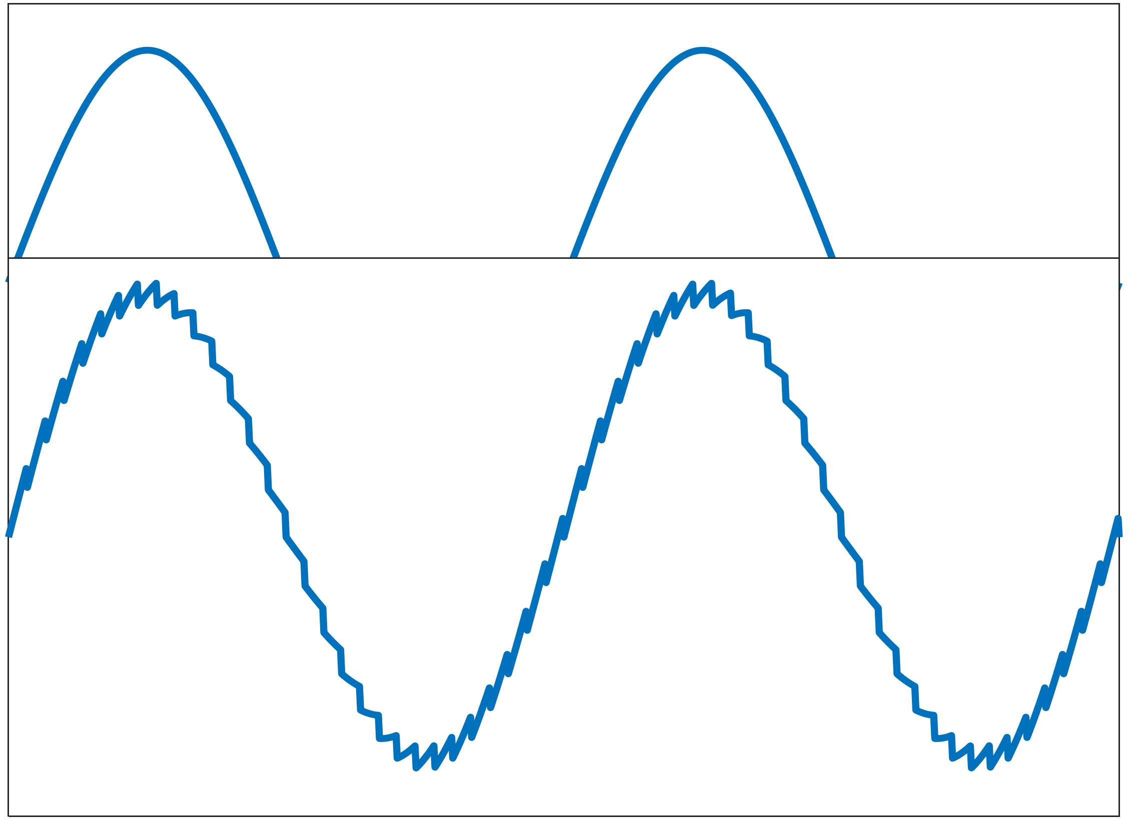


CPU vs FPGA Simulations

2 Ways to simulate power electronics

- CPU
  - Cheaper hardware
  - Can run continuous domain simulation
  - Run any code gen compatible block
- FPGA
  - Multiple orders of magnitude faster
  - Requires discrete domain simulation
  - Uses single precision floating point values





Real-Time Simulation and Testing

Complete Solution

Simulink Real-Time

MathWorks instrumentation

Toolboxes

Simscape/SimMechanics/SimPowerSystems

HDL Coder

MathWorks Kernel

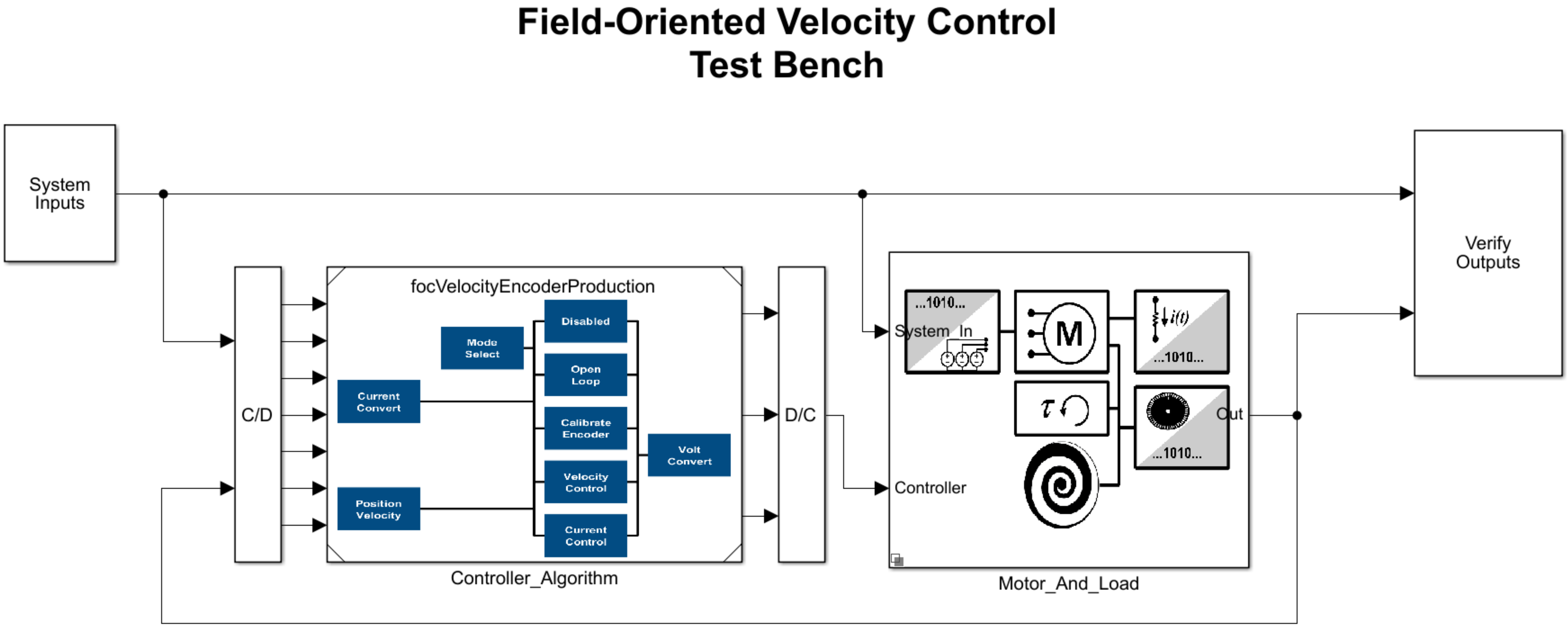
Speedgoat real-time target machines

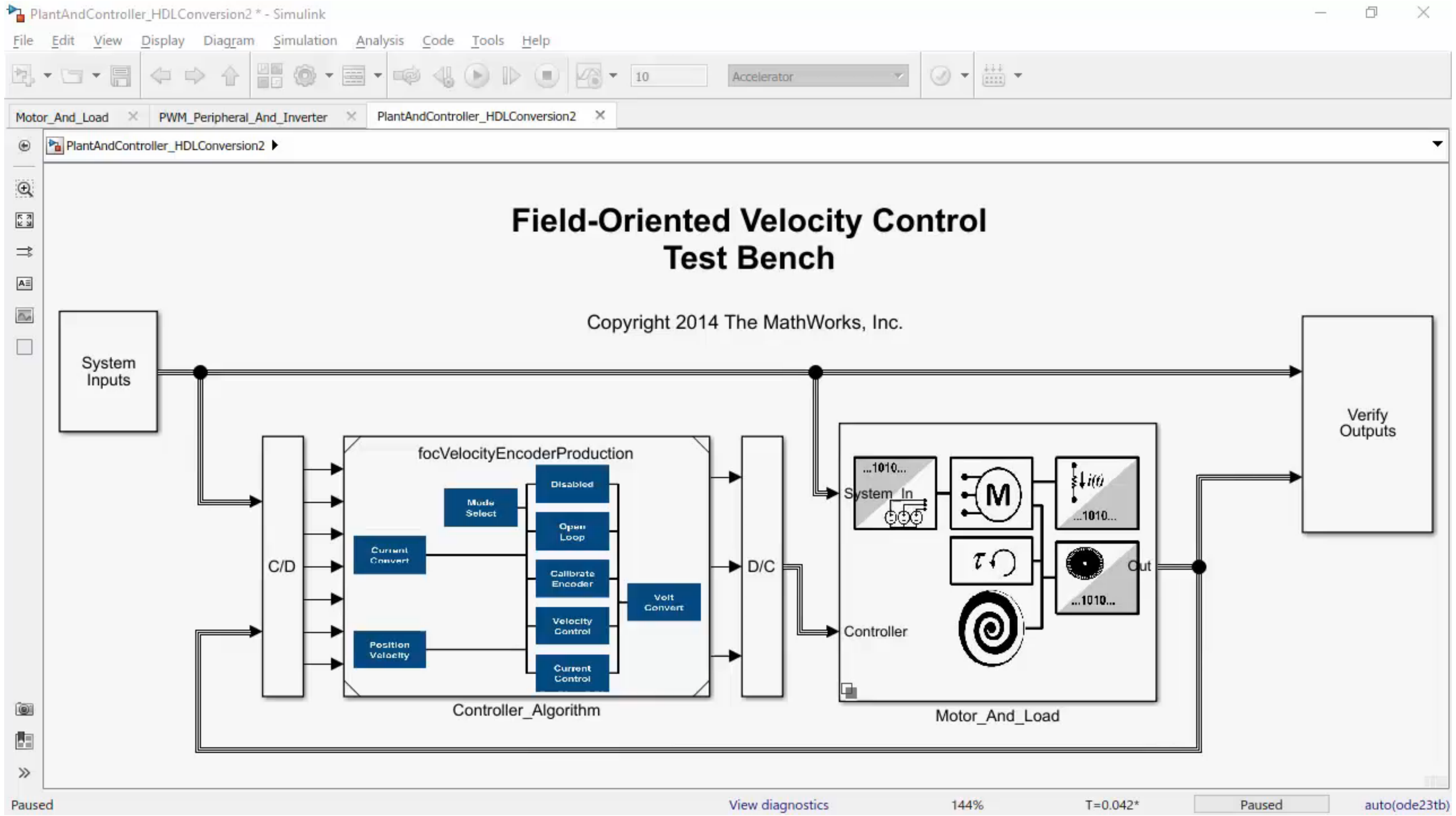
Speedgoat I/O Modules and protocol support

Speedgoat driver library

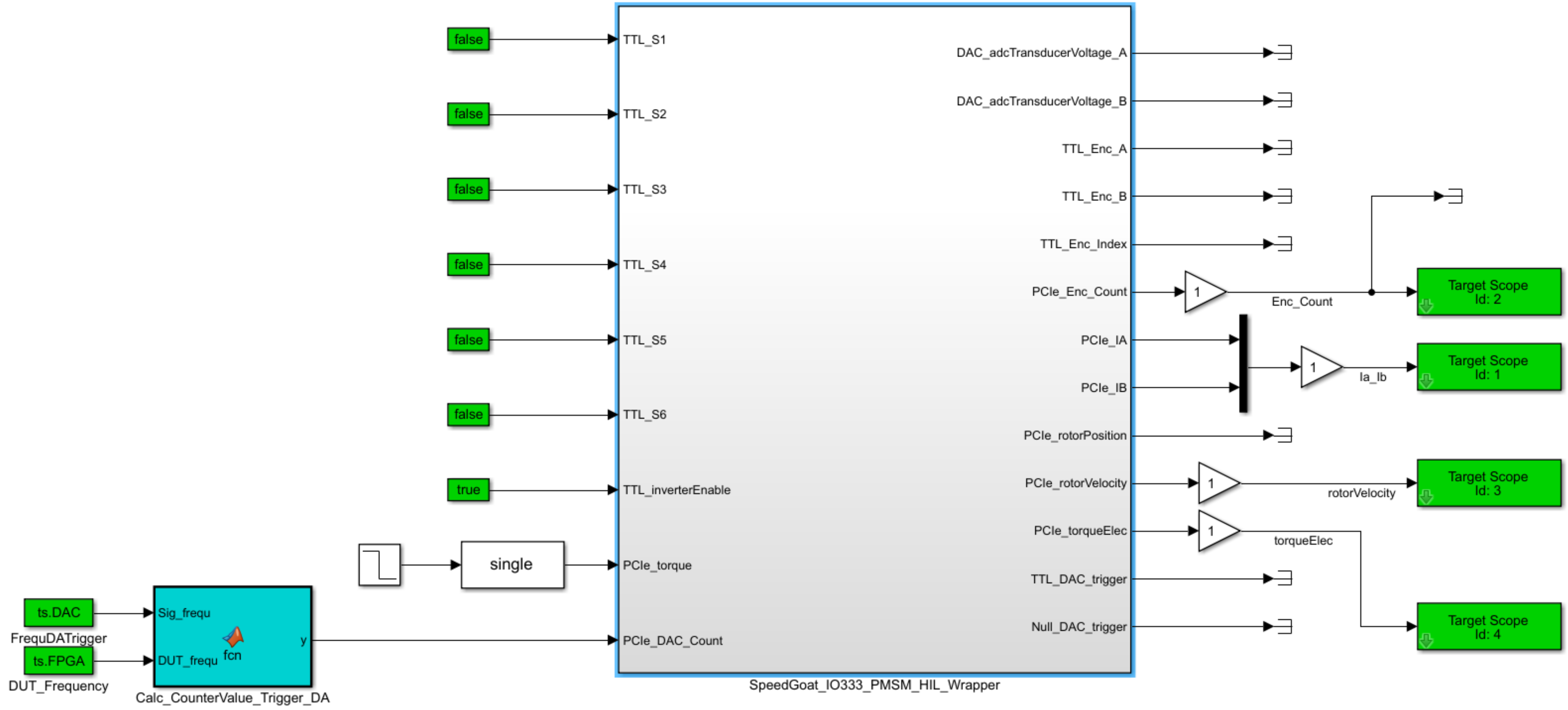
FPGA-based solutions

System Level Model of a Motor and Inverter in Simulink

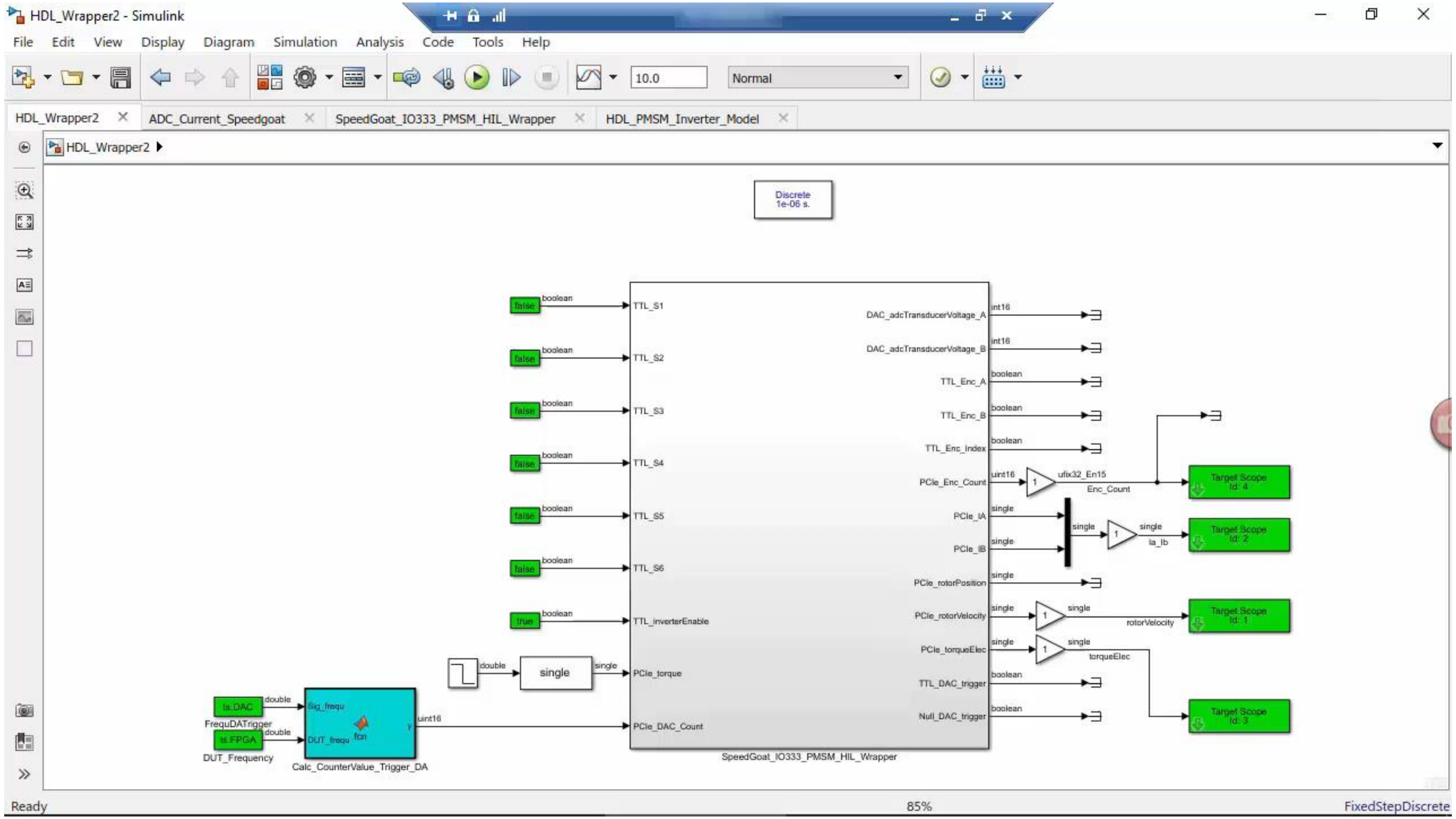



PlantAndController_HDLConversion2 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
Accelerator
Motor_And_Load
PWM_Peripheral_And_Inverter
PlantAndController_HDLConversion2
Field-Oriented Velocity Control
Test Bench
Copyright 2014 The MathWorks, Inc.
System Inputs
Verify Outputs
C/D
focVelocityEncoderProduction
Disabled
Mode Select
Open Loop
Current Convert
Calibrate Encoder
Volt Convert
Velocity Control
Position Velocity
Current Control
Controller_Algorithm
D/C
System_In
Controller
Out
Motor_And_Load
Paused
View diagnostics
144%
T=0.042*
auto(ode23tb)

HIL Simulation Using Simulink Real-Time and Speedgoat Target Hardware

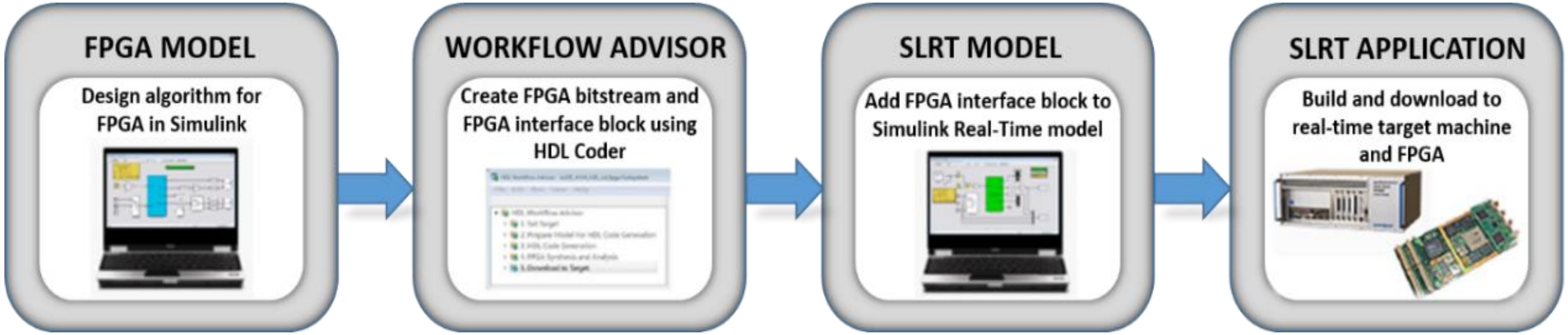


Use of HDL Coder to Generate Floating-Point HDL From the Simulink Model to Achieve 1 MHz Time-Steps



High Level Process for Deploying Model to FPGA

1. Create high level subsystem for defining I/O
2. Convert model to discrete time
3. Convert all double precision signals to single precision signals
4. Use HDL workflow advisor to setup model settings
5. Use HDL workflow advisor to use all HDL compatible blocks
6. Use HDL workflow advisor to create Xilinx Vivado project and perform synthesis
7. Deploy model to the Speedgoat real-time machine.



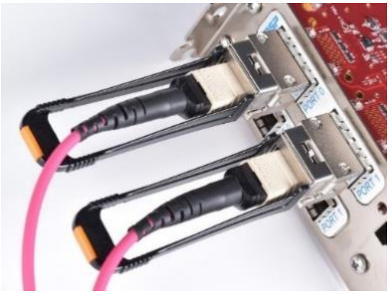
Simulink Programmable FPGA I/O modules
Optimized for Power Electronics HIL and RCP

The IO331-335 I/O modules are optimized for HIL simulation of real power stages. The card combines fast, low-latency analog and digital I/O capabilities, and is optimized for use with HDL Coder Workflow Advisor from MathWorks.

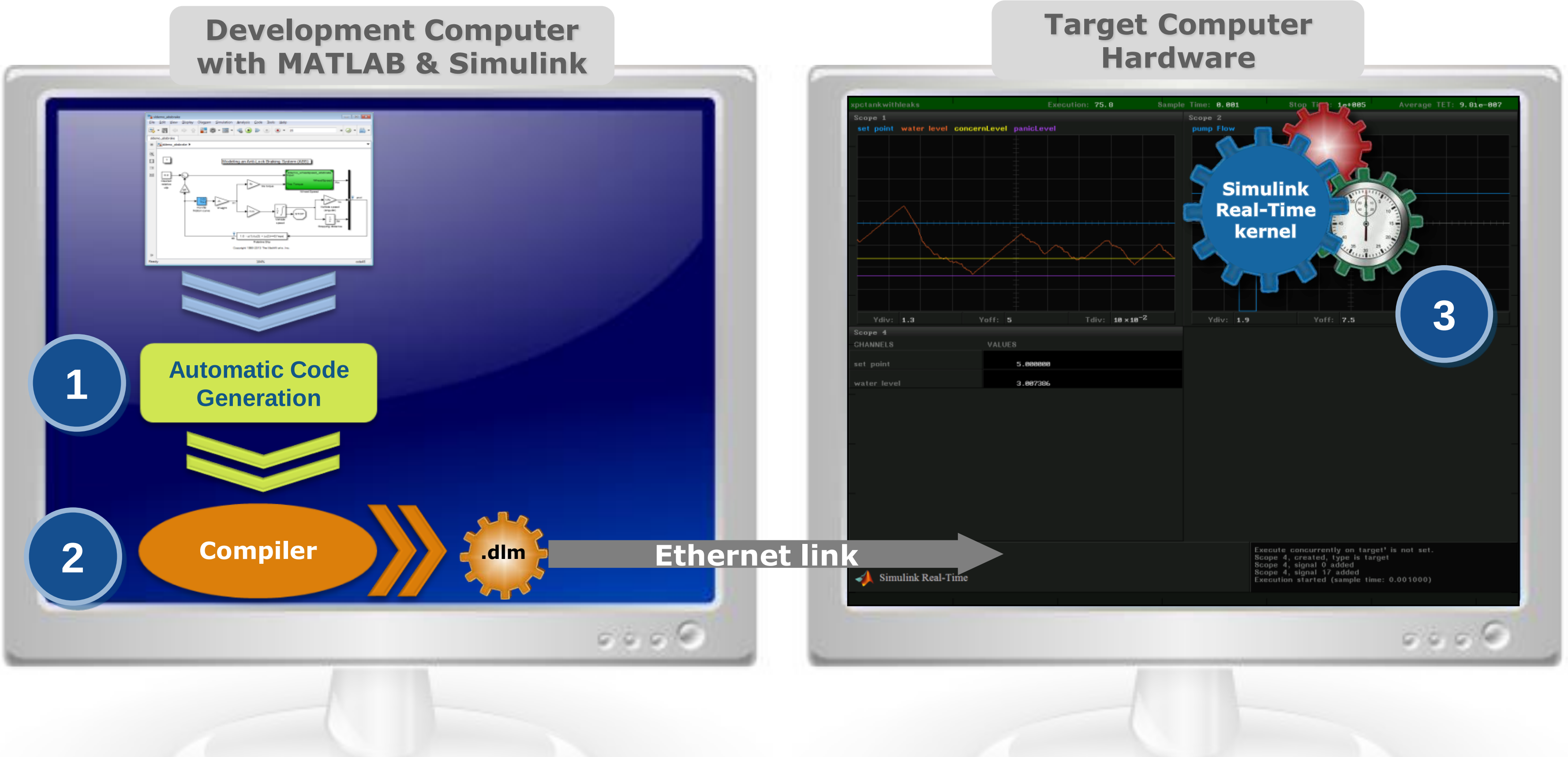
Analog connectivity:
16 x 5 MHz ADC, +/-10V, ENOB > 13-bit at 5 MHz
16 x 2 MHz DAC, +/-10V, settling time <1us

Multi-Gigabit Transceivers:
4 x MGT for inter-board communication
Enables scalability - I/O and computational resources

Selectable rear plug-ins add:
Digital TTL/RS422 I/O support for PWM / Encoder
Front SFP cages to access MGT at the out side of the enclosure



Simulink Real-Time: *From desktop simulation to real-time*

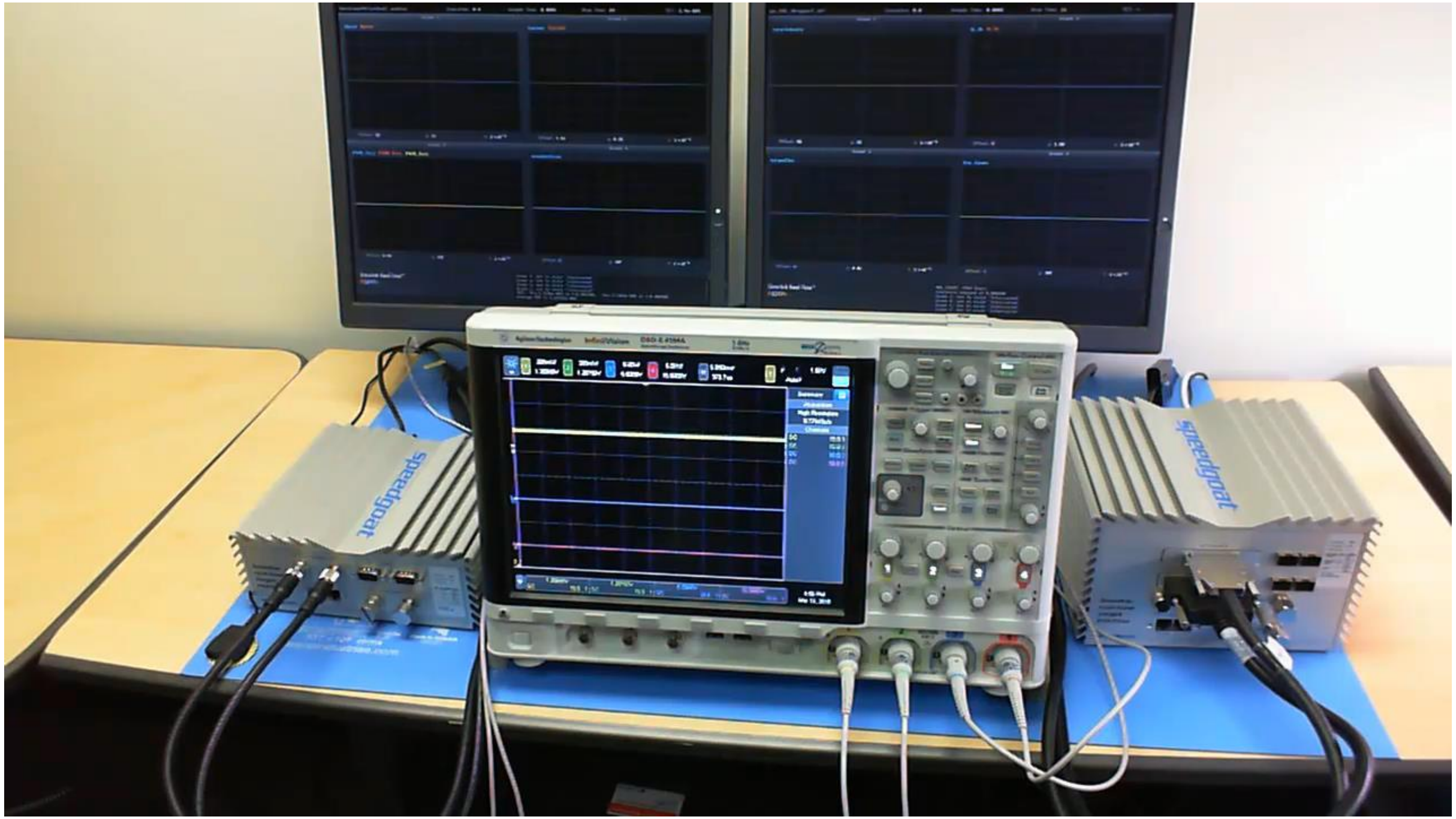


Creation of real-time applications from Simulink models and loading them onto dedicated target computer hardware in 3 automated steps:

1 Code Generation 2 Compile & Link 3 Download & Ready to Run

Simulink Real-Time: *Connect to your physical system*

- Support for a broad range of I/O types and communication protocols
- Easy drag & drop and configuration within a Simulink model


speedgoat
speedgoat

Call to Action

- Webinar
- Power electronics e-booklet
- Trail license

Training

Q&A

Speaker Details

Naga Pemmaraju

Email: Naga.Pemmaraju@mathworks.in

LinkedIn: https://www.linkedin.com/in/n-pemmaraju/

Speaker Details

Vivek Raju

Email: Vivek.Raju@mathworks.in

LinkedIn:https://www.linkedin.com/in/vivekraju87/

Contact MathWorks India

Products/Training Enquiry Booth

Call: 080-6632-6000

Email: info@mathworks.in

- **Share your session feedback:**

  Please fill in your feedback for this session in the feedback form

Thank you