Real-Time Testing Made Easy with Simulink Real-Time
Model-Based Design
Continuous Verification and Validation

System Design
- Environment
- Physical Components
- Algorithms

Component Design

Subsystem Design

Implementation
- Embedded Software: C++, VHDL, Verilog
- Digital Electronics: MCU, DSP, FPGA, ASIC

Verification and Validation

Code Verification and Validation

Subsystem Implementation

Subsystem Integration & Test

System-Level Integration & Test

Integration testing

User Acceptance Testing

Generate

Complete Integration & Test

Requirements
Model-Based Design
Continuous Verification and Validation

Requirements

System Design
- Environment
- Physical Components
- Algorithms

System-Level Specification

Rapid Prototyping

Subsystem Design

Environment
Physical Components
Algorithms

HiL Simulation

User Acceptance Testing

Complete Integration & Test

System-Level Integration & Test

Verification and Validation

Code Verification and Validation

Subsystem Integration & Test

Implementation

Embedded Software
Digital Electronics
- C
- C++
- VHDL, Verilog
- MCU, DSP, FPGA, ASIC

Generate

Subsystem Implementation
Simulink Real-Time Enables Simulation and Testing

Rapidly create real-time applications from Simulink models and run and test them with your hardware under test at normal operating frequencies, speeds, and timing.
Real-Time Simulation and Testing Tasks:

*Rapid Control Prototyping*
Real-Time Simulation and Testing Tasks: 
**Hardware-in-the-loop (HIL) Simulation**

![Diagram of HIL Simulation](image-url)
Additional Real-Time Simulation and Testing Tasks:

*Parametric Evaluation and Performance Assessment*

- **System robustness**
  - Monte Carlo analysis
  - Operational envelope testing

- **Human factors**
  - Human-in-the-loop simulation
  - Virtual reality simulators

- **Calibration**
  - Tune algorithmic coefficients
  - Optimize performance
How does Simulink Real-Time work?

*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 and Link
3. Download and Ready to Run
Instrument your Real-Time Applications

- Simulink Real-Time provides a number of UI options that enable you to communicate with and control real-time applications running on the target machine:
  - Simulink Real-Time Explorer – slrtexplr
  - Simulink External Mode
  - Simulink Real-Time APIs
  - MATLAB UIs
  - MATLAB command scripts

- Use one or more of these tools based on your workflow and interface requirements.
Demonstration – Simulink Real-Time Explorer
Demonstration – Simulink External Mode
Model xpcosc:
simple xPC Target demo model
Demonstration – Batch Simulation
Control and Instrument Your Real-Time Application

Built-in control and monitoring User Interface
Create UIs in MATLAB

Graphical front end for your MATLAB scripts and apps
Simulink Real-Time Deployment

- Runs independently of Simulink
- One Simulink/Simulink Real-Time Target license
- Many target machines
  - Field deployment
  - Complete controller products
  - Stand-alone HIL solutions
  - Etc.
**Speedgoat Real-Time Target Machines**

*Assembled based on your technical requirements*

- Form factors available for office, lab, field, and classroom use
- Optimized for highest real-time performance (Multicore CPUs and FPGAs)
- Fully tested and works out-of-the-box
- Flexible, expandable architecture supporting a wide range I/O connectivity

*Custom engineering and I/O module development available*
Demonstration – Controller Algorithm with Generated Encoder and PWM Peripherals
Example application

Rapid motor control prototyping

- Flexible real-time prototyping platform
- Use of CPU and FPGA
- PWM signal generation and encoder capture
- Synchronization of PWMs, current sensing, and model
Hardware solutions

Leverage the FPGA without needing to know HDL coding

Different use cases

1. Flexible FPGA Code Module functionality
   - PWM generation and capture
   - Incremental and absolute encoders
   - SPI and I2C protocol support
   - And much more

2. Accelerate parts of your Simulink model’s real-time application using automated HDL code generation

All based on the same hardware!
Pushing limits: More components, faster control algorithms
Example of partitioning controller for disparate rates

1 kHz Rate
- Velocity control
- Mode scheduler
- Encoder calibration

10 kHz Rate
- Field oriented control
- ADC to current
- Encoder to position
- Position to velocity
- Voltage to PWM

50 MHz Rate
- PWM peripheral
- Encoder peripheral
Where should a 50 kHz control loop be implemented?

**Microprocessor**
- 1 kHz Rate
  - Velocity control
  - Mode scheduler
  - Encoder calibration

**FPGA**
- 50 MHz Rate
  - PWM peripheral
  - Encoder peripheral

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**50 kHz Rate**
- Field oriented control
- ADC to current
- Encoder to position
- Position to velocity
- Voltage to PWM

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???
What else do we need to be aware of to implement the 50 kHz rate on the FPGA?

**Microprocessor**
- 1 kHz Rate
  - Velocity control
  - Mode scheduler
  - Encoder calibration

**FPGA**
- 50 kHz Rate
  - Field oriented control
  - ADC to current
  - Encoder to position
  - Position to velocity
  - Voltage to PWM
- 50 MHz Rate
  - PWM peripheral
  - Encoder peripheral
Examples of Speedgoat FPGA-based I/O modules for use with HDL Coder

Example: IO323
- Spartan 6 FPGA, 100k
- 32 x SE/16 DF AD
- 08 x DA
- 48 x configurable TTL
- MGT support

Latest Xilinx technologies available
- Artix 7
- Kintex 7
- Kintex Ultrascale
- …

Connect multiple FPGAs
- MGTs (Multi-Gigabit Transceiver) for inter-module communication
- Front SFP connectors for inter-system communication
With the Speedgoat system, changing parameters and tuning the system is very easy and straightforward. It saves us a lot of time."

“There is no need to re-compile and burn each new version of the control algorithm.”

Eyal Bagon
Senior Director Autonomous Vehicle
Mobileye

Eyal Bagon while not driving the car
User Story Examples: Various disciplines

Proterra, Greenville, SC, USA
Zero-Emmission Battery Electric Bus
Hardware-in-the-Loop simulation

Levant Power, Woburn MA, USA
Energy neutral active suspension system
In-vehicle Rapid Controller Prototyping

AGCO, France/Germany/USA
Agricultural vehicles with most energy efficient gearboxes
Hardware-in-the-loop simulation
Speedgoat Target Machine and I/O Offerings

Performance real-time target machine
Office and lab

Mobile real-time target machine
Field and in-vehicle use

Education real-time target machine
Academic use

Analog and digital I/O

Reconfigurable FPGA I/O

Protocol interfaces
Typical I/O used in Automotive Industry

Protocol support
- CAN / LIN / FlexRay
- Shared memory
- SPI / I2C

Passive components
- High precision resistors (thermocouples / RTD)
- Strain gauges

Encoder emulation
- Absolute (SSI) / Incremental
- EnDat, BiSS
- Synchro/Resolver, LVDT/RVDT

Fault insertion
- Wide range of channel counts / fault bus configurations
- Designed for safety critical applications

Timing applications
- Precision Timing Protocol (IEEE1588), GPS, IRIG
Speedgoat Real-Time Target Machines

*Designed for Simulink Real-Time, tailored to your needs*

Speedgoat develops and sells real-time target machine solutions consisting of:
- Real-time target machine
- I/O modules
- Software drivers, cables and tools to connect with a prototype

![Real-time target machine](image1)

![I/O modules installed in target machine](image2)

![I/O cables](image3)

![Terminal boards](image4)

![Driver blocks](image5)

![Simulink test models](image6)

![Documentation](image7)

![HIL rack example](image8)
Simulink Real-Time

Summary

- Seamless integration into MATLAB/Simulink
- An easy way to test your application in a real-time environment
- Runs on Speedgoat target hardware