Five Cool Things You Can Do With Powertrain Blockset

Mike Sasena, PhD
Product Manager
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it: Why are these cool?
  1. Engine control design / calibration → Reduce time on HIL, dyno, vehicle testing
  2. Fuel economy sensitivity → Design more robust systems
  3. Design optimization studies → Explore wider search space
  4. Multidomain simulation via Simscape → Validate detailed subsystem design
  5. Hardware-in-the-loop (HIL) testing → Validate controller virtually
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine controller calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape
  5. Hardware-in-the-loop (HIL) testing
Powertrain Blockset

- New product: R2016b+ (web release)
- Goals:
  - Provide starting point for engineers to build **good plant / controller models**
  - Provide **open** and documented models
  - Provide very **fast**-running models that work with popular HIL systems
Powertrain Blockset Features

Library of blocks

- Energy Storage and Auxiliary Drive
- Drivetrain
- Propulsion

- Transmission
- Vehicle Dynamics
- Vehicle Scenario Builder

Pre-built reference applications
Reference Applications

- Full vehicle models (conventional, EV, multi-mode HEV)
- Virtual engine dynamometers (compression ignition, spark ignition)
Four Use Cases. One Framework.

Use Cases:
1. System design and optimization
2. Controller parameter optimization
3. System integration test
4. Software-hardware integration test (HIL)
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine control design / calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape
  5. Hardware-in-the-loop (HIL) testing

Reduce time on HIL, dyno, vehicle testing
Engine Control Design / Calibration

- Powertrain Blockset includes virtual engine dynamometer reference applications
- These can be used for a variety of engine controls development and calibration activities
- Includes several pre-defined experiments
Automated Calibration Experiment
Executable Test Specification

- Describe the calibration procedure as a Stateflow chart (not a Word doc)
- Test the procedure virtually
- Validate / plan calibration procedure with test engineers
- Start testing on real hardware with refined procedure
Flexible Testing Framework

Use Powertrain Blockset mapped engine blocks with your own data

Create custom engine models using Powertrain Blockset library components

Connect in your own CAE model (e.g., GT-POWER)
Controls-oriented Model Creation

Detailed, design-oriented model

Fast, but accurate controls-oriented model
Engine Control Design / Calibration

- Gather “as calibrated” engine maps
- Automatically calibrate throttle / wastegate
- Define and simulate custom calibration procedures
- Generate engine maps from CAE models

How cool is that?
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine control design / calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape
  5. Hardware-in-the-loop (HIL) testing

Design more robust systems
FTP75 Simulation
Sensitivity Analysis

- Determine sensitivity of the fuel economy to changes in design parameters

- Configure Monte Carlo simulations using Simulink Design Optimization’s graphical interface
  - Create sample sets using random & pseudo-random techniques
  - Define behaviors of interest in the model

- Speed up performance using parallel computing
  - Local: Parallel Computing Toolbox
  - Cluster: MATLAB Distributed Computing Server
Sensitivity Analysis Results

City Cycle

- High variation in fuel economy for variations in wheel radius, vehicle mass, and other parameters
- High sensitivity to variation in wheel radius and injector slope values

Highway Cycle

- Low variation in fuel economy for variations in wheel radius, vehicle mass, and other parameters
- High sensitivity to variation in barometric pressure, but little else
Fuel economy sensitivity

- Run fuel economy, emissions and performance simulations at 50 – 100x real time
- Perform Monte Carlo studies to analyze sensitivity
- Use parallel computing to accelerate the process

How cool is that?
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine control design / calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape
  5. Hardware-in-the-loop (HIL) testing

Explore wider search space
Powertrain Blockset Enables Accessible Optimization Capabilities

50 - 100x Faster Than Real Time

- Simulation Time / Real-Time
- HEV Reference Application

Efficient Optimization

- More drive cycles and design parameters
- Using fewer resources

PC, UI

- Easier implementation
- Simulink Design Optimization UI
Multi-Mode HEV Review

Development of a New Two-Motor Plug-In Hybrid System

Naritomo Higuchi, Yoshihiro Sunaga, Masashi Tanaka and Hiroyo Shimada
Honda R&D Co., Ltd.

EV Mode

Requested Tractive Force [N]

Vehicle Speed [kph]

0 1000 2000 3000 4000 5000 6000 7000 8000

0 20 40 60 80 100 120 140 160

SHEV

Engine / Power Split

EV

Battery

Mot

Gen

Clutch

Front Tires

MathWorks
Multi-Mode HEV Review

Development of a New Two-Motor Plug-In Hybrid System

Naritomo Higuchi, Yoshihiro Sunaga, Masashi Tanaka and Hiroo Shimada
Honda R&D Co., Ltd.

SHEV Mode
Multi-Mode HEV Review

Development of a New Two-Motor Plug-In Hybrid System

Naritomo Higuchi, Yoshihiro Sunaga, Masashi Tanaka and Hiroo Shimada
Honda R&D Co., Ltd.

Engine Mode

Requested Tractive Force [N]

Vehicle Speed [kph]
**Design Optimization Problem Statement**

- Maximize MPGe
  - FTP75 and HWFET
  - Weighted MPGe = 0.55(FTP75) + 0.45(HWFET)

- Optimize Parameters:
  - 5 control parameters
    - EV, SHEV, Engine mode boundaries
  - 1 hardware parameter
    - Final differential ratio

- Use PC
  - Simulink Design Optimization (SDO)
  - Parallel Computing Toolbox (PCT)
Simulink Design Optimization

- Speed Up Best practices
  - Accelerator mode
  - Fast Restart
  - Use Parallel Computing Toolbox
- Specify Simulation timeout
Optimization Results

Simulink Design Optimization → Response Optimization

\[ F_d = \frac{\beta}{(\gamma + \nu)} + \alpha \]

~ 12 Hours

3.42:1

+ 2% MPGe

2.92:1
Design optimization studies

- Define Design Optimization studies with minimal setup effort
- Enable parallel computing with a simple checkbox
- Perform Design Optimization studies overnight on your laptop
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine control design / calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape: Validate detailed subsystem design
  5. Hardware-in-the-loop (HIL) testing
Custom Drivetrain or Transmission

- Replace portions of reference application with custom models assembled from Simscape libraries
- Use Variant Subsystems to shift back and forth based on current simulation task
Engine Cooling System

- Take customization one step further
- Start with “Custom Driveline” variant
- Add Engine Cooling subsystem adapted from `sscfluids_engine_cooling_system`
Conventional Vehicle with Simscape Engine Cooling

1. Heat rejection calculation
2. Heat distributed between oil and coolant
3. Temperature of cylinder used to validate cooling system performance

Local Solver enabled for faster simulation
Multidomain simulation via Simscape

- Create detailed, multi-domain subsystem models with Simscape
- Incorporate them into system level vehicle models from Powertrain Blockset
- Validate subsystem performance with closed loop simulation

How cool is that?
Agenda

- Introduction to Powertrain Blockset

- Five cool things you can do with it:
  1. Engine control design / calibration
  2. Fuel economy sensitivity
  3. Design optimization studies
  4. Multidomain simulation via Simscape
  5. Hardware-in-the-loop (HIL) testing

Validate controller virtually
HIL Testing with Powertrain Blockset HEV Model

- **Speedgoat Rapid Control Prototyping System**
- **Embedded Controller Hardware**
- **CAN Cable**
- **Target Computer Hardware**

- **Target Computer Hardware in-the-loop System**

- **CAN**

![Diagram of HIL Testing with Powertrain Blockset HEV Model](image)
Easily Tune Parameters in Real Time and Save Calibrations

Calibrate parameters at run time in Simulink Real-Time Explorer

Use Simulink Real-Time API to save and compare calibrations directly from MATLAB
Hardware-in-the-loop (HIL) testing

- Validate control algorithm before physical prototypes are available
- Reuse the same vehicle models across the V-cycle
- Tune parameters in real time
- Setup a HIL test in a few hours

How cool is that?
Summary

- With Powertrain Blockset, you can perform Model-Based Design on your automotive systems with a single, seamlessly integrated environment
  - Engine control design / calibration
  - Fuel economy sensitivity
  - Design optimization studies
  - Multidomain simulation via Simscape
  - Hardware-in-the-loop (HIL) testing
If you’d like to learn more, please contact us!

Please send your questions to Mike Sasena at
mike.sasena@mathworks.com