Engine ECU HIL simulation using Matlab-Simulink

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Agenda

Why Hardware-in loop (HIL) simulation

Hardware-in loop introduction and workflow

Typical HIL setup

Software components of HIL system

Matlab-Simulink Model and Results
- Emission norms, safety and customer convenience have been the driving factors of increasing electronic controller hardware and software complexity in the recent years.

- The increased complexity and sophisticated specifications demand rigorous and reliable testing to ensure error free product to the customer.

- The need for testing and validation of the controller software before proto vehicle is immense.
WHY HIL?

Reduction in development cost

Open loop and closed loop verification

Earlier detection of bugs and errors

Huge effort and time to test ECU functions

Simulation of variety of behaviors

Automated Testing

Challenges

Standardization

Complex modeling required
Signal Flows in real system and HIL system

Proto vehicle setup
Simulated vehicle setup
Simulated vehicle setup (HIL)

Image Source: dSPACE GmbH
Software components of HIL system

- Real time system – For simulation of sensors and observation of actuator signals (IO-Open loop test configuration)
- Dynamic Plant model (Closed Loop test configuration)

Matlab/Simulink to describe:
- The definition and configuration of the I/O
- The dynamic behavior of the plant
ECU point of view architecture

- **Engine IO**: Sensor and actuator Interface
- **Simulator IO**: Simulator and Relay control
- **Bus Systems**: CAN and LIN bus interface
- **Vehicle Plant**: Detailed engine and basic vehicle plant model

Diagram elements:
- **Sensors**
- **Actuators**
- **Engine**
- **ECU**

User Interface for model and Plant Interface
Actuator Interface
Crank and CAM sensor Interface
Ignition angle capture
Injection angle, timing capture
Knock sensor simulation
Accelerator pedal simulation
Power supply (Battery Simulation)
ECU controlled relay switching
Analog sensor simulation
Digital switch simulation
Virtual ECU: Basic Functionality of ECU to validate the plant model in SIL mode

Engine Model: Consists of Airpath, Fuel system and Mean torque model

Drivetrain Model: Consists of crankshaft, differential and starter model

To select between virtual ECU and Actual ECU signals (HIL mode)

To output signals to Engine IO and BusSystems
Tester Interface for Manual Closed Loop Testing

**Major Outputs:** Engine RPM, Vehicle speed, Indicated torque, Friction torque, Fuel injected, rail pressure, Intake manifold pressure
Simulation results compared with actual engine dyno data

- Mean Effective torque
- Fuel Injection
- Rail Pressure
- Compressor Output Pressure
- Air mass flow
Advantages of Hardware in loop

- Possible to simulate both Open loop and Closed loop tests
- Possible to simulate certain test cases that are not possible to simulate on proto vehicle
- Automated and regressive testing

Advantages of Matlab/Simulink in Hardware in loop

- Input output libraries of major simulator providers are available in Matlab/Simulink
- Customizable models from different suppliers can be integrated with ease
- Reusability and standardization for different simulators and systems
Thank You

Q&A