Diesel Engine software verification using GT-POWER RT model and dSPACE

Karthikeyan Venkatesan,
Solution Architect, KPIT Technologies
KPIT’s MBD based development (Domains: Powertrain, Body, Chassis & ADAS)

**Automotive Features in production across OEMs & Tier1s developed in MBD**
- Years of Experience in MBD: 12+
- Active Engagements in MBD: 40+
- People with expertise in MBD Technology: 1000+
- Automotive Features in production across OEMs & Tier1s developed in MBD: 250+
- OEMs & Tier1s who rely on KPIT for MBD Technology: 50+

**Area of Excellence**
- Model Based System Engineering
  - Enabling rapid design & Proof of concept of new Powertrain System & Subsystems
- Model Based Software Development
  - Increased flexibility in software development at reduced time & cost
- Integrated Tool Chain
  - For both development & testing of the complete V-cycle

**Solutions**
- Executable Specifications
  - Robust Requirements for Powertrain | Body | Chassis | ADAS
- Application Migration for AUTOSAR Platform
  - SPLA base Architecture | Unique Migration Methodology
- Production Grade Auto-Code Generation
  - Expertise with Embedded Coder, TargetLink | Guidelines for Optimized performance
- State of the Art MBD Tools
  - Model Guideline Checker with Auto-correction | MIL, SIL, HIL Test Automation Framework
Indicative list of organizations for which KPIT has provided production engineering solutions over time.

**Vehicle Manufacturers**

- Ford
- Daimler
- Renault Nissan
- Toyota
- Mazda
- Audi
- Paccar
- GM
- Chrysler
- Jaguar
- Tata
- Aston Martin
- Suzuki
- Hyundai
- Reva
- Kia
- Scania
- Renault
- AIXTRON
- NXP
- Infineon
- Renesas
- Siemens
- Bosch
- Delphi
- Continental
- Yazaki
- Denso
- ALPS
- Gentex
- Samsung
- Lear
- EATON
- Autoliv
- Brose

**Worldwide Presence**

- **USA:** Portland, OR, Detroit, MI, Iselin, NJ, Santa Clara, CA, Sacramento, CA, Irvine, CA, Columbus, IN, Richmond, VA, Houston, TX, Austin, TX, Boca Raton, FL
- **Europe:** London, Paris, Munich, Frankfurt, Amsterdam, Stockholm
- **Middle East:** Dubai
- **South Africa:** Johannesburg
- **India:** Pune, Mumbai, Noida, Bangalore, Hyderabad, Chennai
- **South Korea:** Seoul
- **Japan:** Tokyo, Osaka
- **China:** Shanghai, Beijing
- **Singapore**
- **Brazil:** Sao Paulo
- **South Africa:** Johannesburg
- **Australia:** Sydney

**Suppliers**

- Danfoss
- Siemens
- Mostal
- SL Corporation
- Delphi
- ALPS
- Yazaki
- Continental
- Denso
- Siemens
- ALPS
- Gentex
- Samsung
- Lear
- EATON
- Autoliv
- Brose
- Samsung
- LG
- Panasonic
- Mopho Electronics
- Carlisle
- Magna
We are playing a meaningful role in Industry shaping organizations

**AUTOSAR**
Open and standardized automotive software architecture
Premium partner
We are the largest contributor to AUTOSAR consortium & makers of Worlds 1st AUTOSAR R4.0.3 solution

**JasPar**
Standardization in technology area of in-vehicle network, software for companies in Japan
Premium partner

**ASAM**
Association for Standardisation of Automation and Measuring Systems
Member
Our Diagnostics Solution has been Recommended by one of TOP 3 OEMs in the World

**GENIVI**
Automotive alliance for in-vehicle Infotainment software
Anup Sable, Sr. VP is a Board Member of GENIVI

**BIS**
Bureau of Indian Standards (BIS) for Intelligent Transport Systems
Panel Member
Active role in setting standards for adoption of Intelligent Transport in India

**Oracle**, **SAP**, **IBM**, and **Microsoft**
Partners.
Trend in the Industry w.r.t. fundamental blocks

Infrastructure
- Investments are made in Tools:
  - Adoption of ALM tool to integrate entire VnV cycle
  - Dashboard reporting and analytic tool
  - Tools based FMEA

Test Boundaries
- Test Boundaries are created along with detailed I/O
  - Categorization of requirement and testing needed at each phase like:
    - Functional Testing, System Testing, Tools Interaction Testing

Traceability
- Adoption of ALM tools
  - Creating Test Boundaries

Re Use
- Developing Test Libraries (PLA kind of concepts)
  - Test Allocation
  - Ensure consistency with Test Infrastructure and Test Repeatability

Automation
- Automation is done at multiple levels:
  - Component Level (MIL), System Level (HIL)
  - Requirement Based Validation
  - Test Automation Framework

Virtualization
- ECU/Design Level
  - Sensor /Actuator Models
  - Component Models
  - Complete Plant modeling at system level

Processes
- Processes are getting aligned to meet the demands of standards like
  - Auto Spice, CMMI, ISO 26262
  - Standard demand certain level of maturity at every stage

Training
- Newly introduced tools
  - Impact of standards in the test cycle
  - Integration and Management of Plant models
# Product Engineering – VnV Solutions

Leverage our deep expertise across Automotive Subsystems

<table>
<thead>
<tr>
<th>AUTOSAR &amp; In Vehicle Networks</th>
<th>Engineering Design</th>
<th>Instrument Clusters</th>
<th>Powertrain</th>
<th>Vehicle Diagnostics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• AUTOSAR Strategy</td>
<td>• Powertrain – Exhaust &amp; Filtration</td>
<td>• Cluster Infotainment Hybrids</td>
<td>• Model Based Development</td>
<td>• Diagnostic Design &amp; Specification Solution</td>
</tr>
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<td>• AUTOSAR Integration</td>
<td>• Powertrain – Engine Transmission</td>
<td>• Reconfigurable Clusters</td>
<td>• Software Re-architecture</td>
<td>• Aftersales Solution</td>
</tr>
<tr>
<td>• MCAL &amp; Boot loader</td>
<td>• Powertrain – Fuel Systems</td>
<td>• Migration Solutions</td>
<td>• Systems &amp; Control Engineering</td>
<td>• Diagnostic Consultancy Services</td>
</tr>
<tr>
<td>• Migration Solutions</td>
<td>• Interior/Exterior - Seating</td>
<td>• Cluster Platform Management</td>
<td>• AUTOSAR &amp; Functional Safety Compliance</td>
<td>• Software Development &amp; Validation Services</td>
</tr>
<tr>
<td>• OEM Specific Customization</td>
<td>• Interior/Exterior – Door Trims, Steering, Cockpit</td>
<td>• Automated Validation Solutions</td>
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<td>• Safety Process Consulting</td>
<td>• Model Based Development</td>
<td>• On-Board</td>
<td>• Diagnostic Design &amp; Specification Solution</td>
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<td>• Auto HVAC</td>
<td>• Safety Process Tailoring</td>
<td>• Safety Process &amp; Functional Safety</td>
<td>• Connectivity</td>
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<td>• Functional Safety Engineering &amp; Analysis</td>
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<td>• Business IT</td>
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</tr>
<tr>
<td>• Smart Mirrors &amp; Wipers</td>
<td>• Customization of medini™ analyze</td>
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| Chassis, Safety and Driver Assistance | | | | |
|---------------------------------------| | | | |
| • Night Vision With Pedestrian Detection | | | | |
| • Adaptive Cruise Control             | | | | |
| • Driver Status Monitoring            | | | | |
| • Forward Collision Warning           | | | | |
| • Traffic/Road Sign Recognition       | | | | |

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A team of 560+ engineers in various powertrain and vehicle functions Validation and Verification activities

- Powertrain – ~120 Engineers
- Other Domain ~ 260 Engineers
- Vehicle Functions – ~200 engineer
- ~18% at customer sites and rest in KPIT India centers

Activities involved
- Test Strategy development
- Test framework and vehicle simulators development/enhancement
- HIL Plant model development
- Virtualization strategy development
- Test Procedures Testing based on ISO26262 standards
- Test scripts development
- Test execution
- Test documents, traceability, reports – Test management
HIL Bench Setup @ Bangalore

- dSPACE Simulator
- Fibre Optics Communication
- Serial Communication
- Workstation

- CAN INTERFACE
- ECU
- BOB & Load Box

- Physical Data Exchange

HIL Test Setup @ Pune

- Host User Interface
- USB Interface
- CAN CaseXL

- Host PC
  - Vehicle Model – Matlab/Simulink
  - GMLAN Communication and Flash boot loader specific test cases

- dSPACE Mid Size Simulator
  - Real Time Interface between Test Framework and ECU Hardware

- Real Load
  - HCA Interface between ECU and RDU

- Drive Line ECU

- Analog Signals
- High Speed CAN
- Chassis Expansion CAN

- BLDC Motor Interface
- DC Motor Interface
- Ignition Battery, Voltage, DIO

- Hydraulic Clutch Actuator
- Pressure Sensors
- Values

- DC Motor
Customer Requirements and KPIT HiL Setup

Customer wants to use KPIT knowledge, experiences and manpower to perform software calibration of a development stage ECM for a Diesel engine.

**Host PC**
KPIT Vehicle Model – Matlab/Simulink
( Diesel engine model in GT Power )

**KPIT dSPACE Mid Size Simulator**
Real Time Interface between Test Framework and ECU Hardware

**Actuators and Engine Harness**

**ECU**

**Development stage ECM**

**Calibration Tool**

- **Host User Interface**
- **USB Interface**
- **CAN hardware**
- **PCI Express**
- **High Speed CAN**
- **Chassis Expansion CAN**
- **Analog Signals**

KPIT Vehicle Model – Matlab/Simulink
( Diesel engine model in GT Power )
Diesel Engine software verification using GT-POWER RT model and dSPACE

HiL setup to perform the following test activities:
• HIL-Engine driving strategy for black box testing
• Start and stop of engine.
• Engine Idle operation for some minutes.
• Engine Operation based on Operating Sequence which customer provided to KPIT
• Straight line driving test with various grades required for ECM testing used at test setup.
• Electrical failure tests and threshold tests
• Different Test scenarios of engine performance calibrated after initial test run.
• Automatic Test report generation.
Various challenges faced during the calibration process

• Simulated and actual values read by ECU were not in agreement
• Lot of oscillations in the output received by the ECU during wastegate operation
• Initial Boost pressure is very high and sets diagnostic fault
• The injectors don’t fire during idle operation
• Idle rpm is not stable at the expected value
Few examples of activities performed during the calibration process

• Comparison between values generated by GT Power Model and values received by ECU and tuning of calibration variables:
  • Engine Speed, Hydraulic fluid pressure, Boost Pressure, Rail pressure, Throttle

• Modified parameters in calibration tool to change threshold values

• Implemented custom logic outside S function to control the output from the S function

• Implemented control logic to automate the control thresholds and speed limits of the system

• Modified sensor simulation to match ECU calibration thresholds and simulate acceptable results
Steady State results of real-time response Vs Model
Comparison of Transient Results

- Engine Speed [r/min]
- Turbo Speed [r/min]
- Load Torque [Nm]
- Gas Pressure [bar]
Benefits

Customers can benefit by:

• Easy Control logic verification at an early stage in the development process

• Increased ability to test a combination of 600 electrical and threshold faults using a custom drive cycle in a short span of time

• High flexibility to perform calibration of development software with legacy components
Summary & Conclusion

• Increasing complexities in design and features in automotive embedded systems driving newer trends in V&V methodologies

• KPIT’s experience in V&V spans across various domains and subsystems in automotive systems such as Powertrain, Body, Chassis, Infotainment and so on

• Approach towards providing software verification and testing solutions

• Tools and integration frameworks developed to support various calibration and testing activities
THANK YOU!