Virtual ECUs for high performance transmissions

Presented by:
Ewaut Dewinter
Application software engineer
Contents

- Tremec and high performance DCTs
- Transmission controls and Application Software
- Simulation and testing philosophy
- Performant Simulation Environment
Tremec develops and produces high performance transmissions

<table>
<thead>
<tr>
<th>TREMEC key facts</th>
<th>KUO key facts</th>
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</thead>
<tbody>
<tr>
<td>▪ Fully owned subsidiary of Kuo Group</td>
<td>▪ Controlled by Senderos family</td>
</tr>
<tr>
<td>▪ Focus on high torque/high requirements</td>
<td>▪ Long term strategic holding company</td>
</tr>
<tr>
<td>▪ Leader in performance transmissions &amp; transmission subsystems</td>
<td>▪ Activities in:</td>
</tr>
<tr>
<td>▪ Active in performance Dual Clutch Transmission systems since 2003</td>
<td>– Consumer – food</td>
</tr>
<tr>
<td>▪ Active in Europe, USA, Mid &amp; South America</td>
<td>– Chemical – synthetic rubber &amp; polystyrenes</td>
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<tr>
<td>▪ 1.650 employees</td>
<td>– Automotive – transmissions &amp; aftermarket</td>
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<tr>
<td>▪ 225 m$ turnover LTM 2017</td>
<td>▪ Active in 70 countries – HQ in Mexico City</td>
</tr>
<tr>
<td></td>
<td>▪ 20.000 employees</td>
</tr>
<tr>
<td></td>
<td>▪ 2.100m$ turnover LTM 2017</td>
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</table>
Tremec Belgium focuses on DCT hardware and software

Sales & program management office for North-American OEM’s

USA – Wixom MI

TREMEX center of competence for development & production of performance DCT transmissions & subsystems

- Hardware development of DCTs in the 600 Nm – 1000 Nm range
- Development of Controls hardware and Controls software

Belgium – Zedelgem

TREMEX center of competence for development & production of gear systems

Mexico – Querétaro
Contents

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Tremec has expertise in all disciplines needed for transmission control

**Electronics**
- TCU using multicore technology
- Design compatible with multiple transmission configurations

**Base software**
- AUTOSAR framework and Operating System
- Control and diagnostics of IO
- Communication with other ECUs

**Safety software**
- ISO 26262 compliance
- Safety goal monitoring

**Application software**
- High level functionality for drivability
- Mid level functionality for hydraulic and mechatronic control
- Model based algorithms
- Generic modules calibratable per application

**OBD**
- CARB 1968.2 compliance
- Electrical, Controller, Consistency and Performance Diagnostics
Application software makes the difference in DCT applications

- A DCT gearbox can handle a **wide range of shift feelings**
- A **brand specific car temperament** can be created just by changing software
- The same DCT gearbox can be used in different models
  - different calibrations are used to match driveline experience with type of car

Luxuriously Comfortable  
Ferociously Sporty
Contents

- Tremec and high performance DCTs
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Complete powertrain simulation aids both the Hardware & Software design

HW: Component design
SW: Control algorithm development

Detailed clutch model → Detailed valve model

Simplified clutch model → Simplified valve model
Engine + engine controller → Vehicle Dynamics → CAN communication

Complete Vehicle
Different simulation models are used for different goals

Detailed dynamics
Variable step solver
Focus on correct behavior
No focus on performance

Simplified dynamics
Fixed step solver
Focus on execution time
Approach real behavior

\[
F_{Flow} = \int_{C.S.} (\rho v_x \cdot \vec{v} \cdot \vec{n}) dA = \frac{\rho \cos \theta}{C_D A(x)} \cdot Q^2
\]
Different simulation models are used for different goals

Detailed dynamics
- Variable step solver
- Focus on correct behavior
- No focus on performance

Simplified dynamics
- Fixed step solver
- Focus on execution time
- Approach real behavior

Verifying hardware design
- Developing dedicated controls application

Real-time testing of application on a real or virtual TCU
Contents

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Business case
Tremec targets high performance applications

Parallel development of all components (short time to market)
  ➢ SW development needs to start before HW is finalized
  ➢ Limited availability of test vehicles

OEMs want unique character and stand-out features
  ➢ Agile SW implementation and testing environment
  ➢ Confidence in new algorithms before vehicle testing
  ➢ Possibility to explore new concepts and variants

Tremec needs a performant simulation environment to reach the desired SW maturity
Performant Simulation Environment
Buildup of know-how and initial tools

2011
- Software testing in MiL environment
  - Test patterns applied to inputs
  - Testing of only one software module
- Out-dated HiL setup
  - No in-house knowledge of updating the configuration

2013
- Development of complete vehicle simulation
  - Detailed model of hydraulic and mechatronic transmission components
  - Simplified model of vehicle dynamics
  - Basic implementation of other vehicle controllers

2015
- Development of PiL setup
  - Processor in the Loop: TCU is connected to a simulated vehicle but without IO processing
  - Possibility to test full Application Software functionality and integration

Today
Performant Simulation Environment
PiL setup for full ASW testing

Development of PiL setup

2011
2013
2015
2016
2017
Today

Simulated vehicle + controllers

Sensors/actuators

ECU
Engine

Simulated Transmission IO sent via private CAN bus

TCU
DCT

Physical relation/interface

BCU
Vehicle
Performant Simulation Environment

Further steps towards SiL testing

- Implementation of QTronic Silver and TestWeaver
- Testing of new algorithms without TCU HW needs

Simulated vehicle + controllers

Years:
- 2011
- 2013
- 2015
- 2016
- 2017
- Today
Performant Simulation Environment
Virtual TCU enables flexible ASW testing

Implementation of QTronic Silver and TestWeaver
  Full Application Software compiled into a virtual TCU

Buffer containing IO data

TCU Software

Buffers containing CAN data

Modules processing raw sensor data

Modules generating actuator targets

Modules processing raw CAN data

Modules generating CAN information

vTCU
Performant Simulation Environment
Extension of testing equipment with HiL

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<td>2011</td>
<td>Transition of PiL setup from Windows desktop to Real Time computer</td>
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<tr>
<td>2013</td>
<td>Development of HiL setup as an extension of PiL setup with hardware inputs and outputs</td>
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<tr>
<td>2015</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
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<tr>
<td>2017</td>
<td></td>
</tr>
<tr>
<td>Today</td>
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</table>

- User interaction
- Compile model
- VehicleModel.dll
- VeriStand – NI PXI chassis
- VehicleModel.dll
- XCP
- TCU
Performant Simulation Environment

Extension of testing equipment with HiL

- Transition of PiL setup from Windows desktop to Real Time computer
- Development of HiL setup as an extension of PiL setup with hardware inputs and outputs

Timeline:
- 2011
- 2013
- 2015
- 2016
- 2017
- Today

User interaction

Compile model

VehicleModel.dll

VeriStand – NI PXI chassis

Solenoids

DAQ IO

TCU

XCP

VehicleModel.dll

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Compile model

VeriStand – NI PXI chassis
TestWeaver is used for regression testing and software release validation

Regression testing using TestWeaver

Weekly TestWeaver run
- Python scripts for regression
- Automatic script generation

SW release TestWeaver run
- Regression test of diagnostic routines
- Release documentation
Performant Simulation Environment
Advantages of full virtual testing

- Parallel development of all components (short time to market)
  - SW development needs to start before HW is finalized
  - Limited availability of test vehicles
- OEMs want unique character and stand-out features
  - Agile SW implementation and testing environment
  - Confidence in new algorithms before vehicle testing
  - Possibility to explore new concepts and variants

Silver environment for complete ASW testing and algorithm validation
Performant Simulation Environment
Advantages of full virtual testing

Parallel development of all components (short time to market)

- SW can be developed and tested on new configurations implemented in the VehicleModel
- Silver environment available on each computer

OEMs want unique character and stand-out features

- Immediate testing of the algorithm behavior by the SW developer
- Validation of new algorithms before release to minimize downtime and debugging
- Flexible and modular simulation environment

Silver environment for complete ASW testing and algorithm validation
Proof Of Concept for new projects and algorithms

E-motor + High performance Hybrid DCT
- Shadow shifting
- Flying starts
- Boosted driving

Interface definition

ECU
TCU

Test algorithms by sharing simulation files with OEM

Simulation model update

Successful testing on the first prototype vehicle
Tremec has developed State of the Art simulation and testing capabilities

Multiple methods for simulation to enable virtual SW development

- Modular simulation components that can be protected and shared
- Support for different testing methods and toolchains

**Control oriented modeling – MiL**
- Transmission Model
- High Level SW algorithms

**Interface modeling and integration testing – SiL**
- Transmission Model
- vTCU

**Full integration testing - HiL**
- Transmission Model
- TCU