Future transmission outlook and the implications for calibration

Future Powertrain Conference (20th February 2014)

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Contents

• Historical perspective Transmission Technology
• Key Market Drivers
• Global Industry Transmission Types and Volumes
• Transmission Technology Roadmap
• Calibration - The challenge
• Calibration Solutions
  • Shift Quality
  • Shift Scheduling
Historical Perspective:
Transmission Technology Introduction

Average life cycle of new technologies getting shorter, # of technology options increasing rapidly.
Key Market Drivers – Transmission Sector

- FE and CO2 Regulations
- Market Competitiveness
- Globalization of Powertrain Portfolios
- Expansion of Chinese Applications
- Emerging Markets Needs
- Economic Recovery
- Engine downsizing/boosting Strategies
- Diesel Projects
- Family Approach
- Electrification
- Integrated and Modular

Global CO2 Standards

NA CAFE Fleet

Fleet CAFE increased by 34% over the past 7 years. It needs to increase by another 62% by 2025.
Recent Major Announcements & Activities

• VW is developing a 10-Speed FWD wet DCT
• GM and Ford jointly developing 9-speed FWD and 10-Speed RWD AT’s
• Chrysler will use ZF 9-speed FWD AT and 8-Speed RWD AT across the board
  • Chrysler to produce these units in NA in their facilities
• Hyundai is developing a 10-speed RWD AT
• Rumors of ZF developing a 10-speed RWD for BMW applications
• ZF is developing a 9-Speed wet DCT for Porsche application
• Daimler is developing a 9-speed RWD AT
• Honda is developing a 8-speed FWD wet DCT
• Jatco is working on introducing their CVT-8 in NA
Current Global Transmissions Market

No one clear dominant type

Markets distinct

- Manual
- Automatic

DCT gaining ground

- Euro / China

Source: PwC statistica 2013

Many options for vehicle/powertrain planners, transmission type highly application dependent
Current global market

North America

Europe

South America

China

Japan

Source: PwC statistics 2013

DCT, CVT & MT volumes are increasing in China, CVT penetration is increasing in NA
Automatic transmissions

- Ratios increasing
- Volumes increasing
- China
- North America
- 9/10 Speeds
- Ford 10R / GM 9F / ZF 9HP
- Hyundai 10AT

**GLOBAL - AT Volume Forecast**

- Significant 9/10 Speed options by 2020
DCT transmissions

- Ratios increasing
- Volumes increasing
- 10 Speeds
  - ~50,000 units
- VAG
  - 570 Nm
DCT – Wet or Dry?

Wet Clutch favoured over Dry
CVT

- Volumes increasing
- North America
- Asia
- Europe market declining
- Driveability
- Efficiency
- Saturating below 12M ~ 2020

GLOBAL CVT Volume Forecast

Source: IHS 04-2013

CVT take up entirely market dependent
Summary

AT
- Expanding rapidly from 6-speed to 8, 9 & 10 speeds
- Start/Stop capability with all new transmission
- Emergence of new clutching systems for low losses
- Integrated ETRS (Electronic Transmission Range Select) for all new designs
- Electrification & Modular powertrain approach (Hybridization)

DCT
- Moving from 6-speed to 7, 8, 9 & 10 speeds
- Migration from dry-DCT to wet-DCT clutch system
- Migration from electro-mechanical to electro-hydraulic Controls
- ETRS and Modular Electrification
- Emphasis on Cost Reduction

CVT
- Emergence of Multi-mode CVT’s
- Wider Ratio-Spreads and improved efficiency with significant FE/CO2 benefit
- Steel-Belt dominance
- Half-Toroidal CVT’s are being considered again

AMT
- Migration from electro-mechanical to electro-hydraulic Controls
- No significant growth – Emerging Market Opportunity

MT
- Migrating from 5 to 6-speed, 7-speed for high-end Sports Cars, eClutch

OEMs and transmission suppliers cannot handle this rapid growth with their in-house resources and need to outsource some Design & Development, Integration and Calibration.
Transmission calibration has significantly evolved over the last 18 years

Then

- Small teams
- 4/5 speed AT limited torque converter control
- Limited engine control integration

Now

- Medium/large teams
- 8/9/10 speed AT with sophisticated torque converter control
- Significant engine control capability
- GSI

Next

- 10/11 speed AT with increased torque converter control
- Driving environment/legislation -> Markets
- Platforms
- Increasingly complex engine control (Pedal maps now trans calibration task)
  - Variable torque curves
    - Cylinder de-activation / 2 + 4 stroke / HEV / SCR
Transmission Calibration

Shift Quality

Shift Scheduling

Driver Request Interpretation

Vehicle and System State Interpretation

Driving Situation Detection

Upshift

Downshift

A

B

C
Calibration Tool Solutions
AVL Transmission Calibration
ACT for Chassis Dyno

AVL DRIVE:
- Objective drivability assessment

AVL CAMEO TRANSMISSION:
- Test plans using DoE methods
- Perform controlled automated test runs
- Data evaluation and optimization according the specified drivability target

Ground fixing device & load cell:
- Calculation of longitudinal vehicle acceleration

AVL DRICON:
- Enables fully automated test runs
AVL Transmission
AVL – DRIVE → Objective Shift Quality Tool

1. Measurement of Driver Input & Vehicle Reaction → Data Logging

2. Automated Driving Mode Detection

3. Parameter Calculation – Single Event

4. Driveability Evaluation
   ↓ Single Driving Mode Rating
   ↓ Overall Vehicle Assessment

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Time</th>
<th>Driving manoeuvre</th>
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<tbody>
<tr>
<td>1</td>
<td>11.56-15.59</td>
<td>Drive Away – Launch</td>
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<tr>
<td>2</td>
<td>19.14-20.81</td>
<td>Upshift – During WOT</td>
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<td>3</td>
<td>21.21-24.11</td>
<td>Acceleration – WOT</td>
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<tr>
<td>4</td>
<td>25.54-26.25</td>
<td>Tip Out – After Acceleration</td>
</tr>
</tbody>
</table>

- Acceleration Gradient Disengage: 18.9 [m/s²]
- Acceleration Gradient Engage: 25.5 [m/s²]
- Engagement Shock: 0.48 [m/s²]
- Traction Interruption Time: 0.81 [s]
- Zero Acceleration Time: 0.47 [s]
In Vehicle Crankshaft Torque Measurement
From Pressure to Torque

ICE Working Cycle: (4-stroke)
Pressure measurement: (gasoline, diesel)

Abstraction: (geometric relationships)

actual crankshaft torque

http://konstrukteur4u.de/Motoren/
In Vehicle Crankshaft Torque Measurement Measurement Setup

AVL DRIVE
SQ Ratings

Measurement System

AVL DriCon
Driver Controller System

Indication System

Can-Manipulation

Drive by-wire
TCU
Acc. Sensor
ECU
Engine

CAN-Node
Shift Scheduling

Driver Request Interpretation

Vehicle and System State Interpretation

Driving Situation Detection

Prediction Functions

System Support (eg. SCR)

Range Controls

Decision Logic

Target Gear

TCC State (open, closed, slip, ...)

Trans Gear Ratio (CVT)

Launch & Creep

Neutral Idle Control

...
Shift scheduling = When does the transmission change gear?

- CO₂ Reduction – Fuel economy

- Gear Decision
  - Decide suitable torque converter state

- Situation dependent
- System dependent
- Road dependent
- Market dependent
- Driver dependent
Shift Scheduling
Base Shift Maps & Pedal Map Influences

Trade off - Fuel Economy and Drivability

Driver Defined Modes (Drive, Sport, Eco,..)

Driver Sportiness

Gradient / Payload

Engine Torque (Nm)

Engine Speed (rpm)
The race for gears
AVL Shift Point Optimisation Tool

Shift map automatically generated based on user preferences
Transmission Technology Roadmap
Pass Cars and LD Trucks

Torque-Interrupt Transmissions
- 5 and 6 speed MT
- 7 speed Manual for High-Performance Cars
- AMT & Electrified AMT
- Torque Fill / Fast Shifting AMT
- Speed Matching for Smooth Shifting
- eClutch for MT

Powershift Transmissions
- 6/7Spd Dual Clutch Transmissions
  wet, dry, moist applications
- 8/9/10 Speed w-DCT’s
- ‘Low-Cost’ DCT’s
- Continuously Variable Transmissions - CVTs
- Multi-Mode and High-Efficiency CVTs
- Engine Start / Stop Capability
- ‘Modular Hybridization of Transmissions’
  Integration of DCTs/CVTs with electric final-drive units
- Hydraulic Support Elements
  [Hydraulic Impulse Storage for Stop/Start]
- New Low-Loss Clutching Mechanisms
- 6, 7, 8 speed AT’s
- 6, 8, 9, and 10 speed AT’s
- NVH Optimization
  SW & Math-tool Development
  ACT DRIVE INDICOM
- Development of ‘add-in’ and ‘add-on’ Modules
  Alternative NVH solutions
  Automated Process

2010 | 2015 | 2020
AVL – A GLOBAL PARTNER

Thank you for your Attention!
Full Hybrid and EV penetration is less than 3%, FE/CO2 regulations must be met by Conven. PTs
Estimated time schedule

1\textsuperscript{st} Calibration

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<th>Calibration Phases</th>
<th>Resources</th>
<th>Engineer</th>
<th>Chassis Dyno</th>
<th>Vehicle</th>
<th>Test Plan</th>
<th>Test Run</th>
<th>Data check</th>
<th>Modeling</th>
<th>Optimization</th>
<th>Generate Maps</th>
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Duration ~ 4 weeks

Further calibrations (variants) fast optimization loops

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Repeat process
Shift scheduling = From bad to good

Fuel consumption optimization on NEDC cycle – Gasoline application

Optimum Specific Fuel Consumption Zone

Modifications of reference GSP according to the optimal gears map