AVL's Future Hybrid X Mode
a modular transmission family concept
Global Technology Share
Different Predictions

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<th>Bosch</th>
<th>IHS</th>
<th>AVL</th>
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<tr>
<td>(04/2017)</td>
<td>(10/2017)</td>
<td>(12/2017)</td>
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Boundary Conditions / Variations:
- ~ Legislation
- ~ Consumer
- ~ Tech. Progress

Changing Market
Basis for Decision
Global Technology Share possible solutions

DHT

- GKN Multimode Gen. 2
- Renault LocoBox
- Volkswagen Varo.Drive
- Volkswagen DQ400E

AVL (12/2017)

PLAY IT SAFE!
go Modular
Future Hybrid X Mode
Development of the X Mode

Future Hybrid 7 Mode
Future Hybrid 8 Mode
Industry Feedback
Additional Goals
Research & Development

- benefits
- potential (AT)
- (hydraulic actuation)
- (integrated EM)
- higher efficiency
- smaller package
- more common parts
- modularity & flexibility
- cost focus
- driving comfort
- etc.

X Mode
longit. PHEV
HV+
HV
48V
AT
Modular Transmission Family

HV+ 
HV 
48V 
AT 

Industry Feedback

Industry Feedback

Industry Feedback

Benefits
Potential (AT)
Hydraulic actuation
Integrated EM
Features: Future Hybrid X Mode Layout HV Variant (DHT)

- **Propulsion Source:**
  - Internal Combustion Engine (ICE)
  - 1 Electric Machine (EM)
  - up to E-Segment Vehicles

- **Transmission:**
  - Ravigneaux Planetary Gears Set
  - Manipulating Idler
  - Idler & Final Drive
  - 2 Clutches
  - 2 Brakes

- **Features:**
  - Hybrid Functionality
  - Low Number of Components
  - Opportunity for Modularity (HV, 48V, AT)

- **Operation Modes:** 7
  - 4 ICE/Parallel-Hybrid Modes (PH)
  - 2 Pure Battery Electric Modes (E)
  - 1 Electric Continuously Variable Transmission Mode (ECVT)
Features: Future Hybrid X Mode Power Flow HV Variant (DHT)

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<tr>
<th>BOOST</th>
<th>C1</th>
<th>C2</th>
<th>B1</th>
<th>B2</th>
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<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; PH</td>
<td>ICE</td>
<td>EM</td>
<td>X</td>
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<td>2&lt;sup&gt;nd&lt;/sup&gt; PH</td>
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<td>EM</td>
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<td>3&lt;sup&gt;rd&lt;/sup&gt; PH</td>
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<td>EM</td>
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<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; PH</td>
<td>ICE</td>
<td>EM</td>
<td>X</td>
<td>X</td>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; E</td>
<td>EM</td>
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<td>X</td>
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<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; E</td>
<td>EM</td>
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<tr>
<td>ECVT</td>
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Standstill Charging  X

Design Example:
C-D-Segment Vehicle
Features: Future Hybrid X Mode Launch & Reversing HV Variant (DHT)

**Electric Launch (C-D-Segment Vehicle):**
- no need for: Mechanical Reverse Gear
  - EM Power ~ 110 kW (~200 Nm)
- ICE Cranking: via Clutch C2

![Graph showing Traction Force vs. Driving Speed]
Features: Future Hybrid X Mode Launch HV Variant (DHT)

Low Battery (Stop/Go, Inclination <20\%):
ECVT Launch, no Launch Clutch, 1 EM
- Max. Generated Power \(~ 50\) kW
- ICE Power \(~ 105\) kW (~250 Nm)
Features: Future Hybrid X Mode Use of ECVT HV Variant (DHT)

Dissipationless Shift Control:
- Generic Shift Control
- Increased Efficiency
- Better Durability of Clutches & Brakes

Example: PH3 $\rightarrow$ ECVT $\rightarrow$ PH4

<table>
<thead>
<tr>
<th>Mode</th>
<th>ICE</th>
<th>EM</th>
<th>C1</th>
<th>C2</th>
<th>B1</th>
<th>B2</th>
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</thead>
<tbody>
<tr>
<td>3rd PH</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>T_{c2} = 0 Nm</td>
<td></td>
</tr>
<tr>
<td>ECVT</td>
<td>X</td>
<td>n_{b2} = 0 rpm</td>
<td></td>
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<tr>
<td>4th PH</td>
<td>X</td>
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</tbody>
</table>
Features: Future Hybrid X Mode
Mode Diagram HV Variant (DHT)

- Pure Electric
- Parallel Hybrid
- ECVT

Modes

- E1
- E2
- PH1
- PH2
- PH3
- PH4

Driving Speed in km/h:
- 20 km/h
- 40 km/h
- 60 km/h
- 80 km/h
- 100 km/h
- 120 km/h

ECVT or directly via clutch C2:

- Charging at standstill

ECVT

- generating
- motoring

Power Shifts:
- ... Power Shift + Intermediate Mode
- ... 133 km/h
- ... 123 km/h
- ... 70 km/h
- ... 220 km/h
- ... 210 km/h
- ... 190 km/h
- ... 190 km/h

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Features: Future Hybrid X Mode Traction Force HV Variant (DHT)
Benefits: Future Hybrid X Mode
Modularity

+ 2 Parallel Hybrid Forward Mode
+ 1 Reverse Mode
Benefits: Future Hybrid X Mode Modularity

- **HV**
  - 4 ICE/PH
  - 2 EV
  - 1 ECVT
  - 1 Charge Stand.

- **HV+**
  - 6 ICE/PH + Rev.
  - 2 EV
  - 2 ECVT
  - 1 Charge Stand.

- **48V**
  - 6 ICE/PH + Rev.
  - 2 EV
  - 1 Charge Stand.

- **AT**
  - 6 ICE + Rev.
    - (Launch Clutch B1 or C2/C3 considered)
Benefits: Future Hybrid X Mode
Extended Shift Table

<table>
<thead>
<tr>
<th>BOOST</th>
<th>C1</th>
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<th>C3</th>
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<td>5th PH</td>
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<td>1st ECVT</td>
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<td>2nd ECVT</td>
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<td>Standstill Charging</td>
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Public

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Benefits: Future Hybrid X Mode Traction Force HV/HV+/48V/AT
Benefits: Future Hybrid X Mode
Package HV/HV+/48V/AT

<table>
<thead>
<tr>
<th>Layout Example:</th>
<th>Future Hybrid X Mode HV+:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C-D-Segment Vehicle)</td>
<td></td>
</tr>
<tr>
<td>ICE ~ 105 kW (~250 Nm)</td>
<td>Length &lt; 380 mm (AT: &lt;365 mm)</td>
</tr>
<tr>
<td>EM (HV) ~ 110 kW (~200 Nm)</td>
<td>Height &lt; 500 mm (AT: &lt;390 mm)</td>
</tr>
<tr>
<td>EM (48V) ~ 15-25 kW (~45 Nm)</td>
<td>Width &lt; 540 mm (AT: &lt;520 mm)</td>
</tr>
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</table>

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<thead>
<tr>
<th>similar P2-6DCT:</th>
<th></th>
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<tbody>
<tr>
<td>Length &lt; 490 mm (6DCT: &lt;380 mm)</td>
<td></td>
</tr>
<tr>
<td>Height &lt; 425 mm (6DCT: &lt;425 mm)</td>
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</tr>
<tr>
<td>Width &lt; 520 mm (6DCT: &lt;520 mm)</td>
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<tr>
<td>Weight &lt; 125 kg (6DCT: &lt;71 kg)</td>
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</tbody>
</table>
Benefits: Future Hybrid X Mode
Package HV/HV+/48V/AT
Benefits: Future Hybrid X Mode Modularity and its Opportunities

Core Transmission & Modules:
- High percentage of Common Parts: Clutches/Brakes (C1, C2, B1, B2), Planet Carrier & Rim, Final Drive & Idler, Front Housing
- Interchangeable Modules for Variants
- Common Development Process for Core & Modules
- Flexible Production & Assembly

ONE Core Transmission for all Variants (HV+/HV/48V/AT)

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<tr>
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<th>HV+</th>
<th>HV</th>
<th>AT</th>
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<tr>
<td>Total part number in Variants</td>
<td>226</td>
<td>220</td>
<td>193</td>
</tr>
<tr>
<td>Part number in Core Module</td>
<td>184</td>
<td>184</td>
<td>184</td>
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<tr>
<td>Common parts %</td>
<td>81%</td>
<td>84%</td>
<td>95%</td>
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Benefits: Future Hybrid X Mode Modular Production

Production Workflow:
- Single Main Assembly Line
- Modular Sub-Assemblies
- Quick Changeover Times or Mixed-Model Assembly

Benefits:
- Highly Flexible Production Workflow
- Fast Adjustment of Volume Split
  → Lowering Risk Posed by Changing Markets
Benefits: Future Hybrid X Mode Modularity & Volume Split

Production Scenario:
- Overall Units Produced p.a.: 400,000 Units
- Production Duration: 7 years
- Total Units after 7 years: 2,800,000

Volume Split:
- AT: 52%
- 48V: 26%
- HV/HV+: 22%

Results Future Hybrid X Mode:
- AT lowered cost by 12% compared to a similar 6DCT
- HV+ lowered cost by 22% compared to a similar 6DCT with P2 add-on Module
Recent Development: Longitudinal X Mode Hybrid Transmission

transverse

longitudinal

AVL

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Recent Development: Longitudinal X Mode Hybrid Transmission

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
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Standstill Charging
Recent Development: Longitudinal X Mode Hybrid Transmission

Layout Variant:
- for mid-sized to semi-full-sized SUVs
- transmission spread: 9.3
- transmission length: < 650 mm
Recent Development: Longitudinal X Mode Hybrid Transmission

![Graph showing traction force vs driving speed with modes and slip limit indicated.](image-url)
Future Hybrid X Mode
Summary

Transmission Family on one Assembly Line:

- Outstanding DHT for HV applications
- Modular Concept for all Levels of Electrification
- Flexible & Low Cost
Thank You

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