Outline

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

History of Battery Electric Vehicles

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
Schaeffler's First Electric Drivetrain

► Coaxial Arrangement
► Torque Vectoring
► Powershift
► Offset Arrangement
► Summary

E-Axle Family in Coaxial Arrangement - Overview

► Coaxial Arrangement
► Torque Vectoring
► Powershift
► Offset Arrangement
► Summary
Target BEV Vehicle Application

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

Requirements for BEV vehicle:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target vehicle</td>
<td>SUV (2500 kg)</td>
</tr>
<tr>
<td>vmax</td>
<td>230 kph</td>
</tr>
<tr>
<td>Acceleration from 0-100 kph</td>
<td>6.5 s</td>
</tr>
<tr>
<td>Drivetrain</td>
<td>4WD</td>
</tr>
</tbody>
</table>

E-Axle Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller
E-Axle Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
E-Axle Design

Technical Specification 1-Speed

**Technical data**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight gearbox in kg</td>
<td>16</td>
</tr>
<tr>
<td>Input power in kW max. / continuous</td>
<td>150 / 80</td>
</tr>
<tr>
<td>Input torque Nm max. / continuous</td>
<td>400 / 220</td>
</tr>
<tr>
<td>Input speed in rpm</td>
<td>18000</td>
</tr>
<tr>
<td>Dimensions in mm</td>
<td>Ø 300 x 150</td>
</tr>
<tr>
<td>Ratio</td>
<td>9.2</td>
</tr>
</tbody>
</table>

**Customer benefits**

- Compact due to “Lightweight Differential”
- Modular system with different optional ratios
- Low-axial-space requirements
- Series production

Coaxial Arrangement

Torque Vectoring

Powershift

Offset Arrangement

Summary
1-Speed Efficiency Map

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

**Alternative 1-Speed Design**

**Technical data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight gearbox in kg</td>
<td>15 kg</td>
</tr>
<tr>
<td>Input power in kW max. / continuous</td>
<td>150 / 80 kW</td>
</tr>
<tr>
<td>Input torque Nm max. / continuous</td>
<td>450 Nm</td>
</tr>
<tr>
<td>Input speed in rpm</td>
<td>18000 rpm</td>
</tr>
<tr>
<td>Dimensions in mm</td>
<td>Ø 250 x 170 mm</td>
</tr>
<tr>
<td>Ratio</td>
<td>8.2</td>
</tr>
</tbody>
</table>

**Customer benefits**

- Compact due to “Lightweight Differential”
- Modular system with different optional ratios
- Low-axial-space requirements
- Series production in 2019
Target PHEV Vehicle Application

Requirements for PHEV vehicle

<table>
<thead>
<tr>
<th>Target vehicle</th>
<th>SUV (2500 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. power for WLTP</td>
<td>75 kW</td>
</tr>
<tr>
<td>Max. torque for WLTP</td>
<td>1700 Nm</td>
</tr>
<tr>
<td>Max. speed for WLTP</td>
<td>131 kph</td>
</tr>
</tbody>
</table>

Single-speed design

- Power output in kW max. / continuous: 75 / 45
- Output torque in Nm max. / continuous: 1950 / 1105
- Ratio: 13
- \( v_{\text{max}} \) (hybrid mode): 140 kph

- Limited performance in electric mode, low-startup torque
- No recuperation at high speed, neutral gear necessary
- The solution: 2-speed gearbox

Target PHEV Vehicle Application

Requirements for PHEV vehicle

<table>
<thead>
<tr>
<th>Target vehicle</th>
<th>SUV (2500 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. power for WLTP</td>
<td>75 kW</td>
</tr>
<tr>
<td>Max. torque for WLTP</td>
<td>1700 Nm</td>
</tr>
<tr>
<td>Max. speed for WLTP</td>
<td>131 kph</td>
</tr>
</tbody>
</table>

Two-speed design

- Power output in kW max. / continuous: 75 / 45
- Output torque in Nm max. / continuous: 2850 / 1615
- Ratio: 19 / N / 6.4
- \( v_{\text{max}} \) (hybrid mode): 264 kph

- High-startup torque
- Recuperation at high speed
- Full e-Drive option in urban environment (0-50 kph in 5.4 s)
2-Speed Design

<table>
<thead>
<tr>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight in kg</td>
</tr>
<tr>
<td>Input power in kW max. / continuous</td>
</tr>
<tr>
<td>Output torque Nm max. / continuous</td>
</tr>
<tr>
<td>E-motor speed in rpm</td>
</tr>
<tr>
<td>Dimensions in mm</td>
</tr>
<tr>
<td>Ratio</td>
</tr>
</tbody>
</table>

Customer benefits
- Full e-Drive option with moderate performance by P4
- WLTC driving cycle without combustion engine possible
- Electric AWD option w/o mechanical cardan shaft
- Boost and recuperation functionality at higher speed
- Optional with 48V technology

Flexibility in Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
Flexibility in Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
Flexibility in Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
Flexibility in Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

Torque Vectoring Functionality

- Improved Traction
- High Comfort
- Dynamics & Safety
- Steering Support

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary
## Torque Vectoring Functionality

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

### Without TV understanding
- Neutral steering

### With TV:
- Improved vehicle dynamics & safety: Better steering response and fast intervention in ESC

### Torque Vectoring Module

<table>
<thead>
<tr>
<th>Technical data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight in kg</td>
<td>15</td>
</tr>
<tr>
<td>Power in kW</td>
<td>10</td>
</tr>
<tr>
<td>Torque difference in Nm</td>
<td>1200</td>
</tr>
<tr>
<td>E-motor design</td>
<td>PSM</td>
</tr>
<tr>
<td>Dimensions in mm</td>
<td>Ø 172 x 88 x 110</td>
</tr>
</tbody>
</table>

### Customer benefits
- Improved vehicle dynamics & safety: Better steering response and fast intervention in ESC
- Higher efficiency and faster actuation than comparable hydraulic clutch systems
- Neutral self-steering behavior, less understeering for FWD (verified by steady state circular test ISO 4138)
- Can replace power steering actuator with suitable suspension kinematics
**Powershift 2-Speed Design**

**Technical data**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight in kg (target)</td>
<td>110</td>
</tr>
<tr>
<td>Input power in kW max / continuous</td>
<td>275 / 150</td>
</tr>
<tr>
<td>Output torque Nm max / continuous</td>
<td>5300 / 3000</td>
</tr>
<tr>
<td>E-motor speed in rpm</td>
<td>12000</td>
</tr>
<tr>
<td>Dimensions in mm</td>
<td>Ø 300 x 600</td>
</tr>
<tr>
<td>Ratio</td>
<td>12 / 7 / N</td>
</tr>
</tbody>
</table>

**Customer benefits**

- Powershift design with high performance
- Compact and low-system weight
- Acquisition of development partner

---

**E-Axle Family in Offset Arrangement**
1-Speed Design

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

E-Axe Modular Design for Tomorrow’s Mobility
Scott A. Miller

2018 Schaeffler Symposium
Scott A. Miller - E-Axe Modular Design for Tomorrow's Mobility
Technical Specification 1-Speed

<table>
<thead>
<tr>
<th>Technical data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight gearbox in kg</td>
<td>26</td>
</tr>
<tr>
<td>Input power in kW max. / continuous</td>
<td>150 / 80</td>
</tr>
<tr>
<td>Input torque Nm max. / continuous</td>
<td>400 / 220</td>
</tr>
<tr>
<td>Input speed in rpm</td>
<td>18000</td>
</tr>
<tr>
<td>Offset in mm / Length in mm</td>
<td>165 / 140</td>
</tr>
<tr>
<td>Ratio</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Customer benefits
- Compact and light offset design based on “Lightweight Differential” technology
- Modular system with different optional ratios
- Parking lock system as carry over sub-system
- Series production
Technical Specification 2-Speed

Technical data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight gearbox in kg</td>
<td>25</td>
</tr>
<tr>
<td>Input power in kW max. / continuous</td>
<td>90 / 50</td>
</tr>
<tr>
<td>Input torque Nm</td>
<td>200</td>
</tr>
<tr>
<td>Input speed in rpm</td>
<td>14000</td>
</tr>
<tr>
<td>Offset in mm / Length in mm</td>
<td>127.5 / 230</td>
</tr>
<tr>
<td>Ratio</td>
<td>15 / N / 5</td>
</tr>
</tbody>
</table>

Customer benefits

- Modular system with different optional ratios
- Low axial space requirements
- Series production

Technical Specification 2-Speed 48V

Technical data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight gearbox in kg</td>
<td>50</td>
</tr>
<tr>
<td>Input power in kW @ 48V</td>
<td>20 @ 48V</td>
</tr>
<tr>
<td>Output torque Nm</td>
<td>1100</td>
</tr>
<tr>
<td>Input speed in rpm</td>
<td>20000</td>
</tr>
<tr>
<td>Offset in mm / Length in mm</td>
<td>127.5 / 230</td>
</tr>
<tr>
<td>Ratio</td>
<td>15 / N / 5</td>
</tr>
</tbody>
</table>
Potential CO2 Savings

- Coaxial Arrangement
- Torque Vectoring
- Powershift
- Offset Arrangement
- Summary

**Potential CO2 Savings**

- Higher no. of gears
- Additional drag losses
- Removal of mechanical AWD
Then and Now

<table>
<thead>
<tr>
<th></th>
<th>E-Axle 2011</th>
<th>E-Axle 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2011</strong></td>
<td>Separate</td>
<td>Power Electronics</td>
</tr>
<tr>
<td><strong>2000 Nm (10s)</strong></td>
<td>Peak Torque</td>
<td>4000 Nm (30s)</td>
</tr>
<tr>
<td><strong>60 kW (10s)</strong></td>
<td>Peak Power</td>
<td>150 kW (30s)</td>
</tr>
<tr>
<td><strong>525 mm</strong></td>
<td>Overall Length</td>
<td>515 mm</td>
</tr>
<tr>
<td><strong>90 kg</strong></td>
<td>Weight</td>
<td>75 kg</td>
</tr>
</tbody>
</table>

► Coaxial Arrangement
► Torque Vectoring
► Powershift
► Offset Arrangement
► Summary

Currently in Production with 3 Variants!

► Coaxial Arrangement
► Torque Vectoring
► Powershift
► Offset Arrangement
► Summary

► Production line layout for a capability of 250,000 parts per year
► 7 subsystem assemblies plus 3 final assemblies
► Production in Herzogenaurach has started
► 2nd production line in China at the end of 2018

E-Axle Modular Design for Tomorrow's Mobility
Scott A. Miller
Build an E-Axle
- Configuration: Coaxial or Offset
- Gears: 1- or 2-Speed
- Ratio: 5 to 19
- Torque Vectoring: Yes or No
- Park Lock: Yes or No
- Powershift: Yes or No
- Voltage: Low or High

Modularity for Tomorrow’s Mobility!!!!