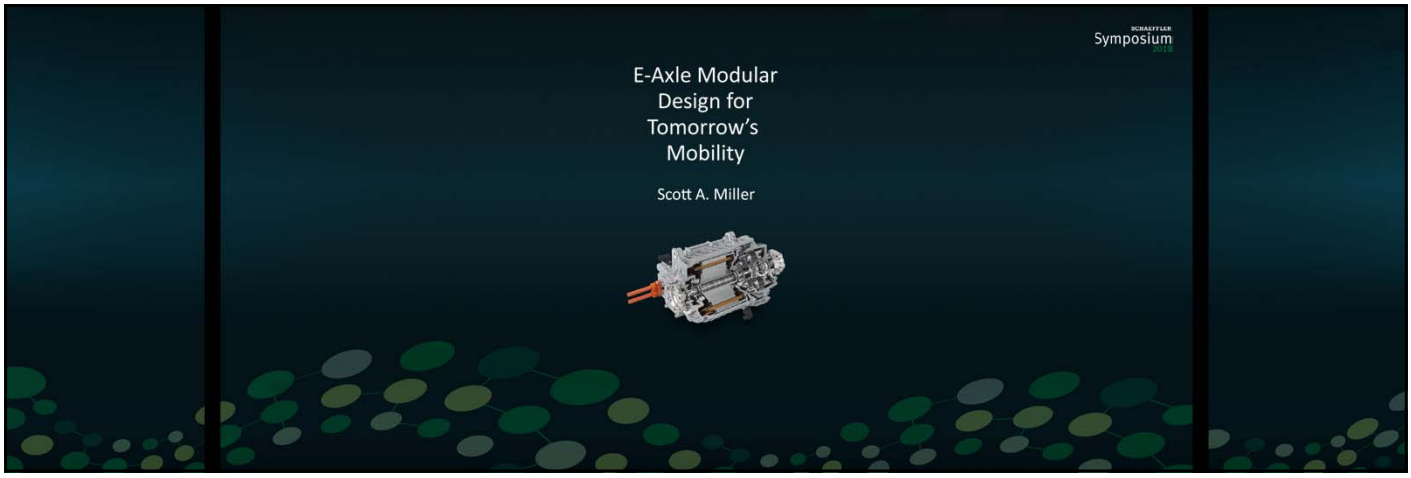

SCHAEFFLER
Schaeffler Symposium September 6, 2018
Mobility for tomorrow


Symposium
E-Axle Modular Design for Tomorrow's Mobility
Scott A. Miller

Outline

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

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

History of Battery Electric Vehicles

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

Lohner Porsche ~ 1900

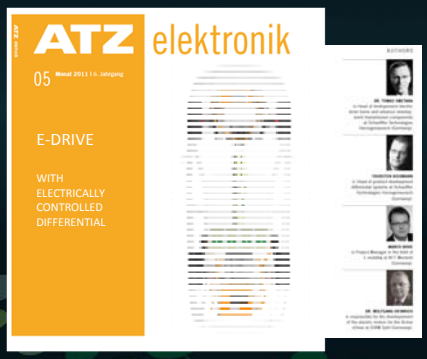
Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Schaeffler's First Electric Drivetrain



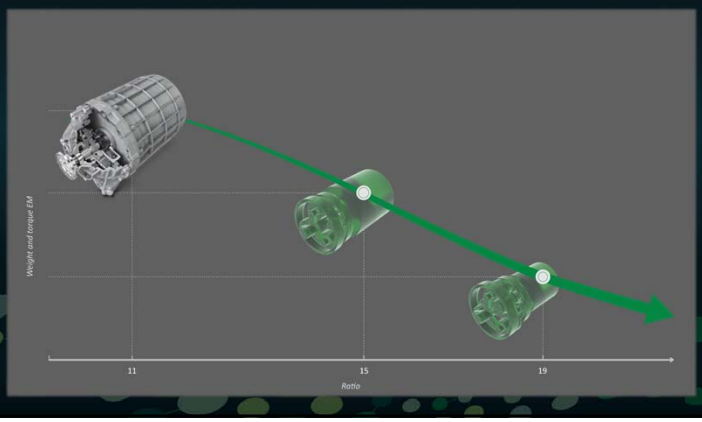
Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Family in Coaxial Arrangement - Overview



Symposium

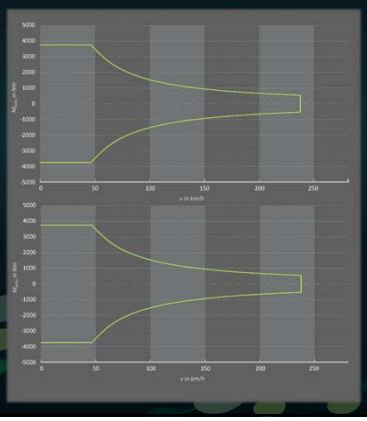
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Target BEV Vehicle Application

Symposium



Requirements for BEV vehicle	
Target vehicle	SUV (2500 kg)
v_{max}	230 kph
Acceleration from 0-100 kph	4.5 s
Drivetrain	4WD

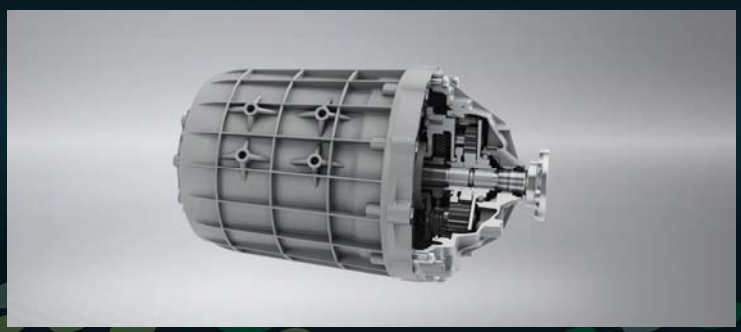
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Design

Symposium



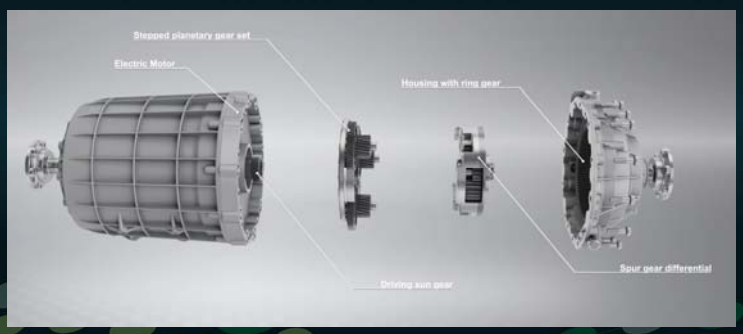
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Design

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Design

Symposium

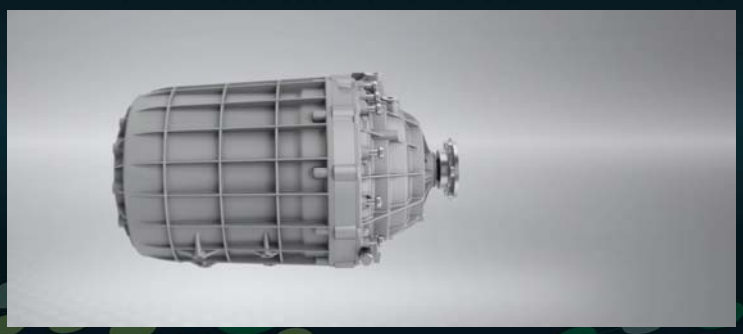
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Design

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Technical Specification 1-Speed

Symposium

Technical data	
Weight gearbox in kg	16
Input power in kW max. / continuous	150 / 80
Input torque Nm max. / continuous	400 / 220
Input speed in rpm	18000
Dimensions in mm	Ø 300 x 150
Ratio	9.2

Customer benefits
Compact due to "Lightweight Differential"
Modular system with different optional ratios
Low-axial-space requirements
Series production

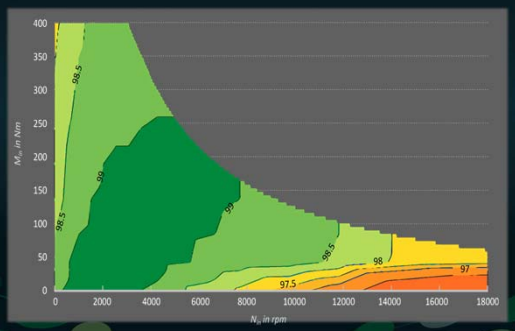
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

1-Speed Efficiency Map

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Alternative 1-Speed Design

Symposium

Technical data	
Weight gearbox in kg	15
Input power in kW max. / continuous	150 / 80
Input torque Nm max. / continuous	450
Input speed in rpm	18000
Dimensions in mm	Ø 250 x 170
Ratio	8.2

Customer benefits
Compact due to "Lightweight Differential"
Modular system with different optional ratios
Low-axial-space requirements
Series production in 2019

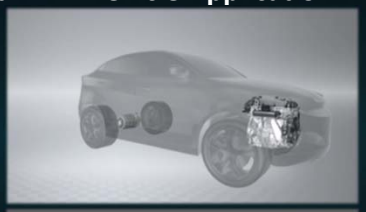
E-Axle Modular Design for Tomorrow's Mobility

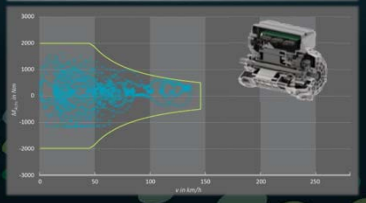
Scott A. Miller

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

Target PHEV Vehicle Application

Symposium





Requirements for PHEV vehicle	
Target vehicle	SUV (2500 kg)
Max. power for WLTP	75 kW
Max. torque for WLTP	1700 Nm
Max. speed for WLTP	131 kph

Single-speed design	
Power output in kW max. / continuous	75 / 45
Output torque in Nm max. / continuous	1950 / 1105
Ratio	13
v_{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

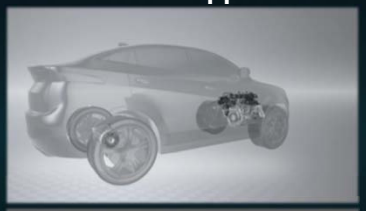
E-Axle Modular Design for Tomorrow's Mobility

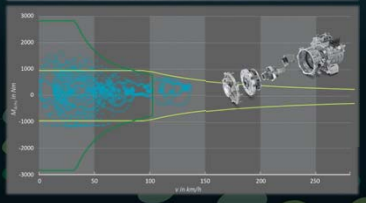
Scott A. Miller

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

Target PHEV Vehicle Application

Symposium





Requirements for PHEV vehicle	
Target vehicle	SUV (2500 kg)
Max. power for WLTP	75 kW
Max. torque for WLTP	1700 Nm
Max. speed for WLTP	131 kph

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_{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)

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

2-Speed Design

Symposium

Technical data	
Weight in kg	69
Input power in kW max. / continuous	75 / 45
Output torque Nm max. / continuous	2850 / 1615
E-motor speed in rpm	18000
Dimensions in mm	Ø 285 x 450
Ratio	19 / N / 6.4

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

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Flexibility in Design

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Flexibility in Design

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Flexibility in Design

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

Flexibility in Design

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

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

Flexibility in Design

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

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Flexibility in Design

Symposium

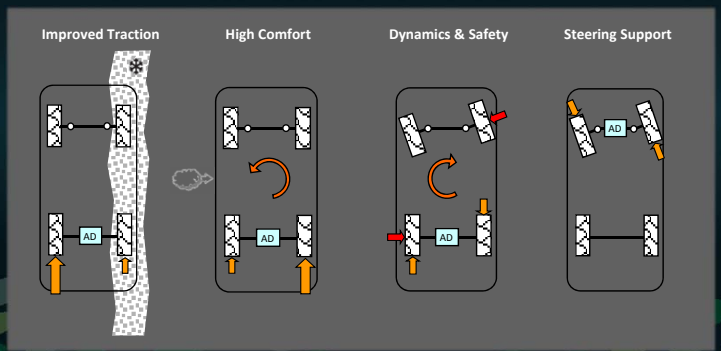
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Torque Vectoring Functionality

Symposium



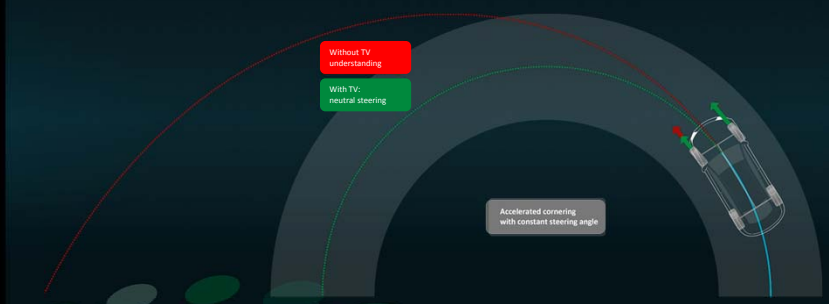
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Torque Vectoring Functionality

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Torque Vectoring Module

Symposium

Technical data	
Weight in kg	15
Power in kW	10
Torque difference in Nm	1200
E-motor design	PSM
Dimensions in mm	Ø 172 x 88 x 110

Customer benefits
Improves vehicle dynamics & safety: Better steering response and fast actuation in ESC intervention
Higher efficiency and faster actuation than comparable hydraulic clutch systems
Neutral self-steering behavior, less understeering for FWD (verified by steady-state circular test ISO4138)
Can replace power steering actuator with suitable suspension kinematics

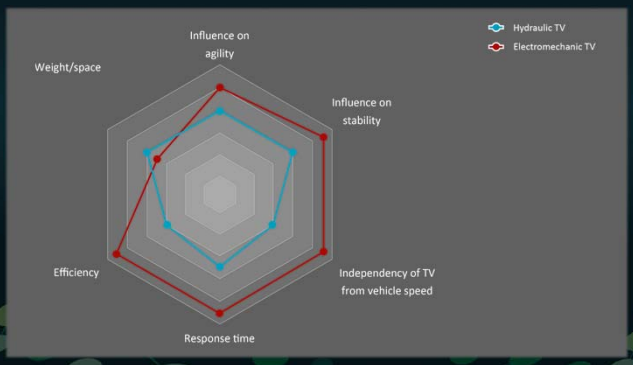
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Active vs Passive Torque Vectoring

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

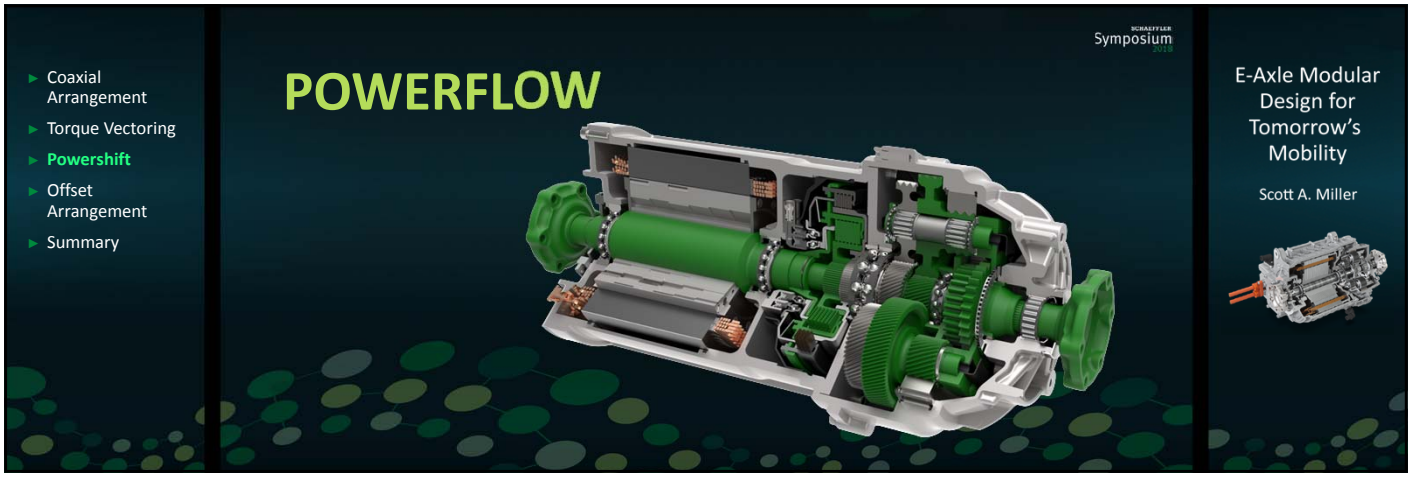
- Coaxial Arrangement
- Torque Vectoring
- **Powershift**
- Offset Arrangement
- Summary

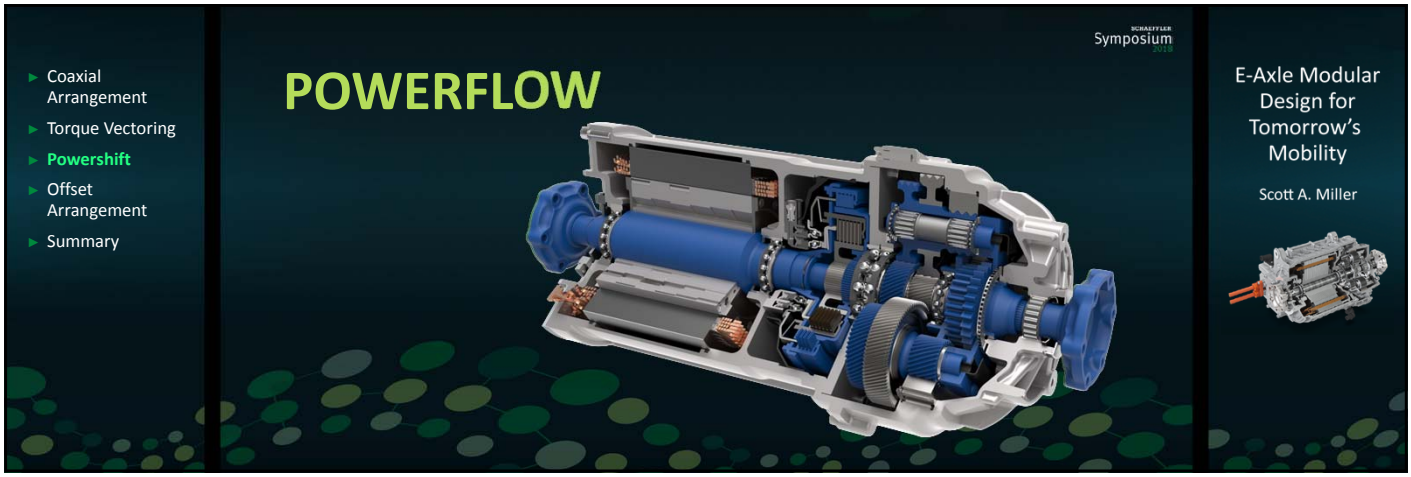
POWERSHIFT
2-Speed

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller


Coaxial Arrangement
Torque Vectoring
Powershift
Offset Arrangement
Summary
POWERFLOW
Symposium
E-Axle Modular Design for Tomorrow's Mobility
Scott A. Miller


Coaxial Arrangement
Torque Vectoring
Powershift
Offset Arrangement
Summary
POWERFLOW
Symposium
E-Axle Modular Design for Tomorrow's Mobility
Scott A. Miller

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

Powershift 2-Speed Design

Symposium

Technical data	
Weight in kg (target)	110
Input power in kW max. / continuous	275 / 150
Output torque Nm max. / continuous	5300 / 3000
E-motor speed in rpm	12000
Dimensions in mm	Ø 300 x 600
Ratio	12 / 7 / N

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

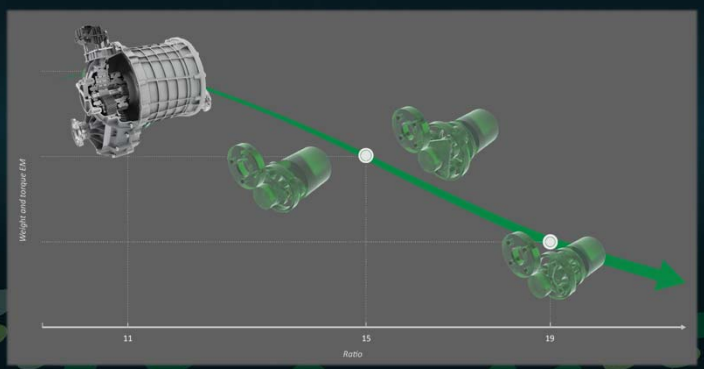
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

E-Axle Family in Offset Arrangement

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

1-Speed Design

Symposium

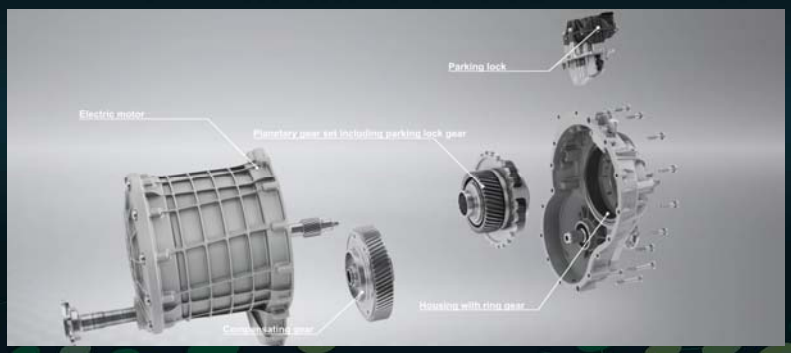
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

1-Speed Design

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

1-Speed Design

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

1-Speed Design

Symposium

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Technical Specification 1-Speed

Symposium

Technical data	
Weight gearbox in kg	26
Input power in kW max. / continuous	150 / 80
Input torque Nm max. / continuous	400 / 220
Input speed in rpm	18000
Offset in mm / Length in mm	165 / 140
Ratio	9.1

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

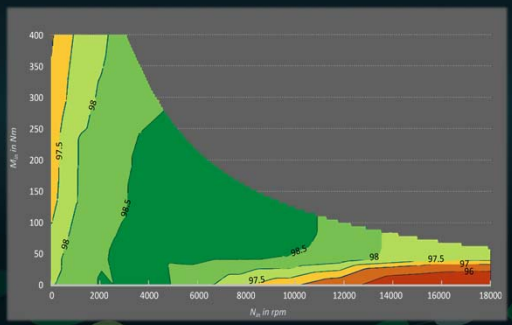
E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Efficiency Map

Symposium



E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Technical Specification 2-Speed

Symposium

Technical data	
Weight gearbox in kg	25
Input power in kW max. / continuous	90 / 50
Input torque Nm	200
Input speed in rpm	14000
Offset in mm / Length in mm	127.5 / 230
Ratio	15 / N / 5

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

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Technical Specification 2-Speed 48V

Symposium

Technical data	
Weight gearbox in kg	50
Input power in kW	20 @ 48V
Output torque Nm	1100
Input speed in rpm	20000
Offset in mm / Length in mm	127.5 / 230
Ratio	15 / N / 5

E-Axle Modular Design for Tomorrow's Mobility

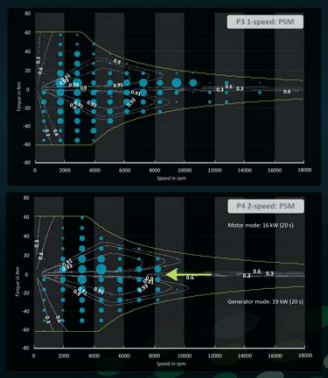
Scott A. Miller

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

Potential C02 Savings

Symposium

Vehicle	C-Segment / FWD	C-Segment / FWD
Drivetrain	Gasoline 3 cyl. 1.0 l / 7-speed DCT dry	see left
Hybrid	Micro 12 V / smart alternator 2.5 kW	see left
	+ 48 V bordnet / 1.4 kWh battery	see left
	P3 1-speed	P4 2-speed	P4 2-speed
Vehicle	beltless	Std w/o alternator	beltless
FEAD	12 V RSG	48 V RSG	48 V RSG
Ratio to wheel	i1=10 / N	i1=15 / i2=5 / N	i1=15 / i2=5 /N
EM @ 42 V / 100°C	PSM 16 kW (20 s)	PSM 16 kW (20 s)	PSM 16 kW (20 s)



E-Axle Modular Design for Tomorrow's Mobility

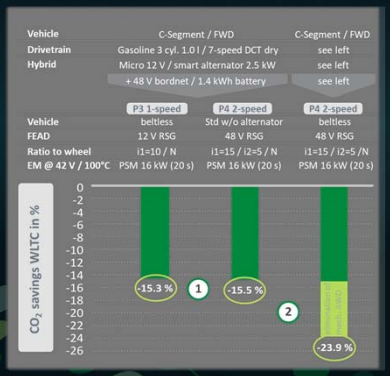
Scott A. Miller

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

Potential C02 Savings

Symposium

Vehicle	C-Segment / FWD	C-Segment / FWD
Drivetrain	Gasoline 3 cyl. 1.0 l / 7-speed DCT dry	see left
Hybrid	Micro 12 V / smart alternator 2.5 kW	see left
	+ 48 V bordnet / 1.4 kWh battery	see left
	P3 1-speed	P4 2-speed	P4 2-speed
Vehicle	beltless	Std w/o alternator	beltless
FEAD	12 V RSG	48 V RSG	48 V RSG
Ratio to wheel	i1=10 / N	i1=15 / i2=5 / N	i1=15 / i2=5 /N
EM @ 42 V / 100°C	PSM 16 kW (20 s)	PSM 16 kW (20 s)	PSM 16 kW (20 s)



1. Higher no. of gears
   - Additional drag losses
2. Removal of mechanical AWD

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Then and Now

Symposium

E-Axle 2011		E-Axle 2018
Separate	**Power Electronics**	Integrated
2000 Nm (10s)	**Peak Torque**	4000 Nm (30s)
60 kW (10s)	**Peak Power**	150 kW (30s)
525 mm	**Overall Length**	515 mm
90 kg	**Weight**	75 kg

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

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

Currently in Production with 3 Variants!

Symposium

- 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

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

Schaeffler Menu of E-Axles

Symposium

- 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!!!!

E-Axle Modular Design for Tomorrow's Mobility

Scott A. Miller

SCHAEFFLER

Schaeffler **Symposium** September 6, 2018

Mobility for tomorrow