TENSION 12 V TO 800 V
EFFICIENT POWERTRAIN SOLUTIONS
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AVL List GmbH
Public
CHANGE OF BOUNDARIES
POWERTRAIN ELECTRIFICATION

Customer Demands
- Driving Experience
- TCO

Vehicle Technology
- Electrification

Legislation
- CO₂
- WLTP
- RDE

Engine
Transmission
Electrification
Vehicle

AVL
TENSION 12 V TO 800 V
WHAT IS THE BEST VOLTAGE LEVEL?

Cost / Complexity

Function

Rightsizing
Standardization

12V
24V
48V
96V
400V
600V
800V

soldar
TENSION 12 V TO 800 V
WHAT IS THE BEST VOLTAGE LEVEL?
12 V IS HERE TO STAY

- Fleets will remain predominantly 12 V due to cost
- 12 V vehicles will have significant impact on fleet fuel consumption
- Innovation for 12 V vehicles is mandatory
12 V
POWER SUPPLY SYSTEM

- After stop/start, **Intelligent Power Supply Systems** will become standard

- Dual Batteries or pure Li-Ion batteries gaining
  - Charge acceptance and discharge power
  - Denso already sold > 1 Mio 12V Li-Ion batteries

Source: www.globaldenso.com
WHAT CAN YOU DO ON POWERTRAIN SIDE?

High Efficiency

- 1,6l TGDI, e-supercharger
- 104 kW/4000 rpm
- FE Target: 90 g/km CO₂

High Performance

- 1,75l TGDI, e-supercharger
- 400Nm / 3500rpm
- 350HP / 6500rpm (148 kW/l)
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48V
WHY STOP AT 48V?

**Significant cost saving...**

max. voltage $< 60$ V

$\Rightarrow$ NO protection against contact required

**... at attractive functionality**

- 14...16+ kW generating
- 8...12+ kW motoring
- Several hybrid options P1, P2, P3, P4
- Unified VDA-standard
4 DRIVERS FOR 48 V
4 DRIVERS FOR 48 V

CO₂
**48 V DRIVER: CO₂ IMPACT OF FUNCTIONALITY**

- **Basis w/o STST**
- **STST+IPSS**
- **Regen Brake**
- **Regen Brake+Boost**
- **Pwtr. Measures enabled by 48V**

**CO₂ Emissions**

- **80%**
- **85%**
- **90%**
- **95%**
- **100%**

C-Segment, 4 cyl. TGDI, automatic transmission, NEDC

**New Basis**

**“Indirect” Benefit**
48 V DRIVER: CO$_2$
IMPACT OF DRIVING CYCLES

*STST inhibited in China City due to energy balance

C-Segment, 4 cyl. TGDI, automatic transmission
4 DRIVERS FOR 48 V

Performance
Electric supercharger 48V

2.0L 4-cylinder 4V TGDI DVVT engine

450 HP

168 kW/L

500 Nm (31.9 bar BMEP)

Bi-Turbo waste gate TC
4 DRIVERS FOR 48 V

Emissions
EMISSION & CO2 IMPROVEMENT

Graph showing emissions improvement over time:
- Velocity [km/h] vs. Time [s]
- CO2 [g] vs. Time [s]
- NOx [mg] vs. Time [s]
- BSG [Nm] vs. Time [s]

Key points:
- 13% reduction in emissions
- Comparison between Base Vehicle and 48V BSG
EMISSION & CO2 IMPROVEMENT

- **Velocity (km/h)**
  - Range: 0 to 160
  - Graph showing acceleration and deceleration patterns.

- **CO₂ [g]**
  - Range: 0 to 8
  - Graph showing emissions over time.

- **NOₓ [mg]**
  - Range: 0 to 12
  - Graph showing emissions over time.

- **BSG [Nm]**
  - Graph showing power output over time.

- **Base Vehicle vs. 48V BSG**
  - Comparison graph highlighting 13% improvement.

- **Emissions**
  - Graph showing total CO₂ and NOₓ emissions over time.
EMISSION & CO2 IMPROVEMENT

- Base Vehicle
- 48V BSG

**CO₂** [
- Base Vehicle: 13%
- 48V BSG: 17%

**NOₓ** [
- Base Vehicle: 13%
- 48V BSG: 17%

**BSG** [Nm]

**Time [s]**
- 0 10 20 30 40 50 60
4 DRIVERS FOR 48 V
48 V DRIVER: ELECTRIC POWER SUPPLY SYSTEM

- Three main trends, pushing 48 V Power Supply System (PSS)
- Fewer opportunities for electrical energy generation
- Increasing continuous power consumption
- More high power consumer
48 V DRIVER: ELECTRIC PSS DESIGN REQUIRED!

Vehicle Measurements

- Gen Power
- Gen Capacity
- DCDC Power
- Boosting Events
48 V DRIVER: ELECTRIC PSS DESIGN REQUIRED!

Power and Energy Analysis
Example: Luxury sedan w/ 48V electric supercharger

- Generator Utilization: $P_{\text{act}}/P_{\text{max}_{\text{act}}}$
- Battery SOC Window
- Energy Share eSC: $E_{\text{eSC}}/E_{\text{electr.}}$

City, Hot city, Race track, Mountain
Market forecasts indicate strong growth of Mild Hybrid, driven by 48 V
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AVL predicts larger volumes of Mild Hybrids, driven by 48 V
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400V
HYBRID ROAD MAP

48 V Mild Hybrid

HV Full Hybrid
TREND TOWARDS PLUG-IN HYBRIDS

- **Legal CO$_2$ Requirements**
  - Legally, electric power is created with 0 g CO$_2$ / Credits

- **Privileges for EV mode**
  - City access, privileges

- **Electric Driving Experience**
HYBRID ROAD MAP

- 48 V Mild Hybrid
- HV Full Hybrid
- HV Plug-In Hybrid

today

CO₂

Electric driving

tomorrow
CLEAR TREND TO DEDICATED HYBRID TRANSMISSIONS (DHT)

- Most hybrid vehicle models use standard transmissions or slight modifications thereof (e.g. P2)
- Dedicated Hybrid Transmissions (DHT) will become standard
- Toyota Prius is dominating hybrid volumes already today with DHT

DHT: Transmission not functional w/o e-machine

Market Share 2014

Source: IHS 2014
AVL FUTURE HYBRID
NEXT GENERATION DHT

Legislation

-10% CO₂ compared to Powersplit

Cost of Ownership

-10% Piece Cost compared to Powersplit

CO₂ emission in NEDC:
- charge sust.: 79gCO₂/km
- certification: 35gCO₂/km
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800V

Confidential
HIGH POWER ELECTRIFICATION MOVING AHEAD

Tesla S P 85D

Audi R8 e-tron

Lexus RX

AMG Electric Drive

BMW i8

More to come …
800V
ADVANTAGES ON ELECTRIC SIDE

- **Double power output compared to 400V at same current!**
- Package & weight wiring
  - Diameter and bending radius
  - Saving of 10 kg in AVL demonstrator

- Package and weight power electronics
  - Double power density

- Connectors:
  - Cheaper ("paid by Amp")
CHARGING SPEED AS DECISIVE FACTOR

500km Range
min

9 km Range
min

>20 km Range
min

@ 40l/min @8l/100km

Tesla Supercharger: 270km/30min
800V CHALLENGES

- **Infrastructure**
  - DC charging standard available
    - But no stations > 500 V
  - AC-Charging possible (Onboard-Charger)
    - But limited charging power (22kW)

- **Auxiliaries**
  - Different voltage levels in vehicle may be required
    - 800V, 400V, 48V, 12V
    - Heater
    - AC-compressor
    - Power steering
    - ...

Source: www.visteon.com
Power Electronics

Availability:

- **Components** and technologies
  - "proven industry standard"

- **Automotive** components
  - test- and release effort, today limited choice

- **Automotive systems**
  - development effort (also required for 400V high power)

Efficiency

- Higher switching losses in IGBTs
- Options:
  - Variable PWM frequency
  - New semiconductor technology
WORLD’S FIRST 800V PASSENGER CAR: AVL COUP-E 800

Peak Power: 200 kW
AVL’S 800V BATTERY

MODULAR POUCH CELL BATTERY WITH AVL BMS

Battery Pack Details
- Configuration: 180s1p
- Installed pack energy: 27,6 kWh
- Pack weight: 255 kg

Highlights
- Self carrying modules
- Bus bar cooling system
- Cell tab clinching instead of Laser welding
- Serviceable E/E box
AVL’S 800V POWER ELECTRONICS

PI450/850 POWER-INVERTER PLATFORM

Technical Data
- U = 850V
- I = 300 A (430 A up to 10s)
- 1200 V IGBT Module
- Water/Glycol- Cooling

Controller Software
- Field Oriented Control Software (FOC)
- Variable PWM Frequency up to 12kHz
- ASM/PSM drives
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12V Baseline Innovations

48V Mainstream

400V Dedicated Hybrid Transmissions

800V High Performance

Plug-in

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Plug-in
THANK YOU