48V Mild Hybrid Systems
Market Needs and Technical Solutions

Ulf Stenzel
AVL Engineering and Technology
Content

- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
- AVL’s Project Examples
Content

- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
- AVL’s Project Examples
Mild Hybrids – Global Market Overview

In 2020 → (10-15)% of global xEV production are Mild Hybrids

Mild Hybrids, per Region

Global xEV Production

Mild HEVs produced in NA in 2020 will most likely be dominated by High Voltage Systems

In 2020 almost all Mild HEV’s produced from European OEMs are 48V Systems

Source: IHS Q3 2013
Mild Hybrids – Market Overview Europe

- No 48V applications in the A segment (e.g. Ford Ka, Chevrolet Spark) forecasted until 2020
- Significant 48V shares in larger vehicle classes and in the B segment (e.g. VW Polo)
- Early implementation in E segment vehicles (e.g. BMW 7 series, MB E-Class) (see 2018)

- Large share of 48V applications in the Mid (e.g. Renault Clio, Ford Mondeo) and Premium (e.g. BMW 7 series, Smart Forfour) segment
  - Entry: e.g. Renault Duster, Dacia Logan
  - Luxury: Porsche Macan, Rolls-Royce Ghost

- High share of German premium OEMs
- No share from Volkswagen projected
- No share from Fiat (and its sub brands) forecasted until 2020

Source: IHS Q3 2013
German OEMs are pushing for 48V

- The LV 148 standard defines a 48V power supply system including its functions and interfaces.
- The standard describes all relevant electrical requirements and test procedures for the new 48V components.
- It is defined by the big 5 German automakers and shows a clear trend out of Europe to push 48V technology towards production.
- These five OEMs have been involved:
  - Audi AG
  - BMW AG
  - Daimler AG
  - Porsche AG
  - Volkswagen AG
Past and Future Progress to meet the 2020 Target

- Overall the required rate of progress to the proposed 2020 targets is slightly greater (4.1%pa) than the rate that has already been achieved over the past five years (3.6%pa).

- However, these figures do not include the effect of flexibilities (i.e. supercredits) that effectively provide free grams. Carmakers are therefore even closer to achieving targets than the data suggests.

- The clear conclusion is that the 2020 target is achievable for makers of all types and sizes of cars with appropriate planning and introduction of fuel consumption reduction measures.

---

Source: European Federation for Transport and Environment (T&E)
Taxes and Incentives for Mild Hybrids in Europe

![Diagram showing taxes and incentives for mild hybrids in Europe.](image)

- **Taxes on acquisition (Bonus – Malus)**
  - **Other vehicles**: 6000 € to 7000 €
  - **Hybrids**: 6000 €

- **Taxes on ownership**
  - **All**: 21.6 €/gCO₂ to 7 €/gCO₂
  - **2 € per g CO₂/km**

- **Taxes on ownership (2014)**
  - **All**: 475 £ to 1030 £

- **Taxes on ownership VED standard rates (per year)**
  - **All**: 460 £ to 815 £

- **Taxes on ownership VED first year rates**
  - **All**: 660 £ to 1040 £

---

*The bonus amounts to a minimum of 2000€ but cannot exceed 10% of the vehicle purchase price including VAT, increased if necessary by the battery cost, if the latter is rented.*
Definition of Hybrids according to Legislation by Region

**From ECE R101:** … means a vehicle,… that, *for the purpose of mechanical propulsion*, draws energy from both of the following on-vehicle sources of stored energy/power:

(a) a consumable fuel;
(b) a battery, capacitor, flywheel/generator or other electrical energy/power storage device

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>USA</th>
<th>CHN</th>
<th>JPN</th>
<th>KOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>12V ST/ST SIN</strong></td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td><strong>12V ST/ST SIG w/o TA</strong></td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td><strong>12V ST/ST SIG with TA</strong></td>
<td>✔</td>
<td>✔ (1)</td>
<td>✔ (1)</td>
<td>✔ (2)</td>
<td>✔</td>
</tr>
<tr>
<td><strong>48V Alternator (aux. supply only)</strong></td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td><strong>48V Mild HEV</strong></td>
<td>✔</td>
<td>✔ (1)</td>
<td>✔ (1)</td>
<td>✔ (2)</td>
<td>✔</td>
</tr>
</tbody>
</table>

SIN…Start in Neutral
SIG…Start in Gear
TA… Torque Assistance

(1) Yes, if energy storage is rechargeable
(2) Yes, if rechargeable and kinetic energy converter
48V Main Drivers – Summary

- Reduction of CO\textsubscript{2} emission to meet future emission legislation
- Comfort enhancement and new functions
- Less integration effort, weight & cost, compared to HV systems (safety, battery)

48V systems have the potential to fill the gap between state-of-the-art 12V Start/Stop systems and high voltage hybrid powertrains.
Content

- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
- AVL’s Project Examples
12V/48V Electrical Architecture

- eBooster
- EPS / EHPS
- Roll Stabilization
- 48V Starter/Generator
- 48V Battery System
- 48V High-Power Consumer

- Classic 12V Boardnet
- DC/DC

- 12V
- 48V
The integration of the E-machine defines the recuperation potential; the engine drag torque reduces the amount of recuperative energy (P2 versus P1/BSG)

Cost advantage high speed E-machine (BSG) versus high torque (ISG); high torque density leads to higher cost

Integration cost & effort; package (ISG, P2), transmission modification (P2)

Preferred system architectures, functionalities and the resulting cost to benefit ratios are depending on vehicle class & vehicle application
BSG Integration Challenges - Impact on Engine

- FEAD Design
  - Belt Durability
  - Variable Belt Tensioner
    - Increase tension during cranking and boost (machine to engine)
    - Increase tension during recuperation (engine to machine)
    - Reduce tension during normal driving to reduce friction loss
- NVH
  - Belt chirp during cranking
- Crankshaft Main Bearing
  - Durability
Besides the main requirements (EM power & torque) as well as packaging constraints the supplier selection also to take care of cooling requirements and NVH.

48V BSG systems vary across different supplier.

As an independent partner AVL can provide comparable and consistent component characterization.
48V Electrical Load Migration – Impact on eStorage

CO₂ reduction only
Start/Stop, Boost, Recuperation

Electrical Load Migration
Chassis Control, Climate Comfort, Engine Components Electrification, eBooster, etc…
### Powertrain Key Components – eStorage System

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>48V</th>
<th>&gt;&gt;48V</th>
<th>200-800V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHEV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Flooded Lead Acid
- Strong effort in the enhancement of advanced carbon added VRLA to meet 48V requirements
- Lead Acid + UCap could be an interim solution

#### Li-ion

#### NiMH
- Migration from High Voltage to 48V with Li-Ion
- Ideally carry over modules from high power Li-ion HV battery packs

Source: Adapted from Dr. Menahem Anderman (2013)
The cell performance varies across cell technologies.

- NMC & LFP cathode materials fulfil current 48V automotive requirements in terms of performance and safety and will be the dominating Lithium-ion technologies in 48V applications.
- LTO (lithium titanate oxide) anodes show excellent life, low temperature performance, safety but lead to high system costs.
Overview 48V Main Functions
ADV. 48V FUNCTIONALITIES IN LEGAL CYCLES – NEDC
ADV. 48V FUNCTIONALITIES IN LEGAL CYCLES – FTP
Content

- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
  - AVL’s Project Examples
The “TWINS”: 12V and 48V LC Super Hybrid

**NEDC CO₂ Emission [g/km]**

- 1,8-litre TSI: -12%
- 1,4-litre TSI with Start/Stop: -18%
- LC Super Hybrid: -24%
- 48V Mild HEV Concept

**Acceleration 0 - 100 kph [s]**

- 1,8-litre TSI
- 1,4-litre TSI with LC Super Hybrid
- Similar Performance
- Potential for further improvement
- 48V Mild HEV Concept
48V Advanced Lead Carbon Battery Diesel Hybrid Prototype

Project Overview

Features:

48V mild hybrid with Belt Starter Generator (BSG) & electric supercharger (VES)

- +20% Power
- -15% CO₂

Engine update for BSG Controls / Operating Strategy
Demo Vehicle Built & Calibration

HYUNDAI Motor Group

Engine & Vehicle

Valeo Belt Starter Generator E-Booster

Lead Acid Battery

AVL UK Expo 2014 / Ulf Stenzel
AVL Engineering Project History since 2002

- Concept Study
- Demo Vehicle
- Testing
- Comp. Dev.

2003
- Eco Target
  - 42V Mild Hybrid
- "Beltless Engine"
  - 42V Mild Hybrid

2005
- Conti VW Touran
  - 42V Mild Hybrid
- JAC Refine
  - 14+x Micro/Mild Hybrid
- EV Demo
  - 42V SW Dev.

2007
- JAC Binyue
  - BSG Demo vehicle
- Drive Benchmark
  - 42V Mild Hybrid
- Start/Stop
  - 12V BSG

2009
- Start/Stop
  - 12V SRM BSG
- Start/Stop
  - 14V + X BSG +AMT.
- AT Start / Stop
  - 48V BSG+switched CS pulley
- LC Super Hybrid
  - 12V BSG + eCharger

2013
- Concept Study „100mpg“
  - <60V
- Case Study „Affordable Hybrid“
  - <60V
- Market evaluation
  - 48V
- LC Super Hybrid
  - 48V BSG + eCharger
- LC Super Hybrid
  - 48V
- ALABC Pack Dev.
  - 48V
- Li-Ion Batt Pack Dev.
  - 48V
- Start/Stop
  - 12V SRM BSG
- Start/Stop
  - 14V + X BSG + UCap
- Start/Stop
  - 12V BSG
- Start/Stop
  - 12V BSG
- Start/Stop
  - 14V + X BSG + UCap

42V Mirco / Mild Hybrid
12V BSG Micro Hybrid
48V Mirco / Mild Hybrid

AVL UK Expo 2014 / Ulf Stenzel
Summary

- In 2020 almost all Mild HEV’s produced from European OEMs are 48V Systems. German OEMs are pushing towards 48V

- Implementation of new 48V HEV functions into an existing platform requires a systematic approach and an independent holistic view on the powertrain architecture and components

- Interdependencies between components need to be fully understood to avoid undesirable impact on:
  - ...Emissions and fuel consumption
  - ...Performance
  - ...Drivability / comfort
  - ...Energy mgmt. / charge balance
Thank you for your Attention!