Individual E-Mobility System Solutions for Automotive and Off-Highway Applications

Dr.-Ing. Martin Lenz, Bosch Engineering GmbH
E-Mobility at Bosch Engineering

The “Powertrain-Map”

- Gasoline
- Diesel
- Alternative fuels
- Hybrid
- Electric / range extender
- Electric / battery
- Electric / fuel cell
- Electric (battery / fuel cell)

1997 | today | future
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Market Trends: Electrification Systems

[in mio. vehicles]

- Non-Powersplit Systems gaining ground.
- Parallel and Electric Axle systems w/ high shares.

**Electric Axles**
- 2010: 1.0 mio.
- 2013: 3.0 mio.
- 2015: 4.8 mio.
- 2020: 9.0 mio.

**Parallel Types**
- 2010: 1.0 mio.
- 2013: 1.5 mio.
- 2015: 2.0 mio.
- 2020: 3.3 mio.

**Power Split**
- Non-Powersplit Systems: 18%
  - 2010: 1.2 mio.
  - 2013: 3.0 mio.
  - 2015: 4.8 mio.
  - 2020: 9.0 mio.

- Parallel Systems: 37%
  - 2010: 0.3 mio.
  - 2013: 0.5 mio.
  - 2015: 0.7 mio.
  - 2020: 1.4 mio.

- eDCT: electrified double clutch
- Serial parallel hybrid
- Parallel mild hybrid
- Parallel strong hybrid

• electric axle drive / Electric Vehicle
  - 2010: 0.3 mio.
  - 2013: 0.4 mio.
  - 2015: 0.6 mio.
  - 2020: 1.3 mio.

• electric axle drive / Hybrid
  - 2010: 0.3 mio.
  - 2013: 0.7 mio.
  - 2015: 1.1 mio.
  - 2020: 1.1 mio.
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“We provide individual E-Mobility solutions”
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Development areas E-mobility

System definition and development

Prototype & demonstrator construction

E/E-architecture, control units, (CAN, Flexray), safety

Chassis & brake system, vehicle dynamics

Engineering powertrain

Infotainment, HMI, cluster

Engineering power electronics

Energy & battery management

E-Infrastructure

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System development

<table>
<thead>
<tr>
<th>Powertrain incl. EM</th>
<th>Conv. ICE</th>
<th>HEV</th>
<th>PHEV</th>
<th>EV REX</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>12V Gen engine</td>
<td>12V Gen engine</td>
<td>HV BSG engine</td>
<td>HV BSG engine</td>
<td>12V Gen engine</td>
<td></td>
</tr>
<tr>
<td>6SM AMT</td>
<td>AMT</td>
<td>AMT</td>
<td>AMT</td>
<td>AMT</td>
<td>AMT</td>
</tr>
<tr>
<td>12V battery</td>
<td>Battery</td>
<td>Battery</td>
<td>Battery</td>
<td>Battery</td>
<td></td>
</tr>
<tr>
<td>12 V</td>
<td>HV 1.3 kWh</td>
<td>HV 12 kWh</td>
<td>HV 15 kWh</td>
<td>HV 20-30 kWh</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Add. components</th>
<th>Inverter 20kW</th>
<th>Inverter 85kW</th>
<th>Inverter 60kW</th>
<th>Inverter 60kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>Charger</td>
<td>Charger</td>
<td>Charger</td>
<td>Charger</td>
</tr>
<tr>
<td>12 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Powertrain Investigation expl. EV

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Operation Strategy**

**Transmission**

**Reference**

|------------------------------------------|------------------------------------|--------------------------------------------|
# Bosch hardware portfolio

<table>
<thead>
<tr>
<th>Products</th>
<th>Mild hybrid</th>
<th>Full hybrid</th>
<th>Plug-in hybrid</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Motor-generator" /></td>
<td><strong>Motor-generator:</strong> 2 product lines</td>
<td>Platform development for various performance levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Power electronics" /></td>
<td><strong>Power electronics</strong> (inverter, DC/DC, AC/DC)</td>
<td>Platform modular for various performance requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Li-ion battery" /></td>
<td><strong>Li-ion battery</strong> (SB LiMotive, joint venture Bosch with Samsung SDI)</td>
<td>Platform modular for various system requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Regenerative braking system" /></td>
<td><strong>Regenerative braking system</strong></td>
<td>Based on conventional systems with adjustments for using brake energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Vehicle control unit" /></td>
<td><strong>Vehicle control unit</strong></td>
<td>Based on controller from conventional powertrain systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**E-Mobility at Bosch Engineering**
Bosch covers major (P)HEV / EV market requirements
Flexible construction kit w/ scalable design and production line concept

**E-Mobility at Bosch Engineering**

**Electric Machine – Product Portfolio**

- **SMG 180**: Separate Motor Generator
- **IMG 300, IMG 290**: Integrated Motor Generator
- **SMG 138**: Separate Motor Generator

**LFe**: Iron length

- **D₀**: Outer stator diameter

**Pm peak @ ca. 250V dc**

- **HEV**: Rough estimation
- **EV**: Rough estimation

**20 25 30 40 60 80 [kW]**

1. **P2 Hybrid**
2. **HEV eAD / eDCT City / Compact EV**
3. **BSG**

**IMG**: Integrated Motor Generator

**SMG**: Separate Motor Generator

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Power Electronics Segmentation

Requirements:
*) Power Split /w boost converter
**) low cost system
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## Bosch “e-Drive” components

### SMG 180/120

Separate Motor Generator

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active diameter / lengths</td>
<td>180 mm / 120 mm</td>
</tr>
<tr>
<td>Peak torque max.</td>
<td>up to 200 Nm [400A&lt;sub&gt;peak&lt;/sub&gt;]</td>
</tr>
<tr>
<td>Speed max.</td>
<td>12,500 rpm</td>
</tr>
<tr>
<td>Mechanical power max.</td>
<td>40 kW (INVCON 2.2)</td>
</tr>
<tr>
<td></td>
<td>80 kW (INVCON 2.3)</td>
</tr>
<tr>
<td>Total mass</td>
<td>28 kg</td>
</tr>
<tr>
<td>Cooling</td>
<td>Water-jacket 8l/min 85°C&lt;sub&gt;max&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sensor type:</td>
<td>Resolver</td>
</tr>
</tbody>
</table>

### INVCON 2.3

Inverter + DC/DC-Converter

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions L x W x H</td>
<td>310 x 190 x 156 mm (w/ connectors)</td>
</tr>
<tr>
<td>Volume</td>
<td>Inverter approx. 5 l (w/o DC/DC connectors)</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt; 7 kg</td>
</tr>
<tr>
<td>Input voltage</td>
<td>100-365 / 100-430V</td>
</tr>
<tr>
<td>Phase current [A]</td>
<td>400 A (continuous)</td>
</tr>
<tr>
<td></td>
<td>450 A (Peak 5 s)</td>
</tr>
<tr>
<td>Cooling</td>
<td>65 °C, max. 85 °C (flow-rate 8 l/min)</td>
</tr>
<tr>
<td>DC/DC-converter</td>
<td>1,8-2,5 kW / 0,7 kW; unidirectional</td>
</tr>
</tbody>
</table>
Vehicle control unit

Inverter
Control Unit **

Battery Management System

Charge Controller

HMI/Navigation

Vehicle Control Unit (VCU)

ABS/ESP®

Range Extender ECU *

Service and diagnosis

HVAC controller

* optional
** DC/DC converter included
Chassis system solutions E-Mobility

- Brake systems
  - Component setup
  - Recuperation
  - Torque coordination

- Vehicle driving dynamics
  - Safety
  - Traction control
  - Torque vectoring
## Regenerative Braking Systems: Overview

### Recommended CRBS for different HEV/EV types

<table>
<thead>
<tr>
<th>Brake System</th>
<th>HEV</th>
<th>Plug-in HEV</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mild</td>
<td>strong</td>
<td></td>
</tr>
<tr>
<td><strong>ESP® w/ RBC</strong></td>
<td>Combination w/ MVP or EVP</td>
<td>Low recuperation &lt; 0,1g</td>
<td>Low cost</td>
</tr>
<tr>
<td>SOP 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ESP® hybrid</strong></td>
<td>Combination w/ MVP or EVP</td>
<td>Recuperation &lt; 0,2g for x-split circuit</td>
<td>Cost &amp; performance optimized</td>
</tr>
<tr>
<td>SOP 2014*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ESP® hev</strong></td>
<td>Combination w/ MVP or EVP</td>
<td>Recuperation &lt; 0,2g for II-split circuit</td>
<td>Modest cost for enhanced performance</td>
</tr>
<tr>
<td>SOP 2012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HAS hev</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOP 2011</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>iBooster hev</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOP 2014</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Target

HEV: Hybrid Electric Vehicle; PHEV: Plug-In Hybrid Electric Vehicle; EV REX: Electric Vehicle with range extender; EV: Electric Vehicle
Product safety and functional safety

- New challenges regarding product safety and functional safety
  - Laws and regulations (e.g. ECE R100, FMVSS 305)
  - Standards (e.g. ISO 6469, ISO 26262)
  - Customer requirements (e.g. HV)

- We provide safety concepts for
  - Electric shock (e.g. U~ 400V)
  - Fire (e.g. I ~ 300A)
  - Unintended acceleration / deceleration
  - Battery hazards (battery fire, hazardous chemicals)
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Active sound enhancement interior and exterior

- Generation of a synthetic engine sound according to driving situation
- Driving-noise emulation for pedestrian safety in electric / hybrid vehicles
- Customer specific applications and adaptation for individual solutions
Charging systems engineering

➔ In-Vehicle Solution
  • Hardware
  • Software
  • Calibration
  • Integration

➔ Non-Conductive Concept
  • Hardware ECU
  • Software

➔ Alternative Concept
  • Investigation
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Smart connectivity

User

Smart Connectivity Service Platform

Smart Connectivity Service Platform

Vehicle

Electrification

Scooter

World

Loader

Truck
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Powertrain simulation and testing

Virtual Powertrain

ECU-Functions
Transmission
Thermal
Electric Power

ICE

Battery
E-machine
Transmission
Bench

Hybrid Test Bench

ICE

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Test procedures for hybrid and electric vehicles

› Consumption measurement in accordance with the test procedures ECE-R101 or CFR40-Part96
› Determination of “real life” fuel consumption and optimization of the operation strategy (drive cycle, ambient temperature etc.)
› Gradient profiles to verify the robustness of the electric system
› Efficiency measurement for different speed-load setpoints
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Electric powertrain fork lift trucks

Control

Information flow

Existing SW/HW

Additional SW/HW

Energy flow

Hydraulic

Electrically

Mechanically

ECU

Engine Control Unit

TCU

Truck Control Unit

BMS

Battery Management System

INV

Inverter

2x

125 Bosch 1866-2011

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Electric powertrain tow truck

Control
- Information flow
- Existing SW/HW
- Additional SW/HW

Energy flow
- Electrically (LV)
- Electrically (HV)
- Mechanically

ECU Engine Control Unit
TCU Truck Control Unit
BMS Battery Management System
INV Inverter

User input

Engine

Starter

Electric motor

Battery

Power Steering

Brake Booster

ECU

TCU

Standard engine strategy

+ Hybrid strategy

INV

DC/DC

trq, n

trq_{eng}, n_{eng}

n_{act}

trq_{eng}', n_{eng}'

INV

Battery

Energy flow Existing SW/HW Additional SW/HW

User input

Electrical powertrain tow truck

Engine

Starter

Electric motor

Battery

Power Steering

Brake Booster

ECU

TCU

Standard engine strategy

+ Hybrid strategy

INV

DC/DC

trq, n

trq_{eng}, n_{eng}

n_{act}

trq_{eng}', n_{eng}'

Battery

2x

2x
Thank you for your attention!