TE Connectivity
Battery Pack Technologies

Steve Wang
2014.12.9
Figures shown are fiscal year 2013 sales in billions (B).

$13.3B sales worldwide

- **Americas**
  - $4.4B
  - 2,375 engineers
  - 10 design centers
  - 38 manufacturing sites

- **China**
  - $2.2B
  - 950 engineers
  - 3 design centers
  - 12 manufacturing sites

- **Asia (excluding China)**
  - $2.3B
  - 1,880 engineers
  - 3 design centers
  - 16 manufacturing sites

- **EMEA**
  - $4.4B
  - 1,700 engineers
  - 5 design centers
  - 33 manufacturing sites
At the Intersection of Electricity and Mobility

BATTERY SYSTEM & POWER DISTRIBUTION UNIT

CONNECT AND PROTECT THE SYSTEM
Connections for:
- Cell to Cell (C2C)
- Cell to BMS (C2BMS)
- Module to Module (M2M)
- Battery Disconnect Unit (BDU)
- AMP+ Manual Service Disconnect (MSD)

CONNECT AND SENSE THE POWER
- Thermal Protection Device (PTC)
- Multi Coil Resolver (MCR)
- AMP+ Low, Medium & High Current Connectors & Headers and HV Cable Assemblies
- HV Relays & Contactors for Main- and Pre-charge

TE protects by design. Connection after connection.
From Generation to Destination - TE is Enabling the EV Age

Completing the connections that power it all. Everyday. Around the globe. Safely and reliably.
Automotive Trend - Electrification
Four Mega trends:

- Legislative regulations, e.g. CO₂, EURO6, max fleet consumptions….
- Urbanization
- Narrow resources
- Individual customer behavior
- Internet of things
Battery costs are the key success factor for e-mobility. While battery costs are still too high the car industry is shifting to

- µHEV with 48V (less costs than HEV)
- HEV with small battery size,
- BEV population will grow slowly.
- PHEV (Plug In Hybrid Electric Vehicles) offering the best compromise and representing the strongest growing segment

**Legislation** requires improved fuel economy (globally inhomogeneous)

<table>
<thead>
<tr>
<th>Type</th>
<th>2015</th>
<th>2020</th>
<th>CAGR</th>
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<tbody>
<tr>
<td>BEV</td>
<td>0.3</td>
<td>0.9</td>
<td>19%</td>
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<tr>
<td>PHEV</td>
<td>0.2</td>
<td>1.2</td>
<td>34%</td>
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<tr>
<td>HEV</td>
<td>1.8</td>
<td>3.1</td>
<td>10%</td>
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</table>

**Car electrification and weight reduction are important trends for the next years to improve efficiency**

- Legislation requires improved fuel economy (globally inhomogeneous)
- **2015** = 130 g/km, **2021** = 95 g/km
- Weight reduction improves fuel consumption by 1-2%

50 kg
Battery Connectivity
Leading OEMs and Battery Pack Manufacturers Choose TE

500 Connections enabling the HV System

100 Cells and more Connectivity enables long Battery Life

6000 Amp Short Circuit Protection matters most

• One company providing the complete battery connectivity and protection system
  - Interconnects for Cells and Modules,
  - Battery Disconnect Units,
  - Contactors & Relays and
  - Sensors

Connecting with TE provides battery makers the freedom to focus on their core competencies

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Cell types

Cylindrical
- long term experience with round cell design
- high reliability
- speed
- difficult to cool
- inefficient packaging

Prismatic
- easy module assembly
- controlled venting
- good cooling
- force to press in housing
- less active material

Pouch
- optimal cooling
- high energy density
- sealing
- stapling of electrodes
- mech. expansion

Prismatic design still dominates next years

Advantages of pouch cells (material) and cylindrical cells (quantity)

Long term trend still vague

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TE Connectivity: One Supplier for Battery Connectivity & Protection Solutions

- Connection Harnesses
- Service Disconnect
- Metal Hybrid PPTC Fuse
- Battery Disconnect Unit
- Resistor & Current Sensors
- Module to Module (M2M) Connector
- Integrated Cell Connection Board (ICB)
- Contactors

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Overview of a Battery Connection Architecture

Battery management system is based on up to 100 cells with 500 connections.

- Signal connection to BMU
- Signal connection to CMS
- Power connection from Negative pole of previous cell to Positive next cell in a row
- Module to module connection (plug-able) with flexible conductor
Battery Module Structure (Prismatic)

- Module to module connection (touch safe)
- Slave BMS / CMS (PCB not displayed)
- Prismatic cells w/o module frame
- Protective cover
- Underneath the cover: Cell connection for power and logic, thermistors
- Cell
Serviceability on battery module level
Battery Protection
Battery Pack Protection Schematic

Types of Protection
- Short Circuit Protection (up to 6kA)
- Battery isolation and circuit control
- Main circuit current measurement
- Fault protection
- Over-temperature detection and current limiting
- EMC and Sealing

Key Applications:
1. Main Relays
2. Pre-charge Relay
3. Accessory Relay (DC)

Further Applications:
4. LV Diagnostics
5. Discharge Relay
6. Main Fuse

5 s rule:
within 5 sec.
<60V
1. Short Circuit Protection

Service Disconnect performs dual functions of **protecting** and servicing the EV system.

**Protection Function**

- Lithium-ion batteries can produce up to 6,000 Amps of current in short circuit.
- SD provides fuse to protect system.
- Integral component to electric vehicle safety strategy.
- Fuse sizing based on EV system architecture to open fast enough to protect but also avoid false blows.
- Fuse behaves differently in the SD and in the vehicle application and needs to be validated in the application.
Short Circuit Protection
Providing safe and simple high voltage serviceability
Service Disconnect performs dual functions of **protecting** and servicing the EV system

**Service Function**

- Allows safe electrical vehicle assembly by engaging the high voltage power after completion of vehicle assembly
- Provides technician ability to safely disconnect the high voltage system when servicing the electric vehicle
2. Battery isolation and circuit control

- **HEV**
  - Average Battery Continuous Current: 50-100 A

- **PHEV**
  - Average Battery Continuous Current: 100-200 A

- **BEV**
  - Average Battery Continuous Current: 150-350 A

**Diagram Notes:**
- **1. Charger Contactor**
- **2a, 2b. Main Contactors**
- **3. Precharge Relay**

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## HV Relays for Hybrid & Electric Vehicles

- Main Contactors
- Precharge Relays
- Charger Contactors
- Auxiliary load contactors

### Specifications

<table>
<thead>
<tr>
<th></th>
<th>Mini K HV</th>
<th>EVC50</th>
<th>EVC80</th>
<th>EVC135</th>
<th>EVC175</th>
<th>EVC225</th>
<th>EVC250</th>
<th>EVC500</th>
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<tr>
<td>Load voltage/ V</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
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<tr>
<td>Carry short circuit current/ kA</td>
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<td>0.5</td>
<td>0.9</td>
<td>2.0</td>
<td>5.0</td>
<td>3.5</td>
<td>6.0</td>
<td>3.5</td>
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<tr>
<td>Continuous rated current (carry)/ A</td>
<td>-</td>
<td>50</td>
<td>80</td>
<td>135</td>
<td>175</td>
<td>225</td>
<td>250</td>
<td>500</td>
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<tr>
<td>emergency break/ kA</td>
<td>0.02</td>
<td>0.4</td>
<td>0.4</td>
<td>1.0</td>
<td>1.2</td>
<td>1.0</td>
<td>2.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- Up to 6kA short circuit capability
- Small size, light weight
- 2nd generation contactors work without gas filling

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3. Integrated Solution: Battery Disconnect Unit
Battery Disconnect Units (BDU) - Overview

FUNCTION: Main disconnect and power destitution for battery pack which includes contactors, current sensor, and fuses

CUSTOM SOLUTIONS: Driven by different architectures, electrical requirements, and packaging size / mounting

Market Trend: Smaller packaging size and Less Weight
Regionally there are strong differences of preferred shielding concepts.

TE offers all three types.

1. Indiv. Shielded (+ best process)
2. Multicore (- worst process)
3. Bundle shielded (- Corrosion in unsealed area)
AMP+ High Voltage Connection Portfolio
Solutions for LV215-1/2 and LV216-2 standards

Current[A] at 125°C

Wire cross section [mm²]

Class 1 up to 20 A / 4mm²
Class 2 up to 40 A / 6mm²
Class 3 up to 80 A / 16mm²
Class 4 up to 180 A (200 A) / 50mm²
Class 5 up to 400 A / 120mm²

Connect

Screw

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Summary
Experts in Connecting and Protecting the Battery

Connectivity:

• **Cell to Cell connections** for easy and cost effective connection of prismatic and pouch cells

• **Cell to BMS connection** with integrated functionality for BMS sense line and circuit protection. Flexible design options to address de-/centralized BMS approach

• **Module to module connection** for smaller package size and faster application/assembly with TE’s quick-connect design vs. bolt-down

• **Wiring harness** for reliable and easy connection of battery system components

Protection:

• **Service Disconnects** for short circuit protection and safe service condition

• **Contactors** for battery isolation and circuit control with battery management

• **Battery Disconnect Unit** provides fault protection

• **Current Sensor** for main circuit current measurement

• **Thermal Protection** for over-temperature detection and current limiting

Connecting with TE allows you to simplify your entire value stream with confidence
Thanks!