NEV Architecture & Electrification System Footprint Overview

Jacky Gu / Chief Engineer
Driving the Next Era of Propulsion

Leading global automotive emissions, fuel economy and aftermarket solutions provider

Global, cost-competitive manufacturing and engineering footprint

Extensive product portfolio to meet current and future market needs

Committed to be a valuable partner, ensuring our customers’ continued success

Advanced internal combustion and next-gen vehicle electrification. Optimized electronic controls.

Aftermarket offerings that provide high quality and reliability to meet OEM performance standards
The Transportation Industry is Changing Rapidly

Rapid change allows new and existing technologies to communicate and work together more efficiently.
The Changing Propulsion Mix

By 2025, 40% of vehicles will be electrified.

Market drivers

The changing propulsion mix 2018-2030

CAGR '18-'25: 1.9%

Source: IHS AUG 2018, West+Eastern Europe incl Russia
## Market Trend on Electrification

### Continuous growth of addressable market ($Bn) of Electrification and PT Electronics

#### Market drivers

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<td>12</td>
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<td>17</td>
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<td>Emission Standards</td>
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<td>Cost/availability of components/technologies</td>
<td>21</td>
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<td>30</td>
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<td>Fuel Economy</td>
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**Total Addressable Market**

- **Electrification CAGR (2018 – 2023):** 27%
- **Electronics CAGR (2018 – 2023):** 3%

**Vehicle Market CAGR (2018 – 2023):** 2%

Source: I.H.S. Nov 2018; DT Nov 2018 TAM

*CAGR: Compound Annual Growth Rate*
Market Driven Portfolio for EV Architecture

It is critical to focus on providing the entire Electronics & Electrification portfolio capabilities.

<table>
<thead>
<tr>
<th>Key components</th>
<th>Vendor</th>
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</thead>
<tbody>
<tr>
<td>Engine Control Unit</td>
<td>Delphi√</td>
</tr>
<tr>
<td>Transmission Control Unit</td>
<td>Delphi√</td>
</tr>
<tr>
<td>Power Distribution Unit</td>
<td>Delphi√</td>
</tr>
<tr>
<td>Local Control Units</td>
<td>Delphi√</td>
</tr>
<tr>
<td>EMS and Hybrid System</td>
<td>Delphi√</td>
</tr>
<tr>
<td>Inverter</td>
<td>Delphi√</td>
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<tr>
<td>DC/DC Converter</td>
<td>Delphi√</td>
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<tr>
<td>On-Board Charger</td>
<td>Delphi√</td>
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<tr>
<td>Battery Controller</td>
<td>Delphi√</td>
</tr>
<tr>
<td>Battery</td>
<td>3rd Party</td>
</tr>
<tr>
<td>Motor</td>
<td>3rd Party</td>
</tr>
</tbody>
</table>
BEV E-Powertrain converges to 3in1+3in1

3-in-1 e-Axle and 3-in-1 high voltage box expected to be the future trend in BEV

Illustration

Example

High Voltage BOX (OBC+DCDC+PDU)
Inverter
Motor Gear Box

Power Electronics Box (Inverter+OBC+DCDC+PDU)
Motor Gear Box

HV BOX (OBC+DCDC+PDU)
Inverter
Motor Gear Box

OBC DCDC
Inverter
Motor Gear Box

Integrated unit

Low

No Integration

Most current CN BEV models
VW: e-Golf use CIDD from PHEV
Volvo: BEV with CIDD

Common BEV

Nissan Leaf
BMW i3
Tesla Model 3
Tesla Model S
GM Bolt BEV
Daimler EVA1

GM Next Gen BEV
Audi/Porsche PPE
Audi e-Tron BEV
VW MEB
BMW Gen5
Daimler EVA2

Nissan Leaf 2nd Gen
BMW i3
Tesla Model 3
Audi e-Tron

Tesla Model S
VW MEB
BMW Gen5
Daimler EVA2

Common BEV
High Voltage Electrification Products Overview

Low cost, high density, rugged with various levels of integration available
Materials required for:
- Single-side cooling to IGBT
- Top side wire bonds
- High temperature operation
- Thermal conductivity
- Performance and reliability
- Manufacture process
- Cost reduction

Innovation Design for:
- Voltage > 700V
- Current > 650Arms
- Frequency > 15kHZ
- Temperature > 105C
- Speed > 16000rpm
- Cost improve > 20%

Affordable and Reliable for:
- Integrated power electronics, motor and reducer
- Modular & scalable design
- Functional safety design
- Manufacture technologies
- Cost reduction
ALL-IN-ONE Approach: Integrated Inverter/Converter & EDM

ALL-IN-ONE: our first-of-its kind innovation to further reduces size, complexity and costs

Various solution to deliver More for Less in one package

- CIDD - Integrated single Inverter/Converter PHEV
- Dual Inverter / Converter
- 425 Amps CIDD PHEV / BEV
- 3in1 EDM BEV

What distinguishes us …

- PACKAGING FLEXIBILITY AND SPACE SAVING
- ENHANCE DURABILITY AND RELIABILITY
- BOOST COST SAVING THROUGH ELIMINATED CONNECTIONS AND HOUSINGS
- SCALABILITY TO BE USED ACROSS VARYING PORTFOLIOS AND HAD ROOM TO GROW
Comprehensive Portfolio of Inverters

Broad range of inverters to apply on PHEV / HEV / BEV with flexible mounting position

Various design of inverters to tailor customers' needs

- 500 Amps Single Inverter
- Un-sealed Inverter
- 3-in-1 Inverter
- Dual Inverter w/ TCU
- Medium Duty Inverter 100kW traction

What distinguishes us …

- Our Viper 25% higher; 30% smaller; 40% lighter
- Next gen Viper in development to enable extra high voltage 800V bus inverters
- Flexibility to move from Si to SiC power switch to enable higher efficiency & lower cost
- Advanced capacitor in development to enable up to 70% reduction in component volume & weight
Electrification Propulsion Trends

2012 Electric Drive System
$30/kw, 1.1kW/kg, 2.7kW/L
91% system efficiency

- Discrete Components
- Silicon Semiconductors
- Rare Earth Motor Magnets

2025 Electric Drive System
$10/kw, 2.2kW/kg, 5.5kW/L
95% system efficiency

- Full integrated Components
- Wide band Semiconductors
- Non-rare Earth Motors
Transition.1: OEMs Shift from Silicon to Silicon Carbide

Unique market transformation being driven by lower costs, faster charging and better performance

Do you plan to use silicon carbide in your inverter by 2025?

As of August 2017
- Yes
- No

As of August 2018
- Yes
- No
- Probable

As of August 2019
- Yes
- No
- Probable
Silicon Carbide Offers Much Lower Losses Than Silicon

Silicon carbide MOSFETs offer significantly lower losses than Si IGBTs at both 400V and 800V.

**400V**

Inverter-level Loss Comparison:
Silicon vs. Silicon Carbide
(same voltage and switching frequency)

<table>
<thead>
<tr>
<th>Phase Current [Amps rms]</th>
<th>Total Inverter Losses [%]</th>
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<tbody>
<tr>
<td>75</td>
<td>29%</td>
</tr>
<tr>
<td>140</td>
<td>35%</td>
</tr>
<tr>
<td>240</td>
<td>45%</td>
</tr>
<tr>
<td>400</td>
<td>59%</td>
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</tbody>
</table>

**800V**

Inverter-level Loss Comparison:
Silicon vs. Silicon Carbide
(same voltage and switching frequency)

<table>
<thead>
<tr>
<th>Phase Current [Amps rms]</th>
<th>Total Inverter Losses [%]</th>
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</thead>
<tbody>
<tr>
<td>100</td>
<td>30%</td>
</tr>
<tr>
<td>200</td>
<td>33%</td>
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<tr>
<td>300</td>
<td>38%</td>
</tr>
<tr>
<td>400</td>
<td>43%</td>
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<tr>
<td>500</td>
<td>48%</td>
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Higher Efficiency of Silicon Carbide

Silicon carbide inverters are the key to driving inverter loss reduction.

Using Cree’s technology, Ford tested the comparison of inverter losses during city and highway cycles.

Compared to silicon, silicon carbide reduces inverter losses by ~78% for combined EPA city + highway cycle.

Enables 5-10% further range for same battery size OR 5-10% reduction in battery cost for same range.
## Driving Cost Savings in Electric Vehicles

The shift from silicon to silicon carbide delivers cost savings for OEMs

<table>
<thead>
<tr>
<th><strong>Battery Electric Vehicle</strong></th>
<th><strong>Silicon Carbide Cuts 800V Inverter Losses</strong></th>
</tr>
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<tbody>
<tr>
<td><img src="image" alt="Battery Electric Vehicle" /></td>
<td><img src="image" alt="Silicon Carbide Cuts 800V Inverter Losses" /></td>
</tr>
</tbody>
</table>

| **~5.0% - 10% Silicon Carbide Battery Savings** | **~$400 - $800**
---|---
| (80kWh battery x $102/kwh battery cost) | |
| **Space / Weight Savings** | $++
---|---
| (battery & inverter) | |
| **Cooling Requirements Savings** | $++
---|---
| **Incremental Cost of Using Silicon Carbide** | **~$200**
---|---
| **Savings per car:** | **$200 – $600**
---|---
| **At 100K vehicles, OEM saves:** | **$20M – $60M**

Source: Cree estimates
Transition.2: Higher Voltage Electrification Propulsion

Higher Power for Premium/Performance drives Bus Voltages
Boost-HV HEV System Architecture

High voltage boost system to improve system efficiency

Intelligent Power Unit
- Li-ion battery
- On-board charger
- DC/DC converter
- Battery control unit

DC cable
Electric compressor
Power Control Unit
- Inverter
- Voltage control unit
- Motor control unit

Atkinson cycle engine
Electric coupled CVT
- Clutch
- Motor
- Generator

Refer to: Development of sport HYBRID i-MMD Control System for 2014 Model Year Accord
**800V BEV System Architecture**

800V voltage BEV system to improve power rating and charging efficiency

**Circuit Voltages**
- HV DC
- HV AC
- 12v DC
- Tubing/Channel

**Connections**
- Un-Shielded Connector
- HV Shield/Sealed Connector
- High Current Shielded Connector
- Un-Shielded Connector
- Ring Terminal

**Requirements:**

- **High voltage, high current electrical system**
  - Up to 800volts and 300A fast DC charging
  - High performance components for robust application
  - Protection for safe operations

- **High frequency AC applications**
  - Up to 400kW power rating
  - 3~5% system efficiency improvement
  - Electrical magnetic interferes and shielding
First in the industry with volume production of 800V silicon carbide inverter
Future Electric Propulsion to be More Smart

Improved efficiency, safety and range for combustion and electrified vehicles

Delphi Technologies’ Intelligent Driving system expands the role of the Propulsion Controller, transforming data into look ahead planning for the propulsion system.
The Path to Grow Together

We need partners to grow with us in the electrification disruption journey

➢ Technology
  ▪ Innovation
  ▪ Speed to market
  ▪ Design to cost

➢ Operations Excellence
  ▪ Flawless launch
  ▪ Capacity flexibility
  ▪ Zero quality defects
  ▪ Localization

➢ Competitiveness
  ▪ Rapid price erosion
  ▪ Buy in selling currency
  ▪ Payment terms aligned with regional customers
Summary

Committed to be a valuable partner, ensuring our customers’ continued success

Delphi Technologies continues innovation on key electrification components
- 1200V both Si IGBT and SiC MOSFET
- Small profile capacitor
- 3-in-1 or all-in-one EDM system optimization

Delphi Technologies continues expanding our manufacturing and design capability in China
THANK YOU