Automotive Future: Electrified and Autonomous

The Transition of an Industry

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We are witnessing the dawn of two disruptive technologies

1. Electric Vehicles

2. Autonomous Driving Vehicles
“The Two Biggest Revolutions in Transport are Electrification and Autonomy. These are the two biggest innovations since the moving production line…and they are both happening at about the same time.”

…Elon Musk* (Tesla)

*Source: BBC News interview 1.13.16
Electric Vehicles
The Game Changers

“All transport with the exception of rockets will be fully electric”…Elon Musk*

Chevy Volt
Plug-In Extended Range EV
53 miles per charge
Then ~250 miles on gas
~$35,000

Tesla Model S
Battery Electric Vehicle
200-300 miles per charge
~$71,000 to $105,000

Nissan Leaf
Battery Electric Vehicle
150 miles per charge (on 2018 model)
~$30,000

Chevy Bolt
Battery Electric Vehicle
238 miles per charge
~$30,000

Tesla Model 3
Battery Electric Vehicle
220 miles per charge
~$35,000

*Source: BBC News interview 1.13.16
Electric Vehicles
What about the dropping price at the pump?

Shale Oil/Gas Fracking

Shale Oil in USA plus OPEC ‘pumping’ causing over-supply
Will low fuel prices at the pump hurt EV Sales?
Electric Vehicle Market
May have moved beyond the question of oil prices

Cheap Oil?

What’s that got to do with air quality in China?
....or anywhere else in the world for that matter
Compelling Reasons for Owning an EV
Pick the one that appeals to you!

- Air Pollution
- Climate Change
- Save Money
- Greenhouse Gases
- or Just to be Cool!!

Reduce Oil Consumption
Say Goodbye to Gasoline
Green & Clean
Hybrid and Electric Vehicles
Current Growth Projections

Global Electrification Market Upward Shift

*Source: IHS July 2017
Sheahan warns against the “gravity of success,” which keeps the mind from seeking new opportunities because it becomes too trusting in the familiar success path. This trend is easy to fall into, because “change is really slow until it isn’t,” he said, explaining that when a market comes together, the tipping point hits a perfect storm, and a new product becomes a hit.
Electric Vehicle Adoption
The Perfect Storm? Maybe

And then came a Singular Event on March 31, 2016

Automotive board rooms all over the world took notice

~80% drop in 6 years
Tesla claims < $190/kWh
GM claims $145/kWh

Battery Pack Costs

*Source: McKinsey January 2017*
And then came March 31, 2016
Historically important moment for EVs

Unveiling of Model 3

115,000 Pre-orders prior to unveiling

Nearly 450,000 pre-orders now
Hybrid & Electric Vehicles
Electrification Architectures

12V Start-Stop
- Fuel saving
- Start-Stop
- Voltage stabilization
- Recuperation
- Acceleration support
- Sailing

Mild Hybrid (48V)
- Fuel saving
- Start-Stop
- Voltage stabilization
- Recuperation
- Acceleration support
- Sailing
- Electric parking
- Electric driving (~2.5mi)

Full Hybrid
- Fuel saving
- Start-Stop
- Voltage stabilization
- Recuperation
- Acceleration support
- Sailing
- Electric parking
- Electric driving (~30mi)

Plug-in Hybrid
- Fuel saving
- Start-Stop
- Voltage stabilization
- Recuperation
- Acceleration support
- Sailing
- Electric parking
- On-board charger
- Electric driving (~30mi)

Electric Vehicle
- Fuel saving
- Start-Stop
- Voltage stabilization
- Recuperation
- Acceleration support
- Sailing
- Electric parking
- On-board charger
- Fully electric driving
Hybrid & Electric Vehicles
Electrification Architectures

- **EV** (Up to 600V)
  - All Electric
  - Tesla, Leaf, Bolt, etc.
  
- **PHEV** (Up to 600V)
  - All Electric Back-up ICE
  - Volt, Volvo XC90, Karma, etc.
  
- **FULL** (Up to 400V)
  - Start-Stop, Regenerative braking
  - Electric & ICE Propulsion
  - Prius, Fusion, etc.
  
- **MILD** (Up to 100V)
  - Start-Stop, Launch Assist
  - Regenerative Braking
  - Includes 48V systems
  - GM eAssist models
  
- **MICRO** (Up to 14V)
  - Start-Stop
  - Up to 14V
  
**Fuel Economy Benefit**
Electrification Architectures
Fastest growing

Growing New Architectures

48 Volt Mild Hybrids
- Smaller gage wiring
- Fused power distribution modules
- Sealed anti-corrosion connections
- Arc detection desirable

Plugin Hybrids PHEVs
- High power
- Large Shielded cables
- Sealed & shielded connection systems
- Charging solutions

Battery Electric BEVs
- Higher power (trending up)
- Large Shielded cables (trending up)
- Sealed & shielded connection systems
- Charging solutions – increased power

New Architectures drive new Requirements and Product Portfolios
Architecture Key Considerations:

- High Voltages & High Currents (lethal)
- EMC Protection (shielding of cables and connections)
- Integration/Compatibility with all systems & sub-systems
- Reliability through life of the vehicle
## High Power Connections Systems

**Product Line Sub-segments**

### Electrification Product Segments (connectors)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Applications</th>
</tr>
</thead>
</table>
| **High Voltage Power Conversion**             | • Inverter  
• Drive motors  
• Motor Generator Unit  
• Battery Output |
| **Chargers & Charging Cables**                | • Charging cord set  
• Mode 3 cable assemblies |
| **High Voltage Auxiliary Modules**            | • DC converter  
• Charger  
• Air conditioning  
• Heater  
• Coolant heater control |
| **Internal Battery Connections**              | • Manual Service Disconnects  
• Battery cell interconnects  
• Battery management |
| **Charging Inlets**                           | • SAE J1772  
• IEC Type II  
• GB-T  
• Combo 1/Combo 2 fast charge |
High Power Wiring
Product Line Sub-segments

Electrification Product Segments (wiring)

High Voltage Shielded Cable
Applications:
• Mild, Full, PHEV, BEV
• Cu and AL core
• Individual and bundle shielded
• OEMs and Tiers

Battery Pack Wiring
Applications:
• Mild, Full, PHEV, BEV
• Primary and HV cable
• LV and HV conn.
• Integration by OEMs and Tiers:
  • Tight packaging

Physical Protection (Coverings)
Applications:
• Mild, Full, PHEV, BEV
• Rigid HV cable protection
• Sealed and unsealed
• Custom per application
• OEMs and Tiers
High Power Electrical Centers

Product Line Sub-segments

Product Segments (electrical centers)

48V Circuit Protection

Applications:
- 48V High Current Loads

Voltage Stabilization

Applications:
- Micro-hybrid vehicles
- Dual battery isolation
- DC/DC converter

High Power Electrical Centers

Applications:
- Mild through EV High Voltage batteries
- < 750Vdc applications
- High current / high voltage power distribution, switching, and circuit protection
- High voltage contactors (up to 400V, 90A)
- Current / voltage sensing
- 48 Volts
High Voltage Architectures
New Product and Process Challenges

Sophisticated HV Cable Protective Coverings
- Bent Aluminum Tubes

HV Cable
- ISO HV Shielded Cable (In-House)
- Copper or Aluminum conductor
- Tin Plated Copper Shielding
- Inner Jacket (PVC & XLPE)
- Outer Jacket (PVC & T4 XLPE)
- 3 mm² to 50 mm²

Ultra-Sonic Welding
- Copper & Aluminum Core

Innovation: HV Shielded Splice (SAE PACE Award Finalist)
- Heat Shrink Tube
- Insulator + Shield
- Ultra-Sonic Weld
- Dual Wall Heat Shrink Tubing

Oval / Flexible-Rigid Conduit

Laminate Flexible Bus-Bars
Portfolio Manifestation in Real Application
Powering the new Chevy Bolt

Chevrolet Bolt
2017 Motor Trend Car of the Year

High Power Wiring & Connections
High Power Architecture is Evident Looking Under the Hood – ‘the orange stuff’

Electrification Portfolio On-board
• Auxiliary power connections
• Power conversion connections
• Internal battery pack connections
• High voltage shielded wiring
• Low voltage wiring
• Battery pack wiring
• Portable Plug-in Charger
Electric Vehicle Charging
Level 1 through Level 3 “Fast Charging”

**Level 1 Charging**

- AC, 120V, 12A
- 1.4kW
- Portable Plug-In Chargers
- OEM Provided in-vehicle

**Level 2 Charging**

- AC, 240V, 16-80A
- 3.8kW-12.2kW
- Wall or Pedestal Mounted
- Home/WorkPlace/Business

**Level 3 Charging**

- DC “Fast Charging” 20kW-150kW
- Infrastructure Stations
- Highway/City Installations
Electric Vehicle Charging
Power levels and Connector Standards

AC Level 1 (120V) and 2 (240V) Charging
Residential, Workplace, Public Charging

- **Level 1**: 1.4kW, 3.8kW, 7.2kW, 9.6kW, 19.2kW

DC Level 3 Fast Charging
Public Charging

- **Level 3**: 24kW, 50kW, 62.5kW, 120kW

Contacts:
Up to 14,000 Plugs/unplugs

Charging Connectors And Vehicle Inlets

SAE J1772
IEC 62196
China

SAE Combo (CCS)

CHAdEOMO

Combo T2
Vehicle Wireless Charging
Coming Soon!

High Tech - State of the Art - Development

- Hands free vehicle charging
- Magnetic Resonance Power Transfer Technology
- Electrical Grid to Vehicle power distribution
- 3.3kW to 11kW power transfer
- Complies with global standard
- Meets FCC and FDA safety criteria
- Every OEM interested
High Voltage Engineering Challenges
Game is won or lost at the electrical interfaces

Hot disconnects - 48V, 50 Amps

Broken Wires - 48V, 20 Amps

Unsealed, non-isolated connector
48V, in 5% salt water

- Arcing effect of a hot disconnect
- Arcing effect of a broken wire
- Intense electro-chemical corrosion

Requires Engineering Solutions
- System designs to deter hot disconnects
- Electrical system with arc fault detection
- Smart cable routings and coverings
- Sealed connections
- Connectors with terminal cavity isolation
- Manufacturing quality controlled processes
Electrification and Autonomy Convergence
Significant Impact to vehicle electrical content

- Electrification
  - 2X Revenue/Vehicle Potential

- Autonomy
  - 1X Revenue/Vehicle Potential

Base Vehicle $1X + Electrified $2X + Autonomous $1X = Converged $4X*

Power, Signal, & Data Increases

Electrification & autonomy convergence = 4X content & revenue potential

* 4X Revenue per vehicle potential as compared to a traditional ICE vehicle
Architecture Convergence
Autonomous Driving Content Growth

Base Line EV Content

Autonomous Content

Base Electric Vehicle
Autonomous Convergence Requires Smart Vehicle Architectures

BRAIN

SYSTEMS INTEGRATION

NERVOUS SYSTEM

INTERNET OF THINGS

Software Enabled Vehicle Features

FEATURES AND CONTENT

High Speed Sensing and Networking

PLATFORMS

Power and Signal Distribution

OTA and Vehicle Connectivity

Sensing

Foundations

Mobility computing platforms

Smart vehicle architecture
Megatrends driving computing power requirements

- Assisted automation
- Conditional automation
- Safety eco-system
- Fully autonomous

Improvements in computing power enabling multiple macro trends

- Increasing levels of Active Safety
- Increasing levels of Electrification
- Increasing levels of Efficiency
- Increasing levels of software & connectivity
- Increasing levels of Infotainment

Convergence of megatrends driving demand for increased computing power
Autonomous Mobility
Creating a safer driving experience

90% of accidents due to human errors – More than 1.3 M deaths on roads globally each year – Someone dies every 30 seconds

Blind Spot Warning
Automatic Emergency Braking

Collision Mitigation
Forward Collision Warning

Lane Departure Warning
Adaptive Cruise Control

Sensor fusion combines data from multiple sensors to enable safety features - 360° coverage

Industry leading active safety technologies can significantly improve road safety
Autonomous Mobility
Active safety is the foundation

Level 0
No automation
Driver is in complete control of vehicle

Level 1
Function-specific automation
Automation of one or more control functions

Level 2
Combined function automation
Automation of two or more control functions

Level 3
Limited self-driving automation
Driver able to cede full control of all safety-critical functions under certain conditions

Level 4
High self-driving automation
Driver able to cede full control of all safety-critical functions for an entire trip

Level 5
Full self-driving automation
No driver required

Level 2 automation delivers 80% of the benefit for 20% of the cost of Level 5

Source: NHTSA and Delphi cost models
Autonomous Mobility
It’s not as far away as you might think…look what has already been done

First coast-to-coast autonomous drive 2015

AUTOMATED DRIVE HIGHLIGHTS
3,400 MILES DRIVEN
99% FULLY AUTOMATED
~3 TERABYTES OF DATA COLLECTED

WE DID IT!
By integrating vehicle-to-everything (V2E™) technology, the car not only drives itself, but it communicates with the world around it.
Autonomous Mobility
The hard stuff is being solved and demonstrated

Most complex highway+urban drive at CES’17

2017

152
Ride & Drives
Day & Nighttime

>1,400
miles traveled in live Las Vegas conditions

~99%
miles traveled in Automated mode

4 x 7
4 vehicles over 7 days at CES

1 Sensing Segment
2 Mapping
3 Path & Motion Planning Segment

DELPHI
## What does it all mean?
Everything…in terms of a vehicle’s electrical architecture

<table>
<thead>
<tr>
<th>2016</th>
<th>2020+</th>
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<tbody>
<tr>
<td><strong>280</strong> connections to manage power and data</td>
<td><strong>25%</strong> increase – up to 350</td>
</tr>
<tr>
<td><strong>3,100m</strong> of cabling per vehicle</td>
<td><strong>67%</strong> increase – up to 5,000m</td>
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<tr>
<td>Exchanges <strong>15,000</strong> data messages per second</td>
<td>Will exchange <strong>100,000</strong> data messages per second</td>
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<tr>
<td><strong>300</strong> diagnostic parameters monitoring systems performance</td>
<td><strong>233%</strong> increase – up to 1,000 parameters</td>
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<tr>
<td>Primarily <strong>12V</strong> powering the vehicle systems</td>
<td>Up to <strong>600V</strong> in multi-voltage systems</td>
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<tr>
<td><strong>184</strong> miniaturized bus leads</td>
<td>Over <strong>300</strong> miniaturized bus leads</td>
</tr>
<tr>
<td><strong>5</strong> aluminum leads</td>
<td>Up to <strong>100</strong> aluminum leads</td>
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# Electrification & Autonomous Mobility

## Key Takeaways

<table>
<thead>
<tr>
<th>Key Point</th>
<th>Description</th>
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<tbody>
<tr>
<td>Vehicle Electrification is posed for rapid growth and mass adoption</td>
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<td>High power portfolio products are technically challenging and high value</td>
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<tr>
<td>High voltage electrical interfaces (contacts) are critical to function,</td>
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<td>reliability, &amp; safety</td>
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<tr>
<td>Vehicle Electrification and Autonomous Mobility are converging rapidly</td>
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<td>Autonomous Mobility drives complex engineering challenges and solutions</td>
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<td>Both trends offer subject-rich environment for members of the IEEE</td>
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<tr>
<td>community</td>
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