Powertrain Strategies for the 21st Century

Gary Horvat
July 23, 2014
Anticipating Customer’s Needs

Key Points
• About DENSO
• How do we get to 50+ mpg
• Short-Term: Improved Combustion and Transmissions
• Long-term: Electrification
• Conclusion
### Profile

**Established**

<table>
<thead>
<tr>
<th></th>
<th>December 16, 1949</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>187.4 billion yen (US$1.8 billion)</td>
</tr>
<tr>
<td>Net sales</td>
<td></td>
</tr>
<tr>
<td>Consolidated basis</td>
<td>4,095.9 billion yen (US$39.8 billion)</td>
</tr>
<tr>
<td>Non-consolidated basis</td>
<td>2,490.8 billion yen (US$24.2 billion)</td>
</tr>
<tr>
<td>Net income</td>
<td></td>
</tr>
<tr>
<td>Consolidated basis</td>
<td>287.4 billion yen (US$ 2.8 billion)</td>
</tr>
<tr>
<td>Non-consolidated basis</td>
<td>219.7 billion yen (US$ 2.1 billion)</td>
</tr>
</tbody>
</table>

**Employees**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidated basis</td>
<td>139,842</td>
</tr>
<tr>
<td>Non-consolidated basis</td>
<td>38,581</td>
</tr>
</tbody>
</table>

**Consolidated subsidiaries**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>185</td>
</tr>
</tbody>
</table>

(Japan 62, North America 26, Europe 35, Asia/Oceania 56, South America/Others 6)

**Affiliates under the equity method**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
</tr>
</tbody>
</table>

(Japan 13, North America 4, Europe 3, Asia/Oceania 11, South America/Others 2)

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Notes:
U.S. dollar amounts have been translated, for convenience only, at the rate of 102.92 yen = US$1, the approximate exchange rate prevailing on March 31, 2014. Billion is used in the American sense of one thousand million.
DENSO’s Business Groups

DENSO is organized into four business groups to strengthen global management.

<table>
<thead>
<tr>
<th>Business Group</th>
<th>Products and Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain Control Systems Business</td>
<td>Gasoline/diesel management systems &amp; components, hybrid and electric vehicles components, transmission control components, starters, alternators</td>
</tr>
<tr>
<td>Electronic Systems Business Group</td>
<td>Engine ECUs, transmission ECUs, semiconductor sensors, IC, power module, EL display</td>
</tr>
<tr>
<td>Thermal Systems Business Group</td>
<td>Car air-conditioning systems, radiators, cooling fans, natural refrigerant (CO₂) heat-pump hot water supply systems</td>
</tr>
</tbody>
</table>

Goals

- To strengthen links between and among projects for greater systemization and mobility.
- To conduct rapid decision-making.
- To strengthen management linking projects from domestic and overseas group companies.
Powertrain has largest percent of DENSO’s sales.

*For fiscal year ended March 31, 2013
DENSO is enhancing its global development system to:

- Develop products that meet customer’s needs in each region
- Cooperate development with regions on technology that is advanced or unique in the regions
- Enhance industry-government-academia cooperation worldwide
2017~2025 GHG Rule Benefits and Costs

- Over lifetime of MY 2017-2025 vehicles:
  - 4 billion fewer barrels of oil consumed
  - 2 billion fewer metric tons of GHGs
  - *Industry costs of $134 to $136 billion*
  - Net benefits of $326 to $451 billion

- **MY 2025 vehicle cost increase of $1,800**

- Benefits and costs are on top of continuing the MY 2016 standards

[Note: all ranges based on 7% and 3% discount rates]
Fuel economy Targets and Requirements

[1] China’s target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
We are already seeing innovations in the marketplace beyond what EPA considered in setting the standards ... just a few examples:

✓ **Powertrain**

Manufacturers are developing new technologies we didn’t even consider in the rule, such as Mazda’s *ultra-capacitor based start-stop system* and Volvo’s *flywheel hybrid system*

Manufacturers are marketing technologies in greater volumes than we projected, such as *increasing popularity of diesels* in the Ram 1500 pickup, and coming in Nissan Titan and BMW sedan

Manufacturers are applying technology differently than we expected, such as Volkswagen’s application of *cylinder deactivation on a 4-cylinder engine*.

✓ **Transmissions**

8-speed transmissions entering market sooner that we projected

9-speeds have been introduced from Chrysler and Daimler

10-speed developments announced by GM/Ford jointly, VW, Hyundai, Kia

New generation *continuously variable transmissions* offered by Nissan, Honda, Subaru, others
And innovations are not just limited to engines and transmissions:

✓ Active Aerodynamics
  Active ride height on Jeep Grand Cherokee and Dodge Ram pickup
  Active grill shutters on Chevy Cruze Eco and Ford Focus

✓ Light-weighting
  Design optimization for geometry and material (Acura MDX, Cadillac ATS, many more)
  Widespread adoption of aluminum hoods and fenders
  Aluminum body structures in mass market vehicles (F150)
DENSO 3 Key Approaches for Fuel Economy Improvement

**Improvement of ICE**
- Advanced combustion
  - Massive EGR
  - Lean burn
  - Atkinson/Miller cycle
- Downsizing/Downspeeding

**Electrification**
- ISS, ISG
- HEV, PHEV
- REV, EV

**Thermal management**
- Heat distribution
  - Coolant flow control
- Waste heat regeneration
Fuel Saving Technologies and Products

Approach for fuel saving:

① Efficiency Improvement of ICE
② Energy Regeneration
③ Load Reduction

① Efficiency Improvement
- Gasoline DI System
  - HP pump
  - Injector
  - Plug
  - Coil
- Diesel CR System
  - HP pump
  - Fuel Rail
  - Injector
  - Air Management System
  - E-VCT*
  - EGR Module

*: Electric – Variable Cam Timing

② Energy Regeneration
- Hybridization
  - Inverter
  - Motor
  - Generator
  - DCDC Converter
  - Battery Monitor Unit
- Energy Generation / Storage Components
  - Alternator
  - Li-ion Battery Pack
  - Heat Pump

③ Load Reduction
- Idle Stop and Start System
- Energy Saving Air Conditioner
  - Starter
  - Li-ion Battery Pack
  - Cold Storage Evaporator
  - E-Compressor
  - Electric Power Saving
    - 1 Passenger A/C
      ('COA' HVAC)

DENSO
Short-term: Fuel Efficiency

Gasoline Direct Injection
• High-pressure fuel pump
• High-pressure fuel injectors
• Advanced combustion
• Advanced Ignition

Other Improvements:
• Down-sizing
• Turbo-charging
• Intercooler
Short-term: Fuel Efficiency

- Downsizing of coil
- Improvement of performance and withstand voltage.
- Improvement of reliability (without resistive code)

- Accuracy improvement of ignition timing (ECU control)
- Improvement of reliability (Reduction of mechanical parts)

- Modularized of ignition system products
- Improvement of withstand voltage (Size up of distributor parts)

- Accuracy improvement of ignition timing
- Reduction of maintenance parts

DENSO
Mid-term: Start/Stop Technology

35.5+ MPG 2016 and Beyond

Start/Stop Technology
- Technical capability
- Market acceptance
Mid-Term Advancements

8, 9,10 Speed Transmissions
Long-term Powertrain Advancements

How do we achieve more than 50 mpg?

Electrification
- Plug-in hybrids
- Extended range vehicles
- Advanced hybrids
- Battery electric vehicles
Long-term: Electrification

How Will We Get There?

• Components
• Cost-value
• Integration
Long-term: Electrification

How Will We Get There?

• Components
• Cost-value
• Integration
Long-term: Electrification

DENSO’s EV/HEV System Components

- LV Battery
- e-Drive
- Cooling fan
- HV Battery
- ENG ECU
- HV ECU
- Climate control system w/e-compressor
- HV Relay
- LV Battery (12V)
- DC-DC Converter
- ICE
- Motor/Generator
- Transaxle
- B-ISG
- B-ISR
- Traction Inverter
- Accelerator pos. sensor
- Bat. Monitor ECU
- Charger
- Energy
- Signal

DENSO
DENSO’s Light Electrification System Components

<table>
<thead>
<tr>
<th>System Architecture</th>
<th>Idling Stop</th>
<th>Micro, Mild HEV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12V</td>
<td>12V Belt ISG</td>
</tr>
<tr>
<td>Function</td>
<td></td>
<td>ISG</td>
</tr>
<tr>
<td>Idling Stop</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Regeneration</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Boost</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Low Speed EV</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Components *</th>
<th>12V</th>
<th>12V Belt ISG</th>
<th>48V Belt ISG</th>
<th>ISG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating Machine</td>
<td></td>
<td>12V ISG</td>
<td>48V ISG</td>
<td>HV ISG</td>
</tr>
<tr>
<td>Battery</td>
<td>12V Li Ion Battery</td>
<td>12V Li Ion Battery (Hi Power)</td>
<td>48V Li Ion Battery</td>
<td></td>
</tr>
</tbody>
</table>

* Black : Mass Product, Blue : Developing

DENSO light electrification system variation can cover system trends.
DENSO can contribute in all areas of EV/HEV system.
Long Term Plan

• Improved Combustion
• Multi-Speed Transmissions
• Downsized and Turbo-Charged
• Reduced Mass
• Cost Effective Electrification
How do all the pieces fit together?

- Collaboration is key
- Technology tradeoffs
- Weighing cost-benefits
- Best systems
Conclusion

Overall Strategy to Meet Future Requirements

Have to look at multiple solutions – under the hood and beyond the powertrain

• Integration of technology
• Maximize system efficiency - Cost
• Quality
• Manufacturing

Affordable and Appealing Vehicles
THANK YOU