高效率車用電機系統

台達電子 機電事業部
EV變頻器開發

蘇維德  Oct 12, 2010
TOP 3 Challenges for Automobile

- Exhaust Emissions CO, NOX, HC, PM
- Greenhouse Gases CO2
- Energy

Source: Volkswagen
Forecasted WTI Crude Oil Price Development to 2020

Source: IEA World Energy Outlook, EIA International Energy Outlook, Ministry of Finance of selected countries, MEES, Samba
Source of Global CO₂ Emissions

Global CO₂ emissions 2007 (%)
Total: 800 Gt/year

- Vegetation: 27%
- Combustion of biomass: <1%
- Oceans: 41.5%
- Soil: 3.5%

Anthropogenic CO₂ emissions (%)
Total: 28 Gt/year

- Power plants: 25.0%
- Domestic fuel and small consumers: 23.0%
- Industry: 19.0%
- Combustion of biomass: 15.0%
- Trucks: 6.0%
- Passenger cars: 5.5%
- Air traffic: 3.0%
- Other traffic: 2.0%
- Ships on open sea: 1.5%

In Europe: Road transport ~ 20%, passenger cars ~ 12%

Source: VDI, EU
Policies on Reducing Emissions

Source: Pew Center on Global Climate Change
European CO₂ Emission Limits

Source: J. D. Power; Roland Berger
US CO₂ Emission Limits

US CO₂ fleet emissions - 2008 and forecast for 2016

- Large SUV
- Compact SUV
- Premium
- Large
- Mid-size
- Small (A/B)

2016 fleet: 170 g/km
US 2016 target: 174 g/km
2008 fleet: 232 g/km

Source: J. D. Power; Roland Berger
The Key

- Including of Alternative Energy Sources in Fuel Production
- Development of CO₂-Neutral Methods in Vehicle Usage
- Resolute Additional Improvement of Powertrain Efficiency with Simultaneous Emission Reduction

Source: Volkswagen
Green Vehicles

- High Efficient Powertrains
- Lighter and Smaller Cars
- Driving Less, Slower and more Constantly
System Complexity

15000 parts, 4.5 km and 80kg of copper wires, 70 processors, 60 actuators; all weather, power cogeneration unit, comfort, entertainment and communication features, cockpit, multi-purpose display, safety and security systems. **All moving on 4 wheels.**

Source: Centro Ricerche Fiat
Common Vehicle Minimum Performance Criteria

- All technologies fulfil at least minimal customer performance criteria

- “Vehicle / Fuel” combinations comply with emissions regulations
  - The 2002 vehicles comply with Euro III
  - The 2010+ vehicles comply with Euro IV

Source: EUCAR / JRC / CONCAWE
## Technology for Improved Fuel Economy and Reduced CO₂ Emissions

<table>
<thead>
<tr>
<th>Technology</th>
<th>% CO₂ Reduction / $100</th>
<th>% CO₂ Red.</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Mech. Friction Comp.</td>
<td></td>
<td>4%</td>
<td>$50</td>
</tr>
<tr>
<td>Electric Power Hydraulic Steering</td>
<td></td>
<td>4%</td>
<td>$70</td>
</tr>
<tr>
<td>Electric Steering</td>
<td></td>
<td>5%</td>
<td>$120</td>
</tr>
<tr>
<td>Turbo/ Supercharging</td>
<td></td>
<td>13%</td>
<td>$450</td>
</tr>
<tr>
<td>Low Rolling Resistance Tires</td>
<td></td>
<td>3%</td>
<td>$150</td>
</tr>
<tr>
<td>Direct Injection/Lean Burn</td>
<td></td>
<td>12%</td>
<td>$600</td>
</tr>
<tr>
<td>Hybrid</td>
<td></td>
<td>33%</td>
<td>$2,200</td>
</tr>
<tr>
<td>Variable Valve Actuation</td>
<td></td>
<td>6%</td>
<td>$425</td>
</tr>
<tr>
<td>Light Weighting</td>
<td></td>
<td>10%</td>
<td>$750</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td>25%</td>
<td>$2,000</td>
</tr>
<tr>
<td>Stop Start</td>
<td></td>
<td>4%</td>
<td>$300</td>
</tr>
<tr>
<td>Stop Start with Regen. Braking</td>
<td></td>
<td>7%</td>
<td>$800</td>
</tr>
<tr>
<td>Electric Motor Assist</td>
<td></td>
<td>5%</td>
<td>$1,000</td>
</tr>
<tr>
<td>Dual Clutch Transmission</td>
<td></td>
<td>7%</td>
<td>$2,000</td>
</tr>
</tbody>
</table>

Source: King Review, Deutsche Bank, NHTSA
Vehicle Weight Reduction

Data source: Ward’s Automotive

\[ y = 0.0059x + 1.2346 \]

\[ R^2 = 0.7303 \]

Source: Massachusetts Institute of Technology
**Vehicle Weight Reduction vs. Fuel Saving**

**Figure 2. Historical and future scenarios of the sales-weighted average vehicle weight in the U.S. LDV fleet**

**Figure 4. Reduction in U.S. LDV fleet annual fuel use**

<table>
<thead>
<tr>
<th>Kilograms</th>
<th>% per year</th>
<th>Total %</th>
<th>Billion liters</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>0.3%</td>
<td>6%</td>
<td>15</td>
<td>2%</td>
</tr>
<tr>
<td>210</td>
<td>0.6%</td>
<td>11%</td>
<td>38</td>
<td>5%</td>
</tr>
<tr>
<td>370</td>
<td>1.0%</td>
<td>20%</td>
<td>75</td>
<td>10%</td>
</tr>
</tbody>
</table>

Source: Massachusetts Institute of Technology
Energy Transformation of Today's Vehicles in NEDC

Source: AVL, Roland Berger
Powertrain System Improvement

- Internal combustion engine (Gasoline/Diesel)
- Stop/start
- Mild hybrid
- Full hybrid
- Plug-in hybrid (parallel)
- Plug-in hybrid (serial/range ext.)
- Fuel cell vehicle
- Electric driving
  - "Emission free"
  - Battery electric vehicle

Degree of electrification:
- 0%
- 100%
CO₂ savings of hybrid concepts

Source: Ricardo, TNO, IEEP, Roland Berger
Cost – CO₂ impact ratio hybrid systems

Overview (Fuel-Saving Potential / Costs)

Savings

%

15%

3 %

3-5%

4-6%

8%

2. Generation

Mild Hybrid

Opportunity

Recup. breaking

15 %

Full Hybrid

Source: Volkswagen
# Powertrain Configurations

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro/mild hybrid</td>
<td>Belt-driven starter-generator, Integrated starter-generator</td>
<td>Upper medium class/premium class, large SUVs, sports cars, transporters/vans</td>
</tr>
<tr>
<td>Full hybrid (PHEV if plug-in function exists)</td>
<td>Parallel hybrid, Power-split hybrid, Second electric axle, Serial hybrid (range extended)</td>
<td>Urban/rural: Volume vehicles, MPVs, small SUVs, light delivery trucks, sports cars</td>
</tr>
<tr>
<td>EV</td>
<td>Battery electric vehicle</td>
<td>Urban: Mini &amp; compact cars, small vans, mini vans, fun cars</td>
</tr>
</tbody>
</table>

**Main applications (vehicle segments):**

- Engine
- Gears
- Coupling
- E-motor

Source: EVS-24-6000536 Michael Valentine-Urbschat & Dr. Wolfgang Bernhart
Main HEV Powertrain Configurations

Series Hybrid:
- Electric motor drives wheels
- Engine’s only job is to generate electricity

Source: Toyota
Main HEV Powertrain Configurations

Parallel Hybrid:

- Engine is main way of driving wheels
- Motor assists for acceleration

Source: Toyota
Main HEV Powertrain Configurations

Series/Parallel Hybrid:

- **Power split device** delivers a continuously variable ratio of engine/motor power to wheels
- Can run in stealth mode on its stored electricity alone

Source: Toyota
Comparison of torque and power for electric motors and ICEs

Torque diagram

- Torque (Nm)
- Speed (rpm)

Power diagram

- Power (kW)
- Speed (rpm)

- Peak performance (electric motor)
- Continuous performance (electric motor)
- Continuous performance (ICE)

Source: Siemens; Daimler
Performance Targets

Source: Modern Electric, Hybrid Electric, and Fuel Cell Vehicles
Performance Targets

Maximum driving force

Range of low gear drive

(Range of low & high gear drive)

Range of high gear drive

Driving force by motor

Velocity

Vmax

Source: Toyota
Performance Targets

Source: Clean Automotive Technology
Features of System

1. Two electric motors
2. Ni-MH battery
3. Power split device

Source: Toyota
Prius (THSII) 2003~

Features of System

1. Two electric motors
2. Ni-MH battery
3. Power split device

High-voltage boost circuit
RX400h (THSII) 2005~

Features of System

1. Two electric motors
2. Ni-MH battery
3. Power split device
4. High-voltage boost circuit

Motor speed reduction device

Source: Toyota
Features of System

1. Two electric motors
2. Ni-MH battery
3. Power split device
4. High-voltage boost circuit
5. Motor speed reduction device

Source: Toyota
Features of System

1. Two electric motors
2. Ni-MH battery
3. Power split device
4. High-voltage boost circuit
5. 2-stage motor speed reduction device

Source: Toyota
Delta Plug-in HEV Test Car
Delta Plug-In HEV Test Car
Specification of Delta Test Car

- Electric Motor: 150kW IPMSM
- Max Horse Power: 201hp
- Max Torque: 41.84kN.m (410 Nm)
- Generator: 30kW IPMSM
- Engine: 1000c.c.
- Battery Capacity: 18kWh
- GVWR: 1660kg
- 0~100km/h: 4.7 sec (measured)
- Max Speed: 250km/h (estimated)
- Driving Range: 20~30 Km/L
Approximated output power and heat loads as percentage of input energy with approximated coolant temperatures.

| Source: DOE, USA 2010 |
The Key Components of Powertrain

Power Control Unit

Motor/Generator

Battery
Safety: The battery has to be intrinsically safe; in case of a crash or short-circuit there may be no thermal ‘thermal runaway’/exothermic behavior.

Cycle life: The number of full charge/discharge cycles until the batteries still retain 80% of their original capacity.

Energy density: How much energy can each kg or liter of battery contain (Wh/kg and Wh/l).

Power density: How much power can each kg or liter of battery deliver per second (W/kg and W/l).

Charge acceptance capacity: How much energy can the batteries absorb per second (W/kg and W/l, relevant for regenerative braking and charging).
Major battery used in high power applications include Li-ion, Ni-Zn, NiMH types

Source: TRI
# Life Cycle & Cost

<table>
<thead>
<tr>
<th>Type</th>
<th>Life cycle</th>
<th>Cost (US$/kwh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb/PbO</td>
<td>100-500</td>
<td>150</td>
</tr>
<tr>
<td>Ni-Cd</td>
<td>600-1,200</td>
<td>300</td>
</tr>
<tr>
<td>Ni-MH</td>
<td>600-1,200</td>
<td>200-350</td>
</tr>
<tr>
<td>Ni-Zn</td>
<td>100-300*</td>
<td>*200-300</td>
</tr>
<tr>
<td>Zn-Air</td>
<td>N.A.</td>
<td>90-120</td>
</tr>
<tr>
<td>Li-FePO4</td>
<td>1,000-2,000</td>
<td>500-800</td>
</tr>
<tr>
<td>Li-ion</td>
<td>800-1,200</td>
<td>&gt;400</td>
</tr>
</tbody>
</table>
Core Competence

Solution for high power Li-ion battery pack

High power battery management technology
(Charging Control, Cell Balance, Thermal management)

Cell Design
- Low Impedance
- High current
- Long cycle life
- Safe for abuse

Advanced Process
- Automation process
- Energy saving
- Cost competitive for high volume
Electric Motor System Challenges

- Very challenging cost target (ICE 3cent/W)
- High efficiency (drive:90~99% ;motor:80~94%)
- Compact size (310*310*220mm Prius II 50kW)
- Extremely high stresses/reliability requirements
  - Wide temperature excursion (-40°C ~ +150°C)
  - Excessive power excursion cycles (500K+)
  - Stresses: vibration (30G/20~1kHz), water/salt spray.
- EMC requirements:
  - 20dB lower Emission limits.(EN55011 class A)
  - 200V/m immunity requirement (IEC61800-3 → 3V/m)
- Long life expectation (10 year+/150,000 miles)
## Electric Motors

### Current status of electric motor technology

<table>
<thead>
<tr>
<th>Input/stator current</th>
<th>AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor speed relative to stator field</td>
<td>Asynchronous</td>
<td>Synchronous</td>
</tr>
<tr>
<td>Rotor field generation</td>
<td>Induction</td>
<td>Permanent magnet</td>
</tr>
<tr>
<td>Type</td>
<td>Induction motor</td>
<td>PMSM (or IPMM)</td>
</tr>
<tr>
<td>Peak efficiency</td>
<td>&gt; 90%</td>
<td>&gt; 94%</td>
</tr>
<tr>
<td>Spec. power&lt;sup&gt;1&lt;/sup&gt; (kW/kg)</td>
<td>Approx. 1.0</td>
<td>Approx. 1.6</td>
</tr>
<tr>
<td>Manufacturing costs</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Automotive application</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Key reasons</td>
<td>Low costs</td>
<td>Low weight, compact design</td>
</tr>
</tbody>
</table>

1) Permanent power
2) Current-excited also possible
3) Synchronous reluctance motor also possible, but lower spec. power

Source: Roland Berger
Power Density Improvement

Motor Cooling System

<table>
<thead>
<tr>
<th>System</th>
<th>Free-Convection</th>
<th>Force-Convection</th>
<th>Liquid-Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Density [kW/L]</td>
<td>5.07</td>
<td>7.6</td>
<td>15.1</td>
</tr>
</tbody>
</table>
Power Density Improvement

Fig. 7b.19  Development of motor output density

Source: Hydrogen Technology: Mobile and Portable Application
Motor/Drivetrain Integration

Source: TOYOTA
Electric Motor System/Drivetrain Integration

- Clutch
- Gearbox
- Stator of integrated drive
- Rotor of integrated drive
- Circular Converter
- Housing
- DC-link Capacitor
- Power Modules
- Clutch Box
- Coolant

Source: DaimlerChrysler AG
Trend of Power Density of HEV Inverter

Source: TOYOTA

- **3rd gen IGBT**
- **4th gen IGBT**
- **5th gen IGBT**

- Prius M/C
- Prius 2nd
- Harrier

- GS450H (32kVA/L) (Continuous power) to SiC

- Camry: 25kW昇圧

- 34kW昇圧

YEAR/MONTH: 97/01 98/01 99/01 00/01 01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01
Power Electronics Integration
Power Electronics Integration

Source: TOYOTA
Delta Confidential
## Industrial vs. Automotive Power Module

<table>
<thead>
<tr>
<th></th>
<th>Industrial use</th>
<th>Automotive use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Less Limitation</td>
<td>Strict Limitation</td>
</tr>
<tr>
<td><strong>Product Volume</strong></td>
<td>Small for high power</td>
<td>Large for high power</td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
<td>AC line</td>
<td>Battery</td>
</tr>
<tr>
<td><strong>EMI</strong></td>
<td>Less Limitation</td>
<td>Strict requirement</td>
</tr>
</tbody>
</table>
Feature of EV/HEV Power Modules

- **Small size**
  .....10L for 100kVA inverter

- **Low cost**
  ...
  Just 5000USD for 100KVA Hybrid system

- **High reliability (long life)**
  .....Usually 10years, 100,000mile life

- **Motor control, battery oriented**
  ....Large stall torque and high speed operation like 10,000rpm operation.
  Battery voltage change widely and this requires the high voltage operation of inverter.

- **Low EMI**
  .....AM radio (around 1MHz band)
Solutions for Automotive Requirements

Requirements

- Size
- Cost
- Reliability
- EMI
- Control Requirement

Solutions

- Cooling Method
- Lateral Construction
- On Chip Sensors
- IPM (Integration)
- Bus Bar
- Chip Performance (IGBT, FWD)
Cooling System Improvement – Direct Cooling (1)

Source: Hitachi
Cooling Improvement – Direct Cooling (2)

2nd Prius Cooler

3rd Prius Cooler

Source: TOYOTA
Cooling System Improvement
– Liquid Cooling and Turbulence (1)
Cooling System Improvement – Liquid Cooling and Turbulence (2)

Source: DEDDS Technology
Cooling System Improvement – Double Sided Cooling Flow (1)

Cooling System Improvement
– Double Sided Cooling Flow (2)

Lateral Structure

2\textsuperscript{nd} Prius Cooler

Base Plate CuMo, AlSiC are used for Mitigation of Thermal Deformation

Al Plate with Hole

Direct Cool Water Path

<table>
<thead>
<tr>
<th></th>
<th>W/O Hole</th>
<th>W/H Hole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Transfer</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Deform</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Source: TOYOTA

62
On Chip Sensors

Synchronous machine needs fast temperature measurement to protect overheat.

Device Temperature at Regeneration

On chip sensor temperature

Thermister Temperature
IPM (Integration)

IPM is introduced by Mitsubishi. By total design of chip and driver by integration. → 20% Volume & 10% Loss Improvement!!

Source: MITSUBISHI
Bus Bar Inductance Reduction

Bus bar inductance makes surge voltage and it makes high frequency pulse current.
IGBT Power Loss Improvement

Reduction of IGBT operation losses


Device using new material

Power losses in inverter application

Overall power loss reduced to 1/3

IGBT turn-off loss
IGBT conduction loss
IGBT turn-on loss

100W
75W
50W
40W
33W

CSTBT™

Source: MITSUBISHI
SiC Device Characteristic

Figure 1. The change in MOSFET on-resistance and conduction losses with temperature. Note that Si cannot withstand temperatures of over 423K (150°C) (Si-red, 4H-SiC-blue, logarithmic y-axis).

Source: Rohm, co., Ltd
SiC Device Advantages

(a) 使用 SiC 的效果

- 可高頻率運作 (100kHz 以上)
- 電子電阻溫度約 2 倍以上（物理特性值）
- 可於高溫下運作 (200°C 以上)
- 能效約為 3 倍（物理特性值）
- 運轉溫度約為 2 倍（物理特性值）

效果

- 壓縮電子元件的小型化
- 壓縮周邊零件的小型化
- 電源轉換器的小型化

SiC diode hybrid inverter prototype

従来品に比べて小型で出力パワーダー密度約1.3倍向上

Volume ratio = 1/3
Power-loss ratio = 0.4

SiC-MOSFET Module
(Dual 100A/1200V)

3-ph inverter using silicon
(state-of-the-art)

Source: MITSUBISHI

3-ph inverter using SiC
(Future prediction)

Source: AIST

Delta Confidential
SiC Device Development History

- **DENSO** company demonstrated a hybrid motor vehicle with a SiC module capable of operating at 280°C in 2007.
- **Rohm** developed a SiC module for electric vehicles capable of operation at 200°C in 2007.
- **Honda** announced the development of a SiC module for hybrid cars in 2007.
- **Cree** introduced a 4-inch silicon carbide substrate in 2007.
- **STMicroelectronics** developed a SiC module with a rated output of 300A in 2008.
- **Rohm** announced the development of SiC MOSFETs with a lower on-resistance in 2008.
- **Honda** announced the development of a SiC module for hybrid cars in 2008.
- **Cree** announced the commercialization of a 4-inch silicon carbide substrate in 2009.
- **STMicroelectronics** announced the commercialization of a SiC module in 2009.
- **Honda** announced the development of a SiC module for hybrid cars in 2010.

Source: NIKKEI ELECTRONICS TAIWAN EDITION
Motor Control

Flux Weakening Control

Speed : 2000 RPM
Eff. = 87.51%
Ld = 170 uH
Lq = 206 uH
Id = 247.49 A
Iq = 428.66 A

Speed : 3000 RPM
Eff. = 88.88%
Ld = 170 uH
Lq = 206 uH
Id = 247.49 A
Iq = 428.66 A

Speed : 6000 RPM
Eff. = 90.47%
Ld = 184 uH
Lq = 292 uH
Id = 232.66 A
Iq = 236.38 A

Speed : 9500 RPM
Eff. = 89.64%
Ld = 190 uH
Lq = 298 uH
Id = 292.36 A
Iq = 106.41 A

Speed : 2000 RPM
Eff. = 89.52%
Ld = 182 uH
Lq = 275 uH
Id = 136.47 A
Iq = 236.38 A

Speed : 3000 RPM
Eff. = 90.03%
Ld = 182 uH
Lq = 275 uH
Id = 136.47 A
Iq = 236.38 A

Speed : 6000 RPM
Eff. = 89.44%
Ld = 195 uH
Lq = 332 uH
Id = 134.34 A
Iq = 112.72 A

Speed : 9500 RPM
Eff. = 88.34%
Ld = 198 uH
Lq = 326 uH
Id = 211.89 A
Iq = 63.54 A

Electric Motor Efficiency Map
Regenerative Braking Control

Hydraulic Braking System with ABS

Feedforward Compensator

Vehicle Dynamics

Feedback Compensator

Regenerative Braking Controller to Improve ABS performance

Source: Advantage of Electric Motor for Anti Skid Control of Electric Vehicle, Shin-ichiro Sakai and Yoichi Hori
# On Board Diagnostics (OBD)

When is a component considered defective?

| Legislated         | Electrical Problem, Exceeding emissions limits  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-or- Disabling other Diagnostic Monitors</td>
</tr>
<tr>
<td>Safety</td>
<td>If a dangerous condition exists for the driver, vehicle, etc.</td>
</tr>
<tr>
<td>Customer</td>
<td>Performance degradation</td>
</tr>
</tbody>
</table>
| Production         | End of Line control  
|                    | -and- Quality control                           |
| Service            | Customers’ satisfaction  
|                    | -and- Repair improvement                        |

**Emissions/safety issues cannot be directly measured.**

→ mapping of these characteristics on measurable ones.

Source: A Short Story of On Board Diagnostics, Volker Lantzs, Volkswagen AG and Robert Gruszczynski, Audi of America
以2002年美國Massachusetts實施OBD檢測結果為例說明

<table>
<thead>
<tr>
<th></th>
<th>動力計檢測</th>
<th>OBD檢測</th>
<th>備註</th>
</tr>
</thead>
<tbody>
<tr>
<td>設備成本</td>
<td>約NTD200萬元</td>
<td>約NTD2萬元</td>
<td>OBD檢測僅需具備掃描診斷器(Scan tool),成本較低</td>
</tr>
<tr>
<td>檢測時間</td>
<td>12~15分鐘</td>
<td>0.5~2分鐘</td>
<td>OBD檢測時間遠較動力計檢測時間為短</td>
</tr>
<tr>
<td>平均修復成本</td>
<td>$250(NTD8,500)</td>
<td>$250(NTD8,500)</td>
<td>OBD維修成本雖較高(劣化即出現MIL訊號),但維修時間短且較精確而可降低誤修機率使得平均修復成本與動力計檢測相近</td>
</tr>
<tr>
<td>不合格率</td>
<td>1~3%</td>
<td>3~5%</td>
<td>OBD檢測在元件劣化有污染之虞時即會被篩選出來</td>
</tr>
<tr>
<td>效益</td>
<td>-</td>
<td>總效益約增加2%</td>
<td>至2002年有OBD II系統之車輛佔50%;隨著新車數量增加其效益將逐漸增加</td>
</tr>
<tr>
<td>污染減量</td>
<td>18065噸(NOx+VOC)</td>
<td>18426噸(NOx+VOC)</td>
<td>OBD檢測可消減361噸NOx+VOC (未計算因提早發現故障之效益)</td>
</tr>
</tbody>
</table>

Source: 車上診斷系統(On-Board Diagnostic-OBD) 法規介紹, ARTC 環保能源部 王傳賢
## Diagnosis Methods

<table>
<thead>
<tr>
<th>電路訊號檢測(輸入元件)</th>
<th>OBD系統評估方式</th>
<th>故障模擬方式</th>
<th>測試項目</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.檢查其電路是否斷線或有無訊號</td>
<td>1.拆除電路接頭使其斷線</td>
<td>如空氣流量感知器及A/F sensor等</td>
<td></td>
</tr>
<tr>
<td>2.檢查訊號合理性</td>
<td>2.使用電子訊號模擬設備</td>
<td></td>
<td></td>
</tr>
<tr>
<td>功能性檢測</td>
<td>檢查該元件作動之輸出功能是否正常</td>
<td>更換為故障元件</td>
<td></td>
</tr>
<tr>
<td>連続或至少在每次行駛循環中診斷其是否超出規範值</td>
<td>在設定故障元件後，須搭配套依污染排放測試，以驗證OBD之偵測功能</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Misfire,觸媒，含氧感知器等</td>
<td></td>
</tr>
</tbody>
</table>

Source: 車上診斷系統(On-Board Diagnostic-OBD) 法規介紹，ARTC 環保能源部 王傳賢
EV/HEV Powertrain OBD Structure

**EV / HEV-Powertrain!**

**Aux. Equipment:**
- Powersteering
- HVAC
- Coolant pump
- Oil-Pump
- Heating

**Fuel System:**
- Control Unit
- Fuel pump

**Transmission:**
- E-Engine
- Oil-pump
- Control module

**Battery Pack:**
- Battery Monitoring Unit
- Cell Supervision Circuit
- Coolant pump

**Charging function:**
- Transformer
- DC/DC-Converter
- Rectifier
- Capacitor-Pack
- Communication-Unit
- Cooling

**REX/Fuel cell:**
- Control unit
- Reformer Control
- Pumps
- Heating for Reformer/Catalyst
- Heating unit for fuel-cell

Source: ZVEI Expertentreffen - Kristronics 18.11.2009
# Diagnostic Trouble Codes (DTC)

**SAE J2012 / ISO15031-6**

<table>
<thead>
<tr>
<th>Powertrain codes</th>
<th>Body codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0xxx - Generic</td>
<td>B0xxx - Generic</td>
</tr>
<tr>
<td>P1xxx - Manufacturer-specific</td>
<td>B1xxx - Manufacturer-specific</td>
</tr>
<tr>
<td>P2xxx - Generic</td>
<td>B2xxx - Manufacturer-specific</td>
</tr>
<tr>
<td>P30xx-P33xx - Manufacturer-specific</td>
<td>B3xxx - Generic</td>
</tr>
<tr>
<td>P34xx-P39xx - Generic</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chassis codes</th>
<th>Network Communication codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0xxx - Generic</td>
<td>U0xxx - Generic</td>
</tr>
<tr>
<td>C1xxx - Manufacturer-specific</td>
<td>U1xxx - Manufacturer-specific</td>
</tr>
<tr>
<td>C2xxx - Manufacturer-specific</td>
<td>U2xxx - Manufacturer-specific</td>
</tr>
<tr>
<td>C3xxx - Generic</td>
<td>U3xxx - Generic</td>
</tr>
</tbody>
</table>

## OBD Standard Diagnostic Trouble Code

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0100</td>
<td>Air Flow Circuit Malfunction</td>
</tr>
<tr>
<td>P0109</td>
<td>Intake Air Temperature Circuit Malfunction</td>
</tr>
<tr>
<td>P0115</td>
<td>Engine Coolant Temperature Circuit Malfunction</td>
</tr>
<tr>
<td>P0120</td>
<td>Throttle Position Sensor Circuit Malfunction</td>
</tr>
<tr>
<td>P0128</td>
<td>Coolant Thermostat Malfunction</td>
</tr>
<tr>
<td>P0130</td>
<td>O2 Sensor Circuit Malfunction</td>
</tr>
<tr>
<td>P0170</td>
<td>Fuel Trim Malfunction (Bank 1)</td>
</tr>
</tbody>
</table>

## MMC Diagnostic Trouble Code (Non OBD Vehicle)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Airflow sensor fault.</td>
</tr>
<tr>
<td>13</td>
<td>Intake air temp sensor fault.</td>
</tr>
<tr>
<td>14</td>
<td>Throttle position sensor fault.</td>
</tr>
<tr>
<td>21</td>
<td>Coolant temp sensor fault.</td>
</tr>
<tr>
<td>22</td>
<td>Crankshaft position sensor</td>
</tr>
<tr>
<td>23</td>
<td>Camshaft position sensor fault.</td>
</tr>
</tbody>
</table>

Source: MITSUBISHI MOTORS
# DTCs for EV/HEV Powertrain

Total number OBD Trouble Codes (DTCs) of 2005 Ford Escape Hybrid = 5012

- **Generic OBDII Parameters** = 2225 DTCs
- **Enhanced OBD Parameters** = 2787 DTCs

<table>
<thead>
<tr>
<th>DTC Code</th>
<th>INI Code</th>
<th>Item</th>
<th>GST Display</th>
<th>FRZF Information Data</th>
<th>Hybrid System Warning Light</th>
<th>High Voltage Battery Warning Light</th>
<th>MIL</th>
<th>Trip</th>
<th>DTC Detecting Condition</th>
<th>Possible Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0395</td>
<td>524</td>
<td>CKP SENSOR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>NEU signal is not sent to the hybrid vehicle control ECU while the engine is</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0396</td>
<td>805</td>
<td>CKP SENSOR CIRCUIT</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>GI pulse signal is not input for 3 sec or more while the engine is running.</td>
<td>Inverter with converter assembly</td>
</tr>
<tr>
<td>P0340</td>
<td>526</td>
<td>CMP SENSOR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>GI signal is not sent to the hybrid vehicle control ECU while the engine is</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0343</td>
<td>747</td>
<td>CMP SENSOR CIRCUIT</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>GI signal is not sent to the hybrid vehicle control ECU while the engine is</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0343</td>
<td>898</td>
<td>CMP SENSOR CIRCUIT</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>GI signal is not sent to the hybrid vehicle control ECU while the engine is</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0501</td>
<td>117</td>
<td>HV ECU POWER SUPPL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Malfunction in the hybrid vehicle control ECU</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0616</td>
<td>142</td>
<td>START SIGNAL/CIRC</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>An ST signal from the hybrid vehicle control ECU is present when the ignition switch OFF</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P062F</td>
<td>143</td>
<td>EEPROM/HV ECU</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>ECU Internal error is detected</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0705</td>
<td>757</td>
<td>SHIFT POS SWITCH</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Park/neutral position switch pattern problem</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0705</td>
<td>758</td>
<td>SHIFT POS SWITCH</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Shifting malfunction (open circuit in M2)</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0851</td>
<td>775</td>
<td>N SIGNAL LINE</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>N signal line malfunction</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0A01</td>
<td>726</td>
<td>INV COOL SENSOR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Sudden change in inverter coolant temperature sensor output</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0A01</td>
<td>726</td>
<td>INV COOL SENSOR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Inverter coolant temperature sensor output deviation</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0A02</td>
<td>719</td>
<td>INV COOL SEN(GND)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Short to GND in the inverter coolant temperature sensor circuit</td>
<td>Hybrid vehicle control ECU</td>
</tr>
<tr>
<td>P0A03</td>
<td>720</td>
<td>INV COOL SEN(OPEN)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Open or short to +B in the inverter coolant temperature sensor circuit</td>
<td>Hybrid vehicle control ECU</td>
</tr>
</tbody>
</table>
OBD Transition

Advanced OBD?

OBD-III?

OBD-II

E-OBD, J-OBD

OBD-I

Remote OBD

Source: MITSUBISHI MOTORS
Advanced OBD

“Virtual Technician” Solution

A DTNA First to Market Telematics Application

Code/Log File Received by the Detroit Diesel Customer Assistance Center Within 3 Minutes of Occurrence
Advanced OBD

Diagnostics & Troubleshooting by CSC using Remedy System:

Flight Recording Log file review:
- identify issue with code

Contact fleet by e-mail:
- advise of event
- select repair facility
- estimated time of arrival

Contact repair facility by e-mail:
- VIN & fleet
- flight recording
- define service procedure
- identify parts required
- ready repair facility for customer visit

Repair Facility
- Freightliner
- Sterling
- Western Star
- DD Distributor

Initiate R.O. and Begin Repair
Our Mission
To provide innovative energy-saving products for a better quality of life

THANK YOU