New Release

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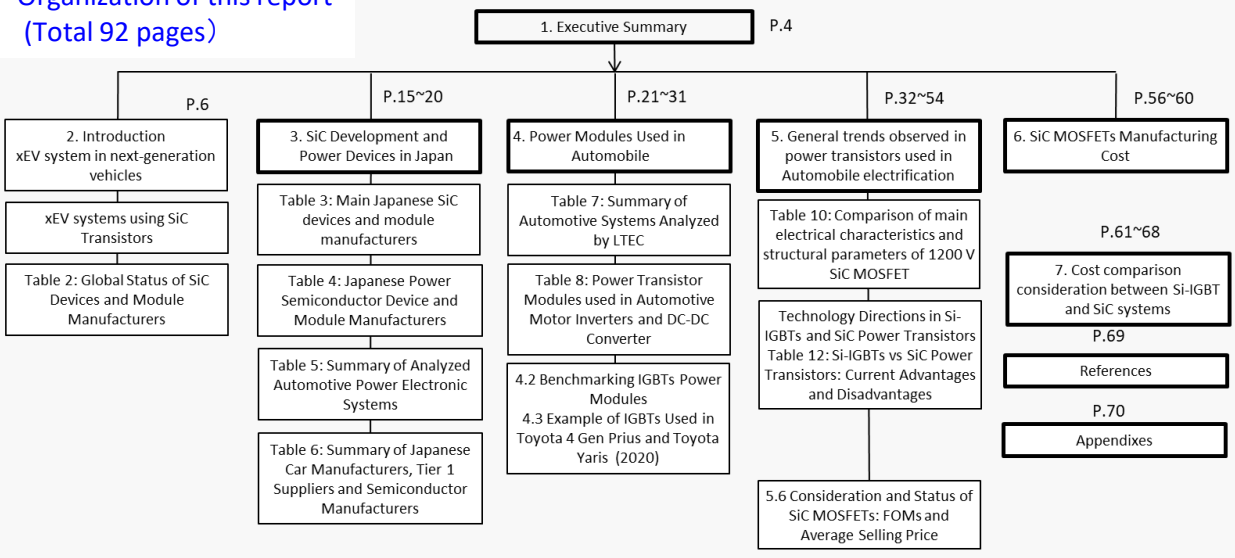
## Si and SiC Power Transistors in the Powertrain of Electric Vehicles (xEVs). A Survey of Japanese Automotive and Semiconductor Manufacturers

## Introduction

Toward the realization of global warming countermeasures and carbon neutrality, the electrification of automobiles is actively progressing.
High withstand voltage power devices (Si-IGBTs, Si RC-IGBTs, SiC-MOSFETs) are the important components that determine "low power loss", "high reliability", and "cost" in electrification of the automobile powertrain.

Since 2015, LTEC has analyzed more than 50 in-vehicle powertrains electronic systems, and based on the analysis results, each company's device performance, regarding automobile manufacturers, tier 1 suppliers, semiconductors and module manufacturers, mounting information, of Japanese manufacturers have been extracted. In this survey report, cost comparisons, benefits of replacing IGBTs by SiC, cost estimates, and technology trends are summarized.

Organization of this report
(Total 92 pages)




Note: The report price may change over time. For current price contact **info@ltecusa.com**.

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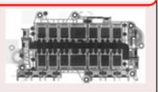
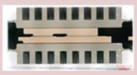
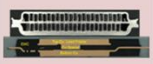
# Excerpts from Survey Report

Table 6 : Summary of Japanese Car Manufacturers, Tier 1 Suppliers and Semiconductor Manufacturers

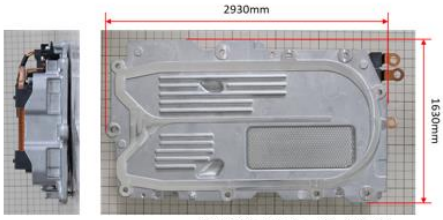
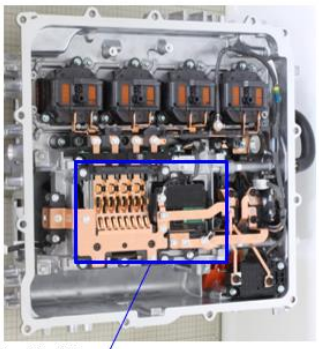
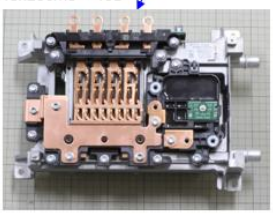
| No | Car Manufacturer | Electronics Parts Suppliers | | Semiconductor Manufacturers | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Infineon | ST-Micro | BYD | Mitsubishi Elec | Fuji Elec | HITACHI | ROHM | Toshiba | Renesas | DENSO |
| 1 | TOYOTA | Tier 1 | DENSO<br>AISIN<br>TOYOTA GOSEI<br>TDK (DCDC)<br>TOYOTA INDUSTRIALS (DCDC) | | | | | | | | | | |
| 2 | HONDA | | In-house | | | | | | | | | | |
| | | Tier 1 | HITACHI Astemo (KEIHIN)<br>HITACHI Astemo (HITACHI AMS)<br>Mitsubishi Elec (DCDC)<br>Shindengen | | | | | | | | | | |
| 3 | NISSAN | | ・In-house (Zama) | | | | | | | | | | |
| | | Tier 1 | Marelli (CALSONIC KANSEI)<br>Marelli (Magnetti Marelli)<br>TDK (DCDC) | | | | | | | | | | |
| 4 | MITSUBISHI | Tier 1 | Meidensya<br>Mitsubishi Elec<br>DENSO | | | | | | | | | | |
| 5 | MAZDA | Tier 1 | DENSO | | | | | | | | | | |
| 6 | SUBARU | Tier 1 | Mitsubishi Elec | | | | | | | | | | |
| 7 | SUZUKI | Tier 1 | Mitsubishi Elec | | | | | | | | | | |
| 8 | VW | Tier 1 | Bosch | | | | | | | | | | |
| 9 | AUDI | Tier 1 | HITACHI Astemo (HITACHI AMS) | | | | | | | | | | |
| 10 | Daimler Benz | Tier 1 | ZF,<br>HITACHI AMS | | | | | | | | | | |
| 11 | BMW | Tier 1 | Delphi | | | | | | | | | | |
| 12 | Jaguar | Tier 1 | Continental | | | | | | | | | | |
| 13 | Peugeot | Tier 1 | Continental | | | | | | | | | | |
| 14 | TESLA | | In-house | | | | | | | | | | |
| | | | In-house | | | | | | | | | | |
| 15 | Ford | Tier 1 | HITACHI Astemo (HITACHI AMS) | | | | | | | | | | |
| 16 | GM | Tier 1 | LG Electric | | | | | | | | | | |
| 17 | Guangzhou Automobile | Tier 1 | Nidec | | | | | | | | | | |
| 18 | Geely Automobile | Tier 1 | Delphi | | | | | | | | | | |
| 19 | BYD | | BYD | | | | | | | | | | |
| 20 | SAIC Motor | Tier 1 | Bosch | | | | | | | | | | |
| 21 | Hyundai | Tier 1 | Hyundai Mobis | | | | | | | | | | |

Table 8: Power Transistor Modules used in Automotive Motor Inverters and DC-DC Converter

| | | Fuji Electric | HITACHI AMS | Denso | Denso | Denso | Keihin |
|---|---|---|---|---|---|---|---|
| System | Product identification | 6MBI800XV-075V-01 | Audi e-tron 55 Quattro Inverter | 2020 TOYOTA Yaris PCU Traction Motor Inverter Power -card | 2016 TOYOTA Prius-4 PCU Traction Motor Inverter Power -card | 2021 TOYOTA MIRAI FC Boost Converter Power -card | 2020 HONDA Fit PCU Traction Motor Inverter |
| | Configuration | 3-Phase Inverter | 3-Phase Inverter Half-Bridge回路 | 3-Phase Inverter Half-Bridge回路 | 3-Phase Inverter Half-Bridge回路 | 4-Phase Interleaved DC-DC Boost Converter | 3-Phase Inverter Half-Bridge回路 |
| | VCC / IC | ~500 V, IC=570A | 360 V | 580 V | ~650 V | 650 V , Ic=200A | 570 V |
| | Power ※Spec of Motor's Power | | Front: 125 kW<br>Rear: 140 kW | 59 kW | 53 kW | 128 kW | 80 kW |
| Power Semiconductor Device | Half-Bridge arm Semiconductor Transistor chip |  |  |  |  |  |  |
| | Transistor configuration per Half-Bridge Switch | | | | | | |
| | Transistor chip size [mm2] | | | | | | |
| | Transistor Area per Switch [mm2] | | | | | | |
| | Free-Wheeling Diode (FWD) chip size [mm2] | | | | | | |
| | Total Switch size (IGBT + FWD) [mm2] | | | | | | |
| | VCE,sat pin) C-E saturation voltage @ Tj=25°C and IC/A = 2 A/mm2 VGE=15V | | | | | | |
| | Power Semiconductor Supplier | | | | | | |
| Module | |  |  |  |  |  |  |
| | |  |  |  |  |  | |
| | Module Size | | | | | | |
| | Cooling | | | | | | |
| | 1-Phase (Half-Bridge) package size | | | | | | |
| | Transistor Size per Switch、AA | | | | | | |
| | Thermal Resistance per Switch Rth,jw @ G=10 L/min | | | | | | |
| | Cooling Configuration | | | | | | |
| | Cooling fluid | | | | | | |
| | Cooling structure | | | | | | |
| | Pressure drop @ G= 10 L/min (Total) | | | | | | |
| | Specific Thermal Resistance per Switch Rth,jwxAA 単位面積当たり熱抵抗 | | | | | | |

# Excerpts from Survey Report

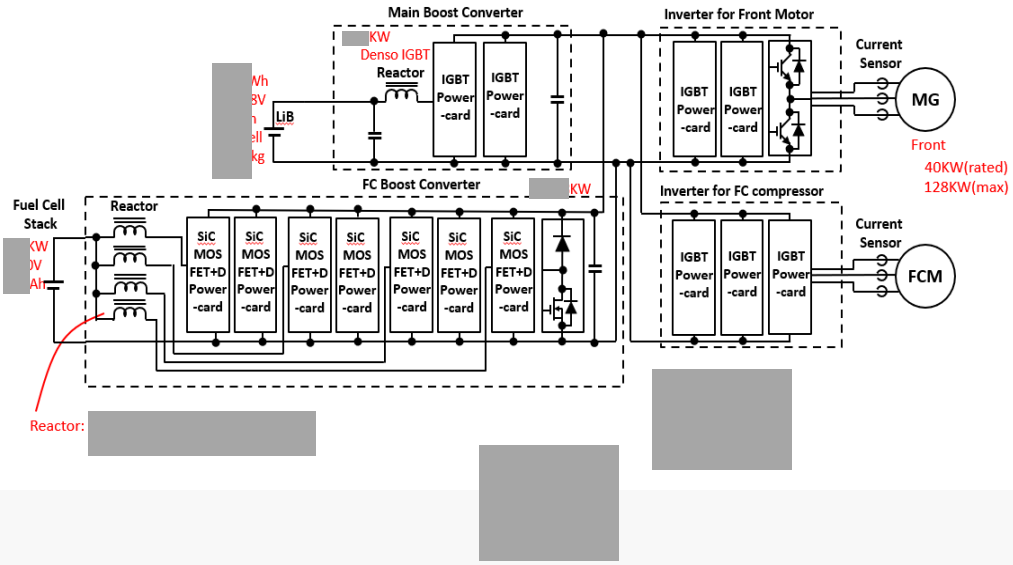
### 7.1 Analysis result of RAV4 and MIRAI

| | 1st Gen. RAV4 PHV (IGBT system) | 2nd Gen. MIRAI FCV (SiC system) |
|---|---|---|
| | **Ad-on Boost Converter**<br>**(located in ad-on module under main module)**<br>  <br>29.3x16.3x5.3cm3 = 25.3L<br>  <br>4281.6g |  <br>  <br>48x48x20cm3 = 46L<br>  |



### 7.2 The 2nd Gen. MIRAI FCV, Boost Converter and Inverter Block Diagram

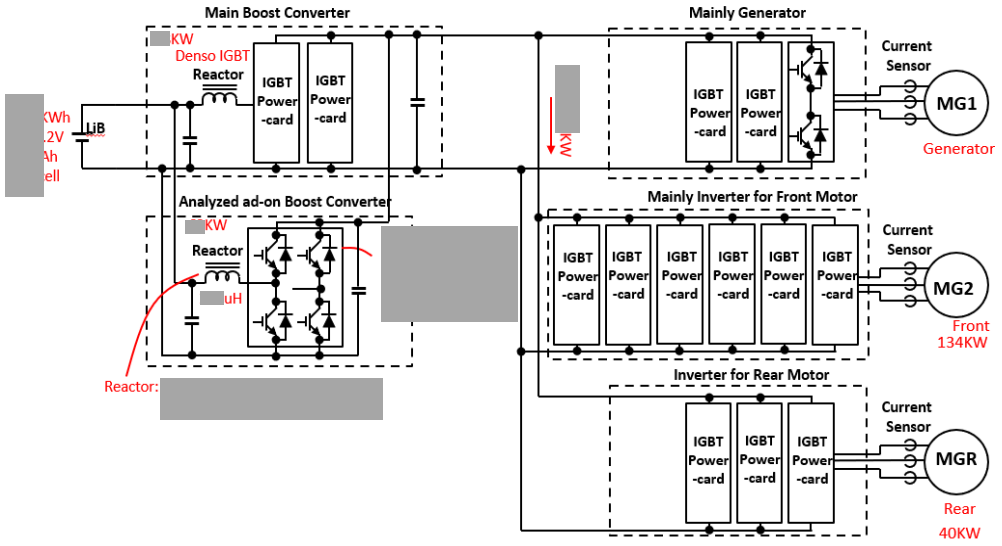
- PCU has 8 IGBT power-cards in main module portion, FC Boost module has 8 SiC MOSFET power-cards



# Excerpts from Survey Report

### 7.3 The 1st Gen. RAV4 PHV, Boost Converter and Inverter Block Diagram

■ PCU has 14 IGBT power-cards in main module portion




IGBT has absolutely advantage in the simple cost comparisons. However, it is estimated that the case using SiC will increase in order to reduce the size due to space limitation.

| | 1st Gen. RAV4 PHV | 2nd Gen. RAV4 PHV (SiC) | MIRAI FCV when use IGBT | 2nd Gen. MIRAI FCV (SiC) | 3rd Gen. MIRAI FCV |
|---|---|---|---|---|---|
| | Main converter + Ad-on Converter | Main converter | Built in the main converter | FC boost converter | Built in the main converter |
| Vbus | 356V | 356V | 650V | 650V | 650V |
| Transistor Vdss | | | | | |
| Power Device | | | | | |
| Gate Driver | | | | | |
| Boost Controller | | | | | |
| Reactor | | | | | |
| Film Capacitor | | | | | |
| Current Sensor, Bus Bar | | | | | |
| Al Chassis | | | | | |
| Total cost | | | | | |

Note 1: It is quite difficult to use 1200V Si-IGBT due to speed drop and rise of switching losses in high voltage and high current condition.
We think that this is one of the reason MIRAI uses SiC instead of IGBT.