Hitachi Double-Side Cooling Power Module from Audi e-tron’s Inverter

Hitachi’s power module and its innovative assembling technology of integrated double-side cooling structure.

SP20516 – POWER report by Amine ALLOUCHE
Laboratory Analysis by Véronique LE TROADEC
January 2020 – SAMPLE
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Executive Summary

The future of mobility will be electric. The new environmental regulations to reduce average CO2 emissions and automotive trends play in favor of stronger vehicle electrification and faster deployment of Electric Vehicles/ Hybrid Electric Vehicles (EV/HEVs). Yole Développement expects that EV/HEV market in number of vehicles will reach 24 Million units by 2024.

Vehicles with high electrification can usually benefit from more incentive mechanisms giving an advantage also to the car owner. Increasing battery energy capacity enables longer driving range of electric cars and powerful electric motors enable strong acceleration and high driving pleasure.

High electric power and needs for inverter downsizing bring challenges on the power module level.

Innovations at this level concern power module aspect (power card-like power module), baseplate structure (pin fin), the cooling technology (double-side cooling).

Hitachi combines all these key innovations in its new integrated 3rd generation double-side cooling power module.

In this 3rd generation double-sided cooling design, Hitachi implements a built-in latest-generation insulated-gate bipolar transistors (IGBTs) and diodes.

This report presents a deep analysis of the Hitachi power module. Supported by a full teardown of the module’s components and housing, this report reveals Hitachi’s innovative assets to assemble its 3rd generation double-sided cooling package as well as the designs of its IGBT and diode.

This report includes an estimated manufacturing cost of all the module’s components and its selling price analysis. It proposes a comparison between double sided cooling automotive power modules from Hitachi, Toyota, and Infineon.

These comparisons highlight differences in the packaging design, dies, and costs.
Synthesis of the Physical Analysis

Package: Double-sided direct cooling (Hitachi Gen 3)
- Dimensions:
  - Die Thickness:
  - Electrical Connection:

Dimensions:

Die Thickness:

Electrical Connection:
Package X-Rays – Terminals Identification

- from X-Rays as shown in the image.
- For instance,
Die Cross-Section – Gate Contact

Layers thickness:
- Xxx layer: xx µm
- Xxx layer: xx µm
- Gate poly contact width: xx µm
- Xxx : xx µm
Die Cross-Section – EDX Material Analysis
Die Cross-Section – Ring

- Guard Ring: \( \text{[value in \( \mu m \)]} \)
Module Process Flow

Overview / Introduction

Company Profile & Supply Chain

Physical Analysis

Manufacturing Process Flow
  - Si IGBT Fab Unit
  - Si IGBT Process Flow
  - Si Diode Fab Unit
  - Si Diode Process Flow
  - Packaging Fab Unit
  - Packaging Process Flow

Cost Analysis

Selling Price Analysis

Comparison

Feedbacks

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# IGBT Wafer Cost Per Process Steps

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<th>Operation Name</th>
<th>Cost [USD/Wafer]</th>
<th>Breakdown</th>
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<td>Synthesis</td>
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Diode Front-End Cost

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<td>Raw wafer Cost</td>
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<td>Equipment Cost</td>
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<td>Clean Room Cost</td>
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<td>Labor Cost</td>
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<td>Consumable Cost</td>
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<tr>
<td>Yield losses Cost</td>
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</tbody>
</table>

The Front-End cost ranges from according to yield variations.

The main part of the wafer cost is due to the
Power Card – Assembly Cost

Power Card Manufacturing Cost Breakdown (Medium Yield)
Module – BoM & Assembly Cost

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<th>Low Yield</th>
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<thead>
<tr>
<th>Module Manufacturing</th>
<th>Low Yield</th>
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<table>
<thead>
<tr>
<th>Package Assembly Cost</th>
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Estimated Manufacturer Price

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<th>Module cost</th>
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<tr>
<td>Manufacturer Gross Profit</td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
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Cost & Price According to Yield Variation

The module manufacturing cost ranges from according to yield variations.

Considering a gross margin of for the module selling price is estimated to range from according to yield variations.
## Hitachi vs Toyota vs Infineon Power Cards

<table>
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<th>Hitachi in Audi e-tron</th>
<th>Toyota Prius DSC</th>
<th>Infineon HybridPACK FF400R07A01E3</th>
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<td>Dimensions</td>
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<tr>
<td>IGBT Size</td>
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<tr>
<td>Commutation cells</td>
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<tr>
<td>Power Card Cost ($)</td>
<td></td>
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<tr>
<td>Cost per cell ($)</td>
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</tbody>
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*One Commutation Cell (Half of Power Card in all cases): Top and Cross-Section – Optical Views*
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