Reverse Costing Analysis

Toyota Prius 4 PCU’ Power Modules

September 2016 - Version 1 - Written by Elena Barbarini
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Contact
This full reverse costing study has been conducted to provide insight on technology data, manufacturing cost and selling price of the IGBT power modules integrates in the PCU of the Toyota Prius 4.

For its latest Prius 4 Toyota designed a new PCU. The PCU is assembled with two types of power modules, one for the motor inverter and the other for the boost converter and generator inverter.

The module integrates the latest packaging of Toyota power card with double side cooling. The module allows an optimization of the modularity and scalability of the PCU’s inverters and a better thermal dissipation thanks to the use of copper heatsink and spacers. The power cards can be placed in parallel to have a single thermal dissipation circuit in a limited space. This package includes two pairs of IGBT and FWD wire bonded and it is plastic molded.

The report offers a deep technical analysis of the module structure and packaging and of the IGBT and diode dies.

Based on a complete teardown analysis, the report also provides an estimation of the production cost of the package, IGBT and diode.

Moreover the report proposes a comparison with the Chevrolet Volt Power module.
Module Design

Power card

Coolant

Adopted structure (N structure)

“Toyota’s Challenge of Applying SiC Power Semiconductors to Environmentally Friendly Vehicles and its update” ISiCPEAW 2016
• Module dimensions: 105 mm x 57 mm
Module Overview

Pins

Module marking

Pins cross section
Module Cross-Section Optical view
Dies A View & Dimensions

IGBT Die Overview

- IGBT Die Area: 16.2 mm² (5.0 mm x 3.2 mm)
- # of IGBTs per 6 inch wafer: 400
Die Cross-Section

Die Cross-Section – Optical View
Die Cross-Section

Die Cross-Section – SEM View

Die Cross-Section – SEM View
Die Cross-Section

Die Cross-Section – SEM View
diode die overview
Global Overview

IGBT manufacturing
1 metal layer, trench, backside
Probe test
Dicing

Diode manufacturing
1 metal layer, backside
Probe test
Dicing

Assembly in package
Final test

IGBT

Diode

Power Module

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• The wafer cost is between $xxx and $xxxx according to yield.

• The main part of the wafer cost is due to the consumables with xxx%. The equipment part counts for xxxx%.
• The dies cost is **between $xxx and $xx according to yield.**
  – Silicon cost accounts for xx% of the cost for medium yield.
  – The probe test, backgrinding and dicing represent xx% of the cost for medium yield.
  – The scrap cost (xxx%) is the total of all the losses during probe test and dicing for medium yield.
The die cost is **between $xxx and $xx according to yield.**

- Silicon cost accounts for xx% of the cost.
- The probe test, backgrinding and dicing represent xx% of the cost.
- The scrap cost (xx%) is the total of all the losses during probe test and dicing.
### Module Cost

<table>
<thead>
<tr>
<th>Component</th>
<th>Base Cost</th>
<th>Unit Cost</th>
<th>Total Unit Cost</th>
<th>Revenue Share</th>
<th>Total Revenue</th>
<th>Contribution Share</th>
<th>Total Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component A</td>
<td>$100</td>
<td>$10</td>
<td>$110</td>
<td>0.05</td>
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<td>0.05</td>
<td>$5.50</td>
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<td>Component B</td>
<td>$200</td>
<td>$20</td>
<td>$220</td>
<td>0.10</td>
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<td>0.10</td>
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<tr>
<td>Component C</td>
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<td>$330</td>
<td>0.15</td>
<td>$16.50</td>
<td>0.15</td>
<td>$16.50</td>
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</table>

**Total Unit Cost:** $660
**Total Revenue:** $32.00

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• The assembled module cost is estimated between $xxx and $xxx according to yield.

• The dies cost (Silicon cost) accounts for about xxx%.

• The copper cost accounts for xxx% of the cost.

• The added value cost is $xx (x%).
• The module manufacturer price is estimated between $\text{xxx}$ and $\text{xxx}$. 
Power module comparison

<table>
<thead>
<tr>
<th></th>
<th>Chevrolet Volt</th>
<th>Toyota Prius</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGBT Dimensions</td>
<td>150x120mm</td>
<td>150x120mm</td>
</tr>
<tr>
<td>IGBT Cost</td>
<td>$1.00</td>
<td>$1.00</td>
</tr>
<tr>
<td>Diode Dimensions</td>
<td>150x120mm</td>
<td>150x120mm</td>
</tr>
<tr>
<td>Diode Cost</td>
<td>$0.20</td>
<td>$1.00</td>
</tr>
</tbody>
</table>

Chevrolet Volt IGBT & Diode

Toyota Prius IGBT & Diode

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• Reverse costing analysis represents the best cost/price evaluation given the publically available data, and estimates completed by industry experts.

• Given the hypothesis presented in this analysis, the major sources of correction would lead to a +/- 10% correction on the manufacturing cost (if all parameters are cumulated).

• These results are open for discussion. We can reevaluate this circuit with your information. Please contact us: