Infineon FF400R07A01E3
Double Side Cooled 700V 400A IGBT Module
Power Semiconductor report by Elena Barbarini
January 2018 – version 1
# SUMMARY

## Overview / Introduction
- Executive Summary
- Reverse Costing Methodology

## Company Profile
- Infineon

## Physical Analysis
- Synthesis of the Physical Analysis
- Package analysis
  - Package opening
  - Package Cross-Section
- IGBT Die
  - IGBT Die View & Dimensions
  - IGBT Die Process
  - IGBT Die Cross-Section
  - IGBT Die Process Characteristic
- Diode Die
  - Diode Die View & Dimensions
  - Diode Die Process
  - Diode Die Cross-Section
  - Diode Die Process Characteristic

## Manufacturing Process
- IGBT Die Front-End Process
- IGBT Die Fabrication Unit
- Diode Die Front-End Process
- Diode Die Fabrication Unit
- Final Test & Packaging Fabrication unit

## Cost Analysis
- Synthesis of the cost analysis
- Yields Explanation & Hypotheses
  - IGBT die
    - IGBT Front-End Cost
    - IGBT Die Probe Test, Thinning & Dicing
    - IGBT Wafer Cost
    - IGBT Die Cost
  - Diode die
    - Diode Front-End Cost
    - Diode Die Probe Test, Thinning & Dicing
    - Diode Wafer Cost
    - Diode Die Cost
  - Complete Module
    - Packaging Cost
    - Final Test Cost
    - Component Cost

## Price Analysis
- Estimation of selling price

## Comparison
- Comparison with Toyota Prius Power Module

## Feedbacks

## Company services
Executive Summary

The hybrid vehicle market is growing as car manufacturers plan the implementation of hybrid systems across the range. In a compact car the maximum power of the motor is 60kW while the hybrid systems used in medium and large vehicles has inverter power that exceed 160kW. But when converting an existing petrol vehicle to a hybrid version, the available space in the engine compartment is often so limited that it is difficult to accommodate a PCU. Thus, it is necessary that the Power Control Unit (PCU) that controls the traction motors of hybrid vehicles has an higher power density and a smaller size.

To achieve these targets, manufacturers have developed different solution such as diminish the wire bonding or uses a double-side cooling structure to efficiently cool power semiconductor chips.

The HybridPACK Double Side Cooled power module is the first double side cooled IGBT module from Infineon specifically designed for automotive inverters. The FF400R07A01E3 is driving 700A and uses a very particular molded structure optimized for cooling and improving the thermal cycles capability and extends the lifetime of the power module.

The terminals are connected directly on the DBC with wire bonding and the dies are dissipated on the front side by alloy spacers.

The IGBT is manufactured with the standard TrenchStop technology design which allows reduction of conduction losses and switching losses. While the diode is an EMCON PN diode.

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

Moreover, the report proposes a comparison the Infineon design and Toyota Prius Inverter Double Side cooled power Module, highlights the differences in design and manufacturing process.
Synthesis of the Physical Analysis

HybridPACK DSC:
- Dimensions: xxmm x xxmm xxxxmm
- Number of Pins: xx pins

IGBT:
- Dimension: xx mm² (xxmm x xxmm)
- Electrical Connection: xxxbonding
- Placement in the package: xxx on lower DBC

Diode:
- Dimension: xx mm² (xxmm x xxmm)
- Electrical Connection: xxx of DBC
- Placement in the package: xxx on lower DBC
Package Markings

Marking:

0000154202

Infineon Logo
FF400R07A01E3 S6
G1725
#RR737701
X-ray Images

Package opening – X-ray View
Package opening - From front side

- Upper DBC’s copper and solder layer
- Spacer

Front side Cu removal
Front side Cu removal
Front side Solder removal
Package Cross-Section

Spacer

Spacer

xxx mm

xxxx alloy

Spacer EDX

Package Cross section
IGBT die dimensions

- Die dimensions: xxx mm² (xxxmm x xxxmm)
- There is no marking on the die.
Die process
Die process current sensor
Die process gate
Die process

Transistor after delayering – SEM View
Die cross section

- Substrate thickness: xxx µm
Gate contact

Die cross section – SEM View
Die cross section

Die cross section – SEM View
Die cross section – Back side

- xx layer thickness: xxµm
- xx layer thickness: xxµm
- xx layer thickness: xxµm

Die cross section – Optical View

P doping and N doping

Si Substrate

xxx layer

xxx layer

xxx solder

Die cross section – SEM View

System Plus Consulting
Diode die Dimensions

- Die dimensions: xxx mm² (xxxmm x xxxmm)
- There is no marking on the die.
Die cross section

Die process – Optical View

Polyimide
Al layer
Doping
doping

Die cross section – Optical View
Die cross section
Description of the Wafer Fabrication Units - IGBT

In our calculation, we simulate a production unit using xxx wafers.

IGBT wafer fab unit:

Name: xxx
Wafer diameter: xxx
Capacity: xxx wafers / month
Year of start: xxx
Most advanced process: Power device
Products: Discrete/Power - Mainly power products; Diodes & IGBT
Location: xxx

This manufacturing line has been created in xxx. We assume that the clean room and equipment are depreciated
**IGBT Process Flow**

- **Front Side**
  - Trench etching

- **Front Side**
  - Gate oxide
  - Poly
  - CMP

- **Front Side**
  - Oxide #1
  - Oxide #2
  - Ti

*IGBT Structure Schematic*
Main steps of economic analysis

- IGBT Front-End Cost
- Diode Front-End Cost
- IGBT Back end Cost
- Diode Back end Cost
- DBS Assembly
- Final Test Cost

We perform the economic analysis of the component with the Power CoSim.
In our simulation, we assume a development and a production ramp up without important technical problem.
IGBT Front-End Cost

The front-end cost ranges from $xxx to $xxx according to yield variations.

The main part of the wafer cost is due to the xx (xxx%).
# IGBT Wafer Cost per process steps

<table>
<thead>
<tr>
<th>Operation name</th>
<th>Wafer Cost (USD/Wafer)</th>
<th>BreakDown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning RCA Multi-Steps</td>
<td>$4.41</td>
<td>1.97%</td>
</tr>
<tr>
<td>Rinse Multi-steps</td>
<td>$8.69</td>
<td>0.17%</td>
</tr>
<tr>
<td>Measurement Multi-Steps</td>
<td>$8.12</td>
<td>2.24%</td>
</tr>
<tr>
<td>LOCOS - LPCVD-Oxide (SiO2)</td>
<td>$1.03</td>
<td>0.26%</td>
</tr>
<tr>
<td>LOCOS - LPCVD-Silicon Nitride (SiN)</td>
<td>$3.73</td>
<td>1.63%</td>
</tr>
</tbody>
</table>

- **Synthesis**: $4.58 (0.12%)
- **Die Cost**: $6.60 (1.80%)
- **Packaging Cost**: $2.23 (0.62%)
- **Component Cost**: $1.46 (0.46%)

## Wet Etching (BOE) Oxide-SiO2
- **PVD-Aluminum (Al)**: $5.82 (5.21%)
- **PVD-Titanium (Ti)**: $3.40 (3.04%)
- **PVD-Nickel (Ni)**: $4.94 (4.13%)

## TMA Activation
- **Deposition**: $4.47 (0.41%)

Total Cost: $36.82 USD
Diode Die Cost

The diode die cost ranges from $xxx to $xxx according to yield variations.

The Front-end manufacturing represents xxxx% of the component cost (medium yield estimation).

Probe test, dicing and scrap account for xxx% of the component cost.
Packaging Cost

Module BOM
- IGBT (x2)
- Diode (x2)
- DBC (x2)
- Spacers
- Leadframe

Module Manufacturing
- Unpacking baseplate
- Base plate cleaning + rinsing + drying
- Solder screen printing on leadframe
- Die placing
- Reflow on DBC
- Visual inspection (Baseplate + DBC + die)
- Subset cleaning + rinsing + drying
- Wire bonding on DBC
- Unpacking terminals
- Solder screen printing on DBC
- Leadframe pick & place
- Space rs pick & place
- Reflow
- Solder deposition
- Emitter plate placing
- Reflow
- Plasma cleaning
- Transfer molding press
- Post Mold Cure
- Yield losses

Package Assembly Cost

Low Yield | Medium Yield | High Yield
--- | --- | ---

Untested Module Cost
Final Module Cost

The module cost ranges from $xxx to $xxx according to yield variations.

The IGBT dies manufacturing represents xxx% of the component cost.

The packaging represents xxx% of the component cost.

Final test and yield losses account for xxx% of the component cost.
Estimated Manufacturer Price

The module manufacturing cost ranges from $xxx to $xxx according to yield variations.

By taking into account a gross margin of xxx% for Infineon (2017 results), the module selling price is estimated to range from $xxx to $xxx according to yield variations.
Comparison between Infineon & Toyota PCU power module

HybridPACK™ DSC and Toyota DSC are two power modules packaging designed by Infineon and Toyota for Hybrid- and Electric Vehicle applications.

<table>
<thead>
<tr>
<th>Module</th>
<th>Size</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infineon</td>
<td>xxxmm x xxxmm x xxxmm</td>
<td>xx$</td>
</tr>
<tr>
<td>Toyota</td>
<td>xxxmm x xxxmm x xxxmm</td>
<td>xxx$</td>
</tr>
</tbody>
</table>

The two modules uses the same half bridge design with two IGBT and diodes assembled in the same molded package.

The main differences, other than the module size, is the uses of material. While Toyota uses xxx for both heatsinks and spacers, Infineon adopt xxx DBS for the heatsinks and xxxx alloys for the spacers.
Related Reports

REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING

Power Semiconductors & Compound
- Infineon FS600R07A2E3 HybridPACK2 100KW 3-phase
- Infineon EconoPACK4™ 1200V IGBT4 Module
- SEMIKRON SKiM306GD12E4
- ROHM 1200V Trench SiC MOSFET
- Infineon CooliR²Die™ Power Module
- Toyota Prius Power Modules
- Infineon FS820R08A6P2B HybridPACK Drive IGBT Module

MARKET AND TECHNOLOGY REPORTS - YOLE DÉVELOPPEMENT

POWER ELECTRONICS
- IGBT Market and Technology Trends 2017
- Power Module Packaging: Material Market and Technology Trends 2017
Business Models Fields of Expertise

- Custom Analyses (>130 analyses per year)
- Reports (>40 reports per year)
- Costing Tools
- Trainings

- Display
- Power
- System
- Packaging
- LED
- IC & RF
- MEMS & Sensor
- PCB
- Imaging

System Plus Consulting

©2018 by System Plus Consulting | Infineon FF400R07A01E3
Contact

Headquarters
21 rue La Noue Bras de Fer
44200 Nantes
FRANCE
+33 2 40 18 09 16
sales@systemplus.fr

Europe Sales Office
Lizzie LEVENEZ
Frankfurt am Main
GERMANY
+49 151 23 54 41 82
llevenez@systemplus.fr

America Sales Office
Steve LAFERRIERE
Phoenix
USA
(310) 600-8267
laferriere@yole.fr

Asia Sales Office
Takashi ONOZAWA
Tokyo
JAPAN
onozawa@yole.fr

Mavis WANG
GREATER CHINA
wang@yole.fr

www.systemplus.fr
Please process my order for “Infineon FF400R07A01E3 Double Side Cooled IGBT” Report

Ref.: SP18375

☐ Full Reverse Costing report: EUR 3,490*

☐ Annual Subscription (including this report as the first of the year):
  ○ 3 reports EUR 8 400*
  ○ 5 reports EUR 12 500*
  ○ 7 reports EUR 16 000*
  ○ 10 reports EUR 21 000*
  ○ 15 reports EUR 27 500*

*For price in dollars please use the day’s exchange rate

*All reports are delivered electronically in pdf format

*For French customer, add 20% for VAT

*Our prices are subject to change. Please check our new releases and price changes on www.systemplus.fr. The present document is valid 6 months after its publishing date: January 2018

SHIP TO
Name (Mr/Ms/Dr/Pr):
......................................................................................
Job Title:
......................................................................................
Company:
......................................................................................
Address:
......................................................................................
City: State:
......................................................................................
Postcode/Zip:
......................................................................................
Country:
......................................................................................
VAT ID Number for EU members:
......................................................................................
Tel:
......................................................................................
Email:
......................................................................................
Date:
......................................................................................
Signature:
......................................................................................

BILLING CONTACT
First Name: .................................................................
Last Name: .................................................................
Email:.................................................................
Phone:.................................................................

PAYMENT
DELIVERY on receipt of payment:

By credit card:
Number: |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
Expiration date: |   |   | / |   |   | Card Verification Value: |   |   |   |

By bank transfer:
HSBC - CAE- Le Terminal -2 rue du Charron - 44800 St Herblain France
BIC code: CCFRFRPP

In EUR
Bank code : 30056 - Branch code : 00955 - Account : 09550003234
IBAN: FR76 3005 6009 5509 5500 0323 439

In USD
Bank code : 30056 - Branch code : 00955 - Account : 09550003247
IBAN: FR76 3005 6009 5509 5500 0324 797

Return order by:
FAX: +33 2 53 55 10 59
MAIL: SYSTEM PLUS CONSULTING
                                                   21 rue La Noué Bras de Fer
                                                   44200 Nantes – France

Contact:
EMAIL: sales@systemplus.fr
TEL: +33 2 40 18 09 16

ABOUT SYSTEM PLUS CONSULTING
System Plus Consulting is specialized in the cost analysis of electronics from semiconductor devices to electronic systems.
A complete range of services and costing tools to provide in-depth production cost studies and to estimate the objective selling price of a product is available.

Our services:

TECHNOLOGY ANALYSIS - COSTING SERVICES - COSTING TOOLS - TRAININGS

www.systemplus.fr - sales@systemplus.fr
TERMS AND CONDITIONS OF SALES

1. INTRODUCTION
The present terms and conditions apply to the offers, sales and deliveries of services managed by System Plus Consulting except in the case of a particular written agreement.

Buyer must note that placing an order means an agreement without any restriction with these terms and conditions.

2. PRICES
Prices of the purchased services are those which are in force on the date the order is placed. Prices are in Euros and worked out without taxes. Consequently, the taxes and possible added costs agreed when the order is placed will be charged on these initial prices.

System Plus Consulting may change its prices whenever the company thinks it necessary. However, the company commits itself in invoicing at the prices in force on the date the order is placed.

3. REBATES and DISCOUNTS
The quoted prices already include the rebates and discounts that System Plus Consulting could have granted according to the number of orders placed by the Buyer, or other specific conditions. No discount is granted in case of early payment.

4. TERMS OF PAYMENT
System Plus Consulting delivered services are to be paid within 30 days end of month by bank transfer except in the case of a particular written agreement.

If the payment does not reach System Plus Consulting on the deadline, the Buyer has to pay System Plus Consulting a penalty for late payment the amount of which is three times the legal interest rate. The legal interest rate is the current one on the delivery date. This penalty is worked out on the unpaid invoice amount, starting from the invoice deadline. This penalty is sent without previous notice.

When payment terms are over 30 days end of month, the Buyer has to pay a deposit which amount is 10% of the total invoice amount when placing his order.

5. OWNERSHIP
System Plus Consulting remains sole owner of the delivered services until total payment of the invoice.

6. DELIVERIES
The delivery schedule on the purchase order is given for information only and cannot be strictly guaranteed. Consequently any reasonable delay in the delivery of services will not allow the buyer to claim for damages or to cancel the order.

7. ENTRUSTED GOODS SHIPMENT
The transport costs and risks are fully born by the Buyer. Should the customer wish to ensure the goods against lost or damage on the base of their real value, he must imperatively point it out to System Plus Consulting when the shipment takes place. Without any specific requirement, insurance terms for the return of goods will be the carrier current ones (reimbursement based on good weight instead of the real value).

8. FORCE MAJEURE
System Plus Consulting responsibility will not be involved in non execution or late delivery of one of its duties described in the current terms and conditions if these are the result of a force majeure case. Therefore, the force majeure includes all external event unpredictable and irresistible as defined by the article 1148 of the French Code Civil?

9. CONFIDENTIALITY
As a rule, all information handed by customers to system Plus Consulting are considered as strictly confidential. A non-disclosure agreement can be signed on demand.

10. RESPONSIBILITY LIMITATION
The Buyer is responsible for the use and interpretations he makes of the reports delivered by System Plus Consulting. Consequently, System Plus Consulting responsibility can in no case be called into question for any direct or indirect damage, financial or otherwise, that may result from the use of the results of our analysis or results obtained using one of our costing tools.

11. APPLICABLE LAW
Any dispute that may arise about the interpretation or execution of the current terms and conditions shall be resolved applying the French law.

It the dispute cannot be settled out-of-court, the competent Court will be the Tribunal de Commerce de Nantes.