Pushed by aggressive legislation, CO₂ reduction is one of the key challenges in the 21st century. The best solution currently available to the automotive industry is the electrification of vehicles, with different levels of electrification depending on the strategies of different car manufacturers. 780,000 battery electric vehicles were shipped in 2017, a number expected to grow to almost 2.8M by 2022. Standard inverter power modules integrate silicon IGBTs, but in electric vehicles the available space in the engine compartment is often so limited that it is difficult to accommodate a power control unit (PCU).

Thus, it is necessary that the PCU, which controls electric vehicles’ traction motors, has a higher power density and therefore is smaller. Thanks to higher thermal and electrical performance, SiC is the new competitor to silicon at high voltages. Nevertheless, high power densities need high thermal dissipation and thus new packages are needed to improve device performance. To achieve these targets, manufacturers have developed different solutions, such as limiting wire bonding or using overmolded structures to efficiently cool the power semiconductor chips.

Tesla is the first high-class car manufacturer to integrate a full SiC power module, in its Model 3. Thanks to its collaboration with STMicroelectronics the Tesla inverter is composed of 24 1-in-1 power modules assembled on a pin-fin heatsink.

The module contains two SiC MOSFETs with an innovative die attach solution and connected directly on the terminals with copper clips and thermally dissipated by copper baseplates.

The SiC MOSFET is manufactured with the latest STMicroelectronics technology design, which allows reduction of conduction losses and switching losses. Based on a complete teardown analysis, the report also provides an estimation of the production cost of the SiC MOSFET and package.

Moreover, the report includes a technical and cost comparison with the Mitsubishi J-Series TP-M power module. It highlights the differences in design of the packaging and the material solutions adopted by the two companies.
## TABLE OF CONTENTS

### Overview/Introduction
- Executive Summary
- Reverse Costing Methodology
- Thermal Issues and Solutions in Automotive Power Modules

### Company Profile
- STMicroelectronics

### Physical Analysis

**Overview of the Physical Analysis**
- Package Analysis
  - Package opening
  - Package cross-section
- MOSFET Die
  - MOSFET die view and dimensions
  - MOSFET die process
  - MOSFET die cross-section
  - MOSFET die process characteristics

### Manufacturing Process
- MOSFET Die Front-End Process
- MOSFET Fabrication Unit
- Final Test and Packaging Fabrication Unit

### Cost Analysis
- Overview of the Cost Analysis
- Yields Explanation and Hypotheses
- MOSFET Die
  - MOSFET front-end cost
  - MOSFET die probe test, thinning and dicing
  - MOSFET wafer cost
  - MOSFET die cost
- Complete Module
  - Packaging cost
  - Final test cost
  - Component cost

### Price Analysis
- Estimation of Selling Price
- Comparison with Mitsubishi J-Series TP-M power module

## AUTHORS

**Elena Barbarini** is in charge of costing analyses for MEMS, IC and Power Semiconductors. She has a deep knowledge of Electronics R&D and Manufacturing environment. Elena holds a Master in Nano-technologies and a PhD in Power Electronics.

**Véronique Le Troadec** has joined System Plus Consulting as a laboratory engineer. Coming from Atmel Nantes, she has extensive knowledge in failure analysis of components and in deprocessing of integrated circuits.

## RELATED REPORTS

**Toyota Prius Power Modules**
*For its latest Prius 4 Toyota has designed a new power control unit (PCU). The PCU has two types of power module, one for the motor inverter and the other for the boost converter and generator inverter.*

September 2016 - EUR 3,490*

**Infineon FF400R07A01E3 Double Side Cooled IGBT Module**
*Discover Infineon’s first double sided cooling power module for automotive.*

January 2018 - Price: EUR 3,490*

**Infineon CooliR²Die™ Power Module**
*The CooliR²Die™ innovative power module from Infineon is an IGBT module for automotive applications integrated into different vehicles.*

September 2016 - EUR 3,290*
Our analysis is performed with our costing tools Power CoSim+ and Power Price+.

System Plus Consulting offers powerful costing tools to evaluate any Power Electronics process or device, the production cost and selling price. All these tools are on sale under corporate license.

**Power Price+**
Parametric costing tool used to evaluate the manufacturing cost of devices using few process related inputs.

**Power CoSim+**
Cost simulation tool to evaluate the cost of any Power Electronics process or device: from single chip to complex structures.

**WHAT IS A REVERSE COSTING®?**
Reverse Costing® is the process of disassembling a device (or a system) in order to identify its technology and calculate its manufacturing cost, using in-house models and tools.

**CONTACTS**

**Headquarters**
22, bd Benoni Goullin
Nantes Biotech
44200 Nantes
France
+33 2 40 18 09 16
sales@systemplus.fr

**America Sales Office**
Steve LAFFERRIERE
Western USA
+1 310-600-8267
lafriere@yole.fr

Troy BLANCHETTE
Eastern USA
+1 704-859-0453
troy.blanchette@yole.fr

**Asia Sales Office**
Takashi ONOZAWA
Japan & Rest of Asia
+81 3 4405 9204
onozawa@yole.fr

Mavis WANG
Greater China
+886 979 336 809
wang@yole.fr

**Europe Sales Office**
Lizzie LEVEZE
Frankfurt am Main
Germany
+49 151 23 54 41 82
llevenez@systemplus.fr

**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:
- **STRUCTURE & PROCESS ANALYSES**
- **CUSTOM ANALYSES**
- **COSTING SERVICES**
- **COSTING TOOLS**
- **TRAININGS**

www.systemplus.fr
sales@systemplus.fr
ORDER FORM

Please process my order for “Tesla Model 3 Inverter with SiC Power Module from STMicroelectronics” Reverse Costing® – Structure, Process & Cost Report
Ref: SP18413

☐ Full Structure, Process & Cost Report : EUR 3,490*
☐ Annual Subscription offers possible from 3 reports, including this report as the first of the year. Contact us for more information.

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

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
22, bd Benoni Goullin
Nantes Biotech
44200 Nantes – France

*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: June 2018

ANNUAL SUBSCRIPTIONS

Each year System Plus Consulting releases a comprehensive collection of new reverse engineering and costing analyses in various domains. You can choose to buy over 12 months a set of 3, 4, 5, 7, 10 or 15 Reverse Costing® reports.
Up to 47% discount!

More than 60 reports released each year on the following topics (considered for 2018):

- Power: GaN - IGBT - MOSFET - Si Diode - SiC
- Imaging: Camera - Spectrometer
- LED and Laser: UV LED – VCSEL - White/blue LED
- Packaging: 3D Packaging - Embedded - SIP - WLP
- Integrated Circuits: IPD – Memories – PMIC – SoC
- RF: FEM - Duplexer
- Systems: Automotive - Consumer - Energy - Telecom
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.