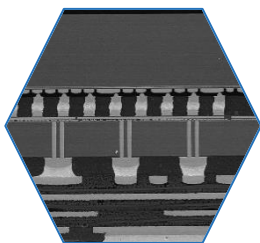
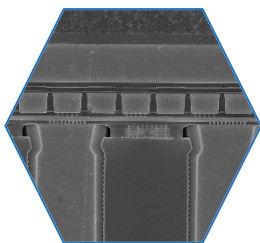
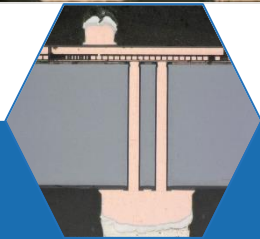


## Intel Foveros 3D Packaging Technology

*Intel Core i5-L16G7: the first utilisation of Intel's Foveros Technology with Package-on-Package configuration in a consumer product.*



**Title:** Intel Foveros 3D packaging technology

**Page:** 190

**Date:** September 2020

**Format:** PDF & Excel file

**Price:** EUR 3,990

**Reference:** SP20555

As feature scaling hits the limits of physics, the semiconductor industry is already researching for “more-than-Moore” technology enablers. In this area, multi-die packages are essential to integrate more functions into a small form factor, whatever is the lithographic technology node. All this must be at low cost and in a short time to market. From this perspective, Intel has developed several interconnect technologies to enable heterogenous integration using chiplets. An early glimpse of the technology enablers was seen in 2018 on an Intel processor, then called Embedded Multi-die interconnect Bridge (EMiB). Today, Intel shows another way to interconnect dies in processor using an active interposer and Foveros technology.

Foveros allows 3D Face-to-Face (F-F) stacking for integration of different types of devices on an active interposer using Through Silicon Vias (TSVs). The interposer is used as a bridge for the different chiplets. However, it also comprises low-power components such as input/output (I/O) connections and power delivery with high performance logic.

The Intel Core i5-L16G7 analyzed in this report features Intel's hybrid packaging technology. This technology relies on Foveros F-F die stacking and Package-on-Package (PoP) configuration. The design aims to integrate 10 nm computing die with SK Hynix LPDDR4 DRAM in a PoP

architecture in a single package. This lowers power consumption and increases core performance while reducing the form factor and z-height to fit ultra-mobile applications.

This report constitutes an exhaustive analysis of the Intel Core i5-L16G7 processor. This report includes a full investigation of Intel's hybrid packaging technology. It features a detailed study of the 3D package including the processor die, Foveros features and interposer die analysis and cross-sections. The report also integrates the physical analysis of the LPDDR4X DRAM dies integrated in the package. Finally, it contains a complete cost analysis and a selling price estimation of the component and a physical comparison with TSMC's Chip-on-Wafer-on-Substrate (CoWoS) technology.

### COMPLETE TEARDOWN WITH

- Detailed photos
- Precise measurements
- Material analysis
- Manufacturing process flow
- Supply-chain evaluation
- Manufacturing cost analysis
- Estimated sales price
- Comparison with TSMC's CoWoS

## TABLE OF CONTENTS

### Overview/ Introduction

#### Company Profile: Intel

#### Samsung Galaxy S Book Teardown

#### Physical Analysis

- Board Analysis
  - ✓ Board overview: Heatsink dimensions, PCB substrate
- Package Analysis
  - ✓ Package on package views
  - ✓ Package on package opening and cross section
- DRAM Memory Analysis
  - ✓ Package view and dimensions
  - ✓ Package and die cross section
- Processor Analysis
  - ✓ Package overview and cross-section: Interposer, PCB substrate
  - ✓ Interposer and processor die analysis

#### Physical Analysis Comparison

#### Intel's Foveros Technology vs. TSMC's CoWoS

#### Manufacturing Process

- DRAM Front-End Process and Fabrication Unit
- Interposer and Processor Front-End Process and Fabrication Unit
- Processor Packaging Process Flow
- Package on Package Assembly

#### Cost Analysis

- Overview of the Cost Analysis
- DRAM Memory Cost Analysis
- Processor Cost Analysis
- Interposer Cost Analysis
  - ✓ Bumping back-end cost and cost per step
  - ✓ Wafer and die cost
  - ✓ Packaging cost and cost per step
  - ✓ Packaging wafer and component cost
- Component Cost Analysis
  - ✓ Package on package cost and cost per step
  - ✓ Final test and component cost

#### Estimated Price Analysis

## AUTHORS



**Stéphane Elisabeth, PhD** has joined System Plus Consulting's team in 2016. Stéphane is Expert Cost Analyst in RF, Sensors and Advanced Packaging. He holds an Engineering Degree in Electronics and Numerical Technology, and a PhD in Materials for Microelectronics.

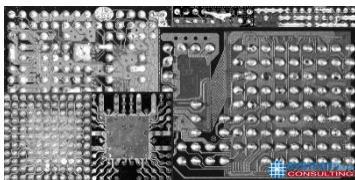


**Belinda Dube** is working for System Plus Consulting as an Engineer & Analyst, Semiconductor Memories. Belinda is also engaged in the development of reverse engineering & costing analyses with the power electronics and compound semiconductors team.



**Nicolas Radufe** is in charge of physical analysis at System Plus Consulting. He has a deep knowledge in chemical and physical analyses. He previously worked in microelectronics R&D for CEA/LETI in Grenoble and for STMicroelectronics in Crolles.

## RELATED REPORTS



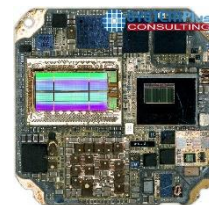
### Fan-Out Packaging Processes Comparison 2020

*In-depth technical and cost overview of key Fan-Out process technologies from Infineon, nepes, TSMC, SEMCO and ASE.*  
February 2020 - EUR 6,490\*



### Advanced System-in-Package Technology in Apple's AirPods Pro

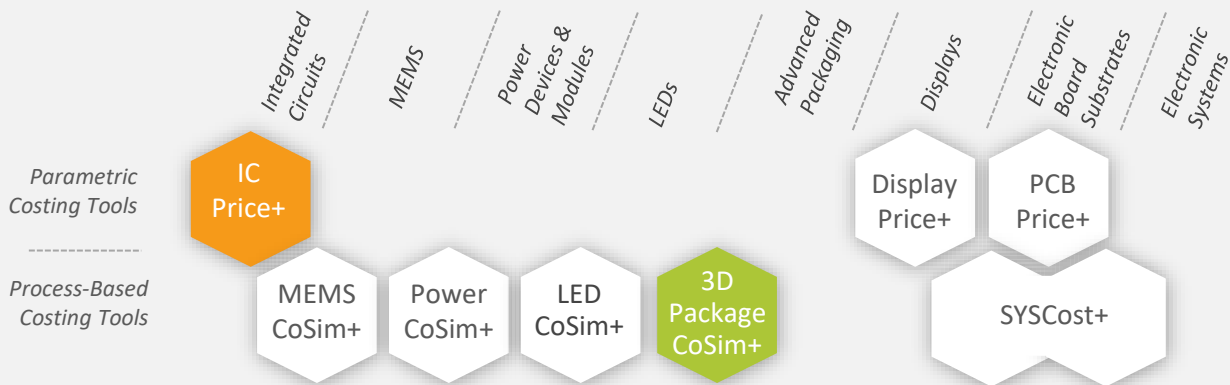
*Analysis of Apple's first SiP found in the latest AirPods, featuring a fully integrated SiP for audio codec and Bluetooth connectivity.*  
March 2020 - EUR 3,990\*



### Advanced packaging technology in the Apple Watch Series 4's SiP

*4 major packaging technologies: ASE's SiP & modified SESUB, TSMC's inFO-ePoP, Skyworks' Double Side BGA.*  
January 2019 - EUR 3,990\*

## COSTING TOOLS



Our analysis is performed with our costing tools 3D Packaging CoSim+ and IC Price+.

System Plus Consulting offers powerful costing tools to evaluate the production cost and selling price from single chip to complex structures.

### 3D Packaging CoSim+

Cost simulation tool to evaluate the cost of any Packaging process: Wafer-level packaging, TSV, 3D integration...

### IC Price+

The tool performs the necessary cost simulation of any Integrated Circuit: ASICs, microcontrollers, memories, DSP, smartpower...

## ABOUT SYSTEM PLUS CONSULTING

### 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

#### Europe Sales Office

Lizzie LEVENEZ  
Frankfurt am Main  
Germany  
+49 151 23 54 41 82  
llevenez@systemplus.fr

#### America Sales Office

Steven LAFERRIERE  
Western USA & Canada  
+1 310-600-8267  
laferriere@yole.fr

Chris YOUUMAN  
Eastern USA & Canada  
+1 919-607-9839  
chris.youuman@yole.fr

#### Asia Sales Office

Takashi ONOZAWA  
Japan & Rest of Asia  
+81 80 4371 4887  
onozawa@yole.fr

Mavis WANG  
Greater China  
TW +886 979 336 809  
CN +8613661566824  
wang@yole.fr

Peter OK  
Korea  
+82 10 4089 0233  
peter.ok@yole.fr

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**
- **TEARDOWN TRACKS**
- **CUSTOM ANALYSES**
- **COSTING SERVICES**
- **COSTING TOOLS**
- **TRAININGS**

www.systemplus.fr  
sales@systemplus.fr

# TERMS AND CONDITIONS OF SALES



**Definitions:** "Acceptance": Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by signing the purchase order which mentions "I hereby accept Yole Développement's Terms and Conditions of Sale".

**"Buyer":** Any business user (i.e. any person acting in the course of its business activities, for its business needs) entering into the following general conditions to the exclusion of consumers acting in their personal interests.

**"Contracting Parties" or "Parties":** The Seller on one hand and the Buyer on the other hand. **"Intellectual Property Rights" ("IPR")** means any rights held by the Seller in its Products, including any patents, trademarks, registered models, designs, copyrights, inventions, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they have been registered or not and including any pending registration of one of the above mentioned rights.

**"Products":** Depending on the purchase order, reports or monitors on MEMS, Imaging, SSL, Advanced Packaging, MedTech, Power Electronics and more, can be bought either on a unit basis or as a bundled offer (i.e. subscription for a period of 12 calendar months).

**"Report"**

Reports are established in PowerPoint and delivered in a PDF format with an additional Excel file. 30 min of Q&A session with an analyst/author can be included for all purchased reports (except the ones bought in one user license). More time can be allocated on a fee basis.

**"License":** For the reports 3 different licenses are proposed. The buyer has to choose one license type:

- One user license: The report is intended for only one identified user at the Company purchasing the report - Sharing is strictly forbidden
- Multi-user license: The report can be shared by the identified user of the Company purchasing the report with an unlimited number of employees of said Company. However these rights are limited to the country of the identified user. Subsidiaries and joint-ventures are excluded.
- Corporate license: The report can be shared by the identified user of the Company purchasing the report with an unlimited number of employees of said Company on a global basis. Subsidiaries are included, while joint-ventures are excluded. Nothing herein is intended to prevent the Yole Group of Companies from offering to sell a report to an employee who shall place an order with Yole Group of Companies for such purpose. **DISCLAIMER:** Notwithstanding the fact that persons within an organisation may be entitled to access a report pursuant to a multi-user license or a corporate license previously sold by Yole Développement, in no event shall Yole Développement incur any liability in any form whatsoever if Yole Développement sells one or more additional licenses to use a report directly to such persons.

**"Monitor"**

Monitors are established and delivered in Excel. An additional PDF can also join it. Q&A with an Analyst is possible for each monitor with a maximum limit of 100h/year. Frequency of the release varies according to the monitor or service.

**"Seller":** Based in Villeurbanne (France, headquarters) Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With more than 70 market analysts, Yole Développement works worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

## 1. SCOPE

**1.1** The Contracting Parties undertake to observe the following general conditions when agreed by the Buyer and the Seller.

ANY ADDITIONAL, DIFFERENT, OR CONFLICTING TERMS AND CONDITIONS IN ANY OTHER DOCUMENTS ISSUED BY THE BUYER AT ANY TIME ARE HEREBY OBJECTED TO BY THE SELLER, SHALL BE WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

**1.2** This agreement becomes valid and enforceable between the Contracting Parties after clear and non-equivocal consent by any duly authorized person representing the Buyer. For these purposes, the Buyer accepts these conditions of sales when signing the purchase order which mentions "I hereby accept Yole Développement's Terms and Conditions of Sale". This results in acceptance by the Buyer.

**1.3** Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email or to the Buyer's address. In the absence of any confirmation in writing, orders shall be deemed to have been accepted.

## 2. MAILING OF THE PRODUCTS

**2.1** Products are sent by email to the Buyer:

- Within a few days from the order for Products already released and paid; or
- Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.

**2.2** The Seller shall by no means be responsible for any delay in respect of article 2.1 above, and including in cases where a new event or access to new contradictory information would require for the analyst extra time to compute or compare the data in order to enable the Seller to deliver a high quality Products.

**2.3** The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in article 3.

**2.4** The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. If the Product's electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that it is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

**2.5** The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity to the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

**2.6** No return of Products shall be accepted without prior information to the Seller, even in case of delayed delivery. Any Product returned to the Seller without providing prior information to the Seller as required under article 2.5 shall remain at the Buyer's risk.

## 3. PRICE, INVOICING AND PAYMENT

**3.1** Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are expressed to be inclusive of all taxes (except for France where VAT will be added). The prices are re-evaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.

**3.2** Payments due by the Buyer shall be sent by cheque payable to Yole Développement, credit card or by electronic transfer to the following account:

HSBC, 1 place de la Bourse 69002 Lyon France

Bank code: 30056

Branch code: 00170

Account n°: 0170 200 1565 87

BIC or SWIFT code: CCFRFRPP

IBAN: FR76 3005 6001 7001 7020 0156 587

To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be mentioned on the order.

**3.4** Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the «BCE» + 7 points, in accordance with article L. 441-6 of the French Commercial Code. Our publications (report, database, tool...) are delivered only after reception of the payment.

**3.5** In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice at the stage in progress, and to take legal action for damages.

## 4. LIABILITIES

**4.1** The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products and for the use and interpretations he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces therefrom.

**4.2** The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement

**4.3** In no event shall the Seller be liable for:

- a) Damages of any kind, including without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or information) arising out of the use of or inability to use the Seller's website or the Products, or any information provided on the website, or in the Products;
- b) Any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.

**4.4** All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

**4.5** All the Products that the Seller sells may, upon prior notice to the Buyer from time to time be modified by or substituted with similar Products meeting the needs of the Buyer. This modification shall not lead to the liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

**4.6** In the case where, after inspection, it is acknowledged that the Products contain defects, the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labour costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.

**4.7** The deadlines that the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. If such deadlines are not met, it shall not lead to any damages or cancellation of the orders, except for non-acceptable delays exceeding [3] months from the stated deadline, without information from the Seller. In such case only, the Buyer shall be entitled to ask for a reimbursement of its first down payment to the exclusion of any further damages.

**4.8** The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to the Products. Although the Seller shall take reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making the Products available, the Seller cannot guarantee that any Product will be free from infection.

## 5. FORCE MAJEURE

The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not the fault of the Seller.

## 6. PROTECTION OF THE SELLER'S IPR

**6.1** All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.

**6.2** The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish the Product, or any part of it to any other party other than employees of its company (only in the country of the primary user). The Buyer shall have the right to use the Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use the Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmittals over any network (including any local area network);
- Use in any timesharing, service bureau, bulletin board or similar arrangement or public display;
- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning the Product.

**6.3** If the Buyer would like to use data coming from the Products for presentations, press announcements and any other projects, the Buyer needs to contact Yole Développement's Public Relations Director ([info@yole.fr](mailto:info@yole.fr)) to get an official authorization and verify data are up to date. In return the Seller will make sure to provide up-to-date data under a suitable public format.

**6.4** The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has sent the Products and shall personally take care of any related proceedings, and the Buyer shall bear related financial consequences in their entirety.

**6.5** The Buyer shall define within its company a contact point for the needs of the contract. This person will be the recipient of each new report. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company. In the context of Bundle and Annual Subscriptions, the contact person shall decide who within the Buyer, shall be entitled to receive the protected link that will allow the Buyer to access the Products.

**6.6** Please note that whether in Bundles or Annual Subscription, all unselected reports will be cancelled and lost after the 12 month validity period of the contract.

**6.7** As a matter of fact the investor of a company, external consultants, the joint venture done with a third party, and so on cannot access the report and should pay a full license price.

## 7. TERMINATION

**7.1** If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be borne by the Seller, following this decision.

**7.2** In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

## 8. MISCELLANEOUS

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party.

The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

## 9. GOVERNING LAW AND JURISDICTION

**9.1** Any dispute arising out or linked to these Terms and Conditions or to any contract/orders entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.

**9.2** French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.