

LED

IC

MEMS

IMAGING

PACKAGING

SYSTEM

POWER

# Murata SAW Thermo-Compensated Band 8 Filter in Low Band Front-End Module

*Murata has introduced thermo-compensated filter technology with a ceramic substrate in the Samsung Galaxy S7's front-end module*



In the front-end filter market, Murata, along with Broadcom, Qorvo, and Skyworks, is an RF components leader. Murata has forged its empire on ceramic passive electronic components and ceramic filters. Today, this old but effective technology is still used. Murata's recent acquisition of Peregrine Semi-

conductor (which specialized in RF CMOS) has provided entry into the smartphone market. The flagship Samsung Galaxy S7 smartphone is the latest one to integrate Murata's front-end module with the FAJ15, featuring Murata's thermo-compensated technology.

The front-end module is located on the smartphone's main board, where Samsung has proposed a different configuration of its LTE front end. Murata's FAJ15 was only found in the Galaxy S7's U.S. version, where it shares the front end with Qorvo and Broadcom.

The FAJ15 is dedicated to LTE low band. It is made with several filter dies assembled on a ceramic substrate. The filters are either bare dies or packages molded into FEM molding. As piezoelectric for SAW technology, the substrate dies are either LN (lithium niobium oxide) or LT (lithium tantalum oxide). The FEM contains two SAW technologies: STD-SAW (standard SAW) and TC-SAW (thermally compensated SAW). This report only focuses on the duplexer for the Band 8 LTE integrated in the FEM. This band's specification required very low thermal drift, so the thermo-compensated layers are integrated to provide better performance relating to thermal changes.

The complete chip fabrication process and a cost estimate of the Band 8 component are presented in this report, along with a brief substrate packaging comparison with FEMs from Qorvo and Broadcom.

**Title:** Murata FAJ15 – TC-SAW Filter

**Pages:** 93

**Date:** August 2016

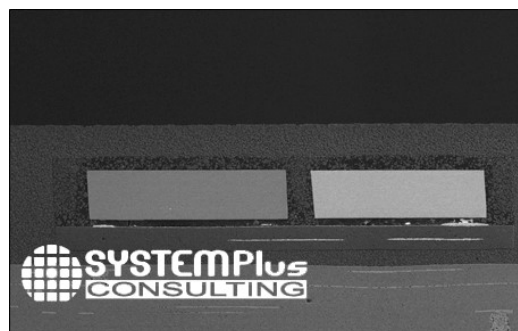
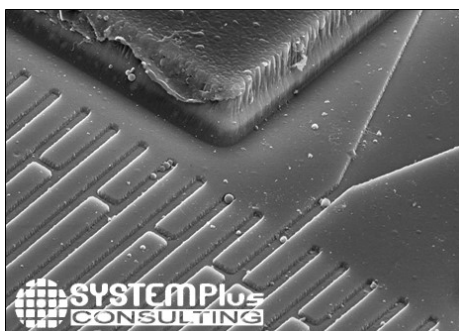
**Format:** PDF & Excel file

**Price:** Full report: EUR 2,990

## COMPLETE TEARDOWN

### WITH:

- Detailed photos
- Precise measurements
- Materials analysis
- Manufacturing process flow
- Supply chain evaluation
- Manufacturing cost analysis
- Estimated sales price
- Package substrate comparison with Qorvo TQF6405 and Broadcom AFEM9040



# TABLE OF CONTENTS

## Overview / Introduction

## Company Profile and Supply Chain

## Samsung Galaxy S7 Teardown

## Physical Analysis

- Physical analysis methodology
- Front-end module package
- Front-end module views
- Front-end module cross-section
- Front-end module dies
- Power amplifier die-view & dimensions
- SPDT switch die-view & dimensions
- Band 8 duplexer - SAW filter die-view & dimensions
- Band 8 duplexer - SAW filter die opening
- Band 8 duplexer - SAW filter die cross-section

## Manufacturing Process Flow

- SAW fabrication unit
- SAW wafer process
- Component packaging

## Cost Analysis

- SAW filter wafer front-end cost
- SAW filter wafer front-end cost per process
- SAW filter front-end probe test, thinning, and dicing cost
- SAW filter die cost
- Band 8 duplexer Package cost analysis
- Estimated sales price

## Substrate Packaging Comparison with FEMs from Qorvo and Broadcom



**Author:**  
Stéphane Elisabeth

Stéphane has a deep knowledge of materials characterizations and electronics systems. He holds an Engineering Degree in Electronics and Numerical Technology, and a PhD in Materials for Microelectronics.



**Author (Lab):**  
Yvon Le Goff

Yvon Le Goff has joined System Plus Consulting in 2011, in order to set up the laboratory of System Plus Consulting. He previously worked during 25 years in Atmel Nantes Technological Analysis Laboratory as fab support in physical analysis, and 3 years at Hirex Engineering in Toulouse, in a DPA lab.

# ANALYSIS PERFORMED WITH OUR COSTING TOOLS MEMS COSIM+ AND IC PRICE+

	Process-Based Costing Tools	Parametric Costing Tools
Integrated Circuits		IC Price+
MEMS	MEMS CoSim+	MEMS Price+
Power Devices & Modules	Power CoSim+	Power Price+
LEDs	LED CoSim+	
Advanced Packaging	3D-Package CoSim+	
Electronic Boards Substrates		PCB Price+
Electronic Systems	SYScost+	
Displays		Display Price+

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

### MEMS CoSim+

Cost simulation tool to evaluate the cost of any MEMS process or device:

**From single chip to complex structures.**

### IC Price+

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

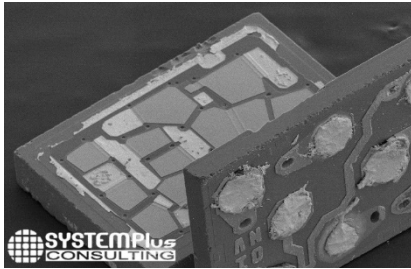
Performed by



## RELATED REPORTS

### Avago AFEM-9040 Avago's New Generation Front-End Module

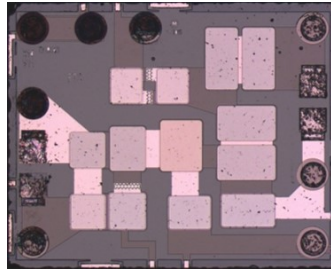
Avago has introduced a new generation of film bulk acoustic resonator (FBAR-BAW) technology in the Samsung Galaxy S7.



Pages: 112  
Date: June 2016  
Full report: EUR 3,290\*

### Qorvo TQF6405 in iPhone 6s Plus SMR-BAW High Band Filter

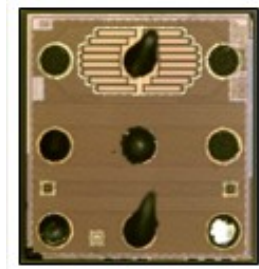
Apple integrates in its smartphone the innovative Solid Mounted Resonators developed by Qorvo.



Pages: 86  
Date: March 2016  
Full report: EUR 2,990\*

### Cavendish Kinetics 32CK417R MEMS Antenna Tuner

Cavendish Kinetics revolutionizes the RF industry with its first MEMS antenna tuner exhibiting extra small size and very low insertion losses.



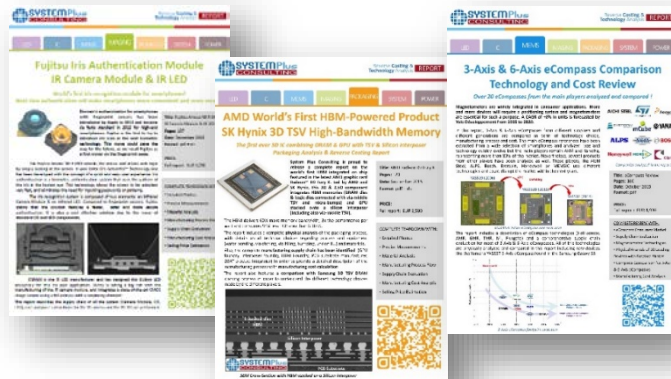
Pages: 102  
Date: June 2015  
Full report: EUR 2,990\*

## ANNUAL SUBSCRIPTION OFFER

Each year System Plus Consulting releases a comprehensive collection of new reverse engineering & 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 40 reports released each year on the following topics (considered for 2016):

- MEMS & Sensors (20 reports):
  - Gyros/Accelerometers/IMU
  - Oscillators/RF switches
  - Pressure sensors/Gas sensors
- Power Electronics & Systems (12 reports):
  - GaN and SiC devices
  - Inverters & modules
  - Automotive radars
  - Head up displays, displays
- ICs (3 reports):
  - Multimedia SoC
  - Ethernet for car IC, etc.
- Imaging & LEDs (11 reports):
  - Camera modules, infrared sensors & cameras
  - LEDs
- Advanced Packaging (5 reports):
  - WLP, TSV
  - Embedded devices, etc.

# ORDER FORM

Please process my order for "Delphi Rear and Side Detection System" Reverse Costing Report

Ref.: SP16283

Full Reverse Costing report: EUR 2,990\*

Annual Subscription (including this report as the first of the year):

- |                                 |             |                                  |             |
|---------------------------------|-------------|----------------------------------|-------------|
| <input type="radio"/> 3 reports | EUR 8 400*  | <input type="radio"/> 7 reports  | EUR 16 000* |
| <input type="radio"/> 4 reports | EUR 11 000* | <input type="radio"/> 10 reports | EUR 21 000* |
| <input type="radio"/> 5 reports | EUR 12 500* | <input type="radio"/> 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](http://www.systemplus.fr). The present document is valid 6 months after its publishing date: September 2016

## 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:.....

## 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](http://www.systemplus.fr) - [sales@systemplus.fr](mailto:sales@systemplus.fr)

## 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 Nouë Bras de Fer

44200 Nantes – France

Contact:

EMAIL: [sales@systemplus.fr](mailto:sales@systemplus.fr)

TEL: +33 2 40 18 09 16



# 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'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 the 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.

"License": For the reports and databases, 3 different licenses are proposed. The buyer has to choose one license:

- One user license: one person at the company can use the report.
- Multi-user license: the report can be used by unlimited users within the company. Subsidiaries and Joint-Ventures are not included.

• Corporate license: purchased under "Annual Subscription" program, the report can be used by unlimited users within the company. Joint-Ventures are not included.

"Products": Depending on the purchase order, reports or database on MEMS, CSC, Optics/MOEMS, Nano, bio... to be bought either on a unit basis or as an annual subscription. (i.e. subscription for a period of 12 calendar months). The annual subscription to a package (i.e. a global discount based on the number of reports that the Buyer orders or accesses via the service, a global search service on line on 1-micronews and a consulting approach), is defined in the order. Reports are established in PowerPoint and delivered on a PDF format and the database may include Excel files.

"Seller": Based in Lyon (France headquarters), Yole Développement is a market research and business development consultancy company, facilitating market access for advanced technology industrial projects. With more than 20 market analysts, Yole works worldwide with the key industrial companies, R&D institutes and investors to help them understand the markets 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-ambiguous 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'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 [1] month from the order for Products already released; 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 Some weeks prior to the release date the Seller can propose a pre-release discount to the Buyer

The Seller shall by no means be responsible for any delay in respect of article 2.2 above, and including incases 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. The prices may be reevaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.

3.2 Yole may offer a pre release discount for the companies willing to acquire in the future the specific report and agreeing on the fact that the report may be release later than the anticipated release date. In exchange to this uncertainty, the company will get a discount that can vary from 15% to 10%.

3.3 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 thereof.

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:

- 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;
- 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 labor 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 [4] 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, labor 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. 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 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.

6.4 The Buyer shall define within its company point of contact for the needs of the contract. This person will be the recipient of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.

6.5 In the context of annual subscriptions, the person of contact shall decide who within the Buyer, shall be entitled to access on line the reports on 1-micronews.com. In this respect, the Seller will give the Buyer a maximum of 10 password, unless the multiple sites organization of the Buyer requires more passwords. The Seller reserves the right to check from time to time the correct use of this password.

6.6 In the case of a multisite, multi license, only the employee of the buyer can access the report or the employee of the companies in which the buyer have 100% shares. As a matter of fact the investor of a company, the joint venture done with a third party etc..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.

Distributed by



Performed by

