Table of Contents

Overview / Introduction 3
- Executive Summary
- Reverse Costing Methodology

Company Profile 6
- Qorvo, Broadcom Limited, Skyworks Solution, STMicroelectronics, Murata Integrated Passive Solutions (Former IPDiA)
- Smartphones Teardown: Xiaomi Mi6, Samsung Galaxy S7, Samsung Galaxy S8, Apple iPhone X
- RF Substrate
- Substrate by Application
- Glass Substrate Market for RF devices

Market Analysis 45
- RF Substrate
- Substrate by Application
- Glass Substrate Market for RF devices

Physical Comparison 45
- Materials Comparison
- Passives density per applications
- Process Comparison
- Cost Comparison

Physical Analysis 47
- Synthesis of the Physical Analysis
- RF IPD for Wifi/Bluetooth Application
  - Qorvo’s IPD
    - Die Views & Dimensions
    - Die Top Structure
    - Die Electrical Structure
    - Die Cross-Section
    - Package Opening
    - Die Process
  - Skyworks’ IPD
  - STMicroelectronics’ IPD
  - RF IPD for LTE/HSPA/EDGE/GSM
  - Broadcom’s IPD
  - Murata’s IPD
  - Skyworks’ IPD

Manufacturing Process Flow 238
- Global Overview
- RF IPD for Wifi/Bluetooth Application
  - Wafer Fabrication Unit
  - Front-End Process Flow
  - RF IPD for LTE/HSPA/EDGE/GSM
  - RF IPD for ISM/SDR

Cost Analysis 284
- Yields Explanation & Hypotheses
- RF IPD for Wifi/Bluetooth Application
  - Qorvo’s IPD Die
    - Main Steps of Economical Analysis
      - Wafer Front-End Cost
      - Wafer Front-End Cost per process steps
      - Back-End 0 Cost: Bumping & Dicing
      - Back-End Final Test
      - Component Cost
  - Skyworks’ IPD
  - STMicroelectronics’ IPD
  - RF IPD for LTE/HSPA/EDGE/GSM
  - Broadcom’s IPD
  - Murata’s IPD
  - Skyworks’ IPD
  - RF IPD for ISM/SDR

Estimated Price Analysis 365

Company services 367
Executive Summary

- This comparative technologies & cost study has been conducted to provide insight on technology & costing data for RF Integrated Passive Devices (IPD) working on different ranges of communication frequency. The report includes the study of seven IPDs found in **flagships smartphones (Apple iPhone X, Samsung Galaxy S7 & S8, LeTv Le Max 2 Pro) or on the market.** This report provides a deep analysis of RF IPD containing inductance, resistor, and capacitance. Its complete System Plus reports portfolio along with decoupling capacitors IPD.

- This comparative technology study was conducted to provide insight regarding technology and cost estimates for RF IPDs in various applications. This report studies nine devices in three applications (Wifi/Bluetooth/cellular communication (LTE/HSPA/GPRS/EDGE), industrial, and scientific/medical short-range devices (ISM/SRD), where five players (Qorvo, Skyworks, Murata, Broadcom, and STMicroelectronics) are active. Besides the ISM/SRD applications, the other devices are extracted from recent smartphones like the new Apple iPhone X.

- All devices are analyzed in detail, and electrical structures of each component are presented. Sizes and technologies are extracted to provide a large sampling of various IDMs’ technical and economical choices. We also provide an overview of passive integration techniques for inductors, resistors, and capacitors.

- This report includes a description of each component, its major characteristics (substrate type (GaAs, silicon, glass), passivation layers, passive integration, etc.) and a comparison of all devices analyzed. Also included is a manufacturing cost estimate for the IPDs.
Smartphones Teardown – Apple iPhone X

Apple iPhone X – Front & Back View
©2017 by System Plus Consulting

Apple iPhone X – Opened View
©2017 by System Plus Consulting

Apple iPhone X – Board Extracted
©2017 by System Plus Consulting
Package Opening

- Package opening reveal

Package Opening – Top View
©2017 by System Plus Consulting
Integrated Passives Devices Applications

Overview / Introduction

Company Profile & Supply Chain
- Qorvo
- Broadcom
- Skyworks
- STMicroelectronics
- Murata Passive Integrated Solution
- Technologies

Physical Analysis
Manufacturing Process Flow
Cost Analysis
Selling Price Analysis
About System Plus

Source: STMicroelectronics
Glass Material Market for RF devices

Glass Substrate Market Forecast for RF applications ($M)

- Company Profile & Supply Chain
  - Qorvo
  - Broadcom
  - Skyworks
  - STMicroelectronics
  - Murata Passive Integrated Solution
  - Technologies

- Physical Analysis
- Manufacturing Process Flow
- Cost Analysis
- Selling Price Analysis
- About System Plus
# Materials Comparison

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Lines</th>
<th>MIM Capacitor</th>
<th>Resistors</th>
<th>Deep Trench Capacitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>WiFi/Bluetooth</td>
<td>♦️ Qorvo ♦️</td>
<td>♦️ ST ♦️</td>
<td>♦️ Skyworks ♦️</td>
<td>♦️ Broadcom ♦️</td>
</tr>
<tr>
<td>LTE/HSPA/EDGE/GSM</td>
<td>♦️ Murata ♦️</td>
<td>♦️ Skyworks ♦️</td>
<td>♦️ Broadcom ♦️</td>
<td>♦️ IPDiA ♦️</td>
</tr>
<tr>
<td>ISM/SRD</td>
<td>♦️ ST ♦️</td>
<td>♦️ Murata ♦️</td>
<td>♦️ Broadcom ♦️</td>
<td>♦️ IPDiA ♦️</td>
</tr>
</tbody>
</table>
Synthesis of the Physical analysis

- **WiFi/Bluetooth**
  - Qorvo’s WiFi IPD
  - Skyworks’s WiFi IPD
  - STMicroelectronics’ Bluetooth IPD
  - Broadcom’s LTE IPD
  - IPDiA’s IMS IPD

- **LTE/HSPA/EDGE/GSM**
  - Murata
  - Skyworks
  - Avago

- **ISM/SRD**
  - STMicro
  - ASPIC
STMicroelectronics’ IPD – Package/Die View & Dimensions

- Package:
- Dimensions:
- Pin Pitch:

- Package Marking:
- Die Marking:

Package Top View

Package Bottom View

Package Side View
STMicroelectronics’ IPD – Die Structure – Top view

Die overview – Optical View
STMicroelectronics’ Bluetooth IPD – Die Structure – Electrical Structure

---

**Overview / Introduction**

**Company Profile & Supply Chain**

**Physical Analysis**
- Synthesis
- Qorvo’s WiFi IPD
- Skyworks’s WiFi IPD
- STMicroelectronics’ Bluetooth IPD
- Broadcom’s LTE IPD
- IPDiA’s IMS IPD

**Manufacturing Process Flow**

**Cost Analysis**

**Selling Price Analysis**

**About System Plus**
STMicroelectronics’ Bluetooth IPD – Die Structure – Top view

Die overview – Optical View

•

•

•

•
Overview / Introduction

Company Profile & Supply Chain

Physical Analysis
- Synthesis
- Qorvo’s WiFi IPD
- Skyworks’s WiFi IPD
- STMicroelectronics’ Bluetooth IPD
- Broadcom’s LTE IPD
- IPDIa’s IMS IPD

Manufacturing Process Flow

Cost Analysis

Selling Price Analysis

About System Plus

STMicroelectronics’ Bluetooth IPD – Die Structure – Top view

Die overview – Optical View

Coupled Inductance
STMicroelectronics’ Bluetooth IPD – Die Cross Section

Cross-Section Plan

Die Cross-Section – Optical View
STMicroelectronics’ Bluetooth IPD – Die Cross Section – Capacitance

Die Cross-Section

Die Cross-Section – Capacitance – SEM View
Global Overview

- WiFi/Bluetooth
  - Qorvo: Die process
    - Thin Film Deposition
    - Lithography steps
    - Probe test
    - Dicing
  - STMicroelectronics: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
  - Skyworks: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
- LTE/HSPA/EDGE/GSM
  - Murata: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
  - Skywork: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
  - Avago: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
- ISM/SRD
  - STMicroelectronics: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
  - iPDIA: Die process
    - Thin Film Deposition
    - Probe test
    - Dicing
Qorvo’s IPD – MEMS Process Flow

drawing not to scale
STMicroelectronics’ IPD – Wafer Front-End Cost

<table>
<thead>
<tr>
<th>Cost Analysis</th>
<th>Substrate Cost</th>
<th>Clean Room Cost</th>
<th>Equipment Cost</th>
<th>Consumable Cost</th>
<th>Labor Cost</th>
<th>Yield Losses Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Front-End Cost Breakdown (Medium Yield)

- Substrate Cost
- Clean Room Cost
- Equipment Cost
- Consumable Cost
- Labor Cost
- Yield Losses Cost
STMicroelectronics’ IPD – Component Cost

Component Cost Breakdown (Medium Yield)

- Front-End Cost
- BE: Test Cost
- BE: Packaging Cost
- BE: Yield losses

Cost Analysis
- Supply Chain
- Yields
- Front-End Cost
- Back-End Cost
- Component Cost

Supply Chain

Yields

Front-End Cost

BE: Packaging Cost

Final Test Cost

Wafer Cost

Nb of potential dies per wafer

Nb of good dies per wafer

Front-End Cost

BE: Packaging Cost

BE: Test Cost

BE: Yield losses

WLP Component Cost

By adding the probe test cost, the wafer cost ranges from...

The number of good dies per wafer is estimated to ranges from...

according to yield variations, which results in a component cost ranging from...

- The die represents...
- The package assembly represents...
- Final test and yield losses account for...
STMicroelectronics’ IPD – Estimated Manufacturer Price

**Component cost**

**Component price**

<table>
<thead>
<tr>
<th></th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
</tr>
<tr>
<td>STMicro Gross Profit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturer Price</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We estimate that STMicroelectronics realizes a better gross margin on the IPD balun due to a good market position. We estimate this gross margin to 50%, which results in a final component price ranging...

This corresponds to the selling price for large volume to OEMs.
Related Reports

**REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING**

**RF**
- Advanced RF SiPs for Cell Phones: Reverse Costing Overview
- Smartphone RF Front-End Module Review
- Silicon Capacitor Technology and Cost Review

**MARKET AND TECHNOLOGY REPORTS - YOLE DÉVELOPPEMENT**

**RF**
- Glass Substrate Manufacturing in the Semiconductor Field
- Advanced RF System-in-Package for Cell Phones 2017
Business Model Fields of Expertise

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

Company services
- Feedbacks
- Contact
- Legal

About System Plus

© 2017 System Plus Consulting | Integrated Passive Devices Review
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 LEVEÑEZ
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
ORDER FORM

Please process my order for “RF IPD Technology & Cost Review” Reverse Costing Report

Ref.: SP17328

☐ Full Reverse Costing report: EUR 3,990*

☐ 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: December 2017

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 - 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 Noué Bras de Fer
44200 Nantes – France

Contact:

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