Camera Module Comparison 2019
Physical Analysis & Cost Comparison

Imaging report by Audrey LAHRACH
January 2019 – version 1
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Executive Summary

Accompanying Yole Development’s CCM Applications 2019 Market report, we have conducted this comparative study to provide insight on the structure and the technology of 28 CCMs extracted from seven flagship smartphones from several major brands: the Apple iPhone X, Samsung Galaxy S9, Huawei P20 Pro, Huawei Mate 20 Pro, Xiaomi Mi8, Oppo Find X and Vivo X21UD.

Four years ago, only two cameras on average could be found in smartphone. Today this number has risen to four in order to add other features such as face recognition, with infrared camera modules, in the front camera or to improve the zoom in the rear camera.

We analyze rear and front-facing CCMs including standard mono modules, dual modules, iris scanners, 3D camera modules and triple modules. We also compare them in terms of structure overview, module integration, lens numbers and dimensions, CMOS Image Sensor resolution, pixel size and other parameters. Additionally, we have studied the costs of these camera modules to compare the economic choices of the manufacturers. We present a historical comparative review in the report for four players, Apple, Samsung, Huawei and Xiaomi, in order to show the evolution of their technological choices.
### Rear Facing

**Dual Camera**
- iPhone X, XS Max
- Samsung galaxy S9
- Oppo Find X
- Xiaomi Mi8
- Vivo X21UD

**Tri Camera**
- Huawei P20 Pro
- Mate 20 Pro

### Front Facing

<table>
<thead>
<tr>
<th>OEM</th>
<th>Smartphone</th>
<th>Position</th>
<th>OS</th>
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<tbody>
<tr>
<td>Apple</td>
<td>iPhone X</td>
<td>Rear</td>
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<tr>
<td>Apple</td>
<td>iPhone X</td>
<td>Front</td>
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<tr>
<td>Xiaomi</td>
<td>Mi9 Explorer</td>
<td>Rear</td>
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<td>P20 Pro</td>
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<td>Mate 20 Pro</td>
<td>Rear</td>
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<td>Huawei</td>
<td>Mate 20 Pro</td>
<td>Front</td>
<td></td>
</tr>
<tr>
<td>Oppo</td>
<td>Find X</td>
<td>Rear</td>
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<tr>
<td>Vivo</td>
<td>X21UD</td>
<td>Rear</td>
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<tr>
<td>Vivo</td>
<td>X21UD</td>
<td>Front</td>
<td></td>
</tr>
</tbody>
</table>
Apple iPhone X, XS Max & XR

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Dual Rear Camera Module Overview
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iPhone X Specs (from DeviceSpecifications)

### Physical Analysis (Consumer)
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### Primary Camera
The primary camera of the mobile device is usually placed at its back and is used for taking photos and recording videos.

<table>
<thead>
<tr>
<th>Sensor model</th>
<th>Sony Exmor RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor type</td>
<td>CMOS (complementary metal-oxide semiconductor)</td>
</tr>
<tr>
<td>Aperture</td>
<td>f/1.8</td>
</tr>
<tr>
<td>Focal length</td>
<td>≈ 3.99 mm (millimeters)</td>
</tr>
<tr>
<td>Image resolution</td>
<td>4032 x 3024 pixels, 12.19 MP (megapixels)</td>
</tr>
<tr>
<td>Video resolution</td>
<td>3840 x 2160 pixels, 8.29 MP (megapixels)</td>
</tr>
</tbody>
</table>

### Video FPS
Information about the maximum number of frames per second (fps), supported by the device while recording a video at a maximum resolution. Some of the main standard frame rates for recording and playing video are 24p, 30p, 60p.

| FPS | 60 fps (frames per second) |

### Features
- Autofocus
- Continuous shooting
- Digital zoom
- Optical image stabilization
- Geotagging
- Panorama
- HDR
- Touch focus
- Face detection
- White balance settings
- ISO settings
- Exposure compensation
- Self-timer
- Scene mode
- Macro mode
- RAW

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Camera Module with flex Top View ©2019 by System Plus Consulting

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Camera Module with flex - Side View ©2019 by System Plus Consulting
Camera Module #1 Teardown

Overview / Introduction/
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Die Area: $xx \text{mm}^2$

(XX X XXmm)

Nb of PGDW per 12-inch wafer: XXX

Pad number: XXX

Pixel array: $xx \text{mm}^2$

(XX X XXmm)

CIS resolution: 4250x3030 (12.9Mp)

- Pixel area: $xx \mu \text{m}^2$
- Pixel size: $xx \mu \text{m}$
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Camera Module Cross-Section – Module #1

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Camera Module Cross-Section – Module #1

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Camera Module #1 Cross-Section – Optical Overview
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Camera Module Cross-Section – Module #1

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Huawei Comparison – Package

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Huawei Mate 20 Pro – Front Camera
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Huawei Mate 20 Pro – NIR Camera
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<td>2 x 12</td>
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<td>Mate 20 Pro (NIR Camera)</td>
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<td>2 x 12</td>
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Huawei Comparison – Sensor Die

<table>
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<th>Ref.</th>
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<th>Pixel array</th>
<th>PGDW</th>
<th>Pad number</th>
<th>Pixel Size</th>
<th>CIS resolution (Mp)</th>
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Huawei P9 – Front Camera
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Huawei P10 – Front Camera
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Huawei P20 Pro – Front Camera
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Huawei Mate 20 Pro – Front Camera
©2018 by System Plus Consulting

Huawei Mate 20 Pro – NIR Camera
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Huawei Comparison – Cross-Section

<table>
<thead>
<tr>
<th>Ref.</th>
<th>OIS/AF</th>
<th>Lens Number</th>
<th>Substrate type</th>
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</table>
### Camera Module Front - Dual

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<th>Lens Module Price</th>
<th>Autofocus Actuator / OIS Price</th>
<th>CIS Die Cost</th>
<th>Final Assembly &amp; Test Cost</th>
<th>Camera Module Cost</th>
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<td><strong>Cost</strong></td>
<td><strong>Breakdown</strong></td>
<td><strong>Cost</strong></td>
<td><strong>Breakdown</strong></td>
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<td><strong>Breakdown</strong></td>
<td><strong>Cost</strong></td>
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<td><strong>Oppo Find X</strong></td>
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<td><strong>Oppo Find X</strong></td>
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</table>
CMOS Camera Modules (CCM) have become a key sensor technology – what are the dynamics and strategies in this highly competitive market?

**KEY FEATURES OF THE REPORT**
- Updated forecasts
- Ecosystem analysis
- Technology update
- New trends and applications
- Special focus on Wafer Level Optics

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- Orbbec’s Front 3D Depth Sensing System in the Oppo Find X
- STMicroelectronics’ Near Infrared Camera Sensor in the Apple iPhone X
- Sony IMX400 Tri-layer Stacked CMOS Image Sensor (CIS) with Integrated DRAM and DSP

**MARKET AND TECHNOLOGY REPORTS - YOLE DÉVELOPPEMENT**

**IMAGING**
- Status of the CMOS Image Sensor Industry 2018
- 3D Imaging & Sensing 2018
Mobile Camera Module Comparison 2019

Analysis and comparison of 28 different visible and infrared cameras in the Apple iPhone X/XS/XR, Samsung Galaxy S9, Huawei Mate 20 Pro and P20 Pro, Xiaomi Mi8 Explorer Edition, Oppo Find X and Vivo X21UD.

With a Compound Annual Growth Rate of 12% between 2017 and 2023, the mobile camera module semiconductor market is one of the most dynamic in the smartphone space. The $9 billion revenue of the CMOS Camera Module (CCM) industry in 2017 was shared between several companies, including LG Innotek, Samsung Electro-Mechanics and Sunny Optical Technology.

The CCM market has seen several innovations this year. The first is the multiple camera approach, seen on all seven of the models we study in this report. The average is around four cameras per smartphone. The second innovation is the generalization of Optical Image Stabilization (OIS) on the rear CCM. Thirdly, four out of seven smartphones have 3D cameras for face recognition.

This overview will tell you the main OEMs’ choices, and reveal the state of the art of camera modules for leading flagships in 2018.

We have conducted this comparative study to provide insight on the structure and the technology of 28 CCMs extracted from seven flagship smartphones from several major brands: the Apple iPhone X/XS/XR, Samsung Galaxy S9, Huawei P20 Pro, Huawei Mate 20 Pro, Xiaomi Mi8 Explorer Edition, Oppo Find X and Vivo X21UD.

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Yole Développement’s Status of the Camera Module Industry 2019 – Focus on WLO is accompanying this report.

COMPLETE TEARDOWN WITH
- Detailed photos
- Precise measurements
- Module cross-sections
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- Material analysis
- Manufacturing process flow
- Supply chain evaluation
- Manufacturing cost analysis
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MOBILE CAMERA MODULE COMPARISON 2019

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AUTHORS

Audrey Lahrach is in charge of costing analyses for IC, LCD & OLED Displays and Sensor Devices. She holds a Master degree in Microelectronics from the University of Nantes.

Guillaume Chevalier has joined System Plus Consulting in early 2018 to perform physical analyses. He holds a two-year university degree in technology of physical measurements and instrumentation techniques, and previously worked for four years for chemistry, mechanical and mass-metrology laboratories.

LINKED REPORT

Status of the Camera Module Industry 2019 – Focus on Wafer Level Optics – Market and Technology Report by Yole Développement

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Last Name: ………………………………………………………………………………………………………………….
Email: …………………………………………………………………………………………………………………………
Phone: …………………………………………………………………………………………………………………………

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

By bank transfer:
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BIC code: CCFRFRPP
- In EUR
  Bank code : 30056 - Branch code : 00955 - Account : 09550003234
  IBAN: FR76 3005 6009 5509 5500 0323 439
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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.