WHITE PAPER

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Sensor Comparison: Are All IMXs Equal?

There have been many reports about the Sony Pregius sensors in recent months. The goal of this White Paper is to show what lies behind the names of these CMOS sensors, such as IMX174 or IMX250, and what the commonalities and differences in this model series are. We also want to differentiate the Pregius sensors from those of Sony's other major CMOS line, the STARVIS sensors.

Contents

1. The sensors in the Pregius series

The sensors in Sony's Pregius series are CMOS sensors, but are based on the CCD sensor structure which Sony has perfected for decades and which has brought it exceptional success. But Sony was no longer able to resist the trend towards CMOS sensors in industrial image processing.

1.1 Structure

To maintain and even improve the excellent image quality of its CCD sensors in the new CMOS sensors, Sony's new development for the Pregius line was a global shutter pixel, which matches or even surpasses earlier CCD pixels with similarly good noise characteristics. Sony applies its Exmor technology here, where the noise-reduced analog signal is converted into a digital signal directly during the parallel columnar reading of the pixels. This not only improves the noise behavior but increases the speed at the same time.

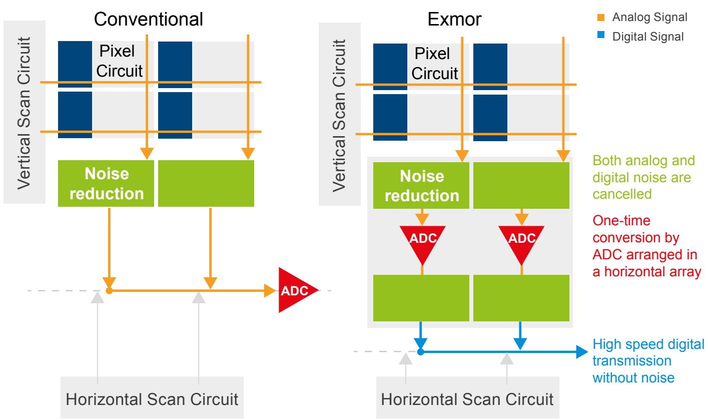

Figure 1: Conventional reading structure compared to the Exmor reading structure

This series was developed for industrial image processing and thus offers short exposure times and exact triggering with very slight delays and excellent efficiency.

1.2 First generation

The first generation of this new sensor series includes the sensors IMX174 and IMX249. They have a pixel pitch of 5.86 µm with a resolution of 1920 x 1200 pixels and thus have no 1:1 relative among Sony's old CCD sensors.

Both of these sensors already reveal Sony's approach of offering two different sensors each based on the same pixel type but with different speeds and sensor features. Sony then offers each simpler version at a lower price. When it comes to the image quality, the differences are only marginal.

Sensor	IMX174/IMX249
Resolution	2,3 MP
Resolution	1920*1200
Sensor format	1/1,2 "
Pixel size	5,86 µm
Max fps @ Basler	164/40 fps

Sensor	IMX174/IMX249
Quantum efficiency	70 %
Dark noise	6,8 e^-
Saturation capacity	32500 e^-
Dynamic range	73,6 dB
SNR	45,10 dB

In the first generation of the Pregius sensors, a particularly notable feature is the very high saturation capacity of over 32 ke^-.

1.3 Second generation

With the second generation of the Pregius series, Sony established a smaller pixel at 3.45 µm.

Sensor	IMX174/ IMX249	IMX252/ IMX265	IMX250/ IMX264	IMX255/ IMX304	IMX253/ IMX267
Resolution MP	2,3 MP	3 MP	5 MP	9 MP	12 MP
Resolution	1920*1200	2048*1536	2448*2048	4112*2176	4112*3008
Sensor format	1/1,2 "	1/1,8 "	2/3 "	1 "	1.1 "
Pixel size	5,86 µm	3,45 µm	3,45 µm	3,45 µm	3,45 µm
max fps @ Basler	164 fps	120 fps	75 fps	40 fps	30 fps

This pixel shows a different behavior in the conversion of light into electrons. Its quantum efficiency (QE) characteristics are very different from those of the first generation.

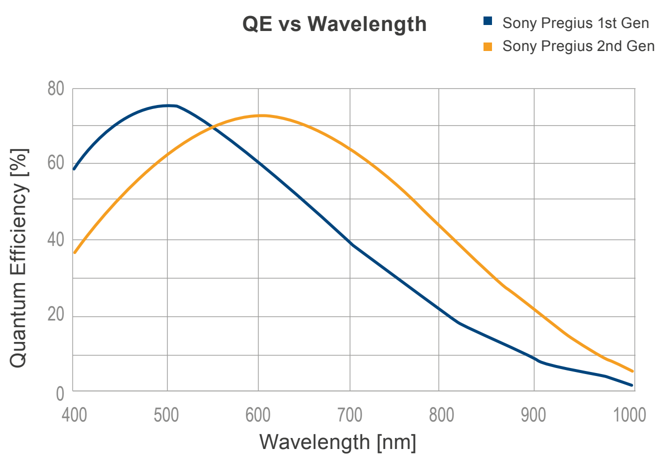

Figure 2: Quantum efficiency of two PREGIUS sensor generations in a comparison; acA1920-50gm (IMX174) as an example of the 1st generation and acA2440-20gm (IMX264) for the 2nd generation

The slight shift in the higher wavelength ranges in the maximum of the curve in particular shows that these are different pixel types that vary accordingly in their imaging behavior.

The slightly different pixel design is also shown in the slightly different EMVA1288 values:

	1st generation	2nd generation			
Sensor	IMX174/ IMX249	IMX252/ IMX265	IMX250/ IMX264	IMX255/ IMX304	IMX253/ IMX267
Quantum efficiency	70 %	66%	67%	65%	65%
Dark noise	6,8 e^-	2,3 e^-	2,3 e^-	2,4 e^-	2,3 e^-
Saturation capacity	32,5 ke^-	10,7 ke^-	10,7 ke^-	10,7 ke^-	10,6 ke^-
Dynamic range	73,6 dB	73 dB	73 dB	72,8 dB	73,5 dB
SNR	45,10 dB	40 dB	40 dB	40,3 dB	40,2 dB

Due to the smaller pixels in the sensors of the 2nd generation, their saturation capacity greatly decreases, which results in values that are more typical for the CMOS sensors.

However, these sensors are also based on the Exmor technology and, as can be seen in the above table, offer excellent noise behavior.

1.4 Functionalities

In terms of its features, the Pregius series is also tailored for industrial image processing. It offers the – in these applications frequently available – option of setting smaller regions of interest (ROIs) to increase the speed and reduce the data load. This is used particularly often in applications where the inspection of smaller image sections is of special interest, such as in printed circuit boards. In PCB inspection, certain components often have greater importance for the functionality of the assembly.

2. The sensors in the STARVIS series

The STARVIS series is a completely different family of sensors. Since this series also includes CMOS sensors, however, its sensors also contain the IMX letters in their type name.

The STARVIS sensor family has existed for quite some time already and was mostly used in surveillance. This is why they were initially available only as color sensors. That has now changed: with the newer monochrome models, the sensors are also increasingly of interest for applications in factory automation. Industrial image processing thus also deals with this line of sensors by now.

2.1 Structure

The STARVIS series consists of rolling shutter sensors with very small pixels of up to 1.85 µm. This series is represented by the sensors IMX178 and IMX226, for example:

	IMX178	IMX226
Resolution	6,4 MP	12,4 MP
Resolution	3096 x 2080	4072 x 3046
Sensor format	1/1,8 “	1/1,7 “
Pixel size	2,4 µm	1,85 µm
Max. fps @ Basler	59 fps	31 fps

An important aspect of this line of sensors is that they are back-illuminated.

2.1.1 Back illumination

With lower pixel sizes, the conventional manufacturing method of sensors makes it very difficult to collect enough light. The reason is that those parts of the pixel that don’t contribute to collecting light, such as amplifiers or A/D converters, are generally mounted on the sensor side that is exposed to the light, which means that they take up part of the surface next to the light-sensitive surface of each pixel. The smaller the pixel, the larger the percentage of the surface that can’t be used to generate electrons. In the pixel sizes of sensors in the STARVIS series, the proportion of these virtually “blind” structures is so large that the quantum efficiency would be extremely low in a normal design. This is why Sony is using a trick that was initially perfected due to a demand for continuously increasing resolutions in the smartphone industry: back illumination. Although a sensor with an illuminated “back” is manufactured in a normal process, which means that the chip surface is assembled with the required electronic structures, the sensor is then turned around so that the actual amplifier and evaluation electronics migrate to the sensor’s back. The light-sensitive part of the sensor is now accommodated in the front. This means that the light-sensitive chip structures and supporting chip structures no longer compete for a shared surface, so that the light-sensitive part can be larger without interfering with the evaluation electronics. This trick actually makes it possible to use nearly the entire pixel surface for the photoelectric reaction.

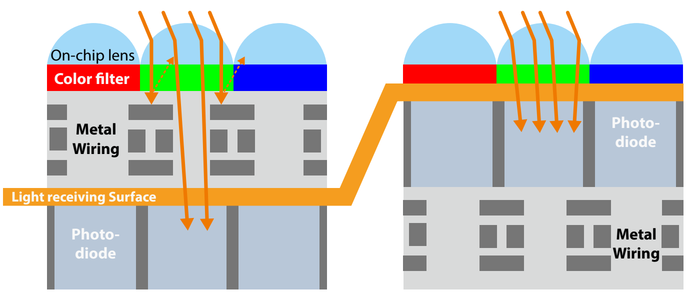

Figure 3: Front-illuminated compared to back-illuminated

Sony combines this technology with the advantages of the low-noise readouts and high speed of the Exmore series and then calls the combination Exmor R.

The models of the STARVIS series only include sensors that rely on this technology and were also slightly optimized for the wavelengths of the adjacent near infrared range, so that they can also deliver good surveillance images even at night.

2.1.2 Functions

The IMX178 and IMX226 sensors were designed for the surveillance area. From the perspective of industrial image processing, this is accompanied by a few functional limitations. The sensors are generally only designed for a free run or the continuous recording of images. Triggering individual images, as is customary in factory automation, was not the original intent here.

Likewise, the sensors – and particularly the 12 MP IMX226 – were only developed for operation with a full or nearly full (4k) resolution. This makes it impossible to achieve increased speed with a simultaneous reduction of the read ROI that is otherwise customary in industrial image processing.

2.2 EMVA1288

However, the back illumination technology made it possible for Sony to achieve excellent EMVA values for such small pixels:

	IMX178	IMX226
QE	81 %	80%
Dark noise	3,2 e-	3,2 e-
Saturation capacity	14,3 ke-	11 ke-
SNR	72,8 dB	71 dB
Dynamic range	41,6 dB	40,4 dB

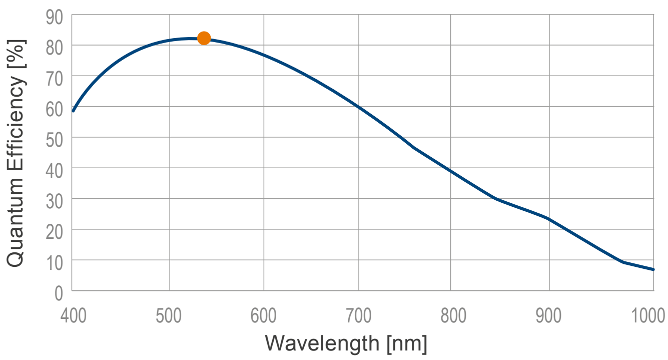

Figure 4: Quantum efficiency of the acA3088-16gm (IMX178), applied over the wavelength

3. Comparison of sensitivity

The sensitivity of the sensors deserves special attention, since Sony considered this a high priority in the STARVIS series. Sensitivity here refers to how much light, or quantity of photons, the sensors need to generate a signal that stands out against the noise. Here the EMVA1288 standard offers the measured value of the “absolute threshold value for sensitivity”. It states the average number of required photons so that the signal to noise ratio is exactly 1.

	STARVIS	First Pregius generation	Second Pregius generation
Absolute threshold value for sensitivity	4	10	3

Overview of the absolute threshold value for sensitivity

From this it can be deduced that the sensors in the second generation of the Pregius series are the most sensitive, closely followed by the STARVIS series.

4. What are the main differences and what do they mean for my application?

The first difference, which also greatly influences the potentially suitable applications, is probably the different shutter between STARVIS and Pregius. The rolling shutter makes many applications in which the examined object or camera moves impossible, since it may result in distortions that will prevent proper image processing. The best example of this includes applications in transport, such as automatic license plate recognition in tolling systems, or for speed or red-light enforcement.

An additional main difference lies in the cameras’ trigger speed. With the Pregius sensors, the triggering is much faster and more exact than in the STARVIS series, which enables applications that require a precise execution of the trigger, such as in 3D or other multi-camera applications where images are subsequently edited together. Examples of this can include bottle inspections, sports analyses or the automated optical inspection (AOI) of circuit boards.

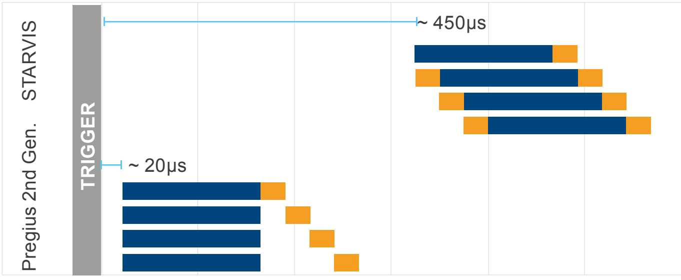

Figure 5: Differences in the reading read out time

In general, the Pregius sensors are increasingly used as a pioneering future-proof replacement for old CCD sensors. The 5 MP variants IMX264 and IMX250 can be used as a replacement for the CCD sensor ICX625, or the IMX267 and IMX255 can substitute for the ICX824. The resulting cameras can then be used for various upgrades or also as replacement cameras without requiring major adjustments to the optical setup of the system.

The STARVIS sensors, in contrast, offer a clear cost benefit compared to the Pregius range. Applications in which the above-stated disadvantages are irrelevant can benefit from the excellent image quality in cases of little movement. With their smaller pixels, the sensors also reach higher resolutions with smaller sensor sizes. But this must be taken into account when choosing the optics.

5. Summary

IMX sensors are definitely not all alike. Even within the Pregius sensor series, there are great certain differences in how the various generations are conceived and implemented. The differences are even greater when the Pregius series is compared with the STARVIS sensors. A careful evaluation in terms of the application requirements and the performance range of the various sensors is thus absolutely crucial.

But all IMX sensors have one thing in common: they feature excellent image quality, which now also validates Sony as a leading high-quality manufacturer in the CMOS market.

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Dominik Lappenküper is responsible for Basler's ace, Basler beat and racer cameras series, and oversees market launches for new camera models. He is also the first point of contact when new features are rolled out for these camera families. He is additionally responsible for liaising with the market to better understand its needs.

Dominik started at Basler in 2011 as part of a work/study program in industrial engineering, and successfully earned his Bachelor of Engineering. He has since completed a Master of Science at the Polytechnic University of Wedel alongside his work at Basler.

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