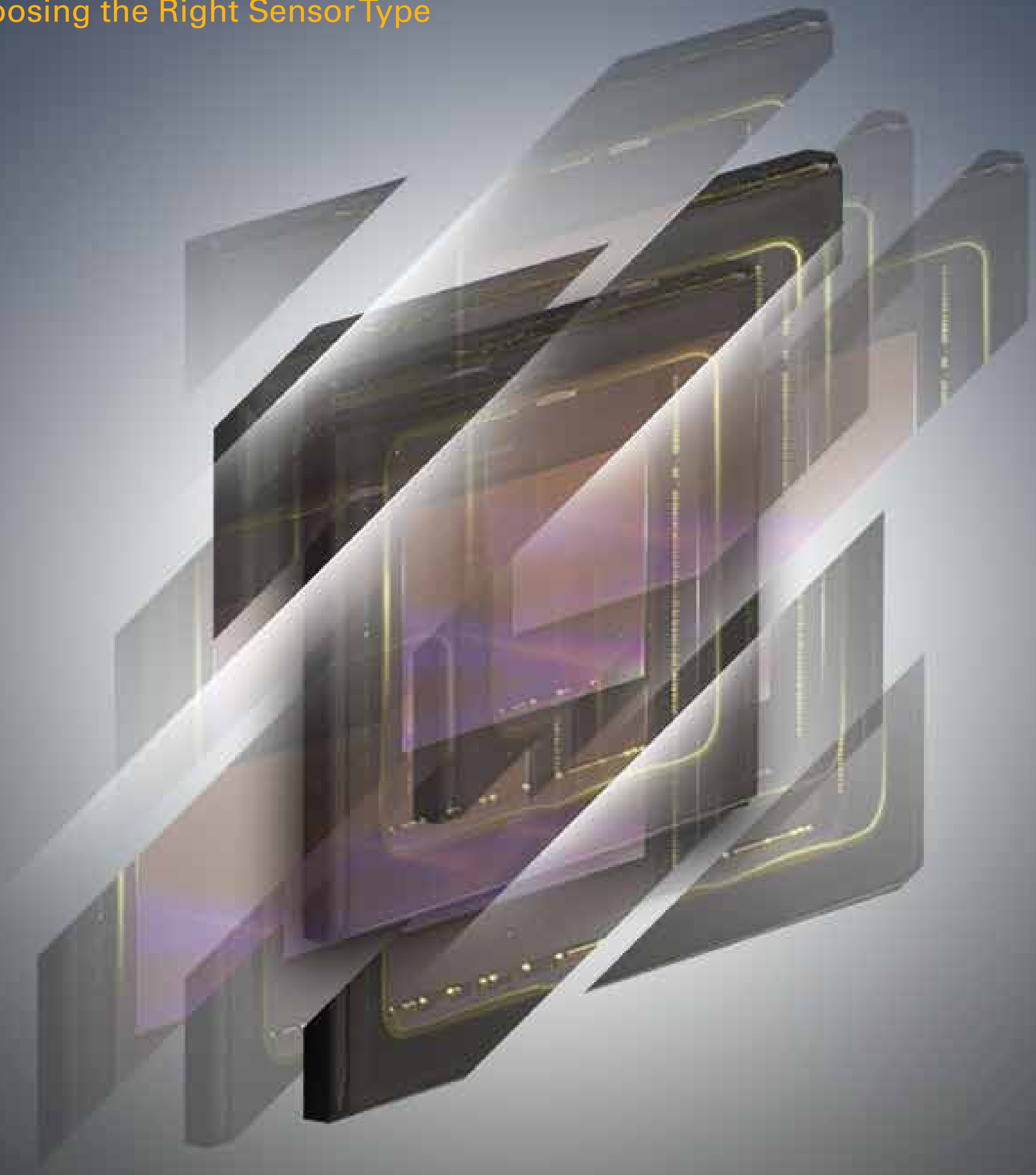
FLIR

SENSOR REVIEW: MONO CAMERAS

- EMVA1288 Specification Comparison Charts
- Guide to Using EMVA1288 Specifications
- Choosing the Right Sensor Type



1288 EMVA Standard Compliant

Measurements are taken based on guidelines in the EMVA 1288 standard; the full definition can be found at EMVA.org. Camera settings are at maximum exposure time and bit depth unless otherwise noted. The pixel format is Mono 16 for mono cameras and Raw 16 for color cameras. Results are captured at room temperature (20°C).

2019 Edition

TABLE OF CONTENTS

HOW TO READ OUR MODEL NUMBERS

What do your model numbers mean?

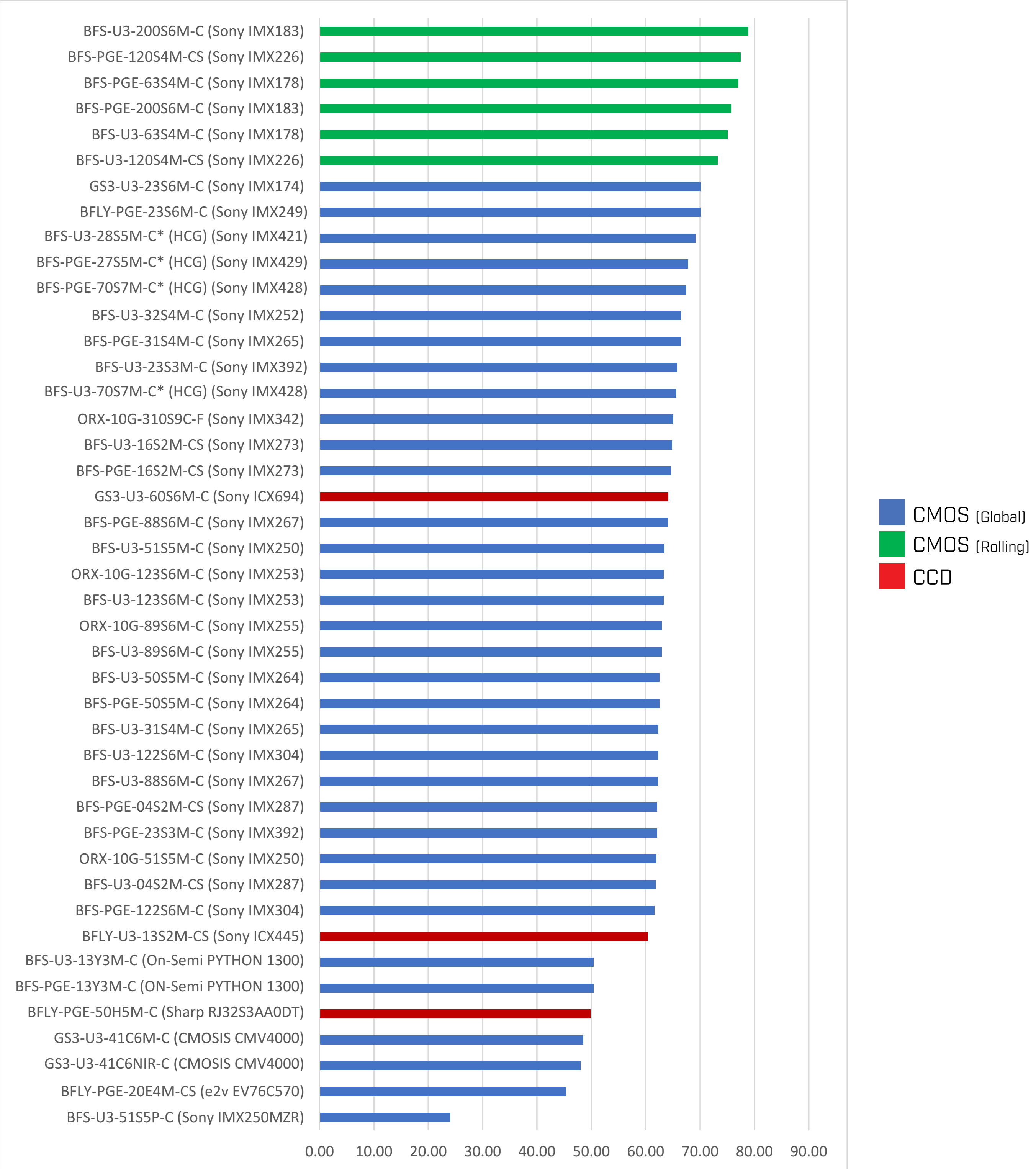
Here is one example of our model numbers and what each section means. Understanding this will give you a quick explanation of the model's specifications and help you when comparing models.

Camera Family	**Interface**	**Megapixels**	**Sensor Brand**	**Sensor Size**	**Color/Mono**	**Lens Mount**
BFS=Blackfly S	U3=USB 3.0	50=5.0 MP	S=Sony	5=2/3"	M=Mono	C=C-Mount
BFLY=Blackfly CM3=Chameleon3 FL3=Flea3 FFMV=FireflyMV FireWire GS2=Grasshopper2 GS3=Grasshopper3 ORX=Oryx	FW=FireWire GE=GigE PGE=PoE GigE 10G=10 Gigabit Ethernet	03=0.3 MP 08=0.8 MP 13=1.3 MP 20=2.0 MP etc	A=Aptina M=Micron K=Kodak C=CMOSIS Y=ON Semi E=E2V H=Sharp	0=Unassigned 1=1/4" 2=1/3", 1/2.8", 1/2.5" 3=1/2" 4=1/1.8" 6=1" 7=1.1" 9=APS-C	C=Color P=Polarized	CS=CS-Mount S=S-Mount BD2=Board-level w/FPC

EMVA1288 Specification Comparison Charts

QUANTUM EFFICIENCY (%) AT 530 nm
(HIGHER IS BETTER)

Quantum efficiency (QE) is the ability of the sensor to turn photons into electrons, or in other words, turn incoming light into an electrical signal for imaging. A higher QE % means greater sensitivity for detecting light. A sensor with a measurement of 79% means that for every 100 photons that hit the sensor an average of 79 will be detected. Please note that the results below are taken at the wavelength of 530nm.

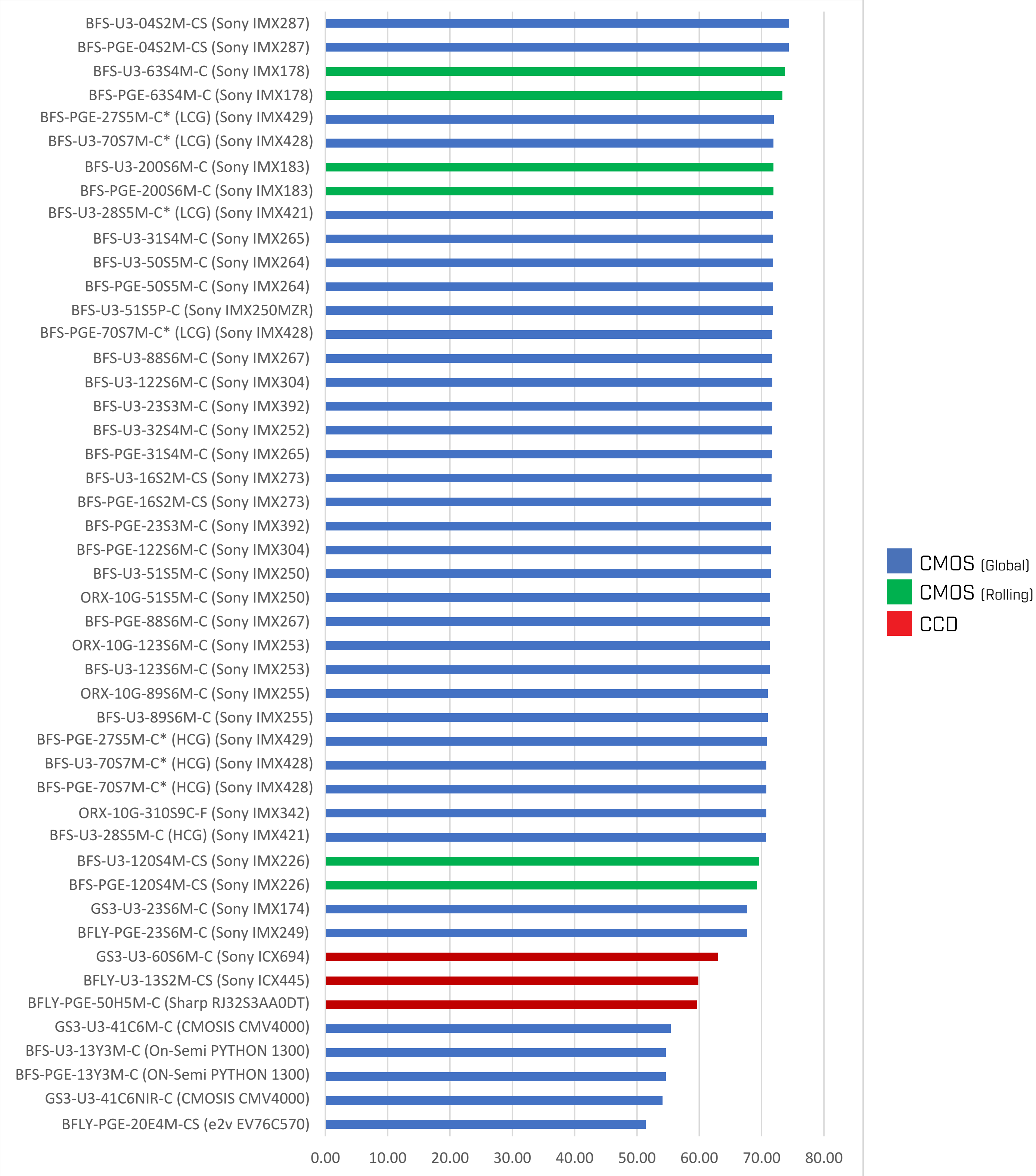


*Low and high conversion gain is explained in section "Selectable Conversion Gain"

Please note that all measurements are taken based on guidelines in the EMVA 1288 standard. Camera settings are at maximum exposure time and bit depth unless otherwise noted. The pixel format is Mono 16 for mono cameras except for the last two Bandwidth and Throughput graphs which are done at Mono 8. Results are captured at room temperature (20°C). For more information on the EMVA 1288 standard please visit EMVA.org.

DYNAMIC RANGE dB
(HIGHER IS BETTER)

Dynamic range describes the camera model's ability to detect the maximum and minimum of light intensities (shadows and highlights). Models with higher dynamic range can detect more detail in the darks and lights.

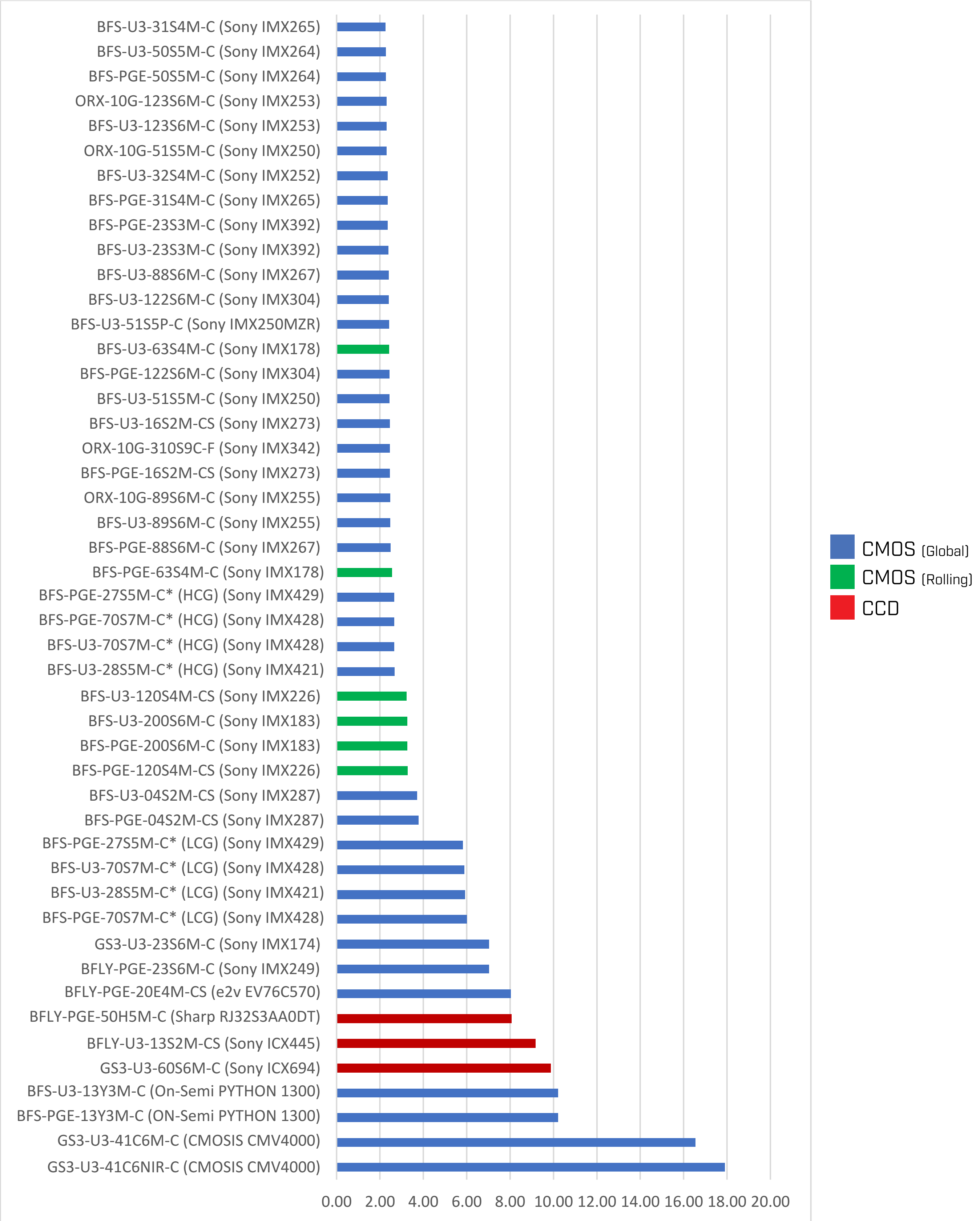


*Low and high conversion gain is explained in section "Selectable Conversion Gain"

TEMPORAL DARK NOISE/READ NOISE e-

(LOWER IS BETTER)

Temporal dark noise (also known as read noise) comes from energy within the sensor and the surrounding sensor electronics. Over time, random electrons are created that fall into the sensor wells and are detected and turned into signal. Models with lower read noise measurements produce cleaner images.

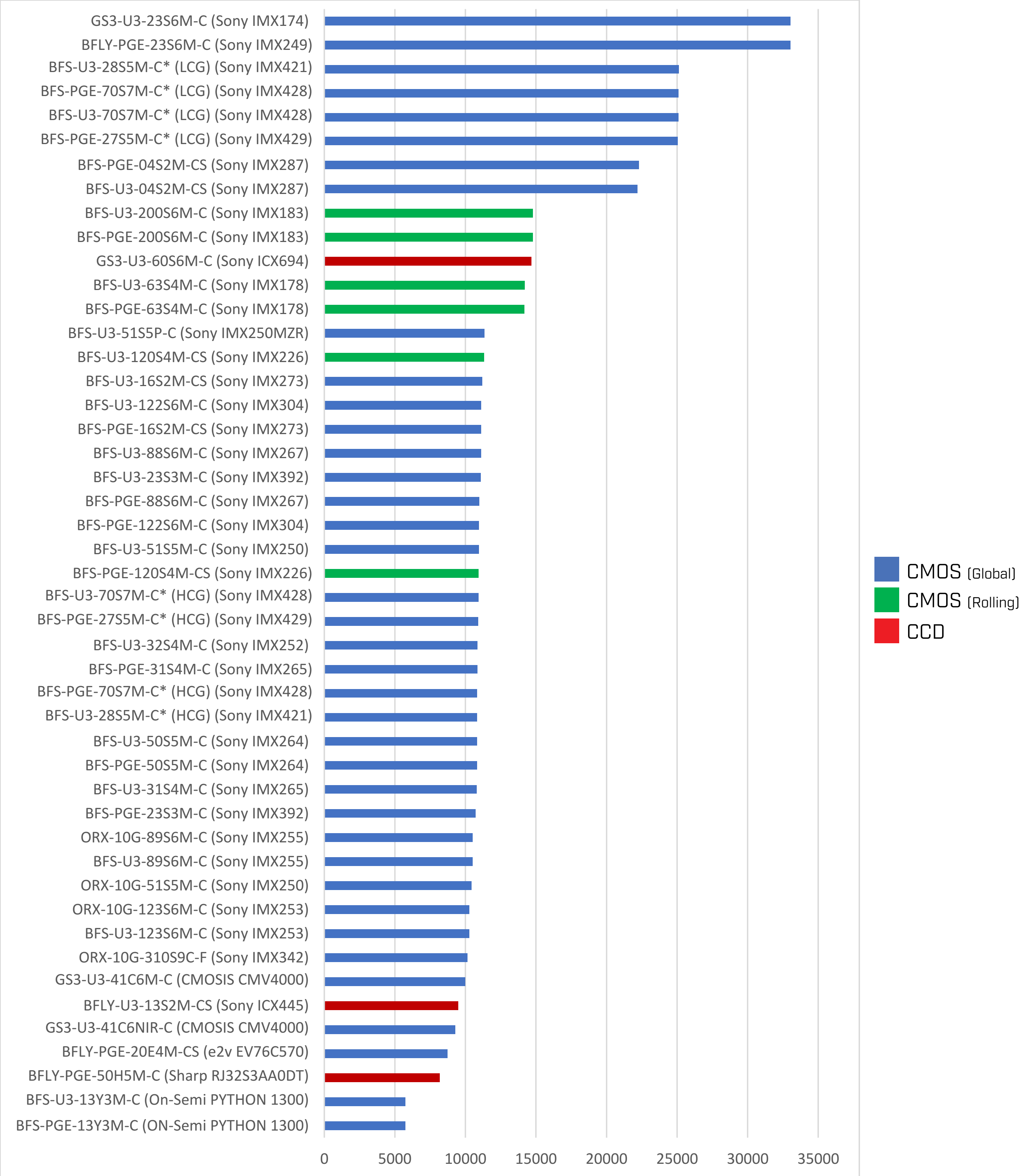


*Low and high conversion gain is explained in section "Selectable Conversion Gain"

SATURATION CAPACITY (WELL DEPTH) e-

(HIGHER IS BETTER, SORTED BY PIXEL SIZE)

The saturation capacity (well depth) is the largest charge a pixel can hold before over-saturation occurs and signal degradation begins. Saturation must be avoided because it diminishes the quantitative ability of the sensor and in the case of CCDs produces image smearing due to a phenomenon known as blooming.

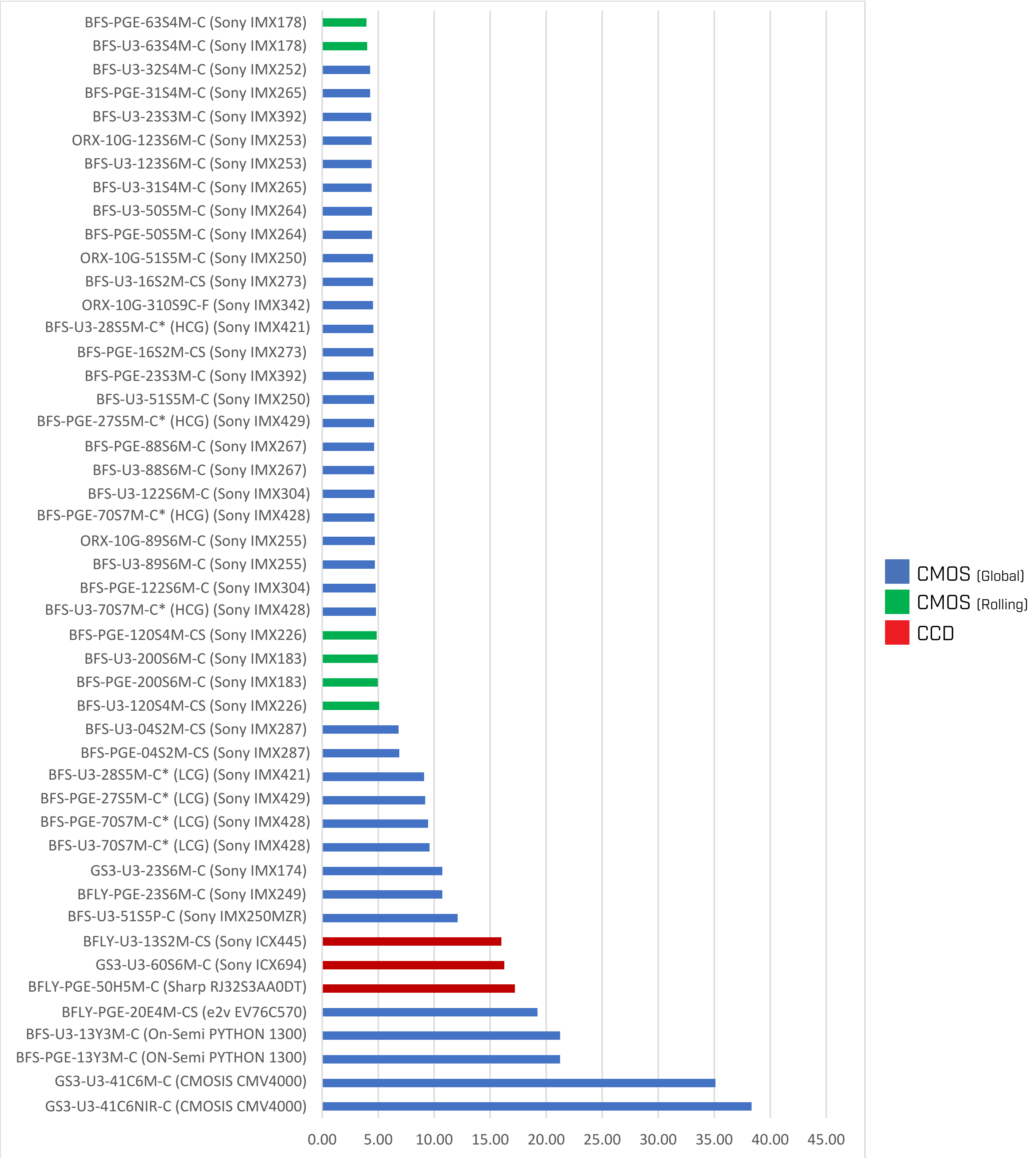


*Low and high conversion gain is explained in section "Selectable Conversion Gain"

ABSOLUTE SENSITIVITY THRESHOLD (γ)

(LESS IS BETTER)

Absolute sensitivity threshold is the minimum number of photons needed to equal the noise level. The lower the number the less light is needed to detect useful imaging data.



*Low and high conversion gain is explained in section "Selectable Conversion Gain"

MONO CAMERA SENSOR REVIEW SORTED BY SENSOR TYPE (CMOS/CCD) AND RESOLUTION

	PART NUMBER	SENSOR		SENSOR SIZE (inches)	INTERFACE	SENSOR TYPE	READOUT	MAX RESOLUTION
CMOS	ORX-10G-310S9C-F	Sony	IMX342	APS-C	10GigE	CMOS	Global shutter	6464 x 4852
	BFS-PGE-200S6M-C	Sony	IMX183	1	PoE GigE	CMOS	Rolling – Global Reset	5472 x 3648
	BFS-U3-200S6M-C	Sony	IMX183	1	USB 3.1 Gen 1	CMOS	Rolling – Global Reset	5472 x 3648
	BFS-PGE-122S6M-C	Sony	IMX304	1.1	PoE GigE	CMOS	Global shutter	4096 x 3000
	BFS-U3-122S6M-C	Sony	IMX304	1.1	USB 3.1 Gen 1	CMOS	Global shutter	4096 x 3000
	BFS-U3-123S6M-C	Sony	IMX253	1.1	USB 3.1 Gen 1	CMOS	Global shutter	4096 x 3000
	ORX-10G-123S6M-C	Sony	IMX253	1.1	10GigE	CMOS	Global shutter	4096 x 3000
	BFS-PGE-120S4M-CS	Sony	IMX226	1/1.7	PoE GigE	CMOS	Rolling – Global Reset	4000 x 3000
	BFS-U3-120S4M-CS	Sony	IMX226	1/1.7	USB 3.1 Gen 1	CMOS	Rolling – Global Reset	4000 x 3000
	BFS-PGE-88S6M-C	Sony	IMX267	1	PoE GigE	CMOS	Global shutter	4096 x 2160
	BFS-U3-88S6M-C	Sony	IMX267	1	USB 3.1 Gen 1	CMOS	Global shutter	4096 x 2160
	BFS-U3-89S6M-C	Sony	IMX255	1	USB 3.1 Gen 1	CMOS	Global shutter	4096 x 2160
	ORX-10G-89S6M-C	Sony	IMX255	1	10GigE	CMOS	Global shutter	4096 x 2160
	BFS-PGE-70S7M-C* (LCG)	Sony	IMX428	1.1	PoE GigE	CMOS	Global shutter	3208 x 2200
	BFS-PGE-70S7M-C* (HCG)	Sony	IMX428	1.1	PoE GigE	CMOS	Global shutter	3208 x 2200
	BFS-U3-70S7M-C* (LCG)	Sony	IMX428	1.1	USB 3.1 Gen 1	CMOS	Global shutter	3208 x 2200
	BFS-U3-70S7M-C* (HCG)	Sony	IMX428	1.1	USB 3.1 Gen 1	CMOS	Global shutter	3208 x 2200
	ORX-10G-71S7M-C* (LCG)	Sony	IMX420	1.1	10GigE	CMOS	Global shutter	3208 x 2200
	ORX-10G-71S7M-C* (HCG)	Sony	IMX420	1.1	10GigE	CMOS	Global shutter	3208 x 2200
	BFS-PGE-63S4M-C	Sony	IMX178	1/1.8	PoE GigE	CMOS	Rolling – Global Reset	3072 x 2048
	BFS-U3-63S4M-C	Sony	IMX178	1/1.8	USB 3.1 Gen 1	CMOS	Rolling – Global Reset	3072 x 2048
	BFS-PGE-50S5M-C	Sony	IMX264	2/3	PoE GigE	CMOS	Global shutter	2448 x 2048
	BFS-U3-50S5M-C	Sony	IMX264	2/3	USB 3.1 Gen 1	CMOS	Global shutter	2448 x 2048
	BFS-U3-50S5M-BD2	Sony	IMX264	2/3	USB 3.1 Gen 1	CMOS	Global shutter	2448 x 2048
	BFS-U3-51S5M-C	Sony	IMX250	2/3	USB 3.1 Gen 1	CMOS	Global shutter	2448 x 2048
	BFS-U3-51S5M-BD2	Sony	IMX250	2/3	USB 3.1 Gen 1	CMOS	Global shutter	2448 x 2048
	BFS-U3-51S5P-C	Sony	IMX250MZR	2/3	USB 3.1 Gen 1	CMOS	Global shutter	2448 x 2048
	ORX-10G-51S5M-C	Sony	IMX250	2/3	10GigE	CMOS	Global shutter	2448 x 2048
	GS3-U3-41C6M-C	CMOSIS	CMV4000	1	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 2048
	GS3-U3-41C6NIR-C	CMOSIS	CMV4000	1	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 2048
	BFS-PGE-31S4M-C	Sony	IMX265	1/1.8	PoE GigE	CMOS	Global shutter	2048 x 1536
	BFS-U3-31S4M-C	Sony	IMX265	1/1.8	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 1536
	BFS-U3-32S4M-C	Sony	IMX252	1/1.8	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 1536
	BFS-PGE-27S5M-C* (LCG)	Sony	IMX429	2/3	PoE GigE	CMOS	Global shutter	1936 x 1464
	BFS-PGE-27S5M-C* (HCG)	Sony	IMX429	2/3	PoE GigE	CMOS	Global shutter	1936 x 1464
	BFS-U3-28S5M-C* (LCG)	Sony	IMX421	2/3	USB 3.1 Gen 1	CMOS	Global shutter	1936 x 1464
	BFS-U3-28S5M-C* (HCG)	Sony	IMX421	2/3	USB 3.1 Gen 1	CMOS	Global shutter	1936 x 1464
	BFLY-PGE-23S6M-C	Sony	IMX249	1	PoE GigE	CMOS	Global shutter	1920 x 1200
	BFS-PGE-23S3M-C	Sony	IMX392	1/2.3	PoE GigE	CMOS	Global shutter	1920 x 1200
	BFS-U3-23S3M-C	Sony	IMX392	1/2.3	USB 3.1 Gen 1	CMOS	Global shutter	1920 x 1200
	GS3-U3-23S6M-C	Sony	IMX174	1	USB 3.1 Gen 1	CMOS	Global shutter	1920 x 1200
	BFLY-PGE-20E4M-CS	e2v	EV76C570	1/1.8	PoE GigE	CMOS	Global shutter	1600 x 1200
	BFS-GE-16S2M-BD2	Sony	IMX273	1/2.9	GigE	CMOS	Global shutter	1440 x 1080
	BFS-PGE-16S2M-CS	Sony	IMX273	1/2.9	PoE GigE	CMOS	Global shutter	1440 x 1080
	BFS-U3-16S2M-CS	Sony	IMX273	1/2.9	USB 3.1 Gen 1	CMOS	Global shutter	1440 x 1080
	BFS-U3-16S2M-BD1	Sony	IMX273	1/2.9	USB 3.1 Gen 1	CMOS	Global shutter	1440 x 1080
	BFS-PGE-13Y3M-C	ON-Semi	PYTHON 1300	1/2	PoE GigE	CMOS	Global shutter	1280 x 1024
CCD	BFS-U3-13Y3M-C	ON-Semi	PYTHON 1300	1/2	USB 3.1 Gen 1	CMOS	Global shutter	1280 x 1024
	BFS-PGE-04S2M-CS	Sony	IMX287	1/2.9	PoE GigE	CMOS	Global shutter	720 x 540
	BFS-U3-04S2M-CS	Sony	IMX287	1/2.9	USB 3.1 Gen 1	CMOS	Global shutter	720 x 540

MEGAPIXELS	MAX FPS	PIXEL SIZE (µm)	QE 530 nm (%)	GAIN (e-)	TEMPORAL DARK NOISE (ADU)	TEMPORAL DARK NOISE (e-)	SNR (dB)	SNR (Bits)	AST (γ)	SATURATION CAPACITY (e-)	DYNAMIC RANGE (dB)	DYNAMIC RANGE (Bits)
31.4	27 FPS	3.45 µm	65.04	6.00	14.75	2.46	40.07	6.66	4.55	10160	70.72	11.75
20.0	6.1 FPS	2.4 µm	75.73	4.23	13.81	3.26	41.70	6.93	4.97	14794	71.89	11.94
20.0	18 FPS	2.4 µm	78.91	4.23	13.81	3.26	41.70	6.93	4.97	14794	71.89	11.94
12.3	10 FPS	3.45 µm	61.60	5.79	14.11	2.43	40.40	6.71	4.76	10971	71.45	11.87
12.3	23 FPS	3.45 µm	62.29	5.76	13.82	2.40	40.46	6.72	4.65	11130	71.69	11.91
12.3	30 FPS	3.45 µm	63.30	6.08	13.99	2.30	40.12	6.66	4.43	10287	71.30	11.84
12.3	68 FPS	3.45 µm	63.30	6.08	13.99	2.30	40.12	6.66	4.43	10287	71.30	11.84
12.0	8.5 FPS	1.85 µm	77.44	5.69	18.60	3.27	40.39	6.71	4.87	10944	69.26	11.50
12.0	31 FPS	1.85 µm	73.27	5.60	18.09	3.23	40.54	6.73	5.09	11323	69.64	11.57
8.8	13.9 FPS	3.45 µm	64.07	5.76	14.25	2.48	40.41	6.71	4.64	10998	71.35	11.85
8.8	32 FPS	3.45 µm	62.26	5.74	13.73	2.39	40.46	6.72	4.64	11107	71.69	11.91
8.8	42 FPS	3.45 µm	62.99	5.79	14.33	2.47	40.22	6.68	4.72	10514	70.97	11.79
8.8	93 FPS	3.45 µm	62.99	5.79	14.33	2.47	40.22	6.68	4.72	10514	70.97	11.79
7.1	17.4 FPS	4.5 µm	68.81	2.52	15.14	6.01	44.00	7.31	9.46	25119	71.73	11.91
7.1	17.4 FPS	4.5 µm	67.45	5.85	15.48	2.65	40.35	6.70	4.67	10846	70.75	11.75
7.1	51 FPS	4.5 µm	66.46	2.53	14.89	5.89	44.00	7.31	9.61	25101	71.89	11.94
7.1	51 FPS	4.5 µm	65.65	5.79	15.41	2.66	40.39	6.71	4.81	10938	70.78	11.76
7.1	112 FPS	4.5 µm	68.42	2.57	15.05	5.85	43.97	7.30	9.28	24969	71.89	11.94
7.1	112 FPS	4.5 µm	66.94	5.97	15.80	2.65	40.18	6.67	4.70	10432	70.41	11.70
6.3	19 FPS	2.4 µm	77.07	4.30	10.98	2.55	41.52	6.90	3.96	14177	73.33	12.18
6.3	59.6 FPS	2.4 µm	75.05	4.31	10.58	2.42	41.52	6.90	4.03	14204	73.73	12.25
5.0	24 FPS	3.45 µm	62.51	5.77	13.10	2.27	40.34	6.70	4.43	10824	71.83	11.93
5.0	35 FPS	3.45 µm	62.51	5.77	13.10	2.27	40.34	6.70	4.43	10824	71.83	11.93
5.0	35 FPS	3.45 µm	62.51	5.77	13.10	2.27	40.34	6.70	4.43	10824	71.83	11.93
5.0	75 FPS	3.45 µm	63.40	5.70	13.87	2.44	40.40	6.71	4.63	10970	71.45	11.87
5.0	75 FPS	3.45 µm	65.06	5.68	13.82	2.43	40.38	6.71	4.51	10917	71.42	11.86
5.0	75 FPS	3.45 µm	24.10	5.63	13.59	2.42	40.55	6.74	12.10	11359	71.81	11.93
5.0	162 FPS	3.45 µm	61.95	6.03	13.96	2.31	40.18	6.67	4.54	10435	71.38	11.86
4.2	90 FPS	5.5 µm	48.50	6.27	103.71	16.53	39.99	6.64	35.11	9983	55.36	9.20
4.2	90 FPS	5.5 µm	48.00	6.64	118.82	17.90	39.68	6.59	38.34	9282	54.06	8.98
3.1	35 FPS	3.45 µm	66.50	5.73	13.46	2.35	40.36	6.70	4.29	10858	71.62	11.90
3.1	57 FPS	3.45 µm	62.36	5.79	13.10	2.26	40.33	6.70	4.43	10791	71.83	11.93
3.1	118 FPS	3.45 µm	66.50	5.73	13.46	2.35	40.36	6.70	4.29	10858	71.62	11.90
2.8	43 FPS	4.5 µm	68.64	2.54	14.76	5.81	43.99	7.31	9.20	25048	71.97	11.95
2.8	43 FPS	4.5 µm	67.82	5.76	15.24	2.64	40.38	6.71	4.64	10912	70.81	11.76
2.8	130 FPS	4.5 µm	70.55	2.51	14.87	5.93	44.00	7.31	9.11	25122	71.84	11.93
2.8	130 FPS	4.5 µm	69.15	5.80	15.47	2.67	40.35	6.70	4.58	10841	70.69	11.74
2.3	41 FPS	5.86 µm	70.14	1.92	13.32	7.02	45.19	7.51	10.72	33022	67.71	11.25
2.3	53 FPS	3.45 µm	62.11	5.77	13.60	2.36	40.30	6.69	4.60	10724	71.49	11.87
2.3	163 FPS	3.45 µm	65.78	5.74	13.72	2.39	40.45	6.72	4.39	11088	71.68	11.91
2.3	163 FPS	5.86 µm	70.14	1.92	13.32	7.02	45.19	7.51	10.72	33022	67.71	11.25
1.9	50 FPS	4.5 µm	45.30	6.70	36.55	8.04	39.41	6.55	19.22	8727	51.38	8.53
1.6	78 FPS	3.45 µm	64.70	5.62	13.72	2.44	40.48	6.72	4.54	11170	71.60	11.89
1.6	78 FPS	3.45 µm	64.60	5.71	14.05	2.46	40.46	6.72	4.58	11127	71.50	11.88
1.6	226 FPS	3.45 µm	64.81	5.73	14.01	2.45	40.48	6.72	4.55	11179	71.58	11.89
1.6	226 FPS	3.45 µm	69.02	5.72	14.08	2.46	40.37	6.71	4.29	10896	71.31	11.84
1.3	84 FPS	4.8 µm	50.45	6.70	68.38	10.21	37.60	6.25	21.22	5756	54.61	9.07
1.3	170 FPS	4.8 µm	50.45	6.70	68.38	10.21	37.60	6.25	21.22	5756	54.61	9.07
0.4	291 FPS	6.9 µm	62.15	2.85	10.77	3.78	43.48	7.22	6.88	22297	74.34	12.35
0.4	522 FPS	6.9 µm	61.82	2.89	10.71	3.71	43.46	7.22	6.81	22187	74.43	12.36

*Low and high conversion gain is explained in section "Selectable Conversion Gain"

Guide to Using EMVA1288 Specifications

What is the EMVA1288 Standard?

The EMVA1288 standard for measuring and reporting imaging performance of image sensors enables sensors to be compared based on objective and consistent measurements.

Combinations of EMVA1288 measurements can be used to easily assess the relative suitability of a sensor for your application. For example, fluorescence microscopy applications where every photon possible should be detected, will benefit from a low Absolute Sensitivity Threshold, which is a combination of Quantum Efficiency and Temporal dark noise. Cameras for autonomous vehicle guidance will require high saturation capacity and dynamic range to perform well in uncontrolled lighting outside.

When comparing sensors, it is important to consider multiple performance criteria. Image sensors are designed to balance trade-offs, and reliance on a single measurement can result in poor overall performance other important criteria are neglected.

Quantum Efficiency

Unit of measurement: Percent (%), Higher is better.

Definition: The percent of photons converted to electrons at a specific wavelength by the sensor. This measurement is often used as an indicator for low light sensitivity.

CMOS and CCD image sensors convert light into electrical signals using the photoelectric effect. When photons enter the photodiode in a pixel, they create a charge by knocking electrons off silicon atoms. The more efficiently a sensor can convert incoming photons into electrical charge, the higher its Quantum Efficiency will be. While no sensor is 100% efficient, Sony CMOS sensors can achieve up to 77% QE, compared to 50% on popular legacy CCD sensors.

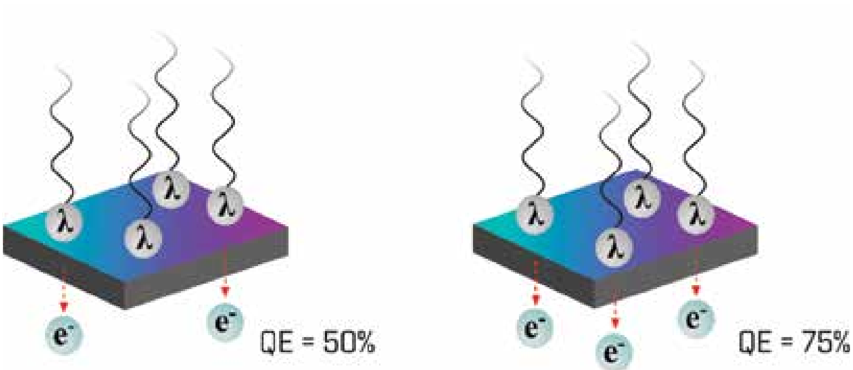


Fig. 1. As more incoming photons are successfully converted into charge, the QE increases proportionally.

QE is wavelength dependant. Silicon is most sensitive to green light with a wavelength of 530 nm, while the QE generally falls to 0% at wavelengths beyond 1050 nm. Monochrome sensors have higher QEs than color sensors, as the RGB color filters restrict the range of wavelengths which can enter the pixel, reducing the number of photons which reach the photodiode. On sensor polarizing filters will also reduce the amount of light that can enter a sensor's pixels, reducing its QE.

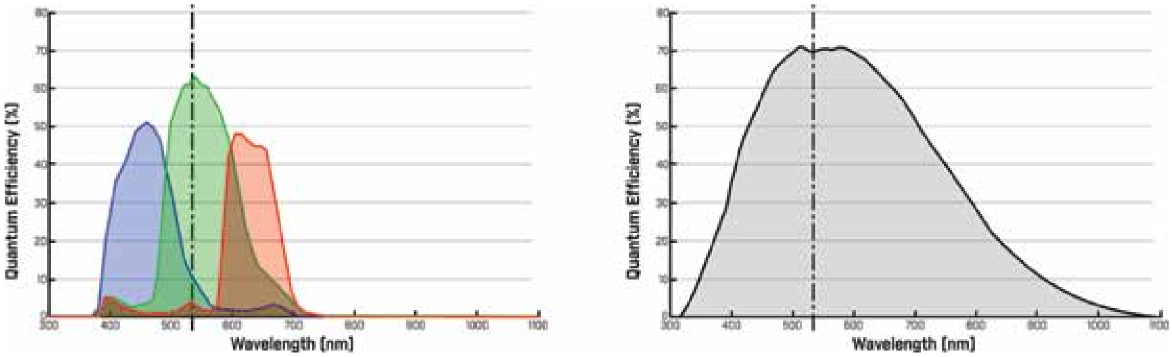


Fig. 2. Example Quantum Efficiency curves of color and monochrome IMX428 Sensors.

Temporal Dark Noise (Read Noise)

Unit of measurement: Electrons (e^-), Lower is better

Definition: Noise in the sensor when there is no signal. With higher temporal dark noise, you can expect a grainy image.

To read the information captured by a pixel on a CMOS image sensor, the charge created by incoming photons is converted to voltage and the voltage value is digitized. Small variations at each step of this process can add up and can appear to show a signal even when no photons entered the sensor. Read noise is not affected by exposure time. Typical read noise values of current CMOS sensors are around 2.5 e^-, while CCD sensors are usually in the range of 8 –10 e^-.

Absolute Sensitivity Threshold

Unit of measurement: Photon (γ), Lower is better.

Definition: The lowest intensity signal which can be detected above the noise floor of a sensor.

Absolute Sensitivity Threshold (AST) combines QE and read noise and provides a much more useful measure of the actual sensitivity of a sensor than either of these measurements alone. AST is weakest signal which can distinguished from the read noise.

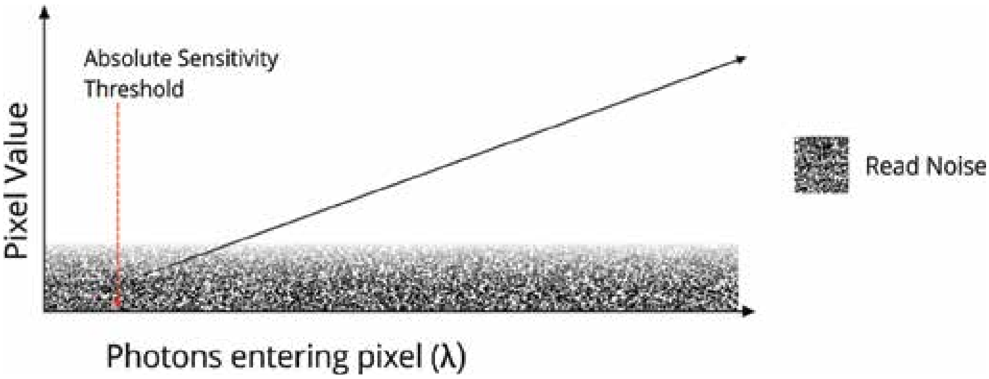


Fig. 3.The absolute sensitivity threshold is the point where the signal becomes distinguishable above the read noise.

AST is a key metric for applications where low-light imaging performance is critical. It is also extremely helpful when comparing sensors with different pixel architectures, as high QE does not necessarily translate into good low-light performance.

Signal to Noise Ratio (SNR)

Unit of measurement: Decibels (dB) or Bits, Higher is better

Definition: Ratio between the signal at saturation versus the noise at saturation.

The higher the signal to noise ratio, the greater the amount of signal there will be relative to noise. Greater SNR yields better contrast and clarity, as well as improved low-light performance. Typical CMOS SNR is about 40 dB, with some achieving an SNR of 44 dB in Low Conversion Gain mode.

dB	Power Ratio
40	10000
30	1000
20	100
10	10
6	4
3	2
0	1

dB is measured on a logarithmic scale. With every increase in 10 dB, the power increases by a factor of 10.

Saturation Capacity

Unit of measurement: Electrons (e-), Larger is better

Definition: Maximum amount of charge that a pixel can hold. A higher saturation capacity usually means a wider range of brightness that can be captured by the sensor.

The photodiode in a pixel can only hold a finite amount of charge. Saturation capacity is the maximum number of electrons that an individual pixel can store. Generally, the larger the surface area of pixel, the greater the saturation capacity. At saturation, additional photons entering a pixel will not result in a further increase in the brightness value recorded by the pixel.

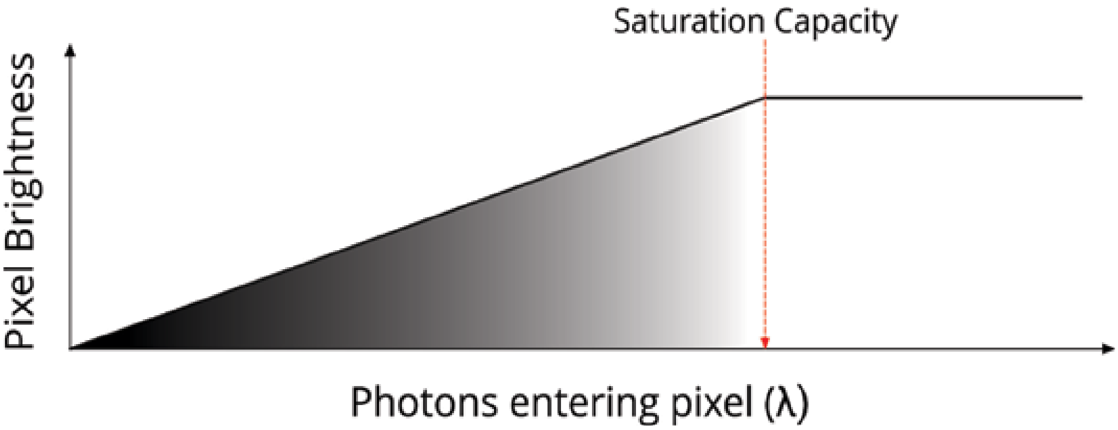


Fig. 4. At saturation, additional light or exposure time will not result in an increase in pixel brightness value.

A small saturation capacity may limit dynamic range. However, due to the dependence of dynamic range on additional factors, a large saturation capacity does not guarantee higher dynamic range.

Dynamic Range

Unit of measurement: Decibels (dB) or Bits

Definition: Ratio between the signal at saturation versus the minimum signal the sensor can measure.

Dynamic range is the difference between the maximum and minimum light intensities that a sensor can detect. A high dynamic range will enable sensors to capture details in both dark shadows and brightly lit highlights.

Dynamic range is important for a wide range of applications including automated optical inspection where identifying defects on dark IC packages and reflective solder joints in a single exposure is desirable, and autonomous vehicles which must be able to detect and avoid obstacles in highly variable and uncontrolled lighting conditions.

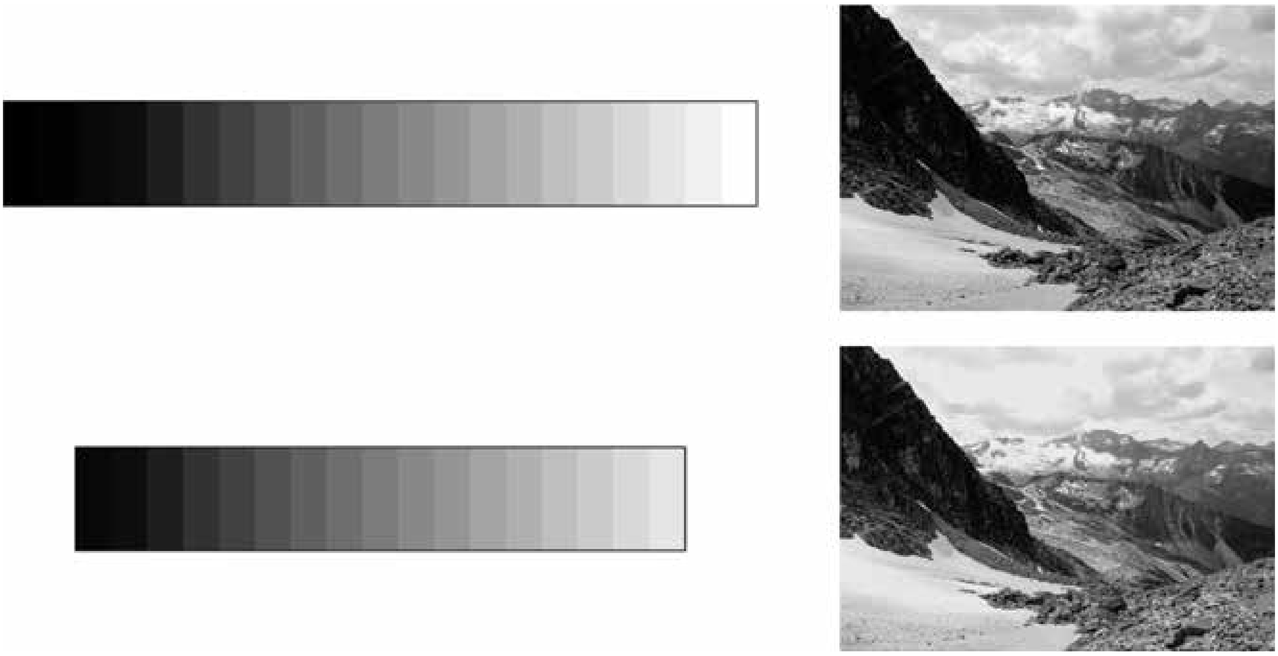


Fig. 5. Reduced dynamic range results in a loss of detail in the brightly lit clouds and shaded rocks.

The dynamic range of images capture by a camera can be limited by reducing the bit-depth of the camera's Analog to Digital Converter (ADC), and by the bit-depth of the pixel format selected. When viewing images on a display, keep in mind that standard LCD displays are limited to 8-bit color, while HDR monitors are limited to 10-bit color. Compressing the dynamic range of higher bit-depth images to display on lower bit-depth displays requires post-processing known as tone mapping.

Gain

Unit of measurement: Electrons over 16 bit ADU (e-/ADU)

Definition: The number of electrons required to observe a change in 16bit ADUs

EMVA Gain is the number of electrons required to increase the pixel value from a 16-bit greyscale value to one value higher. Sensors with higher gain will appear brighter with fewer electrons. High gain can be useful for detecting very weak signals in low light conditions.

Choosing the Right Sensor Type

To ensure you get the right camera for your application, FLIR designs and manufactures machine vision cameras with a wide range of sensors. Understanding the differences in optical format, readout, and pixel structure of these sensors, and how they impact different performance criteria can help you choose the camera that is best for you. For example, inspection of parts on a moving conveyor belt will benefit from global shutter readout, while traffic systems for detecting mobile phone use by drivers will find on-sensor polarizing filters useful for seeing through the glare of car windshields.

Resolution, Pixel Size, and Optical Format

Resolution, pixel size and optical format are closely linked. The optical format of a sensor is a measurement of the physical size of the image sensor. It is measured diagonally across the sensor and represents the diameter of the image circle the lens must produce to completely illuminate the sensor. Sensors can have different aspect ratios but share the same optical format.

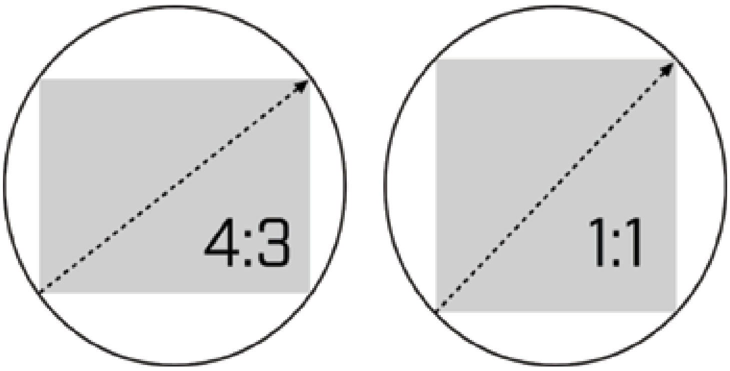


Fig. 6. Sensors of different aspect ratios can share the same optical format.

Increasing the resolution while maintaining the optical format results in a decrease in pixel size. Smaller pixels of the same pixel architecture will generally have a reduced quantum efficiency and saturation capacity. Reducing the pixel size while maintaining resolution results in a decrease in sensor size. Lenses for smaller sensors are generally more compact, lighter and less expensive than lenses designed for larger optical formats.

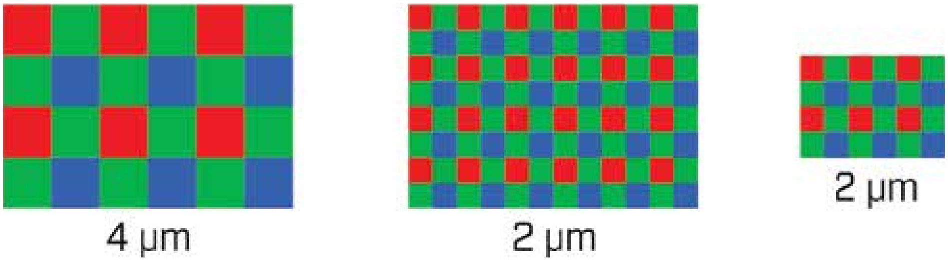


Fig. 7.

<u>Matching the optical format of the lens and sensor is critical.</u> While a sensor with a smaller optical format will work well if paired with a lens of a larger optical format, a sensor with a larger optical format than its lens will not be completely covered by the lens' image circle, resulting in dark, unilluminated corners.

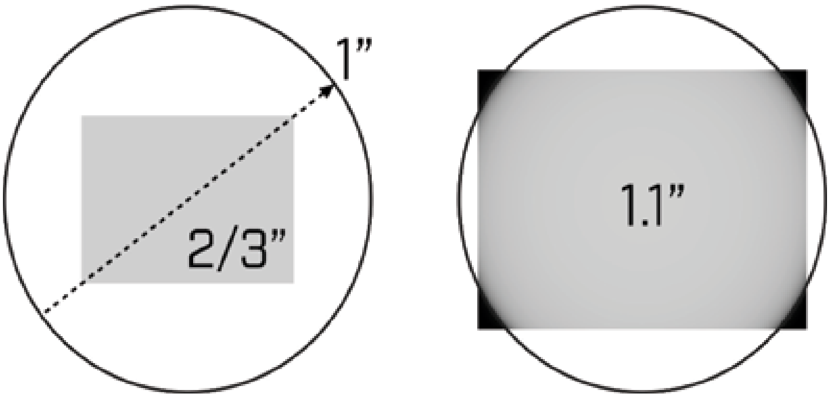


Fig. 8. Dark corners result when a 1.1" sensor is paired with a lens with a 1" optical format. A 2/3" sensor will be fully illuminated.

CMOS Compared to CCD

CMOS is the dominant technology for image sensors. Compared to the CCD sensors they have replaced, CMOS image sensors deliver superior imaging performance across a wide range of metrics including Quantum Efficiency, Absolute Sensitivity, Dynamic Range and Temporal Dark Noise. CMOS image sensors can read pixels much faster than CCDs, yielding large increases in speed for sensors of the same resolution.

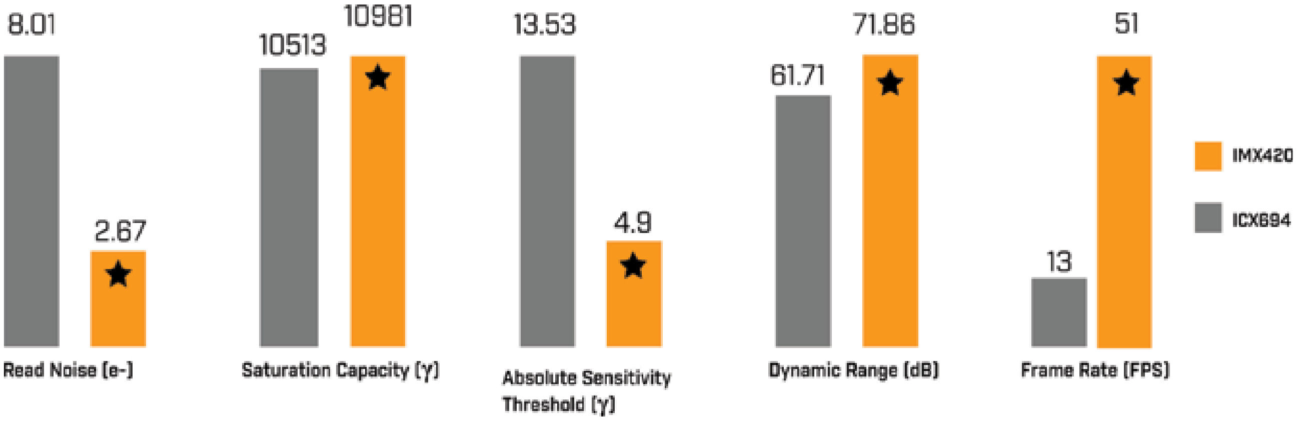


Fig. 9. CMOS image sensors deliver large performance increases compared to CCD sensors.

Sony announced the closure of their CCD manufacturing plant in 2015. These sensors are not recommended for new designs and are only included in this guide are a reference.

Global Shutter Compared to Rolling Shutter

While the practical differences between global and rolling shutter sensors are less of a factor with Sony's success with their Pregius global shutter CMOS technology, traditionally, global shutter was preferred for imaging fast moving objects whereas rolling shutter was preferred for its lower cost and success at low light imaging.

Global shutter sensors have read-out circuitry on each pixel. This enables them to read every pixel across the sensor plane simultaneously. Rolling shutter sensors read each row out sequentially. Global shutter sensors are preferable for imaging moving objects. By reading out all pixels at the same time, they can capture moving objects without any distortion. When rolling shutter sensors capture moving objects, the objects will continue to move as the line-by-line readout takes pace. This means that the object will be in a different position from one line to the next. Depending on the speed of the object being imaged, this can result in significant distortion.

Fig. 10. The moving fan blade continues to turn as lines are read out sequentially resulting in characteristic rolling shutter distortion. By reading out all pixels simultaneously, a global shutter sensor captures the fan without any distortion.

Sony's Pregius line of Global shutter CMOS image sensors sets the standard for global shutter imaging performance. They combine a global shutter with excellent Absolute Sensitivity and Dynamic Range.

Rolling shutter sensors require less complex readout circuitry compared to global shutter sensors. This means they are often less expensive than global shutter sensors. For applications with stationary targets where readout speed is not critical, rolling shutter sensors may be cost-effective alternative to global shutter sensors.

Back-side Illuminated (BSI) Sensors Compared to Front Illuminated Sensors

On most CMOS image sensors, the light sensitive photodiode is located on the back side of the sensor. It sits behind the readout circuitry, which is sandwiched between the photodiode and the microlenses used to direct light into the pixel. Back-side illuminated (BSI) sensors invert the layout of this typical pixel structure. By placing the photodiodes directly under the microlenses, photons can enter the photodiodes more easily, yielding a higher QE.

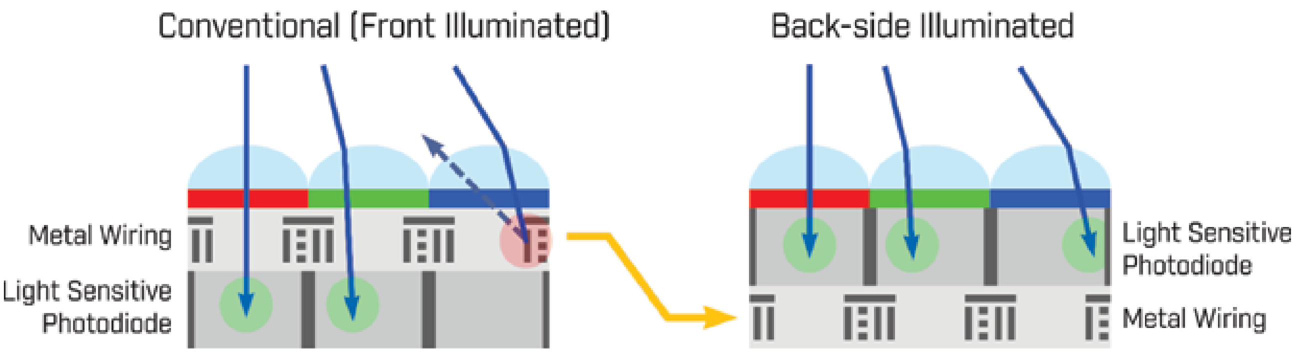


Fig. 11. BSI sensors invert the traditional front illuminated sensor design making it easier for photons to enter each pixel's light sensitive photodiode.

Increased QE, coupled with low-noise read out circuitry, means Sony's rolling shutter STARVIS and Exmore R BSI sensors achieve very low Absolute Sensitivity Thresholds, making them ideally suited for low-light imaging applications. This increased sensitivity enables sensor designers to deliver maintain excellent low-light performance, while reducing pixel sizes, making it possible to produce BSI sensors with significantly higher resolution for a given optical format that would be possible with conventional front illuminated designs.

On-Sensor Polarizing Filters

On-sensor polarizing filters enable new applications by making it possible to detect not only the intensity of light hitting a given point on the image sensor, but also its polarization angle. Sony's IMX250MZR and IMX250MYR sensors are based on their popular five-megapixel IMX250 Pregius global shutter CMOS sensor with the addition polarizing filters below the microlens of each pixel. These filters are oriented to 0°, 45°, 90° and 135°.

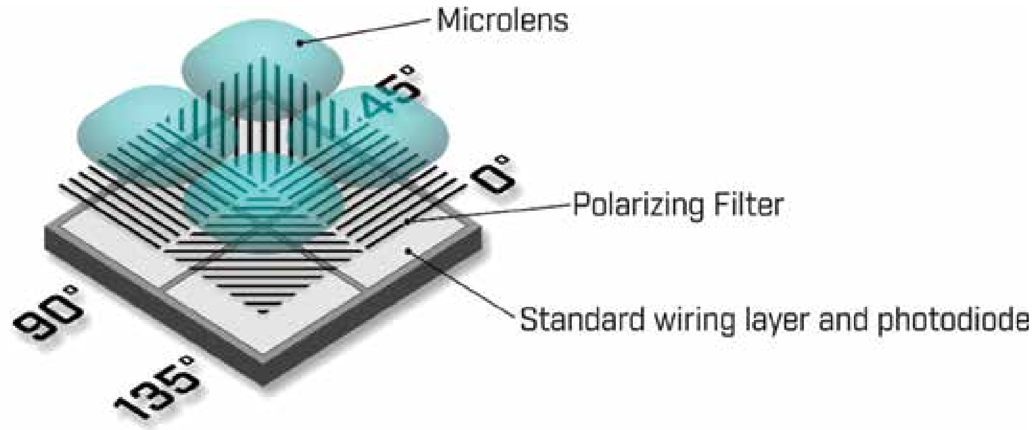


Fig. 12. Polarizing filters of different orientations are sandwiched between the microlenses and wiring layer of a Pregius global shutter, front illuminated CMOS image sensor.

Since these filters limit restrict the light entering each pixel to a relatively narrow range of polarization angles, the QE of sensors with on-sensor polarizing filters will be significantly lower than the standard sensors they are based on.

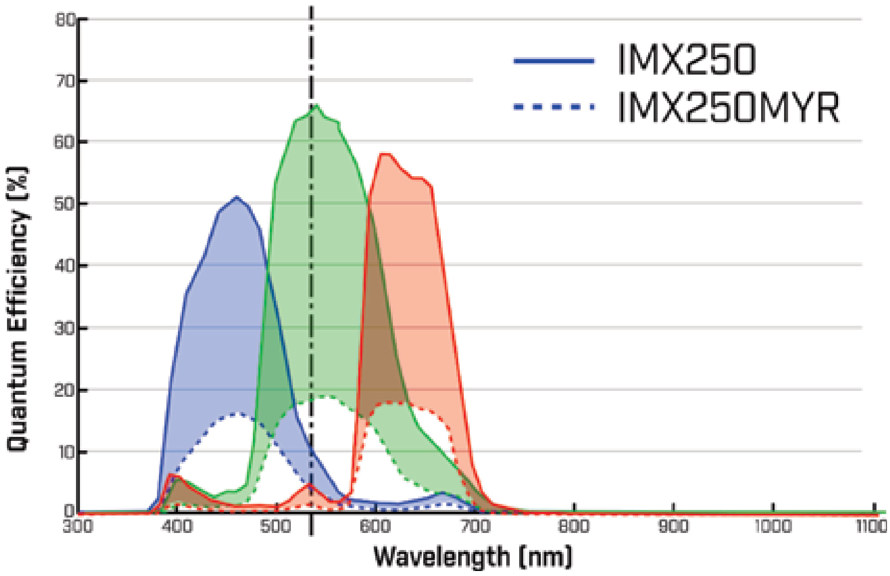


Fig. 13. QE of IMX250 compared to IMX250MZR. The light blocked by the polarizing filters results in a lower QE for the IMX250MZR.

Glare Elimination

Polarizing filters can eliminate unwanted glare on reflective and transparent parts. On-sensor polarization enables these systems to be installed quickly and adjusted dynamically. In addition to simplifying lighting requirements for industrial imaging systems, glare reduction is useful for managing the challenging lighting encountered in outdoor applications.

Fig. 14. Glare reduction.

Degree of Linear Polarization

Degree of Linear Polarization (DoLP) is the proportion of light that is polarized at a given pixel. A perfectly polarized light source would have a DoLP of 100%, while unpolarized light would have a DoLP of 0%. DoLP can be useful for differentiating materials which would otherwise appear identical.

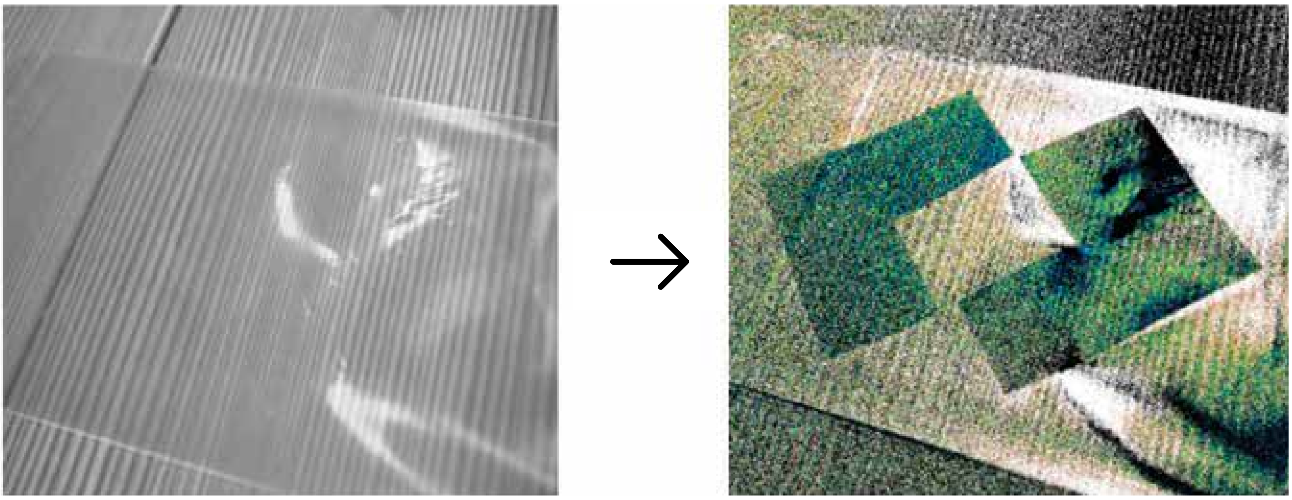


Fig. 15. Difficult to see.

Angle of Linear Polarization

The Angle of Linear Polarization (AoLP) is the average polarization angle of the light at a given pixel. When used in conjunction with a polarized light source, AoLP can be used to greatly enhance the contrast of the fibers in composite materials.

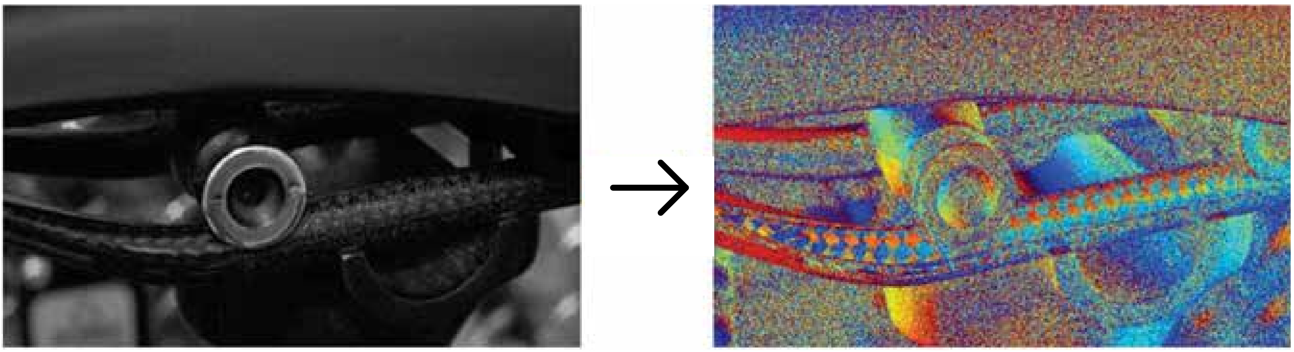


Fig. 16. Orientation of fibers.

Combining Polarization and Color

The IMX250MYR sensor adds a color filter array to the sensor below the polarizing filters. This sensor uses a unique quad-Bayer pattern which prioritizes spatial resolution of the polarization domain over spatial resolution of color information.

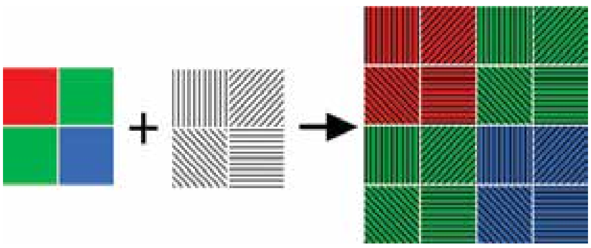


Fig. 17. Red, green and blue pixels are rearranged into 2x2 "super-pixels". Each super-pixel has one polarizing filter of each orientation.

Selectable Conversion Gain

Sony's newest additions to their Pregius family of global shutter CMOS sensors come equipped with a unique new Selectable conversion gain feature. This provides users with control over the gain applied during the analog to digital conversion.

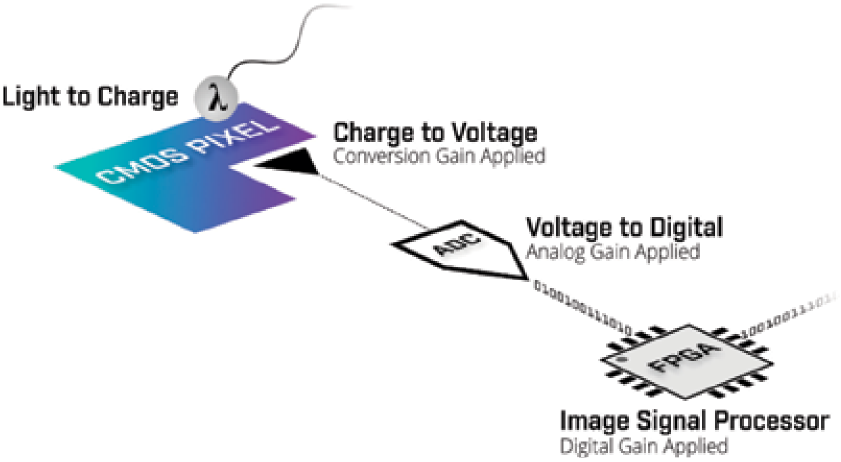


Fig. 18. Gain can be applied to the signal at different points in its path from incoming photon to outgoing digital data.

By selecting between high and low conversion gain, the performance of the sensor can be optimized for high sensitivity or high saturation capacity. Enabling conversion gain is equivalent to adding an additional 7.23 dB of analog gain.

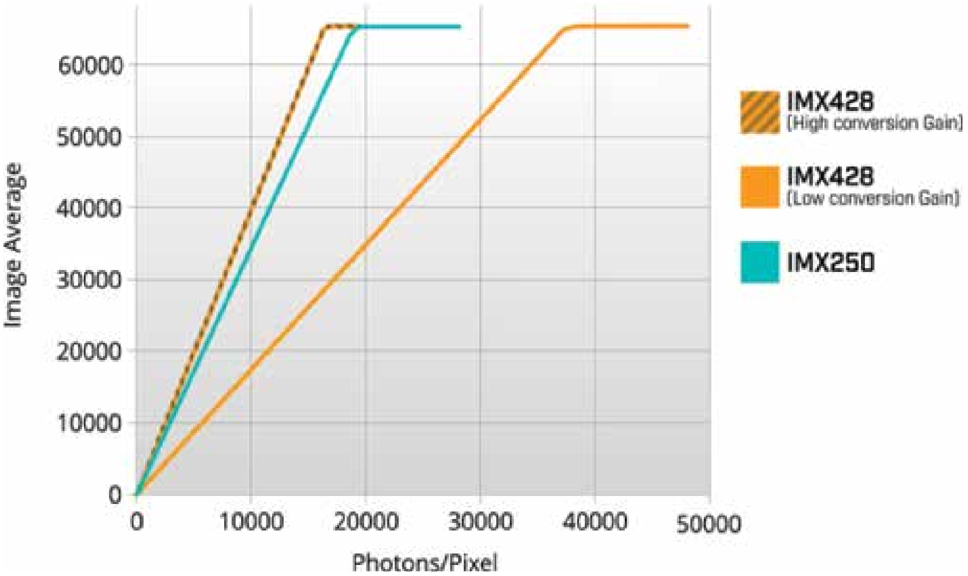


Fig. 19. High conversion gain reaches saturation faster than low conversion gain.

High conversion gain is ideal for low light environments. Read nose is minimized, yielding a low Absolute sensitivity threshold perfect for detecting weak signals with short exposures. Low conversion gain is ideal for brightly lit conditions. Saturation capacity is maximized yielding improved dynamic range. The maximum dynamic range will be limited by the 12-bit ADC.

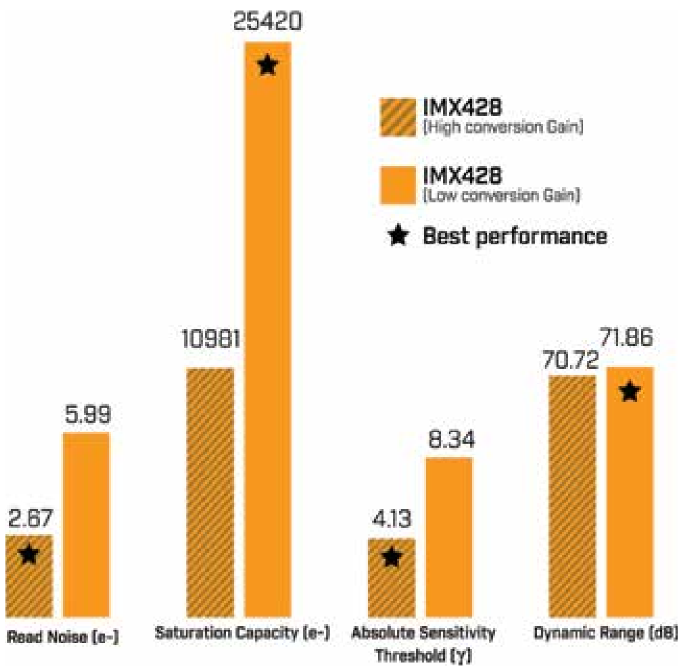


Fig. 20. High Conversion Gain is ideal for low light imaging, while Low Conversion Gain maximizes saturation capacity and dynamic range in brightly lit conditions.

Selectable conversion gain is available on all FLIR Blackfly S cameras based on Sony Pregius sensors with the 4.5 µm pixel architecture.

Near-Infrared Imaging Performance

The silicon used by CMOS image sensors to detect incoming photos, has a relatively low sensitivity to light of wavelengths greater than 900 nm. The average QE for Sony Pregius and STARVIS sensors at 850 nm is 18%, while at 950 this falls to 7%.

For applications which benefit from sensitivity in the Near-Infrared (NIR) wavelengths, Pregius and STARVIS sensors are generally recommended. While their QE at 950 nm may be lower than other sensors optimized for higher QE at this wavelength, the far lower Temporal Dark Noise (read noise) of Pregius sensors easily compensates for this. The low read noise results in Pregius and STARVIS sensors having much better NIR Absolute Sensitivity Threshold. This allows higher gain to be applied, delivering a brighter, clearer image than sensors with higher NIR QE, but lower NIR AST.

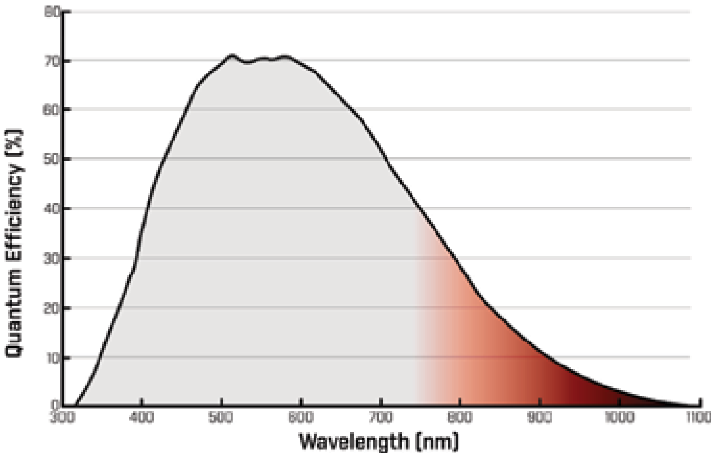


Fig. 21. The Near-Infrared region of the spectrum detectable by the Sony IMX248 CMOS image sensor highlighted in red.

Conclusion

While there is no substitute for obtaining and testing a camera in situ; we hope you've found this guide helpful in narrowing down your initial selection. If you have any questions at all, please do not hesitate to contact our international sales team.

THE AMERICAS
T: +1 866.765.0827 (toll free)
T: +1 604.242.9937
E: mv-sales@flir.com

EUROPE, MIDDLE EAST,
RUSSIA AND AFRICA
T: +49 7141 488817-0
F: +49 7141 488817-99
E: mv-eusales@flir.com

CHINA
T: +86 10 8215 9938
F: +86 10 8215 9936
E: mv-chinasales@flir.com
E: mv-taiwansales@flir.com

JAPAN AND ASIA PACIFIC
T: +81-3-5422-7866
E: mv-japansales@flir.com

THE AMERICAS
T: +1 866.765.0827 (toll free)
T: +1 604.242.9937
E: mv-sales@flir.com

EUROPE, MIDDLE EAST, RUSSIA AND AFRICA
T: +49 7141 488817-0
F: +49 7141 488817-99
E: mv-eusales@flir.com

CHINA
T: +86 10 8215 9938
F: +86 10 8215 9936
E: mv-chinasales@flir.com
E: mv-taiwansales@flir.com

JAPAN AND ASIA PACIFIC
T: +81-3-5422-7866
E: mv-japansales@flir.com

www.flir.com/mv
NASDAQ: FLIR

Specifications are subject to change without notice

DOC NUMBER: 19-0709-B&CS

The World's Sixth Sens