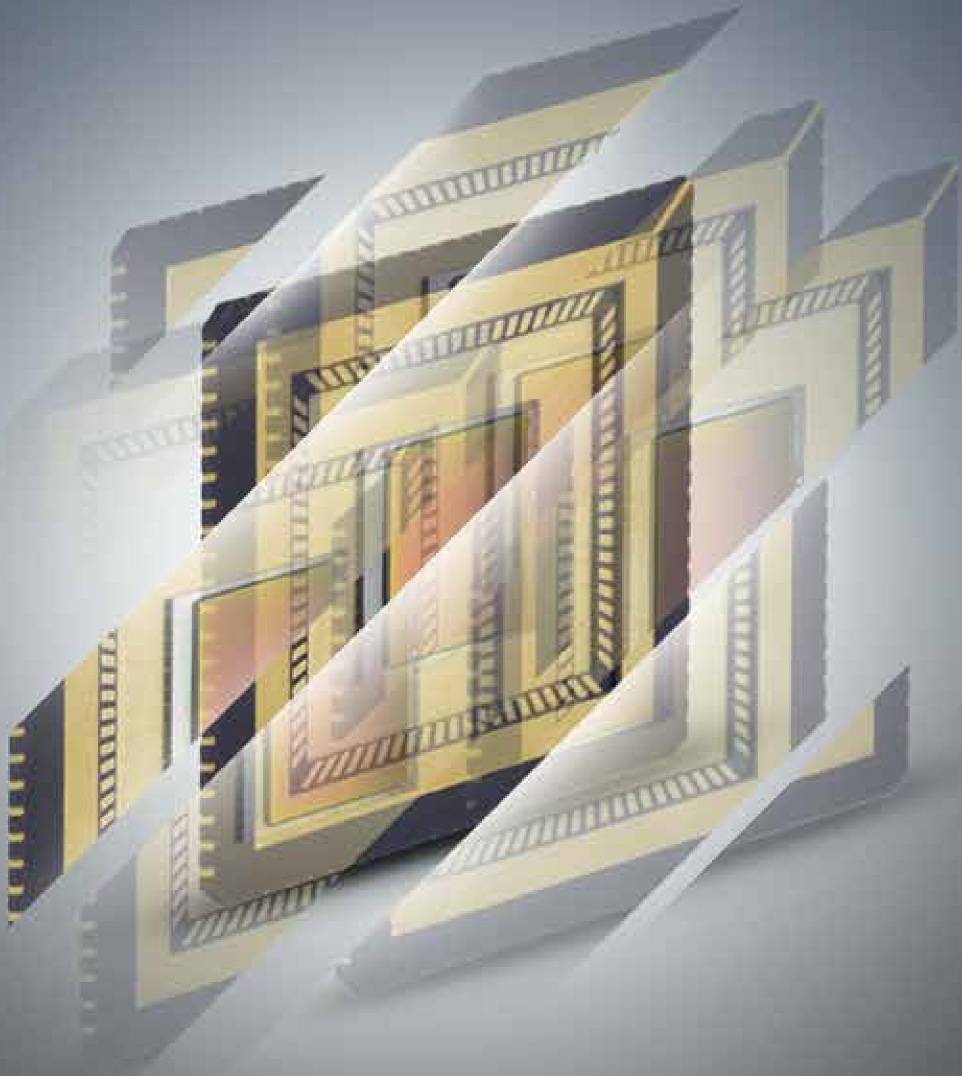
SENSOR REVIEW: MONO CAMERAS

- EMVA1288 Specification Comparison Charts
- Guide to Using EMVA1288 Specifications
- Choosing the Right Sensor Type
- 2022 Edition



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).

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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.

BFS-U3-50S5M-C-BD2-DL

Camera Family
BFS = Blackfly S
BFLY = Blackfly
ORX = Oryx
FFY = Firefly S or DL
CM3 = Chameleon3
GS3: Grassopper3
LD5P = Ladybug5+

Interface
U3=USB 3.0
GE=GigE
PGE=PoE GigE
10G/10GS=
10GigE

Megapixels
04 = 0.4 MP
13 = 1.3 MP
50 = 5.0 MP
310 = 31.0 MP
etc

Sensor Brand
S=Sony
A=Aptina
C=CMOSIS
Y=ON Semi
E=E2V
H=Sharp

Sensor Size
0=Unassigned
1=1/4"
2=1/3",
1/2.8",
1/2.5"
3=1/2"
4=1/1.8"
5 = 2/3"
6=1"
7=1.1"

Color/Mono
M=Mono
C=Color
P=Polarized
NIR=Near
Infrared

Lens Mount
C=C-Mount
CS=CS-Mount
S=S-Mount
BD2=Board-level
w/FPC

Board-level

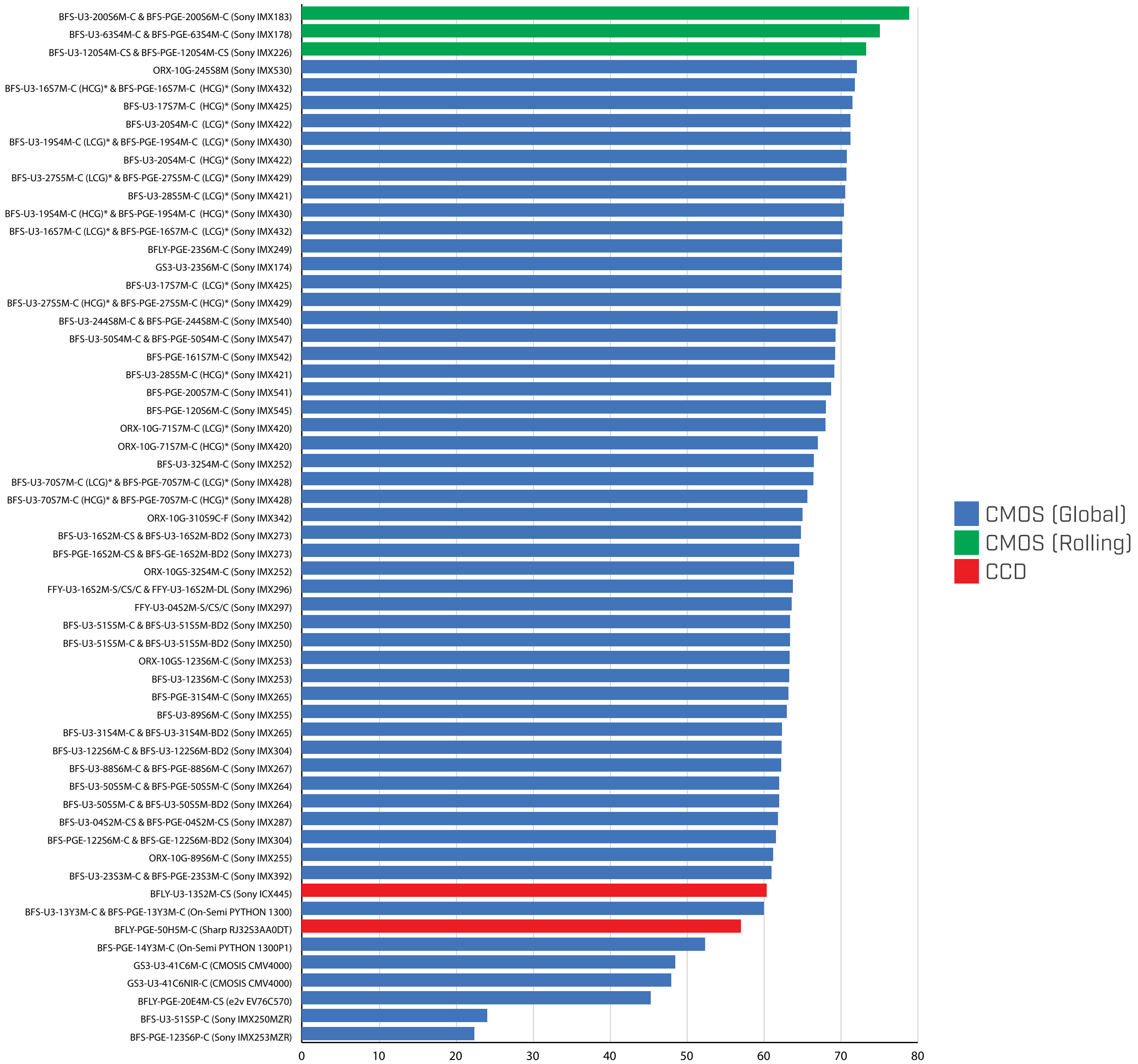
Deep Learning Inference

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.

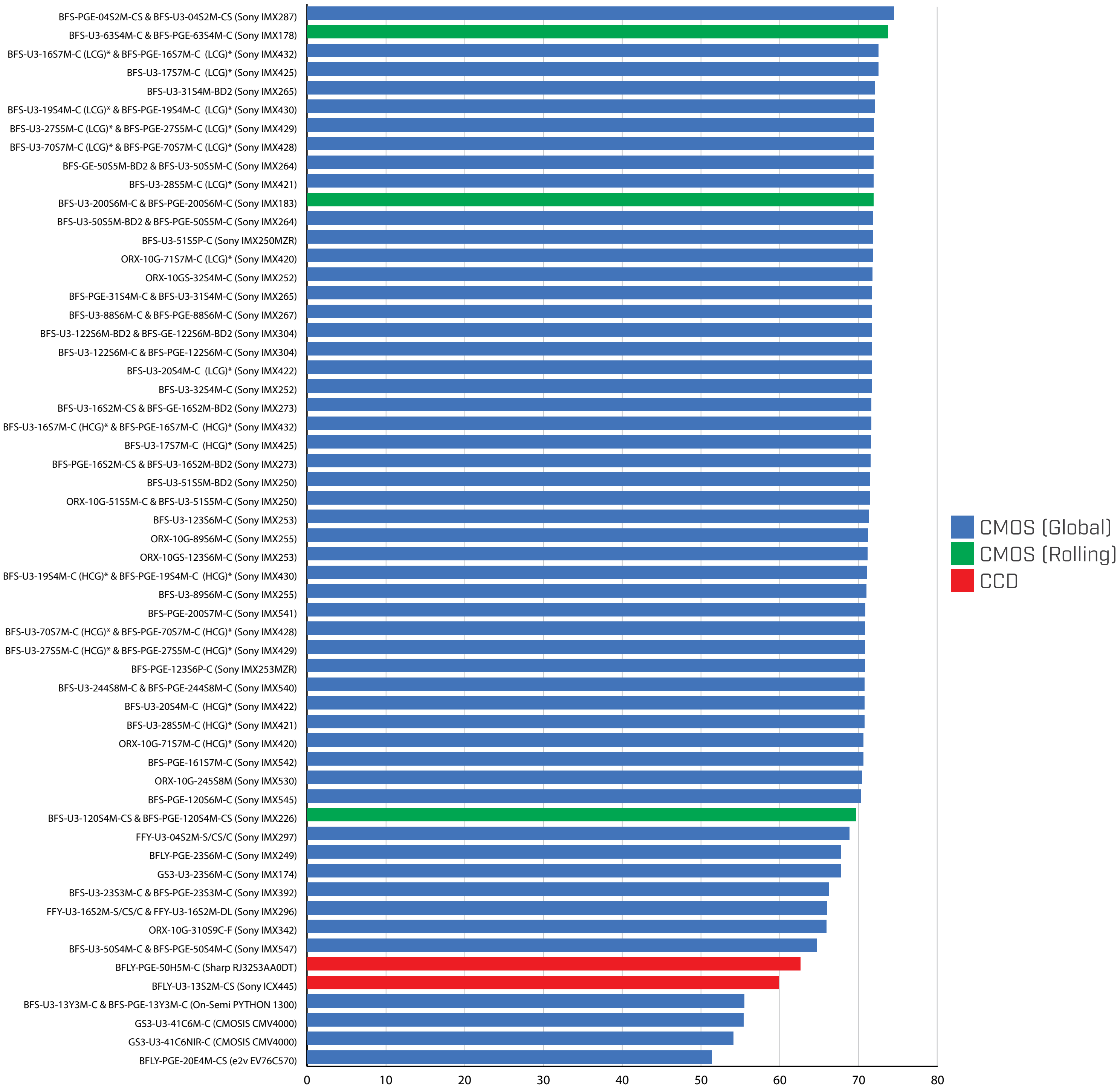


* LCG and HCG stand for low conversion gain and high conversion gain respectively. These are explained in "Selectable Conversion Gain" section.

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.

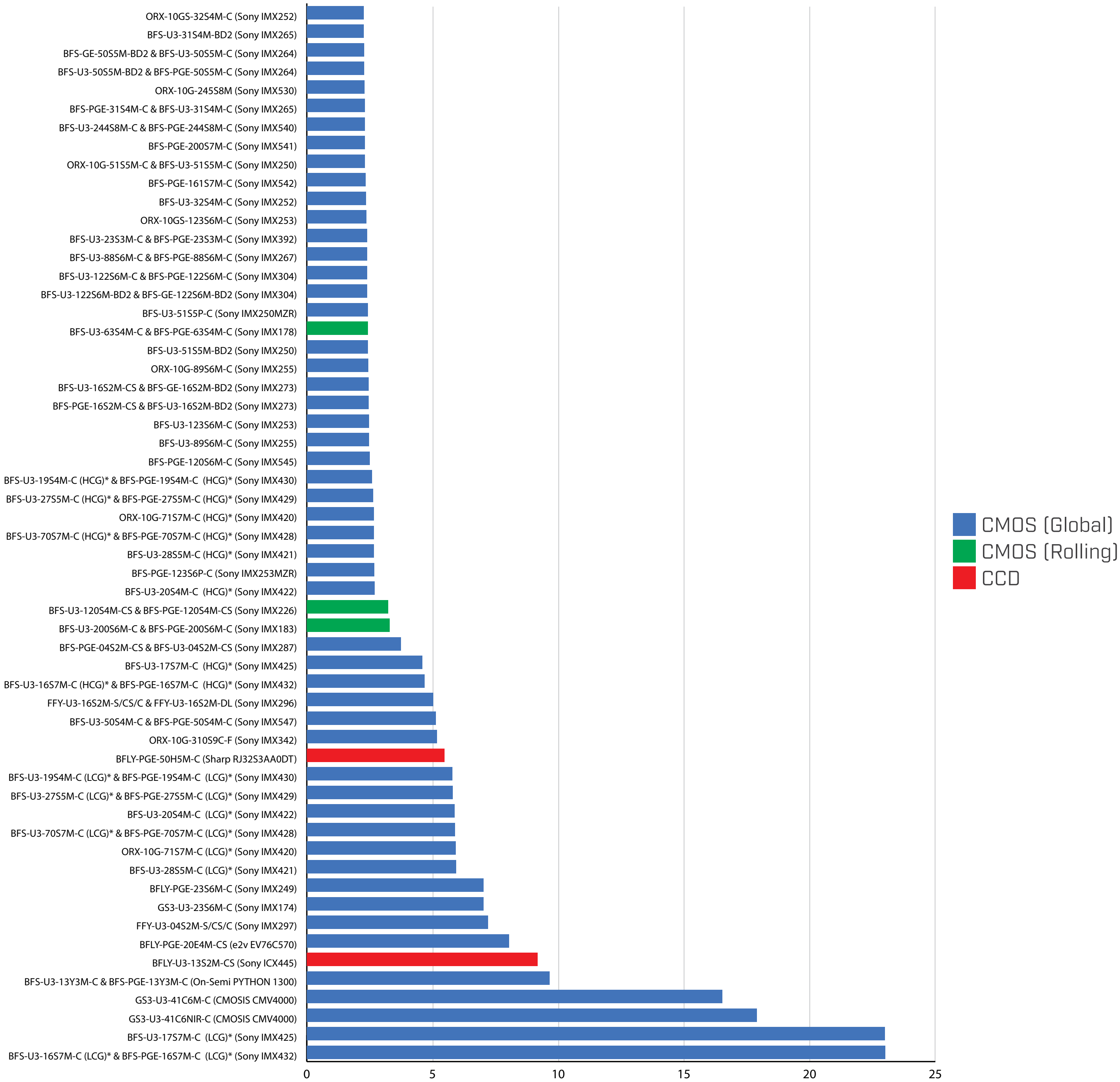


* LCG and HCG stand for low conversion gain and high conversion gain respectively. These are explained in "Selectable Conversion Gain" section.

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.

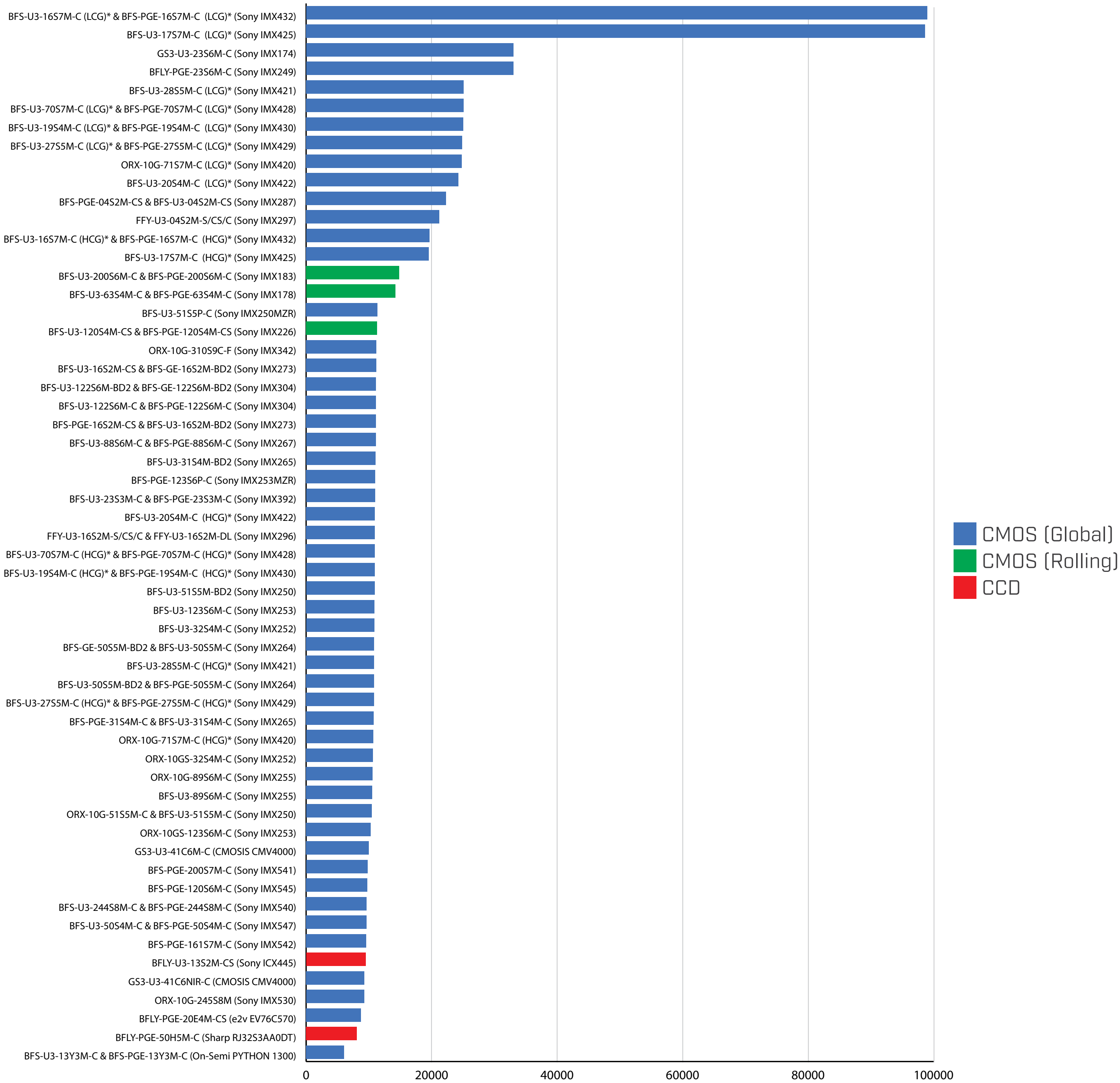


* LCG and HCG stand for low conversion gain and high conversion gain respectively. These are explained in "Selectable Conversion Gain" section.

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.

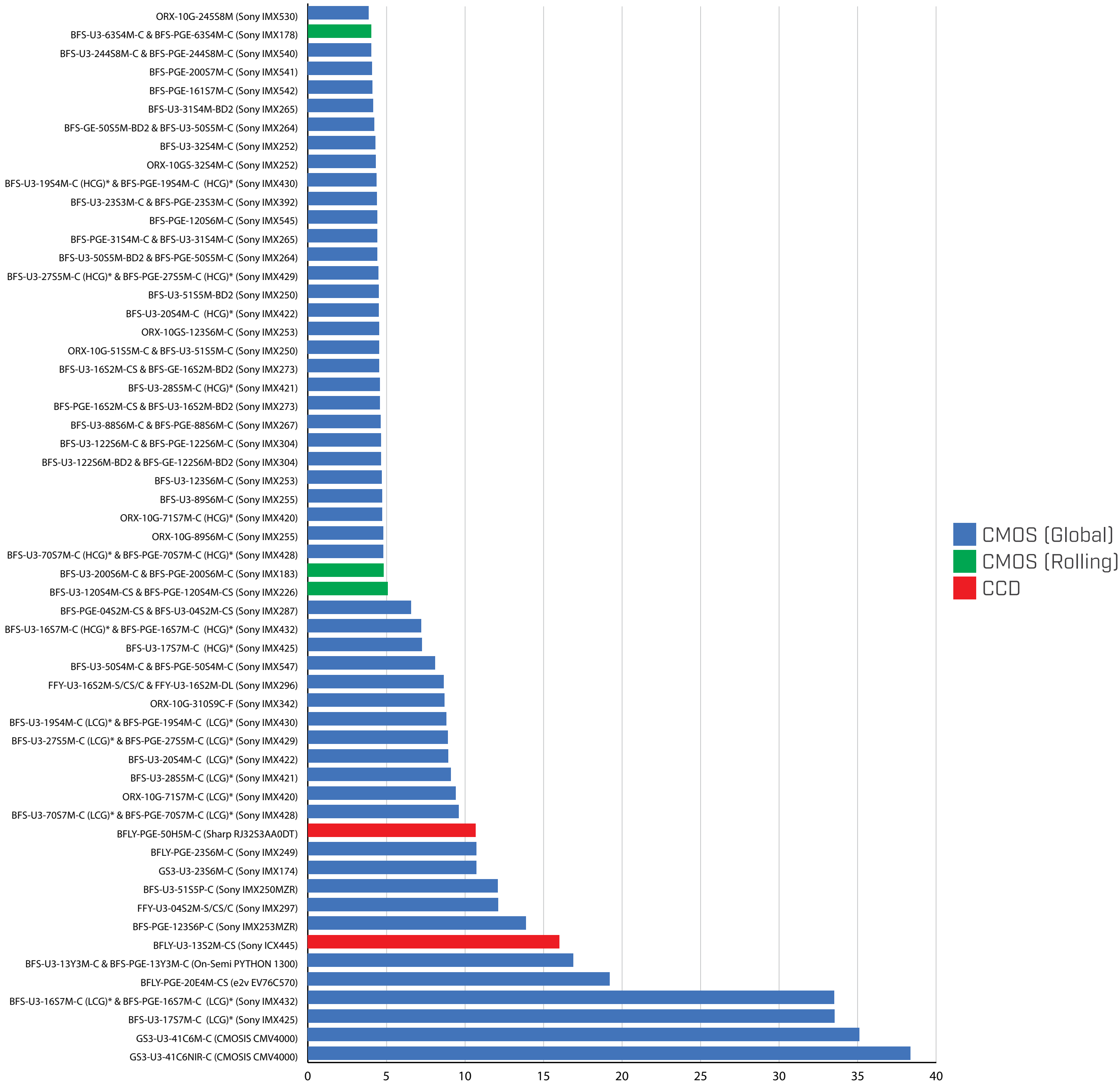


* LCG and HCG stand for low conversion gain and high conversion gain respectively. These are explained in "Selectable Conversion Gain" section.

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.



* LCG and HCG stand for low conversion gain and high conversion gain respectively. These are explained in "Selectable Conversion Gain" section.

Model Number	Sensor Manufacturer	Sensor Name	Sensor Size	Interface	Sensor Type	Readout	Resolution	Mega-pixels	Max FPS	Pixel Size (µm)
GS3-U3-41C6M-C	CMOSIS	CMV4000	1	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 2048	4.2	90 FPS	5.5 µm
GS3-U3-41C6NIR-C	CMOSIS	CMV4000	1	USB 3.1 Gen 1	CMOS	Global shutter	2048 x 2048	4.2	90 FPS	5.5 µm
BFLY-PGE-20E4M-CS	e2v	EV76C570	1/1.8	PoE GigE	CMOS	Global shutter	1600 x 1200	1.9	50 FPS	4.5 µm
BFLY-U3-13S2M-CS	Sony	ICX445	1/3	USB 3.1 Gen 1	CCD	Global shutter	1288 x 964	1.2	30 FPS	3.75 µm
GS3-U3-23S6M-C	Sony	IMX174	1	USB 3.1 Gen 1	CMOS	Global shutter	1920 x 1200	2.3	163 FPS	5.86 µm
BFS-PGE-63S4M-C	Sony	IMX178	1/1.8	PoE GigE	CMOS	Rolling shutter with global reset	3072 x 2048	6.3	19 FPS	2.4 µm
BFS-U3-63S4M-C	Sony	IMX178	1/1.8	USB 3.1 Gen 1	CMOS	Rolling shutter with global reset	3072 x 2048	6.3	59.6 FPS	2.4 µm
BFS-PGE-200S6M-C	Sony	IMX183	1	PoE GigE	CMOS	Rolling shutter with global reset	5472 x 3648	20.0	6.1 FPS	2.4 µm
BFS-U3-200S6M-C	Sony	IMX183	1	USB 3.1 Gen 1	CMOS	Rolling shutter with global reset	5472 x 3648	20.0	18 FPS	2.4 µm
BFS-PGE-120S4M-CS	Sony	IMX226	1/1.7	PoE GigE	CMOS	Rolling shutter with global reset	4000 x 3000	12.0	8.5 FPS	1.85 µm
BFS-U3-120S4M-CS	Sony	IMX226	1/1.7	USB 3.1 Gen 1	CMOS	Rolling shutter with global reset	4000 x 3000	12.0	31 FPS	1.85 µm
BFLY-PGE-23S6M-C	Sony	IMX249	1	PoE GigE	CMOS	Global Shutter	1920 x 1200	2.3	41 FPS	5.86 µm
BFS-U3-51S5M-BD2	Sony	IMX250	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5.0	75 FPS	3.45 µm
BFS-U3-51S5M-C	Sony	IMX250	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5.0	75 FPS	3.45 µm
ORX-10G-51S5M-C	Sony	IMX250	2/3	10GigE	CMOS	Global Shutter	2448 x 2048	5.0	162 FPS	3.45 µm
BFS-U3-51S5P-C	Sony	IMX250MZR	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5.0	75 FPS	3.45 µm
BFS-U3-32S4M-C	Sony	IMX252	1/1.8	USB 3.1 Gen 1	CMOS	Global Shutter	2048 x 1536	3.1	118 FPS	3.45 µm
ORX-10GS-32S4M-C	Sony	IMX252	1/1.8	10GigE	CMOS	Global Shutter	2048 x 1536	3.1	216 FPS	3.45 µm
BFS-U3-123S6M-C	Sony	IMX253	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 3000	12.3	30 FPS	3.45 µm
BFS-PGE-123S6P-C	Sony	IMX253MZR	1.1	PoE GigE	CMOS	Global Shutter	4096 x 3000	12.3	10 FPS	3.45 µm
ORX-10GS-123S6M-C	Sony	IMX253	1.1	10GigE	CMOS	Global Shutter	4096 x 3000	12.3	68 FPS	3.45 µm
BFS-U3-89S6M-C	Sony	IMX255	1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 2160	8.8	42 FPS	3.45 µm
ORX-10G-89S6M-C	Sony	IMX255	1	10GigE	CMOS	Global Shutter	4096 x 2160	8.8	93 FPS	3.45 µm
BFS-GE-50S5M-BD2	Sony	IMX264	2/3	GigE	CMOS	Global Shutter	2448 x 2048	5.0	22 FPS	3.45 µm
BFS-PGE-50S5M-C	Sony	IMX264	2/3	PoE GigE	CMOS	Global Shutter	2448 x 2048	5.0	22 FPS	3.45 µm
BFS-U3-50S5M-BD2	Sony	IMX264	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5.0	35 FPS	3.45 µm
BFS-U3-50S5M-C	Sony	IMX264	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5.0	35 FPS	3.45 µm
BFS-PGE-31S4M-C	Sony	IMX265	1/1.8	PoE GigE	CMOS	Global Shutter	2048 x 1536	3.1	35 FPS	3.45 µm
BFS-U3-31S4M-BD2	Sony	IMX265	1/1.8	USB 3.1 Gen 1	CMOS	Global Shutter	2048 x 1536	3.1	57 FPS	3.45 µm
BFS-U3-31S4M-C	Sony	IMX265	1/1.8	USB 3.1 Gen 1	CMOS	Global Shutter	2048 x 1536	3.1	57 FPS	3.45 µm
BFS-PGE-88S6M-C	Sony	IMX267	1	PoE GigE	CMOS	Global Shutter	4096 x 2160	8.8	13.9 FPS	3.45 µm
BFS-U3-88S6M-BD2	Sony	IMX267	1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 2160	8.9	32 FPS	3.45 µm
BFS-U3-88S6M-C	Sony	IMX267	1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 2160	8.8	32 FPS	3.45 µm
BFS-GE-16S2M-BD2	Sony	IMX273	1/2.9	GigE	CMOS	Global Shutter	1440 x 1080	1.6	78 FPS	3.45 µm
BFS-PGE-16S2M-CS	Sony	IMX273	1/2.9	PoE GigE	CMOS	Global Shutter	1440 x 1080	1.6	78 FPS	3.45 µm
BFS-U3-16S2M-BD2	Sony	IMX273	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	1440 x 1080	1.6	226 FPS	3.45 µm
BFS-U3-16S2M-CS	Sony	IMX273	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	1440 x 1080	1.6	226 FPS	3.45 µm
BFS-PGE-04S2M-CS	Sony	IMX287	1/2.9	PoE GigE	CMOS	Global Shutter	720 x 540	0.4	291 FPS	6.9 µm
BFS-U3-04S2M-CS	Sony	IMX287	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	720 x 540	0.4	522 FPS	6.9 µm
FFY-U3-16S2M-DL	Sony	IMX296	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	1440 x 1080	1.6	60 FPS	3.45 µm
FFY-U3-16S2M-S/CS/C	Sony	IMX296	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	1440 x 1080	1.6	60 FPS	3.45 µm
FFY-U3-04S2M-S/CS/C	Sony	IMX297	1/2.9	USB 3.1 Gen 1	CMOS	Global Shutter	720 x 540	0.4	120 FPS	6.9 µm
BFS-GE-122S6M-BD2	Sony	IMX304	1.1	GigE	CMOS	Global Shutter	4096 x 3000	12.3	10 FPS	3.45 µm
BFS-PGE-122S6M-C	Sony	IMX304	1.1	PoE GigE	CMOS	Global Shutter	4096 x 3000	12.3	10 FPS	3.45 µm
BFS-U3-122S6M-BD2	Sony	IMX304	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 3000	12.3	23 FPS	3.45 µm
BFS-U3-122S6M-C	Sony	IMX304	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	4096 x 3000	12.3	23 FPS	3.45 µm
ORX-10G-310S9C-F	Sony	IMX342	APS-C	10GigE	CMOS	Global Shutter	6464 x 4852	31.4	27 FPS	3.45 µm
BFS-PGE-23S3M-C	Sony	IMX392	1/2.3	PoE GigE	CMOS	Global Shutter	1920 x 1200	2.3	53 FPS	3.45 µm
BFS-U3-23S3M-C	Sony	IMX392	1/2.3	USB 3.1 Gen 1	CMOS	Global Shutter	1920 x 1200	2.3	163 FPS	3.45 µm
ORX-10G-71S7M-C (HCG)*	Sony	IMX420	1.1	10GigE	CMOS	Global Shutter	3208 x 2200	7.1	112 FPS	4.5 µm
ORX-10G-71S7M-C (LCG)*	Sony	IMX420	1.1	10GigE	CMOS	Global Shutter	3208 x 2200	7.1	112 FPS	4.5 µm
BFS-U3-28S5M-C (HCG)*	Sony	IMX421	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	1936 x 1464	2.8	130 FPS	4.5 µm
BFS-U3-28S5M-C (LCG)*	Sony	IMX421	2/3	USB 3.1 Gen 1	CMOS	Global Shutter	1936 x 1464	2.8	130 FPS	4.5 µm
BFS-U3-20S4M-C (HCG)*	Sony	IMX422	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1616 x 1240	2.0	175 FPS	4.5 µm
BFS-U3-20S4M-C (LCG)*	Sony	IMX422	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1616 x 1240	2.0	175 FPS	4.5 µm
BFS-U3-17S7M-C (HCG)*	Sony	IMX425	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	1600 x 1100	1.7	196 FPS	9 µm
BFS-U3-17S7M-C (LCG)*	Sony	IMX425	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	1600 x 1100	1.7	196 FPS	9 µm
BFS-PGE-70S7M-C (HCG)*	Sony	IMX428	1.1	PoE GigE	CMOS	Global Shutter	3208 x 2200	7.1	17.4 FPS	4.5 µm
BFS-PGE-70S7M-C (LCG)*	Sony	IMX428	1.1	PoE GigE	CMOS	Global Shutter	3208 x 2200	7.1	17.4 FPS	4.5 µm
BFS-U3-70S7M-C (HCG)*	Sony	IMX428	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	3208 x 2200	7.1	51 FPS	4.5 µm
BFS-U3-70S7M-C (LCG)*	Sony	IMX428	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	3208 x 2200	7.1	51 FPS	4.5 µm
BFS-PGE-27S5M-C (HCG)*	Sony	IMX429	2/3	PoE GigE	CMOS	Global Shutter	1936 x 1464	2.8	43 FPS	4.5 µm
BFS-PGE-27S5M-C (LCG)*	Sony	IMX429	2/3	PoE GigE	CMOS	Global Shutter	1936 x 1464	2.8	43 FPS	4.5 µm
BFS-U3-27S5M-C (HCG)*	Sony	IMX429	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1936 x 1464	2.8	95 FPS	4.5 µm
BFS-U3-27S5M-C (LCG)*	Sony	IMX429	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1936 x 1464	2.8	95 FPS	4.5 µm
BFS-PGE-19S4M-C (HCG)*	Sony	IMX430	1/1.7	PoE GigE	CMOS	Global Shutter	1616 x 1240	2.0	60 FPS	4.5 µm
BFS-PGE-19S4M-C (LCG)*	Sony	IMX430	1/1.7	PoE GigE	CMOS	Global Shutter	1616 x 1240	2.0	60 FPS	4.5 µm
BFS-U3-19S4M-C (HCG)*	Sony	IMX430	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1616 x 1240	2.0	132 FPS	4.5 µm
BFS-U3-19S4M-C (LCG)*	Sony	IMX430	1/1.7	USB 3.1 Gen 1	CMOS	Global Shutter	1616 x 1240	2.0	132 FPS	4.5 µm
BFS-PGE-16S7M-C (HCG)*	Sony	IMX432	1.1	PoE GigE	CMOS	Global Shutter	1600 x 1100	1.7	69 FPS	9 µm
BFS-PGE-16S7M-C (LCG)*	Sony	IMX432	1.1	PoE GigE	CMOS	Global Shutter	1600 x 1100	1.7	69 FPS	9 µm
BFS-U3-16S7M-C (HCG)*	Sony	IMX432	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	1600 x 1100	1.7	97 FPS	9 µm
BFS-U3-16S7M-C (LCG)*	Sony	IMX432	1.1	USB 3.1 Gen 1	CMOS	Global Shutter	1600 x 1100	1.7	97 FPS	9 µm
ORX-10G-245S8M	Sony	IMX530	1.2	10GigE	CMOS	Global Shutter	5320 x 4600	24.6	44 FPS	2.74 µm
BFS-PGE-244S8M-C	Sony	IMX540	4/3	PoE GigE	CMOS	Global Shutter	5320 X 4600	24.5	5 FPS	2.74 µm
BFS-U3-244S8M-C	Sony	IMX540	4/3	USB 3.1 Gen 1	CMOS	Global Shutter	5320 x 4600	24.5	12 FPS	2.74 µm
BFS-PGE-200S7M-C	Sony	IMX541	1.1	PoE GigE	CMOS	Global Shutter	4540 x 4504	20.2	6 FPS	2.74 µm
BFS-PGE-161S7M-C	Sony	IMX542	1.1	PoE GigE	CMOS	Global Shutter	5320 x 3032	16.1	7.5 FPS	2.74 µm
BFS-PGE-120S6M-C	Sony	IMX545	1/1.1	PoE GigE	CMOS	Global Shutter	4096 x 3000	12	10 FPS	2.74 µm
BFS-PGE-50S4M-C	Sony	IMX547	1/1.8	PoE GigE	CMOS	Global Shutter	2448 x 2048	5	24 FPS	2.74 µm
BFS-U3-50S4M-C	Sony	IMX547	1/1.8	USB 3.1 Gen 1	CMOS	Global Shutter	2448 x 2048	5	72 FPS	2.74 µm
BFS-PGE-13Y3M-C	On-Semi	PYTHON 1300	1/2	PoE GigE	CMOS	Global Shutter	1280 x 1024	1.3	84 FPS	4.8 µm
BFS-U3-13Y3M-C	On-Semi	PYTHON 1300	1/2	USB 3.1 Gen 1	CMOS	Global Shutter	1280 x 1024	1.3	170 FPS	4.8 µm
BFS-PGE-14Y3M-C	On-Semi	PYTHON 1300P1	1/2	PoE GigE	CMOS	Global Shutter	1280 x 1024	1.3	92 FPS	4.8 µm
BFLY-PGE-50H5M-C	Sharp	RJ32S3AA0DT	2/3	PoE GigE	CCD	Global Shutter	2448 x 2048	5.0	7.5 FPS	3.45 µm

Quantum Efficiency (% @530nm)	Gain (ADU/e-)	Temporal Dark Noise (ADU)	Temporal Dark Noise (e-)	SNR (dB)	SNR (Bits)	AbsoluteSensitivity Threshold (γ)	Saturation Capacity (e-)	Dynamic Range (dB)	Dynamic Range (Bits)
48.50	6.27	103.71	16.53	39.99	6.64	35.11	9983	55.36	9.20
48.00	6.64	118.82	17.90	39.68	6.59	38.34	9282	54.06	8.98
45.30	6.70	36.55	8.04	39.41	6.55	19.22	8727	51.38	8.53
60.38	6.51	59.70	9.17	39.77	6.61	16.01	9487	59.84	9.94
70.14	1.92	13.32	7.02	45.19	7.51	10.72	33022	67.71	11.25
77.07	4.30	10.98	2.55	41.52	6.90	3.96	14177	73.33	12.18
75.05	4.31	10.58	2.42	41.52	6.90	4.03	14204	73.73	12.25
75.73	4.17	13.81	3.26	41.70	6.93	4.97	14794	71.89	11.94
78.91	4.17	13.85	3.30	41.71	6.93	4.83	14837	71.84	11.93
76.00	5.88	32.62	5.61	40.32	6.70	8.04	10752	14136.00	10.78
73.27	5.56	18.09	3.23	40.54	6.73	5.09	11323	69.64	11.57
70.14	1.92	13.32	7.02	45.19	7.51	10.72	33022	67.71	11.25
65.06	5.68	13.82	2.43	40.38	6.71	4.51	10917	71.42	11.86
63.40	5.70	13.87	2.44	40.40	6.71	4.63	10970	71.45	11.87
61.95	5.88	13.96	2.31	40.18	6.67	4.54	10435	71.38	11.86
24.10	5.56	13.59	2.42	40.55	6.74	12.10	11359	71.81	11.93
66.50	5.73	13.46	2.35	40.36	6.70	4.29	10858	71.62	11.90
63.93	5.88	13.37	2.26	40.27	6.69	4.32	10648.5	71.72	11.91
63.30	5.88	14.39	2.47	40.37	6.70	4.71	10878	71.27	11.84
22.42	5.56	14.94	2.68	40.41	6.71	13.87	10995	70.77	11.76
63.35	5.88	14.35	2.37	40.12	6.66	4.53	10277	71.08	11.81
62.99	5.88	14.33	2.47	40.22	6.68	4.72	10514	70.97	11.79
61.22	5.88	14.57	2.44	40.25	6.68	4.80	10584	71.13	11.81
65.55	5.56	13.28	2.27	40.35	6.7	4.22	10849	71.87	11.94
66.08	5.56	13.42	2.35	40.52	6.73	4.32	11278	71.93	11.95
62.51	5.77	13.10	2.27	40.34	6.70	4.43	10824	71.83	11.93
62.00	5.88	13.19	2.25	40.28	6.69	4.47	10658	71.77	11.92
63.20	5.88	13.41	2.30	40.32	6.70	4.43	10760	71.69	11.91
66.46	5.88	13.09	2.26	40.43	6.72	4.16	11047.7	72.04	11.97
62.36	5.88	13.10	2.26	40.33	6.70	4.43	10791	71.83	11.93
63.45	5.88	14.16	2.45	40.33	6.70	4.66	10784	71.25	11.83
64.6	5.88	13.62	2.33	40.29	6.69	4.38	10688.70	71.55	11.88
62.26	5.88	13.73	2.39	40.46	6.72	4.64	11107	71.69	11.91
64.00	5.88	13.80	2.41	40.42	6.71	4.58	11007	71.55	11.88
64.60	5.71	14.05	2.46	40.46	6.72	4.58	11127	71.50	11.88
64.81	5.88	14.01	2.45	40.48	6.72	4.55	11179	71.58	11.89
64.81	5.88	14.01	2.45	40.48	6.72	4.55	11179	71.58	11.89
65.00	2.86	10.68	3.74	43.48	7.22	6.57	22302	74.42	12.36
61.82	2.86	10.71	3.71	43.46	7.22	6.81	22187	74.43	12.36
65.45	0.1	0.45	4.91	40.26	6.69	8.26	10612.20	65.86	10.94
63.75	0.09	0.46	5.02	40.39	6.71	8.66	10941.00	65.94	10.95
63.62	0.05	0.34	7.21	43.27	7.19	12.12	21210	68.79	11.43
65.14	5.88	13.65	2.33	40.32	6.7	4.34	10764	71.61	11.89
61.60	5.88	14.11	2.43	40.40	6.71	4.76	10971	71.45	11.87
62.29	5.88	13.82	2.40	40.46	6.72	4.65	11130	71.69	11.91
62.29	5.88	13.82	2.40	40.46	6.72	4.65	11130	71.69	11.91
65.04	5.88	29.80	5.18	40.49	6.72	8.70	11188	65.89	10.94
64.61	5.88	13.54	2.35	40.43	6.71	4.41	11031	71.75	11.92
61.00	5.88	13.7172	2.38827	40.41	6.71	4.39055	10983	66.23	11.00
67.00	5.88	15.89	2.66	40.29	6.69	4.74	10692	70.59	11.73
68.00	2.56	15.23	5.92	43.92	7.30	9.42	24802	71.74	11.92
69.15	5.80	15.47	2.67	40.35	6.70	4.58	10841	70.69	11.74
70.55	2.51	14.87	5.93	44.00	7.31	9.11	25122	71.84	11.93
70.77	5.88	15.73	2.69	40.40	6.71	4.51	10960.9	70.72	11.75
71.27	2.56	15.15	5.87	43.85	7.28	8.93	24277.1	71.63	11.90
71.50	3.22	15.34	4.59	42.91	7.13	7.26	19557	71.53	11.88
70.09	0.65	14.98	22.99	49.94	8.30	33.52	98654	72.46	12.04
70.64	5.88	15.28	2.63	40.36	6.70	4.42	10864	70.82	11.76
71.22	2.56	14.93	5.85	43.97	7.30	8.92	24920	71.88	11.94
65.65	5.88	15.41	2.66	40.39	6.71	4.81	10938	70.78	11.76
66.46	2.56	14.89	5.89	44.00	7.31	9.61	25101	71.89	11.94
67.82	5.88	15.24	2.64	40.38	6.71	3.14	10912	70.81	11.76
68.64	2.56	14.76	5.81	43.99	7.31	6.31	25048	71.97	11.95
69.93	5.88	15.22	2.63	40.34	6.7	4.48	10817.80	70.77	11.75
70.73	2.56	14.80	5.80	43.95	7.3	8.91	24858.90	71.92	11.95
70.85	5.88	14.98	2.60	40.38	6.71	4.37	10920	70.95	11.78
71.58	2.55	14.68	5.81	43.99	7.31	8.82	25090	71.99	11.96
70.43	5.88	14.95	2.59	40.38	6.71	4.38	10921.9	70.98	11.79
71.23	2.5	14.58	5.78	43.99	7.31	8.81	25052.9	72.02	11.96
72.34	3.22	15.31	4.76	42.95	7.13	7.31	19744	71.49	11.87
70.70	0.64	14.80	23.25	49.98	8.30	33.75	99483	72.44	12.03
71.81	3.22	15.16	4.68	42.93	7.13	7.22	19643.6	71.57	11.89
70.22	0.65	14.81	23.01	49.95	8.3	33.49	98965.6	72.48	12.04
72.09	6.67	15.36	2.29	39.66	6.59	3.87	9239	70.4	11.69
68.61	6.67	15.01	2.28	39.9	6.63	4.06	9770	70.9	11.78
69.56	6.67	15.15	2.31	39.83	6.62	4.03	9623	70.72	11.73
68.76	6.67	15.18	2.31	39.91	6.63	4.09	9787	70.83	11.76
69.26	6.67	15.54	2.34	39.81	6.61	4.10	9562	70.55	11.72
68.05	6.67	16.26	2.50	39.89	6.63	4.41	9751	70.23	11.66
67.99	6.67	16.18	2.49	39.99	6.63	4.40	9748	70.26	11.67
69.34	6.67	33.42	5.13	39.83	6.62	8.11	9623	64.66	10.74
60.00	6.25	62.47	9.73	38.02	6.32	17.13	6341	55.85	9.28
60.00	6.67	62.93	9.65	37.81	6.28	16.90	6034	55.48	9.22
52.36	6.67	62.92	9.47	37.83	6.28	19.05	6065	55.68	9.25
57.00	7.69	61.32	5.48	39.08	6.49	10.67	8086	62.61	10.40

*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.

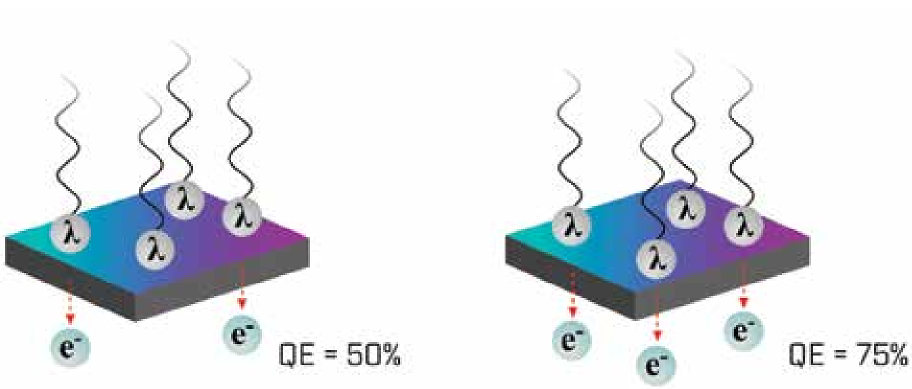


Fig. 1. As more incoming photons are successfully converted into charge, the QE increases proportionally.

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.

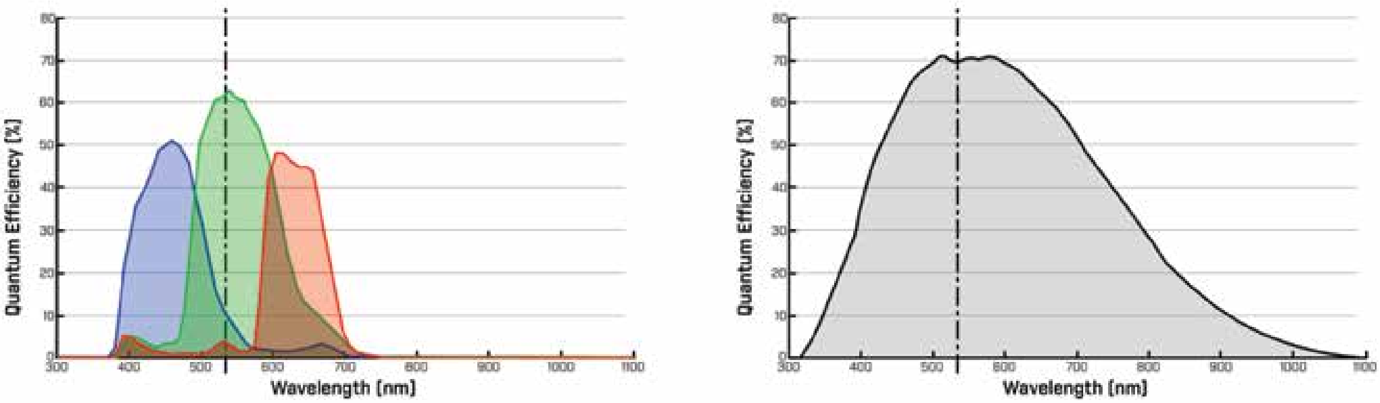


Fig. 2. Example Quantum Efficiency curves of color and monochrome IMX428 Sensors.

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 the weakest signal which can be distinguished.

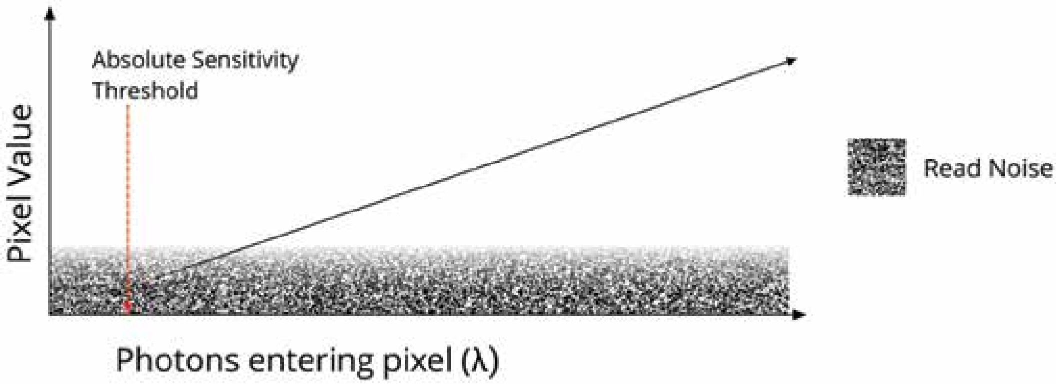


Fig. 3.The absolute sensitivity threshold is the point where the signal becomes distinguishable above the read noise.

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.

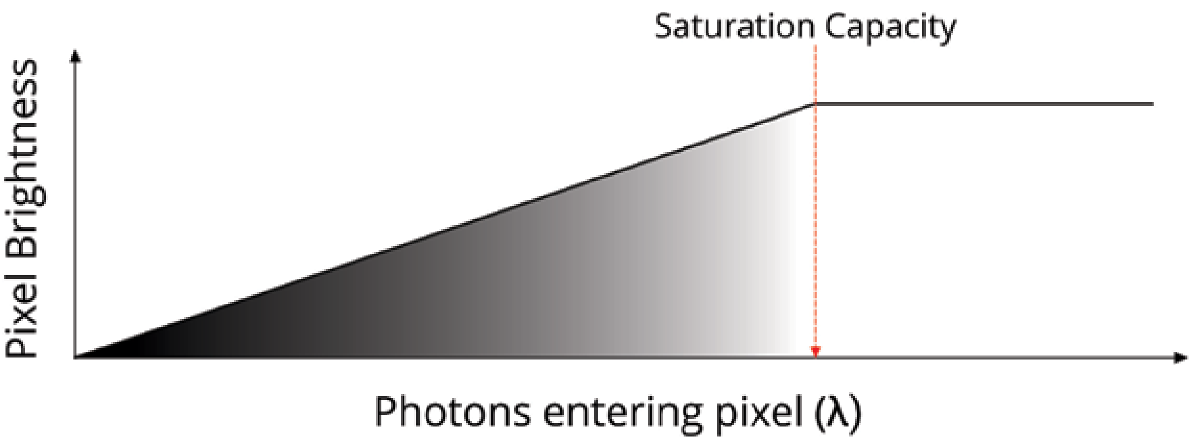


Fig. 4. At saturation, additional light or exposure time will not result in an increase in pixel brightness value.

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.

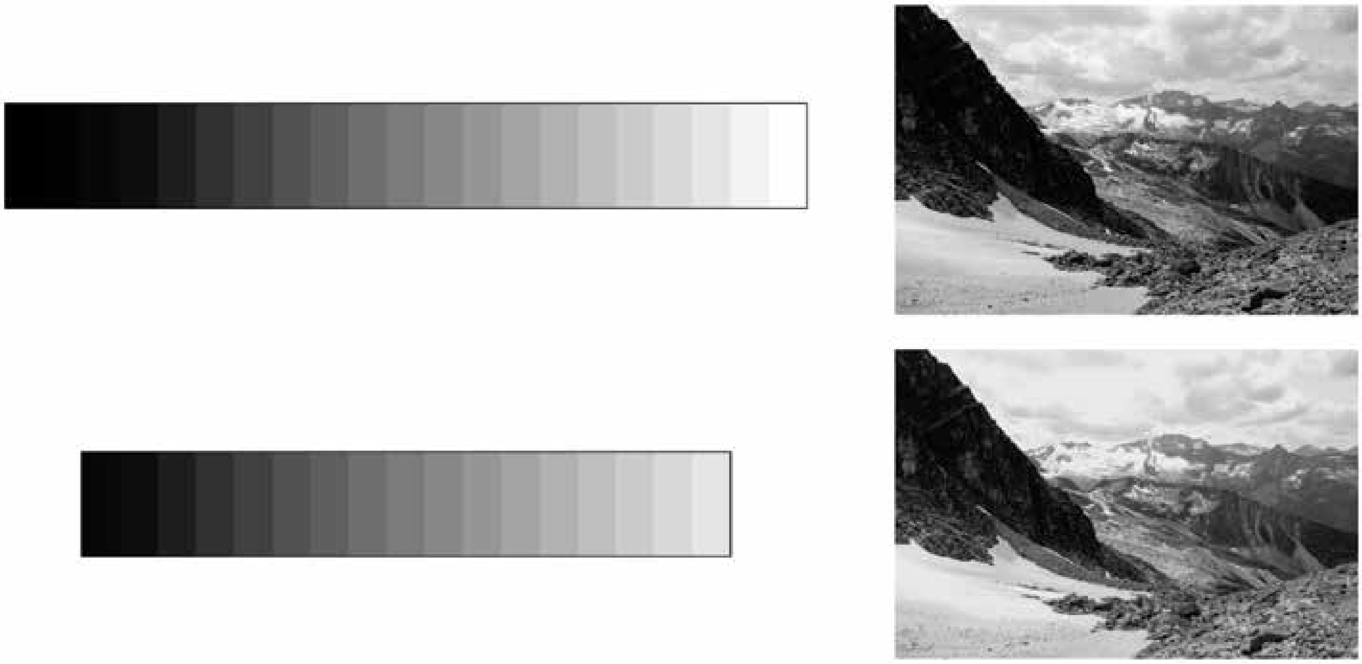


Fig. 5. Reduced dynamic range results in a loss of detail in the brightly lit clouds and shaded rocks.

The dynamic range of images captured 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.

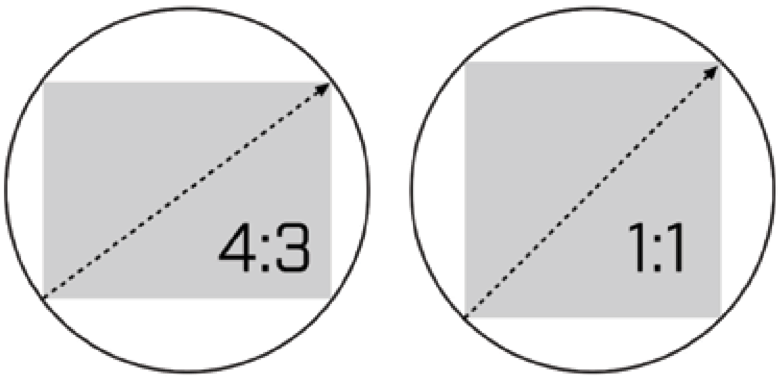


Fig. 6. Sensors of different aspect ratios can share the same optical format.

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.

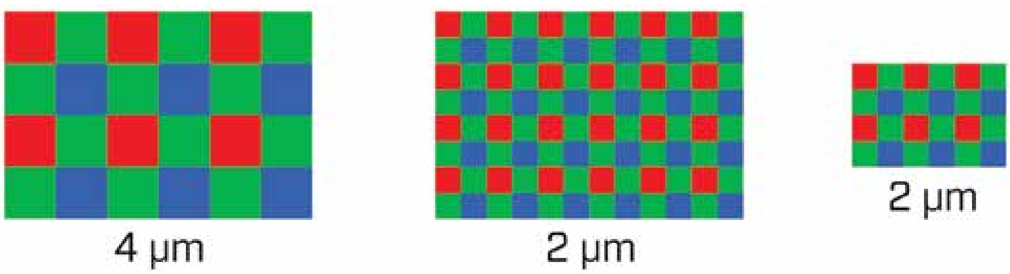


Fig. 7. Smaller pixels can enable higher resolution sensors at a given sensor size, or smaller sensors of a given resolution.

Matching the optical format of the lens and sensor is critical. 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.

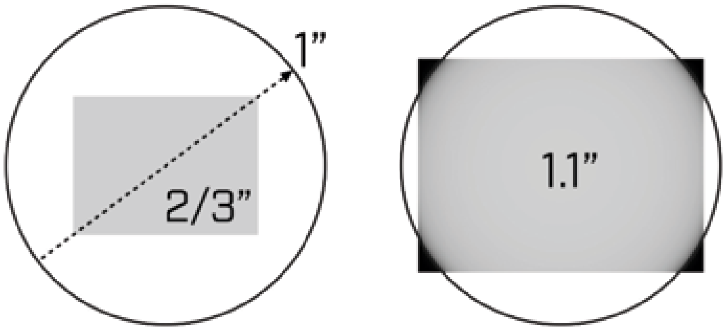


Fig. 8. Dark corners result when a 1.1" sensor is paired with a lens with a 1" optical format. A 2/3" sensor will be fully illuminated.

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.

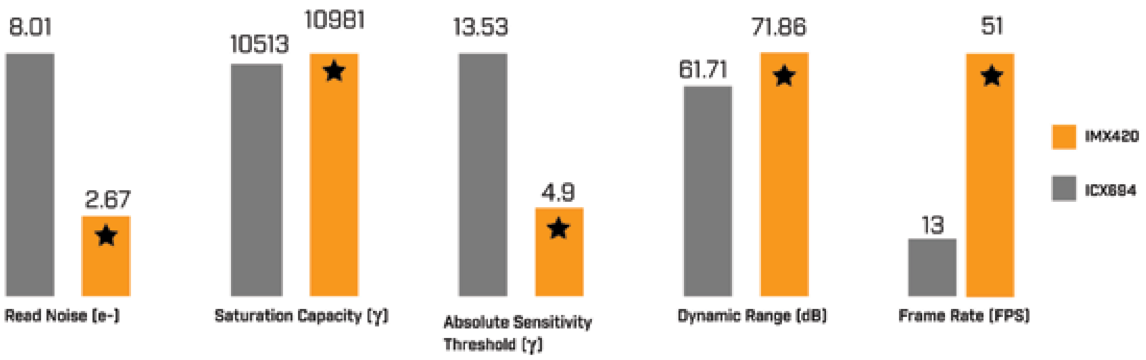


Fig. 9. CMOS image sensors deliver large performance increases compared to CCD sensors.

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 as a reference.

Global Shutter Compared to Rolling Shutter

Global shutter sensors are generally preferred for imaging fast moving objects whereas rolling shutter was preferred for their lower cost and success at low light imaging. With Sony's Pregius global shutter CMOS technology, low light of CMOS sensors (traditionally associated with rolling shutter) are now comparable and in many instances, better than CCD (traditionally associated with global shutter).

Global shutter sensors have readout circuitry on each pixel. This enables them to read every pixel across the sensor plane simultaneously, as if "freezing" the scene. Whereas rolling shutter sensors read each pixel row one at a time. When the target is moving faster than the completion of all rows are read, motion blur occurs – see image below.

To mitigate motion blur, some rolling shutter sensors include a global reset feature where exposure is controlled and all pixels on the sensor are read almost simultaneously, rather than row by row. There is still some delay between each row's readout resulting in a partial reduction in motion blur and other effects typical of rolling shutters.

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 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. Itsits behind the readout circuitry, which is sandwiched between the photodiode and the microlenses used to direct light into the pixel. Back 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.

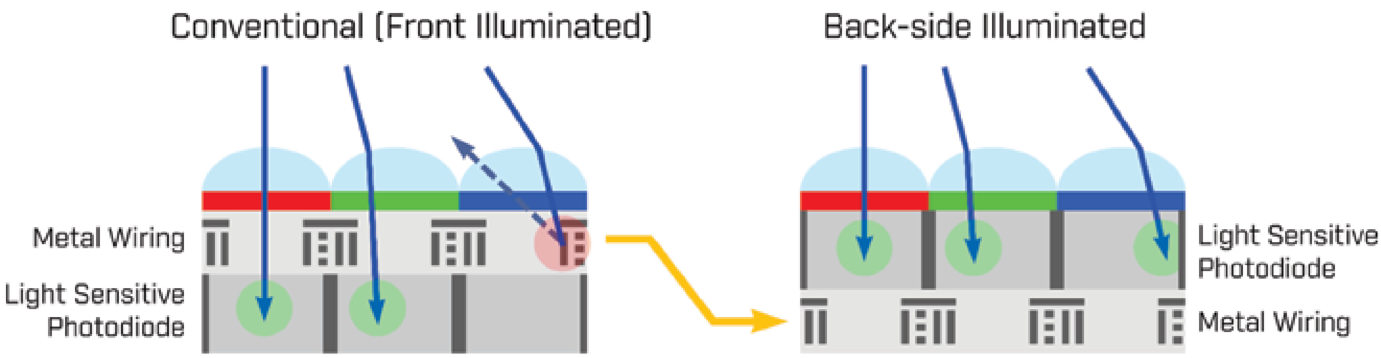


Fig. 11. BSI sensors invert the traditional front illuminated sensor design making it easier for photons to enter each pixel's light sensitive photodiode.

Increased QE, coupled with low-noise read out circuitry, means Sony's rolling shutter STARVIS, Exmor R, and the 4th Generation Pregius 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 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.

Using Polarization Sensors for Glare Reduction & Dynamic Lighting

Many vision systems struggle to overcome the effects of dynamic or excessive light, reflections, haze, and glare from shiny surfaces like glass, plastic, and metal. Often, these systems rely on multiple cameras and filters behind a beam-splitting prism, or a single camera with a rotating filter or filter wheel, resulting in large, complicated, and slow systems.

Blackfly S cameras with polarized sensors have unique features to simultaneously sense the angle and intensity of all polarized light across the sensor. They capture light from four angles in a single frame thereby delivering increased speed, reduced size, complexity, and power consumption compared to existing solutions. Additionally, select Blackfly S GigE models also include lossless compression for increased FPS.

L - Raw polarized image | M - Polarized image with subject of interest highlighted in red | R - Processed image with anti-glare reduction enabled

Sony's On-Sensor Polarization

Sony's IMX253MZR and IMX250MZR sensors are based on their popular 12 MP IMX253 and 5 MP IMX250 Pregius sensors. Each individual pixel has its own polarizing filter - these filters are oriented to 0°, 45°, 90° and 135° and arranged in repeating two-pixel blocks. These sensors have features that minimize the impact of reduced quantum efficiency (QE) resulting from adding polarizing filters to pixels. For instance, the polarizing filters of the IMX250MZR have an extinction ratio of 300:1 at 525 nm, which is high enough to deliver accurate polarimetric data without blocking cross-polarized light. This ensures that even when filter alignment passes a minimal amount of light, enough light will reach the light-sensitive photodiode to capture useful images. This enables capture of low-noise images even in challenging conditions requiring gain to compensate for reduced QE.

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.

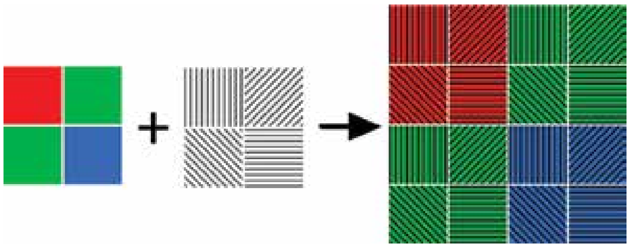


Fig. 17. RGB pixels rearranged into 2x2 “super-pixels”. Each super-pixel has one polarizing filter per orientation and contains all the information necessary

Spinnaker SDK Polarization Features

Dynamic Anti-Glare & Reflection Removal: Spinnaker SDK supports API calls to create a glare reduced image from the source images by choosing the darkest pixel from each polarization quadrant. Using polarimetric measurements, it can dynamically reduce reflections from non-metallic surfaces, thereby reducing system complexity, and saving application development time.

Interpretation and characterization of polarization parameters of light require measurements from all four angles of polarization. To achieve this for each pixel on the sensor, an interpolation process is required, where data from adjacent pixels are combined. This is analogous to how data from adjacent red, green, and blue pixels is combined on color sensors to produce RGB values for each pixel. This process is natively supported by Spinnaker SDK.

Higher frame rates: Select Blackfly S GigE cameras with Sony’s polarized CMOS image sensors enable higher frame rates at high resolution (e.g., up to 14FPS at 12MP) without losing any image data by utilizing Lossless Compression built into the camera’s firmware. This increased processing speed and high resolution can be particularly useful in highly demanding industrial and research-oriented applications.

Selectable Gain For High Sensitivity or High Saturation Capacity

Sony's 3rd Generation 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.

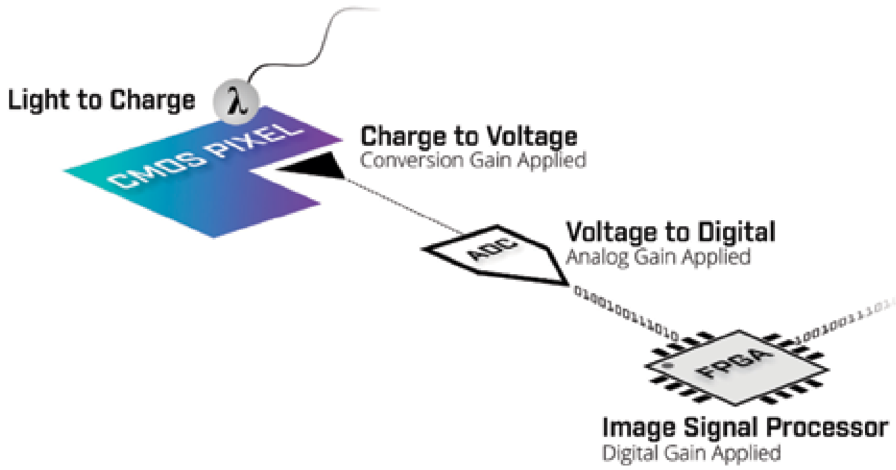


Fig. 18. Gain can be applied to the signal at different points in its path from incoming photon to outgoing digital data.

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 similar to adding an additional 7.23 dB of analog gain.

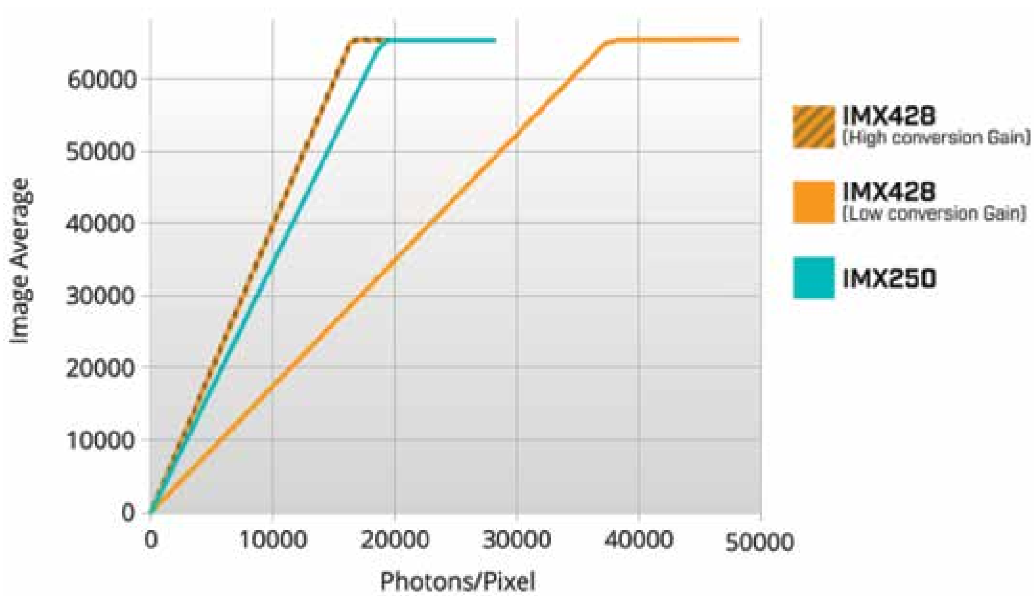


Fig. 19. High conversion gain reaches saturation faster than low conversion gain.

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.

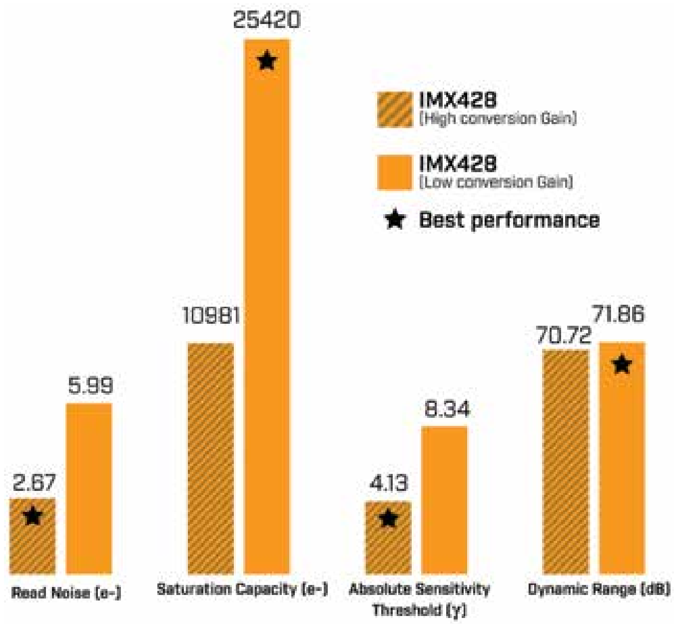


Fig. 20. High Conversion Gain is ideal for low light imaging, while Low Conversion Gain maximizes saturation capacity and dynamic range in brightly lit conditions.

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.

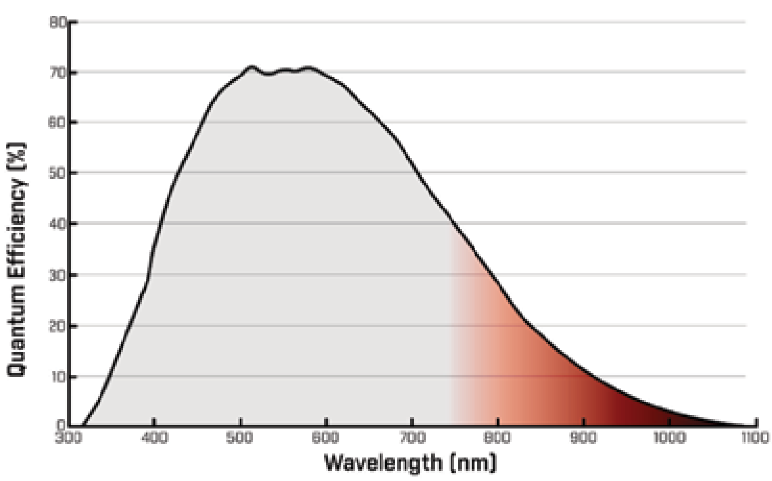


Fig. 21. The Near-Infrared region of the spectrum detectable by the Sony IMX248 CMOS image sensor highlighted in red.

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.

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