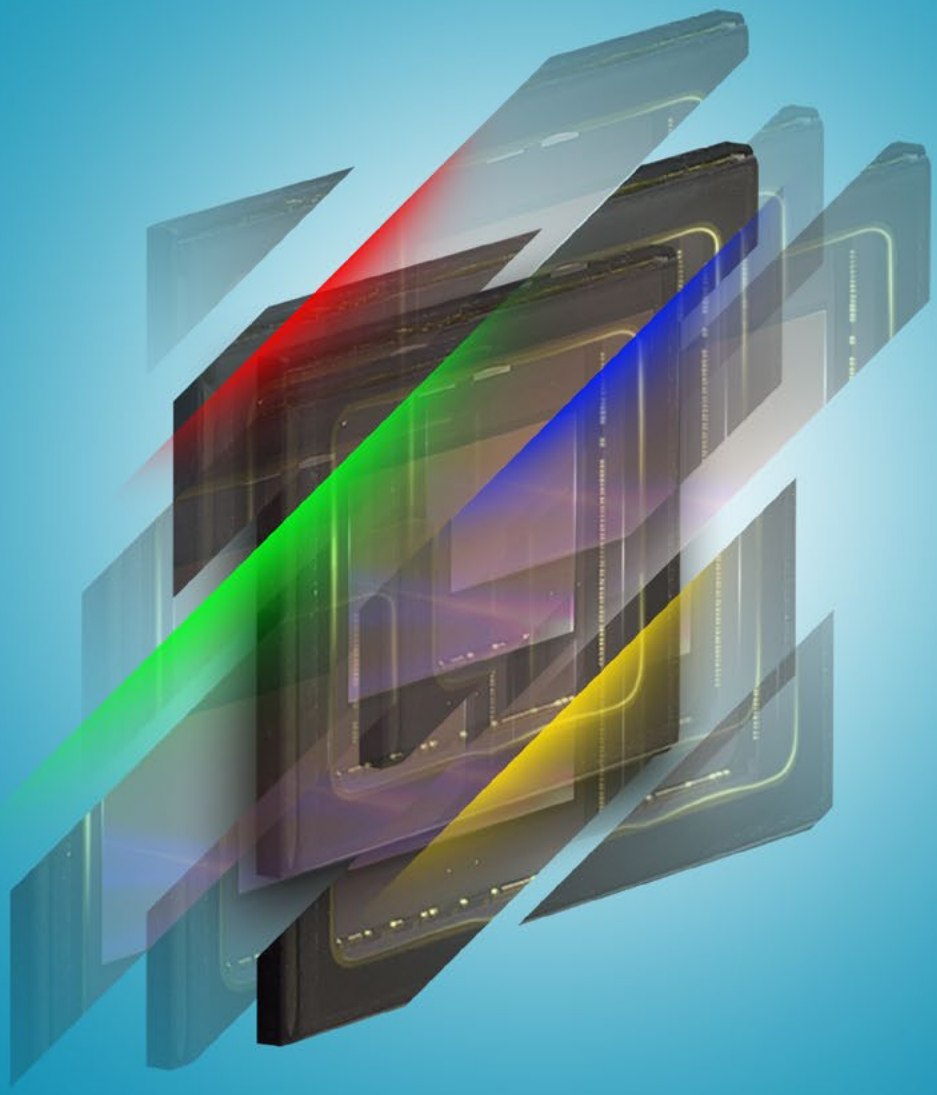
COLOR CAMERA SENSOR REVIEW
Q 4 2 0 1 4



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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).

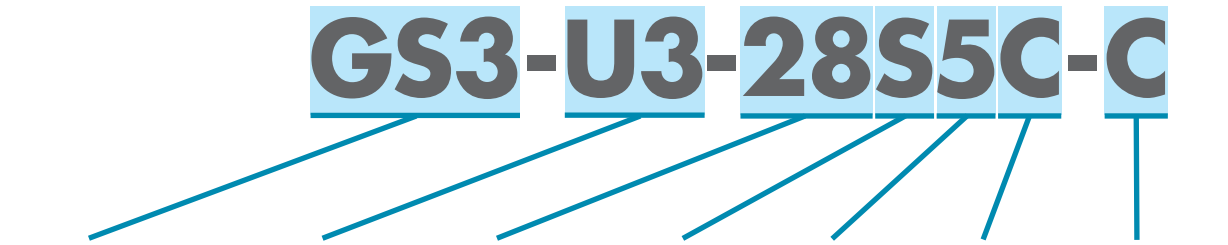
CONTENT

RELEASE NOTES:

Q1 2015
ADDED:
- BLACKFLY GIGE BFLY-PGE-23S6M-C (SONY IMX249)
- BLACKFLY GIGE BFLY-PGE-50H5M-C (SHARP RJ32S3AA0DT)
- GRASSHOPPER3 USB3 GS3-U3-15S5C-C (SONY ICX825 CCD)
- GRASSHOPPER3 USB3 GS3-U3-41S4M-C (SONY ICX808 CCD)
- GRASSHOPPER3 GIGE GS3-PGE-23S6M-C (SONY IMX174 CMOS)

Our Model Numbers Mean Something!

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



Camera Family	Interface	Megapixels	Sensor Brand	Sensor Size	Color/Mono	Lens Mount
GS3=Grasshopper3	U3=USB 3.0	28=2.8MP	S=Sony	5=2/3"	C=Color	C=C-Mount
BFLY=Blackfly	FW=FireWire	03=0.3 MP	A=Aptina	0=Unassigned	M=Mono	CS=CS-Mount
FL3=Flea3	GE=GigE	08=0.8 MP	M=Micron	1=1/4"		
FFMV=FireflyMV FireWire	PGE=PoE GigE	13=1.3 MP	K=Kodak	2=1/3", 1/2.8", 1/2.5"		
GS2=Grasshopper2		20=2.0 MP	C=CMOSIS	3=1/2"		
GX=Grasshopper Express		50=5.0 MP	Y=Cypress	4=1/1.8"		
		etc	E=E2V	6=1"		

COLOR SINGLE LENS CAMERAS

SORTED BY SENSOR TYPE (CCD/CMOS) AND RESOLUTION

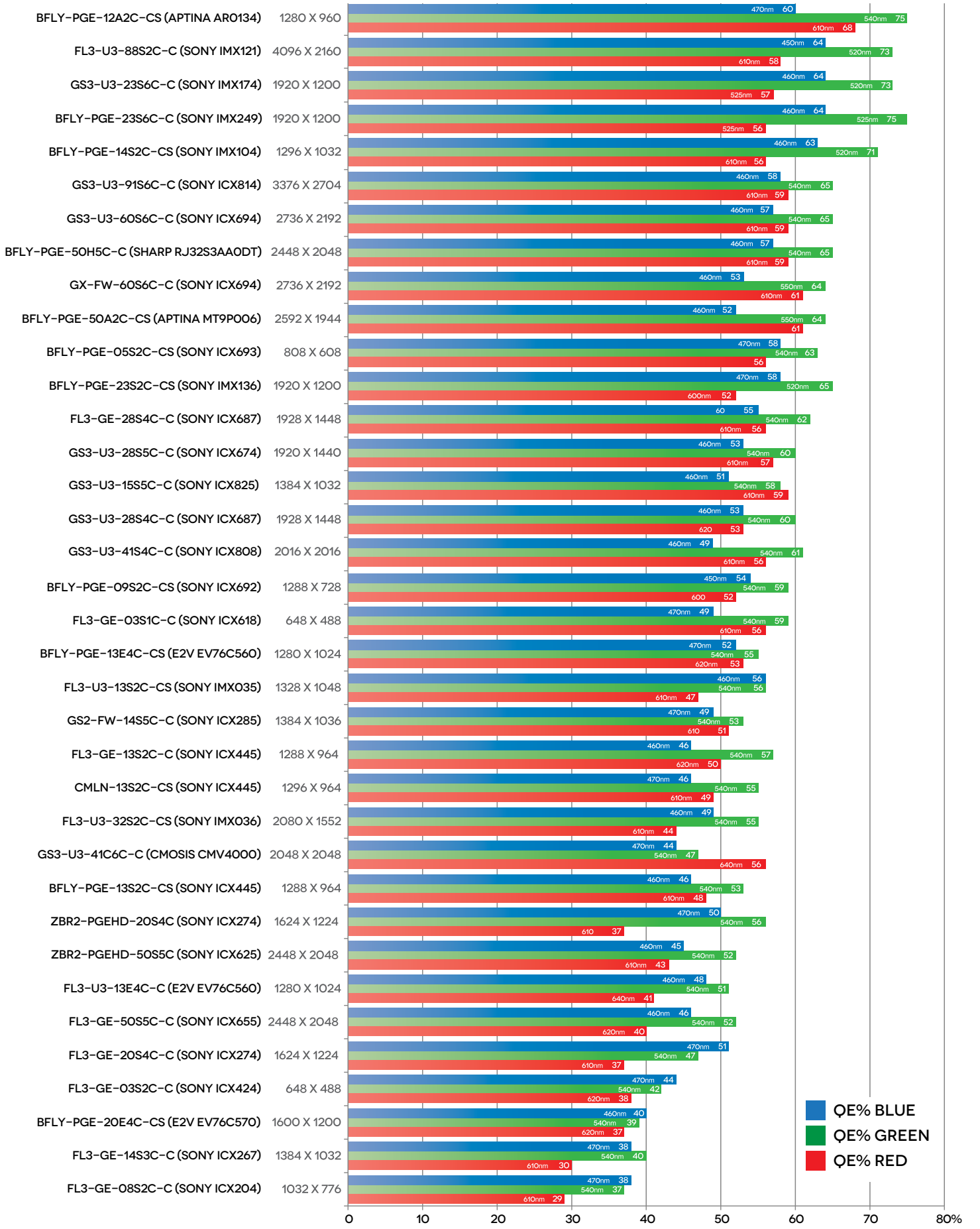
MODEL ID	SENSOR	SENSOR SIZE	INTERFACE	SENSOR TYPE	SHUTTER	MAX RESOLUTION	MAX FRAME RATE	PIXEL SIZE
FL3-GE-03S1C-C	**Sony ICX618**	1/4"	GigE	Global	CCD	648 x 488	120 FPS	5.6 µm
FL3-GE-03S2C-C	**Sony ICX424**	1/3"	GigE	Global	CCD	648 x 488	82 FPS	7.4 µm
BFLY-PGE-05S2C-CS	**Sony ICX693**	1/3"	PoE GigE	Global	CCD	808 x 608	50 FPS	6.0 µm
FL3-GE-08S2C-C	**Sony ICX204**	1/3"	GigE	Global	CCD	1032 x 776	31 FPS	4.65 µm
BFLY-PGE-09S2C-CS	**Sony ICX692**	1/3"	PoE GigE	Global	CCD	1288 x 728	30 FPS	4.08 µm
FL3-GE-13S2C-C	**Sony ICX445**	1/3"	GigE	Global	CCD	1288 x 964	31 FPS	3.75 µm
BFLY-PGE-13S2C-CS	**Sony ICX445**	1/3"	PoE GigE	Global	CCD	1288 x 964	22 FPS	3.75 µm
CMLN-13S2C-CS	**Sony ICX445**	1/3"	USB 2.0	Global	CCD	1296 x 964	18 FPS	3.75 µm
FL3-GE-14S3C-C	**Sony ICX267**	1/2"	GigE	Global	CCD	1384 x 1032	18 FPS	4.65 µm
GS2-FW-14S5C-C	**Sony ICX285**	2/3"	FireWire	Global	CCD	1384 x 1036	30 FPS	6.45 µm
GS3-U3-15S5C-C	**Sony ICX825**	2/3"	USB 3.0	Global	CCD	1384 x 1032	45 FPS	6.45 µm
FL3-GE-20S4C-C	**Sony ICX274**	1/1.8"	GigE	Global	CCD	1624 x 1224	15 FPS	4.4 µm
ZBR2-PGEHD-20S4C	**Sony ICX274**	1/1.8"	PoE GigE	Global	CCD	1624 x 1224	30 FPS	4.4 µm
GS3-U3-28S5C-C	**Sony ICX674**	2/3"	USB 3.0	Global	CCD	1920 x 1440	26 FPS	4.54 µm
FL3-GE-28S4C-C	**Sony ICX687**	1/1.8"	GigE	Global	CCD	1928 x 1448	15 FPS	3.69 µm
GS3-U3-28S4C-C	**Sony ICX687**	1/1.8"	USB 3.0	Global	CCD	1928 x 1448	26 FPS	3.69 µm
GS3-U3-41S4C-C	**Sony ICX808**	1/1.8″	USB 3.0	Global	CCD	2016 x 2016	18 FPS	3.1 µm
ZBR2-PGEHD-50S5C	**Sony ICX625**	2/3"	PoE GigE	Global	CCD	2448 x 2048	15 FPS	3.45 µm
FL3-GE-50S5C-C	**Sony ICX655**	2/3"	GigE	Global	CCD	2448 x 2048	8 FPS	3.45 µm
BFLY-PGE-50H5C-C	**Sharp RJ32S3AA0DT**	2/3″	PoE GigE	Global	CCD	2448 x 2048	7.5 FPS	3.45 µm
GS3-U3-60S6C-C	**Sony ICX694**	1"	USB 3.0	Global	CCD	2736 x 2192	13 FPS	4.54 µm
GX-FW-60S6C-C	**Sony ICX694**	1"	FireWire	Global	CCD	2736 x 2192	11 FPS	4.54 µm
GS3-U3-91S6C-C	**Sony ICX814**	1"	USB 3.0	Global	CCD	3376 x 2704	9 FPS	3.69 µm
BFLY-PGE-12A2C-CS	**Aptina AR0134**	1/3"	PoE GigE	Global	CMOS	1280 x 960	52 FPS	3.75 µm
BFLY-PGE-13E4C-CS	**e2v EV76C560**	1/1.8"	PoE GigE	Global	CMOS	1280 x 1024	60 FPS	5.3 µm
FL3-U3-13E4C-C	**e2v EV76C560**	1/1.8"	USB 3.0	Global	CMOS	1280 x 1024	60 FPS	5.3 µm
BFLY-PGE-14S2C-CS	**Sony IMX104**	1/3"	PoE GigE	Rolling	CMOS	1296 x 1032	60 FPS	3.75 µm
FL3-U3-13S2C-CS	**Sony IMX035**	1/3"	USB 3.0	Rolling	CMOS	1328 x 1048	120 FPS	3.63 µm
BFLY-PGE-20E4C-CS	**e2v EV76C570**	1/1.8"	PoE GigE	Global	CMOS	1600 x 1200	47 FPS	4.5 µm
BFLY-PGE-23S2C-CS	**Sony IMX136**	1/2.8"	PoE GigE	Rolling	CMOS	1920 x 1200	27 FPS	2.8 µm
GS3-U3-23S6C-C	**Sony IMX174**	1/1.2″	USB 3.0	Global	CMOS	1920 x 1200	162 FPS	5.86 µm
BFLY-PGE-23S6C-C	**Sony IMX249**	1/1.2	PoE GigE	Global	CMOS	1920 x 1200	41 FPS	5.86 µm
FL3-U3-32S2C-CS	**Sony IMX036**	1/2.8"	USB 3.0	Rolling	CMOS	2080 x 1552	60 FPS	2.5 µm
GS3-U3-41C6C-C	**CMOSIS CMV4000**	1"	USB 3.0	Global	CMOS	2048 x 2048	90 FPS	5.5 µm
BFLY-PGE-50A2C-CS	**Aptina MT9P006**	1/2.5"	PoE GigE	Rolling	CMOS	2592 x 1944	13 FPS	2.2 µm
FL3-U3-88S2C-C	**Sony IMX121**	1/2.5"	USB 3.0	Rolling	CMOS	4096 x 2160	21 fps	1.55 µm

PEAK QE % MEASURED AT HIGHEST WAVELENGTH (nm)			QE % AT SPECIFIED WAVELENGTH (nm)										
QE RED (PEAK nm) %	QE GREEN (PEAK nm) %	QE RED (PEAK nm) %	QE BLUE (470nm) %	QE GREEN (525nm) %	QE RED (640nm) %	TEMPORAL DARK NOISE (READ NOISE) e-	S/N RATIO MAX dB	S/N RATIO MAX Bits	ABSOLUTE SENSITIVITY THRESHOLD γ	SATURATION CAPACITY (WELL DEPTH) e-	DYNAMIC RANGE dB	DYNAMIC RANGE Bits	GAIN e-/ADU
49 (470)	59 (540)	56 (610)	49	51	56	12.59	41.62	6.91	26.20	14528	60.91	10.12	0.22
44 (470)	42 (540)	38 (620)	44	38	33	12.22	40.40	6.71	34.93	10971	58.72	9.75	0.2
58 (470)	63 (540)	56 (610)	58	59	51	11.41	42.98	7.14	21.46	19847	64.44	10.70	0.36
38 (470)	37 (540)	29 (610)	38	34	25	12.62	40.62	6.75	40.27	11543	58.89	9.78	0.2
54 (450)	59 (530)	52 (600)	52	55	46	8.82	40.45	6.72	18.07	11078	61.51	10.22	0.24
46 (460)	57 (540)	50 (620)	45	51	47	8.71	38.87	6.46	19.10	7701	58.44	9.71	0.12
46 (460)	53 (540)	48 (610)	45	49	43	8.56	39.41	6.55	19.88	8727	59.67	9.91	0.14
46 (470)	55 (540)	49 (610)	46	50	48	7.65	38.04	6.32	17.23	6365	57.85	9.61	0.1
38 (470)	40 (540)	30 (610)	38	36	26	10.52	39.81	6.61	32.94	9573	58.78	9.76	0.17
49 (470)	53 (540)	51 (610)	49	48	47	11.35	41.85	6.95	26.25	15311	62.22	10.34	0.28
51 (460)	58 (540)	59 (610)	50	53	56	8.78	42.97	7.14	18.24	19807	66.59	11.06	0.35
51 (470)	47 (540)	37 (610)	51	43	32	8.34	39.12	6.50	22.04	8162	59.30	9.85	0.13
50 (470)	56 (540)	37 (610)	50	43	32	8.37	39.45	6.55	22.58	8805	59.93	9.95	0.14
53 (460)	60 (540)	57 (610)	52	56	51	9.30	41.40	6.88	18.67	13817	62.98	10.46	0.24
55 (460)	62 (540)	56 (610)	54	58	50	9.01	40.65	6.75	17.55	11618	61.74	10.25	0.19
53 (460)	60 (540)	53 (620)	51	55	49	9.68	40.15	6.67	19.72	10346	60.14	9.99	0.17
49 (460)	61(540)	56 (610)	48	56	48	8.56	37.84	6.29	16.72	6088	56.55	9.39	0.10
45 (460)	52 (540)	43 (610)	44	48	39	9.64	38.34	6.36	22.36	6835	56.00	9.97	0.15
46 (460)	52 (540)	40 (620)	44	48	38	7.95	37.38	6.21	19.04	5467	56.22	9.34	0.09
53 (460)	64 (550)	61 (610)	51	52	58	5.30	36.81	6.11	11.26	4796	58.35	9.69	0.08
57 (460)	65 (540)	59 (610)	55	59	55	10.20	41.56	6.90	19.04	14306	62.52	10.38	0.23
56 (460)	63 (530)	59 (610)	55	60	54	10.00	41.71	6.93	20.10	14836	62.99	10.46	0.24
58 (460)	65 (540)	59 (610)	56	61	53	9.13	40.10	6.66	16.95	10229	60.52	10.05	0.16
60 (470)	75 (540)	68 (610)	60	57	52	5.12	37.49	6.23	9.73	5608	59.97	9.96	0.10
52 (470)	55 (540)	53 (620)	52	51	49	25.66	39.92	6.63	54.85	9826	51.50	8.55	0.17
48 (460)	51 (540)	41 (640)	47	48	41	26.24	37.58	6.24	55.57	5726	46.61	7.74	0.16
63 (460)	71 (520)	56 (610)	62	70	47	3.87	42.97	7.14	6.60	19833	73.15	12.15	0.37
56 (460)	56 (540)	47 (610)	55	52	39	7.95	41.67	6.92	17.46	14685	64.81	10.76	0.25
40 (460)	39 (540)	37 (620)	39	37	32	21.42	38.76	6.44	61.67	7523	50.71	8.42	0.14
58 (470)	65 (520)	52 (600)	58	65	43	4.02	41.38	6.87	7.53	13746	69.65	11.57	0.25
64 (460)	74 (520)	57 (610)	63	73	51	13.89 / 6.78*	45.14	7.50	20.70 / 10.44*	32675	67.13	11.15	0.52
64 (470)	75 (520)	56 (620)	64	75	52	15.06 / 6.97*	45.25	7.51	21.89 / 10.93*	33456	66.65	11.07	0.53
49 (460)	55 (540)	44 (610)	48	51	38	10.00	40.24	6.68	22.06	10569	60.06	9.98	0.19
44 (470)	47 (540)	56 (640)	44	45	46	17.25	39.09	6.49	41.69	8104	53.19	8.83	0.14
52 (460)	64 (550)	61 (610)	51	52	49	5.30	36.81	6.11	11.26	4796	58.35	9.69	0.08
64 (450)	73 (520)	58 (610)	63	73	49	3.06	37.76	6.27	5.26	5966	64.49	10.71	0.12

* Lower number results achieved through our low noise imaging mode - "Video Mode 7"

COLOR SINGLE LENS CAMERAS

PEAK QUANTUM EFFICIENCY % (RANKED BY COLOR CHANNEL AVERAGES)
MEASURED AT HIGHEST PEAK FOR EACH COLOR (HIGHER IS BETTER)



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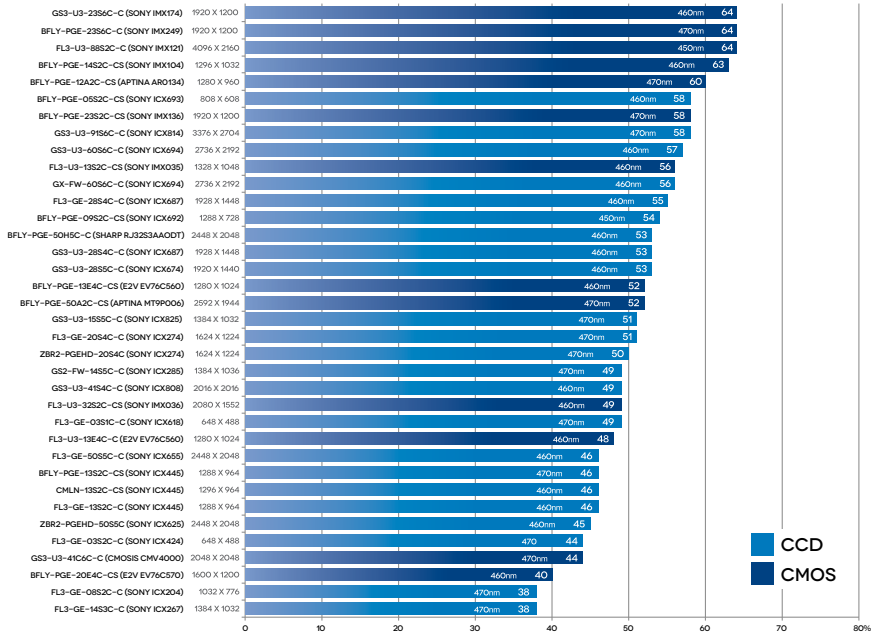
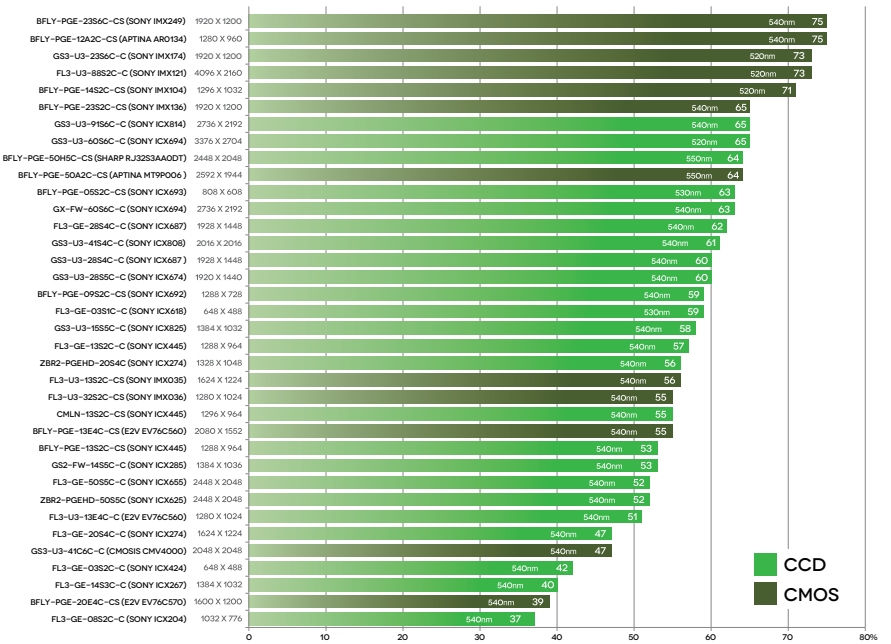
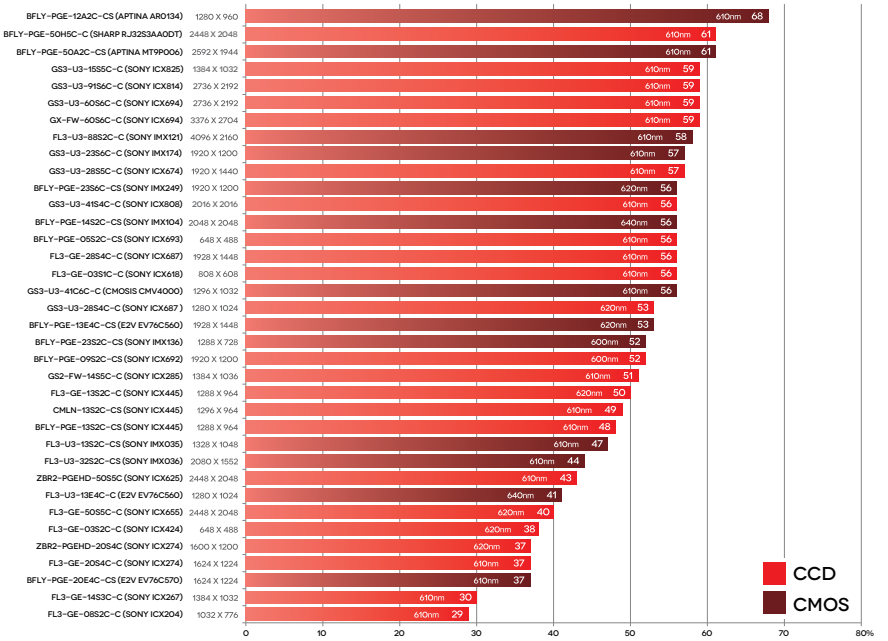
COLOR SINGLE LENS CAMERAS



PEAK QUANTUM EFFICIENCY % BLUE (HIGHER IS BETTER)



PEAK QUANTUM EFFICIENCY % GREEN (HIGHER IS BETTER)



PEAK QUANTUM EFFICIENCY % RED (HIGHER IS BETTER)

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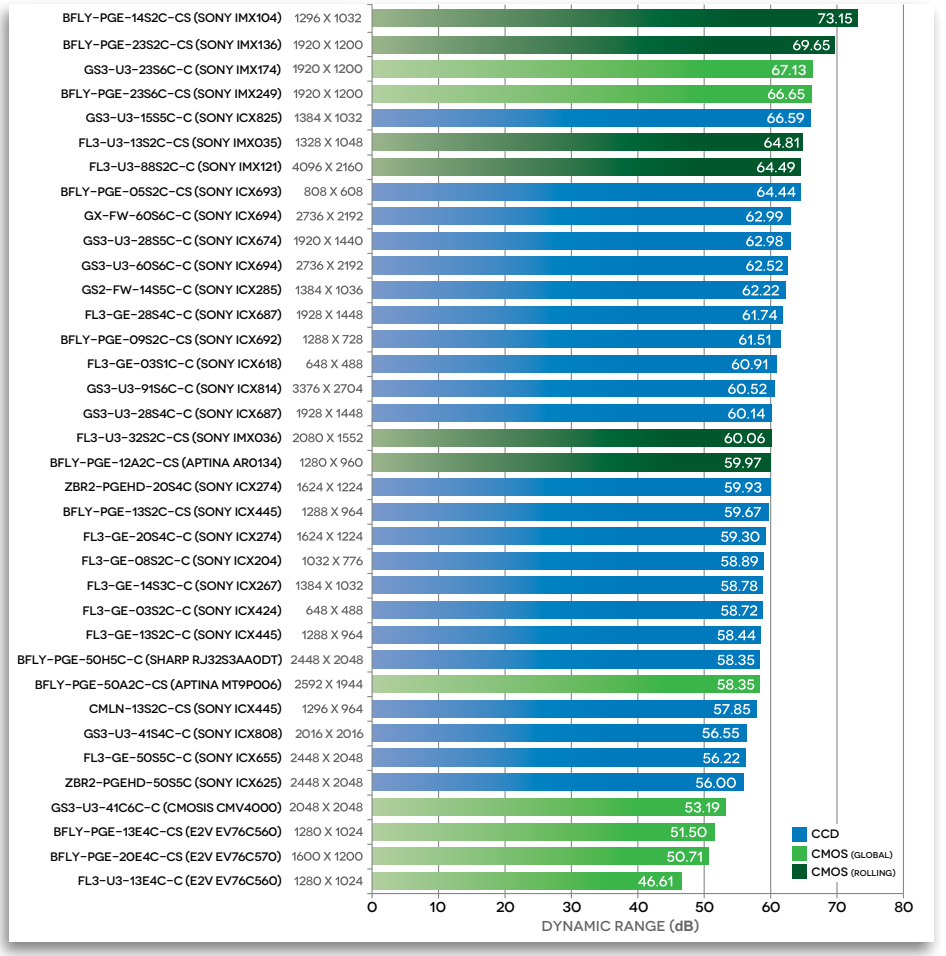
COLOR SINGLE LENS CAMERAS

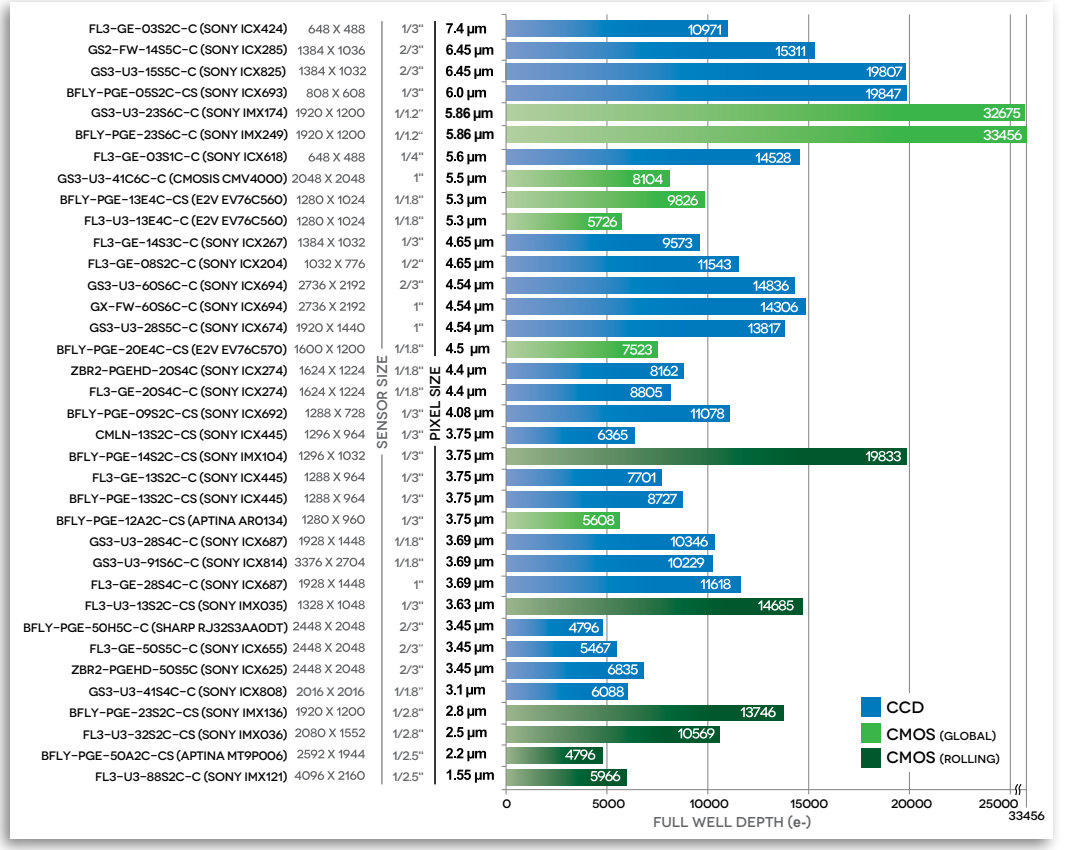
DYNAMIC RANGE dB (HIGHER IS BETTER)



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.

Note: In the case of the same sensor in different camera families, the difference in measurements (QE, dynamic range, temporal dark noise, and full well depth) can be attributed mainly to differences in pixel clock, firmware and board electronics. For example, we see that between the Blackfly and Flea3 with the Sony ICX445 sensor, the Blackfly claims advantages due to its lower pixel clock.

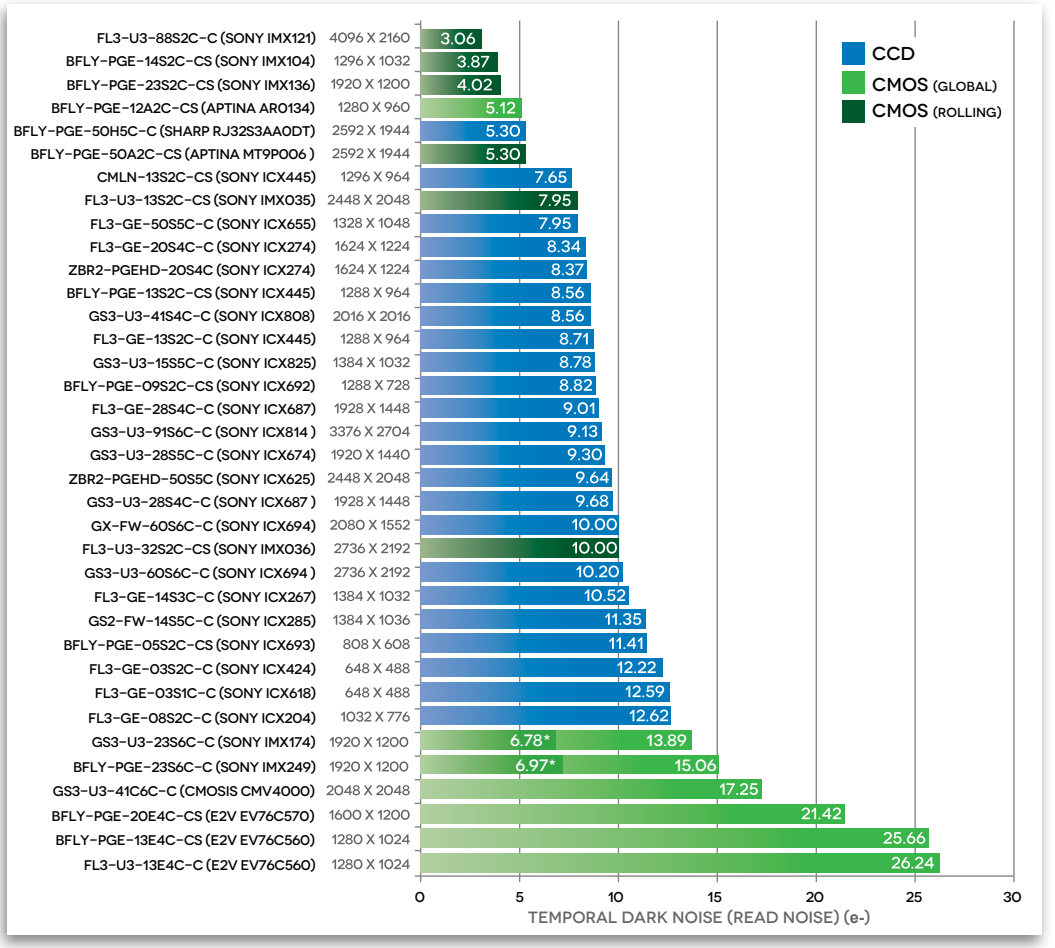
SATURATION CAPACITY (WELL DEPTH) e– (HIGHER IS BETTER, SORTED BY PIXEL SIZE)



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.

COLOR SINGLE LENS CAMERAS

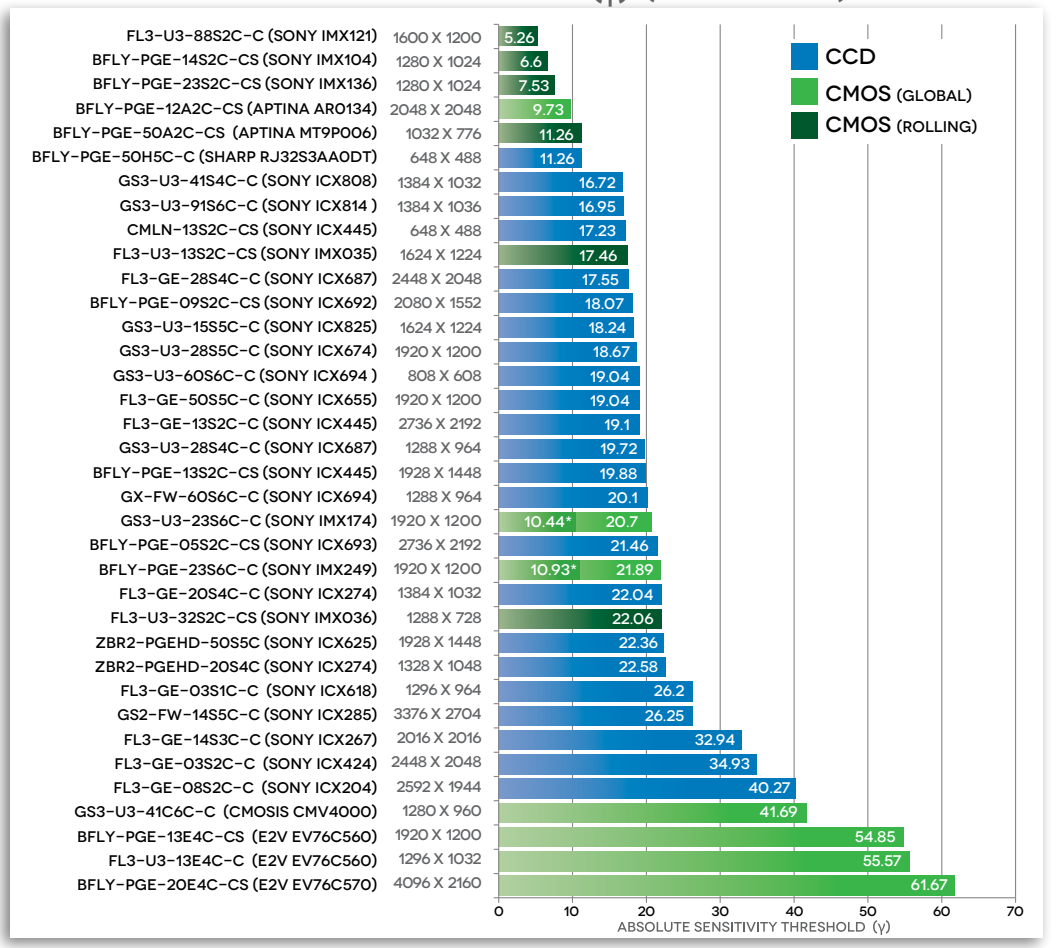
TEMPORAL DARK NOISE / READ NOISE e– (LOWER IS BETTER)



Temporal dark noise or 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 produces cleaner images.

* Lower number results achieved through our low noise imaging mode - "Video Mode 7"

ABSOLUTE SENSITIVITY THRESHOLD (γ) (LESS IS BETTER)

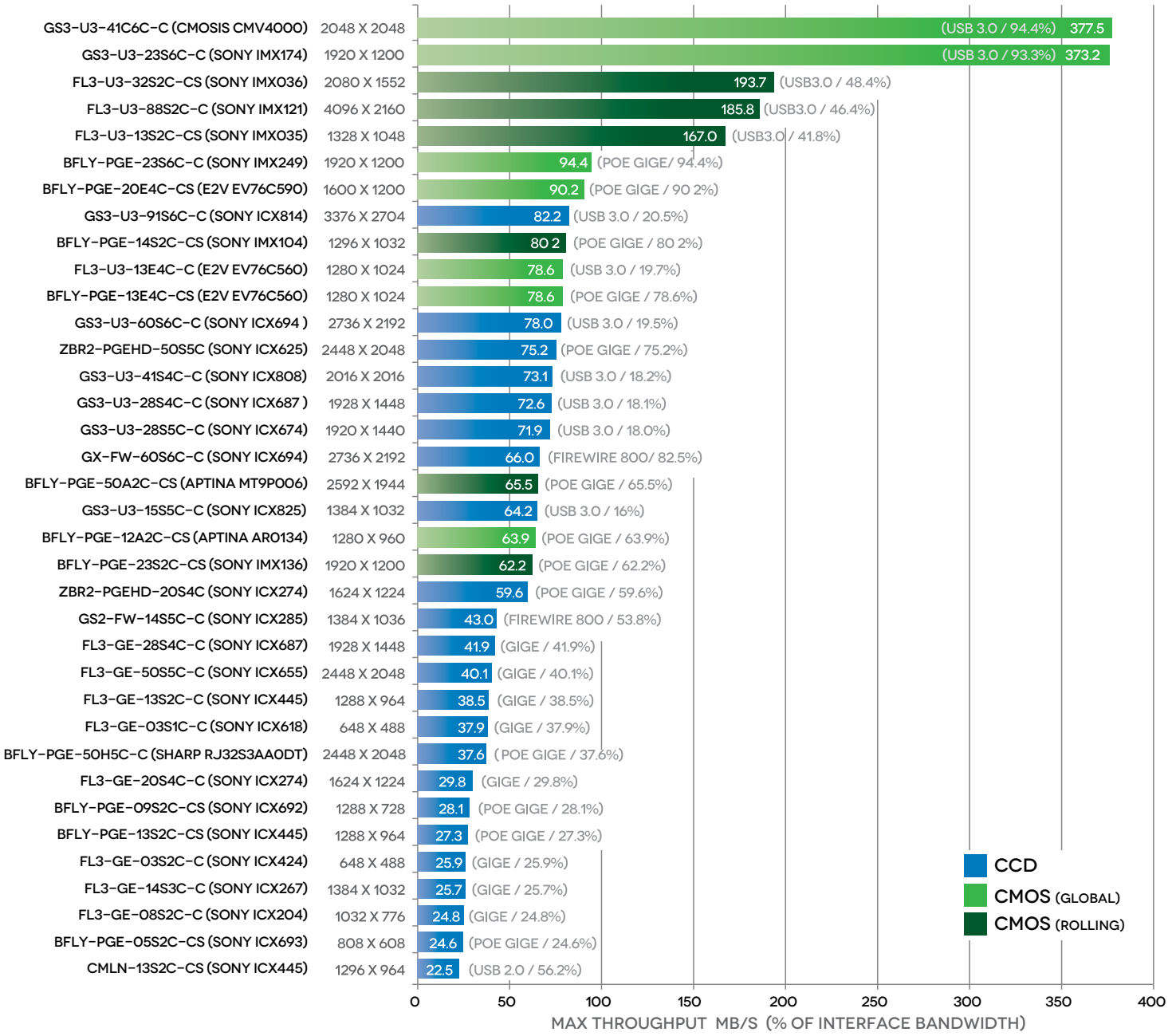


Absolute sensitivity threshold is the minimum number of photons needed to equal the noise level. The lower the number the less light is needed to detect useful imaging data.

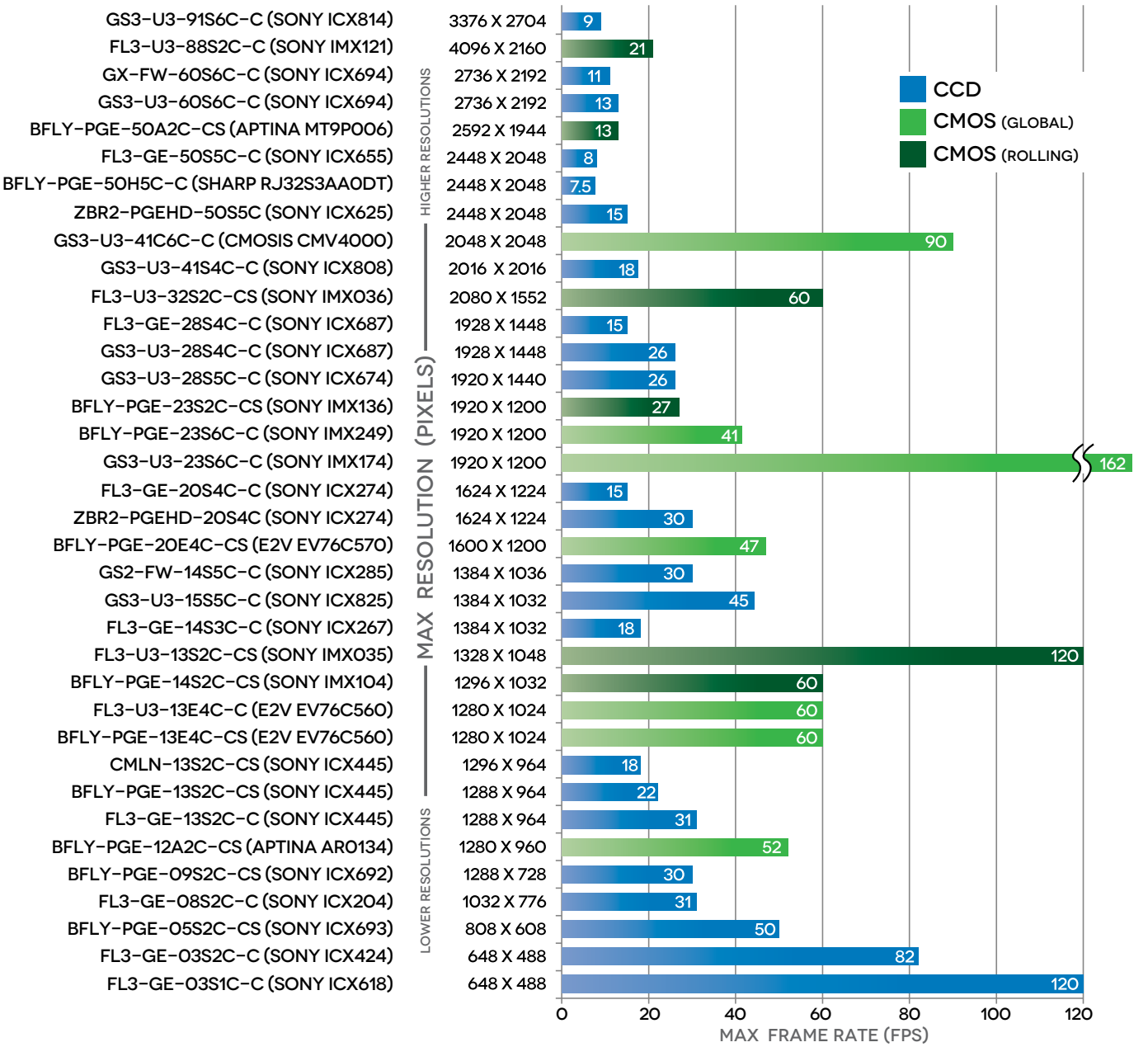
* Lower number results achieved through our low noise imaging mode - "Video Mode 7"

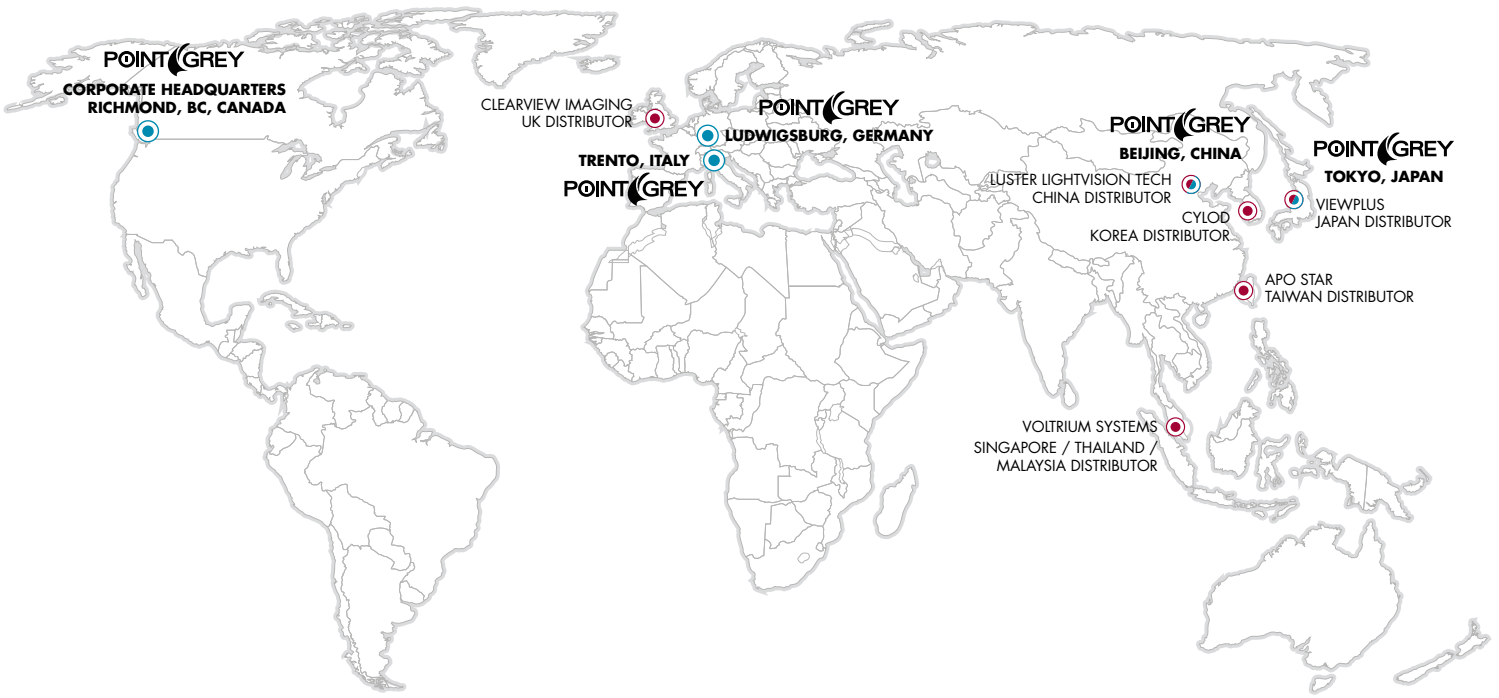
CAMERA THROUGHPUT (MB/S) AND % OF INTERFACE BANDWIDTH

When considering multi-camera setups bandwidth considerations are a must. We calculated the maximum throughput (MB/s) by multiplying the maximum resolution by the maximum frame rate (note: to simplify these calculations an image data format of Mono8 was used). In addition we added the percentage of interface bandwidth which the camera model pumped out. For those calculations we used 400 MB/s for USB 3.0, 100 MB/s for GigE, 80 MB/s for FireWire 800, and 40 MB/s for both FireWire 400 and USB 2.0.



MAX RESOLUTION TO MAX FRAME RATE





POINT GREY
Innovation in Imaging

CANADA (Headquarters)
Point Grey Research, Inc.

12051 Riverside Way
Richmond, BC, Canada
V6W 1K7

T: +1 866.765.0827 (toll free)
T: +1 604.242.9937
F: +1 604.242.9938
E: sales@ptgrey.com
www.ptgrey.com

EUROPE
T: +49 7141 488817-0
F: +49 7141 488817-99
E: eu-sales@ptgrey.com
eu.ptgrey.com

CHINA
T: +86 10 8215 9938
F: +86 10 8215 9936
E: chinasales@ptgrey.com
www.ptgreychina.cn

ASIA
E: asia-sales@ptgrey.com

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