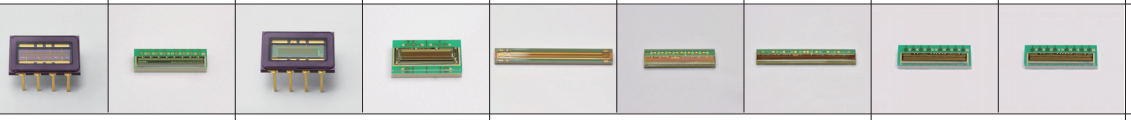
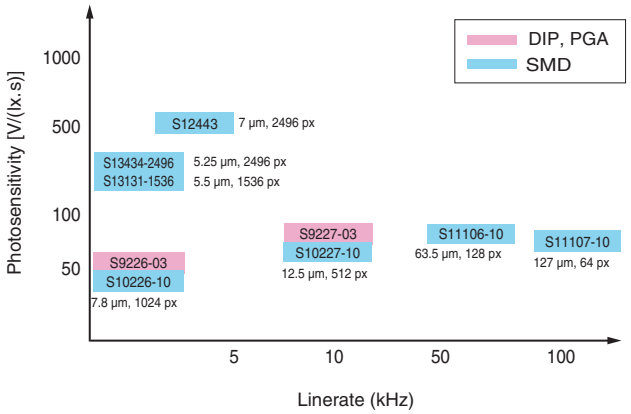
Image sensors for industrial applications

CMOS image sensors

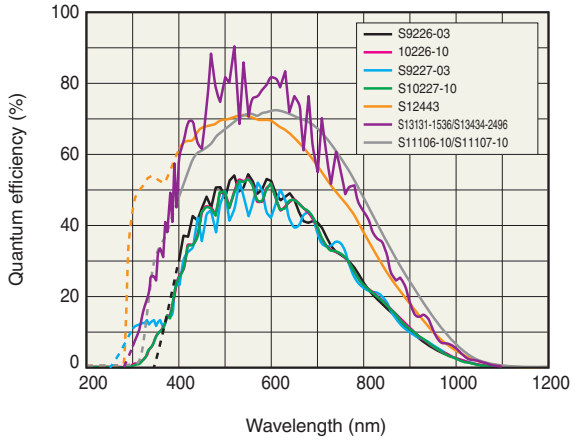
Parameter	S9226-03*1*2	S10226-10*1*2	S9227-03	S10227-10	S12443	S13131-1536*3	S13434-2496	S11106-10*2	S11107-10*2	Unit
Package	Ceramic DIP	Resin mold SMD	Ceramic DIP	Resin mold SMD	Resin mold SMD	Resin mold SMD	Resin mold SMD	Resin mold SMD	Resin mold SMD	-
Package size	12.0 × 7.87	9.1 × 2.4	12.0 × 7.87	9.1 × 4.4	23 × 2.7	9.1 × 2.4	13.8 × 2.1	9.1 × 2.4	9.1 × 2.4	mm
Appearance										-
Output	Monochrome		Monochrome		Monochrome			Monochrome		-
Supply voltage	3.3 to 5		5		3.3			3 to 5		V
Analog/digital	Analog		Analog		Analog			Analog		-
Number of pixels	1024		512		2496	1536	2496	128	64	pixel
Pixel pitch	7.8		12.5		7	5.5	5.25	63.5	127	µm
Pixel height	125		250		125	63.5	63.5	63.5	127	µm
Image size	7.9872 × 0.125		6.4 × 0.25		17.472 × 0.125	8.448 × 0.0635	13.104 × 0.0635	8.06 × 0.0635	8.06 × 0.127	mm
Video data rate max.	0.2		5		10	2	2	10		MHz
Line rate max.	0.194		9.4		3.9	1.3	0.8	64.9	111	kHz
Photosensitivity	50		80		500	280	280	80	75	V/(lx.s)
Conversion efficiency	3.2		1.6		25	45	45	0.75	0.35	µV/e⁻
Dark output voltage*4	0.8		1.0		0.4	1.5	1.5	0.02	0.04	mV
Dark current	5		10		0.26	0.53	0.53	0.43	1.83	fA
Saturation output	3.2		4.3		2	1.4	1.4	4		V
	1000		2688		80	31	31	5333	11429	ke⁻
Readout noise	1.4		0.45		1.2	0.4	0.4	0.7	0.6	mV rms
	438		281		48	9	9	933	1714	e⁻rms
Dynamic range	2280		9550		1670	3500	3500	5700	6600	-
A/D converter	None									-
Anti-blooming function	Possible									-
Electronic shutter function	Impossible		Possible							-
Readout of every pixel	Sequential		Simultaneous							-

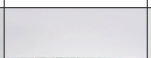
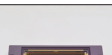
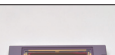
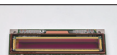
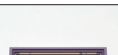
*1: High gain operation *2: 5 V operation *3: S13131-512 (512 pixels) and S13131-736 (736 pixels) are also available. *4: Integration time =10 ms

■ Photosensitivity vs. line rate



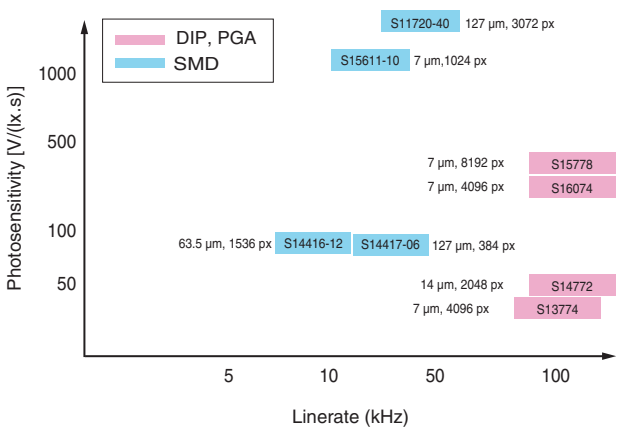
■ Spectral response (typical examples)



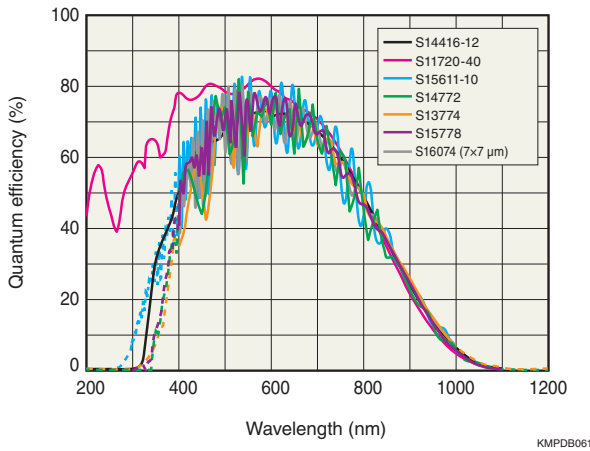
Parameter	S14416-12*1	S14417-06*2	S11720-40*3	S15611-10*4	S14772*5	S13774*5	S15778*5	S16074*5	Unit
Package	Resin mold SMD		Resin mold SMD	Resn mold SMD	Ceramic PGA	Ceramic PGA	Glass epoxy and FeNiCo alloy	Ceramic DIP	-
Package size	114 × 10	61.2 × 12.7	396.5 × 18	13 × 5.8	50.5 × 16.5	50.5 × 16.5	70 × 46	38 × 9.91	mm
Appearance									-
Output	Monochrome		Monochrome	Monochrome	Monochrome	Monochrome	Monochrome	Monochrome	-
Supply voltage	5		5	3.3	3.3	3.3	3.3/1.8	3.3	V
Analog/digital	Analog		Digital	Digital	Digital	Digital	Digital	Digital	-
Number of pixels	1536	384	3072	1024	2048	4096	8192	① 4096 ② 3072 ③ 2048	pixel
Pixel pitch	63.5	127	127	7	14	7	7	① 7 ② 9.3 ③ 14	µm
Pixel height	63.5	127	127	200	14	7	7	① 7 ② 9.3 ③ 14	µm
Image size	97.472 × 0.0635	48.768 × 0.127	390.044 × 0.127	7.168 × 0.200	28.672 × 0.014	28.672 × 0.007	57.344 × 0.007	① 28.672 × 0.007 ② 28.672 × 0.0093 ③ 28.672 × 0.014	mm
Video data rate max.	10		90	40	231	180	360	320	MHz
Line rate max.	6.4	24.7	45.4	34	125	100	100*6	① 35 ② 46 ③ 65	kHz
Photosensitivity	80	75	5100	980	430	360	440	① 360 ② 574 ③ 430	V/(lx.s)
Conversion efficiency	0.75	0.35	25	40	100	340	410	① 336 ② 304 ③ 104	µV/e⁻
Dark output voltage*7	0.02	0.04	250	1.2	1.9	4	4.9	① 4 ② 3.2 ③ 1.9	mV
Dark current	0.43	1.83	160.2	0.48	0.30	0.19	0.19	① 0.19 ② 0.17 ③ 0.29	fA
Saturation output	4		1.4	1.71	1.25	1.25	1.25	1.13	V
	5333	11428	56	43	12.5	3.7	3	① 3.3 ② 3.7 ③ 10.6	ke⁻
Readout noise	0.7	0.6	0.6	0.63	1.2	1.5	1.5	1.6	mV rms
	933	1714	24	16	12	4.2	3.6	① 4.7 ② 5.2 ③ 15.3	e⁻rms
Dynamic range	5700	6600	2333	2700	1100	800	800	1900	-
A/D converter	None		16-bit	12-bit	10-bit/11-bit	10-bit/12-bit	10-bit/11-bit	12-bit	-
Anti-blooming function	Possible								-
Electronic shutter function	Possible								-
Readout of every pixel	Simultaneous								-

*1: S14416-02 (256 pixels) and S14416-06 (768 pixels) are also available. *2: S14417-02 (128 pixels) is also available. *3: S11720-20 (1536 pixels) is also available.
*4: S15611 (ceramic package) is also available. *5: Gain = 8 operation *6: High speed mode *7: Integration time = 10 ms

■ Photosensitivity vs. line rate



■ Spectral response (typical examples)

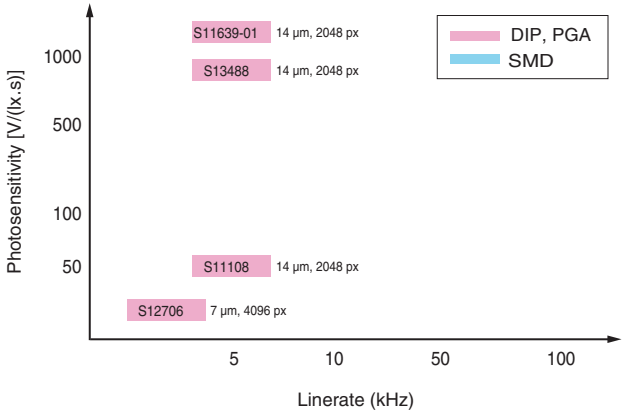


KMPDB0616EC

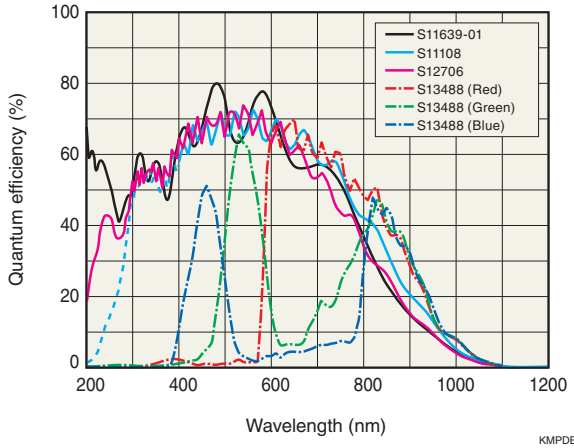
Parameter	S11639-01	S11108	S12706	S13488*1		Unit
Package	Plastic DIP					-
Package size	41.6 × 9.1					mm
Appearance						-
Output	Monochrome	Monochrome	Monochrome	Color		-
Supply voltage	5					V
Analog/digital	Analog					-
Number of pixels	2048	2048	4096	2048		pixel
Pixel pitch	14	14	7	14		µm
Pixel height	200	14	7	42		µm
Image size	28.672 × 0.2	28.672 × 0.014	28.672 × 0.007	28.672 × 0.42		mm
Video data rate max.	10	10	10	10		MHz
Line rate max.	4.6	4.6	2.3	4.6		kHz
Photosensitivity	1300	50	23	Red	65	V/(lx.s)
				Green	85	
				Blue	35	
Conversion efficiency	25	13	25	125		µV/e-
Dark output voltage*2	0.2	0.3	0.2	1.5		mV
Dark current	0.13	0.37	0.13	0.19		fA
Saturation output	2	1.2	2	4		V
	80	92	80	32		ke-
Readout noise	0.4	0.6	1	0.9		mV rms
	16	46	40	7.2		e- rms
Dynamic range	5000	2000	2000	4444		-
A/D converter	None					-
Anti-blooming function	Possible					-
Electronic shutter function	Possible					-
Readout of every pixel	Simultaneous					-

*1: High gain operation, IR cut filter: E-CM500S (t=1.0 mm) *2: Integration time =10 ms

■ Photosensitivity vs. line rate

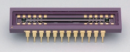
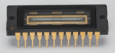


■ Spectral response (typical examples)

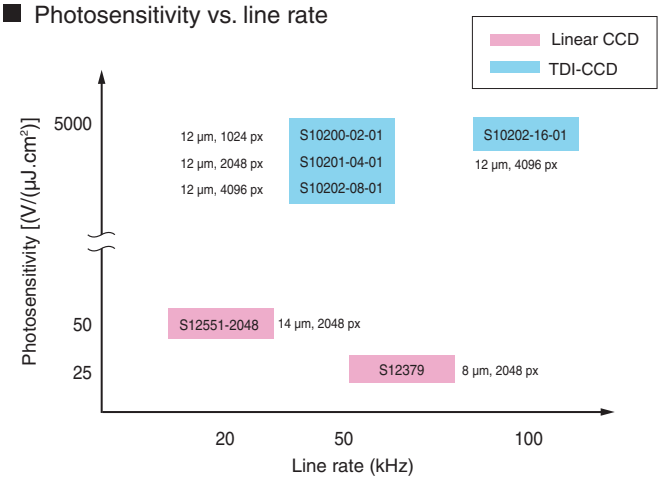


KMPDB0617EA

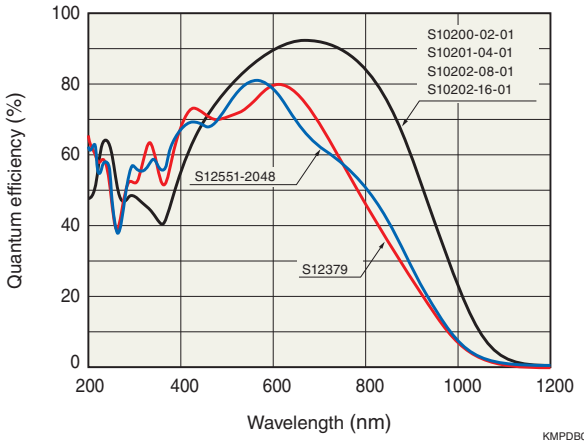
CCD image sensors

Parameter	S12551-2048	S12379	S10200-02-01	S10201-04-01	S10202-08-01	S10202-16-01	Unit
Feature	Easy to use	High speed, Fine pitch	High speed, High sensitivity				-
Type	Interline	Interline	Full Frame Transfer (TDI-CCD)				-
Package size	41.6 × 10.03	36.0 × 12.45	30.48 × 9.91	40.64 × 9.91	66.04 × 9.91	66.04 × 9.91	mm
Appearance							-
Number of pixels	2048	2048	1024	2048	4096	4096	pixels
Stage	1	1	128				-
Pixel pitch	14	8	12				µm
Pixel height	14	8	12				µm
Image size	28.672 × 0.014	16.384 × 0.008	12.288 × 1.536	24.576 × 1.536	49.152 × 1.536		mm
Number of ports	1	4	2	4	8	16	-
Video data rate / port	40	40	30				MHz
Line rate	19 max.	72 max.	50 typ.	50 typ.	50 typ.	100 typ.	kHz
Conversion efficiency	13	21	9.5				µV/e⁻
Full well capacity	100	20	100				ke⁻
Readout noise	40	20	35				e⁻rms
Dynamic range	2500	1000	2800				-
Photosensitivity (λ=600 nm)	60	32	4800				V/(µJ.cm²)
Anti-blooming function	Possible	Possible	Possible				-
Electronic shutter function	Possible	Impossible	Impossible				-
Clock terminal	6	4	8				-

Photosensitivity vs. line rate



Spectral response (typical examples)



KMPDB0404EA

TDI mode

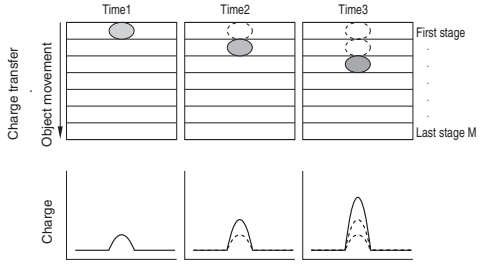
In FFT-CCD, signal charges in each line are vertically transferred during charge readout. TDI mode synchronizes this vertical transfer timing with the movement of the object, so that signal charges are integrated a number of times equal to the number of vertical stages of the CCD pixels. In the TDI mode, the signal charges must be transferred in the same direction at the same speed as those of the object to be imaged. These speeds are expressed by the following equation:

$$v = f \times d$$

v : object moving speed, charge transfer speed f : vertical transfer frequency d : pixel size

In the right gure, when the rst stage charges are transferred to the second stage, an additional charges are produced in the second stage by photoelectric conversion and accumulated. When this operation is continuously repeated until reaching the last stage M (the number of vertical stages), signal charges which are M times greater than the initial charges are accumu-lated. Since the signal charges on each line are output from the CCD horizontal shift register, a two-dimensional image can be continuously acquired. In this way the TDI mode achieves sen-sitivity which is M times higher than linear image sensors (S/N is improved $\sqrt{M}$ times). The TDI mode also improves sensitivity variations compared to frame mode operation.

Schematic diagram showing integrated exposure by TDI mode



KMPDC0139EA

HAMAMATSU

PHOTON IS OUR BUSINESS

Type	Type No.	Output	Main features	Applications						
				Position detection of spot light	Detection of edge	Encoder	Barcode reader	Refracto-meter	Sorting	Machine vision
CMOS	S9226-03	Mono-chrome		●						
	S10226-10		SP, SS, Low cost	●				●		
	S9227-03		High speed, ES, SP	●	●					
	S10227-10		High speed, ES, SP, SS, Low cost	●	●		●	●		
	S12443		High resp., ES, SP, SS, Low cost	●	●	●	●			
	S13131-1536		High resp., ES, SP, SS, Low cost	●	●	●	●			
	S13434-2496		High resp., ES, SP, SS, Low cost	●	●	●	●			
	S11106-10		High speed, ES, SP, SS, Low cost	●	●	●		●		
	S11107-10		High speed, ES, SP, SS, Low cost	●	●	●		●		
	S14416-12		ES, SP	●	●	●				
	S14417-06		High speed, ES, SP	●	●	●				
	S11720-40		High speed, ES, SP		●					●
	S15611-10		High speed, ES, SP, SS, Low cost	●	●	●			●	
	S14772		High resp., High speed, ES, Low cost	●	●	●			●	●
	S13774		High resp., High speed, ES, Low cost	●	●	●			●	●
	S15778		High resp., High speed, ES, Low cost	●	●	●			●	●
	S16074		High resp., High speed, ES, Low cost	●	●	●			●	●
	S11639-01		High resp., ES, SP, UV	●	●					
	S11108		High resp., ES, SP, Low cost	●	●	●			●	●
	S12706		High resp., ES, SP, Low cost	●	●	●			●	●
	S13488	Color	High resp., ES, SP, Low cost						●	
CCD	S12551-2048	Mono-chrome	High resp., High speed, ES, Low cost, UV						●	●
	S12379		High resp., High speed, Low cost, UV						●	●
	S1020x series		High resp., High speed, Low cost, UV, TDI							●

High resp. High sensitivity
High speed High-speed
ES Electronic shutter function
SP Single power supply
SS Small in size
Low cost Low cost
UV UV sensitivity
TDI TDI operation

Glossary

Video data rate
Number of pixels to be output per second

Line rate
Number of lines to be output per second, for outputting all pixels in the image sensor.

Photosensitivity
Output voltage (unit: V/lx·sec) per incident light level, per second, for Tungstan lump, 2856K.

Conversion factor
The conversion efficiency is the charge-to-voltage conversion ratio.
The conversion efficiency (Sv) is expressed by following equation.

$Sv = q \times \Delta Vout/Q$

q: electron charge, ΔVout: Output voltage, Q: signal charge [C]

Saturation output
The difference between output offset voltage and the output voltage when saturated.

Full well capacity
The amount of charge when the output is saturated.

Readout noise
Readout noise is defined as random noise (lower detection limit) coming from the amplifier in the output section.It should be noted that the total noise includes shot noise etc, as well as readout noise.

Dynamic range
Ratio of readout noise and satuation output.The dynamic range (DR) is expressed by following equation.
DR = Saturation output / Readout noise

Spectral response
The relation (photoelectric sensitivity) between the incident light level and resulting photocurrent differs depending on the wavelength of the incident light. This relation between the photoelectric sensitivity is referred to as the spectral response characteristic and is expressed in terms of photo sensitivity or quantum efficiency.We usually define the spectral response range as the range in which the relative sensitivity is higher than 5% or 10% of the peak sensitivity.

Quantum efficiency
This is the number of electrons or holes that can be extracted as photocurrent divided by the number of incident photons. It is commonly expressed in percent (%). The quantum efficiency QE and photo sensitivity S (unit:A/W) have the following relationship at a given wavelength (unit:nm).

$QE = S \times 1240/\lambda \times 100$ [%]

Blooming
A phenomenon in which the photoelectrically converted signal charge in an image sensor exceeds a certain level and spills over into adjacent pixelsor transfer region other than photodiodes (in IT type CCDs).To prevent blooming, some means for discharging excess charge should beimplemented.

Integration time
In image sensor operation, the electric charge generated by light entering in a given time is accumulated and collected to create a signal. The length of this time during which light enters the image sensor is called integration time or accumulation time. In image sensors with electronic shutter function, the intergration time can be set to the order of microsecond.

Electronic shutter function
The electronic shutter function can be used to accumulate a signal charge in shorter time than readout period. The start of integration time can be synchronized with an external trigger by using electronic shutter.

Pixel integration simultaneity
In the time-series integration method, the integration time of each pixel is the same, but the time at which integration is taken is different for each pixel. As such, care must be taken when detecting incident light that varies over time.

HAMAMATSU

www.hamamatsu.com

HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1 Ichino-cho, Chuo-ku, Hamamatsu City, 435-8558 Japan, Telephone: (81)53-434-3311, Fax: (81)53-434-5184
U.S.A.: Hamamatsu Corporation: 360 Foothill Road, Bridgewater, N.J. 08807, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218, E-mail: usa@hamamatsu.com
Germany: Hamamatsu Photonics Deutschland GmbH: Arzbergerstr. 10, D-82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-265-8, E-mail: info@hamamatsu.de
France: Hamamatsu Photonics France S.A.R.L.: 19, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10, E-mail: infos@hamamatsu.fr
United Kingdom: Hamamatsu Photonics UK Limited: 2 Howard Court, 10 Tewin Road, Welwyn Garden City, Hertfordshire AL7 1BW, UK, Telephone: (44)1707-294888, Fax: (44)1707-325777, E-mail: info@hamamatsu.co.uk
North Europe: Hamamatsu Photonics Norden AB: Torshamnsgatan 35 16440 Kista, Sweden, Telephone: (46)8-509 031 00, Fax: (46)8-509 031 01, E-mail: info@hamamatsu.se
Italy: Hamamatsu Photonics Italia S.r.l.: Strada della Moia, 1 int. 6, 20044 Arese (Milano), Italy, Telephone: (39)02-93 58 17 33, Fax: (39)02-93 58 17 41, E-mail: info@hamamatsu.it
China: Hamamatsu Photonics (China) Co., Ltd.: 1201 Tower B, Jiaming Center, 27 Dongsanhuan Beilu, Chaoyang District, 100020 Beijing, P.R.China, Telephone: (86)10-6586-6006, Fax: (86)10-6586-2866, E-mail: hpc@hamamatsu.com.cn
Taiwan: Hamamatsu Photonics Taiwan Co., Ltd.: 8F-3, No. 158, Section2, Gongdao 5th Road, East District, Hsinchu, 300, Taiwan R.O.C. Telephone: (886)3-659-0080, Fax: (886)3-659-0081, E-mail: info@hamamatsu.com.tw

Cat. No. KMPD0005E14
Feb. 2024