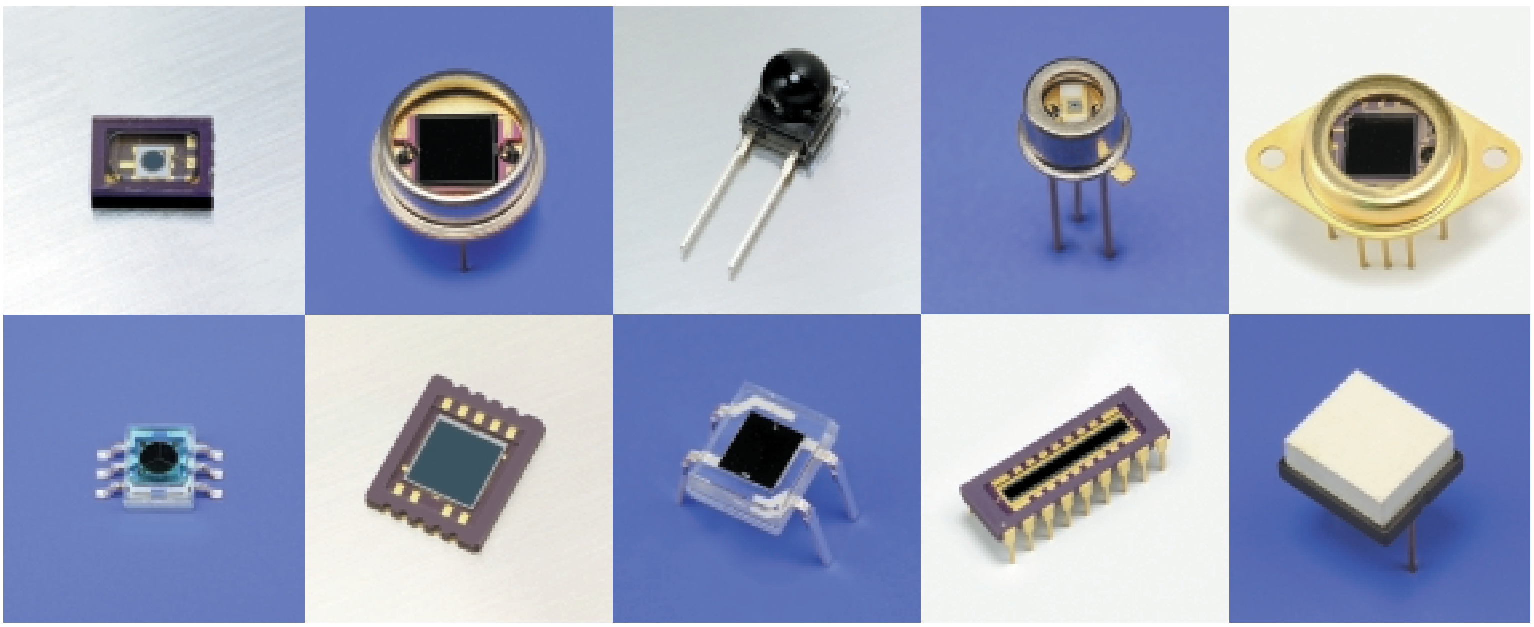
SOLID STATE DIVISION

Selection Guide
May 2006

Si PHOTODIODES



Line-up of Si photodiodes for UV to near IR, radiation

HAMAMATSU

Contents

For detailed data on the products listed in this catalogue, see their datasheets that are available from our website www.hamamatsu.com

Si photodiode

Photodiodes are semiconductor light sensors that generate a current or voltage when the P-N junction in the semiconductor is illuminated by light. The term photodiode can be broadly defined to include even solar batteries, but it usually refers to sensors used to detect the intensity of light. Photodiodes can be classified by function and construction as follows:

· Si photodiode
· Si PIN photodiode
· Si APD (Avalanche photodiode)

All of these types provide the following features and are widely used for the detection of the presence, intensity and color of light.

· Excellent linearity with respect to incident light
· Low noise
· Wide spectral response range
· Mechanically rugged
· Compact and lightweight
· Long life

Si photodiodes manufactured utilizing our unique semiconductor process technologies cover a broad spectral range from the near infrared to ultraviolet and even to high-energy regions. They also feature high-speed response, high sensitivity and low noise. Si photodiodes are used in a wide range of applications including medical and analytical fields, scientific measurements, optical communications and general electronic products. Si photodiodes are available in various packages such as metal, ceramic and plastic packages as well as in surface mount types. We also offer custom-designed devices to meet special needs.

Si photodiode of HAMAMATSU

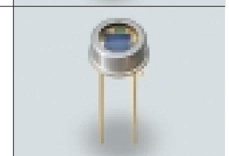
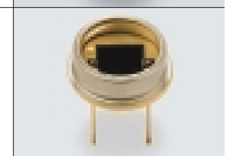
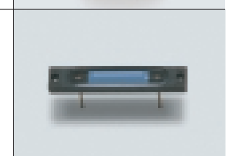
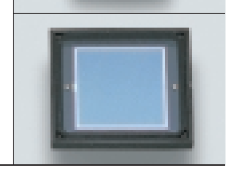
Type	Feature	Product example
Si photodiode	Featuring high sensitivity and low dark current, these Si photodiodes are specifically designed for precision photometry/analytical instrument and general photometry/visible range.	- For UV to near IR - For visible range to near IR - For visible range - RGB color sensor - For VUV (vacuum ultraviolet) detection - For monochromatic light detection - For electron beam detector
Si PIN photodiode	Si PIN photodiodes delivering high-speed response when operated with a reverse bias are widely used for optical communications and optical disk pickup, etc.	- Cut-off frequency: 1 GHz or more - Cut-off frequency: 500 MHz to less than 1 GHz - Cut-off frequency: 100 MHz to less than 500 MHz - Cut-off frequency: 10 MHz to less than 100 MHz - For YAG laser detection
Multi-element type Si photodiode	Si photodiode arrays consist of multiple elements of the same size, formed in a linear or matrix arrangement at an equal spacing in one package. These Si photodiode arrays are used in a wide range of applications such as laser beam position detection and spec-	- Segment type photodiode - One-dimensional, two-dimensional photodiode array - Incident light angle sensor
Si photodiode with preamp, TE-cooled type Si photodiode	Si photodiodes with preamp incorporate a photodiode and a preamplifier chip into the same package. TE-cooled type Si photodiodes are suitable for low-light-level detection where a high S/N is re-	- For analytical and measurement - For optical fiber communication
Si photodiode for radiation	These detectors are comprised of a Si photodiode coupled to a scintillator. These detectors are used for X-ray baggage inspection and non-destructive inspec-	- With scintillator - Large active area type
Si APD *	Si APDs are high-speed, high sensitivity photodiodes having an internal gain mechanism.	- Near IR type - Short wavelength type - Multi-element type
Related product of Si photodiode	HAMAMATSU provides various types of Si photodiode modules.	- RGB color sensor module - Color sensor evaluation circuit - Circuit for Si photodiode - PIN photodiode amplifier (wide band) - Photosensor amplifier

* Si APD is not listed in this catalogue.

Note) HAMAMATSU also provides PSD (Position Sensitive Detector) used to detect the position of incident light spot. PSD is a non-discrete photosensor utilizing the surface resistance of photodiodes.

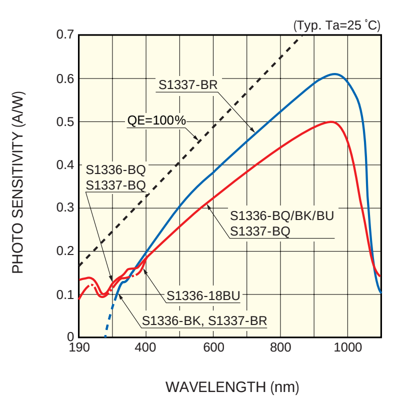
For UV to near IR: UV sensitivity enhanced type

These Si photodiodes have sensitivity in the UV to near IR range.

Type No.	Spectral response range (nm)	Photo sensitivity (A/W)		Dark current VR=10 mV Max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Active area size (mm)	Package	Photo
		λ=λp	λ=200 nm					
S1336-18BU	190 to 1100	0.36	0.075	20	20	1.1 × 1.1	TO-18	
S1336-18BQ		0.5	0.12					
S1336-18BK	320 to 1100		–					
S1336-5BQ	190 to 1100	0.5	0.12	30	65	2.4 × 2.4	TO-5	
S1336-5BK	320 to 1100		–					
S1336-44BQ	190 to 1100		0.12	50	150	3.6 × 3.6		
S1336-44BK	320 to 1100		–					
S1336-8BQ	190 to 1100		0.12	100	380	5.8 × 5.8	TO-8	
S1336-8BK	320 to 1100		–					
S1337-16BQ	190 to 1100	0.5	0.12	30	65	1.1 × 5.9	Ceramic	
S1337-16BR	320 to 1100	0.62	–					
S1337-33BQ	190 to 1100	0.5	0.12	30		2.4 × 2.4		
S1337-33BR	320 to 1100	0.62	–					
S1337-66BQ	190 to 1100	0.5	0.12	100	380	5.8 × 5.8		
S1337-66BR	320 to 1100	0.62	–					
S1337-1010BQ	190 to 1100	0.5	0.12	200	1100	10 × 10		
S1337-1010BR	320 to 1100	0.62	–					

Spectral response

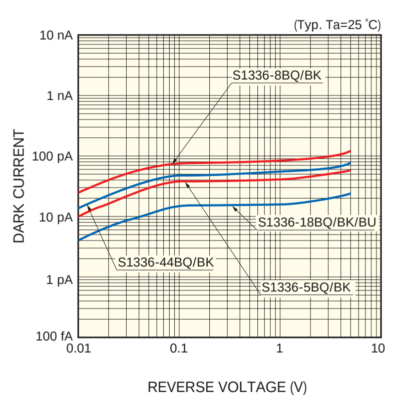
S1336/S1337 series



KSPDB0262EA

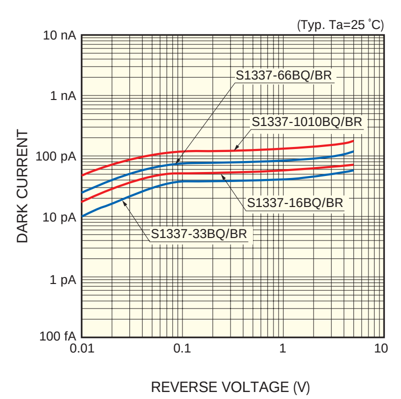
Dark current vs. reverse voltage

S1336 series

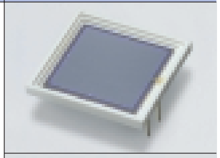
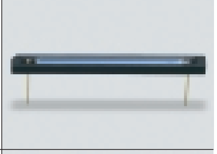


KSPDB0100EA

S1337 series



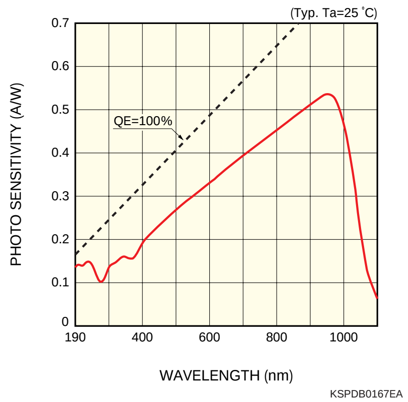
KSPDB0104EB

Type No.	Spectral response range (nm)	Photo sensitivity (A/W)		Dark current VR=10 mV Max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Active area size (mm)	Package	Photo
		λ=lp	λ=200 nm					
S6337-01	190 to 1100	0.53	0.13	1000	3500	18 × 18	Ceramic	
S2551	320 to 1060	0.6	–	1000	350	1.2 × 29.1		
S2281 *	190 to 1100	0.5	0.12	500	1300	ϕ11.3	With BNC connector	
S2281-04 *						ϕ7.98		

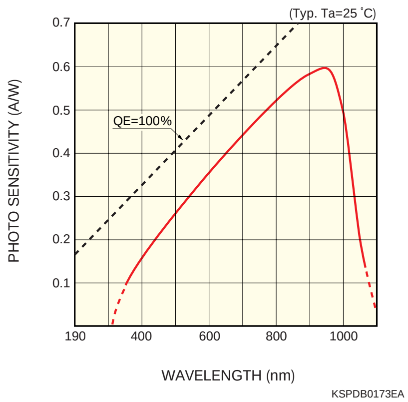
* The S2281 series photodiodes connect to the C9329 photosensor amplifier (using a BNC-BNC cable E2573). Weak photocurrent from these photodiodes can be amplified with low noise.

Spectral response

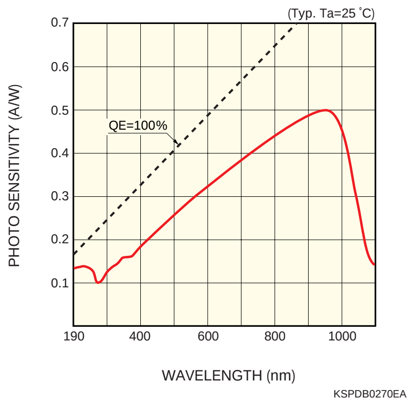
S6337-01



S2551

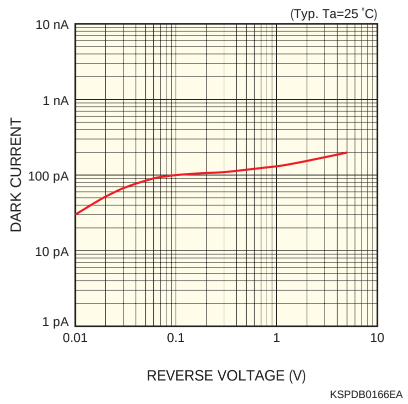


S2281, S2281-04

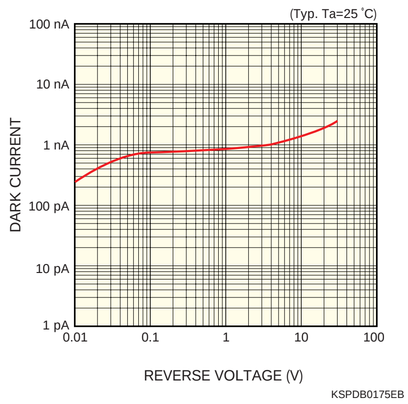


Dark current vs. reverse voltage

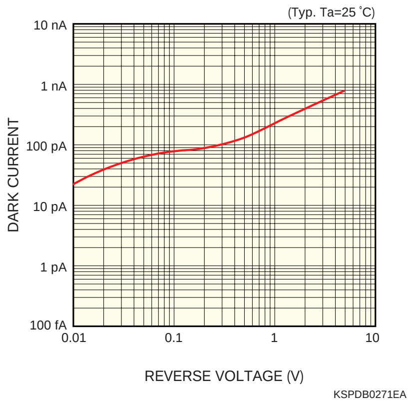
S6337-01



S2551

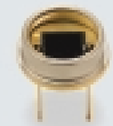
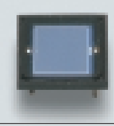
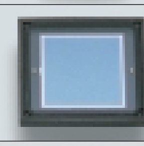
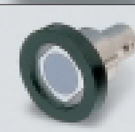


S2281, S2281-04



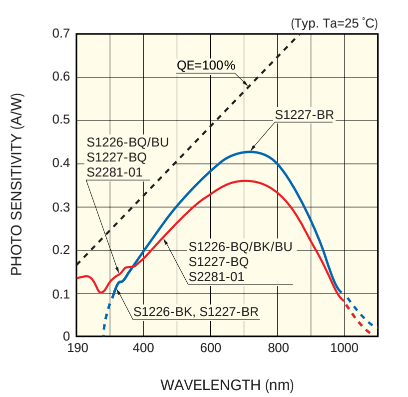
For UV to near IR: UV sensitivity enhanced type (with suppressed IR sensitivity)

These Si photodiodes have suppressed IR sensitivity

Type No.	Spectral response range (nm)	Photo sensitivity (A/W) λ=λp	Photo sensitivity (A/W) λ=200 nm	Dark current VR=10 mV Max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Active area size (mm)	Package	Photo
S1226-18BU	190 to 1000	0.36	0.075	2	35	1.1 × 1.1	TO-18	
S1226-18BQ			0.12					
S1226-18BK	320 to 1000		–					
S1226-5BQ	190 to 1000		0.12	5	160	2.4 × 2.4	TO-5	
S1226-5BK	320 to 1000		–					
S1226-44BQ	190 to 1000		0.12	10	380	3.6 × 3.6		
S1226-44BK	320 to 1000		–					
S1226-8BQ	190 to 1000		0.12	20	950	5.8 × 5.8	TO-8	
S1226-8BK	320 to 1000		–					
S1227-16BQ	190 to 1000	0.36	0.12	5	170	1.1 × 5.9	Ceramic	
S1227-16BR	320 to 1000		–					
S1227-33BQ	190 to 1000		0.12	5	160	2.4 × 2.4		
S1227-33BR	320 to 1000		–					
S1227-66BQ	190 to 1000		0.12	20	950	5.8 × 5.8		
S1227-66BR	320 to 1000		–					
S1227-1010BQ	190 to 1000		0.12	50	3000	10 × 10		
S1227-1010BR	320 to 1000		–					
S2281-01	190 to 1000	0.36	0.12	300	3200	ϕ11.3	With BNC connector	

Spectral response

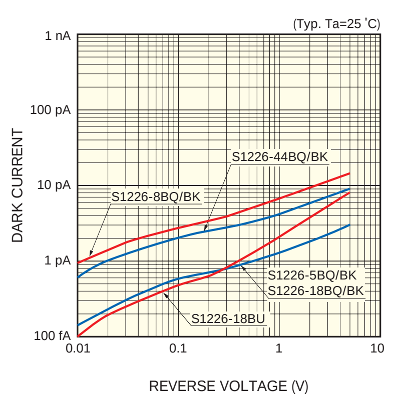
S1226/S1227 series, S2281-01



KSPDB0263EA

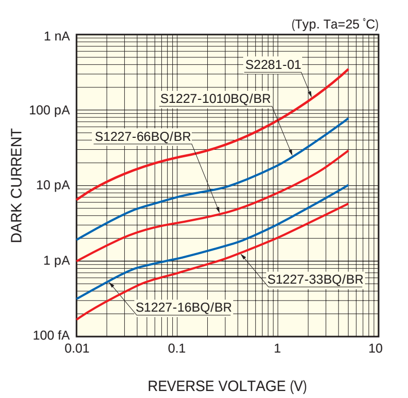
Dark current vs. reverse voltage

S1226 series



KSPDB0275EA

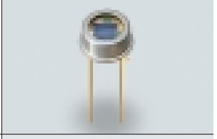
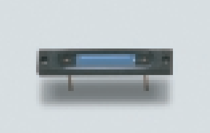
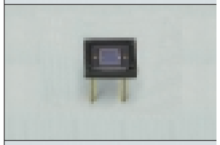
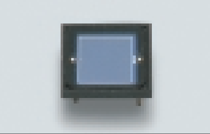
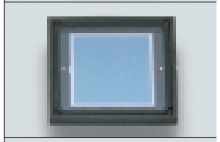
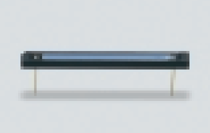
S1227 series, S2281-01



KSPDB0276EA

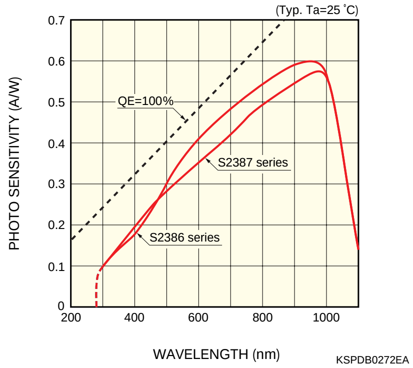
Visible range to near IR: IR sensitivity enhanced type

These Si photodiodes offer enhanced sensitivity especially in the near IR range.

Type No.	Spectral response range (nm)	Photo sensitivity λ=λp (A/W)	Dark current VR=10 mV Max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Active area size (mm)	Package	Photo
S2386-18K	320 to 1100	0.6	2	140	1.1 × 1.1	TO-18	
S2386-18L			2				
S2386-5K			5	730	2.4 × 2.4	TO-5	
S2386-44K			20	1600	3.6 × 3.6		
S2386-45K			30	2300	3.9 × 4.6		
S2386-8K			50	4300	5.8 × 5.8	TO-8	
S2387-16R		0.58	5	730	1.1 × 5.9	Ceramic	
S2387-33R			5		2.4 × 2.4		
S2387-66R			50	4300	5.8 × 5.8		
S2387-1010R			200	12000	10 × 10		
S2387-130R			300	5000	1.2 × 29.1		

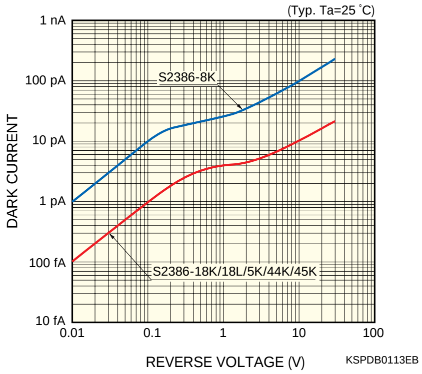
Spectral response

S2386/S2387 series

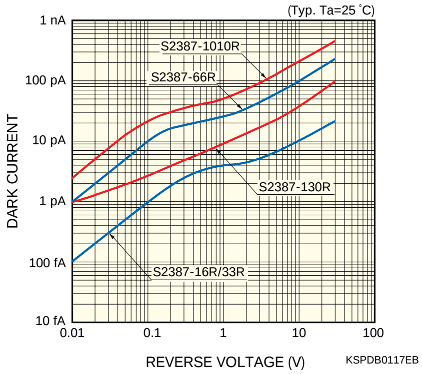


Dark current vs. reverse voltage

S2386 series

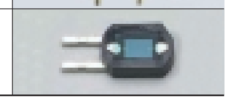
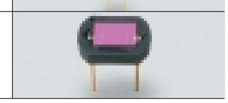
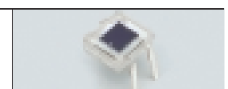
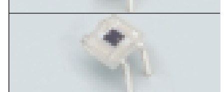
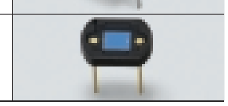


S2387 series



For visible range

These Si photodiodes have sensitivity in the visible range.

Type No.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photo sensitivity λ=λp (A/W)	Dark current VR=1 V Max. (pA)	Active area size (mm)	Package	Photo
Filter type (general use)							
S1087	320 to 730	560	0.3	10	1.3 × 1.3	Ceramic	
S1133					2.4 × 2.8		
S8265	340 to 720	540		20	2.4 × 2.8	Ceramic	
S1787-04	320 to 730	560		10	2.4 × 2.8	Plastic	
Filter type (CIE standard luminous spectral efficiency approximation)							
S9219	480 to 660	550	0.24	500 (VR=10 mV)	ϕ11.3	With BNC connector	
S9219-01			0.22	50 (VR=10 mV)	3.6 × 3.6	TO-5	
S7686			0.38	20	2.4 × 2.8	Ceramic	
Filterless type							
S5493-01	320 to 840	540	0.3	100	2.4 × 2.8	Plastic	
S5627-01				50	1.3 × 1.3		
S7123-01				100	2.46 × 2.46		
S7123-02					2.4 × 2.8	Ceramic	

Filter type (general use)

These are Si photodiodes with visible-compensated filters. S8265 is a high humidity resistance type.

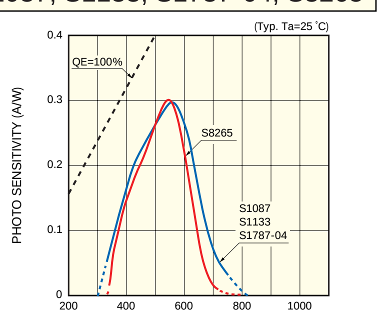
Filter type (CIE standard luminous spectral efficiency approximation)

Filterless type

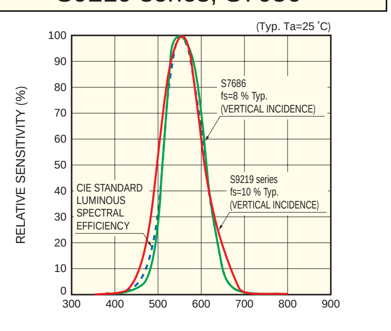
These Si photodiodes provide a spectral response characteristic similar to the visible range sensitivity without using visible-compensated filters. S7123 series is ideal for automotive application to have wide operating temperature.

Spectral response

S1087, S1133, S1787-04, S8265

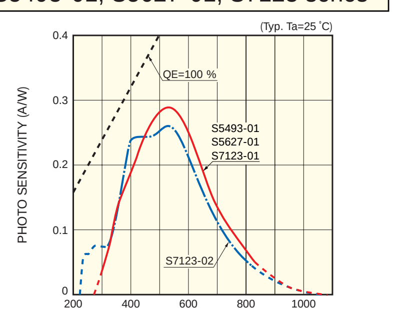


S9219 series, S7686



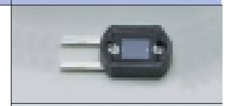
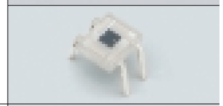
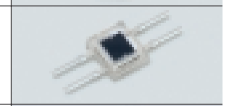
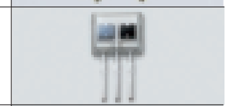
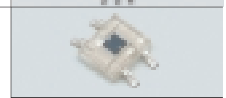
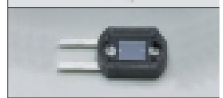
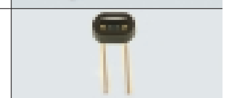
Note) fs: Deviation from CIE standard luminous spectral efficiency

S5493-01, S5627-01, S7123 series



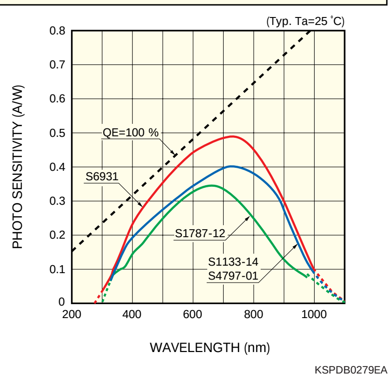
For visible range to near IR

These Si photodiodes have sensitivity in the visible range to near IR. S8753 is a visible to infrared sensor using a dual-element (for visible/infrared) photodiode molded into a package. S6865 series is ideal for automotive application to have wide operating temperature.

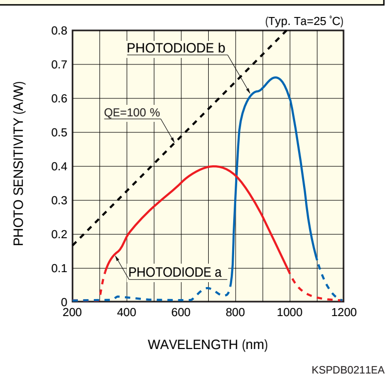
Type No.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photo sensitivity λ=λp (A/W)	Dark current VR=1 V Max. (pA)	Active area size (mm)	Package	Photo
S1787-12	320 to 1000	650	0.35	20	2.4 × 2.8	Plastic	
S4797-01		720	0.4		1.3 × 1.3		
S6931			0.48		2.4 × 2.8	Plastic	
S1133-14			0.4			Ceramic	
S8753	Photodiode a: 320 to 1000	720	0.4	100	1.3 × 1.3	Plastic	
	Photodiode b: 780 to 1100	960	0.65				
S4011-04	320 to 1100	960	0.58	10	1.3 × 1.3	Plastic	
S6865-01					2 × 2		
S1787-08					2.4 × 2.8		
S2833-01							
S1087-01			0.58		1.3 × 1.3	Ceramic	
S1133-01			0.58		2.4 × 2.8		
S6865-02			0.7				

Spectral response

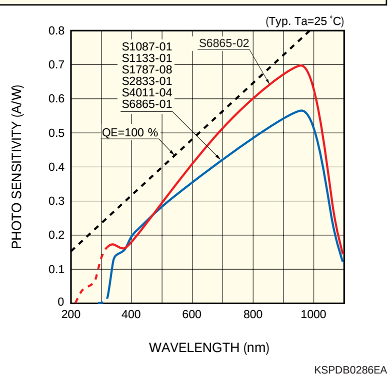
S1787-12, etc.



S8753

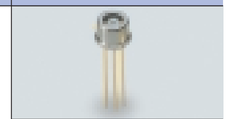
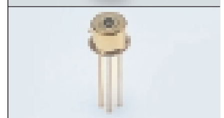
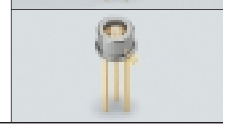


S4011-04, etc.

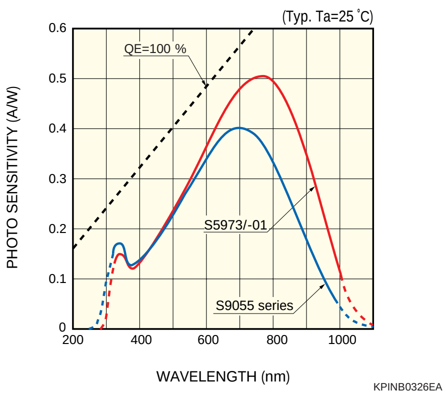


Cut-off frequency: 1 GHz or more

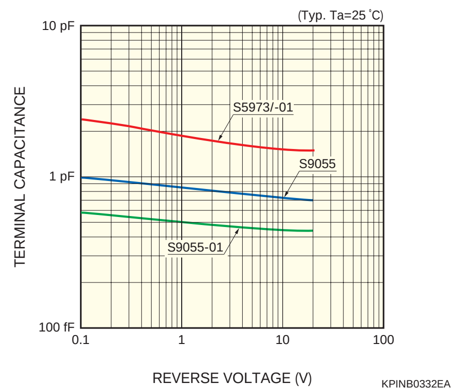
These Si PIN photodiodes deliver a wide bandwidth even with a low bias, making them ideal for high-speed photometry as well as optical communications.

Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity (A/W) λ=780 nm	Photo sensitivity (A/W) λ=830 nm	Terminal capacitance f=1 MHz (pF)	Package	Photo
S5973	1.2 GHz (VR=3.3 V)	ϕ0.4	0.51	0.45	1.6 (VR=3.3 V)	TO-18	
S5973-01							
S9055	1.5 GHz (VR=2 V)	ϕ0.2	0.35	0.25	0.8 (VR=2 V)		
S9055-01	2.0 GHz (VR=2 V)	ϕ0.1			0.5 (VR=2 V)		

Spectral response

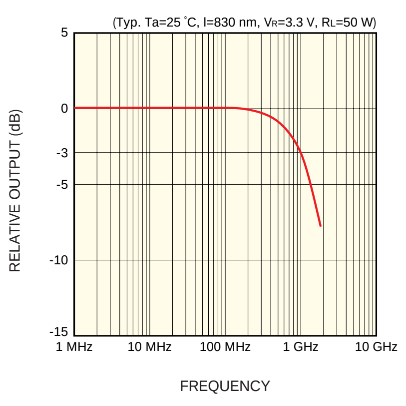


Terminal capacitance vs. reverse voltage



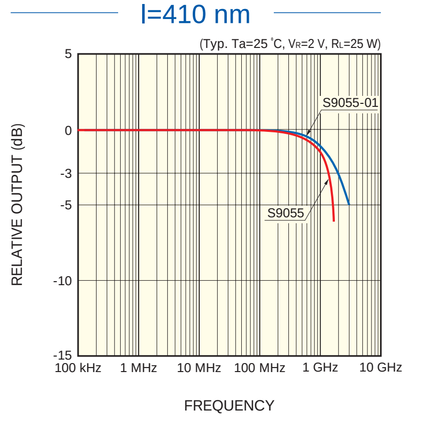
Frequency response

S5973, S5973-01

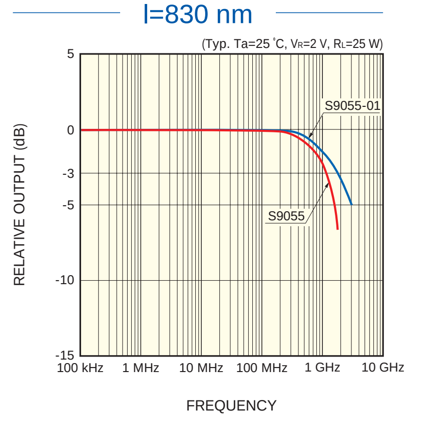


S9055 series

l=410 nm

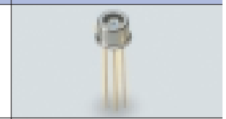
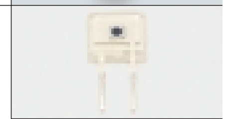
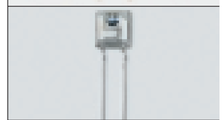
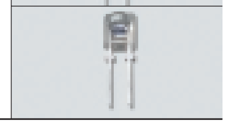


l=830 nm



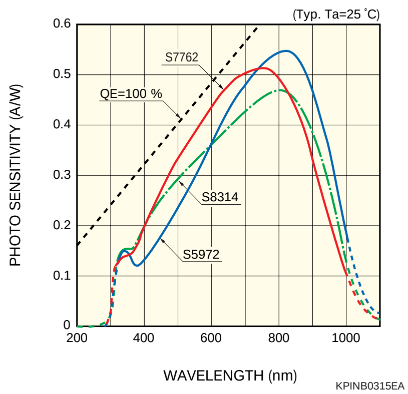
Cut-off frequency: 500 MHz to less than 1 GHz

These Si PIN photodiodes deliver a wide bandwidth even with a low bias

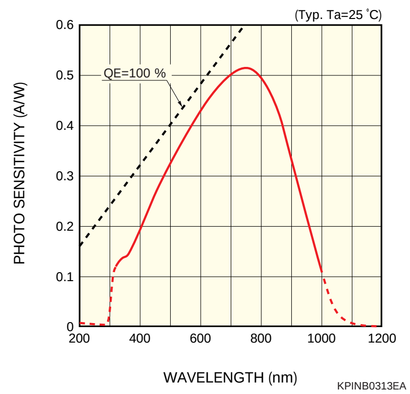
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity (A/W)		Terminal capacitance f=1 MHz (pF)	Package	Photo
			λ=660 nm	λ=780 nm			
S5972	500 (VR=10 V)	ϕ0.8	0.44	0.55	3 (VR=10 V)	TO-18	
S8314	500 (VR=5 V)		0.4	0.46	4 (VR=5 V)	Plastic	
S7762	500 (VR=2.5 V)		0.48	0.5	6 (VR=2.5 V)		
S8701	550 (VR=2 V)	ϕ1.7 (lens diameter)	0.48	0.5	3.5 (VR=2 V)		
S5052	500 (VR=5 V)	ϕ3 (lens diameter)	0.4	0.45	4 (VR=5 V)		
S7797	500 (VR=2.5 V)		0.48	0.51	6 (VR=2.5 V)		

Spectral response

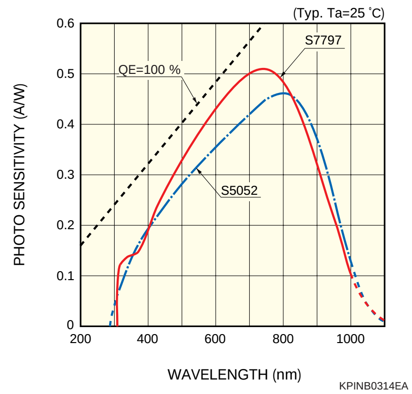
S5972, S8314, S7762



S8701

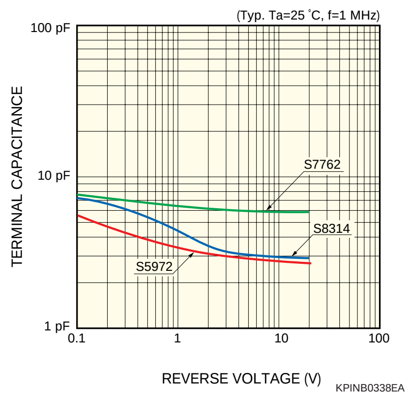


S5052, S7797

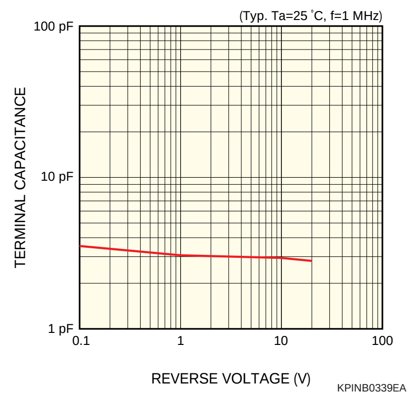


Terminal capacitance vs. reverse voltage

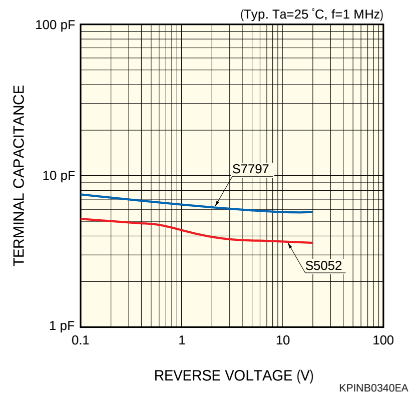
S5972, S8314, S7762



S8701

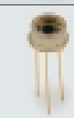
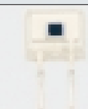
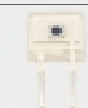
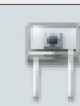


S5052, S7797

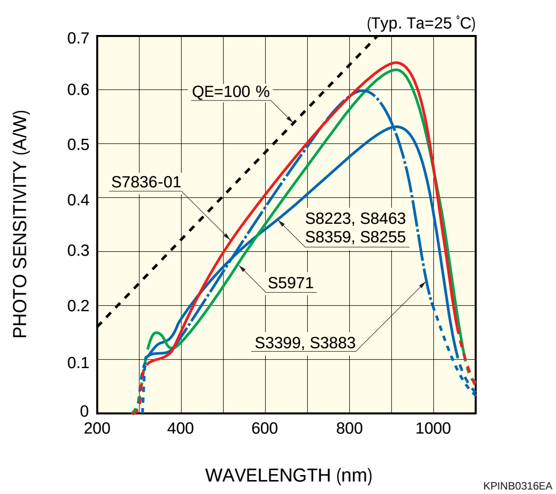


Cut-off frequency: 100 MHz to less than 500 MHz

These Si PIN photodiodes have a large active area (ϕ0.8 to ϕ3.0 mm) yet deliver excellent frequency response characteristics (100 MHz to 300 MHz).

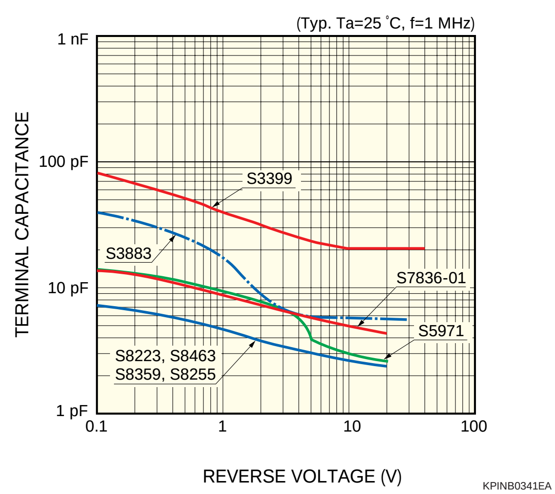
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity (A/W) λ=660 nm	Photo sensitivity (A/W) λ=780 nm	Terminal capacitance f=1 MHz (pF)	Package	Photo
S5971	100 (VR=10 V)	ϕ1.2	0.44	0.55	3 (VR=10 V)	TO-18	
S3399		ϕ3	0.45	0.58	20 (VR=10 V)	TO-5	
S3883	300 (VR=20 V)	ϕ1.5			6 (VR=20 V)		
S7836-01	150 (VR=2.5 V)	1.1 × 1.1	0.45	0.55	6 (VR=2.5 V)	Plastic	
S8223	200 (VR=5 V)	ϕ0.8	0.39	0.48	3 (VR=5 V)		
S8463			0.4	0.48			
S8359		ϕ1.7 (lens diameter)	0.4	0.48			
S8255		ϕ3 (lens diameter)	0.4	0.48			

Spectral response



KPINB0316EA

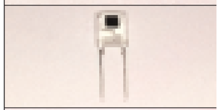
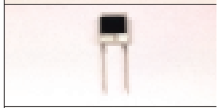
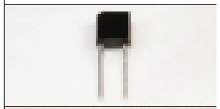
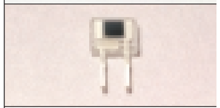
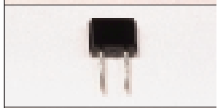
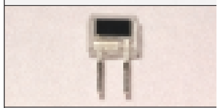
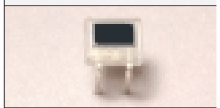
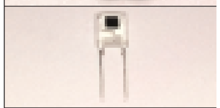
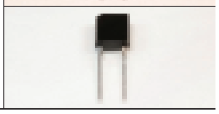
Terminal capacitance vs. reverse voltage



KPINB0341EA

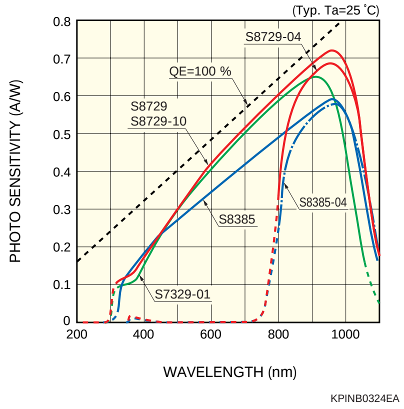
Cut-off frequency: 10 MHz to less than 100 MHz

A wide variety of types are provided including a low-cost plastic package type, metal package type with high reliability and high performance and visible-cut type.

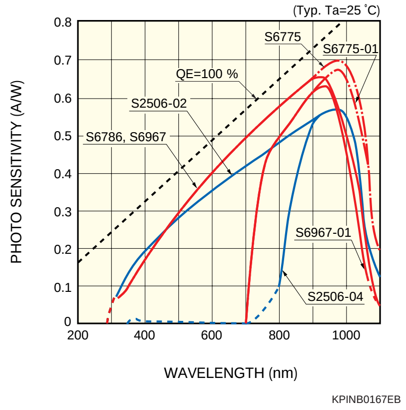
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity (A/W) λ=660 nm	Photo sensitivity (A/W) λ=780 nm	Terminal capacitance f=1 MHz (pF)	Package	Photo
S7329-01	60 (VR=5 V)	2 × 2	0.45	0.55	12 (VR=5 V)	Plastic	
S6786	60 (VR=10 V)	2.77 × 2.77			15 (VR=10 V)		
S6775	15 (VR=10 V)	5.5 × 4.8	0.45	0.55	40 (VR=10 V)		
S6967	50 (VR=10 V)				50 (VR=10 V)		
S6775-01	15 (VR=10 V)		0.54 (λ=830 nm)	0.68 (λ=λp)	40 (VR=10 V)		
S6967-01	50 (VR=10 V)			0.63 (λ=λp)	50 (VR=10 V)		
S8385	25 (VR=5 V)	2 × 2	0.4	0.48	12 (VR=5 V)		
S8385-04			0.44 (λ=830 nm)	0.56 (lλ=λp)			
S8729		2 × 3.3	0.45	0.55	16 (VR=5 V)		
S8729-04			0.52 (λ=830 nm)	0.68 (lλ=λp)			
S8729-10			0.45	0.55			
S2506-02	25 (VR=12 V)	2.77 × 2.77	0.45	0.48	15 (VR=12 V)		
S2506-04			0.25 (λ=830 nm)	0.56 (lλ=λp)			

Spectral response

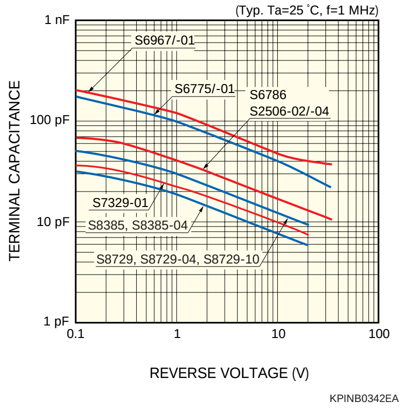
S7329-01, S8385/S8729 series

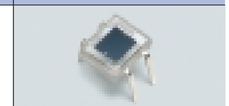
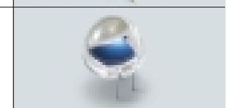
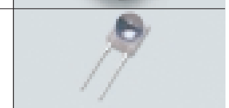
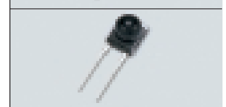
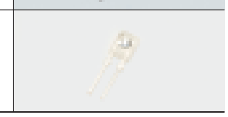


S6786, S6775/S6967/S2506 series



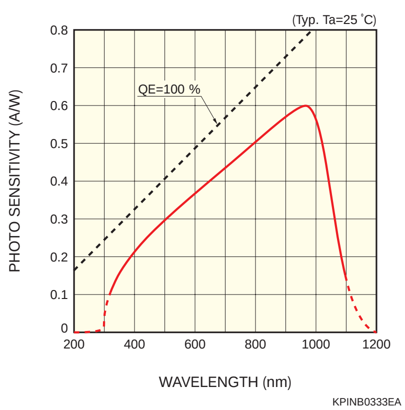
Terminal capacitance vs. reverse voltage



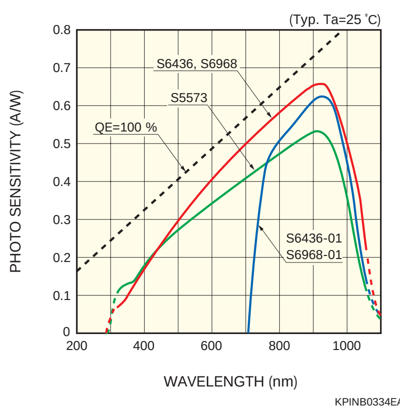
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity λ=λp (A/W)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S4707-01	20 (VR=10 V)	2.4 × 2.8	0.6	14 (VR=10 V)	Plastic	
S6801	15 (VR=10 V)	ϕ14 (lens diameter)	0.63 (λ=850 nm)	40 (VR=10 V)	Plastic with ϕ14 mm lens	
S6968	50 (VR=10 V)			50 (VR=10 V)		
S6801-01	15 (VR=10 V)		0.55 (λ=850 nm)	40 (VR=10 V)		
S6968-01	50 (VR=10 V)			50 (VR=10 V)		
S6436	60 (VR=10 V)	ϕ7 (lens diameter)	0.63 (λ=850 nm)	15 (VR=10 V)	Plastic with ϕ7 mm lens	
S6436-01			0.55 (λ=850 nm)			
S5573	80 (VR=5 V)	ϕ3 (lens diameter)	0.53	3 (VR=5 V)	Plastic with ϕ3 mm lens	

Spectral response

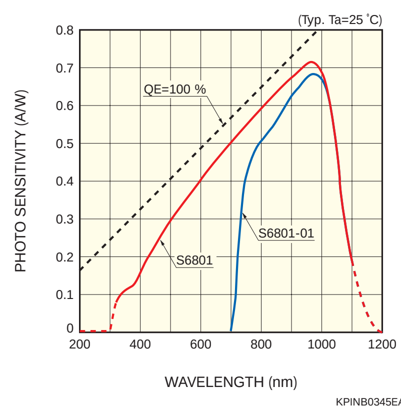
S4707-01



S6436/S6968 series, S5573

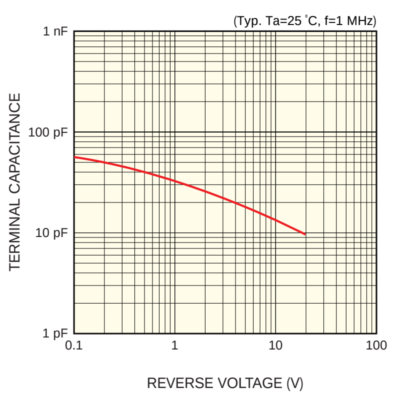


S6801 series

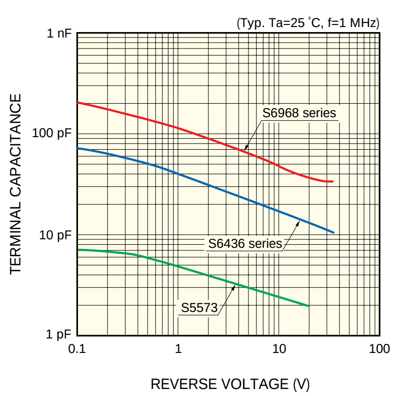


Terminal capacitance vs. reverse voltage

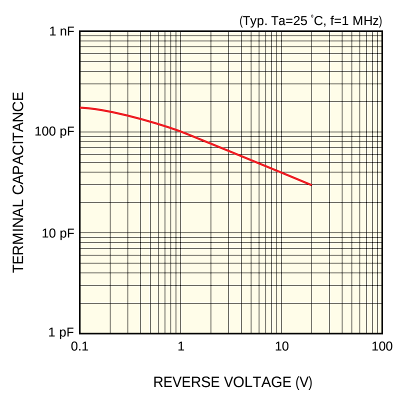
S4707-01

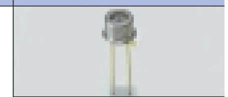
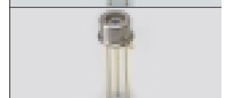
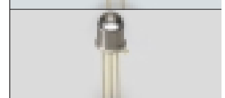
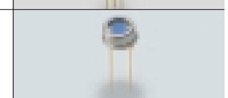
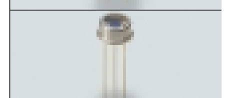
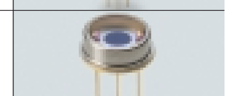
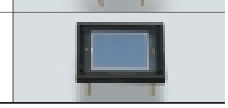


S6436/S6968 series, S5573



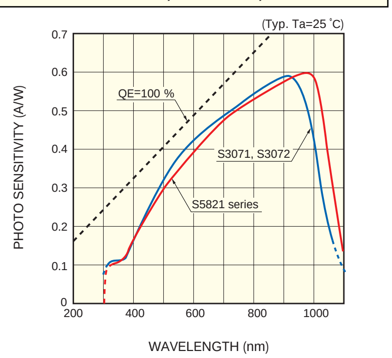
S6801 series



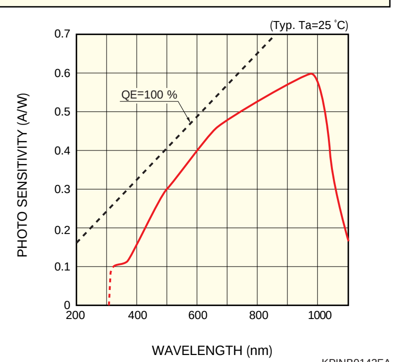
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity (A/W)		Terminal capacitance f=1 MHz (pF)	Package	Photo
			λ=660 nm	λ=780 nm			
S5821	25 (VR=5 V)	ϕ1.2	0.45	0.52	3 (VR=5 V)	TO-18	
S5821-02							
S5821-01		ϕ4.65 (lens diameter)					
S5821-03							
S1223	30 (VR=20 V)	2.4 × 2.8	0.45	0.52	10 (VR=20 V)	TO-5	
S1223-01	20 (VR=20 V)	3.6 × 3.6			20 (VR=20 V)		
S3072	45 (VR=24 V)	ϕ3			7 (VR=24 V)		
S3071	40 (VR=24 V)	ϕ5	0.47	0.54	18 (VR=24 V)	TO-8	
S1722-02	60 (VR=100 V)	ϕ4.1	0.5 (λ=λp)		10 (VR=100 V)	TO-8	
S1723-05	15 (VR=30 V)	10 × 10			100 (VR=30 V)	Ceramic	

Spectral response

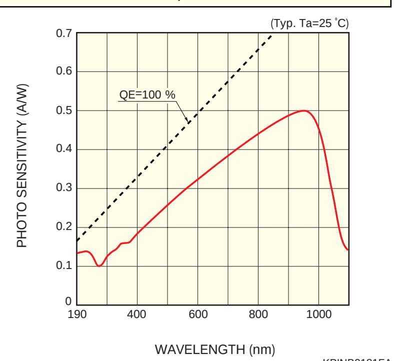
S5821 series, S3071, S3072



S1223 series

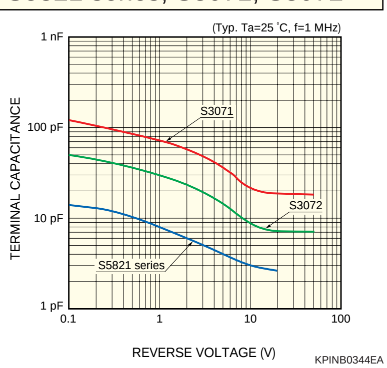


S1722-02, S1723-05

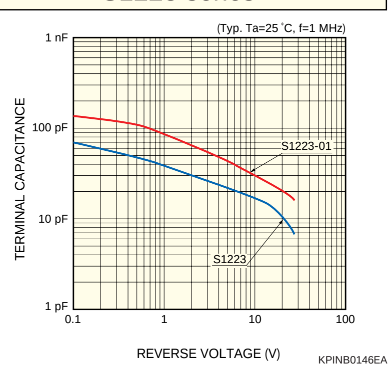


Terminal capacitance vs. reverse voltage

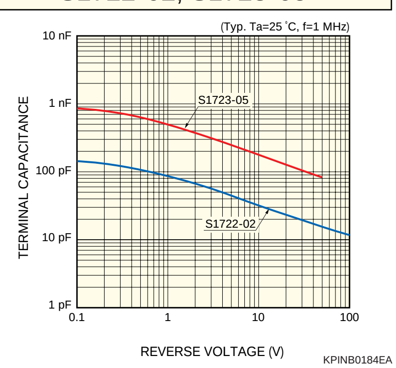
S5821 series, S3071, S3072



S1223 series

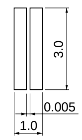
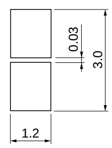
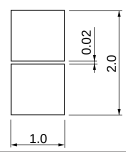
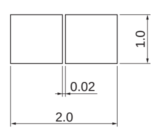
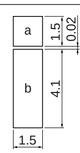
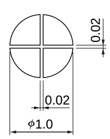
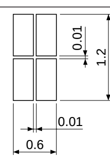
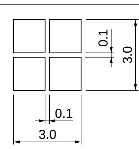


S1722-02, S1723-05



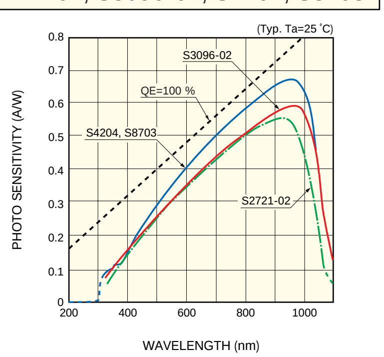
Segmented type photodiode

These Si PIN photodiode arrays consist of 2 or 4 elements having sensitivity in the UV to near IR range.

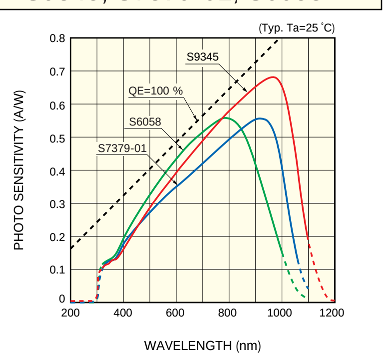
Type No.	Number of elements	Active area size (mm)		Photo sensitivity λ=λp (A/W)	Cut-off frequency VR=10 V, RL=50 Ω (MHz)	Terminal capacitance VR=10 V, f=1 MHz (pF)	Package	Photo
S2721-02	2	1 × 3		0.56	50	5	Plastic	
S3096-02		1.2 × 3		0.58	25			
S4204		1 × 2		0.65	30	3		
S8703		1 × 2						
S9345		1.5 × 1.5 + 1.5 × 4.1		0.55 (l=780 nm)	15	4 (Photo-diode a) / 10 (Photo-diode b)		
S7379-01	4	φ1		0.55	80	1		
S6058		0.6 × 1.2		0.55	150 (VR=3 V)	1 (VR=3 V)		
S4349		3 × 3		0.45	20 (VR=5 V)	25 (VR=5 V)	TO-5	

Spectral response

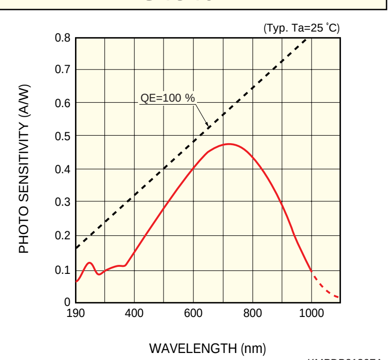
S2721-02, S3096-02, S4204, S8703



S9345, S7379-01, S6058

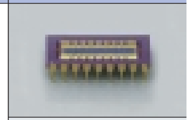
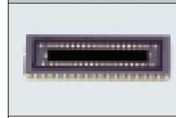
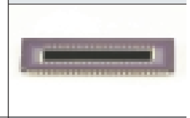
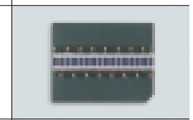
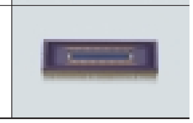


S4349



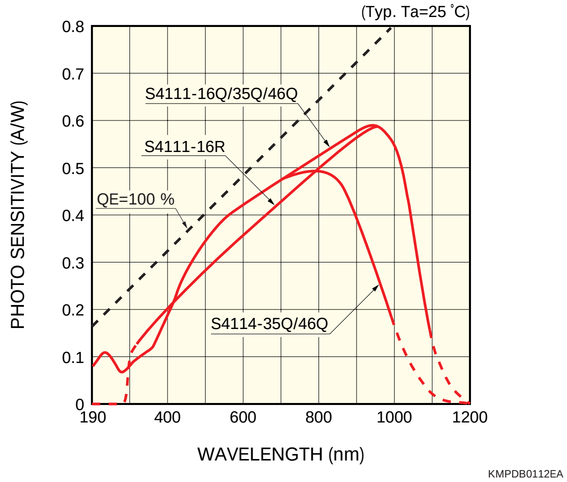
One-dimensional photodiode array (UV to near IR: UV sensitivity enhanced type)

These are Si photodiode linear arrays having rectangular elements equally spaced at a pitch of about 1 mm.

Type No.	Number of elements	Active area size (mm)	Element pitch (mm)	Spectral response range (nm)	Photo sensitivity λ=λp (A/W)	Dark current VR=10 mV Max. (pA)	Package	Photo
S4111-16Q	16	1.45 × 0.9	1.0	190 to 1100	0.58	5	Ceramic	
S4111-16R				320 to 1100				
S4111-35Q	35	4.4 × 0.9		190 to 1100		10		
S4114-35Q	35				0.5	60		
S4111-46Q	46			190 to 1100	0.58	10		
S4114-46Q	46				0.5	60		
S5668-01	16	1.175 × 2.0	1.575	320 to 1100	0.56	1	Glass epoxy	
S5668-02					0.58	5		
S5668-05				320 to 1060	0.56	50		
S3954	76	0.318 × 3.175	0.3425	190 to 1100	0.58	30	Ceramic	

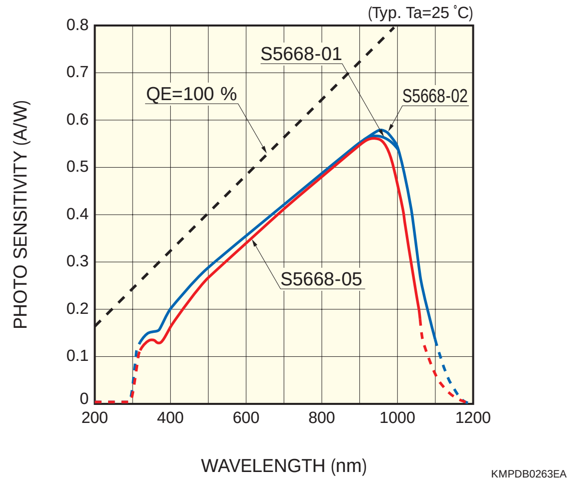
Spectral response

S4111/S4114 series



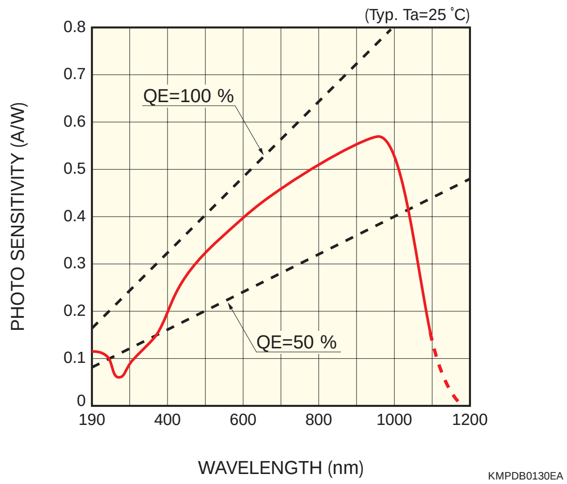
KMPDB0112EA

S5668 series



KMPDB0263EA

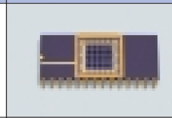
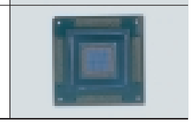
S3954



KMPDB0130EA

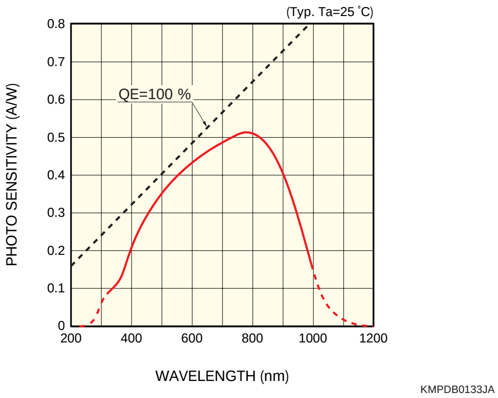
Two-dimensional photodiode array

These Si PIN photodiode arrays consist of multiple elements formed in a matrix pattern.

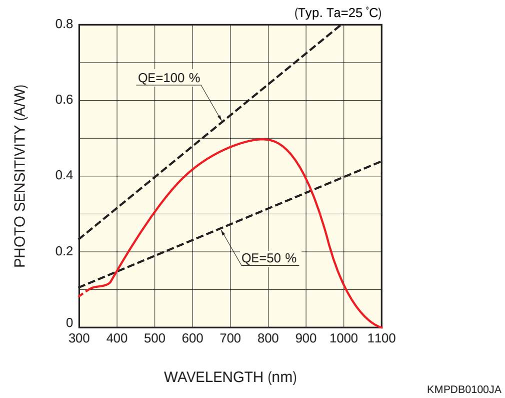
Type No.	Number of elements	Active area size (mm)	Photo sensitivity λ=λp (A/W)	Cut-off frequency VR=5 V, RL=50 W l=690 nm (MHz)	Terminal capacitance VR=5 V, f=1 MHz (pF)	Package	Photo
S7585	5 × 5	1.3 × 1.3	0.5	170	10	Ceramic	
S3805	16 × 16	1.3 × 1.3		100	15	Glass epoxy	

Spectral response

S7585

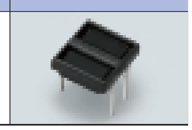


S3805

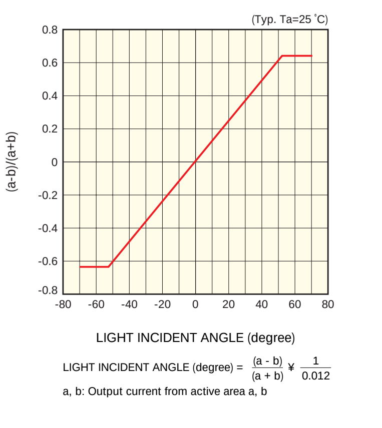


Incident light angle sensor

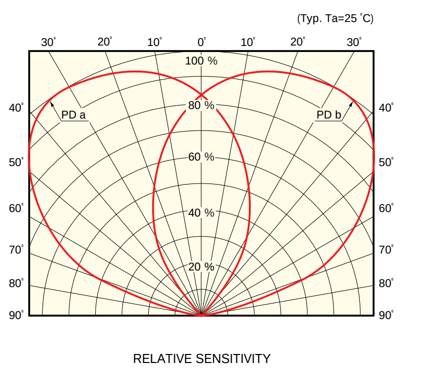
This sensor is designed to detect the incident light angle by processing the output current of 2-element Si PIN photodiode without using any lenses.

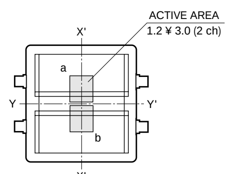
Type No.	Number of elements	Active area size (mm)	Photo sensitivity λ=λp (A/W)	Cut-off frequency VR=10 V (MHz)	Terminal capacitance VR=10 V, f=1 MHz 2 elements total (pF)	Package	Photo
S6560	2	1.2 × 3.0	0.58	25	10	Plastic	

Typical incident angle detection characteristic

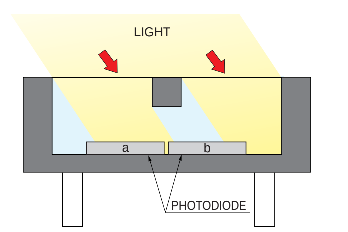


Directivity (along X-X')





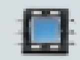
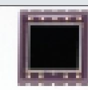
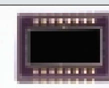
Principle figure



The intensity of light striking the right and left photodiodes varies depending on the incident angle of the light.
This incident angle of the light can be measured by the differential output between the two photodiodes.

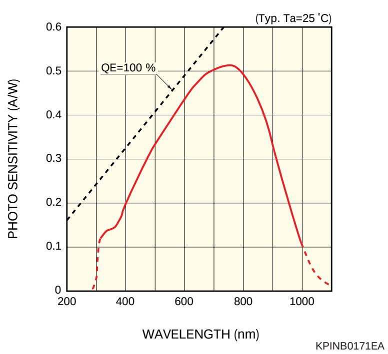
KPINC0015EA

High-speed response Si PIN photodiode

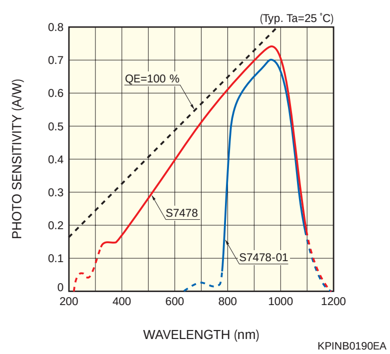
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Photo sensitivity λ=λp (A/W)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S6431	500 (VR=2.5 V)	ϕ0.8	0.48 (λ=660 nm) / 0.5 (λ=780 nm)	6 (VR=2.5 V)	Plastic	
S7481						
S8348	600 (VR=2.5 V)	ϕ0.6		3 (VR=2.5 V)		
S7482						
S7478	20 (VR=10 V)	5 × 5	0.72	40 (VR=10 V)	Plastic	
S7478-01	15 (VR=10 V)		0.7			
S5106	20 (VR=10 V)	5 × 5	0.72	40 (VR=10 V)	Ceramic	
S5107	10 (VR=10 V)	10 × 10		150 (VR=10 V)		
S7509	20 (VR=10 V)	2 × 10		40 (VR=10 V)		
S7510	15 (VR=10 V)	6 × 11		80 (VR=10 V)		

Spectral response

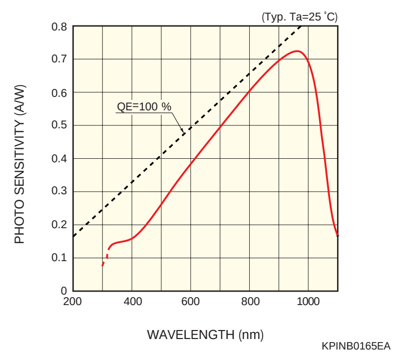
S6431, S7481, S8348, S7482



S7478 series

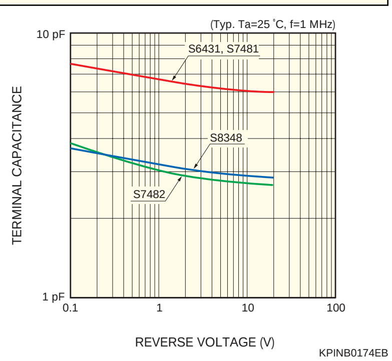


S5106, S5107, S7509, S7510

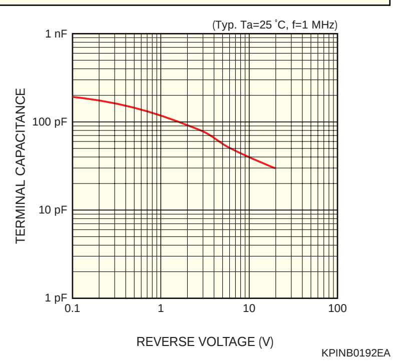


Terminal capacitance vs. reverse voltage

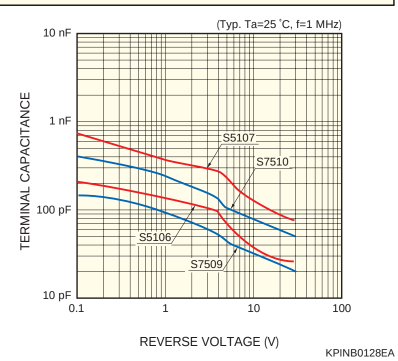
S6431, S7481, S8348, S7482



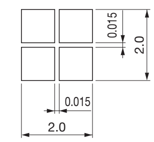
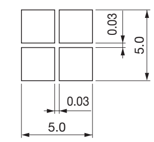
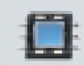
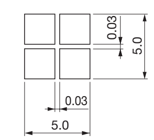
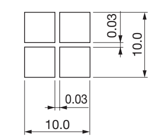
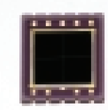
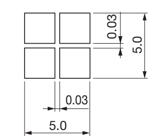
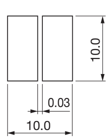
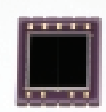
S7478 series



S5106, S5107, S7509, S7510

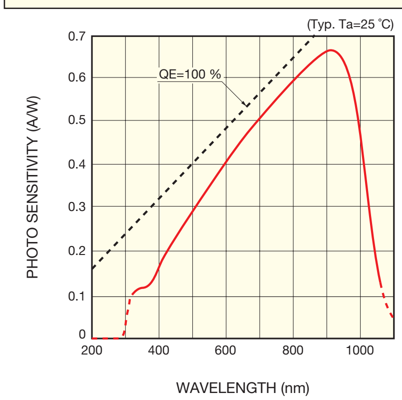


Segmented type photodiode

Type No.	Number of elements	Active area size (mm)		Photo sensitivity λ=λp (A/W)	Cut-off frequency VR=10 V, RL=50 Ω (MHz)	Terminal capacitance VR=10 V, f=1 MHz (pF)	Package	Photo
S6695-01	4	2 · 2		0.65	40 (VR=5 V)	3 (VR=5 V)	Plastic	
S7479		5 · 5		0.72	20	10		
S5980		5 · 5			25	10	Ceramic	
S5981		10 · 10			20	35		
S8594		5 · 5			25	10		
S5870	2	10 · 10			10	50		

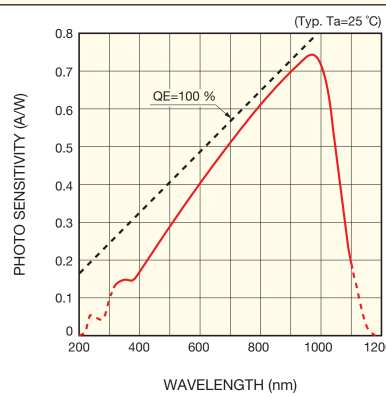
Spectral response

S6695-01



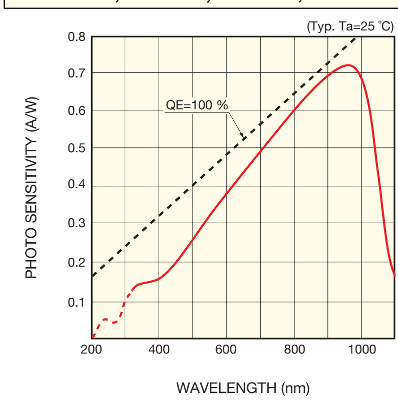
KMPDB0262EA

S7479



KMPDB0138EA

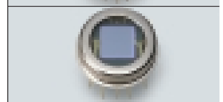
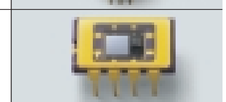
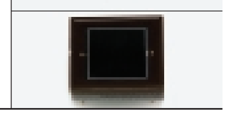
S5980, S5981, S8594, S5870



KMPDB0122EA

Si photodiode with preamp for measurement

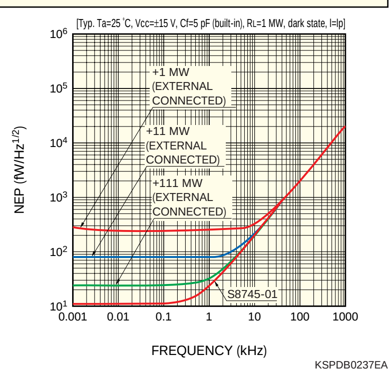
These are low noise photosensors incorporating a large area Si photodiode, op amp and feedback capacitance.

Type No.	Cooling temperature ΔT (˚C)	Active area size (mm)	Spectral response range (nm)	Photo sensitivity (V/nW)		NEP λ=λp, f=10 Hz (fW/Hz$^{1/2}$)	Built-in feedback resistance (GW)	Package	Photo
				λ=λp	λ=200 nm				
S8745-01	Non-cooled	2.4 × 2.4	190 to 1100	0.52	0.12	11	1	Metal	
S8746-01		5.8 × 5.8				15			
S9295	50	10 × 10	190 to 1100	5.1	0.9	4	10		
S9295-01	30					5			
S8785-02 *	50	ϕ15.6 (lens diameter)	320 to 1100	-6.5	–	2		Metal with lens	
S7998	Non-cooled	3 × 3	190 to 1100	0.43 A/W	0.12 A/W		–	Ceramic	
S9269		5.8 × 5.8	320 to 1100	0.62	–	12	1		
S9270		10 × 10				16			

* Inverting amplifier type

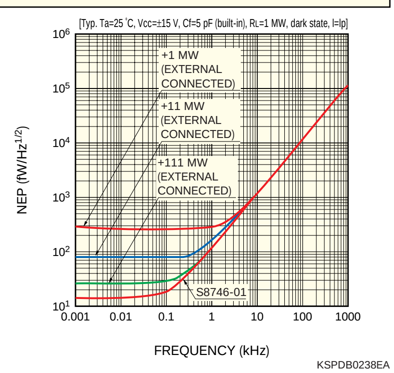
NEP (Noise Equivalent Power) vs. frequency

S8745-01



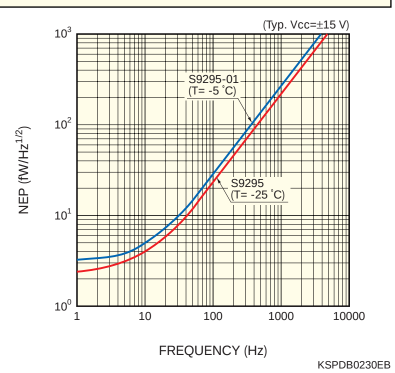
KSPDB0237EA

S8746-01



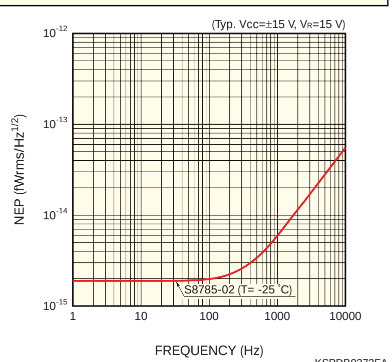
KSPDB0238EA

S9295 series



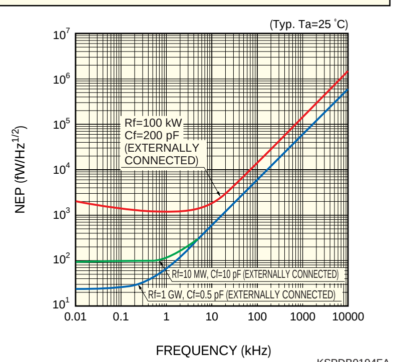
KSPDB0230EB

S8785-02



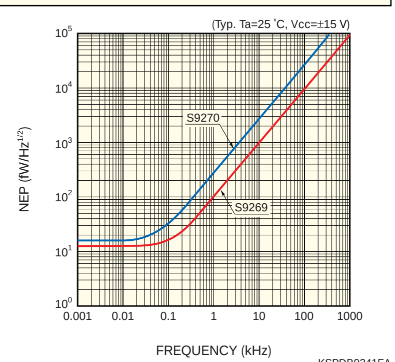
KSPDB0273EA

S7998



KSPDB0194EA

S9269, S9270



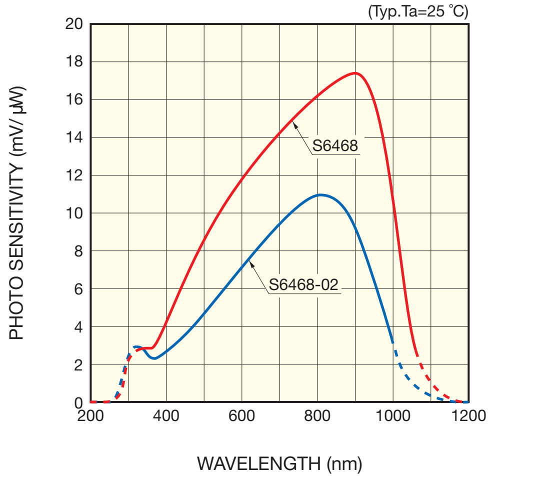
KSPDB0241EA

Si PIN photodiode with preamp for optical fiber communication

These high-speed photosensors consist of a Si PIN photodiode and a preamplifier chip integrated in the TO-18 metal package.

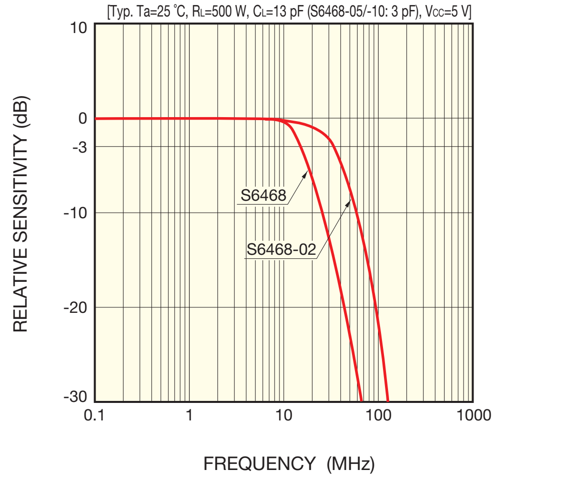
Type No.	Cut-off frequency (MHz)	Active area size (mm)	Spectral response range (nm)	Photo sensitivity (mV/μW) λ=660 nm	λ=780 nm	λ=830 nm	Maximum output voltage amplitude Min. (Vp-p)	Package	Photo
S6468	15	ϕ0.8	320 to 1060	13.5	15.5	16.5	0.5	TO-18	
S6468-02	35		320 to 1000	8.5	11	11			

Spectral response



KPINB0163EB

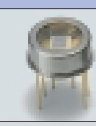
Frequency response



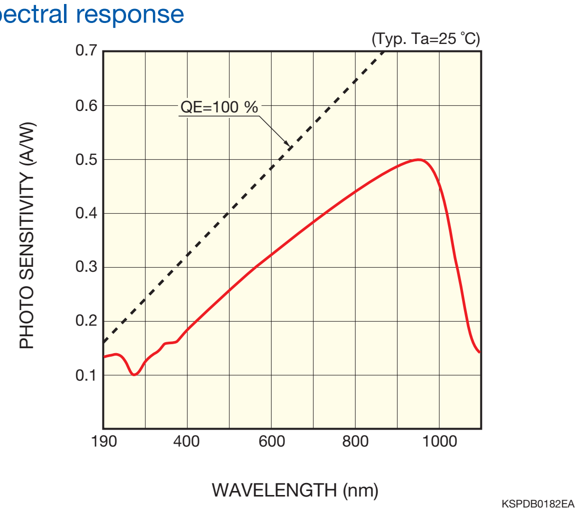
KPINB0126EB

TE-cooled type Si photodiode

These photosensors combine a UV to near infrared Si photodiode with a thermoelectric cooler, deliver low dark current.

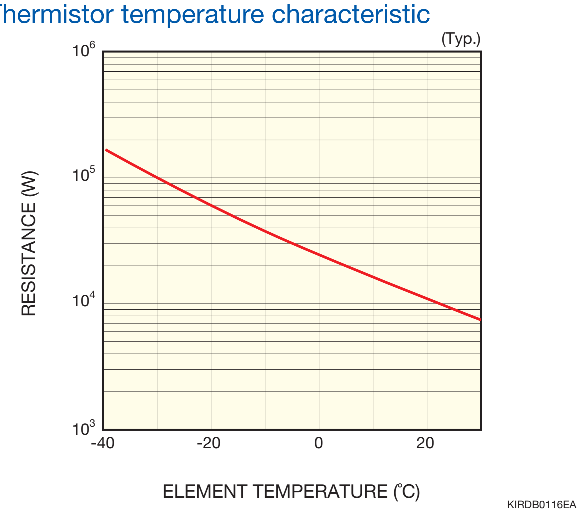
Type No.	Cooling temperature ΔT (˚C)	Active area size (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current VR=10 mV Max. (pA)	Noise equivalent power (W/Hz$^{1/2}$)	Package	Photo
S2592-03	35	2.4 × 2.4	190 to 1100	960	10	8.1×10^{-15}	TO-8	
S2592-04		5.8 × 5.8			25			
S3477-03		2.4 × 2.4			10	1.3×10^{-14}	TO-66	
S3477-04		5.8 × 5.8			25			

Spectral response



KSPDB0182EA

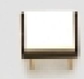
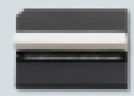
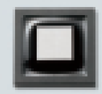
Thermistor temperature characteristic



KIRDB0116EA

Si photodiode with scintillator

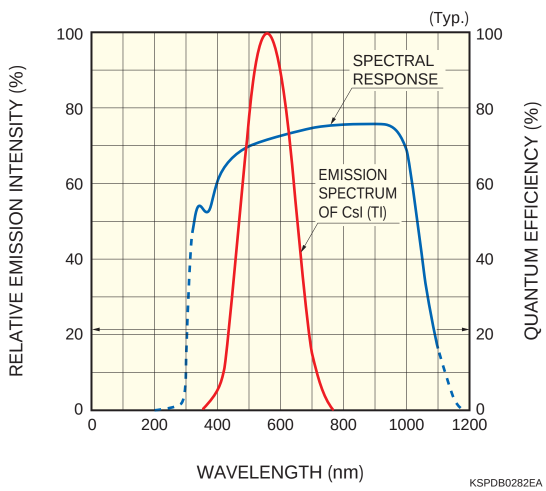
These detectors are comprised of a Si photodiode coupled to a scintillator (ceramic or CsI). Ceramic scintillators have sensitivity to X-rays about 1.8 times higher than CWO and offer high reliability. CsI scintillators also have high sensitivity and are less expensive.

Type No.	Scintillator	Active area size (mm)	Number of elements	Dark current Max. (pA)	X-ray sensitivity * (nA)	Package	Photo
S8559	CsI (Tl)	5.8 × 5.8	1	50	60	Ceramic	
S8193	Ceramic				27		
S5668-11	CsI (Tl)	1.175 × 2.0	16	10	6.0	Glass epoxy	
S5668-34	Ceramic			30	3.1		
S7878	Ceramic	1.3 × 1.3	5 ¥ 5	10	1.2		
S7978		1.28 × 1.28			2.1		

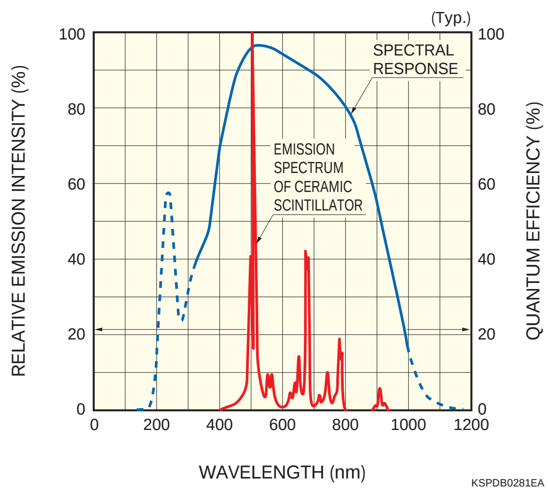
* These are for reference (X-ray tube voltage 120 kV, tube current 1.0 mA, aluminum filter t=6 mm, distance 830 mm), X-ray sensitivity depends on the X-ray equipment operating and setup conditions.

Emission spectrum of scintillator and spectral response

S5668-11



S5668-34

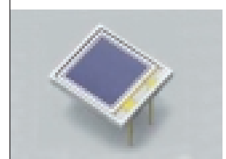


Typical scintillator characteristics

Parameter	Condition	CsI (Tl)	Ceramic scintillator	CWO	Unit
Peak emission wavelength		560	520	540	nm
X-ray absorption coefficient	100 keV	10	7	7.7	-
Refractive index	at peak emission wavelength	1.74	2.2	2.2	-
Decay constant		1	3	5	µs
Afterglow	100 ms after X-ray turn off	0.3	0.01	0.02	%
Density		4.51	7.34	7.9	g/cm^3
Relative emission intensity	CWO=1.0	1.8	1.8	1.0	-
Color		Transparent	Light yellow-green	Transparent	-
Sensitivity non-uniformity		±10	±5	±15	%

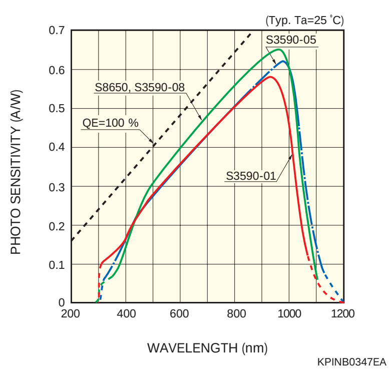
Large active area Si PIN photodiode

These Si PIN photodiodes, mounted on a white ceramic base, are specifically developed for applications in high energy physics and are mainly used being coupled to a scintillator. Because of high resistance to breakdown voltages, these Si PIN photodiodes operate at high reverse voltages allowing a high-speed response despite the large active areas. S3590-18/19 are violet sensitivity enhanced type and S3590-19 is a bare chip type. To improve photodiode-to-scintillator coupling efficiency, we also offer S8650 with epoxy coating windows processed to have a flat surface (flatness: ±5 µm)

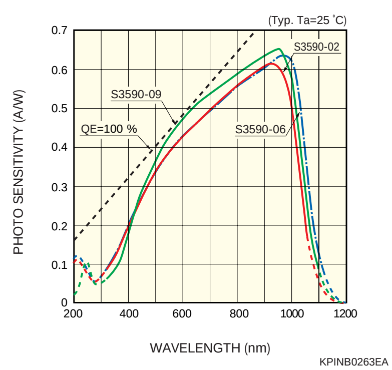
Type No.	Window	Active area size (mm)	Wafer thickness (mm)	Dark current Max. (nA)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S3590-01	Epoxy resin	10 × 10	0.2	5 (V_R=30 V)	75 (V_R=30 V)	Ceramic	
S3590-02	Windowless						
S3590-05	Epoxy resin	9 × 9	0.5	30 (V_R=100 V)	25 (V_R=100 V)		
S3590-06	Windowless						
S3590-08	Epoxy resin	10 × 10	0.3	6 (V_R=70 V)	40 (V_R=70 V)		
S3590-09	Windowless						
S3590-18			0.3	10 (V_R=70 V)			
S3590-19							
S8650	Epoxy resin			6 (V_R=70 V)			

Spectral response

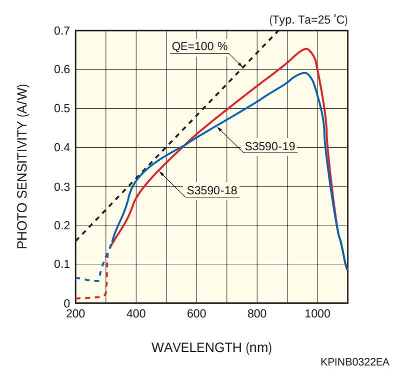
S3590-01/05/08



S3590-02/06/09

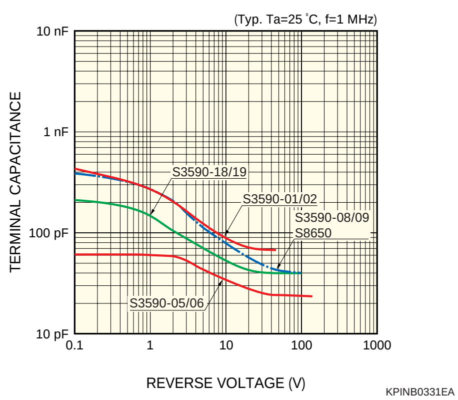


S3590-18/19

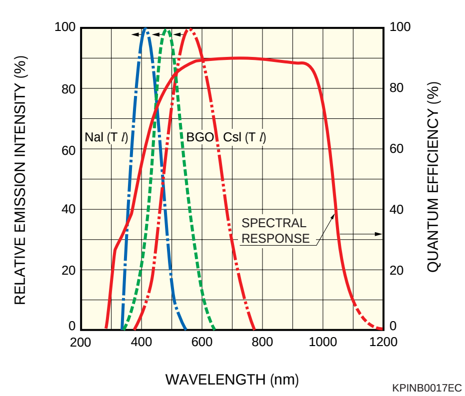


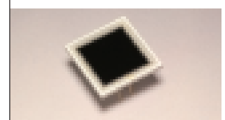
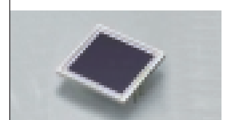
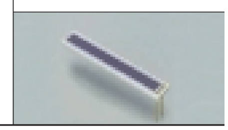
Terminal capacitance vs. reverse voltage

S3590 series, S8650



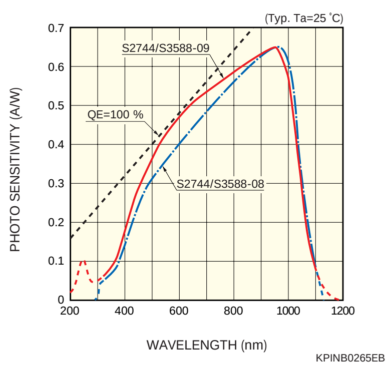
Emission spectrum of scintillators and spectral response (S3590-08)



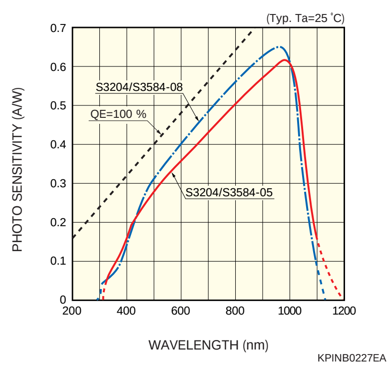
Type No.	Window	Active area size (mm)	Wafer thickness (mm)	Dark current Max. (nA)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S2744-08	Epoxy resin	10 × 20	0.3	10 (VR=70 V)	85 (VR=70 V)	Ceramic	
S2744-09	Windowless						
S3204-05	Epoxy resin	18 × 18	0.5	50 (VR=100 V)	80 (VR=100 V)		
S3204-06	Windowless						
S3204-08	Epoxy resin	18 × 18	0.3	20 (VR=70 V)	130 (VR=70 V)		
S3204-09	Windowless						
S3584-05	Epoxy resin	28 × 28	0.5	100 (VR=100 V)	200 (VR=100 V)		
S3584-06	Windowless						
S3584-08	Epoxy resin	28 × 28	0.3	30 (VR=70 V)	300 (VR=70 V)		
S3584-09	Windowless						
S3588-08	Epoxy resin	3 × 30		10 (VR=70 V)	40 (VR=70 V)		
S3588-09	Windowless						

Spectral response

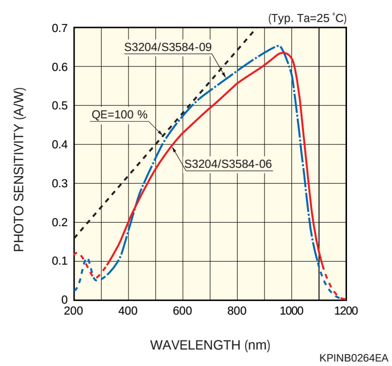
S2744/S3588 series



S3204-05/08, S3584-05/08

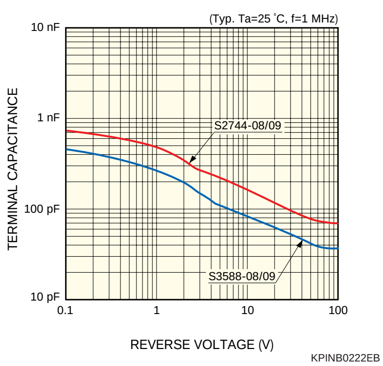


S3204-06/09, S3584-06/09

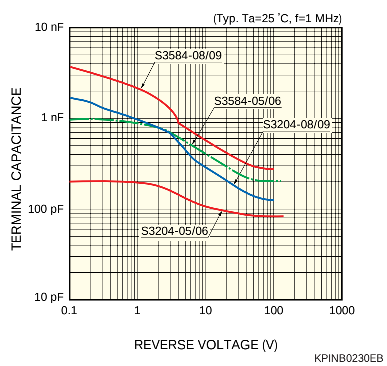


Terminal capacitance vs. reverse voltage

S2744/S3588 series

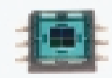


S3204/S3584 series

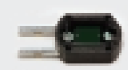
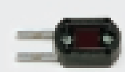


RGB color sensor

These photosensors are color sensors using a 3-element (or 2-element) photodiode with color sensitivity, assembled in one package.

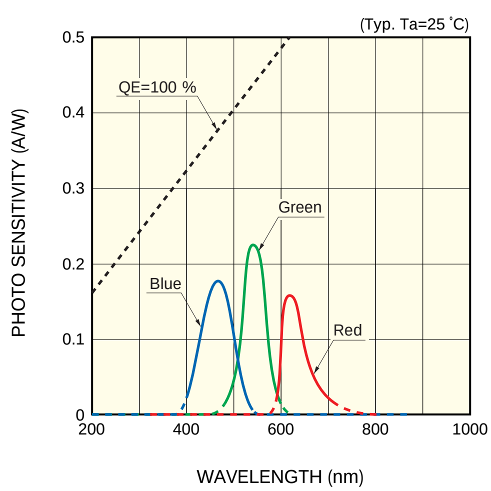
Type No.	Spectral response range (nm)		Peak sensitivity wavelength (nm)	Photo sensitivity λ=λp (A/W)		Dark current V_R=1 V All elements total Max. (pA)	Active area size (mm)		Package	Photo
S7505-01	Blue	400 to 540	460	Blue	0.18	200	Blue	1.5 × 1.5 (× 2)	Surface mount type plastic	
	Green	480 to 600	540	Green	0.23		Green	1.5 × 1.5		
	Red	590 to 720	620	Red	0.16		Red	1.5 × 1.5		
S9032-02	Blue	400 to 540	460	Blue	0.18	100	ϕ2/3 elements		Surface mount type plastic	
	Green	480 to 600	540	Green	0.23					
	Red	590 to 720	620	Red	0.16					
NEW S9702	Blue	400 to 540	460	Blue	0.18	50	1 × 1/3 elements		Surface mount type, small plastic	
	Green	480 to 600	540	Green	0.23					
	Red	590 to 720	620	Red	0.16					
	When compared to the conventional type (S9032-02), S9702 is significantly miniaturized (package size 55 % less in cubic volume, board mount space 43 % less in area).									
S8751	Blue	400 to 540	460	Blue	0.21	100	1 ¥ 1		Surface mount type plastic	
	Green	480 to 600	540	Green	0.25					
	Red	590 to 720	660	Red	0.42					
S8752	Blue	400 to 540	460	Blue	0.21		1 ¥ 1		Plastic	
	Red	590 to 720	660	Red	0.42					

S6428-01, S6429-01 and S6430-01 are monochromatic color sensors sensitive to blue, green and red light, respectively.

Type No.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photo sensitivity λ=λp (A/W)	Dark current V_R=1 V Max. (pA)	Active area size (mm)	Package	Photo
S6428-01	400 to 540	460	0.22	20	2.4 × 2.8	Plastic	
S6429-01	480 to 600	540	0.27				
S6430-01	590 to 720	660	0.45				

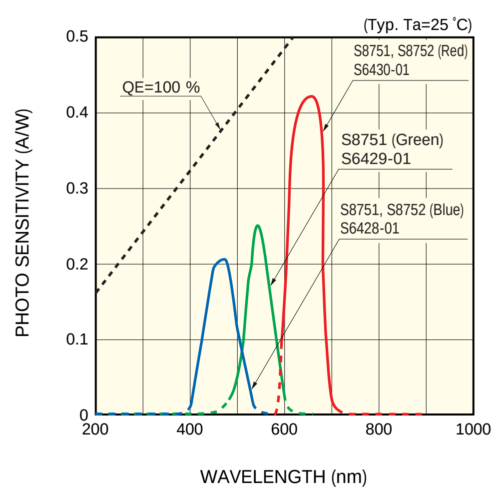
Spectral response

S7505-01, S9032-02, S9702



KMPDB0217EB

S8751, S8752, S6428-01, S6429-01, S6430-01



KSPDB0280EA

Blue sensitivity enhanced type

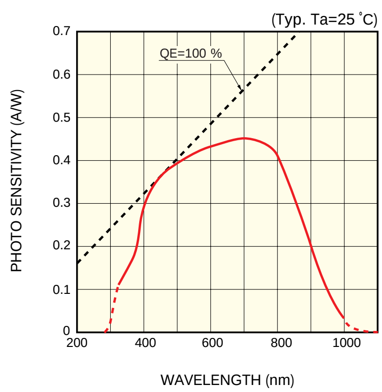
These are photodiodes for blue laser diode detection.

Type No.	Cut-off frequency (MHz)	Active area size (mm)	Peak sensitivity wavelength (nm)	Photo sensitivity (A/W)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S5973-02	1.2 GHz (V_R=3.3 V)	ϕ0.4	760	0.3 (λ=405 nm)	1.6 (V_R=3.3 V)	TO-18	
S9687	500 (V_R=2.5 V)	ϕ0.8		0.3 (λ=405 nm)	6 (V_R=2.5 V)	Surface mount type small ceramic	
S9868 *1	450 *2 (V_R=2.5 V) 300 *3 (V_R=2.5 V)	ϕ0.8	720	0.3 (λ=405 nm) 0.4 (λ=650, 780 nm)	5 (V_R=2.5 V)		
S8284	500 (V_R=3 V)	0.6 × 1.2 (4-segmented)		0.3 (λ=405 nm)	2 (V_R=3 V)	TO-18	
S9195	50 (V_R=10 V)	5 × 5	960	0.28 (λ=405 nm)	60 (V_R=10 V)	TO-8	
S3994-01	20 (V_R=30 V)	10 × 10		0.28 (λ=405 nm)	40 (V_R=30 V)	Ceramic	

*1: Designed for improved falling waveform in response to 780 nm light *2: λ=405 nm, 650 nm *3: λ=780 nm

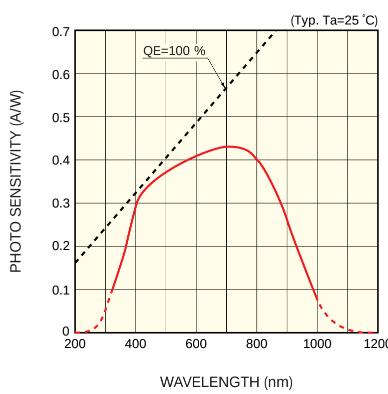
Spectral response

S5973-02



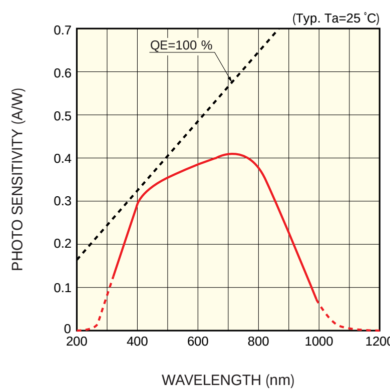
KPINB0337EA

S9687



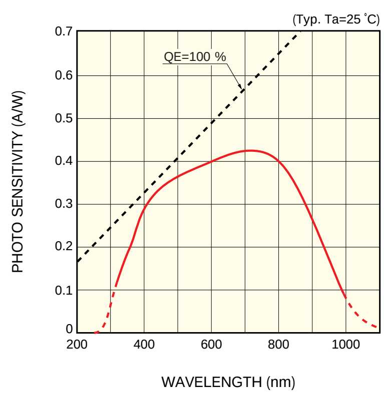
KPINB0285EC

S9868



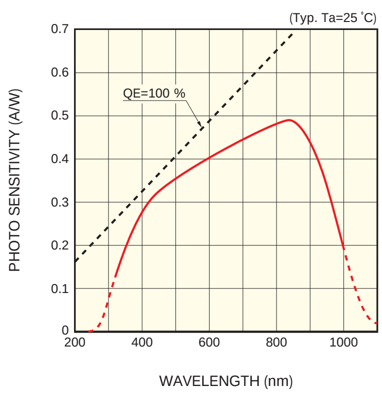
KPINB0307EB

S8284



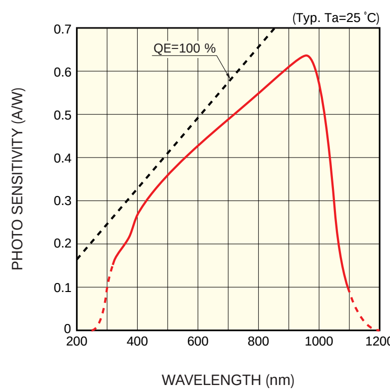
KPINB0195EB

S9195



KPINB0289EA

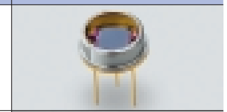
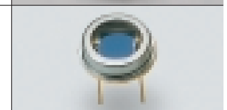
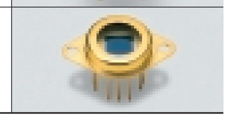
S3994-01



KPINB0198EA

For VUV (vacuum ultraviolet) detection

These Si photodiodes are specially optimized for excimer laser detection (ArF: 193 nm, KrF: 248 nm): sensitive in the vacuum UV (VUV) range.

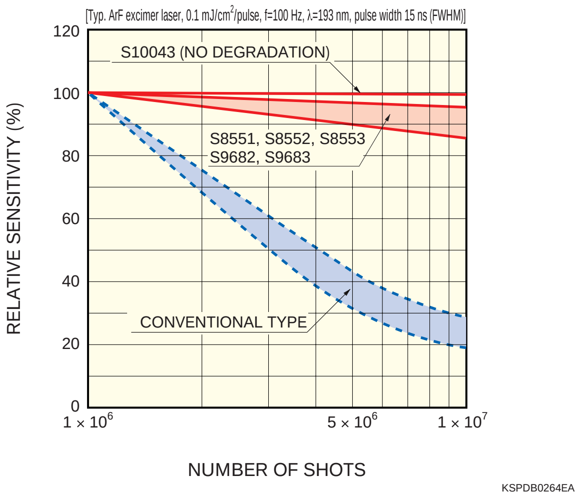
Type No.	Photo sensitivity λ=193 nm (A/W)	Dark current VR=10 mV Max. (nA)	Active area size (mm)	Package	Photo
S8551	0.06	0.5	5.8 × 5.8	TO-8 (Windowless)	
S8552		1.0	10 × 10	Ceramic (Windowless)	
S8553		5.0	18 × 18		
S9682	0.06	0.5	5.8 × 5.8	TO-8	
S9683		1.0	10 × 10	1-inch metal	

High reliability type

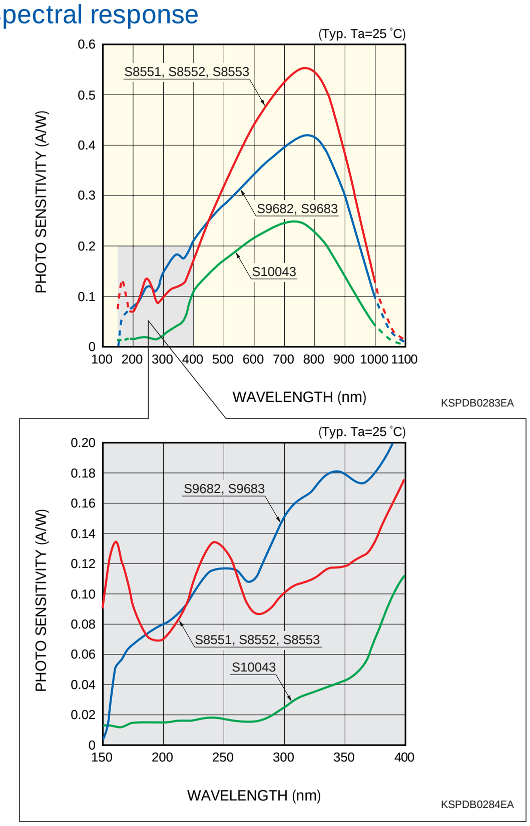
S10043 is greatly improved in sensitivity stability even after exposure to ArF (λ=193 nm) excimer laser.

Type No.	Photo sensitivity λ=193 nm (A/W)	Dark current VR=10 mV Max. (nA)	Active area size (mm)	Package	Photo
NEW S10043	0.015	1.0	10 × 10	Ceramic (Windowless)	

Variation in sensitivity due to UV exposure

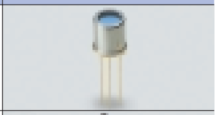
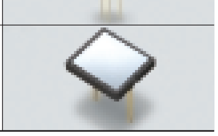


Spectral response



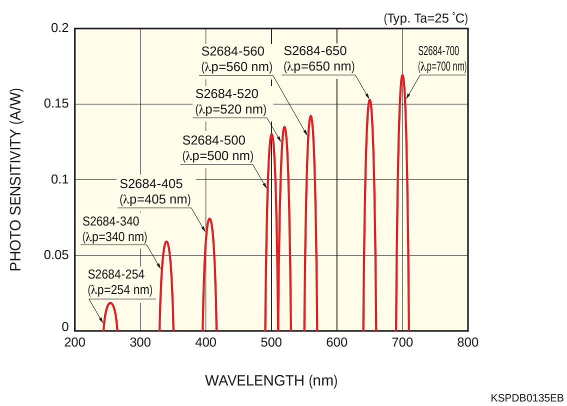
For monochromatic light detection

These photosensors use an interference filter and have high sensitivity only to monochromatic light.

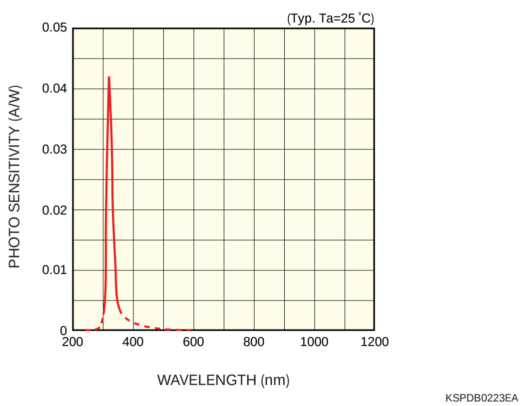
Type No.	Peak sensitivity wavelength (nm)	Spectral response half-width (nm)	Photo sensitivity (A/W)	Dark current VR=10 mV Max. (pA)	Active area size (mm)	Package	Photo
S2684-254	254	10	0.02 (λ=254 nm)	25	3.6 × 3.6	TO-5	
S9050	322	20	0.04 (λ=322 nm)	100	5.83 × 5.83	Ceramic	

Spectral response

S2684-254, etc.



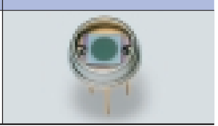
S9050



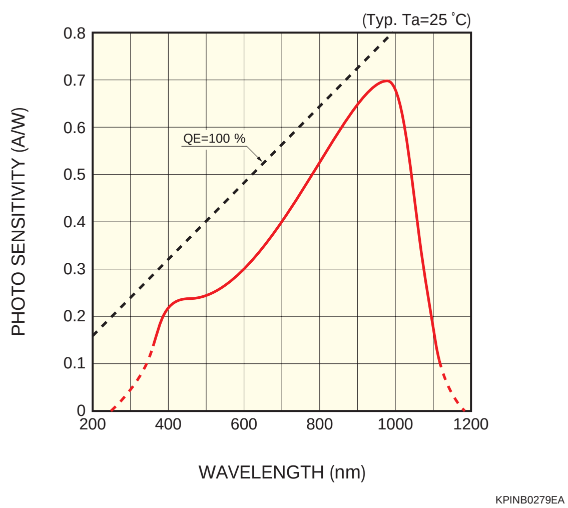
Note) Made to order other than S2684-254.

For YAG laser detection

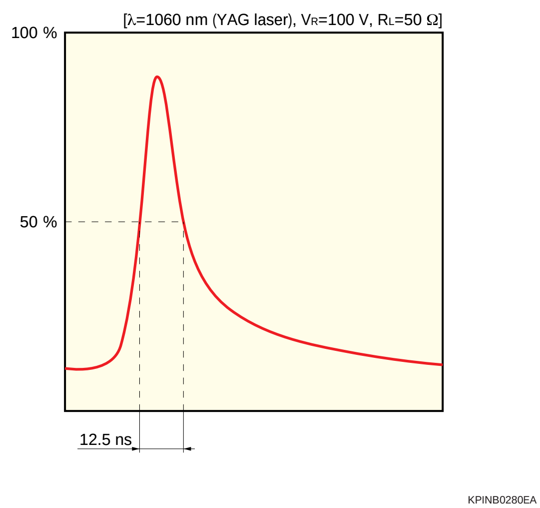
S3759 is a Si PIN photodiode developed to measure infrared energy emitted from YAG lasers (1.06 µm).

Type No.	Active area size (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photo sensitivity λ=1.06 µm (A/W)	Dark current VR=100 V Max. (nA)	Rise time λ=1.06 µm VR=100 V, RL=50 Ω (ns)	Package	Photo
S3759	ϕ0.5	360 to 1120	980	0.38	10	12.5	TO-8	

Spectral response



Response waveform

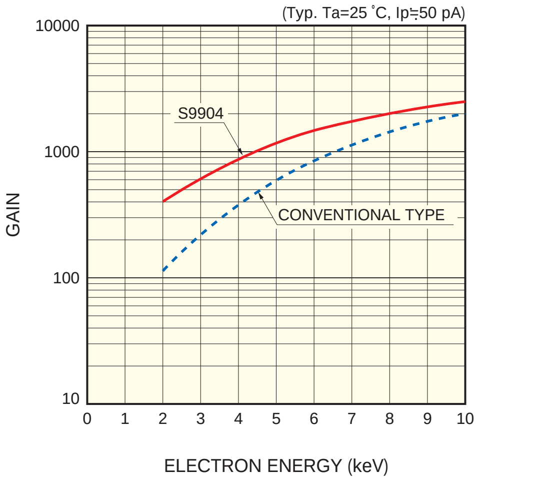


For electron beam detector

This photodiode directly detects low energy (10 keV or less) electron beams with high sensitivity. The structure with an extremely thin dead layer (insensitive layer) makes this photodiode ideal for backscattered electron detector for Scanning Electron Microscope (SEM).

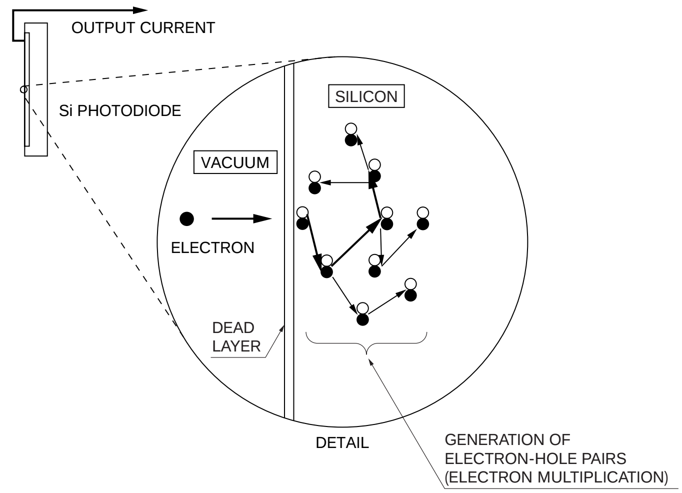
Type No.	Incident electron energy range (keV)	Output current (nA)	Dark current Max. V_R=5 V (nA)	Terminal capacitance V_R=5 V (pF)	Cut-off frequency V_R=5 V (MHz)	Electron multiplying gain	Package	Photo
NEW S9904	2 to 10	60 (Electron energy: 5 keV)	10	400	4	1200 (Electron energy: 5 keV)	Thin ceramic package	

Gain vs. electron energy



KSPDB0259EA

Electron multiplication principle

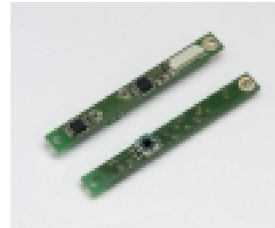


Electrons generate ions as they pass through silicon. This ionization process generates a large number of electron-hole pairs that then multiply the number of electrons.
The electron multiplication can boost the output current by approximately 1200 times at an input electron energy of 5 keV (Refer to "Gain vs. electron energy").

KSPDC0064EA

RGB color sensor module

For TFT-LCD monitor



RGB-LED backlight monitor for TFT-LCD (Liquid Crystal Display)

Features

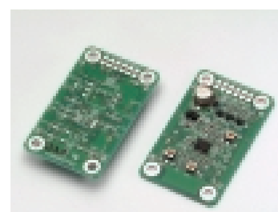
- Built-in RGB color sensor (S9032-02)
  Sensitivity matches wavelengths of RGB-LED backlight for TFT-LCD.
- 3 ch current-to-voltage amplifiers
  Simultaneous output of 3 ch RGB photocurrent
- Configuration and size suitable for side mounting to TFT-LCD
- Suitable for lead-free solder
- Low current consumption: 0.4 mA Typ.
  (1/3 than the conventional type)
- High gain type (C9303-04)

Applications

- RGB-LED backlight monitor for TFT-LCD

Type No.	Photo sensitivity (V/mW)			Cut-off frequency (kHz)
	λp=620 nm	λp=540 nm	λp=460 nm	
C9303-03	-14	-20	-18	16
C9303-04	-108	-156	-122	2.4

Color sensor evaluation circuit


C9331

Color sensor evaluation circuit board

Features

- 3 ch current-to-voltage conversion amplifier for color sensor evaluation
- Color sensors that mount on C9331:
  S7505-01, S9032-02, S8751 (sold separately)

Applications

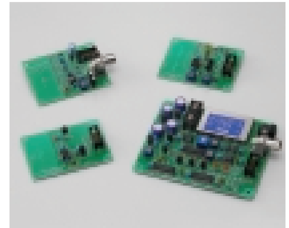
- Evaluation of Hamamatsu color sensor

Type No.	Symbol	Condition	Min.	Typ.	Max.	Unit
Output offset voltage	Vos	Zt=5.1 × 10^5 V/A Without photodiode	-	±40	±50	mV
Trans-impedance adjustment range	Zt		-	1 ¥ 10^5 to 5.1 ¥ 10^5	-	V/A
Amplifier bandwidth	B	Without photodiode	-	DC to 14	-	kHz

(Ta=25 ˚C, Vcc=9.0 V, common to each RGB channel)

Circuit for Si photodiode

Evaluation circuit for Si photodiode



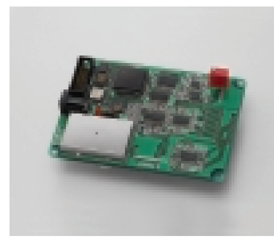
Easy-to-use circuit for Si photodiode operation

Features

- Allows easy evaluation of standard Si photodiodes
- On-board circuit examples for typical applications of Si photodiodes
- Multiple circuits assembled on one board
- Support board (C9052-04) for processing output signals from head board (C9052-01/02/03)

Type No.	Feature
C9052-01	Low noise AC amplifier circuit, photocurrent-to-voltage conversion circuit and wide band amplifier circuit on one board
C9052-02	Light balance detection circuit, light-to-logarithmic voltage conversion circuit and light integration circuit on one board
C9052-03	Two types of light-to-frequency conversion circuits assembled on one board
C9052-04	Power supply circuit for driving C9052-01/-02/-03 and output processing circuit assembled together.

Driver circuit for Si photodiode array



Driver circuit for 16-element photodiode array

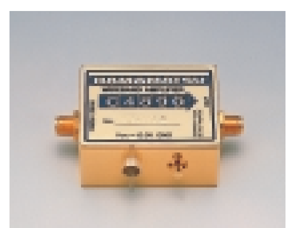
Features

- High precision and high-speed measurement by simultaneous 16-channel readout
- Assembled with pulse generator (8-step adjustable oscillatory frequency) CLK, START, A/D conversion Trig and EOS pulse output
- Choice of gain (conversion impedance): 1 ¥ 10^{6} or 1 ¥ 10^{7} (V/A)
- Single power supply operation: +12 V

Type No.	Suitable sensor
C9004	HAMAMATSU S4111-16 series, S5668 series photodiode arrays are directly mountable on board.

PIN photodiode amplifier (wide band)

Wide bandwidth, high gain, flat gain spectrum



C4890 wide-band amplifier, when connected to a high-speed PIN photodiode (S5971, S5972, S5973, etc.) converts optical signals at a maximum of 1.5 GHz into voltage outputs with exceptionally low distortion and 20 dB gain. C4890 can also be combined with other types of PIN photodiodes and APDs (avalanche photodiodes) to serve as a high-frequency amplifier for optical measurements in a wide range of fields including industry and research applications.

(Vcc=12 V, Input/output is terminated within 50 Ω load)

Type No.	Cut-off frequency -3 dB		Gain f=1 GHz	Gain deviation within bandwidth f=10 MHz to 1 GHz	Group delay time	VSWR		1 dB compression point	Rise time
	Low band (MHz)	High band (GHz)	(dB)	(dB)	(ps)	Input	Output	(dBm)	(ps)
C4890	5.0	1.5	20	±1.0	700	1.1	1.5	7	240

Photosensor amplifier

For low-light-level detection

Digital output function, current-to-voltage conversion amplifier for amplifying very slight photocurrent with low noise

Photodiode, coaxial cable with BNC-BNC plug and RS-232C cable is optional.

Features

- Three sensitivity ranges
- Selectable operation modes (analog output / digital output)
- Serial connection (RS-232C) with PC
- Data logger function, low battery function
- Operates on either dry battery or AC adapter

Type No.	Range	Conversion impedance (V/A)	Frequency bandwidth	Dimension (mm)
C9329	H	10^9	DC to 16 Hz	115 (W) × 40 (H) × 90 (D)
	M	10^7	DC to 1600 Hz	
	L	10^5	DC to 1600 Hz	

With optical fiber

Light-to-voltage conversion amplifier with optical fiber

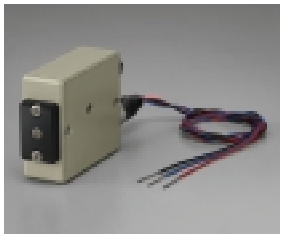
Features

- Easy handling
  Built-in photodiode allows easy detection of light just by connecting to a voltmeter.
- Optical fiber light input
  Measures light at a narrow detection point. Separating the amplifier from the detection point allows measurement in unusual environments and achieves low noise.
- Three sensitivity ranges

Type No.	Range	Photo sensitivity (mV/μW)	Conversion impedance (V/A)	Frequency bandwidth	Dimension (mm)
C6386-01	H	30	10^5	DC to 1 MHz	114 (W) × 39 (H) × 90 (D)
	M	3	10^4	DC to 3 MHz	
	L	0.3	10^3	DC to 10 MHz	

High-speed type

Current-to-voltage conversion amplifier for high-speed Si PIN photodiode



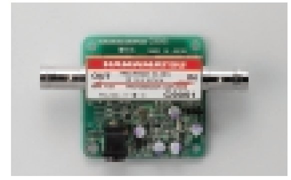
Features

- Wide bandwidth
  DC to 100 MHz Typ. (-3 dB; varied by the photodiode used)
- Easy photodiode connection
  Just inserting the photodiode lead pins makes the connection.
  (Compatible with TO-8, TO-5 and TO-18 packages)
- Adjustable response speed
  Response speed can be adjusted by a trimmer potentiometer easily
- Compact size

Type No.	Conversion impedance (V/A)	Frequency bandwidth	Dimension (mm)
C8366	10^3	DC to 100 MHz	20 (W) × 46 (H) × 52 (D)

Compact type

Current-to-voltage conversion amp



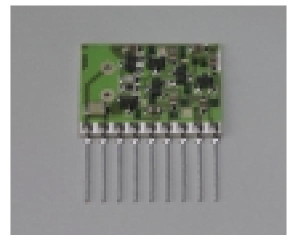
Features

- Compact type for easy assembly
- Usable with photodiodes having large terminal capacitance
- Conversion impedance: 1.0 ¥ 10^8 V/A
- Single +12 V supply voltage operation

Type No.	Conversion impedance (V/A)	Frequency bandwidth	Dimension (mm)
C9051	10^8	DC to 16 Hz	50 (W) · 50 (H) · 19 (D)

Charge amplifier

For radiation and high energy particle detection



H4083 is a low-noise hybrid charge amplifier designed for a wide range of spectrometric applications including soft X-ray and low to high energy gamma-ray spectrometry. The first stage of this amplifier uses a low-noise junction type FET, which exhibits excellent performance when used with a photodiode having a large junction capacitance. H4083 is especially suited for use with HAMAMATSU S3590/S3204 series, etc. Si PIN photodiodes. S3590 series photodiodes can be directly mounted on the backside of H4083, so there will be no increase in stray capaci-

Features

- Low noise
- Compact and lightweight
- Easy handling

Applications

- Detection of X-rays, radiation, high energy particles

Type No.	Amplification method	Input/ output polarity	Charge gain	Noise characteristic (e^-/FWHM)	Negative feedback constant	Power supply (V)	Current consumption (mW)	Dimension (mm)
H4083	Charge-sensitive type	Inverted	0.5 V/pC 22 mV/MeV (Si)	550	50 MΩ//2 pF	±12	150	24 (W) · 19 (H) · 4 (T)

16 · 16 element photodiode array detector

2-D detector using 256-element photodiode with visible sensitivity

C4675 series is a two-dimensional detector using a 16 · 16 (256) element Si PIN photodiode array that has high sensitivity in the visible range. Current-to-voltage conversion amplifiers in the signal amplifier section are connected in parallel to each element of the photodiode array, thereby allowing high-speed parallel signal processing.
C4675 series is also designed to suppress the power consumption so it operates from two power supplies (±15 V).

Features

- Spectral response range: 400 to 1000 nm
- Wide active area: 17.45 · 17.45 mm
  (0.95 ¥ 0.95 mm per element, 1.1 mm pitch)
- Frequency response C4675-102: DC to 1 kHz
  C4675-302: DC to 3 kHz
  C4675-103: DC to 10 kHz
- Parallel signal output by current-to-voltage amplifier
- Low power consumption: 2.5 W Typ.

Applications

- Nerve potential measurement under microscope
- 2-D (wavelength ¥ spatial position) spectrophotometry in visible range
- Fine-modulation light measurement

Type No.	Spectral response range (nm)	Output uniformity (%)	Amp gain (V/A)	Frequency response (Hz)	Supply voltage (V)	Power consumption (W)
C4675-102			10^8	DC to 1 k		
C4675-302	400 to 1000	±15	5 · 10^7	DC to 3 k	±15	2.5
C4675-103			10^7	DC to 10 k		

1. Spectral response

The photocurrent produced by a given level of incident light varies with the wavelength. This relation between the photoelectric sensitivity and wavelength is referred to as the spectral response characteristic and is expressed in terms of photo sensitivity, quantum efficiency, etc.

2. Photo sensitivity: S

This measure of sensitivity is the ratio of incident light expressed in watts (W) on the device, to the resulting photocurrent expressed in amperes (A). It may be represented as either an absolute sensitivity (A/W) or as a relative sensitivity normalized for the sensitivity at the peak wavelength, usually expressed in percent (%) with respect to the peak value. At HAMAMATSU, we usually use absolute sensitivity to express photo sensitivity, and the spectral response range is defined as the region in which the relative sensitivity is higher than 5 % of the peak value.

3. Quantum efficiency: QE

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

$$QE = \frac{S \times 1240}{\lambda} \times 100 \, [\%]$$

where S is the photo sensitivity in A/W at a given wavelength and λ is the wavelength in nm (nanometers).

4. Short circuit current: Isc

The short circuit current is the output current which flows when the load resistance is 0 and is nearly proportional to the device active area. This is often called "white light sensitivity" with regards to the spectral response. This value is measured with light from a tungsten lamp of 2856 K distribution temperature (color temperature), providing 100 lx illuminance.

5. Open circuit voltage: Voc

The open circuit voltage is a photovoltaic voltage generated when the load resistance is infinite and exhibits a nearly constant value independent of the device active area.

6. Infrared sensitivity ratio

This ratio is measured using a light flux of 100 lx emitted from a 2856 K light source, and is defined as the ratio of the output current I_R measured when the light flux is passed through an R-70 (t=2.5 mm) infrared filter to the short circuit current Isc measured without using the infrared filter. It is commonly expressed in percent, as follows:

$$\text{Infrared sensitivity ratio} = \frac{I_R}{Isc} \times 100 \, [\%]$$

7. Dark current: I_D

The dark current is a small current which flows when a reverse voltage is applied to a photodiode even in dark state. This is a major source of noise for cases in which a reverse voltage is applied to photodiodes (PIN photodiode, etc.).

8. Shunt resistance: Rsh

This shunt resistance is the voltage-to-current ratio in the vicinity of 0 V in photodiodes and defined as follows:
Where I_D is the dark current at V_R=10 mV.

$$Rsh \, [\Omega] = \frac{10 \, [mV]}{I_D \, [A]}$$

For applications where no reverse voltage is applied, noise resulting from the shunt resistance becomes predominant.

9. Terminal capacitance: Ct

An effective capacitor is formed at the PN junction of a photodiode. Its capacitance is termed the junction capacitance and is one of parameters that determine the response speed of the photodiode. And it probably causes a phenomenon of gain peaking in I-V conversion circuit using operational amplifier. In HAMAMATSU, the terminal capacitance including this junction capacitance plus package stray capacitance is

10. Rise time: tr

This is the measure of the time response of a photodiode to a stepped light input, and is defined as the time required for the output to change from 10 % to 90 % of the maximum light level (steady output level). The rise time depends on the incident light wavelength and load resistance. For the purpose of data sheets, it is measured with a light source of GaAsP LED (655 nm) or GaP LED (560 nm) and load resistance of 1 kΩ.

11. Cut-off frequency: fc

This is the measure used to evaluate the time response of high-speed PIN photodiodes to a sinewave-modulated light input. It is defined as the frequency at which the photodiode output decreases by 3 dB from the output at 100 kHz. The light source used is a laser diode (830 nm) and the load resistance is 50 Ω. The rise time tr has a relation with the cut-off frequency fc as follows:

$$tr \, [s] = \frac{0.35}{fc \, [Hz]}$$

12. NEP (Noise Equivalent Power)

The NEP is the amount of light equivalent to the noise level of a device. It is the light level required to obtain a signal-to-noise ratio of unity. Our data sheets show the NEP values measured at the peak wavelength λp. Since the noise level is proportional to the square root of the frequency bandwidth, the NEP is measured at a bandwidth of 1 Hz.

$$NEP \, [W/Hz^{1/2}] = \frac{\text{Noise current } [A/Hz^{1/2}]}{\text{Photo sensitivity } [A/W] \text{ at } \lambda p}$$

13. Maximum reverse voltage: V_R Max.

Applying a reverse voltage to a photodiode triggers a breakdown at a certain voltage and causes severe deterioration of the device performance. Therefore the absolute maximum rating is specified for reverse voltage at the voltage somewhat lower than this breakdown voltage. The reverse voltage shall not exceed the maximum rating, even instanta-

Reference

● Physical constant for light and opto-semiconductors

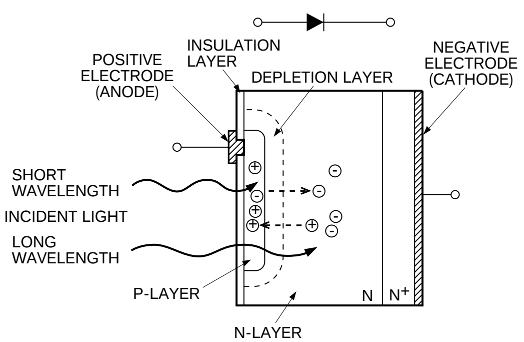
Constant	Symbol	Value	Unit
Electron charge	e or q	1.602×10^{-19}	c
Speed of light in vacuum	c	2.998×10^{8}	m/s
Planck's constant	h	6.626×10^{-34}	J · s
Boltzmann's constant	k	1.381×10^{-23}	J/K
Room temperature thermal energy	kT	0.0259 (T=300 K)	eV
1 eV energy	eV	1.602×10^{-19}	J
Wavelength in vacuum corresponding to 1 eV	-	1240	nm
Dielectric constant of vacuum	εo	8.854×10^{-12}	F/m
Dielectric constant of Si	εsi	12 approx.	-
Dielectric constant of Si oxide	εox	4 approx.	-
Band gap energy of Si	Eg	1.12 approx. (T=25 °C)	eV

■ Principle of operation

Figure 1 shows a cross section of a photodiode. The P-layer material at the active surface and the N material at the substrate form a PN junction which operates as a photoelectric converter. The usual P-layer for a Si photodiode is formed by selective diffusion of boron, to a thickness of approximately 1 μm or less and the neutral region at the junction between the P- and N-layers is known as the depletion layer. By controlling the thickness of the outer P-layer, N-layer and bottom N^+-layer as well as the doping concentration, the spectral response and frequency response can be controlled.

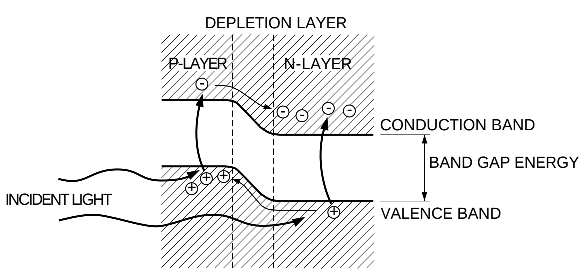
If the light energy is greater than the band gap energy (Eg), the electrons are pulled up into the conduction band, leaving holes in their place in the valence band (See Figure 2). These electron-hole pairs occur throughout the P-layer, depletion layer and N-layer materials. In the depletion layer the electric field accelerates these electrons toward the N-layer and the holes toward the P-layer. Of the electron-hole pairs generated in the N-layer, the electrons, along with electrons that have arrived from the P-layer, are left in the N-layer conduction band. The holes at this time are being diffused through the N-layer up to the depletion layer while being accelerated, and collected in the P-layer valence band. In this manner, electron-hole pairs which are generated in proportion to the amount of incident light are collected in the N- and P-layers. This results in a positive charge in the P-layer and a negative charge in the N-layer. When the electrode are took out from the P-layer and N-layer, and connected to external circuit, electrons will flow away from the N-layer, and holes will flow away from the P-layer toward the opposite respective electrodes. These electrons and holes generating a current flow in a semiconductor are called the carriers.

[Figure 1] Si photodiode cross section



KPDC0002EA

[Figure 2] Si photodiode P-N junction state

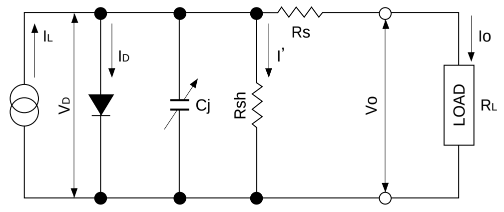


KPDC0003EA

■ Equivalent circuit

An equivalent circuit of a photodiode is shown in Figure 3.

[Figure 3] Photodiode equivalent circuit



KPDC0004EA

- I_L : Current generated by the incident light (proportional to the amount of light)
- I_D : Diode current
- Cj : Junction capacitance
- Rsh: Shunt resistance
- Rs : Series resistance
- I' : Shunt resistance current
- V_D : Voltage across the diode
- Io : Output current
- Vo : Output voltage

Using the above equivalent circuit, the output current Io is given as follows:

$$Io = I_L - I_D - I' = I_L - Is\left(exp\frac{eV_D}{kT} - 1\right) - I' \quad \text{............ (1)}$$

- Is: Photodiode reverse saturation current
- e : Electron charge
- k : Boltzmann's constant
- T : Absolute temperature of the photodiode

The open circuit voltage Voc is the output voltage when Io equals 0. Thus Voc becomes

$$Voc = \frac{kT}{e}\, ln\left(\frac{I_L - I'}{Is} + 1\right) \quad \text{............ (2)}$$

If I' is negligible, since Is increases exponentially with respect to ambient temperature, Voc is inversely proportional to the ambient temperature and proportional to the log of I_L. However, this relationship does not hold for very low light levels.

The short circuit current Isc is the output current when the load resistance R_L equals 0 and Vo equals 0, yielding:

$$Isc = I_L - Is\left(exp\frac{e \cdot (Isc \cdot Rs)}{kT} - 1\right) - \frac{Isc \cdot Rs}{Rsh} \quad \text{...... (3)}$$

In the above relationship, the 2nd and 3rd terms limit the linearity of Isc. However, since Rs is several ohms and Rsh is 10^7 to 10^{11} ohms, these terms become negligible over quite a wide range.

■ Low-light-level detection circuit

Low-light-level detection circuits require measures for reducing electromagnetic noise in the surrounding area, AC noise from the power supply, and internal op amp noise, etc.
Figure 4 shows one measure for reducing electromagnetic noise in the surrounding area.
Extracting the photodiode signal from the cathode terminal is another effective means. An effective countermeasure against AC noise from the power supply is inserting an RC filter or an LC filter in the power supply line. Using a dry cell battery as the power supply also proves effective way. op amp noise can be reduced by selecting an op amp having a low 1/f noise and low equivalent input noise current. Moreover, high-frequency noise can be reduced by using a feedback capacitor (Cf) to limit the circuit frequency range to match the signal frequency bandwidth.
Output errors (due to the op amp input bias current and input offset voltage, routing of the circuit wiring, circuit board surface leak current, etc.) should be reduced, next. A FET input op amp with input bias currents below a few hundred fA or CMOS input op amp with low 1/f noise are selected. Using an op amp with input offset voltages below several millivolts and an offset adjustment terminal will prove effective. Also try using a circuit board made from material having high insulation resistance. As countermeasures against current leakage from the surface of the circuit board, try using a guard pattern or elevated wiring with teflon terminals for the wiring from the photodiode to op amp input terminals and also for the feedback resistor (Rf) and feedback capacitor (Cf) in the input wiring.
HAMAMATSU offers C6386-01, C9051 and C9329 photosensor amplifiers optimized for use with photodiodes for low-light-level detection.

[Figure 4] Photosensor amplifier

(a) C6386-01

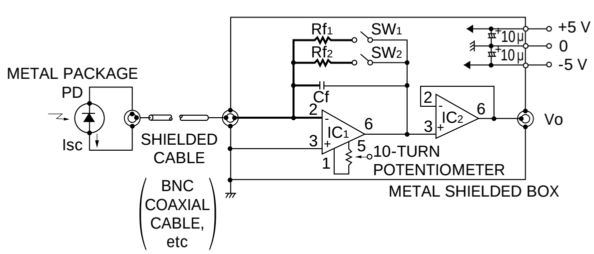
(b) C9051

(c) C9329

The photodiodes, and coaxial cables with BNC-to-BNC plugs are sold separately.

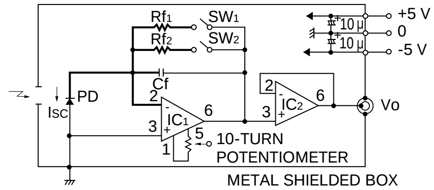
[Figure 5] Low-light-level sensor head

(a) Example using shielded cable to connect to photodiode



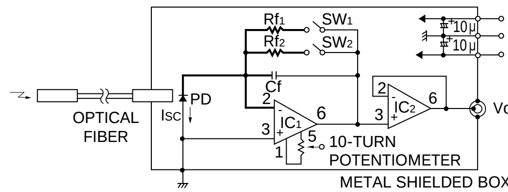
KSPDC0051EB

(b) Example using metal shielded box that contains entire circuit



KSPDC0052EB

(c) Example using optical fiber



KSPDC0053EB

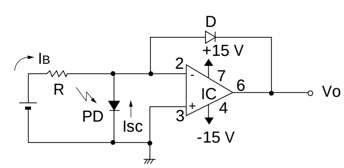
Bold lines should be within guarded pattern or on teflon terminals.
IC_1 : AD549, OPA124, etc.
IC_2 : OP07, etc.
Cf : 10 pF to 100 pF, polystyrene capacitor
Rf : 10 GΩ Max.
SW: Low-leakage reed relay, switch
PD : S1226/S1336/S2386 series, S2281, etc.

Vo = Isc × Rf [V]

■ Light-to-logarithmic-voltage conversion circuit

The voltage output from a light-to-logarithmic voltage conversion circuit (Figure 6) is proportional to the logarithmic change in the detected light intensity. The log diode D for logarithmic conversion should have low dark current and low series resistance. A Base-Emitter junction of small signal transistors or Gate-Source junction of connection type of FETs can also be used as the diode. I_B is the current source that supplies bias current to the log diode D and sets the circuit operating point. Unless this I_B current is supplied, the circuit will latch up when the photodiode short circuit current Isc becomes zero.
HAMAMATSU offers the Si photodiode evaluation circuit C9052-02 that has improved performance versus changes in ambient temperature.

[Figure 6] Light-to-logarithmic-voltage conversion circuit



KPDC0021EA

D : Diode of low dark current and low series resistance
I_B : Current source for setting circuit operation point, I_B << Isc
R : 1 G to 10 GΩ
Io : D saturation current, 10^{-15} to 10^{-12} A
A : FET input op amp

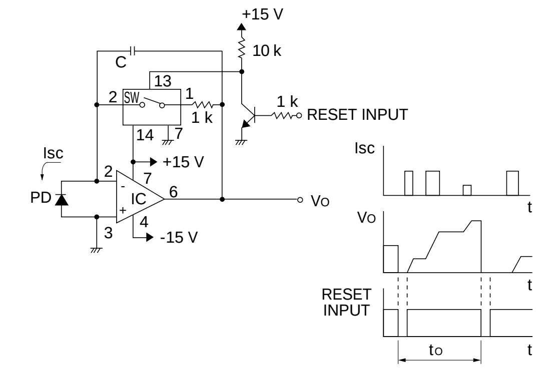
$$Vo \fallingdotseq -0.06 \log \left(\frac{Isc + I_B}{Io} + 1 \right) \ [V]$$

■ Light integration circuit

This is a light integration circuit using integration circuits of photodiode and op amp and is used to measure the integrated power or average power of a light pulse train with an erratic pulse height, cycle and width. The integrator IC in the figure 7

accumulates short circuit current Isc generated by each light pulse in the integration capacitance C. By measuring the output voltage Vo immediately before reset, the average short circuit current can be obtained from the integration time (to) and the capacitance C. A low dielectric absorption type capacitor should be used as the capacitance C to eliminate reset errors. The switch SW is a CMOS analog switch.
HAMAMATSU prepares Si photodiode evaluation circuit C9052-

[Figure 7] Light integration circuit



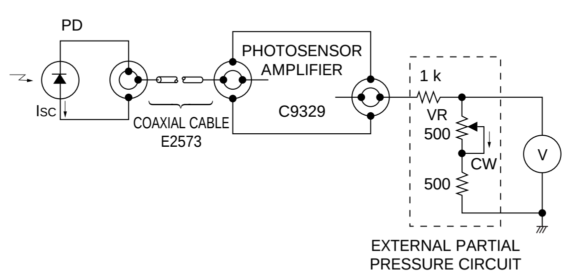
Reset input: Use TTL "L" to reset.
IC : LF356, etc.
SW: CMOS 4066
PD : S1226/S1336/S2386 series, etc.
C : Polycarbonate capacitor, etc.

Vo = Isc ¥ to × $\frac{1}{C}$ [V]

Basic illuminometer (1)

A basic illuminometer circuit can be configured by using HAMAMATSU C9329 photosensor amplifier and S9219 Si photodiode with sensitivity corrected to match human eye response. As shown in Figure 8, this circuit can measure illuminance up to a maximum of 1000 *lx* by connecting the output of C9239 to a voltmeter in the 1 V range via an external resistive voltage divider.
A standard light source is normally used to calibrate this circuit, but if not available, then a simple calibration can be performed with a 100 W incandescent bulb.
To calibrate this circuit, first select the L range on C9329 and then turn the variable resistor VR clockwise until it stops. Block the light to S9219 while in this state, and rotate the zero adjusting volume control on C9329 so that the voltmeter reads 0 mV. Next turn on the incandescent bulb, and adjust the distance between the incandescent bulb and S9219 so that the voltmeter display shows 0.225 V. (The illuminance on S9219 surface at this time is approximately 100 *lx*.) Then turn the VR counterclockwise until the voltmeter display shows 0.1 V. The calibration is now complete.
After calibration, the output should be 1 mV/*lx* in the L range, and 100 mV/*lx* in the M range on C9329.

[Figure 8] Basic illuminometer (1)

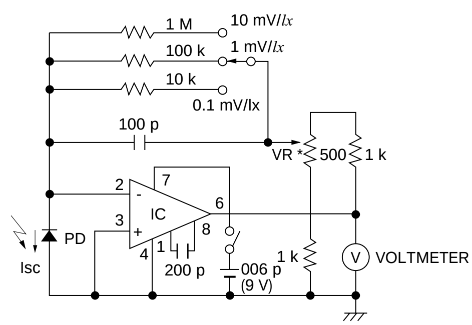


PD: S9219 (4.5 μA/100 *lx*)

Basic illuminometer (2)

This is an basic illuminometer circuit using a visual-compensated Si photodiode S7686 and an op amp. A maximum of 10000 *lx* can be measured with a voltmeter having a 1 V range. It is necessary to use a low consumption current type op amp which can operate from a single voltage supply with a low input bias current.
An incandescent lamp of 100 W can be used for approximate calibrations in the same way as shown above "Basic illuminometer (1)". To make calibrations, first select the 10 mV/*lx* range and short the wiper terminal of the variable resistor VR and the output terminal of the op amp. Adjust the distance between the photodiode S7686 and the incandescent lamp so that the voltmeter reads 0.45 V. (At this point, illuminance on S7686 surface is about 100 *lx*.) Then adjust VR so that the voltmeter reads 1.0 V. Calibration has now been completed.

[Figure 9] Basic illuminometer (2)

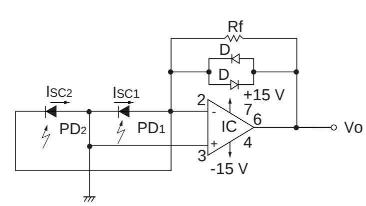


IC : ICL7611, TLC271, etc.
PD: S7686 (0.45 μA/100 *lx*)
* Meter calibration trimmer potentiometer

Light balance detection circuit

Figure 10 shows a light balance detector circuit utilizing two Si photodiodes PD_1 and PD_2 connected in reverse-parallel and an op amp current-voltage converter circuit.
The photoelectric sensitivity is determined by the feedback resistance Rf. The output voltage Vo of this circuit is zero if the amount of light entering the two photodiodes PD_1 and PD_2 is equal. By placing two diodes D in reverse parallel with each other, Vo will be limited range to about ±0.5 V in an unbalanced state, so that the region around a balanced state can be detected with high sensitivity. This circuit can be used for light balance detection between two specific wavelengths using optical filters.
HAMAMATSU prepares Si photodiode evaluation circuit C9052-02.

[Figure 10] Light balance detection circuit



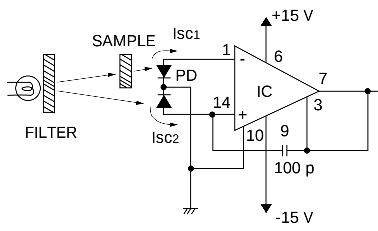
PD: S1226/S1336/S2386 series, etc.
IC : LF356, etc.
D : ISS270A, etc.

Vo = Rf × (Isc2 - Isc1) [V] (Vo < ±0.5 V)

Light absorption meter

This is a light absorption meter using a dedicated IC which provides a logarithmic ratio of two current inputs and two photodiodes (See Figure 11). By measuring and comparing the light intensity from a light source and the light intensity after transmitting through a sample with two photodiodes, light absorbance by the sample can be measured.
To make measurements, optical system such as the incident aperture should first be adjusted to become the output voltage Vo to 0 V so that the short circuit current from the two Si photodiodes is equal. Next, the sample is placed on the light path of one photodiode. At this point, the output voltage value means the absorbance by the sample. The relationship between the absorbance A and the output voltage Vo can be directly read as A= -Vo [V]. If a filter is interposed before the light source as shown in the figure 11, the absorbance of specific light spectrum or monochromatic light can be measured.

[Figure 11] Light absorption meter



KPDC0025EB

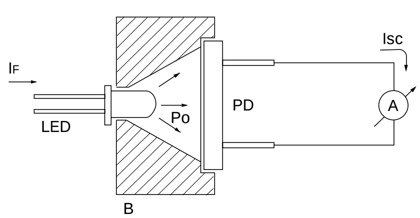
IC : LOG102, LOG112 (Texas Instruments)
PD: S5870, etc.

$$Vo = \log \frac{Isc_1}{Isc_2} \ [V]$$

Total emission measurement of LED

Since the emitting spectral width of LEDs is usually as narrow as about several-ten nanometers, the amount of the LED emission can be calculated from the Si photodiode photo sensitivity at a peak emission wavelength of the LED. In Figure 12, the inner surface of the reflector block B is mirror-processed so that it reflects the light emitted from the side of the LED towards the Si photodiode. Therefore, the total amount of the LED emission can be detected by the Si photodiode.

[Figure 12] Total emission measurement of LED



KPDC0026EA

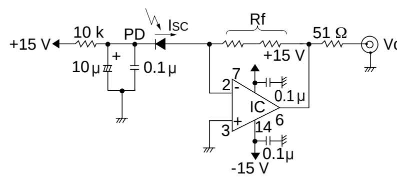
A : Ammeter, 1 mA to 10 mA
PD: S2387-1010R
B : Aluminum block, inner Au plating
S : Photo sensitivity of Si photodiode
Refer to the spectral response chart in the data sheets
S2387-1010R: S=0.58 [A/W] (λ=930 nm)
Po : Total emission

$$Po \fallingdotseq \frac{Isc}{S} \ [W]$$

High-speed photodetector circuit (1)

The high-speed photodetector circuit shown in Figure 13 utilizes a low-capacitance Si PIN photodiode (with a reverse voltage applied) and a high-speed op amp current-voltage converter circuit. The frequency band of this circuit is limited by the op amp device characteristics to less than about 100 MHz.
When the frequency band exceeds 1 MHz, the lead inductance of each component and stray capacitance from feedback resistance Rf exert drastic effects on device response speed. That effect can be minimized by using chip components to reduce the component lead inductance, and connecting multiple resistors in series to reduce stray capacitance.
The photodiode leads should be kept as short as possible and the pattern wiring to the op amp should be made as short and thick as possible. This will lower effects from the stray capacitance and inductance occurring on the circuit board pattern of the op amp inputs and also alleviate effects from photodiode lead inductance. Moreover, a ground plane structure utilizing copper plating at ground potential across the entire board surface will prove effective in boosting device performance.
A ceramic capacitor should be used as the 0.1 μF capacitor connected to the op amp power line, and the connection to ground should be the minimum direct distance.
HAMAMATSU offers C8366 photosensor amplifier for PIN photodiodes with a frequency bandwidth up to 100 MHz and the C9052-01 Si photodiode evaluation circuit with a bandwidth of 100 kHz.

[Figure 13] High-speed photodetector circuit (1)



KPDC0020ED

PD: High-speed PIN photodiode
(S5052, S8314, S5971, S5972, S5973, etc.)
Rf : Two or more resistors are connected in series to eliminate parallel capacitance.
IC : AD745, AD825, LT1360, HA2525, etc.

Vo = -Isc × Rf [V]

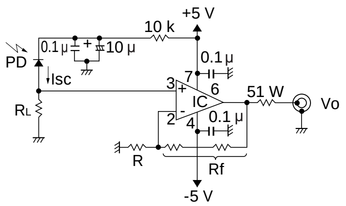
[Figure 14] Photosensor amplifier C8366

High-speed photodetector circuit (2)

The high-speed photodetector circuit in Figure 15 uses load resistance R_L to convert the short circuit current from a low-capacitance Si PIN photodiode (with a reverse voltage applied) to a voltage, and amplifies the voltage with a high-speed op amp. There is no problem with gain peaking based due to phase shifts in the op amp. A circuit with a frequency bandwidth higher than 100 MHz can be attained by selecting the correct op amp. Points for caution in the components, pattern and structure are the same as those listed for the “High-speed photodetector circuit (1)”.

HAMAMATSU offers C9052-01 evaluation circuit for Si photodiodes with a bandwidth up to 1 MHz.

[Figure 15] High-speed photodetector circuit (2)



KPDC0015EB

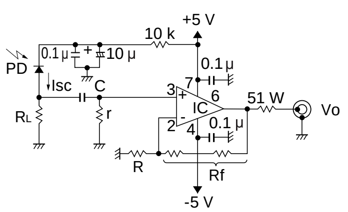
PD : High-speed PIN photodiode (S5052, S8314, S5971, S5972, S5973, etc.)
R_L, R, Rf: Determined by recommended conditions of the op amp
IC : OPA656, OPA657, AD8001, etc.

$$V_o = I_{sc} \times R_L \times \left(1 + \frac{R_f}{R}\right) \text{ [V]}$$

AC photodetector circuit (1)

The AC photodetector circuit in Figure 16 uses load resistance R_L to convert the photocurrent from a low-capacitance Si PIN photodiode (with a reverse voltage applied) to a voltage, and amplifies the voltage with a high-speed op amp. There is no problem with gain peaking based due to phase shifts in the op amp. A circuit with a frequency bandwidth higher than 100 MHz can be attained by selecting the correct op amp. Points for caution in the components, pattern and structure are the same as those listed for the "High-speed photodetector circuit (1)".
HAMAMATSU offers C4890 evaluation circuit for PIN photodiodes with a bandwidth up to 1.5 GHz.

[Figure 16] AC photodetector circuit (1)



KPDC0015EC

PD : High-speed PIN photodiode (S5052, S8314, S5971, S5972, S5973, etc.)
R_L, R, Rf, r: Determined by recommended conditions of the op amp
IC : OPA656, OPA657, AD8001, etc.

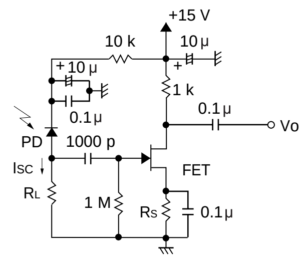
$$V_o = I_{sc} \times R_L \times \left(1 + \frac{R_f}{R}\right) \text{ [V]}$$

[Figure 17] PIN photodiode amplifier C4890

AC photodetector circuit (2)

This AC photodetector circuit utilizes a low capacitance PIN photodiode (with a reverse voltage applied) and a FET serving as a voltage amplifier. Using a low-noise FET allows producing a small yet inexpensive low-noise circuit, which can be used in light sensors for spatial light transmission and optical remote controls, etc. In Figure 18 the signal output is taken from the FET drain. However, for interface to a next stage circuit having low input resistance, the signal output can also be taken from the source or a voltage-follower should be added.
HAMAMATSU offers C9052-01 evaluation circuit for Si photodiodes with a bandwidth up to 1 MHz.

[Figure 18] AC photodetector circuit (2)



KPDC0014EC

PD : High-speed PIN photodiode (S5052, S2506-02, S8314, S5971, S5972, S5973, etc.)
R_L : Determined by sensitivity and "time constant of Ct" of photodiode
Rs : Determined by operation point of FET
FET: 2SK192A, 2SK362, etc.

13. Package/mounting technology

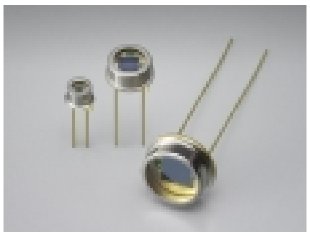
At the Solid State Division of Hamamatsu Photonics, we are constantly at work designing and developing our own package/mounting technology to offer unique semiconductor devices having special features.
Now we will take a brief look at our package/mounting technology for Si photodiodes.

■ Variety of package types

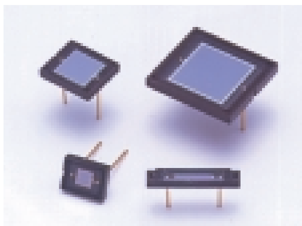
HAMAMATSU offers a diverse selection of package types to meet different customer needs (Figure 19). Metal packages are widely used in applications requiring high reliability. Ceramic packages are used for general applications and plastic packages are used in applications where the main need is low cost. A wide line of packages are also available for surface mounting.

[Figure 19] Package examples

(a) Metal

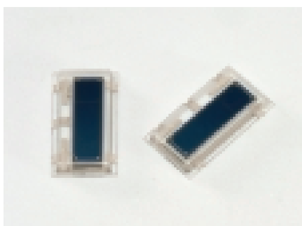


(b) Ceramic

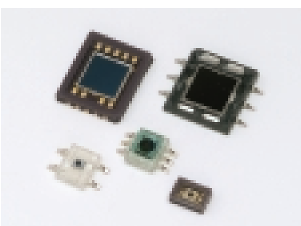


(c) Plastic

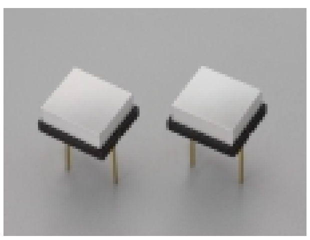
(d) Thin plastic



(e) Surface mount type



(f) With scintillator

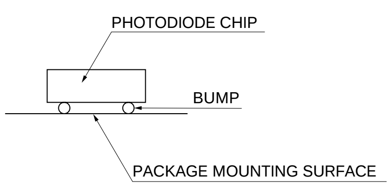


■ Flip-chip mounting

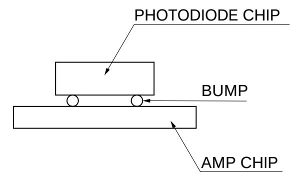
Mounting technology for opto-semiconductors includes not only the 2 stage chip die-bonding and wire-bonding mounting method but also the flip-chip mounting as shown in Figure 20.
Parasitic capacitance and inductance can be a problem when extracting opto-semiconductor device signals from a wire. Flip-chip mounting can prevent this problem and help in downsizing since it utilizes a bump to directly join the chip to the package or an IC chip, etc.

[Figure 20] Example of flip chip mounting

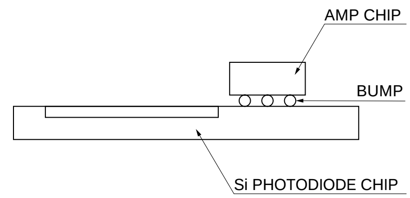
(a) Mounting to a board



(b) Mounting to an amplifier



(c) Mounting an amplifier to a photodiode

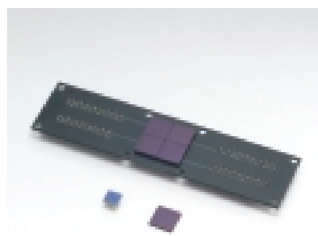


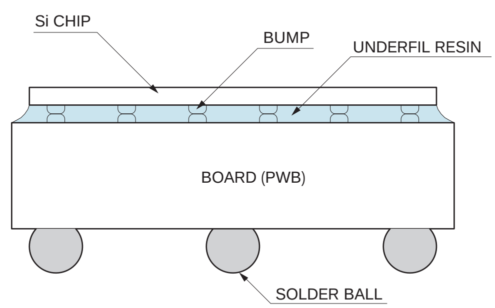
KSPDC0060EA

■ CSP (Chip Size Package) technology

In CSP type photodiodes, the chip and substrate are connected by bump electrodes so there is minimal dead area on the package surface area. This allows utilizing the photosensitive area more effectively. Also multiple devices can be densely arrayed and used in a tile format. There is no wiring so coupling to the scintillator is easy.

[Figure 21] Photo and cross section of CSP type photodiode



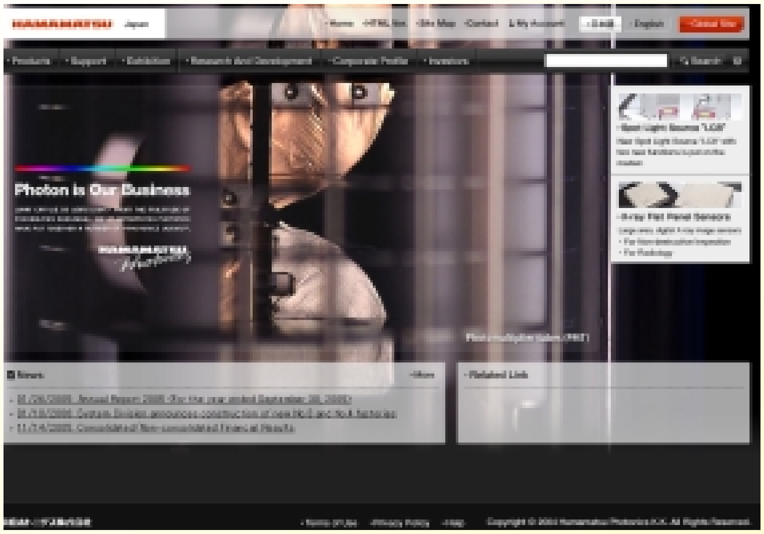


KSPDC0065EA

■ Scintillator coupling

HAMAMATSU also provides detectors configured by a photodiode and scintillator combination. X-rays and radiation converted to visible light by the scintillator are efficiently detected by the photodiode. (See Figure 19 (f).)

We welcome your access to our homepage



www.hamamatsu.com

Please access our homepage to check various information about our latest product catalogues, news, technology introduction and corporate outline.
Some of the new/developmental products in this catalogue may not be available on our web site. Please consult your local sales office for more information.

HAMAMATSU

HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1, Ichino-cho, Hamamatsu City, 435-8558, Japan
Telephone: (81)53-434-3311, Fax: (81)53-434-5184

www.hamamatsu.com

Main Products

Si photodiodes
APD
Photo IC
Image sensors
X-ray flat panel sensors
PSD
Infrared detectors
LED
Devices for optical communication
Devices for car applications
Mini-spectrometers
High energy particle/X-ray detectors
Related products

Hamamatsu also supplies:
Photoelectric tubes
Imaging tubes
Light sources
Imaging and processing
Systems

Hamamatsu Photonics K. K., Solid State Division has been approved by Lloyd's Register Quality Assurance Limited to the Quality Management System Standard.

Information in this catalog is believed to be reliable. However, no responsibility is assumed for possible inaccuracies or omission. Specifications are subject to change without notice. No patent rights are granted to any of the circuits described herein.

Sales Offices

ASIA:
HAMAMATSU PHOTONICS K.K.
325-6, Sunayama-cho,
Hamamatsu City, 430-8587, Japan
Telephone: (81)53-452-2141, Fax: (81)53-456-7889

U.S.A.:
HAMAMATSU CORPORATION
Main Office
360 Foothill Road, P.O. BOX 6910,
Bridgewater, N.J. 08807-0910, U.S.A.
Telephone: (1)908-231-0960, Fax: (1)908-231-1218
E-mail: usa@hamamatsu.com

Western U.S.A. Office:
Suite 110, 2875 Moorpark Avenue
San Jose, CA 95128, U.S.A.
Telephone: (1)408-261-2022, Fax: (1)408-261-2522
E-mail: usa@hamamatsu.com

United Kingdom:
Hamamatsu Photonics UK Limited
Main Office
2 Howard Court, 10 Tewin Road, Welwyn Garden City,
Hertfordshire AL7 1BW, United Kingdom
Telephone: (44)1707-294888, Fax: (44)1707-325777
E-mail: info@hamamatsu.co.uk

South Africa office:
PO Box 1112
Buccleuch 2066
Johannesburg, South Africa
Telephone/Fax: (27)11-802-5505

France, Portugal, Belgium, Switzerland, Spain:
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

Swiss Office:
Dornacherplatz 7
4500 Solothurn, Switzerland
Telephone: (41)32/625 60 60,
Fax: (41)32/625 60 61
E-mail: swiss@hamamatsu.ch

Belgian Office:
Scientific Park,
7, Rue du Bosquet
B-1348 Louvain-La-Neuve, Belgium
Telephone: (32)10 45 63 34
Fax: (32)10 45 63 67
E-mail: epirson@hamamatsu.com

Spanish Office:
Centro de Empresas de Nuevas Tecnologies
Parque Tecnologico del Valles
08290 CERDANYOLA, (Barcelona) Spain
Telephone: (34)93 582 44 30
Fax: (34)93 582 44 31
E-mail: spain@hamamatsu.com

Germany, Denmark, Netherland, Poland:
HAMAMATSU PHOTONICS DEUTSCHLAND GmbH
Arzbergerstr. 10,
D-82211 Herrsching am Ammersee, Germany
Telephone: (49)8152-375-0, Fax: (49)8152-2658
E-mail: info@hamamatsu.de

Danish Office:
Skovbrynet 3
DK-5610 Assens, Denmark
Telephone: (45)4346/6333, Fax: (45)4346/6350
E-mail: lkoldbaek@hamamatsu.de

Netherlands Office:
PO BOX 50.075, 1305 AB ALMERE, The Netherlands
Telephone: (31)36-5382123, Fax: (31)36-5382124
E-mail: info@hamamatsu.nl

Poland Office:
02-525 Warsaw,
8 St. A. Boboli Str., Poland
Telephone: (48)22-660-8340, Fax: (48)22-660-8352
E-mail: jbaszak@hamamatsu.de

North Europe and CIS:
HAMAMATSU PHOTONICS NORDEN AB
Smidesvägen 12
SE-171 41 Solna, Sweden
Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01
E-mail: info@hamamatsu.se

Russian Office:
Riverside Towers
Kosmodamianskaya nab. 52/1, 14th floor
RU-113054 Moscow, Russia
Telephone/Fax: (7) 095 411 51 54
E-mail: info@hamamatsu.ru

Italy:
HAMAMATSU PHOTONICS ITALIA S.R.L.
Strada della Moia, 1/E
20020 Arese, (Milano), Italy
Telephone: (39)02-935 81 733
Fax: (39)02-935 81 741
E-mail: info@hamamatsu.it

Rome Office:
Viale Cesare Pavese, 435
00144 Roma, Italy
Telephone: (39)06-50513454, Fax: (39)06-50513460
E-mail: inforoma@hamamatsu.it

Hong Kong:
HAKUTO ENTERPRISES LTD.
8th Floor World Trade Centre
No. 280 Gloucester Road,
CausewayBay, Hong Kong
Telephone: (852)25125729, Fax: (852)28073155

Taiwan:
HAKUTO Taiwan Ltd.
3F-6, No. 188, Section 5, Nanking East Road
Taipei, Taiwan R.O.C.
Telephone: (886)2-2753-0188
Fax: (886)2-2746-5282

KORYO ELECTRONICS CO., LTD.
9F-7, No.79, Hsin Tai Wu Road
Sec.1, Hsi-Chih, Taipei, Taiwan, R.O.C.
Telephone: (886)2-2698-1143, Fax: (886)2-2698-1147

Republic of Korea:
SANGKI TRADING CO., LTD.
SUITE 431, WORLD VISION BLDG.
24-2 YOIDO-DONG
YOUNGDEUNGPO-KU
SEOUL, 150-877
Telephone: (82)2-780-8515
Fax: (82)2-784-6062

Singapore:
HAKUTO SINGAPORE PTE LTD.
Block 2, Kaki Bukit Avenue 1, #04-01 to #04-04
Kaki Bukit Industrial Estate, Singapore 417938
Telephone: (65)67458910, Fax: (65)67418200

Quality, technology, and service are part of every product.

Cat. No. KSPD0001E02
Aug. 2006 DN
Printed in Japan (4,000)