

Si Photodiodes

Lineup of Si photodiodes for UV to near IR, radiation



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Si photodiodes

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.

■ Hamamatsu Si photodiodes

Type	Feature	Product example
Si photodiode	Featuring high sensitivity and low dark current, these Si photodiodes are specifically designed for precision photometry and general photometry/visible range.	<ul style="list-style-type: none"> • For UV to near IR • For visible range to near IR • For visible range • RGB color sensor • Violet/blue sensitivity enhanced type • For VUV (vacuum ultraviolet) detection • For monochromatic light detection • For electron beam detector • Infrared sensitivity enhanced type
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.	<ul style="list-style-type: none"> • Cutoff frequency: 1 GHz or more • Cutoff frequency: 100 MHz to less than 1 GHz • Cutoff 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 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 spectrophotometry.	<ul style="list-style-type: none"> • Segment type photodiode • One-dimensional photodiode array
Si photodiode with preamp, TE-cooled type Si photodiode	Si photodiodes with preamp incorporate a photodiode and a pre-amplifier chip into the same package. TE-cooled type Si photodiodes are suitable for low-light-level detection where a high S/N is required.	<ul style="list-style-type: none"> • For analytical and measurement instrument
Si photodiode for X-ray detection	These detectors are comprised of a Si photodiode coupled to a scintillator. These detectors are used for X-ray baggage inspection and non-destructive inspection.	<ul style="list-style-type: none"> • With scintillator • Large area Si PIN photodiodes
Si APD*	Si APDs are high-speed, high sensitivity photodiodes having an internal gain mechanism.	<ul style="list-style-type: none"> • Near IR type • Short wavelength type • Multi-element type
Related product of Si photodiode	Hamamatsu provides various types of Si photodiode modules.	<ul style="list-style-type: none"> • RGB color sensor module • Color sensor evaluation circuit • Driver circuit for Si photodiode array • Photodiode module • Signal processing unit for photodiode module • Photosensor amplifier • Charge amplifier

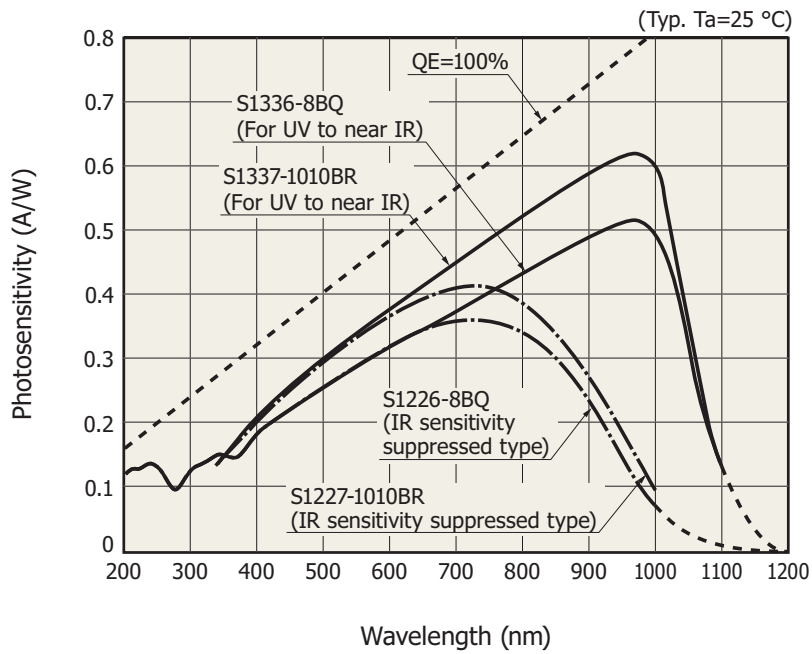
* Si APD is not listed in this catalogue.

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.

Spectral response (typical example)

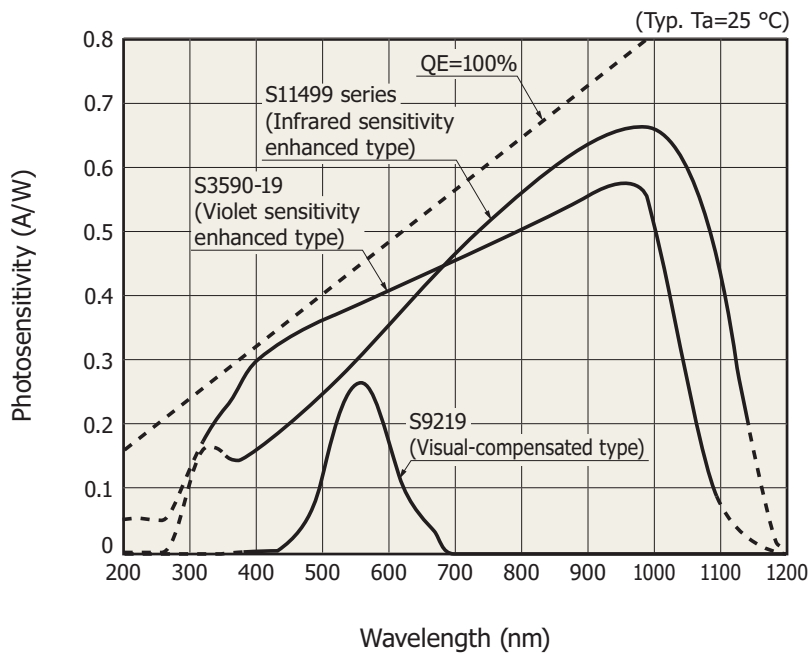
Hamamatsu provides a lineup that covers a variety of spectral response ranges from 200 nm to 1200 nm.

S1226/S1336-8BQ, S1227/S1337-1010BR



KSPDB0300EB

S3590-19, S11499, S9219



KSPDB0301EA

Si photodiode package

Hamamatsu provides a wide variety of packages including metal, ceramic, and plastic.

Si photodiodes for precision photometry

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
For UV to near IR	S1336 series	9	Yes					
	S1337 series (excluding S1337-21)	9		Yes				
	S1337-21	10		Yes				Unsealed
	S2551	10		Yes				
	S2281 series	10					Yes	
For UV to near IR (IR sensitivity suppressed type)	S1226 series	11	Yes					
	S1227 series	11		Yes				
	S2281-01	11					Yes	
For visible range to near IR	S2386 series	12	Yes					
	S2387 series	12		Yes				

Si photodiodes for general photometry/visible range

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
For visible range	Visual-sensitive compensated	S1087, S1133, S8265	13			Yes		
		S1787-04	13			Yes		
	CIE standard luminous efficiency approximation	S9219	13					Yes
		S9219-01	13	Yes				
		S7686	13		Yes			
For visible range to near IR	S1787-12, S4797-01 S4011-06DS S1787-08, S2833-01	14				Yes		
	S1133-14, S1087-01 S1133-01	14		Yes				

High-speed response Si PIN photodiodes

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
Cutoff frequency: 1 GHz or more	S5973/S9055 series	15	Yes					
Cutoff frequency: 100 MHz to less than 1 GHz	S5971, S3399 S3883, S5972	16	Yes					
	S10783, S10784	16			Yes			
Cutoff frequency: 10 MHz to less than 100 MHz	S6775/S8385/ S8729/S2506 series S6967, S4707-01 S6801-01	17			Yes			
	S5821/S1223 series S3071, S3072 S12271	18	Yes					

Multi-element type Si photodiodes

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
Segmented type Si photodiode	S3096-02, S4204, S9345	19			Yes			
	S4349	19	Yes					
One-dimensional photodiode array	S4111/S4114 series	20		Yes				
	S11212-021, S11299-021	20				Yes		Unsealed

Surface mount type Si photodiodes

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
High-speed response Si PIN photodiode	S5106, S5107 S7509, S7510	21		Yes				Surface mount type
Segmented type Si photodiode	S5980, S5981 S5870	21		Yes				Surface mount type
Small package type Si photodiode	S9674 S10625-01CT	22				Yes		Surface mount type
Small package type Si PIN photodiode	S10933-05GT S12158-01CT	22				Yes		Surface mount type

Si photodiodes with preamp, TE-cooled type Si photodiodes

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
Si photodiode with preamp for measurement	S8745-01, S8746-01 S9295 series	23	Yes					
	S9269, S9270	23		Yes				
TE-cooled type Si photodiode	S2592/S3477 series	24	Yes					

Si photodiodes for X-ray detection

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
Si photodiode with scintillator	S8559, S8193	25		Yes				With scintillator
	S11212/S11299 series	25				Yes		With scintillator
Large area type Si PIN photodiode	S3590 series S8650	27		Yes				
	S2744/S3204 S3584/S3588 series	28		Yes				

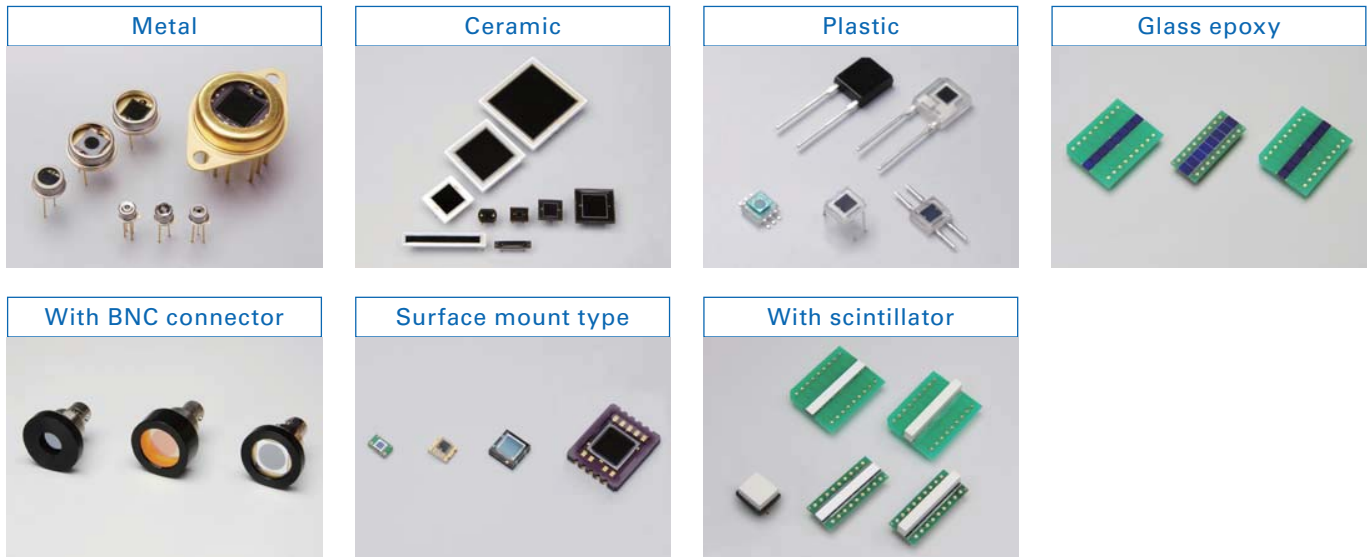
Special application Si photodiodes

Type	Type no.	Page	Metal	Ceramic	Plastic	Glass epoxy	With BNC connector	Remarks
RGB color sensor	S7505-01, S9032-02 S9702	29			Yes			Surface mount type
	S10917-35GT S10942-01CT	29				Yes		Surface mount type
	S6428-01, S6429-01 S6430-01	30			Yes			
Violet/blue sensitivity enhanced type	S5973-02, S9195	31	Yes					
	S3994-01	31		Yes				
For VUV (vacuum ultraviolet) detection	S8551	32	Yes					Unsealed
	S8552, S8553	32		Yes				Unsealed
	S9682, S9683	32	Yes					
	High reliability type	S10043	32		Yes			Unsealed
For monochromatic light detection	S12742-254	33	Yes					
For YAG laser detection	S3759	33	Yes					
Infrared sensitivity enhanced type	S11499 series, S12028	34	Yes					
For electron beam detector	S11141, S11142	34		Yes				Unsealed
CSP (chip size package) type	S10356-01, S10355-01	35				Yes		Unsealed

► Variety of package types

Hamamatsu offers a diverse selection of package types to meet different customer needs. 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.

Other types are also available including those with BNC connector, which facilitates connection to coaxial cable, surface mount types that support reflow soldering, and those with scintillator, which converts X-rays and radiation to visible light.



► Mount technology

At the Solid State Division of Hamamatsu Photonics, we are constantly at work designing and developing our own mount technology to offer unique semiconductor devices having special features.

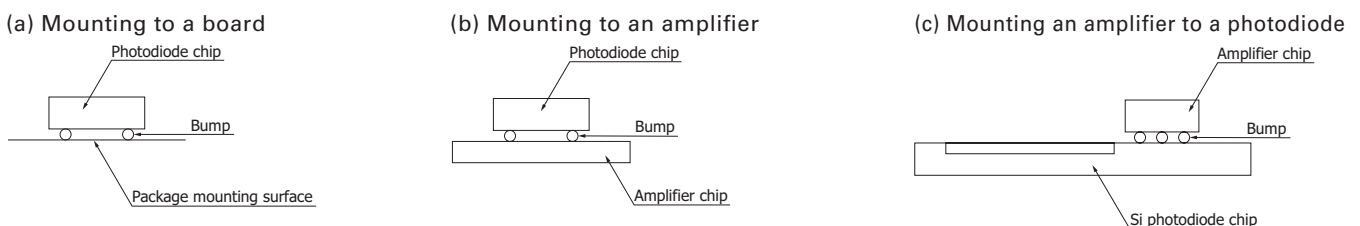
Now we will take a brief look at our mount technology for Si photodiodes.

Flip chip bonding

Mounting technology for opto-semiconductors includes not only the two-stage chip die-bonding and wire-bonding but also the flip chip bonding as shown in Figure 1.

Parasitic capacitance and inductance can be a problem when extracting opto-semiconductor device signals from a wire. Flip-chip bonding can prevent this problem and help in downsizing since it utilizes bumps to directly join the chip to the package or an IC chip, etc.

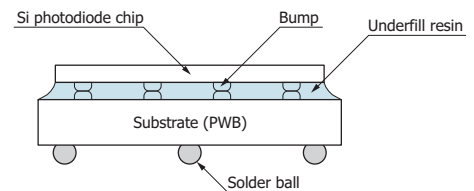
Figure 1 Example of flip chip bonding



CSP (Chip Size Package)

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 2 Cross section of CSP type photodiode



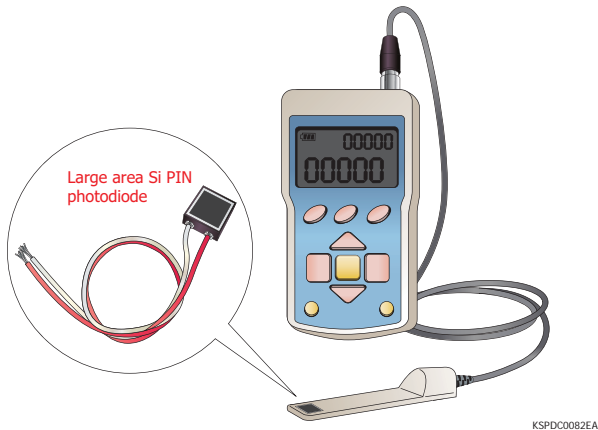
KSPDC0065EB

KSPDC0060EA

Application examples

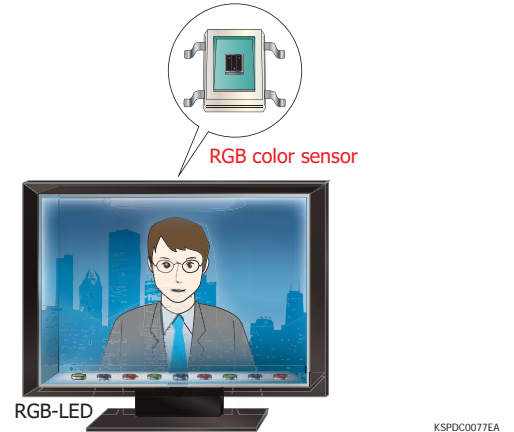
Here, we will introduce several applications of our Si photodiodes.

Optical power meters



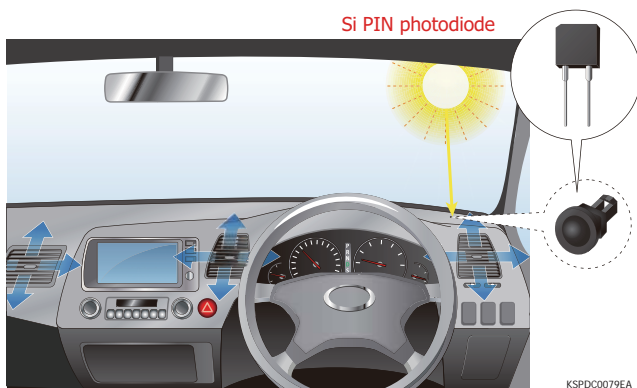
Large area type Si PIN photodiodes are used to measure the light levels of various light sources such as laser diodes and LEDs.

LCD backlight color adjustment



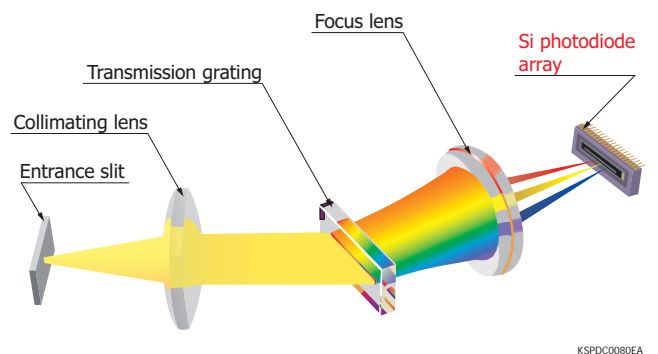
The RGB color sensor detects the white balance of LCD backlight optical waveguides and controls the light level of each RGB LED to stabilize the LCD backlight color.

Sunlight sensors



Si photodiodes are used to detect the amount of sunshine to control the volume of air flow for automotive air conditioners.

Spectrophotometers



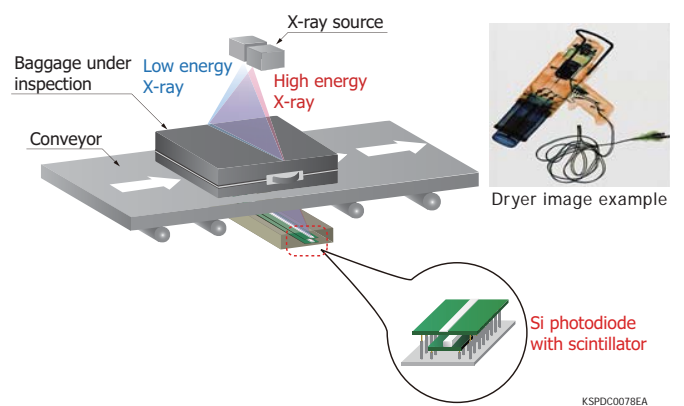
Si photodiode arrays are used to detect light that has been divided into wavelengths through a diffraction grating in spectrophotometers.

Radiation detectors



Si PIN photodiodes with scintillators are used in detectors that measure radiation levels of γ rays and other rays.

Baggage inspection equipment








Si PIN photodiodes with scintillators are used in dual energy imaging of baggage inspection equipment to obtain information about an object such as its type and thickness.

Si photodiodes for precision photometry

For UV to near IR

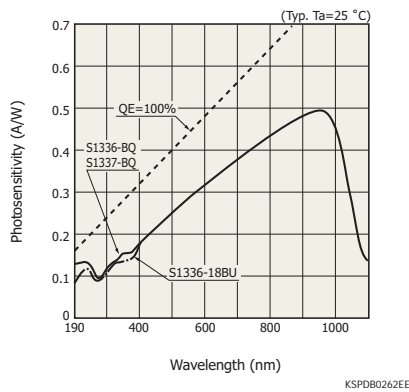
These Si photodiodes have sensitivity in the UV to near IR range.

(Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

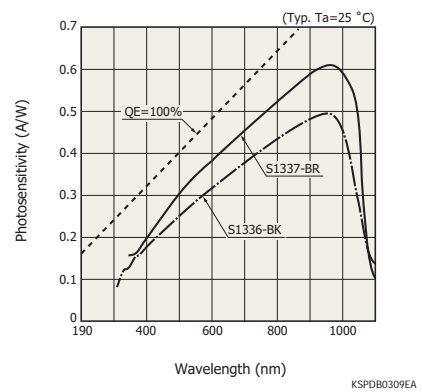
Type no.	Spectral response range (nm)	Photosensitivity (A/W)		Dark current $V_R=10\text{ mV}$ max. (pA)	Terminal capacitance $V_R=0\text{ V}$ $f=10\text{ kHz}$ (pF)	Photosensitive area size (mm)	Package	Photo
		$\lambda=200\text{ nm}$	$\lambda=960\text{ nm}$					
S1336-18BU	190 to 1100	0.075	0.5	20	20	1.1×1.1	TO-18	
S1336-18BQ		0.12						
S1336-18BK	320 to 1100	-						
S1336-5BQ	190 to 1100	0.12						
S1336-5BK	320 to 1100	-						
S1336-44BQ	190 to 1100	0.12						
S1336-44BK	320 to 1100	-						
S1336-8BQ	190 to 1100	0.12						
S1336-8BK	320 to 1100	-						
S1337-16BQ	190 to 1100	0.12	0.5	50	65	1.1×5.9	Ceramic	
S1337-16BR	340 to 1100	-	0.62					
S1337-33BQ	190 to 1100	0.12	0.5	30	380	2.4×2.4	Ceramic	
S1337-33BR	340 to 1100	-	0.62					
S1337-66BQ	190 to 1100	0.12	0.5	100	1100	5.8×5.8	Ceramic	
S1337-66BR	340 to 1100	-	0.62					
S1337-1010BQ	190 to 1100	0.12	0.5	200	1100	10×10	Ceramic	
S1337-1010BR	340 to 1100	-	0.62					

Spectral response

S1336-BQ/BU, S1337-BQ

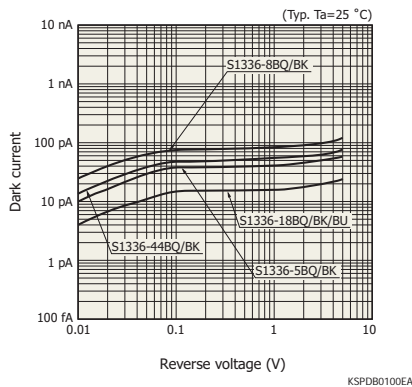


S1336-BK, S1337-BR

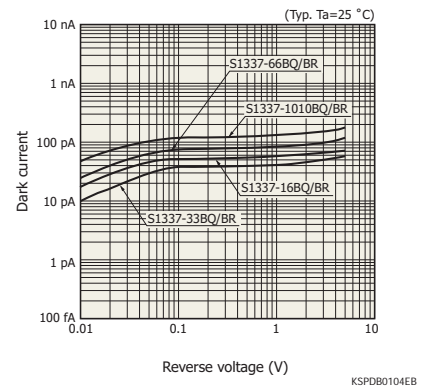


Dark current vs. reverse voltage

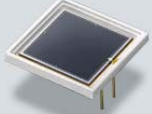



S1336 series



S1337 series



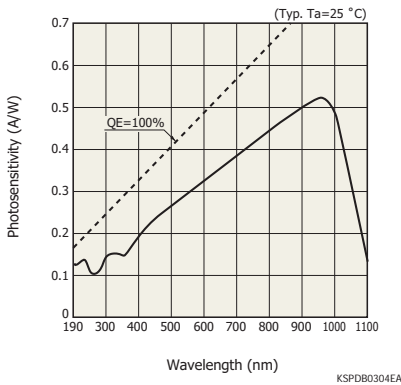
(Typ. Ta=25 °C, unless otherwise noted)

Type no.	Spectral response range (nm)	Photosensitivity (A/W)		Dark current V _R =10 mV max. (pA)	Terminal capacitance V _R =0 V f=10 kHz (pF)	Photosensitive area size (mm)	Package	Photo
		λ=200 nm	λ=960 nm					
S1337-21	190 to 1100	0.13	0.52	500	4000	18 × 18	Ceramic (unsealed)	
S2551	340 to 1060	-	0.6 (λ=920 nm)	1000	350	1.2 × 29.1	Ceramic	
S2281*	190 to 1100	0.12	0.5	500	1300	φ11.3	With BNC connector	
S2281-04*						φ7.98		

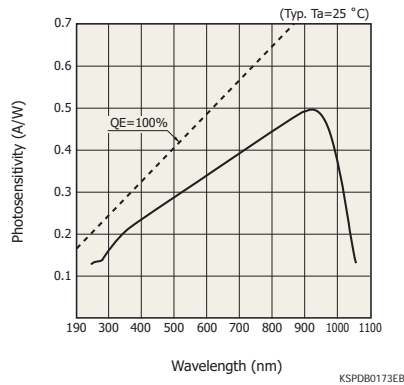
* Connecting a photodiode to the C9329 photosensor amplifier (using a BNC-BNC coaxial cable E2573) allows amplifying the photodiode's weak photocurrent with low noise.

Spectral response

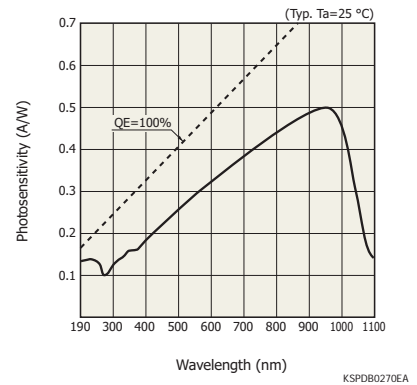
S1337-21



S2551

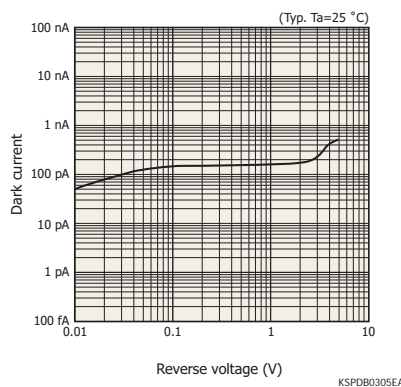


S2281, S2281-04

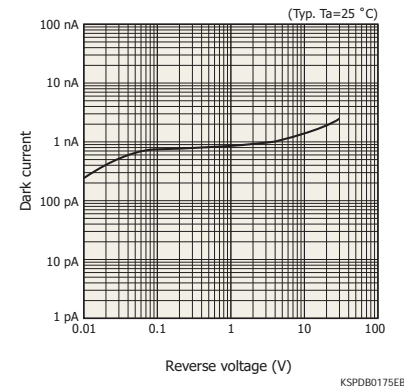


Dark current vs. reverse voltage

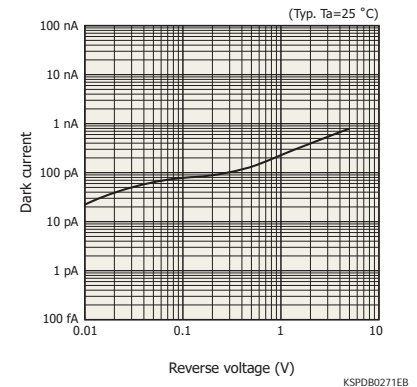
S1337-21



S2551











S2281, S2281-04



For UV to near IR (IR sensitivity suppressed type)

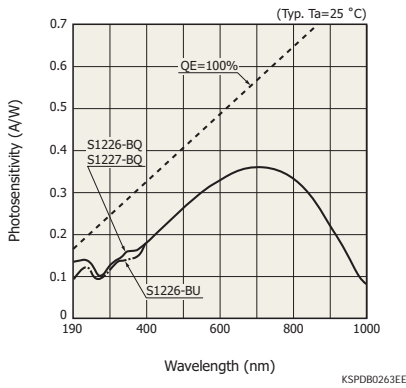
These Si photodiodes have suppressed IR sensitivity.

(Typ. Ta=25 °C, unless specified otherwise)

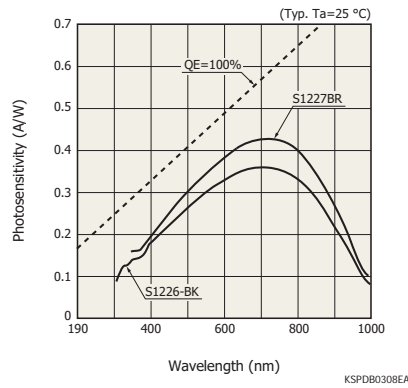
Type no.	Spectral response range (nm)	Photosensitivity (A/W)		Dark current VR=10 mV max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Photosensitive area size (mm)	Package	Photo
		$\lambda=200$ nm	$\lambda=720$ nm					
S1226-18BU	190 to 1000	0.075	0.36	2	35	1.1 × 1.1	TO-18	
S1226-18BQ		0.12						
S1226-18BK	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	500	3.6 × 3.6	TO-5	
S1226-44BK	320 to 1000	-						
S1226-8BQ	190 to 1000	0.12		20	1200	5.8 × 5.8	TO-8	
S1226-8BK	320 to 1000	-						
S1227-16BQ	190 to 1000	0.12		0.36	5	170	1.1 × 5.9	Ceramic
S1227-16BR	340 to 1000	-	0.43					
S1227-33BQ	190 to 1000	0.12	0.36	5	160	2.4 × 2.4	Ceramic	
S1227-33BR	340 to 1000	-	0.43					
S1227-66BQ	190 to 1000	0.12	0.36	20	950	5.8 × 5.8	Ceramic	
S1227-66BR	340 to 1000	-	0.43					
S1227-1010BQ	190 to 1000	0.12	0.36	50	3000	10 × 10	Ceramic	
S1227-1010BR	340 to 1000	-	0.43					
S2281-01	190 to 1000	0.12	0.36	300	3200	φ11.3	With BNC connector	

Spectral response

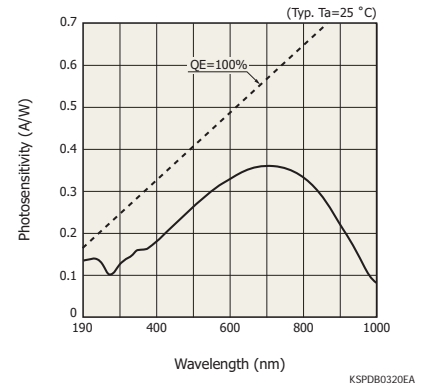
S1226-BU/BQ, S1227-BQ



S1226-BK, S1227-BR

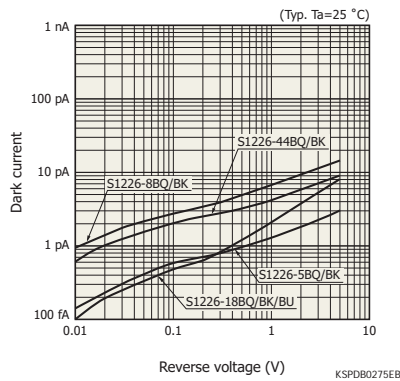


S2281-01

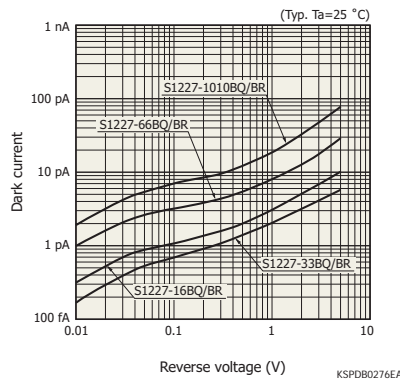


Dark current vs. reverse voltage

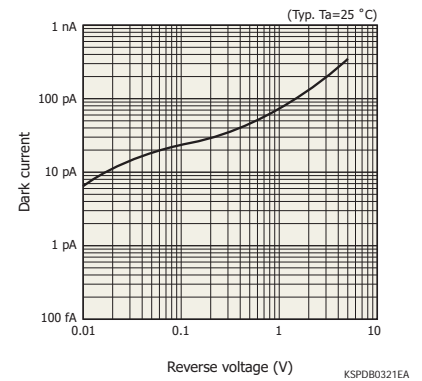
S1226 series



S1227 series



S2281-01



For visible range to near IR

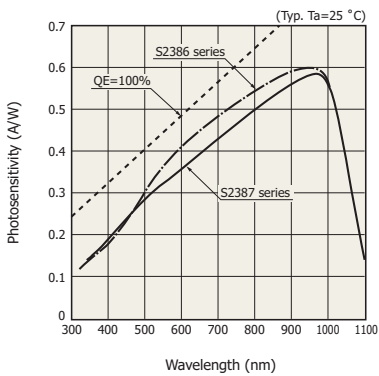
These Si photodiodes offer enhanced sensitivity especially in the near IR range.

(Typ. Ta=25 °C, unless otherwise noted)

Type no.	Spectral response range (nm)	Photosensitivity $\lambda=960$ nm (A/W)	Dark current $V_R=10$ mV max. (pA)	Terminal capacitance $V_R=0$ V $f=10$ kHz (pF)	Photosensitive area size (mm)	Package	Photo
S2386-18K	320 to 1100	0.6	2	140	1.1 × 1.1	TO-18	
S2386-18L							
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	340 to 1100	0.58	5	730	1.1 × 5.9	Ceramic	
S2387-33R					2.4 × 2.4		
S2387-66R			5.8 × 5.8				
S2387-1010R			10 × 10				
S2387-130R			1.2 × 29.1				

Spectral response

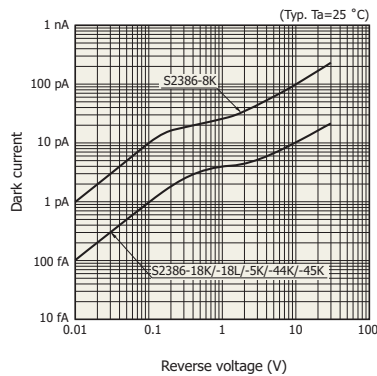
S2386/S2387 series



KSPDB0272ED

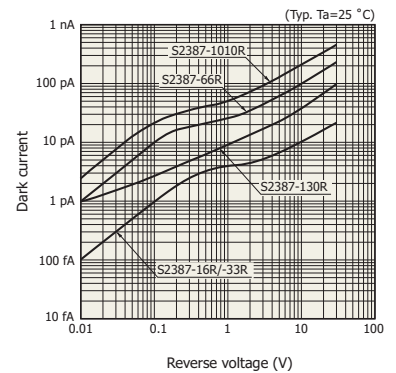
Dark current vs. reverse voltage

S2386 series



KSPDB0113EB

S2387 series



KSPDB0117EB

Si photodiodes for general photometry/visible range

For visible range





These Si photodiodes have sensitivity in the visible range.

(Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)




Type no.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photosensitivity $\lambda=\lambda_p$ (A/W)	Dark current $V_R=1\text{ V}$ max. (pA)	Photosensitive area size (mm)	Package	Photo
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Filter type (general use)

These are Si photodiodes with visible-compensated filters. The S8265 is a high humidity resistance type of S1133.

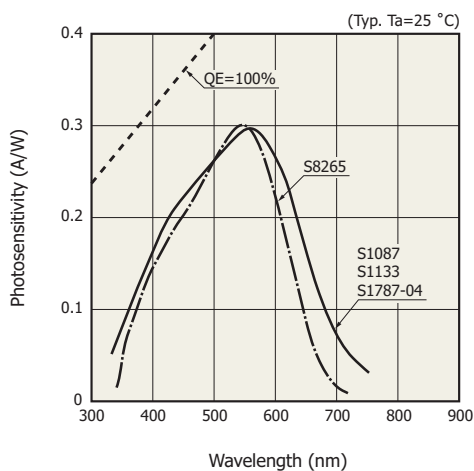
S1087	320 to 730	560	0.3	10	1.3 × 1.3	Ceramic	
S1133					2.4 × 2.8		
S8265	340 to 720	540		20	2.4 × 2.8	Ceramic	
S1787-04	320 to 730	560		10	2.4 × 2.8	Plastic	

Filter type (CIE spectral luminous efficiency approximation)

S9219	380 to 780	550	0.24	500 ($V_R=10\text{ mV}$)	$\phi 11.3$	With BNC connector	
S9219-01			0.22	50 ($V_R=10\text{ mV}$)	3.6 × 3.6	TO-5	
S7686	480 to 660		0.38	20	2.4 × 2.8	Ceramic	

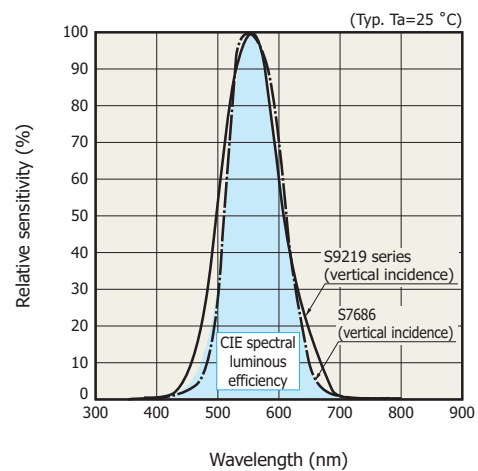
Spectral response

S1087, S1133, S1787-04, S8265



KSPDB0277EC

S9219 series, S7686











KSPDB0285ED

For visible range to near IR

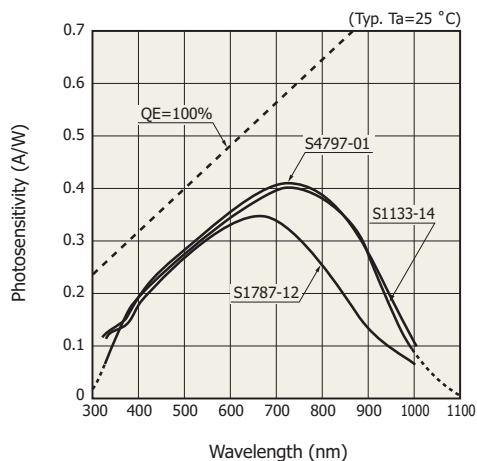
These Si photodiodes have sensitivity in the visible range to near IR.

(Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

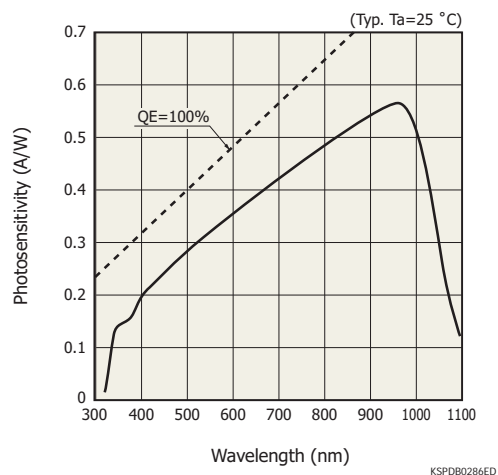
Type no.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photosensitivity $\lambda=\lambda_p$ (A/W)	Dark current $V_R=1\text{ V}$ max. (pA)	Photosensitive area size (mm)	Package	Photo	
S1787-12	320 to 1000	650	0.35	20	2.4 × 2.8	Plastic		
S4797-01		720	0.4		1.3 × 1.3			
S1133-14					2.4 × 2.8	Ceramic		
S4011-06DS	320 to 1100	960	0.58	10	1.3 × 1.3	Plastic		
S1787-08					2.4 × 2.8			
S2833-01								
S1087-01					1.3 × 1.3		Ceramic	
S1133-01					2.4 × 2.8			

Spectral response

S1787-12, S4797-01, S1133-14







S4011-06DS, S1787-08, S2833-01, S1087-01, S1133-01



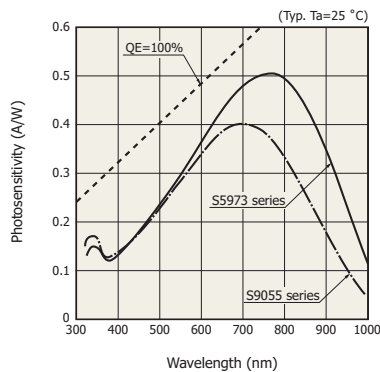
High-speed response Si PIN photodiodes

Cutoff frequency: 1 GHz or more

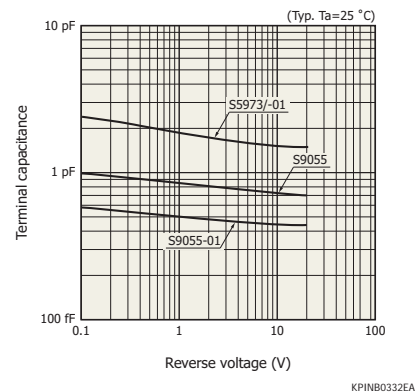
These Si PIN photodiodes deliver a wide bandwidth even with a low bias, making them suitable for high-speed photometry as well as optical communications. (Typ. $T_a=25\text{ }^\circ\text{C}$)

Type no.	Cutoff frequency (GHz)	Photosensitive area size (mm)	Photosensitivity (A/W)		Terminal capacitance $f=1\text{ MHz}$ (pF)	Package	Photo
			$\lambda=780\text{ nm}$	$\lambda=830\text{ nm}$			
S5973	1 ($V_R=3.3\text{ V}$)	$\phi 0.4$	0.51	0.47	1.6 ($V_R=3.3\text{ V}$)	TO-18	
S5973-01							
S9055	1.5 ($V_R=2\text{ V}$)	$\phi 0.2$	0.35	0.25	0.8 ($V_R=2\text{ V}$)		
S9055-01	2 ($V_R=2\text{ V}$)				0.5 ($V_R=2\text{ V}$)		

Spectral response

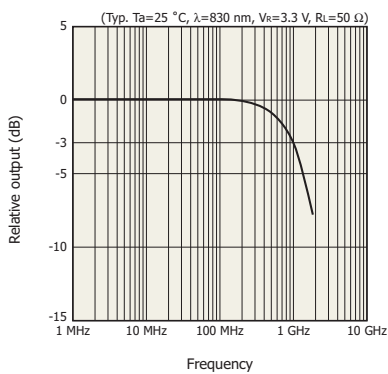


Terminal capacitance vs. reverse voltage



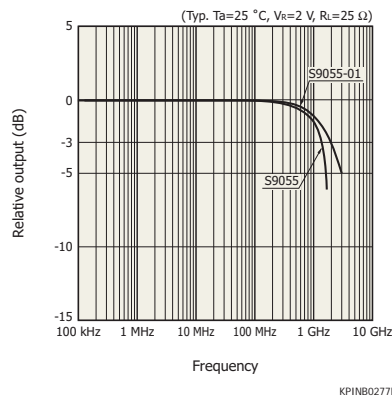
Frequency response

S5973, S5973-01

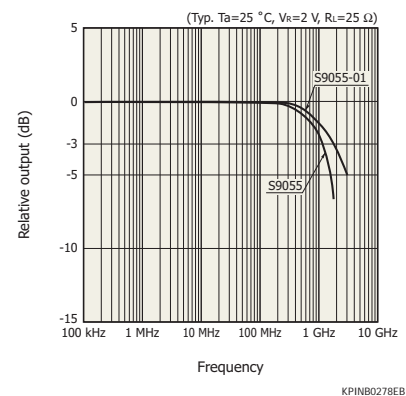


S9055 series

[$\lambda=410\text{ nm}$]







[$\lambda=830\text{ nm}$]



Cutoff frequency: 100 MHz to less than 1 GHz

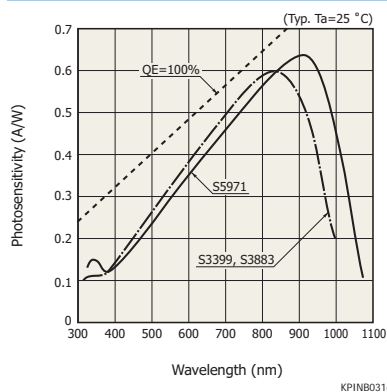
These Si PIN photodiodes have a large photosensitive area ($\phi 0.8$ to $\phi 3.0$ mm) yet deliver excellent frequency response characteristics (100 MHz to 500 MHz).

(Typ. $T_a=25^\circ\text{C}$)

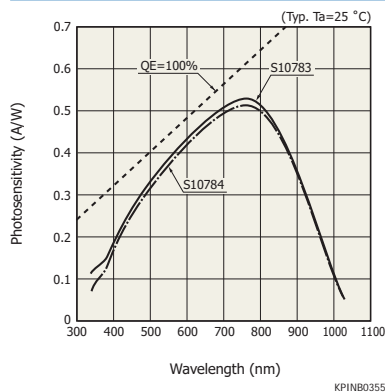
Type no.	Cutoff frequency (MHz)	Photosensitive area size (mm)	Photosensitivity (A/W)		Terminal capacitance $f=1$ MHz (pF)	Package	Photo
			$\lambda=660$ nm	$\lambda=780$ nm			
S5971	100 ($V_R=10$ V)	$\phi 1.2$	0.44	0.55	3 ($V_R=10$ V)	TO-18	
S3399		$\phi 3$	0.45	0.58	20 ($V_R=10$ V)		
S3883	300 ($V_R=20$ V)	$\phi 1.5$			6 ($V_R=20$ V)	TO-5	
S10783	300 ($V_R=2.5$ V)	$\phi 0.8$	0.46	0.52	4.5 ($V_R=2.5$ V)		Plastic
S10784		$\phi 3$	0.45	0.51		Plastic with lens	
S5972	500	$\phi 0.8$	0.44	0.55	3 ($V_R=10$ V)	TO-18	

Spectral response

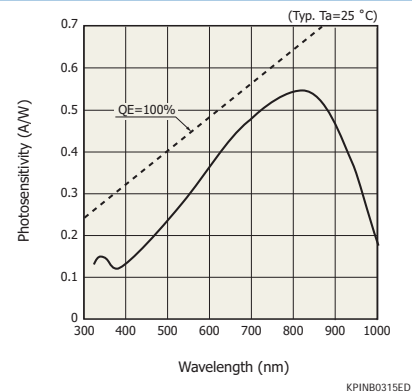
S5971, S3399, S3883



S10783, S10784

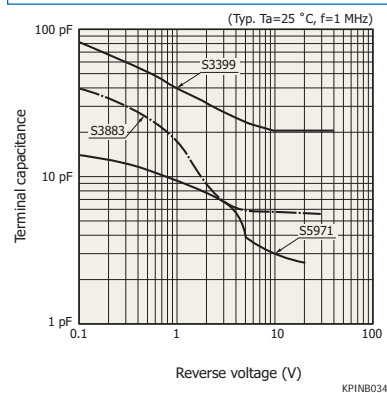


S5972

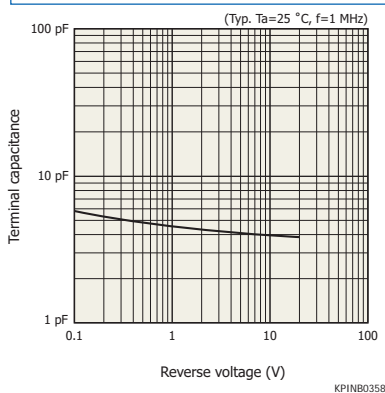


Terminal capacitance vs. reverse voltage

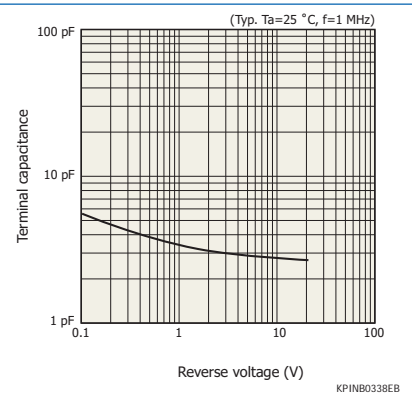
S5971, S3399, S3883



S10783, S10784















S5972



Cutoff frequency: 10 MHz to less than 100 MHz

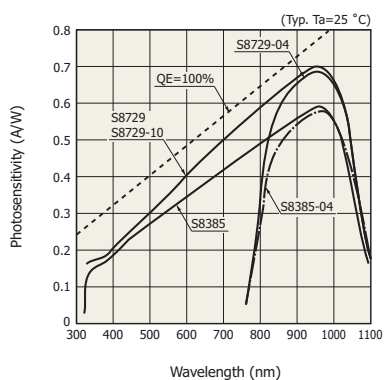
A wide variety of types are provided including a low-cost plastic package type and visible-cut type.

(Typ. $T_a=25\text{ }^\circ\text{C}$)

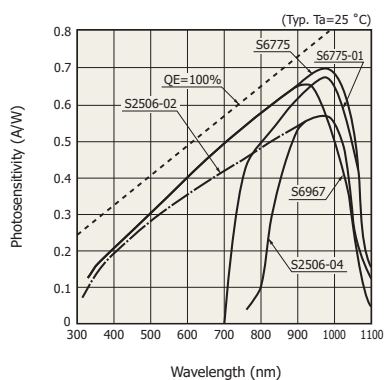
Type no.	Cutoff frequency (MHz)	Photosensitive area size (mm)	Photosensitivity (A/W)		Terminal capacitance f=1 MHz (pF)	Package	Photo
			$\lambda=660\text{ nm}$	$\lambda=780\text{ nm}$			
S6775	15 ($V_R=10\text{ V}$)	5.5 × 4.8	0.45	0.55	40 ($V_R=10\text{ V}$)	Plastic	
S6967	50 ($V_R=10\text{ V}$)				50 ($V_R=10\text{ V}$)		
S6775-01	15 ($V_R=10\text{ V}$)		40 ($V_R=10\text{ V}$)				
S8385		2 × 2	0.4	0.48	12 ($V_R=5\text{ V}$)		
S8385-04			0.44 ($\lambda=830\text{ nm}$)	0.56 ($\lambda=\lambda_p$)			
S8729	25 ($V_R=5\text{ V}$)	2 × 3.3	0.45	0.55	16 ($V_R=5\text{ V}$)		
S8729-04			0.52 ($\lambda=830\text{ nm}$)	0.68 ($\lambda=\lambda_p$)			
S8729-10			0.45	0.55			
S2506-02	25 ($V_R=12\text{ V}$)	2.77 × 2.77	0.4	0.48	15 ($V_R=12\text{ V}$)		
S2506-04			0.25 ($\lambda=830\text{ nm}$)	0.56 ($\lambda=\lambda_p$)			
S4707-01	20 ($V_R=10\text{ V}$)	2.4 × 2.8	0.4	0.48	14 ($V_R=10\text{ V}$)		
S6801-01	15 ($V_R=10\text{ V}$)	$\phi 14$ (lens diameter)	0.52 ($\lambda=830\text{ nm}$)	0.65 ($\lambda=\lambda_p$)	40 ($V_R=10\text{ V}$)		Plastic with $\phi 14\text{ mm}$ lens 

Spectral response

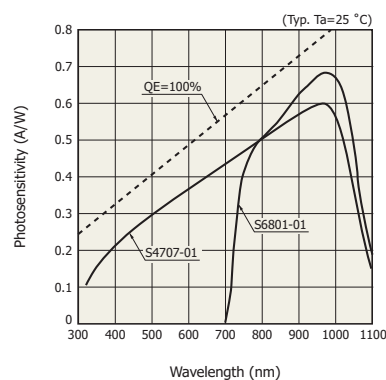
S8385/S8729 series










S6775/S6967/S2506 series



S4707-01, S6801-01

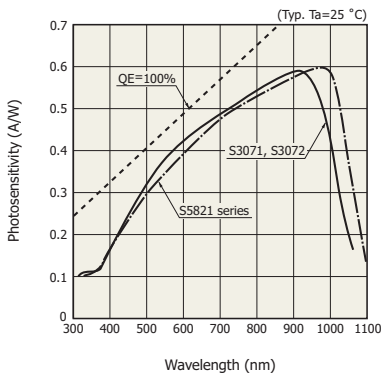


(Typ. $T_a=25\text{ }^\circ\text{C}$)

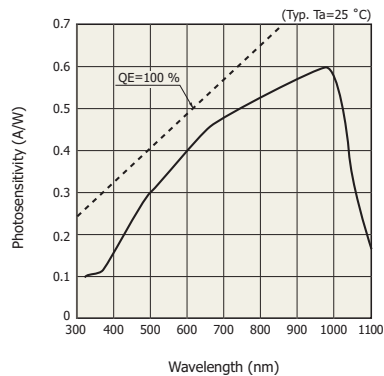
Type no.	Cutoff frequency (MHz)	Photosensitive area size (mm)	Photosensitivity (A/W)		Terminal capacitance $f=1\text{ MHz}$ (pF)	Package	Photo
			$\lambda=660\text{ nm}$	$\lambda=780\text{ nm}$			
S5821	25 ($V_R=10\text{ V}$)	$\phi 1.2$	0.45	0.52	3 ($V_R=10\text{ V}$)	TO-18	
S5821-02							
S5821-01		$\phi 4.65$ (lens diameter)					
S5821-03							
S1223	30 ($V_R=20\text{ V}$)	2.4×2.8	0.45	0.52	10 ($V_R=20\text{ V}$)	TO-5	
S1223-01	20 ($V_R=20\text{ V}$)	3.6×3.6					20 ($V_R=20\text{ V}$)
S3072	45 ($V_R=24\text{ V}$)	$\phi 3$	0.47	0.54	7 ($V_R=24\text{ V}$)	TO-8	
S3071	40 ($V_R=24\text{ V}$)	$\phi 5$					18 ($V_R=24\text{ V}$)
S12271	60 ($V_R=100\text{ V}$)	$\phi 4.1$	0.5 ($\lambda=960\text{ nm}$)		10 ($V_R=100\text{ V}$)		

Spectral response

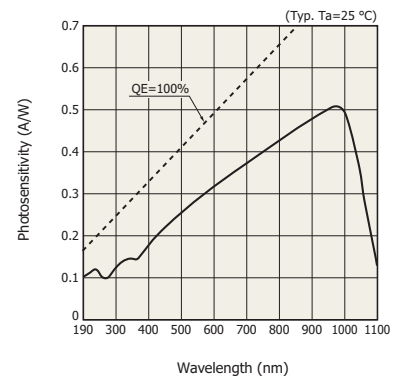
S5821 series, S3071, S3072



S1223 series

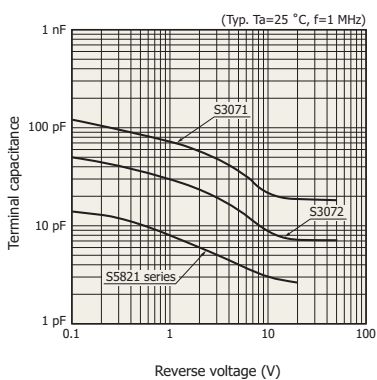


S12271

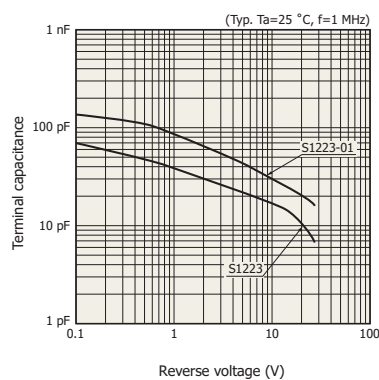


Terminal capacitance vs. reverse voltage

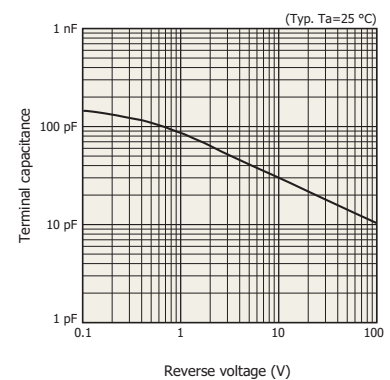
S5821 series, S3071, S3072



S1223 series



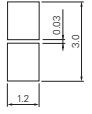

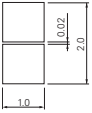

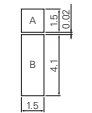
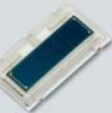


S12271



Multi-element type Si photodiodes

Segmented type Si photodiodes

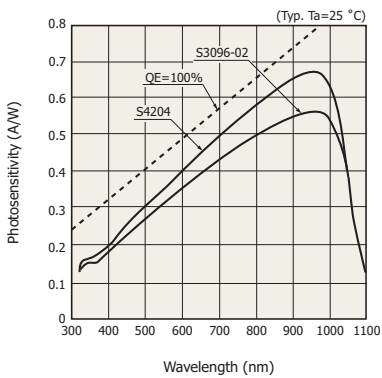
These Si PIN photodiode arrays consist of 2 or 4 elements having sensitivity in the UV to near IR range. (Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

Type no.	Number of elements	Photosensitive area size (mm)	Photosensitivity (A/W)	Cutoff frequency $V_R=10\text{ V}$ $R_L=50\ \Omega$ (MHz)	Dark current $V_R=10\text{ V}$ max. (nA)	Terminal capacitance $V_R=10\text{ V}$ $f=1\text{ MHz}$ (pF)	Package	Photo
S3096-02	2	1.2 × 3 /2-segment 	0.39 ($\lambda=650\text{ nm}$)	25	0.5*	5	Plastic	
S4204		1 × 2 /2-segment 	0.45 ($\lambda=650\text{ nm}$)	30	1*	3		
S9345		1.5 × 1.5 + 1.5 × 4.1 	0.45 ($\lambda=650\text{ nm}$)	15	5*	4 (Photo-diode A) 10 (Photo-diode B)		
S4349	4	3 × 3 /4-segment 	0.45 ($\lambda=720\text{ nm}$)	20 ($V_R=5\text{ V}$)	0.2 ($V_R=5\text{ V}$)	25 ($V_R=5\text{ V}$)	TO-5	

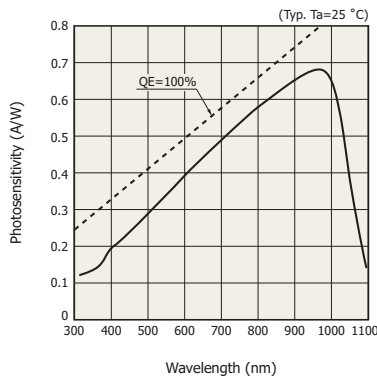
* Total number of elements

Spectral response

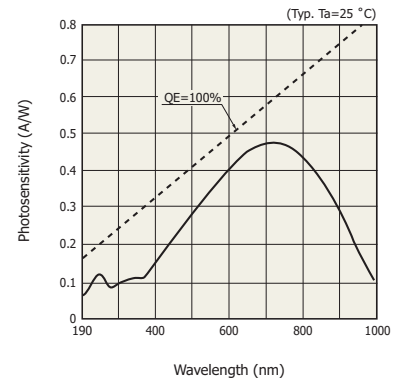
S3096-02, S4204



S9345

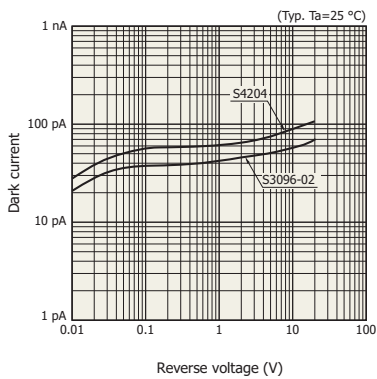


S4349

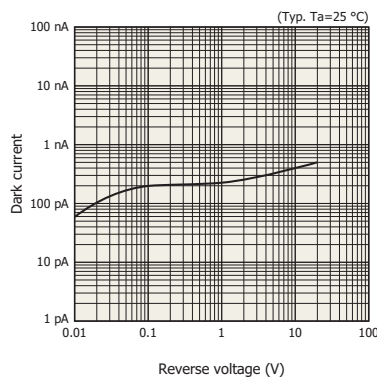


Dark current vs. reverse voltage

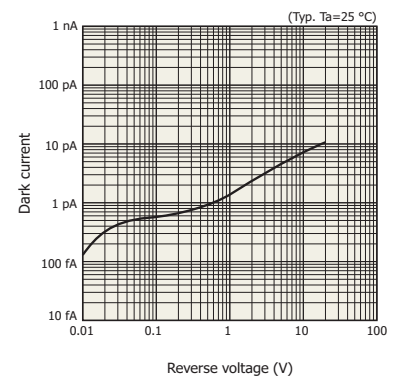
S3096-02, S4204



S9345






S4349



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

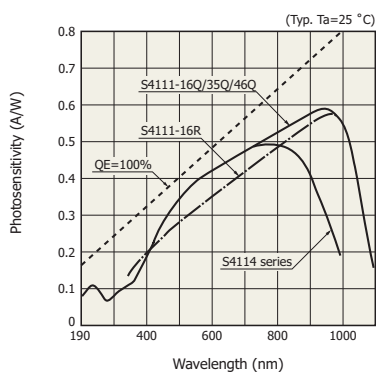
These are Si photodiode linear arrays having rectangular elements equally spaced at a pitch of about 1 mm. (Typ. Ta=25 °C, unless otherwise noted)

Type no.	Number of elements	Photosensitive area size /element (mm)	Element pitch (mm)	Spectral response range (nm)	Photosensitivity λ=960 nm (A/W)	Dark current VR=10 mV max. (pA)	Terminal capacitance VR=0 V f=10 kHz (pF)	Package	Photo	
S4111-16Q	16	1.45 × 0.9	1.0	190 to 1100	0.58	5	200	Ceramic		
S4111-16R				340 to 1100						
S4111-35Q	35	190 to 1100		10					550	
S4111-46Q	46									
S4114-35Q	35	4.4 × 0.9		190 to 1000	0.50*1	60	35		Glass epoxy (unsealed)	
S4114-46Q	46									
S11212-021	16	1.175 × 2.0	1.575	340 to 1100	0.61*2	30	40	Glass epoxy (unsealed)		
S11299-021										

*1: λ=800 nm
*2: λ=920 nm

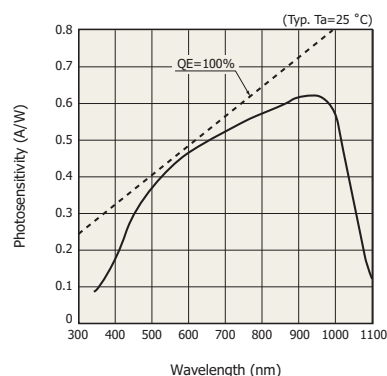
Spectral response

S4111/S4114 series



KMPDB0112EC

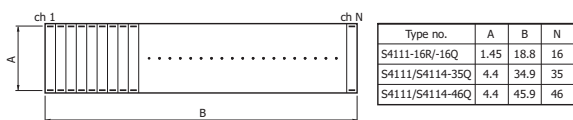
S11212/S11299-021



KMPDB0357EA

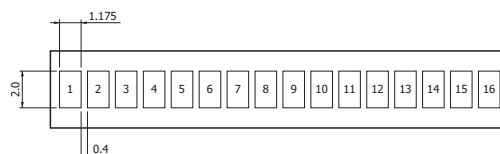
Structure of photosensitive area (unit: mm)

S4111/S4114 series



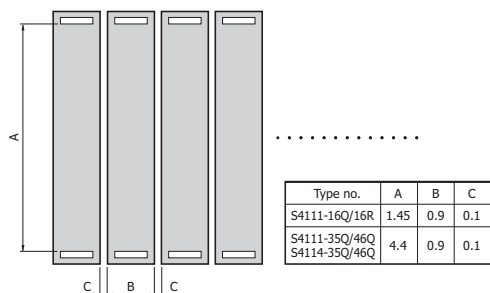
KMPDA0227EB

S11212/S11299-021



KMPDA0228EC

Details of elements (S4111/S4114 series)







KMPDA0112EB

Surface mount type Si photodiodes

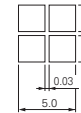

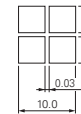

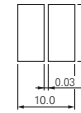

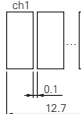

High-speed response Si PIN photodiodes

These are photodiodes sealed in a chip carrier package suitable for surface mounting and allowed solder reflow mounting on PC boards for automated processes. (Typ. Ta=25 °C)

Type no.	Cutoff frequency VR=10 V (MHz)	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity λ=960 nm (A/W)	Terminal capacitance VR=10 V f=1 MHz (pF)	Package	Photo
S5106	20	5 × 5	320 to 1100	0.72	40	Ceramic	
S5107	10	10 × 10			150		
S7509	20	2 × 10			40		
S7510	15	6 × 11			80		

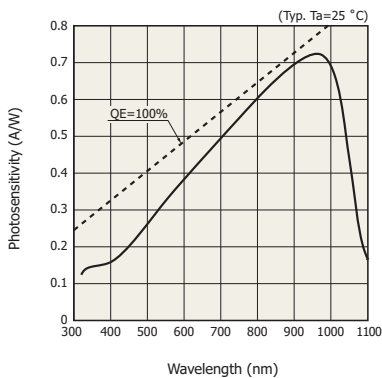
Segmented type Si photodiodes

These Si photodiodes consist of 2 or 4 elements and are integrated into a chip carrier package. (Typ. Ta=25 °C)

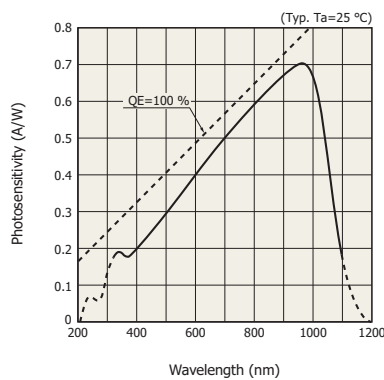
Type no.	Number of elements	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity λ=960 nm (A/W)	Cutoff frequency VR=10 V RL=50 Ω (MHz)	Terminal capacitance VR=10 V f=1 MHz (pF)	Package	Photo
S5980	4	5 × 5 /4-segment 	320 to 1100	0.72	25	10	Ceramic	
S5981		10 × 10 /4-segment 			20	35		
S5870	2	10 × 10 /2-segment 			10	50		
S8558	16	2 × 12.7 /16-segment 			25	5		

Spectral response

S5106, S5107, S7509, S7510, S5980, S5981, S5870

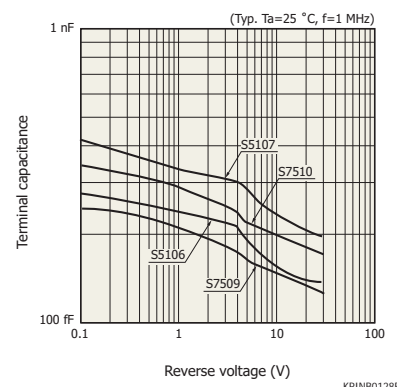


S8558



Terminal capacitance vs. reverse voltage



S5106, S5107, S7509, S7510



Small package type Si photodiodes

These surface mount type Si photodiodes are mounted on small packages. They are tape packaged and allows solder reflow mounting.



(Typ. Ta=25 °C)

Type no.	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity $\lambda=960$ nm (A/W)	Terminal capacitance $V_R=0$ V $f=10$ kHz (pF)	Package	Photo
S9674	2 × 2	320 to 1100	0.7	500	Glass epoxy	
NEW S10625-01CT	1.3 × 1.3		0.54 ($\lambda=940$ nm)	200		

Small package type Si PIN photodiodes

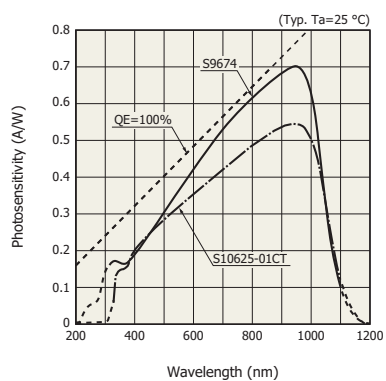
These surface mount type Si PIN photodiodes are mounted on small packages. They are tape packaged and allows solder reflow mounting.

(Typ. Ta=25 °C)

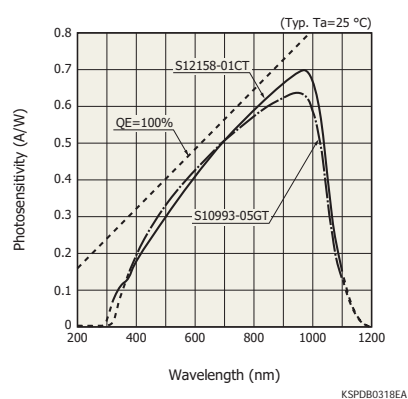
Type no.	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity $\lambda=960$ nm (A/W)	Terminal capacitance $f=1$ MHz (pF)	Package	Photo
NEW S10993-05GT	1.06 × 1.06	380 to 1100	0.6	6 ($V_R=2.5$ V)	Glass epoxy	
S12158-01CT	2.77 × 2.77	320 to 1100	0.7	15 ($V_R=12$ V)		

Spectral response

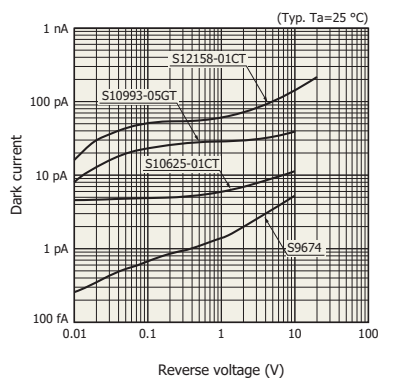
S9674, S10625-01CT



S10993-05GT, S12158-01CT









Dark current vs. reverse voltage



Si photodiodes with preamp, TE-cooled type Si photodiodes

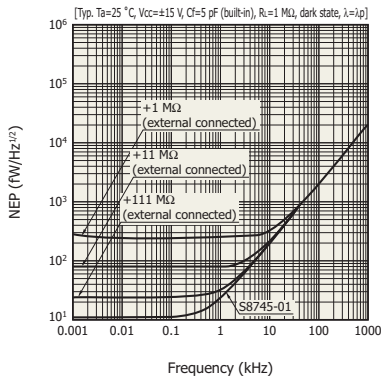
Si photodiodes with preamp for measurement

These are low noise photosensors incorporating a large area Si photodiode, op amp and feedback capacitance. (Typ. $T_a=25\text{ }^\circ\text{C}$)

Type no.	Cooling temperature ΔT ($^\circ\text{C}$)	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity (V/nW)		NEP $\lambda=\lambda_p, f=10\text{ Hz}$ ($\text{fW}/\text{Hz}^{1/2}$)	Built-in feedback resistance (G Ω)	Package	Photo
				$\lambda=200\text{ nm}$	$\lambda=960\text{ nm}$				
S8745-01	Non-cooled	2.4 × 2.4	190 to 1100	0.12	0.52	11	1	Metal	
S8746-01		5.8 × 5.8				15			
S9295	50	10 × 10	340 to 1100	0.9	5.1	4	10	Metal	
S9295-01	30					5			
S9269	Non-cooled	5.8 × 5.8	340 to 1100	-	0.62	12	1	Ceramic	
S9270		10 × 10				16			

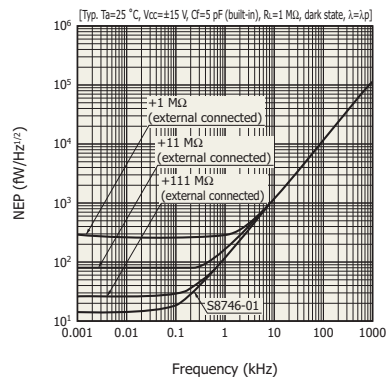
NEP (noise equivalent power) vs. frequency

S8745-01



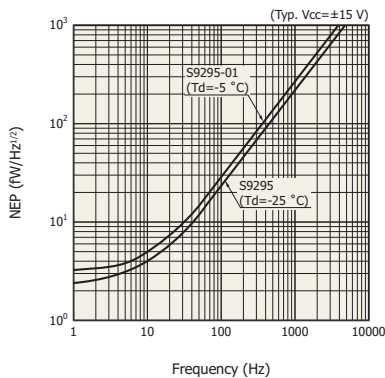
KSPDB0237EA

S8746-01



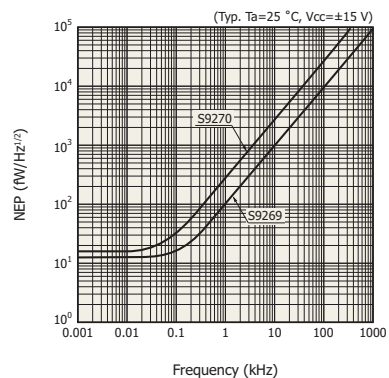
KSPDB0238EA

S9295 series



KSPDB0230EB


S9269, S9270



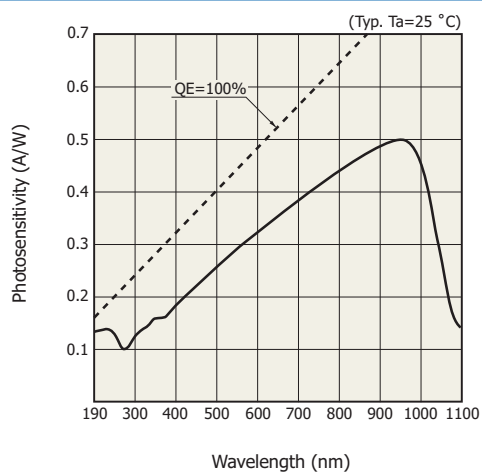
KSPDB0241EA

TE-cooled type Si photodiodes

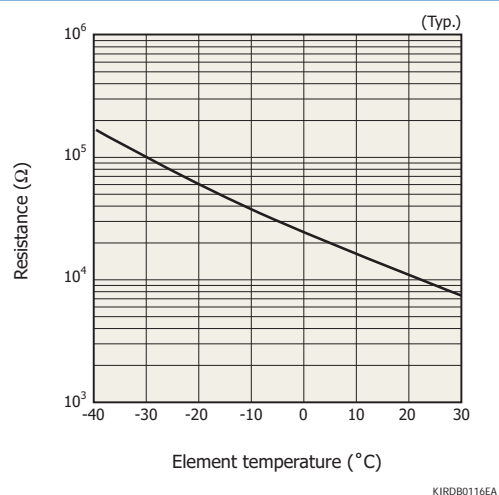
These photosensors combine a UV to near infrared Si photodiode with a TE-cooler and deliver low dark current. (Typ. $T_a=25\text{ }^\circ\text{C}$)

Type no.	Cooling temperature ΔT ($^\circ\text{C}$)	Photosensitive area size (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current $V_R=10\text{ mV}$ (pA)	NEP ($\text{W}/\text{Hz}^{1/2}$)	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	1.3×10^{-14}		
S3477-03		2.4 × 2.4			10	8.1×10^{-15}	TO-66	
S3477-04		5.8 × 5.8			25	1.3×10^{-14}		

Spectral response



Thermistor temperature characteristics











Si photodiodes for X-ray detection

Si photodiodes with scintillator

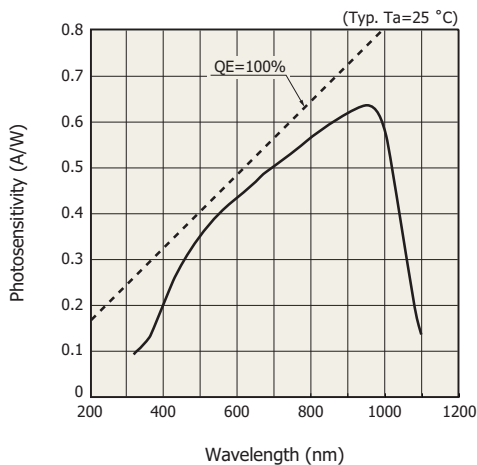
These detectors are comprised of a Si photodiode coupled to a scintillator. Ceramic scintillators have sensitivity to X-rays about 1.2 times higher than CWO and offer high reliability. CsI scintillators also have high sensitivity and are low-cost.

The S11212 and S11299 series photodiode arrays have a back-illuminated structure. They realize superb spectral response and sensitivity uniformity compared to our previous products. (Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

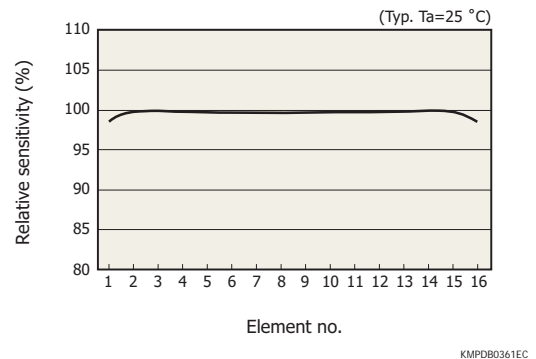
Type no.	Scintillator	Photosensitive area size /element (mm)	Number of elements	Dark current max. $V_R=10\text{ mV}$ (pA)	X-ray sensitivity* (nA)	Package	Photo
S8559	CsI(Tl)	5.8 × 5.8	1	50	52	Ceramic	
S8193	GOS ceramic				30		
S11212-121	CsI(Tl)	1.175 × 2.0	16	30	6.0	Glass epoxy	
S11212-321	GOS ceramic				3.5		
S11212-421	Phosphor sheet				3.0		
S11299-121	CsI(Tl)				6.0		
S11299-321	GOS ceramic				3.5		
S11299-421	Phosphor sheet				3.0		

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

Spectral response (S11212/S11299 series; without scintillator)



Uniformity (S11212/S11299 series; without scintillator)



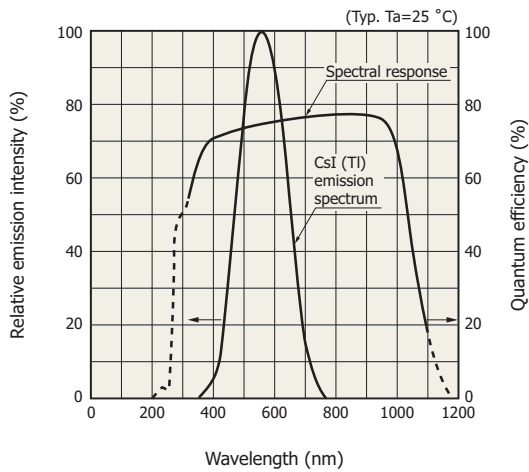
* Spectral response characteristics include the transmittance and reflectance of the adhesive resin used to bond a scintillator.

KMPDB0360EB

KMPDB0361EC

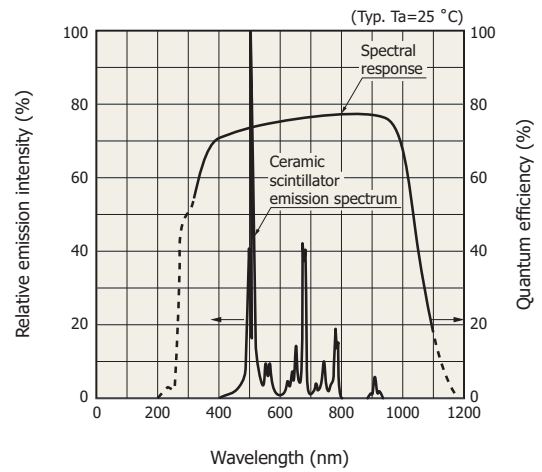
Emission spectrum of scintillator and spectral response

S11212/S11299-121



KSPDB0282EC

S11212/S11299-321



KSPDB0281EC

Typical scintillator characteristics

(Typ. Ta=25 °C)


Parameter	Condition	CsI(Tl)	GOS ceramic	Unit
Peak emission wavelength		560	512	nm
X-ray absorption coefficient	100 keV	10	7	cm ⁻¹
Refractive index	$\lambda = \lambda_p$	1.7	2.2	-
Decay constant		1	3	μ s
Afterglow	100 ms after X-ray turn off	0.3	0.01	%
Density		4.51	7.34	g/cm ³
Color		Transparent	Light yellow-green	-
Sensitivity nonuniformity		± 10	± 5	%

Large area Si PIN photodiodes

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 high voltages, these Si PIN photodiodes operate at high reverse voltages allowing a high-speed response despite the large photosensitive areas.

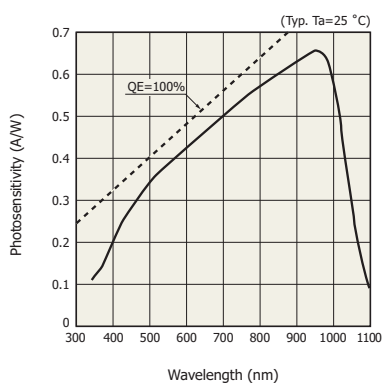
The S3590-18/-19 are violet sensitivity enhanced type and the S3590-19 is an unsealed type. To improve photodiode-to-scintillator coupling efficiency, we also offer the S8650 with epoxy resin coating window processed to have a flat surface.

(Typ. Ta=25 °C, unless otherwise noted)

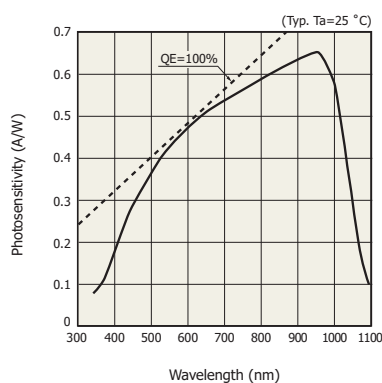
Type no.	Window	Photosensitive area size (mm)	Depletion layer thickness V _R =70 V (mm)	Spectral response range (nm)	Photosensitivity λ=960 nm (A/W)	Dark current max. V _R =70 V (nA)	Terminal capacitance V _R =70 V f=1 MHz (pF)	Package	Photo
S3590-08	Epoxy resin	10 × 10	0.3	340 to 1100	0.66	6	40	Ceramic	
S3590-09	Unsealed								
S3590-18	Epoxy resin				0.65	10			
S3590-19	Unsealed								
S8650	Epoxy resin				0.66	6			

Spectral response

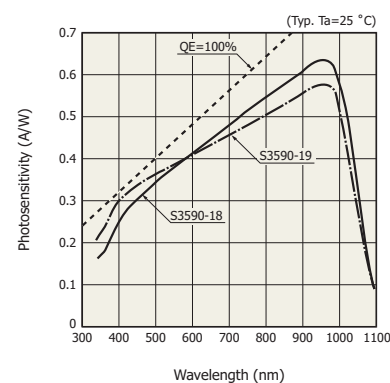
S3590-08, S8650



S3590-09

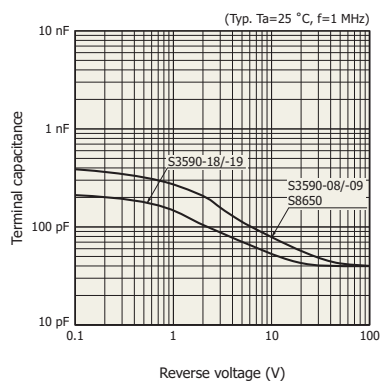


S3590-18/-19

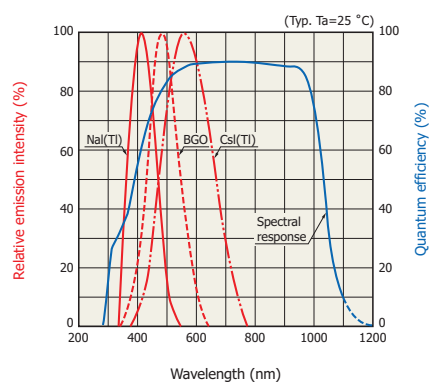


Terminal capacitance vs. reverse voltage





S3590 series, S8650



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

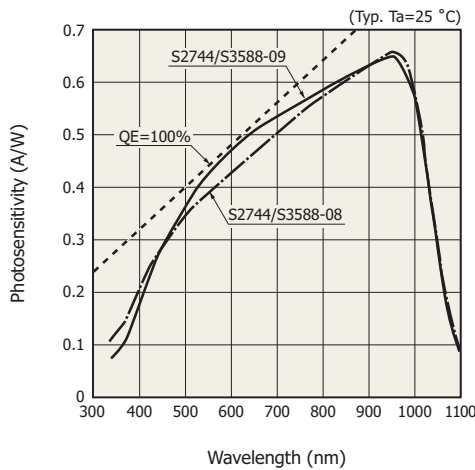


(Typ. Ta=25 °C, unless otherwise noted)

Type no.	Window	Photosensitive area size (mm)	Depletion layer thickness V _R =70 V (mm)	Spectral response range (nm)	Photosensitivity λ=960 nm (A/W)	Dark current max. V _R =70 V (nA)	Terminal capacitance V _R =70 V f=1 MHz (pF)	Package	Photo				
S2744-08	Epoxy resin	10 × 20	0.3	340 to 1100	0.66	10	85	Ceramic					
S2744-09	Unsealed												
S3204-08	Epoxy resin	18 × 18							20	130	30	300	
S3204-09	Unsealed												
S3584-08	Epoxy resin	28 × 28							10	40			
S3584-09	Unsealed												
S3588-08	Epoxy resin	3 × 30											
S3588-09	Unsealed												

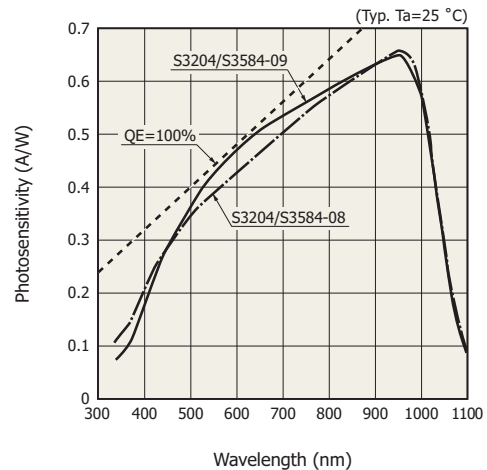
Spectral response

S2744/S3588 series



KPINB0265EE

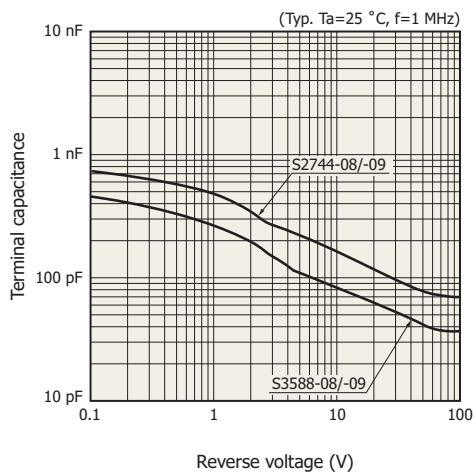
S3204/S3584 series



KPINB0277EC

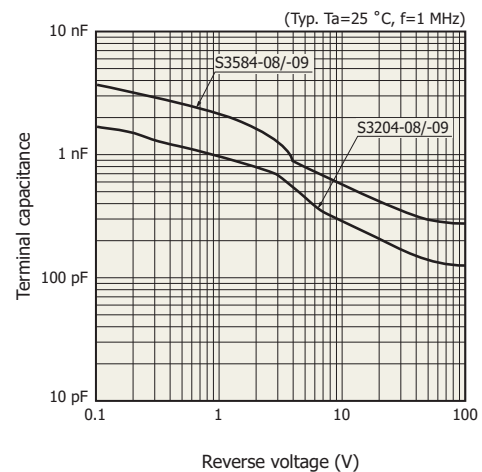
Terminal capacitance vs. reverse voltage

S2744/S3588 series



KPINB0222EA

S3204/S3584 series



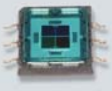




KPINB0230EC

Special application Si photodiodes

RGB color sensors

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

(Typ. Ta=25 °C, unless otherwise noted)

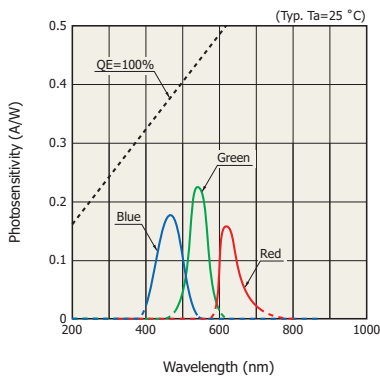
Type no.	Spectral response range (nm)		Peak sensitivity wavelength (nm)	Photosensitivity $\lambda=\lambda_p$ (A/W)		Dark current $V_R=1V$ Total number of elements max. (pA)	Photosensitive area size (mm)		Package	Photo
	Blue	Green		Blue	Green		Blue	Green		
S7505-01	Blue	400 to 540	460	Blue	0.18	200	Blue	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*1	Blue	400 to 540	460	Blue	0.18	100	φ2 / 3-segment		Surface mount type plastic	
	Green	480 to 600	540	Green	0.23					
	Red	590 to 720	620	Red	0.16					
S9702*1	Blue	400 to 540	460	Blue	0.18	50	1 × 1 / 3-segment		Surface mount type, small plastic	
	Green	480 to 600	540	Green	0.23					
	Red	590 to 720	620	Red	0.16					
S10917-35GT	Blue	390 to 530	460	Blue	0.2	50	1 × 1 / 3-segment		Surface mount type, small, glass epoxy	
	Green	470 to 600	540	Green	0.23					
	Red	590 to 680	620	Red	0.17					
S10942-01CT	See the spectral response.			Blue	0.21*2	50	1 × 1 / 3-segment		Surface mount type, small plastic	
				Green	0.25*2					
				Red	0.45*2					

*1: If excessive vibration is continuously applied to the glass filter, there is a risk that the filter may come off, so secure the glass filter with a holder.

*2: Blue: $\lambda=460$ nm, Green: $\lambda=540$ nm, Red: $\lambda=640$ nm

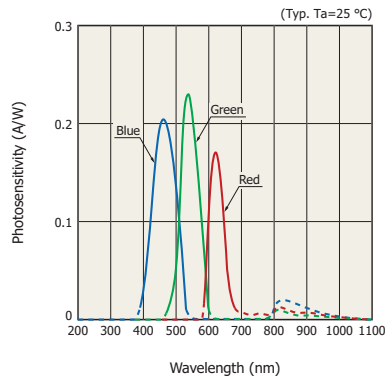
Spectral response

S7505-01, S9032-02, S9702



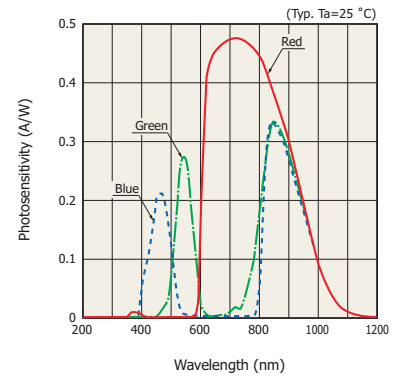
KMPDB0217EB

S10917-35GT



KSPDB0295EA

S10942-01CT






KSPDB0287EA

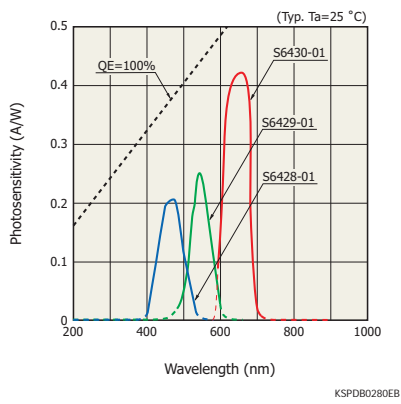
This sensor also has sensitivity in the infrared region, so cut off infrared light as needed.

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

(Typ. Ta=25 °C, unless otherwise noted)

Type no.	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photosensitivity $\lambda=\lambda_p$ (A/W)	Dark current $V_R=1$ V max. (pA)	Photosensitive 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



Violet/blue sensitivity enhanced type

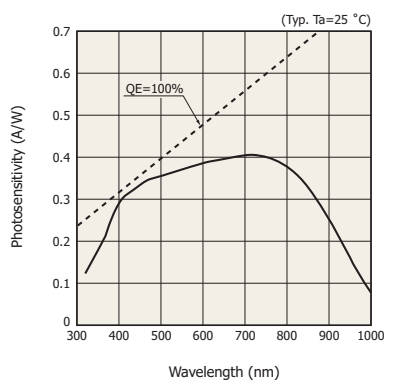
These are photodiodes for blue laser diode detection.

(Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

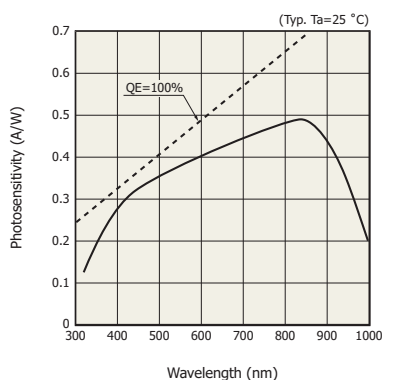
Type no.	Cutoff frequency (MHz)	Photosensitive area size (mm)	Peak sensitivity wavelength (nm)	Photo-sensitivity (A/W)	Dark current max. (nA)	Terminal capacitance $f=1\text{ MHz}$ (pF)	Package	Photo
S5973-02	1000 ($V_R=3.3\text{ V}$)	$\phi 0.4$	760	0.3 ($\lambda=410\text{ nm}$)	0.1 ($V_R=3.3\text{ V}$)	1.6 ($V_R=3.3\text{ V}$)	TO-18	
S9195	50 ($V_R=10\text{ V}$)	5×5	840	0.28 ($\lambda=405\text{ nm}$)	5 ($V_R=10\text{ V}$)	60 ($V_R=10\text{ V}$)	TO-8	
S3994-01	20 ($V_R=30\text{ V}$)	10×10	960	0.25 ($\lambda=400\text{ nm}$)	10 ($V_R=30\text{ V}$)	40 ($V_R=30\text{ V}$)	Ceramic	

Spectral response

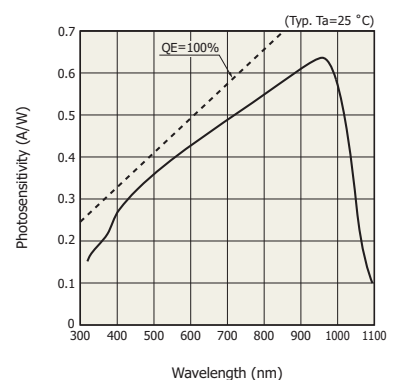
S5973-02



S9195

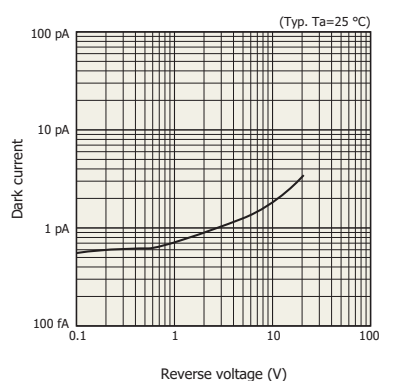


S3994-01

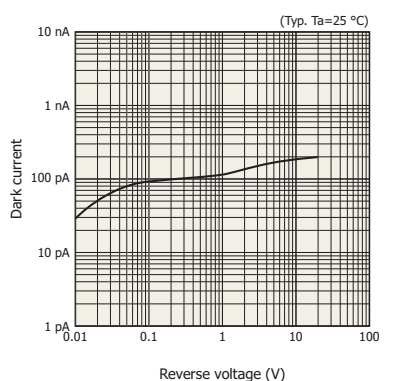


Dark current vs. reverse voltage

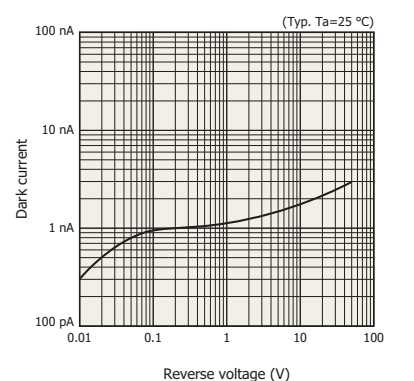
S5973-02



S9195


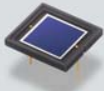
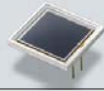
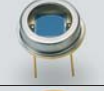
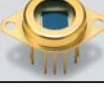


S3994-01



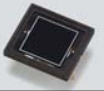
For VUV (vacuum ultraviolet) detection

These Si photodiodes are specially optimized for excimer laser detection (ArF: 193 nm, KrF: 248 nm): sensitive in the vacuum UV (VUV) range. (Typ. Ta=25 °C, unless specified otherwise)

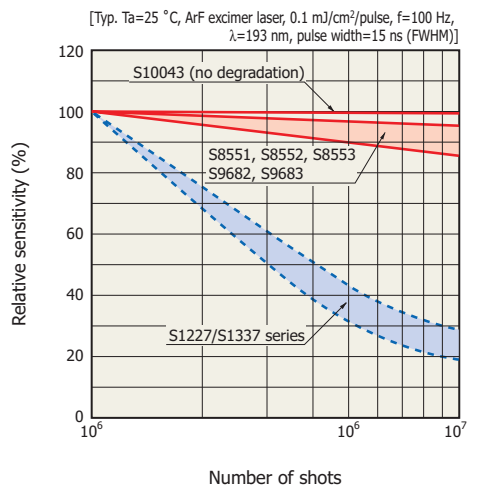
Type no.	Photosensitivity $\lambda=193$ nm (A/W)	Dark current $V_R=10$ mV max. (nA)	Photosensitive area size (mm)	Package	Photo
S8551	0.06	0.5	5.8 × 5.8	TO-8 (unsealed)	
S8552		1.0	10 × 10	Ceramic (unsealed)	
S8553		5.0	18 × 18		
S9682		0.5	5.8 × 5.8	TO-8	
S9683		1.0	10 × 10	1-inch metal	

High reliability type

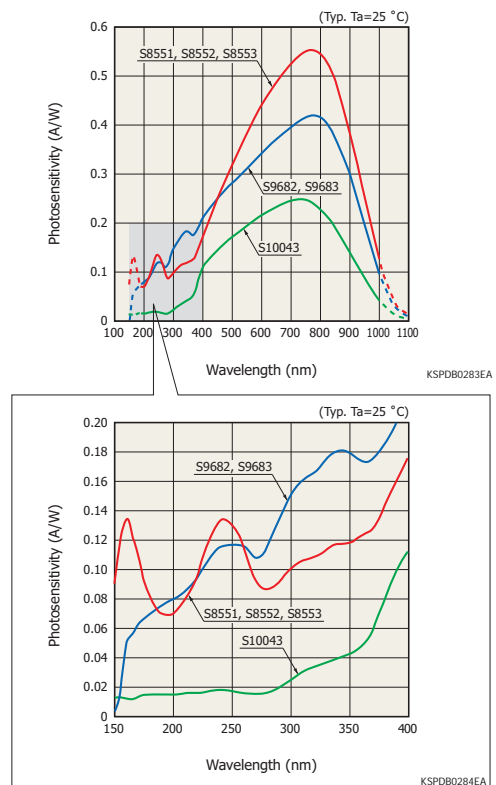
The S10043 is greatly improved in sensitivity stability even after exposure to ArF ($\lambda=193$ nm) excimer laser. (Typ. Ta=25 °C, unless specified otherwise)

Type no.	Photosensitivity $\lambda=193$ nm (A/W)	Dark current $V_R=10$ mV max. (nA)	Photosensitive area size (mm)	Package	Photo
S10043	0.015	1.0	10 × 10	Ceramic (unsealed)	

Variation in sensitivity due to UV exposure




Spectral response

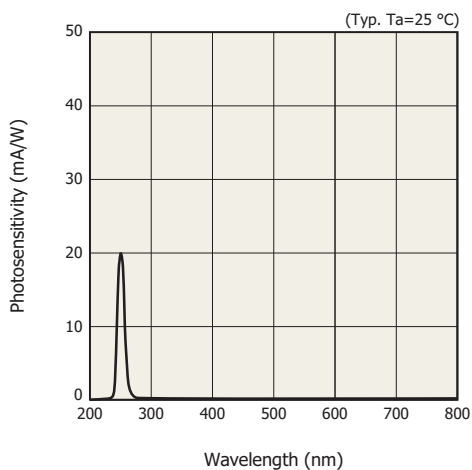


For monochromatic light detection

This photosensor uses an interference filter and has high sensitivity only to monochromatic light. (Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

Type no.	Peak sensitivity wavelength (nm)	Spectral response half-width (nm)	Photosensitivity $\lambda=254\text{ nm}$ (A/W)	Dark current $V_R=10\text{ mV max.}$ (pA)	Photosensitive area size (mm)	Package	Photo
S12742-254	254	10	0.018	25	3.61 × 3.61	TO-5	

Spectral response

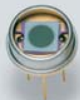


KSPDB0333EA

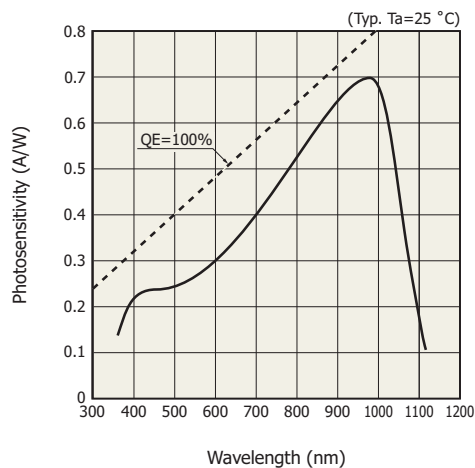
Note: Different types compatible with wavelengths other than the 254 nm center wavelength are also available (made-to-order product).

For YAG laser detection

This is a Si PIN photodiode developed to measure infrared energy emitted from YAG lasers (1.06 μm). (Typ. $T_a=25\text{ }^\circ\text{C}$, unless otherwise noted)

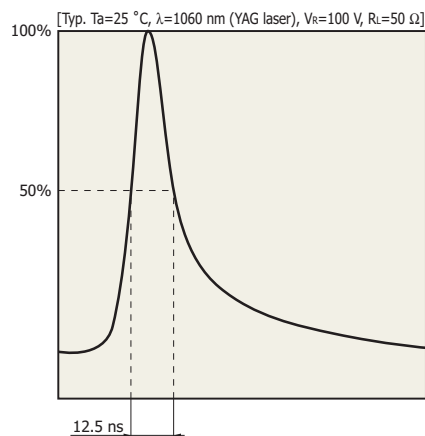
Type no.	Photosensitive area size (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photosensitivity $\lambda=1060\text{ nm}$ (A/W)	Dark current $V_R=100\text{ V max.}$ (nA)	Rise time $\lambda=1060\text{ nm}$ $V_R=100\text{ V, } R_L=50\text{ }\Omega$ (ns)	Package	Photo
S3759	$\phi 5$	360 to 1120	980	0.38	10	12.5	TO-8	

Spectral response



KPINB0279EB




Response waveform



KPINB0280EC

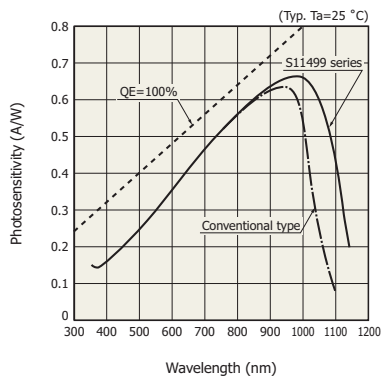
Infrared sensitivity enhanced type

These are Si PIN photodiodes that offer enhanced near-infrared sensitivity due to a MEMS structure formed on the back side of the photodiode. (Typ. Ta=25°C, unless otherwise noted)

Type no.	Photosensitive area size (mm)	Spectral response range (nm)	Photosensitivity $\lambda=1060$ nm (A/W)	Dark current max. (nA)	Terminal capacitance f=1 MHz (pF)	Package	Photo
S11499	$\phi 3$	360 to 1140	0.6	5 (V _R =20 V)	13 (V _R =20 V)	TO-5	
S11499-01	$\phi 5$		0.6	10 (V _R =20 V)	33 (V _R =20 V)	TO-8	
S12028	$\phi 1.2$		0.5 (V _R =10 V)	2 (V _R =10 V)	4 (V _R =10 V)	TO-18	

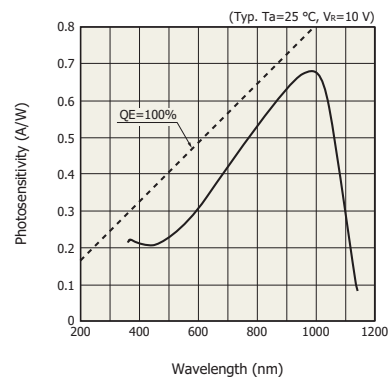
Spectral response

S11499 series



KPINB0368EB

S12028

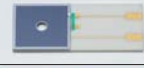



KPINB0376EC

For electron beam detector

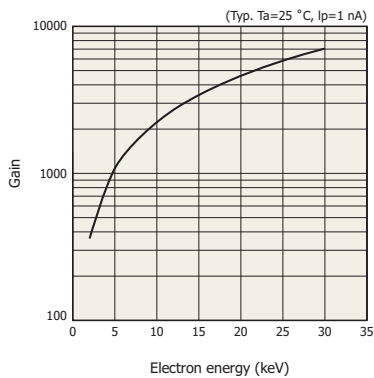
These photodiodes directly detect low energy (10 keV or less) electron beams with high sensitivity. The structure with an extremely thin dead layer (insensitive layer) makes these photodiodes ideal for backscattered electron detector for Scanning Electron Microscope (SEM).

(Typ. Ta=25 °C, unless otherwise noted)

Type no.	Incident electron energy range (keV)	Output current (μ A)	Dark current V _R =5 V max. (nA)	Terminal capacitance V _R =5 V (pF)	Cutoff frequency V _R =5 V (MHz)	Electron multiplying gain	Package	Photo
S11141	2 to 30	1.1	50	500	4	1100 (Electron energy: 5 keV)	Thin ceramic (unsealed)	
S11142		(Electron energy: 5 keV) I _p *2=1 nA	25	250	7			

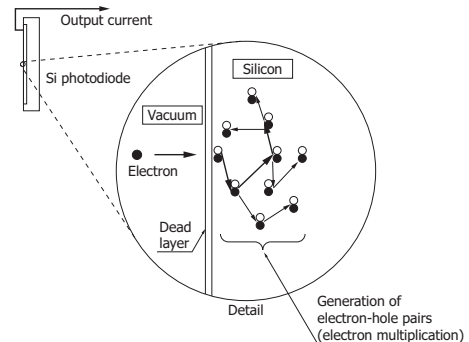
*2: Probe current

Gain vs. electron energy



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Electron multiplication principle


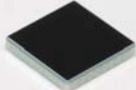


Electrons generate ions as they pass through silicon. This ionization process generates a large number of electron-hole pairs that then multiply the number of electrons. The electron multiplication can boost the output current by approximately 1000 times at an input electron energy of 5 keV (refer to "Gain vs. electron energy").

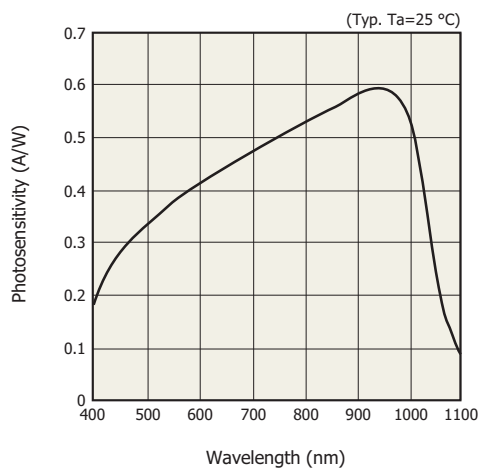
KSPDC0064EC

CSP (chip size package) type

The S10356-01 and S10355-01 are back-illuminated type photodiodes designed to minimize the dead areas at the device edges by using a CSP (chip size package) structure. The CSP also allows using multiple devices in a tiled format. (Typ. Ta=25 °C)

Type no.	Package size (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Photo-sensitivity $\lambda=960$ nm (A/W)	Short circuit current 100 lx, 2856 K (μ A)	Terminal capacitance $V_R=0$ V, $f=10$ kHz (pF)	Package	Photo
S10356-01	3 × 3	400 to 1100	960	0.59	5	60	PWB (unsealed)	
S10355-01	7.52 × 7.52				40	500		

Spectral response



Related products of Si photodiode

RGB color sensor modules

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



(Typ. Ta=25 °C)

Type no.	Photosensitivity (V/mW)			Frequency bandwidth (kHz)	Supply voltage (V)
	$\lambda_p=620$ nm	$\lambda_p=540$ nm	$\lambda_p=460$ nm		
C9303-03	-14	-20	-18	DC to 16	+2.7 to +5.5
C9303-04	-108	-156	-122	DC to 2.4	

Color sensor evaluation circuit

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 (sold separately)

Applications

- Evaluation of Hamamatsu color sensor



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

Type no.	Output offset voltage $Z_t=5.1 \times 10^5$ V/A [without photodiode] (mV)		Conversion impedance (V/A)	Frequency bandwidth [without photodiode] (kHz)	Supply voltage (V)
	Typ.	Max.			
C9331	±40	±50	1×10^5 to 5.1×10^5	DC to 14	+7 to +15

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 $\overline{\text{EOS}}$ pulse output
- Choice of gain (conversion impedance): 1×10^6 V/A or 1×10^7 V/A
- Single power supply operation: +12 V (AC adapter)



Type no.	Applicable sensor
C9004	Hamamatsu S4111-16 series, S5668 series photodiode arrays are directly mountable on board.

Photodiode modules

Integrates a Si photodiode for precision photometry with low-noise amplifier.

The C10439 series is a high-precision photodetector that combines a photodiode and current-to-voltage conversion amplifier.



Features

- Easy handling
- Two switchable photo-sensitivity ranges
- Compact size

(Typ. $T_a=25^\circ\text{C}$)

Type no.	Photosensitive area size (mm)		Photosensitivity $\lambda=\lambda_p$		Conversion impedance		Frequency bandwidth -3 dB		Supply voltage (V)	Dimensions W × D × H (mm)
			High range (mV/nW)	Low range (mV/nW)	High range (V/A)	Low range (V/A)	High range (Hz)	Low range (Hz)		
C10439-01	Si	2.4 × 2.4	500	5	10^9	10^7	DC to 10	DC to 1000	External power supply ± 5 to ± 12	19 × 46 × 52
C10439-02		5.8 × 5.8								
C10439-03		10 × 10								
C10439-07		2.4 × 2.4	0.5	0.005	10^6	10^4	DC to 1000	DC to 100000		
C10439-08		5.8 × 5.8								
C10439-09		10 × 10								
C10439-10	InGaAs	$\phi 1$	1	0.01					19 × 50 × 52	
C10439-11		$\phi 3$								

Signal processing unit for photodiode module

Unit dedicated for photodiode module (C10439 series)

The C10475 converts the output from a photodiode module (C10439 series) into digital signals. Also supplies power to the photodiode module.

Features

- High-resolution digital output (16-bit)
- Data logger function



RS-232C cable is optional.

(Typ. $T_a=25^\circ\text{C}$)

Type no.	Digital output	Minimum measurement time interval (ms)	Supply voltage (V)	Dimensions (W × D × H) (mm)
C10475	Conforms to RS-232C (16-bit)	50	AC adapter (+12) or battery (one 9 V battery)	110 × 100 × 30

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 are optional.

Features

- Three sensitivity ranges
- Selectable operation modes (analog output / digital output)
- Serial connection (RS-232C) with PC
- Data logger function, low battery function

(Typ. Ta=25 °C)

Type no.	Range	Conversion impedance (V/A)	Frequency bandwidth -3 dB (Hz)	Power supply (V)	Dimensions (W × D × H) (mm)
C9329	H	10 ⁹	DC to 16	AC adapter (+12) or battery (one 9 V battery)	115 × 90 × 40
	M	10 ⁷	DC to 1600		
	L	10 ⁵	DC to 1600		

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, etc.
- 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

(Typ. Ta=25 °C)

Type no.	Range	Photosensitivity (mV/μW)	Conversion impedance (V/A)	Frequency bandwidth -3 dB (MHz)	Power supply (V)	Dimensions (W × D × H) (mm)
C6386-01	H	30	10 ⁵	DC to 1	External power supply (±15) or batteries (two 9 V batteries)	115 × 90 × 40
	M	3	10 ⁴	DC to 3		
	L	0.3	10 ³	DC to 10		

High-speed type

- Current-to-voltage conversion amplifier



Features

- C8366: for high speed Si PIN photodiode
C8366-01: for high speed InGaAs photodiode
- Wide bandwidth: DC to 100 MHz typ. (-3 dB; varied by the photodiode used)
- Just inserting the photodiode leads 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

(Typ. Ta=25 °C)

Type no.	Conversion impedance (V/A)	Frequency bandwidth -3 dB (MHz)	Power supply (V)	Dimensions (W × D × H) (mm)
C8366	10 ³	DC to 100	External power supply (±15)	19 × 52 × 46
C8366-01				

Compact type

Current-to-voltage conversion amplifier for low-level-light

Features

- Compact board type for easy assembly
- Usable with photodiodes having large terminal capacitance
- Conversion impedance: 1.0×10^8 V/A



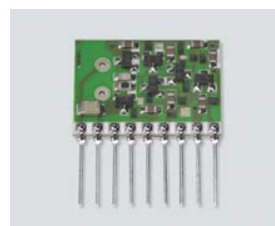
(Typ. Ta=25 °C)

Type no.	Conversion impedance (V/A)	Frequency bandwidth -3 dB (Hz)	Power supply (V)	Dimensions (W × D × H) (mm)
C9051	10^8	DC to 16	AC adapter (+12)	50 × 50 × 19

Charge amplifier

For radiation and high energy particle detection

The 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. The 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 the H4083, so there will be no increase in stray capacitance.



Features

- Low noise
- Compact and lightweight
- Easy handling

Applications

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

(Typ. Ta=25 °C)

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

Description of terms

● 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 photosensitivity or quantum efficiency.

● Photosensitivity: S

This measure of sensitivity is the ratio of photocurrent expressed in amperes (A)—or output voltage expressed in volts (V)—to the incident light expressed in watts (W). It may be represented as either an absolute sensitivity (A/W or V/W unit) 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 photosensitivity, and the spectral response range is defined as the region in which the relative sensitivity is higher than 5% or 10% of the peak value.

● 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):

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

● Short circuit current: Isc

The output current that flows through the photodiode when the load resistance is 0. This is often called “white light sensitivity” with regards to the spectral response, and a tungsten lamp of 2856 K distribution temperature (color temperature) is used for the light source. At Hamamatsu, we indicate the short circuit current at 100 lx illuminance in the table of characteristics in our catalogues.

● Open circuit voltage: Voc

The open circuit voltage is a photovoltaic voltage generated when the load resistance is infinite. The open circuit voltage depends on the light level, but for light levels higher than extremely low levels, it is nearly constant.

● Dark current: Id

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.).

● Shunt resistance: Rsh

The voltage-to-current ratio in the vicinity of 0 V in photodiodes. The shunt resistance is defined as follows: Where Id is the dark current at VR=10 mV.

$$Rsh [\Omega] = \frac{0.01 [V]}{Id [A]}$$

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

● 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 converter using operational amplifier. In Hamamatsu, the terminal capacitance including this junction capacitance plus package stray capacitance is listed.

● 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).

● Cutoff frequency: fc

The frequency at which the photodiode output decreases by 3 dB from the output in the frequency region where the output is constant. The rise time (tr) has a relation with the cutoff frequency (fc) as follows:

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

● 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.

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

● Maximum reverse voltage: VR 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 instantaneously.

Reference (Physical constants related to light and opto-semiconductors)

Constant	Symbol	Value	Unit
Electron charge	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
Thermal energy at room temperature	kT	0.0259 (300 K)	eV
Energy of 1 eV	eV	1.602 × 10 ⁻¹⁹	J
Wavelength equivalent to 1 eV in vacuum	—	1240	nm
Permittivity of vacuum	ε ₀	8.854 × 10 ⁻¹²	F/m
Relative permittivity of silicon	ε _{si}	Approx. 12	—
Relative permittivity of silicon oxide film	ε _{ox}	Approx. 4	—
Band gap energy of silicon	Eg	Approx. 1.12 (25 °C)	eV

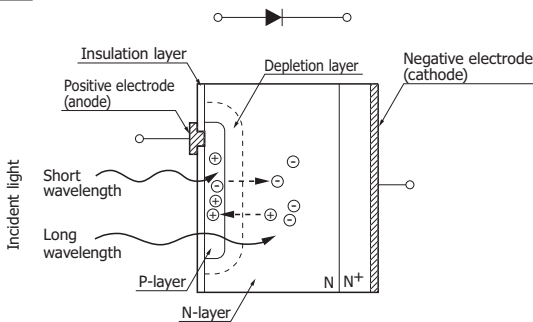
Principle of operation, equivalent circuit

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.

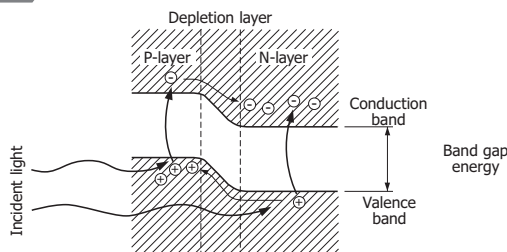
If the light energy is greater than the band gap energy (E_g), the electrons are pulled up into the conduction band, leaving holes in their place in the valence band (see Figure 2). These electron-hole pairs occur throughout the P-layer, depletion layer and N-layer materials. In the depletion layer the 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 an electrode is formed from each of 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



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Figure 2 Si photodiode P-N junction state

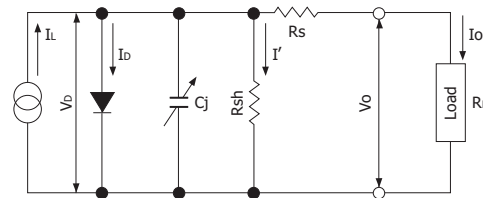


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Equivalent circuit

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

Figure 3 Photodiode equivalent circuit



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- I_L : Current generated by the incident light (proportional to the amount of light)
- V_D : Voltage across the diode
- I_D : Diode current
- C_J : Junction capacitance
- R_{sh}: Shunt resistance
- I' : Shunt resistance current
- R_s : Series resistance
- V_o : Output voltage
- I_o : Output current

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

$$I_o = I_L - I_D - I' = I_L - I_s \left(\exp \frac{q V_D}{k T} - 1 \right) - I' \dots\dots\dots (1)$$

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

The open circuit voltage V_{oc} is the output voltage when I_o equals zero and expressed by equation (2).

$$V_{oc} = \frac{k T}{q} \ln \left(\frac{I_L - I'}{I_s} + 1 \right) \dots\dots\dots (2)$$

If I' is negligible, since I_s increases exponentially with respect to ambient temperature, V_{oc} 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 I_{sc} is the output current when the load resistance (R_L) = 0 and V_o = 0, and is expressed by equation (3).

$$I_{sc} = I_L - I_s \left(\exp \frac{q \times I_{sc} \times R_s}{k T} - 1 \right) - \frac{I_{sc} \times R_s}{R_{sh}} \dots\dots (3)$$

In the above relationship, the 2nd and 3rd terms limit the linearity of I_{sc}. However, since R_s is several ohms and R_{sh} is 10⁷ to 10¹¹ ohms, these terms become negligible over quite a wide range.

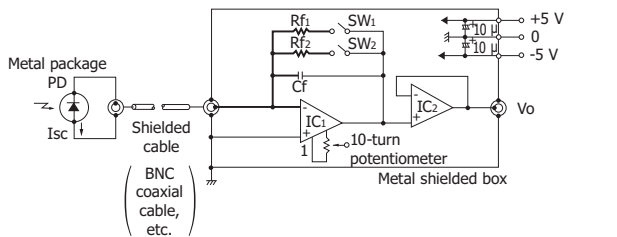
Application circuit examples

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.

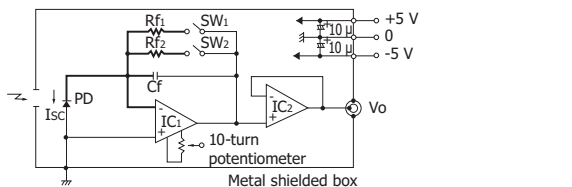
Figure 4 Low-light-level sensor head

(a) Example using shielded cable to connect to photodiode



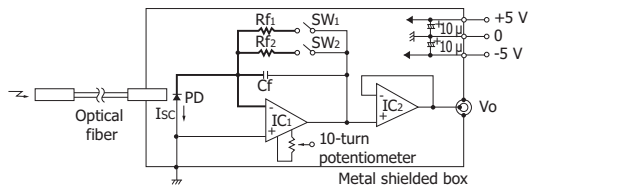
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(b) Example using metal shielded box that contains entire circuit



KSPDC0052EB

(c) Example using optical fiber



KSPDC0053EB

Bold lines should be within guarded pattern or on teflon terminals.

IC1: AD549, OPA124, etc.

IC2: 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.

$$V_o = I_{sc} \times R_f [V]$$

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 us-

ing 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 the C6386-01, C9051 and C9329 photosensor amplifiers optimized for use with photodiodes for low-light-level detection.

Figure 5 Photosensor amplifiers

(a) C6386-01



(b) C9051



(c) C9329

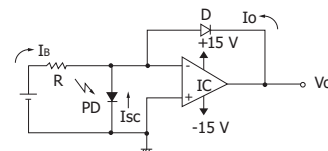


The photodiodes, and coaxial cables with BNC-to-BNC plugs are sold separately.

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 level. 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. Ib is the current source that supplies bias current to the log diode D and sets the circuit operating point. Unless this Ib current is supplied, the circuit will latch up when the photodiode short circuit current Isc becomes zero.

Figure 6 Light-to-logarithmic-voltage conversion circuit



D : Diode of low dark current and low series resistance

Ib : Current source for setting circuit operation point, $I_b \ll I_{sc}$

R : 1 GΩ to 10 GΩ

Io : D saturation current, 10^{-15} to 10^{-12} A

IC: FET-input Op amp, etc.

$$V_o \approx -0.06 \log \left(\frac{I_{sc} + I_b}{I_o} + 1 \right) [V]$$

KPDC0021EA

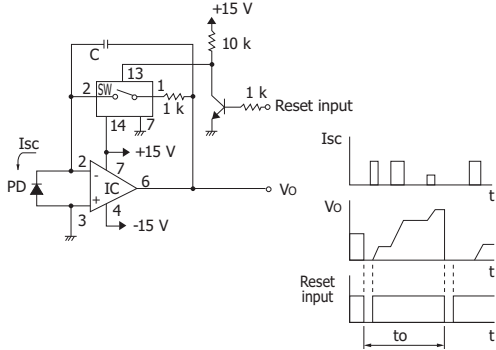
Light integration circuit

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 capaci-

tance C. By measuring the output voltage V_o immediately before reset, the average short circuit current can be obtained from the integration time (t_o) 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.

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.

$$V_o = I_{sc} \times t_o \times \frac{1}{C} [V]$$

KPDC0027EB

Basic illuminometer (1)

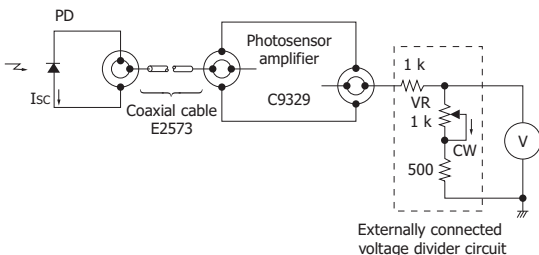
A basic illuminometer circuit can be configured by using Hamamatsu C9329 photosensor amplifier and S9219 Si photodiode with sensitivity corrected to match human eye response. As shown in Figure 8, this circuit can measure illuminance up to a maximum of 1000 lx by connecting the output of the C9329 to 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 white light source.

To calibrate this circuit, first select the L range on the C9329 and then turn the variable resistor VR clockwise until it stops. Block the light to the S9219 while in this state, and rotate the zero adjusting volume control on the C9329 so that the voltmeter reads 0 mV. Next turn on the white light source, and adjust the distance between the white light source and the S9219 so that the voltmeter display shows 0.225 V. (The illuminance on the 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 the C9329.

Figure 8 Basic illuminometer (1)



PD: S9219 (4.5 μA/100 lx)

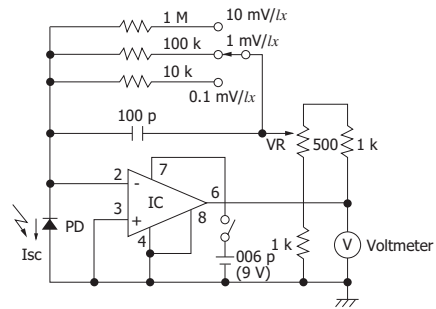
KSPDC0054EB

Basic illuminometer (2)

This is a 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)



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

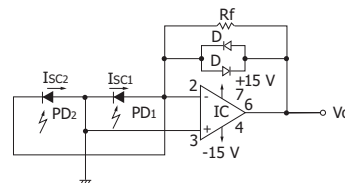
KPDC0018ED

Light balance detection circuit

Figure 10 shows a light balance detector circuit utilizing two Si photodiodes PD1 and PD2 connected in reverse-parallel and an op amp current-voltage converter circuit.

The photoelectric sensitivity is determined by the feedback resistance R_f . The output voltage V_o of this circuit is zero if the amount of light entering the two photodiodes PD1 and PD2 is equal. By placing two diodes D in reverse parallel with each other, V_o 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.

Figure 10 Light balance detection circuit



PD: S1226/S1336/S2386 series, etc.
 IC : LF356, etc.
 D : ISS226, etc.

$$V_o = R_f \times (I_{sc2} - I_{sc1}) [V]$$

($V_o < \pm 0.5 V$)

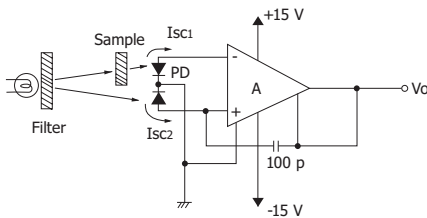
KPDC0017EB

Light absorption meter

This is a light absorption meter using a dedicated IC and two photodiodes which provides a logarithmic ratio of two current inputs (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 V_o 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 V_o can be directly read as $A = -V_o$ [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



A : Log amp
PD: S5870, etc.

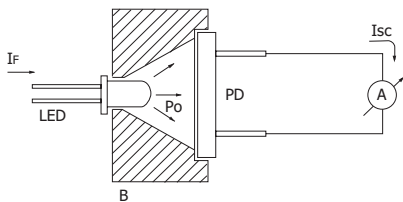
$$V_o = \log (I_{sc1}/I_{sc2}) \text{ [V]}$$

KPDC0025EC

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 photosensitivity 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



A : Ammeter, 1 mA to 10 mA
PD: S2387-1010R
B : Aluminum block, inner Au plating
S : Photosensitivity of Si photodiode
Refer to the spectral response chart in the datasheets.
S2387-1010R: $S \approx 0.58 \text{ A/W}$ ($\lambda=930 \text{ nm}$)
Po: Total emission

$$P_o \approx \frac{I_{sc}}{S} \text{ [W]}$$

KPDC0026EA

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.

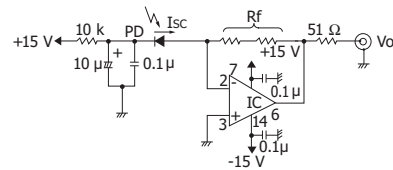
When the frequency band exceeds 1 MHz, the lead inductance of each component and stray capacitance from feedback resistance R_f exert drastic effects on device response speed. That effect can be minimized by using chip components to reduce the component lead inductance, and connecting multiple resistors 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.

Figure 13 High-speed photodetector circuit (1)



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

$$V_o = -I_{sc} \times R_f \text{ [V]}$$

KPDC0020ED

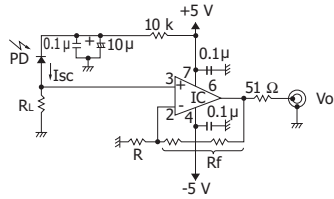
Figure 14 Photosensor amplifier C8366



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)".

Figure 15 High-speed photodetector circuit (2)

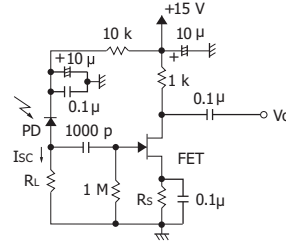


- PD : High-speed PIN photodiode
(S5971, S5972, S5973, S9055, S9055-01, etc.)
 RL, R, Rf: Determined by recommended conditions of the op amp
 IC : AD8001, etc.

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

KPDC0015EE

Figure 17 AC photodetector circuit (2)



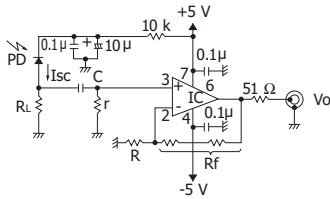
- PD : High-speed PIN photodiode (S2506-02, S5971, S5972, S5973, etc.)
 RL : Determined by sensitivity and "time constant of Ct" of photodiode
 Rs : Determined by operation point of FET
 FET: 2SK362, etc.

KPDC0034EA

AC photodetector circuit (1)

The AC photodetector circuit in Figure 16 uses load resistance RL 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)".

Figure 16 AC photodetector circuit (1)



- PD : High-speed PIN photodiode
(S5971, S5972, S5973, S9055, S9055-01, etc.)
 RL, R, Rf, r: Determined by recommended conditions of the op amp
 IC : AD8001, etc.

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

KPDC0034EA

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 FSO (free space optics) and optical remote controls, etc. In Figure 17 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.

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