HAMAMATSU

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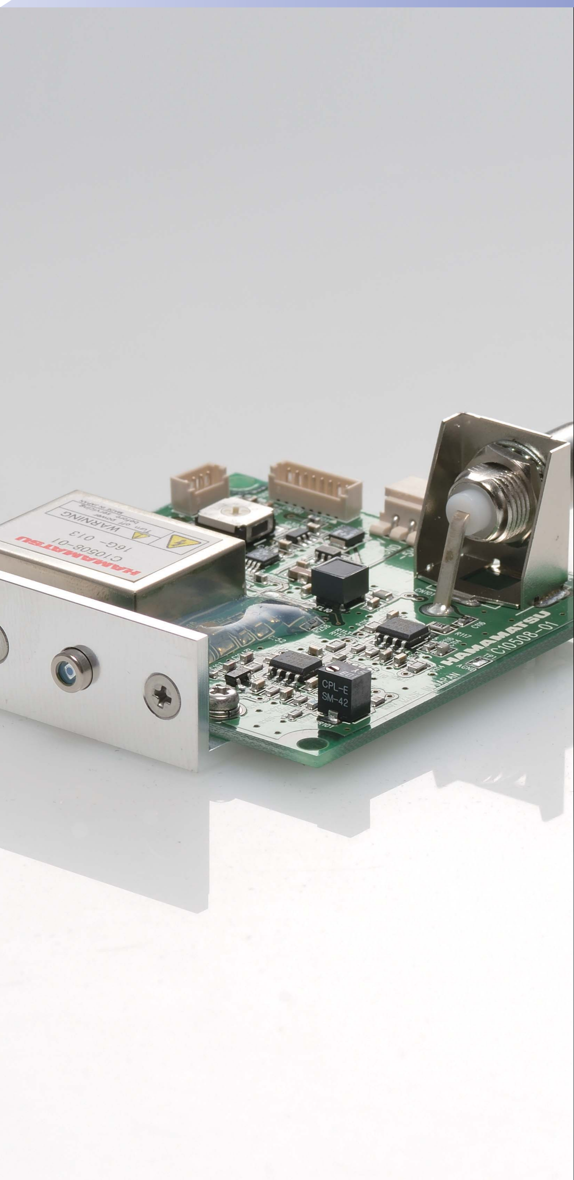
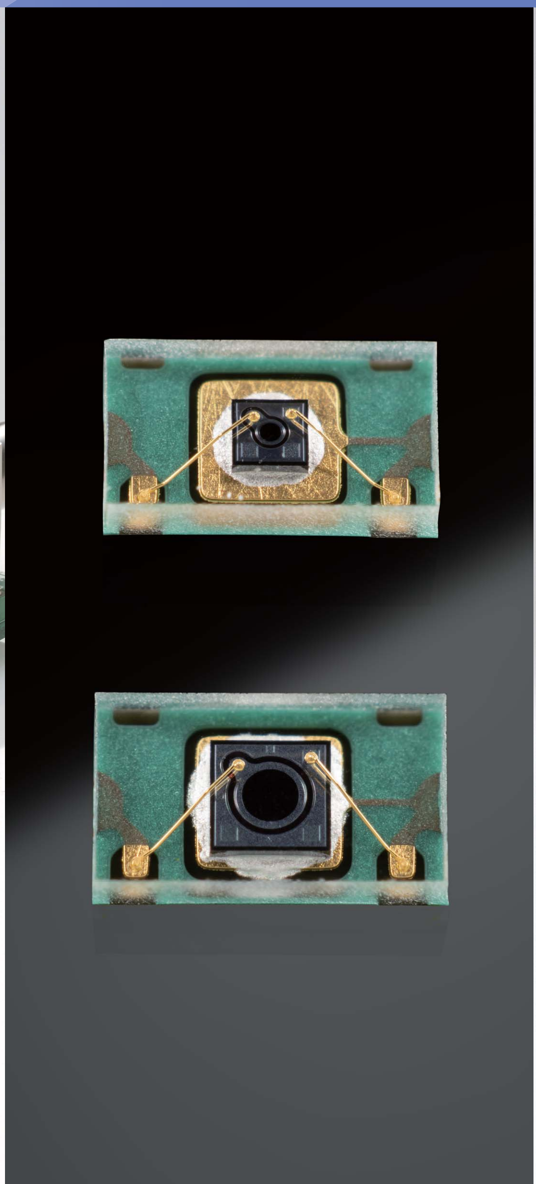
Selection guide - March 2019

Si APD (avalanche photodiode)

High-speed, high sensitivity photodiodes having an internal gain mechanism



■ APD module C10508-01



■ Surface mount type S14645-02, S14645-05

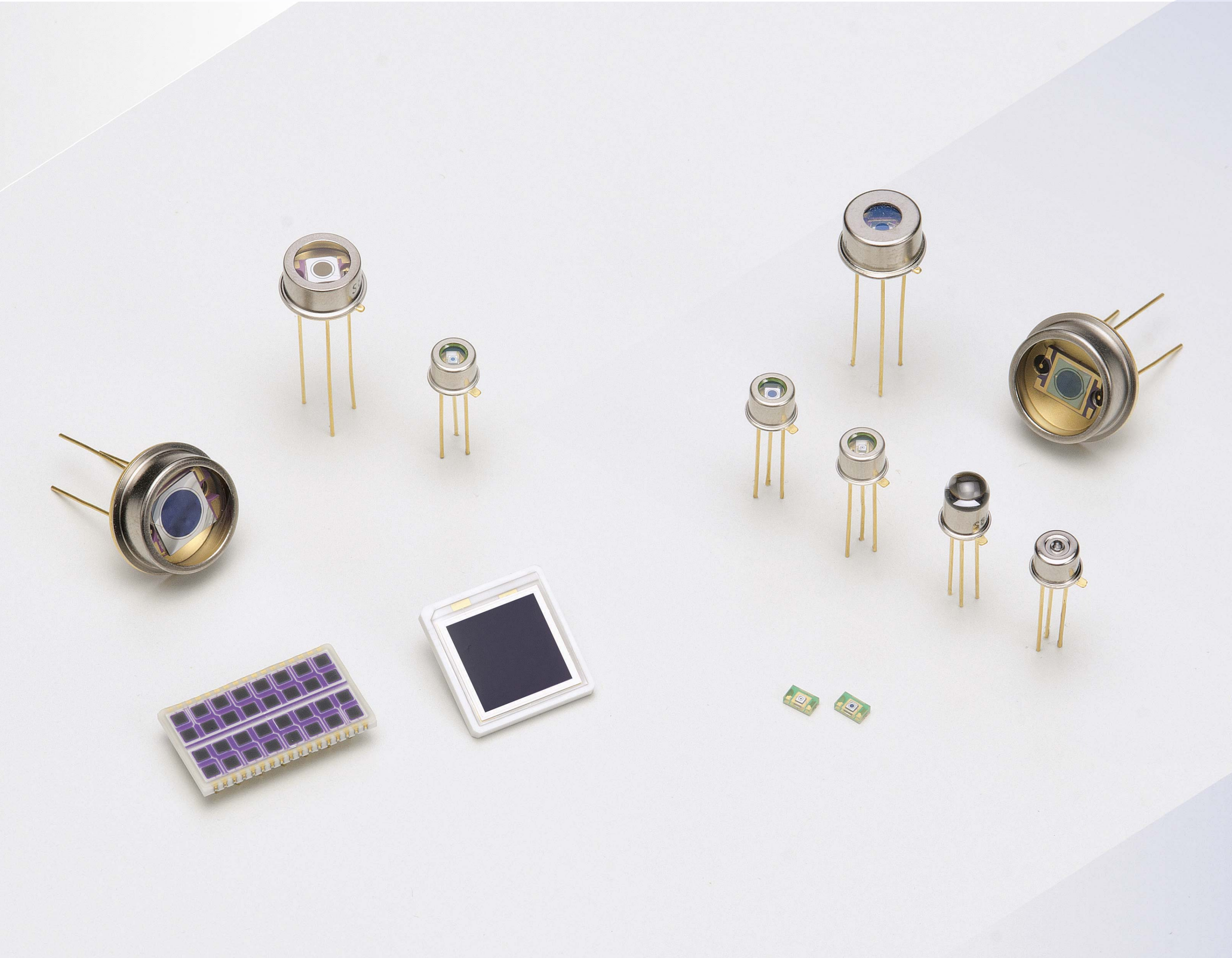
■ Near infrared type S2385

HAMAMATSU PHOTONICS K.K.

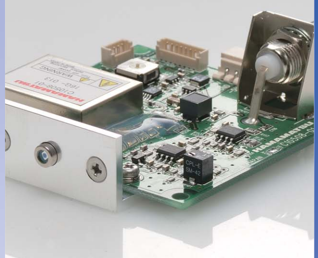
Si Avalanche Photodiode

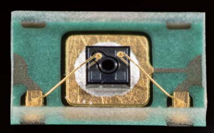
Si APD

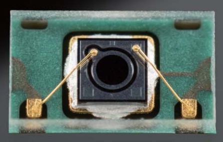
High-speed, high sensitivity photodiodes having an internal gain mechanism

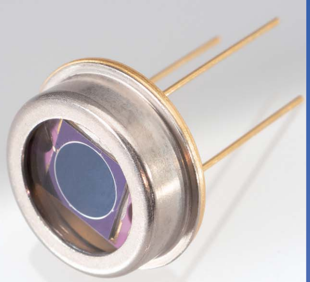


Contents









Si APD (avalanche photodiode)

The APD is a high-speed, high-sensitivity photodiode that internally multiplies photocurrent when reverse voltage is applied. The APD, having a signal multiplication function inside its element, achieves higher S/N than the PIN photodiode and can be used in a wide range of applications such as high-accuracy rangefinders and low-light-level detection that use scintillators. Though the APD can detect lower level light than the PIN photodiode, it does require special care and handling such as the need for higher reverse voltage and more detailed consideration of its temperature-dependent gain characteristics.

Si APD

Type		Recommended wavelength (nm)	Peak sensitivity wavelength (nm)	Type no.	Package	Features	Applications	Page
Short wavelength type	Low-bias operation	200 to 650	620	S12053 series, etc.	Metal	Enhanced sensitivity in the UV to visible region	· Low-light-level detection · Analytical instruments	5
	Low terminal capacitance	320 to 650	600	S8664-K series	Metal			6
				S8664-55/-1010	Ceramic			
				S8550-02				
Near infrared type	Low-bias operation	600 to 800	800	S12023 series, etc.	Metal	High sensitivity in the near IR region and low bias voltage (operating voltage)	· FSO · Optical rangefinders · Optical fiber communication	7
				S14644 series	Surface mount type	Compact, thin, low cost	· Optical rangefinders · Laser radars · FSO	
			760	S14643-02		Compact, thin, low cost, high-speed		
	Low temperature coefficient	600 to 800	800	S12060 series, etc.	Metal	Low temperature coefficient of the bias voltage, easy gain adjustment	· FSO · Optical rangefinders · Optical fiber communication	9
	900 nm band, low terminal capacitance	800 to 1000	860	S12426 series, etc.	Metal	Enhanced sensitivity in the 900 nm band	· Optical rangefinders · Laser radars	10
			840	S14645-02/-05	Surface mount type	Compact, thin		
		890 to 910	900	S14645-02F/-05F		Compact, thin, with filter		
	1000 nm band/ high sensitivity	900 to 1150	960	S11519 series	Metal	Enhanced sensitivity in the 1000 nm band, low bias voltage (operating voltage)	· YAG laser detection, etc.	11
	TE-cooled type	400 to 1000	800	S4315 series	Metal	High S/N	· Low-light-level detection	

APD modules

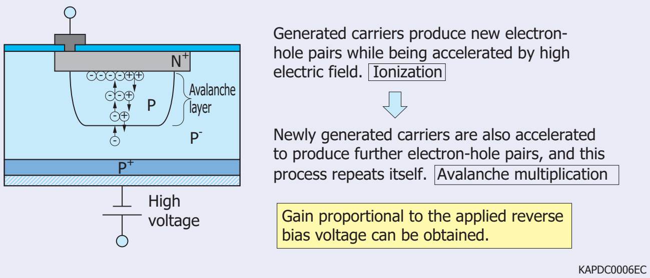
Type	Type no.	Features	Page
Standard type	C12702 series	Contains near infrared type or short wavelength type APD. FC/SMA fiber adapters are also available.	12
High-sensitivity type	C12703 series	High gain type for low-light-level detection	
High-stability type	C10508-01	Digital temperature compensation type, high stability APD module	13
High-speed type	C5658	Can be used over a wide frequency range (up to 1 GHz)	

Principle of avalanche multiplication

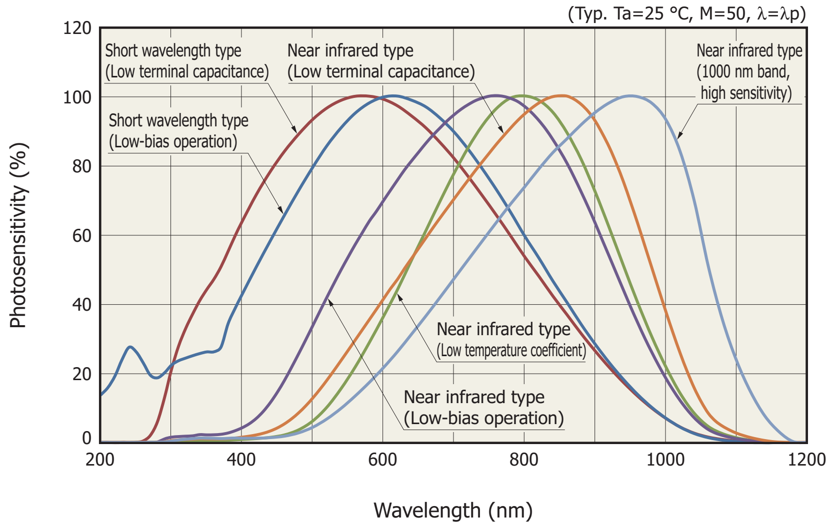
The photocurrent generation mechanism of the APD is the same as that of a normal photodiode. When light enters a photodiode, electron-hole pairs are generated if the light energy is higher than the band gap energy. The ratio of the number of generated electron-hole pairs to the number of incident photons is defined as the quantum efficiency (QE), expressed in percent (%). The mechanism by which carriers are generated inside an APD is the same as in a photodiode, but the APD is different from a photodiode in that it has a function to multiply the generated carriers.

When electron-hole pairs are generated in the depletion layer of an APD with a reverse voltage applied to the PN junction, the electric field causes the electrons to drift toward the N^+ side and the holes to drift toward the P^+ side. The higher the electric field strength, the higher the drift speed of these carriers. However, when the electric field reaches a certain level, the carriers are more likely to collide with the crystal lattice so that the drift speed becomes saturated at a certain speed. If the electric field is increased even further, carriers that escaped the collision with the crystal lattice will have a great deal of energy. When these carriers collide with the crystal lattice, a phenomenon takes place in which new electron-hole pairs are generated. This phenomenon is called ionization. These electron-hole pairs then create additional electron-hole pairs, which generate a chain reaction of ionization.

Principle of APD operation



Spectral response (Si APD) For the absolute sensitivity values, see the individual datasheets.



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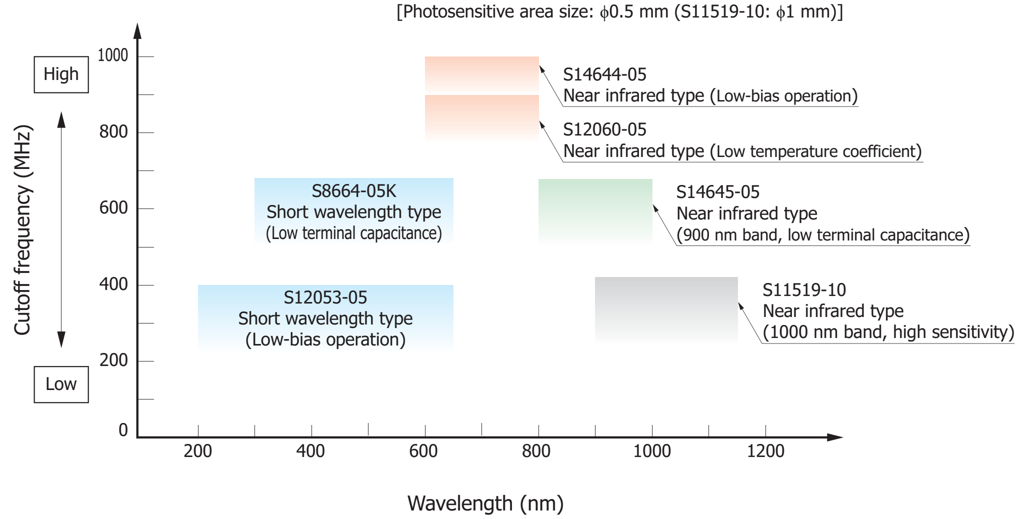
Cutoff frequency vs. recommended wavelength (typical example)



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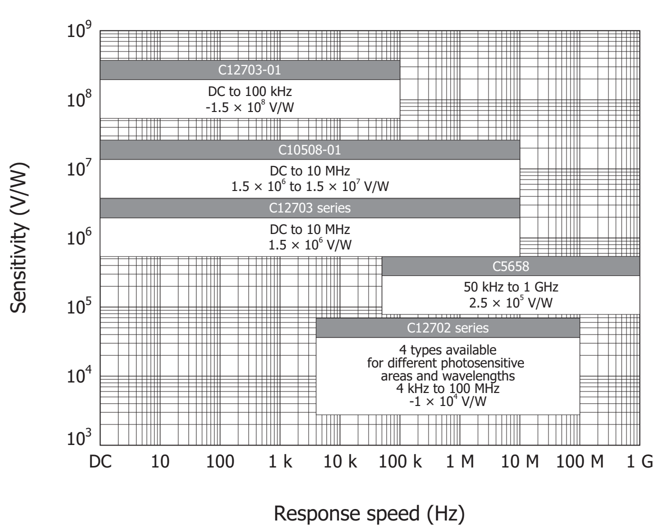
Sensitivity vs. response speed (APD modules)



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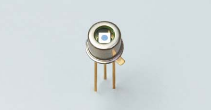
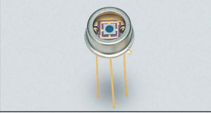
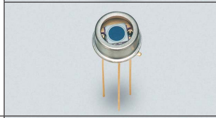
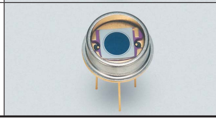
Short wavelength type Si APD

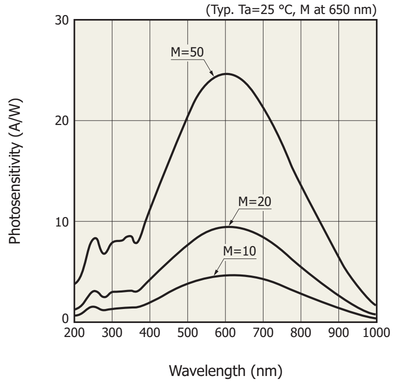
These are short wavelength Si APDs with enhanced sensitivity in the UV to visible region. They offer high gain, high sensitivity, and low noise in the short wavelength region. They are suitable for applications such as low-light-level measurement and analytical instruments.

Low-bias operation

Type no.	Effective photosensitive area*1 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 µA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*2 RL=50 Ω (MHz)	Rise time*2 RL=50 Ω (ns)	Terminal capacitance*2 (pF)	Gain λ=650 nm	Package	
S12053-02	ϕ0.2	200 to 1000	200	0.14	900	0.4	2	50	TO-18	
S12053-05	ϕ0.5				400	0.9	5			
S12053-10	ϕ1.0				250	1.5	15			
S9075	ϕ1.5				100	3.5	30		TO-5	
S5344	ϕ3.0				25	14	120			
S5345	ϕ5.0				8	45	320		TO-8	

*1: Area in which a typical gain can be obtained
*2: Value obtained when operated at the gain indicated in the table

Spectral response



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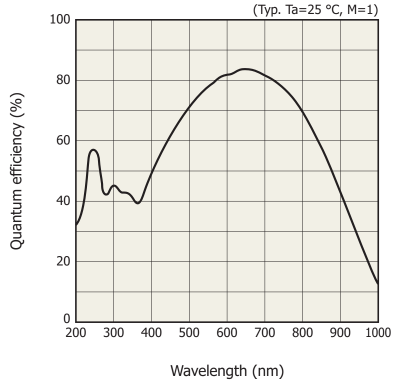
Quantum efficiency vs. wavelength



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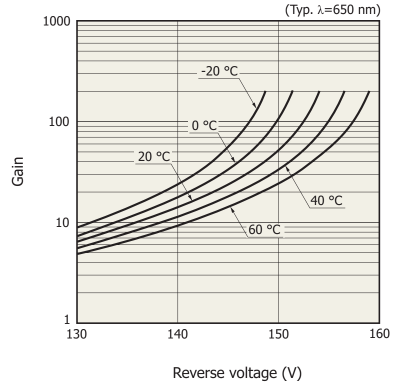
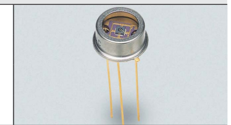
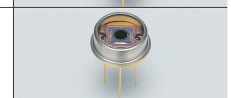
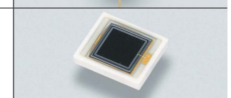
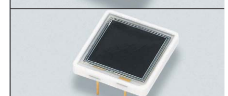
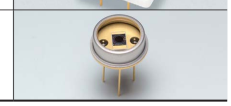
Gain vs. reverse voltage

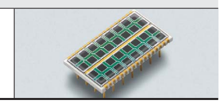


KAPDB0011EC

Low terminal capacitance

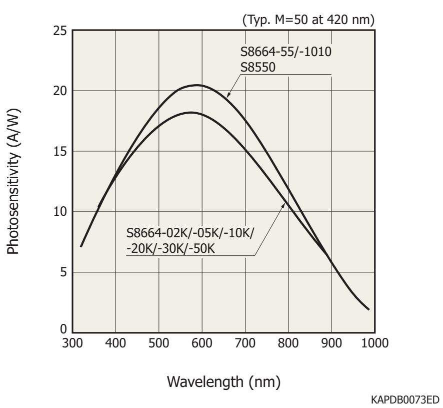
Type no.	Effective photosensitive area*3 (mm)	Spectral response range (nm)	Breakdown voltage max. I_D=100 μA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*4 R_L=50 Ω (MHz)	Rise time*4 R_L=50 Ω (ns)	Terminal capacitance*4 (pF)	Gain λ=420 nm	Package	
S8664-02K	ϕ0.2	320 to 1000	500	0.78	700	0.5	0.8	50	TO-5	
S8664-05K	ϕ0.5				680	0.52	1.6			
S8664-10K	ϕ1.0				530	0.66	4			
S8664-20K	ϕ2.0				280	1.3	11			
S8664-30K	ϕ3.0				140	2.5	22		TO-8	
S8664-50K	ϕ5.0				60	6	55			
S8664-55	5 × 5				40	9	80		Ceramic	
S8664-1010	10 × 10				11	32	270			
S11051-20	ϕ2.0	266			250	1.4	11		TO-8	

4 × 8 element array

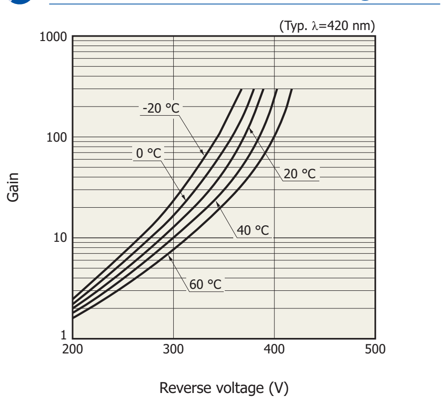
Type no.	Effective photosensitive area*3 (mm)	Spectral response range (nm)	Breakdown voltage max. (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*4 R_L=50 Ω (MHz)	Terminal capacitance*4 (pF)	Gain λ=420 nm	Package	
S8550-02	1.6 × 1.6 (x 32 elements)	320 to 1000	500	0.78	250	9 (per element)	50	Ceramic	

*3: Area in which a typical gain can be obtained
*4: Value obtained when operated at the gain indicated in the table

Spectral response

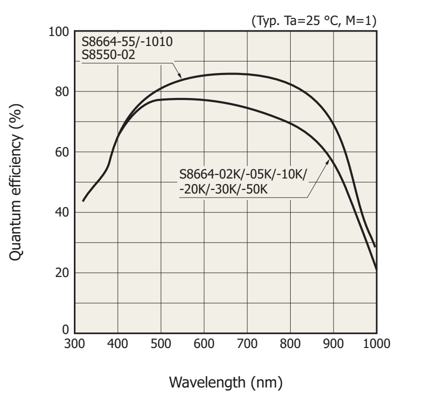


Gain vs. reverse voltage

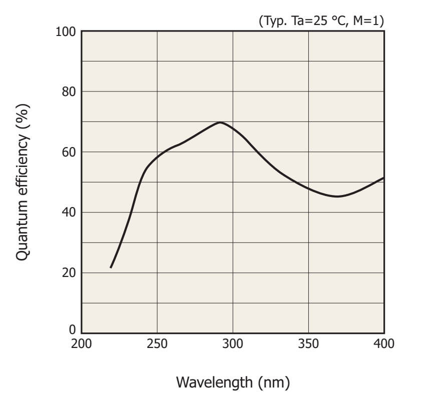


Quantum efficiency vs. wavelength

[S8664 series, S8550-02]



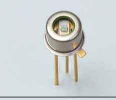
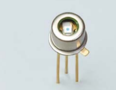
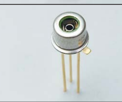
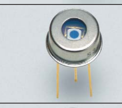
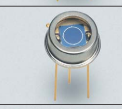
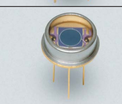
[S11051-20]



Near infrared type Si APD

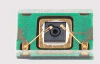
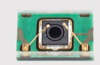
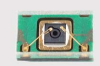
Low-bias operation

These are near infrared Si APDs that operate with low bias voltage. Since high gain can be attained with a bias voltage of 200 V or less, they are suitable for applications such as FSO, laser radar, and optical fiber communication.

Type no.	Effective photosensitive area*1 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 μA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*2 RL=50 Ω (MHz)	Terminal capacitance*2 (pF)	Gain λ=800 nm	Package	
S12023-02	ϕ0.2	400 to 1000	200	0.65	1000	1	100	TO-18	
S12023-05	ϕ0.5				900	2			
S12051									
S12086									
S12023-10	ϕ1.0				600	6			
S12023-10A									
S3884	ϕ1.5				400	10	100	TO-5	
S2384	ϕ3.0				120	40	60		
S2385	ϕ5.0				40	95	40	TO-8	

Surface mount type

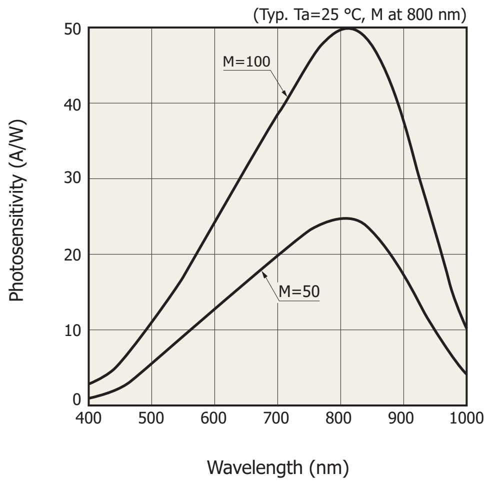
These are low cost, small size Si APDs with a surface-mount plastic package suitable for mass production.

Type no.	Effective photosensitive area*1 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 μA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*2 RL=50 Ω (MHz)	Terminal capacitance*2 (pF)	Gain λ=800 nm	Package	
NEW S14644-02	ϕ0.2	400 to 1000	180	0.63	1200	0.6	100	Plastic	
NEW S14644-05	ϕ0.5				1000	1.6			
NEW S14643-02	ϕ0.2		120	0.42	2000	0.7			

*1: Area in which a typical gain can be obtained
*2: Value obtained when operated at the gain indicated in the table

Spectral response

[S12023 series, S12051, S12086, S3884, S2384, S2385]



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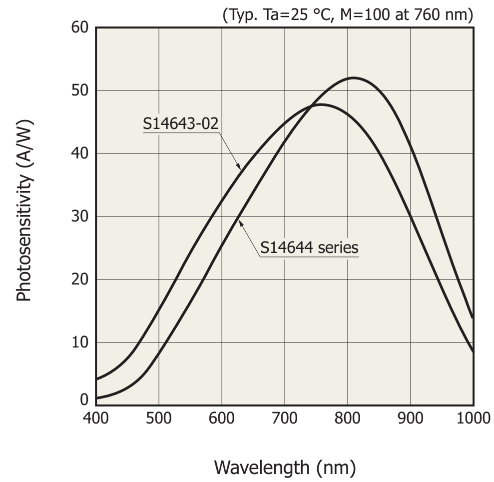
[S14643-02, S14644 series]



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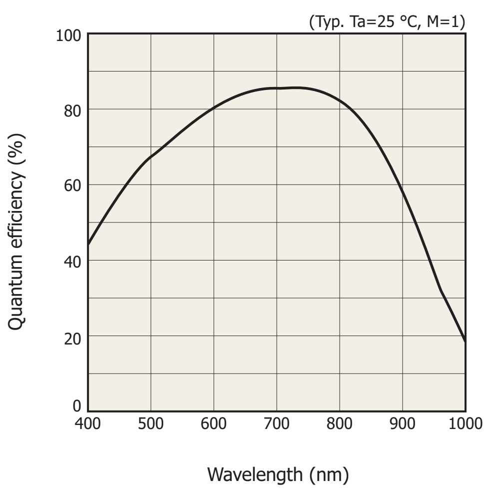
Quantum efficiency vs. wavelength

[S12023 series, S12051, S12086, S3884, S2384, S2385]



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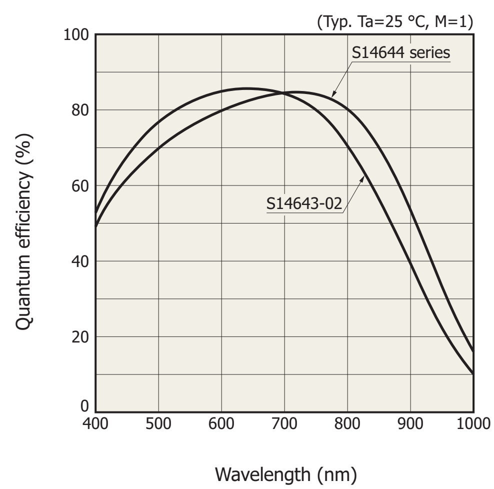
[S14643-02, S14644 series]



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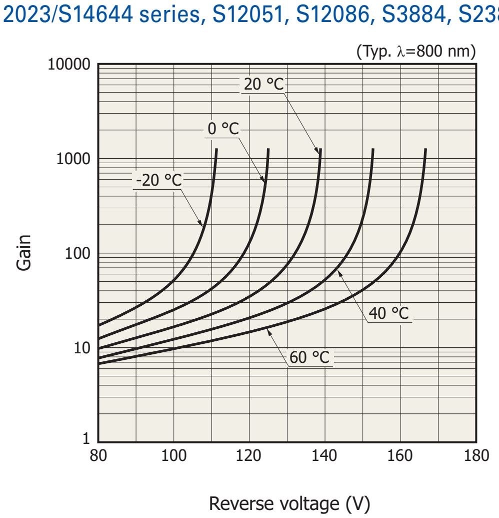
Gain vs. reverse voltage

[S12023/S14644 series, S12051, S12086, S3884, S2384, S2385]



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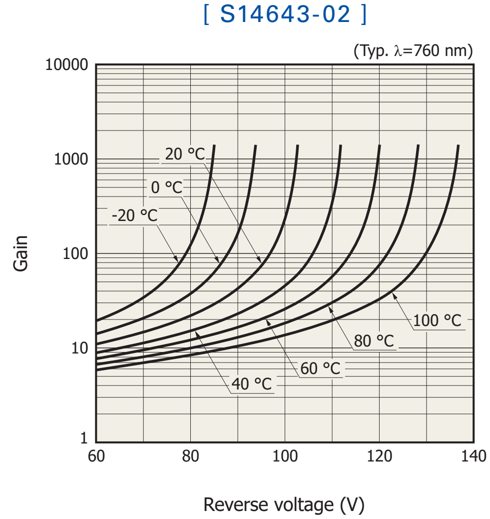
[S14643-02]



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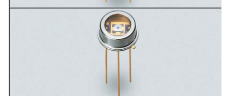
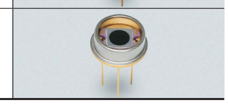
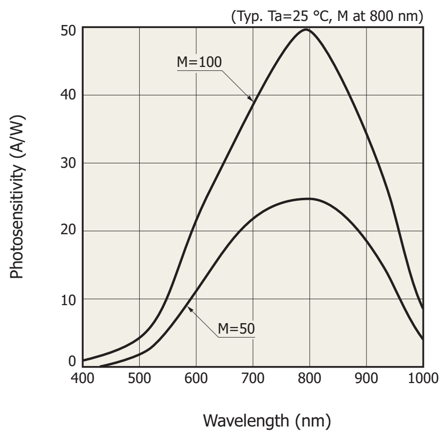
Low temperature coefficient

These are near infrared Si APDs featuring low temperature coefficient of the bias voltage. They produce stable gain over a wide temperature range. They are suitable for applications such as FSO, laser radar, and optical fiber communication.

<table>
<tr><th>Type no.</th><th>Effective photosensitive area*1
(mm)</th><th>Spectral response range
(nm)</th><th>Breakdown voltage max.
ID=100 μA
(V)</th><th>Temp. coefficient of breakdown voltage
(V/°C)</th><th>Cutoff frequency*2
RL=50 Ω
(MHz)</th><th>Terminal capacitance*2
(pF)</th><th>Gain
λ=800 nm</th><th colspan="2">Package</th></tr>
<tr><td>S12060-02</td><td>ϕ0.2</td><td rowspan="6">400 to 1000</td><td rowspan="6">300</td><td rowspan="6">0.4</td><td>1000</td><td>1</td><td rowspan="3">100</td><td rowspan="3">TO-18</td><td></td></tr>
<tr><td>S12060-05</td><td>ϕ0.5</td><td>900</td><td>2.5</td><td></td></tr>
<tr><td>S12060-10</td><td>ϕ1.0</td><td>600</td><td>6</td><td></td></tr>
<tr><td>S6045-04</td><td>ϕ1.5</td><td>350</td><td>12</td><td>100</td><td rowspan="2">TO-5</td><td></td></tr>
<tr><td>S6045-05</td><td>ϕ3.0</td><td>80</td><td>50</td><td>60</td><td></td></tr>
<tr><td>S6045-06</td><td>ϕ5.0</td><td>35</td><td>120</td><td>40</td><td>TO-8</td><td></td></tr>
</table>

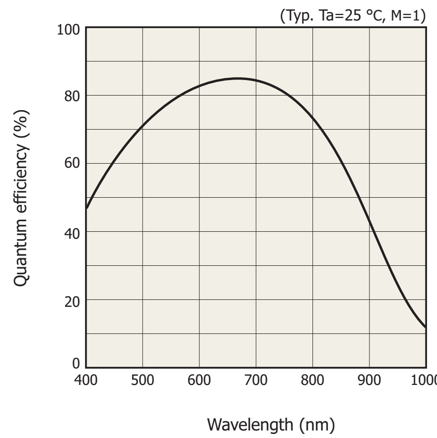
*1: Area in which a typical gain can be obtained
*2: Value obtained when operated at the gain indicated in the table

Spectral response



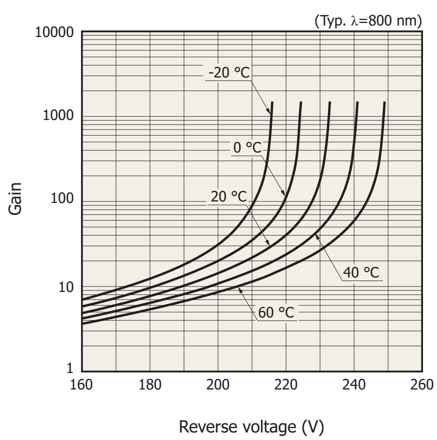
KAPDB0026EB

Quantum efficiency vs. wavelength



KAPDB0027EB

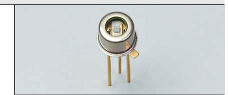
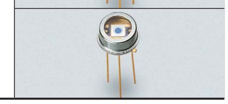
Gain vs. reverse voltage



KAPDB0029EB

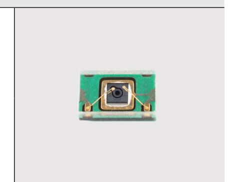
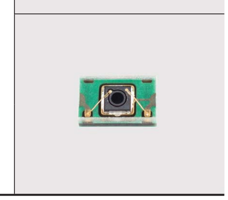
900 nm band, low terminal capacitance

This series is used in laser radar and other applications. It features a gradual curve of gain versus reverse voltage curve, providing stable operation.

Type no.	Effective photosensitive area*3 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 μA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*4 RL=50 Ω (MHz)	Terminal capacitance*4 (pF)	Gain λ=900 nm	Package	
S12426-02	ϕ0.2	400 to 1100	200	1.1	650	0.5	100	TO-18	
S12426-05	ϕ0.5				600	1.1			
S9251-10	ϕ1.0	440 to 1100	350	1.85	380	1.9		TO-5	
S9251-15	ϕ1.5				350	3.6			

Surface mount type

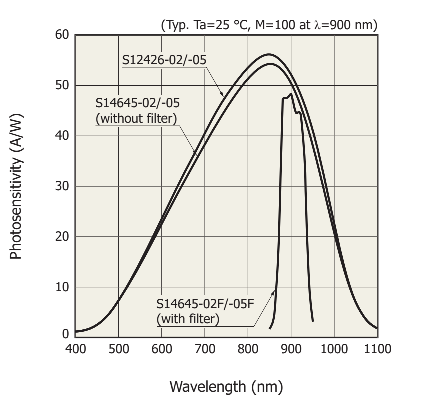
The small, thin leadless package allows reducing the mounting area on a printed circuit board. The S14645-02F and S14645-05F have an on-chip filter matched to a 900 nm light source.

Type no.	Effective photosensitive area*3 (mm)	Spectral response range (nm)	Breakdown voltage max. (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*4 RL=50 Ω (MHz)	Terminal capacitance*4 (pF)	Gain λ=900 nm	Package	
NEW S14645-02	ϕ0.2	400 to 1100	195	1.1	600	0.5	100	Plastic	
NEW S14645-02F		850 to 950							
NEW S14645-05	ϕ0.5	400 to 1100				1			
NEW S14645-05F		850 to 950							

*3: Area in which a typical gain can be obtained
*4: Value obtained when operated at the gain indicated in the table

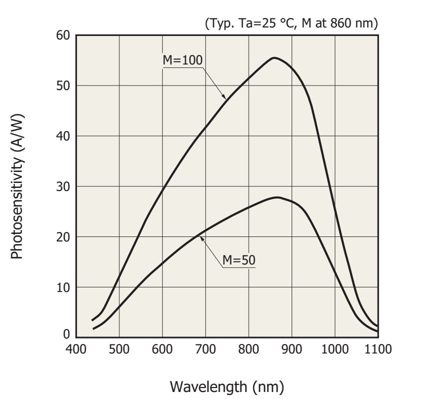
Spectral response

[S12426/S14645 series]



KAPDB0297EC

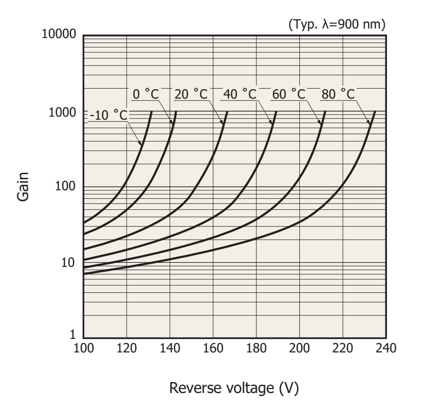
[S9251 series]



KAPDB0079EB

Gain vs. reverse voltage

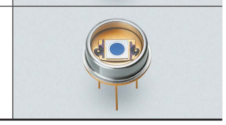
[S12426/S14645 series]



KAPDB0271EA

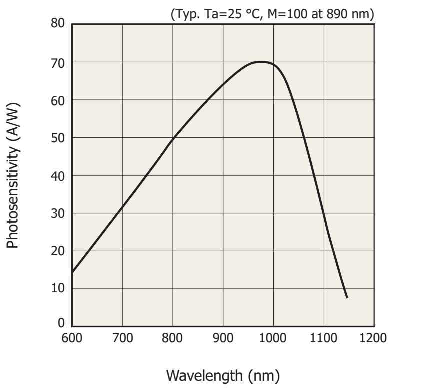
1000 nm band, high sensitivity

The S11519 series incorporates MEMS technology to enhance the sensitivity in the near IR region for YAG laser (1.06 μm) detection.

Type no.	Effective photosensitive area*1 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 μA (V)	Temp. coefficient of breakdown voltage (V/°C)	Cutoff frequency*2 RL=50 Ω (MHz)	Terminal capacitance*2 (pF)	Gain λ=890 nm	Package	
S11519-10	ϕ1.0	600 to 1150	500	1.7	400	2	100	TO-5	
S11519-30	ϕ3.0				230	12		TO-8	

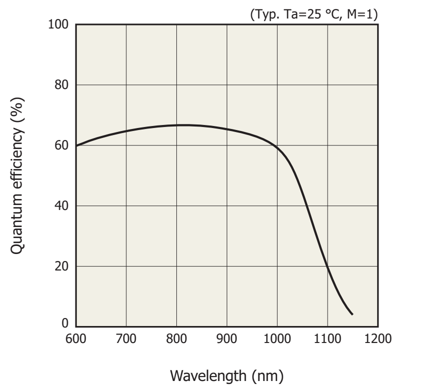
*1: Area in which a typical gain can be obtained
*2: Value obtained when operated at the gain indicated in the table

Spectral response



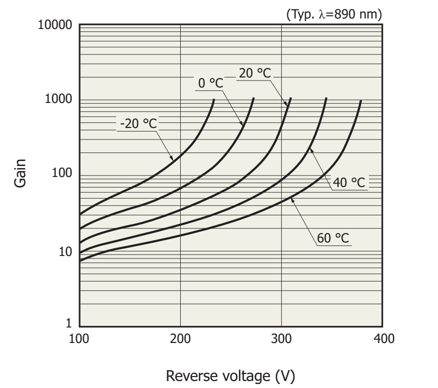
KAPDB0300EC

Quantum efficiency vs. wavelength



KAPDB0301EB

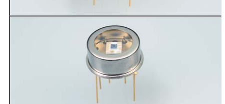
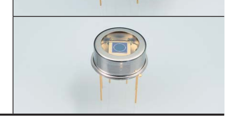
Gain vs. reverse voltage



KAPDB0185EB

TE-cooled type

The S4315 series is a low-bias operation thermoelectrically-cooled type APD capable of high accuracy detection.

Type no.	Cooling temperature ΔT (°C)	Built-in APD	Effective photosensitive area*1 (mm)	Spectral response range (nm)	Breakdown voltage max. ID=100 μA (V)	Cutoff frequency*2 RL=50 Ω (MHz)	Terminal capacitance*2 (pF)	Gain λ=800 nm	Package	
S4315	40	S12023-02	ϕ0.2	400 to 1000	200	1000	1	100	TO-8	
S4315-01		S12023-05	ϕ0.5			900	2	100		
S4315-02		S12023-10	ϕ1.0			600	6	100		
S4315-04		S2384	ϕ3.0			120	40	60		

*1: Area in which a typical gain can be obtained
*2: Value obtained when operated at the gain indicated in the table

APD modules

Standard type

The APD module consists of an amplifier and bias power supply assembled in a compact form to facilitate the use of the Si APD. Running on a +5 V power supply, it can be used for a variety of light detection applications up to 100 MHz of frequency bandwidth.

Near infrared type

Features

- Peak sensitivity wavelength: 800 nm
- Wide bandwidth
- Optical fiber adapters are also available. (sold separately).

Applications

- Si APD evaluation
- FSO
- Barcode readers
- Laser radars
- Optical rangefinders
- Optical communication

Type no.	Effective photosensitive area*3 (mm)	Built-in APD	Cutoff frequency		Photoelectric conversion sensitivity M=30, λ=800 nm (V/W)	Minimum detection limit M=30, λ=800 nm (nW rms)	Temperature stability of gain 25 ± 10 °C (%)	Supply voltage (V)
			Low	High				
C12702-03	ϕ1.0	S12023-10	4 kHz	100 MHz	-6.8×10^4	3	±5 max.	+5
C12702-04	ϕ3.0	S2384		80 MHz	-2.3×10^4	3.6		

Short wavelength type

Features

- Peak sensitivity wavelength: 620 nm
- Wide bandwidth
- Optical fiber adapters are also available (sold separately).

Applications

- Si APD evaluation
- Film scanners
- Laser monitoring

Type no.	Effective photosensitive area*3 (mm)	Built-in APD	Cutoff frequency		Photoelectric conversion sensitivity M=30, λ=620 nm (V/W)	Minimum detection limit M=30, λ=620 nm (nW rms)	Temperature stability of gain 25 ± 10 °C (%)	Supply voltage (V)
			Low	High				
C12702-11	ϕ1.0	S12053-10	4 kHz	100 MHz	-2.5×10^4	5	±5 max.	+5
C12702-12	ϕ3.0	S5344		40 MHz	-1.9×10^4	6.3		

High-sensitivity type

These are high-gain APD modules suitable for low-light-level detection. They can be used for DC light detection.

Features

- Low-light-level detection
- DC light detection
- High gain

Applications

- Si APD evaluation
- Fluorescence measurement
- Barcode readers
- Particle counters
- Film scanners

Type no.	Effective photosensitive area*3 (mm)	Internal APD	Cutoff frequency		Photoelectric conversion sensitivity M=30, λ=800 nm (V/W)	Minimum detection limit M=30, λ=800 nm (nW rms)	Temperature stability of gain 25 ± 10 °C (%)	Supply voltage (V)
			Low	High				
C12703	ϕ1.5	S3884	DC	10 MHz	1.5×10^6	0.63	±5 max.	±12
C12703-01	ϕ3.0	S2384		100 kHz	-1.5×10^8	0.0063		

*3: Area in which a typical gain can be obtained

High-stability type

The C10508-01 consists of an APD, current-voltage converter, high-voltage power supply circuit as well as a microcontroller for adjusting the APD gain and controlling temperature compensation with high accuracy. This makes it easy to adjust the APD gain and even at high gain, stable detection is possible even under temperature fluctuating conditions.

Features

- Gain: adjustable by switch or PC command
- Gain temperature stability: ±5% or less (Gain=250, Ta=0 °C to +40 °C)
- Easy handling: only ±5 V power supply

Applications

- Si APD evaluation
- Power meters
- Low-light-level detection

Type no.	Effective photosensitive area* (mm)	Internal APD	Cutoff frequency		Photoelectric conversion sensitivity M=250, λ=800 nm (V/W)	Minimum detection limit M=250, λ=800 nm (pW rms)	Temperature stability of gain 0 to 40 °C (%)	Supply voltage (V)
			Low	High				
C10508-01	ϕ1.0	S12023-10A	DC	10 MHz	1.25×10^7	63	±5 max.	±5

FC/SMA fiber adapter (sold separately)

FC or SMA fiber adapters can be attached to the following APD modules to allow FC or SMA optical fiber cables to be connected to the modules.

APD module	FC fiber adapter	SMA fiber adapter
C12702-03	A8407-18	A8424-18
C12702-04	A8407-05A	A8424-05A
C12702-11	A8407-18	A8424-18
C12702-12	A8407-05A	A8424-05A
C12703	A8407-05	A8424-05
C12703-01	A8407-05A	A8424-05A
C10508-01	A12855-01	A12855-02

High-speed type

This device can be used in a wide frequency range (up to 1 GHz).

Features

- High-speed light detection
- Flat frequency characteristics
- Compact and lightweight
- Single power supply operation

Applications

- OTDR
- Optical communication
- Laser radars
- FSO
- Optical rangefinders

Type no.	Effective photosensitive area* (mm)	Internal APD	Cutoff frequency		Photoelectric conversion sensitivity M=100, λ=800 nm (V/W)	Minimum detection limit M=100, λ=800 nm (nW rms)	Temperature stability of gain 25 ± 10 °C (%)	Supply voltage (V)
			Low	High				
C5658	ϕ0.5	S12023-05	50 kHz	1 GHz	2.50×10^5	16	±5	+12

* Area in which a typical gain can be obtained

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