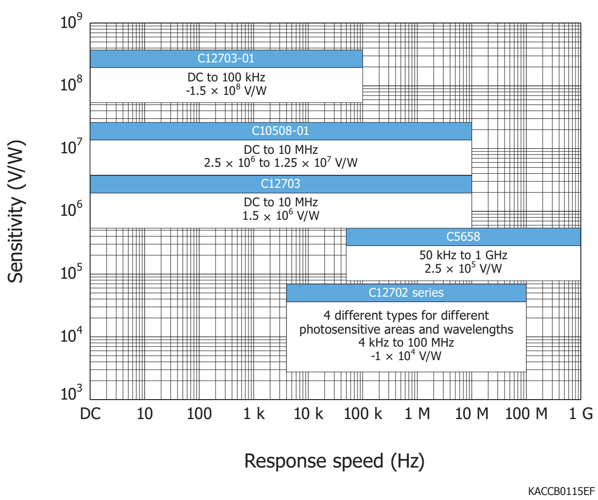
APD modules

APD modules are high-sensitivity photodetectors that integrate an APD (avalanche photodiode), a temperature-compensation bias circuit, and a current-to-voltage converter. The temperature-compensation bias circuit controls the APD bias voltage according to the changes in the ambient temperature and maintains a nearly constant APD gain. The current-to-voltage converter uses high-speed, low-noise bipolar transistors and op amps optimally configured for signal readout from the APD. These APD modules also include a voltage controller with low ripple noise to detect light with high sensitivity. APD modules contain a short wavelength or near infrared type Si APD. Operating an APD module is easy since it works by simply supplying a DC voltage from an external source.

[Figure 1] Sensitivity vs. response speed



1 Features

Stable operation against temperature fluctuations

Applying a high reverse voltage to an APD increases its sensitivity higher than general Si photodiodes. However, ambient temperature fluctuations cause the sensitivity to change even if the same reverse voltage is applied. There are two methods to maintain the APD sensitivity constant: one is a temperature-compensation type that adjusts the reverse voltage applied to the APD according to the ambient temperature, and the other is a thermoelectric cooled type that keeps the APD temperature itself constant.

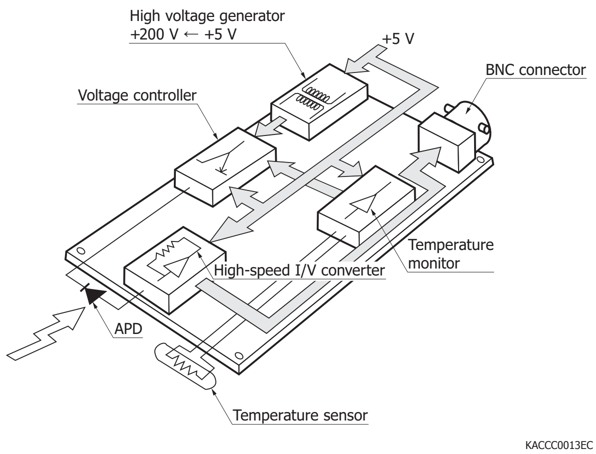
In temperature-compensation APD modules, a high-precision temperature sensor is installed in close proximity to the APD to accurately monitor the APD temperature so that the appropriate reverse voltage relative to the temperature is applied to maintain the gain with high stability. We also provide a digital temperature-compensation APD module that uses an internal microcontroller to perform even more accurate temperature compensation for the APD. In digital temperature-compensation APD modules, the gain is kept very stable over a wide temperature range even at a high gain (250 times).

In thermoelectrically cooled APD modules, the APD chip is mounted on a thermoelectric cooler that is kept at a constant temperature by the internal temperature control circuit so that a stable gain is achieved.

Low noise

Compact and lightweight

[Figure 2] Block diagram (C12702 series)



2 Structure

APD

The APD (avalanche photodiode) is a high-speed, high-sensitivity photodiode that internally multiplies photocurrent when reverse voltage is applied. The internal multiplication function referred to as avalanche multiplication features high photosensitivity that enables measurement of low-level light signals. The APD's ability to multiply signals reduces the effect of noise and achieves higher S/N than the PIN photodiode. The APD also has excellent linearity.
APD modules contain a near infrared or short wavelength type APD.

I/V converter

Because the APD photocurrent becomes minute depending on the incident light level or gain, an I/V converter that amplifies the signal with high S/N is required. APD modules contain an I/V amplifier circuit suitable for each type.

Temperature-compensation bias circuit

The temperature-compensation bias circuit consists of a high voltage generator, temperature sensor, and voltage controller. The high voltage generator increases the voltage applied to the APD module to the bias voltage (around +200 V or more) required by the APD. To stabilize the APD gain according to the changes in the ambient temperature, the voltage controller controls the bias voltage based on the temperature information from the temperature sensor located near the APD.

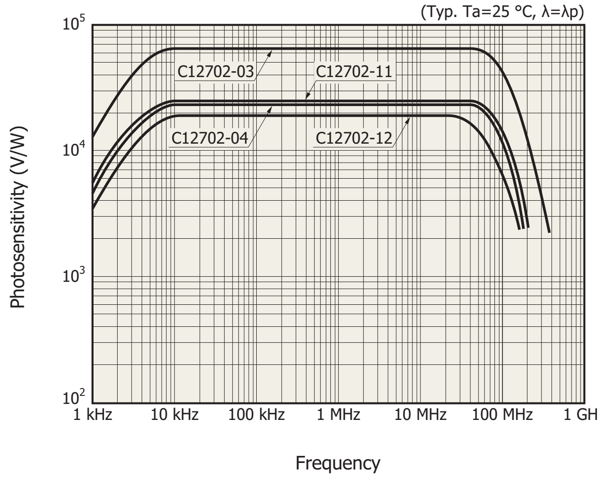
3 Characteristics

Frequency characteristics

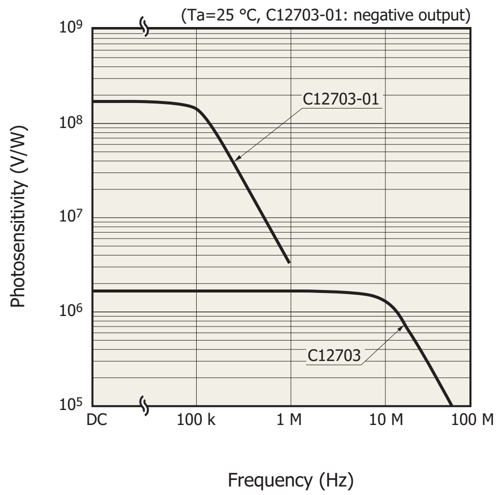
Figure 3 shows the frequency characteristics. A network analyzer is used to modulate the light from the light source to a sine wave, and this modulated light is applied to the APD module. The resulting output signal is acquired, and the frequency characteristics are measured. The frequencies at which the photosensitivity decreases by 3 dB from the flat region are defined as the low band cutoff frequency and high band cutoff frequency.

[Figure 3] Frequency characteristics

(a) C12702 series



(b) C12703 series

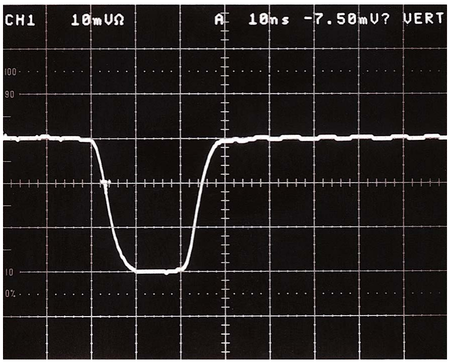


Light pulse response characteristics

Figure 4 shows an example of an output waveform when a light pulse is applied. The C12702-03 has a negative polarity and the C12703 a positive polarity.

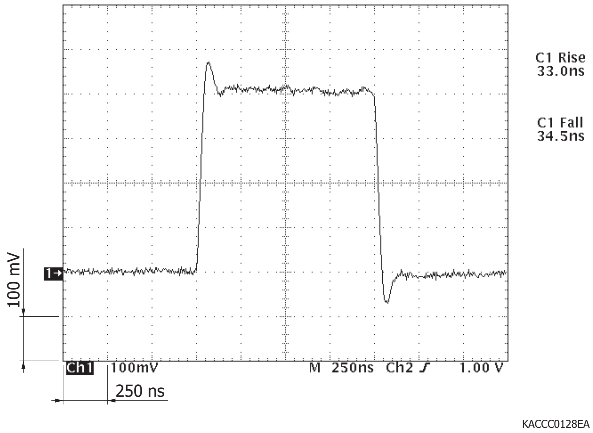
[Figure 4] Examples of output waveforms in response to step light

(a) C12702-03



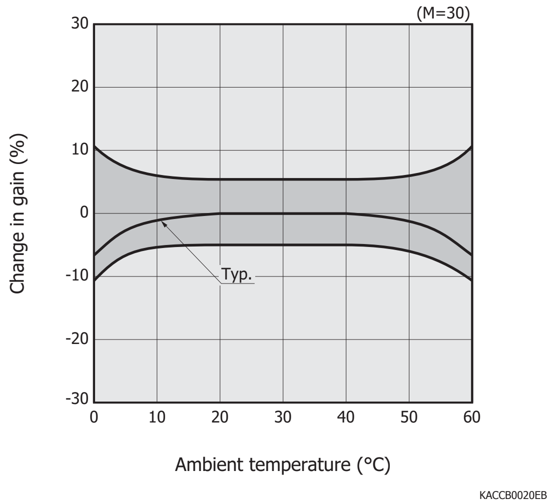
Ta=25 °C, gain=30, incident pulse width=20 ns
X-axis: 10 ns/div., Y-axis: 10 mV/div.

(b) C12703



Ta=25 °C, gain=30, incident pulse width=1 μs
X-axis: 250 ns/div., Y-axis: 100 mV/div.

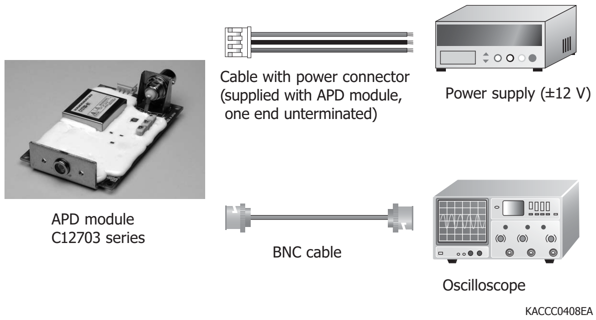
[Figure 5] Temperature characteristics of gain (C12703 series)



4 How to use

Connect the APD module to the DC power supply using the dedicated cable that comes with the APD module (except the C5658). Since the signals from the APD module are output via a coaxial connector, just connect it to output to a measuring device such as an oscilloscope to start making measurements. The C5658 is supplied with a power connector (D-sub). Solder this power connector to a cable (cable is not supplied). The C5658 output is an SMA connector.

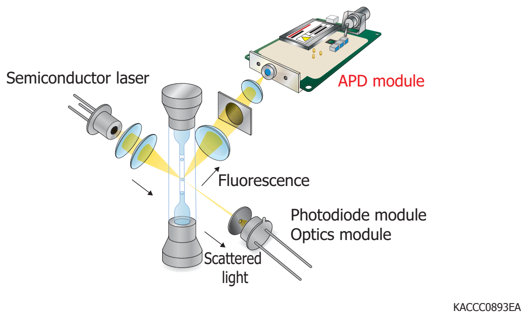
[Figure 6] Connection example (C12703 series)



5 Applications

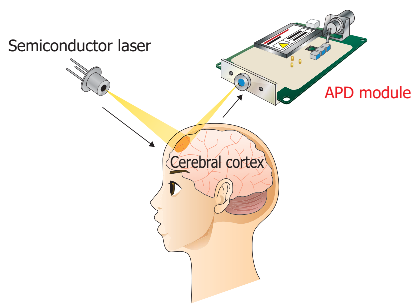
Flow cytometry

So that the type, number, and nucleic acids (DNA and RNA) of cells can be detected, a liquid that contains cells is made to flow at high speeds and is irradiated with a laser. The resulting faint fluorescence is detected.



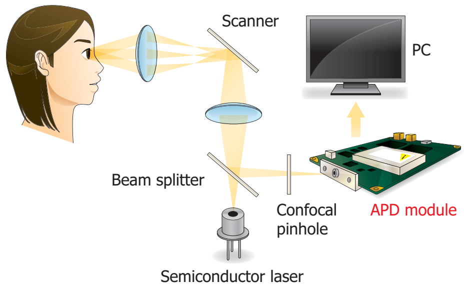
Optical topography

To monitor changes in blood volume in the cerebral cortex, near infrared rays are emitted above the scalp and the APD module detects the scattered light to capture the changes in the hemoglobin concentration in the blood.



Scanning laser ophthalmoscope (SLO)

In ophthalmoscopy, the level of laser light applied to the eyeball is limited due to safety reasons. The APD module is used to detect the low-level reflected light from the eyeball with superb resolution and contrast.



6 Q&A

What is the output voltage amplitude of APD modules?

When shipped from the factory, the output voltage amplitude is set as follows.

Type no.	Output voltage amplitude
C12703	Approx. +10 V
C12703-01	Approx. -10 V
C12702 series	Approx. -0.4 to -0.3 V
C10508-01	Approx. + 3 V
C5658	Approx. +0.7 to +0.8 V

What is the maximum incident light level to APD modules?

The maximum incident light level is calculated for each type by the output voltage amplitude [V] ÷ photoelectric conversion sensitivity [V/W]. Incidentally, the incident light level leading to device destruction is approximately several milliwatts, so take precautions before actually inputting light to the device.

The APD module is not functioning properly. Why is that?

Check the following points:

· Is the power supply wiring correct?

· The termination resistor should have the values shown here.

Type no.	Termination resistor
C12703 series	10 kΩ or more
C10508-01	10 kΩ or more
C12702 series	50 Ω
C5658	50 Ω

· Is the incident light level exceeding the maximum allowable level?

· Is the gain set too high?

If the gain is too high, then the APD dark current will increase, causing the APD's excess noise to increase and lowering the S/N.

Noise signal is superimposed on the output. How can it be avoided?

When ambient fluctuating light enters an APD, it may cause noise to appear in the output. Noise from commercial power sources may become superimposed on the output signal, especially when under fluorescent lamp lighting. We recommend using the APD module in a dark location as much as possible. Also use a series power supply with low ripple noise rather than a switching power supply. If this problem is not solved, then contact our sales office for advise on the ambient condition.

Can optical fibers be connected to an APD module?

For optical fiber connection to the C12702/C12703 series and C10508-01, the FC and SMA type optical fiber adapters (sold separately) are provided. Recommended optical fibers are GI type multimode optical fibers with a quartz core of 50 μm diameter and a clad of 125 μm diameter. No optical fiber can be connected to the C5658. Custom modifications are required for connecting an optical fiber to the C5658.

Are there recommended power supplies?

We will let you know the commercially available, stabilized power supplies that are suited for the APD module to be used. Contact our sales office for details.

Are there recommended light sources?

Use light sources such as an LD or LED that match the spectral response of the APD module. To check the light level that will be input to the APD, we recommend measuring the optical power in advance with a power monitor.

Can an A/D converter be directly connected to the APD module?

Connecting an A/D converter directly to the APD module is not recommended. The A/D converter's input impedance may adversely affect the APD module, making it impossible to obtain satisfactory characteristics.

✿ Can the APD module's electrical characteristics be changed?

We can make a custom modification to the APD mounted in the module and the electrical characteristics such as bandwidth and sensitivity (a service fee is required).

✿ Can the APD module's gain be changed?

On the C12702 series and C12703 series, the APD gain can be changed by using the APD gain adjustment trimmer. Note, however, that this trimmer does not have any scale and stopper mechanism, and can be turned many times. So, before turning the trimmer, it is recommended to allow the reference light to enter the APD and check the output so that the trimmer can be returned to the initial state when needed. The adjustable gain range of this trimmer is from one to over several hundred times where a breakdown occurs.

✿ How are the rise time and fall time of the APD module determined?

The rise time and fall time of the APD module can be calculated from the high band cutoff frequency (-3 dB) (when light pulses with short pulse width are incident) as expressed by equation (1).

Rise time or fall time = 0.35 ÷ high band cutoff frequency ··· (1)

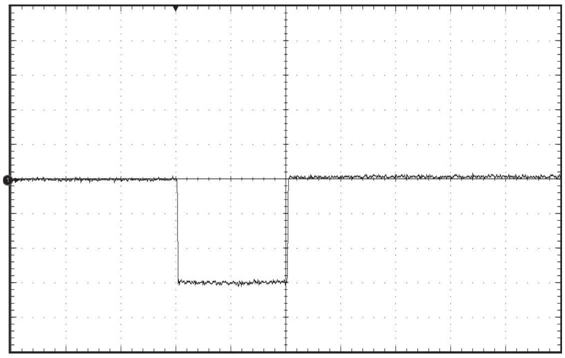
Note: Rise time, fall time:

The time for the output level to transition from 10 to 90% or 90 to 10% of the output waveform peak value when light pulses are incident.

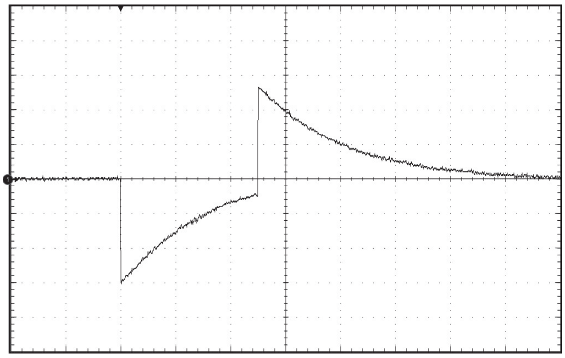
The output waveform when light pulses are incident on the C12702-03 is shown.

[Figure 7] Output waveform examples (C12702-03)

(a) Pulse width: 1 μs



(b) Pulse width: 50 μs



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www.hamamatsu.com

HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1 Ichino-cho, Higashi-ku, Hamamatsu City, 435-8558 Japan, Telephone: (81) 53-434-3311, Fax: (81) 53-434-5184
U.S.A.: Hamamatsu Corporation: 360 Foothill Road, Bridgewater, N.J. 08807, U.S.A., Telephone: (1) 908-231-0960, Fax: (1) 908-231-1218, E-mail: usa@hamamatsu.com
Germany: Hamamatsu Photonics Deutschland GmbH: Arzbergerstr. 10, D-82211 Herrsching am Ammersee, Germany, Telephone: (49) 8152-375-0, Fax: (49) 8152-265-8, E-mail: info@hamamatsu.de
France: Hamamatsu Photonics France S.A.R.L.: 19, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: 33-(1) 69 53 71 00, Fax: 33-(1) 69 53 71 10, E-mail: infos@hamamatsu.fr
United Kingdom: Hamamatsu Photonics UK Limited: 2 Howard Court, 10 Tewin Road, Welwyn Garden City, Hertfordshire AL7 1BW, United Kingdom, Telephone: (44) 1707-294888, Fax: (44) 1707-325777, E-mail: info@hamamatsu.co.uk
North Europe: Hamamatsu Photonics Norden AB: Torshamnsgatan 35 16440 Kista, Sweden, Telephone: (46)8-509 031 00, Fax: (46)8-509 031 01, E-mail: info@hamamatsu.se
Italy: Hamamatsu Photonics Italia S.r.l.: Strada della Moia, 1 int. 6, 20020 Arese (Milano), Italy, Telephone: (39)02-93 58 17 33, Fax: (39)02-93 58 17 41, E-mail: info@hamamatsu.it
China: Hamamatsu Photonics (China) Co., Ltd.: B1201, Jiaming Center, No.27 Dongsanhuan Beilu, Chaoyang District, Beijing 100020, China, Telephone: (86) 10-6586-6006, Fax: (86) 10-6586-2866, E-mail: hpc@hamamatsu.com.cn
Taiwan: Hamamatsu Photonics Taiwan Co., Ltd.: 8F-3, No. 158, Section2, Gongdao 5th Road, East District, Hsinchu, 300, Taiwan R.O.C. Telephone: (886)03-659-0080, Fax: (886)03-659-0081, E-mail: info@hamamatsu.com.tw

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