Module products

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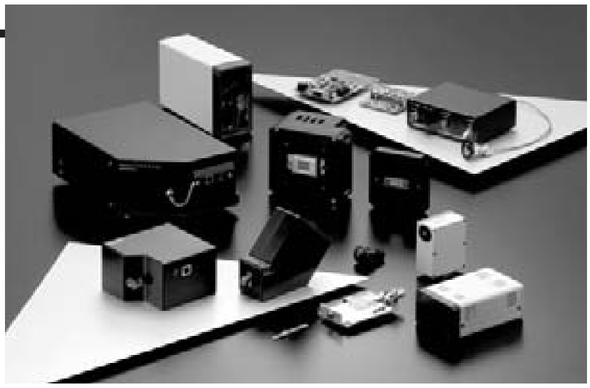


HAMAMATSU provides a wide variety of module products that extract the maximum performance from opto-semiconductors. Custom products are also available by request. Please feel free to consult us.

HAMAMATSU module products

Product	Description
Mini-spectrometer	These mini-spectrometers consist of a HAMAMATSU image sensor, optical elements, and a driver circuit, all assembled together in a compact case.
Distance sensor	These modules are designed to measure distances to a reflective sheet attached to the target object. The distance is measured by emitting pulsed light from a 660 nm semiconductor laser to irradiate the reflective sheet and measuring the time-of-flight required for the laser light to return to the sensor. An omni-directional type is also provided that optically scans 360 degrees all around to accurately detect the distance and angle to a reflective sheet attached to the object.
Smart camera	This is an intelligent camera module that integrates a CMOS area image sensor, an LED, and a signal processing circuit in order to detect the position of a specific target mark.
APD module	These are high-speed, high-sensitivity photodetectors using an APD. An APD, a low-noise amplifier, and a bias power supply are assembled together in a compact case. Simply connecting to a low voltage DC power supply allows light measurements with an S/N level dozens of times higher than PIN photodiodes.
MPPC module	MPPC (multi-pixel photon counter) is a new type of photon-counting device made up of multiple APD pixels operating in Geiger mode. MPPC modules are designed to extract maximum MPPC performance.
Photosensor amplifier	These are current-to-voltage conversion amplifiers specifically designed to amplify photocurrent with low noise.
Photodiode module	Photodiode modules are high-precision photodetectors integrating a Si photodiode and current-to-voltage conversion amplifier. A dedicated signal processing unit is also provided (sold separately).
PSD signal processing circuit	These circuit boards are used for evaluation of PSD (position sensitive detector).
PSD module	PSD modules are high-precision position detectors integrating a PSD and current-to-voltage conversion amplifier. Dedicated signal processing units are also provided (sold separately).
Color sensor module/ evaluation circuit	Color sensor modules contain an RGB color sensor. An evaluation circuit is also provided where a color sensor can be mounted.
Charge amplifier	Low-noise charge amplifiers designed for detecting radiation and high-energy particles. HAMAMATSU S3590 series Si PIN photodiodes can be mounted on the board.
Multichannel detector head	Contains a driver circuit designed for various types of image sensors (CCD area image sensors, NMOS linear image sensors, and InGaAs linear image sensors). A controller for multichannel detector heads is also available (sold separately).
Image sensor circuit	These include driver circuits for various image sensors and pulse generators for NMOS linear image sensors.
PIN photodiode amplifier	This is an amplifier (ten times) for PIN photodiodes with a wide bandwidth (5 MHz to 1.5 GHz) and a flat gain.
Pulsed laser diode module	This is a compact, pulsed laser diode driver module that contains a HAMAMATSU pulsed laser diode.
Special-purpose module	These include “flame eyes” for flame detection, sunlight sensors for automotive air conditioners, etc., and Si photodiode array driver circuits.

1. Mini-spectrometers

Mini-spectrometers are compact polychromators made up of optical elements such as a grating, an image sensor, and its driver circuit which are assembled together into a compact case. Spectrum data is easily acquired by guiding measurement light into a mini-spectrometer through an optical fiber and transferring the sensor output to a PC via the USB connection.

[Figure 1-1] Connecting a mini-spectrometer to a PC via USB

High-performance spectrophotometers are used in a broad range of fields including chemical analysis. However, those instruments are usually large and expensive. Moreover, the measurement samples have to be brought into a laboratory where the spectrophotometer is installed.
By merging the image sensor technology accumulated over many years with MEMS technology such as holographic process, HAMAMATSU succeeded in developing mini-spectrometer products that offer compact size and low cost.
These mini-spectrometers are useful in a wide range of measurement fields including chemical analysis, color measurement, environmental measurement, and process control on production lines. HAMAMATSU also provides ultra-compact models specifically designed to be built into mobile measuring devices.

1 - 1 HAMAMATSU technologies

MEMS technology

HAMAMATSU mini-spectrometers (TM/TG series) use a transmission grating (quartz) fabricated by a holographic process as a wavelength dispersive element. The holographic process is a technique suited for mass production, and a grating can be formed directly onto the matrix, instead of replicating the grating. This grating can separate light into a spectrum precisely and improve measurement throughput. It also reduces stray light levels, so high diffraction efficiency can be obtained with low noise.

[Figure 1-2] SEM photograph of grating

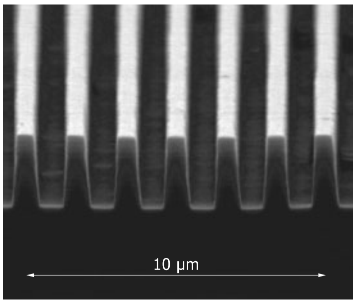
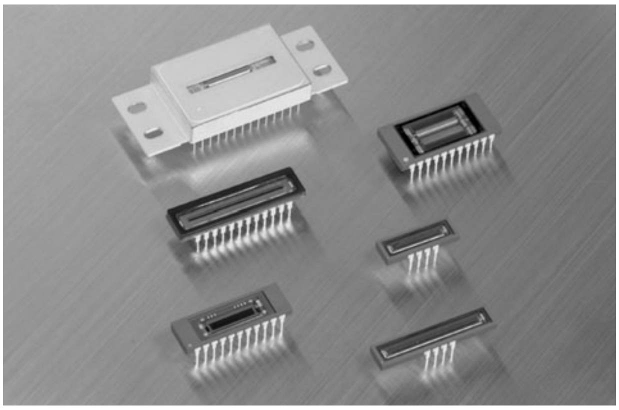


Image sensor technology

The detector serving as the core of the mini-spectrometer is a HAMAMATSU image sensor (back-thinned CCD image sensor, NMOS/CMOS linear image sensor, or InGaAs linear image sensor) which holds a long and well-deserved reputation among users in analysis and measurement fields.

[Figure 1-3] Image sensors used in mini-spectrometers



1 - 2 Structure

Wavelength dispersive spectrometers are broadly grouped into monochromator and polychromator types. Monochromators use a grating as the wavelength dispersing element for separating the incident light into a monochromatic spectrum. Polychromators utilize the principle of monochromators and are designed to allow simultaneous detection of multiple spectra. Mini-spectrometers fall under the polychromator type. In monochromators, an exit slit is usually formed on the focal plane of a focusing lens, while in polychromators an array type detector (image sensor) is placed along the focal plane of the focusing mirror/lens. To make mini-spectrometers (TG series) compact, the polychromators use a collimating lens and focusing mirror/lens with a shorter focal distance compared to monochromators.

Functions of components used in mini-spectrometers are described below.

Entrance slit

This is an aperture through which light to be measured is guided inside. The entrance slit restricts the spatial spread of the measurement light that enters the mini-spectrometer, and the slit image of the incident light is focused on the image sensor. The narrower the entrance slit, the more the spectral resolution is improved, but the throughput becomes lower. An optical fiber is connected to the mini-spectrometer entrance slit.

Collimating mirror/lens

The light passing through the entrance slit spreads at a certain angle. The collimating mirror/lens collimates this slit-transmitted light and guides it onto the grating. An aperture (aperture mask) is used along with the collimating mirror/lens to limit the NA (numerical aperture) of the light flux entering the mini-spectrometer.

Grating

The grating separates the incident light guided through the collimating mirror/lens into each wavelength and lets the light at each wavelength pass through or be reflected at a different diffraction angle. There are two types of gratings for mini-spectrometers: transmission type and reflection type.

Focusing mirror/lens

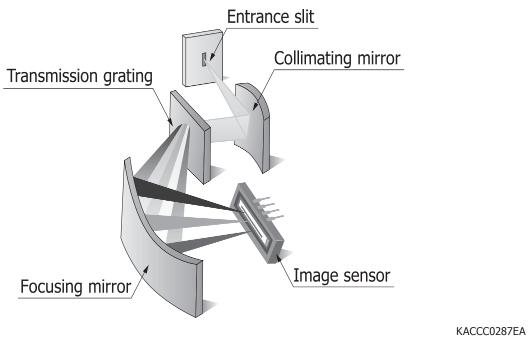
The focusing mirror/lens focuses the light from the grating onto an image sensor in the order of wavelength.

Image sensor

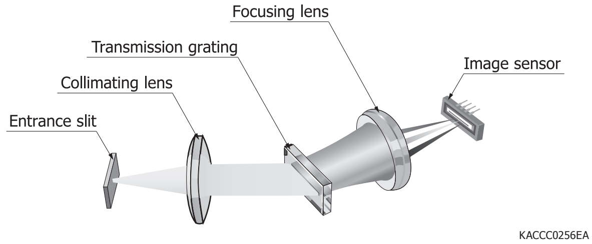
The image sensor converts the spectrum of light focused by the focusing mirror/lens into electrical signals, and then outputs them. Cooled mini-spectrometers incorporate a thermoelectrically cooled image sensor to reduce image sensor noise.

[Figure 1-4] Optical system layouts

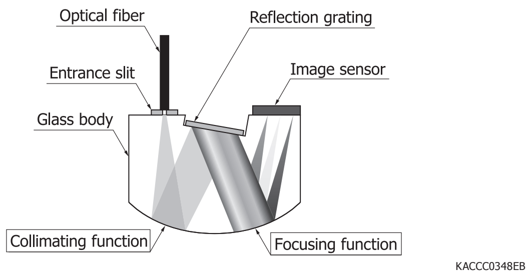
(a) TM series



(b) TG series



(c) RC series



[Figure 1-5] TM series C10082MD

[Figure 1-6] RC series C11010MA

The C11009MA and C11010MA mini-spectrometers are specifically designed for installation into mobile measuring devices. An optical system and an image sensor are assembled together in a compact case (C11009MA: 28 × 28 × 28 mm, C11010MA: 35 × 28 × 20 mm). The optical system integrates collimating and focusing functions into a single spherical mirror to achieve a compact size.

[Table 1-1] HAMAMATSU mini-spectrometers

(a) Module type

Type no.	Type		Spectral response range (nm)	Spectral resolution max. (nm)
C10082CA	TM series	TM-UV/VIS-CCD High sensitivity	200 to 800	6
C10082CAH	TM series	TM-UV/VIS-CCD High resolution	200 to 800	1*
C10082MD	TM series	TM-UV/VIS-MOS Wide dynamic range	200 to 800	6
C10083CA	TM series	TM-VIS/NIR-CCD High sensitivity	320 to 1000	8 (λ=320 to 900 nm)
C10083CAH	TM series	TM-VIS/NIR-CCD High resolution	320 to 1000	1* (λ=320 to 900 nm)
C10083MD	TM series	TM-VIS/NIR-MOS Wide dynamic range	320 to 1000	8
C9404CA	TG series	TG-UV-CCD High sensitivity	200 to 400	3
C9404CAH	TG series	TG-UV-CCD High resolution	200 to 400	1*
C9404MC	TG series	TG-UV-MOS Wide dynamic range	200 to 400	3
C9405CA	TG series	TG-SWNIR-CCD High sensitivity	500 to 1100	5 (λ=550 to 900 nm)
C9405MC	TG series	TG-SWNIR-MOS Wide dynamic range	500 to 1100	5 (λ=550 to 1100 nm)
C9406GC	TG series	TG-NIR Non-cooled type	900 to 1700	7
C9913GC	TG series	TG-cooled NIR-I Low noise (cooled type)	900 to 1700	7
C9914GB	TG series	TG-cooled NIR-II Low noise (cooled type)	1100 to 2200	8
C11118GA	TG series	TG-cooled NIR-III Low noise (cooled type)	900 to 2550	20
C11007MA	RC series	RC-VIS-MOS Spectrometer module	340 to 780	9
C11008MA	RC series	RC-SWNIR-MOS Spectrometer module	640 to 1050	8

* Typical value

(b) Built-in type for mobile measuring device

Type no.	Type		Spectral response range (nm)	Spectral resolution max. (nm)
C11009MA	RC series	RC-VIS-MOS Spectrometer head	340 to 780	9
C11010MA	RC series	RC-SWNIR-MOS Spectrometer head	640 to 1050	8
C10988MA	MS series	MS-VIS-MOS Spectrometer head	340 to 750	14

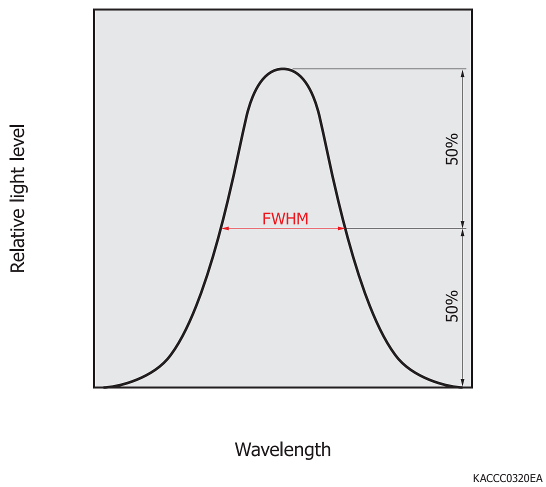
1-3 Characteristics

Spectral resolution

(1) Definition

The spectral resolution of mini-spectrometers is defined based on the full width at half maximum (FWHM). This is the spectral width at 50% of the peak power value as shown in Figure 1-7. Figure 1-8 shows examples of spectral resolution measured with different types of mini-spectrometers.

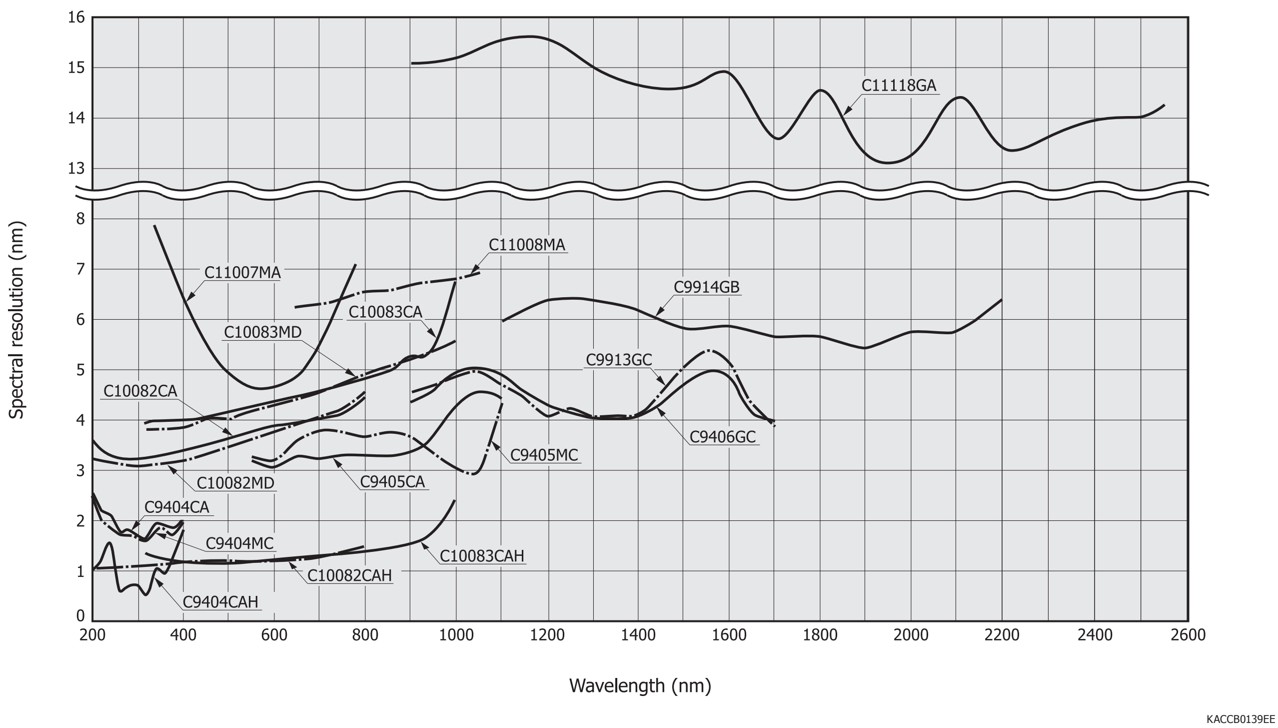
[Figure 1-7] Definition of full width at half maximum



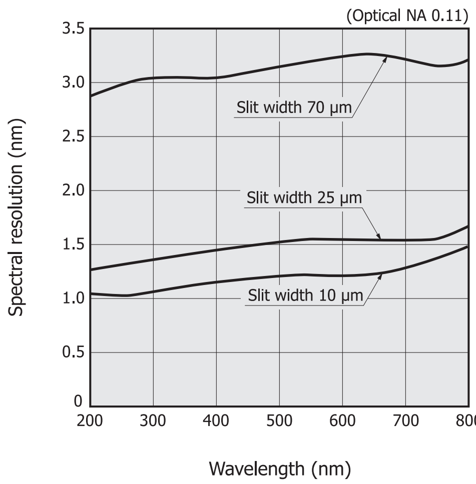
(2) Changing the spectral resolution

The spectral resolution of mini-spectrometers varies depending on the slit width and optical NA. In the C10082CA, for example, the slit width is 70 µm and the optical NA is 0.22. Figure 1-9 shows typical examples of spectral resolution when the optical NA is changed to 0.11 and the slit width is narrowed. This proves that the spectral resolution can be improved down to about 1 nm by changing conditions.
However, narrowing the slit width and reducing the optical NA will limit the light incident on the mini-spectrometer. The light level reaching the image sensor will therefore decrease.
For example, when comparing the C10082CA with the C10082CAH, the slit width of the C10082CA is 70 µm while that of the C10082CAH is 10 µm, which is 1/7 of the C10082CA. This means that the light level passing through the slit of the C10082CAH is 1/7 of the C10082CA. On the other hand, due to differences in the internal NA of each mini-spectrometer, the light level reaching the image sensor in the C10082CAH is approx. 1/4 that of the C10082CA. However, because the spectral resolution of the C10082CAH is approx. 1/4 of the C10082CA, the A/D count obtained from the C10082CAH will be four times greater than the C10082CA. Taking these facts into account, when the light entering the optical fiber is the same level, the A/D count of the C10082CAH will be approx. 1/7 that of the C10082CA.

[Figure 1-8] Spectral resolution vs. wavelength (typical example)



[Figure 1-9] Spectral resolution vs. wavelength (typical example when slit width and optical NA for C10082CA were changed)



(3) Spectral detection width assigned per pixel of image sensor

This section describes the spectral detection width that is assigned per pixel of the image sensor mounted in a mini-spectrometer. The spectral detection width is different from spectral resolution. The approximate spectral detection width assigned per pixel is obtained by dividing the spectral response range by the number of pixels of the image sensor.

- Example: C10082MD
  (spectral response range: 200 to 800 nm, 1024 pixels)

Spectral detection width assigned per pixel
$= (800 - 200)/1024 \approx 0.6$ nm ·································· (1)

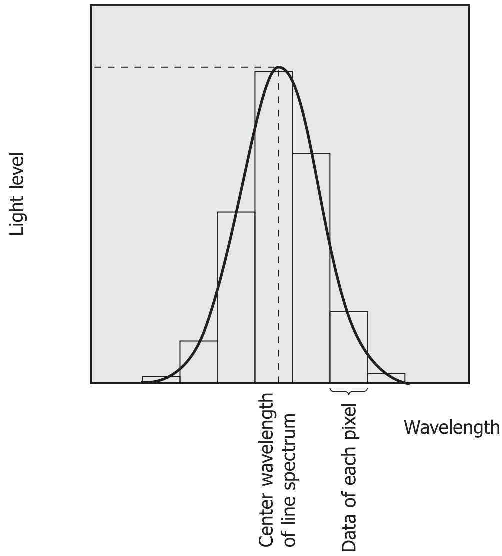
The detection wavelength of any given pixel is calculated from equation (2) using the wavelength conversion factor that is written in the EEPROM in the mini-spectrometer. This allows obtaining the spectral width assigned to any pixel.

Detection wavelength of any given pixel [nm]
$= a_0 + a_1pix + a_2pix^2 + a_3pix^3 + a_4pix^4 + a_5pix^5$ ······ (2)

a_0 to a_5: wavelength conversion factor
pix : any pixel number of image sensor (1 to the last pixel)

HAMAMATSU mini-spectrometers are designed so that the spectral width assigned per pixel in the image sensor is small relative to the spectral resolution. When a line spectrum is measured with a mini-spectrometer, the output is divided into multiple pixels as shown in Figure 1-10. The center wavelength of the line spectrum can be found by approximating this measurement result with a Gaussian curve.

[Figure 1-10] Finding the center wavelength of line spectrum by approximation



Stray light

Stray light is generated as a result of extraneous light entering the detector (image sensor), which should not be measured. The following factors can generate stray light.

- Fluctuating background light
- Imperfections in the grating
- Surface reflection from lens, detector window, and detector active area

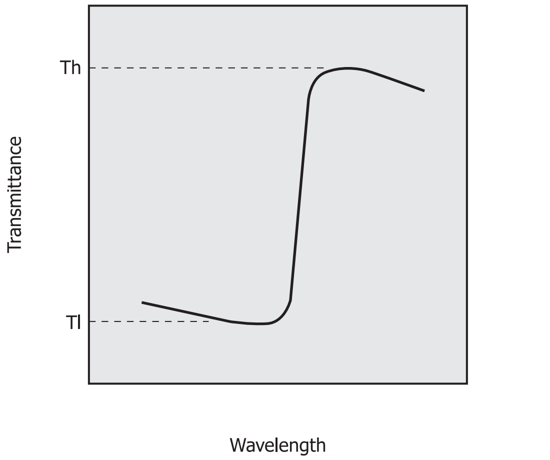
Definition of stray light

There are two methods to define stray light: one method uses a long-pass filter and the other method uses reference light in a narrow spectral range (light output from a monochromator or line spectra emitted from a spectral line lamp, etc.).
The long-pass filter method uses light obtained by making white light pass through a long-pass filter for particular wavelengths. In this case, the stray light is defined as the ratio of transmittance in the "wavelength transmitting" region to transmittance in the "wavelength blocking" region. The stray light level (SL) is defined by equation (3). (See Figure 1-11 for the definitions of Tl and Th.)

$SL = 10 \times \log (Tl/Th)$ ··········· (3)

This definition allows measuring the effects of stray light over a wide spectral range and so is used as an evaluation method suitable for actual applications such as fluorescence measurement. However, be aware that the intensity profile of white light used as reference light will affect the measurement value.

[Figure 1-11] Definitions of Tl and Th



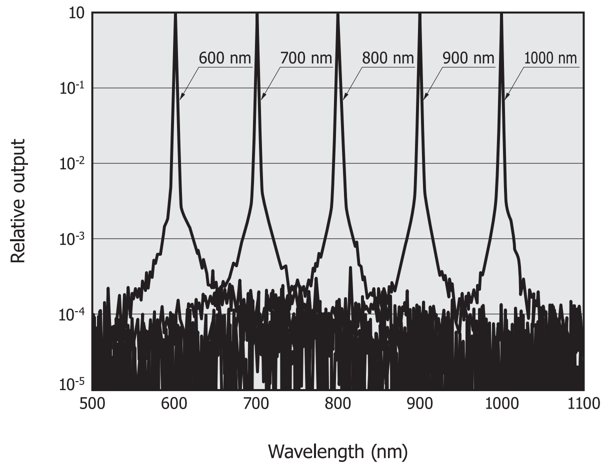
In the other method using reference light in a narrow spectral range, the stray light level (SL) is defined by equation (4).

$$SL = 10 \times (\log I_M/I_R) \cdots\cdots (4)$$

I_M: unnecessary light level that was output at wavelengths deviating from the reference light spectrum
I_R: reference light level

This definition is not affected by the reference light because the measurement conditions are simple.
In both definition methods, the stray light conditions will differ depending on the wavelength to be detected. The stray light should therefore be measured at multiple wavelengths.

[Figure 1-12] Examples of stray light measurement using line spectra (C9405MC)



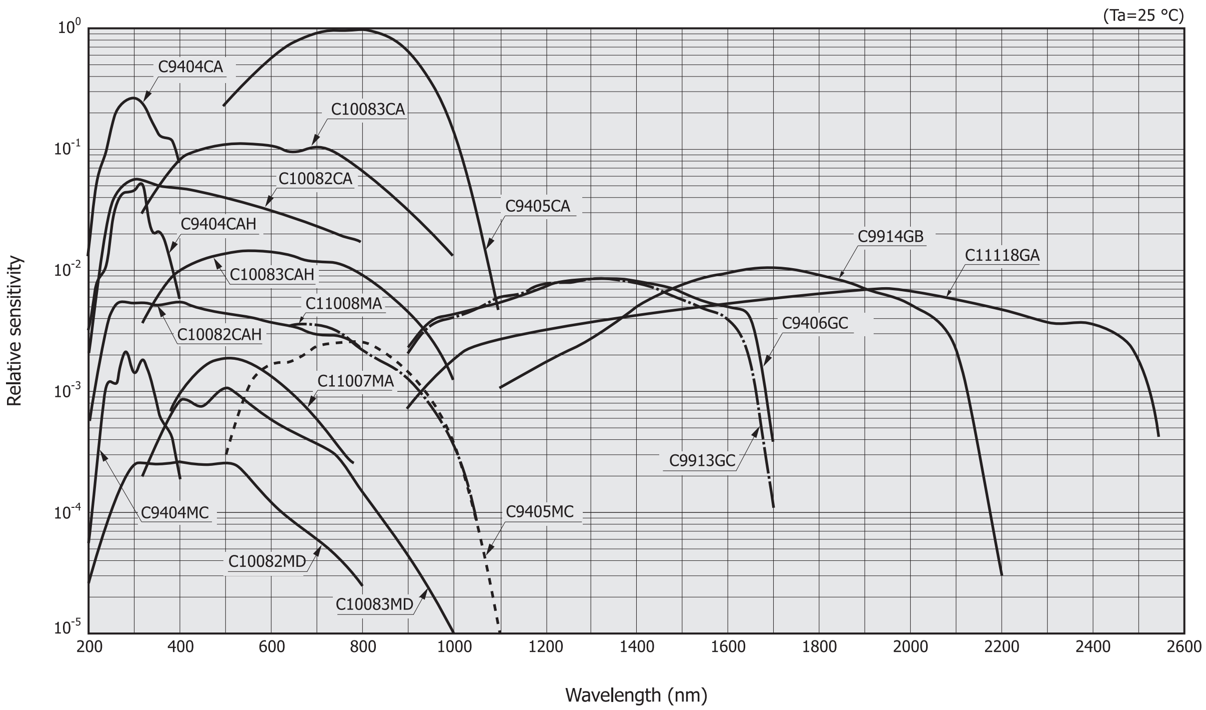
Sensitivity

The output charge of an image sensor mounted in mini-spectrometers is expressed by equation (5).

$$Q(\lambda) = k(\lambda) \cdot P(\lambda) \cdot Texp \cdots\cdots (5)$$

Q(λ) : image sensor output charge [C]
k(λ) : conversion factor for converting the light level entering a mini-spectrometer into image sensor output charge (equals the product of the optical system efficiency, diffraction efficiency of grating, and image sensor sensitivity)
P(λ) : incident light level [W] at each wavelength incident on mini-spectrometer
Texp: integration time [s]

[Figure 1-13] Spectral response



* A/D count when constant light level enters optical fiber
(fiber core diameter: 600 μm, assuming no attenuation in optical fiber)

KACCB0137EE

The output charge Q(λ) of an image sensor is converted into a voltage by the charge-to-voltage converter circuit and then converted into a digital value by the A/D converter. This is finally derived from the mini-spectrometer as an output value. The output value of a mini-spectrometer is expressed by equation (6).

$$I(\lambda) = \varepsilon \cdot Q(\lambda) = \varepsilon \cdot k(\lambda) \cdot P(\lambda) \cdot Texp \cdots\cdots\cdots\cdots (6)$$

I(λ) : mini-spectrometer output value [counts]
ε : conversion factor for converting image sensor output charge into a mini-spectrometer output value (equals the product of the charge-to-voltage converter circuit constant and the A/D converter resolution)

Meanwhile, the sensitivity of a mini-spectrometer is expressed by equation (7).

$$E(\lambda) = I(\lambda) / \{P(\lambda) \cdot Texp\} \cdots\cdots\cdots\cdots (7)$$

E(λ): sensitivity of mini-spectrometer [counts/(W·s)]

Substituting equation (6) into equation (7) becomes:

$$E(\lambda) = \varepsilon \cdot k(\lambda) \cdots\cdots\cdots\cdots (8)$$

[Table 1-2] Wavelength dependence of parameters that determine conversion factor

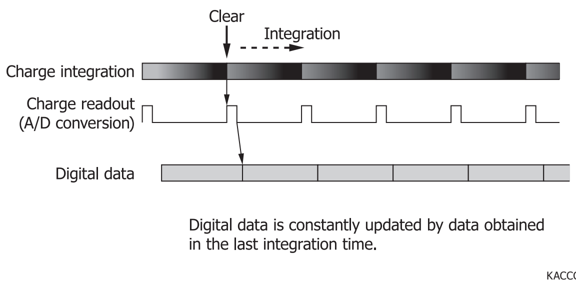
Parameter determining conversion factor	Wavelength dependence
Optical system efficiency	Yes
Diffraction efficiency of grating	Yes
Image sensor sensitivity	Yes
Charge-to-voltage converter circuit constant	No
A/D converter resolution	No

1 - 4 Operation mode

Normal operation mode (free-run operation)

When light enters an image sensor, an electrical charge is generated in each pixel of the image sensor according to the incident light level. This charge accumulates in each pixel during the integration time and is cleared to zero when read out. This means that the charge must be read out before starting integration of newly generated charges. In mini-spectrometers, this cycle of “charge integration → charge readout (A/D conversion) → digital data hold” repeats in a cycle. Digital data is constantly updated with data obtained in the last integration time. When a data request is received from the PC, the mini-spectrometer sends the latest data at that point to the PC. Figure 1-14 shows this operation mode (free-run operation).

[Figure 1-14] Free-run operation



Operation mode during external trigger input

Operation mode in the following mini-spectrometers can be changed by external trigger input.

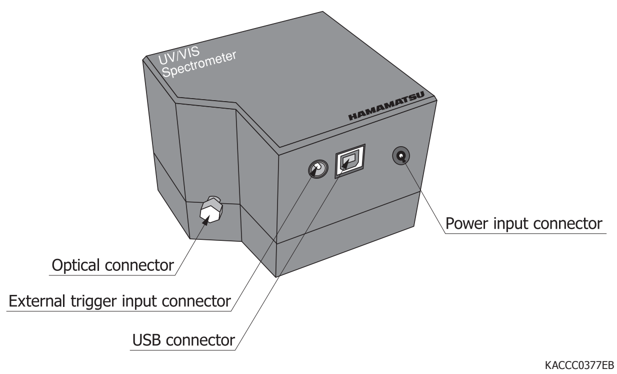
> C9404CA, C9404CAH, C9405CA
> C10082CA, C10082CAH, C10082MD
> C10083CA, C10083CAH, C10083MD

Note: The following mini-spectrometers do not support the external trigger input function: C9404MC, C9405MC, C9406GC, C9913GC, C9914GB, C11007MA, C11008MA, C11009MA, C11010MA, C10988MA

The external trigger input function works with DLL, but does not function on the supplied sample software. If using an external trigger input function, the user software must be configured to support that function.

Use the A10670 coaxial cable for external trigger (sold separately) to connect the mini-spectrometer to a device that outputs digital signals at 0 to 5 V levels.

[Figure 1-15] Mini-spectrometer connectors (C10082CA)



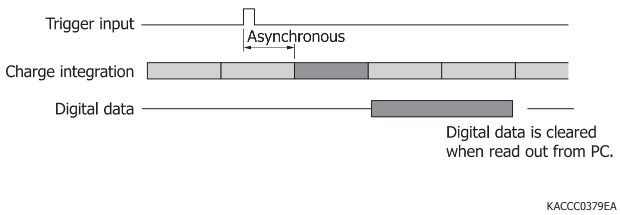
Operation modes using external trigger input are described below.

(1) Data hold by trigger input

This operation mode differs from free-run operation in that data to be held is controlled by trigger input. The mini-spectrometer internally holds digital data accumulated during the integration time that begins just after a trigger input edge (rising or falling edge selectable) is detected. This data being held is then reset when it is read out from the PC. If the next trigger is input while the data is still being held, then that data is updated to new

digital data.
For example, when a mini-spectrometer is used to detect light emitted from a DC mode light source with a shutter installed, then data accumulated in a predetermined integration time can be held by supplying the mini-spectrometer with a trigger input for shutter open operation. High repeatability measurements can be made by setting a shutter open period that is sufficiently longer than the integration time.

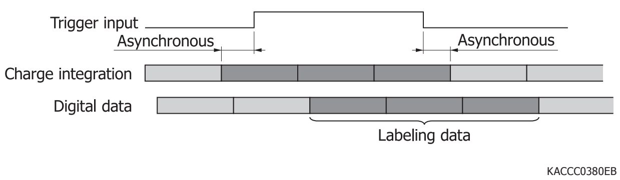
[Figure 1-16] Data hold responding to trigger input



(2) Data labeling during trigger input

This operation mode attaches a label to digital data during the gate period for external trigger input. A label is attached to the digital data corresponding to data integration during trigger input (high level or low level selectable). When the digital data is read out from the PC, the label information can be obtained at the same time.
When acquiring data under different measurement conditions, this mode is suitable for identifying which measurement condition applies to the measurement data. For example, suppose measurements are made under condition A and condition B. Condition A uses no trigger input to make measurements, so there is no labeling. In contrast, condition B uses a trigger input, so a label is attached to the acquired data. Labeling the acquired data in this way during trigger input makes it possible to distinguish between acquired data measurement conditions.

[Figure 1-17] Data labeling at trigger input



1 - 5 Dedicated software

HAMAMATSU mini-spectrometers come with a dedicated software package (CD-ROM).

Dedicated software functions

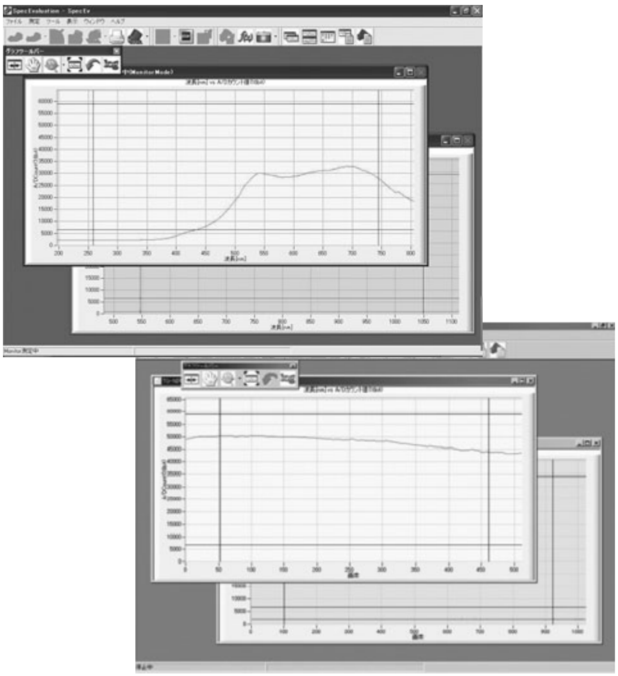
Installing the dedicated software package (sample software, device driver, DLL)*1 into your PC allows running the following basic tasks.

· Measurement data acquisition and save
· Measurement condition setup
· Module information acquisition (wavelength conversion factor*2, mini-spectrometer type, etc.)
· Graphic display
· Arithmetic functions
[Pixel number to wavelength conversion / calculation in comparison with reference data (transmittance, reflectance) / dark subtraction / Gaussian approximation (peak position and count, FWHM)]

*1: Compatible OS: Microsoft Windows Professional Edition 2000 (SP3 or later) / Windows XP Professional (SP1a or later)
Compatible OS for C11118GA (supporting USB 2.0)
Microsoft Windows XP Professional (SP1a or later)/VISTA Business (.NET-Framework 2.0 or later)
*2: Conversion factors for converting the image sensor pixel number into a wavelength. Calculation factors for converting the A/D converted count into a value proportional to the incident light level are not provided.

Note:
Two or more mini-spectrometers (TM series, TG series) can be connected to one PC.
The following three types of sample software are available. Each type of sample software can only be used for the specified mini-spectrometers.
· For TG series (except for C11118GA), TM series
· For RC series
· For C11118GA

[Figure 1-18] Display examples of dedicated software



The dedicated software has four measurement modes: "Monitor" mode, "Measure" mode, "Dark" mode, and "Reference" mode. Table 1-3 shows features in each measurement mode. Data measured in Measure mode, Dark mode*3, and Reference mode*3 can be saved in csv format (loadable into Microsoft Excel®).
Table 1-4 shows the arithmetic functions of the dedicated

software, and Table 1-5 shows limitations on setting parameters.

*3: Dark mode and Reference mode are not provided for the C11118GA. Measure mode has equivalent functions.

Interface

The dedicated software includes a device driver and DLL. By using this DLL, the user can create Windows application software for mini-spectrometer control in a software development environment such as Microsoft Visual C++, Microsoft Visual Basic, and LabVIEW*4. Because Windows application software cannot directly access a USB host controller, the necessary functions should be called from the DLL to allow the software to access the USB host controller via the device driver and USB driver and to control the mini-spectrometer [Figure 1-19].

*4: Operation has been verified only on Microsoft Visual C++® (C11118GA: C++/CLI), Microsoft Visual Basic®, and LabVIEW®. LabVIEW is only supported by the TM series and TG series.

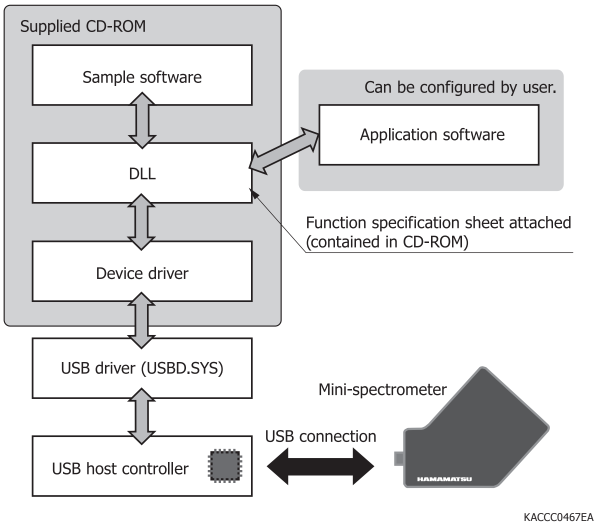
Note: · Microsoft Visual C++, Visual Basic, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.
· LabVIEW is a registered trademark of National Instruments.

[Table 1-3] Measurement modes of dedicated software

Function	Description	Features
Monitor mode	Measurement mode not intended to save acquired data	Graphically displays “pixel no. vs. A/D output value” in real time
Monitor mode	Measurement mode not intended to save acquired data	Graphically displays “wavelength vs. A/D output value” in real time
Monitor mode	Measurement mode not intended to save acquired data	Graphically displays time-series data at a selected wavelength*5
Monitor mode	Measurement mode not intended to save acquired data	Cannot save measurement data
Monitor mode	Measurement mode not intended to save acquired data	Performs dark subtraction
Monitor mode	Measurement mode not intended to save acquired data	Displays reference data
Monitor mode	Measurement mode not intended to save acquired data	Cannot set the number of measurement scans. No limit on scan count.
Measure mode*6	Measurement mode intended to save acquired data	Graphically displays “pixel no. vs. A/D output value” in real time
Measure mode*6	Measurement mode intended to save acquired data	Graphically displays “wavelength vs. A/D output value” in real time
Measure mode*6	Measurement mode intended to save acquired data	Graphically displays time-series data at a selected wavelength*5
Measure mode*6	Measurement mode intended to save acquired data	Saves measurement data
Measure mode*6	Measurement mode intended to save acquired data	Performs dark subtraction
Measure mode*6	Measurement mode intended to save acquired data	Displays reference data
Measure mode*6	Measurement mode intended to save acquired data	Sets the number of measurement scans
Dark mode	Measurement mode for acquiring dark data (used to perform dark subtraction)	Graphically displays “pixel no. vs. A/D output value” in real time
Dark mode	Measurement mode for acquiring dark data (used to perform dark subtraction)	Graphically displays “wavelength vs. A/D output value” in real time
Dark mode	Measurement mode for acquiring dark data (used to perform dark subtraction)	Saves measurement data
Reference mode	Measurement mode for acquiring reference data	Graphically displays “pixel no. vs. A/D output value” in real time.
Reference mode	Measurement mode for acquiring reference data	Graphically displays “wavelength vs. A/D output value” in real time
Reference mode	Measurement mode for acquiring reference data	Saves measurement data
Trigger mode*5	Measurement mode for acquiring data by trigger signal	Software trigger, asynchronous measurement
Trigger mode*5	Measurement mode for acquiring data by trigger signal	Software trigger, synchronous measurement
Trigger mode*5	Measurement mode for acquiring data by trigger signal	External trigger, asynchronous edge
Trigger mode*5	Measurement mode for acquiring data by trigger signal	External trigger, asynchronous level
Trigger mode*5	Measurement mode for acquiring data by trigger signal	External trigger, synchronous edge
Trigger mode*5	Measurement mode for acquiring data by trigger signal	External trigger, synchronous level
Continuous measurement mode*5	Continuous data acquisition by batch data transfer	Graphically displays “pixel no. vs. A/D output count” data at completion of data transfer
Continuous measurement mode*5	Continuous data acquisition by batch data transfer	Graphically displays “wavelength vs. A/D output count” data at completion of data transfer
Continuous measurement mode*5	Continuous data acquisition by batch data transfer	Saves measurement data

*5: Only supported by C11118GA
*6: The Measure mode for the C11118GA also serves as the Dark and Reference modes.

[Figure 1-19] Software configuration example



1-6 New approaches

HAMAMATSU has been actively engaged in developing compact spectrometers and has marketed mini-spectrometer products for spectral detection in the ultraviolet (down to 200 nm) to near infrared (up to 2.55 μm) region. These mini-spectrometers include an ultra-compact (one-inch size), low cost model designed for installation into mobile measuring devices, a high sensitivity type (incorporating a back-thinned CCD image sensor) suitable for low level spectrum measurement, and a cooled type with low noise. Taking advantage of our position as a leading sensor manufacturer, we are also developing CCD image sensors designed exclusively for mini-spectrometers.

Ultra-compact mini-spectrometers MS series

HAMAMATSU has recently developed ultra-compact mini-spectrometers using the state-of-the-art MOEMS (micro-opto-electro-mechanical systems) technology that combines nanotechnology and MEMS technology into image sensors.

[Table 1-4] Arithmetic functions of dedicated software

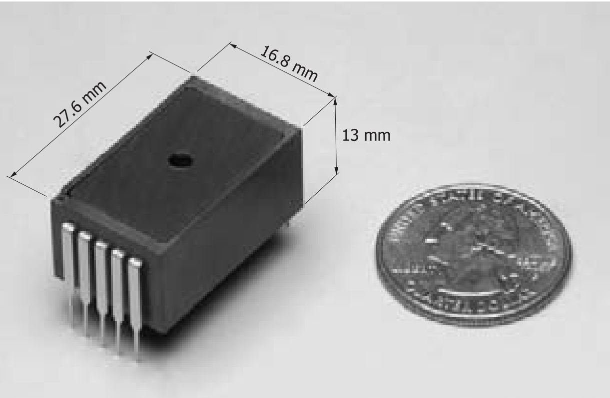
Function	Features
Dark subtraction function	Acquires dark data and subtracts it from measurement data. Displays measurement data after dark subtraction.
Reference data measurement/display function	Measures reference data and displays it graphically
Gaussian fitting function	Fits data in a specified range to Gaussian function

[Table 1-5] Limitations on setting parameters

Parameter	Limitation	
Integration time	6 μs to 40000 μs*1	C11118GA
	5 ms to 1000 ms*1	C9914GB
	5 ms to 10000 ms*1	C10082MD, C10083MD, C9404MC, C9405MC, C9406GC, C9913GC, C11007MA, C11008MA
	10 ms to 10000 ms*1	C10082CA, C10082CAH, C10083CA, C10083CAH, C9404CA, C9404CAH, C9405CA
Gain	High/Low	C10082MD, C10083MD, C9404MC, C9405MC, C9406GC, C9913GC, C9914GB, C11007MA, C11008MA, C11118GA
Scan count	Continuous measurement count depends on the memory size and operation status of PC (not limited during Monitor mode).	

*1: Specified in 1 μs steps

[Figure 1-20] Ultra-compact mini-spectrometer C10988MA



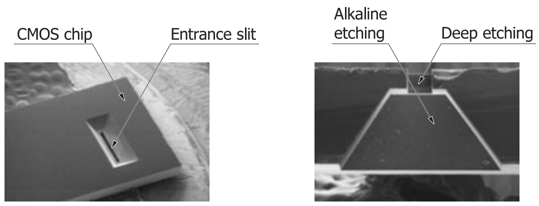
◉ Features of ultra-compact mini-spectrometer

- Thumb size (27.6 × 16.8 × 13 mm)
- Entrance slit is formed on the image sensor by deep etching.

Entrance slit is precisely positioned and formed using the same photomask as the image sensor.

[Figure 1-21] Entrance slit structure

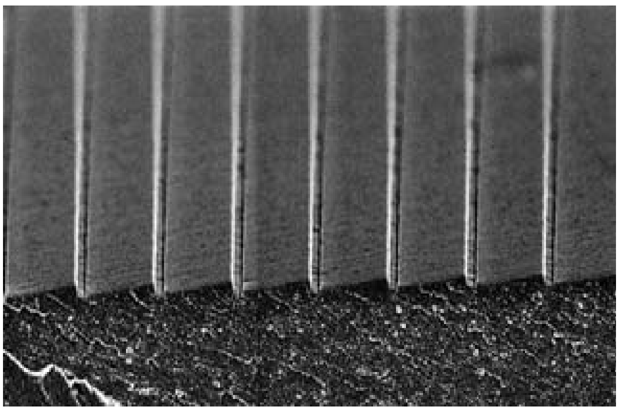
(a) Backside of CMOS chip (b) Cross section of entrance slit



- Replicated grating

The technique for replicating a grating makes use of nanoimprint, which transfers an engraved grating pattern onto a glass body. Ultraviolet-curing resin (replica resin) is attached near the top of a condenser lens, and the grating is replicated on the lens by pressing the grating pattern against the resin while simultaneously irradiating it with ultraviolet light.

[Figure 1-22] SEM photograph of a grating

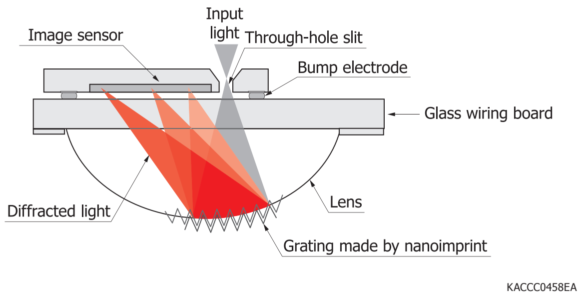


[Table 1-6] Major specifications for ultra-compact mini-spectrometer

Parameter	Specification	Unit
Spectral response range	340 to 750	nm
Spectral resolution (FWHM)*2	12	nm
Wavelength reproducibility*3	±0.5	nm
Spectral stray light*2 *4	-25	dB
Entrance slit size	75 (H) × 750 (V)	µm
Optical NA (numerical aperture)	0.22	-
Number of pixels	256	pixels
Pixel size	12.5 (H) × 1000 (V)	µm
Operating temperature	+5 to +40	°C
Storage temperature	-20 to +70	°C
Weight	9	g

*2: Measured with standard slit
*3: Measured under constant conditions
*4: While a line spectrum is input, the spectral stray light is defined as the ratio of the count measured at the input wavelength, to the count measured at a wavelength 40 nm longer or shorter than the input wavelength.

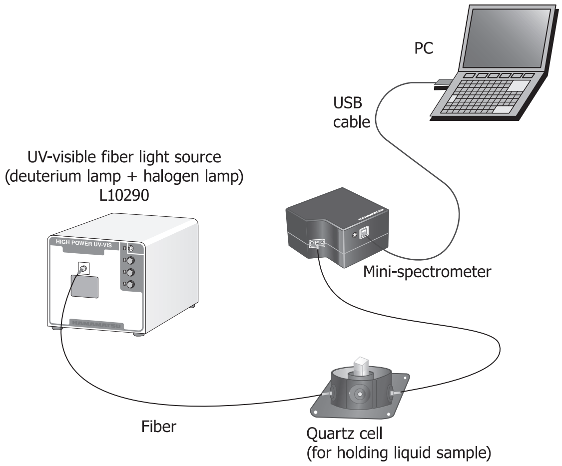
[Figure 1-23] Optical system layout (ultra-compact mini-spectrometer)



10 ▼ Module products

1-7 Applications

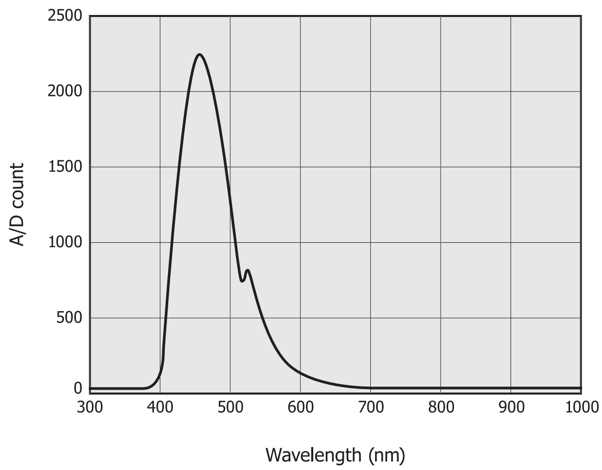
[Figure 1-24] Connection example (measurement of liquid absorbance)



Fluorescence measurement

Figure 1-25 is an example of measuring fluorescence from a 1000 ppm quinine solution (buffer solution: dilute sulfuric acid).

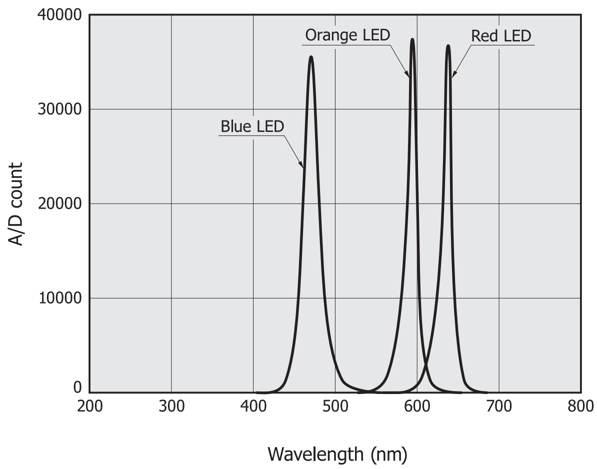
[Figure 1-25] Fluorescence measurement example (C10083CA)



LED emission measurement

(1) Visible LED

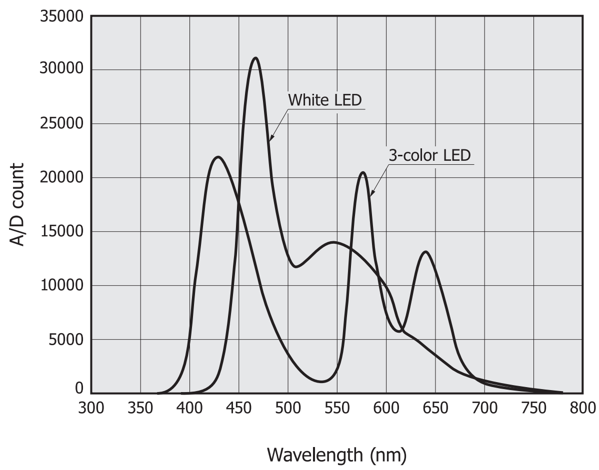
[Figure 1-26] Visible LED measurement example (C10082MD)



(2) White LED and 3-color LED

Figure 1-27 is an example of measuring emissions from a white LED and 3-color LED. White LED light contains wavelength components of various colors as well as blue, and appears white because those colors are mixed together.

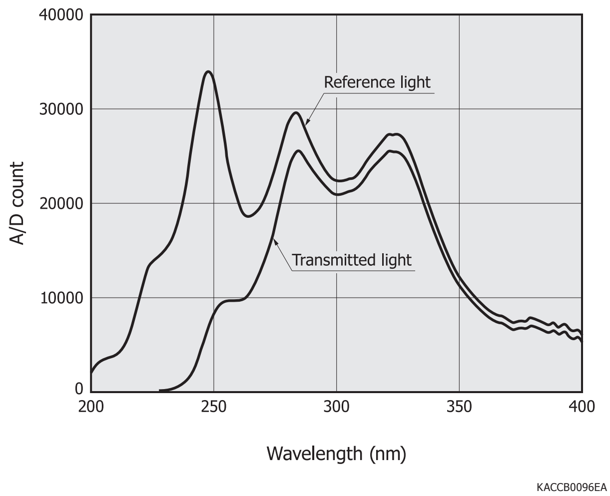
[Figure 1-27] White LED and 3-color LED measurement example (C11007MA)



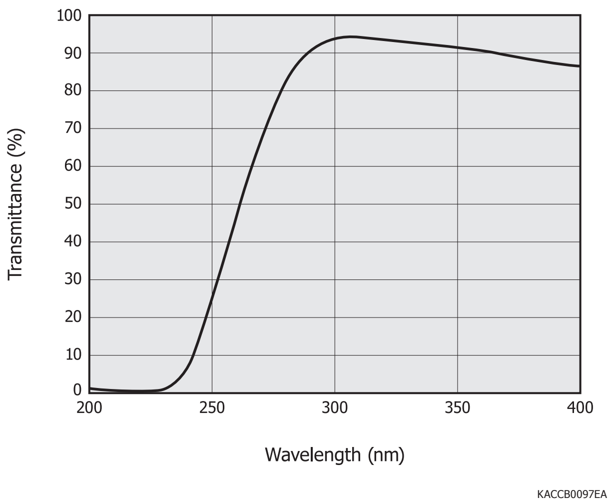
Transmittance measurement

[Figure 1-28] Transmittance (1 mm thick optical window) measurement example (C9404MC)

(a) Measurement value

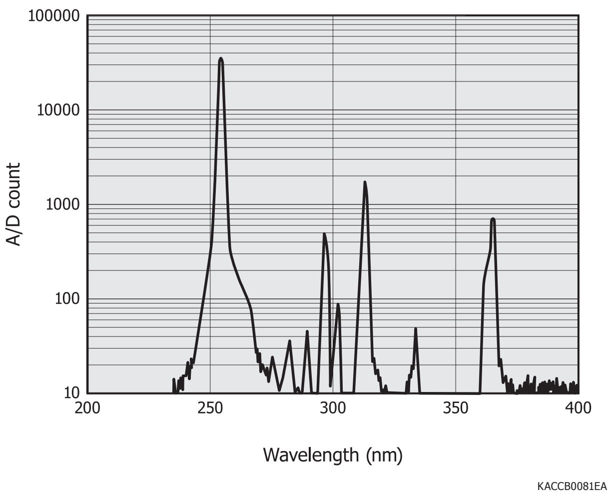


(b) Calculation result



Line spectrum measurement

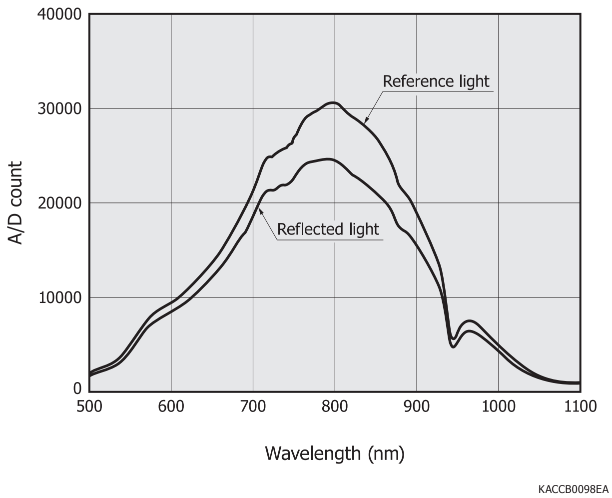
[Figure 1-29] Measurement example of low-pressure mercury lamp's line spectra (C9404MC)



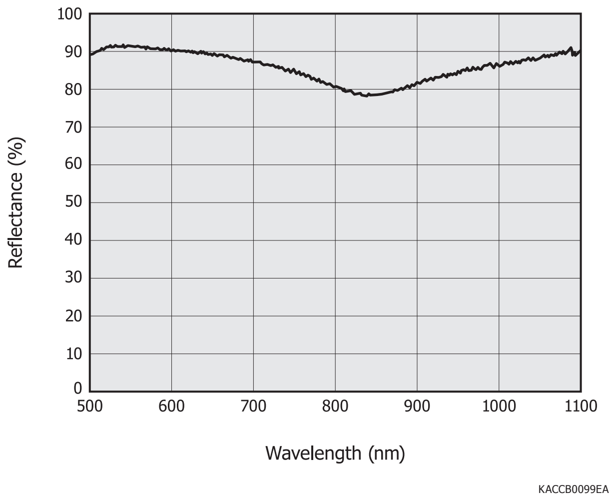
Reflectance measurement

[Figure 1-30] Measurement example of spectral reflectance of reflecting mirror (C9405MC)

(a) Measurement value



(b) Calculation result

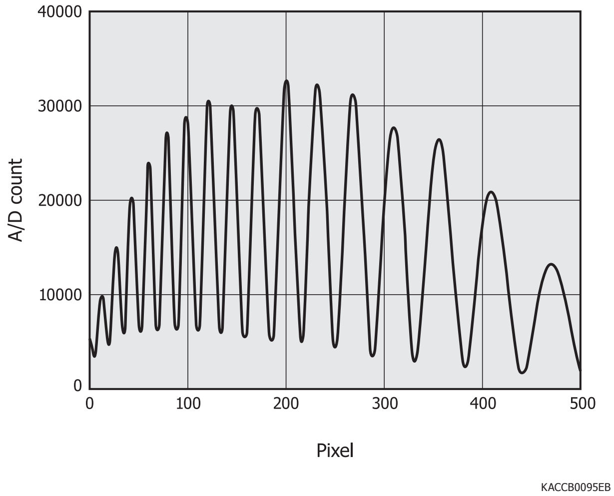


Film thickness measurement

Here we show an example that measures the film thickness of 10 µm thick food wrap (polyvinylidene chloride).

In film thickness measurement utilizing white light interferometry, a rippling interference spectrum is obtained due to reflections between the front and back surfaces of the film. The film thickness can then be determined by calculation from the spectral peak count, wavelength range, refractive index of film, and the angle of incident light.

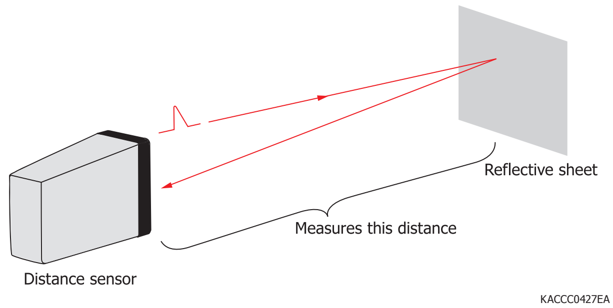
[Figure 1-31] Film thickness measurement example (C9406GC)



2. Distance sensors

These distance sensor modules are designed to measure distances to a reflective sheet attached to the target object. The distance is measured by emitting pulsed light from a 660 nm semiconductor laser to irradiate the reflective sheet and measuring the time-of-flight required for the laser light to return to the sensor.

[Figure 2-1] Measurement of distance to reflective sheet



2 - 1 Features

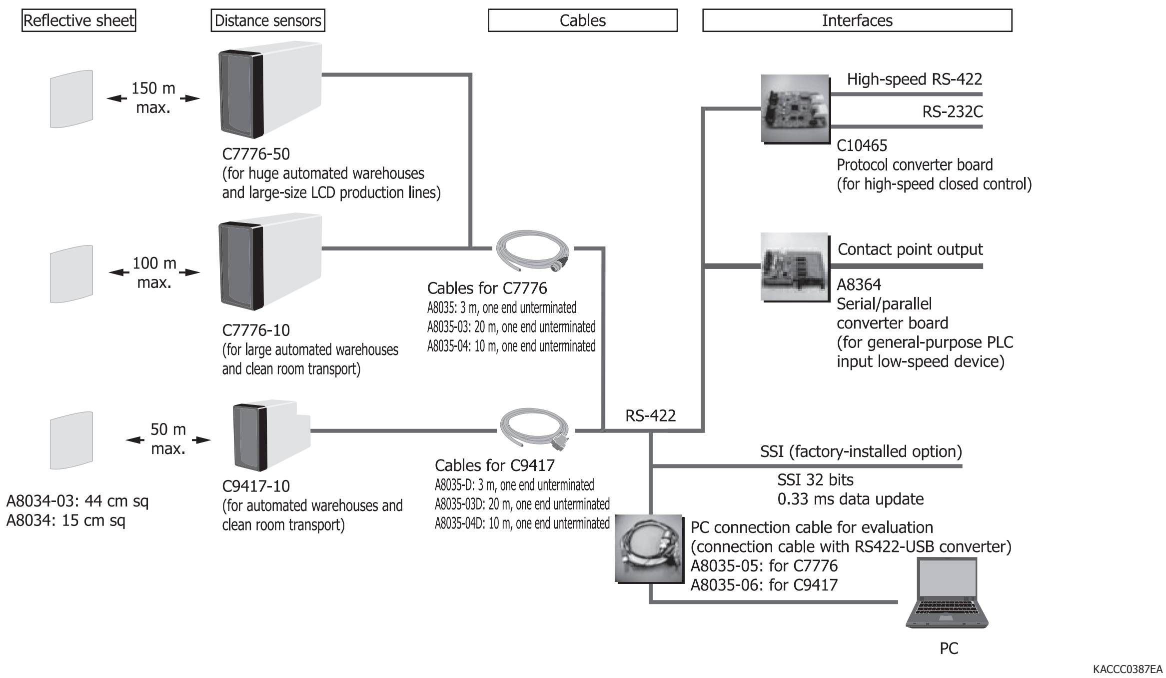
- High-speed response by pulse method: more than 160 measurements per second

Can detect objects moving at a high speed.

- High accuracy

To achieve a time measurement accuracy level of better than 1 ps and a wide operating temperature range, optical self-calibration is performed by switching the lighting of two lasers for self-calibration and for measurement at high speeds. This allows compensating in real time for electronic circuit

[Figure 2-2] Distance sensors and user options



characteristics which vary during measurement.

- Reducing distance-dependent changes in detection light level

The signal light level returning from a target object decreases in inverse proportion to the square of the distance. If the optical system is configured to match a long distance point, this may cause a focus shift and measurement errors due to excessive signal levels when measuring short distance points. To cope with this, our distance sensors use a large aspherical plastic lens having three focal points: long distance, mid-distance, and short distance, so that changes in the detection light level due to different distances are reduced to a minimum. The area ratio of the lens with three types of focal points is set so that a nearly constant amount of signal is obtained up to about 30 m when all signals are summed.
The signal level is high when detecting short distances, so a satisfactory signal is obtained even on small areas on the short-distance lens. The long-distance lens has a focal distance of infinity over approximately the entire lens surface which is made large to maintain a sufficient signal level.

- Red (660 nm) semiconductor laser

The red beam makes it easy to check the optical axis.

- Safety: Laser Class 1 (IEC, JIS, FDA)

- Long service life (MTTF: 90000 h)

Laser is pulse-driven, so temperature increases in the laser are suppressed. This also helps extend the service life.

- Interface: flexible response to meet customer needs

- Low power consumption

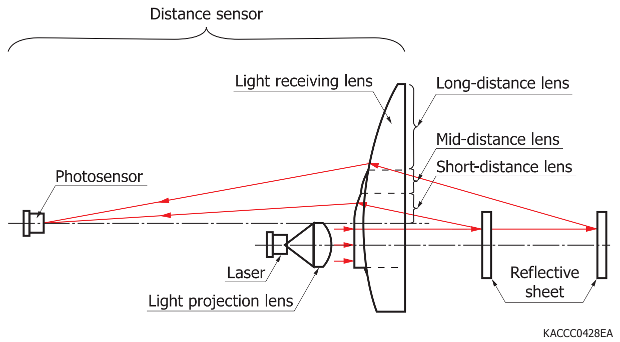
- Compact and lightweight

- High reliability

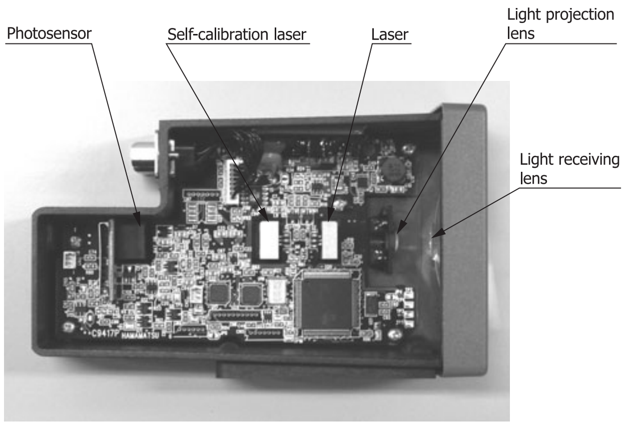
Our distance sensors are highly reliable during vibration and shock as well as during long-term continuous operation since there are no mechanically moving parts which are used in general optical distance measuring devices. Even if signal light is interrupted, measurement starts immediately after the signal light resumes.

2 - 2 Structure

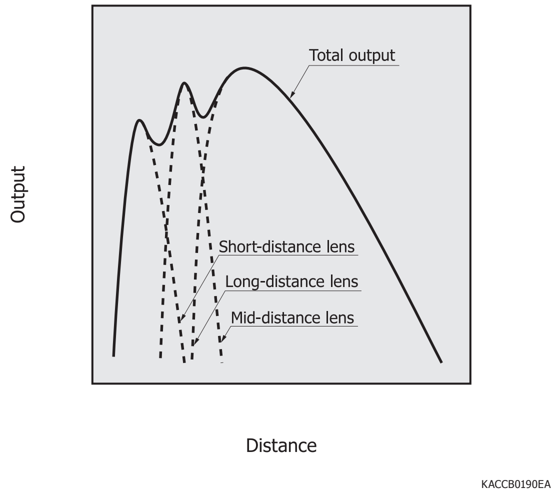
[Figure 2-3] Distance sensor configuration



[Figure 2-4] Internal view of distance sensor (C9417-10)



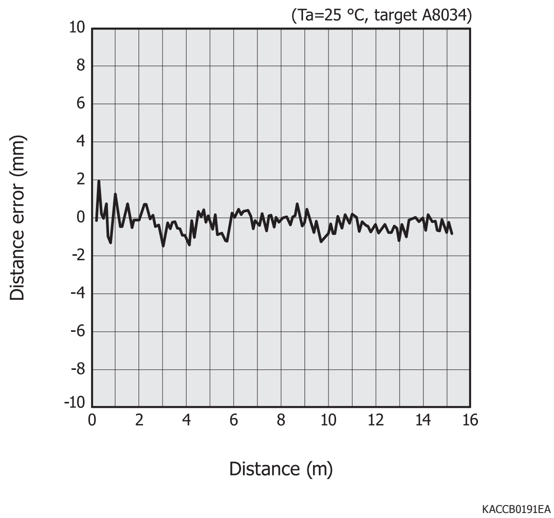
[Figure 2-5] Output vs. distance (distance sensor light receiving lens)



2 - 3 Characteristics

Figure 2-6 is an example of distance errors showing differences between the results measured with a distance sensor and the actual distances.

[Figure 2-6] Distance error vs. distance (C9417-10, typical example)



2-4 How to use

Precautions

(1) Use a specified reflective sheet.

Our distance sensors are designed on the assumption they will be used with the reflective sheet we specify. Using other reflective sheets might result in errors or poor performance even if measurements are possible.

(2) Tilt the reflective sheet at an angle 2 to 3 degrees versus the optical axis and stick it neatly.

If the distance sensor and reflective sheet are exactly facing each other, then reflected light components may vary greatly with changes in the angle. This causes sudden changes in signal level as well as increased distance errors. To prevent this problem, tilting the reflective sheet 2 or 3 degrees is recommended. If there are ripples or wrinkles on the reflective sheet, they may create a problem due to reflected light components the same as described above. Stick the reflective sheet neatly on the object surface.

(3) Install the distance sensor in a location away from noise sources.

If the distance sensor is placed near objects emitting strong electromagnetic noise such as power motors, then such noise might increase fluctuations in measurement.

Tips for optical axis alignment

· When measuring short distances (approx. 10 m or less), align the optical axis using a white sheet placed near the distance sensor. Then gradually move the white sheet away from there. This makes it easier to check the position of the laser beam spot.
· When measuring long distances (approx. 10 m or more), align the optical axis using the reflective sheet. The farther away the reflective sheet is moved, the more difficult it becomes to see the laser beam spot on the reflective sheet. In such cases the beam spot will be easier to see if you view it from the same height as the distance sensor and from right behind the distance sensor.

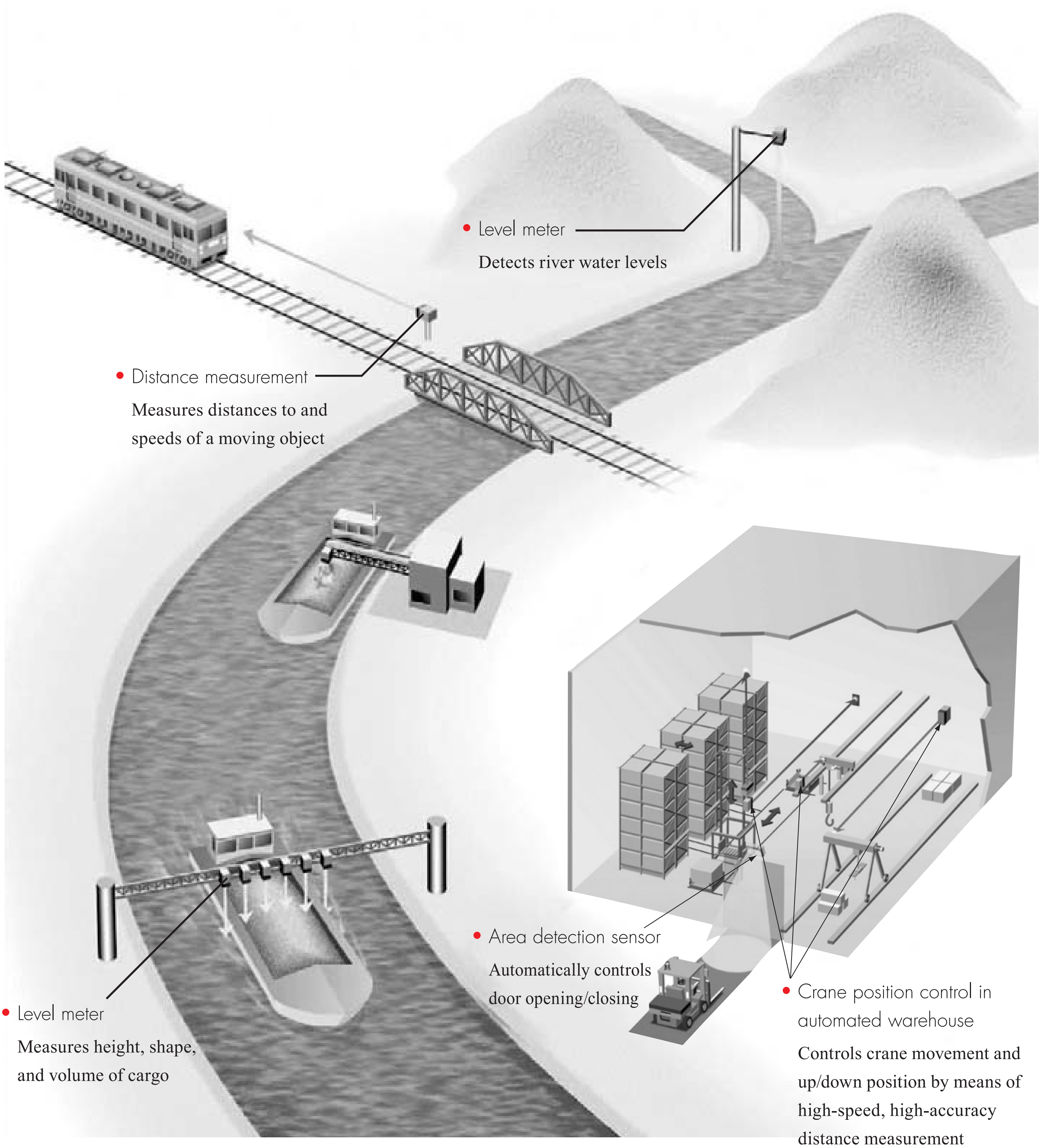
When operation errors occur

When operation errors occur, it might be difficult to identify the causes and correct them if they seldom occur. So we recommend recording the date and time, distance, and signal level when those errors occurred.

2-5 New approaches

In distance measurements such as in FA (factory automation) fields, there are increasing demands for higher measurement accuracy. Performance of components such as light emitting/receiving elements and amplifiers mutually affects the distance sensor measurement accuracy. By taking their mutual balance into account besides improving performance of individual components, we are developing distance sensors with even higher accuracy. In order to expand our product lineup of compact and low cost types, we are working on ways to boost electronic component mounting density and achieve higher optical component integration. We are also working on a distance image sensor that uses the TOF (time-of-flight) method. This sensor will be able to recognize three-dimensional shapes at high speeds by simultaneously capturing distance information and images.

2-6 Applications



3. Smart cameras

Smart cameras are intelligent camera modules designed to detect the position of a specific target mark. These cameras are useful for position control of FA (factory automation) devices, etc.

3 - 1 Features

- Target mark position detection

The CMOS area image sensor in the smart camera detects two-dimensional image data which is then processed in a latter-stage signal processing circuit to acquire the target mark position information.

- Compact and sophisticated

A CMOS area image sensor made by HAMAMATSU is housed in a compact enclosure, along with a signal processing circuit, light source, and optical lens. Results calculated by signal processing are output from the smart camera. Unlike commonly used image processing units, no PC is needed here for signal processing.

- High-speed response

Data update period is 60 frames/s.

- Built-in light source

An infrared LED is incorporated in the module as the light source. This LED corresponds to Laser Class 1.

- High robustness to fluctuating background light

A target mark with a clearly defined shape is used, and the detected two-dimensional image data is signal-processed to extract the characteristic information on the target mark. The camera is not easily affected by fluctuating background light since a built-in light source is used to irradiate the target mark and the image formed by the reflected light is then detected.

3 - 2 Structure

The smart camera consists of the following three components:

(1) Light receiving section

This section is made up of a CMOS area image sensor and an optical lens.

(2) Signal processing circuit

This circuit consists of an arithmetic circuit for extracting the characteristic information on the target mark from the two-dimensional image data detected by the CMOS area image sensor, an LED driver circuit, and an interface.

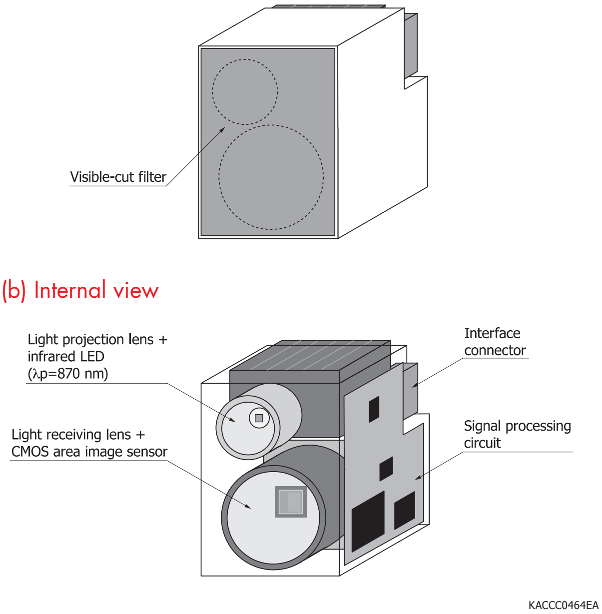
(3) Light source

This is an infrared LED (870 nm) that corresponds to Laser Class 1.

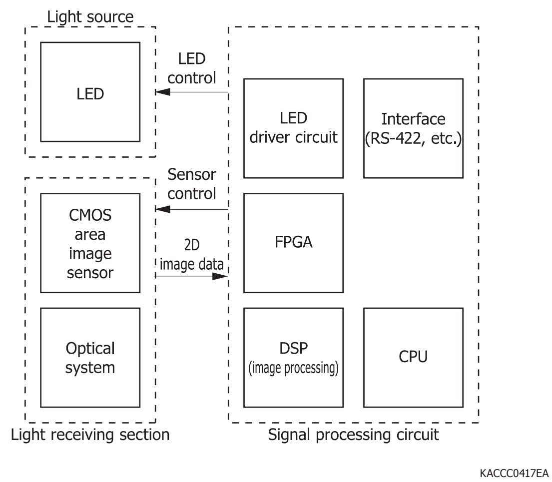
[Figure 3-1] Smart camera structures

(a) External view

(b) Internal view



[Figure 3-2] Block diagram



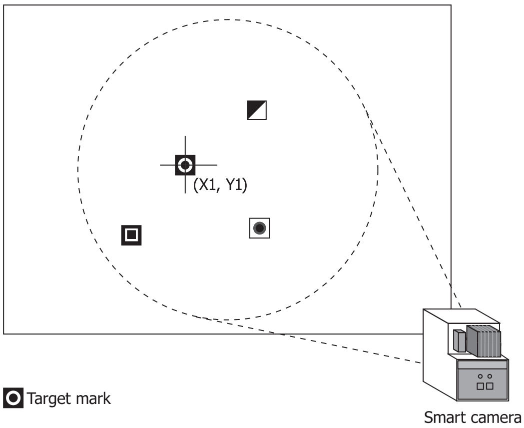
3 - 3 Operating principle

Pulsed light from the LED is irradiated onto the target to be detected, and the reflected light synchronized with the light emission timing is acquired by the CMOS area image sensor as two-dimensional image data. This two-dimensional image data is sent to the latter-stage signal processing circuit where signal processing is performed.

The acquired image is compared with the target mark shape (template) that has been registered beforehand in the signal processing circuit in order to determine the position at which the target mark shape is captured. To do this, arithmetic processing is performed at the same speed as the frame rate

(60 frames/s) of the CMOS area image sensor. The target mark position information is then sent to the host device via the interface.

[Figure 3-3] Coordinates are detected by identifying the target mark only.



3 - 4 New approaches

We are thinking of loading a signal processing algorithm into the smart camera in order to detect the various characteristic information (angles, edge lines, etc.) of a target mark from among image data acquired by the CMOS area image sensor. We are also developing a high-performance type smart camera that makes use of the features of our CMOS area image sensors such as high speed and high resolution.

3 - 5 Applications

- Position detection module
- Position check and control for various FA devices
- Stop position control for stacker crane

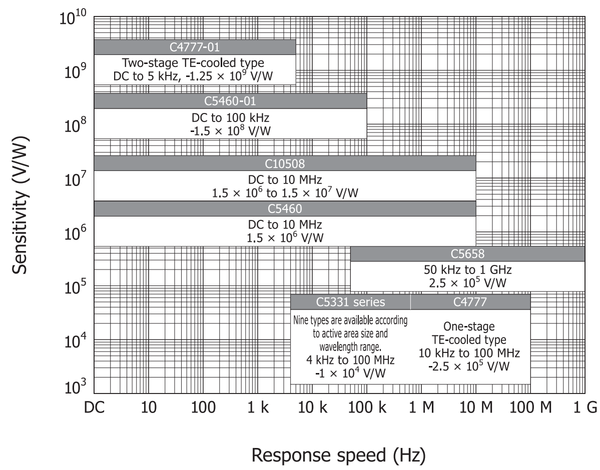
4. APD modules

APD modules are high-sensitivity photodetectors that integrate an APD (avalanche photodiode), a temperature-compensation bias circuit (or temperature control circuit), and a current-to-voltage converter. Operating an APD module is easy since it works by simply supplying a DC voltage from an external source. 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. A temperature-compensation type with stabilized gain and a thermoelectrically cooled type are provided.

Temperature-compensation APD modules (standard type, high sensitivity type, high-speed type) keep the APD gain nearly constant using the high-precision temperature-compensation circuit. Thermoelectrically cooled APD modules maintain a stable gain by controlling the APD temperature at a constant level, thereby allowing high-precision measurement.

[Figure 4-1] Sensitivity vs. response speed (APD modules)



4 - 1 Features

- Stable operation against temperature fluctuations

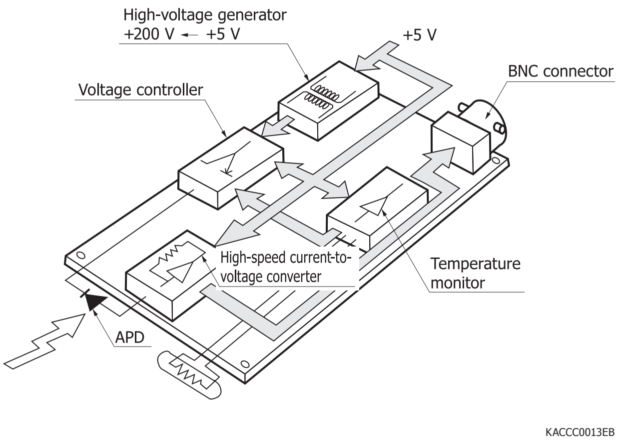
Applying a high reverse voltage to an APD increases its sensitivity higher than general Si photodiodes. However, temperature fluctuations cause the sensitivity to change even if the same reverse voltage is applied. There are two methods to maintain the APD sensitivity constant: one is a temperature-compensation 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. 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 cooling element that is kept at a constant temperature by the internal temperature control circuit so that a very stable gain is achieved with high stability.

- Low noise
- Compact and lightweight

[Figure 4-2] Block diagram (C5331)

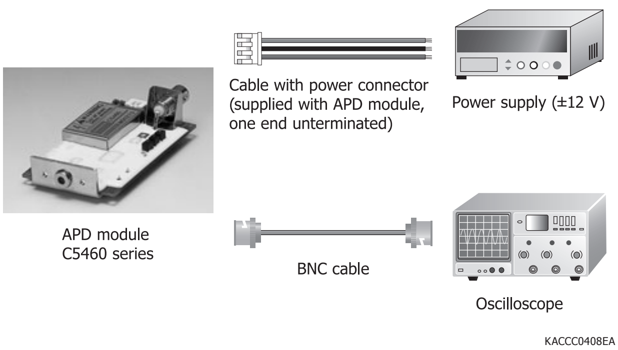


4 - 2 How to use

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 4-3] Connection example (C5460 series)



4 - 3 New approaches

In fields requiring ultra-low light level measurements such as in medical fields, there is an increasing demand for a higher S/N level to obtain better results. HAMAMATSU is continually developing wideband, low-noise APD modules that deliver ever higher S/N levels. To expand our product lineup to include compact and low cost types, we are making intensive efforts to boost electronic component mounting density.

4 - 4 Applications

- Flow cytometry
- Optical topography
- Fluorescence measurement
- Laser radars

5. MPPC modules

MPPC modules are photon-counting modules that contain an MPPC (multi-pixel photon counter) capable of detecting extremely low-level light. These modules deliver excellent photon-counting characteristics by extracting maximum MPPC performance.

MPPC modules consist of an MPPC, current-to-voltage converter, high-speed comparator circuit, high-voltage power supply circuit, temperature-compensation circuit, counter circuit, and microcontroller. A USB 1.1 interface is also included to allow changing the threshold level (detection level for one photon) from a PC. Operating an MPPC module is easy, since it runs on USB bus power and needs no external power supply. Three kinds of outputs are available: analog output, comparator output, and pulse count output (via USB).

Operating an MPPC module requires highly precise voltage control because the MPPC is used in Geiger mode where the reverse voltage versus gain characteristics are very steep and also because the applied reverse voltage range is narrower than that for normal APD. MPPC modules therefore use a microcontroller to control the reverse voltage with high accuracy to ensure highly stable MPPC operation. MPPC modules are a promising tool for photon-counting applications in a wide range of fields such as in fluorescence lifetime measurement, bioluminescence analysis, analytical instrumentation, and high energy physics experiments.

[Table 5-1] HAMAMATSU MPPC modules

Type	Feature
Board type	Available with metal or ceramic package MPPC
CE marking compliant type	Conforms to EMC directives in Europe

5 - 1 Features

- Signal readout circuit optimized for MPPC

Amplifies weak signals from the MPPC and outputs them while maintaining a high S/N level.

- High-voltage power supply circuit and temperature-compensation circuit

The MPPC is used in a state called Geiger mode where a high reverse voltage is applied to yield a very high gain. Ambient temperature fluctuations cause the gain to vary even if the same reverse voltage is applied. So keeping the MPPC gain constant becomes a critical factor.

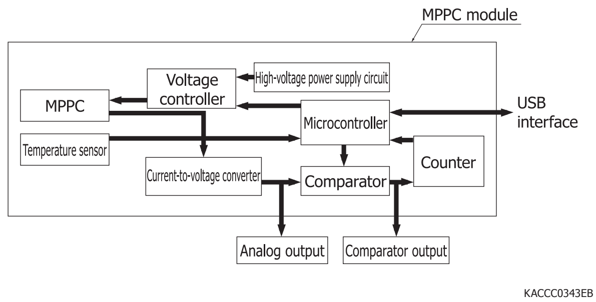
To keep the MPPC gain constant, MPPC modules use a temperature-compensation method that changes the reverse voltage according to the ambient temperature. A high-precision temperature sensor is installed close to the MPPC to constantly monitor the MPPC temperature with high accuracy. The gain can be kept constant with both high accuracy and high stability by applying a temperature-compensated reverse voltage to the MPPC.

- Three types of output format (analog output, comparator output, and pulse count output)
- USB 1.1 interface included
- USB bus power operation (no external power supply required)

Bus power supply is stabilized to achieve low noise.

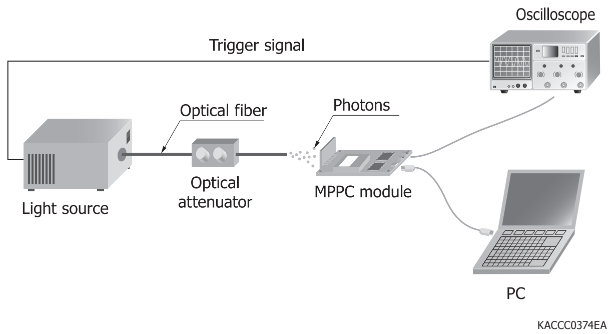
- Compact and lightweight

[Figure 5-1] Block diagram

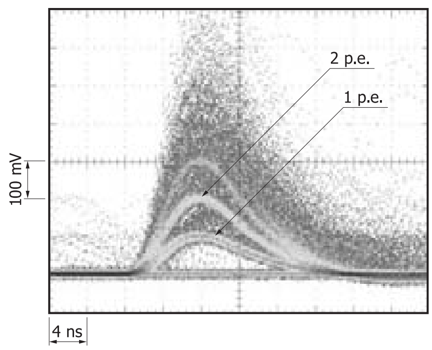


[Figure 5-2] Measurement example

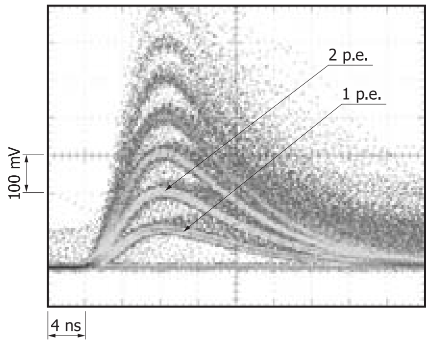
(a) Setup



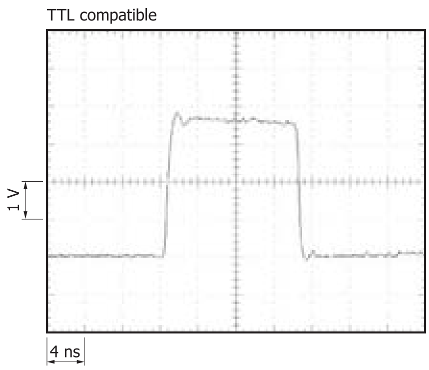
(b) Analog output (C10507-11-025U)



(c) Analog output (C10507-11-050U)



(d) Comparator output (C10507-11-050U)



5 - 2 How to use

After installing the sample software (supplied with the MPPC module) into the PC, connect the MPPC module to the PC using the supplied USB cable. The MPPC module operates on USB bus power from the PC via the USB cable. MPPC module operation can be performed from the PC and the measurement data monitored on the PC.

Analog output and comparator output are taken from the coaxial connector. Connecting the analog output to an oscilloscope allows monitoring its waveform. Connecting the comparator output to a frequency counter allows acquiring its count value.

[Figure 5-3] Connection example

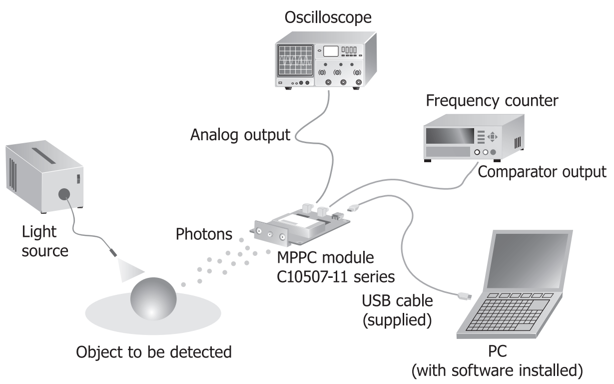


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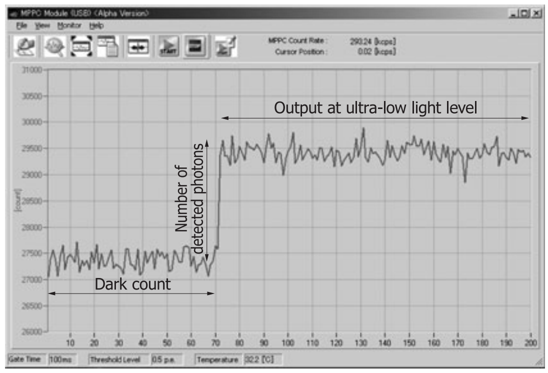
Figure 5-4 is an example of the PC screen, showing the change in output when ultra-low level light is input from dark conditions.

[Figure 5-4] Example of sample software displayed on PC screen



Vertical axis: number of input counts per gate time setting
Horizontal axis: time [1 second per scale division (10)]

5 - 3 New approaches

In ultra-low light level detection applications, there is a growing demand for better detection efficiency and a lower dark count. Besides improving MPPC characteristics, HAMAMATSU is working to enhance its circuit technology to make maximum use of MPPC characteristics.

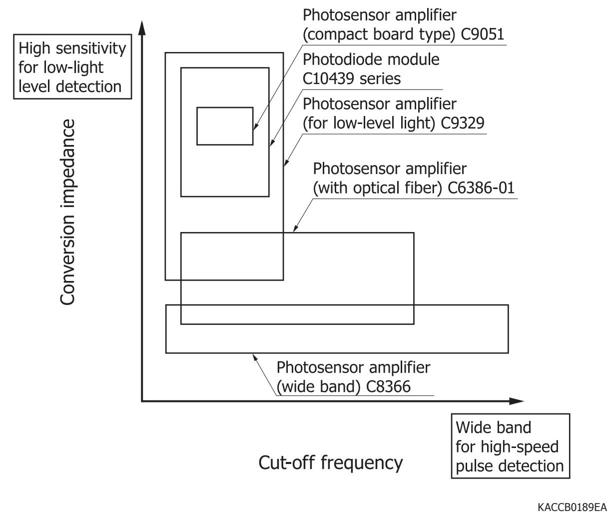
5 - 4 Applications

- Fluorescence lifetime measurement
- Biological flow cytometry
- Bioluminescence analysis
- Ultra-low light level detection
- Analytical instruments

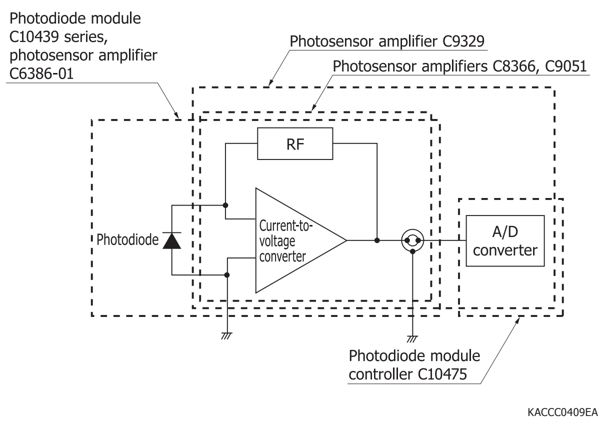
6. Photosensor amplifiers and photodiode modules

To make our photodiodes easier to use, we offer photosensor amplifiers and photodiode modules with an internal current-to-voltage conversion amplifier. Several types with different conversion impedance and frequency characteristics are available as shown in Figure 6-1.

[Figure 6-1] Conversion impedance vs. cut-off frequency



[Figure 6-2] Block diagram



6 - 1 Photosensor amplifiers

Photosensor amplifiers are current-to-voltage conversion amplifiers designed to amplify low-level photocurrent in photodiodes with very low noise.

Features

- High accuracy and low noise

High-precision, low-noise components are used and arranged in a noise-resistant configuration. The C6386-01 and C9329 have a zero adjustment function to eliminate the offset.

- Dry battery operation (C6386-01, C9329)

- Switchable detection sensitivity (C6386-01, C9329)

- Wide bandwidth type available (C8366)

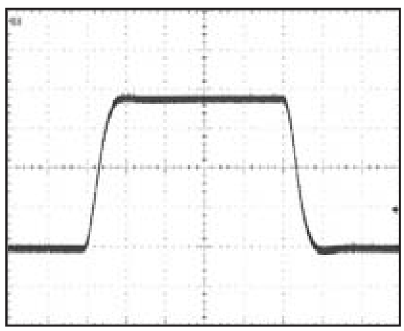
The C8366 wide-band type achieves high-speed response since a trimmer can adjust the feedback capacitance according to the PIN photodiode being connected.

- Optical fiber type available (C6386-01)

The C6386-01 optical fiber type uses an optical fiber that guides light to the internal photodiode. This reduces effects from noise on the photodiode and circuitry even if there is a noise source near the location of the light being measured.

- Recordable measurement data (C9329)

[Figure 6-3] Oscilloscope output example of analog signal (C9329)



Vertical axis: 1 V/div., horizontal axis: 400 μs/div.
S2281-01 Si photodiode with BNC connector (Ct=3300 pF typ.), middle range
Light: infrared LED (L1915-01), pulse width: 2 ms, measuring device: TEKTRONIX TDS3034B (BW 20 MHz)
Ambient temperature: 25 °C, overshoot: approx. 3%

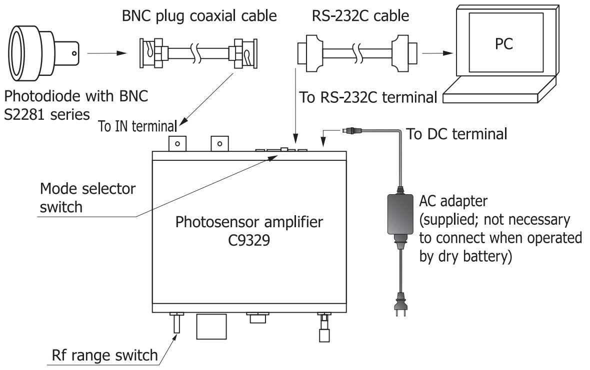
[Table 6-1] HAMAMATSU photosensor amplifiers

Type no.	Feature	Photodiode	Cut-off frequency	Conversion impedance (V/A)	Power supply	Output	Zero adjustment knob
C6386-01	With optical fiber (1 m)	Internally mounted	10 MHz	10^3	External power supply (±15 V) or dry battery (9 V × 2)	Analog	Yes
			3 MHz	10^4			
			1 MHz	10^5			
C8366	Wide bandwidth	Sold separately (high-speed Si PIN photodiode)	100 MHz	10^3	External power supply (±15 V)	Analog	None
C9051	Small board type	Sold separately (terminal capacitance: 15 nF or less)	16 Hz	10^8	AC adapter (12 V)	Analog	None
C9329	For low-level light	Sold separately (terminal capacitance: 5 nF or less)	1600 Hz	10^5, 10^7	AC adapter (12 V) or dry battery (9 V)	Analog Digital	Yes
			16 Hz	10^9			

Usage (C9329)

The input section of this photosensor amplifier is a BNC connector, so use a BNC plug coaxial cable to connect it to a photodiode.
Use a dry battery or AC adapter (supplied) to supply power to the photosensor amplifier.
Analog or digital operation mode is selectable for data output. In analog mode, measurements are made by connecting the output to a measuring device such as an oscilloscope using a BNC plug coaxial cable. In digital mode, digital signals (16 bits) can be obtained by serial connection (RS-232C) to a PC.

[Figure 6-4] Connection example (C9329, digital operation mode)



6-2 Photodiode modules

Photodiode modules are high-precision photodetectors that include a Si photodiode together with a current-to-voltage conversion amplifier. The output is an analog voltage and can be easily checked with a voltmeter, etc.
Photodiode modules have a sensitivity range (high/low) switching function, so a highly accurate output can be obtained by selecting a sensitivity range that matches the light level to be detected. Three types are available with different active areas.
HAMAMATSU also provides a photodiode module controller (sold separately) that converts the output of a photodiode module into digital signals. High-resolution digital signals (16 bits) can be obtained by serial connection (RS-232C) to a PC. Measurement data can then easily be stored into the PC using sample software that comes with the controller. Measurement data can also be stored in the internal memory (data logger function). The controller operates on dry battery and so can be used easily.

Features

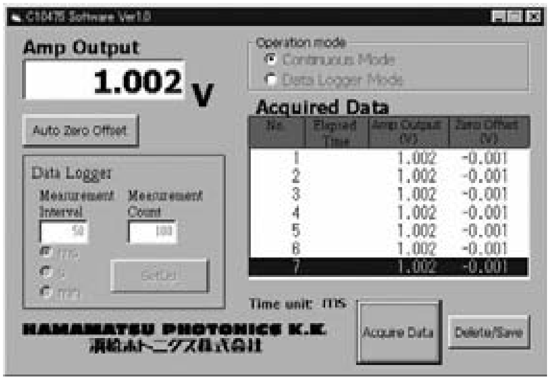
- Internal photodiode

Available with active areas of 2.4 × 2.4 mm, 5.8 × 5.8 mm, and 10 × 10 mm.

- Easy handling due to voltage output
- Selectable sensitivity (high/low range)
- Compact size (half a business card)
- Can be mounted on optical bench rod (M4)
- Photodiode module controller is provided (sold separately).

Measurement data can be easily loaded into a PC using sample software that comes with the controller.

[Figure 6-5] Example of sample software displayed on PC screen

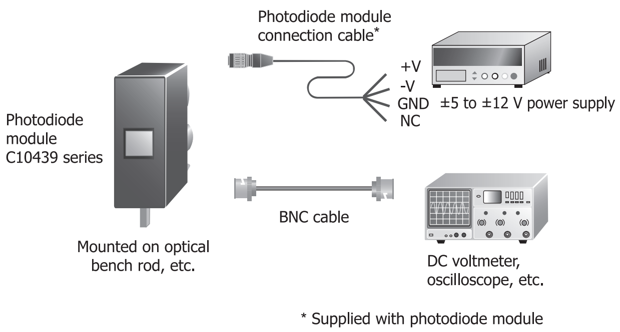


[Table 6-2] HAMAMATSU photodiode modules

Type no.	Active area size (mm)	Output	Conversion impedance (V/A)	Cut-off frequency (Hz)	Supply voltage (V)	Features	Items to be prepared by user
C10439-01	2.4 × 2.4	Analog	Low: 1×10^7 High: 1×10^9	Low: 1000 High: 10	±5 to ±12	● Easy handling ● RoHS compliance ● CE certified	● Photodiode module controller ● PC ● RS-232C cable
C10439-02	5.8 × 5.8						
C10439-03	10 × 10						

[Figure 6-6] Connection examples (C10439 series)

(a) Connection to DC voltmeter or oscilloscope



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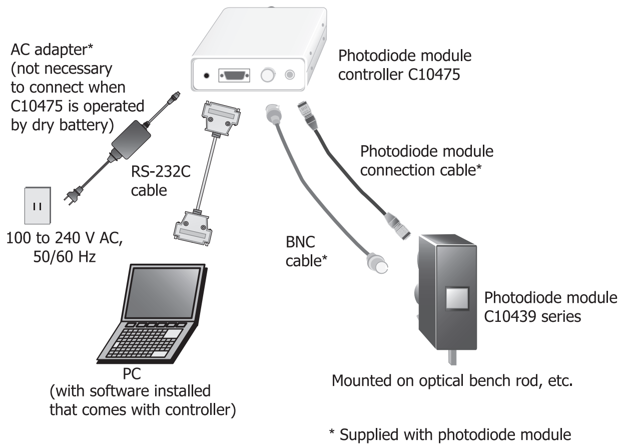
(b) Connection to photodiode module controller



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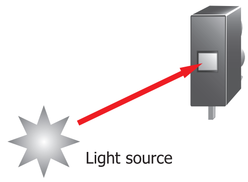
New approaches

We plan to offer high-speed photodiode modules, etc. We will also expand our product lineup to include optical accessories such as filters (band-pass filters, visible-cut filters, etc.), lenses, and optical fibers.

6 - 3 Applications

[Figure 6-7] Photodiode module application examples

(a) Optical power meters, laser/LED monitors, and illuminometers



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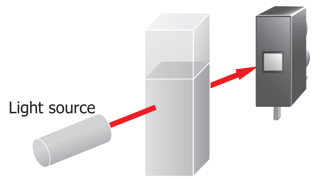
(b) Water pollution measurement



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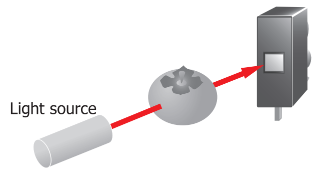
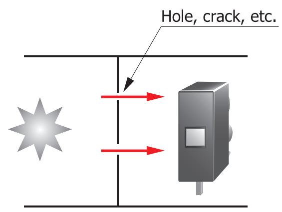
(c) Brix meters



KACCC0412EA

(d) Light leakage detection



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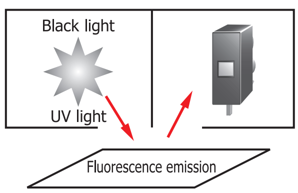
(e) Detection of fluorescence from printed matter



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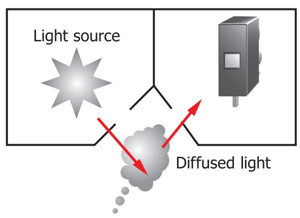
(f) Gas/smoke detection



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7. PSD signal processing circuits and PSD modules

These are easy to use circuits and modules specifically designed for HAMAMATSU PSDs (position sensitive detectors). PSD signal processing circuits are "circuit board" types on which a PSD (sold separately) can be mounted. PSD modules contain a PSD.

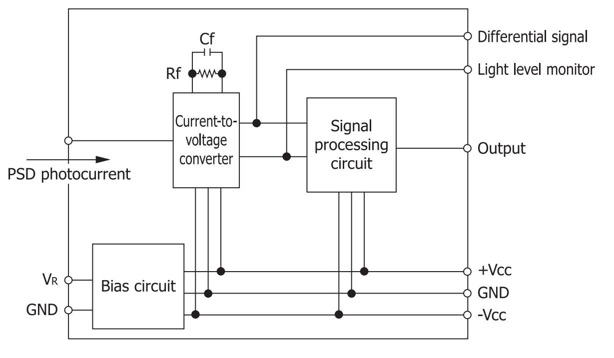
7 - 1 PSD signal processing circuits

PSD signal processing circuits have a current-to-voltage converter that converts photocurrent from a PSD into voltage. The signal is then processed and output as an analog voltage (analog output type) or converted into digital data by an A/D converter and is output (digital output type).

Structure (C3683-01)

The C3683-01 PSD signal processing circuit for DC signals is configured as shown in Figure 7-1. The current-to-voltage converter converts photocurrent from a PSD into voltage which is then processed by the signal processing circuit and is output as an analog voltage matching a corresponding position.

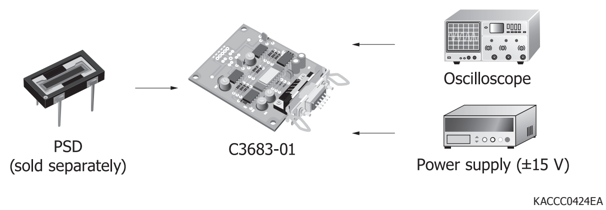
[Figure 7-1] Block diagram (C3683-01)



Usage (C3683-01)

The C3683-01 comes with a connector for wiring to the D-sub connector. Solder this wiring connector to a cable that connects to an oscilloscope (or voltmeter) and power supply (cable is not supplied).

[Figure 7-2] Connection example



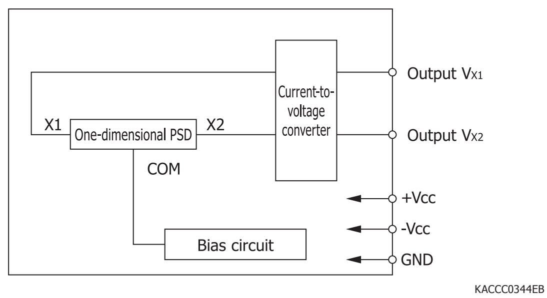
7 - 2 PSD modules

PSD modules are position detection modules that integrate a PSD and current-to-voltage converter into a compact case. When used with a PSD module controller (sold separately), position signals are available from two connectors for analog output and digital output.

Structure

The C10442/C10443 series PSD modules use a HAMAMATSU PSD and a current-to-voltage converter which are assembled together in a case.

[Figure 7-3] Block diagram
(a) C10442 series

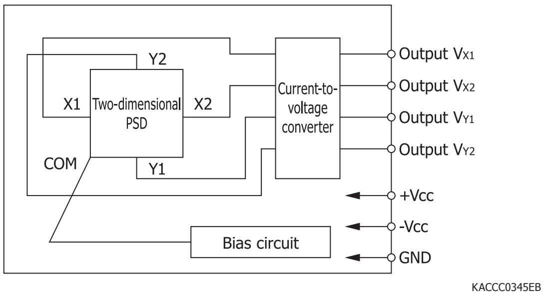


[Table 7-1] HAMAMATSU PSD signal processing circuits

Type no.	Applicable PSD	Compatible signal	Output	Conversion impedance (V/A)	Response speed	Supply voltage (V)	Features	Items to be prepared by user
C3683-01	1D	DC	Analog	1×10^5 *1	16 kHz (cut-off frequency)	±15	● Gain conversion possible	● Power supply (±15 V) ● Lead wires ● Soldering iron ● Oscilloscope (or voltmeter)
C4674	2D							
C5923	1D	AC			3333 Hz fixed (repetition frequency)		● Internal LED driver circuit ● Gain conversion possible	
C7563	2D				333 Hz fixed (repetition frequency)			
C9068	1D	DC	Digital	1×10^5	5 ms min. (signal conversion time)	+12	● Supplied with AC adapter ● Connectable to PC	● PC ● RS-232C cable
C9069	2D							

*1: A two-lead type resistor is in the socket and so can be replaced as needed by the user in a range between 1×10^4 and 1×10^6.
For more details, see the instruction manual that comes with the product.
Note: Output voltage (unit: V) value indicates the light spot position (unit: mm) from the center of the PSD active area (except for C3683-01).

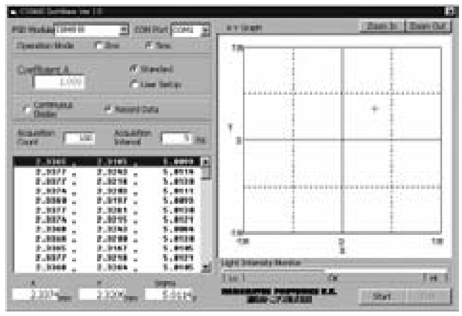
(b) C10443 series



Usage

Connect the PSD module to the PSD module controller. Position signals are available from the two connectors for analog and digital outputs. When using the analog output, connect an oscilloscope or voltmeter to the analog output connector on the controller. The output voltage (unit: V) values indicate the light spot position (unit: mm) from the center of the PSD active area. When using the digital output, connect a PC to the digital output connector on the controller by serial connection (RS-232C). Position information can be easily loaded into the PC by using the sample software that comes with the controller.

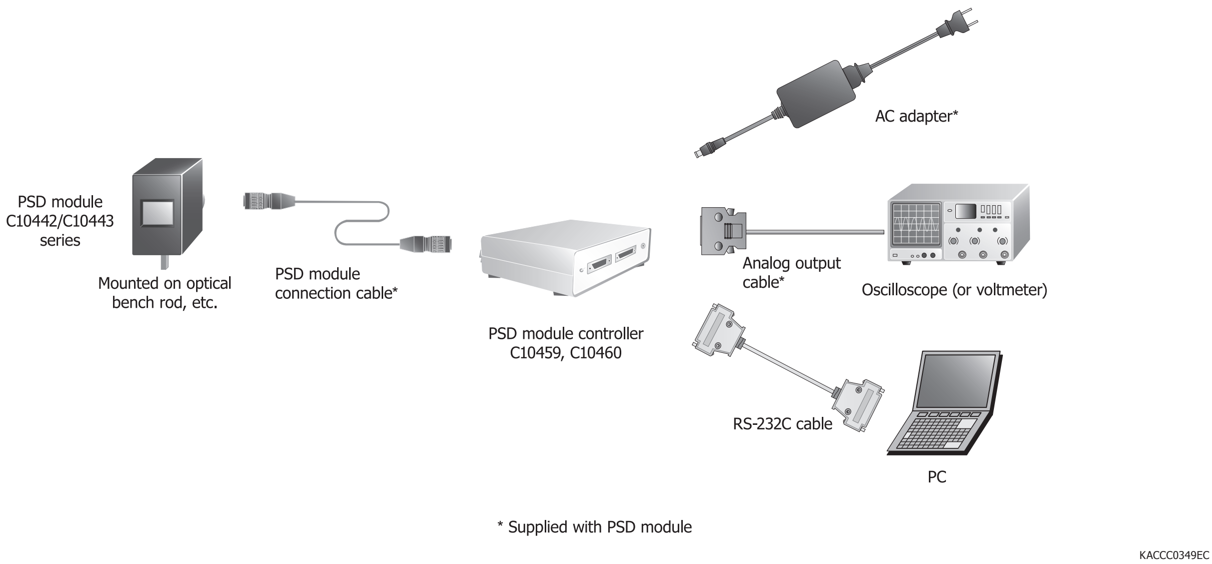
[Figure 7-4] Example of sample software displayed on PC screen



7 - 3 Applications

- Laser optical axis alignment
- Distance sensors
- Liquid level sensors
- Distortion measurement

[Figure 7-5] Connection example



[Table 7-2] HAMAMATSU PSD modules

Type no.	Internal PSD 1D/2D	Internal PSD Active area size (mm)	Output	Conversion impedance (V/A)	Cut-off frequency (kHz)	Supply voltage (V)	Features	Items to be prepared by user
C10442-01	1D	3 × 1	Analog	1×10^5	16	±5 to ±12	• Easy handling • RoHS compliance • CE certified	• PSD module controller • PC • RS-232C cable
C10442-02		6 × 1						
C10442-03		12 × 1						
C10443-01	2D	4 × 4						
C10443-02		9 × 9						
C10443-03		12 × 12						

Note: When PSD module is used with PSD module controller (sold separately).
· Output can be changed to digital output.
· Output can be set so that the output voltage (unit: V) value indicates the light spot position (unit: mm) from the center of the PSD active area.

8. Color sensor modules/ evaluation circuits

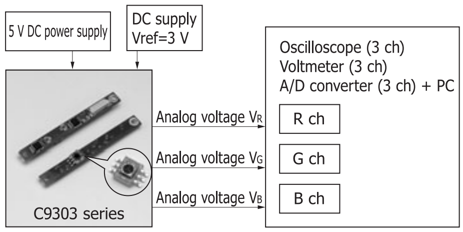
8-1 Color sensor modules

For white balance detection of LCD backlight (RGB-LED type)

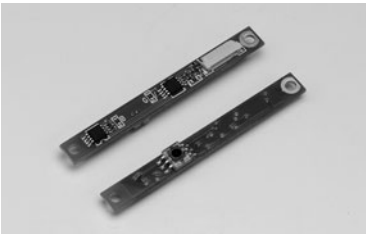
TFT-LCD (liquid crystal display) backlight using RGB-LEDs is drawing attention because they are mercury-free and have good color reproducibility. In order to monitor color changes caused by RGB-LED temperature characteristics and performance degradation, HAMAMATSU provides the C9303 series color sensor modules that detect the white balance on the LCD backlight optical waveguide. Based on these detection results, feedback-controlling the light level of each LED for RGB stabilizes the color on the LCD backlight.

The C9303 series comes in a small size that can easily be mounted on the side of the LCD backlight optical waveguide. The shape and RGB gain can be made to match customer specifications.

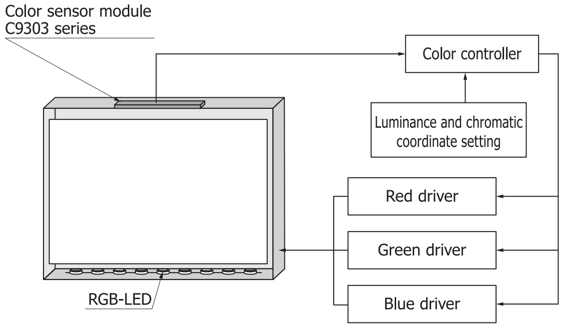
[Figure 8-1] Connection example (C9303 series)



[Table 8-1] HAMAMATSU color sensor modules and evaluation circuit

Product name	Color sensor module			Color sensor evaluation circuit
Type no.	C9303-03	C9303-04	C9315	C9331
Photo				
Features	Standard type	High gain type	● For RGB information measurement of object color ● Has an internal white LED as the light source, converts the reflected light into RGB data, and outputs them to a PC ● Measures small areas using an objective optical fiber ● 12-bit digital output (RS-232C compatible)	● Current-to-voltage conversion amplifier allowing a HAMAMATSU color sensor (S7505-01, S9032-02) to be mounted
	● For white balance detection of LCD backlight (RGB-LED type) ● Small design suited to attach to the side of LCD backlight optical waveguide			
Internal light source	None		Yes (white LED)	None
Internal color sensor	Yes		Yes	None
Conversion impedance	R: 91 kΩ G: 91 kΩ B: 100 kΩ	R: 680 kΩ G: 680 kΩ B: 680 kΩ	–	Variable (1×10^5 to 5.1×10^5 Ω)
Bandwidth	DC to 16 kHz (-3 dB)	DC to 2.4 kHz (-3 dB)	Digital output period: 0.2 s	DC to 14 kHz (-3 dB)
Applications	● White balance detection of LCD backlight (RGB-LED type) ● Evaluation of S9032-02 RGB color sensor		● Measurement of object color ● Color monitoring of opaque body (molded parts, painting, printing, cosmetics, etc.) ● Simple detection of color difference	● Measurement of light source color ● Evaluation of S7505-01 and S9032-02
Object color measurement	Not possible (Light source and optical system are required.)		Possible	Not possible (Light source and optical system are required.)
Light source color measurement	Possible		Not possible	Possible
Accessories	● Dedicated cable with connector		● Dedicated AC adapter ● Sample software (data acquisition, recording, relative chromaticity Yxy display not conforming to CIE) ● White reference card	–

[Figure 8-2] Color adjustment of TFT-LCD backlight using RGB-LED (application example of C9303 series)



LED: made by Lumileds (LUXEON), http://www.philipslumileds.com/
Color controller: made by Delta, http://www.deltaww.com/

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For measurement of RGB digital information on object color

Trying to faithfully convey an object color is difficult in cameras because the color changes due to the background light and film sensitivity. However, the C9315 color sensor module makes this task simple by numerically converting the object color. The C9315 uses a method similar to the stimulus value direct-reading method for detection and allows simple management of the object color. This method is fully practical for applications that monitor color by relative comparison with the color difference from "opaque objects with a close spectral reflectance."

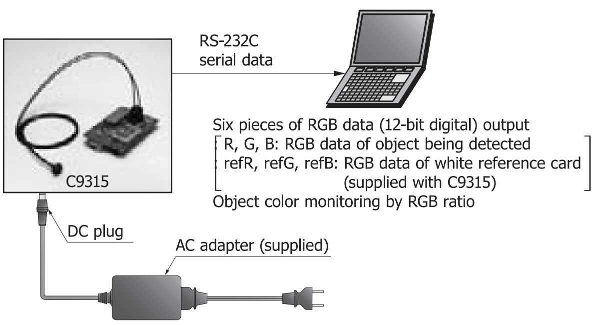
The C9315 color sensor module comes with an objective optical fiber. The internal RGB color sensor detects light reflected from an object illuminated with the white LED and outputs RGB digital data. This objective optical fiber can measure light in very small areas.

The C9315 connected to a PC is suitable for simple color management and detection of difference between colors with a relatively different spectral reflectance. The C9315 cannot be used to detect the absolute color.

Output from the C9315 is 12-bit digital data conforming to RS-232C. This data is loaded into the PC by using sample software that comes supplied with the C9315. The numerically converted RGB color information can also be transferred in real time directly into Microsoft Excel®* spreadsheet cells.

* Microsoft Excel is either a registered trademark or a trademark of Microsoft Corporation in the United States and/or other countries.

[Figure 8-3] Connection example (C9315)



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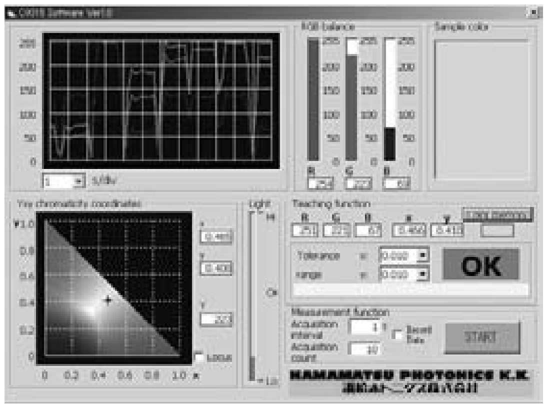
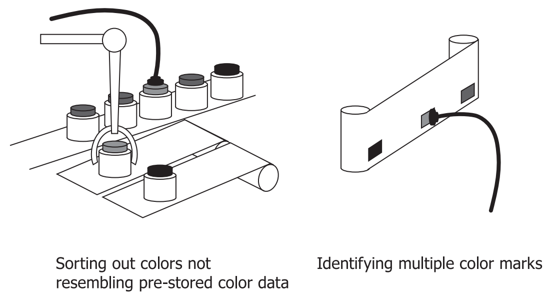
[Figure 8-4] Example of sample software displayed on PC screen



[Figure 8-5] Monitoring color of opaque objects by comparing color differences (application example of C9315)



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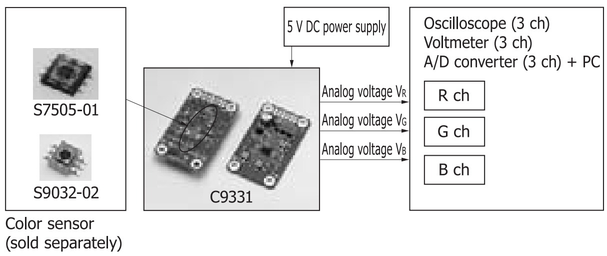
8 - 2 Color sensor evaluation circuit

The C9331 is a circuit board designed for evaluating HAMAMATSU color sensors (S7505-01, S9032-02). It has a current-to-voltage conversion amplifier that simultaneously converts RGB photocurrents to voltages and outputs them. Three trimmers are provided to adjust the photocurrent gains for individual RGB colors.

[Figure 8-6] Connection example (C9331)



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10 ▶ Module products

9. Charge amplifiers

When a high energy particle Si detector is used to detect soft X-rays and gamma rays, its output signal becomes a weak charge pulse at a width of a few dozen nanoseconds. Because the Si detector is itself a capacitive device, its impedance is very high. An operational amplifier (integrator circuit) using a feedback capacitor is therefore mostly used when amplifying the output signal because amplifier performance is important. This amplifier has high input impedance, integrates weak charge pulses, converts the integrated charges into voltage pulses, and amplifies them for output.
This type of amplifier is called the charge amplifier. The first stage of charge amplifiers is usually a low-noise FET, and their open-loop gain is set sufficiently high so that the first stage of charge amplifiers is not affected by the Si detector capacitance. The output stage is a low-impedance buffer so as to drive an external circuit.

9 - 1 Operating principle

When soft X-rays or gamma rays enter a Si detector, signal charge is generated while being amplified according to the particle energy. Due to this charge generation, the input-end potential of the charge amplifier rises at the same time, and a potential with polarity in the opposite direction appears at the output end. However, because the amplifier's open-loop gain is sufficiently high, the output-end potential works so as to instantaneously make the input-end potential zero through the feedback loop.
The signal charge (Qs) is consequently integrated in the feedback capacitance (Cf) and is then output as a voltage pulse. At this point, since the feedback resistance (Rf) for direct current is connected in parallel to the feedback capacitance, the output becomes voltage pulses that slowly discharge with the time constant determined by $\tau = Cf \times Rf$.
If charges are generated over a time interval from 0 to t, the output voltage pulse $e_{out}(t)$ is given by equation (9).

$$e_{out}(t) = -\frac{Qs}{Cf} \times \frac{1 - e^{-t/\tau}}{t_o/\tau} \quad (\text{when } 0 \leq t < t_o)$$

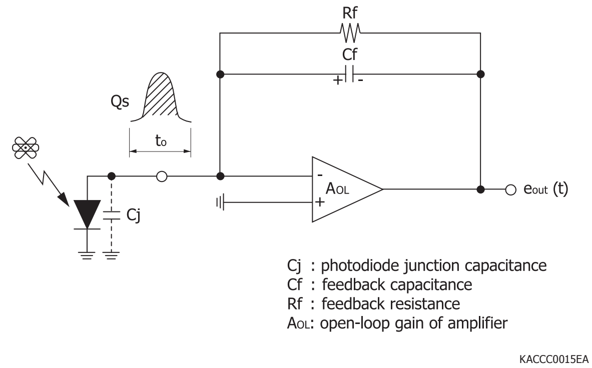
$$e_{out}(t) = -\frac{Qs}{Cf} \times \frac{(e^{t_o/\tau} - 1)}{t_o/\tau}\, e^{-t/\tau} \quad (\text{when } t_o \leq t) \quad \cdots\cdots\cdots\cdots (9)$$

Generally, because $t_o << \tau$, equation (9) is simplified as shown in equation (10).

$$e_{out}(t) = -\frac{Qs}{Cf}\, e^{-t/\tau} \cdots\cdots\cdots\cdots (10)$$

As can be seen from equation (10), the signal charge Qs is converted into a voltage pulse of Vout = -Qs/Cf, which has a width at time constant τ.

[Figure 9-1] Operating principle (charge amplifier)



9 - 2 Characteristics

The following characteristics are usually required of charge amplifiers for soft X-rays and gamma rays.

· High gain
· Low noise
· Excellent output linearity
· High-speed response
· High temperature stability

Gain

The charge amplifier gain (charge gain: Gc) is expressed by equation (11).

$$Gc = \frac{Vout}{Qs} \left(= \frac{1}{Cf}\right) [V/C] \text{ or } [V/pC] \cdots\cdots\cdots\cdots (11)$$

Sensitivity (when Si photodiode is connected to charge amplifier)

Sensitivity is expressed as an output voltage (unit: mV) per 1 MeV of particle energy irradiated on the Si detector.
The amplitude of the signal charge obtained with the Si detector is determined by the energy of radiation such as soft X-rays and gamma rays and also by the semiconductor material.

$$Qs = \frac{E \times q}{\varepsilon} [C] \text{ or } [pC] \cdots\cdots\cdots\cdots (12)$$

E: energy of high energy particle [MeV]
q: electron charge
ε: energy required to generate one electron-hole pair
For Si, this is 3.62 eV (at 300 K) and 3.71 eV (at 77 K).

From equations (11) and (12), the sensitivity (Rs) is expressed as shown in equation (13).

$$Rs = \frac{Vout}{E} = \frac{\frac{Qs}{Cf}}{Qs \times \frac{\varepsilon}{q}} = \frac{q}{Cf} \times \frac{1}{\varepsilon} \; [mV/MeV] \cdots\cdots\cdots\cdots (13)$$

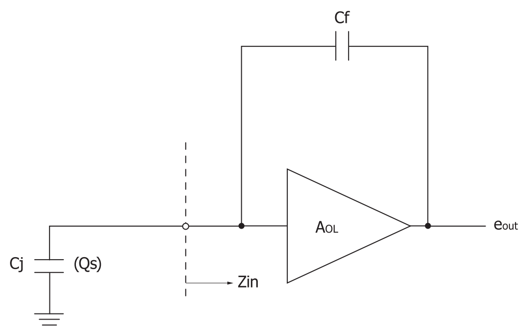
When the H4083 charge amplifier (Cf=2 pF) is used with a Si detector, the sensitivity (Rs) at room temperature is expressed by equation (14).

$$Rs = \frac{q}{Cf} \times \frac{1}{\varepsilon} = \frac{1.6 \times 10^{-19}}{2 \times 10^{-12}} \times \frac{1}{3.62}$$
$$= 2.2 \times 10^{-8}\ \text{V/eV} = 22\ \text{mV/MeV} \cdots\cdots\cdots\cdots (14)$$

Open-loop gain

When detecting soft X-rays or gamma rays with a Si detector, the amount of generated charge will be the same as long as the incident energy is at the same level. The charge amplifier provides constant sensitivity regardless of the photodiode capacitance.
A circuit equivalent to a charge amplifier connected to a Si detector is shown in Figure 9-2.

[Figure 9-2] Equivalent circuit



Cj : junction capacitance
Cf : feedback capacitance
AOL: open-loop gain of amplifier

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The input impedance (Zin) in this equivalent circuit is expressed by equation (15).

$$Z_{in} = \frac{\frac{1}{j\omega Cf}}{1 + A_{OL}(j\omega)} \cdots\cdots\cdots\cdots (15)$$

If the Si detector signal charge is Qs, the amplifier input voltage (e_{in}) is given by equation (16).

$$e_{in} = \frac{Qs}{j\omega Cj + \{1 + A_{OL}(j\omega)\}\, j\omega Cf} \cdots\cdots\cdots\cdots (16)$$

The output voltage (e_{out}) is expressed using equation (17).

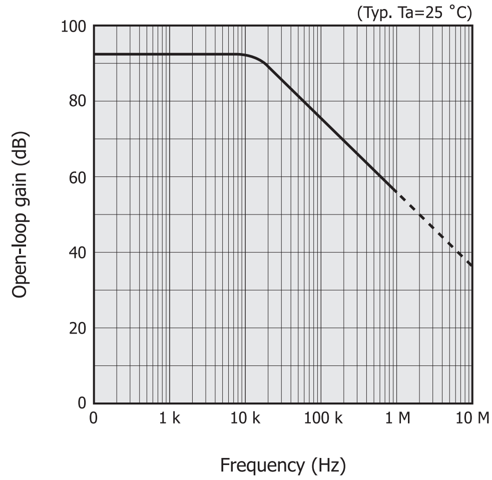
$$e_{out} = A_{OL}(j\omega) \times e_{in} = A_{OL}(j\omega) \times \frac{Qs}{j\omega Cj + \{1 + A_{OL}(j\omega)\}\, j\omega Cf}$$

$$= \frac{Qs}{\frac{j\omega}{A_{OL}(j\omega)}(Cj + Cf) + j\omega Cf} \cdots\cdots\cdots\cdots (17)$$

Since the open-loop gain (A_{OL}) is very high, e_{out} is simplified as in equation (18).

$$e_{out} = \frac{Qs}{j\omega Cf} \cdots\cdots\cdots\cdots (18)$$

[Figure 9-3] Open-loop gain vs. frequency



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Noise

Noise in charge amplifiers is generated by the following three major factors:

(1) Thermal noise in first-stage FET

Thermal noise (e_{n1}) in the first-stage FET is expressed by equation (19).

$$e_{n1} = \sqrt{\frac{8k\,T}{3gm}}\ [\text{V/Hz}^{\frac{1}{2}}] \cdots\cdots\cdots\cdots (19)$$

k : Boltzmann's constant
T : absolute temperature
gm: mutual conductance of first-stage FET

(2) Shot noise

The shot noise (in), which is caused by the gate current of the first FET and the Si detector dark current, is expressed by equation (20).

$$in = \sqrt{2q\,(I_G + I_D)}\ [\text{A/Hz}^{\frac{1}{2}}] \cdots\cdots\cdots\cdots (20)$$

q : electron charge
IG: gate leakage current of first-stage FET
ID: dark current

(3) Thermal noise caused by feedback resistance

The thermal noise (e_{n2}) caused by the feedback resistance (Rf) is given by equation (21).

$$e_{n2} = \sqrt{4k\,T\,Rf}\ [\text{V/Hz}^{\frac{1}{2}}] \cdots\cdots\cdots\cdots (21)$$

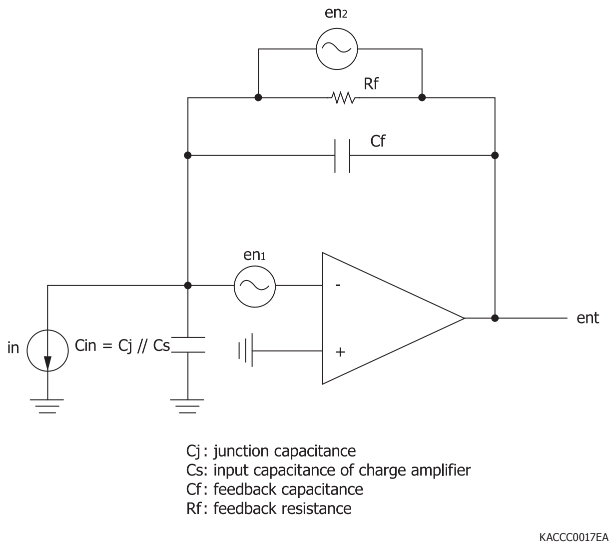
By applying equations (19), (20), and (21), the total noise ent(jw) therefore becomes as shown in equation (22).

$$ent(j\omega) = \sqrt{e_{n1}^2 \times \left(1 + \frac{Cin}{Cf}\right)^2 + \left\{in^2 + \left(\frac{e_{n2}}{Rf}\right)^2\right\} \frac{1}{(j\omega\, Cf)^2}} \cdots (22)$$

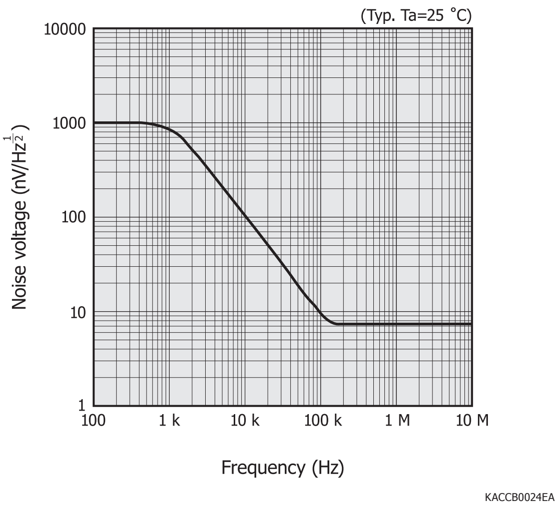
In equation (22), the first term is constant over the entire frequency range and amplified by (1 + Cin/Cf) determined by the input capacitance (Cin). The second term is constant regardless of the input capacitance, but decreases as the frequency is increased.

Figures 9-5 and 9-6 show noise characteristics of the H4083 charge amplifier.

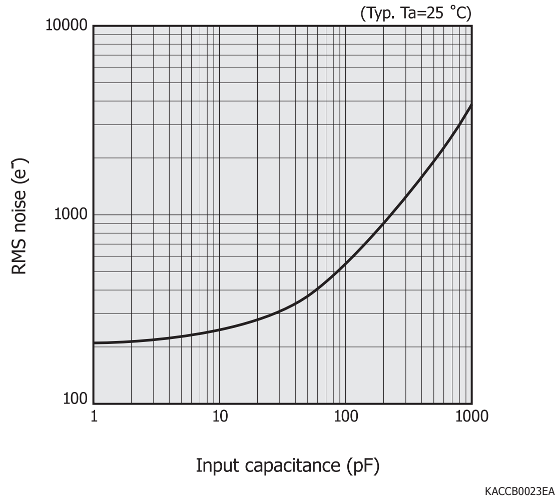
[Figure 9-4] Noise equivalent circuit (charge amplifier)



[Figure 9-5] Noise voltage vs. frequency (H4083)

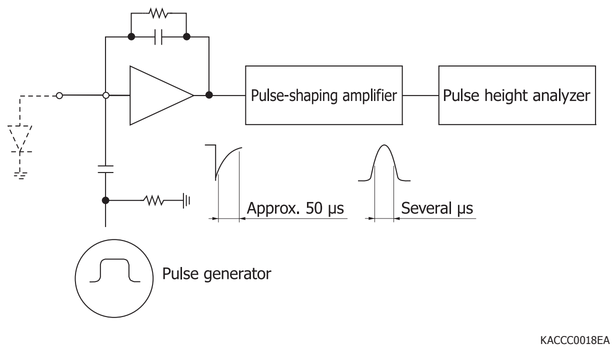


[Figure 9-6] Noise electron count vs. input capacitance (H4083)



Noise measurement and evaluation of charge amplifiers are usually performed using a measurement system like that shown in Figure 9-7.

[Figure 9-7] Noise measurement system



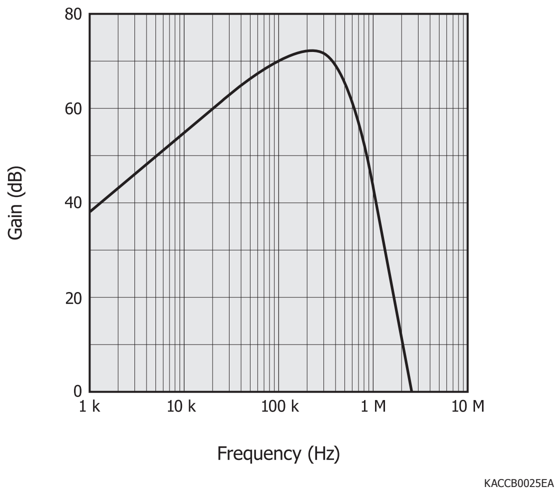
In this system, a charge (Qs) is supplied from the pulse generator via the capacitance connected to the input end of a charge amplifier.

The output from the charge amplifier is amplified with the pulse-shaping amplifier and then input to the pulse height analyzer. The pulse height distribution is measured to obtain the noise based on the half width of the pulse.

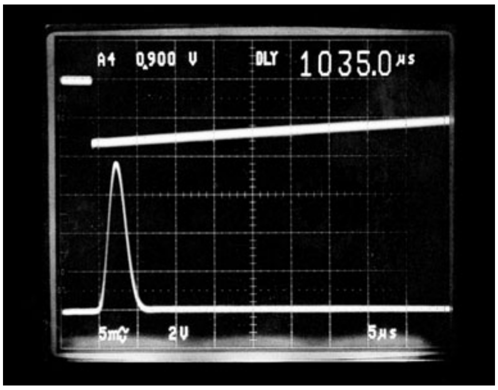
The pulse-shaping amplifier improves the S/N level of the charge amplifier and also serves as a filter. Various types of pulse-shaping amplifiers are available. One of the most widely used pulse-shaping amplifiers is the Gaussian shaping amplifier.

Since the output signal from a charge amplifier is only a few dozen millivolts even after being integrated, it must be amplified by the pulse-shaping amplifier up to a level that matches the input range (0 to 10 V) of the pulse height analyzer.

[Figure 9-8] Frequency characteristic
(Gaussian shaping amplifier, typical example)



[Figure 9-9] Output waveform example
(H4083 used with Gaussian shaping amplifier)

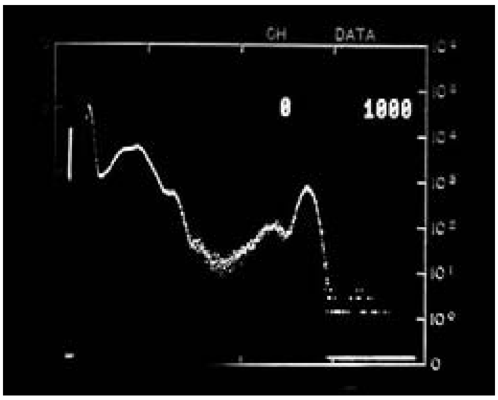


9-3 Applications

Gamma-ray measurement

Figure 9-10 shows a typical pulse height distribution measured using the H4083 charge amplifier connected to a HAMAMATSU S3590-05 Si PIN photodiode which is irradiated with gamma rays from a ^{241}Am radiation source.

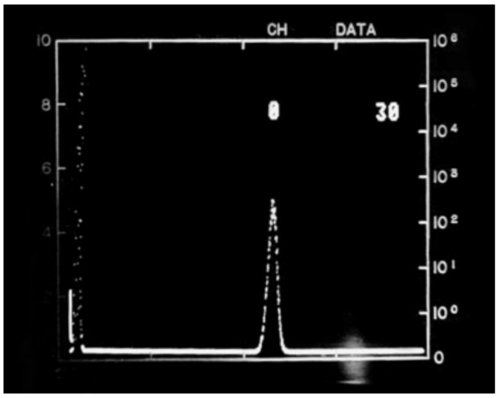
[Figure 9-10] Output waveform example (S3590-05 used with H4083)



Laser output and stability measurements

Figure 9-11 shows a typical pulse height distribution measured using the H4083 charge amplifier connected to a HAMAMATSU S3590-01 Si PIN photodiode which is irradiated with a laser having a pulse half width of 100 ns at a wavelength of 830 nm. The peak channel of the pulse height distribution indicates the average laser power, and the half width represents the fluctuation in the output.

[Figure 9-11] Output waveform example (S3590-01 used with H4083)



10. Image sensor application products

Signal processing circuits for image sensors are complicated compared to those for single-element sensors. HAMAMATSU therefore provides multichannel detector heads and driver circuits designed for use with our main image sensor products. By using the dedicated controller and supplied software, multichannel detector heads easily acquire data onto a PC and evaluate sensor performance.
Besides image sensors, HAMAMATSU also offers products customized for image sensor applications to offer total product supply support for customer needs.

[Table 10-1] HAMAMATSU image sensor application products

Product name	Type	Type no.
Multichannel detector head	For CCD area image sensor	C7041, C9047, C10151, etc.
	For NMOS linear image sensor	C5964 series C8892
	For InGaAs linear image sensor	C8061-01, C10854, etc.
Driver circuit	For CCD area image sensor	C10416, C11287, C11288
	For NMOS linear image sensor	C7883/C7884/ C7885 series
	For CMOS linear image sensor	C9001
	For photodiode array with amplifier	C9118 series
Pulse generator	For NMOS linear image sensor	C8225 series

10 - 1 Multichannel detector heads

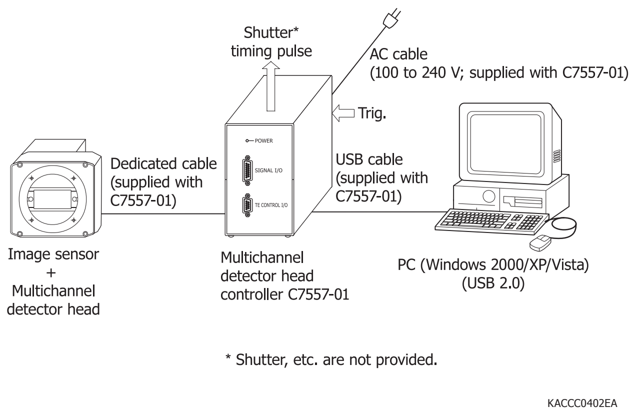
Analog output types

These products are essentially circuit boards built into a compact case and provide an analog output. These can easily be installed in other equipment such as a spectrometer, and are available in a room-temperature type or cooled (air-cooled) type according to the image sensor cooling method. These detector heads (except for a few types) can also be combined with a dedicated controller (C7557-01). When the controller is connected to a PC via USB, these multichannel detector heads can be easily controlled and data collected by running the software supplied with the controller.

[Figure 10-1] Multichannel detector heads C10150 and C10151

[Figure 10-2] Multichannel detector head controller C7557-01

[Figure 10-3] Connections to multichannel detector head and PC

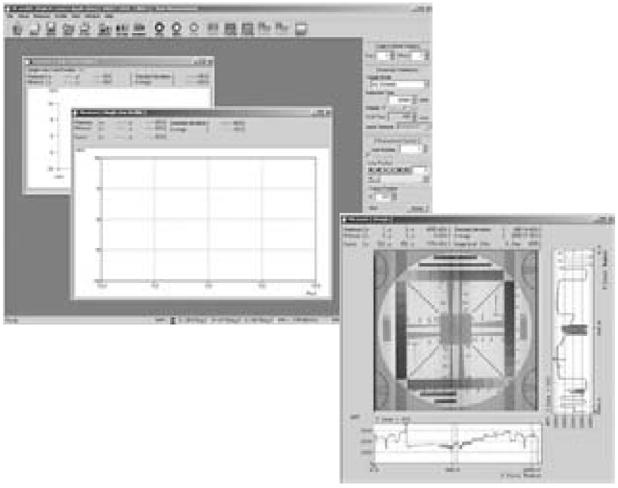


Digital output type

These products are intended for use with a CCD area image sensor or InGaAs linear image sensor and provide a digital output. The signal from each pixel of the image sensor is output as digital data via an internal A/D converter.
These detector heads support outputs of RS-422 parallel, LVDS parallel, USB 2.0, and CameraLink (depends on models).

[Figure 10-4] InGaAs multichannel detector head (digital output type) C10854

[Figure 10-5] Example of sample software displayed on PC screen (digital output type)

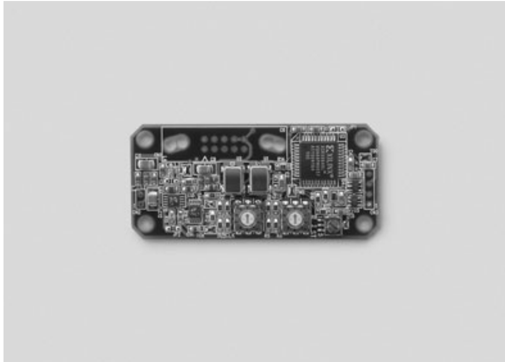


10 - 2 Driver circuits

These driver circuit boards are specifically for use with CCD/NMOS/CMOS image sensors and photodiode arrays with amplifiers, designed by taking their respective characteristics into account. Not limited to evaluation tasks, these circuits can be installed into equipment since they are designed to be compact and easy to use. HAMAMATSU also offers pulse generators for NMOS linear image sensor driver circuits.

[Figure 10-6] Driver circuit C7883 for NMOS linear image sensor

[Figure 10-7] Pulse generator C8225 for NMOS linear image sensor



11. Special-purpose modules

11 - 1 Flame eyes

The "flame eye" is a sensor that monitors flames in oil boilers and heating equipment. It detects light emitted from the flame so that the combustion state can be observed.
This flame eye utilizes a photo IC diode instead of the conventional CdS cell. This flame eye ensures stable detection performance compared to types using a CdS cell or phototransistor.
The flame eye is easy to install since the sensor is integrated into the cable assembly. Two types with different light input directions (head-on type and side-on type) are available.

Features

- Internal photo IC diode

The internal photo IC diode boosts the photocurrent generated from the photodiode approx. 13000 times. The photo IC diode outputs current and can be used the same as a photodiode applied with a reverse voltage.

- Spectral response suitable for detecting oil burner flames
- Cable assembly for easy installation into equipment
- Small output current variations and good output linearity
- RoHS compliant products

[Figure 11-1] Flame eyes

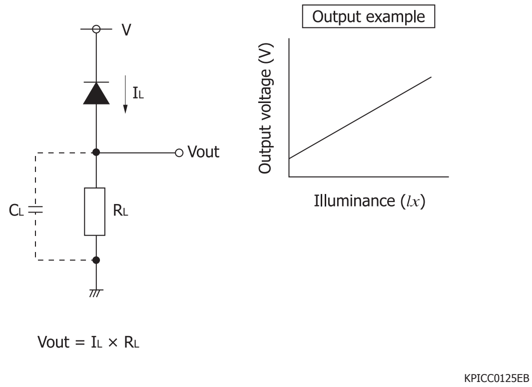
Usage

Unlike CdS cells, the photo IC diode has polarity (anode and cathode), so always be sure to use it with a positive voltage applied to the cathode.
A load resistance (RL) must also be set according to the latter-stage circuit. If high-frequency components must be eliminated, we recommend that a low-pass filter load capacitor (CL) be inserted in parallel with the load resistance. The cut-off frequency (fc) obtained from inserting the low-pass filter load capacitor is expressed by equation (23).

$$fc \approx 1/(2\pi \times C_L \times R_L) \cdots\cdots\cdots\cdots (23)$$

Before using the flame eye, check if the environment where it will be used has noise or not. If needed, take steps to suppress noise such as shielding the cable or adding a capacitor (approx. 0.1 µF between the anode and cathode of the photo IC diode).

[Figure 11-2] Connection example



Applications

- Oil boilers
- Heating equipment
- Safety devices for heaters
- Alarms

11 - 2 Sunlight sensors

Sunlight sensors detect the amount of sunshine and ambient light level. A photodiode with superb linearity relative to the incident light level is built in a small case with a connector. These sensors deliver high reliability and can be used as sunlight sensors for automotive air conditioners.

Features

- High reliability (for automotive use)
- Optical design of cover allows adjusting the directivity to meet application requirements.
- Photosensor (visible light sensor, near infrared light sensor) is selectable according to application.
- Cover shape suitable for dashboard installation

10 ▶ Module products

New approaches

We are thinking of developing the following new types.

· Small type
· Left-right directional detecting type (contains two photo-sensors)
· Combination of visible light sensor and near infrared light sensor

Applications

- Sunlight sensors

Detect the amount of sunshine to control the temperature and the volume of air flow for automotive air conditioners

- Auto light sensors

Detect the ambient light level to automatically turn on the vehicle headlights in tunnels, etc.

- Head-up display brightness adjusting sensors

Detect the ambient brightness to automatically adjust the brightness on the head-up display

- Simple sunlight measurements

11 - 3 Driver circuits for Si photodiode array

Here we introduce a driver circuit for our 16-element Si photodiode array. The combination of these allows high-accuracy, high-speed measurements by simultaneously reading out each signal of the 16 elements. The driver circuit provides a voltage output which makes signal processing easy.
The driver board has solder through-holes that allow direct mounting of the 16-element photodiode array. By adding a commercially available sub-board, this driver circuit can also be used to evaluate HAMAMATSU 16-element InGaAs PIN photodiode array.

Features

- Simultaneous measurement of 16 elements and serial output

Simultaneous readout of 16-element signals allows high-accuracy, high-speed measurements.

- Internal pulse generator

Oscillating frequency is selectable in eight steps with a switch.

- Gain: settable in two steps (1×10^6 V/A, 1×10^7 V/A)

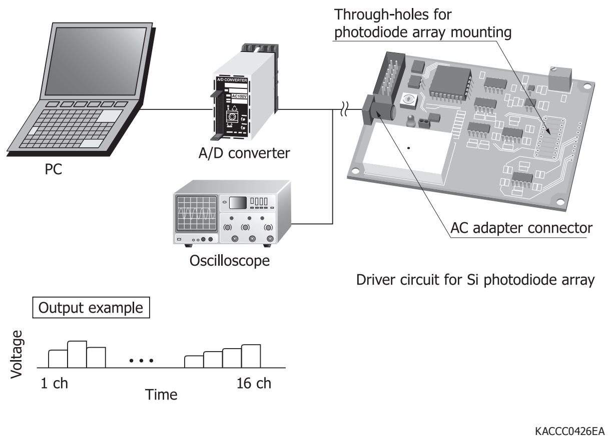
- Noise: 5 mVp-p (1×10^6 V/A)

- Board size: 70 × 95 mm

Usage

Mount the HAMAMATSU 16-element Si photodiode array directly on the board. Power is supplied from an AC adapter (comes with the product).

[Figure 11-3] Connection example



Applications

- Color measurement (print, paper, fire, ink, liquid, etc.)
- Film thickness measurement (SiO_2 film, photoresist film, film, oil film, etc.)
- Emission measurement (plasma monitor, sunlight, quality control for light source and optical fiber)
- Non-destructive measurement (fruit, grain, soil, plastic, blood, oil, etc.)
- Density measurement (chemicals, plating liquid, etching liquid, etc.)
- Simple position measurement