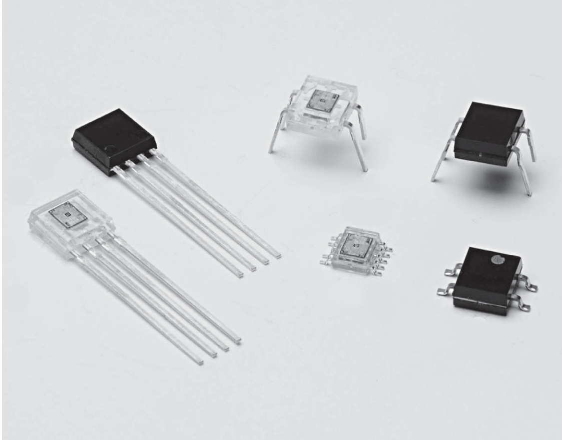
Technical note

HAMAMATSU
PHOTON IS OUR BUSINESS



Light modulation photo IC

Light modulation photo ICs were developed to optically detect objects. Optical detection of objects usually uses a photosensor/light emitter pair, like a photointerrupter and photoreflector which detect an object when it interrupts or reflects light. However, detection errors might occur if fluctuating background light such as room lighting strikes the photosensor. To prevent these detection errors, one typical method uses optical filters by utilizing the difference in wavelengths between the signal light and background light. However, this method does not work if the background light level is too strong. Light modulation photo ICs deal with this problem by using a synchronous detection method to reduce detection errors and ensure a stable output even if fluctuating background light strikes the photosensor. This synchronous detection method pulse-modulates the signal light and detects it in synchronization with the modulation timing to reduce effects from "noise light" that enters the photosensor asynchronously.

1 Features

- Fewer detection errors even if fluctuating background light hits the photosensor

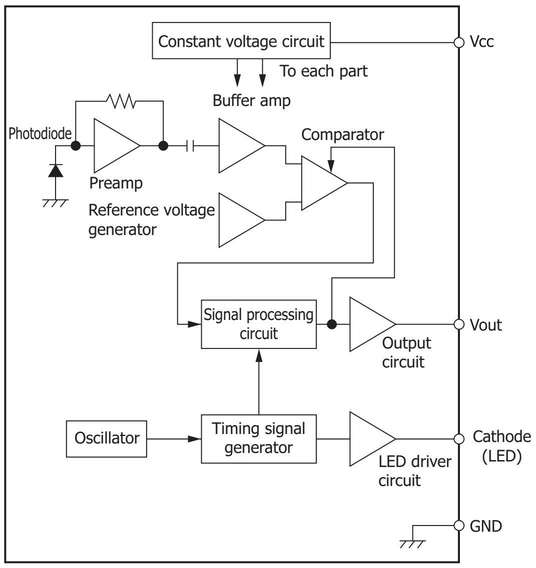
A typical light modulation photo IC consists of an oscillator, a timing signal generator, an LED driver circuit, a photodiode, a preamp, a comparator, a signal processing circuit, an output circuit, and so on, which are all integrated on a monolithic chip. Connecting an external LED to this photo IC allows optical synchronous detection. In optical synchronous detection, signal light is modulated in pulses and detected in synchronization with that modulation timing. This eliminates effects of background light and single synchronous background light generated by asynchronous background light [Figure 1-2].

- Various types are available for handling higher background light levels or offering higher sensitivity.

Hamamatsu provides types usable even under higher background light levels (10000 *lx* typ.), as well as high sensitivity types (lower detection level: 0.2 μW/mm² typ.), and asynchronous type that does not require wiring to a light emitter. These are supplied in various packages (DIP, SIP, and surface mount type).

Types for higher background light level (S4282-51, S6986, S10053) have a preamp with special measures added to deal with DC light input. This ensures reliable detection of signal light even under high-illuminance DC background light. On the other hand, high-sensitivity types (S6809, S6846, S7136/-10) allow making the detection distance even longer.

[Figure 1-1] Block diagram and truth table

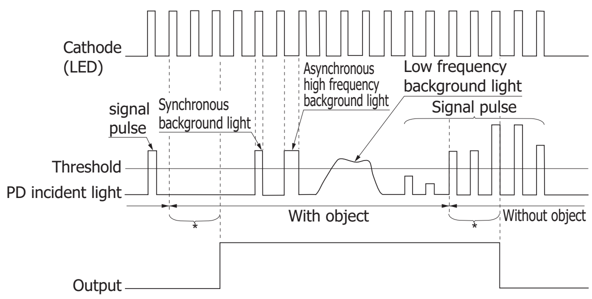


Truth table

Input	Output level
Light on	Low
Light off	High

KPICC0002EB

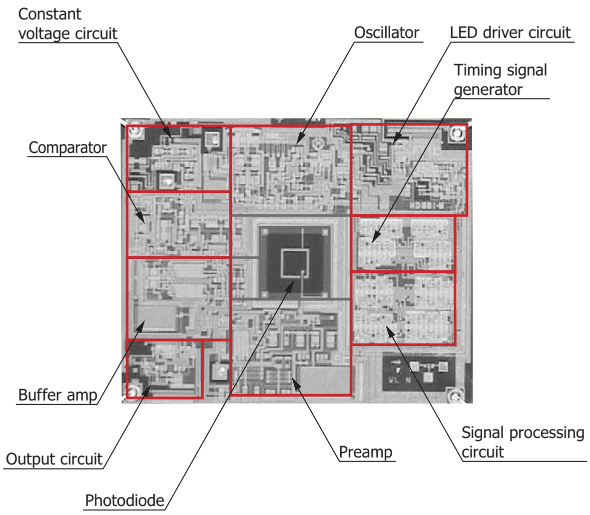
[Figure 1-2] Timing chart



* A signal is judged to be present only when synchronous detection is carried out three consecutive times, and no signal is judged to be present when synchronous detection is not achieved three consecutive times.
Note: Each background light elimination is shown in "4. Background light elimination".

KPICC0182EA

[Figure 1-3] Enlarged photo of chip and block layout



2 Structure

Circuit block configurations of a light modulation photo IC are described below.

(1) Oscillator and timing signal generator

The oscillator produces a reference oscillation output by charging and discharging the internal capacitor with a constant current. The oscillation output is fed to the timing signal generator, which then generates LED drive pulses and other timing pulses for digital signal processing.

(2) LED driver circuit

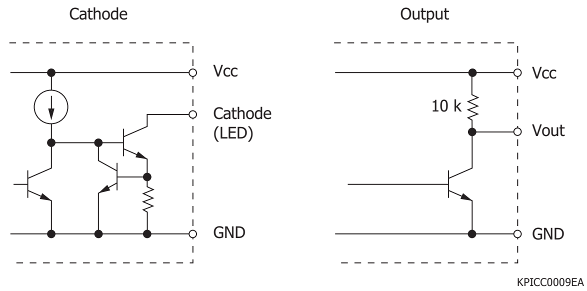
This circuit drives an externally connected LED using the LED drive pulses generated by the timing signal generator. The duty cycle is 1/16. The S4282-51, S6986, and S10053 use a constant current drive, while the S6809, S6846, and S7136/-10 use an open collector drive.

(3) Photodiode and preamp

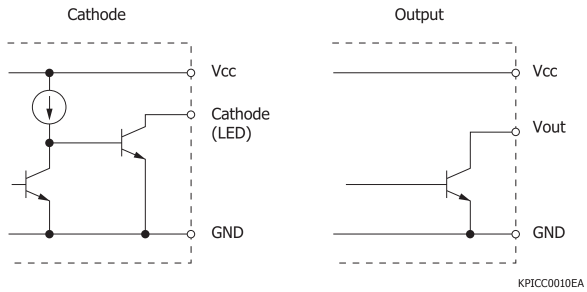
Photocurrent generated in the photodiode is converted to a voltage via the preamp. The preamp in the S4282-51, S6986, and S10053, which are usable at high background light levels, uses an AC amplifier circuit shown in Figure 2-2 to expand the dynamic range versus DC or low-frequency fluctuating background light without impairing signal detection sensitivity.

[Figure 2 -1] Output terminal diagram

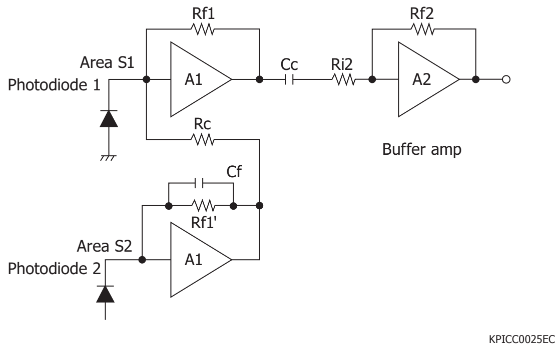
(a) S4282-51, S6986, S10053



(b) S6809, S6846, S7136/-10



[Figure 2-2] Preamp block diagram (S4282-51, S6986, S10053)



(4) Capacitive coupling, buffer amp, and reference voltage generator

Capacitive coupling removes low-frequency background light and also cancels the DC offset in the preamp simultaneously. The buffer amp amplifies the signal up to the comparator level, and the reference voltage generator generates a comparator level signal.

(5) Comparator

The comparator has a hysteresis function that prevents chattering caused by small fluctuations in the incident light.

(6) Signal processing circuit

The signal processing circuit consists of a gate circuit and a digital integration circuit. The gate circuit discriminates the comparator output to prevent possible detection errors caused by asynchronous background light. Background light that enters at the same timing as the signal detection cannot be eliminated by the gate circuit. The digital integration circuit in a subsequent stage cancels out this background light.

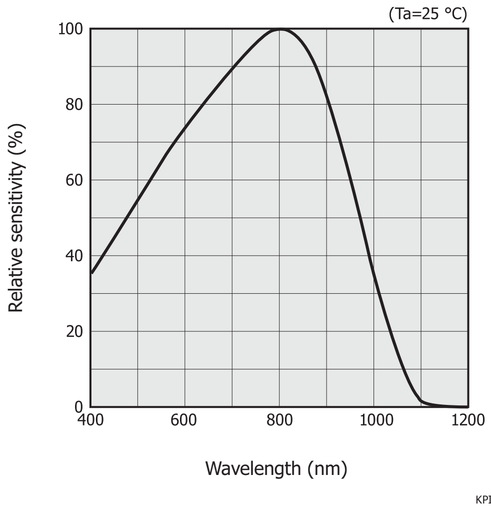
(7) Output circuit

This circuit serves as an output buffer for the signal processing circuit and outputs the signal to an external circuit.

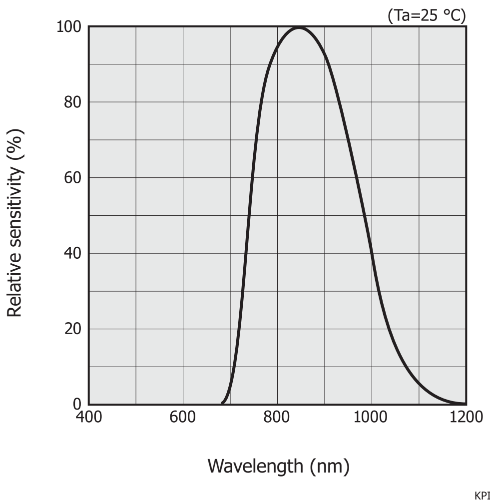
3 Characteristics

[Figure 3-1] Spectral response (typical example)

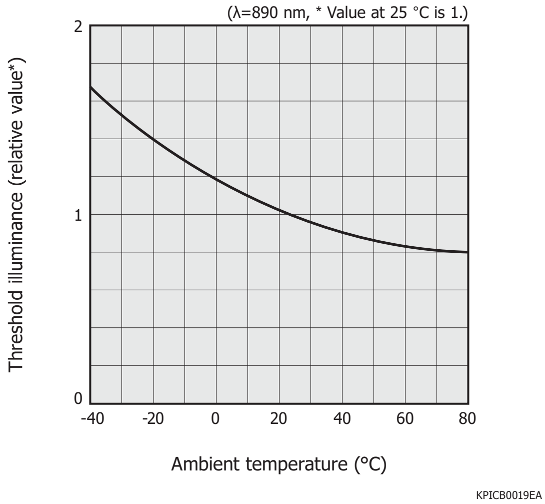
(a) S4282-51, S6986, S10053



(b) S6809, S6846, S7136/-10



[Figure 3-2] Sensitivity temperature characteristics (typical example)



4 Background light elimination

Eliminating low-frequency background light

Direct current and low-frequency noise cause by background light can be separated and subtracted from the signal by means of capacitive coupling between the preamplifier and the nextstage buffer amplifier. In addition to this capacitive coupling, S4282-51, S6986 and S10053 preamps use an AC amplifier [Figure 2-2] to enhance elimination of low-frequency background light. In general, direct-current and low-frequency background light intensity is large, and may saturate the initial-stage amplifier circuit. Therefore, the dynamic range of the initial-stage amplifier must be increased, to ensure that signal components will not be lost due to this saturation in the amplifier. The preamplifier circuit shown in Figure 2-2 consists of two amplifiers: a main amplifier (A1) and another (A1') used for illuminance measurement. This combination allows subtracting the photocurrent of low-frequency components from the input terminal of the main amplifier. PD1 and PD2 are photodiodes arranged in close proximity to each other and have the photosensitive area ratio of equation (1).

$$S1/S2 = Rf1' / Rc = K \cdots\cdots (1)$$

If the photocurrents of PD1 and PD2 are I1 and I2, respectively, then the output voltage change of amplifier A1' caused by I2 produces a current I3 flowing into Rc, which is given by equation (2) because the input point of A1 is the theoretical ground:

$$I3 = Rf1' \times I2 / Rc \cdots\cdots (2)$$

Since I1/I2=K according to equation (1), equation (3) is obtained:

I3 = Rf1' × I1 / (Rc × K) = I1 …… (3)

In this way, the photocurrent of PD1 can be extracted. The photocurrent component of A1 due to low-frequency background light is essentially zero as long as A1' does not become saturated, so the saturation of A1' determines the entire dynamic range. If the ratio of Rf1 to Rf1' is set as m, the expansion ratio for the dynamic range becomes K × m. Meanwhile, with high-frequency input light, the current extraction as explained above is not performed at frequencies sufficiently higher than the cut-off frequency of A1, which is determined by feedback capacitance Cf and feedback resistance Rf1'. Thus the gain of A1 becomes Rf1 and current-to-voltage conversion can be carried out without lowering the gain.

Eliminating high-frequency background light

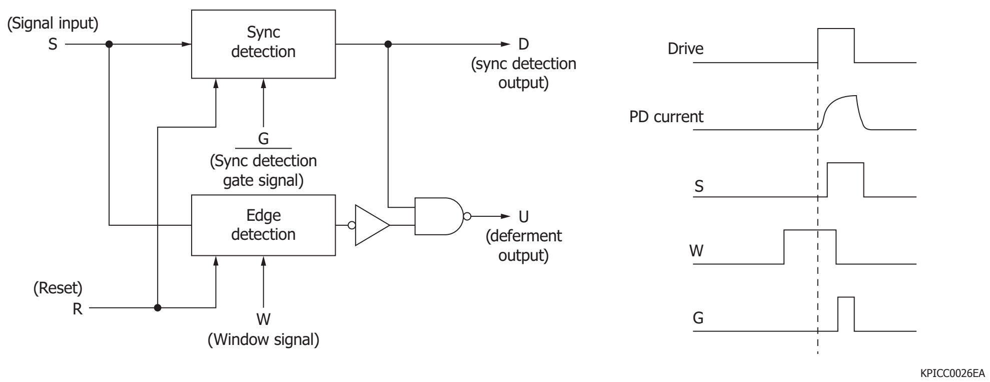
(1) Asynchronous background light

Light entering the sensor at timings other than the LED driver timing is referred to as “asynchronous background light”. Effects from this asynchronous background light can be eliminated through optical synchronous detection. The preamplifier output is sent to the comparator, compared with a reference voltage, and converted into a digital signal S. This digital signal is then input to the synchronous detection gate. Besides this digital signal, a timing signal G is also input to the synchronous detection gate and the digital input signal is detected as a “H” or “L” at the light emission timing of the LED. Figure 4-1 shows the block diagram of the synchronous detection circuit for light modulation photo ICs. This circuit has an edge detection circuit provided in parallel to the synchronous detection gate. When asynchronous background light is input, it usually contains a number of different frequency components which cause pulsed signals of the comparator output to have various pulse widths. Among these, those with longer pulse widths have a high probability of overlapping the LED driver timing (synchronous detection timing). The edge detection circuit is used to eliminate the influence of background light which overlaps the synchronous detection timing. As shown in Figure 4-1, the synchronous detection circuit has a “U” output terminal in addition to the “D” terminal that provides “H” and “L” outputs. The edge detection circuit receives two inputs: an edge detection window signal W and signal input S. Using these inputs, the edge detection circuit outputs “H” when it detects the rising edge of the final input signal edge in the time slot of the edge detection window. In other words, this is a sequential circuit which accepts the time sequence (1, 0) (1, 1) (0, 1) for (W, S). Also, if the output of the edge detection circuit is “L” even when the synchronous detection gate judges that a signal exists, then “L” is available from the “U” output terminal. When the “U” output is “L”, operation of the discrimination circuit at the next stage (where background light effects are removed) is deferred.

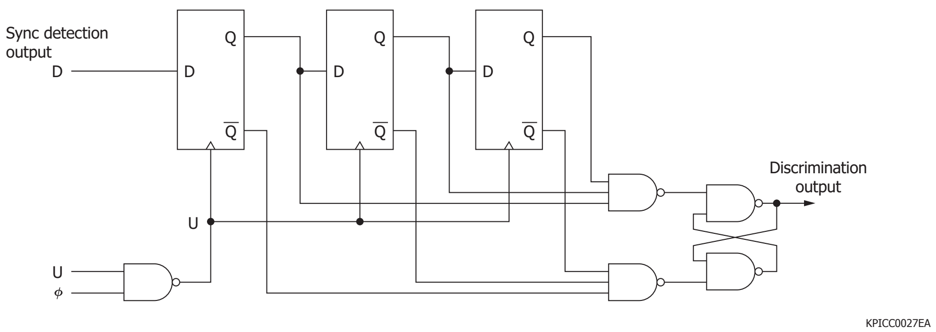
(2) Synchronous background light

Even when synchronous detection is carried out, background light which enters the sensor at the same

[Figure 4-1] Synchrounous detection circuit diagram



[Figure 4-2] Discrimination circuit block diagram



timing as the synchronous detection timing cannot be differentiated from signals from the LED light. However, it is extremely unlikely that the background light input timing will continuously and repeatedly match that of the synchronous detection timing. This fact can be utilized to eliminate effects from any asynchronous background light. In operation of the Hamamatsu light modulation photo ICs, a signal is judged to be present only when synchronous detection is carried out three consecutive times, and no signal is judged to be present when synchronous detection is not achieved three consecutive times. The “U” output described in the preceding section (1) is used to improve this judgment capability. When the “U” output is “L”, no synchronous detection is determined to have taken place and judgment is deferred. Specifically, a 3-stage shift register is used in making judgments, and when the “U” output is “L”, addition of a shift clock to the shift register is prohibited. The block diagram for this discrimination circuit is shown in Figure 4-2.

5 How to use

Optical synchronous detection type photoreflectors and photointerrupters can be easily made by connecting an infrared LED to a light modulation photo IC, which are less affected by fluctuating background light. The light modulation photo IC is used in reflection type sensors that detect an object or proximity to an object by detecting the infrared LED light reflected from the object; and also used in transmission type sensors that detect an object or a passing object by detecting whether the infrared LED light beam is interrupted by the object.
An infrared LED must be connected to the light modulation photo IC in order to perform synchronous detection. In some applications, however, connecting an LED may not be possible. In those cases, asynchronous type photo ICs are used. Asynchronous photo ICs cannot remove fluctuating background light as efficiently as the synchronous type, but they offer the advantage that they can be used without connecting to an infrared LED.

(1) LED drive current enhancement

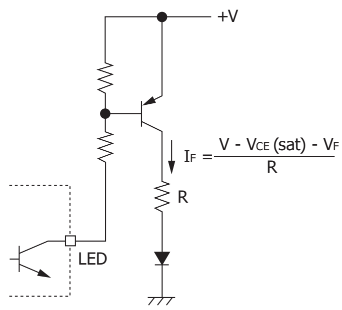
Detecting light over longer distances requires enhancing the LED drive current. This means that an external driver circuit must be added. Figure 5-1 shows simple external circuits using a PNP transistor to enhance the LED drive current. Another method uses a pull-up resistor connected to the LED terminal to convert LED drive pulses to logic signals before inputting the signals to the external LED driver circuit [Figure 5-2]. If the photo IC and the LED drive current operate from the same power supply line, then the supply voltage may fluctuate due to the LED drive current and cause erroneous operation. If this happens, take measures to stabilize the photo IC power terminal.

(2) Sensitivity adjustment

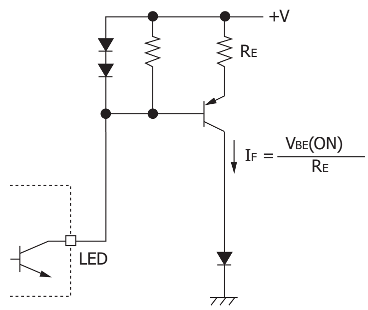
There is no special terminal for adjusting the sensitivity of light modulation photo ICs. If sensitivity must be adjusted, then change the LED drive current. To do this, connect a variable resistor in parallel with the LED for the S4282-51, S6986, and S10053; and connect a variable resistor in series with the LED for the S6809, S6846, and S7136/-10. If using an external circuit to drive the LED, adjust the external circuit constant.

[Figure 5-1] LED drive current enhancing method

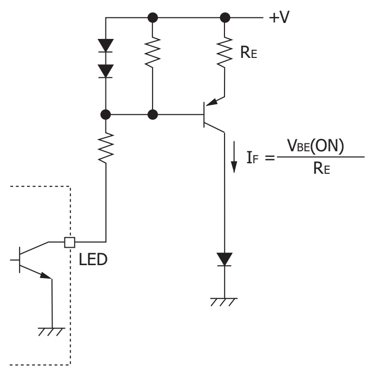
(a) All types



(b) S4282-51, S6986, S10053

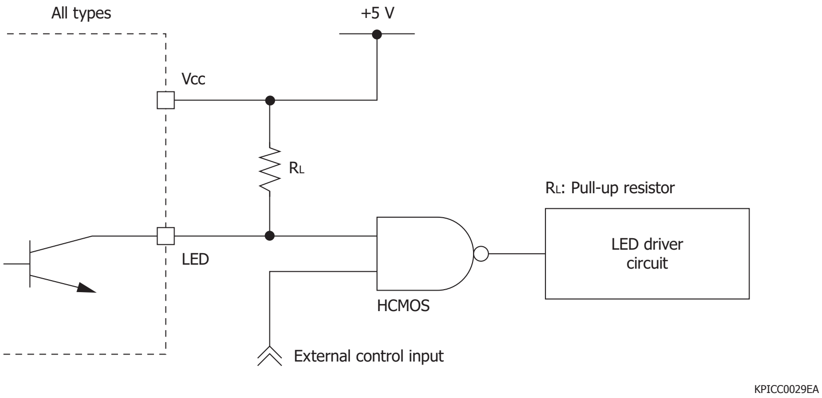


(c) S6809, S6846, S7136/-10



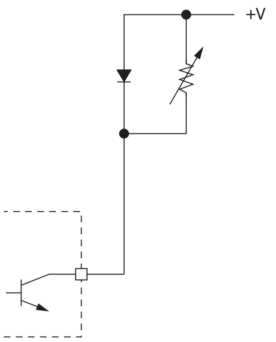
KPICC0028EB

[Figure 5-2] Conversion to logic signal

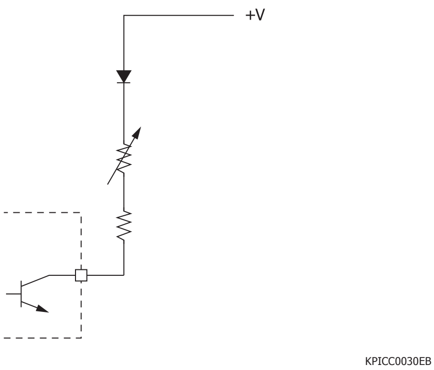


[Figure 5-3] LED drive current adjusting method

(a) S4282-51, S6986, S10053



(b) S6809, S6846, S7136/-10



Information described in this material is current as of May 2019.
Product specifications are subject to change without prior notice due to improvements or other reasons. This document has been carefully prepared and the information contained is believed to be accurate. In rare cases, however, there may be inaccuracies such as text errors. Before using these products, always contact us for the delivery specification sheet to check the latest specifications.
The product warranty is valid for one year after delivery and is limited to product repair or replacement for defects discovered and reported to us within that one year period. However, even if within the warranty period we accept absolutely no liability for any loss caused by natural disasters or improper product use. Copying or reprinting the contents described in this material in whole or in part is prohibited without our prior permission.

HAMAMATSU

www.hamamatsu.com

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

Cat. No. KPIC9001E03 May 2019 DN