SOLID STATE DIVISION

TECHNICAL INFORMATION
SD-18

Characteristic and use of Light modulation photo IC

HAMAMATSU

Contents

Characteristic and use of light modulation photo IC

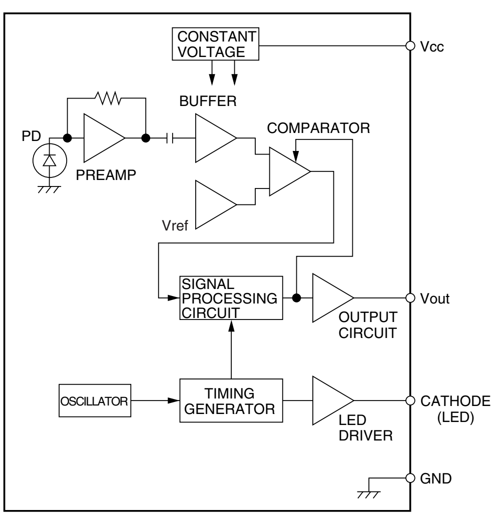
1. Optoelectronic detection of objects

Light modulation photo ICs were developed for the optoelectronic detection of objects. Normally, optoelectronic detection of an object uses a pair of light-emitting and light-receiving elements, like photointerrupters and photoreflectors which detect an object when it interrupts or reflects light. In this case, the sensor device should be used in darkness for reliable detection, because operational errors may occur if background light in the room strikes the light sensor. To prevent this type of error, the conventional method utilizes the difference in wavelength between the signal light and background light to eliminate adverse effects of background light by using an optical filter. However, when the background light intensity is strong, the effectiveness of this method is limited. The Hamamatsu light modulation photo ICs use an optical synchronous detection method which allows stable and reliable operation even when strong background light enters the sensor.

2. Features

A typical light modulation photo IC consists of an oscillator, a timing generator, an LED driver, a photodiode, a preamplifier, a comparator, a signal processing circuit and an output circuit, all integrated on a monolithic chip. Optical synchronous detection is achieved by just hooking an external LED to this photo IC. In optical synchronous detection, signal light is modulated in pulses and detected in synchronization with that modulation timing. This eliminates noise components generated by asynchronous background light.

Figure 2-1 Block diagram and truth table



TRUTH TABLE

INPUT	OUTPUT LEVEL
LIGHT ON	LOW
LIGHT OFF	HIGH

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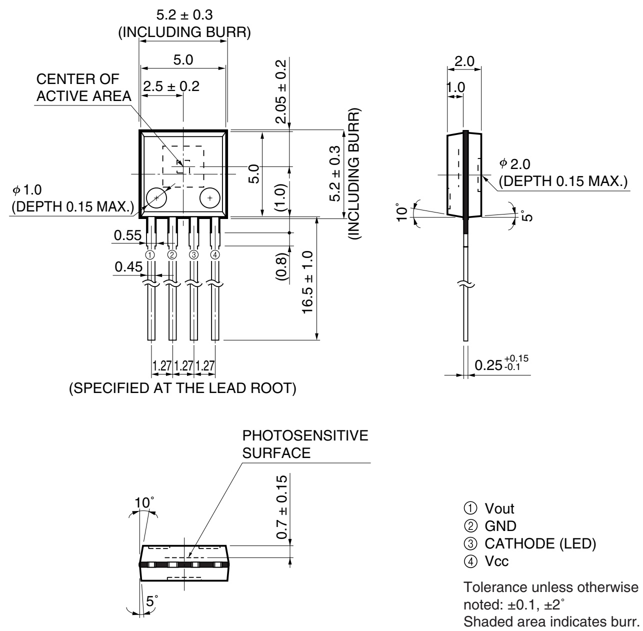
In Hamamatsu S6986 and S4282-51 light modulation photo ICs, the preamplifier circuit serves to cancel out DC light of high illuminance, allowing reliable detection of the signal light even if bright background light enters the sensor. S6846 and S7136 were designed for high sensitivity to make the detection distance even longer.

Figure 2-2 Dimensional outlines

S6986, S6846, S6809



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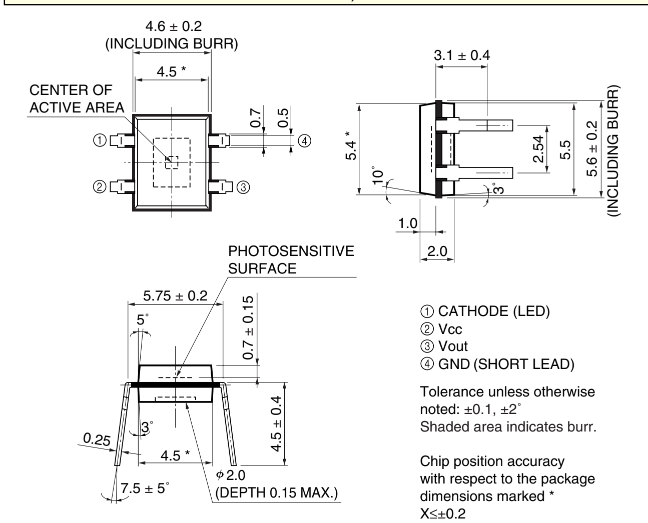
S4282-51, S7136



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3. Configuration

The functions of each block are described below.

(a) Oscillator and timing signal generator

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

(b) LED driver circuit

This circuit drives an external LED using the LED drive pulses created by the timing signal generator. The duty cycle is 1/16, and a constant-current pulse drive is used for S6986 and S4282-51, while an open collector drive for S6846 and S7136. (See Figure 3-1.)

(c) Photodiode and preamplifier circuit

The photodiode is formed on the same monolithic chip. A photocurrent generated in the photodiode is converted to a voltage through the preamp circuit. In S6986 and S4282-51 light modulation photo ICs, the preamplifier circuit uses an AC amplifier to expand the dynamic range versus DC or low-frequency background light, without impairing signal detection sensitivity.

(d) Capacitive coupling, buffer amplifier and reference voltage generator

Capacitive coupling removes low-frequency noise and also cancels the DC offset in the preamplifier. The buffer amplifier boosts the signal up to the comparator level, and the reference voltage generator produces a comparator level signal.

(e) Comparator circuit

The comparator circuit has a hysteresis function, preventing chattering caused by small fluctuations in the input light.

(f) Signal processing circuit

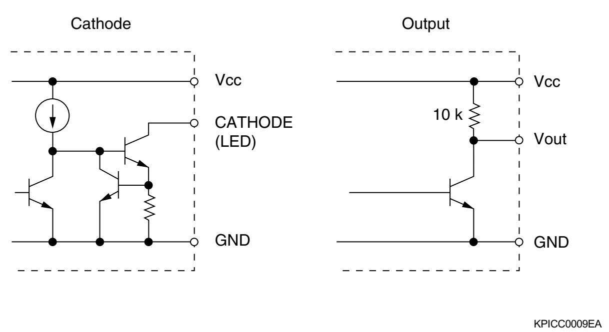
The signal processing circuit consists of a gate circuit and a digital integrator circuit. The gate circuit discriminates input pulses during synchronous detection, to prevent operational errors caused by asynchronous background light. Background light which is synchronized with the signal detection timing cannot be eliminated by the gate circuit. This is canceled out by the digital integrator circuit in a subsequent stage.

(g) Output circuit

This circuit serves as an output buffer for the signal processing circuit and outputs the signal to an external circuit. (See Figure 3-1.)

Figure 3-1 Output terminal diagram

S6986, S4282-51



S6846, S7136, S6809

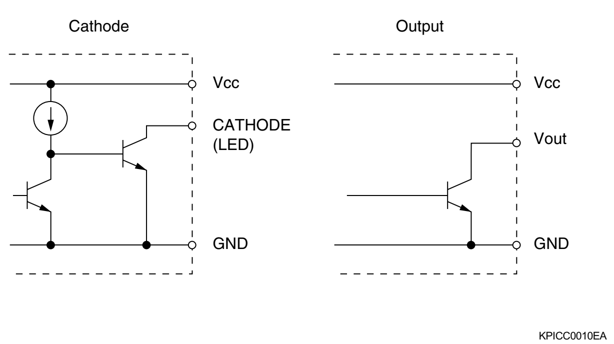
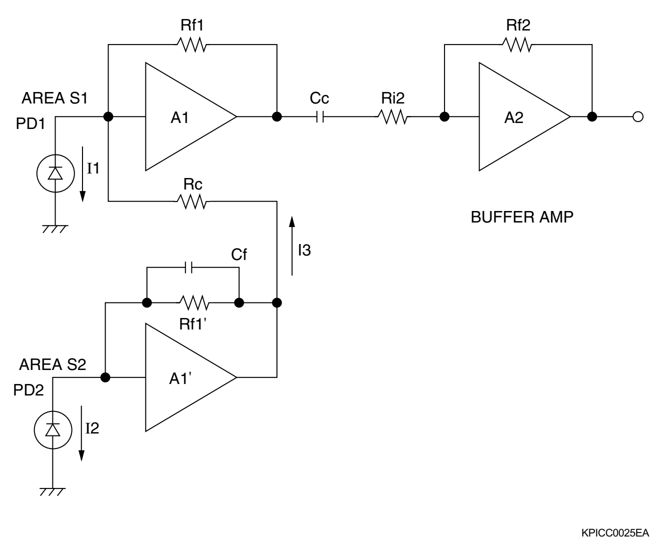


Figure 3-2 Preamp block diagram



4. Background light elimination

4-1 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 next-stage buffer amplifier. In addition to this capacitive coupling, S6986 and S4282-51 preamps use an AC amplifier (Figure 3-2) 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 3-2 consists of two amplifiers: a main amplifier (A_1) and another (A_1') 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 following photosensitive area ratio:

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

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 as follows 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), the following result is obtained:

$$I3 = Rf1' \times I1 / (Rc \times K) = I1 \cdots\cdots (3)$$

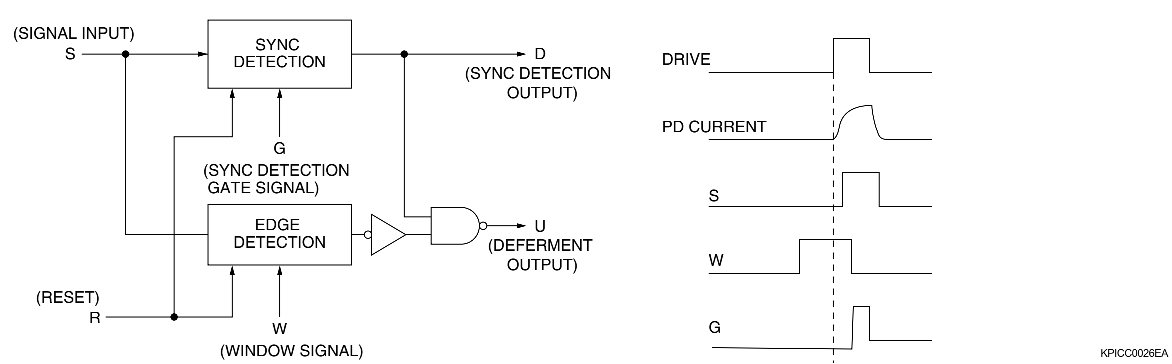
In this way, the photocurrent of PD1 can be extracted. The photocurrent component of A1 due to low-frequency background light is essentially zero as long as A1' does not become saturated, so the saturation of A1' determines the entire dynamic range. If the ratio of Rf1 to Rf1' is set as m, the expansion 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.

4-2 Eliminating high-frequency background light

(a) 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.

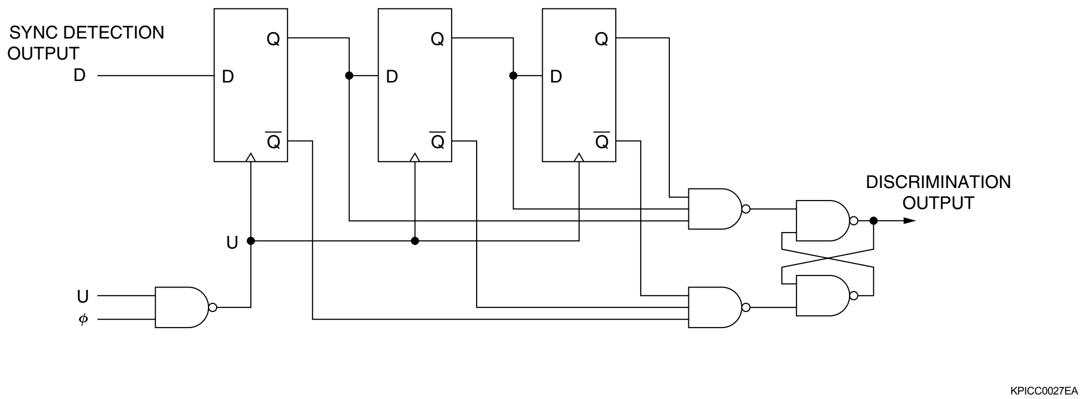
Figure 4-1 Synchrounous detection circuit diagram



(b) Synchronous background light

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

Figure 4-2 Discrimination circuit block diagram



5. Ratings and characteristics

■ Absolute maximum ratings (Ta=25 °C)

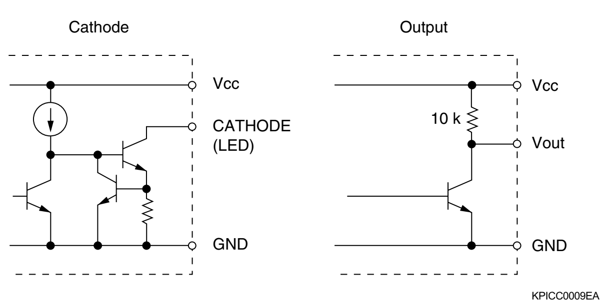
Parameter	Symbol	S4282-51, S6986	S6809, S6846, S7136/-10	Unit
Supply voltage	Vcc	-0.5 to +16		V
Output voltage	Vo	-0.5 to +16		V
Output current	Io	50		mA
Cathode output voltage	Vcath	-0.5 to +16		V
Cathode output current	Icath		70	mA
Power dissipation *1	P	250		mW
Operating temperature	Topr	-25 to +60		°C
Storage temperature	Tstg	-40 to +100		°C
Soldering	-	230 °C, 5 s, at least 1.8 mm away from package surface		-

*1: Derate power dissipation at a rate of -3.3 mW/°C above Ta=25 °C.

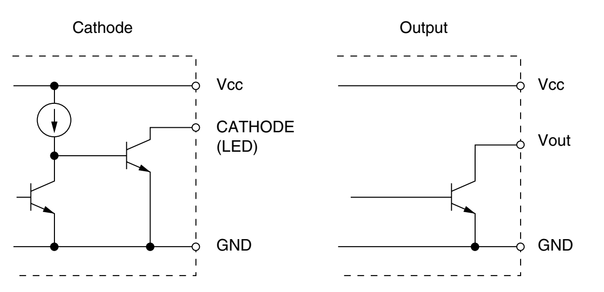
■ Electrical and optical characteristics (Ta=25 °C, Vcc=5 V)

Parameter	Symbol	Condition	S4282-51, S6986 Output: built-in pull-up resistor *2 Cathode: constant current drive			S6809, S6846, S7136 /-10 Output: open collector *3 Cathode: open collector drive			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
Supply voltage	Vcc		4.5	-	16	4.5	-	16	V
Current consumption	Icc	Vo, LED terminals open	-	4	11	-	4	11	mA
Output: Low level output voltage	VOL	IOL=16 mA	-	0.2	0.4	-	0.2	0.4	V
Output: High level output voltage	VOH		4.9	-	-				V
		4.7 kΩ between Vcc and Vo				4.9	-	-	V
Cathode: Low level output voltage	Vcath	Icath=40 mA				-	-	0.8	V
Cathode: Low level output current	Icath	Vcath=1.2 V	15	35	60				mA
Cathode: Pulse cycle	Tp		65	130	220	65	130	220	μs
Cathode: Pulse width	Tw		4	8	13.7	4	8	13.7	μs
H→L Threshold light level	EHL	λ=940 nm No background light	-	0.7	2	-	0.2	1.0	μW/mm²
Hysteresis	-		0.45	0.65	0.95	0.45 0.65 (S6809)	0.65 0.8 (S6809)	0.95 0.95 (S6809)	-
Frequency response	f		0.5	1.25	-	0.5	1.25	-	kHz
Allowable background light level	Ex	Signal light: 5 μW/mm² λp=940 nm Background light: "A" light source	5000	10000	-	2000	3000	-	*lx*

*2:



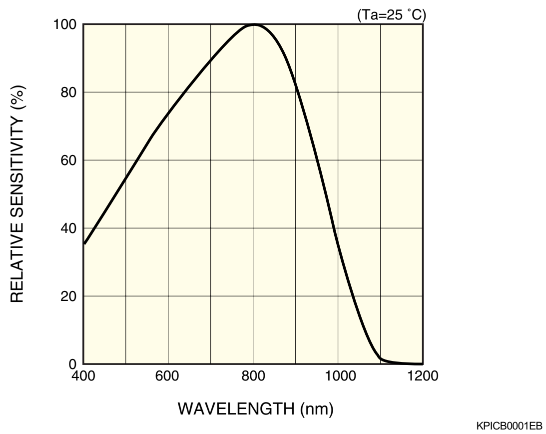
*3:



6. Typical characteristics

Figure 6-1 Spectral response (relative value)

S6986, S4282-51



S6846, S7136, S6809

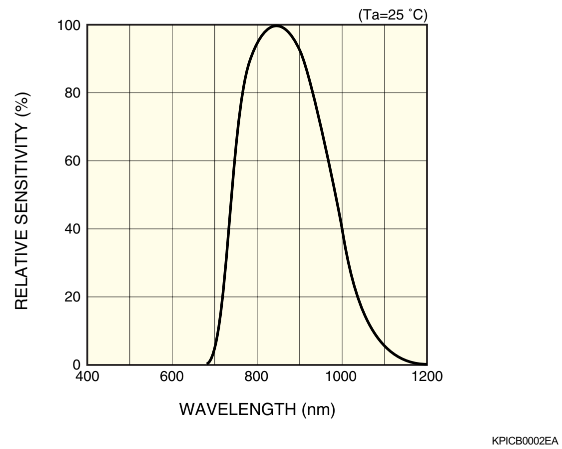
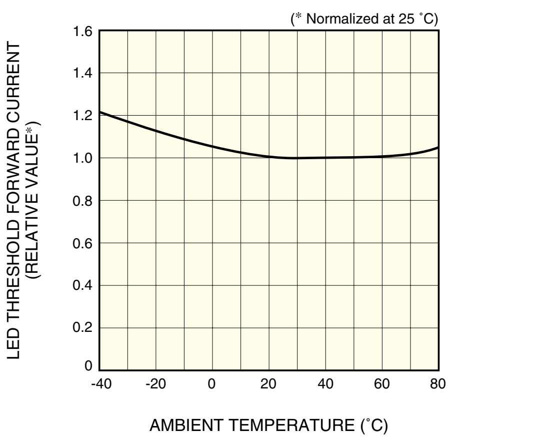


Figure 6-2 Sensitivity temperature characteristics

When used with Hamamatsu LED (L1915)



Light modulation photo IC only

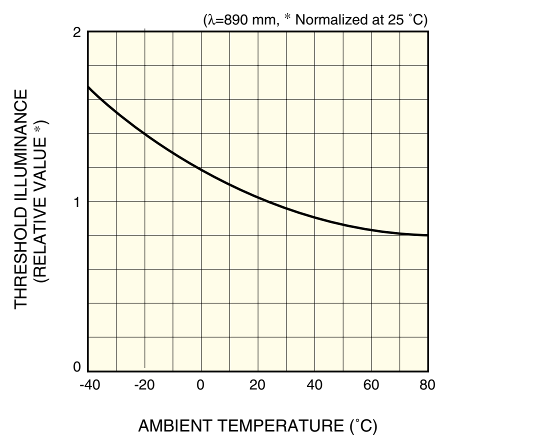


Figure 6-3 LED drive current temperature characteristic (S6986, S4282-51)

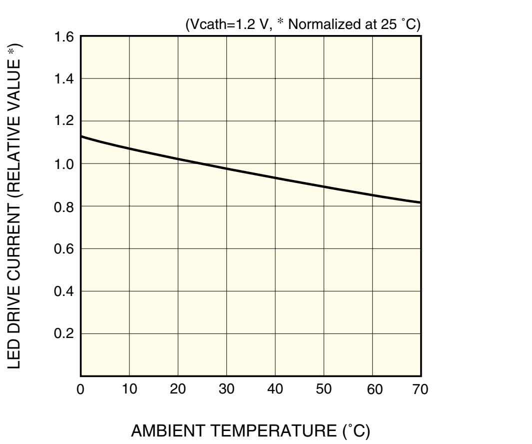


Figure 6-4 Low-level output voltage temperature characteristic

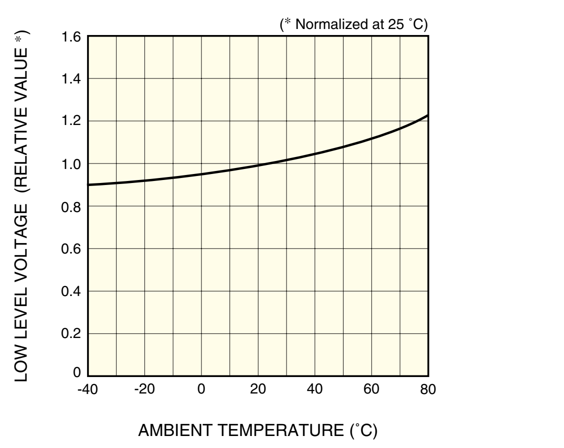


Figure 6-5 Pulse cycle temperature characteristic

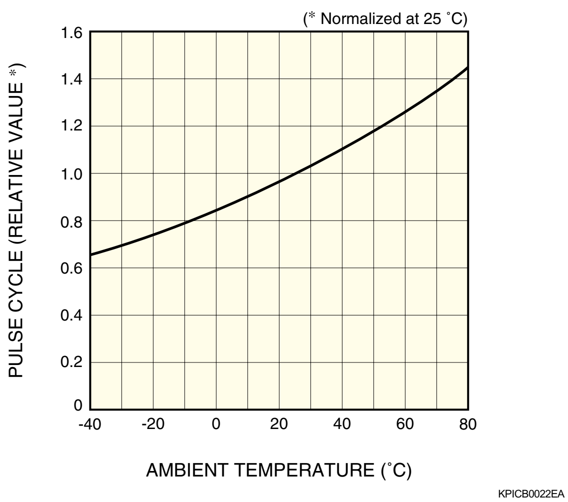
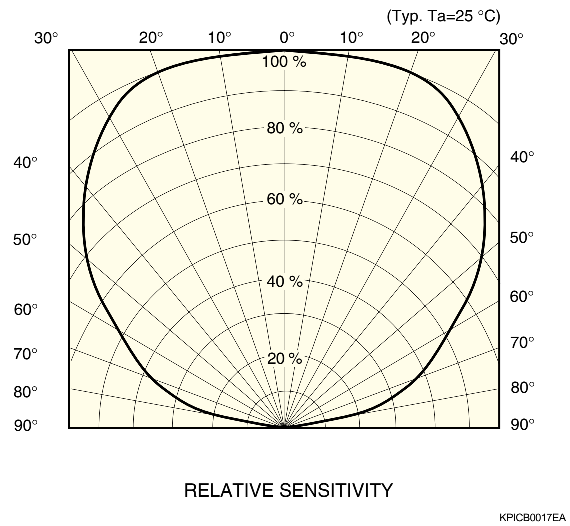


Figure 6-6 Directivity



7. Operation

7-1 Drive current enhancement

The LED terminal of S6986 and S4282-51 is for pulse drive, while that of S6846 and S7136 is for open collector drive. In some applications where the distance to the LED must be long, the LED drive current should be enhanced. In this case, an external drive circuit should be added. Figure 7-1 shows an example of an simple external circuit using a PNP transistor for enhancing drive current. There is another method in which a pull-up resistor is connected to the LED terminal for logic signal conversion before inputting the signal to the external LED drive circuit. (Figure 7-2) This method is effective when synchronizing with other circuits in the system and adding other digital processing functions. Using an HCMOS device for the next-stage logic is recommended. If the power supply line of the photo IC is shared with the LED drive current when it is enhanced, provide adequate decoupling for the power supply terminal of the photo IC.

7-2 Sensitivity adjustment

There is no special terminal for adjusting the sensitivity of light modulation photo ICs. Detection sensitivity can be adjusted by controlling the LED drive current. For this purpose, connect a variable resistor in series with LEDs for operating S6846 and S7136, and connect a variable resistor in parallel with LEDs for S6986 and S4282-51. (See Figure 7-3.) When using an external circuit to drive the LED, adjust the constant of the external circuit.

Figure 7-1 LED drive current enhancement

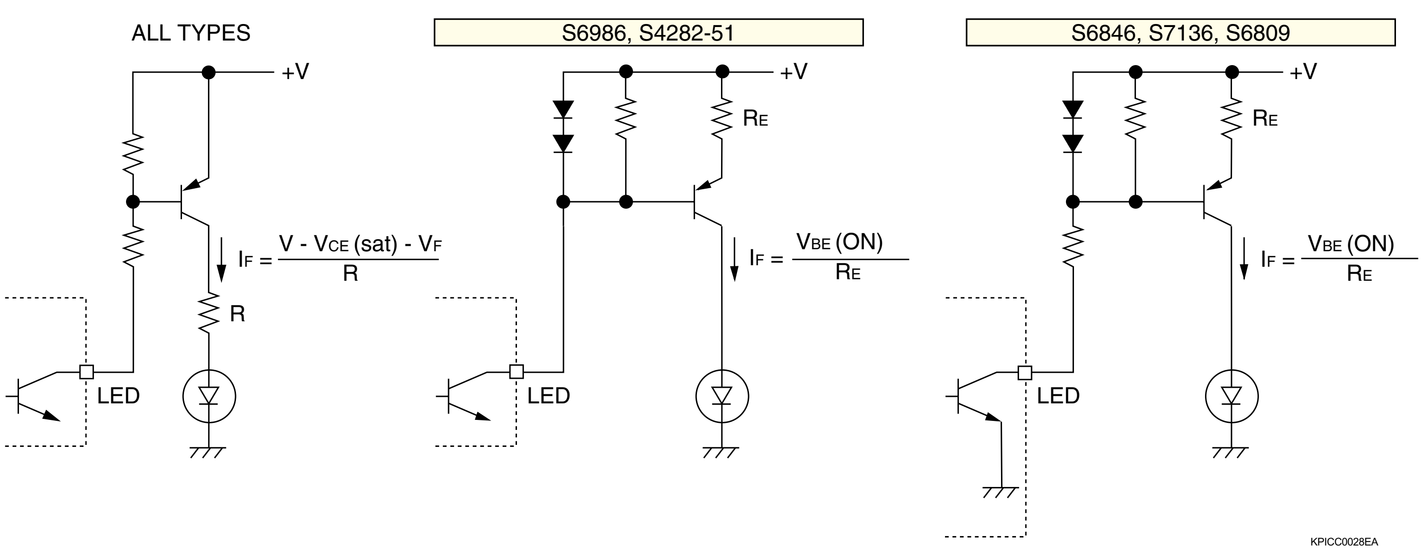


Figure 7-2 Conversion to logic signal

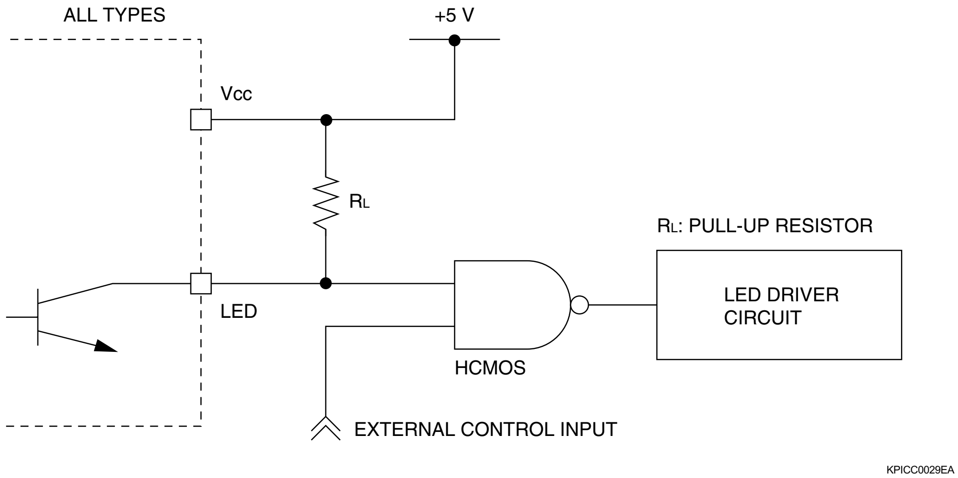
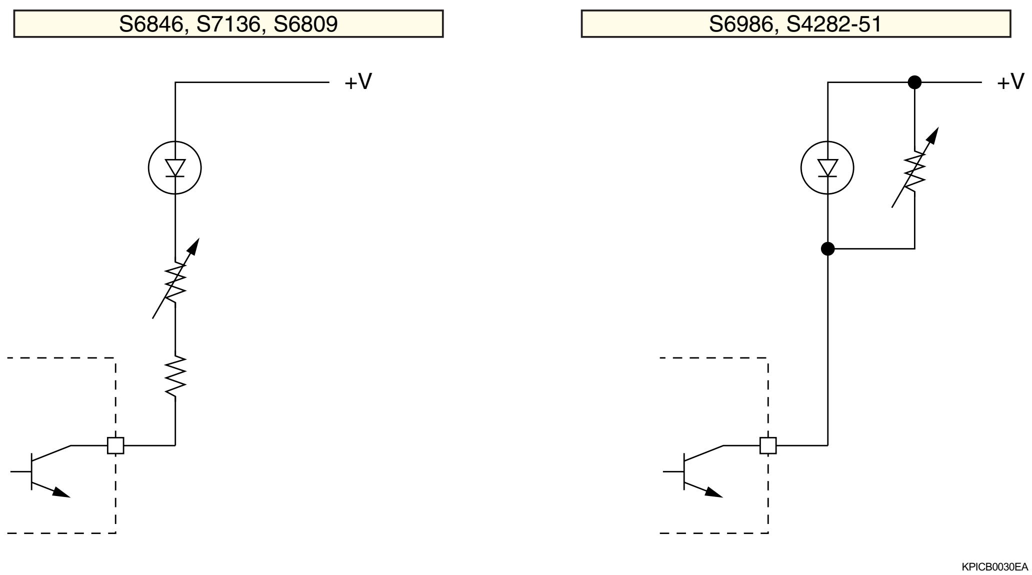


Figure 7-3 LED current adjustment



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Cat. No. KPIC9001E01
Jun. 2002 DN