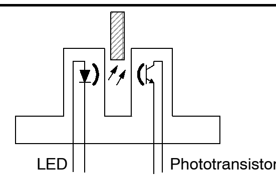
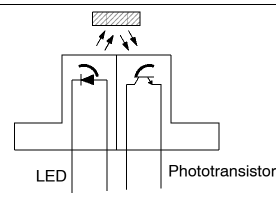
General Technical Information

■ WHAT IS A PHOTOMICROSENSOR?

Photomicrosensors are small photodetectors that use light to sense the presence, absence, or position of objects. They are typically constructed as either slot (transmissive) type or diffuse (reflective) type.

A photomicrosensor — whether it is a slot (transmissive) type or a diffuse (reflective) type — has both (a) an LED (light source), as an emitter, and (b) a device, such as a phototransistor or photo IC, as a receiver. In the slot type, the light-emitting surface of the LED is opposite the light-receiving surface that generates the output signal. Sensing occurs as the quantity of light incident on the receiver is changed by an object that passes through the slot and interrupts the light. In the diffuse reflective type, the light-emitting surface and the light-receiving surface are positioned at an angle to each other so that if an object passes across the light path, the light is reflected toward the receiver element. This receiver generates an output to indicate the presence of the object. The following table provides more details.

■ BASIC PHOTOMICROSENSOR SENSING METHODS

Sensing method	Operating principle	Features
Slot type (Transmissive)	The light source element (LED) and detector element (phototransistor) opposing each other on the same optical axis are housed in a case to detect the presence of an object passing through the slot in the housing. 	• Permits stable sensing of an opaque object, regardless of its color or surface condition. • A variety of gap widths and depths are available.
Diffuse (Reflective)	The light source element (LED) and detector element (phototransistor) are housed in a case with both elements arranged in the same direction, to sense the presence of an object by utilizing the reflecting light from the object when it passes through the path of light emitted from the photomicrosensor. 	• Permits positive sensing of any object, regardless of its thickness, size, or mounting space, because the photomicrosensor is capable of sensing any surface (upper, bottom, and side) of the object. • To protect against external light interference, it can be equipped with a protective filter.

Elements Used in Photomicrosensors

■ EMITTER

The emitter element in all photomicrosensors is a light emitting diode (LED). Some of the LEDs emit red light, and others emit infrared. Advantages of the infrared LEDs are: receiver elements are more sensitive to infrared light; and, the quantity of light emitted by infrared LEDs is greater than that emitted by red LEDs. Advantages of the red LEDs include (1) lower cost, and (2) the use of visible light, allowing an operator to confirm that the device is functioning. With either type of emitter, the LED illuminates only when it is forward biased.

■ RECEIVER

The receiver element in a photomicrosensor may be a phototransistor, or it may be a photo IC consisting of a photodiode and an amplifier mounted on a single chip. Photomicrosensors use transistors that are one of two types — either the phototransistor type, or the Photodarlington type. The phototransistor type uses a single phototransistor.

Photodarlington type of receiver. This type uses an ordinary transistor and a phototransistor mounted on a single chip. The configuration of a Photodarlington transistor is shown in Figure 1.

Photo IC type of receiver. This type consists of a photodiode, an amplifier, a waveform shaping circuit, and an output power transistor integrated on a single chip. An OMRON phototransistor incorporates a temperature compensating circuit with the amplifier stage to assure temperature stability. Refer to Figure 2.

Figure 1. Configuration of a Photodarlington Transistor

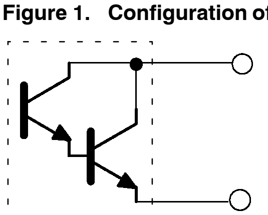
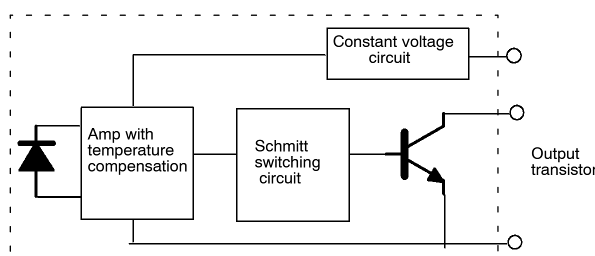


Figure 2. Configuration of an OMRON Photo IC



■ DATA OF RELIABILITY TESTS

The following tables show the results of the reliability tests of photomicrosensors conducted by OMRON.

Failure Rate (MTTF Data)

Phototransistor Output Models

Test	Condition	No. of samples	Component Hours	No. of failures	Failure rate/hr (reliability level: 90%)	Estimated MTTF (h) (average life expectancy)
Soldering heat resistance	260°C, 10 s	198	---	0	---	---
Thermal shock	0°C to 100°C, 5 times	55	---	0	---	---
Temperature cycle	100°C (30 min) to −40°C (30 min)	5,760	(100 times)	0	---	---
Temperature and humidity cycle	65°C to −10°C, 90% to 98%, 1 cycle/24 hrs, 10 cycles	66	---	0	---	---
Soldering ease	230°C, 5 s	165	---	0	---	---
Terminal strength	Tension: 0.5 kg Bending: 90° twice with a bending force of 0.25 kg each	143	---	0	---	---
Shock resistance	1,500G (14,700 m/s^2), 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	110	---	0	---	---
Vibration resistance	20 to 2,000 Hz/ 4 min, 1.5 mm or 10G, for 2 hrs each in X, Y, and Z directions	110	---	0	---	---
Natural drop	75 cm, 3 times	44	---	0	---	---
Continuous operation	T_A = 25°C, I_F = 50 mA	528	7.92×10^5	0	2.90×10^{-6}	3.44×10^5
High-temperature storage	T_A = 100°C	484	4.84×10^5	0	4.75×10^{-6}	2.10×10^5
Low-temperature storage	T_A = −40°C	484	4.84×10^5	0	4.75×10^{-6}	2.10×10^5
High-temperature and high-humidity storage	T_A = 60°C, 90%	396	3.96×10^5	0	5.81×10^{-6}	1.72×10^5
High-temperature reverse bias	T_A = 85°C, V_{CE} = 30V	308	3.08×10^5	0	7.47×10^{-6}	1.34×10^5

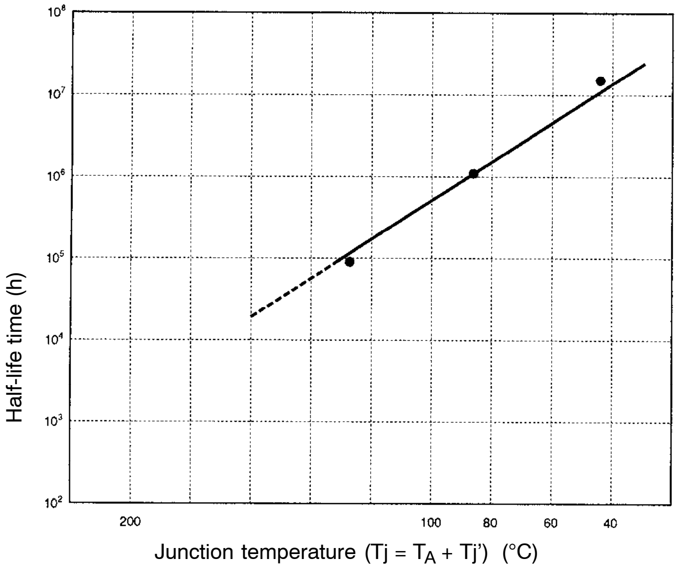
Photo IC Output Models

Test	Condition	No. of samples	Component Hours	No. of failures	Failure rate/hr (reliability level: 90%)	Estimated MTTF (h) (average life expectancy)
Soldering heat resistance	260°C, 10 s	33	---	0	---	---
Thermal shock	0°C to 85°C, 5 times	33	---	0	---	---
Temperature cycle	85°C (30 min) to −40°C (30 min)	5,040	(100 times)	0	---	---
Temperature and humidity cycle	65°C to −10°C, 90% to 98%, 1 cycle/24 hrs, 10 cycles	22	---	0	---	---
Soldering ease	230°C, 5 s	44	---	0	---	---
Terminal strength	Tension: 0.5 kg Bending: 90° twice with a bending force of 0.25 kg each	33	---	0	---	---
Shock resistance	1,500G (14,700 m/s^2), 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	22	---	0	---	---
Vibration resistance	20 to 2,000 Hz/ 4 min, 1.5 mm or 10G, for 2 hrs each in X, Y, and Z directions	22	---	0	---	---
Natural drop	75 cm, 3 times	22	---	0	---	---
Continuous operation	T_A = 25°C, I_F = 50 mA	330	6.60×10^5	0	3.48×10^{-6}	2.87×10^5
High-temperature storage	T_A = 85°C	264	2.64×10^5	0	8.71×10^{-6}	1.15×10^5
Low-temperature storage	T_A = −40°C	264	2.64×10^5	0	8.71×10^{-6}	1.15×10^5
High-temperature and high-humidity storage	T_A = 60°C, 90%	264	2.64×10^5	0	8.71×10^{-6}	1.15×10^5
High-temperature reverse bias	T_A = 75°C, V_{CC} = 16 V, Vout = 28 V	66	6.60×10^4	0	3.48×10^{-5}	2.87×10^4

■ LIFE VS. FORWARD CURRENT AND AMBIENT TEMPERATURE CHARACTERISTICS

The life of a photomicrosensor depends on the junction temperature (Tj) of the LED. The junction temperature (Tj) is determined by the forward current of the LED and the ambient temperature. The following graph shows the relationship between the junction temperatures and half-life time characteristics of the LED, which OMRON obtained from life expectancy tests. The half-life time denotes the time needed to decrease the optical output of an LED to one half of its initial optical output. The light current (I_L) of the detector element of a photomicrosensor will decrease to one half of its initial value when the optical output of the LED built into the photomicrosensor decreases to half of its initial optical output.

Figure 7. LED Junction Temperature vs. Half-Life Time



Explanation

Tj' and Tj can be obtained from the following formulas if I_F is 20 mA and T_A is 40°C.

Tj' = 20 mA x 0.65 = 12°C
Tj = T_A + Tj' = 40°C + 12°C = 52°C

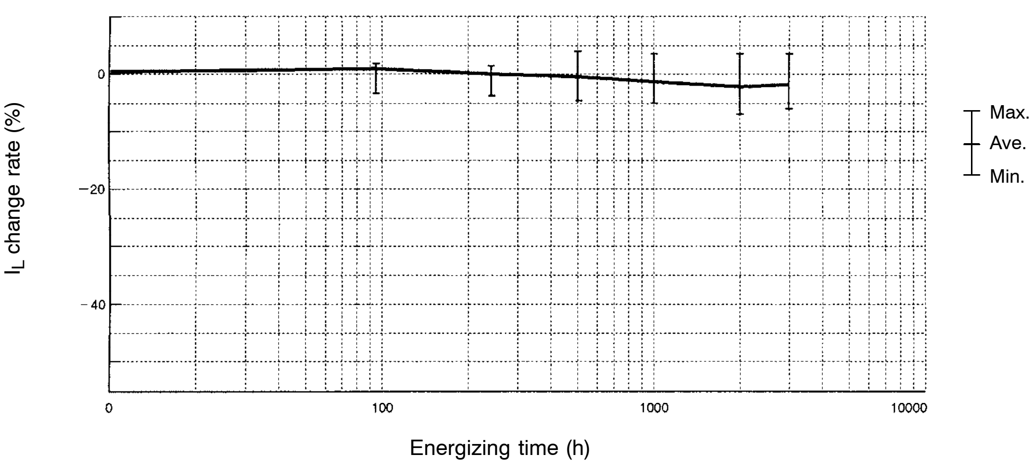
Therefore, if Tj is 52°C, the half-life time of the LED will be 9 x 10^6 hrs.

Note: 1. Tj: Junction temperature
Tj' = I_F (mA) x 0.65

2. The above data was obtained on condition that the photomicrosensor was under a constant temperature stress and electrical stress. Practically, photomicrosensors must be used by considering various ambient condition changes.

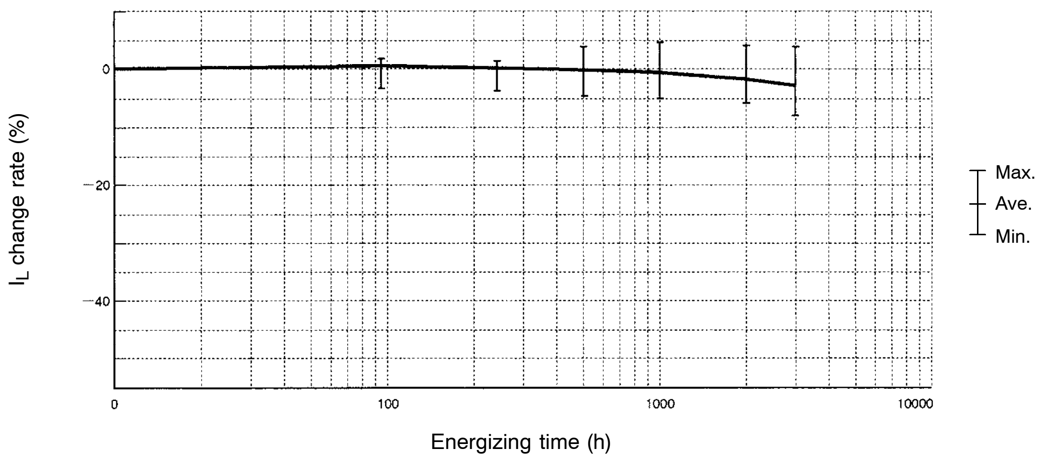
■ LIGHT CURRENT (I_L) CHANGES OF PHOTOTRANSISTOR OUTPUT PHOTOMICROSENSOR

T_A = 25°C, I_F = 20 mA, n = 32

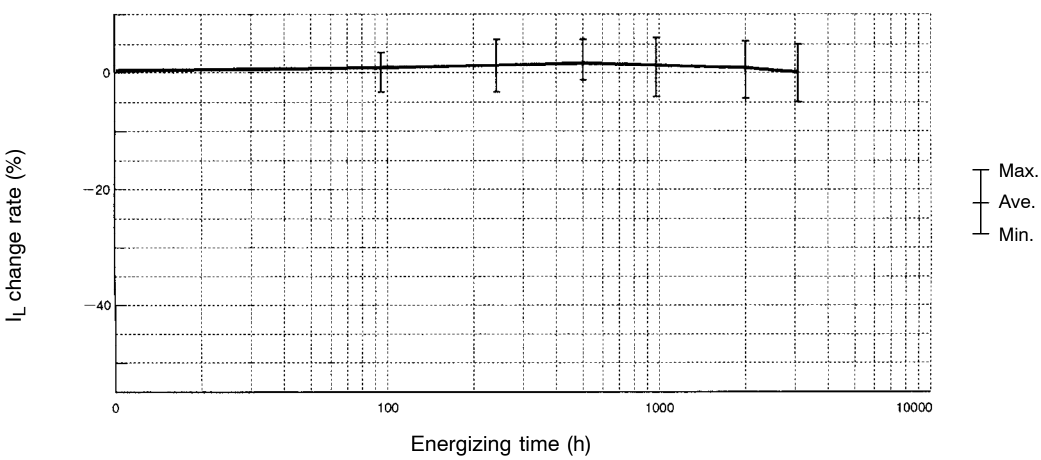


■ LIGHT CURRENT (I_L) CHANGES OF PHOTOTRANSISTOR OUTPUT PHOTOMICROSENSOR (CONTINUED)

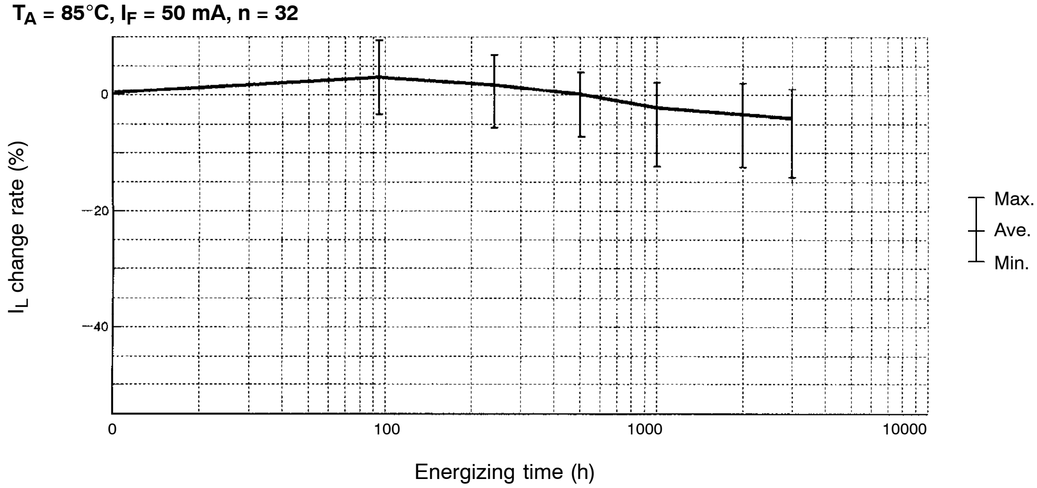
T_A = 25°C, I_F = 50 mA, n = 32



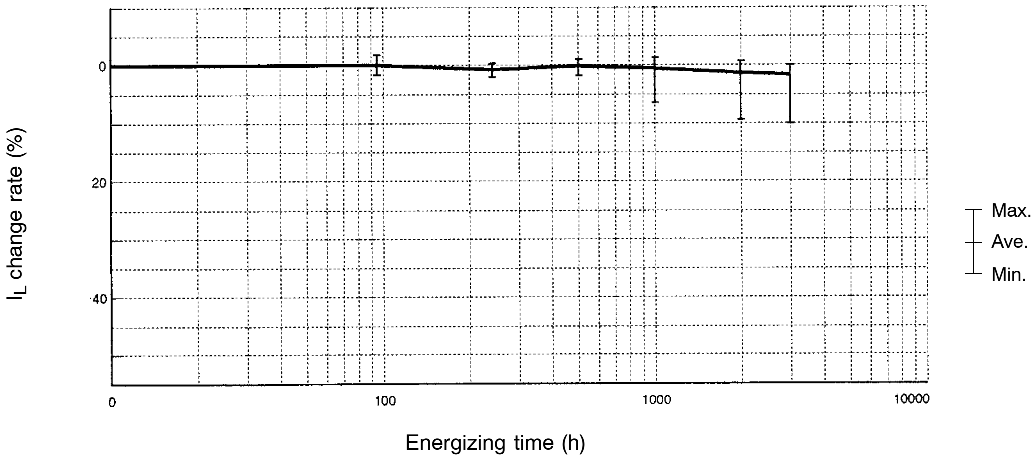
T_A= 85°C, I_F = 10 mA, n = 32



T_A = 85°C, I_F = 50 mA, n = 32

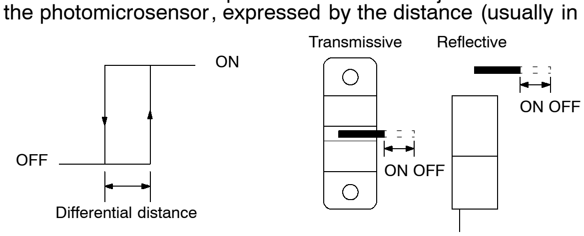
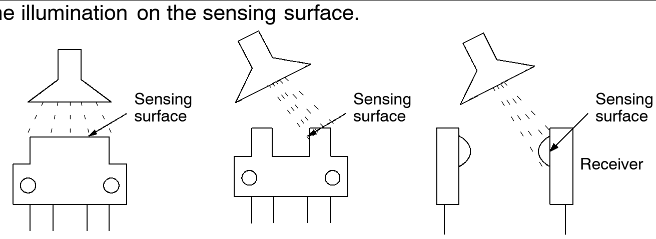


T_A = –40°C, I_F = 50 mA, n = 32



Important Terms

■ TERMINOLOGY (1)

Item	Definition
Light modulation	A method that uses a pulse-modulated LED as the light source to be detected by the receiver in a synchronized system.
Supply voltage	The maximum voltage that can be imposed on the positive (+) terminal with the negative (–) terminal at reference potential.
Current consumption	The current that flows into the positive (+) terminal when the maximum supply voltage is imposed on the positive (+) terminal with the negative (–) terminal at reference potential.
Detectable object	Transmissive models: The smallest opaque object (with a transparency of 0%) that can be detected. Reflective models: An object with a reflection ratio and size that can be detected.
Differential distance	The difference in the locations of a specified detectable object between the detection time and reset time of the photomicrosensor, expressed by the distance (usually in mm). 
Control output	The voltage fall between the OUT and negative (–) terminals when a specified voltage (with specified bias conditions) is imposed on the positive (+) terminal with the negative (–) terminal at reference potential (under the condition that the control output is ON).
Response frequency	The frequency that an object satisfying specified conditions (size, transparency rate, reflection factor, sensing distance, and electric bias) can be repeatedly detected.
Ambient illumination	Defined as the illumination on the sensing surface. 

■ TERMINOLOGY (2)

Symbol	Item	Definition
I_F	Forward current	The maximum DC voltage that is allowed to flow continuously from the anode of the LED to the cathode of the LED under a specified temperature condition.
V_R	Reverse voltage	The maximum negative voltage that can be applied to the anode of the LED with the cathode at reference potential.
V_{CC}	Supply voltage	The maximum positive voltage that can be applied to the voltage terminals of the photo IC with the ground terminal at reference potential.
V_{OUT}	Output voltage	The maximum positive voltage that can be applied to the output terminal with the ground terminal of the photo IC at reference potential.
I_{OUT}	Output current	The maximum current that is allowed to flow in the collector junction of the output transistor of the photo IC.
P_{OUT}	Output permissible dissipation	The maximum power that is consumed by the collector junction of the output transistor of the photo IC.
V_F	Forward voltage	The voltage drop across the LED in the forward direction when a specified bias current is applied to the photo IC.
I_R	Reverse current	The reverse leakage current across the LED when a specified negative bias is applied to the anode with the cathode at reference potential.
V_{OL}	Output low voltage	The voltage drop in the output of the photo IC when the IC output is turned ON under a specified voltage and output current applied to the photo IC.
V_{OH}	Output high voltage	The voltage output by the photo IC when the IC output is turned OFF under a specified supply voltage and bias condition given to the photo IC.
I_{CC}	Current consumption	The current that will flow into the sensor when a specified positive bias voltage is applied from the power source with the ground of the photo IC at reference potential.
I_{FT} ($I_{FT\ OFF}$)	LED current when output is turned OFF	The forward LED current value that turns OFF the output of the photo IC when the forward current to the LED is increased under a specified voltage applied to the photo IC.
I_{FT} ($I_{FT\ ON}$)	LED current when output is turned ON	The forward LED current value that turns ON the output of the photo IC when the forward current to the LED is increased under a specified voltage applied to the photo IC.
ΔH	Hysteresis	The difference in forward LED current value, expressed in percentage, calculated from the respective forward LED currents when the photo IC is turned ON and when the photo IC is turned OFF.
f	Response frequency	The number of revolutions of a disk with a specified shape rotating in the light path, expressed by the number of pulse strings that the photo IC can respond to in one second under specified operating conditions.
I_{FP}	Pulse forward current	The maximum pulse current that is allowed to flow continuously from the anode to cathode of an LED under a specified temperature, a repetition period, and a pulse width condition.
I_C	Collector current	The current that flows to the collector junction of a phototransistor.
P_C	Collector dissipation	The maximum power that is consumed by the collector junction of a phototransistor.
I_D	Dark current	The collector current of a phototransistor at a specified bias with no incident light (i.e., 0*lx*).
I_L	Light current	The collector current of a phototransistor under a specified input current condition and at a specified bias voltage.
V_{CE} (sat)	Collector-emitter saturation voltage	The ON-state voltage between the collector and emitter of a phototransistor under a specified bias current condition.
I_{LEAK}	Leakage current	The collector current of a phototransistor under a specified input current condition and at a specified bias voltage when the phototransistor is not exposed to light.
tr	Rising time	The time required for the leading edge of an output waveform of a phototransistor to rise from 10% to 90% of its final value when a specified input current and bias condition is given to the phototransistor.
tf	Falling time	The time required for the trailing edge of an output waveform of a phototransistor to decrease from 90% to 10% of its final value when a specified input current and bias condition is given to the phototransistor.
V_{CEO}	Collector-emitter voltage	The maximum positive voltage that can be applied to the collector of a phototransistor with the emitter at reference potential.
V_{ECO}	Emitter-collector voltage	The maximum positive voltage that can be applied to the emitter of a phototransistor with the collector at reference potential.