OMRON

Photomicrosensors
Technical Information

Features of Photomicrosensors

The Photomicrosensor is a compact optical sensor that senses objects or object positions with an optical beam. The transmissive Photomicrosensor and reflective Photomicrosensor are typical Photomicrosensors.

The transmissive Photomicrosensor incorporates an emitter and a transmissive that face each other as shown in Figure 1. When an object is located in the sensing position between the emitter and the detector, the object intercepts the optical beam of the emitter, thus reducing the amount of optical energy reaching the detector.

The reflective Photomicrosensor incorporates an emitter and a detector as shown in Figure 2. When an object is located in the sensing area of the reflective Photomicrosensor, the object reflects the optical beam of the emitter, thus changing the amount of optical energy reaching the detector.

“Photomicrosensor” is an OMRON product name. Generally, the Photomicrosensor is called a photointerrupter.

Figure 1 Transmissive Photomicrosensor

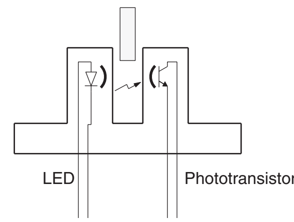
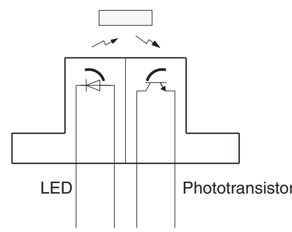


Figure 2 Reflective Photomicrosensor



Datasheet

■ Absolute Maximum Ratings and Electrical and Optical Characteristics

The datasheets of Photomicrosensors include the absolute maximum ratings and electrical and optical characteristics of the Photomicrosensors as well as the datasheets of transistors and ICs. It is necessary to understand the difference between the absolute maximum ratings and electrical and optical characteristics of various Photomicrosensors.

Absolute Maximum Ratings

The absolute maximum ratings of Photomicrosensors and other products with semiconductors specify the permissible operating voltage, current, temperature, and power limits of these products. The products must be operated absolutely within these limits.

Therefore, when using any Photomicrosensor, do not ignore the absolute maximum ratings of the Photomicrosensor, otherwise the Photomicrosensor will not operate precisely. Furthermore, the Photomicrosensor may be deteriorate or become damaged, in which case OMRON will not be responsible.

Practically, Photomicrosensors should be used so that there will be some margin between their absolute maximum ratings and actual operating conditions.

Electrical and Optical Characteristics

The electrical and optical characteristics of Photomicrosensors indicate the performance of Photomicrosensors under certain conditions.

Most items of the electrical and optical characteristics are indicated by maximum or minimum values. OMRON usually sells Photomicrosensors with standard electrical and optical characteristics.

The electrical and optical characteristics of Photomicrosensors sold to customers may be changed upon request. All electrical and optical characteristic items of Photomicrosensors indicated by maximum or minimum values are checked and those of the Photomicrosensors indicated by typical values are regularly checked before shipping so that OMRON can guarantee the performance of the Photomicrosensors.

In short, the absolute maximum ratings indicate the permissible operating limits of the Photomicrosensors and the electrical and optical characteristics indicate the maximum performance of the Photomicrosensors.

Terminology

The terms used in the datasheet of each Photomicrosensor with a phototransistor output circuit or a photo IC output circuit are explained below.

■ Phototransistor Output Photomicrosensor

Symbol	Item	Definition
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 current leakage of the phototransistor when a specified bias voltage is imposed on the phototransistor so that the polarity of the collector is positive and that of the emitter is negative on condition that the illumination of the Photomicrosensor is 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 saturated 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.

■ Phototransistor/Photo IC Output Photomicrosensor

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 during which the output logic of the photo IC can be obtained under a specified bias condition given to the LED and photo IC (the number of pulse strings to which the photo IC can respond in a second).

Design

The following explains how systems using Photomicrosensors must be designed.

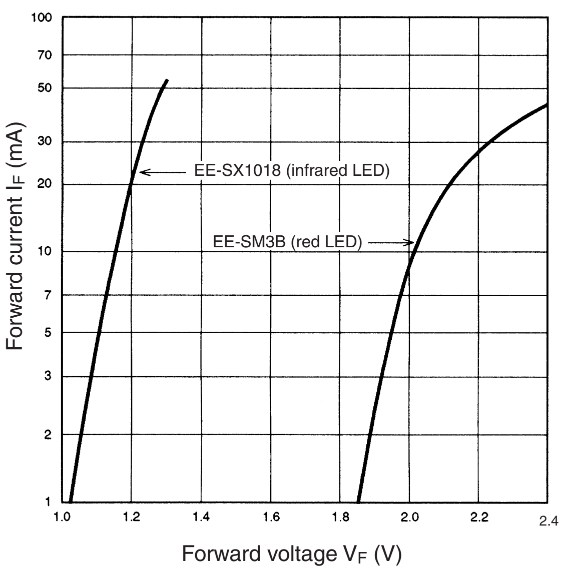
■ Emitter

Characteristics of Emitter

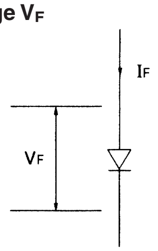
The emitter of each Photomicrosensor has an infrared LED or red LED. Figure 3 shows how the LED forward current characteristics of the EE-SX1018, which has an emitter with an infrared LED, and those of the EE-SM3B, which has an emitter with a red LED, are changed by the voltages imposed on the EE-SX1018 and EE-SM3B. As shown in this figure, the LED forward current characteristics of the EE-SX1018 greatly differ from those of the EE-SM3B. The LED forward current characteristics of any Photomicrosensor indicate how the voltage drop of the LED incorporated by the emitter of the Photomicrosensor is changed by the LED's forward current (I_F) flowing from the anode to cathode. Figure 3 shows that the forward voltage (V_F) of the red LED is higher than that of the infrared LED.

The forward voltage (V_F) of the infrared LED is approximately 1.2 V and that of the red LED is approximately 2 V provided that the practical current required by the infrared LED and that required by the red LED flow into these LEDs respectively.

Figure 3 LED Forward Current vs. Forward Voltage Characteristics (Typical)



Forward Voltage V_F



Driving Current Level

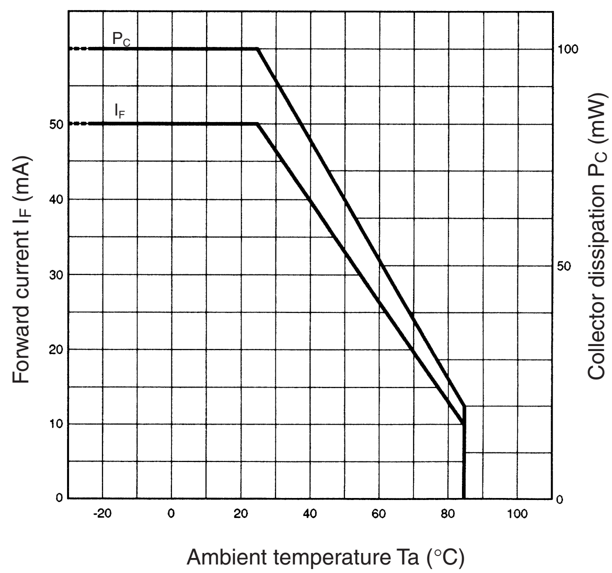
It is especially important to decide the level of the forward current (I_F) of the emitter incorporated by any Photomicrosensor. The forward current must not be too large or too small.

Before using any Photomicrosensor, refer to the absolute maximum ratings in the datasheet of the Photomicrosensor to find the emitter's forward current upper limit. For example, the first item in the absolute maximum ratings in the datasheet of the EE-SX1018 shows that the forward current (I_F) of its emitter is 50 mA at a Ta (ambient temperature) of 25°C. This means the forward current (I_F) of the emitter is 50 mA maximum at a Ta of 25°C. As shown in Figure 4 the forward current must be reduced according to changes in the ambient temperature.

Figure 4 indicates that the forward current (I_F) is approximately 27 mA maximum if the EE-SX1018 is used at a Ta of 60°C. This means that a current exceeding 27 mA must not flow into the emitter incorporated by the EE-SX1018 at a Ta of 60°C.

As for the lower limit, a small amount of forward current will be required because the LED will not give any output if the forward current I_F is zero.

Figure 4 Temperature Characteristics (EE-SX1018)



In short, the forward current lower limit of the emitter of any Photomicrosensor must be 5 mA minimum if the emitter has an infrared LED and 2 mA minimum if the emitter has a red LED. If the forward current of the emitter is too low, the optical output of the emitter will not be stable. To find the ideal forward current value of the Photomicrosensor, refer to the light current (I_L) shown in the datasheet of the Photomicrosensor. The light current (I_L) indicates the relationship between the forward current (I_F) of the LED incorporated by the Photomicrosensor and the output of the LED. The light current (I_L) is one of the most important characteristics. If the forward current specified by the light current (I_L) flows into the emitter, even though there is no theoretical ground, the output of the emitter will be stable. This characteristic makes it possible to design the output circuits of the Photomicrosensor with ease. For example, the datasheet of EE-SX1018 indicates that a forward current (I_F) of 20 mA is required.

Design Method

The following explains how the constants of a Photomicrosensor must be determined. Figure 5 shows a basic circuit that drives the LED incorporated by a Photomicrosensor.

The basic circuit absolutely requires a limiting resistor (R). If the LED is imposed with a forward bias voltage without the limiting resistor, the current of the LED is theoretically limitless because the forward impedance of the LED is low. As a result the LED will burn out. Users often ask OMRON about the appropriate forward voltage to be imposed on the LED incorporated by each Photomicrosensor model that they use. There is no upper limit of the forward voltage imposed on the LED provided that an appropriate limiting resistor is connected to the LED. There is, however, the lower limit of the forward voltage imposed on the LED. As shown in Figure 3, the lower limit of the forward voltage imposed on the LED must be at least 1.2 to 2 V, otherwise no forward current will flow into the LED. The supply voltage of a standard electronic circuit is 5 V minimum. Therefore, a minimum of 5 V should be imposed on the LED. A system incorporating any Photomicrosensor must be designed by considering the following.

- Forward current (I_F)
- Limiting resistor (R) (refer to Figure 5)

As explained above, determine the optimum level of the forward current (I_F) of the LED. The forward current (I_F) of the EE-SX1018, for example, is 20 mA. Therefore, the resistance of the limiting resistor connected to the LED must be decided so that the forward current of the LED will be approximately 20 mA. The resistance of the limiting resistor is obtained from the following.

$$R = \frac{V_{CC} - V_F}{I_F}$$

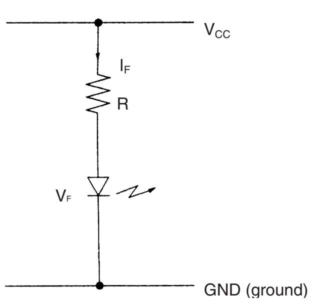
In this case 5 V must be substituted for the supply voltage (V_{CC}). The forward voltage (V_F) obtained from Figure 3 is approximately 1.2 V when the forward current (I_F) of the LED is 20 mA. Therefore, the following resistance is obtained.

$$R = \frac{V_{CC} - V_F}{I_F} = \frac{5 \text{ to } 1.2 \text{ V}}{20 \text{ mA}} = 190\ \Omega$$

$= \text{approx. } 180 \text{ to } 220\ \Omega$

The forward current (I_F) varies with changes in the supply voltage (V_{CC}), forward voltage (V_F), or resistance. Therefore, make sure that there is some margin between the absolute maximum ratings and the actual operating conditions of the Photomicrosensor.

Figure 5 Basic Circuit



The positions of the limiting resistor (R) and the LED in Figure 5 are interchangeable. If the LED is imposed with reverse voltages including noise and surge voltages, add a rectifier diode to the circuit as shown in Figure 6. LEDs can be driven by pulse voltages, the method of which is, however, rarely applied to Photomicrosensors.

In short, the following are important points required to operate any Photomicrosensor.

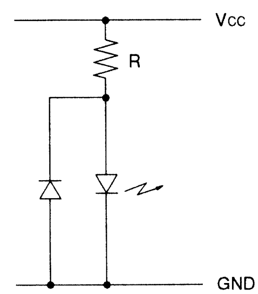
A forward voltage (V_F) of approximately 1.2 V is required if the Photomicrosensor has an infrared LED and a forward voltage (V_F) of approximately 2 V is required if the Photomicrosensor has a red LED.

The most ideal level of the forward current (I_F) must flow into the LED incorporated by the Photomicrosensor.

Decide the resistance of the limiting resistor connected to the LED after deciding the value of the forward current (I_F).

If the LED is imposed with a reverse voltage, connect a rectifier diode to the LED in parallel with and in the direction opposite to the direction of the LED.

Figure 6 Reverse Voltage Protection Circuit



■ Design of Systems Incorporating Photomicrosensors (1)

Phototransistor Output

Characteristics of Detector Element

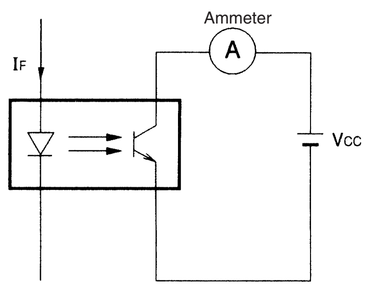
The changes in the current flow of the detector element with and without an optical input are important characteristics of a detector element. Figure 7 shows a circuit used to check how the current flow of the phototransistor incorporated by a Photomicrosensor is changed by the LED with or without an appropriate forward current (I_F) flow, provided that the ambient illumination of the Photomicrosensor is ideal (i.e., 0 ℓx). When there is no forward current (I_F) flowing into the LED or the optical beam emitted from the LED is intercepted by an opaque object, the ammeter indicates several nanoamperes due to a current leaking from the phototransistor. This current is called the dark current (I_D). When the forward current (I_F) flows into the LED with no object intercepting the optical beam emitted from the LED, the ammeter indicates several milliamperes. This current is called the light current (I_L).

The difference between the dark current and light current is 10^6 times larger as shown below.

- When optical beam to the phototransistor is interrupted
  Dark current I_D: 10^{-9} A
- When optical beam to the phototransistor is not interrupted
  Light current I_L: 10^{-3} A

The standard light current of a phototransistor is 10^6 times as large as the dark current of the phototransistor. This difference in current can be applied to the sensing of a variety of objects.

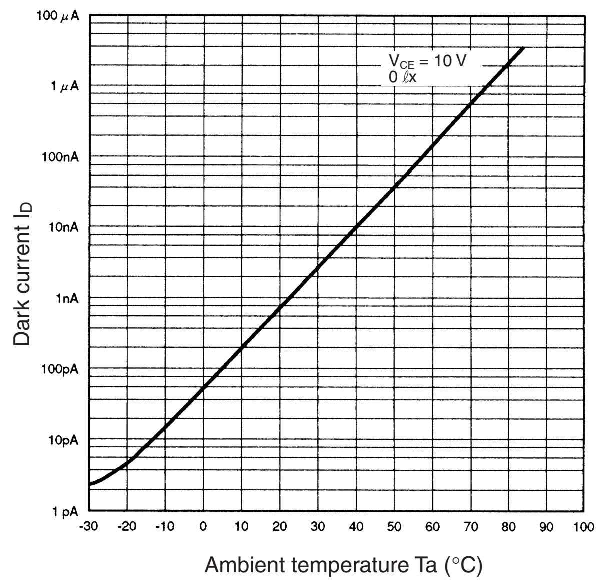
Figure 7 Measuring Circuit



The ambient illumination of the LED and phototransistor incorporated by the Photomicrosensor in actual operation is not 0 ℓx. Therefore, a current larger than the dark current of the phototransistor will flow into the phototransistor when the optical beam emitted from the LED is interrupted. This current is rather large and must not be ignored if the Photomicrosensor has a photoelectric Darlington transistor, which is highly sensitive, as the detector element of the Photomicrosensor. The dark current of the phototransistor incorporated by any reflective Photomicrosensor flows if there is no reflective object in the sensing area of the reflective Photomicrosensor. Furthermore, due to the structure of the reflective Photomicrosensor, a small portion of the optical beam emitted from the LED reaches the phototransistor after it is reflected inside the reflective Photomicrosensor. Therefore, the dark current and an additional current will flow into the phototransistor if there is no sensing object in the sensing area. This additional current is called leakage current (I_{LEAK}). The leakage current of the phototransistor is several hundred nanoamperes and the dark current of the phototransistor is several nanoamperes.

The dark current temperature and light current temperature dependencies of the phototransistor incorporated by any Photomicrosensor must not be ignored. The dark current temperature dependency of the phototransistor increases when the ambient temperature of the Photomicrosensor in operation is high or the Photomicrosensor has a photoelectric Darlington transistor as the detector element of the Photomicrosensor. Figure 8 shows the dark current temperature dependency of the phototransistor incorporated by the EE-SX1018.

Figure 8 Dark Current vs. Ambient Temperature Characteristics (Typical) (EE-SX1018)



Due to the temperature dependency of the phototransistor, the light current (I_L) of the phototransistor as the detector element of the Photomicrosensor increases according to a rise in the ambient temperature. As shown in Figure 9, however, the output of the LED decreases according to a rise in the ambient temperature due to the temperature dependency of the LED. An increase in the light current of the phototransistor is set off against a decrease in the output of the LED and consequently the change of the output of the Photomicrosensor according to the ambient temperature is comparatively small. Refer to Figure 10 for the light current temperature dependency of the phototransistor incorporated by the EE-SX1018.

The light current temperature dependency shown in Figure 10 is, however, a typical example. The tendency of the light current temperature dependency of each phototransistor is indefinite. This means the temperature compensation of any Photomicrosensor is difficult.

Figure 9 LED and Phototransistor Temperature Characteristics (Typical)

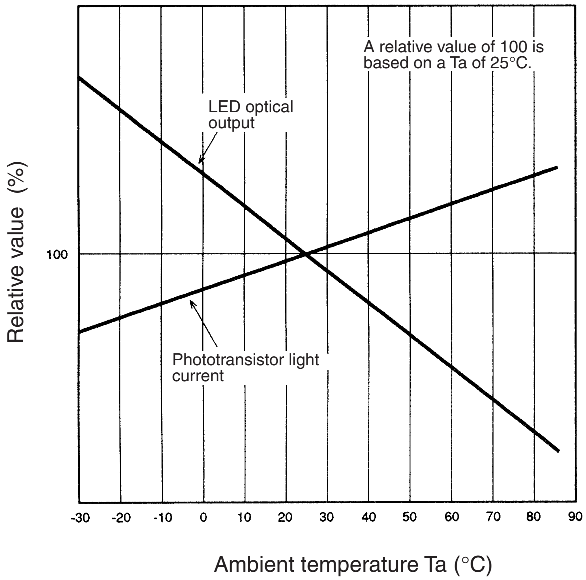
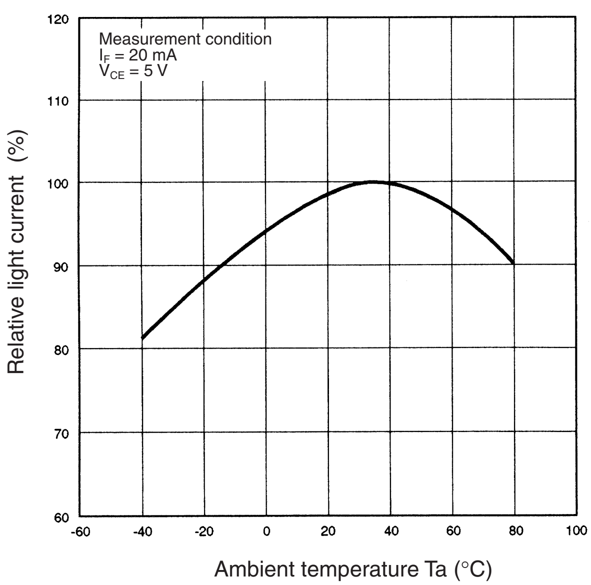


Figure 10 Relative Light Current vs. Ambient Temperature Characteristics (EE-SX1018)



Changes in Characteristics

The following explains the important points required for the designing of systems incorporating Photomicrosensors by considering worst case design technique. Worst case design technique is a method to design systems so that the Photomicrosensors will operate normally even if the characteristics of the Photomicrosensors are at their worst. A system incorporating any Photomicrosensor must be designed so that they will operate even if the light current (I_L) of the phototransistor is minimal and the dark current (I_D) and leakage current of the phototransistor are maximal. This means that the system must be designed so that it will operate even if the difference in the current flow of the phototransistor between the time that the Photomicrosensor senses an object and the time that the Photomicrosensor does not sense the object is minimal.

The worst light current (I_L) and dark current (I_D) values of the phototransistor incorporated by any Photomicrosensor is specified in the datasheet of the Photomicrosensor. (These values are specified in the specifications either as the minimum value or maximum value.)

Table 1 shows the dark current (I_D) upper limit and light current (I_L) lower limit values of the phototransistors incorporated by a variety of Photomicrosensors.

Systems must be designed by considering the dark current (I_D) upper limit and light current (I_L) lower limit values of the phototransistors. Not only these values but also the following factors must be taken into calculation to determine the upper limit of the dark current (I_D) of each of the phototransistors.

- External light interference
- Temperature rise
- Power supply voltage
- Leakage current caused by internal light reflection if the systems use reflective Photomicrosensors.

The above factors increase the dark current (I_D) of each phototransistor.

As for the light current (I_L) lower limit of each phototransistor, the following factors must be taken into calculation.

- Temperature change
- Secular change

The above factors decrease the light current (I_L) of each phototransistor.

Table 2 shows the increments of the dark current (I_D) and the decrements of the light current (I_D) of the phototransistors.

Therefore, if the EE-SX1018 is operated at a Ta of 60°C maximum and a V_{CC} of 10 V for approximately 50,000 hours, for example, the dark current (I_D) of the phototransistor incorporated by the EE-SX1018 will be approximately 4 µA and the light current (I_L) of the phototransistor will be approximately 1 mA because the dark current (I_D) of the phototransistor at a Ta of 25°C is 200 nanoamperes maximum and the light current (I_L) of the phototransistor at a Ta of 25°C is 2 mA minimum.

Table 3 shows the estimated worst values of a variety of Photomicrosensors, which must be considered when designing systems using these Photomicrosensors.

The dispersion of the characteristics of the Photomicrosensors must be also considered, which is explained in detail later. The light current (I_L) of the phototransistor incorporated by each reflective Photomicrosensor shown in its datasheet was measured under the standard conditions specified by OMRON for its reflective Photomicrosensors. The light current (I_L) of any reflective Photomicrosensor greatly varies with its sensing object and sensing distance.

Table 1. Rated Dark Current (I_D) and Light Current (I_L) Values

Model	Upper limit (I_D)	Lower limit (I_L)	Condition
EE-SG3(-B)	200 nA	2 mA	I_F = 15 mA
EE-SX1018, -SX1055 EE-SX1041, -SX1042 EE-SX1070, -SX1071 EE-SX198, -SX199	200 nA	0.5 mA	I_F = 20 mA
EE-SM3 EE-SM3B EE-SJ3W-B EE-SK3W-B	250 nA	1.5 mA	I_F = 3 mA
EE-SB5(-B) EE-SF5(-B) EE-SY110	200 nA	0.2 mA	I_F = 20 mA (see note)
EE-SY201	250 nA	0.3 mA	I_F = 5 mA (see note)
Condition	V_{CE} = 10 V, 0 ℓx Ta = 25°C	V_{CE} = 10 V Ta = 25°C	---

Note: These values were measured under the standard conditions specified by OMRON for the corresponding Photomicrosensors.

Table 2. Dependency of Detector Elements on Various Factors

Elements		Phototransistor	Photo-Darlington transistor
Dark current I_D	**External light interference**	To be checked using experiment	To be checked using experiment
	Temperature rise	Increased by approximately 10 times with a temperature rise of 25°C.	Increased by approximately 28 times with a temperature rise of 25°C.
	Supply voltage	See Figure 11.	See Figure 12.
Light current I_L	**Temperature change**	Approximately –20% to 10%	Approximately –20% to 10%
	Secular change (20,000 to 50,000 hours)	Decreased to approximately one-half of the initial value considering the temperature changes of the element.	Decreased to approximately one-half of the initial value considering the temperature changes of the element.

Figure 11 Dark Current Imposed Voltage Dependency (Typical) (EE-SX1018)

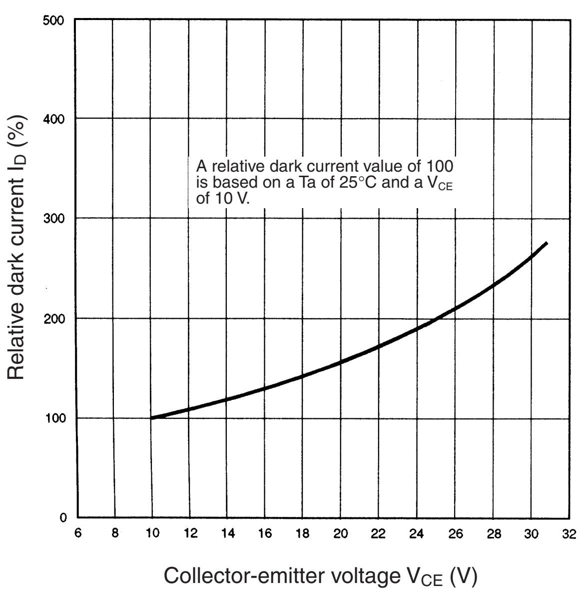


Figure 12 Dark Current Imposed Voltage Dependency (Typical) (EE-SM3B)

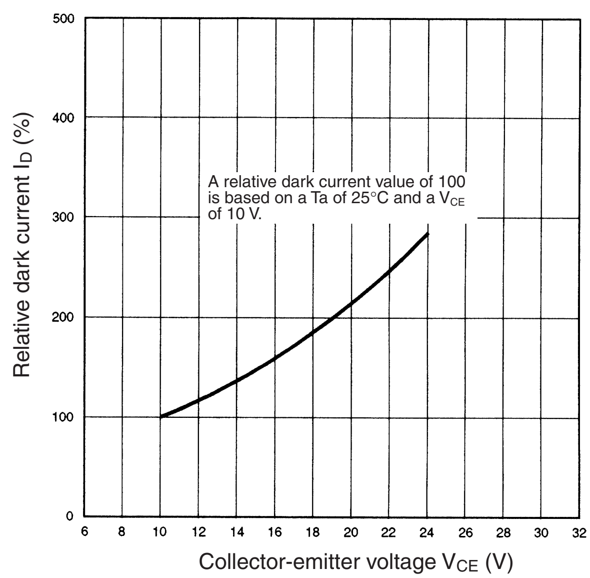


Table 3. Estimated Worst Values of a Variety of Photomicrosensors

Model	Estimated worst value (I_D)	Estimated worst value (I_L)	Condition
EE-SG3(-B)	4 nA	1 mA	I_F = 15 mA
EE-SX1018, -SX1055 EE-SX1041, -SX1042 EE-SX1070, -SX1071 EE-SX198, -SX199	4 nA	0.25 mA	I_F = 20 mA
EE-SM3 EE-SM3B EE-SJ3W-B EE-SK3W-B	25 nA	0.75 mA	I_F = 3 mA
EE-SB5(-B) EE-SF5(-B) EE-SY110	4 nA	0.1 mA	I_F = 20 mA (see note)
EE-SY201	25 nA	0.15 mA	I_F = 5 mA (see note)
Condition	V_{CE} = 10 V, 0 ℓx Ta = 60°C	V_{CE} = 10 V, Operating hours = 50,000 to 100,000 hrs Ta = Topr	---

Note: These values were measured under the standard conditions specified by OMRON for the corresponding Photomicrosensors with an Infrared LED.

Design of Basic Circuitry

The following explains the basic circuit incorporated by a typical Photomicrosensor and the important points required for the basic circuit.

The flowing currents (i.e., I_L and I_D) of the phototransistor incorporated by the Photomicrosensor must be processed to obtain the output of the Photomicrosensor. Refer to Figure 13 for the basic circuit. The light current (I_L) of the phototransistor will flow into the resistor (R_L) if the phototransistor receives an optical input and the dark current (I_D) and leakage current of the phototransistor will flow into the resistor (R_L) if the phototransistor does not receive any optical input. Therefore, if the phototransistor receives an optical input, the output voltage imposed on the resistor (R_L) will be obtained from the following.

IL x RL

If the phototransistor does not receive any optical input, the output voltage imposed on the resistor (R_L) will be obtained from the following.

(I_D + leakage current) x R_L

The output voltage of the phototransistor is obtained by simply connecting the resistor (R_L) to the phototransistor. For example, to obtain an output of 4 V minimum from the phototransistor when it is ON and an output of 1 V maximum when the phototransistor is OFF on condition that the light current (I_L) of the phototransistor is 1 mA and the leakage current of the phototransistor is 0.1 mA, and these are the worst light current and leakage current values of the phototransistor, the resistance of the resistor (R_L) must be approximately 4.7 kΩ. Then, an output of 4.7 V (i.e., 1 mA x 4.7 kΩ) will be obtained when the phototransistor is ON and an output of 0.47 V (i.e., 0.1 mA x 4.7 kΩ) will be obtained when the phototransistor is OFF. Practically, the output voltage of the phototransistor will be more than 4.7 V when the phototransistor is ON and less than 0.47 V when the phototransistor is OFF because the above voltage values are based on the worst light current and leakage current values of the phototransistor. The outputs obtained from the phototransistor are amplified and input to ICs to make practical use of the Photomicrosensor.

Figure 13 Basic Circuit

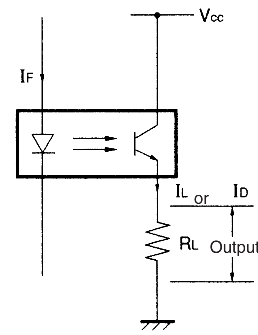
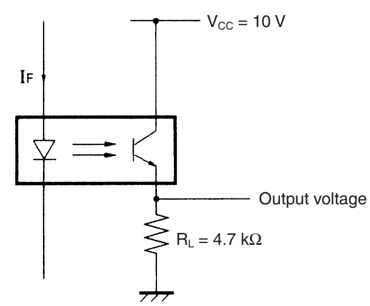


Figure 14 Output Example



Design of Applied Circuit

The following explains the designing of the applied circuit shown in Figure 15.

The light current (I_L) of the phototransistor flows into R_1 and R_2 when the phototransistor receives the optical beam emitted from the LED. Part of the light current (I_L) will flow into the base and emitter of Q_1 when the voltage imposed on R_2 exceeds the bias voltage (i.e., approximately 0.6 to 0.9 V) imposed between the base and emitter of the transistor (Q_1). The light current flowing into the base turns Q_1 ON. A current will flow into the collector of Q_1 through R_3 when Q_1 is ON. Then, the electric potential of the collector will drop to a low logic level. The dark current and leakage current of the phototransistor flow when the optical beam emitted from the LED is intercepted. The electric potential of the output of the phototransistor (i.e., (I_D + leakage current) x R_2) is, however, lower than the bias voltage between the base and emitter of Q_1. Therefore, no current will flow into the base of Q_1 and Q_1 will be OFF. The output of Q_1 will be at a high level. As shown in Figure 16, when the phototransistor is ON, the phototransistor will be seemingly short-circuited through the base and emitter of the Q_1, which is equivalent to a diode, and if the light current (I_L) of the phototransistor is large and R_1 is not connected to the phototransistor, the light current (I_L) will flow into Q_1 and the collector dissipation of the phototransistor will be excessively large.

The following items are important when designing the above applied circuit:

- The voltage output (i.e., I_L x R_2) of the phototransistor receiving the optical beam emitted from the LED must be much higher than the bias voltage between the base and emitter of Q_1.
- The voltage output (i.e., (I_D + leakage current) x R_2) of the phototransistor not receiving the optical beam emitted from the LED must be much lower than the bias voltage between the base and emitter of Q_1.

Therefore, it is important to determine the resistance of R_2. Figure 17 shows a practical applied circuit example using the EE-SX1018 Photomicrosensor at a supply voltage (V_{CC}) of 5V to drive a 74-series TTL IC. This applied circuit example uses R_1 and R_2 with appropriate resistance values.

Figure 15 Applied Circuit

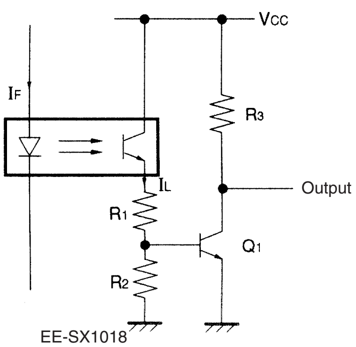


Figure 16 Equivalent Circuit

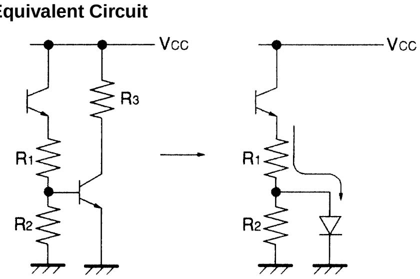
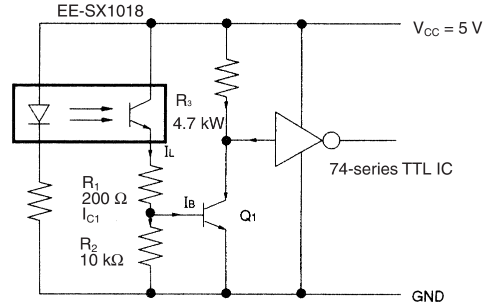


Figure 17 Applied Circuit Example



Calculation of R_2

The resistance of R_2 should be decided using the following so that the appropriate bias voltage (V_{BE}(ON)) between the base and emitter of the transistor (Q_1) to turn Q_1 ON will be obtained.

$$I_{C1} \times R_2 > V_{BE(ON)}$$
$$I_{C1} = I_L - I_B$$
$$\therefore (I_L - I_B) \text{ x } R_2 > V_{BE(ON)}$$

$$\therefore R_2 > \frac{V_{BE(ON)}}{I_L - I_B}$$

The bias voltage (V_{BE}(ON)) between the base and emitter of Q_1 is approximately 0.8 V and the base current (I_B) of Q_1 is approximately 20 µA if Q_1 is a standard transistor controlling small signals. The estimated worst value of the light current (I_L) of the phototransistor is 0.25 mA according to Table 3.

Therefore, the following is obtained.

$$R_2 > \frac{0.8 \text{ V}}{0.25 \text{ mA} - 20 \text{ mA}} = \text{approx. } 3.48 \text{ k}\Omega$$

R_2 must be larger than the above result. Therefore, the actual resistance of R_2 must be two to three times as large as the above result. In the above applied circuit example, the resistance of R_2 is 10 kΩ.

Verification of R_2 Value

The resistance of R_2 obtained from the above turns Q_1 ON. The following explains the way to confirm whether the resistance of R_2 obtained from the above can turns Q_1 OFF as well. The condition required to turn Q_1 OFF is obtained from the following.

$(I_D + \alpha) \text{ x } R_2 < V_{BE(OFF)}$

Substitute 10 kΩ for R_2, 4 µA for the dark current (I_D) according to Table 3, and 10 µA for the leakage current on the assumption that the leakage current is 10 µA in formula 3. The following is obtained.

$$(I_D + a) \times R_2 > V_{BE(ON)}$$
$$(4 \text{ µA} + 10 \text{ µA}) \times 10 \text{ k}\Omega = 0.140 \text{ V}$$
$$V_{BE(OFF)} = 0.4 \text{ V}$$
$$\therefore 0.140 \text{ V} < 0.4 \text{ V}$$

The above result verifies that the resistance of R_2 satisfies the condition required to turn Q_1 OFF.

If the appropriateness of the resistance of R_2 has been verified, the design of the circuit is almost complete.

R_1

As shown in Figure 16, when the phototransistor is ON, the phototransistor will be seemingly short-circuited through the base and emitter of the Q_1, and if the light current (I_L) of the phototransistor is large and R_1 is not connected to the phototransistor, the light current will flow into Q_1 and the collector dissipation of the phototransistor will be excessively large. The resistance of R_1 depends on the maximum permissible collector dissipation (P_C) of the phototransistor, which can be obtained from the datasheet of the Photomicrosensor. The resistance of R_1 of a phototransistor is several hundred ohms. In the above applied circuit example, the resistance of R_1 is 200 Ω.

If the resistance of R_1 is determined, the design of the circuit is complete.

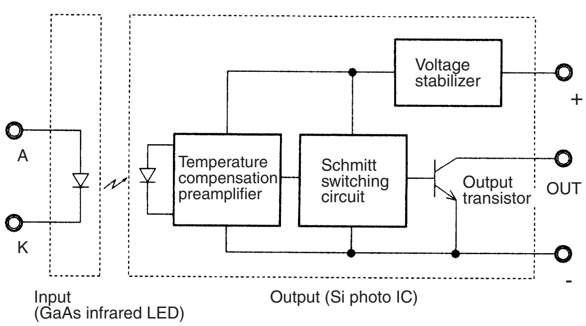
It is important to connect a transistor to the phototransistor incorporated by the Photomicrosensor to amplify the output of the phototransistor, which increases the reliability and stability of the Photomicrosensor. Such reliability and stability of the Photomicrosensor cannot be achieved if the output of the phototransistor is not amplified. The response speed and other performance characteristics of the circuit shown in Figure 15 are far superior to those of the circuit shown in Figure 13 because the apparent impedance (i.e., load resistance) of the Photomicrosensor is determined by R_1, the resistance of which is comparatively small. Recently, Photomicrosensors that have photo IC amplifier circuits are increasing in number because they are easy to use and make it possible to design systems using Photomicrosensors without problem.

■ Design of Systems Incorporating Photomicrosensors (2)

Photo IC Output

Figure 18 shows the circuit configuration of the EE-SX301 or EE-SX401 Photomicrosensor incorporating a photo IC output circuit. The following explains the structure of a typical Photomicrosensor with a photo IC output circuit.

Figure 18 Circuit Configuration



LED Forward Current (I_F) Supply Circuit

The LED in the above circuitry is an independent component, to which an appropriate current must be supplied from an external power supply. This is the most important item required by the Photomicrosensor.

It is necessary to determine the appropriate forward current (I_F) of the LED that turns the photo IC ON. If the appropriate forward current is determined, the Photomicrosensor can be easily used by simply supplying power to the detector circuitry (i.e., the photo IC). Refer to the datasheet of the Photomicrosensor to find the current of the LED turning the photo IC ON. Table 4 is an extract of the datasheet of the EE-SX301/EE-SX401.

Table 4. Abstract of Characteristics

Item	Symbol	EE-SX301, -SX401	
		Value	Condition
LED current when output is turned OFF (EE-SX301)	I_{FTOFF}	8 mA max.	V_{CC} = 4.5 to 16 V Ta = 25°C
LED current when output is turned ON (EE-SX401)	I_{FTON}		

To design systems incorporating EE-SX301 or EE-SX401 Photomicrosensors, the following are important points.

- A forward current equivalent to or exceeding the I_{FTOFF} value must flow into the LED incorporated by each EE-SX301 Photomicrosensors.
- A forward current equivalent to or exceeding the I_{FTON} value must flow into the LED incorporated by the EE-SX401 Photomicrosensors.

The I_{FTON} value of the EE-SX301 is 8 mA maximum and so is the I_{FON} value of the EE-SX401. The forward current (I_F) of LED incorporated by the EE-SX301 in actual operation must be 8 mA or more and so must the actual forward current of (I_F) the LED incorporated by the EE-SX401 in actual operation. The actual forward currents of the LEDs incorporated by the EE-SX301 and EE-SX401 are limited by their absolute maximum forward currents respectively. The upper limit of the actual forward current of the LED incorporated by the EE-SX301 and that of the LED incorporated by the EE-SX401 must be decided according Figure 19, which shows the temperature characteristics of the EE-SX301 and EE-SX401. The forward current (I_F) of the EE-SX301 must be as large as possible within the absolute maximum forward current and maximum ambient temperature shown in Figure 19 and so must be the forward current (I_F) of the EE-SX401. The forward current (I_F) of the EE-SX301 or that of the EE-SX401 must not be close to 8 mA, otherwise the photo IC of the EE-SX301 or that of the EE-SX401 may not operate if there is any ambient temperature change, secular change that reduces the optical output of the LED, or dust sticking to the LED. The forward current (I_F) values of the EE-SX301 and the EE-SX401 in actual operation must be twice as large as the I_{FOFF} values of the EE-SX301 and EE-SX401 respectively. Figure 20 shows the basic circuit of a typical Photomicrosensor with a photo IC output circuit.

If the Photomicrosensor with a photo IC output circuit is used to drive a relay, be sure to connect a reverse voltage absorption diode (D) to the relay in parallel as shown in Figure 21.

Detector Circuit

Supply a voltage within the absolute maximum supply voltage to the positive and negative terminals of the photo IC circuit shown in Figure 18 and obtain a current within the I_{OUT} value of the output transistor incorporated by the photo IC circuit.

Figure 19 Forward Current vs. Ambient Temperature Characteristics (EE-SX301/-SX401)

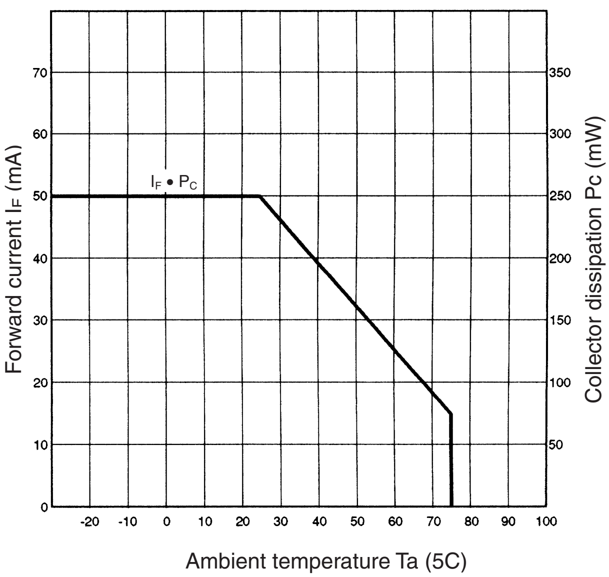


Figure 20 Basic Circuit

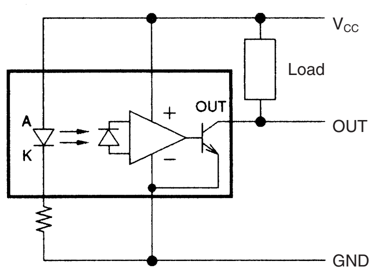
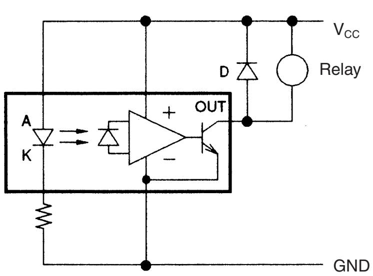


Figure 21 Connected to Inductive Load



Precautions

The following provides the instructions required for the operation of Photomicrosensors.

■ Transmissive Photomicrosensor Incorporating Phototransistor Output Circuit

When using a transmissive Photomicrosensor to sense the following objects, make sure that the transmissive Photomicrosensor operates properly.

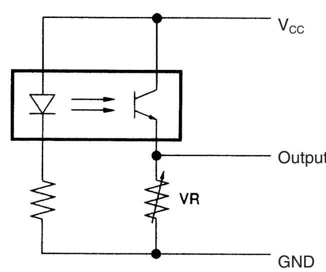
- Highly permeable objects such as paper, film, and plastic
- Objects smaller than the size of the optical beam emitted by the LED or the size of the aperture of the detector.

The above objects do not fully intercept the optical beam emitted by the LED. Therefore, some part of the optical beam, which is considered noise, reaches the detector and a current flows from the phototransistor incorporated by the detector. Before sensing such type of objects, it is necessary to measure the light currents of the phototransistor with and without an object to make sure that the transmissive Photomicrosensor can sense objects without being interfered by noise. If the light current of the phototransistor sensing any one of the objects is $I_L(N)$ and that of the phototransistor sensing none of the objects is $I_L(S)$, the signal-noise ratio of the phototransistor due to the object is obtained from the following.

$$S/N = I_L(S)/I_L(N)$$

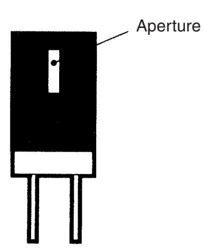
The light current (I_L) of the phototransistor varies with the ambient temperature and secular changes. Therefore, if the signal-noise ratio of the phototransistor is 4 maximum, it is necessary to pay utmost attention to the circuit connected to the transmissive Photomicrosensor so that the transmissive Photomicrosensor can sense the object without problem. The light currents of phototransistors are different to one another. Therefore, when multiple transmissive Photomicrosensors are required, a variable resistor must be connected to each transmissive Photomicrosensor as shown in Figure 22 if the light currents of the phototransistors greatly differ from one another.

Figure 22 Sensitivity Adjustment



The optical beam of the emitter and the aperture of the detector must be as narrow as possible. An aperture each can be attached to the emitter and detector to make the optical beam of the emitter and the aperture of the detector narrower. If apertures are attached to both the emitter and detector, however, the light current (I_L) of the phototransistor incorporated by the detector will decrease. It is desirable to attach apertures to both the emitter and detector. If an aperture is attached to the detector only, the transmissive Photomicrosensor will have trouble sensing the above objects when they pass near the emitter.

Figure 23 Aperture Example



When using the transmissive Photomicrosensor to sense any object that vibrates, moves slowly, or has highly reflective edges, make sure to connect a proper circuit which processes the output of the transmissive Photomicrosensor so that the transmissive Photomicrosensor can operate properly, otherwise the transmissive Photomicrosensor may have a chattering output signal as shown in Figure 24. If this signal is input to a counter, the counter will have a counting error or operate improperly. To protect against this, connect a 0.01- to 0.02-µF capacitor to the circuit as shown in Figure 25 or connect a Schmitt trigger circuit to the circuit as shown in Figure 26.

Figure 24 Chattering Output Signal

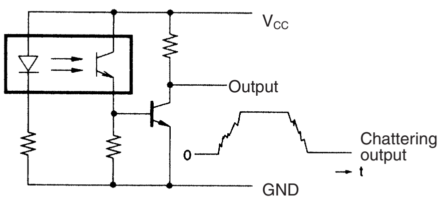


Figure 25 Chattering Prevention (1)

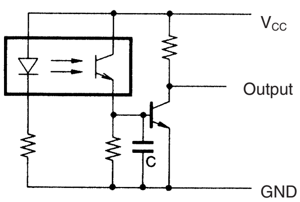
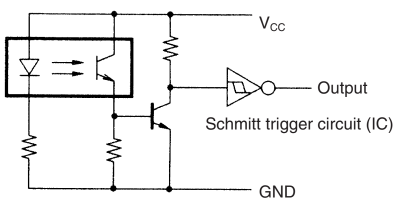


Figure 26 Chattering Prevention (2)



■ Reflective Photomicrosensor Incorporating Phototransistor Output Circuit

When using a reflective Photomicrosensor to sense objects, pay attention to the following so that the reflective Photomicrosensor operates properly.

- External light interference
- Background condition of sensing objects
- Output level of the LED

The reflective Photomicrosensor incorporates a detector element in the direction shown in Figure 27. Therefore, it is apt to be affected by external light interference. The reflective Photomicrosensor, therefore, incorporates a filter to intercept any light, the wavelength of which is shorter than a certain wavelength, to prevent external light interference. The filter does not, however, perfectly intercept the light. Refer to Figure 28 for the light interception characteristics of filters. A location with minimal external light interference is best suited for the reflective Photomicrosensor.

Figure 27 Configuration of Reflective Photomicrosensor

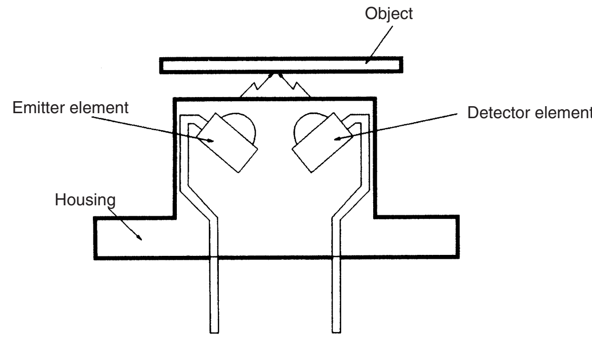


Figure 28 Light Interception Characteristics of Filters

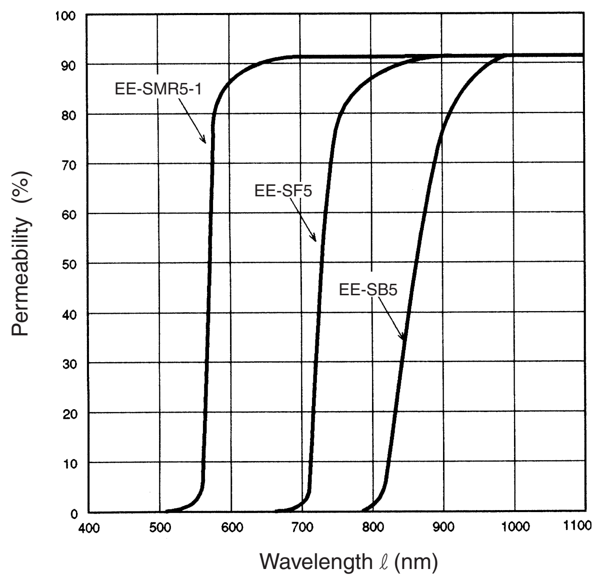
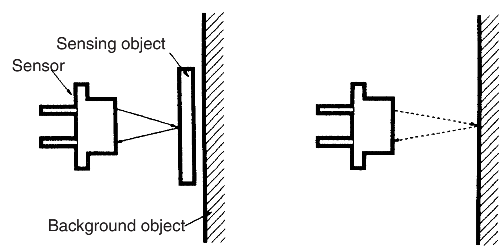


Figure 29 Influence of Background Object



With regard to the background conditions, the following description is based on the assumption that the background is totally dark.

Figure 29 shows that the optical beam emitted from the LED incorporated by a reflective Photomicrosensor is reflected by a sensing object and background object. The optical beam reflected by the background object and received by the phototransistor incorporated by the detector is considered noise that lowers the signal-noise ratio of the phototransistor. If any reflective Photomicrosensor is used to sense paper passing through the sensing area of the reflective Photomicrosensor on condition that there is a stainless steel or zinc-plated object behind the paper, the light current (I_L(N)) of the phototransistor not sensing the paper may be larger than the light current (I_L(S)) of phototransistor sensing the paper, in which case remove the background object, make a hole larger than the area of the sensor surface in the background object as shown in Figure 30, coat the surface of the background object with black lusterless paint, or roughen the surface of the background. Most malfunctions of a reflective Photomicrosensor are caused by an object located behind the sensing objects of the reflective Photomicrosensor.

Unlike the output (i.e., I_L) of any transmissive Photomicrosensor, the light current (I_L) of a reflective Photomicrosensor greatly varies according to sensing object type, sensing distance, and sensing object size.

Figure 30 Example of Countermeasure

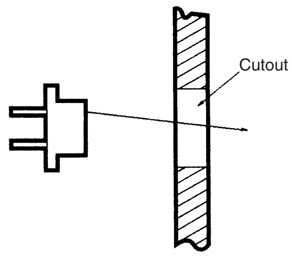
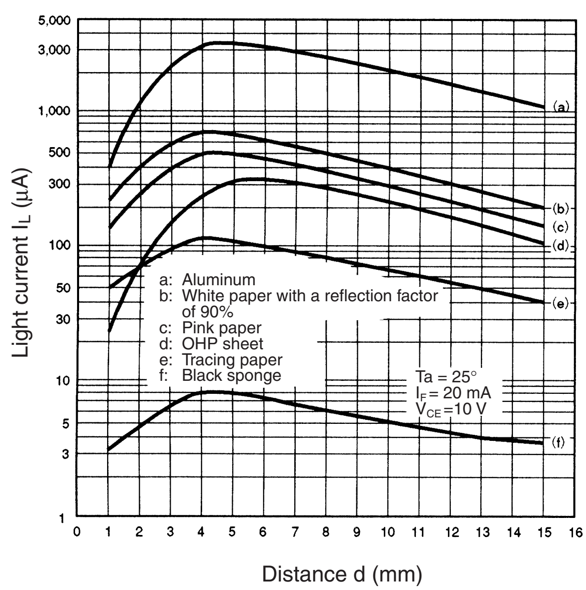


Figure 31 Sensing Distance Characteristics (EE-SF5)



The light current (I_L) of the phototransistor incorporated by the transmissive Photomicrosensor is output when there is no sensing object in the sensing groove of the transmissive Photomicrosensor. On the other hand, the light current (I_L) of the phototransistor incorporated by the reflective Photomicrosensor is output when there is a standard object specified by OMRON located in the standard sensing distance of the reflective Photomicrosensor. The light current (I_L) of the phototransistor incorporated by the reflective Photomicrosensor varies when the reflective Photomicrosensor senses any other type of sensing object located at a sensing distance other than the standard sensing distance. Figure 31 shows how the output of the phototransistor incorporated by the EE-SF5(-B) varies according to varieties of sensing objects and sensing distances. Before using the EE-SF5(-B) to sense any other type of sensing objects, measure the light currents of the phototransistor in actual operation with and without one of the sensing objects as shown in Figure 32. After measuring the light currents, calculate the signal-noise ratio of the EE-SF5(-B) due to the sensing object to make sure if the sensing objects can be sensed smoothly. The light current of the reflective Photomicrosensor is, however, several tens to hundreds of microamperes. This means that the absolute signal levels of the reflective Photomicrosensor are low. Even if the reflective Photomicrosensor in operation is not interfered by external light, the dark current (I_D) and leakage current (I_{LEAK}) of the reflective Photomicrosensor, which are considered noise, may amount to several to ten-odd microamperes due to a rise in the ambient temperature. This noise cannot be ignored. As a result, the signal-noise ratio of the reflective Photomicrosensor will be extremely low if the reflective Photomicrosensor senses any object with a low reflection ratio.

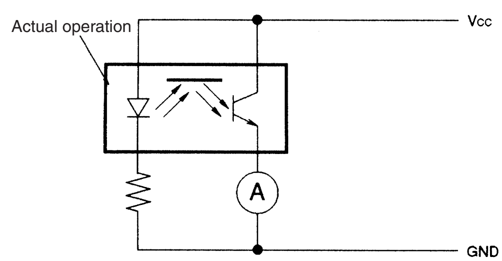
Pay utmost attention when applying the reflective Photomicrosensor to the sensing of the following.

- Marked objects (e.g., White objects with a black mark each)
- Minute objects

The above objects can be sensed if the signal-noise ratio of the reflective Photomicrosensor is not too low.

The reflective Photomicrosensor must be used with great care, otherwise it will not operate properly.

Figure 32 Output Current Measurement



Precautions

■ Correct Use

- Use the product within the rated voltage range.
  Applying voltages beyond the rated voltage ranges may result in damage or malfunction to the product.
- Wire the product correctly and be careful with the power supply polarities.
  Incorrect wiring may result in damage or malfunction to the product.
- Connect the loads to the power supply. Do not short-circuit the loads.
  Short-circuiting the loads may result in damage or malfunction to the product.

■ Structure and Materials

The emitter and detector elements of conventional Photomicrosensors are fixed with transparent epoxy resin and the main bodies are made of polycarbonate. Unlike ICs and transistors, which are covered with black epoxy resin, Photomicrosensors are subject to the following restrictions.

- Low Heat Resistivity
  The storage temperature of standard ICs and transistors is approximately 150°C. The storage temperature of highly resistant Photomicrosensors is 100°C maximum. The heat resistance of the EE-SY169 Series or the EE-SY201/202, which use ABS resin in the case, is particularly low (80°C maximum).
- Low Mechanical Strength
  Black epoxy resin, which is used for the main bodies of ICs and transistors, contains additive agents including glass fiber to increase the heat resistivity and mechanical strength of the main bodies. Materials with additive agents cannot be used for the bodies of Photomicrosensors because Photomicrosensors must maintain good optical permeability. Unlike ICs and transistors, Photomicrosensors must be handled with utmost care because Photomicrosensors are not as heat or mechanically resistant as ICs and transistors. No excessive force must be imposed on the lead wires of Photomicrosensors.

■ Mounting

Screw Mounting

If Photomicrosensors have screw mounting holes, the Photomicrosensors can be mounted with screws. Unless otherwise specified, refer to the following when tighten the screws

Hole diameter	Screw size	Tightening torque
1.5 dia.	M1.4	0.20 N • m
2.1 dia.	M2	0.34 N • m
3.2 dia.	M3	0.54 N • m
4.2 dia.	M4	0.54 N • m

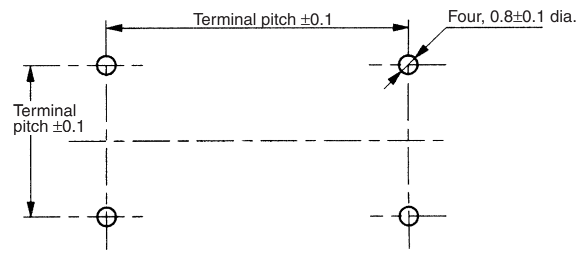
Read the following before tightening the screws.

- The use of a torque screwdriver is recommended to tighten each of the screws so that the screws can be tightened to the tightening torque required.
- The use of a screw with a spring washer and flat washer for the mounting holes of a Photomicrosensor is recommended. If a screw with a spring washer but without a flat washer is used for any mounting hole, the part around the mounting hole may crack.
- Do not mount Photomicrosensors to plates stained with machining oil, otherwise the machining oil may cause cracks on the Photomicrosensors.
- Do not impose excessive forces on Photomicrosensors mounted to PCBs. Make sure that no continuous or instantaneous external force exceeding 500 g (4.9 N) is imposed on any lead wire of the Photomicrosensors.

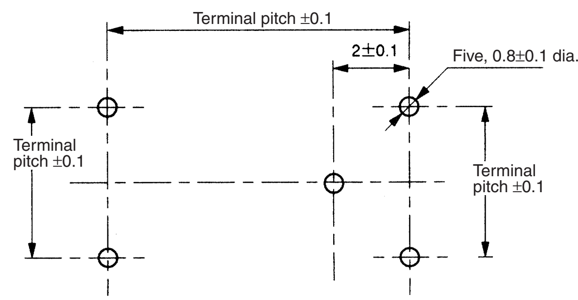
PCB Mounting Holes

Unless otherwise specified, the PCB to which a Photomicrosensor is mounted must have the following mounting holes.

Four Terminals



Five Terminals



■ Soldering

Lead Wires

Make sure to solder the lead wires of Photomicrosensors so that no excessive force will be imposed on the lead wires. If an excessive forces is likely to be imposed on the lead wires, hold the bases of the lead wires.

Soldering Temperature

Regardless of the device being soldered, soldering should be completed quickly so that the devices are not subjected to thermal stress. Care is also required in the processing environment for processes other than soldering so that the devices are not subject to thermal stress or other external force.

Manual Soldering

Unless otherwise specified, the lead wires of Photomicrosensors can be soldered manually under the following conditions.
These conditions must also be maintained when using lead-free solder, i.e., soldering with lead-free solder is possible as long as the following conditions are maintained.

Soldering temperature:	350°C max. (The temperature of the tip of a 30-W soldering iron is approximately 320°C when the soldering iron is heated up.)
Soldering time:	3 s max.
Soldering position:	At least 1.5 mm away from the bases of the lead wires.

The temperature of the tip of any soldering iron depends on the shape of the tip. Check the temperature with a thermometer before soldering the lead wires. A highly resistive soldering iron incorporating a ceramic heater is recommended for soldering the lead wires.

Dip Soldering

The lead wires of Photomicrosensors can be dip-soldered under the following conditions unless otherwise specified.

Preheating temperature:	Must not exceed the storage temperature of the Photomicrosensors.
Soldering temperature:	260°C max. (the lead wires)
Soldering time:	10 s max.
Soldering position:	At least 0.3 mm away from the bases of the housing.

The soldering temperature is specified as the temperature applied to the lead terminals. Do not subject the cases to temperatures higher than the maximum storage temperature. It is also possible for the sensor case to melt due to residual heat of the PCB. When using a PCB with a high thermal capacity (e.g., those using fiber-glass reinforced epoxy substrates), confirm that the case is not deformed and install cooling devices as required to prevent distortion. Particular care is required for the EE-SY169 Series or the EE-SY201/202, which use ABS resin in the case.

Do not use non-washable flux when soldering EE-SA-series Photomicrosensors, otherwise the Photomicrosensors will have operational problems. For other Photomicrosensors, check the case materials and optical characteristics carefully to be sure that residual flux does not adversely affect them.

Reflow Soldering

The reflow soldering of Photomicrosensors is not possible except for the EE-SX1107, -SX1108, -SX1109, -SX1131, -SX4134, EE-SY125 and EE-SY193. The reflow soldering of these products must be performed carefully under the conditions specified in the datasheets of these products, respectively. Before performing the reflow soldering of these products, make sure that the reflow soldering equipment satisfies the conditions.

Compared to general ICs, optical devices have a lower resistance to heat. This means the reflow temperature must be set to a lower temperature. Observe the temperature provides provided in the specifications when mounting optical devices.

External Forces Immediately Following Soldering

The heat resistance and mechanical strength of Photomicrosensors are lower than those of ICs or transistors due to their physical properties. Care must thus be exercised immediately after soldering (particularly for dip soldering) so that external forces are not applied to the Photomicrosensors.

External Forces

The heat resistivity and mechanical strength of Photomicrosensors are lower than those of ICs or transistors. Do not to impose external force on Photomicrosensors immediately after the Photomicrosensors are soldered. Especially, do not impose external force on Photomicrosensors immediately after the Photomicrosensors are dip-soldered.

■ Cleaning Precautions

Cleaning

Photomicrosensors except the EE-SA105 and EE-SA113 can be cleaned subject to the following restrictions.

Types of Detergent

Polycarbonate is used for the bodies of most Photomicrosensors. Some types of detergent dissolve or crack polycarbonate. Before cleaning Photomicrosensors, refer to the following results of experiments, which indicate what types of detergent are suitable for cleaning Photomicrosensors other than the EE-SA105 and EE-SA113.

Observe the law and prevent against any environmental damage when using any detergent.

Results of Experiments

Ethyl alcohol:	OK
Methyl alcohol:	OK
Isopropyl alcohol:	OK
Trichlene:	NG
Acetone:	NG
Methylbenzene:	NG
Water (hot water):	The lead wires corrode depending on the conditions

Cleaning Method

Unless otherwise specified, Photomicrosensors other than the EE-SA105 and EE-SA113 can be cleaned under the following conditions. Do not apply an unclean detergent to the Photomicrosensors.

DIP cleaning:	OK
Ultrasonic cleaning:	Depends on the equipment and the PCB size. Before cleaning Photomicrosensors, conduct a cleaning test with a single Photomicrosensor and make sure that the Photomicrosensor has no broken lead wires after the Photomicrosensor is cleaned.
Brushing:	The marks on Photomicrosensors may be brushed off. The emitters and detectors of reflective Photomicrosensors may have scratches and deteriorate when they are brushed. Before brushing Photomicrosensors, conduct a brushing test with a single Photomicrosensor and make sure that the Photomicrosensor is not damaged after it is brushed.

■ Operating and Storage Temperatures

Observe the upper and lower limits of the operating and storage temperature ranges for all devices and do not allow excessive changes in temperature. As explained in the restrictions given in *Structure and Materials*, elements use clear epoxy resin, giving them less resistance to thermal stress than normal ICs or transistors (which are sealed with black epoxy resin). Refer to reliability test results and design PCBs so that the devices are not subjected to excessive thermal stress.

Even for applications within the operating temperature range, care must also be taken to control the humidity. As explained in the restrictions given in *Structure and Materials*, elements use clear epoxy resin, giving them less resistance to humidity than normal ICs or transistors (which are sealed with black epoxy resin). Refer to reliability test results and design PCBs so that the devices are not subjected to excessive thermal stress. Photomicrosensors are designed for application under normal humidities. When using them in humidified or dehumidified, high-humidity or low-humidity, environments, test performance sufficiently for the application.

LED Drive Currents

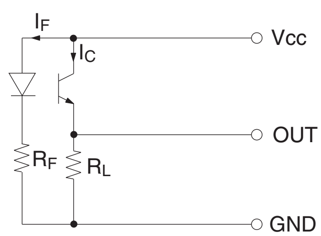
Photomicrosensors consist of LEDs and light detectors. Generally speaking, temporal changes occur to LEDs when power is supplied to them (i.e., the amount of light emitted diminishes). With less light, the photoelectric current is reduced for a sensor with a phototransistor output or the threshold current is increased for a sensor with a photo-IC output. Design circuits with sufficient consideration to the decline in the emitted light level. The reduction in emitted light is far greater for red LEDs than for infrared LEDs. Also, with red LEDs that contain aluminum, aluminum oxide will form if they are powered under high humidities, calling for a greater need for consideration of the decline in the emitted light level.

Light Interceptors

Select a material for the light interceptor with superior interception properties. If a material with inferior light interception properties, such as a plastic that is not black, is used, light may penetrate the interceptor and cause malfunction. With Photomicrosensors, most of which use infrared LEDs, a material that appears black to the human eye (i.e., in the visible light range) may be transparent to infrared light. Select materials carefully.

Guideline for Light Interceptors

When measuring the light interception properties of the light interceptor, use 0.1% maximum light transmission as a guideline.



Criteria

Where,

I_{L1} is the I_L for light reception
I_{L2} is the I_L for light interception by the intercepter
V_{TH} is the threshold voltage
I_{F1} is the I_F for measurement of I_L given in product specifications
I_{F2} is the I_F in actual application (= $(V_{CC} - V_F)/R_F = (V_{CC} - 1.2)/R_F$)
I_{LMAX} is the standard upper limit of the optical current I_L

Then,

Light transmission = $I_{L2}/I_{L1} = \alpha$

Here there should be no problems if the following equation is satisfied.

$V_{TH} \geq (I_{F2}/I_{F1}) \times I_{LMAX} \times R_L \times \alpha$

Caution is required, however, because there are inconsistencies in light transmission.

Reflectors

The reflectors for most Photomicrosensors are standardized to white paper with a reflection ratio of 90%. Design the system to allow for any differences in the reflection ratio of the detection object. With Photomicrosensors, most of which use infrared LEDs, a material that appears black to the human eye (i.e., in the visible light range) may have a higher reflection ratio. Select materials carefully. Concretely, marks made with dye-based inks or marks made with petroleum-based magic markers (felt pens) can have the same reflection ratio for infrared light as white paper.

The reflectors for most Photomicrosensors are standardized to white paper with a reflection ratio of 90%. Paper, however, disperses light relatively easily, reducing the effect of the detection angle. Materials with mirrored surfaces, on the other hand, show abrupt changes in angle characteristics. Check the reflection ratio and angles sufficiently for the application.

The output from most Photomicrosensors is determined at a specified distance. Characteristics will vary with the distance. Carefully check characteristics at the specific distance for the application.

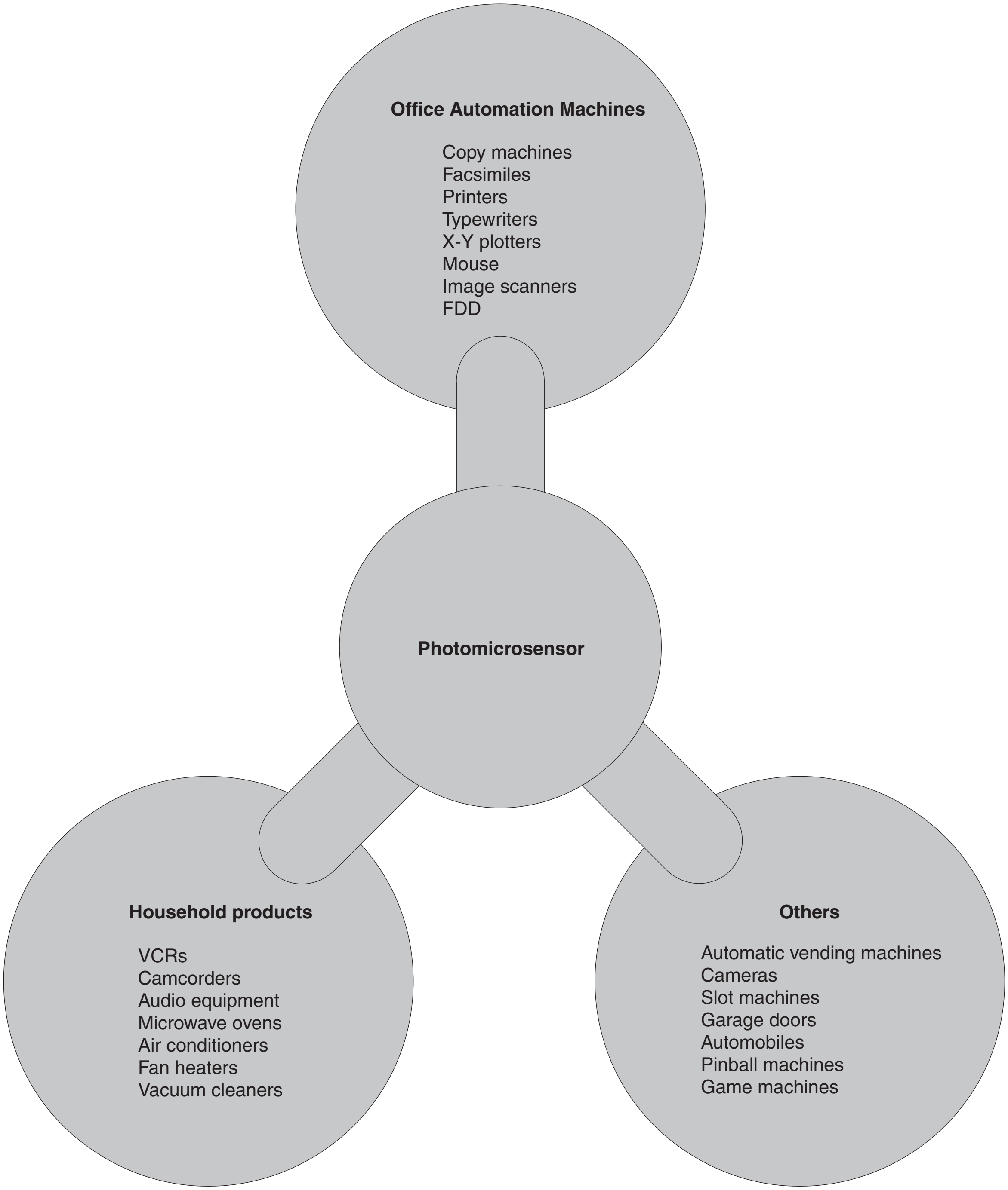
Output Stabilization Time

Photomicrosensors with photo-IC outputs require 100 ms for the internal IC to stabilize. Set the system so that the output is not read for 100 ms after the power supply is turned ON. Also be careful if the power supply is turned OFF in the application to save energy when the Photomicrosensor is not used.

When using a Photomicrosensor with a phototransistor output outside of the saturation region, stabilization time is required to achieve thermal balance. Care is required when using a variable resistor or other adjustment.

Application Examples

Most People May Not Realize the Fact that Photomicrosensors are Built Into Machines and Equipment that are Used Everyday



■ Application Examples

Classification	Products	Sensing example
Household products	VCRs	Rotating reel sensing and tape sensing
	Camcorders	Lens origin sensing and lens control
	Laserdisc players	Rotation sensing and disk size sensing
	Air conditioners/Fan heaters	Louver direction sensing and fan motor rotation sensing
	Microwave ovens	Turntable sensing
	Vacuum cleaners	Carpet and floor discrimination
Office automation machines	Printers/Typewriters	Origin sensing, paper sensing, paper size sensing, and ink ribbon end sensing
	Copy machines	Paper sensing, cassette sensing, and toner sensing
	Facsimiles	Paper sensing, black end mark sensing, paper size sensing
	Floppy disk drives	Disk sensing, origin sensing, and write protect sensing
	Optical disk drives	Disk sensing, disk type sensing, and write protection sensing
	Image scanners	Origin sensing and movement value sensing
	Mouse	Movement direction sensing and movement value sensing
	X-Y plotters	Paper sensing, origin sensing, pen sensing, and movement value sensing
Others	Automatic vending machines/Ticket machines	Coin sensing, coin discrimination, and ticket sensing
	Automobiles/Motorcycles	Speed sensing, steering sensing, and speed alarm control
	Cameras	Film forwarding, lens control, and motor control
	Cash dispensers	Card sensing, bill sensing, mechanical control
	Robot/Machine tools	Mechanical control
	Sewing machines	Motor rotation sensing and needle position sensing
	Pinball machines	Ball sensing, mechanical control, and sensing of remaining balls
	Slot machines	Coil sensing and lever sensing
	Game machines	Prize sensing, coil sensing, and mechanical control
	Garage doors	Door opening and closing sensing

Product Quality Control and Reliability

■ Product Quality Control

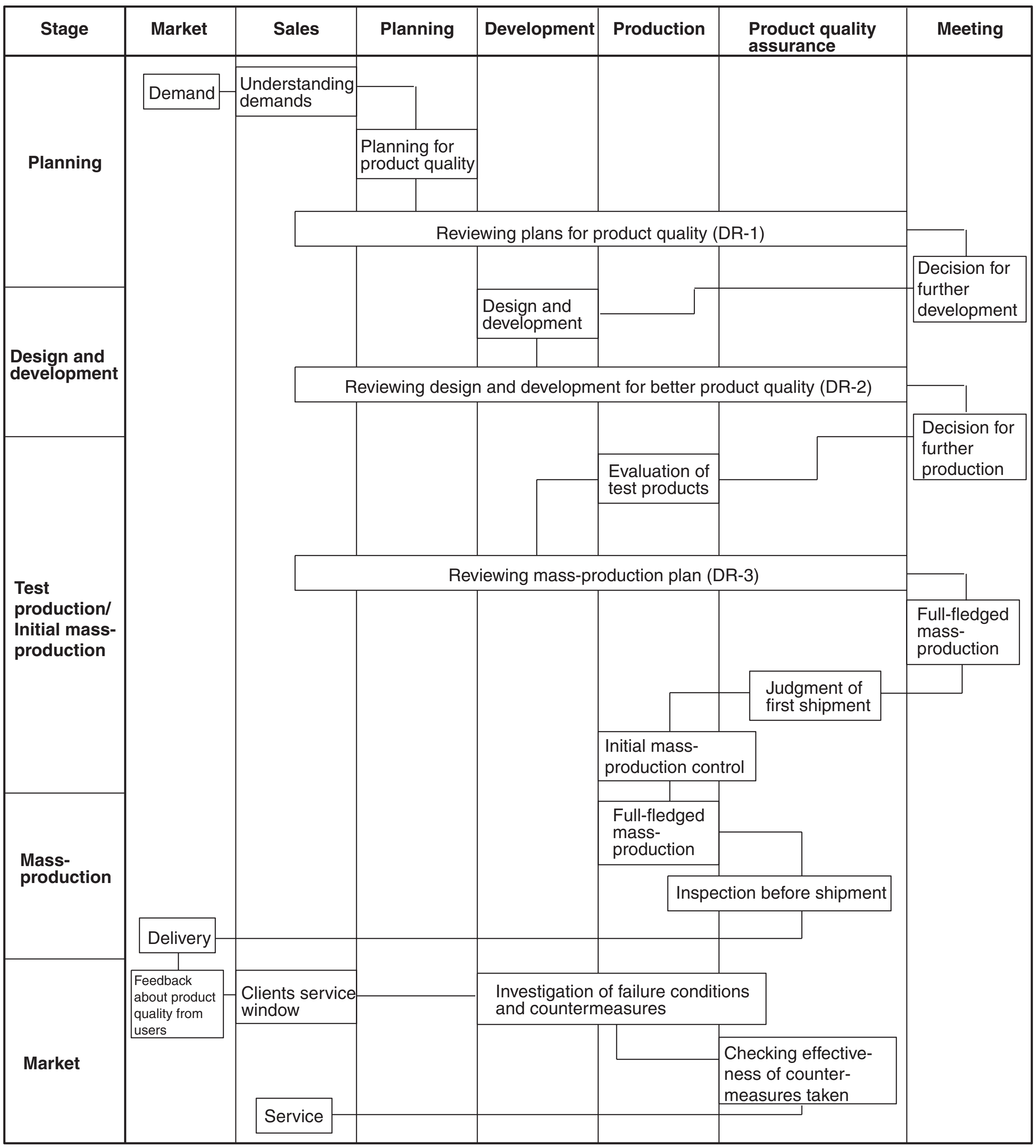
Basic Policy of Product Quality Control

OMRON has been attaching great importance to quality control of its products, with the view of making a contribution to society by producing high-quality products. The table below shows the contents of OMRON's quality control system including marketing surveys and quality control activities conducted by OMRON's various departments so that the products can be shipped in good condition.

The first step to product quality control is to reflect in the development of OMRON's products the users' demands for product quality. After setting the target, we aim at producing the products that are consistently high in quality and can meet the standards that we set. OMRON's basic concept is that each process of production is equally important as it plays an important role in product quality control.

To ensure the quality of OMRON's products in the product quality control system, we carry out various tests such as design check, process control, pre-shipment, and reliability tests.

Figure 33 Product Quality Control Scheme



Quality Control of Products Being Developed

The first step to product quality control is to reflect in the development of OMRON's products the users' demands for product quality. OMRON's DR (design review) system was made to achieve this before OMRON starts the mass production of any product. The DR system enables OMRON's engineers to review the quality of products during the planning, design and development, and initial mass-production stages to solve any quality problems and to maintain excellent product quality. Refer to the following for the steps of the DR system and the purposes of the steps.

Figure 34

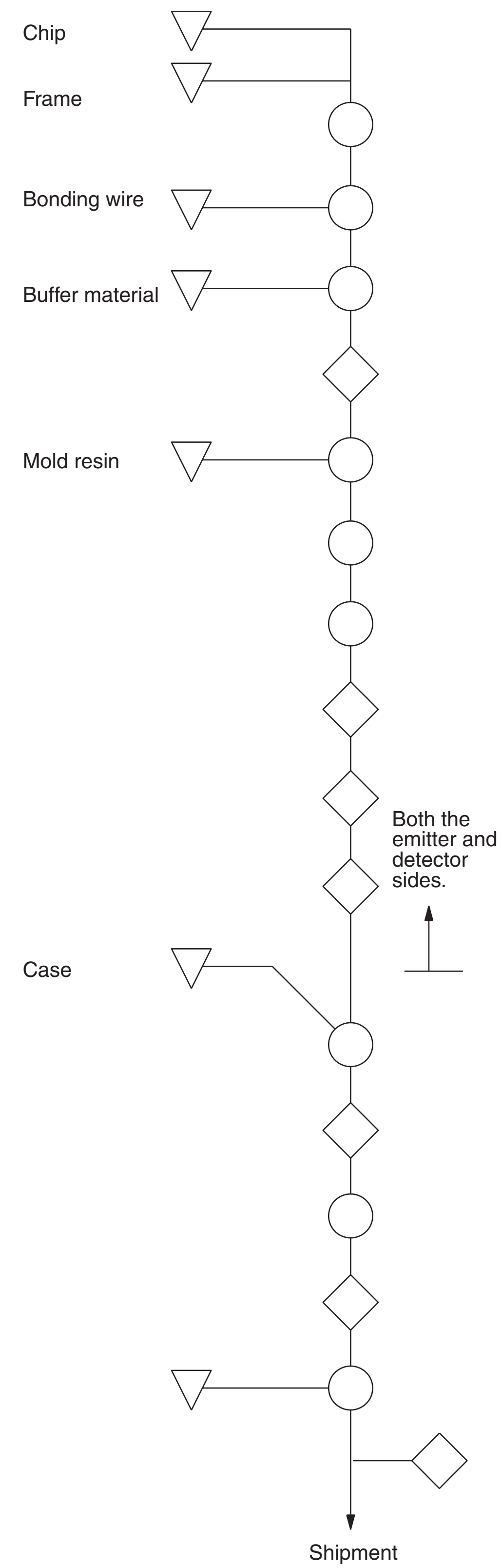
Reviewing plans for product quality (DR-1)	→	Reviewing design and development for better product quality (DR-2)	→	Reviewing mass-production plans (DR-3)
Evaluating the specifications of the products by considering the use, purposes, operating conditions, and target reliability of the products in the planning stages.		Evaluating the design, drawings, trial models, and test results of the products by considering not only the functions but also the productivity, safety, reliability, and production costs of the products.		Evaluating the arrangements required for the mass-production of the products in the test production or initial mass-production stages.

Product Quality Control in Mass-production Stage

To improve the quality of the products in the mass-production stages of OMRON's products, OMRON attaches importance to its staff supervision, the equipment and machines used for the manufacture of the products, the materials of the products, and the manufacturing methods of the products. There are rules for the changes in the design and manufacturing methods of the products and the steps to deal with any abnormality in the mass-production stages to conduct the quality control of the products. Figure 35 shows the flowchart used for the quality control in all the production stages of the EE-SX1041 Transmissive Photomicrosensor.

Figure 35 Quality Control in EESX1041 Photomicrosensor Production Stages

Flowchart (Material / Process)



Production stage	Quality control item
Die bonding	Temperature and bonding strength
Wire bonding	Bonding conditions and bonding strength
Buffer coating (see note)	Resin application state
Appearance test	Bonding state
Molding	Molding conditions
Screening (see note)	Screening conditions
Lead cutting	Equipment conditions
Appearance test	Mold state and lead-cut state
Characteristics test	Electrical characteristics
Debugging (see note)	Test conditions
Assembling	Assembling state
Characteristics test	Electrical characteristics
Marking	Marking state
Appearance test	Appearance
Inspection at random	Electrical characteristics, appearance, and reliability test

Note: Applied to the LED only.

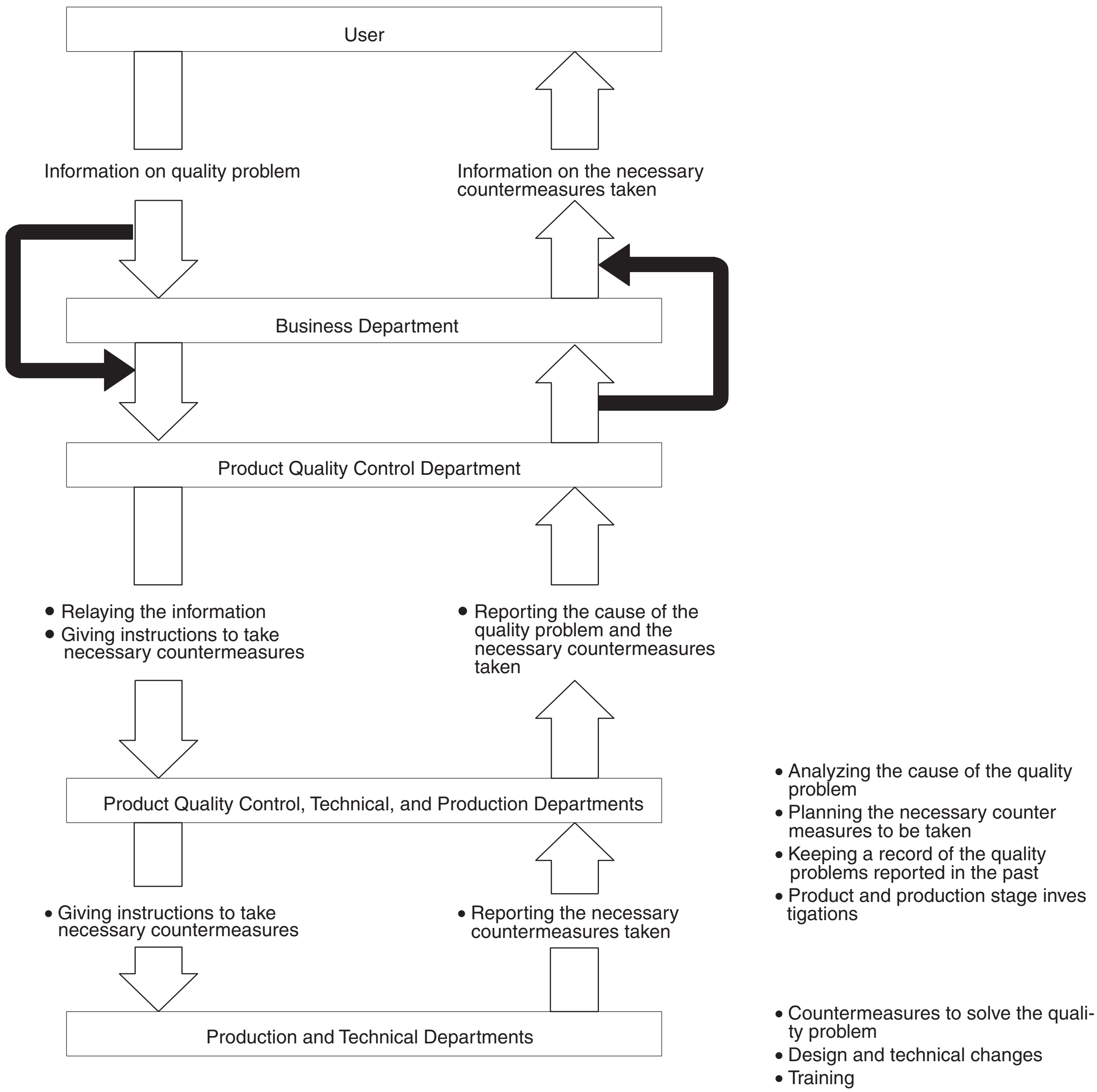
Shipment Product Quality Control

OMRON is conducting product quality control activities in the design and production stages of all OMRON's products. Recently, the failure rate tolerated by users has been less than 10 ppm, which cannot be achieved by any conventional product quality control system. OMRON is complying with OMRON product users' demand by not only conducting the above-mentioned product control activities but also properly managing its design and production stages, conducting tests of OMRON's products to ensure the reliability of the products, and strengthening its troubleshooting technology.

Market Product Quality Control

OMRON is actively collecting comments on the quality of OMRON's products on the market to reflect the results toward the improvement in the quality and reliability of OMRON's all products including any product to be released by OMRON in the future.
The comments include complaints about the quality of OMRON products. If any OMRON product on the market has a quality problem, OMRON's Product Quality Control Department, in cooperation with the departments concerned, promptly finds the cause of the problem, takes necessary countermeasures to solve the problem, and prevents the recurrence of the problem by taking the steps shown in Figure 36.

Figure 36 Treatment of Complaint about Market Product Quality



■ Reliability

Market Product Quality

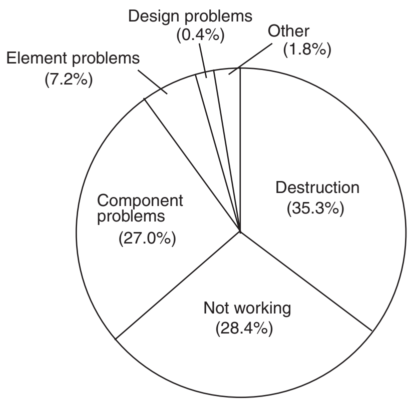
OMRON is making efforts so that OMRON's products can achieve a failure rate of only 10^{-7}/h.

OMRON will continue improving the quality of its products to comply with OMRON product users' demand for product quality while actively providing good after-sales service.

OMRON's products achieved a failure rate of 10 ppm in fiscal 1999. Figure 37 shows the reasons for the return of OMRON products between April 2002 and March 2003.

The reasons for approximately two-thirds of the products sent back were that they were not working or they were destroyed. It is possible that they were not working or they were destructed because excessive voltages were imposed on them or they were not operated properly according to their specifications. To solve such problems, OMRON is actively holding preliminary meetings with customers who will use OMRON products and advise them of the operating conditions required by the products while actively providing them with after-sales service.

Figure 37 Reasons for Products Sent Back (April 2002 to March 2003)



The life of any Photomicrosensor depends on the secular changes of the optical output of the LED built into the Photomicrosensor. The following are the output characteristics of the Photomicrosensor, all of which depend on the optical output of the LED.

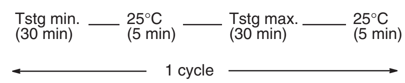
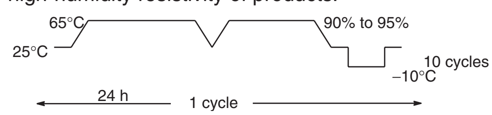
Phototransistor output	Light current (I_L)
Photo IC output	LED current I_{FT} with the photo IC output ON and OFF
Amplifier output (reflective sensor)	Sensing distance d

OMRON has been conducting reliability tests of each type of Photomicrosensor to check the secular changes of the optical output of the LED built into the Photomicrosensor.

Reliability Tests

In principle, Photomicrosensors conform to JEITA standards. The following table shows the details of the reliability tests of Photomicrosensors conducted by OMRON.

Details of Reliability Tests

Classification	Test	Detail	Conforming standard	
Thermal condition test	Soldering heat resistivity	Evaluates the soldering heat resistivity of products. Usually, this test is conducted under the following conditions. Soldering temperature: 260±5°C Soldering time:10±1 s	JEITA ED-4701/300 ED-8121 JIS C7021: A1 IEC Pub68-2-20	
	Thermal shock	Evaluates the resistivity of products to radical temperature changes. Usually, this test is conducted under the following conditions. Ta: 0°C to 100°C (liquid bath) or TstgMIN to TstgMAX (liquid bath)	JEITA ED-4701/300 JIS C7021: A3 IEC Pub68-2-14	
	Temperature cycle	Evaluates the low- and high-temperature resistivity of products. 	JEITA ED-4701/100 JIS C7021: A4 IEC Pub68-2-14	The five-minute storage periods at a temperature of 25°C in the test may be omitted.
	Temperature and humidity cycle	Evaluates the high-temperature and high-humidity resistivity of products. 	JEITA ED-4701/200 JIS C7021: A5 IEC Pub68-2-4	
Mechanical test	Soldering ease	Evaluates the terminal soldering ease of the products. Usually, this test is conducted under the following conditions. Soldering temperature: 230±5°C Soldering time: 5±0.5 s	JEITA ED-4701/300 ED-8121 JIS C7021: A2 IEC Pub68-2-20	
	Terminal strength	Evaluates the resistivity of the terminals of products to the force imposed on the terminals while the products are mounted, wired, or operated. **Tension test** On each terminal of products, a specified load is imposed for 10±1 s in the direction of the terminal. **Bending test** On the tip of each terminal of products, a specified load is imposed to bend the terminal by 90° and to change it back.	JEITA ED-4701/400 ED-8121 JIS C7021: A11 IEC Pub68-2-21	
	Shock resistance	Judges the structural resistivity and mechanical resistivity of products. The conditions of this test vary with the product structure. Usually, this test is conducted under the following conditions. Impact acceleration:14,700 m/s^2 Pulse width: 0.5 ms	JEITA ED-4701/400 ED-8121 JIS C7021: A7 IEC Pub68-2-27	A product may be subjected to this test after it is packed up.
	Vibration resistance	Evaluates the vibration resistivity of products while they are transported or operated. Usually, this test is conducted under the following conditions. Frequency: 100 to 2000 Hz/4 min 200 m/s^2	JEITA ED-4701/400 ED-8121 JIS C7021: A10 IEC Pub68-2-21	A product may be subjected to this test after it is packed up.
	Natural drop	Evaluates the irregular shock resistivity of products while they are handled, transported, or operated. Usually, this test is conducted under the following conditions. Height: 75 cm No. of times: 3	JEITA EIAJ-8121 JIS C7021: A8 IEC Pub68-2-32	A product may be subjected to this test after it is packed up.

Classification	Test	Detail	Conforming standard	
Life expectancy test	Continuous operation	Evaluates the resistivity of products to a continuous, long-time electrical stress and temperature stress. Usually, this test is conducted under the following conditions. Ta: 25±5°C Bias: I_{FMAX} or P_{CMAX}	EIAJ-EDX-8121 EIAJ-SD-121: 201 JIS C7021: B4	A product may be subjected to this test at a high temperature, low temperature, or high temperature and humidity.
	High-temperature storage	Evaluates the resistivity of products to a high-storage temperature for a long time. Usually, this test is conducted under the following conditions. Ta: TstgMAX Time: 1,000 hrs	EIAJ-EDX-8121 EIAJ-SD-121: 115 JIS C7021: B10 IEC Pub68-2-2	
	Low-temperature storage	Evaluates the resistivity of products to a low-storage temperature for a long time. Usually, this test is conducted under the following conditions. Ta: TstgMIN Time: 1,000 hrs	EIAJ-EDX-8121 EIAJ-SD-121: 116 JIS C7021: B12 IEC Pub68-2-1	
	High-temperature and high-humidity storage	Evaluates the resistivity of products to a high-storage temperature and high storage humidity for a long time. Usually, this test is conducted under the following conditions. Ta: 60°C Humidity: 90% Time: 1,000 hrs	EIAJ-EDX-8121 EIAJ-SD-121: 117 JIS C7021: B11 IEC Pub68-2-3	
	High-temperature reverse bias	Evaluates the resistivity of products to a continuous electrical stress and temperature stress.	EIAJ-SD-121: 203 JIS C7021: B8	A product may be subjected to this test at a low temperature, high temperature, or high humidity.

Note: The above testing conditions and testing times depend on the features of each product.

Data from Reliability Tests

The following tables show the results of the reliability tests of typical Transmissive Photomicrosensors with an Infrared LED conducted by OMRON.

Providing this data does not imply that OMRON guarantees the specified reliability level.

Typical Failure Rates (MTTF Data)

EE-SX1041 (Transmissive Phototransistor Output)

Failure Criteria

Item	Symbol	Measuring conditions	Failure criteria	
			General test (see note)	Life test
Forward voltage	V_F	I_F = 30 mA	1.5 V max.	1.8 V max.
Reverse current	I_R	V_R = 4 V	10 μA max.	20 μA max.
Dark current	I_D	V_{CE} = 10 V 0lx	200 nA max.	400 nA max.
Light current	I_L	I_F = 20 mA V_{CE} = 10 V	0.5 mA min. 14 mA max.	Initial value × 0.7 min.

Note: Except life test.

Test Results

Test item	Test conditions (see note 1)	Number of samples	Component hours (h)	Number of failures	Failure rate (1/h) (see note 2)
Continuous operation	Ta = 25°C, I_F = 50 mA 2000 h	22 pcs	4.4×10^4	0	5.22×10^{-5}
High-temperature storage	Ta = 100°C 2000 h	22 pcs	4.4×10^4	0	5.22×10^{-5}
Low-temperature storage	Ta = –30°C 2000 h	22 pcs	4.4×10^4	0	5.22×10^{-5}
High-temperature and high-humidity storage	Ta = 60°C, 90% 2000 h	22 pcs	4.4×10^4	0	5.22×10^{-5}
High-temperature reverse bias	Ta = 85°C, V_{CE} = 30 V 2000 h	22 pcs	4.4×10^4	0	5.22×10^{-5}
Temperature cycle	–30°C (30 min) to 100°C (30 min) 10 times	22 pcs	---	0	---
Shock resistance	14,700 m/s^2, 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	11 pcs	---	0	---
Vibration resistance	20 to 2,000 Hz, 1.5 mm or 98 m/s^2 each in X, Y, and Z directions	11 pcs	---	0	---

Note: 1. The tests after 1001 hours are for reference only.
2. Confidence level of 90%.

EE-SX1235A-P2 (Transmissive Phototransistor Output)

Failure Criteria

Item	Symbol	Measuring conditions	Failure criteria	
			General test (see note)	Life test
Forward voltage	V_F	I_F = 30 mA	1.5 V max.	1.8 V max.
Reverse current	I_R	V_R = 4 V	10 µA max.	20 µA max.
Dark current	I_D	V_{CE} = 10 V 0lx	200 nA max.	400 nA max.
Light current	I_L	I_F = 20 mA V_{CE} = 5 V	0.5 mA min. 14 mA max.	Initial value × 0.7 min.

Note: Except life test.

Test Results

Test item	Test conditions (see note 1)	Number of samples	Component hours (h)	Number of failures	Failure rate (1/h) (see note 2)
Continuous operation	Ta = 25°C, I_F = 50 mA 2000 h	22 pcs	4.4 x 10^4	0	5.22 x 10^{-5}
High-temperature storage	Ta = 100°C 2000 h	22 pcs	4.4 x 10^4	0	5.22 x 10^{-5}
Low-temperature storage	Ta = –40°C 2000 h	22 pcs	4.4 x 10^4	0	5.22 x 10^{-5}
High-temperature and high-humidity storage	Ta = 60°C, 90% 2000 h	22 pcs	4.4 x 10^4	0	5.22 x 10^{-5}
High-temperature reverse bias	Ta = 85°C, V_{CE} = 30 V 2000 h	22 pcs	4.4 x 10^4	0	5.22 x 10^{-5}
Temperature cycle	–40°C (30 min) to 100°C (30 min) 10 times	22 pcs	---	0	---
Shock resistance	294 m/s^2, 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	11 pcs	---	0	---
Vibration resistance	5 to 50 Hz, 1.5 mm or 9.8 m/s^2 each in X, Y, and Z directions	11 pcs	---	0	---

Note: **1.** The tests after 1001 hours are for reference only.
2. Confidence level of 90%.

EE-SX398 (Transmissive Photo-IC Output)

Failure Criteria

Item	Symbol	Measuring conditions	Failure criteria	
			General test (see note)	Life test
Forward voltage	V_F	I_F = 20 mA	1.5 V max.	1.8 V max.
Reverse current	I_R	V_R = 4 V	10 μA max.	20 μA max.
Low-level output voltage	V_{OL}	V_{CC} = 16 V I_{OL} = 16 mA I_F = 0 mA	0.4 V max.	0.48 V max.
High-level output current	I_{OH}	V_{CC} = 16 V V_{OUT} = 28 V I_F = 5 mA	100 μA max.	200 μA max.
Current consumption	I_{CC}	V_{CC} = 16 V	10 mA max.	12 mA max.
LED current when output is OFF	I_{FT}	V_{CC} = 16 V I_{OL} = 16 mA	5 mA max.	Initial value × 1.3 max.

Note: Except life test.

Test Results

Test item	Test conditions (see note 1)	Number of samples	Component hours (h)	Number of failures	Failure rate (1/h) (see note 2)
Continuous operation	Ta = 25°C, I_F = 20 mA, V_{CC} = 5 V 1500 h	22 pcs	3.3×10^4	0	6.96×10^{-5}
High-temperature storage	Ta = 100°C 2000 h	22 pcs	3.3×10^4	0	6.96×10^{-5}
Low-temperature storage	Ta = –40°C 2000 h	22 pcs	3.3×10^4	0	6.96×10^{-5}
High-temperature and high-humidity storage	Ta = 60°C, 90% 2000 h	22 pcs	3.3×10^4	0	6.96×10^{-5}
High-temperature reverse bias	Ta = 85°C, V_{CE} = 30 V 2000 h	22 pcs	3.3×10^4	0	6.96×10^{-5}
Temperature cycle	–40°C (30 min) to 100°C (30 min) 10 times	22 pcs	---	0	---
Shock resistance	14,700 m/s^2, 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	11 pcs	---	0	---
Vibration resistance	20 to 2,000 Hz, 1.5 mm or 98 m/s^2 each in X, Y, and Z directions	11 pcs	---	0	---

Note: 1. The tests after 1001 hours are for reference only.

2. Confidence level of 90%.

EE-SX4235A-P2 (Transmissive Photo-IC Output)

Failure Criteria

Item	Symbol	Measuring conditions	Failure criteria	
			General test (see note)	Life test
Current consumption	I_{CC}	V_{CC} = 5.5 V	16.5 mA max.	19.8 mA max.
Low-level output voltage	V_{OL}	V_{CC} = 4.5 V I_{OUT} = 16 mA with incident	0.35 V max.	0.42 V max.
High-level output voltage	I_{OH}	V_{CC} = 5.5 V V_{OUT} = V_{CC} with incident R_L = 47 kΩ	4.95 V max.	3.96 V max.

Note: Except life test.

Test Results

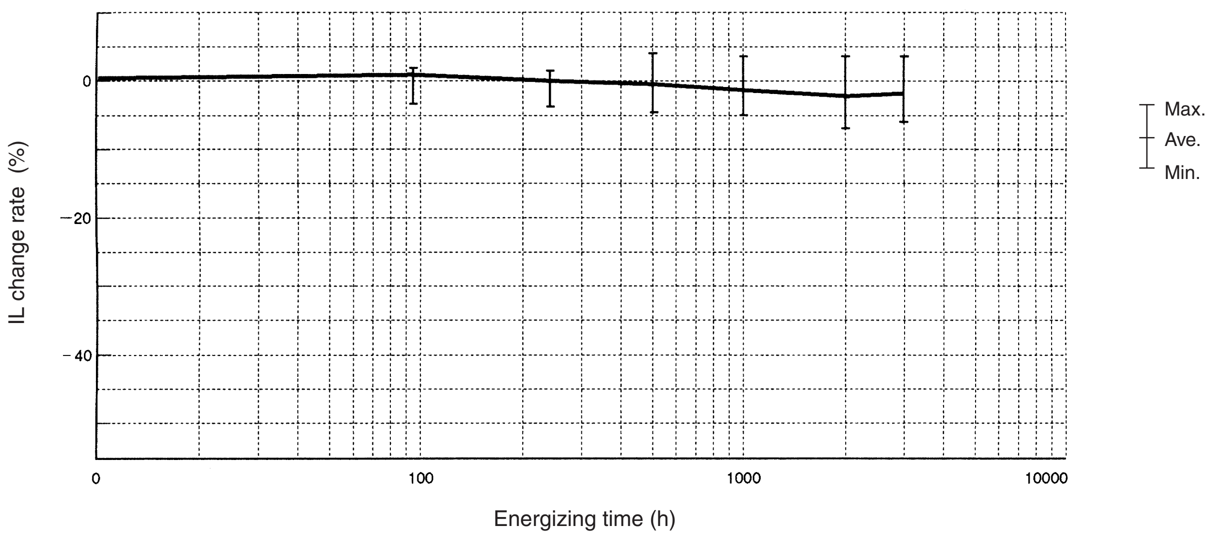
Test item	Test conditions (see note 1)	Number of samples	Component hours (h)	Number of failures	Failure rate (1/h) (see note 2)
Continuous operation	Ta = 25°C, V_{CC} = 5 V 1000 h	22 pcs	2.2 x 10^4	0	1.05 x 10^{-4}
High-temperature storage	Ta = 85°C 1000 h	22 pcs	2.2 x 10^4	0	1.05 x 10^{-4}
Low-temperature storage	Ta = –40°C 1000 h	22 pcs	2.2 x 10^4	0	1.05 x 10^{-4}
High-temperature and high-humidity storage	Ta = 60°C, 90% 1000 h	22 pcs	2.2 x 10^4	0	1.05 x 10^{-4}
Temperature cycle	–40°C (30 min) to 85°C (30 min) 10 times	22 pcs	---	0	---
Shock resistance	294 m/s^2, 0.5 ms, 3 times each in ±X, ±Y, and ±Z directions	11 pcs	---	0	---
Vibration resistance	5 to 50 Hz, 1.5 mm or 9.8 m/s^2 each in X, Y, and Z directions	11 pcs	---	0	---

Note: 1. The tests after 1001 hours are for reference only.
2. Confidence level of 90%.

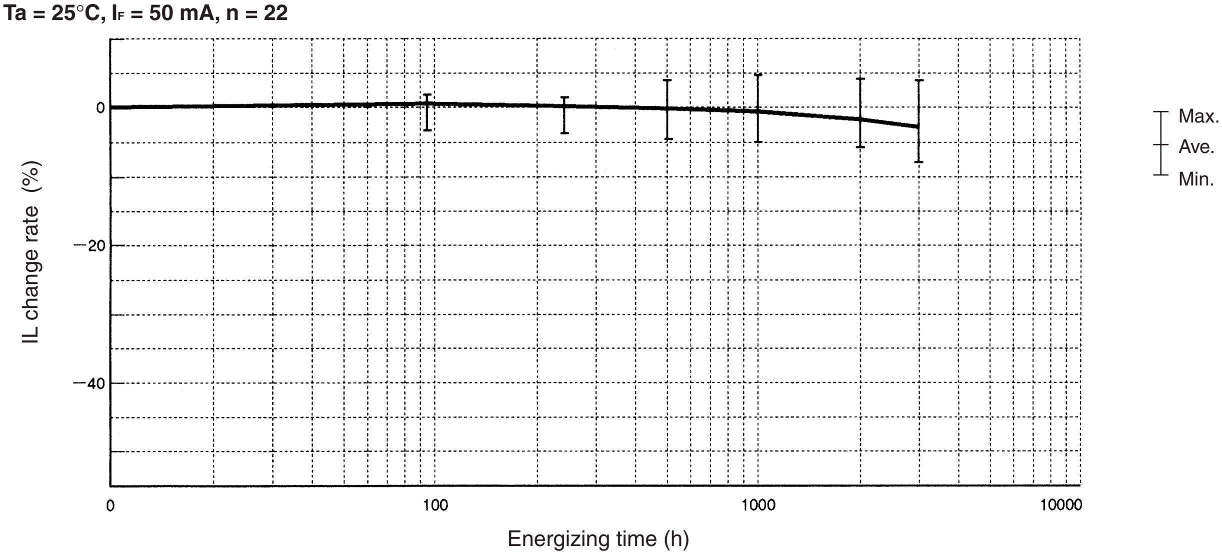
Light Current (I_L) Secular Changes of Phototransistor Output Photomicrosensor

Note: These graphs show the results of reliability testing conducted by OMRON for typical transmissive photomicrosensors (e.g., the EE-SX1041, EE-SX1081, and EE-SX1235A-P2) with an Infrared LED. For the reliability of the Photomicrosensor with a Red LED, please contact your nearest OMRON representative.

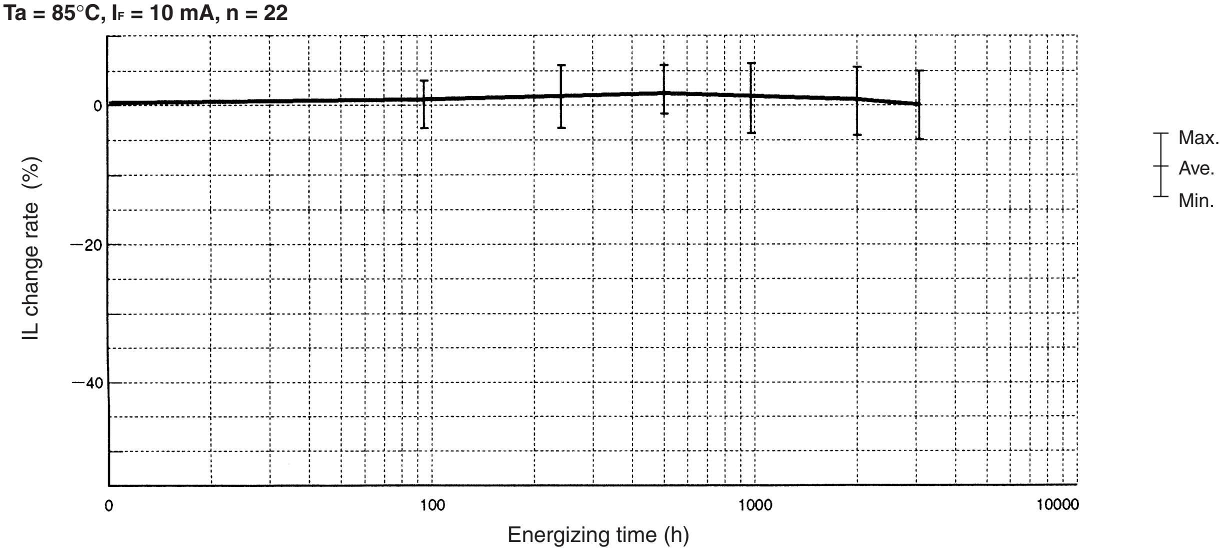
Ta = 25°C, I_F = 20 mA, n = 22



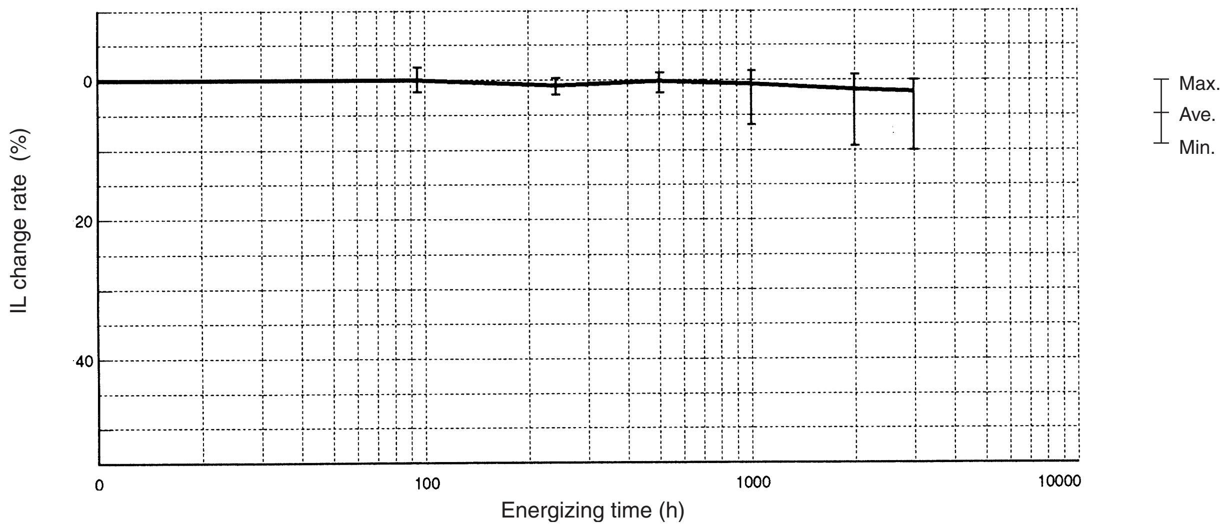
Ta = 25°C, I_F = 50 mA, n = 22



Ta = 85°C, I_F = 10 mA, n = 22



Ta = −25°C, I_F = 50 mA, n = 22



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