Application Note

NEC

PS2500-SERIES

MULTI-CHANNEL PHOTOCOUPLER

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[MEMO]

CAUTION

Within this device there exists GaAs (Gallium Arsenide) material which is a harmful substance if ingested. Please do not under any circumstances break the hermetic seal.

The application circuits and their parameters are for reference only and are not intended for use in actual design-ins.

The information in this document is subject to change without notice.

The mark ★ shows major revised points.

[MEMO]

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1. GENERAL

Recently, photocouplers have been supplanting relays and pulse transformers for complete noise elimination, level conversion, and high-potential isolation. Microprocessor systems are requiring more and more photocouplers on the limited area of PC boards for I/O interface and other purposes. For these requirements, NEC has manufactured multi-channel photocouplers having 4 pins (for one channel) to 16 pins (for four channels). These multi-channel photocouplers are called the PS2500 series photocouplers.

The PS2500 series photocouplers are divided into PS2501, PS2502, PS2505, and PS2506 according to their functions. (PS2501L, PS2502L, PS2505L, and PS2506L have leads formed for surface installation.)

This manual describes features, structures, and basic characteristics of the PS2500 series photocouplers.

2. FEATURES, STRUCTURES, AND PACKAGE DIMENSIONS

2.1 Features

The major feature of PS2500 is very high isolation voltage between input and output. The improvement in dielectric strength of the PS2500 Photocouplers has been accomplished by the double molding package structure.

In addition to high isolation voltage, the PS2500 photocouplers boast high heat resistance and high humidity resistance. Table 1 lists the major features of the PS2500 series photocouplers.

Table 1 Features of PS2500 photocouplers

Features / Product name	High isolation voltage	Abundant I/O functions	High CTR (TYP.)	High V_{CEO} (MIN.)	Response (TYP.)
PS2501 PS2501L*1	5 kV_{ac}	D.C. input, Single transistor output	300 %	80 V	t_r = 3 μs, t_f = 5 μs
PS2502 PS2502L*1		D.C. input, Darlington pair transistor output	2 000 %	40 V	t_r, t_f = 100 μs
PS2505 PS2505L*1		A.C. input, Single transistor output	300 %	80 V	t_r = 3 μs, t_f = 5 μs
PS2506 PS2506L*1		A.C. input, Darlington pair transistor output	2 000 %	40 V	t_r, t_f = 100 μs

Remark Tested in oil (In the air, unwanted arc discharging will occur at 6 to 7 kV_{ac})

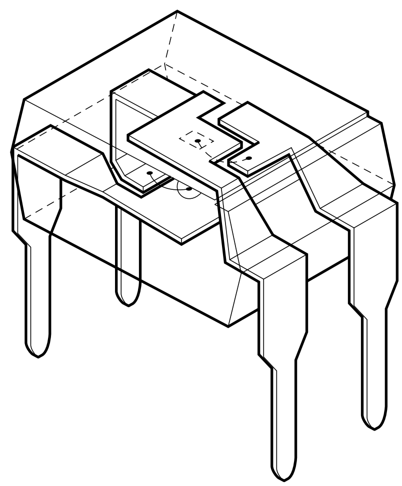
***1** The product name followed by letter L is for a product having leads for surface mount.

2.2 Photocoupler Structure

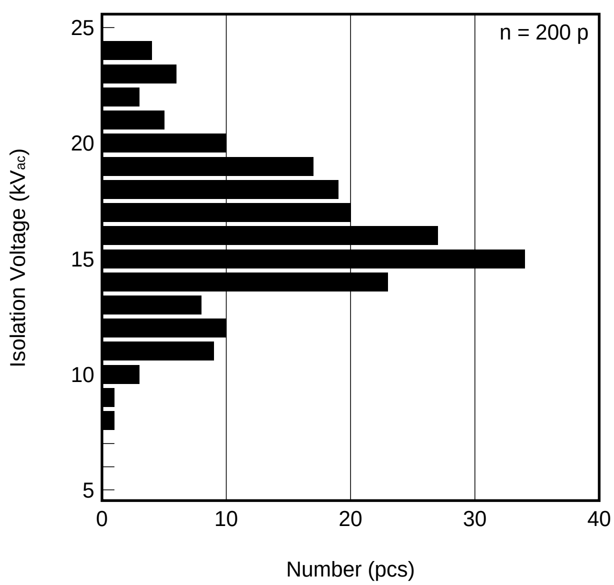
Figure 1 shows the internal perspective view of PS25××-1 photocoupler. A light-emitting diode (LED) is placed opposite a photo-sensitive element (phototransistor or photo Darlington transistor, etc.) with a light-transmittable epoxy resin medium between them. Light signals emitted by the LED are transferred to the photosensitive element via the internal resin medium. To completely cut the effect of external light, black resin is used for the external resin.

Using the above construction, close contact between the inner and outer resins is obtained through the long adjacent area of the inner and outer resins and their identical expansion coefficient. As a result, photocouplers with excellent isolation, withstand voltage, and heat resistance characteristics are realized.

Fig. 1 Internal Perspective View of PS25××-1



★ **Fig. 2 Displays an example of Isolation Voltage distribution. (PS2501, PS2502, PS2505 and PS2506)**

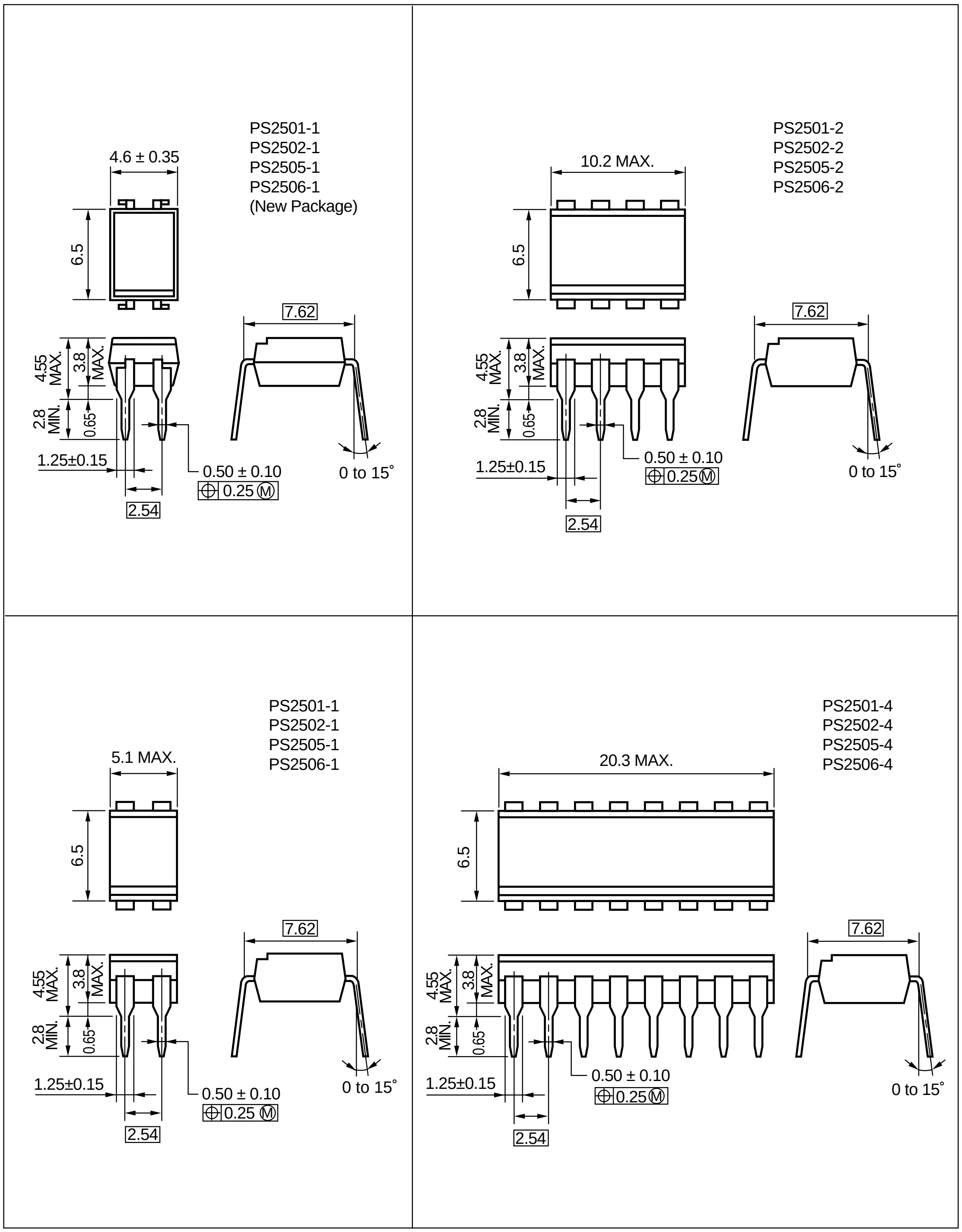


2.3 Dimensions

Figures 3 and 4 show the dimensions of the PS2500 series photocouplers. The PS2500 series photocouplers are very compact and fit for high-density installation on PC boards. For example, the package area occupied by a single channel of the PS2500 series is half that of the PS2600 series (6-pin Dual In-line Package).

★ **Fig. 3 Dimensions (PS2501, PS2502, PS2505, and PS2506)**

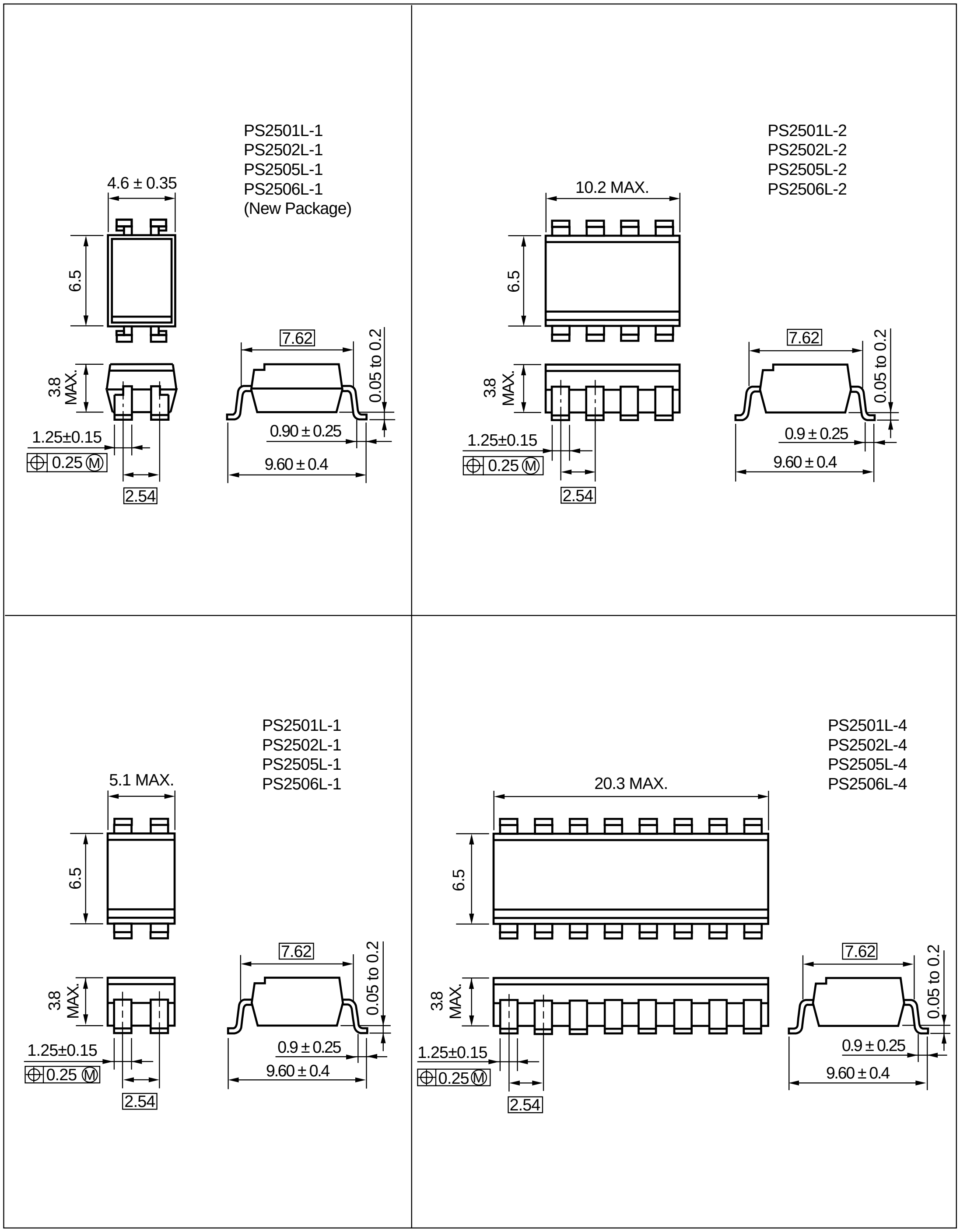
Dimensions (All dimensions in millimeters)



Caution New package 1-ch only

★ **Fig.4 Dimensions (PS2501L, PS2502L, PS2505L, and PS2506L)**

Dimensions (All dimensions in millimeters)



Caution New package 1-ch only

3. CHARACTERISTICS OF PS2501 AND PS2505 PHOTOCOUPLERS

3.1 Current Transfer Ratio (CTR)

The current transfer ratio (CTR) of a photocoupler is the ratio of the value of output current I_C to the value of input forward current I_F ($I_C/I_F \times 100$ %). The CTR is a parameter equivalent to the D.C. current amplification factor h_{FE} of a transistor.

The CTR is one of the most significant characteristics of photocouplers as well as isolation voltage. In circuit designing, CTR must be considered first of all because the CTR.

<1> is dependent upon forward current I_F flowing through the LED.
<2> is affected by ambient temperature, and
<3> varies as time goes by,

Both PS2505 and PS2506 photocouplers (bidirectional input type) have two current transfer ratios (CTRs) because they have two LEDs in the input. For further information, refer to Applications of Photocouplers for A.C. input.

3.1.1 CTR vs. I_F characteristics (I_F: Forward current flowing through the LED)

The current transfer ratio (CTR) depends upon the magnitude of a forward current (I_F). When I_F goes lower or higher than a proper magnitude, the CTR becomes smaller. Figure 5 to 6 shows the CTR vs. I_F characteristics.

Note that rate changes of CTRs are very different at low I_F magnitude (approx. 5 mA), middle I_F magnitude (approx. 5 mA), and high I_F magnitude (approx. 20 mA). Namely, the CTR depends heavily upon the magnitude of forward current I_F in lower and higher current ranges.

In case of using low input current to obtain high output current, see Chapter 4.

Fig. 5 CTR vs. I_F characteristics (Standard value) (PS2501, PS2505)

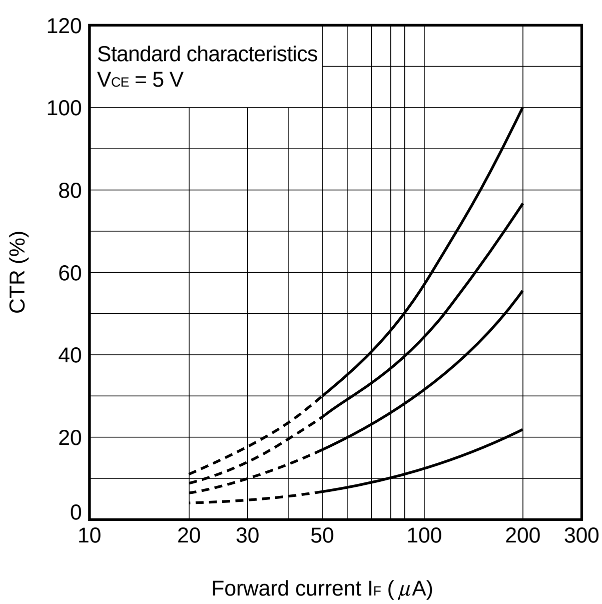
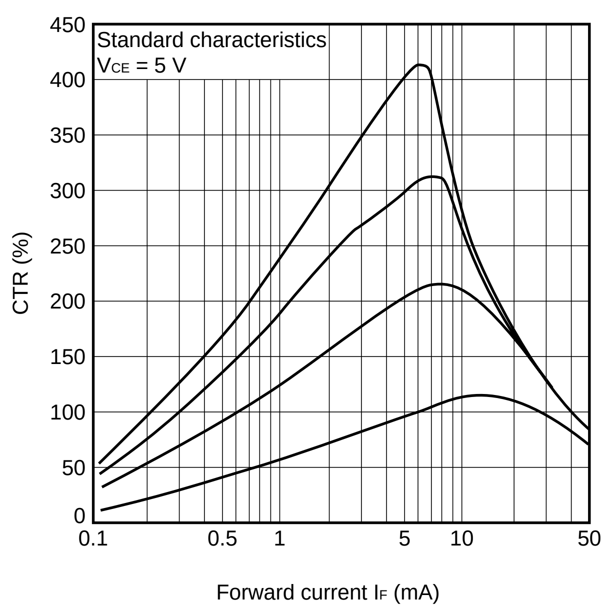


Fig. 6 CTR vs. I_F characteristics (Standard value) (PS2501, PS2505)



For your reference, Figure 7 to 9 display examples of CTR distribution (M, L, K Rank) for PS2501-1.

★ **Fig. 7 CTR distribution example (M rank) (PS2501)**

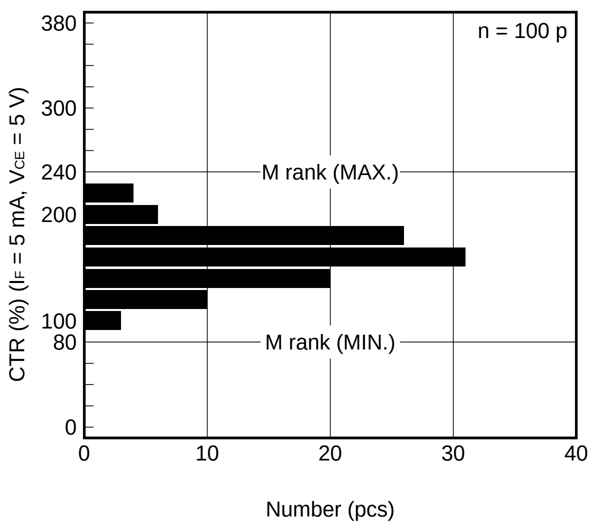
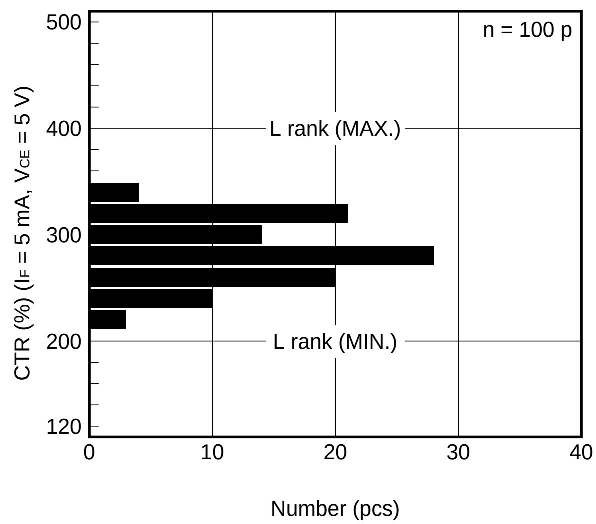
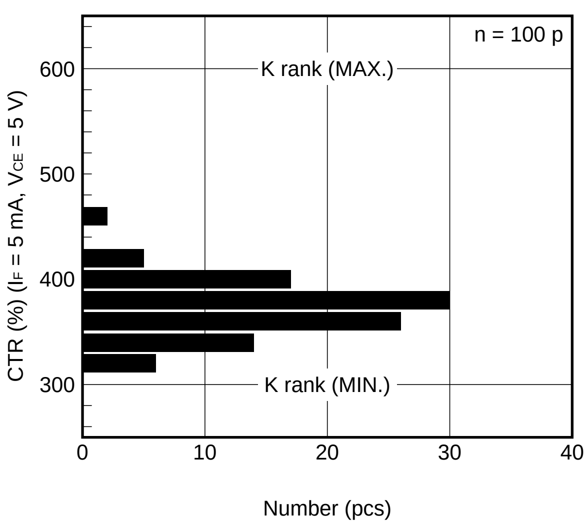


Fig. 8 CTR distribution example (L rank) (PS2501)



★ **Fig. 9 CTR distribution example (K rank) (PS2501)**



3.1.2 CTR vs. T_A characteristics (T_A: Ambient temperature)

The CTR-Temperature characteristic is greatly affected by the total characteristics of light-emission efficiency of the LED and h_{FE} of the phototransistor as the light-emission efficiency has a negative temperature coefficient and h_{FE} has a positive temperature coefficient. See Figure 10.

Fig. 10 CTR vs. T_A characteristics

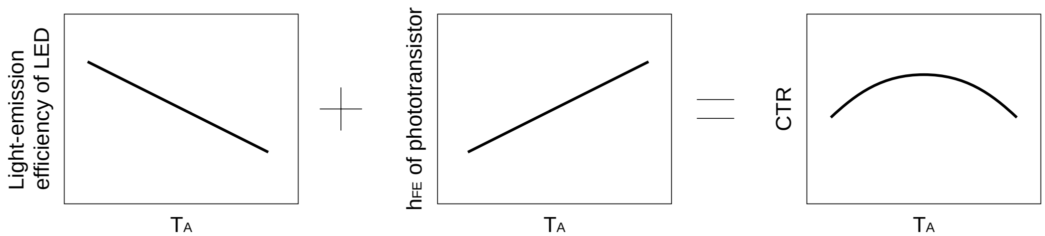
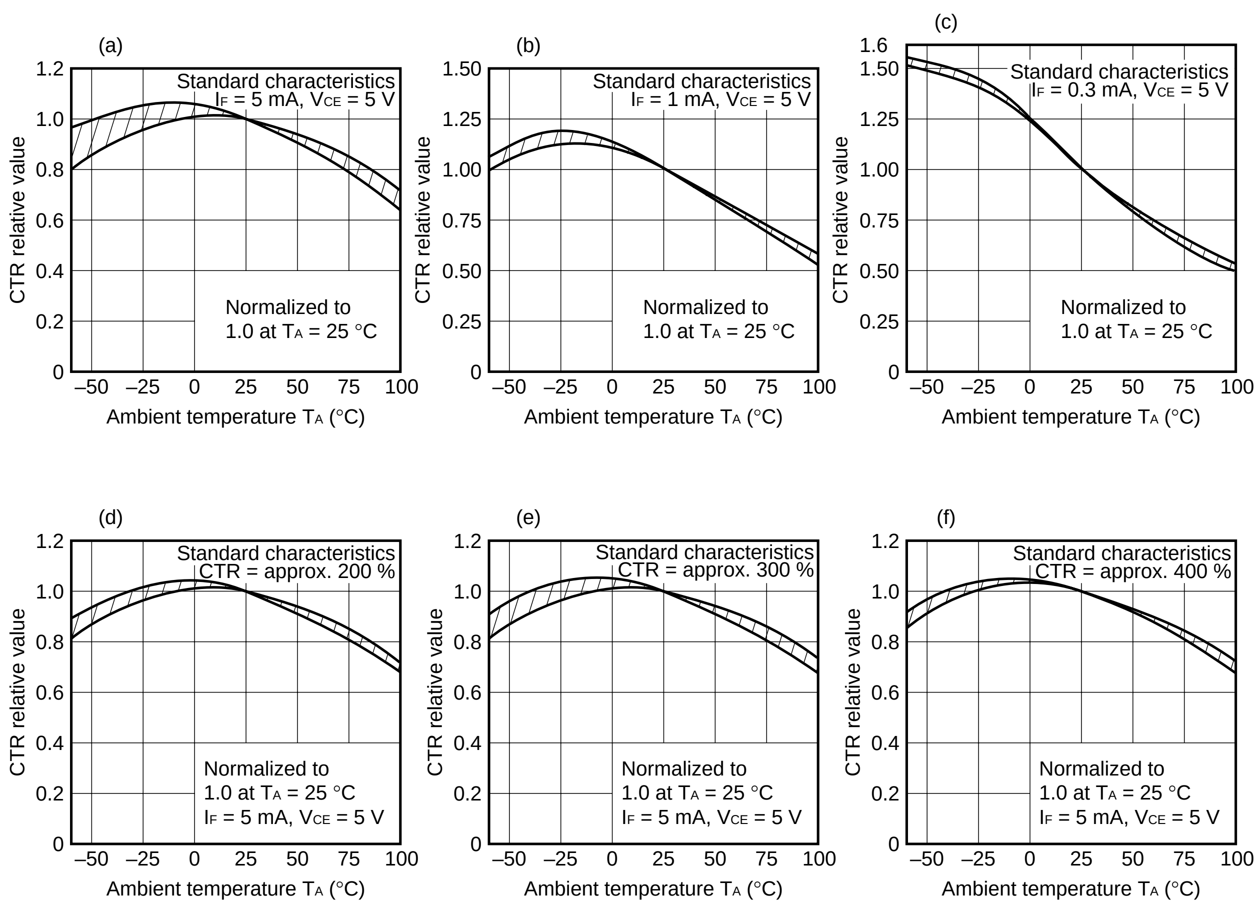


Figure 11 (a) to Figure 11 (f) show CTR vs. T_A characteristics under various conditions.

Fig. 11 (a) to (f) CTR vs. T_A characteristics
(PS2501, PS2505)



3.1.3 Change of CTR over time

The current transfer ratio (CTR) of a photocoupler is determined by the light-emission efficiency of the LED (emitting infrared light), efficiency of light transmission between the LED and the phototransistor, light sensitivity of the phototransistor, and h_{FE} of the transistor.

The change of a CTR over time is mainly caused by the reduction of the light-emission efficiency of the LED. Generally, the CTR is reduced to a greater extent as the forward current I_F increases or as the operating temperature increase. Figures 12 and 13 respectively show estimated changes of CTRs of PS2501 and PS2505 photocouplers over time.

Estimated change of CTRs with time lapse (Standard values)

Fig. 12 CTR vs. time characteristics (PS2501, PS2505)

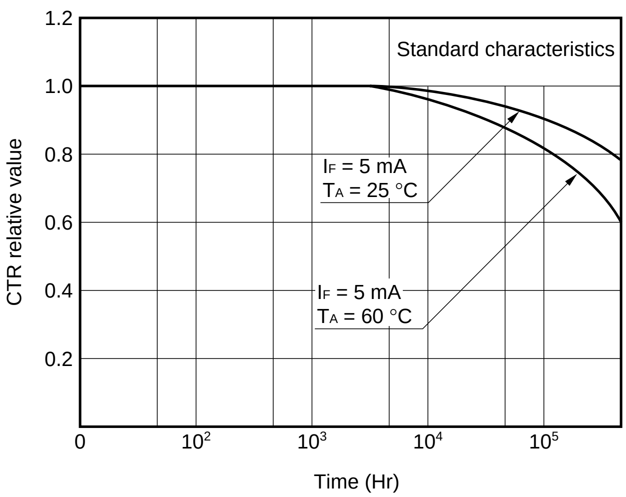
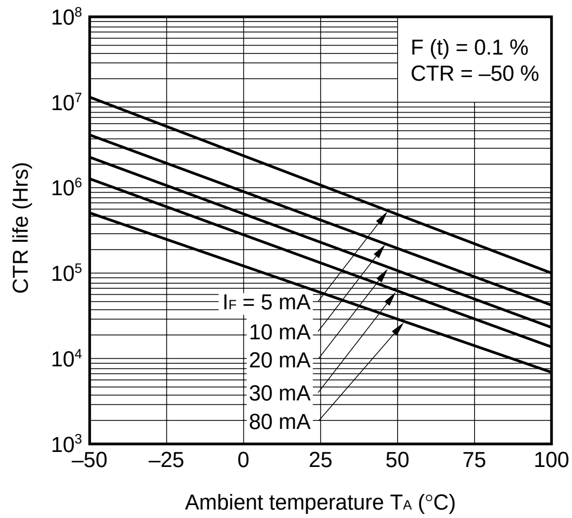


Fig.13 Estimation life (Standard values) (PS2501, PS2505)



3.2 Response Characteristics

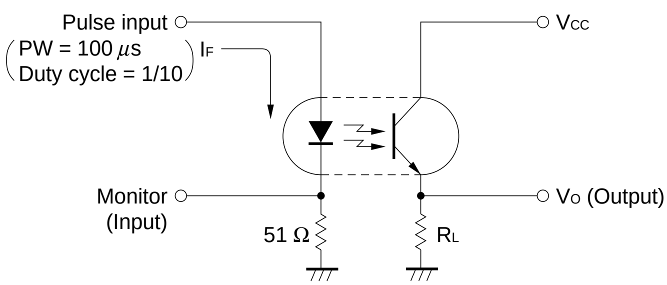
The response characteristics of photocouplers are the same as those of phototransistors. The fall time t_f is expressed by

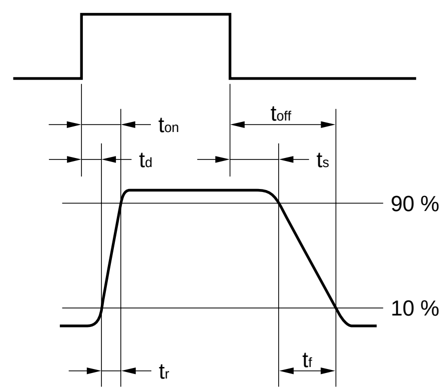
$$t_f \propto R_L \cdot h_{FE} \cdot C_{CB}$$

R_L : Load resistance
h_{FE} : Amplification factor
C_{CB} : Collector-base capacitance

If R_L is too high, t_f becomes too high to be fit for high-speed signal transmission. Select the proper load resistance for the desired signal rate. Similarly, the collector current must fully satisfy the minimum value of the CTR, CTR vs. T_A characteristics, and CTR vs. time characteristics. Otherwise, the phototransistor will operate unsaturated, causing lower response characteristics and malfunction.

Fig. 14 Test circuit for response-time





Figures 15 to 18 show the response time vs. the load resistance which show four CTR parameters.

Fig. 15 Response-time vs. R_L characteristics (PS2501, PS2505)

Fig. 16 Response-time vs. R_L characteristics (PS2501, PS2505)

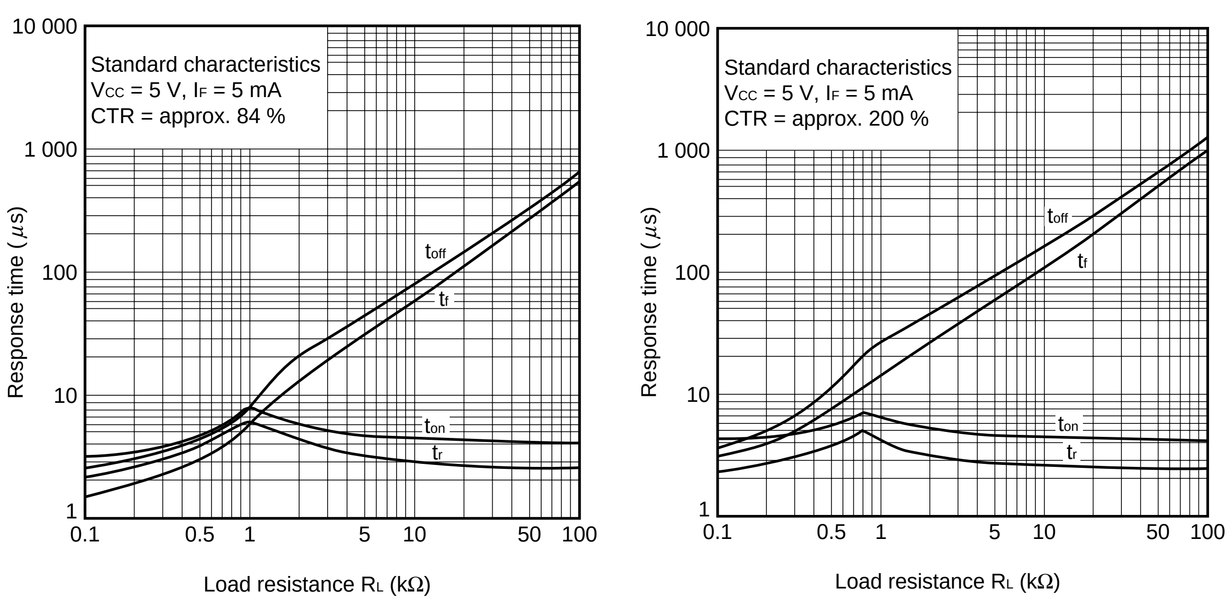


Fig. 17 Response-time vs. RL characteristics (PS2501, PS2505)

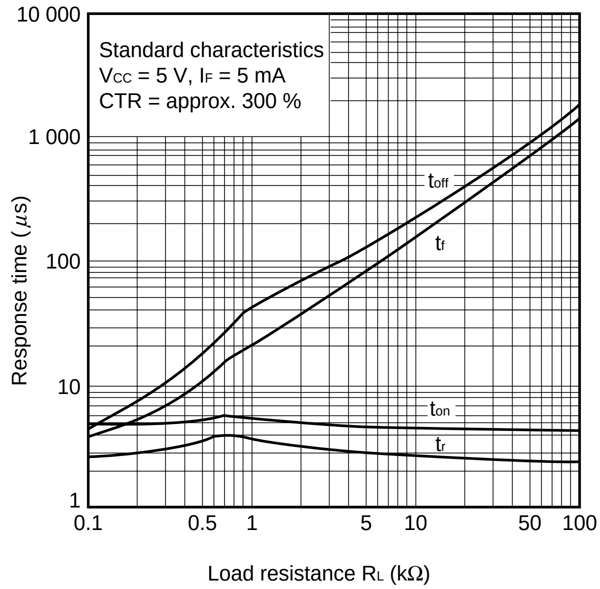
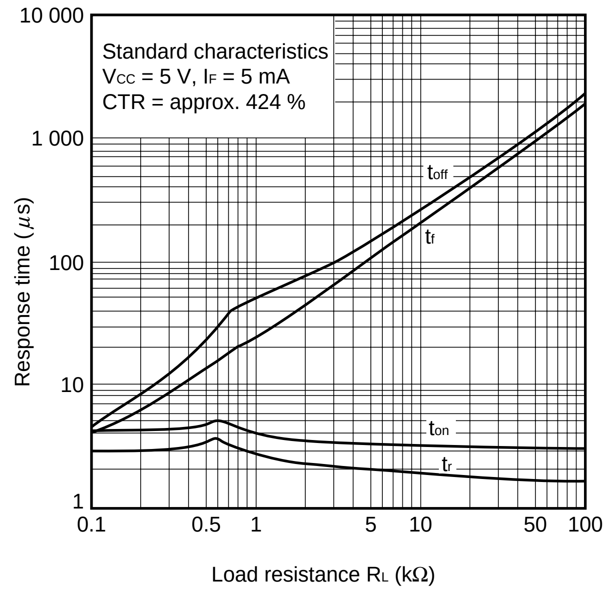


Fig. 18 Response-time vs. RL characteristics (PS2501, PS2505)



Figures 19 to 20 show the response time vs. the ambient temperature characteristics.

Fig. 19 Response-time vs. TA characteristics (PS2501, PS2505)

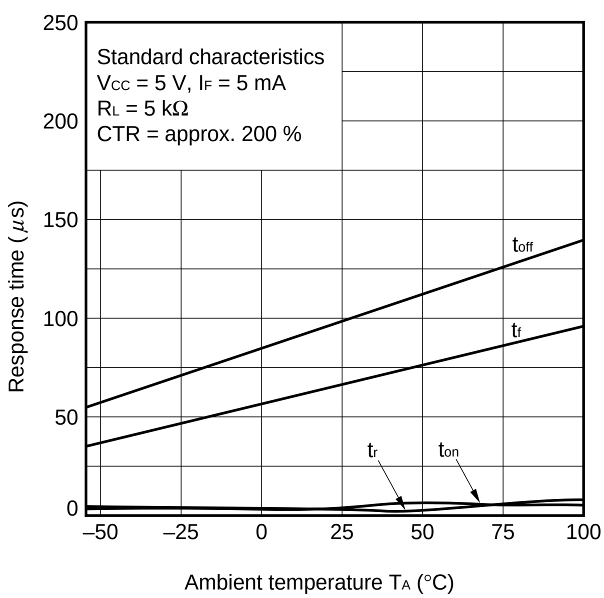
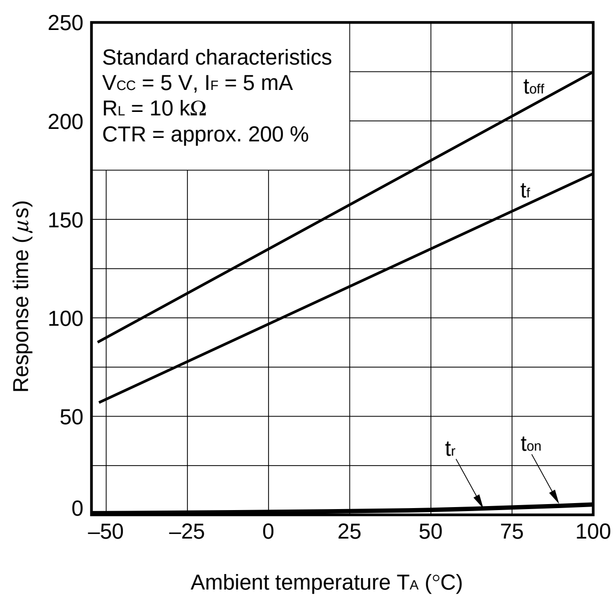


Fig. 20 Response-time vs. TA characteristics (PS2501, PS2505)



Figures 21 to 22 show the response time vs. the forward current characteristics.

Fig. 21 Response-time vs. I_F characteristics (PS2501, PS2505)

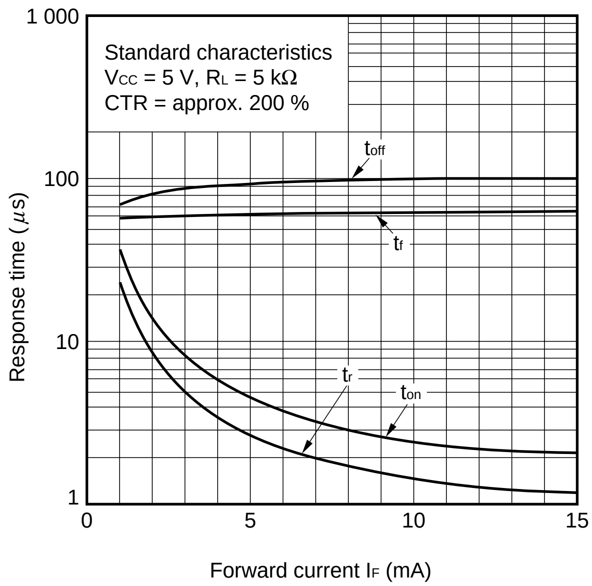
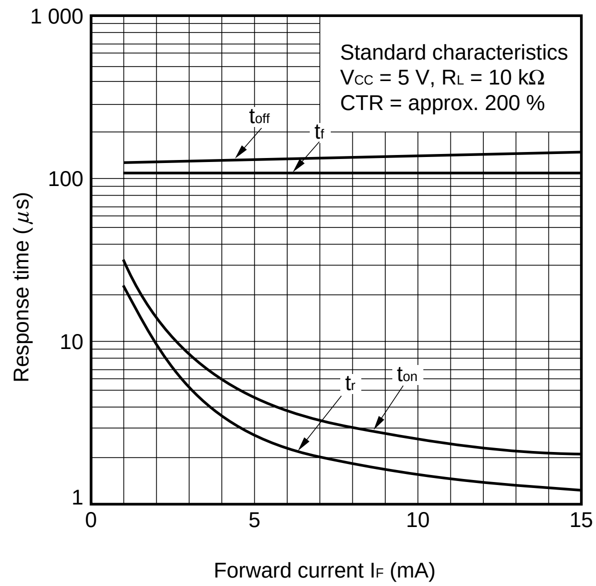


Fig. 22 Response-time vs. I_F characteristics (PS2501, PS2505)



Figures 23 to 24 show the response time vs. the supply voltage characteristics.

Fig. 23 Response-time vs. V_{CC} characteristics (PS2501, PS2505)

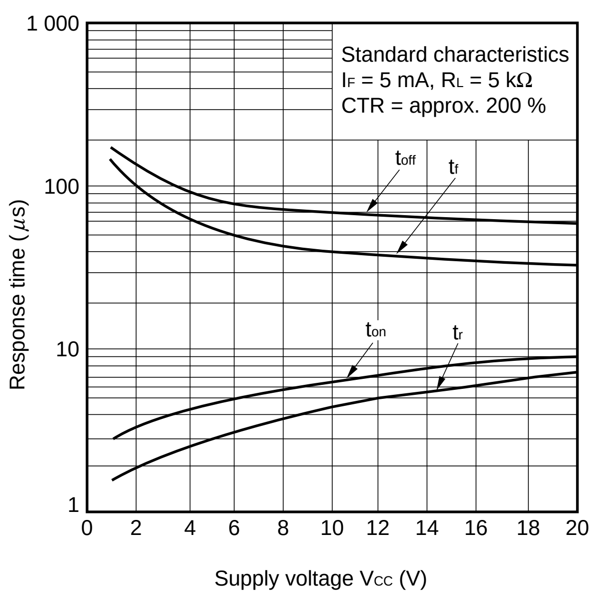
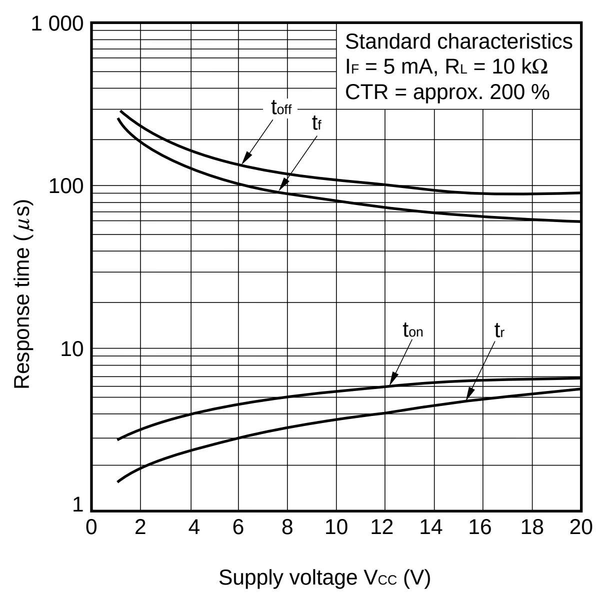


Fig. 24 Response-time vs. V_{CC} characteristics (PS2501, PS2505)



3.3 Other Temperature Characteristics

Almost all characteristics of photocouplers are apt to be affected by ambient temperature (see 3.1.2). Figures 25 to 32 show how V_F (Forward Voltage), I_{CEO} (Collector to Emitter Dark Current), and $V_{CE\ (sat)}$ (Collector Saturation Voltage) are affected by ambient temperature.

Fig. 25 V_F vs. T_A characteristics (PS2501, PS2505)

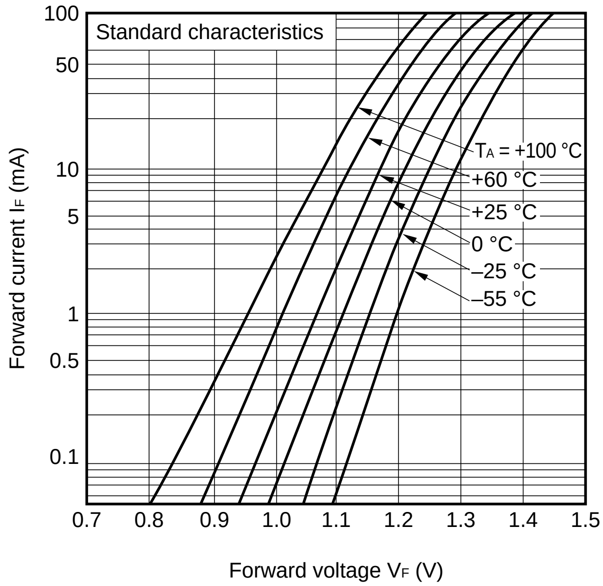


Fig. 26 V_F vs. T_A characteristics (PS2501, PS2505)

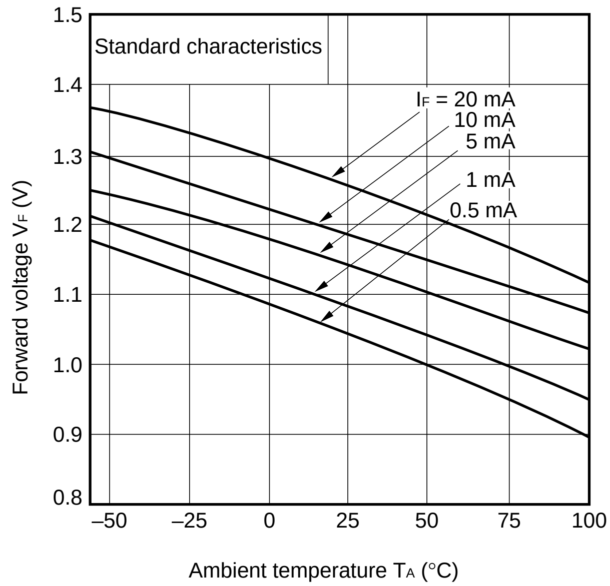


Fig. 27 I_{CEO} vs. T_A characteristics (PS2501, PS2505)

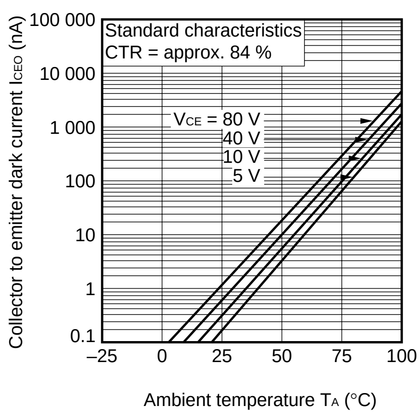


Fig. 28 I_{CEO} vs. T_A characteristics (PS2501, PS2505)

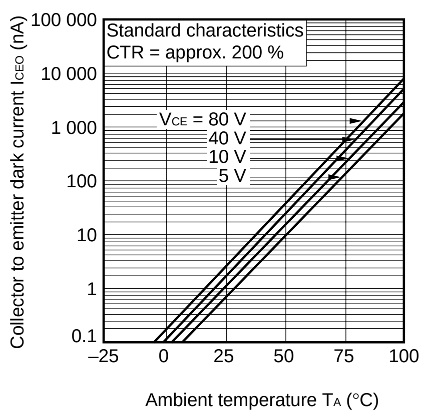


Fig. 29 I_{CEO} vs. T_A characteristics (PS2501, PS2505)

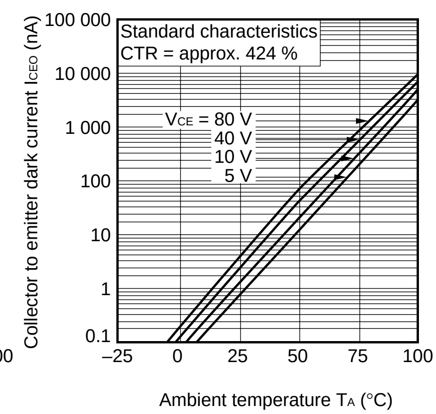


Fig. 30 $V_{CE(sat)}$ vs. T_A characteristics (PS2501, PS2505)

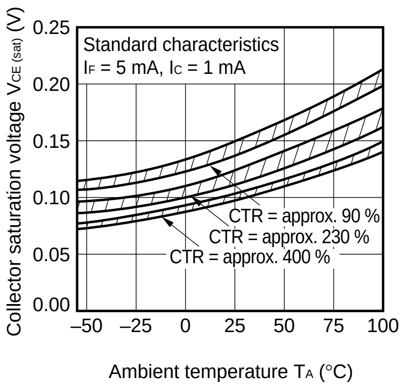


Fig. 31 $V_{CE(sat)}$ vs. T_A characteristics (PS2501, PS2505)

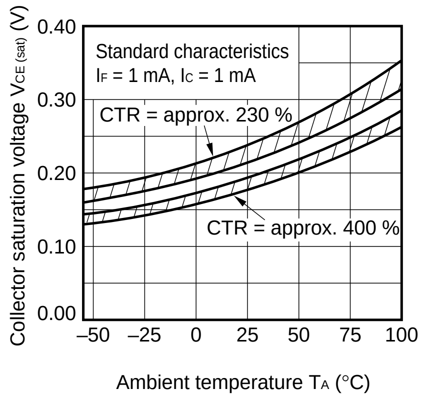
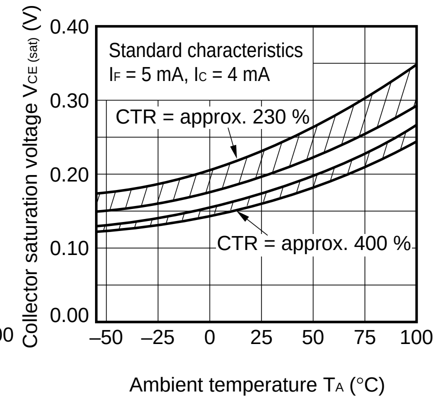


Fig. 32 $V_{CE(sat)}$ vs. T_A characteristics (PS2501, PS2505)

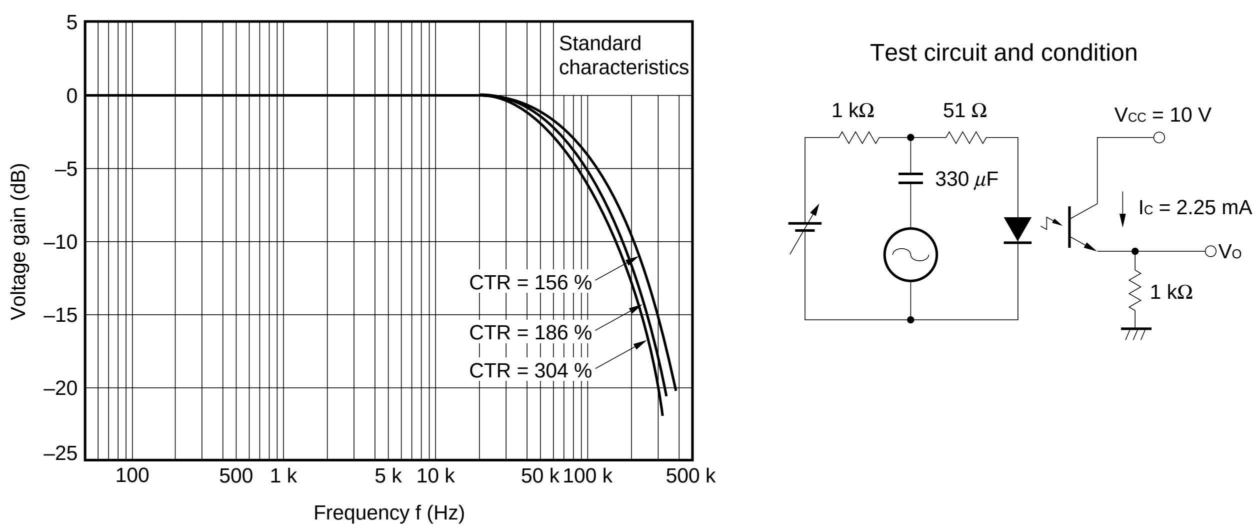


At normal temperature (T_A = 25 °C), the collector to emitter dark current I_{CEO} is very little (about 5 nA (at V_{CE} = 80 V and CTR = about 400 %)), but it will be multiplied by about 10 at an increment of 25 °C. This needs to be kept in mind when using a small output current (I_C) of a photocoupler with a high load.

The rate change of $V_{CE\ (sat)}$ (Collector Saturation Voltage) is about 0.7 % per °C at ambient temperature of 0 °C to 70 °C. In circuit design, the collector output current I_C should be determined under the condition of half or less of the CTR rated values. Otherwise, the saturation voltage $V_{CE\ (sat)}$ will become greater.

For reference, a voltage-gain vs. frequency characteristic using CTR as a parameter is shown below.

Fig. 33 Voltage-gain vs. frequency characteristics (Standard value) (PS2501, PS2505)



4. CHARACTERISTICS OF PS2502 AND PS2506 PHOTOCOUPLERS

The PS2502 and PS2506 photocouplers are higher in sensitivity than the PS2501 and PS2505 photocouplers and can be driven by low input currents.

4.1 CTR-Related Characteristics

The PS2502 and PS2506 photocouplers assure CTR ≥ 200 % at I_F = 1 mA and can be directly driven by CMOS output signals.

See 3.1 for CTR definition and characteristics.

4.1.1 CTR vs. I_F characteristics

As shown in Figure 5, the CTR of a single-transistor output photocoupler (such as the PS2501 and PS2505 photocouplers) is at most 10 % in a low-current area (e.g. I_F = 0.1 mA). However, the CTR of a Darlington-transistor output photocoupler (such as the PS2502 and PS2506 photocouplers) can be greater than 100 % in a low-current area (e.g. I_F = 0.1 mA).

Figures 34 to 35 shows the CTR vs. I_F characteristics of the PS2502 and PS2506 photocouplers.

Fig. 34 CTR vs. I_F characteristics (Standard value) (PS2502, PS2506)

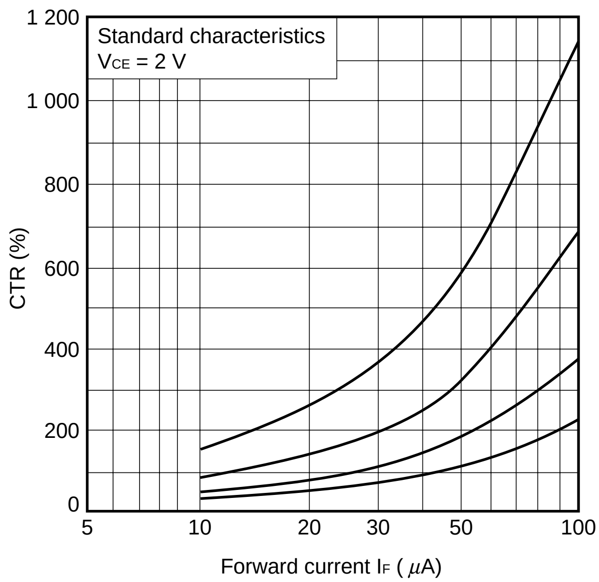
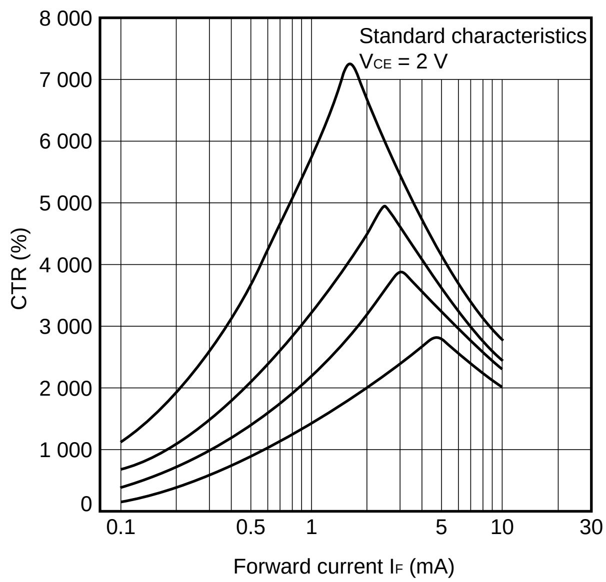


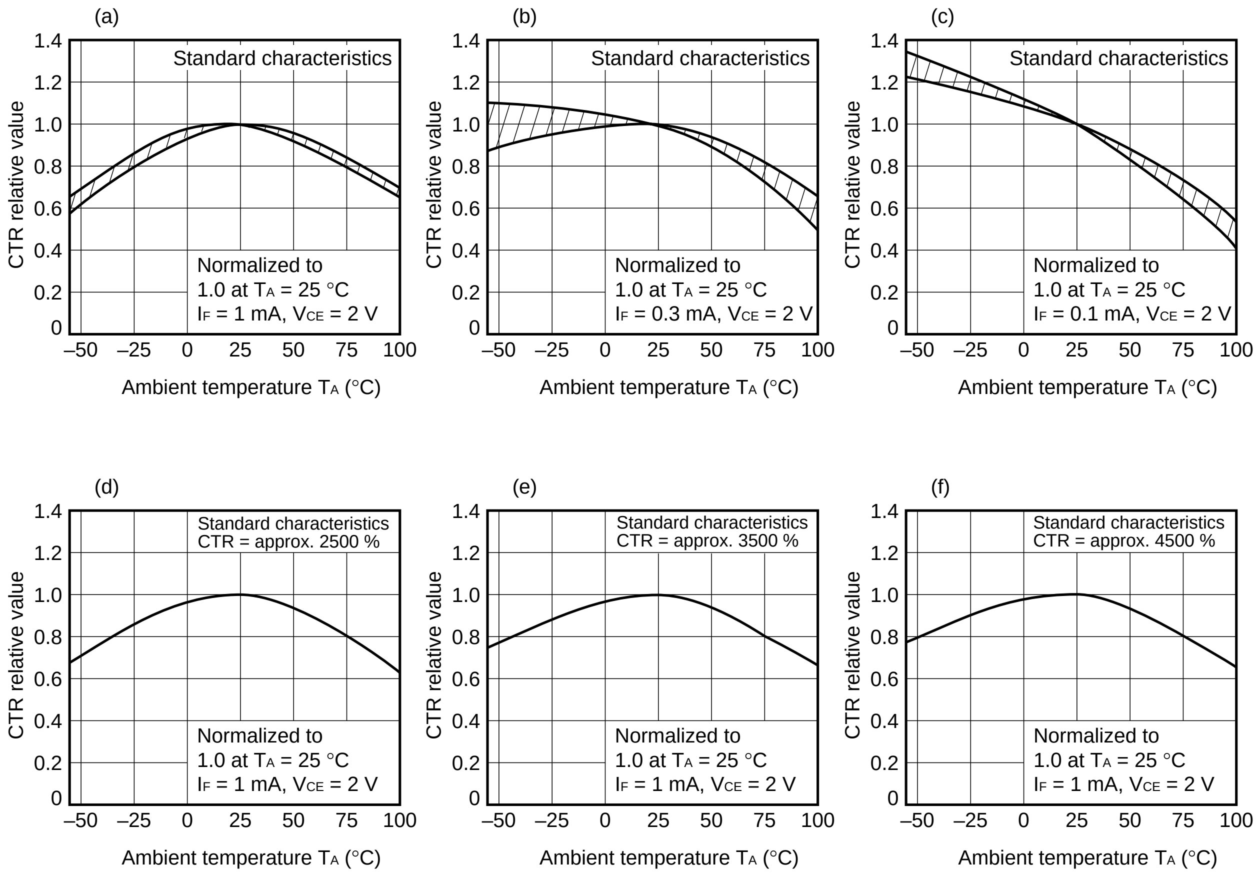
Fig. 35 CTR vs. I_F characteristics (Standard value) (PS2502, PS2506)



4.1.2 CTR vs. temperature characteristics

Figures 36 (a) to 36 (f) show CTR vs. temperature characteristics under various conditions.

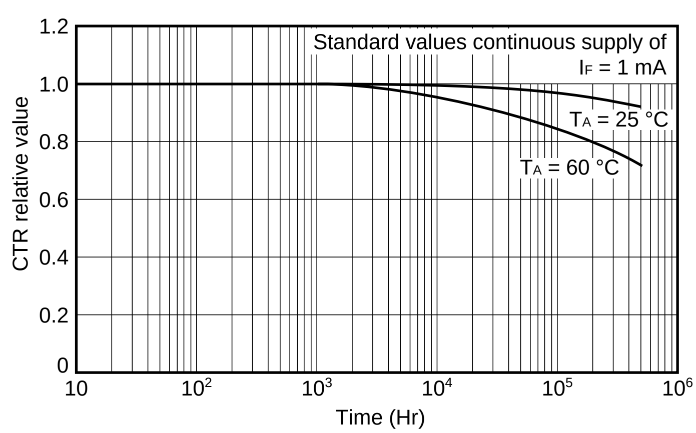
Figs. 36 (a) to (f) CTR vs. temperature characteristics (PS2502, PS2506)



4.1.3 Change of CTR over time

Figure 37 shows the CTR vs. time characteristics of the PS2502 and PS2506 photocouplers.

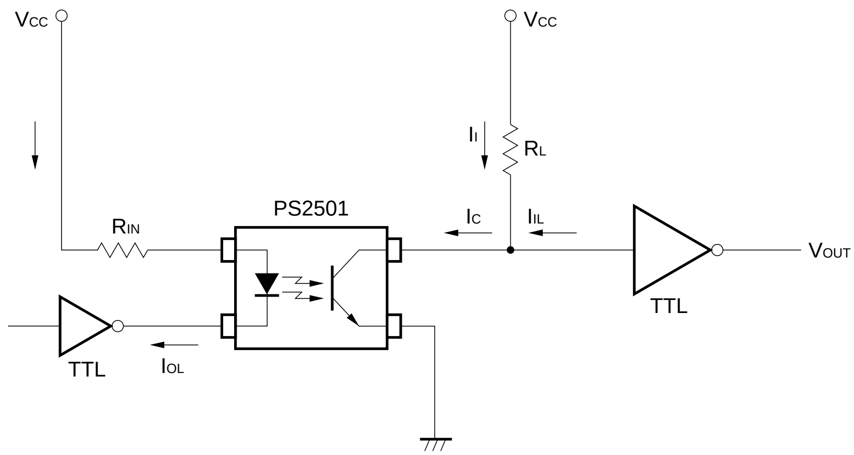
Fig. 37 CTR vs. time characteristics (Standard value)



5. EXAMPLE OF CIRCUIT DESIGN

Here shows an example of circuit design using the PS2501 as a TTL interface shown in Figure 38.

Fig. 38 Circuit TTL interface example



First, assume that the following design standard is set.

<1> Operation temperature range: 0 to 60 °C
<2> Supply voltage: V_{CC} = 5 V
<3> Service life of equipment: 10 years
<4> Signal responsibility: 2k bits/(500 μs)

In Figure 38, if the input LED is driven by TTL, the LED drive current should be designed to be $I_F \leq 16$ mA from relational expression $I_{OL} \leq 16$ mA. Here design is carried out setting.

$$I_F = 5 \text{ mA}$$

At this time, input resistance R_{IN} is calculated as follows.

$$R_{IN} = \frac{V_{CC} - V_F - V_{OL}}{I_F} = \frac{5 - 1.1 - 0.4}{5} = 700\ \Omega$$

First, assume that the following design standard is set.

<1> In addition, the lower limit of CTR is calculated as follows taking 80 % as a reference under the catalog condition.
<2> From Figure 7, temperature change (T_A = 60 °C) 15 % down (with respect to initial value T_A = 25 °C).
<3> From Figure 8, time-dependent change characteristic (10 years, T_A = 60 °C) 20 % down (with respect to initial value 0 years).
<4> Furthermore, a design margin of approximately 30 % to 50 % is assumed taking account of variations.

$$CTR_{(MIN.)} = 80\ \% \times 0.85 \times 0.8 \times 0.6 \fallingdotseq 32.6\ \%$$

Therefore, collector current $I_{C\ (MIN.)}$ is calculated as follows.

$$I_{C\ (MIN.)} = I_F \times CTR_{(MIN.)} = 5 \times 0.326 = 1.63 \text{ mA}$$

This I_C should be greater than sink current I_{IL} of standard TTL and in order to ensure that output is turned on with this input signal, load resistance R_L is as follows.

$$R_L \geq \frac{V_{CC} - V_{IL}}{I_C - (-I_{IL})} = \frac{5 - 0.8}{1.63 - 1.6} = 140\ \text{k}\Omega$$

However, too large R_L may cause output to turn on with a leakage current of the photo transistor or I_{IH} of TTL. Therefore, R_L should be:

$$R_L \leq \frac{V_{CC} - V_{OH}}{I_{CEO} + I_{IH}} = \frac{5 - 2.4}{0.2 + 40} \fallingdotseq 64\ \text{k}\Omega$$

($I_{CEO\ (MAX.)}$ is approximately 200 nA according to Figures 27 to 29.)

Therefore, it is necessary to select a sample with high CTR for optimal design. If 200 % (MIN.) (CTR rank: L specification) is used instead of 80 % (MIN.) that was initially designed, calculation results as follows.

$$R_L \geq \frac{V_{CC} - V_{IL}}{I_C - (-I_{IL})} = \frac{5 - 0.8}{4.08 - 1.6} \fallingdotseq 1.7\ \text{k}\Omega$$

Therefore, by selecting the load resistance in the range of:

$$1.7\ \text{k}\Omega \leq R_L \leq 64\ \text{k}\Omega$$

It is possible to ensure that ON/OFF operation is enabled.

However, since 2k bits/s is specified for switching operation, it is necessary to select R_L of approximately 5 kΩ according to Figures 15 to 20.

6. CONCLUSION

Demand for photocouplers featuring higher insulation and noise elimination is steadily increasing. At the same time, various problems (change of characteristics by ambient temperature and time elapse) will occur in their circuit design. We hope this manual will be helpful in solving such problems.