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Current Transfer Ratio (CTR) and Response Time of Photocouplers / Optocouplers

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Technical Description

Current Transfer Ratio (CTR) and Response Time of Photocouplers / Optocouplers

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Overview

1.Current transfer ratio (CTR)

The current transfer ratio (CTR) is a parameter similar to the DC current amplification ratio of a transistor (h_{FE}) and is expressed as a percentage indicating the ratio of the output current (I_C) to the input current (I_F).

$CTR(\%)=(I_C/I_F) \times 100$

The CTR has the following characteristics and is therefore as important as the insulation tolerance among the characteristics of a photocoupler.

It depends on the current input to the LED (I_F)
It is affected by the room temperature
It changes with the operating time (age)

Sufficient care must therefore be taken with the CTR when designing; if design is not executed making enough allowance for these points, the output may be too small, causing malfunction.

Moreover, an AC (alternating current) input capable photocoupler has two LEDs (light emitting diodes) on the input side, so a CTR will also exist for each of these LEDs.
Even if I_F with the same positive and negative value is input, the value of the output current I_C will differ for each polarity of I_F, so care must be taken on these points as well.

i. CTR dependency on LED input current (I_F)

The CTR depends on the LED input current (I_F), so as shown in Figure 1, the CTR decreases from a maximum point when the input current is both increased and decreased.

Figure 1. Example of CTR Dependency on I_F

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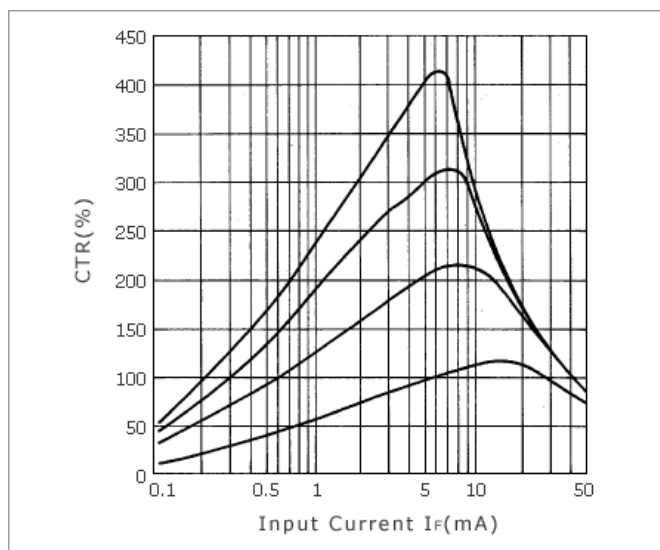
It is particularly important that the positive and negative curves of the CTR vs. input current variation slope differ between the small current area (around $I_F = 1$ mA) and the large current area (around $I_F = 20$ mA). In other words, the value of I_F should be designed larger than necessary because the output current I_C becomes substantially smaller as the value of I_F decreases in the small current area.
Conversely, in the large current area, the output current I_C does not become as large as expected even if the value of I_F increases, so the value of I_C should be designed less than your expectation.

ii. CTR dependency on temperature

Whereas the LED luminous efficiency has a negative temperature coefficient, hFE of the transistor has a positive temperature coefficient. Therefore, the CTR dependency on the temperature is a combination of these two parameters.
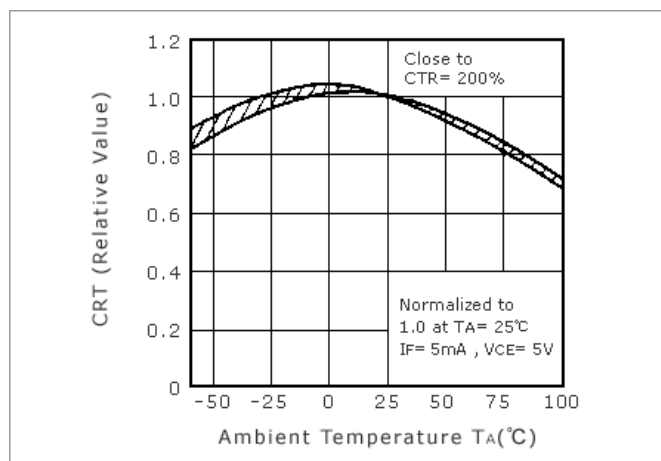As shown in Figure 2, the CTR dependency on the temperature is normally realized by synthesizing the above two temperature coefficients.

Figure 2. Mechanism of CTR Dependency on Temperature

Figure 3 shows an example of an actual product.

Figure 3. Example of CTR Temperature Characteristics

iii. Change of CTR over operating time

The CTR of a photocoupler is based mainly on the following factors.

The luminous efficiency of the LED (light-emitting diode)
The optical coupling efficiency between the LED and the photo-transistor
The photo-electrical conversion efficiency and DC amplification (h_{FE}) of the photo-transistor

The change of the CTR over operating time is mainly caused by a drop in the luminous efficiency of the LED. In general, the larger the LED input current (I_F) and the higher the ambient temperature, the faster the CTR decreases.

Figure 4 shows an example of the estimated curve of the change over time according to differences in the ambient temperature.

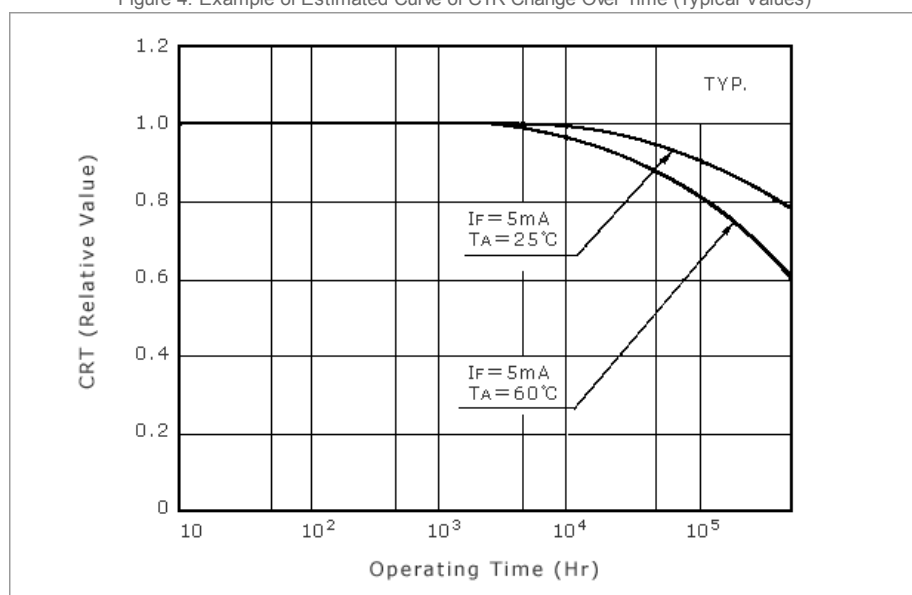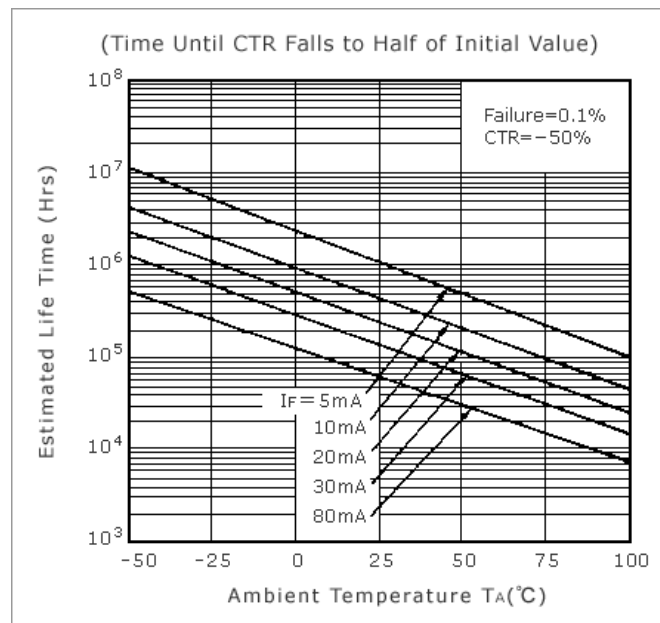Figure 4. Example of Estimated Curve of CTR Change Over Time (Typical Values)

Figure 5 shows an example of the estimated life of a photocoupler according to differences in the LED input current (I_F) and the ambient temperature (T_A).

Figure 5. Example of Estimated Life of Photocoupler Based on CTR

(Time Until CTR Falls to Half of Initial Value)

Failure=0.1%
CTR=−50%

I_F=5mA
10mA
20mA
30mA
80mA

Estimated Life Time (Hrs)
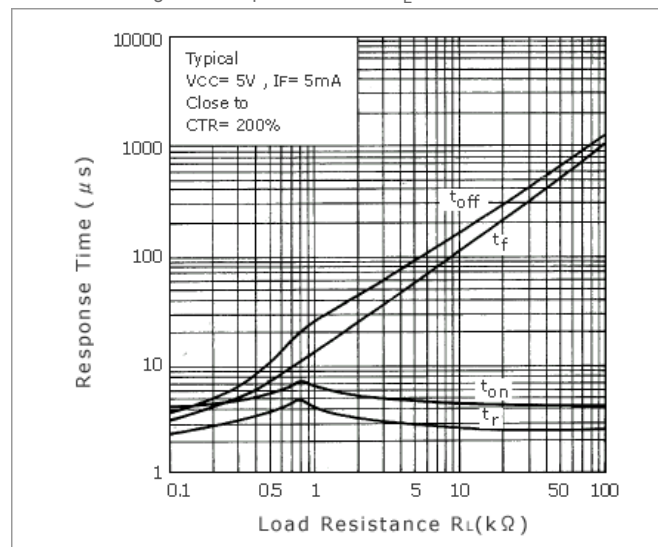
Ambient Temperature T_A(°C)

2.Response time

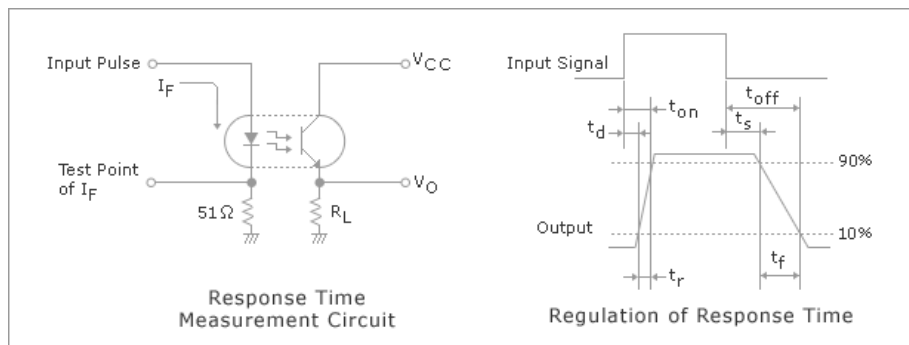The response time of a photocoupler is similar to that of a transistor, and is expressed as follows.

t_f // $R_L \times h_{FE} \times C_{CB}$

R_L: Load resistance, h_{FE}: DC amplification, C_{CB}: Capacitance between collector and base

From this formula, t_f increases as the load resistance increases as shown in Figure 6, so for high-speed signal transfer, the load resistance must be designed as small as possible within the allowable rating range.

Figure 6. Response Time vs. R_L Characteristics

Typical
Vcc= 5V , IF= 5mA
Close to
CTR= 200%

t_{off}
t_f
t_{on}
t_r

Response Time (μs)

Load Resistance R_L(kΩ)

Response Time
Measurement Circuit

Regulation of Response Time

However, when the load resistance is minimized, the transistor may not become completely ON and the output signal may be unstable unless the input current IF and output current IC are determined making sufficient allowance for factors such as the CTR specification range, the temperature characteristics, and the change over time.

Some examples of these characteristics are introduced below.

Figure 7 shows an example of the variation in the response time according to the ambient temperature (T_A).
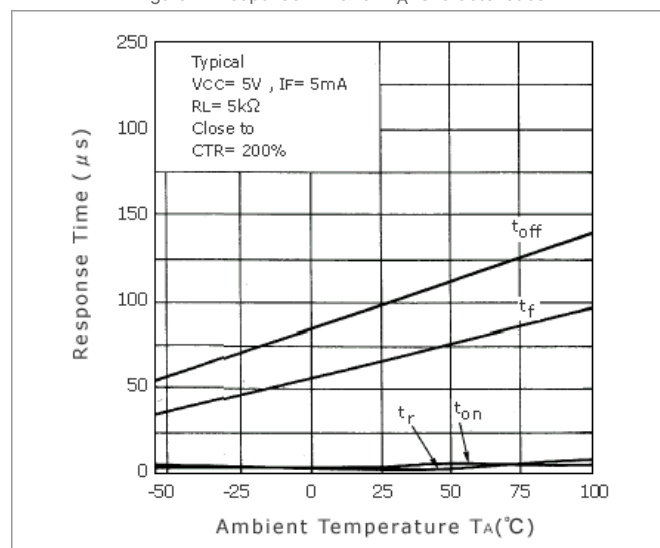
Figure 7. Response Time vs. T_A Characteristics

Figure 8 shows an example of the variation in the response time according to the input current (I_F).
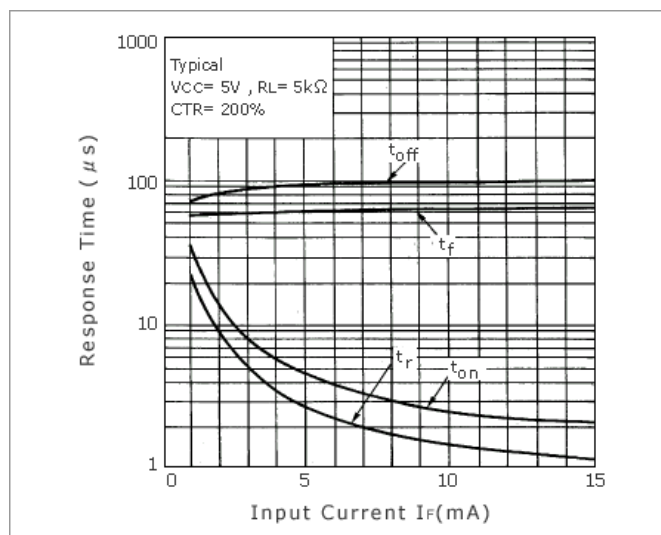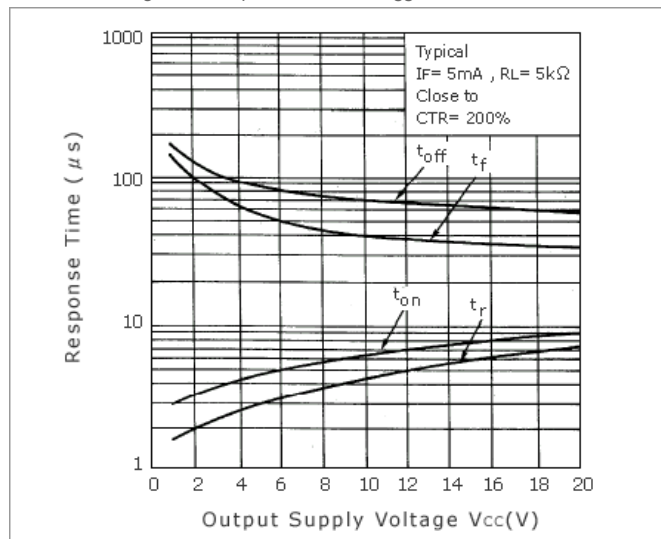
Figure 8. Response Time vs. I_F Characteristics

Figure 9 shows an example of the variation in the response time according to the power supply current (V_{CC}).

Figure 9. Response Time vs. V_{CC} Characteristics

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