Optocoupler/Photocoupler

Lifetime of Optocoupler/Photocoupler

R08AN0015EJ0100
Rev.1.00
Aug. 30, 2024

Introduction

This application note describes about the basic theory of the lifetime of Optocoupler/Photocoupler*1) product, both for transistor output model and IC output model.

It will be also explained how to request specific lifetime data.

*1) In the following text, the term of Optocoupler is only used.

Contents

Basic structure of Optocoupler

1.1 Basic structure

1.1.1 Cross-sectional structure

An Optocoupler is a safety part that is electrically isolated and transmit signals.

To realize this function, the optocoupler is assembled with the LED, Light-Emitting-Diode, and the photodetector facing each other with a resin that transmits light in between as show in Figure1.1.

The input electrical signal is converted to an optical signal once, transmitted through the resin, isolated space, then converted back to an electrical signal and output.

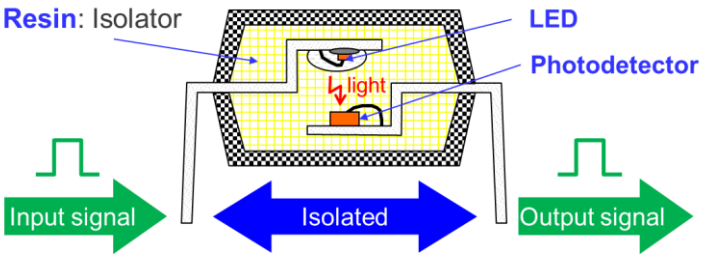

Figure 1.1 Schematic Cross-section of Optocoupler

1.1.2 LED and photodetector

The LEDs mounted on our optocouplers are made of GaAs or AlGaAs. On the other hand, photodetectors are Si products.

Even when operating within the rated specifications, quantum efficiency, photon ratio generated by electrons of input current (in another word the luminous efficiency) of an LED will decrease over time due to current and temperature stress at the PN junction.

Since the degradation of this LED is faster than that of the Si photodetector, LED is dominate in terms of semiconductor chip lifetime.

Our optocouplers are available in models with Transistor output ones and an IC output type, we are using several kinds of LEDs for both models to realize the required characteristics.

The following chapters explain the lifetime of these two types of products.

2. Lifetime of Optocoupler

2.1 Lifetime of Transistor output Optocoupler

2.1.1 CTR

CTR, Current Transfer Ratio, is a parameter that is similar to the DC current amplification factor (hFE) of transistor and represents the ratio of the output current (IC) to the input current (IF) as shown (1).

CTR = (IC / IF) × 100% --- (1)

CTR is, alongside the dielectric strength voltage, one of the most important characteristics of transistor output Optocoupler. It is the item user must pay the most attention to when designing circuits.

CTR of an optocoupler depends mainly on four parameters below.

(i) Luminous efficiency of the LED.
(ii) Optical coupling factor between the LED and the photodetector (here by phototransistor).
(iii) Detection characteristics of the phototransistor.
(iv) Current amplification factor (hFE) of the phototransistor.

It is possible to estimate the lifetime of an optocoupler by determining the percentage of the decrease in CTR that can be tolerated under the same conditions.

2.1.2 Lifetime of Transistor output Optocoupler

The deterioration of the CTR, which is composed of these four parameters, depends mainly on the input current IF and the operating ambient temperature Ta.

For example, in the case of LED, the degradation of its luminous efficacy, which is indicated at (i) in the 2.1.1, over time depends on the current and temperature of the PN junction. We conduct long-term reliability tests for each LED that we adopted, in part, the package structure also taken into account, using multiple combinations of input current (IF) and operating ambient temperature (Ta).

From the results, we calculate each acceleration factor and are able to estimate the lifetime under actual usage conditions.

2.1.3 Request for Lifetime Data of Transistor output Optocoupler.

If you require life data, please contact our sales department or FAE, providing the product part number and the IF and TA required for the lifetime design.

We will submit life data in the format shown in Figure 2.1

Δ CTR is the change rates of the CTR, and defined in equation (2).

$$\Delta \text{CTR}[\%] = \frac{\text{Over time change of CTR\%]}}{\text{initial CTR}[\%]} \quad \text{--- (2)}$$

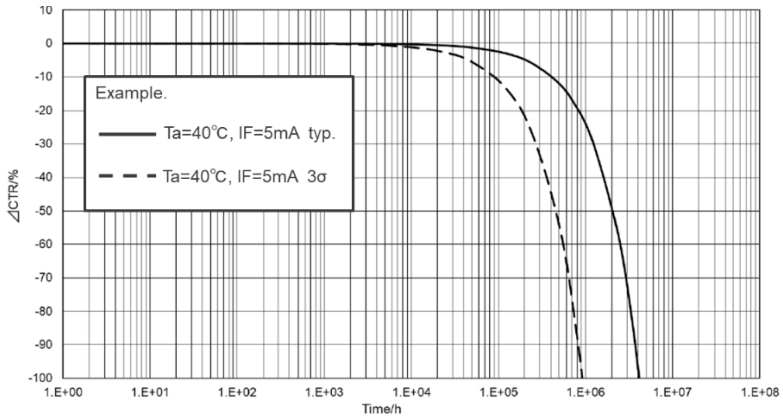

Figure 2.1 Examples of Lifetime data for Transistor output Optocoupler,

We can also accept requests for multiple combinations of IF and Ta.

From this graph, you can estimate the lifetime by designing how much the CTR can drop from the initial value.

Furthermore, the estimated life is inversely proportional to Duty and system operation rate as follows (3).

$$\text{Estimated Life} = \frac{\text{estimated lifetime at Duty (100\%)}}{\text{Actual Duty x System operation rate}} \quad \text{--- (3)}$$

2.2 Lifetime of IC output Optocoupler 1: Gate Driver and for Communication

2.2.1 IFHL, IFLH

For IC output type optocouplers, there is no CTR indicator since the processing is mainly digital in the photodetector IC. In the Gate Driver and Optocoupler for Communication case, the decrease in the LED's luminous efficiency is detected by the Threshold Input Current, IFHL or IFLH, and used to estimate its lifetime.

IFHL: Active Low output threshold current.
IFLH: Active High output threshold current.

IFHL or IFLH of an optocoupler depends mainly on three parameters below.

(i) Luminous efficiency of the LED.
(ii) Optical coupling factor between the LED and the photodetector (here by photodetector built-in IC).
(iii) Detection characteristics of the photodetector.

It is possible to estimate the lifetime of an optocoupler by determining the percentage of the decrease in IFHL or IFLH that can be tolerated under the same conditions.

2.2.2 Lifetime of IC output Optocoupler 1

The deterioration of the IFHL or IFLH, which is composed of these three parameters, depends mainly on the input current IF and the operating ambient temperature Ta in the same way as Transistor output optocoupler.

2.2.3 Request for Lifetime Data of IC output Optocoupler 1

If you require life data, please contact our sales department or FAE, providing the product part number and the IF and Ta required for the lifetime design.

We will submit life data in the format shown in Figure 2.2

ΔIFHL and ΔIFLH are the change rates of the IFHL and IFLH for each, and defined in equation (4) and (5).

$$\Delta \text{IFHL}[\%] = \frac{\text{Over time change of IFHL}[\text{mA}]}{\text{initial IFHL}[\text{mA}]} \quad \text{--- (4)}$$

$$\Delta \text{IFLH}[\%] = \frac{\text{Over time change of IFLH}[\text{mA}]}{\text{initial IFLH}[\text{mA}]} \quad \text{--- (5)}$$

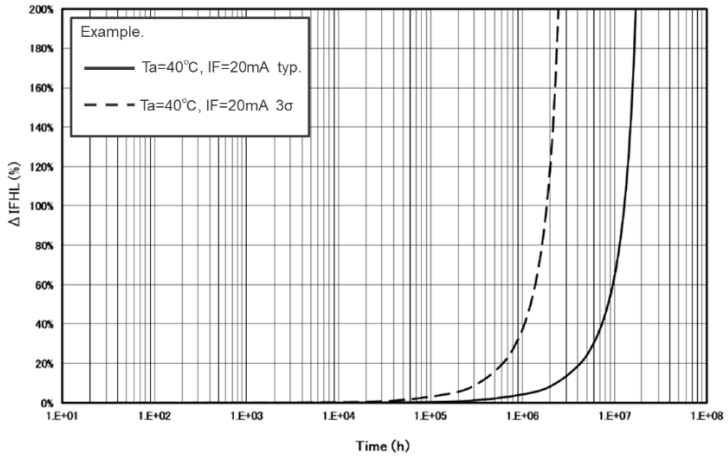

Figure 2.2 Examples of Lifetime data for IC output Optocoupler,

We can also accept requests for multiple combinations of IF and Ta.

From this graph, you can estimate the lifespan by calculating ΔIFHL[%] or ΔIFLH[%] at lifetime end as follows, (6) or (7).

$$\Delta \text{IFHL[\%] at lifetime end} = \frac{\text{Forward current IF[mA] designed by customer} - \text{initial IFHL[mA]}}{\text{initial IFHL[mA]}} \quad \text{--- (6)}$$

$$\Delta \text{IFLH[\%] at lifetime end} = \frac{\text{Forward current IF[mA] designed by customer} - \text{initial IFLH[mA]}}{\text{initial IFLH[mA]}} \quad \text{--- (7)}$$

The horizontal axis of the graph in this document shows the Lifetime when Duty is 100%.

Furthermore, the estimated life is inversely proportional to Duty and system operation rate as follows (8).

$$\text{Estimated Life} = \frac{\text{estimated lifetime at Duty (100\%)}}{\text{Actual Duty x System operation rate}} \quad \text{--- (8)}$$

2.3 Lifetime of IC output Optocoupler 2: Isolation Amp. and Sigma-Delta Modulator

In the case of the Isolation Amplifier and ΔΣ Modulator, the input is the voltage and current to be monitored, and since the LED drive circuit is built into the primary side, it is not possible to determine the lifespan based on IF.

We will provide you with lifetime data for the case where the most severe input conditions are continued, so please let us know the product part number.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Aug.30.24	—	Initial release

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.
   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION (“Vulnerability Issues”). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult application note and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/.