

RS-232 Transceivers

Isolating RS-232 Interfaces with High-Speed Digital Optocouplers

AN1992
Rev.0.00
Mar 14, 2018

Abstract

Many industrial instrumentation applications use digital optocouplers to isolate RS-232 interfaces. This application note discusses the design of an isolated RS-232 interface using Renesas digital high-speed optocouplers.

Contents

1.	Functional Principle and Construction of Optocouplers	2
2.	LED Drive Circuits for Low-Current Voltage Sources	2
3.	Isolated RS-232 Interface	3
3.1	Calculating the Current Setting Resistor Values	4
3.2	Determining the Collector Resistor Values	4
3.3	Signal Waveforms	4
4.	References	4
5.	Revision History	5

List of Figures

Figure 1.	Functional Block Diagram	2
Figure 2.	Optocoupler Constructions	2
Figure 3.	Typical LED Drive Circuit	3
Figure 4.	AC Equivalent Circuit	3
Figure 5.	Recommended LED Drive Circuit	3
Figure 6.	AC Equivalent Circuit	3
Figure 7.	3.75kV Isolated RS-232 Interface	3
Figure 8.	Signal Waveforms for Transmit and Receive Channels	4

1. Functional Principle and Construction of Optocouplers

An optocoupler provides signal transfer between an isolated input and output using an infrared Light Emitting Diode (LED) and a silicon phototransistor ([Figure 1](#)). The LED sends a beam of infrared energy to an optical receiver inside a single package with a light conducting medium between the emitter and the detector. This mechanism provides complete electrical isolation of electronic circuits from input to output while transmitting information from one side to the other, and from one voltage potential to another.

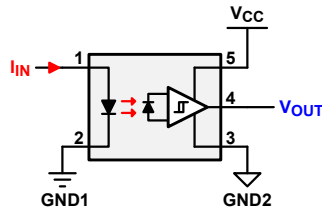


Figure 1. Functional Block Diagram

The manufacturing process and structure of an optocoupler varies between manufacturers. Renesas optocouplers are constructed based on single or double mold processes ([Figure 2](#)), and rated at Moisture Sensitivity Level (MSL) 1.

Typically, the lead frame material is either Cu alloy or Alloy 42 with the plating being either SnBi or NiPdAu. The silicone resin that covers the surface of an LED die is used to extract more light by better matching the index of refraction.

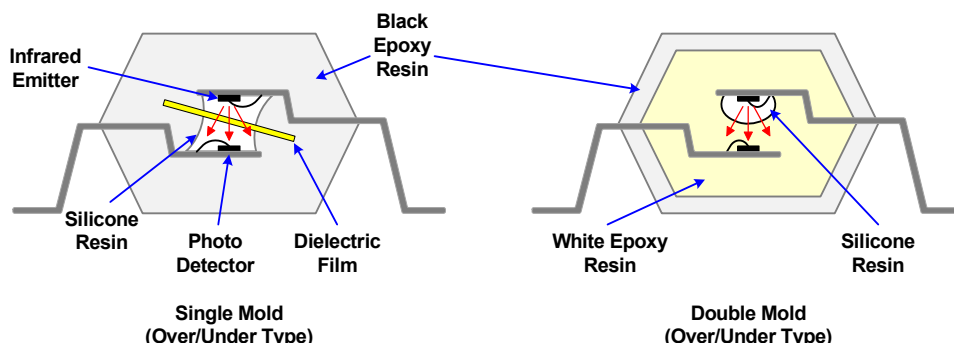


Figure 2. Optocoupler Constructions

The single molded over/under technique provides the best light coupling efficiency because a silicone resin is used as a medium for direct contact between the LED and the Si detector die. To further improve the common-mode noise rejection and isolation voltage, glass or polyamide film is inserted in between the LED and the detector die. A black epoxy resin is used to house the device.

The double molded device is similar to the single molded version but it has an additional inner mold with high dielectric white epoxy resin acting as a light pipe to provide the best reliability.

2. LED Drive Circuits for Low-Current Voltage Sources

[Figure 3 on page 3](#) shows a typical drive circuit for optocouplers using a single resistor (R_S) that sets the forward current of the LED. Its value is calculated using [Equation 1](#):

$$(EQ. 1) \quad R_S = \frac{V_{CC1} - V_F - V_{OL}}{I_F}$$

In [Equation 1](#) V_F and I_F are the typical forward voltage and current of the LED, and V_{CC1} and V_{OL} are the nominal supply voltage and typical low output voltage of the input buffer (B). This buffer is used to ensure a reliable LED drive that is independent of the I/O drive capability of the local MCU or UART.

Due to the optocoupler's internal construction, leakage capacitances (C_{LA} and C_{LC}) exist that allow common-mode transients to capacitively couple from the LED anode and cathode to the output-side ground (Figure 4 on page 3). This coupling can cause forward current to be shunted away from the LED, which could momentarily turn off the LED during an ON condition, or conversely cause current to be injected into the LED, which could momentarily turn on the LED during an OFF condition. In both cases output glitches can occur that lead to data errors.

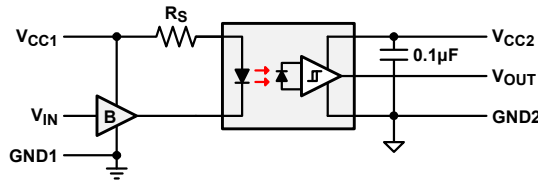


Figure 3. Typical LED Drive Circuit

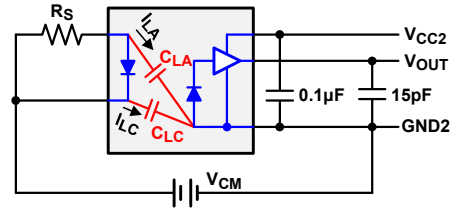


Figure 4. AC Equivalent Circuit

To reduce the risk of output glitches and thus improving common-mode rejection, it is necessary to balance the common-mode impedance at the LED anode and cathode. This is achieved by using two current setting resistors, each with a value of $R_S/2$. Figure 5 shows the recommended drive circuit for optimum CMR and Figure 6 shows its AC equivalent circuit.

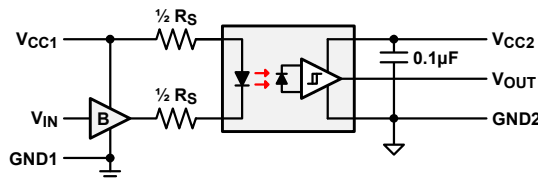


Figure 5. Recommended LED Drive Circuit

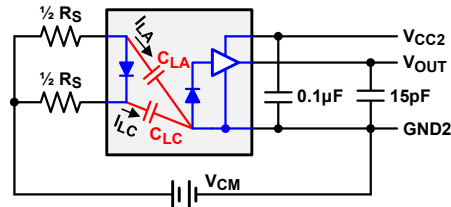


Figure 6. AC Equivalent Circuit

3. Isolated RS-232 Interface

Figure 7 shows an isolated RS-232 interface using PS9121 optocouplers rated for 3.75kV isolation and up to 15Mbps data rate. Its output supply range is from 2.7V to 3.6V. The RS-232 transceiver ICL3221EF is specified with a data rate of 250kbps and operates from a 3.0V to 3.6V supply. Logic buffers (B) are used to drive the necessary LED currents that usually cannot be provided by low-power MCUs or RS-232 receiver outputs.

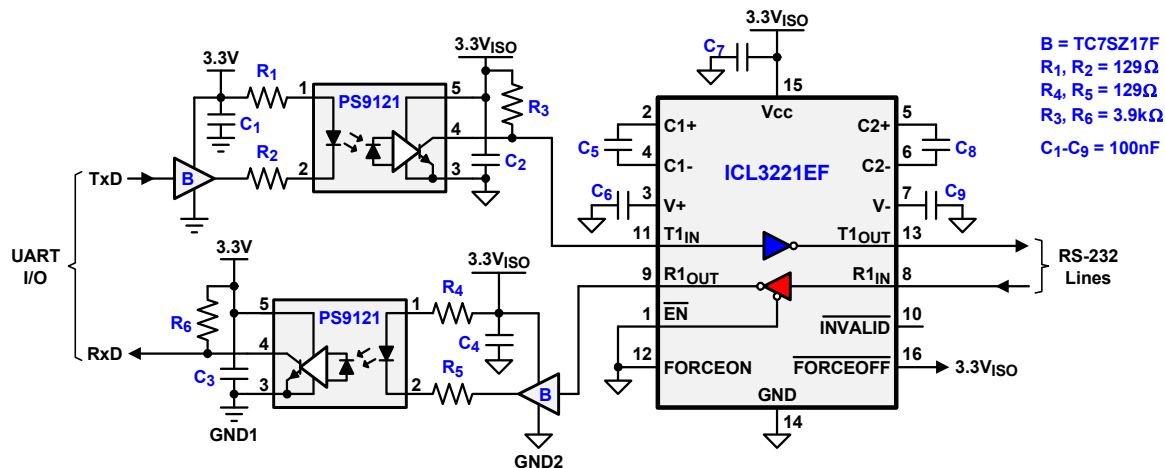


Figure 7. 3.75kV Isolated RS-232 Interface

B = TC7SZ17F
R₁, R₂ = 129Ω
R₄, R₅ = 129Ω
R₃, R₆ = 3.9kΩ
C₁-C₉ = 100nF

3.1 Calculating the Current Setting Resistor Values

To calculate the values of the current setting resistor, the typical LED current is given with 10mA, and the typical forward voltage is specified with 1.65V. For a nominal supply of 3.3V, the output low level voltage of the logic buffer is determined with 0.25V. Then, using [Figure 1](#) the value of R_S is:

$$(EQ. 2) \quad R_S = \frac{V_{S(nom)} - V_{F(typ)} - V_{OL(typ)}}{I_{F(typ)}} = \frac{3.3V - 1.65V - 0.25V}{10mA} = 140\Omega$$

For maximum CMR make R_1 , R_2 , R_4 , and $R_5 = R_S/2$, or 70Ω. Here, use the closest standard value of 68Ω.

3.2 Determining the Collector Resistor Values

The PS9121 optocouplers have open collector outputs that require pull-up resistors (R_3 , R_6). Their value can range from 330Ω to 4kΩ. Although the higher the resistor value, the greater the pulse width distortion. However, since the ICL3221 has a data rate of only 250kbps ($t_{bit} = 4\mu s$), the optocoupler's pulse width distortion of <100ns at 4kΩ remains noncritical. Hence, to lower the output current consumption, R_3 and R_6 are chosen with 3.9kΩ.

3.3 Signal Waveforms

[Figure 8](#) shows the signal waveforms of the isolated interface circuit in [Figure 7](#).

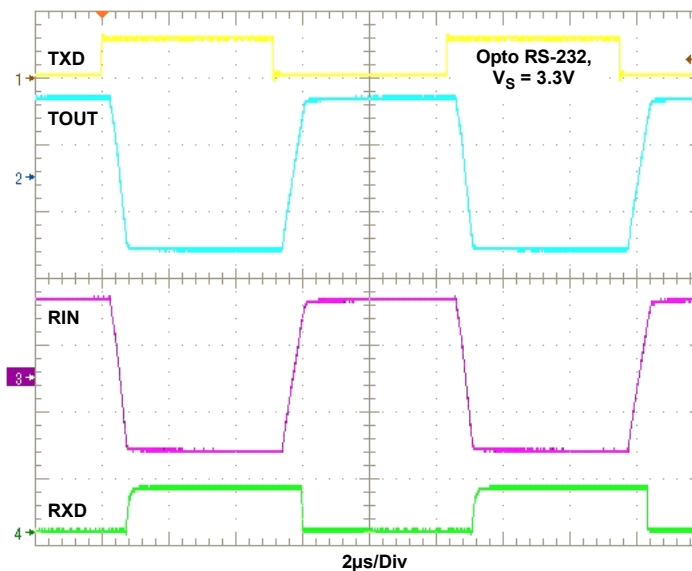


Figure 8. Signal Waveforms for Transmit and Receive Channels

4. References

For more information on optocouplers and RS-232 transceivers, refer to our website.

- [PS9121](#) datasheet: High CMR, 15Mbps Open Collector Output Photocoupler
- [ICL3221E](#) datasheet: ±15kV ESD, 3.3V, 1μA, 250kbps, RS-232 Transmitter/Receiver
- Application note AN3020: A Guide to Designing with Optocouplers

5. Revision History

Rev.	Date	Description
0.00	Mar 14, 2018	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 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 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.
 5. 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.
 6. 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.
 7. 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 and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
 8. 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.
 9. 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.
 10. 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.
 11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
- (Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.

1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited

9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited

Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.

Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.

No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.

17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338