

## RS-232 Transceivers

Isolating RS-232 Interfaces with High-Speed Digital Optocouplers

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### 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

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

### 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.

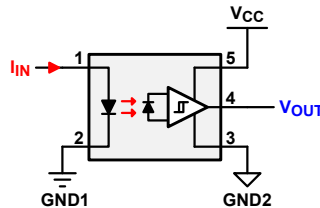


Figure 1. Functional Block Diagram

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.

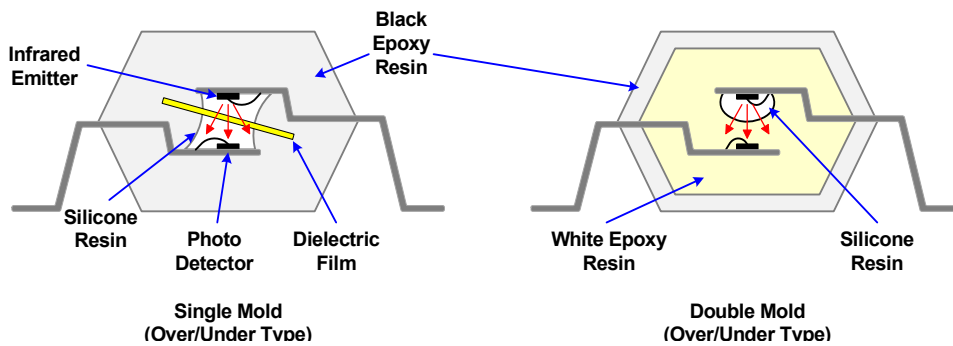


Figure 2. Optocoupler Constructions

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.

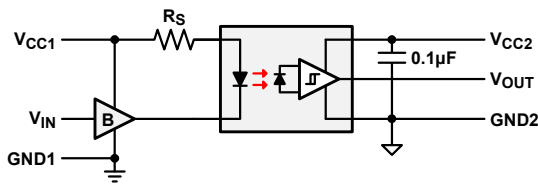


Figure 3. Typical LED Drive Circuit

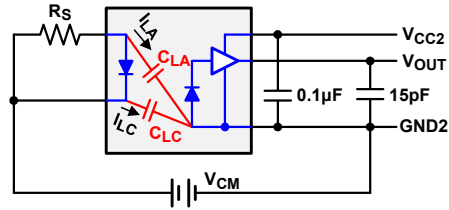


Figure 4. AC Equivalent Circuit

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.

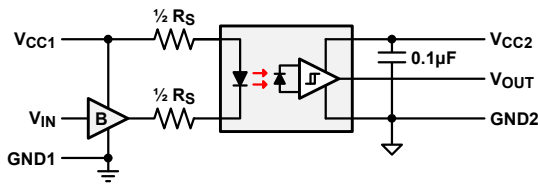


Figure 5. Recommended LED Drive Circuit

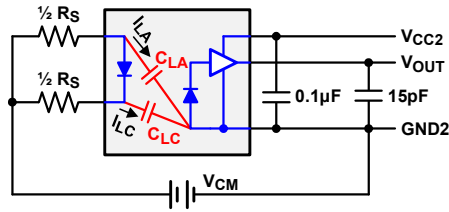


Figure 6. AC Equivalent Circuit

### 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.

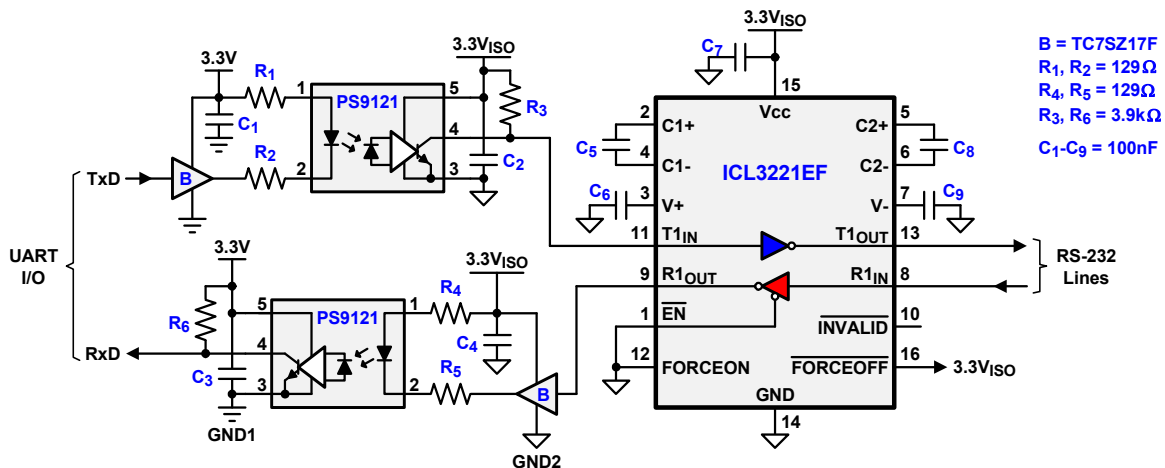


Figure 7. 3.75kV Isolated RS-232 Interface

### 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](#).

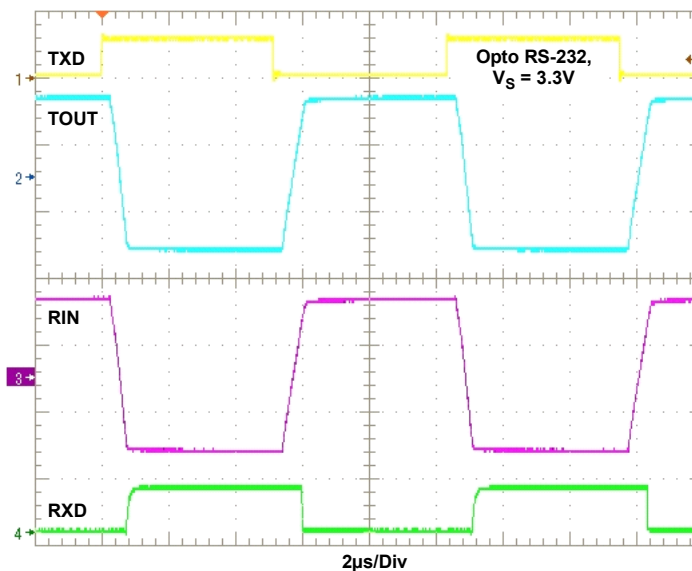


Figure 8. Signal Waveforms for Transmit and Receive Channels

## 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

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