INTRODUCTION
The I²C bus, also known as inter-IC bus, is a bidirectional, two-wire, multi-user bus, as shown in Fig. 1. It was developed by Philips Semiconductors (1) to connect micro controllers, EEPROMs, A/D and D/A converters, I/O interfaces, and other peripherals. The I²C bus consists of two lines: a serial data line (SDA) and a serial clock line (SCL). This serial bus has a data transfer rate of up to 100 kBit/s in the standard mode, up to 400 kBit/s in the fast mode, and up to 1 MBit/s in the fast mode plus. The 3.4 MBit/s high speed mode and the 5 MBit/s ultra fast mode are not considered in this application note, because they require either current-source pull-up circuits or are uni-directional.

A data transmission begins with a START (S) condition, a 7-bit slave address with the read / write designator (R/W), an acknowledge (ACK) bit, 8-bit data following the acknowledge (ACK) bit, and a STOP (P) condition, as shown in Fig. 2.

OPTICAL ISOLATION
For optical isolation between master and slave, an optocoupler is the perfect solution. Due to galvanic isolation, an optocoupler helps to break up ground loops and reduces the electrical noise due to optical light transmission across an isolation barrier.

It can restore the logic level and can be used for signal level transforming between different voltage level domains, e.g. from 5 V to 3.3 V or 24 V.

One channel is required for the serial clock line (SCL) and two channels for the serial data line (SDA) to transmit the data from master to slave and back.

DESIGN CONSIDERATIONS
The I²C bus is an active low data bus using open-collector (open-drain) outputs on master and slave.

When the serial data line (SDA) is pulled down to the logic “L” stage, a voltage divider is formed by the pull-up resistor (R_P), Schottky diode (D), and the internal phototransistor C-E junction. The output voltage (V_O) is the sum of the Schottky diode voltage drop (V_D) and the voltage drop of the phototransistor output (V_{OL}), as shown in Fig. 3.

In the case of the bidirectional serial clock line (SCL), the diode D is not required. In this case, the voltage drop (V_D) will be set to 0. For the logic “H” stage, pull-up resistors (R_P) shown in Fig. 1 are required and can be calculated with the equation below:

\[
R_P = \frac{V_{CC} - V_{OL} - V_D}{I_{OL}}
\]

Note
(1) Reference to UM10204 I²C bus specification and user manual (now NXP Semiconductors):
EXAMPLE CIRCUIT

Fig. 4 depicts an exemplary optical I²C isolator circuit. Vishay’s 10 MBd high speed optocouplers are used: a single channel VO0611 (1) for OC 1 (SDA (backward)) and a dual channel VO0661 (1) for OC 2 (SDA/SCL (forward)). Both are available in SOIC-8 and DIP-8 packages, named as VO2611 (2) and VO4661 (2).

By assuming that SDA/IN/OUT (X1), SDA/OUT/IN (X4), and SCL/IN (X2) are at the logic “L” stage (saturation voltage drop of connected devices at X2 and X4 is neglected), the resistors R1, R2, and R3 set the forward current (IF) through the emitter LEDs of the optocoupler (OC1, OC2) inputs and can be calculated with the equations 2 and 3:

\[ R_1 = R_2 = \frac{V_{CC1} - V_F}{I_F} \]  
(2)

\[ R_3 = \frac{V_{CC2} - V_F}{I_F} \]  
(3)

According to the datasheet figure “Forward Voltage vs. Forward Current” (1), a voltage drop (V_F) of 1.35 V is caused by a forward current (I_F) of 10 mA through the input LED, as shown in Fig. 5.

Notes
(1) www.vishay.com/ppg?84607
(2) www.vishay.com/ppg?84732
By using 5 V as the supply voltage (V_{CC1}, V_{CC2}), values for R_1, R_2, and R_3 can be calculated using the equations 2 and 3:

\[ R_1 = R_2 = \frac{5 \text{ V} - 1.35 \text{ V}}{10 \text{ mA}} = 365 \Omega \]  
\[ R_3 = \frac{5 \text{ V} - 1.35 \text{ V}}{10 \text{ mA}} = 365 \Omega \]

The capacitors C_1 and C_2 stabilize the power supply, and should be placed as close as possible to the optocouplers OC_1 and OC_2.

**WORKING PRINCIPLE**

SCL forward clock transmission:
When SCL/IN (X_2) is at the logic “H” stage, no forward current (I_F) is flowing through the emitter LED (A2/C2) and the optocoupler OC_2 output V_{O2} is also at the logic “H” stage.

When SCL/IN (X_2) is at the logic “L” stage, forward current (I_F) is flowing through the emitter LED (A2/C2) and the optocoupler OC_2 output V_{O2} is also at the logic “L” stage.

SDA forward data transmission:
When SDA/IN/OUT (X_2) is at the logic “H” stage, no forward current (I_F) is flowing through the emitter LED (A1/C1) and the optocoupler OC_2 output V_{O1} is also at the logic “H” stage.

When SDA/IN/OUT (X_2) is at the logic “L” stage, forward current (I_F) is flowing through the emitter LED (A1/C1). The optocoupler OC_1, output V_{O}, and the anode A of the optocoupler OC_1 are at the logic “L” stage, so the emitter LED (A/C) is in reverse mode and bypassed by the diode D_1. Therefore, the emitter LED (A/C) is off and backward data transmission is blocked.

SDA backward data transmission:
When SDA/OUT/IN (X_4) is at the logic “H” stage, no forward current (I_F) is flowing through the emitter LED (A/C) and the optocoupler OC_1 output V_{O} is also at the logic “H” stage.

When SDA/OUT/IN (X_4) is at the logic “L” stage, forward current (I_F) is flowing through the emitter LED (A/C). The optocoupler OC_1, output V_{O}, and the anode A1 are at the logic “L” stage, so the emitter LED (A1/C1) is in reverse mode and bypassed by the diode D_2. Therefore the emitter LED (A1/C1) is off and forward data transmission is blocked.

**CONCLUSION**

It can be seen that by using the Vishay 10 MBd high speed optocoupler series it is easily possible to galvanically isolate I^2C bus systems. Ground loops and electrical noise can be eliminated due to long term proven and robust optical isolation technology.

By choosing Vishay’s small and compact SOIC-8 package board space can be saved. The availability of a dual channel high speed optocoupler in one package provides additional board space savings.

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**RECOMMENDED BILL OF MATERIAL**

<table>
<thead>
<tr>
<th>TABLE 1 - OPTICAL I^2C ISOLATOR</th>
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<tbody>
<tr>
<td>IDENTIFIER</td>
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<tr>
<td>X_1</td>
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<td>OC_1</td>
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<td>OC_2</td>
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**Note**

(1) The closest value to a norm series can be chosen

For technical questions, contact: optocoupleranswers@vishay.com

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