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Optocoupler as Optical Isolator for SPI Bus System

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INTRODUCTION

The serial peripheral interface (SPI) bus as shown in Fig. 1 is a synchronous serial, four-wire, multi-user bus with a clock frequency up to a few MHz. The application areas are inter-chip communication in audio and measurement, LCD displays, SD cards, etc. The SPI bus consists of four lines: a serial clock line (SCLK), master output slave input (MOSI), master input slave output (MISO), and optional slave select (SS).
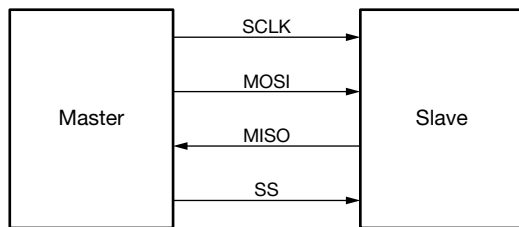
Fig. 1 - 1 Master - 1 Slave SPI Connection

Each line is uni-directional. The master selects a slave by pulling the slave select (SS) line to the logic "L" stage and can communicate with the chosen slave.

In case of more than one slave, each slave needs its own slave select (SS) line.
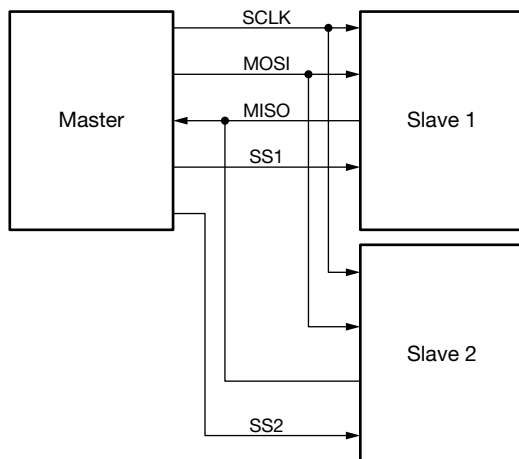
Fig. 2 - 1 Master - 2 Slaves SPI Connection

OPTICAL ISOLATION

In case of electrical noise, coupling effects, or level shifting requirements, an optocoupler is a perfect solution for isolating a master and slave. Due to galvanic isolation, an optocoupler helps to break up ground loops and reduce the noise due to optical light transmission across an isolation barrier. It can also restore the signal logic level and further be used for signal level transforming between different voltage levels, e.g. from 5 V to 3.3 V.

One channel is required for the serial clock line (SCLK), one for the forward data transmission (MOSI), one for the backward data transmission (MISO), and one channel for the slave select line (SS) as shown in Fig. 1.

DESIGN CONSIDERATIONS

When the slave select line (SS) is pulled down to the logic "L" stage, a voltage divider is formed by the pull-up resistor (R_P) and the internal NMOS drain source junction. The output voltage (V_O) is the voltage drop of the open drain output (V_{OL}), as shown in Fig. 3.
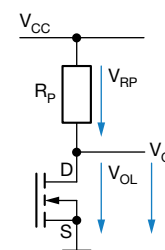
Fig. 3 - Voltage Divider

For the logic "H" stage, pull-up resistors (R_P, as shown in Fig. 4) are required and can be calculated with Equation 1 below:

$$R_P = \frac{V_{CC} - V_{OL}}{I_{OL}} \qquad (1)$$

APPLICATION NOTE

For technical questions, contact: optocoupleranswers@vishay.com

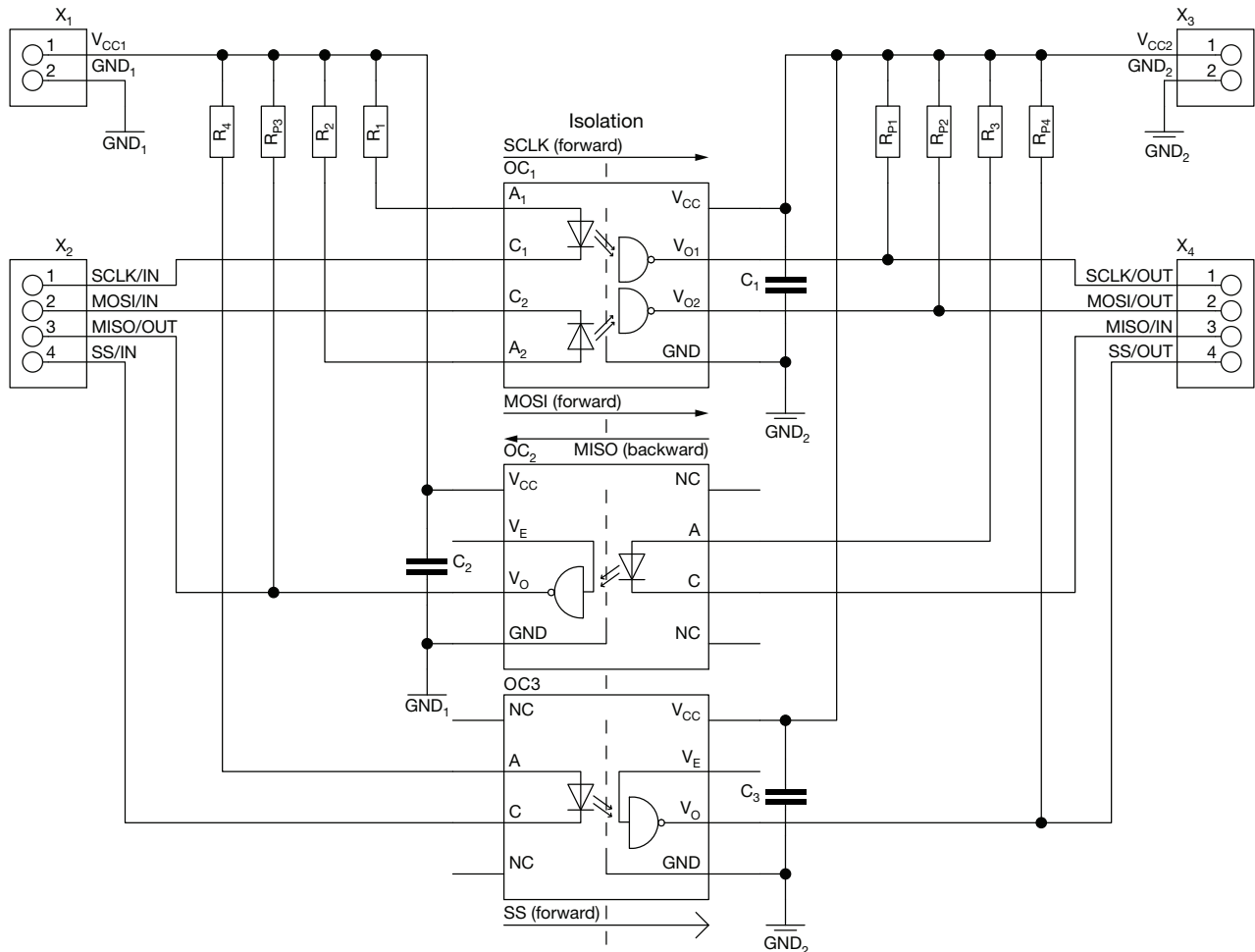# Optocoupler as Optical Isolator for SPI Bus System

EXAMPLE CIRCUIT

Fig. 4 - Example Schematic for Optical SPI Isolator

Fig. 4 depicts an exemplary optical SPI isolator circuit. Vishay's 10 MBd high speed optocouplers are used: a single channel VOH260A [1] for OC_2 (MISO (forward)) and OC_3 (SS (forward)), and a dual-channel VOH263A [2] for OC_1 (SCLK / MOSI (forward)). Both are available in DIP-8 and SOIC-8 packages, named as VOIH060A [3] and VOIH063A [4].

By assuming that SCLK/IN (X_2), MOSI/IN (X_2), MISO/IN (X_4), and SS/IN (X_2) are at the logic "L" stage (saturation voltage drop of connected devices at X_2 and X_4 is neglected), the resistors R_1, R_2, R_3, and R_4 set the forward current (I_F) through the emitter LEDs of the optocoupler (OC_1, OC_2, and OC_3) inputs and can be calculated with Equations 2 and 3:

$$R_1 = R_2 = R_4 = \frac{V_{CC1} - V_F}{I_F} \qquad (2)$$
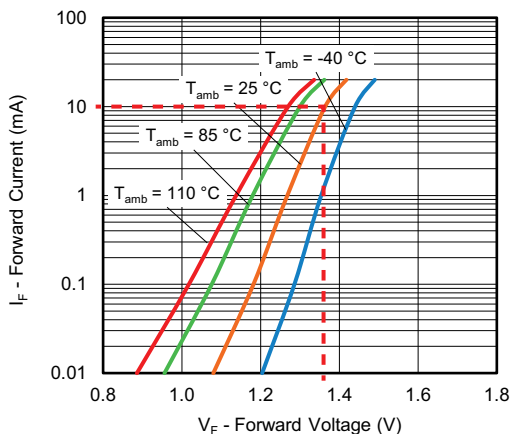
$$R_3 = \frac{V_{CC2} - V_F}{I_F} \qquad (3)$$

According to the datasheet figure "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?80354
[2] www.vishay.com/ppg?80355
[3] www.vishay.com/ppg?80356
[4] www.vishay.com/ppg?80357

APPLICATION NOTE

Optocoupler as Optical Isolator for SPI Bus System

Fig. 5 - VOH260A Datasheet – V_F vs. I_F

By using 5 V as the supply voltage (V_{CC1}, V_{CC2}), values for the resistors R_1, R_2, R_3, and R_4 can be calculated using Equations 4 and 5:

$$R_1 = R_2 = R_4 = \frac{5\ V - 1.35\ V}{10\ mA} = 365\ \Omega\ ^{(1)} \qquad (4)$$

$$R_3 = \frac{5\ V - 1.35\ V}{10\ mA} = 365\ \Omega\ ^{(1)} \qquad (5)$$

The capacitors C_1, C_2, and C_3 stabilize the power supply and should be placed as close as possible to the optocouplers OC_1, OC_2, and OC_3.

Note

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

TRANSMISSION

When SCLK/IN (X_2) is at the logic "H" stage, no forward current (I_F) is flowing through the emitter LED (A_1 / C_1) and the optocoupler OC_1 output V_{O1} is also at the logic "H" stage. When SCLK/IN (X_2) is at the logic "L" stage, forward current (I_F) is flowing through the emitter LED (A_1 / C_1) and the optocoupler OC_1 output V_{O1} is also at the logic "L" stage.

When MOSI/IN (X_2) is at the logic "H" stage, no forward current (I_F) is flowing through the emitter LED (A_2 / C_2) and the optocoupler OC_1 output V_{O2} is also at the logic "H" stage.

When MOSI/IN (X_2) is at the logic "L" stage, forward current (I_F) is flowing through the emitter LED (A_2 / C_2) and the optocoupler OC_1 output V_{O2} is also at the logic "L" stage.

When MISO/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_2 output V_O is also at the logic "H" stage.

When MISO/IN (X_4) is at the logic "L" stage, forward current (I_F) is flowing through the emitter LED (A / C) and the optocoupler OC_2 output V_O is also at the logic "L" stage.

When SS/IN (X_2) is at the logic "H" stage, no forward current (I_F) is flowing through the emitter LED (A / C) and the optocoupler OC_3 output V_O is also at the logic "H" stage.

When SS/IN (X_2) is at logic "L" stage, forward current (I_F) is flowing through the emitter LED (A / C) and the optocoupler OC_3 output V_O is also at the logic "L" stage.

RECOMMENDED PARTS

TABLE1 - OPTICAL SPI ISOLATOR	
IDENTIFIER	**COMMENT**
X_1	Pin header, 2 circuits
X_2	Pin header, 4 circuits
X_3	Pin header, 2 circuits
X_4	Pin header, 4 circuits
R_1	365 Ω resistance
R_2	365 Ω resistance
R_3	365 Ω resistance
R_4	365 Ω resistance
R_{P1}	350 Ω resistance [1]
R_{P2}	350 Ω resistance [1]
R_{P3}	350 Ω resistance [1]
R_{P4}	350 Ω resistance [1]
C_1	100 nF capacitance
C_2	100 nF capacitance
C_3	100 nF capacitance
OC_1	10 MBd (dual) high speed optocoupler VOH263A
OC_2	10 MBd (single) high speed optocoupler VOH260A
OC_3	10 MBd (single) high speed optocoupler VOH260A

Note

(1) Recommended load resistance

CONCLUSION

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

Choosing Vishay's small and compact SOIC-8 package saves board space. The availability of dual-channel, high speed optocouplers in one package provides additional board space savings.

APPLICATION NOTE