# Basics of the standard digital isolators

## Outline:

This document describes fundamental properties and features of standard digital isolators used in communication applications

## Table of Contents

# 1. Overview

This section describes the basic properties and features of the standard digital isolator "DCL54x01" series. This product is an insulated interface composed of buffer logic of high-speed four channels that realizes high common-mode transient immunity (CMTI) of the industry-leading class [Note 1]. The "DCL54x01" series is scheduled to be deployed in ten product types [Note 2].

By adopting our original magnetic coupling type insulated transmission method, high CMTI 100 kV/μs(min) is realized. This contributes to the stable operation of equipment even if affected by noises. It is also suitable for high-speed communication applications because it realizes low pulse-width distortion of 3.0 ns (max) and high-speed data transfer rate 150 Mbps (max). "DCL54x01" series can operate under wide range of supply voltage from 2.25 to 5.5 V. In addition, SOIC16-W packaging complies with UL 1577 and has a 5000 Vrms rating as an isolation voltage.

[Note 1] This is a product with the same rating based on our survey (as of March 2023).
[Note 2] As of March 2023

# 2. Application

## 2.1. Application examples

Industrial automation (programmable logic controller, I/O interface, etc.)
Motor control
Industrial inverters and general-purpose inverters

## 2.2. Examples of inverter applications

The Standard Digital Isolator can communicate at a faster 150 Mbps (max.) than a photocoupler.

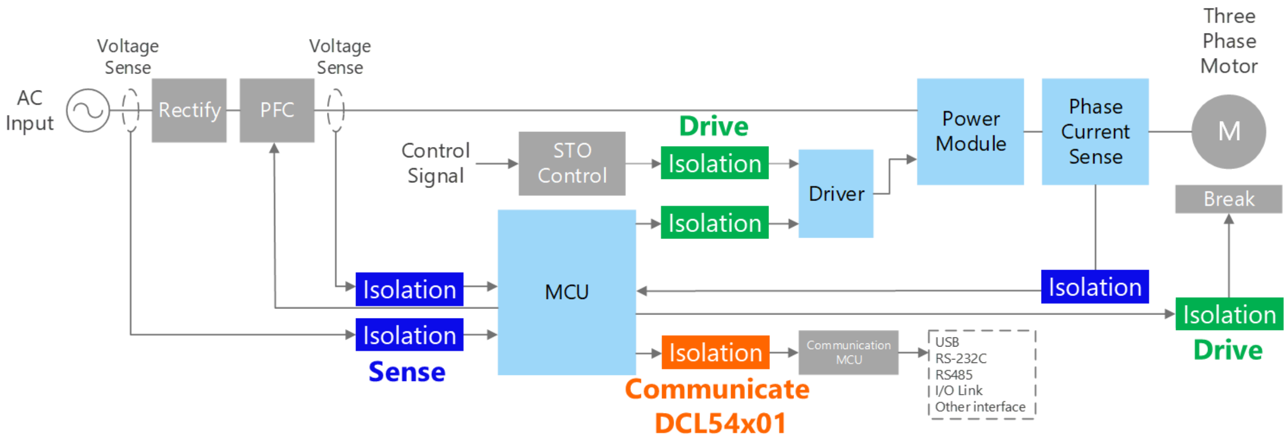



**Figure 2.1 Examples of Inverter System Applications**

## 3. Operating principle of digital isolator

Our digital isolator forms a thick insulating film on a typical semiconductor process and realizes electrical disconnection (= isolation) by signal transmission with high breakdown voltage insulation and magnetic coupling. On off keying method, which high-level and low-level input signal are represented as the carrier wave presence or absence, is adopted as the data coding. Transmitting high frequency carrier wave between inductors enables high quality data transfer.

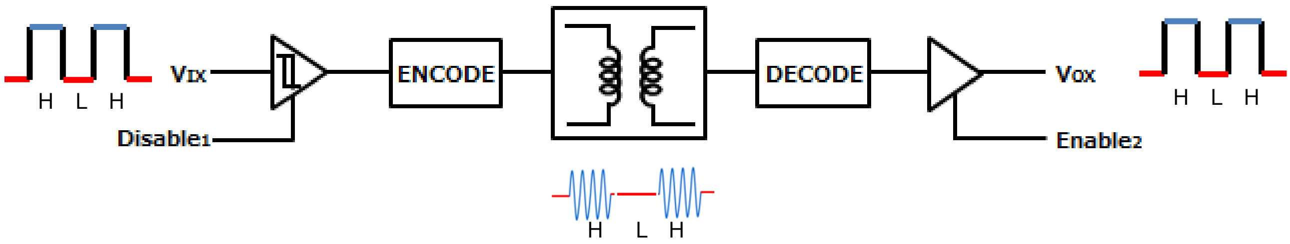



**Figure 3.1 Internal Circuit Configuration**

## 4. Digital isolator structure

The digital isolator consists of a modulation chip with an insulating film (e.g., Si-oxide) and a demodulation chip. It is structured that the magnetic field transmits the input signal from the modulation chip side, and the demodulation chip side receives the data.

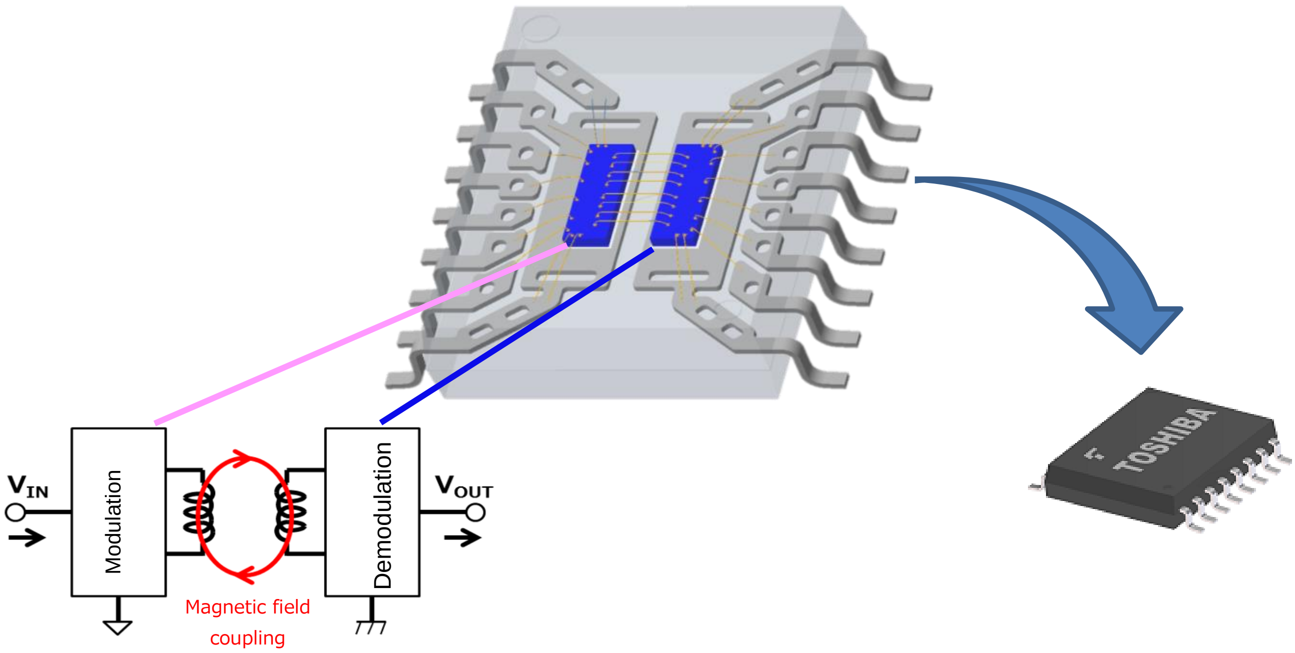



**Figure 4.1 Digital Isolator Structure (Perspective View)**

## 5. The lineup of standard digital isolators

The main lineup of our standard digital isolator products is shown in Table 1.1.[Note 3]
All of the products introduced here have buffer logic type output. In terms of functions, the product lineup comprises a combination of channel configuration, default output logic [Note 4], and enable/disable control. [Note 5] Therefore, suitable products can be selected according to the required functions.

[Note 3] Including the information of products under development.

[Note 4] The default output logic is a function to stabilize the output status when the input signal becomes open or the power supply on the input side is cut off, etc. For example, for a DCL540L01, the output logic can be fixed at low level in the event of an unexpected situation such as an input-signal disconnection. This function can provide a safety redundancy design for the operation of the following system via isolation.

[Note 5] For DCL540L01 or DCL540H01, the output is enabled by the enable control signal High. Conversely, the output is disabled (output high impedance) by the enable control signal low. On the other hand, for DCL541A01 or DCL541B01, the input is disabled by the disabled control signal High, and the output signal defaults as Note 4.

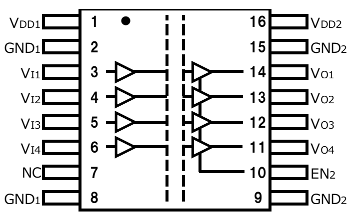
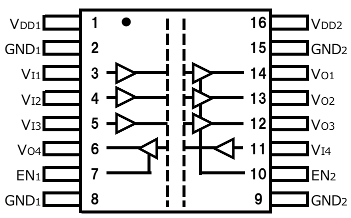
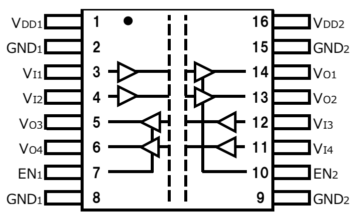
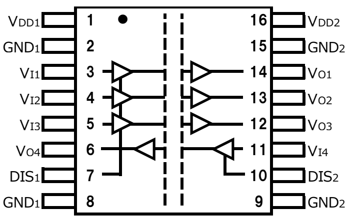
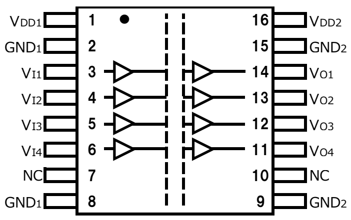
| Part number | DCL540L01 | DCL540H01 | DCL541L01 | DCL541H01 | DCL542L01 | DCL542H01 |
|---|---|---|---|---|---|---|
| Number of channels Forward:Reverse | 4:0 | | 3:1 | | 2:2 | |
| Default output logic | Low | High | Low | High | Low | High |
| Enabled / Disabled control | Output Enable | | | | | |
| Pin layout |  | |  | |  | |
| Package | SOIC16-W | | | | | |
| Propagation delay (Max) | 21.0 ns (@Supply voltage 2.25 to 2.75 V, Temperature range -40 to 110 °C) | | | | | |
| Supply voltage | 2.25 to 5.5 V | | | | | |
| Operating temperature | -40 to 110 °C | | | | | |
| Storage temperature | -65 to 150 °C | | | | | |
| Isolation voltage rating(min) | 5000 Vrms | | | | | |
| Safety standard | UL 1577(Recognized)<br>VDE V 0884-11(Recognized)<br>GB 4943.1-2022(Recognized) | | UL 1577(Recognized)<br>VDE V 0884-11(Planned)<br>GB 4943.1-2022(Recognized) | | | |

**Table 5.1 Standard Digital Isolator Lineup**

| Part number | DCL541A01 | DCL541B01 | DCL540C01 | DCL540D01 |
|---|---|---|---|---|
| Number of channels Forward:Reverse | 3:1 | | 4:0 | |
| Default output logic | Low | High | Low | High |
| Enabled / Disabled control | Input Disable | | None | |
| Pin layout |  | |  | |
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| Operating temperature | -40 to 110 °C | | | |
| Storage temperature | -65 to 150 °C | | | |
| Isolation voltage rating(min) | 5000 Vrms | | | |
| Safety standard | UL 1577(Recognized)<br>VDE V 0884-11(Recognized)<br>GB 4943.1-2022(Recognized) | | | |





**Table 5.2 Standard Digital Isolator Lineup**

# 6. Features of standard digital isolator

## 6.1. Common Mode Transient Immunity (CMTI)

Common-mode noise is a type of noise in which current flows in the same direction by superimposing both signals and GND lines. A digital isolator driven by independent power supplies provides signal transmission with electrically isolation between circuits. However, even in such cases, if either GND potential fluctuates, common-mode noise occurs. This common mode noise causes the displacement current flowing through the coupling capacitance between the primary (input side) and secondary (output side) inside the standard digital isolator. When the current reaches a certain level, it may cause a malfunction not only for the digital isolator, but for the system. Therefore, tolerance to such common-mode noise is essential for the stable operation of the system. CMTI represents the capability to accommodate high slew-rate transient voltages between such GNDs, and the larger CMTI, the higher noise immunity and the better for applications where isolation is required.

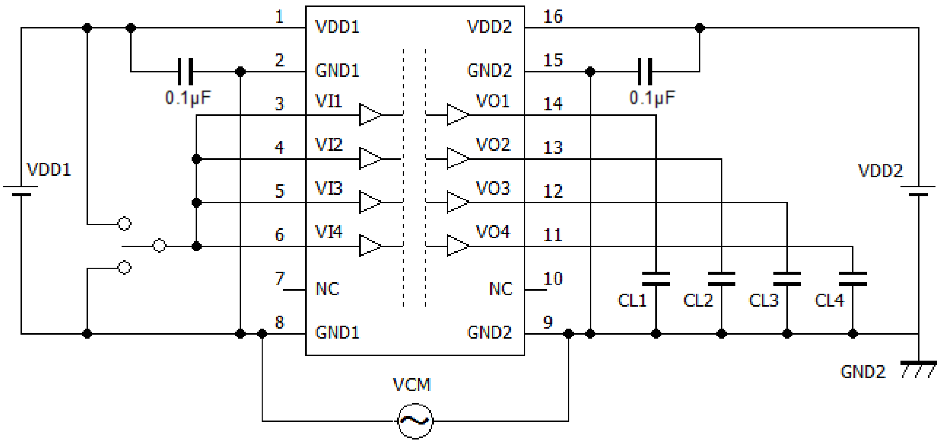



**Figure 6.1 Sample Output-Waveform Measuring Circuit with Common-Mode Voltage $V_{CM}$ Applied**

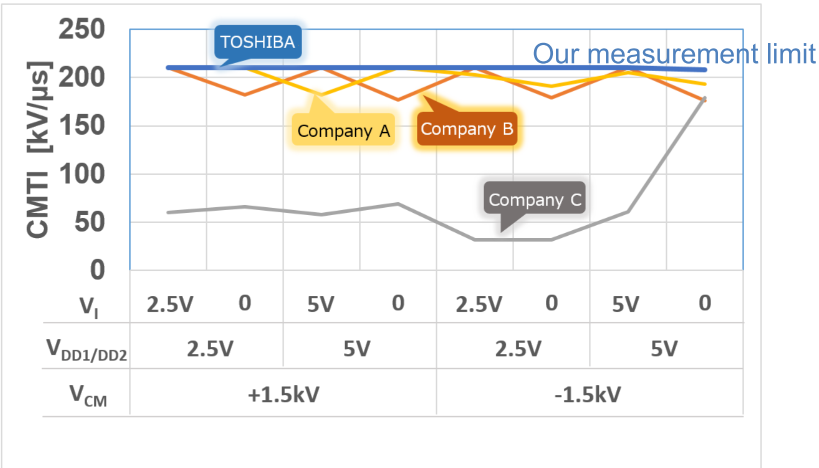



**Figure 6.2 Common Mode Transient Immunity Comparison**

## 6.2. High-speed communication of 150 Mbps data transfer rate

Until now, Toshiba's four-channel photocouplers support only transistor coupler output-type devices, and their data transfer rate has been limited to several kbps to several dozen kbps. In addition, the high-speed communication photocoupler covering until 50 Mbps with single-channel totem-pole output is in our lineup.

On the other hand, the standard digital isolator supports four channels and has a pulse width distortion within 3.0 ns to form a clear eye pattern. It supports up to 150 Mbps data transfer rate. The channel-to-channel propagation delay difference is also within 3.9 ns, facilitating multi-channel design such as SPI communication isolation.

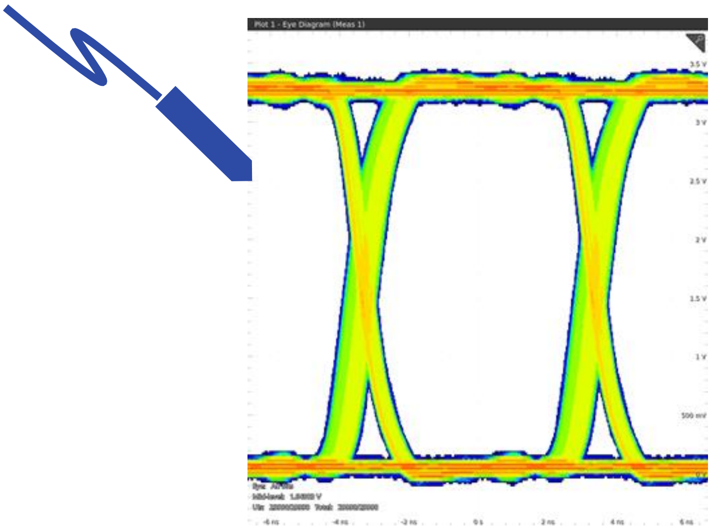


**Figure 6.3 Sample Eye Pattern for DCL541A01 (3.3 V Power Supply 150 Mbps Operation)**

## 6.3. High reliability and safety

Toshiba's CMOS processing and double insulation construction satisfy the following two requirements for the reinforced insulation specified in VDE V 0884-11.

- High dielectric strength with surge capacity of 12.8 kV or more
- Long life with an estimated insulation life of 37.5 years@1 ppm (TDDB test 1.2 kVrms) or more

### 6.3.1. Safety

The double insulation structure adopted in DCL54xx01 series standard digital isolators prevents from the short-failure mode between the primary and secondary sides even if either insulation barrier is broken down. This enhances the safety robustness same as photocouplers.

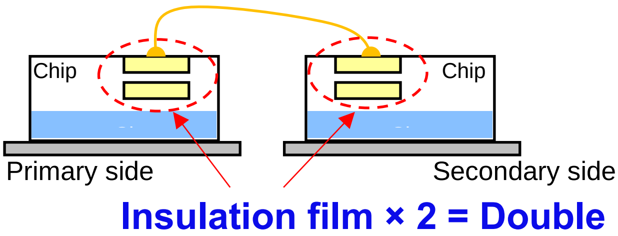



**Figure 6.4 Double insulation structure**

### 6.3.2. Long insulation life

TDDB test results indicate that the insulation life of DCL54xx01 series digital isolators is estimated 70 years or more under specified conditions in VDE V 0884-11. This estimated life is enough against the requirement in VDE V 0884-11 of 37.5 years.

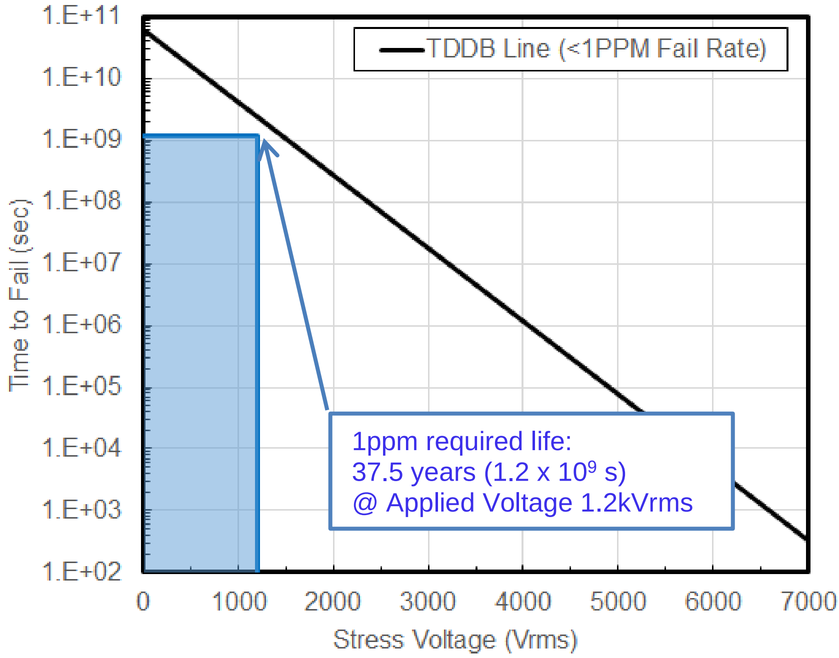



**Figure 6.5 Estimated insulation life data**

### 6.3.3. High isolation voltage

Toshiba standard digital isolators have over 12.8 kV of surge withstand voltage that is result of applying surge voltage (1.2/50 μs waveform) using a combination waveform generator according to IEC 61000-4-5.

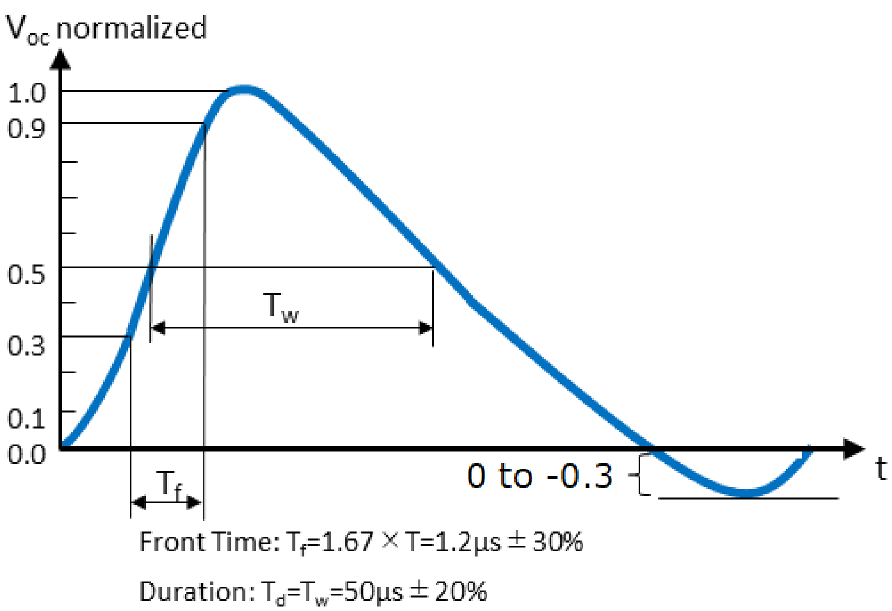



**Figure 6.6 Surge Test Voltage Waveforms**

# 7. Electrical characteristics and application circuit example of standard digital isolator

## 7.1. Switching characteristic

The propagation delay time $t_{pHL}$, $t_{pLH}$ indicates the time from the input signal to output logic inversion. The "HL" part means the direction of the change in the output voltage. Pulse width distortion | $t_{pHL}$-$t_{pLH}$ | indicates the absolute value of the difference between $t_{pHL}$ and $t_{pLH}$ in a single product. It is used as an index to confirm the level of distortion of the transmitted waveform. DCL54xx01 guarantees propagation delay variation in 3.0 ns (max.).

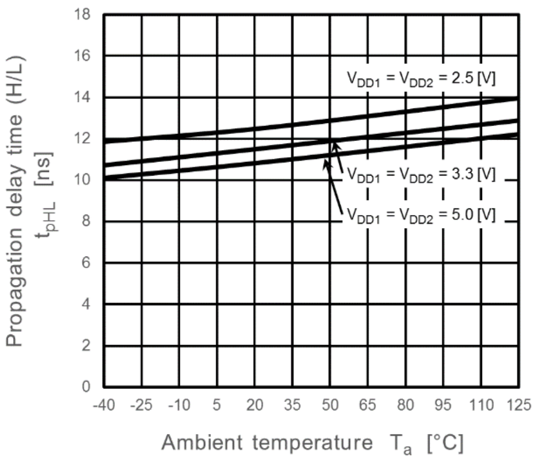



**Figure 7.1 Propagation delay $t_{pHL}$-$T_a$**

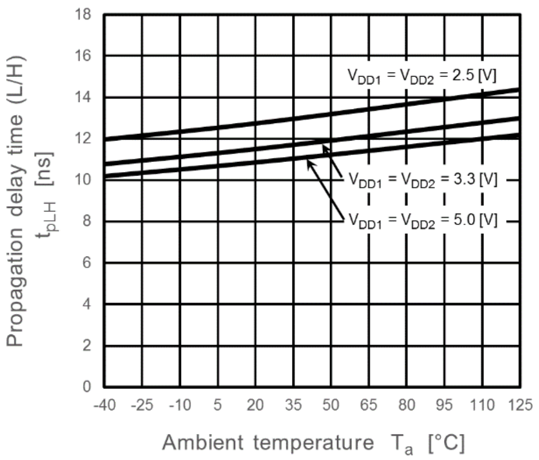



**Figure 7.2 Propagation delay $t_{pLH}$-$T_a$**

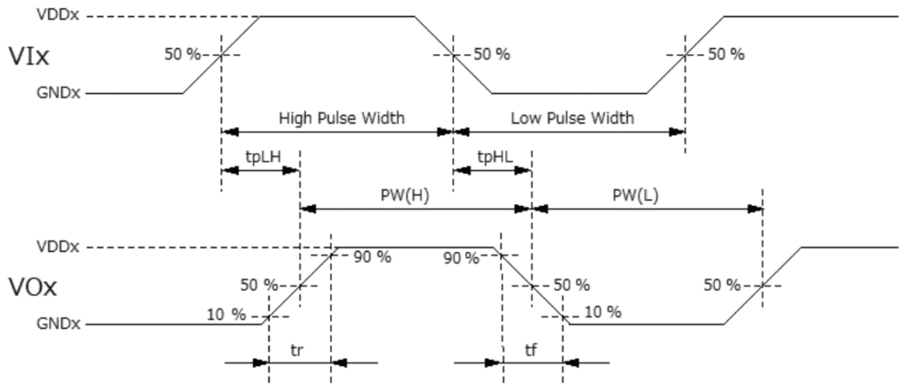



**Figure 7.3 Switching Characteristics Measurement Circuit Diagram**

## 7.2. $V_{OH}$/$V_{OL}$ characteristics

The output voltage characteristics in the figure below show the dependences of the H-level output voltage ($V_{OH}$) and L-level output voltage ($V_{OL}$) on the output current. $V_{OH}$ indicates the output voltage when the output is H, and $V_{OL}$ indicates the output voltage when the output is L.

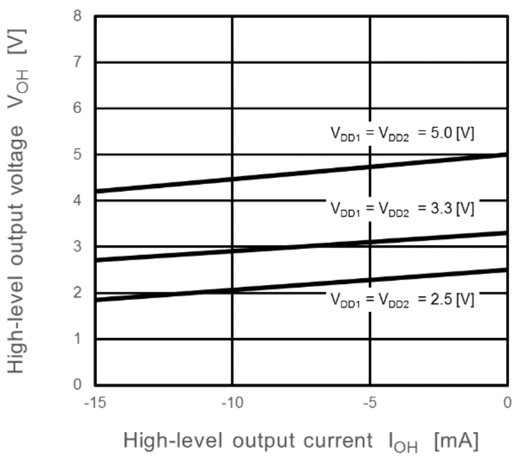



**Figure 7.4 $V_{OH}$-$I_{OH}$**

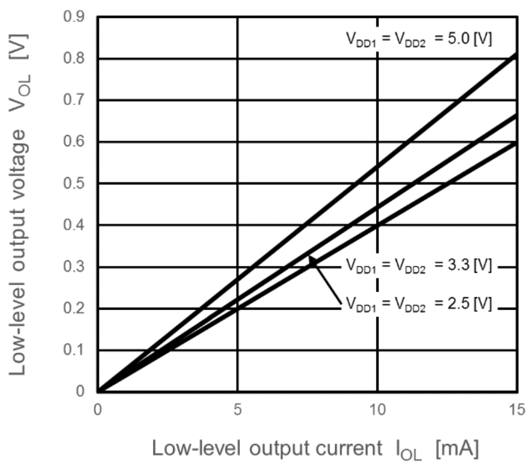



**Figure 7.5 $V_{OL}$-$I_{OL}$**

## 7.3. Power Dissipation Ratings

The figure below shows the power dissipation ratings of SOIC16-W. Please use our standard digital isolators within the following ranges.

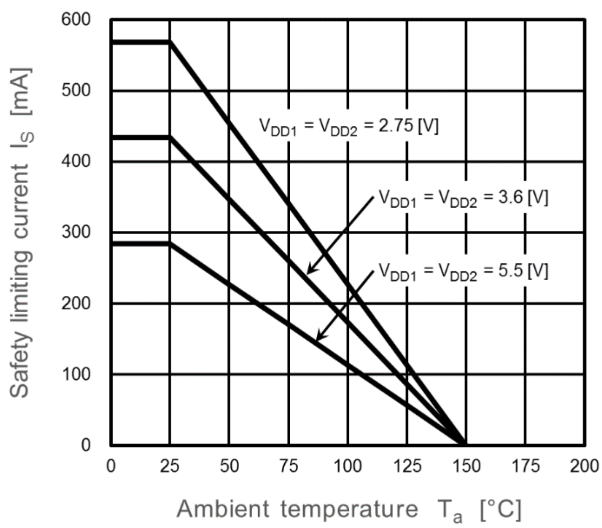



**Figure 7.6 Safety Limits-$T_a$ Ambient Temperature**

### 7.4. Application circuit example (1)

The figure below shows an example of a connection when isolated SPI communication from an external controller is required in a motor control system. Four pins of chip select pin CSN, clock pin SCLK, data input pin SI, and data output pin SO are used for SPI communication.

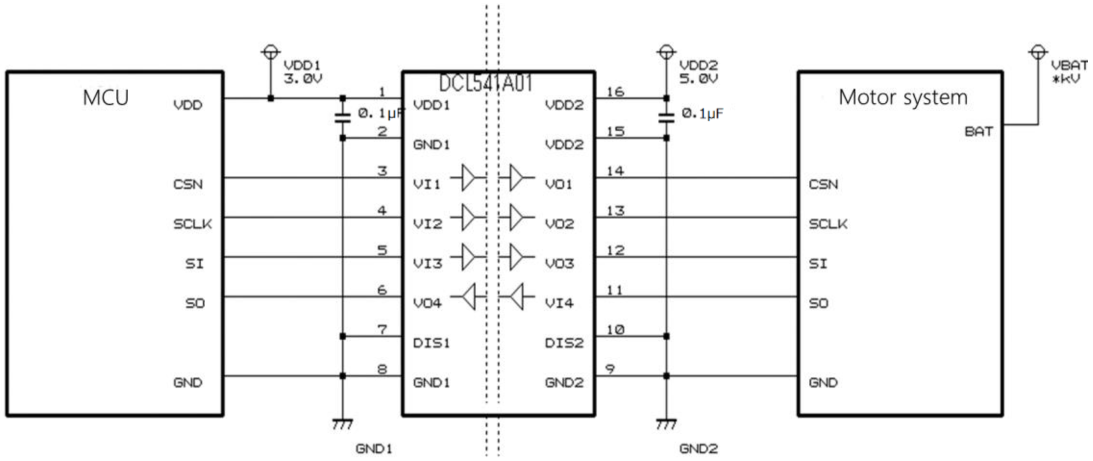



**Figure 7.7 Example of SPI Connection Diagram**

### 7.5. Application circuit example (2)

To stabilize the power supply voltage and stabilize the operation of the product, connect smoothing capacitors between the primary power supply pin (between 1pin $V_{DD1}$ and 2Pin $GND_1$) and the secondary power supply pin (between 16pin $V_{DD2}$ and 15pin $GND_2$). Place a bypass capacitor 0.1 μF with good high-frequency characteristics as close to the root of the IC as possible. (within 10 mm)

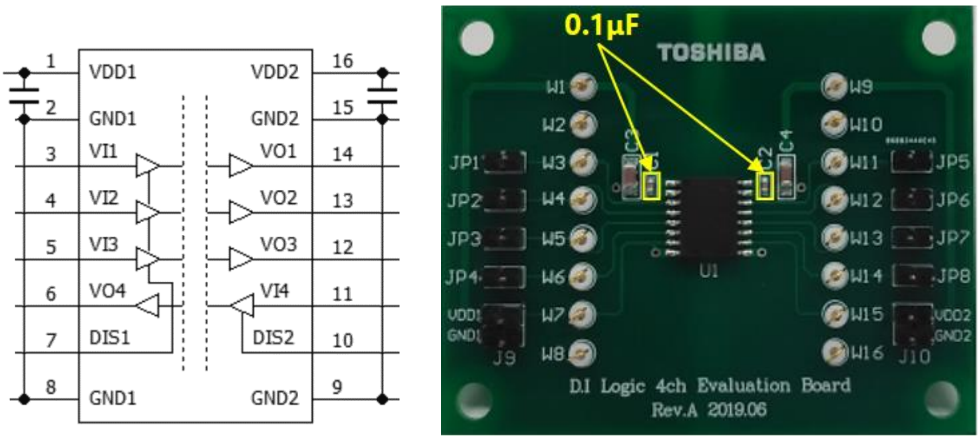
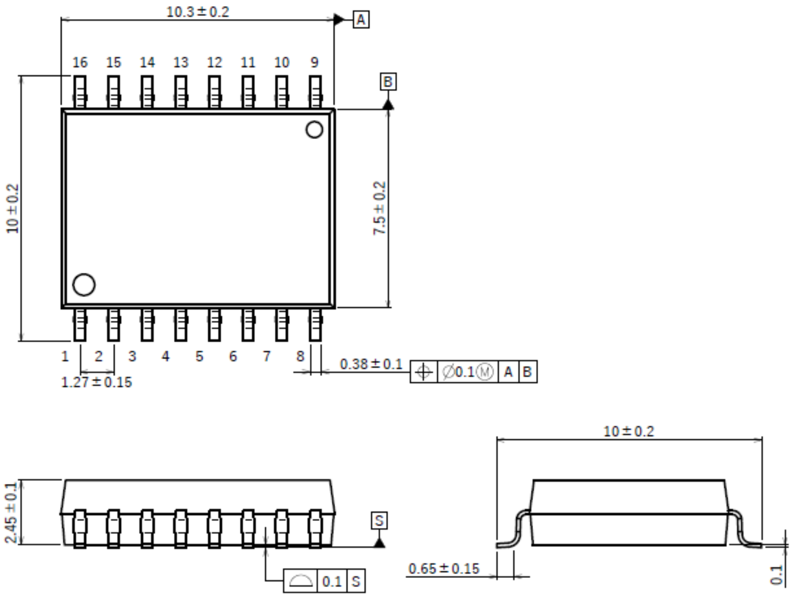
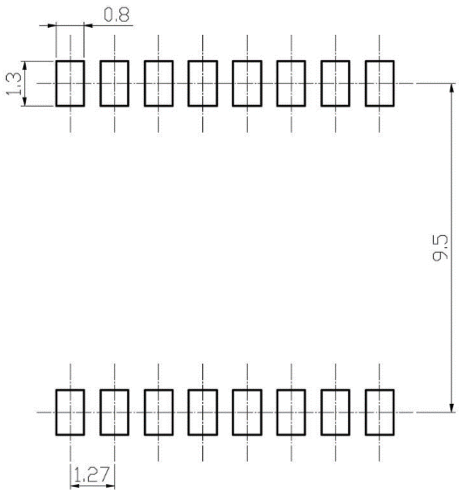



**Figure 7.8 PCB layout example**

## 8. Package information

| | |
|---|---|
| Mounting type | Surface Mount |
| Number of Pins | 16 |
| Package Dimension Width× Length ×Height (mm) | 10.3 × 10.0 × 2.45 (typ.) |
| Package Dimension(mm) |   |
| Land Pattern Example (mm) |   |

## Changelog

| Version | Date | Content of change |
|---|---|---|
| Rev. 1.0 | 2nd Aug. 2021 | First edition |
| Rev. 1.1 | 16th Nov. 2021 | Correction of expressions |
| Rev. 1.2 | 10th Apr. 2023 | Product added.<br>Value changed. |

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