Photorelay TLP172AM ESD countermeasures

Description

This document explains the ESD suppression effect to photorelays using TVS diodes and Zener diodes as an example of TLP172AM.

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1. Introduction

A photorelay (MOSFET output photocoupler) is, literally, a photocoupler whose output side consists of MOSFETs. Therefore, ESD (Electro-Static Discharge) may cause the MOSFET to fail.

The use of devices against malfunction caused by ESD is effective. Toshiba offers a lineup of TVS diodes and Zener diodes to protect devices from overvoltage pulses such as ESD and surges. In this document shows actual examples that explains how to protect photorelay output side (MOSFETs) against ESD damage and improvement level.

2. What is a Photorelay ?

A photorelay is a semiconductor-relay with an infrared LED (light-emitting diode) on the input side and a photodiode array and MOSFETs on the output side. The input and output sides are electrically isolated.
(Reference) Photorelay eBook (Toshiba)

3. ESD and Overvoltage Surges

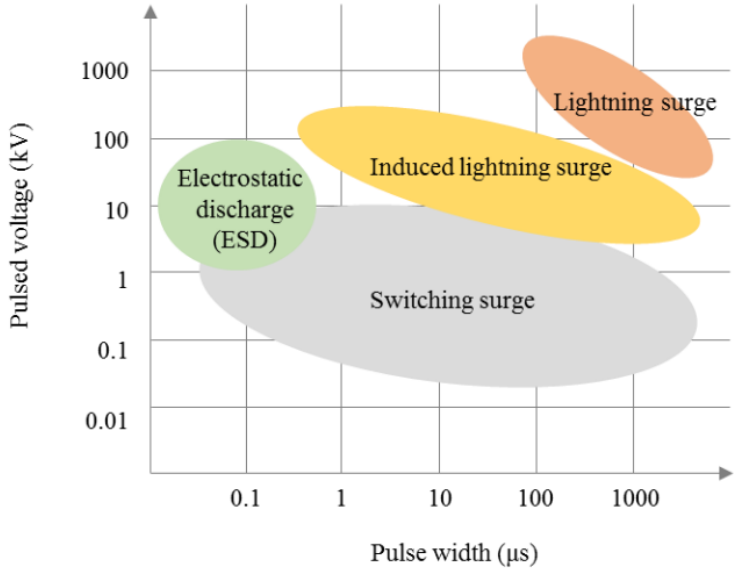
There is a lot of high-voltage noise source around us, which is accompanied by a sudden rise in voltage that damages electronic circuits called surges. Various surges can also occur in electronic circuits, and it is necessary to consider the protection of the circuit. Examples of surges include static electricity entering through connectors where electronic devices are connected to the outside, and surges caused by inductive loads.

・What is an ESD?

An ESD is an electrical discharge phenomenon that occurs when an object with a positive or negative charge accumulates and encounters or approaches. ESD, which occurs when the human body encounters electronic devices, can reach thousands of volts due to the rapid discharge phenomenon, resulting in short pulses on the order of nanoseconds. Semiconductor products that are sensitive to static electricity may be destroyed by ESD, so countermeasures must be taken.

・Other noises

In addition to ESD, there are lightning surges caused by lightning and switching surges, which are transient overvoltage induced by sudden current changes and inductance in circuits and wiring when switches and relays are turned on and off.



Source: Overvoltage protection device Zener diode and ESD protection diode (Toshiba)

Figure 3.1 Classification of overvoltage pulses

4. Overvoltage Protection Devices

This section describes devices that protect semiconductor devices from overvoltage pulses such as ESD. Toshiba offers a lineup of diodes for ESD protection (TVS diodes) and Zener diodes as diode-type protection devices against overvoltage pulses. Figure 4.1 shows how it is connected and how it works.

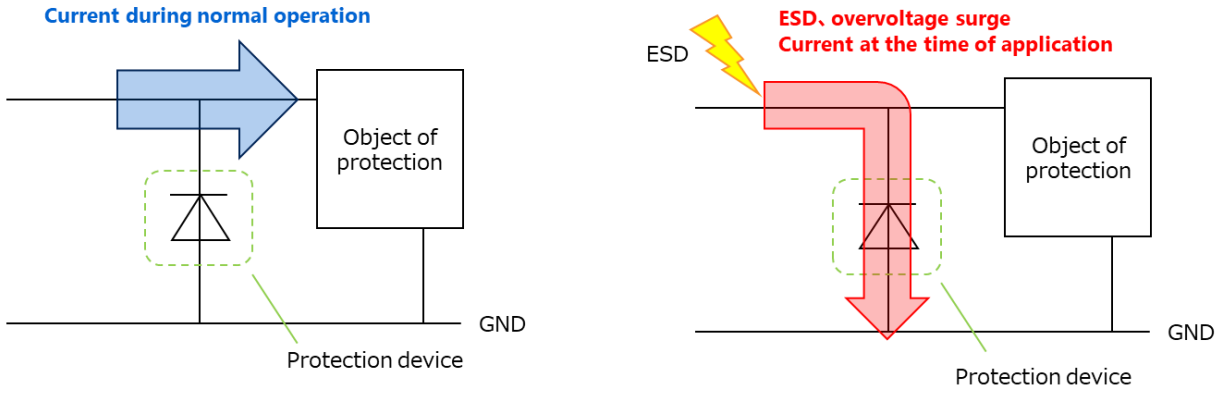


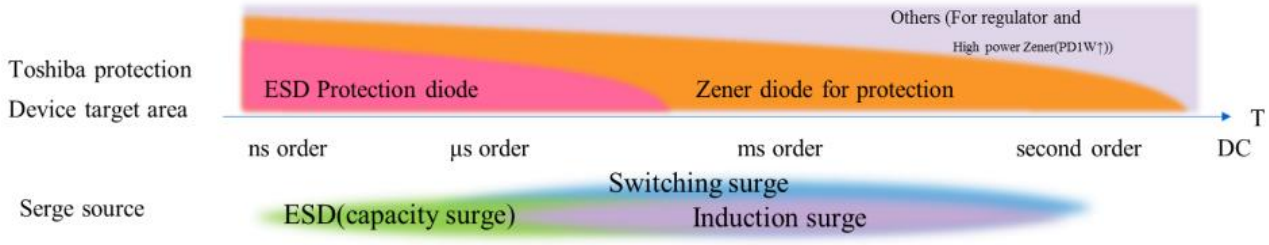
Figure 4.1 Operation of the protection device during normal operation and when a surge is applied

The characteristics of each protection device are shown in Table 4.1, and the corresponding areas are shown in Figure 4.2.

Table 4.1 Features of ESD protection diodes and Zener diodes

	ESD Protection Diode (TVS diode)	Zener Diode
Main applications	Purpose to protect the object from overvoltage pulses on the order of microseconds or less *1	To protect from overvoltage pulse for mor than microseconds (ESD protection application also possible *1)
Capacitance between terminals *2	0.12 to 600 pF	30 to 600 pF
Examples of use locations	Connectors for USB, HDMI, etc. *3	Power supply line, power control line
Remarks	Toshiba lineups mainly low-capacity products of 1 pF or less	If the power dissipation is within the allowable range, overvoltage pulses close to DC can be protected.

*1 Standards: IEC 61000-4-2, IEC 61000-4-5 (8/20 μs condition)
*2 For 5 V line protection
*3 There is a product for the power supply line for protection from 8/20 μs pulses assuming some induced lightning surges.



Source: Overvoltage protection device Zener diode and ESD protection diode (Toshiba)

Figure 4.2 Corresponding areas of ESD protection diodes and Zener diodes suitable for overvoltage protection

(Reference)

- Basics of ESD Protection (TVS) Diodes
- Overvoltage protection device Zener Diode and ESD diode
- Mini catalog Introduction of Toshiba TVS Diodes (ESD Protection Diodes) Line-up
- Mini catalog Introduction of Toshiba Zener Diode for protection

5. Effects of Attaching ESD Protection Devices to Photorelays

In this section, ESD damage protection is shown by combining a protection element on the output side of a photorelay.

5.1. Using Devices

As an example, it is shown that the evaluation results using our photorelay and our ESD protection device.
The photorelay used was an ESD-sensitive TLP172AM (off-state voltage rating V_{OFF}: 60 V).
TLP172AM is a product that is vulnerable to static electricity, which is noted in the data sheet, as shown in Figure 5.1.

Common	Storage temperature		T_{stg}		-55 to 125	
	Operating temperature		T_{opr}		-40 to 110	
	Lead soldering temperature	(10 s)	T_{sol}		260	
	Isolation voltage	(AC, 60 s, R.H. ≤ 60 %)	BV_S	(Note 1)	3750	Vrms

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings.
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note 1: This device is considered as a two-terminal device: Pins 1 and 3 are shorted together, and pins 4 and 6 are shorted together.

Note: This device is sensitive to electrostatic discharge (ESD). Extreme ESD conditions should be guarded against by using proper antistatic precautions for the worktable, operator, solder iron, soldering equipment and so on.

Figure 5.1 Datasheet note describes about ESD

The protection device this time was selected DF2B29FU (TVS diode) and MSZ30V (Zener diode).

In this example, control of 24 V and 20 V power supply lines using an off-state voltage of 60 V photorelay was assumed. Thus, devices that working peak reverse voltage V_{RWM} and Zener voltage V_Z of 24 V or higher, and a clamping voltage of 60 V or lower (since it is necessary to reduce the ESD energy applied to the photorelay output terminals than the V_{OFF}) were selected.

How to select a protection device, please refer this link.

The main specifications of the photorelay and ESD protection devices are shown in Tables 5.1 through 5.3.

Table 5.1 TLP172AM main specification (Link)

TLP172AM	
1-Form-A(Normally opened)	
package	4 pin SO6
Operating temperature	-40 to 110℃
Trigger LED current I_{FT}(max)	3 mA
OFF-state output terminal voltage V_{OFF}	60 V
ON-state resistance R_{ON}(max)	2 Ω
ON-state current I_{ON}	0.5 A
ON-state current (pulsed) I_{ONP}	1.5 A
Isolation voltage BVs(min)	3.75 kVrms
Turn-on time tON(max)	2 ms
Turn-off time tOFF(max)	0.5 ms

Table 5.2 DF2B29FU main specifications (Link)

DF2B29FU		
bidirectional polarity		
Electrostatic discharge voltage (IEC61000-4-2)(Contact) V_{ESD} *Note1	±25 kV	
Electrostatic discharge voltage(IEC61000-4-2)(Air) V_{ESD} *Note1		
Electrostatic discharge voltage(ISO10605)(Contact) V_{ESD} *Note2	±30 kV	
Electrostatic discharge voltage(ISO10605)(Air) V_{ESD} *Note2		
Peak pulse power P_{PK}	140 W	
Peak pulse current I_{PP} *Note3	3 A	
Working peak reverse voltage V_{RWM} (max)	**24 V**	Working peak reverse voltage 24V or more
Reverse breakdown voltage V_{BR} (min)	26 V	
Reverse current I_R	0.1 μA	
Clamp voltage Vc (max) *Note4	**47 V**	Clamp voltage 60V or lower
Dynamic resistance R_{DYN} (typ.) *Note5	1.1 Ω	
Total capacitance Ct (typ.) *Note6	9 pF	

Note 1: IEC 61000-4-2 compliant
Note 2: ISO 10605 compliant (C = 330 pF, R = 2 kΩ)
Note 3: IEC 61000-4-5 compliant
Note 4: Measured with 8/20 μs pulses in the IEC 61000-4-5 standard.
Note 5: TLP parameters: Z_0 = 50 Ω, t_p = 100 ns, t_r = 300 ps,
averaging window t_1 = 30 ns to t_2 = 60 ns, the dynamic resistor is extracted using the least squares method between I_{PP} = 8 to 16 A with TLP characteristics.
Note 6: Capacity values are design guarantees.

Table 5.3 MSZ30V main specifications (Link)

MSZ30V	
Unidirectional polarity	
Electrostatic discharge voltage (Contact, Air) V_{ESD} *Note1	±20 kV
Peak pulse power P_{PK} *Note2	200 W
Peak pulse current I_{PP} *Note2	4.0 A
Zener Voltage V_Z (typ.)	**30 V**
Dynamic Resistance R_{DYN} (typ.) *Note3	1.25 Ω
Clamp Voltage V_C (typ.) *Note3,4	**47.5 V**
Total Capacitance Ct (typ.) *Note5	21 pF
Reverse Current I_R (max)	0.1 μA

Zener Voltage 24V or more

Clamp Voltage 60V or lower

Note 1: IEC61000-4-2 compliant
Note 2: IEC61000-4-5 compliant (t_p = 8 / 20 μs)
Note 3: TLP parameters: Z_0 = 50 Ω, t_p = 100 ns, t_r = 300 ps,
averaging window: t_1 = 30 ns to t_2 = 60 ns, dynamic resistance is TLP I_{TLP1} = 16 A to I_{TLP2} = 30 A
It is extracted using the least squares method in between.
Note 4: I_{TLP} = 16 A
Note 5: V_R = 0 V, f = 1 MHz

5.2. Evaluation Circuit

As shown in Fig. 5.1, a protection device was connected between the output side of the TLP172AM and the ESD tester, and the evaluation was performed. This time, the bidirectional type TVS diode was used. The Zener diode used a unidirectional type with two reverse series connections.

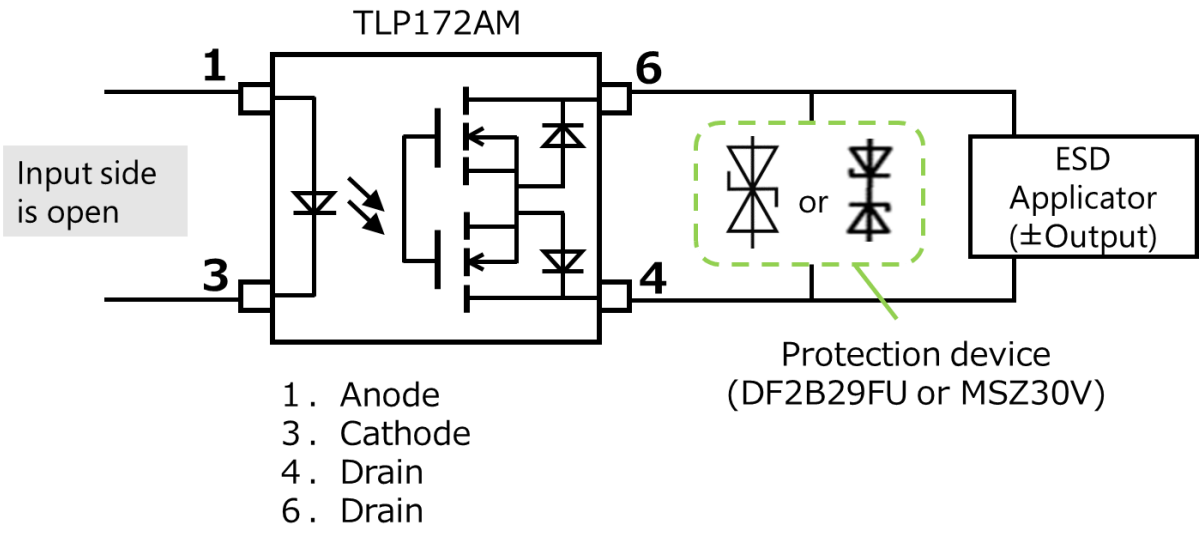


Figure 5.2 Measurement circuit

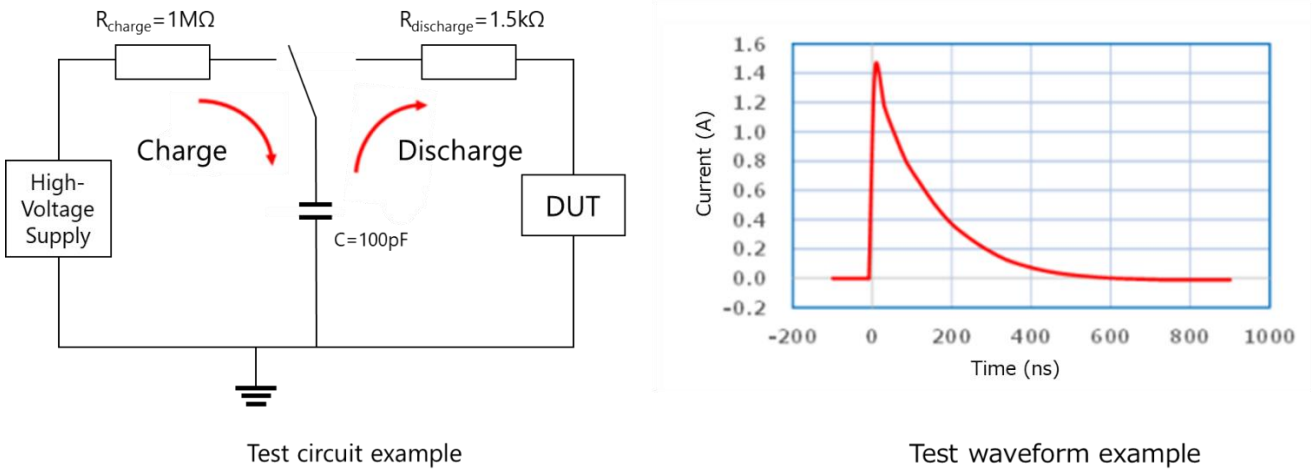
5.3. Evaluation Conditions

Here ESD evaluations were performed under two types of device-level test conditions:

(1) Human Body Model (HBM)
(2) Machine Model (MM)

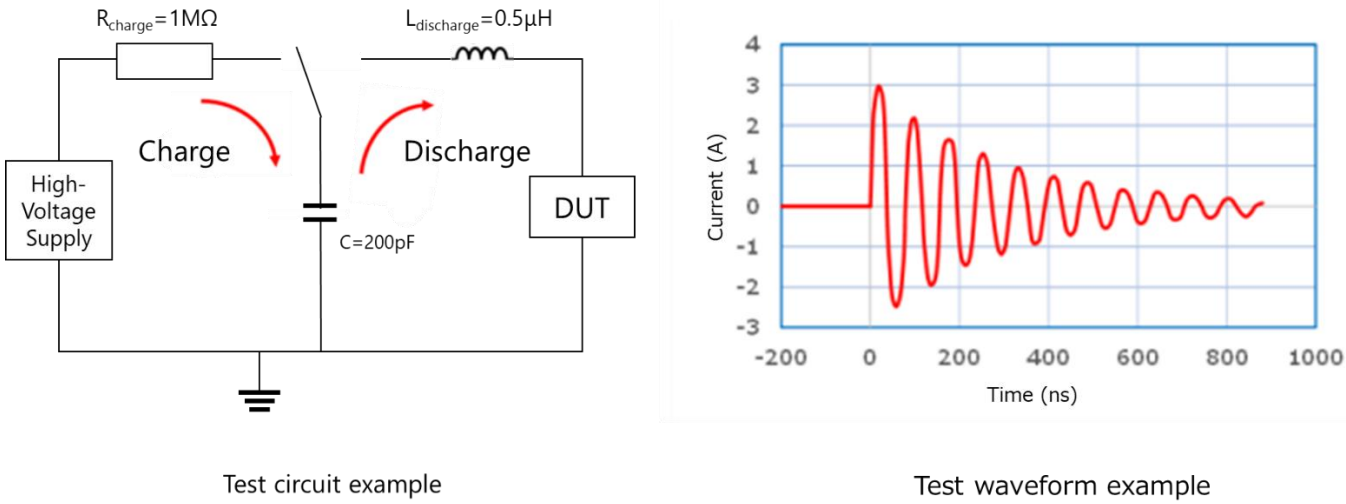
An example of ESD test circuit and test waveform is shown in figures 5.2 and 5.3 respectively. The number of test samples was 10 pieces for each MM and HBM condition. ESD test waveforms were applied to the photorelay output in both directions by an ESD tester, and checked breakdown voltage before and after application. This sequence was repeated by changing of the applied voltage until the TLP172AM was destroyed*.

* The voltage when the TLP172AM output terminals breakdown voltage was deteriorated after the test.



Source: Basics of ESD Protection (TVS) Diodes (Toshiba)

Figure 5.3 Human Body Model (HBM)



Source: Basics of ESD Protection (TVS) Diodes (Toshiba)

Figure 5.4 Machine Model (MM)

5.4. Evaluation Results

Fig. 5.5 and Fig. 5.6 shows the ESD test results of TLP172AM (X-axis: Applied electro-static voltage, Y-axis: number of failures). In case of TLP172AM without any protection device, the failure was observed at ±200 V or less under the MM condition, and at ±1 kV or less under the HBM condition. However, by using protection devices, the failure voltage for the MM condition and the HBM condition was not less than ±300 V and ±3.5 kV respectively.

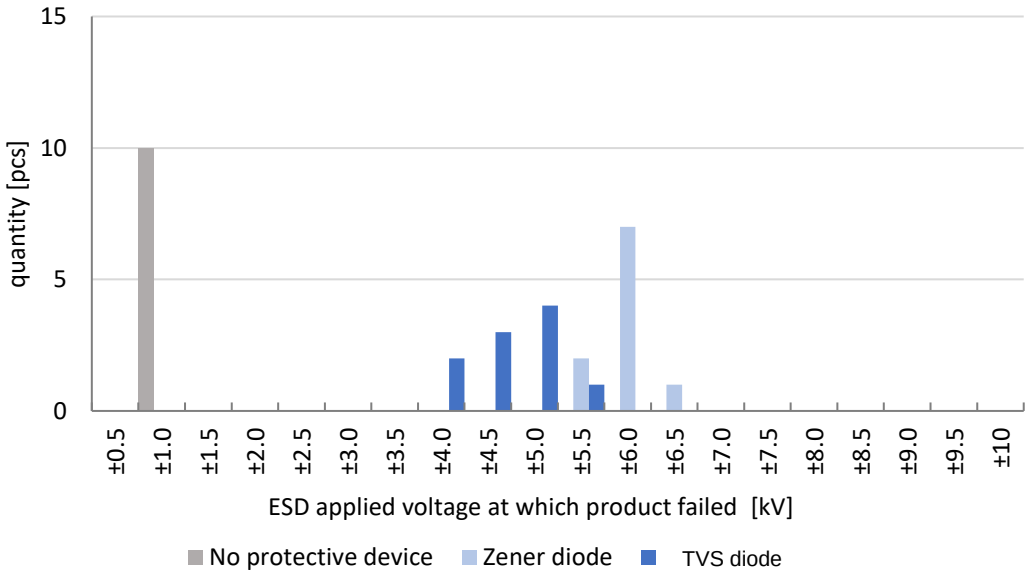


Figure 5.5 TLP172AM ESD-HBM test result

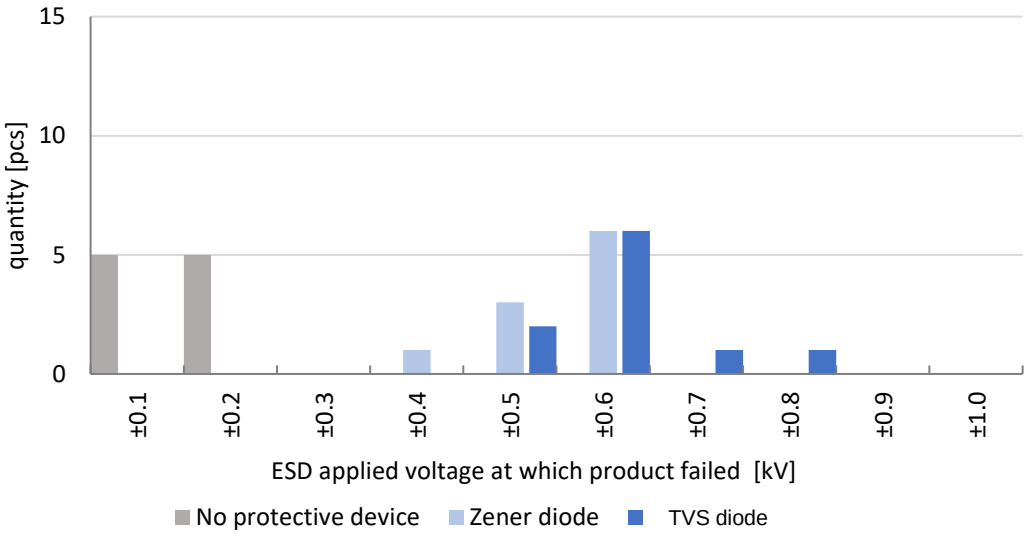


Figure 5.6 TLP172AM ESD-MM test result

6. Summary

In this document, as an example of how to reduce the risk of the ESD damage to photorelay, it was shown the ESD immunity of the TLP172AM when TVS diode or Zener diode are combined on the output terminals (MOSFETs) and how the use of these protection devices can contribute the ESD immunity.

The results shown here are as examples. Users should be considered the selection of ESD protection devices and whether the suitable protection performance is achieved in actual circuits.

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