Diode

What Are TVS Diodes?

With the improvement in performance and downsizing of electronic equipment, parts for semiconductor devices installed on the equipment are also required to be small while offering high performance. Tolerance against static electricity and overvoltage has declined as the microfabrication of semiconductor devices has advanced. Therefore, countermeasures using protective elements are increasingly emphasized. Transient voltage suppressor (TVS) diodes have been developed as specialized products based on Zener diodes to protect semiconductor devices from static electricity and unexpected surge voltage. This application note provides an overview of TVS diodes.

Applications of TVS diodes

This section introduces usage examples of TVS diodes. Since switches and buttons installed on electronic equipment are touched by the human body when they are operated, electrostatic discharge (ESD) may cause damage to the IC or malfunction. To prevent such damage and malfunction, ESD entry is prevented by placing TVS diodes between the switches and the device to be protected (the IC in this case) as shown in Figure 1.

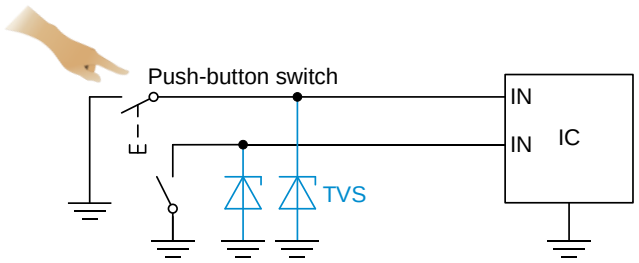

Figure 1. Protection against ESD entering via switches and buttons touched by human body

ESD also enters via USB, HDMI, and other connectors often installed on electronic equipment. Figure 2 shows an example of a USB connector. Since the human body connects cables and USB devices, they are affected by static electricity. The TVS diodes are placed between the connector and the IC to prevent the ESD entry.

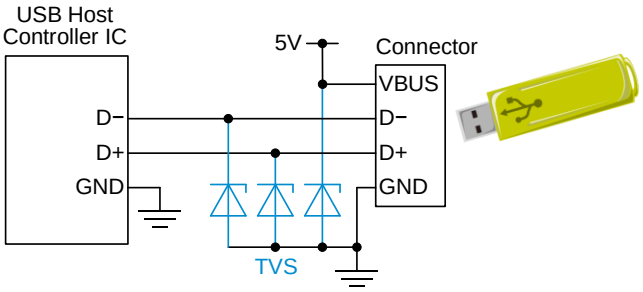

Figure 2. Protection against ESD entering via connector of electronic equipment

Countermeasures against ESD are also important for communication networks. If a network cable that connects devices is touched by an electrically charged human body or object, ESD enters the electronic devices via the cable. Figure 3 shows an example of an automotive controller area network (CAN). The TVS diodes are placed between the connector and IC of the device to be connected with the network cable to prevent the ESD entry.

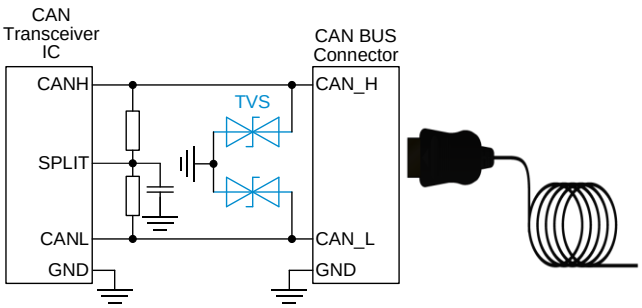

Figure 3. Protection against ESD for communication network

Operations of TVS diodes

TVS diodes are a voltage clamp type of surge protection element. They are designed to absorb a large amount of energy in a short time with low operation resistance and high current rating characteristics.

Figure 4 shows the operations of a TVS diode. The left diagram shows the operation under normal conditions. In this example, the connector is located on the left end and the IC, which is the device to be protected, is located on the right end. They are connected via the wiring and a TVS diode is placed between them. The wiring carries the designed DC voltage and analog or digital signals depending on the application. The TVS diode is normally turned OFF because no breakdown has occurred in the TVS diode.

The right diagram shows the operation when a surge is applied. If the surge voltage exceeds the breakdown voltage of the TVS diode, the surge current flows through the TVS diode and a large part of the current flows to the ground. Then, the TVS diode clamps the voltage and protects the device on the following stage.

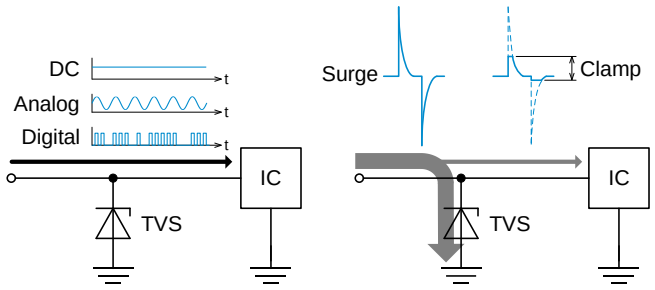

Figure 4. Operations of TVS diode under normal conditions and when surge is applied

Figure 5 shows the I-V characteristics of the TVS diode. Standoff voltage V_{RWM} is most important among these characteristics. This parameter is the maximum voltage immediately before the TVS diode enters the breakdown state. The TVS diode does not operate below this voltage. To prevent breakdown of the TVS diode under normal conditions, it is necessary to use a TVS diode with V_{RWM} higher than the voltage processed with the wiring.

The solid lines of characteristics represent the regions being used. The diode is turned OFF under normal conditions. When a surge is applied, a breakdown occurs and the diode is turned ON for a surge with positive polarity. For a surge with negative polarity, the diode is turned ON above the forward voltage.

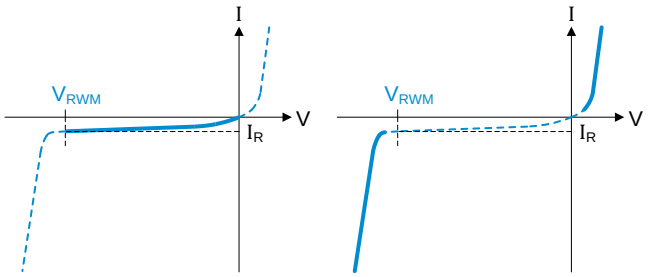

Figure 5. I-V characteristics of TVS diode
Different regions are used under normal conditions and when a surge is applied

Polarities of TVS diodes

TVS diodes are available as both unidirectional and bidirectional products as shown in Figure 6. It is necessary to select products according to the application.

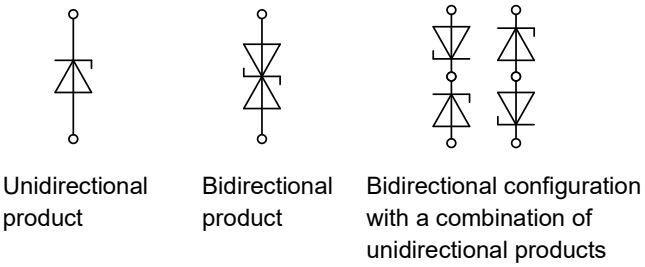

Figure 6. Unidirectional and bidirectional TVS diodes

Figure 7 shows the waveforms if a unidirectional product is connected to the wiring transmitting digital signals designed with reference to the ground and analog signals designed to provide signals centering around the bias voltage. Since the waveform of each signal has positive polarity with reference to the ground, no current flows through the TVS diode. Therefore, the unidirectional products can be used. For the same reason, the bidirectional products can also be used for the signal wiring with positive polarity only.

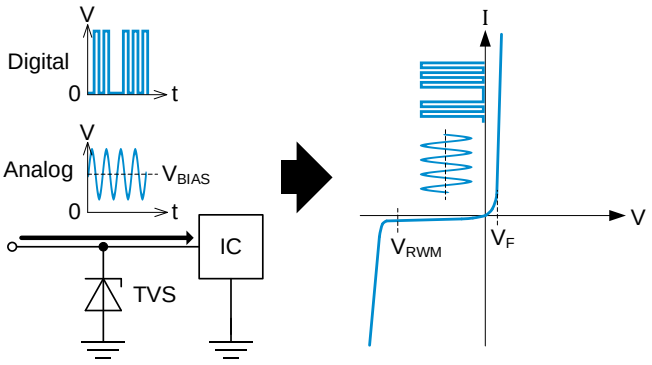

Figure 7. Unidirectional products can be used for the signal wiring with positive polarity

As shown in Figure 8, the bidirectional products are used in wirings for differential digital signals and analog signals with DC cutoff because the amplitudes of these signals are centered around the ground. The bidirectional products can be used because no current flows below V_{RWM}, regardless of whether the signal swings to positive or negative polarity.

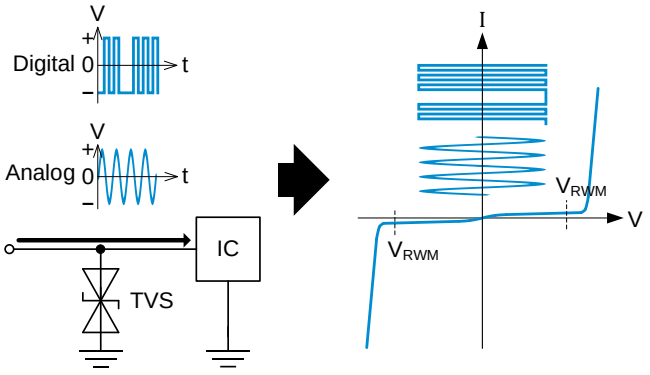

Figure 8. Bidirectional products are used for the signal wiring with both positive and negative polarities

Device structure

Figure 9 shows the vertical structure of a chip (die) manufactured in the pre-processing stage. A generic planar type is employed for the wafer processing. In the manufacturing process, an n^- type semiconductor with a low impurity concentration is formed on an n^+ type silicon substrate. Next, the pn junction is created by forming a p-type semiconductor on the n^- layer. A girdling layer is formed for the p layer to improve the surge breakdown voltage. Various breakdown voltages can be produced by controlling the thicknesses of the n^- and p^+ layers and the impurity concentration. Finally, the chip for a TVS diode is completed by forming the protective film on the top and the electrodes on the top and bottom.

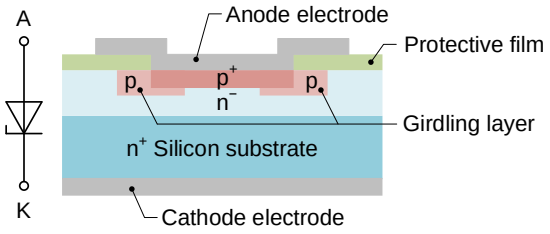

Figure 9. Vertical structure of chip

Figure 10 shows the appearance and sectional view of the package assembled in the post-processing stage. The conventional wire type is shown on the left. The cathode electrode of the chip is connected to the lead frame with soldering. The anode electrode is connected to the lead frame with a wire. The heat dissipation is inefficient because the heat generated in the chip is conducted through the lead frame on the cathode side to the PCB. The failure mode of the wire type is a short-circuit when the pn junction is damaged due to overvoltage or an open when the wire is fused due to overcurrent.

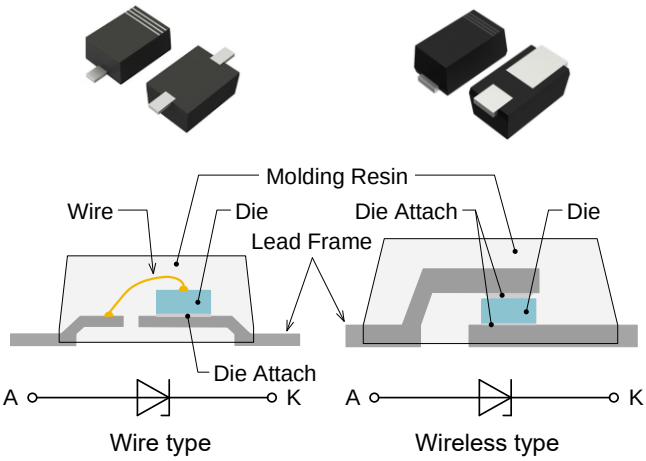

Figure 10. Package appearance and sectional view

The wireless type is shown on the right. Both electrodes of the chip are connected to the lead frame with soldering. Since there is no wire, this type excels in large-current characteristics. It also has an excellent heat dissipation performance because the PCB can be connected directly below the frame connected with the chip. For both overvoltage and overcurrent, the failure mode of the wireless type is often a short-circuit in which the chip is damaged.

In addition to these packages, the RASMID™ (Rohm Advanced Smart Micro Device) series of TVS diodes are listed in ROHM's lineup. Chip-size packages of the RASMID™ TVS diodes have been realized by applying our IC manufacturing technologies to create a unique new process. Figure 11 shows the appearance and sectional view. Naturally, downsizing is possible because the diodes have no lead frame or mold. Furthermore, compared with conventional molded products with the same outline dimensions, RASMID™ has a larger active area for the p-n junction because it is an entirely silicon chip. As a result, larger current and lower resistance characteristics can be achieved, improving the protective performance. The bidirectional type can also be manufactured as one chip.

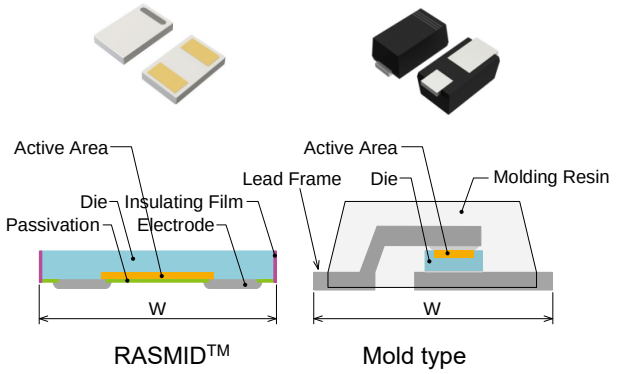

Figure 11. Appearance and sectional view of RASMID™ and mold type

If the outline dimensions are the same, RASMID™ has a larger active area for the p-n junction because it is an entirely silicon chip. As a result, a higher protective performance can be achieved.

Application Notes

- Selection Method and Usage of TVS Diodes

- PCB Layout for TVS Diodes

- Differences between TVS and Zener Diodes

Notice

1) The information contained in this document is intended to introduce ROHM Group (hereafter referred to asROHM) products. When using ROHM products, please verify the latest specifications or datasheets before use.

2) ROHM products are designed and manufactured for use in general electronic equipment and applications (such as Audio Visual equipment, Office Automation equipment, telecommunication equipment, home appliances, amusement devices, etc.) or specified in the datasheets. Therefore, please contact the ROHM sales representative before using ROHM products in equipment or devices requiring extremely high reliability and whose failure or malfunction may cause danger or injury to human life or body or other serious damage (such as medical equipment, transportation, traffic, aircraft, spacecraft, nuclear power controllers, fuel control, automotive equipment including car accessories, etc. hereafter referred to as Specific Applications). Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties arising from the use of ROHM Products for Specific Applications.

3) Electronic components, including semiconductors, can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against physical injury, and damage to any property, which a failure or malfunction of products may cause.

4) The information contained in this document, including application circuit examples and their constants, is intended to explain the standard operation and usage of ROHM products, and is not intended to guarantee, either explicitly or implicitly, the operation of the product in the actual equipment it will be used. As a result, you are solely responsible for it, and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties arising from the use of such information.

5) When exporting ROHM products or technologies described in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, such as the Foreign Exchange and Foreign Trade Act and the US Export Administration Regulations, and follow the necessary procedures in accordance with these provisions.

6) The technical information and data described in this document, including typical application circuits, are examples only and are not intended to guarantee to be free from infringement of third parties intellectual property or other rights. ROHM does not grant any license, express or implied, to implement, use, or exploit any intellectual property or other rights owned or controlled by ROHM or any third parties with respect to the information contained herein.

7) No part of this document may be reprinted or reproduced in any form by any means without the prior written consent of ROHM.

8) All information contained in this document is current as of the date of publication and subject to change without notice. Before purchasing or using ROHM products, please confirm the latest information with the ROHM sales representative.

9) ROHM does not warrant that the information contained herein is error-free. ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties resulting from errors contained in this document.

ROHM SEMICONDUCTOR

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

ROHM Customer Support System

https://www.rohm.com/contactus