Overvoltage protection device
Zener diode and ESD protection diode

Overview

This document describes the applications and features of the TVS diode: ESD protection diode and Zener diode suitable for overvoltage protection while touching the types of electrostatic discharge (ESD) and overvoltage surge.

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1. Introduction

Semiconductors used in electronic equipment have been improved in performance and miniaturized by advancing new processes development and miniaturization. However, the tolerance for unexpected voltage fluctuations has been decreased and overvoltage pulses such as electrostatic discharge ESDs (Electro Static Discharge) and surges adversely affect the semiconductors. For this reason, the importance of protective devices used in electronic equipment is increasing.

We have the lineup for two types of products: ESD protection diodes and Zener diodes that protect the object from overvoltage pulses. This document describes the applications and usage of these protective devices.

2. Overvoltage Pulses Surrounding Electronic Devices

If an overvoltage pulse caused by surge or ESD is applied to the circuit of an electric device, it may cause dielectric breakdown, functional stoppage, or deterioration of semiconductor components. These overvoltage pulses are classified according to the cause of occurrence as shown in Fig. 2.1, and their pulse widths and voltages are different. Each overvoltage pulse is described below.

○ Electrostatic discharge (ESD)

ESD is a discharge phenomenon that occurs when an object (dielectric) with accumulated positive and negative charges comes into contact or approaches. The ESD generated by contact between the human body and electronic equipment suddenly discharges to several thousand volts, becoming short pulses on the order of nanoseconds.

○ Lightning surge

Lightning surges based on lightning can be divided into direct lightning surges and induced lightning surges. Direct lightning surge refers directly to the surge when lightning hit directly. On the other hand, an induced lightning surge is a surge induced by electromagnetic pulses generated by lightning. Lightning surges have high energy and are often difficult to protect, while induced lightning surges have low energy and the countermeasure is possible. Due to the inductive phenomenon, induced lightning surges become long pulses from the microsecond order to the millisecond order.

○ Switching surge

Switching surge is a transient overvoltage induced by a sudden current change and inductance of a circuit or wiring when a switch, relay, or other device is turned on/off (open/close). It is generated by inductance and capacitance in the circuit, resulting in short pulses on the order of nanoseconds to long pulses on the order of milliseconds.

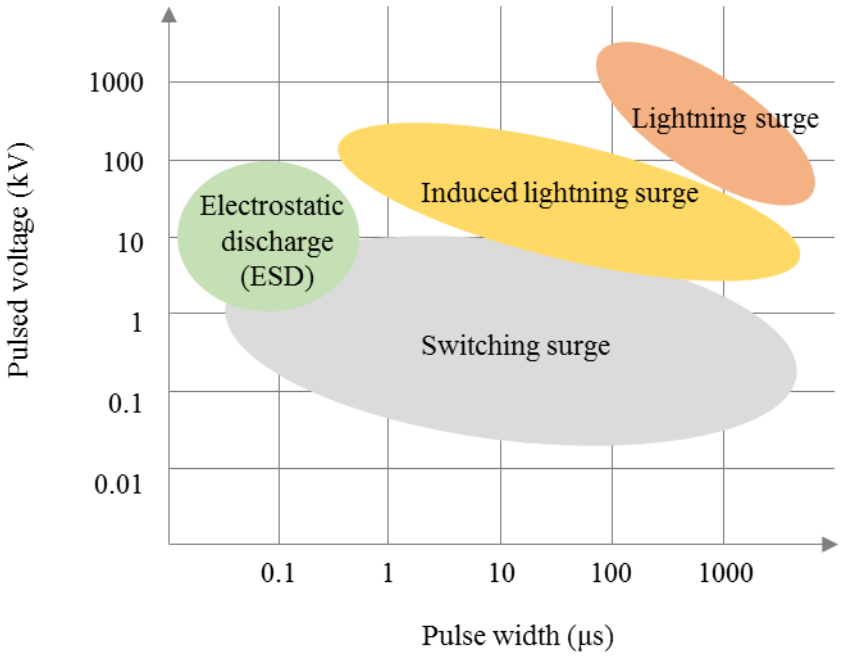


Figure 2.1 Classification of Overvoltage Pulse

3. Protection devices

This section explains the connection method and operation of the diode type protection device against overvoltage pulses.

For diode-type protection devices, connect the cathode to the energized line and the anode to GND as shown in Fig. 3.1. At this time, select the one where the breakdown voltage of the protection device has a margin with respect to the potential between the energized line and GND. In this way, the protection device does not operate during normal operation of the equipment. However, if an overvoltage pulse exceeding the breakdown voltage is applied, current flows through the protection device to the GND to protect the object.

We have a lineup of ESD protection diodes and Zener diodes as protection devices, and the connection method and operation are the same, but their characteristics are different. Each feature is described below.

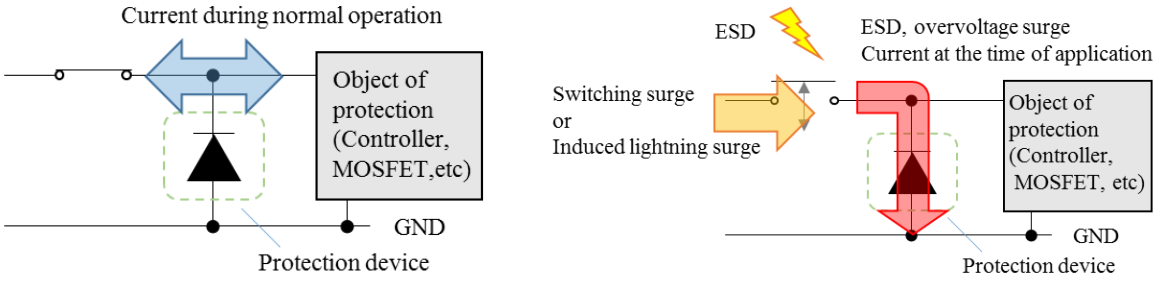


Figure 3.1 Operation Image of Protection Device during Normal Operation and when ESD and Overvoltage Surge are Applied

3.1 ESD protection diode

It is important to have a low terminal capacitance C_T as the key performance required for the protection device on the signal line. Our ESD protection diodes feature not only standard capacitance products but also low capacitance products, and we have many type of products as shown in Fig. 3.2.

It is important to protect the object from transient pulses, such as ESDs, because it is likely to be generated by contacting an object with external connectors, such as USB and HDMI, which are increasingly being installed in electric equipment. At the same time, in normal operation, if the signal frequency is high (USB, HDMI, etc.), the protection device component must be selected so as not to reduce the signal quality. We offer a range of products that emphasize the performance of protecting objects from pulses on the order of nanoseconds that are compatible with IEC61000-4-2 of electrostatic models. In addition, products conformable to IEC61000-4-5 (which is a microsecond-order over-voltage modelling because of the recent importance of protecting electronic devices from induced lightning(8/20μs))are also available. (For protection of longer overvoltage pulses, refer to the Zener diode for overvoltage protection in the next chapter.)

This is an application note about the basics of ESD Protection (TVS) Diodes.

→ Click Here

Signal line Application	Ct(typ.)	VRWM (max)(V)	0.62x0.32mm SOD-962 (SL2)	1.0x0.6mm SOD-882 (CST2)	1.0x0.6mm SOD-923	1.6x0.8mm SOD-523 (ESC)	2.5x1.25mm SOD-323 (USC)
USB3.2(10Gbps) Thunderbolt3(20Gbps) HDMI2.1(16Gbps) Wi-fi, Bluetooth(2.4GHz)	0.1 ~0.15pF	3.6V	New! DF2B5M4ASL	-	-	-	-
		5.5V	New! DF2B6M4ASL DF2B7M3SL				
USB3.1(10Gbps) HDMI2.0(6Gbps)	0.2 ~0.35pF	3.6V,3.3V	New! DF2B5M5SL DF2B5M4SL New! DF2S5M5SL DF2S5M4SL	DF2B5M4CT DF2B5M5CT DF2S5M4CT (under development)	-	-	-
		5.5V,5V	New! DF2B6M5SL DF2B6M4SL New! DF2S6M5SL DF2S6M4SL	DF2B6M4CT DF2B6M5CT DF2S6M4CT DF2B6.8M1ACT (under development)	-	-	-
NFC, Senser		8V,11V 18.5V,24V	DF2B12M4SL DF2B20M4SL DF2B26M4SL	- (under development)	DF2B20M4FS #	-	-
USB3.0(5Gbps)	0.5 ~0.6pF	3.3V	New! DF2S5M5SL (under development)	DF2S5M5CT	DF2S5M4FS #	-	-
		5V	DF2S6M5SL (under development)	DF2S6M5CT	DF2S6M4FS #		
USB2.0(480Mbps)	0.9 ~1.5pF	5.5V,5V	DF2B6USL	DF2S6.8UCT	DF2S6.8UFS DF2S6.8MFS	-	-
		19V	-	DF2S24UCT	-		
GPIO, Audio,I2C etc (100MHz~kHz)	~45pF	5.5V	New! DF2B7BSL DF2B7ASL	DF2B7ACT DF2B7PCT	DF2B7AFS #	DF2B7AE DF2B6.8E #	DF2B7AFU
		3.6V, 3.3V	New! DF2B5BSL DF2B5SL	DF2B5PCT			
Automotive CAN FlexRay/ LIN		1.5~12V Othes	DF2S5.1~8.2ASL	DF2S5.6~30CT	DF2S5.1~30FS	-	DF2S12FU DF2B18FU # DF2B29FU # DF2B36FU #

#:Automotive

Other Application	Ct(typ.)	VRWM (max)(V)	1.6x0.8mm SOD-963 (CST2C)	2.5x1.25mm SOD-323 (USC)	2.0x2..0mm UDFN6B
Power line (VCC,VBAS)	45pF以上	5.5V 10V 12.6V 21,22V	New! DF2S6P2CTC DF2S12P2CTC DF2S14P2CTC DF2S23P2CTC	New! DF2S6P2FU DF2S12P2FU DF2S14P2FU DF2S23P2FU	DF6S25P3NU (under development)

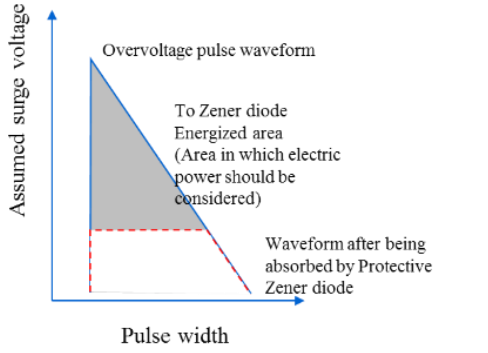
Figure 3.2 Diode Line-up for Toshiba ESD Protection (Single Product)

3.2 Zener Diodes for Overvoltage Protection

Our Zener diode is characterized by its ability to protect the object from transient overvoltage pulses as well as overvoltage pulses close to DC, which are difficult to protect with ESD protection diodes.

In addition to ESD, there are induced lightning surges and switching surges with long pulse widths (on the order of microseconds to milliseconds) as overvoltage pulses to be considered in circuit design. In order to protect the object from overvoltage pulses with such long pulse widths, it is necessary to select a product according to the assumed surge energy. In the case of overvoltage pulses such as that shown in Figure 3.3, the gray portion in the figure will be energized to the Zener diode, so it is necessary to check whether the power is acceptable. Use Equation 3.2.1 to approximate a square wave and calculate the pulse width. The surge power tolerance for each product is set as shown in Fig. 3.4. Confirm that the Zener surge power tolerance for t_W after approximating the square wave is not a problem in designing.

$$t_W = \frac{1}{P_P}\int_0^{t_1} P_{Z(t)}dt \quad \text{..... Expression 3.2.1}$$



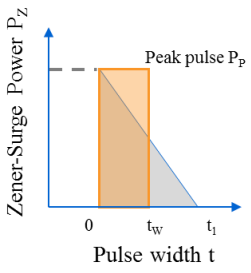


Figure. 3.3 Example of derivation of pulse width by approximating square wave from surge waveform

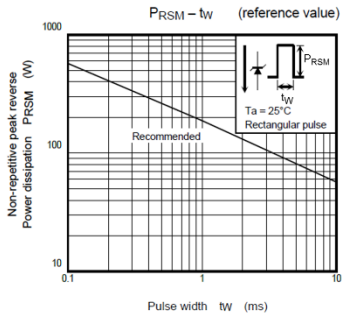


Figure. 3.4 Example of surge power tolerance

Examples of Applications	Ct(typ.)	Zener voltage $V_{Z\,typ}$(V)	1.0x0.6mm SOD-523 (ESC)	2.5x1.25mm SOD-323 (USC)	2.0×2.1mm SOT-323 (USM)	2.9x2.5mm SOT-346 (S-mini)
Low voltage protection	125	5.6	CEZ5V6	CUZ5V6	MUZ5V6	MSZ5V6
5V power lines	105	6.2	CEZ6V2	CUZ6V2	MUZ6V2	MSZ6V2
5V power lines	88	6.8	CEZ6V8	CUZ6V8	MUZ6V8	MSZ6V8
9V power lines	44	12	CEZ12V	CUZ12V	MUZ12V	MSZ12V
12V power line	35	16	CEZ16V	CUZ16V	MUZ16V	MSZ16V
20V power line	26	24	CEZ24V	CUZ24V	MUZ24V	MSZ24V

Figure 3.5 Small Zener Diode Line-up for Protection
Other lineup includes medium-sized Zener diodes Click Here

4. Conclusion

This document introduces the types of overvoltage pulses and our lineup of protection devices, such as the ESD protecting devices shown in Figures 4.1 and Table 4.1, respectively. In order to protect the object from overvoltage pulses such as ESD and surge, it is important to select a protection device according to the application. We would be pleased to utilize the protection devices introduced in this document to reduce the risk of fault caused by overvoltage pulses. I would like to ask you for our protection devices in the future as well.

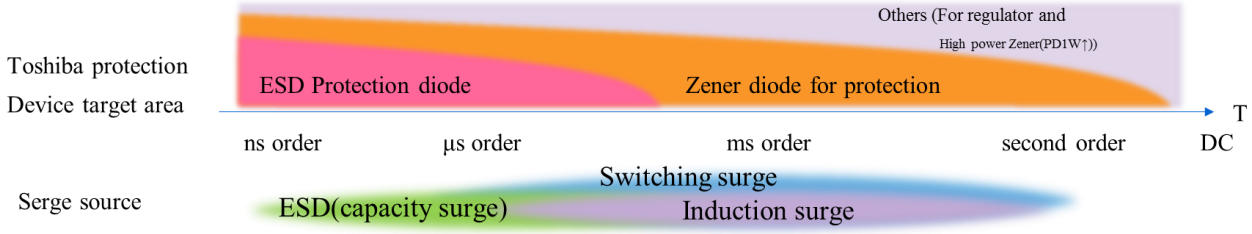


Fig.4.1 Corresponding area of ESD protection diode and Zener diode suitable for overvoltage protection

Table 4.1 Summary characteristics of ESD Protection Diodes and Zener Diodes

	ESD protection 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 more than microseconds (ESD protection application also possible*1)
Capacitance between terminals*2	0.12pF to 600pF	100 pF to 600pF (scheduled for future lineup)
Examples of Use Locations	Connectors for USB, HDMI, etc.*3	Power supply line, power control line
Remarks	Our lineup is centered on products with low capacities of less than 1pF.	If the power dissipation is within the allowable range, overvoltage pulses close to DC can also be protected.

*1 compliant standard: IEC61000-4-2, IEC61000-4-5 (8/20µs condition)
*2 For protecting 5V lines
*3 There is a product for the power supply line for protection from 8/20µs pulses assuming some induced lightning surges.

Introduction page of ESD protection diode Click Here

Lineup includes medium-sized Zener diodes Click Here

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