Chip Varistors that Absorb Static Electricity

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1 Necessity of ESD Countermeasures

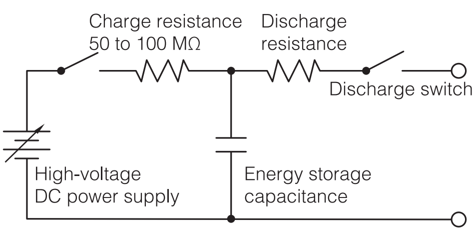
As miniaturization and reduction of power consumption of electronic devices progress, more emphasis is placed on immunity to static electricity. Static electricity enters devices through input or output buttons or gaps in device housings and causes errors or serious problems such as the destruction of internal circuits. For this reason, there have been more regulations regarding immunity to Electro-Static Discharge (ESD) for general electronic devices or automobiles, and countermeasures using ESD protection components, such as chip varistors or zener diodes, have become necessary.

2 What is Static Electricity?

ESD Test Model

An ESD test model is shown in Figure 1.

Figure 1



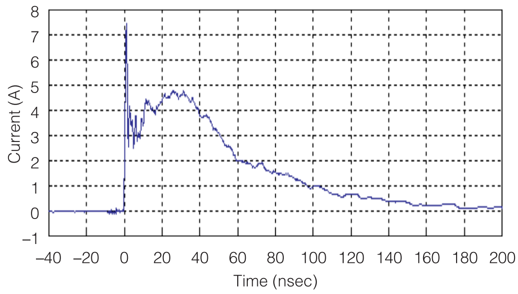
In the human body model, energy storage capacitance: 150 pF, discharge resistance: 330 Ω

First, the left side switch is closed to store electricity in the capacitor. Next, the right side switch is closed (by opening the left side switch) and the energy stored in the capacitor is discharged to simulate ESD. As for combinations of energy storage capacitance and discharge resistance, there are various models according to the assumed amount of ESD. As a human body model, IEC61000-4-2 provides the values of 150 pF for energy storage capacitance and 330 Ω for discharge resistance. Each manufacturer also sets their own ESD test specifications, and there are various requirements concerning ESD charge voltages or the number of times to apply ESD. In addition, as the relationship between humidity and ESD charge voltage is shown in IEC61000-4-2, environments differ between the manufacturing process and the market, and it is necessary to provide models and conditions that are appropriate for each environment and to conduct evaluations.

Characteristics of EDS Waveform

A typical ESD waveform (a human body model with a 2 kV charge voltage) is shown in Figure 2.

Figure 2

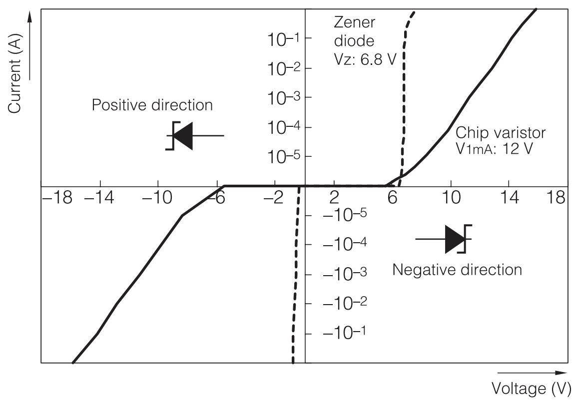


The rise time is as fast as less than 1 nsec, and the peak current is as large as 7.5 A.

3 Chip Varistor's Characteristics

The current-voltage characteristics of a chip varistor and a zener diode are shown in Figure 3.

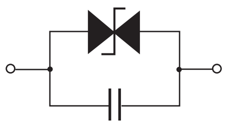
Figure 3 Current-Voltage Characteristic Examples



These elements have nonlinear characteristics; utilizing the characteristic that the resistance of the elements themselves changes according to the amount of voltage applied to the elements, they let noise escape to the ground and protect the subsequent stage circuits. In circuits, they are placed between the line and GND.

The equivalent circuit of a chip varistor is shown in Figure 4.

Figure 4　Equivalent Circuit of a Varistor Element



In this circuit, two zener diode elements that have been reversely connected in series and a capacitance component are connected in parallel. In a steady state (when the resistance of the path on the zener diode side is very large), it behaves as an element having electrostatic capacitance like a chip capacitor, but the resistance of the path on the zener diode side switches to a low resistance and clamps ESD voltage when ESD is applied. When the current-voltage characteristics of the zener diode and chip varistor in Figure 3 are compared to each other, their rise characteristics (curves) vary widely. However, steep current-voltage characteristics do not always mean superior ESD clamping performance. When comparing zener diodes and chip varistors, it is necessary to evaluate the clamp characteristics exhibited when ESD is actually applied.

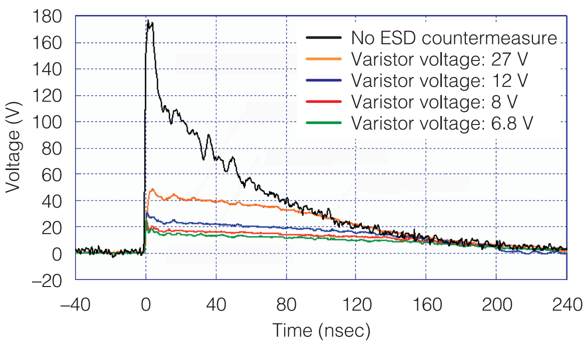
4 | How to Select Chip Varistors

■ Selection based on Varistor Voltage

Reminders and key points in selecting chip varistors are provided in the following.

The primary purpose of using a chip varistor is to increase the immunity of devices against ESD. A key point for selecting varistors is to select items with the lowest varistor voltage possible with respect to the voltage of the circuit that must be protected. TDK offers chip varistors with low varistor voltages as low as 6.8 V. The ESD clamp characteristics according to varistor voltage are shown in Figure 5.

Figure 5　Measured Waveform (ESD voltage = 1 kV)

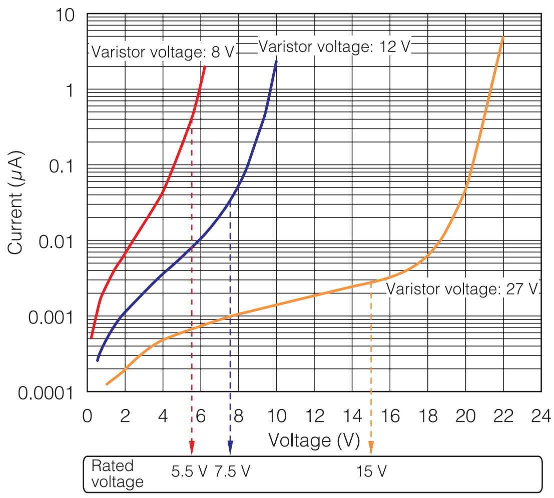


Generally, items with low varistor voltages have a higher ESD clamp effect, and items with larger capacitance have a higher ESD clamping effect when they have the same the varistor voltage. It is clear that voltage is suppressed by the use of varistors, compared to cases in which no ESD countermeasures are applied.

■ Selection based on Leakage Currents

The second reminder in selecting chip varistors is to select items with low leakage currents in circuits. One of the reasons for the increase in the necessity of ESD countermeasures is the increase of mobile electronic devices and their miniaturization. At the same time, requirements concerning leakage currents on the component level are becoming stricter, to allow the devices to be used for as long a time as possible with batteries mounted inside. A key point in making selections is to select items that provide higher rated voltages (maximum allowable circuit voltage) than the voltages of the circuits to which the varistors are applied. The current-voltage characteristics according to varistor voltage are shown in Figure 6.

Figure 6



In general, items with lower varistor voltages have lower rated voltages and cause larger leakage currents. Selections based on leakage currents require caution as they have a tendency that is contrary to that of the previously-described selection of items with good ESD clamp characteristics.

■ Selection based on Capacitance

The third reminder in selecting chip varistors is to select items that take into consideration impacts on transmitted signals. In cases where countermeasures are applied to high-speed signal lines such as USB, it is necessary to select items that have a small impact on signal quality. A key point in making selections is to select items that have cutoff frequencies that are approximately at least three to five times higher than the signal frequencies. Generally, it is said that signal quality has no problem if it can be transmitted at the fifth harmonic frequency, and this is why such a standard was established; however, in actuality, characteristics required for components may become higher due to impacts from output waveforms of ICs, PCBs or connectors. This key point also requires caution, as it has a tendency that is contrary to that of selecting items with good ESD clamp characteristics, as was previously described. The transmission waveforms according to cutoff frequency (size of capacitance) are shown in Figure 7. The original waveform is of a high-speed USB 2.0 (480 Mbps). With the item having a cutoff frequency at the fifth harmonic frequency or higher, almost no changes were observed in the signal waveform, compared to items with no ESD protection elements. However, for items with a cutoff frequency that was lower than the fifth harmonic frequency, the signal waveform had a smaller margin to the mask.

Figure 7