ESD control-Modelling ESD waveforms

Introduction

Electronic models of ESD events are important for testing the ESD sensitivity of components and systems. In general, ESD can often be modelled as a simple electronic circuit (Figure 1). Different component values are used to generate different ESD waveforms to simulate specific types of ESD events, as will be discussed in the next three sections.

Figure 1: A general ESD model

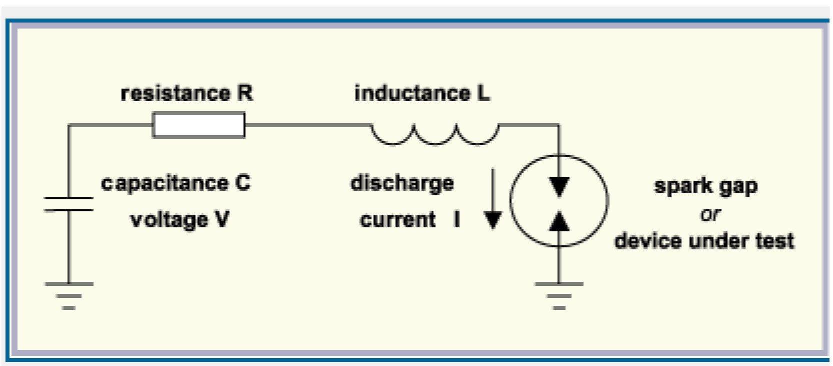

Figure 1: A general ESD model

A capacitor C is charged to an ESD voltage V. On initiating the ESD event, the ESD current flows through a circuit resistance R, inductance L and the load device or spark gap.

The ESD waveform characteristics can be matched to real ESD events by careful choice of the capacitance, circuit resistance and inductance. Occasionally, additional components are required for tailoring the waveform to a real application.

This type of model is used both in ESD immunity tests for electromagnetic compatibility (EMC) and in semiconductor device ESD sensitivity testing. Typical component values are shown in Table 1.

Table 1: Typical ESD model simulation component values

ESD Model	R (W)	C (pF)	L (nH)
Human body model HBM (Component ESD sensitivity test)	1,500	100	stray
Human body model HBM (System ElectroMagnetic Compatibility test)	330	150	stray
Machine model MM(Component ESD sensitivity test)	stray	200	stray
Charged device model CDM(Component ESD sensitivity test)	<10	4–30 (component capacitance)	<10

Human body model (HBM)

The human body model (HBM) is the most widely-used ESD model, as the human body is one of the most frequent sources of troublesome ESD in the real world. The ESD event occurs when a charged person touches another object or ground path, and is characterised by a unidirectional waveform (Figure 2).

Figure 2: Human Body Model (HBM) ESD waveform

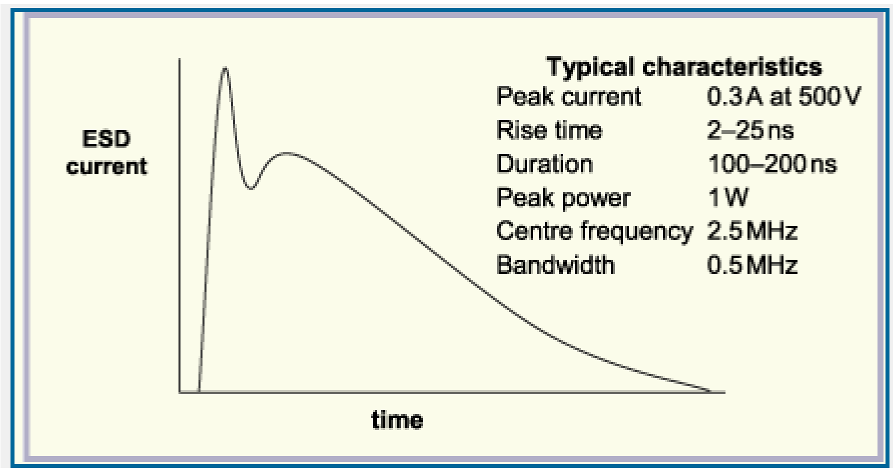

Figure 2: Human Body Model (HBM) ESD waveform

The peak current of the waveform increases in proportion to the human body voltage and (in the component test HBM model) is approximately 0.3A for a body voltage of 500V. HBM waveforms are used in EMC immunity test and semiconductor device ESD withstand voltage test. The latter is used to measure the ability of a component to withstand ESD during manufacturing processes and handling.

Slightly different component values are currently used in each application.

HBM ESD withstand voltage values are those normally quoted in a semiconductor device ESD specification.

Machine model (MM)

Machine model is used in a semiconductor device ESD sensitivity test to simulate a discharge from a large metal machine part, trolley or object that has become charged to a high voltage. It typically has a ringing waveform, although if the load has significant resistance the waveform may become unidirectional like the HBM waveform (Figure 3).

Figure 3: Machine model (MM) ESD waveform

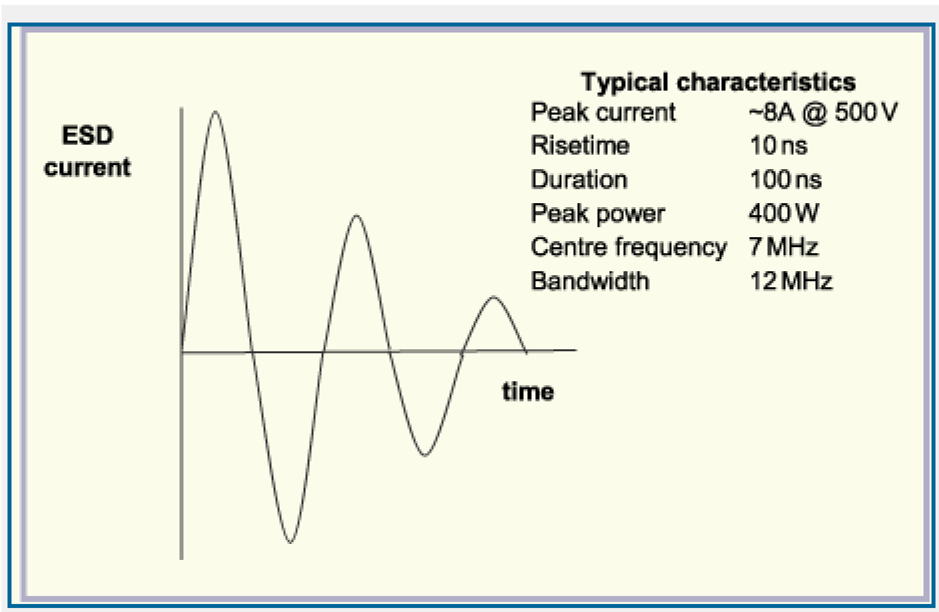

Figure 3: Machine model (MM) ESD waveform

There is a strong correlation between HBM and MM sensitivity in electronic devices. MM ESD withstand voltage is typically one tenth of HBM, e.g. a 500V HBM device will withstand 50V MM. This is explained by the high peak current, which is approximately an order of magnitude greater in MM for the same ESD voltage. In practice the peak current is rather variable and is dependent on stray inductance and resistance in the discharge circuit.

Charged device model (CDM)

Charged device model (CDM) is used in a semiconductor device ESD sensitivity test to simulate the situation where a semiconductor device is charged to a high voltage, for example by triboelectrification of its package. It is subsequently able to discharge to a grounded surface.

This mechanism has become more significant with the increase of chip sizes (and hence their capacitance), and use of automated assembly techniques.

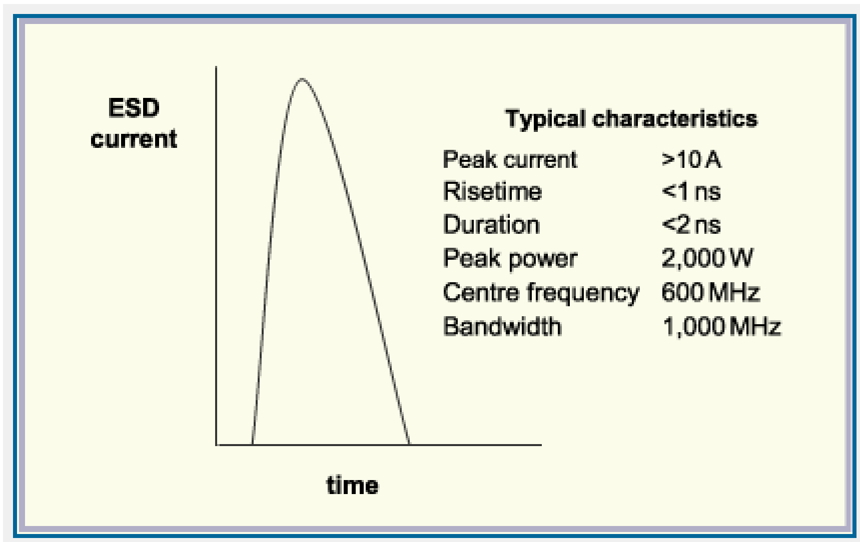

Figure 4: Charged device model (CDM) ESD waveform

CDM typically has a fast impulse-like waveform (Figure 4). It is a 'single pin' discharge, originating in charge stored within the device and discharging through the pin. In contrast, HBM and MM are 'double pin' discharges with the incident ESD current originating in an external source, passing through the device and returning to ground through a second pin.

Device internal protection structures are sometimes ineffective against CDM, due to its single pin nature (protection structures operate by clamping voltages between the pins). CDM can damage the internal structure of a device by voltage drops experienced across the internal structure and wiring, due to the fast high current characteristics of the waveform.

Charged device model damage is most frequent in automated assembly processes. A component may become charged during handling and discharge on placement onto a PCB. Alternatively, a charged PCB may discharge to the component on placement. A charged PCB may also discharge to an earthed metal part of the machine structure, and the transient currents on the board may damage components.

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