A Current Measurement Procedure for the ESD Generators according to the EN 61000-4-2

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Abstract: This paper presents a measurement technique for the Electrostatic Discharge (ESD) generators, which are constructed according to the EN 61000-4-2. Using a measurement system according to the European Standard 61000-4-2, the current that a ESD generator produces is measured for different voltage levels. The waveform of the current is recorded using an oscilloscope at 2.5 GHz and the current values at 30 ns and 60 ns are calculated. Automating this procedure the ESD generator is checked if it is in the actual limits that the European Standard defines. This procedure is a useful tool to recognise whether an ESD generator needs calibration or not.

Keywords: Electrostatic Discharge (ESD), European Standard EN 61000-4-2, ESD generators, ESD measurement system, calibration

1. Introduction

ESD is defined as the sudden transfer of charge between objects at different electrostatic potentials [1, 2]. Electrostatic discharge can change the electrical characteristics of a semiconductor device, degrading or destroying it. Electrostatic discharge also may upset the normal operation of an electronic system, causing equipment malfunction or failure.

Electrostatic charge is created whenever two different materials comes into contact and are then separated. Creating electrostatic charge by contact and separation of materials is known as "triboelectric effect". It involves the transfer of electrons between materials. The atoms of a material with no static charge have an equal number of positive (+) protons in their nucleus and negative (-) electrons orbiting the nucleus. For example, a person walking across the floor generates static electricity as shoe soles contact and then separate from the floor surface. The charge is transferred between objects normally via a spark when the potential across the narrowing air gap is high enough to cause breakdown [3, 4].

It is obvious that ESD is a transient overvoltage pulse with a steep rising edge, a high current amplitude but low energy content. A considerable amount of effort has been made to study ESD current waveforms and it has been shown that the amplitudes and risetimes vary with the charging voltages, approach speeds, electrode types and humidity [5-7].

A wide variety of engineering models have been proposed to simulate electrostatic discharge events but in general they fall into two categories [8, 9]. The first one is the Human Body Model (HBM), which simulates the direct contact of a charged human body and a component. The second is the Charged Device Model (CDM), which simulates the contact between a charged component with another component. The major difference between these two models is the risetime and the fall time of the ESD current pulse. The HBM current waveform has typically a risetime less than 10 ns and fall time between 50 and 300 ns. The CDM current waveform has typically a risetime and fall time below 1 ns and 10 ns respectively [10].

2. The European Standard 61000-4-2

The European standard 61000-4-2 relates to equipment, systems, sub-systems and peripherals which may be involved in static electricity discharges owing to environmental and installation conditions, such as low relative humidity, use of low conductivity carpets etc., which may exist in allocations classified in standards relevant to electric and electronic equipment [11].

According to the standard the electrostatic discharges can occur either as contact discharges or as air discharges. Contact discharge is the preferred test method and air discharges shall be used in cases, where contact discharges cannot be applied. The range of the test level voltages for the contact discharges is 2 to 8 kV and for the air discharges is 2 to 15 kV. The HBM pulse that the ESD generator must produce is shown in figure 1.

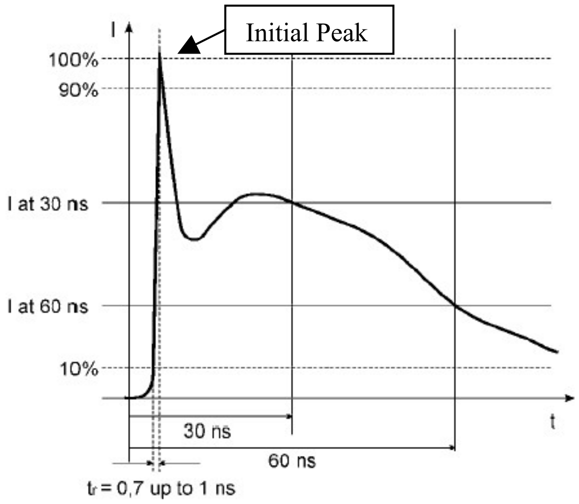

Fig. 1: Typical waveform of the output current of the ESD generator [11].

The pulse of figure 1 is divided in two parts: A first peak called as "Initial Peak", caused by a discharge of the hand (where there is the maximum current I_{max}) and a second peak, which is caused by a discharge of the body. The rise time of the Initial Peak is between 0.7 ns and 1 ns and its amplitude depends on the charging voltage of the ESD simulator. The rise time is defined as the time needed the current to reach the 90% of I_{max}, having as beginning point the time when the current is 10% of I_{max}. Also, in figure 1 is shown how the current values at 30 or 60 ns can be easily calculated.

3. Measurement of Discharge Current

3.1 The ESD measurement set up

Figure 2 shows the ESD current measurement set-up. An ESD event caused by an ESD generator was measured by the Tektronix oscilloscope model TDS 7254B, whose bandwidth ranged from dc to 2.5 GHz. Also, a resistive load was used, as the European Standard defines. This resistive load (Pellegrini target MD 101) [12, 13] was designed to measure discharge currents by ESD events on the target area and its bandwidth is ranged from dc to above 1 GHz. Figure 3 shows the insertion loss of the target, where it is obvious that MD 101 has a linear behaviour from dc until almost 5 GHz [12]. The equivalent circuit of the measurement set-up is also shown in figure 4.

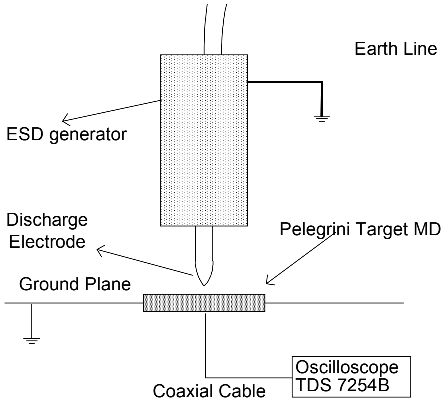

Fig. 2: ESD current measurement set-up.

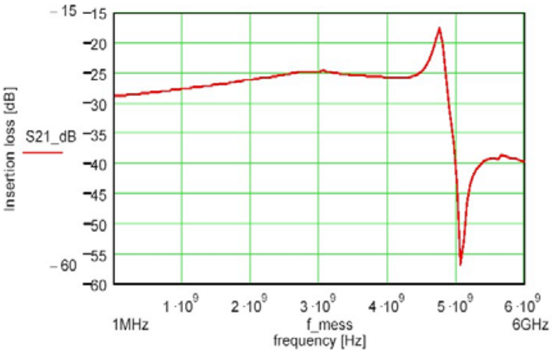

Fig. 3: Insertion loss of the Pellegrini target MD 101 [12].

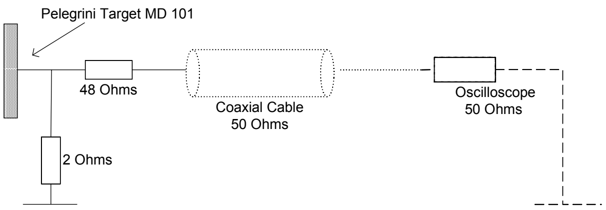

Fig. 4: Equivalent circuit of the measurement set-up.

In order the measurement set-up to be unaffected by surrounding systems, the experiment was conducted in an anechoic chamber, and cables were set away from the discharge gap. The generator's capacitance was charged with positive polarity, and the charging voltages were set to 2, 4, 8 and 15 kV. The temperature and relative humidity were measured and found 23±1°C and 45±3 %, respectively.

3.2 Measurement data processing

In order the signal of the current to be smoothed, a data processing of the current waveform was obtained. Smoothing is a method according to which it is assumed that the signal is continuous and not discrete. Therefore the y-coordinate of a point, which diverges from the expected value, can be calculated through its vicinal points. Adding equal number of precedent and ensuing points at the y-coordinate y_k of the point, the average value can be calculated according to the following equation [14]:

$$y_k^* = \frac{1}{2m+1} \cdot \sum_{n=k-m}^{k+m} y_n \tag{1}$$

where 2m+1 is the total number of the points which contribute to the calculation of the value y_k^* (m precedent + m ensuing + observation point).

The result of smoothing can be seen clearly in figure 5. The quantized waveform (input waveform) taken by a measurement system is converted into the smoothed output waveform.

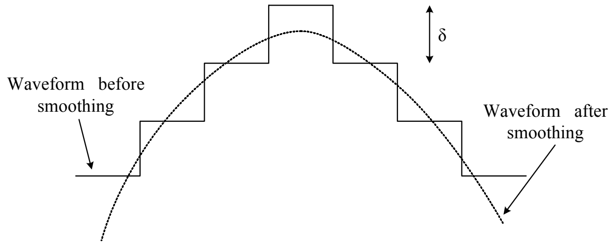

Figure 5: A smoothed waveform digitally saved.

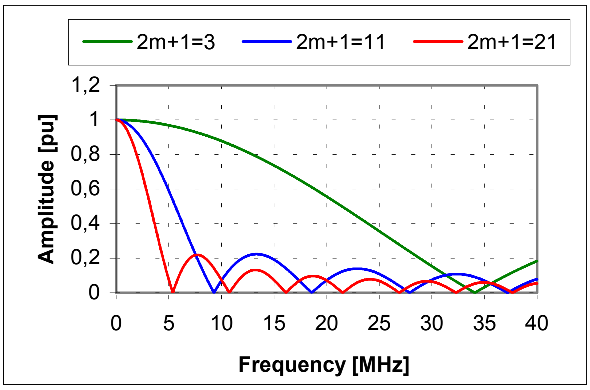

Figure 6: The characteristic frequency of the equivalent low pass filter with the sum (2m+1) as parameter.

Smoothing gives the same results that a low pass filter would give. The cut down frequency of this filter is a function of the number (2m+1) (number of the points, which contribute to the y-coordinate calculation of the smoothed waveform). The characteristic frequency of the equivalent low pass filter is shown in figure 6, while in figure 7 the cut down frequency (-3db) of this filter can be seen.

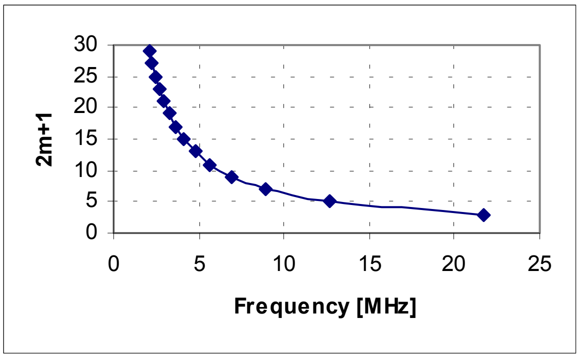

Figure 7: Cut down frequency (-3db) of the equivalent low pass filter as a function of the sampling number.

3.3 Measurement results

A typical representative oscillogram of the current waveforms taken by the digital oscilloscope is shown in figure 8, for a discharge voltage at 4 kV. These signals are in the time domain and it is obvious that they are similar to the typical waveform of the output current as it was described in figure 1. The initial peak and the second peak can easily be seen in this figure.

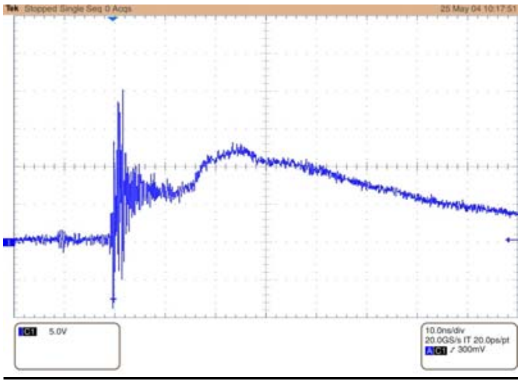

Figure 8: Current waveform taken by the oscilloscope TDS 7254B when the charging voltage was 4 kV.

Taking the measurement data of the current waveform, which is depicted on figure 8 a further analysis and better representation is possible using Excel. In figure 9 the current waveform for 4 kV voltage discharge from 0 ns to 200 ns and also the ESD current for the brief period from 100 ns to 105 ns is shown. The current value at the initial peak (I_{max}) is 16.4 A at 100,5 ns, which is in accordance to the Standard defining that I_{max} is 15±10% A at 4 kV discharge. From the current measurement data easily can be found, using an appropriate program written in Matlab, that the time needed by the current to reach the 10% and 90% of I_{max}, is 99,7 ns and 100,45 ns respectively. Consequently, t_r=100,45-99,7=0,75 ns, which proves that the ESD generator used is in accordance to the European Standard, since the prescribed rise time must be between 0.7 and 1 ns.

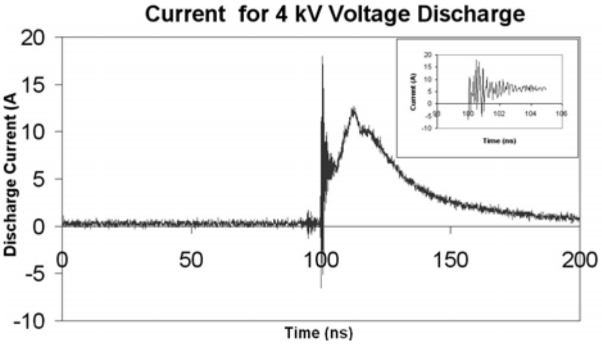

Figure 9: Discharge current when the charging voltage is 4 kV, using Excel.

The Tektronix oscilloscope has many capabilities, since a Pentium IV processor with OS Win 2000, is embodied to it. Many mathematical functions can be implemented using the oscilloscope instead of a desktop PC.

One more advantage of the Tektronix oscilloscope is that it can work as an oscilloscope of lower bandwidth. In figures 10 and 11 two different current waveforms are shown for the oscilloscope working at 20 MHz and 100 MHz respectively. Making a comparison of these two waveforms to the waveform in figure 8 that has been taken for the full bandwidth (2,5 GHz) of the oscilloscope, it is concluded that for higher bandwidth the accuracy is greater. Also, it is concluded that the smoothing process is not necessary for the current waveform of figure 8. Although a possible smoothing of the current waveform would give a more normal shape, this action would lead to great inaccuracies. A smoothed waveform would be a waveform taken from an oscilloscope working at a bandwidth of MHz (as it can be seen in figure 6) and not at GHz, as the Standard defines.

The initial peak and consequently the rise time and the current values at 30 ns and 60 ns are calculated with greater accuracy. This is the reason why the European Standard EN 61000-4-2 defines that the oscilloscope for the calibration of the ESD generator must have a bandwidth of at least 1 GHz. This calculation can be obtained using Matlab for the process of the current measurement data. For the current waveform of figure 8 the current values at 30 ns and 60 ns were found 6,1 A and 2,9 A respectively. The points at 30 ns or 60 ns are defined starting by the time that the current is 10 % of I_{max} and not from 0 ns as it is depicted in figures 8 and 9. According to the Standard as the waveform parameters is concerned, these values are accepted, since the EN 61000-4-2 defines that for the 4 kV charge the current at 30 ns and 60 ns must be 8±30% A and 4±30% A, respectively.

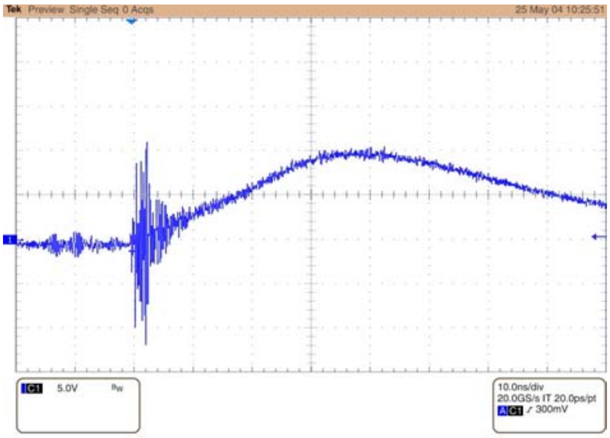

Figure 10: Discharge current waveforms, for a charging voltage of 4 kV, when the oscilloscope works at 20 MHz.

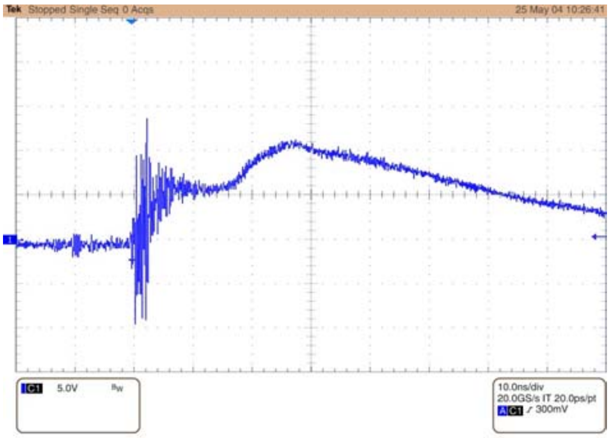

Figure 11: Discharge current waveforms when the charging voltage is 4 kV, when the oscilloscope works at 100 MHz.

4. Conclusions

The calibration of laboratory instruments is extremely significant factor due to the high cost it may have and the accuracy needed for the measurements. This procedure can be automated for the ESD phenomenon, in order the current parameters of the waveforms that the ESD generators produce to be examined according to EN 61000-4-2. In this way it can be found whether these generators need calibration or not. In order a High Voltage Laboratory to be able to conduct the procedure whether an ESD generator needs calibration or not, it must have an oscilloscope working at least at 1 GHz as the Standard defines and the ESD current measurement set-up with the resistive load as it was described in this paper.

This procedure can be automated and in a few minutes can be easily found whether the ESD generator needs calibration or not. An appropriate program written in Matlab can process the current measurement data and calculate the initial peak, the current values at 30 ns and 60 ns and to find whether these values are in accordance to the Standard or not. A smoothing procedure in order the current waveform to be more distinguishable cannot be followed, because such an action would be against the Standard.

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