June, 2015

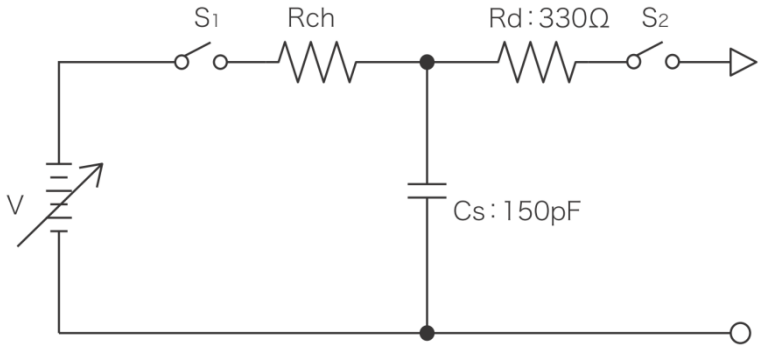
Points of ESD Test and Tips for Countermeasures

Hideki Kimura
Noise Laboratory Co., Ltd.

1. Outline of the Test

The ESD test specified in IEC61000-4-2 simulates electrostatic discharge from a charged human body and evaluates the presence or absence of deviation or damage from normal operation.
As a specific test method, the static electricity charged in the capacitor is applied directly to the test equipment or indirectly using a test jig. But the applied static electricity rises very quickly and is GHz band. Since it has an extremely wide band high frequency component, it is not a simple withstand voltage test but a resistance test against a high frequency electromagnetic field generated secondarily, and it is easy if sufficient measures are not taken based on it. It is a rigorous test that causes defects.

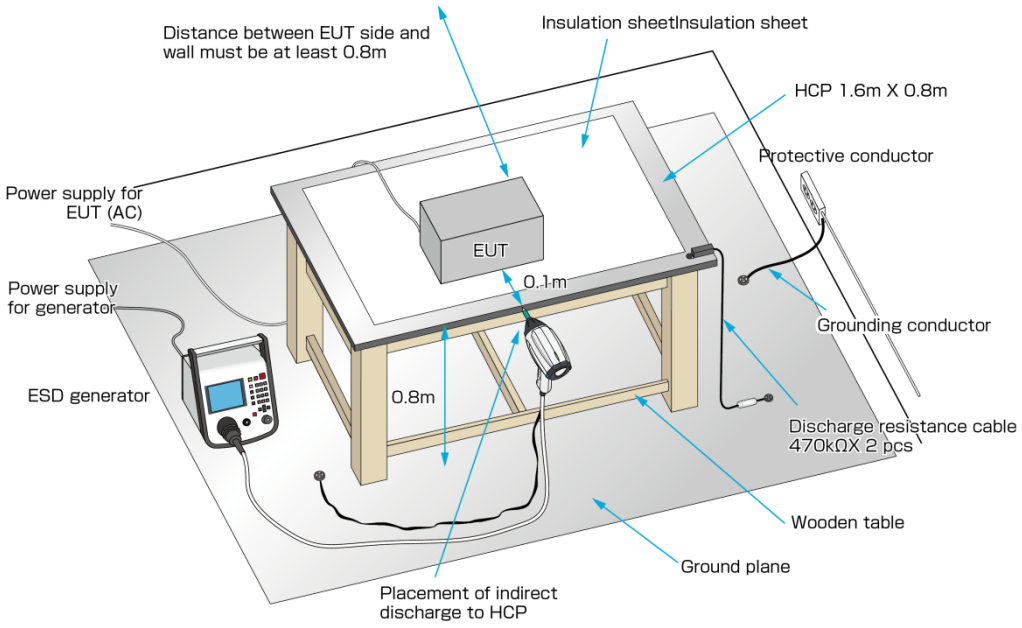
As a test environment, it is recommended to carry out in a shield room or an anechoic chamber because electrostatic discharge during the test may cause problems in surrounding electronic devices.
Then, a metal plate (reference ground plane) that serves as a reference potential for the applied static electricity is laid on the floor surface of the test area, and the test equipment is placed on the metal plate (reference ground plane) via an insulation support base having a specified height.
The general values of the capacitor and discharge resistance used in the generation circuit are 150pF and 330Ω, respectively, which are the representative values of the capacitance and discharge resistance of the human body.
However, since the model is not a human body with bare hands but a human body with a metal object such as a tool, the value of the discharge resistance is correspondingly lower. (In the case of bare hands, the typical value is around 2 kΩ)



Simplified circuit diagram of ESD Simulator

The method of applying static electricity is classified into "direct discharge" in which static electricity is directly applied to the test equipment and "indirect discharge" in which a jig called a coupling plate is used.
Direct discharge is intended for parts that are expected to come into direct contact with the human body in normal use, of which conductive parts are contact discharge (which generates voltage while in contact with the target) and Air discharge (close the charged electrode from a distance) to the non-conductive part. The application method is different from that.
All of the electrostatic discharges that actually occur are air discharges. But since the air discharges are greatly affected by the surrounding environment such as humidity and so on, it has been found to be disadvantageous due to poor quantification in the tests. For this reason, it is stipulated that the contact discharge method is preferentially selected as a method advantageous for quantification.

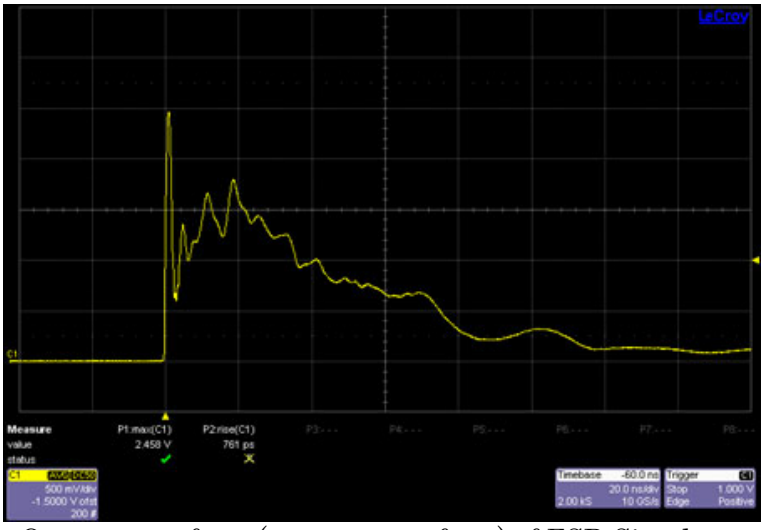
Indirect discharge is tested by applying it to a jig (metal plate) called a coupling plate, assuming electrostatic discharge to a nearby metal object such as a steel desk or adjacent equipment.
However, instead of causing a secondary discharge from the coupling plate to the test equipment, the evaluation is based on the electromagnetic coupling between the coupling plate and the test equipment.



Example of test equipment layout

2. Test Points

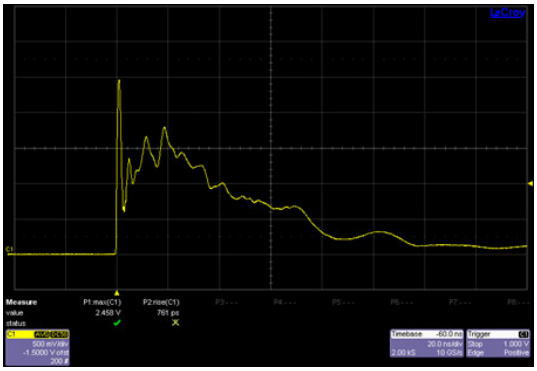
The output waveform of the ESD Simulator is a composite waveform with a sharp rise and a gentle rise.
A sharp rise can be obtained by the parasitic capacitance (distributed capacitance) generated between the discharge gun and the test equipment, and a gentle rise is the discharge curve obtained by CR of 150pF / 330Ω.



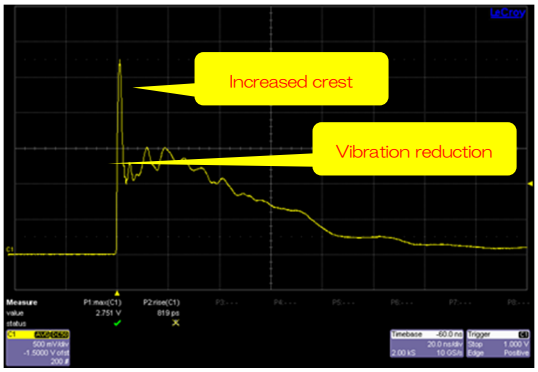
Output waveform (current waveform) of ESD Simulator

Although the action on the test equipment is different, both pulses contain high-frequency components, which are affected by the handling of the discharge gun and the positional relationship with the test equipment.
Here, we will introduce some cases that can affect the output waveform of the tester, with an awareness of improving the quantitativeness and reproducibility of the test.

The first is how to hold the discharge gun, and it is desirable to consciously unify this.
Especially in the static electricity test that lasts for a long time, the weight of the discharge gun may make the hands tired, and it is sometimes seen that the discharge gun is supported by both hands.
However, if the human body, which is a conductor, parasitizes the discharge gun, it affects the high-frequency action of the discharge gun, and as a result, it becomes a factor that impairs the quantitativeness.
In addition, the discharge gun is equipped with a GND cable that mainly functions as a return path for the gentle rising part, but if this GND cable is also held by hand, it will cause a change in the waveform.
Therefore, it is necessary to be careful not to touch the part other than the grip of the discharge gun unnecessarily.

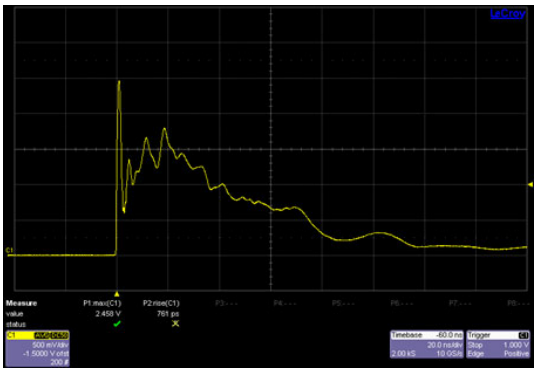


Standard waveform

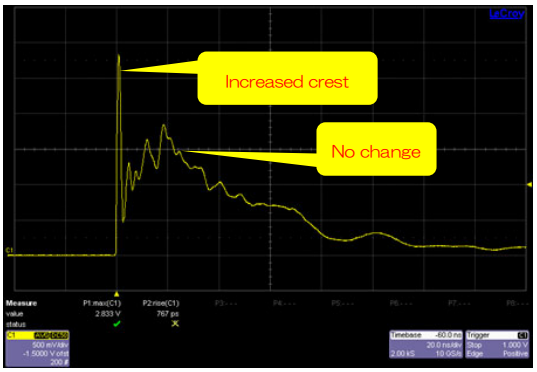


In case of touching the part other than the grip of the discharge gun

Furthermore, it is necessary to consider the angle of the discharge gun with respect to the applied surface.
The biggest feature of the ESD test is the sharp rise with a high frequency element. As mentioned above, this sharp rise can be obtained by the distributed capacitance between the discharge gun and the applied surface.
In other words, since this distributed capacitance changes depending on the angle of the discharge gun with respect to the applied surface, if the discharge gun cannot be held at a right angle to the applied surface, the applied waveform will change in an unexpected manner.
Therefore, it is necessary to pay attention to the angle of the discharge gun with respect to the applied surface.

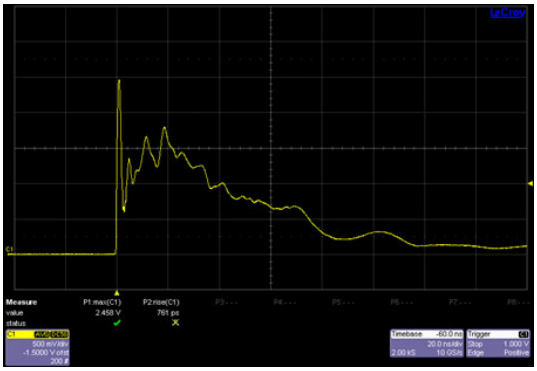


Standard waveform

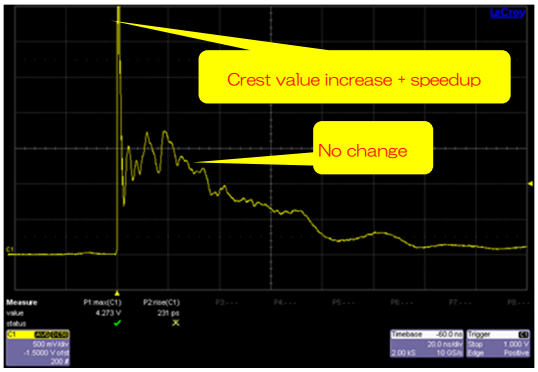


When the angle of the discharge gun is not right angle

When contact discharge is performed on the exterior of the test equipment, that part is often painted. But it must break through the paint and make proper contact with the conductive part, if the application point is painted.
If this is not done, spark discharge will occur in a small gap corresponding to the thickness of the coating, and a very fast rising current, that is, a threatening pulse containing more high frequency components than usual will be applied. Therefore, depending on the specifications of the equipment under test, the test may be stricter than the standard requirements.



Standard waveform



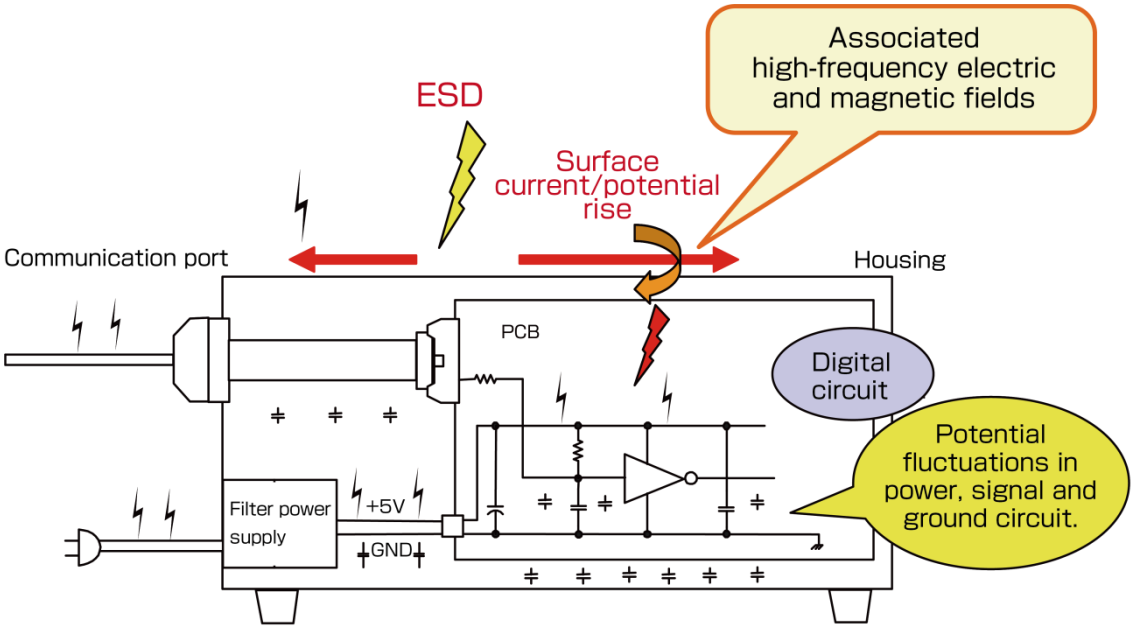
Incomplete contact with the painted surface

Since the ESD test is carried out with a discharge gun, it is a test involving human intervention, and there are many uncertain factors such as the handling of the discharge gun and the influence of the human body, and it is difficult to pursue quantitativeness.
Therefore, it is important to work on the test with at least this in mind in order to improve the quantitativeness of the test as much as possible.

3. Countermeasure tips

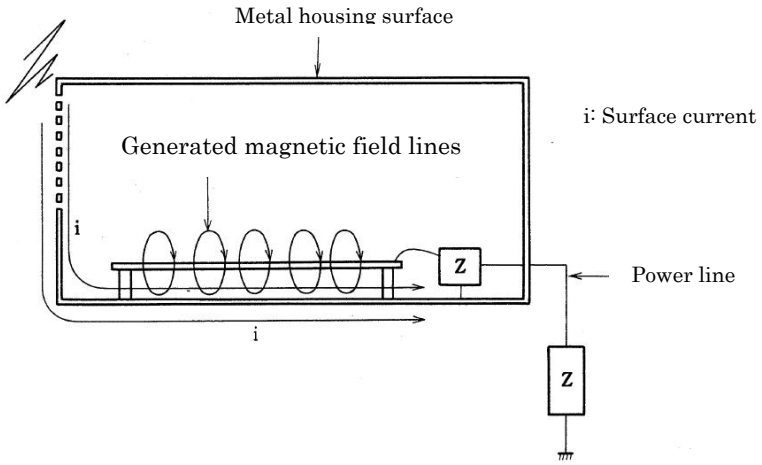
As mentioned above, the ESD test is not just a withstand voltage test, but also a resistance test against a secondary high-frequency electromagnetic field, and the point of countermeasures is how to prevent this high-frequency element from being generated and how to make it difficult to receive.

When static electricity is applied to the housing of the test equipment, the discharge current quickly diffuses as a surface current on the surface of the housing and couples with the horizontal coupling plate or ground plane via stray capacitance.
After that, the electric charge on the housing flows to the ground connection of the test equipment via the shortest path with low impedance. The electromagnetic field secondarily generated in this state transition is coupled to the internal board, parts, wiring, etc., and threatens the operation of the device.



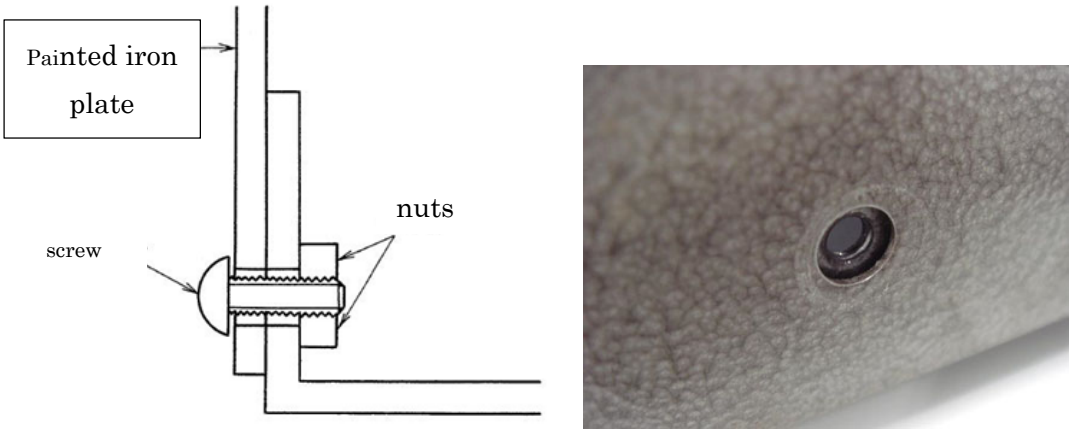
Impact on test equipment in electrostatic test

At this time, when the discharge current diffuses on the surface of the housing or flows to the ground connection of the test device, a magnetic field having a high frequency element is generated. So that the circuit of the test device exposed to the magnetic field is affected by inductive coupling.
Further, when the electric potential of the housing rises due to the application of static electricity, an electric field having a high frequency element is generated, so that the circuit of the test equipment exposed to the electric field is affected by the capacitive coupling.
The electric field / magnetic field having these high-frequency elements generates a small electric field / magnetic field when the current diffuses on the surface of the housing and becomes low in density, and the coupling to the circuit is weak.
However, if there is a high-frequency discontinuity (such as a part that obstructs the current flow or a part where the current is concentrated) such as a seam of the housing or a screwed part in the current path, the impedance is adjusted there. An electromagnetic field will be generated.



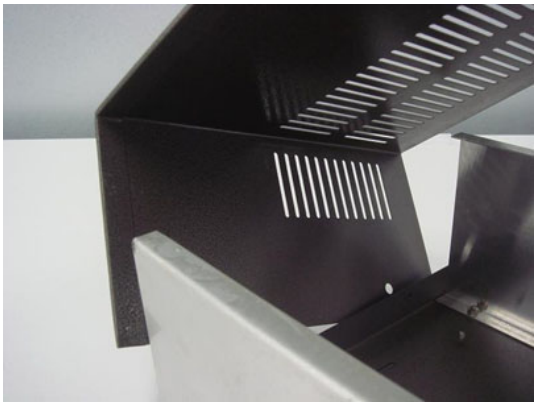
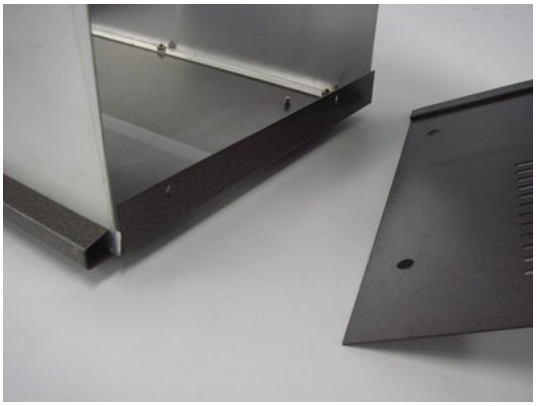
How discharge current flows to ground

For this reason, it is a rule of thumb to take measures against static electricity that the static electricity applied to the housing is immediately diffused and then smoothly flowed to the ground. If this is not done, it will be difficult to take measures.
As a specific point to note, for example, in the case of a structure in which a sheet metal is screwed, the paint on the part where the screws and nuts come into contact may be removed, or a chrysanthemum washer may be inserted. It is important to be aware of the condition.



Remove the paint from the parts where the screws and nuts come into contact

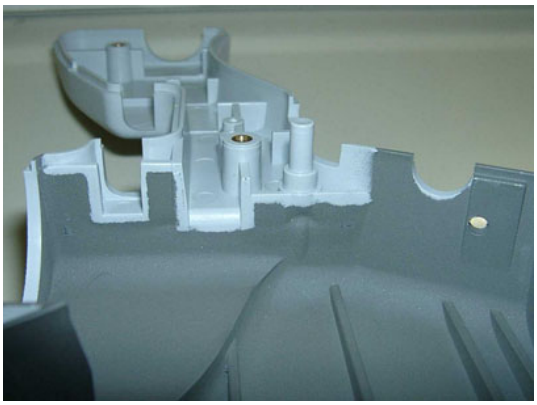
Similarly, it is indispensable to remove the paint or insert a gasket on the part where the sheet metals come into contact with each other so that all the sheet metals have an integrated structure.
Such a housing structure is effective not only in ESD test but also in "radiation emissions" and "radiation immunity".

Peel off the paint from the parts where the sheet metals contact each other
(combined with gasket)

Furthermore, the influence of the potential difference must be taken into consideration.
By applying static electricity, the housing potential of the test equipment rises, but if the potential of the circuit also rises at this time, no potential difference is generated, so no particular problem occurs.
However, if the circuit potential is different with respect to the rise in the housing potential, a potential difference will occur, and the state will be susceptible to the danger of secondary discharge and the electromagnetic field.
Therefore, it is desirable that the circuit ground be equal to the housing potential.
However, if the circuit becomes a path for static electricity due to the potential difference that occurs in each part of the housing, the potential difference that occurs when there are multiple units, etc. Since the connection of the above will have a large effect, it is necessary to take measures to eliminate the potential difference.

It should be noted that the discussion so far is only for a metal housing, and when the test device is a resin housing, the test is mainly based on the air discharge.
The air discharge discharges the internal sheet metal or parts through a gap on the surface of the housing, and in some cases, static electricity directly enters the circuit itself.
At that time, it is possible to take measures against the incoming static electricity with a varistor or the like, but one of the measures is to prevent the static electricity from entering the inside of the housing, that is, to prevent the electric discharge from being received.
In addition, If it is affected by an electromagnetic field generated by an air discharge or an indirect discharge, a metal plate to guard the electromagnetic field inside the housing or a conductive coating is applied to the inside of the housing to provide a shielding effect.




Example of conductive coating on the inside of the housing

Here, we introduce the "impact adapter (neighborhood probe)" as a useful tool for countermeasures. The "impact adapter (neighborhood probe)" is a jig for reproducing the electric field / magnetic field that can be generated by applying static electricity. By removing the exterior of the test equipment and verifying it naked, it is possible to search for parts that require countermeasures.
There are two types of impact adapters, "for electric fields" and "for magnetic fields", so it is possible to determine which effect is dominant by using these properly.
Since the output of the square wave impulse noise tester also has a high-speed rise like the ESD generator, it can be used for static electricity countermeasures by using a dedicated proximity probe.

Shock Electric Field Adapter　　Shock Magnetic Field Adapter

4. Conclusion

When taking measures against static electricity, it is necessary to take these measures into consideration, since the method of measures greatly differs depending on the material of the EUT, the structure of the housing, and the internal circuit configuration. Also, in order not to cause a difference in the test results, it is important to work with quantification as much as possible.