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A Comparative Evaluation of Electrostatic Discharge Testing Requirements in IEC 61000-4-2:2025 and ISO 10605:2023

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Abstract

Electrostatic Discharge (ESD) remains one of the causes of failures in modern electronics, especially in microelectronics. This paper provides a critical comparative analysis of the recently released IEC 61000-4-2:2025 and the updated ISO 10605:2023. Both standards define immunity requirements. The recent revisions introduced methodologies for calibration, waveform verification, and application-specific testing, such as for wearable products and Electric Vehicles (EVs). This study analyses the various requirements of both standards with respect to test levels, test equipment requirements, waveform specifications, calibration requirements of the ESD generator (with Air and Contact Discharge Tips), verification aspects of the ESD test setup, test setup and test procedure, Measurement Uncertainty (MU) considerations, test setups specified for wall-mounted equipment and wearable devices, compliance criteria, etc. Furthermore, it evaluates and highlights the significant technical changes in IEC 61000-4-2:2025, specifically the introduction of second peak current (Ip2), the standardized calibration for air discharge tips, and the introduction of Annex J for wearable devices, along with other technical changes in the standard. The novelty of this study is to highlight the provisions of both the latest published standards by comparing them.

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1. INTRODUCTION

1.1 Background and Definition

The testing of Electromagnetic Compatibility (EMC) has undergone a significant transformation with the release of IEC 61000-4-2:2025[1] and ISO 10605:2023[2]. As electronic systems migrate towards higher power densities and smaller architectures, the methodologies used to simulate human body discharge must evolve to ensure long-term reliability.

Electrostatic Discharge (ESD) is the sudden, high-voltage flow of electricity between objects with different charges, creating a threat to modern, miniaturized electronics[1-3].

As the sensitivity of sub-micron semiconductor nodes increases, devices become smaller and more integrated. Electrostatic Discharge (ESD) is no longer just involved with manufacturing activities but is a critical field-reliability threat.

ESD can cause permanent damage, resulting in immediate failure or latent defects that cause devices to fail in the field over time. Modern Semiconductor devices (i.e., MOSFETs) have tiny dimensions and thin insulating layers. A small discharge can damage such thin layers, leading to catastrophic failure.

If we talk about the source of ESD generation, human handling is a major factor, with daily activities like walking on carpet generating thousands of volts[4,8]. Other sources include automated machinery, shipping materials, and connectors.

Although both IEC 61000-4-2 and ISO 10605 refer to ESD testing, they serve different purposes and focus on different electronic systems. IEC 61000-4-2 has a wide scope, making it suitable for various electronic products, including consumer electronics, industrial equipment, and more[4]. The latest edition of IEC 61000-4-2:2025 was released to modernize ESD testing for rapidly evolving technologies such as wearable devices, while improving the reproducibility of test results[1,6,7]. On the other hand, ISO 10605 is customized for the automotive sector, addressing ESD testing requirements specific to that industry, and the updated standard includes some significant technical changes.

1.2 Type of Discharges

1.2.1 Contact Discharge

In this method, the generator tip is directly connected to the device under test, and the required voltage level is applied to the device.

1.2.2 Air Discharge

In this method, the air discharge tip is not directly connected to the device under test; instead, the discharge is generated across an air gap and performed on insulated surfaces.

In commercial and industrial devices, ESD testing is performed as specified in the IEC standard with the specified RC network, whereas in automotive devices/vehicles, ESD testing also depends on the location of the components, whether they are used on the exterior or interior side.

The growing divergence between consumer and automotive reliability lies fundamentally in the source impedance and capacitance.

Consumer products (IEC 2025): Use a 150 pF capacitor, which simulates a person (human body simulation) touching a device in an open environment.

Automotive products (ISO 2023): In addition to the 150 pF capacitor, a 330 pF capacitor is also mandated to simulate a person seated inside a vehicle cabin, where the body's proximity to the metallic chassis increases capacitance.

1.3 Scope and Objectives

Comparing the IEC 2025 and ISO 2023 frameworks and providing a roadmap for cross-industry hardware designers by:

- Conducting a comprehensive comparative evaluation of the core testing parameters, such as test levels, test equipment, waveform specifications (Ip2, second peak requirement), calibration of the ESD generator (with air and contact discharge tips), verification of the ESD generator, test setups and test procedures, Measurement Uncertainty (MU) considerations, test setups for wall-mounted equipment, test requirements for wearable devices, and compliance criteria.

- Highlighting the transition from legacy 2008-era protocols to the modern requirements introduced in IEC 61000-4-2:2025 and ISO 10605:2023.
- Evaluating the impact of the newly introduced requirements, such as air-discharge tip calibration in the 2025 IEC update, and comparing the waveform pulse parameters, specifically the second peak current (Ip2).
- Assessing the adequacy of the new Annex J (wearables) and Annex I (wall-mounted equipment) in the 2025 IEC revision for non-grounded devices and contrasting these with the Field Coupling Plane (FCP) grounding philosophies of the 2023 automotive standard.

The objective behind this analysis is to understand the gaps where a component tested as "safe" for domestic/commercial devices (tested according to IEC 2025) might fail catastrophically when placed in a car door handle (to be tested according to ISO 2023). This may happen because the automotive standard, for example, uses a 330 pF capacitor, delivering more than double the energy compared to the 150 pF capacitor used in the commercial standard. Therefore, it is very challenging for automotive engineers to handle such energy using small components in modern automotive electronics.

1.4 Contribution of this Paper

This paper provides a comparative analysis of the latest IEC 2025 and ISO 2023 standards. A similar comparison was conducted for the previous versions of both standards to highlight the differences[4].

2. THEORETICAL FRAMEWORK AND STANDARD EVOLUTION

2.1 The Physics of Human-Metal Discharge

- The simplified model used in both standards represents the human body as a Capacitor (Cs) and a discharge Resistor (Rd). The discharge equation presents the mathematical approximation of the ESD current waveform, accounting for the rapid initial peak and the slower body-discharge tail.
- The energy stored in the generator is defined as $E = \frac{1}{2}CV^2$. This forms the theoretical basis for the "severity gap" between commercial and automotive testing.

2.2 Revision of IEC 61000-4-2: Edition 2.0 (2008) to 3.0 (2025)

- Edition 2.0 (2008) focused on desktop and industrial equipment with fixed grounding, and the IEC 2025 update was necessitated by the rise of ungrounded mobile devices and wearable technology.
- Highlight the transition from simple current verification to mandatory air-tip calibration and the introduction of the new second-peak parameter in the current waveform.

2.3 Revision of ISO 10605: 2008 to 2023

- ISO 10605 evolved as a specialized branch of IEC 61000-4-2 to address the unique environment of a vehicle, including both its interior and exterior.
- The 2023 revision reflects the shift toward Electric Vehicles (EVs), expanding its scope to include high-voltage unshielded power systems. It also includes the requirements for Field Coupling Planes (FCPs) and adjusts the discharge interval to 1 second to better simulate real-world service and passenger scenarios.

3. METHODOLOGIES

A comparative methodology is used for this analysis to compare the ESD immunity procedures specified in the newly released standards IEC 61000-4-2:2025[1] and ISO 10605:2023[2], which are selected as representative frameworks for general electronic equipment and automotive electronics, respectively.

Key parameters, were extracted from the standards and organized into a structured comparison matrix. The analysis is more focused on the provisions mentioned above in the latest edition of the IEC standard, IEC 61000-4-2:2025[1], and compares them

with the corresponding provisions specified in the updated edition of ISO 10605:2023[2].

3.1 Test levels comparison

3.1.1 IEC 61000-4-2:2025 (Discharge Voltages)

The preferred range of test voltage levels specified in IEC is summarised in Table 1, and additional information related to the application of the test levels is provided in Annex A of the IEC. The maximum contact discharge specified by the standard is ±8 kV, and the maximum air discharge is ±15 kV[1].

Table 1. Test levels[1]

Level	Contact discharge test voltage	Air discharge test voltage
1	±2 kV	±2 kV
2	±4 kV	±4 kV
3	±6 kV	±8 kV
4	±8 kV	±15 kV

3.1.2 ISO 10605:2023

The standard also suggests test severity levels, as an example, for automotive components and vehicles for direct/indirect contact discharges and air discharges, categorized by location and product category, as specified in Annex C of the ISO standard and summarized in Table 2. The ISO standard specifies a maximum contact discharge of ±15 kV and a maximum air discharge of ±25 kV, depending on the product type and category[2].

Table 2. Test severity levels[2]

Test severity level	Category 1	Category 2	Category 3
Component test - for direct contact discharge			
L4i	±8 kV	±8 kV	±15 kV
L3i	±6 kV	±8 kV	±8 kV
L2i	±4 kV	±4 kV	±6 kV
L1i	±2 kV	±2 kV	±4 kV
Component test- for direct air discharge			
L4i	±15 kV	±15 kV	±25 kV
L3i	±8 kV	±8 kV	±15 kV
L2i	±4 kV	±6 kV	±8 kV
L1i	±2 kV	±4 kV	±6 kV
Component test - for indirect contact discharge			
L4i	±8 kV	±15 kV	±20 kV
L3i	±6 kV	±8 kV	±15 kV
L2i	±4 kV	±4 kV	±8 kV
L1i	±2 kV	±2 kV	±4 kV
Component test - Packaging and handling - for direct contact discharge (connector pins)			
Full function after test	±1 kV	±2 kV	±4 kV
Component test - Packaging and handling - for direct air discharge			
Full function after test	±8 kV	±15 kV	±25 kV
Vehicle test - for contact discharge (test points accessible only from inside vehicle)			
L4i	±6 kV	±8 kV	±8 kV
L3i	±4 kV	±4 kV	±6 kV
L2i	±2 kV	±2 kV	±2 kV
L1i	Not applicable	Not applicable	Not applicable
Vehicle test - for air discharge (test points accessible only from inside vehicle)			
L4i	±8 kV	±15 kV	±15 kV
L3i	±6 kV	±8 kV	±8 kV
L2i	±4 kV	±4 kV	±6 kV
L1i	±2 kV	±2 kV	±4 kV
Vehicle test - for contact discharge (test points accessible only from outside vehicle)			
L4i	±6 kV	±8 kV	±8 kV
L3i	±4 kV	±6 kV	±6 kV
L2i	±2 kV	±2 kV	±4 kV
L1i	Not applicable	Not applicable	±2 kV
Vehicle test - for air discharge (test points accessible only from outside vehicle)			
L4i	±15 kV	±15 kV	±25 kV
L3i	±8 kV	±8 kV	±15 kV
L2i	±4 kV	±6 kV	±8 kV
L1i	±2 kV	±4 kV	±6 kV

3.2 Test Equipment Specification

Both standards specify equivalent requirements with respect to the contact and air discharge tips, output voltage accuracy, holding time, and output voltage polarity. Comparison of ESD generator output voltage is as summarised in Table 3.

Table 3. Generator output voltage comparison[1,2]

Mode	IEC 61000-4-2	ISO 10605
Contact discharge mode	**±2 kV to ±8 kV**	**±2 kV to ±15 kV**
Air discharge mode	**±2 kV to ±15 kV**	**±2 kV to ±25 kV**

Moreover, both IEC and ISO standards specify the RC networks as summarised in Table 4.

Table 4. RC Network comparison[1,2]

RC Network (Storage capacitance / disch. resistance)	IEC 61000-4-2	ISO 10605
150 pF/330 Ω	Yes	Yes
150 pF/2000 Ω	No	Yes
330 pF/330 Ω	No	Yes
330 pF/2000 Ω	No	Yes

i.e., a storage capacitance of 150 pF and a discharge resistance of 330 Ω, to simulate discharge from the human body. On the other hand, ISO specifies RC networks with storage capacitances of 150 pF and 330 pF, and discharge resistances of 330 Ω and 2000 Ω. The 150 pF capacitor is generally used for exterior-side testing of the vehicle with discharge resistances of 330 Ω or 2000 Ω, whereas the 330 pF capacitor is used for interior-side vehicle components with discharge resistances of 330 Ω or 2000 Ω. (A 330 Ω discharge resistance is used when an interior component is touched with a metallic object, whereas a 2000 Ω discharge resistance is used when the interior component is touched through a person's skin)[2].



Figure 1. ESD generator with contact and air discharge tip.

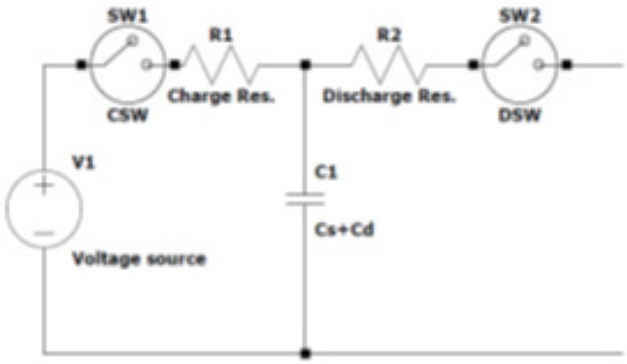


Figure 2. ESD generator circuit diagram.

Pictures of the ESD generator and its internal circuit diagram are shown in Figures 1 and 2, respectively.

C1=Cs+Cd=150 pF/330 pF

R2=330 Ω/2000 Ω

3.3 Waveform Specification

Table 5. Current waveform specification comparison ISO & IEC (Contact Mode)[1,2]

Network	Peak current/test voltage (A/kV)	Current/ test voltage (A/kV)	Current/ test voltage (A/kV)
150 pF/ 330 Ω	3.75	2 (at 30 ns)	1 (at 60 ns)

Table 6. Second peak current as specified in IEC 61000-4-2[1]

Network	Test Level (kV)	2nd peak current (A) (Ip2)	2nd Peak current/ test voltage (A/ kV)
150 pF/ 330 Ω	2	4.5	2.25
	4	9.0	2.25
	6	13.5	2.25
	8	18.0	2.25
	15	33.8	2.25

As mentioned in Table 5 the waveform specification for RC network 150 pF/330 Ω as specified in both standards, are identical. Illustrative ESD discharge current waveforms, plotted for illustrative purposes based on IEC 61000-4-2:2025 at 2 kV (150 pF/330 Ω discharge network) and ISO 10605:2023 at 1 kV (330 pF/2000 Ω discharge network), are presented in Figures 3 and 4, respectively[1,2].

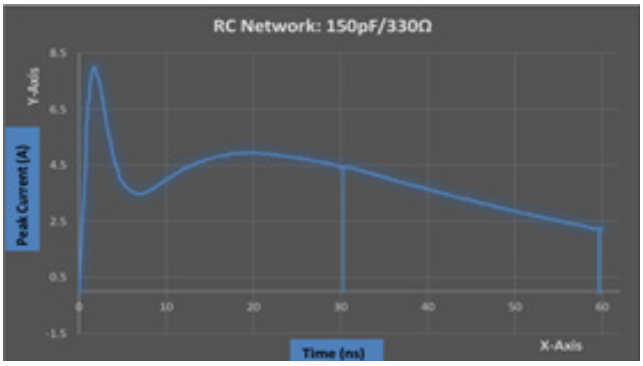


Figure 3. Illustrative ESD discharge current waveform based on IEC 61000-4-2:2025 at 2 kV (150 pF/330 Ω).

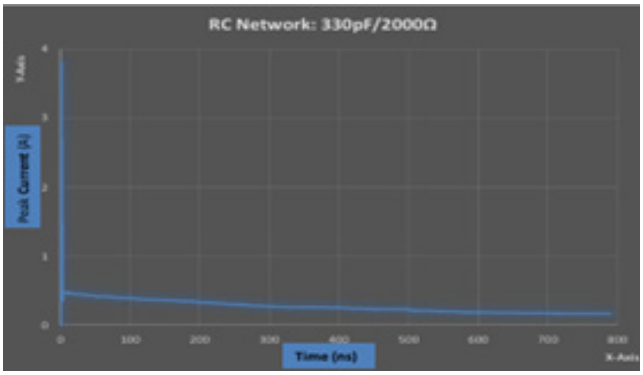


Figure 4. Illustrative ESD discharge current waveform based on ISO 10605: 2023 at 1 kV (330 pF/2000 Ω).

From the above waveform illustration, it can be observed that the initial current rise of the 150 pF/330 Ω discharge network specified in IEC 61000-4-2:2025 (0.8 ns ± 25%) is comparable to that of the 330 pF/2000 Ω discharge network specified in ISO 10605:2023 (0.7 ns to 1.0 ns). This indicates that both standards maintain a similar fast transient response during the initial phase of the ESD event.

The illustrated peak current waveforms represent the approximate proportional relationship between the charging voltage and peak current (approximately 3.75 A/kV) for the calibrated ESD waveforms of both discharge networks. For the ISO 10605:2023 discharge network (330 pF/2000 Ω), the peak current at 1 kV is approximately 3.75A, whereas the IEC 61000-4-2 discharge network (150 pF/330 Ω) produces an approximately 7.5 A peak current at 2 kV. Therefore, the peak current scales proportionally with the applied charging voltage, while the initial peak current characteristic remains comparable for the respective calibrated waveforms.

The current decay analysis shows that the 330 pF/2000 Ω discharge network produces a longer current tail compared with the 150 pF/330 Ω network due to its higher stored energy and charge capacity. Although both networks produce a similar initial peak current and rise time, the increased pulse duration of the 330 pF/2000 Ω waveform results in higher energy transfer to the device under test. Hence, the severity of the ESD event is influenced not only by the peak current but also by the decay characteristics and total energy delivered.

ISO 10605 also specifies waveform characteristics for additional RC discharge networks, namely 150 pF/2000 Ω and 330 pF/330 Ω, which are used to address specific automotive testing requirements. The severity of an ESD waveform is primarily governed by its rise time, peak current, and current decay characteristics.

Therefore, the overall severity of an ESD event depends on the selected RC discharge network and the applied test voltage defined by the respective standard.

The new edition of IEC specifies the second peak current (Ip2) during discharge within the 10% to 40% time frame, and this also needs to be taken into account during calibration, as given in Table 6, which was not included in the previous edition[3]. The aim of this addition is to improve the consistency and repeatability of ESD testing[5-7]. On the other hand, ISO does not specify this second peak current requirement.

The new version of IEC also includes the requirement for calibration of ESD generators in air discharge mode to standardize ESD testing. This ensures more comparable, consistent, and repeatable test results when testing is performed using different ESD generators by different test laboratories[6,7].

ISO does not specify any particular verification method for air discharge mode and does not recommend verification due to its complexity. However, it mentions various methods that may be used for verification, as specified in Annex E of the ISO standard[2]. Here, only the parameters for the 150 pF/330 Ω RC network are compared, as the 150 pF/330 Ω RC network is specified in the IEC standard.

3.4 Calibration of ESD Generator (with Air and Contact Discharge Tip)

3.4.1 Contact Discharge Mode Calibration

ISO standards mostly use the term **"verification"** instead of **"calibration".** However, both standards specify similar equipment requirements for calibration and parameters for calibration with some differences, as compared in the tables below.

Table 7 highlights the equipment requirements where the specifications of both standards differ. The remaining requirements, i.e., the current targets, have identical specifications, and the attenuators are specified as per the requirements. The current target and oscilloscope are shown in Figures 4 and 5, respectively.

Table 7. Comparison of equipment required for calibration[1,2]

Equipment required	Specification (IEC)	Specification (ISO)
High voltage meter/Electro static volt meter with resistive HV divider	At least 15kV with overall accuracy ±1%	At least 25kV with overall accuracy at least 5%
Oscilloscope	BW of ≥ 2 GHz and a sampling rate of ≥ 8 GS/s	At least 1 GHz analogue bandwidth
Reference plane with the coaxial current target mounted	At least 1.5m × 1.2m	At least 1.2m × 1.2m

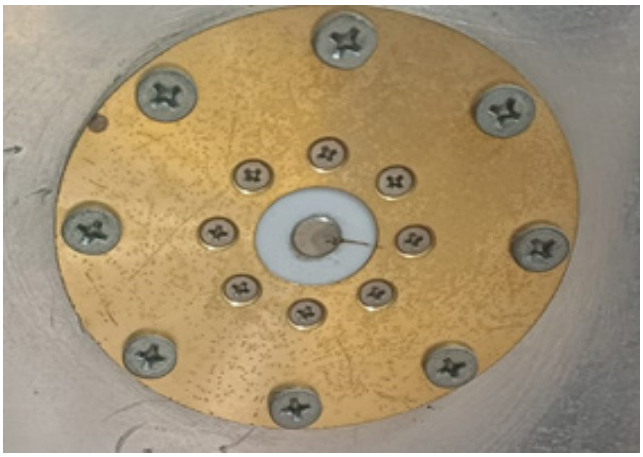


Figure 5. ESD current target.



Figure 6. Oscilloscope.

Table 8. Comparison of calibration parameters[1,2]

Parameter	Specification (IEC)	Specification (ISO)
The peak or 1st peak value of the discharge current, in A	Specified	Specified
The 2nd peak value of the discharge current, in A	Specified	Not specified
The value of the current at 30ns	Specified	Specified
The value of the current at 60ns	Specified	Specified
The rise time of the current, in ns	Specified	Specified

Both standards specify the above-mentioned parameters (Table 8) for calibration, except that the second peak value of the discharge current is not specified in the ISO standard. In addition, both standards specify an identical calibration procedure.

3.4.2 Air discharge mode calibration

As mentioned above, the ISO standard does not recommend air discharge verification. However, the IEC standard specifies the calibration requirements for the ESD generator with an air discharge tip according to the construction of the air discharge tip.

3.5 Verification of the ESD Test Equipment

IEC standard specifies the process for verification of the ESD generator before testing, as specified. On the other hand, ISO specifies that the ESD generator shall be verified periodically at user defined intervals in accordance with the specified ISO verification procedure. However, it does not specify practical verification before each test.

3.6 Test Setup Requirements and Test Methods

Both standards specify different test setup requirements based on the DUT's use/application. The IEC standard specifies various test setup requirements based on the DUT's normal use, i.e., as table-top equipment or floor-standing equipment. The IEC standard specifies the use and requirements of various components such as the Reference Ground Plane (RGP), Horizontal Coupling Plane (HCP), Vertical Coupling Plane (VCP), bleeder resistors, insulating support, etc. It also specifies the test setup requirements for ungrounded table-top and floor-standing equipment.

Similarly, the ISO standard specifies the test setup for different installation conditions with direct and indirect modes of testing under powered-up conditions. In ISO, testing is performed using a Ground Plane (GP) or a GP with a Field Coupling Plane (FCP), as specified, for direct and indirect discharges, whereas the HCP and VCP are used for indirect discharges in the IEC standard. ISO also specifies the test setup and procedure for components during packaging and handling under unpowered conditions.

Apart from components and packaging, the ISO standard also specifies the test method for vehicle interiors and exterior parts.

The IEC standard specifies one discharge for discharge current. If the product standard does not specify otherwise, 10 discharges shall be applied for each polarity with a minimum interval of 1s. Detailed guidelines in this regard are also specified in Annex E of the IEC standard. In addition, the ISO standard specifies that at least three contact and air discharges, with a minimum time interval of 1s, are required for different configurations, as applicable.

The comparison of the environmental conditions at the test location of both standards is given in Table 9.

Table 9. Environmental conditions[1,2]

Parameter	IEC 61000-4-2	ISO 10605
Ambient Temperature	15°C to 35°C	15°C to 35°C
Relative Humidity	30% to 60%	20% and 60%
Atmospheric Pressure	86kPa to 106kPa	Not specified

3.7 Measurement Uncertainty (MU) Considerations

Improved measurement uncertainty details are given in the new edition of IEC compared to the old version for the evaluation of uncertainty in peak discharge current measurements[11]. ISO only refers to IEC for the evaluation of measurement uncertainty.

3.8 Test Setup for Wall-Mounted Equipment

The new edition of IEC includes the test setup requirements for particular types of equipment, such as wall-mounted equipment, as specified in Annex I of the IEC 61000-4-2.

3.9 Test Requirements for Wearable Devices

IEC included the testing requirements for wearable devices used on different parts of the human body, such as the head, arm, wrist, and waist[2].

The IEC standard specifies the testing of such products according to the procedure discussed above for other devices as table-top equipment. Before the release of the new IEC edition, research had already been conducted on wearable devices[8-10]. The IEC standard also recommended an experimental test procedure for wearable devices using a special 200pF/50Ω generator[2]. This special generator was introduced considering the most severe discharge current condition from a wearable device worn on the waist. The ISO standard specifies the testing of various electronic items, including Advanced Driver-Assistance Systems (ADAS), infotainment electronic systems, and others used in vehicles, according to the standard procedure only, and does not recommend any additional special requirements for such devices.

3.10 Performance Criteria

Both the standards provide guidelines about the performance criteria classification, which is evaluated during or after the test. The possible performance criteria may be specified in product standards or as per the manufacturer's/customer's specifications. The IEC standard specifies the application of performance criteria, such as performance criterion A, B and C. However, performance criterion C is not applicable for the evaluation of the test results.

The ISO standard specifies the test evaluation criteria as the Function Performance Status Classification (FPSC), which is categorized into four status levels: Status I, Status II, Status III, and Status IV[2]. ISO also specifies how the Function Performance Status is related to the test severity level. The comparison of the performance criteria of both standards is given in Table 10.

Table 10. Comparison of performance criteria[1,2]

Performance Criteria	IEC 61000-4-2	ISO 10605
A (Status I)	Normal operation of the product	Normal operation
B (Status II)	Permissible degradation or temporary loss of function but self-recoverable	Permissible degradation or temporary loss of function but self-recoverable
C (Status III)	Loss of function that is not self-recoverable and requires external intervention	Loss of function that is not self-recoverable and requires simple external intervention
(Status IV)	Not specified	Loss of function that is not self-recoverable and requires more extensive external intervention

4. CONCLUSION AND DISCUSSION

The comparative analysis of IEC 61000-4-2 (2025 edition) and ISO 10605 (2023 edition) reveals important differences in their approaches to Electrostatic Discharge (ESD) immunity testing, reflecting the distinct operational environments for which these standards are designed. While both frameworks share the common objective of evaluating the robustness of electronic systems against ESD events, their methodologies and test severities vary according to industry requirements.

While IEC 61000-4-2:2025 provides a universal baseline for ESD immunity testing, ISO 10605:2023 extends these principles to automotive-specific scenarios with higher stress conditions and system-level requirements. As electronic systems become more interconnected, particularly in electric vehicles, autonomous systems, and IoT-enabled devices, the distinction between these standards becomes increasingly important for engineers designing products across multiple industries.

The updated IEC 61000-4-2:2025 standard focuses primarily on commercial and industrial equipment and introduces improvements in calibration accuracy, waveform verification, and generator characterization. Notably, the introduction of an additional pulse parameter (Ip2) and stricter generator calibration procedures enhance repeatability and consistency across testing laboratories. These refinements ensure more reliable testing of ESD immunity for consumer electronics, industrial devices, and information technology equipment.

On the other hand, ISO 10605:2023 is specifically developed for the automotive environment, where electronic modules operate under more complex and variable electrical conditions. The standard incorporates additional discharge networks and higher test severity levels, including air discharge voltages of up to 25 kV, to realistically simulate electrostatic events caused by occupants, service personnel, or assembly processes. It also defines both component-level and vehicle-level testing procedures, reflecting the integrated nature of modern automotive electronics. This makes the standard particularly relevant for modern vehicles that incorporate various electronic systems, Advanced Driver-Assistance Systems (ADAS), and infotainment systems.

ISO introduced an alternative test procedure with a field coupling plane for direct and indirect discharges, changed the number of discharges and the time interval for indirect discharges on components in the powered-up condition, improved the procedure for packaging and handling test method and introduced optional test setup for electronic modules. ISO standard also focuses on the influence of environmental conditions, details of current target specification, guidance for the automatic-operated ESD testing method.

Another key point that is important to note is that both the latest versions of standards include the important technical changes compared to previous editions considering the requirements of ESD testing in different types of products. IEC added an improved calibration procedure of ESD generators; specified the testing procedures for wall-mounted and wearable devices, provided guidelines for improved measurement uncertainty. Also specified the aspects of influence of the environmental conditions, rationale related to generator and waveform specifications, details of current target specification, radiated field generation during ESD phenomena, setup details for post-installation tests, escalation strategies etc.

4.1 Technical Implications for Products Tested According to IEC 61000-4-2 and ISO 10605

The selected ESD immunity standard directly influences the product's design robustness, test severity, and compliance requirements.

IEC 61000-4-2:2025

- Uses lower-energy discharge networks (typically 150 pF/330 Ω), representing human-body ESD events encountered during normal handling.
- This network produces high initial current, low stored energy, narrow pulse width, short current tail, higher-frequency dominant and can create logic upset, latch-up, transient malfunction, stresses semiconductor junctions etc.
- Compliance demonstrates that the product can withstand typical user-generated electrostatic discharges without degradation of performance.
- Products passing IEC testing are generally suitable for standard operating environments but may not withstand the more severe ESD events experienced in automotive applications.

ISO 10605:2023

- Includes higher-energy discharge networks such as 330 pF/2000 Ω, producing significantly greater discharge energy than IEC 61000-4-2.
- The ISO waveform, owing to its higher capacitance and greater stored energy, produces a broader current pulse with a longer current tail, imposing increased thermal and electromagnetic stress on automotive electronic systems.
- Simulates ESD events arising from vehicle occupants, synthetic seat materials, dry climatic conditions, and vehicle assembly/service operations.
- Requires products to tolerate more severe current waveforms and higher energy transfer.

In conclusion, both frameworks play complementary roles in ESD compliance. IEC 61000-4-2:2025 enhances global consistency in general EMC testing, while ISO 10605:2023 addresses the specialized reliability requirements of automotive electronics. Future compliance strategies may increasingly integrate insights from both standards, enabling manufacturers to develop highly resilient electronic systems capable of withstanding real-world electrostatic disturbances across diverse operational environments.

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