URSI-RCRS 2024, ARIES/GEHU, Bhimtal, India, 22 - 25 October, 2024

Impact of plastic housing impurity on ESD failure

Joydeep Pal, Razic M. M. Mohammed and Bibhu Nayak
Robert Bosch GmbH, Gerlingen, Baden-Württemberg, Germany, https://www.bosch.com

Abstract

In this study, the authors conducted an Electrostatic Direct Discharge (ESDD) failure analysis of a nitrogen oxide sensor (NOx) based on the ISO 10605 (2008) standard. Subsequently authors proposed a simple and practical method to determine the impact of housing conductivity in order to prevent such failures. A quartz crystal oscillator IC integrated within the NOx sensor was observed to be the most sensitive to the electrostatic discharge. Thus, during the measurement, the electric field at the oscillator IC was recorded for different voltages (kV) of an ESD gun placed on the top housing of the sensor. The captured field data was then processed in a simulation environment to determine the specific material conductivity limit of the sensor housing, in order to maintain the E-field near the oscillator below the failure threshold of the sensor.

1. Introduction

The ESDD test is an important aspect of ensuring the reliability and robustness of electronic components and devices [1]. The test is designed to assess the susceptibility of electronic components to damage or malfunction caused by electrostatic discharge. The requirements for ESDD testing may vary depending on the specific industry, application, and standards to which the electronic components or devices must adhere. All the standard tests are done with Air or contact discharge method [2]. Thus, protection from failure due to such ESD discharge has been extensively discussed in the open literature. Fundamentally, two approaches are employed in protecting electronic devices from ESD: firstly, reducing likelihood of ESD and secondly, adding ESD protection circuitry to the electronic devices. To reduce the likelihood of ESD, charge generation mechanisms which cause ESD have to be reduced. The first method involves the use of protection equipment to control generation of static charges. This includes room ionizers, local ionizers, ESD wrist straps etc. The second method requires additional circuit elements on ICs which provide an alternate path for charge conduction, in case of an ESD event without affecting the circuitry. This results in clamping the pad/pin level voltage to a safe level in case of an ESD event [3], [4].

In this paper the authors have studied the static ESD failure of NOx sensor. The NOx sensor is a crucial component of the NOx reduction aftertreatment system utilized in diesel vehicles with urea-based Selective Catalytic Reduction (SCR) systems. Positioned upstream of the SCR catalyst, the sensor directly measures the engine-out NOx gas concentration, aiding in the determination of the optimal amount of urea injection. Additionally, the NOx sensor downstream of the SCR catalyst is employed to monitor the catalyst's performance. Accurate NOx measurement is essential for compliance with increasingly stringent NOx emissions regulations. Furthermore, the NOx sensor has the capability to measure O2 concentration, similar to a wide-range air-fuel sensor.

In this study, the authors observed a functional failure of a Crystal Oscillator IC within a NOx sensor integrated with the microcontroller unit, which is designed to provide a stable and precise clock signal. This failure occurred simply by placing a charged ESD gun (at 15 kV) on the top housing just above the IC. The functional failure of an on-chip IC due to static charge of an ESD gun is so far not explicitly discussed or analyzed in open literature. We captured the specific voltage of the ESD gun in standard test condition, at which the normal sensor operations were interrupted. The measured dada was further postprocessed in the simulation environment and eventually developed a simple and realistic method to protect the device from such practical scenarios.

2. Model Setup in Simulation Environment

The ESDD sensitivity of the NOx sensor was performed in an ALSE (Absorber-Lined Shield Enclosure) chamber as per ISO 10605 (2008) standard as shown in Fig. 1.

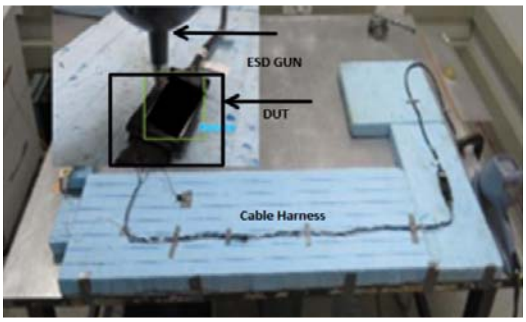

Figure 1. ESDD measurement setup in ALSE according to ISO10605 and in the closeup, the ESD gun on top of the NOx sensor.

The failure of the sensor response was noted when the ESD gun kept on the DUT housing just above the oscillator IC with 15 kV excitation. It was important to observe that the failure noted while keeping the charged ESD gun, without discharging the gun thru the bleeder resistor.

Authors has emulated the measurement environment as a simplified model in CST simulator as shown in Fig. 2. The DUT housing is emulated as dielectric slab of ε_r = 4.3 and conductivity σ = 0 S/m. The ESD gun is put just above a dielectric slab above the table ground.

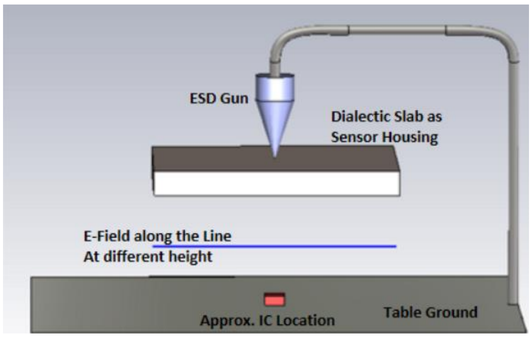

Figure 2. Simulation Model of the measurement in; ESD gun is placed on the top housing of the sensor just above the victim IC.

ESD failure is caused due to the malfunctioning of the oscillator IC while putting the gun just above the IC location. This can be attributed to the static E-Field coupling with the IC from the gun. Thus, E-Field distribution beneath the dielectric slab and around the IC is captured in the simulation in different height from the IC and for varying dielectric slab conductivity.

Authors tried to analyze the E-Field inside the DUT housing near the IC and devise an easy method to arrest the failure by reducing the field coupling below the threshold of the IC without disturbing the of the sensor responses.

3. Simulation Results and validation

The simulated E-Filed is shown in Fig. 3 for varying height from the IC towards the slab. The increased field can be attributed to the decreased distance from the static charged source.

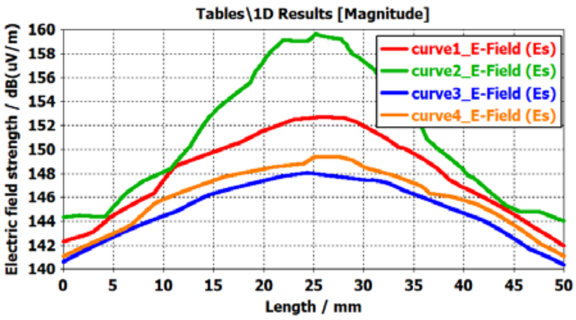

Figure 3. Simulated E-Field along the blue line in Fig. 2 between IC and the dielectric slab at different Hight.

The conductivity of the housing material is varied further to observe the E-Field variation within the stated region which is depicted in Fig. 4. It is noted that with increased conductivity the E-Field along the blue line (Fig. 2) is increased, where the minimum field is noted for σ = 0 S/m of the slab.

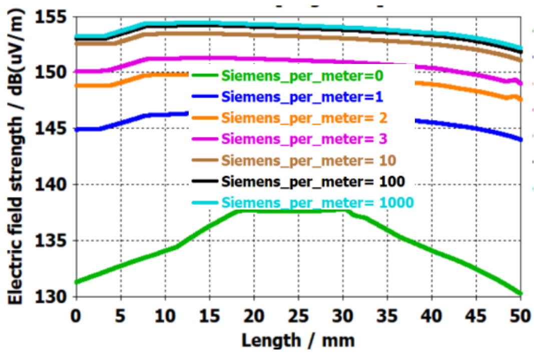

Figure 4. Simulated E-Field along the blue line in Fig. 2 between IC and the dielectric slab for different conductivity of the dielctric.

The increased field can be attributed to the E-Field confinement between the dielectric slab and the table ground. With increasing conductivity, the capacitive effect within the region in increasing, hence concentrating the field. Thus, for specific conductivity of the housing material the E-Field near the victimized IC can be controlled and keep well below the threshold for smooth response of the NOx sensor.

With the findings above ESD measurement was done with various condition. It can be observed the test passed when the discharge happens away from the IC or by reducing the conductivity of the housing.

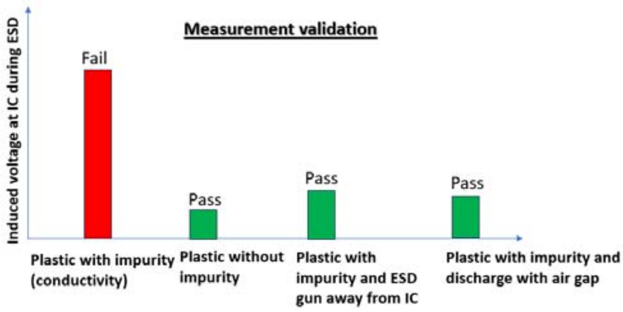

Figure 5. Measurement validation

4. Conclusion

In this paper, a simple and realistic simulation method was developed to understand and mitigate ESD failure mechanism of a crystal Oscillator under the influence of housing parameter. This study can be enhanced further to determine the threshold of failure voltage with respect to impurity. Eventually it can be a design guideline for choosing the housing material.

6. Acknowledgements

We would like to thank Mr. Sooraj Somanathan of Bosch Global Software Ltd. (BGSW), India for his support and technical inputs.

7. References

1. S. Voldman, ESD: Circuits and Devices, NJ, Hoboken:Wiley, 2006.

2. "IEC International Standard 61000-4-2", EMC-Part 4-2: Testing and measurement techniques-Electrostatic discharge immunity test, 2007.

3. J. E. Vinson and J. J. Liou, "Electrostatic discharge in semiconductor devices: protection techniques," in Proceedings of the IEEE, vol. 88, no. 12, pp. 1878-1902, Dec. 2000, doi: 10.1109/5.899057.

4. T. L. Welsher, T. J. Blondin, G. T. Dangelmayer and Y. Smooha, "Design for electrostatic-discharge (ESD) protection in telecommunications products", vol. 69, no. 3, pp. 77-96, 1990.