AN4326
Application note

Increasing the M24LRXXE-R family ESD robustness on antenna using an external ESD protection

Introduction

The Electrostatic discharge (ESD) absolute maximum ratings for the M24LRXXE-R family, once mounted on an antenna, are specified at 4 kV (test done following the IEC 61000-4-2 contact and air method).

An external ESD protection component can improve the ESD robustness of the M24LRXXE-R on antenna.

This document explains how to choose the ESD protection, how to implement it, and gives ESD performance measurement results based on the ANT10-M24LR16E demonstration antenna embedding the STMicroelectronics DSILC6-4P6 ESD protection.

Table 1 lists the microcontrollers concerned by this application note.

Table 1. Applicable products

Type	Part numbers / Product categories
Microcontrollers	M24LR04E-R, M24LR16E-R, M24LR64E-R

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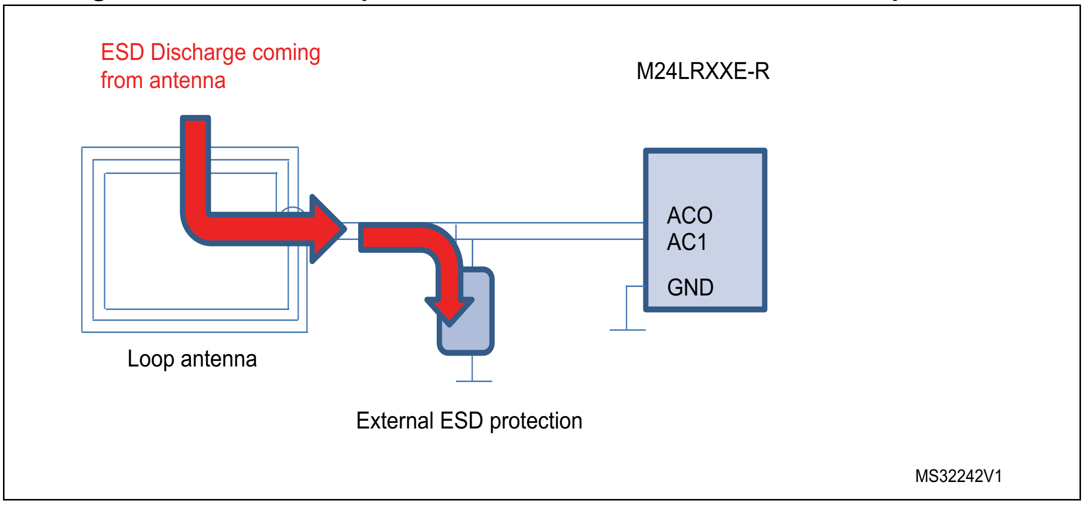
1 External ESD protection implemented on an M24LR16E antenna

During the IEC61000-4-2 tests, electrostatic discharges are applied in air or by contact using an ESD gun.

Note: See AN3353 “IEC 61000-4-2 standard testing”.

The ESD is conducted by the antenna and dissipated by the AC0 and AC1 pins built-in ESD protections. An external ESD protection placed between the potential ESD source (the antenna) and the M24LRXXE-R can improve the M24LRXXE-R ESD robustness.

Figure 1. External ESD protection on M24LRXXE-R 13.56 MHz loop antenna



2 Choosing the external ESD protection

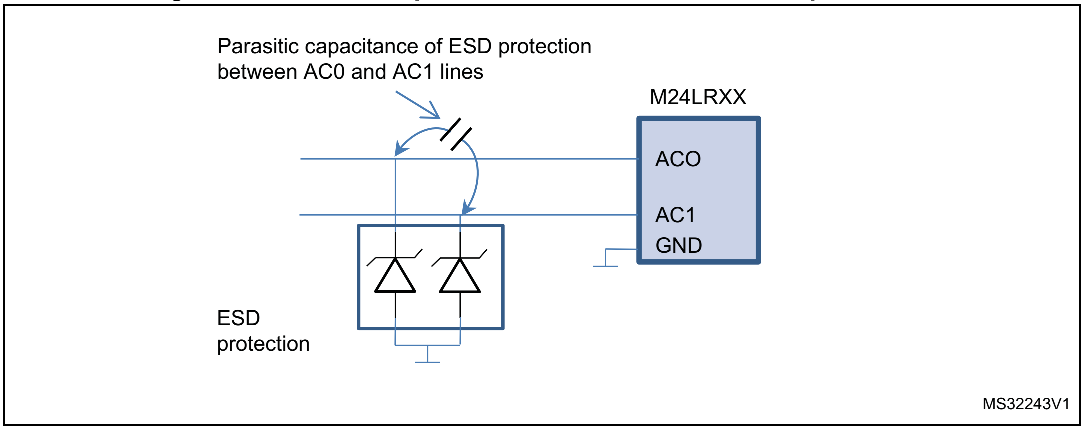
The role of an ESD protection is to sink the high current under thousands of volts delivered during the discharge to avoid damages inside the Integrated circuit (IC).

To achieve this, the ESD protection must sink the current discharge, maintaining a voltage level acceptable for the IC component.

Different parameters must be taken into account when choosing the external ESD protection: the break down voltage, the forward voltage, and the parasitic capacitance at 13.56 MHz.

Figure 2 describes the equivalent schematic of the ESD protection mounted on the antenna. Two individual transil diodes are used to protect AC0 and AC1 RF inputs of the M24LRXXE-R.

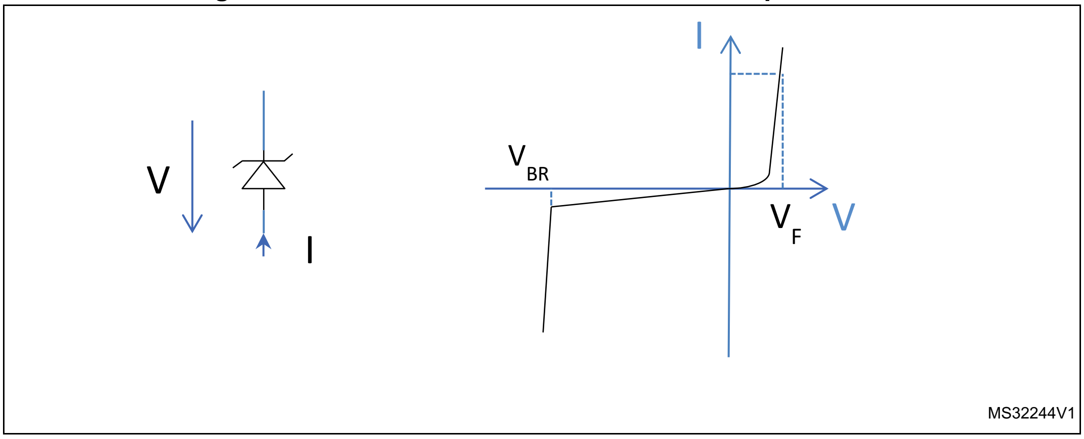
Figure 2. Electrical equivalent schematic of the ESD protection



2.1 Break down voltage and forward voltage of the ESD protection

Figure 3 illustrates the electrical characteristics of an ESD protection.

Figure 3. Electrical characteristics of an ESD protection



The break down voltage (V_{BR}) determines the voltage level at which the ESD protection turns on. To protect the M24LRXXE-R efficiently, the V_{BR} must be as low as possible.

However, during an RF operation, the RF voltage values present between AC0 and GND, and AC1 and GND, are applied to the external ESD protection. As a consequence, the external ESD protection also clamps the RF voltage on AC0 and AC1 as soon as it exceeds V_{BR}. When RF readers use a low modulation index to communicate with tags, the RF modulation can be canceled, causing communication holes at short distance. Overcoming this by using a high V_{BR} ESD protection will lead to a weak protection of the M24LRXXE-R.

To offer the best ESD protection to the M24LRXXE-R (8 kV at contact discharge and 15 kV at air discharge), the external ESD protection voltage levels should be:

- $V_{BR} \leq 9$ V
- $V_F \leq 1$ V

The voltage level received on AC0 and AC1 depends on the reader power and antenna, as well as on the tag antenna. The distance at which the communication stops then depends on these parameters but also on the modulation index used by the reader. The RF performance of the M24LRXXE-R tag using an external ESD protection must be validated in the customer's system.

Since the ESD is affected by the antenna, the ESD robustness must also be validated by the customer.

Note: Section 5 and Section 6 show the IEC61000-4-2 ESD test results and the RF read range results using an NFC phone with a 65 x 45 mm 6-turn antenna.

2.2 Parasitic capacitance of the ESD protection and tag antenna design

Placing an external ESD protection between the antenna and the M24LRXXE-R causes an additional parasitic capacitance between the AC0 and AC1 lines.

If C_{par} is the parasitic capacitance between AC0 and AC1 due to the external ESD protection, and $C_{M24LRXXE-R}$ is the M24LRXXE-R built-in tuning capacitance, the total capacitance used to design the tag antenna inductance becomes:

$$C_{tot} = C_{M24LRXXE-R} + C_{par}$$

The inductance of the antenna must then satisfy:

$$Lantenna = \frac{1}{(C_{tot} \times 2 \times \pi \times F_{tune})^2}$$

where F_{tune} is the tuning frequency of the tag.

Note: See AN2972 for more details on antenna design basics.

The read range of the M24LRXXE-R is given by the distance at which the AC0-AC1 AC magnitude voltage reaches 2 V, or the AC0-GND (or AC1-GND) voltage reaches 1.8 V. At this voltage level, the external ESD protection is not active and behaves as a parasitic capacitance. The maximum read range only depends on the reader (power and antenna) and the tag antenna (dimension and turns) and the tag antenna tuning frequency.

As a consequence, the total capacitance value, including the external ESD protection, is a key parameter for antenna tuning and performance. Its value must be evaluated before designing the antenna.

This can be done by simply mounting the ESD protection on an existing antenna and then calculating the total capacitance from the tuning frequency obtained with (F_{tune1}) and without (F_{tune2}):

$$(F_{tune2}/F_{tune1})^2 = \frac{C_{M24LRXXE\text{-}R}}{C_{tot}} \Rightarrow C_{tot} = \frac{C_{M24LRXXE\text{-}R}}{(F_{tune2}/F_{tune1})^2}$$

3 Layout rules

Note: See AN576.

The layout and placement of the external ESD protection are an important point in the protection efficiency: the external ESD protection must be placed between the ESD source (antenna) and the M24LRXXE-R. The external ESD protection must be placed as close as possible to the ESD source (antenna). The connection between the M24LRXXE-R and the antenna must start from the ESD protection.

Figure 4. Efficient ESD protection implementation

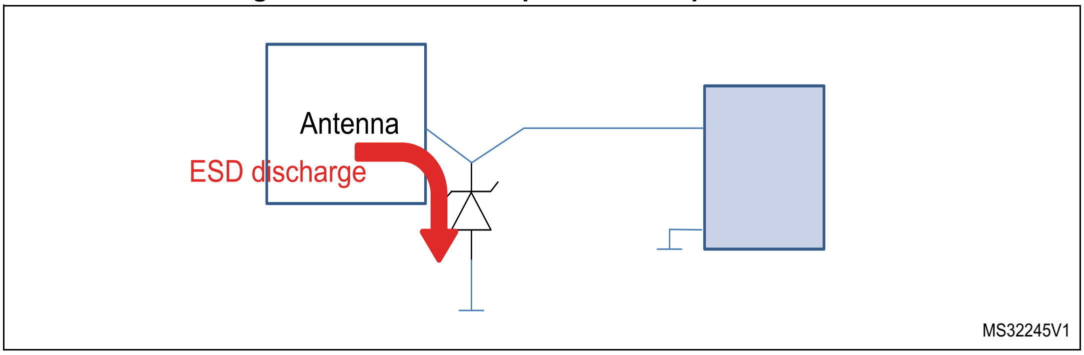
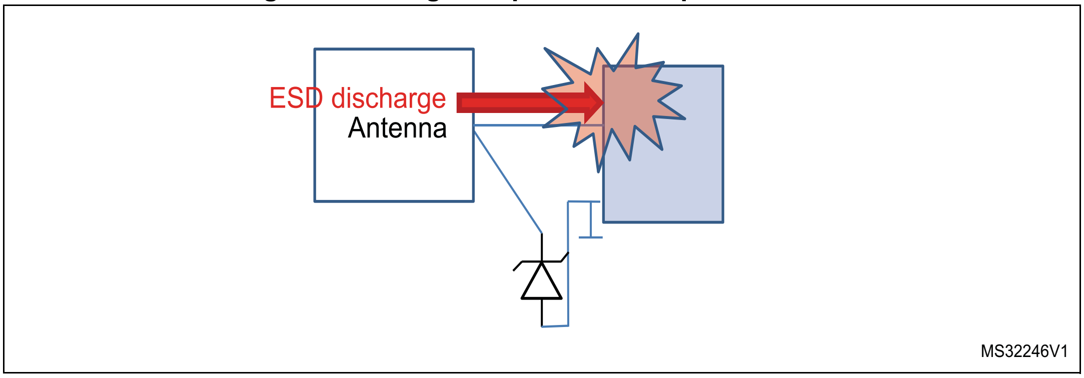


Figure 5. Wrong ESD protection implementation



Note: It is also recommended to use a ground plane instead of ground wires.

4 Implementation example

The implementation example uses the DSILC6-4P6 ESD protection and the M24LR16E-R I²C/ISO15693 Dual Interface EEPROM.

4.1 DSILC6-4P6 connection on the M24LR16E-R antenna

The pinning on ANT10-M24LR16E is as follows:

- pins 1 and 3 (respectively I/O1 and I/O2) are left floating but can also be connected to the ground
- pin 2 (GND) is connected to the ground plane
- pin 5 (Vcc) is left floating
- pins 4 and 6 (I/O4 and I/O3 respectively) are connected to the antenna.

Figure 6. DSILC6-4P6 pinout description

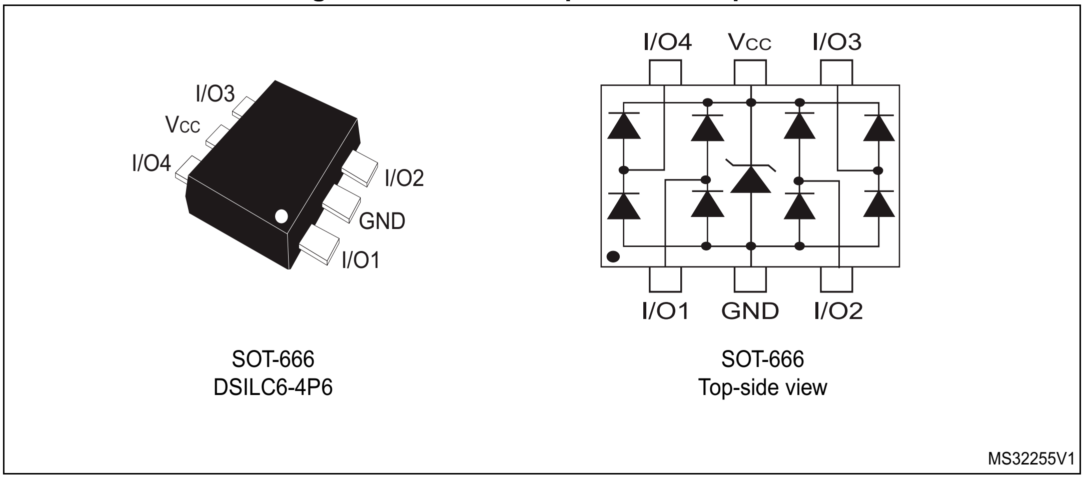
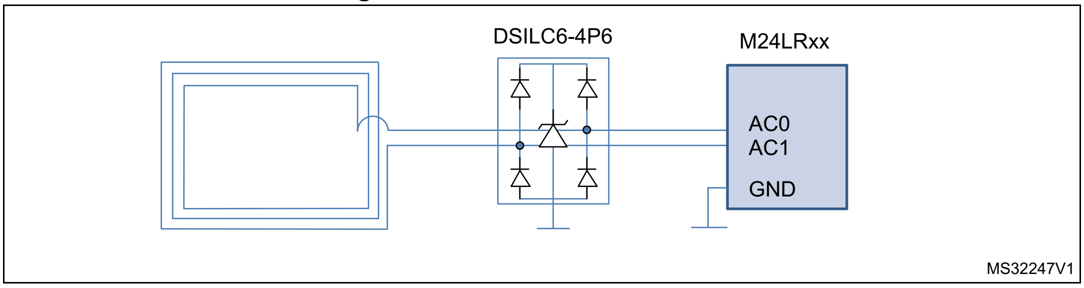


Figure 7. DSILC6-4P6 connection



Note: The typical V_{BR} voltage of the DSILC6-4P6 between I/O4 and GND, and between I/O3 and GND, has been measured at 8.1 V at 25 °C.

4.2 ANT10-M24LR16E layout

Figure 8. ANT10-M24LR16E layout general view

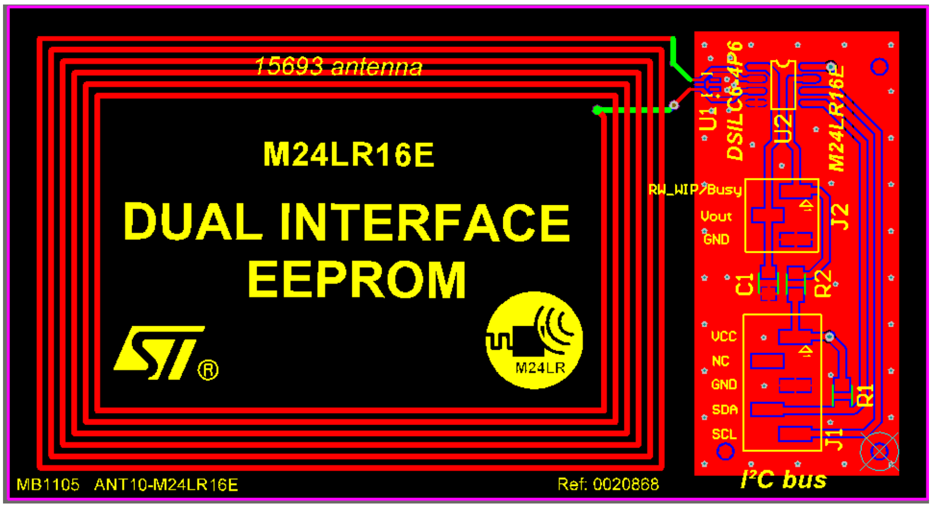
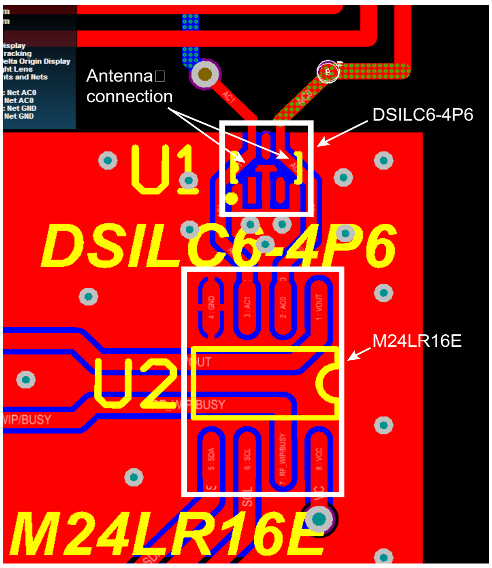


Figure 9. Antenna and M24LR16E connections to DSILC6-4P6



5 ESD test results with DSILC6-4P6 ESD protection and M24LR16E-R

ESD tests have been performed on the Printed circuit board (PCB), with two setups:

- +/-8 kV contact discharge, according to IEC 61000-4-2 standard
- +/-15 kV air discharge, according to IEC 61000-4-2 standard.

IEC 61000-4-2 standard defines the test setup for an equipment not connected to the earth (see *Figure 10*).

Figure 10. IEC 61000-4-2 test setup

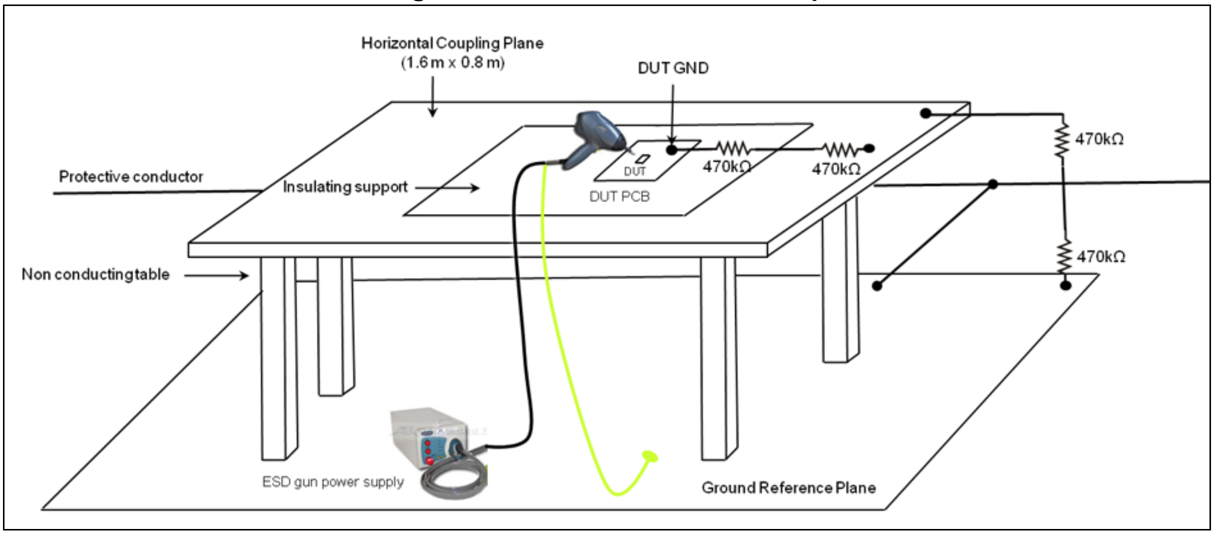


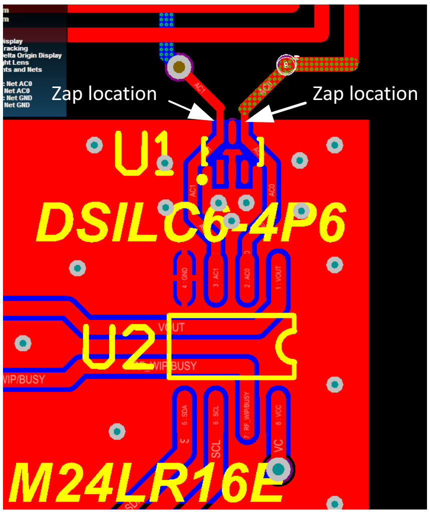
Figure 11. ESD measurement bench

For contact and air discharges, 10 shoots for each polarity per area zap have been performed, with a frequency = 1 Hz.

5.1 IEC 61000-4-2 contact discharge description and results

For a contact discharge, 2 zap locations are on the ESD protection terminals (see *Figure 12*).

Figure 12. Zap locations for contact discharge



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After the shoot sequence (2x +/-10 shoots, so 40 shoots), the M24LR16ER operation is tested with a reader to check if there is no modification before and after the ESD test.

ESD tests results show that the M24LR16E, protected with the DSILC6-4SC6, is compliant with IEC 61000-4-2, level 4 (i.e. +/-8 kV contact), and withstands ESD surges higher than 12 kV.

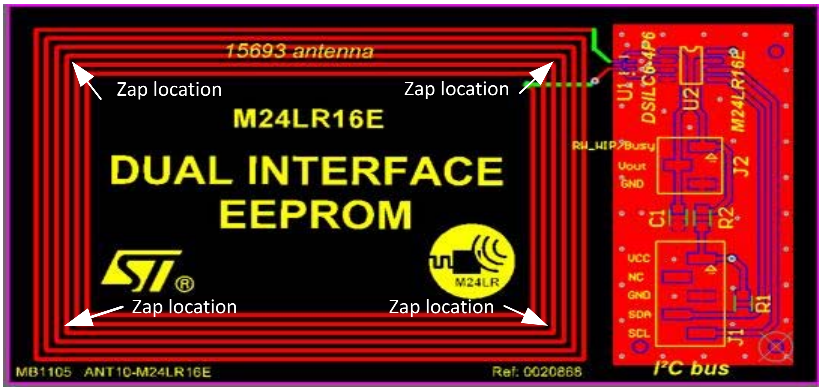
Table 2. ESD contact discharge results

ESD voltage	+/-8 kV contact	+/-10 kV contact	+/-12 kV contact
Result	Ok	Ok	Ok

5.2 IEC 61000-4-2 air discharge description and results

For an air discharge, 4 zap locations, at each corner of the antenna, have been taken (see *Figure 13*).

Figure 13. Zap locations for air discharge



After the shoot sequence (4x +/-10 shoots, so 80 shoots), the M24LR16ER operation is tested with a reader to check if there is no modification before and after the ESD test.

ESD tests results show that the M24LR16E, protected with the DSILC6-4SC6, is compliant with IEC 61000-4-2, level 4 (i.e. +/-15 kV air), and withstands ESD surges higher than 16 kV.

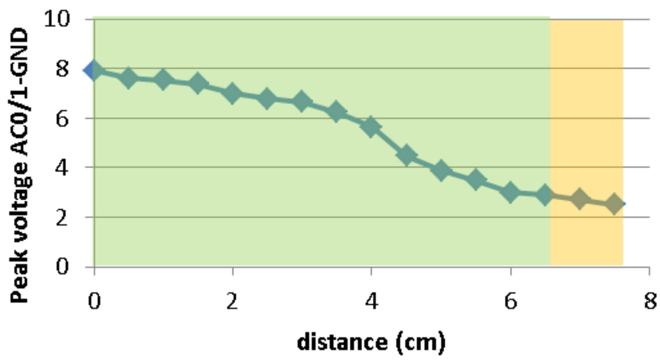
Table 3. ESD air discharge results

ESD voltage	+/-10 kV contact	+/-15 kV contact	+/-16 kV contact
Result	Ok	Ok	Ok

6 RF read range test with NFC phones

Figure 14 shows an example measurement of the RF voltage amplitude between AC0/1 and GND pins, using a Nexus S NFC phone placed at various distances.

Figure 14. Voltage and read range measurement



The green area represents the distance at which the ANT10-M24LR16E is read by the Nexus S.

The orange area represent the distance ranges where the ANT10-M24LR16E tag answers the phone's request without being read by the phone.

The maximum read range for ANT10-M24LR16E using a Nexus S NFC phone is 6.5 cm, which is comparable to an equivalent ISO class 1 credit card size antenna without an external ESD protection (ANT1-M24LRXXE-R).

At 0 cm, the ESD protection is still turned OFF ($V_{AC0/1\text{-}GND} < V_{BR}$) and does not affect the communication between the M24LRXXE-R and the NFC phone.

7 Revision history

Table 4. Document revision history

Date	Revision	Changes
25-July-2013	1	Initial release.