

Intrinsically Static-Dissipative Reel

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ABSTRACT

Polystyrene, black, intrinsically static-dissipative (ISD) reels and polystyrene antistatic-coated reels used for shipping integrated circuits in tape-and-reel configuration were tested for surface-resistance performance at low (11.7%) and high (50.3%) relative humidity (RH) after 1 hour and 48 hours, respectively. Static-charge decay also was measured under low-humidity conditions. The test results show that the antistatic-coated or dipped reels have poor surface resistance at low RH and acceptable surface resistance at high RH. The ISD reel's surface resistance is independent of relative humidity. As for static decay, the dipped reel had a 1000-V to 100-V decay time of ~20 seconds, whereas the ISD reel's static decay time was 0.01 second. Due to surface-resistance characteristics, TI uses the ISD reel at all assembly/test sites to improve ESD protection for components packed with, and without, moisture-barrier bags.

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1 Introduction

Static electricity is a natural phenomenon. Delicate electronic components easily are damaged by electrostatic discharge (ESD), and resultant faults in assembled finished products can be costly. Packing media used to protect products delivered to customers against ESD include trays, tape and reel, tubes or magazines, boxes, and bags. These items should have a surface resistance in the static-dissipative range of greater than $1 \times 10^4 \Omega$, but less than $1 \times 10^{11} \Omega$, per ANSI/EOS/ESD S11.11-93, in order to control a discharge. If the surface resistance is too small, a charge can dissipate too quickly and electrically overstress the integrated circuits (ICs) within the packing medium.

Currently, tape and reel is the most common packing medium in use at Texas Instruments, and testing has shown that the current method's level of ESD protection decreases as the relative humidity (RH) decreases. The traditional reel is constructed of glass-filled ABS or polystyrene and is dipped in an antistatic agent to provide conductivity. This type of coating easily wears through by contact with electronic components or general handling and no longer provides the needed ESD protection. For example, unreeling the carrier tape from a reel rubs and abrades the static-dissipative coating on the inside surface of the flanges. Additionally, the coating easily can be removed by washing and does not work effectively at low relative humidity due to lack of moisture in the air. Low relative humidity is of concern because this condition (below 12% RH) is present within a sealed moisture-barrier bag with desiccant. This is why reels with an antistatic coating need tight surface-resistance (SR) monitoring to ensure compliance to original specifications. A better alternative is the intrinsically static-dissipative (ISD) reels because they maintain a constant surface resistance, regardless of relative humidity.

This application report shows the surface-resistance performance of ISD reels versus typically coated antistatic dipped reels, at room conditions and at low humidity, to simulate the environment inside and outside a moisture-barrier bag. Additionally, by reviewing how surface resistance is controlled for each type of reel, this application report explains why ISD reels can better protect electrostatic-sensitive devices from being electrically overstressed.

2 Plastic Conductivity

Various methods can be used to alter the electrical characteristics of plastics to prevent charge buildup or to provide surface resistance within the static-dissipative range; that is, integrating electrically conductive additives, surface application of antistatic agents, or incorporating internal chemical antistatic agents. The first two are discussed because these are the two in use on reels shipped by Texas Instruments.

2.1 Impregnating the Polymer With Electrically Conductive Additives

The most common additives used are carbon-black powder, graphite fiber, and metallized fillers. These inert conductive fillers have antistatic properties, independent of atmospheric humidity. Carbon black is an electrical conductor made of finely divided particles of amorphous carbon produced by incomplete combustion of petroleum or natural gas. Typically, carbon black is used in plastics for four reasons:

- It is an electrically conductive filler.
- It is a black pigment.
- It absorbs ultraviolet radiation.
- It obstructs transmission of radiant energy.

Polymers filled with carbon black, above a certain concentration, become conductive. Loadings of 10% or more are required for conductivity, but at this level, mechanical and physical properties of the plastics are degraded and need an impact modifier (Imod) to maintain strength properties. This 10% also will make the reel color black.

Electron flow through a carbon-black/polymer composite is achieved when the carbon black forms a conductive network within the polymer. In theory, electron flow occurs when the carbon-black aggregates are in contact or are separated by very small gaps. The electrons tunnel through the resistive polymer from aggregate to aggregate, creating connections that allow electrical conductivity (see Figure 1). The more aggregates that are in contact, or close enough for tunneling to occur, the greater the composite's electrical conductivity, up to the concentration point. The surface area and structure of the carbon black heavily influences the concentration point.

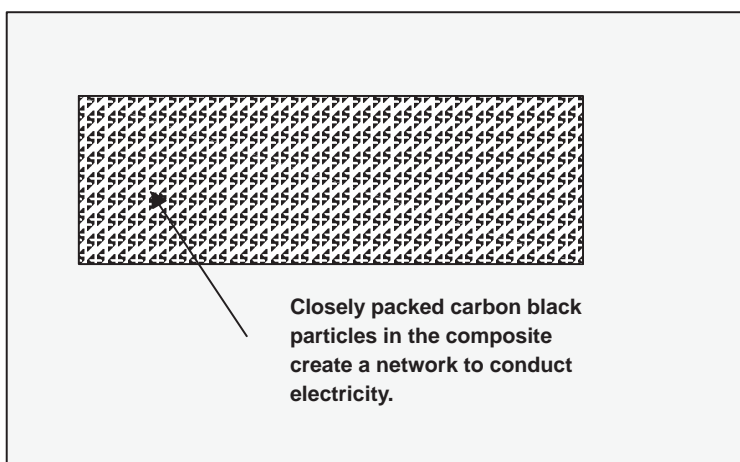


Figure 1. Carbon-Black/Polymer Composite

The main disadvantage of carbon black is sloughing, which is the shedding of carbon particles. Depending upon the level of handling, carbon-black composites may not be suitable for cleanroom applications due to the shedding of carbon particles. This type of contamination has not been an issue with the ISD reel.

2.2 Surface Application of an Antistatic Agent

Topical antistatic agents applied to the surface of plastics usually are transparent, so that the base polymer color is unaffected. The coating combines with moisture in the air to provide a conductive surface. As previously mentioned, this type of coating is very fragile and easily can be washed or rubbed off. As the coating is diminished, so is the ESD protection.

Antistatic agents have two halves of opposite chemical nature: a hydrophilic head and a hydrophobic tail. The top portion of the antistatic agent, or head, is polarized and attracts water, ions, and salts from the surroundings onto the surface of the reel to form a conductive layer, as shown in Figure 2.[1] This type of antistatic agent is widely used because it is cheap and performs well in high-humidity environments. If there is not enough moisture, such as in a moisture-barrier bag, there is a poorly conducting layer on the surface of the reel. The tail (everything below the hydrophilic head) buries itself in the plastic body to provide an easily removable anchor. Another drawback of antistatic agents is that they tend to have a greasy feel, which makes them less suitable for cleanroom applications because of the potential for ionic and chemical contamination.[1]

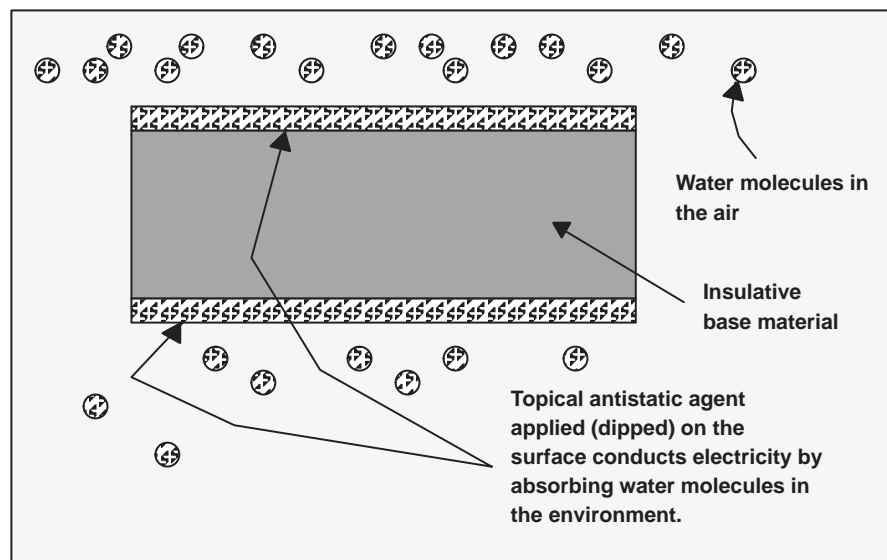


Figure 2. Material Coated With Antistatic Agent

Both methods of imparting conductivity to the reels have their advantages and disadvantages. When all the factors are considered, the impregnation method is the clear choice because the ESD protection cannot be worn, washed off, or affected by the amount of relative humidity. Although the carbon does have sloughing, there is not enough to be concerned about when packaging assembled integrated circuits.

3 Test Plan and Equipment

Measuring surface resistance under low- and high-humidity conditions quantifies how much the topical (dipped) coating is degraded by low relative humidity and ensures that the material is static dissipative. A static-decay test ensures that the material meets industry standards for charge decay, so that the material does not hold a charge that can damage the ICs. These tests, along with other tests outlined in TI's quality standard (QSS 003-008), qualifies the ISD reel for use within TI.

Surface-resistance tests are performed using a PRS 801 meter, 5-LB NFPA probe, and dry chamber. The Trek 156 Charge-Plate Monitor is used to measure static decay. Each is described in section 3.1.

3.1 Equipment List

- PRS 801 meter – an instrument for measuring the surface resistance of a given material
- 5-LB NFPA probe – a concentric-ring probe specified in ANSI/EOS/ESD S11.11-93. This probe weighs 5 pounds and standardizes the pressure applied by the probe on the specimen.
- Dry chamber – an enclosed dry compartment for conditioning specimens in a low-humidity environment
- Trek 156 Charge-Plate Monitor – an instrument for measuring a material's ability to dissipate the induced voltage through the material with proper grounding

3.2 Test Procedure

3.2.1 *Surface-Resistance Measurement*

3.2.1.1 Resistance Measurement at Ambient Relative Humidity

Use this procedure to measure resistance of two reels at ambient relative humidity:

1. Clearly mark the plastic-reel surfaces to identify the specimen's orientation, e.g., inner-surface A, inner-surface B, inner-surface C, outer-surface A, outer-surface B, outer-surface C, and outer-surface D (see Figure 3).
2. Based on the ANSI/EOS/ESD S.11.11 test method, connect the electrode assembly to the instrumentation (see Figure 4).
3. Place the reel on the specimen support, and position the concentric-ring electrode assembly in the approximate center of the marked surface (see Figures 5 and 6).
4. Energize the instrumentation at 10 V. If the indicated resistance is less than $1 \times 10^6 \Omega$, record the value after 5 seconds, then proceed to step 6.
5. If the indicated resistance is equal to or greater than $1 \times 10^6 \Omega$, adjust the voltage source to 100 V. Resistance readings higher than $1 \times 10^6 \Omega$ need a higher voltage for measurement accuracy. Record the surface resistance indicated.
6. Repeat steps 3 through 5 for the remaining marked surfaces.
7. Repeat the above test procedure for the other reel.

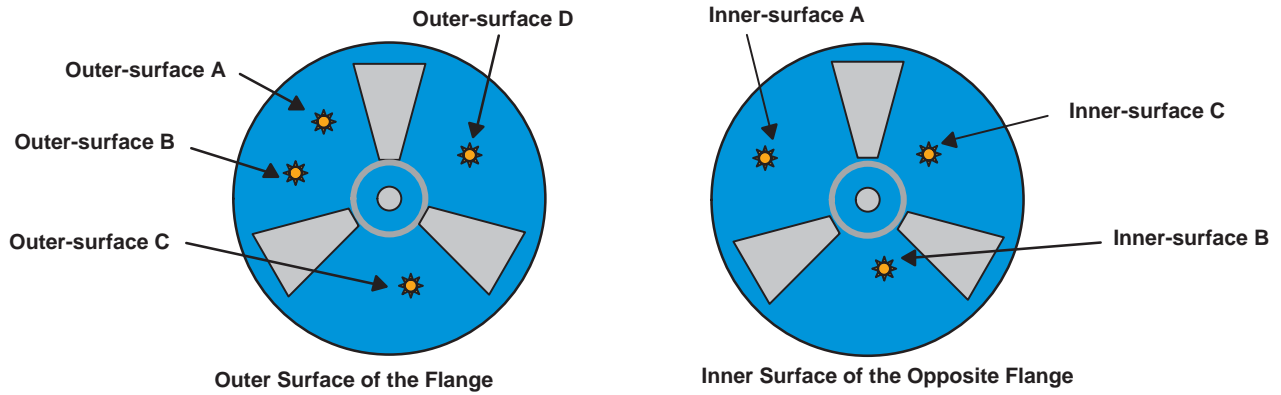


Figure 3. Resistance-Measurement Locations

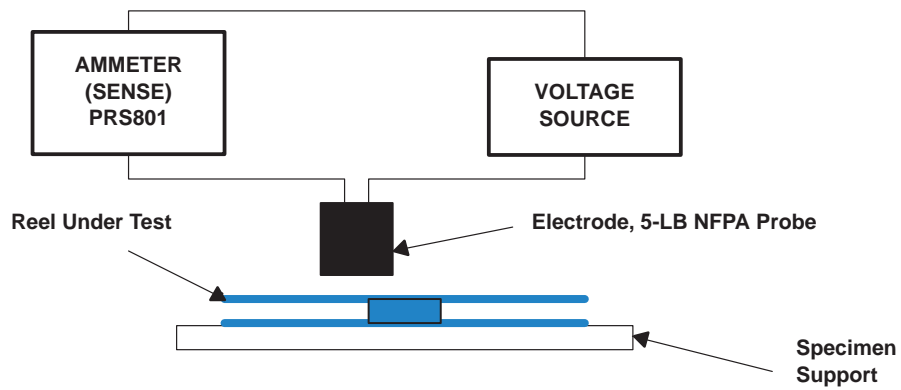


Figure 4. Resistance-Measurement Setup

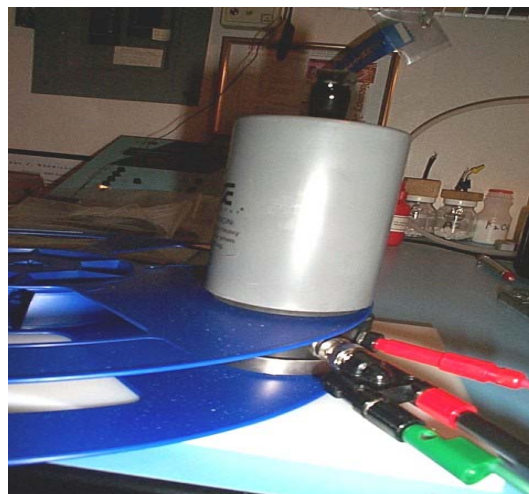


Figure 5. Measuring Surface Resistance on the Inner Surface



Figure 6. Measuring Resistance on the Outer Surface

3.2.1.2 Resistance Measurement Under Low-Humidity Conditions

Use this procedure to measure resistance of two reels under low-humidity conditions:

1. Condition the reels in a dry chamber at 12% \pm 3% relative humidity and 23°C \pm 3°C for a minimum of 48 hours. This condition simulates the actual relative humidity inside a dry-packed (MBB) bag.
2. Repeat steps 3 through 7 of section 3.2.1.1, with the reels inside the dry chamber.

3.2.1.3 Data Reporting

Record the minimum, maximum, and mean surface resistances for each reel tested, indicating the temperature, relative humidity, and duration of the test.

3.2.2 Charge-Decay Measurement

The charge-decay test measures the rate of decay of a charged isolated object to 10% of its original value. Federal Test Method Standard No. 101, Test Method Number 4046, specifies that the charged object at \pm 5000 V should drain the voltage to \pm 500 V in less than 2 seconds. This test has fixtures for planar objects, which poses a difficult problem in measuring charge decay of reels due to their complex construction. Because there is not enough plane surface to set up the test fixtures, the charge-plate monitor (CPM) was used to measure the reel's capability to dissipate the induced voltage, with proper grounding. A charged object at \pm 1000 V should drain to \pm 100 V in less than 2 seconds. One advantage of the CPM is its capability to measure the rate of decay through the material, from top to bottom.

Use the Trek 156 Charge-Plate Monitor to measure the static decay time (see Figure 7):

1. Using the same preconditioned reels used in section 3.2.1.2, measure the time it takes for the reels charged at +1000 V to drain to +100 V, and record the results. Tests should be done inside the dry chamber.
2. Repeat step 1 to drain $-$ 1000 V to $-$ 100 V and record the results.



Figure 7. Trek 156 Charge-Plate Monitor

4 Data and Results

Table 1. Antistatic-Coated Reel, Dipped, Blue

Sample Location	Surface Resistance (Ω)	
	Ambient Conditions (50.3% RH, 71.5°F)	Low Relative Humidity (48-Hour Soak at 11.7% RH, 73.2°F)
1. Inner-surface A	4.9×10^{10}	9×10^{12}
2. Inner-surface B	1.3×10^{11}	3.3×10^{13}
3. Inner-surface C	1.3×10^9	1.5×10^{11}
4. Outer-surface A	4.5×10^{10}	4.1×10^{12}
5. Outer-surface B	9.6×10^{10}	1.9×10^{13}
6. Outer-surface C	2.2×10^{10}	7.4×10^{12}
7. Outer-surface D	1.1×10^{11}	4.7×10^{11}
Average	6.47×10^{10}	1.04×10^{13}
Minimum	1.3×10^9	1.5×10^{11}
Maximum	1.3×10^{11}	3.3×10^{13}
Std. Dev.	4.79×10^{10}	1.18×10^{13}

Table 2. Intrinsically Static-Dissipative (ISD) Reel, Carbon-Loaded Polystyrene, Black

Sample Location	Surface Resistance (Ω)	
	Ambient Conditions (50.3% RH, 71.5°F)	Low Relative Humidity (48-Hour Soak at 11.7% RH, 73.2°F)
1. Inner-surface A	7.5×10^8	4.1×10^{10}
2. Inner-surface B	1.1×10^9	8.1×10^9
3. Inner-surface C	7.8×10^9	3×10^{10}
4. Outer-surface A	4.5×10^9	1.1×10^{11}
5. Outer-surface B	1.1×10^7	6.1×10^{10}
6. Outer-surface C	9.8×10^{10}	4.1×10^{11}
7. Outer-surface D	5.4×10^6	5.9×10^9
Average	1.6×10^{10}	9.51×10^{10}
Minimum	5.4×10^6	5.9×10^9
Maximum	9.8×10^{10}	4.1×10^{11}
Std. Dev.	3.62×10^{10}	1.43×10^{11}

Table 3. Static-Charge Decay

Description	Decay from +1000 V to +100 V† (seconds)	Decay from -1000 V to -100 V† (seconds)
Antistatic-coated reel, blue	20.36	16.5
ISD reel, carbon-loaded polystyrene, black	0.01	0.36

† Reels were conditioned at 11.7% RH, 73.2°F in a dry chamber for 48 hours before testing.

5 Discussion of Results

In practical applications where the devices are dry-packed at a condition below 12% RH, the intrinsically static-dissipative (ISD) reel performs better than the antistatic-coated reel. The ISD reel was slightly affected by the low-humidity environment and, except for a few cases, remained in the static-dissipative range, while the antistatic-coated reel became insulative (see Table 4). A lower concentration of carbon at surfaces A and C is attributed to the surface resistance falling outside the static-dissipative range for the ISD reel. These localized insulative zones do not affect the overall performance of the reel. At ambient conditions, both reels were in the static dissipative range, with the ISD reel having a lower average surface resistance and standard deviation. With regard to static decay, the ISD reel drains the static-voltage charge to less than 10% of the original value in less than 2 seconds, while the antistatic-coated reels failed to meet the 2-second requirement for static-dissipative material, as defined by Federal Test Method Standard 101.

These results indicate that the ISD reel provides better ESD protection than the topically coated reel at low humidity and ambient conditions. In essence, the ISD reel minimizes tribo-electric charging and dissipates any charge that is generated. This cannot be said for the topically coated reel, which allows for the possibility that the ICs it is protecting could be electrically overstressed.

In this evaluation, a concentric-ring fixture was used to measure the surface resistance in ohms. ANSI/EOS/ESD S.11.11 specifies the inner electrode diameter (D1) to be 1.2 inches (30.48 mm) and the outer electrode inner diameter (D2) to be 2.25 inches (57.15 mm). Using this concentric-ring geometry, the resistance can be converted to an equivalent surface resistivity in ohms per square by multiplying the resistance value by 10. If the ring geometry is different, use this equation:

$$\text{Surface resistivity, } \rho_s = 2\pi R / \ln(D2/D1)$$

Table 4 shows ESD resistance in ohms and ohms/square in terms of material classification. The conversion is provided because most TI quality standards rate ESD materials in terms of surface resistivity. This helps in making an accurate comparison.

Table 4. ESD Resistance

Measurement	Conductive	Static Dissipative	Insulative	Reference
Resistance (Ω)	$<1 \times 10^4$	Greater than 1×10^4 , but less than 1×10^{11}	$>1 \times 10^{11}$	ANSI/EOS/ESD S11.11-93
Surface resistivity (Ω/square)	$<1 \times 10^5$	Greater than 1×10^5 , but less than 1×10^{12}	$>1 \times 10^{12}$	EIA 541

6 Conclusions

The ISD reel is static dissipative in low- and high-humidity environments and can dissipate 90% of a charge within 2 seconds, whereas the antistatic-coated reel is very dependent upon the amount of relative humidity, may become insulative at <12% RH, and does not meet the static decay standard for static-dissipative materials. Therefore, it is concluded that, when semiconductor devices are packed in tape and reel, they receive better ESD protection with the ISD reel, with or without drypacking, than with the topically coated reel. The test results support qualification of the ISD reel and implementation at all TI assembly/test sites. The TI Worldwide Packing Team is working with its subcontractors so that all TI products are shipped using the ISD reel.

7 Glossary

Amorphous: having no real or apparent crystalline form

Anion: the ion in an electrolyzed solution that migrates to the anode; *broadly*: a negatively charged ion

Cation: the ion in an electrolyzed solution that migrates to the cathode; *broadly*: a positively charged ion

Hydroscopic: readily taking up and retaining moisture under some conditions of humidity and temperature

Hydrophilic: having a strong affinity for water

Hydrophobic: lacking affinity for water

Impact Modifier (Imod): A compound used to improve impact, toughness, ozone resistance, ultraviolet resistance, and heat resistance of polymers

Micropore: a very fine pore

Nonionic: not ionic; *especially*: not dependent on a surface-active anion for effect

Polymer: substance containing a large number of structural units joined by the same type of linkage. These substances often form a chain-like structure.

Polymerization: chemical reaction in which two or more molecules combine to form a larger molecule that contains repeating structural units

Surfactant (or surface-active): Altering the properties, especially lowering the tension at the surface of contact between phases. Wetting agents are typical surface-active substances.

8 References

1. *Methods to Increase Plastic Conductivity*, Dr. Lian Na, Cpak PTE Ltd.
2. *For Protection of Electrostatic Discharge Susceptible Items – Surface Resistance Measurement of Static Dissipative Planar Materials*, EOS/ESD-S11.11-1993.
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9 Acknowledgment

The authors thank Tom Diep, TI ESD Specialist, for his consultation; Bob Vermillion, Bob Vermillion and Associates, for conducting these tests; and Mike Hayden, WPL World-Wide Packing Commodity Manager, for his guidance.

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