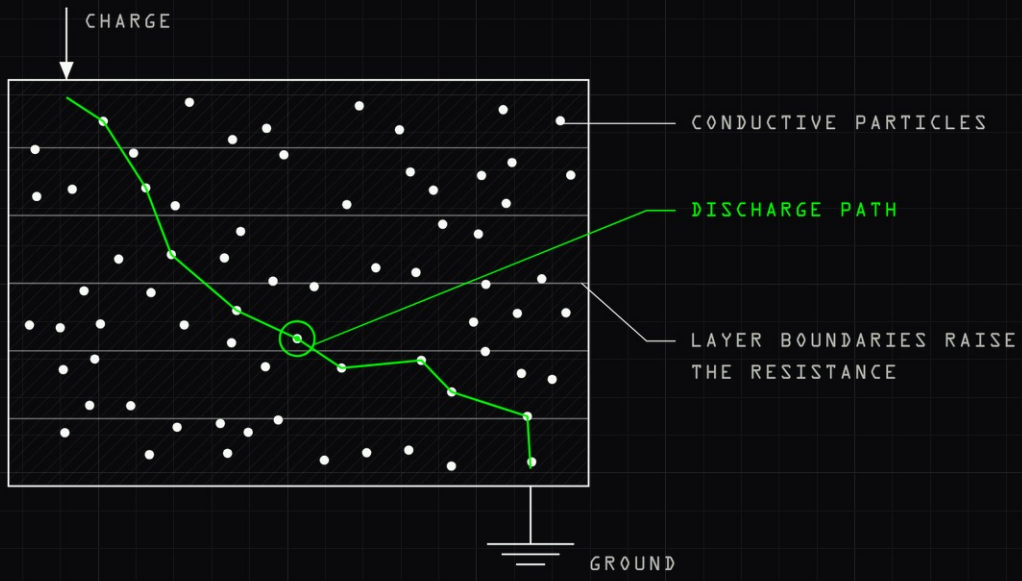
FIBERTHREE

SECTION A–A . DISSIPATIVE STRUCTURE



WHITE PAPER . WP008

ESD PARTS IN FFF PRINTING

How are electrostatic dissipative parts printed, designed and tested to IEC 61340?

DOCUMENT

WP008

FIBERTHREE WHITE PAPER

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00 . EXECUTIVE SUMMARY

In electronics manufacturing, fixtures, grippers and workpiece holders must discharge electrostatic charges in a controlled way. According to IEC 61340-5-3, the target range lies between 1 × 10^4 and 1 × 10^{11} Ω. According to its data sheet, F3 PA ESD reaches a surface resistance of 10^5 to 10^8 Ω and combines this with the strength of a polyamide.

The resistance of a printed part, however, is not that of the filament. Research shows: printing usually increases the resistance, it depends on direction and on layer height, temperature, infill and post-processing.

AT A GLANCE

- **Discharge path along the beads,** not through many layers.
- **Full infill** and a defined grounding point.
- **Dry the filament** and use a wear-resistant nozzle.
- **Measure every part** to IEC 61340-2-3, in a defined climate and at the point where it is meant to discharge.

Recommendation: Run the discharge path along the beads, use full infill, provide a grounding point and measure every part to IEC 61340-2-3.

10^5–10^8 Ω	10^4–10^{11} Ω	260–290 °C
Surface resistance F3 PA ESD, data sheet	dissipative range, IEC 61340-5-3	Print temperature F3 PA ESD

01 BACKGROUND

Plastics are insulators. If one part rubs against another, it becomes electrostatically charged, and the charge stays where it was created. If it discharges abruptly, it can destroy sensitive electronics or ignite a spark in potentially explosive areas.

Electronics manufacturing therefore sets up protected areas in which all surfaces, tools and fixtures discharge charges in a controlled way. Printed fixtures, workpiece holders, grippers and housings used there must be made of a dissipative material.

FFF is ideal for such parts: fixtures are single pieces or small series and are often needed at short notice. Dissipative filaments, however, behave differently from unfilled ones. Their resistance depends on how they are printed and how they are measured. This paper explains the basics, shows the effects of printing and describes our F3 PA ESD.

FIG. 1: SCHEMATIC

SECTION A–A . DISSIPATIVE STRUCTURE

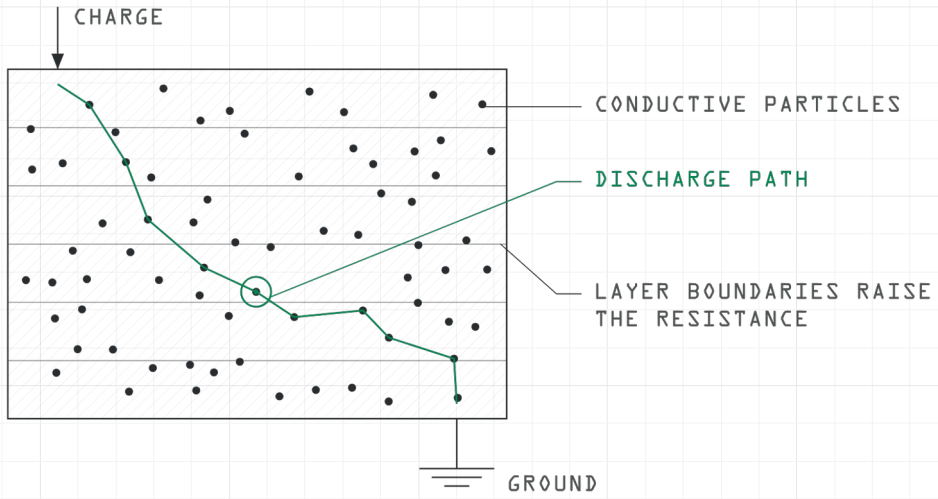


FIG. 1 Conductive particle network with discharge path to ground, schematic, not to scale.

02 BASICS AND STANDARDS

Materials are divided into three classes according to their electrical resistance. The limits according to IEC 61340-5-3 are:

CLASS	RESISTANCE	BEHAVIOUR
Conductive	below 1×10^4 Ω	Charge flows away very quickly. On contact with charged components the discharge itself can be too fast
Dissipative	1×10^4 to below 1×10^{11} Ω	Charge flows away in a controlled way. The target range for fixtures and workpiece holders
Insulating	from 1×10^{11} Ω	Charge remains. Unfilled plastics

TAB. 1 Resistance classes according to IEC 61340-5-3.

In everyday language, dissipative materials are often called “ESD” or “antistatic”. ESD stands for electrostatic discharge, the event to be protected against.

THE MOST IMPORTANT STANDARDS

STANDARD	CONTENT
IEC 61340-5-1 (DIN EN 61340-5-1)	Requirements for ESD control programmes and protected areas (EPA)
IEC TR 61340-5-2	User guide to IEC 61340-5-1
IEC 61340-5-3	Classification of packaging by resistance: conductive, dissipative, insulating
IEC 61340-2-3 (DIN EN 61340-2-3)	Test methods for resistance and resistivity of solid materials in the range 10 kΩ to 1 TΩ
IEC 60079-32-1	Electrostatic hazards in potentially explosive atmospheres

TAB. 2 Standards on electrostatics and ESD protection.

Which limit applies to a part is defined by the user’s ESD control programme. Parts for potentially explosive areas are subject to their own requirements, which must be tested separately.

03 HOW DISSIPATIVE FILAMENTS WORK

A plastic becomes dissipative when conductive particles are added to it, usually carbon black, carbon nanotubes or graphene. As long as the particles are isolated, the material remains insulating. Only above a certain concentration do they touch to form a continuous network, and the resistance drops by several orders of magnitude. This threshold is called the percolation threshold [Dijkshoorn et al. 2021].

The network is sensitive. Anything that pulls the particles apart or separates them increases the resistance: shear in the nozzle, pores, interfaces between the beads, moisture. That is why a printed part does not automatically have the resistance of the filament.

For practice it is important that conductivity does not depend on the filament alone. It only arises in the part when the particle network is preserved across beads and layers. Every decision in printing that affects pores or interfaces therefore also affects the resistance.

04 EFFECT OF PRINTING

The resistance of a printed part depends on direction and on the printing process. Several studies agree on this.

FROM FILAMENT TO PART

TU Braunschweig measured 14 conductive filaments in three stages: as filament, as a freely extruded strand and as a printed structure. Printing generally increased the resistivity. Filaments with nanotubes or graphene lost less conductivity and scattered less than those containing only carbon black [Polymers 16(20), 2891, 2024]. The manufacturing conditions of the filament itself also affect the resistance [Polymers 15(22), 4452, 2023].

DIRECTION

Along the bead, the current flows through the material of one bead. Across it and through the layers it has to cross the interfaces between the beads, where contact resistances and small pores interrupt the network. The resistance is therefore lowest along the bead and usually highest in the build direction [Dijkshoorn et al. 2021].

PRINT PARAMETERS

- **Layer height:** in studies with conductive PLA, thinner layers gave fewer pores, more conductive paths and a lower resistance [Abdalla et al. 2020].
- **Temperature:** a higher nozzle temperature can improve the fusion of the beads and lower the contact resistance between them.
- **Infill:** full infill and sufficient overlap between the beads reduce pores.
- **Annealing:** heat treatment after printing changes the resistance of the extruded strand [Stankevich et al. 2023]. Annealed ESD parts should therefore be re-measured.

SURFACE AND MOISTURE

The outermost layer of a bead can contain fewer particles than its interior. The surface resistance is therefore often higher than the volume resistance. In polyamide, absorbed moisture also changes the resistance. Measurements are therefore made in a defined climate according to IEC 61340-2-3.

For design this means treating the discharge path like a load path: the path from the point of contact to the grounding point should run along the beads as far as possible and through fully filled areas. Where the path has to pass through many layers, a higher resistance is to be expected.

Which influences prevail for a particular part is ultimately shown only by measurement. The notes in this chapter help to understand the measurement and to make targeted improvements.

05 F3 PA ESD

F3 PA ESD is a modified polyamide 6 with permanent electrostatic dissipation. It combines the strength and toughness of our polyamides with a surface resistance in the dissipative range.

PROPERTY	F3 PA ESD
Base	PA 6, modified
Surface resistance	10^5 to 10^8 Ω according to data sheet, dissipative according to IEC 61340-5-3
Mechanics	very high strength, low tendency to warp
Surface	matt black
Print temperature	260–290 °C

TAB. 3 Properties of F3 PA ESD according to the data sheet.

TYPICAL APPLICATIONS

- Workpiece holders and assembly fixtures for circuit boards and assemblies
- Gripper fingers and suction cup holders in electronics assembly
- Test adapters and contacting aids
- Carriers, trays and storage in the protected area
- Housings and covers for sensitive electronics

PRINTING RECOMMENDATIONS

- **Dry:** like all polyamides, dry before printing (WP002).
- **Lay beads in the discharge direction:** the path between the point of contact and the grounding point should run along the beads as far as possible, not through many layers.
- **Full infill** in areas that must discharge.
- **Provide a grounding point:** for example a hole for a screw or a threaded insert through which the part is connected to ground (WP005).

- **Wear-resistant nozzle:** conductively modified filaments are more abrasive than unfilled ones (WP006).
- **Check post-processing:** sanding, painting or annealing can change the surface resistance. Always re-measure afterwards.

F3 PA ESD is particularly suitable for parts that are mechanically loaded in addition to being dissipative, such as gripper fingers or workpiece holders that are changed frequently. Here the strength and toughness of the polyamide pay off.

As with all dissipative parts: release is based on measurement of the finished part according to Chapter 06.

06 MEASURING AND TESTING

An ESD part is released only once its resistance has been measured on the finished part. Data sheet values describe the material, not the printed part.

MEASUREMENT METHODS ACCORDING TO IEC 61340-2-3

MEASUREMENT	WHAT IT SHOWS
Surface resistance	resistance along the surface between two electrodes
Point-to-point resistance	resistance between two points on the part, practical for finished parts
Resistance to ground	resistance from the point of contact to the grounding point, decisive in the protected area
Volume resistance	resistance through the material, for example through the layers

TAB. 4 Measurement methods according to IEC 61340-2-3.

POINTS TO WATCH

- **Climate:** store parts in a defined climate before measuring. Polyamide changes its resistance with moisture content.
- **Contact:** the electrodes must sit firmly. On rough, ribbed FFF surfaces the readings otherwise scatter strongly [Vasques et al. 2025].
- **Direction:** measure at the point and in the direction in which the part is meant to discharge in use.
- **Test voltage:** the standard specifies it depending on the resistance range. With filled plastics, different voltages give different values.
- **Repeat:** re-measure ESD parts in use regularly, as provided for in the ESD control programme according to IEC 61340-5-1.

07 CONCLUSION

Dissipative filaments make ESD-safe fixtures possible in FFF printing, but the resistance of a printed part is not that of the filament. It depends on direction, layer height, temperature, infill and post-processing. With the discharge path along the beads, full infill, a defined grounding point and a measurement on the finished part, F3 PA ESD can be used safely.

REFERENCES

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ABOUT FIBERTHREE

Fiberthree develops and produces technical filaments for FFF printing in Darmstadt, with polyamide at the heart of the portfolio. Building on our background as an engineering office, we also offer engineering, training and contract manufacturing on more than 30 printers, from first sample to small series.

WHITE PAPER SERIES

All white papers are available at www.fiberthree.com. We update the series regularly; the latest version applies.

NO.	TOPIC	HELPS WITH
WP001	Plastics for the FFF Process: Material Overview and Process Comparison	Choosing material and process
WP002	Effect of Moisture on Polymers in the FFF Process	Drying filament and keeping it dry
WP003	Annealing and Post-Processing of FFF Parts	Annealing, conditioning, finishing
WP004	Design for Manufacturing in the FFF Process	Designing parts for FFF
WP005	Heat-Setting Threaded Inserts in FFF Parts	Detachable screw connections
WP006	Nozzle Selection for Filled Filaments	Nozzle material and diameter
WP007	Print Bed and Adhesion	First-layer adhesion
WP008	**Electrostatic Dissipative (ESD) Parts in FFF Printing (this paper)**	**Printing and testing ESD parts**
WP009	Interlayer Adhesion in the Build Direction: Nozzle Temperature, Print Speed and Hotend	Strength in the z direction

TAB. 5 Overview of the Fiberthree white papers.

FIBERTHREE

START WITH THE RIGHT MATERIAL

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QUALITY

ISO 9001

DIN EN ISO 9001:2015 .
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