

Electrostatic Discharge

Choose yourself and new technologies



Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

References

Basic:
Ott H. W., *Electromagnetic Compatibility Engineering*, Wiley, Hoboken, NJ, 2009

Additional:
Williams T., *EMC for Product Designers*, Elsevier-Newnes, 4-th ed., Oxford, 2007



Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

Source of illustrative materials

All the illustrative materials have been taken from:
Ott H. W., *Electromagnetic Compatibility Engineering*, Wiley, Hoboken, NJ, 2009



Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English
at Wrocław University of Technology

Electrostatic Discharge

Static electricity is familiar to all of us as the static cling of clothing, as arcing occurring when touching a doorknob or other metal object, and as lightning. Uncontrolled electrostatic discharge (ESD) has become a hazard to the electronics industry.

Wrocław University of Technology Master programmes in English
at Wrocław University of Technology

STATIC GENERATION

Static electricity can be created in many different ways, but the most common is by contact and subsequent separation of materials.

Wrocław University of Technology Master programmes in English
at Wrocław University of Technology

STATIC GENERATION

Table below is a typical triboelectric series.

TABLE 15-1. Triboelectric Series

POSITIVE	
1. Air	18. Hard rubber
2. Human skin	19. Mylar TM
3. Adhesion	20. Epoxy glass
4. Glass	21. Nickel, copper
5. Mica	22. Brass, silver
6. Human hair	23. Gold, platinum
7. Nylon	24. Polystyrene foam
8. Wood	25. Acrylic
9. Fur	26. Polyester
10. Lead	27. Celluloid
11. Silk	28. Oxide
12. Aluminum	29. Polyurethane foam
13. Paper	30. Polyethylene
14. Cotton	31. Polypropylene
15. Wood	32. PVC (vinyl)
16. Steel	33. Silicone
17. Amber	34. Teflon SM

NEGATIVE

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC GENERATION

When two materials are in contact, electrons will transfer from the material higher on the list to the material lower on the list. The magnitude of the charge created depends on the position of the materials in the triboelectric series and also on the surface cleanliness, pressure of the contact, amount of rubbing, surface area in contact, smoothness of surface, and the speed of separation.

HUMAN CAPITAL Wrocław University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC GENERATION

Charge is measured in coulombs. We normally refer to the electrostatic potential (measured in volts) of an object, rather than its charge. The relationship between charge, voltage, and capacitance is

$$V = \frac{Q}{C}$$

As two materials are separated, the charge imbalance Q remains fixed; therefore, the product VC is a constant. When the materials are close together, the capacitance is large; hence, the voltage is low. As the materials are separated, the capacitance decreases and the voltage increases.

HUMAN CAPITAL Wrocław University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC GENERATION

Means of Static Generation	Electrostatic Voltage	
	10% to 20% Relative Humidity	65% to 90% Relative Humidity
Walking across carpet	35,000	1500
Walking on vinyl floor	12,000	250
Worker moving at bench	6000	100
Opening a vinyl envelope	7000	600
Picking up common polyethylene bag	20,000	1200
Sitting on chair padded with polyurethane foam	18,000	1500

HUMAN CAPITAL Wrocław University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC GENERATION

Static electricity is a surface phenomenon.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC GENERATION

Electrostatic discharge is a three-step process:

1. A charge is generated on an insulator.
2. This charge is transferred to a conductor by contact or induction.
3. The charged conductor comes near a metal object and a discharge occurs.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

HUMAN BODY MODEL

Humans are a prime source of electrostatic discharge.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

HUMAN BODY MODEL

The human body model (HBM) for ESD

RANGE OF VALUES	
C_b	50 to 250 pF
R_b	500 to 10k Ω
V_b	0 to 20 kV

HUMAN CAPITAL
Wrocław University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

HUMAN BODY MODEL

Typical waveshape produced by a 150-pF, 330-ohm human body model discharge into a special 2 Ω test target

HUMAN CAPITAL
Wrocław University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

STATIC DISCHARGE

Charge accumulated on an object leaves the object by one of two ways, leakage or arcing.

HUMAN CAPITAL
Wrocław University of Technology

Wroclaw University of Technology Master programmes in English at Wroclaw University of Technology

STATIC DISCHARGE

The minimum impedance that should be used in grounding a person is 250 kΩ. Grounded wrist straps usually have a 1 MΩ resistance to ground.

HUMAN CAPITAL Wroclaw University of Technology

Wroclaw University of Technology Master programmes in English at Wroclaw University of Technology

ESD PROTECTION IN EQUIPMENT DESIGN

Effective ESD immunity design requires

First, prevent or minimize the entry of the transient currents by:

- Effective design of the enclosure
- Cable shielding
- Providing transient protection on all conductors of unshielded external cables

Second, harden sensitive circuits, such as:

- Resets
- Interrupts
- Other critical control inputs

Third, write transient hardened software capable of detecting, and if possible, correcting errors in the following:

- Program flow
- Input/output (I/O) data
- Memory

HUMAN CAPITAL Wroclaw University of Technology

Wroclaw University of Technology Master programmes in English at Wroclaw University of Technology

ESD PROTECTION IN EQUIPMENT DESIGN

Energy from a static discharge can be coupled to an electronic circuit:

1. By direct conduction
2. By field coupling, including
 - a. Capacitive coupling
 - b. Inductive coupling

HUMAN CAPITAL Wroclaw University of Technology

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

ESD PROTECTION IN EQUIPMENT DESIGN

A circuit or system may be protected from a static discharge by any of the following:

1. Eliminating the static buildup on the source
2. Insulating the product to prevent a discharge
3. Providing an alternative path for the discharge current to bypass the sensitive circuits
4. Shielding the circuit against the electric fields produced by the discharge
5. Decreasing loop areas to protect the circuit from the magnetic fields produced by the discharge

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

ESD PROTECTION IN EQUIPMENT DESIGN

ESD-induced effects in electronic systems can be divided into three categories:

1. Hard errors
2. Soft errors
3. Transient upset

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

HUMAN BODY MODEL

The human body model (HBM) for ESD

$C_b = 150 \text{ pF}$
 $R_b = 330 \text{ } \Omega$

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology **Master programmes in English**
at Wrocław University of Technology

PREVENTING ESD ENTRY

The three most common points of ESD entry are the enclosure, cables, and keyboards or control panels.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology **Master programmes in English**
at Wrocław University of Technology

ESD GROUNDING

The first thing to remember about ESD grounding is that the ac power cord's green-wire ground is a high impedance at ESD frequencies.
The real ground or reference for ESD is the chassis (or metallic enclosure) or ESD ground plate within the product, and its free-space capacitance.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund

Wrocław University of Technology **Master programmes in English**
at Wrocław University of Technology

NONGROUNDED PRODUCTS

On a product with no external ground connection (e.g., a handheld calculator), the ESD current path will be from the entry point through the part of the product with the largest capacitance (i.e., lowest impedance) to ground. On many small handheld products, the part with the largest capacitance to ground is the printed circuit board. The solution is to provide an alternative path with lower impedance (larger capacitance) to ground for the ESD current to flow through. This is usually accomplished by adding an ESD ground plate to the product underneath the PCB.

HUMAN CAPITAL
Wrocław University of Technology
Project co-financed from the EU European Social Fund
