
Contents

Foreword 1	ix
Foreword 2	xi
Preface	xiii
Introduction	xvii
Chapter 1. ESD Standards: From Component to System	1
1.1. Standards: From component to system.	1
1.1.1. Increasingly sensitive electronics	1
1.2. Component level standards: HBM, MM, CDM, HMM	3
1.3. Standards at the system level	6
1.3.1. The IEC 61000-4-2 standard or ESD gun.	8
1.3.2. Problems linked to the standard: IEC 61000-4-2.	13
1.3.3. HMM (Human Metal Model)	14
1.3.4. Standard model ISO 10605	16
1.3.5. CDE (Cable Discharge Event) model	17
1.4. Conclusion	18
Chapter 2. Characterization Techniques	21
2.1. Component level electrical characterization techniques	22
2.1.1. TLP/VF-TLP measurements	23
2.1.2. The transient-TLP.	25
2.1.3. Adaptation of the TLP for reflectometry	27

2.2. System measurement methods	38
2.2.1. Voltage measurement by probes	38
2.2.2. Measurement of grounding currents through a 1 Ω method	39
2.2.3. Measurement of currents by induced magnetic field	41
2.3. Injection methods	55
2.3.1. Injection in conduction mode – DPI method	56
2.3.2. Near-field injection	57
2.4. Failure analysis techniques	59
2.4.1. Static light emission microscopy (EMMI)	59
2.4.2. Dynamic light emission microscopy (PICA)	60
2.4.3. Laser stimulation techniques	62
2.4.4. Photoelectric laser stimulation (PLS)	64
2.4.5. Detection of latent defects by low frequency noise measurements	65
2.5. Conclusion	68
Chapter 3. Protection Strategies Against ESD	71
3.1. ESD design window	71
3.2. Elementary protective components	75
3.2.1. Protection strategies	76
3.2.2. Elementary protection structures	80
3.2.3. Self-protection of an output level	87
3.2.4. Localized protection	91
3.2.5. Centralized protection	93
3.3. Discrete protections	101
3.4. Challenges of the protection strategy at the system level	103
3.5. Conclusion	109
Chapter 4. Modeling and Simulation Methods	111
4.1. Physical simulation: TCAD approach to the optimization of elementary protections	111
4.1.1. Description of the structure	113
4.1.2. Simulator calibration	115
4.1.3. Robustness prediction	119
4.1.4. Focalization phenomena	122
4.1.5. Benefits of 3D modeling	125

4.2. Electrical simulation: Compact modeling	126
4.2.1. Diode modeling	127
4.2.2. Modeling of the bipolar transistor	127
4.2.3. MOS transistor model	135
4.2.4. Modeling of the thyristor	140
4.3. Behavioral simulation for prediction at the system level	142
4.3.1. IBIS models: advantages and limitations	145
4.3.2. Setting up a power supply network	156
4.3.3. Extraction of parameters from measurements	156
4.3.4. Application to system modeling	163
4.3.5. Validation of the behavioral models through the system approach	165
4.3.6. Addition of failure criteria	172
4.4. Conclusion	175
Chapter 5. Case Studies	177
5.1. Case 1: Interaction between two types of protection	177
5.2. Case 2: Detection of latent defaults caused by CDM stress	182
5.3. Case 3: The impact of decoupling capacitors in propagation paths in a circuit	190
5.3.1. Analysis of test configuration no. 1	191
5.3.2. Validation of the results by near-field mapping	197
5.3.3. Analysis of test configuration no. 2	198
5.4. Case 4: Functional failure linked to a decoupling capacitor.	201
5.5. Case 5: Fatal failure in an LIN circuit	207
5.6. Case 6: Functional failure in a 16-bit microcontroller	215
5.6.1. Description of the studied 16-bit microcontroller circuit and its test conditions	217
5.6.2. Measurement results	219
5.6.3. Modeling and simulation	222
5.7. Conclusion	225
Conclusion	227
Bibliography	235
Index	255