

---

## TABLE OF CONTENTS

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 THREATS, MODELS, REAL-LIFE SCENARIOS.....</b>	<b>2</b>
2.1 THREATS IN ELECTRONIC PRODUCTION LINES.....	2
2.2 MODELS TO DESCRIBE THE THREATS.....	2
2.3 REAL-LIFE SCENARIOS – CORRELATION BETWEEN THREATS AND MODELS BASED ON WAVEFORMS .....	3
2.3.1 <i>Introduction</i> .....	3
2.3.2 <i>Examples and Discussion: Human Body Model</i> .....	4
2.3.3 <i>Examples and Discussion: Charged Device Model</i> .....	6
2.3.4 <i>Summary</i> .....	11
2.4 DESCRIPTION OF DIFFERENT TYPES OF PROCESSES IN GENERAL TERMS – MANUAL, SEMI- AUTOMATED, FULLY AUTOMATED .....	11
<b>3.0 RISK ASSESSMENT AND PROCESS CAPABILITIES .....</b>	<b>12</b>
3.1 DO WE EXPECT ESD-FAILURES IN AN EPA DESIGNED ACCORDING TO INTERNATIONAL STANDARDS? THE NEED FOR A PROCESS RELATED RISK ANALYSIS.....	12
3.1.1 <i>Process-Related Risk Analysis</i> .....	12
3.1.2 <i>Practical Examples</i> .....	15
3.1.3 <i>Summary and Conclusion</i> .....	18
3.2 PROCESS CAPABILITY & TRANSITIONAL ANALYSIS .....	18
3.2.1 <i>Introduction</i> .....	18
3.2.2 <i>Failure Models from a Process Point of View</i> .....	19
3.2.3 <i>Analysis Concepts</i> .....	20
3.2.4 <i>Performing Process Capability and Transitional Analysis</i> .....	23
3.2.5 <i>Other Process Capability and Transition Analysis Examples</i> .....	30
3.2.6 <i>Conclusions</i> .....	31
3.3 ESD RISK EVALUATION OF AUTOMATIC SEMICONDUCTOR PROCESS EQUIPMENT .....	31
3.3.1 <i>Introduction</i> .....	31
3.3.2 <i>Main Section of the Guideline</i> .....	31
3.3.3 <i>Conclusion and Outlook</i> .....	37
3.4 PROCESS AND EQUIPMENT ESD CAPABILITY MEASUREMENTS.....	38
3.4.1 <i>Introduction</i> .....	38
3.4.2 <i>Measurement Techniques</i> .....	39
3.4.3 <i>Discussion of Results</i> .....	45
3.4.4 <i>Process Capability</i> .....	48
3.4.5 <i>Conclusion</i> .....	49
3.5 FURTHER PUBLISHED ARTICLES .....	50
<b>4.0 TEST METHODS AND STANDARDS WORK .....</b>	<b>52</b>
4.1 HIGH-LEVEL SUMMARY OF MEASUREMENT PROCEDURES.....	52
4.1.1 <i>Resistance Measurements</i> .....	52

---

4.1.2 Voltage Measurements .....	54
4.2 ESD ASSOCIATION STANDARDS WORKING GROUP ACTIVITIES .....	54
<b>5.0 SUMMARY .....</b>	<b>54</b>
<b>6.0 OUTLOOK.....</b>	<b>56</b>
<b>7.0 BIBLIOGRAPHY .....</b>	<b>56</b>

**Figures**

Figure 1: Typical Damages Caused by HBM-Type Stress Observed in Physical Failure Analysis after Lift-off on Silicon Level .....	4
Figure 2: Current of a Discharge of Personnel into a Pellegrini Target (VHBM = 1,060 Volts), Depending on the Speed of Approach.....	5
Figure 3: Static Voltages Generated by Walking Test (Heavy Movement) using Different Combinations of ESD Measures (Footwear/Floor) .....	6
Figure 4: Simplified Schematic of a CDM Tester .....	7
Figure 5: CDM Discharges of a Product Compared to a Typical CDM Discharge Generated by a CDM Tester (JEDEC Head and Field Plate) at a Discharge Voltage of 1 Kilovolt.....	8
Figure 6: JEDEC CDM Test Head used for Current Measurements in the Field.....	9
Figure 7: CDM Discharge of Devices on a Silicon Wafer with an Isolating Tape on the Backside.....	10
Figure 8: CDM Discharges in a Delta Castle Handler.....	11
Figure 9: PGA Test Socket, Charged by Opening and Closing .....	15
Figure 10: Arrows are Showing Where the Metallic Needles Contacted Printed Metal Lines on the PCB.....	16
Figure 11: Characterizing the Critical Path and Identifying Transition Points .....	21
Figure 12: Personnel Body Voltage Generation Transport Transition Measurements .....	23
Figure 13: Personnel Measuring PCB Conductor with Contact Voltmeter .....	24
Figure 14: CDM Discharge .....	24
Figure 15: CDM Discharge from Part in Ungrounded Tray Charged by Person.....	25
Figure 16: Instrument Carrier with Portable CPM and Recording Device .....	26
Figure 17: Recorded Field Voltages .....	26
Figure 18: Recorded Field Voltages at 12 Inches from Charged Reference Material .....	27
Figure 19: Device Charge Sharing Measurement with Portable CPM.....	28
Figure 20: Discharge Current vs. Charge Voltage – MQFP Device at 2.5 mm .....	28
Figure 21: Device Sharing Recording in SMT .....	29
Figure 22: DiscRFID Tag in Space CDM Discharge Waveform @ 100 ns .....	30
Figure 23: RFID Tag on Grounded Metal MM Discharge Waveform @ 100 ns .....	30
Figure 24: Device Transport Hybrid Waveform .....	30
Figure 25: Garment Discharge Hybrid Waveform .....	30
Figure 26: Walking Pattern for Personnel Voltage Test .....	39
Figure 27: Person Connected to CPM and HIDVM.....	40
Figure 28: Devices Used for Testing .....	41
Figure 29: Discharge Target.....	42
Figure 30: Discharge Test Fixture .....	43
Figure 31: Devices Used for Testing .....	43
Figure 32: Discharge Current vs. Charge voltage .....	46
Figure 33: Discharge Current vs. Charge voltage .....	47
Figure 34: Risk Assessment of Damage of ESDS Due to Discharges from Charged Personnel or Charged Conductors or Electric Fields Caused by Charged Personnel or Conductors .....	55
Figure 35: Risk Assessment of Damage of ESDS Due to Discharges into Conducting Surfaces .....	56

**Tables**

Table 1:	Possible ESD Risk in Typical PCB Assembly Process Steps.....	17
Table 2:	HIDVM Measurements of SOT23 Package .....	41
Table 3:	HIDVM Measurements of 240-Pin MQFP Package .....	42
Table 4:	Discharge Current Measurements at 25 mm .....	44
Table 5:	Discharge Current Measurements at 2.5 mm .....	44
Table 6:	Comparison of Discharge Current between the CDM Tester and the Discharge Target (DT) at 25 mm – DT value from Discharge Target, CDM value from CDM Tester .....	45
Table 7:	Comparison of Discharge Current between the CDM Tester and the Discharge Target (DT) at 2.5 mm – DT value from Discharge Target, CDM value from CDM Tester .....	45
Table 8:	Compilations of Recent EOS/ESD Symposia Publications (2005–2013) on Process Risk Assessment.....	51
Table 9:	Compilation of Measurement Methodologies Which can be Applied to Process Risk Assessment (HIDVM: Contact-Based High-Impedance Digital Voltmeter).....	55