# TABLE OF CONTENTS

1.0 **INTRODUCTION** .................................................................................................................. 1

2.0 **THREATS, MODELS, REAL-LIFE SCENARIOS** ............................................................... 2

   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 **Introduction** .............................................................................................................. 3

       2.3.2 **Examples and Discussion: Human Body Model** ...................................................... 4

       2.3.3 **Examples and Discussion: Charged Device Model** .................................................. 6

       2.3.4 **Summary** .................................................................................................................. 11

   2.4 **DESCRIPTION OF DIFFERENT TYPES OF PROCESSES IN GENERAL TERMS – MANUAL, SEMI-AUTOMATED, FULLY AUTOMATED** .......................................................... 11

3.0 **RISK ASSESSMENT AND PROCESS CAPABILITIES** ....................................................... 12

   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 **Process-Related Risk Analysis** .................................................................................. 12

       3.1.2 **Practical Examples** ................................................................................................... 15

       3.1.3 **Summary and Conclusion** ....................................................................................... 18

   3.2 **PROCESS CAPABILITY & TRANSITIONAL ANALYSIS** .................................................. 18

       3.2.1 **Introduction** .............................................................................................................. 18

       3.2.2 **Failure Models from a Process Point of View** .......................................................... 19

       3.2.3 **Analysis Concepts** .................................................................................................. 20

       3.2.4 **Performing Process Capability and Transitional Analysis** ........................................ 23

       3.2.5 **Other Process Capability and Transition Analysis Examples** ..................................... 30

       3.2.6 **Conclusions** .......................................................................................................... 31

   3.3 **ESD RISK EVALUATION OF AUTOMATIC SEMICONDUCTOR PROCESS EQUIPMENT** ............................................................................................................................. 31

       3.3.1 **Introduction** .............................................................................................................. 31

       3.3.2 **Main Section of the Guideline** ............................................................................... 31

       3.3.3 **Conclusion and Outlook** .......................................................................................... 37

   3.4 **PROCESS AND EQUIPMENT ESD CAPABILITY MEASUREMENTS** ......................... 38

       3.4.1 **Introduction** .............................................................................................................. 38

       3.4.2 **Measurement Techniques** ....................................................................................... 39

       3.4.3 **Discussion of Results** .............................................................................................. 45

       3.4.4 **Process Capability** .................................................................................................. 48

       3.4.5 **Conclusion** .............................................................................................................. 49

   3.5 **FURTHER PUBLISHED ARTICLES** ............................................................................... 50

4.0 **TEST METHODS AND STANDARDS WORK** ................................................................... 52

   4.1 **HIGH-LEVEL SUMMARY OF MEASUREMENT PROCEDURES** .................................. 52

       4.1.1 **Resistance Measurements** ....................................................................................... 52
4.1.2 Voltage Measurements

4.2 ESD Association Standards Working Group Activities

5.0 SUMMARY

6.0 OUTLOOK

7.0 BIBLIOGRAPHY

Figures

Figure 1: Typical Damages Caused by HBM-Type Stress Observed in Physical Failure Analysis after Lift-off on Silicon Level

Figure 2: Current of a Discharge of Personnel into a Pellegrini Target (VHBM = 1,060 Volts), Depending on the Speed of Approach

Figure 3: Static Voltages Generated by Walking Test (Heavy Movement) using Different Combinations of ESD Measures (Footwear/Floor)

Figure 4: Simplified Schematic of a CDM Tester

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

Figure 6: JEDEC CDM Test Head used for Current Measurements in the Field

Figure 7: CDM Discharge of Devices on a Silicon Wafer with an Isolating Tape on the Backside

Figure 8: CDM Discharges in a Delta Castle Handler

Figure 9: PGA Test Socket, Charged by Opening and Closing

Figure 10: Arrows are Showing Where the Metallic Needles Contacted Printed Metal Lines on the PCB

Figure 11: Characterizing the Critical Path and Identifying Transition Points

Figure 12: Personnel Body Voltage Generation Transport Transition Measurements

Figure 13: Personnel Measuring PCB Conductor with Contact Voltmeter

Figure 14: CDM Discharge

Figure 15: CDM Discharge from Part in Ungrounded Tray Charged by Person

Figure 16: Instrument Carrier with Portable CPM and Recording Device

Figure 17: Recorded Field Voltages

Figure 18: Recorded Field Voltages at 12 Inches from Charged Reference Material

Figure 19: Device Charge Sharing Measurement with Portable CPM

Figure 20: Discharge Current vs. Charge Voltage – MQFP Device at 2.5 mm

Figure 21: Device Sharing Recording in SMT

Figure 22: DiscRFID Tag in Space CDM Discharge Waveform @ 100 ns

Figure 23: RFID Tag on Grounded Metal MM Discharge Waveform @ 100 ns

Figure 24: Device Transport Hybrid Waveform

Figure 25: Garment Discharge Hybrid Waveform

Figure 26: Walking Pattern for Personnel Voltage Test

Figure 27: Person Connected to CPM and HIDVM

Figure 28: Devices Used for Testing

Figure 29: Discharge Target

Figure 30: Discharge Test Fixture

Figure 31: Devices Used for Testing

Figure 32: Discharge Current vs. Charge voltage

Figure 33: Discharge Current vs. Charge voltage

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

Figure 35: Risk Assessment of Damage of ESDS Due to Discharges into Conducting Surfaces
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