Contents

Foreword by Christian Moreau ix

Foreword by Claude Sarno xi

Acknowledgments xiii

Introduction xv

List of Acronyms xxi

List of Notations xxiii

Chapter 1. Reliability of Systems Without Maintenance 1

1.1. Classification of systems 4
1.1.1. Maintenance-free systems 4
1.1.2. Systems with maintenance 4
1.2. Principal quantities of reliability 4
1.2.1. The probability density 5
1.2.2. The probability of failure 7
1.2.3. The survival function 8
1.2.4. The instantaneous failure rate 9
1.2.5. The mode of a distribution 10
1.2.6. The cumulative failure rate 11
1.2.7. Links between different functions 11
1.2.8. MTTF notion 12
1.2.9. Residual lifespan 12
1.3. The main distributions 14
1.3.1. The exponential distribution 14

1.3.2. The Weibull distribution . . . 17
1.3.3. Normal distribution . . . 26
1.3.4. The log-normal distribution . . . 28
1.4. Context . . . 31
1.4.1. Theoretical basis of JESD85 . . . 31
1.4.2. Problem when there are no observed failures . . . 35
1.4.3. Theoretical analysis . . . 36
1.4.4. Example of a HTOL test on integrated circuits . . . 38

Chapter 2. Reliability of Systems with Maintenance . . . 41

2.1. Counting process . . . 41
2.2. Different types of maintenance . . . 43
2.3. Preventive maintenance . . . 45
2.3.1. General formulation . . . 45
2.3.2. Formulation for accidental failures . . . 47
2.3.3. Formulation for aging failures . . . 47
2.4. Corrective maintenance . . . 53
2.4.1. Hypothesis . . . 53
2.4.2. Renewal process . . . 53
2.4.3. Analytical solutions . . . 56

Chapter 3. Application to Aging Mechanisms with Maintenance . . . 71

3.1. Characteristics . . . 71
3.2. Approximate solutions . . . 72
3.2.1. The stabilization time of the Rocof is very low compared to the operational period . . . 72
3.2.2. The asymptotic value of the Rocof is never reached . . . 74
3.2.3. Other cases . . . 76
3.3. Generalizations . . . 91
3.3.1. Mix of distributions . . . 91
3.3.2. Competitive mechanisms . . . 92
3.3.3. Serial system . . . 95
3.3.4. Parallel systems . . . 97
3.3.5. “K/n” redundancy systems . . . 103
3.3.6. Summary . . . 104
3.4. Impact of physical factors . . . 105
3.5. Impact of the mission profile . . . 108
3.5.1. Sedyakin’s principle . . . 109
3.5.2. Physical equivalent contribution with Sedyakin’s principle . . . 111
3.5.3. Case of a heterogeneous profile . . . 123

Chapter 4. Impact at the Reliability Level 129

4.1. Concept of MTBF 129
4.2. Estimation of MTBF 130
4.3. Impact of the delivery flow 134
4.4. Example of a digital component with a fine engraving size 135
4.4.1. Case where the Weibull shape parameter is equal to 1 135
4.4.2. Case where the shape parameter is not equal to 1 138
4.5. Application at the cost of a burn-in 142
4.5.1. Cases where no burn-in is done 143
4.5.2. Cases where a burn-in is done 144

Chapter 5. Application to Maintenance 149

5.1. Reliability growth 152
5.2. BTN maintenance “Better than New” 155
5.3. WTO “Worse than Old” maintenance 158
5.4. Maintenance by attrition 159
5.5. Maintenance on a complete subset 161
5.5.1. Cases where we replace the defective system with a new one. . . . 162
5.5.2. Cases where we replace the complete system with a new one. . . . 163
5.6. Systems with k/n redundancy 166
5.6.1. Cases where we replace the defective system with a new one. . . . 166
5.6.2. Cases where we replace the complete system 167

Chapter 6. Application to Safety 169

6.1. Estimation of exposure time 170
6.2. Case of components with aging 171
6.2.1. Theoretical approach for systems with maintenance 172
6.2.2. Case of catastrophic failures 172
6.2.3. Case of aging failures 173
6.2.4. OR gate 180
6.2.5. AND gate 183

Chapter 7. Maintenance Strategy in Operational Safety 187

Appendix 193

References 197

Index 199