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Reliability data handbook – Universal model for reliability prediction of electronics components, PCBs and equipment

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RELIABILITY DATA HANDBOOK – UNIVERSAL MODEL FOR RELIABILITY PREDICTION OF ELECTRONICS COMPONENTS, PCBs AND EQUIPMENT

FOREWORD

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IEC 62380, which is a technical report, has been prepared by IEC technical committee 47: Semiconductor devices.

The text of this standard is based on the following documents:

Enquiry draft	Report on voting
47/1705/DTR	47/1722A/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This technical report does not follow the rules for structuring international standards as given in Part 2 of the ISO/IEC Directives.

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The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This reliability calculation guide for electronic and optical card, is an important progress compared to older guides. Calculation models take directly into account the influence of the environment. The thermal cycling seen by cards, function of mission profiles undergone by the equipment, replace environment factor which is difficult to evaluate. These models can handle permanent working, on/off cycling and dormant applications. On the other hand, failure rate related to the component soldering, is henceforth-included in component failure rate.

RELIABILITY DATA HANDBOOK – UNIVERSAL MODEL FOR RELIABILITY PREDICTION OF ELECTRONICS COMPONENTS, PCBs AND EQUIPMENT

1 Scope

This technical report provides elements to calculate failure rate of mounted electronic components. It makes equipment reliability optimization studies easier to carry out, thanks to the introduction of influence factors.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086 (all parts), *Primary batteries*

IEC 60099 (all parts), *Surge arresters*

IEC 60115 (all parts), *Fixed arrestors for use in electronic equipment*

IEC 60146, (all parts), *Semiconductor convertors – General requirements and line commutated convertors*

IEC 60255 ((all parts), *Electrical relays*

IEC 60269 (all parts), *Low-voltage fuses*

IEC 61951 (all parts), *Secondary cells and batteries containing alkaline or other non-alkaline electrolytes – Portable sealed rechargeable single cells*

IEC 60326 (all parts), *Printed boards*

IEC 60368 (all parts), *Piezoelectric filtgers of assessed quality*

IEC 60384 (all parts), *Fixed capacitors for use in electronic equipment*

IEC 60393 (all parts), *Potentiometers for use in electronic equipment*

IEC 60535, *Jet fans and regulators*

IEC 60539 (all parts), *Directly heated negative temperature coefficient thermistors*

IEC 60721-3 (all Parts 3), *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities*

IEC 60738 (all parts), *Thermistors - Directly heated positive step-function temperature coefficient*

IEC 60747 (all parts) *Semiconductor devices - Discrete devices*

IEC 60747-12 (all Parts 12) *Semiconductor devices - Part 12: Optoelectronic devices*

IEC 60747-12-2, *Semiconductor devices – Part 12: Optoelectronic devices – Section 2: Blank detail specification for laser diode modules with pigtail for fibre optic systems and sub-systems*

IEC 60748 (all parts) *Semiconductor devices – Integrated circuits*

IEC 60879, *Performance and construction of electric circulating fans and regulators*

IEC 60948, *Numeric keyboard for home electronic systems (HES)*

IEC 61019 (all parts), *Surface acoustic wave (SAW) resonators*

IEC 61051 (all parts), *Varistors for use in electronic equipment*

IEC 61248 (all parts), *Transformers and inductors for use in electronic and telecommunication equipment*

IEC 61747 (all parts), *Liquid crystal and solid-state display devices*

IEC 61261 (all parts), *Piezoelectric ceramic filters for use in electronic equipment – A specification in the IEC quality assessment system for electronic components (IECQ)*

IEC 61951 (all parts), *Secondary cells and batteries containing alkaline or other non-acid electrolytes*

IEC 61951-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells*

IEC 61951-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Nickel-metal hydride*

IEC 62007 (all parts), *Semiconductor optoelectronic devices for fibre optic system applications*

IEC 62255 (all parts), *Multicore and symmetrical pair/quad cables for broadband digital communications (high bit rate digital access telecommunication networks) - Outside plant cables*

ETS 300 019, *Environmental engineering (EE); Environmental conditions and environmental tests for telecommunications equipment*

ISO 9000:2000, *Quality management systems – Fundamentals and vocabulary*

UTE C 96-024:1990, *Modèles thermiques simplifiés des circuits intégrés monolithiques*

3 Terms and definitions

For the purposes of this technical report, the following definitions apply.

3.1
spatial
Mission profiles corresponding to the MIL-HDBK-217F "Space; flight" environment.

NOTE Only one working phase is taken into account during each orbital revolution (LEO), or earth revolution (GEO).

Table 1 – Mission profiles for spatial

Application types	$(t_{ac})_1$ °C	τ_1	τ_{on}	τ_{off}	n_1 cycles/year	ΔT_1 °C/orbit
Low earth orbit (LEO) with On/Off cycling	40	0,15	0,15	0,85	5256	$\frac{\Delta Tjc}{3}+7$
Low earth orbit (LEO) permanent working	40	1	1	0	5256	3
Geostationary earth orbit (GEO) permanent working	40	1	1	0	365	8

3.2
military
Mission profiles corresponding to the MIL-HDBK-217F "Ground; mobile" environment.

NOTE Two working phases are taken into account:

Phase 1: 36 annual switch on

Phase 2: 365 days of dormant mode

Table 2 – Mission profiles for military

Application type	$(t_{ac})_1$ °C	τ_1	τ_{on}	τ_{off}	n_1 cycles/year	ΔT_1 °C/cycle	n_2 cycles/year	ΔT_2 °C/cycle
Portable Radio	26	0,01	0,01	0,99	36	$\frac{\Delta Tj}{3}+15$	365	8

4 Conditions of use

4.1 Introductory remarks

4.1.1 Theory of reliability predictions

Calculation of a reliability prediction for non-redundant equipment is the very first step in any complete reliability study concerning that equipment, and indeed, of any study of the reliability, availability, or safety of a system.

Reliability predictions are based on numerous assumptions, all of which need to be verified (choice of component family, for example).

A reliability study of an item entails not only verifying these assumptions, but also optimizing its reliability (qualification of components and mounting processes, minimizing risk of external failure, etc).

A reliability prediction is essential, but no more so than research into the best possible reliability for least cost.

This handbook provides all the information needed to calculate electronic component and equipped printed circuit board failure rates: failures rates delivered include the influence of component mouting processes.

4.1.2 Structure of the handbook

The handbook is specifically designed as an aid to research into how to maximize equipment reliability, and to assist in the design of the equipment, by introducing various influencing factors (see also 4.3). In order to meet this objective, it is important that any reliability prediction should begin with the start of design (and then be finalised in accordance with 4.5.4). Similarly, the choice of values for the influencing factors should not be automatic.

4.1.3 Data source

The reliability data contained in the handbook is taken mainly from field data concerning electronic equipment operating in four kinds of environment:

a) «Ground; stationary; weather protected» (in other words: equipment for stationary_use on the ground in weather protected locations, operating permanently or otherwise).

This applies mainly to telecommunications equipment and computer hardware.

b) «Ground; stationary; non weather protected» (in other words: equipment for stationary_use on the ground in non-weather protected locations).

This relates mainly to public payphones and GSM relays.

c) «Airborne, Inhabited, Cargo» (in other words: equipment used in a plane, benign conditions).

This relates to on board calculators civilian planes.

d) «Ground; non stationary; moderate» (in other words: equipment for non-stationary use on the ground in moderate conditions of use).

This concerns mainly on board automotive calculators and military mobile radio.

By processing the raw data (statistical processes, results based on geographic distribution, according to equipment type, etc.), it has been possible to include various influencing factors and eliminate the main aberrant values. Other influencing factors are derived from the experience of experts (failure analyses, construction analyses, results of endurance tests).

The values adopted are those considered most probable at the present time (1992-2001).

This databook does not give any part count values, because mission profiles are needed in order to have credible values.

4.2 Assumptions adopted for TR 62380

4.2.1 Nature of data

4.2.1.1 Reliability data

The reliability data in this handbook comprises failure rates and, for some (very few) component families, life expectancy.

Failure rates are assumed to be constant either for an unlimited period of operation (general case) or for limited periods: in these particular cases the laws governing failure rates versus time have not been adopted in the interests of simplicity.

Apart from a few exceptions (see section 4.2.1.3), the wear-out period is never reached by electronic components; in the same way it is accepted, again apart from some exceptions (see section 4.2.1.2), that the added risks of failure during the first few months of operation can be disregarded.

4.2.1.2 The infant mortality period

In practice, except for a few component families, the increased risk of failure during the first months of operation can be disregarded, because of the diversity of reasons for variations or uncertainty in the failure rate. This superficially simplistic hypothesis is in fact very realistic. It is confirmed by field data concerning the operation of equipment designed very carefully, with well chosen components (based on compatibility with use) and produced by a well controlled production system, as is generally the case for the components covered by this handbook.

4.2.1.3 Wear-out period

For the vast majority of components, the -wear-out period (during which failures take on a systematic character) is far removed from the periods of use (which range from 3 to 20 years).

There are, however, two cases in which the occurrence of wear-out failures should be taken into account (the failure rate of which increases with time):

a) For some families, if due care is not taken, the wear-out mechanisms may give rise to systematic failures after too short a period of time; metallization electromigration in active components, for example.

   This risk needs to be eliminated by a good product design, and it is important to ensure this by qualification testing. In other words, it should not be taken into account for a prediction, and should be eliminated by qualification testing and by technical evaluation, which are, therefore, of critical importance.

b) For some (few) component families, the wear-out period is relatively short. For these families, this handbook explains how to express the period for which the failure rate can be considered constant. This life expectancy is subject to influencing factors.

   Such families include relays, aluminium capacitors (with non-solid electrolyte), laser diodes, optocouplers, power transistors in cyclic operation, connectors and switches and keyboards.

   For these component families, it is important to ensure that the life expectancy given by the handbook is consistent with the intended use. If not, room for manoeuvring is fairly restricted: you can reduce the stresses, change the component family (or sub-family: for aluminium capacitors with non-solid electrolyte, there are several types characterized by different qualification tests).

Provision can also be made for preventive maintenance.

NOTE: As before, and in the interests of simplicity, this handbook does not give the wear-out failure mathematical model (for which the failure rate increases over time), but a period during which the rate can be considered constant (in some cases the period at 10% of the cumulative failure rate).

4.2.2 Nature of failures

4.2.2.1 Intrinsic failures

The data in this handbook covers intrinsic failures (apart from the few exceptions given in 4.2.2.2).

In practice (see section 4.1.3), the raw reliability data has been processed to eliminate non-intrinsic component failures.

4.2.2.2 Special case of non-intrinsic residual failures due to electrical overloads

There is, necessarily, a small proportion of non-intrinsic failures in the data, because it is impossible to detect all the non-intrinsic failures when they are residual.

Take, for example, the reliability of the components used in equipment located “at the heart” of a system, which is significantly better than that of the components located at the periphery (in other words connected to the external environment). It is understood that this is due to residual overloads, since the equipment is assumed adequately protected.

For the purpose of this handbook, we have therefore included an utilisation factor to take into account nonintrinsic residual failures due to the electrical environment for active components.