MIL-HDBK-217E
27 OCTOBER 1986
SUPERSEDING
MIL-HDBK-217D
15 JANUARY 1982

MILITARY HANDBOOK

RELIABILITY PREDICTION
OF
ELECTRONIC EQUIPMENT

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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DEPARTMENT OF DEFENSE
WASHINGTON DC 20301

RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

1. This standardization handbook was developed by the Department of Defense with the assistance of the military departments, federal agencies, and industry.

2. Every effort has been made to reflect the latest information on reliability prediction procedures. It is the intent to review this handbook periodically to ensure its completeness and currency.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Rome Air Development Center, AFSC, ATTN: RBE-2, Griffiss Air Force Base, New York 13441-5700, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

This revision, based upon recently completed studies, provides the following changes:

1. An environmental factor (π_E, GMS) in all failure rate models for equipment installed in missile silos.

2. New failure rate models for:

   a. Surface Acoustic Wave (SAW) Devices.
   b. Semiconductor Lasers.
   c. Helium/Cadmium Lasers.
   d. Solid State Relays.
   e. Time Delay Relays.
   f. Thumbwheel Switches.
   g. Integrated Circuit Sockets.
   h. Meters.
   i. Filters.
   j. Vidicons.
   k. Very Large Scale Integrated Circuits (VLSI).
   l. Analog Microprocessors.

3. Revised failure rate models for:

   a. Magnetrons.
   b. Circuit Breakers.
   c. Incandescent Lamps.
   d. Fuses.
   e. Crystals.
   f. Cathode Ray Tubes (CRTs).

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FIGURES

1. SCOPE

1.1 Purpose. This handbook establishes uniform methods for predicting the reliability of military electronic equipment and systems. It provides a common basis for reliability predictions during acquisition programs for military electronic systems and equipment. It also establishes a common basis for comparing and evaluating reliability predictions of related or competitive designs.

1.2 Application. This handbook contains two methods of reliability prediction -"Part Stress Analysis" in Section 5.1 and "Parts Count" in Section 5.2. These methods vary in degree of information needed to apply them. The Part Stress Analysis Method requires the greater amount of detail information and is applicable during the later design phase when actual hardware and circuits are being designed. The Parts Count Method requires less information, generally that concerning quantities of different part types, quality level of parts, and the application environment. This method is applicable in the early design phase and during proposal formulation.

1.3 Computerized Reliability Prediction. RADC-ORACLE is a computer program developed to aid in applying the part stress analysis procedure of MIL-HDBK-217. Based on equipment environmental characteristics, piece part count, electronic stresses, submodule repair rates and system configuration, the program calculates piece part failure rates, equipment failure rates, mean-time-to-failure, availability and repair rates. ORACLE is available at cost to all DoD elements for their use or for use on a specific contract as government furnished property (GFP). Information may be obtained from RADC/RBET, Griffiss AFB NY 13441-5700.

2. REFERENCED DOCUMENTS

The documents cited in this section are for guidance and information.

2.1 Government documents. This handbook cites some specifications which have been cancelled or which describe devices that are not to be used for new design. This information is necessary because some of these devices are used in so-called "off-the-shelf" equipment which the Department of Defense purchases.

SPECIFICATIONS

FEDERAL

W-C-375	Circuit Breaker, Molded Case, Branch Circuit and Service
W-F-1726	Fuse, Cartridge, Class H (This covers renewable and nonrenewable)
W-F-1814	Fuse, Cartridge, High Interrupting Capacity
W-L-111	Lamp, Incandescent Miniature, Tungsten Filament

MILITARY

MIL-C-5	Capacitors, Fixed, Mica-Dielectric, General Specification for
MIL-R-11	Resistor, Fixed, Composition (Insulated) General Specification for
MIL-R-19	Resistor, Variable, Wirewound (Low Operating Temperature) General Specification for
MIL-C-20	Capacitor, Fixed, Ceramic Dielectric (Temperature Compensating) Established and Nonestablished Reliability, General Specification for
MIL-C-25	Capacitor, Fixed, Paper-Dielectric, Direct Current (Hermetically Sealed in Metal Cases), General Specification for
MIL-R-26	Resistor, Fixed, Wirewound (Power Type), General Specification for
MIL-T-27	Transformer and Inductor (Audio, Power, and High Power, and High Power Pulse) General Specification for
MIL-C-62	Capacitor, Fixed Electrolytic (DC, Aluminum, Dry Electrolyte, Polarized) General Specification for

MIL-C-81	Capacitor, Variable, Ceramic Dielectric (Trimmer), General Specification for
MIL-C-92	Capacitor, Variable, Air Dielectric (Trimmer), General Specification for
MIL-R-93	Resistor, Fixed, Wirewound (Accurate), General Specification for
MIL-R-94	Resistor, Variable, Composition, General Specification for
MIL-V-95	Vibrator, Interrupter and Self-Rectifying
MIL-C-3098	Crystal Unit, Quartz, General Specification for
MIL-C-3607	Connector, Coaxial, Radio Frequency, Series Pulse, General Specifications for
MIL-C-3643	Connector, Coaxial, Radio Frequency, Series NH, Associated Fittings, General Specification for
MIL-C-3650	Connector, Coaxial, Radio Frequency, Series LC
MIL-C-3655	Connector, Plug and Receptacle, Electrical (Coaxial Series Twin) and Associated Fittings, General Specification for
MIL-C-3767	Connector, Plug and Receptacle (Power, Bladed Type) General Specification for
MIL-S-3786	Switch, Rotary (Circuit Selector, Low-Current (Capacity), General Specification for
MIL-S-3950	Switch, Toggle, Environmentally Sealed, General Specification for
MIL-C-3965	Capacitor, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, General Specification for
MIL-C-5015	Connector, Electrical, Circular Threaded, AN Type, General Specification for
MIL-F-5372	Fuse, Current Limiter Type, Aircraft
MIL-R-5757	Relay, Electrical (For Electronic and Communication Type Equipment), General Specification for

MIL-R-6106	Relay, Electromagnetic (Including Established Reliability (ER) Types), General Specification for
MIL-L-6363	Lamp, Incandescent, Aviation Service, General Requirement for
MIL-S-8805	Switches and Switch Assemblies, Sensitive and Push, (Snap Action) General Specification for
MIL-M-10304	Meter, Electrical Indicating, Panel Type, Ruggedized, General Specification for
MIL-R-10509	Resistor, Fixed Film (High Stability), General Specification for
MIL-C-10950	Capacitor, Fixed, Mica Dielectric, Button Style, General Specification for
MIL-C-11015	Capacitor, Fixed, Ceramic Dielectric (General Purpose), General Specification for
MIL-C-11272	Capacitor, Fixed, Glass Dielectric, General Specification for
MIL-C-11693	Capacitor, Feed Through, Radio Interference Reduction AC and DC, (Hermetically Sealed in Metal Cases) Established and Nonestablished Reliability, General Specification for
MIL-R-11804	Resistor, Fixed, Film (Power Type), General Specification for
MIL-C-12889	Capacitor, By-Pass, Radio - Interference Reduction, Paper Dielectric, AC and DC, (Hermetically Sealed in Metallic Cases), General Specification for
MIL-R-12934	Resistor, Variable, Wirewound, Precision, General Specification for
MIL-C-14157	Capacitor, Fixed, Paper (Paper Plastic) or Plastic Dielectric, Direct Current (Hermetically Sealed in Metal Cases) Established Reliability, General Specification for
MIL-C-14409	Capacitor, Variable (Piston Type, Tubular Trimmer), General Specification for
MIL-F-15160	Fuse, Instrument, Power and Telephone
MIL-C-15305	Coil, Fixed and Variable, Radio Frequency, General Specification for

MIL-F-15733	Filter, Radio Inteference, General Specification for
MIL-C-18312	Capacitor, Fixed, Metallized (Paper, Paper Plastic or Plastic Film) Dielectric, Direct Current (Hermetically Sealed in Metal Cases), General Specification for
MIL-F-18327	Filter, High Pass, Low Pass, Band Pass, Band Suppression and Dual Functioning, General Specification for
MIL-R-18546	Resistor, Fixed, Wirewound (Power Type, Chassis Mounted), General Specification for
MIL-S-19500	Semiconductor Device, General Specification for
MIL-R-19523	Relay, Control, Naval Shipboard
MIL-R-19648	Relay, Time Delay, Thermal, General Specification for
MIL-C-19978	Capacitor, Fixed Plastic (or Paper-Plastic) Dielectric (Hermetically Sealed in Metal, Ceramic or Glass Cases), Established and Nonestablished Reliability, General Specification for
MIL-T-21038	Transformer, Pulse, Low Power, General Specification for
MIL-C-21097	Connector, Electrical, Printed Wiring Board, General Purpose, General Specification for
MIL-R-22097	Resistor, Variable, Nonwirewound (Adjustment Types), General Specification for
MIL-R-22684	Resistor, Fixed, Film, Insulated, General Specification for
MIL-S-22710	Switch, Rotary (Printed Circuit), (Thumbwheel, Inline and Pushbutton), General Specification for
MIL-C-23183	Capacitor, Fixed or Variable, Vacuum Dielectric, General Specification for
MIL-C-23269	Capacitors, Fixed, Glass Dielectric, Establilshed Reliability, General Specification for
MIL-R-23285	Resistor, Variable, Nonwirewound, General Specification for
MIL-F-23419	Fuse, Instrument Type, General Specification for
MIL-T-23648	Thermistor, (Thermally Sensitive Resistor), Insulated, General Specification for

MIL-C-24308	Connector, Electric, Rectangular, Miniature Polarized Shell, Rack and Panel, General Specification for
MIL-C-25516	Connector, Electrical, Miniature, Coaxial, Environment Resistant Type, General Specification for
MIL-C-26482	Connector, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting) Receptacles and Plugs, General Specification for
MIL-C-28748	Connector, Electrical, Rectangular, Rack and Panel, Solder Type and Crimp Type Contacts, General Specification for
MIL-R-28750	Relay, Solid State, General Specification for
MIL-M-38510	Microcircuits, General Specification for
MIL-C-38999	Connector, Electrical, Circular, Miniature, High Density, Quick Disconnect, (Bayonet, Threaded, and Breech Coupling) Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for
MIL-C-39001	Capacitor, Fixed, Mica Dielectric, Established Reliability, General Specification for
MIL-R-39002	Resistor, Variable, Wire-Wound, Semi-Precision, General Specification for
MIL-C-39003	Capacitor, Fixed, Electrolytic, (Solid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-R-39005	Resistor, Fixed, Wirewound, (Accurate) Established Reliability, General Specification for
MIL-C-39006	Capacitor, Fixed, Electrolytic (Nonsolid Electrolyte) Tantalum Established Reliability, General Specification for
MIL-R-39007	Resistor, Fixed, Wirewound (Power Type) Established Reliability, General Specification for
MIL-R-39008	Resistor, Fixed, Composition, (Insulated) Established Reliability, General Specification for
MIL-R-39009	Resistor, Fixed, Wirewound (Power Type Chassis Mounted) Established Reliability, general Specification for
MIL-C-39010	Coil, Fixed, radio Frequency, Molded, established Reliability, General Specification for

MIL-C-39012	Connector, Coaxial, Radio Frequency, General Specification for
MIL-C-39014	Capacitor, Fixed, Ceramic Dielectric (General Purpose) Established Reliability, General Specification for
MIL-R-39015	Resistor, Variable, Wirewound (Lead Screw Actuated) Established Reliability, General Specification for
MIL-R-39016	Relay, Electromagnetic, Established Reliability, General Specification for
MIL-R-39017	Resistor, Fixed, Film (Insulated), Established Reliability, general Specification for
MIL-C-39018	Capacitor, Fixed, Electrolytic (Aluminum Oxide) Established Reliability and Nonestablished Reliability, General Specification for
MIL-C-39019	Circuit Breakers, Magnetic, Low Power, Sealed, Trip-Free, General Specification for
MIL-C-39022	Capacitor, Fixed, Metallized Paper, Paper-Plastic Film, or Plastic Film Dielectric, Direct and Alternating Current (Hermetically Sealed in Metal Cases) Established Reliability, General Specification for
MIL-R-39023	Resistor, Variable, Nonwire Wound, Precision, General Specification for
MIL-R-39035	Resistor, Variable, Nonwire Wound (Adjustment Type) Estblished Reliability, General Specification for
MIL-P-55110	Printed Wiring Boards
MIL-R-55182	Resistor, Fixed, Film, Estblished Reliability, General Specification for
MIL-C-55302	Connector, Printed Circuit, Subassembly and Accessories
MIL-C-55514	Capacitor, Fixed, Plastic (or Metallized Plastic) Dielectric, Direct Current, In Non-Metal Cases, General Specification for
MIL-C-55629	Circuit Breaker, Magnetic, Unsealed, Trip-Free, General Specification for
MIL-T-55631	Transformer, Intermediate Frequency, Radio Frequency, and Discriminator, General Specification for

MIL-C-81511	Connector, Electrical, Circular, High Density, Quick Disconnect, Environment Resisting, and Accessories, General Specification for
MIL-C-83383	Circuit Breaker, Remote Control, Thermal, Trip-Free, General Specification for
MIL-R-83401	Resistor Networks, Fixed, Film, General Specification for
MIL-C-83421	Capacitor, Fixed Supermetallized Plastic Film Dielectric (DC, AC or DC and AC) Hermetically Sealed in Metal Cases, Established Reliability, General Specification for
MIL-C-83723	Connector, Electrical (Circular Environment Resisting), Receptacles and Plugs, General Specification for
MIL-R-83725	Relay, Vacuum, General Specification for
MIL-R-83726	Relay, Time Delay, Electric and Electronic, General Specification for
MIL-C-83733	Connector, Electrical, Miniature, Rectangular Type, Rack to Panel, Environment Resisting, 200 Degrees C Total Continuous Operating Temperature, General Specification for
MIL-S-83734	Socket, Plug-in Electronic Components, General Specification for

STANDARDS

MILITARY

MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-975	NASA Standard Electrical, Electronic and Electromechanical Parts List
MIL-STD-1547	Parts, Materials and Processes for Space Launch Vehicles, Technical Requirements for

(Copies of specifications and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Nongovernment documents.

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 91-84	Graphic Symbols for Logic Functions, Institute of Electrical and Electronics Engineers

(Application for copies should be addressed to: Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.)

3. DEFINITIONS

3.1 Acronyms. The following are definitions of acronyms used in this document:

AIM - avalanche induced migration

ALSTTL - advanced low power Schottky transistor transistor logic

ASTTL - advanced Schottky transistor transistor logic

CCD - charge coupled device

CML - current mode logic

CMOS - complementary metal oxide semiconductor

CMOS/SOS - CMOS fabricated on silicon on sapphire

DIP - dual in-line package

DTL - diode transistor logic

EAPROM - electrically alterable, programmable read only memory

ECL - emitter coupled logic

EEPROM - electrically erasable, programmable read only memory

EPROM - erasable, programmable read only memory

FET - field effect transistor

FTTL - fast transistor transistor logic

HCMOS - high speed CMOS

HMOS - high speed MOS

HTCMOS - high speed TTL compatible CMOS

HTTL - high speed transistor transistor logic

IIL - integrated injection logic

ISL - integrated Schottky logic

I^3L - isoplanar integrated injection logic

IMPATT - impact avalanche and transit time

LED - light emitting diode

LSTTL - low power Schottky transistor transistor logic

LTTL - low power transistor transistor logic

MNOS - metal nitride oxide semiconductor

MOS - metal oxide semiconductor

NMOS - N channel metal oxide semiconductor

PIN - P intrinsic N

PMOS - P channel metal oxide semiconductor

PROM - programmable read only memory

RAM - random access memory

ROM - read only memory

SAW - surface acoustic wave

STTL - Schottky transistor transistor logic

TTL - transistor transistor logic

TWT - traveling wave tube

UV - ultra-violet

4. GENERAL REQUIREMENTS

4.1 The Reliability Problem

When it is proposed to design an electronic system to perform a complex and demanding job, it is assumed that the required investment will be justified according to the perfection by which the job is performed or by the large number of times which the system can do the job. This assumption cannot be justified when a system fails to perform upon demand or fails to perform repeatedly. Thus, it is not enough simply to show that a chasm can be spanned by a bridge; the bridge must continue to span the chasm for a long time to come while carrying useful loads.

In the design of complex electronic systems, such an assumption as mentioned above, is, in fact, not accepted. Instead, considerable effort is made to obtain reliable system performance. Unlike bridge building and other evolving technologies, it is recognized that the electronics art, especially complex military systems, is often in revolution. It is sometimes referred to as an exploding technology. Without time for orderly evolution of systems, applications of electronics suffer most from unreliability. The ratio of new to tried and true portions of electronic systems is relatively high; therefore, until the new becomes tried and true, its reliability must be suspect. As an inevitable but not suprising result, it can be concluded that reliability remains a special problem in electronics and will remain so, as long as the technology is in revolution rather than evolution.

Reliability is a consideration at all levels of electronics, from materials to operating systems, because materials go to make up parts, parts compose assemblies, and assemblies are combined in systems of ever increasing complexity and sophistication. Therefore, at any level of development and design, it is natural to find the influence of reliability engineering acting as a discipline founded to devote special engineering attention to the unreliability problem. Reliability engineering is concerned with the time degradation of materials, physical and electronic measurements, equipment design, processes and system analysis, and synthesis. None of these can be isolated from the overall electronics context, but must be carried on in conjunction with many other disciplines.

4.2 The Role of Reliability Prediction in Engineering

To be of value, a prediction must be timely. However, the earlier it is needed the more difficulties will be encountered. It is certainly true that the earlier a prediction has to be made about the unknown nature of a future event, the more difficult it is to make a meaningful prediction. As an example, it can be seen that the reliability of an electronic equipment is known with certainty after it has been used in the field until it is worn out and its failure history has been faithfully recorded. But for purposes of doing anything about the reliability of this equipment, this knowledge has no value. Before this point, reliability cannot be known with certainty; but a great deal of knowledge about reliability can be accumulated over a short early period in the equipments' useful life. Even though the degree of certainty of knowledge is less, there is some opportunity to do something to influence the reliability of the remaining life portion.

Similarly, considering the various stages back through installation, shipment, test, production, test design, development, procurement, etc., less and less can be known with certainty about reliability. However, what is known or predicted becomes more and more valuable as a basis for taking action. After all, there is no value in simply knowing that a certain failure will occur at some specific time in the future. The value comes in having the opportunity to do something to prevent the failure from occurring. Once this is done the future is changed from what was predicted with certainty. Thus, prediction becomes part of a process of "designing the future".

An early prediction is made on the basis of very little knowledge in order to form a rational basis for doing something about changing the basis of the prediction. The process, in order to have any meaning at all, requires predicting, acting, measuring (or gaining new knowledge), then repredicting, acting again and remeasuring continually throughout a program of development.

The two trends in the prediction art are (1) to gain better records of class characteristics in more usable and realistic forms and (2) to develop improved techniques for applying the consequent knowledge to predictions in appropriate confidence settings. The current state-of-the-art in reliability predictions rests at the level of development of these data and techniques. Much room remains for advancing the state-of-the-art.

4.3 Limitations of Reliability Predictions

The art of predicting the reliability of electronic equipment has practical limitations such as those depending on data gathering and technique complexity. Considerable effort is required to generate sufficient data on a part class to report a statistically valid reliability figure for that class. Casual data gathering on a part class occasionally accumulates data more slowly than the advance of technology in that class; consequently, a valid level of data is never attained. In the case of many part classes, the number of people participating in data gathering all over the industry is rather large with consequent varying methods and conditions which prevent exact coordination and correlation. Also part reliability in the field use of equipment is difficult to examine due to the lack of suitable data being acquired. Thus, it can be seen that derivation of failure rates (being mean values) is empirically difficult and obtaining valid confidence values is practically precluded because of lack of correlation.

The use of failure rate data, obtained from field use of past systems, is applicable on future concepts depending on the degree of similarity existing both in the hardware design and in the anticipated environments. Data obtained on a system used in one environment may not be applicable to use in a different environment, especially if the new environment substantially exceeds the design capabilities. Other variants that can affect the stated failure rate of a given system are: different uses, different operators, different maintenance practices, different measurement techniques or definitions of failure. When considering the comparison between similar but unlike systems, the possible variations are obviously even greater.

Thus, a fundamental limitation on reliability prediction is the ability to accumulate data of known validity for the new application. Another fundamental limitation is the complexity of prediction techniques. Very simple techniques omit a great deal of distinguishing detail and the prediction suffers inaccuracy. More detailed techniques can become so bogged down in detail that the prediction becomes costly and may actually lag the principal hardware development effort.

This revision of the Handbook includes two methods of reliability prediction - "Part Stress Analysis" in Section 5.1 and "Parts Count" in Section 5.2. These methods vary in degree of information needed to apply them. The Part Stress Analysis requires the greatest amount of detail and is applicable during the later design phase where actual hardware and circuits are being designed. The Parts Count Method requires less information, generally that dealing with quantity of different part types, quality level of the parts, and the application environment. This method is applicable in the early design phase and during bid proposal formulation. Both methods will be revised periodically and new prediction methods will be added as they are developed. Neither method applies to a nuclear survivability environment nor do they consider the effects of ionizing radiation.

The content of this Handbook has been approved by the Military Services and has been coordinated with appropriate segments of Industry. It provides a common basis for reliability predictions during acquisition programs for military electronic systems and equipments. It also establishes a common basis for comparing and evaluating reliability predictions of related or competitive designs. The failure rates and their associated adjustment factors presented herein are based upon evaluation and analysis of the best available data at the time of issue.

5. DETAILED REQUIREMENTS

5.1 Part Stress Analysis Prediction.

5.1.1 General Factors.

5.1.1.1 Applicability. This method is applicable when most of the design is completed and a detailed parts list including part stresses is available. It can also be used during later design phases for reliability trade-offs vs. part selection and stresses. This section contains failure rate models for a broad variety of parts used in electronic equipment. The parts are grouped by major categories and, where appropriate, are subgrouped within categories. The major categories are listed in Table 5.1.1-1. For mechanical and electromechanical parts not covered by this Handbook, refer to Bibliography item 47.

TABLE 5.1.1-1: MAJOR PART CATEGORIES FOR PART STRESS ANALYSIS

PART CATEGORY	SECTION
Microelectronics	5.1.2
Discrete Semiconductors	5.1.3
Tubes	5.1.4
Lasers	5.1.5
Resistors	5.1.6
Capacitors	5.1.7
Inductive	5.1.8
Rotary	5.1.9
Relays	5.1.10
Switches	5.1.11
Connectors	5.1.12
Wire & Printed Wire Boards	5.1.13
Connections	5.1.14
Meters	5.1.15
Quartz Crystals	5.1.16
Incandescent Lamps	5.1.17
Electronic Filters	5.1.18
Fuses	5.1.19
Miscellaneous	5.1.20

5.1.1.2 Part Quality. The quality of a part has a direct effect on the part failure rate and appears in the part models as a factor, π_Q. Many parts are covered by specifications that have several quality levels, hence, the part models have values of π_Q that are keyed to these quality levels. Such parts with their quality designators are shown in Table 5.1.1-2. The detailed requirements for these levels are clearly defined in the applicable specification, except that definitions of microelectronic quality levels S-1, B-1, B-2, D, and D-1 are contained in Table 5.1.2.7-1.

TABLE 5.1.1-2: PARTS WITH MULTI-LEVEL QUALITY SPECIFICATIONS

PART	QUALITY DESIGNATORS
Microelectronics	S, S-1, B, B-1, B-2 D, D-1
Discrete Semiconductors	JANTXV, JANTX, JAN
Capacitors, Established Reliability (ER)	D, C, S, R, B, P, M, L
Resistors, Established Reliability (ER)	S, R, P, M
Coils, Molded, R.F., Reliabiity (ER)	S, R, P, M
Relays, Established Reliability (ER)	R, P, M, L

Some parts are covered by older specifications, usually referred to as Non-ER, that do not have multi-levels of quality. These part models generally have two quality levels designated as "MIL. SPEC.", and "Lower". If the part is procured in complete accordance with the applicable specification, the π_Q value for MIL. SPEC, should be used. If any requirements are waived, or if a commercial part is procured, the π_Q value for Lower should be used.

The foregoing discussion involves the "as procured" part quality. Poor equipment design, production, and testing facilities can degrade part quality. The use of the higher quality parts requires a total equipment design and quality control process commensurate with the high part quality. It would make little sense to procure high quality parts only to have the equipment production procedures damage the parts or introduce latent defects. Total equipment program descriptions as they might vary with different part quality mixes is beyond the scope of this Handbook. Reliability management and quality control procedures are described in other DoD standards and publications. Nevertheless, when a proposed equipment development is pushing the state-of-the-art and has a high reliability requirement necessitating high quality parts, the total equipment program should be given careful scrutiny and not just the parts quality. Otherwise, the low failure rates as predicted by the models for high quality parts will not be valid.

5.1.1.3 Use Environment. All part reliability models include the effects of environmental stresses through the environmental factor, π_E, except for the effects of ionizing radiation. The descriptions of these environments are shown in Table 5.1.1-3. The π_E factor is quantified within each part failure rate model. These environments encompass the major areas of equipment use. Some equipment will experience more than one environment during its normal use, e.g., equipment in spacecraft. In such a case, the reliability analysis should be segmented, namely, missile launch (M_L) conditions during boost into and return from orbit, and space flight (S_F) while in orbit.

TABLE 5.1.1-3 ENVIRONMENTAL SYMBOL AND DESCRIPTION

ENVIRONMENT	π_E SYMBOL	DESCRIPTION
Ground, Benign	G_B	Nonmobile, laboratory environment readily accessible to maintenance; includes laboratory instruments and test equipment, medical electronic equipment, business and scientific computer complexes.
Ground, Missile Silo	G_{MS}	Missiles and support equipment in ground silos.
Ground, Fixed	G_F	Conditions less than ideal such as installation in permanent racks with adequate cooling air and possible installation in unheated buildings; includes permanent installation of air traffic control, radar and communications facilities.
Ground, Mobile	G_M	Equipment installed on wheeled or tracked vehicles; includes tactical missile ground support equipment, mobile communication equipment, tactical fire direction systems.
Space, Flight	S_F	Earth orbital. Approaches benign ground conditions. Vehicle neither under powered flight nor in atmospheric reentry; includes satellites and shuttles.
Manpack	M_P	Portable electronic equipment being manually transported while in operation; includes portable field communications equipment and laser designations and rangefinders.

TABLE 5.1.1-3 ENVIRONMENTAL SYMBOL AND DESCRIPTION (Cont)

ENVIRONMENT	π_E SYMBOL	DESCRIPTION
Naval, Sheltered	N_S	Sheltered or below deck conditions, protected from weather; includes surface ships communication, computer, and sonar equipment.
Naval Unsheltered	N_U	Nonprotected surface shipborne equipment exposed to weather conditions; includes most mounted equipment and missile/projectile fire control equipment.
Naval Undersea Unsheltered	N_{UU}	Equipment immersed in salt water; includes sonar sensors and special purpose anti-submarine warfare equipment.
Naval, Submarine	N_{SB}	Equipment installed in submarines; includes navigation and launch control systems.
Naval, Hydrofoil	N_H	Equipment installed in a hydrofoil vessel.
Airborne, Inhabited, Cargo	A_{IC}	Typical conditions in cargo compartments occupied by aircrew without environment extremes of pressure, temperature, shock and vibration and installed on long mission transport aircraft.
Airborne, Inhabited, Trainer	A_{IT}	Same as A_{IC} but installed on high performance aircraft such as trainer aircraft.
Airborne, Inhabited, Bomber	A_{IB}	Typical conditions in bomber compartments occupied by aircrew without environment extremes of pressure, temperature, shock and vibration and installed on long mission bomber aircraft.
Airborne, Inhabited, Attack	A_{IA}	Same as A_{IC} but installed on high performance aircraft such as used for ground support.

TABLE 5.1.1-3 ENVIRONMENTAL SYMBOL AND DESCRIPTION (Cont)

ENVIRONMENT	π_E SYMBOL	DESCRIPTION
Airborne, Inhabited, Fighter	A_{IF}	Same as A_{IC} but installed on high performance aircraft such as fighters and intercepters.
Airborne, Uninhabited, Cargo	A_{UC}	Bomb bay, equipment bay, tail, or where extreme pressure, vibration, and temperature cycling may be aggravated by contamination from oil, hydraulic fluid and engine exhaust. Installed on long mission transport aircraft.
Airborne, Uninhabited, Trainer	A_{UT}	Same as A_{UC} but installed on high performance aircraft such as used for trainer aircraft.
Airborne, Uninhabited, Bomber	A_{UB}	Bomb bay, equipment bay, tail or where extreme pressure, vibration and temperature cycling may be aggravated by contamination from oil, hydraulic fluid and engine exhaust. Installed on long mission bomber aircraft.
Airborne, Uninhabited, Attack	A_{UA}	Same as A_{UC} but installed on high performance aircraft such as used for ground support.
Airborne, Uninhabited, Fighter	A_{UF}	Same as A_{UC} but installed on high performance aircraft such as fighters and intercepters.
Airborne, Rotary Winged	A_{RW}	Equipment installed on helicopters; includes laser designators and fire control systems.
Missile, Launch	M_L	Severe conditions related to missile launch (air and ground), and space vehicle boost into orbit, vehicle re-entry and landing by parachute. Conditions may also apply to rocket propulsion powered flight.

TABLE 5.1.1-3 ENVIRONMENTAL SYMBOL AND DESCRIPTION (Cont)

ENVIRONMENT	Π_E SYMBOL	DESCRIPTION
Cannon, Launch	C_L	Extremely severe conditions related to cannon launching of 155 mm. and 5 inch guided projectiles. Conditions apply from launch to target impact.
Undersea, Launch	U_{SL}	Conditions related to undersea torpedo mission and missile launch.
Missile, Free Flight	M_{FF}	Missiles in non-powered free flight.
Airbreathing Missile, Flight	M_{FA}	Conditions related to powered flight of air breathing missile; includes cruise missiles.

5.1.1.4 Part Failure Rate Models. Part failure rate models for microelectronic parts are significantly different from those for other parts and are presented entirely in Section 5.1.2. Another type of model is used on most other parts; a typical example is the following one for discrete semiconductors:

$$\lambda_p = \lambda_b (\Pi_E \times \Pi_A \times \Pi_{S2} \times \Pi_C \times \Pi_Q)$$

where

λ_p is the part failure rate,

λ_b is the base failure rate usually expressed by a model relating the influence of electrical and temperature stresses on the part.

Π_E and the other Π factors modify the base failure rate for the category of environmental application and other parameters that affect the part reliability.

The Π_E and Π_Q factors are used in all models and other Π factors apply only to specific models. The applicability of Π factors is identified in each subsection. An overall list of Π factors used in models other than microelectronics is presented in Table 5.1.1-4.

The base failure rate (λ_b) models are presented in each part subsection along with identification of the applicable model factors. Tables of calculated λ_b values are also provided for use in manual calculations. The model equations can, of course, be incorporated into computer programs for machine processing. The tabulated values of λ_b are cut off at the part ratings with regard to temperature and stress, hence, use of parts beyond these cut off points will overstress the part. The use of the λ_b models in a computer program should take the part rating limits into account. The λ_b equations are mathematically continuous beyond the part ratings but such failure rate values are invalid in the overstressed regions.

All the part models include both catastrophic and drift failures and are based upon a constant failure rate, except for some rotary devices that show an increasing failure rate. Failures associated with connection of parts into circuit assemblies are not included within the part failure rate models. Information on connection reliability is provided in Sections 5.1.13 and 5.1.14.

5.1.1.5 Thermal Aspects. The use of this prediction method requires the determination of the temperatures to which the parts are subjected. Since parts reliability is sensitive to temperature, the thermal analysis of any design should fairly accurately provide the ambient temperatures needed in using the part models. Of course, lower temperatures produce better reliability but also can produce increased penalties in terms of added loads on the environmental control system, unless achieved through improved thermal design of the equipment. The thermal analysis should be part of the design process and included in all the trade-off studies covering equipment performance, reliability, weight, volume, environmental control systems, etc. For general guidance and detailed thermal analysis procedures, refer to Item 48 and 69 of Bibliography.

TABLE 5.1.1-4

Π FACTORS FOR PART FAILURE RATE MODELS EXCEPT MICROELECTRONICS

Π FACTOR	DESCRIPTION
Common Factors - Used in all or many part categories	
Π_E	Environment - Accounts for influence of undefined environmental variables including temperature variability. Related to application categories (Table 5.1.1-3).
Π_Q	Quality - Accounts for effects of different quality levels.
Discrete Semiconductors	
Π_A	Application - Accounts for effect of application in terms of circuit function.
Π_R	Rating - Accounts for effect of maximum power or current rating.
Π_C	Complexity - Accounts for effect of multiple devices in a single package.
Π_{S2}	Voltage Stress - Adjusts model for a second electrical stress (application voltage) in addition to wattage included within λ_b.
Π_F	Frequency and peak operating power factor, also pulsed duty cycle factor.
Π_I	Forward peak current factor.
Π_T	Temperature - Accounts for effects of temperature.
Π_M	Matching networks - Accounts for effects of type of matching networks.
Lasers	
Π_O	Gas overfill factor.
Π_B	Ballast factor.
Π_{OS}	Active optical surface factor.

TABLE 5.1.1-4 (Cont.)
π FACTORS FOR PART FAILURE RATE MODELS EXCEPT MICROELECTRONICS

Lasers	
π_C	Cleanliness factor.
π_{REP}	Factor to convert pulse rate to time for pulsed lasers.
π_{COOL}	Flashlamp cooling factor.
Tubes	
π_C	Construction factor.
π_L	Learning factor.
π_u	Utilization factor.
Resistors	
π_R	Resistance - Adjusts model for the effect of resistor ohmic values.
π_C	Construction Class - Accounts for influence of construction class of variable resistors as defined in individual part specifications.
π_V	Voltage - Adjusts for effect of applied voltage in variable resistors in addition to wattage included within λ_b.
π_{TAPS}	Tap Connections on Potentiometers - Accounts for effect of multiple taps on resistance element.
Capacitors	
π_{SR}	Series Resistance - Adjusts model for the effect of series resistance in circuit application of some electrolytic capacitors.
π_{CV}	Capacitance Values - Adjusts model for effect of capacitance related to case size.
π_C	Construction Factor - Accounts for effects of hermetic and non-hermetic seals on CL & CLR capacitors.
π_{CF}	Configuration factor - Accounts for effects of fixed and variable constructions on CG capacitors.

TABLE 5.1.1-4 (Cont.)
π FACTORS FOR PART FAILURE RATE MODELS EXCEPT MICROELECTRONICS

Inductive Devices	
π_Q	Family - Adjusts model for influence of family type as defined by individual part specifications.
π_C	Construction factor - Accounts for effects of fixed and variable constructions.
Rotating devices	
π_S	Factor related to size of synchros & resolvers.
π_N	Factor related to number of brushes on synchros & resolvers.
π_T	Temperature factor for elapsed-time meters.
Relays	
π_C	Contacts - Accounts for contact quantity and form.
π_{CYC}	Cycling - Accounts for time rate of actuation.
π_L	Load - Accounts for type of contact load.
π_F	Family - Accounts for construction and application.
Switches	
π_C	Contacts - Accounts for contact quantity and form.
π_{CYC}	Cycling - Accounts for time rate of actuation.
π_L	Load - Accounts for type of contact load.
Connectors	
π_P	Contacts - Accounts for quantity of contacts.
π_K	Cycling - Accounts for time rate of mating and unmating.

TABLE 5.1.1-4 (Cont.)
Π FACTORS FOR PART FAILURE RATE MODELS EXCEPT MICROELECTRONICS

Meters	
Π_A	Application factor.
Π_F	Function factor.
Incandescent Lamps	
Π_u	Utilization factor.
Π_A	Application factor.

CAUTION

THE FAILURE RATES PRESENTED APPLY TO EQUIPMENT UNDER NORMAL OPERATING CONDITIONS, i.e., WITH POWER ON AND PERFORMING ITS INTENDED FUNCTIONS IN ITS INTENDED ENVIRONMENT. EXTRAPOLATION OF ANY OF THE BASE FAILURE RATE MODELS BEYOND THE TABULATED VALUES SUCH AS HIGH OR SUB-ZERO TEMPERATURE, OR ELECTRICAL STRESS VALUES ABOVE 1.0 OR AT 0 OR EXTRAPOLATION OF ANY ASSOCIATED MODIFIERS IS COMPLETELY INVALID.

5.1.2 Microelectronic Devices. This section presents failure rate prediction models for nine major classes of microelectronic devices:

This revision of MIL-HDBK-217 has eliminated the use of terminology such as SSI, MSI, LSI and VLSI as descriptions of complexity for the models in this section. The C1 and C2 factors used in previous revisions represented the contribution to failure due to complexity, C1 for the chip contribution and C2 as part of the package contribution. A new C1 has been introduced, this reflects the contribution to the chip failure rate due to factors such as complexity, technology, and in some cases due to the programming of Programmable Read Only Memory (PROM). The old C3 package complexity failure rate has been retitled C2.

In the title description of each monolithic device type, Bipolar represents all TTL, ASTTL, DTL, ECL, CML, ALSTTL, HTTL, FTTL, LTTL, STTL, LSTTL, IIL, I^3L and ISL devices. MOS represents all metal-oxide semiconductor microcircuits which includes MNOS, PMOS, CMOS, and NMOS fabricated on various substrates such as sapphire, polycrystalline, or single crystal silicon. From the I.C. chip standpoint, the hybrid model is structured to accommodate all of the monolithic chip types and various complexity levels.

Monolithic memory complexity factors are expressed in the number of bits in accordance with JEDEC STD 21A. This standard, which is used by all government and industry agencies that deal with microcircuit memories, states that memories of 1024 bits and greater shall be expressed as K bits, where 1K = 1024 bits. For example, a 16K memory has 16,384 bits, a 64K memory has 65,536 bits and a 1M memory has 1,048,576 bits. Exact numbers of bits are not used for memories of 1024 bits and greater.

MICROELECTRONIC DEVICES

MONOLITHIC

The monolithic device models, along with parameter descriptions and instructions for quantifying the parameters are presented in Sections 5.1.2.1 through 5.1.2.6. The tables used for quantifying the model parameters are presented in Section 5.1.2.7.

For devices having both linear and digital functions not covered by MIL-M-38510, use the linear model. Line drivers and line receivers are considered linear devices, but if any device exceeds 1,000 transistors, use the model in Section 5.1.2.6.

Models for magnetic bubble memories and a model for Surface Acoustic Wave (SAW) devices are listed after the hybrid section.

Table 5.1.2.7-17 contains cross reference commercial type parts to MIL-M-38510 type parts.

Table 5.1.2.7-18 contains the gate, transistor and bit counts for MIL-M-38510 devices. For linear devices not covered by MIL-M-38510, use the transistor count as determined from the schematic diagram.

For microprocessors, do not use the complexity tables. Microprocessors are classified by the number of bits in the data word. This notation is used in data sheets and application notes. For example, the 8080 is an 8 bit microprocessor, the 8086 is a 16 bit microprocessor, etc.

For digital devices not convered by MIL-M-38510, use the gate count as determined from the logic diagram. A J-K to R-S flip flop is equivalent to 6 gates when used as part of an LSI circuit. For the purpose of this Handbook, a gate is considered to be any one of the following functions: AND, OR, exclusive OR, NAND, NOR and inverter. When a logic diagram is unavailable, use device transistor count to determine gate count using the following expressions:

Bipolar: No. Gates = No. Transistors ÷ 3.0

CMOS: No. Gates = No. Transistors ÷ 3.75

Other MOS: No. Gates = No. Transistors ÷ 3.0

5.1.2.1 Monolithic Bipolar and MOS Digital Devices, Including Shift Registers, Configurable Gate Arrays*, Programmable Logic Arrays (PLA) and Programmable Array Logic (PAL).

Part operating failure rate model (λ_p):

$$\lambda_p = \pi_Q (C_1 \pi_T \pi_V + C_2 \pi_E) \pi_L \text{ Failures}/10^6 \text{ hours}$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4) and is found in Tables 5.1.2.7-5 thru 5.1.2.7-13.

π_V is the voltage stress derating factor, Table 5.1.2.7-14.

π_E is the application environment factor, Table 5.1.2.7-3.

C_1 is the circuit complexity factor based on gate count and technology as follows:

Monolithic Bipolar And MOS Digital Devices Including Shift Registers and Configurable Gate Arrays*

For 1 to 100 gates, $C_1 = .01$

For >100 to 1,000 gates, $C_1 = .02$

For >1,000 to 3,000 gates, $C_1 = .04$

For >3,000 to 10,000 gates, $C_1 = .08$

For >10,000 to 30,000 gates, $C_1 = .16$

Programmable Logic Arrays (PLA) and Programmable Array Logic (PAL)

For 1 to 100 gates, $C_1 = 0.06$

For >100 to 1,000 gates, $C_1 = 0.12$

For >1,000 to 5,000 gates, $C_1 = 0.24$

C_2 is the package complexity failure rate, Table 5.1.2.7-16.

π_L is the device learning factor, Table 5.1.2.7-2.

*For Configurable Gate Arrays, π_L = 10. If test data verifying the circuit design/performance of a discrete cell or gate is provided to the procuring activity, then π_L = 1 can be used. This data should consist of ac/dc parametric data. (See JAN microcircuit specification M38510/600 or M38510/605 for typical data requirements.)

5.1.2.2 Monolithic Bipolar and MOS Linear Devices.

Part operating failure rate model (λ_p):

$$\lambda_p = \pi_Q (C_1\pi_T\pi_V + C_2\pi_E)\ \pi_L \text{ Failures}/10^6 \text{ hours}$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4) and is found in Tables 5.1.2.7-10 or 5.1.2.7-13.

π_V is the voltage stress derating factor, Table 5.1.2.7-14

π_E is the application environment factor, Table 5.1.2.7-3

C_1 is the circuit complexity factor based on transistor count as follows:

For 1 to 100 transistors, $C_1 = 0.01$

For >100 to 300 transistors, $C_1 = 0.02$

For >300 to 1000 transistors, $C_1 = 0.04$

C_2 is the package complexity failure rate, Table 5.1.2.7-16.

π_L is the device learning factor, Table 5.1.2.7-2.

5.1.2.3 Monolithic Bipolar and MOS Digital Microprocessor Devices.

Part operating failure rate model (λ_p):

$$\lambda_p = \pi_Q\,(C_1\pi_T\pi_V + C_2\pi_E)\,\pi_L \text{ Failures}/10^6 \text{ hours:}$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4) and is found in Tables 5.1.2.7-5 thru 5.1.2.7-13.

π_V is the voltage stress derating factor, Table 5.1.2.7-14

π_E is the application environment factor, Table 5.1.2.7-3

C_1 is the circuit complexity failure rate based on bit count.

NOTE: Do not use Table 5.1.2.1-19 to determine microprocessor gate count. Microprocessors are classified by the number of bits in their data word, see page 5.1.2-2.

For microprocessors up to 8 bits, $C_1 \approx 0.03$

For 16 bit microprocessors, $C_1 = 0.06$

For 32 bit microprocessors, $C_1 = 0.12$

C_2 is the package complexity failure rate, Table 5.1.2.7-16

π_L is the device learning factor, Table 5.1.2.7-2

5.1.2.4 Monolithic Bipolar and MOS Random Access Memories (RAMs).

Part operating failure rate mode (λ_p):

$$\lambda_p = \pi_Q (C_1\pi_T\pi_V + C_2\pi_E) \pi_L \text{ Failures}/10^6 \text{ hours}$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4) and is found in Tables 5.1.2.7-5 thru 5.1.2.7-13

π_V is the voltage stress derating factor, Table 5.1.2.7-14

π_E is the application environment factor, Table 5.1.2.7-3

C_1 is the circuit complexity factor based on bit count and technology.

MOS

For Dynamic RAMs up to 16K bits, $C_1 = 0.025$

For Dynamic RAMs >16K to 64K bits, $C_1 = 0.05$

For Dynamic RAMs >64K to 256K bits, $C_1 = 0.10$

For Dynamic RAMs >256K to 1M bits, $C_1 = 0.20$

For Static RAMS up to 4K bits, $C_1 = .05$

For Static RAMs >4K to 16K bits, $C_1 = .10$

For Static RAMs >16K to 64K bits, $C_1 = .20$

For Static RAMs >64K to 256K bits, $C_1 = .40$

(cont'd on next page)

BIPOLAR

For Static RAMS up to 4K bits, $C_1 = .05$

For Static RAMS >4K to 16K bits, $C_1 = .10$

C_2 is the package complexity failure rate, Table 5.1.2.7-16

π_L is the device learning factor, Table 5.1.2.7-2

5.1.2.5 Read Only Memories (ROMs) and Programmable Read Only Memories (PROMs). Includes PROMs with Fusible Link Programming, Avalanche Induced Migration (AIM), Ultra-Violet Erasable (UVEPROMs), Electrically Erasable (EEPROMs) and Electrically Alterable (EAPROMs)

$$\lambda_p = \pi_Q (C_1\pi_T\pi_V + C_2\pi_E)\,\pi_L$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4), and is found in Tables 5.1.2.7-5 thru 5.1.2.7-13

π_V is the voltage stress derating factor, Table 5.1.2.7-14

π_E is the application environment factor, Table 5.1.2.7-3

C_1 is the device complexity failure rate based upon bit count and technology.

MOS ROM

For devices up to 16K bits, $C_1 = 0.035$

For devices with >16K to 64K bits, $C_1 = 0.07$

For devices with >64K to 256K bits, $C_1 = 0.14$

For devices with >256K to 1M bits, $C_1 = 0.28$

MOS PROM (UVEPROM, EEPROM, EAPROM)

For devices up to 16K bits, $C_1 = 0.06$

For devices with >16K to 64K bits, $C_1 = 0.12$

For devices with >64K to 256K bits, $C_1 = 0.24$

For devices with >256K to 1M bits, $C_1 = 0.48$

BIPOLAR ROM/PROM (Fusible Link & AIM)

For devices up to 16K bits, $C_1 = 0.06$

For devices with >16K to 64K bits, $C_1 = 0.12$

C_2 is the package complexity failure rate, Table 5.1.2.7-16

π_L is the device learning factor, Table 5.1.2.7-2

5.1.2.6 Monolithic Bipolar or MOS Analog Microprocessor Devices*.

Part operating failure rate model (λ_p):

$$\lambda_p = \pi_Q \pi_A (C_1 \pi_T \pi_V + C_2 \pi_E) \pi_L \text{ Failures}/10^6 \text{ hours}$$

where:

λ_p is the device failure rate in F/10^6 hours

π_Q is the quality factor, Table 5.1.2.7-1

π_A is the analog signal factor, = 1.24

π_T is the temperature acceleration factor, based on technology (Table 5.1.2.7-4) and is found in Tables 5.1.2.7-5 thru 5.1.2.7-13

π_V is the voltage stress derating factor, Table 5.1.2.7-14

π_E is the application environment factor, Table 5.1.2.7-3

C_1 is the circuit complexity failure rate based on bit count

For signal processors up to 16 bits, C_1 = 0.06

C_2 is the package complexity failure rate, Table 5.1.2.7-16

π_L is the device learning factor, Table 5.1.2.7-2

* Analog microprocessor is defined as any microprocessor with on-chip circuitry capable of accepting or outputting an analog signal, also called signal processor.

5.1.2.7 Tables for the Monolithic Model Parameters.

TABLE 5.1.2.7-1. π_Q, Quality Factors

QUALITY LEVEL	DESCRIPTION	π_Q
S	Procured in full accordance with MIL-M-38510, Class S requirements. Class S listing on QPL-38510.	0.25
S-1	Procured in full compliance with the requirements of MIL-STD-975 or MIL-STD-1547 and have procuring activity specification approval.	0.75
B	Procured in full accordance with MIL-M-38510, Class B requirements. Class B listing on QPL-38510.	1.0
B-1	Fully compliant with all requirements of Paragraph 1.2.1 of MIL-STD-883 and procured to a MIL Drawing, DESC Drawing or other government approved documentation.	2.0
B-2	Not fully compliant with requirements of Paragraph 1.2.1 of MIL-STD-883 and procured to government approved documentation including vendor's equivalent Class B requirements.	5.0
D	Hermetically sealed parts with normal reliability screening and manufacturer's quality assurance practices. *Nonhermetic parts encapsulated with organic material must be subjected to 160 hours burn-in at 125°C, 10 temperature cycles (-55°C to 125°C) with end point electricals and high temperature continuity test at 100°C.	10.0
D-1	Commercial (or non-mil standard) part, *encapsulated or sealed with organic materials (e.g., epoxy, silicone or phenolic).	20.0

* NONHERMETIC PARTS SHOULD ONLY BE USED IN CONTROLLED ENVIRONMENTS (e.g., GROUND BENIGN OR GROUND FIXED ENVIRONMENTS).

TABLE 5.1.2.7-2. π_L, LEARNING FACTORS

The learning factor π_L is 10 under any of the following conditions:

(1) New device in initial production.
(2) Where major changes in design or process have occurred.
(3) Where there has been an extended interruption in production or a change in line personnel (radical expansion).
(4) For all new and unproven technologies.

The factor of 10 can be expected to apply until conditions and controls have stabilized. This period extends for four months of continuous production.

π_L is equal to 1.0 under all production conditions not stated in (1), (2) and (3) above.

TABLE 5.1.2.7-3. APPLICATION ENVIRONMENT FACTOR π_E

ENVIRON-MENT	π_E
G_B	0.38
G_{MS}	0.65
G_F	2.5
G_M	4.2
M_P	3.8
N_{SB}	4.0
N_S	4.0
N_U	5.7
N_H	5.9
N_{UU}	6.3
A_{RW}	8.5
A_{IC}	2.5
A_{IT}	3.0

ENVIRON-MENT	π_E
A_{IB}	5.0
A_{IA}	4.0
A_{IF}	6.0
A_{UC}	3.0
A_{UT}	4.0
A_{UB}	7.5
A_{UA}	6.0
A_{UF}	9.0
S_F	0.9
M_{FF}	3.9
M_{FA}	5.4
U_{SL}	11.
M_L	13.
C_L	220.

TABLE 5.1.2.7-4 TECHNOLOGY TEMPERATURE FACTOR TABLES (SEE NOTES BELOW)

Technology	Package Type	π_T Table Number	A
ASTTL, CML, TTL, HTTL, FTTL, DTL, ECL, ALSTTL	Hermetic Nonhermetic	5.1.2.7-5 5.1.2.7-6	4635. 5214.
LTTL & STTL	Hermetic Nonhermetic	5.1.2.7-6 5.1.2.7-7	5214. 5794.
LSTTL	Hermetic Nonhermetic	5.1.2.7-7 5.1.2.7-8	5794. 6373.
IIL, I^3L, ISL & MNOS	Hermetic Nonhermetic	5.1.2.7-9 5.1.2.7-12	6952. 9270.
PMOS, NMOS & HMOS	Hermetic Nonhermetic	5.1.2.7-7 5.1.2.7-11	5794. 8111.
CMOS, HCMOS, & HTCMOS CMOS/SOS	Hermetic Nonhermetic	5.1.2.7-8 5.1.2.7-12	6373. 9270.
Linear (Bipolar & MOS)	Hermetic Nonhermetic	5.1.2.7-10 5.1.2.7-13	7532. 10429.

NOTE 1. $\pi_T = 0.1(e^x)$

where

$$x = -A \left(\frac{1}{T_J + 273} - \frac{1}{298}\right)$$

A = value from above Table

T_J = device worst case junction temperature ($^{\circ}$C).

e = natural logarithm base, 2.718

(Notes continued for Table 5.1.2.7-4)

NOTE 2. T_J, the worst case junction temperature, shall be measured or estimated using the following expression:

$$T_J = T_C + \theta_{JC}P$$

where:

T_C is case temperature (^oC.).

θ_{JC} is junction to case thermal resistance (^oC/watt) for a device soldered into a printed circuit board. If θ_{JC} is not available, use a value contained in a specification for the closest equivalent device or use the table on page 5.1.2.7-5.

P is the worst case power realized in a system application. If the applied power is not available, use the maximum power dissipation from the device specification or from the specification for the closest equivalent device.

If T_C cannot be determined, use the following:

ENVIRO.	G_B	G_{MS}	G_F	G_M	M_P	N_{SB}	N_S	N_U	N_H	N_{UU}	A_{RW}	A_{IC}	A_{IT}	A_{IB}
$T_C(^oC.)$	35	36	45	50	40	45	45	80	45	25	60	60	60	60
ENVIRO.	A_{IA}	A_{IF}	A_{UC}	A_{UT}	A_{UB}	A_{UA}	A_{UF}	S_F	M_{FF}	M_{FA}	U_{SL}	M_L	C_L	
$T_C(^oC)$	60	60	95	95	95	95	95	45	60	50	40	60	45	

(Notes continued for Table 5.1.2.7-4)

θ_{JC} values for MIL-M-38510 devices. (From MIL-M-38510F, Appendix C.)

PACKAGE TYPE LETTER	MAX θ_{J-C} (^{o}C/W)	DESCRIPTION
A	70	14-lead FP (1/4" x 1/4")
B	70	14-lead FP (3/16" x 1/4")
C	50	14-lead DIP (1/4" x 3/4")
D	70	14-lead FP (1/4" x 3/8")
E	50	16-lead DIP (1/4" x 7/8")
F	68	16-lead FP (1/4" x 3/8")
G	60	8-lead can
H	70	10-lead FP (1/4" x 1/4")
I	60	10-lead can
J	40	24-lead DIP (1/2" x "1-1/4")
K	53	24-lead FP (3/8" x 5/8")
L	40	24-lead DIP (1/4" x 1-1/4")
M	60	12-lead can
P	50	8-lead DIP (1/4" x 3/8")
Q	30	40-lead DIP (9/16" x 2-1/16")
R	40	20-lead DIP (1/4" x 1-1/16")
S	60	20-lead FP (1/4" x 1/2")
V	40	18-lead DIP (1/4" x 15/16")
W	40	22-lead DIP (3/8" x 1-1/8")
	55	24-lead FP (1/4" x 3/8")

For other devices, or if θ_{JC} cannot be determined, use the following:

Package Type	Die Attach*	Number of Package Pins	
		$\leq$ 22 pins	> 22 pins
Hermetic DIPs	Eutectic	30	25
	Epoxy or Glass	125	100
Nonhermetic DIPs	Eutectic	30	25
	Epoxy or Glass	125	100
Hermetic Flatpacks	Eutectic	40	35
	Epoxy or Glass	125	100
Hermetic Cans	Eutectic	30	NA
	Epoxy or Glass	125	NA

* If the die attach method cannot be determined, assume that epoxy die attach is used for hermetically packaged CMOS and eutectic die attach for all other hermetic packages.

TABLE 5.1.2.7-5: π_T VS JUNCTION TEMPERATURE FOR HERMETIC ASTTL, CML, TTL, HTTL, FTTL, DTL, ECL & ALSTTL

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.35	77	1.0	103	2.5
27	0.11	53	0.38	79	1.1	105	2.7
29	0.12	55	0.41	81	1.2	110	3.2
31	0.14	57	0.45	83	1.3	115	3.7
33	0.15	59	0.49	85	1.4	120	4.3
35	0.17	61	0.53	87	1.5	125	5.0
37	0.18	63	0.58	89	1.6	135	6.6
39	0.20	65	0.63	91	1.7	145	8.7
41	0.22	67	0.68	93	1.8	150	9.9
43	0.24	69	0.74	95	1.9	155	11.
45	0.27	71	0.80	97	2.1	165	14.
47	0.29	73	0.87	99	2.2	175	18.
49	0.32	75	0.93	101	2.4		

TABLE 5.1.2.7-6: π_T VS JUNCTION TEMPERATURES FOR HERMETIC LTTL & STTL: NONHERMETIC ASTTL, CML, TTL, HTTL, FTTL, DTL, ECL & ALSTTL

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.41	77	1.4	103	3.8
27	0.11	53	0.45	79	1.5	105	4.1
29	0.13	55	0.50	81	1.6	110	4.9
31	0.14	57	0.55	83	1.7	115	5.8
33	0.16	59	0.60	85	1.9	120	6.9
35	0.18	61	0.66	87	2.0	125	8.1
37	0.20	63	0.72	89	2.2	135	11.
39	0.22	65	0.79	91	2.4	145	15.
41	0.24	67	0.87	93	2.6	150	18.
43	0.27	69	0.95	95	2.8	155	20.
45	0.30	71	1.0	97	3.0	165	27.
47	0.33	73	1.1	99	3.3	175	35.
49	0.37	75	1.2	101	3.5		

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TABLE 5.1.2.7-7: π_T VS JUNCTION TEMPERATURE FOR HERMETIC LSTTL, PMOS, NMOS & HMOS: NONHERMETIC LTTL & STTL

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.48	77	1.8	103	5.7
27	0.11	53	0.53	79	2.0	105	6.1
29	0.13	55	0.59	81	2.2	110	7.5
31	0.15	57	0.66	83	2.4	115	9.1
33	0.17	59	0.73	85	2.6	120	11.
35	0.19	61	0.81	87	2.9	125	13.
37	0.21	63	0.90	89	3.1	135	19.
39	0.24	65	1.00	91	3.4	145	27.
41	0.27	67	1.10	93	3.7	150	31.
43	0.30	69	1.20	95	4.0	155	37.
45	0.34	71	1.40	97	4.4	165	50.
47	0.38	73	1.5	99	4.8	175	67.
49	0.43	75	1.6	101	5.2		

TABLE 5.1.2.7-8: π_T VS JUNCTION TEMPERATURE FOR HERMETIC CMOS, HCMOS, HTCMOS & CMOS/SOS: NONHERMETIC LSTTL

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.56	77	2.4	103	8.5
27	0.12	53	0.63	79	2.7	105	9.2
29	0.13	55	0.71	81	3.0	110	12.
31	0.15	57	0.80	83	3.3	115	14.
33	0.17	59	0.89	85	3.6	120	18.
35	0.20	61	1.0	87	4.0	125	22.
37	0.23	63	1.1	89	4.4	135	32.
39	0.26	65	1.3	91	4.8	145	46.
41	0.30	67	1.4	93	5.3	150	56.
43	0.34	69	1.6	95	5.8	155	66.
45	0.38	71	1.8	97	6.4	165	93.
47	0.44	73	1.9	99	7.0	175	129.
49	0.49	75	2.2	101	7.7		

TABLE 5.1.2.7-9: π_T VS JUNCTION TEMPERATURE FOR HERMETIC IIL, I^{3}L, ISL & MNOS

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.65	77	3.2	103	13.
27	0.12	53	0.74	79	3.6	105	14.
29	0.14	55	0.84	81	4.0	110	18.
31	0.16	57	0.96	83	4.5	115	22.
33	0.18	59	1.1	85	5.0	120	28.
35	0.21	61	1.2	87	5.6	125	35.
37	0.25	63	1.4	89	6.2	135	54.
39	0.28	65	1.6	91	6.9	145	81.
41	0.33	67	1.8	93	7.6	150	99.
43	0.38	69	2.0	95	8.5	155	120.
45	0.43	71	2.3	97	9.4	165	173.
47	0.50	73	2.5	99	10.	175	247.
49	0.57	75	2.9	101	11.		

TABLE 5.1.2.7-10: π_T VS JUNCTION TEMPERATURE FOR HERMETIC LINEAR

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.76	77	4.3	103	19.
27	0.12	53	0.88	79	4.8	105	21.
29	0.14	55	1.0	81	5.5	110	27.
31	0.16	57	1.2	83	6.1	115	35.
33	0.19	59	1.3	85	6.9	120	45.
35	0.23	61	1.5	87	7.8	125	57.
37	0.27	63	1.7	89	8.7	135	91.
39	0.31	65	2.0	91	9.8	145	142.
41	0.36	67	2.3	93	11.	150	175.
43	0.42	69	2.6	95	12.	155	216.
45	0.49	71	2.9	97	14.	165	323.
47	0.57	73	3.3	99	15.	175	474.
49	0.66	75	3.8	101	17.		

TABLE 5.1.2.7-11: π_T VS JUNCTION TEMPERATURE FOR NONHERMETIC PMOS, NMOS & HMOS

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	0.89	77	5.7	103	28.
27	0.12	53	1.0	79	6.5	105	32.
29	0.14	55	1.2	81	7.4	110	42.
31	0.17	57	1.4	83	8.4	115	55.
33	0.20	59	1.6	85	9.6	120	72.
35	0.24	61	1.9	87	11.	125	93.
37	0.29	63	2.2	89	12.	135	154.
39	0.34	65	2.5	91	14.	145	248.
41	0.40	67	2.9	93	16.	150	311.
43	0.47	69	3.3	95	18.	155	390.
45	0.55	71	3.8	97	20.	165	600.
47	0.65	73	4.4	99	22.	175	907.
49	0.76	75	5.0	101	25.		

TABLE 5.1.2.7-12: π_T VS JUNCTION TEMPERATURE FOR NONHERMETIC IIL, I^3L, ISL, MNOS, CMOS, HCMOS, HTCMOS & CMOS/SOS

T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T	T_J(°C)	π_T
25	0.10	51	1.2	77	10.	103	63.
27	0.12	53	1.5	79	12.	105	72.
29	0.15	55	1.7	81	14.	110	100.
31	0.18	57	2.0	83	16.	115	136.
33	0.23	59	2.4	85	18.	120	184.
35	0.27	61	2.9	87	21.	125	248.
37	0.33	63	3.4	89	24.	135	439.
39	0.40	65	4.0	91	28.	145	756.
41	0.49	67	4.7	93	32.	150	982.
43	0.59	69	5.5	95	37.	155	1269.
45	0.71	71	6.4	97	43.	165	2081.
47	0.85	73	7.5	99	49.	175	3337
49	1.0	75	8.7	101	56.		

TABLE 5.1.2.7-13: π_T VS JUNCTION TEMPERATURE FOR NONHERMETIC LINEAR

T_J (^oC)	π_T	T_J (^oC)	π_T	T_J (^oC)	π_T	T_J (^oC)	π_T
25	0.10	51	1.7	77	18.	103	142.
27	0.13	53	2.0	79	21.	105	165.
29	0.16	55	2.5	81	25.	110	236.
31	0.20	57	3.0	83	30.	115	335.
33	0.25	59	3.6	85	35.	120	472.
35	0.31	61	4.4	87	41.	125	659.
37	0.39	63	5.2	89	49.	135	1252.
39	0.48	65	6.3	91	57.	145	2308.
41	0.59	67	7.5	93	67.	150	3100.
43	0.73	69	9.0	95	78.	155	4135.
45	0.90	71	11.	97	91.	165	7212.
47	1.10	73	13.	99	106.	175	12272.
49	1.40	75	15.	101	123.		

TABLE 5.1.2.7-14: π_V, VOLTAGE STRESS DERATING FACTOR

TECHNOLOGY	π_V
CMOS, $V_{DD} < 12$ volts	1.0
CMOS, 12 volts $\leq V_{DD} \leq$ 20 volts	Equation 1 (below) or Table 5.1.2.7-15
CMOS/SOS and all technologies other than CMOS	1.0

V_{DD} is the maximum supply voltage rating.

Equation 1: For operating supply voltage from 12 to 20 volts

$$\pi_V = 0.110\,(e^X)$$

where: $$X = \frac{0.168 V_s\,(T_J + 273)}{298}$$

V_s is the operating supply voltage in actual application

T_J is the device worst case junction temperature (°C)

e is the natural logarithm base, 2.718

TABLE 5.1.2.7-15: π_V FOR CMOS WITH $12 \leq V_{DD} \leq 20$ VOLTS

V_S	T_J (°C)					
(V.)	25	50	75	100	125	150
12	.83	.98	1.2	1.4	1.6	1.9
13	.98	1.2	1.4	1.7	2.0	2.4
14	1.2	1.4	1.7	2.1	2.5	3.1
15	1.4	1.7	2.1	2.6	3.2	3.9
16	1.6	2.0	2.5	3.2	4.0	5.0
17	1.9	2.4	3.1	3.9	5.0	6.3
18	2.3	2.9	3.8	4.8	6.2	8.0
19	2.7	3.5	4.6	5.9	7.8	10.2
20	3.2	4.2	5.6	7.4	9.8	12.9

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TABLE 5.1.2.7-16: C_2, PACKAGE COMPLEXITY FAILURE RATES IN FAILURES PER 10^6 HOURS

Number of Functional Pins	PACKAGE TYPE*				
	Hermetic DIPs with Solder or Weld Seal, Leadless Chip Carriers (LCC)	Hermetic DIPs with Glass Seal	Nonhermetic DIPs	Hermetic Flatpacks with Axial Leads on 50 Mil Centers	Hermetic Cans
3	---	---	---	---	0.0003
4	---	---	---	0.0004	0.0005
6	0.0019	0.0013	0.0018	0.0008	0.0011
8	0.0026	0.0021	0.0026	0.0013	0.0020
10	0.0034	0.0029	0.0034	0.0020	0.0031
12	0.0041	0.0038	0.0043	0.0028	0.0044
14	0.0048	0.0048	0.0051	0.0037	0.0060
16	0.0056	0.0059	0.0061	0.0047	0.0079
18	0.0064	0.0071	0.0070	0.0058	---
22	0.008	0.010	0.009	0.008	---
24	0.009	0.011	0.010	0.010	---
28	0.010	0.014	0.012	---	---
36	0.013	0.020	0.016	---	---
40	0.015	0.024	0.019	---	---
64	0.025	0.048	0.033	---	---
80	0.032	---	---	---	---
128	0.053	---	---	---	---
180	0.076	---	---	---	---

*If seal type for hermetic DIP is unknown, assume glass seal.

The tabulated values are determined by the following equations:

Hermetic DIPs with solder or weld seals, Leadless Chip Carrier (LCC) $C_2 = 2.8 \times 10^{-4}(N_p)^{1.08}$

Hermetic DIPs with glass seals $C_2 = 9.0 \times 10^{-5}(N_p)^{1.51}$

Nonhermetic DIPs $C_2 = 2.0 \times 10^{-4}(N_p)^{1.23}$

Hermetic Flatpacks $C_2 = 3.0 \times 10^{-5}(N_p)^{1.82}$

Hermetic Cans $C_2 = 3.0 \times 10^{-5}(N_p)^{2.01}$

where: N_p is the number of pins on a device package which are connected to some substrate location ($3 \leq N_p \leq 180$).

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TABLE 5.1.2.7- 17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
REF10	12403	LM139	11201	PAL16R6A-2	50409
LM101A	10103	LM140H-05	10702	PAL16L8A	50401
LM102	10601	LM140H-12	10703	PAL16R8A	50402
10501	06001	LM140H-15	10704	PAL16L8A-2	50407
10502	06002	LM140H-24	10705	PAL16R8A-2	50408
10504	06201	LM140K-05	10706	1802D	47001
10505	06003	LM140K-12	10707	DG181A	11101
10506	06004	LM140K-15	10708	DG182A	11102
10507	06005	LM140K-24	10709	1832	47201
10509	06006	14013B	05151	DG184A	11103
10524	06301	14023B	05053	DG185A	11104
10525	06302	14093B	17701	1853	47401
10531	06101	PAL14H4	50303	DG187-A	11105
10535	06104	PAL14L4	50308	DG188A	11106
10576	06103	LM141H-05	10702	DG190A	11107
10597	06202	LM141H-12	10703	DG191A	11108
LM106	10303	LM141H-15	10704	LM193	11202
10631	06102	LM141H-24	10705	LF198	12501
LM108A	10104	14502	17403	LM199A	12401
PAL10H8	50301	MC14069	17401	LM199	12404
PAL10L8	50306	LF147	11906	DG200	12301
LM109	10701	LM148	11001	HI200	12301
LM110	10602	LM149	11002	2003	14103
LM111	10304	LM150K	11705	DG201	12302
LM117H	11703	LF151	11904	HI201	12302
LM117K	11704	1524	12601	PAL20R4A	50504
LM118	10107	LM1524	12601	PAL20R6A	50503
LM120H-05	11501	LF153	11905	PAL20L8A	50501
LM120H-12	11502	15482	00601	PAL20R8A	50502
LM120H-15	11503	LF155	11401	LH2101A	10105
LM120H-24	11504	LF155A	11404	LH2108A	10106
LM120K-05	11505	1558	10108	LH2110	10603
LM120K-12	11506	LF156	11402	LH2111	10305
LM120K-15	11507	LF156A	11405	2114	23802
LM120K-24	11508	LF157	11403	2114A	23804
DAC1221LD	12707	LF157A	11406	2117	24001
LM124	11005	PAL16C1	50305	2117	24002
PAL12H6	50302	PAL16H2	50304	2117	24003
PAL12L6	50307	PAL16L2	50309	2147	23801
LM129A	12402	PAL16R4A	50404	2147H	23803
LM129B	12406	PAL16X4	50405	2147H-3	23805
LM137H	11803	PAL16A4	50406	2147H-2	23807
LM137K	11804	PAL16R4A-2	50410	2148H	23806
LM138K	11706	PAL16R6A	50403	2164	24401

TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
2164	24402	DG300	11601	4014B	05752
2164	24403	DG301A	11602	4015A	05703
2316E	40301	3018A	10801	4015B	05753
24401	24401	DG302A	11603	4016A	05801
2500	12204	DG303A	11604	4016B	05851
2510	12205	DG304A	11605	4017A	05601
2516	22101	3045	10802	4017B	05651
25LS174	33106	DG305A	11606	40174B	17505
25LS175	33107	DG306A	11607	4018A	05602
2520	12206	DG307A	11608	4018B	05652
2532	22201	MC3101	15501	4019A	05302
0026	03501	MC3106	15502	4019B	05352
DS0026	03501	MC3111	15503	4020A	05603
MH0026	03501	MK34000	40301	4020B	05653
2600	12202	34069	17401	4021A	05704
2616	40301	3516E	40301	4021B	05754
2620	12203	3636	21002	4022A	05604
OP27A	13503	4000A	05201	4022B	05654
2700	12201	4000B	05251	4023A	05003
2708	22001	4001A	05202	4023B	05053
2716	22101	4001B	05252	4024A	05605
27S180	20903	4002A	05203	4024B	05655
27S181	20904	4002B	05253	4025A	05204
27S191	21002	4006A	05701	4025B	05254
2732	22202	4006B	05751	4027A	05102
NMC2816	22601	4007A	05301	4027B	05152
28S166A	21002	4007UB	05351	4028A	05901
28S166A	21004	4008A	05401	4028B	05951
2901A	44001	4008B	05451	4030A	05303
2901C	44001	4009A	05501	4030B	05353
2905	44101	4009UB	05551	4031A	05705
2906	44102	4010A	05502	4031B	05755
2907	44103	4010B	05552	4034A	05706
2915A	44104	40106B	17702	4034B	05756
2916A	44105	40107B	17402	4041A	05505
2917A	44106	40109B	17404	4041UB	05555
2918	44201	4011A	05001	4043A	05103
29611	20402	4011B	05051	4043B	05153
29621	20805	4012A	05002	4048A	05304
29631	20904	4012B	05052	4048B	05354
29651	20902	4013A	05101	4049A	05503
29651	20908	4013B	05151	4049UB	05553
29681	21002	4014A	05702	4050A	05504

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TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
4050B	05554	4564	24401	53S841	20902
TMS4050	23502	4564	24402	53S841	20908
TMS4050	23504	4564	24403	5400	00104
4060A	05X01	4741	11003	54L00	02004
TMS4060	23501	506	19001	54H00	02304
TMS4060	23503	506A	19002	54S00	07001
4066A	05802	507	19003	54LS00	30001
4066B	05852	507A	19004	54F00	33001
4067B	17801	508A	19005	54ALS00	37001
4069UB	17401	509A	19006	54HC00	65001
4070B	17203	HPROM512	20101	5401	00107
4070B	05353	51C67	29103	54L01	02006
4071B	17101	51C67	29106	54H01	02306
4072B	17102	52116	40301	5402	00401
4073B	17003	MM5280	23505	54L02	02701
4075B	17103	MM5280	23506	54S02	07301
4076B	17501	5300-1	20301	54LS02	30301
4077B	17204	5301-1	20302	54F02	33301
4081B	17001	MCM5303	20101	54ALS02	37301
4082B	17002	MCM5304	20102	5403	00109
4085B	17201	5305-1	20401	54L03	02006
4086B	17202	5306-1	20402	54S03	07002
4093B	17701	53S1680	21001	54LS03	30002
4095B	17502	53S1681	21002	5404	00105
4096B	17503	AD532S	13903	54C04	17401
MKB4096	23602	5330	20701	54L04	02005
MKB4096	23604	5331	20702	54H04	02305
4097B	17802	AD534T	13901	54S04	07003
4098B	17504	AD534S	13902	54LS04	30003
4099B	17601	5340-1	20801	54F04	33002
4116	24001	5341-1	20802	54ALS04	37006
4116	24002	53S440	20601	5405	00108
4116	24003	53S441	20602	54S05	07004
4136	11004	5348-1	20804	54LS05	30004
4156	11003	5349-1	20805	5406	00801
4213	13904	5352-1	20601	5407	00803
4502B	17403	5353-1	20602	5408	01601
4508B	17602	5380-1	20903	54S08	08003
4514B	17301	5380-2	20903	54H08	15501
4515B	17302	5381-1	20904	54H08	15504
4532B	17303	5381-2	20904	54LS08	31004
4555B	17304	53S840	20901	54F08	34001
4556B	17305	53S840	20907	54ALS08	37401

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TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
5409	01602	54116	01503	54F151	33901
54S09	08004	5412	00106	54153	01403
54LS09	31005	54LS12	30006	54S153	07902
5410	00103	54121	01201	54LS153	30902
54L10	02003	54L121	04201	54F153	33902
54H10	02303	54122	01202	54154	15201
54S10	07005	54L122	04202	54155	15202
54LS10	30005	54LS122	31403	54LS155	32601
54F10	33003	54123	01203	54156	15203
54ALS10	37002	54LS123	31401	54LS156	32602
54HC10	65002	54LS124	31701	54157	01405
54ALS1000	38401	54125	15301	54S157	07903
54ALS1002	38402	54LS125	32301	54LS157	30903
54ALS1003	38403	54LS125A	32301	54F157	33903
54ALS1004	38409	54126	15302	54S158	07904
54ALS1005	38410	54LS126	32302	54LS158	30904
54ALS1008	38404	5413	15101	54F158	33904
54H101	02205	54LS13	31301	5416	00802
54ALS1010	38405	54132	15103	54160	01303
54ALS1011	38406	54LS132	31303	54LS160	31503
54ALS1020	38407	54HC132	65005	54LS160A	31503
54H103	02206	54S133	07009	54161	01306
54ALS1032	38408	54ALS133	37005	54LS161	31504
54ALS1034	38411	54S134	07010	54LS161A	31504
54ALS1035	38412	54S135	07502	54162	01305
54107	00203	54S138	07701	54LS162	31511
54LS107	30108	54LS138	30701	54LS162A	31511
54LS109	30109	54ALS138	37701	54163	01304
54F109	34102	54S139	07702	54LS163	31512
54ALS109	37102	54LS139	30702	54LS163A	31512
54S11	08001	5414	15102	54164	00903
54H11	15502	54LS14	31302	54L164	02802
54LS11	31001	54S140	08101	54LS164	30605
54F11	34002	54145	01005	54165	00904
54ALS11	37402	54147	15601	54LS165	30608
54S112	07102	54148	15602	54LS165A	30608
54LS112	30103	54LS148	36001	54LS166	30609
54F112	34103	54S15	08002	54LS168	31505
54ALS112A	37103	54LS15	31002	54LS169	31506
54S113	07103	54150	01401	54LS169A	31506
54LS113	30104	54151	01406	5417	00804
54S114	07104	54S151	07901	54170	01801
54LS114	30105	54LS151	30901	54LS170	31902

TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/
54LS173	36101
54174	01701
54S174	01705
54LS174	30106
54F174	34107
54ALS174	37201
54175	01702
54S175	07106
54LS175	30107
54F175	34104
54ALS175	37202
54180	01901
54181	01101
54S181	07801
54LS181	30801
54182	01102
54S182	07802
54LS190	31513
54LS191	31509
54192	01308
54LS192	31507
54193	01309
54L193	02503
54LS193	31508
54194	00905
54S194	07601
54LS194	30601
54LS194A	30601
54F194	33601
54195	00906
54S195	07602
54LS195	30602
54LS195A	30602
54LS196	32001
54LS197	32002
5420	00102
54L20	02002
54H20	02302
54S20	07006
54LS20	30007
54F20	33004
54ALS20	37003
54HC20	65003
54H21	15503
54LS21	31003
54H22	02307
54S22	07007
54LS22	30008
54LS221	31402
5423	00402
54LS240	32401
54F240	33201
54ALS240	38301
54LS241	32402
54F241	33202
54ALS241	38302
54ALS242	38506
54ALS243	38507
54LS244	32403
54F244	33203
54ALS244	38303
5425	00403
54S251	07905
54LS251	30905
54F251	33905
54S253	07908
54LS253	30908
54F253	33908
54ALS253	3XX01
54S257	07906
54LS257	30906
54LS257B	30906
54F257	33906
54S258	07907
54LS258	30907
54LS258B	30907
54F258	33907
54LS259	31603
54LS259B	31605
5426	00805
54LS26	32102
54LS261	31801
54LS266	30303
5427	00404
54LS27	30302
54ALS27	37302
54LS273	32501
54LS279	31602
5428	16201
54LS28	30204
54ALS28	38402
54LS280	32901
54F280	34901
54LS283	31202
54F283	34201
54S287	20302
54S288	20702
54LS290	32003
54LS293	32004
54LS295B	30606
54LS298	30909
5430	00101
54L30	02001
54H30	02301
54S30	07008
54LS30	30009
54ALS30	37004
54HC30	65004
5432	16101
54LS32	30501
54F32	33501
54ALS32	37501
54LS324	31702
54LS348	36002
54F352	33909
54F353	33910
54365	16301
54LS365	32201
54366	16302
54LS366	32203
54367	16303
54LS367	32202
54368	16304
54LS368	32204
5437	00302
54LS37	30202
54ALS37	38401
54LS373	32502
54LS374	32503

TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
54F374	34105	54S51	07401	54H74	02203
54LS375	31604	54LS51	30401	54S74	07101
54LS377	32504	54F521	34701	54LS74	30102
54F378	34108	5453	00503	54F74	34101
54F379	34109	54H53	04003	54ALS74	37101
5438	00303	54F534	34106	5475	01501
54LS38	30203	5454	00504	54LS75	31601
54LS390	32701	54H54	04004	5476	00204
54LS393	32702	54L54	04102	54H76	02204
54LS395A	30607	54LS54	30402	54LS76	30110
5440	00301	54LS540	32404	54LS76A	30110
54H40	02401	54LS541	32405	5477	01502
54S40	07201	54H55	04005	54L78	02104
54LS40	30201	54L55	04103	5479	00207
54ALS40	38407	54S570	20401	5480	00604
54S412	42101	54S571	20402	5482	00601
5442	01001	54S572	20601	5483	00602
54L42	02901	54S573	20602	54LS83A	31201
54LS42	30703	54ALS574	37104	54S85	08201
54LS424	42201	54ALS576	37105	5485	15001
54S428	42301	54S64	07402	54LS85	31101
5443	01002	54F64	33401	54ALS857	37901
54L43	02902	54LS640	32804	5486	00701
5444	01003	54ALS640	38501	54L86	02601
54L44	02903	54ALS641	38502	54S86	07501
5445	01004	54ALS642	38503	54L86	30502
5446	01006	54ALS643	38504	54F86	34501
54L46	02904	54ALS645	38505	54ALS874	37106
5447	01007	54LS646	32804	54ALS876	37107
54L47	02905	54LS648	32805	5490	01307
54LS47	30704	54S65	07403	54L90	02501
54S472	20805	54LS670	31901	54LS90	31501
54S473	20804	5470	00206	5492	01301
54S474	20802	54L71	02101	54LS92	31510
54S475	20801	5472	00201	54C929	23901
5448	01008	54L72	02102	5493	01302
5449	01009	54H72	02201	54L93	02502
54LS490	32703	5473	00202	54LS93	31502
5450	00501	54L73	02103	54L93A	02502
54H50	04001	54H73	02202	54C930	23902
5451	00502	54LS73	30101	5495	00901
54H51	04002	5474	00205	54L95	02801
54L51	04101	54L74	02105	54LS95	30603

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TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
54LS95B	30603	6208	19008	7611	20302
5496	00902	6216	19003	76160	21001
54LS96	30604	064	11903	76161	21002
55107	10401	6504	24501	76165	21005
55108	10402	6508	23901	7620	20401
55113	10405	6514	24502	7621	20402
55114	10403	6516	29102	76321	21101
55115	10404	65162	29101	7640	20801
SMJ5517	29101	65162	29104	7641	20802
SMJ5517	29105	65162	29105	76L42A	02906
5532A	13102	6518	23902	7642	20601
55325	13001	65262	29103	7643	20602
55326	13002	MCM6604A	23602	7644	20603
55327	13003	MCM6604A	23604	76L70	02805
5534A	13101	MCM6605	23601	7680	20903
SE5537	12502	MCM6605	23603	7681	20904
55450	12901	IM6654	21901	7684	20901
55451	12902	6665	24401	7685	20902
55452	12903	6665	24402	771	11904
55453	12904	6665	24403	77S180	20903
55454	12905	6800	40001	77S181	20904
55460	12906	6810	40201	77S184	20901
55461	12907	S6831B	40301	77S185	20902
55462	12908	68A316E	40301	77S190	21001
55463	12909	68316E	40301	77S191	21002
55464	12910	071	11904	772	11905
555	10901	710	10301	774	11906
556	10902	LM710	10301	78MG	11701
557	10903	711	10302	78G	11702
IM5603A	20201	LM711	10302	78M05	10702
AD561	13301	714	13502	7805	10706
IM5623	20202	7181	01101	NC7810LC	22501
56831B	40301	072	11905	78M12	10703
AD571	13401	LM723	10201	7812	10707
AD584S	12801	MM7280	23505	78M15	10704
AD584T	12802	MM7280	23506	7815	10708
061	11901	074	11906	78M24	10705
6108	19007	LM741A	10101	7824	10709
6116	19001	LM747A	10102	7831	10406
6116	29101	7558	10108	7832	10407
6116	29104	7602	20701	79MG	11801
6116	29105	7603	20702	79G	11802
062	11902	7610	20301	79M05	11501

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TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
7905	11505	82S185	20902	93L01	02907
79M12	11502	82S190	21001	9301	15206
7912	11506	82S191	21002	9304	00603
79M15	11503	82S191B	21004	9308	01503
7915	11507	82S23	20701	93L08	04502
79M24	11504	8224	42201	9309	01404
7924	11508	82S2708	20905	93L09	04601
DAC-08	11301	8228	42301	93L10	02504
DAC-08A	11302	8250	15204	9311	15201
Z-80	48002	8251	15205	9312	01402
Z-80A	48001	8252	15206	93L12	04602
Z80ACPU	48001	8264	24401	9314	01504
Z-80B	48003	8264	24402	93L14	04501
Z80CPU	48002	8264	24403	93L16	02505
Z80BCPU	48003	9093	03304	9317	15802
Z8001	52001	AM9130CFC	23701	93L18	04301
Z8001A	52003	AM9130AFC	23702	9318	15603
Z8002	52002	AM9130CDM	23703	932	03101
Z8002A	52004	AM9130CFM	23703	9321	15801
8080A	42001	AM9130ADM	23704	9322	01405
82S10	23101	AM9130AFM	23704	93L22	04603
82S10	23107	AM91L30CF	23705	93L24	04401
82S11	23102	AM91L30AF	23706	9324	15002
82S11	23108	AM91L30CDM	23707	93L28	02803
82S115	20803	AM91L30CFM	23707	9328	15902
8212	42101	AM91L30ADM	23708	933	03105
82S123	20702	AM91L30 AFM	23708	9334	16001
82S126	20301	AM9140CFC	23709	9338	15701
82S126A	20303	AM9140AFC	23710	9341	01101
82S129	20302	AM9140CDM	23711	93410	23001
82S129A	20304	AM9140CFM	23711	93411	23003
82S130	20401	AM9140ADM	23712	93412	23109
82S130A	20403	AM9140AFM	23712	93L412	23111
82S131	20402	AM91L40CDC	23713	93415	23101
82S131A	20404	AM91L40AFC	23714	93L415	23103
82S136	20601	AM91L40CDM	23715	93415	23105
82S137	20602	AM91L40CFM	23715	93415	23107
82S137A	20604	AM91L40ADM	23716	93417	20301
82S140	20801	AM91L40AFM	23716	93419	23201
82S141	20802	9218	40301	9342	01102
82S180	20903	930	03001	93L420	23004
82S181	20904	93L00	02804	93421	23002
82S184	20901	9300	15901	93422	23110

TABLE 5.1.2.7-17: CROSS REFERENCE FOR COMMERCIAL TYPE TO MIL-38510 TYPE (CONT'D)

COMMERCIAL	M38510/	COMMERCIAL	M38510/	COMMERCIAL	M38510/
93L422	23112	93453	20602	946	03004
93422A	23114	93460	20906	948	03302
93L422A	23115	93461	20905	950	03303
93425	23102	935	03002	951	03201
93L425	23104	93510	21001	9LS51	30401
93425	23106	93Z510	21003	9LS54	30402
93425A	23108	93511	21002	957	03103
93L425A	23113	93Z511	21002	958	03104
93427	20302	93Z511	21004	9601	01204
93436	20401	936	03003	9602	01205
93438	20801	9380	06604	9614	10403
93446	20402	9382	00601	9615	10404
93448	20802	9383	00602	962	03005
93450	20903	940	03002	SBP9900A	46001
93451	20904	944	03102	SBP9989	46501
93452	20601	945	03301		

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
TTL				
00101-A	7.	0.04	1G	14
00101-B	7.	0.04	1G	14
00101-C	7.	0.04	1G	14
00101-D	7.	0.04	1G	14
00102-A	7.	0.08	2G	14
00102-B	7.	0.08	2G	14
00102-C	7.	0.08	2G	14
00102-D	7.	0.08	2G	14
00103-A	7.	0.12	3G	14
00103-B	7.	0.12	3G	14
00103-C	7.	0.12	3G	14
00103-D	7.	0.12	3G	14
00104-A	7.	0.16	4G	14
00104-B	7.	0.16	4G	14
00104-C	7.	0.16	4G	14
00104-D	7.	0.16	4G	14
00105-A	7.	0.24	6G	14
00105-B	7.	0.24	6G	14
00105-C	7.	0.24	6G	14
00105-D	7.	0.24	6G	14
00106-A	7.	0.12	3G	14
00106-B	7.	0.12	3G	14
00106-C	7.	0.12	3G	14
00106-D	7.	0.12	3G	14
00107-A	7.	0.16	4G	14
00107-B	7.	0.16	4G	14
00107-C	7.	0.16	4G	14
00107-D	7.	0.16	4G	14
00108-A	7.	0.24	6G	14
00108-B	7.	0.24	6G	14
00108-C	7.	0.24	6G	14
00108-D	7.	0.24	6G	14
00109-C	7.	0.16	4G	14
00201-A	7.	0.11	8G	13
00201-B	7.	0.11	8G	13
00201-C	7.	0.11	8G	13
00201-D	7.	0.11	8G	13
00202-A	7.	0.22	16G	14
00202-B	7.	0.22	16G	14
00202-C	7.	0.22	16G	14
00202-D	7.	0.22	16G	14
00203-C	7.	0.22	16G	14
00204-E	7.	0.22	16G	16
00204-F	7.	0.22	16G	16
00205-A	7.	0.22	12G	14
00205-B	7.	0.22	12G	14
00205-C	7.	0.22	12G	14
00205-D	7.	0.22	12G	14
00206-A	7.	0.11	11G	14
00206-B	7.	0.11	11G	14
00206-C	7.	0.11	11G	14
00206-D	7.	0.11	11G	14
00207-A	7.	0.22	12G	14
00207-B	7.	0.22	12G	14
00207-C	7.	0.22	12G	14
00207-D	7.	0.22	12G	14
00301-A	7.	0.20	2G	14
00301-B	7.	0.20	2G	14
00301-C	7.	0.20	2G	14
00301-D	7.	0.20	2G	14
00302-A	7.	0.40	4G	14
00302-B	7.	0.40	4G	14
00302-C	7.	0.40	4G	14
00302-D	7.	0.40	4G	14
00303-A	7.	0.40	4G	14
00303-B	7.	0.40	4G	14
00303-C	7.	0.40	4G	14
00303-D	7.	0.40	4G	14
00401-A	7.	0.24	4G	14
00401-B	7.	0.24	4G	14
00401-C	7.	0.24	4G	14
00401-D	7.	0.24	4G	14
00402-E	7.	0.12	2G	16
00402-F	7.	0.12	2G	16
00403-A	7.	0.12	2G	14
00403-B	7.	0.12	2G	14
00403-C	7.	0.12	2G	14
00403-D	7.	0.12	2G	14
00404-A	7.	0.18	3G	14
00404-B	7.	0.18	3G	14
00404-C	7.	0.18	3G	14
00404-D	7.	0.18	3G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
TTL				
00501-A	7.	0.10	6G	14
00501-B	7.	0.10	6G	14
00501-C	7.	0.10	6G	14
00501-D	7.	0.10	6G	14
00502-A	7.	0.10	6G	14
00502-B	7.	0.10	6G	14
00502-C	7.	0.10	6G	14
00502-D	7.	0.10	6G	14
00503-A	7.	0.07	5G	13
00503-B	7.	0.07	5G	13
00503-C	7.	0.07	5G	13
00503-D	7.	0.07	5G	13
00504-A	7.	0.07	4G	14
00504-B	7.	0.07	4G	14
00504-C	7.	0.07	4G	14
00504-D	7.	0.07	5G	14
00601-A	7.	0.28	21G	14
00601-B	7.	0.28	21G	14
00601-C	7.	0.28	21G	14
00601-D	7.	0.28	21G	14
00602-E	7.	0.55	36G	16
00602-F	7.	0.55	36G	16
00603-E	7.	0.30	22G	16
00603-F	7.	0.30	22G	16
00604-A	7.	0.17	14G	14
00604-B	7.	0.17	14G	14
00604-C	7.	0.17	14G	14
00604-D	7.	0.17	14G	14
00701-A	7.	0.26	4G	14
00701-B	7.	0.26	4G	14
00701-C	7.	0.26	4G	14
00701-D	7.	0.26	4G	14
00801-A	7.	0.32	6G	14
00801-B	7.	0.32	6G	14
00801-C	7.	0.32	6G	14
00801-D	7.	0.32	6G	14
00802-A	7.	0.32	6G	14
00802-B	7.	0.32	6G	14
00802-C	7.	0.32	6G	14
00802-D	7.	0.32	6G	14
00803-A	7.	0.32	6G	14
TTL				
00803-B	7.	0.32	6G	14
00803-C	7.	0.32	6G	14
00803-D	7.	0.32	6G	14
00804-A	7.	0.32	6G	14
00804-B	7.	0.32	6G	14
00804-C	7.	0.32	6G	14
00804-D	7.	0.32	6G	14
00805-A	7.	0.22	4G	14
00805-B	7.	0.22	4G	14
00805-C	7.	0.22	4G	14
00805-D	7.	0.22	4G	14
00901-A	7.	0.42	37G	14
00901-B	7.	0.42	37G	14
00901-C	7.	0.42	37G	14
00901-D	7.	0.42	37G	14
00902-E	7.	0.40	39G	16
00902-F	7.	0.40	39G	16
00903-A	7.	0.32	36G	14
00903-B	7.	0.32	36G	14
00903-C	7.	0.32	36G	14
00903-D	7.	0.32	36G	14
00904-E	7.	0.37	62G	16
00904-F	7.	0.37	62G	16
00905-E	7.	0.36	47G	16
00905-F	7.	0.36	47G	16
00906-E	7.	0.37	41G	16
00906-F	7.	0.37	41G	16
01001-E	7.	0.23	18G	16
01001-F	7.	0.23	18G	16
01002-E	7.	0.23	18G	16
01002-F	7.	0.23	18G	16
01003-E	7.	0.23	18G	16
01003-F	7.	0.23	18G	16
01004-E	7.	0.34	18G	16
01004-F	7.	0.34	18G	16
01005-E	7.	0.34	18G	16
01005-F	7.	0.34	18G	16
01006-E	7.	0.47	44G	16
01006-F	7.	0.47	44G	16
01007-E	7.	0.47	44G	16
01007-E	7.	0.47	44G	16

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
TTL				
01008-E	7.	0.47	37G	16
01008-F	7.	0.47	37G	16
01009-A	7.	0.47	34G	14
01009-B	7.	0.47	34G	14
01009-C	7.	0.47	34G	14
01009-D	7.	0.47	34G	14
01101-J	7.	0.80	63G	24
01101-K	7.	0.80	63G	24
01101-L	7.	0.80	63G	24
01101-Z	7.	0.80	63G	24
01102-E	7.	0.80	19G	16
01102-F	7.	0.80	19G	16
01201-A	7.	0.22	8G	14
01201-B	7.	0.22	8G	14
01201-C	7.	0.22	8G	14
01201-D	7.	0.22	8G	14
01202-A	7.	0.17	10G	14
01202-B	7.	0.17	10G	14
01202-C	7.	0.17	10G	14
01202-D	7.	0.17	10G	14
01203-E	7.	0.38	20G	16
01203-F	7.	0.38	20G	16
01204-A	7.	0.14	8G	14
01204-B	7.	0.14	8G	14
01204-C	7.	0.14	8G	14
01204-D	7.	0.14	8G	14
01205-E	7.	0.29	14G	16
01205-F	7.	0.29	14G	16
01301-A	7.	0.27	26G	14
01301-B	7.	0.27	26G	14
01301-C	7.	0.27	26G	14
01301-D	7.	0.27	26G	14
01302-A	7.	0.27	25G	14
01302-B	7.	0.27	25G	14
01302-C	7.	0.27	25G	14
01302-D	7.	0.27	25G	14
01303-E	7.	0.50	60G	16
01303-F	7.	0.50	60G	16
01304-E	7.	0.50	58G	16
01304-F	7.	0.50	58G	16
01305-E	7.	0.50	60G	16
01305-F	7.	0.50	60G	16
01306-E	7.	0.50	57G	16
01306-F	7.	0.50	57G	16
01307-A	7.	0.27	15G	14
01307-C	7.	0.27	15G	14
01307-D	7.	0.27	15G	14
01308-E	7.	0.49	50G	16
01308-F	7.	0.49	50G	16
01309-E	7.	0.49	48G	16
01309-F	7.	0.49	48G	16
01401-J	7.	0.38	26G	24
01401-K	7.	0.38	26G	24
01401-L	7.	0.38	26G	24
01401-Z	7.	0.38	26G	24
01402-E	7.	0.27	17G	16
01402-F	7.	0.27	17G	16
01403-E	7.	0.29	16G	16
01403-F	7.	0.29	16G	16
01404-E	7.	0.25	16G	16
01404-F	7.	0.25	16G	16
01405-E	7.	0.28	19G	16
01405-F	7.	0.28	19G	16
01406-E	7.	0.27	17G	16
01406-F	7.	0.27	17G	16
01501-E	7.	0.28	24G	16
01501-F	7.	0.28	24G	16
01502-A	7.	0.28	24G	14
01502-B	7.	0.28	24G	14
01502-C	7.	0.28	24G	14
01502-D	7.	0.28	24G	14
01503-J	7.	0.63	56G	24
01503-K	7.	0.63	56G	24
01503-L	7.	0.63	56G	24
01503-Z	7.	0.63	56G	24
01504-E	7.	0.33	26G	16
01504-F	7.	0.33	26G	16
01601-A	7.	0.20	4G	14
01601-B	7	0.20	4G	14
01601-C	7.	0.20	4G	14
01601-D	7.	0.20	4G	14
01602-A	7.	0.20	4G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
TTL				
01602-B	7.	0.20	4G	14
01602-C	7.	0.20	4G	14
01602-D	7.	0.20	4G	14
01701-E	7.	0.44	36G	16
01701-F	7.	0.44	36G	16
01702-E	7.	0.26	24G	16
01702-F	7.	0.26	24G	16
01801-E	7.	0.77	100G	16
01801-F	7.	0.77	100G	16
01901-A	7.	0.27	14G	14
01901-B	7.	0.27	14G	14
01901-C	7.	0.27	14G	14
01901-D	7.	0.27	14G	14
LTTL				
02001-A	8.	0.00	1G	14
02001-B	8.	0.00	1G	14
02001-C	8.	0.00	1G	14
02001-D	8.	0.00	1G	14
02002-A	8.	0.01	2G	14
02002-B	8.	0.01	2G	14
02002-C	8.	0.01	2G	14
02002-D	8.	0.01	2G	14
02003-A	8.	0.01	3G	14
02003-B	8.	0.01	3G	14
02003-C	8.	0.01	3G	14
02003-D	8.	0.01	3G	14
02004-A	8.	0.02	4G	14
02004-B	8.	0.02	4G	14
02004-C	8.	0.02	4G	14
02004-D	8.	0.02	4G	14
02005-A	8.	0.02	6G	14
02005-B	8.	0.02	6G	14
02005-C	8.	0.02	6G	14
02005-D	8.	0.02	6G	14
02006-A	8.	0.02	4G	14
02006-B	8.	0.02	4G	14
02006-C	8.	0.02	4G	14
02006-D	8.	0.02	4G	14
02101-A	8.	0.01	8G	14
LTTL				
02101-B	8.	0.01	8G	14
02101-C	8.	0.01	8G	14
02101-D	8.	0.01	8G	14
02102-A	8.	0.01	8G	14
02102-B	8.	0.01	8G	14
02102-C	8.	0.01	8G	14
02102-D	8.	0.01	8G	14
02103-A	8.	0.02	14G	14
02103-B	8.	0.02	14G	14
02103-C	8.	0.02	14G	14
02103-D	8.	0.02	14G	14
02104-A	8.	0.02	16G	14
02104-B	8.	0.02	16G	14
02104-C	8.	0.02	16G	14
02104-D	8.	0.02	16G	14
02105-A	8.	0.02	12G	14
02105-B	8.	0.02	12G	14
02105-C	8.	0.02	12G	14
02105-D	8.	0.02	12G	14
HTTL				
02201-A	7.	0.14	8G	14
02201-B	7.	0.14	8G	14
02201-C	7.	0.14	8G	14
02201-D	7.	0.14	8G	14
02202-A	7.	0.27	16G	14
02202-B	7.	0.27	16G	14
02202-C	7.	0.27	16G	14
02202-D	7.	0.27	16G	14
02203-A	7.	0.27	12G	14
02203-B	7.	0.27	12G	14
02203-C	7.	0.27	12G	14
02203-D	7.	0.27	12G	14
02204-E	7.	0.27	16G	16
02204-F	7.	0.27	16G	16
02205-A	7.	0.21	10G	14
02205-B	7.	0.21	10G	14
02205-C	7.	0.21	10G	14
02205-D	7.	0.21	10G	14
02206-A	7.	0.42	12G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
HTTL				
02206-B	7.	0.42	12G	14
02206-C	7.	0.42	12G	14
02206-D	7.	0.42	12G	14
02301-A	7.	0.20	1G	14
02301-B	7.	0.20	1G	14
02301-C	7.	0.20	1G	14
02301-D	7.	0.20	1G	14
02302-A	7.	0.40	2G	14
02302-B	7.	0.40	2G	14
02302-C	7.	0.40	2G	14
02302-D	7.	0.40	2G	14
02303-A	7.	0.59	3G	14
02303-B	7.	0.59	3G	14
02303-C	7.	0.59	3G	14
02303-D	7.	0.59	3G	14
02304-A	7.	0.80	4G	14
02304-B	7.	0.80	4G	14
02304-C	7.	0.80	4G	14
02304-D	7.	0.80	4G	14
02305-A	7.	1.20	6G	14
02305-B	7.	1.20	6G	14
02305-C	7.	1.20	6G	14
02305-D	7.	1.20	6G	14
02306-A	7.	0.79	4G	14
02306-B	7.	0.79	4G	14
02306-C	7.	0.79	4G	14
02306-D	7.	0.79	4G	14
02307-A	7.	0.40	2G	14
02307-B	7.	0.40	2G	14
02307-C	7.	0.40	2G	14
02307-D	7.	0.40	2G	14
02401-A	7.	0.27	2G	14
02401-B	7.	0.27	2G	14
02401-C	7.	0.27	2G	14
02401-D	7.	0.27	2G	14
LTTL				
02501-A	8.	0.07	15G	14
02501-B	8.	0.07	15G	14
02501-C	8.	0.07	15G	14
LTTL				
02501-D	8.	0.07	15G	14
02502-A	8.	0.06	25G	14
02502-B	8.	0.06	25G	14
02503-C	8.	0.06	25G	14
02503-E	8.	0.13	48G	16
02503-F	8.	0.13	48G	16
02504-D	8.	0.06	25G	16
02504-E	8.	0.17	38G	16
02504-F	8.	0.17	38G	16
02505-E	8.	0.17	38G	16
02505-F	8.	0.17	38G	16
02601-A	7.	0.04	4G	14
02601-B	7.	0.04	4G	14
02601-C	7.	0.04	4G	14
02601-D	7.	0.04	4G	14
02701-A	7.	0.02	4G	14
02701-B	7.	0.02	4G	14
02701-C	7.	0.02	4G	14
02701-D	7.	0.02	4G	14
02801-A	8.	0.02	37G	14
02801-B	8.	0.02	37G	14
02801-C	8.	0.02	37G	14
02801-D	8.	0.02	37G	14
02802-A	7.	0.12	36G	14
02802-B	7.	0.12	36G	14
02802-C	7.	0.12	36G	14
02802-D	7.	0.12	36G	14
02803-E	7.	0.27	72G	16
02803-F	7.	0.27	72G	16
02804-E	7.	0.12	40G	16
02804-F	7.	0.12	40G	16
02805-A	7.	0.05	36G	14
02805-B	7.	0.05	36G	14
02805-C	7.	0.05	36G	14
02805-D	7.	0.05	36G	14
02901-E	7.	0.12	18G	16
02901-F	7.	0.12	18G	16
02902-E	7.	0.12	18G	16
02902-F	7.	0.12	18G	16
02903-E	7.	0.12	18G	16
02903-F	7.	0.12	18G	16

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LTTL				
02904-E	7.	0.24	44G	16
02904-F	7.	0.24	44G	16
02905-E	7.	0.24	44G	16
02905-F	7.	0.24	44G	16
02906-E	7.	0.03	18G	16
02906-F	7.	0.03	18G	16
02907-E	7.	0.07	18G	16
02907-F	7.	0.07	18G	16
DTL				
03001-A	8.	0.05	2G	14
03001-B	8.	0.05	2G	14
03001-C	8.	0.05	2G	14
03001-D	8.	0.05	2G	14
03002-A	8.	0.14	6G	14
03002-B	8.	0.14	6G	14
03002-C	8.	0.14	6G	14
03002-D	8.	0.14	6G	14
03003-A	8.	0.14	6G	14
03003-B	8.	0.14	6G	14
03003-C	8.	0.14	6G	14
03003-D	8.	0.14	6G	14
03004-A	8.	0.09	4G	14
03004-B	8.	0.09	4G	14
03004-C	8.	0.09	4G	14
03004-D	8.	0.09	4G	14
03005-A	8.	0.07	3G	14
03005-B	8.	0.07	3G	14
03005-C	8.	0.07	3G	14
03005-D	8.	0.07	3G	14
03101-A	8.	0.13	2G	14
03101-B	8.	0.13	2G	14
03101-C	8.	0.13	2G	14
03101-D	8.	0.13	2G	14
03102-A	8.	0.10	2G	14
03102-B	8.	0.10	2G	14
03102-C	8.	0.10	2G	14
03102-D	8.	0.10	2G	14
03103-A	8.	0.13	4G	14
03103-B	8.	0.13	4G	14
DTL				
03103-C	8.	0.13	4G	14
03103-D	8.	0.13	4G	14
03104-A	8.	0.17	4G	14
03104-B	8.	0.17	4G	14
03104-C	8.	0.17	4G	14
03104-D	8.	0.17	4G	14
03105-A	8.	0.02	2G	14
03105-B	8.	0.02	2G	14
03105-C	8.	0.02	2G	14
03105-D	8.	0.02	2G	14
03201-A	8.	0.18	6G	14
03201-B	8.	0.18	6G	14
03201-C	8.	0.18	6G	14
03201-D	8.	0.18	6G	14
03301-A	8.	0.07	8G	14
03301-B	8.	0.07	8G	14
03301-C	8.	0.07	8G	14
03301-D	8.	0.07	8G	14
03302-A	8.	0.07	8G	14
03302-B	8.	0.07	8G	14
03302-C	8.	0.07	8G	14
03302-D	8.	0.07	8G	14
03303-A	8.	0.07	8G	14
03303-B	8.	0.07	8G	14
03303-C	8.	0.07	8G	14
03303-D	8.	0.07	8G	14
03304-A	8.	0.14	16G	14
03304-B	8.	0.14	16G	14
03304-C	8.	0.14	16G	14
03304-D	8.	0.14	16G	14
03501-C	22.	0.80	18T	14
03501-G	22.	0.80	18T	8
03501-M	22.	0.80	18T	12
HTTL				
04001-A	7.	0.14	6G	14
04001-B	7.	0.14	6G	14
04001-C	7.	0.14	6G	14
04001-D	7.	0.14	6G	14
04002-A	7.	0.14	6G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
HTTL				
04002-B	7.	0.14	6G	14
04002-C	7.	0.14	6G	14
04002-D	7.	0.14	6G	14
04003-A	7.	0.14	5G	14
04003-B	7.	0.14	5G	14
04003-C	7.	0.14	5G	14
04003-D	7.	0.14	5G	14
04004-A	7.	0.14	5G	14
04004-B	7.	0.14	5G	14
04004-C	7.	0.14	5G	14
04004-D	7.	0.14	5G	14
04005-A	7.	0.08	3G	14
04005-B	7.	0.08	3G	14
04005-C	7.	0.08	3G	14
04005-D	7.	0.08	3G	14
LTTL				
04101-A	7.	0.01	6G	14
04101-B	7.	0.01	6G	14
04101-C	7.	0.01	6G	14
04101-D	7.	0.01	6G	14
04102-C	7.	0.01	5G	14
04103-A	7.	0.01	3G	14
04103-B	7.	0.01	3G	14
04103-C	7.	0.01	3G	14
04103-D	7.	0.01	3G	14
04201-A	8.	0.11	8G	14
04201-B	8.	0.11	8G	14
04201-C	8.	0.11	8G	14
04201-D	8.	0.11	8G	14
04202-A	8.	0.08	10G	14
04202-B	8.	0.08	10G	14
04202-C	8.	0.08	10G	14
04202-D	8.	0.08	10G	14
04301-E	7.	0.12	24G	16
04301-F	7.	0.12	24G	16
04401-E	7.	0.12	28G	16
04401-F	7.	0.12	28G	16
04501-E	7.	0.18	30G	16
04501-F	7.	0.18	30G	16

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LTTL				
04502-J	7.	0.34	60G	24
04502-K	7.	0.34	60G	24
04601-E	7.	0.15	16G	16
04601-F	7.	0.15	16G	16
04602-E	7.	0.14	17G	16
04602-F	7.	0.14	17G	16
04603-E	7.	0.13	19G	16
04603-F	7.	0.13	19G	16
CMOS				
05001-C	13.	0.20	4G	14
05001-D	13.	0.20	4G	14
05002-A	13.	0.20	2G	14
05002-C	13.	0.20	2G	14
05002-D	13.	0.20	2G	14
05003-A	13.	0.20	3G	14
05003-C	13.	0.20	3G	14
05003-D	13.	0.20	3G	14
05051-A	15.	0.20	4G	14
05051-C	15.	0.20	4G	14
05051-D	15.	0.20	4G	14
05052-A	15.	0.20	2G	14
05052-C	15.	0.20	2G	14
05052-D	15.	0.20	2G	14
05053-A	15.	0.20	3G	14
05053-C	15.	0.20	3G	14
05053-D	15.	0.20	3G	14
05101-A	13.	0.20	24G	14
05101-C	13.	0.20	24G	14
05101-D	13.	0.20	24G	14
05102-A	13.	0.20	30G	16
05102-C	13.	0.20	30G	16
05102-D	13.	0.20	30G	16
05103-A	13.	0.20	24G	15
05103-B	13.	0.20	24G	15
05103-D	13.	0.20	24G	15
05151-A	15.	0.20	24G	14
05151-C	15.	0.20	24G	14
05151-D	15.	0.20	24G	14
05152-A	15.	0.20	30G	14

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TABLE 5.1.2.7-18 MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
05152-C	15.	0.20	30G	14
05152-D	15.	0.20	30G	14
05153-A	15.	0.20	24G	14
05153-C	15.	0.20	24G	14
05153-D	15.	0.20	24G	14
05201-A	13	0.20	3G	12
05201-C	13.	0.20	3G	12
05201-D	13.	0.20	3G	12
05202-A	13.	0.20	4G	14
05202-C	13.	0.20	4G	14
05202-D	13.	0.20	4G	14
05203-A	13.	0.20	2G	12
05203-C	13.	0.20	2G	12
05203-D	13.	0.20	2G	12
05204-A	13.	0.20	3G	14
05204-C	13.	0.20	3G	14
05204-D	13.	0.20	3G	14
05251-A	15.	0.20	3G	14
05251-C	15.	0.20	3G	14
05252-D	15.	0.20	4G	14
05253-A	15.	0.20	2G	14
05253-C	15.	0.20	2G	14
05253-D	15.	0.20	2G	14
05254-A	15.	0.20	3G	14
05254-C	15.	0.20	3G	14
05254-D	15.	0.20	3G	14
05301-A	13.	0.20	3G	14
05301-C	13.	0.20	3G	14
05301-D	13.	0.20	3G	14
05302-E	13.	0.20	12G	16
05302-F	13.	0.20	12G	16
05303-A	13.	0.20	4G	14
05303-C	13.	0.20	4G	14
05303-D	13.	0.20	4G	14
05304-E	13.	0.20	24G	16
05304-F	13.	0.20	24G	16
05351-A	15.	0.20	3G	14
05351-C	15.	0.20	3G	14
05351-D	15.	0.20	3G	14
05352-E	15.	0.20	12G	14
05352-F	15.	0.20	12G	14
CMOS				
05353-A	15.	0.20	4G	14
05353-C	15.	0.20	4G	14
05353-D	15.	0.20	4G	14
05354-E	15.	0.20	3G	16
05354-F	15.	0.20	3G	16
05401-E	13.	0.20	58G	16
05401-F	13.	0.20	58G	16
05451-E	15.	0.20	58G	16
05451-F	15.	0.20	58G	16
05501-E	13.	0.20	6G	16
05501-F	13.	0.20	6G	16
05502-E	13.	0.20	6G	16
05502-F	13.	0.20	6G	16
05503-E	13.	0.20	6G	16
05503-F	13.	0.20	6G	16
05504-E	13.	0.20	6G	16
05504-F	13.	0.20	6G	16
05505-A	13.	0.20	12G	14
05505-C	13.	0.20	12G	14
05505-D	13.	0.20	12G	14
05551-E	15.	0.20	6G	16
05551-F	15.	0.20	6G	16
05552-E	15.	0.20	6G	16
05552-F	15.	0.20	6G	16
05553-E	15.	0.20	6G	16
05553-F	15.	0.20	6G	16
05554-E	15.	0.20	6G	16
05554-F	15.	0.20	6G	16
05555-A	15.	0.20	12G	14
05555-C	15.	0.20	12G	14
05555-D	15.	0.20	12G	14
05601-E	13.	0.20	47G	16
05601-F	13.	0.20	47G	16
05602-E	13.	0.20	57G	16
05602-F	13.	0.20	57G	16
05603-E	13.	0.20	132G	16
05603-F	13.	0.20	132G	16
05604-E	13.	0.20	39G	16
05604-F	13.	0.20	39G	16
05605-A	13.	0.20	81G	14
05605-C	13.	0.20	81G	14

TABLE 5.1.2.7-18 MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
05605-D	13.	0.20	81G	14
05651-E	15.	0.20	47G	16
05651-F	15.	0.20	47G	16
05652-E	15.	0.20	57G	16
05652-F	15.	0.20	57G	16
05653-E	15.	0.20	132G	16
05653-F	15.	0.20	132G	16
05654-E	15.	0.20	39G	16
05654-F	15.	0.20	39G	16
05655-A	15.	0.20	81G	14
05655-C	15.	0.20	81G	14
05655-D	15.	0.20	81G	14
05701-A	13.	0.20	109G	14
05701-C	13.	0.20	109G	14
05701-D	13.	0.20	109G	14
05702-E	13.	0.20	55G	16
05702-F	13.	0.20	55G	16
05703-E	13.	0.20	58G	16
05703-F	13.	0.20	58G	16
05704-E	13.	0.20	55G	16
05704-F	13.	0.20	55G	16
05705-E	13.	0.20	263G	16
05705-F	13.	0.20	263G	16
05706-J	13.	0.20	56G	24
05706-K	13.	0.20	56G	24
05751-A	15.	0.20	109G	14
05751-C	15.	0.20	109G	14
05751-D	15.	0.20	109G	14
05752-E	15.	0.20	55G	16
05752-F	15.	0.20	55G	16
05753-E	15.	0.20	58G	16
05753-F	15.	0.20	58G	16
05754-E	15.	0.20	55G	16
05754-F	15.	0.20	55G	16
05755-E	15.	0.20	263G	16
05755-F	15.	0.20	263G	16
05756-J	15.	0.20	56G	24
05756-K	15.	0.20	56G	24
05801-A	13.	0.20	4G	14
05801-C	13.	0.20	4G	14
05801-D	13.	0.20	4G	14

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
05802-A	13.	0.20	4G	14
05802-C	13.	0.20	4G	14
05802-D	13.	0.20	4G	14
05851-A	15.	0.20	4G	14
05851-C	15.	0.20	4G	14
05851-D	15.	0.20	4G	14
05852-A	15.	0.20	4G	14
05852-C	15.	0.20	4G	14
05852-D	15.	0.20	4G	14
05901-E	13.	0.20	38G	16
05901-F	13.	0.20	38G	16
05951-E	15.	0.20	38G	16
05951-F	15.	0.20	38G	16
ECL				
06001-E	7.	0.22	4G	16
06001-F	7.	0.22	4G	16
06002-E	7.	0.22	4G	16
06002-F	7.	0.22	4G	16
06003-E	7.	0.16	3G	16
06003-F	7.	0.16	3G	16
06004-E	7.	0.16	3G	16
06004-F	7.	0.16	3G	16
06005-E	7.	0.16	3G	16
06005-F	7.	0.16	3G	16
06006-E	7.	0.11	2G	16
06006-F	7.	0.11	2G	16
06101-E	7.	0.16	24G	16
06101-F	7.	0.16	24G	16
06102-E	7.	0.19	24G	16
06102-F	7.	0.19	24G	16
06103-E	7.	0.11	42G	16
06103-F	7.	0.11	42G	16
06104-E	7.	0.20	24G	16
06104-F	7.	0.20	24G	16
06201-E	7.	0.22	4G	16
06201-F	7.	0.22	4G	16
06202-E	7.	0.33	6G	16
06202-F	7.	0.33	6G	16
06301-E	7.	0.15	4G	16

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
ECL				
06301-F	7.	0.15	4G	16
06302-E	7.	0.13	4G	16
06302-F	7.	0.13	4G	16
STTL				
07001-A	7.	0.20	4G	14
07001-B	7.	0.20	4G	14
07001-C	7.	0.20	4G	14
07001-D	7.	0.20	4G	14
07002-A	7.	0.20	4G	14
07002-B	7.	0.20	4G	14
07002-C	7.	0.20	4G	14
07002-D	7.	0.20	4G	14
07003-A	7.	0.30	6G	14
07003-B	7.	0.30	6G	14
07003-C	7.	0.30	6G	14
07003-D	7.	0.30	6G	14
07004-A	7.	0.30	6G	14
07004-B	7.	0.30	6G	14
07004-C	7.	0.30	6G	14
07004-D	7.	0.30	6G	14
07005-A	7.	0.15	3G	14
07005-B	7.	0.15	3G	14
07005-C	7.	0.15	3G	14
07005-D	7.	0.15	3G	14
07006-A	7.	0.10	2G	14
07006-C	7.	0.10	2G	14
07006-D	7.	0.10	2G	14
07006-D	7.	0.10	2G	14
07007-A	7.	0.10	2G	14
07007-B	7.	0.10	2G	14
07007-C	7.	0.10	2G	14
07007-D	7.	0.10	2G	14
07008-A	7.	0.06	1G	14
07008-B	7.	0.06	1G	14
07008-C	7.	0.06	1G	14
07008-D	7.	0.06	1G	14
07009-E	7.	0.06	1G	16
07009-F	7.	0.06	1G	16
07010-E	7.	0.14	1G	16

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
STTL				
07010-F	7.	0.14	1G	16
07101-A	7.	0.27	12G	14
07101-B	7.	0.27	12G	14
07101-C	7.	0.27	12G	14
07101-D	7.	0.27	12G	14
07102-E	7.	0.27	16G	16
07102-F	7.	0.27	16G	16
07103-A	7.	0.27	16G	14
07103-B	7.	0.27	16G	14
07103-C	7.	0.27	16G	14
07103-D	7.	0.27	16G	14
07104-A	7.	0.27	16G	14
07104-B	7.	0.27	16G	14
07104-C	7.	0.27	16G	14
07104-D	7.	0.27	16G	14
07105-E	7.	0.79	36G	16
07105-F	7.	0.79	36G	16
07106-E	7.	0.52	24G	16
07106-F	7.	0.52	24G	16
07201-A	7.	0.24	2G	14
07201-B	7.	0.24	2G	14
07201-C	7.	0.24	2G	14
07201-D	7.	0.24	2G	14
07301-A	7.	0.25	4G	14
07301-B	7.	0.25	4G	14
07301-C	7.	0.25	4G	14
07301-D	7.	0.25	4G	14
07401-A	7.	0.12	6G	14
07401-B	7.	0.12	6G	14
07401-C	7.	0.12	6G	14
07401-D	7.	0.12	6G	14
07402-A	7.	0.09	5G	14
07402-B	7.	0.09	5G	14
07402-C	7.	0.09	5G	14
07402-D	7.	0.09	5G	14
07403-A	7.	0.09	5G	14
07403-B	7.	0.09	5G	14
07403-C	7.	0.09	5G	14
07403-D	7.	0.09	5G	14
07501-A	7.	0.55	4G	14
07501-B	7.	0.55	4G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
STTL				
07501-C	7.	0.55	4G	14
07501-D	7.	0.55	4G	14
07502-E	7.	0.42	8G	16
07502-F	7.	0.42	8G	16
07601-E	7.	0.70	47G	16
07601-F	7.	0.70	47G	16
07602-E	7.	0.70	41G	16
07602-F	7.	0.70	41G	16
07701-E	7.	0.33	16G	16
07701-F	7.	0.33	16G	16
07702-E	7.	0.41	18G	16
07702-F	7.	0.41	18G	16
07801-J	7.	0.99	63G	24
07801-K	7.	0.99	63G	24
07801-L	7.	0.99	63G	24
07801-Z	7.	0.99	63G	24
07802-E	7.	0.99	19G	16
07802-F	7.	0.99	19G	16
07901-E	7.	0.39	17G	16
07901-F	7.	0.39	17G	16
07902-E	7.	0.39	16G	16
07902-F	7.	0.39	16G	16
07903-E	7.	0.43	15G	16
07903-F	7.	0.43	15G	16
07904-E	7.	0.34	15G	16
07904-F	7.	0.34	15G	16
07905-E	7.	0.47	17G	16
07905-F	7.	0.47	17G	16
07906-E	7.	0.55	15G	16
07906-F	7.	0.55	15G	16
07907-E	7.	0.48	15G	16
07907-F	7.	0.48	15G	16
07908-E	7.	0.55	16G	16
07908-F	7.	0.55	16G	16
08001-A	7.	0.23	3G	14
08001-B	7.	0.23	3G	14
08001-C	7.	0.23	3G	14
08001-D	7.	0.23	3G	14
08002-A	7.	0.23	3G	14
08002-B	7.	0.23	3G	14
08002-C	7.	0.23	3G	14
STTL				
08002-D	7.	0.23	3G	14
08003-A	7.	0.31	4G	14
08003-B	7.	0.31	4G	14
08003-C	7.	0.31	4G	14
08003-D	7.	0.31	4G	14
08004-A	7.	0.31	4G	14
08004-B	7.	0.31	4G	14
08004-C	7.	0.31	4G	14
08004-D	7.	0.31	4G	14
08101-A	7.	0.48	2G	14
08101-B	7.	0.48	2G	14
08101-C	7.	0.48	2G	14
08101-D	7.	0.48	2G	14
08201-E	7.	0.60	31G	16
08201-F	7.	0.60	31G	16
LINEAR				
10101-A	22.	0.35	23T	14
10101-B	22.	0.35	23T	14
10101-C	22.	0.40	23T	14
10101-D	22.	0.35	23T	14
10101-G	22.	0.33	23T	8
10101-H	22.	0.33	23T	10
10101-P	22.	0.40	23T	8
10102-A	22.	0.35	46T	14
10102-B	22.	0.35	46T	14
10102-C	22.	0.40	46T	14
10102-D	22.	0.35	46T	14
10102-I	22.	0.35	46T	10
10103-C	22.	0.40	21T	14
10103-G	22.	0.33	21T	8
10103-H	22.	0.33	21T	10
10103-P	22.	0.40	21T	8
10104-C	22.	0.40	29T	14
10104-G	22.	0.33	29T	8
10104-H	22.	0.33	29T	10
10104-P	22.	0.40	29T	8
10105-E	22.	0.40	42T	16
10105-F	22.	0.40	42T	16
10106-E	22.	0.40	58T	16

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LINEAR				
10106-F	22.	0.40	58T	16
10107-C	22.	0.40	36T	14
10107-G	22.	0.33	36T	8
10107-H	22.	0.33	36T	10
10107-P	22.	0.40	36T	8
10108-G	22.	0.33	46T	8
10201-A	40.	0.35	20T	14
10201-B	40.	0.35	20T	14
10201-C	40	0.40	20T	14
10201-D	40.	0.35	20T	14
10201-H	40.	0.35	20T	10
10201-I	40.	0.35	20T	10
10301-C	21.	0.40	9T	14
10301-G	21.	0.33	9T	8
10301-H	21.	0.33	9T	10
10302-C	21.	0.40	18T	14
10302-F	21.	0.35	18T	16
10302-H	21.	0.33	18T	10
10303-A	30.	0.35	13T	14
10303-G	30.	0.33	13T	8
10304-G	36.	0.33	23T	8
10304-H	36.	0.33	23T	10
10305-E	36.	0.40	46T	16
10305-F	36.	0.35	46T	16
10401-A	7.	0.55	29T	14
10401-B	7.	0.55	29T	14
10401-C	7.	0.55	29T	14
10401-D	7.	0.55	29T	14
10402-A	7.	0.55	25T	14
10402-B	7.	0.55	25T	14
10402-C	7.	0.55	25T	14
10402-D	7.	0.55	25T	14
10403-E	7.	0.40	6T	16
10403-F	7.	0.40	6T	16
10404-E	7.	0.40	35T	16
10404-F	7.	0.40	35T	16
10405-E	7.	0.40	8T	16
10405-F	7.	0.40	8T	16
10406-E	7.	0.22	9T	16
10406-F	7.	0.22	9T	16
10407-E	7.	0.22	9T	16
LINEAR				
10407-F	7.	0.22	9T	16
10601-C	36.	0.40	19T	14
10601-G	36.	0.35	19T	8
10601-G	36.	0.35	19T	8
10601-H	36.	0.33	19T	10
10602-C	36.	0.40	19T	14
10602-G	36.	0.35	19T	8
10602-H	36.	0.33	19T	7
10603-E	36.	0.40	38T	16
10603-F	36.	0.40	38T	16
10701-X	35.	0.89	19T	3
10701-Y	35.	3.60	19T	3
10702-X	35.	0.89	18T	3
10703-X	35.	0.89	18T	3
10704-X	35.	0.89	18T	3
10705-X	40	0.89	18T	3
10706-Y	35.	3.60	17T	3
10707-Y	35.	3.60	17T	3
10708-Y	35.	3.60	17T	3
10709-Y	40.	3.60	17T	3
10801-A	15.	0.35	4T	14
10801-C	15.	0.40	4T	14
10801-D	15.	0.35	4T	14
10801-M	15.	0.35	4T	14
10802-A	15.	0.35	5T	14
10802-C	15.	0.40	5T	14
10802-D	15.	0.35	5T	14
10901-C	18.	0.40	23T	14
10901-G	18.	0.30	23T	8
10901-P	18.	0.37	23T	8
10902-C	18.	0.40	46T	14
10903-C	18.	0.40	23T	14
11001-A	22.	0.35	88T	14
11001-C	22.	0.40	88T	14
11001-D	22.	0.35	88T	14
11002-A	22.	0.35	88T	14
11002-C	22.	0.40	88T	14
11002-D	22.	0.35	88T	14
11003-A	22.	0.35	68T	14
11003-C	22.	0.40	68T	14
11003-D	22.	0.35	68T	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LINEAR				
11004-C	22.	0.40	60T	14
11005-A	36.	0.35	102T	14
11005-C	36.	0.40	102T	14
11005-D	36.	0.35	102T	14
11101-A	36.	0.35	22T	14
11101-C	36.	0.40	22T	14
11101-D	36.	0.35	22T	14
11101-I	36.	0.35	22T	10
11102-A	36.	0.35	22T	14
11102-C	36.	0.40	22T	14
11102-D	36.	0.35	22T	14
11102-I	36.	0.35	22T	10
11103-A	36.	0.35	30T	14
11103-D	36.	0.35	30T	14
11103-E	36.	0.40	30T	16
11104-A	36.	0.35	30T	14
11104-D	36.	0.35	30T	14
11104-E	36.	0.40	30T	16
11105-A	36.	0.35	15T	14
11105-C	36.	0.40	15T	14
11105-D	36.	0.35	15T	14
11105-I	36.	0.35	15T	10
11106-A	36.	0.35	15T	14
11106-C	36.	0.40	15T	14
11106-D	36.	0.35	15T	14
11106-I	36.	0.35	15T	10
11107-A	36.	0.35	30T	14
11107-C	36.	0.40	30T	14
11107-D	36.	0.35	30T	14
11108-A	36.	0.35	30T	14
11108-C	36.	0.40	30T	14
11108-D	36.	0.35	30T	14
11201-A	36.	0.35	32T	14
11201-C	36.	0.40	32T	14
11201-D	36.	0.35	32T	14
11202-G	36.	0.33	16T	8
11202-P	36.	0.40	16T	8
11301-E	36.	0.40	84T	16
11302-E	36.	0.40	84T	16
11401-G	22.	0.33	19T	8
11401-H	22.	0.33	19T	10
11401-P	22.	0.40	19T	8
11402-G	22.	0.33	19T	8
11402-H	22.	0.33	19T	10
11402-P	22.	0.40	19T	8
11403-G	22.	0.33	19T	8
11403-H	22.	0.33	19T	10
11403-P	22.	0.40	19T	8
11404-G	22.	0.33	19T	8
11405-G	22.	0.33	19T	8
11405-H	22	0.33	19T	10
11405-P	22.	0.40	19T	8
11406-G	22.	0.33	19T	8
11406-H	22.	0.33	19T	10
11406-P	22.	0.40	19T	8
11501-X	10.	0.89	23T	3
11502-X	17.	0.89	23T	3
11503-X	20.	0.89	23T	3
11504-X	29.	0.89	23T	3
11505-Y	10.	3.60	21T	3
11506-Y	17.	3.60	21T	3
11507-Y	20.	3.60	21T	3
11508-Y	29.	3.60	21T	3
CMOS				
11601-C	15.	0.40	42T	14
11601-D	15.	0.35	42T	14
11601-I	15.	0.25	42T	10
11602-C	15.	0.40	27T	14
11602-D	15.	0.35	27T	14
11602-I	15.	0.25	27T	10
11603-C	15.	0.40	54T	14
11603-D	15.	0.35	54T	14
11604-C	15.	0.40	54T	14
11604-D	15.	0.35	54T	14
11605-C	15.	0.40	38T	14
11605-D	15.	0.35	38T	14
11605-I	15.	0.25	38T	10
11606-C	15.	0.40	25T	14
11606-D	15.	0.35	25T	14
11606-I	15.	0.25	25T	10

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
11607-C	15.	0.40	50T	14
11607-D	15.	0.35	50T	14
11608-C	15.	0.40	50T	14
11608-D	15.	0.35	50T	14
LINEAR				
11701-X	40.	0.89	17T	4
11702-X	40.	3.60	17T	4
11703-X	40.	0.89	26T	3
11704-Y	40.	3.60	26T	3
11801-X	40.	0.89	23T	4
11802-Y	40.	3.60	23T	4
11803-X	40.	0.89	30T	3
11804-Y	40.	3.60	30T	3
11901-G	36.	0.33	33T	8
11901-P	36.	0.40	33T	8
11902-C	36.	0.40	66T	14
11902-G	36.	0.33	66T	8
11902-P	36.	0.40	66T	8
11903-C	36.	0.40	132T	14
11903-D	36.	0.35	132T	14
11904-G	36.	0.33	28T	8
11904-P	36.	0.40	28T	8
11905-C	36.	0.40	54T	14
11905-G	36.	0.33	54T	8
11905-P	36.	0.40	54T	8
11906-C	36.	0.40	124T	14
11906-D	36.	0.35	124T	14
12201-G	40.	0.30	50T	8
12201-H	40.	0.30	50T	14
12202-G	40.	0.30	40T	8
12202-H	40.	0.30	40T	8
12203-G	40.	0.30	40T	8
12203-H	40.	0.30	40T	8
12204-G	40.	0.30	30T	8
12204-H	40.	0.30	30T	8
12205-G	40.	0.30	30T	8
12205-H	40.	0.30	30T	8
12206-G	40.	0.30	31T	8
12206-H	40.	0.30	31T	8

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
12301-C	15.	0.40	36T	14
12301-I	15.	0.35	36T	10
12302-E	30.	0.40	72T	16
12303-C	15.	0.40	18T	14
12303-I	15.	0.35	18T	10
12304-E	15.	0.40	18T	16
LINEAR				
12401-X	30.	0.12	19T	2
12401-Y	30.	0.14	19T	4
12401-G	30.	0.18	19T	8
12402-X	30.	0.12	8T	2
12402-Y	30.	0.14	8T	4
12402-G	30.	0.18	8T	8
12403-X	30.	0.12	21T	2
12403-Y	30.	0.14	21T	4
12403-G	30.	0.18	21T	8
12404-X	30.	0.12	19T	2
12404-Y	30.	0.14	19T	4
12404-G	30.	0.18	19T	8
12406-X	30.	0.12	8T	2
12406-Y	30.	0.14	8T	4
12406-G	30.	0.18	8T	8
12501-G	15.	0.33	62T	8
12501-P	15.	0.33	62T	8
12502-P	15.	0.40	61T	8
12601-E	40.	0.40	71T	16
12801-G	30.	0.33	16T	8
12802-G	30.	0.33	16T	8
12901-C	7.	0.27	10T	14
12901-P	7.	0.21	10T	8
12902-C	7.	0.27	10T	14
12902-P	7.	0.21	10T	8
12903-C	7.	0.27	14T	14
12903-P	7.	0.21	14T	8
12904-C	7.	0.27	14T	14
12904-P	7.	0.21	14T	8
12905-C	7.	0.27	18T	14
12905-P	7.	0.21	18T	8
12906-C	7.	0.27	10T	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LINEAR				
12906-P	7.	0.21	10T	8
12907-C	7.	0.27	10T	14
12907-P	7.	0.21	10T	8
12908-C	7.	0.27	14T	14
12908-P	7.	0.21	14T	8
12909-C	7.	0.27	14T	14
12909-P	7.	0.21	14T	8
12910-C	7.	0.27	18T	14
12910-P	7.	0.21	18T	8
13001-E	25.	1.40	32T	16
13002-E	7.	1.40	32T	16
13003-E	7.	1.40	32T	16
13101-G	22.	0.33	21T	8
13101-P	22.	0.40	21T	8
13102-G	22.	0.33	42T	8
13102-P	22.	0.40	42T	8
13301-E	16.5	0.50	96G	16
13301-Z	16.5	0.50	96G	16
13401-V	7.	0.80	173G	19
13901-I	22.	0.33	49T	10
13901-C	22.	0.40	49T	14
13902-I	22.	0.33	49T	10
13902-C	22.	0.40	49T	14
13903-I	22.	0.33	28T	10
13903-C	22.	0.40	28T	14
14103-E	50.	1.00	7T	16
TTL				
15001-E	7.	0.49	31G	16
15001-F	7.	0.49	31G	16
15002-E	7.	0.49	32G	16
15002-F	7.	0.49	32G	16
15101-A	7.	0.18	2G	14
15101-B	7.	0.18	2G	14
15101-C	7.	0.18	2G	14
15101-D	7.	0.18	2G	14
15102-A	7.	0.18	6G	14
15102-B	7.	0.18	6G	14
15102-C	7.	0.18	6G	14
15102-D	7.	0.18	6G	14

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
TTL				
15103-A	7.	0.18	4G	14
15103-B	7.	0.18	4G	14
15103-C	7.	0.18	4G	14
15103-D	7.	0.18	4G	14
15201-J	7.	0.27	21G	24
15201-K	7.	0.27	21G	24
15201-L	7.	0.27	21G	24
15201-Z	7.	0.27	21G	24
15202-E	7.	0.20	15G	16
15202-F	7.	0.20	15G	16
15203-E	7.	0.20	15G	16
15203-F	7.	0.20	15G	16
15204-A	7.	0.14	15G	14
15204-B	7.	0.14	15G	14
15204-C	7.	0.14	15G	14
15204-D	7.	0.14	15G	14
15205-E	7.	0.19	18G	16
15205-F	7.	0.19	18G	16
15206-E	7.	0.19	18G	16
15206-F	7.	0.19	18G	16
15301-C	7.	0.30	4G	14
15301-D	7.	0.30	4G	14
15302-C	7.	0.35	4G	14
15302-D	7.	0.35	4G	14
HTTL				
15501-A	7.	0.35	4G	14
15501-B	7.	0.35	4G	14
15501-C	7.	0.35	4G	14
15501-D	7.	0.35	4G	14
15502-A	7.	0.26	3G	14
15502-B	7.	0.26	3G	14
15502-C	7.	0.26	3G	14
15502-D	7.	0.26	3G	14
15503-A	7.	0.18	2G	14
15503-B	7.	0.18	2G	14
15503-C	7.	0.18	2G	14
15503-D	7.	0.18	2G	14
15504-A	7.	0.35	4G	14
15504-B	7.	0.35	4G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
HTTL				
15504-D	7.	0.35	4G	14
TTL				
15601-E	7.	0.39	31G	16
15601-F	7.	0.39	31G	16
15602-E	7.	0.33	29G	16
15602-F	7.	0.33	29G	16
15603-E	7.	0.42	24G	16
15603-F	7.	0.42	24G	16
15701-E	7.	0.74	98G	16
15701-F	7.	0.74	98G	16
15801-E	7.	0.28	18G	16
15801-F	7.	0.28	18G	16
15802-E	7.	0.40	46G	16
15802-F	7.	0.40	46G	16
15901-E	7.	0.47	40G	16
15901-F	7.	0.47	40G	16
15902-E	7.	0.42	72G	16
15902-F	7.	0.42	72G	16
16001-E	7.	0.47	59G	16
16001-F	7.	0.47	59G	16
16101-A	7.	0.21	4G	14
16101-B	7.	0.21	4G	14
16101-C	7.	0.21	4G	14
16101-D	7.	0.21	4G	14
16201-A	7.	0.32	4G	14
16201-B	7.	0.32	4G	14
16201-C	7.	0.32	4G	14
16201-D	7.	0.32	4G	14
16301-E	7.	0.28	7G	16
16301-F	7.	0.28	7G	16
16302-E	7.	0.55	7G	16
16302-F	7.	0.55	7G	16
16303-E	7.	0.28	8G	16
16303-F	7.	0.28	8G	16
16304-E	7.	0.16	8G	16
16304-F	7.	0.16	8G	16

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
17001-A	15.	0.20	4G	14
17001-C	15.	0.20	4G	14
17001-D	15.	0.20	4G	14
17002-C	15.	0.20	2G	14
17002-D	15.	0.20	2G	14
17003-C	15.	0.20	3G	14
17003-D	15.	0.20	3G	14
17101-A	15.	0.20	4G	14
17101-C	15.	0.20	4G	14
17101-D	15.	0.20	4G	14
17102-A	15.	0.20	2G	14
17102-C	15.	0.20	2G	14
17102-D	15.	0.20	2G	14
17103-A	15.	0.20	3G	14
17103-C	15.	0.20	3G	14
17103-D	15.	0.20	3G	14
17201-A	15.	0.20	6G	14
17201-C	15.	0.20	6G	14
17201-D	15.	0.20	6G	14
17202-A	15.	0.20	5G	14
17202-C	15.	0.20	5G	14
17202-D	15.	0.20	5G	14
17203-A	15.	0.20	4G	14
17203-C	15.	0.20	4G	14
17203-D	15.	0.20	4G	14
17204-A	15.	0.20	4G	14
17204-C	15.	0.20	4G	14
17204-D	15.	0.20	4G	14
17301-J	15.	0.20	120G	24
17301-K	15.	0.20	120G	24
17301-X	15.	0.20	120G	24
17301-Y	15.	0.20	120G	24
17302-J	15.	0.20	104G	24
17302-K	15.	0.20	104G	24
17302-X	15.	0.20	104G	24
17302-Y	15.	0.20	104G	24
17303-E	15.	0.20	34G	16
17303-F	15.	0.20	34G	16
17304-E	15.	0.20	34G	16
17304-F	15.	0.20	34G	16

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
17305-E	15.	0.20	26G	16
17305-F	15.	0.20	26G	16
17401-A	15.	0.20	6G	14
17401-C	15.	0.20	6G	14
17401-D	15.	0.20	6G	14
17402-A	15.	0.20	6G	14
17402-C	15.	0.20	6G	14
17402-D	15.	0.20	6G	14
17403-E	15.	0.20	12G	16
17403-F	15.	0.20	12G	16
17404-E	15.	0.20	32G	16
17404-F	15.	0.20	32G	16
17501-E	15.	0.20	52G	16
17501-F	15.	0.20	52G	16
17502-C	15.	0.20	20G	14
17502-D	15.	0.20	20G	14
17503-C	15.	0.20	21G	14
17503-D	15.	0.20	21G	14
17504-E	15.	0.20	20G	16
17504-F	15.	0.20	20G	16
17505-E	15.	0.20	36G	16
17505-F	15.	0.20	36G	16
17601-E	15.	0.20	76G	16
17601-F	15.	0.20	76G	16
17602-J	15.	0.20	56G	24
17602-K	15.	0.20	56G	24
17602-Z	15.	0.20	56G	24
17701-A	15.	0.20	4G	14
17701-C	15.	0.20	4G	14
17701-D	15.	0.20	4G	14
17702-A	15.	0.20	6G	14
17702-C	15.	0.20	6G	14
17702-D	15.	0.20	6G	14
17801-J	15.	0.20	80G	24
17801-K	15.	0.20	80G	24
17801-Z	15.	0.20	80G	24
17802-J	15.	0.20	92G	24
17802-K	15.	0.20	92G	24
17802-Z	15.	0.20	92G	24
17803-E	15.	0.20	41G	16
17803-F	15.	0.20	41G	16

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
19001-X	30.	1.20	52T	28
19002-X	30.	1.20	52T	28
19003-X	30.	1.20	36T	28
19004-X	30.	1.20	36T	28
19005-E	30.	0.73	28T	16
19006-E	30.	0.73	18T	16
TTL PROM				
20101-J	7.	0.58	512B	24
20101-K	7.	0.58	512B	24
20101-Z	7.	0.58	512B	24
20102-J	7.	0.58	512B	24
20102-K	7.	0.58	512B	24
20102-Z	7.	0.58	512B	24
20201-E	7.	0.72	1024B	16
20201-F	7.	0.72	1024B	16
20202-E	7.	0.72	1024B	16
20202-F	7.	0.72	1024B	16
STTL PROM				
20301-E	7.	0.74	1024B	16
20301-F	7.	0.74	1024B	16
20302-E	7.	0.74	1024B	16
20302-F	7.	0.74	1024B	16
20303-E	7.	0.74	1024B	16
20303-F	7.	0.74	1024B	16
20304-E	7.	0.74	1024B	16
20304-F	7.	0.74	1024B	16
20401-E	7.	0.79	2048B	16
20401-F	7.	0.79	2048B	16
20402-E	7.	0.79	2048B	16
20402-F	7.	0.79	2048B	16
20601-V	7.	0.79	4096B	18
20601-Z	7.	0.79	4096B	18
20602-V	7.	0.79	4096B	18
20602-Z	7.	0.79	4096B	18
20603-E	7.	0.79	4096B	16
20603-F	7.	0.79	4096B	16
20701-E	7.	0.74	256B	16

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
STTL PROM				
20701-F	7.	0.74	256B	16
20702-E	7.	0.74	256B	16
20702-F	7.	0.74	256B	16
20801-J	7.	1.00	4096B	24
20801-K	7.	1.00	4096B	24
20801-X	7.	1.00	4096B	24
20802-J	7.	1.00	4096B	24
20802-K	7.	1.00	4096B	24
20802-X	7.	1.00	4096B	24
20803-J	7.	1.00	4096B	24
20803-K	7.	1.00	4096B	24
20803-X	7.	1.00	4096B	24
20804-Y	7.	1.00	4096B	20
20805-Y	7.	1.00	4096B	20
20901-V	7.	0.72	8192B	18
20902-V	7.	0.72	8192B	18
20903-J	7.	1.40	8192B	24
20903-K	7.	1.40	8192B	24
20904-J	7.	1.40	8192B	24
20904-K	7.	1.40	8192B	24
20905-J	7.	1.40	8192B	24
20905-K	7.	1.40	8192B	24
20906-J	7.	1.40	8192B	24
20906-K	7.	1.40	8192B	24
20907-J	7.	1.40	8192B	24
20907-K	7.	1.40	8192B	24
20908-J	7.	1.40	8192B	24
20908-K	7.	1.40	8192B	24
21001-J	7.	1.00	16384B	24
21001-K	7.	1.00	16384B	24
21002-J	7.	1.00	16384B	24
21002-K	7.	1.00	16384B	24
21003-J	7.	1.00	16384B	24
21003-K	7.	1.00	16384B	24
21004-J	7.	1.00	16384B	24
21004-K	7.	1.00	16384B	24
21005-J	7.	1.00	16384B	24
21005-K	7.	1.00	16384B	24

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS EPROM				
21901-J	8.	1.80	4096B	24
NMOS EPROM				
22001-J	30.	1.80	8192B	24
22101-J	6.	1.90	16384B	24
22201-J	6.	1.00	32768B	24
22202-J	6.	1.00	32768B	24
22601-J	6.	1.00	16384B	24
TTL RAM				
23001-E	7.	0.80	256B	16
23001-F	7.	0.80	256B	16
23002-E	7.	0.80	256B	16
23002-F	7.	0.80	256B	16
23003-E	7.	0.80	256B	16
23003-F	7.	0.80	256B	16
23004-E	7.	0.41	256B	16
23004-F	7.	0.41	256B	16
23101-E	7.	0.94	1024B	16
23101-F	7.	0.94	1024B	16
23101-Y	7.	0.94	1024B	24
23102-E	7.	0.94	1024B	16
23102-F	7.	0.94	1024B	16
23102-Y	7.	0.94	1024B	24
LSTTL RAM				
23103-E	7.	0.41	1024B	16
23103-F	7.	0.41	1024B	16
23103-Y	7.	0.41	1024B	24
23104-E	7.	0.41	1024B	16
23104-F	7.	0.41	1024B	16
23104-Y	7.	0.41	1024B	24
STTL RAM				
23105-E	7.	0.94	1024B	16
23105-F	7.	0.94	1024B	16
23105-Y	7.	0.94	1024B	24

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
STTL RAM				
23106-E	7.	0.94	1024B	16
23106-F	7.	0.94	1024B	16
23106-Y	7.	0.94	1024B	24
23107-E	7.	0.94	1024B	16
23107-F	7.	0.94	1024B	16
23107-Y	7.	0.94	1024B	24
23108-E	7.	0.94	1024B	16
23108-F	7.	0.94	1024B	16
23108-Y	7.	0.94	1024B	24
23109-W	7.	0.94	1024B	22
23109-X	7.	0.94	1024B	24
23109-Y	7.	0.94	1024B	24
23110-W	7.	0.94	1024B	22
23110-X	7.	0.94	1024B	24
23110-Y	7.	0.94	1024B	24
LSTTL RAM				
23111-W	7.	0.50	1024B	22
23111-X	7.	0.50	1024B	24
23111-Y	7.	0.50	1024B	24
23112-W	7.	0.50	1024B	22
23112-X	7.	0.50	1024B	24
23112-Y	7.	0.50	1024B	24
23113-E	7.	0.41	1024B	16
23113-F	7.	0.41	1024B	16
STTL				
23114-W	7.	0.94	1024B	22
23114-Y	7.	0.94	1024B	24
LSTTL				
23115-W	7.	0.50	1024B	22
23115-Y	7.	0.50	1024B	24
23115-X	7.	0.50	1024B	24
STTL RAM				
23201-X	7.	0.94	576B	28

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
STTL RAM				
23201-Y	7.	0.94	576B	28
23201-Z	7.	0.94	576B	28
NMOS RAM				
23501-U	20.	1.00	4096B	24
23501-W	20.	1.00	4096B	22
23502-U	20.	1.00	4096B	24
23502-V	20.	1.00	4096B	18
23502-U	20.	1.00	4096B	24
23503-W	20.	1.00	4096B	22
23504-U	20.	1.00	4096B	24
23504-V	20.	1.00	4096B	18
23505-W	20.	1.00	4096B	22
23506-W	20.	1.00	4096B	22
23601-W	20.	1.00	4096B	22
23602-E	20.	1.00	4096B	16
23603-W	20.	1.00	4096B	22
23604-E	20.	1.00	4096B	16
23701-X	7.	0.60	4096B	22
23702-X	7.	0.60	4096B	22
23703-W	7.	0.69	4096B	22
23703-X	7.	0.69	4096B	22
23704-W	7.	0.69	4096B	22
23704-X	7.	0.69	4096B	22
23705-X	7.	0.39	4096B	22
23706-X	7.	0.39	4096B	22
23707-W	7.	0.44	4096B	22
23707-X	7.	0.44	4096B	22
23708-W	7.	0.44	4096B	22
23708-X	7.	0.44	4096B	22
23709-X	7.	0.60	4096B	22
23710-X	7.	0.60	4096B	22
23711-W	7.	0.69	4096B	22
23711-X	7.	0.69	4096B	22
23712-W	7.	0.69	4096B	22
23712-X	7.	0.69	4096B	22
23713-X	7.	0.39	4096B	22
23714-X	7.	0.39	4096B	22
23715-W	7.	0.44	4096B	22
23715-X	7.	0.44	4096B	22

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
NMOS RAM				
23716-W	7.	0.44	4096B	22
23716-X	7.	0.44	4096B	22
23801-V	7.	1.20	4096B	18
23801-Z	7.	1.20	4096B	18
23802-V	7.	1.00	4096B	18
23802-Z	7.	1.00	4096B	18
23803-V	7.	1.20	4096B	18
23804-V	7.	1.00	4096B	18
23805-V	7.	1.20	4096B	18
23806-V	7.	1.20	4096B	18
23807-V	7.	1.20	4096B	18
CMOS RAM				
23901-E	7.	0.20	1024B	16
23901-F	7.	0.20	1024B	16
23902-V	7.	0.20	1024B	18
NMOS RAM				
24001-E	20.	1.00	16384B	16
24001-F	20.	1.00	16384B	16
24001-Z	20.	1.00	16384B	18
24002-E	20.	1.00	16384B	16
24002-F	20.	1.00	16384B	16
24002-Z	20.	1.00	16384B	18
24003-E	20.	1.00	16384B	16
24003-F	20.	1.00	16384B	16
24003-Z	20.	1.00	16384B	18
24401-E	7.	1.00	65536B	16
24401-Z	7.	1.00	65536B	18
24402-E	7.	1.00	65536B	16
24402-Z	7.	1.00	65536B	18
24403-E	7.	1.00	65536B	16
24403-Z	7.	1.00	65536B	18
CMOS				
24501-V	7.	0.20	4096B	18
24502-V	7.	0.20	4096B	18
29101-J	7.	1.00	16384B	24

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
CMOS				
29101-X	7.	1.00	16384B	32
29102-J	7.	1.00	16384B	24
29102-X	7.	1.00	16384B	32
29103-R	7.	1.00	16384B	20
29103-Y	7.	1.00	16384B	20
29104-J	7.	1.00	16384B	24
29104-X	7.	1.00	16384B	32
29105-J	7.	1.00	16384B	24
29105-X	7.	1.00	16384B	32
29106-R	7.	1.00	16384B	20
29106-Y	7.	1.00	16384B	20
LSTTL				
30001-A	7.	0.02	4G	14
30001-B	7.	0.02	4G	14
30001-C	7.	0.02	4G	14
30001-D	7.	0.02	4G	14
30002-A	7.	0.02	4G	14
30002-B	7.	0.02	4G	14
30002-C	7.	0.02	4G	14
30002-D	7.	0.02	4G	14
30003-A	7.	0.04	6G	14
30003-B	7.	0.04	6G	14
30003-C	7.	0.04	6G	14
30003-D	7.	0.04	6G	14
30004-A	7.	0.04	6G	14
30004-B	7.	0.04	6G	14
30004-C	7.	0.04	6G	14
30004-D	7.	0.04	6G	14
30005-A	7.	0.02	3G	14
30005-B	7.	0.02	3G	14
30005-C	7.	0.02	3G	14
30005-D	7.	0.02	3G	14
30006-A	7.	0.02	3G	14
30006-B	7.	0.02	3G	14
30006-C	7.	0.02	3G	14
30006-D	7.	0.02	3G	14
30007-A	7.	0.01	2G	14
30007-B	7.	0.01	2G	14
30007-C	7.	0.01	2G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LSTTL				
30007-D	7.	0.01	2G	14
30008-A	7.	0.01	2G	14
30008-B	7.	0.01	2G	14
30008-C	7.	0.01	2G	14
30008-D	7.	0.01	2G	14
30009-A	7.	0.01	1G	14
30009-B	7.	0.01	1G	14
30009-C	7.	0.01	1G	14
30009-D	7.	0.01	1G	14
30101-A	7.	0.05	16G	14
30101-B	7.	0.05	16G	14
30101-C	7.	0.05	16G	14
30101-D	7.	0.05	16G	14
30102-A	7.	0.05	12G	14
30102-B	7.	0.05	12G	14
30102-C	7.	0.05	12G	14
30102-D	7.	0.05	12G	14
30103-E	7.	0.05	16G	16
30103-F	7.	0.05	16G	16
30104-A	7.	0.05	16G	14
30104-B	7.	0.05	16G	14
30104-C	7.	0.05	16G	14
30104-D	7.	0.05	16G	14
30105-A	7.	0.05	16G	14
30105-B	7.	0.05	16G	14
30105-C	7.	0.05	16G	14
30105-D	7.	0.05	16G	14
30106-E	7.	0.15	36G	16
30106-F	7.	0.15	36G	16
30107-E	7.	0.10	24G	16
30107-F	7.	0.10	24G	16
30108-A	7.	0.05	16G	14
30108-B	7.	0.05	16G	14
30108-C	7.	0.05	16G	14
30108-D	7.	0.05	16G	14
30109-E	7.	0.05	16G	16
30109-F	7.	0.05	16G	16
30110-E	7.	0.05	16G	16
30110-F	7.	0.05	16G	16
30201-A	7.	0.03	2G	14
30201-B	7.	0.03	2G	14
30201-C	7.	0.03	2G	14
30201-D	7.	0.03	2G	14
30202-A	7.	0.07	4G	14
30202-B	7.	0.07	4G	14
30202-C	7.	0.07	4G	14
30202-D	7.	0.07	4G	14
30203-A	7.	0.07	4G	14
30203-B	7.	0.07	4G	14
30203-C	7.	0.07	4G	14
30203-D	7.	0.07	4G	14
30204-A	7.	0.07	4G	14
30204-B	7.	0.07	4G	14
30204-C	7.	0.07	4G	14
30204-D	7.	0.07	4G	14
30301-A	7.	0.03	4G	14
30301-B	7.	0.03	4G	14
30301-C	7.	0.03	4G	14
30301-D	7.	0.03	4G	14
30302-A	7.	0.04	3G	14
30302-B	7.	0.04	3G	14
30302-C	7.	0.04	3G	14
30302-D	7.	0.04	3G	14
30303-A	7.	0.07	4G	14
30303-B	7.	0.07	4G	14
30303-C	7.	0.07	4G	14
30303-D	7.	0.07	4G	14
30401-A	7.	0.02	6G	14
30401-B	7.	0.02	6G	14
30401-C	7.	0.02	6G	14
30401-D	7.	0.02	6G	14
30402-A	7.	0.01	5G	14
30402-B	7.	0.01	5G	14
30402-C	7.	0.01	5G	14
30402-D	7.	0.01	5G	14
30501-A	7.	0.06	4G	14
30501-B	7.	0.06	4G	14
30501-C	7.	0.06	4G	14
30501-D	7.	0.06	4G	14
30502-A	7.	0.06	4G	14
30502-B	7.	0.06	4G	14
30502-C	7.	0.06	4G	14

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LSTTL				
30502-D	7.	0.06	4G	14
30601-E	7.	0.13	47G	16
30601-F	7.	0.13	47G	16
30602-E	7.	0.12	41G	16
30602-F	7.	0.12	41G	16
30603-A	7.	0.12	37G	14
30603-B	7.	0.12	37G	14
30603-C	7.	0.12	37G	14
30603-D	7.	0.12	37G	14
30604-E	7.	0.11	39G	16
30604-F	7.	0.11	39G	16
30605-A	7.	0.15	36G	14
30605-B	7.	0.15	36G	14
30605-C	7.	0.15	36G	14
30605-D	7.	0.15	36G	14
30606-A	7.	0.16	48G	14
30606-B	7.	0.16	48G	14
30606-C	7.	0.16	48G	14
30606-D	7.	0.16	48G	14
30607-E	7.	0.16	48G	16
30607-F	7.	0.16	48G	16
30608-E	7.	0.20	62G	16
30608-F	7.	0.20	62G	16
30609-E	7.	0.21	68G	16
30609-F	7.	0.21	68G	16
30701-E	7.	0.06	16G	16
30701-F	7.	0.06	16G	16
30702-E	7.	0.06	18G	16
30702-F	7.	0.06	18G	16
30703-E	7.	0.07	18G	16
30703-F	7.	0.07	18G	16
30704-E	7.	0.07	44G	16
30704-F	7.	0.07	44G	16
30801-J	7.	0.19	63G	24
30801-K	7.	0.19	63G	24
30801-L	7.	0.19	63G	24
30801-Z	7.	0.19	63G	24
30901-E	7.	0.06	17G	16
30901-F	7.	0.06	17G	16
30902-E	7.	0.06	16G	16
30902-F	7.	0.06	16G	16
LSTTL				
30903-E	7.	0.09	15G	16
30903-F	7.	0.09	15G	16
30904-E	7.	0.04	15G	16
30904-F	7.	0.04	15G	16
30905-E	7.	0.07	17G	16
30905-F	7.	0.07	17G	16
30906-E	7.	0.11	15G	16
30906-F	7.	0.11	15G	16
30907-E	7.	0.11	15G	16
30907-F	7.	0.11	15G	16
30908-E	7.	0.08	16G	16
30908-F	7.	0.08	16G	16
30909-E	7.	0.12	15G	16
30909-F	7.	0.12	15G	16
31001-A	7.	0.04	3G	14
31001-B	7.	0.04	3G	14
31001-C	7.	0.04	3G	14
31001-D	7.	0.04	3G	14
31002-A	7.	0.04	3G	14
31002-B	7.	0.04	3G	14
31002-C	7.	0.04	3G	14
31002-D	7.	0.04	3G	14
31003-A	7.	0.02	2G	14
31003-B	7.	0.02	2G	14
31003-C	7.	0.02	2G	14
31003-D	7.	0.02	2G	14
31004-A	7.	0.04	4G	14
31004-B	7.	0.04	4G	14
31004-C	7.	0.05	4G	14
31004-D	7.	0.05	4G	14
31005-A	7.	0.04	4G	14
31005-B	7.	0.04	4G	14
31005-C	7.	0.04	4G	14
31005-D	7.	0.04	4G	14
31101-E	7.	0.11	31G	16
31101-F	7.	0.11	31G	16
31201-E	7.	0.21	42G	16
31201-F	7.	0.21	42G	16
31202-E	7.	0.21	42G	16
31202-F	7.	0.21	42G	16
31301-A	7.	0.04	2G	14

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LSTTL				
31301-B	7.	0.04	2G	14
31301-C	7.	0.04	2G	14
31301-D	7.	0.04	2G	14
31302-A	7.	0.12	6G	14
31302-B	7.	0.12	6G	14
31302-C	7.	0.12	6G	14
31302-D	7.	0.12	6G	14
31303-A	7.	0.08	4G	14
31303-B	7.	0.08	4G	14
31303-C	7.	0.08	4G	14
31303-D	7.	0.08	4G	14
31401-E	7.	0.11	20G	16
31401-F	7.	0.11	20G	16
31402-E	7.	0.15	16G	16
31402-F	7.	0.15	16G	16
31403-A	7.	0.06	10G	14
31403-B	7.	0.06	10G	14
31403-C	7.	0.06	10G	14
31403-D	7.	0.06	10G	14
31501-A	7.	0.08	15G	14
31501-B	7.	0.08	15G	14
31501-C	7.	0.08	15G	14
31501-D	7.	0.08	15G	14
31502-A	7.	0.08	25G	14
31502-B	7.	0.08	25G	14
31502-C	7.	0.08	25G	14
31502-D	7.	0.08	25G	14
31503-E	7.	0.18	60G	16
31503-F	7.	0.18	60G	16
31504-E	7.	0.18	57G	16
31504-F	7.	0.18	57G	16
31505-E	7.	0.19	63G	16
31505-F	7.	0.19	63G	16
31506-E	7.	0.19	60G	16
31506-F	7.	0.19	60G	16
31507-E	7.	0.19	50G	16
31507-F	7.	0.19	50G	16
31508-E	7.	0.19	48G	16
31508-F	7.	0.19	48G	16
31509-E	7.	0.19	59G	16
31509-F	7.	0.19	59G	16
LSTTL				
31510-A	7.	0.08	26G	14
31510-B	7.	0.08	26G	14
31510-C	7.	0.08	26G	14
31510-D	7.	0.08	26G	14
31511-E	7.	0.18	60G	16
31511-F	7.	0.18	60G	16
31512-E	7.	0.18	58G	16
31512-F	7.	0.18	58G	16
31513-E	7.	0.19	62G	16
31513-F	7.	0.19	62G	16
31601-E	7.	0.07	24G	16
31601-F	7.	0.07	24G	16
31602-E	7.	0.04	8G	16
31602-F	7.	0.04	8G	16
31603-E	7.	0.20	59G	16
31603-F	7.	0.20	59G	16
31604-E	7.	0.07	24G	16
31604-F	7.	0.07	24G	16
31605-E	7.	0.20	59G	16
31605-F	7.	0.20	59G	16
31801-E	7.	0.21	46G	16
31801-F	7.	0.21	46G	16
31901-E	7.	0.28	305G	16
31901-F	7.	0.28	305G	16
31902-E	7.	0.22	100G	16
31902-F	7.	0.22	100G	16
32001-A	7.	0.08	43G	14
32001-B	7.	0.08	43G	14
32001-C	7.	0.08	43G	14
32001-D	7.	0.08	43G	14
32002-A	7.	0.08	42G	14
32002-B	7.	0.08	42G	14
32002-C	7.	0.08	42G	14
32002-D	7.	0.08	42G	14
32003-A	7.	0.08	19G	14
32003-B	7.	0.08	19G	14
32003-C	7.	0.08	19G	14
32003-D	7.	0.08	19G	14
32004-A	7.	0.08	25G	14
32004-B	7.	0.08	25G	14
32004-C	7.	0.08	25G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LSTTL				
32004-D	7.	0.08	25G	14
32102-A	7.	0.02	4G	14
32102-B	7.	0.02	4G	14
32102-C	7.	0.02	4G	14
32102-D	7.	0.02	4G	14
32201-E	7.	0.13	7G	16
32201-F	7.	0.13	7G	16
32202-E	7.	0.12	7G	16
32202-F	7.	0.12	7G	16
32203-E	7.	0.13	8G	16
32203-F	7.	0.13	8G	16
32204-E	7.	0.12	8G	16
32204-F	7.	0.12	8G	16
32301-C	7.	0.11	4G	14
32301-D	7.	0.11	4G	14
32302-C	7.	0.12	4G	14
32302-D	7.	0.12	4G	14
32401-R	7.	0.28	10T	20
32401-S	7.	0.28	10T	20
32402-R	7.	0.30	10T	20
32402-S	7.	0.30	10T	20
32403-R	7.	0.30	10T	20
32403-S	7.	0.30	10T	20
32404-R	7.	0.30	12T	20
32404-S	7.	0.30	12T	20
32405-R	7.	0.30	12T	20
32405-S	7.	0.30	12T	20
32501-R	7.	0.15	80G	20
32501-S	7.	0.15	80G	20
32502-R	7.	0.22	74G	20
32502-S	7.	0.22	74G	20
32503-R	7.	0.22	80G	20
32503-S	7.	0.22	80G	20
32504-R	7.	0.15	90G	20
32504-S	7.	0.15	90G	20
32601-E	7.	0.06	15G	16
32601-F	7.	0.06	15G	16
32602-E	7.	0.06	15G	16
32602-F	7.	0.06	15G	16
32701-E	7.	0.14	60G	16
32701-F	7.	0.14	60G	16
32702-A	7.	0.14	66G	14
32702-B	7.	0.14	66G	14
32702-C	7.	0.14	66G	14
32702-D	7.	0.14	66G	14
32703-E	7.	0.14	82G	16
32703-F	7.	0.14	82G	16
32801-C	7.	0.30	10G	14
32801-D	7.	0.30	10G	14
32802-C	7.	0.30	10G	14
32802-D	7.	0.30	10G	14
32803-R	7.	0.52	18G	20
32803-S	7.	0.52	18G	20
32901-A	7.	0.15	46G	14
32901-B	7.	0.15	46G	14
32901-C	7.	0.15	46G	14
32901-D	7.	0.15	46G	14
ASTTL				
33001-A	7.	0.06	4G	14
33001-B	7.	0.06	4G	14
33001-C	7.	0.06	4G	14
33001-D	7.	0.06	4G	14
33001-X	7.	0.06	4G	20
33001-Y	7.	0.06	4G	20
33002-A	7.	0.08	6G	14
33002-B	7.	0.08	6G	14
33002-C	7.	0.08	6G	14
33002-D	7.	0.08	6G	14
33002-X	7.	0.08	6G	20
33002-Y	7.	0.08	6G	20
33003-A	7.	0.04	3G	14
33003-B	7.	0.04	3G	14
33003-C	7.	0.04	3G	14
33003-D	7.	0.04	3G	14
33003-X	7.	0.04	3G	20
33003-Y	7.	0.04	3G	20
33004-A	7.	0.03	2G	14
33004-B	7.	0.03	2G	14
33004-C	7.	0.03	2G	14
33004-D	7.	0.03	2G	14

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
ASTTL				
33004-X	7.	0.03	2G	20
33004-Y	7.	0.03	2G	20
LSTTL				
33106-E	7.	0.15	36G	16
33106-F	7.	0.15	36G	16
33107-E	7.	0.10	24G	16
33107-F	7.	0.10	24G	16
ASTTL				
33201-R	7.	0.41	10G	20
33201-S	7.	0.41	10G	20
33202-R	7.	0.50	10G	20
33202-S	7.	0.50	10G	20
33203-R	7.	0.50	10G	20
33203-S	7.	0.50	10G	20
33301-A	7.	0.07	4G	14
33301-B	7.	0.07	4G	14
33301-C	7.	0.07	4G	14
33301-D	7.	0.07	4G	14
33401-A	7.	0.03	5G	14
33401-B	7.	0.03	5G	14
33401-C	7.	0.03	5G	14
33401-D	7.	0.03	5G	14
33501-A	7.	0.09	4G	14
33501-B	7.	0.09	4G	14
33501-C	7.	0.09	4G	14
33501-D	7.	0.09	4G	14
33601-E	7.	0.25	47G	16
33601-F	7.	0.25	47G	16
33901-E	7.	0.12	17G	16
33901-F	7.	0.12	17G	16
33902-E	7.	0.11	16G	16
33902-F	7.	0.11	16G	16
33903-E	7.	0.13	19G	16
33903-F	7.	0.13	19G	16
33904-E	7.	0.08	15G	16
33904-F	7.	0.08	15G	16
33905-E	7.	0.13	17G	16
ASTTL				
33905-F	7.	0.13	17G	16
33906-E	7.	0.13	15G	16
33906-F	7.	0.13	15G	16
33907-E	7.	0.14	15G	16
33907-F	7.	0.14	15G	16
33908-E	7.	0.12	16G	16
33908-F	7.	0.12	16G	16
34001-A	7.	0.07	4G	14
34001-B	7.	0.07	4G	14
34001-C	7.	0.07	4G	14
34001-D	7.	0.07	4G	14
34002-A	7.	0.05	3G	14
34002-B	7.	0.05	3G	14
34002-C	7.	0.05	3G	14
34002-D	7.	0.05	3G	14
34101-A	7.	0.09	12G	14
34101-B	7.	0.09	12G	14
34101-C	7.	0.09	12G	14
34101-D	7.	0.09	12G	14
34102-E	7.	0.09	16G	16
34102-F	7.	0.09	16G	16
34103-E	7.	0.11	16G	16
34103-F	7.	0.11	16G	16
34501-A	7.	0.15	4G	14
34501-B	7.	0.15	4G	14
34501-C	7.	0.15	4G	14
34501-D	7.	0.15	4G	14
34501-X	7.	0.15	4G	20
34701-R	7.	0.18	26G	20
34701-S	7.	0.18	26G	20
LSTTL				
36001-E	7.	0.11	29G	16
36001-F	7.	0.11	29G	16
36002-E	7.	0.14	30G	16
36002-F	7.	0.14	30G	16
ALSTTL				
37001-A	7.	0.07	4G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
ALSTTL				
37001-B	7.	0.07	4G	14
37001-C	7.	0.07	4G	14
37001-D	7.	0.07	4G	14
37002-A	7.	0.04	3G	14
37002-B	7.	0.04	3G	14
37002-C	7.	0.04	3G	14
37002-D	7.	0.04	3G	14
37003-A	7.	0.02	2G	14
37003-B	7.	0.02	2G	14
37003-C	7.	0.02	2G	14
37003-D	7.	0.02	2G	14
37004-A	7.	0.00	1G	14
37004-B	7.	0.00	1G	14
37004-C	7.	0.00	1G	14
37004-D	7.	0.00	1G	14
37005-E	7.	0.00	1G	16
37005-F	7.	0.00	1G	16
37006-A	7.	0.14	6G	14
37006-B	7.	0.14	6G	14
37006-C	7.	0.14	6G	14
37006-D	7.	0.14	6G	14
37101-A	7.	0.01	6G	14
37101-B	7.	0.01	6G	14
37101-C	7.	0.01	6G	14
37101-D	7.	0.01	6G	14
37102-E	7.	0.01	8G	16
37102-F	7.	0.01	8G	16
37103-E	7.	0.01	8G	16
37103-F	7.	0.01	8G	16
37104-R	7.	0.02	42G	20
37104-S	7.	0.02	42G	20
37105-R	7.	0.02	42G	20
37105-S	7.	0.02	42G	20
37106-L	7.	0.02	62G	24
37106-K	7.	0.02	62G	24
37107-L	7.	0.02	62G	24
37107-K	7.	0.02	62G	24
37301-A	7.	0.09	4G	14
37301-B	7.	0.09	4G	14
37301-C	7.	0.09	4G	14
37301-D	7.	0.09	4G	14
ALSTTL				
37302-A	7.	0.07	3G	14
37302-B	7.	0.07	3G	14
37302-C	7.	0.07	3G	14
37302-D	7.	0.07	3G	14
37401-A	7.	0.09	4G	14
37401-B	7.	0.09	4G	14
37401-C	7.	0.09	4G	14
37401-D	7.	0.09	4G	14
37402-A	7.	0.04	3G	14
37402-B	7.	0.04	3G	14
37402-C	7.	0.04	3G	14
37402-D	7.	0.04	3G	14
37501-A	7.	0.11	4G	14
37501-B	7.	0.11	4G	14
37501-C	7.	0.11	4G	14
37501-D	7.	0.11	4G	14
37701-E	7.	0.06	16G	16
37701-F	7.	0.06	16G	16
37901-K	7.	0.20	44G	24
37901-L	7.	0.20	44G	24
38301-R	7.	0.14	10G	20
38301-S	7.	0.14	10G	20
38302-R	7.	0.17	10G	20
38302-S	7.	0.17	10G	20
38303-R	7.	0.17	10G	20
38303-S	7.	0.17	10G	20
38401-A	7.	0.03	4G	14
38401-B	7.	0.03	4G	14
38401-C	7.	0.03	4G	14
38401-D	7.	0.03	4G	14
38402-A	7.	0.04	4G	14
38402-B	7.	0.04	4G	14
38402-C	7.	0.04	4G	14
38402-D	7.	0.04	4G	14
38403-A	7.	0.03	4G	14
38403-B	7.	0.03	4G	14
38403-C	7.	0.03	4G	14
38403-D	7.	0.03	4G	14
38404-A	7.	0.04	4G	14
38404-B	7.	0.04	4G	14
38404-C	7.	0.04	4G	14

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TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
ALSTTL				
38404-D	7.	0.04	4G	14
38405-A	7.	0.03	3G	14
38405-B	7.	0.03	3G	14
38405-C	7.	0.03	3G	14
38405-D	7.	0.03	3G	14
38406-A	7.	0.03	3G	14
38406-B	7.	0.03	3G	14
38406-C	7.	0.03	3G	14
38406-D	7.	0.03	3G	14
38407-A	7.	0.02	2G	14
38407-B	7.	0.02	2G	14
38407-C	7.	0.02	2G	14
38407-D	7.	0.02	2G	14
38408-A	7.	0.06	4G	14
38408-B	7.	0.06	4G	14
38408-C	7.	0.06	4G	14
38408-D	7.	0.06	4G	14
38409-A	7.	0.07	6G	14
38409-B	7.	0.07	6G	14
38409-C	7.	0.07	6G	14
38409-D	7.	0.07	6G	14
38410-A	7.	0.07	6G	14
38410-B	7.	0.07	6G	14
38410-C	7.	0.07	6G	14
38410-D	7.	0.07	6G	14
38411-A	7.	0.08	6G	14
38411-B	7.	0.08	6G	14
38411-C	7.	0.08	6G	14
38411-D	7.	0.08	6G	14
38412-A	7.	0.08	6G	14
38412-B	7.	0.08	6G	14
38412-C	7.	0.08	6G	14
38412-D	7.	0.08	6G	14
38501-R	7.	0.26	18G	20
38501-S	7.	0.26	18G	20
38502-R	7.	0.25	18G	20
38502-S	7.	0.25	18G	20
38503-R	7.	0.15	18G	20
38503-S	7.	0.15	18G	20
38504-R	7.	0.29	18G	20
28504-S	7.	0.29	18G	20

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
ALSTTL				
38505-R	7.	0.35	18G	20
38505-S	7.	0.35	18G	20
38506-C	7.	0.18	10G	14
38506-D	7.	0.18	10G	14
38507-C	7.	0.18	10G	14
38507-D	7.	0.18	10G	14
NMOS				
40001-Q	7.	1.00	1300G	40
40201-J	7.	1.00	1024G	24
40301-J	7.	1.00	16384G	24
42001-Q	20.	1.70	1100G	40
STTL				
42101-J	7.	0.80	70G	24
42101-K	7.	0.80	70G	24
42101-L	7.	0.80	70G	24
42201-E	7.	0.79	70G	16
NMOS				
42301-Z	7.	1.20	120G	28
LSTTL				
44001-Q	7.	1.60	537G	40
44001-Z	7.	1.60	537G	42
44101-T	7.	1.00	77G	24
44101-Z	7.	1.00	77G	24
44102-J	7.	1.00	85G	24
44102-Z	7.	1.00	85G	24
44103-R	7.	1.00	77G	20
44103-S	7.	1.00	77G	20
44104-J	7.	1.00	77G	24
44104-Z	7.	1.00	77G	24
44105-J	7.	1.00	85G	24
44105-Z	7.	1.00	85G	24
44106-R	7.	1.00	77G	20
44106-S	7.	1.00	77G	20

TABLE 5.1.2.7-18: MICROELECTRONIC PARAMETERS (CONT'D)

M38510/ XXXXXXX	Vcc (V.)	Pd (W.)	Complexity	Np
LSTTL				
44201-E	7.	0.83	24G	16
44201-F	7.	0.83	24G	16
IIL				
46001-Y	6.	0.75	3100G	64
CMOS				
47001-Q	11.	0.50	1375G	40
47201-J	11.	0.50	4096G	24
47201-K	11.	0.50	4096G	24
47401-E	11.	0.50	27G	16
47401-F	11.	0.50	27G	16
NMOS				
48001-Q	5.	1.00	2833G	40
48002-Q	5.	1.00	2833G	40
48003-Q	5.	1.00	2833G	40
STTL				
50301-R	12.	2.00	34G	20
50301-Y	12.	2.00	34G	20
50203-R	12.	2.00	36G	20
50302-Y	12.	2.00	36G	20
50303-R	12.	2.00	34G	20
50303-Y	12.	2.00	34G	20
50304-R	12.	2.00	34G	20
50304-Y	12.	2.00	34G	20
50305-R	12.	2.00	35G	20
50305-Y	12.	2.00	35G	20
50306-R	12.	2.00	34G	20
50306-Y	12.	2.00	34G	20
50307-R	12.	2.00	34G	20
50307-Y	12.	2.00	34G	20
50308-R	12.	2.00	34G	20
50208-Y	12.	2.00	34G	20
50309-R	12.	2.00	34G	20
50309-Y	12.	2.00	34G	20
STTL				
50401-R	12.	0.10	98G	20
50401-Y	12.	0.10	98G	20
50407-R	12.	0.10	98G	20
50407-Y	12.	0.10	98G	20
50501-L	12.	1.20	100G	24
50501-3	12.	1.20	100G	28
NMOS				
52001-Q	7.	2.20	5833G	40
52001-X	7.	2.20	5833G	48
52002-Q	7.	2.20	5833G	40
52002-X	7.	2.20	5833G	48
52003-Q	7.	2.20	5833G	40
52003-X	7.	2.20	5833G	48
52004-Q	7.	2.20	5833G	40
52004-X	7.	2.20	5833G	48
CMOS				
65001-C	7.	0.30	4G	14
65001-2	7.	0.30	4G	20
65002-C	7.	0.30	3G	14
65002-2	7.	0.30	3G	20
65003-C	7.	0.30	2G	14
65003-2	7.	0.30	2G	20
65004-C	7.	0.30	1G	14
65004-2	7.	0.30	1G	20
65005-C	7.	0.30	4G	14
65005-2	7.	0.30	4G	20

5.1.2.8 Example Failure Rate Calculations for Monolithic Devices.

Example One

Description: An 8192 bit N-channel MOS UVEPROM in a Ground, Fixed application, junction temperature of 55°C, procured to vendor equivalent B-2 quality level. The production line has been in continuous production. The device is a ceramic/metal DIP, solder seal hermetic package with 24 pins.

From Section 5.1.2.5, the operating failure rate model is:

$$\lambda_p = \pi_Q(C_1\pi_T\pi_V + C_2\pi_E)\pi_L$$

Section 5.1.2.5	C_1 for 8192 bits = 0.06
Table 5.1.2.7-1	Quality Level B-2: $\pi_Q = 5.0$
Table 5.1.2.7-3	Ground, Fixed Environment: $\pi_E = 2.5$
Table 5.1.2.7-4	NMOS, Hermetic Package, corresponding to π_T Table 5.1.2.7-7: $\pi_T = 0.59$
Table 5.1.2.7-14	$\pi_V = 1.0$
Table 5.1.2.7-16	24 pin Hermetic DIP solder seal: $C_2 = 0.009$
Table 5.1.2.7-2	$\pi_L = 1$

$$\lambda_p = 5.0\left[(0.06 \times 0.59 \times 1.0) + (0.009 \times 2.5)\right] 1.0$$

$$\lambda_p = 0.29 \text{ failures}/10^6 \text{ hours.}$$

Example Two

Description: Device type 54170 is being used in an airborne inhabited, trainer environment. The device is procured as quality level B-2 and has been in continuous production. The device is in a 16 pin, glass seal hermetic C-DIP package. The device has a worst case power dissipation of 0.77 watts.

The type number shows that the device is included in MIL-M-38510, described in slash sheet 18, type 01. The device is fabricated using TTL digital bipolar technology.

Table 5.1.2.7-19 shows a 100 gate complexity for this device. Since the device complexity is equal to 100 gates, the model in Section 5.1.2.1 applies:

$$\lambda_p = \pi_Q(C_1\pi_T\pi_V + C_2\pi_E)\pi_L$$

Table 5.1.2.7-1	Quality Level B-2: $\pi_Q = 5.0$
Table 5.1.2.7-3	Airborne Inhabited, Trainer Environment: $\pi_E = 3.0$
Table 5.1.2.7-4	TTL, Hermetic Package, corresponding to π_T Table 5.1.2.7-5: $T_C = 60^\circ C$ $T_J = T_C + \theta_{JC}P = 60 + 50(0.77) = 99^\circ C$
Table 5.1.2.7-5	$\pi_T = 2.2$
Table 5.1.2.7-14	$\pi_V = 1.0$
Section 5.1.2.1	For 1 to 1,000 gate complexity: $C_1 = 0.02$
Table 5.1.2.7-16	16 pin hermetic DIP, glass seal: $C_2 = 0.0059$
Table 5.1.2.7-2	$\pi_L = 1.0$

$$\lambda_p = 5.0 \left[(0.02 \times 2.2 \times 1.0) + (0.0059 \times 3.0)\right] 1.0$$

$$\lambda_p = 0.31 \text{ failures}/10^6 \text{ hours.}$$

Example Three

Consider a Zilog Z80, 8 bit microprocessor in a 40 pin ceramic DIP with a metal lid. The device is installed in an airborne uninhabited trainer equipment and is operating at a case temperature of 95°C. The device has been screened to full MIL-M-38510 Class B requirements. It dissipates 0.500 watts and has a case to junction thermal resistance of 40°C/watt.

The microprocessor has been fabricated using NMOS technology.

From Section 5.1.2.3

$$\lambda_p = \pi_Q(C_1\pi_T\pi_V + C_2\pi_E)\pi_L$$

Section 5.1.2.3	For 8 bit device: $C_1 = 0.03$
Table 5.1.2.7-1	$\pi_Q = 1.0$
Table 5.1.2.7-2	$\pi_L = 1.0$ since the Z80 is a mature part
	$T_J = T_C + \theta_{JC}P = 95 + 40(.5) = 115^0$
Table 5.1.2.7-7	For 115°C $\pi_T = 9.1$
Table 5.1.2.7-3	$\pi_E = 4.0$
Table 5.1.2.7-16	$C_2 = 0.015$
Table 5.1.2.7-14	π_V for V_{CC} of 5.V = 1.0

$$\lambda_p = 1.0\ [(0.03 \times 9.1 \times 1.0) + (0.015 \times 4.0)]\ 1.0$$

$$\lambda_p = 0.33 \text{ failures}/10^6 \text{ hours}$$

5.1.2.9 Hybrid Microcircuit.

The hybrid failure rate model is:

$$\lambda_p = \left\{\Sigma N_C\,\lambda_C\,\pi_G + \left[N_R\,\lambda_R + \Sigma N_I\,\lambda_I + \lambda_S\right]\pi_F\,\pi_E\right\}\pi_Q\,\pi_D$$

(failures/10^6 hour)

where:

$\Sigma N_C \lambda_C \pi_G$	is the sum of the adjusted failure rates for the active components, packaged resistors, and capacitors in the hybrid from Section 5.1.2.9.1
N_C	is the number of each particular component
λ_C	is the component failure rate
π_G	is the die correction factor Table 5.1.2.9-1
$N_R \lambda_R$	is the number of (N_R) and failure rate contribution (λ_R) of the chip or substrate resistors (Section 5.1.2.9.2)
$\Sigma N_I \lambda_I$	is the sum of the failure rate contributions of the interconnections (λ_I) from Section 5.1.2.9.3.
λ_S	is the failure rate contribution of the hybrid package. (Table 5.1.2.9-4).
π_E	is the environmental factor for the film resistors, interconnections and package from Table 5.1.2.9-5.
π_Q	is the quality factor from Table 5.1.2.9-6.
π_D	is the density factor from Table 5.1.2.9-7.
π_F	is the circuit function factor = 1.0 for digital hybrids = 1.25 for linear or linear-digital combinations

5.1.2.9.1 Active Components and Capacitors. The sum of the adjusted failure rates for the active components and capacitors shall be calculated as follows:

N_C is the number of each particular component

λ_C is the failure rate contribution for a particular component predicted using the correct model from the following sections in this handbook:

Integrated Circuits	Section 5.1.2
Discrete Semiconductors	Section 5.1.3
Packaged Resistors	Section 5.1.6
Capacitor	Section 5.1.7

When calculating λ_C for integrated circuits, use quality factor "B" and hermetic temperature factor "π_T." For discrete semiconductors, use quality factor "JANTXV." For capacitors and resistors, use quality factor level "M." Use the environmental factor corresponding to the application environment of the hybrid, and assume a component ambient temperature equal to the temperature of the hybrid package.

If the maximum rated stress for a die is unknown, it shall be assumed to be the same as that for a discretely packaged die of the same type. If the same die has several ratings based on the discrete package type, the lower value will be assumed. Power rating used should be based on case temperature for discrete semiconductors.

π_G adjusts the calculated discrete component failure rate to a transistor or diode die or capacitor chip failure rate. For packaged components, and IC dice, $\pi_G = 1$. Also, for IC dice let $C_2 = 0$ when calculating λ_C per the models in Section 5.1.2.

TABLE 5.1.2.9-1
DIE AND CAPACITOR CHIP CORRECTION FACTORS

Component	π_G
Integrated Circuits	1.0
Transistors	.4
Diodes	.2
Capacitor Chips	.8

5.1.2.9.2 Chip and Substrate Resistors. The failure rate contribution of the chip or substrate resistors used in the hybrid (either on chips or directly on the substrate) is calculated as the product:

$N_R \lambda_R$

Where:

N_R is the number of chip or substrate resistors

λ_R is the failure rate of the chip or substrate resistors and is:

TABLE 5.1.2.9-2

BASE FAILURE RATES FOR CHIP OR SUBSTRATE RESISTORS

.00010	for $T \leq 50^oC$
.00015	for $50 < T \leq 80^oC$
.0002	for $80 < T \leq 100^oC$
.00025	for $100 < T \leq 125^oC$
.0003	for $125 < T \leq 150^oC$

Where T is the hybrid package temperature.

5.1.2.9.3 Interconnections. The failure contribution of the interconnections is the product:

$N_I \lambda_I$

Where:

N_I	is the number of interconnections
λ_I	is the temperature dependent failure rate for the interconnections from Table 5.1.2.9-3.

Interconnections, as defined for this model are counted as one for every wire. Each beam lead or solder bump shall also be counted as one interconnection.

Only active (current carrying) interconnections shall be counted

A bond is considered bimetallic if any one of the bond interfaces involves more than one type of metal

Active die attach bonds (die to substrate bonds) are not counted as interconnections

Redundant interconnections shall be counted as only one interconnection

If an accurate count of the actual interconnections cannot be obtained, the following approximations may be made:

Component	Number of Interconnections
Each IC Chip Bonding Pad	1
Each Transistor	2
Each Diode	1
Each Capacitor	2
Each External Lead	1
Each Chip Resistor	2

TABLE 5.1.2.9-3

INTERCONNECTIONS FAILURE RATE (λ_I)

TEMPERATURE (C)*	λ_{I1}	λ_{I2}
25.	0.000174	0.000174
30.	0.000230	0.000218
35.	0.000302	0.000271
40.	0.000394	0.000334
45.	0.000508	0.000410
50.	0.000650	0.000499
55.	0.000826	0.000604
60.	0.00104	0.000727
65.	0.00130	0.000871
70.	0.00162	0.00103
75.	0.00201	0.00123
80.	0.00247	0.00145
85.	0.00302	0.00170
90.	0.00367	0.00199
95.	0.00444	0.00231
100.	0.00534	0.00268
105.	0.00639	0.00310
110.	0.00762	0.00356
115.	0.00904	0.00409
120.	0.0106	0.00467
125.	0.0125	0.00531
130.	0.0147	0.00603
135.	0.0171	0.00682
140.	0.0199	0.00770
145.	0.0231	0.00866
150.	0.0266	0.00971

* Hybrid package temperature

λ_{I1} is for bimetal bonds (Gold-Aluminum)

λ_{I2} is for single metal bonds (Aluminum-Aluminum, Gold-Gold, etc) or solder

$$\lambda_{I1} = .000174e^{\left[(-5075)\left(\frac{1}{T+273} - \frac{1}{298}\right)\right]} \text{ for } T \leq 150^{o}\text{C}.$$

(cont'd on next page)

$$\lambda_{I2} = .000174e^{\left[(-4056)\left(\frac{1}{T+273} - \frac{1}{298}\right)\right]}$$

T = package temperature (^{o}C.)

If metal system is unknown, assume worst case (λ_{I1}).

TABLE 5.1.2.9-4
PACKAGE FAILURE RATE (λ_S)*

S	25C 70C	30C 80C	35C 90C	40C 100C	45C 110C	50C 120C	55C 130C	60C 140C	65C 150C
1.75	0.0011	0.0015	0.0020	0.0026	0.0034	0.0044	0.0056	0.0072	0.0090
	0.0113	0.0174	0.0261	0.0383	0.0551	0.0778	0.1081	0.1478	0.1990
2.00	0.0017	0.0023	0.0030	0.0039	0.0051	0.0065	0.0084	0.0106	0.0134
	0.0167	0.0257	0.0385	0.0566	0.0815	0.1151	0.1599	0.2186	0.2944
2.25	0.0024	0.0032	0.0042	0.0055	0.0071	0.0092	0.0118	0.0149	0.0188
	0.0235	0.0362	0.0543	0.0798	0.1148	0.1622	0.2253	0.3079	0.4148
2.50	0.0032	0.0043	0.0057	0.0075	0.0097	0.0125	0.0160	0.0202	0.0255
	0.0319	0.0491	0.0736	0.1081	0.1556	0.2199	0.3054	0.4175	0.5624
2.75	0.0042	0.0057	0.0075	0.0098	0.0127	0.0164	0.0210	0.0266	0.0335
	0.0420	0.0645	0.0968	0.1421	0.2045	0.2890	0.4014	0.5487	0.7390
3.00	0.0054	0.0073	0.0096	0.0126	0.0163	0.0210	0.0268	0.0341	0.0429
	0.0537	0.0825	0.1239	0.1819	0.2618	0.3700	0.5138	0.7024	0.9461
3.25	0.0068	0.0091	0.0120	0.0157	0.0204	0.0263	0.0336	0.0427	0.0537
	0.0673	0.1034	0.1551	0.2278	0.3279	0.4633	0.6435	0.8797	1.1848
3.50	0.0084	0.0112	0.0147	0.0193	0.0251	0.0323	0.0413	0.0524	0.0660
	0.0827	0.1270	0.1906	0.2800	0.4030	0.5694	0.7908	1.0810	1.4560
3.75	0.0101	0.0135	0.0178	0.0233	0.0303	0.0391	0.0499	0.0634	0.0798
	0.0999	0.1536	0.2305	0.3384	0.4871	0.6883	0.9559	1.3067	1.7600
4.00	0.0120	0.0161	0.0212	0.0278	0.0361	0.0465	0.0595	0.0755	0.0951
	0.1191	0.1830	0.2746	0.4032	0.5804	0.8201	1.1390	1.5569	2.0971
4.50	0.0165	0.0220	0.0291	0.0381	0.0494	0.0637	0.0814	0.1033	0.1301
	0.1629	0.2503	0.3757	0.5517	0.7940	1.1219	1.5582	2.1300	2.8690
5.00	0.0216	0.0289	0.0381	0.0500	0.0649	0.0836	0.1069	0.1356	0.1708
	0.2138	0.3286	0.4932	0.7242	1.0424	1.4728	2.0456	2.7963	3.7663
5.50	0.0275	0.0366	0.0484	0.0634	0.0823	0.1061	0.1356	0.1721	0.2168
	0.2713	0.4170	0.6258	0.9191	1.3228	1.8691	2.5959	3.5485	4.7795
6.00	0.0339	0.0452	0.0597	0.0782	0.1016	0.1308	0.1673	0.2122	0.2674
	0.3347	0.5143	0.7720	1.1336	1.6317	2.3054	3.2020	4.3770	5.8954
6.50	0.0408	0.0544	0.0719	0.0942	0.1223	0.1575	0.2014	0.2555	0.3220
	0.4030	0.6193	0.9295	1.3650	1.9646	2.7759	3.8554	5.2702	7.0985
7.00	0.0481	0.0642	0.0848	0.1111	0.1442	0.1858	0.2375	0.3014	0.3797
	0.4753	0.7304	1.0962	1.6097	2.3170	3.2737	4.5468	6.2153	8.3714
7.50	0.0557	0.0743	0.0982	0.1286	0.1671	0.2152	0.2751	0.3491	0.4398
	0.5505	0.8460	1.2697	1.8646	2.6838	3.7920	5.2666	7.1993	9.6968
8.00	0.0635	0.0847	0.1120	0.1467	0.1905	0.2454	0.3137	0.3981	0.5016
	0.6277	0.9647	1.4478	2.1262	3.0603	4.3239	6.0055	8.2093	11.0572

$$* \lambda_S = \left[0.011S\ 1-e^{-(S^2/50)}\right] e \left[-5203\left(\frac{1}{T+273} - \frac{1}{298}\right)\right]$$

T = Package Temperature (°C)

S = Seal Perimeter (inches)

MICROELECTRONIC DEVICES

HYBRID

TABLE 5.1.2.9-5: ENVIRONMENTAL FACTOR FOR RESISTORS, INTERCONNECTIONS AND PACKAGES

ENVIRON-MENT	π_E
G_B	0.20
G_{MS}	0.27
G_F	0.78
G_M	2.2
M_P	2.0
N_{SB}	1.0
N_S	1.7
N_U	3.2
N_H	3.1
N_{UU}	3.4
A_{RW}	4.5
A_{IC}	1.5
A_{IT}	1.5

ENVIRON-MENT	π_E
A_{IB}	2.5
A_{IA}	2.0
A_{IF}	3.0
A_{UC}	2.5
A_{UT}	2.5
A_{UB}	4.0
A_{UA}	3.0
A_{UF}	4.0
S_F	0.32
M_{FF}	2.1
M_{FA}	2.9
U_{SL}	6.1
M_L	7.0
C_L	120.

5.1.2.9.4 Substrates and Metallization.

5.1.2.9.4.1 Hermetic Packages Enclosing More Than One Substrate. Each substrate shall be treated as a separate hybrid. Each substrate shall include its own density and function factor; however, only the largest substrate (area) or the substrate mounted on or serving as the package header (if all are of equal size) shall include a package factor. The hybrid failure rate will be the sum of the failure rates for the individual substrates.

5.1.2.9.4.2 Multilayered Metallization. The model is valid for up to seven layers of metallization.

MICROELECTRONIC DEVICES

HYBRID

TABLE 5.1.2.9-6: π_Q, Quality Factors

QUALITY LEVEL	DESCRIPTION	π_Q
S	Procured to the Class S requirements of MIL-STD-883, Method 5008, and MIL-M-38510 and Appendix G thereto (or MIL-STD-883, Methods 5004 and 5005 and MIL-M-38510) and listed in the MIL-M-38510 QML Supplement for Hybrid Microcircuits.	.25
S-1	Procured in full compliance with the requirements of MIL-STD-975 or MIL-STD-1547 and have procuring activity specification approval.	.4
B	Procured to the Class B requirements of MIL-STD-883, Method 5008, and MIL-M-38510 and Appendix G thereto (or MIL-STD-883, Methods 5004 and 5005 and MIL-M-38510) and listed in the MIL-M-38510 QML Supplement for Hybrid Microcircuits.	.5
B-1	Procured to the Class B requirements of MIL-STD-883, Method 5008, and MIL-M-38510 and Appendix G thereto (or MIL-STD-883, Methods 5004 and 5005 and MIL-M-38510). Includes MIL Drawing, DESC Drawing or other government approved documentation.	1.0
D	Hermetically sealed parts with manufacturer's normal reliability screening and quality assurance practices.	20.0

MICROELECTRONIC DEVICES

HYBRID

TABLE 5.1.2.9-7: DENSITY FACTOR (π_D)

$$\text{Density} = \frac{\text{Number of Interconnections}}{(A_S + .10)}$$

A_S = area of substrate (sq. inches)

$\pi_D = .2 + .15\ (\sqrt{\text{Density}}\ )$

Density	π_D	Density	π_D
15.	0.78	160.	2.10
20.	0.87	165.	2.13
25.	0.95	170.	2.16
30.	1.02	175.	2.18
35.	1.09	180.	2.21
40.	1.15	185.	2.24
45.	1.21	190.	2.27
50.	1.26	195.	2.29
55.	1.31	200.	2.32
60.	1.36	205.	2.35
65.	1.41	210.	2.37
70.	1.45	215.	2.40
75.	1.50	220.	2.42
80.	1.54	225.	2.45
85.	1.58	230.	2.47
90.	1.62	235.	2.50
95.	1.66	240.	2.52
100.	1.70	245.	2.55
105.	1.74	250.	2.57
110.	1.77	255.	2.60
115.	1.81	260.	2.62
120.	1.84	265.	2.64
125.	1.88	270.	2.66
130.	1.91	275.	2.69
135.	1.94	280.	2.71
140.	1.97	285.	2.73
145.	2.01	290.	2.75
150.	2.04	295.	2.78
155.	2.07	300.	2.80

NOTE: The density term is intended as a measure of the mechanical complexity of the hybrid as a whole.

5.1.2.9.5 Prediction Example for Hybrid Microcircuits.

Microcircuit Description - Driver

Package:	Hermetic Flatpack 1.15 x .95 in. seal, .75 x .75 in. substrate
Interconnections:	34 Gold-Aluminum, 4 solder
Active Components:	1 - LM106 1 - μA741 2 - Si NPN Transistor, 60% stress ratio (power and voltage), linear application < 1 watt. 2 - Si PNP Transistor, 60% stress ratio (power and voltage), linear application < 1 watt. 2 - Si General Purpose Diode, 60% stress ratio (power and voltage), small signal, metallurgically bonded.
Passive Components:	2 - Ceramic Chip Capacitors, 60% stress ratio, 1000 pf. 17 - Thick Film Resistors
Environment:	Naval Unsheltered, 65°C package temperature

Screened to MIL-STD-883, Method 5008, in accordance with Appendix G to MIL-M-38510, not listed in QML. From Table 5.1.2.9-6, $\pi_Q = 1.0$

Example Calculation:

$$\lambda_p = \left\{\Sigma N_C \lambda_C \pi_G + \left[N_R \lambda_R + \Sigma N_I \lambda_I + \lambda_S\right] \pi_F \pi_E\right\} \pi_Q \pi_D$$

Failure Rates for Components ($\lambda_C \pi_G$):

LM106 die, 13 transistors, page 5.1.2.2-1:

$$\pi_Q \left[C_1 \pi_T \pi_V + C_2 \pi_E\right] \pi_L \times \pi_G$$

$$1.0 \left[(0.01 \times 8.3 \times 1.0) + (0 \times 5.7)\right] 1 \times 1 = 0.08$$

μA741 die, 23 transistors, page 5.1.2.2-1 (same model as LM106 above):

$$1.0 \left[(0.01 \times 9.2 \times 1.0) + (0 \times 5.7)\right] 1 \times 1 = 0.09$$

Si NPN transistor die, 60% stress ratio, page 5.1.3.1-1:

$$\lambda_b \; (\pi_E \pi_A \pi_Q \pi_R \pi_{S2} \pi_C) \; \pi_G$$

$$(.0029)\ 21\ (1.5)\ 0.12\ (1.0)\ 0.88\ (1.0)\ 0.4 = 0.0039$$

Si PNP transistor die, 60% stress ratio, page 5.1.3.1-1 (same model as NPN transistor above):

$$(.0049)\ 21\ (1.5)\ 0.12\ (1.0)\ 0.88\ (1.0)\ 0.4 = 0.0065$$

Si general purpose diode die, 60% stress ratio, page 5.1.3.4-1:

$$\lambda_b \; (\pi_E \pi_Q \pi_R \pi_A \pi_{S2} \pi_C) \; \pi_G$$

$$(.0019)\ 21\ (.15)\ 1.0\ (1.0)\ 0.7\ (1.0)\ .2 = 0.0008$$

Ceramic chip capacitor, 60% stress ratio, 1000 pf., page 5.1.7.4-1:

$$\lambda_b \; (\pi_E \pi_Q \pi_{CV}) \; \pi_G$$

$$(.0063)\ 12.4\ (1.0)\ 1.0\ (.8) = 0.06$$

Thick film resistor, Table 5.1.2.9-2:

.00015

Package, Table 5.1.2.9-4, seal perimeter = 4.2 in.

$\lambda_S = .108$

Interconnection, Table 5.1.2.9-3:

Au-Al: .00130
Solder: .000871

$\pi_E = 3.2$, Table 5.1.2.9-5

$\pi_Q = 1.0$, Table 5.1.2.9-6

Density = 38/(.563 + .10) = 57.3

$\pi_D = 1.34$, Table 5.1.2.9-7

$\pi_F = 1.25$ (for linear application, page 5.1.2.9-1)

$$\lambda_p = \{.08 + .09 + 2\ (.0039) + 2\ (.0065) + 2\ (.0008) + 2\ (.06) + [17(.00015) + 34\ (.00130) + 4\ (.00087) + .108]\ (1.25)\ 3.2\}\ 1.0\ (1.34)$$

$\lambda_p = 1.3$ failures/10^6 hours.

MICROELECTRONIC DEVICES

BUBBLE MEMORIES

5.1.2.10 Magnetic Bubble Memories*. The magnetic bubble memory device in its present form is a non-hermetic assembly of two major structural segments:

a. A basic bubble chip or die consisting of a memory or a storage area (e.g., an array of minor loops), and required control and detection elements (e.g., generators, various gates and detectors), and,

b. A magnetic structure to provide controlled magnetic fields consisting of permanent magnets, coils, and a housing.

These two structural segments of the device are interconnected by a mechanical substrate and lead frame. The interconnect substrate in the present technology is normally a printed circuit board. It should be noted that this model does not include external support microelectronic devices required for magnetic bubble memory operation. The general form of the operating failure rate model is:

$$\lambda_p = \lambda_1 + \lambda_2$$

where:

λ_p = operating failure rate in failures/10^6 hrs.

λ_1 = failure rate of the control and detection structure.

λ_2 = failure rate of the memory storage area.

*See Bibliography Item No. 60

5.1.2.10.1 Failure Rate of the Control and Detection Structure (λ_1).

The expansion of λ_1 is:

$$\lambda_1 = \pi_Q\left[N_C C_{11}\pi_{T1}\pi_W + (N_C C_{21}+C_2)\pi_E\right]\pi_D\pi_L$$

where:

π_Q = quality factor, Table 5.1.2.7-1

N_C = number of bubble chips per packaged device

C_{11} & C_{21} = device complexity failure rates for the control and detection elements, Table 5.1.2.10-1

C_2 = package complexity failure rate, Table 5.1.2.7-16

π_{T1} = temperature acceleration factor. Use the values in Table 5.1.2.7-12. Use $T_J = T_{CASE} + 10$ (all in ^oC.)

π_W = write duty cycle factor, Table 5.1.2.10-4

π_E = application environment factor Table 5.1.2.7-3

π_D = duty cycle factor, Table 5.1.2.10-3

π_L = device learning factor, Table 5.1.2.7-2. Because this is a relatively new technology, justification should be given for use of $\pi_L = 1$.

5.1.2.10.2 Failure Rate of the Memory Storage Area (λ_2).

The expansion of λ_2 is:

$$\lambda_2 = \pi_Q N_C(C_{12}\pi_{T2} + C_{22}\pi_E)\pi_L$$

where:

π_Q = quality factor, Table 5.1.2.7-1

N_C = number of bubble chips per packaged device

C_{12} & C_{22} = device complexity failure rates Table 5.1.2.10-2.

π_{T2} = temperature acceleration factor. Use the values in Table 5.1.2.7-8. Use $T_J = T_{CASE} + 10$ (all in ^oC.)

π_E = application environment factor, Table 5.1.2.7-3

π_L = device learning factor, Table 5.1.2.7-2. Because this is a relatively new technology, justification should be given for use of $\pi_L = 1$.

TABLE 5.1.2.10-1: C_{11} & C_{21}, DEVICE COMPLEXITY FAILURE RATES FOR CONTROL & DETECTION STRUCTURE IN MAGNETIC BUBBLE DEVICES IN FAILURES PER 10^6 HOURS.

N_1	C_{11}	C_{21}	N_1	C_{11}	C_{21}
4	.0017	.00014	500	.011	.00041
50	.0045	.00024	550	.012	.00042
100	.0060	.00028	600	.012	.00042
150	.0070	.00031	650	.013	.00043
200	.0079	.00033	700	.013	.00044
250	.0086	.00035	750	.013	.00045
300	.0093	.00036	800	.014	.00046
350	.0099	.00038	850	.014	.00046
400	.010	.00039	900	.014	.00047
450	.011	.00040	950	.015	.00047
			1000	.015	.00048

Tabulated values are determined from the following equations:

$$C_{11} = .00095(N_1)^{.40} \; \& \; C_{21} = .0001\,(N_1)^{.226}$$

where:

N_1 = the number of dissipative elements on a chip (gates, detectors, generators, etc.) and is ≤ 1000.

MICROELECTRONIC DEVICES

BUBBLE MEMORIES

TABLE 5.1.2.10-2: C_{12} & C_{22} DEVICE COMPLEXITY FAILURE RATES FOR MEMORY STORAGE STRUCTURE FOR MAGNETIC BUBBLE DEVICES IN FAILURES PER 10^6 HOURS.

NO. BITS IN (10^3)	C_{12}	C_{22}	NO. BITS IN $(10)^3$	C_{12}	C_{22}
66	.0020	.00028	1049	.0045	.00064
92	.0022	.00031	2097	.0055	.00079
131	.0024	.00035	4194	.0068	.00097
262	.0030	.00042	8389	.0084	.0012
524	.0036	.00052			

Tabulated values are determined from the following equations:

$$C_{12} = .00007\ (N_2)^{.3} \ \& \ C_{22} = .00001\ (N_2)^{.3}$$

where:

N_2 = the number of bits and is $\leq 9\ (10)^6$.

TABLE 5.1.2.10-3: π_D, DUTY CYCLE FACTOR, FOR MAGNETIC BUBBLE DEVICES

D*	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
π_D	.10	.19	.28	.37	.46	.55	.64	.73	.82	.91	1.0

* - The tabulated values are determined from

$$\pi_D = .9D + 0.1 \text{ for } 0 \leq D \leq 1.0$$

D is the device duty cycle and is application dependent. It is a function of the usage the bubble device experiences during the time the power is applied to the equipment using the device.

$$D = \frac{\text{Average device data rate for the application}}{\text{manufacturer's maximum rated data-rate}} \leq 1.$$

where: the application data rate is averaged over the time that the power is applied to the using equipment.

TABLE 5.1.2.10-4. π_W, WRITE-DUTY CYCLE FACTOR FOR MAGNETIC BUBBLE DEVICES.

D	R/W				
	1	10	100	1000	>2154
1.0	10	5.0	2.5	1.3	1
.9	9.1	4.6	2.4	1.2	1
.8	8.2	4.2	2.2	1.2	1
.7	7.3	3.8	2.1	1.2	1
.6	6.4	3.4	1.9	1.2	1
.5	5.5	3.0	1.8	1.1	1
.4	4.6	2.6	1.6	1.1	1
.3	3.7	2.2	1.5	1.1	1
.2	2.8	1.8	1.3	1	1
.1	1.9	1.4	1.2	1	1
.05	1.5	1.2	1.1	1	1
<.03	1	1	1	1	1

Tabulated values are determined from the following equations:

$$\pi_W = \left(D \frac{10}{(R/W)^{.3}} - 1 \right) + 1 \quad \text{for } 1 \leq R/W < 2154$$

$$= 1 \text{ for } R/W < 1 \text{ and } R/W \geq 2154$$

where:

R/W = no. of reads per write

D = device duty cycle (see footnote in Table 5.1.2.10-3)

For seed-bubble generator use table value divided by 4, or use 1, whichever is greater.

5.1.2.10.3 Example Failure Rate Calculations.

Example One: Find the operating failure rate for a single chip 92K bit magnetic bubble memory, $40^{o}C$. case temperature, ground benign environment. The device has a 14-pin nonhermetic DIP enclosure with 10 pins connected, 1 major loop, 3 dissipative control elements (generate, replicate and detector bridge), and 144 transfer gates. Device has been in continuous production and is used at D = 1.0 and R/W = 10.

For control and detection structure, Section 5.1.2.10.1,

$$\lambda_1 = \pi_Q \left[N_C C_{11} \pi_{T1} \pi_W + (N_C C_{21} + C_2)\pi_E\right] \pi_D \pi_L$$

Table 5.1.2.7-1	Quality level D-1, $\pi_Q = 20$
Section 5.1.2.10.1	$N_C = 1$
Table 5.1.2.10-1	N_1 = 1 major loop + 3 dissipative elements + 144 gates = 148, $C_{11} = .007$, $C_{21} = .00031$
Table 5.1.2.7-12	$T_J = 40 + 10 = 50^{o}C.$, $\pi_{T1} = 1.1$
Table 5.1.2.10-4	D = 1, R/W = 10; $\pi_W = 5$
Table 5.1.2.7-16	Nonhermetic, 10 pins, $C_2 = .0034$
Table 5.1.2.7-3	For G_B, $\pi_E = .38$
Table 5.1.2.10-3	D = 1, $\pi_D = 1$
Table 5.1.2.7-2	$\pi_L = 1$

$$\lambda_1 = 20\left\{\left[(1)(.007)(1.1)(5)\right] + \left[(1)(.00031) + .0034\right](.38)\right\}(1)(1)$$

$$= 20\ (.0385 + .0014)$$

$= .80$ failures/10^6 hours.

MICROELECTRONIC DEVICES

BUBBLE MEMORIES

For magnetic storage area, Section 5.1.2.10.2,

$$\lambda_2 = \pi_Q N_C (C_{12}\pi_{T2} + C_{22}\pi_E)\pi_L$$

Table 5.1.2.7-1 Quality level D-1, $\pi_Q = 20$

Section 5.1.2.10.1 $N_C = 1$

Table 5.1.2.10-2 No. of bits = 92,000,

$C_{12} = .0022$, $C_{22} = .00031$

Table 5.1.2.7-8 $T_J = 40 + 10 = 50^\circ C.$, $\pi_{T2} = .53$

Table 5.1.2.7-3 For G_B, $\pi_E = .38$

Table 5.1.2.7-2 $\pi_L = 1$

$$\lambda_2 = (20)(1)\left[(.0022)(.53) + (.00031)(.38)\right](1)$$

$$= 20\left[.001166 + .0001178\right]$$

$$= .026 \text{ failures}/10^6 \text{ hours.}$$

From Section 5.1.2.10,

$$\lambda_p = \lambda_1 + \lambda_2$$

$$= .80 + .026$$

$$= .83 \text{ failures}/10^6 \text{ hours.}$$

Example Two: Find the operating failure rate for a single chip 1 megabit magnetic bubble memory at 40°C. case temperature in a benign ground environment. The device has 2 generators, 8 detector elements, 512 replicate/swap gates, 4 boot loop gates and is contained in a nonhermetic DIP with 19 pins connected. The applicationrequires 10 reads per write and a data rate equal to the maximum rated value of 100kHz. The device uses a seed generator and is in early production.

For control and detection structure, Section 5.1.2.10.1,

$$\lambda_1 = \pi_Q \left[N_C C_{11} \pi_{T1} \pi_W + (N_C C_{21} + C_2)\ \pi_E\right] \pi_D \pi_L$$

Table 5.1.2.7-1 Quality level D-1, $\pi_Q = 20$

Section 5.1.2.10.1 $N_C = 1$

Table 5.1.2.10-1 N_1 = 2 generators + 8 detector elements + 512 replicate/swap gates + 4 boot loop gates = 526

$C_{11} = .012 \qquad C_{21} = .00041$

Table 5.1.2.7-12 $T_J = 40 + 10 = 50^\circ C.$, $\pi_{T1} = 1.1$

Table 5.1.2.10-4 $D = 100kHz./100kHz. = 1$, $R/W = 10$

$\pi_W = 5/4 = 1.25$ for seed bubble generator.,

Table 5.1.2.7-16 Nonhermetic, 19 pins, $C_2 = .0075$

Table 5.1.2.7-3 For G_B, $\pi_E = .38$

Table 5.1.2.10-3 $D = 1$, $\pi_D = 1$

Table 5.1.2.7-2 Early production, $\pi_L = 10$

$$\lambda_1 = 20 \left\{\left[(1)(.012)(1.1)(1.25)\right] + \left[(1)(.00041) + .0075\right] (.38)\right\} (1)(10)$$

$$= 20\ (.0165 + .003)\ 10$$

$$= 3.9 \text{ failures}/10^6 \text{ hours.}$$

For magnetic storage area, section 5.1.2.10.2,

$$\lambda_2 = \pi_Q N_C (C_{12}\pi_{T2} + C_{22}\pi_E)\pi_L$$

Table 5.1.2.7-1 Quality level D-1, $\pi_Q = 20$

Section 5.1.2.10.1 $N_C = 1$

Table 5.1.2.10-2 No. of bits = $1049(10)^3$,

$C_{12} = .0045$, $C_{22} = .00064$

Table 5.1.2.7-8 $T_J = 40 + 10 = 50^\circ C.$, $\pi_{T2} = .53$

Table 5.1.2.7-3 For G_B, $\pi_E = .38$

Table 5.1.2.7-2 Early production, $\pi_L = 10$

$$\lambda_2 = (20)(1)\left[(.0045)(.53) + (.00064)(.38)\right](10)$$

$$= 20\ (.002385 + .000243)10$$

$= .53$ failures/10^6 hours.

From Section 5.1.2.10,

$$\lambda_p = \lambda_1 + \lambda_2$$

$$= 3.9 + .53$$

$= 4.4$ failures/10^6 hours.

SURFACE ACOUSTIC WAVE DEVICES

5.1.2.11 Surface Acoustic Wave (SAW) Devices. The part operating failure rate model (λ_p) is:

$$\lambda_p = 2.1\pi_Q\pi_E \text{ failures}/10^6 \text{ hours.}$$

where:

π_E = environmental factor (Table 5.1.2.11-1)

π_Q = 0.1 for high quality part, subjected to 10 temperature cycles, (-55°C to 125°C) with end point electrical test

π_Q = 1.0 commercial part

TABLE 5.1.2.11-1: ENVIRONMENTAL MODE FACTOR

ENVIRON-MENT	π_E	ENVIRON-MENT	π_E
G_B	1.0	A_{IB}	13.0
G_{MS}	1.4	A_{IA}	10.0
G_F	3.9	A_{IF}	15.0
G_M	11.0	A_{UC}	13.0
M_P	10.0	A_{UT}	10.0
N_{SB}	5.0	A_{UB}	20.0
N_S	8.5	A_{UA}	15.0
N_U	16.0	A_{UF}	20.0
N_H	16.0	S_F	1.6
N_{UU}	17.0	M_{FF}	11.0
A_{RW}	23.0	M_{FA}	15.0
A_{IC}	7.5	U_{SL}	31.0
A_{IT}	7.5	M_L	35.0
		C_L	600.0

DISCRETE SEMICONDUCTORS

5.1.3 Discrete Semiconductors. The semiconductor transistor and diode sections present the failure rates on the basis of ambient or case temperature and includes the effect of various quality grades and adjustment factors on the failure rate. An analytical model of the failure rate is also presented.

The applicable MIL specification for transistors and diodes is MIL-S-19500. The quality levels (JAN, JANTX, JANTXV) are as defined in MIL-S-19500.

The general failure rate model for transistors and diodes is:

$$\lambda_p = \lambda_b \; (\pi_E \times \pi_A \times \pi_Q \times \pi_R \times \pi_{S2} \times \pi_C) \text{ failures}/10^6 \text{ hours}$$

where the various factors are defined in Section 5.1.1.

The various types of semiconductors require different failure rate models that vary to some degree from the basic model. The semiconductor generic groups are shown in Table 5.1.3-1. The specific failure rate model and the π factor values for each group are shown in the section dealing with that group.

TABLE 5.1.3.-1: DISCRETE SEMICONDUCTOR GENERIC GROUPS

Part Type		Group
A. Transistors		
Silicon NPN Silicon PNP	Germanium PNP Germanium NPN	I
Field Effect Transistors		II
Unijunction		III
B. Diodes and Rectifiers		
Silicon (General)	Germanium (General)	IV
Voltage Regulator (Zener, Avalanche) Voltage Reference (Temp. Comp., Zener, Avalanche)		V
Thyristors (Silicon Control Rectifiers)		VI
C. Microwave Semiconductors and Special Devices		
Detectors	Mixers	VII
Varactors, IMPATT, GUNN, Step Recovery, Tunnel, PIN		VIII
Microwave Transistors		IX
D. Opto-Electronic Devices		X
E. Semiconductor Laser Devices		XI

The equation for the base failure rate, λ_b, is:

$$\lambda_b = Ae^x$$

where:

$$x \text{ is } \left(\frac{N_T}{273 + T + (\Delta T)S}\right) + \left(\frac{273 + T + (\Delta T)S}{T_M}\right)^P$$

A is a failure rate scaling factor.

e is the natural logarithm base, 2.718.

N_T, T_M and P are shaping parameters.

T is the operating temperature in degrees C, ambient or case, as applicable (see Section 5.1.3.11 for instructions)

ΔT is the difference between typical maximum allowable temperature with no junction current or power (total derating) and the typical maximum allowable temperature with full rated junction current or power.

S is the stress ratio of operating electrical stress to rated electrical stress (see Section 5.1.3.11 for S calculation).

The values for the constant parameters are shown in Table 5.1.3-2. The resulting base failure rates as functions of temperature and electrical stress are shown in tables for each part type in Sections 5.1.3.1 through 5.1.3.8. These tables are based on the typical maximum junction temperatures (fuly derated) of 100 degrees C for germanium (70 degrees C for microwave types), and 175 degrees C for silicon (150 degrees C for microwave types) devices as well as a value of 25 degrees C for the maximum temperature at which full rated operation is permitted. If device temperature ratings are different from these values, see Section 5.1.3.11 for S and T corrections to compensate for these differences. The values of ΔT for the device types stated above remain constant regardless of the values of T_S and T_{MAX}.

The base failure rate tables contain failure rates up to full rated conditions. If a particular operating condition of S and T is high enough to fall into a blank portion of the table, the device is over-stressed and should not be used.

TABLE 5.1.3-2: DISCRETE SEMICONDUCTOR BASE FAILURE RATE PARAMETERS

Group	Part Type	λ_b Constants				ΔT
		A	N_T	T_M	P	
Transistors						
I	Si, NPN	0.0189	-1052	448	10.5	150
	Si, PNP	0.0648	-1324	448	14.2	150
	Ge, PNP	6.5	-2142	373	20.8	75
	Ge, NPN	21	-2221	373	19	75
II	FET	0.52	-1162	448	13.8	150
III	Unijunction	3.12	-1779	448	13.8	150
Diodes						
IV	Si, Gen. Purp.	0.172	-2138	448	17.7	150
	Ge, Gen. Purp.	126	-3568	373	22.5	75
V	Zener/Avalanche	0.0068	-800	448	14	150
VI	Thyristors	0.82	-2050	448	9.6	150
VII	Microwave					
	Ge, Detectors	0.33	-477	343	15.6	45
	Si, Detectors	0.14	-392	423	16.6	125
	Si, Schottky Det.	0.005	-392	423	16.6	125
	Ge, Mixers	0.56	-477	343	15.6	45
	Si, Mixers	0.19	-394	423	15.6	125
VIII	Varactor, PIN, Step Recovery & Tunnel	0.93	-1164	448	13.8	150
	IMPATT, Gunn	See Section 5.1.3.8				
Transistors IX	Microwave	See Section 5.1.3.9				
Opto-Electronic X	LED's, Isolators and Displays	See Section 5.1.3.10				
XI	AlGaAs DH Stripe GaAs SH Stripe InGaAs/InGaASP DH Stripe	See Section 5.1.3.11				

5.1.3.1 Transistors, Group I

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Si, NPN Si, PNP Ge, PNP Ge, NPN

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_A \times \pi_Q \times \pi_R \times \pi_{S2} \times \pi_C) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.3.1-1 through 5.1.3.1-10.

TABLE 5.1.3.1-1: GROUP I TRANSISTORS ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	35
G_{MS}	1.6	A_{IA}	20
G_F	5.8	A_{IF}	40
G_M	18	A_{UC}	15
M_P	12	A_{UT}	25
N_{SB}	9.8	A_{UB}	60
N_S	9.8	A_{UA}	35
N_U	21	A_{UF}	65
N_H	19	S_F	0.4
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	9.5	U_{SL}	36
A_{IT}	15	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

CONVENTIONAL TRANSISTORS

TABLE 5.1.3.1-2: π_A FOR GROUP I TRANSISTORS

Application	π_A
Linear	1.5
Switch	0.7
Si, low noise r.f., <1W.	15.0

TABLE 5.1.3.1-3: π_Q FOR GROUP I TRANSISTORS

Quality Level	π_Q
JANTXV	0.12
JANTX	0.24
JAN	1.2
Lower*	6.0
Plastic**	12.0

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.

TABLE 5.1.3.1-4: π_R FOR GROUP I TRANSISTORS

Power Rating (watts)	π_R
$\leq$ 1 1	
> 1 to 5	1.5
> 5 to 20	2.0
> 20 to 50	2.5
> 50 to 200	5.0

DISCRETE SEMICONDUCTORS

CONVENTIONAL TRANSISTORS

TABLE 5.1.3.1-5: π_{S2} FOR GROUP I TRANSISTORS

Voltage Stress, $S_2 = \dfrac{\text{Applied } (V_{CE})}{\text{Rated } (V_{CEO})} \times 100$

S_2 (percent)	π_{S2}*
100	3.0
90	2.2
80	1.62
70	1.2
60	0.88
50	0.65
40	0.48
30	0.35
20	0.30
10	0.30
0	0.30

* $\pi_{S2} = 0.14(10)^{(.0133)S_2}$ for $S_2 \geq 25$

$\pi_{S2} = 0.3$ for $S_2 < 25$

TABLE 5.1.3.1-6: π_C FOR GROUP I TRANSISTORS

Complexity (1)	π_C
Single Transistor	1.0
Dual (Unmatched)	0.7
Dual (Matched)	1.2
Darlington	0.8
Dual Emitter	1.1
Multiple Emitter	1.2
Complementary Pair	0.7

(1) Each transistor in a case must be treated individually for complexity factor. Its failure rate, λ_b, modified by other π factors and then multiplied by this complexity factor. If only one transistor of a pair is used, treat as an independent item with π_C = 1.0.

DISCRETE SEMICONDUCTORS

CONVENTIONAL TRANSISTORS

TABLE 5.1.3.1-7: MIL-S-19500 TRANSISTORS, GROUP I, SILICON, NPN BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00049	.00060	.00071	.00084	.00099	.0012	.0014	.0017	.0021	.0027
10	.00056	.00067	.00079	.00093	.0011	.0013	.0016	.0019	.0025	.0034
20	.00063	.00075	.00089	.0010	.0012	.0015	.0018	.0023	.0030	.0043
30	.00071	.00084	.00099	.0012	.0014	.0017	.0021	.0027	.0038	
40	.00079	.00093	.0011	.0013	.0016	.0019	.0025	.0034	.0049	
50	.00089	.0010	.0012	.0015	.0018	.0023	.0030	.0043		
60	.00099	.0012	.0014	.0017	.0021	.0027	.0038			
70	.0011	.0013	.0016	.0019	.0025	.0034	.0049			
80	.0012	.0015	.0018	.0023	.0030	.0043				
90	.0014	.0017	.0021	.0027	.0038					
100	.0016	.0019	.0025	.0034	.0049					
110	.0018	.0023	.0030	.0043						
120	.0021	.0027	.0038							
130	.0025	.0034	.0049							
140	.0030	.0043								
150	.0038									
160	.0049									

DISCRETE SEMICONDUCTORS

CONVENTIONAL TRANSISTORS

TABLE 5.1.3.1-8: MIL-S-19500 TRANSISTORS, GROUP I, SILICON, PNP BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP (^oC)	POWER STRESS .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00065	.00082	.0010	.0012	.0015	.0018	.0021	.0026	.0033	.0044
10	.00076	.00095	.0012	.0014	.0017	.0020	.0024	.0030	.0040	.0056
20	.00088	.0011	.0013	.0016	.0019	.0023	.0028	.0036	.0050	.0077
30	.0010	.0012	.0015	.0018	.0021	.0026	.0033	.0044	.0065	
40	.0012	.0014	.0017	.0020	.0024	.0030	.0040	.0056	.0092	
50	.0013	.0016	.0019	.0023	.0028	.0036	.0050	.0077		
60	.0015	.0018	.0021	.0026	.0033	.0044	.0065			
70	.0017	.0020	.0024	.0030	.0040	.0056	.0092			
80	.0019	.0023	.0028	.0036	.0050	.0077				
90	.0021	.0026	.0033	.0044	.0065					
100	.0024	.0030	.0040	.0056	.0092					
110	.0028	.0036	.0050	.0077						
120	.0033	.0044	.0065							
130	.0040	.0056	.0092							
140	.0050	.0077								
150	.0065									
160	.0092									

TABLE 5.1.3.1-9: MIL-S-19500 TRANSISTORS, GROUP I, GERMANIUM, PNP BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0031	.0038	.0047	.0056	.0067	.0080	.0096	.011	.014	.017
10	.0041	.0050	.0060	.0071	.0085	.010	.012	.015	.019	.025
20	.0053	.0063	.0075	.0090	.011	.013	.016	.021	.028	.041
30	.0067	.0080	.0096	.011	.014	.017	.023	.031	.048	
40	.0085	.010	.012	.015	.019	.025	.036	.057		
50	.011	.013	.016	.021	.028	.041				
60	.014	.017	.023	.031	.048					
70	.019	.025	.036	.057						
80	.028	.041								
90	.048									

TABLE 5.1.3.1-10: MIL-S-19500 TRANSISTORS, GROUP I, GERMANIUM, NPN BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0077	.0095	.012	.014	.017	.020	.025	.030	.037	.046
10	.010	.012	.015	.018	.022	.026	.032	.040	.051	.067
20	.013	.016	.019	.023	.028	.034	.043	.055	.075	.11
30	.017	.020	.025	.030	.037	.046	.061	.084	.13	
40	.022	.026	.032	.040	.051	.067	.095	.15		
50	.028	.034	.043	.055	.075	.11				
60	.037	.046	.061	.084	.13					
70	.051	.067	.095	.15						
80	.075	.11								
90	.13									

5.1.3.2 Transistors, Group II

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Silicon Field Effect Transistors, Gallium Arsenide FET

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_A \times \pi_Q \times \pi_C) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.3.2-1 through 5.1.3.2-5.

TABLE 5.1.3.2-1: GROUP II TRANSISTORS ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	35
G_{MS}	1.4	A_{IA}	30
G_F	4.0	A_{IF}	40
G_M	18	A_{UC}	10
M_P	12	A_{UT}	15
N_{SB}	6	A_{UB}	55
N_S	8.6	A_{UA}	50
N_U	21	A_{UF}	65
N_H	19	S_F	0.6
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	7.5	U_{SL}	36
A_{IT}	9	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

FET

TABLE 5.1.3.2-2: π_A FOR GROUP II TRANSISTORS

Application	π_A
Silicon	
Linear	1.5
Switch	0.7
High Frequency (>400 HMz & aver power <300 mW)	5.0
GaAs	
Low Noise	0.7
Driver ($\leq$100 mW)	50.0

TABLE 5.1.3.2-3: π_C FOR GROUP II TRANSISTORS

Complexity	π_C
Single Device	1.0
Dual Unmatched	0.7
Dual Matched	1.2
Dual Complementary	0.7
Tetrode	1.1

TABLE 5.1.3.2-4: π_Q FOR GROUP II TRANSISTORS

Quality Level	π_Q
Silicon	
JANTXV	0.12
JANTX	0.24
JAN	1.2
Lower*	6.0
Plastic**	12.0
GaAs***	.24

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.
***Must be burned-in for 168 hours at 125°C case temperature.

FET

TABLE 5.1.3.2-5: MIL-S-19500 TRANSISTORS, GROUP II, FET BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(^oC)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0092	.011	.014	.016	.019	.022	.026	.032	.040	.052
10	.011	.013	.015	.018	.021	.025	.030	.037	.047	.066
20	.012	.014	.017	.020	.024	.028	.034	.043	.059	.089
30	.014	.016	.019	.022	.026	.032	.040	.052	.076	
40	.015	.018	.021	.025	.030	.037	.047	.066	.11	
50	.017	.020	.024	.028	.034	.043	.059	.089		
60	.019	.022	.026	.032	.040	.052	.076			
70	.021	.025	.030	.037	.047	.066	.11			
80	.024	.028	.034	.043	.059	.089				
90	.026	.032	.040	.052	.076					
100	.030	.037	.047	.066	.11					
110	.034	.043	.059	.089						
120	.040	.052	.076							
130	.047	.066	.11							
140	.059	.089								
150	.076									
160	.11									

5.1.3.3 Transistors, Group III

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Unijunction

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_E \times \pi_Q \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.3.3-1 through 5.1.3.3-3.

TABLE 5.1.3.3-1: GROUP II TRANSISTORS ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	35
G_{MS}	1.4	A_{IA}	20
G_F	4	A_{IF}	40
G_M	18	A_{UC}	15
M_P	12	A_{UT}	25
N_{SB}	9.3	A_{UB}	60
N_S	9.3	A_{UA}	35
N_U	21	A_{UF}	65
N_H	19	S_F	1
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	9.5	U_{SL}	36
A_{IT}	15	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

UNIJUNCTION

TABLE 5.1.3.3-2: π_Q FOR GROUP III TRANSISTORS

Quality Level	π_Q
JANTXV	0.5
JANTX	1.0
JAN	5.0
Lower*	25.0
Plastic**	50.0

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.

TABLE 5.1.3.3-3: MIL-S-19500 TRANSISTORS, GROUP III, UNIJUNCTION BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0065	.0088	.012	.105	.019	.025	.031	.040	.052	.073
10	.0080	.011	.014	.018	.023	.029	.037	.048	.065	.096
20	.0097	.013	.016	.021	.027	.034	.043	.058	.083	.13
30	.012	.015	.019	.025	.031	.040	.052	.073	.11	
40	.014	.018	.023	.029	.037	.048	.065	.096	.16	
50	.016	.021	.027	.034	.043	.058	.083	.13		
60	.019	.025	.031	.040	.052	.073	.11			
70	.023	.029	.037	.048	.065	.096	.16			
80	.027	.034	.043	.058	.083	.13				
90	.031	.040	.052	.073	.11					
100	.037	.048	.065	.096	.16					
110	.043	.058	.083	.13						
120	.052	.073	.11							
130	.065	.096	.16							
140	.083	.13								
150	.11									
160	.16									

5.1.3.4 Diodes, Group IV

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Silicon, General Purpose Germanium, General Purpose

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_R \times \pi_A \times \pi_{S2} \times \pi_C) \text{ failures/}10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.3.4-1 through 5.1.3.4-8.

TABLE 5.1.3.4-1: GROUP IV TRANSISTORS ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	30
G_{MS}	1.4	A_{IA}	25
G_F	3.9	A_{IF}	35
G_M	18	A_{UC}	25
M_P	12	A_{UT}	30
N_{SB}	4.8	A_{UB}	50
N_S	4.8	A_{UA}	40
N_U	21	A_{UF}	50
N_H	19	S_F	1
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	15	U_{SL}	36
A_{IT}	20	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

DIODES, GENERAL PURPOSE

TABLE 5.1.3.4-2: π_Q FOR GROUP IV DIODES

Quality Level	π_Q
JANTXV	0.15
JANTX	0.3
JAN	1.5
Lower*	7.5
Plastic**	15.0

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.

TABLE 5.1.3.4-3: π_R FOR GROUP IV DIODES

Current Rating (amps)	π_R
$\leq$ 1	1
> 1 to 3	1.5
> 3 to 10	2.0
> 10 to 20	4.0
> 20 to 50	10.0

TABLE 5.1.3.4-4: π_A FOR GROUP IV DIODES

Application	π_A
Analog Circuits (<500 ma)	1.0
Switching (<500 ma)	0.6
Power Rectifier ($\geq$ 500 ma)	1.5
Power Rectifier (HV stacks) V max >600	2.5/junction

TABLE 5.1.3.4-5: π_{S2} FOR GROUP IV DIODES

$$\text{Voltage Stress, } S_2 = \frac{\text{Applied } (V_R)}{\text{Rated } (V_R)} \times 100$$

V_R = diode reverse voltage

S_2 (Percent)	π_{S2}
0 to 60	0.70
>60 to 70	0.75
>70 to 80	0.80
>80 to 90	0.90
>90 to 100	1.0

TABLE 5.1.3.4-6: π_C CONSTRUCTION FACTOR

Contact Construction	π_C
Metallurgically Bonded	1
Non-metallurgically Bonded (spring loaded contacts)	2

DISCRETE SEMICONDUCTORS

DIODES, GENERAL PURPOSE

TABLE 5.1.3.4-7: MIL-S-19500 DIODES, GROUP IV, SILICON BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	CURRENT STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00010	.00015	.00021	.00028	.00037	.00049	.00063	.00082	.0011	.0016
10	.00013	.00019	.00025	.00034	.00045	.00058	.00075	.0010	.0014	.0021
20	.00017	.00023	.00031	.00041	.00053	.00069	.00090	.0012	.0018	.0031
30	.00021	.00028	.00037	.00049	.00063	.00082	.0011	.0016	.0026	
40	.00025	.00034	.00045	.00058	.00075	.0010	.0014	.0021	.0040	
50	.00031	.00041	.00053	.00069	.00090	.0012	.0018	.0031		
60	.00037	.00049	.00063	.00082	.0011	.0016	.0026			
70	.00045	.00058	.00075	.0010	.0014	.0021	.0040			
80	.00053	.00069	.00090	.0012	.0018	.0031				
90	.00063	.00082	.0011	.0016	.0026					
100	.00075	.0010	.0014	.0021	.0040					
110	.00090	.0012	.0018	.0031						
120	.0011	.0016	.0026							
130	.0014	.0021	.0040							
140	.0018	.0031								
150	.0026									
160	.0040									

DISCRETE SEMICONDUCTORS

DIODES, GENERAL PURPOSE

TABLE 5.1.3.4-8: MIL-S-19500 DIODES, GROUP IV, GERMANIUM BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	CURRENT STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00038	.00053	.00072	.00098	.0013	.0017	.0023	.0030	.0040	.0055
10	.00059	.00080	.0011	.0014	.0019	.0025	.0033	.0045	.0061	.0088
20	.00089	.0012	.0016	.0021	.0028	.0037	.0049	.0069	.010	.016
30	.0013	.0017	.0023	.0030	.0040	.0055	.0077	.012	.020	
40	.0019	.0025	.0033	.0045	.0061	.0088	.014	.024		
50	.0028	.0037	.0049	.0069	.010	.016				
60	.0040	.0055	.0077	.012	.020					
70	.0061	.0088	.014	.024						
80	.010	.016								
90	.020									

5.1.3.5 Diodes, Group V

SPECIFICATION	STYLE	DESCRIPTION
MIL-STD-19500		Voltage Regulator and Voltage Reference (Avalanche and ZENER)

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \; (\pi_E \times \pi_A \times \pi_Q)$ failures/10^6 hours

For λ_b see pages 5.1.3-2 and 5.1.3-3. The other factors are shown in Tables 5.1.3.5-1 through 5.1.3.5-4.

TABLE 5.1.3.5-1: GROUP V DIODES ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	45
G_{MS}	1.4	A_{IA}	25
G_F	3.9	A_{IF}	45
G_M	18	A_{UC}	7.5
M_P	12	A_{UT}	10
N_{SB}	5.8	A_{UB}	70
N_S	8.7	A_{UA}	40
N_U	21	A_{UF}	70
N_H	19	S_F	1
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	4.5	U_{SL}	36
A_{IT}	6.5	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

ZENER AND AVALANCHE DIODES

TABLE 5.1.3.5-2: π_A FOR GROUP V DIODES

Application	π_A
Voltage Regulator	1.0
Voltage Reference (Temp Compensated)	1.5

TABLE 5.1.3.5-3: π_Q FOR GROUP V DIODES

Quality Level	π_Q
JANTXV	0.3
JANTX	0.6
JAN	3.0
Lower*	15.0
Plastic**	30.0

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.

TABLE 5.1.3.5-4: MIL-S-19500 ZENER DIODES, GROUP V, BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00042	.00049	.00055	.00063	.00070	.00079	.00090	.0010	.0013	.0016
10	.00047	.00053	.00060	.00068	.00076	.00086	.00099	.0012	.0015	.0020
20	.00051	.00058	.00065	.00073	.00082	.00094	.0011	.0013	.0018	.0026
30	.00055	.00063	.00070	.00079	.00090	.0010	.0013	.0016	.0023	
40	.00060	.00068	.00076	.00086	.00099	.0012	.0015	.0020	.0031	
50	.00065	.00073	.00082	.00094	.0011	.0013	.0018	.0026		
60	.00070	.00079	.00090	.0010	.0013	.0016	.0023			
70	.00076	.00086	.00099	.0012	.0015	.0020	.0031			
80	.00082	.00094	.0011	.0013	.0018	.0026				
90	.00090	.0010	.0013	.0016	.0023					
100	.00099	.0012	.0015	.0020	.0031					
110	.0011	.0013	.0018	.0026						
120	.0013	.0016	.0023							
130	.0015	.0020	.0031							
140	.0018	.0026								
150	.0023									
160	.0031									

5.1.3.6 Diodes, Group VI

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Thyristors Silicon Control Rectifier

Part oprating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_Q \times \pi_E \times \pi_R \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.3.6-1 through 5.1.3.6-4.

TABLE 5.1.3.6-1: GROUP VI DIODES ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	35
G_{MS}	1.4	A_{IA}	20
G_F	3.9	A_{IF}	40
G_M	18	A_{UC}	15
M_P	12	A_{UT}	25
N_{SB}	5.8	A_{UB}	60
N_S	8.7	A_{UA}	35
N_U	21	A_{UF}	65
N_H	19	S_F	1
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	9.5	U_{SL}	36
A_{IT}	15	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

THYRISTOR

TABLE 5.1.3.6-2: π_Q FOR GROUP VI DIODES

Quality Level	π_Q
JANTXV	0.5
JANTX	1.0
JAN	5.0
Lower*	25.0
Plastic**	50.0

*Hermetic packaged devices.
**Devices sealed or encapsulated with organic materials.

TABLE 5.1.3.6-3: π_R FOR GROUP VI THYRISTORS

Rated Average Forward Anode Current (amps)	λ_R
$\leq$ 1	1
> 1 to 5	3
> 5 to 25	10
> 25 to 50	15

DISCRETE SEMICONDUCTORS

THYRISTOR

TABLE 5.1.3.6-4: MIL-S-19500 DIODES, GROUP VI, THYRISTORS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP (°C)	POWER STRESS									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00067	.00097	.0013	.0018	.0025	.0033	.0044	.0059	.0081	.011
10	.00086	.0012	.0017	.0022	.0030	.0040	.0054	.0073	.010	.015
20	.0011	.0015	.0020	.0027	.0036	.0048	.0066	.0091	.013	.020
30	.0013	.0018	.0025	.0033	.0044	.0059	.0081	.011	.017	
40	.0017	.0022	.0030	.0040	.0054	.0073	.010	.015	.023	
50	.0020	.0027	.0036	.0048	.0066	.0091	.013	.020		
60	.0025	.0033	.0044	.0059	.0081	.011	.017			
70	.0030	.0040	.0054	.0073	.010	.015	.023			
80	.0036	.0048	.0066	.0091	.013	.020				
90	.0044	.0059	.0081	.011	.017					
100	.0054	.0073	.010	.015	.023					
110	.0066	.0091	.013	.020						
120	.0081	.011	.017							
130	.010	.015	.023							
140	.013	.020								
150	.017									
160	.023									

5.1.3.7 Diodes, Group VII

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Microwave Detectors and Mixers, Silicon and Germanium Silicon Schottky Detectors

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times \pi_E \times \pi_Q$ failures/10^6 hours

where the factors are shown in Tables 5.1.3.7-1 through 5.1.3.7-7.

TABLE 5.1.3.7-1: GROUP VII DIODES ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	65
G_{MS}	1.7	A_{IA}	50
G_F	6.4	A_{IF}	70
G_M	31	A_{UC}	50
M_P	35	A_{UT}	60
N_{SB}	8	A_{UB}	105
N_S	11	A_{UA}	80
N_U	33	A_{UF}	110
N_H	54	S_F	1
N_{UU}	58	M_{FF}	36
A_{RW}	78	M_{FA}	50
A_{IC}	30	U_{SL}	110
A_{IT}	40	M_L	120
		C_L	2,000

DISCRETE SEMICONDUCTORS

MICROWAVE DIODES

TABLE 5.1.3.7-2: π_Q FOR GROUP VII DIODES

Quality Level	π_Q
JANTXV	1.0
JANTX	2.0
JAN	3.5
Lower*	5.0

*Hermetic packaged devices.

DISCRETE SEMICONDUCTORS

MICROWAVE DIODES

TABLE 5.1.3.7-3: MIL-S-19500 DIODES, GROUP VII, SILICON MICROWAVE DETECTORS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.036	.038	.040	.042	.044	.047	.051	.055	.063	.075
10	.037	.039	.042	.044	.047	.050	.054	.061	.072	.093
20	.039	.041	.043	.046	.049	.053	.059	.069	.087	.12
20	.041	.043	.045	.048	.052	.058	.067	.083	.11	
40	.043	.045	.048	.051	.057	.065	.079	.11		
50	.044	.047	.051	.055	.063	.075	.099	.15		
60	.047	.050	.054	.061	.072	.093	.14			
70	.049	.053	.059	.069	.087	.12				
80	.052	.058	.067	.083	.11					
90	.057	.065	.079	.11						
100	.063	.075	.099	.15						
100	.072	.093	.14							
120	.087	.12								
130	.11									

TABLE 5.1.3.7-4: MIL-S-19500 DIODES, GROUP VII, GERMANIUM MICROWAVE DETECTORS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.061	.064	.066	.069	.072	.076	.081	.086	.092	.10
10	.067	.070	.073	.077	.082	.087	.094	.10	.11	.13
20	.074	.078	.083	.088	.095	.10	.12	.13	.15	.18
30	.084	.090	.097	.11	.12	.13	.16	.19		
40	.099	.11	.12	.14	.16	.19				
50	.13	.14	.17	.20						
60	.17	.21								

DISCRETE SEMICONDUCTORS

MICROWAVE DIODES

TABLE 5.1.3.7-5: MIL-S-19500 DIODES, GROUP VII, SILICON MICROWAVE MIXERS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.048	.051	.054	.057	.060	.064	.069	.076	.086	.10
10	.050	.053	.056	.060	.063	.068	.074	.084	.10	.13
20	.053	.056	.059	.063	.067	.073	.082	.096	.12	.17
30	.055	.058	.062	.066	.072	.080	.092	.11	.16	
40	.058	.061	.065	.070	.078	.089	.11	.15		
50	.060	.064	.069	.076	.086	.10	.14	.20		
60	.063	.068	.074	.084	.10	.13	.19			
70	.067	.073	.082	.096	.12	.17				
80	.072	.080	.092	.11	.16					
90	.078	.089	.11	.15						
100	.086	.10	.14	.20						
110	.10	.13	.19							
120	.12	.17								
130	.16									

TABLE 5.1.3.7-6: MIL-S-19500 DIODES, GROUP VII, GERMANIUM MICROWAVE MIXERS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.10	.11	.11	.12	.12	.13	.14	.15	.16	.17
10	.11	.12	.12	.13	.14	.15	.16	.17	.19	.22
20	.13	.13	.14	.15	.16	.18	.20	.22	.26	.30
30	.14	.15	.17	.18	.20	.23	.26	.32		
40	.17	.18	.21	.24	.27	.33				
50	.21	.24	.28	.34						
60	.30	.36								

DISCRETE SEMICONDUCTORS

MICROWAVE DIODES

TABLE 5.1.3.7-7: MIL-S-19500 DIODES, GROUP VII, SILICON SCHOTTKY DIODE DETECTORS BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP (°C)	POWER STRESS									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0013	.0013	.0014	.0015	.0016	.0017	.0018	.0020	.0022	.0027
10	.0013	.0014	.0015	.0016	.0017	.0018	.0019	.0022	.0026	.0033
20	.0014	.0015	.0016	.0016	.0018	.0019	.0021	.0025	.0031	.0044
30	.0015	.0015	.0016	.0017	.0019	.0021	.0024	.0030	.0041	
40	.0015	.0016	.0017	.0018	.0020	.0023	.0028	.0038		
50	.0016	.0017	.0018	.0020	.0022	.0027	.0035	.0054		
60	.0017	.0018	.0019	.0022	.0026	.0033	.0049			
70	.0018	.0019	.0021	.0025	.0031	.0044				
80	.0019	.0021	.0024	.0030	.0041					
90	.0020	.0023	.0028	.0038						
100	.0022	.0027	.0035	.0054						
110	.0026	.0033	.0049							
120	.0031	.0044								
130	.0041									

5.1.3.8 Diodes, Group VIII

SPECIFICATION	STYLE	DESCRIPTION
MIL-S-19500		Varactor, PIN, IMPATT Step Recovery, Tunnel & Gunn

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times \pi_E \times \pi_Q \times \pi_R \times \pi_A$ failures/10^6 hours

where: λ_b = 0.5 for IMPATT, 0.6 for Gunn, Table 5.1.3.8-5 for others and remaining factors are in Tables 5.1.3.8-1 through 5.1.3.8-4.

TABLE 5.1.3.8-1: GROUP VIII DIODES ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	45
G_{MS}	1.4	A_{IA}	25
G_F	3.9	A_{IF}	45
G_M	18	A_{UC}	7.5
M_P	12	A_{UT}	10
N_{SB}	5.8	A_{UB}	70
N_S	8.7	A_{UA}	40
N_U	21	A_{UF}	70
N_H	19	S_F	1
N_{UU}	20	M_{FF}	12
A_{RW}	27	M_{FA}	17
A_{IC}	4.5	U_{SL}	36
A_{IT}	6.5	M_L	41
		C_L	690

DISCRETE SEMICONDUCTORS

VARACTOR, STEP RECOVERY, TUNNEL

TABLE 5.1.3.8-2: π_Q FOR GROUP VIII DIODES

Quality Level	π_Q
GUNN & IMPATT	1.0
All other diodes	
JANTXV	0.5
JANTX	1.0
JAN	5.0
Lower*	25.0

*Hermetic packaged devices.

TABLE 5.1.3.8-3: π_R POWER RATING FACTOR

Power Rating	π_R
PIN Diodes	
$\leq$ 10W	0.5
$>$ 10W to 100W	*1.3
$>$ 100W to 1000W	*2.0
$>$ 1000W to 3000W	*2.4
All other Diodes	1.0

*π_R = .326(ln P) - .25 for $10 \leq P \leq 3000$W.

TABLE 5.1.3.8-4: π_A APPLICATION FACTOR

APPLICATION	π_A
Varactors	
Voltage Control	0.5
Multiplier	2.5
All other Diodes	1.0

TABLE 5.1.3.8-5: MIL-S-19500 DIODES, GROUP VIII VARACTORS, STEP RECOVERY, PIN & TUNNEL BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

TEMP	POWER STRESS									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.016	.020	.024	.029	.034	.040	.047	.057	.071	.094
10	.019	.023	.027	.032	.038	.045	.053	.066	.085	.12
20	.022	.026	.031	.036	.042	.050	.061	.077	.10	.16
30	.024	.029	.034	.040	.047	.057	.071	.094	.14	
40	.027	.032	.038	.045	.053	.066	.085	.12	.19	
50	.031	.036	.042	.050	.061	.077	.10	.16		
60	.034	.040	.047	.057	.071	.094	.14			
70	.038	.045	.053	.066	.085	.12	.19			
80	.042	.050	.061	.077	.10	.16				
90	.047	.057	.071	.094	.14					
100	.053	.066	.085	.12	.19					
110	.061	.077	.10	.16						
120	.071	.094	.14							
130	.085	.12	.19							
140	.10	.16								
150	.14									
160	.19									

5.1.3.9 Microwave Transistors, Group IX

SPECIFICATION	DESCRIPTION
MIL-S-19500	Bipolar microwave power transistor for frequencies above 200 MHz and average power $\geq$ 1 watt.

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_B \pi_Q \pi_A \pi_F \pi_T \pi_M \pi_E$$

where:

λ_B = 0.10 failure/10^6 hours

π_Q = quality factor, Table 5.1.3.9-1

π_A = application factor, Table 5.1.3.9-2

π_F = factor for frequency and peak operating power, Table 5.1.3.9-3

π_T = temperature factor, Table 5.1.3.9-4

π_M = matching network factor, Table 5.1.3.9-5

π_E = environmental factor, Table 5.1.3.9-6

See bibliography items 42-46 for the model background.

TABLE 5.1.3.9-1: π_Q QUALITY FACTOR FOR MICROWAVE TRANSISTORS

QUALITY LEVEL	π_Q*
JANTXV with IR scan for die attach and screen for barrier layer pin-holes on gold metallized devices	1
JANTX or Equivalent	2
JAN or Equivalent	4
Lower Quality	10

*These quality values apply to hermetically sealed devices only, and <u>do not</u> apply to devices sealed or encapsulated with orgranic materials.

DISCRETE SEMICONDUCTORS

MICROWAVE TRANSISTORS

TABLE 5.1.3.9-2: π_A APPLICATION FACTOR

APPLICATION	π_A
Pulse Amplifier, Duty Factor < 5%	1
Pulse Amplifier, Duty Factor $\geq$ 5%, $\leq$ 30%	2
Pulse Amplifier, Duty Factor > 30%	4
Continuous Wave	4
Oscillator	4

TABLE 5.1.3.9-3: π_F FACTOR FOR OPERATING POWER AND FREQUENCY

Freq. (GHz.)	PEAK OPERATING POWER (WATTS)							
	1 to 5	10	20	30	50	100	200	300
0.1 to 0.4	1	1	1	1	1	1	3	10
> 0.4 to 1.0	1.5	1.5	1.5	1.5	2	5	10	
> 1.0 to 1.5	1.5	1.5	1.5	1.5	3	10		
> 1.5 to 2.0	2.0	2.0	6.0	10	20			
> 2.0 to 3.0	4.0	8.0	20					
> 3.0 to 4.0	10.0	30						

DISCRETE SEMICONDUCTORS

MICROWAVE TRANSISTORS

TABLE 5.1.3.9-4: π_T TEMPERATURE FACTOR

(See Note Below)

T (^oC)	V_C/BV_{CES} for Aluminum				V_C/BV_{CES} for Refractory Metal-Gold			
	0.40	0.45	0.50	0.55	0.40	0.45	0.50	0.55
100	0.38	0.76	1.1	1.5	0.1	0.2	0.3	0.4
110	0.57	1.1	1.7	2.3	.14	.28	.42	.56
120	0.83	1.7	2.5	3.3	.18	.36	.54	.72
125	1.0	2.0	3.0	4.0	.20	.40	.60	.80
130	1.2	2.4	3.6	4.8	.22	.44	.66	.88
140	1.7	3.4	5.1	6.8	.26	.52	.78	1.0
150	2.4	4.7	7.1	9.4	.30	.60	.90	1.2
160	3.2	6.5	9.7	13.	.34	.68	1.0	1.4
170	4.4	8.7	13.	17.	.38	.76	1.1	1.5
180	5.8	12.	17.	23.	.42	.84	1.3	1.7
190	7.7	15.	23.	31.	.46	.92	1.4	1.8
200	10.	20.	30.	40.	0.5	1.0	1.5	2.0

NOTES:

Tabulated values of π_T are derived from the following equations:

For Aluminum, $\pi_T = 3.96(10)^7 \left(\frac{V_C}{BV_{CES}} - .35\right) e^{-\left(\frac{5770}{T+273}\right)}$ for $100 \leq T \leq 200$

$$\pi_T = 7.58\left(\frac{V_C}{BV_{CES}} - .35\right) \text{ for } T < 100$$

For Refractory Metal-Gold, $\pi_T = 2\left(\frac{V_C}{BV_{CES}} - .35\right)$ for $T < 100$

$$\pi_T = 0.08\ (T-75)\left(\frac{V_C}{BV_{CES}} - .35\right) \text{ for } 100 \leq T \leq 200$$

where:

T is peak junction temperature (^oC),
V_C is operating voltage (volts),
and BV_{CES} is collector-emitter breakdown with base shorted to emitter (volts).

TABLE 5.1.3.9-5: π_M MATCHING NETWORK FACTOR

INTERNAL MATCHING	π_M
Input & Output	1
Input Only	2
No Matching	4

TABLE 5.1.3.9-6: π_E GROUP IX TRANSISTORS ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	6
G_{MS}	1.1	A_{IA}	3.5
G_F	2	A_{IF}	6
G_M	7.8	A_{UC}	5
M_P	7.4	A_{UT}	7
N_{SB}	3.6	A_{UB}	10
N_S	4.7	A_{UA}	7
N_U	11	A_{UF}	10
N_H	11	S_F	1
N_{UU}	12	M_{FF}	7.5
A_{RW}	16	M_{FA}	11
A_{IC}	2.5	U_{SL}	22
A_{IT}	3.5	M_L	25
		C_L	250

5.1.3.10 Opto-electronic Semiconductor Devices, Group X.

SPECIFICATION	DESCRIPTION
MIL-S-19500	Light Emitting Diodes (LED)
MIL-S-19500	Opto-electronic Coupler (Isolator)
None	LED Alpha-numeric Display Phototransistor Photodiode

The part failure rate model λ_p, is:

$$\lambda_p = \lambda_b \pi_T \pi_E \pi_Q \text{ failures}/10^6 \text{ hours}$$

where:

λ_b = base failure rate in failures/10^6 hours, Table 5.1.3.10-3

π_T = temperature factor, Table 5.1.3.10-2

π_E = environmental factor, Table 5.1.3.10-1

π_Q = quality factor, Table 5.1.3.10-4

TABLE 5.1.3.10-1: GROUP X OPTO-ELECTRONIC SEMICONDUCTOR DEVICES, ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	5.5
G_{MS}	1.2	A_{IA}	3.5
G_F	2.4	A_{IF}	8
G_M	7.8	A_{UC}	3
M_P	7.7	A_{UT}	5.5
N_{SB}	3.7	A_{UB}	8
N_S	5.7	A_{UA}	5.5
N_U	11	A_{UF}	10
N_H	12	S_F	1
N_{UU}	13	M_{FF}	7.8
A_{RW}	17	M_{FA}	11
A_{IC}	2.5	U_{SL}	23
A_{IT}	3.5	M_L	26
		C_L	450

DISCRETE SEMICONDUCTORS

OPTO-ELECTRONIC DEVICES

TABLE 5.1.3.10-2: π_T OPTO-ELECTRONIC SEMICONDUCTOR DEVICE TEMPERATURE FACTOR

$$\pi_T = 8.01 \times 10^{12} \exp - \left[\frac{8111}{T_J + 273}\right]$$

where T_J is operating junction temperature in °C.

T_J may be calculated by using the following equations:

$T_J = T_A + (\theta_{JC} + \theta_{CA})$ P for device with heat sink, or

$T_J = T_A + \theta_{JA}P$ for device without heat sink

$T_J = T_C + \theta_{JC}P$ with or without heat sink

where:

T_A = ambient temperature in °C.

θ_{JC} = junction to case thermal resistance

θ_{CA} = case to ambient thermal resistance

P = power dissipated by device

θ_{JA} = junction to ambient thermal resistance

T_J (°C)	π_T
0	1.0
5	1.7
10	2.9
15	4.7
20	7.6
25	12
30	19
35	29
40	45
45	67
50	100
55	150
60	210
65	300
70	430
75	600
80	840
85	1200
90	1500
95	2100
100	2900
105	3800
110	5100
115	6700

If information is not available to use the equation above, use the following assumptions (T_A = ambient temperature):

Discrete LED	$T_J = T_A + 20^\circ C$
LED Display	$T_J = T_A + 30^\circ C$
Phototransistor	$T_J = T_A + 30^\circ C$
Photodiode	$T_J = T_A + 15^\circ C$
Single Isolators	
Photodiode Detector	$T_J = T_A + 15^\circ C$
Phototransistor Detector	$T_J = T_A + 20^\circ C$
Photoresistor Detector	$T_J = T_A + 20^\circ C$
Dual Isolators	
Photodiode Detector	$T_J = T_A + 20^\circ C$
Phototransistor Detector	$T_J = T_A + 30^\circ C$
Photoresistor Detector	$T_J = T_A + 30^\circ C$

TABLE 5.1.3.10-3: OPTO-ELECTRONIC SEMICONDUCTOR DEVICE BASE FAILURE RATE, λ_b, IN FAILURES PER 10^6 HOURS

Device	λ_b	Device	λ_b
Single LED	.00065	Alpha-Numeric Displays*	
Single Isolators		1 character	.00050
		1 character w/logic chip	.00068
Photodiode Detector	.0010		
Phototransistor Detector	.0055	2 character	.00071
Light Sensitive Resistor	.0025	2 character w/logic chip	.00089
Dual Isolators		3 character	.00088
Photodiode Detector	.0015	3 character w/logic chip	.0011
Phototransistor Detector	.0074		
Light Sensitive Resistor	.0040	4 character	.0010
Phototransistor	.0015	5 character	.0011
		6 character	.0012
Photodiode	.0011	7 character	.0013
		8 character	.0014
		9 character	.0015
		10 character	.0016

*The number of characters in a display is the number of characters contained in a single sealed package. For example, a 4 character display comprising 4 separately packaged single characters mounted together would be 4 one-character displays, not 1 four-character display.

TABLE 5.1.3.10-4: π_Q QUALITY FACTOR

QUALITY LEVEL	JANTXV	JANTX	JAN	LOWER*	PLASTIC**
π_Q	0.01	0.02	0.1	0.5	1.0

*Applies to all hermetic packaged alpha-numeric displays and to NON-JAN hermetic packaged LED's and isolators.
**Applies to all devices encapsulated with organic materials.

5.1.3.11 Semiconductor Laser Devices, Group XI

SPECIFICATION	DESCRIPTION
None	Aluminum gallium arsenide (AlGaAs), Double Heterojunction (DH), Stripe-geometry, Proton-isolated or Oxide-isolated structure, Optical Flux Density less than $3MW/CM^2$
None	Gallium Arsenide (GaAs), Single Heterojunction (SH), Stripe-geometry, Proton-isolated or Oxide-isolated structure, Optical Flux Density less than $3MW/CM^2$
None	Indium gallium arsenide/Indium gallium arsenide phosphorus (InGaAs/InGaAsP), DH, Stripe-geometry, Proton-isolated or Oxide-isolated structures, Optical Flux Density less than $3MW/CM^2$

The part failure rate model λ_p is:

$$\lambda_p = \lambda_b \pi_E$$

where

λ_p = total device failure rate ($F/10^6$ hours)

λ_b = average failure rate ($F/10^6$ hours)

π_E = environmental factor (Table 5.1.3.11-1)

The failure rate prediction procedure is as follows:

Step 1: Calculate the average failure rate (λ_b)

Step 1A: Calculate the average optical power output degradation rate using the following equation:

$$\tau_p = \tau_b \pi_T \pi_I \pi_C \pi_A \pi_F$$

where

τ_p = semiconductor laser optical power output degradation rate (%/1000 hours)

τ_b = base degradation rate (%/1000 hours) (Table 5.1.3.11-2)

DISCRETE SEMICONDUCTORS

SEMICONDUCTOR LASER DEVICES

π_T = temperature factor = $\exp\left[\frac{-E}{(T+273)}\right]$, T = Case Temperature (°C) (Table 5.1.3.11-3) and where E = apparent activation energy/Boltzman's Constant (Table 5.1.3.11-2). π_t is valid for $+25^\circ C \leq T \leq +100^\circ C$

π_C = construction factor (Table 5.1.3.11-4)

π_A = application factor (Table 5.1.3.11-5)

π_F = pulsed duty cycle factor (Table 5.1.3.11-6)

π_I = forward peak current factor (Table 5.1.3.11-7). (For Variable Current Sources use the initial current value). π_I is valid for $0 \leq I \leq 25$ amps

Step 1B: Calculate the mean life of the device by the following procedure:

1) P_s = rated optical power output (mw)

2) define the required optical power output (Pr).

3) calculate the allowable degradation (D) as follows:

$$D(\%) = \frac{P_s - P_r}{P_s} \times 100$$

4) Mean life (U) = $D(\%)/\tau_p$

Note: Each laser must be replaced when it reaches P_r to make the calculated mean life (U) valid.

Step 1C: Calculate the average failure rate using:

$$\lambda_b = 1/U$$

Step 2: Calculate the average semiconductor laser failure rate using the equation:

$$\lambda_p = \lambda_b \pi_E$$

DISCRETE SEMICONDUCTORS

SEMICONDUCTOR LASER DEVICES

TABLE 5.1.3.11-1: ENVIRONMENTAL MODE FACTORS, π_E

Environment	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	7.8
M_P	7.7
N_{SB}	3.7
N_S	5.7
N_U	11
N_H	12
N_{UU}	13
A_{RW}	17
A_{IC}	2.5
A_{IT}	3.5
A_{IB}	5.5
A_{IA}	3.5
A_{IF}	8
A_{UC}	3
A_{UT}	5.5
A_{UB}	8
A_{UA}	5.5
A_{UF}	10
S_F	1
M_{FF}	7.8
M_{FA}	11
U_{SL}	23
M_L	26
C_L	450

TABLE 5.1.3.11-2: DEGRADATION EQUATION PARAMETERS

Device Type	E	τ_b ($\times 10^5$)
AlGaAs	4635	2.21
GaAs	4635	2.81
InGaAs/InGaAsP	5784	188

TABLE 5.1.3.11-3: TEMPERATURE FACTOR, π_T

T_C (^oC)	AlGaAs or GaAs ($\times 10^{-6}$) π_T	InGaAs/InGaAsP ($\times 10^{-8}$) π_T
20	0.14	0.27
25	0.18	0.37
30	0.23	0.51
35	0.29	0.70
40	0.37	0.94
45	0.47	1.3
50	0.59	1.7
55	0.73	2.2
60	0.90	2.9
65	1.1	3.7
70	1.4	4.7
75	1.6	6
80	2	7.7
85	2.4	9.6
90	2.8	12
95	3.4	15
100	4	18

TABLE 5.1.3.11-4: CONSTRUCTION FACTOR, π_C

Construction	π_C
Facet Coat or Hermetic Package	1.0
No Facet Coat or Hermetic Package	3.3

TABLE 5.1.3.11-5: APPLICATION FACTOR, π_A

Application	π_A
Variable Current Source with optical feedback	1.0
Fixed Current Source	1.5

SEMICONDUCTOR LASER DEVICES

TABLE 5.1.3.11-6: PULSED DUTY CYCLE FACTOR, π_F

Duty Cycle	π_F*
1.0	1.00
0.9	0.95
0.8	0.90
0.7	0.85
0.6	0.75
0.5	0.70
0.4	0.65
0.3	0.55
0.2	0.45
0.1	0.30

*$\pi_F = \sqrt{\text{duty cycle}}$

TABLE 5.1.3.11-7: FORWARD CURRENT FACTOR, π_I

Forward Current, I (Ma)	π_I*
25,000	978
20,000	841
15,000	691
10,000	525
9,000	488
8,000	451
7,000	412
6,000	371
5,000	328
4,000	281
3,000	231
2,000	176
1,000	110
900	102
800	94
700	86
600	77
500	68
400	59
300	48
200	37
100	23
50	14

*$\pi_I = I^{0.68}$

5.1.3.12 Instructions for Use of Semiconductor Models.

5.1.3.12-1 Device Ratings. Transistors are normally rated at maximum power dissipation and diodes at maximum current permissible. Usually each device is given two temperature rating points:

1 T_{MAX} - Maximum permissible junction temperature.

2 T_S - Maximum ambient or case temperature at which 100 percent of the rated load can be dissipated without causing the specified maximum junction temperature to be exceeded. (Case temperatures are given primarily for power devices used on heat sinks.)

As the ambient or case temperature rises above the T_S value, the internal temperature rise (i.e., the power load) must be decreased so that the T_{MAX} is not exceeded. This is illustrated in Figure 5.1.3.11-1.

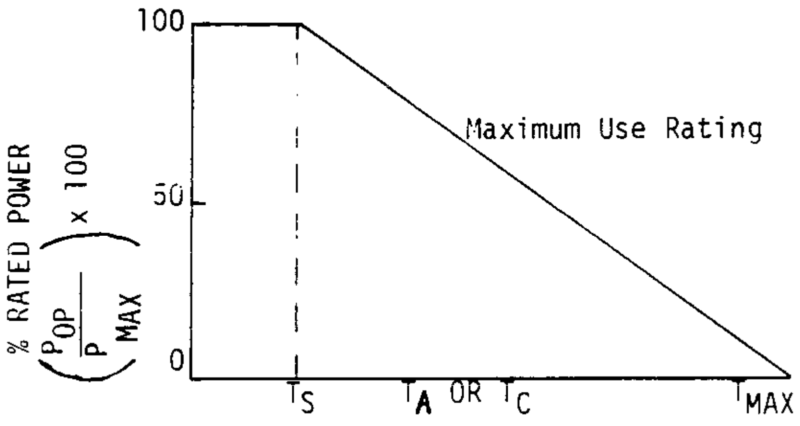

FIGURE 5.1.3.12-1. Conventional Derating Curve

Note:

T_S = temperature at which derating begins

T_{MAX} = maximum rated junction temperature

T_A = ambient temperature

T_C = case temperature

P_{OP} = actual power dissipated

P_{MAX} = maximum rated power at T_S

Maximum junction temperature (T_{MAX}) is normally 175 or 200°C for silicon and 100°C for germanium devices. T_S is usually 25°C, but it can be higher.

Some devices have a multipoint derating curve as shown by the solid line in the example of Figure 5.1.3.12-2.The failure rate of a device with multipoint derating can be estimated with the present models by assuming the device to be linearly derated from T_S to T_{MAX} as shown by the dashed line. The use of this assumption will result in a predicted failure rate higher than that the device might actually experience, with the amount of error dependent upon the difference between the two rating values where $T_{S'}$ intersects the assumed and actual rating plots.

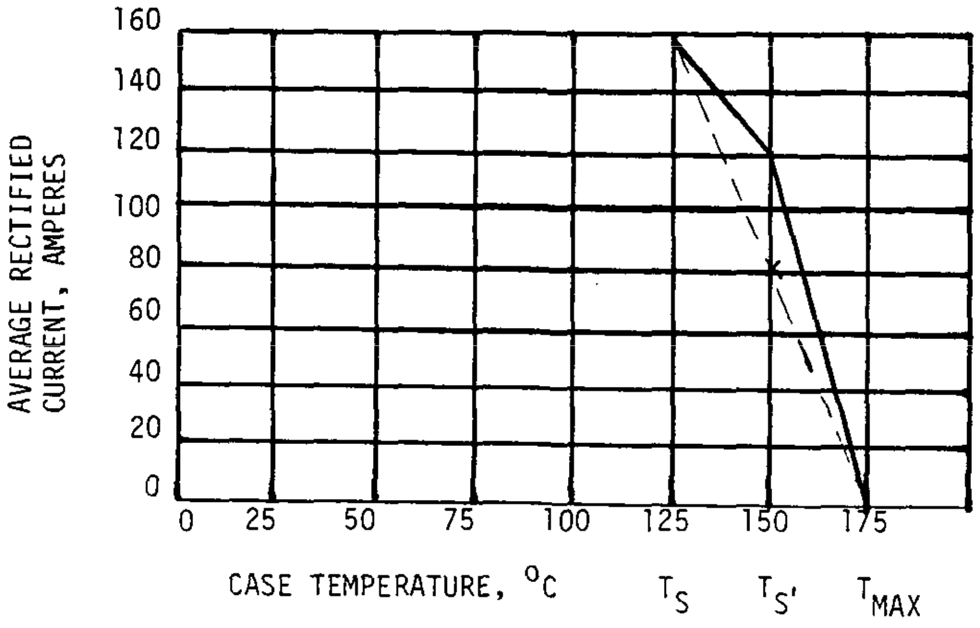

Figure 5.1.3.12-2 Multipoint Derating Curve for 1N3263 Power Diode

Since semiconductors may be rated based upon ambient or case temperatures, the following guidance is included for calculating base failure rates:

1 No Heat Sink Used and Ambient Rating Known - Calculate stress and temperature (if necessary) per paragraph 5.1.3. .2 and use base failure rate table.

<u>2</u> <u>No Heat Sink Used and Only Case Rating Known</u> - If device rating based upon ambient temperature cannot be determined, calculate the base failure rate as in <u>1</u> above <u>and multiply by 10</u>.

<u>3</u> <u>Heat Sink Used and Case Rating Known</u> - Calculate base failure rate as in <u>1</u> above.

<u>4</u> <u>Heat Sink Used and Only Ambient Rating Known</u> - If device rating based upon case temperature cannot be determined, calculate base failure rate as in <u>1</u> above.

5.1.3.12.2 Determining Appropriate Stress Ratio and Temperature.

The base failure rate tables are based upon ambient or case temperature (T degrees C) and electrical stress ratio (S). The following instructions show the methods for calculating S. In some cases, the operating ambient or case T must be corrected before entering the failure rate tables. These corrections, where needed, are indicated in (7) below. Operating junction temperatures do not have to be calculated to use the models.

(1) Groups I, II & III Transistors.

a. Single device in case.

For Silicon, $S = \frac{P_{OP}}{P_{MAX}}$ (C.F.) For Germanium, $S = \frac{P_{OP}}{P_{MAX}}$

where:

P_{OP} = actual power dissipated

P_{MAX} = maximum rated power at T_S

C.F. = stress correction factor per (7) below

b. Dual device in single case (equally rated).

$$S = \left[\frac{P_1}{P_S} + P_2\left(\frac{2P_S - P_T}{P_T \times P_S}\right)\right] (\text{C.F.})$$

where:

S = stress ratio of side being evaluated

P_1 = power dissipation in side being evaluated

P_2 = power dissipation in other side of device

P_S = maximum power rating at T_S of one side of the dual device with the other side not operating (one side rating)

P_T = maximum rating at T_S with both sides operating (both side rating)

<u>NOTE</u>: Specifications for dual devices in one case usually give a maximum rating for each device and a total power rating which is significantly less than the sum of individual ratings.

C.F. = stress correction factor per (7) below for silicon

C.F. = 1.0 for germanium

(2) Groups IV & VI General Purpose Diodes & Thyristors.

For Silicon, $S = \frac{I_{OP}}{I_{MAX}}$ (C.F.) For Germanium, $S = \frac{I_{OP}}{I_{MAX}}$

where:

I_{OP} = operating average forward current

I_{MAX} = maximum rated average forward current at T_S

C.F. = stress correction factor per (7) below

(3) Group V Zener Diodes

Zener diodes are rated for maximum current or power or both. Either rating may be used as follows:

$$S = \frac{P_{OP}}{P_{MAX}}\text{(C.F.)} \quad \text{or } S = \frac{I_{Z(OP)}}{I_{Z(MAX)}}\text{(C.F.)}$$

where:

P_{OP} = actual power dissipated

P_{MAX} = maximum rated power at T_S

$I_{Z(OP)}$ = actual operating zener current

$I_{Z(MAX)}$ = maximum rated zener current at T_S

C.E. = stress correction factor per (7) below

(4) Group VII Microwave Mixer Diodes

$$S = \frac{\text{Operating Spike Leakage (ergs)}}{\text{Rated Burnout Energy at 25 degrees C.}}$$

(5) Group VII Microwave Detector Diodes

$$S = \frac{P_{OP}\ \text{(Operating Power Dissipation)}}{P_{MAX}\ \text{(Rated Power at 25 degrees C.)}}$$

(6) Group VIII Varactor, Step Recovery, PIN, IMPATT, Gunn and Tunnel Diodes.

$$S = \frac{P_{OP}}{P_{MAX}}\ (\text{C.F.})$$

where:

P_{OP} = actual power dissipated

P_{MAX} = maximum rated power at T_S

C.F. = stress correction factor per (7) below

(7) Stress Correction Factor (C.F.) and temperature corrections for Silicon Devices.

a. Devices with T_S = 25 degrees C & T_{MAX} = 175 degrees C to 200 degrees C.

C.F. = 1

b. Devices with T_S >25 degrees C & T_{MAX} = 175 degrees C to 200 degrees C.

$$C.F. = \frac{175 - T_S}{150}$$

c. Devices with T_S = 25 degrees C & T_{MAX} <175 degrees C.

$$C.F. = \frac{T_{MAX} - 25}{150}$$

<u>and</u> enter λ_b table with $T = T_A + (175 - T_{MAX})$

or $T = T_C + (175 - T_{MAX})$

d. Devices with T_S >25 degrees C & T_{MAX} <175 degrees C.

$$C.F. = \frac{T_{MAX} - T_S}{150}$$

<u>and</u> enter λ_b tables with $T = T_A + (175 - T_{MAX})$

or $T = T_C + (175 - T_{MAX})$

5.1.3.13. Examples of Use of Semiconductor Models.

5.1.3.13.1. Examples of Stress Ratio Calculations for Dual Transistors.

Example 1.

For a 2N2060

Ratings $P_S = 0.500$ w

$P_T = 0.600$ w

Given operating conditions

Side one P = 0.1 w

Side two P = 0.4 w

For side one

$$S = \frac{P_1}{P_S} + P_2\left(\frac{2P_S - P_T}{P_T \times P_S}\right)$$

$$S = \frac{0.1}{0.5} + 0.4\left(\frac{2 \times 0.500 - 0.6}{0.6 \times 0.5}\right)$$

$$S = 0.2 + 0.4\left(\frac{0.4}{0.3}\right) = 0.2 + 0.4\ (1.333)$$

$$= 0.2 + 0.5333$$

$$S = 0.733$$

For side two

$$S = \frac{0.4}{0.5} + 0.1\left(\frac{2 \times 0.5 - 0.6}{0.6 \times 0.5}\right)$$

$$S = \frac{0.4}{0.5} + 0.1\ (1.333) = 0.8 + 0.1333$$

$$S = 0.9333$$

Example 2.

For the same transistor as Example 1

Given operating conditions

Side one P = 0 w

Side two P = 0.5 w

For side one

$$S = 0 + 0.5\,(1.333) = 0.666$$

For side two

$$S = \frac{0.5}{0.5} + 0\,(1.333) = 1.0$$

Though there is no dissipation in side one, because of the heating from side two, the stress ratio is still 0.666. If one side of a dual is not connected, treat as single transistor.

Example 3.

For the same transistor as Example 1

Given operating conditions

Side one P = 0.300 w

Side two P = 0.300 w

For either side

$$S = \frac{0.3}{0.5} + 0.3\,(1.333)$$

$$S = 0.6 + 0.4$$

$$S = 1.0$$

5.1.3.13.2. Examples of Failure Rate Calculations

Example 1.

Step (1) Given: Silicon NPN general purpose JAN grade transistor in linear service at 0.4 of its rated maximum power of 1 watt in fixed ground installation at 30 degrees C. ambient, rated for 1 watt at 25 degrees C. with T_{MAX} = 175 degrees C., and operated at 60 percent of maximum voltage.

Step (2) Stress ratio, $S = \frac{P_{OP}(C.F.)}{P_{MAX}} = 0.4 \times 1.0 = 0.4$

$C.F. = 1$ for T_S = 25 degrees C. and T_{MAX} = 175 degrees C.

Step (3) From Tbl 5.1.3.1-7 for T = 30 degrees C. and S = 0.4, $\lambda_b = 0.0012$ failures/10^6 hours

Step (4) From Tbl 5.1.3.1-1 Fixed Ground, $\pi_E = 5.8$

Step (5) From Tbl 5.1.3.1-2 for linear operation, $\pi_A = 1.5$

Step (6) From Tbl 5.1.3.1-3 for JAN quality level, $\pi_Q = 1.2$

Step (7) From Tbl 5.1.3.1-4 for 1 watt rating, $\pi_R = 1.0$

Step (8) From Tbl 5.1.3.1-5 at 60 percent of rated voltage, $\pi_{S_2} = .88$

Step (9) From Tbl 5.1.3.1-6, for single transistor, $\pi_C = 1.0$

Step (10) Perform the calculation:

$$\lambda_P = \lambda_b (\pi_E \times \pi_A \times \pi_Q \times \pi_R \times \pi_{S_2} \times \pi_C)$$

$$\lambda_p = 0.0012 (5.8 \times 1.5 \times 1.2 \times 1.0 \times .88 \times 1.0)$$

$$\lambda_p = 0.011 \text{ failures}/10^6 \text{ hours}$$

Example 2.

Step (1) Given: Field effect transistor (FET), JANTX grade, operating at 80 milliwatts at 500 MHz in airborne inhabited fighter service at 60 degrees C ambient temperature. (Rated at 200 milliwatts, T_S = 25 degrees C. and T_{MAX} = 175 degrees C.).

Step (2) Stress ratio, $S = \left(\frac{P_{OP}}{P_{MAX}}\right)$ C.F. $= \frac{80}{200} \times 1.0 = 0.4$

C.F. = 1 for T_S = 25°C. and T_{MAX} = 175°C.

Step (3) From Tbl 5.1.3.2-5 for T = 60 degrees C. and S = 0.4, λ_b = 0.031 failures/10^6 hours

Step (4) From Tbl 5.1.3.2-1 A_{IF} environment, π_E = 40

Step (5) From Tbl 5.1.3.2-2 freq. >400 MHz, power <300 mw, π_A = 5.0

Step (6) From Tbl 5.1.3.2-4 JANTX grade, π_Q = 0.24

Step (7) From Tbl 5.1.3.2-3 single transistor, π_C = 1.0

Step (8) Perform the calculation:

$$\lambda_p = \lambda_b(\pi_E \times \pi_A \times \pi_Q \times \pi_C)$$

$$\lambda_p = 0.031\,(40 \times 5.0 \times 0.24 \times 1.0)$$

$$\lambda_p = 1.5 \text{ failures}/10^6 \text{ hours}$$

Example 3.

Step (1) Given: Silicon diode, JAN grade, in ground mobile service operating at 0.4 rated maximum current, and at 30 degrees C. ambient in logic switching with 20 percent of rated voltage. Rated 1 amp. at 25 degrees C. with T_{MAX} = 200 degrees C., the device has a metallurgically bonded contact.

Step (2) Stress ratio, $S = (I_{OP}/I_{MAX})$ C.F. = (.4/1) 1.0 = .4

C.F. = 1.0 for T_S = 25 degrees C. and T_{MAX} = 200 degrees C.

Step (3) From Tbl 5.1.3.4-7 for S = 0.4 and T = 30 degrees C, λ_b = 0.00049 failure/10^6 hours

Step (4) From Tbl 5.1.3.4-1 ground mobile service, $\pi_E = 18$

Step (5) From Tbl 5.1.3.4-2 JAN grade, $\pi_Q = 1.5$

Step (6) From Tbl 5.1.3.4-3 for 1 amp, $\pi_R = 1.0$

Step (7) From Tbl 5.1.3.4-4 logic switching, $\pi_A = 0.6$

Step (8) From Tbl 5.1.3.4-5 20 percent rated voltage, $\pi_{S_2} = 0.7$

Step (9) From Tbl 5.1.3.4-6 metallurgically bonded contacts, $\pi_C = 1.0$

Step (10) Perform the calculation:

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_R \times \pi_A \times \pi_{S_2} \times \pi_C)$$

$$\lambda_p = 0.00049 (18 \times 1.5 \times 1.0 \times 0.6 \times 0.7 \times 1.0)$$

$$\lambda_p = 0.0056 \text{ failures}/10^6 \text{ hours}$$

Example 4.

Step (1) Given: Silicon dual transistor (complementary), JAN grade, rated for 0.25 W. at 25 degrees C., one side only, and 0.35 W. at 25 degrees C., both sides, with T_{MAX} = 200 degrees C., operating in linear service at 50 degrees C. ambient in a sheltered naval environment. Side one, NPN, operating at 0.1 W. and 50 percent of rated voltage and side two, PNP, operating at 0.05 W. and 30 percent of rated voltage.

Step (2) For side one, stress ratio,

$$S = \left[\frac{P_1}{P_S} + P_2\left(\frac{2P_S - P_T}{P_T \times P_S}\right)\right] (C.F.)$$

C.F. = 1.0 for T_S = 25 degrees C. and T_{MAX} = 200 degrees C.

$$S = \left[\frac{0.1}{0.25} + 0.05\left(\frac{2 \times 0.25 - 0.35}{0.35 \times 0.25}\right)\right](1.0)$$

$$S = 0.48$$

Step (3) From Tbl 5.1.3.1-7 for T = 50 degrees C. and S = 0.48, $\lambda_b = 0.0018$ failures/10^6 hours

Step (4) From Tbl 5.1.3.1-1 naval sheltered, $\pi_E = 9.8$

Step (5) From Tbl 5.1.3.1-2 linear, $\pi_A = 1.5$

Step (6) From Tbl 5.1.3.1-3, JAN grade, $\pi_Q = 1.2$

Step (7) From Tbl 5.1.3.1-4 for .25 watt, $\pi_R = 1.0$

Step (8) From Tbl 5.1.3.1-5 at 50 percent of rated voltage, $\pi_{S_2} = 0.65$

Step (9) From Tbl 5.1.3.1-6 for complementary pair, $\pi_C = 0.7$

Step (10) Perform the calculation for side one:

$$\lambda_p = \lambda_b (\pi_E \times \pi_A \times \pi_Q \times \pi_R \times \pi_{S_2} \times \pi_C)$$

$$\lambda_p = 0.0018 \ (9.8 \times 1.5 \times 1.2 \times 1.0 \times 0.65 \times 0.7)$$

$\lambda_p = 0.014$ failures/10^6 hours for side one

Step (11) For side two, stress ratio,

$$S = \frac{0.05}{0.25} + 0.1 \left(\frac{2 \times 0.25 - 0.35}{0.35 \times 0.25} \right)$$

$$S = 0.37$$

Step (12) From Tbl 5.1.3.1-8 for T = 50 degrees C. and S = 0.37, λ_b=0.0021 failures/10^6 hours

Step (13) π_E, π_A, π_Q, π_R and π_C same as for side one

Step (14) From Tbl 5.1.3.1-5 at 30 percent of rated voltage, $\pi_{S_2} = 0.35$

Step (15) Perform the calculation for side two:

$$\lambda_p = \lambda_b \cdot (\pi_E \times \pi_A \times \pi_Q \times \pi_R \times \pi_{S_2} \times \pi_C)$$

$$\lambda_p = 0.0021\ (9.8 \times 1.5 \times 1.2 \times 1.0 \times 0.35 \times 0.7)$$

λ_p 0.0091 failures/10^6 hours for side two

Example 5.

Step (1) Given: Silicon diode, JANTX grade, in fixed ground service at 0.6 rated maximum current and 40 percent rated voltage in power rectifier operation at 60 degrees C. case temperature. Device rated at 5 amps, T_S = 100 degrees C. case temperature and T_{MAX} = 150 degrees C. and has a metallurgically bonded contact.

Step (2) Stress ratio, S = 0.6 (C.F.)

From Sec. 5.1.3.11.2 $C.F. = \frac{T_{MAX} - T_S}{150} = \frac{150 - 100}{150} = 0.333$

$S = 0.6 \times 0.333 = 0.2$

Temperature for λ_b computation, $T = T_C + (175 - T_{MAX})$

$T = 60 + (175 - 150)$

$T = 85$

Step (3) From Tbl 5.1.3.4-7 for T = 85 degrees C. and S = 0.2, $\lambda_b = 0.00076$ failures/10^6 hours

Step (4) From Tbl 5.1.3.4-1 fixed ground, $\pi_E = 3.9$

Step (5) From Tbl 5.1.3.4-2 JANTX grade, $\pi_Q = 0.3$

Step (6) From Tbl 5.1.3.4-3 5 amps, $\pi_R = 2.0$

Step (7) From Tbl 5.1.3.4-4 power rectifier, $\pi_A = 1.5$

Step (8) From Tbl 5.1.3.4-5 at 40 percent of rated voltage, $\pi_{S_2} = 0.7$

Step (9) From Tbl 5.1.3.4-6 for metallurgically bonded contacts, $\pi_C = 1.0$

Step (10) Perform the calculation:

$$\lambda_p = \lambda_b \ (\pi_E \times \pi_Q \times \pi_R \times \pi_A \times \pi_{S_2} \times \pi_C)$$

$$\lambda_p = 0.00076 \ (3.9 \times 0.3 \times 2.0 \times 1.5 \times 0.7 \times 1.0)$$

$$\lambda_p = 0.0019 \text{ failures}/10^6 \text{ hours}$$

Example 6.

Step (1) Given: Microwave transistor, JANTX Equivalent quality, in mobile ground environment as a pulse amplifier at 20% duty factor with a peak power output of 30 watts at 1.5 GHz. The device package has input and output matching networks and uses refractory metal-gold metallization. V_C = 28 volts and BV_{CES} = 56 volts. The peak junction temperature is 140°C.

Step (2) From Tbl 5.1.3.9-1 JANTX Equivalent, $\pi_Q = 2$.

Step (3) From Tbl 5.1.3.9-2 pulse amplifier with 20% duty factor, $\pi_A = 2$.

Step (4) From Tbl 5.1.3.9-3 1.5 GHz. & 30 watts, $\pi_F = 1.5$.

Step (5) $V_C/BV_{CES} = 28/56 = 0.5$. From Tbl 5.1.3.9-4 $V_C/BV_{CES} = 0.5$, T = 140°C., and with refractory metal-gold metallization, $\pi_T = 0.78$.

Step (6) From Tbl 5.1.3.9-5 input and output matching networks, $\pi_M = 1$.

Step (7) From Tbl 5.1.3.9-6 mobile ground (G_M), π_E = 7.8

Step (8) Perform the calculation:

$$\lambda_P = \lambda_B \pi_Q \pi_A \pi_F \pi_T \pi_M \pi_E$$

$$= 0.1\ (2)\ 2\ (1.5)\ 0.78\ (1)\ 7.8$$

$$= 3.7 \text{ failures}/10^6 \text{ hr.}$$

Example 7

Step (1) Given: A commercial quality plastic-encapsulated single optoisolator is used in a Ground, Benign application, junction temperature 65°C. The optoisolator uses a photodiode detector.

Step (2) Table 5.1.3.10 $\lambda_p = \lambda_b \pi_T \pi_E \pi_Q$

Step (3) Table 5.1.3.10-3 Base Failure Rate λ_b = .0010

Step (4) Table 5.1.3.10-2 Temperature Factor π_T = 300

Step (5) Table 5.1.3.10-1 Environmental Factor π_E = 1.0

Step (6) Table 5.1.3.10-4 Quality Factor π_Q = 1.0

Step (7) λ_p = 0.0010 (300) (1.0) (1.0) = 0.30 failures per 10^6 hours

Example 8

Step (1) Given: A discrete, hermetic light emitting diode (LED) procured in accordance with MIL-S-19500 is used in an Airborne, Inhabited, Trainer application environment. The device is a JAN quality part operating at a case temperature of 60°C. Package case-to-junction thermal resistance θ_{JC} is 500°C/watt. The device dissipates 50 mW.

Step (2) Table 5.1.3.10 $\lambda_p = \lambda_b \pi_T \pi_E \pi_Q$

Step (3) Table 5.1.3.10-3 Discrete LED, Base Failure Rate λ_b = 0.00065

Step (4) Table 5.1.3.10-1 Airborne Inhabited Trainer Environment π_E = 3.5

Step (5) Table 5.1.3.10-2 $T_C = 60^\circ C$ $P = .05w$ $\theta_{JC} = 500^\circ C/watt$

$T_J = T_C + \theta_{JC} P = 60 + 500(.05) = 60 + 25 = 85^\circ C$

From Table 2.2.10-3, π_T = 1200

Step (6) Table 5.1.3.10-4 JAN Quality Level π_Q = 0.1

Step (7) λ_p = 0.00065 (1200) (3.5) (0.1) = 0.27 failures per 10^6 hours

Example 9

Step (1) Given: A 10mW AlGaAs Double Heterostructure (DH) stripe geometry laser is used in a Ground, Fixed environment, case temperature is 55°C, it has a facet coat, it has a fixed current source, the application is continuous wave (DC), the forward current is 100ma, and the minimum acceptable optical power output is 5mw.

Step (2) Section 5.1.3.11 Step 1A, calculate the average optical output degradation rate (τ_p)

$$\tau_p = \tau_b \pi_T \pi_I \pi_C \pi_A \pi_F$$

Step (3) Table 5.1.3.11-2 $\tau_b = 2.21 \times 10^5$ (%/1000 hours)

Step (4) Table 5.1.3.11-3 $\pi_T = 0.73 \times 10^{-6}$

Step (5) Table 5.1.3.11-7 $\pi_I = 23$

Step (6) Table 5.1.3.11-4 $\pi_C = 1.0$

Step (7) Table 5.1.3.11-5 $\pi_A = 1.5$

Step (8) Table 5.1.3.11-6 $\pi_F = 1.0$

Step (9) $\tau_p = 2.21 \times 10^5 (0.73 \times 10^{-6}) (23) (1.0) (1.5) (1.0) = 5.56$ %/1000 hours

Step (10) Section 5.1.3.11 Step 1B, calculate the mean life of the device

Step (11) Allowable degradation (D)

$$D(\%) = \frac{P_s - P_r}{P_s} \times 100 = \frac{10\text{mw} - 5\text{mw}}{10\text{mw}} \times 100 = 50\%$$

Step (12) Mean life (U)

$$U = D(\%)/\tau_p = 50\%/5.56\%/1000 \text{ hours} = 8993 \text{ hours}$$

Step (13) Section 5.1.3.11 Step 1C, calculate the average failure rate (λ_b)

λ_b = 1/U = 111 failures per 10^6 hours

Step (14) Section 5.1.3.11 Step 2, calculate the average semiconductor laser failure rate (λ_p)

$\lambda_p = \lambda_b \pi_E$ = 111 failures 10^6 hours (2.4) = 266.4 failures per 10^6 hours

5.1.4 Tubes, Electronic Vacuum

5.1.4.1 All Types Except Traveling Wave Tubes (TWTs) and Magnetrons.

The operating failure rate model (λ) is:

$$\lambda_p = \lambda_b \times \pi_E \times \pi_L$$

where

λ_p = tube operating failure rate in failures/10^6 hr.
λ_b = base failure rate in failures/10^6 hr and is a function of tube type and operating parameters (see Table 5.1.4.1-1).
π_E = environmental factor (see Table 5.1.4.1-4).
π_L = learning factor (see Table 5.1.4.1-5).

TABLE 5.1.4.1-1: λ_b, BASE FAILURE RATE FOR TUBES
(includes both random and wearout failures)

TUBE TYPE	λ_b (f./10^6 hrs.)
RECEIVER	
Triode, Tetrode, Pentode	5
Power Rectifier	10
CRT	9.6
THYRATRON	50
CROSSED FIELD AMPLIFIER	
QK681	260
SFD261	150
PULSED GRIDDED	
2041	140
6952	390
7835	140
TRANSMITTING	
Triode } Peak Pwr$\le$200 kW, Freq$\le$200 MHz,	75
Tetrode & Pentode } Aver Pwr$\le$2kW	100
If any of above limits are exceeded	250
VIDICONS	
Antimony trisulfide (Sb_2S_3) photoconductive material	51
Silicon diode array photoconductive material	48

TABLE 5.1.4.1-1 (Cont'd)
λ_b, BASE FAILURE RATE FOR TUBES

TUBE TYPE	λ_b (f./10^6 hr.)
TWYSTRON	
VA144	**850**
VA145E	**450**
VA145H	**490**
VA913A	**230**

PULSED KLYSTRON

TYPE NO.	λ_b	TYPE NO.	λ_b
4KMP10000LF	43	L3403	93
8568	230	SAC42A	100
L3035	66	VA842	18
L3250	69	Z5010A	150
		ZM3038A	190

If the pulsed klystron of interest is not listed above, use Table 5.1.4.1-3.

TUBE TYPE	λ_b (f./10^6 hr.)
KLYSTRON	
Low Power (e.g., local oscillator)	**30**

Continuous Wave Type (CW.)

TYPE NO.	λ_b	TYPE NO.	λ_b
3K3000LQ	9	4KM50SJ	38
3K50000LF	54	4KM50SK	37
3K210000LQ	150	4KM3000LR	140
3KM300LA	64	4KM50000LQ	79
3KM3000LA	19	4KM50000LR	57
3KM50000PA	110	4KM170000LA	15
3KM50000PA1	120	8824	130
3KM50000PA2	150	8825	120
4K3CC	610	8826	280
4K3SK	29	VA800E	70
4K50000LQ	30	VA853	220
4KM50LB	28	VA856B	65
4KM50LC	15	VA888E	230

If the CW. klystron of interest is not listed above, use Table 5.1.4.1-2.

TABLE 5.1.4.1-2
λ_b, BASE FAILURE RATES FOR CW. KLYSTRONS*

P (kW.)	F (MHz.)							
	300	500	800	1000	2000	4000	6000	8000
0.1	43	52	66	75	120	210	310	400
1.0	44	53	67	76	120	210	310	400
3.0	46	55	69	78	120	220	310	
5.0	48	58	71	81	130	220		
8.0	52	61	75	84	130			
10.	54	63	77	86	130			
30.	76	85	99	110				
50.	97	110	120	130				
80.	130	140	150					
100.	150	160						

* $\lambda_b = 1.09 P + .0461 F + 29$

where: P = average output power in kW.
F = operating frequency in MHz.

The following are the limits that describe the region of validity for the λ_b equation. Values of P and F must satisfy all three limits:

$0.1 \leq P \leq 100$

$300 \leq F \leq 8000$

$P \leq 8.0(10)^{6} \quad (F)^{-1.7}$

TABLE 5.1.4.1-3
λ_b, BASE FAILURE RATES FOR PULSED KLYSTRONS*

P (MW.)	F (GHz.)							
	0.2	0.4	0.6	0.8	1.0	2.0	4.0	6.0
.01	66	66	66	66	66	66	66	66
.30	66	66	67	67	67	68	70	71
.80	66	67	67	68	68	71	75	80
1.0	67	67	68	68	69	72	78	84
3.0	68	70	71	73	75	84	100	
5.0	69	72	75	78	81	95	120	
8.0	71	75	80	85	90	110	160	
10.	72	78	84	90	95	120		
25.	81	95	110	120	140	210		

* $\lambda_b = 2.94\ FP + 66$

where: F = operating frequency in GHz.
P = peak output power in MW.

The following are the limits that describe the region of validity for the λ_b equation. Values of P and F must satisfy all three limits:

$.01 \leq P \leq 25$

$0.2 \leq F \leq 6$

$P \leq 490(F)^{-2.95}$

TABLE 5.1.4.1-4

Environmental Mode Factors

ENVIRONMENT	π_E
G_B	0.5
G_{MS}	0.6
G_F	1.0
G_M	9
M_P	18
N_{SB}	7.6
N_S	7.6
N_U	13
N_H	28
N_{UU}	30
A_{RW}	40
A_{IC}	2
A_{IT}	5.5
A_{IB}	7.5

ENVIRONMENT	π_E
A_{IA}	6.5
A_{IF}	10
A_{UC}	2.5
A_{UT}	6.5
A_{UB}	9.5
A_{UA}	8
A_{UF}	15
S_F	0.5
M_{FF}	18
M_{FA}	25
U_{SL}	53
M_L	61
C_L	1,000

TABLE 5.1.4.1-5

π_L, LEARNING FACTOR FOR TUBES*

t (Yrs.)	1	2	3
π_L	10	2.3	1

* $\pi_L = 10(t)^{-2.1}$ for $1 \leq t \leq 3$

$= 10$ for $t < 1$

$= 1$ for $t > 3$

Where t = number of years since introduction to military field use.

5.1.4.2 Traveling Wave Tubes (TWT). The operating failure rate for TWTs is:

$\lambda_p = \lambda_b \Pi_E$ in failures/10^6 hr.

where:

Π_E = environmental factor (see Table 5.1.4.2-2).

$\lambda_b = 11\,(1.00012)^P (1.16)^F$ (see Table 5.1.4.2-1).

where:

P = rated power (peak, if pulsed mode) in watts for $.001 < P < 20{,}000$
F = operating frequency in GHz. for $0.3 < F < 18$. If the operating frequenc
is a band or two different values, use the geometric mean of the end points or of the two values for F.

TABLE 5.1.4.2-1. λ_b, BASE FAILURE RATES FOR TWTS (f./10^6 hr

P (Power, watts)	F (Frequency, GHz)								
	0.1	1	2	4	6	8	10	12	14
0-10	11	13	15	20	27	36	49	65	88
100	11	13	15	20	27	36	49	66	89
500	12	14	16	21	28	38	52	69	93
1,000	13	14	17	22	30	41	55	74	99
3,000	16	18	21	29	38	52	70	93	130
5,000	20	23	27	36	49	66	88	120	160
8,000	29	33	38	52	70	94	130	170	230
10,000	37	42	49	66	89	120	160	220	290
15,000	67	77	89	120	160	220	290	350	530
20,000	120	140	160	220	300	400	540	720	970

TABLE 5.1.4.2-2

Environmental Mode Factors for TWTs

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IA}	9
G_{MS}	1.3	A_{IF}	20
G_F	3	A_{UC}	6
G_M	10	A_{UT}	10
M_P	18	A_{UB}	18
N_{SB}	6.3	A_{UA}	10
N_S	6.3	A_{UF}	25
N_U	6	S_F	0.2
N_H	28	M_{FF}	18
N_{UU}	30	M_{FA}	25
A_{RW}	40	U_{SL}	53
A_{IC}	5	M_L	80
A_{IT}	9	C_L	1,000
A_{IB}	15		

5.1.4.3 Magnetrons. The operating failure rate for magnetrons is:

$$\lambda_p = \lambda_b \times \pi_U \times \pi_E \times \pi_C$$

where

λ_p = total device failure rate (failure/10^6 filament hours)

π_U = utilization factor (see Table 5.1.4.3-1)

π_E = environmental factor (see Table 5.1.4.3-2)

π_C = construction factor

= 1, CW magnetrons (rated power < 5 Kw)
= 1, coaxial pulsed magnetrons
= 5.4, conventional pulsed magnetrons

λ_b = base failure rate (f/10^6 filament hrs)

= 18, CW magnetrons (rated power < 5 Kw)

= $19\ (f)^{0.73}\ (P)^{0.20}$, pulsed magnetron (see Table 5.1.4.3-3)

where

f = frequency (GHz)
P = rated peak power (Mw)

TABLE 5.1.4.3-1: UTILIZATION FACTORS

Utilization (radiate hours/filament hours)	π_U
0.0	0.44
0.1	0.50
0.2	0.55
0.3	0.61
0.4	0.66
0.5	0.72
0.6	0.78
0.7	0.83
0.8	0.89
0.9	0.94
1.0	1.0

$\pi_U = 0.44 + 0.56(R)$, R = radiate hours/filament hours

TABLE 5.1.4.3-2: ENVIRONMENTAL FACTORS

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	13
G_{MS}	1.1	A_{IF}	20
G_F	2	A_{UC}	5
G_M	4	A_{UT}	13
M_P	36	A_{UB}	19
N_{SB}	15	A_{UA}	16
N_S	15	A_{UF}	30
N_U	26	S_F	1
N_H	56	M_{FF}	36
N_{UU}	60	M_{FA}	50
A_{RW}	80	U_{SL}	106
A_{IC}	4	M_L	160
A_{IT}	11	C_L	2000
A_{IB}	15		

TABLE 5.1.4.3-3: BASE FAILURE RATE FOR PULSED MAGNETRONS

P (Power, Mw)	F(Frequency, GHz)													
	0.1	0.5	1	5	10	20	30	40	50	60	70	80	90	100
0.01	1.41	4.56	7.56	24.5	40.7	67.4	90.6	112	131	150	168	185	201	218
0.05	1.94	6.29	10.4	33.8	56.0	92.9	125	154	181	207	232	256	279	301
0.1	2.23	7.23	12.0	38.8	64.3	107	144	177	208	238	266	294	320	346
0.3	2.78	9.00	14.9	48.4	80.2	133	179	221	260	297	332	366	399	431
0.5	3.08	9.97	16.5	53.6	88.8	147	198	244	288	328	368	405	442	447
1	3.54	11.4	19.0	61.5	102	169	228	281	330	337	422	466	507	548
3	4.41	14.3	23.7	76.6	127	211	283	350	412	470	526	580	632	683
5	4.88	15.8	26.2	84.9	141	234	314	387	456	521	583	642	700	756

$$\lambda_b = 19(f)^{0.73}(P)^{0.20}$$

LASERS

5.1.5 Lasers. This section presents failure rate models for laser peculiar items used in the following six major classes of laser equipment (see Bibliography Item 40):

Helium/Neon & Helium/Cadmium	Section 5.1.5.1
Argon Ion	Section 5.1.5.2
CO_2 Sealed	Section 5.1.5.3
CO_2 Flowing	Section 5.1.5.4
Solid State, Nd:YAG Rod	Section 5.1.5.5
Solid State, Ruby Rod	Section 5.1.5.6

The models and failure rates presented in this section apply to the laser peculiar items only, i.e., those items wherein the lasing action is generated and controlled. In addition to the laser peculiar items, there are other assemblies used with lasers that contain electronic parts and mechanical devices (pumps, valves, hoses, etc.). The failure rates for these parts should be determined with the same procedures as used for other electronic and mechanical devices in the equipment or system of which the laser is a part. The electronic device failure rates are in other parts of this Handbook and the mechanical device failure rates are in Bibliography Item 47.

The laser failure rate models have been developed at the "functional," rather than "piece part" level because the available data were not sufficient for "piece part" model development. Nevertheless, the laser functional models are included in this Handbook in the interests of completeness. These laser models will be revised to include piece part models and other laser types when the data become available.

Because each laser family can be designed using a variety of approaches, the failure rate models have been structured on three basic laser functions which are common to most laser families, but may differ in the hardware implementation of a given function. These functions are the lasing media, the laser pumping mechanism (or pump), and the coupling method.

The general laser failure rate model is:

$$\lambda_{LASER} = \lambda_{MEDIA} + \lambda_{PUMP} + \lambda_{COUPLING}$$

Examples of media-related hardware and influence factors are the solid state rod, gas, gas pressure, vacuum integrity, gas mix, outgassing, and tube diameter. The electrical discharge, the flashlamp, and energy level are examples of pump-related hardware and influence factors. The coupling function contributors are the "Q" switch, mirrors, windows, crystals, substrates, coatings, and level of dust protection provided.

LASERS

The λ_{PUMP} term in the λ_{LASER} equation is zero for helium/neon, helium/cadmium, argon ion, CO_2 sealed and CO_2 flowing lasers because the pumping mechanisms for these lasers contain no laser peculiar items. Pumping is accomplished with electronic parts and circuitry. Failure rates for these parts are not included in this section but they should be included in the reliability analysis of the system or equipment containing the laser. Also, some of the terms in the above general λ_{LASER} equation have modifying factors depending upon the laser type. These factors are shown in the following subsections.

LASERS

5.1.5.1 Helium/Neon and Helium/Cadmium Lasers

$$\lambda_p = \pi_E \lambda_{MEDIA} + \pi_E \lambda_{COUPLING}$$

where

λ_p = the laser failure rate in failures/10^6 operating hours.

π_E = the environmental application factor, and its value is determined from Table 5.1.5.7-1.

λ_{MEDIA} = the failure rate contribution of the lasing media, and its value is 84 failures/10^6 operating hours for helium/neon lasers, and 228 failures/10^6 operating hours for helium/cadmium lasers.

$\lambda_{COUPLING}$ = is the failure rate contribution of the laser coupling hardware, and its value is 0.1 failures/10^6 operating hours.

It should be noted that the laser failure rate prediction model can be simplified and rewritten as:

$$\lambda_{He/Ne} = 84.1 \pi_E$$

$$\lambda_{He/Cd} = 228.1 \pi_E$$

5.1.5.2 Argon Ion Lasers

$$\lambda_{AI} = \pi_E \lambda_{MEDIA} + \pi_E \lambda_{COUPLING}$$

where:

λ_{AI}	is the argon ion laser failure rate in failures/10^6 operating hours.
π_E	is the environmental application factor and its value is determined from Table 5.1.5.7-1.
λ_{MEDIA}	is the failure rate contribution of the lasing media, and its value is 457 failures/10^6 operating hours for argon ion lasers.
$\lambda_{COUPLING}$	is the failure rate contribution of the laser coupling hardware, and its value is 6 failures/10^6 operating hours for argon ion lasers. It should be noted that the predominant argon laser failure mechanism is related to the gas media (as reflected in λ_{MEDIA}); however, when the tube is refilled periodically (preventive maintenance) the mirrors (as part of $\lambda_{COUPLING}$) can be expected to deteriorate after approximately 10^4 hours of operation if in contact with the discharge region.

It should be noted that the argon ion failure rate prediction model can be simplified and rewritten as:

$$\lambda_{AI} = 463 \pi_E$$

5.1.5.3 Carbon Dioxide, Sealed Lasers.

$$\lambda_{CO_2\ SEALED} = \pi_E\ \pi_O\ \pi_B\ \lambda_{MEDIA} + \pi_E\ \pi_{OS}\ \lambda_{COUPLING}$$

where:

$\lambda_{CO_2\ SEALED}$ is the carbon dioxide sealed laser failure rate in failures/10^6 hours.

π_E is the environmental application factor, and its value is determined from Table 5.1.5.7-1.

π_O is the gas overfill factor, and its value is determined from Table 5.1.5.7-2.

π_B is the ballast factor, and its value is determined from Table 5.1.5.7-3.

λ_{MEDIA} is the failure rate contribution of the lasing media, and its value is determined from Tbl 5.1.5.7-4 which is based on the empirical expression:

$$\lambda_{MEDIA} = 69\ I - 450 \quad \text{failures}/10^6\ \text{hr.}$$

where: I = Current (ma.) through discharge tube, and ≥ 10 ma. and ≤ 150 ma.

π_{OS} is equal to the number of active optical surfaces and is determined from Figure 5.1.5.7-1.

$\lambda_{COUPLING}$ is the failure rate contribution of the laser coupling hardware; that is, lenses, mirrors, prisms, exit windows, etc. Its value is 10 failures/10^6 operating hours for carbon dioxide sealed lasers.

The sealed carbon dioxide failure rate model can be rewritten as:

$$\lambda_{CO_2\ SEALED} = (\pi_O\ \pi_B\ \lambda_{MEDIA} + 10\ \pi_{OS})\pi_E$$

5.1.5.4 Carbon Dioxide, Flowing Lasers.

$$\lambda_{CO_2\ FLOWING} = \pi_E\ \lambda_{MEDIA} + \pi_E\ \pi_{OS}\ \lambda_{COUPLING}$$

where:

$\lambda_{CO_2\ FLOWING}$ is the carbon dioxide flowing laser failure rate in failures/10^6 operating hours.

π_E is the environmental application factor, and its value is determined from Table 5.1.5.7-1.

λ_{MEDIA} is the failure rate contribution of the lasing media and its value approaches zero for carbon dioxide flowing lasers. This is because this type of laser is much less susceptible to leaks and long term gas decomposition than a sealed system. The flowing gas also acts as a purge in removing contamination and precluding its entrapment. Therefore, except for tube breakage (which has rarely been observed) optics deterioration appears the predominant failure mechanism and this is accounted for under $\lambda_{COUPLING}$.

π_{OS} is equal to the number of active optical surfaces and is determined from Figure 5.1.5.7-1.

$\lambda_{COUPLING}$ is the failure rate contribution of the laser coupling hardware; that is, lenses, mirrors, prisms, exit windows, etc. Its value is determined from Tbl 5.1.5.7-5 which is based on the empirical expression:

$$\lambda_{COUPLING} = 300\ P \quad \text{failures}/10^6\ \text{hr.}$$

where P = laser beam average power output in kilowatts.

It should be noted that the carbon dioxide flowing laser failure rate prediction model can be simplified and rewritten as:

$$\lambda_{CO_2\ FLOWING} = (300P)\ \pi_E\ \pi_{OS}$$

5.1.5.5 Solid State Neodymium-Yttrium-Aluminum-Garnet (ND:YAG) Rod Lasers

$$\lambda_{Nd:YAG} = \pi_E \lambda_{MEDIA} + \lambda_{PUMP} \pi_E \pi_C \pi_{OS} \lambda_{COUPLING}$$

where:

$\lambda_{Nd:YAG}$	is the solid state neodymium doped yttrium-aluminum-garnet rod laser failure rate in failures 10^6 operating hours.
λ_E	is the environmental application factor, and its value is determined from Table 5.1.5.7-1.
λ_{MEDIA}	is the failure rate contribution of the lasing media, and its value is 0.1 failures/10^6 operating hours for Nd:YAG lasers.
λ_{PUMP}	is the failure rate contribution of the pumping mechanism which, for solid state lasers, is highly affected by the flashlamp or flashtube contribution and can be expressed as:

$$\lambda_{PUMP} = \pi_E \lambda_{PUMP/HOURS}$$

where:

λ_E	is the environmental application factor, and its value is determined from Table 5.1.5.7-1.
$\lambda_{PUMP/HOURS}$	is the failure rate contribution of the flashlamp or flashtube in failures/10^6 operating hours, and its value is determined by converting pump pulses from failures per 10^6 pulses to failures/10^6 operating hours. The value for $\lambda_{PUMP/HOURS}$ is determined as indicated in Figures 5.1.5.7-2 or 5.1.5.7-3.
π_C	is the coupling cleanliness factor, and its value is to be determined from Table 5.1.5.7-8.
π_{OS}	is equal to the number of active optical surfaces and is determined from Figure 5.1.5.7-1.
$\lambda_{COUPLING}$	is the failure rate contribution of the laser coupling hardware; that is, lenses, mirrors, prisms, exit window, etc. Its value is 16.3 failures/10^6 operating hours for solid state Nd:YAG lasers.

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It should be noted that the solid state Nd:YAG laser failure rate prediction model can be rewritten as:

$$\lambda_{Nd:YAG} = \pi_E\,(0.1 + \lambda_{PUMP/HOURS} + 16.3\,\pi_C\,\pi_{OS})$$

5.1.5.6 Solid State, Ruby Rod Lasers.

$\lambda_{RUBY} = \pi_E \lambda_{MEDIA} + \lambda_{PUMP} + \pi_E \pi_C \pi_{OS} \lambda_{COUPLING}$

λ_{RUBY} is the solid state ruby rod laser failure rate in failure/10^6 operating hours.

π_E is the environmental application factor, and its value is determined from Table 5.1.5.7-1.

λ_{MEDIA} is the failure rate contribution of the lasing media in failures/10^6 operating hours, and its value is determined by converting from failures per 10^6 pulses to failures/10^6 operating hours. The value for λ_{MEDIA} is determined as indicated in Figure 5.1.5.7-4.

λ_{PUMP} is the failure rate contribution of the pumping mechanism which for solid state lasers is highly affected by the flashlamp or flashtube contribution and can be expressed as:

$$\lambda_{PUMP} = \pi_E \lambda_{\substack{PUMP \\ HOURS}}$$

where:

π_E is the environmental application factor, and its value is determined from Table 5.1.5.7-1.

$\lambda_{\substack{PUMP \\ HOURS}}$ is the failure rate contribution of flashlamp or flashtube in failures/10^6 operating hours, and its value is determined by converting from failures per 10^6 pulses to failures/10^6 operating hours. The value for $\lambda_{\substack{PUMP \\ HOURS}}$ is determined as indicated in Figures 5.1.5.7-2 or 5.1.5.7-3 as applicable.

π_C is the coupling cleanliness factor, and its value is to be determined from Table 5.1.5.7-8.

π_{OS} is equal to the number of active optical surfaces and is determined from Figure 5.1.5.7-1.

$\lambda_{COUPLING}$ is the failure rate contribution of the laser coupling hardware; that is, lenses, mirrors, prisms, exit windows, etc. Its value is 16.3 failures/10^6 operating hours for solid state ruby lasers.

It should be noted that the solid state ruby failure rate prediction model can be rewritten as:

$$\lambda_{RUBY} = \pi_E \left(\lambda_{MEDIA} + \lambda_{PUMP\ HOURS} + 16.3\ \Pi_C\ \Pi_{OS}\right)$$

5.1.5.7 Tables and Figures for Laser Model Parameters. This section presents the tables and figures for quantifying the parameters of the laser failure rate models in Sections 5.1.5.1 through 5.1.5.6.

TABLE 5.1.5.7-1

Environmental Mode Factors

ENVIRONMENT	Π_E
G_B	0.2
G_{MS}	0.3
G_F	1
G_M	5
M_P	2.3
N_{SB}	1.1
N_S	5
N_U	5
N_H	3.6
N_{UU}	3.9
A_{RW}	5.2
A_{IC}	3
A_{IT}	4
A_{IB}	6.5
A_{IA}	5
A_{IF}	7
A_{UC}	5
A_{UT}	6
A_{UB}	10
A_{UA}	8
A_{UF}	10
S_F	0.2
M_{FF}	2.4
M_{FA}	3.3
U_{SL}	7.0
M_L	8
C_L	N/A

TABLE 5.1.5.7-2

GAS OVERFILL FACTOR, Π_O**

CO_2 OVERFILL * PERCENT	Π_O
0	1.00
25	0.75
50	0.50

* Overfill percent is based on the percent increase over the optimum CO_2 partial pressure which is normally in the range of 1.5 to 3 Torr for most sealed CO_2 lasers.

** The equation for Π_O is:

$$\Pi_O = -0.01\ (\%\ \text{overfill}) + 1.$$

TABLE 5.1.5.7-3

BALLAST FACTOR, Π_B *

PERCENT OF BALLAST VOLUMETRIC INCREASE	Π_B
0	1.0
50	0.58
100	0.33
150	0.19
200	0.11

*The equation for Π_B is:

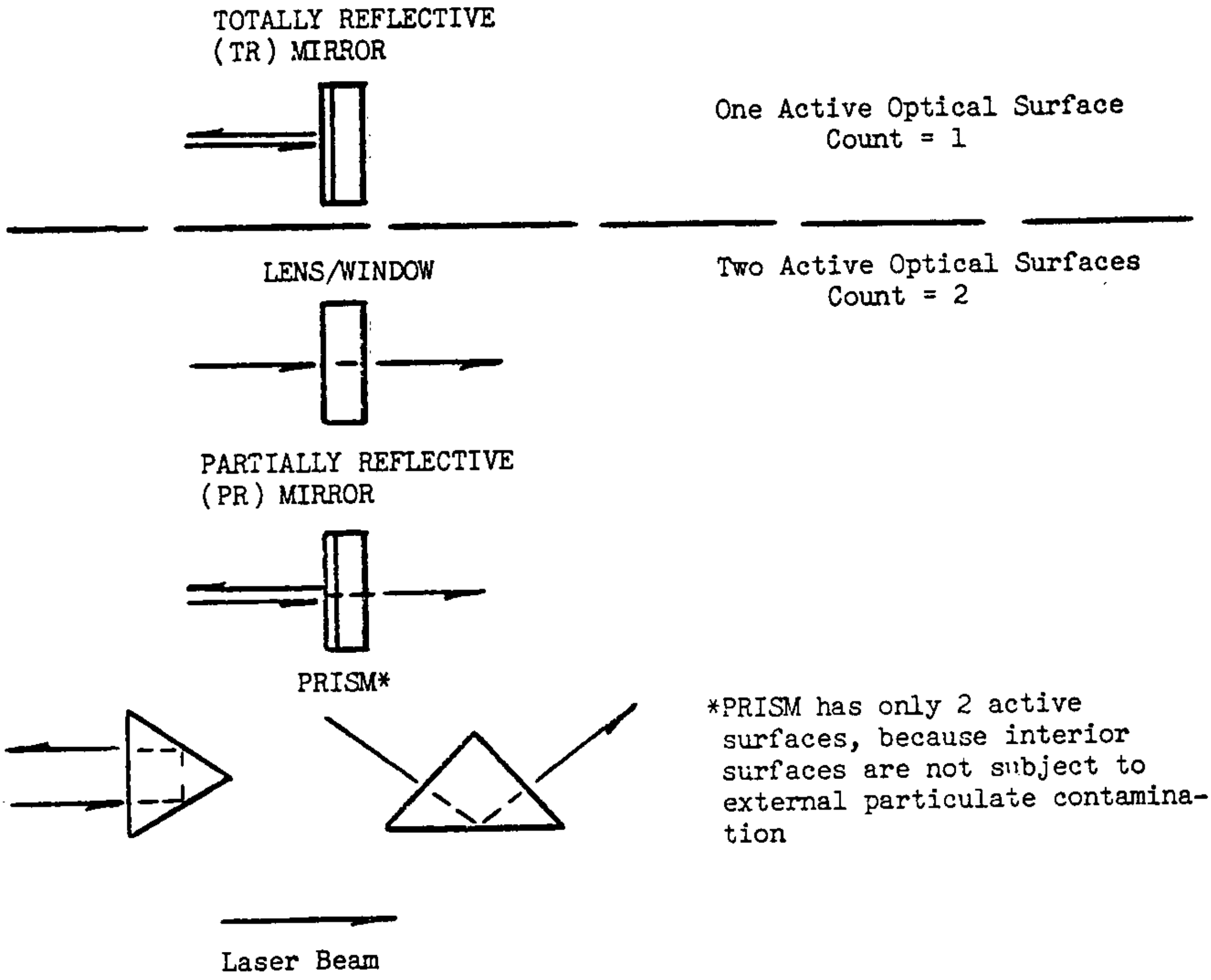
$$\Pi_B = \left(\frac{1}{3}\right)^{\frac{\%\ \text{Vol. Inc.}}{100}}$$

TABLE 5.1.5.7-4

λ_{MEDIA} VALUES FOR CO_2 SEALED LASERS

Current, I* (in milliamperes)	λ MEDIA (failures/10^6 hours)
10	240
20	930
30	1,620
40	2,310
50	3,000
100	6,450
150	9,900

*The current I is tube current, and the values for I must be equal to or greater than 10 and equal to or less than 150 milliamperes.



*PRISM has only 2 active surfaces, because interior surfaces are not subject to external particulate contamination

Only active optical surfaces are counted. An active optical surface is one with which the laser energy or beam interacts. Internally reflecting surfaces are not counted.

FIGURE 5.1.5.7-1. EXAMPLES OF ACTIVE OPTICAL SURFACES AND COUNT

LASERS

TABLE 5.1.5.7-5: $\lambda_{COUPLING}$ VALUES * FOR CO_2 FLOWING LASERS

Power (kilowatts)	$\lambda_{COUPLING}$ (failures/10^6hours)
0.01	3
0.1	30
1.0	300

*NOTE: The values shown are valid only for power levels up to one kilowatt. Beyond this range other glass failure mechanisms begin to predominate and alter the $\lambda_{COUPLING}$ values. It should also be noted that CO_2 flowing laser optical devices are the primary source of failure occurrence. A preventive maintenance program on optical devices would greatly extend laser life; however, procedures must be tailored to the individual design of each system. Typical optical cleaning methods are as follows:

1. Use optical-quality pressurized gas (DUST-OFF, or equivalent) and a camel's hair brush to remove dust, nonsoluble particulates and nongreasy deposits.
   NOTE: Most pressurized air is contaminated and will degrade laser optics.

2. Clean remaining deposits, for example fingerprints, and salty deposits, with an optical-coating compatible cleaning solution and a high quality lens tissue.
   NOTE: DO NOT USE BREATH. It contains acidic compounds and organisms that may degrade the glass and optic coatings.

3. Wash with a mild, neutral pH, clear detergent (Joy, or equivalent) 3 drops per liter of water, well mixed, and thoroughly rinse with distilled water.
   NOTE: DO NOT USE ammonia containing detergents that may react with the coating. Test any detergent for ammonia content.

4. Cautions:
   a. Use of special gloves for handling recommended.
   b Careful use of 20 to 30 percent alcohol solutions with sterile cotton swabs (change swabs frequently).
   NOTE: No not use methyl alcohol in the makeup of this solution. Specially denatured alcohol, for example type SD26a, with a strong ethanol (ethyl alcohol base), or equivalent can be used. The alcohol solution should be mixed in distilled water or equivalent to prevent the intoduction of a soluble salt deposit on the optics. Contact the optics manufacturer for other recommended cleaning procedures.

TABLE 5.1.5.7-6

REPETITION RATE FACTORS, π_{REP}

Repetition or Pulse* Rate (pulses per second)	π_{REP}
1	3,600
5	18,000
10	36,000
15	54,000
20	72,000

*Note: Repetition rates for military solid state lasers are generally in the 1 to 20 pps range. Repetition rates other than shown have not been observed and corresponding π_{REP} values certified.

TABLE 5.1.5.7-7

FLASHLAMP COOLING FACTORS, π_{COOL}

Cooling Media	π_{COOL}
Gas, Air	1.0
Gas, Inert	1.0
Liquid, Deionized Water	0.1
Liquid, Water-Glycol	0.1
Liquid, Fluorocarbon	0.1

TABLE 5.1.5.7-8

COUPLING CLEANLINESS FACTOR

CLEANLINESS LEVEL*	π_C
Rigorous cleanliness procedures, equipment, and trained maintenance personnel. Plus bellows provided over optical train.	1
Minimal precautions during opening, maintenance, repair, and testing. Plus bellows provided over optical train.	30
Minimal precautions during opening, maintenance, repair, and testing. No bellows provided over optical train.	60

*NOTE: Although sealed systems tend to be reliable once compatible materials have been selected and proven, extreme care must still be taken to prevent the entrance of particulates during manufacturing, field flashlamp replacement, or routine maintenance/repair. Contamination is the major cause of solid state laser malfunction, and special provisions and vigilance must continually be provided to maintain the cleanliness level required. π_C values can vary from 1 up to 60.

The empirical formula used to determine $\lambda_{\text{PUMP HOURS}}$ for xenon lamps is:

$$\lambda_{\text{PUMP HOURS XENON}} = \left[\pi_{\text{REP}}\right] \left[2000 \left(\frac{E_j}{dL\sqrt{T}}\right)^{8.58}\right] \left[\pi_{\text{COOL}}\right] \text{ failures}/10^6 \text{ hr.}$$

where:

$\lambda_{\text{PUMP HOURS XENON}}$	is the failure rate contribution of the xenon flashlamp or flashtube* in failures/10^6 operating hours. The flashlamps evaluated herein are linear types used for military solid state laser systems.
π_{REP}	is the pulse or repetition rate factor used to convert from failures per 10^6 pulses to failures/10^6 operating hours, and its value is determined from Table 5.1.5.7-6.
E_j	is the flashlamp or flashtube input energy per pulse in joules, and its value is determined from the actual or design input energy parameter except that for input energy levels equal to or less than 30 joules, $E_j = 30$.
d	is the flashlamp or flashtube inside diameter in millimeters, and its value is determined from the actual design parameter of the flashlamp utilized.
L	is the flashlamp or flashtube arc length in inches, and its value is determined from the actual design parameter of the flashlamp utilized.
$\sqrt{T}$	is the truncated pulse width in microseconds, and its value is determined from the actual design parameter of the pulse forming network (PFN) used to pulse the flashlamp or flashtube. Pulse tails do not affect reliability, and the maximum value of T is 100 microseconds for any truncated pulse width exceeding 100 microseconds. For shorter duration pulses, pulse width is to be measured at 10 percent of the maximum current amplitude.
π_{COOL}	is the cooling factor due to various cooling media immediately surrounding the flashlamp or flashtube, and its value is determined from Table 5.1.5.7-7.
*Note:	Typical values for Xenon flashlamps in military Nd:YAG rangefinders and designators are $E_j = 40$ joules, $d = 4$ millimeters, $L = 2$ inches, and $T = 100$ microseconds. The repetition or pulse rate ranges from 1 to 20 pps, and the lamps are normally liquid cooled.

Figure 5.1.5.7-2. Determination of $\lambda_{\text{PUMP HOURS}}$ for Xenon Flashlamps

The empirical formula used to determine $\lambda_{\text{PUMP HOURS}}$ for Krypton lamp is:

$$\lambda_{\text{PUMP HOURS KRYPTON}} = \left[625\right] \left[10^{\left(0.9 \frac{P}{L}\right)}\right] \left[\pi_{\text{COOL}}\right] \text{ failures}/10^6 \text{ hr.}$$

where:

$\lambda_{\text{PUMP HOURS KRYPTON}}$	is the failure rate contribution of the krypton flashlamp or flashtube in failures/10^6 operating hours. The flashlamps evaluated herein are the continuous wave (CW) type and are most widely used for commercial solid state applications. They are approximately 7mm in diameter and 5 to 6 inches long. Average power is typically 4 KW.
P	is the average input power in kilowatts, and its value is determined from the actual design parameter for the flashlamp utilized.
L	is the flashlamp or flashtube arc length in inches, and its value is determined from the actual design parameter of the flashlamp utilized.
π_{COOL}	is the cooling factor due to various cooling media immediately surrounding the flashlamp or flashtube, and its value is determined from Table 5.1.5.7-7.

Figure 5.1.5.7-3. Determination of $\lambda_{\text{PUMP HOURS}}$ for Krypton Flashlamps

The empirical formula used to determine λ_{MEDIA} is:

$$\lambda_{MEDIA} = \left[\pi_{REP}\right]\left[43.5 \quad F^{2.52}\right] \text{ failures}/10^6 \text{ hr.}$$

where:

π_{REP} is the pulse or repetition rate factor used to convert from failures/10^6 pulses to failures/10^6 operating hours, and its value is determined from Table 5.1.5.7-6.

F is the energy density in Joules per cm.^{2}/pulse over the cross-sectional area of the laser beam which is nominally equivalent to the cross-sectional area of the laser rod and its value is determined from the actual design parameter of the laser rod utilized.

Figure 5.1.5.7-4. Determination of λ_{MEDIA} for Solid State Ruby Lasers

5.1.5.8 Examples of Laser Failure Rate Prediction.

5.1.5.8.1 Example of Failure Rate Calculation for He/Ne Lasers.

Given. A helium neon laser device to be used in a military ground mobile application.

Step 1 - The failure rate model of Section 5.1.5.1 applies:

$$\lambda_{He/Ne} = 84.1\ \pi_E$$

Step 2 - From Table 5.1.5.7-1 $\pi_E = G_M = 5.0$.

Step 3 - Calculate $\lambda_{He/Ne}$:

$$\lambda_{He/Ne} = 84.1\ \pi_E$$

$$= 84.1\ (5)$$

$= 421.$ failures/10^6 hours in a ground mobile application.

5.1.5.8.2 Example of Failure Rate Calculation and Reliability Prediction for a Solid State, Nd:YAG Rod Laser.

Given. Nd: YAG laser designator using a xenon flashlamp which is cooled by an eutectic water-glycol solution. The laser is being used in the A_{UF} environment. Design parameters are:

Pulse or Repetition Rate = 10 pps
Flashlamp input energy (per pulse) = 30 joules
Flashlamp inside diameter = 4 millimeters
Flashlamp arc length = 2 inches
Pulse width (including both tails) = 120 microseconds
Optical train enclosed in bellows

In addition, strict field maintenance, repair, and test procedures will be written, validated, and provided for use by trained specialists in appropriately clean and controlled facilities.

Find: Airborne failure rate ($\lambda_{Nd:YAG}$)

Step 1 - The failure rate model of Section 5.1.5.5 applies:

$$\lambda_{Nd:YAG} = \pi_E \left(0.1 + \lambda_{\substack{PUMP\\HOURS}} + 16.3\,\pi_C\,\pi_{OS}\right)$$

Step 2 - From Tbl 5.1.5.7-1, $\pi_E = 10$ for A_{UF}

solid state Nd:YAG lasers.

Step 3 - Calculate $\lambda_{\substack{PUMP\\HOURS}}$ for Xenon flashlamps from

$$\lambda_{\substack{PUMP\\HOURS\\XENON}} = \pi_{REP} \left[2000 \left(\frac{E_j}{dL\sqrt{T}} \right)^{8.58} \right] \pi_{COOL}$$

From the given design parameters and Figure 5.1.5.7-2 notes:

3a - E_j = 30 joules
d = 4 mm
L = 2 in
T = 100 µs (refer to Figure 5.1.5.7-2

3b - From Table 5.1.5.7-7, π_{COOL} = 0.1 for Liquid, Water-Glycol cooling media.

3c - $$\lambda_{\substack{PUMP\\HOURS\\XENON}} = (36{,}000) \left[2000 \left(\frac{30}{4 \times 2\sqrt{100}} \right)^{8.58} \right] (0.1)$$

$= 1{,}600$ failures/10^6 operating hours

Step 4 - From Table 5.1.5.7-8, π_C = 1 for the most stringent cleanliness level (as is specified).

Step 5 - From Fig 5.1.5.7-1, determine π_{OS}:

5a - Make parts list and count of optical train:

(1) One totally reflective (TR) mirror
(2) One Prismatic "Q" Switch
(3) One partially reflective (PR) mirror
(4) One exit lens or window

5b - Determine active optical surfaces:

(1) One TR mirror = 1
(2) One "Q" Switch = 2
(3) One PR mirror = 2
(4) One exit lens = 2

π_{OS}, Active Optical Surfaces = 7 total

Step 6 - Calculate $\lambda_{Nd:YAG}$:

$$\lambda_{Nd:YAG} = \pi_E \left(0.1 + \lambda_{\substack{PUMP \\ HOURS}} + 16.3 \, \pi_C \, \pi_{OS}\right)$$

$$= 10 \left[0.1 + 1{,}600 + (16.3)(1)(7)\right]$$

$$= 17{,}000 \quad \text{failures}/10^6 \text{ operating hours.}$$

5.1.6 Resistors. This section includes the active resistor specifications and, in addition, some older/inactive specifications are included because of the large number of equipments still in field use which contain these parts. For each specification, the analytical model for the part failure rate, λ_p, is given followed by the quantitative values of the model elements. The following resistors are included:

Composition, Fixed

MIL-R-11	Resistors, Fixed, Composition (Insulated)
MIL-R-39008	Resistors, Fixed, Composition (Insulated) Established Reliability

Film, Fixed

MIL-R-10509	Resistors, Fixed, Film (High Stability)
MIL-R-11804	Resistors, Fixed, Film (Power Type)
MIL-R-22684	Resistors, Fixed, Film, Insulated
MIL-R-39017	Resistors, Fixed, Film, Insulated, Established Reliability
MIL-R-55182	Resistors, Fixed, Film, Established Reliability

Network, Film, Fixed

MIL-R-83401	Resistor Network, Fixed, Film

Wirewound, Fixed

MIL-R-26	Resistors, Fixed, Wirewound (Power Type)
MIL-R-93	Resistors, Fixed, Wirewound (Accurate)
MIL-R-18546	Resistors, Fixed, Wirewound (Power Type, Chassis Mounted)
MIL-R-39005	Resistors, Fixed, Wirewound (Accurate), Established Reliability
MIL-R-39007	Resistors, Fixed, Wirewound (Power Type), Established Reliability
MIL-R-39009	Resistors, Fixed, Wirewound (Power Type, Chassis Mounted) Established Reliability

Thermistor

MIL-T-23648	Thermistor (Thermally Sensitive Resistor) Insulated

Non-wirewound, Variable

MIL-R-94	Resistors, Variable, Composition
MIL-R-22097	Resistors, Variable, Non-wirewound (Lead Screw Actuated)
MIL-R-23285	Resistors, Variable, Film
MIL-R-39023	Resistors, Variable, Non-wirewound, Precision
MIL-R-39035	Resistors, Variable, Cermet or Carbon Film (Lead Screw Actuated) Established Reliability

Wirewound, Variable

MIL-R-19	Resistors, Variable, Wirewound (Low Operating Temperature)

MIL-R-22	Resistors, Variable, Wirewound (Power Type)
MIL-R-12934	Resistors, Variable, Wirewound, Precision
MIL-R-27208	Resistors, Variable, Wirewound (Lead Screw Actuated)
MIL-R-39002	Resistors, Variable, Wirewound, Semi-Precision
MIL-R-39015	Resistors, Variable, Wirewound, (Lead Screw Actuated), Established Reliability

The general model for resistors is as follows:

$$\lambda_p = \lambda_b (\pi_E \times \pi_R \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

The general model for the variable resistors is as follows:

$$\lambda_p = \lambda_b (\pi_{TAPS} \times \pi_R \times \pi_V \times \pi_C \times \pi_E \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

The factors shown are defined in Section 5.1.1 and the following sections provide quantitative values related to specific types or classes of resistors. The general model used to quantify the λ_b term is as follows:

$$\lambda_b = Ae^{B}\left(\frac{T+273}{N_T}\right)^{G} e \left[\left(\frac{S}{N_s}\right)\left(\frac{T+273}{273}\right)\right]^{J^{H}}$$

where,

A is an adjustment factor for each type of resistor to adjust the model to the appropriate failure rate level.

e Is the natural logarithm base, 2.718

T is the ambient operating temperature (degrees C)

N_T Is a temperature constant

B is a shaping parameter

G, H, J are acceleration constants

N_s is a stress constant

S is the electrical stress and is the ratio of operating power to rated power.

The quantitative values for the base failure rate model factors are given in Tables 5.1.6-1 and 5.1.6-2 for the different resistor types. The last column of these tables shows the table number that lists the resulting base failure rate values.

RESISTORS

TABLE 5.1.6-1
FIXED RESISTOR BASE FAILURE RATE (λ_b) FACTORS

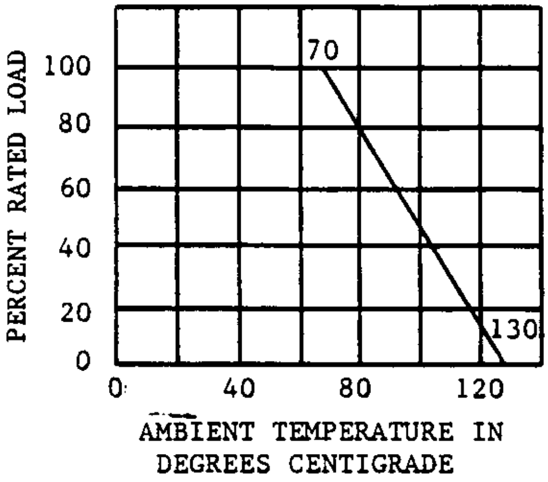
Style	MIL-R Spec	A	B	N_T	G	N_s	H	J	λ_b Table No.
RB	93	$3.1(10)^{-3}$	1	398	10	1	1.5	1	5.1.6.4-4
RBR	39005	$3.1(10)^{-3}$	1	398	10	1	1.5	1	5.1.6.4-4
RC	11	$4.5(10)^{-9}$	12	343	1	0.6	1	1	5.1.6.1-4
RCR	39008	$4.5(10)^{-9}$	12	343	1	0.6	1	1	5.1.6.1-4
RD	11804	$7.33(10)^{-3}$	0.202	298	2.6	1.45	1.3	0.89	5.1.6.2-9
RE	18546	$1.5(10)^{-4}$	2.64	298	1	0.466	1	1	5.1.6.4-12
RER	39009	$1.5(10)^{-4}$	2.64	298	1	0.466	1	1	5.1.6.4-12
RL	22684	$3.25(10)^{-4}$	1	343	3	1	1	1	5.1.6.2-4
RLR	39017	$3.25(10)^{-4}$	1	343	3	1	1	1	5.1.6.2-4
RN	10509	$5.0(10)^{-5}$	3.5	398	1	1	1	1	5.1.6.2-5
RNR	55182	$5.0(10)^{-5}$	3.5	398	1	1	1	1	5.1.6.2-5
RTH	No	λ_b Model				See	Sec. 5.1.6.5		
RW	26	$1.48(10)^{-3}$	1	298	2	0.5	1	1	5.1.6.4-8
RWR	39007	$1.48(10)^{-3}$	1	298	2	0.5	1	1	5.1.6.4-8
RZ	83401					See	Sec. 5.1.6.3		

TABLE 5.1.6-2
VARIABLE RESISTOR BASE FAILURE RATE (λ_b) FACTORS

Style	MIL-R Spec	A	B	N_T	G	N_s	H	J	λ_b Table No.
RA	19	$3.98(10)^{-2}$	0.514	313	5.28	1.44	1	4.46	5.1.6.6-16
RK	39002	$3.98(10)^{-2}$	1.050	358	5.28	1.44	1	4.46	5.1.6.6-16
RJ	22097	$1.90(10)^{-2}$	0.445	358	7.3	2.69	1	2.46	5.1.6.7-5
RJR	39035	$1.90(10)^{-2}$	0.445	358	7.3	2.69	1	2.46	5.1.6.7-5
RP	22	$4.81(10)^{-2}$	0.334	298	4.66	1.47	1	2.83	5.1.6.6-22
RQ	39023	$1.8(10)^{-2}$	1	343	7.4	2.55	1	3.6	5.1.6.7-16
RR	12934	$7.35(10)^{-2}$	1.03	358	4.45	2.74	1	3.51	5.1.6.6-17
RT	27208	$6.2(10)^{-3}$	1	358	5	1	1	1	5.1.6.6-5
RTR	39015	$6.2(10)^{-3}$	1	358	5	1	1	1	5.1.6.6-5
RV	94	$2.46(10)^{-2}$	0.459	343	9.3	2.32	1	5.3	5.1.6.7-10
RVC	23285	$2.57(10)^{-2}$	1	398	7.9	2.45	1	4.3	5.1.6.7-15

The ER resistor family generally has four qualification failure rate levels when tested per the requirements of the applicable ER specification. These qualification failure rate levels differ by a factor of ten. However, field data has shown that these failure rate levels differ by a factor about three, hence the Π_Q values have been set accordingly.

The use of the resistor models requires the calculation of the electrical power stress ratio, S = operating power/rated power, or per Section 5.1.6.8 for variable resistors. The models have been structured such that derating curves do not have to be used to find the base failure rate. The rated power for the S ratio is equal to the full nominal rated power of the resistor. For example, MIL-R-39008 has the following derating curve:



If a 1 watt resistor were being used in an ambient temperature of 90°C., the rated power for the S calculation would still be 1 watt, not 67% of 1 watt. Of course, while the derating curve is not needed to determine the base failure rate, it must still be observed as the maximum operating condition. To aid in determining if a resistor is being used within rated conditions, the base failure rate tables show entries up to certain combinations of stress and temperature. If a given operating stress and temperature point falls in the blank portion of the base failure rate table, the resistor is overstressed. Such misapplication would require an analysis of the circuit and operating conditions to bring the resistor within rated conditions.

5.1.6.1 Composition Resistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39008	RCR	Insulated Fixed Composition Est. Rel.
MIL-R-11	RC	Insulated Fixed Composition

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q) \text{ (Failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.1-1 through -4.

TABLE 5.1.6.1-1

ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{UT}	7
G_{MS}	1.2	A_{UB}	10
G_F	2.9	A_{UA}	7
G_M	8.3	A_{UF}	15
M_P	8.5	S_F	1
N_{SB}	4.0	M_{EF}	8.6
N_S	5.2	M_{FA}	13
N_U	12	U_{SL}	25
N_H	13	M_L	29
N_{UU}	14	C_L	490
A_{RW}	19		
A_{IC}	3		
A_{IT}	3.5		
A_{IB}	5		
A_{IA}	3.5		
A_{IF}	6.5		
A_{UC}	5		

TABLE 5.1.6.1-2

π_R, Resistance Factor

Resistance Range (ohms)	π_R
Up to 100 K	1.0
> 0.1MΩ to 1 MΩ	1.1
> 1.0MΩ to 10 MΩ	1.6
> 10MΩ	2.5

MIL-R-39008, RCR; MIL-R-11, RC

5.1.6.1 Composition Resistors (cont'd)

TABLE 5.1.6.1-3

π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
MIL-R-11	5.0
LOWER	15.

MIL-R-39008, RCR: MIL-R-11, RC

TABLE 5.1.6.1-4: MIL-R-39008 & MIL-R-11 RESISTORS, FIXED, COMPOSITION, BASE FAILURE RATES, λ_b

TEMP (°C)	S, RATIO OF OPERATING TO RATED WATTAGE									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00007	.00009	.00010	.00012	.00015	.00017	.00020	.00024	.00028	.00033
10	.00011	.00013	.00015	.00018	.00021	.00025	.00030	.00036	.00043	.00051
20	.00015	.00018	.00022	.00026	.00031	.00037	.00045	.00053	.00064	.00076
30	.00022	.00026	.00031	.00038	.00046	.00055	.00066	.00079	.00096	.0011
40	.00031	.00038	.00045	.00055	.00067	.00081	.00098	.0012	.0014	.0017
50	.00044	.00054	.00066	.00080	.00098	.0012	.0014	.0018	.0021	.0026
60	.00063	.00078	.00095	.0012	.0014	.0017	.0021	.0026	.0032	.0039
70	.00090	.0011	.0014	.0017	.0021	.0026	.0032	.0039	.0048	.0059
80	.0013	.0016	.0020	.0025	.0031	.0038	.0047	.0058		
90	.0018	.0023	.0029	.0036	.0045	.0056				
100	.0026	.0033	.0041	.0052	.0065					
110	.0038	.0047	.0060							
120	.0054									

MIL-R-39017, RLR: MIL-R-55182, RNR
MIL-R-22684, RL: MIL-R-10509, RN

5.1.6.2 Film Resistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39017	RLR	Fixed Film, Insulated, Est. Rel.
MIL-R-22684	RL	Fixed Film, Insulated
MIL-R-55182	RN (R, C, or N)	Fixed Film, Est. Rel.
MIL-R-10509	RN	Fixed Film, Insulated

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b(\pi_E \times \pi_R \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.2-1 through 5.1.6.2-5.

TABLE 5.1.6.2-1: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	6.5
G_{MS}	1.2	A_{IA}	6
G_F	2.4	A_{IF}	9
G_M	7.8	A_{UC}	7
M_P	8.8	A_{UT}	6.5
N_{SB}	4.2	A_{UB}	15
N_S	4.7	A_{UA}	15
N_U	14	A_{UF}	20
N_H	14	S_F	0.4
N_{UU}	15	M_{FF}	8.9
A_{RW}	19	M_{FA}	12
A_{IC}	2.5	U_{SL}	26
A_{IT}	3	M_L	30
		C_L	510

RESISTORS

MIL-R-39017, RLR: MIL-R-55182, RNR
MIL-R-22684, RL: MIL-R-10509, RN

TABLE 5.1.6.2-2: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
Up to 100K	1.0
>0.1M to 1M	1.1
>1.0M to 10M	1.6
>10M	2.5

TABLE 5.1.6.2-3: π_Q QUALITY FACTOR

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
MIL-R-10509	5.0
MIL-R-22684	5.0
Lower	15.0

MIL-R-39017, RLR: MIL-R-55182, RNR
MIL-R-22684, RL: MIL-R-10509, RN

TABLE 5.1.6.2-4: MIL-R-22684 & MIL-R-39017 RESISTORS, FIXED, FILM (INSULATED) BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00059	.00066	.00073	.00080	.00089	.00098	.0011	.0012	.0013	.0015
10	.00063	.00070	.00078	.00086	.00096	.0011	.0012	.0013	.0014	.0016
20	.00067	.00075	.00084	.00093	.0010	.0012	.0013	.0014	.0016	.0018
30	.00072	.00081	.00090	.0010	.0011	.0013	.0014	.0016	.0018	.0020
40	.00078	.00087	.00098	.0011	.0012	.0014	.0016	.0017	.0019	.0022
50	.00084	.00095	.0011	.0012	.0014	.0015	.0017	.0019	.0022	.0024
60	.00092	.0010	.0012	.0013	.0015	.0017	.0019	.0022	.0024	.0027
70	.0010	.0011	.0013	.0015	.0017	.0019	.0021	.0024	.0027	.0031
80	.0011	.0013	.0014	.0016	.0018	.0021	.0024	.0027		
90	.0012	.0014	.0016	.0018	.0021	.0024	.0027			
100	.0013	.0015	.0018	.0020	.0023	.0027				
110	.0015	.0017	.0020	.0023	.0026					
120	.0017	.0020	.0023							
130	.0019	.0022								
140	.0022									

MIL-R-39017, RLR: MIL-R-55182, RNR
MIL-R-22684, RL: MIL-R-10509, RN

TABLE 5.1.6.2-5: MIL-R-10509 & MIL-R-55182 RESISTORS, FIXED, FILM, BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00061	.00067	.00074	.00082	.00091	.0010	.0011	.0012	.0014	.0015
10	.00067	.00074	.00082	.00091	.0010	.0011	.0012	.0014	.0015	.0017
20	.00073	.00082	.00091	.0010	.0011	.0013	.0014	.0016	.0017	.0019
30	.00080	.00090	.0010	.0011	.0013	.0014	.0016	.0017	.0019	.0022
40	.00088	.00099	.0011	.0012	.0014	.0016	.0017	.0020	.0022	.0025
50	.00096	.0011	.0012	.0014	.0015	.0017	.0020	.0022	.0025	.0028
60	.0011	.0012	.0013	.0015	.0017	.0019	.0022	.0025	.0028	.0032
70	.0012	.0013	.0015	.0017	.0019	.0022	.0025	.0028	.0032	.0036
80	.0013	.0014	.0016	.0019	.0021	.0024	.0028	.0031	.0036	.0041*
90	.0014	.0016	.0018	.0021	.0024	.0027	.0031	.0035	.0040	.0046
100	.0015	.0017	.0020	.0023	.0026	.0030	.0035	.0040	.0045	.0052
110	.0017	.0019	.0022	.0025	.0029	.0034	.0039	.0045	.0051	.0059
120	.0018	.0021	.0024	.0028	.0033	.0038	.0043	.0050	.0058	.0067
130	.0020	.0023	.0027	.0031	.0036	.0042	.0049	.0056	.0065	
140	.0022	.0026	.0030	.0035	.0040	.0047	.0054			
150	.0024	.0028	.0033	.0038	.0045					
160	.0026	.0031	.0036							
170	.0029									

*Do not use MIL-R-10509 (Characteristic B) below this line. Points below are overstressed.

MIL-R-11804, RD

Power Film

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-11804	RD	Power Film

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_R \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.2-6 through 5.1.6.2-9.

TABLE 5.1.6.2-6: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	7
G_{MS}	1.2	A_{IA}	5.5
G_F	2.4	A_{IF}	10
G_M	8.8	A_{UC}	8
M_P	11	A_{UT}	15
N_{SB}	5.1	A_{UB}	20
N_S	5.1	A_{UA}	10
N_U	15	A_{UF}	25
N_H	18	S_F	1
N_{UU}	19	M_{FF}	12
A_{RW}	25	M_{FA}	16
A_{IC}	3.5	U_{SL}	34
A_{IT}	6	M_L	39
		C_L	660

MIL-R-11804, RD

TABLE 5.1.6.2-7: π_Q QUALITY FACTOR

Failure Rate Level	π_Q
MIL-SPEC	1.0
Lower	3.0

TABLE 5.1.6.2-8: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
10 to 100	1.0
>100 to 100K	1.2
>100K to 1M	1.3
>1M	3.5

MIL-R-11804, RD

TABLE 5.1.6.2-9: MIL-R-11804 POWER FILM, RESISTOR BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(^oC)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0089	.0093	.0098	.010	.011	.012	.013	.014	.015	.016
10	.0090	.0095	.010	.011	.011	.012	.013	.014	.015	.017
20	.0092	.0097	.010	.011	.012	.013	.014	.015	.016	.017
30	.0094	.0099	.010	.011	.012	.013	.014	.015	.017	
40	.0096	.010	.011	.011	.012	.013	.015	.016	.017	
50	.0098	.010	.011	.012	.013	.014	.015	.016		
60	.010	.011	.011	.012	.013	.014	.016	.017		
70	.010	.011	.012	.013	.014	.015	.016			
80	.010	.011	.012	.013	.014	.015	.017			
90	.011	.011	.012	.013	.015	.016				
100	.011	.012	.013	.014	.015	.017				
110	.011	.012	.013	.014	.016					
120	.012	.012	.014	.015	.016					
130	.012	.013	.014	.015	.017					
140	.012	.013	.014	.016						
150	.013	.014	.015	.017						
160	.013	.014	.016							
170	.014	.015	.016							
180	.014	.015								
190	.015	.016								
200	.015									
210	.016									

MIL-R-83401, RZ

5.1.6.3 Resistor Network.

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-83401	RZ	Resistor Networks, Fixed, Film

Part operating failure rate model (λ_p):

$$\lambda_P = .00066 \, (N_R \times \Pi_T \times \Pi_E \times \Pi_Q) \text{ failures}/10^6 \text{ hours}$$

where:

N_R is the number of film resistors in use (do not include resistors that are not used)

Π_T is the temperature factor, Table 5.1.6.3-1

Π_E is the environmental factor, Table 5.1.6.3-2

Π_Q is the quality factor, Table 5.1.6.3-3

MIL-R-83401, RZ

TABLE 5.1.6.3-1. TEMPERATURE FACTOR, π_T*

T_P (°C.)	π_T	T_P (°C.)	π_T	T_P (°C.)	π_T
25	1.0	60	4.2	95	13.3
30	1.25	65	5.0	100	15.4
35	1.56	70	5.9	105	17.8
40	1.92	75	7.1	110	20.
45	2.4	80	8.3	115	24.
50	2.9	85	9.8	120	27.
55	3.5	90	11.4	125	31.

$$* - \pi_T = \mathrm{Exp}\left[-4056\left(\frac{1}{T_P + 273} - \frac{1}{298}\right)\right]$$

where T_P is package temperature in °C. If T_P is unknown, it can be estimated using $T_P = T_A + 55S$. T_A is ambient temperature (°C.) and S is the ratio of total operating power/package rated power. Any device operating at T_P >125°C. is over-stressed.

TABLE 5.1.6.3-2
ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	7.8
M_P	8.8
N_{SB}	4.2
N_S	4.7
N_U	14
N_H	14
N_{UU}	15
A_{RW}	19
A_{IC}	2.5
A_{IT}	3
A_{IB}	6.5
A_{IA}	6
A_{IF}	9
A_{UC}	6
A_{UT}	6.5

ENVIRONMENT	π_E
A_{UB}	15
A_{UA}	15
A_{UF}	20
S_F	1
M_{FF}	8.9
M_{FA}	12
U_{SL}	26
M_L	30
C_L	510

TABLE 5.1.6.3-3. QUALITY FACTOR, π_Q

QUALITY LEVEL	π_Q
MIL-SPEC	1
Lower	3

MIL-R-39005, RBR; MIL-R-93, RB

5.1.6.4 Wirewound Resistors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39005	RBR	Accurate Fixed Wirewound, ER
MIL-R-93	RB	Accurate Fixed Wirewound

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\Pi_E \times \Pi_R \times \Pi_Q) \text{ (failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.4-1 through -4.

TABLE 5.1.6.4-1

Environmental Mode Factors

ENVIRON-MENT	Π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	9.8
M_P	12
N_{SB}	5.2
N_S	5.2
N_U	16
N_H	18
N_{UU}	20
A_{RW}	27
A_{IC}	9
A_{IT}	15
A_{IB}	20
A_{IA}	15
A_{IF}	20
A_{UC}	20
A_{UT}	25
A_{UB}	40
A_{UA}	25
A_{UF}	45
S_F	1.5
M_{FF}	12.0
M_{FA}	17.0
U_{SL}	36.0
M_L	41.0
C_L	610.0

TABLE 5.1.6.4-2

Π_R, Resistance Factor

Resistance Range (ohms)	Π_R
Up to 10K	1.0
>10 K to 100 K	1.7
>100 K to 1 M	3.0
>1 M	5.0

TABLE 5.1.6.4-3

Π_Q, Quality Factor

Failure Rate Level	Π_Q
S	0.03
R	0.1
P	0.3
M	1.0
MIL-R-93	5.0
LOWER	15.

MIL-R-39005, RBR: MIL-R-93, RB

TABLE 5.1.6.4-4: MIL-R-93 & MIL-R-39005 RESISTORS, FIXED, WIRE-WOUND (ACCURATE) BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0033	.0035	.0037	.0041	.0045	.0050	.0057	.0065	.0075	.0086
10	.0033	.0035	.0038	.0042	.0047	.0052	.0059	.0068	.0079	.0092
20	.0034	.0036	.0039	.0043	.0048	.0054	.0062	.0072	.0084	.0099
30	.0034	.0037	.0040	.0044	.0050	.0057	.0066	.0076	.0090	.011
40	.0035	.0038	.0042	.0046	.0052	.0060	.0070	.0082	.0097	.012
50	.0037	.0039	.0043	.0049	.0055	.0064	.0075	.0088	.011	.013
60	.0038	.0041	.0046	.0052	.0059	.0069	.0081	.0096	.012	.014
70	.0041	.0044	.0049	.0055	.0064	.0075	.0089	.011	.013	.016
80	.0044	.0048	.0053	.0061	.0070	.0083	.0099	.012	.015	.018
90	.0048	.0053	.0059	.0068	.0079	.0094	.011	.014	.017	.021
100	.0055	.0060	.0068	.0078	.0092	.011	.013	.016	.020	.026
110	.0065	.0071	.0080	.0093	.011	.013	.016	.020	.025	.032
120	.0079	.0087	.0099	.012	.014	.017	.021	.026	.033	.042
130	.010	.011	.013	.015	.018	.022	.028			
140	.014	.016								

MIL-R-39007, RWR; MIL-R-26, RW

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39007	RWR	Power Type, Fixed Wirewound, ER
MIL-R-26	RW	Power Type, Fixed Wirewound

Part operating failure rate model (λ_P):

$$\lambda_P = \lambda_b(\pi_E \times \pi_R \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.4-5 through -8.

TABLE 5.1.6.4-5

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.5
G_M	8.3
M_P	11
N_{SB}	4.9
N_S	4.9
N_U	14
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	1.5
A_{IT}	3.5
A_{IB}	7.5
A_{IA}	7
A_{IF}	10
A_{UC}	5.6
A_{UT}	7
A_{UB}	15
A_{UA}	15
A_{UF}	20
S_F	0.6
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

TABLE 5.1.6.4-6

π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
MIL-R-26	5.0
LOWER	15.

MIL-R-39007, RWR: MIL-R-26, RW

TABLE 5.1.6.4-7: RESISTANCE FACTOR π_R

MIL-R-39007 Style	Resistance Range (ohms)							
	Up to 500	>500 to 1K	>1K to 5K	>5K to 7.5K	>7.5K to 10K	>10K to 15K	>15K to 20K	>20K
RWR 71	1.0	1.0	1.2	1.2	1.6	1.6	1.6	NA
RWR 74	1.0	1.0	1.0	1.2	1.6	1.6	NA	NA
RWR 78	1.0	1.0	1.0	1.0	1.2	1.2	1.2	1.6
RWR 80	1.0	1.2	1.6	1.6	NA	NA	NA	NA
RWR 81	1.0	1.6	NA	NA	NA	NA	NA	NA
RWR 82	1.0	1.6	1.6	NA	NA	NA	NA	NA
RWR 84	1.0	1.0	1.1	1.2	1.2	1.6	NA	NA
RWR 89	1.0	1.0	1.4	NA	NA	NA	NA	NA

MIL-R-39007, RWR: MIL-R-26, RW

TABLE 5.1.6.4-7
RESISTANCE FACTOR, π_R (CONT'D)

MIL-R-26 Style	Resistance Range (ohms)					
	Up to 100	>100 to 1K	>1K to 10K	>10K to 100K	>100K to 150K	>150K to 200K
RW 10	1.0	1.0	1.0	1.0	1.2	1.6
RW 11	1.0	1.0	1.0	1.2	1.6	↑
RW 12	1.0	1.0	1.2	1.6	↑	↑
RW 13	1.0	1.0	1.0	2.0	↑	↑
RW 14	1.0	1.0	1.0	2.0	↑	↑
RW 15	1.0	1.0	1.2	2.0	↑	↑
RW 16	1.0	1.2	1.4	NA	↑	↑
RW 20	1.0	1.0	1.6	NA	↑	↑
RW 21	1.0	1.0	1.2	2.0	↑	↑
RW 22	1.0	1.0	1.2	1.6	↑	↑
RW 23	1.0	1.0	1.0	1.4	↑	↑
RW 24	1.0	1.0	1.0	1.2	↑	NA
RW 29	1.0	1.0	1.4	NA	NA	↓
RW 30	1.0	1.2	1.6	NA	↓	↓
RW 31	1.0	1.0	1.4	NA	↓	↓
RW 32	1.0	1.0	1.2	NA	↓	↓
RW 33	1.0	1.0	1.0	1.4	↓	↓
RW 34	1.0	1.0	1.0	1.4	↓	↓
RW 35	1.0	1.0	1.0	1.4	↓	↓
RW 36	1.0	1.0	1.2	1.5	↓	↓
RW 37	1.0	1.0	1.2	1.6	↓	↓
RW 38	1.0	1.0	1.0	1.4	1.6	↓
RW 39	1.0	1.0	1.0	1.4	1.6	2.0
RW 47	1.0	1.0	1.0	1.4	1.6	2.0
RW 55	1.0	1.0	1.4	2.4	↑	↑
RW 56	1.0	1.0	1.2	2.6	↑	↑
RW 67	1.0	1.0	1.0	NA	NA	NA
RW 68	1.0	1.0	1.0	NA	↓	↓
RW 69	1.0	1.0	NA	NA	↓	↓
RW 70	1.0	1.2	1.4	NA	↓	↓
RW 74	1.0	1.0	1.2	1.6	↓	↓
RW 78	1.0	1.0	1.0	1.6	↓	↓
RW 79	1.0	1.0	1.4	NA	↓	↓
RW 80	1.0	1.2	1.6	NA	↓	↓
RW 81	1.0	1.2	NA	NA	↓	↓

MIL-R-39007, RWR: MIL-R-26, RW

TABLE 5.1.6.4-8: MIL-R-26 & MIL-R-39007 RESISTORS, FIXED, WIRE-WOUND, (POWER TYPE) BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0042	.0051	.0062	.0076	.0093	.011	.014	.017	.021	.025
10	.0045	.0055	.0068	.0084	.010	.013	.016	.019	.024	.029
20	.0048	.0060	.0074	.0092	.011	.014	.017	.022	.027	.033*
30	.0052	.0065	.0081	.010	.013	.016	.020	.025	.031	
40	.0056	.0071	.0089	.011	.014	.018	.022	.028	.035	
50	.0061	.0077	.0097	.012	.016	.020	.025	.032	.040	
60	.0066	.0084	.011	.014	.017	.022	.028	.036		
70	.0072	.0092	.012	.015	.020	.025	.032	.042		
80	.0078	.010	.013	.017	.022	.028	.037	.048		
90	.0085	.011	.014	.019	.025	.032	.042	.055		
100	.0093	.012	.016	.021	.028	.037	.048			
110	.010	.014	.018	.024	.031	.042	.055			
120	.011	.015	.020	.027	.036	.047	.063			
130	.012	.017	.022	.030	.040	.054				
140	.014	.019	.025	.034	.046	.062				
150	.015	.021	.028	.038	.052	.071				
160	.017	.023	.032	.043	.060					
170	.019	.026	.036	.049	.068					
180	.021	.029	.040	.056	.078					
190	.023	.033	.046	.064						
200	.026	.037	.052	.074						
210	.029	.042	.059	.084						
220	.033	.047	.068	.097						
230	.037	.053	.077							
240	.042	.061	.088							
250	.047	.069	.10							
260	.054	.079								
270	.061	.091								
280	.069	.10								
290	.079									
300	.091									
310	.10									

*Do not use MIL-R-39007 Resistors below this line. Points below are overstressed.

MIL-R-39009, RER: MIL-R-18546, RE

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39009	RER	Power Types, Chassis Mounted, Fixed Wirewound, ER
MIL-R-18546	RE	Power Type, Chassis Mounted, Fixed Wirewound

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.4-9 through -12.

TABLE 5.1.6.4-9

Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	8.3
M_P	11
N_{SB}	4.9
N_S	4.9
N_U	14
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	2.5
A_{IT}	3.5
A_{IB}	7.5
A_{IA}	7
A_{IF}	10
A_{UC}	5.6
A_{UT}	7
A_{UB}	15
A_{UA}	15
A_{UF}	20
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

TABLE 5.1.6.4-10

π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
MIL-R-18546	5.0
LOWER	15.

MIL-R-39009, RER: MIL-R-18546, RE

Table 5.1.6.4-11
π_R Factor

Resistance Factor, π_R, for Characteristic G of MIL-R-18546 and Inductively Wound Styles of MIL-R-39009

Style	Rated Power (W)	Resistance Range (ohms)						
		Up to 100	>100 to 500	>500 to 1K	>1K to 5K	>5K to 10K	>10K to 20K	20K
RE 60 RER 60	5	1.0	1.0	1.2	1.2	1.6	NA	NA
RE 65 RER 65	10	1.0	1.0	1.0	1.2	1.6	NA	NA
RE 70 RER 70	20	1.0	1.0	1.0	1.2	1.2	1.6	NA
RE 75 RER 75	30	1.0	1.0	1.0	1.0	1.1	1.2	1.6
RE 77	75	1.0	1.0	1.0	1.0	1.0	1.2	1.6
RE 80	120	1.0	1.0	1.0	1.0	1.0	1.2	1.6

Resistance Factor, π_R, for Characteristic N of MIL-R-18546 and Noninductively Wound Styles of MIL-R-39009

Style	Rated Power (W)	Resistance Range (ohms)						
		Up to 100	>100 to 500	>500 to 1K	>1K to 5K	>5K to 10K	>10K to 20K	>20K
RE 60 RER 40	5	1.0	1.0	1.2	1.6	NA	NA	NA
RE 65 RER 45	10	1.0	1.0	1.2	1.6	NA	NA	NA
RE 70 RER 50	20	1.0	1.0	1.0	1.2	1.6	NA	NA
RE 75 RER 55	30	1.0	1.0	1.0	1.1	1.2	1.4	NA
RE 77	75	1.0	1.0	1.0	1.0	1.2	1.6	NA
RE 80	120	1.0	1.0	1.0	1.0	1.1	1.4	NA

MIL-R-39009, RER: MIL-R-18546, RE

TABLE 5.1.6.4-12: MIL-R-18546 & MIL-R-39009 RESISTOR, FIXED, WIREWOUND (POWER TYPE, CHASSIS MOUNTED) BASE FAILURE RATES, λ_b

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0021	.0026	.0032	.0040	.0049	.0061	.0076	.0094	.012	.014
10	.0023	.0029	.0036	.0045	.0056	.0070	.0087	.011	.014	.017
20	.0025	.0032	.0040	.0051	.0064	.0080	.010	.013	.016	.020
30	.0028	.0035	.0045	.0057	.0072	.0092	.012	.015	.019	
40	.0031	.0039	.0050	.0064	.0082	.011	.013	.017	.022	
50	.0034	.0044	.0056	.0072	.0093	.012	.016	.020	.026	
60	.0037	.0048	.0063	.0082	.011	.014	.018	.023		
70	.0041	.0054	.0070	.0092	.012	.016	.021	.027		
80	.0045	.0060	.0079	.010	.014	.018	.024			
90	.0050	.0066	.0088	.012	.016	.021	.028			
100	.0055	.0073	.0098	.013	.018	.024	.032			
110	.0060	.0081	.011	.015	.020	.027				
120	.0066	.0090	.012	.017	.023	.031				
130	.0073	.010	.014	.019	.026					
140	.0081	.011	.015	.021	.030					
150	.0089	.012	.017	.024	.034					
160	.0098	.014	.019	.027						
170	.011	.015	.022	.031						
180	.012	.017	.024							
190	.013	.019	.027							
200	.014	.021	.030							
210	.016	.023								
220	.017	.026								
230	.019									
240	.021									
250	.023									

MIL-T-23648, RTH

5.1.6.5 Thermistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-T-23648	RTH	Bead, Disk and Rod Type

The predicted failure rate is given as follows:

$$\lambda_p = \lambda_b \pi_E \pi_Q$$

where

λ_b = .021 for bead type, style 24, 26, 28, 30, 32, 34, 36, 38, 40

= .065 for disk type, style 6, 8, 10

= .105 for rod type, style 12, 14, 16, 18, 20 22, 42

π_E = values in Table 5.1.6.5-1

π_Q = 1 for MIL-SPEC parts;

= 15 for lower quality parts.

TABLE 5.1.6.5-1: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	21
G_{MS}	1.5	A_{IA}	17
G_F	4.8	A_{IF}	42
G_M	25	A_{UC}	6.4
M_P	17	A_{UT}	12
N_{SB}	7.9	A_{UB}	29
N_S	14	A_{UA}	24
N_U	19	A_{UF}	59
N_H	25	S_F	1
N_{UU}	27	M_{FF}	17
A_{RW}	37	M_{FA}	23
A_{IC}	4.8	U_{SL}	49
A_{IT}	8.6	M_L	57
		C_L	950

5.1.6.6 Variable Resistor, Wirewound

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39015	RTR	Variable Lead Screw Activated Wirewound, Established Reliability
MIL-R-27208	RT	Variable Lead Screw Activated Wirewound

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_{TAPS} (\pi_E \times \pi_R \times \pi_Q \times \pi_V) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.6-1 through 5.1.6.6-5 and 5.1.6.8-5.

TABLE 5.1.6.6-1: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	8
G_{MS}	1.2	A_{IA}	6
G_F	2.4	A_{IF}	10
G_M	9.8	A_{UC}	3
M_P	15	A_{UT}	8
N_{SB}	5.7	A_{UB}	15
N_S	5.7	A_{UA}	10
N_U	13	A_{UF}	20
N_H	23	S_F	1
N_{UU}	25	M_{FF}	15
A_{RW}	33	M_{FA}	21
A_{IC}	2.5	U_{SL}	45
A_{IT}	4	M_L	51
		C_L	870

RESISTORS

MIL-R-39015, RTR: MIL-R-27208, RT

TABLE 5.1.6.6-2: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
10 to 2K	1.0
>2K to 5K	1.4
>5K to 20K	2.0

TABLE 5.1.6.6-3: π_Q QUALITY FACTOR

Failure Rate Level	π_Q
S	.02
R	.06
P	.2
M	.6
MIL-R-27208	3.
Lower	10.

TABLE 5.1.6.6-4: π_V VOLTAGE FACTOR

Ratio of Applied* Voltage to Rated Voltage	π_V
0 to 0.1	1.10
>0.1 to 0.2	1.05
>0.2 to 0.6	1.00
>0.6 to 0.7	1.10
>0.7 to 0.8	1.22
>0.8 to 0.9	1.40
>0.9 to 1.0	2.00

$*V_{Applied} = \sqrt{RP_{Applied}}$

R = total pot, resistance

V_{Rated} = 40v for RT 26 and 27

V_{Rated} = 90v for RTR 12, 22 and 24; RT 12 and 22

MIL-R-39015, RTR: MIL-R-27208, RT

TABLE 5.1.6.6-5: MIL-R-39015 & MIL-R-27208 RESISTORS, VARIABLE, WIREWOUND (LEAD SCREW ACTUATED) BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0089	.0098	.011	.012	.013	.015	.016	.018	.020	.022
10	.0094	.010	.012	.013	.014	.016	.017	.019	.021	.024
20	.010	.011	.012	.014	.015	.017	.019	.021	.024	.026
30	.011	.012	.013	.015	.017	.019	.021	.023	.026	.029
40	.012	.013	.015	.016	.018	.021	.023	.026	.029	.033
50	.013	.014	.016	.018	.020	.023	.026	.029	.033	.037
60	.014	.016	.018	.020	.023	.026	.029	.033	.037	.042
70	.016	.018	.020	.023	.026	.030	.033	.038	.043	.049
80	.018	.020	.023	.026	.030	.034	.039	.044	.050	.057
90	.021	.024	.027	.031	.035	.040	.046	.052	.060	
100	.024	.028	.032	.037	.042	.048	.055			
110	.029	.033	.038	.044	.051	.058				
120	.035	.041	.047	.054						
130	.044	.051	.059							
140	.056									

MIL-R-12934, RR

Wirewound, Precision

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-12934	RR	Precision Wirewound

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_Q \; (\pi_R \times \pi_V \times \pi_C \times \pi_E) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.6-6 through 5.1.6.6-11 and 5.1.6.8-5.

TABLE 5.1.6.6-6: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	10
G_{MS}	1.2	A_{IA}	9.5
G_F	2.4	A_{IF}	15
G_M	11	A_{UC}	10
M_P	24	A_{UT}	10
N_{SB}	8.4	A_{UB}	20
N_S	8.4	A_{UA}	15
N_U	14	A_{UF}	20
N_H	37	S_F	1
N_{UU}	39	M_{FF}	24
A_{RW}	53	M_{FA}	34
A_{IC}	6.5	U_{SL}	71
A_{IT}	7.5	M_L	81
		C_L	1400

TABLE 5.1.6.6-7: π_Q QUALITY FACTOR

Failure Rate Level	π_Q
MIL-SPEC	2.5
Lower	5.0

MIL-R-12934, RR

TABLE 5.1.6.6-8: π_C CONSTRUCTION CLASS FACTOR

Construction Class*	π_C
RR09A2A9J103	2.0
3	1.0
4	3.0
5	1.5

*Sample type designation to show how construction class can be found.

TABLE 5.1.6.6-9: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
100 to 10K	1.0
>10K to 20K	1.1
>20K to 50K	1.4
>50K to 100K	2.0
>100K to 200K	2.5
>200K to 500K	3.5

TABLE 5.1.6.6-10: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.1	1.10
>0.1 to 0.2	1.05
>0.2 to 0.6	1.00
>0.6 to 0.7	1.10
>0.7 to 0.8	1.22
>0.8 to 0.9	1.40
>0.9 to 1.0	2.00

*$V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 250v for RR0900, RR1100, RR1300, RR2000, RR3000, RR3100, RR3200, RR3300, RR3400, RR3500

V_{Rated} = 423v for RR3600, RR3700

V_{Rated} = 500v for RR1000, RR1400, RR2100, RR3800, RR3900

MIL-R-12934, RR

TABLE 5.1.6.6-11: MIL-R-12934 POTENTIOMETERS, WIREWOUND PRECISION BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.10	.11	.11	.12	.12	.12	.13	.13	.14	.14
10	.11	.11	.12	.12	.13	.14	.14	.15	.15	.16
20	.12	.12	.13	.14	.14	.15	.16	.16	.17	.18
30	.13	.13	.14	.15	.16	.16	.17	.18	.19	.20
40	.14	.15	.15	.16	.17	.18	.20	.21	.22	.23
50	.15	.16	.17	.18	.20	.21	.22	.24	.26	.27
60	.17	.18	.19	.21	.22	.24	.26	.28	.30	.32
70	.19	.20	.22	.24	.26	.28	.30	.33	.36	.39
80	.21	.23	.25	.28	.30	.33	.36	.40	.43	.48
90	.24	.27	.30	.33	.36	.40	.44	.49	.54	
100	.28	.31	.35	.39	.44	.49	.54			
110	.33	.38	.42	.48	.54	.61				
120	.40	.45	.52	.59						
130	.49	.56	.65							
140	.60									

MIL-R-19, RA & MIL-R-39002, RK

WIREWOUND, SEMIPRECISION

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-19	RA	Semiprecision
MIL-R-39002	RK	Semiprecision

(Note: MIL-R-39002 is not an established reliability potentiometer.)

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_{TAPS}(\pi_R \times \pi_V \times \pi_Q \times \pi_E) \text{ (failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.6-12 through -16 and 5.1.6.8-5

TABLE 5.1.6.6-12

Environmental Mode Factors

ENVIRON-MENT	π_E *
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	16
M_P	17
N_{SB}	7
N_S	7
N_U	N/A
N_H	27
N_{UU}	29
A_{RW}	38
A_{IC}	6.5
A_{IT}	7.5
A_{IB}	10
A_{IA}	9.5
A_{IF}	15
A_{UC}	N/A
A_{UT}	N/A
A_{UB}	N/A
A_{UA}	N/A
A_{UF}	N/A
S_F	1
M_{FF}	N/A
M_{FA}	N/A
U_{SL}	N/A
M_L	N/A
C_L	N/A

*N/A: Not normally used.

TABLE 5.1.6.6-13

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	2.0
LOWER	4.0

MIL-R-19, RA: MIL-R-39002, RK

TABLE 5.1.6.6-14: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
10 to 2K	1.0
>2K to 5K	1.4
>5K to 10K	2.0

TABLE 5.1.6.6-15: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.1	1.10
>0.1 to 0.2	1.05
>0.2 to 0.6	1.00
>0.6 to 0.7	1.10
>0.7 to 0.8	1.22
>0.8 to 0.9	1.40
>0.9 to 1.0	2.00

*$V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 50v for RA10

= 75v for RA20X-XC, F

= 130v for RA30X-XC, F

= 175v for RA20X-XA

= 275v for RK09

= 320v for RA30X-XA

MIL-R-19, RA: MIL-R-39002, RK

TABLE 5.1.6.6-16: MIL-R-19 & MIL-R-39002 VARIABLE SEMIPRECISION WIREWOUND RESISTORS, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.055	.059	.063	.067	.072	.077	.083	.089	.095	.10
10	.058	.063	.069	.075	.081	.088	.095	.10	.11	.12
20	.063	.069	.076	.084	.092	.10	.11	.12	.13	.15
30	.069	.077	.086	.095	.11	.12	.13	.15	.17	.19
40	.076	.086	.098	.11	.13	.14	.16	.18	.21	.24
50	.085	.098	.11	.13	.15	.18	.20	.24	.27	.32
60	.096	.11	.13	.16	.19	.22	.26	.31	.37	.44
70	.11	.13	.16	.20	.24	.29	.35	.43	.52	.63
80	.13	.16	.20	.25	.31	.39	.48	.60	.75	.93
90	.16	.20	.26	.33	.42	.54	.69	.89	1.1	
100	.19	.25	.34	.45	.59	.78	1.0			
110	.24	.33	.45	.62	.85					
120	.31	.45								
130	.42									

MIL-R-22, RP

WIREWOUND, POWER

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-22	RP	High Power

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_Q(\pi_R \times \pi_V \times \pi_C \times \pi_E) \text{ (failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.6-17 through -22 and 5.1.6.8-5.

TABLE 5.1.6.6-17

Environmental Mode Factors

ENVIRON-MENT	π_E *
G_B	1
G_{MS}	1.3
G_F	3.0
G_M	16
M_P	17
N_{SB}	7
N_S	7
N_U	N/A
N_H	27
N_{UU}	29
A_{RW}	38
A_{IC}	6.5
A_{IT}	7.5
A_{IB}	10
A_{IA}	9.5
A_{IF}	15
A_{UC}	N/A
A_{UT}	N/A
A_{UB}	N/A
A_{UA}	N/A
A_{UF}	N/A
S_F	1
M_{FF}	N/A
M_{FA}	N/A
U_{SL}	N/A
M_L	N/A
C_L	N/A

*N/A: Not normally used.

TABLE 5.1.6.6-18

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	**2.0**
Lower	**4.0**

MIL-R-22, RP

TABLE 5.1.6.6-19: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
1 to 2K	1.0
>2K to 5K	1.4
>5K to 10K	2.0

TABLE 5.1.6.6-20: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.1	1.10
>0.1 to 0.2	1.05
>0.2 to 0.6	1.00
>0.6 to 0.7	1.10
>0.7 to 0.8	1.20
>0.8 to 0.9	1.40
>0.9 to 1.0	2.00

*$V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 250v for RP06, RP10

= 500v for others

TABLE 5.1.6.6-21: π_C CONSTRUCTION CLASS FACTOR

CONSTRUCTION CLASS	STYLE	π_C
Enclosed	RP07, RP11, RP16	2.0
Unenclosed	All other styles are unenclosed.	1.0

MIL-R-22, RP

TABLE 5.1.6.6-22: MIL-R-22 POWER WIREWOUND RESISTORS, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.064	.069	.074	.079	.084	.090	.097	.10	.11	.12
10	.067	.073	.078	.085	.091	.098	.11	.11	.12	.13
20	.071	.077	.084	.091	.099	.11	.12	.13	.14	.15
30	.076	.083	.091	.099	.11	.12	.13	.14	.16	
40	.081	.089	.099	.11	.12	.13	.15	.16		
50	.087	.097	.11	.12	.14	.15	.17			
60	.095	.11	.12	.14	.15	.17				
70	.10	.12	.14	.15	.18					
80	.12	.13	.15	.18						
90	.13	.15	.18							
100	.15	.17								
110	.17									
120	.20									

MIL-R-22097, RJ: MIL-R-39035, RJR

5.1.6.7 Variable Nonwirewound Resistors
Nonwirewound Trimmer Resistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-22097	RJ	Trimmer
MIL-R-39035	RJR	Trimmer, ER

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_{TAPS}(\pi_R \times \pi_V \times \pi_Q \times \pi_E) \text{ (failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.7-1 through -5 and 5.1.6.8-5.

TABLE 5.1.6.7-1

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.9
G_M	11
M_P	18
N_{SB}	5.7
N_S	5.7
N_U	15
N_H	27
N_{UU}	29
A_{RW}	39
A_{IC}	3
A_{IT}	6
A_{IB}	7
A_{IA}	4.5
A_{IF}	10
A_{UC}	7.5
A_{UT}	15
A_{UB}	15
A_{UA}	10
A_{UF}	25

ENVIRON-MENT	π_E
S_F	1
M_{FF}	18
M_{FA}	25
U_{SL}	53
M_L	61
C_L	1,000

TABLE 5.1.6.7-2

π_Q, Quality Factor

Failure Rate Level	π_Q
S	.02
R	.06
P	.2
M	.6
MIL-R-22097	3.
LOWER	10.

MIL-R-22097, RJ: MIL-R-39035, RJR

TABLE 5.1.6.7-3: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
10 to 50K	1.0
>50K to 100K	1.1
>100K to 200K	1.2
>200K to 500K	1.4
>500K to 1M	1.8

TABLE 5.1.6.7-4: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.8	1.00
>0.8 to 0.9	1.05
>0.9 to 1.0	1.20

$*V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 200v for RJ & RJR26; RJ & RJR50

= 300v for all others

MIL-R-22097, RJ: MIL-R-39035, RJR

TABLE 5.1.6.7-5: MIL-R-22097 & MIL-R-39035 NONWIREWOUND TRIMMER RESISTORS, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.021	.022	.023	.023	.024	.025	.026	.027	.028	.029
10	.021	.022	.023	.024	.025	.026	.027	.028	.030	.031
20	.022	.023	.024	.025	.026	.027	.029	.030	.031	.033
30	.023	.024	.025	.026	.028	.029	.030	.032	.033	.035
40	.024	.025	.026	.028	.029	.031	.032	.034	.036	.038
50	.025	.026	.028	.029	.031	.033	.035	.037	.039	.041
60	.026	.028	.030	.031	.033	.036	.038	.040	.043	.045
70	.028	.030	.032	.034	.036	.039	.042	.044	.047	.050
80	.030	.033	.035	.038	.040	.043	.046	.050	.053	.057
90	.034	.036	.039	.042	.045	.049	.053	.057	.061	
100	.038	.041	.044	.048	.052	.056	.061			
110	.043	.047	.051	.055	.060	.066				
120	.050	.055	.060	.066						
130	.060	.066	.073							
140	.074									

MIL-R-94, RV

Variable Composition Resistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-94	RV	Low Precision

Part operating failure rate model (λ_p):

$$\lambda p = \lambda_b \times \pi_{TAPS}(\pi_R \times \pi_V \times \pi_Q \times \pi_E) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.6.7-6 through -10 and 5.1.6.8-5.

TABLE 5.1.6.7-6

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.8
G_M	17
M_P	21
N_{SB}	8
N_S	8
N_U	21
N_H	32
N_{UU}	34
A_{RW}	46
A_{IC}	30
A_{IT}	35
A_{IB}	55
A_{IA}	55
A_{IF}	75
A_{UC}	40
A_{UT}	40
A_{UB}	65
A_{UA}	65
A_{UF}	90
S_F	1
M_{FF}	21
M_{FA}	29
U_{SL}	62
M_L	71
C_L	1,200

TABLE 5.1.6.7-7

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	2.5
LOWER	5.0

MIL-R-94, RV

TABLE 5.1.6.7-8: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
50to 50K	1.0
>50K to 100K	1.1
>100K to 200K	1.2
>200K to 500K	1.4
>500K to 1M	1.8

TABLE 5.1.6.7-9: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.8	1.00
>0.8 to 0.9	1.05
>0.9 to 1.0	1.20

*$V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 500v for RV4X--XA&XB

= " " 2RV7X--XA&XB

= 350v for RV2X--XA&XB

" " RV4X--XA&XB

" " RV5X--XA&XB

" " RV6X--XA&XB

= 250v for RV1X--XA&XB

= 200v for all other types

MIL-R-94, RV

TABLE 5.1.6.7-10: MIL-R-94 VARIABLE COMPOSITION RESISTOR, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.027	.028	.030	.031	.032	.034	.035	.037	.038	.040
10	.028	.029	.031	.033	.034	.036	.038	.040	.042	.045
20	.029	.031	.033	.035	.037	.040	.042	.045	.048	.051
30	.031	.033	.036	.038	.041	.045	.048	.052	.056	.060
40	.033	.036	.039	.043	.047	.051	.056	.061	.067	.073
50	.036	.039	.044	.049	.054	.060	.067	.074	.082	.091
60	.039	.045	.050	.057	.065	.073	.083	.094	.11	.12
70	.045	.052	.060	.069	.080	.093	.11	.12	.14	.17
80	.053	.063	.074	.088	.10	.12	.15	.17		
90	.065	.079	.096	.12	.14	.17				
100	.084	.11	.13	.16						
110	.11	.15								

MIL-R-23285, RVC: MIL-R-39023, RQ

Variable Film and Precision Resistors

SPECIFICATION	STYLE	DESCRIPTION
MIL-R-39023	RQ	Nonwirewound, Precision
MIL-R-23285	RVC	Film

Part operating failure rate model (λ_p):

$$\lambda p = \lambda_b \times \pi_{TAPS}(\pi_R \times \pi_V \times \pi_Q \times \pi_E) \text{ (failures/}10^6\text{ hours)}$$

where the factors are shown in Tables 5.1.6.7-11 through -16 and 5.1.6.8-5.

TABLE 5.1.6.7-11

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.9
G_M	11
M_P	18
N_{SB}	7.2
N_S	7.2
N_U	15
N_H	27
N_{UU}	29
A_{RW}	39
A_{IC}	3.5
A_{IT}	6.5
A_{IB}	9.5
A_{IA}	6.5
A_{IF}	15
A_{UC}	10
A_{UT}	20
A_{UB}	30
A_{UA}	20
A_{UF}	40
S_F	1
M_{FF}	18
M_{FA}	25
U_{SL}	53
M_L	61
C_L	1,000

TABLE 5.1.6.7-12

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	2
Lower	4

RESISTORS

MIL-R-23285, RVC: MIL-R-39023, RQ

TABLE 5.1.6.7-13: π_R RESISTANCE FACTOR

Resistance Range (ohms)	π_R
to 10K	1.0
>10K to 50K	1.1
>50K to 200K	1.2
>200K to 1M	1.4
>1M	1.8

TABLE 5.1.6.7-14: π_V VOLTAGE FACTOR

Ratio of Applied Voltage to Rated Voltage*	π_V
0 to 0.8	1.00
>0.8 to 0.9	1.05
>0.9 to 1.0	1.20

$*V_{Applied} = \sqrt{RP_{Applied}}$ R = total pot, resistance

V_{Rated} = 250V for RQ090, 110, 150, 200, 300

= 500V for RQ100, 160, 210

= 350V for RVC5, 6

MIL-R-23285, RVC

TABLE 5.1.6.7-15: MIL-R-23285 VARIABLE FILM RESISTORS, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.028	.029	.031	.032	.033	.035	.036	.037	.039	.041
10	.029	.030	.032	.033	.035	.037	.038	.040	.042	.044
20	.030	.031	.033	.035	.037	.039	.041	.044	.046	.049
30	.031	.033	.035	.037	.040	.042	.045	.048	.051	.055
40	.032	.035	.037	.040	.043	.046	.050	.054	.058	.062
50	.034	.037	.040	.044	.047	.052	.056	.061	.066	.072
60	.036	.040	.044	.048	.053	.058	.064	.071	.078	.086
70	.039	.044	.049	.054	.060	.067	.075	.084	.093	.10
80	.043	.048	.055	.062	.070	.079	.090	.10	.11	.13
90	.048	.055	.063	.073	.083	.096	.11	.13	.15	.17
100	.055	.064	.075	.087	.10	.12	.14	.16	.19	.22
110	.064	.076	.091	.11	.13	.15	.18	.22	.26	.31
120	.077	.094	.11	.14	.17	.21	.25	.30	.37	.45
130	.096	.12	.15	.19	.23	.29	.36	.44	.55	
140	.12	.16	.20	.26	.33	.42	.53			
150	.17	.22	.29	.38	.50					
160	.24	.33	.44							
170	.37									

MIL-R-39023, RQ

TABLE 5.1.6.7-16: MIL-R-39023 VARIABLE NONWIREWOUND PRECISION RESISTORS, BASE FAILURE RATES, λ_b

(See Section 5.1.6.8 for stress ratio calculation)

TEMP	S, RATIO OF OPERATING TO RATED WATTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.023	.023	.024	.025	.026	.027	.028	.030	.031	.032
10	.024	.025	.026	.027	.029	.030	.031	.033	.034	.036
20	.026	.027	.029	.030	.032	.033	.035	.037	.039	.041
30	.028	.030	.032	.034	.036	.038	.040	.042	.045	.047
40	.032	.034	.036	.039	.041	.044	.047	.050	.053	.057
50	.037	.039	.042	.046	.049	.053	.057	.061	.065	.070
60	.044	.047	.051	.055	.060	.065	.070	.076	.083	.090
70	.053	.058	.064	.070	.076	.084	.091	.10	.11	.12
80	.068	.076	.083	.092	.10	.11	.12	.14		
90	.092	.10	.11	.13	.14	.16				
100	.13	.15	.17	.19						
110	.20	.23								

5.1.6.8 Calculation for S, Taps and Ganging.

For potentiometers connected as rheostats, use Table 5.1.6.8-1.

For potentiometers connected conventionally, use Table 5.1.6.8-2.

TABLE 5.1.6.8-1

Calculation of S for Rheostats

The stress ratio (S) is defined as:

$$S = \frac{(I_{op\ max})^2}{\pi_{ganged}\ (I_{max\ rated})^2}$$

where:

I_{opmax} is the maximum current which will be passed through the rheostat in the circuit.

$I_{max\ rated}$ is the current rating of the potentiometer.

If current rating not given, use:

$$I_{max\ rated} = \sqrt{P_{rated}/R_P}$$

where:

P_{rated} is power rating of potentiometer.

R_p is potentiometer resistance.

π_{ganged} is factor to correct power rating to account for multiple potentiometers ganged on a common shaft, as obtained from Table 5.1.6.8-4

TABLE 5.1.6.8-2

Calculation of Stress Ratio for Potentiometers Connected Conventionally

The stress ratio (S) is defined by the equation:

$$S = \frac{P_{applied}}{\pi_{eff} \cdot \pi_{ganged} \quad P_{rated}}$$

where:

$P_{applied}$	is the equivalent power input to the potentiometer when it is not loaded (i.e., wiper lead disconnected). Its value is computed as the square of the input voltage, divided by the potentiometer total resistance. $P_{applied} = \left(V_{in}^{2}/R_P\right)$
P_{rated}	is the power rating of the potentiometer.
π_{ganged}	is a correction factor to correct for the reduction in effective rating of the potentiometer due to the close proximity of two or more potentiometers when they are ganged together on a common shaft. The values of π_{ganged} are obtained from Table 5.1.6.8-4.
π_{eff}	is a correction factor for the electrical loading effect on the wiper contact of the potentiometer. Its value is a function of the type of potentiometer, its resistance, and the load resistance.

TABLE 5.1.6.8-2 (Cont'd)

Calculation of Stress Ratio for Potentiometers

The value of π_{eff} can be obtained directly from Table 5.1.6.8-3 or calculated as follows:

$$\pi_{eff} = \frac{R_L^{\,2}}{R_L^{\,2} + K_H\left(R_P^{\,2} + 2R_PR_L\right)}$$

where:

R_L = load resistance (IF R_L is variable, use lowest value). R_L is the total resistance between the wiper arm and one end of the potentiometer.

R_P = potentiometer resistance.

K_H is constant dependent upon the style shown below.

POTENTIOMETER MIL-SPEC	TYPE STYLE	K_H
MIL-R-19	RA	0.5
MIL-R-22	RP	1.0
MIL-R-94	RV	0.5
MIL-R-12934	RR1000, 1001, 1003, 1400, 2100, 2101, 2102, 2103	0.3
MIL-R-12934	all other types	0.2
MIL-R-22097	RJ11, RJ12	0.3
MIL-R-22097	all other types	0.2
MIL-R-23285	RVC	0.5
MIL-R-27208	RT22, 24, 26, 27	0.2
MIL-R-27208	all other types	0.3
MIL-R-39002	RK	0.5
MIL-R-39015	RTR 22, 24	0.17
MIL-R-39015	RTR12	0.3
MIL-R-39023	RQ	0.3
MIL-R-39035	RJR	0.3

TABLE 5.1.6.8-3

Loaded Potentiometer Derating Factor, π_{eff}.

	K_H				
R_L/R_P	0.5	1.0	0.167	0.2	0.3
0.1	.02	.008	.05	.04	.03
0.2	.05	.03	.15	.13	.07
0.3	.10	.05	.25	.22	.16
0.4	.15	.08	.35	.31	.23
0.5	.20	.11	.43	.38	.29
0.6	.25	.14	.49	.45	.35
0.7	.29	.17	.55	.51	.40
0.8	.33	.20	.60	.55	.45
0.9	.37	.22	.63	.59	.49
1.0	.40	.25	.67	.63	.53
1.5	.53	.36	.77	.74	.65
2.0	.62	.44	.83	.80	.72
3.0	.72	.56	.89	.87	.81
4.0	.78	.64	.91	.90	.86
5.0	.82	.69	.93	.92	.88
10.0	.90	.83	.96	.96	.94
100.0	.99	.98	1.00	1.00	.99

TABLE 5.1.6.8-4

Ganged-Potentiometer Factor, π_{ganged}

Number of Sections	First Potentiometer Next to Mount	Second in Gang	Third in Gang	Fourth in Gang	Fifth in Gang	Sixth in Gang
Single	1.0	Not Applicable				
Two	0.75	0.60	Not Applicable			
Three	0.75	0.50	0.60	Not Applicable		
Four	0.75	0.50	0.50	0.60	Not Applicable	
Five	0.75	0.50	0.40	0.50	0.60	Not Applicable
Six	0.75	0.50	0.40	0.40	0.50	0.60

TABLE 5.1.6.8-5

Potentiometer Taps Factor, π_{taps} (1

N_{taps} (2	π_{taps}	N_{taps} (2	π_{taps}	N_{taps} (2	π_{taps}
3	1.00	13	2.67	23	5.20
4	1.11	14	2.88	24	5.49
5	1.24	15	3.12	25	5.79
6	1.38	16	3.35	26	6.09
7	1.53	17	3.59	27	6.40
8	1.69	18	3.85	28	6.72
9	1.87	19	4.10	29	7.04
10	2.06	20	4.37	30	7.36
11	2.25	21	4.64	31	7.69
12	2.45	22	4.92	32	8.03

(1 Model: $$\pi_{taps} = \frac{N_{taps}^{3/2}}{25} + 0.792$$

(2 N_{taps} is the number of potentiometer taps, including the wiper and end terminations.

:1.6.9 Example Failure Rate Calculations.

Example 1

Given: Type RCR fixed composition 12,000 ohm resistor per MIL-R-39008, level M rated at 0.5 watts is being used in airborne inhabited cargo environment. The resistor ambient temperature is 60° C. and is dissipating 0.2 watts.

Step 1 - The failure rate information for this resistor is in Section 5.1.6.1 The part failure rate is:

$\lambda p = \lambda_b \times \pi_E \times \pi_R \times \pi_Q$ (failures/10^6 hrs.)

Step 2 - Stress ratio, $S = P_{APPLIED}/P_{RATED}$

$= 0.2/0.5$

$= 0.4$

Step 3 - From Table 5.1.6.1-4, entering with $T = 60^{\circ}C.$ and $S = 0.4$,

$\lambda_b = .0012$ f./10^6 hrs.

NOTE: If T & S were at values showing no λ_b value (such as $T = 90°C.$ & $S = 0.8$), the resistor would be operating above rated conditions. Re-design would be necessary to bring the resistor within rating.

Step 4 - From Tbl 5.1.6.1-1 $\pi_E = 3$ for A_{IC}

Step 5 - From Tbl 5.1.6.1-2 $\pi_R = 1$ for 12,000 ohms.

Step 6 - From Tbl 5.1.6.1-3 $\pi_Q = 1$ for level M.

Step 7 - $\lambda_p = \lambda_b \times \pi_E \times \pi_R \times \pi_Q$

$= 0.0012 \ (3) \ (1) \ (1)$

$\lambda_p = 0.0036$ f./10^6 hrs.

Example 2

Given: Type RE77 fixed noninductive wirewound chassis mounted 5,900 ohm resistor per MIL-R-18546 rated at 75 watts is being used in a fixed ground environment. The resistor ambient temperature is 55°C. and is dissipating 40 watts.

Step 1 - The failure rate information for this resistor is in Section 5.1.6.4 under MIL-R-18546 & MIL-R-39009. The part failure rate is:

$\lambda_p = \lambda_b (\pi_E \times \pi_R \times \pi_Q)$

Example Failure Rate Calculations (Con't)

Step 2 - Stress ratio, S $= P_{APPLIED}/P_{RATED}$
$= 40/75$
$= 0.53$

Note that P_{RATED} is the full 75 watts and not a lower level as indicated by the derating curve in MIL-R-18546. Derating is accounted for in the base failure rate model and table.

Step 3 - From Tbl 5.1.6.4-12 entering with T = 55°C. and S = 0.53,
$\lambda_b = 0.0108$

Step 4 - From Tbl 5.1.6.4-9 $\pi_E = 2.4$ fixed ground.

Step 5 - From Tbl 5.1.6.4-10 $\pi_Q = 5.0$ for MIL-R-18546.

Step 6 - From Tbl 5.1.6.4-11 $\pi_R = 1.2$ for RE77 non-inductive wound.

Step 7 - $\lambda_p = \lambda_b \times \pi_E \times \pi_R \times \pi_O$
$= 0.0108\ (2.4)\ (1.2)\ (5)$
$= 0.16\ ./10^6$ hrs.

Example 3

Given: Type RV1SAYSA505A variable 500K ohm resistor procured per MIL-R-94, rated at 0.2 watts is being used in a fixed ground environment. The resistor ambient temperature is 40°C. and is dissipating 0.06 watts. The resistance connected to the wiper contact varies between 1 megohm and 3 megohms.

Step 1 - The failure rate information for this resistor is in Section 5.1.6.7 under MIL-R-94. The part failure rate is: $\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_R \times \pi_V \times \pi_Q \times \pi_E$

Step 2 - Base failure rate, λ_b, requires the calculation of stress ratio, S, per Table 5.1.6.8-2 where:

$$S = \frac{P_{OP}}{\pi_{eff} \times \pi_{ganged} \times P_{RATED}}$$

$\pi_{eff} = 0.62$ from Tbl 5.1.6.8-3 ($K_u = 0.5$ for MIL-R-94 and $R_L/R_p = 10^6/500,000$ from Tbl 5.1.6.8-2 R_L is 10^6 ohms, the lowest wiper load resistance).

Example Failure Rate Calculations (Con't)

π_{ganged} = 1.0, only 1 element used - no ganging.

Then

$$S = \frac{0.06}{0.62\ (1.0)\ \ (0.2)}$$

$$= .48$$

Step 3 - Base failure rate, λ_b, is determined from Tbl 5.1.6.7-1Centering with S = .48 and T = 40°C.

λ_b = 0.046

Step 4 - Entering Table 5.1.6.8-5 with N = 3 for this part (no additional taps used),

π_{TAPS} = 1.0

Step 5 - π_V is determined from Table 5.1.6.7-9

This part type RV1SAYSA505A has a 250 volt maximum rating (see Table 5.1.6.7-9

$$V_{APPLIED} = \sqrt{R\ P_{APPLIED}}$$

$$= \sqrt{5\ (10)^5\ (0.06)} = 173 \text{ volts}$$

$$\frac{V_{APPLIED}}{V_{RATED}} = \frac{173}{250} = .69$$

π_V = 1.0 from Table 5.1.6.7-10

Step 6 - From Tbl 5.1.6.7-8 π_R = 1.4 for 500K ohms.

Step 7 - From Tbl 5.1.6.7-6 π_E = 1.8 for fixed ground environment.

Step 8 - From Tbl 5.1.6.7-7 π_Q = 2.5 for part procured per MIL-R-94.

Step 9 - $\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_R \times \pi_V \times \pi_Q \times \pi_E$

$= 0.046\ (1.0)\ (1.4)\ \ (1.0)\ \ (2.5)\ \ (1.8)$

$= 0.29\ \ f./10^6$ hours.

5.1.7 Capacitors. The following capacitors are included in this section:

Paper/Plastic Film

MIL-C-25	Capacitors, Fixed, Paper
MIL-C-11693	Capacitors, Fixed, Paper, Metallized Paper, Metallized Plastic, RFI Feed-Thru, Established Reliability and Non-Established Reliability
MIL-C-12889	Capacitors, Fixed, Paper, RFI Bypass
MIL-C-14157	Capacitors, Fixed, Paper-Plastic,Established Reliability
MIL-C-18312	Capacitors, Metallized Paper, Paper-Plastic, Plastic
MIL-C-19978	Capacitors, Fixed, Plastic (or Paper-Plastic), Established and Non-Established Reliability
MIL-C-39022	Capacitors, Fixed, Metallized, Paper-Plastic Film or Plastic Film Dielectric, Established Reliability
MIL-C-55514	Capacitors, Plastic, Metallized Plastic, Established Reliability
MIL-C-83421	Capacitors, Super-Metallized Plastic, Established Reliability

Mica

MIL-C-5	Capacitors, Fixed, Mica
MIL-C-10950	Capacitors, Fixed, Mica, Button Style
MIL-C-39001	Capacitors, Fixed, Mica, Established Reliability

Glass

MIL-C-11272	Capacitors, Glass
MIL-C-23269	Capacitors, Fixed, Glass, Established Reliability

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Ceramic

MIL-C-20	Capacitors, Fixed, Ceramic (Temperature Compensating)
MIL-C-11015	Capacitors, Fixed, Ceramic (General Purpose)
MIL-C-39014	Capacitors, Fixed, Ceramic (General Purpose), Established Reliability
MIL-C-55681	Capacitors, Fixed, Ceramic, Chip, Style CDR-21

Electrolytic

MIL-C-62	Capacitors, Fixed, Electrolytic (DC, Aluminum, Dry Electrolyte, Polarized)
MIL-C-3965	Capacitors, Fixed, Electrolytic (Non-solid Electrolyte), Tantalum
MIL-C-39003	Capacitors, Fixed, Electrolytic, Tantalum, Solid Electrolyte, Established Reliability
MIL-C-39006	Capacitors, Fixed, Electrolytic, Tantalum, Non-solid Electrolyte, Established Reliability
MIL-C-39018	Capacitors, Fixed, Electrolytic, Aluminum Oxide
MIL-C-83500	Capacitors, Fixed, Electrolytic, Tantalum, Non-hermetic

Variable Capacitors

MIL-C-81	Capacitors, Variable, Ceramic
MIL-C-92	Capacitors, Air, Trimmer
MIL-C-14409	Capacitors, Variable, Piston Type, Tubular Trimmer
MIL-C-23183	Capacitors, Vacuum or Gas, Fixed and Variable

The general model for capacitors is as follows:

$$\lambda_p = \lambda_b (\pi_E \times \pi_{CV} \times \pi_{SR} \times \pi_Q \times \Pi_C) \text{ failures}/10^6 \text{ hours}$$

where these factors are as defined in Sec. 5.1.1 The applicability of specific π factors is shown with each subsequent part type. The general model for capacitor base failure rates (λ_b) is as follows:

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$$\lambda_b = A\left[\left(\frac{S}{N_S}\right)^H + 1\right] e^{B\left(\frac{T+273}{N_T}\right)^G}$$

where,

A	is an adjustment factor for each different type of capacitor, to adjust the model to the proper failure rate.
S	represents the ratio of operating to rated voltage. Operating voltage is the sum of the applied D.C. voltage and the peak A.C. voltage.
N_S	is the stress constant.
e	is the natural logarithm base, 2.718.
T	is the operating ambient temperature in degrees Centigrade.
N_T	is a temperature constant.
B	is a shaping parameter.
G	and H are acceleration constants.

Values of these constants for the various capacitor styles are shown in Tables 5.1.7-1 and -2.

TABLE 5.1.7-1
FIXED CAPACITOR BASE FAILURE RATE (λ_b) CONSTANTS

STYLE	MIL-C-SPEC	A	B	N_T	G	N_S	H	λ_b TABLE NOS
CA	12889	8.6×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-5
CB	10950							
	Max Rated T=85°C	5.3×10^{-3}	1.2	358	6.3	0.4	3	5.1.7.2-13
	Max Rated T=150°C	5.3×10^{-3}	1.2	423	6.3	0.4	3	5.1.7.2-14
CC & CCR	20							
	Max Rated T=85°C	2.6×10^{-9}	14.3	358	1.0	0.3	3	5.1.7.4-11
	Max Rated T=125°C	2.6×10^{-9}	14.3	398	1.0	0.3	3	5.1.7.4-12
CE	62	2.8×10^{-3}	4.09	358	5.9	0.55	3	5.1.7.6-8
CFR	55514							
	Max Rated T=85°C	9.9×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-32
	Max Rated T=125°C	9.9×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-33
CH	18312							
	Max Rated T=85°C	6.9×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-26
	Max Rated T=125°C	6.9×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-27
CHR	39022	See Style CH						
CK	11015							
	Max Rated T=85°C	3.0×10^{-4}	1.0	358	1.0	0.3	3	5.1.7.4-4
	Max Rated T=125°C	3.0×10^{-4}	1.0	398	1.0	0.3	3	5.1.7.4-5
	Max Rated T=150°C	3.0×10^{-4}	1.0	423	1.0	0.3	3	5.1.7.4-6

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TABLE 5.1.7-1 (Cont'd)
FIXED CAPACITOR BASE FAILURE RATE (λ_b) CONSTANTS

STYLE	MIL-C-SPEC	A	B	N_T	G	N_S	H	λ_b TABLE NOS
CKR	39014							
	Max Rated T=85°C	3.0×10^{-4}	1.0	358	1.0	0.3	3	5.1.7.4-4
	Max Rated T=125°C	3.0×10^{-4}	1.0	398	1.0	0.3	3	5.1.7.4-5
CL	3965							
	Max Rated T=85°C	1.65×10^{-3}	2.6	358	9.0	0.4	3	5.1.7.5-11
	Max Rated T=125°C	1.65×10^{-3}	2.6	398	9.0	0.4	3	5.1.7.5-12
	Max Rated T=175°C	1.65×10^{-3}	2.6	448	9.0	0.4	3	5.1.7.5-13
CLR	39006							
	Max Rated T=125°C	1.65×10^{-3}	2.6	398	9.0	0.4	3	5.1.7.5-12
	Max Rated T=175°C	1.65×10^{-3}	2.6	448	9.0	0.4	3	5.1.7.5-13
CM	5							
	Max Rated T=70°C	8.60×10^{-10}	16.0	343	1.0	0.4	3	5.1.7.2-5
	Max Rated T=85°C	8.60×10^{-10}	16.0	358	1.0	0.4	3	5.1.7.2-6
	Max Rated T=125°C	8.60×10^{-10}	16.0	398	1.0	0.4	3	5.1.7.2-7
	Max Rated T=150°C	8.60×10^{-10}	16.0	423	1.0	0.4	3	5.1.7.2-8
CMR	39001							
	Max Rated T=125°C	8.60×10^{-10}	16.0	398	1.0	0.4	3	5.1.7.2-7
	Max Rated T=150°C	8.60×10^{-10}	16.0	423	1.0	0.4	3	5.1.7.2-8
CP	25							
	Max Rated T=85°C	8.6×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-5
	Max Rated T=125°C	8.6×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-6

TABLE 5.1.7-1 (Cont'd)
FIXED CAPACITOR BASE FAILURE RATE (λ_b) CONSTANTS

STYLE	MIL-C-SPEC	A	B	N_T	G	N_S	H	λ_b TABLE NOS
CPV	14157							
	Max Rated T=65°C	5.0×10^{-4}	2.5	338	18.0	0.4	5	5.1.7.1-18
	Max Rated T=85°C	5.0×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-19
	Max Rated T=125°C	5.0×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-20
CQ & CQR	19978							
	Max Rated T=65°C	5.0×10^{-4}	2.5	338	18.0	0.4	5	5.1.7.1-18
	Max Rated T=85°C	5.0×10^{-4}	2.5	358	18.0	0.4	5	5.1.7.1-19
	Max Rated T=125°C	5.0×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-20
	Max Rated T=170°C	5.0×10^{-4}	2.5	443	18.0	0.4	5	5.1.7.1-21
CRH	83421	5.5×10^{-4}	2.5	398	18.0	0.4	5	5.1.7.1-37
CSR	39003							
	Max Rated T=125°C	3.75×10^{-3}	2.6	398	9.0	0.4	3	5.1.7.5-5
CU	39018	2.54×10^{-3}	5.09	398	5.0	0.5	3	5.1.7.6-4
CY	11272							
	Max Rated T=125°C	8.25×10^{-10}	16.0	398	1.0	0.5	4	5.1.7.3-5
	Max Rated T=200°C	8.25×10^{-10}	16.0	473	1.0	0.5	4	5.1.7.3-6
CYR	23269	8.25×10^{-10}	16.0	398	1.0	0.5	4	5.1.7.3-5
CZ	11693							
	Max Rated T=85°C	1.15×10^{-3}	2.5	358	18.0	0.4	5	5.1.7.1-11
	Max Rated T=125°C	1.15×10^{-3}	2.5	398	18.0	0.4	5	5.1.7.1-12
	Max Rated T=150°C	1.15×10^{-3}	2.5	423	18.0	0.4	5	5.1.7.1-13

TABLE 5.1.7-2. VARIABLE CAPACITOR BASE FAILURE RATE (λ_b) CONSTANTS

STYLE	MIL-C-SPEC	A	B	N_T	G	N_S	H	λ_b TABLE NOS
CG	23183 Max Rated T=85°C	1.12×10^{-2}	1.59	358	10.1	0.17	3	5.1.7.10-5
	Max Rated T=100°C	1.12×10^{-2}	1.59	373	10.1	0.17	3	5.1.7.10-6
	Max Rated T=125°C	1.12×10^{-2}	1.59	398	10.1	0.17	3	5.1.7.10-7
CT	92	1.92×10^{-6}	10.8	358	1.0	0.33	3	5.1.7.9-3
CV	81 Max Rated T=85°C	2.24×10^{-3}	1.59	358	10.1	0.17	3	5.1.7.7-4
	Max Rated T=125°C	2.24×10^{-3}	1.59	398	10.1	0.17	3	5.1.7.7-5
PC	14409 Max Rated T=125°C	7.3×10^{-7}	12.1	398	1.0	0.33	3	5.1.7.8-4
	Max Rated T=150°C	7.3×10^{-7}	12.1	423	1.0	0.33	3	5.1.7.8-5

MIL-C-25, CP;
MIL-C-12889, CA

5.1.7.1 Paper and Plastic Film Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-25	CP	Paper
MIL-C-12889	CA	Paper, RFI Bypass

Part operating failure rate model (λ_p):

$$\lambda p = \lambda_b(\pi_E \times \pi_Q \times \pi_{CV}) \quad \text{failures}/10^6 \text{ hrs}$$

where the factors are shown in Tables 5.1.7.1-1 through -6

TABLE 5.1.7.1-1
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.9
G_M	8.3
M_P	10
N_{SB}	4.8
N_S	5.7
N_U	14
N_H	15
N_{UU}	16
A_{RW}	22
A_{IC}	3.5
A_{IT}	5
A_{IB}	8
A_{IA}	6.5
A_{IF}	10
A_{UC}	10
A_{UT}	15
A_{UB}	25
A_{UA}	30
A_{UF}	35
S_F	1
M_{FF}	10
M_{FA}	14
U_{SL}	30
M_L	34
C_L	570

TABLE 5.1.7.1-2
Base Failure Rate Tables for Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table No.
12889	All	5.1.7.1-5
25	CP04, 5, 8, 9, 10, 11, 12, 13; Char K	5.1.7.1-6
	CP25, 26, 27, 28, 29, 40, 41, 67, 69, 70, 72, 75, 76, 77, 78, 80, 81, 82; Char E, F	5.1.7.1-5

MIL-C-25, CP: MIL-C-12889, CA

TABLE 5.1.7.1-3

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	3
Lower	7

TABLE 5.1.7.1-4

π_{CV}, Capacitance Factor

Capacitance *	π_{CV}
MIL-C-25 *:	
.0034uF.	0.7
.15 "	1.0
2.3 "	1.3
16. "	1.6
MIL-C-12889	
All	1.0

* $\pi_{CV} = 1.2C^{.095}$

where C is μF.

MIL-C-25, CP: MIL-C-12889, CA

*TABLE 5.1.7.1-5: CAPACITORS, FIXED, PAPER, DIRECT CURRENT, BASE FAILURE RATE, λ_b ($T = 85^{\circ}C$ MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00088	.00090	.0011	.0018	.0036	.0075	.015	.029	.051	.086
10	.00089	.00092	.0011	.0018	.0036	.0077	.016	.029	.052	.088
20	.00092	.00095	.0011	.0018	.0037	.0079	.016	.030	.054	.091
30	.00097	.0010	.0012	.0019	.0039	.0084	.017	.032	.057	.096
40	.0011	.0011	.0013	.0021	.0044	.0092	.019	.035	.063	.11
50	.0013	.0013	.0016	.0025	.0052	.011	.022	.042	.075	.13
60	.0017	.0017	.0021	.0034	.0069	.015	.030	.056	.10	.17
70	.0027	.0028	.0034	.0055	.011	.024	.048	.090	.16	.27
80	.0060	.0062	.0074	.012	.024	.051	.10	.20	.35	.59

*See Table 5.1.7.1-2 for applicability to spec. and style.

MIL-C-25, CP: MIL-C-12889, CA

*TABLE 5.1.7.1-6: CAPACITORS, FIXED, PAPER, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00086	.00089	.0011	.0017	.0035	.0074	.015	.028	.051	.085
10	.00087	.00089	.0011	.0017	.0035	.0074	.015	.029	.051	.085
20	.00087	.00090	.0011	.0017	.0035	.0075	.015	.029	.051	.086
30	.00088	.00090	.0011	.0018	.0035	.0075	.015	.029	.051	.086
40	.00089	.00092	.0011	.0018	.0036	.0076	.015	.029	.052	.088
50	.00091	.00094	.0011	.0018	.0037	.0078	.016	.030	.053	.090
60	.00095	.00098	.0012	.0019	.0039	.0082	.017	.031	.056	.094
70	.0010	.0011	.0013	.0020	.0041	.0088	.018	.034	.060	.10
80	.0011	.0012	.0014	.0023	.0046	.0099	.020	.038	.067	.11
90	.0014	.0014	.0017	.0028	.0056	.012	.024	.046	.081	.14
100	.0019	.0019	.0023	.0037	.0076	.016	.033	.062	.11	.18
110	.0030	.0031	.0037	.0060	.012	.026	.052	.099	.18	.30
120	.0063	.0065	.0078	.013	.026	.054	.11	.21	.37	.62

*See Table 5.1.7.1-2 for applicability to spec. and style.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-11693	CZ	Paper, Metallized Paper Metallized Plastic, RFI Feed-Thru, ER and Non-ER

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b(\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.7.1-7 through -13.

TABLE 5.1.7.1-7

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	8.3
M_P	10
N_{SB}	4.8
N_S	8.8
N_U	14
N_H	15
N_{UU}	16
A_{RW}	22
A_{IC}	3.5
A_{IT}	5
A_{IB}	8
A_{IA}	6.5
A_{IF}	10
A_{UC}	10
A_{UT}	15
A_{UB}	25
A_{UA}	20
A_{UF}	35
S_F	1
M_{FF}	10
M_{FA}	14
U_{SL}	30
M_L	34
C_L	570

Table 5.1.7.1-8
Base Failure Rate Tables
for Capacitor Spec. and Style

Spec. MIL-C	Style	λ_b Table No.
11693	Characteristic E, W	5.1.7.1-11
	Characteristic K	5.1.7.1-12
	Characteristic P	5.1.7.1-13

Table 5.1.7.1-9
π_Q, Quality Factor

Failure Rate Level	π_Q
M	1.0
Non-ER	3.0
LOWER	10.

Table 5.1.7.1-10
π_{CV}, Capacitance Factor

Capacitance *	π_{CV}
0.0031 µF.	0.7
0.061 µF.	1.0
1.8 µF.	1.5

* $\pi_{CV} = 1.4C^{0.12}$
where C is µF.

MIL-C-11693, CZ

*TABLE 5.1.7.1-11: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0012	.0012	.0015	.0023	.0047	.010	.020	.039	.069	.12
10	.0012	.0012	.0015	.0024	.0048	.010	.021	.039	.070	.12
20	.0012	.0013	.0015	.0025	.0050	.011	.021	.041	.072	.12
30	.0013	.0013	.0016	.0026	.0053	.011	.023	.043	.076	.13
40	.0014	.0015	.0018	.0029	.0058	.012	.025	.047	.084	.14
50	.0017	.0018	.0021	.0034	.0069	.015	.030	.056	.10	.17
60	.0023	.0023	.0028	.0045	.0092	.019	.039	.075	.13	.22
70	.0037	.0038	.0045	.0073	.015	.031	.064	.12	.21	.36
80	.0080	.0083	.0099	.016	.032	.069	.14	.26	.47	.79

*See Table 5.1.7.1-8 for applicability to spec. and style.

MIL-C-11693, CZ

*TABLE 5.1.7.1-12: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b ($T = 125^{o}C$ MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
10	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
20	.0012	.0012	.0014	.0023	.0047	.010	.020	.038	.068	.11
30	.0012	.0012	.0014	.0023	.0047	.010	.020	.039	.069	.12
40	.0012	.0012	.0015	.0024	.0048	.010	.021	.039	.070	.12
50	.0012	.0013	.0015	.0024	.0049	.010	.021	.040	.072	.12
60	.0013	.0013	.0016	.0025	.0052	.011	.022	.042	.075	.13
70	.0014	.0014	.0017	.0027	.0055	.012	.024	.045	.080	.13
80	.0015	.0016	.0019	.0031	.0062	.013	.027	.051	.090	.15
90	.0019	.0019	.0023	.0037	.0075	.016	.032	.061	.11	.18
100	.0025	.0026	.0031	.0050	.010	.022	.044	.083	.15	.25
110	.0040	.0041	.0050	.0080	.016	.035	.070	.13	.24	.40
120	.0084	.0087	.010	.017	.034	.072	.15	.28	.49	.83

*See Table 5.1.7.1-8 for applicability to spec. and style.

MIL-C-11693, CZ

*TABLE 5.1.7.1-13: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 150°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
10	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
20	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
30	.0012	.0012	.0014	.0023	.0047	.0099	.020	.038	.068	.11
40	.0012	.0012	.0014	.0023	.0047	.010	.020	.038	.068	.11
50	.0012	.0012	.0015	.0023	.0048	.010	.020	.039	.069	.12
60	.0012	.0012	.0015	.0024	.0048	.010	.021	.039	.070	.12
70	.0012	.0013	.0015	.0024	.0049	.010	.021	.040	.071	.12
80	.0013	.0013	.0016	.0025	.0051	.011	.022	.042	.074	.12
90	.0013	.0014	.0017	.0027	.0055	.012	.023	.045	.079	.13
100	.0015	.0015	.0018	.0030	.0060	.013	.026	.049	.087	.15
110	.0017	.0018	.0022	.0035	.0071	.015	.030	.058	.10	.17
120	.0022	.0023	.0028	.0045	.0091	.019	.039	.074	.13	.22
130	.0033	.0034	.0040	.0065	.013	.028	.057	.11	.19	.32
140	.0058	.0060	.0072	.012	.024	.050	.10	.19	.34	.58
150	.014	.014	.017	.028	.057	.12	.24	.46	.82	1.4

*See Table 5.1.7.1-8 for applicability to spec. and style.

MIL-C-14157, CPV;
MIL-C-19978, CQ AND CQR

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-14157	CPV	Paper and Plastic Film, Est. Rel.
MIL-C-19978	CQ and CQR	Paper and Plastic Film, ER and Non-ER

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b(\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.7.1-14 through -21.

TABLE 5.1.7.1-14

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	7.8
M_P	9.2
N_{SB}	4.4
N_S	5.7
N_U	13
N_H	14
N_{UU}	15
A_{RW}	20
A_{IC}	2.5
A_{IT}	3
A_{IB}	5.5
A_{IA}	3
A_{IF}	8
A_{UC}	3
A_{UT}	9.5
A_{UB}	20
A_{UA}	10
A_{UF}	30

ENVIRON-MENT	π_E
S_F	1
M_{FF}	9.3
M_{FA}	13
U_{SL}	27
M_L	31
C_L	530

Table 5.1.7.1-15
Base Failure Rate Tables
for Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table No.
14157	CPV07	5.1.7.1-18
	CPV09	5.1.7.1-20
	CPV17	5.1.7.1-19
19978	Char. P, L	5.1.7.1-18
	Char. E, F, G, M	5.1.7.1-19
	Char. K, Q, S	5.1.7.1-20
	Char. T	5.1.7.1-21

MIL-C-14157, CPV: MIL-C-19978, CQ and CQR

Table 5.1.7.1-16
π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
L	3.0
MIL-C-19978 Non-ER	10.0
LOWER	30.

Table 5.1.7.1-17
π_{CV}, Capacitance Factor

Capacitance	π_{CV}
MIL-C-14157: *	
.0017 μF.	0.7
.027 "	1.0
.20 "	1.3
1.0 "	1.6
MIL-C-19978: **	
.00032	0.7
.033	1.0
1.0	1.3
15.0	1.6

* $\pi_{CV}=1.6C^{0.13}$

** $\pi_{CV}=1.3C^{0.077}$

where C is μF.

MIL-C-14157, CPV: MIL-C-19978, CQ and CQR

*TABLE 5.1.7.1-18: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 65°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00053	.00054	.00065	.0011	.0021	.0045	.0092	.017	.031	.052
10	.00055	.00057	.00069	.0011	.0022	.0048	.0096	.018	.032	.055
20	.00061	.00062	.00075	.0012	.0025	.0052	.011	.020	.036	.060
30	.00071	.00073	.00088	.0014	.0029	.0061	.012	.023	.042	.070
40	.00094	.00097	.0012	.0019	.0038	.0080	.016	.031	.055	.092
50	.0015	.0016	.0019	.0030	.0061	.013	.026	.050	.088	.15
60	.0034	.0035	.0042	.0068	.014	.029	.059	.11	.20	.33

*See Table 5.1.7.1-15 for applicability to spec. and style.

MIL-C-14157, CPV: MIL-C-19978, CQ and CQR

*TABLE 5.1.7.1-19: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00051	.00053	.00063	.0010	.0021	.0044	.0089	.017	.030	.050
10	.00052	.00053	.00064	.0010	.0021	.0045	.0090	.017	.030	.051
20	.00054	.00055	.00066	.0011	.0022	.0046	.0093	.018	.031	.053
30	.00057	.00058	.00070	.0011	.0023	.0049	.0099	.019	.033	.056
40	.00063	.00064	.00077	.0012	.0025	.0054	.011	.021	.037	.062
50	.00074	.00076	.00092	.0015	.0030	.0064	.013	.024	.043	.073
60	.00099	.0010	.0012	.0020	.0040	.0085	.017	.033	.058	.097
70	.0016	.0016	.0020	.0032	.0064	.014	.028	.052	.093	.16
80	.0035	.0036	.0043	.0070	.014	.030	.061	.11	.20	.34

*See Table 5.1.7.1-15 for applicability to spec. and style.

MIL-C-14157, CPV: MIL-C-19978, CQ and CQR

*TABLE 5.1.7.1-20: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.049
10	.00050	.00052	.00062	.0010	.0020	.0043	.0088	.017	.029	.050
20	.00051	.00052	.00062	.0010	.0020	.0043	.0088	.017	.030	.050
30	.00051	.00053	.00063	.0010	.0021	.0044	.0089	.017	.030	.050
40	.00052	.00053	.00064	.0010	.0021	.0044	.0090	.017	.030	.051
50	.00053	.00055	.00066	.0011	.0021	.0046	.0092	.017	.031	.052
60	.00055	.00057	.00068	.0011	.0022	.0048	.0096	.018	.032	.055
70	.00059	.00061	.00073	.0012	.0024	.0051	.010	.020	.035	.059
80	.00067	.00069	.00083	.0013	.0027	.0057	.012	.022	.039	.066
90	.00081	.00083	.0010	.0016	.0033	.0069	.014	.027	.047	.079
100	.0011	.0011	.0013	.0022	.0044	.0094	.019	.036	.064	.11
110	.0018	.0018	.0022	.0035	.0071	.015	.030	.058	.10	.17
120	.0037	.0038	.0045	.0073	.015	.031	.064	.12	.21	.36

*See Table 5.1.7.1-15 for applicability to spec. and style.

MIL-C-14157, CPV: MIL-C-19978, CQ and CQR

*TABLE 5.1.7.1-21: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 170°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
($^\circ$C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.049
10	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.049
20	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.049
30	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.049
40	.00050	.00052	.00062	.0010	.0020	.0043	.0087	.017	.029	.050
50	.00050	.00052	.00062	.0010	.0020	.0043	.0088	.017	.030	.050
60	.00051	.00052	.00063	.0010	.0021	.0044	.0088	.017	.030	.050
70	.00051	.00053	.00063	.0010	.0021	.0044	.0089	.017	.030	.051
80	.00052	.00054	.00065	.0010	.0021	.0045	.0091	.017	.031	.051
90	.00054	.00055	.00066	.0011	.0022	.0046	.0093	.018	.031	.053
100	.00056	.00058	.00069	.0011	.0023	.0048	.0097	.018	.033	.055
110	.00060	.00062	.00074	.0012	.0024	.0052	.010	.020	.035	.059
120	.00067	.00069	.00083	.0013	.0027	.0057	.012	.022	.039	.066
130	.00079	.00081	.00098	.0016	.0032	.0068	.014	.026	.046	.078
140	.0010	.0010	.0013	.0020	.0041	.0087	.018	.033	.060	.10
150	.0015	.0015	.0018	.0030	.0060	.013	.026	.049	.087	.15
160	.0026	.0027	.0032	.0052	.011	.023	.046	.087	.15	.26
170	.0061	.0063	.0075	.012	.025	.052	.11	.20	.36	.60

*See Table 5.1.7.1-15 for applicability to spec. and style.

CAPACITORS
MIL-C-18312, CH;
MIL-C-39022, CHR

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-18312	CH	Metallized Paper, Paper-Plastic, Plastic
MIL-C-39022	CHR	Metallized Paper, Est. Rel

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \; (\pi_E \times {}_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs.}$$

where the factors are shown in Tables 5.1.7.1-22 through -27.

TABLE 5.1.7.1-22

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	7.8
M_P	9.2
N_{SB}	4.4
N_S	5.7
N_U	13
N_H	14
N_{UU}	15
A_{RW}	20
A_{IC}	2.5
A_{IT}	2.5
A_{IB}	5.5
A_{IA}	3
A_{IF}	8
A_{UC}	3
A_{UT}	9.5
A_{UB}	20
A_{UA}	10
A_{UF}	30
S_F	1
M_{FF}	9.3
M_{FA}	13
U_{SL}	27
M_L	31
C_L	530

Table 5.1.7.1-23
Base Failure Rate Tables
for Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table No.
39022	CHR09 and CHR12 (50V rated), CHR49	5.1.7.1-26
	CHR09,12 (above 50 volt rated), CHR01, 10, 19, 29, 59	5.1.7.1-27
18312	Char R Char N	5.1.7.1-26 5.1.7.1-27

MIL-C-18312, CH: MIL-C-39022, CHR

Table 5.1.7.1-24
π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
L	3.0
MIL-C-18312	
Non-ER	7.0
LOWER	20.

Table 5.1.7.1-25
π_{CV}, Capacitance Factor

Capacitance *	π_{CV}
0.0029 µF.	0.7
0.14 "	1.0
2.4 "	1.3

* $\pi_{CV} = 1.2C^{0.092}$

where C is µF.

MIL-C-18312, CH: MIL-C-39022, CHR

*TABLE 5.1.7.1-26: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00070	.00073	.00087	.0014	.0028	.0060	.012	.023	.041	.069
10	.00072	.00074	.00089	.0014	.0029	.0061	.012	.024	.042	.071
20	.00074	.00076	.00091	.0015	.0030	.0063	.013	.024	.043	.073
30	.00078	.00081	.00097	.0016	.0032	.0067	.014	.026	.046	.077
40	.00086	.00089	.0011	.0017	.0035	.0074	.015	.028	.051	.085
50	.0010	.0011	.0013	.0020	.0041	.0088	.018	.034	.060	.10
60	.0014	.0014	.0017	.0027	.0055	.012	.024	.045	.080	.13
70	.0022	.0023	.0027	.0044	.0089	.019	.038	.072	.13	.22
80	.0048	.0050	.0059	.0096	.019	.041	.084	.16	.28	.47

*See Table 5.1.7.1-23 for applicability to spec. and style.

MIL-C-18312, CH: MIL-C-39022, CHR

*TABLE 5.1.7.1-27: CAPACITORS, FIXED, PAPER OR PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00069	.00071	.00086	.0014	.0028	.0059	.012	.023	.041	.068
10	.00069	.00072	.00086	.0014	.0028	.0060	.012	.023	.041	.068
20	.00070	.00072	.00086	.0014	.0028	.0060	.012	.023	.041	.069
30	.00070	.00072	.00087	.0014	.0028	.0060	.012	.023	.041	.069
40	.00071	.00074	.00088	.0014	.0029	.0061	.012	.024	.042	.070
50	.00073	.00075	.00090	.0015	.0030	.0063	.013	.024	.043	.072
60	.00076	.00079	.00094	.0015	.0031	.0066	.013	.025	.045	.075
70	.00082	.00085	.0010	.0016	.0033	.0070	.014	.027	.048	.081
80	.00092	.00095	.0011	.0018	.0037	.0079	.016	.030	.054	.091
90	.0011	.0011	.0014	.0022	.0045	.0096	.019	.037	.065	.11
100	.0015	.0015	.0019	.0030	.0061	.013	.026	.050	.088	.15
110	.0024	.0025	.0030	.0048	.0098	.021	.042	.080	.14	.24
120	.0051	.0052	.0063	.010	.020	.043	.088	.17	.30	.50

*See Table 5.1.7.1-23 for applicability to spec. and style.

CAPACITORS
MIL-C-55514, CFR

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-55514	CFR	Plastic, Metallized Plastic, ER

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \; (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs.}$$

where the factors are shown in Tables 5.1.7.1-28 through -33.

TABLE 5.1.7.1-28
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.9
G_M	9.3
M_P	11
N_{SB}	5
N_S	5.7
N_U	16
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	3.5
A_{IT}	6.5
A_{IB}	9.5
A_{IA}	6.5
A_{IF}	15
A_{UC}	10
A_{UT}	20
A_{UB}	25
A_{UA}	20
A_{UF}	40

ENVIRON-MENT	π_E
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

Table 5.1.7.1-29
Base Failure Rate Tables
for Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table Number
55514	Char. M, N	5.1.7.1-32
	Char. Q, R, S	5.1.7.1-33

MIL-C-55514, CFR

Table 5.1.7.1-30

π_Q, Quality Factor Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
LOWER	10.0

Table 5.1.7.1-31

π_{CV}, Capacitance Factor

Capacitance*	π_{CV}
.0049 μF.	.7
0.33 μF.	1.0
7.1 μF.	1.3
38. μF.	1.5

* $\pi_{CV} = 1.1C^{0.085}$

where C is μF.

MIL-C-55514, CFR

*TABLE 5.1.7.1-32: CAPACITORS, FIXED, PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0010	.0010	.0012	.0020	.0041	.0087	.018	.033	.059	.10
10	.0010	.0011	.0013	.0021	.0042	.0088	.018	.034	.060	.10
20	.0011	.0011	.0013	.0021	.0043	.0091	.018	.035	.062	.10
30	.0011	.0012	.0014	.0022	.0045	.0096	.020	.037	.066	.11
40	.0012	.0013	.0015	.0025	.0050	.011	.022	.041	.073	.12
50	.0015	.0015	.0018	.0029	.0059	.013	.026	.048	.086	.14
60	.0020	.0020	.0024	.0039	.0079	.017	.034	.064	.11	.19
70	.0032	.0032	.0039	.0063	.013	.027	.055	.10	.18	.31
80	.0069	.0071	.0085	.014	.028	.059	.12	.23	.40	.68

*See Table 5.1.7.1-29 for applicability to spec. and style.

MIL-C-55514, CFR

*TABLE 5.1.7.1-33: CAPACITORS, FIXED, PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00099	.0010	.0012	.0020	.0040	.0085	.017	.033	.058	.098
10	.0010	.0010	.0012	.0020	.0040	.0086	.017	.033	.058	.098
20	.0010	.0010	.0012	.0020	.0041	.0086	.017	.033	.059	.099
30	.0010	.0010	.0012	.0020	.0041	.0087	.018	.033	.059	.099
40	.0010	.0011	.0013	.0020	.0041	.0088	.018	.034	.060	.10
50	.0011	.0011	.0013	.0021	.0043	.0090	.018	.035	.062	.10
60	.0011	.0011	.0014	.0022	.0044	.0094	.019	.036	.064	.11
70	.0012	.0012	.0015	.0024	.0048	.010	.020	.039	.069	.12
80	.0013	.0014	.0016	.0026	.0054	.011	.023	.044	.077	.13
90	.0016	.0016	.0020	.0032	.0065	.014	.028	.053	.094	.16
100	.0022	.0022	.0027	.0043	.0087	.019	.038	.071	.13	.21
110	.0035	.0036	.0043	.0069	.014	.030	.060	.11	.20	.34
120	.0073	.0075	.0090	.015	.029	.062	.13	.24	.43	.72

*See Table 5.1.7.1-29 for applicability to spec. and style.

MIL-C-83421, CRH

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-83421	CRH	Super-Metallized Plastic; ER

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \ (\pi_E \times \pi_Q \times \pi_{CV})$ failure/10^6 hrs.

where the factors are shown in Tables 5.1.7.1-34 through -37.

TABLE 5.1.7.1-34
Environmental Mode Factor

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.3
G_F	3.7
G_M	7.8
M_P	9.2
N_{SB}	4.4
N_S	5.7
N_U	13
N_H	14
N_{UU}	15
A_{RW}	20
A_{IC}	4
A_{IT}	4
A_{IB}	5.5
A_{IA}	4
A_{IF}	8
A_{UC}	9.5
A_{UT}	10
A_{UB}	20
A_{UA}	10
A_{UF}	30
S_F	1
M_{FF}	9.3
M_{FA}	13
U_{SL}	27
M_L	31
C_L	530

Table 5.1.7.1-35
Π_Q, Quality Factor

Failure Rate Level	Π_Q
S	0.03
R	0.1
P	0.3
M	1.0
LOWER	10.0

Table 5.1.7.1-36
Π_{CV}, Capacitance Factor

Capacitance *	Π_{CV}
.0029 μF.	.7
.14 μF.	1.0
2.4 μF.	1.3
23.0 μF.	1.6

* $\pi_{CV} = 1.2C^{0.092}$

where C is μF.

MIL-C-83421, CRH

TABLE 5.1.7.1-37: CAPACITORS, FIXED, PLASTIC, DIRECT CURRENT, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00055	.00057	.00068	.0011	.0022	.0047	.0096	.018	.032	.054
10	.00055	.00057	.00068	.0011	.0022	.0048	.0096	.018	.032	.055
20	.00056	.00057	.00069	.0011	.0023	.0048	.0097	.018	.033	.055
30	.00056	.00058	.00069	.0011	.0023	.0048	.0098	.018	.033	.055
40	.00057	.00059	.00070	.0011	.0023	.0049	.0099	.019	.033	.056
50	.00058	.00060	.00072	.0012	.0024	.0050	.010	.019	.034	.058
60	.00061	.00063	.00075	.0012	.0025	.0052	.011	.020	.036	.060
70	.00065	.00067	.00081	.0013	.0026	.0056	.011	.022	.038	.064
80	.00073	.00076	.00091	.0015	.0030	.0063	.013	.024	.043	.072
90	.00089	.00091	.0011	.0018	.0036	.0076	.015	.029	.052	.087
100	.0012	.0012	.0015	.0024	.0049	.010	.021	.040	.070	.12
110	.0019	.0020	.0024	.0038	.0078	.017	.033	.063	.11	.19
120	.0040	.0042	.0050	.0081	.016	.035	.070	.13	.24	.40

5.1.7.2 MICA Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-5	CM	MICA
MIL-C-39001	CMR	MICA (Dipped), Est. Rel.

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs.}$$

where the factors are shown in Tables 5.1.7.2-1 through -8.

TABLE 5.1.7.2-1

Environmental Mode Factors

ENVIRON-MENT	Π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	8.8
M_P	11
N_{SB}	5
N_S	6.2
N_U	15
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	3.5
A_{IT}	4
A_{IB}	8
A_{IA}	4
A_{IF}	10
A_{UC}	15
A_{UT}	15
A_{UB}	35
A_{UA}	15
A_{UF}	40
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

Table 5.1.7.2-2

Base Failure Rate Tables for Capacitor Spec and Style

Spec MIL-C	Style		λ_b Table Number
5	Temp.range	M	5.1.7.2-5
	Temp.Range	N	5.1.7.2-6
	Temp.Range	O	5.1.7.2-7
	Temp.Range	P	5.1.7.2-8
39001	Temp.Range	O	5.1.7.2-7
	Temp.Range	P	5.1.7.2-8

MIL-C-5, CM: MIL-C-39001, CMR

Table 5.1.7.2-3

Π_Q, Quality Factor

Failure Rate Level	Π_Q
T	0.01
S	0.03
R	0.1
P	0.3
M	1.0
L	1.5
Non-ER Dipped	3
Non-ER Molded	6
LOWER	15.

Table 5.1.7.2-4

Π_{CV}, Capacitance Factor

Capacitance *	Π_{CV}
2.1 pF.	.5
38 pF.	.75
300 pF.	1.0
.002 μF.	1.3
.0086 μF.	1.6
.029 μF.	1.9
.084 μF.	2.2

* $\pi_{CV} = 0.45C^{.14}$ where C is pF.

MIL-C-5, CM: MIL-C-39001, CMR

*TABLE 5.1.7.2-5: CAPACITORS, FIXED, MICA, BASE FAILURE RATE, λ_b (T = 70°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00030	.00033	.00041	.00058	.00086	.0013	.0019	.0026	.0036	.0049
10	.00047	.00052	.00066	.00093	.0014	.0020	.0030	.0042	.0058	.0077
20	.00075	.00083	.0011	.0015	.0022	.0032	.0047	.0067	.0092	.012
30	.0012	.0013	.0017	.0024	.0035	.0052	.0075	.011	.015	.020
40	.0019	.0021	.0027	.0038	.0056	.0082	.012	.017	.023	.031
50	.0031	.0034	.0043	.0060	.0089	.013	.019	.027	.037	.050
60	.0049	.0054	.0068	.0096	.014	.021	.030	.043	.059	.080
70	.0078	.0086	.011	.015	.023	.033	.049	.069	.095	.13

*See Table 5.1.7.2-2 for applicability to spec. and style.

MIL-C-5, CM: MIL-C-39001, CMR

*TABLE 5.1.7.2-6: CAPACITORS, FIXED, MICA, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00017	.00019	.00024	.00034	.00051	.00075	.0011	.0015	.0021	.0028
10	.00027	.00030	.00038	.00054	.00079	.0012	.0017	.0024	.0033	.0044
20	.00042	.00047	.00059	.00084	.0012	.0018	.0027	.0038	.0052	.0070
30	.00066	.00074	.00093	.0013	.0019	.0029	.0042	.0059	.0081	.011
40	.0010	.0012	.0015	.0020	.0030	.0045	.0065	.0092	.013	.017
50	.0016	.0018	.0023	.0032	.0047	.0070	.010	.014	.020	.027
60	.0025	.0028	.0036	.0050	.0074	.011	.016	.023	.031	.042
70	.0040	.0044	.0056	.0078	.012	.017	.025	.035	.048	.065
80	.0062	.0069	.0087	.012	.018	.027	.039	.055	.076	.10

*See Table 5.1.7.2-2 for applicability to spec. and style.

MIL-C-5, CM: MIL-C-39001, CMR

*TABLE 5.1.7.2-7: CAPACITORS, FIXED, MICA, BASE FAILURE RATE, λ_b (T = 125^{o}C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(^{o}C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00005	.00006	.00007	.00010	.00015	.00022	.00032	.00045	.00062	.00083
10	.00008	.00008	.00011	.00015	.00022	.00033	.00048	.00068	.00093	.0012
20	.00011	.00013	.00016	.00022	.00033	.00049	.00071	.0010	.0014	.0019
30	.00017	.00019	.00024	.00034	.00050	.00073	.0011	.0015	.0021	.0028
40	.00025	.00028	.00036	.00050	.00074	.0011	.0016	.0023	.0031	.0042
50	.00038	.00042	.00053	.00075	.0011	.0016	.0024	.0034	.0046	.0062
60	.00057	.00063	.00080	.0011	.0017	.0025	.0036	.0050	.0069	.0093
70	.00085	.00094	.0012	.0017	.0025	.0037	.0053	.0075	.010	.014
80	.0013	.0014	.0018	.0025	.0037	.0055	.0080	.011	.016	.021
90	.0019	.0021	.0027	.0037	.0055	.0082	.012	.017	.023	.031
100	.0028	.0031	.0040	.0056	.0083	.012	.018	.025	.035	.047
110	.0042	.0047	.0059	.0084	.012	.018	.027	.038	.052	.070
120	.0063	.0070	.0089	.013	.018	.027	.040	.056	.077	.10

*See Table 5.1.7.2-2 for applicability to spec. and style.

MIL-C-5, CM: MIL-C-39001, CMR

*TABLE 5.1.7.2-8: CAPACITORS, FIXED, MICA, BASE FAILURE RATE, λ_b (T = 150°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00003	.00003	.00004	.00005	.00008	.00011	.00017	.00024	.00033	.00044
10	.00004	.00004	.00005	.00008	.00011	.00017	.00024	.00034	.00047	.00064
20	.00006	.00006	.00008	.00011	.00017	.00024	.00036	.00050	.00069	.00093
30	.00008	.00009	.00012	.00016	.00024	.00036	.00052	.00073	.0010	.0014
40	.00012	.00013	.00017	.00024	.00035	.00052	.00076	.0011	.0015	.0020
50	.00018	.00020	.00025	.00035	.00051	.00076	.0011	.0016	.0022	.0029
60	.00026	.00029	.00036	.00051	.00075	.0011	.0016	.0023	.0031	.0042
70	.00038	.00042	.00053	.00074	.0011	.0016	.0024	.0033	.0046	.0062
80	.00055	.00061	.00077	.0011	.0016	.0024	.0034	.0049	.0067	.0090
90	.00080	.00089	.0011	.0016	.0023	.0035	.0050	.0071	.0098	.013
100	.0012	.0013	.0016	.0023	.0034	.0050	.0073	.010	.014	.019
110	.0017	.0019	.0024	.0034	.0050	.0074	.011	.015	.021	.028
120	.0025	.0028	.0035	.0049	.0073	.011	.016	.022	.030	.041
130	.0036	.0040	.0051	.0072	.011	.016	.023	.032	.044	.060
140	.0053	.0059	.0074	.010	.015	.023	.033	.047	.065	.087
150	.0078	.0086	.011	.015	.023	.033	.049	.069	.095	.13

*See Table 5.1.7.2-2 for applicability to spec. and style.

MIL-C-10950, CB

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-10950	CB	Button Mica

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs}$$

where the factors are shown in Tables 5.1.7.2-9 through -14.

TABLE 5.1.7.2-9

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	8.8
M_P	11
N_{SB}	5
N_S	5.2
N_U	15
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	3.5
A_{IT}	4
A_{IB}	8
A_{IA}	4
A_{IF}	10
A_{UC}	15
A_{UT}	15
A_{UB}	35
A_{UA}	15
A_{UF}	40
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

Table 5.1.7.2-10

Base Failure Rate Tables for Capacitor Spec & Style

Spec MIL-C	Style	λ_b Table Number
10950	CB50	5.1.7.2-13
	Other	5.1.7.2-14

Table 5.1.7.2-11

Π_{CV}, Capacitance Factor

Capacitance *	Π_{CV}
8.0 pF.	.5
47. "	.75
162. "	1.0
509. "	1.3
1260. "	1.6
2650. "	1.9
5010. "	2.2

* $\pi_{CV} = .31C^{0.23}$

where C is pF.

MIL-C-10950, CB

Table 5.1.7.2-12
π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-SPEC	5.0
Lower	15.0

MIL-C-10950, CB

*TABLE 5.1.7.2-13: CAPACITORS, MICA, BUTTON, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0067	.0074	.0094	.013	.019	.029	.042	.059	.082	.11
10	.0071	.0078	.0099	.014	.021	.030	.044	.063	.086	.12
20	.0076	.0084	.011	.015	.022	.033	.047	.067	.092	.12
30	.0082	.0091	.011	.016	.024	.035	.051	.073	.10	.13
40	.0090	.010	.013	.018	.026	.039	.056	.080	.11	.15
50	.010	.011	.014	.020	.029	.043	.063	.089	.12	.17
60	.012	.013	.016	.023	.033	.050	.072	.10	.14	.19
70	.013	.015	.019	.027	.039	.058	.084	.12	.16	.22
80	.016	.018	.023	.032	.047	.070	.10	.14	.20	.26

*See Table 5.1.7.2-10 for applicability to spec. and style.

MIL-C-10950, CB

*TABLE 5.1.7.2-14: CAPACITORS, MICA, BUTTON, BASE FAILURE RATE, λ_b (T = 150°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0058	.0064	.0081	.011	.017	.025	.036	.051	.071	.095
10	.0059	.0066	.0083	.012	.017	.026	.037	.052	.072	.097
20	.0061	.0067	.0085	.012	.018	.026	.038	.054	.074	.099
30	.0062	.0069	.0087	.012	.018	.027	.039	.055	.076	.10
40	.0064	.0071	.0090	.013	.019	.028	.040	.057	.079	.11
50	.0067	.0074	.0094	.013	.019	.029	.042	.059	.082	.11
60	.0070	.0078	.0098	.014	.020	.030	.044	.062	.086	.11
70	.0074	.0082	.010	.015	.022	.032	.046	.066	.090	.12
80	.0079	.0088	.011	.016	.023	.034	.049	.070	.096	.13
90	.0085	.0094	.012	.017	.025	.037	.053	.075	.10	.14
100	.0093	.010	.013	.018	.027	.040	.058	.082	.11	.15
110	.010	.011	.014	.020	.030	.044	.064	.091	.12	.17
120	.011	.013	.016	.023	.033	.049	.072	.10	.14	.19
130	.013	.014	.018	.026	.038	.056	.082	.12	.16	.21
140	.015	.017	.021	.030	.044	.065	.095	.13	.18	.25
150	.018	.020	.025	.035	.052	.077	.11	.16	.22	.29

*See Table 5.1.7.2-10 for applicability to spec. and style.

MIL-C-11272, CY;
MIL-C-23269, CYR

5.1.7.3 Glass Capacitors

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-11272	CY	Glass Capacitors
MIL-C-23269	CYR	Glass Capacitors, Est. Rel

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs.}$$

where the factors are shown in Tables 5.1.7.3-1 through -6.

TABLE 5.1.7.3-1
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.4
G_M	8.8
M_P	11
N_{SB}	5
N_S	6.2
N_U	15
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	3.5
A_{IT}	4
A_{IB}	8
A_{IA}	4
A_{IF}	10
A_{UC}	15
A_{UT}	15
A_{UB}	35
A_{UA}	15
A_{UF}	40
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

Table 5.1.7.3-2
Base Failure Rate Tables for
Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table Number
23269	All	5.1.7.3-5
11272	Temp. Range C	5.1.7.3-5
11272	Temp. Range D	5.1.7.3-6

Table 5.1.7.3-3
π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
L	3
Non-ER	3
LOWER	10.

Table 5.1.7.3-4
π_{CV}, Capacitance Factor

Capacitance *	π_{CV}
.22 pF.	.5
3.9 "	.75
30. "	1.0
200. "	1.3
870. "	1.6
3000. "	1.9
8500. "	2.2

* $\pi_{CV} = 0.62C^{0.14}$
where C is pF.

MIL-C-11272, CY: MIL-C-23269, CYR

*TABLE 5.1.7.3-5: CAPACITORS, FIXED, GLASS, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00005	.00005	.00005	.00007	.00010	.00015	.00023	.00036	.00055	.00082
10	.00007	.00007	.00008	.00010	.00014	.00022	.00035	.00054	.00083	.0012
20	.00011	.00011	.00012	.00015	.00022	.00033	.00052	.00081	.0012	.0018
30	.00016	.00017	.00018	.00023	.00032	.00049	.00078	.0012	.0018	.0027
40	.00024	.00025	.00027	.00034	.00048	.00074	.0012	.0018	.0028	.0041
50	.00036	.00037	.00041	.00051	.00072	.0011	.0017	.0027	.0041	.0061
60	.00054	.00055	.00061	.00076	.0011	.0017	.0026	.0041	.0062	.0091
70	.00080	.00082	.00091	.0011	.0016	.0025	.0039	.0061	.0092	.014
80	.0012	.0012	.0014	.0017	.0024	.0037	.0058	.0091	.014	.020
90	.0018	.0018	.0020	.0025	.0036	.0055	.0087	.014	.021	.031
100	.0027	.0028	.0030	.0038	.0054	.0082	.013	.020	.031	.046
110	.0040	.0041	.0045	.0057	.0080	.012	.019	.030	.046	.068
120	.0060	.0061	.0068	.0085	.012	.018	.029	.045	.069	.10

*See Table 5.1.7.3-2 for applicability to spec. and style.

MIL-C-11272, CY: MIL-C-23269, CYR

*TABLE 5.1.7.3-6: CAPACITORS, FIXED, GLASS, BASE FAILURE RATE, λ_b (T = 200°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE									
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00001	.00001	.00001	.00001	.00002	.00003	.00004	.00006	.00010	.00014
10	.00001	.00001	.00001	.00002	.00002	.00004	.00006	.00009	.00014	.00020
20	.00002	.00002	.00002	.00002	.00003	.00005	.00008	.00013	.00019	.00028
30	.00002	.00002	.00003	.00003	.00005	.00007	.00011	.00018	.00027	.00040
40	.00003	.00003	.00004	.00005	.00007	.00010	.00016	.00025	.00038	.00056
50	.00005	.00005	.00005	.00006	.00009	.00014	.00022	.00035	.00053	.00078
60	.00006	.00007	.00007	.00009	.00013	.00020	.00031	.00049	.00074	.0011
70	.00009	.00009	.00010	.00013	.00018	.00028	.00044	.00068	.0010	.0015
80	.00013	.00013	.00014	.00018	.00025	.00039	.00061	.00096	.0015	.0022
90	.00018	.00018	.00020	.00025	.00035	.00055	.00086	.0013	.0020	.0030
100	.00025	.00026	.00028	.00035	.00050	.00077	.0012	.0019	.0029	.0042
110	.00035	.00036	.00039	.00049	.00070	.0011	.0017	.0026	.0040	.0059
120	.00049	.00050	.00055	.00069	.00098	.0015	.0024	.0037	.0056	.0083
130	.00069	.00070	.00078	.00097	.0014	.0021	.0033	.0052	.0079	.012
140	.00096	.00099	.0011	.0014	.0019	.0030	.0047	.0073	.011	.016
150	.0014	.0014	.0015	.0019	.0027	.0042	.0065	.010	.016	.023
160	.0019	.0019	.0021	.0027	.0038	.0058	.0092	.014	.022	.032
170	.0027	.0027	.0030	.0037	.0053	.0082	.013	.020	.031	.045
180	.0037	.0038	.0042	.0053	.0075	.011	.018	.028	.043	.063
190	.0052	.0054	.0059	.0074	.010	.016	.025	.039	.060	.89
200	.0073	.0075	.0083	.010	.015	.023	.035	.055	.084	.12

*See Table 5.1.7.3-2 for applicability to spec. and style.

5.1.7.4 Ceramic Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-11015	CK	Ceramic, General Purpose
MIL-C-39014	CKR	Ceramic, General Purpose, Est. Rel.

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \, (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hrs.}$$

where the factors are shown in Tables 5.1.7.4-1 through -6.

TABLE 5.1.7.4-1
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.6
G_M	7.8
M_P	11
N_{SB}	5
N_S	5.5
N_U	12.4
N_H	16
N_{UU}	18
A_{RW}	24
A_{IC}	3
A_{IT}	3
A_{IB}	5
A_{IA}	3
A_{IF}	6
A_{UC}	7.5
A_{UT}	8
A_{UB}	10
A_{UA}	8
A_{UF}	15
S_F	0.8
M_{FF}	11
M_{FA}	15
U_{SL}	32
M_L	36
C_L	610

Table 5.1.7.4-2
π_Q Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
L	3
Non-ER	3
LOWER	10.

Table 5.1.7.4-3
π_{CV}, Capacitance Factor

Capacitance *	π_{CV}
6.1 pF.	.5
240. "	.75
3300. "	1.0
.036 µF.	1.3
.24 "	1.6
1.1 "	1.9
4.3 "	2.2

* $\pi_{CV} = .41C^{0.11}$
where C is pF.

MIL-C-11015, CK: MIL-C-39014, CKR

*TABLE 5.1.7.4-4: CAPACITORS, FIXED, CERAMIC (GENERAL PURPOSE), BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00067	.00083	.0013	.0022	.0036	.0058	.0088	.013	.018	.024
10	.00069	.00086	.0013	.0022	.0037	.0060	.0091	.013	.019	.025
20	.00071	.00088	.0014	.0023	.0038	.0061	.0093	.014	.019	.026
30	.00073	.00091	.0014	.0024	.0039	.0063	.0096	.014	.020	.027
40	.00075	.00093	.0014	.0024	.0040	.0065	.0099	.014	.020	.027
50	.00077	.00096	.0015	.0025	.0042	.0067	.010	.015	.021	.028
60	.00079	.00099	.0015	.0026	.0043	.0068	.010	.015	.021	.029
70	.00081	.0010	.0016	.0026	.0044	.0070	.011	.016	.022	.030
80	.00083	.0010	.0016	.0027	.0045	.0072	.011	.016	.023	.031

*Applicable to styles CKR 13, 48, 64, 72 of MIL-C-39014.
Applicable to "A" rated temperature of MIL-C-11015 as shown in type designation, e.g., CK61AW222M.

MIL-C-11015, CK: MIL-C-39014, CKR

*TABLE 5.1.7.4-5: CAPACITORS, FIXED, CERAMIC (GENERAL PURPOSE), BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00062	.00077	.0012	.0020	.0034	.0054	.0082	.012	.017	.023
10	.00063	.00079	.0012	.0021	.0034	.0055	.0084	.012	.017	.023
20	.00065	.00081	.0013	.0021	.0035	.0056	.0086	.013	.018	.024
30	.00067	.00083	.0013	.0022	.0036	.0058	.0088	.013	.018	.024
40	.00068	.00085	.0013	.0022	.0037	.0059	.0090	.013	.018	.025
50	.00070	.00088	.0014	.0023	.0038	.0061	.0093	.013	.019	.026
60	.00072	.00090	.0014	.0023	.0039	.0062	.0095	.014	.019	.026
70	.00074	.00092	.0014	.0024	.0040	.0064	.0097	.014	.020	.027
80	.00076	.00094	.0015	.0025	.0041	.0066	.010	.015	.020	.028
90	.00077	.00097	.0015	.0025	.0042	.0067	.010	.015	.021	.028
100	.00079	.00099	.0015	.0026	.0043	.0069	.010	.015	.021	.029
100	.00081	.0010	.0016	.0026	.0044	.0071	.011	.016	.022	.030
120	.00084	.0010	.0016	.0027	.0045	.0072	.011	.016	.023	.031

*Applicable to styles CKR05-12, 14-16, 17-19, 73, 74 of MIL-C-39014.
Applicable to "B" rated temperature of MIL-C-11015 as shown in type designation, e.g., CK61BX681M.

MIL-C-11015, CK: MIL-C-39014, CKR

*TABLE 5.1.7.4-6: CAPACITORS, FIXED, CERAMIC (GENERAL PURPOSE), BASE FAILURE RATE, λ_b (T = 150°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00059	.00074	.0011	.0019	.0032	.0051	.0078	.011	.016	.022
10	.00061	.00076	.0012	.0020	.0033	.0053	.0080	.012	.016	.022
20	.00062	.00078	.0012	.0020	.0034	.0054	.0082	.012	.017	.023
30	.00064	.00080	.0012	.0021	.0035	.0055	.0084	.012	.017	.023
40	.00065	.00082	.0013	.0021	.0035	.0057	.0086	.013	.018	.024
50	.00067	.00083	.0013	.0022	.0036	.0058	.0088	.013	.018	.024
60	.00068	.00085	.0013	.0022	.0037	.0059	.0090	.013	.018	.025
70	.00070	.00087	.0013	.0023	.0038	.0061	.0092	.013	.019	.026
80	.00072	.00090	.0014	.0023	.0039	.0062	.0095	.014	.019	.026
90	.00073	.00092	.0014	.0024	.0040	.0064	.0097	.014	.020	.027
100	.00075	.00094	.0014	.0024	.0041	.0065	.0099	.014	.020	.028
110	.00077	.00096	.0015	.0025	.0042	.0067	.010	.015	.021	.028
120	.00079	.00098	.0015	.0026	.0043	.0068	.010	.015	.021	.029
130	.0081	.0010	.0016	.0026	.0044	.0070	.011	.016	.022	.030
140	.00083	.0010	.0016	.0027	.0045	.0072	.011	.016	.022	.030
150	.00085	.0011	.0016	.0027	.0046	.0073	.011	.016	.023	.031

*Applicable to "C" rated temperature of MIL-C-11015 as shown in type designation, e.g., CK61CZ471M.

MIL-C-20, CC/CCR

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-20	CC/CCR	Ceramic, Temperature Compensating
MIL-C-55681	CDR-21	Ceramic, Chip

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times (\pi_E \times \pi_Q \times \pi_{CV}) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.7.4-7 through -12.

TABLE 5.1.7.4-7
Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	8.8
M_P	11
N_{SB}	5
N_S	5
N_U	17
N_H	16
N_{UU}	18
A_{RW}	24
A_{IC}	2.5
A_{IT}	3.5
A_{IB}	7.5
A_{IA}	7
A_{IF}	10
A_{UC}	4.5
A_{UT}	15
A_{UB}	30
A_{UA}	25
A_{UF}	45
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	32
M_L	36
C_L	610

Table 5.1.7.4-8
Base Failure Rate Tables
for Capacitor Spec and Style

Spec MIL-C	Style	λ_b Table Number
20	CC 20,25,30,32,35,45,85,95-97	5.1.7.4-11
	CC 5-9,13-19,21,22,26,27,31,33,36,37,47,50-57,75-79,81-83 CCR 05-09,13-19,54-57,75-79,81-83,90	5.1.7.4-12

Table 5.1.7.4-9
π_Q, Quality Factor

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
Non-ER	3
LOWER	10.

Table 5.1.7.4-10
π_{CV}, Capacitor Factor

Capacitance *	π_{CV}
.25 pF.	.5
7.4 "	.75
81. "	1.0
720. "	1.3
4100. "	1.6
.017 µF.	1.9
.058 "	2.2

* $\pi_{CV} = .59C^{0.12}$

where C is pF.

MIL-C-20, CC/CCR

*TABLE 5.1.7.4-11: CAPACITORS, CERAMIC, TEMPERATURE COMPENSATING, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00015	.00018	.00028	.00048	.00080	.0013	.0019	.0028	.0040	.0054
10	.00022	.00027	.00042	.00071	.0012	.0019	.0029	.0042	.0059	.0080
20	.00033	.00041	.00063	.0011	.0018	.0028	.0043	.0063	.0088	.012
30	.00049	.00061	.00094	.0016	.0026	.0042	.0064	.0094	.013	.018
40	.00073	.00091	.0014	.0024	.0039	.0063	.0096	.014	.020	.027
50	.0011	.0014	.0021	.0035	.0059	.0094	.014	.021	.029	.040
60	.0016	.0020	.0031	.0052	.0088	.014	.021	.031	.044	.059
70	.0024	.0030	.0046	.0078	.013	.021	.032	.046	.065	.088
80	.0036	.0045	.0069	.012	.019	.031	.047	.069	.097	.13

*See Table 5.1.7.4-8 for applicability to spec. and style.

MIL-C-20, CC/CCR

*TABLE 5.1.7.4-12: CAPACITORS, CERAMIC, TEMPERATURE COMPENSATING, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.00005	.00006	.00009	.00016	.00027	.00043	.00065	.00094	.0013	.0018
10	.00007	.00009	.00014	.00023	.00038	.00061	.00093	.0014	.0019	.0026
20	.00010	.00013	.00019	.00033	.00055	.00087	.0013	.0019	.0027	.0037
30	.00014	.00018	.00028	.00047	.00078	.0013	.0019	.0028	.0039	.0053
40	.00021	.00026	.00040	.00067	.0011	.0018	.0027	.0040	.0056	.0076
50	.00030	.00037	.00057	.00096	.0016	.0026	.0039	.0057	.0080	.011
60	.00042	.00053	.00082	.0014	.0023	.0037	.0056	.0082	.011	.016
70	.00061	.00076	.0012	.0020	.0033	.0053	.0080	.012	.016	.022
80	.00087	.0011	.0017	.0028	.0047	.0075	.011	.017	.023	.032
90	.0012	.0016	.0024	.0040	.0068	.011	.016	.024	.034	.046
100	.0018	.0022	.0034	.0058	.0097	.015	.024	.034	.048	.065
110	.0026	.0032	.0049	.0083	.014	.022	.034	.049	.069	.094
120	.0037	.0046	.0071	.012	.020	.032	.048	.070	.099	.13

*See Table 5.1.7.4-8 for applicability to spec. and style.

MIL-C-39003, CSR

5.1.7.5 Tantalum Electrolytic Capacitors

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-39003	CSR	Tantalum Electolytic (solid), Est. Rel.

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \left(\Pi_E \times \Pi_{SR} \times \Pi_Q \times \Pi_{CV}\right) \text{ failures}/10^6 \text{ hours}$$

TABLE 5.1.7.5-1

Environmental Mode Factors

ENVIRONMENT	Π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	7.8
M_P	9.2
N_{SB}	4.4
N_S	4.9
N_U	13
N_H	14
N_{UU}	15
A_{RW}	20
A_{IC}	2.5
A_{IT}	2.5
A_{IB}	7
A_{IA}	3
A_{IF}	7.5
A_{UC}	4.5
A_{UT}	6
A_{UB}	25
A_{UA}	10
A_{UF}	30
S_F	0.8
M_{FF}	9.3
M_{FA}	13
U_{SL}	27
M_L	31
C_L	530

Table 5.1.7.5-2
Series Resistance,
π_{SR} for MIL-C-39003

Circuit Resistance (ohms/volt)	π_{SR}
>0.8 to 1.0	.066
>0.6 to 0.8	.10
>0.4 to 0.6	.13
>0.2 to 0.4	.20
>0.1 to 0.2	.27
0 to 0.1	.33

Table 5.1.7.5-3
π_{CV}, Capacitance Factor

Capacitance*	π_{CV}
.003 uF.	0.5
.091 "	0.75
1.0 "	1.0
8.9 "	1.3
50. "	1.6
210. "	1.9
710. "	2.2

* $\pi_{CV} = 1.0C^{0.12}$
where C is uF.

Table 5.1.7.5-4
π_Q, Quality Factor

Failure Rate Level	π_Q
D	0.001
C	0.01
S	0.03
R	0.1
B	0.1
P	0.3
M	1.0
L	1.5
LOWER	10.

MIL-C-39003, CSR

TABLE 5.1.7.5-5: CAPACITORS, FIXED, ELECTROLYTIC (SOLID) TANTALUM, BASE FAILURE RATE, λ_b

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0042	.0046	.0058	.0082	.012	.018	.026	.037	.051	.068
10	.0043	.0048	.0060	.0085	.012	.019	.027	.038	.052	.070
20	.0045	.0050	.0063	.0088	.013	.019	.028	.040	.055	.074
30	.0048	.0053	.0067	.0094	.014	.021	.030	.042	.058	.078
40	.0051	.0057	.0072	.010	.015	.022	.032	.046	.063	.084
50	.0057	.0063	.0079	.011	.016	.024	.035	.050	.069	.093
60	.0064	.0071	.0090	.013	.019	.028	.040	.057	.078	.11
70	.0075	.0083	.011	.015	.022	.032	.047	.067	.092	.12
80	.0092	.010	.013	.018	.027	.040	.058	.082	.11	.15
90	.012	.013	.017	.023	.034	.051	.074	.11	.14	
100	.016	.018	.023	.032	.047	.070	.10	.14		
110	.024	.027	.034	.047	.070	.10	.15			
120	.039	.043	.054	.076	.11	.17	.24			

MIL-C-3965, CL;
MIL-C-39006, CLR

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-3965	CL	Tantalum, Electrolytic (Non-solid)
MIL-C-39006	CLR	Tantalum, Electrolytic (Non-solid) Est. Rel.

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \ (\pi_E \times \pi_C \times \pi_Q \times \pi_{CV})$ failures/10^6 hours.

where the factors are shown in Tables 5.1.7.5-6 through -13.

TABLE 5.1.7.5-6

ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.4
G_M	10
M_P	11
N_{SB}	5
N_S	6.7
N_U	15
N_H	16
N_{UU}	17
A_{RW}	23
A_{IC}	2.5
A_{IT}	4
A_{IB}	6.5
A_{IA}	6
A_{IF}	10
A_{UC}	8.5
A_{UT}	15
A_{UB}	20
A_{UA}	20
A_{UF}	40
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	31
M_L	36
C_L	610

TABLE 5.1.7.5-7
BASE-FAILURE RATE TABLES FOR CAPACITOR
SPECIFICATION AND STYLE

Spec MIL-C	Style	λ_b Table No.
3965	CL24, 25, 26, 27, 34, 35, 36, 37	5.1.7.5-11
	CL20, 21, 22, 23, 30, 31, 32, 33, 40, 41, 42, 43, 46, 47, 48, 49, 51, 52, 53, 54, 55, 56, 64, 65, 66, 67, 70, 71, 72, 73	5.1.7.5-12
	CL14, 16, 10, 13, 17, 18,	5.1.7.5-13
39006	all	5.1.7.5-12

CAPACITORS
MIL-C-3965, CL;
MIL-C-39006, CLR

TABLE 5.1.7.5-8
π_Q, QUALITY FACTOR

Failure Rate Level	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
L	1.5
Non-ER	3
LOWER	10.

TABLE 5.1.7.5-9
π_{CV}, CAPACITANCE FACTOR

Capacitance *	π_{CV}
.091 uF.	0.7
20. "	1.0
1100. "	1.3

* $\pi_{CV} = .82C^{0.066}$ where C is μF.

MIL-C-3365, CL
MIL-C-39006, CLR

Table 5.1.7.5-10
MIL-C-3965/MIL-C-39006 Construction Factor, π_C

Construction Type	π_C
Slug, All Tantalum	0.3
Foil, Hermetic*	1.0
Slug, Hermetic*	2.0
Foil, Non-Hermetic*	2.5
Slug, Non-Hermetic*	3.0

*Type of seal identified as follows:

1 MIL-C-3965 (CL) - Note last letter in part number:

G - Hermetic

E - Non-Hermetic

Example: CL10BC700TPG is hermetic

2 MIL-C-39006 (CLR) - Consult individual part specification sheet (slash sheet)

NOTE:

Foil Types - CL 20, 21, 22, 23, 30, 31, 32
33, 51, 52, 53, 54, 70, 71, 72, 73

CLR 25, 27,35, 37, 53,71, 73

Slug Types - CL 10, 13, 14, 16, 17, 18, 55, 56,
66, 67

CLR 10, 14, 17, 65, 69, 89

All Tantalum - CLR 79

MIL-C-3965, CL: MIL-C-39006, CLR

*TABLE 5.1.7.5-11: CAPACITORS, TANTALUM (NONSOLID), BASE FAILURE RATE, λ_b ($T = 85^oC$ MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(^oC)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0021	.0023	.0029	.0041	.0061	.0091	.013	.019	.026	.034
10	.0023	.0025	.0032	.0045	.0067	.0099	.014	.020	.028	.038
20	.0026	.0028	.0036	.0051	.0075	.011	.016	.023	.031	.042
30	.0030	.0033	.0042	.0059	.0087	.013	.019	.027	.036	.049
40	.0036	.0040	.0051	.0072	.011	.016	.023	.032	.044	.060
50	.0047	.0052	.0066	.0092	.014	.020	.029	.042	.057	.077
60	.0065	.0072	.0091	.013	.019	.028	.041	.058	.079	.11
70	.0098	.011	.014	.019	.029	.042	.062	.087	.12	.16
80	.017	.018	.023	.033	.048	.071	.10	.15	.20	.27

*See Table 5.1.7.5-7 for applicability to spec. and style.

MIL-C-3965, CL: MIL-C-39006, CLR

*TABLE 5.1.7.5-12: CAPACITORS, TANTALUM (NONSOLID), BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
($^{\circ}$C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0018	.0020	.0026	.0036	.0053	.0079	.011	.016	.022	.030
10	.0019	.0021	.0026	.0037	.0055	.0081	.012	.017	.023	.031
20	.0020	.0022	.0028	.0039	.0057	.0085	.012	.018	.024	.032
30	.0021	.0023	.0029	.0041	.0061	.0090	.013	.019	.026	.034
40	.0023	.0025	.0032	.0045	.0066	.0097	.014	.020	.028	.037
50	.0025	.0028	.0035	.0049	.0072	.011	.016	.022	.030	.041
60	.0028	.0031	.0040	.0056	.0082	.012	.018	.025	.034	.046
70	.0033	.0037	.0046	.0065	.0096	.014	.021	.029	.040	.054
80	.0041	.0045	.0057	.0080	.012	.017	.025	.036	.049	.066
90	.0052	.0058	.0073	.010	.015	.022	.033	.046	.064	
100	.0071	.0079	.010	.014	.021	.031	.045	.063		
110	.011	.012	.015	.021	.031	.045	.066			
120	.017	.019	.024	.034	.050	.073	.11			

*See Table 5.1.7.5-7 for applicability to spec. and style.

MIL-C-3965, CL: MIL-C-39006, CLR

*TABLE 5.1.7.5-13: CAPACITORS, TANTALUM (NONSOLID), BASE FAILURE RATE, λ_b (T = 175°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0017	.0019	.0024	.0034	.0050	.0074	.011	.015	.021	.028
10	.0017	.0019	.0024	.0034	.0051	.0075	.011	.015	.021	.029
20	.0018	.0020	.0025	.0035	.0052	.0076	.011	.016	.022	.029
30	.0018	.0020	.0025	.0036	.0053	.0078	.011	.016	.022	.030
40	.0019	.0021	.0026	.0037	.0054	.0080	.012	.016	.023	.030
50	.0019	.0021	.0027	.0038	.0056	.0083	.012	.017	.023	.031
60	.0020	.0022	.0028	.0040	.0058	.0086	.013	.018	.024	.033
70	.0021	.0023	.0030	.0042	.0062	.0091	.013	.019	.026	.035
80	.0023	.0025	.0032	.0045	.0066	.0098	.014	.020	.028	.037
90	.0025	.0027	.0035	.0049	.0072	.011	.016	.022	.030	
100	.0028	.0031	.0039	.0054	.0080	.012	.017	.024	.034	
110	.0032	.0035	.0044	.0062	.0092	.014	.020	.028	.039	
120	.0037	.0041	.0052	.0073	.011	.016	.023	.033		
130	.0046	.0051	.0064	.0090	.013	.020	.029	.040		
140	.0059	.0065	.0082	.012	.017	.025	.037	.052		
150	.0079	.0088	.011	.016	.023	.034	.049	.070		
160	.011	.013	.016	.022	.033	.049	.071			
170	.018	.019	.025	.035	.051	.076				

*See Table 5.1.7.5-7 for applicability to spec. and style.

CAPACITORS
MIL-C-39018, CU, CUR

5.1.7.6 Aluminum Electrolytic Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-39018	CUR	Aluminum Oxide Electrolytic, ER
MIL-C-39018	CU	Aluminum Oxide Electrolytic

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times \pi_E \times \pi_Q \times \pi_{CV}$ failures/10^6 hours.

where the factors are shown in Tables 5.1.7.6-1 through -4.

TABLE 5.1.7.6-1

ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	12
M_P	12
N_{SB}	5.8
N_S	6.7
N_U	13
N_H	19
N_{UU}	20
A_{RW}	27
A_{IC}	9.5
A_{IT}	10
A_{IB}	10
A_{IA}	10
A_{IF}	15
A_{UC}	25
A_{UT}	30
A_{UB}	30
A_{UA}	30
A_{UF}	40
S_F	1
M_{FF}	12
M_{FA}	17
U_{SL}	36
M_L	41
C_L	690

TABLE 5.1.7.6-2
π_Q, QUALITY FACTOR

FAILURE RATE LEVEL	π_Q
S	0.03
R	0.1
P	0.3
M	1.0
Non-ER	3.
Lower	10

TABLE 5.1.7.6-3
π_{CV}, CAPACITANCE FACTOR

Capacitance*	π_{CV}
2.5 µF.	0.4
55. "	0.7
400. "	1.0
1700. "	1.3
5500. "	1.6
14,000. "	1.9
32,000. "	2.2
65,000. "	2.5
120,000. "	2.8

* $\pi_{CV} = .34C^{0.18}$ where C is µF.

MIL-C-39018, CU, CUR

TABLE 5.1.7.6-4: CAPACITORS, FIXED, ELECTROLYTIC, ALUMINUM OXIDE, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0055	.0059	.0067	.0083	.011	.015	.021	.028	.038	.050
10	.0065	.0068	.0078	.0097	.013	.017	.024	.033	.044	.058
20	.0077	.0081	.0093	.012	.015	.021	.029	.039	.052	.069
30	.0094	.0099	.011	.014	.019	.025	.035	.048	.064	.084
40	.012	.012	.014	.018	.023	.032	.044	.060	.080	.11
50	.015	.016	.019	.023	.030	.042	.057	.078	.10	.14
60	.021	.022	.025	.031	.041	.056	.077	.10	.14	.18
70	.029	.030	.035	.043	.057	.078	.11	.15	.20	.26
80	.042	.044	.050	.063	.083	.11	.16	.21	.28	.37
90	.064	.067	.077	.095	.13	.17	.24	.32	.43	*
100	.10	.11	.12	.15	.20	.27	.38	.51		
110	.17	.18	.21	.26	.34	.46	.63	.86		
120	.30	.32	.37	.46	.60	.82	1.1			

*Do not use styles CU 16, 17 and 71 below this line.

CAPACITORS
MIL-C-62, CE

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-62	CE	Aluminum, Dry Electrolyte

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b \times \pi_E \times \pi_Q \times \pi_{CV} \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.7.6-5 through -8.

TABLE 5.1.7.6-5

ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.4
G_M	12
M_P	12
N_{SB}	5.8
N_S	6.7
N_U	13
N_H	19
N_{UU}	20
A_{RW}	27
A_{IC}	9.5
A_{IT}	10
A_{IB}	10
A_{IA}	10
A_{IF}	15
A_{UC}	25
A_{UT}	30
A_{UB}	30
A_{UA}	30
A_{UF}	40
S_F	1
M_{FF}	12
M_{FA}	17
U_{SL}	36
M_L	41
C_L	690

TABLE 5.1.7.6-6
π_Q, QUALITY FACTOR

Quality Level	π_Q
MIL-Spec	3
Lower	10

TABLE 5.1.7.6-7
π_{CV}, CAPACITANCE FACTOR

Capacitance	π_{CV}
3.2 µF.	0.4
62. "	0.7
400. "	1.0
1600. "	1.3
4800. "	1.6
12,000. "	1.9
26,000. "	2.2
50,000. "	2.5
91,000. "	2.8

* $\pi_{CV} = .32C^{0.19}$ where C is µF.

MIL-C-62, CE

TABLE 5.1.7.6-8: CAPACITORS, ALUMINUM, DRY ELECTROLYTE, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0064	.0067	.0074	.0089	.011	.015	.020	.026	.034	.045
10	.0078	.0082	.0090	.011	.014	.018	.024	.032	.042	.055
20	.0099	.010	.011	.014	.017	.023	.030	.040	.053	.069
30	.013	.014	.015	.018	.023	.030	.040	.053	.070	.091
40	.018	.019	.021	.025	.031	.041	.055	.073	.096	.13
50	.026	.027	.030	.036	.046	.060	.080	.11	.14	.18
60	.041	.042	.047	.056	.071	.093	.12	.16	.22	.28
70	.068	.070	.078	.093	.12	.15	.21	.27	.36	.47
80	.12	.13	.14	.17	.21	.28	.37	.49	.65	.85

5.1.7.7 Variable Ceramic Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-81	CV	Variable Ceramic

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times (\pi_E \times \pi_Q)$ failures/10^6 hours

where the factors are covered by Tables 5.1.7.7-1 through -5.

TABLE 5.1.7.7-1

Environmental Mode Factors

Environment	π_E
G_B	1
G_{MS}	1.3
G_F	3.4
G_M	9.8
M_P	17
N_{SB}	7.9
N_S	7.7
N_U	20
N_H	25
N_{UU}	27
A_{RW}	36
A_{IC}	3.5
A_{IT}	4
A_{IB}	10
A_{IA}	10
A_{IF}	10
A_{UC}	15
A_{UT}	25
A_{UB}	70
A_{UA}	65
A_{UF}	75
S_F	0.8
M_{FF}	17
M_{FA}	23
U_{SL}	49
M_L	56
C_L	950

TABLE 5.1.7.7-2
BASE FAILURE RATE TABLES FOR
CAPACITOR SPECIFICATION AND STYLE

Spec MIL-C	Style	λ_b Table No.
81	CV11,14,21,31, 32,34,40,41	5.1.7.7-4
	CV35, 36	5.1.7.7-5

TABLE 5.1.7.7-3
π_Q, QUALITY FACTOR

Quality Level	π_Q
MIL-Spec	4
Lower	20

MIL-C-81, CV

*TABLE 5.1.7.7-4: CAPACITORS, VARIABLE, CERAMIC, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP ($^{\circ}$C)	S, RATIO OF OPERATING TO RATED VOLTAGE .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0030	.0065	.016	.035	.066	.11	.18	.26	.37	.51
10	.0031	.0068	.017	.036	.069	.12	.18	.27	.39	.53
20	.0033	.0073	.018	.039	.073	.12	.20	.29	.41	.57
30	.0036	.0079	.020	.042	.080	.14	.21	.32	.45	.62
40	.0041	.0089	.022	.047	.089	.15	.24	.35	.50	.69
50	.0047	.010	.026	.055	.10	.18	.28	.41	.59	.80
60	.0058	.013	.031	.068	.13	.22	.34	.51	.72	.98
70	.0076	.017	.041	.088	.17	.28	.45	.66	.94	1.3
80	.011	.023	.058	.12	.24	.40	.63	.94	1.3	1.8

*See Table 5.1.7.7-2 for applicability to spec. and style.

MIL-C-81, CV

*TABLE 5.1.7.7-5: CAPACITORS, VARIABLE, CERAMIC, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0028	.0061	.015	.033	.061	.10	.16	.24	.35	.47
10	.0028	.0062	.015	.033	.062	.11	.17	.25	.35	.48
20	.0029	.0063	.016	.034	.064	.11	.17	.25	.36	.49
30	.0030	.0065	.016	.035	.066	.11	.18	.26	.37	.51
40	.0031	.0068	.017	.036	.068	.12	.18	.27	.39	.53
50	.0033	.0071	.018	.038	.072	.12	.19	.29	.41	.56
60	.0035	.0077	.019	.041	.077	.13	.21	.31	.44	.60
70	.0038	.0084	.021	.045	.084	.14	.23	.34	.48	.65
80	.0043	.0095	.023	.050	.095	.16	.25	.38	.54	.74
90	.0050	.011	.027	.059	.11	.19	.30	.44	.63	.86
100	.0062	.013	.033	.072	.14	.23	.36	.54	.76	1.0
110	.0079	.017	.043	.092	.17	.30	.47	.69	.98	1.3
120	.011	.024	.059	.13	.24	.41	.64	.96	1.4	1.9

*See Table 5.1.7.7-2 for applicability to spec. and style.

MIL-C-14409, PC

5.1.7.8 Variable Piston Type Capacitors.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-14409	PC	Variable, Piston Type Tubular Trimmer

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times (\pi_E \times \pi_Q)$ failures/10^6 hours

where the factors are shown in Tables 5.1.7.8-1 through -5.

TABLE 5.1.7.8-1
Environmental Mode Factors

Environment	π_E
G_B	1
G_{MS}	1.2
G_F	2.9
G_M	9.3
M_P	14
N_{SB}	6.9
N_S	7.2
N_U	8.4
N_H	22
N_{UU}	24
A_{RW}	32
A_{IC}	3
A_{IT}	3
A_{IB}	3.5
A_{IA}	3
A_{IF}	5
A_{UC}	10
A_{UT}	20
A_{UB}	30
A_{UA}	20
A_{UF}	40
S_F	1
M_{FF}	15
M_{FA}	20
U_{SL}	43
M_L	49
C_L	830

TABLE 5.1.7.8-2
BASE FAILURE RATE TABLES FOR
CAPACITOR SPECIFICATION AND STYLE

Spec MIL-C	Style	λ_b Table No.
14409	G, H, J, L, T	5.1.7.8-4
	Char. Q	5.1.7.8-5

TABLE 5.1.7.8-3
π_Q, QUALITY FACTOR

Quality Level	π_Q
MIL-Spec	3
Lower	10

MIL-C-14409, PC

*TABLE 5.1.7.8-4: CAPACITORS, VARIABLE, PISTON TYPE, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0030	.0036	.0051	.0082	.013	.021	.031	.045	.063	.085
10	.0041	.0049	.0070	.011	.018	.028	.042	.061	.085	.11
20	.0055	.0066	.0094	.015	.024	.038	.057	.082	.11	.16
30	.0075	.0089	.013	.020	.033	.051	.077	.11	.16	.21
40	.010	.012	.017	.028	.044	.069	.10	.15	.21	.29
50	.014	.016	.024	.037	.060	.094	.14	.20	.29	.39
60	.019	.022	.032	.051	.082	.13	.19	.28	.39	.52
70	.025	.030	.043	.069	.11	.17	.26	.38	.53	.71
80	.034	.041	.059	.093	.15	.23	.35	.51	.71	.96
90	.047	.055	.079	.13	.20	.32	.48	.69	.96	1.3
100	.063	.075	.11	.17	.27	.43	.65	.94	1.3	1.8
110	.086	.10	.15	.23	.37	.58	.88	1.3	1.8	2.4
120	.12	.14	.20	.31	.51	.79	1.2	1.7	2.4	3.3

*See Table 5.1.7.8-2 for applicability to spec. and style.

MIL-C-14409, PC

*TABLE 5.1.7.8-5: CAPACITORS, VARIABLE, PISTON TYPE, BASE FAILURE RATE, λ_b (T = 150°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0018	.0022	.0031	.0050	.0081	.013	.019	.027	.038	.052
10	.0025	.0029	.0042	.0067	.011	.017	.025	.036	.051	.069
20	.0033	.0039	.0056	.0089	.014	.022	.034	.049	.068	.092
30	.0044	.0052	.0074	.012	.019	.030	.045	.065	.090	.12
40	.0058	.0069	.0099	.016	.025	.040	.060	.086	.12	.16
50	.0077	.0092	.013	.021	.034	.053	.079	.11	.16	.22
60	.010	.012	.018	.028	.045	.070	.11	.15	.21	.29
70	.014	.016	.023	.037	.060	.093	.14	.20	.28	.38
80	.018	.022	.031	.049	.079	.12	.19	.27	.38	.51
90	.024	.029	.041	.066	.11	.17	.25	.36	.50	.68
100	.032	.038	.055	.087	.14	.22	.33	.48	.67	.91
110	.043	.051	.073	.12	.19	.29	.44	.64	.89	1.2
120	.057	.068	.097	.15	.25	.39	.59	.85	1.2	1.6
130	.076	.091	.13	.31	.33	.52	.78	1.1	1.6	2.1
140	.10	.12	.17	.27	.44	.69	1.0	1.5	2.1	2.8
150	.13	.16	.23	.37	.59	.92	1.4	2.0	2.8	3.8

*See Table 5.1.7.8-2 for applicability to spec. and style.

MIL-C-92, CT

5.1.7.9 Variable Air Trimmer Capacitors

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-92	CT	Variable, Air, Trimmer

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times (\pi_E \times \pi_Q)$ failures/10^6 hours:

where the factors are shown in Tables 5.1.7.9-1 through -3.

TABLE 5.1.7.9-1

Environmental Mode Factors

Environment	π_E
G_B	1
G_{MS}	1.3
G_F	3.4
G_M	9.8
M_P	17
N_{SB}	7.9
N_S	7.7
N_U	20
N_H	25
N_{UU}	27
A_{RW}	36
A_{IC}	3.5
A_{IT}	4
A_{IB}	10
A_{IA}	10
A_{IF}	10
A_{UC}	15
A_{UT}	25
A_{UB}	70
A_{UA}	65
A_{UF}	75
S_F	1
M_{FF}	17
M_{FA}	23
U_{SL}	49
M_L	56
C_L	950

Table 5.1.7.9-2

π_Q, Quality Factor

Failure Rate Level	π_Q
MIL-Spec	5
Lower	20

MIL-C-92, CT

TABLE 5.1.7.9-3: CAPACITORS, VARIABLE, AIR, TRIMMER, BASE FAILURE RATE, λ_b (T = 85°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.0074	.0089	.013	.020	.032	.051	.076	.11	.15	.21
10	.010	.012	.017	.027	.044	.069	.10	.15	.21	.28
20	.014	.016	.023	.037	.059	.093	.14	.20	.28	.38
30	.018	.022	.031	.050	.080	.13	.19	.27	.38	.52
40	.025	.030	.042	.067	.11	.17	.26	.37	.52	.70
50	.034	.040	.057	.091	.15	.23	.35	.50	.70	.94
60	.046	.054	.078	.12	.20	.31	.47	.68	.94	1.3
70	.062	.073	.10	.17	.27	.42	.63	.91	1.3	1.7
80	.083	.099	.14	.23	.36	.57	.85	1.2	1.7	2.3

MIL-C-23183, CG

5.1.7.10 Vacuum or Gas Capacitors

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-23183	CG	Vacuum or Gas, Fixed and Variable

Part operating failure rate model (λ_p):

$\lambda_p = \lambda_b \times (\pi_E \times \pi_Q \times \pi_{CF})$ failures/10^6 hours:

where the factors are shown in Tables 5.1.7.10-1 through -7.

TABLE 5.1.7.10-1

Environmental Mode Factors

Environment	π_E
G_B	1
G_{MS}	1.3
G_F	3.4
G_M	10
M_P	18
N_{SB}	8.7
N_S	7.7
N_U	24
N_H	28
N_{UU}	30
A_{RW}	40
A_{IC}	6.5
A_{IT}	10
A_{IB}	15
A_{IA}	10
A_{IF}	25
A_{UC}	40
A_{UT}	65
A_{UB}	105
A_{UA}	65
A_{UF}	150
S_F	1
M_{FF}	N/A
M_{FA}	N/A
U_{SL}	N/A
M_L	N/A
C_L	1,000

Table 5.1.7.10-2
Base Failure Rate Tables for MIL-C-23183 Capacitor Styles

Style	λ_b **Table No.**
CG 20,21,30,31,32,40,41,42, 43,44,51,60,61,62,63,64,67	5.1.7.10-5
CG 65,66	5.1.7.10-6
CG 50	5.1.7.10-7

Table 5.1.7.10-3
π_Q **Quality Factor**

Failure Rate Level	π_Q
MIL-Spec	3
Lower	20

Table 5.1.7.10-4
π_{CF}, Configuration Factor

Configuration	π_{CF}
Fixed	0.1
Variable	1.0

MIL-C-23183, CG

*TABLE 5.1.7.10-5: CAPACITORS, VACUUM OR GAS, FIXED AND VARIABLE, BASE FAILURE RATE, λ_b (T = 85^{o}C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(^{o}C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.015	.033	.081	.17	.33	.56	.88	1.3	1.9	2.5
10	.016	.034	.084	.18	.34	.58	.92	1.4	1.9	2.7
20	.017	.036	.090	.19	.37	.62	.98	1.5	2.1	2.8
30	.018	.040	.098	.21	.40	.68	1.1	1.6	2.2	3.1
40	.020	.044	.11	.24	.45	.76	1.2	1.8	2.5	3.4
50	.024	.052	.13	.28	.52	.88	1.4	2.1	2.9	4.0
60	.029	.063	.16	.34	.64	1.1	1.7	2.5	3.6	4.9
70	.038	.083	.20	.44	.83	1.4	2.2	3.3	4.7	6.4
80	.054	.12	.29	.62	1.2	2.0	3.2	4.7	6.6	9.1

*See Table 5.1.7.10-2 for applicability to spec. and style.

*TABLE 5.1.7.10-6: CAPACITORS, VACUUM OR GAS, FIXED AND VARIABLE, BASE FAILURE RATE, λ_b (T = 100°C MAX RATED)

TEMP (°C)	S, RATIO OF OPERATING TO RATED VOLTAGE .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.014	.032	.078	.17	.32	.54	.85	1.3	1.8	2.5
10	.015	.032	.080	.17	.33	.56	.87	1.3	1.8	2.5
20	.015	.034	.084	.18	.34	.58	.91	1.4	1.9	2.6
30	.016	.036	.088	.19	.36	.61	.96	1.4	2.0	2.8
40	.018	.039	.095	.21	.39	.66	1.0	1.5	2.2	3.0
50	.020	.043	.11	.23	.43	.73	1.2	1.7	2.4	3.3
60	.022	.049	.12	.26	.49	.83	1.3	2.0	2.8	3.8
70	.027	.058	.14	.31	.59	1.0	1.6	2.3	3.3	4.5
80	.034	.073	.18	.39	.74	1.3	2.0	2.9	4.2	5.7
90	.045	.099	.24	.53	.99	1.7	2.7	3.9	5.6	7.7
100	.066	.14	.36	.77	1.5	2.5	3.9	5.8	8.2	11.

*See Table 5.1.7.10-3 for applicability to spec. and style.

MIL-C-23183, CG

TABLE 5.1.7.10-7: CAPACITORS, VACUUM OR GAS, FIXED AND VARIABLE, BASE FAILURE RATE, λ_b (T = 125°C MAX RATED)

TEMP	S, RATIO OF OPERATING TO RATED VOLTAGE									
(°C)	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0	.014	.030	.075	.16	.31	.52	.82	1.2	1.7	2.4
10	.014	.031	.077	.17	.31	.53	.83	1.2	1.8	2.4
20	.014	.032	.078	.17	.32	.54	.85	1.3	1.8	2.5
30	.015	.033	.080	.17	.33	.56	.88	1.3	1.9	2.5
40	.016	.034	.084	.18	.34	.58	.91	1.4	1.9	2.6
50	.016	.036	.088	.19	.36	.61	.96	1.4	2.0	2.8
60	.018	.038	.095	.20	.39	.65	1.0	1.5	2.2	3.0
70	.019	.042	.10	.22	.42	.72	1.1	1.7	2.4	3.3
80	.022	.047	.12	.25	.48	.81	1.3	1.9	2.7	3.7
90	.025	.055	.14	.29	.55	.94	1.5	2.2	3.1	4.3
100	.031	.067	.17	.36	.68	1.2	1.8	2.7	3.8	5.2
110	.040	.087	.21	.46	.87	1.5	2.3	3.5	4.9	6.7
120	.055	.12	.29	.64	1.2	2.0	3.2	4.8	6.8	9.3

5.1.7.11 Example Failure Rate Calculations.

Example 1

Given: A 400 V.D.C. rated capacitor type CQ09A1KE153K3 is being used in a fixed ground environment, 55°C ambient temperature, and 200 Vdc applied with 50 Vrms @ 60 Hz. The capacitor is being procured in full accordance with the applicable specification.

Step 1 - The letters "CQ" in the type designation indicate that the spec is MIL-C-19978 (from Tbl 5.1.7-1) and that it is a Non-ER quality level. Also, the 1st "K" in the designation indicates characteristic K.

Step 2 - The failure rate expression for this capacitor (see sec. 5.1.7.1) is

$$\lambda_p = \lambda_b \times \pi_E \times \pi_Q \times \pi_{CV}$$

Step 3 — Voltage stress ratio must account for both the applied DC volts and the peak AC voltage, hence,

$$S = \frac{200 + \sqrt{2}\ (50)}{400}$$

$$= \frac{200 + 71}{400}$$

$$= .68$$

Step 4 - Since this capacitor is style CQ09, characteristic K, use Table 5.1.7.1-20 for λ_b (as directed by Tbl 5.1.7.1-15). With voltage stress of 0.68 and 55°C temperature,

$$\lambda_b = .0094 \text{ f.}/10^6 \text{ hrs.}$$

Step 5 - From Tables 5.1.7.1-14 and -15, and -16:

$\pi_E = 2.4$ $\pi_{CV} = 1.0$

$\pi_Q = 10$

Step 6 = $\lambda_p = \lambda_b \pi_E \pi_Q \pi_{CV}$

$= .0094\ (2.4)\ (10)\ (1)$

$= .23$ f./10^6 hrs.

<u>Example 2</u>

Given: 6.8 µf CSR solid tantalum capacitor per MIL-C-39003 rated at 75 Vdc and level R reliability is being used at 40 Vdc, 75°C ambient temperature in an airborne uninhabited fighter environment. The effective resistance between the capacitor and the power supply is 80 ohms.

Step 1 - The failure rate from section 5.1 7.5. is

$\lambda_p = \lambda_b \pi_E \pi_{SR} \pi_Q \pi_{CV}$

Step 2 - The voltage stress ratio is

$$S = \frac{\text{applied V}}{\text{Rated V}}$$

$$= \frac{40}{75}$$

$$= .53$$

Step 3 - From Tbl 5.1.7.5-5 with S = .53, T = 75°C,

$\lambda_b = .028$ f./10^6 hr.

Step 4 - π_{SR} is determined from Tbl 5.1.7.5-2 first calculating ohms/applied volts.

$\frac{80}{40} = 2.0$ ohms/volt.

$\pi_{SR} = 0.1$

Step 5 - From Tables 5.1.7.5-1, -3, and -4

π_E = 30 for A_{UF} π_{CV} = 1.3

π_Q = 0.1 for R level quality.

Step 6 - $\lambda_p = \lambda_b \pi_E \pi_{SR} \pi_Q \pi_{CV}$

$= .028 \ (30) \ (0.1) \ (0.1) \ (1.3)$

$\lambda_p = .011$ f./10^6 hr.

5.1.8 Inductive Devices. This section describes the method of calculating the failure rates of certain inductive devices. The following inductive devices are included:

Transformers	
MIL-T-27	Transformers and Inductors (Audio, Power, and High Power Pulse)
MIL-T-21038	Transformers, Low Power Pulse
MIL-T-55631	Transformers, IF, RF, and Discriminator
Coils	
MIL-C-15305	Coils, Fixed and Variable, RF
MIL-C-39010	Coils, Molded, RF, ER

INDUCTIVE DEVICES
MIL-T-27, MIL-T-21038,
MIL-T-55631

5.1.8.1 Transformers.

SPECIFICATION	STYLE	DESCRIPTION
MIL-T-27	TF	Audio, Power, and High Power Pulse
MIL-T-21038	TP	Low Power Pulse
MIL-T-55631	-	IF, RF, and Discriminator

The general model for these devices is as follows:

$$\lambda_p = \lambda_b (\pi_E \times \Pi_Q)$$

λ_p = failures/10^6 hours

λ_b = base failure rate

π_E = environmental factor

Π_Q = quality factor

The general model for the base failure rate:

$$\lambda_b = Ae^x \text{ where } x = \left(\frac{T_{HS} + 273}{N_T}\right)^G$$

T_{HS} = Hot spot temperature in degrees C and e is natural logarithm base, 2.718.

N_T = Temperature constant

G = Acceleration constant

A = Adjustment factor for different insulation classes

See Tables 5.1.8.1-1 thru 5.1.8.1-4 for equation constants. The models are valid only if T_{HS} is not above the temperature rating for a given insulation class.

INDUCTIVE DEVICES
MIL-T-27, MIL-T-21038, MIL-T-55631

TABLE 5.1.8.1-1
Transformer Base Failure Rate Model Constants versus Insulation Class

SPECIFICATION	Insulation Class					
MIL-T-27	Q	R	S	V	T	U
MIL-T-21038	Q	R	S	T	U	V
MIL-T-55631	O	A	B	C	-	-
Model Constants	Maximum Rated Operating Temperature					
	85°C	105°C	130°C	155°C	170°C	>170°C
A	0.00159	0.0018	0.00152	0.00458	0.00508	0.0065
N_T	329	352	364	409	398	477
G	15.6	14.0	8.7	10.0	3.8	8.4

TABLE 5.1.8.1-2
Quality Factor, π_Q

Family Type	Mil-Spec.	Lower
Pulse Transformers	1.5	5.0
Audio Transformers	3.0	7.5
Power Transformers and Filters	8.0	30.0
RF Transformers	12.0	30.0

INDUCTIVE DEVICES
MIL-T-27, MIL-T-21038, MIL-T-55631

TABLE 5.1.8.1-3

ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.6
G_F	5.7
G_M	12
M_P	11
N_{SB}	5.1
N_S	5.7
N_U	14
N_H	16
N_{UU}	18
A_{RW}	24
A_{IC}	4.5
A_{IT}	6
A_{IB}	6
A_{IA}	6
A_{IF}	9
A_{UC}	6.5
A_{UT}	6.5
A_{UB}	7.5
A_{UA}	7.5
A_{UF}	10
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	32
M_L	36
C_L	610

INDUCTIVE DEVICES
MIL-T-27, MIL-T-21038, MIL-T-55631

Devices in accordance with the three specifications included in this section are identified by the classification scheme used in each specification. The following information will help in determining the Insulation Class and the Family Type if only the specification and type designation are known:

a. MIL-T-27. An example type designation per this specification is

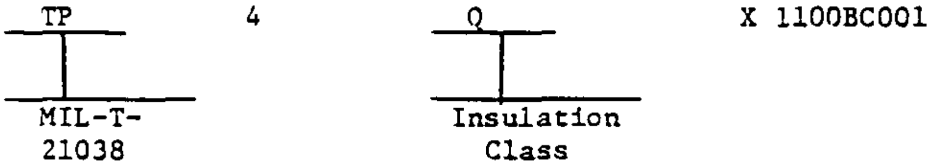
The Insulation Class symbols are the same as used in Tables 5.1.8.1-1. The codes used for Family Type are

Power transformer + filter: 01 thru 09, 37 thru 41

Audio transformer: 10 thru 21, 50 thru 53

Pulse transformer: 22 thru 36, 54

b. MIL-T-21038. All parts in this specification are pulse transformers. An example type designation is



The Insulation Class symbols are the same as used in Table 5.1.8.1-1.

c. MIL-T-55631. The transformers are designated with the following types, grades, and classes

Type I - Intermediate frequency transformer.
Type II - Radio frequency transformer.
Type III - Discriminator transformer.

Grade 1 - For use when immersion and moisture resistance tests are required.
Grade 2 - For use when moisture resistance test is required
Grade 3 - For use in sealed assemblies.

Class 0 - 85° maximum operating temperature.
Class A - 105° C maximum operating temperature.
Class B - 125°C maximum operating temperature.
Class C - > 125°C maximum operating temperature.

NOTE: The class denotes the maximum operating temperature (temperature rise plus maximum ambient temperature).

INDUCTIVE DEVICES
MIL-T-27, MIL-T-21038, MIL-T-55631

TABLE 5.1.8.1-4

TRANSFORMER BASE FAILURE RATES, λ_b, in f./10^6 HRS.

T_{HS}	MAXIMUM RATED OPERATING TEMPERATURE					
	85°C	105°C	130°C	155°C	170°C	>170°C
0	0.0017	0.0019	0.0016	0.0047	0.0064	0.0066
5	0.0017	0.0019	0.0017	0.0047	0.0066	0.0066
10	0.0017	0.0019	0.0017	0.0047	0.0067	0.0066
15	0.0018	0.0019	0.0017	0.0047	0.0068	0.0066
20	0.0019	0.0019	0.0018	0.0047	0.0069	0.0066
25	0.0020	0.0020	0.0018	0.0048	0.0071	0.0066
30	0.0021	0.0020	0.0019	0.0048	0.0072	0.0066
35	0.0023	0.0021	0.0019	0.0049	0.0074	0.0067
40	0.0025	0.0022	0.0020	0.0049	0.0076	0.0067
45	0.0029	0.0023	0.0021	0.0050	0.0078	0.0067
50	0.0034	0.0024	0.0022	0.0050	0.0080	0.0068
55	0.0041	0.0026	0.0023	0.0051	0.0082	0.0068
60	0.0053	0.0029	0.0024	0.0052	0.0084	0.0068
65	0.0073	0.0032	0.0026	0.0053	0.0087	0.0069
70	0.0108	0.0036	0.0028	0.0054	0.0090	0.0069
75	0.0175	0.0042	0.0030	0.0056	0.0093	0.0070
80	0.0319	0.0051	0.0033	0.0058	0.0096	0.0070
85	0.0666	0.0064	0.0036	0.0060	0.0099	0.0071
90		0.0084	0.0040	0.0062	0.0103	0.0072
95		0.0116	0.0046	0.0065	0.0107	0.0073
100		0.0171	0.0052	0.0068	0.0111	0.0074
105		0.0271	0.0061	0.0072	0.0116	0.0075
110			0.0072	0.0077	0.0121	0.0076
115			0.0087	0.0083	0.0126	0.0078
120			0.0107	0.0090	0.0132	0.0079
125			0.0134	0.0098	0.0138	0.0081
130			0.0172	0.0109	0.0145	0.0083
135				0.0122	0.0152	0.0085
140				0.0138	0.0161	0.0088
145				0.0159	0.0169	0.0090
150				0.0186	0.0179	0.0094
155				0.0221	0.0190	0.0097
160					0.0201	0.0101
165					0.0214	0.0106
170					0.0228	0.0111
175						0.0117
180						0.0124
185						0.0132

INDUCTIVE DEVICES
MIL-C-15305
MIL-C-39010

5.1.8.2 Coils.

SPECIFICATION	STYLE	DESCRIPTION
MIL-C-15305	-	Fixed and Variable, RF
MIL-C-39010	-	Molded, RF, ER

The general operating model for these devices is as follows:

$$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times \pi_C)$$

where: λ_p = Total failure rate in failures/10^6 hours

λ_b = Base failure rate

π_E = Environmental factor

π_Q = Quality factor

π_C = Construction factor (fixed or variable).

The general model for the base failure rate:

$$\lambda_b = Ae^x \text{ where } x = \left(\frac{T_{HS} + 273}{N_T}\right)^G$$

where: T_{HS} = Hot spot temperature in degrees C and e is natural logarithm base, 2.718.

N_T = Temperature Constant

G = Acceleration Constant

A = Adjustment factor for different insulation classes.

See Tables 5.1.8.2-1 thru 5.1.8.2-5 for equation constants. The models are valid only if T_{HS} is not above the temperature rating for a given insulation class.

INDUCTIVE DEVICES
MIL-C-15305
MIL-C-39010

TABLE 5.1.8.2-1

Coil Base Failure Rate Model Constants versus Insulation Class

Specification	Insulation Class			
MIL-C-15305	O	A	B	C
MIL-C-39010	-	A	B	F
Model Constants	Maximum Rated Operating Temperature			
	85°C	105°C	125°C	150°C
A	3.35×10^{-4}	3.79×10^{-4}	3.19×10^{-4}	9.63×10^{-4}
N_T	329	352	364	409
G	15.6	14.0	8.7	10.0

TABLE 5.1.8.2-2
Quality Factor, π_Q

Failure Rate Level	π_Q Factor
S	0.03
R	0.1
P	0.3
M	1.0
MIL-C-15305	4.0
Lower	20.0

INDUCTIVE DEVICES
MIL-C-15305, MIL-C-39010

TABLE 5.1.8.2-3
Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.3
G_F	3.6
G_M	12
M_P	11
N_{SB}	5.1
N_S	5.7
N_U	14
N_H	16
N_{UU}	18
A_{RW}	24
A_{IC}	4
A_{IT}	4.5
A_{IB}	5.5
A_{IA}	4.5
A_{IF}	9
A_{UC}	5
A_{UT}	6.5
A_{UB}	7.5
A_{UA}	6.5
A_{UF}	10
S_F	1
M_{FF}	11
M_{FA}	15
U_{SL}	32
M_L	36
C_L	610

TABLE 5.1.8.2-4
Construction Factor, π_C

Construction	π_C
Fixed	1
Variable	2

INDUCTIVE DEVICES
MIL-C-15305
MIL-C-39010

TABLE 5.1.8.2-5

COIL BASE FAILURE RATES, λ_b, in f./10^6 HRS.

T_{HS}	MAXIMUM RATED OPERATING TEMPERATURE			
	85°C	105°C	125°C	150°C
0	0.0004	0.0004	0.0003	0.0010
5	0.0004	0.0004	0.0004	0.0010
10	0.0004	0.0004	0.0004	0.0010
15	0.0004	0.0004	0.0004	0.0010
20	0.0004	0.0004	0.0004	0.0010
25	0.0004	0.0004	0.0004	0.0010
30	0.0004	0.0004	0.0004	0.0010
35	0.0005	0.0004	0.0004	0.0010
40	0.0005	0.0005	0.0004	0.0010
45	0.0006	0.0005	0.0004	0.0010
50	0.0007	0.0005	0.0005	0.0011
55	0.0009	0.0005	0.0005	0.0011
60	0.0011	0.0006	0.0005	0.0011
65	0.0015	0.0007	0.0005	0.0011
70	0.0023	0.0008	0.0006	0.0011
75	0.0037	0.0009	0.0006	0.0012
80	0.0067	0.0011	0.0007	0.0013
85	0.0140	0.0013	0.0008	0.0013
90		0.0018	0.0008	0.0013
95		0.0024	0.0010	0.0014
100		0.0036	0.0011	0.0014
105		0.0057	0.0013	0.0015
110			0.0015	0.0016
115			0.0018	0.0017
120			0.0022	0.0019
125			0.0028	0.0021
130				0.0023
135				0.0026
140				0.0029
145				0.0033
150				0.0039

INDUCTIVE DEVICES
MIL-C-15305
MIL-C-39010

a. MIL-C-15305. All parts in this specification are r.f. coils. An example type designation is

LT	4	K	001
MIL-C-15305	Insulation Class		

The codes used for the Insulation Class are

Class B: 4, 5, 6

Class O: 7, 8, 9

Class A: 10, 11, , 12

b. MIL-C-39010. An example type designation per this specification is

M	39010/01	A	1R0	K	M
Military designator	Document sheet number	Class	Inductance	Inductance tolerance	Failure rate level

The insulation class symbols are the same as used in Table 5.1.8.2-1.

5.1.8.3 Determination of Hot Spot Temperature. The failure rate λ_p, of the inductive device is a function of the hot spot temperature of the inductive device. This hot spot temperature can be obtained by direct measurement or by approximation.

Although the latter method is normally used, there may be times when the direct measurement technique would be advisable.

5.1.8.3.1 Direct Measurement.

a) Average Temperature Rise, Change in Resistance Method as described in MIL-T-27 (4.8.14) or MIL-T-21038 (4.7.14)

$$\Delta T = \frac{R - r}{r} (t + 234.5) - (T - t)$$

where

ΔT = Temperature rise in degrees Celsius specified maximum ambient temperature

R = resistance of winding in ohms at temperature $(T + \Delta T)$

r = resistance of winding in ohms at temperature (t)

t = specified initial ambient temperature in degrees Celsius

T = maximum ambient temperature in degrees Celsius (at time of power shutoff); T shall not differ from t by more than 5°C.

For transformers, rated voltage shall be applied to the primary with the specified loads across the secondaries. For inductors, rated d-c and a-c, current shall be applied to the windings.

b) Hot Spot Temperature Rise

Approximate value by assuming temperature-rise of hot spot is 10 percent greater than highest average temperature-rise as measured or as estimated by approximate methods. See para 5.1.8.3.2.

Actual measurement requires burying of thermocouples or thermistors in coils; hence is not feasible to measure on completed part. However for developmental devices, this step should be seriously considered where temperature is significant.

5.1.8.3.2 Approximation. Approximation of the hot spot temperature can be determined by referring to Figures 5.1.8.3-1 through 5.1.8.3-4 which gives the average temperature rise. Use the figure which best correlates to the known input data. If Figure 5.1.8.3-2 is used to determine the temperature, use of a MIL-T-21038 transformer, case AF will give the most practical result. The hot spot temperature is then calculated as follows:

$$T_{HS} \approx T_A + 1.1\ (\Delta T)$$

T_{HS} = Hot spot temperature (C°)

T_A = ambient temperature (C°)

ΔT = temperature rise (C°)

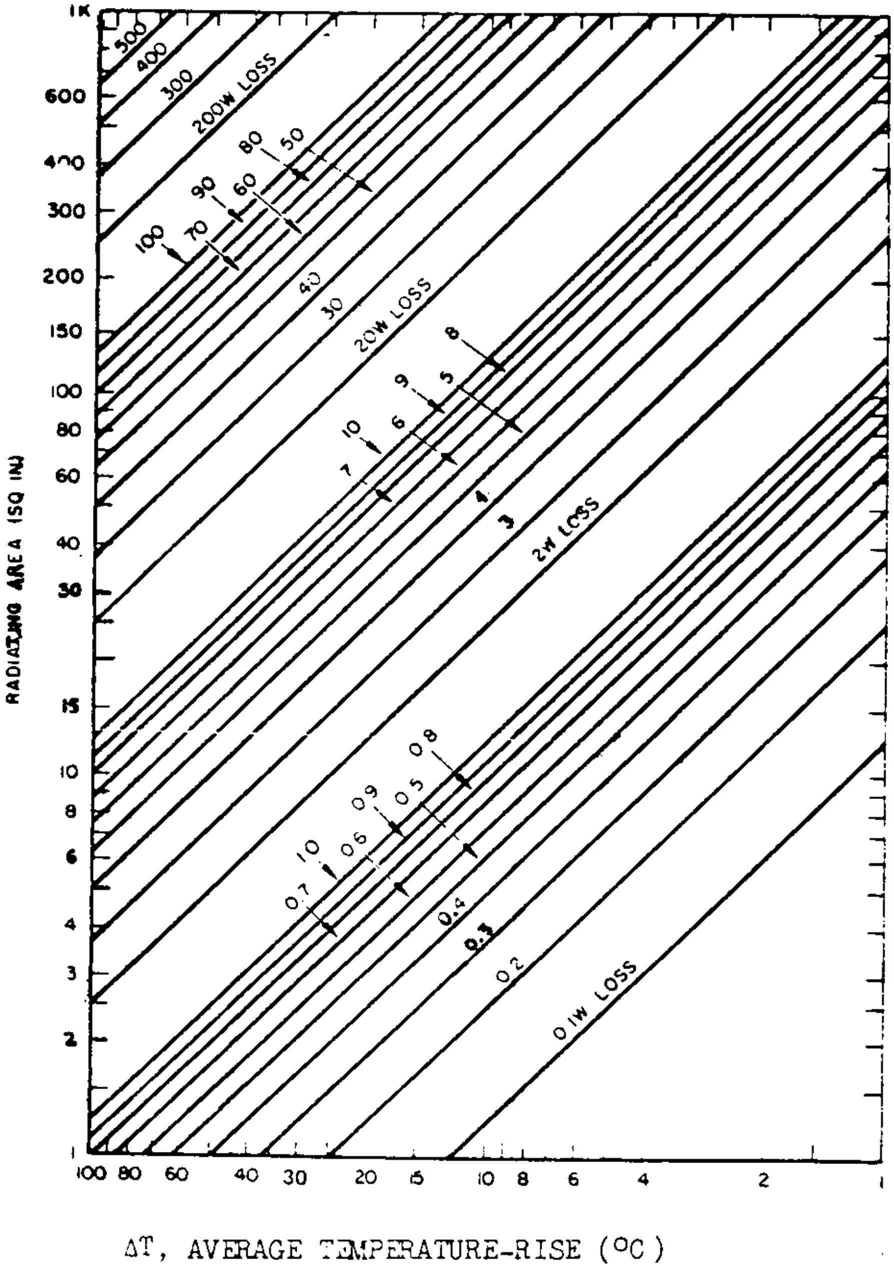
When using Figures 5.1.8.3-1 through 5.1.8.3-4 it is advisable to follow the order of precedence established via Table 5.1.8.3-1.

TABLE 5.1.8.3-1
ESTIMATE OF AVERAGE TEMPERATURE-RISE*

Reference	Input Data	To Calculate Approximate Average Temperature-Rise**	Comment
Figure 5.1.8.3-1 (Step 1A)	Power loss (watts) Radiating surface area of case (sq in.)	Enter graph with radiating area on ordinate; locate intersection with appropriate line for power loss and read temperature-rise on abscissa.	Radiating area readings include heat losses due to both radiation and convection. This method preferred for MIL-T-21038 & MIL-C-15305.
Figure 5.1.8.3-2 (Step 1B)	Power loss (watts) Case symbol per MIL-T-27	Enter graph with case symbol on ordinate; locate intersection with appropriate line for power loss and read temperature-rise on abscissa.	Case symbols represent standard case sizes.
Figure 5.1.8.3-3 (Step 1C)	Power loss (watts) Transformer weight (lb)	Enter graph with weight on abscissa; locate intersections with appropriate line for power and loss and read temperature-rise on ordinate.	This calculation is possible because of actual relationship between size and weight of conventional transformers.
Figure 5.1.8.3-4 (Step 1D)	Power input (watts) Transformer weight (lb) Assumed 80 percent efficiency	Enter graph with weight on abscissa; locate intersection with appropriate line for power input and read probable temperature-rise on ordinate.	Note error possibility in efficiency assumption; use Figure 5.1.8.3-1 and 5.1.8.3-2 preferably.

*Hot-Spot Temperature = Ambient Air Temperature plus 1.1 times average temperature rise (or measured coil temperature).

**Graphs give predicted temperature rise in still air and in absence of nearby heat radiation from other components; if forced air cooling or heat radiation is used, it is preferable to measure transformer temperature under operating conditions. Measure power loss or input at normal use frequency.



NOTE: **Equation** for curves is $\Delta T = 125\ W_L/A$

where: W_L = power loss (watts), ΔT is °C.

A - radiating area (in^2).

Figure 5.1.8.3-1 Power Loss and Radiating Area Known: Estimate Average Temperature-Rise (Step 1A)

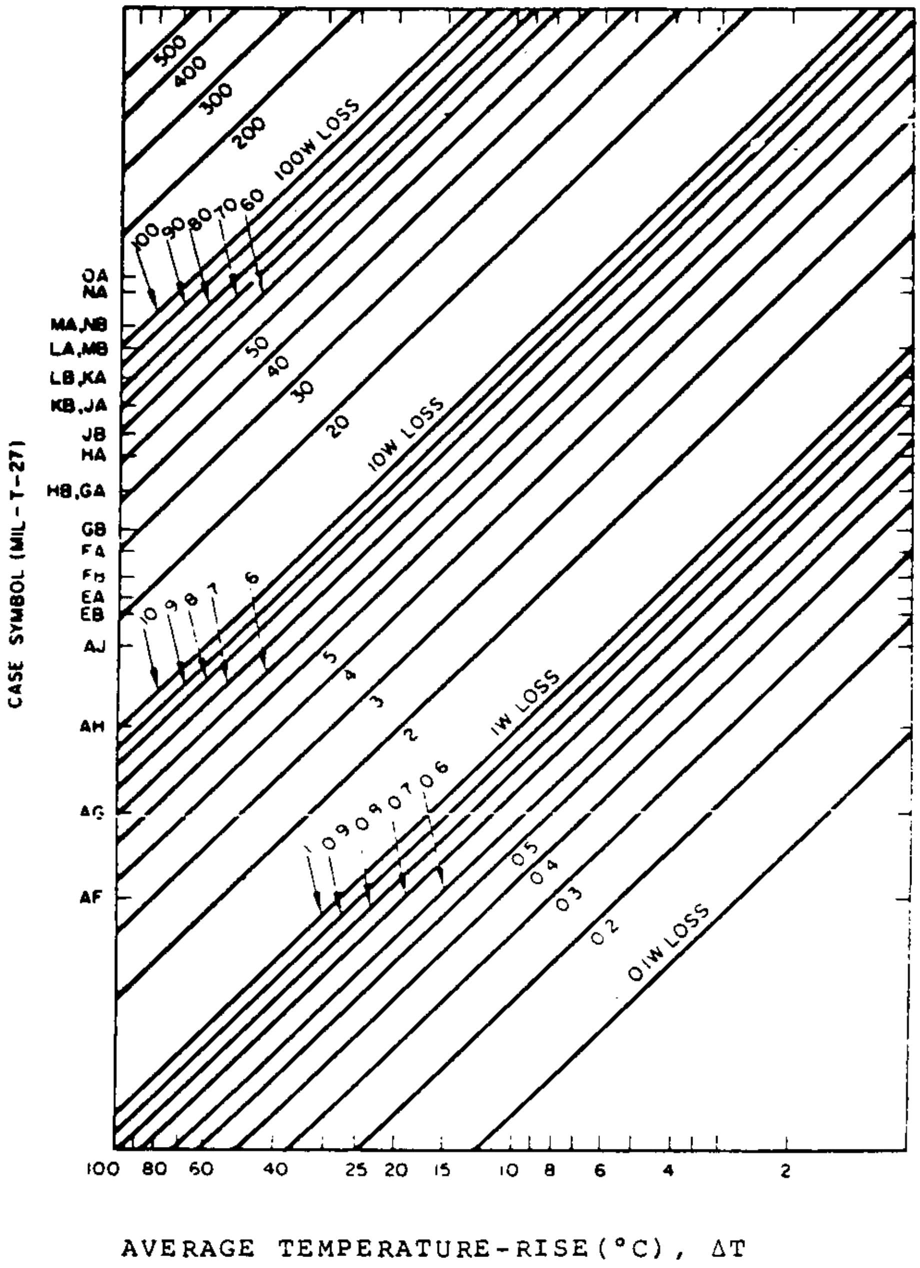
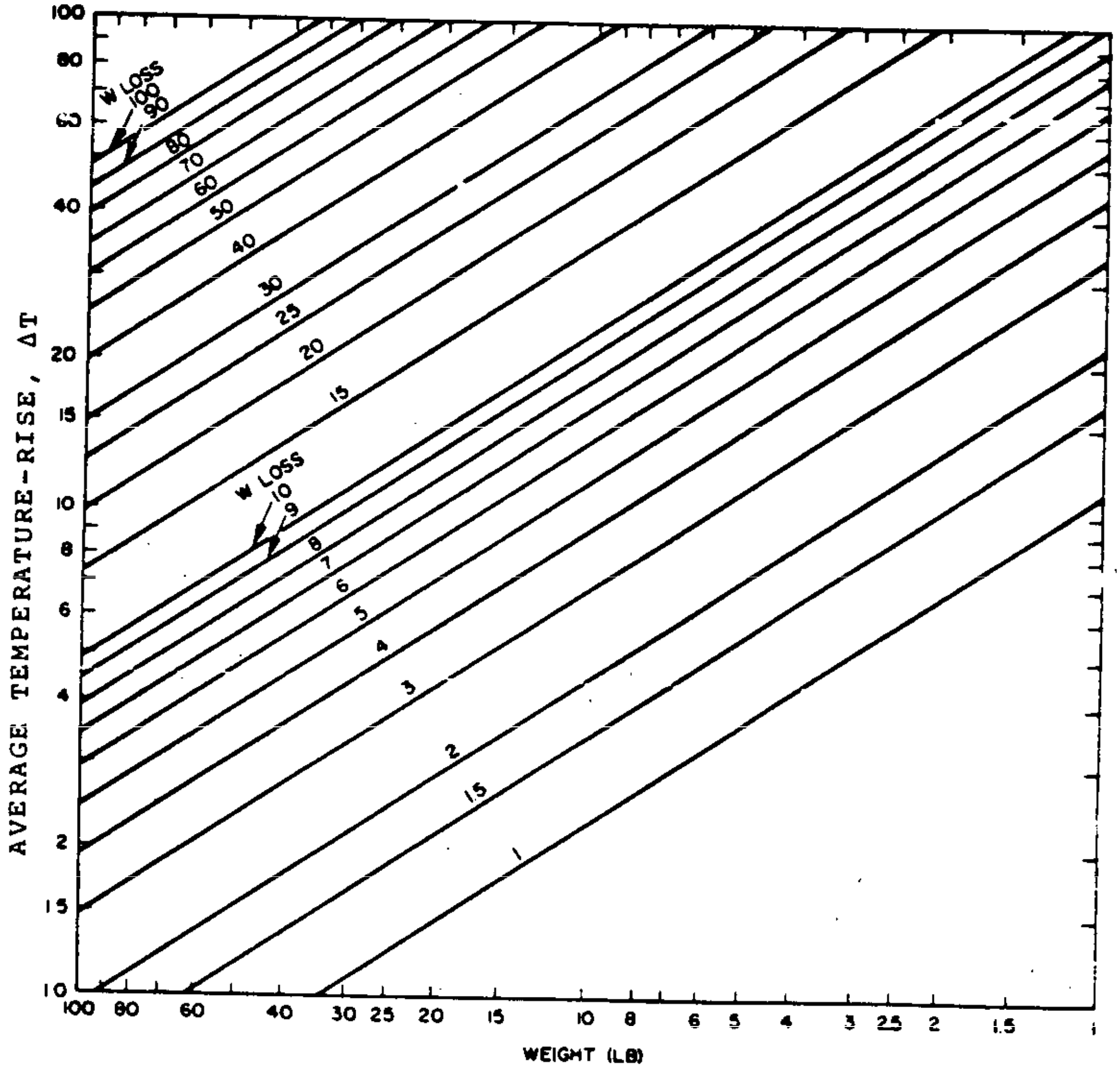


Figure 5.1.8.3-2 Power Loss and Case Symbol Known: Estimate Average Temperature-Rise (Step 1B)



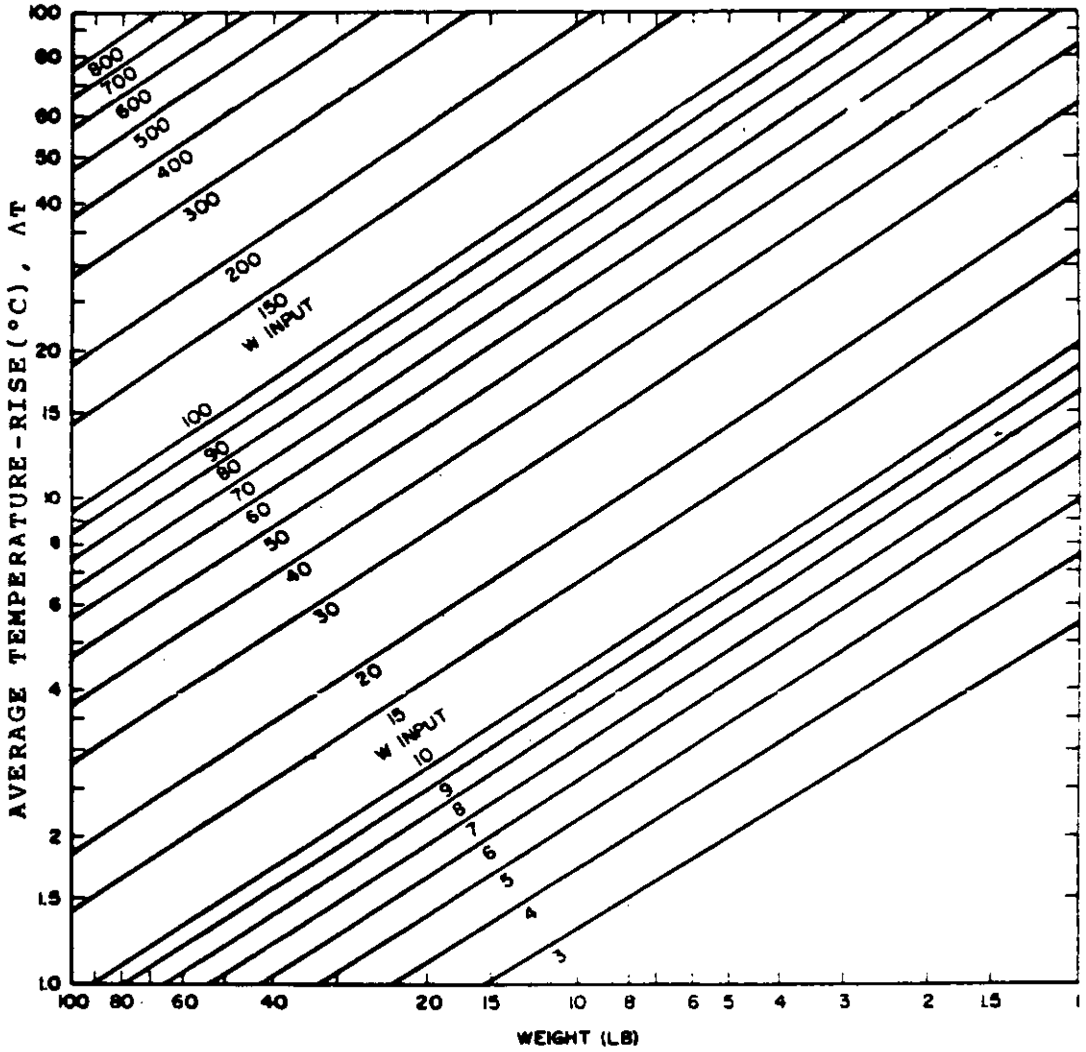
NOTE: Equation for curves is $\Delta T = 11.5\, W_L/(WT.)^{.6766}$

where: ΔT is °C,

W_L = power loss (watts)

WT. = weight (lbs.)

Figure 5.1.8.3-3 Power Loss and Weight Known: Estimate Average Temperature-Rise (Step 1C)



NOTE: Equation for curves is $\Delta T = 2.1\ W_i/(WT.)^{.6766}$

where ΔT is °C,

W_i = input power (watts)

WT.= weight (lbs.)

Figure 5.1.8.3-4 Power Input and Weight Known: Estimate Average Temperature-Rise (Based on 80 Percent Efficiency) (Step 1D)

5.1.8.4 Prediction Methodology.

π_E; From Tbl 5.1.8.1-3 for transformers or Table 5.1.8.2-3 for coils.

π_Q; From Tbl 5.1.8.1-2 for transformers or Table 5.1.8.2-2 for coils.

π_C; For coils only - from Table 5.1.8.2-4.

λ_b;

1) Determine Temperature rise by approximation method, see Tbl 5.1.8.3-1 or by measurement. See para 5.1.8.3.1 or 5.1.8.3.2.

2) Calculate T_{HS} by para 5.1.8.3.2.

3) Enter Table 5.1.8.1-4 or 5.1.8.2-5. to determine λ_p as a function of T_{HS} transformer class, and part type.

λ_p; Calculate λ_p from equation

$\lambda_p = \lambda_b\ (\pi_E \times \pi_Q)$ for transformers or

$\lambda_p = \lambda_b\ (\pi_E \times \pi_Q \times \pi_C)$ for coils.

5.1.8.5 Example Failure Rate Calculation

Given: Power transformer with type designation TF5SX03GA203 procured per the requirements of MIL-T-27. The transformer has a 6 watt power loss and will be used in a fixed ground environment with 40°C ambient temperature.

Step 1 - Determine average temperature rise, ΔT, using Figure 5.1.8.3-2 by entering with 6 watts loss and symbol GA (from type designation)

$$\Delta T = 14°C$$

Step 2 - Determine hot spot temperature, T_{HS}, per para. 5.1.8.3.2.

$$\begin{aligned} T_{HS} &= T_A + 1.1\ \Delta T \\ &= 40° + 1.1\ (14°) \\ &= 40° + 15.4° \\ &= 55.4°C \end{aligned}$$

Step 3 - Determine base failure rate, λ_b, using Table 5.1.8.1-4 entering with T_{HS} = 55.4°C and Class S insulation (from type designation). Class S has 130°C. max. rated operating temperature per Table 5.1.8.1-1.

$$\lambda_b = 0.0023$$

Step 4 - Determine Π_Q from Table 5.1.8.1-2
Π_Q = 8.0 for power transformer procured per Mil-Spec.

Step 5 - Determine π_E from Table 5.1.8.1-3
π_E = 5.7 for fixed ground environment.

Step 6 - Determine device failure rate using equation in para. 5.1.8.1

$$\begin{aligned} \lambda_p &= \lambda_b\ (\pi_E \times \Pi_Q) \\ &= 0.0023\ (5.7 \times 8) \\ &= 0.10\ f/10^6\ hr. \end{aligned}$$

MOTORS

5.1.9 Rotating Devices

5.1.9.1 Motors. This section describes the method to be used for calculating failure rates of motors with power ratings below one horsepower. The types of motors that the predictive techniques were developed from include polyphase, capacitor start and run and shaded pole. Its application may be extended to other types of fractional horsepower motors utilizing rolling element grease packed bearings. The model is dictated by two failure modes, i.e., bearing failures and winding failures. Application of the model to D.C. brush motors assumes that brushes are inspected and replaced and are not a failure mode. Motors included using these models cover applications of electronic cooling using fans and blowers as well as other motor applications. Reference (44) contains a more comprehensive treatment of motor life prediction for motor applications where continuous operation at extremes of temperature, speed or load are anticipated. The reference should be reviewed when bearing loads exceed 10 percent of rated load, speeds exceed 24,000 rpm or motor loads include motor speed slip of greater than 25 percent.

The instantaneous failure rates, or hazard rates, experienced by motors are not constant but increase with time. The failure rate model for motors presented in this section is the average failure rate for the motor operating time period, t. The average failure rate, λ_p, has been obtained by dividing the cumulative hazard rate by t, and can be treated as a constant failure rate and added to other part failure rates of this Handbook.

MOTORS

The failure rate model is:

$$\lambda_p = \left(\frac{t^2}{\alpha_B{}^3} + \frac{1}{\alpha_W} \right) \times 10^6 \text{ (failures}/10^6 \text{ hours)}$$

where

λ_p = the average failure rate (failures/10^6 hours)

t = motor operating time period, selected by the user, for which average failure rate is calculated (hours). Each motor must be replaced when it reaches the end of this operating period to make the calculated λ_p valid.

α_B = Bearing Weibull Characteristic Life as determined from Table 5.1.9.1-1 for constant ambient temperature operation or Section 5.1.9.1.1 for cycled temperature.

α_W = Winding Weibull Characteristic Life as determined from Table 5.1.9.1-1 for constant ambient temperature operation or Section 5.1.9.1.2 for cycled temperature.

TABLE 5.1.9.1-1. BEARING & WINDING CHARACTERISTIC LIFE, α_B & α_W, vs. AMBIENT TEMPERATURE, T.

T (°C.)	α_B * (HR.)	α_W * (HR.)	T (°C.)	α_B * (HR.)	α_W * (HR.)
-40	305	$1.9(10)^8$	55	43800	$2.3(10)^5$
-35	312	1.2 "	60	34600	1.8 "
-30	330	$7.4(10)^7$	65	27300	1.4 "
-25	372	4.7 "	70	21700	1.1 "
-20	463	3.1 "	75	17300	$8.8(10)^4$
-15	661	2.0 "	80	13900	7.0 "
-10	1080	1.4 "	85	11200	5.7 "
-5	1920	$9.2(10)^6$	90	9100	4.6 "
0	3570	6.4 "	95	7430	3.8 "
5	6750	4.5 "	100	6100	3.1 "
10	12600	3.2 "	105	5030	2.5 "
15	22800	2.3 "	110	4170	2.1 "
20	38800	1.6 "	115	3470	1.8 "
25	59600	1.2 "	120	2910	1.5 "
30	78300	$8.9(10)^5$	125	2440	1.2 "
35	85600	6.6 "	130	2060	1.0 "
40	80200	5.0 "	135	1750	$8.9(10)^3$
45	68200	3.8 "	140	1490	7.5 "
50	55200	2.9 "			

$$* \quad \alpha_B = \left\{ 10^{\left(2.534 - \frac{2357}{T+273}\right)} + 1 \Big/ \left[10^{\left(20 - \frac{4500}{T+273}\right)} + 300 \right] \right\}^{-1}$$

$$\alpha_W = 10^{\left(\frac{2357}{T+273} - 1.83\right)}$$

where T is ambient temperature in °C.

5.1.9.1.1 Bearing Characteristic Life Resulting from Thermal Cycling

$$\alpha_B = \frac{(h_1 + h_2 + h_3 + \text{-------} h_m)}{\frac{h_1}{\alpha_{B_1}} + \frac{h_2}{\alpha_{B_2}} + \frac{h_3}{\alpha_{B_3}} + \text{- - -} \frac{h_m}{\alpha_{B_m}}}$$

where: (See Figure 5.1.9.1-1)

h_1 = time at temperature T_1

h_2 = time to cycle from temperature T_1 to T_3

h_3 = time at temperature T_3

h_m = time at temperature T_m

α_{B_1} = bearing life at T_1 from Table 5.1.9.1-1

α_{B_2} = bearing life at T_2 from Table 5.1.9.1-1

α_{B_m} = bearing life at T_m from Table 5.1.9.1-1

$$T_2 = \frac{T_1 + T_3}{2}$$

from example of Figure 5.1.9.1-1,

$$T_m = T_4 = \frac{T_3 + T_1}{2} \quad \text{and } h_m = h_4$$

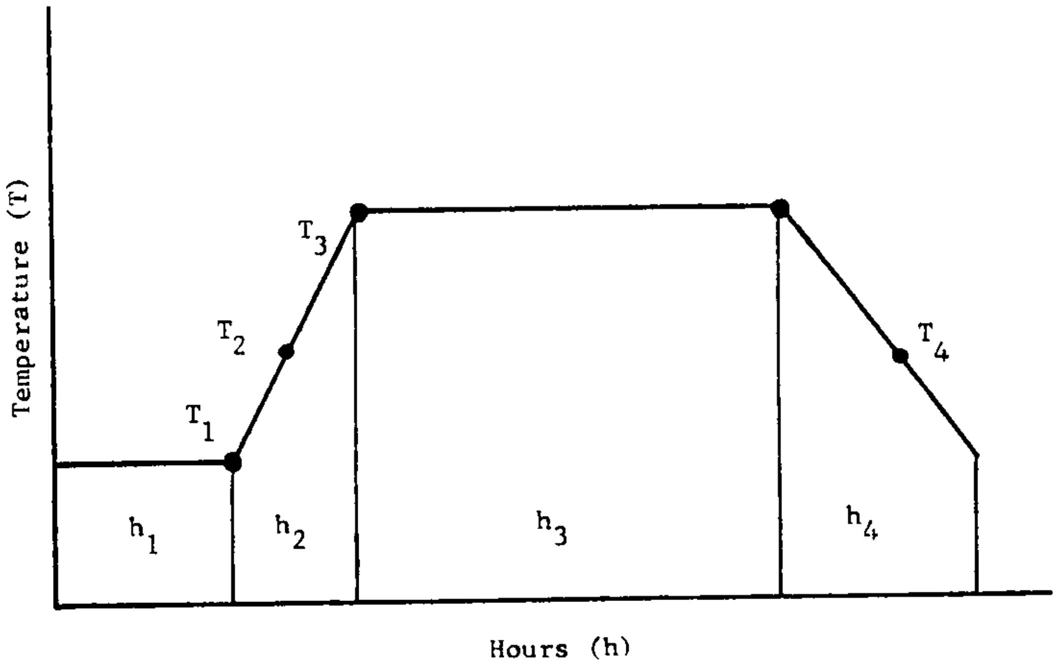


FIGURE 5.1.9.1-1 THERMAL CYCLE

5.1.9.1.2 Winding Characteristic Life Resulting from Thermal Cycling

$$\alpha_w = \frac{(h_1 + h_2 + h_3 + - - - - - - h_m)}{\frac{h_1}{\alpha_{w_1}} + \frac{h_2}{\alpha_{w_2}} + - - - - - - \frac{h_m}{\alpha_{w_m}}}$$

where: (See Figure 5.1.9.1-1)

h_1 = time at temperature T_1

h_2 = time to cycle from temperature T_1 to T_3

h_3 = time at temperature T_3

h_m = time at temperature T_m

α_{w_1} = winding life at T_1 from Table 5.1.9.1-1

α_{w_2} = winding life at T_1 to T_3 from Table 5.1.9.1-1

α_{w_m} = winding life at T_m from Table 5.1.9.1-1

$$T_2 = \frac{T_1 + T_3}{2}$$

from example of Fig 5.1.9.1-1, $T_m = T_4 = \frac{T_3 + T_1}{2}$ and $h_m = h_4$

5.1.9.2 Synchros & Resolvers. The part failure rate model (λ_p) is:

$$\lambda_p = \lambda_b (\pi_S \times \pi_N \times \pi_E) \text{ failures}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.9.2-1 thru 5.1.9.2-4 Synchros and resolvers are predominatly used in service requiring only slow and infrequent motion. Mechanical wearout problems are not serious so that the electrical failure mode dominates, and no mechanical mode failure rate is required in the model above.

TABLE 5.1.9.2-1 λ_b FOR RESOLVERS & SYNCHROS VS. FRAME TEMPERATURE*

T(°C)	λ_b(f/10^6 hrs)	T(°C)	λ_b(f/10^6 hrs)
30	.0083	85	.0325
35	.0088	90	.0407
40	.0095	95	.0523
45	.0103	100	.0690
50	.0114	105	.0937
55	.0126	110	.131
60	.0142	115	.191
65	.0162	120	.288
70	.0187	125	.453
75	.0221	130	.744
80	.0265	135	1.28

* - $\lambda_b = .00535\, e^{\left(\frac{T+273}{334}\right)^{8.5}}$

where T = frame temperature (°C) and e = natural logarithm base, 2.718. If frame temperature is unknown, assume T = 40 + ambient temperature.

TABLE 5.1.9.2-2 π_S FOR SYNCHROS AND RESOLVERS, BASED ON TYPE AND SIZE

DEVICE TYPE	π_S		
	Size 8 or Smaller	Size 10-16	Size 18 or Larger
Synchro	2	1.5	1
Resolver	3	2.25	1.5

TABLE 5.1.9.2-3 π_N FOR SYNCHROS AND RESOLVERS, BASED ON NUMBER OF BRUSHES

Number of Brushes	π_N
2	1.4
3	2.5
4	3.2

TABLE 5.1.9.2-4
ENVIRONMENTAL MODE FACTORS

ENVIRON-MENT	π_E
G_B	1.2
G_{MS}	1.3
G_F	2.3
G_M	12
M_P	12
N_{SB}	5.6
N_S	8.1
N_U	16
N_H	18
N_{UU}	19
A_{RW}	26
A_{IC}	2.5
A_{IT}	4
A_{IB}	6
A_{IA}	4
A_{IF}	8.5
A_{UC}	9.5
A_{UT}	15
A_{UB}	25
A_{UA}	15
A_{UF}	35
S_F	1
M_{FF}	12
M_{FA}	17
U_{SL}	35
M_L	40
C_L	680

5.1.9.3 Elapsed Time Meters. The part operating failure rate model (λ_p) is:

$$\lambda_p = \lambda_b (\Pi_T \times \Pi_E) \text{ failure}/10^6 \text{ hours}$$

where the factors are shown in Tables 5.1.9.3-1 thru 5.1.9.3-3.

TABLE 5.1.9.3-1 λ_b FOR E. T. METERS

TYPE	λ_b (f./10^6 hr.)
A.C.	20
Inverter Driven	30
Commutator D.C.	80

TABLE 5.1.9.3-2 Π_T FOR E. T. METERS

Operating T (°C.) / RATED T (°C.)	Π_T
0 to .5	.5
.6	6
.8	.8
1.0	1.0

TABLE 5.1.9.3-3

Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.5
G_M	12
M_P	12
N_{SB}	5.6
N_S	8.8
N_U	16
N_H	18
N_{UU}	19
A_{RW}	26
A_{IC}	3
A_{IT}	5
A_{IB}	7.5
A_{IA}	5
A_{IF}	10
A_{UC}	9.5
A_{UT}	15
A_{UB}	25
A_{UA}	15
A_{UF}	35
S_F	1
M_{FF}	12
M_{FA}	17
U_{SL}	35
M_L	40
C_L	N/A

5.1.9.4 Example Failure Data Calculations

Example 1.

Given: Fractional horsepower motor operating in an ambient temperature of 120°C. Find failure rate for replacement of motors in 1000 hours.

Step 1. From Table 5.1.9.1-1 at 120°C.

$$\alpha_B = 2910 \text{ hours}$$

$$\alpha_W = 15000 \text{ hours}$$

Step 2. From Section 5.1.9.1,

$$\lambda_p = \left(\frac{t^2}{\alpha_B^3} + \frac{1}{\alpha_W} \right) x\ 10^6$$

$$\lambda_p = \left(\frac{1000^2}{2910^3} + \frac{1}{15000} \right) x\ 10^6 = 110.\ \text{failures}/10^6 \text{ hours}$$

Example 2.

Given: Fractional Horsepower Motor operating at a thermal duty cycle of:

2 hours at 100°C ambient
8 hours at 20°C ambient
0.5 hours to change temperature

Find average failure rate for 4000 hours operating time.

Step 1. Tabulate operating temperatures:

$T_1 = 100°C$; $h_1 = 2$ hours

$T_2 = \frac{100 + 20}{2} = 60°C$; $h_2 = 1$ hour

$T_3 = 20°C$; $h_3 = 8$ hours

Step 2. Determine bearing and winding life from Table 5.1.9.1-1

$T_1 = 100^oC$; $\alpha_B = 6100$ hours; $\alpha_W = 31000$ hours

$T_2 = 60^oC$; $\alpha_B = 34600$ hours; $\alpha_W = 180000$ hours

$T_3 = 20^oC$; $\alpha_B = 38800$ hours; $\alpha_W = 1600000$ hours

Step 3. Calculate bearing life and winding life from Sections 5.1.9.1.1 and 5.1.9.1.2.

$$\alpha_B = \frac{2 + 1 + 8}{\frac{2}{6100} + \frac{1}{34600} + \frac{8}{38800}} = 19500 \text{ hours}$$

$$\alpha_W = \frac{2 + 1 + 8}{\frac{2}{31000} + \frac{1}{180000} + \frac{8}{1600000}} = 146000 \text{ hours}$$

Step 4. Calculate average failure rate.

$$\lambda_p = \left(\frac{t^2}{\alpha_B^3} + \frac{1}{\alpha_W}\right) \text{x } 10^6$$

$$\lambda_p = \left(\frac{(4000)^2}{(19500)^3} + \frac{1}{146000}\right) \text{x } 10^6$$

$\lambda_p = 9.0$ failures/10^6 hrs

Example 3.

Given: A size 18 synchro with 2 brushes and operating in a Ground Fixed service environment, with a frame temperature of 70° C.

Step 1. Approximate the frame temperature, if not known or cannot be measured, in the following manner:

Frame temperature = ambient + 40° C.

In this example the frame temperature is given as 70° C.

Step 2. Derive the base failure rate, λ_b, by inserting the frame temperature into Tbl 5.1.9.2-1 for a value of 0.0187 failures/10^6 hours.

Step 3. From Tbl 5.1.9.2-2 Π_S for a size 18 synchro is 1.0.

Step 4. From Tbl 5.1.9.2-3, Π_N for 2 brushes is 1.4.

Step 5. From Tbl 5.1.9.2-4 Π_E for Ground Fixed service environment is 2.3.

Step 6. The total failure rate, λ_p, is obtained by multiplying the λ_b term and Π terms, as shown in the model:

$$\lambda_p = \lambda_b (\pi_S \times \pi_N \times \pi_E)$$

$$= 0.0187 (1.0 \times 1.4 \times 2.3) \doteq 0.060 \text{ failures}/10^6 \text{ hours.}$$

5.1.10 Relays.

5.1.10.1 Mechanical Relays

TABLE 5.1.10.1-1: **Prediction Procedure for Relays**

Part Specifications Covered

Military Specifications

1. MIL-R-5757
2. MIL-R-6106
3. MIL-R-19523
4. MIL-R-39016
5. MIL-R-19648
6. MIL-R-83725
7. MIL-R-83726*

Part failure rate model (λ_p)

$(\lambda_p) = \lambda_b \, (\pi_E \times \pi_C \times \pi_{cyc} \times \pi_F \times \pi_Q)$ (failures/10^6 hours)

where the factors are shown in these tables:

π_E - Table 5.1.10.1-4 & 5

π_C - Table 5.1.10.1-6

π_F - Table 5.1.10.1-8

π_{cyc} - Table 5.1.10.1-7

π_Q - Table 5.1.10.1-9

Note - Values of π_{cyc} for cycling rates beyond the basic design limitations of the relay are not valid. Design Specifications should be consulted prior to evaluation of π_{cyc}.

* - Prediction procedure does not apply to Class C (solid state) relays of this specification.

TABLE 5.1.10.1-1: Prediction Procedure for Relays (Cont'd)

Base failure rate model (λ_b)

$$\lambda_b = \lambda_T \pi_L$$

where $\lambda_T = A e^x$

$$\pi_L = e^y$$

$$y = \left(\frac{S}{N_S}\right)^H$$

$$x = \left(\frac{T + 273}{N_T}\right)^G$$

T = Ambient operating temperature in °C

S = Operating load current/rated resistive load current

e = 2.718, natural logarithm base.

Constants	λ_T (85°C)	λ_T (125°C)	π_L (Lamp)	π_L (Inductive)	π_L (Resistive)
A	5.55×10^{-3}	5.4×10^{-3}	-	-	-
N_T	352.0	377.0	-	-	-
N_S	-	-	0.2	0.4	0.8
G	15.7	10.4	-	-	-
H	-	-	2.0	2.0	2.0

NOTE: Table 5.1.10.1-2 contains λ_T
Table 5.1.10.1-3 contains π_L

TABLE 5.1.10.1-2 **Relay Failure Rate (λ_T) vs Ambient Temperature**

T (°C)	Relay Temperature Rating	
	85°C	125°C
25	0.0060	0.0059
30	0.0061	0.0060
40	0.0065	0.0063
50	0.0072	0.0066
60	0.0085	0.0071
70	0.0110	0.0079
75	0.0130	0.0084
80	0.0160	0.0090
85	0.0210	0.0097
90		0.0110
95		0.0120
100		0.0130
105		0.0150
110		0.0180
115		0.0210
120		0.0250
125		0.0310

TABLE 5.1.10.1-3 **π_L - Stress Factor vs Load Type**

S	Load Type		
	Resistive	Inductive	Lamp
0.05	1.00	1.02	1.06
0.10	1.02	1.06	1.28
0.20	1.06	1.28	2.72
0.30	1.15	1.76	9.49
0.40	1.28	2.72	54.6
0.50	1.48	4.77	
0.60	1.76	9.49	
0.70	2.15	21.4	
0.80	2.72		
0.90	3.55		
1.00	4.77		

$$S = \frac{\text{Operating Load Current}}{\text{Rated Resistive Load Current}}$$

TABLE 5.1.10.1-4
MIL SPEC
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	1
G_{MS}	1.3
G_F	2.3
G_M	8.2
M_P	21
N_{SB}	8
N_S	8
N_U	14
N_H	32
N_{UU}	34
A_{RW}	46
A_{IC}	5.5
A_{IT}	6
A_{IB}	10
A_{IA}	7.5
A_{IF}	10
A_{UC}	8
A_{UT}	9
A_{UB}	15
A_{UA}	10
A_{UF}	15
S_F	1
M_{FF}	21
M_{FA}	29
U_{SL}	62
M_L	71
C_L	N/A

TABLE 5.1.10.1-5
LOWER QUALITY
Environmental Mode Factors

ENVIRON-MENT	π_E
G_B	2
G_{MS}	2.3
G_F	4.6
G_M	25
M_P	63
N_{SB}	24
N_S	24
N_U	38
N_H	96
N_{UU}	100
A_{RW}	140
A_{IC}	9.5
A_{IT}	15
A_{IB}	20
A_{IA}	15
A_{IF}	25
A_{UC}	20
A_{UT}	25
A_{UB}	40
A_{UA}	30
A_{UF}	45
S_F	2
M_{FF}	63
M_{FA}	82
U_{SL}	190
M_L	210
C_L	N/A

TABLE 5.1.10.1-6: π_C Factor For Contact Form

Contact Form	π_C
SPST	1.00
DPST	1.50
SPDT	1.75
3PST	2.00
4PST	2.50
DPDT	3.00
3PDT	4.25
4PDT	5.50
6PDT	8.00

This table applies to active conducting contacts.

TABLE 5.1.10.1-7: π_{cyc} Factor For Cycling Rates

Cycle Rate (Cycles per Hour)	π_{cyc} (MIL-SPEC)
$\geq$ 1.0	$\frac{\text{Cycles per Hour}}{10}$
< 1.0	0.1

Cycle Rate (Cycles per Hour)	π_{cyc} (Lower Quality)
> 1000	$\left(\frac{\text{Cycles per Hour}}{100}\right)^2$
10-1000	$\frac{\text{Cycles per Hour}}{10}$
< 10	1.0

TABLE 5.1.10.1-8 Failure Rate Factor (Π_F) For Relay Application and Construction Type

Contact Rating	Application Type	Construction Type	π_F MIL-SPEC	π_F Lower Quality
Signal current (low mv and ma)	Dry circuit	Armature (long)	4	8
		Dry reed	6	18
		Mercury wetted	1	3
		Magnetic latching	4	8
		Balanced armature	7	14
		Solenoid	7	14
0-5 amp	General purpose	Armature (long)	3	6
		Balanced armature	5	10
		Solenoid	6	12
	Sensitive (0-100 mw)	Armature (long and short)	5	10
		Mercury wetted	2	6
		Magnetic latching	6	12
		Meter movement	100	100
		Balanced armature	10	20
	Polarized	Armature (short)	10	20
		Meter movement	100	100
	Vibrating reed	Dry reed	6	12
		Mercury wetted	1	3
	High speed	Armature (balanced and short)	25	NA
		Dry reed	6	NA
	Thermal time delay	Bimetal	10	20
	Electronic time delay, non-thermal		9	12
	Latching, magnetic	Dry reed	10	20
		Mercury wetted	5	10
		Balanced armature	5	10
5-20 amp	High voltage	Vacuum (glass)	20	40
		Vacuum (ceramic)	5	10
	Medium power	Armature (long and short)	3	6
		Mercury wetted	1	3
		Magnetic latching	2	6
		TO ADD: "Mechanical latching"	3	6
		Balanced armature	2	6
		Solenoid	2	6
25-600 amp	Contractors (high current)	Armature (short)	7	14
		Mechanical latching	12	24
		Balanced armature	10	20
		Solenoid	5	10

TABLE 5.1.10.1-9: Quality Factor (π_Q) For Relay Application

Failure Rate Level	π_Q
R	0.1
P	0.3
M	1.0
L	1.0

For relays other than ER, use π_Q = 1.5

EXAMPLE

Given: A relay rated at 125°C is operated in a ground fixed environment with an ambient temperature of 30°C. The relay is double-pole, double-throw with a resistive load of 50 percent of rated load. The relay is expected to be cycled at an average of 5 cycles per hour. The relay is a balanced armature, general purpose relay with MIL-SPEC quality.

Find: The failure rate of the relay.

Step 1: From Table 5.1.10.1-2 λ_T is 0.006 failures/10^6 hours, based on the ambient temperature of 30°C for 125°C rated relay.

Step 2: From Table 5.1.10.1-3 π_L = 1.48 for a resistive load at 50 percent rating.

Step 3: From Table 5.1.10.1-5 π_E = 2.3 for ground fixed environment, MIL-SPEC.

Step 4: From Table 5.1.10.1-6 π_C = 3.0 for double-pole, double-throw contacts.

Step 5: From Table 5.1.10.0-7 π_{cyc} = 0.5 for 5 cycles $\left(\frac{5 \text{ cycles per hour}}{10}\right)$.

Step 6: From Table 5.1.10.1-8 π_F = 5.0 for a balanced armature, general purpose relay.

Step 7. From Table 5.1.10.1-9 π_Q = 1.0.

Step 8. The failure rate is determined by substituting the factors into the failure rate mathematical model:

$$\lambda_p = \lambda_b \left(\pi_E \times \pi_C \times \pi_{cyc} \times \pi_F \times \pi_Q\right)$$

$$\lambda_b = \lambda_T \pi_L = 0.006 \times 1.48 = 0.0089 \text{ failures}/10^6 \text{ hours}$$

$$\lambda_p = 0.0089 \,(2.3 \times 3.0 \times 0.5 \times 5.0 \times 1.0) = 0.154 \text{ failures}/10^6 \text{ hours.}$$

5.1.10.2 Solid State Relays (SSR)

Specification	Description
MIL-R-28750	Relay, Solid State

The part failure rate prediction procedure is as follows:

Step 1: If a Parts List and/or Schematic Diagram are available.

Step 1A: Calculate a failure rate for each particular component in the SSR assembly using the correct model from the following sections:

Integrated Circuits	Section 5.1.2
Discrete Semiconductors	Section 5.1.3
Resistors	Section 5.1.6
Capacitors	Section 5.1.7
Inductive Devices	Section 5.1.8
Relays	Section 5.1.10
Interconnection Assemblies	Section 5.1.13

Step 1B: Sum the failure rate contribution for each component. The SSR failure rate (λ_p) then is:

$$\lambda_p = \sum_{i=1}^{n} \lambda_i$$

where

λ_p = SSR failure rate (F/10^6 hours)

λ_i = failure rate of each individual component (F/10^6 hours)

Step 2: If a parts list but no schematic diagram is available, or if the part complement can be determined by other means (e.g., disection).

Step 2A: Calculate a failure rate for each component type and for the SSR as an assembly using the procedure discussed in Section 5.2.

Step 3: If no parts list or schematic diagram are available, calculate the SSR failure rate using the following model:

$$\lambda_p = \lambda_b \times \pi_Q \times \pi_E$$

where

λ_p = SSR failure rate (F/10^6 hours)

λ_b = base failure rate = 0.4 F/10^6 hours

π_E = environmental factor (Table 5.1.10.2-1)

π_Q = quality factor

= 1, MIL-SPEC quality
= 3, lower quality

TABLE 5.1.10.2-1: ENVIRONMENTAL FACTOR

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	13
G_{MS}	1.3	A_{IF}	25
G_F	3.3	A_{UC}	10
G_M	13	A_{UT}	16
M_P	10	A_{UB}	37
N_{SB}	5.2	A_{UA}	23
N_S	7.1	A_{UF}	42
N_U	17	S_F	0.85
N_H	16	M_{FF}	10
N_{UU}	17	M_{FA}	14
A_{RW}	23	U_{SL}	31
A_{IC}	6.5	M_L	35
A_{IT}	9.5	C_L	590
A_{IB}	21		

5.1.10.3 Hybrid and Solid State Time Delay Relays (TDR)

Specification	Description
MIL-R-83726	Relay, Time Delay, Hybrid and Solid State

The part failure rate prediction procedure is as follows:

Step 1: If a Parts List and/or Schematic Diagram are available.

Step 1A: Calculate a failure rate for each particular component in the TDR assembly using the correct model from the following sections:

Integrated Circuits	Section 5.1.2
Discrete Semiconductors	Section 5.1.3
Resistors	Section 5.1.6
Capacitors	Section 5.1.7
Inductive Devices	Section 5.1.8
Relays	Section 5.1.10
Interconnection Assemblies	Section 5.1.13

Step 1B: Sum the failure rate contribution for each component. The TDR failure rate (λ_p) then is:

$$\lambda_p = \sum_{i=1}^{n} \lambda_i$$

where

λ_p = TDR failure rate (F/10^6 hours)

λ_i = failure rate of each individual component (F/10^6 hours)

Step 2: If a parts list but no schematic diagram is available, or if the part complement can be determined by other means (e.g. disection).

Step 2A: Calculate a failure rate for each component type and for the TDR as an assembly using the procedure discussed in Section 5.2.

Step 3: If no parts list or schematic diagram are available and the TDR is a hybrid electronic TDR, calculate the TDR failure rate using the current model for electronic time delay relays (Section 5.1.10).

Step 4: If no parts list or schematic diagram are available and the TDR is an all solid state TDR, calculate the TDR failure rate using the model:

$$\lambda_p = \lambda_D + \lambda_R$$

where

λ_p = TDR failure rate (F/10^6 hours)

λ_D = delay circuit failure rate (F/10^6 hours)

λ_R = relay circuit failure rate (F/10^6 hours)

Step 4A: Calculate the delay circuit failure rate (λ_D).

$$\lambda_D = \lambda_b \times \pi_E \times \pi_Q$$

where

λ_b = base failure rate = 0.5 F/10^6 hours

π_E = environmental factor (Table 5.1.10.3-1)

π_Q = quality factor
= 1, MIL-SPEC quality
= 4, lower quality

Step 4B: Calculate the relay circuit failure rate (λ_R) using the procedure given in Section 5.1.10.2.

Step 4C: Calculate the total TDR failure rate (λ_p).

$$\lambda_p = \lambda_D + \lambda_R$$

TABLE 5.1.10.3-1: ENVIRONMENTAL FACTORS

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	18
G_{MS}	1.5	A_{IF}	35
G_F	4.8	A_{UC}	14
G_M	16	A_{UT}	23
M_P	12	A_{UB}	52
N_{SB}	8.4	A_{UA}	38
N_S	8.8	A_{UF}	59
N_U	20	S_F	0.58
N_H	18	M_{FF}	12
N_{UU}	20	M_{FA}	17
A_{RW}	26	U_{SL}	35
A_{IC}	8.2	M_L	40
A_{IT}	13	C_L	680
A_{IB}	30		

5.1.11 Switches.

5.1.11.1 Toggle or pushbutton (single body)

Part Specifications Covered	Description
MIL-S-3950 MIL-S-8805 MIL-S-8834 MIL-S-22885 MIL-S-83731	Snap-action toggle or pushbutton

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_C \times \pi_{cyc} \times \pi_L) \text{ failures}/10^6 \text{ hours}$$

where factors are shown in:

π_E Table 5.1.11.4-1

π_C Table 5.1.11.4-2

π_{cyc} Table 5.1.11.4-3

π_L Table 5.1.11.4-4

Base failure rate model (λ_b):

Description	MIL-SPEC	Lower Quality
Snap action	0.00045	0.034
Non-snap action	0.0027	0.04

5.1.11.2 Basic Sensitive

Part Specifications Covered	Description
MIL-S-8805	Basic Sensitive

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_{cyc} \times \pi_L) \text{ failures}/10^6 \text{ hours}$$

where factors are shown in:

π_E Table 5.1.11.4-1

π_{cyc} Table 5.1.11.4-3

π_L Table 5.1.11.4-4

Base failure rate model (λ_b):

$\lambda_b = \lambda_{bE} + \frac{n}{2} \lambda_{bC}$ (if actuation differential is >0.002 inches)

$\lambda_b = \lambda_{bE} + \frac{n}{2} \lambda_{b}0$ (if actuation differential is <0.002 inches)

n = the number of active contacts

Description	MIL-SPEC	Lower Quality
λ_{bE}	0.1	0.1
λ_{bC}	0.0009	0.45
λ_{b0}	0.0018	1.25

5.1.11.3: Rotary (wafer)

Part Specifications Covered	Description
MIL-S-3786	Rotary, ceramic or glass wafer, silver alloy contacts

Part operating failure rate model (λ_p):

$$\lambda_p = \lambda_b (\pi_E \times \pi_{cyc} \times \pi_L) \text{ failures}/10^6 \text{ hours}$$

where factors are shown in:

π_E	Table 5.1.11.4-1
π_{cyc}	Table 5.1.11.4-3
π_L	Table 5.1.11.4-4

Base failure rate model (λ_b):

$\lambda_b = \lambda_{bE} + n\ \lambda_{bF}$ (for ceramic RF wafers)

$\lambda_b = \lambda_{bE} + n\ \lambda_{bG}$ (for rotary switch medium power wafers)

n = the number of active contacts

Description	MIL-SPEC	Lower Quality
λ_{bE}	0.0067	0.1
λ_{bF}	0.00003	0.02
λ_{bG}	0.00003	0.06

5.1.11.4 Thumbwheel

Part Specifications Covered	Description
MIL-S-22710	Switches, Rotary (Printed Circuit), (Thumbwheel, In-Line, and Pushbutton)

Part operating failure rate model (λ_p):

$\lambda_p = (\lambda_1 + n\lambda_2) \times \pi_E \times \pi_{cyc} \times \pi_L$ failures/10^6 hours

where λ_1 and λ_2 are base failure rate constants (unique values for MIL-SPEC and commercial quality grades)

λ_1 = 0.0067 failures/10^6 hours, MIL-SPEC quality

= 0.086 failures/10^6 hours, lower quality

λ_2 = 0.062 failures/10^6 hours, MIL-SPEC quality

= 0.089 failures/10^6 hours, lower quality

n = number of active contacts

π_E = environmental factors (see Table 5.1.11.4-1)

π_{cyc} = cycling rate factor (see Table 5.1.11.4-3)

π_L = load type factor (see Table 5.1.11.4-4)

CAUTION: This model applies to the switching function only. The model does not consider the contribution of any discrete components (e.g., resistors, diodes, lamp) which may be mounted on the switch. The failure rate of these devices must be calculated using the appropriate section of this handbook and added to the failure rate of the switch.

This model applies to a single switch section. This type of switch is frequently ganged to provide the required function. The model must be applied to each section individually.

TABLE 5.1.11.4-1: ENVIRONMENTAL MODE FACTORS

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.2
G_F	2.9
G_M	14
M_P	21
N_{SB}	7.9
N_S	7.9
N_U	20
N_H	32
N_{UU}	34
A_{RW}	46
A_{IC}	8
A_{IT}	8
A_{IB}	15
A_{IA}	15
A_{IF}	20
A_{UC}	10
A_{UT}	10
A_{UB}	20
A_{UA}	20
A_{UF}	25
S_F	1
M_{FF}	21
M_{FA}	29
U_{SL}	63
M_L	71
C_L	1,200

TABLE 5.1.11.4-2: π_C FACTOR FOR CONTACT FORM AND QUANTITY

Contact Form	π_C
SPST	1.0
DPST	1.5
SPDT	1.75
3PST	2.0
4PST	2.5
DPDT	3.0
3PDT	4.25
4PDT	5.5
6PDT	8.0

TABLE 5.1.11.4-3: π_{cyc} FACTOR FOR CYCLING RATES

Switching Cycles per Hour	π_{cyc}
$\leq$ 1 cycle/hour	1.0
> 1 cycle/hour	number of cycles/hour

TABLE 5.1.11.4-4: π_L STRESS FACTOR FOR SWITCH CONTACTS

Stress S	Load Type		
	Resistive	Inductive	Lamp
0.05	1.00	1.02	1.06
0.1	1.02	1.06	1.28
0.2	1.06	1.28	2.72
0.3	1.15	1.76	9.49
0.4	1.28	2.72	54.6
0.5	1.48	4.77	
0.6	1.76	9.49	
0.7	2.15	21.4	
0.8	2.72		
0.9	3.55		
1.0	4.77		

where $S = \frac{\text{operating load current}}{\text{rated resistive load}}$

$$\pi_L = e^{(S/.8)^2} \text{ for resistive.}$$

$$= e^{(S/.4)^2} \text{ for inductive.}$$

$$= e^{(S/.2)^2} \text{ for lamp.}$$

NOTE: When the switch is rated by inductive load, then use resistive π_L.

5.1.11.5 Circuit Breakers

Specification	Description
MIL-C-55629	Circuit Breakers, Magnetic, Unsealed, Trip-Free
MIL-C-83383	Circuit Breakers, Remote Control, Thermal, Trip-Free
MIL-C-39019	Circuit Breakers, Magnetic, Low Power, Sealed, Trip-Free Service
W-C-375	Circuit Breakers, Molded Case, Branch Circuit and Service

The part operating failure rate model (λ_p) is:

$$\lambda_p = \lambda_b \times \pi_C \times \lambda_Q \times \pi_E \times \pi_u$$

where

λ_p = circuit breaker failure rate (failures/10^6 hours)

λ_b = base failure rate

= 0.020 failures/10^6 hours, magnetic circuit breakers

= 0.038 failures/10^6 hours, thermal circuit breakers

= 0.038 failures/10^6 hours, thermal-magnetic circuit breakers

π_C = configuration factor (see Table 5.1.11.5-1)

π_Q = quality factor

= 1.0, MIL-SPEC quality

= 8.4, lower quality

π_E = environmental factor (see Table 5.1.11.5-2)

π_u = a factor to account for a higher failure rate when the circuit breaker is also used as a power on-off switch for the equipment.

= 1.0, not used as a switch

= 10.0, used as a switch

SWITCHES

TABLE 5.1.11.5-1: CONFIGURATION FACTOR

Configuration	π_C
SPST	1.00
DPST	2.00
3PST	3.00
4PST	4.00

TABLE 5.1.11.5-2: ENVIRONMENTAL FACTOR

ENVIRONMENT	π_E	ENVIRONMENT	π_E
G_B	1	A_{IB}	10
G_{MS}	1.2	A_{IA}	7.5
G_F	2.3	A_{IF}	10
G_M	8.2	A_{UC}	8
M_P	21	A_{UT}	9
N_{SB}	8	A_{UB}	15
N_S	8	A_{UA}	10
N_U	14	A_{UF}	15
N_H	32	S_F	1
N_{UU}	34	M_{FF}	21
A_{RW}	46	M_{FA}	29
A_{IC}	5.5	U_{SL}	62
A_{IT}	6	M_L	71
		C_L	N/A

5.1.11.6 Examples

Example 1

Given: A MIL-SPEC toggle switch is used in a ground fixed environment. The switch is a snap action switch and is single-pole, double-throw. It is operated on the average of one cycle per hour, and load current is 50 percent of rated and is resistive.

Find: The failure rate of the switch.

Step 1: The base failure rate (λ_b) is found in section 5.1.11.1 and is determined to be 0.00045 failures/10^6 hours.

Step 2: The environmental factor (π_E) for ground fixed environment is determined from Table 5.1.11.4-1 to be 2.9.

Step 3: The contact form factor (π_C) is determined from Table 5.1.11.4-2. For a single-pole, double-throw switch, π_C is 1.75.

Step 4: The cycling factor (π_{cyc}) is determined from Table 5.1.11.4-3 to be equal to 1.0.

Step 5: The stress factor (π_L) from Table 5.1.11.4-4 for 50 percent stress factor and a resistive load is determined to be 1.48.

Step 6: The failure rate mathematical model for toggle switches is:

$$\lambda_p = \lambda_b (\pi_E \times \pi_C \times \pi_{cyc} \times \pi_L)$$

Substituting for these factors:

$$\lambda_p = 0.00045 (2.9 \times 1.75 \times 1.0 \times 1.48)$$

$$\lambda_p = 0.0034 \text{ failures}/10^6 \text{ hours.}$$

Example 2

Given: A MIL-SPEC rotary switch is installed in an airborne inhabited, trainer environment. It has a medium power wafer, one deck, and six contacts. The switch is cycled an average of 5 cycles per hour, and the load current is 50 percent of rated current and is resistive.

Find: The failure rate of the switch.

Step 1: The base failure rate (λ_b) is determined from section 5.1.11.3.

$$\lambda_b = \lambda_{bE} + n\,\lambda_{bG}$$

Substituting the values from section 5.1.11.3

$$\lambda_b = 0.0067 + 6\,(0.00003)$$

$$\lambda_b = 0.00688 \text{ failures}/10^6 \text{ hours}$$

Step 2: The environmental factor (π_E) for airborne inhabited, trainer is determined from Table 5.1.11.4-1 to be 8.0.

Step 3: The cycling factor (π_{cyc}) is determined from Table 5.1.11.4-3 to be 5.0.

Step 4: The stress factor (π_L) is determined from Table 5.1.11.4-4 to be 1.48.

Step 5: The failure rate mathematical model for rotary switches is:

$$\lambda_p = \lambda_b\,(\pi_E \times \pi_{cyc} \times \pi_L)$$

Substituting values determined in the formula:

$$\lambda_p = 0.00688\,(8.0 \times 5.0 \times 1.48)$$

$$\lambda_p = 0.41 \text{ failures}/10^6 \text{ hours.}$$

Example 3

Given: A MIL-SPEC 2AMP resistive rated thumbwheel switch is installed in an airborne inhabited, cargo environment at a 40°C ambient temperature. The switch has five active contacts. It is cycled an average of 2 cycles per hour, and the load current is 5 percent of rated current and is resistive. The switch has four 1/4watt, 10 ohm class M carbon composition (RCR) resistors mounted on the switch printed circuit card. The resistors are an integral part of the switch and cannot be removed and replaced if they fail.

Find: The failure rate of the switch as an assembly.

Step 1: Calculate switch failure rate

$\lambda_1 = 0.0067$ failures/10^6 hours

$\lambda_2 = 0.062$ failures/10^6 hours

$n = 5$

$\pi_E = 8$

$\pi_{cyc} = 2$

$\pi_L = 1.0$

$\lambda_p = (\lambda_1 + n\lambda_2) \times \pi_E \times \pi_{cyc} \times \pi_L$

$\lambda_p = (0.0067 + (5 \times 0.062)) \times 8 \times 2 \times 1.00$

$\lambda_p = 5.067$ failures/10^6 hours.

Step 2: Calculate resistors failure rate from section 5.1.6.1.

$\lambda_p = \lambda_b \times \pi_E \times \pi_R \times \pi_Q$ failures/10^6 hours

$\lambda_b = 0.00055$ failures/10^6 hours (40°C, 0.4 stress)

$\pi_E = 3$

$\pi_R = 1$

$\pi_Q = 1$

$\lambda_p = .00055 \times 3 \times 1 \times 1$

$\lambda_p = 0.0016$ failures/10^6 hours.

Step 3: Calculate total switch assembly failure rate

$\lambda = \lambda_{switch} + 4 \times \lambda_{resistors}$

$\lambda = 5.067$ failures/10^6 hours + 0.006 failures/10^6 hours

$\lambda = 5.073$ failures/10^6 hours.

5.1.12 Connectors

5.1.12.1 Connector, General (except printed circuit board types)

TABLE 5.1.2.1-1: PREDICTION PROCEDURE FOR CONNECTORS

Part Specifications Covered (Table 5.1.12.1-2 shows connector configurations)

Specification	Description	Specification	Description
MIL-C-24308	Rack & Panel	MIL-C-3607	Coaxial, RF
MIL-C-28748		MIL-C-3643	
MIL-C-28804		MIL-C-3650	
MIL-C-83513		MIL-C-3655	
MIL-C-83733		MIL-C-25516	
MIL-C-5015	Circular	MIL-C-39012	
MIL-C-26482		MIL-C-55235	
MIL-C-28840		MIL-C-55339	
MIL-C-38999		MIL-C-3767	Power
MIL-C-81511		MIL-C-22992	
MIL-C-83723		MIL-C-49142	Triaxial, RF

Part failure rate model (λ_p)

The failure rate model (λ_p) is for a mated pair of connectors. For a single connector, divide λ_p by two.

$$\lambda_p = \lambda_b (\pi_E \times \pi_p \times \pi_K) \text{ failures}/10^6 \text{ hours}$$

where

π_E Table 5.1.12.1-6 and Table 5.1.12.1-7

π_p Table 5.1.12.1-8

π_K Table 5.1.12.1-9

TABLE 5.1.12.1-1. Base Failure Rate

Base Failure Rate Model (λ_b)

$$\lambda_b = Ae^x$$

$$\text{where } x = \frac{N_T}{T+273} + \left(\frac{T+273}{T_o}\right)^P$$

e = 2.718, natural logarithm base

T = operating temperature (°C)

= ambient + temperature rise (Tbl 5.1.12.1-4)

Constants	Insert Material			
	A	B	C	D
A	0.02	0.431	0.19	0.77
T_o	473	423	373	358
N_T	-1592	-2073.6	-1298	-1528.8
P	5.36	4.66	4.25	4.72

Calculated values of λ_b for selected operating temperatures are shown in Table 5.1.12.1-5.

TABLE 5.1.12.1-2: CONFIGURATION, APPLICABLE SPECIFICATION, AND INSERT MATERIAL FOR CONNECTORS

Configuration	Specification	Insert Material (Table 5.1.12.1-3)			
		A	B	C	D
Rack and Panel	MIL-C-28748		X		
	MIL-C-83733		X		
	MIL-C-24308	X	X		
	MIL-C-28804	X	X		
	MIL-C-83513	X	X		
Circular	MIL-C-5015		X		X
	MIL-C-26482	X	X		X
	MIL-C-28840	X	X		
	MIL-C-38999	X	X		
	MIL-C-81511		X		
	MIL-C-83723		X		
Power	MIL-C-3767		X		X
	MIL-C-22992		X		X
Coaxial	MIL-C-3607			X	
	MIL-C-3643			X	
	MIL-C-3650			X	
	MIL-C-3655			X	
	MIL-C-25516			X	
	MIL-C-39012			X	
	MIL-C-55235			X	
	MIL-C-55339		X	X	
Triaxial	MIL-C-49142		X	X	

TABLE 5.1.12.1-3. Temperature Ranges of Insert Materials

Type	Common Insert Materials	Temperature Range (°C)*
A	Vitreous glass, alumina ceramic, polyimide	-55 to 250
B	Diallyl phthalate, melamine, fluorosilicone, silicone rubber, polysulfone, epoxy resin	-55 to 125
C	Polytetrafluoroethylene (teflon) chlorotrifluoroethylene (kel-f)	-55 to 200
D	Polyamide (nylon), polychloroprene (neoprene), polyethylene	-55 to 125

*These temperature ranges indicate maximum capability of the insert material only. Connectors using these materials generally have a reduced temperature range caused by other considerations of connector design. Applicable connector specifications contain connector operating temperature range.

TABLE 5.1.12.1-4. Insert Temperature Rise (°C) versus Contact Current

Amperes Per Contact	Contact Size			
	22 GA	20 GA	16 GA	12 GA
2	3.6	2.3	1.0	.36
3	7.5	4.9	2.1	.76
4	12.9	8.3	3.6	1.3
5	19.4	12.6	5.4	2.0
6	27.2	17.6	7.5	2.8
7	36.2	23.4	10.0	3.7
8	46.3	30.0	12.8	4.7
9	57.6	37.3	16.0	5.8
10	70.0	45.3	19.4	7.1
15		95.9	41.1	15.0
20			69.9	25.5
25			105.7	54.0
30				71.9
35				92.0
40				

$\Delta T = 0.989\ (i)^{1.85}$ for 22 gauge contacts

$\Delta T = 0.64\ (i)^{1.85}$ for 20 gauge contacts

$\Delta T = 0.274\ (i)^{1.85}$ for 16 gauge contacts

$\Delta T = 0.1\ (i)^{1.85}$ for 12 gauge contacts

ΔT = °C insert temperature rise

i = amperes per contact

NOTE: Operating temperature of the connector is usually assumed to be the sum of the ambient temperature surrounding the connector plus the temperature rise generated in the contact. If the connector is mounted on a suitable heat sink, the heat sink temperature is usually taken as ambient. For those circuit design conditions which generate a contact hot spot, this hot spot temperature rise is added to the ambient to obtain the operating temperature.

For RF coaxial connectors, assume $\Delta T = 5°C$ except for high power RF application then use $\Delta T = 50^{o}C$.

TABLE 5.1.12.1-5. **Operating Temperature versus Base Failure Rate (λ_b) (Failures/10^6 Hours)**

Temperature (°C)	Insert Material*			
	A	B	C	D
0	0.00006	0.00025	0.0020	0.0038
10	0.00008	0.00031	0.0027	0.0048
20	0.00009	0.00044	0.0033	0.0061
30	0.00012	0.00056	0.0041	0.0078
40	0.00014	0.00075	0.0049	0.0099
50	0.00017	0.00094	0.0059	0.0125
60	0.00020	0.0012	0.0073	0.0159
70	0.00023	0.0015	0.0087	0.0202
80	0.00028	0.00188	0.0106	0.0258
90	0.00032	0.00231	0.0131	0.033
100	0.00038	0.00288	0.0161	0.043
110	0.00044	0.00362	0.0197	0.056
120	0.00051	0.00450	0.0246	0.074
130	0.00059	0.00556		
140	0.00069	0.00694		
150	0.00081	0.00869		
160	0.00096	0.01093		
170	0.00110	0.01381		
180	0.00133	0.01756		
190	0.00159	0.02243		
200	0.00190	0.02894		
210	0.00229			
220	0.00279			
230	0.00343			
240	0.00426			
250	0.00536			

*If a mating pair of connectors uses two types of insert materials, use the average of the base failure rates for the two insert types.

TABLE 5.1.12.1-6

MIL-SPEC Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.1
G_F	1.2
G_M	8.3
M_P	8.5
N_{SB}	4.1
N_S	5.3
N_U	13
N_H	13
N_{UU}	14
A_{RW}	19
A_{IC}	2
A_{IT}	3
A_{IB}	4.5
A_{IA}	4
A_{IF}	6.5
A_{UC}	5
A_{UT}	8
A_{UB}	10
A_{UA}	9.5
A_{UF}	15
S_F	1
M_{FF}	8.5
M_{FA}	12
U_{SL}	25
M_L	29
C_L	490

TABLE 5.1.12.1-7

Lower Quality Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1.5
G_{MS}	1.9
G_F	4.7
G_M	25
M_P	17
N_{SB}	8.1
N_S	11
N_U	27
N_H	26
N_{UU}	28
A_{RW}	37
A_{IC}	10
A_{IT}	10
A_{IB}	15
A_{IA}	15
A_{IF}	20
A_{UC}	15
A_{UT}	15
A_{UB}	20
A_{UA}	20
A_{UF}	30
S_F	1.5
M_{FF}	17
M_{FA}	24
U_{SL}	50
M_L	58
C_L	970

TABLE 5.1.12.1-8. Values of Failure Rate Multiplier, π_P, for Number of Active Contacts in a Connector

Number Of Active Contacts	π_P	Number Of Active Contacts	π_P
1	1.00	65	13.20
2	1.36	70	14.60
3	1.55	75	16.10
4	1.72	80	17.69
5	1.87	85	19.39
6	2.02	90	21.19
7	2.16	95	23.10
8	2.30	100	25.13
9	2.44	105	27.28
10	2.58	110	29.56
11	2.72	115	31.98
12	2.86	120	34.53
13	3.00	125	37.22
14	3.14	130	40.07
15	3.28	135	43.08
16	3.42	140	46.25
17	3.57	145	49.60
18	3.71	150	53.12
19	3.86	155	56.83
20	4.00	160	60.74
25	4.78	165	64.85
30	5.60	170	69.17
35	6.46	175	73.70
40	7.42	180	78.47
45	8.42	185	83.47
50	9.50	190	88.72
55	10.65	195	94.23
60	11.89	200	100.00

For coaxial and triaxial connectors, the shield contact is counted as an active contact.

π_P is a function of the number of active contacts:

$$\pi_P = e^{\left(\frac{N-1}{N_o}\right)^q}$$

A contact is the conductive element in a connector which mates with another element for the purpose of transferring electrical energy.

where $N_o = 10$

$q = 0.51064$

N = number of active contacts

TABLE 5.1.12.1-9. π_K Mating/Unmating Factor

Mating/Unmating Cycles (per 1000 hours)	π_K
0-0.05	1.0
>0.05-0.5	1.5
>0.5-5	2.0
>5-50	3.0
>50	4.0

One cycle includes both connect and disconnect.

5.1.12.2 Printed Circuit Board Connector.

Table 5.1.12.2-1 Prediction Procedure for PCB Connectors

Specification	Description
MIL-C-21097	One-Piece Connector
MIL-C-55302	Two-Piece Connector

Part Failure Rate Model (λ_p)

The failure rate, λ_p, is for a mating pair of connectors and is:

$$\lambda_p = \lambda_b (\Pi_E \times \Pi_P \times \Pi_K) \text{ failures}/10^6 \text{ hours}$$

where the factors are:

Π_E	Table 5.1.12.2-4 or 5
Π_P	Table 5.1.12.2-6
Π_K	Table 5.1.12.2-7

Base Failure Rate (λ_b)

$$\lambda_b = Ae^x$$

$$\text{where } x = \left(\frac{N_T}{T+273}\right) + \left(\frac{T+273}{T_o}\right)^P$$

e = 2.718, natural logarithm base
T = operating temperature (°C)
= ambient + temperature rise (Table 5.1.12.2-2)

A = 0.216
T_o = 423
P = 4.66
N_T = -2073.6

λ_b values are shown in Table 5.1.12.2-3.

TABLE 5.1.12.2-2. Connector Temperature Rise (°C) Versus Contact Current and Contact Size

Amperes/Contact	26 GA	22 GA	20 GA
1	2.1	0.99	0.64
2	7.6	3.6	2.3
3	16.0	7.5	4.9
4	27.3	12.9	8.3
5	41.2	19.4	12.6

$\Delta T = 2.1\ (i)^{1.85}$ for 26 GA

$\Delta T = 0.989\ (i)^{1.85}$ for 22 GA

$\Delta T = 0.64\ (i)^{1.85}$ for 20 GA

Note 1: ΔT = °C temperature rise
i = amperes per contact

Note 2: The operating temperature of the connector is usually assumed to be the sum of the ambient temperature surrounding the connector plus the temperature rise generated in the contact.

TABLE 5.1.12.2-3. Operating Temperature Versus Base Failure Rate (λ_b) in Failures/Million Hours

Temperature (°C)	λ_b
0	0.00013
10	0.00016
20	0.00021
30	0.00028
40	0.00037
50	0.00047
60	0.0006
70	0.0008
80	0.0009
90	0.0011
100	0.0014
110	0.0018
120	0.0022
130	0.0028
140	0.0035
150	0.0043
160	0.0055
170	0.007
180	0.0088
190	0.011
200	0.014

PCB CONNECTORS

TABLE 5.1.12.2-4

MIL SPEC Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1
G_{MS}	1.3
G_F	3.4
G_M	8.3
M_P	8.5
N_{SB}	4.1
N_S	5.7
N_U	13
N_H	13
N_{UU}	13
A_{RW}	19
A_{IC}	3.5
A_{IT}	6.5
A_{IB}	9.5
A_{IA}	6.5
A_{IF}	15
A_{UC}	3.5
A_{UT}	6.5
A_{UB}	9.5
A_{UA}	6.5
A_{UF}	15
S_F	1
M_{FF}	8.5
M_{FA}	12
U_{SL}	25
M_L	29
C_L	490

TABLE 5.1.12.2-5

Lower Quality Environmental Mode Factors

ENVIRONMENT	π_E
G_B	1.5
G_{MS}	2.2
G_F	6.8
G_M	17
M_P	17
N_{SB}	8.2
N_S	12
N_U	27
N_H	26
N_{UU}	26
A_{RW}	37
A_{IC}	7.5
A_{IT}	15
A_{IB}	20
A_{IA}	15
A_{IF}	30
A_{UC}	7.5
A_{UT}	15
A_{UB}	20
A_{UA}	15
A_{UF}	30
S_F	1.5
M_{FF}	17
M_{FA}	24
U_{SL}	50
M_L	58
C_L	970

TABLE 5.1.12.2-6 Values of Failure Rate Modifier, π_P, for Number of Active Pins in a Connector

N	π_P	N	π_P
1	1.00	65	13.20
2	1.36	70	14.60
3	1.55	75	16.10
4	1.72	80	17.69
5	1.87	85	19.39
6	2.02	90	21.19
7	2.16	95	23.10
8	2.30	100	25.13
9	2.44	105	27.28
10	2.58	110	29.56
11	2.72	115	31.98
12	2.86	120	34.53
13	3.00	125	37.22
14	3.14	130	40.07
15	3.28	135	43.08
16	3.42	140	46.25
17	3.57	145	49.60
18	3.71	150	53.12
19	3.86	155	56.83
20	4.00	160	60.74
25	4.78	165	64.85
30	5.60	170	69.17
35	6.46	175	73.70
40	7.42	180	78.47
45	8.42	185	83.47
50	9.50	190	88.72
55	10.65	195	94.23
60	11.89	200	100.00

Π_P is a function of the number of active pins

$$\pi_P = e^{\left(\frac{N-1}{N_o}\right)^q}$$

where $N_o = 10$

$q = 0.51064$

N = number of active pins

TABLE 5.1.12.2-7. . Cycling Rate Factor π_K

Cycling Frequency (Matings/1000 Hours)	π_K
0 - 0.05	1.0
> 0.05 - 0.5	1.5
> 0.5 - 5.0	2.0
> 5.0 - 50.0	3.0
>50.0	4.0

A cycle is defined as the mating and unmating of a connector.

5.1.12.3 Integrated Circuit (IC) Socket Prediction Procedure.

SPECIFICATION	DESCRIPTION
MIL-S-83734	Sockets, Plug-in Electronic Components

The part failure rate model is:

$\lambda_p = \lambda_b \times \pi_E \times \pi_P$

where

λ_p = total failure rate (f/10^6 hours)
λ_b = base failure rate = 0.00042 f/10^6 hours
π_E = environmental factor (Table 5.1.12.3-1)
π_P = contact factor (Table 5.1.12.3-2)

TABLE 5.1.12.3-1: ENVIRONMENTAL FACTORS

Environment	π_E	Environment	π_E
G_B	1.0	A_{IA}	10*
G_{MS}	1.3	A_{IF}	13*
G_F	3.1	A_{UC}	10*
G_M	17*	A_{UT}	10*
M_P	11*	A_{UB}	13*
N_{SB}	5.4	A_{UA}	13*
N_S	7.3*	A_{UF}	20*
N_U	18*	S_F	1.0
N_H	17*	M_{FF}	11*
N_{UU}	19*	M_{FA}	16*
A_{RW}	25*	U_{SL}	33*
A_{IC}	6.7*	M_L	39*
A_{IT}	6.7*	C_L	650*
A_{IB}	10*		

* It is recommended that I.C. sockets should only be used in this environment if socketed device is restrained.

IC SOCKETS

TABLE 5.1.12.3-2: CONTACT FACTOR

Number of Active Contacts	π_P
6	2.02
8	2.30
10	2.58
14	3.14
16	3.42
18	3.71
20	4.00
22	4.31
24	4.62
28	5.26
36	6.66
40	7.42
48	9.06
50	9.50
64	12.93

$$\pi_P = \exp\left(\frac{N-1}{N_o}\right)^q$$

where

N_o = 10

q = 0.51064

N = number of active contacts (active indicates electrical current current flow through the contact)

5.1.12.4 Example Failure Rate Calculations

Example 1.

Given: A MIL-SPEC connector, with 20 GA pins, uses insert material, type B. The connector has 20 active pins and is installed in a ground fixed environment with an ambient temperature of 20°C. The load current is expected to be 5 amperes, and the connector is expected to be connected and disconnected once every 200 operating hours.

Find: The failure rate of the connector.

Step 1. The insert temperature rise is determined to be 13°C derived from Table 5.1.12.1-4 for size 20 GA pins at 5 amperes.

The operating temperature is determined from:

Operating temperature = ambient temperature + insert temperature rise.

Operating temperature = $25^{\circ}C + 13^{\circ}C = 38^{\circ}C$.

Step 2. The insert material is type B. Utilizing Table 5.1.12.1-5, the base failure rate for type B insert material at 38°C is 0.00073 failures/10^6 hours.

Step 3. The environmental factor (π_E) for ground fixed is 1.2 as shown in Table 5.1.12.1-6. The pin density factor (π_p) is 4.0 as shown in Table 5.1.12.1-8 for 20 active pins. The π_K factor is 2.0 as determined from Table 5.1.12.1-9 for mating/unmating cycles of 5/1000 hours.

Step 4. The failure rate of the connector is found by substituting the values of λ_b, π_E, π_p, and π_K into the part failure rate model.

$$\lambda_p = \lambda_b (\pi_E \times \pi_p \times \pi_K)$$

$$\lambda_p = 0.00073 (1.2 \times 4.0 \times 2.0)$$

$$\lambda_p = 0.0070 \text{ failures}/10^6 \text{ hours for a mated pair.}$$

For a single connector, per Table 5.1.12.1-1.

$$\lambda_p = .007/2 = 0.0035 \text{ failures}/10^6 \text{ hours.}$$

CONNECTORS

Example 2.

Given: A lower quality connector, with 16 GA pins, uses insert material, type D. The connector has 10 active pins and is installed in an airborne inhabited, fighter environment with an ambient temperature of 40°C. The load current is expected to be 5.0 amperes, and the connector is expected to be connected and disconnected once every 20 hours.

Find: The failure rate of the connector.

Step 1. The insert temperature rise is determined to be 5.5°C, derived from Table 5.1.12.1-4, for size 16 GA pins at 5.0 amperes.

The operating temperature is determined from:

Operating temperature = ambient temperature + insert temperature rise.
Operating temperature = $40^{0} + 5.5^{0}C = 45.5^{0}C$.

Step 2. The insert material is type D. Utilizing Table 5.1.12.1-5 the base failure rate for type D insert material at 45.5°C is 0.0113 failures/10^6 hours.

Step 3. The environmental factor (π_E) for airborne inhabited, fighter lower quality is 20 as shown in Table 5.1.12.1-7. The pin density factor (π_p) is 2.58 as shown in Table 5.1.12.1-8 for 10 active pins. The π_K factor is 3.0 as determined from Table 5.1.12.1-9 for 50 mating/unmating cycles per 1000 hours.

Step 4. The failure rate of the connector is determined by substituting the values of λ_b, π_E, π_p, and π_K into the part failure rate model:

$$\lambda_p = \lambda_b (\pi_E \times \pi_p \times \pi_K)$$

$$\lambda_p = 0.0113 (20 \times 2.58 \times 3.0)$$

λ_p = 1.75 failures/10^6 hours for a mated pair.

For a single connector, per Table 5.1.12.1-1:

λ_p = 1.75/2 = .88 failures/10^6 hours.

EXAMPLE 3.

Given: A two-piece printed circuit board connector (MIL-C-55302) with 50 active pins will be utilized in a ground fixed environment in which the connector is expected to be connected and disconnected once every 300 hours of operation. Pin size is 22 gage. Ambient temperature will be 25°C, and the expected load current will be 2.0 amperes.

Find: The failure rate of the connector.

Step 1. Calculate the operating temperature by adding the temperature rise in the connector to the ambient temperature, 25°C.

From Table 5.1.12.2-2 ΔT for 22 gage when 2.0 amperes are flowing = 3.6°C.

Operating temperature = ambient + heat rise.
Operating temperature = 25°C + 3.6°C = 28.6°C.

Step 2. From Tbl 5.1.12.2-3 λ_b is determined to be 0.00027 for 28.6°.

Step 3. From Tbl 5.1.12.2-4, π_E for ground environment and MIL-SPEC quality is 3.4.

Step 4. From Tbl 5.1.12.2-6 π_P for 50 pins is determined to be 9.5.

Step 5. From Tbl 5.1.12.2-7 π_K for 3.33 matings/1000 hours is determined to be 2.0.

Step 6. The failure rate of the connector is determined by substituting the values determined into the failure rate equation:

$$\lambda_P = \lambda_b (\pi_E \times \pi_P \times \pi_K)$$

$$\lambda_p = 0.00027 \; (3.4 \times 9.5 \times 2)$$

$$\lambda_p = 0.0174 \text{ failures}/10^6 \text{ hours.}$$

5.1.13 Interconnection Assemblies with Plated Through Holes (PTH).

For other assemblies not using PTH's use Section 5.1.14, Connections.

The failure rate model for plated through hole (PTH) assemblies is:

$$\lambda_p = \lambda_b \pi_Q \pi_E \left[n_1 (\pi_C) + n_2 (\pi_C + 13) \right] \text{ failures}/10^6 \text{ hours/assembly}$$

where

λ_p = base failure rate, Table 5.1.13-1

π_Q = quality factor, Table 5.1.13-2

π_E = environmental factor, Table 5.1.13-4

n_1= quantity of wave soldered functional PTH's

n_2 = quantity of hand soldered PTH's

π_C = complexity factor, Table 5.1.13-5

TABLE 5.1.13-1: BASE FAILURE RATE λ_b

Technology	λ_b failures/10^6 hours
Printed Wiring Assemblies	.000041
Discrete Wiring w/Electroless Deposited PTH*	.00026

*Applies to two or less levels of circuitry

TABLE 5.1.13-2: QUALITY FACTOR π_Q

Quality Grade	π_Q
Manufactured to MIL-SPEC or comparable IPC Standards	1
Lower Quality	2

TABLE 5.1.13-3
SOLDER APPLICATION FACTOR

Process	* Rework Percentage %	** π_S
Wave Solder	0-6	0
	7	0.1
	10	0.5
	15	1.2
	20	1.9
	25	2.6
	30	3.3
	35	4.0
	40	4.7
	over 40	6.0
	unknown	6.0

$* \; \% = \dfrac{\text{no. of reworked connections} \times 100}{\text{total no. of soldered connections}}$ for most recent month.

$** \; \pi_S = .14\,(\%) - .88$

TABLE 5.1.13-5
COMPLEXITY FACTOR π_C

Number of Circuit Planes	π_C
≤ 2	1
3	1.3
4	1.5
5	1.8
6	2.0
7	2.2
8	2.4
9	2.6
10	2.7
11	2.9
12	3.1
13	3.2
14	3.4
15	3.5
16	3.7
Discrete Wiring w/PTH	1

For greather than 16 circuit planes,

$\pi_C = .55\,\ell^{.63}$

ℓ = quantity of circuit planes

TABLE 5.1.13-4
ENVIRONMENTAL MODE FACTORS

Environment	π_E
G_B	1
G_{MS}	1.3
G_F	2.3
G_M	7.7
M_P	6.9
N_{SB}	4.1
N_S	5.3
N_U	12
N_H	13
N_{UU}	14
A_{RW}	19
A_{IC}	2.5
A_{IT}	4.5
A_{IB}	8
A_{IA}	5.5
A_{IF}	10
A_{UC}	7.5
A_{UT}	15
A_{UB}	25
A_{UA}	20
A_{UF}	35
S_F	1
M_{FF}	8.7
M_{FA}	12
U_{SL}	25
M_L	29
C_L	500

Example 1

Given: A plated through hole printed wiring assembly having 6 circuit planes and 700 PTHs is to be used in an uninhabited trainer airborne environment. 560 of the PTHs are filled by wave soldering and 140 by hand soldering. 8 percent of the wave solder connections require rework. All elements of the assembly are in accordance with military specifications.

Step 1 - The general failure rate expression is:

$$\lambda_p = \lambda_b \pi_Q \pi_E [N_1(\pi_C + \pi_S) + N_2(\pi_C + 13)].$$

Step 2 - From Table 5.1.13.-1 the base failure rate for printed wiring assemblies is:

λ_b = .000041 failures/10^6 hr.

Step 3 - From Tables 5.1.13.-2 and 5.1.13.-4:

π_Q = 1

π_E = 15 for A_{UT}.

Step 4 - From Table 5.1.13.-5 for 6 circuit planes:

π_C = 2.

Step 5 - From Table 5.1.13.-3 the application factor for wave solder with 8% rework is:

π_S = 0.2

Step 6 - From the example statement:

N_1 = 560
N_2 = 140.

Step 7 - Obtain the failure rate by substituting values into the model:

$$\lambda_p = .000041 \ (1) \ (15) \ [560(2 + 0.2) + 140(2 + 13)]$$
$$= 2.0 \ \text{failures}/10^6 \ \text{hours}.$$

Example 2

Given: A discrete wiring with electroless deposited PTHs assembly having 2 levels of circuitry and 600 PTHs is to be used in a fixed ground environment. All PTHs are filled by wave soldering, 18 percent of which require rework. All elements of the assembly are in accordance with IPC specifications.

Step 1 - The general failure rate expression, all connections formed by wave solder (See Section 5.1.13.1) is:

$$\lambda_p = \lambda_b \pi_Q \pi_E \left[N_1(\Pi_C + \Pi_S)\right] \text{ because } N_2 = 0$$

Step 2 - From Tables 5.1.13.-1, 5.1.13.-2, and 5.1.13.-4:

λ_b = .00026 failures/10^6 hours
π_Q = 1
π_E = 2.3 for G_F.

Step 3 - From Tables 5.1.13.-3 and 5.1.13.-5:

π_S = 1.6 (18% rework)

π_C = 1.

Step 4 - Given in the example statement:

N = 600.

Step 5 - Obtain the failure rate by substituting the values into the model:

$$\lambda_p = .00026\ (1)\ (2.3)\ (600)\ (1 + 1.6)$$
$$= .93 \text{ failures}/10^6 \text{ hours.}$$

5.1.14 Connections. The failure rate model in this section applies to connections used on all assemblies except those using plated through holes. The failure rate of the structure which supports the connections and parts, *e.g., non-plated-through* hole boards and terminal strips, is considered to be zero.

$$\lambda_p = \Pi_E \sum_{i=1}^{n} N_i \lambda_{bi} (\Pi_{Ti} \times \Pi_{Qi})$$

where:

Π_E = *environmental factor* (Table 5.1.14-2)

N_i = number of connections of the ith type

λ_{bi} = base failure rate of the ith type connection (Table 5.1.14-1)

Π_{Ti} = tool type factor of the ith type connection (Table 5.1.14-3 for crimp type)

= 1 for all types except crimp

Π_{Qi} = quality factorof the ith type connection (Table 5.1.14-4 for crimp type)

= 1 for all types except crimp

TABLE 5.1.14-1

λ_{bi}, BASE FAILURE RATE

CONNECTION TYPE	λ_{bi} (F/10^6 hrs)
Hand Solder, w/o wrapping	.0026
Crimp	.00026
Weld	.00005
Solderless Wrap	.0000035
Hand Soldered, w/wrapping	.00014
Clip Termination	.00012
Reflow Solder	.000069

TABLE 5.1.14-2
ENVIRONMENTAL MODE FACTORS

Environment	π_E
G_B	1
G_{MS}	1.1
G_F	2.1
G_M	7.3
M_P	7.3
N_{SB}	3.5
N_S	4.4
N_U	9.9
N_H	11
N_{UU}	12
A_{RW}	16
A_{IC}	2.5
A_{IT}	4.5
A_{IB}	5.5
A_{IA}	5
A_{IF}	7.5
A_{UC}	3
A_{UT}	6
A_{UB}	7.5
A_{UA}	7
A_{UF}	9.5
S_F	1
M_{FF}	7.3
M_{FA}	10
U_{SL}	22
M_L	25
C_L	420

TABLE 5.1.14-3
TOOL TYPE FACTORS *π_T) FOR CRIMP CONNECTIONS

Tool Type	π_{Ti}
Automated	1
Manual	2

Notes: 1. Automated encompasses all powered tools not handheld.

2. Manual includes all handheld tools.

TABLE 5.1.14-4
QUALITY FACTORS (π_Q) FOR CRIMP CONNECTIONS

Quality Grade	π_{Q1}	Comments
Automated	1.0	Daily pull tests recommended.
Manual Tools:		
Upper	0.5	Only MIL-SPEC or equivalent tools and terminals, pull test at beginning and end of each shift, color coded tools and terminations.
Standard	1.0	Only MIL-SPEC tools, pull test at beginning of each shift
Lower	10.0	Anything less than standard criteria.

Example Failure Rate Calculations

Example 1

Given: A solderless wrap wiring assembly is to be used in an inhabited cargo airborne environment. The assembly consists of 1560 wraps and 156 of the posts are connected to either the ground or voltage planes with reflow solder.

Step 1 - The general failure rate expression is:

$$\lambda_p = \Pi_E \left[(N_1 \lambda_{b1} \Pi_{T1} \Pi_{Q1}) + (N_2 \lambda_{b2} \Pi_{T2} \Pi_{Q2}) \right]$$

where:

λ_{b1} = solderless wrap base failure rate

N_1 = quantity of solderless wraps

Π_{T1} = tool type factor for solderless wrap

Π_{Q1} = quality factor for solderless wrap

λ_{b2} = reflow soldered base failure rate

N_2 = quantity of solder connections

Π_{T2} = tool type factor for reflow solder

Π_{Q2} = quality factor for reflow solder

Step 2 - From Tables 5.1.14-1, 5.1.14-4, and the example statement:

$\Pi_E = 2.5$ for A_{IC}

$\lambda_{b1} = .0000035$ failures/10^6 hours $\quad N_1 = 1560$

$\lambda_{b2} = .000069$ failures/10^6 hours $\quad N_2 = 156$

$\Pi_{T1} = \Pi_{T2} = \Pi_{QT} = \Pi_{Q2} = 1$

Step 3 - Obtain the failure rate by substituting values into the model:

$$\lambda_p = 2.5 \left[(.0000035)(1560)(1)(1) + (.000069)(156)(1)(1)\right]$$
$$= .041 \text{ failures}/10^6 \text{ hours.}$$

Example 2

Given: A wrapped and soldered wiring assembly is to be used in a fixed ground environment. The assembly consists of 4000 wrapped and soldered connections.

Step 1 - The general failure rate expression is:

$$\lambda_p = \Pi_E \lambda_b N \Pi_T \Pi_Q$$

Step 2 - From Tables 5.1.14-1, 5.1.14-2, and the example statement:

$\Pi_E = 2.1$ for fixed ground

$\lambda_b = .00014$ failures/10^6 hours.

$\Pi_T = \Pi_Q = 1$

$N = 4000$

Step 3 - Obtain the failure rate by substituting the values into the model:

$$\lambda_p = (2.1)(.00014)\ (4000)(1)(1)$$

$$= 1.176 \text{ failures}/10^6 \text{ hours.}$$

Example 3

Given: A clip termination wiring assembly is to be used in a sheltered naval environment. The assembly consists of 2400 clip terminations and 100 of the posts are connected to either the ground or voltage planes by reflow solder connections.

Step 1 - The general failure rate expression (See Section 5.1.13.2) is:

$$\lambda_p = \Pi_E\left[(N_1\lambda_{b1}\Pi_{T1}\Pi_{Q1}) + (N_2\lambda_{b2}\Pi_{T2}\Pi_{Q2})\right]$$

where:

λ_{b1} = clip termination base failure rate

N_1 = quantity of clip terminations

Π_{T1} = tool type factor for clip terminations

Π_{Q1} = quality factor for clip terminations

λ_{b2} = reflow solder base failure rate

N_2 = quantity of reflow solder connections

Π_{T2} = tool type factor for reflow solder

Π_{Q2} = quality factor for reflow solder

Step 2 - From Tables 5.1.14-1 and 5.1.14-2 and the problem statement:

Π_E = 4.4 for N_S

λ_{b1} = .00012 failures/10^6 hours N_1 = 2400

λ_{b2} = .000069 failures/10^6 hours. N_2 = 100

$\Pi_{T1} = \Pi_{T2} = \Pi_{Q1} = \Pi_{Q2} = 1$

Step 3 - Obtain the failure rate by substituting values into the model:

$$\lambda_p = 4.4\left[(.00012)\ (2400)(1)(1) + (.000069)\ (100)\ (1)\ (1)\right]$$
$$= 1.298 \text{ failures}/10^6 \text{ hours.}$$

Example 4

Given: A reflow solder printed wiring assembly (no PTHs) is to be used in a space flight environment. The assembly consists of theprinted wiring board and 300 reflow solder connections.

Step 1 - The general failure rate expression (See Section 5.1.13.2) is:

$$\lambda_p = \Pi_E\ \lambda_b\ N\Pi_T\Pi_Q$$

Step 2 - From Tables 5.1.14-1, 5.1.14-2 and the example statement:

Π_E = 1 for S_F

λb = .000069 failures/10^6 hours.

$\Pi_T = \Pi_Q = 1$

Step 3 - Obtain the failure rate by substituting the values into the model:

λ_p = (1)(.000069) (300) (1)(1)

= .021 failures/10^6 hours.

Example 5

Given: An assembly to be used in a fixed ground environment contains 200 crimp connections. The connections are applied with a handheld power tool of a standard quality grade.

Step 1 - The general failure rate expression is:

$\lambda_p = \pi_E (N \lambda_b \pi_T \pi_Q)$

Step 2 - From Tables 5.1.14-1 through 5.1.14-4 and the problem statement:

π_E = 2.1

N = 200

λ_b = .00026 f./10^6 hr.

π_T = 2

π_Q = 1

Step 3 - Obtain the failure rate by substituting the values into the failure rate expression:

λ_p = (2.1)(200)(.00026)(2)(1)

= .22 f./10^6 hr.

5.1.15 Meters

5.1.15.1 Panel Meters

Specification	Description
MIL-M-10304	Meter, Electrical Indicating, Panel Type, Ruggedized.

The part operating failure rate model (λ_p) is:

$$\lambda_p = \lambda_b(\pi_A \times \pi_F \times \pi_Q \times \pi_E)$$

where

λ_p = meter failure rate in failures/10^6 hours

λ_b = base failure rate
= 0.090 F/10^6 hours

π_A = application factor
= 1.0, Direct Current
= 1.7, Alternating Current

π_F = function factor
= 1.0, Ammeter
= 1.0, Voltmeter
= 2.8, Other (meters whose basic meter movement construction is an ammeter with associated internal conversion elements)

π_Q = quality factor
= 1.0, MIL-SPEC quality
= 3.4, lower quality

π_E = environmental factor (see Table 5.1.15-1)

TABLE 5.1.15-1 : ENVIRONMENTAL FACTOR

Environment	π_E	Environment	π_E
G_B	1.0	A_{IA}	42
G_{MS}	1.4	A_{IF}	42
G_F	3.8	A_{UC}	50
G_M	24	A_{UT}	50
M_P	26	A_{UB}	73
N_{SB}	11	A_{UA}	73
N_S	14	A_{UF}	73
N_U	36	S_F	2.1
N_H	41	M_{FF}	13
N_{UU}	29	M_{FA}	N/A
A_{RW}	60	U_{SL}	N/A
A_{IC}	21	M_L	94
A_{IT}	21	C_L	N/A
A_{IB}	42		

* N/A - Not normally applied

5.1.15.2 Example Failure Rate Calculations

Example 1.

Given: A MIL-M-10304 panel AC ammeter used in an airborne cargo inhabited environment.

Step 1.

The failure rate of the meter is found by substituting the values of λ_b, π_A, π_F, π_Q and π_E into the part failure rate model:

$$\lambda_p = \lambda_b(\pi_A \times \pi_F \times \pi_Q \times \pi_E) \text{ failures}/10^6 \text{ hours}$$

$$\lambda_p = 0.09(1.7 \times 1.0 \times 1.0 \times 21) \text{ failures}/10^6 \text{ hours}$$

$$\lambda_p = 3.2 \text{ F}/10^6 \text{ hours}$$

Example 2.

Given: A commercial panel type frequency meter with a construction similar to MIL-M-10304 panel meters. The meter operates the same as a DC ammeter. It is used in a ground, mobile application.

Step 1.

The failure rate of the meter is found by substituting the values of λ_b, π_A, π_F, π_Q and π_E into the part failure rate model:

$$\lambda_p = \lambda_b(\pi_A \times \pi_F \times \pi_Q \times \pi_E) \text{ failures}/10^6 \text{ hours}$$

$$\lambda_p = 0.09(1.0 \times 2.8 \times 3.4 \times 24) \text{ failures}/10^6 \text{ hours}$$

$$\lambda_p = 21 \text{ F}/10^6 \text{ hours}$$

5.1.16 Quartz Crystals

Specification	Description
MIL-C-3098	Crystal Units, Quartz

The part operating failure rate model (λ_p) is:

$$\lambda_p = \lambda_b \times \pi_Q \times \pi_E$$

where

λ_p = quartz crystal failure rate (F/10^6 hours)

λ_b = base failure rate

$\lambda_b = 0.013\ (f)^{0.23}$ failures/10^6 hours (f = frequency (MHz))

π_Q = quality factor

= 1.0, MIL-SPEC quality
= 2.1, lower quality

π_E = environmental factor (see Table 5.1.16-1)

TABLE 5.1.16-1: ENVIRONMENTAL FACTOR

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	17
G_{MS}	1.2	A_{IF}	17
G_F	2.6	A_{UC}	19
G_M	10	A_{UT}	19
M_P	11	A_{UB}	28
N_{SB}	5.4	A_{UA}	28
N_S	6.5	A_{UF}	28
N_U	14	S_F	1
N_H	16	M_{FF}	11
N_{UU}	17	M_{FA}	15
A_{RW}	23	U_{SL}	30
A_{IC}	9	M_L	35
A_{IT}	9	C_L	500
A_{IB}	17		

5.1.17 Lamps

5.1.17.1 Lamps, Incandescent

SPECIFICATION	DESCRIPTION
MIL-L-6363	Lamps, Incandescent, Aviation Service
W-L-111	Lamp, Incandescent, (Electric, Miniature, Tungsten-Filament)

The part operating failure rate model (λ_p) is:

$$\lambda_p = \lambda_b \times \pi_u \times \pi_A \times \pi_E$$

where

λ_p = incandescent lamp failure rate (F/10^6 hours)

λ_b = base failure rate

λ_b = $0.074(V_r)^{1.29}$ f/10^6 hrs. (V_r = rated voltage (volts)) (see Table 5.1.17-1

π_u = utilization factor (see Table 5.1.17-2

π_A = application factor

= 1.0, AC applications
= 3.3, DC applications

π_E = environmental factor (see Table 5.1.17-3

TABLE 5.1.17-1 : BASE FAILURE RATE

V_r	λ_b
5	0.590
6	0.746
12	1.825
14	2.23
24	4.46
28	5.45
37.5	7.94

LAMPS

TABLE 5.1.17-2: UTILIZATION FACTORS

Utilization (Illuminate hours/ equipment operate hours)	π_U
< 0.10	0.10
0.10 to 0.90	0.72
> 0.90	1.0

TABLE 5.1.17-3: ENVIRONMENTAL FACTORS

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	4.4
G_{MS}	1.1	A_{IF}	4.4
G_F	1.6	A_{UC}	4.8
G_M	3.4	A_{UT}	4.8
M_P	3.5	A_{UB}	5.8
N_{SB}	2.4	A_{UA}	5.8
N_S	2.7	A_{UF}	5.8
N_U	4.1	S_F	1.4
N_H	4.4	M_{FF}	3.5
N_{UU}	4.5	M_{FA}	4.2
A_{RW}	5.3	U_{SL}	6.1
A_{IC}	3.2	M_L	6.5
A_{IT}	3.2	C_L	27
A_{IB}	4.4		

5.1.17.2 Examples For Use of Lamp Models

Example 1:

Given: A 6.3 volt incandescent lamp, used as a tail warning radar indicator in the inhabited portion of a fighter aircraft. The voltage source is AC. The ratio of illuminate hours to equipment operate hours is less than 5%.

Step 1: Calculate the base failure rate (λ_b)

$\lambda_b = 0.074\ (6.3)^{1.29} = 0.795$ F/10^6 hours

Step 2: From Table 5.1.17-2 ., $\pi_u = 0.10$

Step 3: From Table 5.1.17-3 A_{IF} service, $\pi_E = 4.4$

Step 4: Application factor AC service, $\pi_A = 1.0$

Step 5: Calculate the total lamp failure rate (λ_p)

$\lambda_p = \lambda_b \times \pi_u \times \pi_E \times \pi_A$

$\lambda_p = (0.795 \times 0.10 \times 4.4 \times 1.0)$ F/10^6 hours

$\lambda_p = 0.350$ F/10^6 hours

Example 2:

Given: A 12 volt incandescent lamp, used as a power indicator in a ground, fixed environment. The voltage source is DC. The ratio of illuminate hours to equipment operate hours is 1.0.

Step 1: Calculate the base failure rate (λ_b)

$\lambda_b = 0.074\ (12)^{1.29} = 1.83$ F/10^6 hours

Step 2: From Table 5.1.17-2 , $\pi_u = 1.0$

Step 3: From Table 5.1.17-3 G_F service, $\pi_E = 1.6$

Step 4: Application factor DC service, $\pi_A = 3.3$

Step 5: Calculate the total lamp failure rate (λ_p)

$$\lambda_p = \lambda_b \times \pi_U \times \pi_E \times \pi_A$$

$$\lambda_p = (1.83 \times 1.0 \times 1.6 \times 3.3) \text{ F}/10^6 \text{ hours}$$

$$\lambda_p = 9.66 \text{ F}/10^6 \text{ hours}$$

5.1.18 Electronic Filters (Non-tunable) Prediction Procedure

Specification	Description
MIL-F-15733	Filters, Radio Frequency Interference
MIL-F-18327	Filters; High Pass, Low Pass, Band Pass, Band Suppression, and Dual Functioning (Non-tunable)

The part failure rate prediction procedure is as follows:

Step 1: If a Parts List and/or Schematic Diagram are available.

Step 1A: Calculate a failure rate for each particular component in the filter assembly using the correct model from the following sections:

Integrated Circuits	Section 5.1.2
Discrete Semiconductors	Section 5.1.3
Resistors	Section 5.1.6
Capacitors	Section 5.1.7
Inductive Devices	Section 5.1.8
Printed Wiring Assemblies	Section 5.1.13
Crystals	Section 5.1.16

Step 1B: Sum the failure rate contribution for each component. The filter failure rate (λ_p) then is:

$$\lambda_p = \sum_{i=1}^{n} \lambda_i$$

where

λ_p = filter failure rate (F/10^6 hours)

λ_i = failure rate of each individual component (F/10^6 hours)

Step 2: If a parts list but no schematic diagram is available, or if the part complement can be determined by other means (e.g. disection).

Step 2A: Calculate a failure rate for each component type and for the filter as an assembly using the procedure discussed in Section 5.2.

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Step 3: If no parts list or schematic diagram are available, calculate the filter failure rate using the following model:

$$\lambda_p = \lambda_b \times \pi_Q \times \pi_E$$

where

λ_p = filter failure rate (F/10^6 hours)

λ_b = base failure rate

= 0.0219 F/10^6 hours for MIL-F-15733, ceramic-ferrite construction (styles FL 10-16, 22, 24, 30-32, 34, 35, 38, 41-43, 45, 47-50, 61-65, 70, 81-93, 95, 96)

= 0.120 F/10^6 hours for MIL-F-15733, discrete LC components (styles FL 37, 53, 74)

= 0.120 F/10^6 hours for MIL-F-18327, discrete LC components (composition 1)

= 0.265 F/10^6 hours for MIL-F-18327, discrete LC and crystal components (composition 2)

π_E = environmental factor (Table 5.1.18-1)

π_Q = quality factor

= 1, MIL-SPEC quality
= 2.9, lower quality

TABLE 5.1.18-1: ENVIRONMENTAL FACTOR

Environment	π_E	Environment	π_E
G_B	1	A_{IA}	8.8
G_{MS}	1.1	A_{IF}	8.8
G_F	2.1	A_{UC}	10
G_M	6	A_{UT}	10
M_P	6.4	A_{UB}	13
N_{SB}	3.7	A_{UA}	13
N_S	4.3	A_{UF}	13
N_U	7.9	S_F	1.7
N_H	8.7	M_{FF}	6.4
N_{UU}	9.2	M_{FA}	8.2
A_{RW}	11	U_{SL}	14
A_{IC}	5.5	M_L	16
A_{IT}	5.8	C_L	120
A_{IB}	8.8		

5.1.18.1 Examples

Example 1:

Step 1: Given: A MIL-F-18327, Composition 1 band pass filter that is used in a ground, fixed environment. A parts list is provided with the following part complement:

RF Coil, MIL-SPEC	- 4 each
Plastic Capacitor, MIL-SPEC	- 5 each
Paper/Plastic Capacitor, MIL-SPEC	- 2 each
Mica Capacitor, MIL-SPEC	- 1 each
Printed Wiring Board, 2-Sided	- 1 each
Solder Connections	- 24 each

Step 2: From Section 5.2 calculate a failure rate for each componenet type.

Plastic (CRH) .0085 f/10^6 hours
Paper/Plastic (CH) .049 f/10^6 hours
Mica (CM) .011 f/10^6 hours
RF Coil .011 f/10^6 hours
PW board .0029 f/10^6 hours
Connections .00017 f/10^6 hours

Step 3: From Section 5.2 calculate a failure rate for the filter assembly.

$$\lambda_p = (4 \times .011) + (5 \times .0085) + (2 \times .049) + (1 \times .011) + (1 \times .0029) + (24 \times .00017)$$

$$\lambda_p = 0.2025 \text{ f}/10^6 \text{ hours}$$

Example 2:

Step 1: Given: A MIL-F-18327, Composition 1 band pass filter that is used in a ground, fixed environment. No parts list or schematic diagrams are available and the part complement can not be determined.

Step 2: From Section 5.1.18 Step 3 Calculate a failure rate for the filter assembly.

$$\lambda_p = \lambda_b \times \pi_Q \times \pi_E$$

Step 2A: $\lambda_b = 0.120$ f/10^6 hours

Step 2B: $\pi_Q = 1$

Step 2C: Table 5.1.18-1 $\pi_E = 2.1$, GF

Step 2D: $\lambda_p = 0.120$ f/10^6 hours x 1 x 2.1

$\lambda_p = 0.252$ F/10^6 hours

5.1.19 Fuses

SPECIFICATION	DESCRIPTION
W-F-1726	Fuse, Cartridge Class H
W-F-1814	Fuse, Cartridge, High Interrupting Capacity
MIL-F-5372	Fuse, Current Limiter Type, Aircraft
MIL-F-23419	Fuses, Instrument Type
MIL-F-15160	Fuses; Instrument, Power and Telephone (nonindicating), style F01

The part operating failure rate model is:

$$\lambda_p = \lambda_b \times \pi_E$$

where

λ_p = total device operating failure rate (f/10^6 hours)

λ_b = base failure rate = 0.010 f/10^6 hours

π_E = environmental factor (see Table 5.1.19-1)

TABLE 5.1.19-1: ENVIRONMENTAL FACTORS

Environment	π_E	Environment	π_E
G_B	1.0	A_{IA}	12
G_{MS}	1.2	A_{IF}	12
G_F	2.3	A_{UC}	13
G_M	7.5	A_{UT}	13
M_P	8.1	A_{UB}	18
N_{SB}	4.4	A_{UA}	18
N_S	5.2	A_{UF}	18
N_U	10	S_F	1.8
N_H	12	M_{FF}	8.1
N_{UU}	12	M_{FA}	11
A_{RW}	16	U_{SL}	20
A_{IC}	6.8	M_L	22
A_{IT}	6.8	C_L	230
A_{IB}	12		

5.1.20 Miscellaneous Parts.

TABLE 5.1.20-1
FAILURE RATES FOR MISCELLANEOUS PARTS (FAILURES/10^6 HOURS)

Part Type	Specification	Failure Rate
Vibrators	MIL-V-95	
60-cycle		15.0
120-cycle		20.0
400-cycle		40.0
Lamps		
Neon Lamps		0.20
Fiber Optic Cables (single fiber types only)		0.1 (per fiber·km)
Single Fiber Optic Connectors*		0.1
Microwave elements (coaxial & waveguide)		
Attenuators (fixed and variable)		see resistors, type RD
Fixed Elements (directional couplers, fixed stubs & cavities)		see coaxial connectors
Variable Elements (tuned stubs & tuned cavities)		0.1

*Caution: Excessive mating-demating cycles may seriously degrade reliability

TABLE 5.1.20-1 (Cont'd)

FAILURE RATES FOR MISCELLANEOUS PARTS (FAILURES/10^6 HOURS)

PART TYPE	FAILURE RATE
Microwave Ferrite Devices	
Isolators & Circulators ($\leq$ 100W.)	$0.1 \times \pi_{E1}$***
Isolators & Circulators (> 100W.)	$0.2 \times \pi_{E1}$
Phase Shifter (latching)	$0.1 \times \pi_{E1}$
Dummy Loads	
< 100W.	$0.01 \times \pi_{E2}$***
100W. to $\leq$1000W.	$0.03 \times \pi_{E2}$
> 1000W.	$0.1 \times \pi_{E2}$
Terminations (thin or thick film loads used in stripline and thin film circuits	$0.03 \times \pi_{E2}$

*** - See Table 5.1.20-2 for π_E values.

TABLE 5.1.20-2

ENVIRONMENTAL MODE FACTORS FOR MICROWAVE FERRITE DEVICES AND DUMMY LOADS

ENVIRON-MENT	π_{E1}	π_{E2}
G_B	1	1
G_{MS}	1.2	1.2
G_F	2.4	2.4
G_M	8.8	8.8
M_P	7.7	11
N_{SB}	3.7	5.1
N_S	6.2	5.1
N_U	12	15
N_H	12	18
N_{UU}	13	19
A_{RW}	17	25
A_{IC}	3.5	3
A_{IT}	4.5	5.5
A_{IB}	7	8
A_{IA}	6.5	5.5
A_{IF}	10	10
A_{UC}	4.5	8
A_{UT}	6.5	15
A_{UB}	9.5	20
A_{UA}	7.5	15
A_{UF}	15	30
S_F	1	1
M_{FF}	7.8	12
M_{FA}	11	16
U_{SL}	23	34
M_L	26	39
C_L	450	660

5.2 Parts Count Reliability Prediction. This prediction method is applicable during bid proposal and early design phases. The information needed to apply the method is (1) generic part types (including complexity for microelectronics) and quantities, (2) part quality levels, and (3) equipment environment. The general expression for equipment failure rate with this method is:

$$\lambda_{EQUIP} = \sum_{i=1}^{i=n} N_i (\lambda_G \pi_Q)_i \qquad (1)$$

for a given equipment environment where:

λ_{EQUIP} = total equipment failure rate (failures/10^6 hr.)

λ_G = generic failure rate for the i th generic part (failures/10^6 hr.)

π_Q = quality factor for the i th generic part

N_i = quantity of i th generic part

n = number of different generic part categories.

The above expression (1) applies if the entire equipment is being used in one environment. If the equipment comprises several units operating in different environments (such as avionics with units in airborne inhabited (A_I) and uninhabited (A_U) environments), then equation (1) should be applied to the portions of the equipment in each environment. These "environment-equipment" failure rates should be added to determine total equipment failure rate. Environmental symbols are as defined in Table 5.1.1-3, page 5.1.1-3.

The quality factors to be used with each part type are shown with the applicable λ_G tables and are not necessarily the same values that are used in Section 5.1, Part Stress Analysis. Multi-quality levels are presented for microelectronics, discrete semiconductors, and for established reliability (ER) resistors and capacitors. The λ_G values for the remaining parts apply providing that the parts are procurred in accordance with the applicable parts specifications and, for these parts, π_Q=1. Microelectronic devices have an additional multiplying factor, π_L (learning factor) as defined in Table 5.2-9.

It should be noted that no generic failure rates are shown for hybrid microcircuits. Each hybrid is a fairly unique device. Since none of these devices have been standardized, their complexity cannot be determined from their name or function. Identically or similarly named hybrids can have a wide range of complexity that thwarts categorization for purposes of this prediction method. If hybrids are anticipated for a design, their use and construction should be thoroughly investigated on an individual basis with application of the prediction model in Section 5.1.2.9.

The failure rates for this procedure were calculated using the failure rate models of Section 5.1 The values used for the model parameters are shown in Tables 5.2-20 through 5.2-25. For the discrete parts a stress ratio of 0.5 was used.

TABLE 5.2-1 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS DIGITAL DEVICES INCLUDING SHIFT REGISTERS IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF GATES	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR MOS	0.0057 0.0061	0.0075 0.0080	0.0211 0.0222	0.0331 0.0349	0.0275 0.0282	0.0301 0.0313	0.0301 0.0313	0.0670 0.0805	0.0416 0.0428	0.0400 0.0401	0.0643 0.0680
>100 - 1000	BIPOLAR MOS	0.0106 0.0115	0.0137 0.0147	0.0368 0.0391	0.0573 0.0608	0.0469 0.0484	0.0517 0.0540	0.0517 0.0540	0.1218 0.1489	0.0707 0.0730	0.0666 0.0668	0.1104 0.1178
>1,000 - 3,000	BIPOLAR MOS	0.0207 0.0225	0.0265 0.0285	0.0704 0.0750	0.1094 0.1164	0.0890 0.0920	0.0984 0.1030	0.0984 0.1030	0.2366 0.2907	0.1339 0.1385	0.1253 0.1257	0.2101 0.2250
>3,000-10,000	BIPOLAR MOS	0.0569 0.0604	0.0796 0.0835	0.2427 0.2519	0.3900 0.4039	0.3330 0.3388	0.3599 0.3691	0.3599 0.3691	0.7055 0.8137	0.5084 0.5176	0.5074 0.5083	0.7668 0.7965
>10,000-30,000	BIPOLAR MOS	0.0995 0.1066	0.1348 0.1426	0.3919 0.4103	0.6227 0.6507	0.5237 0.5354	0.5701 0.5886	0.5701 0.5886	1.1976 1.4141	0.7960 0.8144	0.7789 0.7808	1.2153 1.2749
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR MOS	0.0280 0.0317	0.0310 0.0347	0.0431 0.0468	0.0370 0.0408	0.0491 0.0529	0.0794 0.1106	0.0855 0.1166	0.1067 0.1378	0.0976 0.1287	0.1157 0.1469	0.0114 0.0125
>100 - 1000	BIPOLAR MOS	0.0506 0.0580	0.0555 0.0630	0.0755 0.0829	0.0655 0.0730	0.0855 0.0929	0.1524 0.2147	0.1624 0.2247	0.1973 0.2596	0.1825 0.2446	0.2122 0.2745	0.0208 0.0231
>1,000 - 3,000	BIPOLAR MOS	0.0980 0.1129	0.1073 0.1222	0.1447 0.1596	0.1260 0.1409	0.1634 0.1783	0.3011 0.4257	0.3197 0.4443	0.3851 0.5098	0.3571 0.4817	0.4132 0.5378	0.0405 0.0451
>3,000-10,000	BIPOLAR MOS	0.2979 0.3277	0.3370 0.3667	0.4933 0.5230	0.4151 0.4449	0.5714 0.6012	0.7244 0.9736	0.8026 1.0518	1.0761 1.3253	0.9588 1.2081	1.1933 1.4425	0.1177 0.1269
>10,000-30,000	BIPOLAR MOS	0.5022 0.5618	0.5616 0.6212	0.7994 0.8589	0.6805 0.7400	0.9182 0.9778	1.3365 1.8349	1.4554 1.9538	1.8714 2.3698	1.6931 2.1915	2.0496 2.5481	0.2017 0.2201
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR MOS	0.0364 0.0402	0.0404 0.0422	0.0711 0.0718	0.0915 0.0953	1.3380 1.3391						
>100 - 1000	BIPOLAR MOS	0.0645 0.0720	0.0693 0.0728	0.1187 0.1201	0.1552 0.1627	2.2052 2.2075						
>1,000 - 3,000	BIPOLAR MOS	0.1242 0.1390	0.1318 0.1388	0.2236 0.2265	0.2942 0.3091	4.1350 4.1397						
>3,000-10,000	BIPOLAR MOS	0.4073 0.4371	0.4837 0.4977	0.8956 0.9015	1.1184 1.1482	17.2391 17.2484						
>10,000-30,000	BIPOLAR MOS	0.6686 0.7282	0.7653 0.7933	1.3795 1.3911	1.7502 1.8097	26.2427 26.2611						

TABLE 5.2-2 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS DIGITAL DEVICES INCLUDING SHIFT REGISTERS IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF GATES	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR	0.0061	0.0080	0.0222	0.0349	0.0282	0.0313	0.0313	*******	0.0428	0.0401	0.0680
	MOS	0.0094	0.0117	0.0323	0.0517	0.0341	0.0414	0.0414	*******	0.0529	0.0409	0.1107
>100 - 1000	BIPOLAR	0.0115	0.0147	0.0391	0.0608	0.0484	0.0540	0.0540	*******	0.0730	0.0668	0.1178
	MOS	0.0179	0.0220	0.0593	0.0945	0.0601	0.0743	0.0743	*******	0.0932	0.0683	0.2032
>1,000 - 3,000	BIPOLAR	0.0225	0.0285	0.0750	0.1164	0.0920	0.1030	0.1030	*******	0.1385	0.1257	0.2250
	MOS	0.0354	0.0432	0.1155	0.1837	0.1154	0.1436	0.1436	*******	0.1791	0.1287	0.3957
>3,000-10,000	BIPOLAR	0.0604	0.0835	0.2519	0.4039	0.3388	0.3691	0.3691	*******	0.5176	0.5083	0.7965
	MOS	0.0863	0.1128	0.3330	0.5386	0.3858	0.4502	0.4502	*******	0.5987	0.5143	1.1379
>10,000-30,000	BIPOLAR	0.1066	0.1426	0.4103	0.6507	0.5354	0.5886	0.5886	*******	0.8144	0.7808	1.2749
	MOS	0.1584	0.2013	0.5724	0.9200	0.6294	0.7507	0.7507	*******	0.9765	0.7927	1.9577
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR	0.0317	0.0347	0.0468	0.0408	0.0529	*******	*******	*******	*******	*******	0.0125
	MOS	0.0744	0.0774	0.0895	0.0834	0.0955	*******	*******	*******	*******	*******	0.0227
>100 - 1000	BIPOLAR	0.0580	0.0630	0.0829	0.0730	0.0929	*******	*******	*******	*******	*******	0.0231
	MOS	0.1434	0.1483	0.1683	0.1583	0.1782	*******	*******	*******	*******	*******	0.0434
>1,000 - 3,000	BIPOLAR	0.1129	0.1222	0.1596	0.1409	0.1783	*******	*******	*******	*******	*******	0.0451
	MOS	0.2836	0.2929	0.3303	0.3116	0.3490	*******	*******	*******	*******	*******	0.0856
>3,000-10,000	BIPOLAR	0.3277	0.3667	0.5230	0.4449	0.6012	*******	*******	*******	*******	*******	0.1269
	MOS	0.6691	0.7081	0.8644	0.7863	0.9426	*******	*******	*******	*******	*******	0.2080
>10,000-30,000	BIPOLAR	0.5618	0.6212	0.8589	0.7400	0.9778	*******	*******	*******	*******	*******	0.2201
	MOS	1.2445	1.3040	1.5417	1.4228	1.6605	*******	*******	*******	*******	*******	0.3822
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR	0.0402	0.0422	0.0718	0.0953	1.3391						
	MOS	0.0828	0.0590	0.0777	0.1379	1.3493						
>100 - 1000	BIPOLAR	0.0720	0.0728	0.1201	0.1627	2.2075						
	MOS	0.1573	0.1064	0.1319	0.2480	2.2278						
>1,000 - 3,000	BIPOLAR	0.1390	0.1388	0.2265	0.3091	4.1397						
	MOS	0.3097	0.2061	0.2500	0.4798	4.1802						
>3,000-10,000	BIPOLAR	0.4371	0.4977	0.9015	1.1482	17.2484						
	MOS	0.7785	0.6324	0.9485	1.4896	17.3294						
>10,000-30,000	BIPOLAR	0.7282	0.7933	1.3911	1.8097	26.2611						
	MOS	1.4109	1.0626	1.4851	2.4925	26.4232						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-3 GENERIC FAILURE RATE, λ_G, FOR PROGRAMMABLE LOGIC ARRAYS (PLA) AND PROGRAMMABLE ARRAY LOGIC (PAL) IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF GATES	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR MOS	0.0227 0.0253	0.0255 0.0285	0.0507 0.0576	0.0717 0.0822	0.0500 0.0544	0.0597 0.0666	0.0597 0.0666	0.2296 0.3107	0.0712 0.0782	0.0494 0.0502	0.1284 0.1507
>100 - 1000	BIPOLAR MOS	0.0445 0.0498	0.0496 0.0555	0.0960 0.1098	0.1345 0.1555	0.0919 0.1007	0.1109 0.1247	0.1109 0.1247	0.4469 0.6093	0.1299 0.1437	0.0854 0.0868	0.2386 0.2832
>1,000 - 5,000	BIPOLAR MOS	0.0886 0.0992	0.0985 0.1102	0.1888 0.2164	0.2637 0.3057	0.1791 0.1966	0.2168 0.2445	0.2168 0.2445	0.8867 1.2114	0.2523 0.2800	0.1629 0.1658	0.4665 0.5558
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR MOS	0.0920 0.1144	0.0951 0.1174	0.1072 0.1295	0.1011 0.1235	0.1132 0.1356	0.3856 0.5726	0.3917 0.5786	0.4129 0.5998	0.4038 0.5907	0.4220 0.6089	0.0410 0.0479
>100 - 1000	BIPOLAR MOS	0.1787 0.2234	0.1837 0.2284	0.2037 0.2483	0.1937 0.2383	0.2136 0.2583	0.7649 1.1387	0.7748 1.1487	0.8097 1.1836	0.7948 1.1686	0.8247 1.1985	0.0800 0.0938
>1,000 - 5,000	BIPOLAR MOS	0.3543 0.4437	0.3637 0.4530	0.4011 0.4904	0.3824 0.4717	0.4198 0.5091	1.5260 2.2736	1.5447 2.2923	1.6101 2.3577	1.5821 2.3297	1.6381 2.3858	0.1589 0.1865
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR MOS	0.1005 0.1228	0.0790 0.0895	0.0936 0.0980	0.1556 0.1779	1.3676 1.3745						
>100 - 1000	BIPOLAR MOS	0.1927 0.2374	0.1465 0.1674	0.1637 0.1725	0.2834 0.3281	2.2644 2.2782						
>1,000 - 5,000	BIPOLAR MOS	0.3805 0.4698	0.2861 0.3281	0.3137 0.3312	0.5506 0.6399	4.2534 4.2811						

TABLE 5.2-4 GENERIC FAILURE RATE, λ_G, FOR PROGRAMMABLE LOGIC ARRAYS (PLA) AND PROGRAMMABLE ARRAY LOGIC (PAL) IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF GATES	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR	0.0253	0.0285	0.0576	0.0822	0.0544	0.0666	0.0666	*******	0.0782	0.0502	0.1507
	MOS	0.0447	0.0504	0.1184	0.1832	0.0897	0.1274	0.1274	*******	0.1390	0.0546	0.4067
>100 - 1000	BIPOLAR	0.0498	0.0555	0.1098	0.1555	0.1007	0.1247	0.1247	*******	0.1437	0.0868	0.2832
	MOS	0.0887	0.0995	0.2314	0.3575	0.1712	0.2463	0.2463	*******	0.2653	0.0958	0.7953
>1,000 - 5,000	BIPOLAR	0.0992	0.1102	0.2164	0.3057	0.1966	0.2445	0.2445	*******	0.2800	0.1658	0.5558
	MOS	0.1769	0.1982	0.4596	0.7097	0.3376	0.4877	0.4877	*******	0.5232	0.1836	1.5800
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR	0.1144	0.1174	0.1295	0.1235	0.1356	*******	*******	*******	*******	*******	0.0479
	MOS	0.3704	0.3734	0.3856	0.3795	0.3916	*******	*******	*******	*******	*******	0.1087
>100 - 1000	BIPOLAR	0.2234	0.2284	0.2483	0.2383	0.2583	*******	*******	*******	*******	*******	0.0938
	MOS	0.7355	0.7405	0.7604	0.7504	0.7704	*******	*******	*******	*******	*******	0.2154
>1,000 - 5,000	BIPOLAR	0.4437	0.4530	0.4904	0.4717	0.5091	*******	*******	*******	*******	*******	0.1865
	MOS	1.4678	1.4772	1.5146	1.4959	1.5332	*******	*******	*******	*******	*******	0.4297
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR	0.1228	0.0895	0.0980	0.1779	1.3745						
	MOS	0.3789	0.1905	0.1333	0.4340	1.4353						
>100 - 1000	BIPOLAR	0.2374	0.1674	0.1725	0.3281	2.2782						
	MOS	0.7494	0.3694	0.2430	0.8402	2.3998						
>1,000 - 5,000	BIPOLAR	0.4698	0.3281	0.3312	0.6399	4.2811						
	MOS	1.4940	0.7321	0.4722	1.6641	4.5243						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-5 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS LINEAR DEVICES IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF TRANSISTORS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR	0.0069	0.0086	0.0229	0.0358	0.0266	0.0306	0.0306	0.1217	0.0404	0.0346	0.0712
	MOS	0.0069	0.0086	0.0229	0.0358	0.0266	0.0306	0.0306	0.1217	0.0404	0.0346	0.0712
>100 - 300	BIPOLAR	0.0125	0.0151	0.0377	0.0579	0.0407	0.0482	0.0482	0.2246	0.0615	0.0486	0.1146
	MOS	0.0125	0.0151	0.0377	0.0579	0.0407	0.0482	0.0482	0.2246	0.0615	0.0486	0.1146
>300 - 1,000	BIPOLAR	0.0234	0.0276	0.0653	0.0989	0.0662	0.0802	0.0802	0.4263	0.0992	0.0719	0.1949
	MOS	0.0234	0.0276	0.0653	0.0989	0.0662	0.0802	0.0802	0.4263	0.0992	0.0719	0.1949
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR	0.0404	0.0430	0.0532	0.0481	0.0584	0.2259	0.2310	0.2490	0.2413	0.2567	0.0147
	MOS	0.0404	0.0430	0.0532	0.0481	0.0584	0.2259	0.2310	0.2490	0.2413	0.2567	0.0147
>100 - 300	BIPOLAR	0.0726	0.0761	0.0901	0.0831	0.0971	0.4419	0.4489	0.4734	0.4629	0.4839	0.0265
	MOS	0.0726	0.0761	0.0901	0.0831	0.0971	0.4419	0.4489	0.4734	0.4629	0.4839	0.0265
>300 - 1,000	BIPOLAR	0.1351	0.1401	0.1600	0.1501	0.1700	0.8717	0.8817	0.9166	0.9016	0.9315	0.0493
	MOS	0.1351	0.1401	0.1600	0.1501	0.1700	0.8717	0.8817	0.9166	0.9016	0.9315	0.0493
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR	0.0476	0.0420	0.0636	0.0943	1.1404						
	MOS	0.0476	0.0420	0.0636	0.0943	1.1404						
>100 - 300	BIPOLAR	0.0824	0.0663	0.0911	0.1461	1.5599						
	MOS	0.0824	0.0563	0.0911	0.1461	1.5599						
>300 - 1,000	BIPOLAR	0.1491	0.1108	0.1380	0.2398	2.2337						
	MOS	0.1491	0.1108	0.1380	0.2398	2.2337						

TABLE 5.2-6 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS LINEAR DEVICES IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF TRANSISTORS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR MOS	0.0110 0.0110	0.0134 0.0134	0.0374 0.0374	0.0612 0.0612	0.0345 0.0345	0.0451 0.0451	0.0451 0.0451	******* *******	0.0549 0.0549	0.0355 0.0355	0.1423 0.1423
>100 - 300	BIPOLAR MOS	0.0207 0.0207	0.0246 0.0246	0.0666 0.0666	0.1086 0.1086	0.0566 0.0566	0.0771 0.0771	0.0771 0.0771	******* *******	0.0904 0.0904	0.0503 0.0503	0.2568 0.2568
>300 - 1,000	BIPOLAR MOS	0.0399 0.0399	0.0465 0.0465	0.1231 0.1231	0.2002 0.2002	0.0979 0.0979	0.1381 0.1381	0.1381 0.1381	******* *******	0.1570 0.1570	0.0753 0.0753	0.4793 0.4793
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR MOS	0.1115 0.1115	0.1140 0.1140	0.1243 0.1243	0.1192 0.1192	0.1295 0.1295	******* *******	******* *******	******* *******	******* *******	******* *******	0.0292 0.0292
>100 - 300	BIPOLAR MOS	0.2148 0.2148	0.2183 0.2183	0.2323 0.2323	0.2253 0.2253	0.2393 0.2393	******* *******	******* *******	******* *******	******* *******	******* *******	0.0554 0.0554
>300 - 1,000	BIPOLAR MOS	0.4195 0.4195	0.4244 0.4244	0.4444 0.4444	0.4344 0.4344	0.4543 0.4543	******* *******	******* *******	******* *******	******* *******	******* *******	0.1072 0.1072
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR MOS	0.1187 0.1187	0.0673 0.0673	0.0715 0.0715	0.1654 0.1654	1.1548 1.1548						
>100 - 300	BIPOLAR MOS	0.2246 0.2246	0.1170 0.1170	0.1070 0.1070	0.2882 0.2882	1.5888 1.5888						
>300 - 1,000	BIPOLAR MOS	0.4334 0.4334	0.2122 0.2122	0.1697 0.1697	0.5241 0.5241	2.2916 2.2916						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-7 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS DIGITAL MICROPROCESSOR DEVICES IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
8	BIPOLAR	0.0173	0.0229	0.0645	0.1016	0.0845	0.0925	0.0925	0.2040	0.1280	0.1234	0.1973
	MOS	0.0186	0.0244	0.0679	0.1069	0.0867	0.0960	0.0960	0.2446	0.1315	0.1237	0.2085
16	BIPOLAR	0.0330	0.0432	0.1188	0.1862	0.1536	0.1688	0.1688	0.3849	0.2321	0.2212	0.3601
	MOS	0.0357	0.0462	0.1257	0.1967	0.1580	0.1757	0.1757	0.4661	0.2390	0.2219	0.3824
32	BIPOLAR	0.0705	0.0940	0.2664	0.4208	0.3510	0.3836	0.3836	0.8355	0.5321	0.5149	0.8180
	MOS	0.0758	0.0998	0.2802	0.4418	0.3598	0.3974	0.3974	0.9979	0.5459	0.5163	0.8627
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
8	BIPOLAR	0.0852	0.0945	0.1319	0.1132	0.1506	0.2398	0.2585	0.3239	0.2959	0.3519	0.0346
	MOS	0.0963	0.1057	0.1431	0.1244	0.1617	0.3333	0.3519	0.4174	0.3893	0.4454	0.0380
16	BIPOLAR	0.1602	0.1768	0.2435	0.2102	0.2768	0.4674	0.5007	0.6173	0.5674	0.6673	0.0655
	MOS	0.1825	0.1992	0.2658	0.2325	0.2991	0.6543	0.6877	0.8043	0.7543	0.8542	0.0724
32	BIPOLAR	0.3492	0.3882	0.5445	0.4664	0.6227	0.9694	1.0475	1.3210	1.2038	1.4333	0.1414
	MOS	0.3938	0.4329	0.5892	0.5110	0.6673	1.3432	1.4214	1.6949	1.5777	1.8121	0.1552
		MFF	MFA	USL	ML	CL						
8	BIPOLAR	0.1113	0.1241	0.2191	0.2814	4.1291						
	MOS	0.1225	0.1293	0.2213	0.2926	4.1326						
16	BIPOLAR	0.2068	0.2262	0.3935	0.5100	7.3647						
	MOS	0.2292	0.2367	0.3979	0.5323	7.3716						
32	BIPOLAR	0.4586	0.5146	0.9136	1.1697	17.2628						
	MOS	0.5032	0.5356	0.9224	1.2143	17.2766						

TABLE 5.2-8 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR AND MOS DIGITAL MICROPROCESSOR DEVICES IN NONHERMETIC PACKAGES ($f/10^6$ hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
8	BIPOLAR MOS	0.0186 0.0283	0.0244 0.0354	0.0679 0.0983	0.1069 0.1574	0.0867 0.1043	0.0960 0.1264	0.0960 0.1264	******* *******	0.1315 0.1619	0.1237 0.1260	0.2085 0.3365
16	BIPOLAR MOS	0.0357 0.0551	0.0462 0.0682	0.1257 0.1865	0.1967 0.2977	0.1580 0.1932	0.1757 0.2365	0.1757 0.2365	******* *******	0.2390 0.2998	0.2219 0.2264	0.3824 0.6385
32	BIPOLAR MOS	0.0758 0.1146	0.0998 0.1438	0.2802 0.4018	0.4418 0.6438	0.3598 0.4302	0.3974 0.5190	0.3974 0.5190	******* *******	0.5459 0.6675	0.5163 0.5253	0.8627 1.3748
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
8	BIPOLAR MOS	0.1431 0.2711	0.1057 0.2337	0.1617 0.2898	0.1057 0.2337	0.1617 0.2898	******* *******	******* *******	******* *******	******* *******	******* *******	0.0380 0.0684
16	BIPOLAR MOS	0.2658 0.5219	0.1992 0.4552	0.2991 0.5552	0.1992 0.4552	0.2991 0.5552	******* *******	******* *******	******* *******	******* *******	******* *******	0.0724 0.1332
32	BIPOLAR MOS	0.5892 1.1013	0.4329 0.9450	0.6673 1.1794	0.4329 0.9450	0.6673 1.1794	******* *******	******* *******	******* *******	******* *******	******* *******	0.1552 0.2768
		MFF	MFA	USL	ML	CL						
8	BIPOLAR MOS	0.1225 0.2505	0.1293 0.1798	0.2213 0.2389	0.2926 0.4206	4.1326 4.1630						
16	BIPOLAR MOS	0.2292 0.4852	0.2367 0.3377	0.3979 0.4331	0.5323 0.7884	7.3716 7.4324						
32	BIPOLAR MOS	0.5032 1.0153	0.5356 0.7376	0.9224 0.9929	1.2143 1.7264	17.2766 17.3982						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-9 GENERIC FAILURE RATE, λ_G, FOR MOS DYNAMIC RAMS IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0119	0.0142	0.0328	0.0491	0.0361	0.0419	0.0419	0.1496	0.0534	0.0432	0.0928
>16K - 64K	MOS	0.0219	0.0250	0.0529	0.0767	0.0528	0.0634	0.0634	0.2701	0.0766	0.0541	0.1422
>64K - 256K	MOS	0.0410	0.0454	0.0882	0.1241	0.0789	0.0987	0.0987	0.5003	0.1120	0.0641	0.2249
>256K - 1M	MOS	0.0798	0.0869	0.1613	0.2228	0.1350	0.1733	0.1733	0.9661	0.1884	0.0902	0.3985
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.0565	0.0595	0.0716	0.0656	0.0777	0.2492	0.2552	0.2764	0.2673	0.2855	0.0231
>16K - 64K	MOS	0.1002	0.1037	0.1177	0.1107	0.1247	0.4830	0.4900	0.5145	0.5040	0.5250	0.0417
>64K - 256K	MOS	0.1829	0.1864	0.2004	0.1934	0.2074	0.9450	0.9520	0.9765	0.9660	0.9870	0.0770
>256K - 1M	MOS	0.3507	0.3547	0.3706	0.3627	0.3786	1.8719	1.8799	1.9077	1.8958	1.9197	0.1486
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.0650	0.0564	0.0797	0.1201	1.3497						
>16K - 64K	MOS	0.1100	0.0851	0.1032	0.1737	1.5751						
>64K - 256K	MOS	0.1927	0.1325	0.1293	0.2564	1.6104						
>256K - 1M	MOS	0.3619	0.2324	0.1923	0.4344	1.8942						

TABLE 5.2-10 GENERIC FAILURE RATE, λ_G, FOR MOS DYNAMIC RAMS IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0200	0.0233	0.0581	0.0912	0.0508	0.0672	0.0672	0.6907	0.0787	0.0450	0.1995
>16K - 64K	MOS	0.0380	0.0433	0.1035	0.1609	0.0821	0.1140	0.1140	1.3523	0.1273	0.0578	0.3556
>64K - 256K	MOS	0.0734	0.0821	0.1895	0.2924	0.1377	0.2000	0.2000	2.6647	0.2133	0.0715	0.6516
>256K - 1M	MOS	0.1445	0.1602	0.3640	0.5594	0.2524	0.3760	0.3760	5.2951	0.3911	0.1051	1.2520
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.1632	0.1662	0.1783	0.1723	0.1844	1.8260	1.8320	1.8532	1.8441	1.8623	0.0485
>16K - 64K	MOS	0.3136	0.3171	0.3311	0.3241	0.3381	3.6366	3.6436	3.6681	3.6576	3.6786	0.0923
>64K - 256K	MOS	0.6096	0.6131	0.6271	0.6201	0.6341	7.2522	7.2592	7.2837	7.2732	7.2942	0.1783
>256K - 1M	MOS	1.2042	1.2082	1.2241	1.2161	1.2321	14.4863	14.4942	14.5221	14.5102	14.5341	0.3513
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.1716	0.0984	0.0944	0.2267	1.3751						
>16K - 64K	MOS	0.3234	0.1693	0.1325	0.3870	1.6257						
>64K - 256K	MOS	0.6194	0.3008	0.1881	0.6831	1.7118						
>256K - 1M	MOS	1.2153	0.5690	0.3098	1.2878	2.0968						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-11 GENERIC FAILURE RATE, λ_G, FOR MOS STATIC RAMS IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 4K	MOS	0.0219	0.0250	0.0529	0.0767	0.0528	0.0634	0.0634	0.2701	0.0766	0.0541	0.1422
>4K - 16K	MOS	0.0414	0.0461	0.0906	0.1281	0.0826	0.1026	0.1026	0.5058	0.1177	0.0702	0.2331
>16K - 64K	MOS	0.0802	0.0876	0.1638	0.2270	0.1387	0.1773	0.1773	0.9718	0.1943	0.0965	0.4069
>64K - 256K	MOS	0.1573	0.1700	0.3078	0.4205	0.2473	0.3227	0.3227	1.8983	0.3417	0.1429	0.7463
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 4K	MOS	0.1093	0.1037	0.1205	0.1240	0.1247	0.5215	0.4900	2.0017	0.4565	0.5250	0.0417
>4K - 16K	MOS	0.1957	0.1893	0.2084	0.2124	0.2132	0.9917	0.9559	2.6767	0.9292	0.9957	0.0779
>16K - 64K	MOS	0.3648	0.3577	0.3792	0.3836	0.3845	1.9241	1.8838	3.8187	1.8536	1.9286	0.1495
>64K - 256K	MOS	0.6995	0.6915	0.7154	0.7204	0.7214	3.7807	3.7358	5.8893	3.7024	3.7857	0.2918
		MFF	MFA	USL	ML	CL						
<= 4K	MOS	0.1100	0.0851	0.1032	0.1737	1.5751						
>4K - 16K	MOS	0.1965	0.1377	0.1400	0.2690	1.8235						
>16K - 64K	MOS	0.3657	0.2377	0.2032	0.4472	2.1122						
>64K - 256K	MOS	0.7004	0.4325	0.3190	0.7912	2.4762						

TABLE 5.2-12 GENERIC FAILURE RATE, λ_G, FOR MOS STATIC RAMS IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 4K	MOS	0.0380	0.0433	0.1035	0.1609	0.0821	0.1140	0.1140	*******	0.1273	0.0578	0.3556
>4K - 16K	MOS	0.0738	0.0827	0.1920	0.2965	0.1414	0.2039	0.2039	*******	0.2191	0.0776	0.6599
>16K - 64K	MOS	0.1449	0.1608	0.3665	0.5636	0.2562	0.3799	0.3799	*******	0.3969	0.1113	1.2604
>64K - 256K	MOS	0.2868	0.3165	0.7131	1.0938	0.4822	0.7281	0.7281	*******	0.7470	0.1726	2.4533
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 4K	MOS	0.3227	0.3171	0.3339	0.3374	0.3381	*******	*******	*******	*******	*******	0.0923
>4K - 16K	MOS	0.6224	0.6160	0.6352	0.6391	0.6399	*******	*******	*******	*******	*******	0.1792
>16K - 64K	MOS	1.2183	1.2111	1.2326	1.2371	1.2380	*******	*******	*******	*******	*******	0.3522
>64K - 256K	MOS	2.4064	2.3984	2.4224	2.4273	2.4283	*******	*******	*******	*******	*******	0.6972
		MFF	MFA	USL	ML	CL						
<= 4K	MOS	0.3234	0.1693	0.1325	0.3870	1.6257						
>4K - 16K	MOS	0.6232	0.3060	0.1987	0.6957	1.9248						
>16K - 64K	MOS	1.2192	0.5744	0.3207	1.3007	2.3149						
>64K - 256K	MOS	2.4074	1.1058	0.5540	2.4981	2.8816						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-13 GENERIC FAILURE RATE, λ_G, FOR BIPOLAR STATIC RAMS IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 4K	BIPOLAR	0.0196	0.0225	0.0471	0.0680	0.0491	0.0576	0.0576	0.2024	0.0709	0.0535	0.1236
>4K - 16K	BIPOLAR	0.0374	0.0418	0.0816	0.1148	0.0791	0.0950	0.0950	0.3762	0.1121	0.0752	0.2043
		AIC	AIT	AIE	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 4K	BIPOLAR	0.0907	0.0851	0.1019	0.1054	0.1061	0.3657	0.3342	1.8459	0.3106	0.3692	0.0359
>4K - 16K	BIPOLAR	0.1622	0.1551	0.1765	0.1810	0.1819	0.6886	0.6483	2.5832	0.6183	0.6931	0.0673
		MFF	MFA	USL	ML	CL						
<= 4K	BIPOLAR	0.0914	0.0764	0.0995	0.1551	1.5693						
>4K - 16K	BIPOLAR	0.1631	0.1256	0.1436	0.2446	2.0300						

TABLE 5.2-14 GENERIC FAILURE RATE, λ_G, FOR BIPOLAR STATIC RAMS IN NONHERMETIC PACKAGES ($f/10^6$ hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 4K	BIPOLAR	0.0219	0.0250	0.0529	0.0767	0.0528	0.0634	0.0634	*******	0.0766	0.0541	0.1422
>4K - 16K	BIPOLAR	0.0418	0.0467	0.0931	0.1323	0.0864	0.1065	0.1065	*******	0.1236	0.0765	0.2415
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 4K	BIPOLAR	0.1093	0.1037	0.1205	0.1240	0.1247	*******	*******	*******	*******	*******	0.0417
>4K - 16K	BIPOLAR	0.1994	0.1923	0.2138	0.2182	0.2191	*******	*******	*******	*******	*******	0.0788
		MFF	MFA	USL	ML	CL						
<= 4K	BIPOLAR	0.1100	0.0851	0.1032	0.1737	1.5751						
>4K - 16K	BIPOLAR	0.2003	0.1430	0.1509	0.2818	2.0415						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-15 GENERIC FAILURE RATE, λ_G, FOR MOS ROM DEVICES IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0172	0.0208	0.0497	0.0750	0.0562	0.0646	0.0646	0.2180	0.0836	0.0698	0.1426
>16K - 64K	MOS	0.0314	0.0364	0.0796	0.1169	0.0824	0.0977	0.0977	0.3909	0.1206	0.0899	0.2182
>64K - 256K	MOS	0.0583	0.0651	0.1291	0.1831	0.1191	0.1472	0.1472	0.7132	0.1701	0.1040	0.3340
>256K - 1M	MOS	0.1146	0.1266	0.2447	0.3436	0.2176	0.2727	0.2727	1.3955	0.3083	0.1738	0.6219
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.0828	0.0878	0.1077	0.0978	0.1177	0.3533	0.3633	0.3982	0.3832	0.4131	0.0337
>16K - 64K	MOS	0.1459	0.1519	0.1760	0.1640	0.1881	0.6829	0.6950	0.7372	0.7191	0.7553	0.0603
>64K - 256K	MOS	0.2617	0.2677	0.2918	0.2798	0.3039	1.3297	1.3418	1.3840	1.3659	1.4020	0.1098
>256K - 1M	MOS	0.5098	0.5192	0.5565	0.5378	0.5752	2.6432	2.6619	2.7273	2.6993	2.7554	0.2148
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.0968	0.0870	0.1280	0.1875	2.2181						
>16K - 64K	MOS	0.1628	0.1313	0.1692	0.2724	2.7008						
>64K - 256K	MOS	0.2785	0.1976	0.2058	0.3882	2.7503						
>256K - 1M	MOS	0.5360	0.3660	0.3521	0.7060	4.3094						

TABLE 5.2-16 GENERIC FAILURE RATE, λ_G, FOR MOS ROM DEVICES IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0285	0.0336	0.0851	0.1339	0.0768	0.1001	0.1001	*******	0.1190	0.0724	0.2920
>16K - 64K	MOS	0.0541	0.0621	0.1506	0.2347	0.1236	0.1686	0.1686	*******	0.1915	0.0951	0.5169
>64K - 256K	MOS	0.1036	0.1163	0.2710	0.4188	0.2013	0.2891	0.2891	*******	0.3120	0.1144	0.9314
>256K - 1M	MOS	0.2052	0.2292	0.5285	0.8149	0.3820	0.5565	0.5565	*******	0.5920	0.1946	1.8168
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.2322	0.2372	0.2571	0.2471	0.2671	*******	*******	*******	*******	*******	0.0692
>16K - 64K	MOS	0.4446	0.4506	0.4747	0.4627	0.4868	*******	*******	*******	*******	*******	0.1313
>64K - 256K	MOS	0.8591	0.8651	0.8892	0.8772	0.9013	*******	*******	*******	*******	*******	0.2517
>256K - 1M	MOS	1.7047	1.7140	1.7514	1.7327	1.7701	*******	*******	*******	*******	*******	0.4986
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.2461	0.1459	0.1485	0.3369	2.2536						
>16K - 64K	MOS	0.4615	0.2492	0.2103	0.5712	2.7717						
>64K - 256K	MOS	0.8760	0.4333	0.2881	0.9857	2.8922						
>256K - 1M	MOS	1.7309	0.8373	0.5166	1.9009	4.5931						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-17 GENERIC FAILURE RATE, λ_G, FOR MOS PROM (UVEPROM, EEPROM, EAPROM) DEVICES IN HERMETIC PACKAGES ($f/10^6$ hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0268	0.0310	0.0674	0.0987	0.0693	0.0823	0.0823	0.3330	0.1012	0.0748	0.1840
>16K - 64K	MOS	0.0506	0.0569	0.1150	0.1642	0.1086	0.1331	0.1331	0.6211	0.1560	0.1000	0.3009
>64K - 256K	MOS	0.0967	0.1059	0.1998	0.2778	0.1714	0.2179	0.2179	1.1736	0.2408	0.1240	0.4994
>256K - 1M	MOS	0.1913	0.2083	0.3861	0.5329	0.3223	0.4142	0.4142	2.3163	0.4497	0.2138	0.9527
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.1242	0.1291	0.1491	0.1391	0.1591	0.5843	0.5943	0.6292	0.6142	0.6441	0.0514
>16K - 64K	MOS	0.2286	0.2346	0.2587	0.2467	0.2708	1.1449	1.1570	1.1992	1.1811	1.2173	0.0957
>64K - 256K	MOS	0.4271	0.4331	0.4572	0.4451	0.4692	2.2537	2.2658	2.3080	2.2899	2.3260	0.1806
>256K - 1M	MOS	0.8406	0.8499	0.8873	0.8686	0.9060	4.4912	4.5099	4.5753	4.5473	4.6034	0.3562
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.1381	0.1106	0.1411	0.2258	2.2358						
>16K - 64K	MOS	0.2455	0.1787	0.1954	0.3551	2.7361						
>64K - 256K	MOS	0.4439	0.2923	0.2582	0.5536	2.8210						
>256K - 1M	MOS	0.8668	0.5553	0.4568	1.0368	4.4508						

TABLE 5.2-18 GENERIC FAILURE RATE, λ_G, FOR MOS PROM (UVEPROM, EEPROM, EAPROM) DEVICES IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	MOS	0.0462	0.0530	0.1282	0.1997	0.1045	0.1431	0.1431	*******	0.1621	0.0793	0.4400
>16K - 64K	MOS	0.0895	0.1008	0.2366	0.3662	0.1791	0.2547	0.2547	*******	0.2776	0.1089	0.8130
>64K - 256K	MOS	0.1744	0.1939	0.4430	0.6818	0.3124	0.4611	0.4611	*******	0.4840	0.1418	1.5236
>256K - 1M	MOS	0.3467	0.3842	0.8725	1.3409	0.6042	0.9006	0.9006	*******	0.9361	0.2495	3.0011
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	MOS	0.3802	0.3852	0.4051	0.3952	0.4151	*******	*******	*******	*******	*******	0.1122
>16K - 64K	MOS	0.7407	0.7467	0.7708	0.7588	0.7829	*******	*******	*******	*******	*******	0.2173
>64K - 256K	MOS	1.4512	1.4573	1.4814	1.4693	1.4934	*******	*******	*******	*******	*******	0.4238
>256K - 1M	MOS	2.8890	2.8983	2.9357	2.9170	2.9544	*******	*******	*******	*******	*******	0.8426
		MFF	MFA	USL	ML	CL						
<= 16K	MOS	0.3942	0.2116	0.1763	0.4849	2.2966						
>16K - 64K	MOS	0.7576	0.3807	0.2659	0.8672	2.8577						
>64K - 256K	MOS	1.4681	0.6963	0.3992	1.5778	3.0642						
>256K - 1M	MOS	2.9151	1.3633	0.7388	3.0852	4.9372						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-19 GENERIC FAILURE RATE, λ_G, FOR BIPOLAR ROM/PROM (FUSIBLE LINK AND AIM) DEVICES IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	BIPOLAR	0.0242	0.0281	0.0604	0.0882	0.0649	0.0754	0.0754	0.2519	0.0943	0.0741	0.1616
>16K - 64K	BIPOLAR	0.0445	0.0496	0.0960	0.1345	0.0919	0.1109	0.1109	0.4469	0.1299	0.0854	0.2386
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	BIPOLAR	0.1148	0.1068	0.1307	0.1357	0.1367	0.4522	0.4074	2.5609	0.3740	0.4572	0.0445
>16K - 64K	BIPOLAR	0.1917	0.1837	0.2076	0.2126	0.2136	0.8197	0.7748	2.9283	0.7414	0.8247	0.0800
		MFF	MFA	USL	ML	CL						
<= 16K	BIPOLAR	0.1158	0.1301	0.1367	0.2065	2.2289						
>16K - 64K	BIPOLAR	0.1927	0.1465	0.1637	0.2834	2.2644						

TABLE 5.2-20 GENERIC FAILURE RATE, λ_G, FOR BIPOLAR ROM/PROM (FUSIBLE LINK AND AIM) DEVICES IN NONHERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
<= 16K	BIPOLAR	0.0268	0.0309	0.0672	0.0985	0.0692	0.0822	0.0822	*******	0.1011	0.0748	0.1835
>16K - 64K	BIPOLAR	0.0498	0.0554	0.1095	0.1551	0.1005	0.1245	0.1245	*******	0.1434	0.0868	0.2823
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
<= 16K	BIPOLAR	0.1237	0.1287	0.1486	0.1387	0.1586	*******	*******	*******	*******	*******	0.0513
>16K - 64K	BIPOLAR	0.2225	0.2275	0.2474	0.2375	0.2574	*******	*******	*******	*******	*******	0.0936
		MFF	MFA	USL	ML	CL						
<= 16K	BIPOLAR	0.1377	0.1104	0.1410	0.2284	2.2357						
>16K - 64K	BIFCLAR	0.2365	0.1670	0.1723	0.3272	2.2780						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-21 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR OR MOS ANALOG MICROPROCESSOR DEVICES IN HERMETIC PACKAGES (f/10^6 hours)

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR MOS	0.0330 0.0357	0.0432 0.0462	0.1188 0.1257	0.1862 0.1967	0.1536 0.1580	0.1688 0.1757	0.1688 0.1757	0.3849 0.4661	0.2321 0.2390	0.2212 0.2219	0.3601 0.3824
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR MOS	0.1602 0.1825	0.1768 0.1992	0.2435 0.2658	0.2102 0.2325	0.2768 0.2991	0.4674 0.6543	0.5007 0.6877	0.6173 0.8043	0.5674 0.7543	0.5673 0.8542	0.0655 0.0724
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR MOS	0.2068 0.2292	0.2262 0.2367	0.3935 0.3979	0.5100 0.5323	7.3647 7.3716						

TABLE 5.2-22 GENERIC FAILURE RATE, λ_G, FOR MONOLITHIC BIPOLAR OR MOS ANALOG MICROPROCESSOR DEVICES IN NONERMETIC PACKAGES (f/10^6 hours.

DEVICE DESCRIPTION		APPLICATION ENVIRONMENT										
NO. OF BITS	TECHNOLOGY	GB	GMS	GF	GM	MP	NSB	NS	NU	NH	NUU	ARW
1 - 100	BIPOLAR MOS	0.0357 0.0551	0.0462 0.0682	0.1257 0.1865	0.1967 0.2977	0.1580 0.1932	0.1757 0.2365	0.1757 0.2365	******* *******	0.2390 0.2998	0.2219 0.2264	0.3824 0.6385
		AIC	AIT	AIB	AIA	AIF	AUC	AUT	AUB	AUA	AUF	SF
1 - 100	BIPOLAR MOS	0.1825 0.4386	0.1992 0.4552	0.2658 0.5219	0.2325 0.4885	0.2991 0.5552	******* *******	******* *******	******* *******	******* *******	******* *******	0.0724 0.1332
		MFF	MFA	USL	ML	CL						
1 - 100	BIPOLAR MOS	0.2292 0.4852	0.2367 0.3377	0.3979 0.4331	0.5323 0.7884	7.3716 7.4324						

******* Nonhermetic parts should NOT be used in this environment

TABLE 5.2-23

π_Q, QUALITY FACTORS FOR USE WITH TABLES 5.2-1 THROUGH 5.2-22

QUALITY LEVEL	π_Q
S	0.25
S-1	0.75
B	1
B-1	2
B-2	5
D	10
D-1	20

*See Table 5.1.2.7-1 for descriptions of quality levels.

TABLE 5.2-24

π_L, LEARNING FACTOR FOR USE WITH TABLES 5.2-1 THROUGH 5.2.22

The learning factor π_L is 10 under any of the following conditions:

(1) New device in initial production.

(2) Where major changes in design or process have occurred.

(3) Where there has been an extended interruption in production or a change in line personnel (radical expansion).

(4) For all new and unproven technologies.

The factor of 10 can be expected to apply until conditions and controls have stabilized. This period can extend for as much as six months of continuous production.

π_L is equal to 1.0 under all production conditions not stated in (1), (2), (3) and (4) above.

TABLE 5.2-25 GENERIC FAILURE RATE, λ_G, FOR DISCRETE SEMICONDUCTORS (f./10^6 hours)

(See Table 5.2-26 for π_Q Values)

PART TYPE	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
TRANSISTORS														
Si NPN	.069	.12	.033	.14	.052	.094	.16	.27	.068	.29	.11	2.0	.0025	.0040
Si PNP	.11	.19	.052	.22	.082	.15	.26	.44	.11	.47	.18	3.0	.0038	.0062
Ge NPN	3.4	6.0	1.6	6.9	2.6	4.6	6.3*	11.*	2.7*	12.*	4.5*	63.	.066	.11
Ge PNP	1.3	2.3	.61	2.6	.96	1.7	2.4*	4.1*	1.0*	4.4*	1.7*	24.	.025	.040
Si FET	2.0	2.3	.50	2.6	.59	1.8	4.4	4.8	.87	5.7	1.3	37.	.048	.067
Unijunction	4.8	8.3	2.3	9.5	3.6	6.4	12.	20.	5.0	22.	8.3	130.	.16	.22
DIODES														
Si Gen Purpose	.026	.031	.016	.037	.021	.028	.060	.075	.037	.075	.045	.55	.00066	.00093
Ge Gen Purpose	.36	.43	.22	.50	.29	.39	.61*	.77*	.38*	.77*	.46*	4.4	.0042	.0057
Zener & Avalanche	.088	.16	.016	.16	.023	.095	.18	.31	.034	.31	.045	2.1	.0027	.0038
Thyristor	.73	1.3	.35	1.5	.55	.98	1.8	3.1	.78	3.4	1.3	19.	.022	.031
Si Microwave Det	12.	15.	7.0	16.	7.3	18.	25.	33.	16.	34.	19.	***	.18	.31

*This value is valid only for electrical stress, $S \leq 0.3$ as defined in Section 5.13
**Do not use in these environments since temperature normally encountered combined with normal power dissipation are above the device ratings.
***Not normally used in this environment.

TABLE 5.2-25 GENERIC FAILURE RATE, λ_G, FOR
DISCRETE SEMICONDUCTORS (f./10^6 hours) (Contd)
(See Table 5.2-26 for π_Q Values)

PART TYPE	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
Ge Microwave Det	36.*	47.*	22.*	51.*	29.*	57.*	**	**	**	**	**	***	.42	.71
Si Microwave Mix	16.	21.	9.7	23.	13.	25.	35.	45.	22.	48.	26.	***	.25	.43
Ge Microwave Mix	62.*	80.*	37.*	86.*	49.*	96.*	**	**	**	**	**	***	.70	1.2
Varactor, Step Recovery, Tunnel	8.2	15.	1.5	15.	2.1	8.9	17.	30.	3.2	30.	4.3	180.	.24	.33
Gunn & Impatt	15.	27.	27.	.27	3.9	16.	24.	42.	4.5	42.	6.0	410.	.60	.84
PIN	11.	19.	1.9	19.	2.8	12.	23.	39.	4.2	39.	5.6	240.	.31	.43
LED	.14	.22	.098	.31	.14	.67	.60	.88	.33	1.1	.60	6.2	.0065	.0078
Single Isolator	1.2	1.8	.83	2.7	1.2	5.7	5.1	7.4	2.8	9.3	5.1	52.	.055	.066
Bipolar Microwave Power Transistor	4.0	6.9	2.9	6.9	4.0	18.	9.7	14.	6.9	14.	9.7	230.	.79	.87

*This value is valid only for electrical stress, $S \leq 0.3$ as defined in Section 5.13

**Do not use in these environments since temperature normally encountered combined with normal power dissipation are above the device ratings.

***Not normally used in this environment.

TABLE 5.2-25 GENERIC FAILURE RATE, λ_G, FOR DISCRETE SEMICONDUCTORS (f./10^6 hours) (Contd)

(See Table 5.2-26 for π_Q Values)

PART TYPE	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
TRANSISTORS													
Si NPN	.016	.063	.051	.036	.14	.032	.054	.028	.028	.10	.044	.0010	.095
Si PNP	.025	.098	.080	.056	.22	.049	.083	.043	.043	.17	.070	.0015	.15
Ge NPN	.53	3.1	1.9	1.3	7.0	.93	1.7	.89	.89	4.5*	1.0	.027	2.8
GE PNP	.20	1.2	.70	.49	2.6	.35	.65	.33	.33	1.8*	.39	.010	1.1
Si FET	.22	1.2	.98	.69	2.7	.61	.99	.46	.32	2.0	.85	.029	1.8
Unijunction	.73	4.3	3.4	2.4	9.8	2.0	3.4	1.7	1.7	7.7	2.7	.16	
DIODES													
Si Gen Purp	.0031	.019	.015	.010	.043	.0087	.015	.0038	.0038	.035	.011	.00066	6.1
Ge Gen Purp	.025	.26	.14	.098	.59	.062	.12	.031	.031	.42*	.058	.0042	.026
Zener & Avalanche	.012	.063	.053	.038	.14	.034	.056	.026	.017	.10	.050	.0027	.19
Thyristor	.10	.66	.50	.36	1.5	.29	.51	.23	.16	1.2	.36	.033	.10
Si Microwave Det	1.3	7.3	10.	7.5	28.	6.7	11.	2.2	1.6	11.	10.	.18	.87

*This value is valid only for electrical stress, S$\leq$ 0.3 as defined in Section 5.13

**Do not use in these environments since temperature normally encountered combined with normal power dissipation are above the device ratings.

***Not normally used in this environment.

TABLE 5.2-25 GENERIC FAILURE RATE, λ_G, FOR DISCRETE SEMICONDUCTORS (f./10^6 hours) (Contd)

(See Table 5.2-26 for π_D Values)

PART TYPE	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
Ge Microwave Det	3.6	22.*	35.	25.	84.*	17.	31.	6.2	4.5	**	19.	.42	21.
Si Microwave Mix	1.7	10.	14.	10.	39.	9.1	15.	3.0	2.2	16.	14.	.25	.53
Ge Microwave Mix	6.2	38.*	59.	42.	150.*	28.	52.	11.	7.7	**	33.	.70	29.
Varactor, Step Recovery, Tunnel	1.0	5.9	4.8	3.4	14.	3.0	5.1	2.3	1.5	9.9	4.2	.24	9.0
Gunn & Impatt	2.3	11.	10.	7.2	25.	7.2	11.	5.2	3.5	13.	12.	.60	22.
PIN	1.4	7.7	6.3	4.4	18.	3.9	6.6	3.0	2.0	13.	5.5	.31	12.
LED	.033	.31	.22	.15	1.0	.073	.17	.078	.051	1.5	.038	.0065	.22
Single Isolator	.28	2.6	1.8	1.3	8.6	.62	1.4	.66	.43	13.	.32	.055	1.9
Bipolar Microwave Power Transistor	1.9	9.0	11.	7.6	29.	6.4	10.	4.4	3.4	16.	7.8	.79	19.

*This value is valid only for electrical stress, S≤ 0.3 as defined in Section 5.13

**Do not use in these environments since temperature normally encountered combined with normal power dissipation are above the device ratings.

***Not normally used in this environment.

TABLE 5.2-26

π_Q, QUALITY FACTORS FOR TABLE 5.2-25

PART TYPES	JANTXV	JANTX	JAN	NON-MIL HERMETIC	PLASTIC
MICROWAVE DIODES	0.3	0.6	1.0	1.4	-----
MICROWAVE TRANSISTORS	0.25	0.5	1.0	2.5	-----
ALL OTHERS	0.1	0.2	1.0	5.0	10.0

TABLE 5.2-27 GENERIC FAILURE RATE, λ_G, (f./10^6 hr.) FOR RESISTORS

(See Table 5.2-29 for π_Q Values)

RESISTORS, FIXED			USE ENVIRONMENT													
CONSTRUCTION	STYLE	MIL-R-SPEC	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
Composition	RCR	39008	.0045	.0065	.0039	.0084	.0045	.025	.017	.024	.012	.036	.017	.36	.0005	.0006
"	RC	11	.023	.032	.019	.042	.023	.12	.083	.12	.060	.18	.083	1.8	.0025	.0030
Film	RLR	39017	.0094	.010	.0039	.014	.0047	.030	.028	.028	.013	.037	.012	.69	.0012	.0015
"	RL	22684	.047	.051	.020	.070	.023	.15	.14	.14	.064	.18	.060	3.5	.0062	.0074
"	RNR	55182	.011	.012	.0045	.016	.0054	.034	.032	.032	.015	.043	.014	.78	.0014	.0017
"	RN	10509	.054	.058	.022	.081	.027	.17	.16	.16	.074	.21	.069	3.9	.0069	.0083
", Power	RD	11804	.071	.091	.045	.13	.078	.32	.14	.27	.11	.34	.21	8.2	.012	.014
", Network	RZ	83401	.36	.39	.15	.54	.18	1.1	1.5	1.5	.59	2.0	.63	18.	.025	.030
Wirewound	RBR	39005	.15	.19	.087	.19	.15	.26	.27	.44	.22	.49	.27	5.4	.0085	.010
Accurate	RB	93	.73	.97	.44	.97	.73	.31	1.4	2.2	.097	2.5	1.4	27.	.043	.051
Wirewound	RWR	39007	.13	.14	.027	.18	.064	.42	.33	.33	.12	.44	.15	9.4	.014	.015
Power	RW	26	.64	.68	.14	.91	.32	2.1	1.6	1.6	.61	2.2	.76	47.	.069	.076
Wirewound	RER	39009	.077	.082	.027	.11	.038	.25	.20	.20	.075	.27	.094	5.5	.0080	.0095
Ch. Mount	RE	18546	.38	.41	.14	.55	.19	1.3	1.0	1.0	.38	1.3	.47	28.	.040	.048

TABLE 5.2-27 GENERIC FAILURE RATE, λ_G, (f./10^6 hr.) FOR RESISTORS (Contd)

(See Table 5.2-29 for π_Q Values)

RESISTORS, FIXED			USE ENVIRONMENT												
CONSTRUCTION	STYLE	MIL-R-SPEC	G_F	G_M	M_L	M_{FA}	M_{FF}	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
Composition	RCR	39008	.0021	.011	.038	.012	.0076	.0052	.0095	.0038	.0029	.033	.0048	.0005	.015
"	RC	11	.011	.054	.19	.058	.038	.026	.048	.019	.015	.17	.024	.0025	.076
Film	RLR	39017	.0033	.012	.047	.017	.013	.011	.019	.0064	.0057	.027	.017	.0005	.034
"	RL	22684	.016	.061	.23	.085	.063	.057	.095	.032	.029	.14	.086	.0025	.17
"	RNR	55182	.0037	.014	.054	.019	.014	.013	.021	.0072	.0064	.031	.019	.0006	.038
"	RN	10509	.018	.070	.27	.097	.072	.064	.11	.036	.032	.16	.093	.0028	.19
", Power	RD	11804	.030	.11	.51	.20	.15	.13	.22	.063	.063	.21	.22	.012	.41
", Network	RZ	83401	.087	.47	1.8	.52	.38	.27	.51	.17	.15	1.5	.26	.025	.79
Wirewound,	RBR	39005	.021	.095	.40	.16	.11	.10	.16	.046	.046	.18	.16	.013	.31
Accurate	RB	93	.11	.48	2.0	.78	.55	.52	.80	.23	.23	.91	.82	.064	1.6
Wirewound	RWR	39007	.023	.15	.65	.24	.18	.16	.25	.076	.076	.32	.21	.0083	.45
Power	RW	26	.12	.75	3.3	1.2	.90	.81	1.2	.38	.38	1.6	1.1	.042	2.3
Wirewound	RER	39009	.022	.091	.39	.14	.11	.093	.15	.044	.044	.20	.12	.0080	.26
Ch. Mount	RE	18546	.11	.45	2.0	.72	.53	.47	.72	.22	.22	.99	.60	.040	1.3

TABLE 5.2-27 GENERIC FAILURE RATE, λ_G, (f./10^6 hr.) FOR RESISTORS (Contd)

(See Table 5.2-29 for π_Q Values)

RESISTORS, VARIABLE			USE ENVIRONMENT													
CONSTRUCTION	STYLE	MIL-R-SPEC	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
Wirewound,	RTR	39015	.11	.15	.045	.18	.072	.60	.22	.33	.067	.44	.18	13.	.014	.017
Trimmer	RT	27208	.54	.72	.23	.91	.36	3.0	1.1	1.7	.33	2.2	.89	67.	.070	.084
W.W. Prec.	RR	12934	10.	11.	7.1	17.	8.2	58.	21.	28.	14.	28.	14.	1300.	.820	.98
W.W. Semi-	RA	19	4.5	4.7	3.1	7.1	3.6	18.	*	*	*	*	*	*	.30	.36
Prec.	RK	39002	4.5	4.7	3.1	7.1	3.6	18.	*	*	*	*	*	*	.30	.36
W. W. Power	RP	22	3.8	4.0	2.6	6.0	3.0	15.	*	*	*	*	*	*	.31	.40
Non-W.W.,	RJR	39035	.10	.16	.070	.23	.14	.90	.27	.40	.20	.66	.40	21.	.020	.024
Trimmer	RJ	22097	.52	.81	.35	1.2	.70	4.5	1.3	2.0	.99	3.3	2.0	110.	.099	.12
Composition	RV	94	9.7	9.7	5.3	13.	6.2	8.1	16.	16.	9.9	22.	9.9	170.	.12	.14
Non-W.W.Pre	RQ	39023	.84	1.2	.45	1.9	.84	5.1	3.8	5.7	1.9	7.5	3.8	99.	.086	.10
Film	RVC	23285	.78	1.1	.42	1.8	.78	4.7	2.9	4.4	1.5	5.9	2.9	100.	.095	.11

*Not normally used in these environments

TABLE 5.2-27 GENERIC FAILURE RATE, λ_G, (f./10^6 hr.) FOR RESISTORS (Contd)

(See Table 5.2-29 for π_Q Values)

RESISTORS, VARIABLE			USE ENVIRONMENT												
CONSTRUCTION	STYLE	MIL-R-SPEC	G_F	G_M	M_L	M_{FA}	M_{FF}	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
Wirewound,	RTR	39015	.037	.18	.92	.34	.24	.22	.35	.088	.088	.31	.32	.014	.66
Trimmer	RT	27208	.19	.89	4.6	1.7	1.2	1.1	1.8	.44	.44	1.5	1.6	.070	3.3
W.W., Prec.	RR	12934	2.2	11.	63.	33.	23.	20.	34.	7.7	7.7	21.	29.	.820	62.
W.W., Semi-	RA	19	.85	7.6	*	*	*	5.5	9.5	2.5	2.5	*	7.5	.30	*
Prec.	RK	39002	.85	7.6	*	*	*	5.5	9.6	2.5	2.5	*	7.5	.30	*
W.W. Power	RP	22	1.0	6.4	*	*	*	5.5	9.1	2.4	2.4	*	8.1	.31	*
Non-W.W.,	RJR	39035	.061	.26	1.4	.54	.39	.37	.57	.12	.12	.41	.55	.020	1.1
Trimmer	RJ	22097	.30	1.3	7.1	2.7	2.0	1.8	2.8	.60	.60	2.1	2.7	.099	5.4
Composition	RV	94	.25	3.0	13.	4.4	3.2	2.8	4.5	1.1	1.1	5.7	3.8	.12	8.2
Non-W.W.Pre	RQ	39023	.29	1.4	7.9	2.7	1.9	1.7	2.7	.71	.71	3.2	2.2	.086	4.9
Film	RVC	23285	.30	1.3	7.3	2.7	2.0	1.8	2.8	.75	.75	2.3	2.6	.095	5.3

*not normally used in these environments.

TABLE 5.2-28 GENERIC FAILURE RATE, λ_G, (f.10^6 hr.) FOR CAPACITORS

(See Table 5.2-29 for π_Q Values)

CAPACITORS, FIXED			USE ENVIRONMENT													
DIELECTRIC	STYLE	MIL-C SPEC	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
PAPER	CP	25	.073	.090	.040	.11	.056	.25	.25	.31	.13	.44	.19	6.2	.011	.012
"	CA	12889	.11	.14	.061	.18	.088	.39	.71	.89	.35	1.2	.53	7.5	.012	.013
PAPER/PLASTIC	CZR	11693	.033	.040	.018	.050	.025	.11	.11	.14	.056	.20	.084	2.8	.0048	.0057
"	CPV	14157	.0066	.012	.0055	.018	.0055	.044	.024	.049	.0073	.073	.023	1.1	.0021	.0025
"	CQR	19978	.0066	.012	.0055	.018	.0055	.044	.024	.049	.0073	.073	.023	1.1	.0021	.0025
"	CHR	39022	.0091	.017	.0075	.024	.0091	.060	.034	.067	.010	.10	.032	1.5	.0029	.0034
"	CH	18312	.063	.12	.053	.17	.063	.043	.24	.47	.070	.70	.22	11.	.020	.024
PLASTIC	CFR	55514	.028	.041	.015	.065	.028	.10	.096	.12	.048	.19	.096	2.5	.0041	.0045
"	CRH	83421	.0096	.013	.0096	.019	.0096	.048	.027	.053	.025	.080	.027	1.2	.0023	.0030
MICA	CMR	39001	.0054	.011	.0047	.014	.0054	.031	.039	.090	.039	.10	.039	.45	.0005	.0006
"	CM	5	.032	.066	.028	.084	.032	.19	.23	.54	.23	.62	.23	2.7	.0030	.0036
"	CB	10950	.40	.80	.35	1.0	.40	2.3	1.6	3.8	1.6	4.3	1.6	57.	.091	.11
GLASS	CYR	23269	.0035	.0070	.0031	.0088	.0035	.020	.025	.059	.036	.057	.025	.29	.0003	.0003
"	CY	11272	.011	.021	.0093	.026	.011	.060	.075	.18	.075	.20	.075	.88	.0010	.0010

*Not normally used in these environments

TABLE 5.2-28 GENERIC FAILURE RATE, λ_G, (f.10^6 hr.) FOR CAPACITORS (Continued)

(See Table 5.2-29 for π_Q Values)

CAPACITORS, FIXED			USE ENVIRONMENT												
DIELECTRIC	STYLE	MIL-C SPEC	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
PAPER	CP	25	.021	.094	.15	.11	.38	.11	.16	.062	.052	.18	.17	.011	.32
"	CA	12889	.025	.15	.20	.14	.60	.12	.20	.075	.063	.66	.18	.012	.37
PAPER/PLASTIC	CZR	11693	.012	.042	.068	.049	.17	.048	.072	.042	.023	.082	.075	.0048	.14
"	CPV	14157	.0050	.017	.028	.020	.068	.019	.029	.012	.0092	.033	.031	.0021	.056
"	CQR	19978	.0050	.017	.028	.020	.068	.019	.029	.012	.0092	.033	.031	.0021	.056
"	CHR	39022	.0069	.024	.038	.027	.094	.026	.041	.017	.013	.045	.042	.0029	.077
"	CH	18312	.049	.17	.27	.19	.66	.19	.28	.12	.089	.32	.30	.020	.54
PLASTIC	CFR	55514	.0079	.040	.063	.046	.16	.045	.066	.024	.021	.080	.069	.0041	.13
"	CRH	83421	.0085	.019	.030	.022	.075	.021	.032	.013	.010	.036	.034	.0023	.062
MICA	CMR	39001	.0018	.012	.014	.010	.049	.0067	.012	.0046	.0037	.045	.0056	.0005	.019
"	CM	5	.011	.071	.082	.060	.29	.040	.071	.028	.022	.27	.034	.0030	.11
"	CB	10950	.23	.88	1.4	1.1	3.6	1.0	1.5	.49	.47	1.7	1.5	.091	2.9
GLASS	CYR	23269	.0007	.0077	.0088	.0065	.032	.0043	.0077	.0030	.0024	.030	.0037	.0003	.012
"	CY	11272	.0020	.023	.027	.019	.095	.013	.023	.0090	.0072	.088	.011	.0010	.037

*Not normally used in these environments

TABLE 5.2-28 GENERIC FAILURE RATE, λ_G, (f.10^6 hr.) FOR CAPACITORS (Continued)

(See Table 5.2-29 for π_Q Values)

CAPACITORS, FIXED			USE ENVIRONMENT													
DIELECTRIC	STYLE	MIL-C SPEC	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
CERAMIC	CKR	39014	.012	.019	.012	.023	.012	.092	.032	.040	.030	.060	.032	2.3	.0036	.0040
"	CK	11015	.036	.057	.036	.069	.036	.28	.096	.12	.090	.18	.096	6.8	.011	.012
"	CCR	20	.013	.014	.0048	.019	.0067	.046	.085	.10	.015	.15	.051	.68	.0010	.0010
Ta, SOL	CSR	39003	.021	.049	.017	.052	.017	.14	.089	.22	.040	.027	.054	3.2	.0055	.0066
Ta, NON-SOL	CLR	39006	.046	.050	.019	.077	.031	.18	.20	.20	.083	.39	.15	4.0	.0061	.0067
" "	CL	3965	.14	.15	.057	.23	.093	.53	.59	.59	.25	1.2	.44	12.	.018	.020
Al OXIDE	CU	39018	1.4	1.4	1.3	2.1	1.4	3.7	6.9	6.9	5.8	9.2	6.9	63.	.073	.087
" DRY	CE	62	2.2	2.2	2.1	3.3	2.2	5.9	15.	.15	12.	19.	15.	84.	.088	.11
CAPACITORS, VARIABLE																
CERAMIC	CV	81	4.6	4.6	1.6	4.6	1.8	17.	45.	48.	10.	51.	17.	340.	.32	.41
PISTON	PC	14409	.63	.74	.63	1.1	.63	6.7	6.8	10.	3.4	14.	6.8	110.	.098	.12
AIR, TRIMMER	CT	92	8.5	8.5	3.0	8.5	3.4	31.	90.	97.	21.	100.	35.	520.	.40	.52
VACUUM	CG	23183	17.	26.	11.	43.	17.	69.	170.	270.	100.	390.	170.	*	1.2	1.6

*Not normally used in these environments

TABLE 5.2-28 GENERIC FAILURE RATE, λ_G, (f.10^6 hr.) FOR CAPACITORS (Continued)

(See Table 5.2-29 for π_Q Values)

CAPACITORS, FIXED			USE ENVIRONMENT												
DIELECTRIC	STYLE	MIL-C SPEC	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
CERAMIC	CKR	39014	.0059	.030	.056	.041	.14	.040	.059	.020	.019	.050	.064	.0029	.12
"	CK	11015 .018	.089	.17	.12	.42	.12	.18	.061	.056	.15	.19	.0087	.35	
"	CCR	20 .0027	.017	.020	.015	.069	.010	.018	.0056	.0056	.067	.0098	.0010	.030	
Ta, SOL	CSR	39003	.014	.055	.081	.058	.22	.053	.084	.029	.026	.13	.078	.0044	.16
Ta, NON-SOL	CLR	39006	.0092	.077	.10	.076	.27	.069	.11	.044	.033	.16	.098	.0001	.20
" "	CL	3965	.028	.23	.31	.23	.83	.21	.32	.13	.099	.48	.29	.018	.59
Al OXIDE	CU	39018	.22	1.7	1.8	1.3	5.6	.98	1.7	.61	.53	3.5	1.2	.073	2.9
" DRY	CE	62	.29	2.6	2.5	1.8	9.0	1.2	2.3	.82	.71	7.9	1.3	.088	3.7
CAPACITORS, VARIABLE															
CERAMIC	CV	81	1.2	4.5	8.8	6.5	26.	5.7	8.9	2.8	2.8	16.	7.9	.26	16.
PISTON	PC	14409	.39	2.0	3.1	2.3	10.	1.6	2.9	.96	.92	3.2	1.7	.098	4.9
AIR, TRIMMER	CT	92	1.8	8.4	15.	11.	48.	7.9	14.	4.2	4.2	31.	8.0	.40	23.
VACUUM	CG	23183	4.6	17.	*	*	*	23.	38.	11.	11.	70.	33.	1.2	*

*Not normally used in these environments

TABLE 5.2-29

π_Q FACTOR FOR RESISTORS AND CAPACITORS

FAILURE RATE LEVEL	$*\pi_Q$
L	1.5
M	1.0
P	.3
R	.1
S	.03

*For Non-ER parts (styles with only 2 letters in Tables 5.2-27 and 5.2-28), π_Q = 1 providing parts are procured in accordance with the part specification; if procured as commercial (NON-MIL) quality, use π_Q = 3. For ER parts (styles with 3 letters), use the π_Q value for the "letter" failure rate level procured.

TABLE 5.2-30 GENERIC FAILURE RATE, λ_G, FOR INDUCTIVE & ELECTROMECHANICAL PARTS (f./10^6 hr.)

PART TYPE	USE ENVIRONMENT												
	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B
MAGNETRONS													
Cont Wave	230	270	72	360	200	1400	290	340	90	540	230	36000	18
Coax Pulsed	560	650	170	860	480	3500	690	820	220	1300	560	86000	43
Conv Pulsed	3000	3500	930	4700	2600	19000	3700	4400	1200	7000	3000	470000	230
INDUCTIVE													
Low Pwr Pulse Xfmr	.023	.023	.018	.035	.023	.094	.038	.038	.033	.051	.033	2.0	.0030
Audio Xfmr	.047	.047	.035	.070	.047	.19	.076	.076	.066	.10	.066	4.0	.0060
High Power	.19	.19	.14	.28	.19	.74	.35	.35	.31	.47	.31	14.	.020
Pulse & Power Transformer, Filter													
R.F. Xfmr	.19	.19	.14	.28	.19	.75	.31	.31	.27	.41	.27	16.	.024
R.F. Coils, Fix	.0098	.012	.0087	.020	.0098	.052	.019	.021	.014	.029	.019	1.1	.0017
R.F. Coils, Var	.020	.024	.017	.039	.020	.11	.037	.043	.029	.057	.037	2.2	.0034
MOTORS	7.1	7.1	7.1	7.1	7.1	7.1	35.	35.	35.	35.	35.	*	1.6
RELAYS													
General Purp	1.1	1.5	.83	1.5	.91	7.0	1.8	2.6	1.4	2.6	1.6	*	.13
Contractor, HC	2.2	4.9	2.7	4.9	2.9	23.	5.7	8.5	4.6	8.5	5.1	*	.43
Latching	1.1	1.5	.83	1.5	.91	7.0	1.8	2.6	1.4	2.6	1.6	*	.13
Reed	1.0	1.4	.75	1.4	.82	6.3	2.0	3.0	1.6	3.0	1.8	*	.11
Thermal Bi-met	2.4	3.3	1.8	3.3	2.0	15.	3.8	5.7	3.0	5.7	3.4	*	.29
Meter Movement	7.6	10.	5.6	10.	6.1	46.	12.	18.	9.4	18.	11.	*	.89
Solid State	5.2	8.4	2.6	10	3.8	9.2	9.2	15	4.0	17	6.4	240	.40
Time Delay Hyb & Sol St	14	23	6.7	28	10	22	28	41	11	47	18	580	.90

TABLE 5.2-30 GENERIC FAILURE RATE, λ_G, FOR INDUCTIVE & ELECTROMECHANICAL PARTS (f./10^6 hr.) (Continued)

PART TYPE	USE ENVIRONMENT												
	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B
SWITCHES													
Toggle & Push Button	.015	.015	.0080	.020	.0080	.046	.020	.020	.010	.025	.010	1.2	.0010
Sensitive	2.2	2.2	1.2	3.0	1.2	6.9	3.0	3.0	1.5	3.7	1.5	180.	.15
Thumbwheel	8.4	8.4	4.5	11	4.5	26	11	11	5.6	14	5.6	670	.56
Other Rotary	4.9	4.9	2.6	6.6	2.6	15.	6.6	6.6	3.3	8.2	3.3	400.	.33
Circuit Breakers													
Thermal	.86	1.1	.63	1.1	.68	5.2	1.1	1.7	.91	1.7	1.0	*	.11
Magnetic	.45	.60	.33	.60	.36	2.8	.60	.90	.48	.90	.54	*	.060
CONNECTORS													
Cir/Rack/Panel	.12	.13	.059	.19	.089	.56	.36	.42	.21	.64	.34	5.1	.0055
Coaxial	.12	.13	.058	.19	.087	.55	.34	.40	.20	.60	.32	5.3	.0060
PCBs	.096	.14	.052	.22	.28	.096	.14	.20	.074	.32	.14	2.6	.0027
I.C. Sockets	.019	.019	.013	.025	.013	.048	.025	.025	.019	.039	.019	1.3	.0019
Interconnect Assemblies	.23	.33	.10	.41	.19	.78	.82	1.0	.31	1.4	.62	21.	.041
TUBES	See Section 5.1.4												
LASERS	See Section 5.1.5												

*Not normally used in these environments

TABLE 5.2-30 GENERIC FAILURE RATE, λ_G, FOR INDUCTIVE & ELECTROMECHANICAL PARTS (f./10^6 hr.) (Continued)

PART TYPE	USE ENVIRONMENT													
	G_{MS}	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
MAGNETRONS														
Cont. Wave	20	36	72	900	650	2900	650	1000	230	230	360	1100	18	1900
Coax Pulsed	48	86	170	2200	1600	6900	1600	2400	560	560	860	860	43	4600
Conv Pulsed	260	470	930	12000	8400	37000	8400	13000	3000	3000	4700	14000	230	25000
INDUCTIVE														
Low Power Pulse Xfmr	.0048	.019	.047	.052	.038	.14	.034	.053	.019	.017	.078	.051	.0030	.10
Audio Xfmr	.0096	.037	.094	.10	.076	.28	.069	.11	.037	.033	.16	.10	.0060	.20
High Power	.032	.13	.37	.38	.28	1.1	.24	.37	.13	.12	.75	.32	.020	.69
Pulse & Power Transformer, Filter														
R.F. xfmr	.038	.15	.38	.41	.30	1.1	.28	.42	.15	.13	.62	.40	.024	.80
R.F. Coils, Fix	.0032	.0066	.026	.029	.021	.079	.019	.029	.011	.0094	.043	.028	.0017	.056
R.F. Coils, Var	.0065	.013	.052	.058	.043	.16	.039	.059	.021	.019	.087	.057	.0034	.11
MOTORS	1.6	2.4	7.1	*	*	*	*	2.4	2.4	2.4	55.	4.5	*	*
RELAYS														
General Purp	.16	.32	1.2	4.1	3.0	11.	2.8	4.4	1.1	1.1	2.6	4.4	.13	8.4
Contractor, HC	.52	1.0	4.0	13.	9.6	35.	9.2	14.	3.6	3.6	8.4	14.	.43	27.
Latching	.16	.32	1.2	4.1	3.0	11.	2.8	4.4	1.1	1.1	2.6	4.4	.13	8.4
Reed	.13	.27	1.1	3.5	2.5	9.7	2.3	3.7	.92	.92	3.2	3.5	.11	6.9
Thermal Bi-met	.35	.69	2.7	8.9	6.4	23.	6.1	9.5	2.4	2.4	5.6	9.4	.29	18.
Meter Movement	1.1	2.1	8.2	27.	20.	72.	19.	30.	7.4	7.4	17.	29.	.89	56.
Solid State	.52	1.3	5.2	5.6	4.0	14	4.0	6.4	2.8	2.1	6.8	6.8	.34	12
Time Delay Hyb & Sol St	1.3	3.7	13	14	10	34	10	15	7.2	6.3	17	17	.63	30

TABLE 5.2-30. GENERIC FAILURE RATE, λ_G, FOR INDUCTIVE & ELECTROMECHANICAL PARTS (f./10^6 hr.) (Continued)

PART TYPE	USE ENVIRONMENT													
	G_{MS}	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
SWITCHES														
Toggle & Push Button	.0012	.0029	.014	.029	.021	.071	.021	.032	.0079	.0079	.020	.034	.0010	.063
Sensitive	.18	.44	2.1	4.4	3.2	11.	3.2	4.8	1.2	1.2	3.0	5.1	.15	9.5
Thumbwheel	.67	1.6	7.8	16	12	40	12	18	4.4	4.4	11	19	.56	35
Other Rotary	.40	.95	4.6	9.5	6.9	23.	6.9	11.	2.6	2.6	6.6	11.	.33	21.
Circuit Breakers														
Thermal	.14	.26	.93	3.3	2.4	8.1	2.4	3.6	.91	.91	1.6	3.9	.11	7.1
Magnetic	.072	.14	.49	1.7	1.3	4.3	1.3	1.9	.48	.48	.84	2.0	.060	3.7
CONNECTORS														
Cir/Rack/Panel	.011	.017	.25	.14	.10	.43	.16	.18	.073	.057	.40	.12	.0055	.23
Coaxial	.012	.017	.24	.14	.10	.42	.17	.19	.077	.059	.38	.14	.0060	.25
PCBs	.0034	.024	.12	.070	.050	.22	.078	.090	.040	.028	.20	.053	.0027	.12
I.C. Sockets	.0025	.0060	.033	.031	.021	.076	.021	.033	.014	.010	.035	.037	.0019	.064
Interconnect Assemblies	.049	.094	.32	.49	.36	1.2	.28	.53	.22	.17	.49	.57	.041	1.0
TUBES	See Section 5.1.4													
LASERS	See Section 5.1.5													

*Not normally used in these environments

TABLE 5.2-31 π_Q FACTOR FOR USE WITH TABLE 5.2-30

PART TYPE	QUALITY LEVEL	
	MIL-SPEC	NON-MIL
MAGNETRONS	N/A	N/A
INDUCTIVE	1	3
MOTORS	1	6
RELAYS, SOLID STATE	1	3
RELAYS, TIME DELAY (HYBRID & SOLID STATE)	1	4
RELAYS, ALL OTHERS	1	6
SWITCHES, TOGGLE & SENSITIVE	1	20
SWITCHES, THUMBWHEEL	1	1.5
SWITCHES, OTHER ROTARY TYPES	1	50
CIRCUIT BREAKERS	1	8.4
CONNECTORS	1	3
INTERCONNECTION ASSEMBLIES	1	10

TABLE 5.2-32 GENERIC FAILURE RATE, λ_G, FOR MISCELLANEOUS PARTS (f./10 hr.)

PART TYPE	USE ENVIRONMENT												
	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B
SAWS	21	26	16	32	16	47	32	42	26	42	26	1300	2.1
QUARTZ CRYSTALS	.54	.54	.29	.54	.29	.74	.90	.90	.61	.90	.61	16	.032
LAMPS, INCANDESCENT													
AC Applications	17	17	13	17	13	21	23	23	19	23	19	110	3.9
DC Applications	57	57	41	57	41	69	75	75	62	75	62	350	13
ELECTRONIC FILTERS													
Ceramic-ferrite Construction	.19	.19	.12	.19	.12	.24	.28	.28	.22	.28	.22	2.6	.022
Discrete LC Comp Construction	1.1	1.1	.66	1.1	.66	1.3	1.6	1.6	1.2	1.6	1.2	14	.12
Discrete LC & Crystal Comp. Construction	2.3	2.3	1.5	2.3	1.5	2.9	3.4	3.4	2.7	3.4	2.7	32	.27
FUSES	.12	.12	.068	.12	.068	.16	.18	.18	.13	.18	.13	2.3	.010
METERS	See Section 5.1.15												

TABLE 5.2-32 GENERIC FAILURE RATE, λ_G, FOR MISCELLANEOUS PARTS (f./10 hr.)

PART TYPE	USE ENVIRONMENT													
	G_{MS}	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}
SAWS	2.9	8.2	23	30	22	74	21	33	18	10	34	36	3.4	64
QUARTZ CRYSTALS	.038	.083	.32	.48	.35	1.1	.35	.51	.21	.17	.45	.54	.032	.96
LAMPS, INCANDESCENT														
AC Applications	4.3	6.3	13	16	14	26	14	17	11	9.4	16	18	5.5	24
DC Applications	14	21	44	54	45	84	45	57	35	31	53	58	18	79
ELECTRONIC FILTERS														
Ceramic-ferrite Construction	.024	.046	.13	.18	.14	.35	.14	.19	.094	.083	.17	.20	.037	.31
Discrete LC Comp. Construction	.13	.25	.72	.98	.77	1.9	.77	1.0	.52	.44	.95	1.1	.20	1.7
Discrete LC & Crystal Comp. Construction	.29	.56	1.6	2.2	1.7	4.2	1.7	2.3	1.1	.98	2.1	2.4	.45	3.7
FUSES	.012	.023	.075	.11	.081	.22	.081	.12	.052	.044	.10	.12	.018	.20
METERS	See Section 5.1.15													

TABLE 5.2-33

π_Q FACTOR FOR USE WITH TABLE 5.2-32

PART TYPE	QUALITY LEVEL	
	MIL-SPEC	NON-MIL
SAWS	N/A	N/A
QUARTZ CRYSTALS	1	2.1
LAMPS, INCANDESCENT	N/A	N/A
FILTERS, ELECTRONIC	1	2.9
FUSES	N/A	N/A

TABLE 5.2-34 AMBIENT TEMPERATURE FOR ALL PARTS (EXCEPT MICROCIRCUITS)

ENVIRONMENT	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
T_A(°C.)	55	55	55	55	55	55	71	71	71	71	71	40	30	30
ENVIRONMENT	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}	
T_A(°C.)	40	55	45	45	55	35	40	40	40	75	20	30	35	

TABLE 5.2-35 JUNCTION TEMPERATURES FOR MICROCIRCUITS

ENVIRONMENT	A_{IA}	A_{IB}	A_{IC}	A_{IF}	A_{IT}	A_{RW}	A_{UA}	A_{UB}	A_{UC}	A_{UF}	A_{UT}	C_L	G_B	G_{MS}
T_J(°C.)	70	70	70	70	70	70	105	105	105	105	105	55	45	46
ENVIRONMENT	G_F	G_M	M_{FA}	M_{FF}	M_L	M_P	N_H	N_S	N_{SB}	N_U	N_{UU}	S_F	U_{SL}	
T_J(°C)	55	60	60	70	70	50	55	55	55	90	35	55	50	

TABLE 5.2-36 MODEL PARAMETERS FOR DISCRETE SEMICONDUCTORS*

PART TYPE	π_A	π_R	π_{S2}	π_C
TRANSISTORS				
Si NPN	1.5	1.0	1.0	1.0
Si PNP	1.5	1.0	1k.0	1.0
Ge NPN	1.5	1.0	1.0	1.0
Ge PNP	1.5	1.0	1.0	1.0
Si FET	1.5	---	---	1.0
Unijunction	---	---	---	---
DIODES				
Si Gen Purpose	1.0	1.0	0.70	1.0
Ge " "	1.0	1.0	0.70	1.0
Zener & Avalanche	1.0	---	---	---
Thryistor	---	1.0	---	---
Si Microwave Det	---	---	---	---
Ge " "	---	---	---	---
Si " Mix	---	---	---	---
Ge " "	---	---	---	---
Varactor, Step Recovery, Tunnel	1.0	1.0	---	---
Gunn & Impatt ****	1.0	1.0	---	---
PIN	1.0	1.3	---	---
LED**	---	---	---	---
Single Isolator**	---	---	---	---
Bipolar Microwave Power Transistor***	2.0	---	---	---

* Used JAN quality π_Q from Section 5.1.3.

** Used $T_J = T_A + 30$ in °C. to determine π_T
Used $\lambda_b = .0055$ (Phototransistor Detector)

*** $\pi_F = 1.5$
$\pi_M = 1.0$
π_T computed using $T = T_A + 100$ and refractory metal gold $V/BV_{CES} = 0.5$

**** Used $\lambda_b = 0.6$
$\pi_Q = 1.0$

TABLE 5.2-37 MODEL PARAMETERS FOR RESISTORS & CAPACITORS

STYLE	QUALITY LEVEL	π_R	STYLE	QUALITY LEVEL	TEMP. π_{CV}	RATING
RCR	M	1.1	CP	MIL-SPEC.	1	125
RC	MIL-R-11	"	CA	" "	"	85
RLR	M	"	CZR	M	"	125
RL	MIL-R-22684	"	CPV	M	"	"
RNR	M	"	CQR	M	"	"
RN	MIL-R-10509	"	CHR	"	"	"
RD	MIL-SPEC.	1.0	CH	NON-ER	"	"
RZ*	"	NA	CFR	M	"	"
RBR	M	1.7	CRH	"	"	"
RB	MIL-R-93	"	CMR	"	"	"
RWR	M	1.1	CM	MOLDED	"	"
RW	MIL-R-26	"	CB	MIL-SPEC.	"	150
RER	M		CYR	M	"	125
RE	MIL-R-18546	"	CY	NON-ER	"	125
RTR	M	1.4	CKR	M	"	"
RT	MIL-R-27208	"	CK	NON-ER	"	"
RR*	MIL-SPEC.	"	CCR	M	"	"
RA	"	"	CSR*	"	"	"
RK	"	"	CLR*	"	"	"
RP*	MIL-SPEC.	1.4	CL*	NON-ER	"	"
RJR	M	1.2	CU	"	1.3	
RJ	MIL-R-22097	"	CE	"	"	"
RV	MIL-SPEC.	"	CV	"		85
RQ	"	"	PC	"		125
RVC	"	"	CT	"		
			CG*	"		85

* - for RZ, $N_R = 10$

" RR, $\pi_C = 1.5$

" RP, CLR & CL, $\pi_C = 1$

for CSR, $\pi_{SR} = 0.4$

" CG, $\pi_{CF} = 1$

" all variable resistors, $\pi_V = 1$, $\pi_{TAPS} = 1$

TABLE 5.2-38 MODEL PARAMETERS FOR INDUCTIVE & ELECTROMECHANICAL PARTS

MAGNETRONS	λ_b(f/10^6 filament hrs.)	π_u	π_C
Cont. Wave	18	1.0	1
Coax Pulsed	60	.72	1
Conv. Pulsed	60	.72	5.4

INDUCTIVE DEVICES	QUALITY LEVEL	INSULATION MAX. Rated Temp ($^oC.$)	ΔT($^oC.$)
Low power pulse transformer	MIL-SPEC.	130	10
Audio Transformer	"	"	"
High power pulse & power transformer, filter	"	"	30
R.F. transformer	"	"	10
R.F. Coils, fixed	MIL-C-15305	125	"
R.F. Coils, variable	"	"	"

MOTORS	t = 15,000 hrs.

RELAYS	QUALITY	LOAD TYPE	π_C	π_{CYC}	π_F	RATING
Gen. Purpose	MIL-SPEC.	Resistive	3	1	5	125
Contractor, high current	"	Inductive	3	1	5	"
Latching	"	Resistive	3	1	5	"
Reed	"	"	1	2	6	85
Thermal, bi-metal	"	Inductive	1	1	10	125
Meter Movement	"	Resistive	1	1	100	"
Solid State	"	λ_b = .40 f./10^6 hrs.				
Time Delay (Hybrid & Solid State)	"	λ_b = .50 f./10^6 hrs. (Delay base failure rate) λ_R - (Assumed equal to λ_b for solid state relay)				

* Used snap-action type

**Used λ_b = .000041

π_Q = 1.0

π_S = 0

π_C = 2.0 (Assumed 6 circuit planes)

TABLE 5.2-38 MODEL PARAMETERS
FOR INDUCTIVE & ELECTROMECHANICAL PARTS (Continued)

SWITCHES	QUALITY	LOAD TYPE	π_{CYC}	CONTACT FORM	
Toggle & Pushbutton	MIL-SPEC.	Resistive	1	DPST	
Sensitive	"	"	1	n=1, activation diff. >002"	
Thumbwheel	"	"	1	N=6	
Other Rotary	"	"	30	n=24	
Ckt Bkrs, Thermal	"	$\pi_C = 3$			
Ckt Bkrs, Magnetic	"	$\pi_C = 3$			
CONNECTORS	QUALITY	INSERT MATERIAL	$\Delta T(^{o}C.)$	π_P	π_K
Circular, Rack & Panel	MIL-SPEC.	B	10	7.42	1 for G_B & S_F 1.5 for C_L, M_{FA}, M_{FF}, M_L, U_{SL} 2 for G_{MS}, G_F, N_H, N_S, N_{SB}, N_U, N_{UU} 3 for A_{IA}, A_{IB}, A_{IC}, A_{IF}, A_{IT}, A_{RW}, A_{UA}, A_{UB}, A_{UC}, A_{UF}, A_{UT}, G_M, M_P
Coaxial	"	C	5	1.36	
Printed Circuit Board	"	NA	10	7.42	
Interconnection Assemblies**	$N_1 = 500$, $N_2 = 0$				

TABLE 5.2-39

MODEL PARAMETERS FOR MISCELLANEOUS PARTS

PART TYPE	QUALITY LEVEL	DEVICE FACTORS
SAWS	N/A	
QUARTZ CRYSTALS	MIL-SPEC	f = 50 MHz.
LAMPS, INCANDESCENT	N/A	π_A = 1.0 (AC APPLICATIONS) π_A = 3.3 (DC APPLICATIONS) π_U = .72 V_R = 28 VOLTS
FILTERS, ELECTRONIC	MIL-SPEC	
FUSES	N/A	

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