NOTICE OF CHANGE

NOT MEASUREMENT SENSITIVE

MIL-HDBK-217F
NOTICE 1
10 JULY 1992

MILITARY HANDBOOK
RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

To all holders of MIL-HDBK-217F

1. The following pages of MIL-HDBK-217F have been revised and supersede the pages listed.

New Page(s)	Date	Superseded Page(s)	Date
vii		vii	2 December 1991
5-3		5-3	2 December 1991
5-4		5-4	2 December 1991
5-7		5-7	2 December 1991
5-8	2 December 1991	5-8	Reprinted without change
5-9		5-9	2 December 1991
5-10	2 December 1991	5-10	Reprinted without change
5-11	2 December 1991	5-11	Reprinted without change
5-12		5-12	2 December 1991
5-13		5-13	2 December 1991
5-14	2 December 1991	5-14	Reprinted without change
5-19		5-19	2 December 1991
5-20	2 December 1991	5-20	Reprinted without change
6-15		6-15	2 December 1991
6-16	2 December 1991	6-16	Reprinted without change
7-1	2 December 1991	7-1	Reprinted without change
7-2		7-2	2 December 1991
12-3		12-3	2 December 1991
12-4	2 December 1991	12-4	Reprinted without change
A-1	2 December 1991	A-1	Reprinted without change
A-2		A-2	2 December 1991
A-3		A-3	2 December 1991
A-4	2 December 1991	A-4	Reprinted without change
A-5		A-5	2 December 1991
A-6		A-6	2 December 1991
A-7		A-7	2 December 1991
A-8		A-8	2 December 1991
A-9		A-9	2 December 1991
A-10	2 December 1991	A-10	Reprinted without change
A-11	2 December 1991	A-11	Reprinted without change
A-12		A-12	2 December 1991
A-13		A-13	2 December 1991
A-14		A-14	2 December 1991
A-15	2 December 1991	A-15	Reprinted without change
A-16		A-16	2 December 1991

AMSC N/A

AREA-RELI

2. Retain the pages of this notice and insert before the Table of Contents.

3. Holders of MIL-HDBK-217F will verify that page changes and additions indicated have been entered. The notice pages will be retained as a check sheet. The issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military handbook is revised or canceled.

Custodians:
Army - CR
Navy - EC
Air Force - 17

Preparing Activity:
Air Force - 17

Project No. RELI-0068

Review Activities:
Army - MI, AV, ER
Navy - SH, AS, OS
Air Force - 11, 13, 14, 15, 18, 19, 99

User Activities:
Army - AT, ME, GL
Navy - CG, MC, YD, TD
Air Force - 85

FOREWORD

MIL-HDBK-217F, Notice 1 is issued to correct minor typographical errors in the basic F Revision. MIL-HDBK-217F (base document) provides the following changes based upon recently completed studies (see Ref. 30 and 32 listed in Appendix C):

1. New failure rate prediction models are provided for the following nine major classes of microcircuits:

   - Monolithic Bipolar Digital and Linear Gate/Logic Array Devices
   - Monolithic MOS Digital and Linear Gate/Logic Array Devices
   - Monolithic Bipolar and MOS Digital Microprocessor Devices (Including Controllers)
   - Monolithic Bipolar and MOS Memory Devices
   - Monolithic GaAs Digital Devices
   - Monolithic GaAs MMIC Devices
   - Hybrid Microcircuits
   - Magnetic Bubble Memories
   - Surface Acoustic Wave Devices

This revision provides new prediction models for bipolar and MOS microcircuits with gate counts up to 60,000, linear microcircuits with up to 3000 transistors, bipolar and MOS digital microprocessor and co-processors up to 32 bits, memory devices with up to 1 million bits, GaAs monolithic microwave integrated circuits (MMICs) with up to 1,000 active elements, and GaAs digital ICs with up to 10,000 transistors. The C_1 factors have been extensively revised to reflect new technology devices with improved reliability, and the activation energies representing the temperature sensitivity of the dice (π_T) have been changed for MOS devices and for memories. The C_2 factor remains unchanged from the previous Handbook version, but includes pin grid arrays and surface mount packages using the same model as hermetic, solder-sealed dual in-line packages. New values have been included for the quality factor (π_Q), the learning factor (π_L), and the environmental factor (π_E). The model for hybrid microcircuits has been revised to be simpler to use, to delete the temperature dependence of the seal and interconnect failure rate contributions, and to provide a method of calculating chip junction temperatures.

2. A new model for Very High Speed Integrated Circuits (VHSIC/VHSIC Like) and Very Large Scale Integration (VLSI) devices (gate counts above 60,000).

3. The reformatting of the entire handbook to make it easier to use.

4. A reduction in the number of environmental factors (π_E) from 27 to 14.

5. A revised failure rate model for Network Resistors.

6. Revised models for TWTs and Klystrons based on data supplied by the Electronic Industries Association Microwave Tube Division.

5.1 MICROCIRCUITS, GATE/LOGIC ARRAYS AND MICROPROCESSORS

DESCRIPTION
1. Bipolar Devices, Digital and Linear Gate/Logic Arrays
2. MOS Devices, Digital and Linear Gate/Logic Arrays
3. Field Programmable Logic Array (PLA) and Programmable Array Logic (PAL)
4. Microprocessors

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

Bipolar Digital and Linear Gate/Logic Array Die Complexity Failure Rate - C_1

Digital		Linear		PLA/PAL	
No. Gates	C_1	No. Transistors	C_1	No. Gates	C_1
1 to 100	.0025	1 to 100	.010	Up to 200	.010
101 to 1,000	.0050	101 to 300	.020	201 to 1,000	.021
1,001 to 3,000	.010	301 to 1,000	.040	1,001 to 5,000	.042
3,001 to 10,000	.020	1,001 to 10,000	.060		
10,001 to 30,000	.040				
30,001 to 60,000	.080				

MOS Digital and Linear Gate/Logic Array Die Complexity Failure Rate - C_1*

Digital		Linear		PLA/PAL	
No. Gates	C_1	No. Transistors	C_1	No. Gates	C_1
1 to 100	.010	1 to 100	.010	Up to 500	.00085
101 to 1,000	.020	101 to 300	.020	501 to 2,000	.0017
1,001 to 3,000	.040	301 to 1,000	.040	2,001 to 5,000	.0034
3,001 to 10,000	.080	1,001 to 10,000	.060	5,001 to 20,000	.0068
10,001 to 30,000	.16				
30,001 to 60,000	.29				

*NOTE: For CMOS gate counts above 60,000 use the VHSIC/VHSIC-Like model in Section 5.3

Microprocessor
Die Complexity Failure Rate - C_1

No. Bits	Bipolar C_1	MOS C_1
Up to 8	.060	.14
Up to 16	.12	.28
Up to 32	.24	.56

All Other Model Parameters

Parameter	Refer to
π_T	Section 5.8
C_2	Section 5.9
π_E, π_Q, π_L	Section 5.10

5.2 MICROCIRCUITS, MEMORIES

DESCRIPTION

1. Read Only Memories (ROM)
2. Programmable Read Only Memories (PROM)
3. Ultraviolet Eraseable PROMs (UVEPROM)
4. "Flash," MNOS and Floating Gate Electrically Eraseable PROMs (EEPROM). Includes both floating gate tunnel oxide (FLOTOX) and textured polysilicon type EEPROMs
5. Static Random Access Memories (SRAM)
6. Dynamic Random Access Memories (DRAM)

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

Die Complexity Failure Rate - C_1

Memory Size, B (Bits)	MOS				Bipolar	
	ROM	PROM, UVEPROM, EEPROM, EAPROM	DRAM	SRAM (MOS & BiCMOS)	ROM, PROM	SRAM
Up to 16K	.00065	.00085	.0013	.0078	.0094	.0052
$16K < B \le 64K$	.0013	.0017	.0025	.016	.019	.011
$64K < B \le 256K$	.0026	.0034	.0050	.031	.038	.021
$256K < B \le 1M$	.0052	.0068	.010	.062	.075	.042

A_1 Factor for λ_{cyc} Calculation

Total No. of Programming Cycles Over EEPROM Life, C	Flotox[1]	Textured-Poly[2]
Up to 100	.00070	.0097
$100 < C \le 200$	.0014	.014
$200 < C \le 500$	.0034	.023
$500 < C \le 1K$	.0068	.033
$1K < C \le 3K$	.020	.061
$3K < C \le 7K$	.049	.14
$7K < C \le 15K$	.10	.30
$15K < C \le 20K$	.14	.30
$20K < C \le 30K$	.20	.30
$30K < C \le 100K$	.68	.30
$100K < C \le 200K$	1.3	.30
$200K < C \le 400K$	2.7	.30
$400K < C \le 500K$	3.4	.30

1. $A_1 = 6.817 \times 10^{-6}$ (C)
2. No underlying equation for Textured-Poly.

A_2 Factor for λ_{cyc} Calculation

Total No. of Programming Cycles Over EEPROM Life, C	Textured-Poly A_2
Up to 300K	0
$300K < C \le 400K$	1.1
$400K < C \le 500K$	2.3

All Other Model Parameters

Parameter	Refer to
π_T	Section 5.8
C_2	Section 5.9
π_E, π_Q, π_L	Section 5.10
λ_{cyc} (EEPROMS only)	Page 5-5

$\lambda_{cyc} = 0$ For all other devices

5.3 MICROCIRCUITS, VHSIC/VHSIC-LIKE AND VLSI CMOS

DESCRIPTION
CMOS greater than 60,000 gates

$$\lambda_p = \lambda_{BD}\pi_{MFG}\pi_T\pi_{CD} + \lambda_{BP}\pi_E\pi_Q\pi_{PT} + \lambda_{EOS} \quad \text{Failures}/10^6 \text{ Hours}$$

Die Base Failure Rate - λ_{BD}

Part Type	λ_{BD}
Logic and Custom	0.16
Gate Array and Memory	0.24

All Other Model Parameters

Parameter	Refer to
π_T	Section 5.8
π_E, π_Q	Section 5.10

Manufacturing Process Correction Factor - π_{MFG}

Manufacturing Process	π_{MFG}
QML or QPL	.55
Non QML or Non QPL	2.0

Package Type Correction Factor - π_{PT}

	π_{PT}	
Package Type	Hermetic	Nonhermetic
DIP	1.0	1.3
Pin Grid Array	2.2	2.9
Chip Carrier (Surface Mount Technology)	4.7	6.1

Die Complexity Correction Factor - π_{CD}

Feature Size	Die Area (cm^2)				
(Microns)	$A \le .4$	$.4 < A \le .7$	$.7 < A \le 1.0$	$1.0 < A \le 2.0$	$2.0 < A \le 3.0$
.80	8.0	14	19	38	58
1.00	5.2	8.9	13	25	37
1.25	3.5	5.8	8.2	16	24

$$\pi_{CD} = \left(\left(\frac{A}{.21}\right)\left(\frac{2}{X_s}\right)^2(.64)\right) + .36$$

A = Total Scribed Chip Die Area in cm^2 $\quad$ X_s = Feature Size (microns)

Die Area Conversion: $cm^2 = MIL^2 \div 155,000$

Package Base Failure Rate - λ_{BP}

Number of Pins	λ_{BP}
24	.0026
28	.0027
40	.0029
44	.0030
48	.0030
52	.0031
64	.0033
84	.0036
120	.0043
124	.0043
144	.0047
220	.0060

$$\lambda_{BP} = .0022 + \left((1.72 \times 10^{-5})(NP)\right)$$

NP = Number of Package Pins

Electrical Overstress Failure Rate - λ_{EOS}

V_{TH} (ESD Susceptibility (Volts))*	λ_{EOS}
0 - 1000	.065
> 1000 - 2000	.053
> 2000 - 4000	.044
> 4000 - 16000	.029
> 16000	.0027

$$\lambda_{EOS} = (-\ln(1 - .00057 \exp(-.0002\, V_{TH})))/.00876$$

V_{TH} = ESD Susceptibility (volts)

* Voltage ranges which will cause the part to fail. If unknown, use 0 - 1000 volts.

5.4 MICROCIRCUITS, GaAs MMIC AND DIGITAL DEVICES

DESCRIPTION
Gallium Arsenide Microwave Monolithic Integrated Circuit (GaAs MMIC) and GaAs Digital Integrated Circuits using MESFET Transistors and Gold Based Metallization

$$\lambda_p = [\, C_1 \pi_T \pi_A + C_2 \pi_E \,] \pi_L \pi_Q \text{ Failures}/10^6 \text{ Hours}$$

MMIC: Die Complexity Failure Rates - C_1

Complexity (No. of Elements)	C_1
1 to 100	4.5
101 to 1000	7.2

1. C_1 accounts for the following active elements: transistors, diodes.

Digital: Die Complexity Failure Rates - C_1

Complexity (No. of Elements)	C_1
1 to 1000	25
1,001 to 10,000	51

1. C_1 accounts for the following active elements: transistors, diodes.

Device Application Factor - π_A

Application	π_A
MMIC Devices	
Low Noise & Low Power (≤ 100 mW)	1.0
Driver & High Power (> 100 mW)	3.0
Unknown	3.0
Digital Devices	
All Digital Applications	1.0

All Other Model Parameters

Parameter	Refer to
π_T	Section 5.8
C_2	Section 5.9
π_E, π_L, π_Q	Section 5.10

DESCRIPTION

Hybrid Microcircuits

$$\lambda_p = [\Sigma N_c \lambda_c] (1 + .2 \pi_E) \pi_F \pi_Q \pi_L \text{ Failures/}10^6 \text{ Hours}$$

N_c = Number of Each Particular Component

λ_c = Failure Rate of Each Particular Component

The general procedure for developing an overall hybrid failure rate is to calculate an individual failure rate for each component type used in the hybrid and then sum them. This summation is then modified to account for the overall hybrid function (π_F), screening level (π_Q), and maturity (π_L). The hybrid package failure rate is a function of the active component failure modified by the environmental factor (i.e., (1 + .2 π_E)). *Only the component types listed in the following table are considered to contribute significantly to* the overall failure rate of most hybrids. All other component types (e.g., resistors, inductors, etc.) are considered to contribute insignificantly to the overall hybrid failure rate, and are assumed to have a failure rate of zero. This simplification is valid for most hybrids; however, if the hybrid consists of mostly passive components then a failure rate should be calculated for these devices. If factoring in other component types, assume $\pi_Q = 1$, $\pi_E = 1$ and T_A = Hybrid Case Temperature for these calculations.

Determination of λ_c

Determine λ_c for These Component Types	Handbook Section	Make These Assumptions When Determining λ_c
Microcircuits	5	$C_2 = 0$, $\pi_Q = 1$, $\pi_L = 1$, T_J as Determined from Section 5.12, $\lambda_{BP} = 0$ (for VHSIC), $\pi_E = 1$ (for SAW).
Discrete Semiconductors	6	$\pi_Q = 1$, T_J as Determined from Section 6.14, $\pi_E = 1$.
Capacitors	10	$\pi_Q = 1$, T_A = Hybrid Case Temperature, $\pi_E = 1$.

NOTE: If maximum rated stress for a die is unknown, assume the same as for a discretely package die of the same type. If the same die has several ratings based on the discrete packaged type, assume the lowest rating. Power rating used should be based on case temperature for discrete semiconductors.

Circuit Function Factor - π_F

Circuit Type	π_F
Digital	1.0
Video, 10 MHz < f < 1 GHz	1.2
Microwave, f > 1 GHz	2.6
Linear, f < 10 MHz	5.8
Power	21

All Other Hybrid Model Parameters

π_L, π_Q, π_E	Refer to Section 5.10

5.6 MICROCIRCUITS, SAW DEVICES

DESCRIPTION
Surface Acoustic Wave Devices

$$\lambda_p = 2.1\,\pi_Q\,\pi_E \text{ Failures}/10^6 \text{ Hours}$$

Quality Factor - π_Q

Screening Level	π_Q
10 Temperature Cycles (-55°C to +125°C) with end point electrical tests at temperature extremes.	.10
None beyond best commerical practices.	1.0

Environmental Factor - π_E

Environment	π_E
G_B	.5
G_F	2.0
G_M	4.0
N_S	4.0
N_U	6.0
A_{IC}	4.0
A_{IF}	5.0
A_{UC}	5.0
A_{UF}	8.0
A_{RW}	8.0
S_F	.50
M_F	5.0
M_L	12
C_L	220

5.7 MICROCIRCUITS, MAGNETIC BUBBLE MEMORIES

The magnetic bubble memory device in its present form is a non-hermetic assembly consisting of the following two major structural segments:

1. A basic bubble chip or die consisting of 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).

2. 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 model is based on Reference 33. The general form of the failure rate model is:

$$\lambda_p = \lambda_1 + \lambda_2 \text{ Failures/}10^6 \text{ Hours}$$

where:

λ_1 = Failure Rate of the Control and Detection Structure

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

λ_2 = Failure Rate of the Memory Storage Area

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

Chips Per Package - N_C

N_C	=	Number of Bubble Chips per Packaged Device

Temperature Factor – π_T

$$\pi_T = (.1) \exp\left[\frac{-Ea}{8.63 \times 10^{-5}} \left(\frac{1}{T_J + 273} - \frac{1}{298}\right)\right]$$

Use:

E_a	=	.8 to Calculate π_{T1}.
E_a	=	.55 to Calculate π_{T2}
T_J	=	Junction Temperature (°C), $25 \le T_J \le 175$
T_J	=	T_{CASE} + 10°C

Device Complexity Failure Rates for Control and Detection Structure - C_{11} and C_{21}

C_{11}	=	$.00095(N_1)^{.40}$
C_{21}	=	$.0001(N_1)^{.226}$
N_1	=	Number of Dissipative Elements on a Chip (gates, detectors, generators, etc.), $N_1 \le 1000$

5.7 MICROCIRCUIT, MAGNETIC BUBBLE MEMORIES

Write Duty Cycle Factor - π_W

$$\pi_W = \frac{10D}{(R/W)^{.3}}$$

π_W = 1 for $D \le .03$ or $R/W \ge 2154$

$$D = \frac{\text{Avg. Device Data Rate}}{\text{Mfg. Max. Rated Data Rate}} \le 1$$

R/W = No. of Reads per Write

NOTE:
For seed-bubble generators, divide π_W by 4, or use 1, whichever is greater.

Duty Cycle Factor - π_D

$$\pi_D = .9D + .1$$

$$D = \frac{\text{Avg. Device Data Rate}}{\text{Mfg. Max. Rated Data Rate}} \le 1$$

Device Complexity Failure Rates for Memory Storage Structure - C_{12} and C_{22}

$$C_{12} = .00007(N_2)^{.3}$$

$$C_{22} = .00001(N_2)^{.3}$$

N_2 = Number of Bits, $N_2 \le 9 \times 10^6$

All Other Model Parameters

Parameter	Section
C_2	5.9
π_E, π_Q, π_L	5.10

Temperature Factor For All Microcircuits - π_T

	TTL, STTL, ASTTL, CML, HTTL, FTTL, DTL, ECL	BiCMOS, LSTTL, LTTL, ALSTTL	IIL, ISL	Digital MOS, VHSIC CMOS	Linear (Bipolar & MOS)	Memories (Bipolar & MOS), MNOS	GaAs MMIC	GaAs Digital
Ea(eV) → T_J (°C)	.4	.5	.6	.35	.65	.6	1.5	1.4
25	.10	.10	.10	.10	.10	.10	3.20E-09	1.00E-08
30	.13	.14	.15	.13	.15	.15	8.40E-09	2.50E-08
35	.17	.19	.21	.16	.23	.21	2.10E-08	5.90E-08
40	.21	.25	.31	.19	.34	.31	5.20E-08	1.40E-07
45	.27	.34	.43	.24	.49	.43	1.30E-07	3.10E-07
50	.33	.45	.61	.29	.71	.61	2.90E-07	6.80E-07
55	.42	.59	.85	.35	1.0	.85	6.70E-07	1.50E-06
60	.51	.77	1.2	.42	1.4	1.2	1.50E-06	3.10E-06
65	.63	1.0	1.6	.50	2.0	1.6	3.20E-06	6.40E-06
70	.77	1.3	2.1	.60	2.8	2.1	6.80E-06	1.30E-05
75	.94	1.6	2.9	.71	3.8	2.9	1.40E-05	2.50E-05
80	1.1	2.1	3.8	.84	5.2	3.8	2.90E-05	4.90E-05
85	1.4	2.6	5.0	.98	7.0	5.0	5.70E-05	9.40E-05
90	1.6	3.3	6.6	1.1	9.3	6.6	1.10E-04	1.70E-04
95	1.9	4.1	8.5	1.3	12	8.5	2.10E-04	3.20E-04
100	2.3	5.0	11	1.5	16	11	4.00E-04	5.80E-04
105	2.7	6.2	14	1.8	21	14	7.50E-04	1.00E-03
110	3.2	7.5	18	2.1	28	18	1.40E-03	1.80E-03
115	3.7	9.2	23	2.4	35	23	2.40E-03	3.10E-03
120	4.3	11	28	2.7	45	28	4.30E-03	5.30E-03
125	5	13	35	3.1	58	35	7.50E-03	9.00E-03
130	5.8	16	44	3.5	73	44	1.30E-02	1.50E-02
135	6.7	19	54	3.9	92	54	2.20E-02	2.40E-02
140	7.7	23	67	4.4	120	67	3.70E-02	3.90E-02
145	8.8	27	82	5.0	140	82	6.10E-02	6.30E-02
150	10	32	100	5.6	180	100	1.00E-01	1.00E-01
155	11	37	120	6.3	220	120	1.60E-01	1.60E-01
160	13	43	150	7.0	270	150	2.60E-01	2.40E-01
165	15	50	180	7.8	330	180	4.10E-01	3.70E-01
170	16	59	210	8.7	400	210	6.40E-01	5.70E-01
175	18	68	250	9.6	480	250	9.90E-01	8.50E-01

$$\pi_T = .1 \exp\left(\frac{-Ea}{8.617 \times 10^{-5}}\left(\frac{1}{T_J + 273} - \frac{1}{298}\right)\right)$$ Silicon Devices

$$\pi_T = .1 \exp\left(\frac{-Ea}{8.617 \times 10^{-5}}\left(\frac{1}{T_J + 273} - \frac{1}{423}\right)\right)$$ GaAs Devices

E_a = Effective Activation Energy (eV) (Shown Above)

T_J = Worse Case Junction Temperature (Silicon Devices) or Average Active Device Channel Temperature (GaAs Devices). See Section 5.11 (or Section 5.12 for Hybrids) for T_J Determination.

NOTES:

1. $T_J = T_C + P\theta_{JC}$
   - T_C = Case Temperature (°C)
   - P = Device Power Dissipation (W)
   - θ_{JC} = Junction to Case Thermal Resistance (°C/W)

   θ_{JC} should be obtained from the device manufacturer, MIL-M-38510, or from the default values shown in Section 5.11 for the closest equivalent device.
2. Use Digital MOS column for HC, HCT, AC, ACT, C and FCT technologies.
3. Table entries should be considered valid only up to the rated temperature of the component under consideration.

5.9 MICROCIRCUITS, C_2 TABLE FOR ALL

Package Failure Rate for all Microcircuits - C_2

Number of Functional Pins, N_p	Package Type: Hermetic: DIPs w/Solder or Weld Seal, Pin Grid Array (PGA)[1], SMT (Leaded and Nonleaded)	DIPs with Glass Seal[2]	Flatpacks with Axial Leads on 50 Mil Centers[3]	Cans[4]	Nonhermetic: DIPs, PGA, SMT (Leaded and Nonleaded)[5]
3	.00092	.00047	.00022	.00027	.0012
4	.0013	.00073	.00037	.00049	.0016
6	.0019	.0013	.00078	.0011	.0025
8	.0026	.0021	.0013	.0020	.0034
10	.0034	.0029	.0020	.0031	.0043
12	.0041	.0038	.0028	.0044	.0053
14	.0048	.0048	.0037	.0060	.0062
16	.0056	.0059	.0047	.0079	.0072
18	.0064	.0071	.0058		.0082
22	.0079	.0096	.0083		.010
24	.0087	.011	.0098		.011
28	.010	.014			.013
36	.013	.020			.017
40	.015	.024			.019
64	.025	.048			.032
80	.032				.041
128	.053				.068
180	.076				.098
224	.097				.12

1. $C_2 = 2.8 \times 10^{-4} (N_p)^{1.08}$
2. $C_2 = 9.0 \times 10^{-5} (N_p)^{1.51}$
3. $C_2 = 3.0 \times 10^{-5} (N_p)^{1.82}$
4. $C_2 = 3.0 \times 10^{-5} (N_p)^{2.01}$
5. $C_2 = 3.6 \times 10^{-4} (N_p)^{1.08}$

NOTES:

1. SMT: Surface Mount Technology
2. DIP: Dual In-Line Package
3. If DIP Seal type is unknown, assume glass
4. The package failure rate (C_2) accounts for failures associated only with the package itself. Failures associated with mounting the package to a circuit board are accounted for in Section 16, Interconnection Assemblies.

5.12 MICROCIRCUITS, T_J DETERMINATION, (FOR HYBRIDS)

Typical Hybrid Characteristics

Material	Typical Usage	Typical Thickness, L_i (in.)	Feature From Figure 5-1	Thermal Conductivity, K_i $\left(\frac{W/in^2}{°C/in}\right)$	$\left(\frac{1}{K_i}\right)(L_i)$ $(in^2\ °C/W)$
Silicon	Chip Device	0.010	A	2.20	.0045
GaAs	Chip Device	0.0070	A	.76	.0092
Au Eutectic	Chip Attach	0.0001	B	6.9	.000014
Solder	Chip/Substrate Attach	0.0030	B/E	1.3	.0023
Epoxy (Dielectric)	Chip/Substrate Attach	0.0035	B/E	.0060	.58
Epoxy (Conductive)	Chip Attach	0.0035	B	.15	.023
Thick Film Dielectric	Glass Insulating Layer	0.0030	C	.66	.0045
Alumina	Substrate, MHP	0.025	D	.64	.039
Beryllium Oxide	Substrate, PHP	0.025	D	6.6	.0038
Kovar	Case, MHP	0.020	F	.42	.048
Aluminum	Case, MHP	0.020	F	4.6	.0043
Copper	Case, PHP	0.020	F	9.9	.0020

NOTE: MHP: Multichip Hybrid Package, PHP: Power Hybrid Package (Pwr: ≥ 2W, Typically)

$$\theta_{JC} = \frac{\sum_{i=1}^{n} \left(\frac{1}{K_i}\right)(L_i)}{A}$$

n = Number of Material Layers

K_i = Thermal Conductivity of i^{th} Material $\left(\frac{W/in^2}{°C/in}\right)$ (User Provided or From Table)

L_i = Thickness of i^{th} Material (in) (User Provided or From Table)

A = Die Area (in^2).. If Die Area cannot be readily determined, estimate as follows:
$A = [\ .00278\ (\text{No. of Die Active Wire Terminals}) + .0417]^2$

Estimate T_J as Follows:

$$T_J = T_C + (\theta_{JC})(P_D)$$

T_C = Hybrid Case Temperature (°C). If unknown, use the T_C Default Table shown in Section 5.11.

θ_{JC} = Junction-to-Case Thermal Resistance (°C/W) (As determined above)

P_D = Die Power Dissipation (W)

5.13 MICROCIRCUITS, EXAMPLES

Example 1: CMOS Digital Gate Array

Given: A CMOS digital timing chip (4046) in an airborne inhabited cargo application, case temperature 48°C, 75mW power dissipation. The device is procured with normal manufacturer's screening consisting of temperature cycling, constant acceleration, electrical testing, seal test and external visual inspection, in the sequence given. The component manufacturer also performs a B-level burn-in followed by electrical testing. All screens and tests are performed to the applicable MIL-STD-883 screening method. The package is a 24 pin ceramic DIP with a glass seal. The device has been manufactured for several years and has 1000 transistors.

$$\lambda_p = (C_1\pi_T + C_2\pi_E)\,\pi_Q\pi_L \qquad \text{Section 5.1}$$

C_1	=	.020	1000 Transistors ≈ 250 Gates, MOS C_1 Table, Digital Column	
π_T	=	.29	Determine T_J from Section 5.11	
			$T_J = 48°C + (28°C/W)(.075W) = 50°C$	
			Determine π_T from Section 5.8, Digital MOS Column.	
C_2	=	.011	Section 5.9	
π_E	=	4.0	Section 5.10	
π_Q	=	3.1	Section 5.10	
			Group 1 Tests	50 Points
			Group 3 Tests (B-level)	30 Points
			TOTAL	80 Points

$$\pi_Q = 2 + \frac{87}{80} = 3.1$$

π_L	=	1	Section 5.10

$$\lambda_p = [\,(.020)(.29) + (.011)\,(4)\,]\,(3.1)(1) = .15 \text{ Failure}/10^6 \text{ Hours}$$

Example 2: EEPROM

Given: A 128K Flotox EEPROM that is expected to have a T_J of 80°C and experience 10,000 read/write cycles over the life of the system. The part is procured to all requirements of Paragraph 1.2.1, MIL-STD-883, Class B screening level requirements and has been in production for three years. It is packaged in a 28 pin DIP with a glass seal and will be used in an airborne uninhabited cargo application.

$$\pi_p = (C_1\,\pi_T + C_2\,\pi_E + \lambda_{cyc})\,\pi_Q\,\pi_L \qquad \text{Section 5.2}$$

C_1	=	.0034	Section 5.2
π_T	=	3.8	Section 5.8
C_2	=	.014	Section 5.9

6.8 TRANSISTORS, HIGH FREQUENCY, GaAs FET

Matching Network Factor - π_M

Matching	π_M
Input and Output	1.0
Input Only	2.0
None	4.0

Quality Factor - π_Q

Quality	π_Q
JANTXV	.50
JANTX	1.0
JAN	2.0
Lower	5.0

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	2.0
G_M	5.0
N_S	4.0
N_U	11
A_{IC}	4.0
A_{IF}	5.0
A_{UC}	7.0
A_{UF}	12
A_{RW}	16
S_F	.50
M_F	9.0
M_L	24
C_L	250

6.9 TRANSISTORS, HIGH FREQUENCY, SI FET

SPECIFICATION
MIL-S-19500

DESCRIPTION
Si FETs (Avg. Power < 300 mW, Freq. > 400 MHz)

$$\lambda_p = \lambda_b \pi_T \pi_Q \pi_E \quad \text{Failures}/10^6 \text{ Hours}$$

Base Failure Rate - λ_b

Transistor Type	λ_b
MOSFET	.060
JFET	.023

Temperature Factor - π_T

T_J (°C)	π_T	T_J (°C)	π_T
25	1.0	105	3.9
30	1.1	110	4.2
35	1.2	115	4.5
40	1.4	120	4.8
45	1.5	125	5.1
50	1.6	130	5.4
55	1.8	135	5.7
60	2.0	140	6.0
65	2.1	145	6.4
70	2.3	150	6.7
75	2.5	155	7.1
80	2.7	160	7.5
85	3.0	165	7.9
90	3.2	170	8.3
95	3.4	175	8.7
100	3.7		

$$\pi_T = \exp\left(-1925\left(\frac{1}{T_J + 273} - \frac{1}{298}\right)\right)$$

T_J = Junction Temperature (°C)

Quality Factor - π_Q

Quality	π_Q
JANTXV	.50
JANTX	1.0
JAN	2.0
Lower	5.0

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	2.0
G_M	5.0
N_S	4.0
N_U	11
A_{IC}	4.0
A_{IF}	5.0
A_{UC}	7.0
A_{UF}	12
A_{RW}	16
S_F	.50
M_F	9.0
M_L	24
C_L	250

7.1 TUBES, ALL TYPES EXCEPT TWT AND MAGNETRON

DESCRIPTION
All Types Except Traveling Wave Tubes and Magnetrons. Includes Receivers, CRT, Thyratron, Crossed Field Amplifier, *Pulsed Gridded, Transmitting, Vidicons, Twystron, Pulsed* Klystron, CW Klystron

$$\lambda_p = \lambda_b \pi_L \pi_E \text{ Failures}/10^6 \text{ Hours}$$

Base Failure Rate - λ_b
(Includes Both Random and Wearout Failures)

Tube Type	λ_b
Receiver	
Triode, Tetrode, Pentode	5.0
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. ≤ 200 KW, Avg. Pwr. ≤ 2KW, Freq. ≤ 200 MHz	75
Tetrode & Pentode, Peak Pwr. ≤ 200 KW, Avg. Power ≤ 2KW, Freq. ≤ 200 KW	100
If any of the above limits exceeded	250
Vidicon	
Antimony Trisulfide (Sb_2S_3) Photoconductive Material	51
Silicon Diode Array Photoconductive Material	48
Twystron	
VA144	850
VA145E	450
VA145H	490
VA913A	230
Klystron, Pulsed*	
4KMP10000LF	43
8568	230
L3035	66
L3250	69
L3403	93
SAC42A	100
VA842	18
Z5010A	150
ZM3038A	190

* If the pulsed Klystron of interest is not listed above, use the Alternate Pulsed Klystron λ_b Table on *the following page.*

Tube Type	λ_b
Klystron, Low Power,	
(e.g. Local Oscillator)	30
Klystron, Continuous Wave*	
3K3000LQ	9.0
3K50000LF	54
3K210000LQ	150
3KM300LA	64
3KM3000LA	19
3KM50000PA	110
3KM50000PA1	120
3KM50000PA2	150
4K3CC	610
4K3SK	29
4K50000LQ	30
4KM50LB	28
4KM50LC	15
4KM50SJ	38
4KM50SK	37
4KM3000LR	140
4KM50000LQ	79
4KM50000LR	57
4KM170000LA	15
8824	130
8825	120
8826	280
VA800E	70
VA853	220
VA856B	65
VA888E	230

* If the CW Klystron of interest is not listed above, use the Alternate CW Klystron λ_b Table on the *following page.*

7.1 TUBES, ALL TYPES EXCEPT TWT AND MAGNETRON

Alternate* Base Failure Rate for Pulsed Klystrons - λ_b

P(MW)	F(GHz) .2	.4	.6	.8	1.0	2.0	4.0	6.0
.01	16	16	16	16	16	16	16	16
.30	16	16	17	17	17	18	20	21
.80	16	17	17	18	18	21	25	30
1.0	17	17	18	18	19	22	28	34
3.0	18	20	21	23	25	34	51	
5.0	19	22	25	28	31	45	75	
8.0	21	25	30	35	40	63	110	
10	22	28	34	40	45	75		
25	31	45	60	75	90	160		

λ_b = 2.94 (F)(P) + 16

F = Operating Frequency in GHz, $0.2 \le F \le 6$

P = Peak Output Power in MW, $.01 \le P \le 25$ and $P \le 490\ F^{-2.95}$

*See previous page for other Klystron Base Failure Rates.

Alternate* Base Failure Rate for CW Klystrons - λ_b

P(KW)	F(MHz) 300	500	800	1000	2000	4000	6000	8000
0.1	30	31	33	34	38	47	57	66
1.0	31	32	33	34	39	48	57	66
3.0	32	33	34	35	40	49	58	
5.0	33	34	35	36	41	50		
8.0	34	35	37	38	42			
10	35	36	38	39	43			
30	45	46	48	49				
50	55	56	58	59				
80	70	71	73					
100	80	81						

λ_b = 0.5P + .0046F + 29

P = Average Output Power in KW, $0.1 \le P \le 100$ and $P \le 8.0(10)^6(F)^{-1.7}$

F = Operating Frequency in MHz, $300 \le F \le 8000$

*See previous page for other Klystron Base Failure Rates.

Learning Factor - π_L

T (years)	π_L
≤ 1	10
2	2.3
≥ 3	1.0

π_L = $10(T)^{-2.1}$, $1 \le T \le 3$
= 10, $T \le 1$
= 1, $T \ge 3$

T = Number of Years since Introduction to Field Use

Environment Factor - π_E

Environment	π_E
G_B	.50
G_F	1.0
G_M	14
N_S	8.0
N_U	24
A_{IC}	5.0
A_{IF}	8.0
A_{UC}	6.0
A_{UF}	12
A_{RW}	40
S_F	.20
M_F	22
M_L	57
C_L	1000

12.2 ROTATING DEVICES, SYNCHROS AND RESOLVERS

DESCRIPTION
Rotating Synchros and Resolvers

$$\lambda_p = \lambda_b \pi_S \pi_N \pi_E \text{ Failures}/10^6 \text{ Hours}$$

NOTE: Synchros and resolvers are predominately used in service requiring only slow and infrequent motion. Mechanical wearout problems are infrequent so that the electrical failure mode dominates, and no mechanical mode failure rate is required in the model above.

Base Failure Rate - λ_b

T_F (°C)	λ_b	T_F (°C)	λ_b
30	.0083	85	.032
35	.0088	90	.041
40	.0095	95	.052
45	.010	100	.069
50	.011	105	.094
55	.013	110	.13
60	.014	115	.19
65	.016	120	.29
70	.019	125	.45
75	.022	130	.74
80	.027	135	1.3

$$\lambda_b = .00535 \exp\left(\frac{T_F + 273}{334}\right)^{8.5}$$

T_F = Frame Temperature (°C)

If Frame Temperature is Unknown Assume
T_F = 40 °C + Ambient Temperature

Number of Brushes Factor - π_N

Number of Brushes	π_N
2	1.4
3	2.5
4	3.2

Size Factor - π_S

DEVICE TYPE	π_S Size 8 or Smaller	π_S Size 10-16	π_S Size 18 or Larger
Synchro	2	1.5	1
Resolver	3	2.25	1.5

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	2.0
G_M	12
N_S	7.0
N_U	18
A_{IC}	4.0
A_{IF}	6.0
A_{UC}	16
A_{UF}	25
A_{RW}	26
S_F	.50
M_F	14
M_L	36
C_L	680

12.3 ROTATING DEVICES, ELAPSED TIME METERS

DESCRIPTION
Elapsed Time Meters

$$\lambda_p = \lambda_b \pi_T \pi_E \text{ Failures}/10^6 \text{ Hours}$$

Base Failure Rate - λ_b

Type	λ_b
A.C.	20
Inverter Driven	30
Commutator D.C.	80

Temperature Stress Factor - π_T

Operating T (°C)/Rated T (°C)	π_T
0 to .5	.5
.6	.6
.8	.8
1.0	1.0

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	2.0
G_M	12
N_S	7.0
N_U	18
A_{IC}	5.0
A_{IF}	8.0
A_{UC}	16
A_{UF}	25
A_{RW}	26
S_F	.50
M_F	14
M_L	38
C_L	N/A

APPENDIX A: PARTS COUNT RELIABILITY PREDICTION

Parts Count Reliability Prediction - This prediction method is applicable during bid proposal and early design phases when insufficient information is available to use the part stress analysis models shown in the main body of this Handbook. The information needed to apply the method is (1) generic part types (including complexity for microcircuits) and quantities, (2) part quality levels, and (3) equipment environment. The equipment failure rate is obtained by looking up a generic failure rate in one of the following tables, multiplying it by a quality factor, and then summing it with failure rates obtained for other components in the equipment. The general mathematical expression for equipment failure rate with this method is:

$$\lambda_{EQUIP} = \sum_{i=1}^{i=n} N_i (\lambda_g \pi_Q)_i \qquad \text{Equation 1}$$

for a given equipment environment where:

λ_{EQUIP} = Total equipment failure rate (Failures/10^6 Hours)

λ_g = Generic failure rate for the i^{th} generic part (Failures/10^6 Hours)

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 in the equipment

Equation 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 systems 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 defined in Section 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 the Part Stress Analysis. Microcircuits have an additional multiplying factor, π_L, which accounts for the maturity of the manufacturing process. For devices in production two years or more, no modification is needed. For those in production less than two years, λ_g should be multiplied by the appropriate π_L factor (See page A-4).

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.

The failure rates shown in this Appendix were calculated by assigning model default values to the failure rate models of Section 5 through 23. The specific default values used for the model parameters are shown with the λ_g Tables for microcircuits. Default parameters for all other part classes are summarized in the tables starting on Page A-12. For parts with characteristics which differ significantly from the assumed defaults, or parts used in large quantities, the underlying models in the main body of this Handbook can be used.

Generic Failure Rate, λ_g (Failures/10^6 Hours) for Microcircuits. See Page A-4 for π_Q Values
(Defaults: π_T Based on Ea Shown, Solder or Weld Seal DIPs/PGAs (No. Pins as Shown Below), π_L = 1 (Device in Production ≥ 2 Yr.))

Section #	Part Type	Environ. → T_J (°C) →	G_B 50	G_F 60	G_M 65	N_S 60	N_U 65	A_{IC} 75	A_{IF} 75	A_{UC} 90	A_{UF} 90	A_{RW} 75	S_F 50	M_F 65	M_L 75	C_L 60
	Bipolar Technology															
5.1	Gate/Logic Arrays, Digital (Ea = .4)															
	1 - 100 Gates	(16 Pin DIP)	.0036	.012	.024	.024	.035	.025	.030	.032	.049	.047	.0036	.030	.069	1.2
	101 - 1000 Gates	(24 Pin DIP)	.0060	.020	.038	.037	.055	.039	.048	.051	.077	.074	.0060	.046	.11	1.9
	1001 to 3000 Gates	(40 Pin DIP)	.011	.035	.066	.065	.097	.070	.085	.091	.14	.13	.011	.082	.19	3.3
	3001 to 10,000 Gates	(128 Pin PGA)	.033	.12	.22	.22	.33	.23	.28	.30	.46	.44	.033	.28	.65	12
	10,000 to 30,000 Gates	(180 Pin PGA)	.052	.17	.33	.33	.48	.34	.42	.45	.68	.65	.052	.41	.95	17
	30,000 to 60,000 Gates	(224 Pin PGA)	.075	.23	.44	.43	.63	.46	.56	.61	.90	.85	.075	.53	1.2	21
5.1	Gate/Logic Arrays, Linear (Ea = .65)															
	1 - 100 Transistors	(14 Pin DIP)	.0095	.024	.039	.034	.049	.057	.062	.12	.13	.076	.0095	.044	.096	1.1
	101 - 300 Transistors	(18 Pin DIP)	.017	.041	.065	.054	.078	.10	.11	.22	.24	.13	.017	.072	.15	1.4
	301 - 1000 Transistors	(24 Pin DIP)	.033	.074	.11	.092	.13	.19	.19	.41	.44	.22	.033	.12	.26	2.0
	1001 - 10,000 Transistors	(40 Pin DIP)	.050	.12	.18	.15	.21	.29	.30	.63	.67	.35	.050	.19	.41	3.4
5.1	Programmable Logic Arrays (Ea = .4)															
	Up to 200 Gates	(16 Pin DIP)	.0061	.016	.029	.027	.040	.032	.037	.044	.061	.054	.0061	.034	.076	1.2
	201 to 1000 Gates	(24 Pin DIP)	.011	.028	.048	.045	.065	.054	.063	.077	.10	.089	.011	.057	.12	1.9
	1001 to 5000 Gates	(40 Pin DIP)	.022	.052	.087	.082	.12	.099	.11	.14	.19	.16	.022	.10	.22	3.3
	MOS Technology															
5.1	Gate/Logic Arrays, Digital (Ea = .35)															
	1 to 100 Gates	(16 Pin DIP)	.0057	.015	.027	.027	.039	.029	.035	.039	.056	.052	.0057	.033	.074	1.2
	101 to 1000 Gates	(24 Pin DIP)	.010	.026	.045	.043	.062	.049	.057	.066	.092	.083	.010	.053	.12	1.9
	1001 to 3000 Gates	(40 Pin DIP)	.019	.047	.080	.077	.11	.088	.10	.12	.17	.15	.019	.095	.21	3.3
	3001 to 10,000 Gates	(128 Pin PGA)	.049	.14	.25	.24	.36	.27	.32	.36	.51	.48	.049	.30	.69	12
	10,001 to 30,000 Gates	(180 Pin PGA)	.084	.22	.39	.37	.54	.42	.49	.56	.79	.72	.084	.46	1.0	17
	30,000 to 60,000 Gates	(224 Pin PGA)	.13	.31	.53	.51	.73	.59	.69	.82	1.1	.98	.13	.63	1.4	21
5.1	Gate/Logic Arrays, Linear (Ea = .65)															
	1 to 100 Transistors	(14 Pin DIP)	.0095	.024	.039	.034	.049	.057	.062	.12	.13	.076	.0095	.044	.096	1.1
	101 to 300 Transistors	(18 Pin DIP)	.017	.041	.065	.054	.078	.10	.11	.22	.24	.13	.017	.072	.15	1.4
	301 to 1,000 Transistors	(24 Pin DIP)	.033	.074	.11	.092	.13	.19	.19	.41	.44	.22	.033	.12	.26	2.0
	1001 to 10,000 Transistors	(40 Pin DIP)	.05	.12	.18	.15	.21	.29	.30	.63	.67	.35	.05	.19	.41	3.4
5.1	Floating Gate Programmable Logic Array, MOS (Ea =.35)															
	Up to 16K Gates	(24 Pin DIP)	.0046	.018	.035	.035	.052	.035	.044	.044	.070	.070	.0046	.044	.10	1.9
	16K to 64K Gates	(28 Pin DIP)	.0056	.021	.042	.042	.062	.042	.052	.053	.084	.083	.0056	.052	.12	2.3
	64K to 256K Gates	(28 Pin DIP)	.0061	.022	.043	.042	.063	.043	.054	.055	.086	.084	.0061	.053	.13	2.3
	256K to 1M Gates	(40 Pin DIP)	.0095	.033	.064	.063	.094	.065	.080	.083	.13	.13	.0095	.079	.19	3.3
5.1	Microprocessors, Bipolar (Ea = .4)															
	Up to 8 Bits	(40 Pin DIP)	.028	.061	.098	.091	.13	.12	.13	.17	.22	.18	.028	.11	.24	3.3
	Up to 16 Bits	(64 Pin PGA)	.052	.11	.18	.16	.23	.21	.24	.32	.39	.31	.052	.20	.41	5.6
	Up to 32 Bits	(128 Pin PGA)	.11	.23	.36	.33	.47	.44	.49	.65	.81	.65	.11	.42	.86	12
5.1	Microprocessors, MOS (Ea = .35)															
	Up to 8 Bits	(40 Pin DIP)	.048	.089	.13	.12	.16	.16	.17	.24	.28	.22	.048	.15	.28	3.4
	Up to 16 Bits	(64 Pin PGA)	.093	.17	.24	.22	.29	.30	.32	.45	.52	.40	.093	.27	.50	5.6
	Up to 32 Bits	(128 Pin PGA)	.19	.34	.49	.45	.60	.61	.66	.90	1.1	.82	.19	.54	1.0	12

Generic Failure Rate, λ_g (Failures/10^6 Hours) for Microcircuits. See Page A-4 for π_Q Values
(Defaults: π_T Based on Ea Shown, Solder or Weld Seal DIPs/PGAs (No. Pins as Shown Below), π_L = 1 (Device in Production ≥ 2 Yr.))

Section #	Part Type	Environ.→ T_J (°C) →	G_B 50	G_F 60	G_M 65	N_S 60	N_U 65	A_{IC} 75	A_{IF} 75	A_{UC} 90	A_{UF} 90	A_{RW} 75	S_F 50	M_F 65	M_L 75	C_L 60
5.2	MOS Technology															
	Memories, ROM (Ea = .6)															
	Up to 16K	(24 Pin DIP)	.0047	.018	.036	.035	.053	.037	.045	.048	.074	.071	.0047	.044	.11	1.9
	16K to 64K	(28 Pin DIP)	.0059	.022	.043	.042	.063	.045	.055	.060	.090	.086	.0059	.053	.13	2.3
	64K to 256K	(28 Pin DIP)	.0067	.023	.045	.044	.066	.048	.059	.068	.099	.089	.0067	.055	.13	2.3
	256K to 1 MB	(40 Pin DIP)	.011	.036	.068	.066	.098	.075	.090	.11	.15	.14	.011	.083	.20	3.3
5.2	Memories, PROM, UVEPROM, EEPROM, EAPROM (Ea = .6) (NOTE: λ_{cyc} = 0 Assumed for EEPROM)															
	Up to 16K	(24 Pin DIP)	.0049	.018	.036	.036	.053	.037	.046	.049	.075	.072	.0048	.045	.11	1.9
	16K to 64K	(28 Pin DIP)	.0061	.022	.044	.043	.064	.046	.056	.062	.093	.087	.0062	.054	.13	2.3
	64K to 256K	(28 Pin DIP)	.0072	.024	.046	.045	.067	.051	.061	.073	.10	.092	.0072	.057	.13	2.3
	256K to 1 MB	(40 Pin DIP)	.012	.038	.071	.068	.10	.080	.095	.12	.16	.14	.012	.086	.20	3.3
5.2	Memories, DRAM (Ea = .6)															
	Up to 16K	(18 Pin DIP)	.0040	.014	.027	.027	.040	.029	.035	.040	.059	.055	.0040	.034	.080	1.4
	16K to 64K	(22 Pin DIP)	.0055	.019	.036	.034	.051	.039	.047	.056	.079	.070	.0055	.043	.10	1.7
	64K to 256K	(24 Pin DIP)	.0074	.023	.043	.040	.060	.049	.058	.076	.10	.084	.0074	.051	.12	1.9
	256K to 1 MB	(28 Pin DIP)	.011	.032	.057	.053	.077	.070	.080	.12	.15	.11	.011	.067	.15	2.3
5.2	Memories, SRAM, (MOS & BiMOS) (Ea = .6)															
	Up to 16K	(18 Pin DIP)	.0079	.022	.038	.034	.050	.048	.054	.083	.10	.073	.0079	.044	.098	1.4
	16K to 64K	(22 Pin DIP)	.014	.034	.057	.050	.073	.077	.085	.14	.17	.11	.014	.065	.14	1.8
	64K to 256K	(24 Pin DIP)	.023	.053	.084	.071	.10	.12	.13	.25	.27	.16	.023	.092	.19	1.9
	256K to 1 MB	(28 Pin DIP)	.043	.092	.14	.11	.16	.22	.23	.46	.49	.26	.043	.15	.30	2.3
5.2	Bipolar Technology															
	Memories, ROM, PROM (Ea = .6)															
	Up to 16K	(24 Pin DIP)	.010	.028	.050	.046	.067	.062	.070	.10	.13	.096	.010	.058	.13	1.9
	16K to 64K	(28 Pin DIP)	.017	.043	.071	.063	.091	.095	.11	.18	.21	.14	.017	.081	.18	2.3
	64K to 256K	(28 Pin DIP)	.028	.065	.10	.085	.12	.15	.16	.30	.33	.19	.028	.11	.23	2.3
	256K to 1 MB	(40 Pin DIP)	.053	.12	.18	.15	.21	.27	.29	.56	.61	.33	.053	.19	.39	3.4
5.2	Memories, SRAM (Ea = .6)															
	Up to 16K	(24 Pin DIP)	.0075	.023	.043	.041	.060	.050	.058	.077	.10	.084	.0075	.052	.12	1.9
	16K to 64K	(28 Pin DIP)	.012	.033	.058	.054	.079	.072	.083	.12	.15	.11	.012	.069	.15	2.3
	64K to 256K	(28 Pin DIP)	.018	.045	.074	.065	.095	.10	.11	.19	.22	.14	.018	.084	.18	2.3
	256K to 1 MB	(40 Pin DIP)	.033	.079	.13	.11	.16	.18	.20	.35	.39	.24	.033	.14	.30	3.4
5.3	VHSIC Microcircuits, CMOS	Refer to Section 5.3, VHSIC CMOS														
5.4	GaAs MMIC (Ea = 1.5)															
	1 to 100 Elements	*(8 Pin DIP)*	*.0013*	*.0052*	*.010*	*.010*	*.016*	*.011*	*.013*	*.015*	*.022*	*.021*	*.0013*	*.013*	*.031*	*.57*
	101 to 1000 Active Elements (Default: Driver and High Power (> 100 mW))	(16 Pin DIP)	.0028	.011	.022	.022	.034	.023	.028	.030	.047	.045	.0028	.028	.068	1.2
	GaAs Digital (Ea = 1.4)															
5.4	1 to 1000 Active Elements	(36 Pin DIP)	.0066	.026	.052	.052	.078	.054	.067	.078	.12	.11	.0066	.065	.16	2.9
	1001 to 10,000 Active Elements	(64 Pin PGA)	.013	.050	.10	.10	.15	.10	.13	.15	.23	.20	.013	.13	.30	5.5

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Quality Factors - π_Q

Description	π_Q
Class S Categories: 1. Procured in full accordance with MIL-M-38510, Class S requirements. 2. Procured in full accordance with MIL-I-38535 and Appendix B thereto (Class U). 3. Hybrids: (Procured to Class S requirements (Quality Level K) of MIL-H-38534.	.25
Class B Categories: 1. Procured in full accordance with MIL-M-38510, Class B requirements. 2. Procured in full accordance with MIL-I-38535, (Class Q). 3. Hybrids: Procured to Class B requirements (Quality Level H) of MIL-H-38534.	1.0
Class B-1 Category: 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. (Does not include hybrids). For hybrids use custom screening section below.	2.0

Learning Factor - π_L

Years in Production, Y	π_L
≤ .1	2.0
.5	1.8
1.0	1.5
1.5	1.2
≥ 2.0	1.0

$\pi_L = .01 \exp(5.35 - .35Y)$

Y = Years generic device type has been in production

Quality Factors (cont'd): π_Q Calculation for Custom Screening Programs

Group	MIL-STD-883 Screen/Test (Note 3)	Point Valuation
1*	TM 1010 (Temperature Cycle, Cond B Minimum) and TM 2001 (Constant Acceleration, Cond B Minimum) and TM 5004 (or 5008 for Hybrids) (Final Electricals @ Temp Extremes) and TM 1014 (Seal Test, Cond A, B, or C) and TM 2009 (External Visual)	50
2*	TM 1010 (Temperature Cycle, Cond B Minimum) or TM 2001 (Constant Acceleration, Cond B Minimum) TM 5004 (or 5008 for Hybrids) (Final Electricals @ Temp Extremes) and TM 1014 (Seal Test, Cond A, B, or C) and TM 2009 (External Visual)	37
3	Pre-Burn in Electricals TM 1015 (Burn-in B-Level/S-Level) and TM 5004 (or 5008 for Hybrids) (Post Burn-in Electricals @ Temp Extremes)	30 (B Level) 36 (S Level)
4*	TM 2020 Pind (Particle Impact Noise Detection)	11
5	TM 5004 (or 5008 for Hybrids) (Final Electricals @ Temperature Extremes)	11 (Note 1)
6	TM 2010/17 (Internal Visual)	7
7*	TM 1014 (Seal Test, Cond A, B, or C)	7 (Note 2)
8	TM 2012 (Radiography)	7
9	TM 2009 (External Visual)	7 (Note 2)
10	TM 5007/5013 (GaAs) (Wafer Acceptance)	1
11	TM 2023 (Non-Destructive Bond Pull)	1

$$\pi_Q = 2 + \frac{87}{\Sigma \text{ Point Valuations}}$$

*NOT APPROPRIATE FOR PLASTIC PARTS

NOTES:
1. Point valuation only assigned if used independent of Groups 1, 2 or 3.
2. Point valuation only assigned if used independent of Groups 1 or 2.
3. Sequencing of tests within groups 1, 2 and 3 must be followed.
4. TM refers to the MIL-STD-883 Test Method.
5. Nonhermetic parts should be used only in controlled environments (i.e., G_B and other temperature/humidity controlled environments).

EXAMPLES:
1. Mfg. performs Group 1 test and Class B burn-in: $\pi_Q = 2 + \frac{87}{50+30} = 3.1$
2. Mfg. performs internal visual test, seal test and final electrical test: $\pi_Q = 2 + \frac{87}{7+7+11} = 5.5$

Other Commercial or Unknown Screening Levels	$\pi_Q = 10$

Supersedes page A-5 of Revision F

Generic Failure Rate - λ_g (Failures/10^6 Hours) for Discrete Semiconductors

Section #	Part Type	Env.→ G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F	M_F	M_L	C_L
		T_J (°C) → 50	60	65	60	65	75	75	90	90	75	50	65	75	60
	DIODES														
6.1	General Purpose Analog	.0036	.028	.049	.043	.10	.092	.21	.20	.44	.17	.0018	.076	.23	1.5
6.1	Switching	.00094	.0075	.013	.011	.027	.024	.054	.054	.12	.045	.00047	.020	.060	.40
6.1	Fast Recovery Pwr. Rectifier	.065	.52	.89	.78	1.9	1.7	3.7	3.7	8.0	3.1	.032	1.4	4.1	28
6.1	Power Rectifier/ Schottky Pwr.	.0028	.022	.039	.034	.082	.073	.16	.16	.35	.13	.0014	.060	.18	1.2
6.1	Transient Suppressor/Varistor	.0029	.023	.040	.035	.084	.075	.17	.17	.36	.14	.0015	.062	.18	1.2
6.1	Voltage Ref/Reg. (Avalanche and Zener)	.0033	.024	.039	.035	.082	.066	.15	.13	.27	.12	.0016	.060	.16	1.3
6.1	*Current Regulator*	.0056	.040	.066	.060	.14	.11	.25	.22	.46	.21	.0028	.10	.28	2.1
6.2	Si Impatt (f ≤ 35 GHz)	.86	2.8	8.9	5.6	20	11	14	36	62	44	.43	16	67	350
6.2	Gunn/Bulk Effect	.31	.76	2.1	1.5	4.6	2.0	2.5	4.5	7.6	7.9	.16	3.7	12	94
6.2	Tunnel and Back	.004	.0096	.027	.019	.058	.025	.032	.057	.097	.10	.002	.048	.15	1.2
6.2	PIN	.028	.068	.19	.14	.41	.18	.22	.40	.69	.71	.014	.34	1.1	8.5
6.2	Schottky Barrier and Point Contact (200 MHz ≤ f ≤ 35 GHz)	.047	.11	.31	.23	.68	.30	.37	.67	1.1	1.2	.023	.56	1.8	14
6.2	Varactor	.0043	.010	.029	.021	.063	.028	.034	.062	.11	.11	.0022	.052	.17	1.3
6.10	Thyristor/SCR	.0025	.020	.034	.030	.072	.064	.14	.14	.31	.12	.0012	.053	.16	1.1
	TRANSISTORS														
6.3	NPN/PNP (f < 200 MHz)	.00015	.0011	.0017	.0017	.0037	.0030	.0067	.0060	.013	.0056	.000073	.0027	.0074	.056
6.3	Power NPN/PNP (f < 200 MHz)	.0057	.042	.069	.063	.15	.12	.26	.23	.50	.22	.0029	.11	.29	2.2
6.4	Si FET (f ≤ 400 MHz)	.014	.099	.16	.15	.34	.28	.62	.53	1.1	.51	.0069	.25	.68	5.3
6.9	Si FET (f > 400 MHz)	.099	.24	.64	.47	1.4	.61	.76	1.3	2.3	2.4	.049	1.2	3.6	30
6.8	GaAs FET (P < 100 mW)	.17	.51	1.5	1.0	3.4	1.8	2.3	5.4	9.2	7.2	.083	2.8	11	63
6.8	GaAs FET (P ≥ 100 mW)	.42	1.3	3.9	2.5	8.5	4.5	5.6	13	23	18	.21	6.9	27	160
6.5	Unijunction	.016	.12	.20	.18	.42	.36	.80	.74	1.6	.66	.0079	.31	.88	6.4
6.6	RF, Low Noise (f > 200 MHz, P < 1W)	.094	.23	.63	.46	1.4	.60	.75	1.3	2.3	2.4	.047	1.1	3.6	28
6.7	RF, Power (P ≥ 1W)	.045	.091	.23	.18	.50	.18	.23	.32	.55	.73	.023	.41	1.1	11

Generic Failure Rate - λ_g (Failures/10^6 Hours) for Discrete Semiconductors (cont'd)

Section #	Part Type	G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F	M_F	M_L	C_L
	Env.→ / T_J (°C)→	50	60	65	60	65	75	75	90	90	75	50	65	75	60
	OPTO-ELECTRONICS														
6.11	Photodetector	.011	.029	.13	.074	.20	.084	.13	.17	.23	.36	.0057	.15	.51	6.6
6.11	Opto-Isolator	.027	.070	.31	.17	.47	.20	.30	.42	.56	.85	.013	.35	1.2	16
6.11	Emitter	.00047	.0012	.0056	.0031	.0084	.0035	.0053	.0074	.0098	.015	.00024	.0063	.021	.28
6.12	Alphanumeric Display	.0062	.016	.073	.040	.11	.046	.069	.096	.13	.20	.0031	.082	.28	3.6
6.13	Laser Diode, GaAs/Al GaAs	5.1	16	78	39	120	58	86	86	110	240	2.6	87	350	3600
6.13	Laser Diode, In GaAs/In GaAsP	9.0	28	135	69	200	100	150	150	200	400	4.5	150	600	6200
7	TUBES	See Section 7 (Includes Receivers, CRTs, Cross Field Amplifiers, Klystrons, TWTs, Magnetrons)													
8	LASERS	See Section 8													

Discrete Semiconductor Quality Factors - π_Q

Section Number	Part Types	JANTXV	JANTX	JAN	Lower	Plastic
6.1, 6.3, 6.4, 6.5, 6.10, 6.11, 6.12	Non-RF Devices/ Opto-Electronics*	.70	1.0	2.4	5.5	8.0
6.2	High Freq Diodes	.50	1.0	5.0	25	50
6.2	Schottky Diodes	.50	1.0	1.8	2.5	----
6.6, 6.7, 6.8, 6.9	RF Transistors	.50	1.0	2.0	5.0	----
6.13	*Laser Diodes	π_Q = 1.0 Hermetic Package = 1.0 Nonhermetic with Facet Coating = 3.3 Nonhermetic without Facet Coating				

Generic Failure Rate, λ_g (Failure/10^6 Hours) For Resistors

Section #	Part Type	Style	MIL-R-	Env. → G_B / T_A (°C) → 30	G_F 40	G_M 45	N_S 40	N_U 45	A_{IC} 55	A_{IF} 55	A_{UC} 70	A_{UF} 70	A_{RW} 55	S_F 30	M_F 45	M_L 55	C_L 40
9.1	Composition	RCR	39008	.00050	.0022	.0071	.0037	.012	.0052	.0065	.016	.025	.025	.00025	.0098	.035	.36
9.1	Composition	RC	11	.00050	.0022	.0071	.0037	.012	.0052	.0065	.016	.025	.025	.00025	.0098	.035	.36
9.2	Film, Insulated	RLR	39017	.0012	.0027	.011	.0054	.020	.0063	.013	.018	.033	.030	.00025	.014	.044	.69
9.2	Film, Insulated	RL	22684	.0012	.0027	.011	.0054	.020	.0063	.013	.018	.033	.030	.00025	.014	.044	.69
9.2	Film, RN (R, C or N)	RNR	55182	.0014	.0031	.013	.0061	.023	.0072	.014	.021	.038	.034	.00028	.016	.050	.78
9.2	Film	RN	10509	.0014	.0031	.013	.0061	.023	.0072	.014	.021	.038	.034	.00028	.016	.050	.78
9.3	Film, Power	RD	11804	.012	.025	.13	.062	.21	.078	.10	.19	.24	.32	.0060	.18	.47	8.2
9.4	Film, Network	RZ	83401	.0023	.0066	.031	.013	.055	.022	.043	.077	.15	.10	.0011	.055	.15	1.7
9.5	Wirewound, Accurate	RBR	39005	.0085	.018	.10	.045	.16	.15	.17	.30	.38	.26	.0068	.13	.37	5.4
9.5	Wirewound, Accurate	RB	93	.0085	.018	.10	.045	.16	.15	.17	.30	.38	.26	.0068	.13	.37	5.4
9.6	Wirewound, Power	RWR	39007	.014	.031	.16	.077	.26	.073	.15	.19	.39	.42	.0042	.21	.62	9.4
9.6	Wirewound, Power	RW	26	.013	.028	.15	.070	.24	.066	.13	.18	.35	.38	.0038	.19	.56	8.6
9.7	Wirewound, Power, Chassis Mounted	RER	39009	.0080	.018	.096	.045	.15	.044	.088	.12	.24	.25	.0040	.13	.37	5.5
9.7	Wirewound, Power, Chassis Mounted	RE	18546	.0080	.018	.096	.045	.15	.044	.088	.12	.24	.25	.0040	.13	.37	5.5
9.8	Thermistor	RTH	23648	.065	.32	1.4	.71	1.6	.71	1.9	1.0	2.7	2.4	.032	1.3	3.4	62
9.9	Wirewound, Variable	RTR	39015	.026	.056	.36	.17	.59	.17	.27	.36	.60	1.1	.013	.53	1.6	25
9.9	Wirewound, Variable	RT	27208	.026	.056	.36	.17	.59	.17	.27	.36	.60	1.1	.013	.53	1.6	25
9.10	Wirewound, Variable, Precision	RR	12934	.36	.80	7.7	3.2	13	3.9	5.8	7.8	11	26	.18	12	37	560
9.11	Wirewound, Variable, Semiprecision	RA	19	.15	.35	3.1	1.2	5.4	1.9	2.8	*	*	9.0	.075	*	*	*
9.11	Wirewound, Variable, Semiprecision	RK	39002	.15	.35	3.1	1.2	5.4	1.9	2.8	*	*	9.0	.075	*	*	*
9.12	Wirewound, Variable, Power	RP	22	.15	.51	2.9	1.2	5.0	1.6	2.4	*	*	7.6	.076	*	*	*
9.13	Nonwirewound, Variable	RJR	39035	.033	.10	.50	.21	.87	.19	.27	.52	.79	1.5	.017	.79	2.2	35
9.13	Nonwirewound, Variable	RJ	22097	.033	.10	.50	.21	.87	.19	.27	.52	.79	1.5	.017	.79	2.2	35
9.14	Composition, Variable	RV	94	.050	.11	1.1	.45	1.7	2.8	4.6	4.6	7.5	3.3	.025	1.5	4.7	67
9.15	Nonwirewound, Variable Precision	RQ	39023	.043	.15	.75	.35	1.3	.39	.78	1.8	2.8	2.5	.021	1.2	3.7	49
9.15	Film, Variable	RVC	23285	.048	.16	.76	.36	1.3	.36	.72	1.4	2.2	2.3	.024	1.2	3.4	52

NOTE: 1) * Not Normally used in this Environment
2) T_A = Default Component Ambient Temperature (°C)

Quality	Established Reliability Styles S	R	P	M	MIL-SPEC	Lower
π_Q	.030	.10	.30	1.0	3.0	10

Generic Failure Rate, λ_g (Failures/10^6 Hours) for Capacitors

Section #	Part Type or Dielectric	Style	MIL-C-	Env.→ G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F	M_F	M_L	C_L
				T_A (°C)→ 30	40	45	40	45	55	55	70	70	55	30	45	55	40
10.1	Paper, By-Pass	CP	25	.0036	.0072	.033	.018	.055	.023	.03	.070	.13	.083	.0018	.044	.12	2.1
10.1	Paper, By-Pass	CA	12889	.0039	.0087	.042	.022	.070	.035	.047	.19	.35	.13	.002	.056	.19	2.5
10.2	Paper/Plastic, Feed-through	CZR	11693	.0047	.0096	.044	.034	.073	.030	.040	.094	.15	.11	.0024	.058	.16	2.7
10.3	Paper/Plastic Film	CPV	14157	.0021	.0042	.017	.010	.030	.0088	.013	.026	.048	.044	.0010	.023	.063	1.1
10.3	Paper/Plastic Film	CQR	19978	.0021	.0042	.017	.010	.030	.0088	.013	.026	.048	.044	.0010	.023	.063	1.1
10.4	Metallized Paper/Plastic	CHR	39022	.0029	.0058	.023	.014	.041	.012	.018	.037	.066	.060	.0014	.032	.088	1.5
10.4	Metallized Plastic/Plastic	CH	18312	.0029	.0058	.023	.014	.041	.012	.018	.037	.066	.060	.0014	.032	.088	1.5
10.5	Metallized Paper/Plastic	CFR	55514	.0041	.0083	.042	.021	.067	.026	.048	.086	.14	.10	.0020	.054	.15	2.5
10.6	Metallized Plastic	CRH	83421	.0023	.0092	.019	.012	.033	.0096	.014	.034	.053	.048	.0011	.026	.07	1.2
10.7	MICA (Dipped or Molded)	CMR	39001	.0005	.0015	.0091	.0044	.014	.0068	.0095	.054	.069	.031	.00025	.012	.046	.45
10.7	MICA (Dipped)	CM	5	.0005	.0015	.0091	.0044	.014	.0068	.0095	.054	.069	.031	.00025	.012	.046	.45
10.8	MICA (Button)	CB	10950	.018	.037	.19	.094	.31	.10	.14	.47	.60	.46	.0091	.25	.68	11
10.9	Glass	CYR	23269	.00032	.00096	.0059	.0029	.0094	.0044	.0062	.035	.045	.020	.00016	.0076	.030	.29
10.9	Glass	CY	11272	.00032	.00096	.0059	.0029	.0094	.0044	.0062	.035	.045	.020	.00016	.0076	.030	.29
10.10	Ceramic (Gen. Purpose)	CK	11015	.0036	.0074	.034	.019	.056	.015	.015	.032	.048	.077	.0014	.049	.13	2.3
10.10	Ceramic (Gen. Purpose)	CKR	39014	.0036	.0074	.034	.019	.056	.015	.015	.032	.048	.077	.0014	.049	.13	2.3
10.11	Ceramic (Temp. Comp.)	CCR	20	.00078	.0022	.013	.0056	.023	.0077	.015	.053	.12	.046	.00039	.017	.065	.68
10.11	Ceramic Chip	CDR	55681	.00078	.0022	.013	.0056	.023	.0077	.015	.053	.12	.046	.00039	.017	.065	.68
10.12	Tantalum, Solid	CSR	39003	.0018	.0039	.016	.0097	.028	.0091	.011	.034	.057	.055	.00072	.022	.066	1.0
10.13	Tantalum, Non-Solid	CLR	39006	.0061	.013	.069	.039	.11	.031	.061	.13	.29	.18	.0030	.089	.26	4.0
10.13	Tantalum, Non-Solid	CL	3965	.0061	.013	.069	.039	.11	.031	.061	.13	.29	.18	.0030	.089	.26	4.0
10.14	Aluminum Oxide	CUR	39018	.024	.061	.42	.18	.59	.46	.55	2.1	2.6	1.2	.012	.49	1.7	21
10.15	Aluminum Dry	CE	62	.029	.081	.58	.24	.83	.73	.88	4.3	5.4	2.0	.015	.68	2.8	28
10.16	Variable, Ceramic	CV	81	.08	.27	1.2	.71	2.3	.69	1.1	6.2	12	4.1	.032	1.9	5.9	85
10.17	Variable, Piston	PC	14409	.033	.13	.62	.31	.93	.21	.28	2.2	3.3	2.2	.016	.93	3.2	37
10.18	Variable, Air Trimmer	CT	92	.080	.33	1.6	.87	3.0	1.0	1.7	9.9	19	6.1	.040	2.5	8.9	100
10.19	Variable, Vacuum	CG	23183	0.4	1.3	6.7	3.6	13	5.7	10	58	90	23	.20	*	*	*

NOTE: 1) * Not Normally used in this Environment
2) T_A = Default Component Ambient Temperature (°C)

Quality	Established Reliability Styles S	R	P	M	L	MIL-SPEC	Lower
π_Q	.030	.10	.30	1.0	3.0	3.0	10

Generic Failure Rate, λ_g (Failures/10^6 Hours) for Inductive and Electromechanical Parts

Section #	Part Type	MIL-	Env.→ G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F	M_F	M_L	C_L
			T_A (°C)→ 30	40	45	40	45	55	55	70	70	55	30	45	55	40
	INDUCTIVE DEVICES															
11.1	Low Power Pulse XFMR	T-21038	.0035	.023	.049	.019	.065	.027	.037	.041	.052	.11	.0018	.053	.16	2.3
11.1	Audio XFMR	T-27	.0071	.046	.097	.038	.13	.055	.073	.081	.10	.22	.0035	.11	.31	4.7
11.1	High Pwr. Pulse and Pwr. XFMR, Filter	T-27	.023	.16	.34	.13	.45	.21	.27	.35	.45	.82	.011	.37	1.2	16
11.1	RF XFMR	T-55631	.028	.18	.39	.15	.52	.22	.29	.33	.42	.88	.014	.42	1.2	19
11.2	RF Coils, Fixed or Molded	C-15305 C-39010	.0017	.0073	.023	.0091	.031	.011	.015	.016	.022	.052	.00083	.025	.073	1.1
11.2	RF Coils, Variable	C-15305	.0033	.015	.046	.018	.061	.022	.03	.033	.044	.10	.0017	.05	.15	2.2
	ROTATING DEVICES															
12.1	Motors		1.6	2.4	3.3	2.4	3.3	7.1	7.1	31	31	7.1	1.6	*	*	*
12.2	Synchros		.07	.20	1.5	.70	2.2	.78	1.2	7.9	12	5.1	.035	1.7	7.1	68
12.2	Resolvers		.11	.30	2.2	1.0	3.3	1.2	1.8	12	18	7.6	.053	2.6	11	100
	ELAPSED TIME METERS															
12.3	ETM-AC		10	20	120	70	180	50	80	160	250	260	5.0	140	380	*
12.3	ETM-Inverter Driver		15	30	180	105	270	75	120	240	375	390	7.5	210	570	*
13.3	ETM-Commutator DC		40	80	480	280	720	200	320	640	1000	1040	20	560	1520	*
	RELAYS															
13.1	General Purpose		.13	.28	2.1	1.1	3.8	1.1	1.4	1.9	2.1	7.0	.066	3.5	10	*
13.1	Contactor, High Current		.43	.89	6.9	3.6	12	3.4	4.4	6.2	6.7	22	.21	11	32	*
13.1	Latching		.13	.28	2.1	1.1	3.8	1.1	1.4	1.9	2.1	7.0	.066	3.5	10	*
13.1	Reed		.11	.23	1.8	.92	3.3	.96	1.2	2.1	2.3	6.3	.054	3.0	9.0	*
13.1	Thermal, Bi-metal		.29	.60	4.6	2.4	8.2	2.3	2.9	4.1	4.5	15	.14	7.6	22	*
13.1	Meter Movement		.88	1.8	14	7.4	26	7.1	9.1	13	14	46	.44	24	67	*
13.2	Solid State		.40	1.2	4.8	2.4	6.8	4.8	7.6	8.4	13	9.2	.16	4.8	13	240
13.2	Hybrid and Solid State Time Delay		.50	1.5	6.0	3.0	8.5	6.0	9.5	11	16	12	.20	6.0	17	300
	SWITCHES															
14.1	Toggle or Pushbutton		.0010	.0030	.018	.0080	.029	.010	.018	.013	.022	.046	.0005	.025	.067	1.2
14.2	Sensitive	S-8805	.15	.44	2.7	1.2	4.3	1.5	2.7	1.9	3.3	6.8	.074	3.7	9.9	180
14.3	Rotary Wafer	S-3786	.33	.99	5.9	2.6	9.5	3.3	5.9	4.3	7.2	15	.16	8.2	22	390
14.4	Thumbwheel	S-22710	.56	1.7	10	4.5	16	5.6	10	7.3	12	26	.28	14	38	670
14.5	Circuit Breaker, Thermal	C-83383	.11	.23	1.7	.91	3.1	.80	1.0	1.3	1.4	5.2	.057	2.8	7.5	N/A
14.5	Circuit Breaker, Magnetic	C-55629	.060	.12	.90	.48	1.6	.42	.54	.66	.72	2.8	.030	1.5	4.0	N/A
	CONNECTORS															
15.1	Circular/Rack/Panel		0.011	0.14	.12	.069	.20	.059	.098	.23	.34	.37	.0054	.16	.53	6.8
15.1	Coaxial		.012	.015	.13	.075	.21	.060	.10	.22	.32	.38	.0061	.16	.54	7.3
15.2	Printed Circuit Board Connector		.0054	.021	.063	.035	.10	.059	.11	.085	.16	.19	.0027	.078	.27	3.4
15.3	IC Sockets		.0019	.0058	.027	.012	.035	.015	.023	.021	.025	.048	.00097	.027	.070	1.3
16.1	Interconnection Assemblies (PCBs)		.053	.11	.37	.69	.27	.27	.43	.85	1.5	1.0	.027	.53	1.4	27

NOTE: 1) * Not normally used in this environment
2) T_A = Default Component Ambient Temperature (°C)

Generic Failure Rate, λ_g (Failures/10^6 Hours) for Miscellaneous Parts

Section #	Part Type Dielectric	MIL-	Env.→ G_B T_A (°C)→ 30	G_F 40	G_M 45	N_S 40	N_U 45	A_{IC} 55	A_{IF} 55	A_{UC} 70	A_{UF} 70	A_{RW} 55	S_F 30	M_F 45	M_L 55	C_L 40
	SINGLE CONNECTIONS															
17.1	Hand Solder, w/o Wrapping		.0026	.0052	.018	.010	.029	.010	.016	.016	.021	.042	.0013	.023	.062	1.1
17.1	Hand Solder, w/Wrapping		.00014	.00028	.00098	.00056	.0015	.00056	.00084	.00084	.0011	.0022	.00007	.0013	.0034	.059
17.1	Crimp		.00026	.00052	.0018	.0010	.0029	.0010	.0016	.0016	.0021	.0042	.00013	.0023	.0062	.11
17.1	Weld		.000050	.000100	.000350	.000200	.000550	.000200	.000300	.000300	.000400	.000800	.000025	.000450	.001200	.021000
17.1	Solderless Wrap		.0000035	.000007	.000025	.000014	.000039	.000014	.000021	.000021	.000028	.000056	.0000018	.000031	.000084	.0015
17.1	Clip Termination		.00012	.00024	.00084	.00048	.0013	.00048	.00072	.00072	.00096	.0019	.00006	.0011	.0029	.050
17.1	Reflow Solder		.000069	.000138	.000483	.000276	.000759	.000276	.000414	.000414	.000552	.001104	.000035	.000621	.001656	.02898
	METERS, PANEL															
18.1	DC Ammeter or Voltmeter	M-10304	0.09	0.36	2.3	1.1	3.2	2.5	3.8	5.2	6.6	5.4	0.099	5.4	N/A	N/A
18.1	AC Ammeter or Voltmeter	M-10304	0.15	0.61	3.8	1.8	5.4	4.3	6.4	8.9	11	9.2	0.17	9.2	N/A	N/A
19.1	Quartz Crystals	C-3098	.032	.096	.32	.19	.51	.38	.54	.70	.90	.74	.016	.42	1.0	16
20.1	Lamps, Incandescent, AC		3.9	7.8	12	12	16	16	16	19	23	19	2.7	16	23	100
20.1	Lamps, Incandescent, DC		13	26	38	38	51	51	51	64	77	64	9.0	51	77	350
	ELECTRONIC FILTERS															
21.1	Ceramic-Ferrite	F-15733	.022	.044	.13	.088	.20	.15	.20	.24	.29	.24	.018	.15	.33	2.6
21.1	Discrete LC Comp.	F-15733	.12	.24	.72	.48	1.1	.84	1.1	1.3	1.6	1.3	.096	.84	1.8	14
21.1	Discrete LC & Crystal Comp.	F-18327	.27	.54	1.6	1.1	2.4	1.9	2.4	3.0	3.5	3.0	.22	1.9	4.1	32
22.1	FUSES		.010	.020	.080	.050	.11	.090	.12	.15	.18	.16	.009	.10	.21	2.3

π_Q Factor for Use with Section 11-22 Devices

Section #	Part Type	Established Reliability	MIL-SPEC	Non-MIL
11.1, 11.2	Inductive Devices	.25*	1.0	10
12.1, 12.2, 12.3	Rotating Devices	N/A	N/A	N/A
13.1	Relays, Mechanical	.60	3.0	9.0
13.2	Relays, Solid State and Time Delay (Hybrid & Solid State)	N/A	1.0	4
14.1, 14.2	Switches, Toggle, Pushbutton, Sensitive	N/A	1.0	20
14.3	Switches, Rotary Wafer	N/A	1.0	50
14.4	Switches, Thumbwheel	N/A	1.0	10
14.5	Circuit Breakers, Thermal	N/A	1.0	8.4
15.1, 15.2, 15.3	Connectors	N/A	1.0	2.0
16.1	Interconnection Assemblies	N/A	1.0	2.0
17.1	Connections	N/A	N/A	N/A
18.1	Meters, Panel	N/A	1.0	3.4
19.1	Quartz Crystals	N/A	1.0	2.1
20.1	Lamps, Incandescent	N/A	N/A	N/A
21.1	Electronic Filters	N/A	1.0	2.9
22.1	Fuses	N/A	N/A	N/A

* Category applies only to MIL-C-39010 Coils.

Default Parameters for Discrete Semiconductors

Section #	Part Type	λ_b	π_T	π_M	π_S	π_C	π_A	π_R	Comments
5.0	MICROCIRCUITS	All Defaults provided with λ_g Table							
	DIODES								
6.1	General Purpose Analog	.0038			.42	1.0			Voltage Stress = .7, Metallurgically Bonded Contacts
6.1	Switching	.001			.42	1.0			Voltage Stress = .7, Metallurgically Bonded Contacts
6.1	Fast Recovery Power Rectifier	.069			.42	1.0			Voltage Stress = .7, Metallurgically Bonded Contacts
6.1	Transient Suppressor/Varistor	.0031			1.0	1.0			Metallurgically Bonded Contacts
6.1	Power Rectifier	.003			.42	1.0			Voltage Stress = .7, Metallurgically Bonded Contacts
6.1	Voltage Ref/Reg. (Avalanche & Zener)	.002			1.0	1.0			Metallurgically Bonded Contacts
6.1	Current Regulator	.0034			1.0	1.0			Metallurgically Bonded Contacts
6.2	Si Impatt ($\leq$ 35 GHz)	.22					1.0	1.0	
6.2	Gunn/Bulk Effect	.18					1.0	1.0	
6.2	Tunnel and Back	.0023					1.0	1.0	
6.2	PIN	.0081					1.0	2.0	Rated Power = 1000W
6.2	Schottky Barrier and Point Contact (200 MHz $\leq$ frequency $\leq$ 35 GHz)	.027			1.0	1.0			
6.2	Varactor	.0025			2.5	1.0			Multiplier Application
6.10	Thyristor/SCR	.0022			.51			1.0	Voltage Stress = .7, Rated Forward Current = 1 Amp
	TRANSISTORS								
6.3	NPN/PNP (f < 200 MHz)	.00074			.21		.70	.77	Voltage Stress = .5, Switching Application, Rated Power = .5W
6.3	Power NPN/PNP (f < 200 MHz)	.00074			.54		1.5	5.5	Voltage Stress = .8, Linear Application, Rated Power = 100W
6.4	Si FET (f $\leq$ 400 MHz)	.012					.70		MOSFET, Small Signal Switching
6.9	Si FET (f > 400 MHz)	.060							MOSFET
6.8	GaAs FET (P < 100 mW)	.052		1.0			1.0		Low Noise Application, 1 $\leq$ f $\leq$ 10 GHz, Input and Output Matching
6.8	GaAs FET (P $\geq$ 100 mW)	.13		1.0			1.0		Pulsed Application, 5 GHz, 1W Average Output Power, Input and Output Matching
6.5	Unijunction	.0083							
6.6	RF, Low Noise, Bipolar (f > 200 MHz, P < 1W)	.18			.39			.77	Voltage Stress = .7, Rated Power = .5W
6.7	RF, Power (P $\geq$ 1W)	.08	.36	1.0			1.6		1 GHz, 100W, T_J = 130°C for all Environments, Voltage Stress = .45, Gold Metallization, Pulsed Application, 20% Duty Factor, Input and Output Matching

Default Parameters for Discrete Semiconductors

Section #	Part Type	λ_b	π_T	π_M	π_S	π_C	π_A	π_R	Comments
	OPTO-ELECTRONICS								
6.11	Photodetector	.0055							Phototransistor
6.11	Opto-Isolator	.013							Phototransistor, Single Device
6.11	Emitter	.00023							LED
6.12	Alphanumeric Display	.0030							7 Character Segment Display
6.13	Laser Diode, GaAs/Al GaAs	3.23			1.0 (π_P)		.77		For Environments with $T_J > 75°C$, assume $T_J = 75°C$, Forward Peak Current = .5 Amps ($\pi_I = .62$), Pulsed Application, Duty Cycle = .6, Pr/Ps = .5 ($\pi_P = 1$)
6.13	Laser Diode, In/GaAs/In GaAsP	5.65			1.0 (π_P)		.77		For Environments with $T_J > 75°C$, assume $T_J = 75°C$, Forward Peak Current = .5 Amps ($\pi_I = .62$), Pulsed Application, Duty Cycle = .6, Pr/Ps = .5 ($\pi_P = 1$)

Default Parameters for Resistors

Section #	Part Type	Style	MIL-R-SPEC	π_R	π_V	π_{TAPS}	Comments
9.1	Composition	RCR	39008	1.1			Pwr. Stress = .5, 1M ohm
9.1	Composition	RC	11	1.1			Pwr. Stress = .5, 1M ohm
9.2	Film, Insulated	RLR	39017	1.1			Pwr. Stress = .5, 1M ohm
9.2	Film, Insulated	RL	22684	1.1			Pwr. Stress = .5, 1M ohm
9.2	Film, RN (R, C or N)	RNR	55182	1.1			Pwr. Stress = .5, 1M ohm
9.2	Film	RN	10509	1.1			Pwr. Stress = .5, 1M ohm
9.3	Film, Power	RD	11804	1.0			Pwr. Stress = .5, 100 ohm
9.4	Fixed, Network	RZ	83401				Pwr. Stress = .5, $T_C = T_A + 28°C$, 10 Film Resistors
9.5	Wirewound, Accurate	RBR	39005	1.7			Pwr. Stress = .5,100K ohms
9.5	Wirewound, Accurate	RB	93	1.7			Pwr. Stress = .5, 100K ohms
9.6	Wirewound, Power	RWR	39007	1.1			Pwr. Stress = .5, 5K ohms, RWR 84
9.6	Wirewound, Power	RW	26	1.0			Pwr. Stress = .5, 5K ohms, RW10
9.7	Wirewound, Power, Chassis Mounted	RER	39009	1.1			Pwr. Stress = .5, Noninductively Wound, 5K ohm, RER 55
9.7	Wirewound, Power, Chassis Mounted	RE	18546	1.1			Pwr. Stress = .5, MIL-R-18546, Char. N, 5K ohm, RE75
9.8	Thermistor	RTH	23648				Disk Type
9.9	Wirewound, Variable	RTR	39015	1.4	1.1	1.0	Pwr. Stress = .5, 5K ohms, 3 Taps, Voltage Stress = .1
9.9	Wirewound, Variable	RT	27208	1.4	1.1	1.0	Pwr. Stress = .5, 3 Taps, Voltage Stress = .1
9.10	Wirewound, Variable, Precision	RR	12934	1.4	1.1	1.0	Pwr. Stress = .5, Construction Class 5 (π_c = 1.5), 50K ohm, 3 Taps, Voltage Stress = .1
9.11	Wirewound, Variable, Semiprecision	RA	19	1.4	1.0	1.0	Pwr. Stress = .5, 5K ohms, 3 Taps, Voltage Stress = .5
9.11	Wirewound, Semiprecision	RK	39002	1.4	1.0	1.0	Pwr. Stress = .5, 3 Taps, Voltage Stress = .5
9.12	Wirewound, Variable, Power	RP	22	1.4	1.0	1.0	Pwr. Stress = .5, 3 Taps, Voltage Stress = .5, Unenclosed (π_c = 1)
9.13	Nonwirewound, Variable	RJR	39035	1.2	1.0	1.0	Pwr. Stress = .5, 200K ohm, 3 Taps, Voltage Stress = .5
9.13	Nonwirewound, Variable	RJ	22097	1.2	1.0	1.0	Pwr. Stress = .5, 200K ohm, 3 Taps, Voltage Stress = .5
9.14	Composition, Variable	RV	94	1.2	1.0	1.0	Pwr. Stress = .5, 200K ohm, 3 Taps, Voltage Stress = .5
9.15	Nonwirewound, Variable Precision	RQ	39023	1.2	1.0	1.0	Pwr. Stress = .5, 200K ohm, 3 Taps, Voltage Stress = .5
9.15	Film, Variable	RVC	23285	1.2	1.0	1.0	Pwr. Stress = .5, 200K ohm, 3 Taps, Voltage Stress = .5

Default Parameters for Capacitors

Section #	Part Type or Dielectric	Style	MIL-C-SPEC	π_{CV}	Temp. Rating	Comments
10.1	Paper, By-Pass	CP	25	1.0	125	Voltage Stress = .5, .15 μF
10.1	Paper, By-Pass	CA	12889	1.0	85	Voltage Stress = .5, .15 μF
10.2	Paper/Plastic, Feed-through	CZR	11693	1.0	125	Voltage Stress = .5, .061 μF
10.3	Paper/Plastic Film	CPV	14157	1.0	125	Voltage Stress = .5, .027 μF
10.3	Paper/Plastic Film	CQR	19978	1.0	125	Voltage Stress = .5, .033 μF
10.4	Metallized Paper/Plastic	CHR	39022	1.0	125	Voltage Stress = .5, .14 μF
10.4	Metallized Plastic/Plastic	CH	18312	1.0	125	Voltage Stress = .5, .14 μF
10.5	Metallized Paper/Plastic	CFR	55514	1.0	125	Voltage Stress = .5, .33 μF
10.6	Metallized Plastic	CRH	83421	1.0	125	Voltage Stress = .5, .14 μF
10.7	MICA (Dipped or Molded)	CMR	39001	1.0	125	Voltage Stress = .5, 300 pF
10.7	MICA (Dipped)	CM	5	1.0	125	Voltage Stress = .5, 300 pF
10.8	MICA (Button)	CB	10950	1.0	150	Voltage Stress = .5, 160 pF
10.9	Glass	CYR	23269	1.0	125	Voltage Stress = .5, 30 pF
10.9	Glass	CY	11272	1.0	125	Voltage Stress = .5, 30 pF
10.10	Ceramic (Gen. Purpose)	CK	11015	1.0	125	Voltage Stress = .5, 3300 pF
10.10	Ceramic (Gen. Purpose)	CKR	39014	1.0	125	Voltage Stress = .5, 3300 pF
10.11	Ceramic (Temp. Comp.)	CCR	20	1.0	125	Voltage Stress = .5, 81 pF
10.11	Ceramic Chip	CDR	55681	1.0	125	Voltage Stress = .5, 81 pF
10.12	Tantalum, Solid	CSR	39003	1.0	125	Voltage Stress = .5, 1.0 μF, .6 ohms/volt, series resistance, π_{SR} = .13
10.13	Tantalum, Non-Solid	CLR	39006	1.0	125	Voltage Stress = .5, Foil, Hermetic, 20 μF, π_C = 1
10.13	Tantalum, Non-Solid	CL	3965	1.0	125	Voltage Stress = .5, Foil, Hermetic, 20 μF, π_C = 1
10.14	Aluminum Oxide	CUR	39018	1.3	125	Voltage Stress = .5, 1700 μF
10.15	Aluminum Dry	CE	62	1.3	85	Voltage Stress = .5, 1600 μF
10.16	Variable, Ceramic	CV	81		85	Voltage Stress = .5
10.17	Variable, Piston	PC	14409		125	Voltage Stress = .5
10.18	Variable, Air Trimmer	CT	92		85	Voltage Stress = .5
10.19	Variable, Vacuum	CG	23183		85	Voltage Stress = .5, Variable Configuration

Default Parameters for Inductive and Electromechanical Parts

Section #	Part Type	MIL-SPEC	π_C	π_{CYC}	π_F	Comments
	INDUCTIVE					
11.1	Low Pwr. Pulsed, XFMR	MIL-T-21038				Max. Rated Temp. = 130°C, ΔT = 10°C
11.1	Audio XFMR	MIL-T-27				Max. Rated Temp. = 130°C, ΔT = 10°C
11.1	High Pwr. Pulse and Pwr. XFMR, Filter	MIL-T-27				Max. Rated Temp. = 130°C, ΔT = 30°C
11.1	RF Transformers	MIL-T-55631				Max. Rated Temp. = 130°C, ΔT = 10°C
11.2	RF Coils, Fixed or Molded	MIL-C-15305	1			Max. Rated Temp. = 125°C, ΔT = 10°C
11.2	RF Coils, Variable	MIL-C-15305	2			Max. Rated Temp., = 125°C, ΔT = 10°C
	ROTATING DEVICES					
12.1	Motors					t = 15,000 hours (Assumed Replacement Time)
12.2	Synchros					$T_F = T_A + 40$, Size 10 - 16, 3 Brushes
12.2	Resolvers					$T_F = T_A + 40$, Size 10 - 16, 3 Brushes
	Elapsed Time Meters (ETM)					
12.3	ETM-AC					Op. Temp/Rated Temp. = .5 (π_T = .5)
12.3	ETM-Inverter Driver					Op. Temp/Rated Temp. = .5 (π_T = .5)
12.3	ETM-Commutater DC					Op. Temp/Rated Temp. = .5 (π_T = .5)
	RELAYS					
13.1	General Purpose		3	1	5	Max. Rated Temp. = 125°C , DPDT, MIL-SPEC, 10 Cycles/Hour, 4 Amp., General Purpose, Balanced Armature, Resistive Load, s = .5
13.1	Contactor, High Current		3	1	5	Max. Rated Temp. = 125°C, DPDT, MIL-SPEC, 10 Cycles/Hour, 600 Amp., Solenoid, Inductive Load, s = .5
13.1	Latching		3	1	5	Max. Rated Temp. = 125°C, MIL-SPEC, 4 Amp., Mercury Wetted, 10 Cyles/Hour, DPDT, Resistive Load, s = .5
13.1	Reed		1	2	6	Max. Rated Temp. = 85°C, MIL-SPEC, Signal Current, Dry Reed, 20 Cycles/Hour, SPST, Resistive Load, s = .5
13.1	Thermal Bi-Metal		1	1	10	Max. Rated Temp. = 125°C, MIL-SPEC, Bi-Metal, 10 Cycles/Hour, SPST, Inductive Load, 5 Amp., s = .5
13.1	Meter Movement		1	1	100	Max. Rated Temp. = 125°C, MIL-SPEC, Polarized Meter Movement, 10 Cycles/Hour, SPST, Resistive Load, s = .5
13.2	Solid State	MIL-R-28750				No Defaults
13.2	Time Delay Hybrid and Solid State	MIL-R-83726				No Defaults