

Product Reliability Report

This report presents the product reliability data for Maxim's analog products. The data was acquired from extensive reliability stress testing performed in 1996. It is separated into seven fabrication processes: 1) Standard Metal-Gate CMOS (SMG); 2) Medium-Voltage Metal-Gate CMOS (MV1); 3) Medium-Voltage Silicon-Gate CMOS (MV2); 4) 3 μ m Silicon-Gate CMOS (SG3); 5) 5 μ m Silicon-Gate CMOS (SG5); 6) 1.2 μ m Silicon-Gate CMOS; and 7) Bipolar (BIP) processes.

Over 8,967,000 device hours have been accumulated for products stressed at an elevated temperature (135°C) during this period. The data in this report is considered typical of Maxim's production. As you will see, Maxim's products demonstrate consistently high reliability.



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Fabrication Processes

Maxim is currently running the following seven major fabrication processes:

- SMG (Standard Metal-Gate CMOS)
- MV1 (Medium-Voltage Metal-Gate CMOS)
- MV2 (Medium-Voltage Silicon-Gate CMOS)
- SG3 (3-Micron Silicon-Gate CMOS)
- SG5 (5-Micron Silicon-Gate CMOS)
- SG1.2 (1.2-Micron Silicon-Gate CMOS)
- Bipolar (18/12-Micron)

SMG

SMG is a 6-micron, 24V, metal-gate CMOS process. It has conservative design rules, but is appropriate for many SSI and MSI circuit designs. This very popular fabrication process is used to produce many of Maxim's products.

MV1

MV1 is a 12-micron, 44V, metal-gate CMOS process, used exclusively to produce our analog switch product line.

MV2

MV2 is a 5-micron, 44V, silicon-gate CMOS process, also used in our analog switch production line.

SG3, SG5, and SG1.1

SG3 is a 3-micron, 12V, silicon-gate CMOS process. SG5 is a 5-micron, 20V, silicon-gate CMOS process. SG1.2 is a 1.2-micron, 6V, silicon-gate CMOS process. SG3, SG5, and SG1.2 have become our future process standards.

Bipolar

Bipolar is an 18-micron, 44V or 12-micron, 24V bipolar process, used chiefly for precision references, op amps, and A/D converters.

Reliability Methodology

Maxim's quality approach to reliability testing is conservative. Each of the seven fabrication processes has been qualified using the following industry-standard tests: Life Test, 85/85, Pressure Pot, HAST, High-Temperature Storage Life, and Temperature Cycling (Table 1). Each process has been qualified and proven to produce inherently high-quality product.

Maxim's early conservative approach included burn-in as a standard stage of our production flow.

Burn-in ensured that our customers were receiving a quality product. Now, with the addition of our own sophisticated fabrication facility, we have improved the innate product quality to the point where burn-in adds little reliability value.

Each time a new fabrication process is introduced at Maxim, an Infant Mortality evaluation (burn-in evaluation) is initiated at the same time as process qualification. Through this Infant Mortality evaluation we can identify fabrication process defects at an early stage of production. Using the data in Table 2 (Infant Mortality Evaluation Results) and Figure 9 (Infant Mortality Pareto Chart) we can identify which category should next be improved. The data shown demonstrates the positive direction of Maxim's quality standards. It illustrates our continued dedication to providing the lowest overall-cost solution to our customers, through superior quality products.

Maxim's SMG, MV1, MV2, SG3, SG5, SG1.2, and Bipolar processes clearly meet or exceed the performance and reliability expectations of the semiconductor industry. These processes are qualified for production. Cross-sectional views of these seven processes are shown in Figures 1–7.

Reliability Program

TABLE 1. MAXIM PROCESS RELIABILITY TESTS

TEST NAME	CONDITIONS	SAMPLING PLAN ACC/SS
Life Test	+135°C/1000 hrs.	1/77
85/85	+85°C, 85% R.H., 1000 hrs. with Bias	1/77
Pressure Pot	+121°C, 100% R.H., 2 ATM, 168 hrs.	0/77
Temperature Cycling	-65°C to +150°C Air-to-Air/1000 Cycling	1/77
High-Temp. Storage Life	+150°C/1000 hrs.	1/77

Maxim has implemented a series of Quality and Reliability programs aimed at building the highest quality, most reliable analog products in the industry.

Reliability Program Steps

All products, processes, packages, and changes in

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Process Technologies

This section defines the layer-by-layer construction steps used in the fabrication of each process.

(1) SMG (Refer to Figure 1)

Layer	Description	Dimension
1	P-Well Diffusion	10µm
2	P+ Diffusion	2µm
3	N+ Diffusion	2µm
4	Gate-Oxide Growth	900Å
5	Threshold Implant	
6	Contact Etch	
7	Metallization	1µm (Al, Si-1%)
8	Passivation	0.8µm (Si ₃ N ₄ over SiO ₂)

(2) MV1 (Refer to Figure 2)

Layer	Description	Dimension
0	Buried Layer	10µm
1	EPI Deposit	19µm
2	P-Well Diffusion	10µm
3	P+ Diffusion	3µm
4	N+ Diffusion	3µm
5	Gate-Oxide Growth	1975Å
6	Threshold Implant	
7	Contact	
8	Metallization	1µm (Al, Si-1%)
9	Passivation	0.8µm (Si ₃ N ₄ over SiO ₂)

(3) MV2 (Refer to Figure 3)

Layer	Description	Dimension
1	Buried Layer	24.0µm
2	P Well	10.0µm
3	P+ Diffusion	1.5µm
4	N+ Diffusion	1.5µm
5	Gate-Oxide Growth	1000Å
6	P-Ch Threshold Adjust	
7	Polysilicon	4500Å
8	NLDD	
9	PLDD	
10	N+ Ohmic	
11	Contact	
12	Metal	1.0µm
13	Passivation	0.8µm

(4) SG3 (Refer to Figure 4)

Layer	Description	Dimension
1	P Well	6.0µm
2	PNP Base	
3	Zener Implant	
4	Active Area	1.5µm
5	P Guard	
6	N Guard	
7	P-Ch Threshold Adjust	
8	Poly 2	7000Å
9	Poly 1	4000Å
10	N+ Block	
11	P+ Select	
12	Thin Film	
13	CrSi Contact	
14	Contact	
15	Metal	1.0µm
16	Passivation	0.8µm (Si ₃ N ₄ over SiO ₂)

(5) SG5 (Refer to Figure 5)

Layer	Description	Dimension
1	P-Well Diffusion	8µm
2	PNP Base Drive	
3	Zener Implant	
4	Active Area/Field Ox	1µm
5	N Guard	
6	P Guard	
7	Threshold Adjust	
8	Gate-Oxide Growth	750Å
9	Polysilicon 1	4400Å
10	Cap Oxide	1000Å
11	Polysilicon 2	4400Å
12	N+ Implant (Source/Drain)	
13	P+ Implant (Source/Drain)	
14	Chrome/Si Thin-Film Deposit	
15	Contact	
16	Metallization	1µm
17	Passivation	0.8µm (Si ₃ N ₄ over SiO ₂)

(6) SG1.2 (Refer to Figure 6)

Layer	Description	Dimension
0	Mark Layer on P Substrate	
1	N+ Buried Layer	4µm
2	P+ Buried Layer	6µm
3	P Well	2.8µm
4	NPN Base	
5	PNP Base	
6	Active Area	
7	P Guard	
8	N Guard	
9	Gate-Oxide Growth	230Å
10	Poly 1	4200Å
11	Poly 2	4200Å
12	NMOS LDD	
13	N+ Implant (Source/Drain)	0.3µm
14	P+ Implant (Source/Drain)	0.3µm
15	Thin Film (Chrome/Si)	
16	Contact	
17	TF Contact	
18	Metal 1	6000Å
19	Metal 1 Options	
20	Via	
21	Metal 2	1.0µm
22	Passivation	8000Å

(7) BIP (Refer to Figure 7)

Layer	Description	Dimension
1	N+ Buried Layer	4.5µm
2	P+ Isolation	20µm
3	P Base	3µm
4	N+ Emitter	2.5µm
5	Capacitor	1500Å
6	Contact Etch	
7	Aluminum	11kÅ (Al, Si-1%)
8	Passivation	8kÅ (Si ₃ N ₄ over SiO ₂)

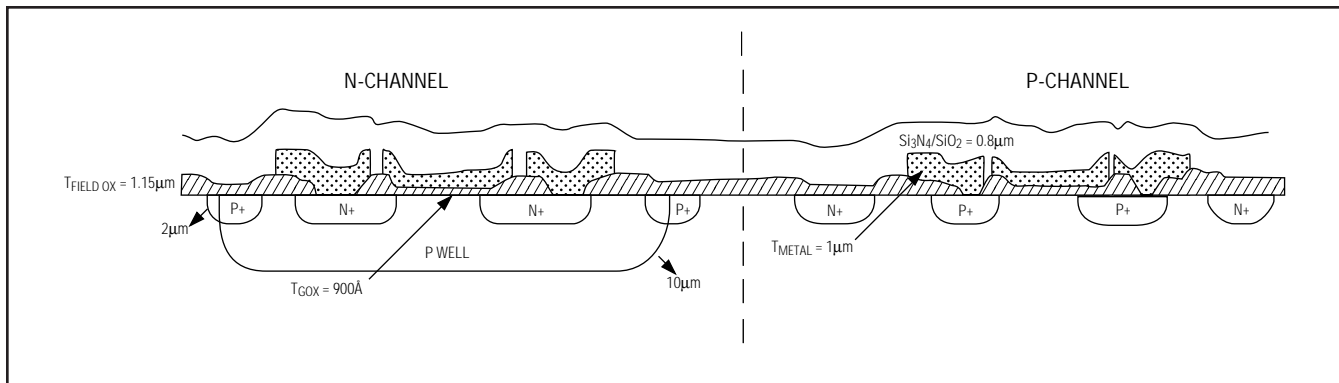


Figure 1. SMG Process

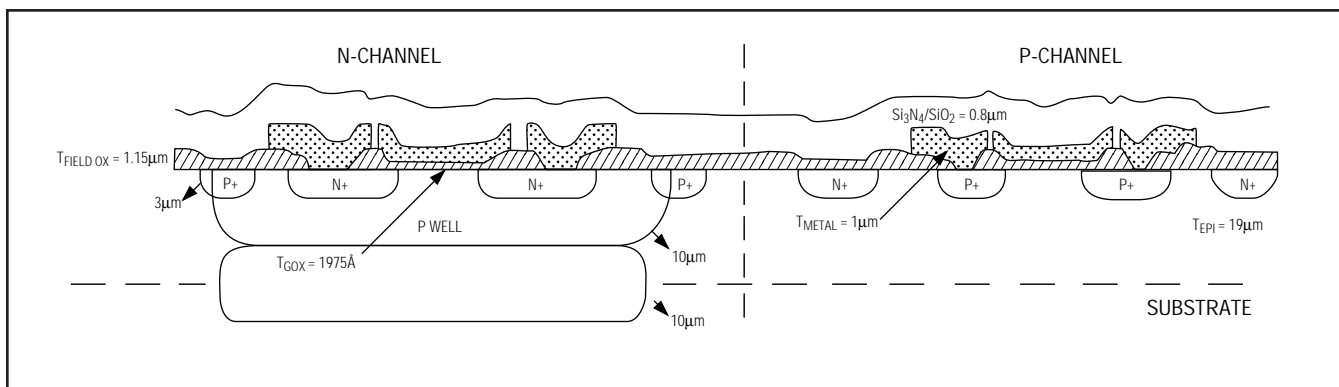


Figure 2. MV1 Process

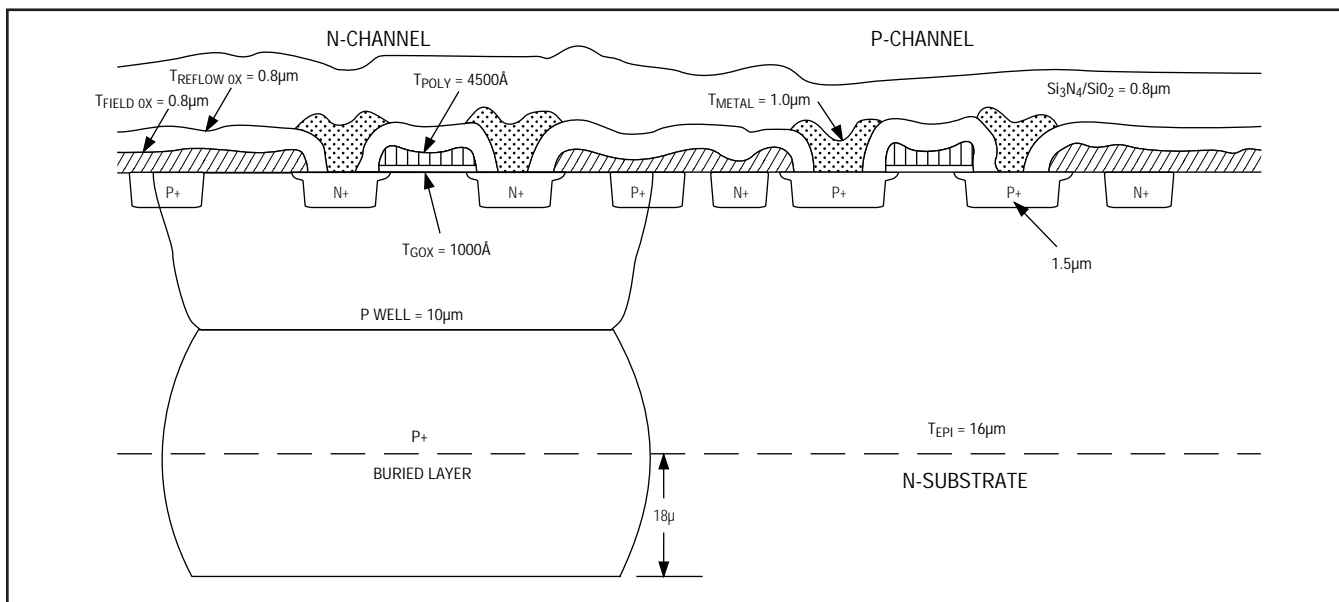


Figure 3. MV2 Process

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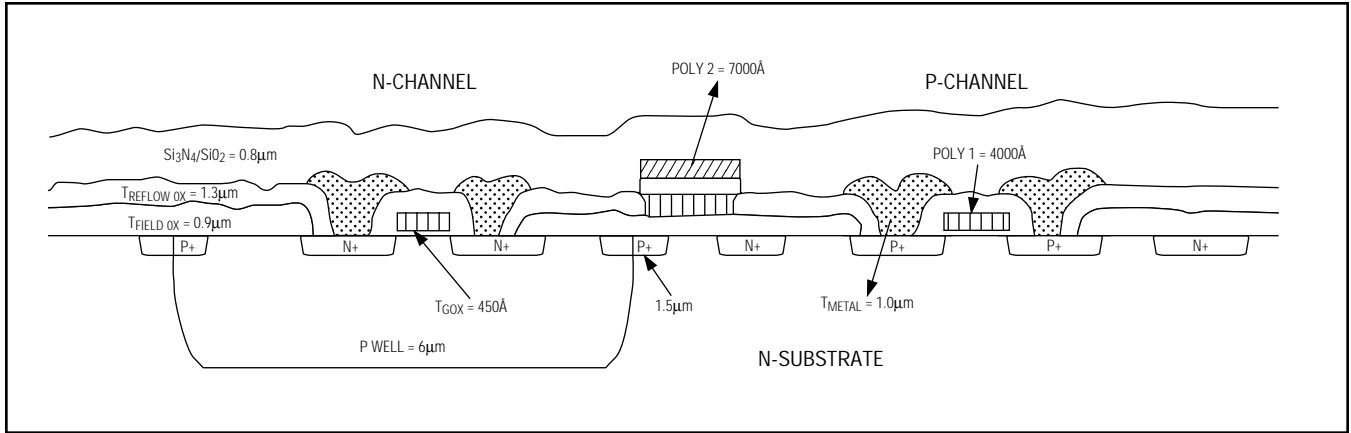


Figure 4. SG3 Process

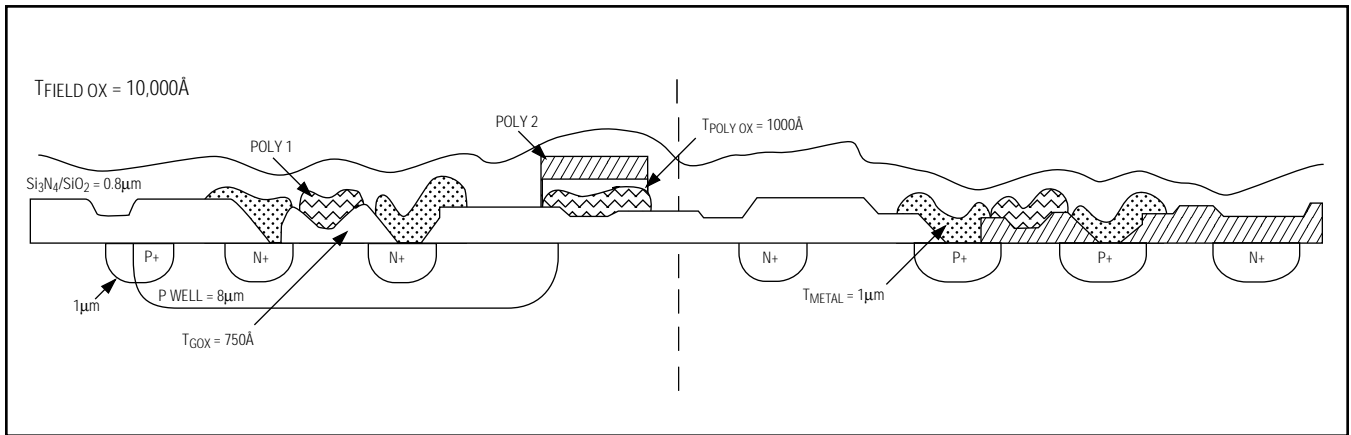


Figure 5. SG5 Process

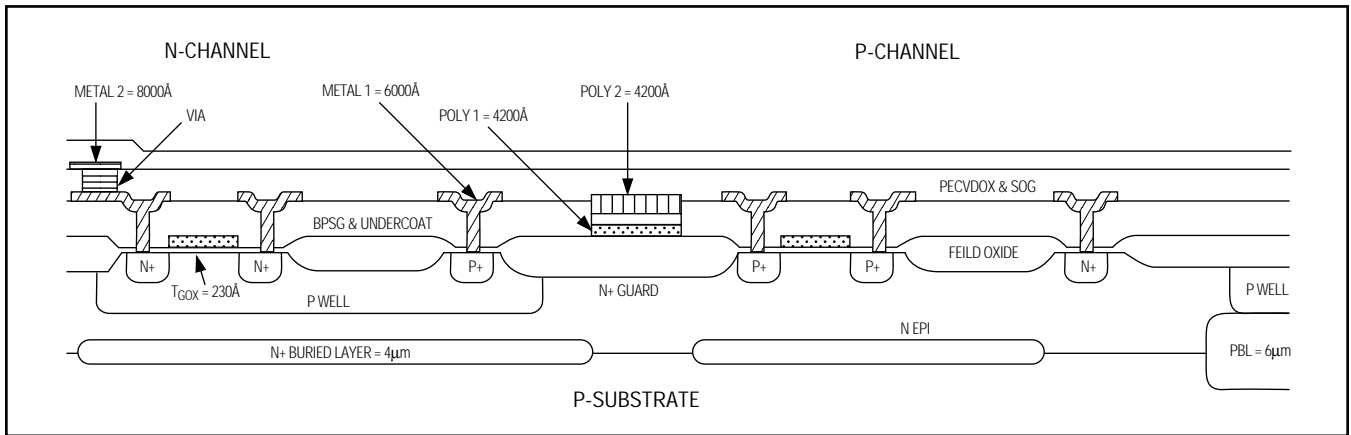


Figure 6. SG1.2 Process

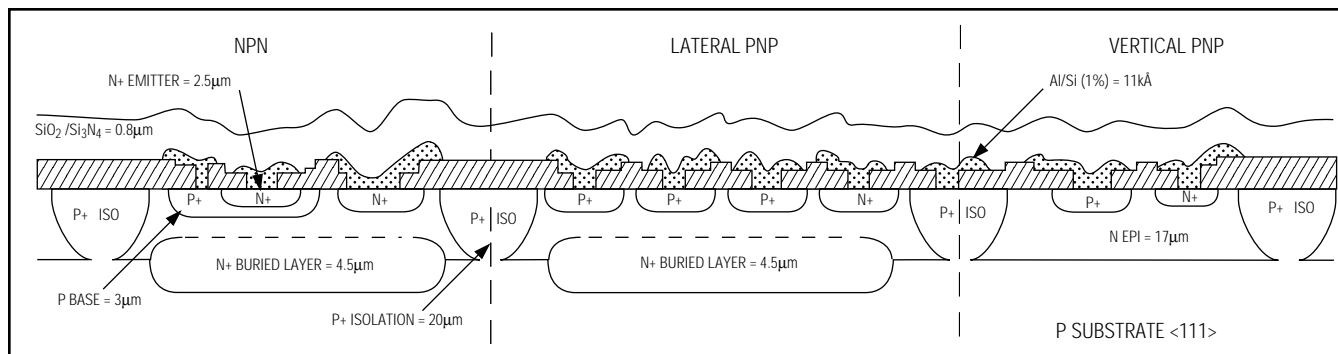


Figure 7. Bipolar Process

manufacturing steps must be subjected to Maxim's reliability testing before release to manufacturing for mass production. Our reliability program includes the following steps:

- Step 1: Initial Reliability Qualification Program
- Step 2: Ongoing Reliability Monitor Program
- Step 3: In-Depth Failure Analysis and Corrective Action

Tables 5–11 show the results of long-term Life Tests by process and device type. Tables 12–16 show the results of the 85/85, Pressure Pot, HAST, Temperature Cycling, and High-Temperature Storage Life tests, by device type. Tables 17 and 18 show hybrid product reliability.

Step 1: Initial Reliability Qualification Program

Maxim's product reliability test program meets EIA-JEDEC standards and most standard OEM reliability test requirements.

Table 1 summarizes the qualification tests that are part of Maxim's reliability program. Before releasing products, we require that three consecutive manufacturing lots from a new process technology successfully meet the reliability test requirements.

Step 2: Ongoing Reliability Monitor Program

Each week Maxim identifies three wafer lots per process per fab to be the subjects of reliability monitor testing. Each lot is Pressure Pot tested, and tested to 192 hours of High-Temperature Life (at 135°C). On a quarterly basis, one wafer lot per process per fab is identified and subjected to the same long-term reliability tests as defined in Table 1. Test results are fed back into production.

Step 3: In-Depth Failure Analysis and Corrective Action

Our technical failure-analysis staff is capable of analyzing every reliability test failure to the device level. If an alarming reliability failure mechanism or trend is identified, the corrective action is initiated automatically. This proactive response and feedback ensures that discrepancies in any device failure mechanism are corrected before becoming major problems.

Designed-In High Reliability

A disciplined design methodology is an essential ingredient of manufacturing a reliable part. No amount of finished-product testing can create reliability in a marginal design.

To design-in reliability, Maxim began by formulating a set of physical layout rules that yield reliable products even under worst-case manufacturing tolerances. These rules are rigorously enforced, and every circuit is subjected to computerized Design Rule Checks (DRCs) to ensure compliance.

Special attention is paid to Electrostatic Discharge (ESD) protection. Maxim's goal is to design every pin of every product to withstand ESD voltages in excess of 2000V, through a unique protection structure. In the case of our RS-232 interface circuits, products can even withstand ±15kV ESD using the human-body model, ±8kV ESD using IEC1000-4-2 contact discharge, or ±15kV ESD using IEC1000-4-2 air-gap discharge. Maxim tests each new product for designed 50mA latchup protection.

Designs are extensively simulated (using both circuit and logic simulation software) to evaluate performance under worst-case conditions. Finally, every design is checked and rechecked by independent teams before being released to mask making.

Wafer Inspection

All wafers are fabricated using stable, proven

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processes with extremely tight control. Each wafer must pass numerous in-process checkpoints (such as oxide thickness, alignment, critical dimensions, and defect densities), and must comply with Maxim's demanding electrical and physical specifications.

Finished wafers are inspected optically to detect any physical defects. They are then parametrically tested to ensure full conformity to Maxim's specifications. Our parametric measurement system is designed to make the precision measurements that will ensure reliability and reproducibility in analog circuits.

We believe our quality-control technology is the best in the industry, capable of resolving current levels below 1pA, and of producing less than 1pF capacitance. Maxim's proprietary software allows automatic measurement of subthreshold characteristics, fast surface-state density, noise, and other parameters crucial to predicting long-term stability and reliability. Every Maxim wafer is subject to this rigorous screening at no premium to our customers.

Failure-Rate History

The graph below (Figure 8) illustrates Maxim's Failures-in-Time (FIT) rate performance. It also

highlights the progressive improvements made in this FIT rate, a trend that we expect to see continue, thanks to our established continuous-improvement methodology.

Infant Mortality Evaluation

Maxim evaluates each process and product family's Infant Mortality rate immediately after achieving qualified status. Through Infant Mortality analysis, we can identify the common defects for each process or product family. For an illustration of Maxim's low Infant Mortality rate, refer to Table 2. Figure 9 is an Infant Mortality pareto chart showing each category of failures; categories are prioritized based on relative frequency.

Reliability Data Merits of Burn-In

Figure 10 plots Failure Rate versus Time for the metal-gate CMOS process. The plot is based on Table 3's Life Test data and Table 2's Infant Mortality evaluation data, both applied to a General Reliability model. From this data, the benefit of production burn-in can be derived.

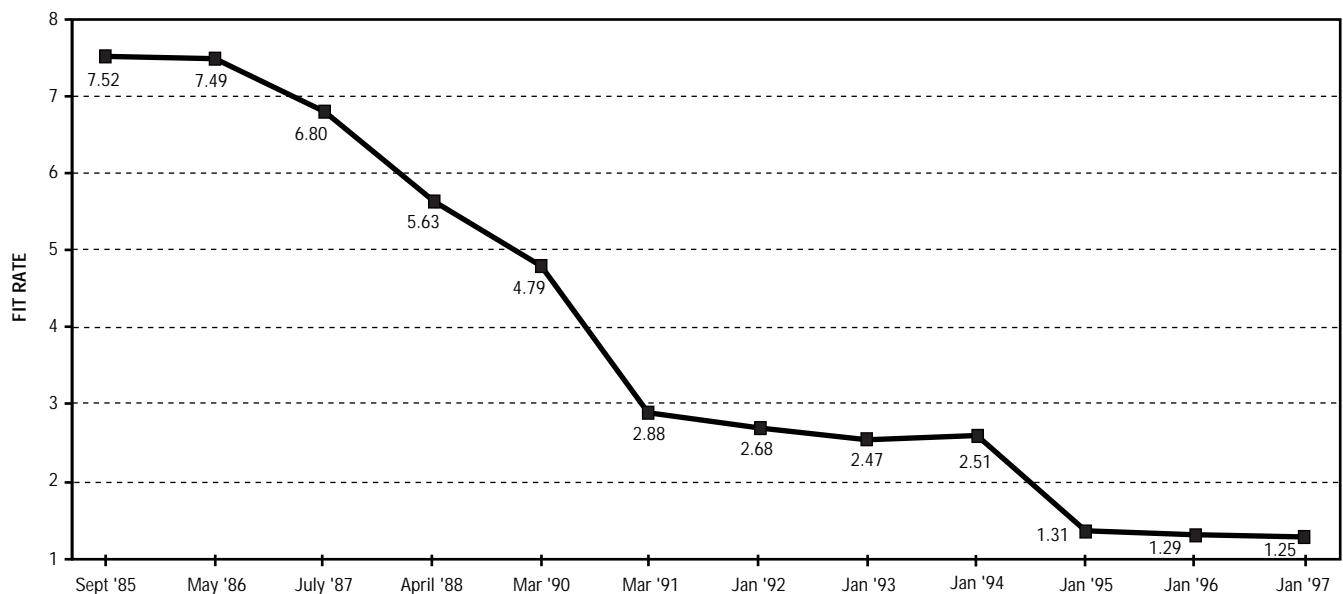


Figure 8. Maxim FIT Rates Over Time

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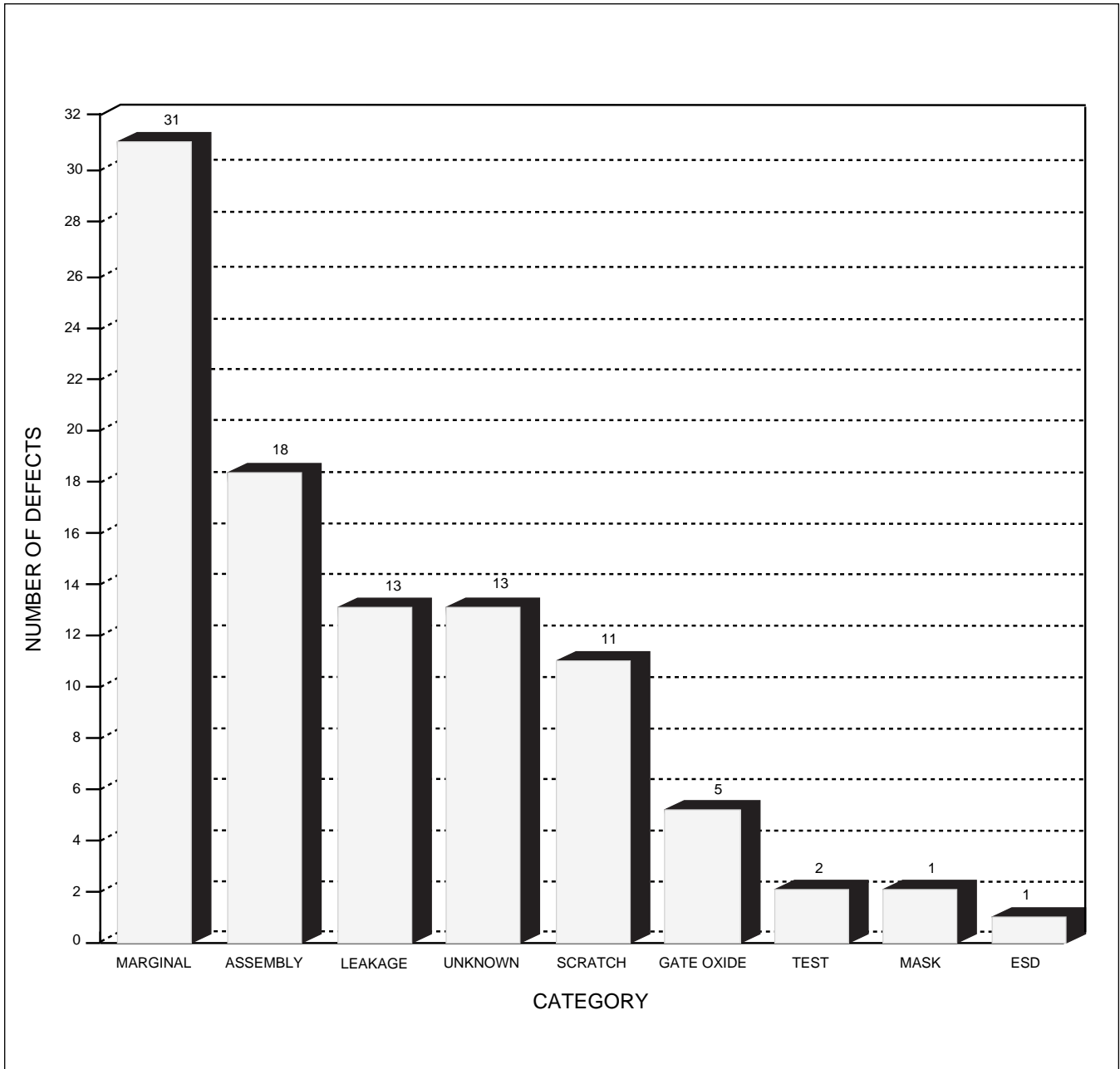


Figure 9. Infant Mortality Pareto Chart

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TABLE 2. INFANT MORTALITY EVALUATION RESULTS

PRODUCT	LOT	BI TEMP (°C)	SS	FAILURES	PPM	ANALYSIS
MV1 PROCESS						
DG201ACJ	XRCAAB184C	135	11,698	1	85	1-MARGINAL LEAKAGE
DG211CJ	XRCAAB217Q	135	9642	4	414	4-MARGINAL LEAKAGE
DG212CJ	XRCBAA208Q	135	11,834	2	169	2-MARGINAL LEAKAGE
DG509ACJ	XROCAA045Q	135	12,629	11	871	7-ISOFF CONTAMINATION, 1-HIGH ICC, 3 TIMING
DG508ACJ	XROBAB029Q	135	10,216	2	195	1-IDON, IDOFF
DG508ACJ	XROBAC030Q	135	7912	0	0	
Subtotals			63,931	20	312.8	
MV2 PROCESS						
DG411DY	XRLADB016A	135	10,338	1	97	1-MARGINAL LEAKAGE
	XRLADB017B	135	10,482	0	0	
	XRLADB018B	135	10,068	2	199	2-MARGINAL LEAKAGE
Subtotals			30,888	3	97	
SMG PROCESS						
ICM7218CIPI	XDDCAA096A	135	6886	0	0.0	1-MARGINAL LEAKAGE, 1-UNKNOWN
	XDDCAA102A	135	6824	2	293	
ICM7218AIPI	XDDAAA097A	135	6694	0	0.0	
	XDDAAA098A	135	6927	0	0.0	
ICM7218BIPI	XDDBAA099B	135	6959	0	0.0	
Subtotals			34,290	2	58.3	
ICM7218AIPI	BDDACZ012Q	135	11,674	1	85	1-UNKNOWN
	BDDACA015B	135	3101	1	322	1-UNKNOWN
ICM7218BIPI	BDDBCZ010Q	135	12,355	1	80	1-UNKNOWN
Subtotals			27,130	3	110	
MAX1232CPA	XPPAJQ003BR	135	844	0	0.0	1-DIE SCRATCH, 1-PACKAGE CRACK
	XPPAJQ003C	135	6447	2	310	
	XPPAJQ006A	135	12,390	0	0.0	
	XPPAJQ007B	135	13,330	0	0.0	
Subtotals			33,011	2	60.6	
MAX232CPE	XPWAAA039AA	150	5324	0	0.0	1-INTERMITTENT BOND WIRE OPEN (HEEL OF WEDGE BOND) 2-BOND WIRE SHORT FAILURES 1-MECHANICAL DAMAGE, 1-GATE-OXIDE DEFECT 1-INTERMITTENT BOND WIRE OPEN (HEEL OF WEDGE BOND), 1-GATE-OXIDE DEFECT, 1-MARG. HIGH R _{IN} THRESHOLD (CAUSE UNKNOWN) 1-BOND WIRE OPEN WEDGE BONDS @ LEADFRAME, 1-HIGH IEE DUE TO GATE-OXIDE DEFECT 1-LOW R _{1IN} RESISTANCE SCRATCH ON DIE, 1-HIGH IEE GATE-OXIDE DEFECT, 1-HIGH R _{2IN} RESISTANCE ERR. FUSE BLOWN 1-HIGH R _{1IN} RESISTANCE ERR. FUSE BLOWN, 1-T _{1OUT} STUCK HIGH UNKNOWN DAMAGE IN FA, 1-R _{2IN} INPUT THRESHOLD MARG. FAIL 2-UNKNOWN 1-UNKNOWN 1-UNKNOWN
	XPWAAA040AA	150	5627	1	177.7	
	XPWAAA044AB	150	5831	0	0.0	
	XPWAAA048AB	125	5575	2	358.7	
	XPWAAA050AA	125	5768	2	346.7	
	XPWAAA074AA	150	4643	3	646.1	
	XPWAAA147A	150	10,372	2	192.8	
	XPWAAA147B	150	10,789	0	0.0	
	XPWBAA012A	150	10,070	3	297.9	
	XPWBAA012B	150	10,929	3	274.5	
MAX232CPE	XKMAAA005Q	135	15,727	2	127	
MAX202CPE	XKMAAA007A	135	6277	1	159	
MAX232CPE	XKMAAA008A	135	30,888	1	32	
Subtotals			128,330	20	155.8	
MAX690CPA	XPYAJA208A	150	9443	4	423.6	1-AC FAILURE NO SCRATCH, 2-MARGINAL HIGH RESET THRESHOLD NO SCRATCH, 1-FUNCTIONAL FAILURE DUE TO DIE SCRATCH 2-DIE SCRATCH ON SILICON SUBSTRATE, 1-DIE SCRATCH ON METAL LINES 1-RESET THRESHOLD DUE TO DIE SCRATCH, 1-MARGINAL I _{BAT} NO SCRATCH, 1-GATE-OXIDE RUPTURE POSSIBLY ESD DAMAGE
	XPYAJA208BA	150	4702	3	638.0	
	XPYAJA209A	150	9873	3	303.9	
	XPYAJA208B	150	4295	0	0.0	
Subtotals			28,313	10	353.2	
MAX1044CPA	NEAABZ003B	135	2010	1	497	1-UNKNOWN
	NEAAVN020B	135	3191	0	0	
	NEAABZ003A	135	5511	2	363	2-UNKNOWN
Subtotals			10,712	3	280	

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TABLE 2. INFANT MORTALITY EVALUATION RESULTS (continued)

PRODUCT	LOT	BI TEMP (°C)	SS	FAILURES	PPM	ANALYSIS
SMG PROCESS (continued)						
MAX667CPA	XEVAJA035A XEVANA046A XEVANB048B	135 135 135	9823 8201 5015	1 5 0	102 610 0	1-PARAMETRIC 1-PARAMETRIC, 4-FUNCTIONAL 1-UNKNOWN
Subtotals			23,039	6	260	
MAX202CPE	NHUABO013A NHUABO007A NHUABO004B	135 135 135	7262 9450 9977	2 2 0	275 212 0	2-FUNCTIONAL, UNKNOWN 1-MASKING DEFECT, 1-UNKNOWN
Subtotals			26,689	4	150	
MAX202ECPE	NDOBCO005A NDOBCO005J NDOBCO006A NDOBCN009A	135 135 135 135	4257 4630 4255 13,440	1 3 0 0	235 648 0 0	1-DIE SCRATCH 1-BAUD CRATER, 2-UNKNOWN
Subtotals			26,582	4	152	
SG3 PROCESS						
MAX485CPA	XKNACA009A XKNACA011A XKNACB016C	135 135 135	8654 9689 6239	1 2 1	115 206 160	1-LEAKAGE 2-UNKNOWN 1-UNKNOWN
Subtotals			24,582	4	162	
MAX705CPA	XTOACZ010A XTOACA014Q XTOACB015B	135 135 135	7026 6759 4895	1 2 0	142 295 0	1-HIGH ICC 2-PARAMETRIC
Subtotals			18,680	3	160	
MAX712CPE MAX713CPE	XAABCA009A XAAACA013A XAAACA016A	135 135 135	12,505 11,873 10,530	3 2 2	239 168 189	3-PARAMETRIC 2-PARAMETRIC 1-FUNCTIONAL, 1-PARAMETRIC
Subtotals			34,908	7	200	
MAX692ACPA	NTABGO01O	135	12,033	2	166	2-PARAMETRIC
Subtotals			12,033	2	166	
MAX488ECPA MAX490ECPA MAX491ECPD MAX489ECPD	XIKGBA037A XIKDBB028C XIKEBB033B XIKHBB036B	135 135 135 135	4590 3347 6470 749	1 0 1 0	217 0 154 0	1-UNKNOWN 1-UNKNOWN
Subtotals			15,156	2	131	
SG5 PROCESS						
MAX232ACPE	XETAZZ063Q	135	10,016	6	599	2-BOND WIRE SHORT TO DIE EDGE, 1-BOND WIRE SMASH, 1-DIE SCRATCH, 1-HIGH ICC, 1-LOW SLEW RATE
MAX232ACPE MAX202ACPE MAX232ACPE	XETAZZ058Q XETAZA075A XETAZA099Q	135 135 135	10,181 14,977 10,425	1 4 3	98 267 288	1-OXIDE DEFECT 2-DIE SCRATCH, 2-UNKNOWN 3-HIGH ICC
Subtotals			45,599	14	307	
MAX452CPA MAX454CPD MAX455CPP	XFPAUB004A XFPAVA011Q XFPAVA009Q	135 135 135	5592 6565 16,236	2 0 5	358 0 308	2-Vos 4-Vos, 1-FUNCTIONAL FAILURE
Subtotals			28,393	7	246.5	
MAX732CPA	XPKABB254A XPKABB261A XPKABB263A	135 135 135	10,848 11,657 12,333	2 1 2	184 86 162	1-AC FAILURE, 1-UNKNOWN 1-AC FAILURE 1-AC FAILURE
Subtotals			34,838	5	143	
SG1.2 PROCESS						
MAX7219CN	BDRAAZ014A BDRAAZ026B BDRAAZ029A	135 135 135	10,091 16,648 11,347	3 3 1	297 180 88	3-UNKNOWN 3-UNKNOWN 1-UNKNOWN
Subtotals			38,086	7	184	
BIP PROCESS						
MAX901BCPE	VWHABB074C VWHABB079D VWHABB083A VWHABB083B	135 135 135 135	4100 4650 6415 4587	1 1 0 2	243 215 0 436	1-LEAKAGE 1-HIGH ICC 2-PARAMETRIC
Subtotals			19,752	4	202	
Combined Totals			704,942	132	187	

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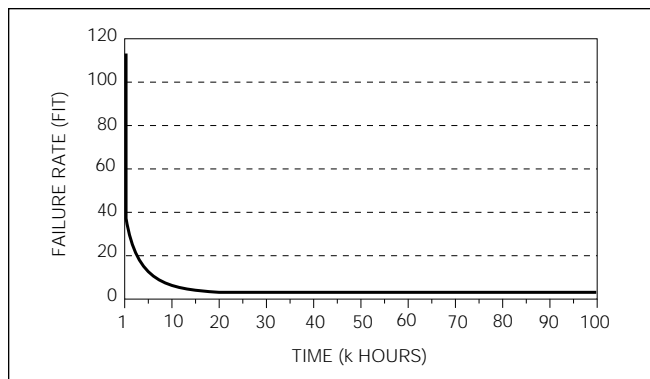


Figure 10. Failure Rate at the Field (55°C for Metal-Gate CMOS Process)

TABLE 3. LIFE TEST RESULT OF MAXIM PRODUCTS FOR EACH PROCESS (Combined Test Conditions: 135°C and 1000 Hrs.)

PROCESS	SAMPLE SIZE	REJECTS	FIT@ 25°C	FIT@ 55°C
SMG	2250	0	0.09	1.59
MV1	385	0	0.54	9.23
MV2	467	0	0.45	7.68
SG3	1602	0	0.13	2.24
SG5	846	1	0.54	9.36
SG1.2	1618	2	0.28	4.89
BIP	1799	1	0.26	4.4
Total	8967	4	0.13	2.3

TABLE 4. LIFE TEST DATA SUMMARY

PRODUCT FAMILY	NUMBER OF LOTS	NUMBER OF FAILURES	TOTAL UNITS TESTED	DEGREE OF FREEDOM	X ² 60% VALUE	X ² 90% VALUE	FIT @ 25°C	
							60% CONF. LEVEL	90% CONF. LEVEL
Converters (Note 1)	73	11	5399	24	24.7	32.5	1.21	1.60
Linear (Note 2)	251	46	19,530	94	96.4	111.3	1.31	1.51
Timers/Counters/ Display Drivers	3	0	240	2	1.38	3.62	1.52	4.0
Sum Total of All Product Lots	327	57	25,169	116	118.8	135.3	1.25	1.42

Note 1: A/D Converters, D/A Converters

Note 2: Voltage References, Operational Amplifiers, Power-Supply Circuits, Interface, Filters, Analog Switches, and Multiplexers

Table 3's data summarizes the reliability effect of production burn-in. Essentially, only four units out of 8,967 were found to be outside the specification after 1000 hrs of operation at 135°C. This is equal to an FIT rate of 0.13 at 25°C.

In comparison, the Infant Mortality rate is equal to 132 units out of 704,942 after 12 hrs at 135°C, which has an equivalent FIT rate of approximately 0.794. In practical terms, 0.019%/six years (or 0.003%/year) of the total population would be found as defective through the first six years of operation, with an addi-

tional 0.009%/year failing over the remaining life of the product.

Life Test at 135°C

Life Test is performed using biased conditions that simulate a real-world application. This test estimates the product's field performance. It establishes the constant failure-rate level and identifies any early wearout mechanisms. The tested product is kept in a controlled, elevated-temperature environment, typically at 135°C. This test can detect design, manufacturing, silicon, contamination,

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metal integrity, and assembly-related defects.

Test Used: High-Temperature Life and Dynamic Life Test (DLT)
Test Conditions: 135°C, 1000 hrs., inputs fed by clock drivers at 50% duty cycle
Failure Criteria: Must meet data sheet specifications
Results: See **Tables 5–11**

Humidity Test

The most popular integrated circuit (IC) packaging material is plastic. Plastic packages are not hermetic; therefore, moisture and other contaminants can enter the package. Humidity testing measures the contaminants present and the product's resistance to ambient conditions. Contaminants can be introduced during both wafer fabrication and assembly, and they can negatively affect product performance. Pressure Pot, 85/85, and HAST tests are used for this evaluation.

85/85 Test

Maxim tests plastic-encapsulated products with an 85/85 test to determine the moisture resistance capability of our products under bias conditions. This test can detect the failure mechanisms found in Life Test. In addition, it can detect electrolytic and chemical corrosion.

Test Used: 85/85
Test Conditions: 85°C, 85% Relative Humidity, biased, 1000 hrs.
Failure Criteria: Must meet all data sheet parameters
Results: See **Table 12**

Pressure Pot Test

This test simulates a product's exposure to atmospheric humidity, which can be present during both wafer fabrication and assembly. Although an IC is covered with a nearly hermetic passivation layer (upper-surface coat), the bond pads must be exposed during bonding. Pressure Pot testing quickly determines if a potentially corrosive contaminant is present.

Test Used: Pressure Pot
Test Conditions: 121°C, 100% RH, no bias, 168 hrs.
Failure Criteria: Any opened bond or visual evidence of corrosion
Results: See **Table 13**

HAST Test

Highly Accelerated Steam and Temperature (HAST) testing is quickly replacing 85/85 testing. It serves the same basic function as 85/85 in typically 10% of the time, making HAST tests useful for immediate feedback and corrective action.

Test Used: HAST
Test Conditions: 120°C, 85% RH, biased, 100 hrs.
Failure Criteria: Must meet all data sheet specifications
Results: See **Table 14**

Temperature Cycling Test

This test measures a component's response to temperature changes and its construction quality. The test cycles parts through a predetermined temperature range (usually -65°C to +150°C). Both fabrication and assembly problems can be discovered using Temperature Cycling, but the test typically identifies assembly quality.

Test Used: Temperature Cycling
Test Conditions: -65°C to +150°C, 1000 cycles
Failure Criteria: Must meet all data sheet specifications
Results: See **Table 15**

High-Temperature Storage Life Test

This test evaluates changes in a product's performance after being stored for a set duration (1000 hrs.) at a high temperature (150°C). It is only useful for failure mechanisms accelerated by heat.

Test Used: High-Temperature Storage Life
Test Conditions: 150°C, 1000 hrs. unbiased
Failure Criteria: Must meet all data sheet specifications
Results: See **Table 16**

Hybrid Products Reliability Data

Maxim's hybrid product reliability data is presented in **Tables 17** and **18**. **Table 17** is the Life Test data for products tested in 1996. **Table 18** is the Temperature Cycling test data for hybrid products.

Process Variability Control

Reliability testing offers little value if the manufacturing process varies widely. A standard assumption, which is often false, is that test samples pulled from production are representative of the total population. Sample variability can be lessened by increasing the number of samples pulled. However, unless a process is kept "in control," major variations can invalidate reliability test results, leading to incorrect

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conclusions and diminishing the integrity of failure-rate estimates. Uncontrolled processes also make it difficult to prove failure rates of less than 10 FIT.

Maxim monitors the stability of critical process parameters through the use of computerized Statistical Process Control (SPC). Over 125 charts are monitored in-line during wafer production. Additionally, over 100 process parameters are monitored at Wafer Acceptance. Maxim has a target Capability Coefficient (Cpk) goal of 1.5, which is equivalent to 7ppm. In addition to SPC, Maxim uses Design of Experiments (DOE) to improve process capability,

optimize process targeting, and increase robustness.

Reliability Test Results

TABLE 5. LIFE TEST AT 135°C/1000 HRS. FOR THE METAL-GATE CMOS PROCESS (SMG)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
MAX634	9551	8 PDIP	77	0	0	0
ICM7555	9551	TO99	77	0	0	0
MAX8211	9552	8 PDIP	77	0	0	0
MAX421	9552	14 PDIP	77	0	0	0
MAX232	9553	16 PDIP	74	0	0	0
MAX232	9602	16 WSO	400	0	0	0
MAX202E	9603	16 PDIP	75	0	0	0
MAX8211	9612	8 SO	77	0	0	0
MAX232	9613	8 SO	77	0	0	0
MAX850	9616	16 PDIP	78	0	0	0
MAX202E	9622	16 PDIP	80	0	0	0
MAX202E	9623	16 PDIP	80	0	0	0
MAX850	9623	8 SO	77	0	0	0
MAX8211	9624	8 SO	77	0	0	0
MAX232	9626	16 PDIP	74	0	0	0
MAX211E	9627	28 SSOP	65	0	0	0
MAX211E	9631	28 SSOP	80	0	0	0
MAX8212	9633	8 SO	77	0	0	0
MAX232	9634	16 PDIP	80	0	0	0
MAX850	9635	8 SO	80	0	0	0
MAX211	9635	28 SSOP	76	0	0	0
MAX844	9636	8 SO	79	0	0	0
MAX232	9638	16 PDIP	77	0	0	0
MAX667	9640	8 PDIP	80	0	0	0
MAX654	9641	14 PDIP	79	0	0	0
Totals			2250	0	0	0

Note: Products included in this Life Test data are: A/D Converters, Operational Amplifiers, Power-Supply Circuits, Interface, and Display Drivers/Counters.

TABLE 6. LIFE TEST AT 135°C/1000 HRS. FOR THE MEDIUM-VOLTAGE METAL-GATE CMOS PROCESS (MV1)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
DG201	9612	16 PDIP	74	0	0	0
DG302	9626	16 PDIP	77	0	0	0
MAX359	9637	16 PDIP	80	0	0	0
DG509	9638	16 PDIP	77	0	0	0
DG301	9638	16 PDIP	77	0	0	0
Totals			385	0	0	0

Note: Products included in this Life Test data are: Analog Switches and Analog Multiplexers.

TABLE 7. LIFE TEST AT 135°C/1000 HRS. FOR THE MEDIUM-VOLTAGE SILICON-GATE CMOS PROCESS (MV2)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
DG411	9553	16 PDIP	77	0	0	0
MAX305	9611	16 PDIP	77	0	0	0
MAX303	9626	16 PDIP	77	0	0	0
MAX319	9637	8 SO	79	0	0	0
MAX303	9637	16 PDIP	77	0	0	0
MAX333	9638	20 PDIP	80	0	0	0
Totals			467	0	0	0

TABLE 8. LIFE TEST AT 135°C/1000 HRS. FOR THE 3µm SILICON-GATE CMOS PROCESS (SG3)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
MAX708	9551	8 PDIP	79	0	0	0
MAX706	9552	8 PDIP	76	0	0	0
MXD1210	9606	8 PDIP	79	0	0	0
MAX4501	9611	8 PDIP	78	0	0	0
MAX4502	9611	8 PDIP	77	0	0	0
MAX3222	9613	18 PDIP	80	0	0	0
MAX707	9613	8 PDIP	77	0	0	0
MAX4503	9615	8 PDIP	70	0	0	0
MAX4504	9615	8 PDIP	70	0	0	0
MAX4514	9615	8 PDIP	79	0	0	0
MAX4516	9615	8 PDIP	70	0	0	0
MAX4517	9615	8 PDIP	50	0	0	0
MAX4518	9615	14 PDIP	79	0	0	0
MAX4519	9615	14 PDIP	79	0	0	0
MAX4515	9616	8 PDIP	80	0	0	0
MAX797	9616	16 SO	77	0	0	0
MAX785	9623	28 SSOP	65	0	0	0
MAX782	9624	36 SSOP	65	0	0	0
MAX797	9624	16 SO	80	0	0	0
MAX705	9626	8 PDIP	77	0	0	0
MAX785	9630	28 SSOP	38	0	0	0
MAX706	9640	8 PDIP	77	0	0	0
Totals			1602	0	0	0

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TABLE 9. LIFE TEST AT 135°C/1000 HRS. FOR THE 5µm SILICON-GATE CMOS PROCESS (SG5)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)			NOTES
				192	500	1000	
MAX232A	9552	16 PDIP	77	0	0	0	Gate oxide defect
TSC427	9606	8 PDIP	80	0	0	0	
MAX528	9607	18 PDIP	221	1	0	0	
MAX232A	9613	16 PDIP	77	0	0	0	
MX7534	9619	20 PDIP	79	0	0	0	
MAX232A	9619	16 PDIP	79	0	0	0	
MAX232A	9629	16 PDIP	77	0	0	0	
MAX232A	9639	16 PDIP	76	0	0	0	
MAX232A	9648	16 PDIP	80	0	0	0	
Totals			846	1	0	0	

Note: Products included in this Life Test data are: A/D Converters, D/A Converters, Interface, and Switched Capacitor Filters.

TABLE 10. LIFE TEST AT 135°C/1000 HRS. FOR THE 1.2µm SILICON-GATE CMOS PROCESS (SG1.2)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)			NOTES
				192	500	1000	
MAX619	9546	8 SO	77	0	0	0	Mask defect
MAX619	9548	8 SO	77	0	0	0	
MAX7219	9553	24 PDIP	77	0	0	0	
MAX7219	9601	24 PDIP	77	0	0	0	
MAX8864S	9601	5 SOT23	69	0	0	0	
MAX8864T	9602	5 SOT23	68	0	0	0	
MAX8863T	9602	5 SOT23	58	0	0	0	
MAX811L	9604	8 PDIP	79	0	0	0	
MAX1600	9613	28 SSOP	77	0	0	1	
MAX8864S	9621	5 SOT23	68	0	0	0	
MAX8863T	9622	5 SOT23	58	0	0	0	
MAX1247	9624	16 PDIP	51	0	0	0	
MAX7219	9630	24 PDIP	80	0	0	0	
MAX7219	9633	24 PDIP	80	0	0	0	
MAX1600	9633	28 SSOP	75	0	0	0	
MAX1604	9640	28 SSOP	77	0	0	0	
MAX7219	9641	24 PDIP	79	0	0	0	
MAX7219	9642	24 PDIP	77	0	0	0	
MAX7219	9643	24 PDIP	80	0	0	0	
MAX7219	9644	24 PDIP	77	0	0	0	
MAX7219	9645	24 PDIP	77	0	0	0	
MAX7219	9646	24 PDIP	80	1	0	0	Threshold shift
Totals			1618	1	0	1	

TABLE 11. LIFE TEST AT 135°C/1000 HRS. FOR THE BIPOLAR PROCESS (BIPOLAR)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)			NOTES	
				192	500	1000		
MX580	9549	TO52	77	0	0	0	Lifted bond	
MAX477	9601	8 PDIP	79	0	0	0		
MXL1013	9603	8 PDIP	80	0	0	0		
MAX400	9604	8 PDIP	77	0	0	0		
MAX471	9607	8 SO	45	0	0	0		
REF02	9608	8 PDIP	77	0	0	0		
MAX471	9609	8 PDIP	80	0	0	0		
MAX724	9612	TO220	80	0	0	0		
MAX872	9612	8 PDIP	76	0	0	0		
MAX4111	9613	8 PDIP	77	0	0	0		
MAX471	9614	8 PDIP	80	0	0	0		
MXL1013	9618	8 PDIP	77	0	0	0		
MAX675	9618	8 PDIP	77	0	0	0		
REF02	9621	8 PDIP	75	0	0	0		
REF02	9623	8 PDIP	73	0	0	0		
MAX872	9624	8 PDIP	80	0	0	0		
MAX471	9625	8 PDIP	73	1	0	0		
MAX492	9627	8 PDIP	80	0	0	0		
MX636	9631	14 PDIP	80	0	0	0		
MAX4102	9637	8 SO	79	0	0	0		
REF02	9638	8 PDIP	77	0	0	0		
MXL1001	964	18 PDIP	20	0	0	0		
Totals			1799	1	0	0		

Note: Products included in this Life Test data are: Voltage References and Operational Amplifiers.

TABLE 12. TEMPERATURE AND HUMIDITY (85/85) TEST RESULTS

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)			NOTES
				192	500	1000	
MAX619	9546	8 PDIP	73	0	0	0	Leakage
MAX921	9547	8 SO	39	0	0	0	
MAX619	9548	8 PDIP	74	0	0	0	
REF01	9550	8 SO	77	0	0	0	
DG411	9553	16 PDIP	77	0	0	0	
MAX8211	9552	8 PDIP	77	0	0	0	
MAX706	9552	8 PDIP	77	0	0	0	
MAX7219	9553	24 PDIP	44	0	0	0	
MAX478	9548	8 SO	42	0	0	0	
MAX202E	9604	16 WSO	26	0	0	0	
MAX7219	9601	24 PDIP	45	0	0	0	
MAX400	9604	8 PDIP	45	0	0	0	
MAX471	9607	8 SO	45	0	0	0	
REF02	9608	8 PDIP	77	0	0	0	
MAX707	9613	8 PDIP	77	0	0	0	
MAX305	9611	16 PDIP	77	0	0	1	
MAX8211	9612	8 SO	77	0	0	0	
MAX675	9618	8 PDIP	45	0	0	0	
MAX1247	9624	16 PDIP	77	0	0	0	
REF02	9623	8 PDIP	45	0	0	0	
MAX705	9626	8 PDIP	77	0	0	0	
MAX303	9626	16 PDIP	77	0	0	1	
MAX8211	9624	8 SO	76	0	0	0	
MAX8212	9636	8 SO	38	0	0	0	
MAX692	9637	8 SO	45	0	0	0	
MAX8212	9633	8 SO	77	0	0	0	
MAX706	9640	8 PDIP	77	0	0	0	
MAX303	9637	16 PDIP	72	0	0	0	
REF02	9638	8 PDIP	45	0	0	0	
Totals			1800	0	0	2	

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**TABLE 13. PRESSURE POT TEST AT 121°C/100% RH
15 PSIG/168 HRS. (ALL PLASTIC PACKAGES)**

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS) 168	NOTES
MX7574	9528	16 PDIP	45	0	
MAX619	9546	8 SO	45	0	
MAX619	9548	8 SO	45	0	
MAX478	9548	8 SO	43	0	
MAX246	9549	40 PDIP	45	0	
MAX245	9549	40 PDIP	45	0	
MAX247	9549	40 PDIP	45	0	
REF01	9550	8 SO	36	0	
MAX8211	9552	8 PDIP	45	0	
MAX706	9552	8 PDIP	45	0	
DG411	9553	16 PDIP	45	0	
MAX232	9553	16 PDIP	45	0	
MAX7219	9553	24 PDIP	45	0	
DG303	9601	16 WSO	45	0	
MAX726	9601	TO220	20	0	
MAX7219	9601	24 PDIP	45	0	
MAX1600	9601	28 SSOP	45	0	
MAX232	9602	16 WSO	76	0	
MAX8863T	9602	5 SOT23	60	0	
MAX8864S	9602	5 SOT23	53	0	
MAX202E	9603	16 PDIP	45	0	
MAX400	9604	8 PDIP	45	0	
MAX811L	9604	8 PDIP	45	0	
MAX471	9604	8 SO	77	0	
MAX850	9607	8 SO	77	0	
MAX232A	9608	16 PDIP	45	0	
MAX850	9611	8 SO	77	0	
MAX8211	9611	8 SO	42	0	
MAX809L	9611	3 SOT23	43	0	
MAX8864T	9612	5 SOT23	59	0	
MAX305	9612	16 PDIP	45	0	
MAX471	9612	8 PDIP	77	0	
MAX872	9612	8 PDIP	77	0	
MAX786	9612	28 SSOP	45	0	
REF02	9613	8 PDIP	45	0	
MAX232	9613	16 PDIP	45	0	
MAX707	9613	8 PDIP	45	0	
DG201	9613	16 PDIP	45	0	
MAX809L	9613	3 SOT23	45	0	
MAX724	9614	TO220	77	0	
MAX809L	9614	3 SOT23	44	0	
MAX243	9615	16 SO	45	0	
MXL1013	9618	8 PDIP	45	0	
MAX675	9618	8 PDIP	45	0	
MAX243	9621	16 SO	44	0	
MAX511	9621	14 SO	73	0	
REF02	9621	8 PDIP	77	0	
MAX8864S	9621	5 SOT23	77	0	
MAX8863T	9622	5 SOT23	77	0	
MAX4501	9622	5 SOT23	72	0	
REF02	9623	8 PDIP	45	0	
MAX1247	9624	16 PDIP	25	0	
MAX8211	9624	8 SO	45	0	
MAX872	9624	8 PDIP	76	0	
MAX471	9625	8 PDIP	77	0	
MAX232A	9626	16 SO	45	0	

TABLE 13 (continued)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS) 168	NOTES
MAX232	9626	16 PDIP	45	0	
MAX705	9626	8 PDIP	45	0	
DG302	9626	16 PDIP	45	0	
MAX303	9626	16 PDIP	45	0	
MAX809L	9626	3 SOT23	45	0	
MAX492	9627	8 PDIP	77	0	
MAX1630	9627	28 SSOP	45	0	
MAX211E	9627	28 SSOP	45	0	
MAX809L	9628	3 SOT23	45	0	
MAX232A	9629	16 PDIP	45	0	
MAX232A	9630	16 SO	42	0	
MAX7219	9630	24 PDIP	77	0	
MAX620	9633	18 PDIP	77	0	
MAX734	9633	8 SO	77	0	
MAX8212	9633	8 SO	45	0	
MAX203	9635	20 WSO	45	0	
MAX211	9635	28 SSOP	77	0	
MX7226	9636	20 WSO	77	0	
MAX487	9636	8 PDIP	77	0	
MAX8212	9636	8 SO	45	0	
MAX232	9636	16 PDIP	77	0	
MAX488	9636	8 SO	45	0	
DG301	9636	16 PDIP	45	0	
MAX692A	9637	8 SO	45	0	
MAX519	9637	16 SO	77	0	
MAX203	9637	20 WSO	45	0	
MAX303	9637	16 PDIP	45	0	
MAX797	9638	16 SO	77	0	
MAX232	9638	16 PDIP	45	0	
REF02	9638	8 PDIP	45	0	
MAX232A	9639	16 PDIP	45	0	
MAX492	9639	8 PDIP	77	1	High input offset voltage
MAX817L	9639	8 PDIP	77	0	
MAX1604	9640	28 SSOP	77	0	
MAX232A	9640	16 SO	45	0	
MAX706	9640	8 PDIP	45	0	
MAX1604	9640	28 SSOP	77	0	
MAX782	9641	36 SSOP	80	0	
MAX7219	9642	24 PDIP	77	0	
MAX797	9642	16 SO	77	0	
MAX7219	9643	24 PDIP	77	0	
MAX7219	9644	24 PDIP	77	0	
MAX235	9644	24 PDIP	77	0	
MAX211	9644	28 SSOP	77	0	
MAX7219	9645	24 PDIP	77	0	
MAX203	9645	20 PDIP	77	1	Capacitor open
MAX235	9645	24 PDIP	77	0	
MAX235	9646	24 PDIP	77	0	
MAX7219	9646	24 PDIP	45	0	
MAX233	9646	20 DIP	77	0	
MAX233A	9649	20 WSO	77	0	
MAX233A	9650	20 WSO	77	0	
Totals			6167	2	

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**TABLE 14. HAST TEST RESULTS
120°C/85% RH/BIASED/100 HRS.**

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS) 100	NOTES
MAX232	9602	16 WSO	25	0	
MAX8864T	9602	5 SOT23	25	0	
MAX8863T	9602	5 SOT23	25	0	
MAX811	9604	8 PDIP	25	0	
MX636	9607	16 WSO	25	0	
MX636	9611	14 PDIP	25	0	
DG201	9612	16 PDIP	25	0	
MAX724	9612	TO220	25	0	
MAX872	9612	8 PDIP	25	0	
MAX471	9614	8 PDIP	25	0	
MAX786	9617	28 SSOP	25	0	
MAX4123	9618	8 SO	25	0	
MAX4125	9620	8 SO	25	0	
MAX202	9620	16 WSO	25	0	
MAX8864S	9621	5 SOT23	25	0	
MAX8863T	9622	5 SOT23	25	0	
MAX4501	9622	5 SOT23	25	0	
MAX872	9624	8 PDIP	25	0	
MAX471	9625	8 PDIP	25	0	
MAX235	9626	24 PDIP	25	0	
MAX492	9627	8 PDIP	23	0	
MAX211E	9627	28 SSOP	25	0	
MAX232A	9629	16 PDIP	25	0	
MAX233A	9629	20 PDIP	25	0	
MAX203	9635	20 WSO	25	0	
MAX211	9635	28 SSOP	25	0	
MAX488	9636	8 SO	25	0	
MAX203	9637	20 WSO	25	1	Capacitor open
MAX232	9638	16 PDIP	25	0	
MAX232A	9639	16 PDIP	25	0	
MAX203	9640	20 WSO	25	0	
MAX235	9644	24 PDIP	25	0	
MAX7219	9645	24 PDIP	25	0	
MAX235	9645	24 PDIP	25	0	
MAX235	9646	24 PDIP	25	0	
MAX7219	9646	24 PDIP	24	0	
MAX233A	9651	20 WSO	25	0	
Totals			946	1	

**TABLE 15. TEMPERATURE CYCLING
-65°C TO +150°C 1000 CYCLES
(ALL PACKAGE TYPES)**

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				168	168	168
MAX619	9546	8 SO	74	0	0	0
MAX619	9548	8 SO	75	0	0	0
MAX478	9548	8 SO	45	0	0	0
MX580	9549	TO52	45	0	0	0
REF01	9550	8 SO	77	0	0	0
ICM7555	9551	TO99	45	0	0	0
MAX8211	9552	8 PDIP	77	0	0	0
MAX232A	9552	16 PDIP	77	0	0	0
MAX706	9552	8 PDIP	77	0	0	0
MAX421	9552	14 PDIP	45	0	0	0
DG411	9553	16 PDIP	77	0	0	0
MAX203	9553	16 PDIP	77	0	0	0
MAX7219	9553	24 PDIP	45	0	0	0
DG303	9601	16 WSO	77	0	0	0
MAX7219	9601	24 PDIP	45	0	0	0
MAX8864S	9601	5 SOT23	47	0	0	0
MAX232	9602	16 WSO	77	0	0	0
MAX8864T	9602	5 SOT23	44	0	0	0
MAX8863T	9602	5 SOT23	60	0	0	0
MAX202E	9603	16 PDIP	45	0	0	0
MAX202E	9604	16 WSO	44	0	0	0
MAX400	9604	8 PDIP	45	0	0	0
MAX811L	9604	8 PDIP	45	0	0	0
MAX471	9607	8 SO	45	0	0	0
REF02	9608	8 PDIP	77	0	0	0
MAX305	9611	16 PDIP	77	0	0	0
MAX809L	9611	3 SOT23	44	0	0	0
DG201	9612	16 PDIP	77	0	0	0
MAX8211	9612	8 PDIP	77	0	0	0
MAX724	9612	TO220	77	0	0	0
MAX872	9612	8 PDIP	77	0	0	0
MAX232A	9613	16 PDIP	77	0	0	0
MAX232	9613	16 PDIP	77	0	0	0
MAX707	9613	8 PDIP	77	0	0	0
MAX471	9614	8 PDIP	77	0	0	0
MAX809L	9614	3 SOT23	44	0	0	0
MXL1013	9618	8 PDIP	45	0	0	0
MAX675	9618	8 PDIP	44	0	0	0
REF02	9621	8 PDIP	44	0	0	0
MAX8864S	9621	5 SOT23	72	0	0	0
MAX8863T	9622	5 SOT23	77	0	0	0
MAX4501	9622	5 SOT23	67	0	0	0
REF02	9623	8 PDIP	44	0	0	0
MAX1247	9624	16 PDIP	45	0	0	0
MAX8211	9624	8 SO	77	0	0	0
MAX872	9624	8 PDIP	77	0	0	0
MAX471	9625	8 PDIP	77	0	0	0
MAX232	9626	16 PDIP	77	0	0	0
MAX705	9626	8 PDIP	77	0	0	0
DG302	9626	16 PDIP	77	0	0	0
MAX303	9626	16 PDIP	77	0	0	0
MAX492	9627	8 PDIP	77	0	0	0
MAX1630	9627	28 SSOP	45	0	0	0
MAX232A	9629	16 PDIP	77	0	0	0
MX636	9631	14 PDIP	77	0	0	0
MAX8212	9633	8 SO	77	0	0	0
MAX211	9635	28 SSOP	76	0	0	0
MAX488	9636	8 SO	45	0	0	0
DG301	9636	16 PDIP	77	0	0	0
MAX692A	9637	8 SO	45	0	0	0
MAX303	9637	16 PDIP	77	0	0	0
MAX232	9638	16 PDIP	77	0	0	0
REF02	9638	8 PDIP	77	0	0	0
MAX232A	9639	16 PDIP	77	0	0	0
MAX492	9639	8 PDIP	75	0	0	0
MAX706	9640	8 PDIP	77	0	0	0
MAX7219	9644	24 PDIP	45	0	0	0
MAX7219	9645	24 PDIP	45	0	0	0
MAX7219	9646	24 PDIP	45	0	0	0
Totals			4436	0	0	0

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TABLE 16. HIGH-TEMPERATURE STORAGE LIFE TEST 150°C/1000 HRS. (ALL PACKAGE TYPES)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
MAX3480	9538	28 PDIP	45	0	0	0
MAX619	9548	8 SO	77	0	0	0
MAX478	9548	8 SO	43	0	0	0
MX580	9549	TO52	45	0	0	0
REF01	9550	8 SO	45	0	0	0
MAX634	9551	8 PDIP	45	0	0	0
ICM7555	9551	TO99	45	0	0	0
MAX8211	9552	8 PDIP	45	0	0	0
MAX232A	9552	16 PDIP	45	0	0	0
MAX706	9552	8 PDIP	45	0	0	0
MAX421	9552	14 PDIP	45	0	0	0
DG411	9553	16 PDIP	45	0	0	0
MAX232	9553	16 PDIP	45	0	0	0
MAX7219	9553	24 PDIP	45	0	0	0
DG303	9601	16 WSO	45	0	0	0
MAX7219	9601	24 PDIP	45	0	0	0
MAX8864S	9601	5 SOT23	45	0	0	0
MAX8864T	9602	5 SOT23	44	0	0	0
MAX8863T	9602	5 SOT23	42	0	0	0
MAX202E	9603	16 PDIP	45	0	0	0
MAX202E	9604	16 WSO	45	0	0	0
MAX400	9604	8 PDIP	45	0	0	0
MAX811L	9604	8 PDIP	45	0	0	0
MAX471	9607	8 SO	45	0	0	0
REF02	9608	8 PDIP	45	0	0	0
MAX305	9611	16 PDIP	43	0	0	0
DG201	9612	16 PDIP	45	0	0	0
MAX8211	9612	8 SO	45	0	0	0
MAX724	9612	TO220	45	0	0	0
MAX872	9612	8 PDIP	45	0	0	0
MAX232A	9613	16 PDIP	45	0	0	0
MAX232	9613	16 PDIP	45	0	0	0
MAX707	9613	8 PDIP	45	0	0	0
MAX471	9614	8 PDIP	45	0	0	0
MAX233A	9617	20 WSO	14	0	0	0
MAX233A	9618	20 WSO	14	0	0	0
MAX675	9618	8 PDIP	45	0	0	0
REF02	9621	8 PDIP	44	0	0	0
MAX8864S	9621	5 SOT23	73	0	0	0
MAX8863T	9622	5 SOT23	42	0	0	0
REF02	9623	8 PDIP	45	0	0	0
MAX8211	9624	8 SO	45	0	0	0
MAX872	9624	8 PDIP	45	0	0	0
MAX471	9625	8 PDIP	45	0	0	0
MAX705	9626	8 PDIP	45	0	0	0
DG302	9626	16 PDIP	45	0	0	0
MAX303	9626	16 PDIP	45	0	0	0
MAX492	9627	8 PDIP	45	0	0	0
MAX232A	9629	16 PDIP	45	0	0	0
MAX8212	9633	8 SO	45	0	0	0
MAX203	9635	20 WSO	45	0	0	0
MAX211	9635	28 SSOP	45	0	0	0
DG301	9636	16 PDIP	45	0	0	0
MAX203	9637	20 WSO	45	0	0	0
MAX303	9637	16 PDIP	41	0	0	0
MAX232	9638	16 PDIP	45	0	0	0
REF02	9638	8 PDIP	45	0	0	0
MAX233	9638	20 PDIP	45	0	0	0
MAX232A	9639	16 PDIP	45	0	0	0
MAX706	9640	8 PDIP	45	0	0	0
MAX203	9640	20 WSO	45	0	0	0
MAX233	9641	20 PDIP	45	0	0	0
MAX7219	9644	20 PDIP	45	0	0	0
MAX681	9644	14 PDIP	77	0	0	0
MAX235	9644	24 PDIP	45	0	0	0

TABLE 16 (continued)

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
MAX211	9644	28 SSOP	45	0	0	0
MAX203	9644	20 PDIP	45	0	0	0
MAX203	9645	20 PDIP	45	0	0	0
MAX235	9645	24 PDIP	45	0	0	0
MAX235	9646	24 PDIP	44	0	0	0
MAX7219	9646	24 PDIP	45	0	0	0
MAX233	9646	20 PDIP	45	0	0	0
Totals			3253	0	0	0

TABLE 17. HYBRID PRODUCTS LIFE TEST 135°C/1000 HRS

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				192	500	1000
MAX246	9549	40 PDIP	75	0	0	0
MAX245	9549	40 PDIP	77	0	0	0
MAX247	9549	40 PDIP	75	0	0	0
MAX233A	9617	20 WSO	63	0	0	0
MAX233A	9618	20 WSO	63	0	0	0
MAX203	9635	20 WSO	77	0	0	0
MAX233	9638	20 PDIP	77	0	0	0
MAX203	9640	20 WSO	77	0	0	0
MAX233	9641	20 PDIP	77	0	0	0
MAX681	9644	14 PDIP	76	0	0	0
MAX235	9644	24 PDIP	77	0	0	0
MAX203	9644	20 PDIP	77	0	0	0
MAX203	9645	20 PDIP	76	0	0	0
MAX235	9645	24 PDIP	76	0	0	0
MAX235	9646	24 PDIP	77	0	0	0
MAX233	9646	20 PDIP	77	0	0	0
Totals			1197	0	0	0

TABLE 18. HYBRID PRODUCTS TEMPERATURE CYCLING -65°C TO +150°C/1000 CYCLES

DEVICE TYPE	DATE CODE	PKG.	SAMPLE SIZE	FAILURES (HRS)		
				200	500	1000
MAX3480	9538	28 PDIP	45	0	0	0
MAX252	9543	40 PDIP	44	0	0	0
MAX625	9544	24 PDIP	45	0	0	0
MAX246	9549	40 PDIP	77	0	0	0
MAX245	9549	40 PDIP	75	0	0	0
MAX247	9549	40 PDIP	75	0	0	0
MAX233A	9617	20 WSO	74	0	0	0
MAX233A	9618	20 WSO	77	0	0	0
MAX203	9635	20 WSO	43	0	0	0
MAX203	9637	20 WSO	43	0	0	0
MAX233	9638	20 PDIP	77	0	0	0
MAX203	9640	20 WSO	45	0	0	0
MAX233	9641	20 PDIP	77	0	0	0
MAX681	9644	16 PDIP	77	0	0	0
MAX235	9644	24 PDIP	76	0	0	0
MAX203	9644	20 PDIP	77	0	0	0
MAX203	9645	20 PDIP	77	0	0	0
MAX235	9645	24 PDIP	77	0	0	0
MAX235	9646	24 PDIP	76	0	0	0
MAX233	9646	20 PDIP	77	0	0	0
Totals			1334	0	0	0

Appendix 1: Determining Acceleration Factor

Definition of Terms

An acceleration factor is a constant used in reliability prediction formulas that expresses the enhanced effect of temperature on a device's failure rate. It is usually used to show the difference (or acceleration effect) between the failure rate at two temperatures. In simple terms, a statement such as, "The failure rate of these devices operating at 150°C is five-times greater than the failure rate at 25°C," implies an acceleration factor of 5.

The acceleration factor used in the semiconductor industry is a result of the Arrhenius equation stated below:

Where:

$$\text{Acceleration Factor} = Ke^{\frac{E_a}{k} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

K = an experimentally determined constant

E_a = the activation energy

k = Boltzmann's constant

T₁ = actual use temp. in degrees Kelvin

T₂ = test temp. in degrees Kelvin

How to Use the Arrhenius Equation

The first step in using the Arrhenius equation given above is to determine an activation energy (E_a), which may be done in one of two ways.

The first method involves using failure analysis techniques to determine the actual failure mechanism. The activation energies for many failure mechanisms have already been determined, and tabulated in published literature. Although all processes are not exactly the same, the activation energy of a particular failure mechanism is mainly determined by physical principles. A published activation energy will not be the exact figure associated with a particular process, but it will be a very close approximation.

The dominant failure mechanisms in Maxim's Life Tests have activation energies in the range of 0.8eV to 1.2eV. We have conservatively chosen 0.8eV for the purposes of computing the acceleration factors used in this report. Actual acceleration factors are

probably greater than those quoted.

The second method of determining an activation energy is empirical. Two groups of devices are tested at different temperatures, and the difference between their failure rates is measured. An example is shown below:

Group 1 = 9822 failures after 100 hrs. of operation at 150°C.

Group 2 = 1 failure after 100 hrs. of operation at 25°C.

The acceleration factor for this particular failure mechanism between these two temperatures is, therefore, 9822.

Where:

$$9822 = e^{\frac{E_a}{k} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

E_a = the unknown activation energy

k = 8.63 x 10⁻⁵eV/°K

T₁ = 25°C + 273°C or 298°K

T₂ = 150°C + 273°C or 423°K

Substituting:

$$9822 = e^{\frac{E_a}{8.63 \times 10^{-5}} \left(\frac{1}{298} - \frac{1}{423} \right)}$$

$$9822 = e^{E_a \times 11.49}$$

Taking the natural log of both sides:

$$\text{Log}_e 9822 = E_a \times 11.49$$

$$\frac{\text{Log}_e 9822}{11.49} = E_a$$

Therefore, E_a = 0.8eV

Assuming that this activation energy represents the dominant failure mechanism of the device under consideration, it may then be used to determine the acceleration factor between any two temperatures as follows:

Between 150°C and 70°C, for example:

$$\text{Acceleration Factor} = e^{\frac{0.8}{8.63 \times 10^{-5}} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

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Where:

$$T_1 = 70^\circ\text{C} + 273^\circ\text{C} = 343^\circ\text{K}$$

$$T_2 = 150^\circ\text{C} + 273^\circ\text{C} = 423^\circ\text{K}$$

Substituting for $T_1 + T_2$ and solving for e yields the result:

$$\text{Acceleration Factor} = 165$$

The acceleration factor between 150°C and 70°C is 165.

Appendix 2: Determining Failure Rate

Definition of Terms

The Mean Time Between Failures (MTBF) is the average time it takes for a failure to occur. For example, assume a company tests 100 units for 1000 hrs. The total device-hours accrued would be 100 x 1000, or 100,000 device-hours. Now assume two units were found to be failures. Roughly, it could be said that the MTBF would equal:

$$\text{MTBF} = \frac{\text{Total Device Hrs.}}{\text{Total No. of Failures}} = \frac{100,000}{2} = 50,000 \text{ hrs.}$$

The Failure Rate (FR) is equal to the reciprocal of the MTBF, or:

$$\text{FR} = \frac{1}{\text{MTBF}} = \frac{1}{50,000} = 0.00002$$

If this number is multiplied by 1×10^5 , the failure rate in terms of percent per 1000 hrs. is obtained; i.e., 2%.

A common reliability term also used to express the failure rate is Failures-in-Time, or FIT. This is the number of failures per billion device-hours, and is obtained by dividing the Failure Rate by 10^{-9} :

$$\frac{\text{FR}}{10^{-9}} = \text{FIT.}$$

Using the above example:

$$\begin{aligned} \text{FIT} &= 0.00002/10^{-9} \\ &= 20,000 \end{aligned}$$

The FIT rate is, therefore, shorthand for the number of units predicted to fail in a billion (10^9) device-hours at the specified temperature.

Calculating Failure Rates and FITs

The failure rate can be expressed in terms of the following four variables:

A = The number of failures observed after test

B = The number of hours the test was run

C = The number of devices used in the test

D = The temperature acceleration factor
(see Appendix 1)

Using data in **Table 2**, a failure rate at 25°C can now be calculated:

$$A = 57$$

$$B = 192$$

$$C = 25,169$$

$$D = 9822 \text{ (Assuming } E_a = 0.8\text{eV, and a test temperature of } 150^\circ\text{C)}$$

Substituting:

$$\text{FR} = \frac{57}{192 \times 25,169 \times 9822} = 1.20 \times 10^{-9}$$

Expressing this in terms of the FIT rate:

$$\text{FIT} = 1.20$$

To determine the FIT rate at a new temperature, the acceleration factor (D) must be recalculated from the Arrhenius equation given in Appendix 1.

Including Statistical Effects in the FIT Calculation

Because a small random sample is being chosen from each lot, the statistical effects are significant enough to mention. With most published failure rate figures, there is an associated confidence level number. This number expresses the confidence level that the actual failure rate of the lot will be equal to or lower than the predicted failure rate.

The failure rate calculation, including a confidence level, is determined as follows:

$$\text{FR} = \frac{X^2}{2\text{DH}}$$

Where:

X^2 = the Chi square value

2DH = 2 times the total device hours

$$= 2 \times (B \times C \times D)$$

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The Chi square value is based on a particular type of statistical distribution. However, all that is required to arrive at this value is knowing the number of failures. In this example, there were 57 failures. The Chi square value is found using a standard X^2 distribution table. The tabular values are found using the factors $(1 - CL)$, where CL is the desired confidence level, and $2(N + 1)$ is the degree of freedom.

The value of $(1 - CL)$ for a 60% confidence level is $(1 - 0.60) = 0.40$.

The number of degrees of freedom is $2(57 + 1) = 116$.

The Chi square value found under the values of 0.40 and 116 degrees of freedom is 119.

Therefore, the failure rate found using a 60% confidence level is:

$$FR = \frac{119}{9.49 \times 10^{10}} = 1.25 \times 10^{-9}$$

Expressed as Failure-in-Time rate:

$$FIT = 1.25$$

Referring to **Table 2**, one can see that for Maxim's product, there is a 60% confidence level that no more than 1.25 units will fail per billion (10^9) device-hours of operation at 25°C.

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