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DIODE

STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR

JANTX 1N3016B

FEBRUARY 1979

Prepared
For

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transisters, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the zener diode JANTX1N3016B manufactured by Siemens and Motorola.

A total of 48 samples from each manufacturer was submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 High-Speed Computer-Controlled Tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all the test devices during the power/temperature stress conditions. The voltage was set by V_F and the current was varied in order to comply with the specified power rating for the device. At least one of the devices was subjected to maximum rated power (MRP). All remaining devices were subjected to no less than 90% of MRP. See Figure 1

for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress Process. The diodes were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent of maximum rated power (MRP) for 2500 hours or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1. (*See Notes at end of text.)

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to 1600 hours of stress at maximum rated power in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50% or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II Process. Group III was subjected to 112 hours of stress at maximum rated power in increments of 16 hours. The temperature was increased in steps of 25°C, commencing at 150°C and terminating at 300°C or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed

on all specified electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Siemens. The Siemens sample lot completed 1010 hours of Group I Testing before the lot was stopped because more than 50% of the devices failed. Fourteen failures occurred 10 hours into the 125% MRP step. Serial number 2263 failed due to excessive I_R leakage. Serial number 2259 failed the minimum B_V limit. Serial numbers 2254, 2256, 2257, 2258, 2260, 2261, 2262, 2265, 2266, 2267, 2268 and 2269 failed the maximum B_V limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 1.630mA from an initial mean of 643.nA to a final mean of 1.631mA.
2) The mean value for B_V changed 7.374V from an initial mean of 6.696V to a final mean of 14.07V.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.2 Motorola. The Motorola sample lot completed 1010 hours of Group I Testing before the lot was stopped due to a failure rate exceeding 50% of the lot. The first failure occurred 10 hours into the 125% MRP step. Serial number 2213 failed due to excessive I_R leakage. The next failure occurred 50 hours into the 125% MRP step. Serial number 2207

failed the maximum ^{B}V limit. The next failure occurred 250 hours into the 125% MRP step. Serial number 2205 failed due to excessive ^{I}R leakage. The next failure occurred 150 hours into the 150% MRP step. Serial number 2202 failed the maximum BV limit. Two failures occurred 50 hours into the 175% MRP step. Serial number 2211 failed the maximum ^{B}V limit. Serial number 2215 failed the minimum ^{B}V limit. The next failure occurred 150 hours into the 175% MRP step. Serial number 2208 failed the maximum MRP limit. The final failure occurred 250 hours into the 175% MRP step. Serial number 2203 failed due to excessive ^{I}R leakage. Typical characteristics of this sample lot's performance were:

1) The mean value for ^{I}R changed 1.114mA from an initial mean of 4.398μA to a final mean of 1.118mA.
2) The mean value for ^{B}V changed 175.0mV from an initial mean of 6.820V to a final mean of 6.995V.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.3 Statistical Summary - Group I. Table 4 outlines the results of Group I - Power Stress Process for each of the electrical parameters and all measurement points for both Siemens and Motorola.

3.2 Group II - Temperature Stress I

3.2.1 Siemens. The Siemens sample lot completed 1120 hours of Group II Testing before being stopped because 50% of lot had failed. The first two

failures occurred 160 hours into the 150°C-temperature step. Serial numbers 2275 and 2281 failed the maximum ^{B}V limit. The next five failures occurred 160 hours into the 200°C-temperature step. Serial number 2285 failed due to excessive ^{I}R leakage. Serial number 2285 failed due to excessive ^{I}R leakage. Serial numbers 2273, 2282, 2283 and 2284 failed the maximum ^{B}V limit. The last nine failures occurred 16 hours into the 225oC-temperature step. Serial numbers 2270, 22771, 2273, 2274, 2276, 2277, 2278, 2279 and 2280 failed the maximum ^{B}V limit. Typical characteristics of this sample lot's performance were:

1) The mean value for ^{I}R changed 196.4μA from an initial mean of 1.297μA to a final mean of 197.7μA.
2) The mean value for ^{B}V changed 354.0mV from an initial mean of 6.652V to a final mean of 7.006V.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.2 Motorola. The Motorola sample lot completed 1120 hours of Group II Testing before being stopped because more than 50% of the lot failed. The first failure occurred 160 hours into the 175°C-temperature step. Serial number 2230 failed the minimum ^{B}V limit. The next three failures occurred 160 hours into the 200°C-temperature step. Serial number 2227 failed because of excessive ^{I}R leakage. Serial number 2228 failed the maximum ^{B}V limit. Serial number 2229 failed the minimum ^{B}V limit. The final eleven failures occurred 160 hours into the 250°C-temperature step. Serial

numbers 2222, 2224, 2225, 2226, 2231 and 2233 failed because of excessive I_R leakage. Serial numbers 2218, 2220, 2221, 2223 and 2232 failed the maximum B_V limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 4.989mA from an initial mean of 5.715µA to a final mean of 4.995mA.
2) The mean value for B_V changed 17.00mV from an initial mean of 6.820V to a final mean of 6.803V.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.3 Statistical Summary - Group II. Table 5 of this report outlines the results of Group II - Temperature Stress I Testing, for each of the electrical parameters and all of the measurement points pertaining to both Siemens and Motorola.

3.3 Group III - Temperature Stress II

3.3.1 Siemens. The Siemens sample lot completed 64 hours of Group III Testing before the lot was stopped because of a failure rate exceeding 50% of the lot. The first failures occurred 16 hours into the 200°C-temperature step. Serial numbers 2252, 2287 and 2294 failed the maximum B_V limit. The final failures occurred 16 hours into the 225°C-temperature step. Serial numbers 2251, 2253, 2286, 2288, 2289, 2290, 2291, 2292, 2293, 2295, 2297, 2299 and 2301 failed the maximum B_V limit. Typical

characteristics of this sample lot's performance were:

1) The mean value for I_R changed 4.001μA from an initial mean of 1.530μA to a final mean of 5.531μA.

2) The mean value for B_V changed 4.613V from an initial mean of 6.657V to a final mean of 11.27V.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.2 Motorola. The Motorola sample lot completed the entire 112-hour Group III Testing with six catastrophic failure. The first two failures occurred 16 hours into the 200°C-temperature step. Serial number 2241 failed the minimum B_V limit. Serial number 2243 failed because of excessive I_R leakage. The next failure occurred 16 hours into the 225°C-temperature step. Serial number 2248 failed due to excessive I_R leakage. The next failure occurred 16 hours into the 275°C-temperature step. Serial number 2235 failed because of excessive I_R leakage. The last failures occurred 16 hours into the 300°C-temperature step. Serial number 22400 failed the minimum B_V limit. Serial number 2246 failed the maximum B_V limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 843.5μA from an initial mean of 552.1nA to a final mean of 844.1μA.

2) The mean value for B_V changed 567.0mV from an initial mean of 6.815V to a final mean of 6.248V.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.3 Statistical Summary - Group III. Table 6 outlines the results of Group III - Temperature Stress II Testing, for each of the electrical parameters and all of the measurement points for both Siemens and Motorola.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 were used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in Figures 3 and 5, respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

Both Siemens and Motorola experienced a large failure rate throughout all three stress tests, but the Motorola devices were more durable with

their failures occurring later than Siemens in each group. The failure mode common to all three groups was the I_R maximum limit failure and the B_V maximum limit failure. In some cases the I_R failures were shorted devices and the B_V failures were opened devices.

In the Group I Testing, the devices from both sample lots failed due to the thermal effects of excess power. In some cases the internal lead bonding metal melted and flowed up the silver lead wire, which in turn disconnected from the die. Other devices failed due to shorting of the junction, probably caused by alloying with the melted metal at elevated temperatures.

Many devices in the Group II and III Testing failed due to the effects of overheating. In some cases probe testing of the dice after opening the packages showed shorts. The most probable cause of the shorts is alloying of the molten die metal into the silicon.

A plot showing cumulative failure distribution for Groups II and III was drawn for the Siemens and Motorola sample lots (Figures 2 and 3, and 4 and 5, respectively). Figures 2 and 3 display the data for the Siemens sample lot used to calculate an activation energy of 1.34eV. Figures 4 and 5 display the data for the Motorola sample lot used to calculate an activation energy of 1.57eV.

A broken circle around a marked point on the graph indicates a freak failure not calculated as part

of the regression line. A solid circle around a marked point indicates an isolated main failure point. The regression line was calculated using the least squares method.

Because of visual defects caused by the extreme heat of the stress tests, serial numbers 2287, 2294, 2301, 2229, 2225 and 2221 were not calculated as part of the regression line.

The activation energy was calculated from the formula:

$$E = \left[\ell n \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^{\circ}\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^{\circ}$C of 16% failure for Group II.

T_2 = temperature in $^{\circ}$C of 16% failure for Group III.

NOTE:

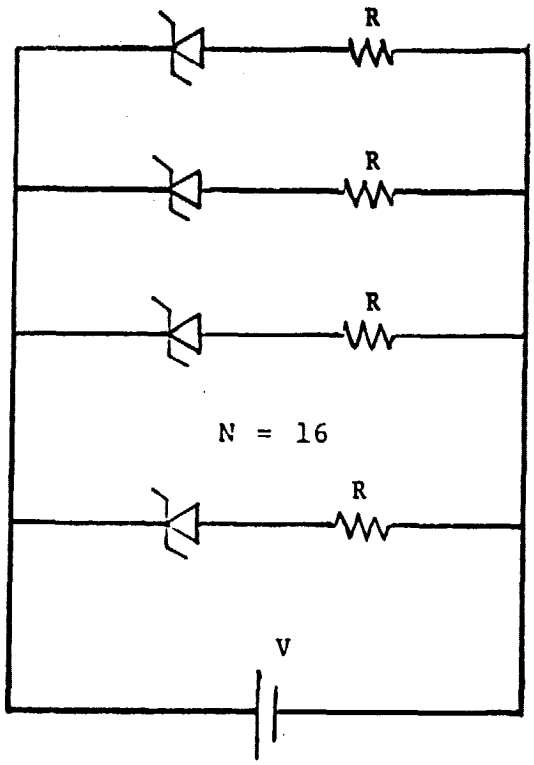
* Conditions for failure:

A) Open or short

B) Leakage exceeds the maximum limit by 100 times.

C) Other parameters exceed MIL limits by 50% or more.

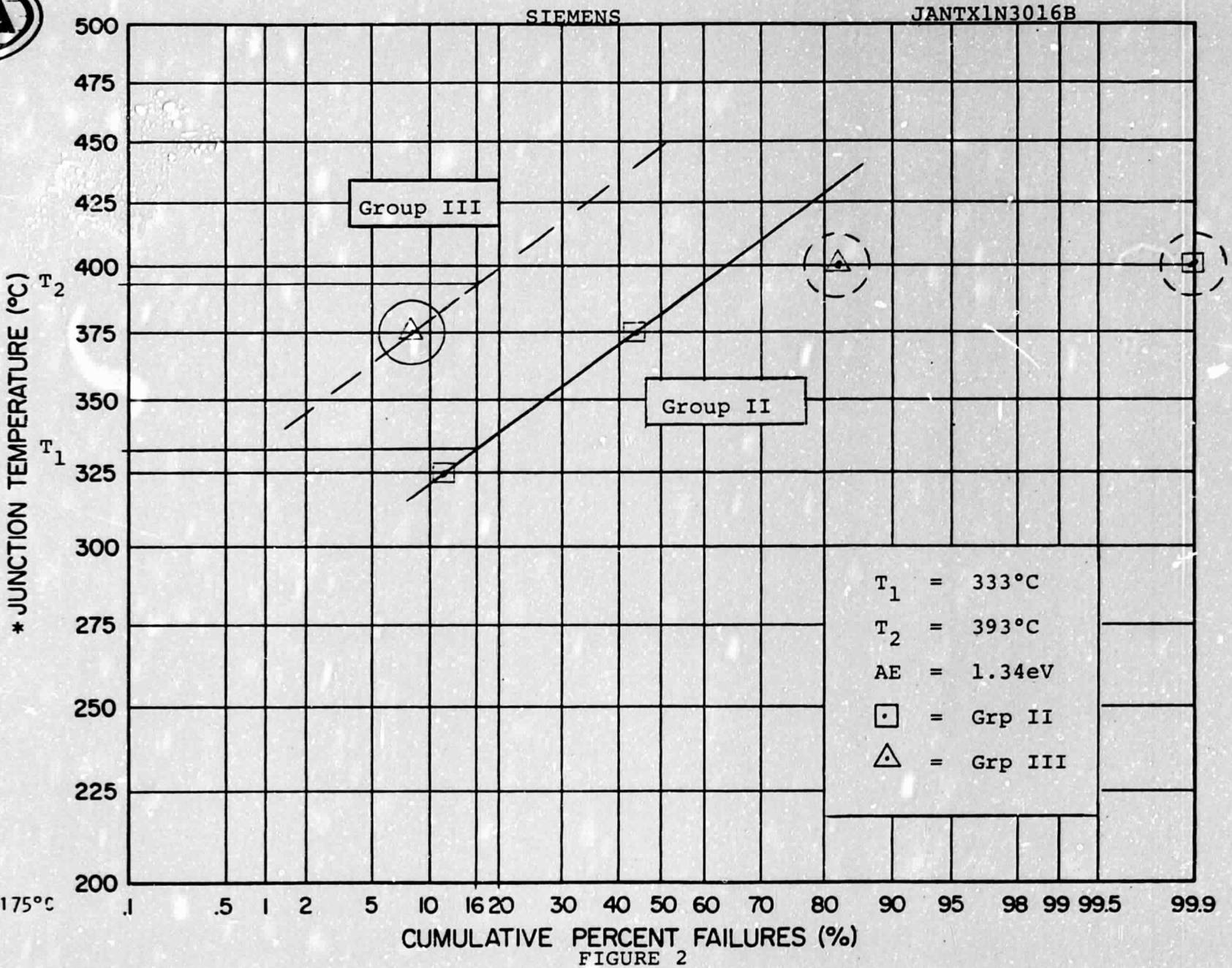
ZENER DIODES



$R = VZ \div 1.75\ IZ_{MAX} \pm 50\%$

$P_d = VZ^2 \div R$

FIGURE 1
Power/Temperature Stress Circuit
for JANTX1N3016B

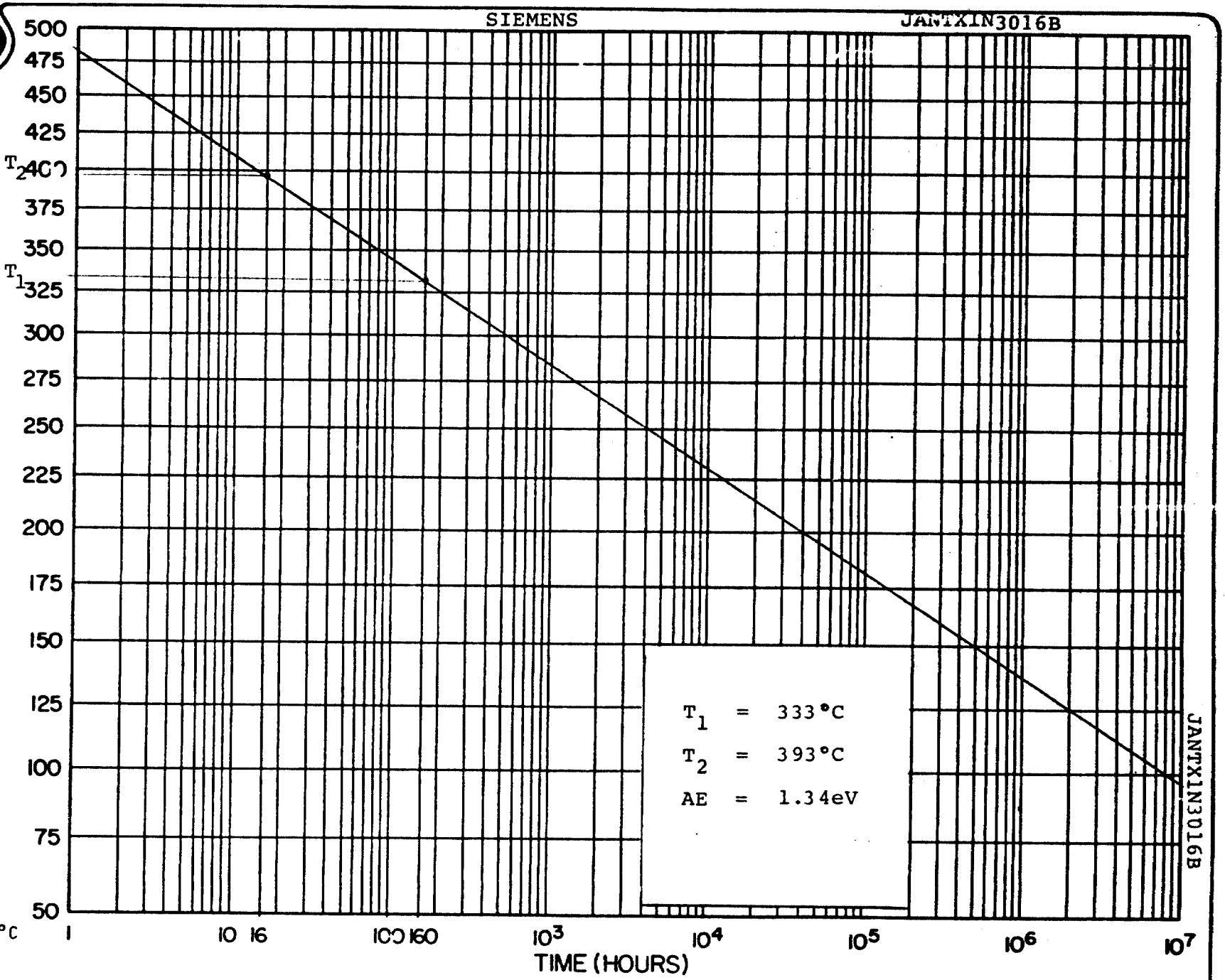


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 2

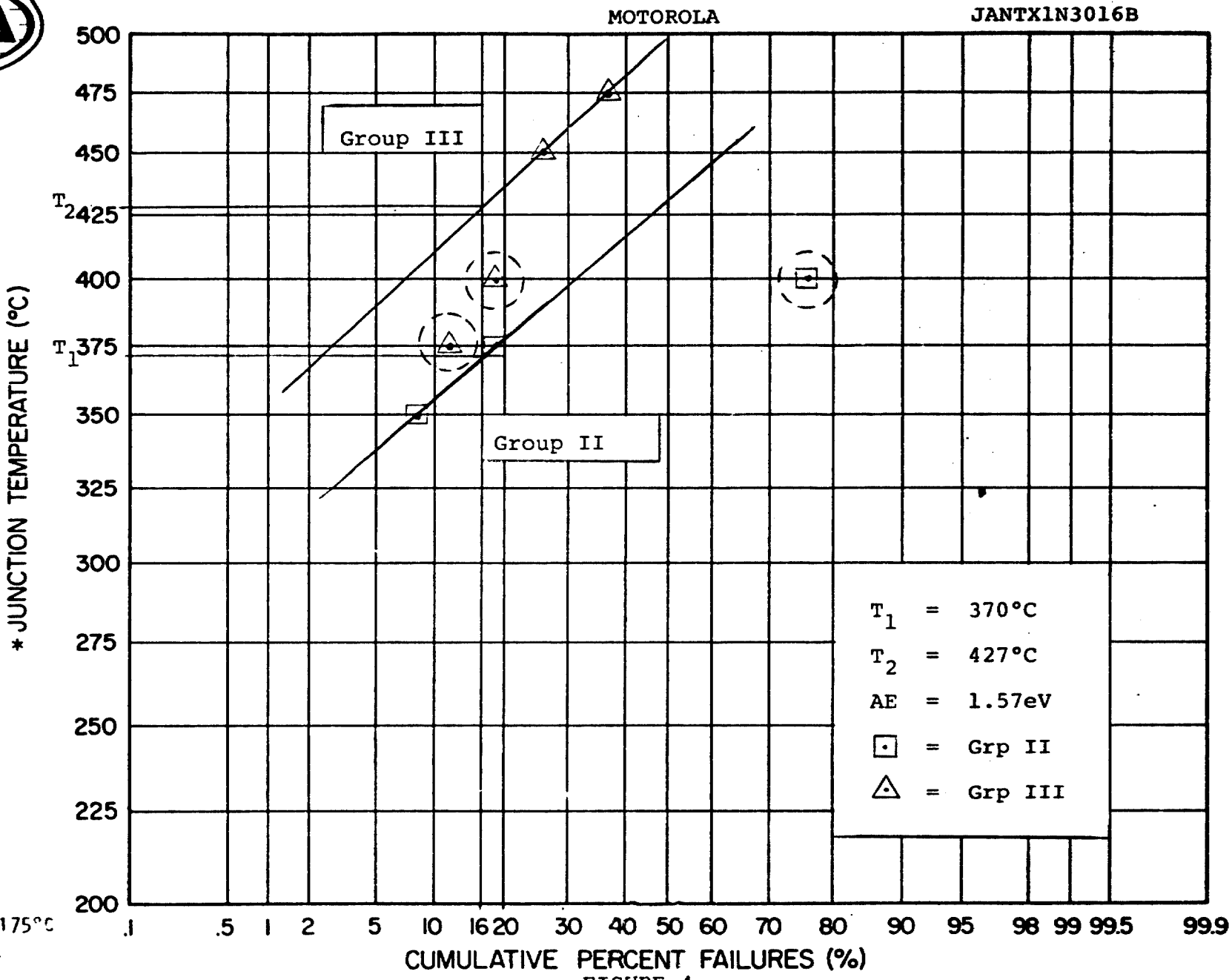
Cumulative Percent Failures Versus Junction Temperature, Siemens



*NOTE

$T_J \approx T_A + .175°C$

FIGURE 3
Time Steps Versus Junction Temperature, Siemens

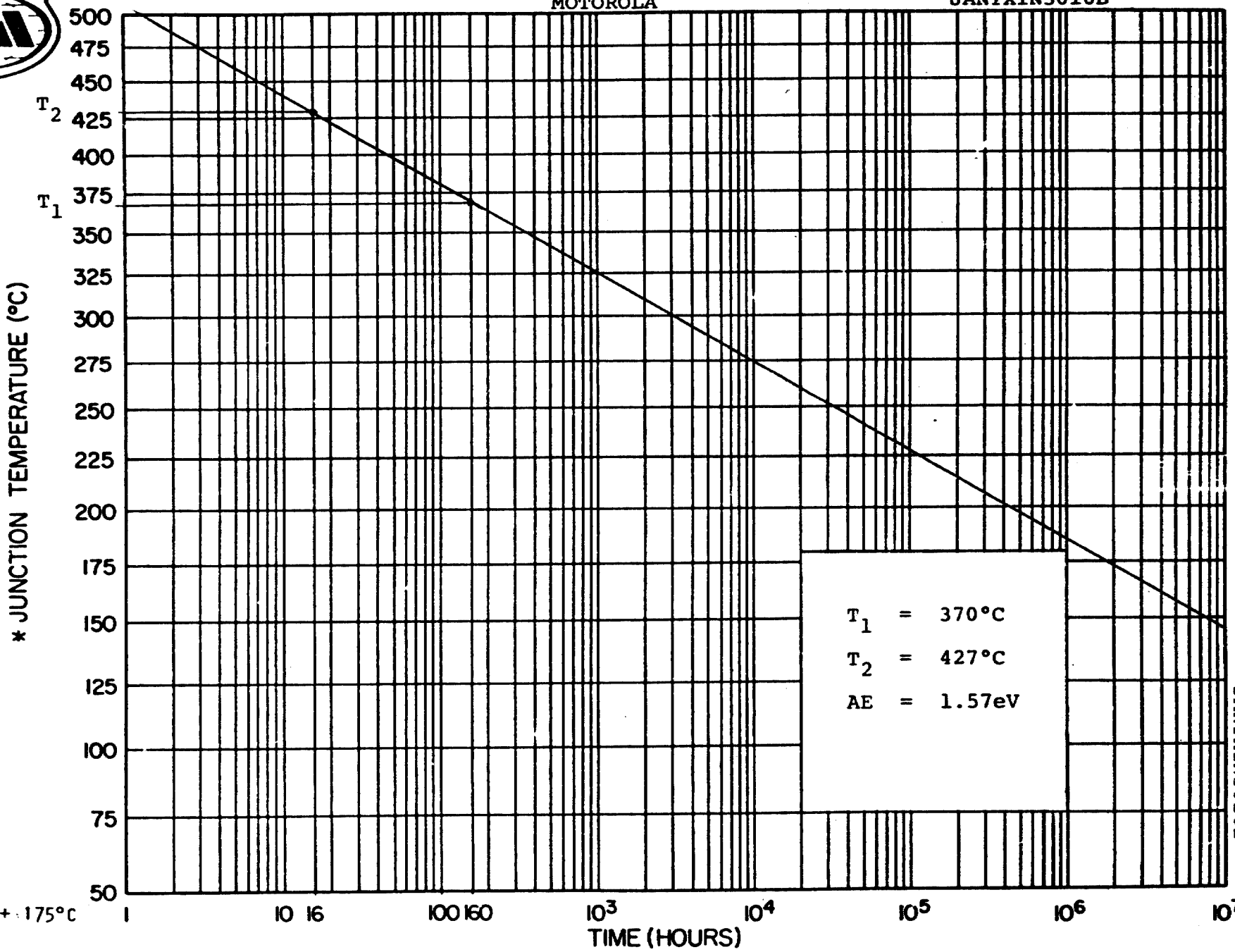


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Motorola

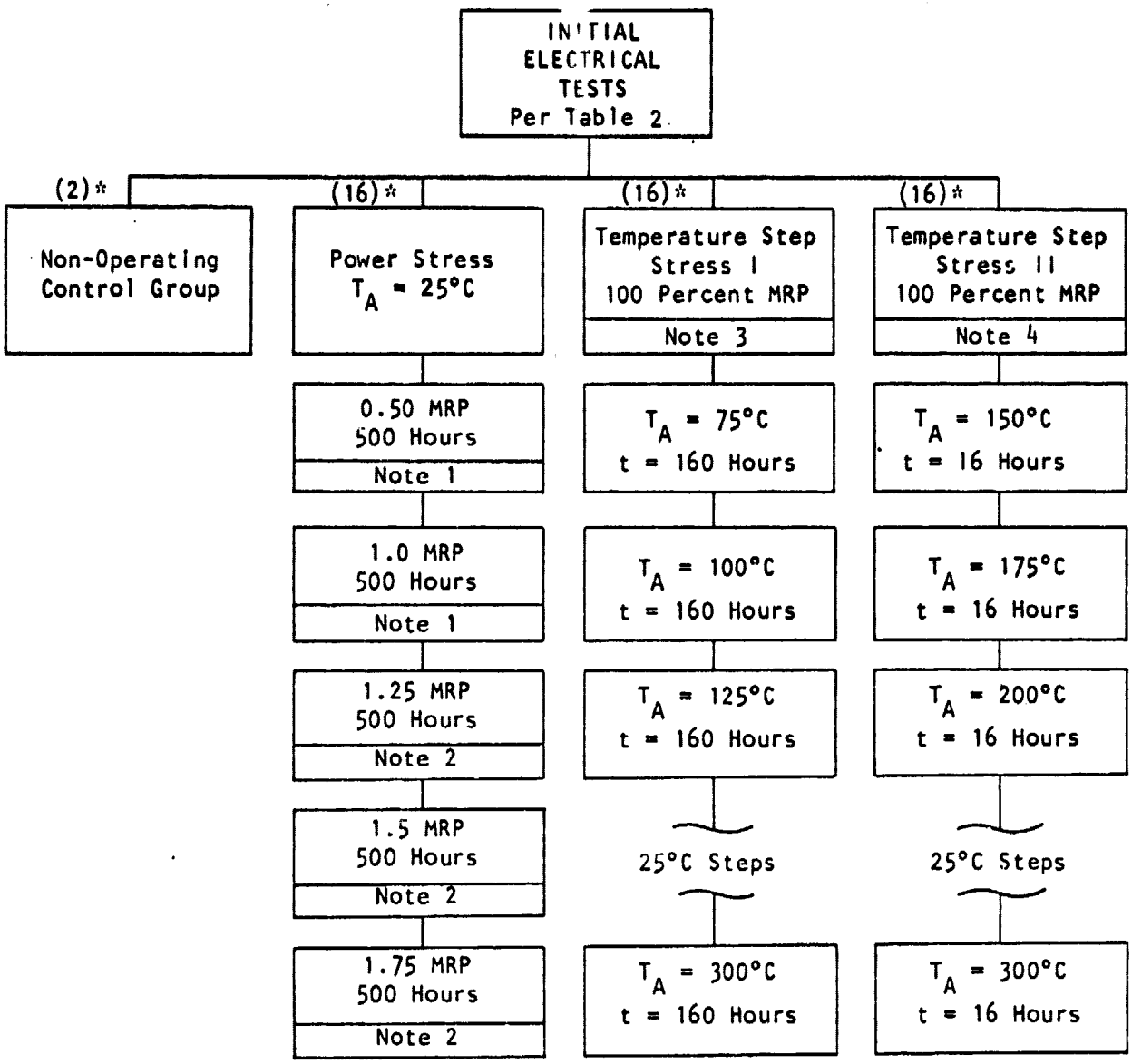


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5
Time Steps Versus Junction Temperature, Motorola

TABLE 1
TEST FLOW DIAGRAM



*Quantity per manufacturer (Siemens & Motorola)

NOTES:

1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
3) Electrical measurements per Table 2 were made at the end of each 160 hours.
4) Electrical measurements per Table 2 were made at the end of each 16 hours.

TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_R	@ V_R = 5.2V		.15		15.	mA
B_V	@ I_Z = 37.0 mA	6.46	7.14	3.23	10.71	V

NOTES:

TABLE 3
POWER STRESS BURN-IN CONDITIONS

V_Z = 6.8v	
I_Z	Percent P_D
73.5mA	50
147.0mA	100
183.75mA	125
220.5mA	150
257.25mA	175

NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of ±1% of the reading and ± one digit except for readings greater than 9.99mA which have an absolute accuracy of ±2% of the reading and ± one digit. The data also have a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

TABLE 4
GROUP I — POWER STRESS DATA SUMMARY

PARAMETER	I_R = 150µA(MAX)		B_V=6.46V(MIN) 7.14(MAX)					
CONDITIONS AND LIMIT	@ V_R = 5.2V		I_Z = 37.0mA					
IDENTIFICATION	SIE	MOT	SIE	MOT				
INITIAL DATA								
MIN VALUE	35.10nA	52.80nA	6.519V	6.518V				
MAX VALUE	2.270µA	54.40µA	7.007V	7.060V				
MEAN	643.5nA	4.398µA	6.696V	6.820V				
STD DEV	545.3nA	13.98µA	152.3mV	147.6mV				
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	68.50nA	1.578µA	3.000mV	-5.000mV				
150 HRS	77.90nA	1.920µA	4.000mV	-4.000mV				
250 HRS	80.60nA	1.603µA	0V	-2.000mV				
500 HRS	83.90nA	1.674µA	0V	1.000mV				
100% POWER								
550 HRS	31.80nA	99.00nA	0V	-4.000mV				
650 HRS	50.20nA	7.532µA	1.000mV	-3.000mV				
750 HRS	63.10nA	7.342µA	14.00mV	4.000mV				
1000 HRS	694.5nA	23.02µA	15.00mV	0V				
125% POWER								
1010 HRS	*1.630mA	13.68µA	7.374V	-7.000mV				
1025 HRS	JOB STOPPED	14.05µA	JOB STOPPED	-10.00mV				
1050 HRS		14.47µA		0V				
1150 HRS		15.36µA		-3.00mV				
1250 HRS		4.888µA		-8.00mV				
1500 HRS		4.654µA		-4.00mV				

(continued on second sheet)

TABLE 4 (Cont'd)

(continued from first sheet) GROUP I — POWER STRESS DATA SUMMARY

PARAMETER	I_R = 150µA(MAX)		B_V=6.46V(MIN) 7.14(MAX)					
CONDITIONS AND LIMITS	@ V_R = 5.2V		I_Z = 37.0mA					
IDENTIFICATION	SIE	MOT	SIE	MOT				
INITIAL DATA								
MIN VALUE	35.10nA	52.80nA	6.519V	6.518V				
MAX VALUE	2.270µA	54.40µA	7.007V	7.060V				
MEAN	643.5nA	4.398µA	6.696V	6.820V				
STD DEV	543.3nA	13.96µA	152.3mV	147.6mV				
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS		3.329µA		-5.00mV				
1525 HRS		3.096µA		1.000mV				
1550 HRS		3.693µA		-7.000mV				
1650 HRS		2.866µA		6.000mV				
1750 HRS		12.67µA		12.00mV				
2000 HRS		6.922µA		17.00mV				
175% POWER								
2010 HRS		4.102µA		14.00mV				
2025 HRS		4.123µA		18.00mV				
2050 HRS		5.642µA		*73.00mV				
2150 HRS		985.5µA		15.00mV				
2250 HRS		*1.114mA		*175.0mV				
2500 HRS	↓ ↓	JOB STOPPED	↓ ↓	JOB STOPPED				
FINAL DATA								
MIN VALUE	0.000A	0.000A	2.000mV	6.642V				
MAX VALUE	9.990mA	9.990mA	17.12V	7.778V				
MEAN	1.631mA	1.118mA	14.07V	6.995V				
STD DEV	3.485mA	3.137mA	5.505V	6.876V				

* NOTE: Catastrophic reject(s) removed from data after this point

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	I_R = 150μA(MAX)		B_V=6.46V(MIN) 7.14(MAX)					
CONDITIONS AND LIMITS	V_R = 5.2V		I_Z = 37.0mA					
IDENTIFICATION	SIE	MOT	SIE	MOT				
INITIAL DATA								
MIN VALUE	108.0nA	55.10nA	6.533V	6.532V				
MAX VALUE	5.430μA	53.20μA	6.830V	7.067V				
MEAN	1.297μA	5.715μA	6.652V	6.820V				
STD DEV	1.398μA	14.62μA	91.44mV	161.9mV				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS / TEMP (T_A)								
160 / 75°C	250.0nA	3.608μA	-1.000mV	0.000V				
320 / 100°C	250.0nA	3.608μA	13.00mV	4.000mV				
480 / 125°C	284.0nA	26.23μA	15.00mV	7.000mV				
640 / 150°C	130.0nA	22.86μA	3.000mV	6.000mV				
800 / 175°C	266.0nA	13.12μA	61.00mV	16.00mV				
960 / 200°C	*717.1μA	*661.4μA	*354.0mV	-17.00mV				
1120 / 225°C	196.4μA	*4.989mA	*354.0mV	-17.00mV				
1280 / 250°C	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED				
1440 / 275°C	↓ ↓	↓ ↓	↓ ↓	↓ ↓				
1600 / 300°C								
FINAL DATA								
FINAL TEMP	225°C	225°C	225°C	225°C				
MIN VALUE	11.30nA	0.000mA	6.673V	6.535V				
MAX VALUE	1.280mA	9.990mA	7.257V	7.006V				
MEAN	197.7μA	4.995mA	7.006V	6.803V				
STD DEV	354.2μA	4.995mA	195.9mV	157.6mV				

*NOTE: Catastrophic reject(s) removed from data after this point

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JAN1XIN3OL6b

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY

PARAMETERS	I_R = 150µA(MAX)		B_V=6.46V(MIN) 7.14(MAX)					
CONDITIONS AND LIMITS	V_R = 5.2V		I_Z = 37.0mA					
IDENTIFICATION	SIE	MOT	SIE	MOT				
INITIAL DATA								
MIN VALUE	108.0nA	12.80nA	6.525V	6.533V				
MAX VALUE	13.00µA	3.750µA	6.792V	7.056V				
MEAN	1.530µA	552.1nA	6.657V	6.815V				
STD DEV	3.092µA	873.2nA	97.44mV	144.5mV				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS TEMP (T_A)								
16 150°C	-598.4nA	14.26µA	-2.000mV	-6.000mV				
32 175°C	-489.0nA	28.11µA	1.000mV	-5.000mV				
48 200°C	9.650µA	1.254mA	*4.613V	-442.0mV				
64 225°C	4.001µA	720.3µA	*4.613V	20.00mV				
80 250°C	JOB STOPPED	278.0µA	JOB STOPPED	24.00mV				
96 275°C	↓ ↓	788.0µA	↓ ↓	23.00mV				
112 300°C		843.5µA		*-567.0mV				
FINAL DATA								
FINAL TEMP	225°C	300°C	225°C	300°C				
MIN VALUE	21.00nA	40.00pA	6.761V	428.0mV				
MAX VALUE	21.10µA	9.990mA	64.82V	7.104V				
MEAN	5.531µA	844.1µA	11.27V	6.248V				
STD DEV	6.192µA	2.758mA	14.86V	1.846V				

*NOTE. Catastrophic reject(s) removed from data after this point

DGA

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX			SIEMENS	MOTOROLA	SIEMENS	MOTOROLA	SIEMENS	MOTOROLA
I_R		150	μA		*+181.24	*+90.313	*+130.67	*+817.12	+3.1409	*+560.88
B_V	6.46	7.14	V		*+.82344	+.01056	*+.11414	-.00014	*+2.3063	*-.13614

* NOTE: Catastrophic reject(s) removed from data after this point

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY JAN TX1N3016B

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	1 12 1	A C B	1	D
15 hr.	JOB STOPPED		0	-
25 hr.			1	C
100 hr.			0	-
100 hr.			1	A
250 hr.			0	-
150% 10 hr.			0	-
15 hr.			0	-
25 hr.			0	-
100 hr.			1	C
100 hr.			0	-
250 hr.			0	-
175% 10 hr.			0	-
15 hr.			0	-
25 hr			2	E
100 hr.			1	C
100 hr.			1	A
250 hr.			JOB STOPPED	

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	-	0	-
100° C	0	-	0	-
125°C	0	-	0	-
150°C	2	C	0	-
175°C	0	-	1	B
200°C	1 4	A C	1 1 1	A C D
225°C	9	C	6 1 4	A D C
250°C	JOB STOPPED		JOB STOPPED	
275°C				
300°C				

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	-	0	-
175°C	0	-	0	-
200°C	3	C	1 1	A B
225°C	13	C	1	D
250°C	JOB STOPPED		0	-
275°C			1	A
300°C			1 1	B C

MFR "A" - SIEMENS

MFR "B" - MOTOROLA

NOTES:
A - I_R > 15mA

B - B_V < 3.23V

C - B_V > 10.71V

D - Shorted (verified by failure analysis)

E - Open (verified by failure analysis)

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX1N3016B

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	1	A
125% 10 hr.	1	A&B	1	A
15 hr.	JOB STOPPED		0	–
25 hr.	↓	↓	0	–
100 hr.	↓	↓	0	–
100 hr.	↓	↓	0	–
250 hr.	↓	↓	0	–
150% 10 hr.	↓	↓	0	–
15 hr.	↓	↓	0	–
25 hr.	↓	↓	0	–
100 hr.	↓	↓	0	–
100 hr.	↓	↓	1	A
250 hr.	↓	↓	0	–
175% 10 hr.	↓	↓	0	–
15 hr.	↓	↓	0	–
25 hr.	↓	↓	0	–
100 hr.	↓	↓	1 \ 1	B \ C
100 hr.	↓	↓	0	–
250 hr.	↓	↓	JOB STOPPED	

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	–	0	–
100° C	0	–	0	–
125 °C	0	–	1	A
150 °C	0	–	0	–
175 °C	1	B	0	–
200 °C	2	B	0	–
225 °C	0	–	0	–
250 °C	JOB STOPPED		JOB STOPPED	
275 °C	↓	↓	↓	↓
300 °C	↓	↓	↓	↓

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150 °C	0	–	0	–
175 °C	0	–	2	A
200 °C	1 \ 4	A \ B	0	–
225 °C	0	–	0	–
250 °C	JOB STOPPED		1	A
275 °C	↓	↓	1	B
300 °C	↓	↓	0	–

MFR "A" - SIEMENS

MFR "B" - MOTOROLA

NOTES: A - I_R > .15mA

B - B_V > 7.14V

C - B_V < 6.46V

APPENDIX A

FAILURE ANALYSIS

POWER STRESS

FAILURE ANALYSIS

Date 10 November 1978

J/N 2CN242-34.. P/N 1N3016B MFR MOTOROLA

	Limits: 6.46-7.14V	Limit: 150uA Max.			
S/N	PIV -volts- @ 37mA	I_R @ 5.2 V.dc	V_F @ ___ dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
2211	open arcs @ 200V	open		47 (175% power 50 Hrs. Tot)	B_V
2213	shorted	∞		17 (100% power 500 Hrs. Tot)	I_R
2215	open	open		47 (175% power 50 Hrs. Tot)	B_V

INTERNAL VISUAL INSPECTION

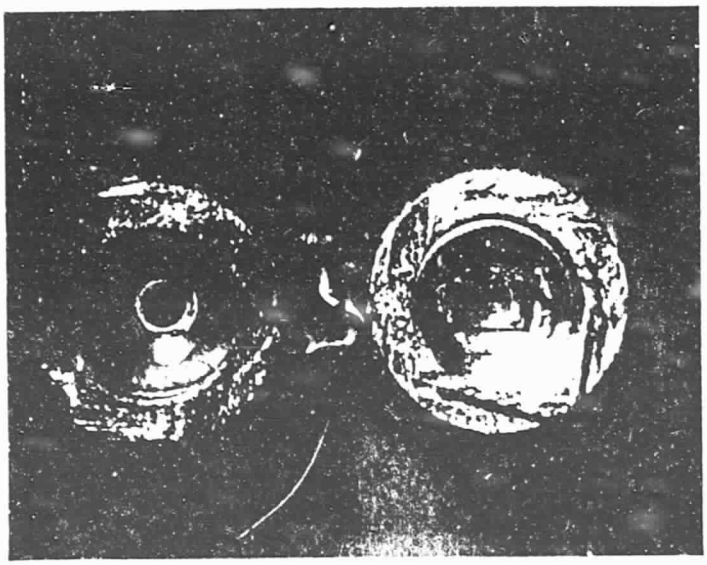
S/N 2211 and 2215 were open at the bonding connection between the top of the die and the internal wire (see Figure A-1).
S/N 2213 has no visual defects.

CONCLUSIONS

All these Motorola samples failed due to the thermal effects of excess power. S/N 2211 and 2215 failed because the internal lead bonding material melted and flowed up the silver lead wire, thus disconnecting the die. S/N 2213 failed due to shorting of the junction probably due to alloying with the metal at elevated temperature.

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable



FICURE A-1
S/N 2211, Motorola, 6X.
The case has been cut and folded back, showing the
open connection between the die and the internal wire.

APPENDIX B

FAILURE ANALYSIS

TEMPERATURE STRESS I

FAILURE ANALYSIS

Date 10 November 1978

J/N 2CN242-34B **P/N** 1N3016B **MFR** MOTOROLA

Limits: 6.46-7.14V Limit: 150μA

S/N	PIV -volts @ 37mA	I_R @ 5.2 V.dc	V_F @ ____dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
2221	open*	open*		15 (225°C 480 Hrs. Tot)	I_R
2225	unstable; no reading*	unstable; no reading*		15 (225°C 48 Hrs. Tot)	I_R
2229	open*	open*		13 (200°C 960 Hrs. Tot)	B_V
	(*Die is shorted at probe test)				

INTERNAL VISUAL INSPECTION

All three samples have opens at the soldered connection between the top of the die and the internal lead wire (see Figure B-1).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

FAILURE ANALYSIS

Date 10 November 1978

J/N 2CN242-34B P/N 1N3016B MFR SIEMENS

	Limits: 6.46-7.14V	Limit: 150μA Max.			
S/N	PIV -volts- @ 37mA	I_R @ 5.2V.dc	V_F @ ___dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
2271	7.9(R)	50μA, (D), (R) capac. loop		13 (200°C 960 Hrs. Tot)	B_V
2273	unstable no reading	unstable no reading		13 (200°C 960 Hrs. Tot)	B_V
2274	R (Uns)	R (Uns)		15 (225°C 1120 Hrs. Tot)	I_R

INTERNAL VISUAL INSPECTION

All three Siemens samples have separated at the bonding joint between the die and the internal wire. The junction coating has decomposed and has become soft and tarry (see Figure B-2).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

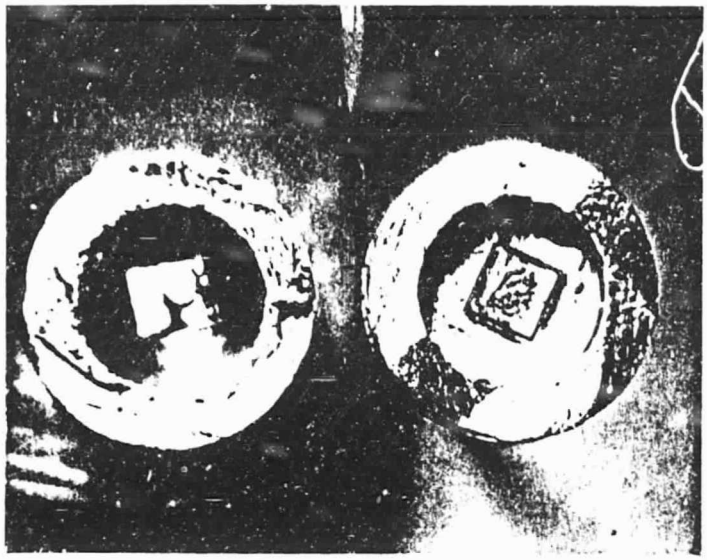


FIGURE B-1
S/N 2229, Internal View of Motorola Diode, 7X.
Note loss of bonding material from the
top of the die and the open die-to-wire connection.

FIGURE B-2
S/N 2271, Typical Siemens Diode, 5X.
The die has separated from the case and is
covered with decomposed junction coating.

CONCLUSION

All six samples failed due to the effects of overheating. Probe testing of the dice after opening the packages showed that all six are shorted. The most probable cause of the shorts is alloying of the molten die metal into the silicon. The most vulnerable feature of these diodes is the low melting point of the internal lead attach bonnding material.

APPENDIX C

FAILURE ANALYSIS

TEMPERATURE STRESS II

FAILURE ANALYSIS
(TEMPERATURE STRESS II)

Date 11 May 1978

J/N 2CN242-34C P/N 1N3016B MFR MOTOROLA

	Limits: 6.46-7.14V	Limit: 150μA Max.			
S/N	PIV -volts- @ 27mA	I_R @ 5.2V.dc	V_F @ ___dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
2236	6.7	150μA		03 (150°C)	I_R
2237	- open -			13 (275°C)	I_R
2237	6.8	0.2μA	---Internally probed---		
2248	0.5(R)	can't reach(R)		11 (250°C)	CAT
2248	shorted		---Internally probed---		

INTERNAL VISUAL INSPECTION

The silicon junction coating is somewhat darkened on all samples. S/N 2236 and 2237 have lifted internal leads. S/N 2848 has a lifted die (see Figures C-1 and C-2).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

FAILURE ANALYSIS
(TEMPERATURE STRESS II)

Date 11 May 1978

J/N 2CN242-34C **P/N** 1N3016B **MFR** SIEMENS

Limits: 6.46-7.14V
Limit: 150μA

S/N	PIV -volts- @ 37mA	I_R @ 5.2V.dc	V_F @ ___dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
2287	can't reach 37mA - opens	0.4μA		13 (275°C)	CAT
2287	6.3	0.75μA ---	Internally probed---		
2294	- o p e n -			13 (275°C)	CAT
2294	6.1	1.0μA ---	Internally probed ---		
2301	can't reach (R)	.2mA		15(275°C)	I_R 165μA

INTERNAL VISUAL INSPECTION

All samples have darkened silicon junction coating. S/N 2287 has a lifted die, and S/N 2294 and 2301 have lifted internal leads (see Figures C-3 and C-4).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

CONCLUSIONS

These samples failed because they were exposed to heat in excess of the melting temperature of the die attach and internal lead metal. All the samples except Motorola S/N 2236 were either open or were making intermittent contact. S/N 2236 had been rejected for 10% excess leakage, but the part was marginally acceptable at the time of this analysis.

The specific failure modes of the individual samples were as follows:

	S/N	FAILURE MODE
Motorola:	2236	Lifted internal lead.
	2237	Same as above.
	2248	Lifted die. Die nickel plate separated.
Siemens:	2287	Lifted die.
	2294	Lifted internal lead.
	2301	Lifted internal lead.

The Siemens silicon dice were undamaged electrically, as demonstrated by internal probing of the devices. Two of the three Motorola dice were also good. This indicates that both might have withstood greater stress than they did if higher melting bonding material was used.

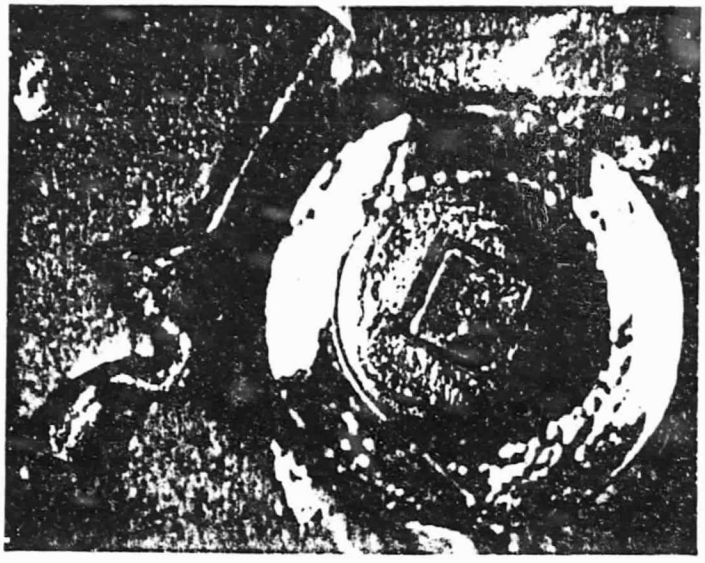


FIGURE C-1
S/N 2236, Top of Motorola Die Showing Detached Internal Anode Lead, 12X.
Note the lead attach bonding material has reflowed and is now on the S-bend of the lead.

FIGURE C-2
S/N 2248, Motorola Device Showing Loss of Metallurgic Bond to Cathode, 12X.
Cathode post shown on left; underside of die shown on right.

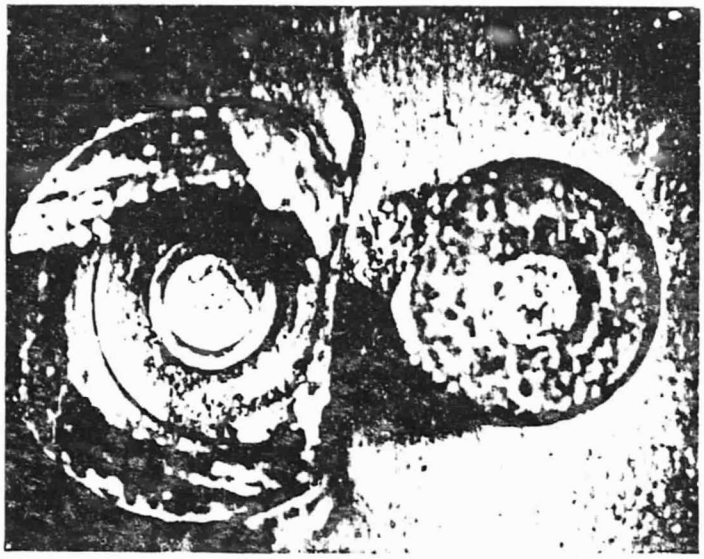


FIGURE C-3
S/N 2287, Siemens Device Showing Loss of
Metallurgic Bond to Cathode Post, 12X.
Device bond lost metallurgic bond to cathode post and is bonded only to anode lead. The anode lead is enclosed in a silicon coating used to cover the die surface. Cathode post shown on the left; underside of die shown on the right.

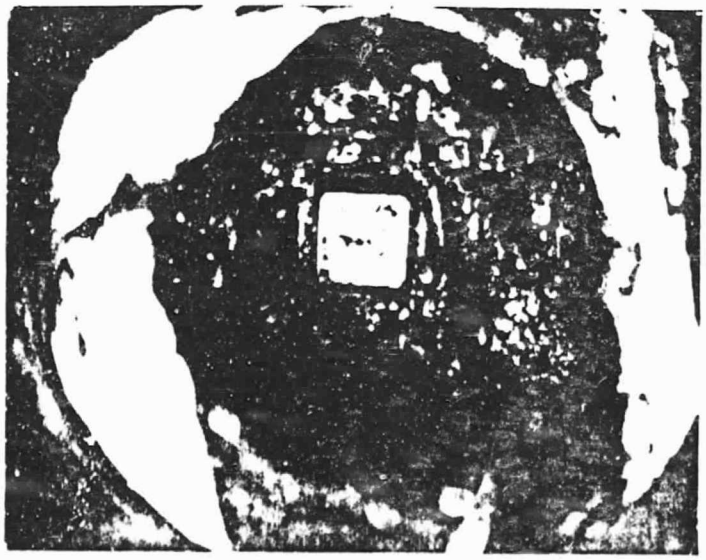


FIGURE C-4
S/N 2301, Top Surface of Die, Siemens, 20X.
The rough brownish material is charred
silicon used to coat the die junction.